Influence of dissolved salts and impurities in seawater on heat transfer degradation and fluid flow through fuel channels and debris bed

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ABSTRACT:

During the Fukushima Daiichi nuclear disaster, a large quantity of seawater was injected directly into the nuclear reactors to cool the reactor cores and stabilize the thermal response. However, even after 5 years, very little is known about the efficacy of that process and to what extent seawater injection contributed to the progression of the accident. Raw or untreated water—and salt water in the case of Fukushima—contains contaminants, deposited on the fuel or inside the debris bed, that directly affect heat transfer and flow characteristics. Investigators will leverage their expertise in (1) understanding the influence of scaling or fouling on flow boiling-heat transfer; (2) understanding the influence of boiling on formation of scaled deposits; (3) advanced non-intrusive neutron or radiation imaging techniques; and 4) modelling complex thermal-hydraulics and severe accident scenarios, —using MELCOR and other codes, to understand and correlate the effect of contaminants (primarily salts) dissolved in raw water on the degradation of heat transfer and fluid flow in a reactor core and debris bed. The experimental research will be constructed at KSU to investigate the long term coolability issues of raw water. One of the major constituents of the dissolved impurities of sea water is sodium chloride which will be tagged with ^{24}Na radioactive tracers to continuously monitor deposition rate at different time scales of these experiments such as hours to days. These radioactive salt tracers can be produced from neutron irradiation using MARK-II TRIGA reactor at KSU. Customized radiation detector arrays at KSU will be used for measuring these local deposition rates by measuring the changes in counts at different spatial locations. The neutron imaging, x-ray imaging and high speed visual imaging systems at KSU will be used to simultaneously obtain void fraction and two-phase flow images. Debris bed cooling experiments with raw water (with dissolved salts) will be performed using sintered metallic porous solids and metallic particles with wide range of particle size distributions to simulate inhomogeneous permeability of the ex-vessel debris bed. Decay heat inside the debris bed will be experimentally simulated using inductive heating. Flow and temperature profile measurements throughout the bed will be performed using optical fiber based probes. The experimental data for localized salt deposits, local void fraction, distributed temperature measurements, water and vapor flow, and local heat transfer will improve understanding and significantly reduce the uncertainty in safety analysis. Presenting correlations as to the effects of raw water on heat transfer and fluid flow is another outcome. Correlations will be published and available for incorporation into beyond design basis accident codes (e.g. MELCOR and MAAP).