From: <jjpowers@firstenergycorp.com>
To: <erd@nrc.gov>
Date: 03/22/2007 1:10:32 PM
Subject: PowerPoint slides for Davis-Besse Exponent Report NRC Teleconference

Eric,
Here are slides for our 1500 teleconference.
Jim
----- Forwarded by James J. Powers/FirstEnergy on 03/22/2007 02:00 PM -----

"Daniel Bullen"
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<rlatanision@exponent.com>, "David
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Subject
PowerPoint slides

Gentlemen:

Attached are the PowerPoint slides for this afternoon's conference call with the NRC.

Dan

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(See attached file: Summary Slides - Exponent Report Conclusions (3-22-07).ppt)

F-40

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Key Conclusions of Exponent's December 15, 2006 Report:

"Review & Analysis of the Davis-Besse March 2002 Reactor Pressure Vessel Head Wastage Event"

Ron Latanision, Dan Bullen, David Taylor

Exponent *Failure Analysis Associates*

March 22, 2007

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Principal Conclusion

- Large undercut wastage cavity at CRDM Nozzle 3 developed between October/November 2001 and February 2002
- Basis:
  - Detailed stress analysis of nozzle/weld at Nozzle 3
  - NRC/ANL 2006 crack growth data for actual DB CRDM Nozzle 3 Alloy 600 material
  - Fracture mechanics studies of crack growth
  - Axial nozzle crack leak rate vs. crack length above weld
  - Weld crack leak rate vs. weld crack dimensions
  - Detailed CFD modeling of thermal hydraulic conditions in developing wastage cavity
  - NRC/ANL 2005 data on wetted molten metaboric acid corrosion of low alloy steel
  - Identification of thermal hydraulic conditions leading to rapid metal removal by mechanical jet action and by corrosion due to wetted molten metaboric acid
  - Final wastage cavity morphology
  - Plant operating history

Cracking/Wastage Timeline

- 12RFO – April/May 2000:
  - Nozzle 3 axial crack has grown to about 0.5 inches above and about 0.8 inches below the weld, total length around 2.5 inches
  - The leak rate from the 0.5 inch axial above-weld crack is estimated at 0.0004 gpm
  - Rapid evaporation to dry-out occurs at this leak rate
  - Sub-surface metal removal at a low rate occurs by mechanical erosion with very little annulus enlargement
  - Total boric acid accumulation from the leakage through this crack at 12RFO is estimated at less than 1 cubic inch
  - This boric acid accumulation may have been visible on the RPV head if there had been no boric acid deposits from leaking CRDM flanges
  - Cleaning of CRDM flange leakage boric acid from the RPV head would have removed any deposits from the leaking crack
  - No annulus enlargement would have been visible even if the RPV head had been clean

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Cracking/Wastage Timeline (cont'd)

- **April/May 2001:**
  - Nozzle 3 axial crack has grown to about 1.0 inch above the weld
  - The leak rate from this crack is estimated at 0.01 gpm, similar to the total leakage estimated from all cracks at Nozzle 2 in February 2002
  - Sub-surface metal removal at a low rate by mechanical erosion continues and metal removal has likely caused a wastage cavity to form similar in size to that found at Nozzle 2 in February 2002
  - At this leak rate, moisture penetrates into the bottom of the wastage cavity
  - Metal temperatures remain high enough to result in phase transformation of boric acid to metaboric acid and melting
  - Presence of molten metaboric acid and moisture results in acceleration of metal removal at the bottom of the wastage cavity

Cracking/Wastage Timeline (cont'd)

- May/October 2001:
  - Nozzle 3 axial crack has grown to about 1.1 inches above the weld by October 2001
  - The leak rate from this crack is estimated at 0.02 gpm
  - The upward growing axial nozzle crack and downward growing wastage cavity have intersected
  - Mechanical erosion at the bottom of the wastage cavity increases due to the change in crack jet direction and high velocity jet impingement
  - Moisture penetrates further into the bottom of the wastage cavity due to the higher leak rate
  - Metal temperatures still remain high enough to result in phase transformation of boric acid to metaboric acid and melting
  - Combined action of wetted molten metaboric acid corrosion and mechanical action rapidly removes the 1 inch of remaining low alloy steel covering the weld
  - Undercutting of the wastage cavity likely begins

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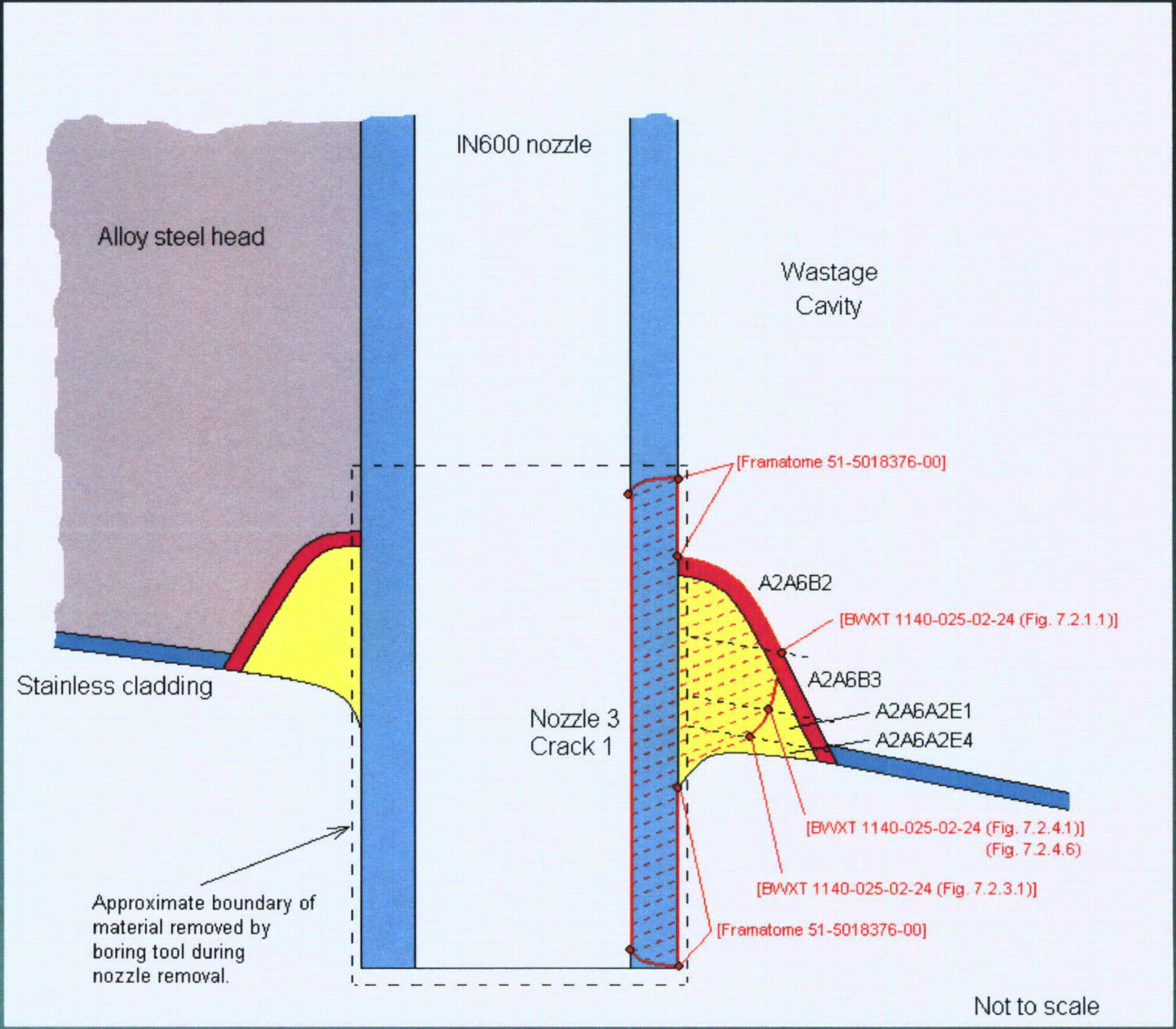
CRDM Nozzle 3 and Weld Cracking



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Cracking/Wastage Timeline (cont'd)

- **October/November 2001:**
  - Large pre-existing weld crack is uncovered by the rapidly downward growing wastage cavity
  - Leak rate increases to around 0.16 gpm
  - Cavity metal wall temperatures remain higher than phase transformation to and melting temperature of metaboric acid
  - High velocity high flow jet impingement and wetted molten metaboric acid corrosion cause rapid wastage cavity growth, undercutting, and large cavity by February 2002
  - Significant moisture penetrates to the RPV head underneath the existing boric acid deposit from CRDM leakage
  - Head surface metal temperature remains high enough to form molten metaboric acid and presence of moisture from higher leak rate results in top-down wastage of RPV alloy steel evident in final wastage cavity morphology

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CRDM Nozzle 3 Weld Cracking

- Metallurgical examination of the Nozzle 3 weld revealed a through weld crack
  - Crack extended radially across the weld from the nozzle OD to the RPV head alloy steel
  - Crack was through weld from bottom to top
  - Crack was much wider than the axial crack in Nozzle 3 above the weld

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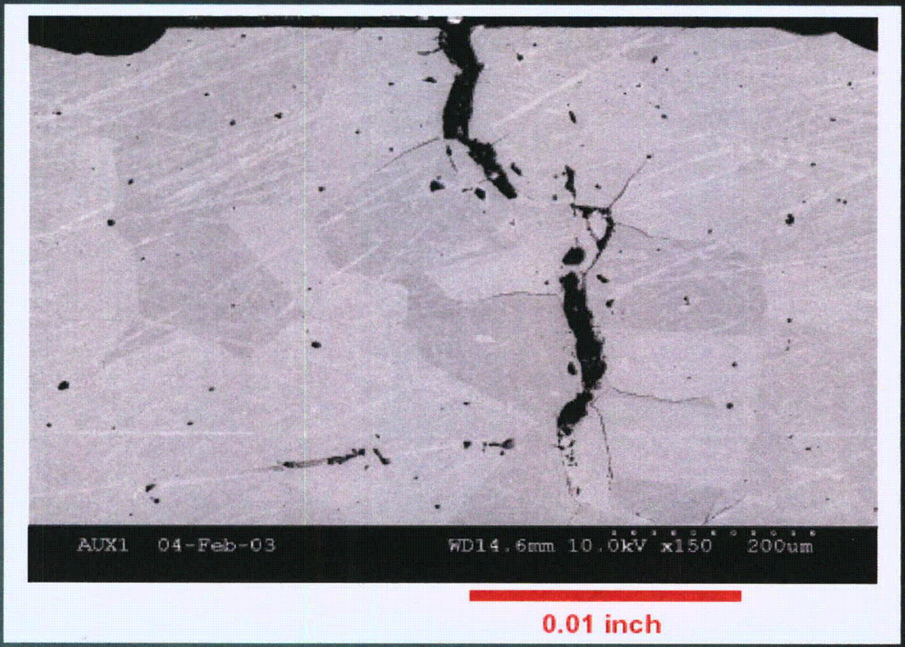
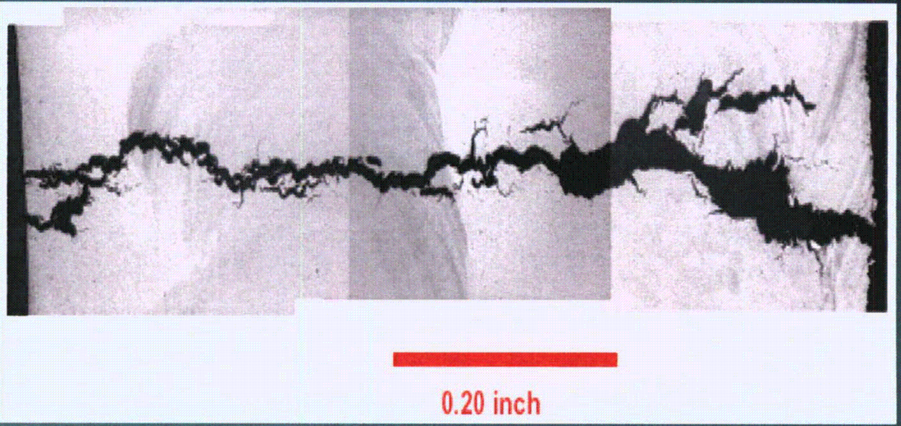
CRDM Nozzle 3 Weld Cracking (cont'd)

- Scanning electron micrograph of CRDM Nozzle 3 crack at 180° location showing typical width of PWSCC nozzle cracks. Maximum crack width is about 20 microns (0.0008 inches)



- Optical micrograph of J-groove weld crack in CRDM Nozzle 3 at 10° location. Nominal crack width is about 400 microns (0.016 inches), about 20 times larger than the PWSCC crack in the same nozzle



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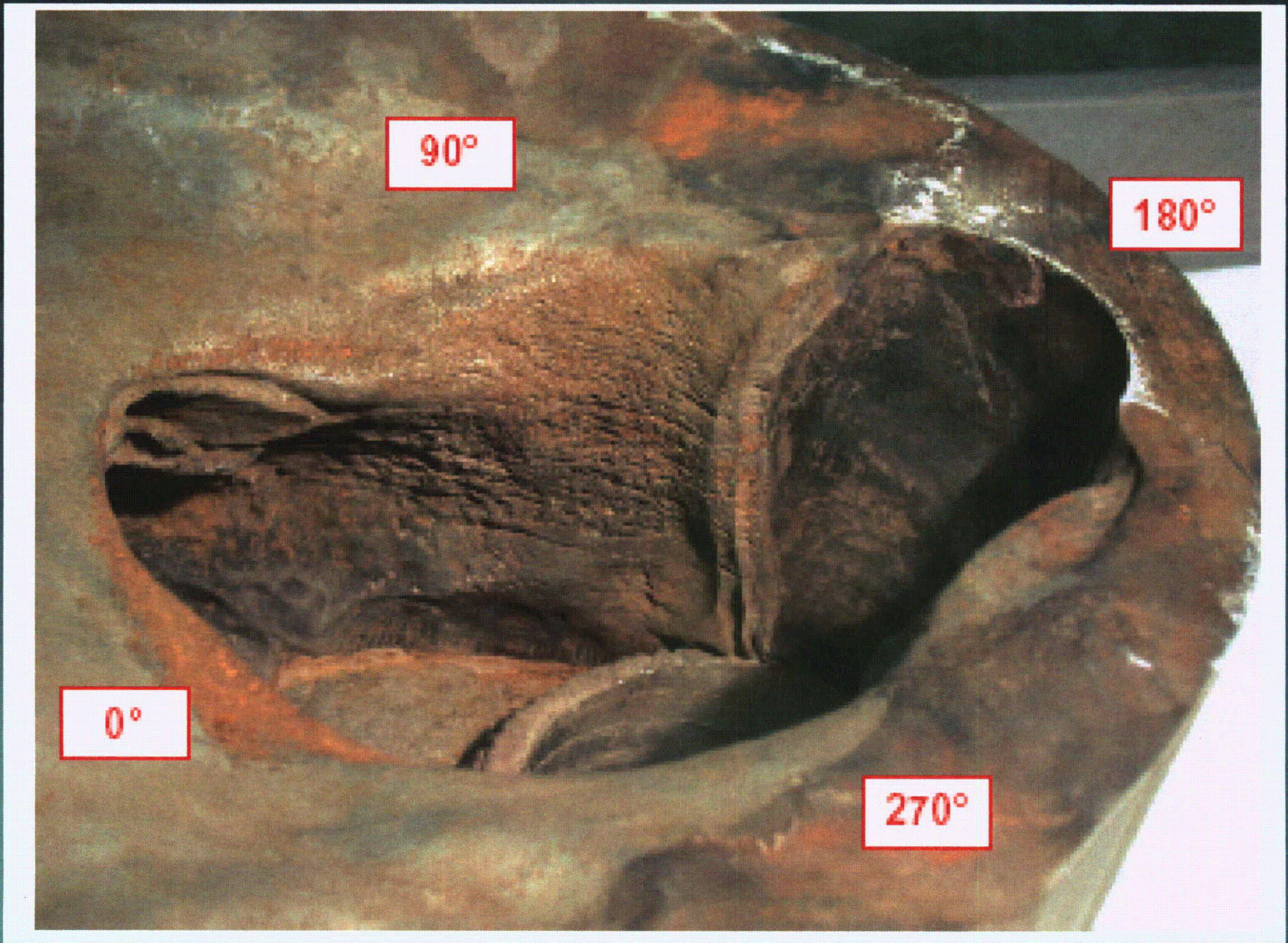
Final Wastage Cavity at CRDM Nozzle 3



CRDM Nozzle 3 Cracking Behavior

- Nozzle 3 Alloy 600 Heat M3935 was shown to be highly susceptible to PWSCC
- Heat M3935 was used at Davis-Besse in the central 5 nozzles out of 69 total nozzles
- Cracking behavior of CRDM nozzles made from Heat M3935 has been highly variable

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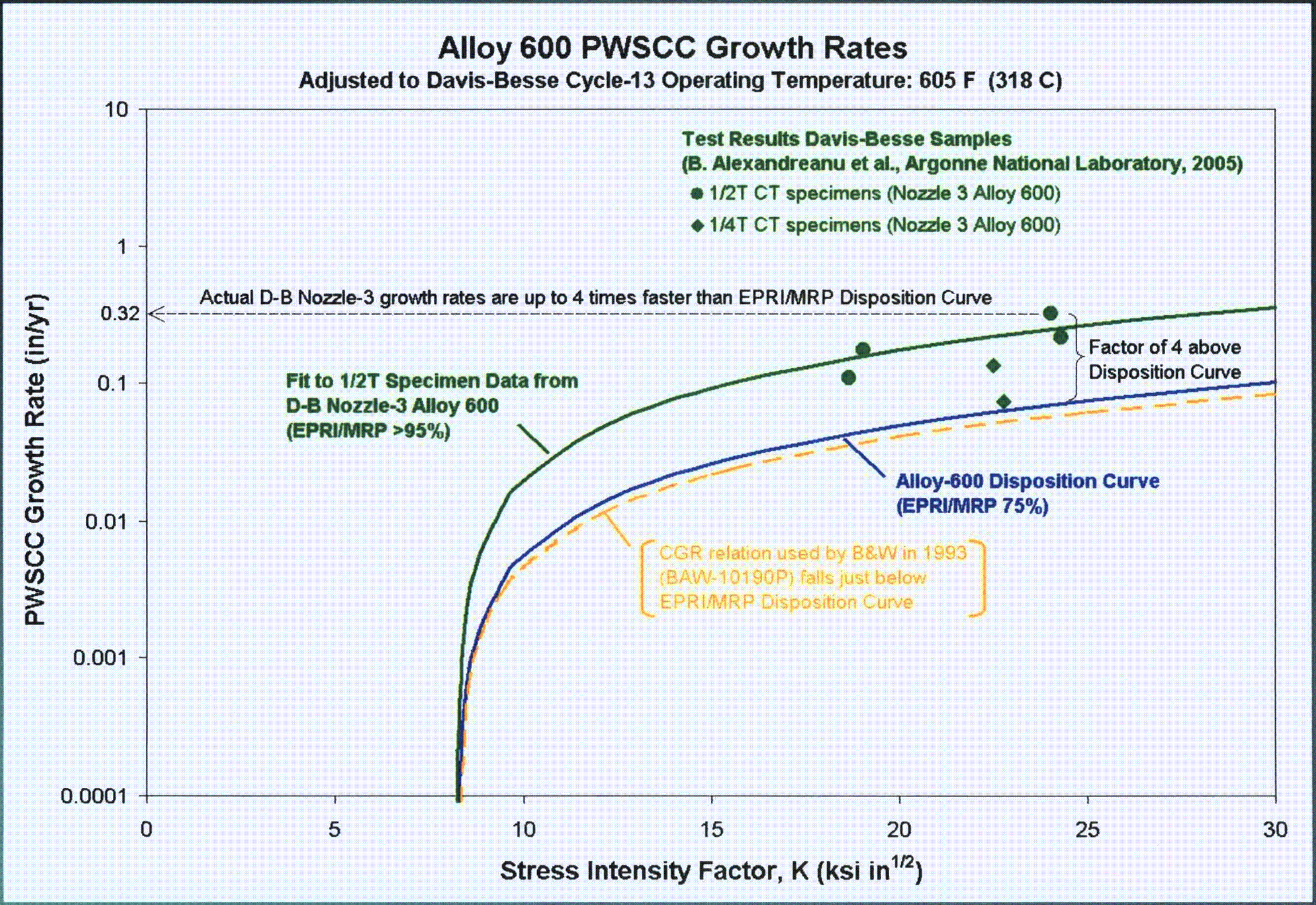
CRDM Nozzle 3 Cracking Behavior (cont'd)



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CRDM Nozzle 3 Cracking Behavior (cont'd)

- Actual Nozzle 3 Alloy 600 material exhibited very high crack growth rates in NRC/ANL work reported in 2006
- Crack growth rates for Nozzle 3 Alloy 600 material were 3 to 4 times industry expected rates, at 95th percentile of data
- Explains why the Nozzle 3 axial crack grew to 1.23 inches above the weld and 4.08 inches in total length
- Led to conclusion that cracking timeline for CRDM Nozzle 3 was much shorter than previously thought

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