MERcury Intense Target (MERIT) Overview

Van Graves, ORNL

Syringe Procurement Kickoff Meeting
Airline Hydraulics
Bensalem, PA
Oct 28, 2005
Background

- Proof-of-principle experiment to investigate the interaction of a proton beam with a Hg jet inside a high-strength magnetic field
  - If successful, method might be used as production target in new physics facility

- Primary diagnostic for the beam-jet interaction is optical
  - Multiple high-speed cameras will be used to record interaction

- Collaborative effort among multiple national laboratories, universities, and research facilities

- Experiment to be conducted at CERN (Geneva) in April 2007
Prior Work

- **E951 Tests (H.Kirk - BNL)**
  - 1cm dia, 2.5m/s Hg jet
  - 24 GeV 4TP beam
  - No magnetic field
  - *Jet dispersal observed* 

- **CERN/Grenoble Tests**
  (A.Fabich,J.Lettry - NuFACT’02)
  - 4cm dia, 12m/s Hg jet
  - 0,10,20T magnetic field
  - No proton beam
  - *Jet stabilization with increasing field*
Experiment Profile

- **Hg Jet**
  - 1-cm diameter, 20 m/s, delivered to coincide with magnet peak field
  - Required flow rate of 1.57 liter/s (25gpm)

- **Magnet**
  - 16-cm diameter bore that Hg system must fit within
  - 15 Tesla magnetic field
  - Peak field duration ~1 sec
  - Magnet cool-down time ~30 minutes

- **Environment**
  - 24 GeV proton beam, up to 28x10^{12} (TP) per 2μs spill
  - 1-atm air environment inside target delivery system primary containment
  - Total integrated dose 10^4 rads

- **Geometry**
  - Hg jet 100 milliradians off magnet axis
  - Proton beam 67 milliradians off magnet axis
  - Jet intersects beam at magnet Z=0

- **Up to 100 beam pulses for the CERN test delivered in a pulse-on-demand mode**
Experiment Geometric Configuration

Experiment is prototypic of a N.F. facility target layout

- Magnet tilt (wrt beam) = 66 mrad (3.8°)
- Hg jet tilt (wrt magnet axis) = 100 mrad (5.7°)
- Hg jet center intersects beam center at Z=0

- Jet in same direction as beam
Experiment Layout

- Hg target is a self-contained module inserted into the magnet bore
- Two containment barriers between the Hg and the tunnel environment
MERIT Layout

Hyd Pump & Controls in TT2

TT10

ISR (Control Room Location)

TT2A

MERIT

TT2
LabView-Based Control System

• Remote control over long distance limited choices
  – Analog I/O modules need to be close to equipment and power supplies

• LabView controller on laptop computer was chosen
  – National Instruments recommends CompactPCI I/O modules
  – Communicates to laptop via EtherNet cable
  – Allows custom operator interface, data logging if required during development
  – Should allow straightforward integration with other control systems

• Control system development to begin late October
MERIT Side View

- Tilt limited syringe length
- CERN facility constraints limited syringe width
Hg System Schematic

Single Window (2)

Primary Containment

Secondary Containment

Solenoid Bore

Filtered Ventilation

Double Window (2)

Primary Containment

Hg Vapor Monitor No. 1

Hg Vapor Monitor No. 2

Sect. A-A

Hg Target System Containment Boundaries
(pts: Aug. 24, 2005)
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)
Primary Containment

- Hg supply flow path
  - 1-inch Sch 40 pipe
  - 1-inch flex metal hose w/sanitary fittings *(want smooth wall – can hydraulic hose be used?)*
    - 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
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

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Name</th>
<th>Nominal Size</th>
<th>Flow (gal/min)</th>
<th>Length (inches)</th>
<th>Flow Area (inches²)</th>
<th>Velocity (feet/sec)</th>
<th>Reynolds No.</th>
<th>fL/ D + K</th>
<th>P Stag. Out (psig)</th>
<th>dP Stag. Total (psid)</th>
<th>P Static Out (psig)</th>
<th>dP Static Total (psid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hg Cylind</td>
<td>10 inch</td>
<td>24.9</td>
<td>15</td>
<td>78.854</td>
<td>0.101</td>
<td>6.86E+04</td>
<td>0.0296</td>
<td>784</td>
<td>2.77E-05</td>
<td>783.9</td>
<td>784</td>
</tr>
<tr>
<td>2</td>
<td>Cylinder D1</td>
<td>1 inch</td>
<td>24.9</td>
<td>1.5</td>
<td>0.864</td>
<td>9.24</td>
<td>6.56E+05</td>
<td>0.0256</td>
<td>780</td>
<td>0.199779</td>
<td>772.2</td>
<td>772</td>
</tr>
<tr>
<td>3</td>
<td>Cylinder D1</td>
<td>1 inch</td>
<td>24.9</td>
<td>0.8</td>
<td>0.864</td>
<td>9.24</td>
<td>6.56E+05</td>
<td>0.0136</td>
<td>777</td>
<td>0.302768</td>
<td>769</td>
<td>769</td>
</tr>
<tr>
<td>4</td>
<td>Hg Manifold</td>
<td>1 inch</td>
<td>24.9</td>
<td>16.1</td>
<td>0.864</td>
<td>9.24</td>
<td>6.56E+05</td>
<td>0.2745</td>
<td>774</td>
<td>9.772281</td>
<td>765.9</td>
<td>756</td>
</tr>
<tr>
<td>5</td>
<td>Hose Inlet</td>
<td>1 inch</td>
<td>24.9</td>
<td>2.1</td>
<td>0.864</td>
<td>9.24</td>
<td>6.56E+05</td>
<td>0.0358</td>
<td>761</td>
<td>0.279691</td>
<td>752.8</td>
<td>752</td>
</tr>
<tr>
<td>6</td>
<td>Flex Metal</td>
<td>1 inch</td>
<td>24.9</td>
<td>10.5</td>
<td>0.945</td>
<td>8.449</td>
<td>6.27E+05</td>
<td>0.17</td>
<td>760</td>
<td>1.110492</td>
<td>753.7</td>
<td>753</td>
</tr>
<tr>
<td>7</td>
<td>Hg Supply</td>
<td>1 inch</td>
<td>24.9</td>
<td>1.86</td>
<td>0.594</td>
<td>13.433</td>
<td>7.91E+05</td>
<td>0.0284</td>
<td>755</td>
<td>0.469346</td>
<td>738.7</td>
<td>738</td>
</tr>
<tr>
<td>8</td>
<td>Hg Supply</td>
<td>1 inch</td>
<td>24.9</td>
<td>6.7</td>
<td>0.594</td>
<td>13.433</td>
<td>7.91E+05</td>
<td>0.1024</td>
<td>752</td>
<td>1.690654</td>
<td>735.3</td>
<td>734</td>
</tr>
<tr>
<td>9</td>
<td>Hg Supply</td>
<td>1 inch</td>
<td>24.9</td>
<td>44</td>
<td>0.594</td>
<td>13.433</td>
<td>7.91E+05</td>
<td>0.6726</td>
<td>747</td>
<td>11.1028</td>
<td>730.8</td>
<td>720</td>
</tr>
<tr>
<td>10</td>
<td>Plenum</td>
<td>5 inch</td>
<td>24.9</td>
<td>3</td>
<td>20.006</td>
<td>0.399</td>
<td>1.36E+05</td>
<td>0.0105</td>
<td>721</td>
<td>0.000153</td>
<td>720.6</td>
<td>721</td>
</tr>
<tr>
<td>11</td>
<td>Nozzle</td>
<td>1/2 inch</td>
<td>24.9</td>
<td>4</td>
<td>0.108</td>
<td>74.271</td>
<td>1.86E+06</td>
<td>0.1491</td>
<td>469</td>
<td>75.21312</td>
<td>-53.5</td>
<td>75.21312</td>
</tr>
</tbody>
</table>

### All Junction Table

<table>
<thead>
<tr>
<th>Jct</th>
<th>Name</th>
<th>Junction Type</th>
<th>Elevation Inlet (inches)</th>
<th>Loss Factor (K)</th>
<th>ΔH (inches)</th>
<th>P In (psig)</th>
<th>P Stag. Out (psig)</th>
<th>dP Stag. Total (psid)</th>
<th>P Static In (psig)</th>
<th>P Static Out (psig)</th>
<th>dP Static Total (psid)</th>
<th>T Inlet (deg. F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Syringe Pl Assigned I</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>784</td>
<td>784</td>
<td>0</td>
<td>784</td>
<td>783.9</td>
<td>0</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>Area Chan Area Chan</td>
<td></td>
<td>0</td>
<td>4.128.12</td>
<td>7.895</td>
<td>784</td>
<td>780</td>
<td>3.8729</td>
<td>784</td>
<td>772.2</td>
<td>11.682</td>
<td>68.2</td>
</tr>
<tr>
<td>3</td>
<td>Bend 1</td>
<td>Bend</td>
<td>0</td>
<td>0.33841</td>
<td>5.388</td>
<td>780</td>
<td>780</td>
<td>3.011</td>
<td>727</td>
<td>769</td>
<td>3.011</td>
<td>68.2</td>
</tr>
<tr>
<td>4</td>
<td>Bend 2</td>
<td>Bend</td>
<td>1.15</td>
<td>0.27347</td>
<td>4.354</td>
<td>776</td>
<td>774</td>
<td>2.7736</td>
<td>769</td>
<td>752.8</td>
<td>2.774</td>
<td>68.2</td>
</tr>
<tr>
<td>5</td>
<td>Bend 3</td>
<td>Bend</td>
<td>18</td>
<td>0.33841</td>
<td>5.388</td>
<td>780</td>
<td>780</td>
<td>3.3789</td>
<td>756</td>
<td>752.8</td>
<td>3.379</td>
<td>68.3</td>
</tr>
<tr>
<td>6</td>
<td>Pipe to Fl Area Chan</td>
<td></td>
<td>19.5</td>
<td>0.00733</td>
<td>0.117</td>
<td>760</td>
<td>760</td>
<td>0.0572</td>
<td>752</td>
<td>753.7</td>
<td>-1.223</td>
<td>68.3</td>
</tr>
<tr>
<td>7</td>
<td>Flex to Tub Area Chan</td>
<td></td>
<td>19.5</td>
<td>0.60087</td>
<td>7.999</td>
<td>759</td>
<td>755</td>
<td>3.924</td>
<td>753</td>
<td>738.7</td>
<td>13.901</td>
<td>68.3</td>
</tr>
<tr>
<td>8</td>
<td>Tubing Ber Bend</td>
<td></td>
<td>19.5</td>
<td>0.17406</td>
<td>5.857</td>
<td>755</td>
<td>752</td>
<td>2.8734</td>
<td>738</td>
<td>735.3</td>
<td>2.873</td>
<td>68.3</td>
</tr>
<tr>
<td>9</td>
<td>Tubing Ber Bend</td>
<td></td>
<td>19.5</td>
<td>0.17406</td>
<td>5.857</td>
<td>750</td>
<td>747</td>
<td>2.8734</td>
<td>734</td>
<td>730.8</td>
<td>2.873</td>
<td>68.3</td>
</tr>
<tr>
<td>10</td>
<td>Plenum Inl Area Chan</td>
<td></td>
<td>19.5</td>
<td>0.94145</td>
<td>31.682</td>
<td>736</td>
<td>721</td>
<td>15.5414</td>
<td>720</td>
<td>720.6</td>
<td>-0.952</td>
<td>68.3</td>
</tr>
<tr>
<td>11</td>
<td>Nozzle Inl Area Chan</td>
<td></td>
<td>19.5</td>
<td>17.240.17</td>
<td>512.271</td>
<td>721</td>
<td>469</td>
<td>251.2909</td>
<td>721</td>
<td>755.894</td>
<td>68.3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Spray</td>
<td>Spray Disc</td>
<td>19.5</td>
<td>0.78106</td>
<td>802.957</td>
<td>394</td>
<td>0</td>
<td>393.8837</td>
<td>-111</td>
<td>-504.6</td>
<td>393.884</td>
<td>75</td>
</tr>
</tbody>
</table>

**OAK RIDGE NATIONAL LABORATORY**
**U. S. DEPARTMENT OF ENERGY**

Airline Hydraulics 28 Oct 2005
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 – desire to change syringe design pressure to 1500 psi (103 bar) to match Hg cylinder rating
Primary Containment Cross Section

- Hg Supply Tube: $\varnothing 25.4$
- Optics (mirrors, lenses, splitters)
- Fiber Bundles
- Optic Windows
- Secondary Containment: $\varnothing 156.9$
- Magnet Bore: ID=162mm
- Reflector
- Primary Containment
- Hg Jet
- Dimensions: 35, 76.2
Secondary Containment

- SS and Lexan enclosure around entire primary system
- Contains Hg vapors/leaks, provides access to monitor Hg vapors
- Provides access to optical diagnostics, hydraulics, and sensors
- Incorporates beam windows
Secondary Containment Access Ports

- Optical diagnostics
- Instrumentation
- Hydraulics
- Hg drain & fill (without opening secondary)
- Hg extraction (in event of major leak in primary containment)
Hg Delivery System Procurement Plan

- Syringe system procured first because of expected long lead time on cylinders
- Details of primary/secondary containments & baseplate being finalized
  - Expect to begin procurement process in Nov/Dec
- Syringe system to be integrated by containment fabricator
# Test Plan

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet testing at MIT</td>
<td>Oct-Dec 2005</td>
</tr>
<tr>
<td>Hg nozzle tests at Princeton</td>
<td>Oct-Dec 2005</td>
</tr>
<tr>
<td>- Iterate nozzle design as needed</td>
<td></td>
</tr>
<tr>
<td>Hg target system testing at ORNL</td>
<td>April-June 2006</td>
</tr>
<tr>
<td>- Includes optical diagnostics</td>
<td></td>
</tr>
<tr>
<td>- Initially test with water to develop syringe control system</td>
<td></td>
</tr>
<tr>
<td>- Incorporate Princeton nozzle design, iterate if necessary</td>
<td></td>
</tr>
<tr>
<td>- Practice Hg fill and extraction</td>
<td></td>
</tr>
<tr>
<td>- Hg jet characterized</td>
<td></td>
</tr>
<tr>
<td>Integrated test at MIT</td>
<td>Aug-Sept 2006</td>
</tr>
<tr>
<td>- Practice CERN installation sequence</td>
<td></td>
</tr>
<tr>
<td>- Hg jet in magnetic field characterized</td>
<td></td>
</tr>
<tr>
<td>Ship system to CERN</td>
<td>Nov 2006</td>
</tr>
<tr>
<td>Experiment scheduled at CERN</td>
<td>April 2007</td>
</tr>
</tbody>
</table>