Review of NFMCC Studies 1 and 2: Target Support Facilities

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Meeting on High Power Targets
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Neutrino Factory Studies

- ORNL completed two studies describing support facilities for neutrino factories
  - 2000, Graphite Target
  - 2001, Mercury Jet Target
  - Included descriptions of targets, expected radiation, required shielding, remote handling systems, and rough cost estimates

- ORNL documents used as contributions to broader scope NFMCC documents
Study 1 - Carbon Target

- 16 GeV, 1.5 MW proton beam
- 1.5 cm diameter, 80 cm long graphite rod inside a helium environment
- Target held by two spoke-like graphite supports
- 15 cm diameter containment tube
- 20 T magnetic field
Study 2 – Mercury Jet Target

- 24 GeV, 1 MW proton beam
- 1 cm diameter, 30 m/s jet
- 20 T magnetic field
- Removable nozzle assembly inside an iron core
Study 2 Target-Capture Facility

- 24 GeV, 1 MW proton beam on Hg target
- Upgradeable to 4 MW
- 20 T target solenoids
- 1.25 T capture solenoids
- 5-m steel shield for unlimited personnel access

Facility concept development
- Beam, target parameters
- Neutronic analysis
- Shielding requirements
- Equipment definition
- RH requirements, crane sizing
- Cost estimate
The Target/Capture Facility is 40-m Long

- Removable, stacked shielding allows personnel in the crane hall
- 50-ton crane and bridge manipulator are the primary remote handling tools
Hg-Jet Target/Beam Absorber is a Closed Loop System

- Hg jet interaction region: $r = 5 \text{ mm} \times 30 \text{ cm long}$
- 110 liters of Hg total volume
- $V = 30 \text{ meters/s}$
- $Q = 2.4 \text{ liters/s}$
Hg-Target Hot Cell

- All components can be remotely replaced
Maintenance requirements for the target system components

- Most of the target system components are life-of-the-facility
- Key components are replaced every 2-3 yrs

<table>
<thead>
<tr>
<th>Component (Class)</th>
<th>Failure Mode</th>
<th>Dose Rate (Rad/h)</th>
<th>Expected Life (yrs)</th>
<th>Replacement Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle Insert</td>
<td>erosion, embrittled beam window</td>
<td>&gt;10^6</td>
<td>2-3</td>
<td>11-16</td>
</tr>
<tr>
<td>Beryllium Window</td>
<td>embrittlement</td>
<td>10^4 – 10^5</td>
<td>2</td>
<td>7-11</td>
</tr>
<tr>
<td>Isolation Valve</td>
<td>mechanical</td>
<td>10^4 – 10^5</td>
<td>5-7</td>
<td>1-2 (plus time for beryllium window repl.)</td>
</tr>
<tr>
<td>Filters</td>
<td>saturated</td>
<td>Contamination</td>
<td>2</td>
<td>2-3</td>
</tr>
<tr>
<td>Pumps, Valves</td>
<td>mechanical</td>
<td>Contamination</td>
<td>5-7</td>
<td>2-3</td>
</tr>
<tr>
<td>Heat Exchanger, Piping, Tanks</td>
<td>mechanical</td>
<td>Contamination</td>
<td>&gt; 40</td>
<td>5-8</td>
</tr>
</tbody>
</table>
The Target and High Field Solenoids Are Contained in a Common Cryostat

- The cryostat is a trunnion-mounted beam that simplifies initial installation of coil modules
- The resistive coils and target nozzle are mounted coaxially in the large SC solenoid
Tungsten-Carbide Radiation Shielding Protects the Superconducting Coils

- Solenoids are lifetime components
- W-C balls are 2-6 mm diam.
- Water-cooled flow channels
- Stainless steel shell and rib design
Component Weights and Sizes

- Weight and size of major components established the facility dimensions and lifting requirements

<table>
<thead>
<tr>
<th>Component</th>
<th>Outer Diam. (cm)</th>
<th>Length (cm)</th>
<th>Module Wt. (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive Module</td>
<td>110</td>
<td>180</td>
<td>47,500</td>
</tr>
<tr>
<td>Iron Plug</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HC1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HC2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HC3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>W-C Shield</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Main Cryostat + Shield Beam</td>
<td>270</td>
<td>740</td>
<td>73,600</td>
</tr>
<tr>
<td>SC1</td>
<td>256</td>
<td>178</td>
<td>61,000</td>
</tr>
<tr>
<td>SC2-3</td>
<td>202</td>
<td>183</td>
<td>21,700</td>
</tr>
<tr>
<td>2-3 Shield</td>
<td>128</td>
<td>183</td>
<td>59,600</td>
</tr>
<tr>
<td>SC4-5</td>
<td>176</td>
<td>351</td>
<td>17,900</td>
</tr>
<tr>
<td>4-5 Shield</td>
<td>148</td>
<td>351</td>
<td>86,400</td>
</tr>
<tr>
<td>SC6 + Shield</td>
<td>104</td>
<td>50</td>
<td>&lt;4,000</td>
</tr>
<tr>
<td>SC7 + Shield</td>
<td>104</td>
<td>185</td>
<td>11,800</td>
</tr>
<tr>
<td>SC8 + Shield</td>
<td>104</td>
<td>185</td>
<td>10,800</td>
</tr>
<tr>
<td>SC9 + Shield</td>
<td>104</td>
<td>185</td>
<td>9,600</td>
</tr>
<tr>
<td>SC10 + Shield</td>
<td>104</td>
<td>185</td>
<td>8,400</td>
</tr>
<tr>
<td>SC11 + Shield</td>
<td>104</td>
<td>185</td>
<td>7,700</td>
</tr>
<tr>
<td>SC12 + Shield</td>
<td>104</td>
<td>185</td>
<td>6,600</td>
</tr>
<tr>
<td>Decay Coils + Shield (6)</td>
<td>87</td>
<td>296</td>
<td>12,600</td>
</tr>
</tbody>
</table>
The Maintenance Cell is Located on the Crane Hall Level

- Sized for handling cryostat modules
- Located above the target hot cell with a hatch access
- Staging area for bringing new components into the crane hall
- Waste handling area

Maintenance Cell Plan View
Unlimited Personnel Access is Permitted in the Crane Hall

- 5.2 meters of steel + 30 cm of concrete to limit worker dose to 0.0025 mSv (0.25 mrem/h)

- 2 meters of steel in the tunnel to meet ground water protection requirements
R&D Issues Identified

- **Graphite target**
  - Detailed target design
  - Beam dump design, incl. coolant connections/piping
  - Utility connections in target region
  - Details for helium environment, purge air

- **Mercury jet target**
  - Thermal mixing of pool by jet
  - Nozzle erosion

- **Shielding for high-field solenoids (W-C spheres)**
  - Ball distribution
  - Pressure drop
  - Heat transfer coefficient
Summary

- Previous studies provided concepts for Target Support Facilities based on graphite and mercury jet targets
- A logical method was used to determine facility size
  - The facilities were based on size and weight of the solenoids and the radiation shielding that protects the superconducting coils
  - Rad shielding was sized to permit unlimited worker access in the crane hall
  - The decay channel (tunnel) is shielded to meet ground water protection requirements
- Remote handling systems were incorporated into the facility design even at the early conceptual stage