2010 State of the Fleet Assessment of Flow-Accelerated Corrosion Program Effectiveness

State of the Fleet

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Technical Update, March 2011

EPRI Project Manager

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ACKNOWLEDGMENTS

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This report describes research sponsored by EPRI.

EPRI acknowledges the utilities that hosted these assessments and the utility engineers who assisted in the assessment efforts. The contributions of Bo Clark and David Smith of EPRI are also acknowledged.

This publication is a corporate document that should be cited in the literature in the following manner:

2010 State of the Fleet Assessment of Flow-Accelerated Corrosion Program Effectiveness: State of the Fleet. EPRI, Palo Alto, CA: 2011. 1022607.

PRODUCT DESCRIPTION

Flow-accelerated corrosion (FAC) is a degradation mechanism that attacks piping and equipment in nuclear power plants. Because of the numerous problems caused by FAC, nuclear utilities maintain programs to control its harmful effects. These programs generally consist of a combination of analysis, inspections, and repairs. The Electric Power Research Institute (EPRI) has been a leader in supplying the technology to support these tasks.

Recent experience, particularly in foreign plants, has once again shown that technology is not enough to solve the problem of damage caused by FAC. Rather, program management failures have been responsible for at least two recent FAC-caused failures.

In light of the importance of the programmatic aspects of FAC programs, five assessments of utility FAC programs were made using host utility personnel, an outside utility expert, and a representative of EPRI. This report documents the results of these assessments, which were a continuation of similar assessments made by EPRI in 2009.

Results and Findings

This report describes the results of the five assessments and presents generic recommendations for program improvements. This report should benefit both FAC engineers as well as plant management by providing items to improve the efficiency and effectiveness of FAC programs. The participating utility programs received a detailed assessment report specific to their sites.

Challenges and Objectives

FAC programs require constant attention to avoid costly problems. Managing FAC programs has, at times, been difficult. FAC engineers and their management will benefit from reading this report because it will provide information that will help them to compare their programs with those of the rest of the industry. Recent experience has confirmed that inattention to the programmatic control of FAC programs has led to costly and dangerous conditions.

Applications, Value, and Use

Utility management is encouraged to continue to assess and improve their FAC programs to avoid situations that are far more expensive to correct than to prevent.

EPRI Perspective

The EPRI programmatic guidance, predictive software, focused inspections, effective water treatments, and proactive repairs and replacements remain at the core of the approach used in FAC programs in the United States. The importance of optimizing FAC programs is an important part of EPRI’s continuing efforts in this area. Such optimization is especially timely in light of economic pressures on utilities along with schedule pressure to limit the length of refueling outages.

Approach

A sample of five U.S. nuclear sites was selected, considering utility structure, plant size, and plant type. These five sites were visited and their FAC programs assessed using a combination of host utility procedures and a CHECWORKS™ Users Group position paper. The results of these assessments as well as recommendations for other nuclear units are described in this report.

Keywords
Flow-accelerated corrosion
FAC
Inspection programs

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1
INTRODUCTION

1.1 Flow-Accelerated Corrosion

Flow-accelerated corrosion (FAC) is a degradation mechanism that attacks carbon steel and low-alloy steels in power plant environments. FAC has been responsible for many leaks and ruptures in nuclear and fossil power plants. In several instances, FAC related ruptures have caused fatalities. In many other cases, degradation caused by FAC has required extensive replacements of damaged piping and components (e.g., feedwater heater shells). *Flow-Accelerated Corrosion in Power Plants*, TR-106611-R1 [1] is a compendium of information on FAC including examples of industry experience.

1.2 Utility Programs to Protect against FAC

Prior to 1986, there were limited programs in place at nuclear utilities in the US to protect against FAC. In December 1986, there was a rupture in the condensate system at Surry Unit 2. This rupture resulted in four fatalities and extensive plant damage.

As a result of this accident, both the nuclear utilities and their regulators began to pay much greater attention to FAC. In 1989, the US Nuclear Regulatory Commission issued a Generic Letter requiring US nuclear plants to have inspection programs in place to protect high energy piping systems against degradation caused by FAC, United States Nuclear Regulatory Commission, Generic Letter 89-08 [2].

1.2.1 Millstone Unit 3

In December 1990, there was a simultaneous rupture of two lines in the heater drain system at Millstone Unit 3 [1]. Post accident investigations revealed that the FAC program at Millstone 3 had serious programmatic deficiencies. As a result of this finding, EPRI and CHUG (CHECWORKS™ Users Group) sponsored a limited number of plant visits to ascertain the state of a sampling of utility programs. This work was subsequently expanded into visits to most of the nuclear utilities in the United States.

1.2.2 NSAC-202L

Based on a desire to capture the results of the plant visits a "best practices" document was drafted. This document underwent an extensive review process including multiple reviews by the CHUG membership and a final review by the NRC. The resulting document, known by its original issue number – NSAC-202L, has been revised three times. The latest revision was issued in 2006, *Recommendations for an Effective Flow-Accelerated Corrosion Program: TR-1011838 (NSAC-202L-R3)*. EPRI, Palo Alto, CA: 2006. [3]

1.3 Present Work

As it has been more than 15 years since the original set of utility visits were performed, and since there have been many changes to utility programs, In 2009, CHUG recommended to EPRI that a review of the state of the industry be made. This work is described in *State of the Fleet Project to Assess Flow-Accelerated Corrosion Program Effectiveness: 1019177*. EPRI, Palo Alto, CA: 2009. [4]

As a result of this work, the CHUG membership again recommended further assessments. This report describes these assessments.

1.4 Outline of Report

This report is broken down as follows:

- Section 3 presents the criteria used to select sites to be visited and some details concerning the visits
- Section 4 presents a summary of the observations at each visit
- Section 5 presents recommendations and conclusions
- Appendices describe the assessment plans used for the visits.

2
OBJECTIVES

In general, the scope for each assessment team was to review the host utility's program to control flow-accelerated corrosion. The review encompassed the program to control FAC in both safety related and non-safety related systems, including large-bore piping and small-bore piping.

The main objectives of this work were to:

- Perform several plant visits to nuclear sites and assess the state of their FAC programs
- Examine assessment results and determine:
  - Best practices
  - Generic areas for improvement
  - Downward trends
- It is not intended for each assessment to be identical, but rather, to align with station needs and understand processes and practices in a way to benefit the CHUG Membership.
- Document these observations in a report including recommendations for actions by CHUG to improve the current practices.

3
PLANT VISITS

3.1 Selection Criteria

In the US nuclear fleet, there are differing numbers of units per sites, number of sites per utility and there are various management structures in place. To select a reasonable sample for the five sites to be visited, the following criteria were used:

- A mix of BWRs and PWRs
- A mix of single-sited utilities and multiple-sited utilities
- A mix of single-unit sites and multiple-unit sites

3.2 Plants Selected

Based on the above criteria as well as practical considerations including outage schedule and date of last self-assessment, the following sites were selected for visits:

- PWR-AA – a two-unit site operated by a utility with multiple sites. The utility has a corporate program that oversees the FAC program at all of their sites.
- BWR-BB – a two-unit site operated by a utility with multiple sites. The utility has a corporate program that oversees the FAC program at all of their sites.
- PWR-CC – a two-unit site operated by a utility with no other nuclear assets. There is no corporate program.
- PWR-DD – a two-unit site operated by a utility with multiple sites. The utility has a corporate program that oversees the FAC program at all of their sites. This is a similar situation as PWR-AA.
- PWR-EE – a single-unit site operated by a utility with no other nuclear assets. There is no corporate program. This is a similar situation to PWR-CC.

3.3 Visits

Plant visits were of either 2, 3 or 4 days duration. Typically, the assessment team was made up of one representative from EPRI, one or two utility peers, site assessors, and in some cases corporate participation.

Generally, the procedures of the host utility were used in conjunction with the CHUG Position Paper Number 7. [5]

The visits took place in the time period from August 2010 through February 2011.

4

OBSERVATIONS MADE DURING VISITS

This section will summarize some of the observations made at each site visited. The assessment plan presented in Appendix A was generally used in all of these assessments. Any significant deviations from this plan will be discussed individually.

4.1 PWR-AA

PWR-AA is a two-unit station which is operated by a multi-site utility with a corporate program. Corporate procedures govern the operation of the FAC program at all of the utility's sites. A four day assessment of the FAC program was conducted using an EPRI representative and an experienced FAC engineer from another utility. Host utility personnel including the corporate FAC coordinator, site FAC coordinator, site FAC backup and the FAC engineers from to other corporate sites were also included in the assessment team.

4.1.1 Executive Summary

The overall program to control FAC at PWR-AA is effectively organized, current with respect to required documentation and has maintained a high level of performance over recent years. Specifically, based on the information obtained during the assessment there is evidence that:

- The responsible program personnel are trained and well qualified.
- Personnel assignments have been stable and turnover has not been an issue.
- The program is consistent with the recommendations of EPRI report NSAC-202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program" which is the industry standard for FAC control.
- Critical program work is being independently reviewed, checked and documented.
- Degraded piping is being proactively and systematically replaced.
- The number of inspections being performed appears to be adequate based on the plant design, chemistry history, and current program status including the inspection and replacement history.
- Excellent communications exist within the Utility-AA FAC team.

The results of this assessment identified no Deficiencies, two Gaps, several Recommendations to support continued program improvements, and a number of program Strengths.

4.1.2 Deficiencies

No deficiencies were identified during the assessment.

4.1.3 Gaps

Two Gaps were identified during the Assessment.

1. Alloy sampling of piping materials for the detection of trace Chromium has been identified by EPRI and the FAC industry as an important factor in the identification of potential non-susceptible components. Moreover, INPO has recognized the use of this as a vital part of an effective FAC program and found it used widely in the industry. Although other Utility-AA plants have incorporated this practice, PWR-AA has not.
2. Improvements should be made to the overall process for tracking and documenting all operating experiences associated with the FAC program. Operating experience is a key element in the successful implementation of FAC programs and should be clearly evaluated, dispositioned, and documented. The FAC program governing document should include requirements with respect to expectations for updating the operating experience database.

4.1.4 Recommendations

In an effort to make the program even better, the following recommendations are offered to Utility-AA and PWR-AA for consideration:

1. The PWR-AA program owner has not attended the industry CHECWORKS™ User's Group (CHUG) meetings in several years. INPO has encouraged the station program owners to participate with the conferences, so that they are aware of findings at similar stations. The importance of participating with the industry cannot be overstated. Therefore, it is important that the FAC program engineer return to a consistent level of participation with the CHUG conferences.
2. PWR-AA has reviewed the CHECWORKS™ models for determination of remaining service life of components. For components with a relatively short remaining service life, they are selected for examination, or evaluated accordingly. Notably, some components have a Negative Time to Critical Thickness, or "Negative Time to T_{crit}." It is recommended that for lines containing components with a Negative Time to T_{crit}, that a table be created with a comments field indicating how these were dispositioned. This may easily be tracked on a line-by-line approach.
3. PWR-AA has reviewed the CHECWORKS™ models for Line Correction Factors outside of the calibrated range of 0.5 to 2.5. A similar chart should be developed to show which modeled lines are outside of this range. A comments field can provide what actions have been taken to address whether or not further work is required to "calibrate" the line. INPO has identified documentation of this as an expectation, in recent evaluation of station FAC programs.
4. A formal plan should be developed to document all previous inspections of feedwater heater shells, the schedule for future inspections including the manufacturer information and the

basis for the timing of the inspections. This plan should be documented in the FAC Program Quarterly Health Report as a method of communicating to management.

5. A process for documenting the current status of the CHECWORKS™ models should be developed based on the vendor tech report that is provided as part of their periodic independent review. The resulting document should include an appropriate level of review and verification.
6. A process should also be developed for documenting updates and revisions to the Susceptible Non-Modeled program. The original vendor calculations could be used as a format for this process and include the appropriate level of review and verification. This expectation should also be captured in the program governing document.
7. The AltraFAC data evaluation sheets should be included in the outage reports and formally processes thru records. A clarification should be made to the program governing document with respect to the required information to include in the summary reports and outage reports.

4.1.5 Strengths

The following program Strengths were noted during the assessment:

1. Strong ownership of program. It is evident that the PWR-AA FAC program engineer, the Utility-AA corporate program owner, and the complete Utility-AA FAC team understand and embrace the responsibilities associated with their program.
2. There is strong evidence of management support for the program. This includes dedication of adequate personnel and resources to do the work, proactive replacements of worn components, and the past and current work to continually improve the program.
3. Key personnel are trained and knowledgeable in their area of responsibility, and there has been stability in the assignments. This stability also includes the site and corporate FAC program owner.
4. The program is consistent with the recommendations of EPRI report NSAC-202L-R3, “Recommendations for an Effective Flow-Accelerated Corrosion Program” which is the industry standard for FAC control.
5. Outage inspection scopes have been optimized during recent outages. The number of inspections performed is generally on the low side of industry averages due to the comprehensive evaluation of inspection data and the maturity of the overall program.
6. The Utility-AA FAC Team approach to outage activities is a unique and comprehensive process that provides absolute consistency to all major aspects of the program. Resources from corporate and the different sites are pulled together to perform scope reviews, prepare components for inspection, apply grid maps, perform NDE/UT data collection, and most importantly collaborate on the data evaluation process.
7. All Utility-AA FAC Team personnel are NDE/UT qualified. This supports not only the data collection process but provides an overall comprehensive understanding of the techniques and processes required for this critical phase of the program.

8. The FAC program procedure provides extensive details with respect to developing inspection plans and evaluation of the data collected. These two program processes have created some of the most significant challenges for new program owners and this detailed information will support any turnover or development of new program participates.
9. There are formal communication ties between the thermal performance engineers and FAC program owners. This process is incorporate in the procedures and ensures that plant issues relevant to the program are communicated, evaluated and documented.
10. The PWR-AA program has developed 10 year outage inspection scope plans. This process encourages long term planning and support for the program.
11. The Utility-AA CHECWORKS™ SFA models and basis documents are independently reviewed and updated every 3-4 years. The models are maintained as part of standard program processes but this independent review provides and additional level of detail and verification from an outside source. These reviews include all assumptions used in model development, chemistry and operational information changes, inspection data incorporation and wear rate analysis evaluations.

4.2 BWR-BB

BWR-BB is a two-unit station which is operated by a multi-site utility with a corporate program. Corporate procedures govern the operation of the FAC program at all of the utility's sites. A three day assessment of the FAC program was conducted using an EPRI representative and an experienced FAC engineer from another utility. Host utility personnel including three corporate FAC engineers, the current site FAC program owner, and the past site FAC program owner were also included in the assessment team.

Due to time limitations, this assessment focused on the program owner and key element sections of the self assessment guide and did not provide a detailed review of the CHECWORKS™ models or program interfaces. The observations followed the structure of the Corporate-BB's self-assessment guide and classify results into areas for improvement, performance deficiencies, recommendations, beneficial practices, and strengths.

4.2.1 Executive Summary

The overall program to control FAC at BWR-BB is effectively organized, current with respect to required documentation and has maintained a high level of performance even with a significant amount of turnover and transition. Specifically, based on the information obtained during the assessment there is evidence that:

- There is strong program ownership. The Corporate FAC program engineer for BWR-BB understands and embraces the responsibilities associated with their program.
- The program is consistent with the recommendations of EPRI report NSAC-202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program" which is the industry standard for FAC control.
- Degraded piping is being proactively and systematically replaced.

- The number of inspections being performed appears to be adequate based on the plant design, chemistry history, and current program status including the inspection and replacement history.
- There has been turnover in the BWR-BB corporate program owner and the BWR-BB site lead since 2008. This is not considered a significant issue but has created some minor roadblocks. The strength of program documentation, including a turnover checklist, has proven beneficial in this process but continued focus on documentation will be critical in managing transition issues.

The results of this assessment identified no areas for improvement, 4 performance deficiencies, several recommendations to support continued program improvements, 2 beneficial practices, and 4 program Strengths.

4.2.2 Areas for Improvement

No areas for improvement were identified during the assessment.

4.2.3 Performance Deficiencies

1. Alloy sampling of piping materials for the detection of trace Chromium has been identified by EPRI and the FAC industry as an important factor in the identification of potential non-susceptible components. Moreover, INPO has recognized the use of this as a vital part of an effective FAC program and found it used widely in the industry. BWR-BB has not incorporated alloy sampling into their FAC program inspection process.
2. The CHECWORKS™ model analysis runs are not currently segmented by temperature and flow regimes. The models are currently being revised by a support vendor to incorporate this recommendation.
3. There is currently no formal documentation for the evaluation of susceptible not-modeled lines. This is a significant aspect of any FAC program and should be clearly documented including a formal review process. All susceptible not modeled lines should be categorized with respect to their susceptibility and consequence.
4. Feedwater Heater shell inspections have been a key issue in recent INPO program evaluations. BWR-BB has not inspected all heater shells and there is no formal plan or appropriate management approval for these inspections. A formal overall inspection plan for feedwater heater shells should be developed, communicated to, and approved by management.

4.2.4 Recommendations

In an effort to make the program even better, the following recommendations are offered to Utility-BB and BWR-BB for consideration:

1. The BWR-BB program has an identified owner and backup but the responsibilities are not clearly specified in the program notebooks. It is recommended that the roles and responsibilities be clarified in the program documentation.
2. Not all program personnel have received CHECWORKS™ software training. Utility-BB corporate owns the models and has been trained but the site program participants have not been trained. Most industry program participants have attended the software training. It is recommended that all program personnel be trained in the use of the EPRI CHECWORKS™ software.
3. There is no FAC training provided for any of the program interface personnel from other groups (systems, operations, maintenance, etc.). Introductory training should be provided to interface personnel and the CHECWORKS™ User's Group (CHUG) has created a CBT for that purpose.
4. Revise procedures to incorporate an official requirement for adding inspection locations at the connections or change of materials interfaces. This appears to be the current practice but there is no procedural requirement.
5. The CHECWORKS™ model documentation did not include all plant heat balances used to specify the power level or uprate conditions. Documentation should be included for all power levels or uprate conditions to verify model inputs and ensure consistency. The additional heat balances have been located but need to be included in the documentation. The model documentation also needs to be updated to include all assumptions used in the modeling process.
6. All updates to the susceptibility analysis should include a checked or reviewed by signature and a revision log.
7. BWR-BB has reviewed the CHECWORKS™ models for Line Correction Factors outside of the calibrated range of 0.5 to 2.5. A chart or table should be developed to show which modeled lines are outside of this range and/or contain negative times to critical thickness. A comments field can provide what actions have been taken to address whether or not further work is required to "calibrate" the line or resolve the negative times to Tcrit. INPO has identified this documentation as an expectation in recent evaluation of station FAC programs.
8. There has been a significant amount of inspection coverage associated with orifices and control valves but there is no reference documentation with respect to completeness. BWR-BB should develop a list of orifice and control valves in FAC susceptible systems and the associated information should be documented in a retrievable format.
9. Repairs, replacements, and material upgrades are documented in FAC drawings and PNIDs but there may be some issues with the multiple materials used in the pipe specifications for a single line. Configuration control issues may arise without some additional controls applied. Utility-BB should ensure there is an appropriate feedback loop added to this process.

10. Improve the long range plan and strategy to be more forward looking in the inspection and replacement area. The plan should also include a better process for communicating to management with the possibility of using the health reporting process for communication.
11. Enhance the program health criteria to indicate that an assessment is required every 3 years to keep the program green.

4.2.5 Beneficial Practices

1. A one page data sheet has been developed for NDE that simplifies the process and contains all the information associated with the planned inspection.
2. The CHECWORKS™ Pass 2 analysis runs are compared before and after each outage to evaluate changes in the line correction factors and predicted times to critical thicknesses. This documentation is also included in the Outage Technical Package following the outages.

4.2.6 Strengths

The following program Strengths were noted during the assessment:

1. Strong ownership of program. It is evident that the Corporate FAC program engineer for BWR-BB understands and embraces the responsibilities associated with their program.
2. The FAC program documentation including the notebooks for Fleet, Site and individual Units contain all the program information needed for turnover and transition issues.
3. FAC Program Health Reporting process is very comprehensive and informative.
4. The Utility-BB CHECWORKS™ SFA models are independently reviewed and updated every 6 years or 3 operating cycles. The models are maintained as part of standard program processes but this independent review provides and additional level of detail and verification from an outside source. These reviews include all assumptions used in model development, chemistry and operational information changes, inspection data incorporation and wear rate analysis evaluations.

4.3 PWR CC

PWR-CC is a two-unit station which is operated by a utility with no other nuclear assets. There is no corporate program. Site procedures govern the operation of the FAC program at this site. A three day assessment of the FAC program was conducted using an EPRI representative and two experienced FAC engineers from other utilities. Host utility personnel including the site FAC program owner, and the backup FAC program owner were also included in the assessment team.

4.3.1 Executive Summary

The overall program to control FAC at PWR-CC is effectively organized, reasonably current with respect to required documentation and has maintained a high level of performance even with a significant amount of turnover and transition. Specifically, based on the information obtained during the assessment there is evidence that:

- There is strong program ownership as demonstrated by the availability of personnel.
- The program is consistent with the recommendations of EPRI report NSAC-202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program" which is the industry standard for FAC control.
- Excellent water chemistry has kept the rates of FAC low and the number of replacements low compared to most other PWRs.
- The number of inspections being performed appears to be more than adequate based on the plant design, chemistry history, and current program status including the inspection and replacement history.
- There have been several program owners at the plant site over the last ten years. This is not considered a significant issue but has created some minor roadblocks including out-of-date documentation. However, efforts have been underway to improve the state of the documentation.
- The program owner is trained and well qualified. A backup program owner has been identified, is being trained, and should be qualified before the next outage in the spring of 2011.
- Critical program work is being independently reviewed, checked and documented.

The results of this assessment identified no Areas for Improvement, three Performance Deficiencies, and one Gap, several Recommendations to support continued program improvements, and five program Strengths.

4.3.2 Areas for Improvement

No areas for improvement were identified during the assessment.

4.3.3 Performance Deficiencies

1. The CHECWORKS™ model analysis runs are not currently segmented by temperature and flow regimes. This situation leads to inaccurate line correction factors, and limited utility of the model. While the CHECWORKS™ underlying database appears to be good, lack of properly defined analysis runs coupled with very conservative component evaluations have lead to extremely conservative predictions.
2. The system susceptibility evaluation for both the modeled and un-modeled piping (including small bore piping) is out of date and should be revisited and probably revised.

3. While the station procedure calls for having "qualified" UT procedures, and while the NDE contractor has its own NDE procedures, there does not seem to be a mechanism in place for PWR-CC to review and approve the contractor's procedure.

4.3.4 Gaps

One Gap was identified during the Assessment.

Improvements should be made to the existing process for tracking and documenting all operating experiences associated with the FAC program. Operating experience is a key element in the successful implementation of FAC programs and should be clearly evaluated, dispositioned, and documented. The FAC program governing document should include requirements with respect to the expectations for updating the operating experience database.

4.3.5 Recommendations

In an effort to make the program even better, the following recommendations are offered to PWR-CC for consideration:

1. As the program documentation is in the process of being reviewed and updated, it is recommended that a gap analysis be prepared comparing the program documentation with NSAC-202L Revision 3, NRC Inspection Guidelines 49001 and the INPO EPG-06. This activity should help ensure that proper programmatic details are included in the program documentation.
2. There is no FAC training provided for any of the program interface personnel from other groups (systems, operations, maintenance, etc.). Introductory training should be provided to interface personnel and the CHECWORKS™ User's Group (CHUG) has created a CBT for that purpose.
3. A formal plan should be developed to document all previous inspections of feedwater heater shells, the schedule for future inspections including the basis for the timing of the inspections. This plan should be documented and communicated to management.
4. Revise procedures to incorporate a requirement for adding inspection locations at the connections or change of materials interfaces. This appears to be the current practice but there is no procedural requirement.
5. Alloy sampling of piping materials for the detection of trace Chromium has been identified by EPRI and the FAC industry as an important factor in the identification of potential non-susceptible components. Moreover, INPO has recognized the use of this as a vital part of an effective FAC program and found it used widely in the industry. Although other utility plants have incorporated this practice, PWR-CC has been slow to perform alloy measurements. It is therefore recommended that PWR-CC consider the increased use of alloy sampling.
   Note that as PWR-CC has the required instrumentation and a detailed chromium measurement procedure in place.

4.3.6 Strengths

The following program Strengths were noted during the assessment:

1. Strong ownership of program. It is evident that the FAC program engineer, the designated backup, and the complete the utility FAC team understand and embrace the responsibilities associated with their program.
2. The program is generally consistent with the recommendations of EPRI report NSAC-202L-R3, “Recommendations for an Effective Flow-Accelerated Corrosion Program” which is the industry standard for FAC control.
3. There is strong evidence of management support for the program. This includes dedication of adequate personnel and resources to do the work and the current efforts to update the program documentation and continue to meet industry standards.
4. The excellent water chemistry used during virtually all of units’ operation has kept the FAC rates to very low values. Thus, the inspection program can focus on the most susceptible areas in the plants.
5. The draft Outage Scope Development Guide, currently in the approval process and the Outage Summary Report summary report are both above industry norms.

4.4 PWR-DD

PWR-DD is a single-unit station which is operated by a multi-site utility with a corporate program. Corporate procedures govern the operation of the FAC program at all of the utility’s sites. A three day assessment of the FAC program was conducted using an EPRI representative and an experienced FAC engineer from another utility. Host utility personnel including the corporate FAC engineer, the current site FAC program owner, the current program back-up engineer and a program owner from one of the other sites were also included in the assessment team.

4.4.1 Executive Summary

The overall program to control FAC at PWR-DD shows substantial recent improvements. Significant efforts have been focused on correcting program deficiencies noted during previous assessments or evaluations. The program contains all the key elements as defined in EPRI report NSAC-202L-R3 but as communicated in the performance deficiencies and learning opportunities could benefit from improvements in the area of documentation and retrieval. Specifically, based on the information obtained during the assessment there is evidence that:

- There is strong program ownership. The current program engineer is trained and well qualified and embraces the responsibilities associated with their program.
- The program is consistent with the recommendations of EPRI report NSAC-202L-R3, “Recommendations for an Effective Flow-Accelerated Corrosion Program” which is the industry standard for FAC control.
- Degraded piping is being proactively and systematically replaced.

- The number of inspections being performed appears to be adequate based on the plant design, chemistry history, and current program status including the inspection and replacement history.
- Critical program work is being independently reviewed, checked and documented.
- There is a planned turnover in program ownership and renewed focus on documentation will be critical in managing transition issues.

The results of this assessment identified no areas for improvement, 3 performance deficiencies, 6 learning opportunities, and 3 program Strengths.

4.4.2 Areas for Improvement

No areas for improvement were identified during the assessment.

4.4.3 Performance Deficiencies

1. Alloy sampling of piping materials for the detection of trace Chromium has been identified by EPRI and the FAC industry as an important factor in the identification of potential non-susceptible components. Moreover, INPO has recognized the use of this as a vital part of an effective FAC program and found it used widely in the industry. PWR-DD has not incorporated alloy sampling into their FAC program inspection process.
2. The CHECWORKS™ model documentation does not include critical reference information including necessary input and commonly used output reports. The current level of documentation does not provide a complete basis for the analysis that would be beneficial during program transition or turnover.
3. PWR-DD is not currently following their process for communicating, reviewing, and documenting leaking valves, malfunctioning steam traps, abnormal alignments or other issues that could affect piping degradation. These communication processes should be formalized and documented for all program activities including outage planning.

4.4.4 Learning Opportunities

In an effort to make the program stronger, the following learning opportunities are offered to PWR-DD for consideration:

1. Engineering and Training need to work together to formally implement introductory FAC training for program interface personnel (systems, operations, maintenance, etc.). There was a previous PER corrective action program item that was closed on this issue but the training is not being performed. The CHECWORKS™ User's Group (CHUG) has created a CBT for that purpose that can be easily incorporated into the training process.
2. The PWR-DD program engineer has reviewed the CHECWORKS™ models for Line Correction Factors outside of the calibrated range of 0.5 to 2.5 and components that have negative times to the critical thickness. A chart or table should be developed to show which modeled lines are outside of this range and/or contain negative times to critical thickness. A

comments field can provide what actions have been taken to address whether or not further work is required to "calibrate" the line or resolve the negative times to Tcrit. INPO has identified this documentation as an expectation in recent evaluation of station FAC programs.

3. Repairs, replacements, and material upgrades are documented in FAC drawings and PNIDs but there may be some issues with the multiple materials used in the pipe specifications for a single line. Configuration control issues may arise without some additional controls applied. PWR-DD should strengthen the design change review process for FAC associated issues and ensure there is an appropriate feedback loop added to this process.
4. The EPRI recommendations, design standard, and system susceptibility evaluation should be made consistent with respect to exclusion criteria. There were other inconsistencies noted with the exclusion criteria under section F for chromium content that need to be clarified with respect to replacement choice verses exclusion criteria.
5. Radiography (RT) has been used effectively during inspections of small bore piping on components in many parts of the industry. PWR-DD should re-evaluate with their NDE support teams the possibility of using RT for small bore inspections.
6. The long range planning information included in the Plant Health Committee presentation should be incorporated and maintained in the strategic plan section of the program health report.

4.4.5 Strengths

The following program Strengths were noted during the assessment:

1. PWR-DD Site Management decided to pro-actively replace all priority 1 and a significant portion of the priority 2 Susceptible Not Modeled lines in lieu of inspecting. Replacements were performed during the first 3 refueling outages.
2. The corporate team shares resources from site to site which provides consistency to all major aspects of the program. Resources from corporate and the different sites are pulled together to perform scope reviews, collaborate on the data evaluation process, and support model updates.
3. Corporate has developed their own access database to manage and provided site specific responses to internal and external operating experiences (OE). Any member of the FAC team can input OE and all sites are required to respond with respect to their applicability. Recent OE has also been incorporated into the program health reports.

4.5 PWR-EE

PWR-EE is a single-unit station which is operated by a utility with no other nuclear assets. There is no corporate program. Site procedures govern the operation of the FAC program at this site. A three day assessment of the FAC program was conducted using an EPRI representative and two experienced FAC engineers from other utilities. Host utility personnel including the site FAC program owner, and the backup FAC program owner were also included in the assessment team.

4.5.1 Executive Summary

The overall program to control FAC at the PWR-EE Plant is effectively organized, reasonably current with respect to required documentation and has maintained a high level of performance with a minimum amount of turnover and transition. Specifically, based on the information obtained during the assessment there is evidence that:

- There is strong program ownership as demonstrated by the availability of qualified personnel.
- The program is consistent with the recommendations of EPRI report NSAC-202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program" which is the industry standard for FAC control.
- Recent equipment changes have allowed improvements to the secondary water chemistry. These improvements have reduced the rates of FAC.
- The number of inspections being performed appears to be adequate based on the plant design, chemistry history, and current program status including the inspection and replacement history.
- The program documentation is comprehensive and is up-to-date.
- The program owner and program backup are trained and well qualified. Additionally, the former program owner has maintained his qualifications and is available if needed.
- Critical program work is being independently reviewed, checked and documented.

The results of this assessment identified no Areas for Improvement, no Performance Deficiencies, and no Gaps. Nine recommendations to support continued program improvements, and seven program Strengths are documented.

4.5.2 Areas for Improvement

No areas for improvement were identified during the assessment.

4.5.3 Performance Deficiencies

No performance deficiencies were identified during the assessment.

4.5.4 Gaps

No gaps were identified during the assessment.

4.5.5 Recommendations

In an effort to make the program even better, the following recommendations are offered to the PWR-EE Plant for consideration:

1. Alloy sampling of piping materials for the detection of trace Chromium has been identified by EPRI and the FAC industry as an important factor in the identification of potential non-susceptible components. Moreover, INPO has recognized the use of this as a vital part of an effective FAC program and found it used widely in the industry. PWR-EE has, in the past, conducted alloy measurements, but this practice has been virtually abandoned. The current program owner has instituted plans to reinstitute alloy measurements. This measure would strengthen the FAC program and should be adopted. CHUG Position Paper #5 should be consulted for more information.
2. The backup program owner has been fully qualified to the standards at PWR-EE; however, has not taken the EPRI course "FAC 201 – Flow Accelerated Corrosion for the Program Owner." It is recommended that she do so in the near future.
3. It is recommended that training in the programmatic aspects of FAC be prepared and given to supervisory personnel. A CHUG 2011 project was proposed to develop such training; however it is unlikely to be funded this year.
4. It is recommended that training be given to the program interfaces in the basics of FAC. The EPRI Computer Based Training module (*Computer-Based Training Module on Flow-Accelerated Corrosion (FAC) for non-FAC Personnel: 1013249,* EPRI, Palo Alto, CA: 2006) or equivalent is recommended.
5. CHECWORKS™ uses an open database. To fully realize the capabilities of the program, it is recommended that the program owner be trained in Microsoft Access.
6. Although the CHECWORKS™ model is being correctly used, it is recommended that the Pass 2 results be reviewed and documented. While it is recognized that some of these reviews are currently being done and informally documented, benefit would be obtained by formalizing this process. Included in this documentation would be: discussion of the value of the line correction factor, discussion of the scatter on the plots of predicted versus measured wear, and the presence of negative time to critical thickness.
7. Currently feedwater heater shells are inspected by measuring thickness on a predetermined grid. However experience has shown that local thinning areas (often where internal protuberances come near the shell wall) do occur. It is suggested that the inspection approach be modified to consider this possibility.
8. It is useful to include sketches of the inspection location on the NDE datasheets. Although there is a space on the form for such a sketch, this feature is not generally used.
9. Recent work sponsored by CHUG has shown that there is sufficient measurement uncertainties present to cause necessary re-inspections. To deal with this situation, CHUG has developed methods to reduce the conservatisms present in the analysis process. It is recommended that the Total Points Method be used to analyze components with more than two sets of inspection data to see if inspections can be deferred or eliminated.

4.5.6 Strengths

The following program Strengths were noted during the assessment:

1. Strong ownership of program. It is evident that the FAC program engineer, the designated backup, and the complete utility FAC team understand and embrace the responsibilities associated with their program. Further, the program is generally consistent with the recommendations of EPRI report NSAC202L-R3, "Recommendations for an Effective Flow-Accelerated Corrosion Program" which is the industry standard for FAC control.
2. There is strong evidence of management support for the program. This includes dedication of adequate personnel and resources to do the work and the current efforts to enhance the program.
3. There are current efforts underway to improve outage automation. These efforts include improving the inspection scoping process and evaluation process. These efforts include obtaining a post-processor to automate the processing of CHECWORKS™ results.
4. A complete validation of the CHECWORKS™ model is being conducted by an experienced FAC contractor.
5. An important part of the program owner's responsibility is conducting periodic FAC Program Oversight Meetings. This is an important mechanism for continuing communications between the program owner and the other involved parties.
6. A part of the documentation of the program is a desktop instruction manual which is a good practice and will assist any future program turnover.
7. Conservative re-inspection indices are used. This ensures that re-inspections will be conducted in a timely fashion.

5
RECOMMENDATIONS AND CONCLUSIONS

Based on the five visits performed, the following conclusions can be drawn:

- In general all the FAC programs observed are designed to follow NSAC-202L. All of the sites visited have mature programs in compliance with consensus industry standards.
- All sites visited have programs that cover large-bore modeled, large-bore not-modeled and small-bore components.
- Inspection coverage appeared adequate at all sites.
- The use of either custom or vendor supplied tools to assist in managing results from CHECWORKS™ SFA is becoming useful and effective.

Based on an assessment of these visits, the following recommendation is offered:

- Continued visits are recommended to seek out new good practices which would be of benefit to other plant owners and for continuous improvement of programs within the industry.

6 REFERENCES

1. Electric Power Research Institute, *Flow-Accelerated Corrosion in Power Plants*, TR-106611-R1, 1998.
2. United States Nuclear Regulatory Commission, Generic Letter 89-08, May 1989.
3. *Recommendations for an Effective Flow-Accelerated Corrosion Program (NSAC-202L-R3)*. EPRI, Palo Alto, CA: 2006. 1011838.
4. *State of the Fleet Project to Assess Flow-Accelerated Corrosion Program Effectiveness*. EPRI, Palo Alto, CA: 2009. 1019177.
5. CHUG Position Paper No. 7, "Self-Assessment Guidance to Support Flow-Accelerated Corrosion Programs," June 2007.
6. *Flow-Accelerated Corrosion Investigations of Trace Chromium,* EPRI, Palo Alto, CA: 2006. 1013249.
7. CHUG Position Paper No. 5, "Chromium Sampling," September 2006.

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APPENDIX: GENERIC ASSESSMENT PLAN USED

OBJECTIVES/SCOPE

The scope of this assessment is to review *XXXXX Company's* program to control flow-accelerated corrosion at the *XXXXX Site*. To the extent of available time, the objective of the assessment is to evaluate the overall program status or health by following the guidelines provided in CHUG Position Paper No. 7, "Self-Assessment Guidance to Support Flow-Accelerated Corrosion Programs", June 2007. This review will encompass the program to control FAC in both safety related and non-safety related systems, including large-bore piping and small-bore piping. An outline of the assessment methodology and associated questions is provided below.

FAC PROGRAM OWNER

- What resources are being allocated and are they sufficient to implement the program effectively?
  - Site, Corporate, Vendor
- Is management providing oversight to ensure the FAC program is being implemented effectively?
- Who is the program owner? Who has overall authority and responsibility?
- If a fleet-wide program is involved, does the fleet lead adequately communicate industry information to the site owners?
- Is personnel turnover causing a lack of continuity in knowledge or implementation?
- Are program backups identified and in place?
- How are interdepartmental communications specified and documented with respect to FAC issues?
- If outside contractors are used, does the program owner properly review (check) and understand the work being performed?
- Have all program personnel received EPRI CHECWORKS™ Software training?
  - Owner, Backup, Corporate
- Have all program personnel received EPRI FAC Program Owner Training?
  - Owner, Backup, Corporate
- Have personnel interfacing with the FAC program been trained on how FAC affects their responsibilities?
- Do you perform a regular review of plant leaks and valve leak-bys, and incorporate them into the inspection scope?

- Are plant personnel interviewed on a regular basis to identify abnormal plant alignments, etc?
- Are you involved in review of Design Changes? If so, what types of recommendations are made?
- Are trace alloy contents being measured for inspected components?
- How often are the program procedures and/or processes reviewed?
- Has any weld attack and/or entrance effect been seen?
- How many FAC-related leaks occurred during the last cycle?
- Is there evidence of continual improvement to the program and how is it measured?
- Is programmatic status effectively and periodically communicated to utility management (e.g., program health reports, etc.)

FAC PROGRAM ELEMENTS

Programmatic Procedures or Documents

- Is the FAC program well defined by a program document or procedure that has been recently reviewed for effectiveness?
- Are the roles and responsibilities of each person involved clearly defined?
- Are the current revisions of the corporate documents implemented at the Site?
- Are there appropriate procedures in place to control activities of the responsible groups?
- Is the FAC program part of or referenced in an Aging Management, Re-Licensing or Equipment Reliability program? Are these programs periodically updated with the latest FAC program information?
- Are FAC program documents, such as program drawings, program notebooks, evaluations, and procedures, up to date?

System Susceptibility

- Does a formal, comprehensive evaluation identify susceptible systems and lines?
- What criterion was used for susceptibility analysis?
- Is the program owner conducting interviews with plant operations/maintenance personnel to determine plant conditions that can affect FAC susceptibility (e.g., valve leak-by, abnormal system alignments, etc.) How are they communicated and documented?
- What has been done to locate vendor supplied piping?
- What has been done to locate historical replacements?
- What has been done to locate carbon steel pup pieces, nozzles, and safe ends in high chrome lines?
- How are small bore (2” and under) piping systems handled with respect to susceptibly and program inclusion?
- Was the system susceptibility analysis checked or independently reviewed by the appropriate personnel?

- Is the system susceptibility analysis documented properly?
- When was the Susceptibility Analysis last reviewed or updated?

Documentation

- Are the FAC procedures up to date with current revisions utilized?
- Are the FAC Predictive Analysis/Modeling tools up-to-date (e.g., latest version of CHECWORKS™)?
- Are NDE procedures up to date with current revisions utilized?
- How is the component inspection database maintained?
- Are the recent Outage Reports and/or Health Reports completed in a timely manner as prescribed in the procedure?
- Are the Basis Documents (CHECWORKS™ Models and Susceptible Non Modeled Reports) properly documented and up to date?
- Review at least one CHECWORKS™ System Run Definition to ensure that the documentation includes the necessary information. (References, Drawings, Output files, etc.)

CHECWORKS™ Model

- Which CHECWORKS™ version is being used?
- What is the basis for the Plant Heat Balance Diagram used in the CHECWORKS™ model?
- Are all components in the piping system included?
- Is there a basis for the assumptions used?
- Are all the system drawings included in the calculation package and marked appropriately?
- Has the plant undergone a power uprate and is it appropriately evaluated?
- Have cycle specific chemistry conditions been included in the model?
- Has the model been updated to include the projected operating hours till the next outage, current chemistry conditions and all recent inspection data?
- Have the Pass 2 analysis runs been updated?
- Have line correction factors been reviewed for each line or system, and the results considered in inspection plans? Are they documented?
- Are the analysis runs appropriately segmented by temperature and flow regimes?
- Do any of the analysis lines span both sides of valves where phase change may be occurring (e.g., heater drain line control valves)?
- Do any of the analysis lines span both sides of orifices where phase change may be occurring?
- Has your model been evaluated by a third party, e.g., EPRI, vendor, etc.?
- Has the model been reviewed/verified, documented and properly signed off?

Susceptible Not-Modeled (SNM)

- Is there a formal evaluation for susceptible not-modeled lines?
- Is there a basis for the assumptions used?

- What criterion was used to appropriately categorize the lines?
- Are all of the susceptible small-bore lines, whose failures could adversely impact personnel safety or force a plant shutdown, included in the FAC program? (Some level of inspection?)
- Are the system flow diagrams or drawings used included in the calculation package and marked appropriately?
- Has the SNM program been reviewed/verified, documented and properly signed off?

Inspection Planning

- Are the inspection locations being selected per best industry practice (for example, NSAC-202L) for modeled lines and susceptible-not-modeled lines?
- Are the Pass 1 and Pass 2 analysis models used in the selection process?
- Is a trending process using previous inspection results part of the selection process?
- Are recent and past industry events considered during the inspection planning?
- Are the susceptible components and piping downstream of all control valves and orifices covered in the program?
- Is the cross under piping inspected on a regular basis?
- Are the piping components in the area of replaced materials being included in the inspection program? (dissimilar metal connection areas)
- Is the component inspection list reviewed by someone other than the person who generated the list?
- Does the component inspection list contain the reason or logic for each component selection?
- Are there guidelines used for inspection sample expansion in the case of high or unexpected wear?
- Are inputs from other groups included in the inspection planning process? (e.g., Valve Group, Leak Repair History, Systems, Operations, etc.)
- Are the results of the inspection planning process formally documented?
- How far in advance of the outage is the inspection scope issued?
- How are emergent inspection scope additions handled pre-outage? Are emergent issues postponed to the following outage?

Performing Inspections

- Are there formal procedures for performing inspections?
- Is the origin of the grid appropriately marked to ensure repeatability of exam data?
- Are the markers being used for grid layout permanent enough to ensure repeatability?
- Does the grid layout cover the entire component?
- Is the grid size consistent with EPRI recommendations?
- Do the grid patterns extend 6” in the upstream (minimum) and downstream 2 pipe diameters (minimum), where appropriate?
- Are the NDE inspectors properly certified?
- Are the RT exams planned and conducted properly?

- Are baseline measurements taken on all components that are being replaced with susceptible material?
- Are suspect readings verified for accuracy?
- Are trace alloy contents being measured for inspected components?
- Are pictures or sketches used to aid partitioning?
- Is there a formal system for organizing and maintaining the inspection data files?
- Are inspection methods consistent with current best industry practice?

Data Evaluation

- Is there a formal process for Data Evaluation?
- Are the component wear calculations automated?
- Are the acceptance evaluations performed for each component documented and reviewed?
- Are appropriate safety margins used in calculating remaining component life?
- Are the inspection results compared to the model predictions?
- Are the computer models being updated with the inspection data in a timely manner?
- Are any changes in the operating parameters being considered in the data evaluation?
- Are there formal procedures or processes for documenting detailed evaluations performed by the Pipe Stress Group?
- Is the Stress Group providing minimum wall thickness values for components prior to the scheduled inspections?
- Is the communication between the FAC engineer and the Stress Analysis engineer concerning data evaluation documented properly?

Repair/Replacement Options

- Are repairs performed by a specific procedure or formal process?
- Is sample expansion comprehensive for components that do not satisfy acceptance criteria?
- Are external repairs of any type used?
- When internal weld repair is used, is the surface ground to the original contour and roughness?
- Are material upgrades or replacements performed using a formal process?
- Are material upgrades reviewed and approved by the appropriate engineering disciplines?
- How are repairs, replacements, and upgrades documented and communicated to appropriate groups?
- Are any lines designated as either carbon or stainless? Are replacements documented accordingly?

- It should be noted that material replacement may not be effective for erosive damage described in a recent EPRI report.[1] For these cases, repeated preventative maintenance or design changes to eliminate the problem may be needed.

Long Term Strategy

- Does the site being evaluated have an effective long term strategy in place? Has the Long Range Plan been submitted to and approved by management?
- Is the Long Range Plan part of a re-licensing document or commitment?
- Does the strategy focus on reducing the wear rates and/or replacement with FAC-resistant materials?
- Have the analytical models been updated to reflect current information, and used to evaluate long term options?
- Is the current plant chemistry or water treatment effectively used to control Flow Accelerated Corrosion? Is there a Long Range Plan for secondary side chemistry?
- Is there a goal for iron transport at monitored locations?
- Is there a long-term inspection plan for the feedwater heaters?
- Are system and chemistry changes reviewed and evaluated by the appropriate individual or department?
- Are inspection and replacement goals developed and documented for the next 3 to 5 years? The next 5 to 10 years?

Documentation

- Is the FAC program well defined by a program document or procedure that has been recently reviewed for effectiveness?
- Is the system susceptibility analysis defined, well documented, and up-to-date?
- How are the CHECWORKS™ Models documented?
- How is the Susceptible-Not-Modeled Program documented?
- How is the outage inspection plan documented?
- How are Outage Reports documented?
- How are inspections and data evaluations (e.g., wear calculations) documented?
- How is the history of all inspection locations documented?

Corrective Action Program/Industry Issues/OE

- Is the corrective action program being used to document program issues?
- Is the corrective action program database being reviewed for FAC-related issues, such as leaking valves and systems operating abnormally?
- Are program communications with the industry in regard to FAC issues sufficient?

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[1] *Recommendations for Controlling Cavitation, Flashing, Liquid Droplet Impingement, and Solid Particle Erosion in Nuclear Power Plant Piping Systems*: EPRI, Palo Alto, CA: 2004**.** 1011231.

- Is the FAC program owner actively involved in industry organizations, such as the CHECWORKS™ Users Group?
- Are operating experiences (both internal and external) being reviewed and considered for potential impact on the FAC program?
- How is Operating Experience identified for review? How is it tracked & how is it incorporated it into the inspection scope?

Audits/Assessments/Benchmarking

- Are audits, assessments, and benchmarking being scheduled and performed?
- When was the last program assessment or benchmarking performed?
- Were the results addressed and incorporated?

FAC PROGRAM OWNER AND INTERFACES

Thermal Performance Coordinator

- Have you received FAC training?
- What type of monitoring is performed to identify leaking valves and steam traps?
- Are all normally closed vent and drain lines to the condenser monitored?
- How often is the monitoring performed?
- Are the results quantified (e.g., lbm/hr or MWe losses)?
- How are the results documented?
- Are the results formally transmitted to the FAC coordinator?
- How many leaking valves and steam traps currently exist?
- Can you identify leaks to the condensers?

Stress Analysis

- Have you received FAC training?
- Are Tcrits for planned inspection locations being determined before the outage/inspection?
- ASME Section III and B31.7 Pipe
  - Are there any FAC susceptible ASME Class 1, 2 or 3 or B31.7 piping components?
    - If yes, are there formal stress results (e.g., computer output and stress reports) available?
    - If yes, what are the structural evaluation criteria for determining Tcrit?
    - If yes, what loads are considered when determining Tcrit? Are envelope loads used?
- B31.1 Large-Bore Pipe
  - Are there formal stress results (e.g., computer output and stress reports) available?
    - If no, how are component loads determined?
  - What are the structural evaluation criteria for determining Tcrit?

    - What loads are considered when determining Tcrit? Are envelope loads used?
- B31.1 Small-Bore Pipe
    - Are there formal stress results (e.g., computer output and stress reports) available?
        - If no, how are component loads determined?
    - What are the structural evaluation criteria for determining Tcrit?
    - What loads are considered when determining Tcrit? Are envelope loads used?
- How are Tcrits for nozzles determined?
- How are worn vessel shells evaluated?
- Is OD weld overlay ever used to repair worn components?
    - If yes, what criteria are used?
- Are repair or overlay caps ever used on vessels?
    - If yes how are they evaluated?

Design Engineering (Plant Modifications)

- Have you received FAC training?
- Is the FAC coordinator on the review list for piping and equipment modifications?
- When lines, or portions of lines, are replaced with non-susceptible material, what is done to ensure no carbon steel pup pieces are used or left in the system?
    - Are carbon steel nozzles left in the system?
    - Are carbon steel valves left in the system?
- Are backing rings allowed for new or replacement pipe?
- What drawings and documents are updated after modifications are completed? What is the time frame for updates to drawings and documents, including model updates?

Maintenance Coordinator

- Have you received FAC training?
- Is the FAC coordinator always notified when a valve is to be replaced?
- Are valves sometimes purchased with attached expanders/reducers?
    - If yes, is there a check made to be sure the material is not FAC susceptible?
- Are new valves sometimes installed using pup pieces to make up for a shorter valve or assembly?
    - If yes, is the pup piece checked to ensure it is not lower in chromium that the remainder of the pipe?
- Is the FAC coordinator officially notified whenever there is a piping or equipment leak?
- Is there a “leak log”? Does the FAC coordinator have access to it?

Chemistry – PWR/CANDU

- Have you received FAC training?
- What is the current chemistry (concentration of amines and hydrazine, cold pH)?
- How long has the plant been running with this chemistry?
- Are any chemistry changes planned?
- Is there a Long Range Plan for secondary side chemistry?
- Did the plant ever operate with a low pH?
- Is there any copper in the system that limits the chemistry?
- How is chemistry data transmitted to the FAC coordinator? How often?
- Where is the chemical injection relative to the demineralizers?
- Is the injection symmetrical for all trains?
- What is the final feedwater oxygen?
- What is the iron concentration at each monitor location?

Chemistry – BWR

- Have you received FAC training?
- Have you measured oxygen in the main steam? In the drains?
- What are the current oxygen concentrations in the final feedwater? In the main steam line?
- How long has the plant been running with these conditions?
- Are you running NMCA? How long? Zinc injection? How long?
- Are any chemistry changes planned?
- Is there a Long Range Plan for secondary side chemistry?
- How is the chemistry data transmitted to the FAC coordinator? How often?
- What is the iron concentration at each monitor location?

Steam, Feedwater, and Heater Drains System Engineers

- Have you received FAC training?
- Is the auxiliary feedwater ever used during normal operation? How much is it used during start-up and shutdown?
- Is there flow in the bypass lines around the feedwater control valves during normal operation?
- Are there currently any leaking valves in the steam cycle?
- Are there currently any leaking feedwater heater tubes? MSR tubes?
- If one does leak, is the FAC coordinator notified?
- Are any of the feedwater heaters supposed to be operating superheated?
    - If yes, have the superheated conditions been verified with shell inspections?
- Are any of the feedwater heaters scheduled to be replaced in the next couple of outages?
    - If yes, is the FAC coordinator involved?

- Is any portion of the steam cycle being used differently than designed?
- What is the communications with the FAC coordinator when a system is to be used off-design?

Valve Engineering

- Have you received FAC training?
- Is the FAC coordinator notified when valves are opened for maintenance or inspection?
- Is the FAC coordinator notified when a valve is not operating as intended (e.g., cycling)?

NDE Technician

- Have you received FAC training?
- How is small-bore piping being inspected?
- What is done if an extra circumferential weld is encountered in the area to be inspected?
- Do the UT inspections include both sides of the weld toes?
- What is the gridding around longitudinal welds?
- Whose procedures are being used (e. g., corporate, site or contractors)?
- What is done when the lowest UT reading is in the last row?
- Is grid sizing per NSAC-202L guidelines? If not, what criteria are used?

CHECWORKS™ MODEL

Model Construction

- Plant Global Data
  - Heat Balance Diagram (HBD)
    - Does the CHECWORKS™ HBD correctly portray the plant HBD?
    - Does a power level exist for each power level that the plant has operated at for extended periods of time?
  - Steam Cycle Data
    - Was thermodynamic data and flow rate taken from the correct locations on the plant Heat Balance Diagrams or thermodynamic models?
    - Was thermodynamic data and flow rate correctly calculated when combining data for parallel trains and different phases?
  - Chemistry Data
    - Were appropriate water treatments defined based on chemistry history?
    - Were actual concentrations or target values used for historical chemistry data?
  - Plant Periods
    - Is operating time actual online hours or calendar hours?
    - Has a maintenance outage been created to encapsulate each component inspection and replacement (exception online inspections)?

    - Are the correct water treatments applied to the correct periods?
    - Are the correct power levels applied to the correct periods?

- Line Data
  - Are all lines and components in the model supposed to be there?
  - Does the model include incomplete, susceptible non-modeled (SNM), or non-susceptible lines and/or components?
  - Does the model correctly reflect the susceptibility evaluation? (Has the model been updated to reflect changes in the susceptibility evaluation?)
  - Is a separate line modeled for each parallel train?
  - Has duty factor been considered and input?
  - Were all lines associated to the correct HBD location (except Z-type lines)?
  - Have actual station operating conditions been verified against modeled parameters?
  - Component Data
  - Geometry Code Selection
    - Were control valves (type 8 vs. 24) used under the correct circumstances?
    - Were 100 series geometry codes used for elbows with counterbore (where known)?
    - Was type 9 pipe included in the correct locations?
    - Were the geometry codes for piping based on the upstream component (other than type 9)?
  - Material Specified
    - Was Trace Alloy content override used?
    - If the material alloy content is different from the standard, has the proper alloy content been specified?
  - Replacements
    - Have component replacements been handled correctly?
  - Tcrit
    - Is the criteria used to determine Tcrit valid?
  - Tnom /Schedule
    - Does it meet the plant design specification and/or industry standard?
  - Elbow R/D
    - Have all the elbows been evaluated for the correct R/D since the default value is 1.5 (long radius elbow)?
  - Orientation Angle
    - Has the orientation angle of components been verified?

- Nozzles
  - Are the correct geometry codes applied to the inlet type nozzles versus the outlet type nozzles?
  - Forged nozzles typically have a variation in thickness (usually thicker) compared to the piping? Is this true in the model?
- Component naming convention
  - Was the proper naming convention used to identify the type of component?

- Flow Segments
  - Is every component included in the flow segment?
  - Have FAC isometric drawings been used to establish connectivity and validate component sequence in lines?
  - Are the right section of the tee's associated to the right flow segment?
  - Do all components in a flow segment have the same flow rate?
- Network Flow Analysis (NFA)
  - Do NFAs contain the correct flow segments?
  - Are the NFA boundary conditions valid?
  - Does the NFA output appear valid?
- Wear Rate Analysis (WRA) Run Definitions
  - Does each modeled line appear in a WRA Run?
  - Are Runs defined by temperature and chemistry boundaries?
  - Do Runs include parallel trains?
  - Has the correct WRA option been selected for each Run?
  - Was Advanced Run Definition (ARD) used?
    - If multiple power levels exist in the model, is the Advanced Run Definition used? (Note: NFA or HBD can be used in addition to ARD.)
    - Is thermodynamic and flow rate data entered directly on the ARD for all Z-type and Chemistry Only Line Association (COLA) lines?
    - Are Duty Factors used for lines with part-time operation?
    - Have flow factors been entered correctly?

NDE Evaluation and Interpretation

- Do gridding conventions allow accurate identification of wear?
- Are inspections imported to the correct historical component
- Were UT datasheets reviewed for correct partitioning?
- Was a picture or sketch used to aid partitioning?

- Is the correct analysis method selected based on geometry code?
- Is the Point-to-Point option used under the correct circumstances?
- Are the Tmeas options used correctly?
- Have all sections of a component been analyzed with the correct method? Is the area method used? If so, is an adequate justification provided?

Pass 2 Analysis

- Has a Pass 2 wear rate analysis been performed?
- Has the calibration of each WRA Run been documented based on:
  - Line Correction Factor (LCF)
  - Scatter Plot evaluation
  - Cluster identification and investigation
- Have outlying data points been sufficiently researched?
- Has the inspection scope been compared against NSAC 202L recommendations?
- Has the model been updated with UT data after each outage?

Independent Verification

- Has initial modeling been reviewed?
- Have reports been obtained and reviewed for accuracy?
- Were replaced components incorporated in the model? If not, how are replaced components addressed? If so, was the replacement information verified and the model so updated?
- Has the model been updated with UT data after each outage?
- Was a Pass 2 Analysis performed and verified?

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