Characterizing Fuel Response and Quantifying Coolable Geometry of High-Burnup Fuel

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ABSTRACT:

There exists a desire to extend the operational life of fuel within United States' current civilian nuclear reactor fleet for the purpose of improving economics. Through use of the nuclear industry's regulatory process via 10CFR50.59, a change in operations must be verified to not compromise the safety of a nuclear reactor. Therefore, it is necessary to comprehensively evaluate and understand the implications of extending the fuel life on safety criteria tied to the existing and operational light water reactors (LWRs) under anticipated operational occurrences (AOOs) and design basis accidents (DBAs) – including, but not limited to Loss of Coolant Accidents (LOCAs). In 1973, the rulemaking hearing on emergency core cooling systems (ECCSs) for LWRs resulted in a formal acceptance criterion for reactors to be satisfied during LOCAs to provide "*Additional assurance that substantial meltdown can be prevented*". This hearing placed requirements for which the ECCS is held accountable in supporting design limits on nuclear fuel regarding (1) peak cladding temperature, (2) cladding oxidation, (3) hydrogen generation, (4) coolable geometry, and (5) long-term cooling. The exploration of impacts on extended burnup of currently qualified fuel systems has been investigated by both the Nuclear Regulatory Commission (NRC) and vested industry members under varied burnup states for many years. A recent comprehensive study was completed by the NRC which details many of these accounts. The outcome of NUREG-2121 resulted in a number of new observations including the final, bulletized conclusion: "*The amount of fuel that is dispersed [during a fuel failure] can vary widely, from a puff of dust to large amounts of fragmentation and pulverized fuel. Although evidence points to likely fuel dispersion in many tests, this phenomenon was not systematically investigated nor documented in the majority of test programs*. With this conclusion drawn, and because *"fuel fragmentation appears to increase with burnup"* it is likely that larger quantities of fuel will disperse at burnup levels greater than 62.5 GWD/MTu. This logic has historically led vendors and utilities to produce overly conservative safety analyses as it is untenable to argue that under an AOO or DBA at burnup levels greater than the licensed threshold that (4) coolable geometry and (5) long-term cooling will not be compromised. While this approach is conservative and bounding from a regulatory perspective, it limits the potential operational space of our current fleet and begs the questions – 'what is the actual impact of fuel dispersion in-core after fuel failure?' and 'does high burnup dispersed fuel compromise coolable geometry and long-term cooling?'. This study seeks to objectively answer these two questions through empirical and numerical means. The outcome of this study will yield an objective means of assessing two criteria (coolable geometry and long-term cooling) within the existing regulatory process to comprehensively understand whether it is feasible to increase burnup while satisfying 10 CFR 50.46. This will be accomplished while leveraging existing experimental infrastructure at Oregon State University, as well as the recently coupled BISON code and Nuclear Regulatory Commission code – TRACE.