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THIN INSULATOR SHAPES

PDO 6984249, Final Report

J. C. Daly, Project Leader

Project Team:
R. J. Melton

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**Kansas City
Division**

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Prepared by J. C. Daly, D/814, under PDO 6984249

Electrical insulator material of less than 0.020-inch thickness with a potential of withstanding 80 kilovolts was requested for an experimental program. Materials such as fluorocarbons, polysulfones, and polyimides may have this capability, if the resin is sufficiently clean and the correct assembly environment is provided. Various processes were investigated for fabricating one full and one half-size insulator.

Several fabricating techniques were tried to produce a final part: tape wrapping and sintering, emulsion coating with final sintering, solvent deposition of soluble thermoplastic materials, and fluidized bed coating and final sizing of a hot-melt, coated mandrel.

These investigations substantiated, in part, the initial supposition that plastic materials currently available are capable of high levels of dielectric strength, if both the material and assembly area are thoroughly clean and if cleanliness of the environment is controlled. Unfortunately, the results of the effects were not sufficient to obtain the 8000 volts/mil desired by the customer. The highest value attained was approximately 5000 volts/mil.

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THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

A prime contractor for the
Atomic Energy Commission
Contract Number AT(29-1)-613 USAEC

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SUMMARY

The project was originated to support experimental work. Initial effort was placed on tape coating a full-size mandrel. Two types of fluorocarbon tapes were formed into the shape, and then sintered at 650°F to form a continuous barrier. While one of these units had an electrical failure level of 42 kilovolts DC, the others were well below this level at failure. This technique was discarded because wrapping was difficult in the laboratory and handling the good dielectric material attracted dirt which, in turn, caused electrical failures. The electrical fixture shown in Figure 1 was used for these tests. Also, sintering required a high temperature of 650°F, which tended to oxidize the copper form used as a base.

*Coating is extended to eliminate breakdown.

Figure 1. Electrical Fixture for Testing Dielectric Strength

The project plan scheduled investigations into emulsion coating using Teflon dispersions 30 and 41X, which are based on tetrafluoroethylene, and Teflon dispersion 120, which is based on fluorinated ethylene-propylene (FEP)*. It was also proposed that fluidized bed applications be refined to produce a finished part of 0.020- to 0.025-inch thickness without a final machining operation. Materials proposed for this part of the project were Teflon FEP powder, a high-density polyethylene (Corvel), ** Phenoxy, *** and polyimide powder from the 3M Company. The same forms, half scale as shown in Figures 2 and 4 were to be used for solvent and varnish deposition methods. Materials available for this phase of the investigation were XPI 182, an experimental polyimide from American Cyanamide Corporation; and Polymer 360 varnish, a polyaryl sulfone from the 3M Company.

The original plan discussed above was modified to evaluate a hypothesis discussed with the Design Agency. Wrapping with fluorocarbon polymer tape was attempted to test the theory that starting material of high polymer weights would produce better electrical results. Teflon tape was originally proposed and tried but polychlorotrifluoroethylene copolymer (KEL-F) tape was substituted in the last four units because of fabrication ease and ability to measure the molecular weight. The highest electrical operating level was achieved with high molecular weight KEL-F as shown in Table 1.

Progress on the project was impeded by equipment failures, lack of environmental controls, safety considerations, and mold release problems. These combined to delay all phases of the work too long for an effective investigation. For example, the emulsion coating technique was tried with existing in-plant equipment; this technique proved inadequate from both application and cosmetic requirements. It was then decided to design and build a recycling hood; lack of priority delayed the design and installation of this hood. Handling equipment for 30-percent solids solutions was ordered, but the potential corrosive nature of the solvents required special heat exchangers which delayed delivery six months. Fortunately, fluidized bed equipment was on hand. This permitted investigation of the fluid bed coating process. Since polyethylene resins were involved, and since it was desired that parts be produced to specific wall thicknesses, the mold shown in Figures 2 and 4 was obtained. This mold permitted coating of the male mandrel which could then be placed in the female portion and sized by pressing, as shown in Figure 4. Parts produced by this method are shown in Figure 3. A limited sample experiment was conducted with Eastman Chemical Company Polycarbonate K-1, the results of which are shown in Table 2.

*E. I. du Pont de Nemours and Co. Inc.

**Polymer Corp.

***Union Carbide Corp.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to investigate some methods of forming materials which exhibited a good level of potential dielectric standoff. The forming was to be accomplished without subsequent finishing operations, if possible. The requirement of avoiding the final machining operation stemmed from an observation by the Design Agency that plastic materials generally appear to lose the ability to stand high electrical differential when the naturally formed surface is disturbed. The problem occurs particularly with materials having the ability to withstand voltages in excess of 6000 volts per mil. These and other observations have been made by J. C. Anderson in the 1964 edition of Dielectrics.¹ The phenomena is probably best understood from that part of the discussion in which Anderson describes the disturbance of the molecular segment which causes an imbalance in the intrinsic properties of the material, contributes to a thermal instability, and is followed by the discharge breakdown phenomenon.

PRIOR WORK

No related prior work has been done at Bendix Kansas City.

ACTIVITY

In an effort to circumvent the problems contributed by final machine finishing, other fabrication techniques were proposed. The first of these was a wrapping technique. By this method, the tape of the desired material would be wrapped half-lap over itself and fused into a solid mass by increasing the temperature to the softening point for the polymer. The material would then soften and form a solid sheath or part. The limitations of this approach are that all surfaces to be coated must be positive projected surfaces. Use of this technique was attempted with KEL-F and Teflon TFE films. Six attempts were made on a full-scale conical part supplied by Development Support Engineering.

Wrapping the cones did not produce a very reliable structure because of steppage and irregularities. The best parts in the series of tests were produced by the lapped lay-up pattern of film on contact paper or by using a sheet of material cut to the conical shape. The desired shape was cut using sheet metal pattern techniques, placed on the part, and fused at 600°F. The best appearing part was produced using sheet, while the best electrical part was made from lapped film. These materials produced parts which failed at 42 kilovolts DC (2 kilovolts/second loading) and withstood a 30-kilovolt surge but not a 40-kilovolt surge. The material was ultra-high molecular

weight KEL-F. The maximum breakdown voltage from parts made with this material was 26 kilovolts. Two other parts made of KEL-F having a normal commercial molecular weight failed at 31 and 34 kilovolts (Table 1).

Use of the above material was encouraging and led to another attempt involving an emulsion available from DuPont. With these materials a good spray system is needed to obtain coverage. The equipment available at the time used air as a propelling medium and resulted in spotty coverage and inclusions in the coating. An airless sprayer was obtained to improve spray coverage. The most effective unit available had the advantage of being equipped with a heater for warming the spray solutions which made it possible to handle more viscous solutions. The unit was also fitted with an electrostatic charging unit which, it was felt, would be helpful when the emulsions were sprayed. It originally appeared that the desired unit with a stainless steel heater would be readily available. However, the equipment ordered could only be supplied for 220-volt service which was not immediately available in the Materials Engineering Laboratory. A request was made for this service and four months were required for installation. Additional delay and problems were experienced, particularly with the heat exchanger, further delaying the application. The plan called for using the male portion of the heated mold as a spray mandrel. The cone at the extreme right rear of Figure 3 was prepared with this equipment in June, 1969.

Problems encountered in assembling existing pieces of equipment and obtaining supporting services limited the productive output of the investigation. A final problem of a mold release usable at 500°F made production of the required parts impossible in the time span of the project. Mold release was finally achieved near the end of the project by using a combination of ingredients. This release agent is capable of withstanding the high temperatures required for material-forming techniques used in this project. The release has an added advantage of being completely removable by washing. A patent disclosure was filed on the mold release,² but not pursued by Bendix since each ingredient had release properties previously covered in individual patents by the corporations producing the respective materials.

A secondary achievement of the project was that the limited generation of data indicated the magnitude of difference in electrical characteristics obtainable when maintaining even minimal cleanliness standards with the material. These results are especially dramatic at higher electrical stress levels. As shown in Table 2, the values achieved for Polymer K-1, made in a protected enclosure, were 3100 to 4800 volts/mil in a 0.0075-inch thickness, which compares to the 2500 volts/mil normally obtained.

Figure 2. Diagram of Male and Female Portions of Mold Used to Produce Parts

Figure 3. Parts Produced by Molding Operation

Figure 4. Prototype Equipment Used for Molding to Size

Table 1. Fluorocarbon Insulation Tests

Sample	Description of Insulation	Type of Fluorocarbon	Test Results
1	0.005-inch thick sheet, 3 layers	Polytetrafluoroethylene Teflon TFE	Not tested
2	0.005-inch thick sheet, 3 layers	Teflon TFE	Arcing at 20 KV DC in air Arcing at 26 KV DC in oil
3	Not recorded	Polychlorotrifluoro- ethylene KEL-F 300 series	Failed at 34 KV DC
4	0.005-inch thick tape lay-up, 3 layers	Low (150 second)* zero strength time material	Failed at 31 KV DC in seam
5	0.007-inch thick tape lay-up, 2 layers	High (289 second) zero strength time material	Potential applied at 2KV/Sec failed at 42 KV DC
6	0.005-inch thick tape wrapped longitudinally	Low (150 second) zero strength time material	Not tested; too much mate- rial buildup at top; material did not fuse at bottom.
* Zero strength time test per ASTM D-1430			

Table 2. Dielectric Breakdown Strength For Eastman K-1

Six-Inch Diameter Laboratory 2000 ml/Flask		
Voltage Breakdown (kv DC)	Sample Thickness ($\times 10^{-2}$)	Volts/Mil
36.0	7.5	4800
25.0	7.4	3380
25.0	8.0	3125
Film Cast in Hood		
12.50	5.0	2500

Shrinkage rates for both the fluidized bed techniques and the solvent casting techniques were much larger than had originally been anticipated. The magnitudes indicate some factor beyond polymer shrinkages. Perhaps crystalline changes, solvent removal, and differential coefficient of thermal expansion are the causes.

ACCOMPLISHMENTS

Test results indicated that currently available plastic materials have high dielectric strength (5000 volts/mil) if both the material and assembly area are thoroughly clean and if cleanliness of the environment is controlled.

A mold release which would work satisfactorily at 500 degrees C was developed.

FUTURE WORK

The problems encountered in this study will need investigation and resolution before the production items can be achieved. Unfortunately, the general types of shapes and fabrication problems discussed are common to an increasing number of Design Agency requests. It is recommended that a new project be funded to further investigate fabrication techniques with the materials discussed herein and the newer materials, such as polyquinoxalines, polyimides, and polysulfones.

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REFERENCES

- ¹J. C. Anderson, Dielectrics. London: Chapman and Hall (1964).
- ²"Inorganic Polytetrafluorocarbon Processing Aid," Patent Disclosure P-282 (December 19, 1969).