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FY2021 December Monthly Status Report for the VTR

January 2021

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Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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FY2021 December Status

SOLVING ENERGY CHALLENGES THROUGH SCIENCE

Versatile Test Reactor

Tom O'Connor, Federal Program Manager

Greetings All! I hope this note finds you well and having found some time to relax over the holidays. December was very much bitter-sweet for the project. On the sweet side, issuing the draft VTR Environmental Impact Statement (EIS) was an impressive accomplishment. It was the Department's first EIS for a reactor, addressing two sites and incorporating risk informed approaches to establishing the bounding accidents to be analyzed. I am very appreciative of the hard work, patience and professionalism that produced it and set the bar for the rest of the nuclear industry to follow. I am confident that we will be able to issue the final VTR EIS in Fiscal Year (FY) 2021. Obviously, the appropriation of $45 million is bitter, especially so given the approval of Critical Decision (CD)-1, language in the Energy Act of 2020, which authorized $295 million in FY 2021 and receiving Secretarial approval for the use of a plutonium-bearing driver fuel. The FY 2021 budget does not negate the need for VTR in any way, shape or form. Two things are demanded of us in FY 2021. First, we need to work smartly and efficiently with the dollars provided. These critical activities are focused on addressing risks, and the sooner we can clear them off our plate, the better. Second, we need to finalize our partnership strategy with Natrium and other ongoing Nuclear Energy programs so that VTR can capitalize on their efforts and further minimize the impacts from the limited FY 2021 funding. I have said it before and will say it again – I am proud to be working with you on VTR. Now, stay well and get back to work!

Jordi Roglans-Ribas, Program Overview

VTR technical leads participated in the National Academy of Sciences review on December 7. Tom O'Connor provided an overview of the VTR project, Tom Fanning presented the core design and safety; Kevan Weaver presented the planned experimental vehicles illustrating how VTR can help to advance nuclear technology that can support innovation in existing and advanced reactors; and Doug Crawford presented the planned fuel cycle and waste management. The meeting went very well, and the project received positive feedback.

Several meetings with the French Alternative Energies and Atomic Energy Commission (CEA) took place in December. An Executive Committee meeting between the U.S. Department of Energy (DOE) and CEA was held on December 11 and the agreements included initiating work for two Special Topics of Collaboration (STCs) on neutron physics and safety analysis modeling, proceeding with the signature of several others, and forming a working group to discuss exchange of intellectual property.

Lee Nelson participated in the Idaho National Laboratory (INL) Supplier Engagement Webinar Series. December's webinar centered on supply chain for the VTR and advanced nuclear. Lee was joined by Nick Smith, Deputy Director for the National Reactor Innovation Center (NRIC), and Corey McDaniel, INL's Director for Industry Engagement.

As previously mentioned, the draft VTR EIS was issued by the Environmental Protection Agency (EPA) on December 31, which allows the 45-day public comment period to begin. The public comment period will be open through February 16 unless an extension is requested. The EIS can be viewed at https://www.federalregister.gov/documents/2020/12/21/2020-27951/notice-of-availability-of-draft-versatile-test-reactor-environmental-impact-statement or on the VTR SharePoint site. Public hearings are scheduled for January 27 at 6:30 pm Eastern Time (ET) and January 28 at 8:30 pm ET. To register, visit

https://www.energy.gov/ne/articles/us-department-energy-announces-public-hearings-draft-versatile-test-reactor.

The FY 2021 VTR budget appropriation was finalized at $45 million instead of $65 million as the project had been planning. Discussions started on the reduction of scope in different project areas that will be necessary to adapt to the final appropriation. The scope and milestones will be finalized in early January.

George Malone, Reactor Technical Integration

General Electric-Hitachi (GEH)/Bechtel National Incorporated (BNI) Design Engineering Support

Continued Release 5 work with authorization received in November. Continued to advance the following work:

- Planning and scheduling Release 5 Technology Maturation Planning activities for the period of November 7, 2020, to January 31, 2021.
- Further defining of plant-level requirements to ensure such requirements are available and traced in DOORS.
- Update the framework for the Technology Readiness Assessment (TRA) Program and review this framework to progress the overall program approach and support low technical readiness level (TRL) component progression.
- Technical maturation plans for B11 Reactor Module, B12 Control Rod Drive Mechanism (CRDM), B21 Electromagnetic (EM) Pump, and F42 In-Vessel Transfer Machine (IVTM).
- ANSYS Maxwell modeling in support of Argonne National Laboratory's (ANL) SAS4A/SASSYS-1.
- Started Heat Rejection System EM Pump Optioneering.
- Performed additional review of the Critical Technology Elements (CTE) to support the TRA program. Additional CTE were identified and added to the existing list. The CTE are screened to identify the Technology Readiness characteristics that needs to be addressed in the technology maturation plans (TMPs).
- ANL-GEH interfacing work activities between J11 (Core and Fuel Services) and B11. This effort provides a key framework for collaboration to facilitate critical interfaces definition, coordination, and risk reduction.
- Resolution of action items resulting from the Special Purpose Review (SPR) of the B24 Heat Rejection System. Continued preparation of B24 Pump Study and resolved comments with BEA.
- Updated the VTR Project Master Parts List (MPL) to incorporate changes/additions requested by BEA and updates from the Experiment Transport Vehicle (ETV) SPR.
- Continued Requirements Management work to reduce overall project risk, specifically firming stakeholder, plant, and common requirements with BEA via regular review meetings, workshops, and training.

Issued two documents which provide input to the refueling time and motion study: SPC-2970, VTR Dismountable Test Assembly Strategy, and SPC-2974, VTR Maintenance Capability Strategy.

TerraPower Support

Completed all Cesium sequestration tests. Prepared and transmitted the test report to INL.

Initiated project closeout activities. Requests were sent to INL for disposition of relevant hardware, supply, and software. The contract expired at the end of 2020.

TerraPower (TP) and GEH coordinated on scope transfer from GEH to TP for tasks such as casks and refueling time and motion studies.

Argonne National Laboratory Support

Provided engineering support for reviews of various engineering documents provided by GEH and BNI. Supported the B11/J11 weekly meetings with GEH and reviewed their near-term schedule.

Fast Flux Test Facility (FFTF) Documentation and Data Recovery

Located 71 thermal striping documents and only three remain yet to be retrieved. Ordering and collating the documents and drafting a summary overview management report. Avoidance of thermal striping is an important aspect of a Sodium Fast Reactor (SFR) design. Adjacent sodium streams, with different temperatures and oscillating, when impinging on steel structures will impose high-cycle thermal stresses and eventually high-cycle fatigue will occur. These phenomena were investigated in depth during design of the FFTF and the Clinch River Breeder Reactor (CRBR). As an indication of the importance of avoiding thermal striping, temperature differences necessary to avoid thermal striping, in an operational sense, were contained in the Technical Specifications in the FFTF Final Safety Analysis Report (FSAR) and more importantly in the Limiting Conditions for Operation (LCOs).

Reviewed operating experience and documents related to the washing of sodium wetted components. The Pacific Northwest National Laboratory (PNNL) FFTF Finding and Retrieval team provided a summary report on the approach used in defueling the FFTF to GEH and BNI. To ensure that the highest quality information was provided, the report was reviewed by the Columbia Basin Consulting Group (CBCG) prior transmittal.

In support of the fuel fabrication process, PNNL is looking for the documentation of assembling an HT-9 fuel assembly from its respective components, such as wire wrap, clad pins, end caps, rails, and ducts. The PNNL FFTF Finding and Retrieval team is searching for documents and procedures used to assemble the seven HT-9 metal fuel fabrication (MFF) tests that were irradiated in the FFTF. It is anticipated that a list of candidate documents and procedures will be available in late January.

VTR Control Rod Mechanical Design Analysis

Calculated a first-cut number indicating the nominal mechanical lifetime of a VTR absorber assembly. The VTR absorber bundle contained 37 pins with HT-9 cladding and with an HT-9 inner duct and outer duct. The calculated value of 760 Effective Full Power Days (EFPD) should be regarded as a bounding high number. VTR dimensions, core physics, and thermohydraulic information was used wherever available, and where not, FFTF placeholder

or default information were used. Developed and incorporated a list of the missing information into a Design Information Request (DIR). Most of the information in the DIR is reactor physics information. A meeting will be held with ANL staff the first week in January. Incorporation of the missing VTR reactor physics information into the analysis will produce a more accurate mechanical lifetime. The current factor limiting the design lifetime is excessive contact stresses between the B4C pellet and the cladding. However, when the new information in the DIR is incorporated into the mechanical lifetime analysis, elimination of bundle looseness and absorber bundle over-compaction may become the limiting factor. This has yet to be determined.

Rabbit Design for the VTR

Installation of the Rabbit proof of principle test at Texas A&M is progressing and hooking up sensors and gas lines to the Rabbit test continued.

Calculation Support for VTR Waste Form Analysis

PNNL continued researching historical documentation to support development of programmatic spent fuel treatment functional and operational requirements (F&ORs). PNNL staff considered scenarios for fuel processing that included mitigating approaches from a safety perspective for fuel handling, cleaning, transport, processing and final disposition. Many concepts being considered have been used in the past by FFTF and Experimental Breeder Reactor (EBR)-II programs, with other novel approaches being scrutinized. Staff have finished reading background, safety and function and requirements documentation from previous applicable programs and are beginning work on iterations for the VTR F&ORs alongside INL/VTR. Next, a concerted initial design effort for x-reactor will begin that will be compiled in a document as the final deliverable for this task.

Thomas Fanning, Nuclear Technical Integration

Fuel Design and Analysis

Identified tasks to be retained, rescoped, or descoped in FY 2021 consistent with the VTR funding appropriation. Clarified TerraPower scope and expectations for the February report on HT9 sourcing and supplier qualification. Considered implications of inclusion of specific impurity elements in Pu feedstock and discussed as guidance for Savannah River National Laboratory (SRNL) personnel assessing Pu sources and feedstock processing options.

Fuel Manufacturing

Focused on maturing the manufacturing equipment designs and defining the manufacturing process details. Completed and closed out a design review for the Quality Assurance-related “slug processor” prototype. The responsible engineer is now shifting focus to the fuel slug demolding system design. The complete procurement package for the casting equipment and glovebox prototype system is also on track to be completed in January; and, in collaboration with TerraPower, a draft F&OR document for the rod loading system prototype has been updated and is undergoing final review. TerraPower completed a draft functional requirement document for a sodium settling machine for internal preliminary review. Los Alamos National Laboratory (LANL) is writing a new report assessing options for plutonium supply and completion is expected by the January milestone date. SRNL efforts continue to accelerate, having expanded the team contributing to the SRNL-led trade study of Pu

treatment techniques to include broad expertise in the diverse array of treatment options and various permutations. The team continued to collaborate with the LANL Carlsbad office to support assessment of Waste Isolation Pilot Plant (WIPP) applicability of VTR fresh fuel scrap, including evaluation of a potential metallic waste form that would significantly reduce the costs and technical risks over the reference alternative.

Transient Safety Analysis

Completed and issued ANL-VTR-46/ECAR-4733 Rev. 2, *Safety Analysis for the Versatile Test Reactor Conceptual Design*. This report documents the updated VTR safety analysis model, incorporating the evolution of the design over the past year primarily with respect to the primary heat transport system. Performed analyses with SAS for protected and unprotected versions of the transient overpower, loss of heat sink, and station blackout transients as well as additional transient scenarios analyzed in support of ongoing VTR probabilistic risk assessment (PRA) and design activities. Completed a revision to the confirmatory analyses with TRACE for steady-state conditions. The safety analysis team conducted a review and identified several actions to resolve discrepancies in pressure drop predictions and intermediate heat exchanger (IHX) temperature distributions. Transient computational fluid dynamics (CFD) simulations of the VTR hot pool during the Protected Station Blackout scenario are ongoing. Recent work showed that the computational effort can be reduced significantly by neglecting the influence of bypass flow paths in the CFD model during the transient. In future work, the SAS model used in the coupling will be updated to be consistent with ANL-VTR-46/ECAR-4733 Rev. 2.

Discussed work scope for an upcoming collaboration with CEA related to validation and uncertainty quantification (UQ) of available French SFR data to support verification and validation (V&V) of the VTR. Continued verification of the detailed core radial expansion model.

Sodium Fire Hazard Analysis and Software Verification & Validation (V&V)

Located and reviewed additional sodium spray/drip fire reports that documented experiments conducted by Atomics International in the 1970s. The data from these reports are important to understand the physics of sodium droplet formation and break up. Updated recommendations for the Sodium Fire Protection System strategy are being developed based on the updated understanding of spray droplet formation/behavior and analysis using NACOM.

Continued software V&V activities for the Simplified Radionuclide Transport (SRT) code Version 2.0, which is being used for mechanistic source term calculations. Prepared and transmitted draft versions of four SRT software quality assurance program (SQAP) documents for discussion with the authorization body.

Probabilistic Risk Assessment

Continued work on quantifying the reliability of Reactor Vessel Auxiliary Cooling System (RVACS) performance during transient scenarios. Reviewed results of an initial set of sensitivity analyses to identify influential parameters. In addition, reviewed recent changes to the RVACS design for incorporation into a new system model. The safety basis team is preparing for a Technology Inclusive Content of Applications (TICAP) tabletop exercise in 2021. This will include outlining how the safety basis information developed for VTR could be assembled into a safety analysis report (SAR) document utilizing the TICAP guidance.

Kevan Weaver, Experiments Technical Integration

The Experiments Team within the VTR program is currently aligned with four main experiment vehicle types: Normal Test Assembly (NTA), Dismountable Test Assembly (DTA), Extended Length Test Assembly (ELTA), and the Rabbit Test Assembly (RTA). These experiment assembly types align with the project as it moves toward preliminary design. National laboratory technical experts lead the design and development of each of the experiment vehicles and cross-cutting support areas, and are supported by other national laboratory personnel, university partners, and industry partners.

Selected key accomplishments within the four experiment vehicle types and support areas are included below.

ELTA – Molten Salt Cartridge Loop Development
Technical Lead: Joel McDuffee, ORNL
Partners: University of Utah, University of Idaho, MIT, TerraPower

- Led a discussion between TerraPower and VTR safety concerning the need for double-containment between reactor sodium coolant and experimental salt.
- Annular Flow Characterization
  - New test section delivery was delayed by vendor due to COVID-19 supply chain. It is now expected in January.
  - A RELAP5-3D model of the ELTA-molten salt (MS) annular design is nearly complete (loop design to be implemented subsequently), to provide added verification of the TRANSFORM and TerraPower results and support future SQA efforts.
  - Verified TerraPower's ELTA-MS annular design performance comparison using Modelica TRANSFORM.
  - Construction of ELTA-MS 37-tube design in progress for verification of TerraPower's model.
- Pressure and corrosion sensor development
  - Thermal testing yielded some results that were initially inconsistent with the finite element models (FEM) used in the analysis. Expanded the test matrix to characterize the temperature-dependance of the aluminum sensor in air to confirm hypotheses and have elected to shift the thermal analysis to its own paper due to its complexity warranting a more thorough analysis. Due to unexpected experimental results and working toward understanding the effect of temperature transients on the corrosion sensor performance, thermal testing with an Ni sensor will begin in January, but with an expanded set of tests. Assembled the Ni sensor and will seek to reproduce the experimental results obtained from the Al sensor with the Ni sensor once we understand how temperature affects the sensor.

ELTA – Gas Cartridge Loop Development
Technical Lead: Piyush Sabharwall, INL
Partners: Texas A&M, University of Michigan, General Atomics

- Modified the high-temperature, high-pressure SS-316 loop to easily incorporate circulators and HTA filtration media.
- Installed a Residual Gas Analyzer to the vacuum system.
- Installed and calibrated leak-in valve for pressure reduction system.
- Performed non-isothermal simulations using COMSOL for flow and heat transfer in the portion of the Fission Product Venting System (FPVS) with an elbow.
- Mass balance for argon were checked for validation of the COMSOL numerical model.
- Continued testing of a newly designed high-temperate heating stage for thermal and microstructural property measurements.
- Developed a preliminary linear variable differential transformer (LVDT) experimental design.
- Designed a high-temperature and high-pressure chamber to investigate LIBS performance in VTR-relevant environment.
- Completed CFD simulations of forced and natural helium circulation in the gas cooled cartridge loop (GCL).

Upcoming Events:

VTR EIS Public Hearing, January 27, 2021, 6:30 pm ET and January 28, 2021, 8:30 pm ET

VTR Quarterly Integration Meeting, February 2021 (Date to be announced)

NURETH-19, 19th International Meeting on Nuclear Reactor Thermal Hydraulics, postponed until March 2022, Brussels, Belgium. Abstracts due February 14, 2021

IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR21), May 10 -13, 2021, China. Full papers for DOE review due by February 19