Irradiation, Transient Testing and Post Irradiation Examination of Ultra High Burnup Fuel

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ABSTRACT:

The U.S. nuclear power industry is under financial duress due to low natural gas prices and as a result several plants have shutdown. To make the energy source more competitive the industry has kicked off a "Nuclear Promise" initiative to cut operational cost by 30%. Nuclear fuel makes up 1/3 of plant's operational budget and an important focus is to improve core design energy utilization efficiency by reducing operational constraints. The regulatory burnup limit, 62 GWd/MTU, has been identified as a constraint for approximately 1/3 of the U.S. nuclear fleet. Establishing a technical basis for burnup increase has been hampered by observations of severe fuel fragmentation under loss-of-coolant-accident (LOCA) conditions. The U.S. Nuclear Regulatory Commission (NRC) has identified fuel fragmentation as a key issue to be addressed for burnup extension. Test data available thus far suggests the burnup threshold for fuel fragmentation may be influenced by pre-transient power. High burnup fuel up to 73 GWd/MTU showed resistance to fragmentation with pre-transient powers less than 7 kW/m while fuel with pre-transient power >15 kW/m severely fragmented. If a clear, consistently observed relationship between burnup, pre-transient power, and severe fragmentation could be defined it could form the basis for operating limits on high burnup fuel. These operating limits would be a significant contribution to the industry's effort to pursue burnup extension in a manner that would not introduce severe fragmentation. Ongoing research with commercially irradiated fuel prevented the systematic investigation of the proposed pre-transient power history effect because material with the required operational power history is not available.

This proposal aims to generate test samples of the required power history to complete the research and has the following high level objectives: (1) investigate the influence of pre-transient power on fuel fragmentation at burnups above the current U.S. regulatory burnup limit, (2) evaluate if the proposed pre-transient power effect is path dependent, i.e., could high burnup fuel be reconditioned at lower power to be resistant to fragmentation, (3) evaluate fragmentation mechanisms to enable model development, and (4) generate suitable test material for LOCA testing in the Transient Test Reactor (TREAT). Suitable fuel, already in DOE possession, has been identified for re-irradiation in the Advanced Test Reactor (ATR). High burnup fuel will be re-irradiated at two power levels, 9-11 and 11-13 kW/m. The fuel will be subjected to fuel fragmentation testing before and after re-irradiation to determine the effect of pre-transient power on fragmentation and to determine if the effect is path dependent. Additional irradiation with lower burnup fuel is also planned to serve as backup and, more importantly, repeat some of the tests in a more controlled manner. The lower burnup fuel will first be irradiated at high power to 65 GWd/MTU, then irradiated at targeted power levels similar to the initially tested high burnup material. The re-irradiation power level for later tests will be determined based on results obtained from initial test results to refine the understanding of the pre-transient power effect.