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Byron Station Thermal Power Measurement

September 18, 2003

A/1

Agenda and Opening Remarks

Jim Meister

Vice President - Engineering

Agenda

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- Opening remarks
- Background on ultrasonic feedwater (FW) flow measurement
- Chronology of ultrasonic flow meter (UFM) implementation
- UFM test plan and results
- Root cause and corrective actions
- Safety implications
- Future plans/actions
- Closing remarks

Opening Remarks

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- Several in-depth investigations performed, from 1999 to 2002, to determine reason for megawatt (MW) differences between Byron and Braidwood
- Test plan identified problem with UFM measurement of FW flow in August 2003
- Preliminary root cause determined to be UFM correction factor error caused by pressure pulses in FW piping which were caused by resonance
- Prior to 2003 test plan, multiple rigorous reviews conducted to evaluate all causes considered plausible
- Amount of reactor overpower initially determined acceptable with respect to safety analyses criteria
- Broad review of UFM decision making initiated

Background on Ultrasonic FW Flow Measurement

Bill Kouba

Exelon Engineering Director

Background on Ultrasonic FW Flow Measurement

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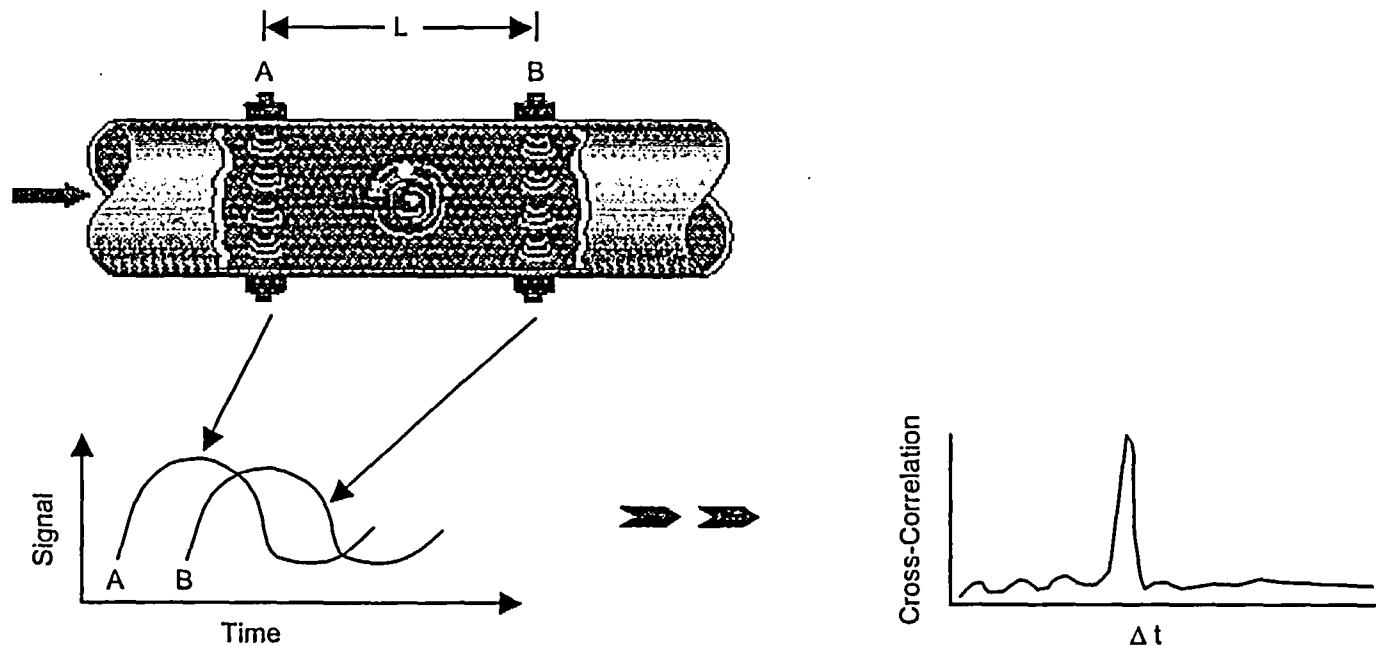
- Purpose of UFM's
 - More accurately measure FW flow
 - Potentially recover MW lost due to FW venturi flow inaccuracies
- Installation was not part of a measurement uncertainty recapture (i.e., Appendix K) uprate
 - No intent to raise power beyond existing licensed limit
 - Five percent power uprate moved plants from Appendix K to Best Estimate loss of coolant accident (LOCA) basis

Background on Ultrasonic FW Flow Measurement (cont.)

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- UFM captures the signature at A and B and calculates the travel time



Background on Ultrasonic FW Flow Measurement (cont.)

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How the UFM Works

- Signal sent through each of the two sets of transducers is modified by eddies
- Eddy modification “fingerprints” signal
- Time delay for “fingerprint” movement is determined by a statistical technique called cross-correlation
- Plant UFM “correction factor” is calculated by dividing the UFM mass flow by that from the venturi

Background on Ultrasonic FW Flow Measurement (cont.)



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- Installation verified by UFM vendor
 - In accordance with vendor procedures
 - NRC subsequently approved UFM technology in March 2000 for use in Appendix K uprates
 - Vendor procedures consistent with NRC-approved topical report
- UFM installed on each FW branch line supplying steam generators
- UFM's installed in the same manner on the four Byron/Braidwood units
- Correction factors used in calorimetric calculation to correct FW flow
- Correction factors determined periodically, after a defined change in power (potential de-fouling event), or plant parameter trending

Chronology of UFM Implementation

Bill Kouba

Chronology of UFM Implementation **Exelon**SM

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- UFM^s implemented at Braidwood – June 1999
- UFM^s implemented at Byron – May 2000
- Electrical output differences identified between Braidwood and Byron
 - Upon initial installation
 - Following five percent power uprate in 2001
- Multiple evaluations conducted from 1999 through 2002 to determine reason for differences in electrical output

Chronology of UFM Implementation

Summary of Evaluations



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- Evaluations performed June 1999 to May 2000
 - Dual instrument test with ultrasonic flow instruments, and UFM vendor review of Byron installation
 - Additional validation testing at Braidwood to verify data acquisition based on venturi cleaning methodologies
 - Internal Exelon design review
 - Secondary plant parameters, fuel utilization, heat rates, implementing procedures
- Evaluations concluded Byron UFM implementation was installed and operating within criteria established for UFM technology

Chronology of UFM Implementation

Summary of Evaluations (cont.)



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- Independent Exelon review performed in February 2002
 - Identifies fuel burn-up anomalies
 - Recommends additional detailed evaluation
- Byron removes UFM venturi correction factors pending evaluation of fuel burn-up concern
- Exelon Nuclear Fuels organization determines fuel burn-up is within predicted range
 - Byron reinstates UFM correction factors after determination

Chronology of UFM Implementation

Summary of Evaluations (cont.)

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- UFM vendor, Corporate Engineering, and site review UFM implementation – March 2002
 - Installation and operational criteria verified including piping, transducers, cables, software, and test procedures
 - Comparison testing conducted between common FW header and individual FW lines
 - Study concludes UFM measured flow per design and implemented properly
 - Continuous data subsequently recorded in response to a recommendation from this study

Chronology of UFM Implementation **Exelon**SM

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- NRC resident inspector issues unresolved item in inspection report
- NRC issues letter to Exelon concerning Byron Unit 1 thermal power level
- Exelon response concludes Byron Unit 1 UFM's installed consistent with NRC guidance, and that Unit 1 is operating within its licensed thermal power limit
- Exelon Engineering test plan initiated – March 2003

UFM Test Plan and Results

Bill Kouba

UFM Test Plan and Results



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- Purpose of test plan – identify reasons for electrical output differences between Byron/Braidwood stations
- Investigate long-term trends of specific plant parameters
 - Monitor correction factor trends on Byron Unit 1 with continuous data link to UFM vendor
 - Observe performance during steady state, power changes, pre/post-refueling outage
- Use additional UFM on common FW header upstream of UFM's on individual FW lines
 - Check venturi flow sum and existing UFM flow sum
 - Determine if difference between common header UFM and sum of individual FW line UFM's at Byron Unit 1 is within statistical allowance

UFM Test Plan and Results

Results of Testing



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- Braidwood Unit 1 comparison showed very close correlation between common header and individual line UFM's
- Comparison of common FW header UFM to sum of individual FW line UFM's on Byron Unit 1 was not within statistical allowance
- Signal noise observed on some individual FW line UFM's
- Common FW header UFM's had no signal noise
- Definite problem identified, decisions made to reduce power

UFM Test Plan and Results

Power Reductions



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- Byron Unit 1 reduced power 32 MWe
 - Based on correction factor differences between common FW header UFM and individual FW line UFM
 - Correction factors reset to 1
- Signal noise anomalies, in conjunction with common header to individual line comparisons, were used to determine extent of condition for other units
- Byron Unit 2 reduced power 22 MWe
 - Based on noise observed in one of four individual FW line UFM signals
 - Correction factors conservatively reset to 1

UFM Test Plan and Results

Power Reductions (cont.)



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- Braidwood Unit 1 not affected because of very close correlation between common header UFM and sum of individual FW line UFM
- Braidwood Unit 2 reduced power 11 MWe
 - Based on noise observed in two of four individual FW line UFM signals
- ENS notifications made in accordance with license condition

Root Cause and Corrective Actions

Brad Adams

Site Engineering Director

Root Cause and Corrective Actions

Overview

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- Formed root cause analysis team to determine root cause of UFM inaccurate FW flow measurements
- Preliminary root cause
 - UFM correction factor error
 - Correction factor error caused by noise impact on time delay
 - Bias on calculated time delay (flow) varies at different power levels
 - Resulting bias varies as a function of noise structure and intensity

Root Cause and Corrective Actions

Overview



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- Preliminary root cause (cont.)
 - Presence of noise in individual loops' flow signal caused a non-linearity in calculated venturi correction factor as a function of power level
 - Noise caused by pressure pulses in FW piping
 - Pressure pulses in FW piping caused by resonance
 - Resonance in FW piping caused by a driver at the natural acoustic frequency of the piping

Root Cause and Corrective Actions

Corrective Actions

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- Removed correction factors to eliminate error
- Installation of common FW header UFM to provide for an alternate calculation of correction factor
- Revising appropriate site procedures to check UFM for noise
 - Acceptance criteria established for correction factor determination
- Independent technical review
- Evaluation performed on portion of decision making regarding use of UFM's, team has been chartered to comprehensively evaluate decision making on a broader level and over the life span of this issue

Safety Implications

Brad Adams

Safety Implications

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- Byron Unit 1 overpower limited to 101.6%, Byron Unit 2 overpower limited to 100.4%
- Braidwood Unit 2 overpower limited to 100.3%
- Evaluations of LOCA, non-LOCA, containment, and dose analyses being performed
- Evaluations being performed with conservative assumptions that envelope historical power levels
- Preliminary results indicate applicable safety analyses acceptance criteria were met

Future Plans/Actions

Brad Adams

Future Plans/Actions

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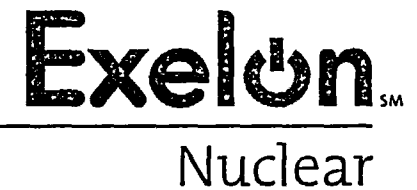
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- Project plan in progress to install common FW header UFMs
 - Testing has determined common header UFM's are free of noise
- Scheduled completion for Byron/Braidwood units is September/October 2003
- Independent technical review
- Broad review of decision making initiated
 - Results will be shared with NRC

Closing Remarks

Jim Meister

Closing Remarks



- Root cause is UFM correction factor error caused by pressure pulses in FW piping
- Low safety significance of overpower condition
- UFM implementation at Byron Units 1 and 2, and Braidwood Unit 2 pending formal evaluation of root cause and corrective actions
- Actions were taken historically to investigate power level anomalies
- Previous evaluations were rigorous and resource intensive
- Overall review of decision making has been initiated