EURISOL DS PROJECT

Task#2: MULTI-MW TARGET DESIGN

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On behalf of the EURISOL-DS Collaboration

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“Research Infrastructure Action- Structuring the European Research Area”
EURISOL-DS Project Contract no. 515768 RIDS
**EURISOL Target Stations**

100 kW direct targets
- **RIB production:**
  - Spallation-evaporation
  - Main: P-rich
    - (10 to 15 elements below target material)
  - Residues: N-rich
    - (A few elements below target material)
- Target materials:
  - Oxides
  - Carbides
  - Metal foils
  - Liquid metals

<table>
<thead>
<tr>
<th>Participants:</th>
<th>Duration:</th>
</tr>
</thead>
<tbody>
<tr>
<td>~20 institutions</td>
<td>2005-2009</td>
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<table>
<thead>
<tr>
<th>Contributors:</th>
<th>12 Tasks are active</th>
</tr>
</thead>
<tbody>
<tr>
<td>~20 institutions</td>
<td></td>
</tr>
</tbody>
</table>

**EU support (~30%):**
- ~9.2 MEuros

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MMW fission target
- **RIB production:**
  - Fission
  - N-rich
  - Wide range
    - Z = 10 to Z = 60
- Target material:
  - U (baseline)
  - Th
- Converter:
  - Hg

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2nd Oxford-Princeton High-Powered Target Workshop, Y. Kadi November 6, 2008
### EURISOL-DS Targetry Challenges

EURISOL shall deliver beams 3 orders of magnitude higher intensity than in presently operating facilities.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Units</th>
<th>Nval</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converter Target material</td>
<td>Z_{conv}</td>
<td>-</td>
<td>Hg (liquid)</td>
<td>LBE</td>
</tr>
<tr>
<td>Secondary Target material</td>
<td>Z_{targ}</td>
<td>-</td>
<td>UC_{x}, BeO</td>
<td></td>
</tr>
<tr>
<td>Beam particles</td>
<td>Z_{beam}</td>
<td>-</td>
<td>Proton</td>
<td></td>
</tr>
<tr>
<td>Beam particle energy</td>
<td>E_{beam}</td>
<td>GeV</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Beam current</td>
<td>I_{beam}</td>
<td>mA</td>
<td>4</td>
<td>2 – 5</td>
</tr>
<tr>
<td>Beam time structure</td>
<td></td>
<td>–</td>
<td>CW</td>
<td>50Hz 1ms pulse</td>
</tr>
<tr>
<td>Gaussian beam geometry</td>
<td>\alpha_{beam}</td>
<td>mm</td>
<td>15</td>
<td>&lt; 25, parabolic</td>
</tr>
<tr>
<td>Beam power</td>
<td>P_{beam}</td>
<td>MW</td>
<td>4</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Converter length</td>
<td>I_{conv}</td>
<td>cm</td>
<td>45</td>
<td>85</td>
</tr>
<tr>
<td>Converter radius (cylinder)</td>
<td>r_{conv}</td>
<td>cm</td>
<td>8</td>
<td>4 – 15</td>
</tr>
<tr>
<td>Hg temperature</td>
<td>T_{conv}</td>
<td>°C</td>
<td>150 – 200</td>
<td>&lt;&lt; 357</td>
</tr>
<tr>
<td>Hg flow rate</td>
<td>Q_{conv}</td>
<td>ton/s</td>
<td>0.1 – 0.2</td>
<td>&lt;&lt; 1</td>
</tr>
<tr>
<td>Hg speed</td>
<td>V_{conv}</td>
<td>m/s</td>
<td>~5</td>
<td>&lt;&lt; 15</td>
</tr>
<tr>
<td>Hg pressure drop</td>
<td>AP_{1}</td>
<td>bar</td>
<td>1 – 2</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Hg overpressure</td>
<td>AP_{2}</td>
<td>bar</td>
<td>5 – 7</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>UC_{x} temperature</td>
<td>T_{targ}</td>
<td>°C</td>
<td>2000</td>
<td>500-2500</td>
</tr>
</tbody>
</table>

The originally proposed Hg–jet formation
Diameter of jet 10 – 20 mm; Q=2.5 l/s; p>50 bars!!!
Task#2 – Multi-MW Liquid Hg Target

- Compact Hg-loop with beam widow
- Confined transverse film windowless

Deliverables:

1. **Engineering study** of the thermal hydraulics, fluid dynamics and construction materials of a window or window-free liquid-metal converter.
2. Study of an innovative **waste management** in the liquid Hg-loop e.g. by means of Hg distillation.
3. Engineering **design and construction** of a functional Hg-loop.
4. Off-line testing and validation of the thermal hydraulics and fluid dynamics.
5. Engineering **design of the entire target station** and its handling method.
PbBi Alternative – Neutron Balance

Neutron absorbing region

Neutron producing region

Hg

Neutral balance boundary

PbBi

Neutron producing region
PbBi Alternative – Neutron Spectrum

Neutron flux (d/n/cm²/dE/prim)

Energy (MeV)

Hg Target 10 cm Rad
PbBi Target 10 cm Rad
Hg Target 40 cm Rad
PbBi Target 40 cm Rad
**180° Coaxial Bend Target**

**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>( \phi )</td>
<td>172</td>
<td>kg/s</td>
</tr>
<tr>
<td>Entrance temperature</td>
<td>( T_{in} )</td>
<td>(&lt; 60)</td>
<td>C</td>
</tr>
<tr>
<td>Exit temperature</td>
<td>( T_{ex} )</td>
<td>(&lt; 180)</td>
<td>C</td>
</tr>
<tr>
<td>Pressure drop</td>
<td>( \Delta P )</td>
<td>(&lt; 5)</td>
<td>Bar</td>
</tr>
<tr>
<td>Static pressure</td>
<td>( P_e )</td>
<td>(&lt; 5)</td>
<td>Bar</td>
</tr>
</tbody>
</table>

4MW thermal power

Beam, 4MW

Hg Inflow (DN100)

Flow reverser

Beam entrance window

Guide tube

Liquid metal hull

Outflow (DN100)

v=2.2 m/s

Re=490000

v=4 ... 6.2 m/s

Re=870000

v=4.5 m/s

Re=1900000
Task#2 – Multi-MW Liquid Hg Target

Hg converter and secondary fission targets

Proton beam

Window

LM Target

Hg In

Hg Out
Task#4 – Fission Target
Task#2 – 3D view of the fission target

New design (1)

- Beam line (grounded)
- HV bars for Q-poles (4x3)
- Extraction electrodes
- Heater
- Insulator
- Target container
- Quadrupole doublet (3)

U+C target:
- L = 120 mm
- φ = 30 mm
- φ_{hole} = 10 mm

EURISOL-DS Task 4 Meeting, Legnaro, 07/09/2007
F. Negoita, negoita@tandem.nipne.ro
MAFF Fission Target Integration

Fission Target Tube

Hg inlet

Hg outlet

Hg Proton to Neutron converter

Proton Beam

2nd Oxford-Princeton High-Powered Target Workshop, Y. Kadi November 6, 2008
Multi-MW facility Layout
NEUTRON FLUX

Neutron flux (n/cm²/s/MW of beam)

Vertical direction

Beam axis

-20 0 20 40 60 80
Large RIB production for the proposed neutron-rich isotopes.
Clear advantage in using natural uranium.
Possibility of investigating the lower end of the *terra incognita*, e.g. Nd-157, Tb-167
Radioactive Ions Production

Isotope production (Isotope/cm³/s/MW of beam)

UC₃ Targets:
- Natural Uranium (0.7% U-235)
- Density: 3 g/cm³
Power Densities

- More than one order of magnitude difference between the free surface Hg-J (~22 kW/cm³/MW) and the confined Hg targets (BLD, ~2 kW/cm³/MW)
- BDL and IS: Beam window suffering important power densities (~1 kW/cm³/MW → extra cooling plus radiation resistant material needed)
- Peak power densities similar to ESS and SNS
Liquid Hg Loop for tests of target mock-ups and other components

IPUL variant

PSI variant

1 – test section; 2 – Hg loop DN100; 3 – heat exchanger; 4 – flowmeter;
5 – supply tank; 6 – level meter; 7 – electromagnetic pump; 8 – heat exchanger;
9 – vacuum pump; 10 – argon vessel; M1…M3 – pressure meter; P – vacuum
gauge; T1…T4 – thermocouple; V1…V6 – valve; VF – dosing valve;
TASK #2 – Liquid Hg Loop @ IPUL
Experiments of Hg “curtain” in InGaSn Loop

Transverse Hg – film

Modules of transverse film Test chambers injectors

InGaSn test loop of transverse film target module

P=3 bar; Q~1.5 l/s

a – with rectangular cell inner structure
b – with round cell inner structure
c – with parallel separator inner structure
Liquid Hg Loop – Transverse Film

Fig.19
Experimental unit of transverse film injector
1 - inlet tube; 2 - transverse film former; 3 - liquid metal distributor; 4 - flowmeter;
5 - supply tank; 6 - outlet tube.
Task#2 – Hg Waste Management (D2)
B) Activation of Hg

→ induced activity comparable to the research reactor + α emitters

B. Rapp et al. (CEA)

2nd Oxford-Princeton High-Powered Target Workshop, November 6, 2008
• Hf and Lu present as an oxide deposit on Hg were removed by contacting the liquid metal with oxide materials with a rough surface:
  • Sintered corundum
  • Molecular sieve
  • Oxides stick to the surface of these materials

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**Graphs:**

1. Before cleaning:
   - Hf-172
   - Lu-172
   - Lu-173
   - Au-194

2. After cleaning:
   - Hg
   - Au-194
D) Disposal of liquid Hg

A schematic layout for liquid Hg-target disposal strategy

Chemical stabilization of Hg as an inorganic compound, e.g. HgS, HgSe, HgO, Hg₂Cl₂, HgCl₂

Extrapolation from laboratory scale to “industrial” scale still to be done
## Task#2 – Milestone monitoring

<table>
<thead>
<tr>
<th>No.</th>
<th>Milestones and expected result of this task:</th>
<th>Months due</th>
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<tbody>
<tr>
<td>M1</td>
<td>Engineering study of the Hg converter</td>
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<tr>
<td>M1.1</td>
<td>Computation Hg fluid dynamics</td>
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<tr>
<td>M1.2</td>
<td>Study of a possible windowless Hg converter</td>
<td>9</td>
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<tr>
<td>M1.3</td>
<td>Decision on draft design parameters</td>
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<td>M2</td>
<td>Innovative waste management in the liquid Hg-loop</td>
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<tr>
<td>M2.1</td>
<td>Decision on optimum extraction method</td>
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<tr>
<td>M2.2</td>
<td>Full scale implementation of extraction method</td>
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<tr>
<td>M3</td>
<td>Engineering design construction of a functional Hg loop</td>
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<tr>
<td>M3.1</td>
<td>Overall design and layout of Hg loop</td>
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<tr>
<td>M3.2</td>
<td>Design and construction of components</td>
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<td>M3.3</td>
<td>Assembly of complete Hg loop with window free jet</td>
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<td>M4</td>
<td>Off line test of thermal and fluid dynamics</td>
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<td>M4.1</td>
<td>Test of Hg loop components</td>
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<td>M4.2</td>
<td>Operation of complete Hg loop with window free jet</td>
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<tr>
<td>M5</td>
<td>Engineering design of a complete target station</td>
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<tr>
<td>M5.1</td>
<td>Study of HV platform and services</td>
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<td>M5.2</td>
<td>Study of remote handling equipment</td>
<td>36</td>
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<tr>
<td>M5.3</td>
<td>Overall design of multi-MW target station</td>
<td>44</td>
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</table>

- **Done**
- **In progress**
- **Finalized**
- **Planned**
- **In progress**
Thank you for your attention and to all contributors...