IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Workshop on the Current Status of Structural Material Development for Molten Salt Reactors and Related Challenges

IAEA Headquarters, Vienna, Austria
and virtual participation via Cisco Webex

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Information Sheet

Introduction

The introduction of Small Modular Reactors (SMRs), particularly innovative non-water-cooled designs, marks a new paradigm in the global energy sector. Among these, Molten Salt Reactors (MSRs) are increasingly recognized as a transformative technology within the nuclear power landscape, promising advancements in safety, flexibility, and efficiency for sustainable and clean energy deployment.

As part of the International Atomic Energy Agency's (IAEA) efforts to support the development and deployment of innovative reactor technologies, MSRs offer unique advantages, including low operating pressure, inherent safety characteristics, and fuel flexibility. These features make MSRs attractive options for future energy systems, including floating nuclear power plants, power supply for ports and remote regions, and maritime nuclear propulsion. With their ability to operate at high temperatures and accommodate a wide range of fuel cycles, MSRs are also particularly suited for hybrid energy applications, such as thermal energy storage, hydrogen production, industrial process heat, and closing the nuclear fuel cycle through the transmutation of transuranic elements from spent fuel of conventional water-cooled reactors.

Typical MSR fuels include enriched uranium, plutonium, TRansUranium (TRU) elements from reprocessed spent nuclear fuels, and uranium-233 produced from thorium. MSR fuels generally consist of fission material halides (fluorides or chlorides) dissolved in a carrier salt.

MSR technology provides significant advantages over conventional solid-fuel reactor designs:

- A high coefficient of thermal expansion which provides a large negative temperature coefficient of reactivity. Because the fuel is liquid, it expands when heated, thus slowing down the rate of nuclear reactions and making the reactor self-regulating.
- The possibility of continuous fission-product removal using physical (helium sparging) and pyrochemical processes. Fuel salt can be processed in an online mode or in batches to retrieve fission products and actinides. Actinides are then reintroduced into the fuel circuit.
- Minimization of excess reactivity, which in solid-fuel systems must be compensated through complex control mechanisms. The continuous circulation and adjustment of the liquid fuel during operation allow for active management of fuel composition and reactivity. Furthermore, MSRs operate at low system pressure due to the high boiling point of fuel salt and the continuous removal of gaseous fission products, thereby enhancing inherent safety and simplifying containment requirements.
- Better resource utilization by achieving higher fuel burn-up than with conventional reactors using uranium solid fuel. TRU elements could in principle remain in the fluid fuel of the core, be destroyed in the neutron flux, either by direct fissioning or transmutation to fissile elements until they eventually all undergo fission.
- The avoidance of the expense of transport and fabrication of new fuel elements.

In MSRs, radionuclides (including activation and fission products) are distributed within the reactor circuit, gas off and processing systems, rather than being confined within the solid fuel cladding. This introduces new challenges for materials compatibility, corrosion control, and containment integrity.

Currently, numerous countries are actively pursuing MSR research and development, like: Belgium, Canada, China, Czech Republic, Denmark, France, Germany, India, Indonesia, Italy, Japan, the Republic of Korea, the Netherlands, the Russian Federation, Sweden, Switzerland, the United-Kingdom and the United States of America.

The IAEA Workshop on Molten Salt Reactor Fuels: Recent Developments and Future Challenges (held on 21–25 July 2025) highlighted several common challenges and priorities across the community. Ensuring high fuel salt purity and establishing international standards for synthesis and quality assurance are essential for obtaining reliable and comparable data. Significant gaps remain in thermophysical and thermochemical properties, and even trace impurities can strongly influence corrosion, performance, and waste management. Radiolytic effects on fuel salt chemistry, are not yet well understood, requiring further experimental and analytical development. There is a clear need for consistent modelling frameworks and a shared international database to support validation and cross-comparison of simulation results. Isotopic enrichment, particularly of ^{7}Li and ^{37}Cl, poses a major supply challenge, and isotopic impurities must be managed within fuel cycle strategies. Large-scale facilities for salt production are lacking, and the development of continuous purification, advanced instrumentation, and real-time monitoring is critical for industrial deployment. Finally, accurate system modelling requires integrated coupling of neutronics, thermal-hydraulics, and chemistry codes, supported by collaborative international efforts and open-source development to accelerate technology validation and optimization.

A consistent theme emerging from these findings was that structural materials for reactor systems and related fuel cycles represent one of the critical enabling technologies for MSRs. These container materials must withstand high temperatures, fuel salts containing fission products, radiation damage, and long-term mechanical stresses while maintaining integrity, safety, and manufacturability.

A large body of literature exists on the corrosion of metallic alloys by molten fluoride and chloride salts, both in thermal and forced convection loops. The major impurities that must be removed to prevent severe corrosion of container metals are moisture and oxide contaminants. Considerable effort has been devoted worldwide to salt purification using HF/H_2 sparging of molten salts. However, significant work remains to develop analytical and purification methods capable of identifying oxygen-containing species (oxide type, hydroxyl), purifying the molten-salt mixture, and accurately determining the oxygen content in salt melts.

The adoption of new MSR designs, with both fast and thermal spectra, as well as the potential application of MSRs as industrial heat sources, introduces new challenges. These include higher salt operating temperatures, up to 750°C, metallic barriers, graphite moderators, and reflectors capable of functioning under strong neutron fluxes. Ensuring compatibility of salts with structural materials in fuel and coolant circuits, alongside the development of suitable fuel processing materials, is therefore a critical priority.

Next steps for selecting container materials and solid moderators must involve irradiation testing, corrosion assessment, tellurium exposure evaluation, mechanical property characterization, and fabrication trials to finalize compositions for scale-up. This includes the procurement of large commercial heats of reference materials and conducting long-term mechanical property and corrosion tests of at least 10 000 hours. Additionally, development of design methods and rules is required to enable the safe and reliable design of selected materials.

To support design optimization and licensing, an integrated multi-physics modelling framework is needed to capture the complex interactions among neutronics, thermal-hydraulics, fuel salt chemistry, and materials corrosion phenomena. Such a framework should incorporate depletion calculations to track changes in fuel salt composition during reactor operation, including makeup additions and fission products' removal. It should enable multi-physics simulations integrating neutron transport, heat transfer, and mass transport within the fuel salt, as well as thermodynamic and kinetic models describing fuel salt chemistry, including the behaviour of fission products (e.g., tellurium) and impurities (e.g., O, Fe, Ni, Cr). Finally, system-level transient models and corrosion models are necessary to evaluate structural material surface damage under operational conditions.

Building on the outcomes of the IAEA Technical Meeting on Reactor Physics, Thermal Hydraulics and Plant Design of Molten Salt Reactors (held on 22–25 April 2025) and the IAEA Workshop on Molten Salt Reactor Fuels: Recent Developments and Future Challenges (held on 21–25 July 2025), the IAEA identified the urgent need for coordinated international collaboration for the development of MSR technologies. Members of the IAEA Technical Working Group on Fuel Cycle Facilities (TWG-FCF) and participants of previous IAEA MSR events recommended that the IAEA organize a Workshop on Structural Material Development for Molten Salt Reactors and Related Challenges, to address these cross-cutting issues and foster collaboration among Member States.

Objectives

The purpose of the event is to bring together key stakeholders, including technology developers, regulators, materials scientists, industry representatives and research organizations, to discuss the current status of the development and deployment of structural materials for molten salt reactors, including challenges and future directions.

Target Audience

Participation in the workshop is subject to designation by Governments or national organizations. The workshop is open to participants from all IAEA Member States with existing or planned MSR projects.

Working Language(s)

English.

Topics

The following topics are expected to be covered and discussed:

1. Status of MSR technology development, with a focus on structural material requirements:
    - Recent research and development results on candidate structural materials suitable for MSR environments.
    - Material selection and qualification for high-temperature, corrosion-resistant, and irradiated conditions, and the current status of qualification of structural materials for MSR environments.
2. Corrosion mechanisms in molten fluoride and chloride salts for MSRs and related fuel cycle applications, including the effects of radiolysis and impurities, with special attention to:
    - Embrittlement from helium produced by transmutation of nickel;
    - Corrosion and grain boundary embrittlement caused by fission products, particularly tellurium.

      Compatibility of molten salts and structural materials under operational conditions.
3. Experimental methods and loop testing for structural materials in contact with molten salts to simulate realistic operational conditions.
4. Multi-physics modelling to capture the complex interactions among neutronics, thermal-hydraulics, fuel salt chemistry and materials corrosion phenomena.
5. Advanced manufacturing techniques and robotics for MSRs and related fuel cycle applications.
6. Methods and plans to monitor the integrity of structural materials chosen for MSRs.
7. Licensing, regulatory, and safety considerations related to structural materials in MSRs, including code qualification for nuclear construction and standards such as the ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” Division 5, “High Temperature Reactors”, including Article HHA-3000 for graphite core components and assemblies.

8. Lessons learned from pilot-scale MSR projects and industry experience.
9. Collaborative approaches to data sharing, standardization, and future research priorities, fostering international cooperation and harmonization of testing and qualification protocols.

Participation and Registration

All persons wishing to participate in the event have to be designated by an IAEA Member State or should be members of organizations that have been invited to attend.

In order to be designated by an IAEA Member State or invited organization, participants are requested to submit their application via the InTouch+ platform (https://intouchplus.iaea.org) to the competent national authority (Ministry of Foreign Affairs, Permanent Mission to the IAEA or National Atomic Energy Authority) or organization for onward transmission to the IAEA by **31 March 2026**, following the registration procedure in InTouch+:

1. Access the InTouch+ platform (https://intouchplus.iaea.org):
   - Persons with an existing NUCLEUS account can sign in to the platform with their username and password;
   - Persons without an existing NUCLEUS account can register here.

2. Once signed in, prospective participants can use the InTouch+ platform to:
   - Complete or update their personal details under 'Complete Profile' and upload the relevant supporting documents;
   - Search for the relevant event under the 'My Eligible Events' tab;
   - Select the Member State or invited organization they want to represent from the drop-down menu entitled 'Designating Authority' (if an invited organization is not listed, please contact InTouchPlus.Contact-Point@iaea.org);
   - If applicable, indicate whether a paper is being submitted and complete the relevant information;
   - If applicable, indicate whether financial support is requested and complete the relevant information (this is not applicable to participants from invited organizations);
   - Based on the data input, the InTouch+ platform will automatically generate the Participation Form (Form A) and/or the Grant Application Form (Form C);
   - Submit their application.

Once submitted through the InTouch+ platform, the application, together with the auto-generated form(s), will be transmitted automatically to the required authority for approval. If approved, the application, together with the applicable form(s), will automatically be sent to the IAEA through the online platform.

NOTE: The application for financial support should be made, together with the submission of the application, by **31 March 2026**.

For additional information on how to apply for an event, please refer to the InTouch+ Help page. Any other issues or queries related to InTouch+ can be sent to InTouchPlus.Contact-Point@iaea.org.

Selected participants will be informed in due course on the procedures to be followed with regard to administrative and financial matters.

Participants are hereby informed that the personal data they submit will be processed in line with the Agency's Personal Data and Privacy Policy and is collected solely for the purpose(s) of reviewing and assessing the application and to complete logistical arrangements where required. The IAEA may also use the contact details of Applicants to inform them of the IAEA's scientific and technical publications, or the latest employment opportunities and current open vacancies at the IAEA. These secondary purposes are consistent with the IAEA's mandate. Further information can be found in the Data Processing Notice concerning IAEA InTouch+ platform.

Papers and Presentations

The IAEA encourages participants to deliver presentations on the work of their respective institutions that falls under the topics listed above.

Submission of a presentation should be confirmed, together with the submission of the main application via the InTouch+ platform, by **31 March 2026**.

Expenditures and Grants

No registration fee is charged to participants.

The IAEA is generally not in a position to bear the travel and other costs of participants in the event. The IAEA has, however, limited funds at its disposal to help meet the cost of attendance of certain participants. Upon specific request, such assistance may be offered to normally one participant per country, provided that, in the IAEA's view, the participant will make an important contribution to the event.

The application for financial support should be made, together with the submission of the application, by **31 March 2026**.

Venue

The event will be held at the Vienna International Centre (VIC), where the IAEA's Headquarters are located. Participants must make their own travel and accommodation arrangements.

General information on the VIC and other practical details, such as a list of hotels offering a reduced rate for IAEA participants, are listed on the following IAEA web page:

www.iaea.org/events.

Participants are advised to arrive at Checkpoint 1/Gate 1 of the VIC one hour before the start of the event on the first day in order to allow for timely registration. Participants will need to present an official photo identification document in order to be admitted to the VIC premises.

Visas

Participants who require a visa to enter Austria should submit the necessary application to the nearest diplomatic or consular representative of Austria at least four weeks before they travel to Austria. Since Austria is a Schengen State, persons requiring a visa will have to apply for a Schengen visa. In States where Austria has no diplomatic mission, visas can be obtained from the consular authority of a Schengen Partner State representing Austria in the country in question.

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Subsequent correspondence on scientific matters should be sent to the Scientific Secretary/Secretaries and correspondence on other matters related to the event to the Administrative Secretary.

Event Web Page

Please visit the following IAEA web page regularly for new information regarding this event:

https://www.iaea.org/events/EVT2504152