Overview of NuScale Testing Programs

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INTRODUCTION

The design of a new generation of nuclear power reactors is underway with an emphasis on safety and passive systems. The NuScale Power, LLC (NuScale) small modular reactor (SMR**)** is a state of the art design that incorporates multiple systems of natural circulation passive safety to ensure that fuel damage does not occur. Passive safety systems are provided for emergency core cooling, core decay heat removal, and containment cooling. These passive safety systems eliminate external power requirements under accident conditions.

Moreover, the NuScale SMR relies on natural circulation to drive the primary coolant during normal operation. The integrated reactor module is designed such that the core heats the primary coolant causing it to rise through a central hot leg after which it turns in an upper plenum and is cooled by two helical coil steam generators. The lower temperature coolant then flows down the cold leg downcomer where it reaches the entrance of the core to complete the coolant flow circuit.

These innovations result in an SMR consisting of first-of-a-kind (FOAK) structures, systems, and components (SSC's) that are unique to the NuScale design. To complete the design and commercialization of the NuScale SMR, comprehensive testing of these SSCs is required. To identify required tests, NuScale uses a structured process based on identified risk areas, assessment of technology readiness, and risk-informed analysis of physical phenomena that influence plant performance. Testing requirements are also identified by our engineering, testing and code development functional groups for code validation, system characterization, environmental and equipment qualification, and design and manufacturability evaluations. These requirements are detailed in a comprehensive reactor qualification test plan, which documents all testing and environmental qualification activities required as part of the design, certification, manufacture and commercial deployment of the NuScale SMR.

A current focus of NuScale's test program is on SSC thermal-hydraulic and characterization testing and testing to support code development and validation, which is central to the design and analysis of the NuScale SMR. Code development and assessment activities focus on physical phenomena influencing plant transient behavior. Representative examples of three such test programs are discussed in the balance of this paper. These programs are conducted under the strict quality assurance and reporting requirements of 10 CFR 50 Appendix B, 10 CFR Part 21 and NQA-1 2008/2009 addenda.

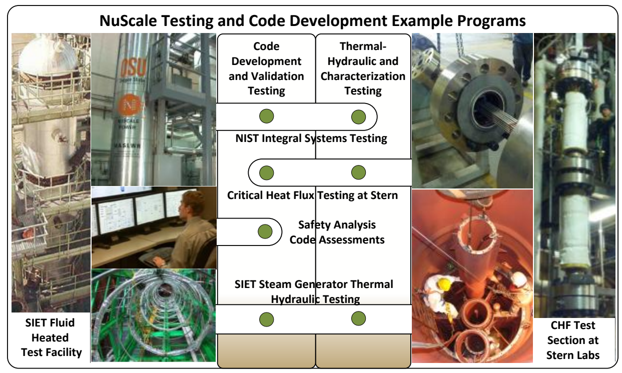

Fig. 1. NuScale testing and code development programs

TEST PROGRAMS

Critical Heat Flux Testing—Completed

NuScale's SMR uses natural circulation driven flows in the reactor coolant system to provide reliable core heat removal during normal plant operating and for accident conditions. These flow conditions are outside of the operating range of the existing commercial PWR fleet, and are in an area where little critical heat flux (CHF) test data exists.

To obtain CHF test data suitable to validate the fuel bundle design and safety analysis codes, NuScale has completed a major test program to obtain CHF data for its fuel using a full-length, full-power, electrically heated fuel assembly mock-up with spacer grids. This testing was performed at Stern Laboratories in Ontario, Canada from September 2012 through March 15, 2013. Testing was conducted over a wide range of natural circulation flow rates and pressures with both uniform and cosine shape power profiles.

The U.S. Nuclear Regulatory Commission (NRC) performed a thorough inspection of NuScale's oversight and conduct of this test program. Although one Severity

Level IV violation was identified related to the initial procurement and supplier evaluation activities, there was no impact to the test data and the inspection team concluded that NuScale's and Stern's QA policies and procedures comply with the applicable federal requirements and were implemented effectively in support of this CHF testing activity.

Data from this CHF test program is being used to define the limiting conditions for fuel performance and to validate NuScale's safety analysis computer codes. The test results show that the NuScale fuel has a significant safety margin under natural circulation flow conditions.

Helical Coil Steam Generator Testing—Currently Active

NuScale's SMR uses two compact, highly efficient helical coil steam generators (HCSGs) with many proprietary FOAK design features. These HCSGs are collocated at the top of the cold leg downcomer annulus, and were chosen to reduce the overall power unit size for factory fabrication. The natural circulation driven flows in the reactor coolant system results in operating conditions that are outside of the range where test data exists to validate the HCSG design and safety analysis codes.

To obtain the HCSG test data required for its SMR, NuScale has embarked on two major test programs utilizing full-length, high pressure and temperature, steam generator tubes to investigate the important physical phenomena and processes that occur in the steam generator tubes and on the primary side of the tube bank. The first test focuses on secondary side performance and consists of a set of several isolated tubes that are highly instrumented with well controlled boundary conditions. The second test focuses on overall primary and secondary side performance and consists of a true prototypic bank of tubes operated at prototypic primary and secondary flow conditions. Both of these tests are being conducted utilizing specialized facilities at Società Informazioni Esperienze Termoidrauliche (SIET) in Piacenza, Italy.

Taken together, the two test facilities provide complete characterization of the single and two-phase flow pressure drops, average void fraction, heat transfer coefficient, temperature and pressure profiles, and structural dynamic conditions.

NuScale Integral Scaled Test (NIST)—Currently Active

The systems and subsystems of the NuScale SMR are highly integrated and optimized into a compact modular package optimized for factory fabrication, resulting in a nuclear steam supply system that departs from the traditional designs in many areas. Because of these unique design features and natural circulation operating conditions for the NuScale SMR, existing integral systems test data has limited direct applicability to the NuScale design. For this reason NuScale has developed its own integral systems test facility to obtain this test data. The NIST facility is a 1:3 length scale, 1:253 volume, scale and 1:1 time scale integral test built on the Oregon State University (OSU) campus. It was originally developed and constructed in the 2000–2003 timeframe by Idaho National Engineering and Environmental Laboratory, OSU, and NEXANT-Bechtel. [1] Since 2008 NuScale has leased the facility and has made a number of proprietary modifications to bring the facility configuration into line with the current SMR design.

Testing at NIST will generate well-scaled thermal-hydraulic data for system characterization and safety code validation while also providing a platform for the design and test of plant operational procedures, control logic schemes and to inform safety methodology development. Planned testing at NIST includes loss-of-coolant accident (LOCA), non-LOCA, flow stability and startup testing. A significant portion of the LOCA testing has already been completed and analyzed by NuScale using the NRELAP5 systems analysis code. [2]

SUMMARY

NuScale is developing a unique SMR design that incorporates numerous FOAK components and systems which require comprehensive testing. NuScale has developed a process for identifying required tests and has a documented test program that is currently focused on SSC thermal-hydraulic and characterization testing and testing to support code development and validation. Three ongoing or recently completed test programs are discussed that support the current test program objectives and development of FOAK SSCs.

REFERENCES

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