High Fluence Low Flux Embrittlement Models of LWR Reactor Pressure Vessel Embrittlement and a Supporting Database from the UCSB ATR-2 Irradiation Experiment

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ABSTRACT:

The proposed research constitutes a central part of the DOE Light Water Reactor Sustainability Program (LWRSP) related to the Reactor Pressure Vessel (RPV) Life Extension Task LWRS-1. Our current NEUP on this topic, which ends this fiscal year, is being carried out in close collaboration with the lead researcher A for the RPV program at DOE National Laboratory A; this collaboration and coordination will continue in the new NEUP. The central objective of this research is to develop calibrated physically based models that provide accurate, quantitative predictions of transition temperature shifts (TTS) in RPV alloys for *low flux-high fluence* end of extended life conditions a key objectives of the LWRSP program. The models will be informed, calibrated and validated by experimental observations derived from both a large number of existing databases, as well from a very large *new experimental irradiation program* that we are conducting at Test Reactor A at National Laboratory B as part of a national user program.

The new models will build on very successful research that has been carried our to predict TTS for low to intermediate flux vessel pertinent conditions, for fluence levels to up to the originally licensed 40 years of vessel life. These models have recently been extended to treat high fleunce conditions over a range of flux. However, the new models must be informed, calibrated and validated by addition experiments. New features of these models include: a) proper treatment of flux effects in accelerated test reactor irradiations needed to reach high fluence in a timely manner; and, b) inclusion of so-called late blooming phases (LBP) that could cause very severe embrittlement at high fluence, even in low Cu steels.

Progress will require new irradiations**.** To this end, are carrying out a major new RPV irradiation experiment as part of a user facility program at National Laboratory B. Post irradiation examinations and analysis of the new and previous databases is the core of this proposed research. This experiment will irradiate a very large matrix of alloys (≈ 186) and various specimen types at four irradiation temperatures [250, 270, 290 (baseline) and 310°C] to a maximum fluence of ≈ 10^{20} n/cm^2, producing 819 alloyirradiation combination conditions. The peak flux of ≈ 3.5×10^{12} n/cm^2-s, bridges lower flux test reactor and surveillance conditions (<10^{12} n/cm^2-s) and the high flux test reactor conditions up to more than 10^{14} n/cm^2-s. There is no other experimental program in the world aimed at reaching high fluence in a way that can be assessed over a range of fluxes spanning more than 4 orders of magnitude. The new experiment will also provide a large inventory of model alloys and RPV steels specifically designed to investigate LBP, which does not currently exist. RPV steels from various surveillance programs are also included. The experiment will also contain 50 new alloys. Other studies will be directed at verifying the Master (toughness-temperature) Curve Method in sensitive alloys at high fluence (there are no existing data in this case) and PIA remediation of embrittlement.