MERIT Hg System Final Design Review

Hg Target System Design

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MERIT Collaboration Meeting  
MIT Plasma Science & Fusion Center  
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Outline - Component Details

• Syringe
• Primary containment
• Secondary containment
• Baseplates
**Hg Delivery System**

- Capacity 23 liters Hg (~760 lbs)
- Provides 1 cm dia, 20 m/s jet for up to 12 sec
- Secondary containment size 960 mm x 1475 mm x 960 mm
- Estimated weight 2T with Hg
Hg Syringe System
Hg Syringe System

- Hg flow rate 1.6 liter/s (24.9 gpm)
- Piston velocity 3.0 cm/s (1.2 in/sec)
- Hg cylinder force 525 kN (118 kip)
Fathom Flow Simulation

- System diagram for Hg flow
- Results indicate maximum pressure requirement of ~780 psi (50 bar) for baseline plenum/nozzle configuration
- Design system for max pressure of 1000 psig (70 bar)
# Fathom Details

## Pipe Output Table

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Other Fathom Simulations

- 1/2" tubing bend
  - Cylinder pressure 1200 psi (83 bar)

- No-bend short 1/2" tube
  - Cylinder pressure 710 psi (48 bar)

- 1" tubing bend
  - Cylinder pressure 780 psi (54 bar)

- All 1/2" tubing from end of flex metal hose, no plenum
  - Cylinder pressure 1910 psi (130 bar)

- Any non-plenum design should minimize number of bends & length of nozzle tubing

- Don't let syringe pump limit nozzle configuration - recommend changing system design pressure to 1500 psi (103 bar) to match Hg cylinder rating
Non-Plenum Nozzles

- Room is available to eliminate plenum, keep tubing under beam
- Flow streamlines become more of an issue
  - Desire to move bend further from nozzle
Syringe Procurement

- Complete system design based on specified requirements
- Piston pump (inside secondary containment)
  - One 10-inch Hg Pump Cylinder
  - Two 6-inch Drive Cylinders (one with integrated position sensor)
  - Tie beam
  - Baseplate
  - Hydraulic hoses inside secondary for operating Drive Cylinders
- Hydraulic pump (outside secondary containment)
  - Pump, motor, reservoir
  - Proportional, directional control valve
  - Hydraulic hoses between pump & secondary containment
  - Motor controller
  - Variable voltage transformer for U.S. and European operation
- Hydraulic fluid (drum)
- Integration of system components
- System testing with water
Syringe Procurement Status

- RFQ sent to 5 vendors, 4 submitted quotes
  - Requested prices for std cylinders & SS cylinders
  - Low bid: $60K (std), $68K (SS)
  - Subcontract awarded to Airline Hydraulics (Edison, NJ)
  - Chose SS cylinder option
  - Kickoff meeting being scheduled for next week

- Vendor required to host a syringe design review 30 days after contract award, prior to ordering materials
Syringe Hydraulic Schematic

Motor control cabinet

Control cabinet

Motor power

Low fluid level signal

Low fluid level signal

Pressure signal

Pressure signal

Filter dirty signal

Filter dirty signal

480 VAC, 3Ph, 60 Hz

380 VAC, 3Ph, 50 Hz

SYRINGE PUMP

HYDRAULIC PUMP UNIT

SYRINGE PUMP

HYDRAULIC PUMP UNIT

Pressure gage

Sump tank

NEEDED FOR TEST

Bill of Materials

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Primary Containment

- **Hg supply flow path**
  - 1-inch Sch 40 pipe
  - 1-inch flex metal hose w/sanitary fittings
  - 1-inch, 0.065-wall rigid tubing
  - 5-inch diameter plenum
  - 12mm-dia, 1mm-wall rigid tubing

- **Hg jet return path**
  - 1/4-inch plate weldment chamber
  - 6-inch to 2-1/2-inch eccentric reducer
  - 2-1/2-inch flex metal hose w/sanitary fittings
  - Sump tank
Normal Syringe Operations

- Slowly extend cylinder to fill Hg cylinder from sump
- Slowly retract cylinder to starting position & prefill Hg supply piping
- Some time after trigger is received, ramp cylinder to full speed
  - Need engineering solution to prevent possibility of sudden cylinder start – will discuss with syringe vendor
- Steady-state jet for 1 sec
- Ramp cylinder to zero velocity
  - Sudden stop can cause flow separation & Hg hammer
Sump Tank

- Fabrication: 1/4" plate SS304L/316L
- Ports for Hg fill & extraction, Hg level sensor, syringe vents, breather checkvalves, supply line relief
Sump Tank Analysis

- 800-lb Hg load on tank bottom
- Min FOS > 9
Manifold

- Designed for socket weld fabrication, SS304L/316L

- Channels
  - Flow – 1" pipe
  - Hg cylinder vent – 1/2" tube
  - Sump drain – 3/4" pipe
  - Pressure transducer – 1/2" tube
  - Relief valve – 3/4" tube

- FEA results
  - FOS = 4.8 for 1000 psi
  - Will be redesigned for 1500 psi
Hg Plenum

- Fabrication incorporates nozzle, beam window, and Hg supply tubing
- Replaceable module
Hg Plenum Analysis

- Based on static 800 psig internal pressure, no dynamic loading
- Min FOS = 0.51, further design required
Primary Containment Pressure Ratings

- Pressure Ratings Table
Primary Containment Beam Windows

- Single layer Ti6Al4V, 1mm thick
- Hg deflector acts as beam window, made from same material
- Horizontal beam kick
  - 6mm @ primary window
  - 18mm @ secondary window
- Downstream window sized to accommodate horizontal beam kick and small changes in magnet tilt
Hg Deflector

- Simplifying analysis indicates imparted force on plate of 425N (95lb)
- Using Ti6Al4V thickness of 1mm gives a safety factor < 1
- Recommend deflector thickness of 2mm
  - FS = 3.5
Accommodating Tilt Changes

- Hg delivery system can accommodate some amount of decreasing tilt angle and keep beam in windows
  - 30mrad upstream
  - 33mrad downstream
Beam Window Fabrication Issues

- Do not have definitive answer to question of weldability between Ti6Al4V and SS304L/316L

- If reliable process is found, it likely will require some development by fabricator to establish welding parameters
  - Material samples and added cost

- Can windows be SS316L/304L?
Secondary Containment

- SS304L/316L 1/2" bottom plate, 1/4" front, sheet metal sides & back (7ga, 0.179")
  - May add stiffeners to sides & back
- Flexible sleeve (non-metallic, combustibility issue)
- SS304L/316L cylindrical sleeve (13ga, 0.089")
- Passive filtration
  - Filtered inlet and outlet, both will be have shutoff gates
Secondary Containment Double Beam Windows

- Similar in construction to Hg plenum
- SS pipe with Ti6Al4V caps
  - All Ti if necessary, but attachment to secondary containment still an issue
- Flexible tubing back to hydraulic system
- Pressurize and monitor to detect failure
  - Can also vacuum monitor, but pump and larger tubing required
  - Will test at ORNL, determine final method
Secondary Containment Access Ports

- Optical diagnostics
- Instrumentation
- Hydraulics
- Hg drain & fill (without opening secondary)
- Hg extraction (in event of major leak in primary containment)
Secondary Containment Monitoring and Filtering

- Two Hg vapor monitors for secondary volume
- Passive filtration with shutoff, can connect to active filtration system
  - Will have single cartridge rather than respirators
- Third vapor monitor for passive filter exhaust and/or tunnel monitoring
- Investigating whether monitors can be moved away from experiment
Baseplates

- Purpose – provide mobility, alignment, and structural support for experiment components
  - Experiment requires magnet tilt of 66mrad (3.8°)

- Two baseplates
  - Target transporter
  - Common baseplate
Target Transporter

- Transports Hg system inside tunnel using Hilman rollers
  - O/A length 62" (1.6m)
- Rails for Hg system cart wheels
- Jack bolts prevent rolling
- Swivel hoist rings for lifting & cart tie-down
- Material: AL6061-T6
Common Baseplate

- Shares design with transporter baseplate
  - O/A length 124" (3.15m)
- Rollers used to grossly align solenoid to beam
- Provides lateral movement of solenoid for alignment to beam once rollers removed
Design Constraints & Requirements

• Total supported weight
  – Magnet: 9000 lbs
  – Hg System with 23liter Hg: 4000 lbs
  – Baseplate: 1000 lbs
  – Movement requires lateral force of 700 lbs ($\mu_s = 0.05$ per Hilman)

• Maximum width of 1.3m (51") to meet CERN facility constraints

• Fabrication material to be non-magnetic (chose AL 6061-T6)

• Must have lifting & leveling provisions

• Currently not anchored to floor – is there a need?
Common Baseplate Structure

- 4-inch AL channel frame, I-beam internal supports
- Hilman roller support plates
- Welded leveling jack gusset plates
- Side-load swivel hoist rings for lifting
- Removable jack stand gussets
Magnet Lateral Alignment

- Gross adjustment provided by Hilman rollers
- Low-friction surface plate sits between magnet support plate and baseplate
- Weld studs with nuts hold final position
- Jackbolts provide lateral moving force
- Lateral adjustment range ±25mm
Common Baseplate Structural Analysis – 3 Rollers

- Condition: loaded baseplate carried by 3 Hilman rollers

- Min FOS = 0.65 in extremely localized area due...
Common Baseplate Structural Analysis – 4 Lift Jacks

- **Condition**: loaded baseplate supported by 4 hydraulic jacks
- **Min FOS > 4**

![Diagram showing structural analysis of baseplate with 4 lift jacks and deformation scale]
Common Baseplate Structural Analysis – 4 Leveling Jacks

• Condition: loaded baseplate supported by 4 leveling jacks

• Min FOS=1.8 in localized areas
Some Final Design Details

- Some dimensions of Hg delivery system can't be finalized until syringe design is complete.
- Will need magnet as-built height on its base.
Remaining Design Work

- Finalize procured component details for drawings
- Drawing check
- Sensor / instrumentation wiring diagram
- Generate fabrication vendor list
- Write procurement specification
Design Issues

- Nozzle configuration – plenum vs non-plenum
- Nozzle details – length, exit features
- Final dimensions for syringe system, magnet height