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Mr. J. E. Dyer, Administrator
United States Nuclear Regulatory Commission
Region III
801 Warrenville Road
Lisle, IL 60532-4351

Subject: Confirmatory Action Letter Response – Management and Human Performance Root Cause Analysis Report on Failure to Identify Reactor Pressure Vessel Head Degradation

Ladies and Gentlemen:

On March 13, 2002, the Nuclear Regulatory Commission (NRC) issued a Confirmatory Action Letter (CAL) regarding the Reactor Pressure Vessel (RPV) head degradation at the Davis-Besse Nuclear Power Station, Unit 1 (DBNPS). The CAL required the FirstEnergy Nuclear Operating Company (FENOC) to determine the root causes of the degradation and meet with the NRC to discuss that information. On April 18, 2002, by FENOC letter Serial Number 1-1270, the technical Root Cause Analysis Report of the event was submitted. This report was discussed in several subsequent meetings with the NRC and the Advisory Committee on Reactor Safeguards. During these meetings, it was communicated that the management and human performance issues associated with the RPV head degradation would be further addressed in a Management and Human Performance Root Cause Analysis Report. This report has been completed and is enclosed. This report was prepared by a team that was independent of the DBNPS management organization and authorized by the President of FENOC.

This Root Cause Analysis Report provided the basis for discussion with the NRC during the meeting in the NRC Region III offices on August 15, 2002, and also provided the basis for discussion of associated corrective actions during the NRC IMC 0350 Panel meeting scheduled for August 20, 2002, in Oak Harbor, OH.

If you have any questions or require additional information, please contact Mr. Patrick J. McCloskey, Manager – Regulatory Affairs, at (419) 321-8450.

Very truly yours,

Enclosure and Attachment

cc: USNRC Document Control Desk
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FirstEnergy, DAVIS-BESSE NUCLEAR POWER STATION

Root Cause Analysis Report

Failure to Identify Significant Degradation of the Reactor Pressure Vessel Head

CR 02-0685, 02-0846, 02-0891, 02-1053, 02-1128, 02-1583 02-1850 02-2584, and 02-2585

DATE: August 13, 2002

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Acronyms

AIT	NRC Augmented Inspection Team
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BA	Boric Acid
BAC	Boric Acid Control
BACC	Boric Acid Corrosion Control
B&W	Babcock & Wilcox
BWOG	Babcock & Wilcox Owners Group
CAC	Containment Air Coolers
CAF	Corrective Action Form
CATPR	Corrective Action to Prevent Recurrence
CARB	Corrective Action Review Board
CATS	Corrective Action Tracking System
CNRB	Company Nuclear Review Board
CPI	Chemistry Performance Indicator
CR	Condition Report
CRDM	Control Rod Drive Mechanism
CTMT	Containment
DBNPS	Davis-Besse Nuclear Power Station
DOE	Department of Energy
EAB	Engineering Assessment Board
E&CF	Event and Causal Factor
EFPY	Effective Full Power Years
EPRI	Electric Power Research Institute
FENOC	FirstEnergy Nuclear Operating Company
GL	NRC Generic Letter
HEPA	High Efficiency Particulate Air
HPES	Human Performance Evaluation System
IN	NRC Information Notice
INPO	Institute of Nuclear Power Operations
ISEG	Independent Safety Evaluation Group
ISI	Inservice Inspection

LCO	Limiting Condition for Operation
LOCA	Loss of Coolant Accident
MORT	Management Oversight and Risk Tree
NDE	Non-Destructive Examination
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
PCAQ	Potential Condition Adverse to Quality
PCAQR	Potential Condition Adverse to Quality Report
ppm	Parts per million
PRC	Project Review Committee
PSA	Probabilistic Safety Assessment
psig	Pounds per square inch
PWR	Pressurized Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
QA	Quality Assurance
QAPM	Quality Assurance Program Manual
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RFO	Refueling Outage
RPV	Reactor Pressure Vessel
RV	Reactor Vessel
RWP	Radiation Work Permit
SE	Southeast
SRB	Station Review Board
SRO	Senior Reactor Operator
SwRI	Southwest Research Institute
TM	Temporary Modification
TVA	Tennessee Valley Authority
USAR	Updated Safety Analysis Report
UT	Ultrasonic Examination
VHP	Reactor Pressure Vessel Head Penetration
VP	Vice President
VT	Visual Examination
WANO	World Association of Nuclear Opearators

1.0 Executive Summary

1.1 Overall Conclusions

The Davis-Besse Plant had a significant outage in 1985. Since that time the plant has been a top performer, but starting in the mid-1990s a flattening or decrease in performance can be seen. The managers brought in during the 1980s event are gone and many of the managers developed during that period left the company and are now in key positions throughout the industry. Several of the plant evaluations both in-house and by outside organizations have noted this issue over the past three years. Several actions were taken to improve this performance but not as promptly as needed.

Over time, the plant appeared to become complacent. In many areas, a minimum compliance standard existed in management and thus throughout the Davis-Besse organization. The plant did not use industry experience or vendors effectively, and in many areas became isolated from the industry. In the case of the Boric Acid Corrosion Control (BACC) Program, the plant actually went from a minimum compliance standard to a standard that focussed on justifying existing conditions. This resulted in a lack of appreciation of the significance of the Reactor Coolant System (RCS) leakage and boric acid control. There was a lack of sensitivity to nuclear safety and the focus was to justify existing conditions. The overall conclusion is that Management ineffectively implemented processes and thus failed to detect and address plant problems as opportunities arose.

1.2 Problem Statement

Significant degradation of the Davis-Besse reactor pressure vessel (RPV) head base metal was discovered during the thirteenth refueling outage (13RFO) in March 2002. In April 2002, a technical Root Cause Analysis Report was issued on the degradation of the Davis-Besse RPV head (Technical Root Cause Analysis Report). That Report also identified a number of overall management issues that set the genisus for this report. The report concluded that station personnel had failed to identify corrosion of the base metal of the RPV head over a period of years despite several opportunities to do so. The purpose of this report is to identify the root causes and contributing causes of the issues associated with the failure to identify the corrosion of the RPV head.

This report is different from the analyses of other Davis-Besse events because it broadly evaluates facts and focuses on the underlying management and organizational reasons for the events. In particular, this report reviews data from the 1980s to the present and evaluates a sense of different events. The Root Cause Team used the Event & Causal Factors Analysis, Management Oversight and Risk Tree (MORT), and Hazard-Barrier-Target Analysis to perform its analyses. Finally, the Team focused on the underlying reasons for human performance and management failures.

1.3 Event Narrative

Davis-Besse is a raised loop pressurized water reactor (PWR) manufactured by Babcock & Wilcox (B&W). The RPV head has 69 control rod drive mechanism (CRDM) nozzles welded to the RPV head. Each CRDM nozzle is constructed of Alloy 600 and is attached to the RPV head by an Alloy 182 J-groove weld. The RPV head is constructed of low-alloy steel and is internally clad with stainless steel. There is a service structure surrounding the RPV head. The bottom of the service structure support skirt has openings called "mouse holes" to permit visual inspections through the use of a pole-mounted camera.

During performance of inspections of the CRDM nozzles during 13RFO, significant degradation of the RPV top head base metal was discovered. The Technical Root Cause Analysis Report concluded that corrosion of the RPV head was caused by boric acid corrosion resulting from CRDM nozzle leakage. The CRDM leakage resulted from through-wall cracking of the CRDM nozzles caused by primary water stress corrosion cracking (PWSCC). That Report also concluded that a reasonable estimate of the time-frame for the appearance of leakage on the RPV head from the CRDM nozzle cracking is approximately 1994-1996, and that the corrosion rate began to increase significantly starting at about 11RFO in 1998 and acted for a four-year period of time. During this period, boric acid accumulated sufficiently and provided the necessary environment to begin significant RPV head corrosion. The pre-existence of accumulation of boric acid from other sources, such as CRDM flange leaks, may have accelerated the corrosion and increased its severity.

Additionally, the Technical Root Cause Analysis Report concluded that the accumulation of boric acid on the RPV head allowed the nozzle leaks to go undetected and uncorrected in time to prevent damage to the head. Boric acid that accumulated on the top of the RPV head over a period of years inhibited the station's ability to confirm visually that neither nozzle leakage nor RPV corrosion was occurring. The Report also noted that other evidence of the boric acid leakage existed in the containment building but its association with possible nozzle leaks was not recognized at the time. This evidence consisted of 1) iron oxide, boric acid and moisture found in containment atmosphere radiation monitor filters, 2) boric acid accumulations in the containment air coolers (CACs), and 3) boric acid accumulations on the RPV flange. While these conditions were all identified at the time, their collective significance was not recognized.

A summary of the relevant boric acid events follows.

Industry Experience with Boric Acid Corrosion Prior to 1988 - Several incidents of boric acid corrosion (including one event involving corrosion of the Turkey Point RPV head) occurred between the late 1970s and the mid-1980s. These events led to the Nuclear Regulatory Commission (NRC) to issue Generic Letter (GL) 88-05 in 1988. GL 88-05 required each license holder for a PWR to have a boric acid control program. In response to this Generic Letter, Davis-Besse issued a boric acid corrosion control procedure in 1989.

Leaking CRDM Flanges in the 1990s – Davis-Besse and other B&W plants experienced leakage from the CRDM flange gaskets. As a result, Davis-Besse replaced its gaskets over several outages from 6RFO in 1990 through 10RFO in 1996. However, Davis-Besse also experienced leaks with the new gaskets in 8RFO (1993), 11RFO (1998), and 12RFO

(2000). Thus, in every outage from 7RFO through 12RFO, CRDM flange leakage was identified (either from the original gaskets or the replaced gaskets).

1993 Evaluations of the Risk of CRDM Nozzle Cracking – In 1993, both the Babcock & Wilcox Owners Group (BWOG) and the NRC issued safety evaluations, which concluded that the potential for cracking in the CRDM nozzles did not present a near-term safety concern and that visual inspections of the RPV head areas would provide adequate capability to detect leaks from nozzle cracking.

Evaluation of a Service Structure Modification to Facilitate Inspection of the RPV Head – In the 1990s, Davis-Besse proposed a modification to install openings in the service structure to facilitate inspection and cleaning of boric acid from the RPV head. However, this modification was repeatedly deferred.

10RFO (1996) – One CRDM flange exhibited signs of leakage during 10RFO. The boric acid on the RPV head was powdery and white. The boric acid was very thin at the front edge with powder and small clumps of boric acid on top. Based upon a justification that the boric acid would not impact the RPV head given its high temperature, boric acid was left on the RPV head.

Generic Letter 97-01 - In April of 1997, NRC issued GL 97-01, which requested plants to describe their program for ensuring the timely inspection of CRDM penetrations. In July of 1997, the BWOG responded to the GL 97-01, concluding that PWSCC for CRDM nozzles would not become a long-term safety issue provided that leakage inspections of the RPV head were performed.

11RFO (1998) – CRDM nozzle 31 was identified as having a minor flange leak, and it was not repaired. Boric acid deposits were identified flowing out of the mouse holes in the southeast quadrant of the RPV head flange. The boric acid was a reddish rusty color. During the removal of boric acid from the RPV head, the boric acid was noted to be brittle and porous. Other than these areas of accumulated boric acid, the RPV head was judged to be basically clean. Based on the 1996 assessment that the boric acid would not impact the RPV head given its high temperature, boric acid was left on the RPV head.

1998 - - Boric Acid Wastage of Body-to-Bonnet Nuts for RC-2 Pressurizer Spray Valve - In 1998, two body-to-bonnet flange nuts on RC-2 Pressurizer Spray Valve at Davis-Besse were identified as missing. The root cause analysis report for this event concluded that the nuts were missing as a result of boric acid corrosion. The NRC took escalated enforcement action against Davis-Besse for this event.

12RFO (2000) - Steam cutting occurred on CRDM flange nozzle 31, resulting in boric acid leakage. A pile of boron was identified on top of the insulation. The boron on the RPV head was a red, rusty color and hard. Additionally, boric acid had accumulated on the RPV head flange behind the studs flowing out of the mouse holes in the southeast quadrant. The boric acid had a red, rusty appearance. The cleaning of the RPV head during the outage was not fully successful, and some boric acid deposits were left behind on the RPV head. In interviews, the engineer stated that he was running out of time to continue cleaning the RPV head (the RPV head was scheduled to return to the RPV during the next shift). No written evaluation was performed to allow the boric acid to remain on the RPV head.

Fouling of the Radiation Monitor Filters in 1998-2001 - In 1998, fouling of the containment atmosphere radiation monitor filters occurred. There were boric acid and iron oxide deposits on the filters. The desposits had a "yellow" or "brown" appearance. From May of 1999 until April 2001, filter changes were required on an irregular 1 to 3-week interval (and sometimes once every 1 to 3 days). Accumulation of boric acid on the radiation monitor filters was recognized to be symptomatic of an RCS leak as soon as it occurred. Efforts were made, especially during the cycle 12 mid-cycle outage in 1999 and later during 12RFO in 2000, to locate the source of leakage, but without success. By November of 2001, filter replacements were required approximately every other day.

Containment Air Cooler (CAC) Cleaning in 1998-2001 - In 1998 and 1999, cleaning of boric acid from the CACs was needed nineteen times. Although the boric acid was generally reported to be white, a written post-job critique indicated a "rust color" was noticed "on and in the boron being cleaned away" from CAC 1. In June 2000, CAC plenum pressure again began to decrease, requiring resumption of cleaning. This was followed by five total cleanings in June, August, October and December of 2000. Cleanings continued in 2001, with four more (total) in January, February, March, and May.

13RFO (2002) – The boric acid degradation of the RPV head was discovered.

1.4 Data Analysis

The Root Cause Analysis Team (Team) used Event & Causal Factor Analysis, Hazard-Barrier-Target Analysis, and Management Oversight and Risk Tree (MORT) Analysis to determine the root causes of the failure to identify the degradation of the RPV head.

1.4.1 Event & Causal Factor Analysis

The key insight that was gained from the Event and Causal Factors (E&CF) Analysis is that organizational performance in response to industry knowledge about boric acid, as well as its potential safety implications to the plant, was evident in the late 1980s and early 1990s. Thereafter, organizational performance declined in both respects, and the decline is evident beginning about 1996.

The E&CF Analysis of the boric acid issues related to the RPV head, CACs, radiation monitor filters, and the RC-2 event identified several common causes. These are:

- Less than adequate safety focus

- Less than adequate implementation of the corrective action program
- Less than adequate boric acid corrosion control program implementation
- Lack of safety analysis for identified conditions

1.4.2 Hazard-Barrier-Target Analysis

A Hazard-Barrier-Target analysis was performed for implementation of the Boric Acid Corrosion Control (BACC) Program as it related to the RPV head and associated buildup of boric acid in 1998 (11RFO) and 2000 (12RFO). The Team identified barriers that were or should have been in place to prevent significant corrosion of the RPV head, and then evaluated whether the barriers existed, were used, and were effective.

In summary, implementation of the Boric Acid Corrosion Control Program did not meet minimum regulatory standards. The Boric Acid Corrosion Control Procedure, NG-EN-00324, had weaknesses (for example, it did not identify the CRDM nozzles as a potential leakage source). However, if it had been properly implemented, then it generally would have provided adequate barriers for identifying, assessing, and correcting boric acid leakage to prevent corrosion. However, many of these barriers either were not used or were inadequately implemented during 11RFO and 12RFO. For example, the BACC Procedure required removal of boric acid from components, but the cleaning was not effective in removing all of the boric acid from the RPV head in 11RFO and 12RFO. Because the boric acid was not fully cleaned from the RPV head, the inspections failed to identify that there were leaks in the CRDM nozzles. Furthermore, because boric acid was not fully removed from the RPV head, a complete inspection was not performed to identify whether there was corrosion of the RPV head. Although Engineering prepared a justification for leaving boric acid on the RPV head, that justification incorrectly assumed that the boric acid leakage was from the CRDM flanges onto a hot RPV head that was not susceptible to significant corrosion. Because the inspections did not identify the CRDM nozzle leakage, action was not taken to stop the CRDM nozzle leakage and to prevent boric acid corrosion.

1.4.3 MORT Analysis

In performing the MORT analysis, the Team focussed on the key management responsibilities that most impact safe operations. These responsibilities pertain to the areas of policies and their implementation, risk assessment systems, and programs that support safety focus. Based upon this focus, the Team analyzed the following branches of MORT risk tree:

Technical Information System

Davis-Besse had a well-defined structure for collection and dissemination of information related to boric acid accumulation and corrosion and PWSCC. Davis-Besse also had adequate technical knowledge regarding the effects of boric acid and the potential for PWSCC of the CRDM nozzles. Davis-Besse also had collected and internally disseminated sufficient information to have enabled it to have identified the CRDM nozzle leaks and prevent severe corrosion of the RPV head.

Davis-Besse did not adequately apply and integrate its technical knowledge and information. Furthermore, Davis-Besse did not adequately compare new information regarding changed conditions at the plant with previous conditions. For example:

- In 10 RFO, 11RFO, and 12RFO, Davis-Besse left boric acid on top of the RPV head and therefore was unable to identify indications of boric acid leakage from cracks in CRDM nozzles and corrosion of the base metal carbon steel in the top of the RPV head.

- Red and brown boric acid was identified on the RPV head in 10RFO, 11RFO, and 12RFO, but Davis-Besse attributed it to aging rather than corrosion.

- Lessons learned from the RC-2 boric acid corrosion event in 1998 do not appear to have been applied to the subsequent conditions involving the RPV head.

- From 1999 to 2001, Davis-Besse did not recognize the collective significance of the increase in the unidentified reactor coolant leakage, the increase in the frequency of clogging of the CACs due to boric acid, the increase in the frequency of clogging of the radiation monitor filters, and the changes in the physical characteristics of the boric acid on the RPV head.

These failures resulted in less than adequate analyses and decision-making with regard to the nuclear safety implications of boric acid on the RPV head.

Hazards Analysis Process

Processes and programs used between 1988 and 2001 that address hazard analyses contained the necessary elements for ensuring that the design and licensing basis of the plant was maintained, including satisfying the regulatory requirements of 10 CFR 50.59. **However, evaluations and decisions were made without the adequate performance of supporting safety analyses.** For example, safety analyses were not performed for clogging of the radiation monitor filters or the boric acid left on the RPV head.

Corrective Action Program

Davis-Besse in general identified and documented the nonconforming conditions involving the boric acid on the RPV head and other boric acid related issues. However, **personnel at all levels of the organization did not effectively implement other elements of the corrective action process.** For example:

- The categorization of the adverse conditions, and the selection of the level of evaluation for those conditions, allowed the use of superficial cause analysis techniques. Boric acid accumulation on the RPV head never received more than an apparent cause evaluation, even though there were repeat events.

- The cause determinations for identified problems associated with the degradation of the RPV head and other boric acid issues were less than adequate dating back to at least 1996. In particular, the boric acid on the RPV head was attributed to CRDM flange leakage, rather than CRDM nozzle leakage. This hampered the organization's ability to evaluate the potential for damage to the RPV head.

- There were a number of problems related to the adequacy of corrective actions. On a number of occasions, the plant was restarted without taking corrective action for identified problems, including restarting the plant in 10RFO, 11RFO, and 12RFO without fully removing the boric acid from the RPV head. In other cases, corrective action was not taken for identified adverse conditions. In still other cases, corrective action documents were closed by means of reference to actions specified in other documents that were still open, but the referenced action was never taken. In other cases, corrective actions were not effective in correcting the problem.

- There were recurring problems with respect to boric acid issues that were not documented as an adverse trend. In other cases, the causes of recurring problems were not identified and corrected in a timely manner. This included recurring CRDM flange leakage, recurring accumulations of boric acid left on the RPV head, an adverse trend involving a drop in plenum pressure for the Containment Air Coolers due to boric acid coating of the cooling coils, increases in unidentified RCS leakage, frequent clogging of the radiation monitor filters, repeat events with Reactor Coolant Pump (RCP) flange and gasket leakage from 1996 through 2002, and 20 work orders in 22 years on RC-2 Pressurizer Spray Valve packing leakage.

These failures in implementation resulted in missed opportunities to identify the nuclear safety impact of the boric acid corrosion to the RPV head from 1996 to 2002.

Operations' Involvement

The Team examined the Control Room's assessment of conditions identified in CRs and PCAQRs, along with information from several interviews. From these, the Team observed that Operations did not take an active role in advocating actions to improve the condition of the plant. However, the Team's review of Condition Reports clearly demonstrated a tendency by Operations to underestimate the impact of reported problems on equipment health and operability. Their collective treatment of the issues suggests that the resolution of the problems was viewed as purely an engineering responsibility. Except for the pursuit of the RCS unidentified leak rate by the Plant Manager, the Team found that Operations was largely not visible.

Independent Oversight Programs

The Team initially intended to perform a MORT analysis of the independent oversight activities performed by Quality Assurance (QA) and the Company Nuclear Review Board (CNRB) related to PWSCC of the CRDM nozzles and boric acid corrosion. However, as the investigation proceeded, the Team determined that there are a relatively small number of relevant facts that pertain to QA and the CNRB, and that this number does not permit an adequate MORT analysis. However, the Team does observe that there was little evidence of QA's involvement in this area, and the documented findings by QA were of mixed quality. Additionally, FENOC is performing assessments of QA and CNRB.

Task Performance Errors

Five organizational-level errors were examined. The task performance errors considered were the failures to recognize the significance of the boron accumulating on the RPV head, the boron and iron oxide plugging of containment radiation monitor filters, and the increasing frequency of Containment Air Cooler fouling with boric acid; the failure to effectively determine and correct the sources of leakage from the RCS; and the ineffectiveness of the corrective actions taken in response to the RC-2 event in 1998. Since other sections of MORT addressed the facts related to these errors, a separate investigation using the specific Task Performance Sections of MORT was unwarranted, and the task performance errors were evaluated within the Management Risk Assessment Section.

The Team identified common features related to the organizational errors, including:

- The conditions were identified on Condition Reports on numerous occasions, but not necessarily every time the condition appeared.
- The assessments of operability and importance of the condition to safety were ineffective.
- Condition Reports were not properly categorized (they were categorized relatively low).
- The cause analyses were shallow and focused on managing the symptoms rather than the causes of the identified problems.
- The station tended to defer or re-assign resolution of the problem.
- The collective significance of the conditions in containment was not evaluated.
- Senior management oversight of resolution of conditions (except for the RCS Unidentified Leak Rate) was not visible.

Corporate/Management Goals

For many years, Davis-Besse was operated as a stand alone plant. Davis-Besse has been isolated to the point where the Plant Management openly discussed this unit as stand alone.

In the past three years, FENOC has had a common vision, mission, and fundamental building blocks of Safety, People, Reliability and Cost. However, Davis-Besse has had few policy-level documents and no policy statement dedicated to the subject of safety. The written policies that do exist have been inconsistent and incomplete in their treatment of employee and nuclear safety. As a result, the Team concludes that the concept of safety has not been given sufficient prominence or focus in the written policy area.

The FENOC management monetary incentive program rewards production more than safety at senior levels of the organization. For example, the Nuclear Incentive Compensation for 2002 provides for incentive compensation for various factors related to safety and production, and FENOC officers and plant directors are to receive most of their incentive compensation based upon production. This supports misalignment of the organizational priorities, and inhibits the transition of the organization to a safety-first philosophy.

These are not causes of the boric acid issues but are important considerations for the future in assuring that safety is of primary importance.

MORT Conclusions

The Team collectively evaluated the above findings to determine the underlying reason why these failures occurred. Based upon its evaluation, the Team reached the following conclusion:

> ***Less than Adequate Nuclear Safety Focus - Production focus, established by management, combined with taking minimum actions to meet regulatory requirements, resulted in acceptance of degraded conditions.***

In addition to the facts discussed above, other facts also led to this conclusion. For example:

- In numerous interviews, personnel repeatedly stressed that plant activities were driven by production concerns.
- In numerous interviews, personnel indicated that they believed that they did not need to take actions to address certain issues because those actions were not necessitated by regulatory requirements such as the technical specifications.
- There were repeated cases of operating with degraded plant components, including the CACs, radiation monitor filters, unidentified RCS leakage, and the RC-2 valve.
- On a number of occasions, the organization restarted the plant with degraded conditions, including restarting the plant with known CRDM flange leakage and boric acid on the RPV head.

The Team's investigation identified that nuclear safety was effectively integrated into practices and programs in the late 1980s and early 1990s. The transition from adequate to inadequate work practices occurred subtly, but was reflected in the direction management gave to site personnel after the early 1990s. In the mid-1990s, top quality people left the station, and Davis-Besse became more disassociated from the industry. The station's focus and level of rigor moved to support the perceived goals (cost, schedule, minimum compliance status quo). The results were programs that were weakened in their ability to identify and address potential safety concerns. Corrective actions tended to be simplistic and superficial, and lacked rigorous analysis to support conclusions. The use of technical information tended to be selective, utilizing whatever information supported the perceived site goals.

1.5 Root Cause Determination

Based upon its analysis, the Team identified a number of root causes, contributing causes, and observations for the failure to identify boric acid corrosion of the RPV head.

Root Causes

1. **There was a less than adequate nuclear safety focus (a production focus combined with taking minimum actions to meet regulatory requirements).**
2. **Implementation of the Corrective Action Program was less than adequate, as indicated by the following:**
   - **Addressing symptoms rather than causes**
   - **Low categorization of conditions**
   - **Inadequate cause determinations**

- **Inadequate corrective actions**
- **Inadequate trending**

3. **The organization failed to integrate and apply key industry information and site knowledge and to compare new information on plant conditions to baseline knowledge.**
4. **Personnel did not comply with the Boric Acid Corrosion Control Procedure and Inservice Inspection Program, including failure to remove boric acid from the RPV head and to inspect the affected areas for corrosion and leakage from nozzles.**

Contributing Causes

1. Evaluations and decisions were made without hazard analyses.
2. The Corrective Action Program has provisions that do not reflect state-of-the-art practice in the industry.

Related Observations

1. The Alloy 600 material used in the original design of the CRDM nozzles was susceptible to cracking and leakage, and the original gaskets in the CRDM flanges were susceptible to leakage.
2. Training was not provided to some individuals who inspected for boric acid, and the training following the RC-2 event was less than adequate.
3. The RPV head inspection activities and resolution of problems were not coordinated through the BACC Coordinator.
4. The BACC Procedure does not specifically reference the CRDM nozzles as one of the probable locations of leakage.
5. Condition reports associated with the boric acid issues tended to stay unresolved until significant degradation occurred.
6. There was little evidence of QA's involvement in this area, and the documented findings by QA were of mixed quality.
7. The FENOC monetary incentive program rewards production more than safety at senior levels of the organization.
8. The written policies have been inconsistent and incomplete in their treatment of employee and nuclear safety and do not support a strong safety focus.
9. Operations had minimal involvement in resolution of boric acid issues.
10. Management had minimal entries into containment and observations of conditions in the containment.

1.6 Extent of Condition

The Technical Root Cause Analysis Report discusses activities that are being performed to determine whether other components have been affected by PWSCC or boric acid corrosion. Additionally, the Root Cause Analysis Team believes that other plant activities may be adversely affected by the causes discussed above.

Currently, the Davis-Besse Building Block Plans include reviews to assess the adequacy of systems, organizations, and programs to support safe and reliable operation. Specifically:

- The System Health Assurance Plan provides for reviews of systems.

- The Management and Human Performance Excellence Plan includes a review of functional areas (organizations).
- The Program Compliance Plan provides for reviews of programs.

These reviews include assessments of the adequacy of past corrective actions, use of industry and operating experience, modifications, program ownership, communication of safety information, and system walkdowns. The owners of the Building Block Plans should review their activities to ensure that their plans account for the findings and conclusions of this report.

1.7 Corrective Actions

1.7.1 Corrective Actions for Root Causes

The key corrective actions are described below, arranged by root cause:

Less than Adequate Nuclear Safety Focus

- Prior to issuance of this report, FENOC had already identified a number of management and organizational weaknesses and had issued the Management and Human Performance Excellence Plan. This plan includes extensive changes in the officers, directors, and managers responsible for Davis-Besse, a Management Monitoring Process, and case study training on how the event happened, what barriers broke down, and what needs to be different in the future.

Less than Adequate Implementation of the Corrective Action Program

- The Program Compliance Plan includes a detailed review of the Corrective Action Program by outside consultants.
- The Corrective Action Review Board (CARB), which reviews select corrective action document evaluations, will be used to enforce higher standards for cause evaluations and effective corrective action. This board will also be chaired by a Director level position.
- Review existing long-standing issues for possible categorization as a significant condition adverse to quality (SCAQ).
- Require the use of formal cause determination techniques for root cause evaluations to ensure analytical rigor is applied to the analysis.
- Define and implement the training requirements necessary for cause evaluation, especially for equipment analysis.
- Implement an effective site wide equipment trending program.
- The Senior Management Team shall review and endorse all root causes.

Less than Adequate Analyses of Safety Implications

- Establish the FENOC Hierarchy of Documents for Davis-Besse to ensure consistent policies and standards at all FENOC plants for performing analyses of safety implications.

Less than Adequate Compliance with Boric Acid Corrosion Control (BACC) Procedure

- Provide training to applicable personnel and managers on the need to remove boric acid from components, to inspect for signs of corrosion, and to perform inspections for signs of boric acid in component internals.

- Reinforce standards and expectations for procedure compliance and the need for work practice rigor, and test the organization to ensure that those standards have been accepted.

1.7.2 Corrective Actions for Contributing Factors

The key corrective actions are described below, arranged by cause:

Lack of Hazard Analyses
- Establish the FENOC decision-making process at Davis-Besse, including performance of hazard analyses.

Corrective Action Procedure
- Review and benchmark the Corrective Action Procedure against industry standards.
- The Program Compliance Building Block Plan includes a detailed review of the Corrective Action Program by outside consultants.

1.7.3 Other Relevant Corrective Actions and Improvements

Design – Replace the corroded RPV head with a new head from the Midland Plant, and manufacture and install a new RPV head that does not use Alloy 600 for the CRDM nozzles.

Training – Provide training on the BACC Procedure to applicable personnel.

Coordination of Boric Acid Control Activities – Provide training to the BACC Coordinator and other program owners to ensure that they are aware of their responsibilities, and implement the Return to Service Plan Building Blocks on program ownership.

BACC Procedure – Establish a Boric Acid Nuclear Operating Procedure for FENOC PWRs that lists the CRDM nozzles as one of the probable locations of leakage.

Untimely Corrective Action - Review the Corrective Action Program to identify whether it contains appropriate provisions for ensuring the timely resolution of conditions, and revise the Program as appropriate.

Quality Assurance - The Nuclear Quality Assurance organization is performing an assessment to determine the adequacy of its audits and surveillances, and it should revise its activities as appropriate.

Incentive Program Focuses on Production - Management incentives should be realigned to place more reward for safety and safe operation of the station when the management positions reside at the station (e.g. Site Vice President and below).

Policies Do Not Support Safety - Establish a FENOC-level policy emphasizing the safety philosophy.

Operations Involvement – Establish a method to integrate Operations into problem solving and promote Operations ownership of problem resolutions.

Management Observations – Develop a plan for increased presence of management in the field during outages and normal operations.

1.8 Experience Review

The Davis-Besse Root Cause Analysis Reference Guide states that a review should be conducted to determine why corrective actions for similar problems were not effective and why the proposed corrective actions are different from those previously taken.

The Technical Root Cause Analysis Report states that previous experience with boric acid degradation at Davis-Besse and other nuclear power plants was not effectively used to prevent the corrosion of the RPV head. In particular, the preventive actions for the RC-2 event were not effective.

The proposed preventive actions discussed above are different from those taken in response to the previous events. Specifically, the proposed preventive actions have the following elements that were not present in the actions for the RC-2 event:

- New Management – Since December of 2001, the top tiers of management at Davis-Besse have been entirely changed, with new managers that have outside experience and high safety standards.
- Emphasis on Safety – New management has developed a Management and Human Performance Excellence Plan, which includes establishment and communication of standards of excellence and a management monitoring process to ensure those standards are enforced.
- Corrective Actions – FENOC will be taking extensive actions to improve corrective actions, including appointment of a Director level position to head the Corrective Action Review Board and actions to improve categorization of conditions, cause determinations, analyses of the safety implications of adverse conditions, corrective actions, and trending.
- Procedure Compliance – FENOC will be performing case study training, which will include emphasis on the need to adhere to procedures and the potential consequences of a failure to do so.

These actions are substantially broader and more comprehensive than the corrective actions taken for the RC-2 event. Davis-Besse should perform reviews to ensure that the corrective actions specified in this report are effective.

2.0 Root Cause Analysis Team

The Root Cause Analysis Team (Team) consists largely of FirstEnergy Nuclear Operating Company (FENOC) employees from Perry, Beaver Valley, and Davis-Besse who are qualified in conducting assessments and root cause analyses. The Team was augmented with independent contractors who specialize in conducting root cause analyses and assessments of nuclear power plants. Additionally, members of the Institute of Nuclear Power Operations (INPO) provided input to the activities of the Team.

The Charter for the Team is provided in Attachment 1. A summary of the condition reports prepared by the Team is presented in Attachment 2. The team spent more than 4600 person-hours in performing it investigation.

The remainder of this section identifies the individuals who participated on or assisted the Root Cause Analysis Team and provides a brief summary of their experience.

Team Members

Steven A. Loehlein, FENOC (Beaver Valley, Principal Consultant, Nuclear), Team Lead - Steve Loehlein graduated with a Bachelor of Science degree in Mechanical Engineering from the University of Pittsburgh in 1976. He is a Licensed Professional Engineer, with nineteen years experience in the nuclear industry at the Beaver Valley Power Station, including design and construction engineering, maintenance, engineering assurance, and construction field support. He possesses an Senior Reactor Operator (SRO) equivalency certification for the SNUPPS reactor. He is qualified as an Event Response Team Leader, and in root cause analysis techniques. He was the team leader for the technical root cause analysis performed in March and April of 2002 in response to the boric acid corrosion damage found on the Davis-Besse Reactor head.

Mario P. DeStefano, FENOC (Perry, Supervisor of the Maintenance Assessment Unit of Nuclear Quality Assurance (NQA)) – Mario DeStefano has a total of 25 years nuclear power experience, including 6 years in the U.S. Navy and the remainder in commercial construction and operation. He has held various positions including Quality Control Inspector, Maintenance Supervisor, and Maintenance Superintendent. His previous involvement in corrective action processes includes Chairman of the Corrective Action Review Board (CARB) at the Perry Plant, which has responsibility for performing management level review of all significant condition reports. He participated as a member of the Common Cause Analysis team, which identified the root causes and recommended corrective actions to improve station performance following a poor operating cycle. He also participated in the FENOC NQA examination in June of 2002 of five condition reports related to the Davis-Besse degraded reactor head.

Randall L. Rossomme – FENOC (Beaver Valley, NQA Supervisor) - Randy Rossomme has been employed by Duquesne Light and FENOC at the Beaver Valley site since 1980. He is

currently assigned to the Oversight and Process Improvement Department. He holds degrees in engineering and human resource management. In addition to several years as a lead quality assurance auditor, he is a qualified instructor for FENOC Root Cause Methodology.
He has participated previously in root cause investigations at Beaver Valley, including investigation of equipment failures and human performance errors. He also led the FENOC NQA examination in June of 2002 of five condition reports related to the Davis-Besse degraded reactor head.

Ihor (Bill) Babiak, FENOC (Perry, NQA Sr. Nuclear Engineer) – Bill Babiak has 18 years of power plant experience, all within FENOC. He carries expertise in technical investigations, technical assessments/audits, project management and technical problem solving of mechanical fluid systems. He is certified under ANSI N45.2.23 as a Nuclear Quality Assurance Lead Auditor and meets the requirements of Section 4.1 of ANSI/ANS 3.1 – 1981. He is also certified as a root cause investigator/team lead for the TapRoot and Alamo root cause analysis methods. He participated as an assessment team member for Perry plant's Latent Issues evaluation and is a member of CNRB Safety Evaluation Subcommittee. He also participated in the FENOC NQA examination in June of 2002 of five condition reports related to the Davis-Besse degraded reactor head.

Bobby G. Villines, FENOC (Davis-Besse, Component Reliability Engineer) – Bobby Villines has 17 years of nuclear experience, including 11 years at Davis-Besse. He has been an Event Investigator and Root Cause Evaluator, and has performed root cause investigations for equipment and human performance events. He also has training in root cause analysis, Management Oversight and Risk Tree MORT), Kepner-Tregoe Equipment Troubleshooting, and human performance evaluation system (HPES).

Joseph C. Sturdavant, FENOC (Davis-Besse, Root Cause Team Analyst) - Joe Sturdavant is a Root Cause Analyst at Davis Besse. He has 22 years nuclear power experience. Following completion of Navy Nuclear Power School and Reactor Plant Prototype, he served on a nuclear powered submarine. He was also employed at H. B. Robinson nuclear plant. During the last 3 years, he has performed equipment and human performance root cause analysis in the areas of operations, maintenance and engineering activities at Davis-Besse. He is trained in various root cause analysis techniques, including MORT.

William A. Mugge, FENOC (Davis-Besse, Manager of Nuclear Training) – Bill Mugge has twenty-two years of nuclear power plant experience in the areas of engineering, operations, maintenance, training, and personnel supervision. He has an engineering degree, has held an SRO license, and has been qualified as Shift Technical advisor at Davis-Besse. He brings a long-term understanding of the Davis-Besse site to the team.

Susan E. Spanos, FENOC (Davis-Besse, Nuclear Administrative Associate) – Sue Spanos has 10 years of experience in technical administrative support and established the system for organizing, tracking, storing, and retrieving the documents reviewed and used by the Team during the investigation. The tracking system allows the Team to link the factual basis for the investigation to the analytical methods and to retrieve information as needed.

Additional Technical Expertise Utilized by the Team

Lesley A. Wildfong, Conger & Elsea (Senior Consultant) – Lesley Wildfong has a Bachelor of Science degree in Nuclear Engineering from Oregon State University and 25 years of experience in both the commercial nuclear industry and the Department of Energy (DOE) weapons complex, including 10 years as a Shift Technical Advisor and 4 years as an SRO instructor at a nuclear power plant. Her areas of expertise include nuclear safety, design basis and integrated plant operations, emergency operations, criticality safety. She is a certified MORT Instructor and Investigator for nuclear plants, NRC, DOE and the Ukrainian Atomic Energy Agency. She has conducted investigations for the DOE, power plants (including two that that have experienced Confirmatory Action Letters), industrial generators of radioisotopes, and the National Science Foundation in Antarctica.

Richard D. Smith, Conger & Elsea (Consultant) – Dick Smith graduated with a Bachelor of Science degree in Engineering Physics from the University of Tennessee in 1969. He has over 30 years of nuclear safety experience with the DOE (and predecessor organizations) Oak Ridge Operations Office, and as a manager in the Tennessee Valley Authority (TVA) nuclear Safety Review Staff and Nuclear Manager's Review Group. He received training in Accident Investigation in 1971 and has conducted, led and evaluated investigations throughout his nuclear career. After his retirement from TVA in 1997, he joined Conger and Elsea, Inc. as an instructor in accident investigation techniques.

Spyros Traiforos, ENERCON (Safety Management/Root Cause Evaluator) – Dr. Traiforos has a Ph.D. in Nuclear Engineering from the University of Maryland and twenty-eight years of commercial nuclear power plant and DOE facility safety experience. He has participated in over fifty compliance and performance-based on-site team inspections and assessments of nuclear power plants and nuclear facilities. He has supported the NRC in many Diagnostic Evaluations and safety system functional inspections and the DOE in safety management evaluations and operational readiness reviews. He has extensive experience in performing root cause evaluations and assessing corrective action programs.

Industry Assessment of Management Aspects and Decision-Making

Tony Muschara, INPO (Human Performance Specialist)
Arthur Rone, INPO (Organizational Effectiveness)
E. J. Galbreath, INPO, Senior Representative,
Barry Wallace, Human Performance Specialist, D.C. Cook, member of the INPO team

3.0 Problem Statement

3.1 Reason for Investigation

As documented in Condition Report (CR) 02-0891, through-wall cracking was identified during thirteenth refueling outage (13RFO) in some of the CRDM nozzles on the Davis-Besse reactor pressure vessel (RPV) head. Further investigation of this condition in March of 2002 led to the identification of significant degradation of the RPV head base metal at nozzle 3 and additional corrosion at nozzle 2. In April of 2002, a Root Cause Analysis Report was issued on the technical causes of the degradation of the Davis-Besse RPV head (Technical Root Cause Analysis Report). That Report also identified a number of management issues that were contributing causes to the degradation, and concluded that station personnel had failed to identify corrosion of the base metal of the RPV head over a period of years despite several opportunities to do so.

The purpose of this report is to identify the root causes and contributing causes of the issues associated with the failure to identify the corrosion of the RPV head. This report also responds to that portion of CR 02-1850 that requests a root cause evaluation of issues related to the failure to identify the head degradation. This root cause report also encompasses the investigation for the following Condition Reports: 02-00685, 02-00846, 02-01053, 02-01128, 02-01583, 02-02584, and 02-02585.

3.2 Consequences of the Condition

The RPV head is an integral part of the reactor coolant pressure boundary, and its integrity is vital to the safe operation of the plant. Degradation of the RPV head or other portions of the reactor coolant pressure boundary can pose a significant safety risk if permitted to progress to the point where there is an increased risk of a loss of coolant accident (LOCA). As indicated in a letter to NRC dated April 8, 2002, entitled *Safety Significance Assessment of the Davis-Besse Nuclear Power Station, Unit 1 Reactor Vessel Head Degradation*, analysis indicates that the as-found condition of the affected nozzles would not have resulted in failure of the pressure integrity of the reactor coolant system. The degraded condition had been progressing over a period of time, without knowledge of the condition. Further degradation could have resulted in a breach of the reactor coolant pressure boundary, increase in RCS leakage, shutdown and, if actions were not taken, a LOCA. The analysis showed that the plant could have been safely shut down if such a LOCA were to have occurred. Nevertheless, the RPV was in a seriously degraded condition that should not have occurred.

3.3 Actions Already Taken

At the time of discovery, the plant was in 13RFO and was already in a safe, shutdown condition. Ongoing outage activities related to the repair of the CRDM nozzle on the RPV head were suspended.

A root cause analysis report was issued on the technical causes of the RPV head degradation, which also identified a number of management issues that were causes of the degradation. (Technical Root Cause Analysis Report). Based upon the identification of these issues and management's own assessment of the situation, FENOC developed a Return to Service Plan on May 21, 2002, to correct the causal factors and management issues and to ensure that Davis-Besse is ready for safe and reliable operation and sustained performance improvement. The Return to Service Plan includes the following Building Block Plans:

- Reactor Head Resolution Plan, which provides for replacement of the existing Davis-Besse RPV head with a RPV head purchased from the uncompleted Midland nuclear plant.
- Containment Health Assurance Plan, which provides for inspections and evaluations to determine the extent of boric acid deposition and ensure that the condition of the containment will support safe and reliable operation.
- System Health Assurance Plan, which evaluates the readiness of safety systems for safe and reliable operation.
- Program Compliance Plan, which evaluates the readiness of programs to support safe and reliable operation.
- Restart and Post-Restart Test Plan, which provides for testing to identify and disposition any leakage in the reactor coolant system (RCS) prior to restart.
- Management and Human Performance Excellence Plan, which provides for an assessment of managerial and organizational issues surrounding the degradation of the RPV head and creation of a comprehensive leadership and organizational development plan for the site.
- Restart Action Plan, which coordinates, monitors, and closes actions required for restart.

These plans are living documents that are revised as necessary to account for new information. The Management and Human Performance Excellence Plan includes a provision for performance of a formal root cause analysis of management and organizational issues. This report constitutes the formal root cause analysis mentioned in that Plan. As described in that Plan, the information in this report will be used to help prepare a comprehensive leadership and organizational development plan for the site, which will include actions to be taken prior to restart and longer-term actions to achieve and sustain a new standard of excellence.

4.0 Event Narrative

4.1 Background

Davis-Besse is a raised loop pressurized water reactor (PWR) manufactured by Babcock and Wilcox (B&W). The reactor licensed thermal power output is 2772 megawatts. The plant achieved initial criticality on August 12, 1977. The RPV has an operating pressure of 2155 psig and a design pressure of 2500 psig. Davis-Besse has accumulated 15.78 effective full power years (EFPY) of operation when the plant was shut down for 13RFO.

The RPV head has 69 control rod drive mechanism (CRDM) nozzles welded to the RPV head. Of these, 61 are used for CRDMs, seven are spare, and one is used for the RPV head vent piping. Each CRDM nozzle is constructed of Alloy 600 and is attached to the RPV head by an Alloy 182 J-groove weld. The RPV head is constructed of low-alloy steel and is internally clad with stainless steel. Figures 1, 2 and 3 show the arrangement of the Davis-Besse RPV head. Figure 1 is a section view through the RPV centerline, Figure 2 is a plan view from the top of the RPV closure head, and Figure 3 shows how the CRDM nozzles are welded into the RPV head.

There is a service structure surrounding the RPV head. The bottom of the service structure support skirt has openings called "mouse holes", which permits visual inspections through the use of a pole-mounted camera.

On August 12, 2001, Davis-Besse received NRC Bulletin 2001-01, *Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles* (reference 10.3.5). In discussions held with the NRC on November 28, 2001, in response to this bulletin, Davis-Besse committed to a 100% qualified visual inspection, non-destructive examination (NDE) of 100% of the CRDM nozzles and characterization of flaws through destructive examination should cracks be detected. During performance of these inspections during 13RFO in March 2002, significant degradation of the RPV top head base metal was discovered at nozzle 3 and additional corrosion was identified at nozzle 2.

4.2 Summary of the Technical Causes of the Degradation

The Technical Root Cause Analysis Report concluded that corrosion of the RPV head was caused by boric acid corrosion resulting from cracks in the CRDM nozzles, and that the through-wall cracking of the CRDM nozzles was caused by primary water stress corrosion cracking (PWSCC).

The Technical Root Cause Analysis Report also concluded that a reasonable time-frame for the appearance of leakage on the RPV head from the CRDM nozzle cracking is approximately 1994-1996. As discussed below, the sequence of relevant events suggests that the corrosion rate began to increase significantly starting at about 11RFO in 1998 and acted for a four-year period of time. During this period, boric acid accumulated sufficiently and provided the necessary environment to begin significant RPV head corrosion.

Additionally, the Technical Root Cause Analysis Report concluded that boric acid had accumulated on the top of the RPV head over a period of years. This accumulation of boric acid inhibited the station's ability to confirm visually that neither nozzle leakage nor RPV corrosion was occurring, and allowed the nozzle leaks to go undetected and uncorrected in time to prevent damage to the head.

The Technical Root Cause Analysis Report also noted that other evidence of the boric acid leakage existed in the containment building but was not recognized at the time. This evidence consisted of 1) iron oxide, boric acid and moisture found on the containment atmosphere radiation monitor filters, 2) boric acid accumulations in the containment air coolers (CACs), and 3) discolored boric acid accumulations on the RPV flange. While these conditions were all identified at the time, their collective significance was not recognized.

4.3 Sequence of Events

The following is a summary of the relevant events. Figure 5 depicts the changes in plant conditions over time.

Industry Experience with Boric Acid Corrosion Prior to 1988

Several incidents between the late 1970s and the mid-1980s led to the NRC in 1988 to issue GL 88-05, *Boric Acid Corrosion of Carbon Steel Reactor Pressurizer Boundary Components in PWR Plants* (reference 10.3.1). In particular, GL 88-05 discussed an event at Turkey Point Unit 4 in 1987 in which over 500 pounds of boric acid deposits were found on the RPV head. These deposits were kept wet from a leak rate of less than 0.45 gpm from a Conoseal above the RPV head. The resulting corrosion of the Turkey Point RPV head was approximately 0.25 inches in depth. Based upon this and other incidents of boric acid corrosion, GL 88-05 required all license holders for PWRs to address four areas in the plant specific boric acid program. Davis-Besse responded to this Generic Letter. Based upon the concerns in the GL, Davis-Besse issued a Boric Acid Corrosion Control program procedure (NG-EN-00324) in 1989. NRC evaluated this procedure and found it acceptable in a letter dated February 8, 1990. (reference 10.3.44)

Leaking CRDM Flanges in the 1990s

Leakage from CRDM flange gaskets was experienced early in life at B&W designed plants. As a result, B&W recommended replacing the original CRDM flange gasket with an improved graphite/SST spiral wound gasket to fix the leakage problems. Graphite/SST gaskets and corrosion resistant nut rings were installed at Davis-Besse over several outages from 6RFO through 10RFO, and all had been replaced by 1996.

It has been reported by Framatome that Davis-Besse is the only plant to have experienced leaks with the new gaskets and bolting materials. Specifically, Davis-Besse experienced the following leaks with the new gaskets:

- 8RFO Replaced gasket on nozzle 66 (a minor leaker)
- 11RFO Small leak detected at nozzle 31 (was not repaired)
- 12RFO Nozzle 31 identified as leaker and repaired. Nozzles 3, 6, 11, and 51 identified as possible leakers and the gaskets were replaced

In every outage from 7RFO through 12RFO, CRDM flange leakage was identified (either from the original gaskets or the replaced gaskets).

Evaluation from 1990 to 2000 of a Service Structure Modification to Facilitate Inspection of the RPV Head

In the early 1990s, several B&W design plants began cutting openings in the service structure surrounding the RPV head to afford better access to the center top of the RPV head for inspection and cleaning. Framatome ANP (Framatome Technologies, Inc. at the time) provided proposals to Davis-Besse over a period of several years to perform this work. In 1990, Davis-Besse proposed a modification to install the openings to the service structure. However, Davis-Besse did not install these openings and the modification was cancelled.

The need for the modification was reviewed periodically throughout the 1990s. For example, another modification was proposed in 1994 to install the openings during 11RFO. In 1997, the modification was deferred until 12RFO; in 1998, the modification was deferred until 13RFO; and in 2000, the modification was deferred until 14RFO. Based on industry documents, it was incorrectly believed that Davis-Besse was not yet susceptible to the types of nozzle cracking described in industry operating experience at the that stage of the plant's operating life.

7RFO (1991)

In 1991 (7RFO), the RCS engineer reported an excessive amount of boron on the RPV head. The boron flowed through the mouse holes and stopped on the RPV head flange by the closure bolts. The CRDM flanges were inspected, and 21 were identified as leaking and 15 were repaired.

1993 Evaluations of the Risk of CRDM Nozzle Cracking

On May 26, 1993, the Babcock & Wilcox Owners Group (BWOG) issued BAW-10190P, *Safety Evaluation For B&W Design Reactor Vessel Head Control Rod Drive Mechanism Nozzle Cracking* (reference 10.2.7) summarizing the stress analysis, crack growth analysis, leakage assessment, and wastage assessment for flaws initiating on the inner surface of the B&W designed CRDM nozzles. The overall conclusion reached in this evaluation was that the potential for cracking in the CRDM nozzles did not present a near-term safety concern. On November 19, 1993, the NRC issued its *Safety Evaluation for Potential Reactor Vessel Head Adaptor Tube Cracking*. The NRC staff also concluded that there was no immediate safety concern for cracking of the CRDM penetrations. (reference 10.3.20)

On December 14, 1993, the BWOG Materials Committee issued BAW-10190P Addendum 1, *External Circumferential Crack Growth Analysis for B&W Design Reactor Vessel Head CRDM Nozzles* (reference 10.2.8) providing an evaluation of external circumferential crack growth, gross leak-before-break mechanism, and the stress effects of CRDM nozzle straightening. The report concluded that there was no possibility for an external circumferential flaw indication to grow circumferentially to the point of becoming a safety concern. It was concluded that the GL 88-05 walkdown visual inspections of the RPV head areas would provide adequate leak detection capability.

8RFO (1993)

In 1993 (8RFO), an inspection of the RPV head was performed. The CRDM flange inspection revealed 15 leaking flanges. Boron deposits were found to be dripping through the gaps in the insulation forming stalactites. The boron deposits started forming stalagmites on the RPV head. More boron deposits were found coming through gaps in the insulation and clinging to the side of the CRDM nozzles. Some of the boron deposits were reddish brown in color. Based on the results of the head inspection, the RPV head and flange were cleaned with deionized water. The effectiveness of the cleaning could not be verified in that the RPV head had already been returned to the RPV. A cleaning effectiveness inspection was recommended as a follow-up activity for the next outage. Additionally, during this outage, significant boric acid corrosion was identified on the vent flange for one of the steam generators at Davis-Besse.

9RFO (1994)

In 1994 (9RFO), the CRDM flanges were inspected. Eight CRDM flanges were identified as leaking and repaired during this outage. No records have been identified indicating whether a visual inspection of the RPV head was completed. A video inspection of the weep holes was an activity in the outage schedule. There were no reports of boric acid deposit interference problems with inspection equipment.

10RFO (1996)

As discussed in Potential Condition Adverse to Quality Report (PCAQR) 98-0649 and as confirmed in interviews with the engineer responsible for performing inspections of the CRDM flanges during 10RFO, one CRDM flange exhibited signs of minor leakage during 10RFO. Additionally, the majority of the RPV head was inspected except for the top center. Conservatively, it appears that boric acid extended from behind nozzles 2, 3, 4, and 5 to the bottom of the insulation. The boric acid was powdery and white. Boric acid seemed to be flowing toward the mouse holes. The boric acid was very thin at the front edge with powder and small clumps of boric acid on top. The remaining area of the RPV head was clean with speckles of white boric acid deposit. Based upon an Engineering justification that the boric acid would not impact the RPV head given its high temperature, boric acid was left on the RPV head.

Generic Letter 97-01

In April of 1997, NRC issued GL 97-01, *Degradation of CRDM/CEDM Nozzle and other Vessel Closure Head Penetrations* (reference 10.3.2). The letter requested plants to describe their program for ensuring the timely inspection of PWR CRDM and other reactor pressure vessel head penetrations (VHP). In July of 1997, the BWOG Materials Committee issued BAW-2301, *B&WOG Integrated Response to Generic Letter 97-01: Degradation of Control Rod Drive Mechanism Nozzle and other Vessel Closure Head Penetrations* (reference 10.2.1). On July 28, 1997, Davis-Besse responded to the GL 97-01 endorsing BAW-2301.

The BAW-2301 introduction reiterates conclusions discussed in BAW-10190P and associated NRC safety evaluation issued in 1993. The introduction furthermore states PWSCC for CRDM nozzles and other VHPs would not become a long-term safety issue provided that the enhanced boric acid visual inspections, performed in accordance with GL 88-05, were continued, because an axial crack would lead to a leak on one or more nozzles and result in a significant deposition of boron crystals, and it is very unlikely that this type of accumulation would continue undetected with regular walkdown inspections of the RPV head area.

11RFO (1998)

Nozzle 31 was identified as having a minor flange leak (PCAQR 98-0649), and it was not repaired. Boric acid deposits were identified flowing out of the mouse holes in the southeast quadrant of the RPV head flange. The boric acid was a reddish rusty color. During the head visual inspection, the center nozzles were very difficult to inspect through the mouse holes using available techniques. The engineer noted white streaks on the nozzles. During the removal of boric acid from the RPV head, the boric acid was noted to be brittle and porous. Due to the limited inspection capability, the video evidence suggests that the most conservative estimate of the boric acid present would be to assume that behind nozzles 6, 7, 8, and 9 the boric acid extended to the bottom of the insulation and tapered off to the back of the next nozzle location. Based upon the 1996 justification that the boric acid would not impact the RPV head given its high temperature, boric acid was again left on the RPV head.

1998 - - Boric Acid Wastage of Body-to-Bonnet Nuts for RC-2 Pressurizer Spray Valve

In 1998, two body-to-bonnet flange nuts on RC-2, Pressurizer Spray Valve at Davis-Besse were identified as missing. The root cause analysis report for this event states that the nuts were missing as a result of boric acid corrosion resulting from a leak in the packing of the valve. The NRC took escalated enforcement action against Davis-Besse for this event. (reference 10.3.42). The preventive actions for the RC-2 event at Davis-Besse included the following (Licensee Event Report 1998-0009, Rev. 1):

- Revising the Boric Acid Corrosion Control Program, including benchmarking against industry standards and practices, to reflect higher standards for monitoring, evaluating, documenting and controlling boric acid leakage.
- Providing additional training to management and the technical staff to address the technical issues of boric acid control, and the Boric Acid Corrosion Control Program, the RC-2 event, and industry experience.
- Reinforcing the philosophy of conservative decision-making
- Improving oversight

1999 Mid-Cycle Outage

Nozzle 31 was inspected and showed no signs of leakage.

12RFO (2000)

Based on the CRDM flange inspection, nozzles 3, 6, 11, 31 and 51 flange leaks were repaired. Steam cutting occurred on nozzle 31, and flange repairs were required in addition to just replacing the gasket.

During inspections, a pile of boron was identified on top of the insulation. The boron on the RPV head was a red, rusty color and hard. The underside of nozzle 3 was caked with red boric acid deposits. Additionally, boric acid had accumulated on the RPV head flange behind the studs flowing out of the mouse holes in the southeast quadrant. The boric acid had a red, rusty appearance. Boric acid on the RPV head was identified as a mode restraint.

The cleaning of the RPV head during the outage was not fully successful, and some boric acid deposits were left on the RPV head. In interviews, the engineer stated that he was running out of time to continue cleaning the RPV head (the RPV head was scheduled to return to the RPV during the next shift). Outage management concurred that no additional time and dose should be spent because further attempts would not produce successful results (the washer being used was unable to remove all of the hardened deposits) and the results were believed to be acceptable. Radiation Work Permit (RWP) 2000-5132 package was written as a tool to control radiological exposure for cleaning boric acid from the RPV head on April 6, 2000. The RWP estimated 30 man-hours and a 100 mRem dose for the work. In actuality, there were 282.31 man-hours and 1611 mRem expended for cleaning the RPV head. CR 00-1037 states that the RPV head was cleaned but did not identify that boric acid was left on the RPV head, and a written evaluation was not performed to allow the boric acid to remain on the RPV head.

Fouling of the Radiation Monitor Filters in 1998-2001

In March of 1999, fouling of the containment atmosphere radiation monitor filters occurred. Initially, this fouling was attributed to the disabling of the pressurizer code safety valve rupture discs in late 1998. It was noted that the service life of the filters had decreased, particularly for RE4597BA. However, by May 19, 1999, the boric acid deposits on the filters had developed a "yellow" or "brown" appearance. From May of 1999 until April 2001, filter changes on RE4597BA were required on an irregular 1 to 3-week interval (as compared to a normal 1-month replacement interval for preventive maintenance purposes) and sometimes once every 1 to 3 days.

Accumulation of boric acid on the containment atmosphere monitor filters was recognized to be symptomatic of an RCS leak as soon as it occurred. Interviews with the system engineer indicate that he was told initially by management to consider the boric acid accumulation as a problem with the radiation monitor. However, efforts were made, especially during the cycle 12 mid-cycle outage in 1999 and later during 12RFO in 2000 to locate the source of leakage, without success. By November of 2001, RE4597BA and RE4597AA filter replacements were required approximately every other day.

Analysis performed by an external company (Sargent & Lundy) concluded that there was a steam leak in containment that was producing iron oxide. The report was discounted because it stated that the leakage was likely located high in the containment. No further consideration was given to the information.

Based on the observations that there was a high boric acid accumulation near the CRDM exhaust fans and no leaking CRDM flanges found in 13 RFO, it can now be inferred that the boric acid found in the RE4597 filters (and in the CACs) originated at the CRDM nozzles and was dispersed by the CRDM exhaust fan.

Containment Air Cooler (CAC) Cleaning in 1998-2001

Prior to 1998, no cleanings of the CAC for boric acid fouling had been needed since 1992. In October of 1998, there was a concern over the configuration of the pressurizer code safety valve discharge piping configuration. Short-term remedial action to resolve that concern involved deliberately failing the rupture disks. In November of 1998, PCAQR 98-1980 identified that fouling of the CACs appeared to be resuming, based on plenum pressure trends, coinciding with increased leakage from the pressurizer safety valves. Cleaning of the CACs continued, with 17 cleanings being needed between November 1998 and May 1999. During the May 1999 mid-cycle outage, a pressurizer code safety valve piping modification resolved that issue. However, two subsequent CAC cleanings were still required, one in June 1999 and another in July 1999. Although the boric acid was generally reported to be white, a written post-job critique from July 1999 indicated a "rust color" was noticed "on and in the boron being cleaned away" from CAC 1.

In June 2000, CAC plenum pressure again began to decrease, requiring resumption of cleaning. This was followed by five total cleanings in June, August, October and December of 2000. Cleanings continued in 2001, with four more (total) in January, February, March, and May. Following May 2001, the need to clean the CACs ended for the balance of the operating cycle.

Following 12RFO, but before 13RFO, it was not known whether the repairs to the CRDM flanges had been fully successful. Therefore, the CAC cleaning could potentially have been attributed to CRDM flange leakage. However, 13RFO inspections later revealed that the CRDM flange repairs in 12RFO had been successful.

In summary, there was circumstantial evidence that CAC fouling was related to nozzle leakage prior to 13RFO. Because of variations in plant conditions, CAC fouling, by itself, could not be directly correlated with CRDM nozzle leakage.

13RFO (2002)

No flange leakage was identified during this outage, indicating that previous repairs were successful. The engineers responsible for inspecting the CRDM flanges reported boric acid deposits flowing out of the mouse holes and piled up to 4 inches high in the southeast quadrant on the RPV head flange and extending 360° around the RPV head flange. The boric acid deposits in the southeast quadrant were hard-baked, whereas the deposits around the remainder of the RPV head flange were loose. During the inspection of the RPV head under the insulation, significant boric acid was encountered in the southeast quadrant. In the remaining quadrants, significant piles of boric acid were encountered two to three nozzles in towards the center of the RPV head. The deposits were hard, porous deposits and were a mixture of reddish brown and white deposits. The Technical Root Cause Analysis Report concluded that most of the boric acid deposits found on the Davis-Besse RPV head at 13RFO came from leaking nozzle 3 with potential contributions from nozzle 2.

5.0 Data Analysis

5.1 INPUT

The Root Cause Analysis Team used data from several sources of information as input for its analysis. These sources included the Technical Root Cause Analysis Report and the NQA *Examination of Five Closed Nonconformances Related to the Reactor Pressure Vessel Head* that was issued in June of 2002.

Additionally, the Team collected and reviewed documents related to the events discussed in Section 4. Those documents are listed in Section 10. The Team also interviewed a number of individuals, as identified in Section 11.

5.2 METHODOLOGY

Information-Gathering, Tracking & Retrieval System

The Root Cause Analysis Team established a system for organizing, storing and retrieving information from the original investigation of the technical root causes of the RPV head degradation and new information. The tracking system allowed the Team to link the factual basis for the investigation to the analytical methods and to retrieve information as needed.
The Team established a system that captured over 125 personnel interviews of more than 80 individuals and approximately 700 documents, in performance of the technical root cause and development of the current investigation.

Investigation Methods

The Root Cause Analysis Team used the following methods to perform its root cause analysis:

- Event & Causal Factor Analysis
- Hazards-Barriers-Targets Analysis
- Management Oversight and Risk Tree (MORT) Analysis (including a Change Analysis)

These investigation methods led the team to explore areas of human performance that were beyond those considered in the technical root cause investigation, such as setting of expectations and application of standards, process/program development for control of boric acid corrosion, supervision, and management involvement in rigorous safety analysis and decision-making, especially with regard to industry operating experience from and commitments made to the regulator. Each of these methods is summarized below.

Events & Causal Factors (E&CF) Analysis

This method was developed by and is currently used by the National Transportation Safety Board to investigate major accidents such as commercial airplane crashes or train wrecks. It has become a standard method for conducting investigations. The chart provides the *historical context* for how and why events and conditions occur that allow accidents to happen. The chart organizes information to show the exact sequence of events including the causal factors, other conditions that influenced the event, and assumptions made. It organizes data by time of occurrence and cause/effect, and provides a cause-oriented explanation of the event.

For this root cause investigation, the E&CF chart identifies key plant events and conditions from 1980 to the present. There are four main issues that are tracked on the chart:

- Boric acid corrosion of the reactor vessel head, including the flow of technical information (both internal to the station and from external sources of industry experts and regulators) regarding boric acid's effect on carbon steel and rates of stress corrosion cracking in Alloy 600.
    - The purpose of the investigation of this issue was to determine if the site accepted boric acid leakage or accepted corrosion of the reactor vessel head.
- Boric acid buildup in the containment air coolers, which was indicative of RCS leakage inside containment.
    - The purpose of the investigation of this issue was to determine why the site lived with symptoms of a problem and did not identify the source of the problem and take actions to correct it.
- Boric acid and iron oxide buildup on containment atmosphere radiation monitor filters, which was indicative of increased RCS leakage inside containment.
    - The purpose of the investigation of this issue was to determine why the site lived with symptoms of a problem and did not identify the source of the problem and take actions to correct it.
- Corrosion damage on the carbon steel yoke and nuts for the pressurizer spray valve RC-2 due to RCS leakage of boric acid.
    - The purpose of the investigation of this issue was to determine why the corrective actions for this event were not effective in detecting and preventing corrosion of the RPV head.

These four issues are tracked chronologically in parallel to show the amount of information available through the plant operating history that was indicative of an increasing problem developing on the reactor vessel head.

The E&CF chart provided the context within which specific areas of concern were analyzed using the MORT Analysis System.

Hazard-Barrier-Target Analysis

Barriers exist that can prevent undesired consequences from the impacts of hazards on potential targets. In the Hazard-Barrier-Target analysis, barriers are analyzed by identifying all known applicable administrative and physical barriers to protect the target from hazards. An evaluation is then conducted to determine why the barriers did not exist for the event in question, or if they did exist, why they failed to prevent the event. In particular, the barriers intended to prevent the mishap are identified, listed, and analyzed. Each barrier is then classified as: did not fail, failed, did not use, or did not provide.

A Hazard-Barrier-Target analysis was performed for implementation of the Boric Acid Corrosion Control Program as it related to the RPV head and associated buildup of boric acid in 1998 and 2000. In the analysis, the boric acid was considered to be the hazard, and the carbon steel of the

RPV head was considered to be the target. The Hazard-Barrier-Target analysis was used to determine what barriers were in place to prevent boric corrosion of the reactor vessel head. As discussed in Section 5.3, this method identified several barriers that were not provided, not used, or failed.

In addition to using the results of the Hazard-Barrier-Target analysis directly to draw conclusions, the results were also used as part of the MORT analysis.

Management Oversight & Risk Tree (MORT) Analysis

MORT consists of a fault tree analysis that helps establish all the possible causes for an event. The basic premise of the method is that MORT lists all possible faults and causes in a risk tree with numerous branches. This comprehensive tree enables a knowledgeable individual or group to investigate all possible causes, eliminate causes through deduction or investigation, and determine the root cause(s). MORT is employed by regulatory and oversight agencies (including the NRC) and industries that deal with high hazard operations to provide a comprehensive, rigorous integrated look at specific controls and management factors that impact safe operation. MORT has been a method of investigation used by the NRC for incident investigation teams and augmented inspection teams since 1986.

In performing the MORT analysis, the Team focussed on the key management responsibilities that most impact safe operations. These responsibilities pertain to the areas of policies and their implementation, risk assessment systems, and programs that support safety focus. Based upon this focus, the Team utilized the following branches of MORT risk tree:

- Risk Assessment of Management Systems – This branch of MORT was used to evaluate the management systems, principles and standards used in seeking out and evaluating industry and internal information for the detection and prevention of technical problems. This branch of the analysis provided overall conclusions regarding the management systems and was supported by evaluation of the following lower-tier branches:
    - Technical Information System - This branch of MORT was used to evaluate the gathering and dissemination of technical knowledge and the communication of information from both internal and external sources. This included an evaluation of the threshold for the level of hazards that required a formal engineering analysis, and an assessment of the adequacy of evaluations of emergent information regarding threats to nuclear safety and the design basis.
    - Hazards Analysis Process - This branch of MORT was used to evaluate the adequacy of the management processes for maintaining the design basis for the plant. It included an evaluation of the adequacy of the concepts and standards used in developing the requirements for protection against boric acid corrosion and PWSCC, and an evaluation of the adequacy of the requirements themselves.
    - Program Reviews – This branch of MORT was used to evaluate the programs which ensure that the risk assessment and management process is adequately broad in scope and supported by management at all levels within the organization to ensure early detection and correction of problems with boric acid corrosion. The specific programs selected for review by the Team were the Corrective Action Program (including involvement by Operations). This program was evaluated for its effectiveness in identifying and correcting root causes to prevent recurrence of problems.

- o Organization Reviews – The Team evaluated the independent oversight organizations (Quality Assurance and the Company Nuclear Review Board) to determine their effectiveness with respect to boric acid issues.
- o Task Performance Errors - The Team evaluated the following areas of human task performance to identify breakdowns that led to performance errors:
  - the failure to recognize the significance of the boron buildup on the RPV head;
  - the failure to recognize the significance of the increasing frequency of cleaning of the Containment Air Coolers;
  - the failure to recognize the significance of the boric acid and iron oxide plugging of the radiation monitor filters; and
  - the failure to effectively determine and correct the source(s) of the leakage from the RCS
  - the ineffectiveness of the preventive actions taken in response to the corrosion of the nuts on the RC-2 Pressurize Spray Valve.

  To avoid duplication, these task performance errors were evaluated within the context of the overall Risk Assessment of Management Systems.
- o Corporation/Management Goals - This branch of MORT was used to determine if appropriate emphasis was placed on safety goals relative to production and business goals.

To avoid duplication, these task performance errors were evaluated within the context of the overall Risk Assessment of Management Systems.

5.3 RESULTS

5.3.1 Event and Causal Factors Analysis

The Event and Causal Factors (E&CF) chart was developed throughout the period of the root cause investigation. The original timeline available from the Technical Root Cause served as the starting point. It identified the key areas of interest, and established the basis for the assembly of additional data.

This investigation examined organizational performance that spanned a number of years, and examined patterns of behavior over these periods. Therefore, the E&CF is somewhat non-traditional in appearance. Rather than displaying discrete events and causes, it contains information that shows the periods of time that organizational responses were in place. The intention was to make it as informative as possible, with respect to the important aspects of organizational and human performance.

The key insight that was gained from the E&CF chart analysis is that organizational performance in response to industry knowledge about boric acid, as well as its potential safety implications to the plant, is evident in the late 1980s and early 1990s. Thereafter, organizational performance declined in both respects, and that decline is evident beginning about 1996.

During the investigation, the E&CF chart grew to about 100 feet in length. In order to keep it to a useful size for the report, the report-version begins at the 1996 era, which is the time that the changes in organizational response to degrading plant conditions showed the beginnings of declining performance. The summary of the E&CF chart is provided as Figure 4.

5.3.1.1 Boric Acid Corrosion of the Reactor Vessel Head

The E&CF chart displays the presence of the following causal factors from 1996 until the RPV head corrosion was discovered in 2002:

- Less than adequate safety focus
- Less than adequate implementation of the corrective action program
- Less than adequate boric acid corrosion control program implementation
- No safety analysis was performed for the conditions on the RPV head

5.3.1.2 Boric Acid Buildup in Containment Air Coolers

The E&CF chart displays the presence of the following causal factors from late 1998 until late in cycle 13:

- Less than adequate safety focus
- Less than adequate implementation of the corrective action program
- No safety analysis was performed to assess the operability of the coolers due to repeated fouling with boric acid.

5.3.1.3 Boric Acid Buildup on the Radiation Monitor Filters

The E&CF chart displays the presence of the following causal factors from early in 1999 until late in cycle 13:

- Less than adequate safety focus
- Less than adequate implementation of the corrective action program
- No safety analysis was performed for the conditions in the containment that could be causing the plugging of the filters, nor for ensuring that operability was maintained between filter changes

5.3.1.4 Boric Acid Corrosion Damage to Pressurizer Spray Valve RC-2

In 1998, the yoke on the Pressurizer Spray Valve RC-2 was replaced during 11RFO. In the ensuing months, the plant ran with an active packing leak on the valve, which eventually led to corrosion of fasteners on the valve later in that year. The E&CF chart displays the presence of the following causal factors:

- Less than adequate safety focus
- Less than adequate implementation of the corrective action program
- Less than adequate boric acid corrosion control program implementation

5.3.1.5 Collective Evaluation

The E&CF analysis of the boric acid issues related to the RPV head, CACs, radiation monitor filters, and the RC-2 event identifies several common causes. These are:

- Less than adequate safety focus (Root Cause 6.1.1)
- Less than adequate implementation of the corrective actions program (Root Cause 6.1.2)
- Lack of safety analyses of identified conditions (Contributing Cause 6.2.1)

5.3.2 Hazard-Barrier-Target Analysis

A Hazard-Barrier-Target analysis was performed for implementation of the Boric Acid Corrosion Control Program as it related to the RPV head and associated buildup of boric acid in 1998 (11RFO) and 2000 (12RFO). Tables 1 and 2 provide a matrix of the barriers that should have been in place to detect and prevent corrosion of the RPV head, and evaluates whether each barrier existed and was effective.

The Team identified almost 50 barriers that were or should have been in place under the Boric Acid Corrosion Control (BACC) Program and the Inservice Test Program to prevent significant corrosion of the RPV head. These barriers ranged from appropriate design, training, coordination of boric acid control activities, inspections for boric acid leakage, communication of boric acid leakage, cleaning of boric acid, inspections for boric acid corrosion, assessments of adverse conditions, and corrective and preventive actions for adverse conditions. In summary:

- Design – The design failed to prevent leaks of boric acid. In particular, the Alloy 600 material used in the original design of the CRDM nozzles was susceptible to cracking and leakage, and the original gaskets in the CRDM flanges were susceptible to leakage as discussed in Section 4.3. (Observation 6.3.1)

- Training – A past RCS System Engineer remembers giving training on the BACC Procedure and boric acid corrosion while he was the RCS System Engineer. He was the System Engineer from 1991 to approximately 1997. He thought he may have given this training to Systems Engineering during a morning meeting. He could not remember the specific timeframe. This training could have been given on 4/27/95 as training on NG-EN-00324 was given as noted in the FENOC Integrated Training System, Trainee Tracking System. However, training was not provided to the ISI VT-2 inspector on boric acid corrosion, and training on inspections was not provided to the engineers who conducted the inspections for boric acid in 10RFO and 11RFO. Additionally, as noted in interviews, the inspector performing the 11RFO inspection was given no preparation time or guidance on the procedure he was using for the inspection. Although training was provided to engineering personnel in 1999 on the lessons learned from the RC-2 boric acid corrosion event (including discussions that red or brown boric acid is evidence of corrosion), this training was less than adequate in assisting personnel in recognizing that the red and brown boric acid on the RPV head in 12RFO was evidence of corrosion of the head. (Observation 6.3.2)

- Coordination of Boric Acid Control Activities - The BACC Procedure provided for a Boric Acid Corrosion Control Coordinator to coordinate resolution of boric acid activities during outages. The RPV head inspection activities and resolution of the corrective action documents on the head were not coordinated through the BACC Coordinator. (Observation 6.3.3)

- Inspections for Boric Acid Leakage – The BACC Procedure required inspections of areas capable of developing boric acid leaks. Step 6.1.1 of the Procedure, entitled Principle Leak Locations, states: "All areas and components within the primary system pressure boundaries are capable of developing leaks." The RPV head is included in this definition, but was not specifically referenced in the Procedure as one of the probable locations of leakage. Furthermore, following issuance of BAW 10190P (5/93) (reference 10.2.7) and BAW 2301 (9/97) (reference 10.2.1) which identified nozzle cracking as an issue and the need for inspections of the RPV head for evidence of boric acid from nozzle leakage, the BACC Procedure was not revised to include the RPV head nozzles as "a principle leak location" in Step 6.1.1. (Observation 6.3.4) This resulted in reliance on the inspectors' training, skills, or experience to identify boric acid leakage from the nozzles. While the Team considers this to be a weakness in the Procedure, it was not a causal factor for degradation of the RPV head. Despite the lack of any specific reference in the CRDM nozzles in the BACC Procedure, inspections were performed of the RPV head and were effective in identifying the presence of boric acid on the RPV head. However, contrary to the requirements of the Procedure, those inspections failed to identify all of the sources of boric acid leakage. In particular, because the boric acid was not cleaned from the RPV head, the inspections failed to identify that there were leaks in the CRDM nozzles.

- Communication of Boric Acid Leakage – The BACC Procedure required the communication and documentation of boric acid leakage. In general, this barrier was used. Initial inspections were documented and communicated via the corrective action process. However, as discussed below, thorough follow-up detailed inspections of corrosion were not performed following cleaning.

- Cleaning of Boric Acid – The BACC Procedure required the cleaning of boric acid from the affected components. This barrier failed, in that the cleaning was not effective in removing all of the boric acid from the RPV head in both 11RFO and 12RFO. (Root Causes 6.1.2.d and 6.1.4)

- Inspections for Boric Acid Corrosion – The BACC Procedure required inspections to determine if boric acid could have entered the internals of the component and whether there are signs of corrosion. These barriers were not used (or were only partially used), because boric acid was not fully removed from the RPV head to permit a complete inspection for corrosion. (Root Cause 6.1.4)

- Assessments of Adverse Conditions – The BACC Procedure required assessments to determine the source and root cause of the boric acid leakage, and to identify the extent of damage. These barriers failed. Although assessments of the extent of corrosion were performed on those areas of the RPV head that had been fully cleaned, inspections were not performed to identify the extent of damage to those areas of the RPV head still covered with boric acid. As a result, the evaluations were not effective in identifying that one of the sources of the boric acid leakage was cracking of the CRDM nozzles. Furthermore, assessment of the impact of leaving boric acid on the RPV were not performed in 12RFO, and in 11RFO the Engineering justification incorrectly assumed that boric acid leakage was from the CRDM flanges and that a hot RPV head was not susceptible to significant corrosion. (Root Causes 6.1.2.a, 6.1.2.c, 6.1.2.d, 6.1.3 and 6.1.4)

- Corrective and Preventive Actions – The BACC Procedure required corrective action to stop the leak and prevent recurrence of boric acid corrosion. However, a root cause analysis was not performed, because the significance of the conditions was categorized relatively low under the corrective action program. Additionally, the CRDM nozzle leakage was not identified. As a result, action was not taken to stop the CRDM nozzle leakage and to prevent boric acid corrosion from that leakage. (Root Causes 6.1.2.a, 6.1.2.b, 6.1.2.c, 6.1.2.d and 6.1.4)

In summary, the BACC Procedure generally provided adequate barriers for identifying, assessing, and correcting boric acid leakage to prevent corrosion. The barriers that did not fail were associated with the initial inspection of the boric acid on the RPV head, documentation of the boric acid, and notification of the condition to Shift Supervisor/Shift Manager/management via corrective action documents. The barrier that failed was associated with the cleaning of the boric acid from the RPV head. Because this barrier failed, other barriers were not utilized (e.g., performance of detailed inspection to determine the source of the leak, the magnitude and extent of condition, and the wastage of the affected material). Also, once it was determined that there were indications of corrosion (red/brown boric acid deposits in 11RFO PCAQR 98-767 and 12RFO CR 00-1037), there was no rigorous or detailed analysis of this indication of corrosion, and instead these PCAQRs/CRs were evaluated at the "Apparent Cause" evaluation level.

In addition, the Team evaluated the barriers associated with the Inservice Test Program (DB-PF-03065) under Section XI of the American Society of Mechanical Engineers (ASME) Code, which provides for inspections of the reactor coolant pressure boundary for leakage. The Inservice Test Program states:

> in accordance with IWA-2200, all VT-2 exams shall occur w/in a 6 foot distance of the exam boundary or w/in a 6 foot distance of the floor level directly below the examining components. For components whose external surfaces are inaccessible for direct visual exam, VT-2, only the exam of surrounding area for evidence of leakage shall be required.

Additionally, IAW-5250 Item b of Section XI of the ASME Code states: "If boric acid residues are detected on components, the leakage source and the areas of general corrosion shall be located." Based upon these provisions, the Team concludes that the Inservice Test Program provided adequate barriers to detect leakage due to CRDM nozzle cracks. However, similar to the BACC Program, the Team concludes that these barriers were not used or were ineffectively implemented. In particular, the CRDM nozzles would not have been viewable within the 6-foot distance required by IWA-2200. In reviewing the 1998/2000 exams, it was not clear to the Team what was inspected and how the inspection was performed. However, in 12RFO, the VT-2 exam of the studs could not be performed due to accumulation of dry boron and debris between the bolting and head. Under IAW-5250, the leakage source should have been investigated. However, Condition Report 2000-1037 was designated for Routine/Apparent Cause evaluations, and a root cause evaluation was not performed to find the leakage source. (Root Causes 6.1.2.b and 6.1.4)

5.3.3 MORT Analysis

The following summarizes the principal facts evaluated in each section of the MORT analysis, and provides conclusions with respect to each of those sections.

5.3.3.1 Technical Information System

Under this branch of MORT, the Team considered the adequacy of technical knowledge regarding the effects of boric acid and the potential for PWSCC of the CRDM nozzles, the collection of information regarding boric acid leakage at Davis-Besse, and the analysis of that information.

The Team concludes that Davis-Besse had a well-defined structure for collection and dissemination of information related to boric acid accumulation and corrosion and PWSCC. For example, Davis-Besse Policy M&C-11, Rev. 17, dated October 1998, required Davis-Besse to participate on the B&WOG materials committee which had responsibility for boric acid corrosion and PWSCC and Davis-Besse Policy Nuclear Operation Policy Tech-3, "Corrective Action," issued in October 1998, also encouraged Davis-Besse personnel to promptly identify and communicate problems and potential problems. Similarly, both the Boric Acid Corrosion Control Procedure (NG-EN-00324) and Potential Condition Adverse to Quality Reporting Procedure (NG-QA-00702) required inspections and documentation of boric acid accumulation on corrective action documentation. PCAQRs initiated pursuant to this procedure were required to be reviewed by a multi-disciplinary PCAQ Review Board and to be provided to the Shift Supervisor for his review.

The Team also concludes that Davis-Besse had adequate technical sources available regarding the effects of boric acid and the potential for PWSCC of the CRDM nozzles. For example

- Availability of Information on Boric Acid Corrosion – NRC GL 88-05 (reference 10.3.1) and Information Notice (IN) 86-108 and its supplements (references 10.3.9, 10.3.10, and 10.3.11) provided information on the potential for boric acid corrosion of carbon steel components (including RPV heads). Furthermore, the BWOG Boric Acid Corrosion Data Summary and Evaluation dated April 15, 1994 provided boric acid corrosion rates and listed several variables that affect corrosion rates, such as flow of boric acid solution, acid concentration, exposure time, and temperature. It stated that the surface temperature of wetted items should be determined, keeping in mind that localized cooling of wetted surfaces can occur due to evaporation. (reference 10.2.20). Similarly, the EPRI Boric Acid Corrosion Guidebook stated that dripping water on hot metal surfaces can concentrate boric acid as water boils off, and the boiling process can lower the local temperature to the boiling point of the boric acid (about 212 – 230 °F), which corresponds to point of maximum corrosion. This Guidebook also states that, if the leakage rate is high, or the source is located within the boric acid deposits, the deposits will be wetted leading to high corrosion rates at the vessel head. In summary, Davis-Besse had sufficient sources of information to indicate that the RPV head could be subject to significant corrosion if it were subjected to an active reactor coolant leak.

- Availability of Information on CRDM Nozzle Cracking – NRC GL 97-01 (reference 10.3.2) identified that cracking of reactor pressure vessel head penetrations (VHPs) has occurred as a result of PWSCC and is expected to continue to occur as plants age. This GL further states that, to ensure that the safety significance of VHP cracking remains low, the NRC staff continues to believe that an integrated, long-term program, which includes periodic inspections and monitoring of VHPs, is necessary.

- Involvement in Industry Groups – One of the Davis-Besse design engineers was active on the BWOG materials committee, and was acting chairman at one point.

The Team also concludes Davis-Besse had collected and internally disseminated sufficient information to have enabled it to have identified the CRDM nozzle leaks and prevent severe corrosion of the RPV head.

- Identification of Boric Acid on the RPV Head – Davis-Besse documented the as-found condition of boric acid on the RPV head during each refueling outage. For example, CRDM flange leakage and/or boric acid accumulation on the RPV head was documented on corrective action documents during each refueling outage from 6RFO through 12RFO. (PCAQR 90-120, PCAQR 91-353, PCAQR 93-0132, PCAQR 94-0912, PCAQR 96-0551, PCAQR 98-0649 and 98-0767, and CR 00-0782 and 00-1037, respectively). Additionally, videotapes were routinely made of inspections of the accumulation of boric acid on the RPV head.

- Identification of Changing Conditions regarding the Boric Acid Accumulation – Corrective action documents identified the changing nature of the boric acid accumulation over time. For example, during 10RFO in 1996, PCAQR 96-0551 identified varying sizes of boric acid mounds scattered in various areas of the RPV head, including some "rust or brown stained boron accumulation." By 11RFO in 1998, PCAQR 98-0767 documents that most of the RPV head was covered with an uneven layer of boric acid, along with several "fist" size lumps of boric acid, and that the lumps varied from rust brown to white. By 12RFO in 2000, CR 2000-1037 documented that large deposits of boron had accumulated on the top of the insulation and on the RPV head, and that the boron deposits were "lava like" and flowed from the mouse holes.

- Identification of Changing Conditions in the Containment – As shown on Figure 4, there were several changing conditions inside containment from 1998 through 2001 related to boric acid leakage. In particular, unidentified reactor coolant leakage increased from a baseline level of less than 0.05 gpm in 1997, to about 0.1 gpm in 2000, to about 0.2 gpm by the end of 2001. Similarly, replacement of radiation monitor filters changed from routine monthly replacements for preventive maintenance purposes in 1997, to once every two weeks in 2000 due to boric acid clogging, to once per week in mid-2001 due to boric acid clogging, to once every one or two days by the end of 2001 due to boric acid clogging. Similarly, the number cleanings of the CACs due to boric acid clogging increased from none from during the mid-1990s to 19 in 1998/1999 and continued with five in 2000 and four in 2001.

However, the Team concludes that Davis-Besse did not adequately apply and integrate its technical knowledge of key industry information and its information regarding boric acid deposition at Davis-Besse. Furthermore, Davis-Besse did not adequately compare new information regarding changed conditions at Davis-Besse with previous conditions. These failures resulted in less than adequate analyses and decision-making with regard to the nuclear safety implications of boric acid on the RPV head. (Root Cause 6.1.3) Specifically:

- Failure to Perform Visual Inspections of the RPV Head – The BWOG safety evaluation of the risk from cracking of CRDM nozzles (reference 10.2.7) and the BWOG Integrated Response to Generic Letter 97-01 (reference 10.2.1) provided for visual inspection of the RPV head for signs of boric acid leakage from cracking, and Davis-Besse took credit for the BWOG documents. Additionally, the Boric Acid Corrosion Control Procedure (NG-EN-00324) states that when boric acid deposition is identified, inspections shall be performed to determine the extent of corrosion damage. However, in 10 RFO, 11RFO, and 12RFO, Davis-Besse left boric acid on top of the RPV head and therefore was unable to identify indications of boric acid leakage from cracks in CRDM nozzles and corrosion of the base metal carbon steel in the top of the RPV head.

- Insufficient Consideration of Active Leakage – The EPRI Boric Acid Corrosion Guidebook (references 10.5.2 and 10.5.3) states that boric acid deposits on the RPV head can protect the surface of a component from corrosion by keeping water away from the surface, but that high corrosion rates can occur from wetted boric acid if the leakage rate is high or the source of the leakage is within the boric acid deposits. Davis-Besse took credit for the first part of this statement but did not address the second part even though it knew that there were active leaks from the CRDM flanges and a potential for leaks from the CRDM nozzles.

- Insufficient Consideration of Reddish and Brown Boric Acid – Red and brown boric acid was identified on the RPV head in 10RFO, 11RFO, and 12RFO. Davis-Besse's Boric Acid Corrosion Control Procedure (NG-EN-00324) indicated that corrosion would most likely be exhibited by red rust or red/brown boric acid, but PCAQR 96-0551 and 98-0767 attributed the red and brown boric acid to aging rather than corrosion.

- Lack of Integration of Information on the RC-2 Event – Boric acid corrosion of two nuts on the Davis-Besse RC-2 Pressurizer Spray Valve occurred in 1998 and led to escalated NRC enforcement action in 1999. Lessons learned from this event do not appear to have been applied to the conditions involving the RPV head, even though PCAQR 96-0551 and CR 2000-1037 related to boric acid on the RPV head were closed after this event.

- Insufficient Consideration for Sargent & Lundy Evaluation of Boric Acid on Radiation Monitor Filters – Davis-Besse requested Sargent & Lundy to evaluate a sample of boric acid from the radiation monitor filters, and Sargent & Lundy determined that the boric acid contained iron oxide that was probably formed from a steam leak rather than general corrosion of bare metal or impingement of steam on a surface (reference 10.2.17). The conclusions and recommendations from this report were not accepted by the station, and Davis-Besse closed this issue without finding the source of the iron oxide on the filters.

- No Collective Significance Evaluation – As discussed above, from 1999 to 2001, the unidentified reactor coolant leakage increased, the frequency of clogging of the CACs due to boric acid increased, and the frequency of clogging of the radiation monitor filters increased, at the same time that the nature of the boric acid on the RPV head was significantly changing. However, the collective significance of these factors was not recognized. Furthermore, with respect to the clogging of the radiation monitor filters, the system engineer discussed the matter with management at the morning meeting, and the management team expressed the desire to resolve the issue quickly and to address the issue solely as a problem with the radiation monitoring system.

The initial response to PCAQR 96-0551 exemplifies the failure to adequately apply and integrate technical knowledge of key industry information and information regarding boric acid deposition at Davis-Besse. This PCAQR was generated because boric acid was left on the RPV head during RFO10. The design engineer who performed the inspection of the RPV head designated the boric acid accumulation as an adverse condition, stating:

> The safety evaluation submitted to the NRC for B&W CRDM nozzle cracking issue takes credit of this inspection. The basis being if there is a CRDM nozzle crack, the primary coolant escaping from the through-wall crack will exit from the RV head penetration in the form of flashing borated steam and/or boric acid crystals (snow) which will continue to deposit on the RV head throughout the operating cycle. This deposit can be detected during the head inspection at the end of cycle and corrective action(s) taken. Since the boric acid deposits are not cleaned, it is difficult to distinguish whether the deposits occurred because of the leaking flanges or the leaking CRDM. This situation represents an adverse trend with the potential for greater than marginal consequences.

The PCAQR also notes that leaving boric acid on the RPV head was not in accordance with several steps of the Boric Acid Corrosion Control Procedure (NG-EN-00324), including steps that called for 1) inspections of the area of boric acid buildup to determine if boric acid could have entered into the internals of the component and spread internally to an area that is not visible and is susceptible to boric acid corrosion; and 2) inspections of the area of boric acid buildup to identify any signs of corrosion.

Thus, the initiator of this PCAQR succinctly identified the potential safety concerns with leaving boric acid on the RPV head. However, the Plant Engineering Manager (acting as outage director) disagreed that the condition was non-conforming, stating in the PCAQR that the probability of nozzle cracking was a relatively low, and that boric acid should be removed from the head "as best we can and so as to minimize dose." The manager concluded that this would enable Davis-Besse to monitor any leakage, should a nozzle crack initiate.

Thus, in PCAQR 96-0551, there was sufficient information provided by the initiator to identify the importance of removing boric acid from the RPV head to determine whether CRDM nozzle cracking and corrosion had occurred, but this information was rejected by engineering management in the PCAQR.

5.3.3.2 Hazards Analysis Process

Under this branch of MORT, the Team considered the adequacy of the Davis-Besse hazard analysis program area itself and the adequacy of the processes and programs that prompt entry into the hazards analysis program. The hazard analyses program at Davis-Besse includes evaluations under 10 CFR 50.59, analyses of modifications, and analyses of temporary modifications. The Team concludes that the processes and programs used between 1988 and 2001 that address hazard analyses contained the necessary elements for ensuring that the design and licensing basis of the plant was maintained, including satisfying the regulatory requirements of 10 CFR 50.59. However, the Team also concludes that evaluations and decisions were made without the adequate performance of supporting safety analyses. (Contributing Cause 6.2.1)

Adequacy of the Hazards Analysis Process

The Davis-Besse procedure used for the initiation, preparation, review, and approval of safety reviews and evaluations under 10 CFR 50.59 is NG-NE-0304, "Safety Review and Evaluation." The various revisions of the procedure (between 1988 and 2001) clearly designate the responsibilities for initiating, reviewing, and approving safety evaluations. (The Team notes that most of the descriptions of those responsibilities were recently transferred from NG-NE-0304 to FENOC common procedure NOP-LP-4003, "Evaluation of Changes, Tests and Experiments.") Although the applicability provisions of procedure NG-NE-0304 changed in some minor respects between 1988 and 2001, the more significant provisions remained in each revision. For example, the scope of the procedure was adequate, and included proposed changes to the facility as described in the Updated Safety Analysis Report (USAR), proposed changes to the procedures as described in the USAR, proposed tests or experiments not described in the USAR, and proposed temporary modifications to the facility.

The Team notes that one significant provision was removed from an earlier revision of NG-NE-0304. Revision 2, section 6.2.4, "Change to the Facility as Described in the USAR," instructed personnel to "[r]eview applicable portions of the USAR and lower-tier documents included by reference and determine if the proposed action affects systems, structures, or components described in the USAR." This provision was removed from subsequent revisions to the procedure in the mid-1990s.

Procedure NG-NE-0304 also has a "Hazard Analysis" section, which requires personnel to determine if any of the listed hazards are increased by the proposed activity. These hazards include:

- fire
- flood
- pipe breaks
- pipe whip
- temperature
- humidity
- radiation
- jet effect
- pressure
- seismic events
- sabotage
- missiles
- heavy loads
- toxic gases
- hazardous materials
- wind
- tornado
- electrical noise

This section also notes that although an area in the plant may be suitably designed and qualified for *existing* hazards, a "re-evaluation may be required to re-establish the acceptability of the probability and consequences of potential accidents which may arise from the increased hazard."

The various revisions of procedure NG-NE-0304 required a number of approvals for safety reviews and evaluations, including the preparer, reviewer, qualified safety evaluation approver, and where required, the engineering duty manager, Station Review Board (SRB), and plant manager. The engineering duty manager approval has been required only for safety evaluations initiated by the station; SRB and plant manager approval has been required for safety evaluations pertaining to use-as-is temporary dispositions and temporary mechanical modifications to certain systems; and Company Nuclear Review Board (CNRB) approval has only been needed for changes to Technical Specifications, the operating license, or unreviewed safety questions.

Performance of safety reviews has been required by several plant processes, programs, and procedures, including the corrective action procedure and the processing of temporary and permanent plant modifications. More specifically, procedure NG-QA-00702, "Potential Condition Adverse to Quality Reporting," required performance of a safety review if the disposition of a potential condition adverse to quality (PCAQ) remedial action was "use-as-is" or "repair." Attachment 3 to this procedure, "Weighting Factors Checklist and Instructions," assigned weights to 22 different factors, such as personnel safety (15), potential to violate Technical Specifications (13), and significant effect on system operations (9). The sum of these individual weighting factors was then used to determine the extent/depth of the necessary evaluations/reviews, *i.e.*, the higher the Weighting Factor, the more extensive the evaluation/reviews. The Team notes that this weighting factor process was deleted from the procedure circa 1995.

Several plant procedures concerning processing of temporary and permanent plant modifications have required the performance of safety reviews, including: EN-DP-01200, "Processing Plant Modifications;" NG-EN-00313, "Control of Temporary Modifications;" and EN-DI-01200.5, "Modification Design Reports." These procedures ensure that safety reviews are performed for proposed modifications, both temporary and permanent. In addition, procedure NG-EN-00313 also instructs personnel to consider performing safety evaluations for some activities that may not constitute Temporary Modifications, but nevertheless "may need to be evaluated (for example, an Engineering Evaluation, Safety Review or Safety Evaluation) for impact on other plant programs such as the USAR, Procedures, Security, personnel safety, Environmental Compliance, chemical compatibility, and radioactive discharge/waste/processing."

In summary, the Team concludes that processes and programs used between 1988 and 2001 that address hazard analyses contained the necessary elements for ensuring that the design and licensing basis of the plant was maintained.

Adequacy of Processes/Programs that Prompt Entry into the Hazard Analysis Process

Although the Team found the hazard analysis process itself to be acceptable, it also found that the processes and programs that prompt entry into the hazard analysis process became less restrictive over time, which allowed evaluations and decisions to be made without performance of supporting safety analyses. (Contributing Cause 6.1.1)

The Team identified a number of instances where the hazard analysis process should have been, but was not implemented. For example:

- The Alarm Response procedure for radiation alarms RE 4597AA, BA (Channel 1 and 2), which were clogging with iron particles, did not tie to DB-OP-02522, "Small RCS Leaks." If the Small RCS Leaks procedure had been utilized, then the RPV head leakage may have been identified much earlier.

- The response to CR 99-1300 did not include a safety/hazards analysis of the clogging of the Technical Specification-required radiation monitor filters. Such a safety/hazards analysis may have identified the RPV head leakage much earlier.

- PCAQR 96-0551 was issued to address the presence of boric acid on the RPV head in 10RFO. This PCAQR states: "The extent of the inspection was limited to approximately 50 to 60% of the head area because of the restrictions imposed by the location of the mouse holes." No safety analysis was performed of these conditions. Such a safety/hazards analysis may have led to the identification of the CRDM nozzle leakage much earlier.

- Because of the increasing fuel enrichment at the beginning of the last several cycles, RCS boric acid concentration also increased from 1515 ppm in Cycle 8 to 2022 ppm in Cycle 13. The increasing boric acid concentration was not considered a hazard and therefore, was not evaluated using the hazard analysis process.

In summary, the Team concludes that evaluations and decisions were made without the adequate performance of supporting safety analyses.

5.3.3.3 Program and Organization Reviews

5.3.3.3.1 Corrective Action Program

The Team evaluated the Corrective Action Program and its implementation with respect to the issues involving the boric acid on the RPV head, the clogging of the radiation monitor filters, the need for frequent cleaning of the CACs, and the RC-2 event. In particular, the Team evaluated the following: 1) the policies, procedures, and guidelines for corrective action; 2) the identification and categorization of adverse conditions; 3) determination of the causes of adverse conditions; 4) the effectiveness of corrective actions; and 5) trending of adverse conditions. The Team's findings and conclusions with respect to each of these subjects is presented below.

Policies, Procedures, and Guidelines for Corrective Action

The Team first evaluated the corrective action policies for Davis-Besse. Davis-Besse has had a corrective action policy since the 1980s. For example, the current policy statement entitled *Corrective Action*, dated 10/98, states that personnel shall:

- Identify and communicate problems and potential problems accurately and clearly, stating the description of the problem
- Promptly review and effectively determine the significance of identified problems and potential problems to include characterization of the issue to distinguish the significance for safe operation of the facility.
- Effectively resolve identified problems. This includes:
    - generation and selection of corrective actions that address the causes and are compatible with other site objectives.
    - Prompt implementation of corrective actions; monitoring and adjustment of corrective actions to achieve expected results.
- Effectively analyze identified problems. This includes:
    - Determination of trends related to the frequency, collective significance, nature, and cause of identified problems.
    - Use of objective, accurate, and complete trend data so that sound decisions can be made.