Update on IAEA activities on (V)HTGR including MSRs and SMRs

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13th GIF-IAEA Interface Meeting
IAEA Headquarters, Vienna. 18-19 March 2019
Technology Development for HTGRs

• Objectives
  • Foster international exchange of information related to advances in GCR technology
  • Provide a forum for the collaboration of R&D efforts related to GCR technology
  • Support Member States by providing an understanding of state-of-the-art GCR technology
  • Focus on modular HTGRs

• Activities
  • Plan and organize Consultancy and Technical Meetings
  • Manage Coordinated Research Projects (CRPs)
  • Make contributions to the Advanced Reactor Information System (ARIS) and the SMR booklet
  • Coordinate efforts with other sections and International Organizations; manage Technical Working Groups (TWGs) for Gas Cooled reactors to help develop future project activities
Cooperative Research Projects (CRPs)


- Modular High Temperature Gas Cooled Reactor Safety Design (2014 – 2018) – presented last year in detail and to be discussed in Session III tomorrow


- New coordinated research project on ‘Technologies to enhance the competitiveness and early deployment of SMRs and HTRs’ to start in 2020
To determine the uncertainty in HTGR calculations at all stages of coupled reactor physics, thermal-hydraulics and depletion calculations.

- Set of test cases defined
- 10 member states participating
- Project to be concluded in 2019

Preliminary CFX data shown here for 100 runs: average graphite temperature vs. time (K).
Summary for Phase I

• Uncertainties in calculated k-eff (due to cross section uncertainties)
  – Similar but slightly larger than for LWR / thermal systems
  – All effects due to models, libraries and covariance sets to be quantified
• Proper treatment of the double heterogeneity is required to correctly determine the contribution of cross section uncertainties to k-eff
  – Uncertainties calculated with the Reactivity-Equivalent Physical Transformation method show good agreement
• Some of the top five contributors identified also found to contribute to the uncertainties in light water reactor test cases
  \[ ^{238}\text{U}(n,\gamma), \; ^{235}\text{U}_{(\text{nubar})}, \; ^{235}\text{U}(n,\gamma), \; ^{235}\text{U}_{(\text{fission})}, \; ^{239}\text{Pu}_{(\text{nubar})} \]
  but others, \(^{135}\text{Xe}(n,\gamma)\) and graphite capture or elastic scattering.
• Comparing results and updated SCALE 6.2
  – New covariance matrices / Updated cross sections / update models
  – DOUBLEHET available in SAMPLER
  – Manufacturing variations can be added
IV. HTGRs applications for energy neutral sustainable comprehensive extraction and mineral products development

• A future more sustainable option to perform comprehensive extraction of resources / minerals by using thermal processing – also do U/Th extraction as by product

• Techno-economic investigations on the use of HTGRs as heat/electricity supplier for minerals and uranium/thorium recovery from unconventional resources;
  – phosphate rock using the thermal process during phosphate fertilizer production;
  – copper and gold ores during copper and gold mining/extraction;
  – rare earth elements mining;

• Create a platform for experts in various areas to exchange knowledge and ideas:
  – Resources and products
  – Mineral processing
  – High Temperature Reactors

• 1st RCM Nov 2015
• 2nd RCM 3-6 July 2017
• 3rd RCM 2-6 July 2018
• Use cases are being documented for TECDOC
• Journal paper published in Sustainability:
  http://www.mdpi.com/2071-1050/10/1/235/pdf
Activities of possible interest:

- **Meetings:**
  - TM on the Status of the IAEA Nuclear Graphite Knowledge Base (7-8 Nov 2019)
  - TWG-GCR Meeting in Vienna, (11-13 Nov 2019)
  - Technical Meeting on Technologies to Enhance the Competitiveness and Early Deployment of SMRs and HTGRs (14-15 Nov 2019)

- **Cooperation:**
  - HTR Experimental Facilities and Knowledge Preservation (*discussed tomorrow*)
  - Cooperation on mHTGR Safety Design: Joint IAEA-GIF Technical Meeting on Safety of High Temperature Gas Cooled Reactors (9-11 Dec 2019) – *discussed tomorrow*

- **Education and Training:**
  - Joint ICTP-IAEA Workshop on Physics and Technology of Innovative High Temperature Nuclear Energy Systems (SMR 3281) 14 – 18 October 2019, Trieste, Italy
  - eLearning material for HTGRs under development
SMR activities of possible interest

• Technical Working Group
  – 2nd TWG-SMRs Meeting in Vienna, 8-11 July 2019

• CRPs
  – Development of Approaches, Methods and Criteria for Determining Technical Basis for EPZ for SMR Deployment (joint project with NS – presented later – includes HTRs)
    • Second Research Coordination Meeting 27 – 31 May 2019, Beijing, China
  – Design and Performance Assessment of Passive Engineered Safety Features in Advanced SMRs.
    • 3rd Research Coordination Meeting 3-6 September 2019; Daejeon, Korea
International Technical Working Group on SMR

- To advice and support IAEA programmatic planning and implementation in areas related to technology development, design, deployment and economics of SMRs
- 14 Member States and two International Organizations: European Commission and OECD-NEA as invited observers:

More countries potentially to join: Canada, Japan, Saudi Arabia, South Africa, Tunisia and Ukraine

- Three technical subgroups established:
  - **SG-1**: Development of Generic Users Requirements and Criteria (GURC)
  - **SG-2**: Research, Technology Development and Innovation; Codes and Standards
  - **SG-3**: Industrialization, design engineering, testing, manufacturing, supply chain, and construction technology

- TWG will also address specifically SMR for Non-Electric Applications and coupling with renewables
- 1st TWG Meeting for SMR held on 23 - 26 April 2018 in Vienna
- 2nd Meeting scheduled for 8 – 11 July 2019 in Vienna
CRP I32010 - Design and Performance Assessment of Passive Engineered Safety Features in Advanced SMRs

• Water-cooled SMR focus:
  • MS to collaborate in proposing a common novel approach for
    – designing passive engineered safety features for water-cooled SMRs and
    – offering good practices for assessing their performance and reliability

• 10 member states
• 2016 - 2019

• Focus group topics:
  – Passive Safety System Design and Technology Development
  – Development of Approach and Method for functional reliability Assessment of passive Safety Systems
  – Experimental and Analytical Works for Verification & Validation of Passive Safety Systems

• Expected Results:
  – IAEA TECDOC that discuss specific design and safety characteristics of SMRs and their performance evaluation approach
ACP-100

- ACP100, CNNC SMR, is an innovative PWR based on existing PWR technology, adopting “passive” safety system and “integrated” reactor design technology.

ACP100 ESF:

- Passive core cooling system (PXS)
- Passive Residual Heat Removal system (PRS)
- Passive Containment Cooling System (PCS)

Free volume: ~15000 m³
• Design and construct experimental setups for containment systems
IAEA CRP I3 2010– REPUBLIC OF KOREA

• Commercial PWR vs. SMART vs. SMAT-ITL

- Member states in Europe / Eurasia area that plan to initiate or to expand their nuclear energy programme have identified the need to increase their capacity
  - to make knowledgeable decisions…
  - particularly to become capable to identify and perform technical assessments for SMRs commercially available for near term deployment.

- Overall objective to contribute to a new way to meet the European demand for clean and emission-free flexible sources of electricity.

- Technically aspects supported by NE and NS Departments

- A two-year project (2018/19)

- 3 Workshops in 2018: SMR technology (x2) and on Infrastructure, economic and financing aspects

- In 2019 activities on Non-electric applications, IAEA technology assessment, Regulatory framework and licensing issues; Siting and Design Specific Issues

RER 2/014 Participants / beneficiaries

- Albania
- Armenia
- Azerbaijan
- Croatia
- Czechia
- Greece
- Hungary
- Lithuania
- FYR Macedonia
- Poland
- Romania
- Russia
- Slovakia
- Tajikistan
- Turkey
- Ukraine
Main Features

- Design description and main features of 56 SMR designs
- SMRs are categorized in six (06) types based on coolant type/neutron spectrum:
  - Land Based WCRs
  - Marine Based WCRs
  - HTGRs
  - Fast Reactors
  - MSRs
  - Others

- Next update 2020
- ARIS database submission encouraged
Main Activities (MSRs)

**Background**

- IAEA currently does not have focused systematic activities on MSR technology

**GC60 / 61 resolution**

- "Encourages the Secretariat to explore, in consultation with interested MSs, the need for closer collaboration in technology development for advanced reactor lines by hosting a workshop with the aim of considering launching a new project on molten salt and molten salt cooled advanced reactors“
- “Recommends that the Secretariat continue to explore, in consultation with interested Member States, activities in the areas of innovative nuclear technologies, such as ...... including fast neutron systems, supercritical water-cooled, high-temperature gas cooled and molten salt nuclear reactors, …”

**Actions taken**

- Technical Meeting on the Status of Molten Salt Reactor Technology (31 October – 3 November 2016)
  - 35 participants from 18 member states: Australia, Canada, China, Czech Republic, Denmark, France, India, Indonesia, Italy, Japan, The Netherlands, Russian Federation, Switzerland, Turkey, United Kingdom, USA, Venezuela, EU
- Support the development of a new chapter on MSRs in the IAEA Safeguards Physical Module Volume 6 Nuclear reactors (STR-314-06)
- **TECDOC: “Status of Molten Salt Reactor Technology” under development (~150 pages) – CM planned for Q3 of 2019**

**Future actions**

Depends on stated MS interest and availability of RB / EB contributions
Concluding remarks ...

GIF-IAEA interface / opportunities to cooperate

• Important to coordinate (and not duplicate) activities with other international organizations
  – Already good examples with OECD NEA prismatic benchmarking and uncertainty studies and the database with HTR experimental facilities under development

• Stakeholders are different – but the IAEA HTGR community and the GEN-IV VHTR system members represents a substantial overlap

• Areas of common interest that could be explored
  – Safety (SDC and possibly other in future)
  – Computational methods, V&V, Uncertainty studies
  – Economical analysis
  – Knowledge preservation (graphite database, other)
  – Training and course material (eLearning material under development)

• NEW CRP for 2020 to be defined in detail
  – Proposed: ‘Technologies to enhance the competitiveness and early deployment of SMRs and HTRs’
  – To be confirmed in TM and TWG-GCR members

• From 2020 the GCR / HTGR project is part of the SMR programme.
Thank you!