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# Byron Station
# Thermal Power Measurement

September 18, 2003

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# 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

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# Background on Ultrasonic FW Flow Measurement

Bill Kouba
Exelon Engineering Director

# Background on Ultrasonic FW Flow Measurement

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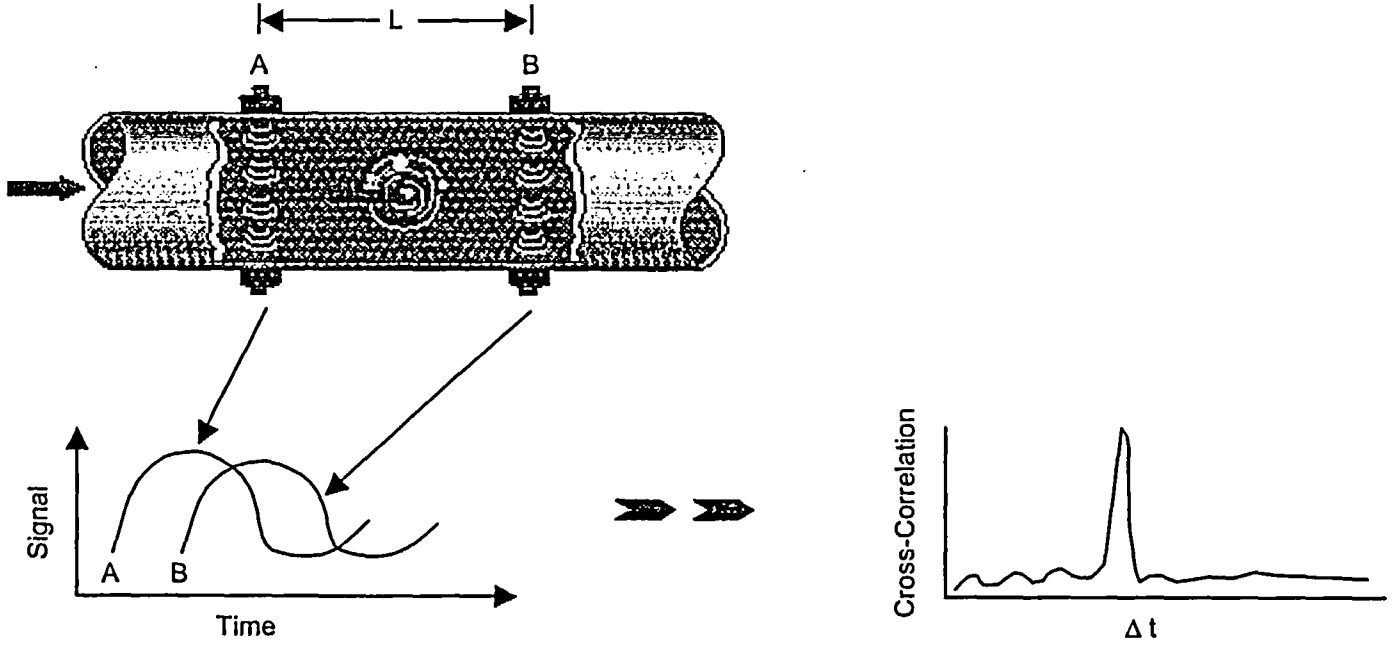
- UFM captures the signature at A and B and calculates the travel time



# 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
- UFMs 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

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# Chronology of UFM Implementation

Bill Kouba

# Chronology of UFM Implementation

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- UFMs implemented at Braidwood – June 1999
- UFMs 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

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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 UFMs installed consistent with NRC guidance, and that Unit 1 is operating within its licensed thermal power limit
- Exelon Engineering test plan initiated – March 2003

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# 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 UFMs 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 UFMs 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 UFMs
- Comparison of common FW header UFM to sum of individual FW line UFMs on Byron Unit 1 was not within statistical allowance
- Signal noise observed on some individual FW line UFMs
- Common FW header UFMs 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 UFMs
  - 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 UFMs
- 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

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# 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 UFMs, team has been chartered to comprehensively evaluate decision making on a broader level and over the life span of this issue

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# 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

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# Future Plans/Actions

Brad Adams

# Future Plans/Actions

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- Project plan in progress to install common FW header UFMs
  - Testing has determined common header UFMs 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

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# Closing Remarks

Jim Meister

# Closing Remarks

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- 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