SSC DETECTOR SOLENOID DESIGN NOTE #3

TITLE: Very Preliminary Conductor and Coil Parameters, Extrapolated from MFTF Solenoid

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I. Conductor & Coil Parameters: MFTF-B Solenoid

A. Conductor parameters

O/A size: 0.5 x 1.25 cm

A_{cond} = O/A cross section area = 0.625 cm^2

J_{cond} = O/A current density

= 2866 A / 0.625 cm^2

= 4586 A/cm^2

A_{cu}/A_{sc} = copper to superconductor area ratio

= 28.8 ~ 29

$A_{cu} = \frac{29}{30} A_{cond} = 0.604\ cm^2$

J_{cu} = 2866 A / 0.604 cm^2 = 4745 A/cm^2

$A_{sc} = \frac{1}{30} A_{cond} = 0.0208\ cm^2$

J_{sc} = 137568 A/cm^2 (Baldi sheet gives 147277 A/cm^2)

q_ℓ = stabilizer heat flux

= 0.22 W/cm^2 (Baldi sheet)

ρ_{cu} = stabilizer (copper) resistivity, at 10K

= ρ_{cu} (20°C) / 110

= $1.72 \times 10^{-6}\ \Omega$-cm / 110

= $1.56 \times 10^{-8}\ \Omega$-cm.

B. Coil parameters

Size of coil: 16.3 cm × 33.6 cm
$A_{coil} = 548\ cm^2$

No turns = 24 × 25 = 600
$A_{T\,cond} = (600)(0.625\ cm^2) = 375\ cm^2$

Coil packing factor
$= A_{T\,cond} / A_{coil}$
$= 375/548$
$= 0.684$ (Baldi sheet gives 0.664)

J_{coil} = coil (or "pack") current density
$= (600)(2866)/548\ A/cm^2$
$= 3138\ A/cm^2$ (Baldi sheet gives $3140\ A/cm^2$)

Surface area "wetting" factor
= 60% of edges + 70% of broad faces (ICEC9)

Total perimeter, $P = 2(0.5 + 1.25)\,cm = 3.50\ cm$
Wetted " , $P_W = 2[(0.6)(0.5) + (0.7)(1.25)]\,cm = 2.35\ cm$

$P_W = \alpha P$

So $\alpha = \frac{P_W}{P} = \frac{2.35}{3.50} = 0.67$

II. Conductor & Coil Parameters - SSC Detector Solenoid

A. Conductor parameters

<u>Assume</u> J_{sc} same as MFTF Solenoid

Therefore $A_{sc} = \frac{5000}{2866}(0.0208\ cm^2)$

$= 1.74\,(0.0208\ cm^2)$

$= 0.0362\ cm^2$

<u>Stability criterion</u> q_e same as MFTF Solenoid

From power balance:

$$q_e = \frac{J_{cu}^2\, \rho_{cu}\, A_{cu}}{P_w}$$

or

$$= \frac{I^2\, \rho_{cu}}{A_{cu}\, P_w}$$

where P_w = cooled (wetted) perimeter $= \alpha P$

$= \alpha\left[2(w+t)\right]$

$$= \frac{I^2\, \rho_{cu}}{\beta\,(wt)\,2(w+t)\alpha}$$

where w & t are width and thickness of conductor

$$\text{and } \beta = \frac{A_{cu}/A_{se}}{A_{cu}/A_{se} + 1}$$

So: $q_\ell' = q_\ell$ (primes indicate detector solenoid)

$$\frac{I'^2 \rho_{cu}'}{2\beta' w't'(w'+t')\alpha'} = \frac{I^2 \rho_{cu}}{2\beta wt(w+t)\alpha}$$

Now, <u>assume</u> $\rho_{cu}' = \rho_{cu}$

$\beta' = \beta$

$\alpha' = \alpha$

then

$$\frac{I'^2}{w't'(w'+t')} = \frac{I^2}{wt(w+t)}$$

$$w't'(w'+t') = wt(w+t)\frac{I'^2}{I^2}$$

$$= (1.25\text{ cm})(0.5\text{ cm})(1.75\text{ cm})\left(\frac{5000}{2866}\right)^2$$

$$= 3.325\text{ cm}^3$$

Also <u>assume</u>

$$\frac{w'}{t'} = \frac{w}{t} = 2.5$$

Substituting and solving for t,

$t = 0.724$ cm; $w = 1.811$ cm

So:

$$J_{cond} = \frac{5000A}{(0.724)(1.811)\ cm^2}$$

$$= 3813\ A/cm^2,$$

which is 83.1% of the value for the MFTF solenoids.

B. Coil parameters

With the same packing factor as the MFTF solenoids,

$$J_{coil} = (0.684)(3813)\ A/cm^2$$
$$= 2609\ A/cm^2$$

C. Validity of assumptions

(1) $J'_{sc} = J_{sc}$: New conductors will surely allow $J'_{sc} > J_{sc}$.

(2) $\rho'_{cu} = \rho_{cu}$: MFTF RRR = 110, this is certainly reasonable for our conductor

(3) $\beta' = \beta$: cu/SC ratio will surely be about equal

(4) $\alpha' = \alpha$: the wetted fraction can be made equal

(5) $w'/t' = 2.5$: for ease of solution only, it's really the perimeter that matters

(6) packing factors equal; since q_ℓ is the same the width of the LHe channels could be the same; voltage ratings of coils probably about the same

D. Summary

A coil current density at 5kA of 2500-2600 A/cm^2 is a good place to start, if the criterion is the same heat flux as MFTF ($0.22\ W/cm^2$).