MERIT Hg System Review

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Executive Summary

- Hg system design has been completed
- Syringe pump fabrication is nearly complete
- Drawing packages for remainder of system are either in fabrication or out for bid
- System testing at ORNL scheduled to begin in May

Now for some details...
Requirements and Operating Conditions

Target system must deliver a stable, unconstrained jet of Hg into a 15 Tesla field

- 1-cm diameter jet at 20 m/s delivered every 30 minutes
  - Q=1.6 liter/s, Re~10^6

- ~1-sec steady state jet during the magnet peak field

- Baseline Hg environment is 1-atm air, also considering running in rough vacuum

- Full-beam interaction length is 30-cm

- Beam line is 120 cm above the tunnel floor

- Up to 100 pulses for the CERN test, >500 operating cycles for system testing
Geometry of the Interaction Region

- Horizontal proton beam
- Magnet axis to beam is 67 milliradians
- Jet to beam is 33 milliradians
  - Jet starts between magnet axis and beam
- The jet centerline crosses the beam center at Z=0 (center of the solenoid)
- 7 milliradian horizontal beam kick
Experiment Layout

- Hg target is a self-contained module inserted into the magnet bore
- Two containment barriers between the Hg and the tunnel environment
- Hydraulic pump will be in adjacent tunnel, personnel in remote control room
Experiment at CERN

- TT10
- Hyd Pump & Controls in TT2
- Access Shaft
- TT2A
- TT2
- MERIT
- ISR (Control Room Location)
Stray Field Plot

- The pump equipment operates in a range of 3000 Gauss to 300 Gauss (1 Tesla = $10^4$ Gauss)
- Hg jet starts in 6-9 Tesla field
Hg Delivery 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
Flow Simulation Using AFT Fathom

- Simulates mechanical piping/flow losses
  - Does not include MHD effects
- Results predicted cylinder pressure of ~780 psi (50 bar) for original plenum/nozzle configuration
- Current nozzle configuration predicts cylinder pressure of ~500 psi (35 bar)
- Syringe design pressure 1500 psi (100 bar), so we have significant excess pressure capacity to accommodate losses due to field effects, which we won't know until integrated testing at MIT
Hg Syringe Performance

- Hg flow rate
  1.6 liter/s
  (24.9 gpm)

- Piston velocity
  3.0 cm/s
  (1.2 in/sec)

- Up to 103 bar
  (1500 psi) Hg pressure in cylinder

- Hg cylinder force
  525 kN (118 kip)
Syringe Status

- Syringe vendor Airline Hydraulics Corp (AHC)
  - Bensalem, PA

- AHC provided system design based on functional requirements specification

- System consists of all syringe pump components

- Status
  - Integration of cylinders & control system starting this week
  - System factory acceptance testing March 30
Additional Syringe Work

- Syringe procurement initiated Sept '05 due to anticipated long delivery of cylinders
- Fabrication dwgs for remainder of system not completed at that time
  - Dwg pkg now complete
- Prefer to award to syringe pump vendor
- Being coordinated by BNL Procurement
Primary Containment

- Hg supply flow path
  - 1-inch Sch 40 SS pipe
  - 1-inch flex rubber hose w/Swagelok fittings
  - 1-inch, 0.065-wall Ti rigid tubing
  - Fabricated Titanium reducer
    - 0.5-inch, 0.065-wall Ti nozzle

- Hg jet return path
  - 1/4-inch plate Ti chamber
  - 4-inch SS flex metal hose w/sanitary fittings
  - SS sump tank
Beam Windows

- Windows fabricated from Ti6Al4V alloy
- Welded attachments provide more usable space for beam
- Single windows for primary containment, double windows for secondary
- Pressurize secondary windows, monitor to detect failure
Titanium Target Module

- Current design of primary/secondary containment modules inserted into magnet utilizes Ti or Ti alloys
  - Alleviates issues with welding dissimilar metals
  - Anodized Ti minimizes some MHD effects by insulating conductive Hg from the piping

- Drawing package currently out for bid
  - Will be coordinated by Princeton Procurement
  - Procurement direction to be decided on cost/schedule considerations

- Material for 2 spare nozzle assemblies will also be procured
Secondary Containment

- SS304L/316L 1/2" bottom plate, 1/4" sides
- SS flexible sleeve
- Ti cylindrical sleeve
- Lexan top
- Ports
  - Optical diagnostics
  - Instrumentation
  - Hydraulics
  - Hg drain & fill (without opening secondary)
  - Hg extraction (in event of major leak in primary containment)
  - Passive filtration
- Fabrication underway at Princeton (except Ti sleeve)
Optical Diagnostics

- 8X 100mm-dia, 6mm-thick sapphire disks with cover plates mechanically attached to jet chamber
  - Disk has been impact-tested at Princeton
- One set of windows configured for reflector assemblies
- BNL to provide splitters, prisms, lenses, bracket, mounting hardware & adjustment mechanisms
Z=0 Section Cut

- Viewports
- Hg Supply
- Optics
- Fiber Bundles
- Secondary Containment
- Reflector
- Mercury Jet
- Primary Containment
Baseplates

- Multiple baseplates required for transport, assembly, and equipment support
- Primarily fabricated from Al 6061-T6
- Fabrication underway at University of Mississippi
Installation Sequence

Transport Hg System

Remove Rollers

Transport Baseplate, Install Magnet

Remove Rollers, Level Magnet

Roll Hg System into Magnet

Add Rollers
LabView-Based Control System

• Remote control over long distance limited control choices

• LabView on laptop computer was chosen as system controller
  – CompactPCI I/O modules at syringe pump control station
  – Communicates to laptop via EtherNet cable
  – Should allow straightforward integration with other MERIT control systems
**Instrumentation & Sensors**

<table>
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<tr>
<th>Controlled Components</th>
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<td>Hydraulic pump</td>
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<th>Analog Sensor Inputs</th>
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<tr>
<td>Hg discharge pressure</td>
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<tr>
<td>Cylinder 1 position*</td>
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<tr>
<td>Hydraulic fluid high pressure</td>
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<th>Digital Sensor Inputs</th>
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<td>Hydraulic filter dirty switch</td>
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* Critical for system operation or safety
Hg Syringe Control System Development Underway
Hg Handling - Properties and Safety Limits

- Atomic Weight: 200.59
- Boiling Point: 357° C
- Specific Gravity: 13.6
- Vapor Pressure: 0.0012 mm Hg
- Vapor Density: 7.0 (air = 1.0 @ 20° C)
- Vapor: colorless, odorless
- Solubility: insoluble in water
- NIOSH/OSHA: 0.05 mg/m3, 10 h/day; 40 h/wk
  - ORNL: action level is set to 0.0125 mg/m3
    - Use respirator with Hg cartridge
Target Test Facility (TTF) – Basis for ORNL's Hg Handling Experience

- Full scale, prototype of the SNS Hg flow loop
- 1400 liters of Hg
- Used to determine flow characteristics
- Develop hands on operating experience
- Major system renovations with Hg-contaminated equipment
- MERIT assy & testing will occur in or near TTF
Mercury Containers/Shipping

- Standard flask is 2.5 liters
- Flask + Hg weighs ~35 kg
- Shipping requirements coordinated by ORNL Transportation Group
- MERIT will require a short (20ft) Sealand container for transport to CERN
  - Ship magnet with Hg system
TTF Operations – Hg Filling

- A peristaltic pump for transferring Hg was successfully tested
  - This is the preferred approach for filling & draining MERIT
  - System designed to fill/drain without opening secondary containment

- Hg handling requires multiple spill/drip precautions and ventilation equipment
Mercury Vapors – Filtering & Monitoring

- Two vapor monitors to be used
  - One for secondary volume, one for tunnel environment
  - Will communicate with control system

- Scavenger portable ventilation system will be used
  - Can be used as stand-alone system or connected to secondary containment
  - Already procured by Princeton

- Passive filtration on secondary containment
  - Sulphur-impregnated charcoal & HEPA filtration
MERIT at MIT and CERN

- Dialogue with CERN & MIT Safety Engineering Group has begun
  - Presentation/discussion with CERN in August ’05
  - Presentation/discussion with MIT at the October Collaboration Meeting

- Formal safety reviews and test/operation plans to be presented to MIT and CERN during summer 2006
**Schedule – Major Milestones**

- **Target Tests at ORNL May-Jul '06**  
  - Integrated with optical diagnostics system

- **Integrated Tests at MIT Aug-Sep '06**  
  - Retest Oct '06 if nozzle reconfiguration needed

- **Ship MERIT equipment to CERN Nov-Dec '06**

- **Beam Tests at CERN Apr '07**  
  - Retest Jun '07, if needed
Conclusions

• Syringe pump system fabrication nearly complete, integration to begin this week
  – Factory acceptance testing March 30

• Final design details & fabrication dwgs of Hg system have been completed
  – Initial nozzle configuration determined
  – Fabrication is underway on baseplates & secondary containment
  – Sump tank assy pkg should be awarded soon
  – Titanium pkg out for bid, delivery could possibly affect testing schedule

• Control system development started, need guidance regarding integration with supervisory experiment control system

• Hg system testing at ORNL will begin as soon as equipment becomes available
  – Water testing followed by Hg