GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM

July 18, 2024

International Collaborations Overview

Paolo Balestra

ART-GCR Methods Lead at Idaho National Laboratory

DOE ART GCR Review Meeting

Hybrid Meeting at INL

July 16-18, 2024

Content

- NEA - Loss of Forced Cooling (LOFC) project
- Civil Nuclear Energy Research and Development Working Group (CNWG)
- GIF - Very High Temperature Reactor (VHTR) - Computational Methods, Validation & Benchmarks (CMVB)
- IAEA - Network for Experiment and Code Validation Sharing (NEXSHARE)

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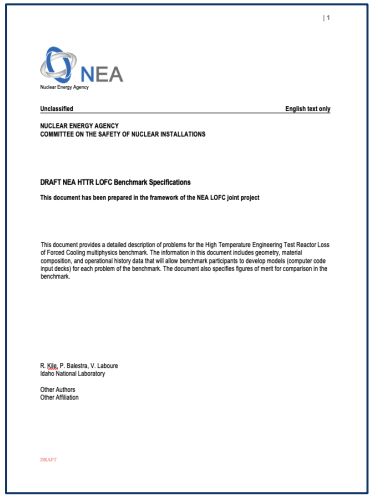
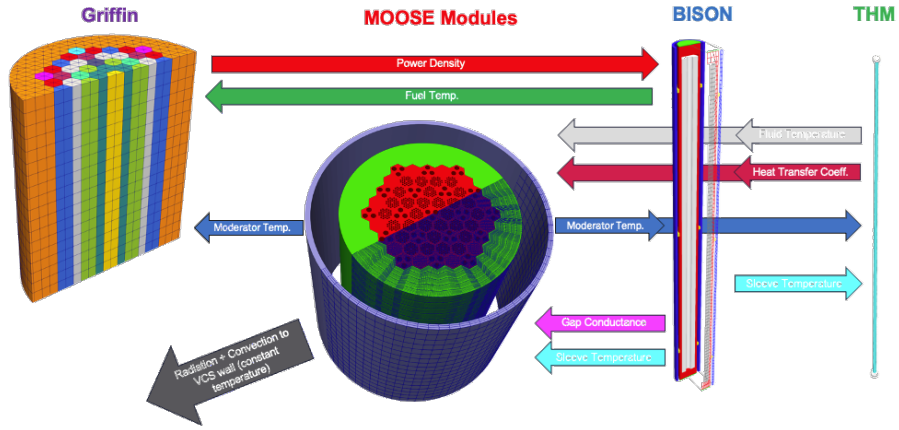
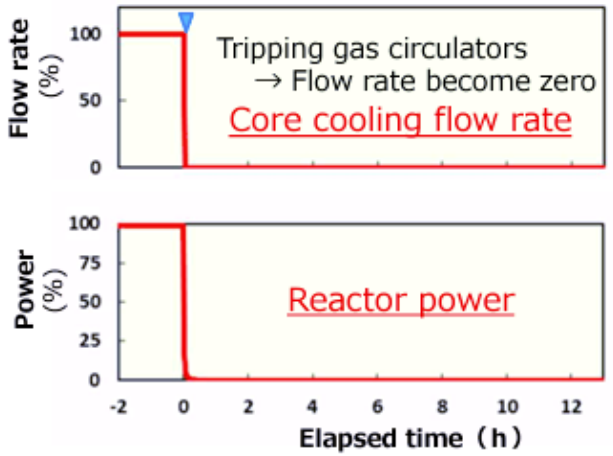
High Temperature Test Reactor (HTTR) Loss of Forced Cooling (LOFC) Project:

- 30MW Gas cooled prismatic reactor capable of reaching 950℃ (Max.) of helium outlet temperature at 4.0MPa.
- The experimental campaign was interrupted in the 2011 it restarted in the 2022. Last test performed 2024.3.27 - Loss of core flow test (Run2) High power 100%(30MW) all circulators tripped.
- Draft Benchmark specification being revised by JAEA and WGAMMA for a possible future benchmark.
- VTB opensource steady state model: https://github.com/idaholab/virtual_test_bed/tree/devel/htgr/httr







https://www.jaea.go.jp/english/news/press/2024/032801/att1.pdf

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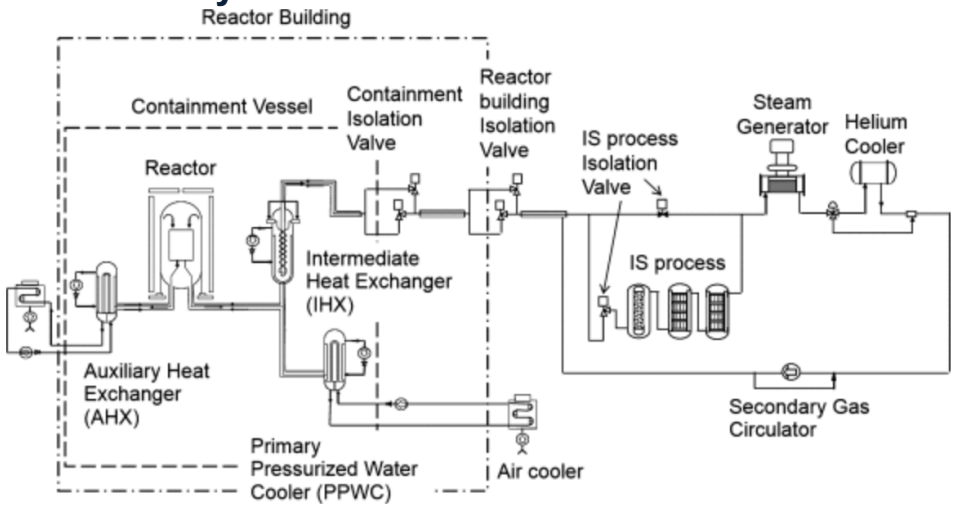
Civil Nuclear Energy Research and Development Working Group (CNWG):

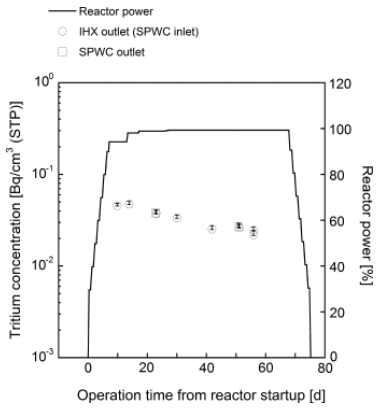
US-Japan BLC-CNWG

- From January 5 to March 21, 2010, JAEA operated the HTTR ramping the reactor power from zero to full power and back to zero in 1800h.
- Although the focus of the experiment was tritium measurement other reactor parameters such as fluid temperatures and Control Rod (CRs) positions were recorded.
  - The model developed using NEAMS tools for the LOFC experiment will be modified adding CR explicit modelling and used to simulate the power ramps
  - A MELCOR model of HTTR will be developed to simulate production and transport of TRITIUM within the reactor.

HTTR systems



Power Ramp Transient



MELCOR

NEAMS
NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

Dipu, Arnoldus Lambertus, et al. "Assessment of amount and concentration of tritium in HTTR-IS system based on tritium behavior during high-temperature continuous operation of HTTR." Annals of Nuclear Energy 88 (2016): 126-134.

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VHTR - Computational Methods, Validation & Benchmarks

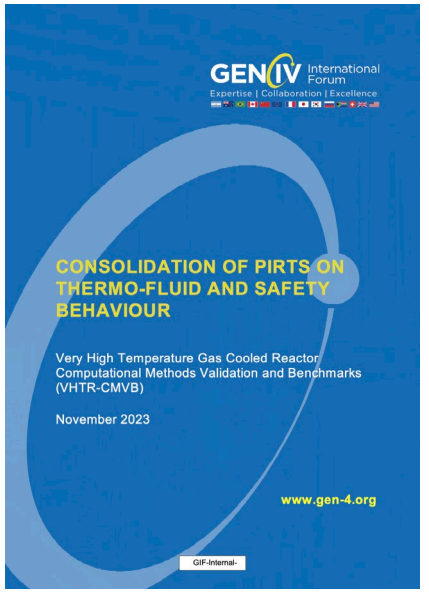
- 5 Work Packages
  - WP1: PIRT
  - WP2: CFD
  - WP3: Reactor physics
  - WP4: Chemistry and Transport
  - WP5: Reactor and Plant Dynamics

CMVB PA	EU	JP	CN	KR	US	UK	CA	AU
	P	P	P	P	P	O	O	O

Date	Event
2018.10.05	• The Project Plan has been approved by all SSC.
End of 2020	• The confirmation of CMVB PA has been received from each signatory, comments have been received from the signatories: EU, Japan, China, Korea, and US.
2021.05.14	• The SSC members approved the updated project plan concerning the subject of signatories
2021.09.01-02	• Signatory from KAERI (05/21/2021), JAEA (06/17/2021), JRC (07/15/2021), and INET (08/31/2021).
2022.09.19-20	• At the 25th CMVB PMB Meeting Canada joined as observer and signatory from the DoE was announced by the end of the 2022.
2023.03.20-21	• Signatory completed KAERI (05/21/2021), JAEA (06/17/2021), JRC (07/15/2021), INET (08/31/2021), US (11/30/2022). Canada and UK expressed interest in becoming participant members, Frederik Reitsma is the new representative for EU and the new technical secretariat Franco Michel-Sendis joined the group.
2023.10.10-11	• Australia Joined the VHTR-CMVB as an Observer, OKITA Shoichiro is the new representative for Japan.
2024.04.15-18	• Dr. Minh Tran is the new observer for Australia

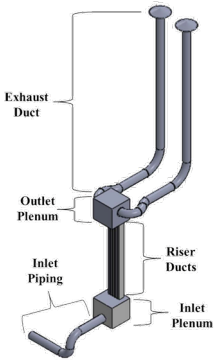
WP1 - Phenomena Identification and Ranking Table (PIRT) Comparison, Evaluation, and Update

- Consolidation of the knowledge about VHTRs important phenomena
  - **Task 1.1:** The Task Leader (DOE) shall construct a template of PIRT values and populated with values from the Task Leader's PIRT. Update members' knowledge of important or poorly understood thermo-fluid and core safety phenomena
  - **Task 1.2:** Consolidation of PIRTs on Chemistry and Transport (including Water Ingress)
  - **Task 1.3:** Construction of a Validation Matrix (Experiments being available and being needed)

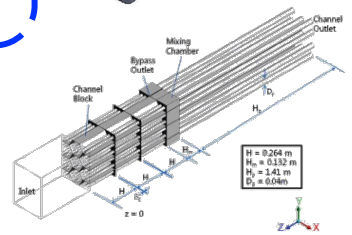


WP2 - Computational Fluid Dynamics

- Validation of CFD tools for VHTR analysis
  - **Task 2.1:** Review the existing guidance reports from OECD/NEA, US NRC, IAEA, etc. and summarize general and specific guidance of using CFD tools in HTGR applications.
  - **Task 2.2:** Thermal mixing effect and pressure drop in the scaled structure of bottom reflectors and hot gas chamber of the HTR-PM blind calculations. INET will provide the description of the test facility, structure geometry, and experimental data in various test conditions
  - **Task 2.3:** Validate CFD numerical models and measure the capability of CFD numerical models to calculate the radiation and convective heat transfer in the air-cooled RCCS. Wisconsin-Madison Air-cooled RCCS experimental facility produced particle image velocimetry that will be used for validating CFD models.
  - **Task 2.4:** Perform CFD validation studies related to the prismatic core bypass flow. Air experiments performed by Seoul National University (SNU) and the MIR experiments performed by INL will be used for validating CFD models.



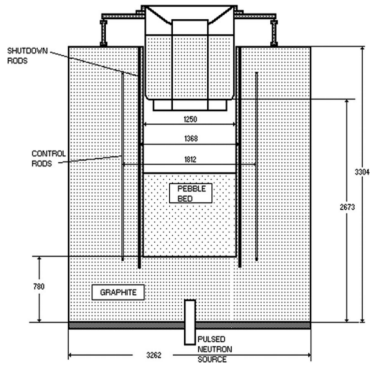
Wisconsin-Madison Air-Cooled RCCS system



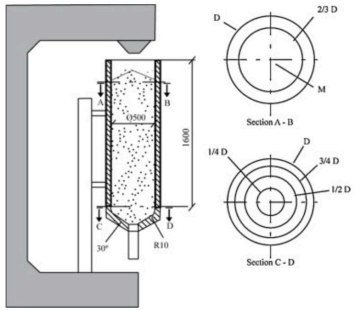
Air experiments performed at Seoul National University (SNU)

WP3 - Reactor Core Physics and Nuclear Data

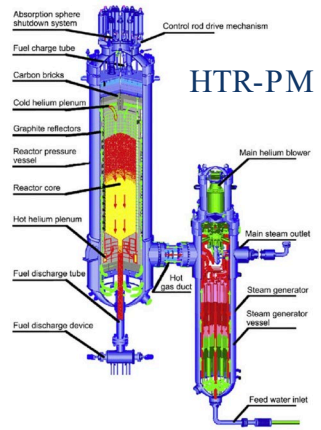
- Validation of Burnup and Reactor physics codes
  - **Task 3.1:** Validate burnup analysis using isotopic data from AGR and HFR-Petten fuel irradiations - compare models for computing decay heat generation rates and source term for accident analyses.
  - **Task 3.2**: Quantify the uncertainty in key safety parameters due to the random distribution of particles and pebbles in a pebble bed reactor - validation against HTR Proteus experiments - then modified to reflect different packing assumptions.
  - **Task 3.3:** Pebble flow characterization - ANABEK experimental data and more recent INET pebble flow experiments.
  - **Task 3.4:** Effect of neutron damage and annealing on thermal and neutronics properties of graphite and matrix carbon - explore models for the determination of the extent of the damage-recovery effects and their impact on static and dynamic neutronic behavior
  - **Task 3.5:** Predict the startup critical configuration of HTR-PM - participants will predict the number of pebbles required for the HTR-PM reactors to achieve criticality under the conditions specified for the startup physics experiments



HTR Proteus Experiments



ANABEK Experiment

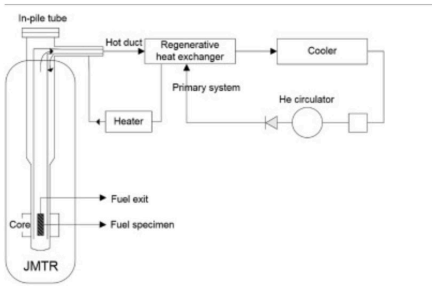


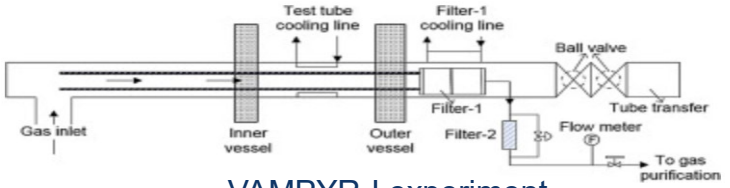
HTR-PM

WP4 - Chemistry and Transport

- Identify the chemistry and transport scenarios of important radionuclides
  - **Task 4.1:** Radionuclide and dust transport and plate-out in the Primary Loop - Reactor Operating Experience and measurements (AVR, Fort St. Vrain, etc.), DEACO dust activity measurements, Limited additional data (Peach Bottom, Storm experiments, HTR-10), Plate-out test facilities(VAMPYR-I, OGL-1 experiment)
  - **Task 4.2:** Radionuclide and dust transport in the reactor building after a break
  - **Task 4.3:** Tritium Transport Models and code verification
  - **Task 4.4:** C-14 Transport Models and code verification

OGL-1 experiment

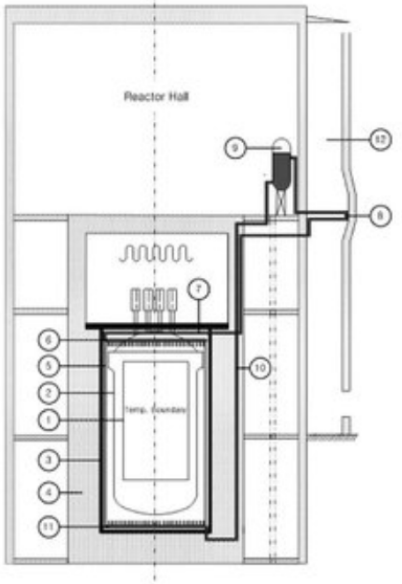




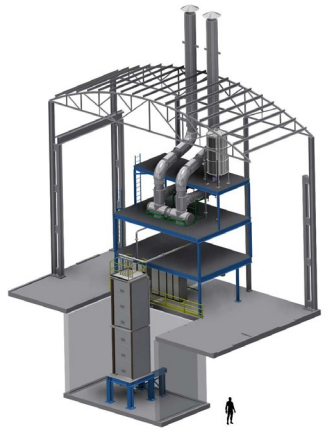
VAMPYR-I experiment

WP5 - Reactor and Plant Dynamics

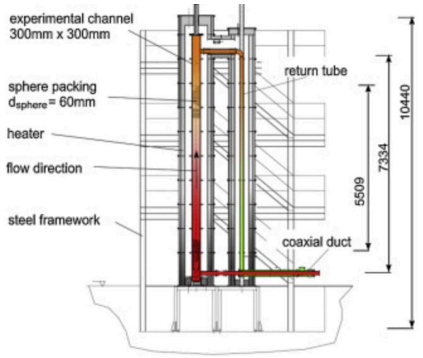
- Establish guidelines for the validation of system models
  - **Task 5.1**: Oregon State University (OSU) High Temperature Test Facility (HTTF)
  - **Task 5.2**: Argonne National Laboratory (ANL) Natural Circulation Shutdown Heat Removal System (NSTF) Experiments in Air-Cooled Reactor Cavity Cooling Systems (RCCS)
  - **Task 5.3**: System Studies of the HTR-10 RCCS Experiments
  - **Task 5.4**: System Studies of the ANL Water-cooled NSTF Experiment
  - **Task 5.5**: KOREA Hybrid RCCS Experiment
  - **Task 5.6**: NACOK II Experiments – Air ingress
  - **Task 5.7**: Code-to-Code Comparisons of operational transients
  - **Task 5.8**: Guidelines for Validation and Application of Systems Analysis Numerical Models



HTR-10 RCCS



NSTF test facility



NACOK test facility

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Major accomplishments/activities in the subject area

- Interregional Workshop on Experimental Testing and Validation for Design and Safety Analysis Computer Codes for Small Modular Reactors, 18–21 June 2024, Vienna, Austria
  - Part of the NHSI by the IAEA, NEXSHARE promotes global cooperation for experiments and code validation for Small Modular Reactors (SMRs).
  - 22 participating organization from 13 member states and more to come.
  - In collaboration with the OECD/NEA, the GEN-IV Forum and EPRI.
  - The NSTF and HTTF US facilities have been included in the database for HTGRs related experiments

IAEA
International Atomic Energy Agency

https://nucleus.iaea.org/sites/connect/NEXPublic/SitePages/Home.aspx

NEX SHARE

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Thank you for your attention, Questions?

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