Magnet Status Report

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Detector Support Group
DSG STAFF
Contents

• Overview
  — Solenoid
  — Torus

• Control, Monitoring, and Interlock Systems
  — Cryogenics Distribution Box
  — Solenoid
  — Torus

• Tasks
  — Torus
  — Solenoid

• Conclusion
Solenoid

- Nominal current 2416 A
- Central field 5 T
  - Uniform field $\Delta B/B < 10^{-4}$
- Temperature 4.2 K
Solenoid Location in Hall B: Space Frame Level I

Solenoid Side View

Solenoid Isometric View

Solenoid Service Tower
Solenoid Service Tower (SST)

Helium from Distribution Box

Valves

Helium Reservoir

Inner Piping

To Magnet

SST with outer shield

SST with vacuum jacket
Piping & Instrumentation Diagram
Solenoid Cryogenic System

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Cryogenic Distribution Box (DBX)
DBX
Bayonet Connections to Torus Service Tower

Buffer Dewar
Solenoid Service Tower
Solenoid built by ITE

Bayonet Connections to Solenoid Service Tower
Piping & Instrumentation Diagram
Solenoid: Cryogenic System

Hardware modification areas circled in red
Torus

- Nominal current 3770 A
- Central field 3.58 T
- Temperature 4.6 K
Torus in Hall B

Torus Front View

Torus Side View
Hall B Torus Cryogenic System Located on Space Frame Level III

Torus Service Tower

Distribution Box
Torus Cryogenic System

Distribution Box

Bayonet Connections to Torus Service Tower

Bayonet Connections to Solenoid Service Tower

Chimney

Chimney (Magnet/Cryo Interface)

Torus Service Tower

Torus Magnet

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Controls, Monitoring, and Interlock System Flowchart

- Excitation chassis
- Solenoid
- Distribution box
- Torus
- LV cRIO
- FastDAQ cRIO
- PLC 1
- PLC 2
- EPICS

Lines:
- Control/info
- RS232
- Ethernet
- Readback

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Distribution box distributes cryogen to Solenoid, Torus, and Cryo-target
Controls, Monitoring, and Interlock System
Cryogenics Distribution Box: PLC Chassis

AB 1756-L72 Control Logix Controller
AB 1756-PA72 Power Supply
AB 1756-EN2T Ethernet Module
Cryocon-18i Temperature Monitors
Magnet operating temp = 4.4—3.9 K

Terranova 924 A Thermocouple Vacuum Gauge
Magnet operating pressure = 1.2—0.9 ATM

185- Liquid Level Instrument
Normal nitrogen liquid level = 69%

AutomationDirect Touch Panel
Used for manual operation
Controls, Monitoring, and Interlock System

Solenoid

Diagram showing connections between various components such as Cryo-con, Vacuum pumping system, Excitation chassis, 435 NBX, 490 NBX, FastDAQ cRIO, LV cRIO, PLC 1, PLC 2, interlock, EPICS, and Magnet power supply.
Control, Monitoring, and Interlock System
Solenoid: PLC System Components

• AB 1756 L72 Contro-logix Allen Bradley
• I/O digital and analog modules
• Relay and sequence of events (SOE) modules
• Cryocon 18i temperature monitors
• 435 and 490 NBX modules
• Remote control power supply
• Touch panel monitors
Solenoid Control, Monitoring, and Interlock System
Chassis 1 PLC components

Chassis 1

AB 1756-L72 Control
Logix Controller

AB 1756-PA72
Power Supply

AB 1756-OF8
Analog Output

AB 1756-EN2T
Ethernet Module

AB 1756-IF16
Analog Inputs
Solenoid Control, Monitoring, and Interlock System
Chassis 2 PLC components

Chassis 2

AB 1756 OW16 Relay Outputs
AB 1756 IV32 Digital Inputs
AB 1756-EN2T Ethernet Module

AB 1756-PA72 Power Supply
AB 1756 IB32 Digital Inputs
AB 1756-IB16ISOE Sequence Of Events

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Control, Monitoring, and Interlock System
Solenoid: cRIO Components

• 9068 NI cRIO and 9030 cRIO NI controllers
• (1) NI 9870 cRIO RS-232 modules
• (8) NI 9239 Analog Input modules
• Low voltage excitation readback chassis
• Temperature, voltage, strain, and hall sensors
Control, Monitoring, and Interlock System

Solenoid: Fast_DAQ cRIO components

• Fast_DAQ cRIO processes data from voltage taps on Solenoid
Control, Monitoring, and Interlock System
Solenoid: cRIO Control Components

“Low Voltage (LV)” cRIO processes data signals from sensors connected to Excitation chassis
Control, Monitoring, and Interlock System
Solenoid: Instrumentation

- Multi Sensor Excitation Readback Chassis
- Cryocon-18i Temperature Monitors
- AutomationDirect Touch Panel
- Remote Control Danfysik System 8500 Power Supply
## TEMPERATURE (CERNOX)

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR8611</td>
<td>Cooldown Helium Supply Temp</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8622A</td>
<td>Lead A Top</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8622B</td>
<td>Lead B Top</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8624A</td>
<td>Lead A Bottom</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8624B</td>
<td>Lead B Bottom</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8670</td>
<td>Lhe Tank Vent (pre-valve)</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8671</td>
<td>Magnet Reservoir Return</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8672</td>
<td>Shield Supply</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8673</td>
<td>Shield Vent</td>
<td>Temperature (Cernox)</td>
</tr>
<tr>
<td>TR8674</td>
<td>Lhe Tank Vent</td>
<td>Temperature (Cernox)</td>
</tr>
</tbody>
</table>

## TEMPERATURE (PT100)

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP8621A</td>
<td>Lead A Warm End</td>
<td>PT100</td>
</tr>
<tr>
<td>TP8621B</td>
<td>Lead B Warm End</td>
<td>PT100</td>
</tr>
<tr>
<td>TP8675</td>
<td>LHE Return Line Temp (outside can)</td>
<td>PT100</td>
</tr>
<tr>
<td>TP8676A</td>
<td>LHE Return Line Temp (outside can)</td>
<td>PT100</td>
</tr>
<tr>
<td>TP8676B</td>
<td>LHE Return Line Temp (outside can)</td>
<td>PT100</td>
</tr>
<tr>
<td>TP8677</td>
<td>LHE Return Line (after pumps)</td>
<td>PT100</td>
</tr>
</tbody>
</table>

## PRESSURE

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT8620</td>
<td>Lead Reservoir Pressure</td>
<td>Pressure</td>
</tr>
<tr>
<td>PT8670</td>
<td>Magnet Reservoir Pressure</td>
<td>Pressure</td>
</tr>
<tr>
<td>PT8675A</td>
<td>LHE Return Line Press</td>
<td>Pressure</td>
</tr>
<tr>
<td>PT8675B</td>
<td>LHE Return Line Press Sub-ATM</td>
<td>Pressure</td>
</tr>
<tr>
<td>PT8677</td>
<td>Inlet to guard vacuum</td>
<td>Pressure</td>
</tr>
<tr>
<td>L8620DP</td>
<td>Lead Reservoir dP LL</td>
<td>dP</td>
</tr>
<tr>
<td>L8670DP</td>
<td>Magnet Reservoir dP LL</td>
<td>dP</td>
</tr>
<tr>
<td>TC8600</td>
<td>Vacuum</td>
<td>Vacuum TC</td>
</tr>
</tbody>
</table>

## LIQUID LEVELS

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL8620SC</td>
<td>Lead Reservoir LL</td>
<td>Superconducting Probe</td>
</tr>
<tr>
<td>LL8670SC</td>
<td>Magnet Reservoir LL</td>
<td>Superconducting Probe</td>
</tr>
</tbody>
</table>

## VALVES

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV8611CD</td>
<td>Cooldown Bottom Fill</td>
<td>EV</td>
</tr>
<tr>
<td>EV8670BY</td>
<td>Lhe Return Valve</td>
<td>EV</td>
</tr>
<tr>
<td>EV8611JT</td>
<td>Top Fill</td>
<td>EV</td>
</tr>
<tr>
<td>EV8612</td>
<td>Bottom Fill</td>
<td>EV</td>
</tr>
<tr>
<td>EV8611CD_LVDT</td>
<td>Cooldown Bottom Fill</td>
<td>EV</td>
</tr>
<tr>
<td>EV8670BY_LVDT</td>
<td>Lhe Return Valve</td>
<td>EV</td>
</tr>
<tr>
<td>EV8611JT_LVDT</td>
<td>Top Fill</td>
<td>EV</td>
</tr>
<tr>
<td>EV8612_LVDT</td>
<td>Bottom Fill</td>
<td>EV</td>
</tr>
<tr>
<td>PV8674</td>
<td>Warm Return Valve</td>
<td>PV</td>
</tr>
<tr>
<td>SV8622</td>
<td>Lead Flow Vent to Atmosphere</td>
<td>Solenoid</td>
</tr>
<tr>
<td>SV8677CR</td>
<td>Warm Return Valve</td>
<td>Solenoid</td>
</tr>
<tr>
<td>SV8622DV</td>
<td>Warm Return Vent to Atmosphere</td>
<td>Solenoid</td>
</tr>
<tr>
<td>F/E/VE8621A</td>
<td>Lead A Flow Control</td>
<td>Analog in/out</td>
</tr>
<tr>
<td>F/E/VE8621B</td>
<td>Lead B Flow Control</td>
<td>Analog in/out</td>
</tr>
<tr>
<td>PV8600</td>
<td>Vacuum Gate Valve</td>
<td>Solenoid Valve</td>
</tr>
</tbody>
</table>

## HEATER

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT8621A</td>
<td>Lead A flag heater</td>
<td>Heater</td>
</tr>
<tr>
<td>HT8621B</td>
<td>Lead B flag heater</td>
<td>Heater</td>
</tr>
<tr>
<td>HTR8620</td>
<td>Lead Reservoir (2 x 20 W)</td>
<td>Heater</td>
</tr>
<tr>
<td>HTR8672</td>
<td>Mag Reservoir Return (3 x 20 W)</td>
<td>Heater</td>
</tr>
</tbody>
</table>

## PRESSURE INDICATOR

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DXXXXX</td>
<td>Relief Valve Vacuum</td>
<td>???</td>
</tr>
</tbody>
</table>

## SYSTEM HEALTH

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 VDC OK</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>UPS Low Power</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>UPS on Battery</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Vacuum pump 1 speed</td>
<td>Analog</td>
</tr>
<tr>
<td></td>
<td>Vacuum pump 2 speed</td>
<td>Analog</td>
</tr>
<tr>
<td></td>
<td>Vacuum pump 1 ON</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Vacuum pump 2 ON</td>
<td>Digital</td>
</tr>
</tbody>
</table>

## Magnet Monitoring/Control

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fast Dump</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Slow Dump</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Power Supply Communications</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Quench Detector Status</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Quench Detector Reset</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Power Supply Resets</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Watchdog/Keep Alive + Reset</td>
<td>Digital</td>
</tr>
<tr>
<td></td>
<td>Power Supply Status</td>
<td>Digital</td>
</tr>
</tbody>
</table>

## VFD's

<table>
<thead>
<tr>
<th>ID</th>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP8676A</td>
<td>Helium vacuum pallet</td>
<td>Mix</td>
</tr>
<tr>
<td>MP8676B</td>
<td>Helium vacuum pallet</td>
<td>Mix</td>
</tr>
</tbody>
</table>
Control, Monitoring, and Interlock System
Torus: PLC Components

• AB 1756 L72 Contrologix Allen Bradley
• I/O digital and analog modules
• Relay and sequence of events (SOE) modules
• Point I/O system
• 435 and 490 NBX modules
• Cryocon 18i temperature monitors
• Remote control power supply
• Touch panel monitors
Control, Monitoring, and Interlock System
Torus: cRIO Components

• NI 9068 cRIO and NI 9074 cRIO Controllers
• (2) NI 9870 cRIO RS-232 modules
• (8) NI 9239 Analog Input modules
• Low voltage excitation readback chassis
• Temperature, voltage, strain, pressure and hall sensors
Control, Monitoring, and Interlock System
Torus: Instrumentation

Low Voltage Torus
NI-9074 cRIO Controller

Fast_DAQ Torus
NI-9068 cRIO Controller

Voltage Tap and Quench Detector Breakout Panel
Solenoid Tasks

• **Communication between PLC ↔ Hall B network** - *Completed*

  — Assigned new IP address and host name for 1756-EN2T1 (local chassis) and 1756-EN2T2 (remote chassis) Ethernet modules, to set up communication with PLC solenoid

  — Set up configurations for each I/O module in local and remote chassis
    ▪ Modified PLC software
Solenoid Tasks

• Communication between PLC ↔ LV cRIO: Programming - Completed

— Generated four subroutines
  ▪ Load cells (force/strain)
  ▪ Cernox Sensors, PT-100 (temperature)
  ▪ Hall Sensors (B-field)

— Modified logic and sequence to control common errors, which appear when communication fails while data is being read

— Created array to read tags sent by cRIO system for each sensor value

— Generated Status_Error and Error_Fill routines to check errors during communication test

— Generated new file project for PLC program for testing purpose
Solenoid Tasks

- **Communication between PLC ↔ LV cRIO: Networking - Completed**
  - Made diagram of communication between PLC, cRIO Fast-Daq, cRIO LV, and EPICS
  - Configured communication of Ethernet generic modules on PLC program to set up communication with Fast_Daq and LV cRIO systems
Solenoid Tasks

• Communication between PLC ↔ LV cRIO: Testing - Completed
  — Set up different resistor values to simulate temperature sensors
    ▪ 60, 50, 40 and 30 KΩ for Cernox sensors
    ▪ 82 and 150 Ω for PT-100 sensors
  — Connected resistors in DB9 connectors and plugged into low voltage excitation readback chassis
  — Monitored readback values in PLC Solenoid from 9/9 to 9/13
    ▪ Test was completed successfully for these type of sensors

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Solenoid Tasks

• Analysis of PLC spreadsheets, layouts, and drawings of control system - Completed
  — Solved mismatch in drawing 0638
    ▪ Signal SV8622_Open was deleted from this drawing; it corresponds only to drawing 0641 in slot 2 remote chassis PLC
  — Added four readback signals for heaters 8620 and 8672 in local Solenoid PLC
    ▪ Spreadsheet and drawing modified
  — Added Current Source Polarity signal in drawing 0639
    ▪ Spreadsheet and drawing modified
Solenoid Tasks

• PID Program for Control Systems - In Progress
  – Researched Piping & Instrumentation diagrams and information related to Solenoid
  – Made list of instrumentation controlled by Solenoid PLC
  – Set up main functions for each electro valve, pneumatic valve, and heater in cryogenic process
  – Modified PID_Controls program and routines to set up control over cryogenics valves (EV and PV) and heaters
Solenoid Task

• Testing of communication Fast_DAQ cRIO ↔ PLC - In Progress
  — Simulate injection voltage in channel 1 of analog input module of cRIO
  — Modified Magnet_Calculation Program in PLC code
    ▪ Generated array to write 20 voltage taps from cRIO_Fast_DAQ.
  — Monitored values in PLC software

• Communication PLC ↔ EPICS – In Progress
  — Generated a list with tag names
  — Defined tags for the Danfysik magnet power supply
Torus Tasks

• **UPS power transfer for Torus controls system** - **Completed**
  — Reconnected all electric strips of control racks into UPS power supply
  — Plugged UPS in outlet that is part of generator circuit for hall
  — Reset communication of PLC for DBX, Torus, and Solenoid
  — Reset communication of cRIO for Torus and Solenoid

• **Voltage injection test in Fast_DAQ cRIO module** - **Completed**
  — Set up voltage injector at channel 1 of cRIO analog input module
  — Injected 2 V for first test and 3 V in second test
  — Monitored reading in PLC Torus — as expected, for both values
Torus Tasks

• **Correct networking information** - *Completed*
  — Generated new spreadsheet with corrected IP addresses and host names for Torus and Solenoid

• **Stabilize pressure in LN\(_2\) reservoir** - *Completed*
  — Programmed cascade PID (2 PIDs max, min) for HTR8554 (heater element)
  — Modified PID_Control program to link HTR8554.MIN tag variable
    ▪ Set default value of tag to 32% of maximum
Conclusions

Solenoid
• Developing programs
  — Fast_Daq Processing
  — Communication_PLL_Solenoid
  — Magnet_Calculation
  — PID_Controls
  — Networking configurations software
• Testing Communications
• Improving control, monitoring, and interlock systems
• Solving discrepancies with documentation (Solenoid-Torus)

Torus
• Supporting
  — Cooldown control activities
  — PLC code debugging
Thank you
## Solenoid-Technical Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of Coils</td>
<td>5</td>
</tr>
<tr>
<td>Coil Structure</td>
<td>Layer wound</td>
</tr>
<tr>
<td>Number of turns in main coils</td>
<td>3704 (2 x 840 + 1012)</td>
</tr>
<tr>
<td>Number of turns in shield coil</td>
<td>1392</td>
</tr>
<tr>
<td>Nominal Current [A]</td>
<td>2416</td>
</tr>
<tr>
<td>Central Field [T]</td>
<td>5.0</td>
</tr>
<tr>
<td>Peak Field [T]</td>
<td>6.56</td>
</tr>
<tr>
<td>Field homogeneity in Ø 2.5x4 cm cylinder</td>
<td>1x10^-4</td>
</tr>
<tr>
<td>Peak field location</td>
<td>Inner turn near warm</td>
</tr>
<tr>
<td>B-Symmetry</td>
<td>Yes</td>
</tr>
<tr>
<td>Inductance [H]</td>
<td>5.89</td>
</tr>
<tr>
<td>Store Energy</td>
<td>&lt; 20[MJ]</td>
</tr>
<tr>
<td>Warm bore Ø [mm]</td>
<td>780</td>
</tr>
<tr>
<td>Total weight [Kg]</td>
<td>18800</td>
</tr>
<tr>
<td>Cooling mode</td>
<td>Conduction cooled</td>
</tr>
<tr>
<td>Supply Temperature[K]</td>
<td>4.2</td>
</tr>
<tr>
<td>Torus - Technical Parameters</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Number of Coils</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>Coil structure</strong></td>
<td>Double pancake potted in Aluminum Case</td>
</tr>
<tr>
<td><strong>Warm bore Ø (mm)</strong></td>
<td>124</td>
</tr>
<tr>
<td><strong>Total weight (Kg)</strong></td>
<td>25,500</td>
</tr>
<tr>
<td><strong>Number of turns per pancake</strong></td>
<td>117</td>
</tr>
<tr>
<td><strong>Number of turns per coil</strong></td>
<td>2x117 = 234</td>
</tr>
<tr>
<td><strong>Conductor</strong></td>
<td>SSC outer dipole cable soldered in 20 mm x 2.5 mm Cu channel</td>
</tr>
<tr>
<td><strong>Turn to Turn Insulation</strong></td>
<td>0.003” E-Glass Tape ½ Lap</td>
</tr>
<tr>
<td><strong>Nominal current (A)</strong></td>
<td>3770</td>
</tr>
<tr>
<td><strong>Ampere turns (-)</strong></td>
<td>882,000</td>
</tr>
<tr>
<td><strong>Peak Field (T)</strong></td>
<td>3.58</td>
</tr>
<tr>
<td><strong>Peak Field Location</strong></td>
<td>Inner turn near warm bore adjacent to cooling tube</td>
</tr>
<tr>
<td><strong>B-Symmetry</strong></td>
<td>Yes</td>
</tr>
<tr>
<td>**</td>
<td>Bdl @ nominal current (Tm)**</td>
</tr>
<tr>
<td><strong>Inductance (H)</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Stored Energy (MJ)</strong></td>
<td>14.2</td>
</tr>
<tr>
<td><strong>Quench Protection/Dump Resistor</strong></td>
<td>Hard wired quench detector / 0.124 Ω dump resistor</td>
</tr>
<tr>
<td><strong>Coil Cooling</strong></td>
<td>Conduction Cooled by Supercritical Helium</td>
</tr>
<tr>
<td><strong>Supply temperature (K)</strong></td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Temperature margin (K)</strong></td>
<td>Min 1.52 (@5.3 K) to Generation temperature 6.82</td>
</tr>
<tr>
<td><strong>Heat Shield Cooling</strong></td>
<td>LN2 Thermo-Siphon</td>
</tr>
</tbody>
</table>