FENOC
FirstEnergy Nuclear Operating Company

5501 North State Route 2
Oak Harbor, Ohio 43449

Lew W. Myers
Chief Operating Officer

419-321-7599
Fax: 419-321-7582

Docket Number 50-346

License Number NPF-3

Serial Number 1-1286

August 21, 2002

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
J.B. Hopkins, DB-1 NRC/NRR Project Manager
S.P Sands, DB-1 NRC/NRR Backup Project Manager
C.S. Thomas, DB-1 Senior Resident Inspector
Utility Radiological Safety Board

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

Prepared by: [signature]
Steven A. Loehlein
Root Cause Lead

Davis-Besse Sponsor: [signature]
Lew W. Myers
Chief Operating Officer

Approved by: [signature]
Robert F. Saunders
President

Table of Contents

Tables

Figures

Attachments

Title

1. Charter for the Root Cause Analysis Team
2. List of Condition Reports on Issues Identified during the Root Cause Analysis

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.

<u>Industry Experience with Boric Acid Corrosion Prior to 1988</u> - 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.

<u>Leaking CRDM Flanges in the 1990s</u> – 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.

<u>Team Members</u>

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 <u>Hazards Analysis Process</u>

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.

This policy also states "that Davis-Besse will be a learning organization. We must learn from events, conditions, evaluations, and trends. The learning should then be used to improve processes and programs. Experience and results should be publicized to other parts of the organization so that they, too, can learn. Learning from oneself and learning from others is necessary for a competitive, continually learning organization."

Similar provisions are contained in the FENOC Quality Assurance Program Manual (QAPM), Revision 2, dated 1/3/02, which includes the following statements:

- The requirements and commitments contained in the QAPM are mandatory and must be implemented, enforced, and adhered to by all individuals and organizations.
- Management at all levels encourages the identification of conditions that are adverse to quality.
- A corrective action program is established and implemented that includes prompt identification, documentation, significance evaluation, and correction of conditions adverse to quality.
- Reports of conditions that are adverse to quality are analyzed to identify trends in quality performance. Significant conditions adverse to quality and significant trends are reported to the appropriate level of management.

In addition to these policies on the corrective action process as a whole, Davis-Besse has also had a policy on root cause analysis. The policy statement entitled *Root Cause Analysis* dated 10/98 provides the following guidance for conducting root cause investigations, analyses, and determinations:

- The policy endorses the use of INPO Good Practice 90-004, Root Cause Analysis, as the methodology for conducting root cause analysis at Davis-Besse.
- "When conducting root cause analysis of complex and significant events, it is expected that the investigation be conducted by personnel who have no direct involvement in the event. Further, for such events, the investigation leader should be a senior, experienced member of management to ensure necessary resources are made available and the necessary effort is put forth into the investigation."
- "Personnel anticipated to perform analysis of complex events on a request basis should be trained in Management Oversight Risk Tree Analysis (MORT) or Human Performance Enhancement System (HPES) analysis."
- "Management of the area in which the event occurred should take the responsibility to initiate root cause analysis. Timely initiation of root cause analysis report should be predicated on thorough completion of analysis of the data."

In summary, the Team concludes that adequate policies had been established for finding and fixing problems.

In addition, the Team reviewed the current guidelines for the corrective action program and the corrective action procedure that was issued in 2000. The Team used a Change Analysis to compare the guidelines and procedures against the elements of a model corrective action program. The Team concluded that, although the program contained marginal elements, it was adequate for a base corrective action program in prescribing instructions for corrective action activities.

However, as discussed below, even though policy, procedures, and guidelines had been established and were adequate for finding and fixing problems, personnel at all levels of the organization did not effectively implement the corrective action process. This resulted in missed opportunities to identify the nuclear safety impact of the boric acid corrosion to the RPV head from 1996 to 2002. The Team concludes that if the Corrective Action Program had been stronger and reflected the state-of-the art, it might have avoided or compensated for some of the problems with the ineffective implementation. (Contributing Cause 6.2.2)

Identification and Categorization of Adverse Conditions

The Team evaluated corrective action documentation from 1996 to 2002 to determine whether Davis-Besse had identified and documented the nonconforming conditions involving the boric acid on the RPV head and other boric acid related issues. Based upon the following facts, the Team concludes that in general these conditions were adequately identified:

- Boric acid accumulation on the RPV head was identified during each refueling outage from 10RFO to 13RFO and was documented on PCAQR 96-0551, PCQAR 98-0767, CR 00-0782, CR 00-1037, CR 02-0685, and CR 02-0846.
- Boric acid accumulation in the CACs was repeatedly identified from 1999 to 2001 and was documented on various corrective action documents, such as PCAQR 98-1980.
- Boric acid clogging of the radiation monitor filters was repeatedly identified from 1999 to 2001 and documented on various corrective action documents, including CR 99-0882, CR 99-0928, and CR 99-1300.
- Boric acid corrosion and other problems with the RC-2 Pressurizer Spray Valve were documented on at least 14 corrective action documents, including PCAQR 98-0915, PCAQR 98-1885, and CR 99-0738. Furthermore, CR 98-0020 was initiated to report a lack of comprehensive actions relative to resolving the management issues associated with this work.

Although adverse conditions involving boric acid were in general identified and documented, 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. (Root Cause 6.1.2.b) For example:

- Boric acid accumulation on the RPV head was designated for an apparent cause evaluation on PCAQR 96-0551, PCQAR 98-0767, CR 00-0782, CR 00-1037, CR 02-0685, and CR 02-0846. PCAQR 96-0551 was initially designated for a root cause analysis. However, more than two years later on 11/2/98, the Plant Engineering Manager approved a downgrading of PCAQR 96-0551 to an apparent cause evaluation noting "an apparent cause analysis will more than support efforts to prevent recurrence." This downgrading occurred despite the fact that recurrence of boric acid deposition on the RPV head had already been documented on PCAQR 98-0767 on 4/25/98. Similarly, PCAQR 98-0767, CR 00-782, CR 00-1047, CR 02-0685, and CR 02-0846 were all considered to be routine and designated for an apparent cause evaluation without corrective action to prevent recurrence (CATPR), even though the conditions represented repeat events and should have been classified as more significant under the Corrective Action Program.

- PCAQR 1998-0649 designated boric acid leakage from the CRDM flanges for an apparent cause evaluation without CATPR, even though this was the second occasion in which the replacement gaskets for the flanges had experienced leakage.
- Boric acid clogging of the radiation monitor filters was designated for an apparent cause evaluation without CATPR on CR 99-0882 and CR 99-0928 and was not classified as an apparent cause evaluation with CATPR until issuance of CR 99-1300.
- PCAQR 1998-1885 on the RC-2 valve was assigned a Category 1 classification, requiring a root cause analysis. However, this occurred only after six PCAQRs had been issued during the previous five months on this same component before this categorization.

Additionally, during interviews, several of the managers acknowledged that adverse conditions are categorized and dispositioned as relatively low.

As discussed below, this low level of evaluation contributed to leaving boric acid on the RPV head and an improper diagnosis of the containment atmospheric conditions.

Determination of Causes for Adverse Conditions

The Team evaluated the determination of causes for the adverse conditions associated with the RPV head and other boric acid issues.

The response to PCAQR 96-0551, which documented boric acid left on the RPV head in 10RFO in April of 1996, exemplifies the ineffective cause determinations related to the boric acid on the RPV head.

- The RCS design engineer who performed the inspection of the RPV head and initiated the PCAQR stated that "the condition of the area from which boron could not be removed is not known." He stated that "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 [nozzles]." He also noted in evaluating the potential for damage to the RPV head from leaking CRDM flanges that "this type of leakage damage is extremely difficult to measure because area of interest can not easily be inspected." Despite these statements, the RPV head was not completely cleaned and inspected for damage or leakage from the CRDM nozzles.
- The station relied upon an engineering justification, which concluded that the boric acid would result in negligible corrosion rates because the temperature of the RPV head was greater than 550 °F. This evaluation of the potential for damage was inaccurate, as discussed in the Technical Root Cause Analysis Report.
- Finally, although this PCAQR was designated for a root cause analysis, the PCAQR was downgraded and closed more than two years later without an approved root cause analysis, without determining whether the CRDM nozzles were leaking or the RPV head was corroding, and without any corrective action or action to prevent recurrence.

With respect to the clogging of the radiation monitor filters, the station made several attempts to identify the source of the clogging. In particular, CR 99-1300 was issued for recurring radiation monitor filter clogging, and was assigned apparent cause with corrective actions to prevent recurrence. Evaluations of the iron oxide on the filters were performed by contractors, but the contractor's conclusions were not utilized by the station. Additionally, the station used thermography and listening devices, which were not able to locate the source of the leak. In the end, none of the actions taken by the station were effective in identifying the source of the leak.

Additionally, although the initial CR on RC-2 valve leakage was issued on 5/20/98, a root cause for the problems with the RC-2 packing was not initiated until PCAQR 98-1885 was issued on 10/16/98. Packing issues were re-identified on RC-2 valve in 12RFO. CR 2000-1001 was written on the RC-2 valve to identify the cause of the packing issues. This resulted in the third root cause analysis for the RC-2 valve, which indicates the ineffectiveness of previous root cause evaluations and preventive actions.

Similarly, Davis-Besse initiated several efforts to identify the cause of the increase in the unidentified RCS leakage, all which were not effective. Finally, the station was not effective in identifying the source of boric acid leakage that lead to the accumulation of boric acid in the CACs.

These failures appear to be symptomatic of a larger problem with cause determinations. For example:

- Quality Assessment issued SR-98-MAINT-07 on 1/19/99 documenting weaknesses in recognition and oversight of collective significance issues and a need for guidance to emphasize management's responsibility for properly recognizing, documenting, and escalating issues and assuring timely corrective actions.
- NQA issued audit AR-01-REGAF-01 on 12/26/01 and stated that "collective significance CRs are not apparently categorized consistently either by category or by evaluation method." It also noted that only three of 32 collective significance reviews received some type of formal documented analysis, and that plant personnel have not been trained in any approach to the evaluation of collective significance problems. This report also identifies that the evaluation for basic and root causes were marginal and appeared to represent poor ownership. NQA recommended use and documentation of formal analytical method for all root and basic cause evaluations.

The Team concludes that 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. This hampered the organization's ability to evaluate the potential for damage to the RPV head. (Root Causes 6.1.2.a and 6.1.2.c) Furthermore, condition reports associated with this review tended to stay unresolved until significant degradation occurred. (Observation 6.3.5)

Corrective Actions

The Team evaluated the adequacy of corrective actions for issues related to boric acid. As a result of this review, the Team identified a number of problems related to the adequacy of corrective actions.

The Team found that on a number of occasions, the plant was restarted without taking corrective action for identified boric acid problems. For example, the plant was restarted in 10RFO, 11RFO, and 12RFO without fully removing the boric acid from the RPV head. Additionally, the plant was restarted from 11RFO with known RC-2 leakage (PCAQR 98-1130) and known CRDM flange leakage (PCAQR 98-0649).

In other cases, corrective action was not taken for identified adverse conditions including boric acid. For example, Engineering and ISEG personnel issued seven extension requests for PCAQR 96-0551. The PCAQR remained open for 2 years and 9 months, and was closed without taking the designated corrective action (e.g., installing access ports in the service structure for the RPV head). Additionally, CR 99-0738 was issued to identify the need to change out RCS valve yokes after RC38 yoke was identified with boric acid corrosion. As documented in CR 02-01449, plans to address these valves in 12RFO and 13RFO were not properly executed. In still another case, CR 00-4138 documented an increase frequency of cleaning of deposits of boric acid in the Containment Air Cooler (CAC) to an interval of once every 8 weeks. The CR assumed that the source of the boric acid deposits was a RCS leak, but stated that "we cannot stop the source of the deposits at this time." Therefore, the corrective actions were aimed at reducing the radiation dose from the cleanings rather than fixing the leak and eliminating the need to clean the CACs. Similarly, CR 01-0039 was issued for a step drop in CAC plenum pressure due to an increase in boric acid in the containment atmosphere. This CR speculated that the cause was a boron ball that had fallen from a component "instead of building up on the component." This CR was closed without taking action to identify the component or eliminate the buildup of boric acid.

The Team identified other cases in which 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. For example, PCAQR 98-0767, which identified boric acid on the RPV head during 11RFO, was closed by reference to the still open PCAQR 96-0551 which identified boric acid on the RPV head during 10RFO. However, PCAQR 96-0551 was later closed without taking corrective action to remove all of the boric acid from the RPV head. Additionally, a mode 4 restraint was tied to CR 00-1037, which documented boric acid on the RPV head during 12RFO. This mode restraint was closed to an open work order to remove the boric acid from the head, but the cleaning work defined in the work order was not completed in full in that boric acid was left on the RPV head.

In other cases, the corrective action was not effective in correcting the boric acid problems. For example, in 10RFO, 11RFO, and 12RFO, the station attempted to clean boric acid from the RPV head, but not all of the boric acid was removed. CR 00-1037 states that during 12RFO the "accumulated boron deposited between the reactor head and the thermal insulation was removed during the cleaning process" and that "no boric acid induced damage to the head surface was noted during the subsequent inspection." In fact, the cleaning was not fully successful, some boric acid was left on the head, and those areas of the head could not be inspected for damage. During interviews, some management personnel at Davis-Besse indicated that at the time they were not aware that boric acid had been left on the RPV head, and an evaluation was not performed to determine the acceptability of leaving boric acid on the head.

There were other problems with the effectiveness of corrective action. For example, PCAQR 98-0915 on 5/5/98 documented corrosion of the RC-2 Pressurizer Spray Valve yoke, and PCAQR 98-1130 was issued on 5/20/98 to initiate an evaluation of the RC-2 packing leak by plant engineering per the boric acid corrosion program. PCAQR 98-1885 was issued to correct this condition, but the corrective actions were not effective. Additionally, CR 98-0020 provided for a root cause evaluation of management issues on the RC-2 event, and actions were taken to prevent recurrence. However, the preventive actions for the RC-2 event were not effective in resolving the condition with the boric acid on the RPV head during 12RFO, and many of the causes identified in the root cause evaluation for the RC-2 event were similar to those identified by an NQA *Examination of Five Closed Nonconformances Related to the Reactor Pressure Vessel Head* on June 13, 2002, and this Report (indicating that the preventive actions for the RC-2 event were not effective in eliminating the root causes of the event).

These problems with the adequacy of the designation and implementation of corrective action were also reflected in other material considered by the Team. For example, the following excerpts from interviews were indicative of the perceptions of station personnel with respect to corrective action:

- All condition reports are emergent, but no one has staff to address them, the attitude is 'just get rid of them.'
- Tell engineers to justify operability and accept deficiencies.
- What we have is a lot of long standing issues.
- Site culture was apathetic. The same people do the same stuff wrong over and over.
- The culture was to analyze everything away.
- We do not do a good job following issues to completion. The hot issues get the attention and others end up getting dropped.

Similarly, other evaluations have identified problems with corrective actions. For example, QA audit AR-99-CORAC-01 in 1999 noted that management was not ensuring corrective actions were implemented in a timely manner and that due dates were being extended with minimal evaluation of the negative ramifications. Similarly, the Condition Report Process owner issued CR 01-2028 on 8/8/01 noting a recurrence of CRs documenting late CR evaluations and corrective actions. Additionally, the January 1998 WANO Peer Review noted: "Minor materiel condition deficiencies are being overlooked because an environment has been established to accept these type of deficiencies."

Based upon the above, the Team concludes that corrective actions assigned and implemented from 1996 to 2002 failed to find and fix the leaks that caused extensive damage to the RPV head and other components. (Root Cause 6.1.2.d)

Recurring Problems and Trending

The Team first evaluated the adequacy of Davis-Besse's policies and procedures on trending of equipment problems. The Team found that Davis-Besse's corrective action policies contained adequate provisions for trending of problems. For example, the *Corrective Action* policy statement, dated 10/98, states that Davis-Besse will effectively analyze identified problems, including determination of trends and use of objective, accurate, and complete trend data so that sound decisions can be made. This policy also states "that Davis-Besse will be a learning organization" and must learn from trends to improve processes and programs. Similarly, the FENOC QA Program Manual, Revision 2, 1/3/02 states that reports of conditions that are adverse to quality are analyzed to identify trends in quality performance. In contrast, the Team determined that the procedural provisions of trending were not adequate. For example, NQA audit report AR-00-CORAC-01 notes that Davis-Besse's trending procedure did not describe a comprehensive vision for trending and analysis, and that expected outputs were not defined and basic requirements and expectations for reporting of trending data were not provided. It also noted that the process was not set up to detect long-term generic problems using historical data, CR coding data, and cause analysis input.

The Team also evaluated the adequacy of actions to identify and correct adverse trends with respect to problems associated with boric acid. The Team found that recurring problems with respect to boric acid issues either were not documented as an adverse trend and/or that the causes of the recurring problems were not identified and corrected. For example:

- As noted in CR 00-0782, CRDM flange leakage was an on-going deficiency since 1980. In particular, in every refueling outage from 7RFO through 12RFO, CRDM flange leakage was identified. Although Davis-Besse replaced the original gaskets for the flanges over a period of years, some of the replacement gaskets also leaked. It was not until 13RFO that no leaking flanges existed.
- As mentioned above, boric acid was left on the RPV head in 10RFO, 11RFO, and 12RFO, but these conditions were not identified as an adverse trend and the collective impact of these conditions was not evaluated.
- CR 00-1547 identified an adverse trend involving a drop in plenum pressure for the Containment Air Coolers due to boric acid coating the cooling coils. The CR was designated as "routine" and the apparent cause was identified as probably being boric acid residue from 12RFO. The remedial action for the CR was cleaning of the coils, without any action to prevent recurrence. Similarly, CR 02-2943 identified 13 previous CRs relative to boric acid on the CACs after the head degradation was found. No previous high level CR was identified or processed for the adverse trend involving the CAC cleaning.
- As discussed above, unidentified RCS leakage continued to increase from 1999 through 2001, and there was frequent clogging of the radiation monitor filters during this same period. Davis-Besse did not identify and correct the cause of these problems.
- There were repeat events with Reactor Coolant Pump (RCP) flange and gasket leakage from 1996 through 2002 (e.g., PCAQR 96-0650, DB-OP-06900, CR 2000-0699, CR 2000-0869).
- PCAQR 98-1885 Root Cause Report states that RC-2 Pressurizer Spray Valve packing leakage resulted in 20 work orders in 22 years. Packing errors recurred in 2000 on RC-2.

Additionally, during this same time period, other groups identified generic concerns with respect to the trending program and evaluation of the collective significance of problems at Davis-Besse. For example:

- Quality Assessment issued SR-98-MAINT-07 on 1/19/99 documenting weaknesses in recognition and oversight of collective significance issues.
- CR 99-1765 documented that the Corrective Action Tracking System (CATS) database was not useful for equipment reliability trending.
- CR 99-2249 documented the absence of a working trending program, stating that "only the most obvious trends are discussed."
- NQA audit report AR-99-CORAC-01 documented that quality trending was not being completed and that a quality trend summary had not been completed in nearly two years. This report also noted that about 80% condition reports reviewed in the audit contained coding errors.
- Similar findings were made the next year in NQA audit report AR-00-CORAC-01. This report states that the area of trending was marginal, with no adverse quality trends identified

in the previous two years. This report also notes that about 80% of the 200 condition reports reviewed in the audit contained coding errors.

- In interviews, the Condition Report Process owner noted that trending capabilities between outages does not exist. Therefore trending of issues that only arise during outages is not provided.
- The Team evaluated over 30 collective significance reviews conducted at Davis-Besse since the beginning of 2001. Of these, only one was related to equipment issues.
- NQA audit report AR-01-REGAF-01, issued on 12/26/01, noted that only three of 32 collective significance reviews received some type of formal documented analysis. It also noted that plant personnel have not been trained in any approach to the evaluation of collective significance problems.
- The root cause for CR 01-1934 identified that Davis-Besse did not have effective equipment trending and contained a corrective action stating that the plant should develop an equipment trending process. In response, the Condition Report Process owner noted than an enhanced equipment trend capability was not necessary for the CR database (CREST) due to the current trending capabilities of the program.

In summary, the Team concludes that equipment and materiel trending failed to identify and correct recurring failures, equipment degradation, and performance issues. (Root Cause 6.1.2.e)

Operation's Involvement

Throughout this investigation, the Team expected to encounter information that would indicate the level of influence that Plant Operators had in attempting to resolve the plant conditions that were linked to the RPV head damage. Instead, except for the pursuit of the RCS unidentified leak rate by the Plant Manager, the Team found that they were largely not visible. (Observation 6.3.9)

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. 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.

The Team did not undertake the task of specifically determining why this lack of involvement occurred. However, interviews with several Operations personnel reflect a perspective found in many interviews of the staff. This is that personnel identified or stated concerns in varying degrees, but would nonetheless perform their duties under the assumption that someone else was responsible to see that issues were resolved.

5.3.3.3.2 Independent Oversight Organizations

The Team initially intended to perform a MORT analysis of the independent oversight activities performed by Quality Assurance (QA) and 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 is a relatively small number of relevant facts that pertain to QA and the CNRB. Given the relative paucity of facts in this area, the Team determined that a MORT analysis of this area would not be meaningful. As a result, the Team is only providing observations regarding the activities of these groups. However, the Team also notes that FENOC has already initiated assessments of QA and the CNRB.

Quality Assurance

The Team identified surveillances and audits performed by QA related to boric acid control.

- On 1/19/99, the QA Manager issued Surveillance Report SR-98-MAINT-07. The QA surveillance included a review of the investigation and resolutions of issues identified during the work on the RC-2 valve. The surveillance concluded the initial response, corrective actions, and management attention to RC-2 issues were inadequate. QA found that when adequate resolutions were not obtained, no other organization(s) stepped up to provide additional assistance and appeared to take a hands-off approach. Furthermore, QA found that when senior management directives were given as assignments, there was confusion among organizations as to what responsibilities they had incurred. However, QA did conclude that the Boric Acid Corrosion Control Procedure NG-EN-00324, met the intent of Generic Letter 88-05. The Team concludes that this surveillance was intrusive and reflected an appropriate evaluation by QA.

- Quality Assessment Audit Report (AR-00-OUTAG-01) was issued on 7-7-00. This audit was performed to assess the effectiveness of various program activities during 12RFO. Engineering was rated as having satisfactory performance and was noted to have several positive attributes, including aggressive cleaning of boric acid accumulation from the reactor head. Additionally, QA determined that Engineering displayed noteworthy persistence in ensuring that the boric acid accumulation was thoroughly cleaned from the reactor head. Given the fact that not all of the boric acid was cleaned from the RPV head during 12RFO and that corrosion of the head was occurring during this time frame, the Team concludes that QA's findings were inconsistent with the facts.

Overall, the Team observes that there was little evidence of QA's involvement in this area, and the documented findings by QA were of mixed quality. (Observation 6.3.6) There are signs that the organization was not effective in identifying problems. However, the Team decided not to pursue the issue further because the identification of problems in this area is not likely to be connected with the root cause of the event, and the Vice President of the FENOC Oversight and Process Improvement Department has initiated an independent root cause investigation that addresses "Failure in QA Oversight to Prevent Significant Degradation of Reactor Pressure Vessel Head (CR 02-02578)".

Company Nuclear Review Board

The Team examined the minutes from the CNRB meetings related to boric acid control.

- On 10/16/96, CNRB Meeting #257 Minutes from 5/22/96 were issued. There was only one area that discussed boric acid, and that discussion pertained to the "significant" amounts of boron located on several casing studs of the Reactor Coolant Pump (RCP) 1-1. It was mentioned that these studs were removed and inspected for degradation, several had to be replaced, and the other three RCPs were inspected and some minor leakage was noted on the RCP 1-2 pump. There was no discussion of the boric acid program.

- The minutes from the 1/7/99 CNRB (Main Committee) Meeting included a discussion by the Engineering & Licensing Subcommittee regarding RC-2 issues, including the sequence of events, major corrective actions, and planned actions. The meeting minutes captured limited discussion on the RC-2 issues and no discussion of the Boric Acid Corrosion Control Program. Additionally, there was some discussion of the frequent cleaning efforts of the CACs. The minutes state that boric acid was plating out on the CACs, which decreased their efficiency and that containment entries were required about every ten days to clean the coolers.

- The meeting minutes from the 7/22/99 CNRB Main Committee Meeting indicate that the committee chairman reviewed two industry situations where management failed to recognize the need for a safety evaluation and let schedule or goal pressures force poor decisions to proceed with work. He cautioned management to be leery of situations that might cause decisions to be driven by goals or schedules and to be knowledgeable of the requirements for doing safety evaluations. Additionally, discussions were held about RCS leakage and problems encountered with the radiation monitors that required filter changes every 36 to 48 hours, and it was stated that an investigation was proceeding on this issue. It also stated that that iron was found on the filters and that Southwest Research has been contacted to investigate this matter. The CNRB committee members questioned if thermography had been used to identify the source of the RCS leakage, and the response indicated that thermography had been used as well as "listening devices." The subcommittee was also updated on continuing plant problems in the areas of RCS leakage, radiation monitors, and Containment Air Coolers/containment temperatures.

The Team concluded that there was not enough factual information gathered during this phase of the analysis to develop a conclusion addressing CNRB. However, the Team observes that no documented information was found that would indicate that the CNRB had been effective in raising the station's awareness regarding degrading plant conditions. The Team determined that further analysis in this area was not warranted as part of this root cause analysis, because CNRB does not typically perform independent inspections to identify problems but instead acts to review problems identified by others. Therefore, insight from CNRB may have helped elevate boric acid leakage as a greater concern, but is unlikely to have identified or prevented the corrosion. Additionally, FENOC has initiated a review of the adequacy of the CNRB.

5.3.3.4 Task Performance Errors

In a typical MORT analysis, task performance errors are analyzed from the perspective of individual errors. In the case of the degradation to the RPV head at Davis-Besse, this approach was modified, in that the errors of importance were the failure to recognize the significance of key plant symptoms, and the organization thereby missed the opportunity to identify the corrosion over time. Initially four errors were considered for evaluation, but during the investigation a fifth was added (related to RCS Unidentified Lead Rate). The five organizational-level errors examined were:

- the failure to recognize the significance of the boron accumulating and left on the RPV head
- the failure to recognize the significance of the boron and iron oxide plugging of containment radiation monitor filter elements
- the failure to recognize the significance of the increasing frequency of Containment Air Cooler fouling with boric acid
- the failure to effectively determine and correct the source(s) of leakage from the RCS
- the ineffectiveness of the corrective actions taken in response to the RC-2 event in 1998, as they related to identifying the importance of brown boric acid deposits

As the Team began to utilize the specific areas of the Task Performance Error Section of MORT, it soon became clear that a slightly different approach would be more effective. A clear pattern of similar organizational response to the plant conditions described above became apparent. The Team then decided to examine the RC-2 event from the perspective of how the organization responded to its problems, prior to it becoming an event.

As the work continued, the Team found that the information needed to answer the questions under Task Performance Errors was already being collected throughout other sections of MORT. For example, a great deal of data had been collected under the program and process reviews. Therefore, other existing sections of MORT were fortified with additional facts from these topics. A separate investigation using the specific Task Performance Sections of MORT became unwarranted, in that it would simply re-apply the same knowledge.

The revised approach analyzed the task performance errors within the Management Risk Assessment Section, by drawing from the conclusions of other sections, and adding specific additional data. Section 5.3.3.6 provides the full description of the approach and its conclusions.

The common features of the organizational errors included:

- 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 conditions to safety tended to be underestimated. (Root Cause 6.1.3)
- The categories assigned to the Condition Reports were relatively low, and root cause analyses were not performed. (Root Cause 6.1.2.b)
- The cause analyses were shallow, and focused on managing the symptoms rather than the causes of the identified problems. (Root Causes 6.1.2.a and 6.1.2.c)
- The station tended to defer or re-assign resolution of the problem. (Root Cause 6.1.2.d)
- The collective significance of the errors was not evaluated.
- Senior management oversight of resolution of conditions (except for the RCS Unidentified Leak Rate) was not visible. (Root Cause 6.1.2.e)

5.3.3.5 Corporate/Management Goals

This portion of the MORT analysis examines Management Policy. The Team examined the treatment of safety (industrial and nuclear) in Davis-Besse policy documents. It also considered management incentives and management presence and involvement in the field. The Team concludes that neither safety policy or compensation incentives were causal factors in the damage to the RPV head. However, they are important considerations for the future, in that they need to be consistent with the philosophy that nuclear safety is of primary importance.

Davis-Besse Policy Statements on Safety

Davis-Besse has few policy-level documents. In particular, there is no overarching document dedicated to the subject of safety. The Team concludes that the written policies that do exist have been inconsistent and incomplete in their treatment of employee and nuclear safety. As a result, they do not support a safety focus. (Observation 6.3.8)

The following describes the content of the existing policy statements. It should be noted that many of these policies were examined back to the mid-1980s, and they have not changed appreciably over the years.

- The DBNPS Philosophy document provides two pages of philosophy emphasizing value to customers of electricity, employees, management style, communication and corporate citizenship. It makes a basic statement "We are committed to a safe work environment, and the safety of co-workers is the responsibility of each of us." There is no mention of nuclear safety.

- Nuclear Operations Policy, Tech – 12, effective 10/1/98, describes the parameters within which the Davis-Besse Nuclear Power Station is operated. There is no mention of nuclear safety.

- Introduction to the Policy Manual for the Nuclear Power Station, dated 8/14/00, describes nuclear safety as being of "paramount importance" which "imposes rigorous requirements".

- Charter DBOMTO, Davis-Besse Outage Management Team Organization, (12/17/99, rev 00), states that safety has three distinct elements:
  - Personnel safety – "Work to achieve a safety culture where employees accept ownership and personal responsibility for working safely"
  - Nuclear safety – ...a conservative operating philosophy where safe operation of the plant is our foremost priority. This is accomplished by maintaining a constant awareness of shutdown risk issues and protected train philosophy in dealing with any changes to scheduled activities..."
  - ALARA – Maintain ALARA "by ensuring that individuals follow expected radiological practices, and the assumptions used to develop work practices and the schedule are maintained."

While there are additional minor examples that were examined, the conclusion of the Team is that the concept of safety has not been given sufficient prominence or focus in the written policy area.

However, the value of separately written policies in the context of today's operation of Davis-Besse is questionable. In recent years, with the formation of FENOC, policy, in effect, is described and implemented via the published Business Plan, which states that the four areas of importance for the organization, in order, are Safety, People, Reliability, and Cost. Therefore, the continuing existence of older policy formats may not be warranted.

Management Incentives

The Team examined the monetary incentives for Davis-Besse personnel to determine whether the incentives prompt safety. With respect to the management incentives, the Team concludes that the FENOC monetary incentive program rewards production more than safety at senior levels of the organization. This supports misalignment of the organizational priorities, and inhibits the transition of the organization to a safety-first philosophy. (Observation 6.3.7)

For example:

- The Nuclear Vice-Presidents' incentive compensation formula includes a contribution for net income of FirstEnergy Solutions. FirstEnergy Solutions includes all nuclear and fossil generation. Therefore, there is a financial incentive to allow investments to be allocated to plants that will generate the best financial return. This can put fossil and nuclear in competition for funds on a basis that does not necessarily consider the possible impact to nuclear safety at the nuclear plants.

- The Nuclear Incentive Compensation for 2002 provides for incentive compensation for various factors related to safety and production. The percentage attributed to safety decreases as the level in the organization rises. At the plant director level and above, incentive compensation is mostly based on production, but the incentive compensation at lower levels is mostly based on safety.

The percentage value assigned to various goals has changed over time, and the historical value of safety as an incentive was more consistent throughout the organizational levels in the past. For example, in 1997, the Davis-Besse Incentive compensation percentage attributed to safety, although not a majority, was fairly constant from the Vice President down and was about equally based on production and safety.

In the 1996 Davis-Besse Incentive compensation, safety was the highest contributor at all levels of management.

Thus, since at least 1997, the monetary incentive program has rewarded production more than safety at senior levels of the organization.

Management Presence and Involvement

A prevailing opinion in many interviews was that management's physical presence in the field has been minimal. Supporting this belief are the actual logs of containment entries by managers and senior managers which identify relatively few entries into containment by management during 11RFO, with some improvement in 12RFO. When questioned on expectation for management presence in the field, the management interviewees stated that there was a field observation program, but that there were no specific expectations for containment. (Observation 6.3.10)

In interviews with recent top site management, there was no pattern in how they believe important matters should be communicated up and down, and they indicated that problems tend to be solved within silos, and that free and open discussion of potential problems is rare.

The Team could not determine if more involved management would have prevented the damage to the RPV head. However, over the years, some individuals in management made assumptions and drew conclusions regarding the conditions on the RPV head with limited or no direct examination of the head.

5.3.3.6 Risk Assessment System Conclusions

This branch of MORT evaluates the aspects necessary for management to be knowledgeable of risks and to assess risks as part of decision-making. As such, it includes the evaluation of the programs designed to provide management with the information to properly assess risk.

The technical root cause investigation conducted in March and April of 2002 concluded that the Davis-Besse organization failed to identify the corrosion of the reactor head base metal until its discovery during maintenance activities. Since the corrosion of the head was not a known condition, the MORT sections that would evaluate management's acceptance of a known risk were not useful to this investigation. Therefore, the applicable sections of the MORT system were those that evaluate why management did not recognize the development of the conditions and the risk associated with them.

The feeders into the conclusions of this MORT section are the results of other major sections of MORT. The sections on Corporate/Management Goals, Technical Information Systems, Hazards Analysis Process, and Corrective Action Program were combined with important elements of the Task Performance Error Section. Together these sections evaluated the following issues:

- evaluation of the failure to recognize the significance of boric acid on the RPV head
- evaluation of the failure to recognize the significance of the increasing frequency of cleaning of the Containment Air Coolers
- evaluation of the failure to recognize the significance of the plugging of the radiation monitor filters with boric acid and iron oxide
- evaluation of the failure to identify and correct the source of increased RCS leakage as anything other than CRDM flange leakage
- comparison of the organization's performance in identifying and resolving the issues with the RC-2 Pressurizer Spray Valve prior to it becoming an event in 1998

The Team compiled extensive MORT section analyses and supporting factual data to answer two questions:

- Why did management not implement effective programs to have prevented the corrosion to the RPV head?

- Why did management not recognize the significance of the degraded conditions in the containment and address them as potentially significant safety concerns?

The Team concludes that the answer to these two questions, and the overall root cause for why the damage to the RPV went undetected by the organization, is as follows:

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. (Root Cause 6.1.1)

Supporting conclusions are:

- The elements of the programs designed to maintain a conservative safety philosophy degraded at the same time as the effects of the RCS leakage worsened. (Contributing Cause 6.2.1)
- Even though management had sufficient involvement in the industry and knowledge of plant conditions, they failed to recognize the significant nuclear safety concerns being manifested in containment. (Root Cause 6.1.3)
- Management pursued symptoms rather than the identification of the causes. (Root Cause 6.1.2.a)

The facts that support these conclusions come from all of the MORT analyses, along with additional evidence, all of which are summarized below.

- The MORT-Corporate/Management Goals section of this report describes how company policies are inconsistent in their treatment of safety. It also shows that the financial incentives for senior-level positions are heavily influenced by production. (Observations 6.3.8 and 6.3.9)

- The Technical Information Systems section concludes that the structure existed for management to have received the correct information to understand the risks of boric acid. However, key industry and site knowledge was not adequately integrated into programs, nor applied by the organization. (Root Cause 6.1.3)

- Similarly, the Hazards Analysis Process section concludes that the program elements necessary to analyze nuclear safety risks were adequate throughout the timeline of events. Over time, though, the processes/programs that prompt entry into these analyses became less restrictive. (Contributing Cause 6.2.1) This reduced the frequency with which the process was applied, and caused some conditions to go unanalyzed for nuclear safety.

- The pattern of an adequate program but flawed implementation was also exhibited in the conclusions of the evaluation of the Corrective Action Program. Once again, the Team judged the policy and process to be sufficient to have successfully identified the corrosion of the RPV head much earlier. However, all levels of the organization failed to implement the Program effectively. Low categorization, superficial cause analyses, ineffective corrective actions, and inadequate equipment trending all contributed to the outcome. (Root Causes 6.1.2.a, 6.1.2.b, 6.1.2.c, 6.1.2.d, 6.1.2.e, and 6.1.3)

The Team concluded that these failures were fundamentally attributable to a less than adequate nuclear safety focus by management. Numerous interviews indicate that production became a source of pride for the station in the years that overall performance of the station improved (late 1980s into early 1990s). Production is a natural goal of the enterprise, and would not necessarily conflict with safety performance. In fact, the Team concluded that safety was treated with adequate rigor in those years when production improvement was clearly evident. Later in the 1990s, safety focus eroded. Further discussion on this appears later in this section of the report.

Dozens of additional facts were compiled by the Team to support the overall conclusion of this section. Listed below are samplings of the important facts that demonstrate a less than adequate nuclear safety focus.

Focus on Production

- In response to a question if leaks found during walkdowns were left un-repaired, a manager noted: "Yes. Some were justified; we determined we could get them next time. We would be subjected to production pressure."

Only Taking Minimum Actions Needed for Regulatory Compliance

- In the early 1990s, Davis-Besse thought that CRDM cracks and leaks were a European problem and that Davis-Besse did not have them. This issue was never discussed as a compliance issue. If it were a compliance issue, it would have went straight to the top of the pack. (interview with a former Director).
- In responding to PCAQR 94-0295, the Supervisor of System Engineer did not believe performance of nozzle inspection was necessary since a formal regulatory commitment had not been made.
- "There was nothing (in the procedure) requiring boric acid off the head." (interview with a former Director).
- Temporary Modification (TM) 01-0019 was processed in November 2001 to remove the iodine filter cartridge for RE 4597AA Containment Atmosphere Normal Range. It was noted in the associated 50.59 evaluation that the increase of iodine levels in the containment was induced by an increase in RCS leak rate from the recent downpower as well as the effect of known fuel leaks. It also notes the purpose of the radiation monitors is to provide positive indication in the control room of RCS leakage. It was noted that removing the iodine channel would not force the station to enter Technical Specifications and was acceptable.
- The RCS unidentified leak rate had been rising throughout the last operating cycle, but did not lead to decisions to shut down the plant in 2001/2002 because the rate was within technical specification limits. Inspection for possible leak sources was conducted only when the opportunity arose in the brief downpower. As stated in an interview with a site manager: "We weren't at the tech spec limit (for RCS unidentified leakage) and we had taken actions to look for leaks and there were plans to look closer during the next outage. Management was monitoring the status daily and we would have taken any necessary actions prior to reaching tech spec limits. We also had the mindset that CRDM flanges were leaking."

Acceptance of Degraded Conditions

- The iodine cartridges on containment leak detection monitors were plugging so much that they were physically by-passed.

- CR 1999-1300 notes that Temporary Modification 99-0022 installed four portable HEPA filtration units in containment to reduce the particulate concentration (iron oxide/boric acid). This action was taken rather than finding and fixing the source of the RCS leaks.
- The Plant Engineering Manager stated in PCAQR 96-0551 that cleaning of boric acid from the RPV head "as best as we can" was adequate.
- "And I can only speak through 98 timeframe...we locked in on dry boron being okay, therefore I can run under that phenomenon. But I don't know why we were never worried about the nozzle cracking, or if we were worried, it was about circumferential cracking, not wastage..." (interview with former VP).
- In 1998/99, the plant ran for approximately 9 months as the RCS leak rate increased. Shut down did not occur until leak rate achieved 0.8 gpm, and after the Containment Air Coolers had been cleaned 17 times.
- Radiation Protection issued CR 00-4138 on 12/21/00 to document an increased frequency of cleaning boron from the CACs. The CR states: "Since we cannot stop the source of deposits at this time, these corrective actions are aimed at reducing the station dose associated with cleaning the CACs to maintain their function." The CACs were cleaned repeatedly without an operability determination. Then in 13RFO, the CACs were declared inoperable. (CR 02-2943)
- Davis-Besse Cycle 13 Operating History, as provided in the DBNPS Business Plan Monthly Performance Report for April 2002 reports that Secondary Plant Chemistry entered the yellow indicator for performance in June, 2001, and entered the red indicator in September, 2001. By the end of the year the Chemistry Performance Indicator (CPI) was greater than 1.5 (1.00 is desired).

Restarting the Plant with Degraded Conditions

- The plant was restarted in 10RFO, 11RFO, and 12RFO without fully removing the boric acid from the RPV head.
- The plant was restarted from 11RFO with known CRDM flange leakage (PCAQR 98-0649).
- Management decided to start the plant at the end of 11RFO, with unresolved leakage from the RC-2 valve. The plant was later shut down for tornado and restarted, without repair to the valve.
- After the tornado, there was debris in the ditches. Despite the existence of the debris, an operator was told to start Circulation Water. He objected stating that the canal had to be drained first due to the debris. The Shift Supervisor responded to him, stating that "if the VP says we start-up then we start-up." The Circulation Water was started and in less than 10 minutes, a shutdown of the system was needed. Operation had wrecked the screens and damaged an impeller. The plant also had to pull all the water boxes and clean them. (Interview with reactor operator)

The following senior and middle management interviews, from the period of 1996 until just prior to the present, were conducted to gain an understanding of their collective management style. The time period was selected because that was when the head damage occurred and when the associated plant conditions were in evidence. These interviews show a pattern of production focus and managing to minimum regulatory requirements.

Former Site Vice President

- His concept of VP at that time was that a strong plant manager ran the plant and the VP provided support and money and would take care of the corporate side of the operations. He would let the plant manager and the rest of the team run the technical show.
- He stated that the responsibility for consistency in programs and identification of issues starts at the lowest levels of the organization and percolates up – they must continue until they get a legitimate answer.

Former Site Vice President

- In response to how the plant got here, he said that standards were no where near his expectations coming into an INPO 1 plant. He said that there was denial of problems all across the board. Over time, the site developed comfort with its status, and an overall feeling that things were fine.

Former Director

- "There was a discussion at least in the PRC for a modification to cut the holes (in the service structure). It was over ½ million bucks for that MOD. We wanted to do it but it was a cost benefit thing."

Former Plant Manager

- He described the reason why the support structure modification was first proposed as an enhancement. Davis-Besse was an outlier, and needed to be ready, in case the NRC invoked the head inspection requirement. As to why it wasn't approved for 11RFO(1998), he stated it was because of lack of cost benefit. The System Engineer did not present it as a regulatory requirement. It would have passed if it had been.
- He stated that all containment was covered with Boric Acid. It was in places in 1996 and 1997 and after the RC-2 event. He stated that it was not acceptable, but was nothing new to see this boric acid.

Former Manager

- In response to a question whether the plant ever had leaks found during walk-down that weren't repaired, he said "Yes. There was a culture that we used engineering to justify why it was ok to proceed. Basically tell engineers to justify operability and accept deficiencies."
- He stated there is a lot of pressure to operate. He felt relieved once as operations manager that we tripped after a long run- - pressure was relieved by tripping. The trip was good, the pressure was off.

Former Manager

- Standards, over time, had unnoticeably slipped. The plant lived with a .15gpm leakage, yet in the Navy the standard was zero.

Internal and external review organizations also provided insight of declining performance in areas that support a nuclear safety focus.

- On 1/1/98, the WANO Peer Review noted: "Minor materiel condition deficiencies are being overlooked because an environment has been established to accept these type of deficiencies.
- The INPO 1999 Evaluation states: "Management has been focused on completing corrective actions rather than on determining the effectiveness of those actions to change the behaviors of management and the workforce."
- INPO 2001 Evaluation of Davis-Besse stated:
  - ➢ There are some indications that the organization may not be sufficiently self-critical or challenging when issues are identified. In these instances, the organization tends to focus on the positive aspects of an issue and not fully consider the potential challenge created or its significance.
  - ➢ "The shift manager seldom challenges engineering on the initial condition report response in regard to equipment operability. In addition, although the data provided by engineering may not provide a complete picture of the equipment condition, few engineering evaluations are requested to obtain further details."
  - ➢ "Some members of the engineering staff have an approach to equipment deficiencies that sets out to prove existing conditions are acceptable instead of probing worst-case scenarios and questioning why equipment remains capable of meeting its design function."
  - ➢ "Some station evaluations suggest that equipment operability is based solely on successful completion of previous surveillance requirements."
  - ➢ "Most system engineering activities are short-term focused, contributing to the lack of long-term attention to equipment performance."
- RHR International report from 1999 (Phase 2 Organization Study Results) drew the following conclusions:

  Organization Purpose and Direction:

  - ➢ The site had a pure operating orientation until the 1990s
  - ➢ Reliability and cost have become Critical Success Areas

  Organizational Structure and Systems:

  - ➢ There is a strong desire to cut out the nonessential; No one seems sure how
  - ➢ A gulf exists between Directors and other levels
  - ➢ Management levels rarely mix
  - ➢ Many Managers avoid raising bad news

  Management team effectiveness

  - ➢ There is little aggressive questioning
  - ➢ Managers avoid rocking each others' boats

  Organizational Processes:

  - ➢ Directors are seen as cautious and conflict averse

In contrast to the focus that appeared in the mid-1990s, the Team's investigation determined that nuclear safety was effectively integrated into practices and programs in the late 1980s and early 1990s. The following is presented to show how plant conditions were previously evaluated:

- A 1987 ISEG review of boric acid issues noted "experience has shown that even relatively hot metal can be sufficiently cooled on the surface by the flow of the leakage so that the surface stays wetter and boric acid corrosion is promoted." ISEG additionally noted: "The event at Turkey Point 4 demonstrates that boric acid will rapidly corrode ferritic (carbon) steel components and also that if a small leakage occurs near hot surfaces and/or surrounding then the boric acid solution will boil and concentrate becoming more acidic and thus more corrosive." This review demonstrates a proper understanding of the potential for boric acid corrosion.
- In 1990, when boric acid accumulation was identified on the pressure vessel head, corrective actions included: cleaning off the boric acid and inspection of the areas under the boric acid for surface irregularities. Additionally, a root cause determination was initiated as the CRDM flange leakage area was determined to be repetitive.
- In 1992, an extensive engineering review relative to CAC fouling was conducted to analyze the limits of operation. No such review was performed for similar component issues in the late 1990s.
- In the early 1990s the VP, when made aware of any boric acid, gave direction to clean it off, including washing the vessel head.

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. A number of interviews provided insight into the changes in management style and site philosophy were changing.

- An Engineering manager stated in the 1990s Davis-Besse migrated away from justifying why it was okay to stay on line to justifying why it was necessary to come off line.
- In response to how the plant arrived to the present day situation, a Vice President noted that top quality people had left the station in the mid-1990s and that Davis-Besse became disassociated with the industry and was not benchmarking. He believed that the station was in a survival mode from the transition in ownership from Centerior to FirstEnergy in 1997.
- A Plant Manager noted that in the early 1990s that ALARA was strengthened, and that there were few people allowed to look at the RPV head and other high dose areas.
- A Design Basis Engineer Manager noted, our standards, over time, had unnoticeably slipped. The organization's standard was "how we have always done it."

Summarizing this transition, the nuclear safety focus of the late 1980s was evident in the site's program adherence and implementation. In this environment, technical information was utilized, corrective actions were based on supporting analysis, and safety concerns were recognized and properly assessed by management. As the focus shifted, implementation and level of rigor moved to support the perceived goals (survival, cost, schedule, 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. Key vendor specialty support was not evident. Procedures, polices and practices were altered and allowed more liberty in meeting requirements.

While the ability of various station programs to properly recognize and resolve problems was diminishing, increased risk with the possibility of reactor vessel nozzle cracking was occurring. One issue for nozzle cracking was simply the age of the plant. Therefore as time passed, risk increased. Despite beliefs that boric acid on the head was from CRDM flanges, there was also acknowledgment that until the boric acid was removed and the head was inspected there was a degree of uncertainty concerning the head's condition. The longer it stayed there, the higher the relative risk if it were being wetted. Industry gained further insight and experience with nozzle cracking both axial and circumferential, and the knowledge of a growing industry issue clearly advertised an increasing risk with the passage of time. However, as risk to Davis-Besse increased, the ability of personnel and programs to identify that risk was diminishing. The point where the station no longer appeared to take aggressive actions for boric acid issues appears to be in 1996, as represented on PCAQR 96-0551. This document presents the last evidence that the threat to the head from boric acid was viewed as important. However, management discounted this evidence. In later outages, there appears to have been little if any consideration given to the results of leaving boric acid on the RPV head.

6.0 Root Cause Determination

Based upon the analysis provided in Section 5.0, the Root Cause Analysis Team identified a number of root causes and contributing causes for the failure to identify boric acid corrosion of the RPV head. The Team also has a number of observations. These causes and observations are discussed in the following sections.

6.1 Root Causes

1. Less than Adequate Nuclear Safety Focus – A production focus established by management, combined with taking minimum actions to meet regulatory requirements, resulted in acceptance of degraded conditions on the RPV head and other components affected by boric acid. (Sections 5.3.1 and 5.3.3.6)

2. Less than Adequate Implementation of the Corrective Action Program - Implementation of the Corrective Action Program was less than adequate (Section 5.3.1), as indicated by the following:

    a. Addressing Symptoms Rather Than Causes - Management pursued symptoms rather than the identification of the causes with respect to the corrosion of the RPV base metal and other boric acid issues. (Sections 5.3.2, 5.3.3.4, and 5.3.3.3.1)

    b. Low Categorization of Conditions - The condition reports and evaluation methods on the RPV head and other boric acid issues were categorized as relatively low, resulting in the use of superficial cause analysis techniques. (Sections 5.3.2, 5.3.3.4, and 5.3.3.3.1)

    c. Less than Adequate Cause Determinations - Cause determinations for identified problems associated with the eventual degradation of RPV head and other boric acid issues lacked rigor and were less than adequate dating back to at least 1996. (Sections 5.3.2, 5.3.3.4, and 5.3.3.3.1)

    d. Less than Adequate Corrective Actions - Corrective actions assigned and implemented from 1996 to 2002 were not effective and failed to find and fix the leaks that caused extensive damage to the RPV head. (Sections 5.3.2, 5.3.3.4, and 5.3.3.3.1)

    e. Less than Adequate Trending - Equipment and materiel trending failed to identify recurring failures, equipment degradation, and performance issues associated with the boric acid on the RPV head and other boric acid issues. (Sections 5.3.3.4 and 5.3.3.3.1)

3. Less than Adequate Analyses of Safety Implications - Failure to integrate and apply key industry information and site knowledge/experience, effectively use vendor expertise, and

compare new information to baseline knowledge led to less than adequate analyses and decision-making with regard to the nuclear safety implications of boric acid on the reactor vessel head and in the containment. (Sections 5.3.2, 5.3.3.2, and 5.3.3.4)

4. Less than Adequate Compliance with Boric Acid Corrosion Control (BACC) Procedure and Inservice Test Program - Contrary to these programs, boric acid was not completely removed from the RPV head. The affected areas were not inspected for corrosion and leakage from nozzles and the sources of the leakage were not determined. (Section 5.3.2)

6.2 Contributing Causes

1. Lack of Hazard Analyses - Evaluations and decisions were made without hazards analyses that may have led to the identification of the nozzle leakage. (Sections 5.3.1, 5.3.3.2, and 5.3.3.6)

2. Corrective Action Procedure – The Corrective Action Procedure has provisions that do not reflect state-of-the-art practice in the industry, which may have allowed less than adequate corrective actions. (Section 5.3.3.3.1)

6.3 Related Observations

1. Design – The design failed to prevent leaks of boric acid. 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. (Section 5.3.2)

2. Training – 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 of the RPV head for boric acid in 10RFO and 11RFO. The training provided following the RC-2 event was less than adequate. (Section 5.3.2)

3. Coordination of Boric Acid Control Activities – The RPV head inspection activities and resolution of the corrective action documents on the head were not coordinated through the BACC Coordinator. (Section 5.3.2)

4. BACC Procedure – The BACC Procedure does not specifically reference the CRDM nozzles as one of the probable locations of leakage. (Section 5.3.2)

5. Untimely Corrective Action - Condition reports associated with the boric acid issues tended to stay unresolved until significant degradation occurred. (Section 5.3.3.3.1)

6. Quality Assurance - There was little evidence of QA's involvement in this area, and the documented findings by QA were of mixed quality. (Section 5.3.3.3.2)

7. Incentive Program - The FENOC monetary incentive program rewards production more than safety at senior levels of the organization. (Section 5.3.3.5)

8. Policies on Safety - The written policies have been inconsistent and incomplete in their treatment of employee and nuclear safety and do not support a strong safety focus. (Section 5.3.3.5)

9. Operations Involvement – Operations had minimal involvement in resolution of boric acid issues. (Section 5.3.3.3.1)

10. Management Observations – Management had minimal entries into containment and observation of conditions in the containment. (Section 5.3.3.5)

7.0 Extent of Condition

Section 6.1 of the Technical Root Cause Analysis Report discusses the activities to determine whether other components have been affected by PWSCC or boric acid corrosion. Based upon the information considered by the Root Cause Analysis Team, the Team believes that other activities may be adversely affected by the same causes identified in Section 6. Therefore, the Team recommends that Davis-Besse conduct reviews to determine whether other hardware, functions, and programs have been impacted by these causes.

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 a series of reviews of systems. These reviews include the following checks: reviews of CRs initiated since 1995 affecting the risk significant functions to verify the adequacy of corrective actions; reviews of Corrective Work Orders initiated since 1995 affecting risk significant functions to verify that degrading trends are not developing; reviews of modifications initiated since 1990 to address deficiencies of the system to support risk significant functions to ensure identified problems were properly resolved; reviews of industry operating experience identified after 1995 on risk significant functions to verify incorporation of lessons learned; elicitation of concerns by operators and maintenance personnel related to how the systems and system components are performing; and system walkdowns to assess the materiel condition of the system.

- The Management and Human Performance Excellence Plan includes a series of reviews of functional areas (organizations). These reviews include checks of: whether there are clear lines of authority and responsibly within the organization; whether staffing levels and resources are sufficient to handle assigned responsibilities; whether individuals have a clear description of their assigned responsibilities; whether individuals satisfy regulatory requirements and commitments for certification, qualification, and experience; whether the training of individuals is current; whether programs within the responsibility of the organization have an individual who is assigned as the owner; whether there are effective methods for communicating safety information within the organization; whether interfaces with other organizations are clearly defined; whether corrective actions and improvements for assessment related to the organization findings within the last two years have been effective; whether the organization has appropriate performance indicators or other goals and objectives; and whether the organization satisfies any other applicable regulatory requirements and commitments.

- The Program Compliance Plan provides for a series of reviews of programs, including: the interfaces with other programs or work groups are controlled; the program appropriately implements operating experience; the program has an appropriate level of management involvement; the program has an owner who is properly qualified; and the roles and responsibilities for program implementation are clearly defined and appropriately implemented.

The owners of the Building Block Plans should review their activities to ensure that the Plans account for the findings and conclusions in this Report.

8.0 Corrective Actions

This section repeats each of the root causes, contributing factors, and related observations in Section 6, and then identifies applicable corrective actions.

8.1 Corrective Actions for Root Causes

1. Less than Adequate Nuclear Safety Focus – A production focus established by management, combined with taking minimum actions to meet regulatory requirements, resulted in acceptance of degraded conditions on the RPV head and other components affected by boric acid. (Root Cause 6.1.1)

   Corrective Actions:

   a. The Management and Human Performance Excellence Plan also has the following relevant actions:

      - Extensive changes have been made in the officers, directors, and managers responsible for Davis-Besse, including establishment and appointment of a new Chief Operating Officer Executive Vice President, and Vice President of Oversight; changes in the site Vice President; and changes in each of the directors. These new individuals bring outside experience and high safety standards.
      - An effective management field presence/involvement plan will be developed to improve management oversight.
      - Management will ensure standards of excellence are communicated, and monitoring will ensure these standards are upheld at all levels. This entails management behaviors, first line supervisor behaviors, and individual worker behaviors. These standards will not only focus on behaviors, but also on the expectations for manager involvement in station activities.
      - A Management Monitoring Process will be used to monitor and trend the performance of specific management oversight activities taken on an individual basis. These will demonstrate the level of involvement of individual managers.
      - Case Study training will be given, which will consist of a review of the timeline of the event with site personnel to ensure all personnel understand how the event happened, what barriers broke down, and what needs to be different in the future.

   b. Assess the Safety Conscious Work Environment of Davis-Besse based on criteria and attributes derived from NRC policy and guidance, and develop an action plan to address any adverse conditions identified by the assessment.

2. Less than Adequate Implementation of the Corrective Action Program – Implementation of the Corrective Action Program was less than adequate. (Root Cause 6.1.2)

Corrective Actions:

a. The Program Compliance Plan includes a detailed review of the Corrective Action Program by outside consultants.

b. The Senior Management Team shall review and endorse all root causes in this report.

a. Addressing Symptoms Rather Than Causes - Management pursued symptoms rather than the identification of the causes with respect to the corrosion of the RPV base metal and other boric acid issues. (Root Cause 6.1.2.a)

Corrective Actions:

a. Ensure that the case study of this and other events (Corrective Action 8.1.1.b) includes emphasis on the need to find and address the causes of adverse conditions and the potential consequences of failures to do so.

b. The Management and Human Performance Excellence Plan also has the following relevant action:

- 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 the Plant Manager or another director level individual.

b. Low Categorization of Conditions - The condition reports and evaluation methods on the RPV head and other boric acid issues were categorized as relatively low, resulting in the use of superficial cause analysis techniques. (Root Cause 6.1.2.b)

Corrective Actions:

a. Ensure that criteria for categorization of the significance of repeat equipment failures are appropriate and utilized by station personal. These criteria should be sufficient to elevate repeat Condition Adverse to Quality (CAQ) failure CRs to a Significant Condition Adverse to Quality (SCAQ) categorization, which requires utilizing of a higher evaluation method.

b. Review existing long-standing issues for possible SCAQ categorization and use of root cause evaluation techniques to obtain resolution of the issues.

c. Less than Adequate Cause Determinations - Cause determinations for identified problems associated with the eventual degradation of RPV head and other boric acid issues lacked rigor and were less than adequate dating back to at least 1996. (Root Cause 6.1.2.c)

Corrective Actions:

a. Require the use of formal cause determination techniques for root and basic cause evaluations to ensure analytical rigor is applied to the analysis. A tiered approach to the number and type of techniques applied should be considered.

b. Define and implement the training requirements necessary for cause evaluations, especially for equipment analysis.

c. Provide periodic independent reviews and self assessments of apparent cause evaluations to provide assurance of quality of these evaluations.

d. Less than Adequate Corrective Actions - Corrective actions assigned and implemented from 1996 to 2002 were not effective and failed to find and fix the leaks that caused extensive damage to the RPV head. (Root Cause 6.1.2.d)

Corrective Actions:

a. Improve the guidance on reviews of the effectiveness of corrective actions with focus on verifying that causes have been fixed, and provide training on the revised guidance.

b. Require the use of safety precedence sequence (step 6 of Root Cause Analyses Reference Guide) for root cause and basic cause analyses.

e. Less than Adequate Trending - Equipment and materiel trending failed to identify recurring failures, equipment degradation, and performance issues associated with the boric acid on the RPV head and other boric acid issues. (Contributing Cause 6.2.1.e)

Corrective Actions:

a. Implement an effective site wide equipment trending program. This program should define what is to be trended periodically (e.g. vendor, failure mode, failure mechanism, environmental, material issues).

b. Perform trending of issues that occur only during outages.

3. Less than Adequate Analyses of Safety Implications - Failure to integrate and apply key industry information and site knowledge/experience, effectively use vendor expertise, and compare new information to baseline knowledge led to less than adequate analyses and decision-making with regard to the nuclear safety implications of boric acid on the reactor vessel head and in the containment. (Root Cause 6.1.3)

Corrective Actions:

a. Establish the FENOC Hierarchy of Documents for Davis-Besse to ensure consistent policies and standards at all FENOC plants, including standards for analyses of safety issues.

4. Less than Adequate Compliance with Boric Acid Corrosion Control (BACC) Procedure and Inservice Test Program - Contrary to these programs, boric acid was not completely removed from the RPV head. The affected areas were not inspected for corrosion and leakage from nozzles and the sources of the leakage were not determined. (Root Cause 6.1.4)

Corrective Actions:

a. 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.

b. Reinforce standards and expectations for procedure compliance and the need for work practice rigor.

8.2 Corrective Actions for Contributing Factors

1. Lack of Hazard Analyses - Evaluations and decisions were made without adequate hazards analyses that may have led to the identification of nozzle leakage. (Contributing Cause 6.2.1)

Corrective Actions:

a. Establish the FENOC decision-making process at Davis-Besse including hazard analyses.

2. Corrective Action Procedure – The Corrective Action Procedure has provisions that do not reflect state-of-the-art practice in the industry, which may have allowed less than adequate corrective actions. (Contributing Cause 6.2.2)

Corrective Actions:

a. Review and benchmark the Corrective Action Procedure against industry standards.

b. The Program Compliance Plan includes a detailed review of the Corrective Action Program by outside consultants.

8.3 Other Relevant Corrective Actions and Improvements

1. Design – The design failed to prevent leaks of boric acid. 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. (Observation 6.3.1)

   Corrective Actions:

   a. The Reactor Head Resolution Plan provides for replacement of the corroded RPV head with a new head from the Midland Plant that uses Alloy 600 for the CRDM nozzles.

   b. Manufacture and install a new RPV head that does not use Alloy 600 for the CRDM nozzles.

2. Training – 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 of the RPV head for boric acid in 10RFO and 11RFO. The training provided following the RC-2 event was less than adequate. (Observation 6.3.2)

   Corrective Actions:

   a. Provide training to personnel who perform ISI and BACC inspections on the BACC Procedure and ASME Code IAW-5250, Item b requirements, with emphasis on the need to inspect areas that are or have been covered with boric acid.

3. Coordination of Boric Acid Control Activities - 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)

   Corrective Actions:

   a. Provide training to the BACC Coordinator to ensure that he is aware of his responsibilities.

4. BACC Procedure – The BACC Procedure does not specifically reference the CRDM nozzles as one of the probable locations of leakage. (Observation 6.3.4)

   Corrective Actions:

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

   b. The Program Compliance Plan includes a detailed review of the BACC and ISI Program by outside consultants.

5. Untimely Corrective Action - Condition reports associated with the boric acid issues tended to stay unresolved until significant degradation occurred. (Observation 6.3.5)

Corrective Actions:

a. 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.

6. Quality Assurance - There was little evidence of QA's involvement in this area, and the documented findings by QA were of mixed quality. (Observation 6.3.6)

Corrective Actions:

a. 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.

b. The Management and Human Performance Excellence Plan also states that a review will be performed of the effectiveness of and make changes to the CNRB to improve the safety focus.

7. Incentive Program Focuses on Production - The FENOC monetary incentive program rewards production more than safety at senior levels of the organization. (Observation 6.3.7)

Corrective Actions:

a. 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 VP and below). The distribution should be consistent among all site positions.

8. Policies Do Not Support Safety - The written policies have been inconsistent and incomplete in their treatment of employee and nuclear safety and do not support a strong safety focus. (Observation 6.3.8)

Corrective Actions:

a. Establish a FENOC-level policy emphasizing the station industrial and nuclear safety philosophy. The policy should be incorporated into procedures, guidelines, job descriptions and performance evaluations, as appropriate. Policies and procedures should include both management and worker responsibility in providing a safe work environment, personal protective equipment, training and working safely. [Note: The recommendation of the Team does not advocate a particular form that the policy may take, and in fact, the old 'policy book' could be eliminated in favor of an approach that is better connected with the Business Plan.]

9. Operations Involvement – Operations had minimal involvement in resolution of boric acid issues. (Observation 6.3.9)

   Corrective Actions:

   a. Integrate Operations into problem solving and promote Operations ownership of problem resolution.

10. Management Observations – Management had minimal entries into containment and observation of conditions in the containment. (Observation 6.3.10)

    Corrective Actions:

    a. Develop a plan for increased presence of management in the field during outages and normal operation.

9.0 Experience Review

Section 7 of the Root Cause Analysis Reference Guide and Attachment 11 of the Programmatic Guideline for the Davis-Besse Condition Report Process state that a review of similar experiences at the plant and the nuclear industry should be conducted to determine:

- whether past occurrences of similar problems indicate a generic or broader scope issue,
- why prior corrective actions for similar problems were not effective, and
- whether the currently proposed preventive actions are different so as to be more effective.

The Technical Root Cause Analysis Report evaluated whether there was previous experience with boric acid corrosion at Davis-Besse and the nuclear industry. As documented in that Report, previous events involving boric acid corrosion had occurred at both Davis-Besse and the nuclear industry. The Report also concluded that this previous experience was not effectively used to prevent the corrosion of the RPV head.

Section 5 above evaluates why the preventive actions for the RC-2 event at Davis-Besse were not effective and why previous industry experience on boric acid corrosion was not effectively used at Davis-Besse.

This section evaluates why the currently proposed preventive actions are different from those taken in response to the RC-2 event and previous industry experience, and why the proposed actions should be more effective.

9.1 Preventive Actions for Previous Events

Davis-Besse's preventive actions for industry experience included the following:

- Development of the Boric Acid Corrosion Control Program
- Evaluations that justified leaving boric acid on the RPV head based on industry experience which indicated that boric acid is not corrosive at temperatures above 550°F.

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.
- Counseling of the Maintenance Manager, Mechanical Services Superintendent, and Mechanical Services Supervisor on expectations of accountability.
- Providing training to Maintenance personnel on NG-DB-00225, "Procedure Use and Adherence".

9.2 Differences between Previous and Proposed Actions

There are a number of differences between the previous corrective actions for the RC-2 event and the corrective actions discussed in Section 8 above. Specifically, the actions in Section 8 have the following elements that were not present in the actions for the RC-2 event:

- New Management – Since December of 2001, the entire top tiers of management at Davis-Besse have changed. In particular, a new position of Chief Operating Officer has been created and filled, a new plant manager from outside of Davis-Besse has been appointed, every Director has been newly appointed (several from outside of Davis-Besse), and most of the managers have been replaced. Additionally, a new Vice President of Oversight position has been created and filled, and this individual will be in charge of oversight activities at all FENOC facilities. Finally, an Executive Vice President position was created and filled with an experienced INPO manager, to further strengthen engineering management oversight at Davis-Besse.

- Safety Focus – To ensure that nuclear safety is the primary responsibility of every employee, FENOC will take several actions. The Management and Human Performance Excellence Plan implements several relevant actions. For example, an effective management field presence/involvement plan will be developed to improve management oversight. Management will ensure standards of excellence are communicated, and monitoring will ensure these standards are upheld at all levels. These standards will not only focus on behaviors, but also on the expectations for manager involvement in station activities.

  Another corrective action is the implementation of a Management Monitoring Process to monitor and trend the performance of specific management oversight activities taken on an individual basis. These will demonstrate the level of involvement of individual managers.

  Lastly, Case Study training will be given, which will consist of a review of the timeline of the event with site personnel to ensure all personnel understand how the event happened, what barriers broke down, and what needs to be different in the future. This training is substantively different than that given to management after the RC-2 event because that training dealt specifically with the issues of boric acid control and related industry experience, while the Case Study focuses specifically on the broader root causes identified in this Report.

- Corrective Actions – FENOC will take numerous actions to address inadequate implementation of the Corrective Action Plan. For instance, with regard to addressing symptoms rather than causes, FENOC will ensure that the Case Study of this and other events includes emphasis on the need to find and address the causes of adverse conditions and the potential consequences of failures to do so.

  In addition, several of the Building Block Plans will implement actions to address this issue. For example, a detailed review of the Corrective Action Program will be performed by outside consultants as part of the Program Compliance Plan. In addition, the Management and Human Performance Excellence Plan requires that the Corrective Action Review Board

(CARB), which reviews select corrective action document evaluations, will be chaired by the Plant Manager or another director-level individual.

FENOC will also implement several corrective actions to address the low categorization of conditions. First, FENOC will ensure the criteria for categorization of the significance of repeat equipment failures are appropriate and utilized by station personnel. These criteria should be sufficient to elevate repeat Condition Adverse to Quality (CAQ) failure CRs to a Significant Condition Adverse to Quality (SCAQ) categorization, which requires utilizing of a higher evaluation method. Long-standing issues will be reviewed for possible SCAQ categorization and use of root cause evaluation techniques to obtain resolution of those issues.

To address the deficiencies in implementing corrective actions, FENOC will improve the guidance on reviews of the effectiveness of corrective actions with focus on verifying that causes have been fixed and provide training on the revised guidance.

With regard to deficiencies in trending, FENOC will implement an effective site-wide equipment trending program. In addition, FENOC will perform trending of issues arising during outages.

- Procedure Compliance – FENOC will be performing Case Study training, which will include emphasis on the need to adhere to procedures and the potential consequences or a failure to do so. Additionally, FENOC will reinforce standards and expectations for procedure compliance and the need for work practices rigor. 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 these corrective actions are effective.

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

10.0 References

The following is a list of references reviewed in preparation of the Technical Root Cause Analysis Report and this Report.

10.1 Davis-Besse References

Procedures

- AD 1844.01, Preventive Maintenance
- AD 1845.01, 50.59 Procedure Safety Evaluations & Review Preparation
- DB-DP-00022, Station Review Board
- DB-MM-09011, Pressurizer Manway Cover Removel and Reinstallation
- DB-MM-09019, OTSG Primary Handhole Maintenance
- DB-MM-09020, OTSG Manway Maintenance
- DB-MM-09117, Reactor Coolant Pump Maintenance
- DB-MM-11053, CRDM Leaking Gasket Replacement (M-515-59),
- DB-OP-00002, Operations Section Event/Incident Notifications and Actions
- DB-OP-00018, Inoperable Equipment Tracking Log
- DB-OP-00022, Station Review Board
- DB-OP-01200, Reactor Coolant System Leakage Management
- DB-OP-02522, Small RCS Leaks
- DB-OP-02529, Fire Procedure
- DB-OP-06412, Process and Area Radiation Monitor System Operating Procedure, EXCERPT
- DB-OP-06900, Plant Heatup
- DB-OP-06901, Plant Startup
- DB-OP-06903, Plant Shutdown and Cooldown
- DB-PF-00204, ASME XI Pressure Testing
- DB-PF-03010, RCS Leakage and RCS Hydrostatic Test
- DB-PF-03065, Pressure and Augmented Leakage Test
- DB-SP-03357, RCS Water Inventory Balance
- EN-DP-00070, Procurement
- EN-DP-01090, Design Verification Procedure
- EN-DP-01142, Core Drill/Cut Out and Barrier Penetrations
- EN-DP-01200, Processing Plant Modifications
- MP 1401.41, Routine CRDM Maintenance
- MP 1700.83, Reactor Coolant Pump Disassembly, Inspection, Repair and Reassembly
- NA-QC-00358, Review of Documents, Systems, Processes and Activities Related to Nuclear Safety
- NG-DB-00018, Operability Determinations
- NG-DB-00116, Outage Nuclear Safety Control
- NG-DB-00202, Test Control
- NG-DB-00302, Davis-Besse Nuclear Power Station Fire Protection

- NG-EN-00301, Plant Modification
- NG-EN-00304, Safety Review and Evaluation
- NG-EN-00304, 50.59 Safety Evaluation
- NG-EN-00324, Boric Acid Corrosion Control
- NG-EN-00313, Control of Temporary Modifications
- NG-IM-00114, Preparation and Control of Administrative Guidelines
- NG-IM-00115, Preparation and Control of Nuclear Group Department and Section/Unit Procedures
- NG-NA-00115, Control of Procedures
- NG-NA-00701, Audits and Surveillance
- NG-NA-00702, Potential Condition Adverse to Reporting
- NG-NA-00711, Quality Trending
- NG-NE-0304, Safety Review and Evaluation
- NG-NP-00400, Materials Management
- NG-NS-00801, Operating License Amendments
- NG-NS-00804, NRC Communications
- NG-NS-0806, Preparation and Control of USAR Changes
- NG-NS-00807, Regulatory Reports
- NG-NT-00600, Training and Qualification
- NG-QA-00707, FENOC Quality Assurance Program Manual
- NOP-ER-1001, Continuous Equipment Performance Improvement
- NOP-ER-2001, Boric Acid Corrosion Control Program
- NOP-LP-2001, Condition Report Process
- NOP-LP-3001, Safety and Health Program
- NOP-LP-4003, 50.59 Safety Evaluation
- NOP-SS-3005, Independent Qualified Reviewer Program
- NT-ST-07044, Nuclear Training Procedure
- PP 1102.10, Surveillance Test Procedure for Plant Shutdown and Cooldown
- ST 5042.02, RCS Water Inventory Balance Procedure Surveillance Test
- ST 5066.00, ASME Section XI Inservice Pressure Tests
- VP-IE-00001, Independent Safety Engineering Organization
- VP-IE-00008, Review of Documents, Systems, Processes, and Activities Related to Nuclear Safety

Potential Condition Adverse to Quality Reports

- 1987-0032, Error in Drilling Control Rod Drive Flange 2-2
- 1988 0345,
- 1989-0058, Boric Acid Corrosion Concerns
- 1990-0120, Boron Leakage and CRDM Stator Cooling
- 1990-0221, CRDM Flange F-2 Slight Erosion of Outer Gasket Groove
- 1990-0433, Torque Values Not Provided to NSR/ASME Code Fasteners
- 1991-0353, Boron on Reactor Vessel Head from Leaking CRDM Flanges
- 1991-0496, Loose Disk Not Cotter Pin from MS735
- 1992-0072, CAC Cooler Degraded Below Acceptable Performance
- 1992-0248, Boron Found in Filter RE4597AA

- 1992-0346, Unusual Amount of Liquid Found in RE 4597AA
- 1993-0098, Reactor Head Vent Flange Leakage
- 1993-0132, Reactor Coolant Found Leaking from CRD Flanges
- 1993-0175, Service Water Piping to CAC's Have Accumulated Boric Acid
- 1993-0221, Undocumented Mech Temp MOD on MS735
- 1993-0287, MS734 and MS735 Closure
- 1993-456, RC-2 Has a Body to Bonnet Leak
- 1994-0295, TERMS A16892 Requires Visual Exam of Reactor Vessel Head each Outage
- 1994-0912, Documents CRDM Leakage
- 1994-0955, MS734 Disk Degradation
- 1994-0974, Documents Scratches and Gouges on Seating Surface Location G-5
- 1994-0975, Document ½ Moon Gouge CRDM Flange M-3
- 1994-1044, MS735 Leakrate Failure
- 1994-1191, RC-2 Packing Leak, SRTP CRD-NRR-07
- 1994-1295, MS734 and MS735 Impacting
- 1994-1338, Westinghouse CRDM part 21
- 1995-0100, Inadequate 10CFR50.59 Review
- 1995-0245, Administrative Procedure Compliance
- 1996-0330, Inadequate Change Reviews
- 1996-0448, MS734 and MS735 Valve Wear
- 1996-0551, Boric Acid on RX Vessel Head, Management Issues
- 1996-0650, VT-2 Exam of RCP Stud Shows Evidence of Boric Acid Leakage
- 1996-1018, Info Notice 96-032 Received Concerning Augmented Inspection of Rx Vessel
- 1997-1597, Operating Experience Assessment Program (OEAP) Review Inadequacies
- 1998-0020, RC-2 with Root Cause Analysis Report
- 1998-0046, Insulation for RC-2 Removed for Inspection and Not Reinstalled
- 1998-0649, Inspection Results of Reactor Vessel Head
- 1998-0650, Video Inspection Results CRDM Nozzle/Head Interface
- 1998-0767, Reactor Vessel Head Inspection Results
- 1998-0824, CAC's 2 and 3 Have Accumulated Boric Acid
- 1998-0915, Yoke on RC-2 is Corroded
- 1998-1130, RC-2 Packing Leak
- 1998-1164, Water Collecting in Sample Line for RE4597AA
- 1998-1642, Apparent Missing Nut
- 1998-1681, Missing Body to Bonnet Stud Nut
- 1998-1716, Functional Evaluation of RC-2 for Past Operability
- 1998-1799, RC-2 MWO Package Discrepancies
- 1998-1885, RC-2 Carbon Steel Nuts
- 1998-1887, Nut in Containment
- 1998-1895, Containment Normal Sump Leakage > 1GPM
- 1998-1904, 1998 Collective Significance Review
- 1998-1924, Functionality of RC-2 as A RCS Pressure Boundary
- 1998-1980, Containment Cooler Plenum Pressure Decreasing

- 1998-1981, HP-0057 Body to Bonnet Bolting
- 1998-1988, RC-2
- 1998-1895, CTMT Normal Sump Leakage in Excess of 1 gpm
- 1998-2011, LER Not Submitted to NRC Within 30 Days.
- 1998-2013, Timeliness Identification RC-2
- 1998-2069, Failure to Take Comprehensive Action for the Resolution of RC-2 Problems
- 1998-2082, Interim Bolting Configuration During RC-2 Bonnet Nut Replacement Under MWO 1-98-1158-00

Condition Reports

- 1998-0020, Multiple Problems with RC-2
- 1999-0372, Containment Rad RE4597AA/AB High
- 1999-0510, RE4597AA OOS Low Flow
- 1999-0738, RC-38 Material Wastage
- 1999-0845, Boric Acid Clumps Room 181
- 1999-0861, RE4597AA Sample Line Full of Water
- 1999-0928, Document Increased RE Filter Change Frequency
- 1999-1098, Issues with DB-OP-01200 RCS Leakage Management
- 1999-1300, RE Filter Analysis Results from Southwest Research Institute and Follow Up Actions
- 1999-1614, LER 1998-009
- 1999-1765, QA Surveillance Report SR-99-ENGRG-08 Identified CATS is Not Useful for Equipment Reliability Trending
- 1999-2249, Non-Compliance With USAR Requirements and Commitments Made to the NRC
- 2000-0781, Boric Acid on RV Studs
- 2000-0782, RV Flange Boric Acid from Weep Holes
- 2000-0903, Two CRDM Flange Fasteners Fail Preservice Exam
- 2000-0994, CRDM Flange F-10 Pitted
- 2000-0995, CRDM Flange D-10 Pitted
- 2000-1001, RC-2 Spray Valve Problems
- 2000-1037, Reactor Head Inspection Indicates Boric Acid Accumulation
- 2000-1210, CRDM D-10 Out of Plum
- 2000-1547, Containment Cooler Plenum Pressure Dropped
- 2000-4138, Increased Frequency of Containment Air Cooler Cleaning
- 2001-0039, Step Drop in Containment Air Cooler Plenum Pressure
- 2001-0487, Higher Containment Temperatures
- 2001-0642, Collective Significance Review of Post-Maintenance Testing Issues
- 2001-0670, Collective Significance of FPRs Generated in 2000
- 2001-0677, Technical Evaluation Documentation Adequacy Collective Significance
- 2001-0890, RCS Leakage Calculation Data Scatter
- 2001-1026, Collective Significance Torque Wrenches Out of Calibration
- 2001-1027, Collective Significance – Dial Calipers and Depth Gauges Out of Calibration

- 2001-1110, RE4597BA Filter Change Occurring More Frequently
- 2001-1191, CRDM Nozzle J-Weld Cracking Due to Inconel 600 Stress Corrosion
- 2001-1335, CAC Air Side Fouling Criteria
- 2001-1696, Safety Tagging Collective Significance Review
- 2001-1746, Weaknesses in the Tracking and Closeout of CARB Comments
- 2001-1747, CARB Charter Compliance
- 2001-1748, Corrective Action Review Board Recommendations
- 2001-1822, Increasing Frequency of RE4597BA Filter Changeout
- 2001-1857, RCS Leakage Anomalies
- 2001-1858, Collective Significance Review of Process Security, Activity Access Control
- 2001-1859, Collective Significance Review of Activity Records Capture CRs
- 2001-1871, Collective Significance Review of Work Management Process
- 2001-1896, Collective Significance Review of CRs Identified by External Oversight
- 2001-1983, Collective Condition Report on Temporary Intake Chlorination System
- 2001-2012, Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles
- 2001-2028, Collective Significance Review of Late CR Evaluations or Corrective Actions
- 2001-2236, Collective Significance Review of Simulator Panel Power Supply Failures
- 2001-2253, Collective Significance Review of Corrective Action Incomplete and Closed
- 2001-2521, Collective Significance Review of Lost Work Orders
- 2001-2706, Collective Significance Review for Operability Determinations
- 2001-2739, Collective Significance Review of CRs Resulting From Troubleshooting
- 2001-2749, Collective Significance Review of CRs on Changes to Computerized Processes
- 2001-2769, Containment Wide Range Radiation Element (RE2387) Spiking
- 2001-2795, RE4597BA Alarm
- 2001-2862, Potential Adverse Trend in Unidentified RCS Leakage
- 2001-2865, Collective Significance Review Enhancement - Guidance
- 2001-2936, Unable to Perform RE4597BA/BB Functional by the Technical Specification
- 2001-2967, CR Program Implementation Deficiencies in Evaluation Documentation
- 2001-3025, RCS Leakage
- 2001-3131, Collective Significance Review – Process Computer Systems Activity ACC. Con.
- 2001-3145, Collective Significance Evaluation of Procedures Not Updated During LAR PR
- 2001-3195, Collective Significance Investigation of Fuel Vendor-Related CRs
- 2001-3223, Collective Significance Review EMPAC Common Process Software Implementation
- 2001-3411, Equipment Failure on Detector Saturation During RE4597BA Testing
- 2002-00233, Collective Significance for SAC #2 Modification
- 2002-00685, Boron Build Up on Reactor Vessel Head

- 2002-00784, Collective Review Nuclear Fuel Related CRs for Common Causes
- 2002-00846, More Boron on Head Than Expected
- 2002-00891, Control Rod Drive Nozzle Crack Indication
- 2002-00932, CRDM Nozzle Crack Indications
- 2002-01051, Collective Significance Review of 13RFO Access Control Process Condition
- 2002-01053, Unexpected Tool Movement
- 2002-01103, Perform A Collective Significance Investigation For 13RFO Spaces Grid Issues
- 2002-01128, Reactor Head Material Finding
- 2002-01449, RCS Valve Repacks Not Performed
- 2002-01527, Collective Significance Review For Fire Protection Related Condition Report
- 2002-01649, Collectively Evaluate Weaknesses in Preparation for 13RFO
- 2002-01850, Compromised Standards
- 2002-02408, Collective Significance – Plant Modification Program Concerns
- 2002-02582, Collective Review of Extent of Condition Inspection CRs for Containment Sump
- 2002-02584, Implementation of Corrective Action Program By Site Personnel
- 2002-02585, Management and Supervisory Oversight and Ownership of Plant Activities
- 2002-02943, Containment Air Cooler Boric Acid Corrosion
- 2002-02974, Past Operability and Reportability Reviews
- 2002-03032, Collective Significance of Drawing Discrepancy Condition Report
- 2002-03266, Painting Occurring in Containment Without An Approved Engineering Work Request
- 2002-03280, Failed Plant System Cleanliness on the Refueling Canal
- 2002-03282, Untimely Resolution of Issues Related to Head Degradation

Audits

- Quality Assessment Corrective Actions Audit AR-99-CORAC-02
- Quality Assessment Corrective Actions Audit AR-00-CORAC-01
- Quality Assessment Corrective Actions Audit AR-93-CORAC-01
- Quality Assessment Corrective Actions Audit AR-94-CORAC-02
- Quality Assessment Corrective Actions Audit AR-96-CORAC-01
- Quality Assessment Corrective Actions Audit AR-96-CORAC-02
- Quality Assessment Corrective Actions Audit AR-00-CORAC-01
- Quality Assessment Corrective Actions Audit AR-98-CORAC-01
- Quality Assessment Corrective Actions Audit AR-99-CORAC-01
- Quality Assessment Corrective Actions Audit AR-97-CORAC-01
- Audit Report AR-00-OUTAG-01
- NAQ Audit AR-01-REGAF-01
- Quality Assessment Audit Report AR-02-OUTAG-01

Memos and Letters

- Memo – LCTS Item 3539 – IN 86-108
- Memo – High Particulate Concentration in Containment
- Memo – Control Rod Drive Nozzle Cracking, PCAQ 96-00551
- Memo – Reactor Vessel Head (RVH) Nozzle Cracking
- Memo – Cycle 12 Periodic Assessment for SUS 079-01, Radiation Monitoring System
- Initial Response to NRC GL 97-01, Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations Serial 2439a
- Response to GL 97-01 Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations Serial2472
- Request for Additional Information Regarding the Response to GL 97-01 Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations, Serial 2569 and Serial 2581
- Responses to Requests for Additional Information Concerning NRC Bulletin 2001-01, Circumferential Cracking of Reactor Pressure Vessel Head Penetrations Nozzles, Serial 2741
- Supplemental Information in Response to NRC Bulletin 2001-01
- Response to NRC Bulletin 2001-01 DRAFTs (4) and FINAL Serial 2731
- Memo – RCP Cover to Case Stud Inspection Req. M80-1188 and NN.1.1.44
- Memo from D. Huffman for Closure of IN90-10, PSWCC
- Memo - RCP Cover to Case Stud Inspection Request
- Memo – Closeout of IN 94-63
- Memo – Closeout of SER 2091
- Memo – Response to IE IN 82-06 A82-1651C
- Letter to J. Keppler – USNRC Region III, IE Bulletin 82-02, Docket #50-346
- Memo LCTS 3817 Closeout
- Response to Inspection Report # 50-346/98021, Serial No. 1-1188
- Response to GL 88-05, Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants
- Memo – Use of the Word "Should" in Procedures
- Announcement for Engineering Assessment Board
- FENOC Engineering Principles and Expectations - DRAFT
- Control Rod Drive Workscope Recommendations
- Monthly Quality Program Report
- Memo - EWR 01-0378-00
- Memo – Justification for the Performance of RFM 87-1275
- Letter to NRC, Serial 1-1077, Information Request Regarding Tapping of Check Valves MS734 and MS735
- Classification of MS734 and MS735
- Memo – Training Programs for Technical Staff
- Memo – Critical Duties List as Requested by 7/10/86 Memo
- Memo – Results of Meeting on Incorporating Industry Experience into Technical Staff Training
- Letter to NRC, Serial 1-1268, 4/8/02, Safety Significant Assessment of the Davis-Besse Nuclear Power Station, Unit 1 Reactor Pressure Vessel Head Degradation

- Letter to NRC, Serial 1-1275, Transmittal of Davis-Besse Nuclear Power Station, Unit 1 Return to Service Plan
- Serial No. 2761, Reactor Pressure Vessel Head Penetration Examination Plans for Davis-Besse Nuclear Power Station
- Serial No. 1-885, Revised Response to Generic Letter 88-05, Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in Pressurized Water Reactor Plants
- Response to Nuclear Regulatory Commission Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles".
- Serial No. 1-885, Revised Response to Generic Letter 88-05, Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in Pressurized Water Reactor Plants
- Memo – MOD 87-1193, Integrated Chemical Sampling Instrumentation Selection – Alkalinity Analyzers
- Letter – Contract Engineering, Reactor Closure Head Access Openings Modification, 3/21/90
- Closeout of IN 86-108, Supplement 3 (TERMS A17920)
- Letter to NRC, Serial No. 2149, License Amendment Application to Revise Technical Specification (TS) 3/4.9.13, Refueling Operations – Spent Fuel Pool Assembly Storage, and TS 5.6, Design Features – Fuel Storage
- Letter Copy of Independent Safety Engineering Charter and Organization Chart sent to Consolidated Edison, Indian Point 2 Station
- Letter to NRC, Serial No. 2745, Transmittal of Davis-Besse Nuclear Power Station Risk Assessment of Control Rod Drive Mechanism Nozzle Cracks
- Letter to NRC, Serial No. 2747, Supplemental Information is Response to the November 28, 2001 Meeting Regarding the Davis-Besse Nuclear Power Station Response to NRC Bulleting 2001-01

Request For Assistance and Work Orders

- Request For Assistance 87-0402-00
- Request For Assistance 87-0864-00
- Request For Assistance 90-0510
- Request For Assistance 90-0828
- Request For Assistance 91-0482
- Request For Assistance 92-0598, MS734 and MS735
- Request For Assistance 97-0029, MS734 and MS735
- Request For Assistance 98-0035 MS734 and MS735
- Request For Assistance 98-0141 RC-2 Packing Leak Injection Pressure Question
- Request For Assistance 00-0076 RC-2 Repack
- Request For Assistance 00-0145 RC-2 Packing Gland Studs
- Work Order 00-001846-000
- Work Order 00-001846-001
- Work Order 00-001861-000, 13R RV Head Work
- Work Order 98-00373-005
- Work Order 2-82-0018-01 RC-2 Packing Change to "Live Loading"

- Work Order 82-2255 Packing Leak
- Work Order 1-87-3699-04 CRD Motors, Cables and Vent Piping Fans
- Work Order 1-88-2457-02 Packing Adjusted
- Work Order 1-98-0558-00
- Work Order 99-003352-000
- Work Order 99-003352-001

7. Meeting Minutes

- Davis-Besse Project Review Group Meeting Minutes
- Davis-Besse PRC Meeting History – Project No MOD 94-0025
- PRG Meeting Minutes, DBB-97-00012
- PRG Meeting Minutes, DBB-97-00048
- Joint PRG and Work Scope Committee Meeting Minutes
- PRG Meeting Minutes MMS-95-00125
- Meeting Minutes Engineering/Licensing Subcommittee 99-001 and 99-002
- Meeting Minutes 97-001, Audit/Quality Assurance/Security Subcommittee
- Meeting Minutes Company Nuclear Review Board Rev 01 5/22/96
- Meeting Minutes Company Nuclear Review Board 9/3/98
- Meeting Minutes Company Nuclear Review Board 1/7/99
- Meeting Minutes Company Nuclear Review Board 4/27/99
- Meeting Minutes Company Nuclear Review Board 5/11/99
- Meeting Minutes Company Nuclear Review Board 7/11/99
- Meeting Minutes Company Nuclear Review Board 9/2/99
- Meeting Minutes Company Nuclear Review Board 1/13/00
- Meeting Minutes - Kalsi Engineering Study for MOD 87-1275, Check Valves MS734 and MS735
- Meeting Minutes – Modification 91-0044, MS734 and MS735 Replacement
- Meeting Minutes – K-T Analysis for MS734 and MS735
- Meeting Minutes – Training Review Board, November 1986
- Meeting Minutes – Training Review Board, June 1989

8. Guidelines/Policies/Manuals/Charters

- FENOC Quality Assurance Program Manual Revision 1
- Administration of the FENOC Quality Assurance Program Manual
- Safety Evaluation Guideline Rev 0
- PSA Level 2 Quantification Guidelines
- DB-PSA Level 1 Quantification Guidelines
- DB-PSA Sys Modeling Guidelines
- DB-PSA Program Guidelines
- DB-PSA Data Collection & Analysis Guides
- Policy Priority Management Tech-29
- Policy Implementing Guideline Priority Management Policy Rev 3
- Policy – Change Management Tech-27 Rev 0

- Guideline – Change Management
- Corrective Action Program Reference Guide Rev 5
- 50.59 Safety Evaluation Guideline Rev 0
- Operations Tech-12 Rev 16
- Nuclear Operations Admin-1 Rev 17
- Delegation of Authority Admin-9 Rev 20
- Corrective Action Tech-3 Rev 18
- Root Cause Analysis Tech-26 Rev 1
- Engineering Evaluations ES-11 Rev 1
- Responses to Regulatory Agency Requests M&C-6 Rev 16
- Babcock & Wilcox Owners Group M&C-11 Rev 17
- Personnel Qualifications Pers.-55 Rev 4
- Davis-Besse Nuclear Power Station Philosophy Phil Rev 2
- Falsification of Records Pers.-38 Rev 17
- Dissemination of Information Within the Company M&C-23 Rev 0
- Dissemination of Information Outside the Company M&C-1 Rev 18
- Policy Manual for the Davis-Besse Nuclear Power Station Intro Rev 20
- Condition Report Process – Programmatic Guideline
- Corrective Action Review Board
- Nuclear Group Policy and Organization, Index Pages, Rev 52
- Charter - Davis-Besse Project Review Committee
- Davis-Besse Project Review Group Charter Rev 3 and Rev 4
- Guideline – Davis-Besse Standard Communication Process Guide fosr Leaders and Team Members Rev 00
- Training Policy – Operating Experience Review Process Rev 1
- Charter – Teamwork Ownership and Pride (TOP) Team Charter Rev 0
- Business Practice 2.1 – FirstEnergy Strategic Vision
- Business Practice 2.2 – FirstEnergy Mission Statement
- Business Practice 2.3 – FirstEnergy Core Values
- Davis-Besse Leadership Development Steering Committee Charter Rev 0
- Developing Nuclear Management Personnel Pers.-58 Rev 3
- Davis-Besse Site Safety Committee Charter Rev 3
- Davis-Besse Outage Management Team Organization Charter Rev 00
- Company Nuclear Review Board Policies and Practices, (Rev 2, and Rev 9-12)
- Davis-Besse Work Scope Committee Charter (Rev 0 thru Rev 4)
- Potential Condition Adverse to Quality Review Board Charter Rev 0, Rev 4 Rev 6-9 and Rev 11)
- FENOC – Root Cause Analysis Reference Guide Rev 3
- Davis-Besse Policy/Charter/Guideline Manual Document Processing
- Davis-Besse Committees, M&C-13 Rev 23
- Station Review Board Charter
- Toledo Edison Philosophy
- Davis-Besse Nuclear Power Station Philosophy
- Policy and Organization of the Davis-Besse Nuclear Power Station Rev 2, Rev 13 and Rev 15 thru Rev 17

- Policy Manual for the Davis-Besse Nuclear Power Station, Rev 19
- Nuclear Group Policy Rev 15
- Nuclear Operations Policy Rev 2, and Rev 15 thru 17
- FENOC Quality Assurance Program Manual Rev 0
- USAR 17.2 Rev 21
- Corrective Action Policy, Tech.-3 Rev 0 and Rev 15 thru Rev17
- PCAQ Review Board Charter Rev 2
- Davis-Besse Nuclear Power Station 10CFR50.59 Manual Rev 0, Rev 1 and Rev 3
- Nuclear Mission Policy and Organization, Rev 12
- Policy – Responses to Regulatory Requests, M&C-6 (Rev 0, Rev 15 and 16)
- Policy – Babcock and Wilcox Owners Group (B&WOG), M&C-12 (Rev 0, Rev 13, Rev 15 and Rev 17)
- Davis-Besse Nuclear Power Station Policy/Charter/Guideline Manual Table of Contents, Rev 116
- Charter – Independent Safety Engineering Charter (Rev 01)

9. Job Descriptions and Open Positions

- Plant Manager Davis-Besse Plant Operations
- Manager - Operations Davis-Besse Plant Operations
- Manager – Maintenance Davis-Besse Plant Operations
- Manager – Plant Engineering Davis-Besse Plant Operations
- Manager – Design Basis Engineering Davis-Besse Engineering and Services
- Manager – Quality Assessment Davis-Besse Nuclear Assurance
- Manager – Radiation Protection Davis-Besse Plant Operations
- Director – Engineering and Services Davis-Besse Engineering and Services
- Open Position Announcement – Manager, Nuclear Outage
- Open Position Announcement – Manager, Nuclear Environmental and Chemistry

10. Other Station Documents

- Davis-Besse 13RFO CRDM Nozzle Examination Report, Revision 1, Framatome ANP UT Report, March 11, 2002.
- Davis-Besse System Health Report, 4th Quarter 2001
- Request For Modification 94-0025 Install Service Structure Inspection Opening
- Inservice Inspection Plan (ISI Plan) Volume II Third Ten-Year Interval Pressure Test Program
- Inservice Inspection Plan (ISI Plan) Volume II Second Ten-Year Interval Pressure Test Program
- Relief Request RR-A3 Insulated ASME Class 1 and 2 Pressure Retaining Bolted Connections
- Relief Request RR-A10 ASME Class 1 and 2 Pressure Retaining Bolted Connections
- System Description:
  - SD-022B Containment Air Cooling System and Recirculation System
  - SD-39A Reactor Coolant System

- Technical Specifications:
  - 3/4.4.6.1 Reactor Coolant Leakage Detection Systems
  - 3/4.4.6.2 Reactor Coolant System Operational Leakage
  - 3/4.4.10 Structural Integrity ASME Code Class 1, 2, and 3 Components
  - Updated Safety Analysis Report Sections.

- Reactor Coolant System Summary Description
  - 5.2 Integrity of Reactor Coolant Pressure Boundary (RCPB)
  - 11.4.4.4.5 Containment Vessel Monitor
  - Fig. 5.1-2 Functional Drawing Reactor Coolant System
  - Fig. 5.1-3 Reactor Coolant System and Supporting Structures - Plan
  - Fig. 5.1-4 Reactor Coolant System and Supporting Structures – Plan
- RWP 2000-5132 Clean Boric Acid from Rx Head
- 11 RFO Log
- 12 RFO Log
- Test Cover Sheet DB-PF-03065, Pressure & Augmented Leakage Test – V-2 Examination Test
- Boric Acid Corrosion Control Inspection Checklist – Reactor Head Flange
- 12 RFO Notes Day 2, April 2, 2002 by Andrew Siemaszko
- LCTS Closeout Form – No. 3664 – NRC IN 86-108 Supplement 1
- Commitment A16892, Complete Actions Regarding CRDM Nozzle Cracking to B&W Plants
- Tour Report, Summary of Presentation at B&W Owners Group Materials Committee Meeting with NRC Staff
- Commitment Entry Record
- MOD 90-0012/Voided
- MOD 94-0025, Install Service Structure Inspection Openings
- Organization Charts
- QAD-99-70050. ISE Review of Implementation Date for MOD 94-0025
- Managers Plant Issues
- Effectiveness Review for CR 1998-0020
- Telecon Prep Meeting Planned Conference Call Participants Bulletin 2001-01 Response
- Pre-Maintenance Approval Form for Work Order 99-003733
- List of Managers/Directors and Their Time In Current Positions
- Engineering Evaluation/Response Sheet to PM Program Supervisor. Initiation of a PM to Inspect the CRD to Reactor Head Each Refueling Outage, Beginning with the Sixth Refueling Outage
- TERMS Item A16892
- LER 1998-009 Rev 1, Reactor Coolant System Pressurizer Spray Valve Not Functional With Two of Eight Body to Bonnet Nuts Missing
- PM 1629 Monitor for CRDM Leakage
- Commitment No. 08406 Inspection of Threaded Fasteners in RC Pressure Boundary

- Figure A-3 Commitment Evaluation Summary CES 96-002
- Maintenance Work Order 1-93-1165-00
- Qualification Card for Andrew Siesmaszko
- Qualification Card for Glenn McIntyre
- Qualification Card for Prasoon Goyal
- General RC-2 Records Search for Packing Leak 1988
- Plant Engineering Job Familiarization Guideline TSM-001 Rev 5
- Lesson Plan TSM-IDE-I1994 for ESP (Boric Acid)
- Glenn McIntyre EST Cycle 99-04 Exam Class #TSM-IDE-1994 Quiz A
- Andrew Siemaszko EST Cycle 99-04 Class #TSM-IDE-1994 Quiz A
- Prasoon Goyal EST Cycle 99-04 Class #TSM-IDE-1994 Quiz A
- Andrew Siemaszko, General Orientation, Job Familiarization Guidelines, TSM-000 R00
- Lesson Plan TSM-BAS-I005 Materials Fundamentals
- Lesson Plan TSM-BAS-I006 Chemistry Control Fundamentals
- Engineering Assessment Board Role/Policy In Support of the Return to Service Plan Rev 0 and Memo
- NFEP-012, 50.59 Written Safety Evaluations, Rev 4
- Engineering Assessment Board Role/Policy In Support of the Return to Service Plan Rev 0
- Davis-Besse Committees
- 2001 Nuclear Incentive Goals
- 2002 Nuclear Incentive Goals
- Engineering Principles and Expectations – DRAFT and FINAL
- 3.0 Programmatic Elements
- Davis-Besse Nuclear Power Station Outages Since 1986
- Commitment 008405, Serial 1527 – GL 88-55
- New Head Arrival Picnic – Summary of Remarks by Tony Alexander
- FENOC Quality Trend Summary First Quarter 2002 Condition Reports
- ISE 87-10049, ISE Inspection of Pressurizer for Possible Boric Acid Corrosion
- Surveillance Package SR-98-Maint-07 Closure Review
- Performance Engineering Department Instruction, Operating Experience Assessment Program – Review Operating Exp. Rev 01
- Condition Report Indicators for MRM
- Boric Acid Corrosion Control Inspection Checklist – Reactor Vessel Head Closure
- Framatome ANP Engineering Record 51-5018965-00 Davis-Besse Head Deposit Sample Characterization (Second Batch, Nozzle #2 Removal) DRAFT
- Davis-Besse Nuclear Power Station NRC Inspection Report No. 50-346/01-05 (DRP)
- Davis-Besse Engineering Work Request 01-0378-00 Request for Larger Access Holes on Bottom of Reactor Head Service Structure Flange
- Davis-Besse Activity Tracking System Document Detail EWR-01-378-00 Control Rod Drive Nozzles
- Boric Acid Corrosion Equation – Answer to Sargent and Lundy Report Question on Significance of Ferris Hydroxide
- Report Requirements Form NP-33-78-49, AFP 1-2 Inoperable – Isolated for Maintenance to Repair MS735

- Test Cover Sheet DB-PF-04162, AFPT Steam Supply Check Valve Reverse Flow Test
- Field Problem Resolution 91-0049-901
- Calculation Sheet C-NSA-083.01-004, Allowable Leakage for MS734 and MS735
- Request For Modification 93-0047, Modify Shafts on MS734 and MS735
- Request For Modification 91-0044, Replace MS734 and MS735
- Calculation Sheet C-ME083.01-234, MS to AFPT Heat Recovering Line 1/23/92
- Calculation Sheet C-ME083.01-234, MS to AFPT Heat Recovering Line 1/19/96
- Equivalent Replacement Resolution ERR 32-2828-001, Replace MS735 Due to Degraded Seat
- Purchase Order 7022415, Framatome Technologies
- Index of Aux Feed Long Standing Issues for MS734 and MS735
- Root Cause Analysis Report Safety Tagging Program Provides Inconsistent Protection
- Nuclear Quality Assessment Self-Assessment Critique Log
- Root Cause Analysis Report Significant Degradation of the Reactor Pressure Vessel Head, CR 2002-0891 (Technical Root Cause Analyses Report)
- Management Containment Entries 11RFO and 12RFO
- USAR Search for Boric Acid Control
- Employee Concerns/Ombudsman Program Annual Report 2000
- Employee Concerns/Ombudsman Program Annual Report 2001
- Framatome Proposal to FirstEnergy for Inspection and Repair Services at Davis-Besse and Task Authorization for Purchase Order 7076448
- Training Attendance Summary TSM-IDE Oral Quiz
- Technical Staff and Managers Training Plan
- FirstEnergy Performance Report First Quarter 2002
- H. Peter Burg's Annual Shareholders Meeting Presentation Slides and Text
- Davis-Besse 2002 Operational Business Plan
- Inservice Test Program Third 10 Year ISI Program Vol. II, Rev 0
- Nuclear Engineering Procedures Manual, Safety Review and Evaluations NEP-012 Rev 0
- E-Mail – Research of Training Records for NG-EN-00324 Rev 0, Boric Acid Control Program
- Engineering Department Instruction Change EN-DP-01200.5 Modification Design Reports Rev 0 Change No. 3
- Results of Search in Process and Area Radiation Monitor for RCS Leakage
- Davis-Besse 2002 Safety Conscious Work Environment Survey Results Summary
- LCTS Closeout – NCR 84-0179 Referenced in SRTP-CRD-NRR-06, Transferred to PCAQ 87-0032
- E-Mail – Sequence of Events For Alarms Received on RE4597 AA/BA
- E-Mail – Index Information in CURATOR Regarding Log 3166
- Davis-Besse Presentation to INPO, July 1999
- 2000 Incentives
- Davis-Besse Nuclear Power Station 1999 Incentive Compensation Performance Measures, Rev 3
- Davis-Besse Short Term 1998 Nuclear Incentive Goals Final
- Davis-Besse 1997 Incentive Compensation Program Performance
- Davis-Besse Local Objectives 1996 Performance Measures May Projected Results
- Centerior Power Generation Group 1996 Strategic Objective Measures

- Group Performance Measures 1995 Incentive Compensation Local Goals
- Synopsis of Phone Call Regarding Company Incentives
- Reactor Coolant Pump Issues List – Excerpts
- Nuclear Group Procedures Table of Contents Rev 11, Rev 12 and Rev 38
- Company Nuclear Review Board Procedures Table of Contents Rev 7
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report, April 2002
- Safety Review TM99-0022, Supply Non-Essential 480 VAC Power to Portable Filtration Units in Containment
- 10CFR50.59 Evaluation TM01-0019, Remove Iodine Filter Cartridge for RE 4597AA Containment Atmosphere Normal Range
- Davis-Besse Milestone Chart 1985 to 2003
- Limiting Condition for Operation
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report – December 2000
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report – December 1999
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report – December 1998
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report – December 1997
- Davis-Besse Nuclear Power Station Business Plan Monthly Performance Report – December 1996
- Davis-Besse Operational Business Plan 2002
- Trainee Tracking Successful Completions
- Davis-Besse Management Timeline
- Independent Safety Engineering Semiannual Report No. 2, September 1986 – January 1987

10.2 Vendor References

1. BWOG Integrated Response to NRC Generic Letter 97-01 Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetrations, BAW-2301, Framatome ANP Report, July 1997
2. Framatome ANP Report 51-5001951-01, Alloy 600 PWSCC Susceptibility Model, December 9, 1998 (Proprietary)
3. Oconee 1 RPV Head Nozzle Leaks presented by Dave Whitaker at EPRI Alloy ITG meeting January 19, 2001
4. Dominion Engineering, Inc. Calculation No. C-5509-00-6 Davis Besse CRDM Leak Rates using ANSYS Crack Opening Area (non-safety related), Revision 0 3/19/2002 (Proprietary)
5. Dominion Engineering, Inc. Calculation No. C-5509-00-7 Davis Besse CRDM Nozzle Crack Opening Displacement Analysis, Revision 0 3/19/2002 (Proprietary)
6. Dominion Engineering, Inc. Calculation No. C-5509-00-5 Leak Rate through Axial Crack in Davis Besse CRDMs (non-safety related), Revision 1 3/19/2002 (Proprietary)
7. BAW-10190P Safety Evaluation for B&W-Design Reactor Vessel Head Control Rod Drive Mechanism Nozzle Cracking (Proprietary)

8. BAW-1019P Addendum 1 External Circumference Crack Growth Analysis for B&W Design Reactor Vessel head CRDM Nozzles (Proprietary)
9. BAW-1019P Addendum 2 Safety Evaluation for Control Rod Drive Mechanism Nozzle J-Groove Weld (Proprietary)
10. BWOG Materials Committee Report 51-1201160-00 Alloy 600 SCC Susceptibility: Scoping Study of Components at Crystal River 3
11. B&W Report 51-1218440-00 Alloy PWSCC Time-To-Failure Models (Proprietary)
12. B&W Report 51-1219143-00 CRDM Nozzle Characterization (Proprietary)
13. Dominion Engineering, Inc. Calculation No. C-5509-00-7 Volume and Weight of Boric Acid Deposits on Vessel Head.
14. B&W Letter, Control Rod Drive Mechanism (CRDM) Gasket Leaks, 6/25/87
15. B&W Letter – Corrosion Wastage, 1/6/88
16. B&W Proposal for MOD – BWNS Job No. 1210598, Proposal for Service Structure Inspection Openings, TE Contract No. C605600D92, 12/8/93
17. Sargent & Lundy, Review of Analysis of Particulates in CTMT 11/2/99
18. Piedmont Management & Technical Services, Inc., Review of Reactor Vessel Top Head CRDM, 9/14/01
19. B&W Owners Group A 16892 Closure Document, Control Rod Drive Penetration Cracking Safety Evaluation Report, 5/26/93
20. B&W Boric Acid Corrosion Data, 4/15/94
21. Kalsi Engineering, Inc. Analysis and Recommendations for MS734 and MS735 Check Valve Slamming Problems, Document No. 1598, 7/10/89
22. Framatome ANP Proposal for Davis-Besse RV Head Lower Service Support Structure (SSS) Access Opening Analysis, 9/21/01
23. Framatome – Davis-Besse Reactor Vessel Head Deposit Characterization Results Final Report 51-5018613-00, June 2002

10.3 NRC References

1. GL 88-05 Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants
2. GL 97-01 Degradation of CRDM/CEDM Nozzle and Other Vessel Closure Head Penetrations
3. Regulatory Guide 1.45 Reactor Coolant Pressure Boundary Leakage Detection Systems
4. Bulletin 82-2 Degradation of Threaded Fasteners in the Reactor Coolant Pressure Boundary of PWR Plants
5. Bulletin 2001-01 Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles
6. Bulletin 2002-01 Reactor pressure Vessel head Degradation and Reactor Coolant Pressure Boundary Integrity
7. IN 80-27 Degradation of Reactor Coolant Pump Studs
8. IN 82-06 Failure of Steam Generator Primary Side Manway Closure Studs
9. IN 86-108 Degradation of RCS Pressure Boundary Resulting From Boric Acid Corrosion
10. IN 86-108 Supplements 1 & 2 Degradation of RCS Pressure Boundary Resulting From Boric Acid Corrosion
11. IN 86-108 Supplement 3 Degradation of RCS Pressure Boundary Resulting From Boric Acid Corrosion
12. IN 90-10 Primary Water Stress Corrosion Cracking (PWSCC) of Inconel 600

13. IN 94-63 Boric Acid Corrosion of Charging Pump Casing Caused by Cladding Cracks
14. IN 96-11 Ingress of Demineralizer Resins Increases Potential for Stress Corrosion Cracking of Control Rod Drive Mechanism Penetrations
15. IN 2001-5 Through-Wall Circumferential Cracking of Reactor Pressure Vessel Head Control Rod Drive Mechanism Penetration Nozzles at Oconee Nuclear Station, Unit 3
16. IN 2000-17 Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V.C. Summer
17. IN 2000-17 Supplement 1 Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V.C. Summer
18. IN 2000-17 Supplement 2 Crack in Weld Area of Reactor Coolant System Hot Leg Piping at V.C. Summer
19. IN 2002-11 Recent Experience with Degradation of Reactor Pressure Vessel Head Safety Evaluation for Potential Reactor Vessel Head Adaptor Tube Cracking, November 19, 1993
20. IEN-86-108, Degradation of Reactor Coolant System Pressure Boundary Resulting from Boric Acid Corrosion
21. GL-88-05, Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants
22. Regulatory Issue Summary 2002-02, Lessons Learned Related to Recently Submitted Decommissioning Plans and License Termination Plans
23. Generic Letter 97-01, Degradation of CRDM/CEDM Nozzle and Other Vessel Closure Head Penetrations. Review of the Responses for the Davis-Besse Nuclear Power Station, Unit 1
24. Generic Letter 97-01, Degradation of CRDM/CEDM Nozzle and Other Vessel Closure Head Penetrations, Request for Additional Information
25. Meeting Summary of 11/08/01 to Discuss Licensee's Response to Bulletin 2001-01
26. Meeting Summary of 11/14/01 to Discuss Licensee's Response to Bulletin 2001-01
27. Documentation of Conference Call of 11/15/01, Response to Bulletin 2001-01
28. Public Meeting To Discuss Licensee's Response to Bulletin 2001-01
29. NRC Visit regarding Response to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles".
30. Meeting Summary of October 24, 2001, to Discuss the Licensee's Response to Bulletin 2001-01
31. Memorandum to James E. Richardson, Director Division of Engineering Technology – From Jack R. Strosnider, Chief Materials and Chemical Engineering, Branch Division of Engineering Technology – Summary of Meeting with Westinghouse Owners Group Concerning Primary Water Stress Corrosion Cracking of Inconel 600 dated September 3, 1992
32. RC-2 NRC Special Inspection Report 350-346/98021
33. IR 89-011, Boric Acid Found on Plant Equipment
34. SEN 190, Pressurizer Spray Valve Bonnet Nuts Dissolved by Boric Acid Leak
35. NRC Regulatory Guide 1.174, An Approach for Using Probabilistic Risk Assessment In Risk-Informed Decisions On Plant-Specified Changes to the Licensing Basis, August 25, 1998
36. NRC Regulatory Guide 1.175, An Approach For Plant-Specific, Risk-Informed Decisionmaking: Inservice Testing, September 15, 1998
37. NRC Regulatory Guide 1.176, An Approach For Plant-Specific, Risk-Informed Decisionmaking: Graded Quality Assurance, September 15, 1998
38. NRC Regulatory Guide 1.177, An Approach for Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications, September 15, 1998

39. Davis-Besse Nuclear Power Station NRC Augmented Inspection Team – Degradation of the Reactor Pressure Vessel Head – Report No. 50-346/02-03 (DRS)
40. NRC Letter Davis-Besse Inspection Report No. 50-346/94016
41. NRC Letter dated 2/8/90, Prevention of Boric Acid Corrosion at Davis-Besse Nuclear Power Station
42. NRC Letter dated 8.8.99, EA 99-138, Notice of Violation for NRC Inspection Report 50-346/98021
43. NRC Inspection Report 50-346/02-03, NRC Augmented Inspection Team – Degradation of the Reactor Pressure Vessel Head

10.4 INPO References

1. SOER 81-12 Reactor Coolant Pump Closure Stud Corrosion
2. SOER 84-5 Bolt Degradation or Failure in Nuclear Power Plants
3. SER 46-80 Reactor Coolant Pump Closure Stud Corrosion
4. SER 35-81 Corrosion of Reactor Coolant System Piping
5. SER 11-82 Reactor Coolant Pump Closure Flange Stud Corrosion
6. SER 57-83 Cracking in Stagnant Boric Acid Piping
7. SER 72-83 Damage to Carbon Steel Bolts and Studs on Valves in Small Diameter Piping Caused by Leakage of Borated Water
8. SER 32-84 Contamination of Reactor Coolant System by Magnetite and Sulfates
9. SER 41-85 Containment Spraying Events
10. SER 13-87 Reactor Vessel Stud Corrosion from Primary Coolant Leak
11. SER 31-87 Pressurizer Vessel Corrosion due to Pressurizer Heater Rupture
12. SER 35-87 Non-Isolable Reactor Coolant System Leak

10.5 Industry References

1. PWSCC of Alloy 600 Materials in PWR Primary System Penetrations, EPRI TR-103696. (Proprietary)
2. EPRI Technical Report -104748 Boric Acid Corrosion Guidebook (Proprietary)
3. EPRI Technical Report -1000975 Boric Acid Corrosion Guidebook, Revision 1 (Proprietary)
4. EPRI Technical Report -103696 PWSCC of Alloy 600 Materials in PWR Primary System Penetrations (Proprietary)
5. MRP-44, Part 2, PWR Materials Reliability Program – Interim Alloy 600 Safety Assessments for US PWR Plants, Part 2: Reactor Vessel Top Head Penetrations (Proprietary)
6. EPRI NP-6301-D, Ductile Fracture Handbook
7. EPRI Technical Report -107621-R1, Steam Generator Integrity Assessment Guidelines: Revision 1 (Proprietary)
8. EPRI Draft Report NP-6864-L, PWR Steam Generator Tube Repair Limits: Technical Support Document for Expansion Zone PWSCC in Roll Transitions
9. MRP Crack Growth Rate Report (Proprietary)
10. EPRI NP-7094, Literature Survey of Cracking of Alloy 600 Penetrations
11. EPRI Boric Acid Corrosion Guidebook, Effect of Flange Clearances in Reducing Oxygen Levels at Bolts Figure 8-6
12. EPRI Managing Boric Acid Corrosion Issues at PWR Power Stations – Final Report

13. Nuclear Management and Resources Council Guidelines for 10CFR50.59 Safety Evaluations dated November 7, 1988
14. Nuclear Management and Resources Council Guidelines for 10CFR50.59 Safety Evaluations dated July 25, 1989
15. Nuclear Management and Resources Council Guidelines for 10CFR50.59 Safety Evaluations dated June 19, 1990

10.6 Other References

1. V.C. Summer Nuclear Station Root Cause Investigation "A" Hot Let Nozzle Weld Cracks
2. Corrective Action Program Evaluation Criteria and Comments from Dorian Congre
3. RHR International Davis-Besse Phase 2 Organization Study Results June – July 1999
4. Davis-Besse Corrective Action Program Review by Congre and Elsea, Inc.
5. Preliminary Results – External Review of Overall Corrective Action Program Considerations by Dorian Congre
6. FENOC Memo – Examination of Five Closed Nonconformances Related to the RPV Head

11.0 Personnel Interviewed

The following is a list of personnel interviews that were considered in preparation of this Report. These interviews were conducted either by the Team or by other FENOC groups (e.g., the Technical Root Cause Analysis Team) from March through July, 2002.

Charles Ackerman, Davis-Besse
William Bentley, Davis-Besse Superintendent – Operations Support
Howard Bergendahl, Vice President Davis-Besse
Jeffrey Berryman, Davis-Besse Nuclear Master Mechanic
Jeffrey Bobetich, Radiation Protection Technician
Cary Bowles, Framatome, Maximum Valve Program Project Manager
Kevin Browning, Davis-Besse Corrective Action Program Evaluator
Kendall Byrd, Davis-Besse Nuclear Engineering (PSA Engineer) Supervisor
Guy Campbell, former Davis-Besse Vice President
Edward Chimahusky, former Davis-Besse RCS System Engineer
George Chung, current Davis-Besse Radiation Monitor Engineer
Robert Coad, former Davisi-Besse Operations and Radiation Protection Manger
Scott Coakley, Davis-Besse Outage Director
Dick Cockrell, Davis-Besse VT-2 Inspector
Rodney Cook, contractor Davis-Besse Regulatory Affairs
John Cunnings, Davis-Besse System Engineering Supervisor
Fred Currence, Framatome 13R Reactor Services Lead
Charles Daft, Davis-Besse ISI Engineer
David Dibert, Davis-Besse Reactor Engineer
Robert Donnellon, former Davis-Besse Director Engineering and Services
David Eshelman, former Davis-Besse Plant Engineering Manager
Randel Fast, Davis-Besse Plant Manager
James Freels, former Davis-Besse Licensing Manager
Steve Fyfitch, Framatome Metallurgist
David Geisen, Davis-Besse Design Basis Engineering Manager
Prasoon Goyal, Davis-Besse B&WOG Material Committee Representative
Mike Hacker, Framatome UT Expert
Daniel Haley, former Davis-Besse RCS System Engineer
John Hartigan, Davis-Besse Mechanical Engineering
Mark Haskins, Davis-Besse Supervisor Self-Evaluation Program
Brian Hennessy, Davis-Besse Corrective Action Program Supervisor
David Hessel, Davis-Besse Nuclear Mechanical Team Leader
Robert Hovland, former Davis-Besse Radiation Monitor System Engineer
John Johnson, former Davis-Besse Corrective Action Program Lead
Daniel Kelley, Davis-Besse Supervisor, Reactor Engineering
James Lash, former Davis-Besse Plant Manager
Michael Leisure, Davis-Besse Senior Specialist
David Lockwood, Davis-Besse Manager Learning Organization and Regulatory Programs
Peter Mainhardt, performed Davis-Besse Reactor Vessel Head Inspections
James Marley, Davis-Besse System Engineering

Eugene Matranga, Davis-Besse System Engineering
Patrick McCloskey, Davis-Besse Chemistry Manager
Glenn McIntyre, former Davis-Besse Mechanical Systems Engineer
Kevin McLain, former Davis-Besse Reactor Operator
Mark McLaughlin, Davis-Besse CRDM Project Manager
John Messina, Davis-Besse Director Work Management
Dale Miller, Davis-Besse Regulatory Affairs Supervisor
Steven Moffitt, Davis-Besse Director Technical Services
Walter Molpus, current Davis-Besse Boric Acid Corrosion Control Program Owner
Lew Myers, Chief Operating Officer, FENOC
John O'Neill, former Davis-Besse PCAQRB Chairman
Randy Patrick, Davis-Besse Shift Engineer
Robert Pell, former Davis-Besse Operations Manager
Ron Pillow, Framatome CRDM Component Engineer
Terry Ploeger, Davis-Besse Shift Manager
Jack Reuter, Master Radiation Control Tester
Douglas Ricci, Davis-Besse Supervisor Nuclear Operations
Michael Roder, former Davis-Besse Shift Manager
Joseph W. Rogers, Davis-Besse Outage Director
Dennis Schreiner, former Davis-Besse Independent Safety Engineering Supervisor
Pete Senuik, Davis-Besse ISI Pressure Test Engineer
Michael Shepherd, Davis-Besse ISI Engineer
Philip Shultz, former Davis-Besse Radiation Protection Manager
Andrew Siemaszko, current Davis-Besse RCS System Engineer
Rebecca Slyker, Davis-Besse Regulatory Affairs
Dennis Snyder, Davis-Besse Maintenance
Anthony Stallard, Davis-Besse Operations Support Superintendent
Charles (Steve) Steagall, Davis-Besse VT-2 Inspector
Charles Steenbergen, Davis-Besse Shift Manager
Henry Stevens, FENOC Manager Quality Assurance
Michael Stevens, former Davis-Besse Maintenance Manager
Lou Storz, former Davis-Besse Vice President Nuclear
Joseph Sturdavant, Davis-Besse Regulatory Affairs
Billy Sutton, Davis-Besse Radiation Protection
Theo Swim, Davis-Besse Design Basis Engineering
James Vetter, Davis-Besse Quality Assessment Supervisor
Andrew Wilson, Davis-Besse Maintenance
Scott Wise, Davis-Besse Operations
John Wood, former FENOC Vice President Engineering Services
Lonnie Worley, former Davis-Besse Director of Support Services
Dale Wuokko, Davis-Besse Regulatory Affairs

Tables

Provided as a separate document

Figures

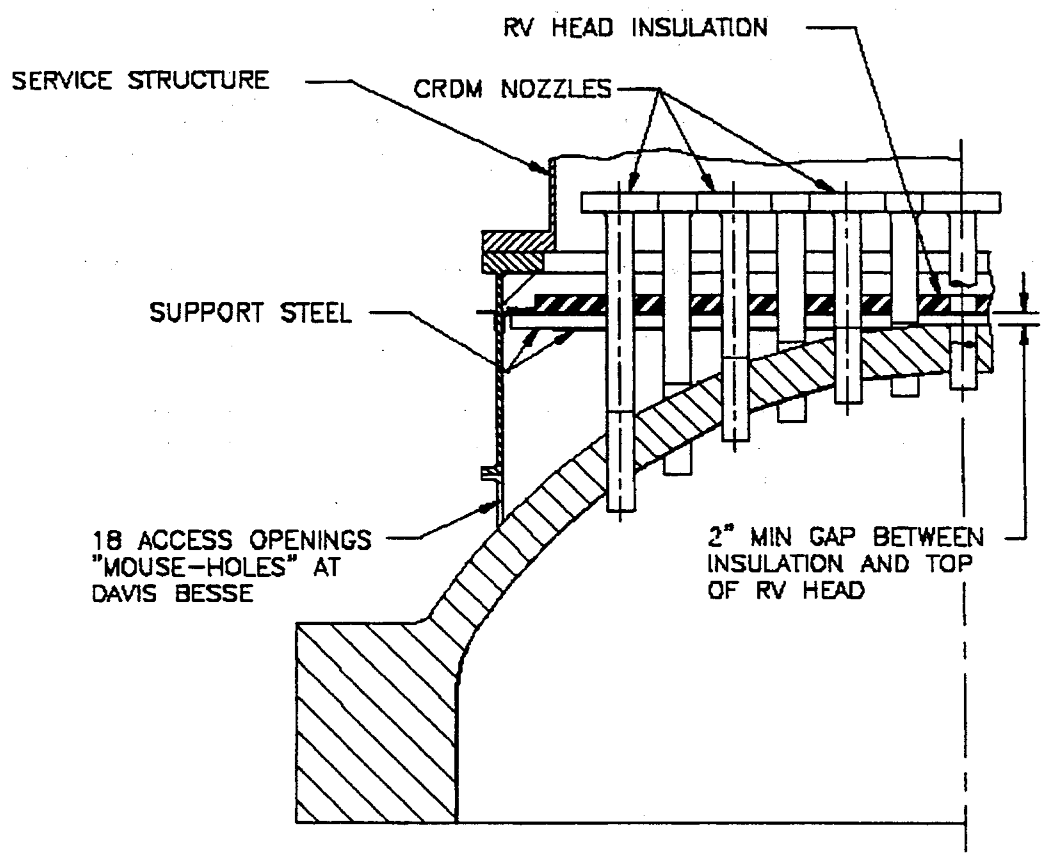


Figure 1. Davis-Besse RPV Top of Head Section View

Source: EPRI/DEI

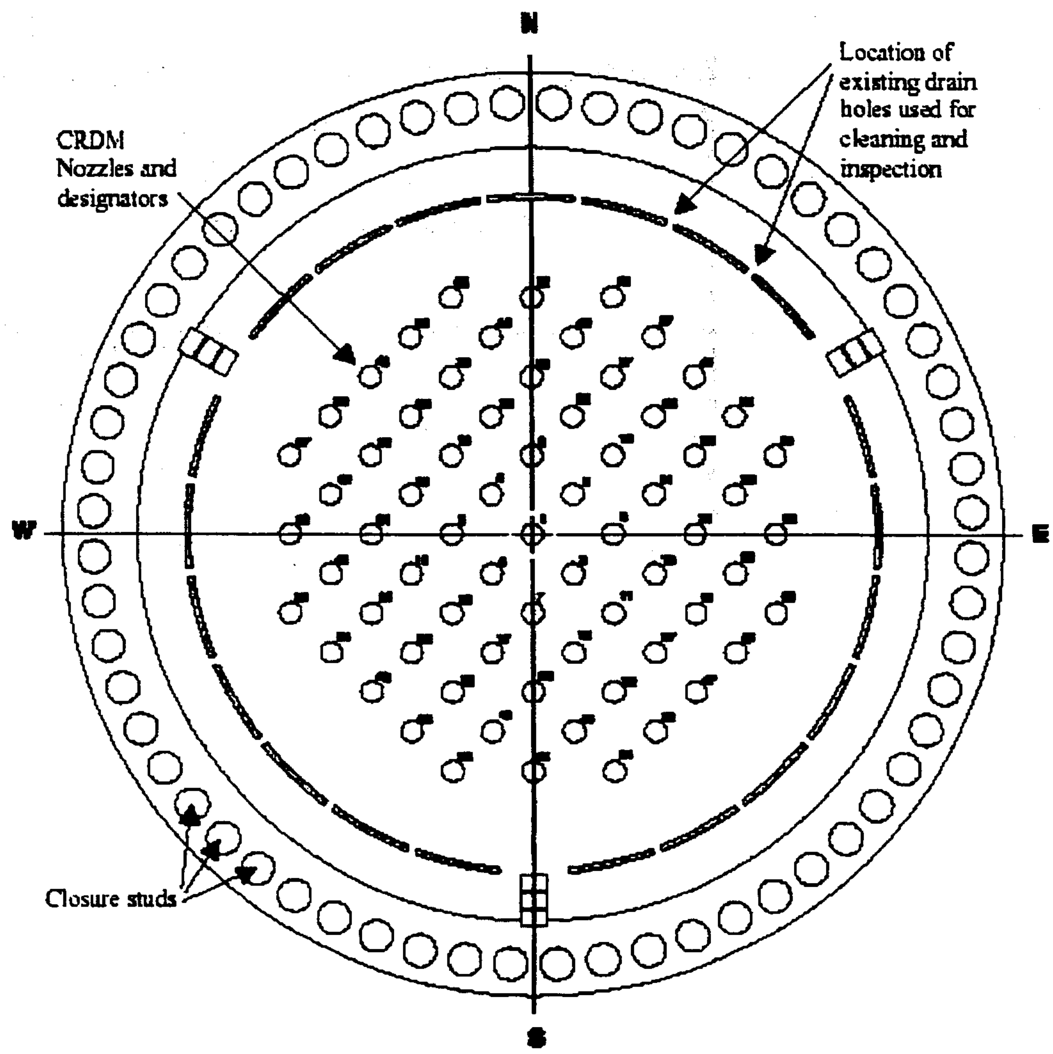


Figure 2. Davis-Besse RPV Top of Head Plan View

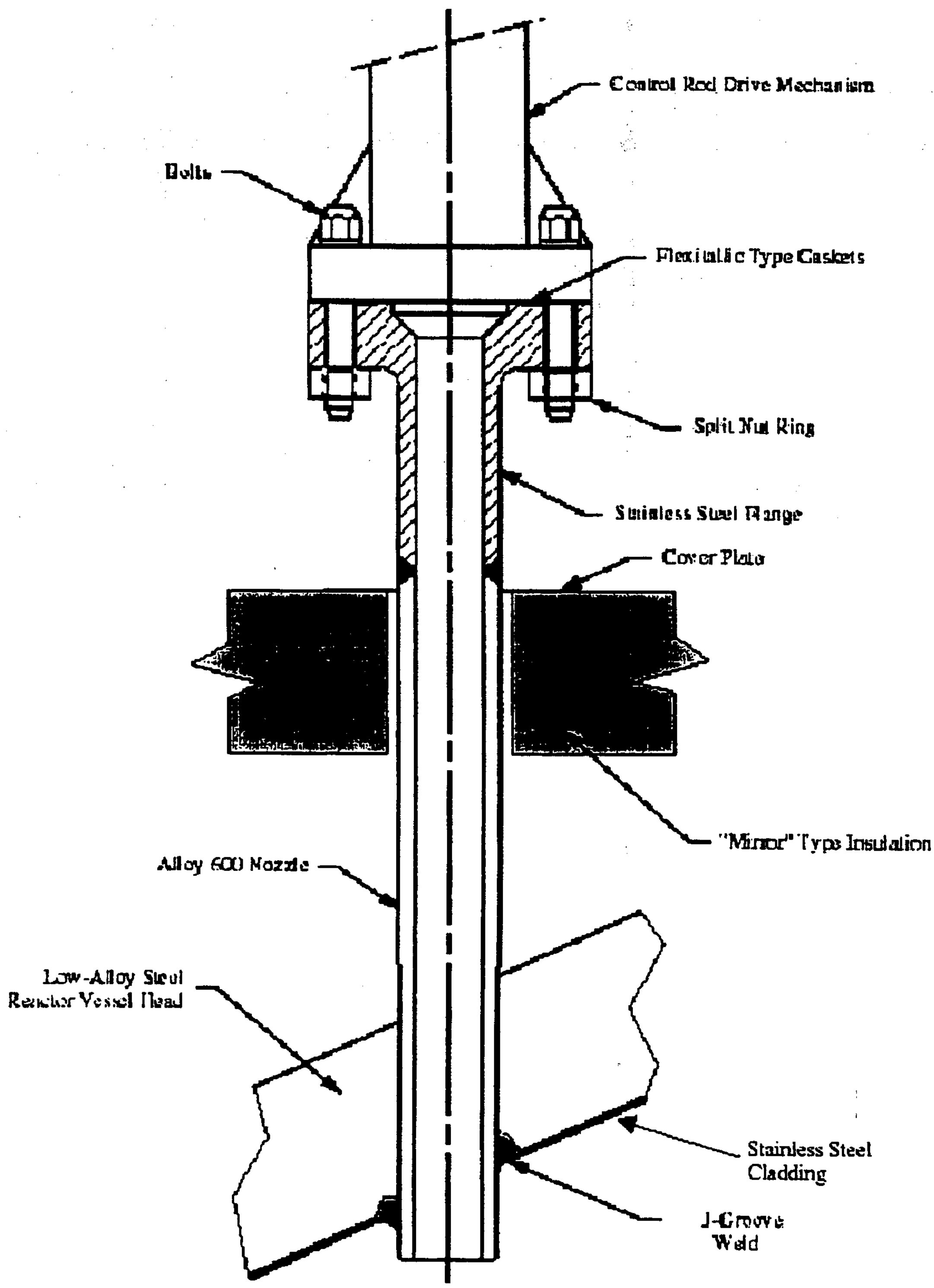


Figure 3. Davis-Besse CRDM Nozzle General Arrangement

Figure 4 - - Summary of Events & Casual Factor Chart, is included as a separate document.

Figure 5 - - Change in Plant Conditions, is included as a separate document.

Attachments

ATTACHMENT 1

CHARTER FOR THE ROOT CAUSE ANALYSIS TEAM

Charter

Condition Report 02-0891 Evaluation

The FirstEnergy Nuclear Operating Company (FENOC) supported by the firm of Conger & Elsea, Inc., will be conducting an analysis and evaluation of the non-technical aspects surrounding the corrosion of the Davis Besse Nuclear Power Station (DBNPS) Reactor Pressure Vessel (RPV) Head base metal as documented in Condition Report (CR) 02-00891. The team should ensure that proper root causes, contributing causes and probable causes and corrective actions are thoroughly evaluated, defined and documented.

The analysis and documentation shall be conducted in accordance with the FENOC corrective action program, Nuclear Operating Procedure NOP-LP-2001, the DBNPS Condition Report Process Programmatic Guideline, and the FENOC Root Cause Analysis Reference Guide. This analysis is performed to identify issues and corrective actions in support of NRC Confirmatory Action Letter (CAL) 3-02-001A, dated May 15, 2002.

The team evaluation problem statement is:

> Over a period of years, the DBNPS organization failed to identify corrosion of the RPV Head base metal.

Additionally, the team shall:

- Evaluate the human performance extent of condition.
- Recommend a corrective actions effectiveness review.

At a minimum the team review shall include the following Condition Reports:

- CR 02-00891, "Ultrasonic testing (UT) performed on the #3 Control Rod Drive Mechanism (CRDM) nozzle revealed indications of through wall axial flaws in the weld region". This CR investigated the technical issues surrounding the corrosion of the RPV Head base metal.
- CR 98-0020, "Multiple problems were identified with Reactor Coolant (RC)-2, the Pressure Spray Valve... this CR be used to conduct an independent review of the management issues associated with RC-2".
- CR 02-01850, Corrective Action Program Guidelines not followed for CR 02-00891 Disposition". This CR will also be evaluated and closed out by the team.

At completion of the above the team shall provide a briefing to DBNPS Senior Management and provide a root cause evaluation report documenting the causes, extent of condition, experience review and recommended corrective actions.

L. W. Myers,

FENOC Chief Operating Officer

ATTACHMENT 2

LIST OF CONDITION REPORTS ISSUED BY THE ROOT CAUSE ANALYSIS TEAM

CR 2002-02662 A simple tool is needed to assist Instructional Staff in the orderly implementation of changes resulting from alterations to Nuclear Training materials specifically System Engineer Qualification Cards.

CR 2002- 02805 During review of CR 98-0020 under "Event Narrative" it was noted that some minor boric acid corrosion was noted on the horizontal surface of the new yoke with only a short operating time with packing leakage. After the first missing nut was found, the subsequent activities and investigations were focused on the missing nut(s). There are no discussions or evaluation on the condition of the "corroded" new yoke within CR 98-0020 and PCAQ 98-1885 with the additional time the yoke was exposed to boric acid.

CR 2002-02879 The root cause report for Condition Report 1998-20 on RC-2 Packing Leak Management Issues identified eight Proposed Corrective Actions in the "Problem Statement" section of the report. A search of the Corrective Action Tracking System, which should track those actions, has failed to find the follow-up actions tracking seven of the eight corrective actions.

CR 02-03602 The commitment tracking program (TERMS) does not appear to have tracked and addressed NRC comments/concerns contained in the 1989 Bulletin Response Audit Report (Log 3166), which documented implementation of the Generic Letter 88-05. Although these enhancements would not have been considered NRC commitments at that time or by today's view either, there should have been some type of evaluation/dispositioning by the plant staff. The NRC Inspection Report clearly indicate these "areas of boric acid corrosion prevention could be enhanced at the Davis-Besse plant" items were more than enhancements and were characterized during the exit meeting as "weaknesses." These items are valid enhancement recommendations.

2002-03712 The Policy Manual for the Davis-Besse Nuclear Power Station currently states "Policy Statements are considered to be in effect following approval and distribution to the Policy Manual. Strict adherence to and conscientious implementation of these policies is mandatory for all Davis-Besse personnel, as well as other individuals who support the Davis-Besse Nuclear Power Station". This document further states "All levels of management should regularly review these policies and identify the need for new and revised policy statements. The information in the manual must be current and used by all management personnel in our day to day activities". This document was signed by the Davis-Besse Vice- President Nuclear on 8/14/00.

In addition to the above, current Policy Admin. - 15, Davis-Besse Policy/Charter/Guideline states "The documents contained in the Davis-Besse Policy/Charter/Guideline shall be reviewed annually for accuracy and revised as necessary". A review of the documents contained in the Davis-Besse Policy/Charter/Guideline Manual revealed that there are many cases where these documents no longer accurately reflect current practices/expectations.

2002-03755 During review of PM 1629, generated as result of the GL 88-05 initial response (Serial Number 1527) and subsequent revised response (Serial Number 1-885) for item 'D', it was noted that the PM does not contain the requirement for CRDM flange gasket replacement prior to outage completion when leaks are identified. The intent is to replace gaskets on leaking CRDM flanges so on startup from a refueling outage it is free of CRDM flange leaks.

2002-03758 During review of CR 98-0020, RC-2 root cause, it was noted that corrective actions described within the root cause report were not fully transcribed into the Corrective Action Tracking System (CATS). Limited space within the CATS "Action Description" does not permit full transfer of the corrective action as described within the root cause report. The CATS item does not capture the intended action and therefore, the recommended action may not have been completed.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
Boric Acid	6.1.1 Principle Leak Locations- All areas and components within primary system pressure boundaries are capable of developing leaks	4			XXXX		Carbon Steel RPV Head	The Reactor Pressure Vessel Head is included in this definition as an area to inspect for boric acid leakage and corrosion. EVALUATORS NOTE: In interview Ref 0402-F the 11RFO inspector stated : I had no training, no background or instructions on what to do. I was to be the DB representative to watch them (Frametome)." Nozzles were not recognized as "principle leak locations" in NG-EN-00324 (Ref 128-B) and all boric acid was not removed for complete inspection of the nozzles.
	NG-324 5.1.1 person finding evidence of the leak shall inform Shift Supervisor of the magnitude and location of the boric acid leak	4				XXXX		PCAQ 98-0649 (Ref 125-B) identified the existence of boric acid residue on 4/18/98. The Shift Supervisor was notified on 4/18/98. This PCAQ evaluated the indications of leaking CRDM flanges. PCAQ 98-0767 (Ref 126-B) identified via video inspection of the area where the CRDM nozzles enter the reactor vessel head on 4/24/98 several "fist" size clumps of boric acid the Shift Manager/Shift Supervisor was notified on 4/25/98. This PCAQ evaluated the boric acid on the RPV Head. The Shift Manager/Shift Supervisor was informed of the initial inspection results stated in PCAQ 98-649 (4/18) and PCAQ 98-767 (4/25). The Shift Supervisor/Shift Manager noted that the RCS leakage was within Tech Spec limits during the last operating cycle.
	NG-324 5.2.1 the Shift Supervisor shall inform Plt Engineering of the location and magnitude of the leak	4				XXXX		Plant Engineering performed the initial inspections documented in PCAQ 98-649 and PCAQ 98-767. The initial inspections identified the magnitude and location of the leaks were documented in these PCAQs. Because Plant Engineering performed the initial inspections, they were already aware of the location and magnitude of the leak.
	NG-324 5.3.2 Plt Eng shall perform and document the necessary inspections of the detected leak	4			XXXX			In PCAQ 98-649 the RCS System Engineer determined the leak was from CRDM flange D10. Design Engineering noted in PCAQ 98-0767 "white streaks on the OD of CRDM housing and this indicates leaking CRDM flanges." EVALUATORS NOTE: This evaluation was performed at the "Apparent Cause" level evaluation. Since the boric acid was not completely removed from the head, inspections to detect a leak could not be performed.
	NG 5.3.3 Plt Eng shall take actions to have boric acid residue removed from the affected component	4			XXXX			In PCAQ 98-767 Design Engineering noted "that there were slight boric acid deposits left on the head." This acceptance was first established in PCAQ 96-551 (Ref 109-B) by the Plant Engineering Manager, "nozzle cracking is, of course, a significant issue. However, at present, the probability of occurrence is relatively low. We should remove boron from the reactor pressure vessel head as best we can as so as to manage dose. This will enable us to monitor any leakage, should a nozzle crack initiate. I also do not believe that the vessel head area is non-conforming." EVALUATORS NOTE: The boric acid was not completely removed from the RPV Head.
	NG-324 5.3.4 Plt Eng shall determine the root cause and source of the leak	4			XXXX			The Management Review Committee (MRC) categorized PCAQ 98-649 and 98-767 at the Apparent Cause level evaluation. EVALUATORS NOTE: There is no tie between the NG-324 requirement to determine "root cause" and NG-702, Corrective Action Program (Ref 358-F) that would have required these CRs to be assigned a "Root Cause" evaluation.
	NG-324 5.3.5 Plt Eng shall forward the inspection report to Design Eng and provide technical information as required	4				XXXX		PCAQ 98-767 was assigned to Design Engineering to evaluate. The 4/24/98 and 5/4/98 video tapes were provided to Design Engineering.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 5.4.1 Design Eng shall assess the information provided by Plt Eng regarding the leak and available industry technical data	4			XXXX			Plant Engineering's initial inspection was documented in PCAQ 98-767. This CR was assigned to Design Engineering to evaluate. In addition to the CR, the initial inspection video and post cleaning video were reviewed. Design Eng's evaluation noted "there were slight boric acid deposits left on the head". He referenced industry technical data (B&W document # 51-1229638-1) stating "the testing showed almost no corrosion occurred at temp greater than 550F). EVALUATORS NOTE: BAW-2301, 7/97 (Item 266-F) notes " the B&WOG safety evaluation concluded that if cracking were to occur it would be predominantly axial in nature. This would lead to a leak on one or more of the nozzles and result in a significant deposition of boron crystals. It is very unlikely that this type of accumulation would continue undetected with regular walkdown inspections (enhanced boric acid visual inspections in accordance with GL 88-05). However, because of the increased attention brought upon by the European PWSCC events, in general more emphasis than that required by GL88-05 has been placed on these inspections."
	NG-324.5.4.1.a Design Eng shall determine the extent of damage incurred	4			XXXX			Design Engineering dispositioned PCAQ 98-767. In PCAQ 98-767 the Design Engineer noted "that there were slight boric acid deposits left on the head." EVALUATORS NOTE: As there was boric acid left on the head, the extent of damage could not be completely determined because all the boric acid deposits were not removed.
	NG-324 5.4.1.b Design Eng shall perform any necessary corrosion calcs for determining extent of degradation	4		XXXX				The Design Engineer noted very slight pitting in the head in the PCAQ 98-767 evaluation. Based on engineering judgement the head thickness will not be impacted. In PCAQ 98-767 the Design Engineer noted "that there were slight boric acid deposits left on the head." EVALUATORS NOTE: Because not all the head was cleaned, the extent of degradation calculations could not be fully determined.
	NG-324 5.4.1.c Design Eng shall determine immediate and/or long term corrective actions to stop the leak and prevent recurrence of boric acid corrosion	4		XXXX				Design Engineering responded to PCAQ 98-767 (Design Engineer and Supervisor) that "the root cause and CATPR for PCAQ 98-551 is in progress." EVALUATORS NOTE: However, CR 98-551 did not identify CATPR for boric acid leaking onto the head. It only provided a means of inspection. A detailed analysis of the "rust brown" boric acid was not performed. Additionally, the entire head was not inspected.
	NG-324 6.3.1 Upon notification of boric acid build up in the plant, Plt Eng. shall perform an initial inspection of affected area to determine as found conditions and document results using dwgs, photos, etc.	4				XXXX		Plant Engineering performed an initial inspection as documented by the Service Water System System Engineer in PCAQ 98-767. This PCAQ documented the video inspections of 4/24/98 and 5/4/98.
	NG-324 6.3.1.a Identify the total amount of boron deposits on each component	4			XXXX			PCAQ 98-767 initiated by the Service Water System Engineer stated "where the CRDM nozzles entered the reactor vessel head indicated several "fist size" clumps of boric acid. Where clumps were not present a light dusting of boric acid was found covering the surface area of the vessel head." EVALUATORS NOTE: The amount of boric acid was specifically qualified as a "total amount." In interview Ref 0402-F the 11RFO inspector, stated: I had no training, no background or instructions on what to do. I was to be the DB representative to watch them (Framatome)."
	NG-324 6.3.1.b Inspect the area of identified boron build up to verify that the boron is localized to the identified area	4				XXXX		In PCAQ 98-767 the Service Water System Engineer provided a diagram showing the "area of clumps of boric acid accumulation on the RPV Head. Where clumps were not present a light dusting of boric acid was found covering the surface area of the vessel head." EVALUATORS NOTE: The area of clumps is approximately 1/4 of RPV Head and other parts of RPV Head were covered with a light dusting of boric acid. The boric acid deposit "localized area" was identified and mapped via the initial inspection in PCAQ 98-767.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.3.1.b Inspect area to determine if boric acid could have entered the internals of a component	4		XXXX				Per PCAQ 98-767 evaluated by the Design Engineer and accepted by his supervisor noting "there were slight boron deposits left on the head after cleaning." This acceptance was first established in PCAQ 96-551 by the Plant Engineering Manager noting, "nozzle cracking is, of course, a significant issue. However, at present, the probability of occurrence is relatively low. We should remove boron from the reactor pressure vessel head as best we can as so as to manage dose." EVALUATORS NOTE: Since all the boric acid was not removed, the head was not fully inspected.
	NG-324 6.3.1.c the affected areas should be inspected to identify signs of corrosion. This will most likely be exhibitied by red rust or red/brown stained boron	4			XXXX			The Design Engineer noted in PCAQ 98-767 the lumps of boric acid on the head "varied from rust brown to white. The rust or brown color is an indication of old boric acid deposits there were slight boron deposits left on the head after cleaning." EVALUATORS NOTE: However, these indicatoins were not evaluated by rigorous root cause methodology. CR 98-0767 was evaluated at the "Apparent Cause" level ("old boric acid deposits" rust brown boric acid is a sign of corrosion).
	NG-324 6.3.1.c If corrosion is present the amount of corrosion should be estimated	4		XXXX				The Design Engineer documented in PCAQ 98-767 that there was no significant pitting of the head. EVALUATORS NOTE: However, the entire head was not cleaned (as noted in Design Engineering's PCAQ 98-767 evaluation) therefore, the amount of corrosion could not fully be estimated.
	NG-324 6.3.1.d the affected component should be carefully inspected to determine if a boric acid solution is present or just crystals and residue	4		XXXX				The Service Water System Engineer performing the 11FRO head inspection identified in PCAQ 98-767 that the boric acid was in fist size clumps and a light dusting on the rest of the head. EVALUATORS NOTE: The inspection of the head is performed with the plant in Mode 5/6 several days into the outage. Therefore, the boric acid is always going to be dry by this time.
	NG-324 6.3.3.e the material that makes up the affected components should be determined. Carbon steel can experience wastage rates up to 1/3 inch per month under ideal conditions. Accelerated corrosion rates occur with temps near 200F and with active leak	4				XXXX		Design Engineering documented in PCAQ 98-767 that carbon steel was involved and needed to be evaluated.
	NG-324 6.3.1.f the temp of the affected component should be determined for both existing and operating conditions. Temps may be estimated from previous log readings	4				XXXX		Design Engineering documented the operating temperature of the head in PCAQ 98-767. "These deposits will not create any corrosion since the head temperature is greater that 550F." "The only time the higher corrosion rate can be encountered is during shutdown and heatup when the temp of the head will be well below 550."
	NG-324 6.3.2 Plt Eng shall notify the Shift Supervisor of any immediate safety concerns raised by the initial inspection	4				XXXX		Plant Engineering notified the Shift Manager/Shift Supervisor (PCAQ 98-649 and PCAQ 98-767). The Shift Supervisor/Shift Manager noted that the RCS leakage was within Tech Spec limits during the last operating cycle.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.3.3 Plt Eng should document exam results in the System Performance Books	4			XXXX			Exam results were not provided in the System Performance Books. However, photographs were provided in the System Performance Book Volume 8.
	NG-324 6.3.3 If required based on the magnitude of the leak and extent of damage Plt Eng shall document the inspections by: a) PCAQ or b) MWO	4		XXXX				The Service Water System Engineer performing the 11RFO head inspection documented the extent of boric acid initially found on the head in PCAQ 98-767. EVALUATORS NOTE: However, as noted in Design Engineering's evaluation of PCAQ 97-767 cleaning of the head was not completely performed as some boric acid ("slight") remained on the head.
	NG-324 6.3.4 If boric acid residue is present Plt Eng. will evaluate the residue present and contact RP if removal is determined to be required	4			XXXX			As noted by Design Engineering, the boric acid was requested to be removed from the head. However, as noted in Part 4A Item C of PCAQ 98-767, not all boric acid was removed from the head ("there were slight boron deposits left on the head after cleaning").
	NG-324 NOTE 6.3.5 if the leak or component damage is extreme Plt Eng. may confer with Design Eng. before taking further action	4				XXXX		Plant Engineering requested Design Engineering assistance as documented in PCAQ 98-767 assignment to Design Engineering.
	NG-324 6.3.5 Plt Eng shall determine whether follow up or detailed inspections are necessary to fully assess component damage and determine corrective actions	4		XXXX				PCAQ 98-767 documents that initial and post cleaning inspections were performed. EVALUATORS NOTE: However, some boric acid was left on the head. Therefore, a complete detailed inspection could not have been performed nor could we could fully assess component damage and determine corrective actions. PCAQ 98-551 documents that "the step 6 .3.1.b 'the area should be inspected to determine if boric acid could have entered the internals of a component and spread internally to a location that is not visible can not be completed."
	NG-324 6.3.5.a.1 If a detailed inspection is deemed necessary, Plt Eng shall write service requests or work requests as necessary for the removal of insulation, scaffolding, cables, or any other type of interference which prevents access to the leak.	4		XXXX				Plant Engineering performed the initial inspections documented in PCAQ 98-649 and PCAQ 98-767. The magnitude and location of the leaks were documented in these PCAQs. The Shift Manager was informed of the initial inspection results stated in PCAQ 98-649. EVALUATORS NOTE: However, there were slight boric acid deposits left on the head after cleaning (Ref CR 98-0767) and interferences were not removed as the service structure modification was not completed as stated in PCAQ 98-0551.
	NG-324 6.3.5.a.2 Plt Eng shall perform subsequent inspections as necessary and include the results with the initial inspection (include detailed description of visible damage, photos, root cause of leak)	4	XXXX					The Service Water System Engineer performing the 11RFO head inspection provided initial and after cleaning video inspection results to Design Engineering as noted in PCAQ 98-767. Design or Plant Engineering did not perform a "root cause" evaluation to determine the cause of the leak. This PCAQ was assigned by the NG-702 (PCAQ process) at the "Apparent Cause" level. EVALUATORS NOTE: There is no tie between NG-324 requirement to determine the root cause of the leak and NG-702 categorization/evaluation significance level.
	NG-324 6.3.6.a.1 if a PCAQ was generated then Design Eng shall review the inspection report	4				XXXX		A PCAQ was generated describing the boric acid found on the head during the initial inspection. Reference PCAQ 98-767 Part 1. PCAQ 98-767 was assigned to Design Engineering to review the inspection results. Design Engineering's review is documented in PCAQ 98-767 Part 4A Item B and Item C dated 7/16/98.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.3.6.a.2 Design Eng shall assess the extent of component damage	4		XXXX				The evaluation performed by Design Engineering of PCAQ 98-767 noted boron was left on the head. EVALUATORS NOTE: Since slight boric acid deposits were left on tne head, the full extent of reactor vessel head damage could not be assessed.
	NG-324 6.3.6.a.6 Design Eng shall determine the corrective actions to be taken to prevent recurrence of boric acid corrosion. These corrective actions should include consideration of MODs and procedure changes	4			XXXX			PCAQ 98-767 Part 4A Item F notes "the root cause evaluation and CATPR for PCAQ 98-551 is in progress. PCAQ 98-767 can be closed once the root cause and CATPR for PCAQ 98-551 are complete. EVALUATORS NOTE: However, the actions for PCAQ 98-551 (wider inspection ports) would not prevent boric acid from leaking onto the head therefore, this is not CATPR of boric acid corrosion as required by this procedure step.
	DB-PF-03065, Pressure Test RCS at 2165 psig on 5/19/98 Step 4.14 Complete the Corrective Measures Evaluation/Action Report for the leakages, boric acid accumulations are corrosion resudues identified on the VT-2 Exam Report	4			XXXX			VT-2 Exam Report (RC 114-F) for the CRD Nozzles (69 nozzles) and Reactor Vessel (T1) boundary examined identified "no leakage noted" by the inspector. Interview (151-F) noted, "I don't know how the step was signed off for the nozzles". The CR 02-0891 (Ref 805-F) technical root cause stated "The person described his entering the Reactor Cavity and walking around the RPV head looking for evidence of leakage from the CRDM nozzles." EVALUATORS NOTE: 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." (Ref 835-F) It appears this is how the VT-2 was performed as the CRDM nozzles would not be viewable with the 6 foot distance required by IWA-2200. However, this exam didn't detect the leaking nozzles or the boron left on on the head following cleaning as noted in PCAQ 98-0787. No link between NG-324 and DB-PF-03065.
	CRDM Nozzle Design	1			XXXX			CRDM nozzle alloy 600 material is susceptible to cracking and leakage as reported in BAW-2301, 7/97 (Item 266-F)
	CRDM Flange Gasket Design	1			XXXX			The CRDM flanges had a history of leakage. Starting in the 1990 outage (6RFO) gaskets were replaced in the CRDM flanges. The plant replaced all of the CRDM flange gaskets by the end of the 1996 RFO (10RFO). (Ref CR 02-0891 Technical Root Cause Evaluation).
	ISI VT-2 inspector training on boric acid corrosion	5	XXXX					The VT-2 inspector stated (Ref 0147-F): "The only training related to ISI activities. Nothing that I recall specifically about boric acid." EVALUATORS NOTE: IWA-5242, "Insulated Components," Item C provides minimal guidance: "Discoloration or residue on surfaces shall be given particular attention from borated reactor coolant leakage." (Ref RC 117-F).
	Engineering training on NG-324 was required reading of procedure.	5	XXXX					A past RCS System Engineer remembers giving training on the 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 (Ref 0714-F). No training records could be found recording that the Plant Engineer who conducted the initial inspection as documented in PCAQ 98-767 was trained prior to performing this inspection. In interview Ref 014-F, 0402-F the 11RFO inspector stated: "In 1998 I was assigned to do the head inspection at the last minute. I had no training, no background or instructions on what to do. I was told Framatome is doing the inspection, I was to be the DB representative to watch them." The 10RFO inspector (Design Eng) noted similar comments and did not receive the training conducted on 4/27/95.

HAZARD-BARRIER-TARGET ANALYSIS
(11RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-702 Attachment 2 Repetitive Q, AQ component failures that are not run to failure are categorized as "Category 2"	4			XXXX			PCAQ 96-767 and 96-649 were categorized as Category 3 and evaluated as "Initial Assessments" (Apparent Cause evaluations) as documented in their respective Part 4 documentation. However, CRD flange leakage was a repetitive component failure as was boron on the RPV Head. Therefore, these PCAQs should have been categorized and evaluated at a higher category.
	NG-702, Attachment 2 Deficiencies that require "use-as-is" or "repair" dispositions are categorized as "Category 2"	4			XXXX			PCAQ 96-649 Part 4A Item E (RCS system Engineer) stated: "As part of this inspection, CRDM D-10 was identified as having a minor leak. Initial and follow-up review of the leaking flange be Davis Besse Plant Engineering indicated no immediate was required, and that this drive should be inspected during 12RFO and repairs made as required." "[I]t is considered acceptable to defer any repairs to CRDM D-10 until 12RFO following reinspection." EVALUATORS NOTE: This appears to be a "use-as-is" disposition. Therefore, this PCAQ should have been categorized as "Category 2."
	NG-702 6.3.2 If CATPR is needed, MRC recommend the cause evaluation level (Apparent Cause, Root cause, or Multi-disciplined Root Cause)	4	XXXX					PCAQ 96-767 and 96-649 were categorized as Category 3/Apparent Cause evaluations. However, as noted in PCAQ 96-649 Part 4A Item E, CRD flange leakage was a repetitive component failure as was boron on the RPV Head. Per NG-324 6.3.6.a.6, CATPR should have been performed, which would require at a minimum root cause evaluation. EVALUATORS NOTE: However, there is no tie between NG-324 requirements for CATPR for a CR/PCAQ and NG-702.

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
Boric Acid	6.1.1 Principle Leak Locations- All areas and components within primary system pressure boundaries are capable of developing leaks	4			XXXX		Carbon Steel RPV Head	The Reactor Pressure Vessel Head is included in this definition as area to inspect for boric acid leakage and corrosion. The new RCS System Engineer performed the head inspection in 12RFO (4/99). The new RCS System Engineer's Job Familiarization Guideline (JFG) for review of NG-324 with his supervisor was completed on 9/28/00 after 12RFO. Engineering Support Continuing Training Cycle 99-04 discussed the Boric Acid Corrosion Control Program (NG-324) following lessons learned from RC-2. The training discussed that one of the signs of boric acid Corrosion on a plant component is red or brown crystal formation. The 99-04 training included a discussion of the NG-324 procedural requirements. Nozzles as leak locations were not recognized as "principle leak locations" in NG-EN-00324 and all boric acid was not removed for complete inspection of the nozzles.
	NG-324 4.4 Definition "Substantial Leakage"- leakage has gone beyond immediate area of the component to affect other components	4			XXXX			The BACCIC/CR 00-0782 (Ref 159-B) identified there was leakage on the flange ... a small quantity has run down the sides of the flange and into the floor." The BACCIC identifies the leakage as "heavy leakage from the head weep holes." The Service Water System Engineer who assisted in the initial head inspection stated in (Ref 402-F) interview "the 2000 inspection showed a difference from 1998. there were signs of corrosion products in the BA; all of the mouseholes were completely plugged so we couldn't get the cameras inserted. I took photos with a digital camera." EVALUATORS NOTE: "Heavy Leakage" is not defined in NG-00324 (Ref 168-B). This leakage should have been identified as "Substantial Leakage," which would have been evaluated by Design Engineering.
	NG-324 4.5 Definition BACC Coordinator - This person will also provide resolution coordination during outages.	4	XXXX					CR 00-0782 (Ref 159-F) states the Shift Manager notified the BACC Coordinator on 4/6/00. CR00-0782 inspections or evaluations were not coordinated through the BACC Coordinator. In interview Ref 0409-F the BACC Coordinator stated, "Although I am the program owner, I don't perform many of the responsibilities called out in the BACC procedure. Workload is a problem. No one has ever talked to me about program ownership or the expectations involved." He was given no specific training or time to perform the boric acid corrosion coordinator responsibilities. He is the System Engineer for several plant systems in addition to the BACC Coordinator duties. In interview 141-F he stated he "had not fully or in great detail" read GL 88-05.
	NG-324 6.2.3.a shall inform Shift Supervisor of the location and magnitude of the leak or boric acid residue	4				XXXX		The Shift Manager/Shift Supervisor was notified via CR 00-0782 on 4/6/00 at approx. 0530 hours. The Shift Manager noted "further evaluation required after detailed inspection delineated in Step 6.4.1 on NG-324 is performed."
	NG-324 6.3.1 Plt Eng shall conduct initial inspection of area (as found)	4				XXXX		The Initial Inspection of the "reactor head flange" was performed as noted on the BACCIC/CR 00-0782. The BACCIC identified component internals or area not visible as the "head, CRD tubes." A "Detailed Inspection" was recommended.
	NG 6.3.1.a should estimate total amount of boron (thickness, density, color, location)	4				XXXX		CR 00-0782 identified the leakage was red/brown in color. The total estimated leakage is approximately 15 gallons. The worst leakage from one weep hole is approximately 1.5 inches thick on the side of the head and pooled on top of the flange. Preliminary inspection of the head through the weep holes indicates clumps of boric acid are present on the east and south sides. Response to CR 00-0782 noted boron deposits were "lava like" and originating from the "mouse holes" and CRD flanges.

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.3.1.d should inspect to determine if active leak present or "just dry crystals and residue."	4		XXXXX				The BACCIC/CR 00-0782 note the boric acid is "dry." The leakage evident from the weep holes appears to be a dried stream in every case. EVALUATORS NOTE: The inspection of the head is performed with the plant in Mode 5/6 several days into the outage therefore, the boric acid is always going to be dry by this time.
	NG-324 6.3.1.e should inspect for signs of corrosion (most likely red or rust or red/brown stained boron).	4				XXXX		The leakage was identified as "heavy leakage from head weep holes" as noted on the BACCIC. CR 00-0782 was initiated and identified boric acid leakage from the weep holes. The CR/BACCIC noted "the leakage is bed/brown in color." In interview 373-F the new RCS System engineer states "it (boric acid) looked much like the 1998 tapes except it was reddish brown, indicating corrosion products." In interview (60-F) the new RCS System Engineer stated I saw it was a little darker, but it also may have been there for 2 years, so it gets a little darker. I thought it was old stuff from 11RFO." EVALUATORS NOTE: However, these indications do not appear to have been evaluated as indicated in the apparent cause evaluation for CR 00-1037 (Ref 160-B).
	NG-324 6.3.1.e if corrosion present, any boric acid deposits should be removed for detailed inspection.	4			XXXX			CR 00-1037 (Ref 160-B) noted "Accumulated boron deposited between the reactor head and the thermal insulation was removed during the cleaning process performed under WO 00-1846-000. No boric acid induced damage to the head surface was noted during the subsequent inspection." In interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. I was given a window of time to do the cleaning and was told the Head would be moved and reinstalled whether we were done or not." In the interview 0060-F the new RCS System Engineer stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage." (Also see ref interview 149-F and 0046-F, 0052-F, 0059-F).
	NG-324.6.3.1.f should determine material that makes up component	4				XXXX		The BACCIC Initial Inspection identified the material affected as stainless steel or carbon steel.
	NG-324 6.3.2 Plt Eng shall notify Shift Supervisor of immediate safety concerns	4				XXXX		The Shift Manager/Shift Supervisor was notified via CR 00-0782 on 4/6/00 at approx. 0530 hours. The Shift Manager noted "further evaluation required after detailed inspection delineated in Step 6.4.1 on NG-324 is performed."
	NG-324 6.3.3 Plt Eng shall document initial inspection on BACCIC or equal	4				XXXX		Plant Engineering documented the initial inspection on BACCIC/CR 00-0782. The initial inspection was conducted of the flange area the head through the weep holes.
	NG-324 6.3.4 Plt Eng shall document and maintain exam results	4				XXXX		BACCIC was initiated to document the 12RFO Initial Inspection results. The BACCIC was attached to CR 00-0782 (Ref 160-B). NG-EN-324 (Ref 168-B) does not require the BACCIC to be sent to Records Management. Follow-up inspection results were documented on CR 00-1037 instead of the Section II of the BACCIC. CR 00-782/BACCIC could not be found in the RCS System Performance Books. It does appear the video tapes taken during the inspections were maintained as the 12 RFO inspector noted in interview Ref 373-F "the Head inspection showed a large flow of boric acid that emerged from the mouseholes and accumulated on the Vessel flange. It looked much like the 1998 tapes except it was reddish-brown, indicating corrosion products."

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of <u>Advertised</u> Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.3.4 shall verify either a CR or a MWO exists if damage warrants a detailed inspection	4		XXXX				CR 00-1037 was initiated to "address the effects of the boron on the head." CR 00-1037 stated "Inspection of the head indicated accumulation of boron in the area of the CRD nozzle penetrations through the head." MWO 00-001846-00 was generated to clean boric acid off the head and from the top of the insulation. CR 00-1037 noted "no boric acid induced damage to the head surface was noted during the subsequent inspection." EVALUATORS NOTE: However, as all the boric acid was not removed, a detailed inspection could not have been completed as was requested on the initial BACCIC in CR 00-0782.
	NG-324 6.3.5 copy of BACCIC, or equal shall be forwarded to Boric Acid Corrosion Control Coordinator	4		XXXX				The BACCIC or CR was not forwarded to the Boric Acid Corrosion Control Coordinator. The BACC Coordinator was not conferred with for the evaluation of the CR.
	NG-324 6.4.1 Plt Eng shall determine if detailed inspection is needed to access damage and corrective actions	4				XXXX		The BACCIC attached to CR 00-0782 recommended a detailed inspection based on "new leakage from head which was not evident during 11 RFO." A Detailed Inspection was not documented on the BACCIC. However, CR 00-1037 (Routine/Apparent Cause) states "Accumulated boron deposited between the reactor head and the thermal insulation was removed during the cleaning process. . . No boric acid induced damage to the head surface was noted." In interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. I was given a window of time to do the cleaning and was told the Head would be moved and reinstalled whether we were done or not." In interview Ref 0060-F the new RCS System Engineer stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage." As all the boric acid wasn't removed, a complete detailed inspection couldn't have been performed.
	NG-324 6.4.1.a If a detailed inspection is deemed necessary, Plt Eng shall verify a WO as necessary for the removal of insulation, scaffolding, cables, or any other type of interference which prevents access to the leak.	4		XXXX				Plant Engineering performed the initial inspections documented in CR 00-0782 and CR 00-1037. The magnitude and location of the leaks was documented in tCR 00-0782. The Shift Manager was informed of the initial inspection results. EVALUATORS NOTE: However, per interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. . . In the interview Ref 0060-F he stated "we cleaned 85% I would say."

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.4.1.b Shall remove Boric Acid that may inhibit detailed inspection	4			XXXX			CR 00-1037 overview of the planned cleaning effort noted " the process (cleaning) will be repeated until most boric acid deposits are removed or as directed by RP." The CR remedial actions states " Accumulated boron deposited between the reactor head and the thermal insulation was removed during the cleaning process. . . No boric acid inducted damage to the head surface was noted." In interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. I was given a window of time to do the cleaning and was told the Head would be moved and reinstalled whether we were done or not." In the interview Ref 0060-F he stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage."
	NG-324 6.4.1.c Shall perform subsequent inspections and include results w/ initial inspection	4		XXXX				CR 00-1037 overview of the planned cleaning effort noted "After initial cleaning a video inspection will be performed by Framatome Technologies." "Should additional cleaning be required the process (cleaning) will be repeated until most boric acid deposits are removed or as directed by RP." A video inspection was performed during the cleaning activity. In interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. I was given a window of time to do the cleaning and was told the Head would be moved and reinstalled whether we were done or not." In the interview Ref 0060-F he stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage." EVALUATORS NOTE: The entire head was not cleaned, therefore, a final inspection was not performed.
	NG-324 6.4.1.c.1 Subsequent inspection should include a detailed description of visible damage.	4		XXXX				CR 00-1037 noted "no boric acid induced damage to the head surface was noted during the subsequent inspection." In interview Ref 373-F the new RCS System Engineer stated "the job (cleaning head) was incomplete because we ran out of time. I was given a window of time to do the cleaning and was told the Head would be moved and reinstalled whether we were done or not." In the interview Ref 0060-F he stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage." Interview 149-F also stated "the area under the insulation that corresponds to the area of the suspected CRDM flanges could not be cleaned . . . he was running out of time." EVALUATORS NOTE: As all the boric acid wasn't removed, a complete detailed inspection couldn't have been performed.

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG--324 6.4.1.c.3 Identification of any other affected components not revealed in the initial inspection.	4			XXXX			CR 00-1037 evaluated by the new RCS System Engineer stated " no boric acid induced damage to the head surface was noted during the subsequent inspection." EVALUATORS NOTE: In the interview Ref 0060-F he stated "We cleaned 85% I would say. Had discussion with everyone that it wasn't all cleaned. Everyone said we would clean it next outage." Interview 149-F also stated "the area under the insulation that corresponds to the area of the suspected CRDM flanges could not be cleaned . . . he was running out of time." As all the boric acid wasn't removed, a complete detailed inspection to determine if other components were affected could not have been performed.
	NG-324 6.4.c.4 If corrosion is present should determine amount of wastage, if possible	4		XXXX				CR 00-1037 noted "no boric acid induced damage to the head surface was noted during the subsequent inspection." EVALUATORS NOTE: See interview Ref 373-F above, the boric acid was not completely cleaned off therefore, a complete determination of wastage could not have been completed.
	NG-324 6.5.1 Plt Eng shall document results on BACCIC or equal and forward to Boric Acid Corrosion Control Coordinator	4		XXXX				CR 00-1037 documented the apparent cause evaluation, remedial actions and inspection results. The BACC Coordinator was not involved or reviewed the disposition of CR 00-1037.
	NG-324 6.5.5 If corrosion is "Moderate" or greater, Plt Eng should determine corrective actions	4			XXXX			CR 00-0782 and CR 00-1037 document the source of the leaks to be CRD flange leakage from F10, D10, C11, F8, G9. Corrective actions were to replace CRD gaskets or repair CRDs as necessary. CR 00-0782 noted the "Main source of leakage can be associated with CRD F10. The bottom of the flange of G9 (EVALUATORS NOTE G9 IS ABOVE CRD NOZZLE 3) drive is inaccessible for inspection due to the boron buildup on the head insulation not allowing full camera insertion. Since the boron is evident only under the flange and not on the vertical surfaces, there is a high probabilty that G9 is a leaking CRD." CR CATS Follow-up items were written to complete repairs. Interview with a Frmatome employee (Interview 156-F) stated "during the last outage (12RFO), when 5 leaking flanges were reported with graphite gaskets, he thought that was a little odd. In his opinion the other 4 CRDs (minus D10) repaired were conservative (i.e., these flanges weren't leaking)."
	NG-324 6.5.7 If corrosion is "Substantial" Design Eng shall perform eval identifying extent of damage and corrective actions.	4			XXXX			CR-00-0782 nor the BACCIC documented initial inspection categorized the corrosion as "significant." Design Engineering was not involved in the evaluation/corrective actions development.
	NG-324 6.5.8 CATPR of boric acid should include MODs and procedure changes	4			XXXX			CATPR was not identified as CR 00-0782 and CR 00-1037 were categorized as Routine/Apparent Cause level evaluations. EVALUATORS NOTE: There is tie between NG-00324 (Ref 168-B) requiring CATPR and NG-NA-00702(Ref 267-F), Corrective Action Program.

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of <u>Advertised</u> Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	NG-324 6.7.2 Boric Acid Corrosion Coordinator provides oversight of all identified boric acid corrosion sites	4		XXXX				The BACC Coordinator did not review or approve disposition for CR 00-1037. In interview Ref 0409-F the BACC Coordinator stated, "Although I am the program owner, I don't perform many of the responsibilities called out in the BACC procedure. Workload is a problem." No one has ever talked to me about program ownership or the expectations involved." He was given no specific training or time to perform the boric acid corrosion coordinator responsibilities. In interview 141-F the BACC Coordinator stated he "had not fully or in great detail" read GL 88-05.
	NG-324 6.7.3.f Boric Acid Corrosion Control Coordinator will maintain awareness of industry experience . . . W/ respect to boric acid corrosion	4			XXXX			In interview Ref 0409-F the BACC Coordinator stated, the BACC Coordinator stated "there does not appear to be a BACC coordinators group in FENOC or industry-wide where we can compare experiences or trade notes. I went to an EPRI conference a few months ago on Boric Acid Corrosion." In interview 141-F the BACC Coordinator stated he "had not fully or in great detail" read GL 88-05.
	NG-324 6.7.4 Boric Acid Corrosion Coordinator will have increased involvement during outages (coordinate decon,develop plans to fix leaks, update Outage Mgnt on repairs)	4			XXXX			The BACC Coordinator did not review or approve the CRs He was not involved in any great detail in the head inspections or deconn/cleaning efforts. In interview Ref 0409-F the BACC Coordinator stated, stated "Although I am the program owner, I don't perform many of the responsibilities called out in the BACC procedure. Workload is a problem." The BACC Coordinator was assigned several plant systems in addition to this function.
	BACCIC Initial inspection determine amount, thickness, density of boron, color (minor, moderate, substantial), area affected	4			XXXX			CR 00-0782 identified the leakage was red/brown in color. The total estimated leakage through the week holes is approximately 15 gallons. The worst leakage from one weep hole is approximately 1.5 inches thick on the side of the head and pooled on top of the flange. Preliminary inspection of the head through the weep holes indicates clumps of boric acid are present on the east and south sides. Response to CR 00-0782 noted boron deposits were "lava like" and originating from the "mouse holes" and CRD flanges. The BACCIC identifies the leakage as "heavy leakage from the head weep holes." EVALUTORS NOTE: "Heavy Leakage" is not defined in NG-324. This leakage should have been defined as "Substantial Leakage." The total amount of boric acid accumulation was not determined, only the flow out of the weep holes.
	BACCIC Initial inspection reason for classification (minor, moderate, substantial)	4			XXXX			The CR 00-0782/BACCIC identifies the leakage as "heavy leakage from the head weep holes." EVALUTORS NOTE: "Heavy Leakage" is not defined in NG-324. This leakage should have been defined as "Substantial Leakage."
	BACCIC Initial inspection identify all other components affected	4				XXXX		The CR 00-0782/BACCIC identifies the affected components as the "head, flange."
	BACCIC Initial inspection identify area not visible	4				XXXX		The CR 00-0782/BACCIC identifies the component internals affected or not visible as the "head, CRD tubes."
	BACCIC Initial inspection identify corrosion present	4				XXXX		The CR 00-0782/BACCIC identifies corrosion present "Yes, red/brown deposits."

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	BACCIC Initial inspection recommends detailed inspection (yes/no) reason	4				XXXX		The CR 00-0782/BACCIC identifies that a Detailed Inspection is recommended and the basis for this recommendation is "new leakage from head which was not evident during 11RFO."
	BACCIC Initial inspection completed by (signature)	4				XXXX		The CR 00-0782/BACCIC was completed by the Service Water System Engineer, who also performed the 11RFO, inspection on 4/6/00.
	BACCIC Detailed inspection and evaluation complete by (signature)	4			XXXX			The BACCIC Part 2 was not completed. EVALUATORS NOTE: NG-324 (Ref 168-B) 6.5.1 states "Plt Eng shall document results on BACCIC or equal." The inspection results were documented on CR 00-1037. See interview 373-F with the new RCS System Engineer identifying that the head was not completely clean of boric acid therefore, a complete detailed inspection could not be performed.
	DB-PF-03065, Pressure Test RCS at 2159 psig on 5/13/00 Att 6 Step 14, IF Boric Acid accumulation and/or corrosion is identified, THEN notify the shift Supervisor and System Engineer in accordance with NG-EN-00324 AND annotate on the VT-2 Examination Report	4			XXXX			The DB-PF-03010 Test Pkg (Ref 115) took credit for the DB-PF-03065 VT-2 Exam Report for the "CRD Nozzles, CRD Flanges and CRD assembiles" boundary examined identified "no leakage" by the inspector. This inspection was conducted from the "Top of the Service Structure" as indicated on the 5/13/00 VT-2 Exam Report (Ref RC 116). A comment was added to the Exam Report "Control rod flanges can be observed from the top of the service structure. The exam was completed by a contract VT-2 Examiner Level II. The CR 02-0891 technical root cause eval stated "however, the CRDM nozzle to CRDM flange weld view is obstructed by the CRDM mechanism and the CRDM flange. It is not clear what is being inspected by this line item." EVALUATORS NOTE: This exam didn't detect the leaking CRDM nozzles or the boron left on on the head following cleaning as noted in interview Ref 0060-F. There is now a link between NG-324, DB-PF-03065 and DB-PF-03010.
	Continuation of discussion of DB-PF-03065, Pressure Test RCS at 2159 psig on 5/13/00							EVALUATORS NOTE: Review of DB-PF-03065 VT-2 Exam and DB-PF-03010 Test Pkg, the Reactor Vessel (T1) wan't inspected. DB-PF-03010 Step 2.2.9 "viewing the CRD flanges via the RCS Service Structure lexicon view ports" was to be performed. However, as noted in the Test Summary Report, " Inspection of CRD via top of service structure. RC didn't was us to enter canal for inspections. Each CRD flange can be observed from the grading on top of the service structure." The Inservice Test Pgm 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 shal be required." (Ref 635-F) This may have been how the VT-2 was accomplished as the CRDM nozzles would not be viewable w/in the 6 foot distance required by IWA-2200. In reviewing the 1998/2000 exams, it's not clear what to inspect and how the isnpection should be performed.

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of Advertised Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	VT-2 exam of Reactor Vessel Bolting was performed via WO 99 00320-00 in Mode 5	4				XXXX		4/5/00 the Reactor Vessel Bolting was examined. The VT-2 inspector noted "unable to perform a valid VT-2 exam on reactor vessel bolting due to the accumulation of dry boron and debris between bolting and head. See attached drawing". The System Engineer was notified at 0330 on 4/6/00. A VT-2 Corrective Measures Evaluation Action Report and CR 00-0781 were generated documenting the condition. Since a VT-2 couln't be completed a VT-3 would be performed to exam the bolting for corrosion (Ref RC 119). EVALUATORS NOTE: IAW-5250 Item b (Ref RC 119) and the Inservice Testing Pgm (Ref 635-F) "If boric acid residues are detected on components, the leakage source and the areas of general corrosion shall be located". CR 00-0781, CR 00-0782 and CR 00-1037 were categorized as Routine/Apparent Cause evals. Part 5 (Remedial Actions) were only performed. A root cause evaluation was not performed to find the leakage source. Boric acid leakage on the Head was a repetitive event. This boric acid residue was not localized and was "Substantial" leakage and required more than an "Apparent Cause/Remedial Action eval per NG-00702 (Ref 267-F).
	CRDM Nozzle Design	1			XXXX			CRDM nozzle alloy 600 material is susceptible to cracking and leakage as reported BAW-2301, 7/97 (Item 266-F)
	CRDM Flange Gasket Design	1			XXXX			The CRDM flanges had a history of leakage. Starting in the 1990 outage (6RFO) gaskets were replaced in the CRDM flanges. The plant replaced all of the CRDM flange gaskets by the end of the 1996 RFO (10RFO). (Ref CR 02-0891 Technical Root Cause Evaluation, Ref 02-0605-F).
	Plt Eng Training JFG (6/99) discuss NG-324	5	XXXX					The new RCS System Engineer performed the head inspection in 12RFO (4/99). His JFG for review of NG-324 with his supervisor was completed on 9/28/00 after 12RFO.
	General Orientation Eng Support Training JFG (10/99) discussion of boric acid corrosion and RC-2 INPO SEN	5		XXXX				The new RCS System Engineer completed his General Orientation Training Materials and Chemistry Fundamentals training on 11/6/99 by waiver due to prior qualifications at ANO. The Materials and Chemistry Fundamentals discussed SEN 190, RC-2 bonnet nuts dissolved and failure of components (especially carbon steel) due to leakage of boric acid at elevated temperatures and moist atmospheres from primary systems.
	Specific Eng Support Training of boric acid corrosion control (11/99 after RC-2 event)	5			XXXX			Engineering Support Continuing Training Cycle 99-04 discussed the Boric Acid Corrosion Control Program (NG-324) following lessons learned from RC-2. The training discussed that one of the signs of boric acid Corrosion on a plant component is red or brown crystal formation. The 99-04 training included a discussion of the NG-324 procedural requirements (Ref 130-B).

HAZARD-BARRIER-TARGET ANALYSIS
(12RFO Inspections)

HAZARD	BARRIERS						TARGET	EVALUATION OR COMMENTS
	List of <u>Advertised</u> Barriers	Safety Precedence Sequence Rating	Did Not Provide	Did Not Use	Failed	Did Not Fail		
	ISI VT-2 inspector training on boric acid corrosion	5	XXXX					The VT-2 inspector stated (Ref 0147-F) The only training related to ISI activities. Nothing that I recall specifically about boric acid." EVALUATORS NOTE: IWA-5242, Insulated Components, Item C provides minimal guidance" "Discoloration or residue on surfaces shall be given particular attention from borated reactor coolant leakage" (Ref RC 117).
	NG-702 Attachment 2 Repetitive Q, AQ component failures that are not run to failure are categorized as "Important"	4			XXXX			CR 00-0782 and CR 00-1037 were categorized as Routine/Apparent Cause evals. CRD flange leakage was a repetitive component failure as was boron on the RPV Head.
	NG-702 6.2.11 If CATPR is needed, recommend the cause evaluation level (Apparent Cause, Root Cause, or Multi-disciplined Root Cause)	4	XXXX					CR 00-0782 and CR 00-1037 were categorized as Routine/Apparent Cause evaluations. Part 5 (Remedial Actions) was only performed. CATPR was not requested by NG-702. CRD flange leakage was a repetitive component failure as was boron on the RPV Head. Per NG-324 6.5.8 CATPR should have been performed which would require at a minimum Apparent Cause/CATPR evaluation. EVALUATORS NOTE: However, there is no tie between NG-324 (Ref 168-B) and NG-702 (Ref 267-F).

Figure 4, Summary of Events & Causal Factor Chart

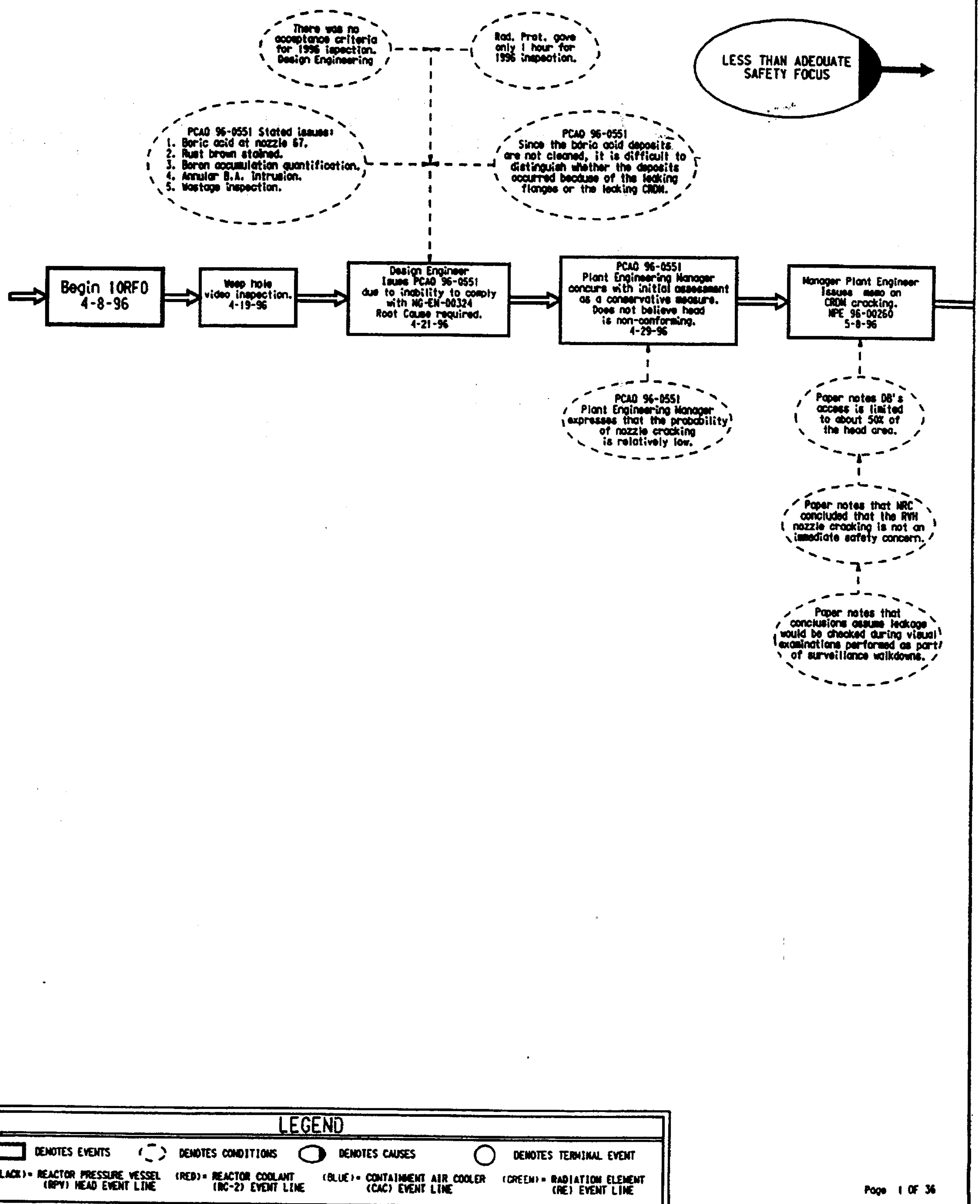


Figure 4, Summary of Events & Causal Factor Chart

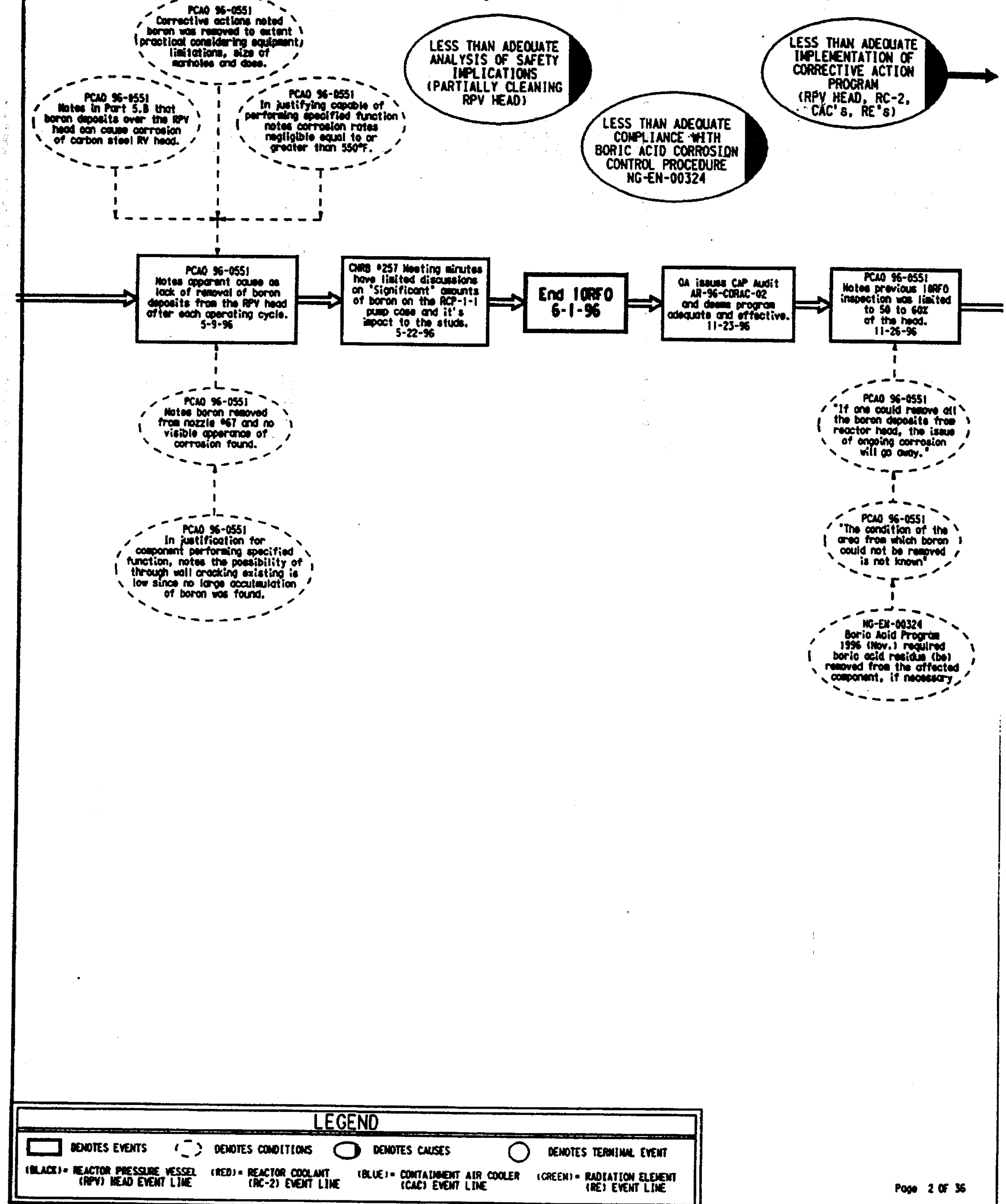
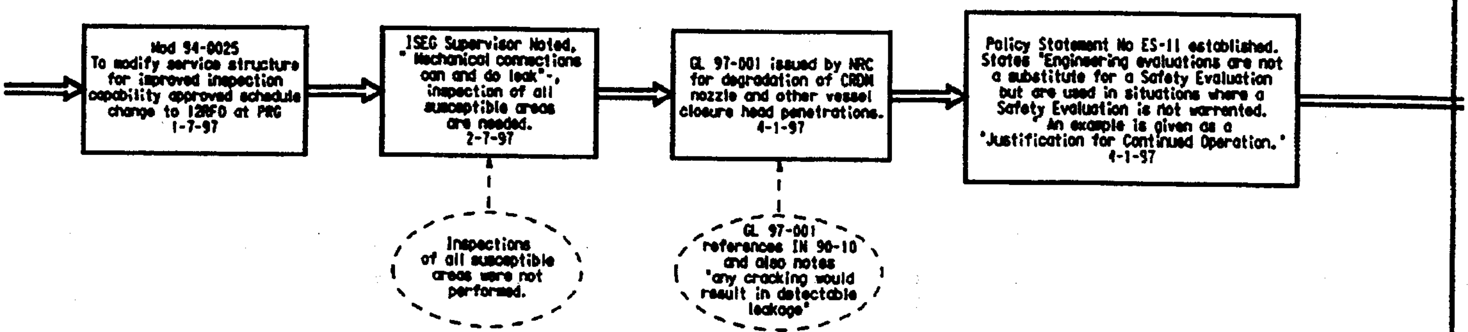


Figure 4, Summary of Events & Causal Factor Chart



LEGEND

DENOTES EVENTS — DENOTES CONDITIONS — DENOTES CAUSES — DENOTES TERMINAL EVENT

(BLACK) = REACTOR PRESSURE VESSEL (RPV) HEAD EVENT LINE — (RED) = REACTOR COOLANT (RC-2) EVENT LINE — (BLUE) = CONTAINMENT AIR COOLER (CAC) EVENT LINE — (GREEN) = RADIATION ELEMENT (RE) EVENT LINE

Figure 4, Summary of Events & Causal Factor Chart

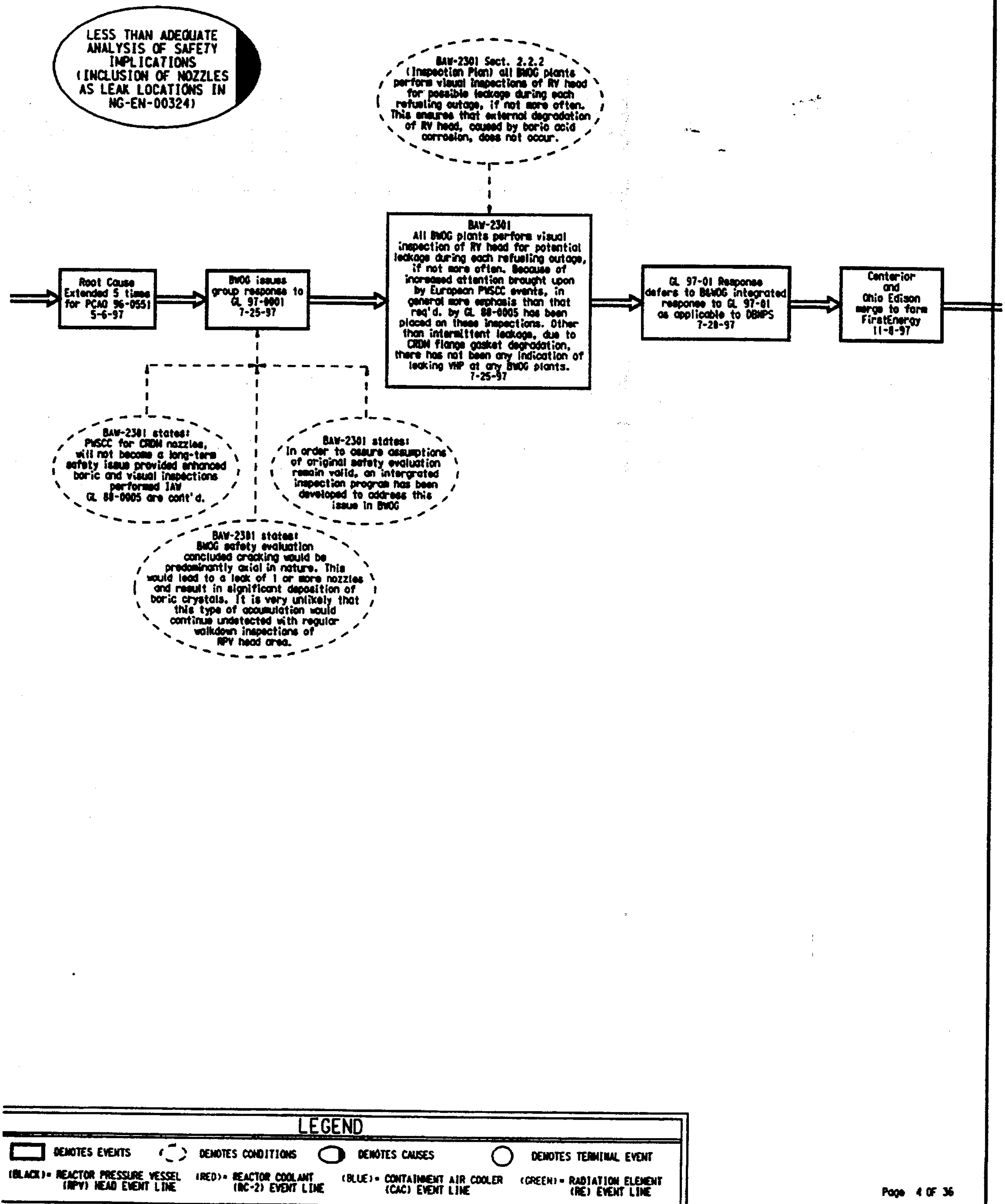


Figure 4, Summary of Events & Causal Factor Chart

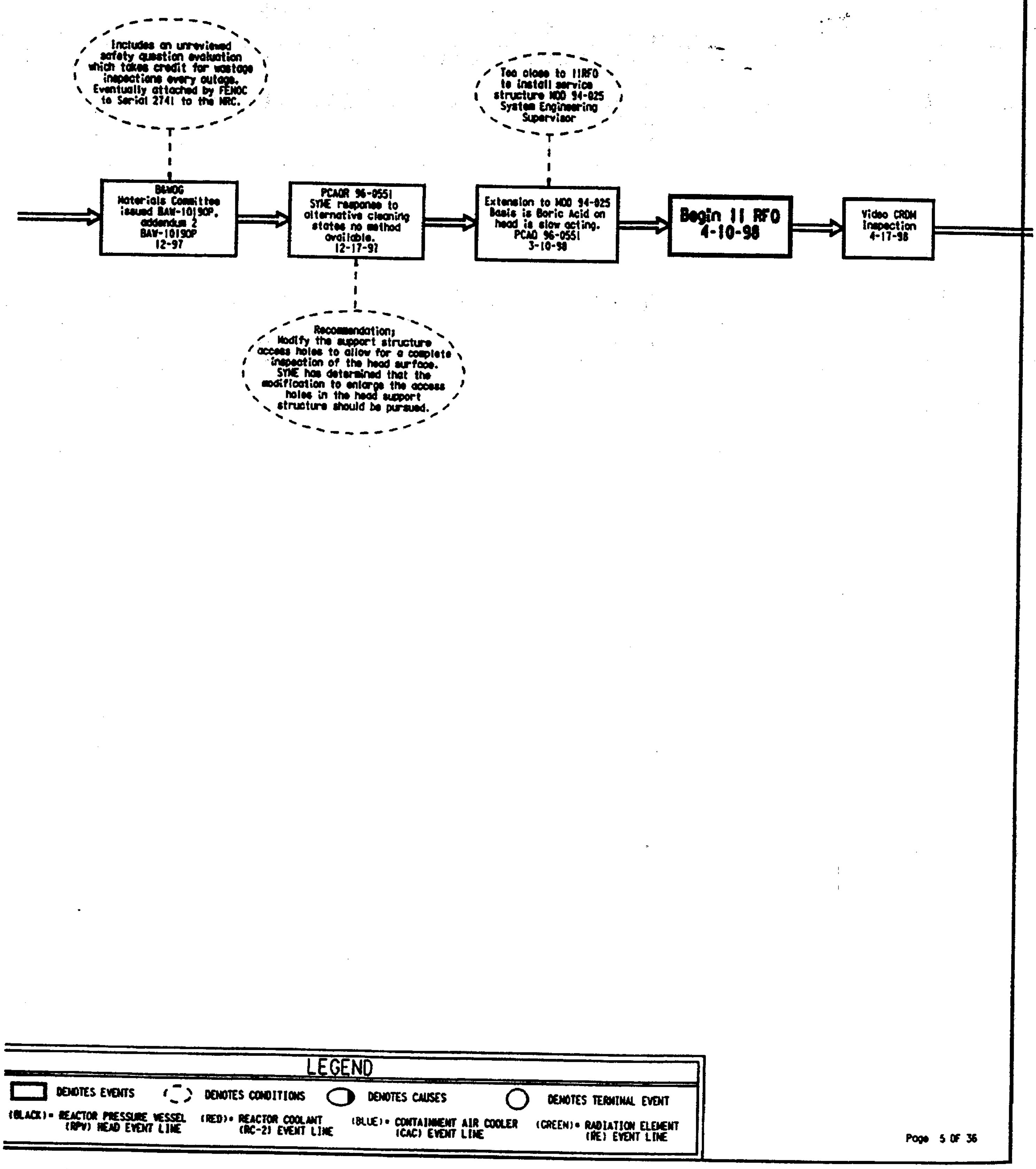


Figure 4, Summary of Events & Causal Factor Chart

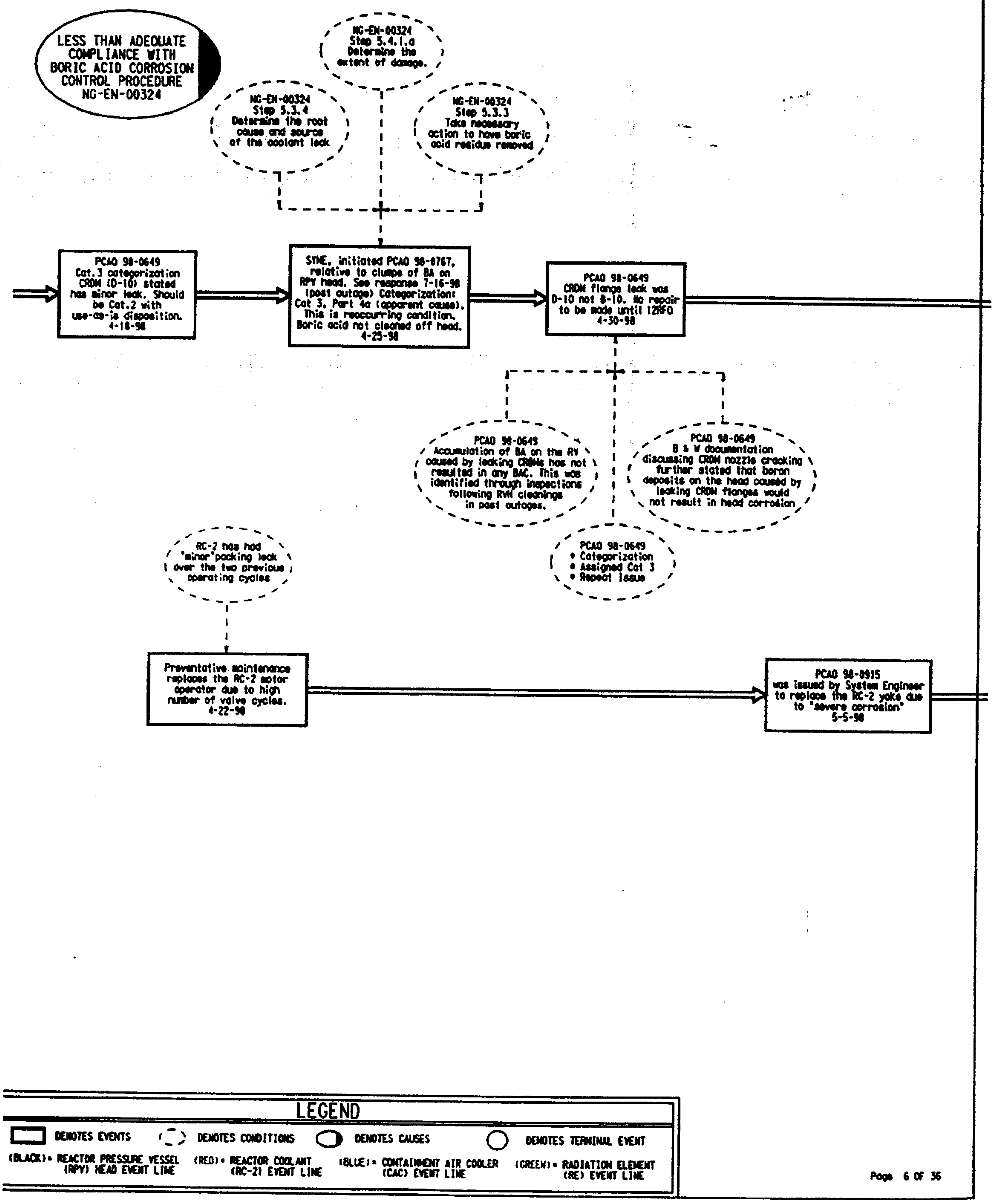


Figure 4, Summary of Events & Causal Factor Chart

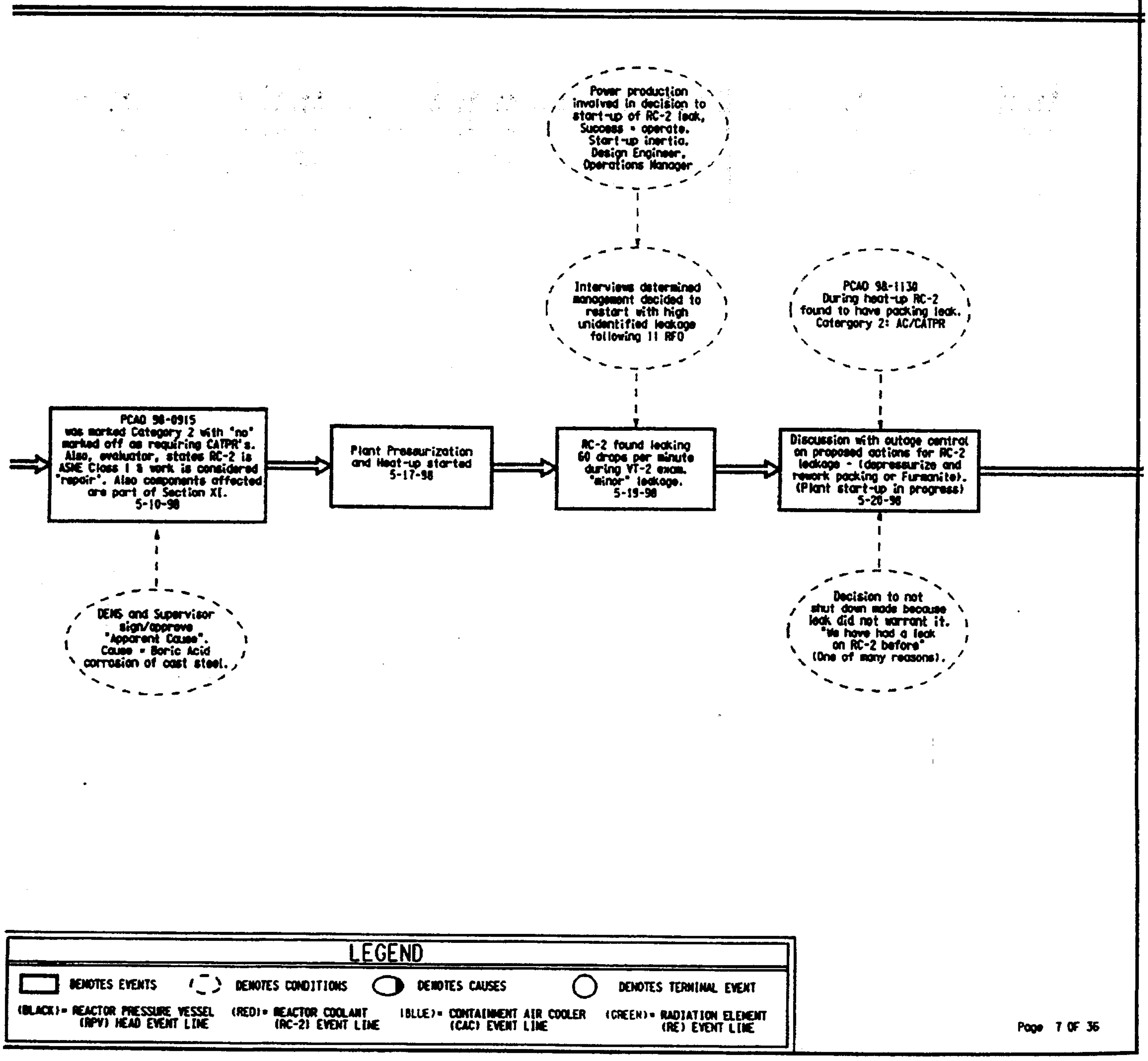


Figure 4, Summary of Events & Causal Factor Chart

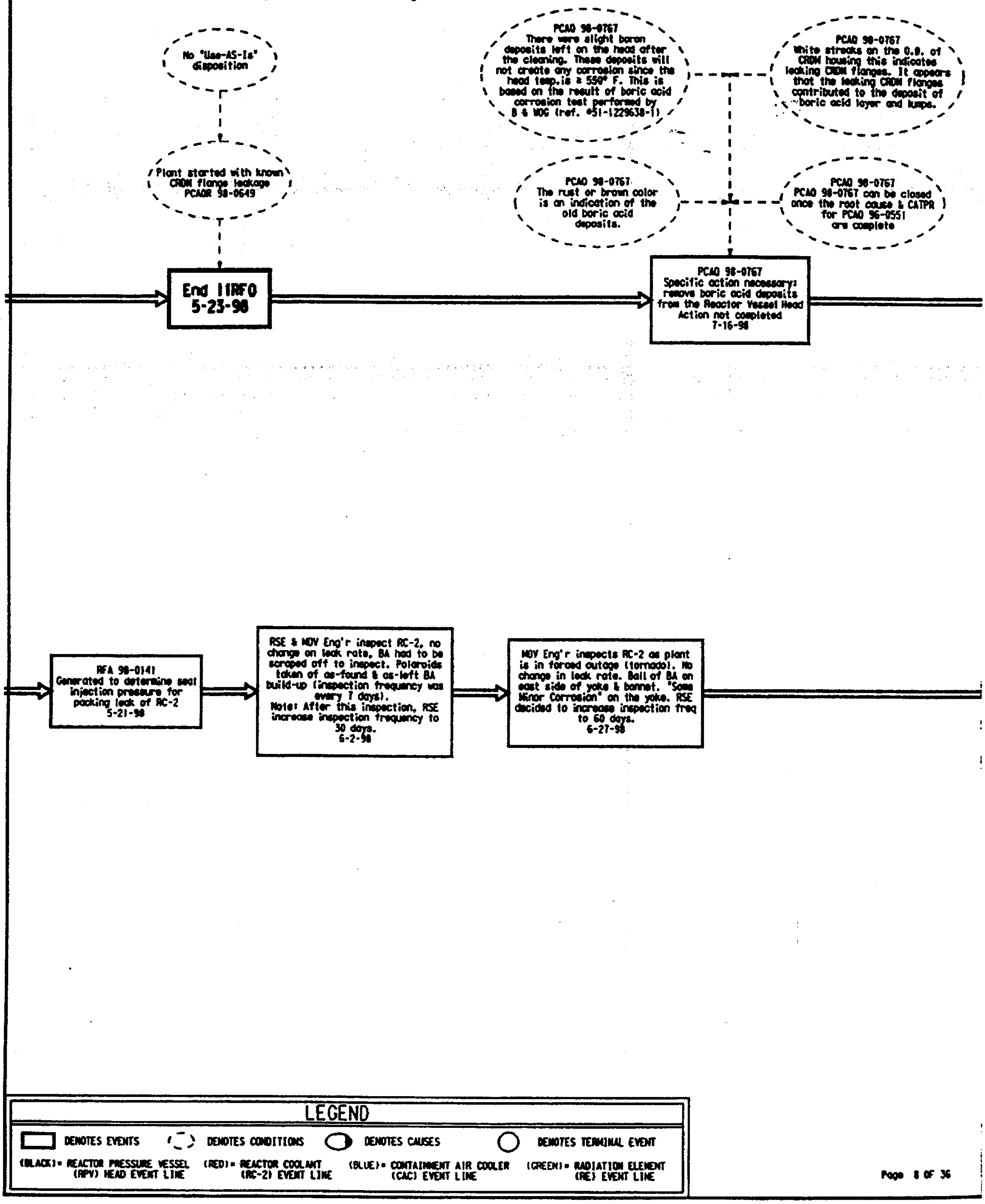


Figure 4, Summary of Events & Causal Factor Chart

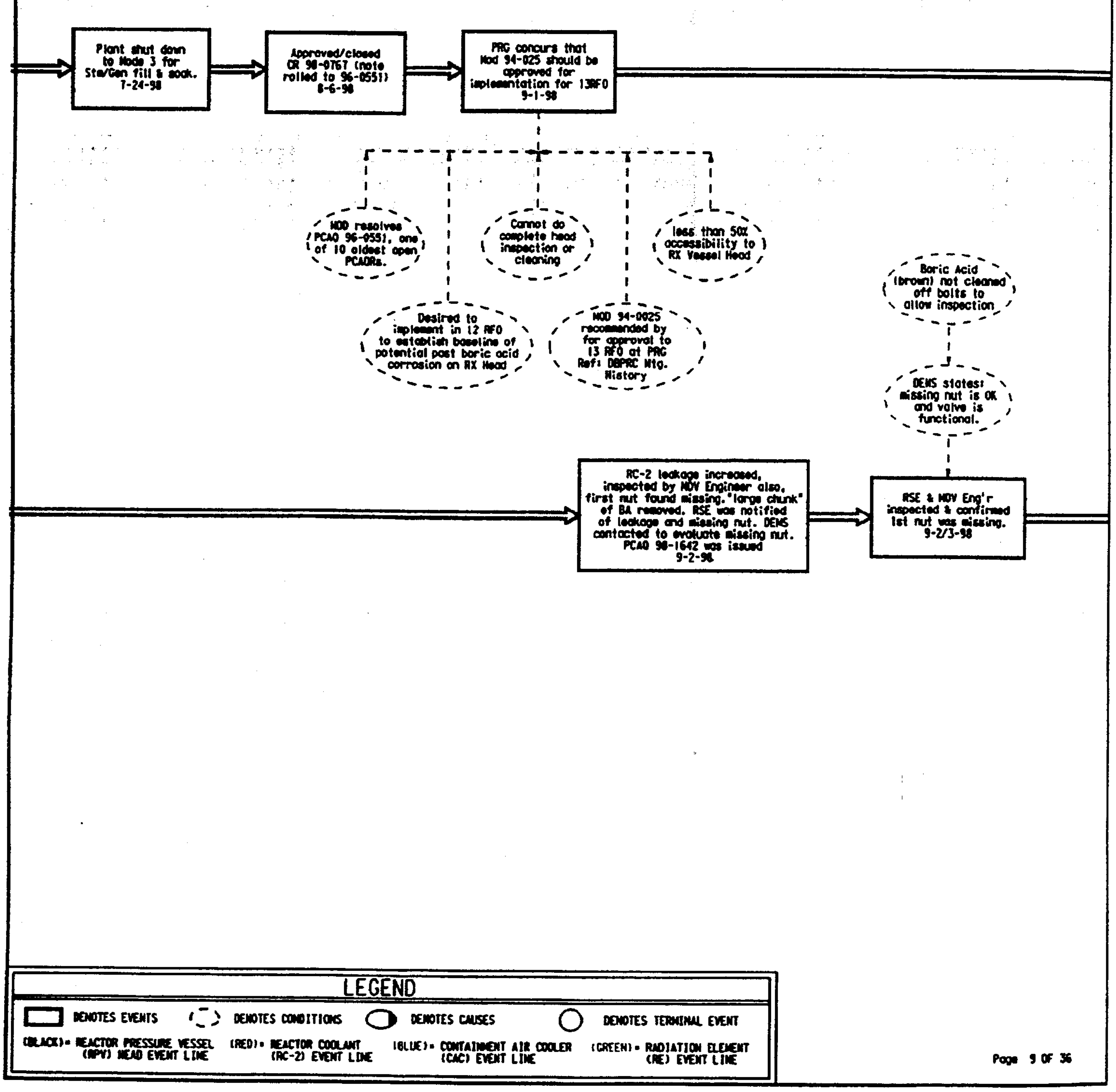


Figure 4, Summary of Events & Causal Factor Chart

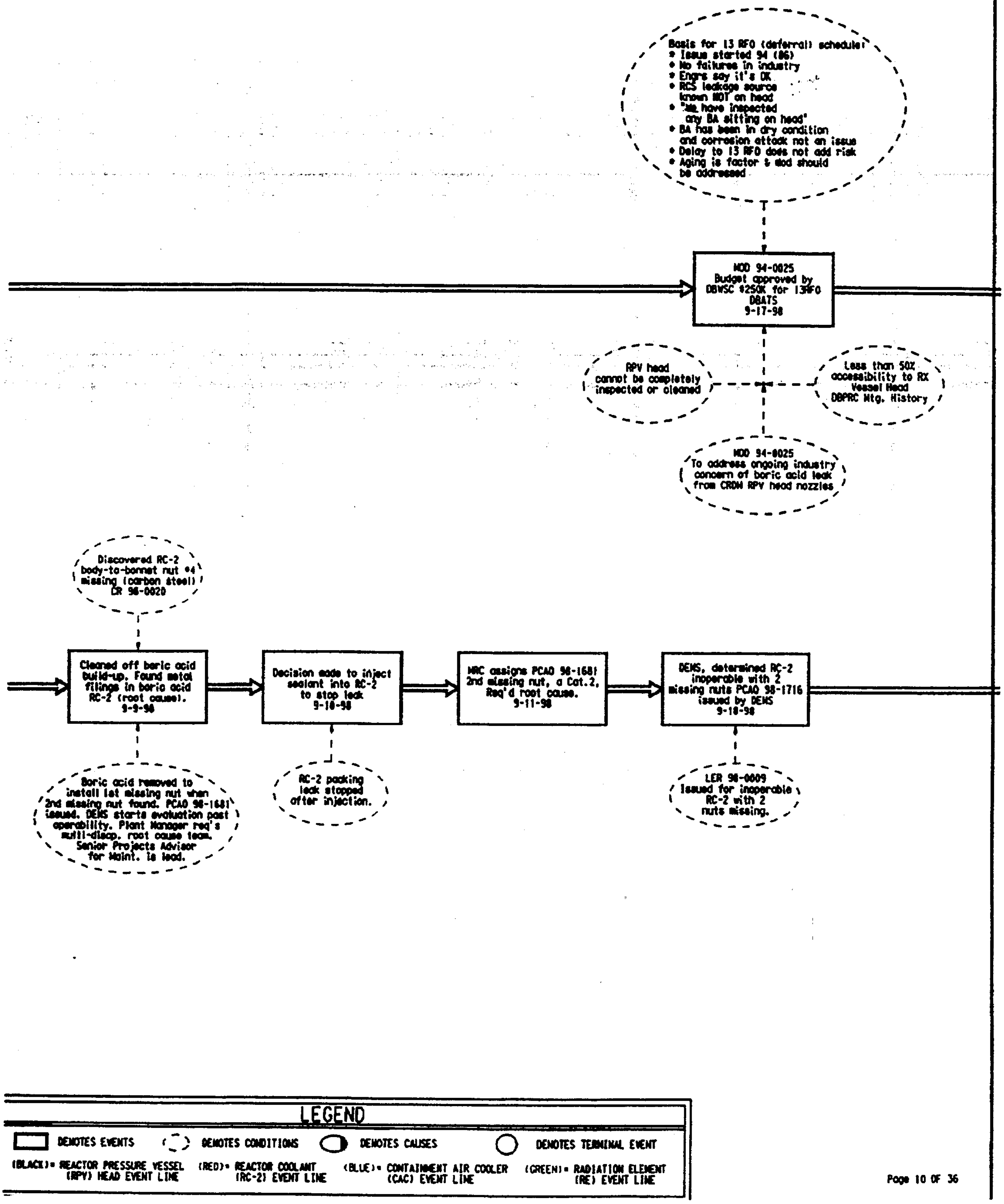


Figure 4, Summary of Events & Causal Factor Chart

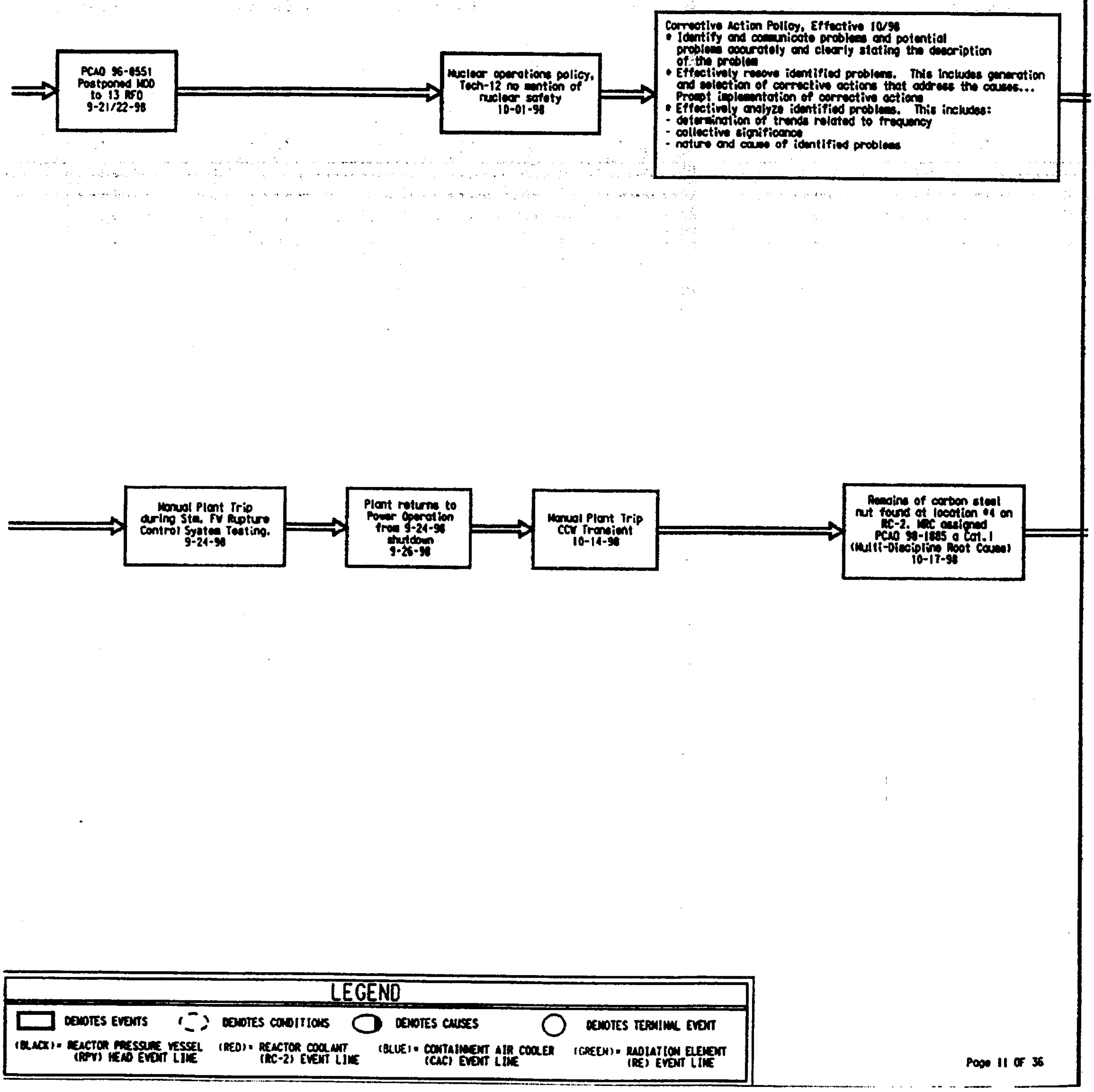


Figure 4, Summary of Events & Causal Factor Chart

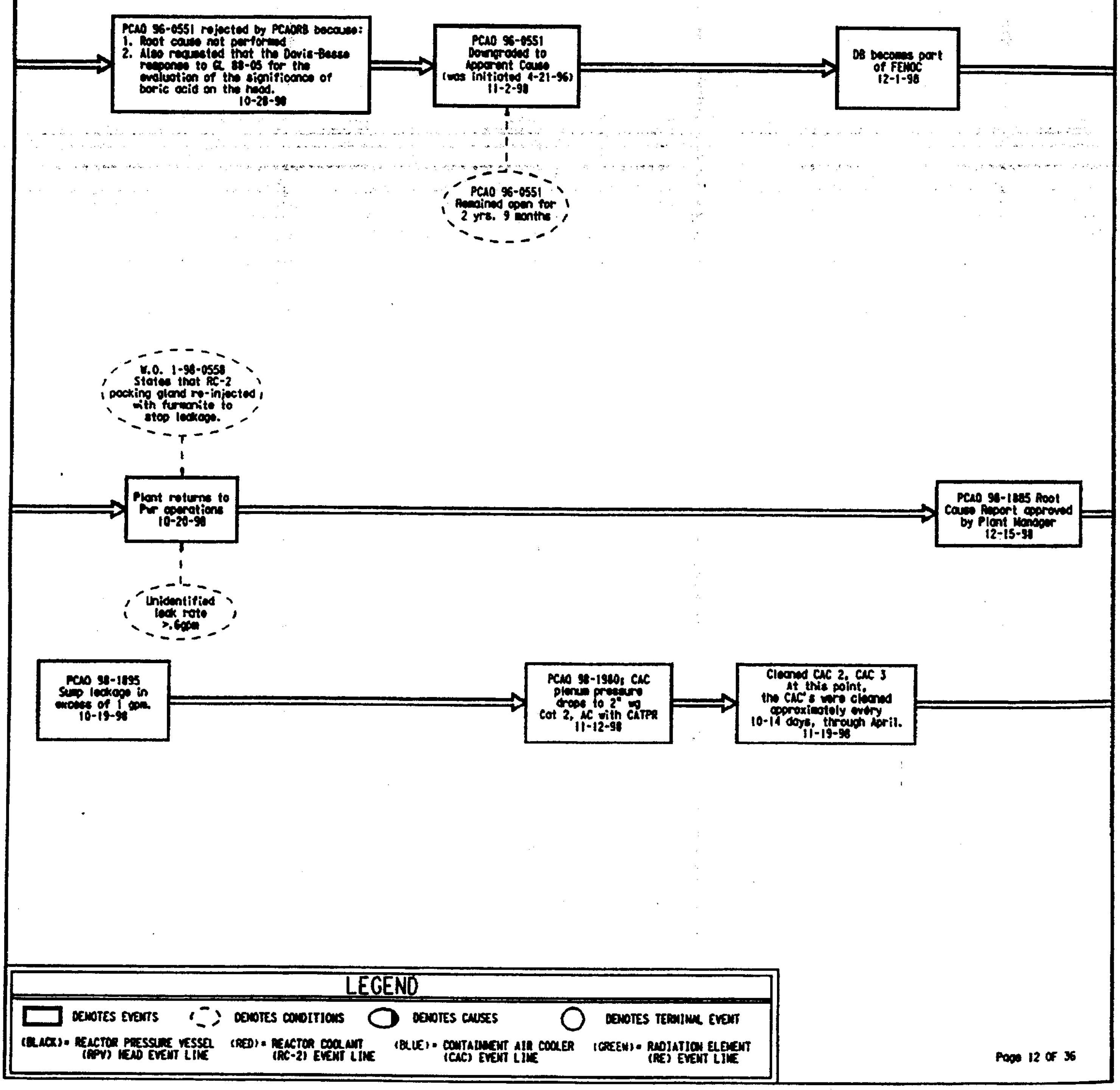


Figure 4, Summary of Events & Causal Factor Chart

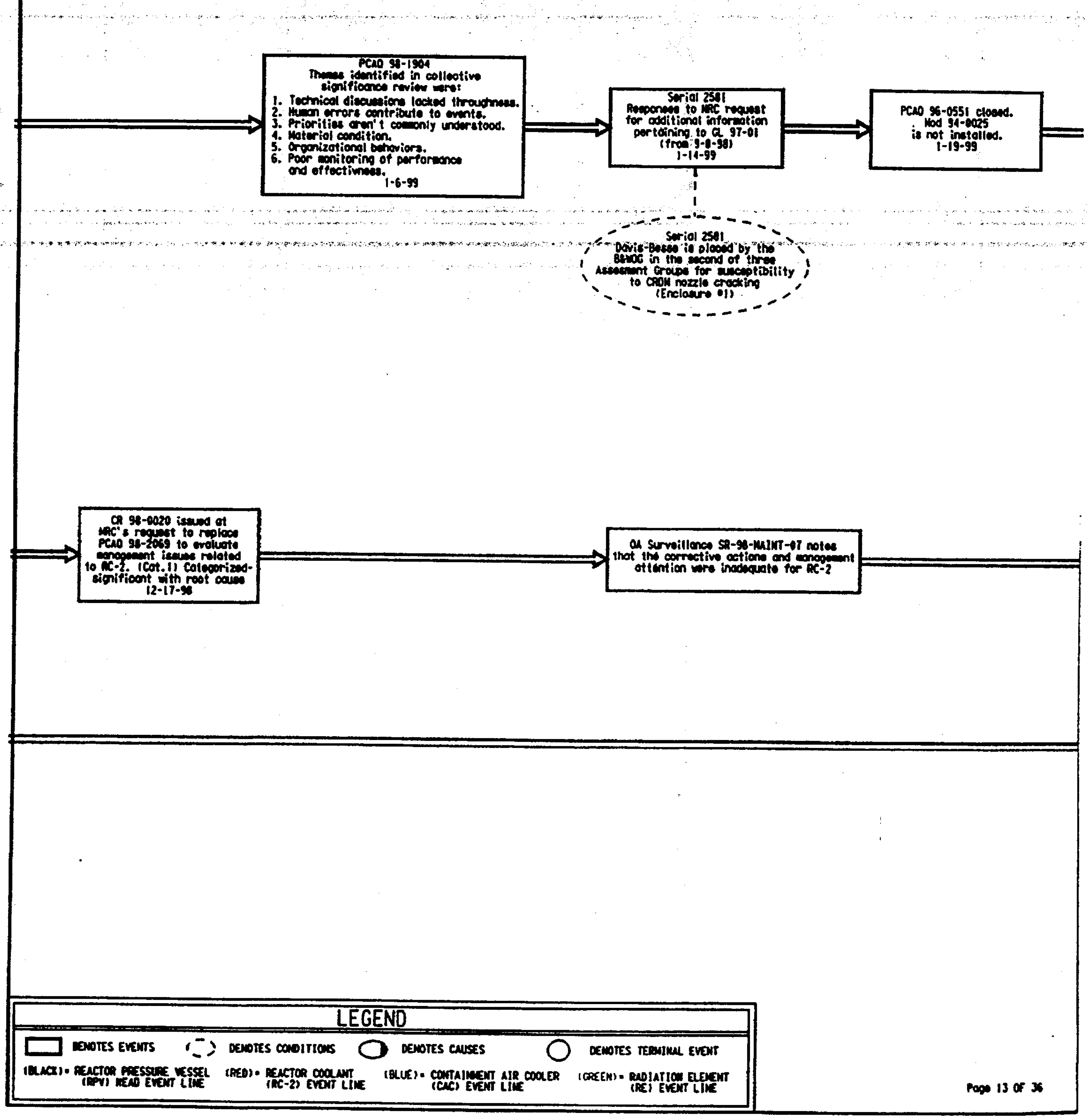


Figure 4, Summary of Events & Causal Factor Chart

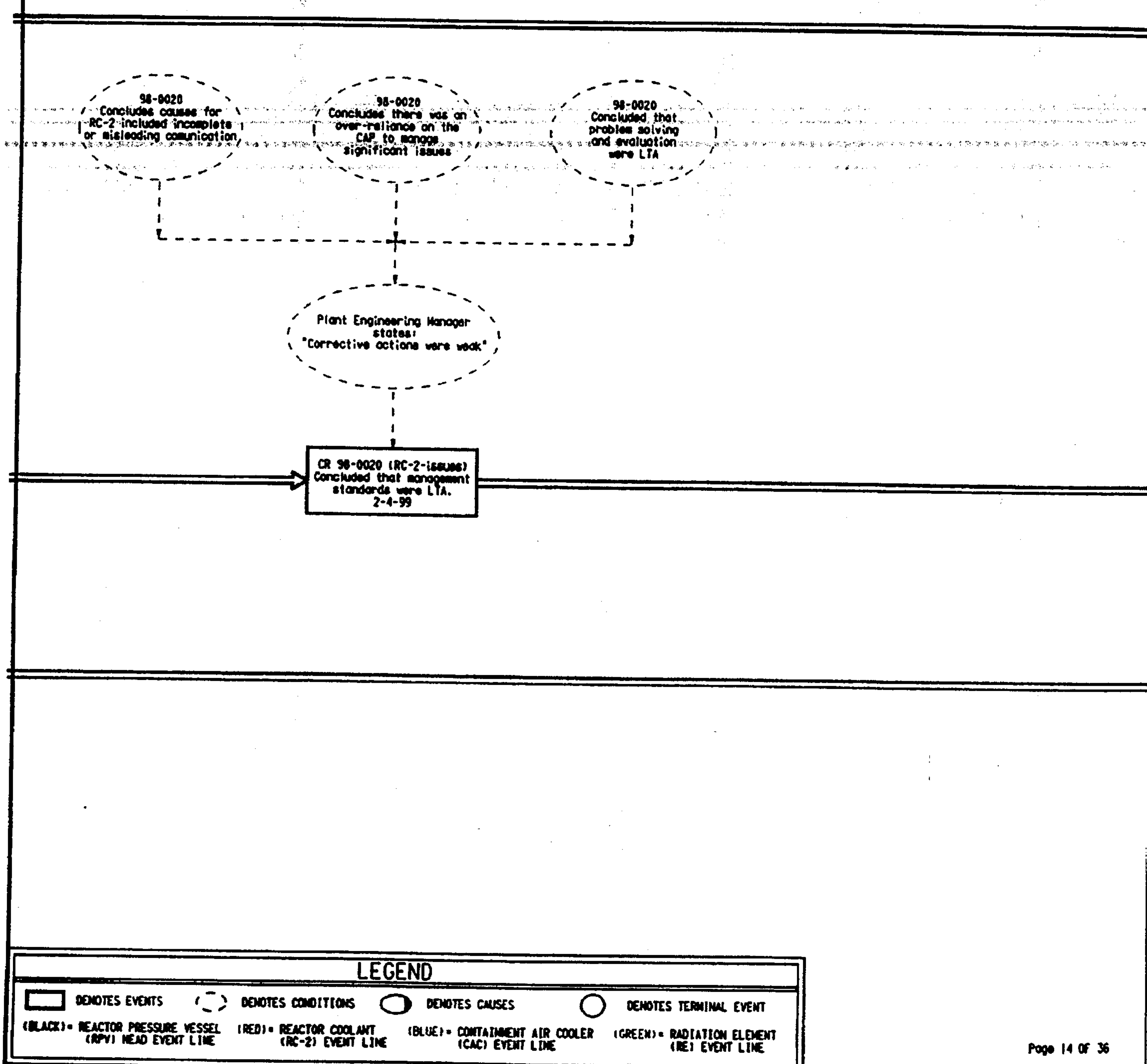


Figure 4, Summary of Events & Causal Factor Chart

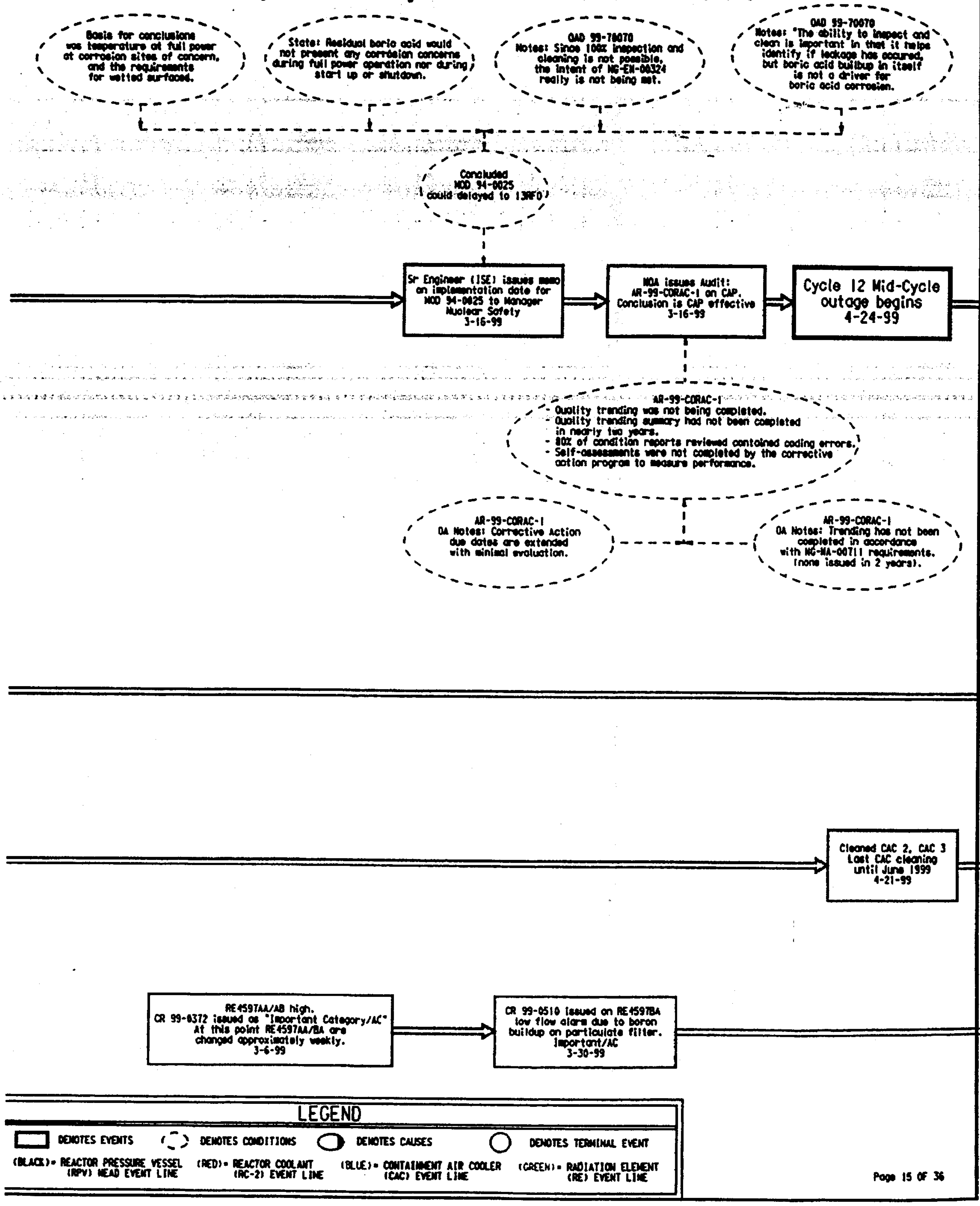


Figure 4, Summary of Events & Causal Factor Chart

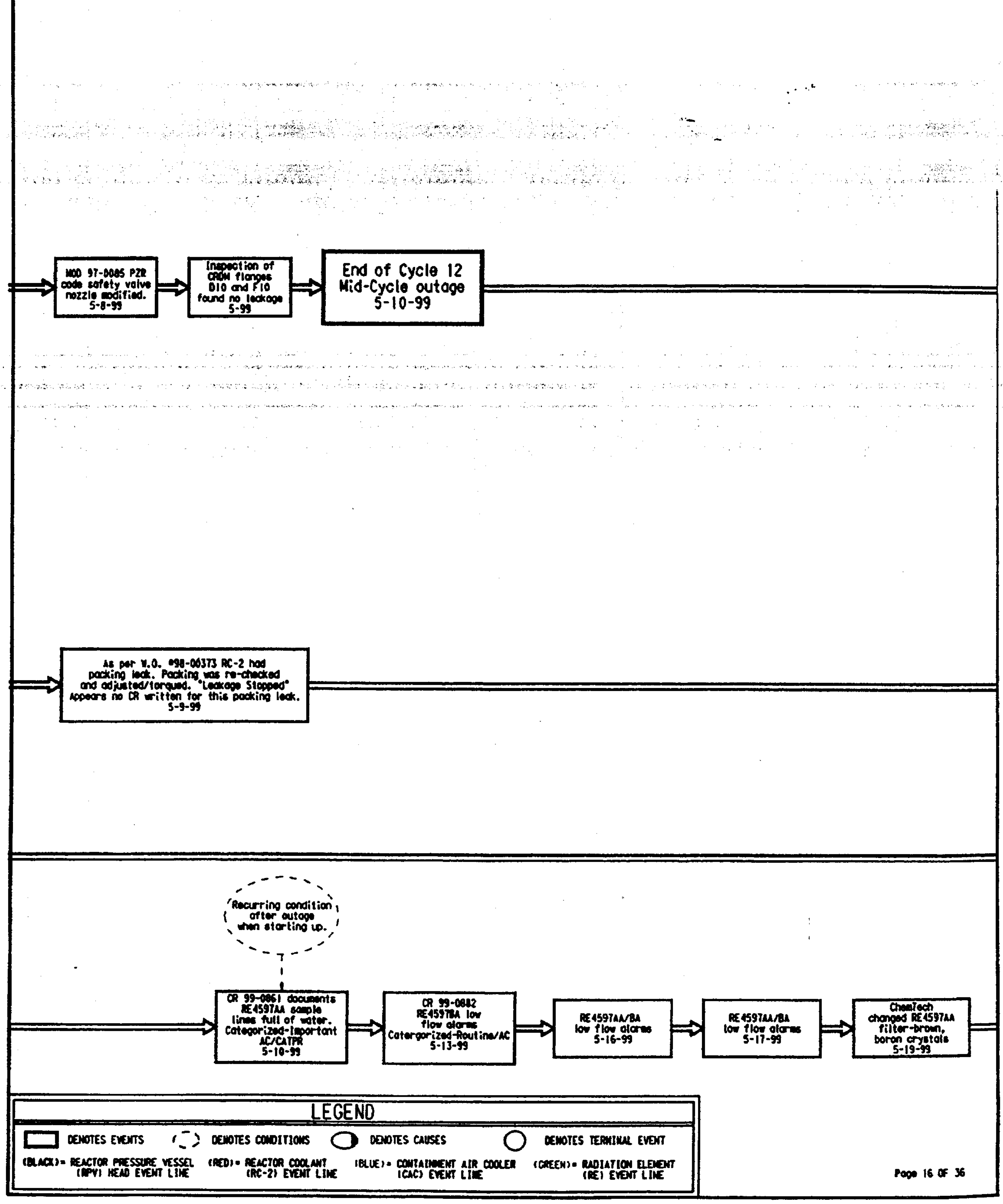


Figure 4, Summary of Events & Causal Factor Chart

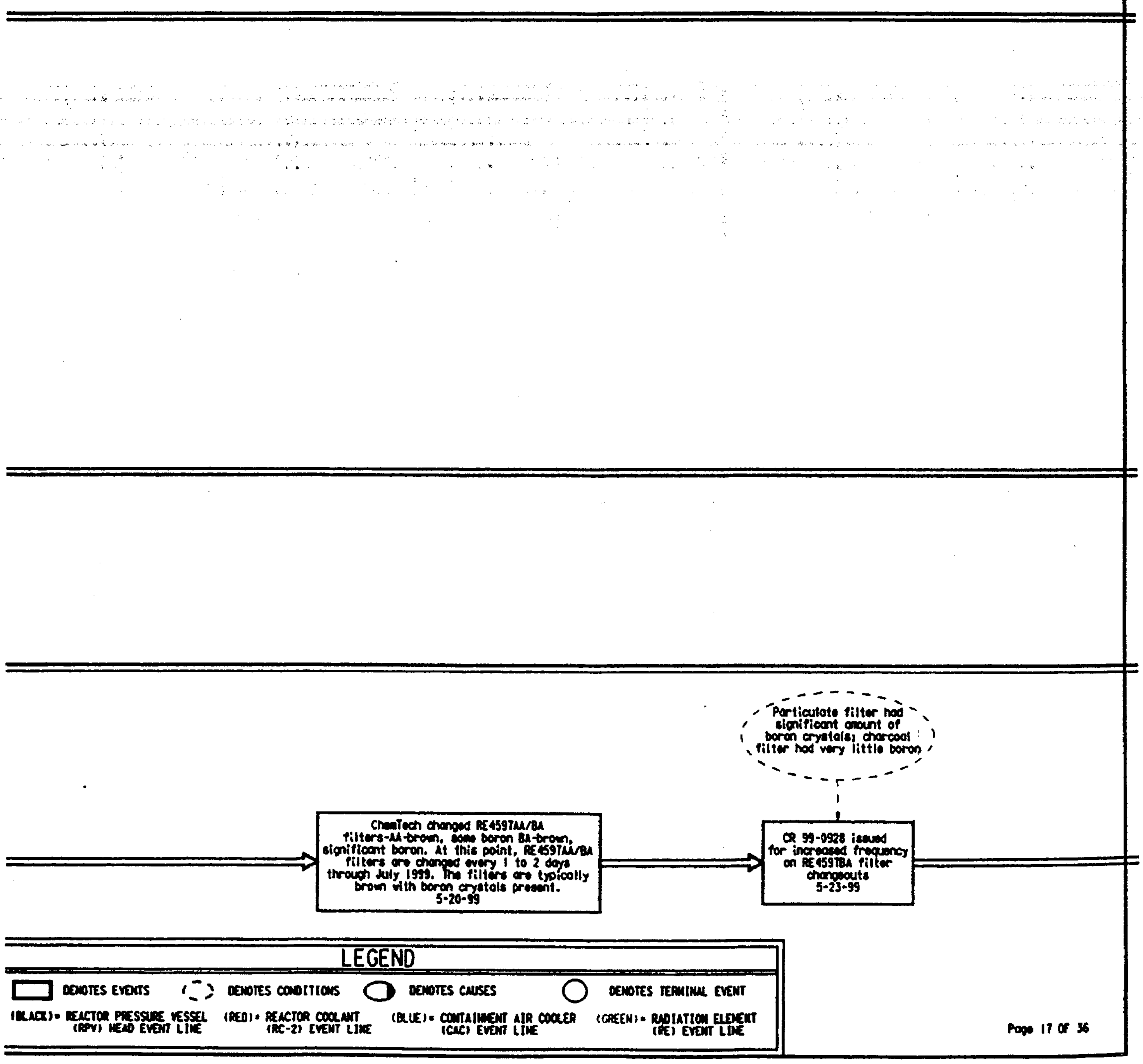


Figure 4, Summary of Events & Causal Factor Chart

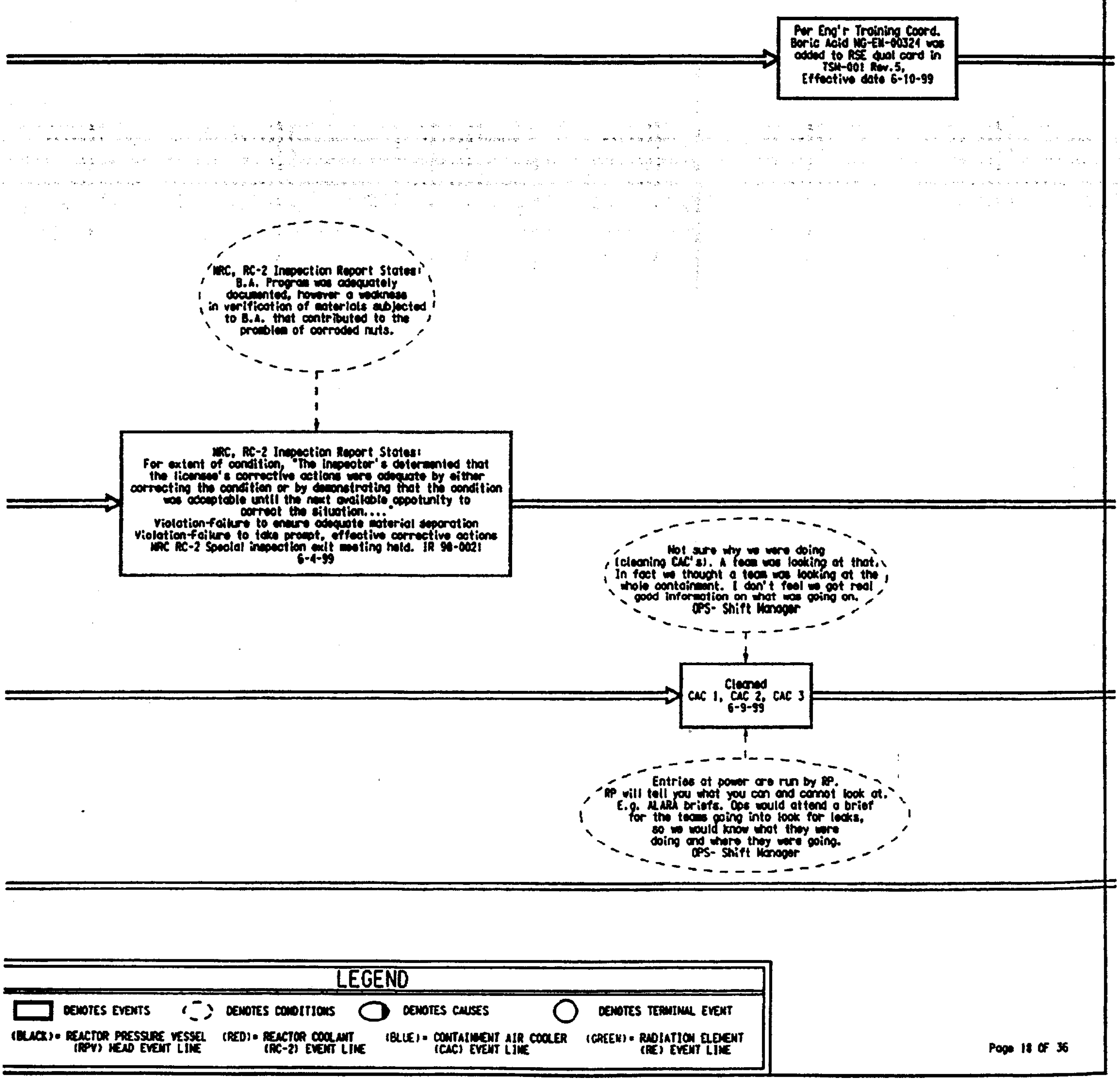


Figure 4, Summary of Events & Causal Factor Chart

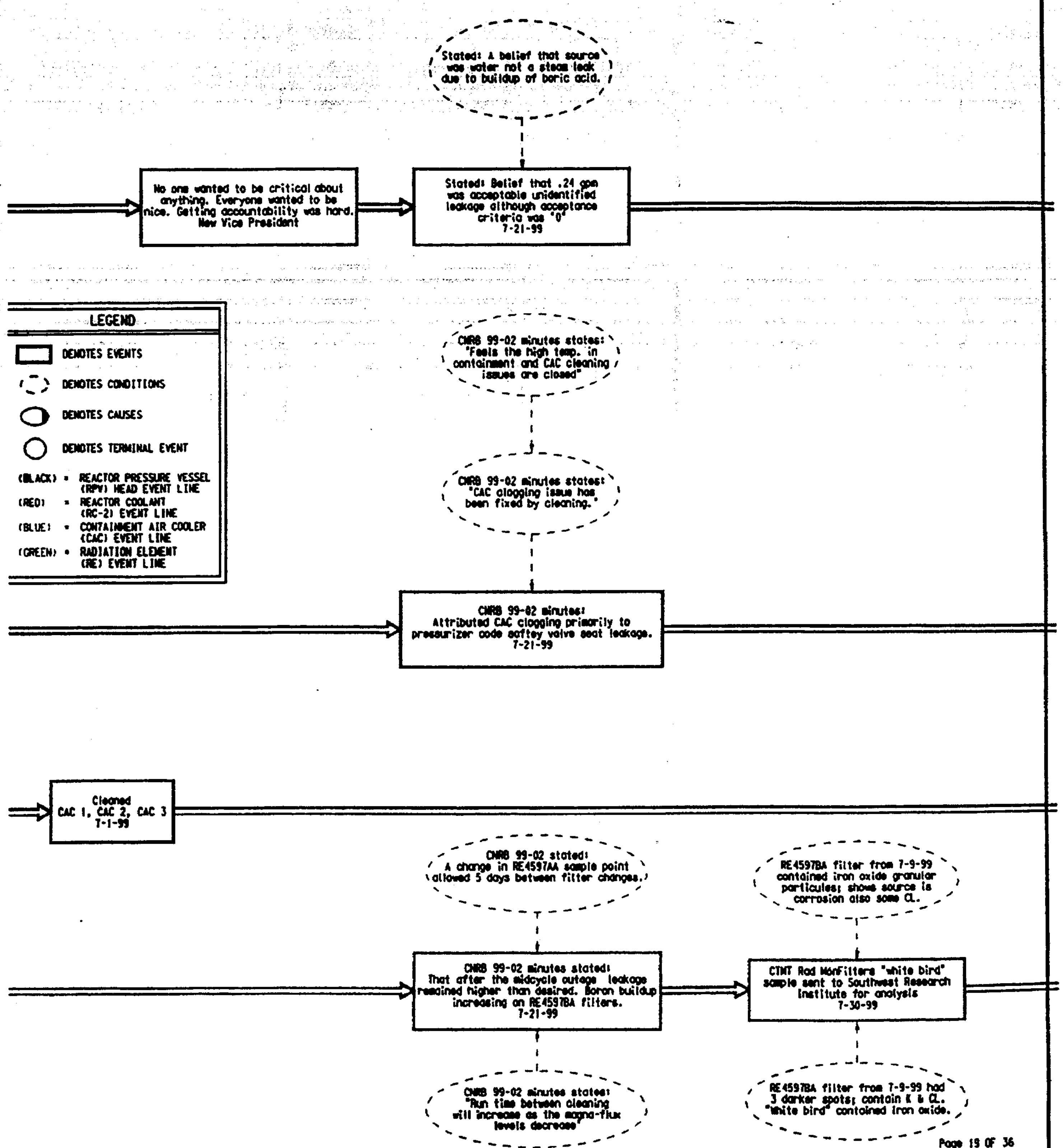


Figure 4, Summary of Events & Causal Factor Chart

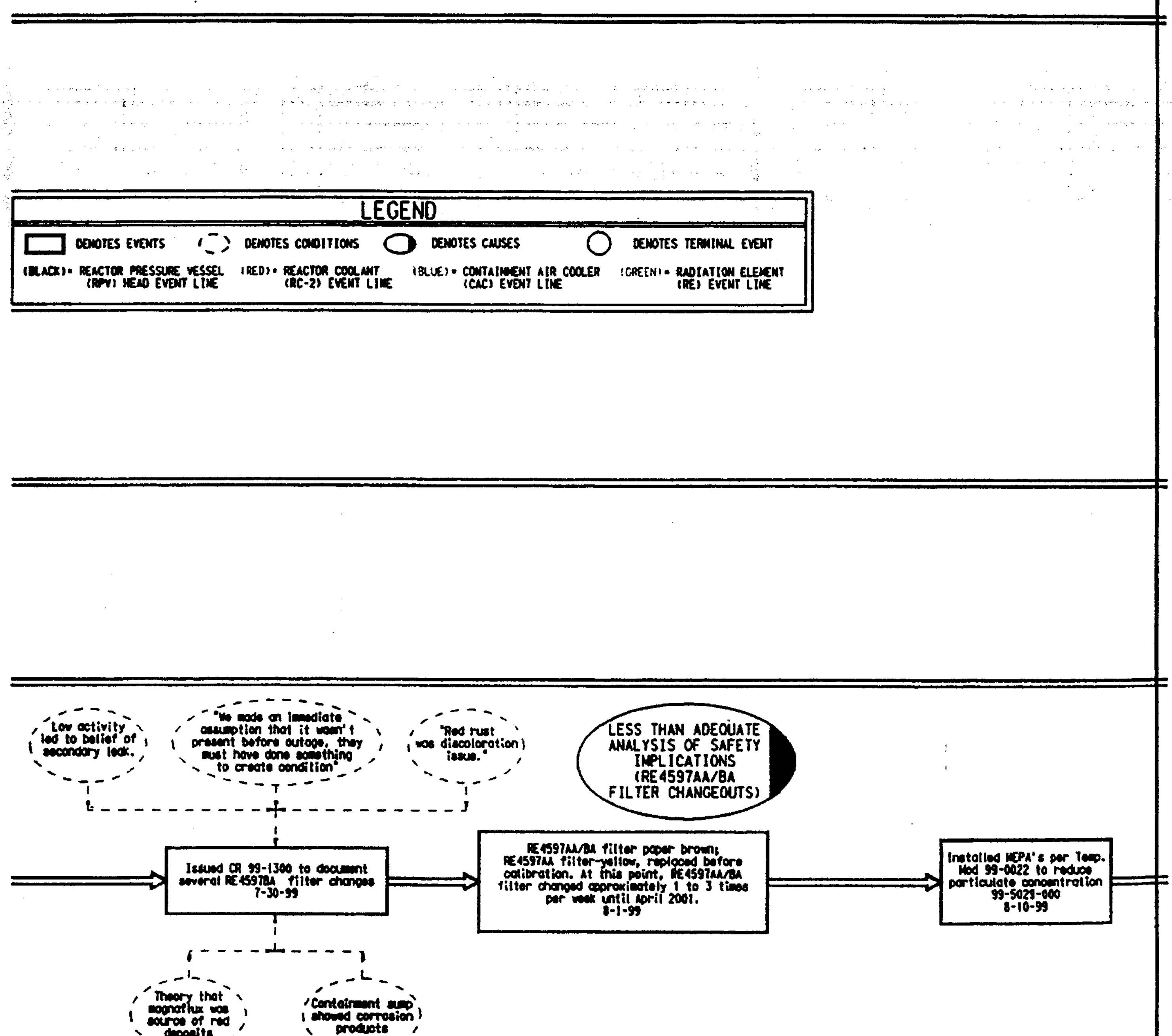


Figure 4, Summary of Events & Causal Factor Chart

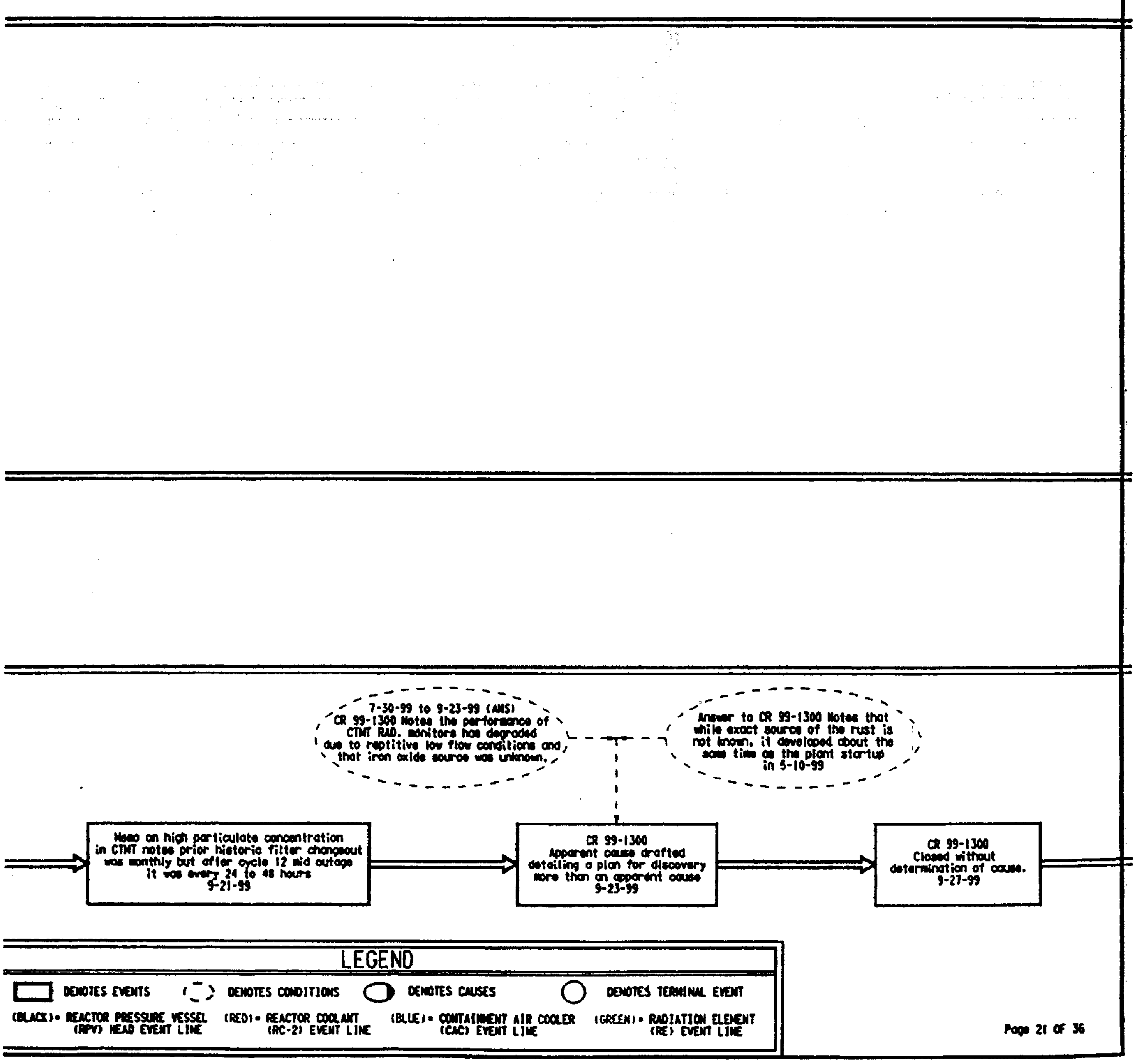


Figure 4, Summary of Events & Causal Factor Chart

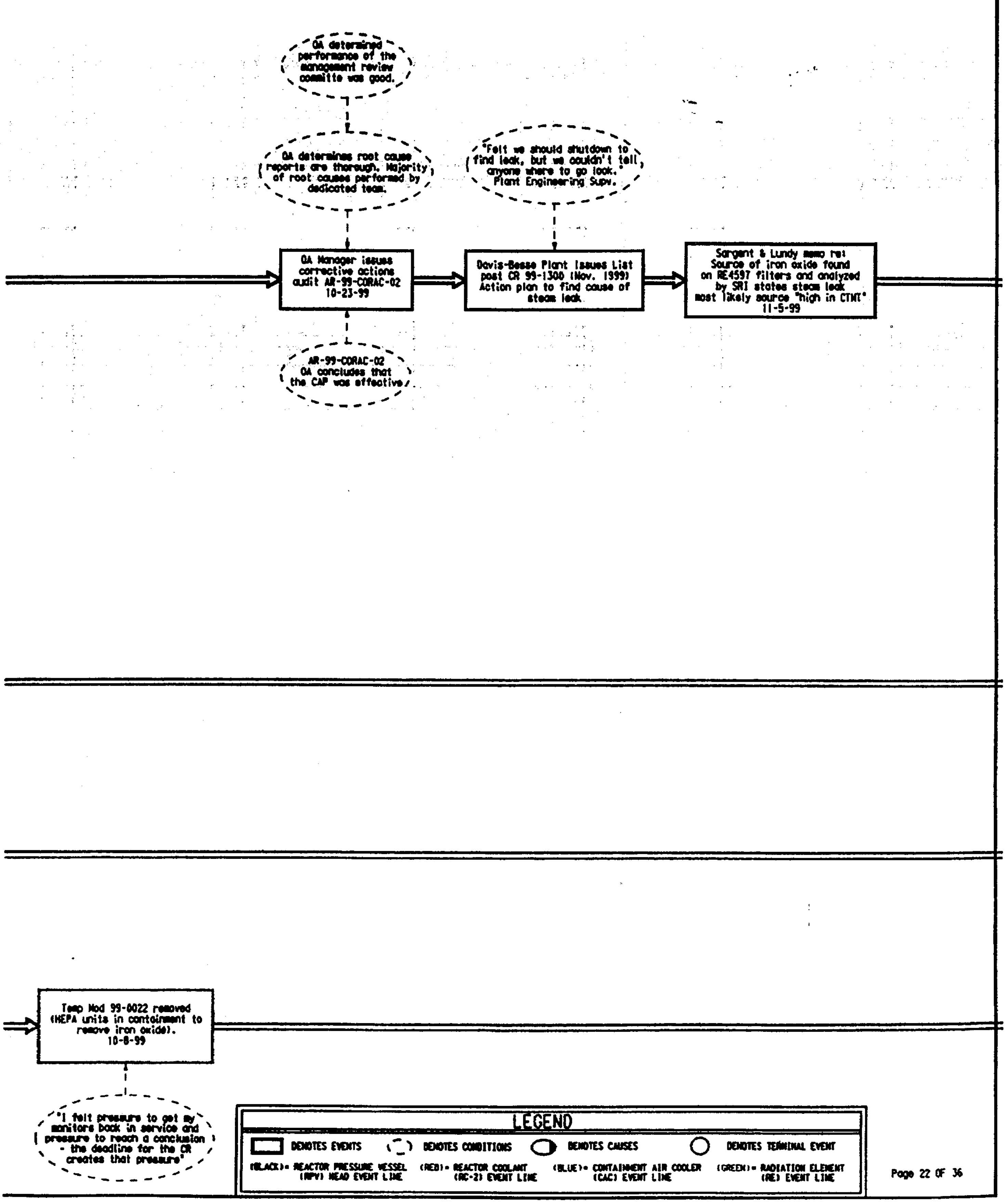


Figure 4, Summary of Events & Causal Factor Chart

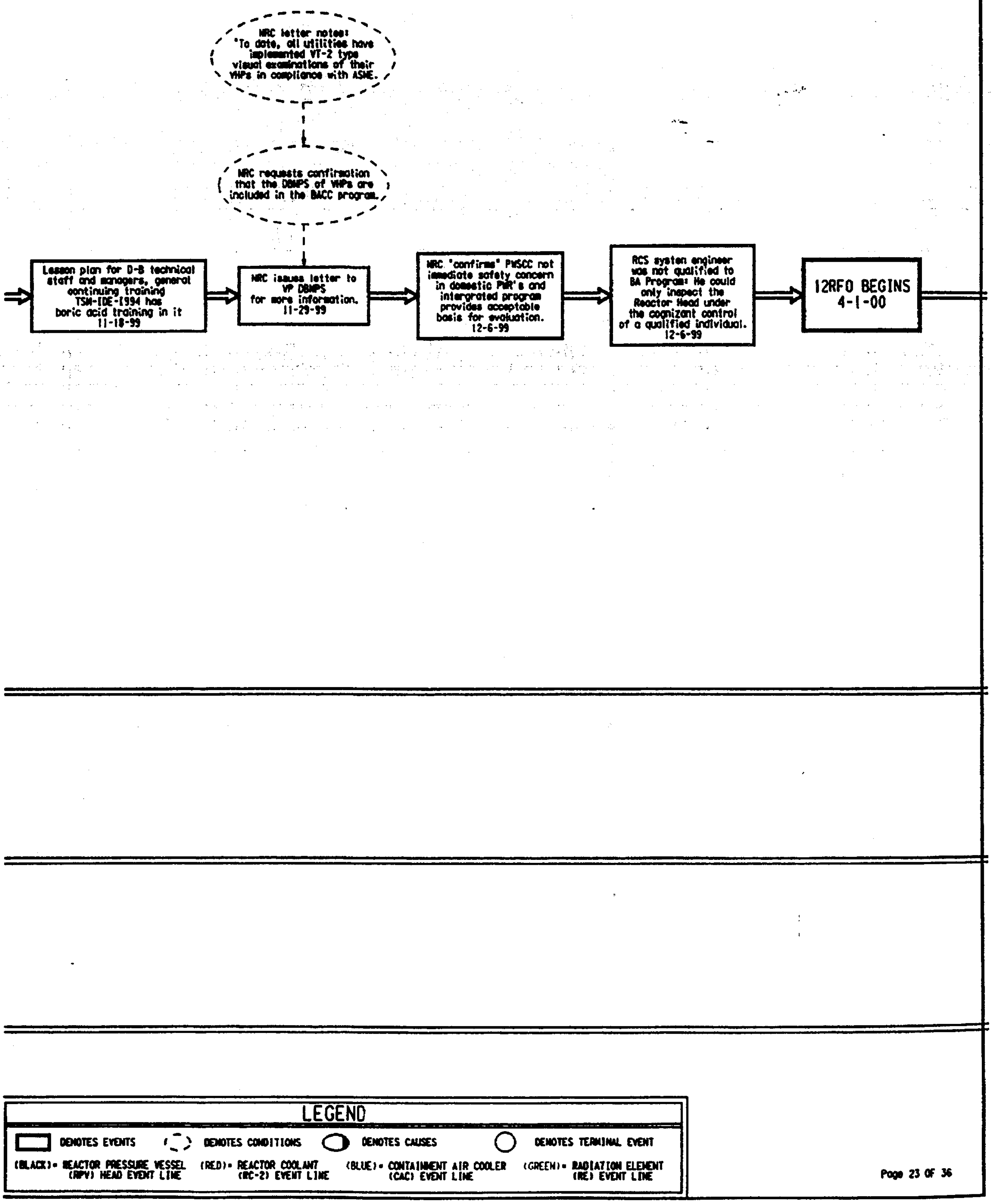


Figure 4, Summary of Events & Causal Factor Chart

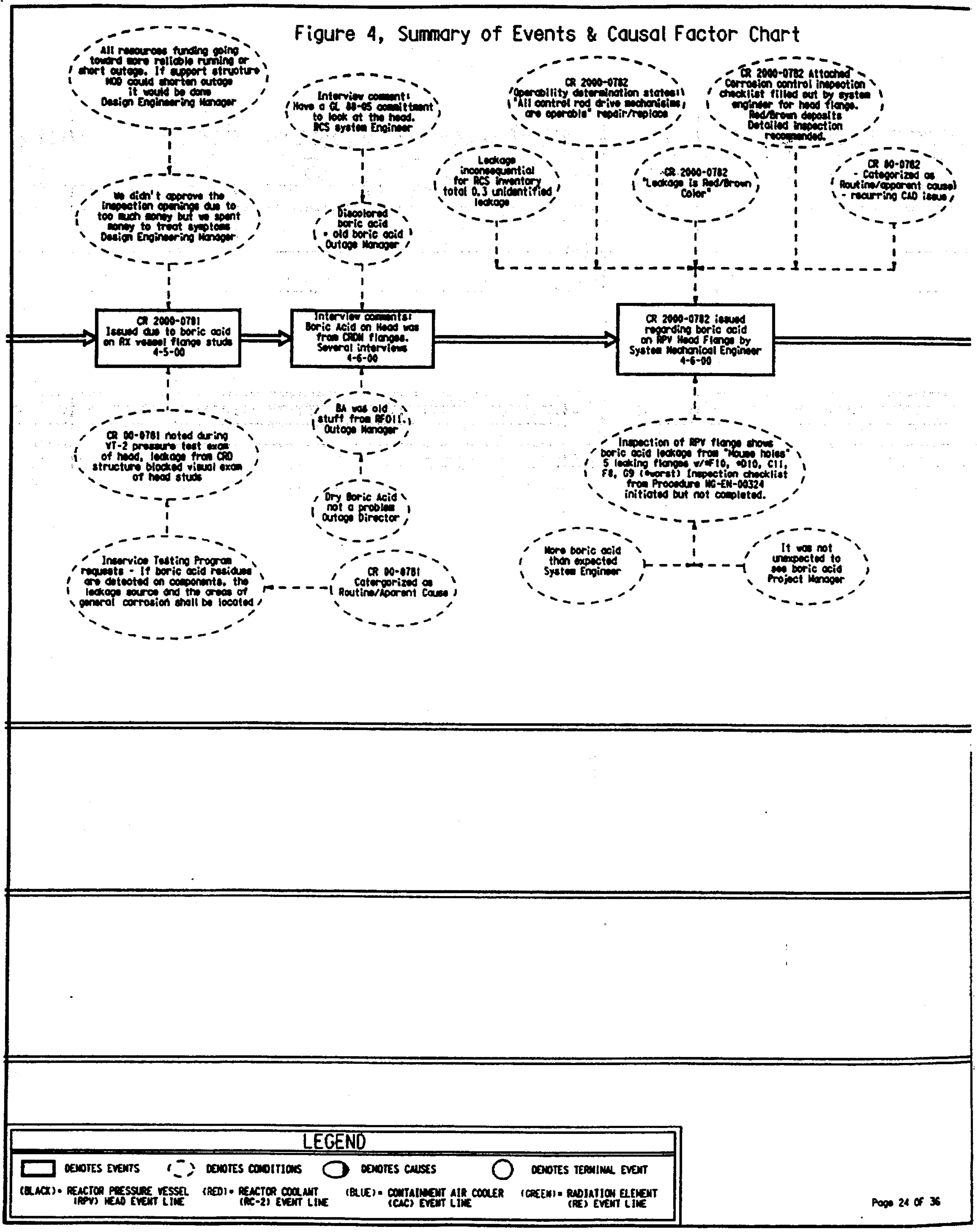


Figure 4, Summary of Events & Causal Factor Chart

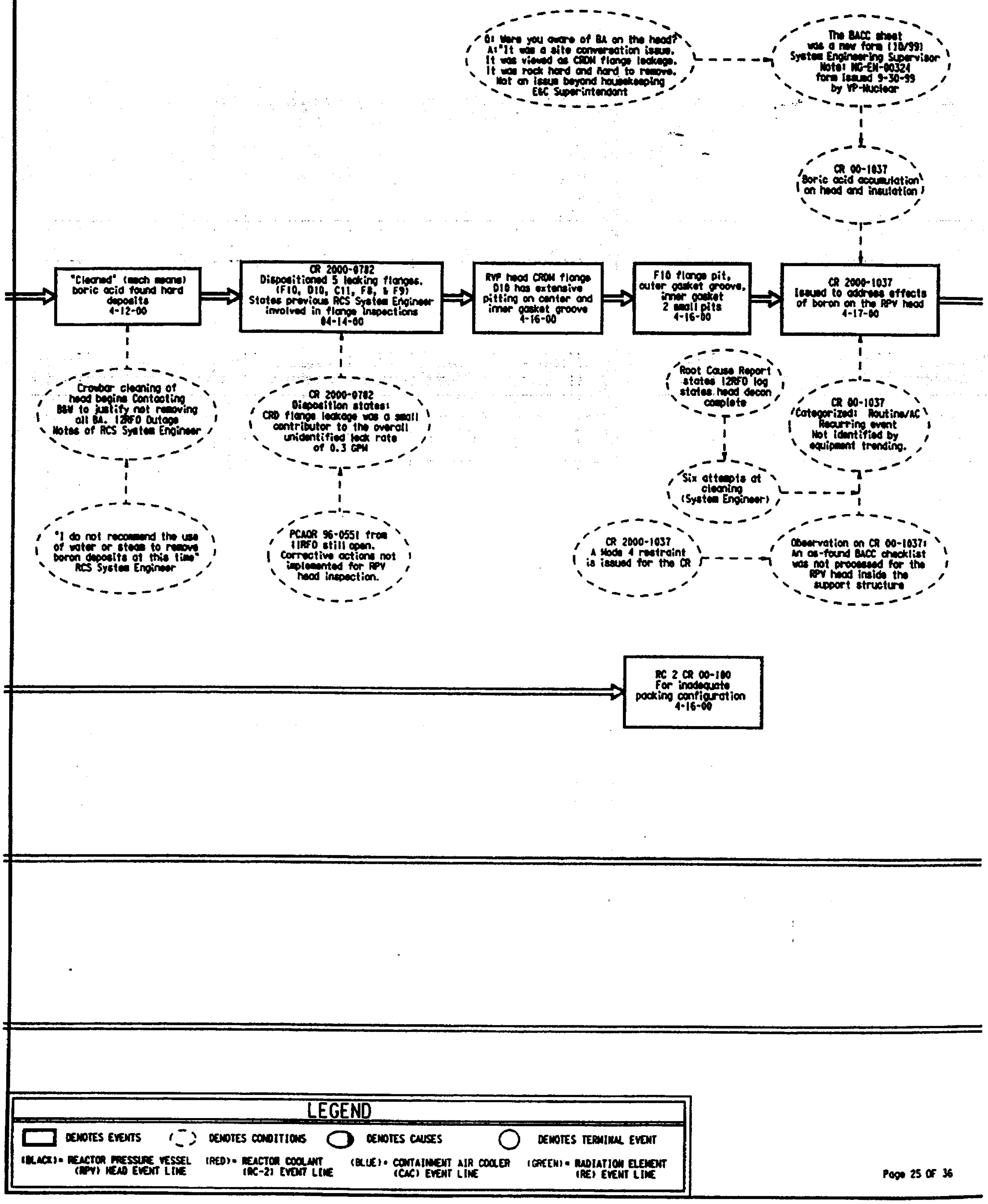


Figure 4, Summary of Events & Causal Factor Chart

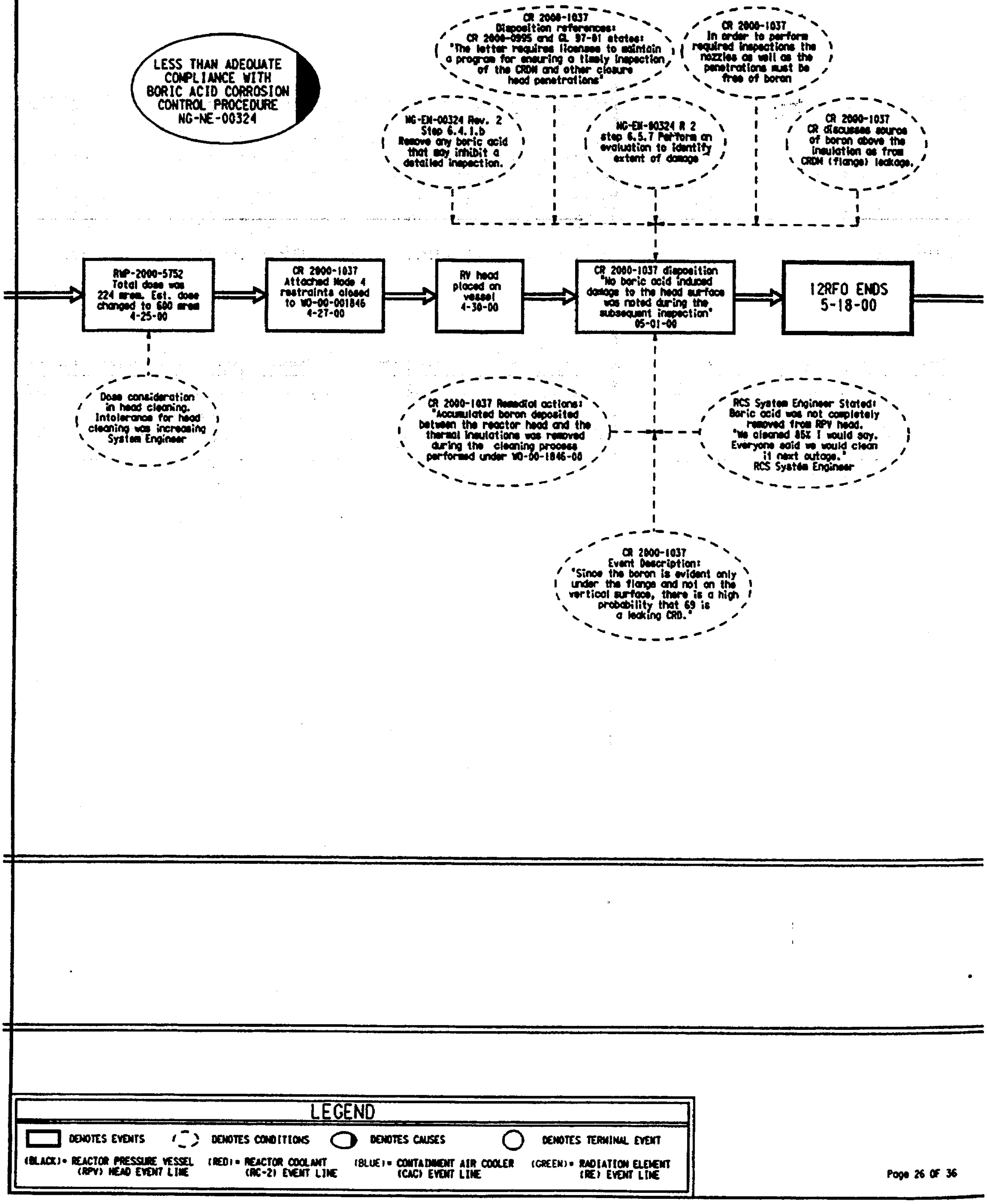


Figure 4, Summary of Events & Causal Factor Chart

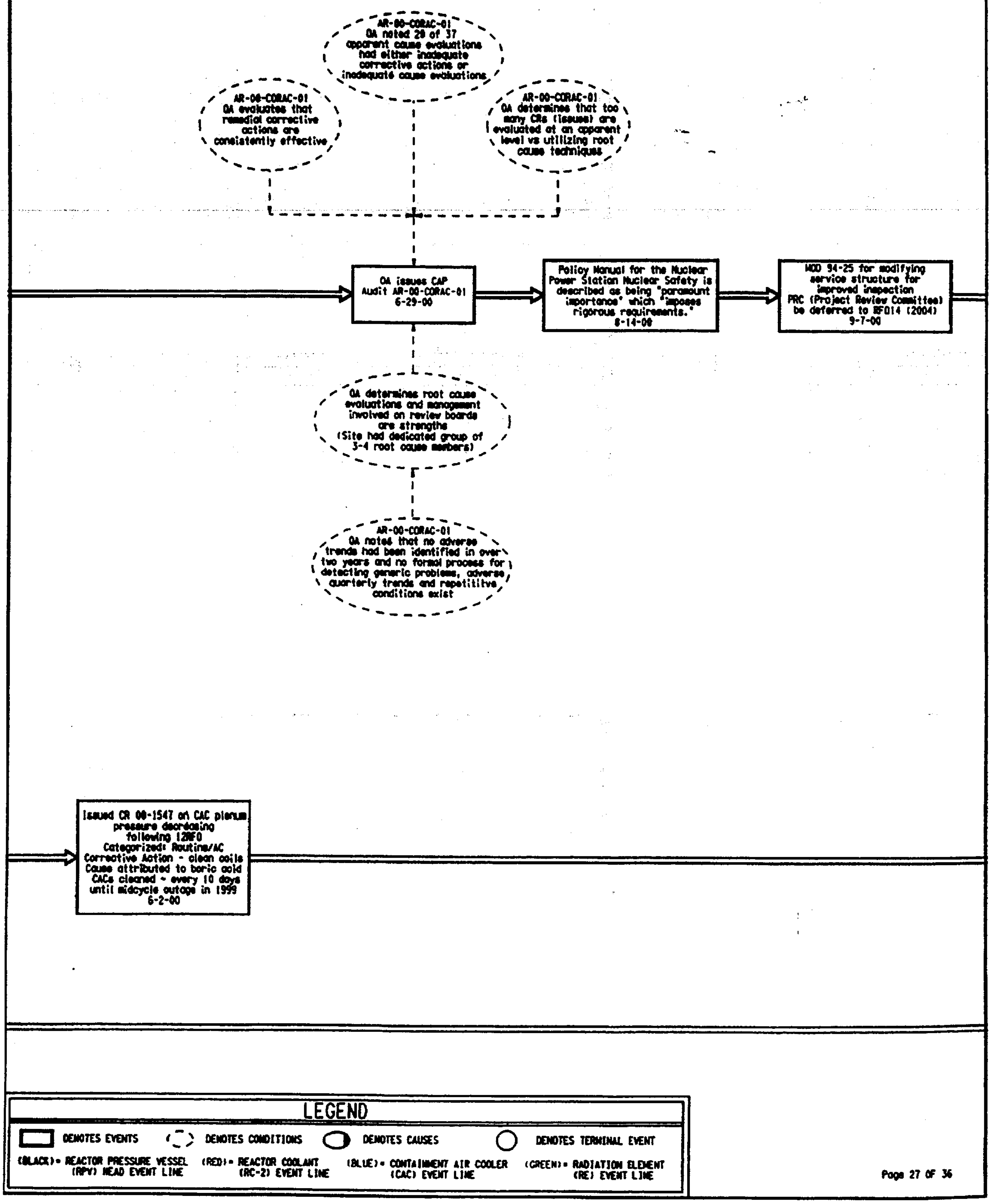


Figure 4, Summary of Events & Causal Factor Chart

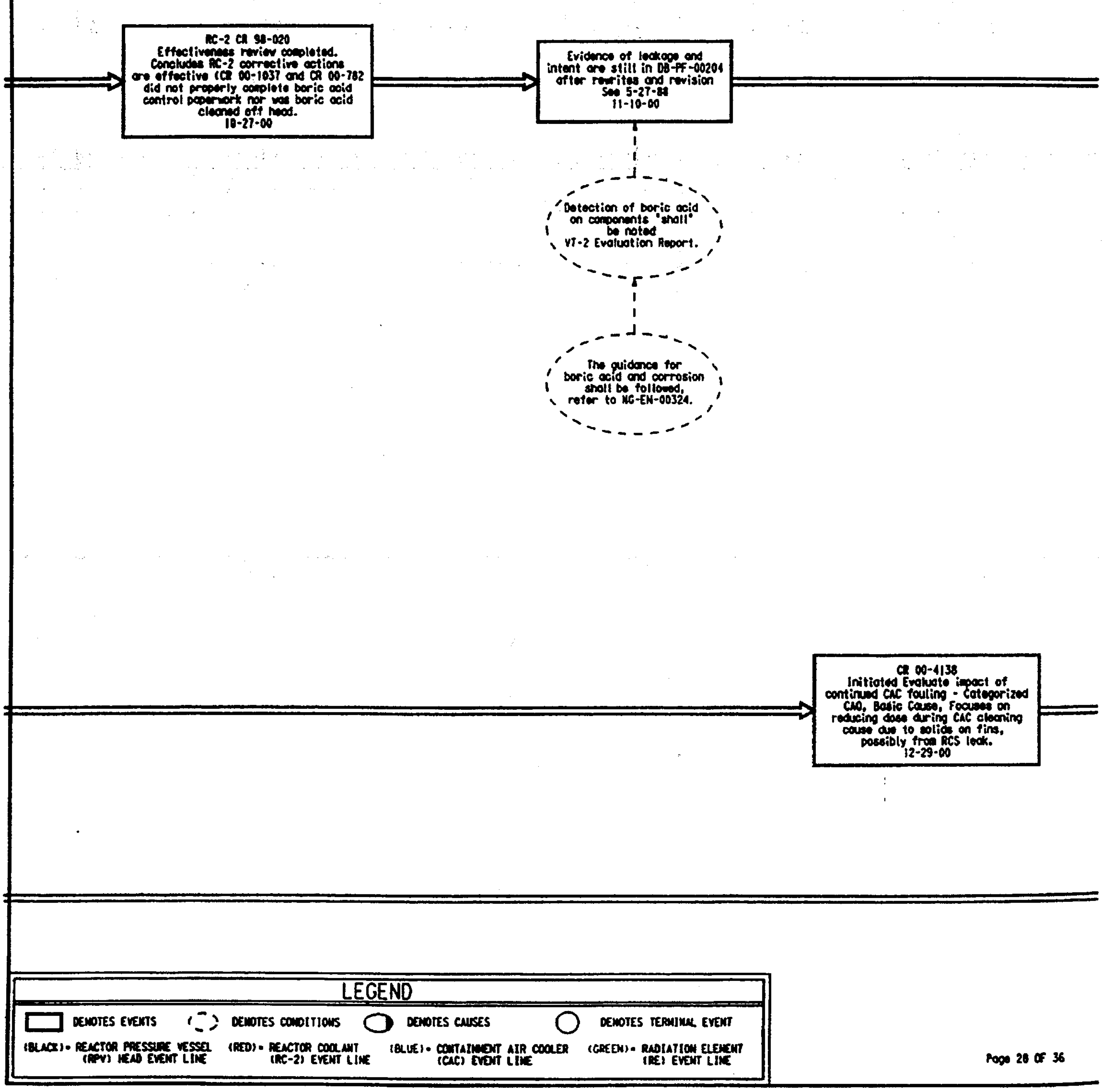


Figure 4, Summary of Events & Causal Factor Chart

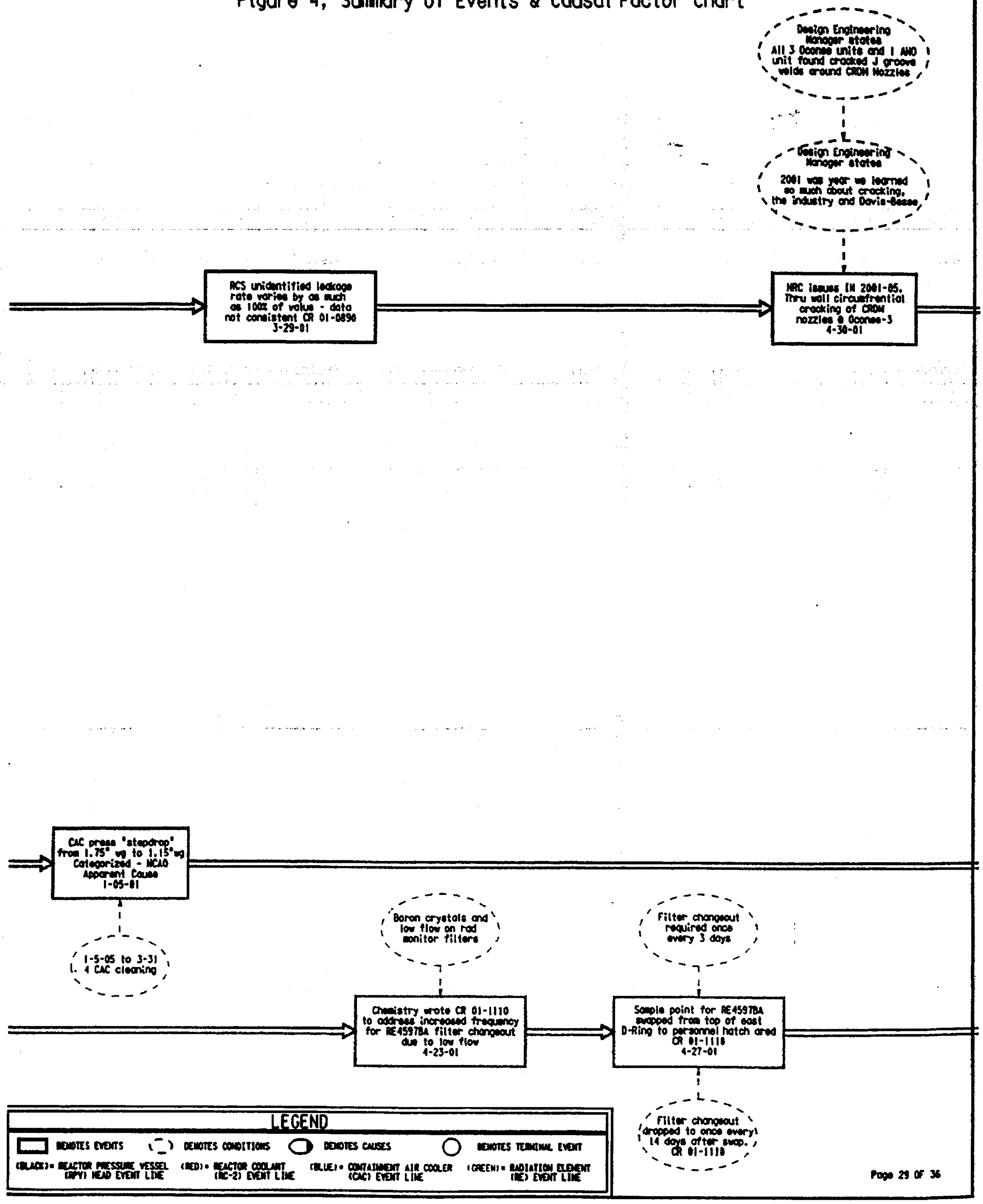
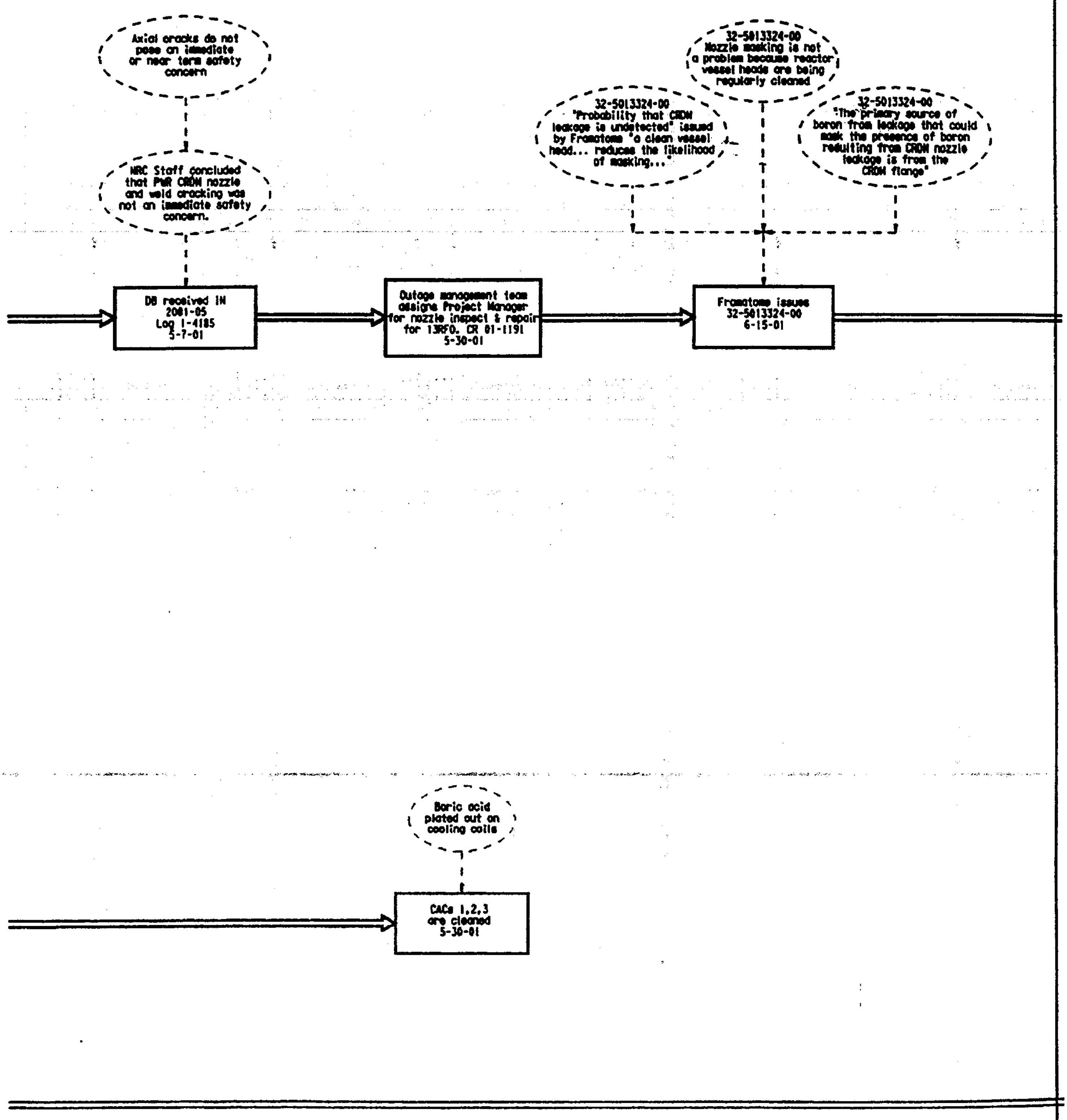


Figure 4, Summary of Events & Causal Factor Chart



LEGEND

DENOTES EVENTS — DENOTES CONDITIONS — DENOTES CAUSES — DENOTES TERMINAL EVENT

(BLACK) = REACTOR PRESSURE VESSEL (RPV) HEAD EVENT LINE
(RED) = REACTOR COOLANT (RC-2) EVENT LINE
(BLUE) = CONTAINMENT AIR COOLER (CAC) EVENT LINE
(GREEN) = RADIATION ELEMENT (RE) EVENT LINE

Figure 4, Summary of Events & Causal Factor Chart

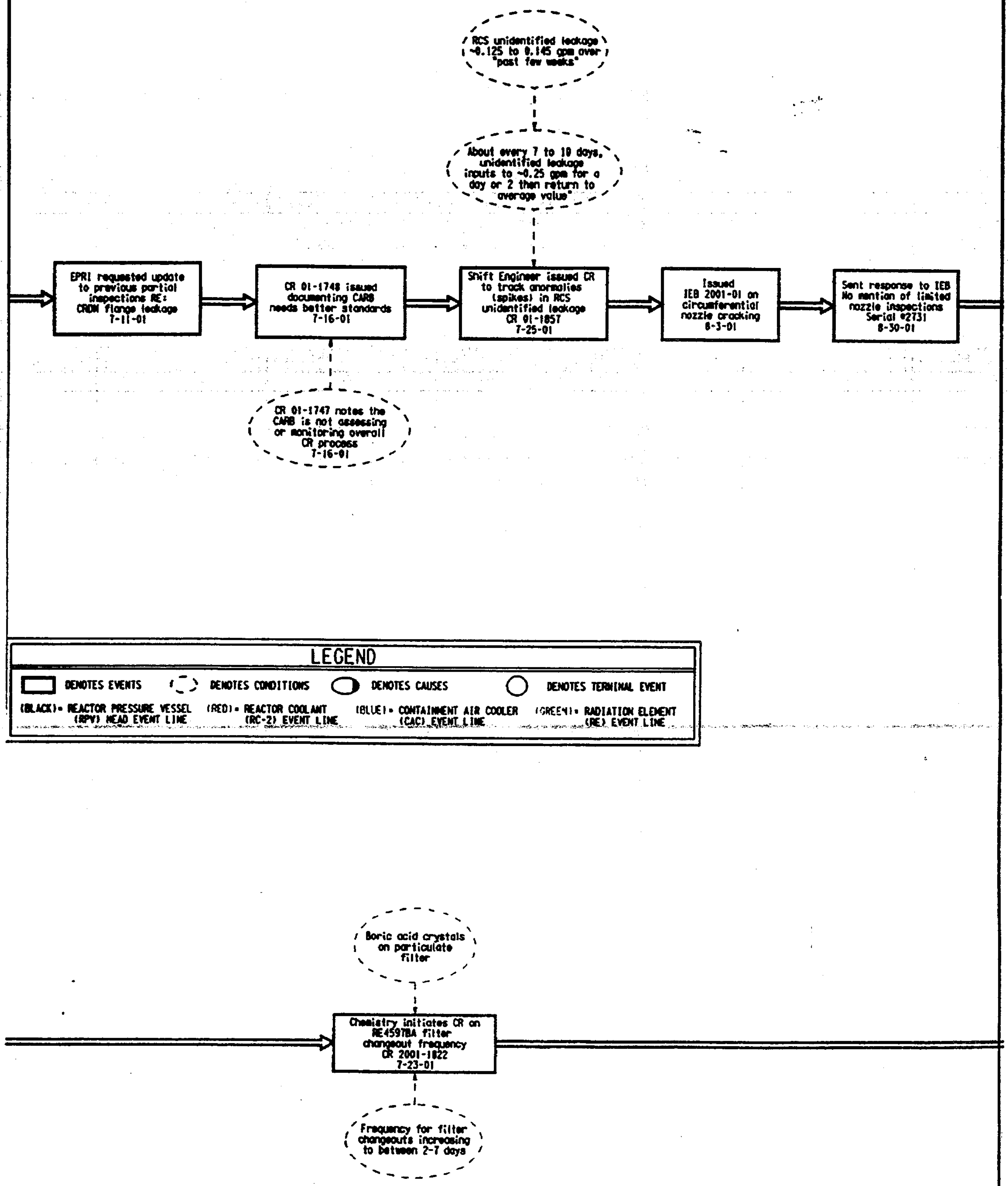


Figure 4, Summary of Events & Causal Factor Chart

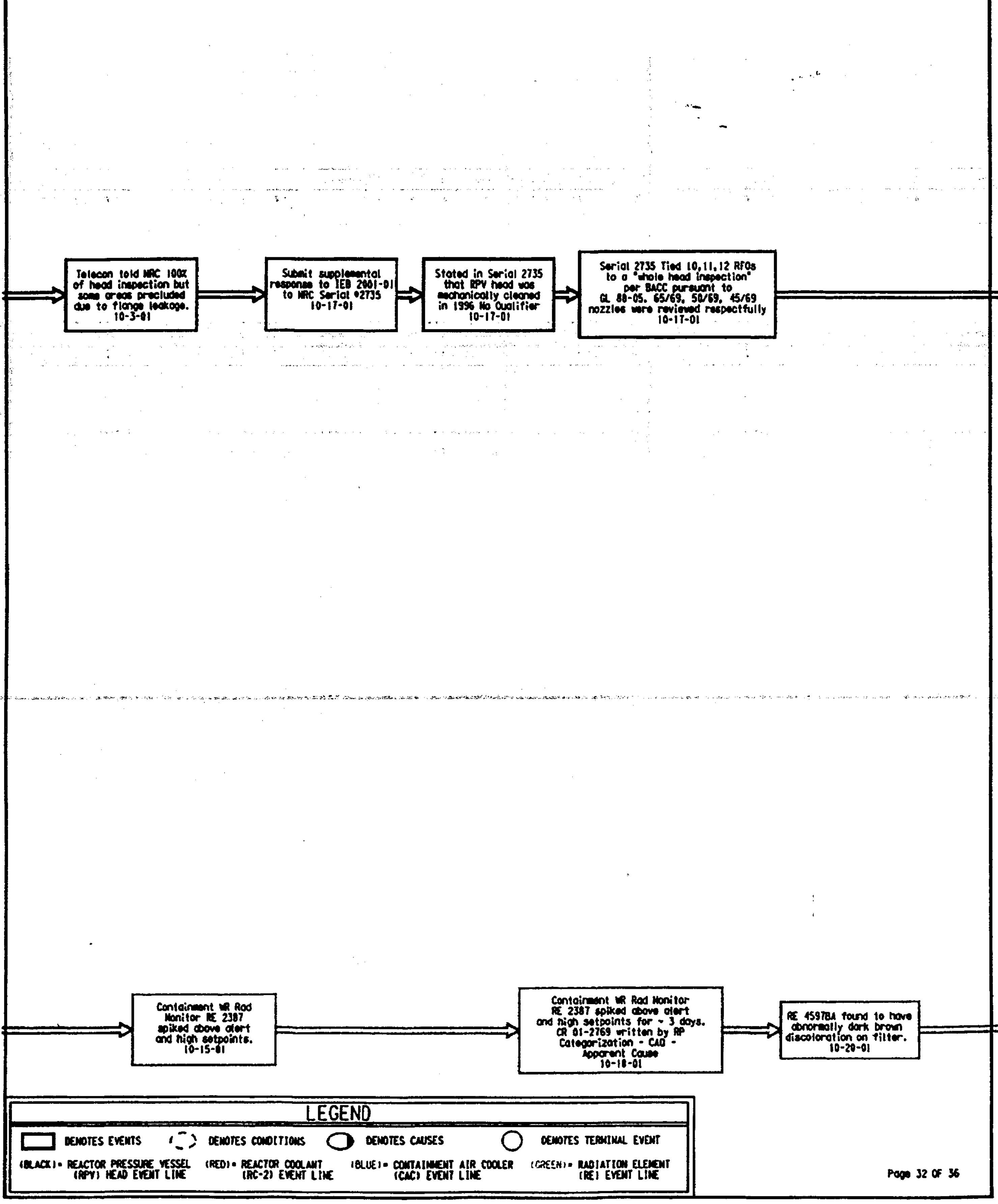


Figure 4, Summary of Events & Causal Factor Chart

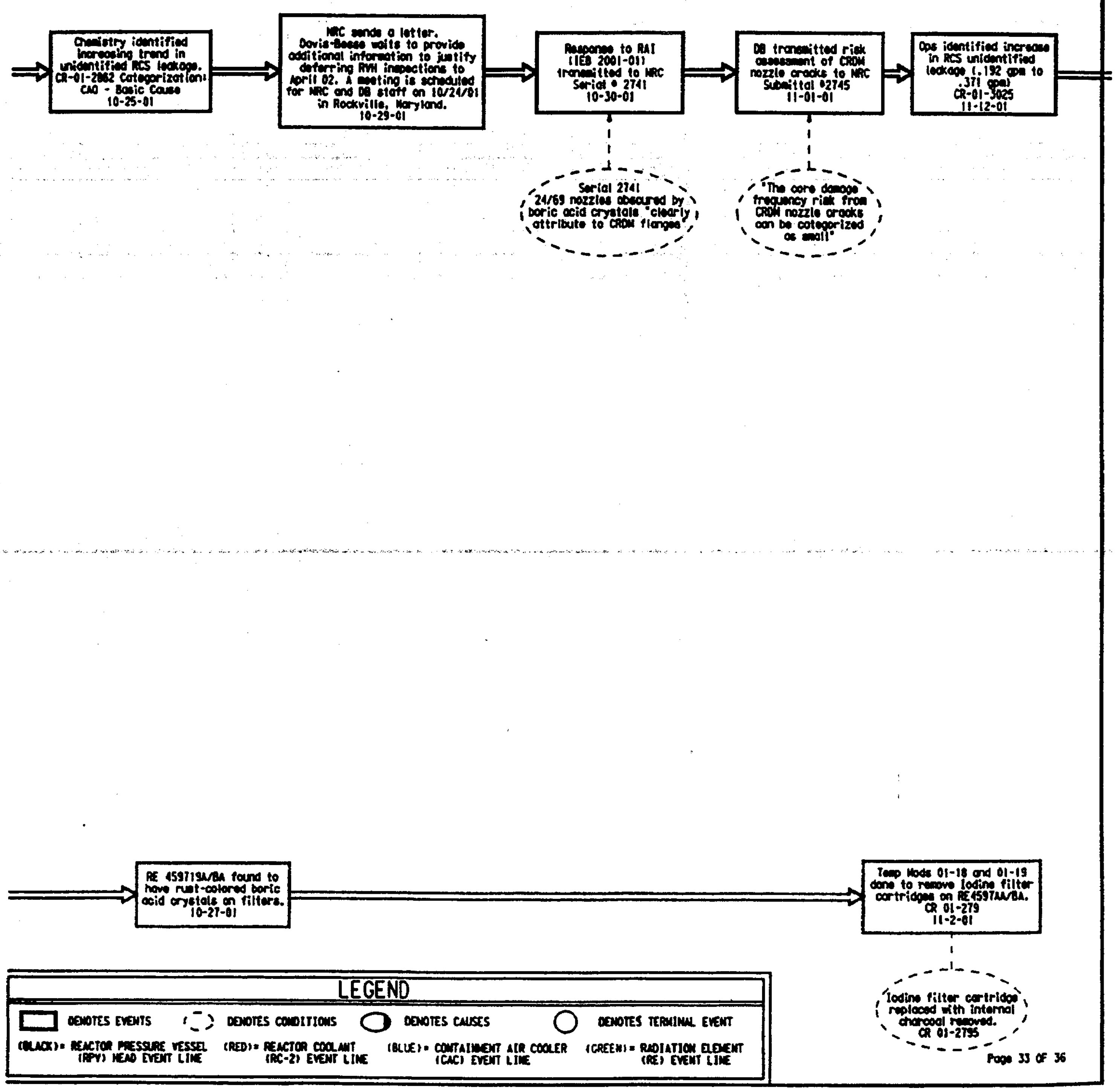
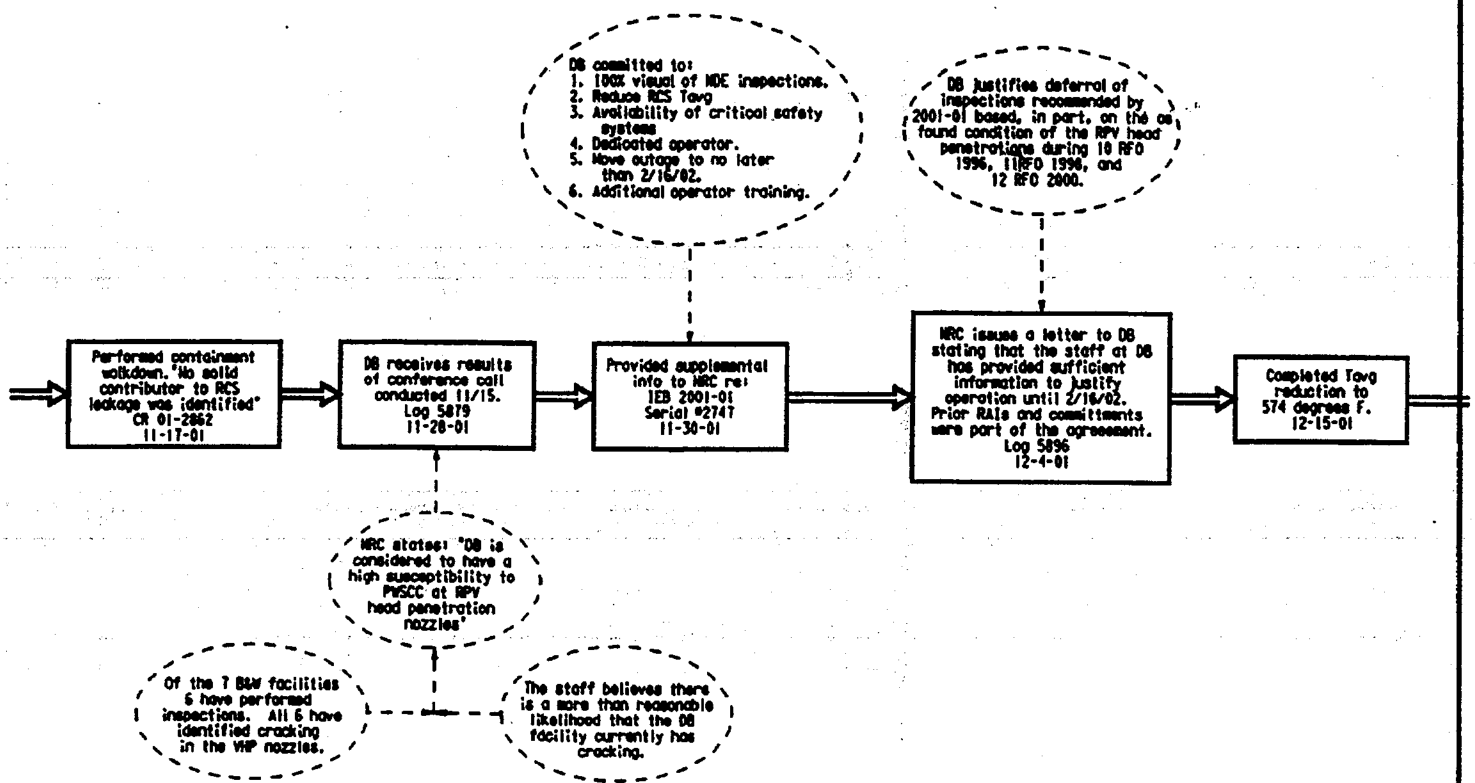


Figure 4, Summary of Events & Causal Factor Chart



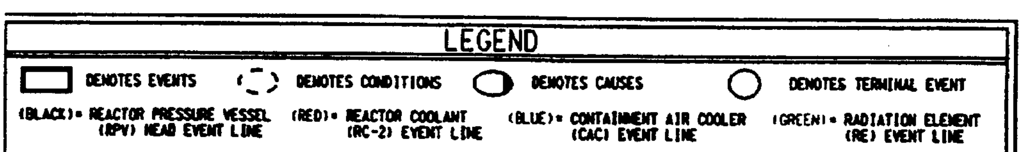
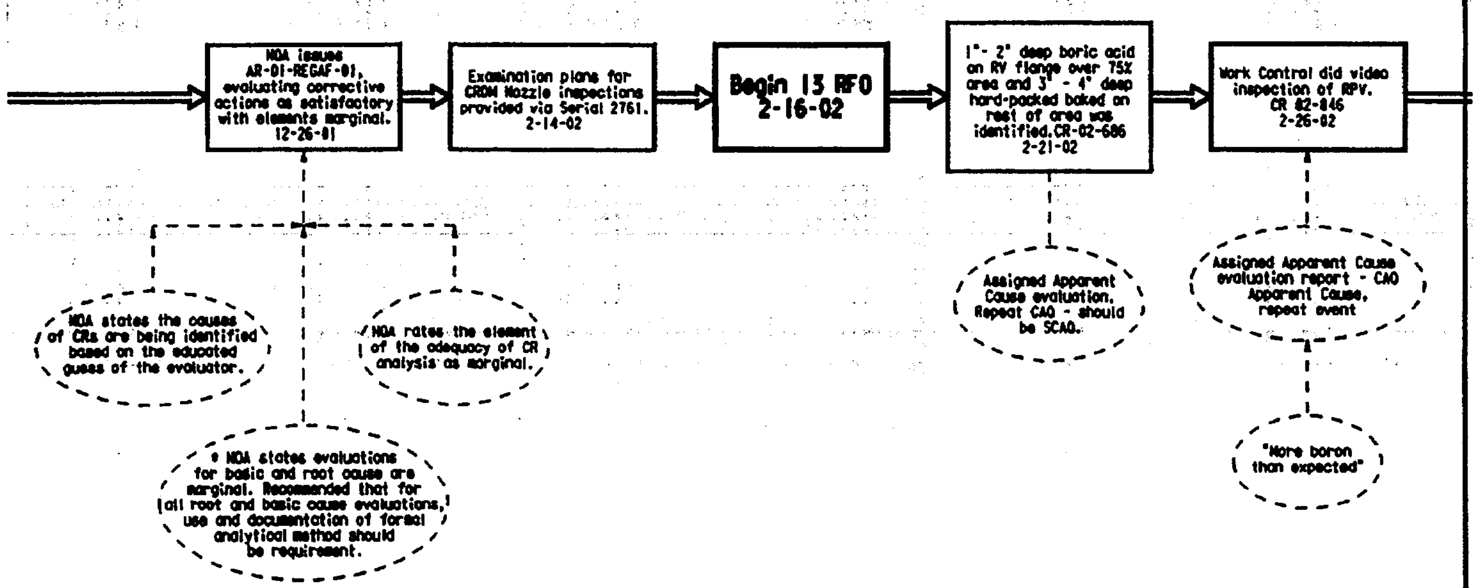


Figure 4, Summary of Events & Causal Factor Chart

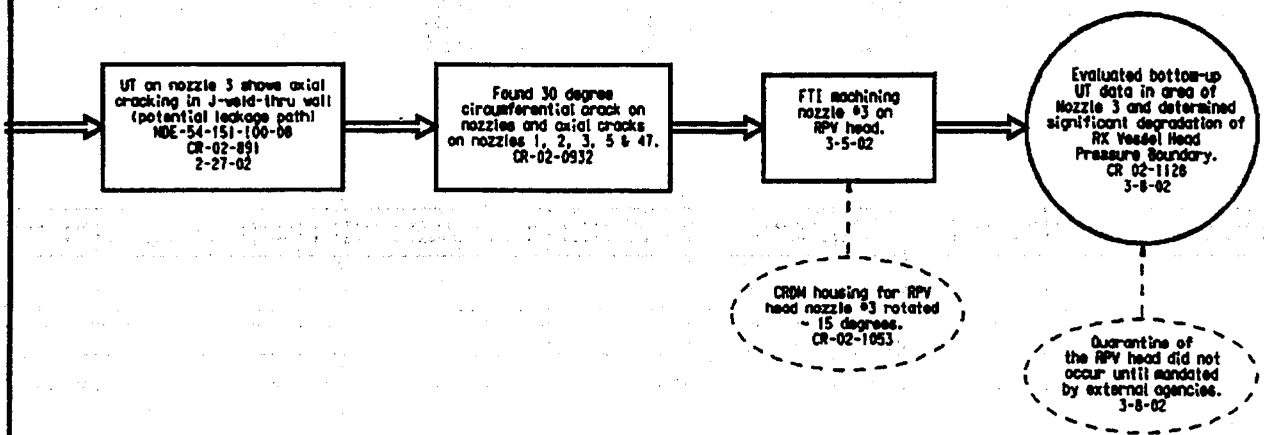


LEGEND

DENOTES EVENTS — DENOTES CONDITIONS — DENOTES CAUSES — DENOTES TERMINAL EVENT

(BLACK) = REACTOR PRESSURE VESSEL (RPV) HEAD EVENT LINE — (RED) = REACTOR COOLANT (RC-2) EVENT LINE — (BLUE) = CONTAINMENT AIR COOLER (CAC) EVENT LINE — (GREEN) = RADIATION ELEMENT (RE) EVENT LINE

Figure 4, Summary of Events & Causal Factor Chart

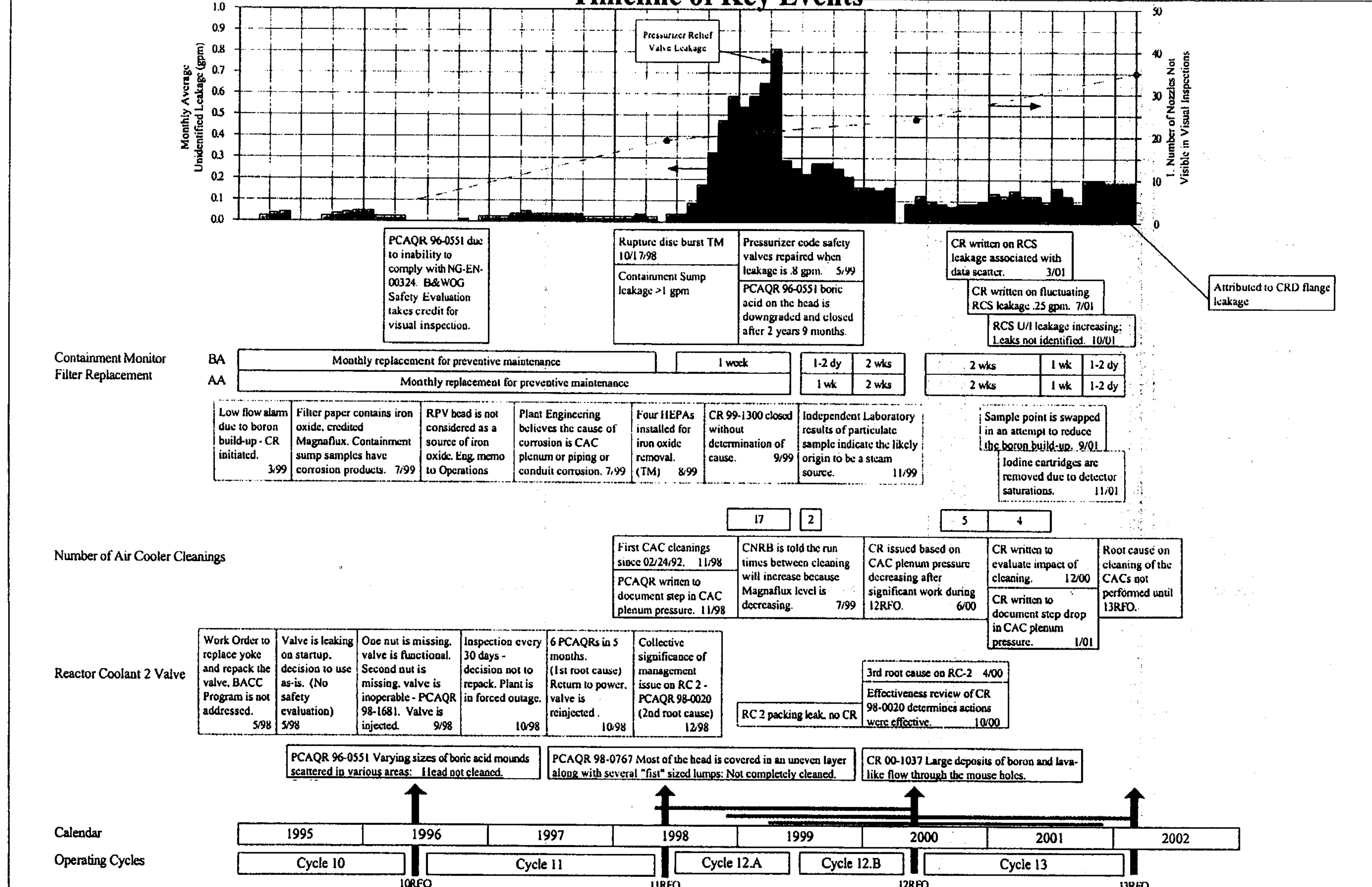


LEGEND

DENOTES EVENTS — DENOTES CONDITIONS — DENOTES CAUSES — DENOTES TERMINAL EVENT

(BLACK) = REACTOR PRESSURE VESSEL (RPV) HEAD EVENT LINE (RED) = REACTOR COOLANT (RC-2) EVENT LINE (BLUE) = CONTAINMENT AIR COOLER (CAC) EVENT LINE (GREEN) = RADIATION ELEMENT (RE) EVENT LINE

Timeline of Key Events



COMMITMENT LIST

The following list identifies those actions committed to by the Davis-Besse Nuclear Power Station (DBNPS) in this document. Any other actions discussed in the submittal represent intended or planned actions the DBNPS. They are described only for information and are not regulatory commitments. Please notify the Manager - Regulatory Affairs (419-321-8450) at the DBNPS of any questions regarding this document or associated regulatory commitments.

COMMITMENTS	DUE DATE
None	