



FY2022 December Monthly Status Report for the Versatile Test Reactor

January 2022

Changing the World's Energy Future

Thomas Fanning



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**Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517**

Project Highlights

Thomas Fanning, Program Overview



Tom O'Connor met with Senate Energy and Water Development Committee staff on Thursday, December 2 to discuss an appeal on the absence of funding for the VTR Project. The appeal emphasized the need to reestablish domestic fast spectrum testing capabilities to support the long-term evolution of advanced reactors to come following the demonstration projects. A follow-up meeting was held December 13 to discuss the role of the VTR in advanced reactor development. The briefing summarized the need for a comprehensive and versatile research and development infrastructure to support long-term technology innovations and a robust regulatory framework.

With extension of the current continuing resolution (CR) into February, staff have begun planning scope for the remainder of fiscal year (FY) 2022 under the assumption of a year-long CR scenario.

Comments on the draft report prepared by the nonproliferation assessment (NPA) team from the Office of Defense Nuclear Nonproliferation (DNN) were submitted and should lead to productive discussions with the National Nuclear Security Administration (NNSA) that further support their conclusions.

Archival of project documentation within Confluence continued. Using a single tool will ensure that a usable archive is available for resuming work should funding be restored. Efforts to generate an index of all documents that can be made more broadly available while avoiding export control restrictions are also underway.

Three milestones were completed in December. Level 3 milestone, *Approve Final Design for Prototype Casting System*, reviewed the final design documents for a prototype fuel casting system and determined the design is capable of meeting VTR project requirements. Level 4 milestone, *Complete U-Pu-Zr-Ga Update to VTR Fuel Performance Design Basis*, provided an update to the VTR fuel performance design basis to include additional information on gallium effects. A second Level 4 milestone, *Complete and Document Design of the REDSHIP Experiment*, included the final design for the REDSHIP (REDuced Scale Hydraulic Inlet Plenum) facility.

A virtual webinar, *The Future of the Versatile Test Reactor: A Key Player in the Nuclear Energy Innovation Ecosystem*, was held December 7. VTR Executive Director Kemal Pasamehmetoglu opened the webinar and was joined by moderator Bryan Cheong (Global America Business Institute (GABI)) and speakers Judy Greenwald (Nuclear Innovation Alliance), Jackie Toth (Good Energy Collective), and Jennifer Gordon (The Atlantic Council Global Energy Center).

A special congratulations to Chris Ritter, VTR's Digital Engineering lead, for being selected as one of the 2021 Distinguished under 40 honorees, an annual awards program sponsored by the Greater Idaho Falls Chamber of Commerce. The award recognizes 10 young professionals from Eastern Idaho who have gone above and beyond to accomplish great things in their career, community, and education.



Nuclear Design

Completed three milestones and continued progress toward five additional milestones due in January. Significant progress was made in fabricating a full-scale prototype driver assembly, including 217 wire-wrapped pins, for the Pressure Drop Experimental Loop for Investigations of Core Assemblies in Advanced Nuclear Reactors (PELICAN) loop. Additional details, including pictures, are provided in the technical summary below.

VTR Plant Engineering

Existing preliminary civil/structural calculations and designs against the draft geotechnical specification are being reviewed to verify consistency. Work scope supports geotechnical investigation field work, scheduled for spring and summer 2022. Performing an analysis at the Materials and Fuels Complex (MFC) to determine the most appropriate site for the geotechnical investigation mobilization laydown area.

VTR Experiments

Materials Extended Length Test Assembly (ELTA) and in-situ crack monitoring activities included the following work: testing methods of insulating pins to reduce noise from pin-clevice interaction, improving acoustic emission signal quality for in-air tests, and polishing samples to get them to American Society for Testing and Materials (ASTM) standard for corrosion tests. A dual argon tank setup has been installed to allow for multi-day tests and in-line gas detectors are being set up.

Upcoming Events:

NURETH-19, 19th International Meeting on Nuclear Reactor Thermal Hydraulics, March 2022 (Virtual conference)

IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR22), April 19-22, 2022 (Vienna/Virtual)

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Technical Highlights

Steve Unikewicz, Reactor Technical Integration



Design Engineering Support

An investigation as to the basis for the 0.70 value for Reactor and Guard Vessel emissivity as part of the Reactor Vessel Auxiliary Cooling System (RVACS) heat removal capacity analysis has been drafted and is under internal review. The rationale for a design decision is expected to be complete in January.

Existing preliminary civil/structural calculations and designs against the draft geotechnical specification are being reviewed to verify consistency. Work scope supports geotechnical investigation field work, scheduled for spring and summer 2022. Performing an analysis at the Materials and Fuels Complex (MFC) to determine the most appropriate site for the geotechnical investigation mobilization laydown area.

Fast Flux Test Facility (FFTF) Documentation and Data Recovery

Located the processes and procedures used to wash fuel at the FFTF, including design of the washing system, but the information was not retrieved. As this information is based on an actual operational washing system, it can be used to improve the efficiency and effectiveness of the VTR washing system. Also located design documents and operating procedures for FFTF Ex-Vessel Transfer Machine (EVTM) but the information was not retrieved.

VTR Control Rod Mechanical Design Analysis

An analytical Benchmark based on the design and operation of the FFTF absorber bundles in being used by Argonne National Laboratory (ANL) and Pacific Northwest National Laboratory (PNNL). The Benchmark is used to resolve any uncertainties in the design and performance of an absorber bundle for a control rod in the VTR. PNNL developed the Benchmark document and provided it to ANL. ANL completed initial Benchmark calculations, documented them in a Benchmark report, and transmitted the information to PNNL to review and compare with PNNL Benchmark calculations.



Thomas Fanning, Nuclear Technical Integration

Fuel Design and Analysis

Completed two significant reports. The first report assessed the potential effects of minor gallium addition to U-Pu-Zr fuel to help address an option to use weapons-grade Pu directly in VTR fuel without chemical purification. The second report was a revision of the VTR Fuel Performance Design Basis. Completed transmission electron microscopy (TEM) examination of samples of U-Pu-Zr-Ga irradiated in Experimental Breeder Reactor-II (EBR-II) experiment X521, confirming the presence of small particles of GaZr_2 as predicted by CALPHAD phase stability studies.

Fuel Manufacturing

Focused efforts on supporting the design/build contract for the prototype casting system and completing the final design. Laboratory and the contractor staff worked together to complete and deliver the final analyses and drawings, and the vendor data package was ultimately submitted and approved, closing PICS milestone, *Approve Final Design for Prototype Casting System*. Continued report preparation detailing layout options for scrap processing systems. The draft report is expected to be ready for review in early January. Continued updating the conceptual design technical evaluation (TEV) for the rod loading system, identifying three focus areas to update, and began work on updated concept for the material transfer system.

Core Design

VTR Reactor Design Uncertainty and Conservatism Assessment: Fuel Manufacturing Sensitivities

The determination and application of uncertainties and conservatisms is an integral component of reactor design to ensure safe and effective operations. These uncertainties and conservatisms are applied to design products and the corresponding design limits to account for the presence of unknown knowns, known unknowns, and unknown unknowns. This provides for the overall design resilience and versatility needed to support the mission of the VTR, establishes and justifies the safety basis, and provides an understandable and quantifiable reserve of margin necessary for support of the eventual operating reactor.

Early phases of design generally apply significant amounts of conservatism and use uncertainties borrowed from similar projects (if available). This provides margin to somewhat reduce the risk of re-work and increases the chance that a design will successfully perform its mission. However, these initial conservatisms and uncertainties still pose project risk as they are either over-conservative (reducing performance and/or increasing costs) or not entirely applicable to the current design (challenging the safety basis). Therefore, early assessments are replaced over time with more explicitly derived uncertainties and with conservatisms appropriate for the overall safety philosophy as the design, manufacturing, and operational plans converge. Replacement of preliminary assessments is typically performed early and iteratively to ensure the risk of unforeseen consequences remains low. This approach is being used for VTR core design efforts. For example, thermal performance has been evaluated using hot channel factors derived from those generated for and applied to the FFTF and EBR-II designs. Given the maturity of the design and that decisions regarding the safety basis, manufacturing, and operations are beginning to be made, these initial uncertainties and conservatisms are in the process of being updated as well.

The Core Design and Fuel Design and Fabrication teams are evaluating the sensitivity of key reactor performance parameters to fuel manufacturing-related variations. This work is performed to aid in establishing fuel fabrication processes. As the fuel fabrication process matures and as-manufactured data is available, these sensitivities and the as-manufactured variability can be combined to yield the final uncertainties of these reactor performance parameters. Analysis of these sensitivities is currently underway. Sensitivities are being evaluated by first identifying a baseline configuration that will have sensitivities to the perturbations that are reasonably bounding. Then, both deterministic and Monte Carlo models representing this baseline condition will be built. Next, suites of perturbations to the baseline models will be made and analyzed for each fuel manufacturing parameter of interest. The suite of perturbations is specifically tailored to evaluate the sensitivity of core reactivity, pin powers, and assembly powers due to varying the parameter locally (near the peak power location) and globally. These sensitivities will then feed into the establishment of fuel manufacturing process requirements.

PELICAN

Continued fabrication of a single, full-size fuel assembly for testing in PELICAN. Previous activities tested individual components including upper and lower reflectors, while upcoming tests will incorporate all components together, including a full-length wire-wrapped fuel bundle, plena, and transition regions, within a single continuous hexagonal duct. Established new capabilities to allow for in-house fabrication of full-length wire-wrapped rods. The tool is capable of wire wrapping fuel rods up to 2-m in length at an average rate of 3 rods per hour and is configurable for several rod and wire diameters over a wide range of helical pitches. The wire-wrapping specifications used for the PELICAN test assembly were determined from literature reviews and communication with former wire-wrapping experts, while dimensions were selected based on the VTR reference design. Securement of wire to the rod ends was achieved by initial resistance spot welding while in the tool, followed by a high-frequency pulsed TIG weld for final securement. Developed and enforced a quality assurance process to ensure traceability of all materials and consistent characteristics. Completed 217 wrapped rods and efforts are continuing for final assembly to the 17 fuel spacer plates and lower reflector. Installation into PELICAN is scheduled to be completed by January 2022 followed by testing at prototypic water flow rates up to 40 kg/s.

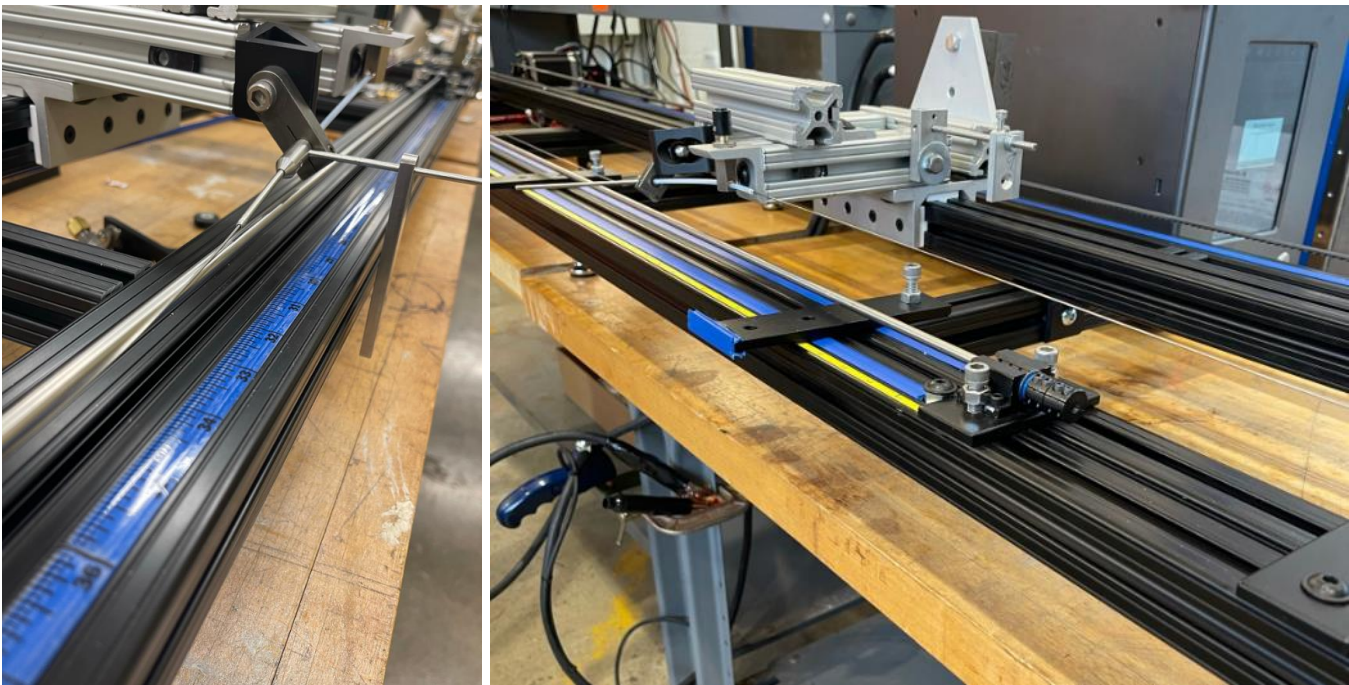


Figure 1. In-house wrapping tool. Wire feed tip (left); end-shaft bearing and tensioning system (right).

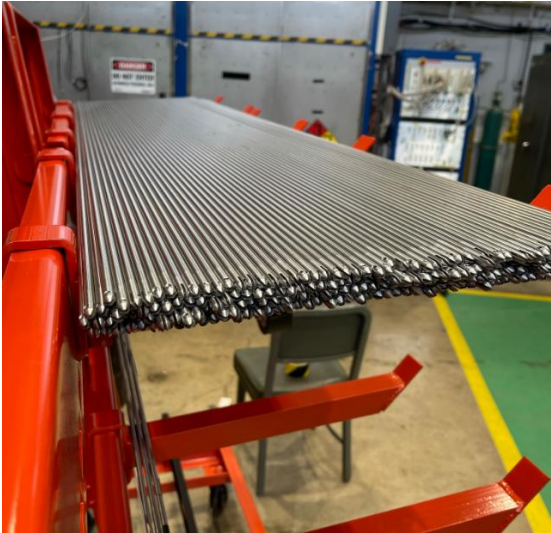


Figure 2. Stock of rods staged for wrapping.



Figure 3. Completed set of wrapped rods.



Figure 4. Detail of wire wrapping.



Figure 5. Detail of final TIG weld securement.

Transient Safety Analysis

Updated VTR safety analyses are being completed to incorporate the evolution of the design, primarily the updates and refinements for the secondary heat transport system, and to incorporate use of the new electromagnetic (EM) pump model in SAS4A/SASSYS-1. Analysis is being completed for protected and unprotected versions of the transient overpower, loss of heat sink, and station blackout (SBO) initiators as well as additional transient scenarios analyzed in support of probabilistic risk assessment (PRA) and design activities. Analysis will be completed and documented in January. Completed application of the new equivalent circuit

electromagnetic (EM) pump model into the VTR SAS4A/SASSYS-1 model. This model eliminates some of the issues with the previous EM pump model, such as the inability to simulate backflow through operating pumps and the limited ability to model pump heating. Completed the theory and user guides for the new EM pump models. Submitted an initial draft of the software test plan for technical review. Completed an ECAR for the SAS/computational fluid dynamics (CFD) coupling module verification testing and the document is undergoing final approvals. Volume of fluid (VOF) multiphase (liquid + gas) SAS-CFD coupled simulations for a protected station blackout (PSBO) scenario have been repeated to verify that previous coupling issues have been resolved. The transient simulations were performed up to 1200 s and are being compared with simpler single-phase simulations.

[Sodium Fire Hazard Analysis and Software Verification & Validation \(V&V\)](#)

Completed the first full draft of the SPCA-ANL sodium fire analysis code manual. Modified sections of the original SPCA-II manual to be consistent with the updated code. All equations in the manual are consistent with those in the code. Reconstructed all figures and tables from the original SPCA-II manual. Continued development of the SPCA-ANL code, with refinements to the flame sheet model to improve constancy of calculations.

[Probabilistic Risk Assessment/Safety Basis/Licensing Modernization Project \(LMP\)](#)

Developed a draft report documenting the LMP process that was utilized to develop Conceptual Safety Design Report (CSDR) inputs. This report contains information regarding the use of the LMP process that is currently within multiple non-public safety basis and PRA reports, including details on the specific PRA analyses conducted as part of the process. However, the report will focus on the procedures and methods, rather than results, since it will be made available for public release. Continued validation efforts of the Simplified Radionuclide Transport (SRT) mechanistic source term code with a goal of reaching a logical stopping point by the end of January. Completed additional analysis of the code bubble transport models and cover gas sodium vaporization models.

Kevan Weaver, Experiments Technical Integration



Continued limited work at the laboratories, including hold-and-restart documentation. Accomplishments within selected experiment vehicle types are included below.

Materials Extended Length Test Assembly (ELTA) and in-situ crack monitoring activities included: testing methods of insulating pins to reduce noise from pin-clevice interaction, improving acoustic emission signal quality for in-air tests, and polishing samples to get them to American Society for Testing and Materials (ASTM) standard for corrosion tests. A dual argon tank setup has been installed to allow for multi-day tests and in-line gas detectors are being set up.