Innovative In-Situ Analysis and Quantification of Corrosion and Erosion of 316 Stainless Steel in Molten Chloride Salt Flow Loops

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ABSTRACT:

The goal of the proposed research is to study in-situ individual and synergistic effects of corrosion, irradiation, and mechanical stress on material removal by corrosion and erosion in 316 stainless steel (referred to as 316SS hereafter) tubes exposed to a molten chloride flow to predict component service lifetimes and design limits. To this end, the thin-layer activation (TLA) analysis technique will be used on 316H SS samples placed in natural convection and forced flow loops. TLA involves pre-irradiating a tube or sheet coupon section with energetic ions to create specific radioisotopes at the future interface with the salt flow. The radioisotope will emit specific gamma rays through its decay process, and these gamma-rays can be detected by specific detectors. Thus, material's loss can be detected through activity loss of the area of interest and the isotopes transport can be detected in-situ in the molten salt flow, such that detection of specific radioisotopes would allow us to track erosion, transport and redeposition rates in-situ, non-intrusively, over thousands of hours of exposure. Utmost consideration will be given to generating data related to the effect of molten chloride flow velocity on material removal by corrosion and erosion, so as to be able to identify the maximum allowable fluid velocity for 316SS where any further thickness loss becomes unacceptable. The effects of thermo-mechanical treatments and pre-irradiation on the 316H SS material removal due to salt flow will also be investigated through separate effects experiments. All the above studies will be closely coupled with detailed pre- and post-test characterization using a suite of materials analysis techniques, so that a mechanistic understanding of 316H SS material removal (and redeposition processes) can be achieved. Testing the thermo-mechanical treatments and pre-irradiation effects on the 316H SS mass loss due to salt flow will inform optimization of the pipe's manufacturing methods with the end goal of achieving highly durable 316H SS surfaces with the best possible long-term corrosion resistance. If time allows, other stainless steels, such as Ni coated 316H SS will be tested as well, since they may perform better than 316H SS. Finally, the results will be implemented as inputs into current system analysis codes under development at industry and national laboratory partners. The research will be conducted collaboratively between a university, a national laboratory, and an industry, all with a leadership role in research and commercialization of MSRs.