SMR Passive Safety and Heat Transport Technologies

Chuk Azih (Project Lead), Geoff Waddington (Technical Lead)

PROJECT OVERVIEW

OBJECTIVE: To develop computational and experimental capabilities at CNL for analysis of passive safety features proposed by various SMR technologies

INITIATIVES AND PRIORITIES: Support the development of new energy related technologies:

Establishing integrated safety margins for new reactor technology demonstration facilities and evaluating the effects of aging on integrated safety margins

STAKEHOLDERS: AECL, CNSC, NRCan

EXPECTED OUTCOME: Capability to address challenges on and vendors on a variety of passive heat removal systems

BACKGROUND

Small Modular Reactors (SMR) technologies improve safety over existing reactors by employing passive safety systems that do not rely on electrical power sources or operators' intervention to function during accidents.

Almost all new SMR concepts employ passive safety systems that some combination of natural convection, radiation, thermal expansion or capillary effects as the main heat removal mechanism.

Although passive safety systems significantly improve reactor safety, not all technical aspects and limitations are well understood.

RESULTS: (Review and Design)

- Documented reviews of literature for passive systems related to:
  Heat Pipe Reactors
  Molten Salt Reactors (MSR)
  Molten-Metal Cooled Reators
  High Temperature Gas Reactor (HTGR)
- Completed pre-conceptual design to re-purpose existing water-based passive cooling loop designed for Gen-IV program

ACHEIVEMENTS

Capabilities

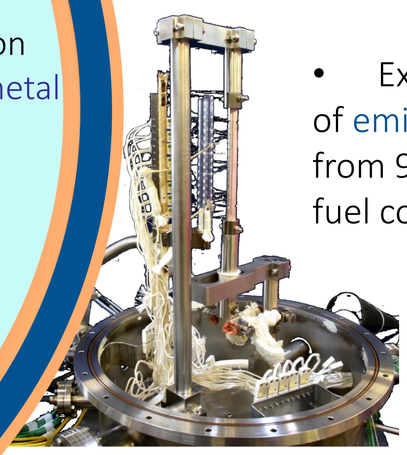
High temperature emissivity facility
Heat pipe reactor cooling test apparatus
Coupled-loop passive safety test facility
Molten salt natural circulation apparatus
Magnetic resonance velocimetry with large eddy simulation
Simulation of natural circulation loops with water, salt and metal working fluids

Collaborations

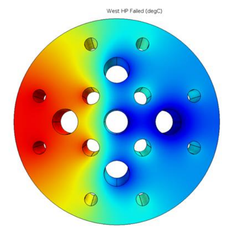
Natural Convection Shutdown Test Facility (NSTF) in Argonne National Labs. Data sharing and building of complementary loops
Magnetic Resonance Imaging (MRI) facility in McMaster University. Magnetic Resonance Velocimetry Capability in Canada

RESULTS: (Design and commissioning)

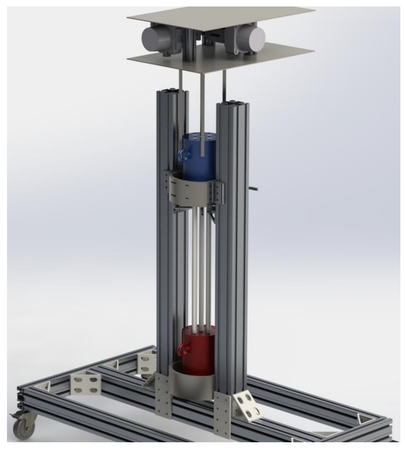
- Designed chloride/fluoride molten salt single natural convection experimental loop for study of natural circulation instabilities. Non-intrusive measurement development.

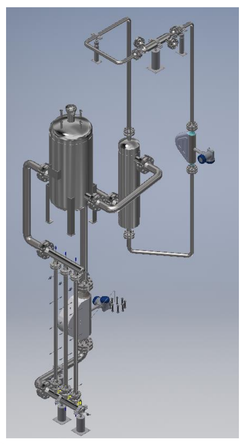


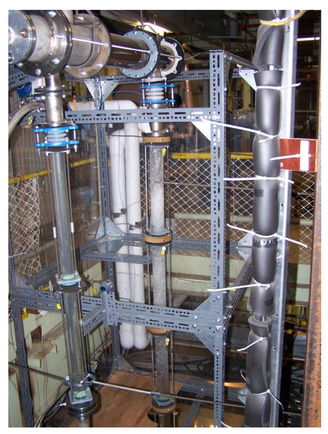
- Extended temperature range of emissivity bell-jar apparatus from 900°C to 1400°C to address fuel cooling gaps in HTGR. Graphite test specimen being designed.
- Identified and obtained simulation tools for assessing passive systems. Identified potential simulation conditions and experimental data.
- Design and construction of heat pipe test apparatus to study heat removal capability under condition such as single and double heat pipe failure, and transient heat load conditions. Using liquid and vapour sodium as the heat transfer fluid .



West HP Failed
Steady State
Heaters at 70%
Heat Pipes at 81%







- Design and construction of coupled-loop passive safety facility. Capable of studies Reactor Cavity Cooling Systems (RCCS) and Direct Reactor Auxiliary Cooling System (DRACS). Water, air, and Dowtherm-A working fluids.

MILESTONES & OUTCOMES

- **Completed:** Identify phenomena of interest for simulation and analysis plan
- Perform first molten metal test
- Modification of Passive loop for SMR

- **Completed:** Four review documents related to passive safety systems in small reactors: HTGR passive systems; MSR passive systems; Water-cooled SMR passive systems; Molten metal and heat-pipe cooled SMR passive systems.
- Fluid-to-fluid scaling analysis for natural circulation loops
- Review of feasibility of non-intrusive measurement techniques for SMR