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ELECTRICAL PROPERTIES OF INDIAN MICA
III. THE EFFECT OF PRE-HEATING

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ABSTRACT The power-factor of Bengal ruby and Madras green muscovite micas of different qualities has been measured after their heat treatment at different temperatures for different periods It is found that their power-factor attains a minimum value after their heat treatment for half an-hour at 200°C.

INTRODUCTION

The effect of temperature on the electrical properties of micas, presumably of different geographical origins, has been studied by several workers, notably, by the British scientists. Dannatt and Goodall (1931) investigated the effect of temperature on the power-factor and permittivity of ruby, green and amber micas over a range covering the working conditions met with in electrical engineering practice. They made measurements at several temperatures up to a maximum of 130°C. The power-factor of each kind of mica was found to increase with temperature, while the variation of permittivity was too small to be of any account. Hartshorn and Rushton (1939) also studied the effect of temperature over the range of 25°C to 90°C on the power-factor and permittivity of typical samples of clear ruby mica, subjected to the action of an alternating voltage at frequencies of 50 to 1000 cycles per second. They observed that under low voltage gradients (less than about 2 kV/mm.), the power-factor increased considerably with rise of temperature while the temperature co efficient of the permittivity was very small, in fact, of the same order as the co-efficient of linear expansion of the electrodes of the experimental condensers. Hackett and Thomas (1941) made a thorough investigation of the effect of temperature on the electric strength of ruby and amber micas. Using specimens of 0.1 mm thickness, the apparent electric strength (electric strength in air) was found to be substantially constant up to 500°C for dark amber mica and up to 300°C for clear green, clear ruby, stained ruby, light brown ruby and silver amber micas. Above these temperatures the apparent electric strength fell rapidly until 700°C was attained and tended to a constant value up to 900°C. They also studied the effect of pre-heating on the electric strength of muscovite mica in air and observed no significant change in its value. It was, however, noticed that when a sample of muscovite mica was subjected to one hour's pre-heating at 150°C, there was a marked increase in its electric strength

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when tested in nitrobenzene at 20°C, where its premature breakdown is known to occur. This increase was greatest for light brown (96%) and least for the stained ruby (19%), with the result that pre-heating caused the apparent electric strength to be of the same order for all the muscovites. In view of the possible practical application of this effect, it was thought of interest to study it in detail. It may be noted here that the effect of pre-heating on other electrical properties of muscovite mica has received no attention as yet. The object of the present investigation was, therefore, to study the effect of pre-heating on the power-factor of different kinds of muscovite mica available in India, so that after suitable heat-treatment they might be efficiently employed in electrical industries where a low power-factor is very essential. Data were obtained to show the effect of the period of pre-heating at a particular temperature as well as of the effect of pre-heating temperatures on their power-factor.

EXPERIMENTAL

For the purpose of our investigation, the two varieties of muscovite mica, namely, the Bengal ruby and the Madras green, available in abundance in in the mica mines of Bihar and Madras respectively, were chosen. Each variety consisted of typical samples of the following qualities, *viz.*, (*i*) Clear, (*ii*) Stained and (*iii*) Stained and slightly spotted. For each quality of mica several test pieces, approximately 2 cm. by 1 cm. and of thickness varying from 2 to 3 mils were carefully cut or split from blocks kindly supplied by the Geological Survey of India. They were then examined carefully under a microscope and only those possessing uniformity in texture, colour and transparency without any pit or loose layer were chosen for test. The selected pieces were then devided into several lots, each lot containing not less than ten such pieces. At each pre-heating temperature, two or more such lots were used, one to study the effect of the period of pre-heating at that temperature and the other to study the effect of pre-heating temperatures in the range 100°C to 900°C on the power factor of a definite quality of ruby and green micas under investigation. For the latter purpose a pre-heating period of half-an-hour at each temperature was chosen.

An electrically heated muffle-furnace was used to pre-heat the test pieces to a desired temperature by adjusting its heating current to a suitable value with the help of an external rheostat. The temperature of the furnace was recorded by means of a calibrated platinum platinum-rhodium thermocouple. It was only when the temperature was found to be steady at a desired value that the mica test pieces were introduced into the furnace and kept there for a desired period. At the end of this period the test pieces were removed to a desiccator contaning anhydrous calcium chloride and fitted with a thermometer and were allowed to cool down to the room temperature. With each test piece, a test condenser was prepared after the method described in previous papers (Datta, Sen Gupta and Mahanti, 1943 ; Mahanti, Mukherjee and Roy, 1945). All such test condensers were then stored in another similar desiccator until measurements were made on them.

Measurements of power-factor and capacity of the test condensers were made by the method of substitution using the same standard condenser and the same Schering bridge as previously described (*loc. cit*). It has been shown that the true power-factor, ϕ_t, of a test condenser is obtained from the relation

$$\phi_t = (C_s/C_T)\,\phi'_T,$$

where ϕ'_T = the effective diluted power-factor of the test condeser, C_s = capacity of the bridge standard condenser in the third arm of the bridge before the substitution of test condenser, C_T = capacity of test condenser. The accuracy of measurements was checked from time to time by measuring the power-factor and permittivity of a standard sample of polyvsterene.

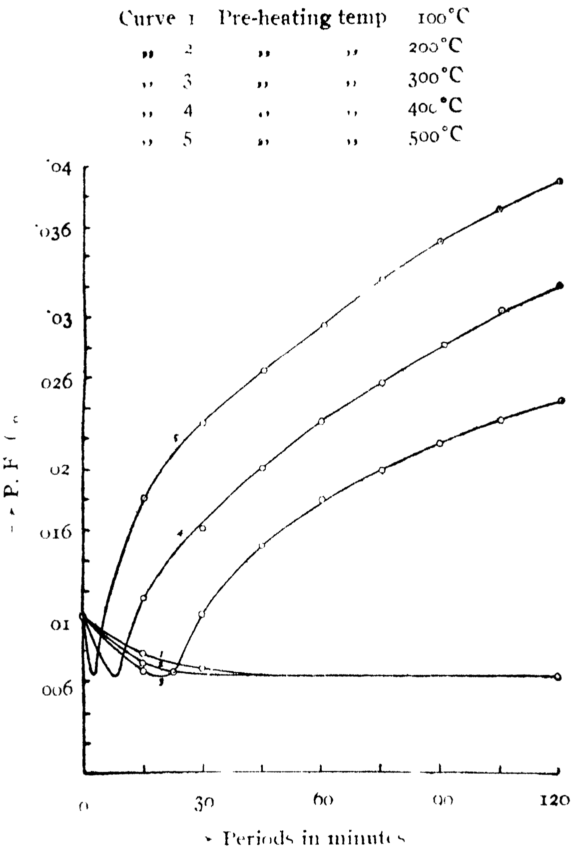

FIG. 1

Effect of Pre-heating Period on the Power-factor of mica
Bengal Ruby Red (Clear)

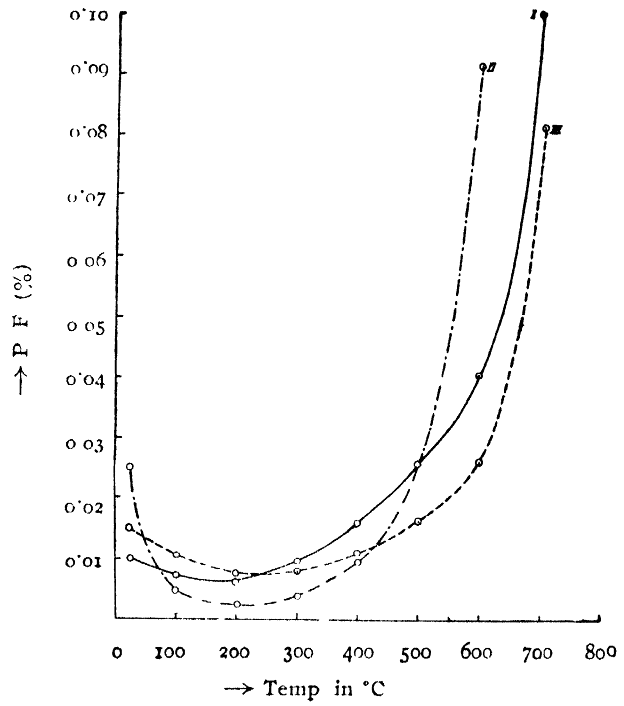

FIG. 2

Bengal Ruby Mica
I—Clear
II—Stained
III—Stained and spotted.

Typical data showing the effect of the period of pre-heating at a number of temperatures on the power-factor of Bengal ruby mica of the clear quality are given in Table I, and represented graphically in Fig. 1. In Tables II and III are included respectively the data of power-factor at various pre-heating temperatures for each quality of the Bengal ruby and Madras green mica and in Figs. 2 and 3, they are shown graphically. Value of power-factor recorded in each table is the average value of several measurements made on several test condensers at each pre-heating temperature.

It may be noted here that a visual inspection of the test pieces after their heat-treatment at different temperatures revealed no change in their colour, condition of surface, texture and transparency up to 500°C for Bengal ruby and up to 400°C for Madras green micas. Beyond these temperatures they were found, however, to lose gradually their transparency and develop silver-white patches on their surface. Finally these patches extended over the whole surface and changed in colour to light straw yellow. Their texture got loose, so much so, that even very fine laminations could be separated very easily out of them. Above 700°C, the test pieces began to swell and at 900°C, they were so delicate that even with a soft touch, they could be easily turned to dust. It was not possible to measure the power-

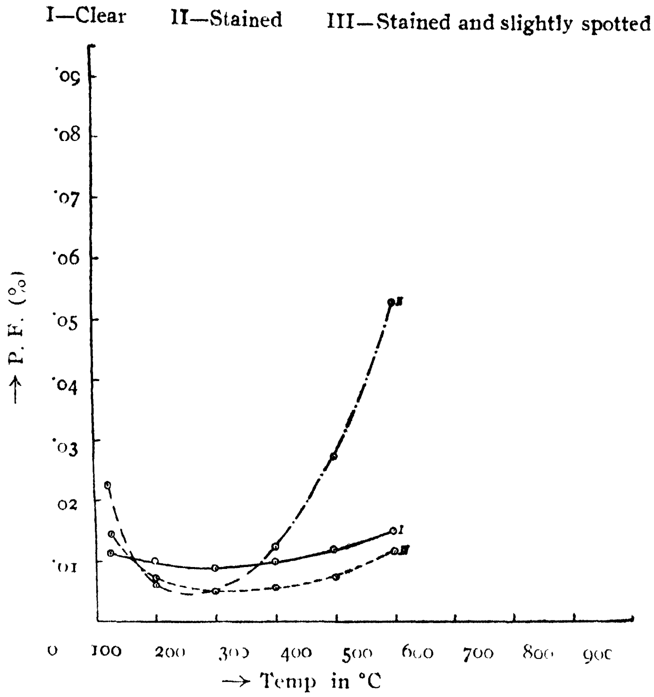

Fig. 3

Madras Green Mica

factor of any quality of Madras green mica above 500°C and of Bengal ruby mica above 700°C. The stained quality of the latter variety showed too high a power-factor even at 600°C and at 700°C, no measurement could be made.

Table I

Bengal Ruby Mica (Clear)

Thickness 2 mils

Average power-factor before pre-heating 0.0104%.

Pre-heating period in minutes	Average power-factor (%)				
	100°C	200°C	300°C	400°C	500°C
1.0	0.0102	0.0102	0.0102	0.0098	0.0094
2.5	0.0098	0.0096	0.0095	0.0085	0.0062
5.0	0.0094	0.0090	0.0088	0.0073	0.0098
7.5	0.0090	0.0086	0.0082	0.0062	0.0130
10.0	0.0085	0.0080	0.0074	0.0080	0.0152
15.0	0.0078	0.0072	0.0066	0.0114	0.0180
30.0	0.0068	0.0062	0.0104	0.0160	0.0230
45.0	0.0062	0.0062	0.0148	0.0200	0.0264
60.0	0.0062	0.0062	0.0178	0.0230	0.0294
75.0	0.0062	0.0062	0.0198	0.0256	0.0324
90.0	0.0062	0.0062	0.0216	0.0280	0.0348
105.0	0.0062	0.0062	0.0230	0.0302	0.0370
120.0	0.0062	0.0062	0.0244	0.0320	0.0388

TABLE II

Bengal Ruby Mica

Period of pre-heating 30 mins.

Pre-heating Temperature (°C)	Average power-factor (%)		
	Clean	Stained	Stained and slightly spotted
Room Temp.	0.0104	0.0252	0.0152
100	0.0068	0.0050	0.0105
200	0.0062	0.0038	0.0075
300	0.0101	0.0047	0.0089
400	0.0158	0.0099	0.0118
500	0.0255	0.0255	0.0162
600	0.0408	0.0910	0.0261
700	0.1036		0.0816

TABLE III

Madras Green Mica

Period of pre-heating 30 mins.

Pre-heating Temperature (°C)	Average power-factor (%)		
	Clean	Stained	Stained and slightly spotted
Room Temp	0.0116	0.0225	0.0145
100	0.0101	0.0061	0.0075
200	0.0083	0.0051	0.0050
300	0.0107	0.0125	0.0055
400	0.0120	0.0275	0.0075
500	0.0150	0.0530	0.0120

CONCLUSIONS

An inspection of the data in Table I or of the curves in Fig. 1 reveals the following interesting features :

(*i*) Irrespective of temperatures up to 500°C the power-factor of muscovite mica at first decreases from its value before heat-treatment with increasing period of pre-heating.

(*ii*) Between 100°C and 200°C, the power-factor first decreases and then attains a constant value after about half-an-hour heat-treatment at 200°C The lower the temperature of pre-heating, the larger is the period of heat-treatment after which the power-factor attains a constant value. At 200°C after about half-an-hour's heat-treatment the power-factor becomes constant.

(iii) Above 200°C and up to 500°C, and beyond which the muscovite mica becomes unsuitable for use after heat-treatment, the power factor although decreases at first, tends to increase with increasing period of pre-heating. The higher the temperature of heat-treatment, the smaller is the period during which the power-factor decreases.

From Tables II and III or from Figs. 2 and 3, it is evident that when the pre-heating temperature is increased, the power-factor of either variety of muscovite mica decreases from the value before heat-treatment to a minimum at about 200°C irrespective of the quality of mica and then increases rather rapidly to a very high value. From the present data, one is therefore led to conclude that to improve the power-factor of muscovite micas for their use in the manufacture of radio condensers, they should undergo a heat-treatment preferably at 200°C for a period not exceeding half-an-hour.

The above behaviour of mica is probably due to the presence of moisture which is completely driven off at 200°C. It is well known that micas usually include a small percentage of interlaminar water and water of crystallisation which can be expelled at and above the boiling point of water. This is distinct from the water of constitution which is only driven off from muscovite above 500°C. Hartschorn and Rushton (*loc. cit.*) are of opinion that the increase of power-factor with rise of temperature especially at low frequencies is due to the effects of dielectric absorption caused by the presence of moisture.

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