U.S. BWR CONDENSATE POLISHING OPTIMIZATION

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Water chemistry in U.S. Boiling Water Reactors (BWRs) has been significantly improved by optimizing the application of ion exchange resins in the CP (condensate polishing) system. EPRI has monitored and supported CP improvements to meet water chemistry goals given in the BWR Water Chemistry Guidelines, particularly those for IGSCC (intergranular stress corrosion cracking) mitigation of reactor internals and piping, to minimize fuel risk due to corrosion and crud deposits and to control chemistry for radiation field reduction.

All thirty-five U.S. BWRs are designed with 100% condensate polishing. Most plants were originally designed with either DB (deep bed) condensate demineralizers or F/D (filter demineralizers). DBs employed mixed beds of bead ion exchange resin and operated with external chemical regeneration using sulfuric acid and sodium hydroxide. F/Ds use mixtures of powdered ion exchange resin that are precoated on filter septa. The original selection of DB or F/D was mainly based on the main condenser cooling water total dissolved solids concentration.

Chemical regeneration of DB resins was abandoned in the 1980s in favor of resin replacement based on ionic loading, mass transfer kinetics or reactor water quality. Design and operating changes were implemented in several steps. All DBs use gel styrene-divinylbenzene cation and anion exchange resins based on higher volume capacities than macroporous resins. Standard porosity anion exchange resin is used, and cation exchange resin crosslinkage has been gradually increased from 8% to 14 – 16%. Most CP systems with DBs have been retrofitted upstream full-flow filtration, avoiding the need for periodic external resin cleaning to remove accumulated iron crud. The DB can now operate without disturbing the ion exchange zone over the entire useful life of the bed, thus improving effluent quality. Other changes that have improved performance include; use of cation and anion resin with particle sizes that are much smaller than original resins, increasing film diffusion limited ion exchange kinetics; elimination of cation resin heels that contribute to sulfur impurities from cation resin decomposition; improvements in flow distribution within the DB vessel; use of anion resin underlays, which act as effective traps for sulfur impurities in the neutral pH condensate chemistry environment of the BWR; optimization of cation:anion ratio of the mixed resin. Overall industry and plant-specific examples of feedwater and reactor water chemistry improvement trends with DBs are presented.

Similarly, F/D system design and operation has been improved to optimize BWR water chemistry. Normally gel cation and anion exchange resins that are size-reduced by mechanical grinding are applied as a flocked mixture to porous septa surfaces to form a resin layer that is approximately 0.2 – 0.3 inches thick. Septa are installed in the F/D vessel in either a bottom or top tubesheet configuration. Although the total ion exchange capacity is much lower than in DBs, the kinetics are much faster due to the small mean particle size, so very high removal efficiencies of influent ionic impurities can be achieved. The precoat support septum design, which is key to achieving high utilization of the available ion exchange capacity, has evolved from original stainless steel mesh and yarn wound types to upright pleated and dual-media types (inner pleats with outer yarn windings or melt-blown layer). Salt challenge testing has been used to compare the effects of septum design ion exchange capability, which has been found to vary based on ion exchange resin and radial flow flux distributions. Changes that have improved F/D filtration and ion exchange performance include; powdered resin pre-mixes that may incorporate inert fibers; pleated septa media for insoluble iron crud removal; improved F/D vessel internal flow distribution for bottom tubesheet designs; improved septa attachment hardware to reduce the potential for resin leakage. Overall industry and plant-specific examples of feedwater and reactor water chemistry improvement trends with F/Ds are presented.

As shown in Figure 1, U.S. BWR fleet average feedwater iron and reactor water sulfate decreased by more than 50% from 2000 to 2010. This improvement was achieved mainly through optimization of condensate polishing system design and operation.

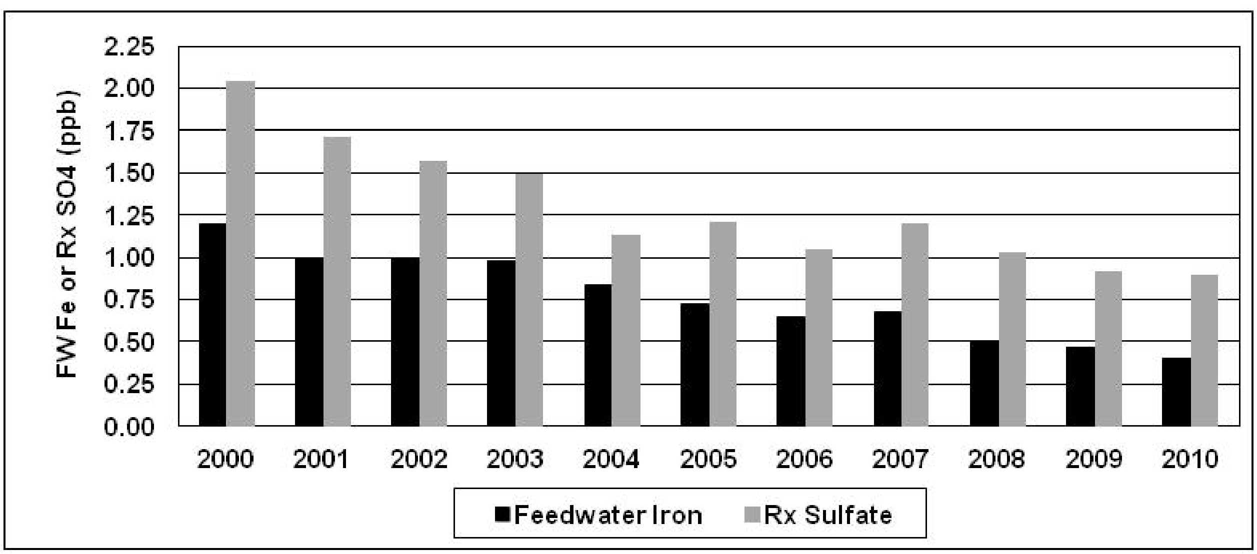

Figure 1. U.S. BWR Average Feedwater Iron and Reactor Water Sulfate, 2000 - 2010