Conductor R & D for QPS

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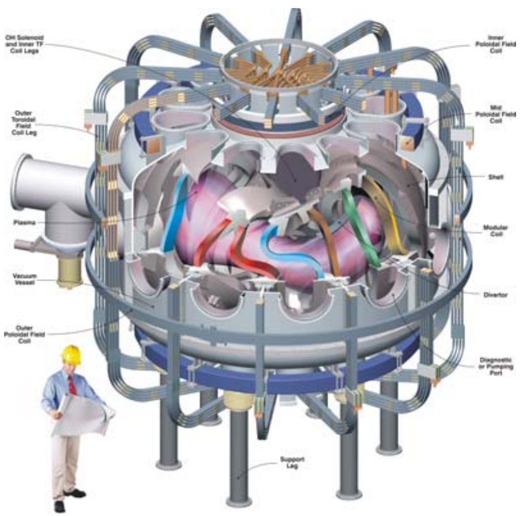
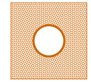
The feasibility of cooling the copper conductor using embedded copper or Teflon tubes is investigated. To prevent the crimping of the tubes during the fabrication of the coils, the tubes were filled with low melting temperature alloy (LMA). The cooling tubes were wound on a drum and then the molten metal (melting temperature = 140oC) was filled in the tubes using gravity. After cooling the filled tubes, they were bent into complex shapes and then reheated to 160oC and the pressurized cold air was used to remove the LMA out of the tube. For a 50-ft tube, about 7.2% by weight LMA remained in the tube. Comparison of the tap water flow measurements with the as received revealed about 19% flow rate loss. In another set of experiments, the as received copper tubes were first coated with Silicon oil prior to filling the tubes. The oil coating seemed to remove most of the LMA using cold pressurized air (only 1-2% by weight remaining), however, the remaining small amount of LMA seemed to have formed pellets that blocked the tube. Similar experiments were also done with Teflon tubes. The weight and flow measurements for the Teflon tube are currently underway.

A Race Track coil was successfully potted using the standard copper conductor (without the cooling tube). The potting of a similar Race Track coil having the embedded cooling copper tubes is planned as a follow up.



1. Conductor Development



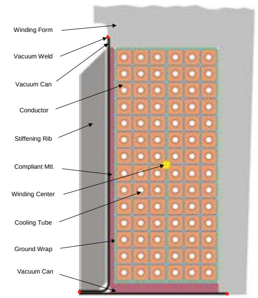
- Internal cooling is unique to the QPS project as it significantly improves the cooling efficiency. However, due to the strain hardening behavior of copper, bending of the modular coils into complex shapes more difficult.

- Before embedding the cooling tube in the modular coils, each copper tube needs to be filled with a low-temperature melting alloy (LMA) to prevent it from crimping during complex bending.

- After the modular coil is bent into the required shapes, the alloy must be melted out of the cooling tube so as provide a path for the cooling water.

Modular Coil Shell (Full Period Assembly) Top View

Modular Coil Cross Section with Internal Cooling Tubes



Flow Rate Measurements for 50-ft long Cu tubes

- Flow Rate in unfilled Cu-Tube = 980 mm3/s;
- Flow Rate in in the same tube after filling and flushing the LMA out: 790 mm3/s
- Loss in Flow Rate = 19%
- Weight percent of the LMA left after flushing it out = 7.2%
- Pre-coating the Cu-tubes with Silicone Oil seemed to prevent bonding of LMA to the Tube surface. The percent of weight remaining of LMA in these cu-tubes was around 0.15%. However, this remaining mass was in the form of little pellets which seemed to affect flow more.

Copper Tube wound on a drum prior to filling with LMA

PTFE Tube Description (Alternative to Copper)

ID = 3.38 mm, Wall Thickness = 0.38 mm
- Advantages: Easier to fill with LMA, easy to bend, very little spring back
- Disadvantage: The LMA cracks during at sharp bends and damages the tube; After draining the LMA out of the tube, a thin layer of LMA on the tube walls still remains; Small tube diameter will be difficult to retrofit with metal fittings; Volume flow rate of cooling fluid will be small due to small ID.

ID = 6.68 mm, Wall thickness = 0.5 mm
- Advantages: Easy to bend; very little spring back; Easier to attach with metal fittings;
- Disadvantage: Heavy LMA produces sagging in the tube at elevated temperatures, which makes it difficult to fill the tube with LMA; a thin layer of LMA on the tube walls still remains;

2. Conductor Fabrication

Preparation of the R&D coil for epoxy impregnation

R&D coil in thermal blanket during epoxy impregnation

Epoxy impregnated coil removed from the winding form

3. Conductor Testing

- Work in progress to determine Mechanical, Thermal, and Thermo-mechanical Properties of stranded copper conductor/CTD 403 composites

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