ADHESIVE AND INSULATING SYSTEMS FOR CRYOGENIC AND SUPERCONDUCTING COILS

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A primary goal in designing a superconducting coil is mechanical stability. It may also be desirable to provide some interturn insulation for coils using large ratios of copper to superconductor. If the superconductor is in strip form for winding into edge-cooled pancakes, an organic adhesive and insulation can provide a convenient means of meeting these criteria. Such an organic system must provide enough flexibility at liquid helium temperatures to accommodate relative motions due to temperature differentials or differences in thermal expansion. Very few organic materials are known to retain any appreciable ultimate elongation at liquid helium temperatures. At liquid nitrogen temperatures fluorinated olefins (Teflons), polyimides (Kapton), polyethylene terephthalate (Mylar), and some polyurethanes retain an ultimate elongation of a few percent. Only the polyurethanes are practical adhesives for large coils and their sensitivity to moisture is a problem during coil assembly.

A practical solution is a two-component system consisting of an insulating film with good elongation properties and a strong adhesive used in a very thin layer. The elongation of the film protects the adhesive from excessive stress if the adhesive is thin enough that it does not fracture due to stress from its own high coefficient of thermal expansion. A two-component system consisting of fluorinated ethylene-propylene (FEP) film and an epoxy adhesive has been investigated for use as a cryogenic adhesive system by Narmco for NASA. A similar system seemed an excellent choice for bonding the superconducting coils for the ANL 12-Foot Bubble Chamber, and was investigated accordingly.

Figure 1 shows the coils for the 12-Foot Bubble Chamber stacked and ready to install in their cryostat. These coils are wound from copper strip 0.100 inch x 2 inches containing six niobium-titanium superconducting wires. The strips are wound into 30 single-layer pancakes, 15.7 foot inside diameters and 17.3 foot outside diameters. The copper was sandblasted just prior to winding. The adhesive used was 100 parts by weight of Shell epoxy 828 with 100 parts of General Mills polyamide 8140 and 10 parts of phenyl glycidyl ether. The interlayer was 0.010 inch of tetrafluoroethylene resin filled with 15% of glass fiber and etched for bonding. The 0.010 inch of filled TFE gave results similar to the 0.005 inch of unfilled FEP used in nearly all tests; except that it handled a little better and the glass content was psychologically advantageous. The coil was designed and built under the direction of John Purcell and has been tested to 18.5 kilogauss successfully.

Figure 2 shows the assembly of a pancake. In the central foreground is a reel of TFE film and a small adhesive roller coater. The copper strip (with imbedded superconductors) enters from the lower left where it has just been automatically sandblasted. The copper strip and the adhesive-coated TFE film are wound together on the coil form. A portion of the completed coil is shown in the background. The men are tightening clamps to align the turns vertically. After winding and curing, excess resin on the top and bottom surfaces of the coil is removed by a hand-held wire brush (the conductor edges were mold released before winding).
Figure 3 shows the 11% increase in block shear and the 25-30% increase in lap-shear values due to adding the proper thickness of FEP interlayer. The greater percent increase in the lap-shear tests is due to the tendency for greater stress concentration in such a test and therefore a greater need for a thick elastic interlayer. In fact, a comparison of the lap and block shear curves reveals that in the former case a 0.004 inch thick FEP layer is optimum and in the latter case a 0.002 inch thick layer is optimum.

Figure 4 shows the increase in block shear and the decrease in average deviation due to thinner epoxy glue lines which in turn result from increasing curing pressure.

Figure 5 illustrates that the room-temperature creep of highly stressed FEP is eliminated in adhesive-bonded thin layers.

In an investigation of surface preparations, it was found that copper washed with acetone and bonded to commercially etched FEP gave a block shear of 1.6 ± 0.1 kpsi at 77°K while sandblasting prior to the acetone wash gave 8.6 ± 2.1 kpsi. Laboratory re-etching of the FEP or acetone washing did not change the adhesive strength.

In a comparison trial, 0.005 inch Kapton was found equivalent to 0.005 inch of FEP at 77°K, slightly inferior at 300°K, and it would undoubtedly be superior at higher temperatures with the proper adhesive, like the amine-cured system described below.

Additional information on the properties of the two-component bonding system has been obtained in connection with the problem of bonding the glass hemispherical windows to their titanium flanges for the optical system of the 12-Foot Bubble Chamber. This data is presented in Figure 6 which shows the increase in lap-shear strength due to the addition of an FEP film. In the case of the glass-to-titanium samples, all failures were in the glass, and the curve illustrates how the FEP, at first, reduces the stress level in the glass and then increases it because of its high coefficient of thermal expansion. The final epoxy selected was Shell 828 resin cured with 22.5 phr of Jones Dabney 841 aromatic amine curing agent. However, the data presented are for 828 resin cured with 90 phr of "NADIC" methyl anhydride and 1% accelerator. The amine cure system was used because it has a lower weight loss under vacuum at 473°K which is the degassing temperature of the vacuum system.

References
