EURISOL Converter Target. Status of METEX

S.Dementjev, R.Milenkovic, S.Joray, F.Barbagallo
Basic performances of the target

**TM-34-07-05 K. Samec / Design of the EURISOL converter target. – PSI 2007**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>symbol</th>
<th>value</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid compound</td>
<td>Hg</td>
<td>13.5</td>
<td>kg/l</td>
</tr>
<tr>
<td>Flow rate</td>
<td>φ</td>
<td>172</td>
<td>kg/s</td>
</tr>
<tr>
<td>Entrance temperature</td>
<td>T_m</td>
<td>&lt; 60</td>
<td>°C</td>
</tr>
<tr>
<td>Exit temperature</td>
<td>T_out</td>
<td>&lt; 180</td>
<td>°C</td>
</tr>
<tr>
<td>Exit temperature</td>
<td></td>
<td>&gt; 150</td>
<td></td>
</tr>
<tr>
<td>Pressure drop</td>
<td>ΔP</td>
<td>&lt; 5</td>
<td>Bar</td>
</tr>
<tr>
<td>Static pressure</td>
<td>P_o</td>
<td>&lt; 5</td>
<td>Bar</td>
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</table>

**Ab.13 l/s**

4MW thermal power
Mock-up of the target

Specification: scale 1 : 1; material – INOX; working liquid – Hg; flowrate – depending on IPUL Hg loop, about 11l/s

PSI drawing: 0-10009.BB.1331
**Mercury Target Experiment**

**METEX 1:**
Hydraulic Hg test of the mock-up with the purpose to check workability and regime of the target operation under close to nominal Hg flowrate: pressure loss, vibrations, cavitations, velocity distribution in the BEW inlet; stress in the welding seams: session 1 - without the blades; session 2 - with the blades

**METEX 2.1:**
Record and analysis of “cavitations noise” with use of acoustic or/and high frequency pressure sensors in collaboration with the Fachhochschule; preparation ongoing, ab 3 months, 25kCHF

**METEX 2.2 (optional in future):**
Hg velocity measurements downstream from the flow reverser:
- Doppler anemometry, Dr. S. Eckert (FZK Dresden – Rosendorf); Prof. Y. Takeda (Hokkaido University); MET-FLOW AG, Lausanne
- US anemometry, Prof. R. Kazy (Kaunas University)
- Potential probes for local velocities measurements near a wall, PSI S. Dementjev.

Duration of the experiment preparation 6-8 months, coast 50-100 kCHF

**METEX 3 (optional in future):**
Measurements of heat transfer coefficients distribution between Hg flow and the BEW shell, PSI, J. Patorski
Meetings:

- IPUL-CERN-PSI technical meetings February 8 and April 18:
  - Requirements to the loop
  - Responsibilities: IPUL – the Hg laboratory and the loop; PSI – the mock-up, measuring system, test matrix, data analysis
  - Safety measures
  - Financing

- IPUL-CERN-PSI “Ready for the test” meeting in May 29 (no decision)

- IPUL-CERN-PSI repeated “Ready for the test “meeting in June 2 (decision to postpone the test)
Documents:

1. TM-34-07-05 /Design of the EURISOL converter target. – PSI 2007


3. AN-34-08-01/2 /Operation Manual for the METEX1-Exeriment in IPUL. – IPUL/PSI, May 18, 2008

4. TM-JS34-342410-1/EURISOL METEX: Cooling and temperature control of the Mercury loop. – PSI, May 2008

5. EURISOL-MR34-005/0 /EURISOL converter target. METEX 1 experiment: Post-processing of the experimental data: test matrix, precalculations, data recording and mining, statistical and advance data analysis. – PSI May 2008

6. Minutes of the meetings
IPUL mercury loop

Basic parameters:

Length of the loop – 13 m
Hg volume – 127 liters
Max flowrate with the mock-up – ca. 11 l/s
Max Hg velocity in the pipes – 1.6 m/s
Max Hg temperature – ca. 88°C (S. Joray)
Cover gas (Ar) pressure - 0-5bar

 EMP pressure head, Platacis info
Total pressure loss in the loop and mock-up (Milenkovic calc)

Hg expansion tank, d250x400
To Ar bottle and ventilation line

Air
↓

Valve 2

HEX 3, pipe d129x2x1750
The target mock-up

1400

Valve 1

HEX 4, d140x1x535

Air →

HEX 2, d180x1x1680
Pipe-line DN100, d108x96

Electromagnetic (potential) Hg flowmeter

HEX 1, d180x1x600

Valve 1

Hg tanks (3 tanks)

2730

3000x4000

1960

1930

2610
METEX 1. Measuring system
Reasons of the METEX 1 postponing

Following the very **high levels of Hg vapors** in the mercury lab at IPUL, and the **lack of internet** connection which forbids a remote operation and control of the loop as well as the data acquisition I have asked for the test to be cancelled. Our visit to IPUL these last days clearly demonstrated that it is too difficult to carry out a proper test of the target mock-up without putting at risk CERN, IPUL and PSI's personnel.

I will take the opportunity of my visit to PSI Tuesday June 17th to discuss in details how to proceed with the test.

I am reluctant to resume the test under these conditions and expose in particular IPUL colleagues to such a harsh environment unless some actions are taken to reduce the Hg vapor levels. A proper **decontamination and refurbishment of the experimental hall** should be carried out as soon as possible with the support of the European Commission. EURISOL-DS is after all an EU Project.

Postponing the run to winter will not resolve this situation since the temperature level is not the dominant factor for the high levels of Hg vapors observed, up to to **6-8 times the allowed concentration with the loop completely empty**!! Most of the mercury vapors are emanating from the floor and side walls.
METEX 1. Distribution of Hg-Concentration in IPUL Hg-laboratory

Average during about 10 minutes
METEX 1. Continuous Measurements of Hg-Concentration in Air

- Measurements near instrumentation table (point No.3)
- In the pit (No.10)

- Actuation of additional ventilation with air cooling, 17°-18°C, day and night
- Night, no the pit ventilation
- Cleaning and washing of the floor
- EMP is on, no Hg in the loop, temperature of the inductor up to 40°C
- Initial state: ventilation is on by day only
- Covering of the lab floor and contaminated units with polyethylene
- Night
- Day
- Day

PSI Hg-analyzer, continuous measurements, alarm, data record

IPUL Hg-analyzer (no alarm and connection to PC because of a technical problem)
On the working conditions in the IPUL Hg-lab

improvement

IPUL made a lot in May and June 2008 to make the situation in Hg-lab acceptable.

We have only possibility to give recommendations. The decisions concerning safety measures in the Hg-lab makes IPUL management.

Participation of a safety expert from PSI or CERN is necessary.

Clear concept is necessary, minimum efforts and expenses for the goal achievement: safety conducting of the experiment for IPUL personnel and the guests.
Measures on the safety conditions improvement were discussed:

- Disposal from the laboratory of idle contaminated units. – It will be done, J. Freibergs decision.
- Cleaning and demercurization of the floor, the pit and the loop (at regular intervals and after Hg leakage). – Corresponding company exists in Latvia (Prof. O. Lielausis information). It is possible to do by IPUL strength as well, demercurizants are necessary.
- INTERNET in the Hg-lab. – Offer from AS “BALTICOM”: 824.23 LVL + felling of several trees (done last week).
- Hg-analyzers with continuous data record and beep alarm: 1 – in the pit; 2 – in the instrumentation tent; 3 – near the loop cover on the floor. – The PSI analyzer (ok); the IPUL analyzer (no communication with PC); CERN analyzer (promised by Y. Kadi).
- Safety facilities: overalls, plastic shoes covers, gloves, gas-masks. – Delivered to IPUL by CERN.
- Safety measures regulations and instructions. – Operation manual by F. Groeschel contains the most common requirement. But the safety regulations and personnel instructions must be prepared by IPUL.
- Corresponding Health insurance for IPUL collaborators are working in the Hg-laboratory is important.
Measures ... a cover to localize and evacuate Hg-vapors from the hot Hg-loop

Version 1: Reliable protection of the lab from Hg vapor, but expensive and fabrication is time consuming

Version 2: Simpler, cheaper and evidently effective ...
Measures ... optimization of the loop

- Optimization of the loop cooling to reduce Hg temperature (and correspondingly Hg evaporation). See the recommendations in S. Joray report from May 2008, expected max Hg temperature is 88°C. It is desirable preliminary to the experiment to conduct US measurements of cooling water flowrate (probably S. Joray).

- Installation of a level detector in the Hg-expansion tank. For Hg leakage detection, the sensor can be fabricated by F. Barbagallo in PSI.

- Application of a CIRCUTOR or other 3-phase net analyzer for the EMP electrical parameters measurements, visualization and record. It is “nice to have” a remote adjustment of the current from PC.
METEX0 MEASUREMENT AND DATA ACQUISITION SYSTEM

Main PC With:
- Labview Program
- Datalogging and Supervisory Control Module
- Citadel Database
- Historical Trend
- Remote Operation Control
- Local and External Ethernet Access

Remote PC
- Archiving Database on PSI AFS and CERN
- Remote control from Main PC
- Test, Analysis during Experiment Run

IPUL NETWORK

WAN (PSI; CERN)
The measuring system lay-out
Differential manometer for hydraulic pressure loss in the mock-up measurements

One pressure tap on inlet and one on outlet pipes of the mock-up. No pressure equalization grooves (!?).

Technical specification:
- Type EJA110 DVS2A.93NA / D3
- Differential pressure range, calibrated 0…10bar
- Max error of differential pressure measurements ±25mbar
- Allowable overload up to 140bar
- Output signal 4…20mA
Manometer for cover gas pressure in the expansion tank measurements

Technical specification:

- Type UT-10-A-SBK-GD-ZMSAAZ-ZZ (WIKA)
- Pressure range, calibrated 0…16bar
- Max error of the pressure measurements ±45mbar
- Allowable overload up to ???bar
- Output signal 4…20mA
- Power supply 12…36V
Acceleration sensor for the mock-up vibration parameters measurements

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**Specifications**

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<th>Model (Single axis or triaxial)</th>
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<td>Range g</td>
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<tr>
<td>Sensitivity mV/g</td>
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</tr>
<tr>
<td>Frequency Range Hz</td>
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<tr>
<td>PiezoSmart (TEDS)</td>
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<tr>
<td>Mounting</td>
<td>Wafer adhesive</td>
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Mock-up

- **Acceleration sensor KISTLER 8632C5**
- **Cable, 12m**
- **Power supply/Coupler KISTLER 5134**
- **Cable, 12m**
- **LeCroy Wave surfer 454**

Instrumentation rack

- **BNC**
- **RJ45**
- **PC**
- **Control desk**
Hg velocity measurements with PORTASONIC flowmeter

Settings of the flowmeter: wall material – stainless steel; sound velocity in Hg – 0000 m/s; a – replaces diameter of pipe; c – wall thickness; b – distance between the sensors calculated by the flowmeter.

\[ V = Q^* / (\pi a^2 /4), \quad Q^* - FM \text{ indication; } V - Hg \text{ velocity.} \]
Thermocouples for Hg temperature control
Start-up of the loop and the test matrix

The following steps will be carried out to start the experiment:

- Purge the target-loop system by filling with Ar of 6 bar and evacuating to 1 mbar three times.
- Maintain the system at 1 mbar for several hours and check pressure evolution during 12 hours (the leak rate above should be confirmed).
- Check the measuring system including the Hg-analyzers.
- Start and check the loop water cooling (no leakage, flow rate if possible).
- Fill the target with Hg by pressurizing the storage vessel up to the indication of the level detector in the expansion vessel. The filling pressure is < 10 bar. The volume of the target-loop system is 801.
- Adjust cover gas pressure 4 bar. Observe the loop during 1 hour. Check the pressure evolution (no leakage). Check Hg-analyzer indications (no rise of the Hg-content in air). Check level of Hg in the expansion tank.
- Start circulating the EMP at low velocity (2 l/s) for 30 min. Observe the indications of the signals. Check Hg flow direction.
- Stop circulation for 30 min to let impurities swim up.
- Check for leakage by sniffing with the mobile Hg vapor monitor along the loop (gas masks are obligatory).
- Check for vibrations by manual verifications.
- Resume circulation for another 30 min (2 l/s).
- Drain the Hg from the loop into the storage vessel, observe loop pressure. Adjust cover gas pressure in the storage vessel > 1 bar.
- Let settle for at least 2 hours.
- Repeat the filling operation as described above.
- Condition the loop until stable operation is achieved: 1 l/s, 2 l/s, 3 l/s, 4 l/s; 5 l/s. Observe the Hg temperature and Hg-analyzers indications.

### Table: Mercury Flowrate [l/s]

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</table>

Measurements of mercury velocity distribution in the target BEW inlet

Measurements of: cover gas pressure in the expansion tank; mercury flowrate in the loop; hydraulic pressure loss in the mock-up; vibrations parameters; stress in the welding seams.

AN-34-08-01/1

EURISOL-MR34-005
Thank You for attention
Vibrations of the target caused by resonance between the natural oscillations of the target structure and vortexes in Hg flow

\[ St = \frac{f \cdot L}{V} \approx 0.2 - 0.3 \]

St - Strouhal number; L – linear scale; v – mercury velocity; f – vortex formation frequency in Hg flow.

Mechanical resonance between these processes can lead to the target vibrations and, correspondingly, under certain conditions, to fatigue failure of the target structure.

\[ v=2.2 \text{ m/s}; \ Re=490000; f=13...26\text{Hz} \]

\[ v=4...6.2\text{ m/s}; \ Re=870000; f=26...52\text{Hz} \]

\[ v=4.5 \text{ m/s}; \ Re=1900000; f=15...30\text{Hz} \]

Figure 5-7. First three natural frequencies of the outer structure with added LM mass

Note: contours show mass-normalised stress, hence indicative of relative value only.
The Hg velocity field

The most interesting flow areas are:

→ The window inlet, to check distribution of Hg velocities around the ring shape channel

→ Downstream from the vanes top to detect the vortex structures
Cavitations in the target

K. Samec gives nominal static pressure about 5 bar, no cavitations risk

\[ K = \frac{P_0 - 0.5 \cdot \rho \cdot V_a^2}{0.5 \cdot \rho \cdot V_{\text{max}}^2} \geq 2 \]

Empirical criterion of cavitations freedom for electromagnetic pump inlet (E. Scherbinin, O. Lielausis, J. Gelfgat, 1976): \( V_a = 4 \text{ m/s} \) and \( V_{\text{max}} = 6 \text{ m/s} \) – volume averaged and peak mercury velocities in the target; \( \rho = 12688 \text{ kg/m}^3 \) - density of mercury; \( P_0 = 8 \cdot 10^5 \text{ Pa} \) - static pressure necessary to suppress cavitations

During the test minimal static pressure necessary to suppress cavitations in the target will be checked experimentally.

As indication 20 … 100kHz cavitation noise will be measured