N227. PWR Secondary Water Chemistry Guidelines

Corrosion damage in PWR steam generators has been a costly problem for the industry, necessitating more frequent inspection and repair and, in several plants, complete steam generator replacement. With many forms of corrosion now well controlled, chemistry guidelines for the secondary systems of PWRs are focusing on reducing intergranular attack and stress corrosion cracking at tube-tube support plate intersections in steam generators. These guidelines signal a new approach to plant chemistry programs -- an approach emphasizing proactive management and plant-specific optimization.

In December 1988, EPRI published "PWR Secondary Water Chemistry Guidelines, Revision 2" (NP-6239). The purpose of that document was to provide operational chemistry guidance to the electric utility industry for minimizing localized corrosion in steam generators and turbines. Since 1988, utility conformity to the guidelines on impurity values has been excellent, with most steam generator blowdown concentrations at or below 10% of the guideline values.

Many forms of corrosion have affected steam generator performance over the years. The move to a slightly alkaline, reducing water chemistry has eliminated most of these problems, and the dominant issues in PWR secondary systems today are intergranular attack (IGA) and stress corrosion cracking (SCC) of steam generator tubing at crevices formed by tube-tube support plate intersections. Despite the good performance of plant chemistry programs, there has recently been a rapid increase in IGA/SCC, as indicated by data on the sleeving or plugging of damaged steam generator tubes. There have been some isolated instances if IGA/SCC in once-through steam generators, but of primary concern are occurrences in recirculating steam generators.

Chemistry To Control IGA/SCC

Recent research has focused on understanding the causes and growth patterns of IGA/SCC. One significant factor is crevice chemistry, especially electrochemical corrosion potential (ECP) and pH. Given that the total concentration of impurities in feedwater has decreased, the ability of a small imbalance of one impurity (e.g., sodium) to affect crevice pH has increased. This is believed to be one of the reasons for the increasing incidence of IGA/SCC.

There are essentially three approaches to controlling crevice corrosion, at least two of which will be necessary at most PWRs with susceptible materials. The first approach focuses on cleanliness: avoiding the buildup of sludge and minimizing the ingress of ionic impurities (particularly lead) that accelerate attack. Sludge accumulates in low- and restricted-flow areas -- at tube-tube support plate intersections, in tube-tubesheet crevices, and on top of the tubesheet. Aggressive impurities then concentrate in these crevices and sludge piles, leading to IGA/SCC problems.

Sludge is composed of corrosion products (primarily ion oxides) released from the construction materials used in the low-temperature parts of the secondary system, such as the moisture separator drain reheaters. This type of corrosion is reduced by a factor of about 10 for each 1-unit increase in feedwater pH. Major advances in pH control are occurring at this time. The ammonia all-volatile treatment (AVT) has been replaced by morpholine in nearly half the PWRs in the U.S., and testing of ethanolamine (ETA), which appears to be superior in several respects to morpholine, started in 1992 at three plants.

As noted above, the continuing improvement in feedwater quality has had the undesirable effect that even small impurity increases cause much bigger swings in crevice pH than in earlier times, when the overall mix of impurities buffered the system. The second approach to reducing crevice corrosion therefore is to control the cation/anion balance, particularly by avoiding caustic conditions. This approach, which has been adopted by several U.S. plants and by most Japanese plants, involves reducing sodium ingress, measuring hideout return to determine actual crevice chemistry, and, if necessary, increasing chloride concentrations slightly.

The third approach to crevice corrosion control is to add inhibitors to the feedwater to reduce the effects of aggressive species present in the crevice environment. Boric acid provides some buffering, thereby helping to avoid extremely caustic conditions, but a more effective additive would be desirable. In laboratory tests sponsored by EPRI, titanates have greatly reduced IGA/SCC, with no identifiable adverse effects. qualification testing on titanates is continuing, and the first plant tests are planned for 1993.

Taken from, "PWR Secondary Water Chemistry Guidelines," by Christopher J. Wood, EPRI Journal, March 1993, pp. 38-41.