From: Eric Duncan
To: Anne Boland; Bill Bateman; Bruce Boger; Charles Weil; Cynthia Pederson; David Hills; Deborah Jackson; Eric Duncan; Gary Shear; Geoffrey Grant; Geoffrey Wright; Gregory Cwalina; James Caldwell; James Davis; James Heller; James Wiggins; Jared Heck; Jay Collins; Jim Dyer; John Grobe; John Jandovitz; John Rutkowski; John Tsao; Joseph Petrosino; Mark Satorius; Matthew Mitchell; Melvin Holmberg; Michael Weber; Michele Evans; Patrick Hiland; Richard Smith; Russell Gibbs; Scott Langan; Steven West; Terence Chan; Thomas Wengert; Tom Bilik ; Victor Hall; William Cullen
Date: 3/21/2007 7:26:10 AM
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To all,

Please find attached the section of the Exponent report that contains Exponent's principle conclusions.

This may help us prepare for our call with FENOC tomorrow.

Eric.

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CHW1 (Charles Weil)
DEH (David Hills)
ERD (Eric Duncan)
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RAG1 (Russell Gibbs)

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GCC (Gregory Cwalina)

JAD (James Davis)
JED2 (Jim Dyer)
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TLC (Terence Chan)
WHC (William Cullen)

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PLH (Patrick Hiland)
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2. Principal Conclusions and Opinions

We have reached the following overall conclusion based on the work described in detail in the subsequent sections of this report.

The large wastage cavity discovered in March 2002 at control rod drive mechanism (CRDM) Nozzle 3 in the Davis-Besse reactor pressure vessel (RPV) head was caused by a unique, unexpected, and unforeseeable combination of high nozzle material susceptibility to primary-water stress corrosion cracking (PWSCC), high residual stresses from welding, rapid and non-linear crack growth, and development of thermal hydraulic conditions that resulted in accelerated attack of the RPV head alloy steel material. This event of the moment occurred around October/November 2001 when the leak rate from an existing J-groove weld crack combined with the leak rate from the CRDM Nozzle 3 crack to raise the total leakage rate to 0.16 gpm (84,000 gallons /year). This leak rate caused rapid catastrophic material removal from the RPV head. This event was not only unexpected, but was not foreseen or predicted by any of the extensive prior experience with boric acid corrosion, or from any of the inspection and analysis of CRDM cracking in nuclear plants worldwide from 1991 through 2002. It was the first occurrence of its kind, ever.

This conclusion is supported by the additional conclusions and opinions presented below, the bases for which are presented in Sections 4 through 10 of this report.

2.1 The discovery of the wastage cavity in the Davis-Besse RPV head and the subsequent industry response both show that this event was totally unexpected, unanticipated and unforeseeable (Section 4).

1. The NDE inspection performed on the Davis-Besse CRDM nozzles at the beginning of 13RFO in February 2002 pursuant to NRC Bulletin 2001-01 found five nozzles with cracks. Several of the cracks at Nozzles 2 and 3 were longer than had been predicted by prior analysis and experience. In particular, one crack

at Nozzle 3 was much longer than any crack previously detected in CRDM nozzles worldwide.

2. Nonetheless, plans were made to repair CRDM Nozzles 2 and 3, where the most significant cracks were detected. The large wastage cavity in the RPV head at Nozzle 3 was unknown and was not discovered until Nozzle 3 unexpectedly moved towards Nozzle 11 during the removal of the bottom section of the nozzle containing the cracks. Subsequent careful examination of the Nozzle 2 borehole revealed a smaller wastage cavity at that location also.

3. The size and extent of the wastage cavity at CRDM Nozzle 3 was totally unexpected and unpredictable, and was much larger than any of the "worst case" scenarios analyzed by industry experts in the decade prior to 2002.

4. Given the unexpected and unanticipated size and depth of the corrosion cavity at Nozzle 3 and its safety significance, the industry and regulatory response to the Davis-Besse event was wide ranging and comprehensive, and is still on-going today, almost five years after the event. The very scope of this effort speaks to the unexpected and unanticipated nature of the Davis-Besse RPV head wastage event and the complex factors that led to it. If the extent of the wastage could have been readily predicted or foreseen on the basis of pre-existing industry analysis and operating experience, clearly the event would never have happened.

2.2 The nuclear industry and regulatory focus of concern, both US and worldwide, for CRDM nozzle cracking, was on the safety issue of circumferential cracks and possible ejection of a CRDM nozzle, which results in a breach of the reactor coolant pressure boundary and a loss-of-coolant accident (LOCA). Significant CRDM nozzle axial cracking leading to RPV head wastage was not foreseen and was not considered either plausible or a safety issue until the Davis-Besse event (Section 5).

1. Cracking of Alloy 600 CRDM nozzles was first detected in the French plant Bugey-3 in 1991, when a very small leak was discovered during a high-pressure hydrotest. Non-destructive examination (NDE) and other inspections of CRDM

nozzles at French, other European, and Japanese plants from 1991 on, identified significant cracking of CRDM nozzles. Subsequent experience with CRDM nozzle cracking prompted utilities in France, Sweden, Belgium, Spain and Japan to institute RPV head replacement programs. In both France and Sweden, an enhanced leakage detection system capable of detecting extremely small leaks was also installed at operating plants.

2. Only a few US plants, and only one B&W plant, performed NDE inspections of a limited number of CRDM nozzles from 1994 through 1999. The US industry and regulatory approach was to wait until nozzles had developed through-wall cracks and began leaking before performing inspections. When extensive cracking was discovered in several B&W designed plants in late 2000 and early 2001, the NRC began to develop rules requiring 100% NDE of CRDM nozzles.

3. The primary focus of the US PWR industry and the NRC from the discovery of cracking at Bugey-3 through to early 2001 was on the potential for CRDM nozzle failure and nozzle ejection, and on the critical axial and circumferential crack sizes that would be required before such failures would occur, and not on any potentially significant wastage of the RPV head. While the potential for boric acid corrosion of the RPV head was considered, it was not regarded as a safety issue. As the Davis-Besse event illustrates, the critical crack size at which boric acid leakage becomes large enough to cause thermal hydraulic conditions such that extremely high rates of metal removal from the RPV head occur, is well below the critical crack size at which nozzle failure might occur.

4. Evaluation and analysis of the experience with CRDM nozzle cracking at B&W plants in late 2000 and early 2001, led to the ranking by the EPRI Materials Reliability Program (MRP) of all US PWR plants by predicted cracking susceptibility. Davis-Besse in particular was predicted in March 2001 to be 3.1 EFPY away from developing cracks similar in size to those discovered at Oconee-3, the most seriously affected US plant at the time where, again, no significant wastage of the RPV head had been reported. In fact, rather than 3.1 EFPY away

from a 0.6-inch crack similar to Oconee-3, Davis-Besse was only a few months away from the development of a fast-growing, 1.23-inch, through-wall CRDM nozzle crack that quickly caused significant RPV head wastage.

5. The worldwide and US experience of actual CRDM cracking, the projected limited extent of CRDM nozzle cracking at Davis-Besse, and the total lack of any identified wastage of the RPV head at any of the plants affected by CRDM cracking all demonstrate that the serious Davis-Besse wastage discovered at CRDM nozzle 3 in March 2002 was unexpected, unanticipated and unforeseeable. I corrected the margin.

2.3 The industry and regulatory focus of concern, both US and worldwide, for boric acid leakage was on the wastage of external components and fittings due to boric acid corrosion, and most of the industry research and effort was directed towards the detection and quantification of this type of corrosion, which was readily detectable by means of visual inspection at refueling outages. Significant RPV head wastage was not foreseen and had not occurred until the Davis-Besse event (Section 6).

1. The majority of the boric acid corrosion that occurred in plants worldwide was the result of dripping and/or impingement of boric acid leakage onto external components such as piping, bolting and fittings in the reactor coolant system. RPV head wastage had been observed at only a few plants, and then only to a limited, shallow extent that was not considered significant.

2. Following the issuance of Generic Letter 88-05 by the NRC in 1988, the US nuclear industry led by Owners Groups and EPRI developed "Boric Acid Corrosion Control (BACC) programs and procedures to detect boric acid leakage before significant wastage occurred. However, it became apparent in 2001 that these inspection techniques and programs were possibly inadequate to detect very small leaks in the narrow annuli around CRDM nozzles. This was especially the case in plants where boric acid from known CRDM flange leakage above the RPV head accumulated on top of the head, thereby masking any minor leakage

from small nozzle cracks, thus making detection by visual inspection virtually impossible.

3. The NRC specifically implemented its own procedure in August 1991 to provide guidance to NRC resident inspectors in their evaluation of the effectiveness of PWR licensees' boric acid corrosion control (BACC) programs, and their compliance with the requirements of GL 88-05. However, the NRC procedure was apparently never performed at Davis-Besse by the NRC resident inspectors assigned to the plant, and was so "infrequently implemented" by NRC resident inspectors at other PWR plants that it was cancelled in September 2001. This occurred at the very time that the NRC and the industry were grappling with the discovery of CRDM nozzle cracks and leaks in the B&W Oconee units, for which BACC programs were then the primary means of identification.

4. The NRC and the industry recognized the limitations of existing leakage detection methods, but did nothing to require either more sensitive leak detection systems such as those which were installed at French and Swedish plants, or NDE inspections of CRDM nozzles at refueling outages to detect cracks before they began to leak.

5. Assessments of potential RPV head wastage from leaking CRDM nozzles by the US industry and accepted by the NRC were erroneous. Maximum metal removal rates of approximately 1.0 cubic inch per year were assumed to be very conservative, whereas actual metal removal rates at Davis-Besse are estimated to have occurred at least 100 times this rate.

6. While extensive testing of boric acid corrosion of low alloy steel components had been performed prior to 2002, the focus of most of this testing was on external leaks, drips and impingement tests on bolting, piping and other components, and not on tests for boric acid leakage into tight annular crevices such as those present around the CRDM nozzles. While some of these tests showed that boric acid could cause rapid corrosion of low alloy steel under certain conditions of concentration and temperature, it was not considered that these conditions could

be achieved in the annular CRDM crevice. The prevailing industry direction prior to the Davis-Besse event was that leaks into nozzle crevices would rapidly cause evaporation of the water, and result in dry boric acid which was widely believed to be non-corrosive to the RPV head steel.

7. Several major corrosion test programs have been undertaken by the NRC and EPRI since the Davis-Besse event in attempts to provide more detailed understanding of the environments that can develop in CRDM crevices due to boric acid leakage from cracked nozzles. Some of these results are available, and provide information about potential corrosion rates under conditions that had not previously been investigated.

8. The extensive wastage cavity discovered at Davis-Besse CRDM nozzle 3 in March 2002 was therefore not considered plausible, and was unforeseen, unpredictable, and unexpected.

2.4 FENOC's response to industry and regulatory concerns about both CRDM nozzle cracking and boric acid corrosion was both responsible and was in accordance with industry recommendations and regulatory requirements (Section 7).

1. FENOC implemented the inspection and monitoring programs developed by both US industry groups and required by the US NRC, for CRDM nozzles and for external boric acid leakage and potential wastage corrosion of external reactor coolant system components.

2. The NCR required and the industry implemented inspection and monitoring programs that could not detect incipient boric acid crevice corrosion in the annulus around the CRDM nozzles, especially where significant boric acid was present from CRDM flange leakage. Experience at the B&W Oconee units in 2000 and 2001 showed that the leakage of boric acid from through wall cracks was in fact very small, and could easily be missed or obscured during visual inspections of the RPV head by deposits from CRDM flange leakage.

3. Two resident NRC inspectors at the Davis-Besse plant monitored FENOC's plant operations, maintenance, and repair activities. No negative findings were documented by the NRC resident inspectors, who were present at the refueling outages in 1996, 1998 and 2000, with respect to CRDM nozzle and RPV head inspections during the inspections conducted as part of FENOC's BACC program mandated by NRC GL 88-05.

4. Nothing in the prior worldwide industry experience with boric acid corrosion of RCS components alerted the B&W plant designers, the PWR industry, the US NRC, or FENOC to the potential for development of the extensive wastage cavity in the RPV head that was found at CRDM nozzle 3 in March 2002.

5. The NRC Inspection Reports for the inspections that occurred during 11RFO and 12RFO made no mention of the inability to fully inspect the RPV head due to boric acid remaining after the cleaning. The report for 12RFO also did not comment on the amount and location of boric acid left on the RPV head.

2.5 PWSCC crack growth rates (CGRs) assumed in the FENOC Root Cause Report were apparently based on the EPRI industry averaged curve. CGR measured in recent tests for the NRC by Argonne National Laboratory (ANL) on samples of actual Alloy 600 from Davis-Besse CRDM Nozzle 3 are three to four times faster than the industry curve predicts. The fact that the CGR for the Nozzle-3 Alloy 600 material is nearly four times that assumed by FENOC for the Davis-Besse event analyses means that the crack growth and the development of the large wastage cavity at CRDM Nozzle 3 occurred over a much shorter period of time than previously estimated (Section 8).

1. Crack growth rates (CGRs) in Alloy 600 (nozzles) and Alloy 182 (welds) can be highly variable and unpredictable. The general scatter in CGR data for both Alloy 600 and 182 spans roughly two orders of magnitude, or a factor of 100. Variations in cracking performance of apparently identical Alloy 600 CRDM nozzles and Alloy 182 welds at other PWR plants also show that the process is highly variable. We attribute this variable performance primarily to the process by which the nozzles are manufactured and installed, in particular the manual

welding process, which can result in highly variable residual stress levels from nozzle to nozzle.

2. In addition, data on crack initiation and growth for both Alloy 600 and Alloy 182 weld metal indicate that the PWSCC process is generally one of initiation of multiple cracks followed by a growth and linkup process as multiple small cracks grow into each other and coalesce to form large cracks. Analysis of the effect of this process, as well as observations in the field, indicate that rapid increases in crack growth can occur when several small cracks, growing relatively slowly, link up in a relatively short time to form a larger crack.

3. The variability in CGR is self evident from the cracking behavior of CRDM Nozzles 2, 3, 4, and 5 at Davis-Besse, all of which are located in the same geometric position on the RPV head, were fabricated from the same heat of Alloy 600 using the same manufacturing processes, were installed using the same manufacturing and welding procedures, and experienced the same operating stress and temperature histories. Yet Nozzle 4 exhibited no cracking, Nozzle 5 was found to have only one very short non-through-wall crack, Nozzle 2 had seven leaking axial cracks (six of which were through wall) plus one circumferential crack, and Nozzle 3 had two through wall axial cracks, one of which was the longest axial crack ever found in a CRDM nozzle, as well as a very large weld crack extending almost completely across the J-groove weld.

4. NRC/ANL test results recently reported (November 2006) for CGRs in actual Davis-Besse CRDM Nozzle 3 Alloy 600 material show that the CGRs for this material are at roughly the 95th percentile of the Alloy 600 database. This CGR is three to four times that assumed in the 2002 FENOC event analysis and root cause report, which was based on the Alloy 600 CGR data generally used by the industry at the time, and which was believed to be conservative.

5. This recent NRC/ANL test data is highly relevant to the analysis of the progression of events at Davis-Besse Nozzle 3, because it implies that the nozzle crack growth, leakage, and wastage cavity formation and growth all occurred over

a much shorter time frame than was previously concluded. Consequently, the previous analyses project time frames for through wall crack growth, leakage, and wastage cavity development that are around three to four years earlier in time than they could possibly have occurred.

6. Similarly, analyses by B&W, EPRI, and others prior to 2002 of the relative susceptibility of the Davis-Besse plant to CRDM nozzle cracking effectively assumed that the Davis-Besse CRDM nozzles would exhibit the same CGR as Oconee-3. It was that assumption that led to the prediction in March 2001 by the EPRI MRP that Davis-Besse was 3.1 EFPY away from experiencing cracking to a similar extent as Oconee-3. That conclusion proved to be incorrect, because the Davis-Besse CGR's were in fact much higher than had been assumed. Our analysis shows that by March 2001, the large crack at Davis-Besse Nozzle 3 had already grown through-wall above the weld, was already leaking significantly, and that the wastage cavity was already established and growing at an accelerating rate.

7. Under the high tensile hoop stresses in the J-groove weld and adjacent nozzle wall, determined from our finite element stress analysis, our analysis shows that the crack driving force for the upper tip of Crack 1 in Nozzle 3 as it grew past the top of the J-groove weld was in excess of 50 ksi-in$^{1/2}$. Subsequent growth of the crack above the weld exhibited decreasing crack driving force, estimated to be at least 24 ksi-in$^{1/2}$ in the latter stages of growth.

8. The NRC/ANL experimental data for Nozzle 3 indicates that at a crack driving force of 50 ksi-in$^{1/2}$, the CGR for the nozzle crack would have been about 0.8 inch per year, and about a quarter-inch per year at 24 ksi-in$^{1/2}$. Based on the crack growth studies we have performed, we conclude that the long axial Crack 1 discovered on the downhill side of Nozzle 3 in 2002, which was responsible for the initial cavity formation and growth, just reached above the top of the weld around the time of the mid-Cycle 12 outage in April-May 1999.

9. Our analysis further shows that this same crack had reached a point far enough above the top of the weld to begin leaking at a very low rate around the time of the 12RFO in April-May 2000, and that the crack had grown to a size sufficient to cause substantial head wastage a year later, in May 2001. This crack would then have reached the measured length, 1.23 inches above the weld, by February 2002.

2.6 Detailed modeling and analysis of the thermal hydraulic conditions in the CRDM annulus has been performed by means of a Computational Fluid Dynamics (CFD) code. CFD analyses have been performed for a range of flows, crack sizes and wastage cavity sizes that cover the range of possible conditions from very low leakage rates into the initially tight cavity, through the crack sizes and leak rates existing at Nozzle 2 in 2002, up to the final large cavity, crack size, and leak rate that existed for the crack at Nozzle 3 in March 2002 crack. These analyses show that thermal hydraulic conditions of velocity, temperature, and wetness develop that can result in extremely high metal wastage rates in the cavity (Section 9).

1. CFD modeling and other calculations show that very high velocities, well over 2000 feet per second, are generated downstream of a leaking nozzle crack. These velocities are high enough to result in aggressive metal removal. The point at which the velocity is at a maximum is generally at the point where the leak flow first encounters an enlarged cross sectional area for flow.

2. For an initially tight annulus, this expansion point would be expected at the exit of the annulus at the top surface of the RPV head. However, the CRDM nozzles in the B&W design are installed with a shrink fit, and the nozzles in question at Davis-Besse (2, 3) had metal-to-metal interference fits that were calculated to remain closed at operating conditions. Thus, the expansion point for the initial leakage, where the crack first begins to leak at a very low flow rate, could occur anywhere along the annulus length wherever the interference fit happened to be relaxed somewhat.

3. The extremely high maximum fluid velocities (up to 2,700 fps) predicted by the CFD modeling near the cracks and in the bottom of the wastage cavity once it

developed imply that material removal by mechanical means was likely at these locations. The momentum of the water droplets traveling at these velocities is sufficient to cause material removal. In addition, both pre-2002 test data and recent (July 2006) data from an EPRI corrosion test program show that penetration rates of up to 8 to 11 inches per year can result from a high-temperature, high-pressure stream of reactor coolant impinging on an alloy steel specimen.

4. As the leak flow expands, water both flashes and is evaporated by heat transfer from the surrounding steel, causing the boric acid to concentrate. Under the initially very low leak rate flow conditions, the temperature rapidly rises to the point where most or all of the water has evaporated and a phase transition from orthoboric acid to metaboric acid occurs. In the absence of moisture, dry or molten boric acid is relatively non-corrosive, and metal removal in nozzle annulus would have occurred relatively slowly, principally due to the erosive action of the high velocity jet from the nozzle crack.

5. As the leak flow from the crack increases and the wastage cavity develops, the CFD model results show that significant changes in the thermal hydraulic conditions occur. The leak flow eventually becomes large enough that heat transfer from the RPV head can no longer evaporate all the water, and moisture persists into the lowest part of the previously slowly growing wastage cavity. However, due to the high metal wall temperatures, metaboric acid continues to be formed and deposited in the nozzle annulus and the wastage cavity from the evaporating coolant leakage. Recently reported data (July 2005) from corrosion tests specifically carried out by the NRC/ANL to investigate this condition show that extremely high steel corrosion rates are possible where moisture is present and wetting of molten metaboric acid occurs.

6. In conjunction with continued metal removal by the high velocity fluid from the nozzle crack, corrosion from wetted molten metaboric acid causes accelerated metal removal at the bottom of the wastage cavity. In addition, the high velocities

and the presence of corrosion product and boric acid particles can result in more rapid metal removal by abrasive water jet cutting. The combination of these metal removal processes results in more rapid metal removal at the bottom of the wastage cavity, so that once the cavity has formed and the leak rate has increased, the wastage cavity grows downward toward the upwardly advancing crack at an accelerating rate.

7. As the leak rate increases further and the cavity grows larger, the top of the nozzle crack eventually grows into the bottom of downward growing wastage cavity. For this condition, the CFD model results show that further significant changes in the thermal hydraulic conditions occur. The leak flow from the part of the crack that extends into the cavity is now directed radially onto the cavity wall at that location, resulting in more rapid metal removal by direct jet impingement. Metal removal at the bottom of the cavity also continues due to corrosion by wetted molten metaboric acid and by abrasive water jet cutting. In addition, significant moisture now persists all the way to the top of the wastage cavity and annulus, causing metal removal from the upper RPV head steel surface to begin due to corrosion under the layer of molten metaboric acid already present on the RPV head.

8. The downward growth of the wastage cavity at an increasing rate eventually uncovers the large, pre-existing weld crack, and the leak flow increases rapidly by an order of magnitude, from about 0.02 to around 0.16 gpm. The CFD model results using this magnitude of leak flow into the large wastage cavity ultimately found at Nozzle 3 show that the conditions for metal removal by jet impingement, abrasive water jet cutting, and corrosion due to wetted molten metaboric acid all persist, but at an increased volumetric rate due to the increased leak flow. As the wastage cavity grows out to its final size and the cavity walls move further away from the nozzle and weld cracks, the effects of direct jet impingement and abrasive water jet cutting decrease as the velocities near the cavity walls decrease. However, the velocities are still sufficient to cause flow assisted boric acid corrosion.

2.7 By April-May 2001, the nozzle crack had grown to the point where aggressive metal removal conditions developed at the bottom of the wastage cavity. Between May and October 2001, the downward growing wastage cavity intersected with the upward growing crack. This resulted in a significant change in the thermal hydraulic conditions in the wastage cavity such that extremely high rates of erosion/corrosion occurred, leading to the large cavity found in March 2002 (Section 10).

1. It is possible that an incipient sub-surface wastage cavity formation had already begun by 12RFO above the crack at CRDM Nozzle 3, this cavity would have been much smaller than the wastage cavity found at Nozzle 2 in 2002, and so would not have been visible by means of typical visual (i.e., remote video) inspections of the RPV head. Any boric acid deposits from this small leak would have been correspondingly small, no more than 1 cubic inch, similar to those found at Oconee-1 in November 2000. Such deposits would have been totally obscured by the large existing boric acid deposits resulting from the CRDM flange leakage problem even if the RPV head had been completely cleaned of boric acid at 12RFO. Finally, any incipient enlargement of the annulus at the RPV head surface had taken place at Nozzle 3 by 12RFO would have been much smaller than that discovered at the top of the Nozzle 2 annulus in March 2002, and it would not have been visible using visual video inspection techniques

2. Shortly prior to October 2001, the long crack at CRDM Nozzle 3 reached a critical length where the downward growing wastage cavity finally intersected with the upward growing crack. A significant change in the thermal hydraulic conditions occurred, particularly immediately opposite the crack exit at the bottom of the wastage cavity where the velocity was high and the leak flow was impinging directly on the wastage cavity wall.

3. The rate of metal removal increased significantly due to the combination of mechanical processes and corrosion by wetted molten metaboric acid. This resulted in more rapid growth of the wastage cavity through the one-inch of steel that remained above the upper surface of the stainless steel cladding. In addition,

moisture was now carried all the way to the top of the wastage cavity and annulus. The presence of the boric acid deposits around Nozzle 3, which were likely molten metaboric acid due to the high head temperature, caused metal removal from the upper RPV head steel surface to begin.

4. Shortly after October/November 2001, the downward growing wastage cavity at CRDM Nozzle 3 reached the upper surface of the weld, and the large pre-existing weld crack was rapidly uncovered. The leak flow increased eightfold from about 0.02 gpm to around 0.16 gpm after the weld crack was fully uncovered, and the sub-surface wastage cavity in line with the cracks grew more rapidly both axially and radially.

5. Also at this time, the increased moisture content of the high leak flow from the combined nozzle and weld cracks caused the wastage rate due to wetted molten metaboric acid corrosion at the top surface of the RPV head around Nozzle 3 to increase. The accelerated metal removal both in the sub-surface cavity and at the RPV head surface resulted in the large wastage cavity found in March 2002.

Given the information cited above, we conclude that there was no sub-surface wastage cavity of significance present at Nozzle 3 at the time of 12RFO in April-May 2000, and therefore no available inspection methodology could have found it. Based on the results of our crack growth analysis and thermal hydraulic modeling, and on the factual observation of the spatial orientation of the cavity relative to the nozzle and weld cracks at Nozzle 3, the appearance of the walls of the wastage cavity and on the plant operating history, we have concluded that the large wastage cavity found during the 13RFO inspection in March 2002 at Nozzle 3 could have formed in as little as a few weeks in the extreme of complete fluid jet cutting of the head. The most likely cause of the wastage cavity includes both mechanical and chemical actions (including flow assisted corrosion), which began to occur at an accelerating rate after a critical point was reached shortly before October 2001. The event of the moment was reached when the large Nozzle 3 crack and the growing wastage crack intersected and quickly uncovered the large pre-existing weld crack at Nozzle 3. The resulting increase in leak

rate caused extremely aggressive conditions to develop at this time and resulted in the rapid removal of metal from the cavity in matter of a few months, forming the large wastage cavity found in March 2002.

MAJOR PARTS

SERIAL NUMBER	HEAT NUMBER	QUAL. PWHT	ACC. PWHT HRS.	ACC. PWHT MINS.	DESCRIPTION
22-213-52-1	122Y282VA1	60	8	30	Closure Head [illegible]
24-213-52-1	C7837-2	50	8	30	Closure Head Center [illegible]
A43-1 43-213-52-1 67-213-52-1	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A5-2 26-5-216-52-11 26-1-216-52-11	M6623 L17BS	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A44-3 44-213-52-3 67-213-52-3	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A44-4 44-213-52-4 67-213-52-4	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A44-5 44-213-52-5 67-213-52-5	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A45-6 45-213-52-6 67-213-52-6	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A45-7 45-213-52-7 67-213-52-7	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A45-8 45-213-52-8 67-213-52-8	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A45-9 45-213-52-9 67-213-52-9	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
A46-10 46-213-52-10 67-213-52-10	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]
[illegible] 46-213-52-11 67-213-52-11	M7929 651316S	N/A	0		Control Rod Housing [illegible] Control Rod Housing [illegible]

MAJOR PARTS

	SERIAL NUMBER	HEAT NUMBER	QUAL. PWHT	ACC. PWHT HRS. MINS.	DESCRIPTION
A46-12	46-213-52-12 67-213-52-12	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A46-13	46-213-52-13 67-231-52-13	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-14	47-213-52-14 67-213-52-14	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-15	47-213-52-15 67-213-52-15	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-16	47-213-52-16 67-213-52-16	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-17	47-213-52-17 67-213-52-17	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-18	47-213-52-18 67-213-52-18	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-19	47-213-52-19 67-213-52-19	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-20	47-213-52-20 67-213-52-20	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A47-21	47-213-52-21 67-213-52-21	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A48-22	48-213-52-22 67-213-52-22	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A48-23	48-213-52-23 67-213-52-23	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt
A48-24	48-213-52-24 67-213-52-24	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapt

MAJOR PARTS

	SERIAL NUMBER	HEAT NUMBER	QUAL. PWHT	ACC. PWHT HRS. MINS.	DESCRIPTION
A48-25	48-213-52-25 67-213-52-25	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A49-26	49-213-52-26 67-213-52-26	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A49-27	49-213-52-27 67-213-52-27	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A49-28	49-213-52-28 67-213-52-28	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A49-29	49-213-52-29 67-213-52-29	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-30	50-213-52-30 67-213-52-30	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-31	50-213-52-31 67-213-52-31	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-32	50-213-52-32 67-213-52-32	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-33	50-213-52-33 67-213-52-33	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-34	50-213-52-34 67-213-52-34	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-35	50-213-52-35 67-213-52-35	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-36	50-213-52-36 67-213-52-36	M7929 651316S	N/A	0	Control Rod Housing Body Control Rod Housing Adapter
A50-37	50-213-52-37 67-213-52-37	M7929 651316J	N/A	0	Control Rod Housing Body Control Rod Housing Adapter

MAJOR PARTS

	SERIAL NUMBER	HEAT NUMBER	QUAL. PWHT	ACC. PWHT HRS. MINS.	DESCRIPTION
A51-38	51-213-52-38 67-213-52-38	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-39	51-213-52-39 67-213-52-39	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-40	51-213-52-40 67-213-52-40	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-41	51-213-52-41 67-213-52-41	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-42	51-213-52-42 67-213-52-42	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-43	51-213-52-43 67-213-52-43	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-44	51-213-52-44 67-213-52-44	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A51-45	51-213-52-45 67-213-52-45	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A52-46	52-213-52-46 67-213-52-46	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A52-47	52-213-52-47 67-213-52-47	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A52-48	52-213-52-48 67-213-52-48	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A52-49	52-213-52-49 67-213-52-49	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-50	53-213-52-50 67-213-52-50	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]

MAJOR PARTS

	SERIAL NUMBER	HEAT NUMBER	QUAL. FWHT	ACC. FWHT HRS. MINS.	DESCRIPTION
A53-51	53-213-52-51 67-213-52-51	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-52	53-213-52-52 67-213-52-52	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-53	53-213-52-53 67-213-52-53	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-54	53-213-52-54 67-213-52-54	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-55	53-213-52-55 67-213-52-55	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-56	53-213-52-56 67-213-52-56	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A53-57	53-213-52-57 67-213-52-57	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A54-58	54-213-52-58 67-213-52-58	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A54-59	54-213-52-59 67-213-52-59	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A54-60	54-213-52-60 67-213-52-60	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A54-61	54-213-52-61 67-213-52-61	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-62	55-213-52-62 67-213-52-62	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-63	55-213-52-63 67-213-52-63	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]

MAJOR PARTS

620-0013-5[illegible]
Page 6 of 6

	SERIAL NUMBER	HEAT NUMBER	QUAL. PWHT	ACC. PWHT HRS. MINS.	DESCRIPTION
A55-64	55-213-52-64 67-213-52-64	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-65	55-213-52-65 67-213-52-65	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-66	55-213-52-66 67-213-52-66	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-67	55-213-52-67 67-213-52-67	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-68	55-213-52-68 67-213-52-68	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
A55-69	55-213-52-69 67-213-52-69	M7929 651316S	N/A	0	Control Rod Housing [illegible] Control Rod Housing [illegible]
	172-2013-52-1 to 12	70099	N/A	0	CRDM [illegible]

620-0013-52 Rev. [illegible]

WELD RECORD

Sheet 1 of 1

WELD NUMBER	MK. TO MK.	P.Q.	QUAL. PWHT	ACC. PWHT	[illegible] (FLUX/QUALIFICATION)
WH7 Rev. 2	22 to 24	3443	50	8:30	442002 (8873/[illegible])
WH9 Rev. 0 WH9 Rev. 2 WH9 Rev. 3	A43 thru A55 Adapter to Mech. Housing Body	1562 1562 1562	N/A N/A N/A	0 0 0	NX8490D
WH11 Rev. 4 WH11 Alt. 1 Rev. 3	Clad Seal Surface to 22	2237 2578	50 48	8:30	To 4628 [illegible] 4497 [illegible] 20959 (3C7 [illegible]) 79541 ([illegible]) D9529T ([illegible])
WH13 Rev. 2	Mech.Housing Buttering to 24	22'4	30	7:18	4F23 [illegible] 4209 [illegible]
WH25 Rev. 4	Mech. Housings to WH13 Buttering	1828	N/A	0	4296 [illegible] 4297 [illegible] 4301 [illegible] NX1669D [illegible] NX90B5D [illegible]

Section 8

CMTR's Pressure Boundary Material
And
Weld heat records

Certified Material Test Reports

a) Closure head flange 122Y282
b) Closure head C7837-2
c) CRDM NiCrFe nozzle body M7929, M-6623
d) CRDM Stainless flange 651316S, L178S
e) CRDM split nut rings 75365, 27127, 68769
f) Closure head lift lug C6529
g) Service structure segments D1671

NiCrFe weld wire for CRDM J-groove Buttering
4F23B, 4205, 4251, 4558

NiCrFe weld wire for CRDM J-grooves
4296, 4297 4301, 4342, NX16C9D, NX90B5D

Other Pressure boundary welds

a) WH-7 Closure head flange to closure head WF 337
b) WH-17 Lift Lug to head Electrode lots 818-020714, 818-020733, 818-020700
c) WH-15 service structure segments to head Electrode lots 818-020673, 818-030193, 818-020032, 818-020672, 818-020689
d) WH-27 Arrow to closure head

Note: The weld control records are included for the "other pressure boundary welds".

Return-path: <prvs=dbnrc=5885330f2@firstenergycorp.com>
Received: from mail2.nrc.gov [148.184.176.43]
by NRNWMS02.NRC.GOV; Fri, 16 Mar 2007 09:41:17 -0400
Received: from gw10.firstenergycorp.com (HELO firstenergycorp.com) ([205.132.73.40])
by mail2.nrc.gov with ESMTP; 16 Mar 2007 09:41:13 -0400
X-Ironport-ID: mail2
X-SBRS: 3.5
X-MID: 7955213
X-IronPort-AV: i="4.14,292,1170651600";
d="pdf'?scan'208"; a="7955213:sNHT1063789980"
Subject:
To: jer7@nrc.gov
X-Mailer: Lotus Notes Release 6.5.4 CCH5 September 12, 2005
Message-ID: <OF49FF21B1.A0717415-ON852572A0.004AED3A-852572A0.004B2D66@FirstEnergyCorp.com>
From: dbnrc@firstenergycorp.com
Date: Fri, 16 Mar 2007 09:40:45 -0400
MIME-Version: 1.0
X-MIMETrack: Serialize by Router on mail04/Servers/FirstEnergy(Release 6.55FP1HF75 | July 21, 2006) at 03/16/2007 09:40:48,
Itemize by SMTP Server on gw12/Servers/FirstEnergy(Release 6.5.5FP1|April 11, 2006) at 03/16/2007 09:40:50 AM,
Serialize by Router on gw12/Servers/FirstEnergy(Release 6.5.5FP1|April 11, 2006) at 03/16/2007 09:40:50 AM
Content-Disposition: inline
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--0__=0ABBF833DFD96BAA8f9e8a93df938690918c0ABBF833DFD96BAA
Content-Type: text/plain;
charset="US-ASCII"

(See attached file: Att-07-15077.pdf)

--0__=0ABBF833DFD96BAA8f9e8a93df938690918c0ABBF833DFD96BAA
Content-Type: application/pdf;
name="Att-07-15077.pdf"
Content-Disposition: attachment; filename="Att-07-15077.pdf"
Content-Transfer-Encoding: base64

Att-07-15077.pdf

Mail Envelope Properties (45FA9E94.7BB : 3 : 38843)

Subject:	
Creation Date	3/16/2007 9:40:45 AM
From:	<dbnrc@firstenergycorp.com>
Created By:	dbnrc@firstenergycorp.com

Recipients
nrc.gov
ch_po.CH_DO
JER7 (John Rutkowski)

Post Office	**Route**
ch_po.CH_DO	nrc.gov

Files	**Size**	**Date & Time**
MESSAGE	625	3/16/2007 9:40:45 AM
Att-07-15077.pdf	1109482	
Mime.822	1520481	

Options

Expiration Date:	None
Priority:	Standard
ReplyRequested:	No
Return Notification:	None
Concealed Subject:	No
Security:	Standard

Junk Mail Handling Evaluation Results
Message is eligible for Junk Mail handling
This message was not classified as Junk Mail

Junk Mail settings when this message was delivered
Junk Mail handling disabled by User
Junk Mail handling disabled by Administrator
Junk List is not enabled
Junk Mail using personal address books is not enabled
Block List is not enabled