Hg System Operation Review

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MERIT Pre-Installation Review
CERN
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Outline

• Hg system description
• Integrated testing results
• Operational experience
• Plans at CERN
Hg System Description

- Syringe pump
- Hydraulic power unit w/control system
- Optical diagnostic system
- Baseplate support structures
Syringe Pump System

- **Primary containment**
  - Hg-wetted components
  - Capacity 23 liters Hg (~760 lbs)
  - Jet duration up to 12 sec

- **Secondary containment**
  - Hg leak/vapor containment
  - Ports for instruments, Hg fill/drain, hydraulics

- **Optical diagnostic components**
  - Passive optics
  - Shadow photography

- **Beam Windows**
  - Ti alloy components that directly interact with beam
  - Single windows on primary, double windows on secondary
Syringe Statistics

- 30hp / 4000psi / 12.9gpm hydraulic pump
- 40 gal vegetable-oil based hydraulic fluid
- Hg flow rate 1.6liter/s (24.9gpm)
- Piston velocity 3.0cm/s (1.2in/sec)
- Up to 100 bar (1500 psi) Hg pressure in cylinder
- Hg cylinder force 525kN (118kip)
Hydraulic Power Unit

- Actuates syringe drive cylinders
- Connected to secondary containment through non-magnetic hoses
- Proportional control valve provides precise hydraulic flow based on command signal from control system
- 200 bar (3000 psi) nominal operating pressure
- Incorporates relief valve to prevent over-pressure condition
- Breather-vent filter isolates reservoir air from tunnel
- Drip pan for small fluid leaks
Ports

- Hydraulics
- Instrumentation
- Optical diagnostics
- Hg drain & fill (without opening secondary)
- Hg extraction (in event of major leak in primary containment)
- Passive filtration
Load Testing of Common Baseplate & Target Cart

- CERN Safety Commission voiced concerns regarding analysis performed on common baseplate design
- Load test performed on structures to verify strength and test adjusting mechanisms
- Estimated component weights
  - Magnet: 12000 lbs (5440 kg)
  - Hg system (with 23 liters Hg): 4000 lbs (1810 kg)
- Test weights
  - Magnet: 13600 lbs (6170 kg) = 113% estimated weight
  - Hg system: 4500 lbs (2040 kg) = 113% estimated weight
In Nominal Test Position

- Baseplate tilt ~ 66mrad
- Elevation matches CAD models
MIT Testing Result Summary

- Completed 14 runs with field (10-15-20 m/s jets, 5-10-15 Tesla fields)
- Syringe pump performed as expected
  - No fluid leaks during testing
- Expected increased Hg pressure due to field, but no effects observed
- Water vapor issues inside jet chamber resulted in addition of strip heater on exterior of chamber
- External bore heater had to be reconfigured due to clearance issues
Hg & Hydraulic Pressure Comparison - 0T vs. 15T
20m/s Hg Jets

Design Pressures:
Hg Cylinder - 100 bar
Hydraulic Cylinders - 200 bar

PortA-0T  PortA-15T  PortB-0T  PortB-15T  Hg-0T  Hg-15T

Pressure (bar) vs. Time (ms)
Nozzle Velocity Comparison - 0T vs. 15T

![Graph showing the comparison of nozzle velocity between 0T and 15T with time on the x-axis and syringe command signal and nozzle velocity on the y-axis.](image-url)
Addition of Strip Heaters

- Approx 0.5L water not removed from system prior to Hg operations at ORNL
- Insertion into magnet caused condensation on viewports
- Modified existing flexible heaters to prevent condensation
- New heaters and controllers procured for CERN operation
Operational Experience

- Hg fill/drain process performed twice without incident
- Small Hg leak occurred at ORNL
  - Contained within secondary, no problems in cleanup
- Control system functions as expected
  - Tested emergency stop conditions
- Hg vapor detection and capture
  - Vapor monitors work as expected
  - Local ventilation system (Scavenger) quickly removes any vapors within secondary, zero emissions detected at exhaust
Hg Fill & Drain Procedures Tested

- Two fill and drain cycles completed
  - MIT cycles observed by CERN personnel
- Peristaltic pump method works well, minimizes spill risk & vapor generation
- Drain into intermediate container reduces chance of overfilling flask
- Flasks weighed empty & full to track inventory
- No spills or operational problems
Hg Leak Experienced

- Very high vapor levels inside secondary detected at ORNL
  - No vapors detected outside secondary
  - Scavenger snorkel successfully removed vapors
- Suspected Hg cylinder bellows & made effort to seal seams
  - Upon disassembly, no vapors detected inside bellows
- Small Hg leak discovered in nozzle supply threaded joint
- Successfully removed liquid and tightened joint
Emergency Stops Tested

- Syringe pump stopped during 20m/s jet creation
- No detrimental effects on equipment
- No noticeable vibration or shudder
Plans at CERN for Hg System

- Transport all equipment into TT2/TT2A
- Open secondary containment prior to Hg loading
  - Procedures in place for this operation
  - Leak check primary containment (pressure decay test without opening primary)
  - Connect optical diagnostics system & adjust viewport optics
  - Install new heater strips
  - Install umbilicals and operate optical diagnostic system
- Close secondary
  - Install other umbilicals (hydraulics, sensors, vapor monitors)
  - Load Hg
- Perform Hg system commissioning tests
  - System can be operated and tested independently of solenoid
Conclusions

- System operating characteristics have been quantified during ORNL and MIT testing
- 15T field induced no additional pressure on Hg piping, system well within design pressures
- Secondary containment has prevented vapor escape
- Valuable operational experience gained
  - Hg leak experienced
    - Detected with instrumentation, contained within secondary, successfully mitigated
  - Control system functionality proven
Operational Testing

- Lifting jacks and lateral position adjustment mechanisms tested
Roller Testing

- Loaded baseplate pushed with pallet jack while on three Hilman rollers
Leveling Jack Testing

- Baseplate adequately supported by four leveling jacks
Hg System Schematic
Secondary Snout Fiducialized

- Marks on exterior of target snout will aid in alignment (tilt and elevation only)
- Service provided by SNS Survey & Alignment Group
Installation Marks

- Optical survey equipment required to see scribe marks
Sumptank Standpipes Added

- Testing revealed potential Hg surge under splash plate could allow Hg to exit sump tank through vents
- Additional height added to eliminate condition
Vapor Monitor Tests

- Both vapor monitors (Jerome 431-X and Mercury Instruments VM3000) tested to verify ability to read vapors through 10m, small-dia tubing
  - Jerome samples every 5 minutes, VM3000 continuously samples
  - Both units detected elevated vapor levels
    - VM3000 within a few seconds
    - Jerome within 2 samples

- Signals integrated into Labview control system
  - VM3000 output correctly read by Labview
  - Having some difficulties with the Jerome unit, discussing with vendor tech support
Hg Syringe Control Operator Interface

- Jet velocity profile
- Syringe control
- Performance feedback
- Data logging
- Operator messages
- Status & alarm indicators
LabView-Based Control System

- LabView on laptop computer was chosen as system controller
  - CompactFieldPoint sensor modules housed in HPU control cabinet

- Hydraulic system controlled via Labview over ethernet
# Instrumentation & Sensors

## Controlled Components

| Hydraulic pump | Proportional control valve |

## Analog Sensor Inputs

<table>
<thead>
<tr>
<th>Hg discharge pressure</th>
<th>Hg level</th>
<th>Hg vapor 1</th>
<th>Hg vapor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder 1 position</td>
<td>Cylinder 2 position</td>
<td>Beam window 1 pressure</td>
<td>Beam window 2 pressure</td>
</tr>
<tr>
<td>Hydraulic fluid port pressures</td>
<td>Eight RTDs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Digital Sensor Inputs

<table>
<thead>
<tr>
<th>Hydraulic filter dirty switch</th>
<th>Hydraulic low level switch</th>
<th>Hydraulic fluid high temperature</th>
<th>Conductivity probe leak detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam trigger</td>
<td></td>
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