BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division

Magnet Note

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Topic: Common Coil Design

Title: Vacuum Impregnation Techniques for Common Coil Test Cassettes

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Vacuum Impregnation Techniques for Common Coil test cassettes.

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The common coil test magnets are two dimensional coil packs, made with reacted niobium tin or hts flat cable wound on a flat bobbin. Due to the brittle nature of both cable types after reaction, the normal collaring and assembly techniques in practice worldwide can cause damage to the conductors. The assembly techniques used in themselves are not sufficient to guarantee training free performance, or even the ability to prevent conductor damage from lorentze forces. For this reason, the coils are impregnated with a cryogenic capable epoxy.

Impregnation run #1

The first impregnation run was done by evacuating the coil mold while de-airing the epoxy. At the end of the de-airing procedure, the vacuum of the mold was used to pull the epoxy from a bell jar into the mold. The mold was at 60C during the epoxy transfer. The results of this technique were quite good, but roughly one third of the coil on one side of the pack exhibited wetting without adequate fill. An interesting note: The glass cloth has roughly the same index of refraction as the impregnation epoxy, and virtually disappears from view after impregnation. The edges of the conductor are clearly visible.

Post analysis of this first run provided significant insights:

1. Closed end molding techniques do not provide the ability to remove any outgassing which occur within the mold.
2. The hard epoxy used to seal the lead breakouts from the mold broke during mold assembly. It is not practical to use hard epoxy seals between mold components, as shifting occurs during assembly. In order to be scalable to practical size magnets, compliant seals must be developed.

The coil was immersed in liquid nitrogen to evaluate the various structure components, specifically the performance of the impregnation epoxy. Since the epoxy is unfilled, any large volumes of epoxy will shrink significantly more than it's neighbors. Results of this dunk and visual examination:

1. The four openings in the G-10 side pieces, measuring about ½ inch by 1 inch, cracked significantly. This volume of epoxy was bounded on three sides by G-10, and the glass cloth covered conductor on the fourth. This cracking could conceivably work it's way into the conductor through the glass cloth during temperature cycles, compromising turn to turn dielectric capability or even the conductor itself.
2. There exists a thin coat of epoxy extending over the steel bobbin material from the coil area. This epoxy cracked also, due to the difference in expansion with the steel. These cracks radiate through the surface of the coil, and also are dielectric withstanding issues.

3. Within the coil existed several areas where the cable was not wound tightly, leaving approximately 20 mil thick epoxy areas. Within these thin sections, the epoxy cracked normal to the long dimension, going from one turn to the next.

Impregnation run #2

The fixturing was significantly modified for this run. Significant add ons:

1. The mold is tipped at about 20 degrees from the horizontal. This is to aid in the removal of outgassing products, and the filling of the mold from bottom to top.
2. The mold is evacuated from the top, and the fill is from the bottom. This allows the vacuum within the mold to remain consistantly good throughout the entire impregnation run. Any outgassing can be drawn actively from the mold.
3. Strip heaters were attached to both the top and bottom mold plates. Temperature controllers independently operated each.
4. RTV was used for seals of the mold edge plates.
5. The curing schedule was 110 C for 5 hours, followed by 125 C for 16, as per CTD.

Results:

1. During the fill, the epoxy boiled violently within the mold, generating large amounts of outgassing. This was caused by two factors: when the epoxy is outgassed, there is a height to the fluid; this height causes a pressure gradient on the order of 2 torr per inch depth. The result is that the bottom of the epoxy reservoir was outgassed at a pressure of 10 torr. This outgassing vs depth was clearly seen during the outgassing phase, the foaming during outgassing crept towards the top surface gradually, showing a time vs pressure dependence on the process. When the mold injection began, the leading edge of the epoxy was pulled from the bottom of the epoxy reservoir. This was the first time the bottom epoxy was exposed to 1 torr pressure, and so it outgassed further.
2. The 2850 (blue epoxy) S-bend seal, used to pass the inner lead through the O-ring seal, cracked while the mold was being assembled. This occurred because the two sides of the lead slot shifted in shear, due to either the cassette being non-flat, or a buildup of epoxy on one side of the lead on the bobbin surface. The blue epoxy is not tolerant of any shifting motion with the cassette.
3. The initial pumpdown did not reach low enough vacuum levels. It was surmised (correctly) that the S-bend seal had failed. By plugging the inner region mold plate holes, and pumping down the inner region, good vacuum was achieved.
4. The overall impregnation of the coil was excellent, with minor surface voids located randomly.

Impregnation run #3

For this run, the following changes were made:

1. The mold was oriented at 90 degrees to horizontal, with the long edge at the top. The four clamp location holes were used for impregnation. The two bottom ones for epoxy introduction, the two on top for pumping.
2. The side glass cloth pieces were added by using transfer tape to hold the cloth the the inner surfaces of the mold plates.
3. After de-airing of the epoxy, the mold was brought up to 50 torr for the epoxy introduction.

Results:

1. The violent boiling outgassing evident on the second run was not visible this time.
2. Impregnation results were good.