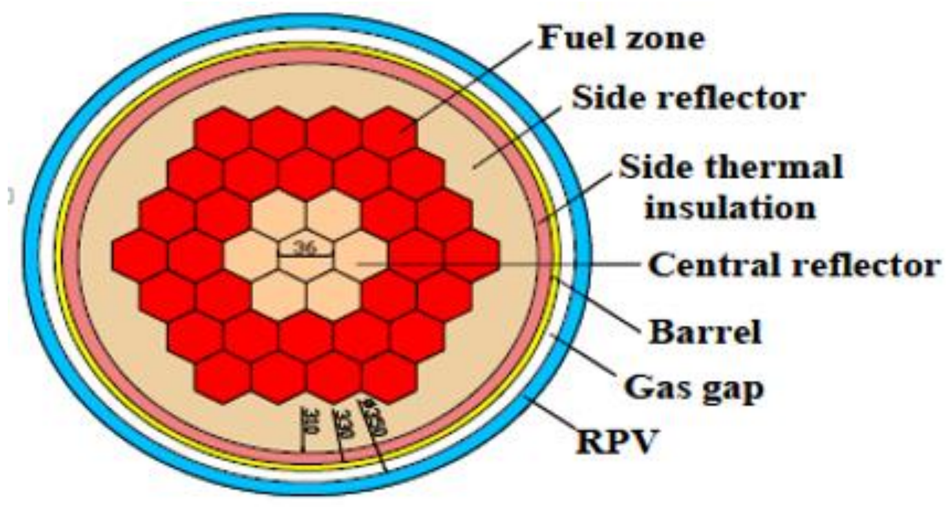
Evaluation of Safety Margin to Failure Conditions for Fuel in Small Modular Reactors

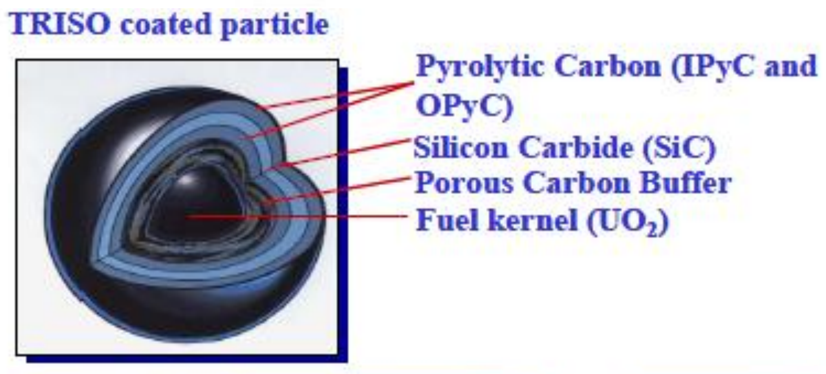
Measured confidence in measurements of safety for fuel in SMRs

Technical Lead: T.N. Thuy Tran

Federal Stakeholder: CNSC

High Temperature Gas-cooled Reactor – HTGR (U-Battery)

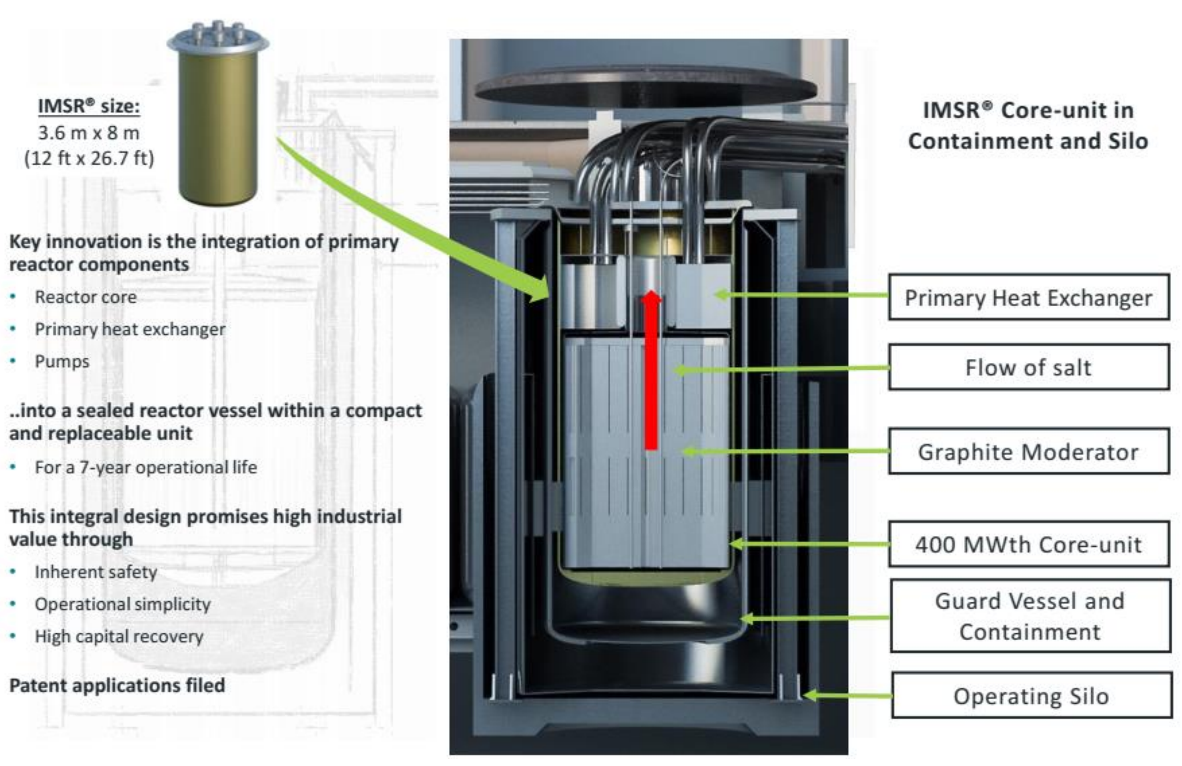




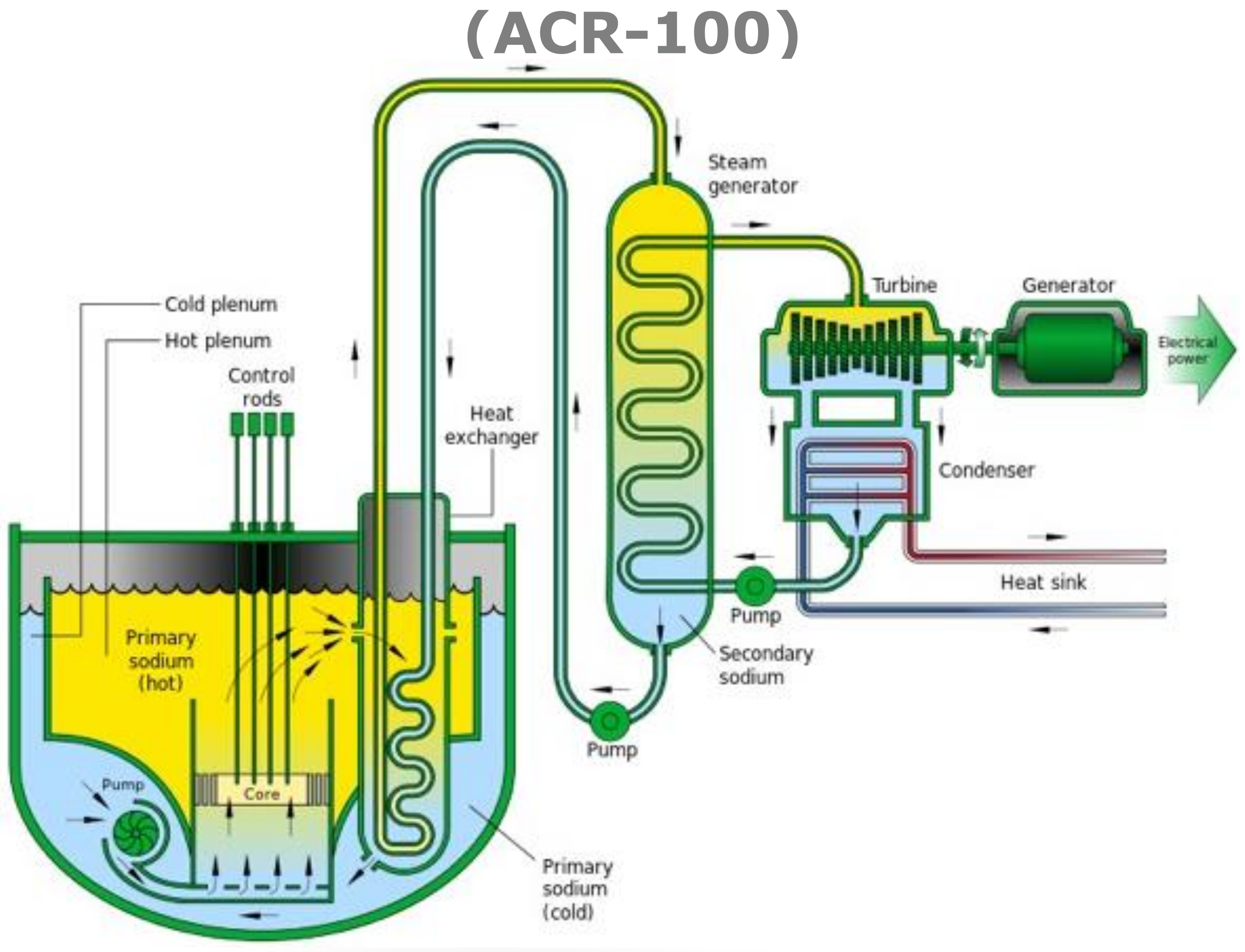
Fuel particles Fuel compacts Fuel block

TRISO Coated fuel particles (left) are formed into fuel compacts (center) and inserted into graphite fuel elements (right).

Molten Salt Reactor – MSR (IMSR)



Sodium-cooled Fast Reactor – SFR (ACR-100)



Background to the problem

To assess methods for evaluation of safety margin to failure conditions for fuel in small modular reactors (SMRs), its important that we ask the right questions that we later need to answer:

- What are the design properties/features claimed as "inherent/passive safety" and their targets - how to verify/measure them?
- What is the nature of the failure – how should it be defined? When does failure occur?
- What protects against failure – is it a claimed safety feature?
- What makes normal operation safe? Why are there limits?

For answering the questions:

- ❖ "Fuel Qualification" and "Safety Margin" may need definitions that better fit the new SMR technologies, particularly for those having coolants other than water.
- ❖ Limits and margins must be evaluated using deterministic techniques.

Achievements from the initial work

Nominal design concepts of SMR that may be used as test cases for the project have been reviewed. Three concepts (HTGR U-Battery, MSR IMSR and SFR ACR-100) have been selected as they are suitable and relevant to recent proposals.

For conducting test evaluations, knowledge gaps can be filled via past experience:

- For HTGR, with TRISO fuel, via the Fort St. Vrain reactor;
- For pool-type MSR, with LEU fuel, via the experiment at ORNL; and
- For pool-type SFR via the EBR III reactor or others.

The next steps (underway) are:

- ❖ Review design basis characteristics and apply Phenomenon Identification and Ranking Table (PIRT) exercises for the three SMR types.
- ❖ Construct a conceptual framework that supports the detailed discussion of specific fuel safety margins.

Expected outcomes

Provide practical guidance on methods to apply in the evaluation of fuel qualification and safety margin quantification.

Peer-reviewed publications on evaluation methodology will be prepared, for the additional benefit to those who will prepare fuel qualification cases that must pass evaluation.

Future work

Move into execution of the main tasks

- Identify failure modes and barriers to failure.
- Identify key parameters and safety limits as likely failure points.
- Test methods for evaluation of safety margin in selected test cases.
- Based on lessons learned, prepare guidance on the methodology for evaluation of fuel safety margin.

Potential collaborations

Interested to pursue further

- Opportunities might arise for value to be leveraged through a future collaboration.
- The Integrated Safety Assessment Methodology (ISAM), which was developed for the Generation-IV International Forum, will be assessed for applicability.