

Preliminary Report on Stycast 2850FT

TS-SSC 90-053

Steve Delchamps
September 4, 1990

Introduction. Loss of prestress in the end clamps of short SSC dipole magnets has been attributed to the thermal contraction of the G-10 insulating pieces (Fermilab drawings 0102-MC-217722 and 0102-MC-217770), which is larger than the contraction of the surrounding stainless steel cylinder (Fermilab drawings 0102-MC-217769 and 0102-MC-217725.)

Two solutions to this problem have been proposed so far: 1) The replacement of the G-10 parts with cast pieces made of "Stycast" (see below) and 2) The use of G-10 parts with the fiber planes perpendicular to the magnet axis, so that contraction in the radial direction is minimized.

At this time, G-10 parts with the fiber planes perpendicular to the magnet axis are on order, and are expected to be available in the middle of September. Meanwhile, lead and return end insulator pieces have been cast in Lab 5 from Stycast 2850FT, have had their dimensions checked with the Cordax 1808 in the ICB quality assurance lab, and are available for installation in DS0311.

We have been hesitating over using the Stycast pieces because while we know from various verbal sources that Stycast is supposed to match the thermal contraction of metals quite well, we have not had quantitative in-house experimental evidence that these claims are true. This memo describes progress made so far on investigating the thermal contraction properties of Stycast 2850FT.

Stycast. The epoxy resin Stycast is in reality a large family of resins available from Emerson and Cuming, Inc. There are about fifty Stycast resins available, and several curing agents may be used with each resin. A complete catalog of Stycast resins and curing agents may be obtained from Jay Hoffman in Lab 5.

The variety of Stycast which has been used in low temperature applications at Fermilab (see for example, reference 4) is Stycast 2850FT. There are actually two kinds of 2850FT, a blue and a black. The blue is used in high voltage applications because of its superior dielectric strength. As far as I know, only the blue kind has been used at Fermilab in the past. The curing agent used has normally been Catalyst 24LV (LV stands for "low viscosity.") Catalyst 24LV does not require an oven cure.

All Stycast resins are proprietary, and no reference I have been able to find so far specifies the composition of the Stycast resin. Stycast 2850FT is a "filled" epoxy resin, that is, a standard resin with material added to modify the thermal and dielectric properties of the final cured material. Jay Hoffman in Lab 5 has isolated the filler from 2850FT. It is a white powder with about the right density and appearance to be alumina (Al_2O_3), but it has not been chemically analyzed.

I wish to clear up at this point one confusing bit of terminology that has been complicating these investigations. This is the term "loaded." As stated, Stycast 2850FT is a *filled* epoxy resin. If the term "loaded" is used to mean "filled," then the Stycast of which we have samples is indeed "loaded Stycast." If the term "loaded" is used to refer to an external load placed on the sample during the curing process, as I have heard at least one knowledgeable person use it, then the Stycast of which we have samples is NOT "loaded Stycast."

Existing Thermal Data. I have obtained from Jay Hoffman the specification sheet on Stycast 2850FT from the Emerson and Cuming catalog. It lists the room temperature properties of Stycast 2850FT cured with Catalyst 11. In particular, the thermal expansion coefficient is given as 29ppm/C. (Type 316 stainless steel has 16.0ppm/C, while the normal range for unfilled epoxies is 30-60ppm/C.)

Since Stycast 2850FT is supposed to match the thermal contraction properties of metals, the manufacturer's data seem surprisingly close to the lower range of unfilled epoxy values. However, the *integrated* contraction between room temperature and liquid helium temperature depends on the details of the thermal expansion as a function of absolute temperature.

Moyses Kuchnir has provided me with two references to the thermal contraction properties of Stycast and other epoxies. These are reference 1 and reference 2.

The authors of reference 1 give data for several Stycast resins including 2850FT. They present results for Stycast 2850FT with and without additional fused quartz (SiO_2 .) In both cases, they used the curing agent Catalyst 11. They don't specify the blue or the black variety of 2850FT resin.

The integrated contraction ($L_{300} - L_4 / L_{300}$) for Stycast 2850FT with no extra filler is 4.2×10^{-3} . (For comparison, they give 3.1×10^{-3} for 304 type stainless steel.) With the additional fused quartz filler, they obtain 3.0×10^{-3} , from which they conclude that it is possible to match the properties of stainless steel quite well by modifying commercially available Stycast 2850FT with extra filler.

The authors of reference 2 give results for several varieties of Stycast resin, cured with various curing agents, including 24LV. For the curing agent Catalyst 11, they obtain an integrated contraction of 5.0×10^{-3} and 5.1×10^{-3} , depending upon the percentage of curing agent used. Both of these values are higher than the values in reference 1. Stycast 2850FT cured with catalyst 24LV gives an integrated contraction of 5.3×10^{-3} .

Moyses Kuchnir has pointed out to me that reference 1 and reference 2 are 23 and 15 years old respectively. The properties of commercially available epoxy resins may change over these time scales. For this reason, a dilatometer measurement is scheduled early this week in Lab 5 to determine the thermal contraction curve for Stycast 2850FT cured with Catalyst 24LV.

Reference 5, which I obtained from Masayoshi Wake, gives thermal contraction data for various filled epoxies with which Wake and the other authors experimented in Japan.

Our Measurement. On the suggestion of Masayoshi Wake, we performed a simple measurement in Lab 2 of the integrated contraction of pieces of several materials between room temperature and liquid nitrogen temperature.

The stycast sample was a 1 inch diameter cylinder of Stycast 2850FT cured with 24LV catalyst measuring 2.878+/- 1 inches at room temperature (299.7K.) A 1 inch diameter stainless steel (type 304) cylinder measuring 2.875 inches at room temperature was prepared for comparison.

Both cylinders were measured before and after immersion in a liquid nitrogen bath. The cylinders were kept immersed in the liquid for several minutes, and then withdrawn and measured with hand calipers as quickly as possible. The fractional contraction of the steel cylinder was 2.78×10^{-3} . The Stycast cylinder value was 4.87×10^{-3} . This is close to what would be expected from reference 2.

We also measured the contraction of two G-10 pieces. The first was a cylinder 1 7/8 inches in diameter, measuring 1.030 inches in length at room temperature. The fiber planes in this piece ran perpendicular to the axis of the cylinder. The fractional contraction along the axis of the cylinder (perpendicular to the fiber planes) was 9.71×10^{-3} , quite a bit larger than the Stycast or the stainless steel.

The second G-10 piece was a hollow circular cylinder (outer diameter .5 inches, thickness .065 inches) with the fiber planes running in the azimuthal direction. The room temperature length of the cylinder was 2.868 inches. The fractional contraction along the axis of the cylinder (in the plane of the fiber layers) was found to be 1.39×10^{-3} . This is the smallest of any of the values obtained, including the stainless steel.

Conclusions. There is some evidence that insulator pieces cast from Stycast 2850FT cured with Catalyst 24LV will have less radial thermal contraction than the standard G-10 insulators, in which the fiber planes lie parallel to the magnet axis.

There is evidence in the literature that 1) further filling of the Stycast resin and 2) curing with Catalyst 11 can further lower the integrated contraction of the insulator pieces.

Finally, the preliminary indication is that G-10 with the fiber planes parallel to the radial direction will give the smallest thermal contraction of any of the materials suggested so far.

Still to Come. As mentioned above, we plan to do our own measurement of the thermal contraction curve of Stycast 2850FT in Lab 5 this week. Furthermore, we have yet to determine the chemical composition of the filler of commercial 2850FT resin, or to experiment with samples cured with catalysts other than 28LV or with modified (e.g. quartz filled) resin.

References

- 1) W.O. Hamilton, D.B. Greene and D.E. Davidson, Thermal Expansion Properties of Epoxies between 2 and 300K, Review of Scientific Instruments, Vol. 39, No. 5, 645-648, May 1967.
- 2) M.J. Mackowski, K.E. West, D.A. Samsel, L.B. Holdeman and P.N. Peters, Expansion coefficients of some epoxies in the temperature range 4-300 K, Cryogenics, January 1976.
- 3) Emerson and Cuming, Inc. Data Sheet.
- 4) M. Kuchnir, Fabrication of Cryogenic Electrical Feedthroughs, TM-596, August 8, 1975.
- 5) K. Ishibashi, M. Wake, M. Kobayashi, and A. Katase, Powder-Filled Epoxy Resin Composites of Adjustable Thermal Contraction, Proceedings of the International Cryogenic Materials and Composites, Munich, July 10-11, 1978.