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Title of Grant: Degradation Assessment of Advanced Welds for Pressure Vessels
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Executive Summary

The objective of this project is to provide data to form the scientific and engineering basis for evaluating risk of irradiation embrittlement in advanced welds on the reactor pressure vessel (RPV). In the 1960s, the Nuclear Regulatory Commission (NRC) mandated that RPVs be forged in one piece due to extreme irradiation embrittlement in submerged-arc welds caused by nanoscale precipitates and dislocation loops. But modern advanced welding technologies exhibit superior quality and performance than conventional arc welds. Hence, there is a need to assess embrittlement risks of modern RPV welding technologies, and to do so at the length scales at which embrittlement mechanisms occur. Our scientific approach utilizes phenomena identification and ranking tables (PIRT) with systematic experiments to rank key nano/microscale embrittlement mechanisms relative to their importance in predicting the figure of merit for the intended RPV application. Work will focus on advanced autogenous electron beam (EB) welds on A508, Class 1, Grade 3 RPV steel; submerged-arc welds will also be studied as a control. We will conduct a series of proton irradiations and leverage prior neutron irradiated specimens of the same alloy feedstock; we will characterize the irradiated microstructure and assess embrittlement through state-of-the-art small-scale mechanical testing. The engineering outcomes are microstructure-yield stress-DBTT correlations for welds across a wide irradiation temperature-dose space; we will generate an updated NUREG/CR-6551 and lay the foundation for NRC to re-regulate RPV welds through follow-on probabilistic risk assessment (PRA) studies. This work is innovative because it challenges long-standing norms on the viability of welds in RPVs and will represent a transformational modernization of the NRC toward a mechanistic-based regulatory approach for RPV integrity. Educationally, four students will work on this project and will become prepared to enter the nuclear workforce.

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Presentations and Publications

The list of publications was submitted with the final report after grant expiration.

- J. Emerson, G. Nemets, E. Marrero Jackson, M.A. Okuniewski, and J.P. Wharry. *Review of irradiation performance of reactor pressure vessel welds*. Submitted to Materials & Design 244 (2024) 113134.

- J.P. Wharry, G. Nemets, E. Marrero, J. Emerson, N. Gehmlich, M.A. Okuniewski, C.D. Clement, and K.S. Mao. *Multimodal characterization of porosity in advanced manufactured and welded nuclear structural alloys*. Microscopy & Microanalysis 29.S1 (2023) 1536-1537.

Patents
N/A