8.0 Coil Thermal Stresses.

Temperatures were calculated for the 15 sec ramp-up, and 2 sec flat top and a 7 sec ramp down. The NIST Kohler plot and fitted equation was used for the magneto-resistance. In my calculations, the temperatures were low compared with Bob’s. This may have been a result of using the average data from the NIST Kohler plot that the upper bound. To make some progress on the stress calculations the time scale was stretched to come closer to Bob’s temperature distribution. The stresses from this analysis are small, less than 5 MPa. The cooldown stresses will require more work. These are discussed on the next page.
Cooldown Stresses

The channels were held at 30K and the temperature distribution was obtained by averaging nodal temperatures with the final temp distribution from the heat-up calculations. This is not rigorous, and is essentially assumed, but it is representative of temperature distribution, and will serve to provide guidance for further analysis and design.

The Von Mises stress is relatively modest, at 43MPa.
The axial tension near the channels is approaching 50 MPa, beyond the design capacity of epoxy bonded systems. Some provision will have to be made to either throttle the cooling gas to limit the channel temperature or design to allow the bond failure.

The shear stresses that peak at 7MPa are within the usual allowables for insulation systems, for which design allowables are in the range of 15 to 30 MPa (with no aid from compression).
Kapton arc sections inserted between every eighth turn on those layers that face the cooling channels.

Photo taken by Dave Rakos at Everson 09-08-04. Kapton layer spaced at every eighth turn relieves axial tension in the layers near the cooling channels.
Cooldown Stress, Global Thermal Differential.

Copper Thermal Expansion Coefficient as a Function of Temperature. The cooldown calculations were conducted for 80 to 100 K for which the copper alpha is about 5e-6 per degK.
Another Thermal Distribution

If there is stratification of He gas or if LN2 floods the bottom of the cryostat there could be a significant thermal differential between top and bottom of the coil. A 77 to 100 K variation is assumed. The resulting 15 MPa stress is Acceptable.

Assumed temperature variation

Resulting Displacements
Eddy Current Temperatures – A Non-Problem

Transient fields induce eddy currents in the conductors as well as in the cryostat plates. This has been investigated for a strip wound solenoid used for FIRE, a fusion experiment. Eddy current heating has been evaluated for the BNL pulsed magnet using the same procedure. The conductor cross section is much lower for the BNL conductor, and the eddy current heating is less than one degree. – a non-problem.

\[ P_e = \frac{a^3 \times b \times Bx^2}{12 \times \rho} \]

\[ P_e = \frac{b^3 \times a \times By^2}{12 \times \rho} \]


Power is in Watts/m for dimensions in meters, \( \rho \) in ohm-m, and B-dot in Tesla/sec. Note that the strip orientation is actually advantageous for resisting eddy currents resulting from the vertical field.

Temperatures due to conductor eddy currents in .5in square conductors subjected to a 14.5T/7sec transient (rampdown)