Passive Decay Heat Removal System

Summary / Objectives:

A major design goal for Generation IV nuclear energy systems is to reduce or eliminate the likelihood and/or extent of reactor core damage incurred during an off-normal operating event, thereby eliminating the need for offsite emergency response. One approach for achieving this objective is to develop inherently safe reactor designs that can passively dissipate decay heat to the environment without relying on operator action during an event of this type. Historically, this approach has been taken for both sodium- and gas-cooled Generation IV reactor types by providing Reactor Cavity Cooling Systems (RCCS) that are designed to passively dissipate decay heat to the environment by natural convection while maintain fuel temperature below the threshold for onset of core damage. This presentation will begin by providing a high level overview of RCCS systems that have been developed for advanced reactor designs over the years. This will be followed by a summary of large scale integral effect tests that are currently underway at Argonne to provide licensing-quality data for two of these systems; i.e., air- and water-cooled RCCS concepts.

Meet the Presenter:

Dr. Mitchell Farmer is currently a Senior Nuclear Engineer and Manager for Light Water Reactor programs in the Nuclear Science and Engineering Division at Argonne National Laboratory. He has over thirty years of experience in various R&D areas related to reactor development, design, and safety. A principal early career focus was in the area has been light water reactor (LWR) severe accident analysis and experiments, followed by a rekindling of this work to address technical issues raised in the wake of the reactor accidents at Fukushima Daiichi. More recently, Dr. Farmer has been heavily involved in the analysis, design, and conduct of experiments related to operations and safety of Generation IV reactor concepts including sodium fast reactors, as well as high-temperature gas cooled reactors. He has over 200 publications in the above mentioned technical areas. Dr. Farmer also served as the Technical Area Lead for the Reactor Safety Technologies Pathway (RST) within the Light Water Reactor Sustainability (LWRS) Program at the US Department of Energy (DOE). Dr. Farmer earned his PhD in Nuclear Engineering from the University of Illinois in 1988.

Expertise | Collaboration | Excellence

MOTIVATION: The accident at the Fukushima Daiichi Nuclear Power Plant was troublesome because the system that actively cools the decay heat did not work. The study of passive cooling systems is important for advanced nuclear reactor systems.

Passive Safety Needs for GenIV

- GenIV initiative defines 8 technological goals, of which 3 are safety related:
  - "S&R 1 – System operations will excel in safety and reliability"
  - "S&R 2 – Very low likelihood and degree of reactor core damage"
  - "S&R 3 – Eliminate the need for offsite emergency response"
- The reactor cavity cooling system (RCCS) has emerged as a leading concept for meeting these goals
  - Possibility to provide inherently safe and fully passive means of decay heat removal
  - Offers a high level of performance with relative simplicity in design
  - Has been under consideration since 1950's
- Though the RCCS is our focus, our ultimate objective is to support the continued development of safe and reliable nuclear power
  - Multi-institutional effort has brought together federal, industry, national laboratories, and universities

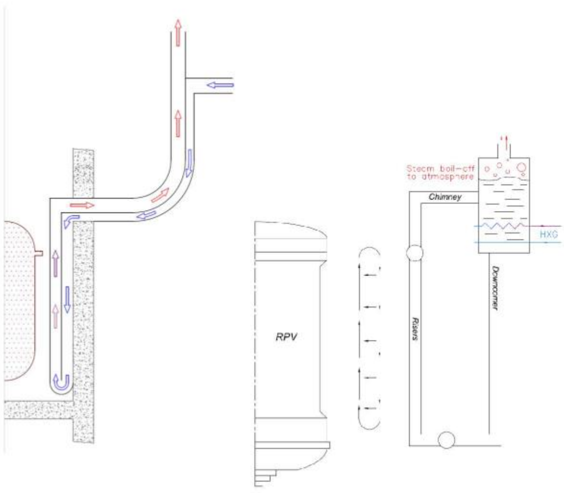
4

FOCUS: The focus is on the reactor cavity cooling system (RCCS) as a system for passive removal of decay heat. It's a simple system that utilizes the natural circulation of air and water but needs to be checked for practical applicability on a variety of scales.

RCCS Overview

- Unique to recent generation of HTGR
  - Natural circulation in laminar and turbulent flow
  - Radiative (primary) and convective heat transfer
- Air and water under consideration
- Considered for both active cooling duration normal operation, and with other designs operating solely as a passive safety system during an accident transient
- Several designs, each unique in geometry, but sharing a common concept, are under design

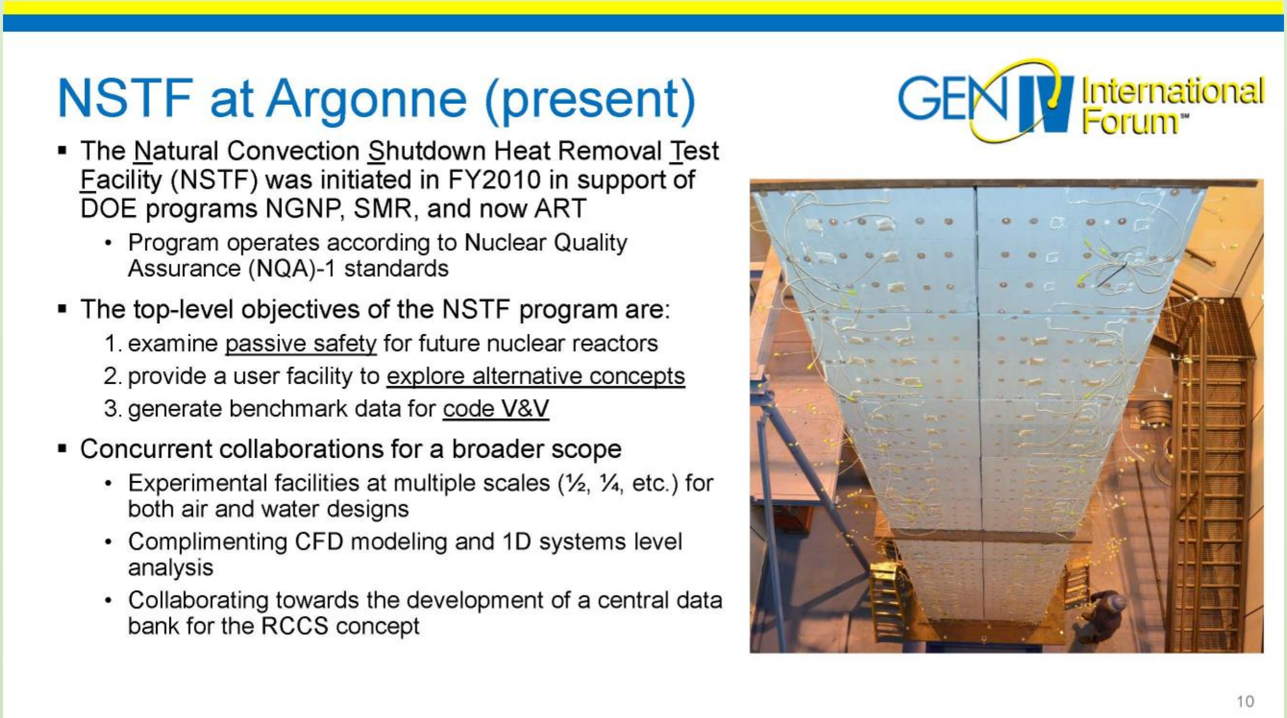
Reactor	RCCS Coolant	Cooling Mode	Country	Power
HTR-10	Water	Natural	China	10 MW_t
VGM	Water	Natural	Russia	20 MW_t
HTTR	Water	Forced	Japan	30 MW_t
PBMR	Water	Natural	South Africa	400 MW_t
SC-HTGR	Water	Natural	USA	625 MW_t
HTR-PM	Water / Air	Natural	China	250 MW_t
GA-MHTGR	Air	Natural	USA	450 MW_t
GT-MHR	Air	Natural	Russia	600 MW_t



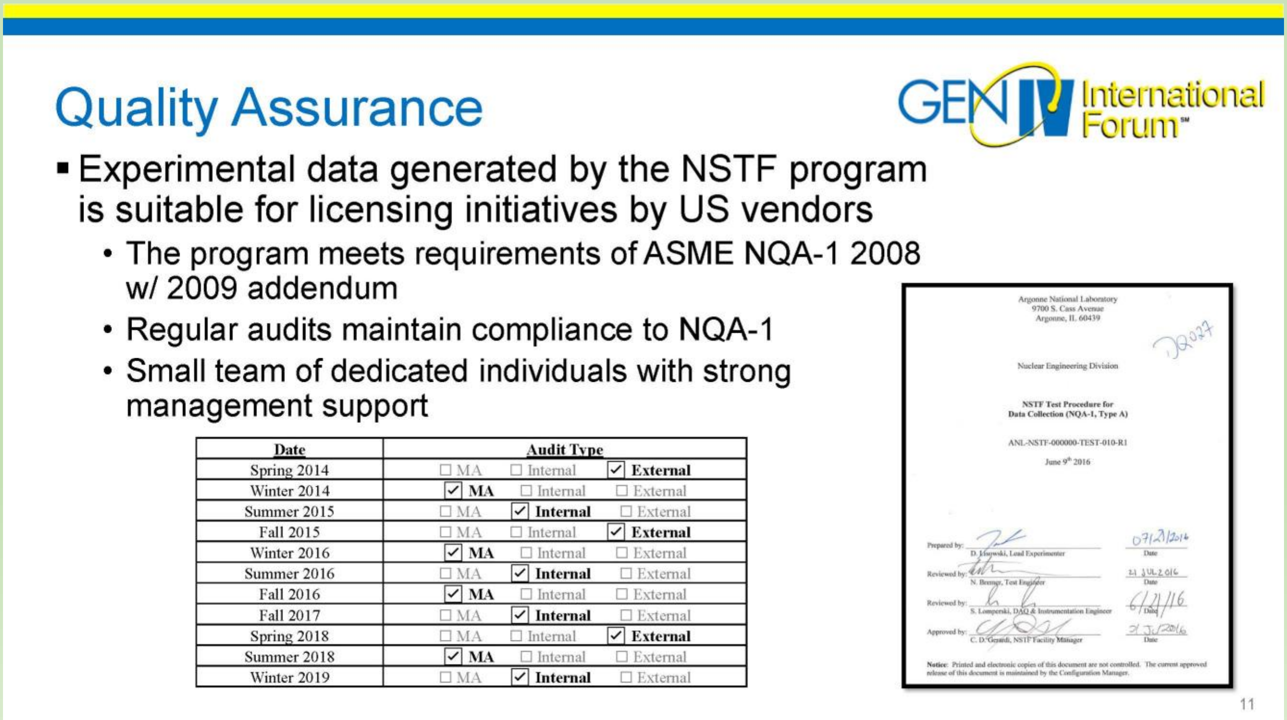
6

GEN IV International Forum℠
Expertise | Collaboration | Excellence

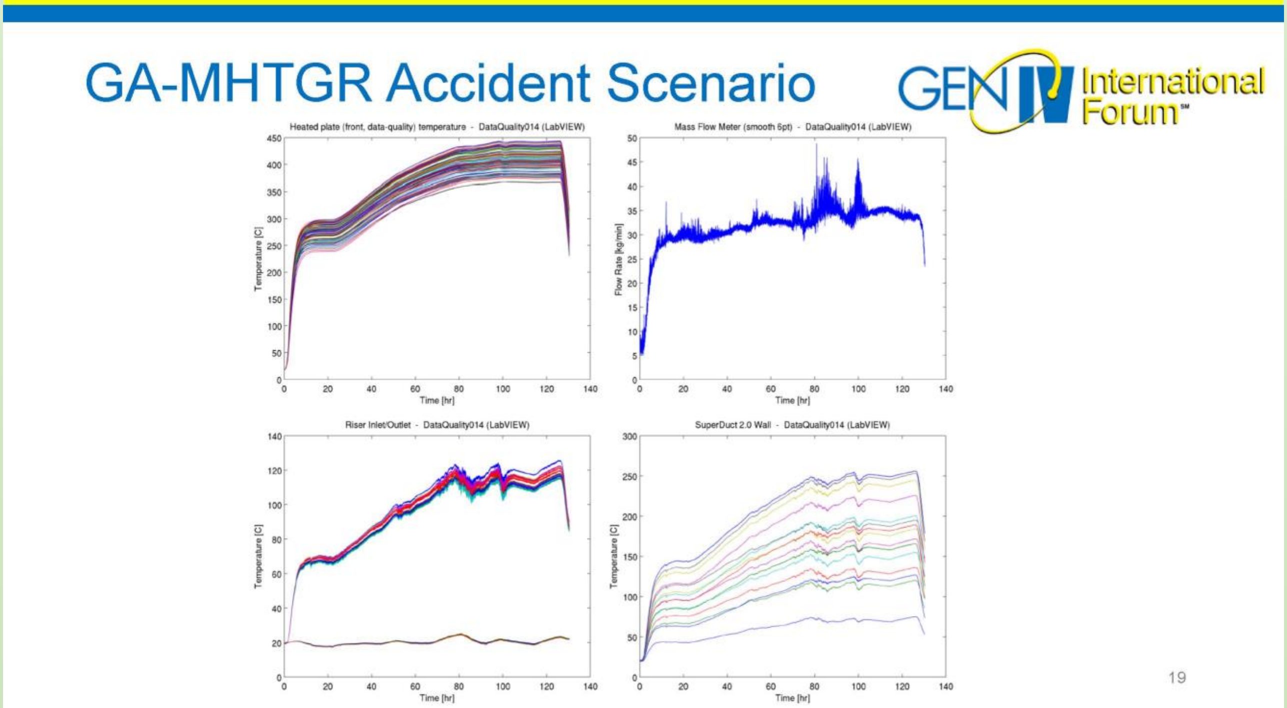
The Natural Convection Shutdown Heat Removal Test Facility: This type of experiment has been performed at ANL since the 1980s, but it has been redesigned to be applicable to advanced reactor nuclear systems.



Quality: Experiments contribute to providing high quality data for code validation and to support the licensing process.



Experimental results: An example of the experimental results of the MHTGR accident scenario is shown below.
Other performance tests have been conducted under various conditions with gas as the working fluid, and the results are presented.



Air to Water Conversion: With conclusion of air-based testing, program has shifted to a water-based operation of the existing test facility. Water-cooled NSTF based on concept design for Framatome 625 MWt SC-HTGR (formally AREVA)

Water Accomplishments

- May 2018 – Completed installation of test facility
  - Primary components: test section, water storage tank, and network piping
  - All sensors, hardware, control valves, etc.
- July 2018 – Shakedown and instrument verification
  - Signed verification sheets
- November 2018 – Single-phase demonstration test
  - Install and verify network piping sensors
  - Initial fill of test loop and system leak-test
- January 2019 – First accepted matrix test at single-phase conditions
  - Baseline ‘normal operation’; steady-state with 30°C inlet temperature
- August 2019 – Completion of single-phase parametric series

30