UN multi-design irradiation campaign: a critical assessment of accelerated burnup and main correlations for mechanistic fuel performance modeling

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ABSTRACT:

The nuclear community is currently developing multiple reactor designs to serve in many different applications. Some examples are Liquid Metal cooled Fast Reactors (LMFR), Small Modular Reactors (SMR), Micro-reactors and Surface Fission Space Reactors. Even though the reactor designs are significantly different, many of them propose to use the high-density, uranium mononitride (UN) fuel in the first or second core generation; in some cases, UN is the only viable technical option to achieve the neutronic performance required [1-3]. Therefore, the qualification of this fuel becomes of primary importance to enable these reactor technologies. The proposing team acknowledges that a fuel qualification campaign is well beyond the scope of NSUF 1.1; thereby, we propose high impact, targeted irradiation experiments paired with limited PIE which will narrow the technical readiness gaps for this fuel.

The cross-disciplinary team of investigators from academia, the national laboratories, and industry propose a scope of work that aims to supply the nuclear community with data on the performance of UN at varied burnups, temperatures, and with targeted, controlled fresh-fuel metrics (geometry, density, impurity concentration, and associated microstructures). To accomplish this, the team must produce a robust array of irradiated UN samples for subsequent, targeted post irradiation examinations (PIE). It is the vision of the team that this data updates and extends the current set of data on UN fuel performance to inform and bolster mechanistic fuel performance modelling. To investigate the impact of variation in these fuel specification parameters, the team must also benchmark the performance of high-purity, high-density UN- as the majority of existing UN irradiation data lacks information on the fresh-fuel purity and density and was synthesized with less attention given to mitigation strategies for oxygen (O) and carbon (C) impurities. The sample matrix and data resulting from the effort, if this NSUF proposal is awarded, will provide an initial step to support fuel qualification for advanced reactor designs proposing use UN as the driver fuel, where multiple design (non-prototypical) conditions will allow investigators to narrow the fuel specification and operational envelope, as well as a step towards targeted experiments in developers next stages of semi-prototypical and prototypical irradiations. Furthermore, the methods proposed here align with the Accelerated Fuel Qualification (AFQ) strategy and will serve as one of the pilot cases for identification of challenges and opportunities of AFQ implementation.

The data produced during PIE, particularly data related to fission gas release and swelling, will be of service to support the development of physics-based models and serve as initial verification and validation (V&V) data. Models will be implemented into the BISON fuel performance code; however, the data could be implemented into industry tools as well. The validated model will be applicable for a variety of reactor concepts by validating the underlying physical parameters within the model to fuel behavior over a wide range of conditions (defect stabilities and kinetics).

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