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BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

DIFFERENTIAL CONTRACTIONS OF ISABELLE MAGNET COMPONENTS

C. Lasky

February 8, 1972

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CRISP 72-6
ISABELLE PROJECT

INTERSECTING STORAGE ACCELERATOR NOTES

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The few measurements made on the composite superconducting braid show that its thermal contraction in the longitudinal direction is close to that of copper and consequently close to that of stainless steel. For the 3.2 m long dipole presently proposed for ISABELLE there will therefore be about 0.125 in. differential contraction between a low carbon steel core and the superconducting windings. Since a tight fit between the coil and the inside bore of the core is considered necessary to prevent motion of the conductors in the magnetic field this differential motion must either be restrained or eliminated. The following analysis shows that the differential motion can be minimized by the use of stainless steel welding straps and a careful selection of the stacking pressure.

A test made by I. Polk on NAL magnet laminations showed that the effective modulus of elasticity of stacked laminations was a non-linear function of the stacking pressure and that for a stacking pressure of about 200 psi

$$E_{\text{eff}} \approx 1 \times 10^6 \text{ lb/in.}^2$$

A second measurement by J. Allinger on a laminated magnet that he was building gave similar results. Until careful tests more precisely define E_{eff} the above value will be used in the following.

For the magnet presently being studied the following parameters hold:

- Area of Laminations (Net) = $A_l = 88 \text{ in.}^2$
- Area of Straps (stainless steel) = $A_s = 8 \text{ in.}^2$
- Elastic Modulus of Lamination = $E_l \approx 1 \times 10^6 \text{ lb/in.}^2$
- Elastic Modulus of Straps = $E_s = 30 \times 10^6 \text{ lb/in.}^2$
- Initial Loading of Core - 250 lb/in.^2 (assumed).

I. Initial Tension in Straps

If straps are welded while core is under initial compression and the pressure then released the conditions of equilibrium require

$$(\Delta L)_s = (\Delta L)_1 \quad \Delta L = \text{Change in Length}$$

$$\therefore \frac{P_s L_s}{A_s E_s} = \frac{P_1 \times L_1}{A_1 \times E_1} \quad \text{where: } L_1 = L_s$$

$$\text{and } P_1 = 250 \times A_1$$

Using the values above

$$P_s = 16000 \text{ lbs or } 4000 \text{ lb/strap}$$

$$\therefore \sigma_s = \frac{P}{A} = \frac{4000}{4 \times \frac{1}{2}} = 2000 \text{ psi @ } 300^\circ \text{K}$$

II. Shrinkage of Core from 300°K to 4.2°K

$$* \Delta L \text{ Core (iron)} = (3.2 \times 40) \times 202 \times 10^{-5} = 0.256 \text{ in.}$$

$$* \Delta L \text{ Straps (stainless)} = 128 \times 296 \times 10^{-5} = 0.379 \text{ in.}$$

$$(\Delta L)_{\text{diff}} = 0.379 - 0.256 = 0.113 \text{ in}$$

The system will come to equilibrium at 4.2°K when the total tensile load in the straps is equal to the total compressive load in the core

$$\frac{(\Delta L) A_s E_s}{L_s} = \frac{(0.113 - \Delta L) A_1 E_1}{L_s}$$

from which $\Delta L = 0.030 \text{ in.}$

$$\text{Total equilibrium contraction} = 0.379 - 0.030$$

$$= 0.349 \text{ in}$$

or 92% that of stainless steel.

* No restraints.

III. Tension in Straps at 4.2°K

$$\text{Incremental } \Delta L = 0.030 \text{ in.}$$

$$\sigma \text{ (incr)} = e \times E = \frac{0.030}{128} \times 30 \times 10^6$$

$$= 7030 \text{ lb/in.}^2$$

$$\sigma \text{ (total)} = 2000 + 7030 = 9030 \text{ lb/in.}^2 \text{ @ } 4.2^\circ\text{K}$$

It would appear from the above that a series of careful measurements on the thermal contraction of a prototype coil section would allow the proper ratioing of lamination to strap area, the proper selection of stacking pressure (to set E_1) and the final selection of strap material to either eliminate completely or at least minimize the differential movement between core and coil package.

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