MYRRHA Technology and Research Facilities in support of Heavy Liquid Metal SMR Fast Reactors


Milan, September 24 – 27, 2019
Motivation of MYRRHA

- MYRRHA – An Accelerator Driven System
  - Demonstrate the ADS concept at pre-industrial scale
    - Can operate in critical and sub-critical modes
  - Demonstrate transmutation
  - Fast neutron source → multipurpose and flexible irradiation facility

<table>
<thead>
<tr>
<th>Accelerator</th>
<th>Reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>particles</td>
<td>power</td>
</tr>
<tr>
<td>protons</td>
<td>65 to 100 MW\textsubscript{th}</td>
</tr>
<tr>
<td>beam energy</td>
<td>(k\text{\textsubscript{eff}})</td>
</tr>
<tr>
<td>600 MeV</td>
<td>0.95</td>
</tr>
<tr>
<td>beam current</td>
<td>spectrum</td>
</tr>
<tr>
<td>2.4 to 4 mA</td>
<td>fast</td>
</tr>
<tr>
<td></td>
<td>coolant</td>
</tr>
<tr>
<td></td>
<td>LBE</td>
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</tbody>
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Target

- main reaction: spallation
- output: \(2 \cdot 10^{17}\) n/s
- material: LBE (coolant)
MYRRHA is a multipurpose research facility, addressing end-markets with both significant societal and economic impact.
MYRRHA Current design

A. Reactor vessel
B. Diaphragm
C. Reactor Cover
D. Primary Heat Exchanger
E. Primary Pump
F. In-Vessel Fuel Handling Machine
G. Core Barrel
H. Reactor core
I. Core Restraint System
**Benefits of phased approach:**

- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol end of 2026

On 07/09/2018 the Belgian government secured **558 M€** to finance:

- The construction and operation of phase 1
- The preparation of phase 2 (R&D 600 MeV)
- The preparation of phase 3 (Reactor R&D and design)
MYRRHA Schedule

High level global planning of MYRRHA Project (2018-2040)

Phase 1: '18-'26
Phase 2 & 3: '27-'33
Phase 3: Commissioning
• Maximize technology transfer from MYRRHA to lead-cooled SMR to benefit from development of MYRRHA
Applicability of MYRRHA R&D for the development of lead SMR

- Component testing and thermal hydraulics
- LBE Chemistry and conditioning
- Materials

- ESCAPE
  - Complot
  - HEXACOM
  - RHAPTER

- MEXICO
  - HELIOS
  - LILIPUTTER-II
  - Heavy Metal Lab

- CRAFT
- LIMITS
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ESCAPE – European Scale Pool Experiment

- 1/6 thermal scale model
- Thermal hydraulic behaviour of HLM in a complex pool geometry
- 27 tons of LBE at 200°C – 350°C
- 100 kW core simulation
- Forced and natural circulation
- Heavily instrumented
- Can be upgraded to 400°C
**COMPLOT – Components Loop Testing**

- Isothermal experimental loop for hydraulic and hydrodynamic behaviour
- Full-scale reactor core components hydraulic tests (12 m tall)
- Temperature range 200 °C – 400 °C
- Mass flow rate 3.5 kg/s – 104.8 kg/s
- Active coolant chemistry control
- 9 tons of LBE
Two-phase water-steam steam loop connected to COMPlot

Representative of MYRRHA Secondary Cooling System

100 kW of power

Testing of heat-transfer performance of reactor heat exchanger tubes at full scale

Testing of forced and natural circulation in the Secondary Cooling System

Testing of anti-freezing strategies

Design parameters secondary system: 25 bar, 250 °C and 1.1 m³/h

Modular design allowing different arrangements

LBE parameters defined by COMPlot
RHAPETER – Remote Handling Proof-of-principle

- Test and validate mechanical components submerged in LBE
- Components: bearings, gears, springs, moving electrical cabling, ...
- Test of mechanical components up to 445 mm diameter and 350 mm height
- Temperatures from 150 °C to 450 °C
- Two shafts to power the component and create different loading situations
- Can be upgraded with a conditioning system
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MEXICO – Mass Exchange In Continuous Operation

- Testing of different oxygen control systems
- Evaluation of efficiency and expected life time of filtration systems for purifying LBE of oxides
- 7 tons of LBE
- Temperatures range from 200 °C to 450 °C
- Upgradable from 350 °C to 550 °C
HELIOS – Heavy Liquid metal Oxygen conditioning System

- LBE conditioning and storage setup
- Investigate conditioning systems
- Study calamity mitigation strategies after possible steam ingress
- Testing of spargers and impellers inserts for gas bubbling
- Operating at 450 °C
LILIPUTTER-II – Liquid Lead alloy Innovative Pump Technology Test Rig

- Small LBE pump test loop modified for filter testing
- Upgraded with oxygen control system for cold trap development
- Limited to 200 °C by a screw spindle pump but upgradable to 400 °C
Heavy Metal Lab

- Laboratory for chemistry experiments with heavy metals
- Study of impurity evaporation from heavy metals under various conditions of temperature and gas atmosphere composition
- Dedicated setups for evaporation up to 1000 °C
- Autoclaves for oxygen sensor and oxygen-pump testing, and for corrosion studies up to 500 °C
- A dedicated lab for polonium release studies from LBE or lead up to 1000 °C under flowing Ar, H2 and H2O and deposition of Po-species on different media
Applicability of MYRRHA R&D for the development of lead SMR

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• Materials
Installation for long term corrosion experiments on candidate materials in flowing LBE

Operates at representative conditions of temperatures, LBE velocities and dissolved oxygen concentrations of MYRRHA

Cold leg runs at 200 °C but is designed for 450 °C

Hot leg is equipped with two material-test sections which can run up to 550 °C

4 tons LBE, 10 kg LBE/s, flow velocities up to 5 m/s

Equipped with oxygen control and monitoring system for long term experiments

Also equipped with 12 test stations for stagnant corrosion tests in oxygen free environment for tests in PbBi, Pb, PbLi and Li
LIMITS – Liquid Metals Test Stands

- Experimental set-ups for mechanical testing of materials in stagnant LBE
- 4 Installations in operation
- Controlled oxygen concentration and continuously monitored
- Temperature up to 550 °C
- Equipped to perform tensile, fracture toughness, slow strain rate, constant load and crack growth rate experiments
- One set-up in a hot-cell for testing of irradiated and alpha-contaminated samples
- One set-up for fatigue tests in liquid metal with an extensometer on the sample
Conclusion

- MYRRHA as technology test platform for Heavy Liquid Metal cooled reactor technology for Gen IV systems and HLM-based SMR’s
  - The MYRRHA reactor programme with its associated R&D and licensing experience can support the development of SMR working with LBE or Lead as coolant.
  - The R&D facilities can be converted or upgraded to the specific needs of lead and contribute to the qualification of materials and components of these systems
  - The design and licensing experience gained during the MYRRHA development can help to accelerate the deployment of the lead fast reactors of the SMR type
  - In a later phase MYRRHA can be used for the further qualification of materials, fuel and components which will help to improve these first generation of lead based SMR’s
A jump in the future for innovation in Belgium
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Studiecentrum voor Kernenergie
Centre d’Etude de l’Energie Nucléaire
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d’Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL