STATUS OF U.S. FAST REACTOR DEVELOPMENT

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INTRODUCTION: Nuclear energy continues to be a vital part of the energy development strategy for the U.S. to enable affordable, reliable, and secure energy. In terms of fast reactor technologies, the U.S. Department of Energy (DOE) continues to work with U.S. companies in public/private partnerships to enable near-term commercial deployment of first-of-a-kind demonstration fast reactors in the U.S. In addition, through DOE Office of Nuclear Energy's (DOE-NE's) research and development (R&D) programs, the U.S. national laboratories are leading complementary R&D efforts that reduce costs, enhance performance, and facilitate licensing of fast reactors.

1. PUBLIC/PRIVATE PARTNERSHIPS

Within the last decade, there has been significant interest and growing investment in advanced reactor technologies from the private sector, with dozens of U.S. reactor companies working on advanced nuclear projects for a wide array of capabilities. About a dozen of these companies are pursuing fast reactor technologies cooled by sodium, lead, gas, or salt. Recognizing the importance of advanced reactors to meeting the Nation's energy goals, the Advanced Reactor Demonstration Program (ARDP) was initiated in fiscal year (FY) 2020 to develop Federal and U.S. nuclear industry partnerships for the construction and demonstration of domestic advanced nuclear reactor designs that are safe and affordable to build and operate. To help implement this program, DOE-NE issued a funding opportunity announcement (FOA) in May 2020 for the most promising domestic advanced reactor designs across the technology maturity spectrum, and subsequently selected ten projects that can be developed over the next two decades. Four of these projects support the development and future demonstration of fast reactor concepts.

Within the ARDP, two innovative designs were selected for the Advanced Reactor Demonstration (ARD) pathway, with the goal of construction and operation by the end of this decade. One of these projects is the 345 mega-watt-electric (MWe) Natrium sodium-cooled fast reactor (SFR) that leverages decades of development and design undertaken by TerraPower and its partner, General Electric-Hitachi. The high operating temperature of the Natrium reactor, coupled with a molten salt thermal energy storage system, will allow the plant to provide flexible electricity output that could complement variable renewable generation technologies such as wind and solar. The Natrium plant will be sited near a retiring coal plant site in the state of Wyoming. Natrium, a pool-type metal-fuel SFR, is being licensed under the 10 CFR Part 50 pathway, which is the two-step licensing approach (construction permit and operating license). A construction permit application (CPA) for the plant was submitted to the U.S. Nuclear Regulatory Commission (NRC) in March 2024 [1]. The NRC completed a draft safety evaluation (SE) in February 2025, with finalization targeted for 2026 [2]. The Natrium CPA marked the first U.S. reactor application utilizing the Licensing Modernization Project (LMP) [3] approach, which is a technology-inclusive, risk-informed performance-based licensing methodology endorsed by the NRC [4].

In addition to the Natrium project, the following three projects that support the development and future demonstration of fast reactor concepts were also selected: Southern Company Services/TerraPower will design, build, and operate the Molten Chloride Reactor Experiment (MCRE) at the Idaho National Laboratory (INL); General Atomics will complete conceptual design of their gas-cooled fast modular reactor concept; and ARC Clean Technology will support the development of a 100 MWe pool type SFR design. In addition, DOE and national laboratories have been partnering with Oklo on its SFR commercialization efforts in terms of siting, fuel fabrication, and other R&D aspects. General Atomics, ARC Clean Technology, and Oklo are currently in pre-application engagement with the NRC, which permits regulatory discussions and alignment on key topics, typically through white papers or topical reports, prior to formal license application submittal (see Appendix A of ref [5] for additional detail on pre-application activities). As MCRE is being built at INL, a DOE facility, oversight and authorization are provided by DOE.

The first fuel for most of these initial advanced reactor demonstrations in the U.S. will be High Assay Low Enriched Uranium (HALEU). In 2019, DOE awarded Oklo with recovered Experimental Breeder Reactor-II (EBR-II) HALEU fuel to use in its first reactor. In April 2025, DOE issued TerraPower, among four other companies, a conditional commitment of HALEU as part of its HALEU Availability Program.

2. R&D OVERVIEW

In terms of the DOE-NE funded R&D programs, which conduct the baseline fast reactor R&D activities, the focus has been on reducing cost, enhancing performance, and addressing licensing issues. These goals are being pursued through focus areas that include technology development, advanced material qualification, methods and database development, and fuels R&D.

The technology development work centers around the continued operation of the Mechanisms Engineering Test Loop (METL), a sodium loop facility with vessels to test small or intermediate sized components, instrumentation, and inspection/repair technologies in sodium. So far, three test articles have been inserted and are being tested in METL: the gear test assembly (GTA), the thermal hydraulic experimental test assembly (THETA), and an inductive level probe system. The GTA was designed to demonstrate the feasibility of using a compact under-sodium refueling mechanism by testing the performance of gears and bearings in the typical sodium environments. THETA is essentially a miniature mock-up of a pool-type SFR at 38 kilowatts (kW) from electrical heat. It is highly instrumented with optical fibers to enable obtaining high fidelity data that may be used for validating computer simulations of nominal and transient conditions. A fourth test article, the Gripper Test Assembly (GrTA) will be inserted this year. It is a full-scale gripper device for fuel handling that shares some of the components with the GTA and is the next test article in the advanced refueling test article series. A fifth test article, called Flow Sensor Test Article (F-STAr) is a high flow test article that will replicate the outlet plenum and upper-internal structure of an SFR core where flow sensors and other instrumentation can be tested. A new sixth test article, the Bearing Test Article (BTA) is being fabricated and focuses on more customized testing of bearings.

In terms of advanced materials, DOE-NE is supporting the code qualification of Alloy 709 (A709) for fast reactor structural materials, which can improve performance and reduce the costs of materials compared to the costs of reference construction material, Type 316H stainless steel. This could be achieved by enabling compact configurations, higher operating temperatures, higher reliability, and longer lifetimes. The A709 work includes creep, fatigue, and creep-fatigue tests on commercial heats of A709 to generate the technical basis for American Society of Mechanical Engineers (ASME) code qualification. In addition, A709-sodium compatibility tests are continuing via two sodium test loops with preliminary data showing better compatibility than 316H stainless steel. In coordination with the Advanced Materials and Manufacturing Technologies program, neutron irradiation of A709 is underway to provide the necessary data to assess irradiation performance.

Under the methods and database development area, efforts continue to recover, maintain, and qualify U.S. fast reactor experimental data and software to support fast reactor licensing efforts. There are now seven fast reactor databases that include measured data related to fast reactor physics, safety, fuels, and sodium from EBR-II, FFTF, TREAT, Zero Power Reactors, and experiments. The modeling and simulation tools that have been developed by the U.S. national laboratories and adopted by industry continue to be qualified and validated using experimental data through international collaborations and benchmarks such as IAEA Coordinated Research Projects.

The objective of U.S. fast reactor fuels R&D is to develop transmutation fuels with improved performance (e.g., higher burnup, low fuel cycle costs). Experiments are conducted to optimize the fabrication casting parameters, and performance is being compared to legacy EBR-II fuel. Fuel additions to control fuel cladding chemical interactions are being explored, including ongoing irradiation testing. Fuel characterization and simulation R&D will validate evolving fuel performance models. Irradiation testing in the Advanced Test Reactor (ATR) continues for fabrication variables and optimized metal alloy compositions. In addition, R&D on sodium-free annular fuels and coatings and barriers for higher temperature applications are continuing.

3. CONCLUSION

In summary, there is significant support and momentum in the U.S. for near-term commercial deployment of fast reactors. The U.S. DOE is continuing to support laboratory-led foundational R&D on advanced reactor and fuel technologies while also supporting private-public partnerships to bring first-of-a-kind demonstrations to the grid within this decade. The submittal of the Natrium CPA in 2024 marks a significant milestone towards this goal, with multiple other fast reactor vendors currently preparing for their license applications submittals in the near future.

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