Assessment of Corrosion Resistance of Candidate Alloys for Accident Tolerant Fuel Cladding under Reactor Conditions

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ABSTRACT:

The development of accident tolerant fuels (ATF) is aimed at avoiding the situation that occurred at Fukushima in 2011. In that station blackout condition, rapid oxidation of the Zircaloy cladding resulted in a highly exothermic zirconium-steam reaction. The rapid oxidation produced hydrogen, which later combusted and caused damage to the secondary containment. To avoid such occurrences in LWRs, the ATF program was initiated to focus on the replacement of zirconium-based alloys with materials that exhibit slower steam oxidation kinetics. In particular, iron-based alloys APMT, T91, HT9, nanostructured ferritics 14YWT, MA956 and new, higher Cr containing Fe-Cr-Al nanofeatured alloys as well as Fe-Cr-Al coatings are attractive in that they are not as reactive as zirconium, they have greater strength, and they are very resistant to stress corrosion cracking.

However, their general corrosion resistance is borderline, and more importantly, no data exists on whether the iron-base alloys being considered for fuel cladding for ATF fuel are susceptible to irradiation-accelerated corrosion. There is also not enough understanding of the mechanisms by which such corrosion rates are accelerated to be of any predictive value to the ATF program. These alloys have to withstand the rigors of normal reactor conditions before their accident-tolerance can be of any use. Therefore the objective of this research is to assess the corrosion behavior of ATF candidate iron-based alloys under normal LWR operating conditions consisting of *high temperature*, *relevant water chemistry* and *irradiation*.

The Principal Investigators David Bartels and Gary Was have developed accelerator-based facilities, which are capable of addressing the issue of irradiation-accelerated corrosion (IAC) of steel, including ATF candidate alloys. The window between the accelerator high vacuum and the high pressure aqueous corrosion cell also serves as the sample through which 3.2 MeV protons pass at University of Michigan, inducing both displacement damage at the surface of the sample in contact with the water, and radiolysis of the water layer near the sample. The complementary system at Notre Dame Radiation Laboratory uses 1-3MeV electrons, resulting in radiolysis of the water, but no displacement damage in the sample. These two systems are used in a coordinated fashion to separate the effects of radiolysis and displacement damage in the corrosion process. Susceptibility to IAC can be quickly assessed without generating radioactive samples, which are much more difficult and expensive to handle.