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FY2020 September Monthly Status Report for the VTR

October 2020

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Changing the World's Energy Future

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Versatile Test Reactor

Tom O'Connor, Federal Program Manager

It was with great pleasure that Mark Arenaz and I received a copy of Deputy Secretary Menezes' letter to Dr. Rita Baranwal approving Critical Decision (CD)-1, *Approve Alternative Selection and Cost Range*, for the Versatile Test Reactor Project. This accomplishment is especially significant due to the efforts and commitments of the VTR team spread across several national laboratories, universities, and industrial partners.

Mark and I have given briefings to Congressional staffers and independent review teams, all of which expressed great doubt that the VTR team could deliver the analysis and documentation necessary to support CD-1 approval, a project the likes of which has not been undertaken by the Department in over 50 years. The challenges facing the VTR team involved more than complex project management and the design of an advanced reactor that would serve the Department for several decades to come; they also included laying down the foundation of a controversial and needed fundamental change enabling the use of a proven uranium /plutonium /zirconium driver fuel. Not only did the VTR team prepare the needed documents, but they also provided answers and interpretations of technical challenges that enabled us to convey to decision makers why the VTR project warranted their confidence and support.

The VTR team has established a high bar, not only for the Department, but also for the critical infrastructure projects that lie ahead. We are confident that through this truly outstanding team, the Department will successfully complete this critical infrastructure project needed to regain its global leadership role in the development of nuclear energy.

Jordi Roglans-Ribas, Program Overview

The VTR Project reached the important milestone of Critical Decision-1 (*Approve Alternative Selection and Cost Range*) approval in September, after the Energy Systems Acquisition Advisory Board (ESAAB) meeting on September 8, and the formal approval Memo from the Deputy Secretary issued on September 11. Reaching this milestone has been a team effort and I would like to congratulate the entire VTR team for this achievement. I would like to acknowledge in particular Tom O'Connor and Mark Arenaz for their leadership and efforts during the multiple reviews that led to this successful outcome, and also Andrew Griffith and Dr. Baranwal for their support of the VTR project and discussions with the National Nuclear Security Administration (NNSA) and other stakeholders.

After welcoming the approval of CD-1, September activities focused on finalizing Fiscal Year (FY) 2020 work and continued planning for FY 2021 activities. All FY 2020 milestones were completed except the award of the design-build master blanket contract. The complexity of the contract has resulted in extended legal negotiations. The work packages and the proposed set of milestones for FY 2021 were completed and loaded in the U.S. Department of Energy (DOE) Program Information Collection System (PICS). Budget planning was also a large focus during the month, as the program anticipates beginning the new FY operating under a Continuing Resolution (CR) funding scenario.

Held a meeting of the Integrated Project Team (IPT) on September 28 to discuss the scope of work for engineering areas to determine the interface framework. With approval of CD-1, the IPT will meet regularly to track actions items that originated with the Director's review, the Project Peer Review (PPR) and the Independent Cost Review (ICR) and to determine what needs to be completed to resolve those actions items. Additional topics will be proposed for discussion at the IPT meetings as needed.

The Idaho National Laboratory's (INL's) demilitarized zone (DMZ) was shutdown due a suspected compromise, disrupting access to VTR information. The DMZ remained disabled for several weeks and access was restored on September 10. Special thanks are extended to INL's Chris Ritter and AnnMarie Marshall for their hard work in establishing a Box location as an interim location to find program documents generally retrieved from SharePoint, and then working to update SharePoint once DMZ access was restored. The Project will assess how to establish a backup procedure to maintain team access to VTR documentation should future incidents impact regular access methods again.

Reviewed the draft VTR Environmental Impact Statement (EIS) and provided comments for the preparation of the public release draft version. DOE anticipates public release in November.

Kemal Pasamehmetoglu participated in a Third Way/Energy for Growth Hub briefing regarding a global assessment of nuclear readiness and energy demand. This briefing was followed by a Paul Day interview from Nuclear Energy Insider.

INL science writer Cory Hatch published *Versatile Test Reactor Key to Answering Big Science Questions for University Researchers*. The article highlights the importance of the VTR's university partners and the experiments being conducted. INL published the article on September 15 and the article was also featured by energycentral.com and electricenergyonline.com.

George Malone, Reactor Technical Integration

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

Prepared the Overall Plant Design Specification which includes critical requirements for the VTR Project and provides further definition of foundational plant-level requirements to ensure such requirements are available and traced in DOORS.

Provided the list of Argonne National Laboratory (ANL) Interfacing Work Activities performed between the B11 (Reactor Module System) and the J11 (Core and Fuel Services). This effort established the key framework of collaboration and helped develop a detailed division of responsibility between ANL/INL and GEH between two key systems developed by separate organizations.

Developed and issued design specifications and requirements for the VTR Plant Instrumentation & Control (I&C) System Architecture, VTR Instrumentation, Reactor Vessel, and Electromagnetic (EM) Pump Component. These inputs allow advancement of the design for systems and components and continue to tie higher-level stakeholder requirements to lower-level requirements.

Completed the VTR Supplier & Technology Early Assessment for four long-lead items: Reactor Module, Control Rod Drive Mechanism (CRDM)/Control Rod Disconnect Driveline (CRDD), EM Pumps, and In-Vessel Transfer Machine (IVTM). These assessments support maturation of critical technology elements to advance the Technology Readiness Level (TRL) of critical components. GEH and Battelle Energy Alliance (BEA) developed a Technology Readiness Assessment (TRA) Process to highlight the relationship between GEH's understanding of the TRA Program and the Supply Chain & Technology Early Assessment Reports. Completion of these reports closed out two FY 2020 VTR project milestones.

Issued B24 Heat Rejection System Design Description (SDD) and piping and instrumentation diagrams (P&IDs). These documents address several open items resulting from the Special Purpose Review (SPR) on the B24 system related to define the requirements for this system. These documents defined the boundaries between Safety Class

(SC), Safety Significant (SS) and Non-Safety (NS) components and identified the recommended codes for piping components in the B24 system. This effort resulted in better guidance to implement changes, additions, and edits to B24 requirements to create a better structural hierarchy of requirements from the Stakeholder to the components.

Prepared site input parameters for Conceptual Design Soil-Structure Interaction Analysis document which provides the In-Structure Response Spectra (ISRS) and other related parameters developed from results of the conceptual design Soil-Structure Interaction (SSI) analysis of the U11 Reactor Facility. This document forms part of the overall methodology which attempts to establish a rational and bounding approach to updated subsurface parameters provided as part of the preliminary Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 data for the VTR Project. GEH performed seismic analysis using the updated site inputs calculation to assess the effects of these changes on the seismic design of the U11 Facility, including evaluation of reactor vessel seismic movement and performance of reactor vessel supports.

TerraPower Support

Disassembled and cleaned the cover gas system used to perform the Cs sequestration test after Cs accumulated in the system and prevented reliable testing. Verification tests after cleaning suggested the system is working. Retested previous samples and started new sample testing.

ANL Support

Performed computational fluid dynamics (CFD) analysis of sodium flow in the reactor vessel plenum volume and through fuel receptacle. The analysis provided calculated pressure drops required by the team and the CFD results were used to provide an updated computer-aided design (CAD) model of the fuel receptacle.

Fast Flux Test Facility (FFTF) Documentation and Data Recovery

Discussed thermal striping during the SPR of the B24 Secondary Heat Rejection System (HRS) and during the ongoing VTR Requirements Review. As noted in August's report, an initial search of multiple FFTF repositories found 59 thermal striping documents on FFTF and 57 on the Clinch River Breeder Reactor (CRBR), most documents containing information useful to the design of the VTR. The documents are being retrieved and should be complete by the end of October.

VTR Control Rod Mechanical Design Analysis

Developing a calculation to determine the mechanical lifetime of a 37-pin control rod absorber bundle in the VTR. VTR dimensions, core physics, and thermohydraulic information is being used wherever available, and where not, FFTF default information is being used. Determined the mechanical lifetime of an absorber bundle by the initial fabrication clearances and the closure of these clearances during operation, which leads to binding or sticking and ends the useful life of the control rod. Anticipate analysis to be complete in mid-November.

Calculation Support for VTR Waste Form Analysis

Researched historical FFTF documentation regarding successful sodium washing of fuel and other related ancillary processes. The purpose is to build on successes established at FFTF and to provide a cross-comparison with those implemented during other fast reactor operations initiatives such as Experimental Breeder Reactor-II (EBR-II). These approaches will be documented and presented for consideration for application at the VTR.

Thomas Fanning, Nuclear Technical Integration

Fuel Design and Analysis

Drafted updates to the fuel performance design basis to address reasons to indicate fuel lifetime using a cladding strain limit rather than a cladding damage fraction, and to document the basis for use of U-Pu-Zr with plutonium content between 0 and 20 wt.%. Completed revisions to the report on preliminary fuel performance assessment of VTR driver fuel during off-normal operations. This evaluation used the revised fission gas release model provided by the BISON developers and should be ready for distribution in October 2020. Scripts to create X421 BISON benchmark models were created using data extracted from the Fuels Irradiation and Physics Database (FIPD) metallic fuel database.

Continued fuel mechanical design efforts to develop details for the fuel assembly lower nozzle and interface with the VTR core gridplate receptacles. TerraPower conducted a readiness review of the modified Full-size Assembly Structural Testing Tower (FASTT) and Test Assembly Handling Machine (TAHM) core component mechanical testing equipment to support VTR fuel assemblies and the system was tested without a VTR test subassembly. A single assembly bending test specification report and a test assembly fabrication plan for core component mechanical tests is being approved for issuance. Planned work scope and tasks for FY 2021, with emphasis on addressing fuel fissile supply questions and elaborating on VTR fuel specification and design details.

Fuel Manufacturing

Continued advancing the design of the fuel manufacturing equipment. Evaluated three variations of an oxidation furnace for fuel scrap passivation based on current oxidation technology already being employed. Focused work on design options to reduce the cycle time, thus increasing throughput to a level matching the anticipated VTR demand. Continued design work on a prototype fuel casting glovebox and furnace, and drawings. Completed P&ID drafts and undergoing required engineering reviews. Made significant progress to advance design of the Quality Assurance (QA) equipment, focused on the "slug processer," designed to cut freshly-cast fuel slugs to their final length and make the required physical measurements in a semi-automated fashion. This design work included specifying specific parts for much of the equipment, focusing on the precision measuring equipment incorporated into the design. Completed a draft Division of Responsibilities document for the rod loading and subassembly assembly stations and routed for internal comment for release in early October. TerraPower issued a report describing the supplier sourcing strategy and supply development plan for HT9 material and continued drafting a HT9 component qualification report. Summarized, issued, and transmitted budgetary quotes for HT9 starting material, cladding supply, and duct supply.

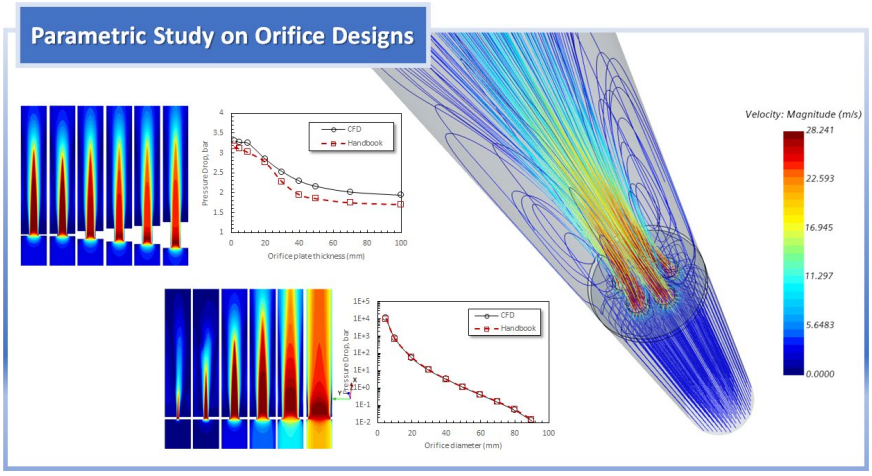
Core Design

Hydraulic Characterization of Potential Orifice Plates

The flow allocation in the various VTR core assemblies needs to be controlled in order to achieve relatively homogeneous temperature distributions. Flow rate can be adjusted using simple orifice plates placed in the inlet nozzle part of the assembly. Due to the high flow rate expected for VTR, some efforts have been focused on better quantifying hydraulics characteristics for various potential orifice plate geometries.

Studied several orifice plate designs as part of parametric evaluations to determine the hydraulic resistance using CFD analysis and handbook-based analytical calculations. This study investigated the effect of orifice design parameters such as plate thickness, orifice hole diameter, number of orifice holes and the orifice hole arrangement.

This work supports both the VTR assembly design activities and core performance assessment and will be validated through the PELICAN experiment.



Workflow Development for Quick Integration of Experiments Impact on Core Performance Characteristics

Examined the impact of various experiment types on VTR core performance. While this can be done with stochastic codes like OpenMC or MCNP, when considering analyses needed between cycles to determine the desirable core configuration for a given cycle (c.f. the OTTER code developed to support those needs), it is necessary to be able to use the deterministic codes selected for VTR analyses (DIF3D and REBUS).

Used OpenMC to model several types of hypothetical experiments, including advanced fuel, blanket fuel, moderator, structural material, and absorber, in order to characterize spectral effects around these experiments. Identified a spatial homogenization scheme that sufficiently captures the spectral effects for experiments that significantly affect the local flux spectrum. OpenMC can now be used to generate multigroup cross-sections and pass those cross-sections to DIF3D/REBUS to perform extensive reloading calculations. This allows significant speed up of the calculation time while accounting for the impact of the experiments on the predicted core performance such as power distribution and reactivity coefficients.

Safety Analysis

Identified discrepancies between the primary system sodium volume information provided by GEH and sodium volumes collected from analysis of the VTR Inventor model. Have begun to identify and resolve the sources of these discrepancies.

ANL and INL are collaborating on the coupling of the SAS4A/SASSYS-1 model of the Protected Station Blackout event with a CFD model of the upper plenum to capture thermal stratification effects. The CFD model of the upper plenum is based on the available CAD geometry and has been able to produce results at the normal operation condition. In this model, there are distinct boundaries at the subassembly outlets that are grouped according to the 26 channels in the SAS4A/SASSYS-1 model, as well as boundaries for each Intermediate Heat Exchanger (IHX). Future work will establish boundaries for the bypass flow paths.

Added a capability to SAS4A/SASSYS-1 to enable the control system model to trip the primary pumps in the VTR, currently not possible for the Advanced Liquid Metal Reactor (ALMR) EM pump model. This development

activity required the creation of new test cases and a Software Test Plan and work is currently under technical review.

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

Completed a final draft of the report *FY 2020 VTR Sodium Fire Analyses and Recommended New Sodium Fire Mitigation Approach,* (ANL-VTR-70), which documents the updated sodium fire analyses along with proposed design recommendations and optimal locations for components of the sodium fire protection system. All necessary reviews and approvals are complete.

Probabilistic Risk Assessment (PRA)

Continued working on reliability of Reactor Vessel Auxiliary Cooling System (RVACS) performance during transient scenarios. Utilized the preliminary Failure Modes and Effects Analysis (FMEA) results to identify influential system parameters. Input parameters to the RVACS model in SAS4A/SASSYS-1 are being compared to the parameters of interest, including initial value ranges which will be utilized for sensitivity analyses.

Continued software V&V activities the Simplified Radionuclide Transport (SRT) code Version 2.0, which is being used for mechanistic source term calculations. The V&V test suite are nearly complete and current efforts focus on finalizing the associated documentation by the end of FY 2020.

Developing a new PRA model and document GitLab repository which will facilitate PRA development efforts by multiple organizations, including assisting with version control, ensuring QA requirements satisfaction, and expediting internal and peer reviews. The workflow of the repository is currently under design, which allows multiple people/organizations to work in parallel while preserving the QA approval chain.

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.

University partners assisted in preparing the report for completion of milestone M3TR-20IN020101043, *Document Recommendations Regarding Experiment Development Contract Extensions*. University partners also supported work on the schedule, budget, and scope for FY 2021 and beyond. Selected key accomplishments within the four experiment vehicle types and support areas are included below.

ELTA – Lead/Lead Bismuth Cartridge Loop Development
Technical Lead: Cetin Unal, LANL
Partners: University of New Mexico, Westinghouse

- Continued work on material corrosion in the lead loop at the University of New Mexico, shown in Figures 1 and 2, and continued work on requirements, analysis, and design for the cartridge loop.

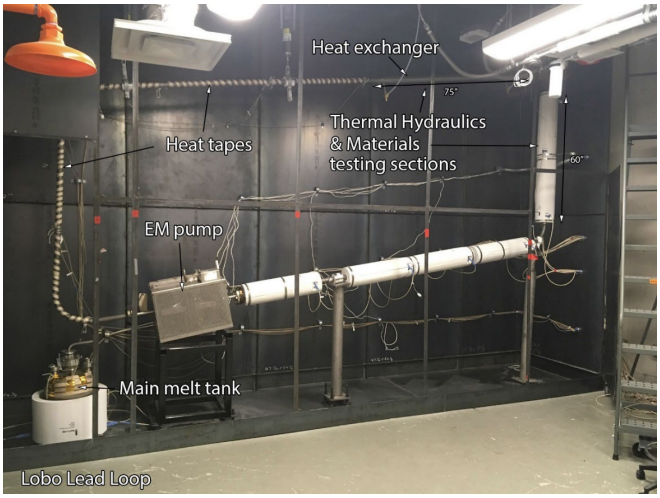


Figure 1. Lobo Lead Loop.

Figure 2. Specimens and holders for the Lobo Lead Loop.

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

- Cartridge design and development
  - Performed optioneering studies of a compact heat exchanger (CHX)
  - Initiated mechanical design for the CHX
    - Initiated fabricability scoping with external vendors: Exergy and VPEI for the tube and shell heat exchanger and Thermocoax for the electrical heating system.

RTA – Rabbit Capability Development
Technical Lead: David Wootan, PNNL
Partners: Texas A&M

- Continued installation of the Rabbit proof of principle test at Texas A&M, including hooking up sensors and gas lines to the Rabbit test.

Upcoming Events:

- VTR Quarterly Integration Meeting, October 22, 2020
- VTR Webinar "Advancing U.S. Nuclear Research and Development," October 29, 2020
- ANS Winter Meeting, November 16 – 19, 2020
- IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR21), May 10 – 13, 2021, China