B.12 "PWR Secondary Water Chemistry Guidelines,"
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Introduction

The sixth revision of the PWR Secondary Water Chemistry Guidelines, published in 2004, describes an effective, state-of-the-art program from which a utility can develop an optimized program for their plant. Previous revisions of these Guidelines have identified a detailed water chemistry program that was deemed to be consistent with the then current understanding of research and field information. Each revision, however, has recognized the impact of these *Guidelines* on plant operation and has noted that utilities should optimize their program based on a plant-specific evaluation prior to implementation. To assist in such plant-specific evaluations, Revisions 4 and 5, issued in 1996 and 2000, respectively, provided an increased depth of detail regarding the corrosion mechanisms affecting steam generators and the balance of plant, and provided additional guidance on how to integrate these and other concerns into the plant-specific optimization process. Revision 6 retains the format of Revisions 4 and 5, and adds to the detailed information contained in these revisions.

Background

The main thrust of the secondary guidelines has always focused on controlling intergranular stress corrosion cracking of steam generator tubing. Successive revisions have tightened impurity limits, and have added recommendations to control sludge build-up using amines and crevice corrosion through molar ratio control. Future additions will probably consider the use of polyacrylic dispersants to minimize sludge deposition.

A committee of industry experts—including utility specialists, nuclear steam supply system vendor representatives, Institute of Nuclear Power Operations representatives, consultants, and EPRI staff—collaborated in reviewing the available data on secondary water chemistry and secondary cycle corrosion. From these data, the committee generated water chemistry guidelines that should be adopted at all PWR nuclear plants. Recognizing that each nuclear plant owner has a unique set of design, operating, and corporate concerns, the guidelines committee developed a methodology for plant-specific optimization.

This sixth revision of the *PWR Secondary Water Chemistry Guidelines*, endorsed by the utility executives of the EPRI Steam Generator Management Project, represents another step in maintaining proactive chemistry programs to limit or control steam generator degradation, with consideration given to corporate resources and plant-specific design/operating concerns.

Key Points and Technical Issues

Revision 6 of the *PWR Secondary Water Chemistry Guidelines*—which provides recommendations for PWR secondary systems of all manufacture and design—includes the following chapters:

Chapter 1 identifies Management Responsibilities. It also describes which elements of the *Guidelines* are mandatory and "shall" requirements under NEI 03-08, Guideline for the Management of Materials Issues, (consistent with NEI 97-06) and which are recommendations. The only mandatory requirement is to have a Strategic Water Chemistry Plan. "Shall" requirements include the Action Level 1, 2 and 3 control parameters and responses and the hold parameters in the control tables of Chapters 5 and 6, including both values and monitoring frequencies for these parameters. The balance of the guidance elements provided in the *Guidelines* are recommendations.

Chapter 2 presents a compilation of corrosion data for steam generator tubing and, to a lesser extent, balance-of-plant materials. It is not intended to relate operational bulk water chemistry to the corrosion phenomena, which is covered in Chapter 3. The corrosion data presented in Chapter 2 serve as the technical bases for each of the specific parameters and programs detailed in the balance of the document. Chapter 2 was revised to reflect recent research results regarding specific impurity effects on IGA/SCC, the effects of hydrazine on flow accelerated corrosion, and regarding the effects of amines on secondary side deposition processes.

Chapter 3 discusses the role of the concentration processes in the various locations of the steam generator and the chemistry "tools" available for modifying the resulting chemistry within these concentrating regions. It briefly identifies the supporting aspects of and the considerations for adopting these chemistry regimes. It refers the reader to more detailed documents for application of the chemistry strategies. The treatment of deposit control practices was significantly modified in Chapter 3 to reflect current practices and currently available methods. Chapter 3 also contains an expanded discussion on thermal performance issues, and new sections on the loss of hydrazine scenario and startup oxidant control.

Chapter 4 presents a detailed methodology for performing the plant-specific optimization that can be used to develop a modified chemistry program that satisfies site-specific concerns. Chapter 4 also presents example startup and operating chemistry parameters and limits that can be used as a starting point for site-specific evaluations. The main discussion of integrated exposure was relocated from Appendix A to Chapters 4 and 7, and the discussion was revised to reflect its removal as a diagnostic parameter from Chapters 5 and 6. Chapter 4 was also revised to include a list of items that should be covered in strategic water chemistry plans.

Chapters 5 and 6 present water chemistry programs for recirculating steam generators (RSGs) and once-through steam generators (OTSGs), respectively. These are the chapters most frequently referred to by chemistry personnel. The tables contained within these chapters provide boundaries of the envelope within which plant-specific optimization should occur.

Chapter 5 was revised to incorporate additional guidance regarding control of wet layup during short outages. The condition to which plants should go to as part of an Action Level 3 response was changed to "<5% power" from "hot or cold shutdown." The control tables for RSGs in Chapter 5 were thoroughly reviewed and edited. Some of the more significant changes to the tables were:

- Inclusion of Action Level 2 and 3 actions for loss of hydrazine.
- Addition of a requirement that plants reduce power to below 5% power if sodium, chloride or sulfate exceed 250 ppb, or if they exceed 50 ppb for more than 100 hours, while between 5% and 30% power.
- Reduction in the blowdown impurity level for sodium at the 30% power hold from 20 to 10 ppb, and addition of an explicit recommendation that plants achieve sodium, chloride and sulfate blowdown concentrations below their respective Action Level 1 concentrations prior to exceeding 30% power.

- Additional guidance was added such that plants are no longer required to go to Action Level 3 as long as the impurity concentrations remain below Action Level 2 values.

- Deletion of integrated exposure as a diagnostic parameter, and inclusion of lead and integrated corrosion product transport as diagnostic parameters.

- Addition of a footnote to allow reduced frequency for sampling for copper for plants that are copper free or have confirmed low levels of copper transport (<20 ppt).

Chapter 6 was revised to incorporate additional guidance regarding control of wet layup during short outages. The Action Level 3 response was modified to indicate that there may be some circumstances under which plant shutdown may not be necessary, and to provide an initial two-hour period with impurities over the Action Level 3 limit (but less than 20 ppb) before shutdown is required. Some of the main changes to the OTSG control tables in Chapter 6 were:

- Inclusion of Action Level 2 and 3 actions for loss of hydrazine.

- Deletion of integrated exposure as a diagnostic parameter, and inclusion of integrated corrosion product transport as diagnostic parameters.

- Addition of guidance indicating that monitoring moisture separator drain concentrations of sodium and chloride is the preferred method to monitor these species, as opposed to monitoring them directly in the feedwater.

- Addition of a footnote to allow reduced frequency for sampling for copper for plants that are copper free or have confirmed low levels of copper transport (<20 ppt).

- Addition of a clarifying note indicating that silica limits are provided to protect the turbines and not the steam generators, and therefore do not fall under the purview of NEI 97-06.

Chapter 7 provides information on data collection, evaluation, and management. This chapter covers use of *EPRI chemWORKS™* modules for evaluating plant data and predicting high-temperature chemistry environments throughout the cycle. Chapter 7 was revised to delete tables detailing sampling data requirements, to add more guidance regarding hideout returns, species to analyze in deposits, and integrated exposure evaluations, and to add a new section regarding effectiveness assessments. A discussion of lead sampling and additional recommendations on corrosion product transport sampling was also added.

Appendix A provides detailed guidance with regard to use of the integrated exposure concept, for example ppb*days. This appendix was created to demonstrate how some plants use integrated exposure in practice. Three plant documents (or summaries of plant documents) are presented, which describe different methodologies for use of integrated exposure.

Appendix B provides a review of PWR steam chemistry considerations. Steam chemistry is controlled in power plants to prevent or control deposition of impurities on turbine blades, to minimize erosion of turbine blades and to control general and localized corrosion of turbine blades and discs, cross over piping and extraction lines. In well-operated nuclear plants, the major consideration for steam chemistry control is the environmentally assisted cracking of turbine blade/disc attachments and FAC of piping in two-phase regions of the BOP. The latter consideration is addressed through pH control by organic amines and/or ammonia based AVT. This revision of the *Guidelines* continues the approach of helping utilities maintain a proactive chemistry program to limit or control steam generator degradation while taking into consideration limits on corporate resources and plant-specific design/operating concerns.

It is recognized that a specific program applicable to all plants cannot be defined due to differences in design, experience, management structure, and operating philosophy. However, the goal is to maximize the availability and operating life of major components such as the steam generator and the turbine. To meet this goal, an effective corporate policy and water chemistry control program are essential and should be based upon the following:

- A recognition of the long-term benefits of, and need for, avoiding or minimizing corrosion degradation of major components.
- Clear and unequivocal management support for operating procedures designed to avoid this degradation.
- Adequate resources of staff, equipment, funds, and organization to implement an effective chemistry control policy.
- An evaluation of the basis for each chemistry parameter, action level and specification, as well as those of similar guidelines.
- Management agreement at all levels, prior to implementing the program, on the actions to be taken in response to off-normal water chemistry and the methods for resolution of conflicts, and unusual conditions not covered by the guidelines.
- Continuing review of plant and industry experience and research and revisions to the program, as appropriate.
- A recognition that alternate water chemistry regimes, if used, should not be a substitute for continued vigilance in adherence to the guidelines.

References for B.12

[1] "PWR Secondary Water Chemistry Guidelines," Revision 6, EPRI Report 1008224 Electric Power Research Institute, 2004.

[2] R.L. Jones, "Mitigating Corrosion Problems in LWRs via Chemistry Changes," Power Plant Chemistry, pp663-669, November 2004.

[3] K. Fruzzetti, "A Review of EPRI PWR Water Chemistry Guidelines," International Conference on Water Chemistry of Nuclear Reactor Systems, San Francisco, October 2004.