On the Arc Resistance of the Silicone Resin

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The arc resistance of the silicone resin was measured with ASTM-D495-46T test, and the results were as follows :

(1) The arc resistance of the alkyl silicone resin was too high to be measured. (2) The phenyl-alkyl silicone resin showed a lower arc resistance than the alkyl silicone resin, and fewer the number of carbons in resin, the higher the arc resistance was. (3) The arc resistances of some phenylalkyl silicone resins were influenced by the curing temperature, and this feature seemed to be related with heat stability.

I. INTRODUCTION

The arc resistance is an withstanding ability of insulating materials exposed to electric arcing. Although many methods to measure the arc resistance are presented, there is no unique method adequate to estimate this ability, because the phenomena on electric arcing are considerably ambiguous. Among these methods, however, the ASTM-D495 arc test seemed to be more adequate[1], and the author adopted this testing method. In this method, a high voltage and low current arc is applied to a test piece, and generally the results by this method will not directly be applied to the case of large current arc, but approximately may be applied to organic materials, especially thermosetting resin.

II. METHOD OF MEASURENMENT

The ASTM-D495-46T test has been partially revised as the D495-48T. Except the case of low arc resistance—for instance, phenolic resin—, however, the difference between the results by 46T and 48T may generally be very small,

Table 1. Sequence of one-minute current steps

Step	Current mA	Time cycle	Total time, sec.
I	10	¼ sec. on, 1¾ sec. off	60
II	10	¼ sec. on, ¾ sec. off	120
III	10	¼ sec. on, ¼ sec. off	180
IV	10	continuous	240
V	20	〃	300
VI	30	〃	360
VII	40	〃	420

because the phenomena on the electric arc are considerably ambiguous. Then for convenience the author adopted D495-46T of which the apparatus was more simple. The method is as follows. A pair of tungsten electrodes of which the diameters are 0.060 in., the end points are made conical (60° cone angle), and the separation is 0.320 in., was put on the surface of the test piece at the angle of 45°. The arc between the electrodes is given as shown in Table 1. According to the D495-46T, the testing step over 420 sec was given, but such steps seemed to be insignificant in the case of low current arc and so they are omitted in Table 1 according to the D495-48T.

When the electric insulating ability of the testing surface between electrodes is lost, the arc is quenched, and the arc maintaining duration is defined as the arc resistance of an insulating solid.

In this work plates of cured silicone resin of about 3mm thick were used as the test pieces.

III. RESULTS AND DISCUSSION

The results are summarized in Fig. 1, in which the values of arc resistance are the mean of ten times measurements. In this figure, E means ethyl radical,

Arc resistance (sec.)	Materials
	Alkyl-silicone resin
420	
	MP-1.6 (at 200°C)
	Laminated glass-silicone resin*
	Molded glass-silicone resin*
360	
	EP-1.4 (at 200°C)
	Asbestos cemented
300	
	Glass-b
240	
	DC-996, MP-1.6, EP-1.4 (at 150°C)
	Glass-a
180	
	EP-1.6 (at 150°C)
120	
	Molded urea resin
60	
	PVC resin
	Phenolic resin
0	Wood

* Alkyl-silicone resin

Fig. 1.

M methyl radical, P phenyl radical and 1.4 or 1.6 is the ratio of organic radical (R) to silicon (Si)——R/Si. For comparison, the other materials than silicone resin were measured and their values are also shown in Fig. 1. Thus the followings are observed.

(1) The arc resistance of the silicone resin is generally very larger than the other organic materials. (2) In the silicone resin, the arc resistances of the alkyl silicone resins are all over 420 sec. On the other hand, the arc resistance of phenyl-silicone resin is smaller. (3) The arc resistance of MP-1.6 resin (M : P : Si=1 : 0.6 :1) and EP-1.4 resin (E : P : Si=1 : 0.4 :1) which were prepared by way of experiment were dependent on the curing temperature. On the other hand, DC-996 which is the trade name of a silicone resin produced by Dow Corning Co. and seems to have a similar composition to MP-1.6[1], showed no change in the arc resistance value irrespective of the curing temperature.

1. **Effect of Curing Condition.** The effect of curing condition on the arc resistance were measured on the phenyl silicone resin.

At first, the relation between curing time and arc resistance for resins cured

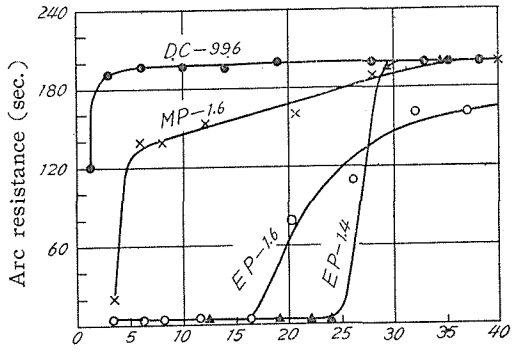

Fig. 2.

at 150°C is shown in Fig. 2. As noticed from this result, after long curing, MP-1.6, EP-1.4 and DC-996 resins showed almost the same arc resistance. Only the DC-996 resin, however, reached to the saturated value rapidly.

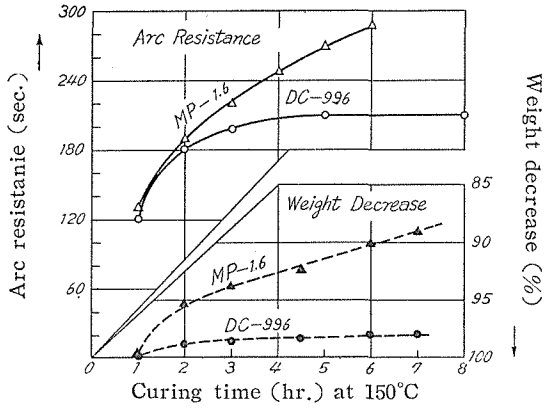

Fig. 3.

Next, when these samples were cured at 200°C, DC-996 resin showed the same value, but the experimentally produced resins showed gradualy higher values than the values when cured at 150°C. The relations between arc resistance and curing time at 200°C for MP-1.6 and DC-996 risins are shown in Fig. 3.

It was considered that this phenomenon was caused by the difference in the inner structure of high polymer. Even though the ratio (R/Si) of organic radicals to silicon in monomer was the same, the different process of polycondensation might produce a polymer of different structure. (An evidence of this phenomenon was given by X-ray diffraction.[3]) In the polycondensation process, smaller chain molecules—especially cyclic molecules—might be considerably evaporated by heating. Considering the relation between arc resistance and molecular structure of the silicone sesin, the carbonization of organic radical may give the main effect on the arc resistance, and generally the more the number of carbon in compounds the lower the value of arc resistance may be. In this case, the phenyl radical especially may give larger effects. This idea shows a good agreement with the results in Fig. 1 in which the alkyl silicone resins have larger values of arc resistance than those of phenyl silicone resin. Thus the evaporation of lower polymers such as cyclic ones means the decrease of phenyl radical per unit volume, and may result in the increase of the arc resisiance. Concerning this speculation, the weight change by heating was measured, and the results are shown in Fig. 3. In this measurement, the weight decrease by the evaporation of solvents in silicone varnish was large at the first period of drying, and to examine the true weight decrease in the silicone resin itself, the weight of the test piece put in oven after one hour was defined as a referenceweight with no solvent (Fig. 3). It is found from Fig. 3 that the change of the arc resistance by curing is very analogous to that of the weight decrease. This fact may be consistent with the above-mentioned speculation. From the viewpoint of the arc resistance alone, the experimentally produced MP-1.6 resin may be a good materials, although the heat stability is poor. It is concluded that DC-996 may have fewer low polymer than the experimentally produced resin.

Thus we may apply the measurement of the arc resistance to the study of the molecular structure of any silicone resin. These phenomena, however, were recognized only in the phenyl silicone resin. On the other hand, at any curing temperature the alkyl silicone resin showed the arc resistance value of over 420 sec. These facts would suggest that the phenyl radical is a main factor of decreasing the arc resistance in the silicone resin.

2. **Relation between Arc Resistance and Type of Silicone Resin.** The differences of arc resistance in the type of silicone resin are partially discussed in Section 1. In this section, they are summarily discussed. As a general rule, the fewer the number of carbon atoms in organic radical is, the lower the arc resistance is.

(a) In the compounds having the same organic radicals, the resin with large R/Si shows a high arc resistance. For instance, in Fig. 2, EP-1.4 resin shows higher value than EP-1.6.

(b) The alkyl silicone resin shows a very high arc resistance of over 420 sec.,

but such a resin is also affected by electric arcing and is gradually deteriorated. In spite of these deterioration, the carbon tracking is not formed on the resin and the electric arcing is maintained. So we may say that the ASTM-D495 test is no adequate method to determine the ability withstanding the electric arcing of such a compound. For such a compound, a new different method is desired. Although it is still open to question, the non-trackng ability of the alkyl silicone is its excellent characteristics differing from the phenyl alkyl silicone.

(c) The phenyl-alkyl silicone resins polymerized from the same monomer do not always show the same arc resistance, and their values are dependent on the curing temperature in the polymerization process.

IV. CONCLUSION

As mentioned above, it is found that for the purpose to estimate the composition and inner structure of the silicone resin, the measurement of the arc resistance is useful and that this method is very simple compared with the other methods for this purpose.

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