Early Hydrogen Water Chemistry in the Boiling Water Reactor: Industry-First Demonstration

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ABSTRACT

Hydrogen injection into the BWR feedwater during power operation has resulted in significant IGSCC reductions. Further, noble metal application (NMCA) during shutdown or On-line NobleChem™ (OLNC) during power operation has greatly reduced the required hydrogen injection rate by catalyzing the hydrogen-oxygen reaction on the metal surfaces, reducing the electrochemical corrosion potential (ECP) at operating temperature to well below the mitigation ECP of -230 mV (SHE) at reactor water hydrogen to oxygen molar ratios of ≥2. Since IGSCC rates increase markedly at reduced temperature, and the potential for crack initiation exists, additional crack mitigation was desired. To close this gap in mitigation, the EPRI BWR Startup ECP Reduction research and development program commenced in 2008 to undertake laboratory and feasibility studies for adding a reductant to the reactor water system during startups. Under this program, ECP reductions of noble metal treated stainless steel sufficient to mitigate IGSCC at startup temperatures were achieved in the laboratory in the absence of radiation at hydrogen, hydrazine and carbohydrazide to oxygen molar ratios of ≥ 2, ≥1.5 and ≥0.7, respectively. Based on the familiarity of operating BWRs with using hydrogen, a demonstration of hydrogen injection during the startup at an actual BWR using noble metals was planned. This process, named EHWC (Early Hydrogen Water Chemistry), differs from the HDS (Hydrogen During Startup) approach that has been successful in Japan in that HDS injects sufficient hydrogen for bulk oxidant reduction whereas EHWC injects a smaller amount of hydrogen, sufficient to achieve a hydrogen:oxidant molar ratio of at least two at noble metal treated surfaces.

The industry-first EHWC demonstration was performed at Exelon's Peach Bottom 3 nuclear power plant in October 2011. Prior to EHWC, Peach Bottom 3 had one NMCA (October 1999) and five annual OLNC applications (starting in 2007). Like all other U.S, BWRs, Peach Bottom 3 uses a mechanical vacuum pump (MVP) to draw initial condenser vacuum during heatup to approximately 5% power and its operation is restricted to <4% H2 in the gas/vapor stream. Acceptance criteria established for the EHWC demonstration were RWCU Inlet H_2/(Tot. Oxidant) Molar Ratio ≥2 and MVP %H2 <4% (gas + vapor).

Temporary equipment was installed for the EHWC demonstration to inject hydrogen gas into the reactor recirculation system through an existing sample line and into the feedwater system through a pressure sensing line during the startup evolution. Hydrogen was supplied from compressed gas cylinders in the reactor building and the existing hydrogen water chemistry (HWC) supply station in the turbine building. Temporary equipment was also used to admit air into the MVP suction stream to dilute injected H_2 gas and special equipment was designed and installed to monitor the $\%H_2$ in the MVP discharge stream. Pt and Ag/AgCl electrodes were available in the mitigation monitoring system (MMS) and extensive plant thermal-hydraulic and chemistry data were collected during the EHWC startup. The Peach Bottom 3 EHWC demonstration was performed safely without impacting the plant startup evolution. The EHWC acceptance criteria were met at low hydrogen injection rates. The results provide the basis for BWRs that have applied noble metals to design an EHWC process to mitigate IGSCC during plant startups effectively and safely while the MVP is in service. Plans for implementing EHWC across the Exelon BWR fleet are discussed.