Foreword

Special issue on the Versatile Test Reactor (VTR)

Guest Editors
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Diverse, affordable, adaptable and easily adoptable, equitable, and clean energy supply for an Earth approaching 10 billion inhabitants is one of the challenges facing humanity in the 21st century. Not exclusively, but with proper integration with other clean energy options, nuclear energy will be an important part of the 21st century's energy landscape.

An important global policy goal should be to rapidly transition to clean energy technologies to combat climate change. Such an objective would contribute to slowing down global warming and should be coupled with adapting to the negative climate effects that are already being experienced. It is widely accepted that highly reliable and safe nuclear energy with practically no greenhouse gas emissions will play an important role during this energy technology transition. However, depending upon the regional needs and applications of nuclear power, a mix from a diverse set of design options (in size, operating parameters, technology choice, etc.), significantly different from present-day nuclear power plants, will be needed. Those designs are referred to as "advanced reactors" generically and present very large variations in their design and operational characteristics. Some of those designs can be demonstrated today, i.e., with existing technologies, although they are amenable to further enhancements for large-scale commercialization. Other designs require additional development, especially regarding the fuels, materials, instrumentation, and sensors needed to fully achieve intended performance goals. A robust research and development (R&D) infrastructure that can support a wide range of design options is critical for the large-scale transition to advanced nuclear energy systems and hence to combat climate change.

For the reasons outlined above, another important and desirable worldwide goal is for nuclear power to increase its share of the power generation mix. In such a context, an important national goal for the United States would be to regain and sustain leadership in advanced nuclear energy systems, assuming an active role similar to the one the country played in the light water reactor technologies field for more than half a century. Such leadership is only possible if there are U.S.-based commercial entities designing and building state-of-the-art reactors tailored to regional needs and if the commercial efforts are nurtured and supported through continuous, sustained innovation. The importance of leadership in this technology goes beyond just the economic benefits. Enabling export of U.S. reactors and associated services is also in the U.S. national—and indeed all of humanity's—security interest as this serves as a vector for influencing and enhancing global safety and security standards. Continuing innovation that can help enhance U.S. nuclear viability and even promote U.S. leadership requires a robust R&D infrastructure, including a powerful irradiation testing capability.

Having benefited from considerable investments over the past decade, the U.S nuclear energy R&D infrastructure is robust, except for a greatly needed high-flux and high-energy neutron irradiation capability. The Versatile Test Reactor (VTR) is aimed at filling this one remaining major gap. It is important to note that such a capability presently exists only in the Russian Federation, while China is also rapidly developing similar capabilities. Having this capability in the United States would enhance the competitiveness of U.S. industry and the U.S. nuclear safety and security posture globally and enable the United States to collaborate more effectively with international nuclear energy partners. Most importantly, within the country, it would ease test scheduling constraints and enhance flexibility in irradiation testing objectives, greatly expanding the types of tests that could be conducted. Thus, progressing in parallel with early new reactor demonstration projects, the VTR would provide a critical missing piece for achieving U.S. nuclear energy goals.

In 2018, the U.S. Department of Energy (DOE) Office of Nuclear Energy (NE) initiated a program to develop a fast spectrum neutron irradiation facility to fill that obvious gap in the domestic R&D infrastructure. This initiative resulted in the VTR project. The mission need was recognized and pursuit of it was approved in February 2019 (Critical Decision 0). In September 2020, the deputy secretary of energy signed off on Critical Decision 1, which approves the selection of the technology and the conceptual design needed to accomplish the mission and approves the associated project cost and schedule ranges.

The project is led by Idaho National Laboratory on behalf of DOE-NE. Five additional national laboratories (Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, and Savannah River National Laboratory), 19 universities, and 10 major industrial partners cooperated on the conceptual design for the VTR project. After the approval of the conceptual design, in September 2020, the project entered the engineering design and construction phase. A design-build contract was signed in June 2022 with a team selected through a competitive process and led by Bechtel National, Inc., partnering with GE Hitachi and TerraPower. Also, the Final Environmental Impact Statement for the VTR was published in May 2022. With a continued appropriate level of support, the VTR could be available in a decade or less and then would be able to foster further innovations for many decades to come.

The VTR is being designed as a state-of-the-art flexible test capability that incorporates a variety of coolant technologies (of course excluding water for obvious reasons). The aim is a 300-MW(thermal) pool-type sodium-cooled reactor. However, it is *not* intended to produce electrical power nor thermal power for use, per se. Instead, the core is optimized to produce fast-spectrum neutrons at very high fluxes and over large volumes. In addition to supporting fundamental science interests, the ability to perform high-energy-neutron experiments over large test volumes will enable, and perhaps even inspire, further innovations to enhance the performance and safety of advanced reactors and to lead to new designs beyond those already under consideration. Access to the VTR will also be invaluable in motivating and developing a new generation of nuclear scientists and engineers.

This special issue of *Nuclear Science and Engineering* (NSE) is intended to present a current snapshot of the VTR design, at the end of its conceptual design phase, and in so doing to describe some of its planned facilities and their technical status. The VTR combines characteristics from a variety of modern reactor concepts into a single one. Whereas all reactors are complex systems, the flexibility of the VTR design and its varied testing facilities compound its technical complexity with their individual challenges. This in turn requires a combination of novel, creative, and unique solutions, even occasionally addressing topics (at least in one instance) that extend the scope of this journal. Therefore, in the selection of the articles we chose to include in this special issue, we strived to cover the VTR system complexity in a comprehensive way. We believe and expect that all articles in this issue are relevant to a hopefully expanding NSE readership, and each and all should be of interest to at least a segment of said readership. Thus, this special issue contains 21 articles that cover scientific and engineering topics and underlying technology considerations. In this respect, this special issue lives up to the name of the journal.

The issue starts with two overview articles—one on the mission, requirements, and description of the VTR and one on the engineering design of the VTR plant. These are followed by six articles on the core design, its methods, and their validation, including planned experiments in support of the core design. These are followed by an article on radiation protection and shielding of the VTR. The next two papers examine fuel performance design basis and fuel performance benchmarks, respectively. A set of five articles follows that address four varied irradiation facilities (cartridge coolant loops). A single paper addresses digital engineering of piping systems. The last four articles are focused on safety and examine the safety basis, transient modeling, and sodium fire analysis.

We hope that besides documenting the design status of the VTR, this special issue will help inspire the future users of the VTR in terms of potential additions to experimental capabilities as the design progresses. We also humbly hope that this special issue will be well received by the NSE readership and that it may help expand the readership and their interests.

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