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Shellac-Amino Resin Blends as Moulded Insulators

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The electrical and thermal properties of moulded discs of shellac-butylated melamine resin and shellac-butylated urea resin blends with and without fillers have been studied from the point of view of their use in electrical industry. Tricresyl phosphate has been found to be a good plasticizer.

THE value of an insulator is judged by its electrical, mechanical and thermal properties and its chemical and moisture resistance. It must possess a good dielectric strength. More important is the dielectric constant, which determines the share of electrical stress absorbed by its material. The dielectric loss of the material determines the power loss and pinpoints the range over which the material can be safely used.

Islam *et al.*[1] determined the impact strength of shellac-melamine resin and shellac-urea resin blends with and without jute powder as filler. They found that the impact strength of the shellac-melamine resin blends increases as the amount of melamine resin in the blends increases, touching a maximum when 100 g shellac and 40 g of melamine resin are blended. There was actually 75% increase in the strength over that of pure shellac. In the case of urea resin blends, a mixture of 100 parts of shellac and 60 parts of resin was found to be the best. It was suggested that at this stage, shellac had gone into the reaction completely. The impact strength of shellac-melamine resin-jute stick powder blends was 5.48 kg cm/cm^2 compared to 4.3 kg cm/cm^2 for shellac-urea resin-jute stick blends. Islam *et al.*[1] also observed that while the water absorption was practically negligible in the case of the shellac-melamine resin blends, it decreased with increase in urea resin content in the case of shellac-urea resin blends.

The essential dielectric and heat transmission characteristics of these modified shellacs with and without fillers are presented in this communication.

Materials and methods

The method of preparation of solutes from varnishes is described elsewhere[2]. Cellulose, china clay and asbestos were used as fillers. For the preparation of homogeneous moulding powders, it was found by repeated experimentation that the filler has to be dried and added to the varnish before being precipitated in water. The ratio of resin to filler used in these studies was 1:1. Uniform discs could be obtained by adding 10% tricresyl phosphate as plasticizer, as the solutes had poor flow and it was considered necessary to add some plasticizer. The discs were moulded at a temperature of 120°C and pressures of 10,000 lb/sq in for 10 min and ejected at the same temperature. Stearic acid was found to be a good mould release agent.

The breakdown strength of the discs was determined as per ASTM D 149-55 T specification, in good grade transformer oil. The voltage across the sample was raised in steps of 2 kV for breakdown voltages greater than 25 kV and in steps of 1 kV for lower voltages at 1 min intervals.

The specimens (Table 1) were conditioned at 0% relative humidity for 48 hr before testing. The methods of measurement and assembly for the determination of dielectric constant and loss are described in an earlier paper[2]. The experimental assembly for the determination of volume resistivity consisted of a Rohde and Schwarz vacuum tube microammeter capable of measuring up to 10^{-3} μA. Instead of discs, thin films were used as specimens in order to increase the measurable resistivity range.

The conventional Lee's disc method was used for the determination of thermal conductivity of the discs.

Results and discussion

The log breakdown voltage (BDV)-log thickness curves for shellac-melamine resin blends with and without tricresyl phosphate as plasticizer are given in Fig. 1. It is seen that the addition of tricresyl phosphate affects the electrical strength of the blend. For specimens of shellac-melamine resin blends, the reduction in breakdown strength (BDS) is 20 V/mil. The log BDV-log thickness relationship for shellac-melamine resin blend discs containing 10% tricresyl phosphate and 100% filler is shown in Fig. 1. For a disc thickness of 100 mil, the BDS for discs containing cellulose, asbestos and china clay is 0.25, 0.29 and 2.07 kV/mil respectively. The curves indicate that the materials obey the law, $V=A^{n}t$ where A and n are empirical constants, V, BDS expressed in kV, and t, thickness in mm. If n is large, the material is said to withstand gaseous discharges. If A is high, the material possesses higher breakdown strength for small thicknesses. Data presented in Table 2 indicate that shellac-melamine resin blends are better than pure shellac, since they have higher n values. Addition of 5% tricresyl phosphate increases the value of n. Asbestos and cellulose pulp do not seem to be good as far as this property is concerned. The addition of china clay does not cause a substantial decrease in the value of n. On the other hand, discs with china clay or asbestos as filler have shown better dielectric strength for thicknesses less than 80 mil. These modified shellacs can be substituted for shellac, because their deformation temperature is as high as 120°C against 70-80°C for shellac.

Table 1 — Compositions of different samples

Sample No.	Shellac %	Butylated melamine formal-dehyde resin %	Butylated urea formal-dehyde resin %	TCP %	Filler %
SMF 64	60	40	—	—	—
SMF 64T	60	40	—	10	—
SMF–A	60	40	—	10	100 (Asbestos)
SMF–CH	60	40	—	10	100 (China clay)
SMF–CE	60	40	—	10	100 (Cellulose)
SUF–A	60	—	40	10	100 (Asbestos)
SUF–CH	60	—	40	10	100 (China clay)
SUF–CE	60	—	40	10	100 (Cellulose)

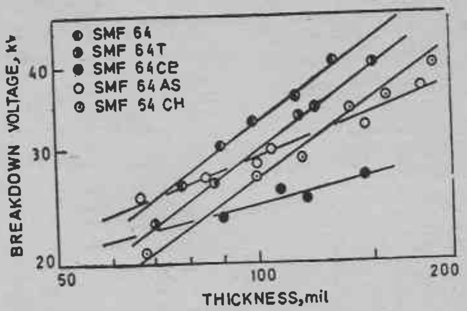

Fig. 1 — Log BDV *vs* log thickness plots for SMF compositions

The dielectric constant (ϵ') and loss (ϵ'') values for some of the modified shellacs at 100 Hz, 10 kHz and 100 kHz and at varying temperatures are given in Table 3. Composition SMF 64 shows very low dielectric loss over the entire frequency and temperature ranges covered. As pointed out earlier, it has good dielectric strength also. The only drawback with it is its lack of flow under heat because of quick polymerization. Addition of tricresyl phosphate up to 10% level is found to rectify this deficiency, but results in a slight decrease in the mechanical strength.

The fillers essentially have two effects on the dielectric constant and loss of these blends. In both shellac-butylated melamine resin blends (SMF) and, shellac-butylated urea resin (SUF) blends, while the dielectric loss increases with increase in temperature (the increase being more at lower frequencies), the dielectric constant tends to flatten out or decrease above 60° C (the decreasing tendency being noticeable above 10 kHz). Compositions SMF-A show minimum variation in dielectric loss with change in temperature and frequency. The resistivities of the compositions are given in Table 4. It is seen that the resistivities of the SMF compositions are lower than those of the shellac compositions.

Table 2 — Values of A and n for modified shellac compositions

Sample No.	A	n
SMF 64	18.94	0.693
SMF 64 T	15.26	0.774
SMF 64 CH	17.70	0.677
SMF 64 A	38.23	0.390
SMF 64 CE	60.17	0.215
SUF	23.90	0.467
Shellac	24.87	0.542

Table 3 — ϵ', ϵ'' values for SMF compositions without fillers

Sample No.	Temp. °C	ϵ' at frequencies of			ϵ'' at frequencies of		
		0.1 kHz	10 kHz	100 kHz	0.1 kHz	10 kHz	100 kHz
SMF 64	20	3.55	3.50	3.33	0.26	2.84	13.71
SMF 64	40	4.91	4.64	4.50	1.03	7.49	7.05
SMF 64	60	5.19	4.97	4.74	1.27	8.20	9.85
SMF 64	80	5.09	4.81	4.55	2.27	10.12	8.67
SMF 64	100	5.39	5.11	4.96	6.31	11.91	11.56
SMF 64 T	30	4.64	4.51	4.33	0.22	12.26	11.29
SMF 64 T	40	4.73	4.73	4.64	0.22	13.03	11.82
SMF 64 T	60	5.18	4.97	4.73	0.44	15.03	12.56
SMF 64 T	80	5.73	5.30	5.06	3.33	18.27	13.85
SMF 64 T	100	8.47	5.43	5.25	45.06	32.11	13.09

Table 4 — Resistivities of selected SMF compositions

Sample No.	Volume resistivity at 20°C (50%RH) (× 10^{13} ohm-cm)	Volume resistivity at 20°C (80%RH) (× 10^{13} ohm-cm)	Surface resistivity at 20°C (80% RH) (× 10^{13} ohm)
Shellac	235	100	110
SMF 64	40.8	15.8	17
SMF 64 T	45.1	14.2	17.2

Table 5 — Thermal conductivities of selected SMF compositions

Sample No.	Temp. of hot face °C	Temp. of cold face °C	Thickness in	Thermal conductivity ($K \times 10^5$) cal/g/cm²/°C
Shellac	—	—	—	51.8
SMF 64	58.5	46.5	0.15	46.7
SMF 64 T	58.6	46.6	0.15	46.7

Thermal conductivity data for the blends are given in Table 5. There is not much variation in the thermal conductivity of the specimens from that of pure shellac. It is evident that for the development of suitable moulded insulators, the procedure of precipitating the varnish and drying it will be uneconomical. But at the same time, the electrical and mechanical properties of this SMF combination are better than those of ordinary shellac insulators because of higher dielectric strength and discharge resistance, low water absorption, higher mechanical strength, higher dielectric constant and low loss and moderate thermal conductivity. Recently, Bhattacharya (personal communication) studied the anti-tacking properties of these blends and found them to be excellent.

The specific gravity of SMF 64 composition is 1.16, and the cost of the material works out to nearly Rs 10/kg, when the cost of the material only is taken into consideration. In effect, for double the price of shellac (shellac price has been put at Rs 5/kg in the calculations), a material having good insulating properties is obtained.

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