From: <rritzman@firstenergycorp.com>
To: <erd@nrc.gov>
Date: Wed, May 2, 2007 5:46 PM
Subject: FENOC response to April 2 letter

Attached is the FENOC response to the Exponent Report questions from the NRC April 2 letter

(See attached file: Exponent Report RAI Approved Copy.pdf)

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F-184

FENOC

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United States Nuclear Regulatory Commission
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Subject: **Request for Response Regarding Report Prepared by Exponent Failure Analysis Associates and Altran Solutions Corporation Regarding Reactor Pressure Vessel Head Wastage at the Davis-Besse Nuclear Power Plant**

On March 20, 2007, the FirstEnergy Nuclear Operating Company (FENOC) submitted a report prepared by Exponent Failure Analysis Associates and Altran Solutions Corporation (Exponent) regarding the Davis-Besse Reactor Vessel Head wastage event to the Nuclear Regulatory Commission (NRC). By letter dated April 2, 2007, the NRC requested a response to four specific issues and a confirmation that the information Exponent provided during the referenced conference calls has not changed, and that the response be provided by May 2, 2007.

FENOC's responses to these four issues are included as Attachment 1 to this letter. These responses are consistent with the information previously provided to the NRC. While additional details are contained in Attachment 1, the technical information previously provided by Exponent has not materially changed.

The April 2, 2007, letter from the NRC states:

> Exponent stated that: (1) no new information was identified in their report that the NRC was not already aware of and was not already readily available;...

As previously stated during the conference calls referenced in the April 2, 2007, letter, the development of the Exponent Report relied upon data that was not known at the time the FENOC Root Cause Report was finalized in August 2002.

The most significant of this data was the metallurgical examination of the Davis-Besse Control Rod Drive Mechanism (CRDM) Nozzle 3 nozzle, weld and cavity, the NRC/Argonne National Laboratory (ANL) crack growth measurements on the Davis-Besse Nozzle 3 Alloy 600 CRDM material, and the NRC/ANL data on the corrosion of low alloy steels in molten metaboric acid. This data was either developed by or later made available to the NRC. The purpose of the Exponent Report was to collect and analyze this information, and the report does make new findings and conclusions.

Future information generated relative to the Exponent Report will be available for NRC review. It should be noted that the Exponent Report is investigative in nature, and was developed using sound, contemporary engineering techniques to determine how research performed by the NRC and others may impact perspectives on the event. The Exponent Report was not intended to be a licensing basis document and, therefore, was not developed under the FENOC design control process.

Attachment 2 identifies that there are no commitments contained in this response. If you should have any questions regarding the content of this letter, please contact Mr. James J. Powers, Director, Fleet Engineering, at (330) 384-4930.

Sincerely,

Danny L. Pace
Senior Vice President, Fleet Engineering

Attachments (2)
1. Response to Request for Written Response
2. Commitment List

CC: NRC Project Manager – Davis-Besse Nuclear Power Station
NRC Resident Inspector - Davis-Besse Nuclear Power Station
NRC Regional Administrator – Region III

Response to Request for Written Response

NRC Request 1:

"provide your perspective on the overall conclusions and assumptions in the Exponent Report, as well as any assessments or interpretations of the Exponent Report provided to you by others and your response(s) thereto;"

FENOC Response:

The Exponent Report was prepared at FENOC's request in support of an on-going insurance claim with Nuclear Electric Insurance Limited (NEIL) and was transmitted to the NRC on March 20, 2007. As set forth below in response to NRC Request 2, the analyses of the Davis-Besse Control Rod Drive Mechanism (CRDM) cracking and Reactor Pressure Vessel (RPV) head degradation in the Exponent Report were developed using information that has been published by the NRC and the industry over the last several years, subsequent to the 2002 submission of the FENOC Root Cause Report and Licensee Event Report (LER) for the event.

As also discussed below in response to NRC Request 2, the conclusions in the Exponent Report with respect to the underlying root causes of the RPV head degradation at Davis-Besse are consistent with the root causes identified by the FENOC Root Cause Report, with the exception that Exponent concluded that the degradation time line was more rapid than originally believed five years ago. FENOC has entered the Exponent Report into the Corrective Action Program, has evaluated the conclusions, and believes that the Exponent organization has set forth an informed analysis that more accurately characterizes the timeline of the reactor head degradation event based on their use of more recently available test data in conjunction with detailed analytical modeling. FENOC has not specifically evaluated all of the assumptions used by Exponent; however, FENOC believes that the conclusions in the Exponent Report reflect a more accurate representation of the timing of the events.

Since the Exponent Report outlined a different perspective on the evolution of the event based on recent research findings, it was provided to the NRC and the Nuclear Energy Institute (NEI). NEI organized a review by an expert panel for the Materials Executive Oversight Group (MEOG) to assess current inspection guidance in light of the conclusions identified in the report. Thus far, there have been no inspection guidance changes or generic safety implications identified; the report summarizing the results of the expert panel review is expected to be completed in

mid-May. Since the matters discussed in the Exponent Report are involved in the insurance arbitration and other litigation, there will be further assessments and interpretations of this report.

NRC Request 2:

"discuss any differences between the Exponent Report information and conclusions drawn therein, and information previously provided in your Root Cause Analysis Report and Licensee Event Report for the Davis-Besse reactor pressure vessel head wastage event. Provide your evaluation of any differences, including which views you conclude are correct, and the rationale for your conclusions;"

FENOC Response:

First, it should be noted that the conclusions of the FENOC Root Cause Report that "leakage from PWSCC [Primary Water Stress Corrosion Cracking] cracks was a necessary precursor to the material loss adjacent to nozzles 2 and 3," and that "these leaks led to local environmental conditions that produced modest material loss around nozzle 2 and much more extensive degradation around nozzle 3," remain valid, and are supported by the Exponent Report. Thus, there is no difference between the FENOC Root Cause Report and the Exponent Report as to the underlying root causes of the RPV head degradation at Davis-Besse.

Similarly, the LER, which was based on the FENOC Root Cause Report, Revision 0, dated April 15, 2002, stated, under "Apparent Cause of Occurrence," that "the probable cause of the axial through-wall flaws was PWSCC in the CRDM nozzle due to material susceptibility in the presence of a suitable environment," and that the "root cause of the degradation of the RPV head is boric acid corrosion resulting from CRDM nozzle leakage over a significant period of time...." Again, there is no difference between the LER and the Exponent Report as to the underlying root causes of the RPV head degradation at Davis-Besse.

The principal and most significant difference between the Exponent Report information and conclusions, and information and conclusions presented in both the LER and the FENOC Root Cause Report, is in the detailed timeline for crack growth, reactor coolant leakage, and wastage cavity development at Davis-Besse CRDM Nozzle 3. As discussed in detail below, the Exponent Report concludes that the timelines for both the crack growth at CRDM Nozzle 3 and the resulting development of the wastage cavity were substantially shorter than those presented in the FENOC Root Cause Report and LER. The Exponent Report further concludes that the development of the large wastage cavity was the result of a unique, unexpected and unforeseeable set of circumstances,

including, but not limited to, a very high crack growth rate for the Alloy 600 nozzle material, the presence of a very large weld crack which significantly increased leakage and metal removal rates late in Cycle 13, and high corrosion rates caused by molten boric acid previously thought to be innocuous to low alloy steel.

The FENOC Root Cause Report stated that "a reasonable time-frame for the appearance of leakage on the RPV head at Davis-Besse is approximately 1994 - 1996. Utilizing an average PWSCC crack growth rate of approximately 4 mm/year through the 16 mm thick CRDM nozzle material, the timeframe at which crack initiation occurred would correspond to approximately 1990 ± 3 years." The FENOC Root Cause Report further stated that the corrosion rate began to increase significantly starting at about the eleventh Refueling Outage (RFO) and acted for a four year period of time.

The investigation that formed the basis for the FENOC Root Cause Report did not have the benefit of three critical items of technical information that became available years later and which, in part, formed the basis for the Exponent Report. These items are:

- The detailed test data published by the NRC/Argonne National Laboratory (ANL) in November 2006 that provided definitive information on the specific crack growth rates for the Davis-Besse CRDM Nozzle 3 Alloy 600 material.

- The results of the detailed metallurgical examinations of the nozzle remains, weld region, and large wastage cavity from CRDM Nozzle 3. This not only provided invaluable information on the nozzle, weld, and cavity, it also identified a previously unknown large weld crack at Nozzle 3. This weld crack was in line with the wastage cavity, had not been found during the non-destructive examination (NDE) inspection prior to the nozzle removal, and clearly contributed significantly to leakage and cavity growth once it was uncovered late in the sequence of events. The results of this metallurgical examination were not available until June 2003.

- The boric acid corrosion data published by the NRC/ANL in July 2005 for corrosion rates in re-wetted molten metaboric acid for thermal-hydraulic conditions that were thought to be present in the annular crevice and wastage cavity during the evolution and growth of leakage of the wastage cavity at Davis-Besse CRDM Nozzle 3.

The impact of these data on the definition of the timeline for crack growth and wastage cavity development was likewise three-fold. First, the crack growth rate data reported by the NRC/ANL program in 2005 was a key input to the fracture mechanics analysis and the development of the more definitive timeline for the growth of the axial crack at Davis-Besse Nozzle 3 CRDM presented in the Exponent Report.

Second, the detailed metallurgical examination of the CRDM Nozzle 3 tube and weld and the identification of the large weld crack at Nozzle 3 was a key input into the analysis of the nozzle and weld crack leakage flow presented in the Exponent Report.

Third, the 2005 NRC/ANL report on boric acid corrosion test data presented for the first time some definitive information on the conditions under which molten metaboric acid, which was previously thought to be non-corrosive to low alloy steel due to the absence of moisture, could in fact lead to high corrosion rates under thermal-hydraulic conditions that allowed moisture to be present.

Moreover, in discussing the possible causes of material loss that led to the wastage cavity formation, it was noted in the FENOC Root Cause Report that "given the current limited experimental data applicable to the observed degradation and the lack of existing detailed analytical calculations of the thermal-hydraulic and thermo-chemical environment along the nozzle leak path, it is not possible to definitely state the exact progression of mechanisms that led to the observed material loss."

Thus, it was acknowledged in the FENOC Root Cause Report that there were uncertainties in the timeline for wastage cavity formation, and recognized that further investigation and the development of additional information by the industry would be needed to develop a more definitive explanation and timeline for the cavity development.

In the Exponent Report, it was noted that experimental data and detailed analytical calculations related to the thermal-hydraulic conditions in the annulus and developing wastage cavity were not available when the FENOC Root Cause Report was developed. In the Exponent Report, it was further noted that:

> "...it was clear that in order to develop a more complete and accurate explanation and a more definitive sequence of events timeline, we would need to at least begin to tackle the major task identified by the root cause team. This was the development of a more quantitative understanding of the thermal-hydraulic conditions

in the annular crevice and the wastage cavity over time, in order to better assess the potential for different metal removal processes and rates to exist at different times. We undertook the CFD [Computational Fluid Dynamic] modeling work with this objective in mind."

Thus, in developing the timeline of the wastage cavity development at Davis-Besse CRDM Nozzle 3, part of the Exponent investigation and analysis was to undertake detailed CFD modeling to provide information on the thermal-hydraulic conditions in the developing wastage cavity. This CFD modeling work provided new results and findings that were not available at the time of the FENOC Root Cause Report, and, in fact, was one of the key missing inputs to the timeline development that the FENOC Root Cause Report identified.

Based on the new data described above and on detailed stress, fracture mechanics and CFD analyses, the following conclusions regarding the timeline for crack growth and RPV head degradation that are different from those discussed in the FENOC Root Cause Report and LER were noted in the Exponent Report:

- Based on the stress and fracture mechanics analyses described in the Exponent Report, Exponent concluded that the axial crack at CRDM Nozzle 3 reached the top of the weld and began leaking in mid-1999, in the middle of Cycle 12, and further, that a through-wall CRDM nozzle crack would have developed in a little over three years. This crack growth timeline is substantially shorter than that presented in the Root Cause Report.

- In the Exponent Report, it was concluded that during 12RFO, in April-May 2000, this crack at CRDM Nozzle 3 would have grown to approximately 0.6 inch above the weld, and that leakage from this crack would have been miniscule.

- In the Exponent Report, it was further concluded that the boric acid accumulation on the RPV head at Nozzle 3 from this leakage would have been less than 1 cubic inch, and that while this small amount of boric acid may have been visible had it not been obscured by much larger deposits of boric acid from leaking CRDM flanges, degradation of the RPV head low alloy steel would not have been visible during 12RFO with "through-the-mouse-hole" video inspection techniques even if the RPV head had been completely cleaned of boric acid deposits. In addition, complete cleaning of the boric acid accumulation from the RPV head at this time would

also have removed the very small amount of boric acid that originated from the CRDM nozzle crack, making it unlikely that the wastage cavity would have been detected.

- With respect to the timeline of cavity growth at CRDM Nozzle 3, it was concluded in the Exponent Report that the downward cavity growth accelerated in the May-October 2001 time period, as the leak rate increased and moisture penetrated into the cavity. The downward growing cavity intersected with the upward growing crack late in 2001, resulting in the rapid removal of the remaining one inch of RPV head metal above the weld and the beginning of under-cutting of the cavity at the leak location. This process then suddenly uncovered the large pre-existing weld crack, resulting in a rapid increase in leak flow, causing the large wastage cavity to develop between October-November 2001 and February 2002 when it was discovered during 13RFO.

Although the exact timing and sequence of the Reactor Vessel Head wastage event will never be known with exact certainty, Exponent has set forth an informed analysis using more recently available test data in conjunction with detailed analytical modeling and sound engineering techniques. FENOC believes that this analysis more accurately characterizes the timeline of the reactor head degradation event than the Root Cause Report developed in 2002. The reason that they are different from the conclusions set forth in the FENOC Root Cause Report and the LER is that the conclusions in the Exponent Report are based on data commissioned by the NRC that has become available since 2002, and on crack growth and CFD analyses performed by Exponent that were completed based on these data.

NRC Request 3:

"discuss any implications, or lack thereof, regarding the adequacy of both the specific and more broad-based corrective actions for the Davis-Besse reactor pressure vessel head wastage event, as well as for the closure of the NRC's Confirmatory Action Letter (CAL) 3-02-001 items. Specifically provide the rationale for your conclusions regarding the adequacy of the corrective actions;"

FENOC Response:

FENOC conducted a review of the corrective actions from the original Root Cause Reports and the actions that closed the Confirmatory Action Letter. The conclusion of this review was that the principal technical root causes of the cracking and subsequent degradation remain in agreement between the two reports. As previously discussed, the root causes of

PWSCC of the CRDM Alloy 600 nozzle material and material loss from the RPV head as a result of leakage from cracked nozzles is consistent in both reports.

The rationale used in the review was focused on the conclusions in the Exponent Report related to the timeline aspect of the degradation. The conclusion of this part of the review was that none of the specific or more broad-based corrective actions for the Davis-Besse RPV head wastage event are affected by the more rapid timeline for the head wastage that the Exponent Report sets forth.

The corrective actions, both completed and on-going, are adequate to assure the safe operation of the Davis-Besse Nuclear Plant. No modifications to any of the corrective actions were determined to be necessary for either the root cause corrective actions or the subject Confirmatory Action Letter as a result of the Exponent Report.

In addition, the Exponent report was submitted to an Expert Panel convened by the NEI Materials Executive Oversight Group (MEOG) for evaluation of the conclusions relative to current industry guidance and to determine whether there are any generic safety implications that result from the conclusions of the report. Thus far, there have been no inspection guidance changes or generic safety implications identified; the report summarizing the results of the expert panel review is expected to be completed in mid-May. The applicable FENOC programs are in compliance with industry guidance; therefore, no changes are anticipated.

NRC Request 4:

"discuss whether you intend to revise your Root Cause Analysis Report and Licensee Event Report, and the rationale for that decision. Also address actions, if any, you are taking to share and evaluate the information in the Exponent Report with other plants and industry groups."

FENOC Response:

As previously stated, the conclusions included in the Exponent Report support the Root Cause Analysis Report and LER conclusions that the root cause of the cracking at CRDM Nozzle 3 was determined to be PWSCC; and that the root cause of the RPV head degradation was the leakage of reactor coolant from these cracks. As discussed in detail previously in the response to NRC Request 2, the Exponent Report includes the conclusion that the development of the large wastage cavity was the result of a unique, unexpected and unforeseeable set of circumstances.

FENOC does not intend to revise the Root Cause Analysis Report. The Exponent Report was developed with the benefit of four additional years of research and data accumulation, and was based on analyses that were not available in 2002. Additionally, the industry has on-going research and other activities to develop additional understandings of both Alloy 600 cracking and boric acid wastage of low alloy steel components such as RPV heads. Consequently, it is expected that reports based on contemporary and relevant information will continue to be published, and it would not serve either the industry or Davis-Besse to continually update the Root Cause Report in light of such new information in an attempt to maintain a legacy report current.

Noting the timeline difference described in FENOC's response to NRC Request 2 above, the LER, as mentioned earlier, was reviewed and accurately reflects the underlying root causes of the Davis-Besse RPV head wastage event. Additionally, as discussed above in FENOC's response to NRC Request 3, there are no changes required to either the specific or broad-based corrective actions taken by FENOC as a result of the Exponent Report. Hence, no supplement or revision to the LER is deemed necessary.

Finally, the Exponent Report has been shared with NEI and the Institute for Nuclear Power Operations, as well as the NRC. In addition, NEI discussed the Exponent Report with the Electric Power Research Institute (EPRI). FENOC believes that this comprehensively involves the US nuclear power industry such that materials programs and related regulation can benefit from a contemporary review and analysis of the Davis-Besse Reactor Vessel Head wastage event.

Commitment List

The following list identifies those actions committed to by FirstEnergy Nuclear Operating Company (FENOC) for the Davis-Besse Nuclear Power Station, Unit No. 1. Any other actions discussed in the submittal represent intended or planned actions by FENOC. They are described only as information and are not regulatory commitments. Please contact Mr. James J. Powers, Director, Fleet Engineering, at (330) 384-4930 with any questions regarding this document or associated regulatory commitments.

Commitment	Due Date
None	N/A