Neutron fluence effects on SC coils and comments

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Fig. 2. Onset ($\chi' = -0.1$), midpoint ($\chi' = -0.5$) and downset ($\chi' = -0.9$) of the superconducting transition in zero field versus fast neutron fluence


**Figure 5.** $T_c/T_{c0}$ versus neutron fluence for $V_3$Si, $Nb_3$Sn, $Nb_3$Ge [30, 31] and MgB$_2$ single crystals [25] (circles), thin films [29] (diamonds) and Mg$^{11}$B$_2$ polycrystals [27] (squares).

Pion Capture Solenoid in the COMET CDR

Irradiation: Neutron Fluence

\[ 8 \times 10^{-4} \text{ n/cm}^2/\text{p} = 4 \times 10^{14} \text{ n/m}^2/\text{sec} \]

\(~10^{22} \text{ n/m}^2 \text{ for } 10^{21} \text{ POT}\)

Same order of ITER spec!!

0.1 MeV
COMET

Refinement of solenoid system

- Enlarge magnet bore to insert more shield
- Estimate degradation from estimated DPA
- Cost?
  - 3 step mandrel: smaller stored energy
  - 2 step mandrel
  - single mandrel: easier support structure

<table>
<thead>
<tr>
<th></th>
<th>MGy/10^{21}p</th>
<th>n/m^2/10^{21}p</th>
<th>DPA/10^{21}p</th>
</tr>
</thead>
<tbody>
<tr>
<td>R500(CDR)</td>
<td>0.6</td>
<td>8 \times 10^{21}</td>
<td>2 \times 10^{-5}</td>
</tr>
<tr>
<td>R600</td>
<td>0.1</td>
<td>2 \times 10^{21}</td>
<td>0.6 \times 10^{-5}</td>
</tr>
<tr>
<td>R700</td>
<td>0.05</td>
<td>0.7 \times 10^{21}</td>
<td>0.3 \times 10^{-5}</td>
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</tbody>
</table>
Same size SC wires

COMET

NF/MC

SC#1-5

SH#4

SC#6-10

SH#2

SC#11-15

SH#3

BP#1

BP#2

Depicted are the same size SC wires in the diagram.
The Proton Beam Parameters

Proton Beam Energy 8 GeV
Rep Rate 50 Hz
Bunch Structure 3 bunches, 320 µsec total
Bunch Width 2 ± 1 ns
Beam Radius 1.2 mm (rms)
Beam $\beta^*$ $\geq 30$cm
Beam Power 4 MW (3.125 × 1015 protons/sec)

COMET: 56kW proton beam
-> 7.9W on the pion capture SC coils
MC/NF: (4000kW/56kW) * 7.9W = 564kW
<table>
<thead>
<tr>
<th>NiSn/NiTi</th>
<th>P (kW)</th>
<th>60/40</th>
<th>P (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC#1-5</td>
<td>2.42</td>
<td>SH#1</td>
<td>967.5</td>
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<tr>
<td>SC#6-10</td>
<td>0.57</td>
<td>SH#2</td>
<td>1107.5</td>
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<td>SC#11-15</td>
<td>0.16</td>
<td>SH#3</td>
<td>36.04</td>
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<tr>
<td>SC#16-26</td>
<td>0.31</td>
<td>SH#4</td>
<td>31.83</td>
</tr>
<tr>
<td>SC#1-26</td>
<td>3.64</td>
<td>SH#1-4</td>
<td>2142.87</td>
</tr>
</tbody>
</table>

ENERGY DEPOSITED IN SC SOLENOIDS (SC#), SHIELDING (SH#).
Radiation dose for the new Pion Capture Solenoid of COMET

- 0.07 MGy/10^{21}p
- 1.3 \times 10^{21} \text{n/m}^2/10^{21}p
- 6.4 \times 10^{20} \text{n/m}^2/10^{21}p \text{ for } >0.1 \text{MeV n}
- 3 \times 10^{-6} \text{DPA/10}^{21}p
COMET : $1.3 \times 10^{21} \text{n/m}^2/10^{21}p = 1\text{n/m}^2/p$

MC/NF $3 \times 10^{15} \text{p/s} \rightarrow 3 \times 10^{15}\text{n/m}^2/\text{s}$

to get $10^{22} \text{n/m}^2$ on SC#6-10

$3 \times 10^{6} \text{s} = 35 \text{days}$

This means that we need to increase the SC wire temperature (may be up to the room temperature) to recover their property by anneal effect every 35 days. The 35-days is too short period. It should be more than 1 year.

to get $10^{21} \text{n/m}^2$ on SC#6-10

$3.5 \text{days}$

HTS instead of resistive magnets looks no hope.
Anneal Effect: SC - Tc & Jc -
Irradiated at LT, and warmed up to RT.


For NbTi, some recovery can be expected even after irradiation \( \sim 5 \times 10^{22}/m^2 \).

Fig. 9. Recovery of \( j_c / j_{0} \) up to room temperature for different samples of Nb-50 wt% Ti (measured at 4.2 K as after [44]. The measurements were made on one filament 1-3: 11 \( \mu \)m filament diameter, No. 4: 21 \( \mu \)m) of molybdenum wires.

Fig. 10. Changes of critical currents measured at 4 T with proton fluence (Nb-45 wt% Ti, 379 core conductor). ○○○ irradiation at 4.2 K, final anneal at room temperature; ... irradiation at 4.2 K, one intermediate and one final anneal to room temperature [33].
Anneal Effect: Stabilizer - Elec. conductivity-
Irradiated at 4K, and warmed up to RT.

14MeV n on Al
ρ0: 0.386
ρ-irrad: 0.772
(nΩm)

J. Nucl. Materials, 49, p161 (1973&74)
Reactor n on Al
fluence up to 2*10^22/m2.

14MeV n on Cu
ρ0: 0.098
ρ-irrad: 0.191
(nΩm)

fluence up to 1*10^21/m2.

- Double of electrical conductivity can be observed at 10^21/m2.
- Full recovery in Al expected by T.C.
- Degradation in Cu will be accumulated even after T.C.

T. Nakamoto (KEK)
Comments

• There are many papers on the SC magnet requirements, design, and study for fusion magnets (ex. ITER) for the radiation effects. We need to learn many things from the papers.

• Then set the requirements on the SC magnets design for the NF/MC.

• Collaboration with fusion group would be very useful.