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A Pathway for Implementation of Advanced Fuel Technologies in Light Water Small Modular Reactors

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ABSTRACT: The success of Small Modular Reactors relies on their flexibility and adaptability to customers' needs while maintaining safer and reliable operations and cost efficiency when compared to other sources of energy. These goals can be achieved by employing well-established nuclear technologies, implement simpler designs and operational schemes, and include the use of passive systems. This is the approach of the Light Water SMR (LW-SMR) which benefit from well-established technologies and operational experience. In order to accelerate the deployment of their reactor design, most LW-SMR vendors have adopted existing LWR fuel technologies with minor adaptations in the assembly design. This is the case of the NuScale SMR core design, currently employing typical PWR fuel assemblies with minor modifications. However, the use of advanced fuel design developed with the introduction of innovative shapes and materials, such as the one proposed by Lightbridge, can provide enormous benefits to the operation of the LW-SMR. The use of such designs may allow power uprates, improved economics, longer fuel cycle lengths, and decreased fuel operating temperatures with subsequent increased margin to safety. By removing the need for spacer grids, the Lightbridge fuel design promotes lower core pressure drops, a very important parameter to consider for power upgrades especially when the core flow is based on natural circulation. NuScale Power is currently looking at the Lightbridge design as a valid alternative to the current fuel in order to increase operational flexibility, safety margins, and the overall competitiveness of their SMR design.

Project Objectives: We will perform a comprehensive thermal-hydraulic characterization of the Lightbridge Helical Cruciform advanced fuel design, creating unique sets of experimental data describing friction factor, velocity fields, and heat transfer behavior under NuScale's LW-SMR normal and off-normal conditions. A combination of isothermal (hydraulic) and non-isothermal (heat transfer) experimental tests, complemented by high-fidelity CFD simulations and fuel performance modeling will:

- Develop pressure drop correlations for Lightbridge fuel in NuScale LW-SMR conditions,
- Increase the understanding of the overall performance of the fuel under simulated NuScale's SMR normal and off-normal conditions,
- Train the next generation of engineering students to use advanced, multi-scale, multi-physics simulation tools, and
- Identify any critical parameters for further evaluation and design.

The project will benefit from the collaboration of NuScale and Lightbridge to accelerate the deployment of advanced fuels for LW-SMR applications. A collaboration with PEGASUS developer, Structural Integrity, will accelerate the future deployment of PEGASUS simulations as a fuel evaluation and design optimization tool for next generation reactors and advanced fuel designs.