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

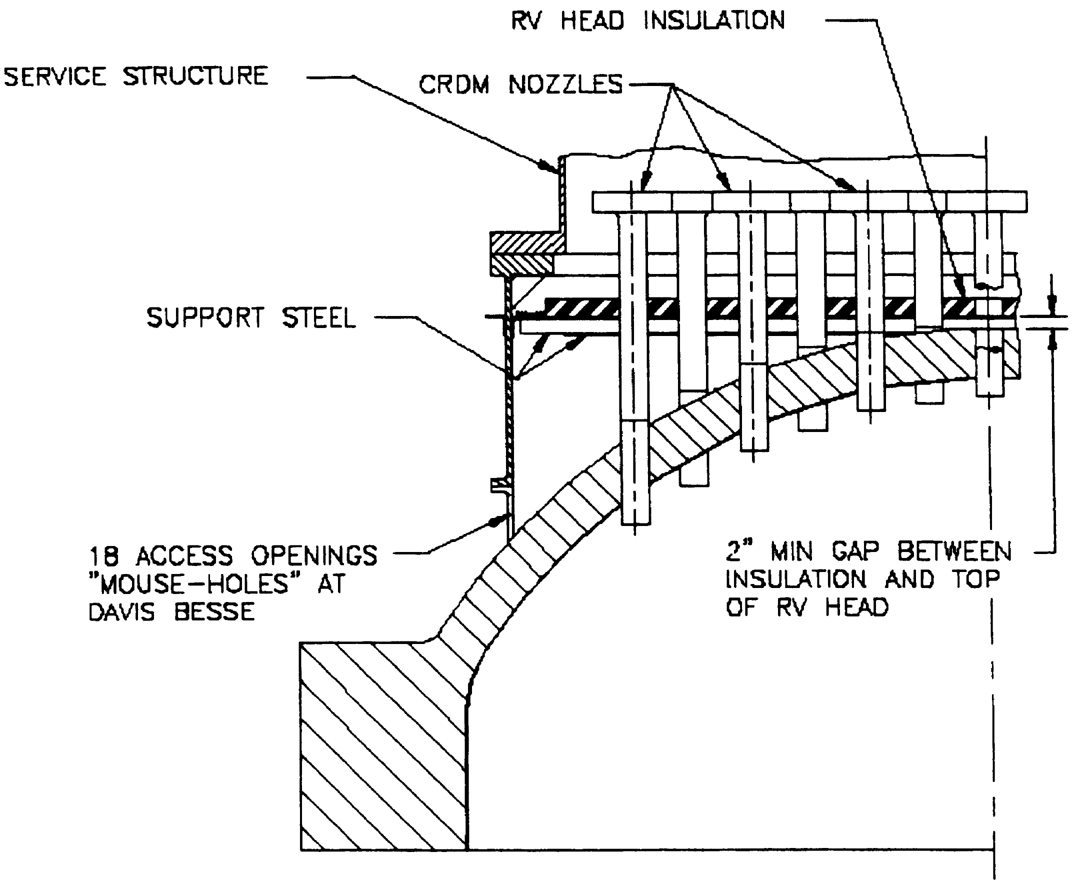


Figure 1. Davis-Besse RPV Top of Head Section View

Source: EPRI/DEI

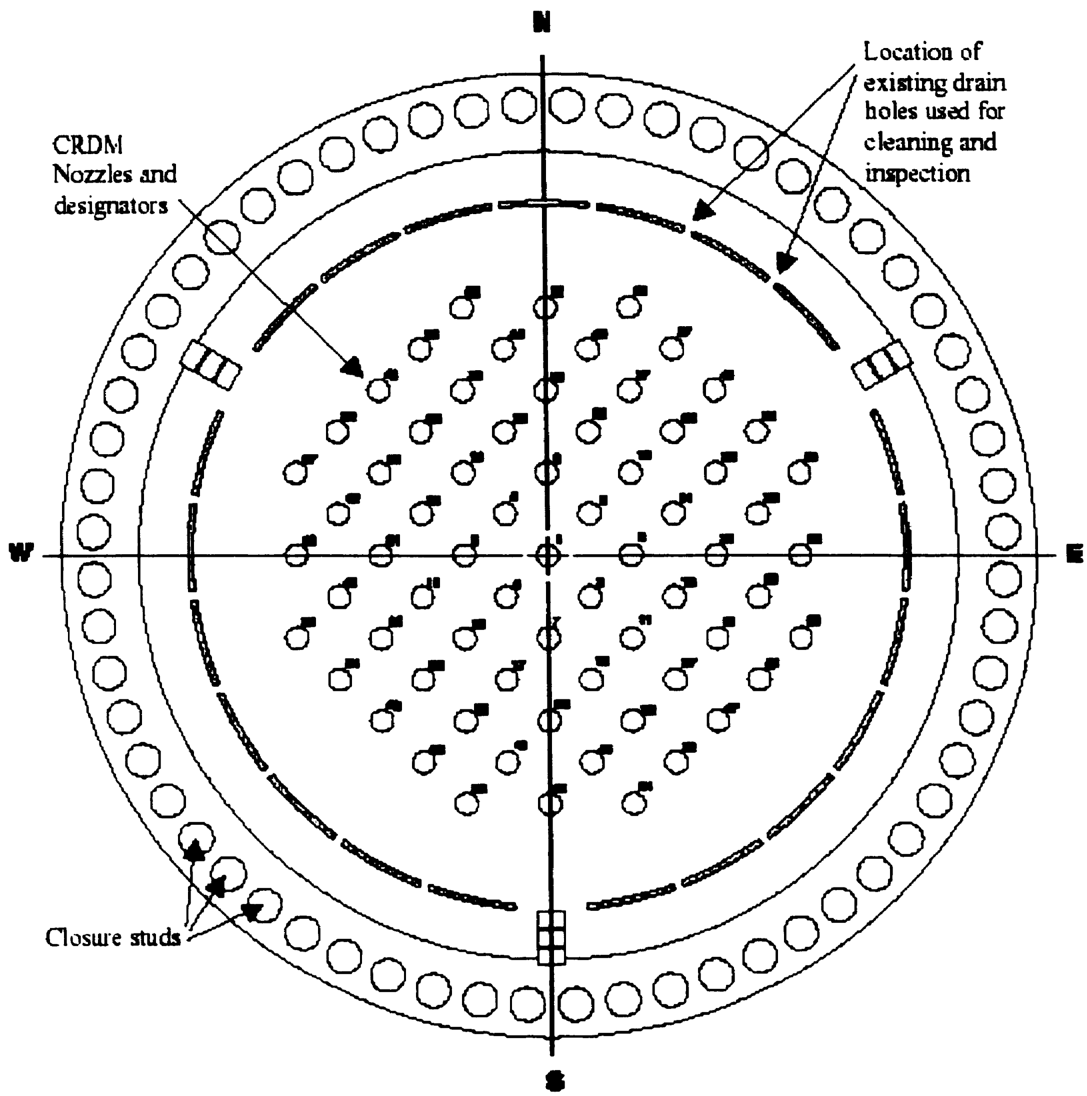


Figure 2. Davis-Besse RPV Top of Head Plan View

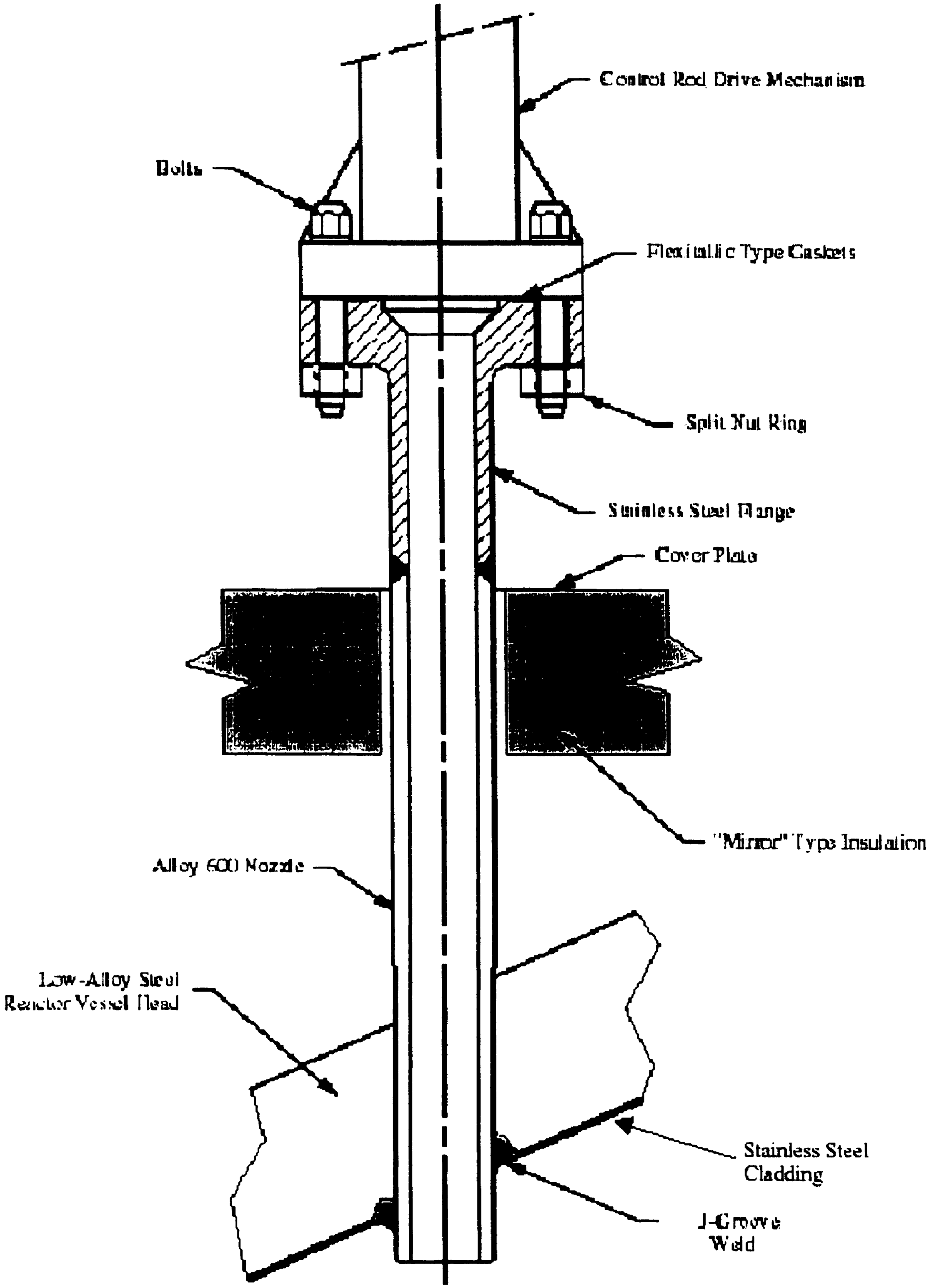


Figure 3. Davis-Besse CRDM Nozzle General Arrangement

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 (Framatome)." 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 96-551 is in progress." EVALUATORS NOTE: However, CR 96-551 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 98-787. "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 |
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| | 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 fully assess component damage and determine corrective actions. PCAQ 96-551 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 96-0551. |
| | 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)

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| | 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 96-551 is in progress. PCAQ 98-767 can be closed once the root cause and CATPR for PCAQ 96-551 are complete. EVALUATORS NOTE: However, the actions for PCAQ 96-551 (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 605-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 635-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 |
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| | 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 98-767 and 98-649 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 98-649 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 98-767 and 98-649 were categorized as Category 3/Apparent Cause evaluations. However, as noted in PCAQ 98-649 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)

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| | 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)

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| | List of Advertised 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." |

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# (12RFO Inspections)

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| | 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)

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| | 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 probability 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 Advertised 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 assemblies" 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. |

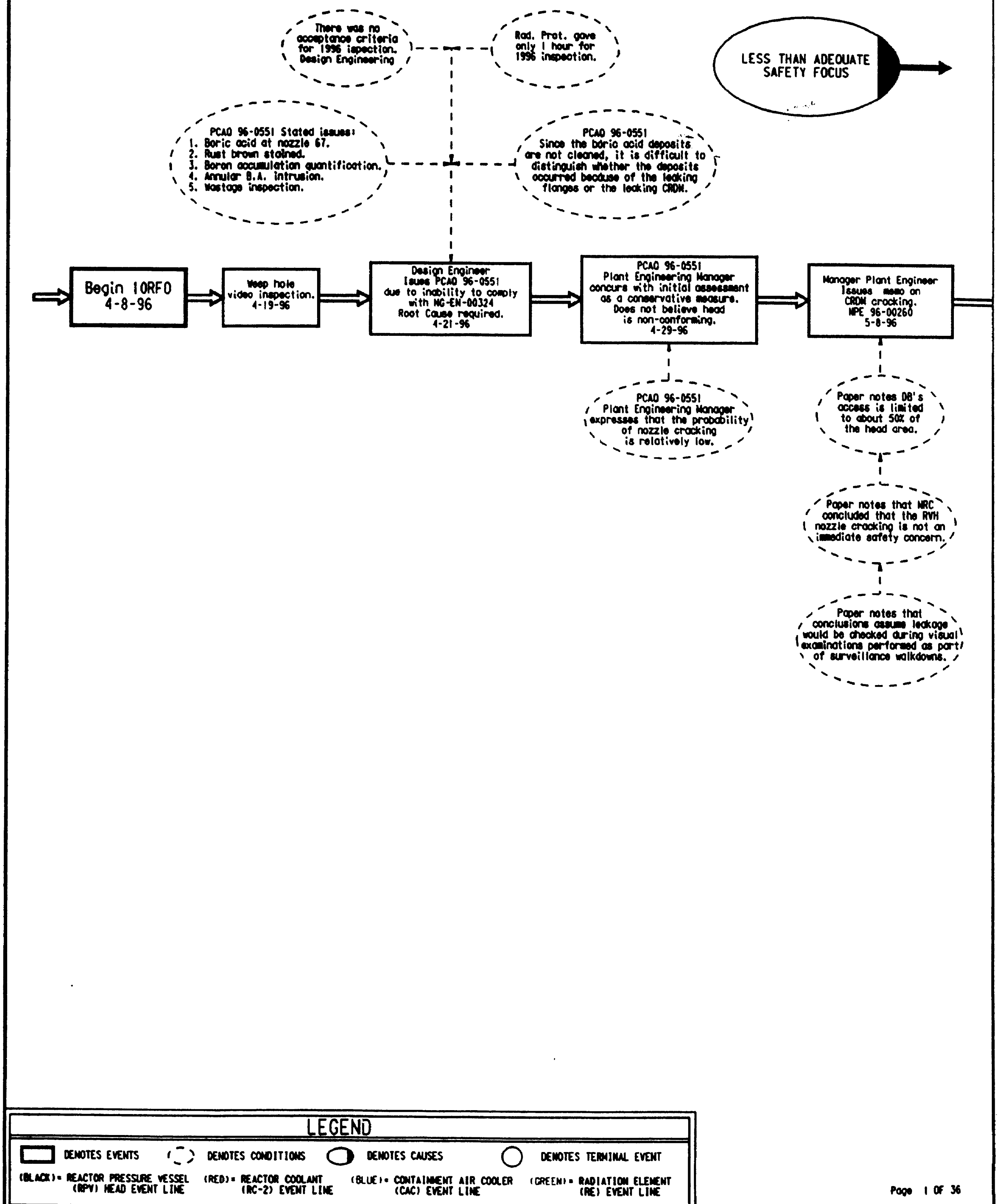
# HAZARD-BARRIER-TARGET ANALYSIS
# (12RFO Inspections)

| 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 Advertised 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



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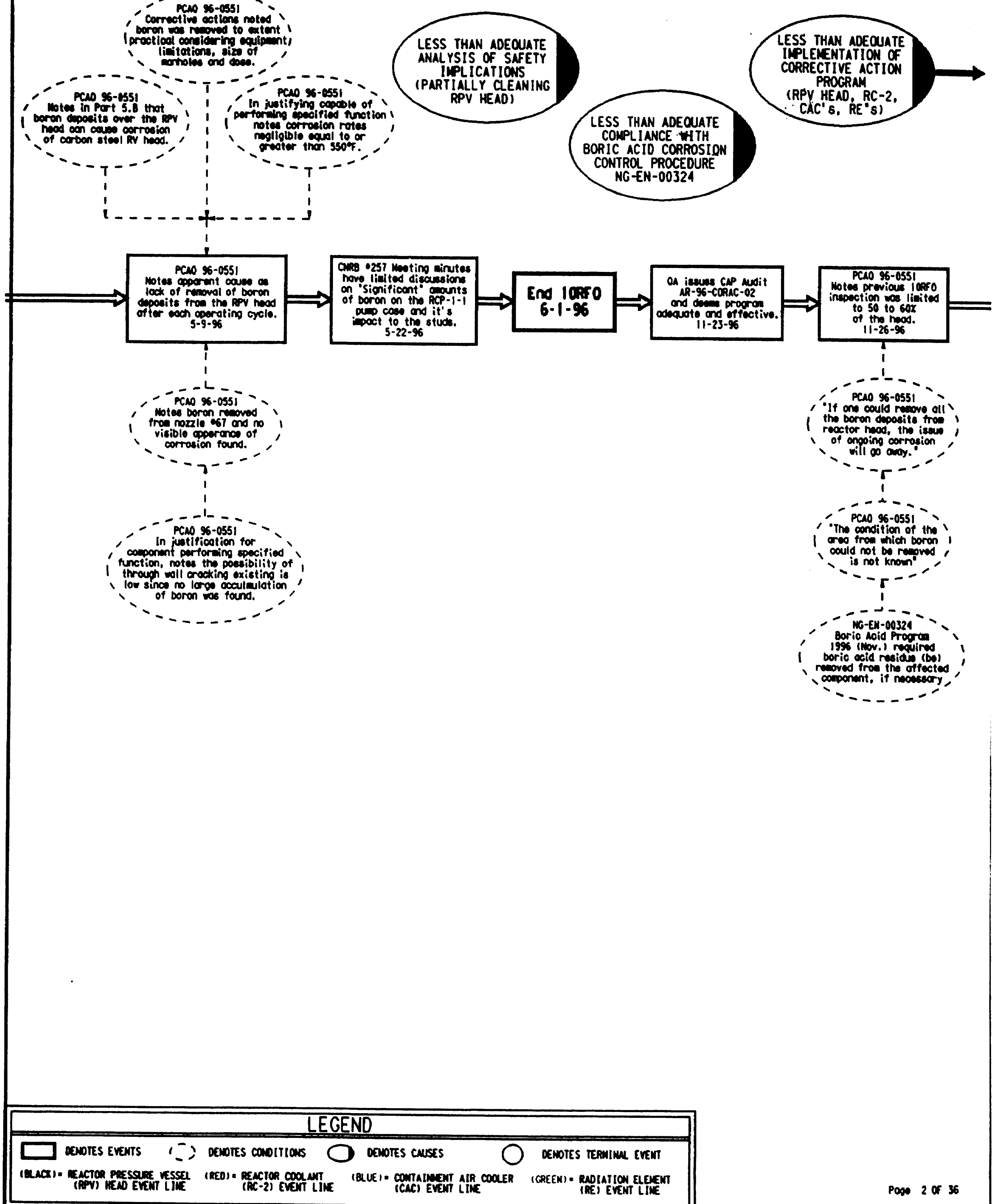

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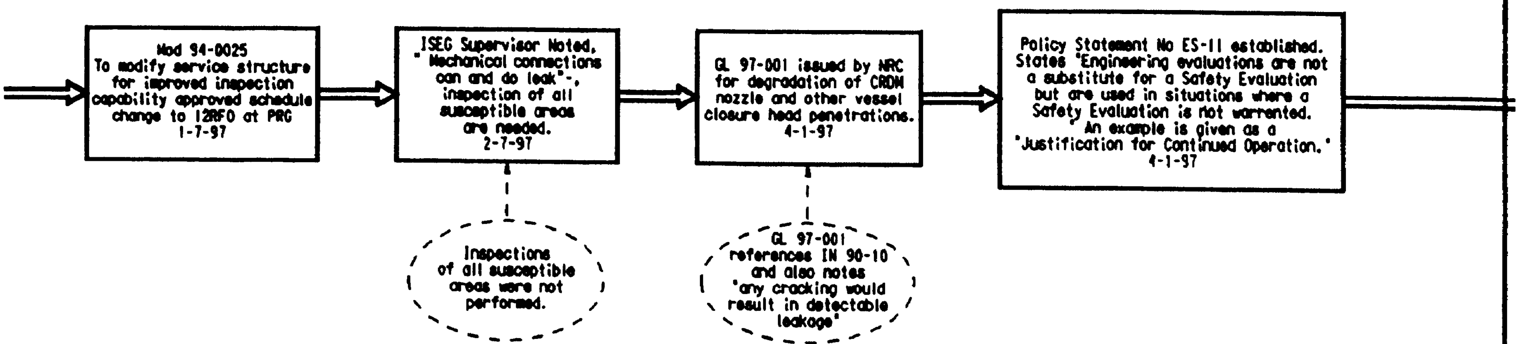


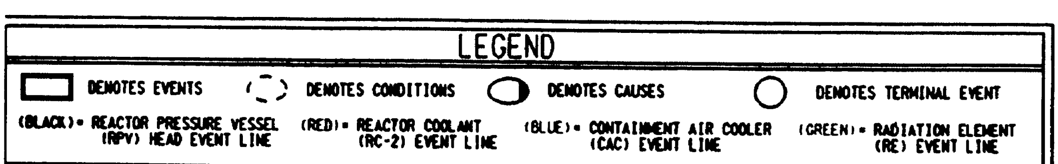

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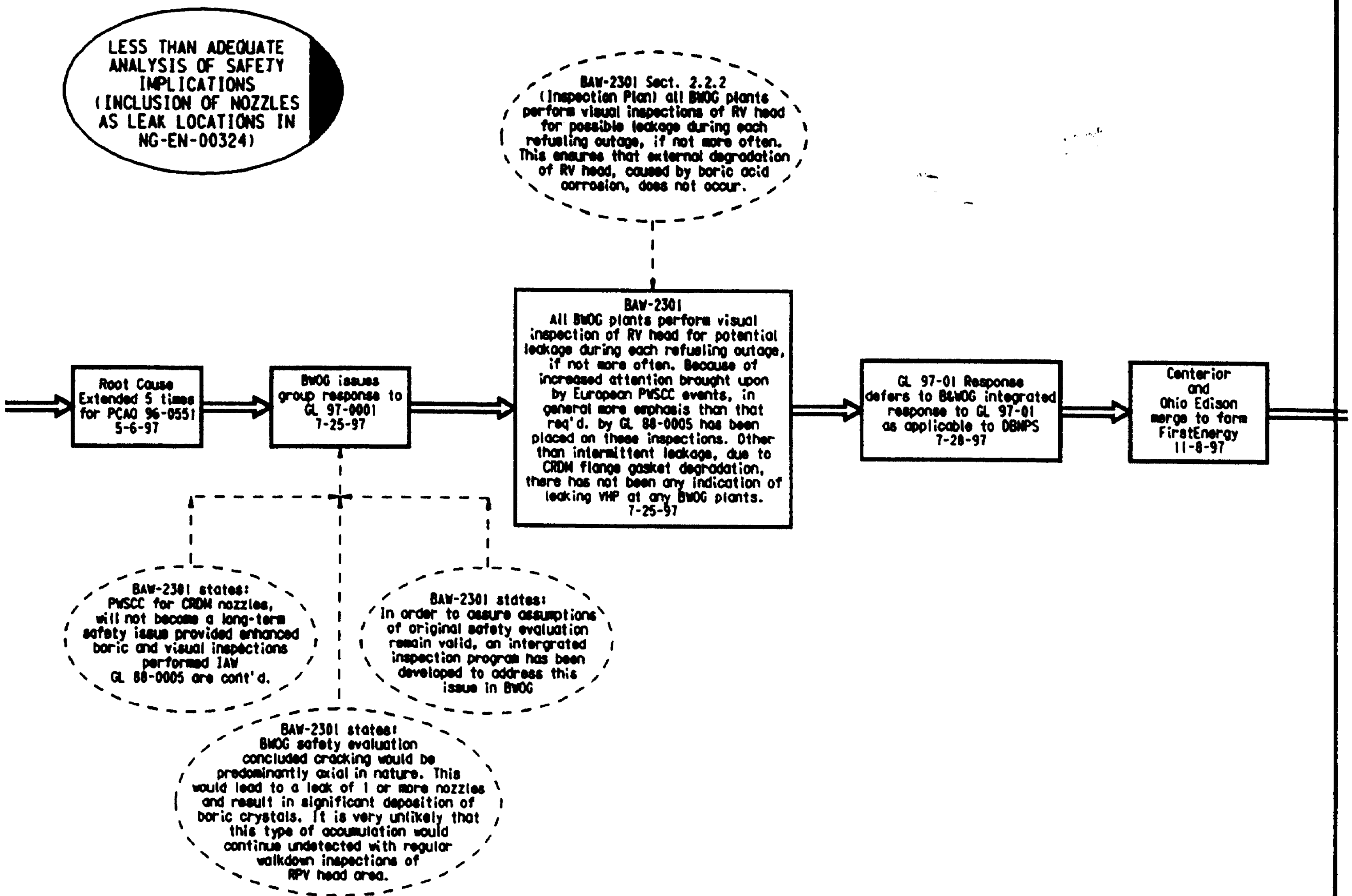


## LEGEND

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

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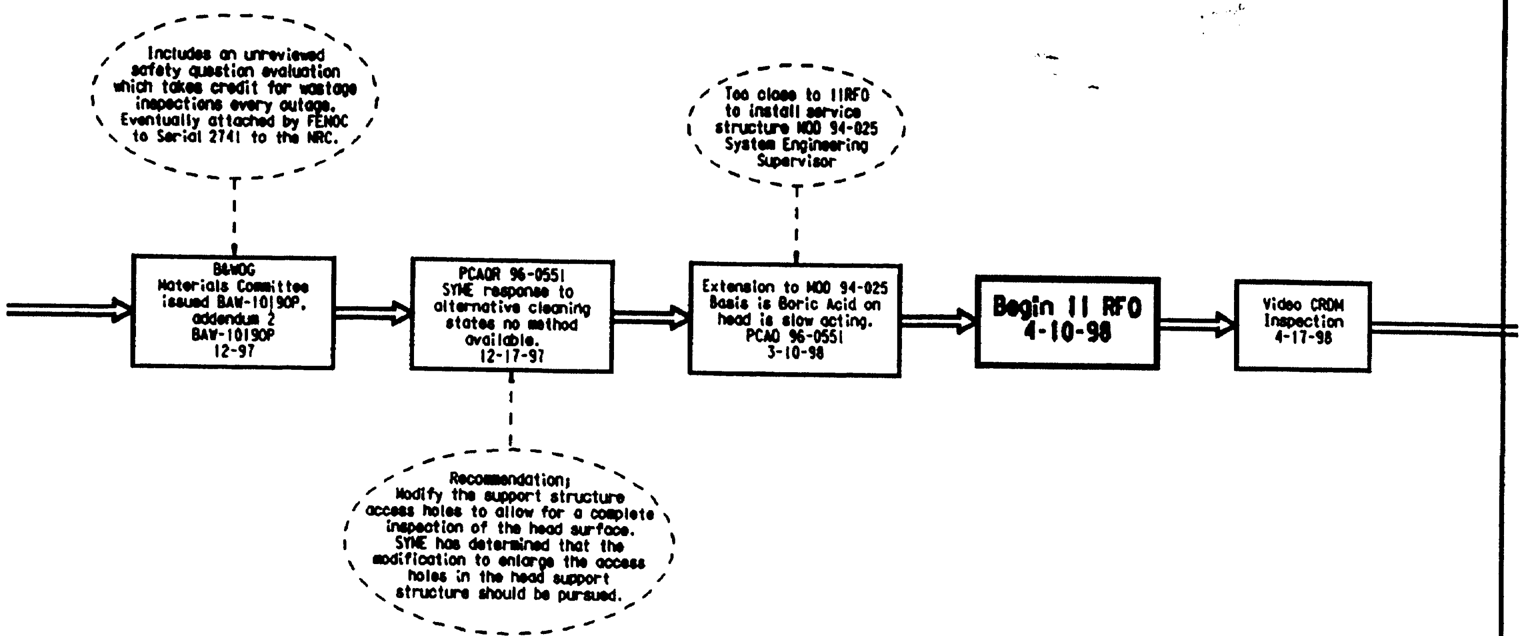


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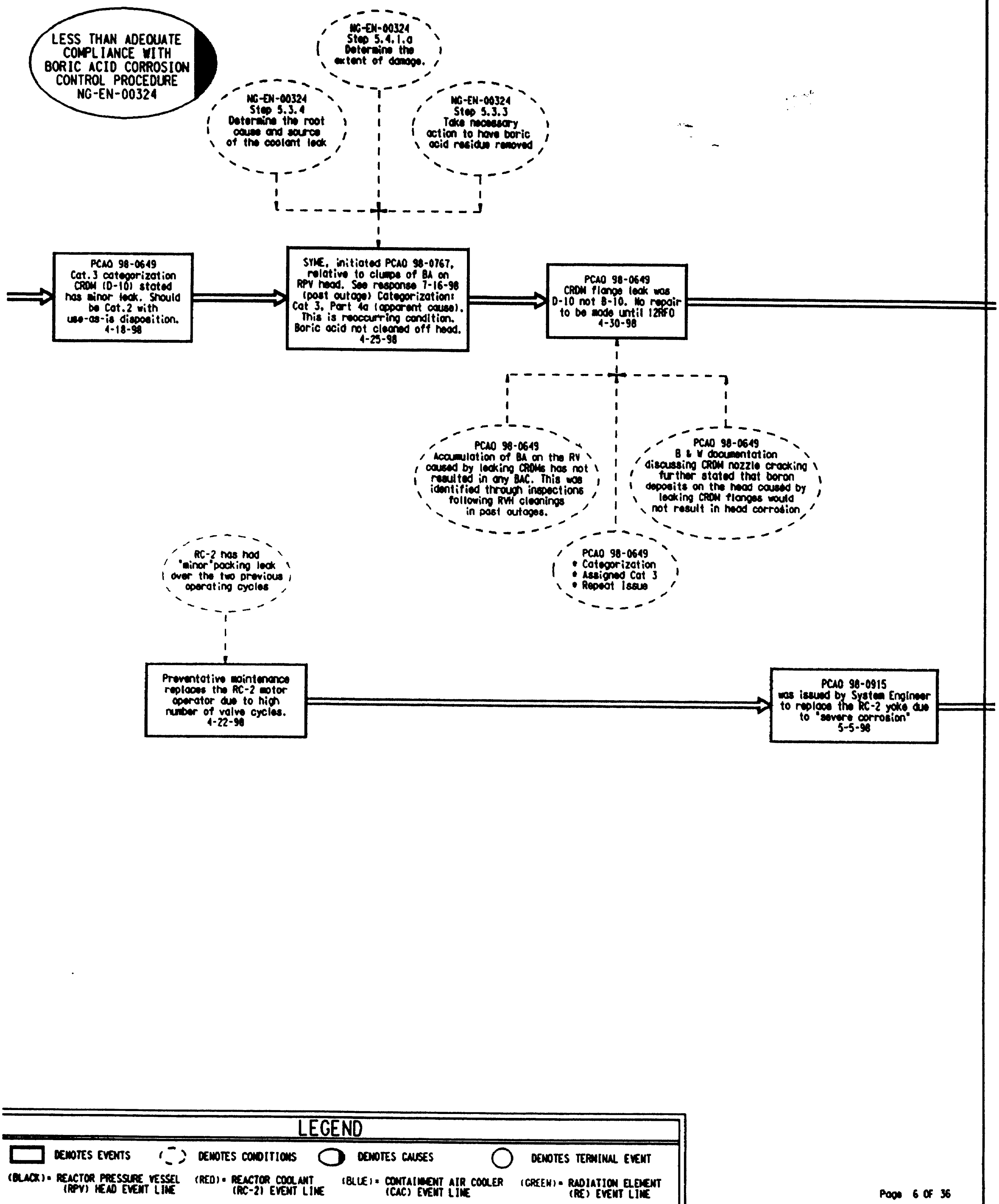

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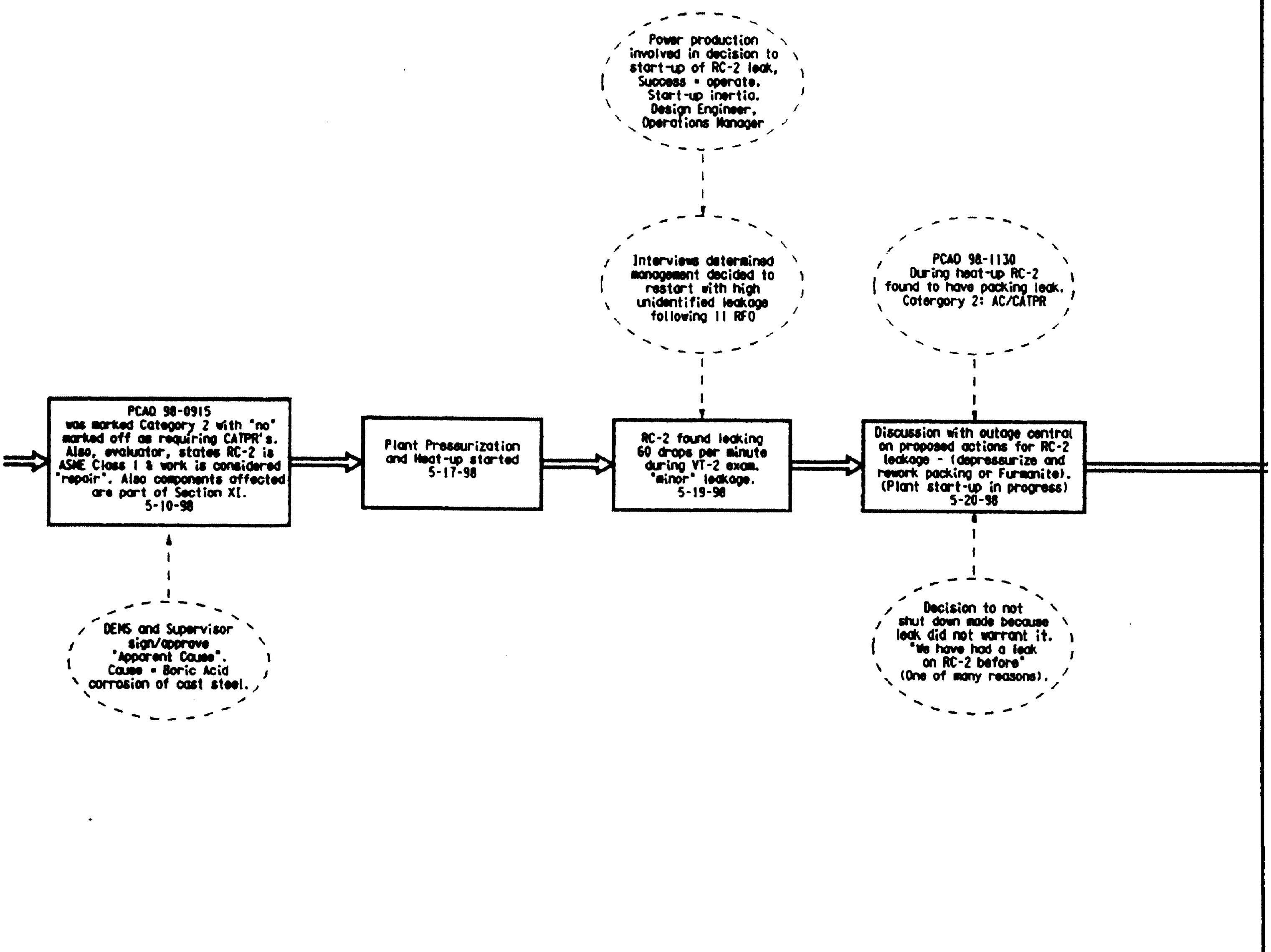


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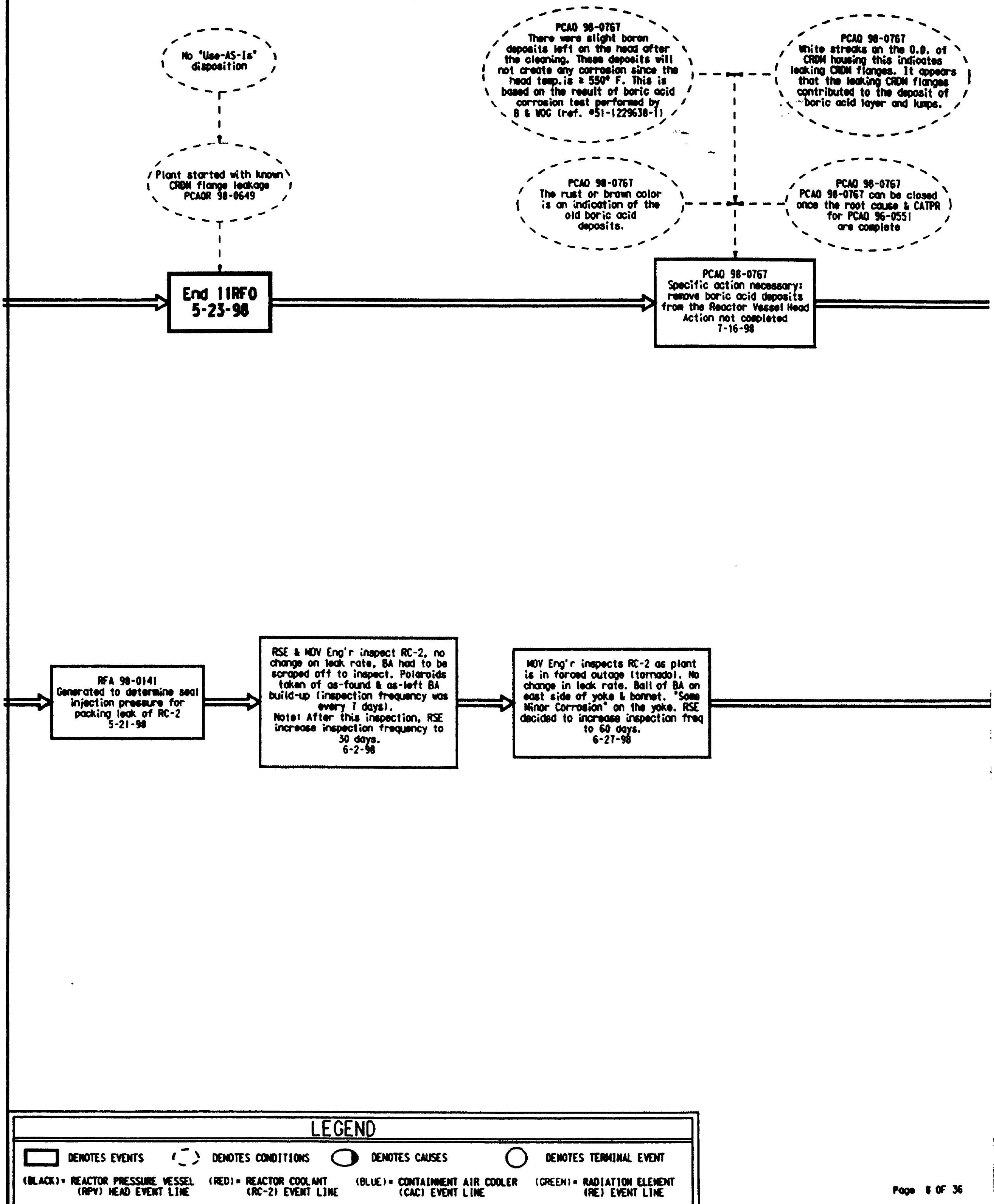

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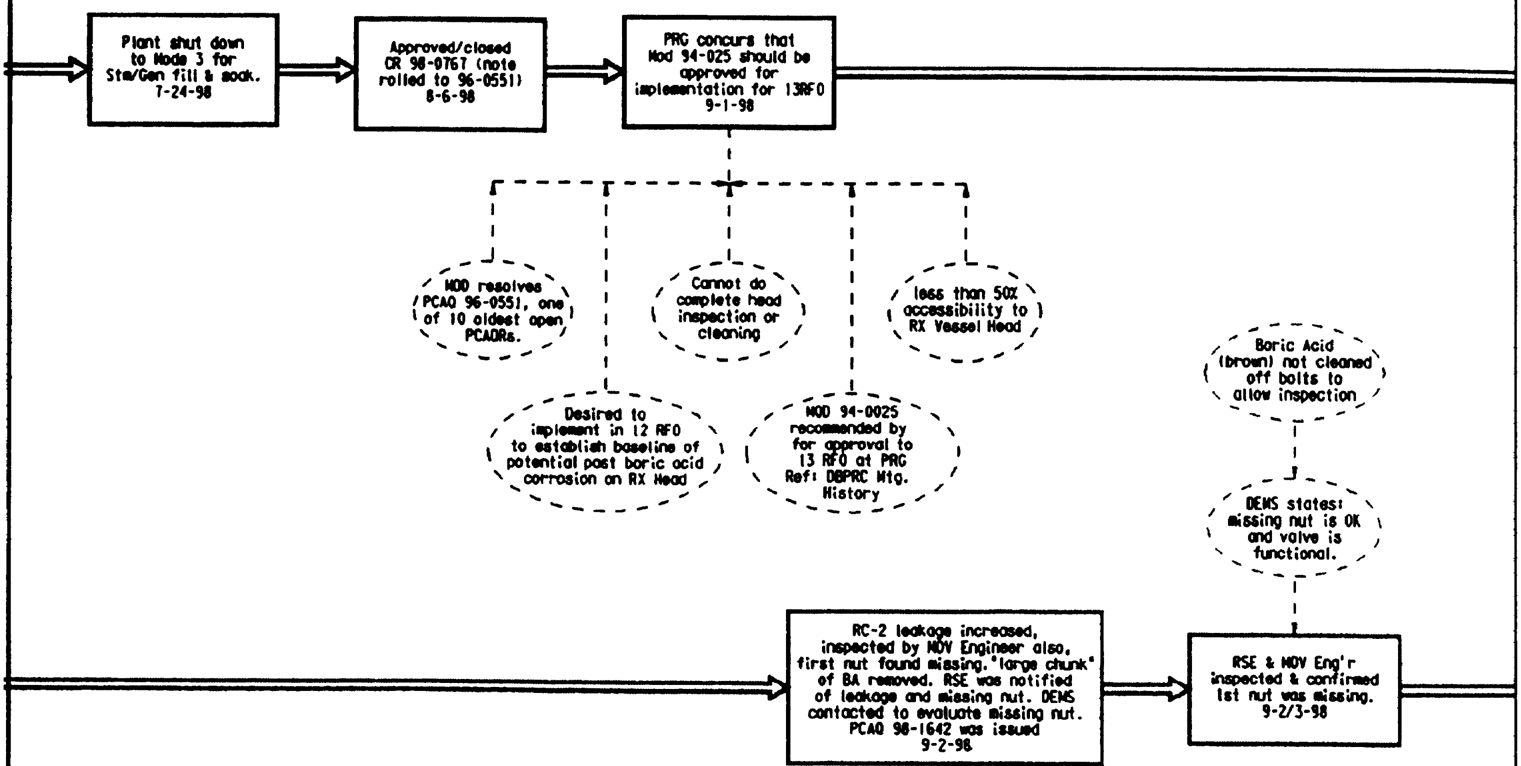


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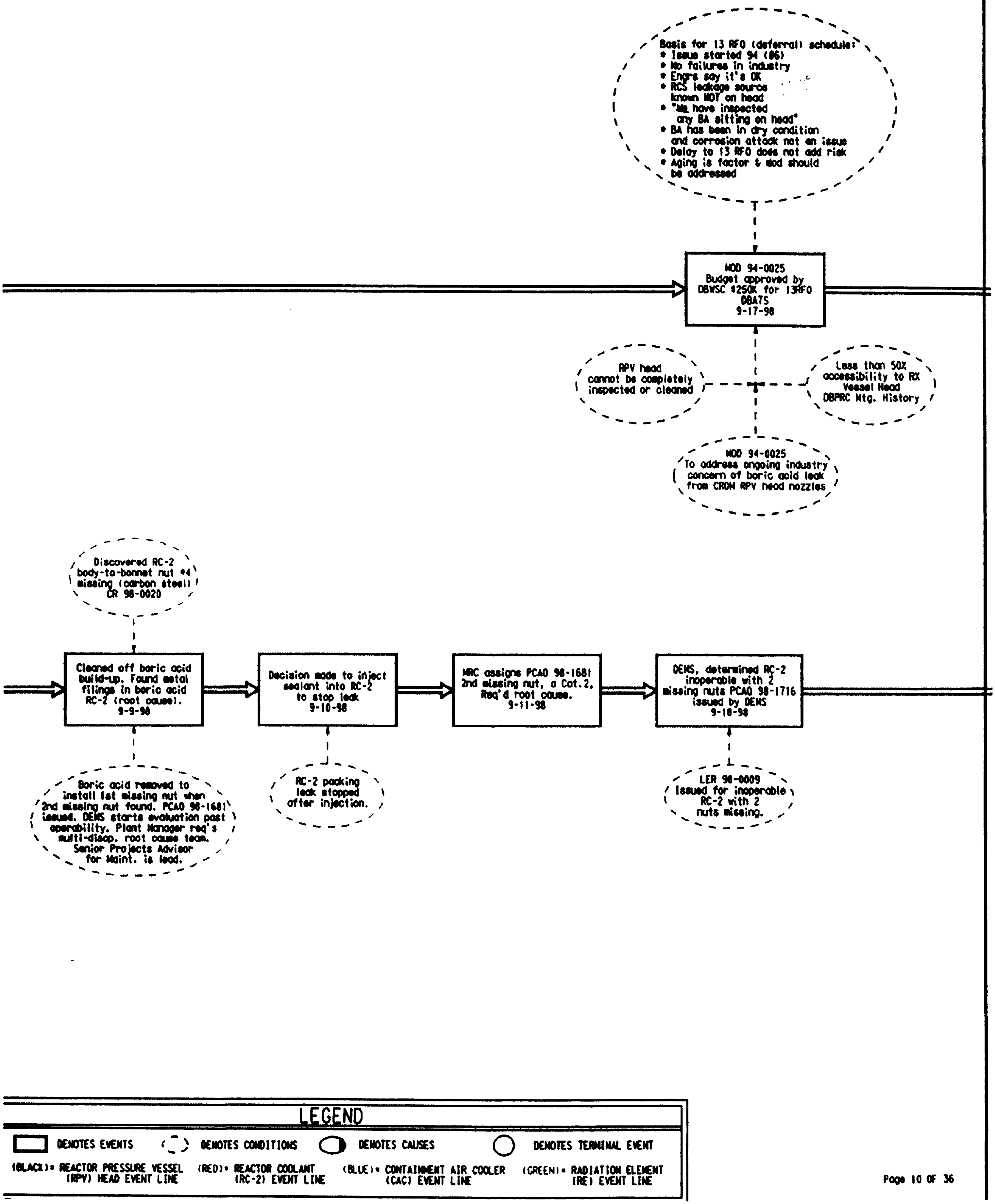

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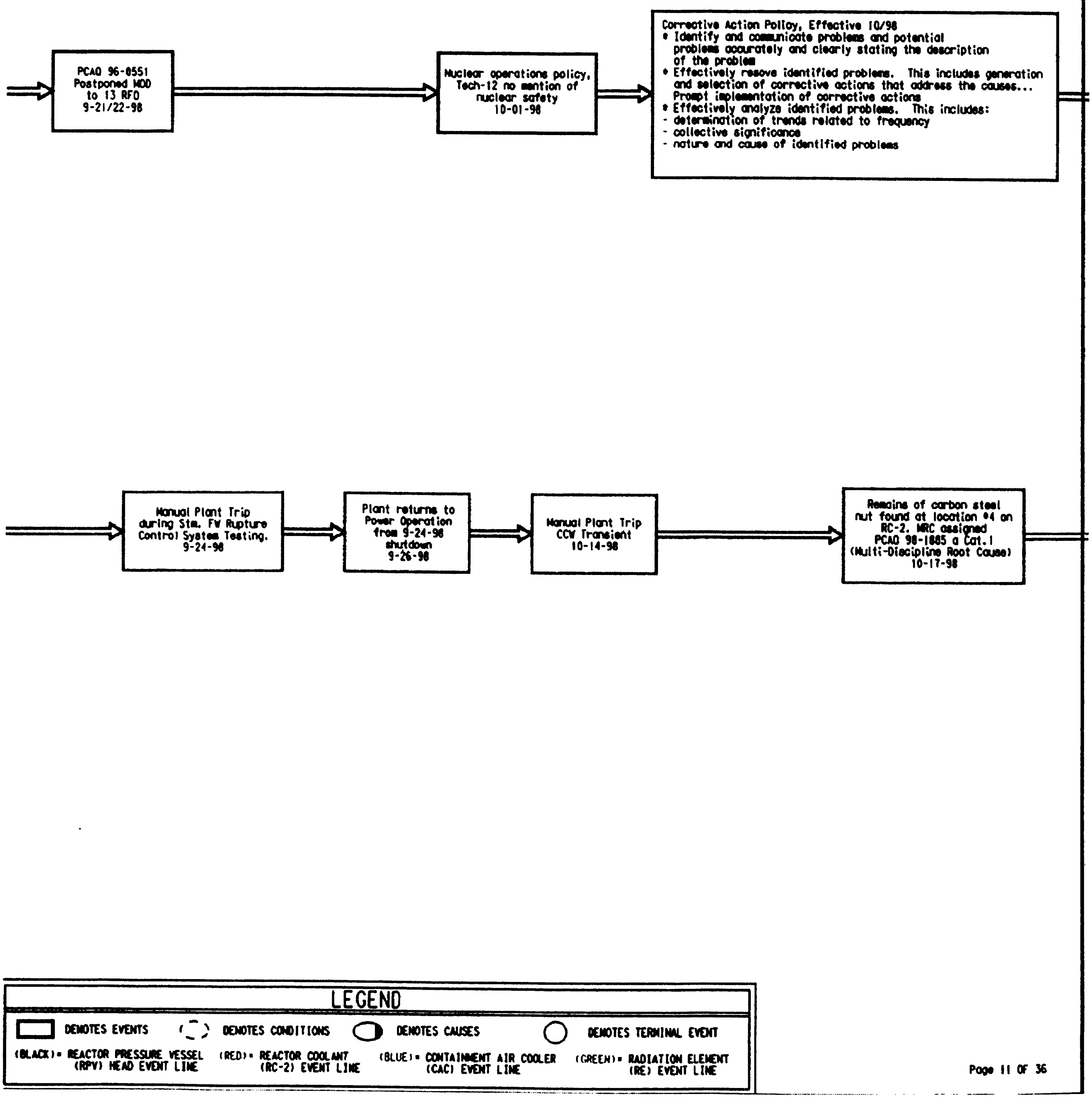

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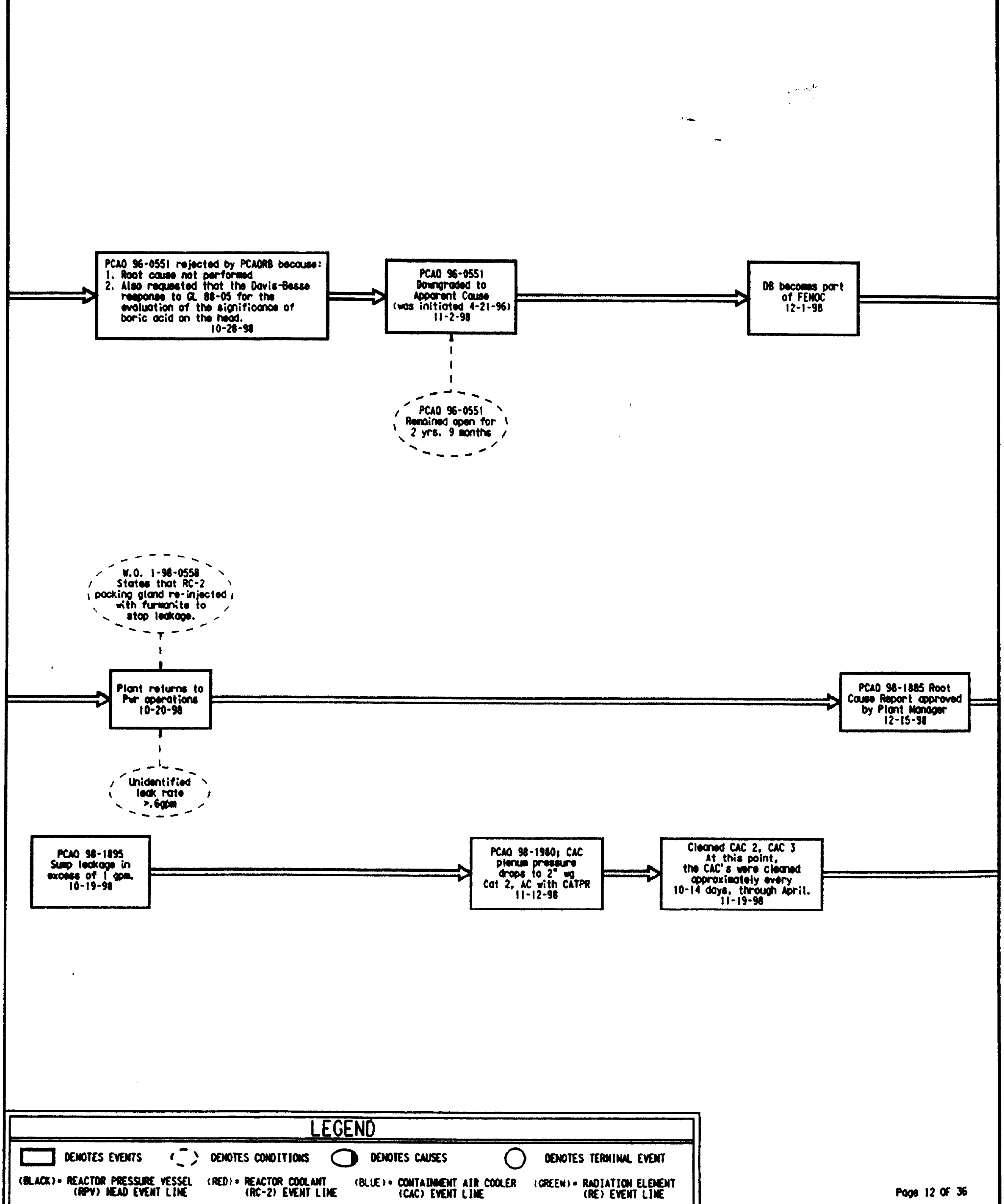

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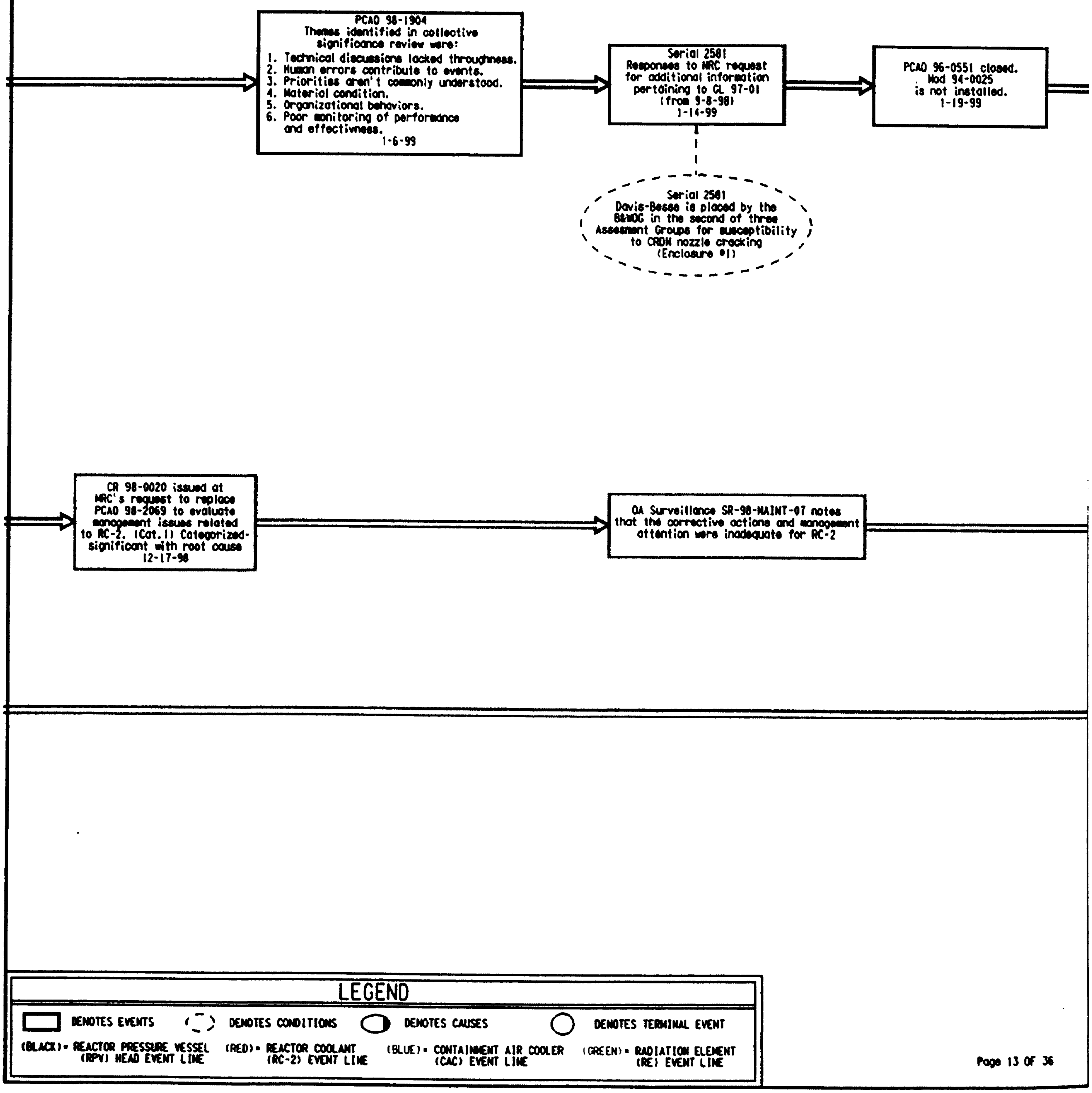

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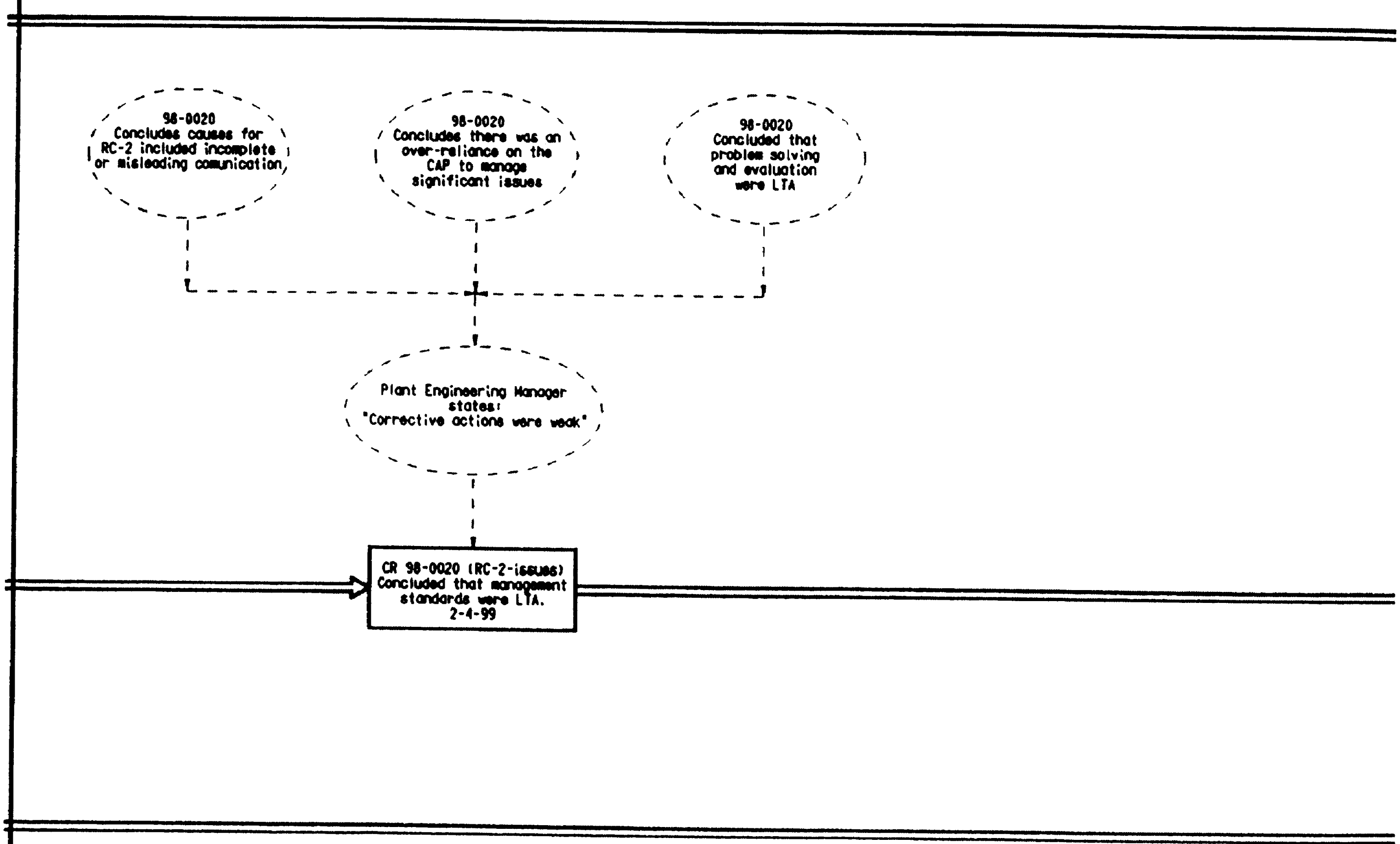


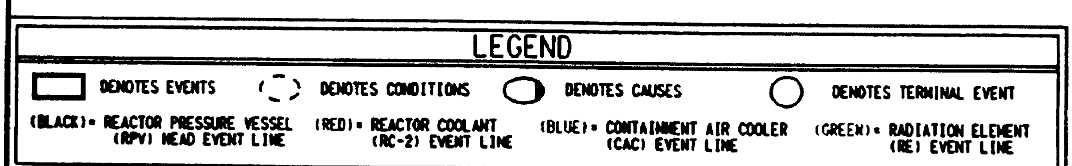

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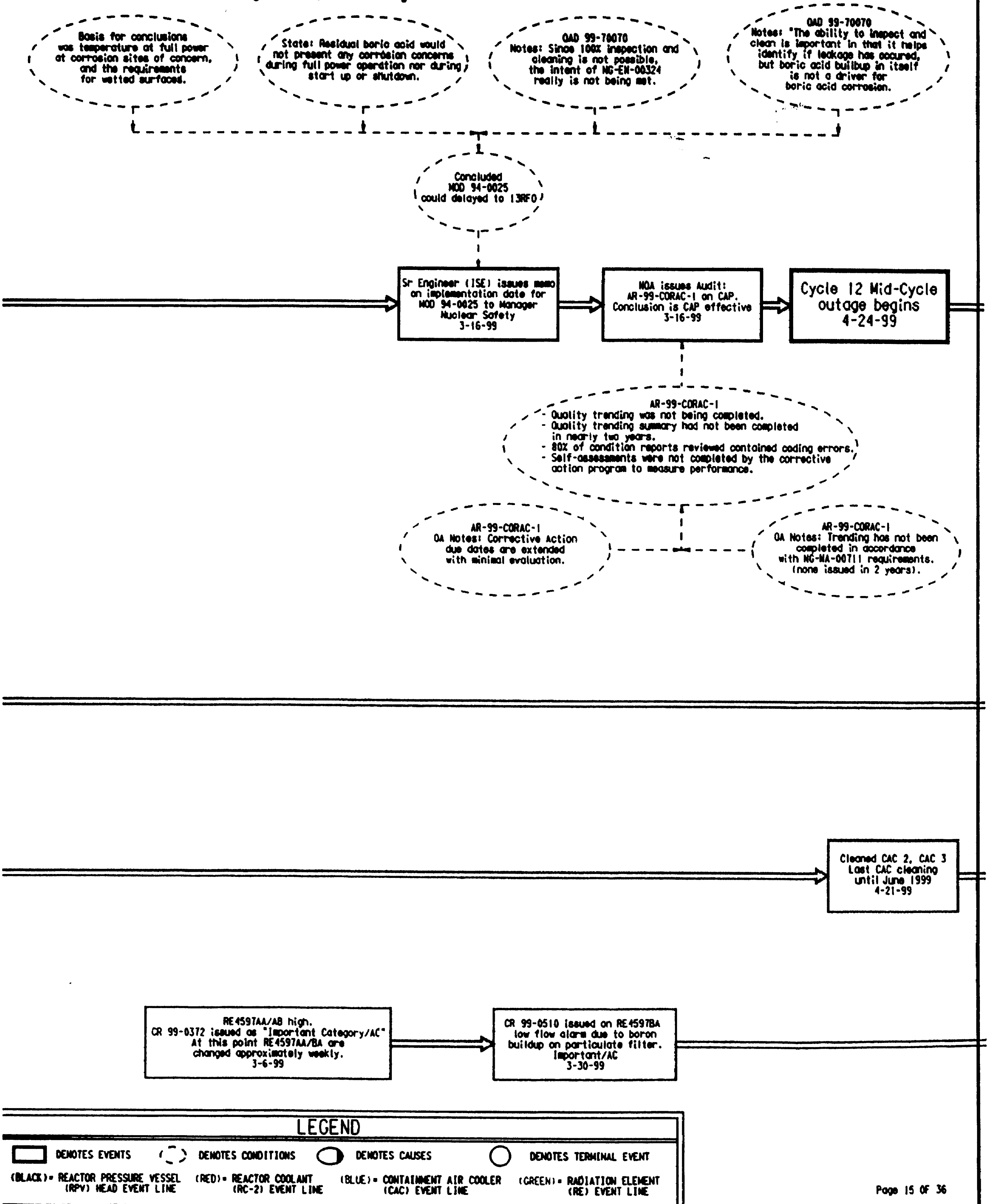

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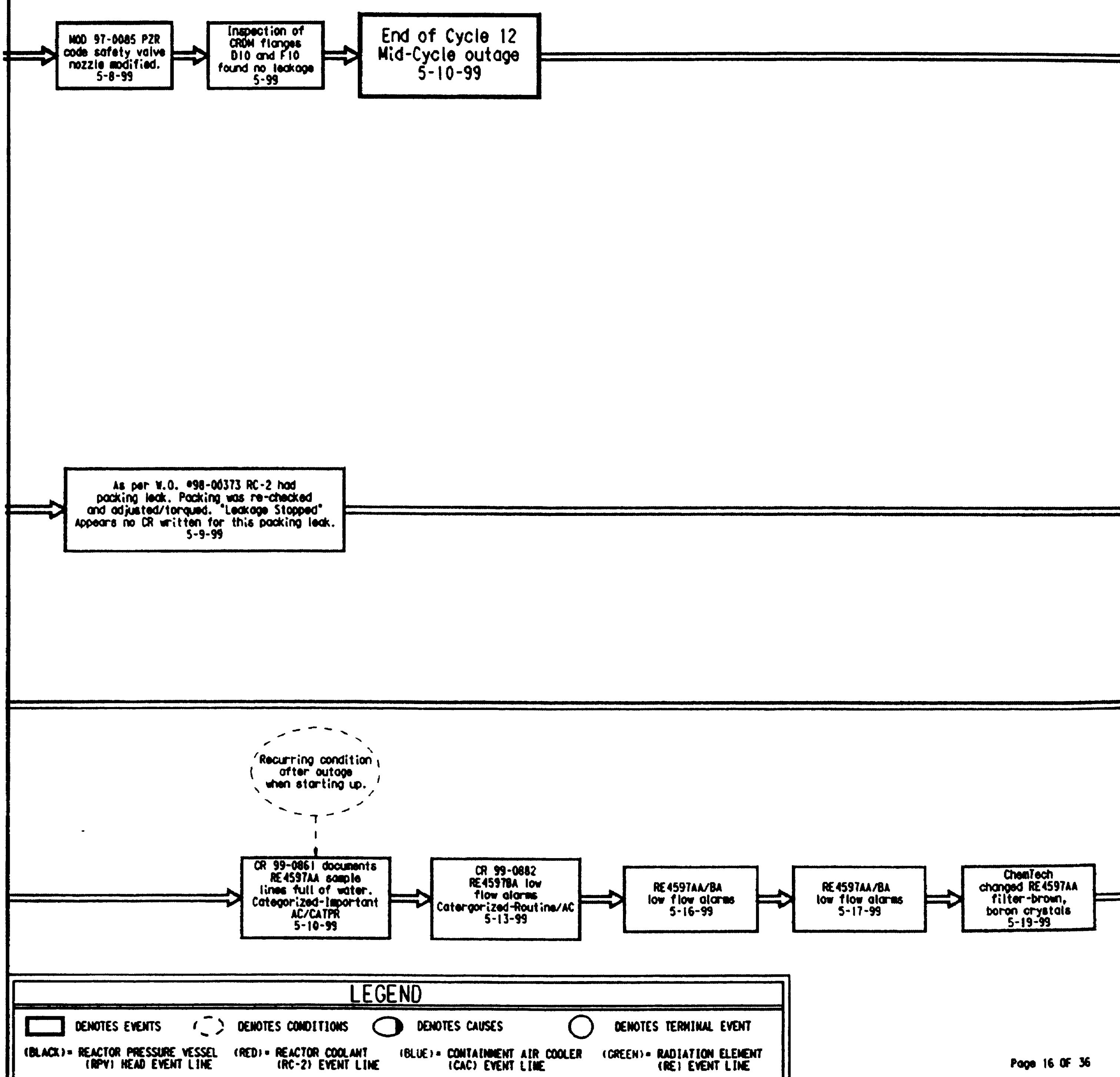

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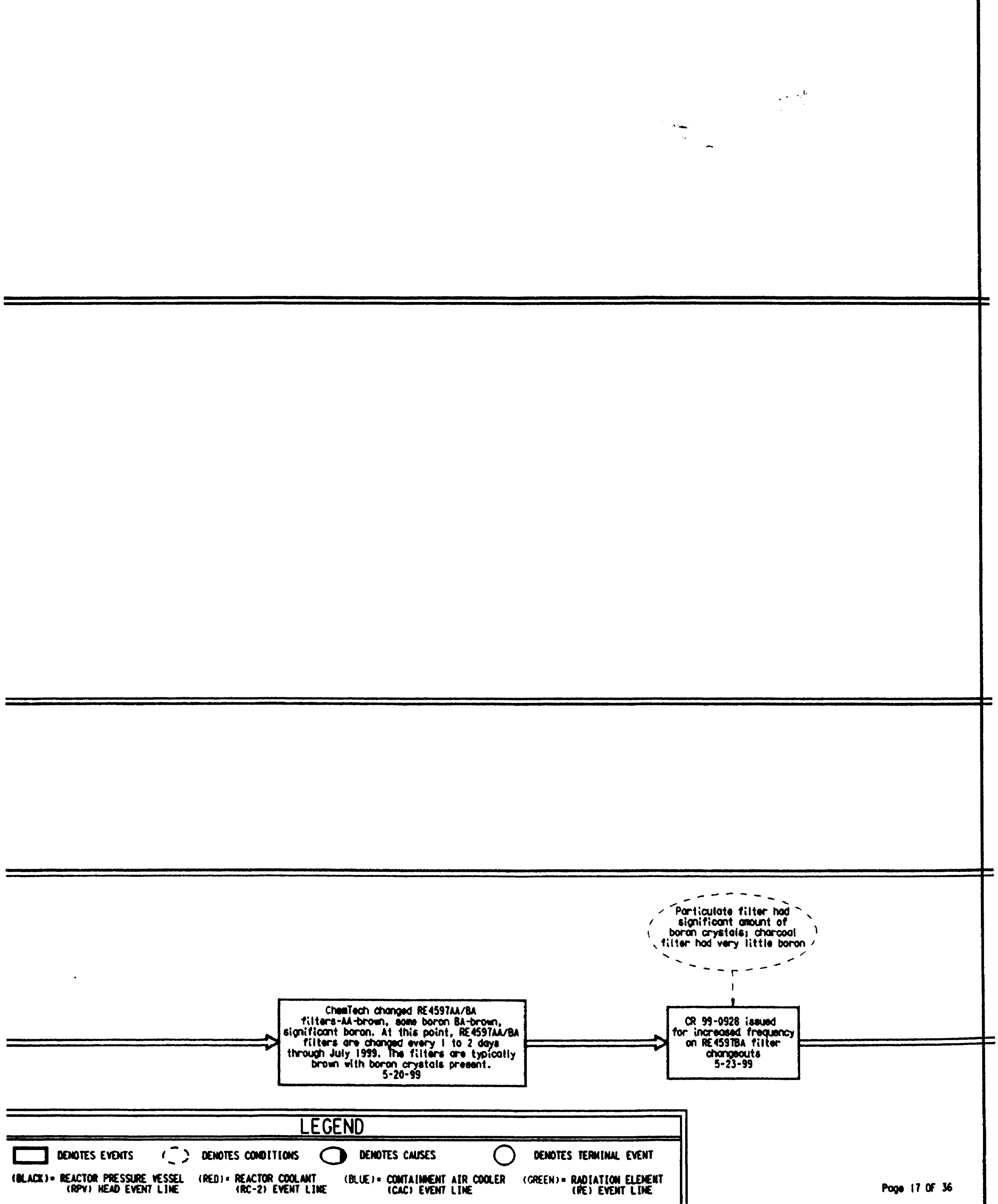

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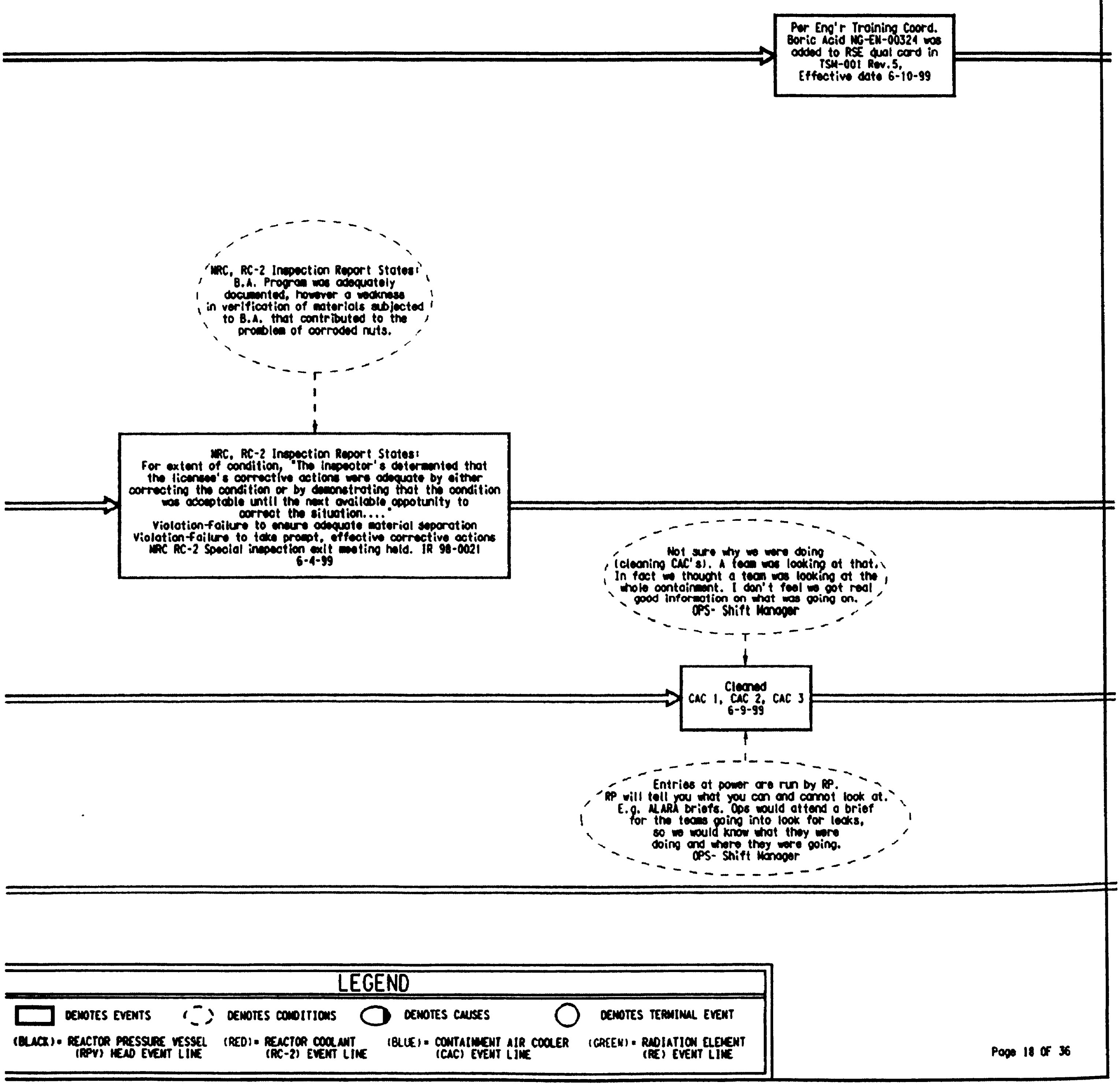

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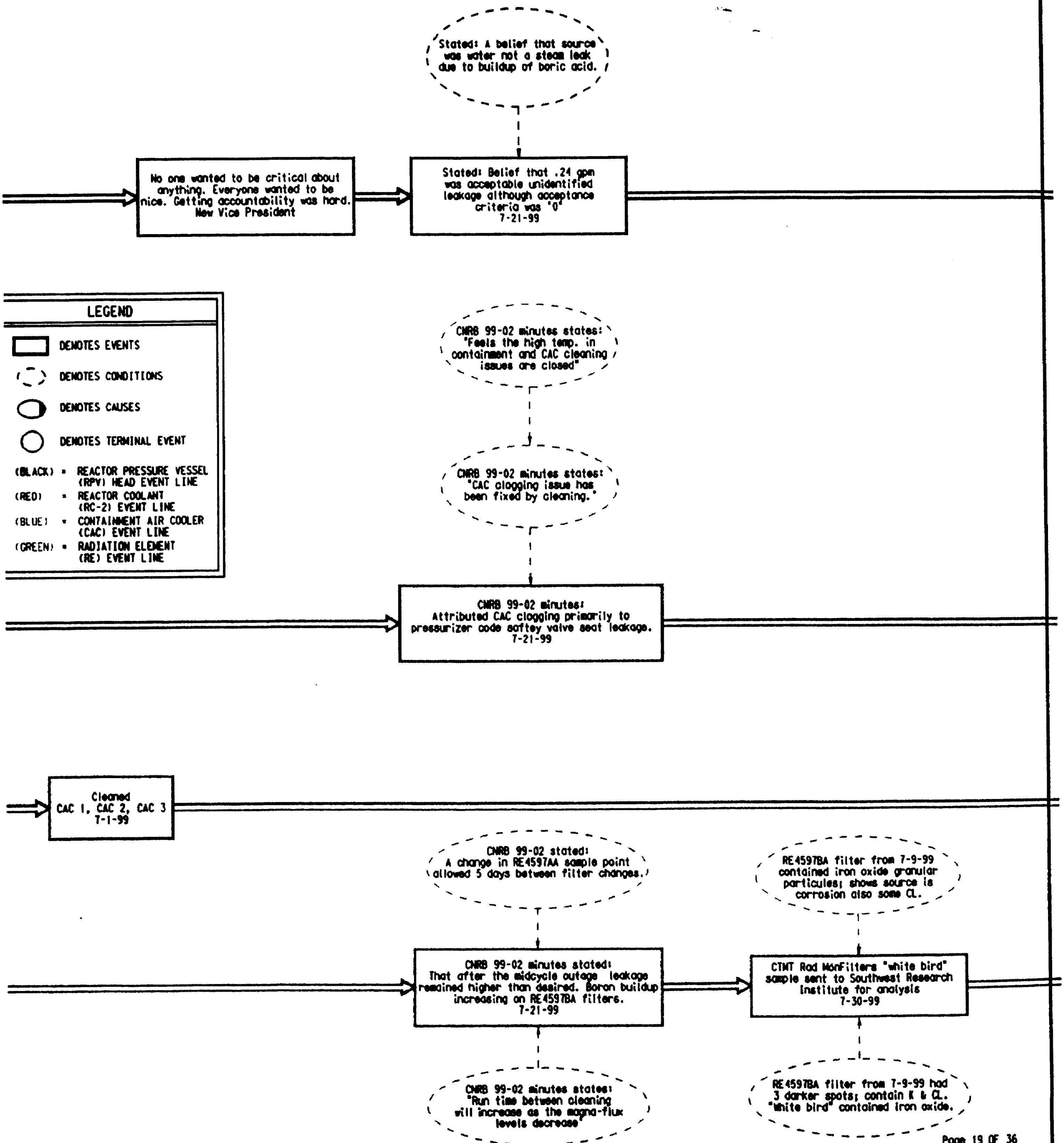

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