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FY2021 August Monthly Status Report for the VTR

September 2021

Thomas Fanning

Changing the World's Energy Future

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FY2021 August Status

SOLVING ENERGY CHALLENGES THROUGH SCIENCE

Versatile Test Reactor

Project Highlights

Jordi Roglans-Ribas, Program Overview

Budget discussions are the Project's primary focus. House and Senate budget marks were identical and did not provide any funding for VTR in Fiscal Year (FY) 2022. Planning will be focused on two scenarios to begin in FY22. First, availability of carryover (C/O) funds only; and second, availability of additional funds under a continuing resolution (CR). Guidance was developed for the team to use the remainder of FY21 to document the status and plans for key VTR systems. This documentation will facilitate a possible future restart and is the top priority under the two funding scenarios. Additional work may be performed if funding beyond C/O is available during CR.

FY22 planning continued with U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) guidance. PICS work packages will assume C/O funds to begin FY22. The design status and technical work that would follow to enable the project to restart will be documented. C/O funds will be stretched during the initial months of FY22, as feasible, to the end of a potential CR. If funds are appropriated, the project could continue and ramp up again.

A thorough review of the current subcontracts, primarily with industry and university partners, is being performed to determine the period of performance and communicate plans after October 1. Individual organizations were contacted to discuss the expectations for scope (documenting status and restart plans) and anticipated spend rates until September 30. In discussions with university partners, we are prioritizing students close to graduation who may be relying on VTR funding to complete their degree.

Templates and documentation guidance were developed and distributed to the technical leads to ensure that all systems and analyses are documented consistently and put in a Hold and Restart mode. The appropriate formats for native files (especially all the requirement and digital engineering files) are being studied so that restart of the project at a future date would be feasible even if the original software had evolved.

Specific guidance was formally transmitted to GE-Hitachi Nuclear Energy Americas, LLC (GEH) regarding priority systems to document before the end of September. Because some priority systems (secondary heat transport; primary sodium purification system; and reactor building general arrangement) had activities under risk reduction purposes (operating funds) and activities supporting the initiation of the preliminary design (capital-funded), discussions have focused on prioritizing the scope for September conforming, to the extent possible, with the remaining availability of the two types of funding. Lower priority systems would also need updated documentation and restart plans. Closeout of activities under the current Release concluding on September 30 were discussed.

Tom O'Connor and Kemal Pasamehmetoglu met with the National Nuclear Security Administration (NNSA) to discuss using plutonium in the VTR metallic alloy fuel and the relative attractiveness of the metallic alloy versus mixed oxide. There was agreement on the VTR position, which should be helpful in further discussions leading to the Nuclear Proliferation Assessment (NPA) study that will be performed for VTR, as agreed in the 2020 NE-NNSA Memorandum of Understanding (MOU). NNSA is drafting the charter and has initiated plans for the performance of the NPA for the VTR fuel.

Nuclear Design

Completed three milestones in August. The first milestone evaluated different plutonium pretreatment options and made recommendations on priorities for plutonium source materials; the second milestone documents completion of a metallic alloy fuels performance benchmark based on results from X430, X421, and Integral Fast Reactor (IFR)-1 irradiation tests; the third milestone documents the potential impact of experiments on the VTR core performance characteristics.

Relocated the PELICAN test loop into a lower pit in preparation of full-length assembly testing. Assembly of this full test article is in progress, where a lower reflector, 17 connector plates, 217 full length fuel pins, and an upper reflector will be joined within a single hexagonal duct.

VTR Plant Engineering

GEH and Bechtel National Incorporated (BNI) are documenting engineering status, open items, and actions required to restart the project. Assigned VTR Project Hold Forms to owners in GEH, BNI, and the national laboratories by Master Parts List (MPL) and topical area. Completed Hold Forms will be placed on the VTR Confluence Site.

Approved and documented the relocation of the M21 Primary Sodium Purification System west of the reactor vessel underneath the Experiment Hall. This will enable easier access to perform replacement of traps using the installed overhead crane.

Continued working with the United Kingdom (UK) Nuclear Decommissioning Agency (NDA) to obtain a UK Export License to retrieve design and operating information about the Dounreay PFR fuel handling machine.

VTR Experiments

Initiated Hold and Restart reports for all experiment vehicle (EV) teams. These reports will identify needed and planned restart activities for each of the EV's and support areas.

Upcoming Events:

Osher Lifelong Learning Institute Lecture "Versatile Test Reactor for Clean Energy Options," September 10, 2021

VTR Quarterly Meeting - Management Review, September 15, 2021

Atlantic Council Webinar, September 23, 2021

American Nuclear Society Winter Meeting, November 30 – December 3, 2021, Washington DC.

NURETH-19, 19th International Meeting on Nuclear Reactor Thermal Hydraulics, March 2022, Brussels, Belgium.

IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR22), April 2022, China

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Technical Highlights

George Malone, Reactor Technical Integration

GEH/ BNI Design Engineering Support

Received direction from Battelle Energy Alliance (BEA) to place the VTR Project in a Hold and Restart status. Held meetings between BEA, BNI, GEH, and TerraPower (TP) to redefine the scope of work for the remainder of FY21.

Continued strategic planning to identify needs for sodium testing across the various MPL and components. Coordinated with BEA to hold a joint meeting with Natrium to identify synergies between the VTR and Natrium project for sodium testing. This meeting will be scheduled in late September or early October. The outcome of the meeting should provide:

1. A complete list of components to test, relevant dates, potential testing locations, and which components require an additional lab to be built.
2. A paper describing the need for any new facilities, what the team recommendations are, alternative options, bases, and pros/cons relevant to decision making.
3. An action plan describing next steps to transition from a plan to actual testing.

Began generating VTR Hold Forms and placing existing work in a hold status for MPLs owned by GEH. Following notification of Project Hold, activities commenced to adjust work for the remaining period and develop plans to document work on the project.

- Reviewed Release 5.4 activities for the remaining period and provided recommendations for scope to complete as planned, scope to stop work and document progress, and scope to stop work without any further documentation needed.
- Developed a checklist to capture all activities needed to be completed to put the project on hold.
- Reviewed the Project Hold Form to document the status of various MPLs and have them ready to take action at project restart.

Fast Flux Test Facility (FFTF) Documentation and Data Recovery

Documented and uploaded information pertaining the radionuclide content of the Cold Traps and the Cesium Traps in the FFTF to Confluence. The information is in the form of radiological surveys and estimates performed during deactivation. Operational information regarding the ease or difficultly of accessing the Cesium Traps during deactivation is also provided in the summary management report.

VTR Control Rod Mechanical Design Analysis

Completed an analytical benchmark to resolve uncertainties in the design of an absorber bundle for a control rod. The document was sent to Argonne National Laboratory (ANL) for review and use in benchmarking the control rod design analysis for the VTR. This benchmark will be used by ANL and Pacific Northwest National Laboratory (PNNL) to resolve any uncertainties in the absorber bundle design.

Thomas Fanning, Nuclear Technical Integration

Fuel Design and Analysis

Identified key activities to complete with remaining FY21 funds. Remaining project work will document work to date on characterization of U-Pu-Zr-Ga fuel from the X521 experiment, from U-Pu-Zr-Ga/HT9 diffusion couples tested thus far, insights into U-Pu-Zr-Ga thermodynamics from CALPHAD analyses, BISON benchmarking, and mechanical design of fuel assembly components.

Oak Ridge National Laboratory (ORNL) prepared a draft on sensitivity and uncertainty quantification of the IFR-1 BISON benchmark. Continued U-Pu-Zr-Ga characterization work focusing on completing microchemical analysis of samples already in hand. Prepared and reviewed a draft report on updated observations of HT9 creep and stress rupture behavior.

Fuel Manufacturing

Began planning to wrap up current efforts before the end of FY21to support the project's Hold and Restart plans. Identified critical scope that may extend into FY22.

Continued to mature the casting glovebox and furnace design. Received draft furnace design data for Idaho National Laboratory (INL) comments including details on crucible design, argon tank design and anchorage details. Design completion will lag into October, requiring the contract commitment to carry over into FY22. Completed a conceptual design report regarding crucible specifics that will be needed for fabrication success.

Focused work on container and storage concepts for feedstock, pins and assemblies, and how the process flow will work with glovebox configurations, throughput, criticality, and fire loading considerations. This effort is supported by the process model developed to support the fabrication system engineering and determine throughput estimates.

Developing a prototype equipment plan to identify scope that will need to be completed as part of the prototype testing effort to test the fabrication processes. This includes such efforts as robotics implementation and Instrumentation & Controls (I&C) implementation.

Continued assembling quality assurance (QA) and demolding processing prototype equipment fabrication packages. Completed fabrication packages and estimates for the crusher and brusher pieces. These fabrication efforts could begin as soon as funding is available. Slug processor, nail head snapper and heel breaker pieces are still being drafted and should be completed prior to the end of FY21. Completed the Functional and Operations Requirements (F&OR) for the QA glovebox.

Reviewing a rod loading conceptual design/technical evaluation document for equipment needed for the rod loading process. Began a University of Idaho (U of I) sodium loading study to evaluate the sodium loading process. Completed a Natrium sodium bonding pre-job plan that was adapted to VTR to support future sodium bonding work scope.

Continued to work on scrap treatment processes including scoping studies and anticipated throughput. A report is being drafted to summarize the scrap processing analyses and pre-conceptual designs related to scrap treatment.

Core Design

Constructed the PELICAN experimental test loop at ANL to support VTR core design efforts and validation needs. Operational since 2020, this facility can produce full scale hydraulic flow conditions for measurement of pressure drop across a single prototypic assembly, including full length axial reflectors, fuel rods, and plena components. Performed an initial testing campaign in 2021 which included commissioning, facility characterization, and experimental testing of the single component test articles. These articles feature variable sized orifice plates, a prototypic upper reflector, a prototypic lower reflector, and multiple reflector conical tips with geometric variations, shown in Figure 1. To meet clearance requirements for installation and testing of a complete full-length assembly, the test facility was dismantled and relocated to a pit within the high bay, shown in Figure 2. Completed in August 2021, this relocation allows the PELICAN total height to extend from its initial 3.6-m height to nearly 7-m. Assembly of this full test article is in progress, where a lower reflector, 17 connector plates, 217 full length fuel pins, and an upper reflector will be joined within a single hexagonal duct test article, shown in Figure 3.

Figure 1. Upper reflector and variable geometric tips.

Figure 2. Relocated test loop in high-bay lower pit.

Figure 3. Assembly detail fuel pin transition in lower reflector.

Safety Analysis

Performed a demonstration transient using the new Electromagnetic Pump (EM) model. The demonstration showed the impact of an over-voltage and an over-frequency transient on a prototypic sodium fast reactor (SFR) model. Results of this demonstration will be included in the September milestone.

Reviewed a draft report on transient confirmatory analysis calculations and feedback was provided to Los Alamos National Laboratory (LANL).

Completing the thermal stratification analysis. Summarized computational fluid dynamics (CFD) simulations in a draft paper for the NURETH-19 conference. Identified an issue that limited the flexibility of performing

SAS4A/SASSYS-1 simulations coupled dynamically with CFD. This issue will be described in further detail in a technical memo and documented as part of the hold and restart forms.

SAS Verification and Validation (V&V)

Preparing a plan and deliverable list to capture the status of the SAS4A/SASSYS-1 V&V work. Four reports are planned: mechanical model verification (containing the control rod expansion verification and core radial expansion models), hydraulic model validation (capturing the status of the Mixing Components Test Facility [MCTF] benchmark), SAS/CFD coupling module verification, and a V&V status report.

Continued MCTF validation. Identified several discrepancies between documentation provided for the SAS4A/SASSYS-1 nodalization and the facility model. Reviewing the stratified compressible volume model to understand the behavior of the layer levels. Assumptions and details of the SAS4A/SASSYS-1 model will be documented.

Safety Basis

Completed reviews for the ex-vessel dose consequence Engineering Calculation and Analysis Report (ECAR) that incorporates the VTR waste streams and prepared the document for final approval. Resolved comments for the VTR ex-vessel hazard evaluation Technical Evaluation (TEV) revision for the VTR.

Completed reviews on the Safety Structure, System, and Component (SSC) classification list with Doors Next Generation (DNG) to support the milestone deliverable and prepared the document for final approval. Continued working the Natural Phenomena Hazard (NPH) design categorization and prepared a draft to support design efforts. Reviewed GEH document deliverables, specifically the mechanical document sets, to help support reactor and facility design.

Probabilistic Risk Assessment (PRA)

Began planning PRA and source term analysis close-out, including documentation to archiving and creating new documents detailing the current status of tasks. Continued validation activities of the Simplified Radionuclide Transport (SRT) source term analysis code aerosol model, including identifying scope for completion under the new project timeline and documenting current progress.

Sodium Fire Hazard Analysis and Software V&V

Continued sodium fire analysis software V&V efforts by verifying material property functions in the source code and documenting code modifications within the code repository. Continued efforts to complete a report to document the status of the Spray Pool Combustion Analysis (SPCA)-ANL sodium fire analysis code. The report documents improvements and modifications made to the SPCA code as well as V&V efforts. Initiated efforts to complete the Sodium Fire Analysis Hold Report.

Kevan Weaver, Experiments Technical Integration

Selected key accomplishments within the four experiment vehicle types and support areas are included below. All team members have begun documenting the current work status and next steps if funding becomes available.

Extended Length Test Assembly (ELTA) – Lead/Lead Bismuth Cartridge Loop Development
Technical Lead: Cetin Unal, LANL
Partners: University of New Mexico (UNM), Westinghouse

- Pump Test Rig, Cartridge Heating System and Duct Heaters, ELTA-CL Conceptual Design
  - Completing year-end reports on Pb pump testing and cartridge stress analysis.
- Westinghouse
  - Completed testing of two Type 316 stainless steel samples in lead; comparable tests in argon are underway. No liquid metal embrittlement has been detected. Tests on Kanthal APMT in liquid lead are the next in sequence.
- UNM Pb-loop
  - Damage to bolts and nuts sealing the melt tank caused a gas leak.
  - Performed preliminary analysis of AM100 corrosion test strips.
  - Completed initial analysis of impeller and wall analysis of Delta loop centrifugal pump.

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

- Annular Flow Characterization
  - Implemented Reynolds number-dependent friction correlations into TRACE models of the thermosyphon test loop (TSTL) to more accurately predict natural convection mass flow rate.
  - Adjusting thermosyphon design in TRACE to achieve mass flow rates and Reynolds numbers similar to those reached in natural convection during postulated molten salt reactor accident scenarios.
- VTR Cartridge Loop Experiment
  - Created the conceptual design of a modular test stand enabling shaft lengths, couplings, bearings, and seals to be tested and characterized for a full-length cartridge style experiment. The test stand is modular and can easily support experiments anywhere from 10 to 50 ft. in length. Instrumentation will be added to monitor shaft position, shaft acceleration, shaft twist, harmonics, and leakage in any seals. This data will be used to characterize the pump system as a whole and will directly impact future pump and drive shaft designs.

- Installed the new VTR experiment vessel in its test stand and connected to the existing TSTL. Contined installation of fiber optic sensors, thermocouples, and fuel rod simulators.

- Pressure and Corrosion Sensor Development
  - Completed integration of a pressure sensor directly into the pressure controller, which will facilitate better pressure control and reduce overhead computing power required by the first-generation sensor design.
  - Completed the software to control corrosion measurements with minor adjustments expected during sensor integration; planned additional testing to close out programmatic efforts under VTR.
  - Continued testing, troubleshooting, and assembly of second generation sensor with the focus on neatly closing out VTR programmatic efforts with a functional prototype.
  - A report describing efforts to test the first-generation sensor in molten salts and the second generation sensor is being compiled to document programmatic efforts.

Support Area – Instrumentation and Controls
Technical Lead: Sacit Cetiner, INL
Partners: ACU, Georgia Tech, MIT, University of Pittsburgh, Cosylab

- Eddy Current Flow Meter (ECFM)
  - Reestablished experimental setup using dry aluminum rod with a motor.
  - Conducted experimental measurements of ECFM sensitivity using dry aluminum rod for a wide range of parameters.
  - Completed COMSOL simulations. Results agree well for trends and magnitude over a wide range of parameters with respect to ECFM sensitivity measurements of the dry aluminum rod.
  - Working to complete a report documenting experimental progress on dry aluminum rod.
  - Completed the work plan and received signed approval to test ECFM in mercury Transient Test Facility (TTF).
  - Sent bent piping parts needed for mercury TTF ECFM testing to the machine shop.
- Self-Powered Neutron Detector (SPND)
  - Completed a draft report documenting all FY21 work on SPNDs and is being reviewed.