INTRA-COMPANY MEMORANDUM
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FirstEnergy

TO H. W. Bergendahl, Vice President - Nuclear

DATE March 22, 2002

FROM S. A. Loehlein, Root Cause Team Leader

MAIL STOP DB3080

SUBJECT Probable Cause Summary Report for CR2002-0891, *Significant Degradation of the Reactor Vessel Head Pressure Boundary*

PHONE DB 8588

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In response to your recent request for a status report on the progress of the Root Cause Investigation into the causes for *the Significant Degradation of the Reactor Vessel Head Pressure Boundary*, attached is the preliminary Probable Cause Summary Report of the Initial Investigative Team for Root Cause.

The full draft report is nearing completion, and should be ready in approximately a week. Should you have any questions or concerns about the content of the attached, please contact me at any time.

SAL:ski

Attachment

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Probable Cause Summary Report

Initial Investigative Team – Root Cause

TEAM CHARTER DETERMINE ROOT AND CONTRIBUTING CAUSES FOR REACTOR PRESSURE VESSEL (RPV) HEAD DAMAGE EXPERIENCED AT NOZZLE #3 AND #2

Development Status of the Root Cause Report

This summary presents the collective judgment of the Root Cause Investigative Team based on the data and evidence that has been characterized at this time in the investigation (current to 3/22/02). The predominant source of visual and measurable evidence currently available is from nozzle #3, and it is sufficient to conclude a Probable Cause for the corrosion experienced on the RPV head. The Root Cause Team believes that the evidence that will be gathered from nozzle #2 in the next few weeks is important to confirm our understanding of the mechanism(s) that led to the larger corrosion region at nozzle #3. It may also provide important additional insight into the initiation mechanism for corrosion at the nozzle/head interface.

Probable Cause

The factors that caused corrosion of the RPV head in the regions of nozzles #2 and #3 are the CRDM nozzle leakage associated with through-wall cracking, followed by boric acid corrosion of the RPV low-alloy steel. Although it is unlikely that the physical evidence will be retrieved to prove what caused the crack(s), the report provides details why Primary Water Stress Corrosion Cracking (PWSCC) is concluded to be the damage mechanism.

Since PWSCC of CRDM nozzles is a known damage mechanism of alloy 600 materials, and similar corrosion as experienced near nozzle #3 has not been reported from this cause at other nuclear plants, the PROBABLE CAUSE does not provide the explanation for the extent of damage that occurred in the evolution of this incident. The Contributing Causes/Causal Factors provide the insight that explains how the consequences of the CRDM nozzle leaks developed.

Contributing Causes

The design of the RPV head/service structure makes access to the top of the head difficult for cleaning and inspection. Deferral of the modification to the service structure for improved access when the modification was first considered resulted in the continued limited ability to prevent significant boric acid accumulations and allow for better visual determination of leakage sources. Since the severity of the damage that occurred to the RPV head is judged to have required years to develop after the initiation of a CRDM nozzle leak, the deferral is considered a CONTRIBUTING CAUSE to the incident.

Probable Cause Summary Report

Initial Investigative Team – Root Cause

Causal Factors

The Root Cause Analysis determined that the major CAUSAL FACTORS that allowed the CRDM nozzle leaks to develop into the corrosion region near nozzle #3 were:

- 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 vessel corrosion was occurring. Evidence available now shows that leakage from the nozzles began 2 to 4 operating cycles ago. Acceptance of the condition of boric acid accumulation on the head was a CAUSAL FACTOR. The investigation concluded that some of the early boric acid accumulation was likely due to CRDM flange leakage, rather than nozzle leakage, but the effect of its accumulation on the head would have been the same regardless of its origin. First, it inhibited inspection of the top of the head and associated nozzles, and secondly, it provided a source of boric acid when leakage from the nozzle provided sufficient moisture to accelerate corrosion.
- Historically, there have been problems with CRDM flange leakage both at Davis-Besse and in the industry. This appears to have obscured the recognition that boric acid accumulation on the RPV head might also be due to nozzle leakage.
- Davis-Besse's boric acid corrosion control program specifically includes the CRDM flanges as an area of concern for the RPV. Potential leakage from CRDM nozzles was not a specific consideration of the program.
- The potential for significant corrosion of the RPV head as a result of accumulating boric acid and local leakage was not recognized as a safety significant issue by the staff and management of the plant. The lack of understanding of this was a CAUSAL FACTOR.
- Containment building related conditions like iron oxide, boric acid and moisture found in radiation monitor filters, boric acid accumulations on the air coolers and boric acid accumulations on the RPV flange were all recognized, but no collective significance was recognized. However, it is not clear if these could have led to the discovery of the problem on the RPV head in time to prevent significant damage.
- Environmental factors, such as temperature conditions and radiation dose, combined with the limited access afforded in the original design of the support structure, and installed head insulation, impeded efforts to inspect and clean the head.

Probable Cause Summary Report

Initial Investigative Team – Root Cause

Other Factors

All three CRDM nozzles that were found to have leaks were located in the center top region of the RPV head. The team was not able to determine how important this location would be to the potential for development of corrosion as a result of an unattended leak, compared to that of a leak that might exist on the steeper sloped regions of the head.

Key Events Timeline

The data analysis results in a most probable timeline of key events that directly led to the development of the corrosion area on the RPV head. The draft report describes how these were determined.

- 1990 (+/- 3 years): CRDM nozzle crack initiated at nozzle #3
- 1994-1996: CRDM nozzle #3 crack propagates through wall of nozzle
- 1998 and 2000: did not identify nozzle leakage on head, nor was boric acid accumulation successfully removed from nozzle #3 region
- 1999: Noteworthy corrosion at nozzle #3 of the RPV head initiated, as evidenced by iron oxide in the Containment atmosphere
- 2002: Significant corrosion discovered on RPV head at nozzle #3, relatively minor damage discovered at nozzle #2

Event dates were established from the baseline determination of when the leak(s) at Nozzle #3 became significant, and were based primarily on the video and photographic evidence of conditions on the head. The evidence places the through-wall leak initiation in the approximate 1994-1996 timeframe. The crack initiation date is an approximation based on expected crack growth rates for an axial crack of the type that formed at nozzle #3.

Rate of Corrosion Propagation

The estimates for how long corrosion was developing on the RPV head were developed from the following key sources:

- 4 years of significant corrosion rates, based on evidence of boric acid accumulation on the head and other visual evidence, such as discoloration of the boric acid deposits, and increasing accumulation on the RPV flange
- Up to 8 inches, maximum progression of the corrosion area (from nozzle #3 toward nozzle #11), based on measurements of the cavity region
- Average rate of 2 inches per year along line from nozzle #3 toward #11
- For the purposes of bounding rate assumptions, a linearly increasing rate results in a maximum rate of 4 inches per year
- Rate in lateral direction is about ½ of that in axial direction

Initial Investigative Team – Root Cause

The estimated corrosion rates are compatible with test results reported in EPRI's Boric Acid Corrosion Guidebook. They are also consistent with the video, photographic, and supporting plant data, that show that significant corrosion was occurring by the 1998 to 1999 timeframe. The size and shape of the corrosion area, combined with the crack size and available boric acid accumulation provides basis that once an adequately sized gap developed between the nozzle and head, the corrosion proceeded primarily in a radial direction.

How Do these Preliminary Results Affect Current Industry Understanding of how to Maintain Plant Safety in Light of the Potential for CRDM Nozzle Cracks

The preliminary conclusions of the Root Cause Team are that the circumstances that led to the significant corrosion of the RPV head at Davis-Besse can be avoided at other PWRs through proper application of existing industry guidance on boric acid leakage management, and monitoring for/correction of CRDM nozzle leakage. This conclusion is based on the evidence that shows that the leak at Davis-Besse had existed long before its detection, but that conditions on the head and other factors delayed its timely identification. Furthermore, the pre-existence of significant accumulation of boric acid provided an environment that may have accelerated initial corrosion rates, once sufficient moisture was available.

It should be noted that there is strong circumstantial evidence that the iron oxide that Davis-Besse began to collect in radiation monitor filters in 1999 was indicative of the RCS leak and corrosion at nozzle #3. As Operational Experience, this information would be potentially beneficial to other plants.

Management and Programmatic Issues

Throughout the investigation, the team identified issues that relate to programmatics. Owing to the team's charter to provide an initial investigation of the event's causes, many of these issues could not be fully developed as part of the early investigation. Several of the important issues are reflected in the CONTRIBUTING CAUSES and CAUSAL FACTORS listed above. The rest are under development.