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Steam Dryer Design Technical Meeting

April 25 - 27, 2005

Agenda

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- Introduction
- Flow-Induced Vibration (FIV)
- New Dryer 50.59 Evaluation
- New Dryer Analyses
  - Design Process Overview
  - Steam Dryer Load Definition
  - Benchmarking Update
  - Finite Element and Stress Analyses
  - Dryer Load Analysis – Load Cases
  - Hammer Test Results
- Dryer Instrumentation
- Startup Test Plan
- Operational Plans for Quad Cities Unit 2 (QC2) and Basis
- Operational Plans for QC1 and Basis
- Revised Commitments for Extended Power Uprate (EPU) Operation

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Introduction

Jim Meister

Vice President – Nuclear Services

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FIV

Chuck Alguire
Engineering Supervisor
Quad Cities Nuclear Power Station

Exelon Actions

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- Exelon established a comprehensive action plan which included three teams to identify actions to prevent future EPU failures
  - Steam Dryer Team
  - EPU Vulnerability Team
  - Vibration Team

Results
Vibration General Assessment

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- Evaluations concluded that all components are acceptable as originally designed for full-cycle operation at full EPU thermal power with the following exceptions:
  - ERV susceptibility to vibration at QC required upgrades of vulnerable parts
  - Target Rock Safety/Relief Valves (S/RVs) showed vibration wear degradation at both Dresden (DR) and QC
- The team identified additional recommendations for enhancements in testing, monitoring, and refueling outage inspections
  - An example is confirmatory vibration testing of Limitorque and Namco limit switches (completed successfully)

QC EPU Vibration Assessment
Vibration Summary – October 2004

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- Validate preventive maintenance (PM) scope and frequency for all evaluated components
  - Electromatic Relief Valve (ERV) PM changes already implemented
- Replace ERV actuator parts for both DR and QC during future rebuilds
- Inspect ERV actuator internals each refueling outage until performance is validated
- Perform focused walkdowns during each refueling outage
- Inspect minimum of one Main Steam Isolation Valve (MSIV) internally each refueling outage until satisfactory performance is demonstrated
- Install upgraded Target Rock S/RVs

QC EPU Vibration Assessment
Open Items from October 2004

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- Perform detailed walkdowns
- Install upgrades on ERV actuators
- Finalize and install upgrade on Target Rock S/RV pilot valve
- Install new steam dryers

QC EPU Vibration Assessment
Actions Completed Since October 2004

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- Actuator components upgraded on all ERVs (Inconel X750 bushings/guide rods and chamfered springs)
  - QC2 upgraded in Spring 2004 refueling outage
  - QC1 upgraded in Spring 2005 refueling outage
  - Will inspect QC2 actuators during the planned outage scheduled to begin on May 9, 2005

QC EPU Vibration Assessment
Actions Completed Since October 2004 (cont.)

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- Target Rock S/RV bellows cap/setpoint spring upgrade
  - Electrolyzed bellows cap, 0.0015" minimum
  - Setpoint spring straightness within 0.02"
  - Coil perpendicularity within 0.03" top/bottom
  - No measurable cap wear after 24 hour shaker table test (simulates one operating cycle at EPU)
  - Installed on QC1 during Spring 2005 refueling outage
  - Install on QC2 during planned outage scheduled to begin on May 9, 2005

QC EPU Vibration Assessment
Actions Completed Since October 2004 (cont.)

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- QC1 Spring 2005 walkdown results
- New steam dryers
  - QC2 during planned outage scheduled to begin May 9, 2005
  - QC1 during planned outage scheduled for May 2005

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New Dryer 50.59 Evaluation

Roger Heyn
Design Engineer
Quad Cities Nuclear Power Station

New Dryer 50.59 Evaluation

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- Significant changes evaluated in 50.59
  - Dryer design loads
  - Increased dryer weight
  - Reduced pressure drop across dryer
  - Displacement of steam/water mass by metal mass
- Dryer design loads
  - Impact on structural integrity of dryer
- Increased dryer weight
  - Negligible impact on reactor internals seismic analyses
  - Impacts support bracket loading (meets Code requirements)

New Dryer 50.59 Evaluation (cont.)

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- Reduced pressure drop
  - Impacts transient and accident pressure distribution
  - Negligible impact on reactor level measurement
  - No change in main steam line (MSL) maximum break flow
- Displacement of steam/water mass by metal mass
  - Impacts transient thermal limits (0.01 Operating Limit Minimum Critical Power Ratio increase)
- Safety Evaluation Report in support of the new steam dryer
  - Report will summarize cycle-independent analyses and evaluations

New Dryer 50.59 Evaluation (cont.)

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- Analyses and evaluations contained in Replacement Steam Dryer Analysis Report for QC1 and QC2
  - Reactor Internal Pressure Differences (RIPD)
    - Steam dryer normal conditions
    - Steam dryer upset conditions
    - Other internal components normal and upset conditions
    - Steam dryer faulted conditions
    - Other internal components faulted conditions
  - Seismic evaluation
  - Structural assessment
  - Anticipated Operational Occurrence evaluations
  - Stability evaluation
  - Appendix R evaluation
  - Anticipated Transients Without Scram

New Dryer 50.59 Evaluation (cont.)

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- Loss of Coolant Accident evaluation
- MSL Break Accident evaluation
- Water level instrumentation evaluation
  - Setpoint analytical bases
  - Channel A / Channel B mismatch
- Other system evaluations
  - Reactor heat balance
  - Reactor Recirculation System
  - Three bundle average quality limit
  - Other systems and evaluations not adversely affected

New Dryer 50.59 Evaluation (cont.)

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- Conclusions based upon analyses that have been completed or are final draft
  - no significant impacts identified (i.e., more than minimal increase)

QC2 New Dryer Load Definition

- New Dryer Loads for QC2 Plant Data (0 – 200 Hz)
  - QC2 Full Scale Pressure Data at EPU (11.24 Mlbs/Hr)
    - 4 Venturi Pressure Gauges
    - 2 Water Reference Legs
    - 1 Strain Gauge ("B" MSL)
  - Analytically Inserted the New Dryer Shape into the Hemholtz Solver
  - New Dryer In-Plant Loads
    - 0 – 100 Hz – Venturi and Water Ref. Leg Pressure Transducer
    - 100 – 200 Hz "B" MSL Strain Gauge (Phased to Maximize)

QC2 New Dryer Load Definition

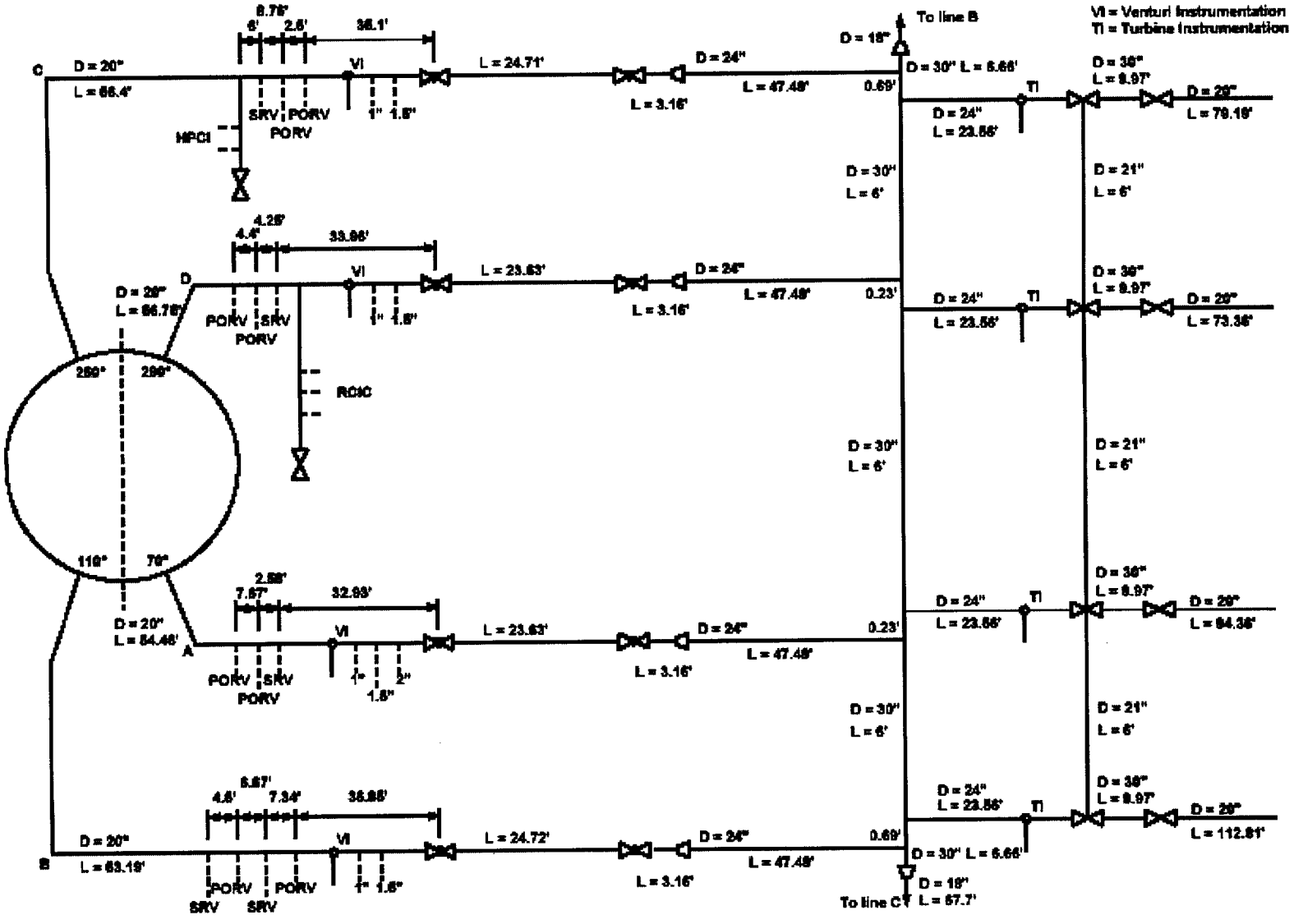


Figure 3-1 Piping geometry used in the acoustic circuit analysis for Quad Cities Unit 2 (QC2).

QC2 New Dryer Load Definition

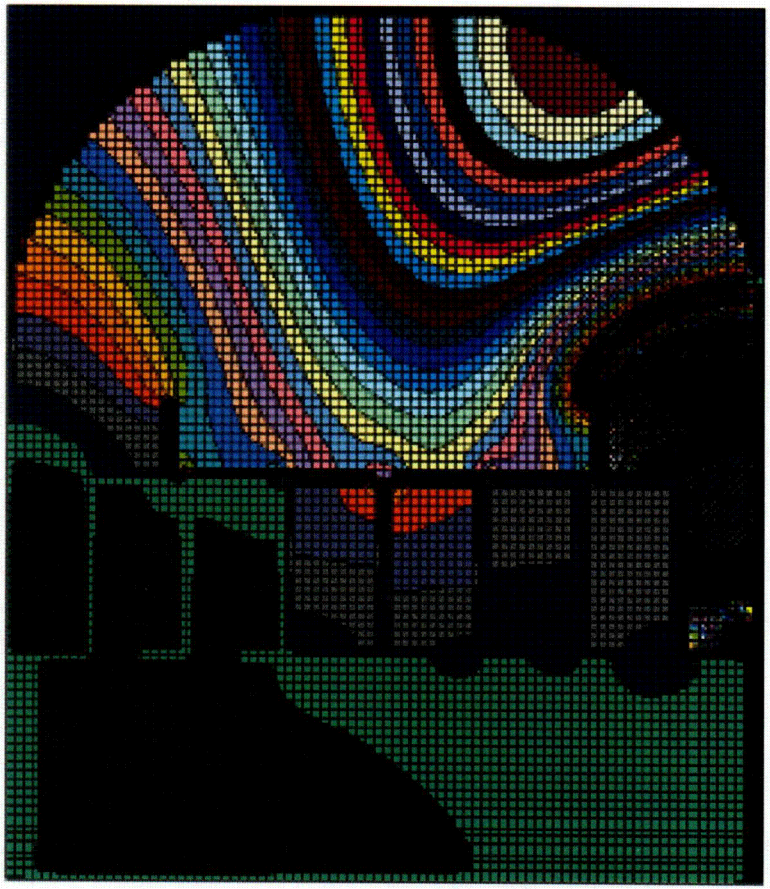
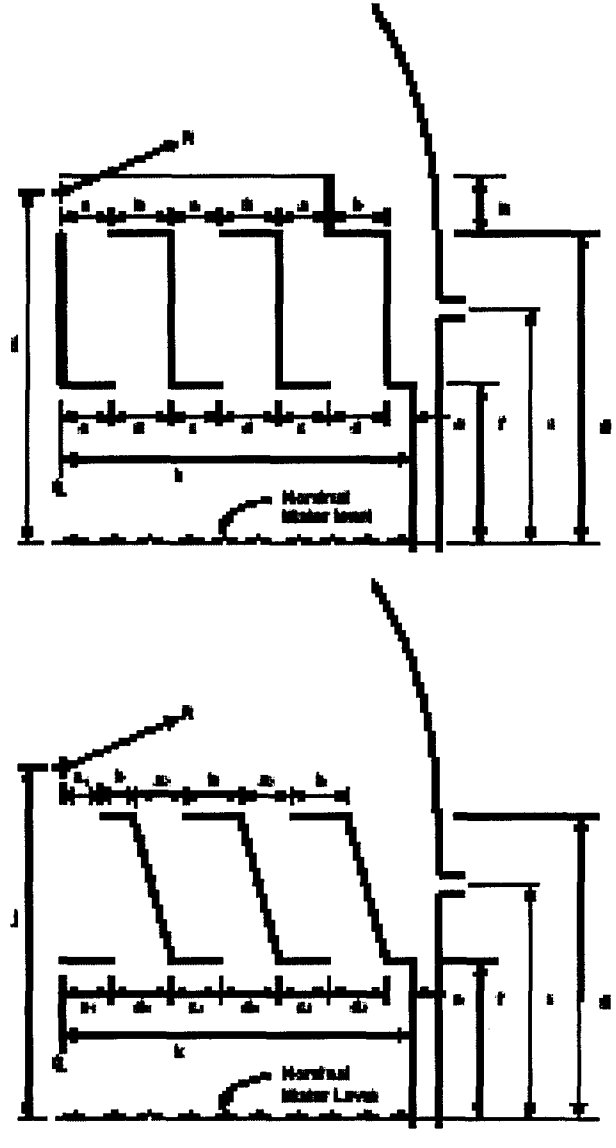


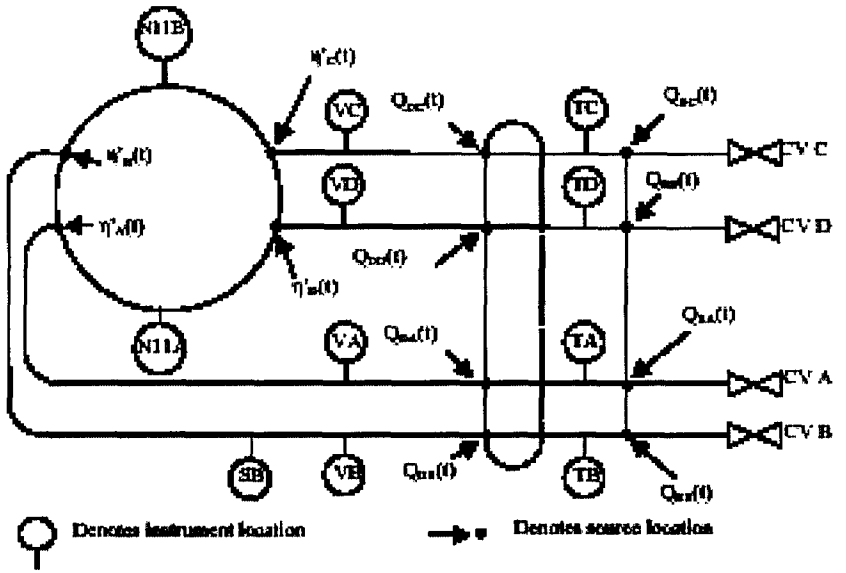
Figure 4-2 **Cross-sectional solution (180 degree azimuth) of the Helmholtz equation at 50 Hz. The right side of the figure is the midpoint between the A and B main steam vent lines, while the left side is the midpoint between the C and D main vent lines. Unit forcing is applied on the A main vent. Portions of the steam dryer are only seen in outline.**

QC2 New Dryer Load Definition



Cross-sectional descriptions of the existing dryer (top) and new dryer (bottom). Dimensions are provided in Table 1.

QC2 New Dryer Load Definition



Symbol	Description	Symbol	Description
$Q_{DA}(t)$	source D ring A line	TA	turbine transducer A line
$Q_{DB}(t)$	source D ring B Line	TB	turbine transducer B line
$Q_{DC}(t)$	source D ring C Line	TC	turbine transducer C line
$Q_{DD}(t)$	source D ring D Line	TD	turbine transducer D line
$Q_{EA}(t)$	source equalizing line A line	VA	venturi transducer A line
$Q_{EB}(t)$	source equalizing line B Line	VB	venturi transducer B line
$Q_{EC}(t)$	source equalizing line C Line	VC	venturi transducer C line
$Q_{ED}(t)$	source equalizing line D Line	VD	venturi transducer D line
CV A	control valve A line	$\eta'_A(t)$	vena contracta A line
CV B	control valve B line	$\eta'_B(t)$	vena contracta B line
CV C	control valve C line	$\eta'_C(t)$	vena contracta C line
CV D	control valve D line	$\eta'_D(t)$	vena contracta D line
N11A	reference leg transducer	N11B	reference leg transducer
SB	strain gage location		

Figure 5-1 Schematic of the assembled model for a D-ring plant showing source locations and locations of measured data.

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Benchmarking Update

Keith Moser
Asset Management Engineer

Benchmarking ACM
Load Definition Methodology

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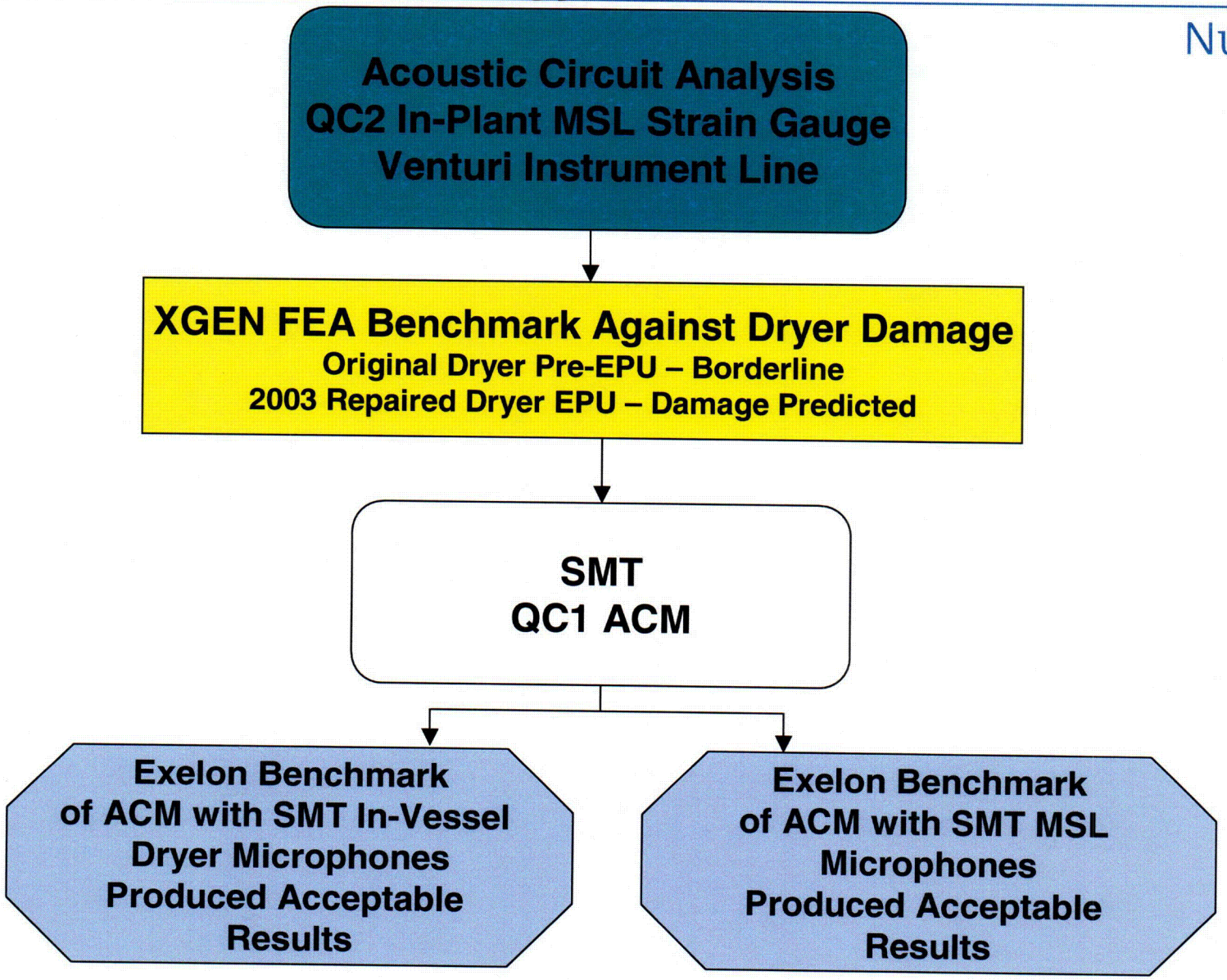

XGEN FEA Benchmark

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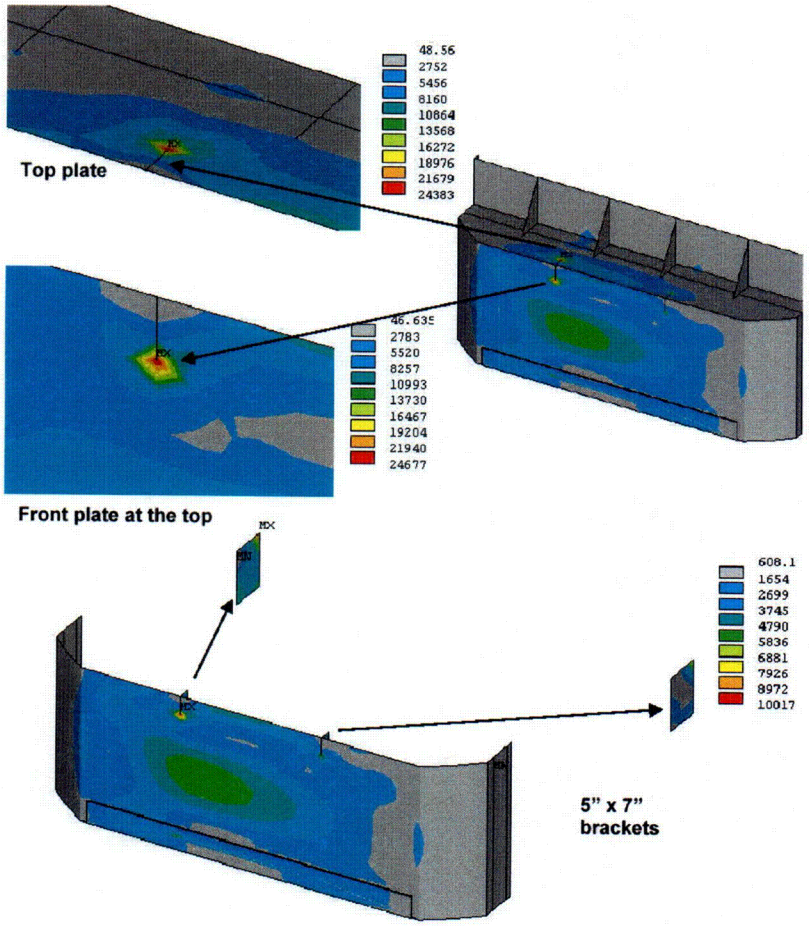
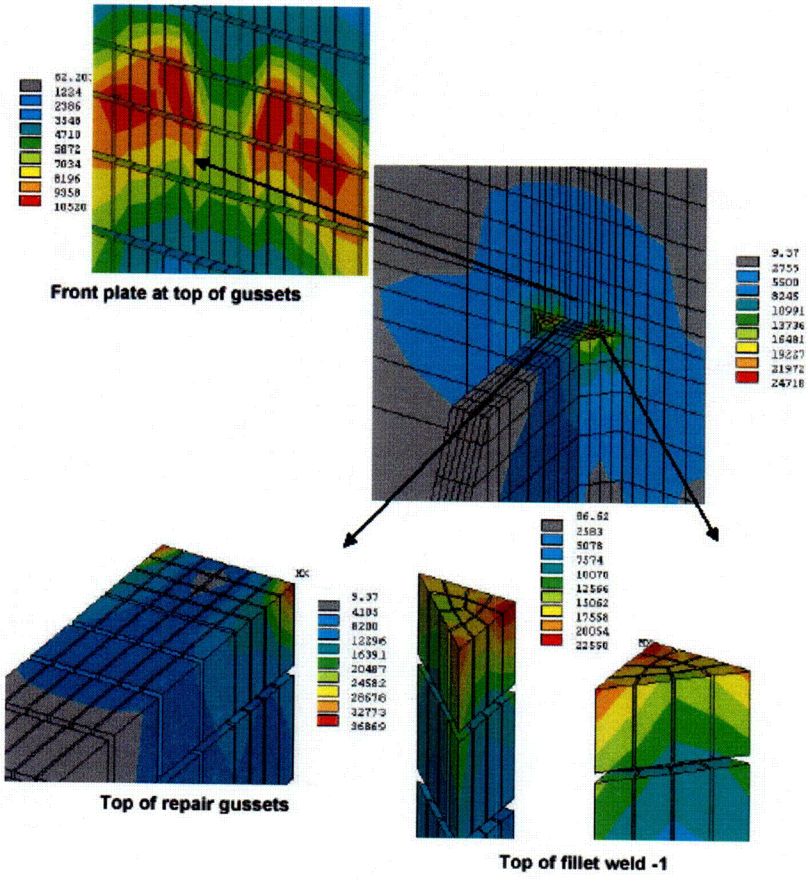


Original Dryer QC2 Pre-EPU CDI Acoustic Circuit



2003 Modified Dryer QC2 EPU CDI Acoustic Circuit

Exelon Steam Dome Benchmark

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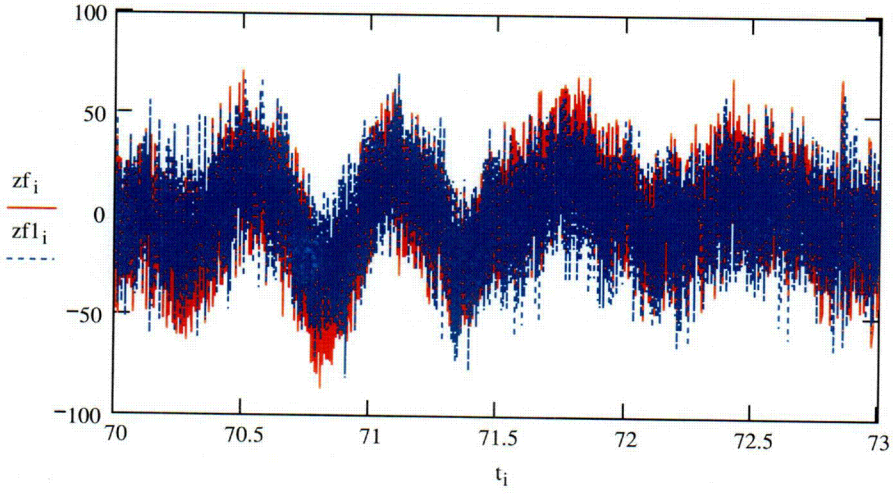
Comparison of Results for Data Point 21:

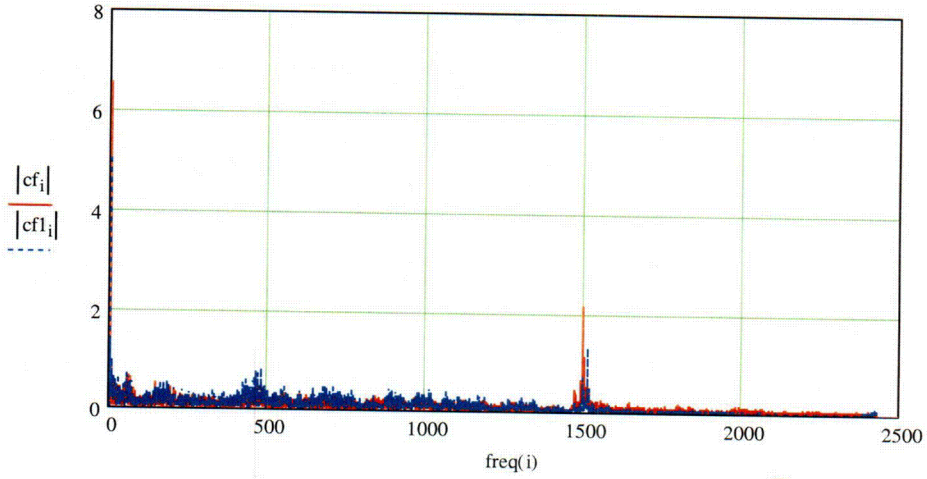
First Benchmark (No Annular Seal in CDI Model) – Data Point M21:

Raw Data M21	CDI Predicted Data M21
$\text{mean}(zf) = 3.70093 \times 10^{-15}$	$\text{mean}(zf1) = 1.46813 \times 10^{-15}$
$\text{Stdev}(zf) = 22.06467$	$\text{Stdev}(zf1) = 20.146$
$\max(zf) = 71.23197$	$\max(zf1) = 70.63575$
$\min(zf) = -86.15166$	$\min(zf1) = -81.85192$

Plot of Filter SMT data (Red) compared to CDI predicted data (Blue) - First Benchmark Data Point M21



Plot of Filter SMT data (Red) compared to CDI predicted data (Blue) - First Benchmark Data Point M21



Exelon Benchmark with MSL

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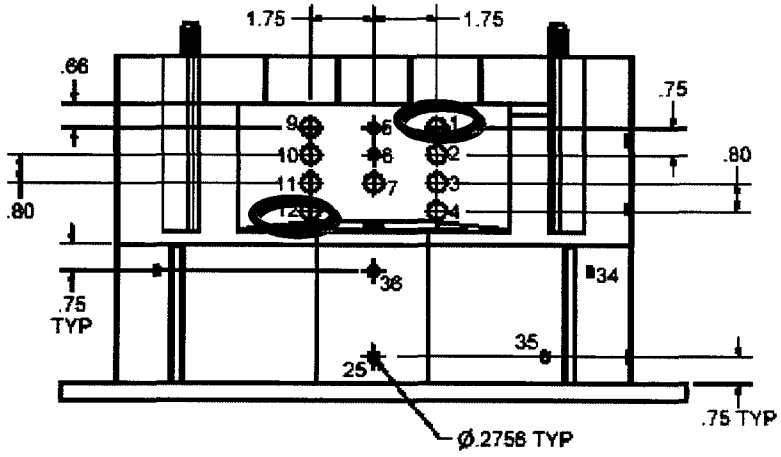
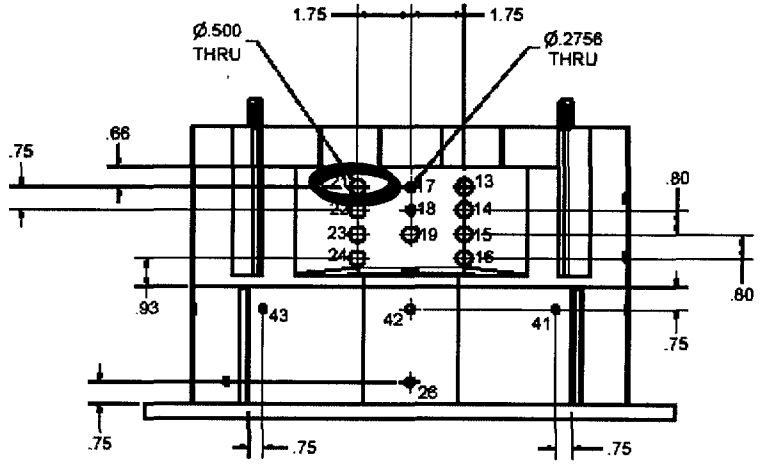
- Exelon requested additional SMT runs during the VY benchmarking effort
  - Flow rate 144 CFM Approx OLTP
  - 8 pressures measured on MSL
    - Down stream of RPV nozzle
    - Up stream of S/RVs
  - SMT of original dryer configuration
- Only 8 microphone data on MSL provided to CDI
- CDI used AC to predict pressures measured on steam dryer at 21 locations
- Locations analyzed to date
  - M1, M12, and M21



90 deg VIEW



270 deg VIEW

Exelon Benchmark with MSL

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- Preliminary results
  - Two predictions provided
    - First prediction incorporated transition cone into the Hemholtz Solution for the steam dome
    - Second prediction truncated transition cone at steam dome to water interface and increased dampening

Transducers	Prediction 1	Measured	Prediction 2
M1	27.8	17.4	15.8
M12	41.7	19.1	26.4
M21	25.3	15.9	12.4

RMS (pa)

Exelon Benchmark with MSL

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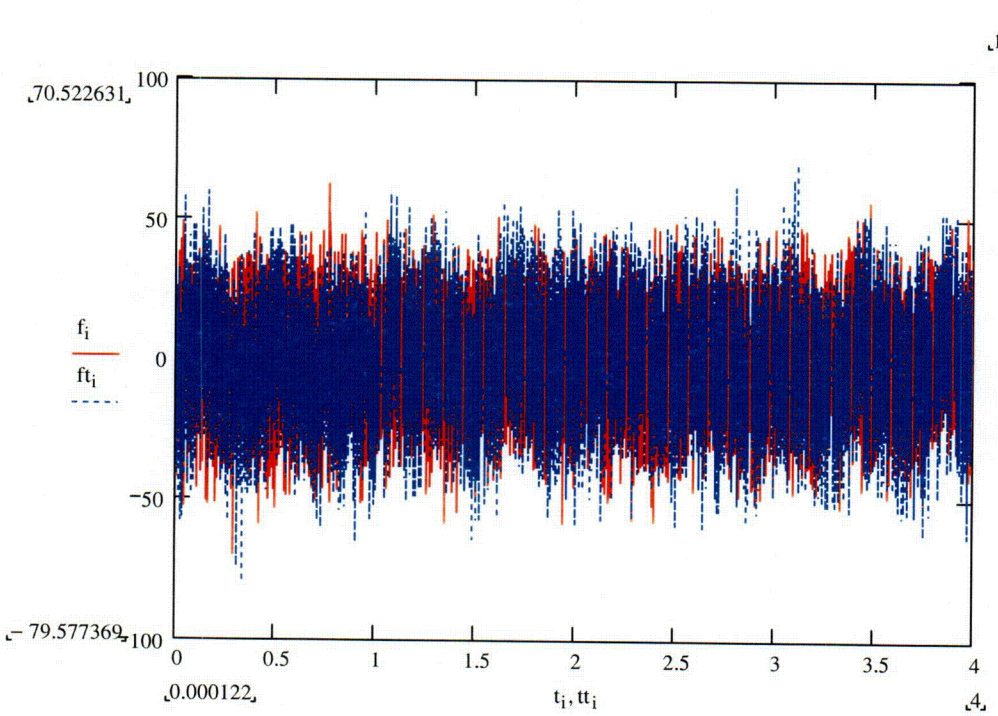

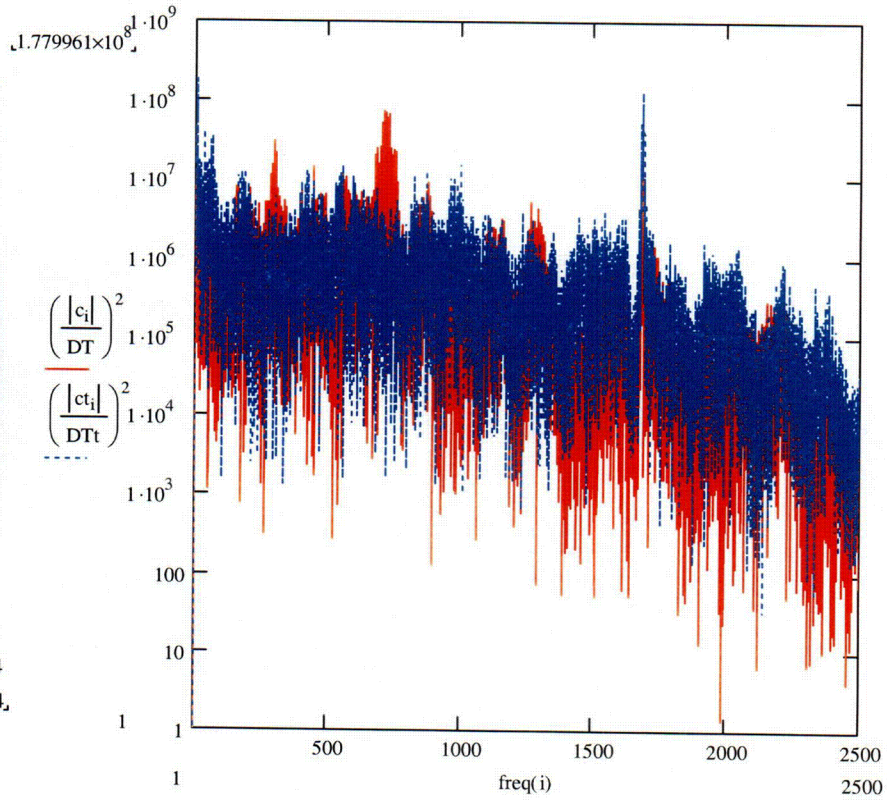

Second Prediction for M1

Blue is measured

Red is predicted

Exelon Benchmark with MSL

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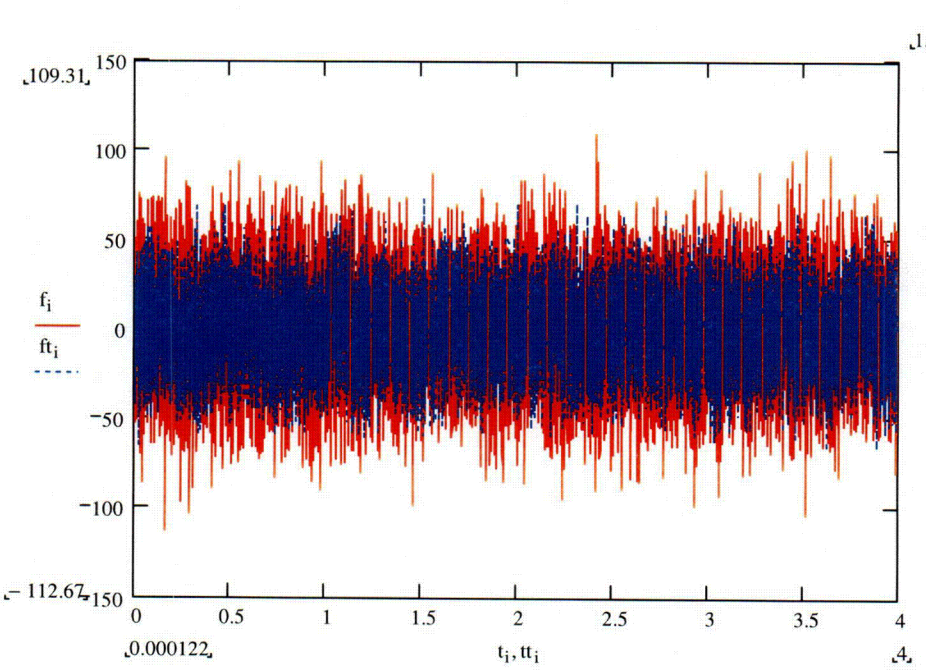

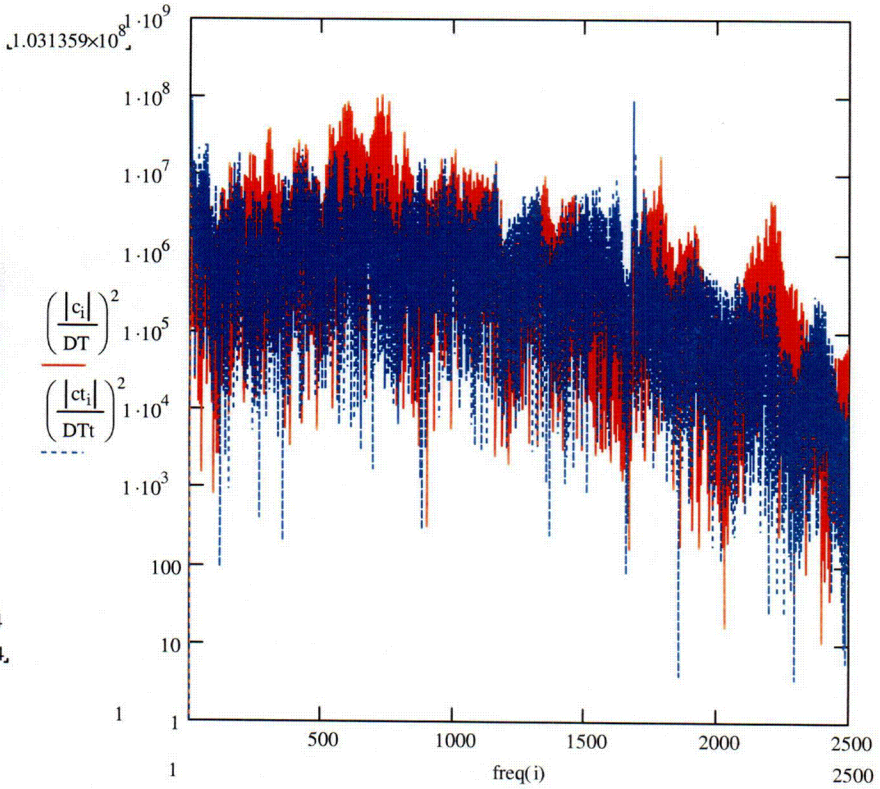

Second Prediction for M12

Blue is measured

Red is predicted

Exelon Benchmark with MSL

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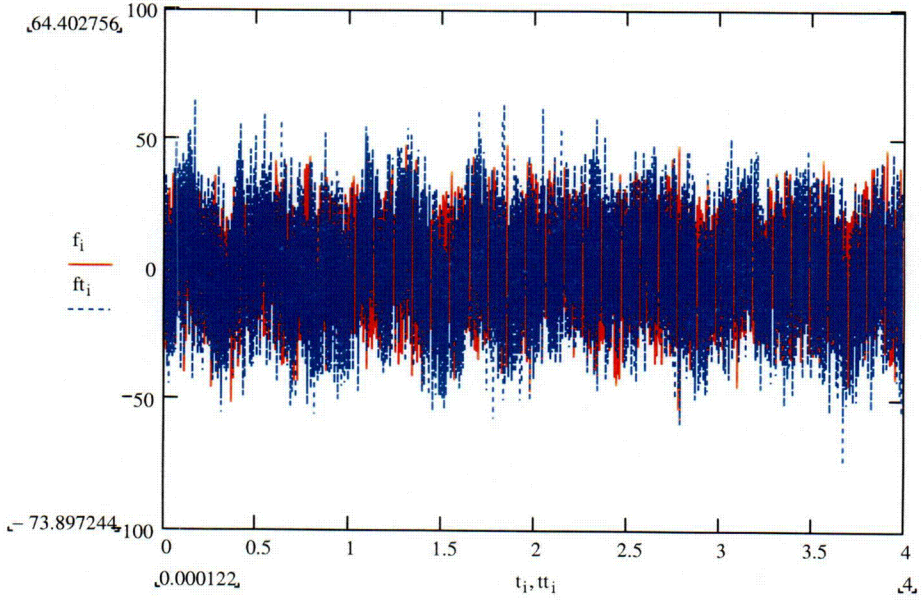

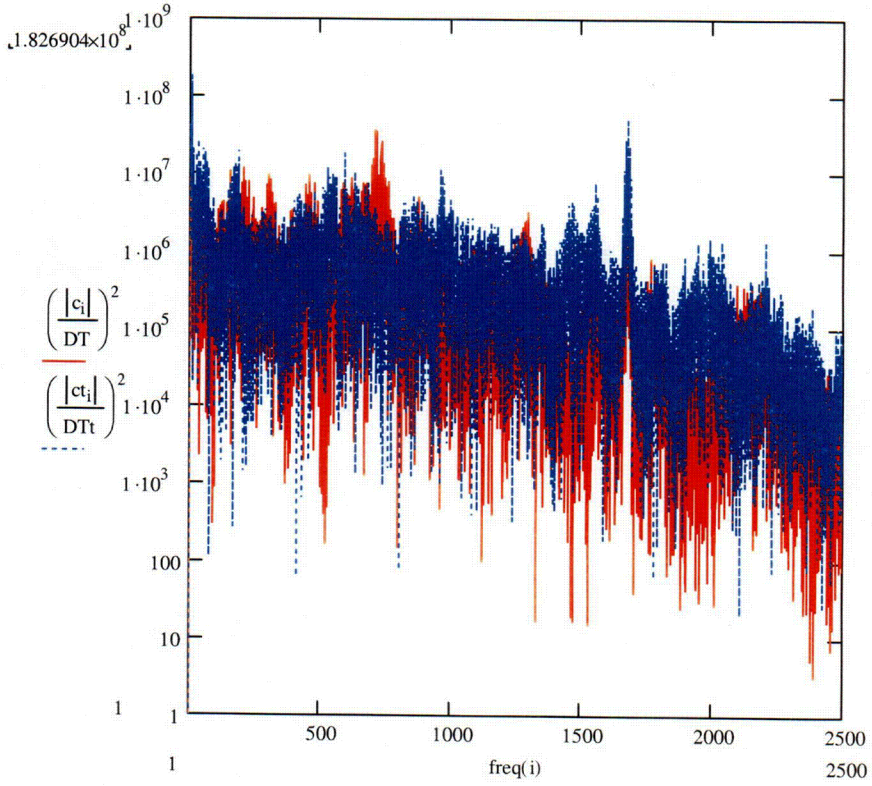

Second Prediction for M21

Blue is measured

Red is predicted

Benchmarking ACM
Load Definition Methodology (cont.)

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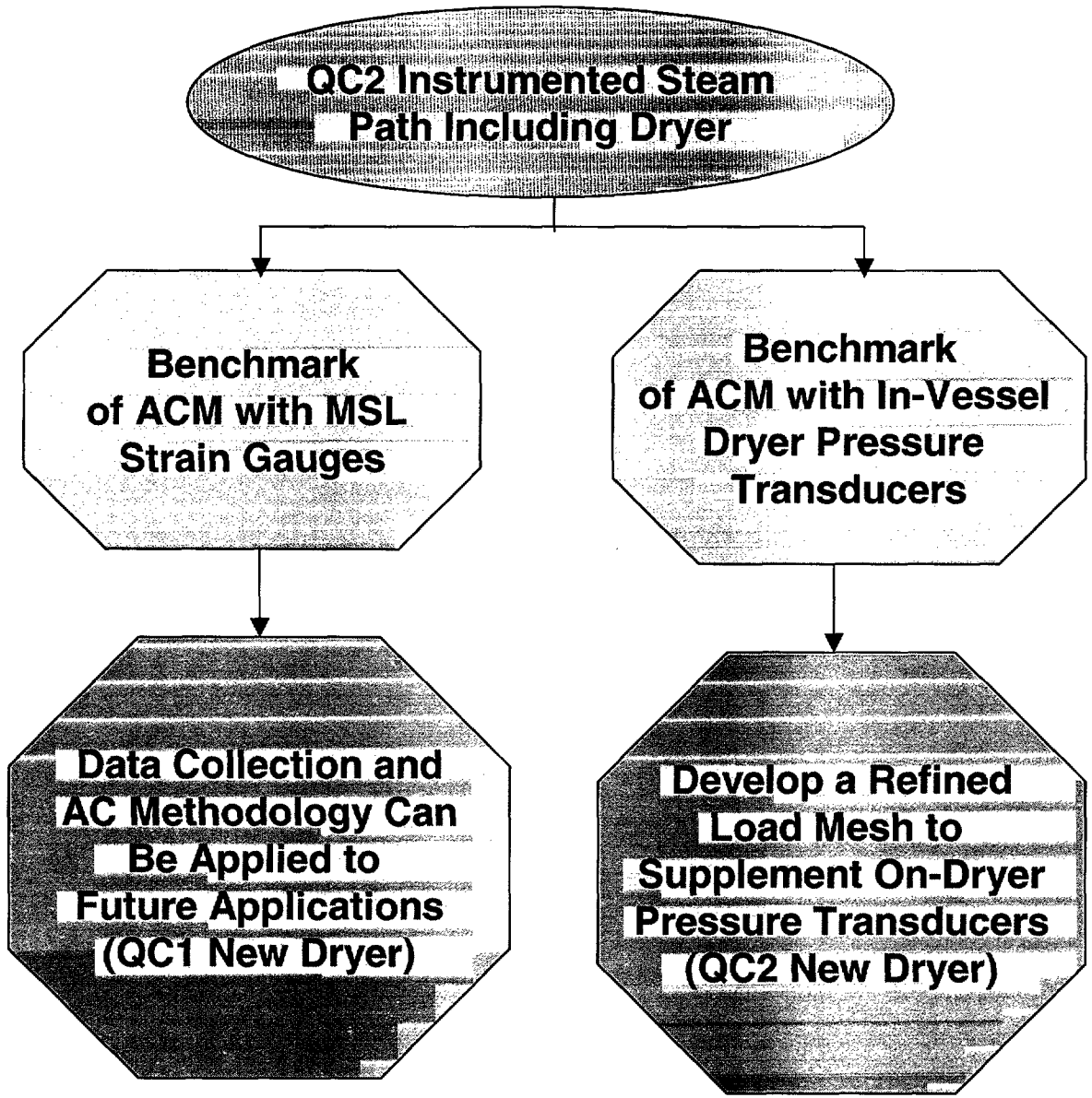

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Startup Test Plan

Brian Strub
Design Engineer
Quad Cities Nuclear Power Station

QC2 Startup Test Strategy

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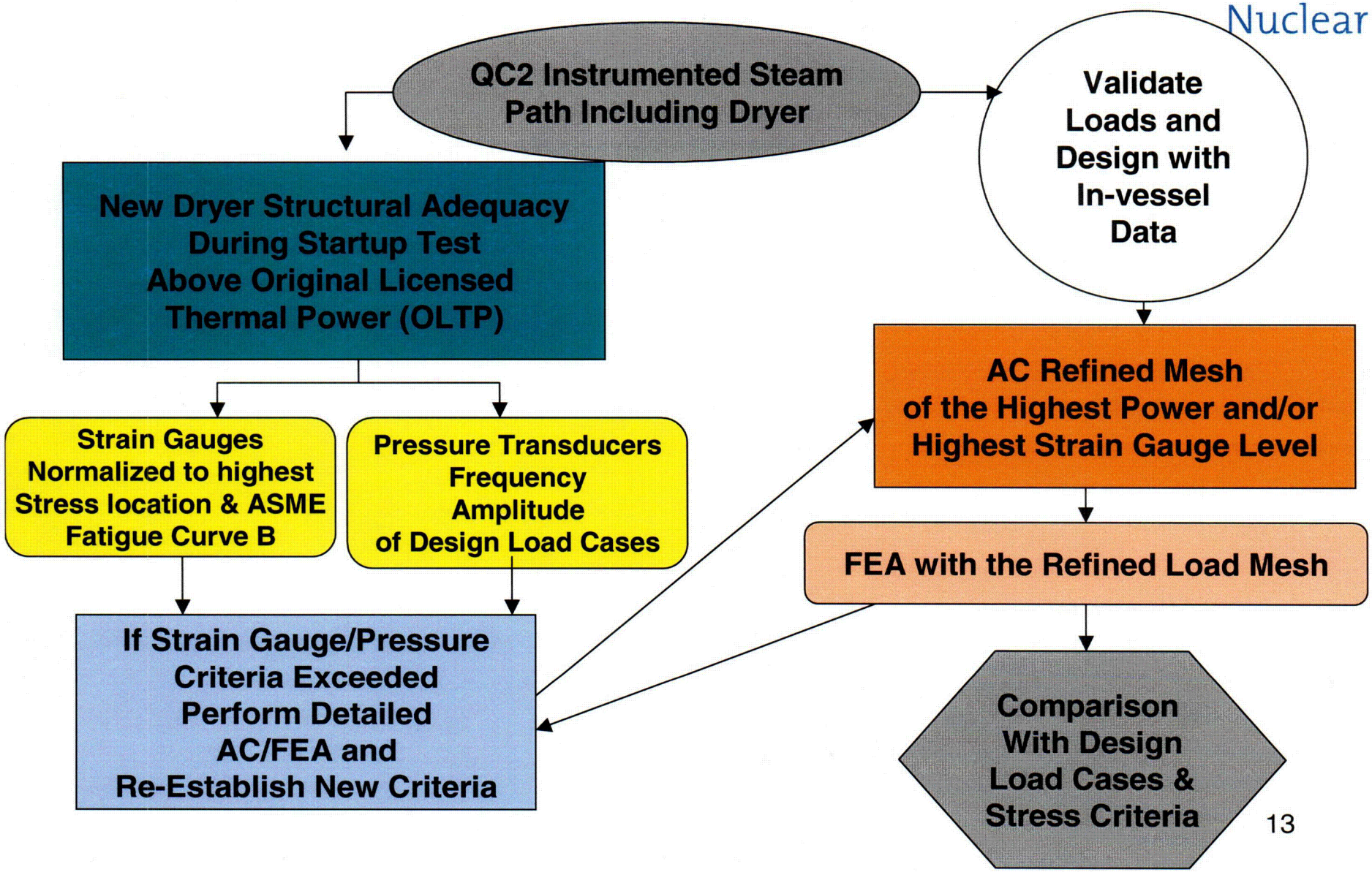

Startup Test Plan
Approach

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- Power will be raised to OLTP level over a 3.5-day period
  - Data will be taken at 33 Test Conditions (TCs) to this point
  - Three levels of Acceptance Criteria evaluated at each power level:
    - Plant Equipment Acceptance Limits: Normal alarm points or established equipment operating limitations based upon historical performance data
    - Level 2 Criteria: Not necessarily alter plant operation or test plan but will initiate an Issue Report (IR)
    - Level 1 Criteria: Initiate an IR and seek immediate resolution; repeat test portion to verify Level 1 can be satisfied; documented resolution within the test procedure (Examples: dryer strain gauges and moisture carryover)
  - Will have Acceptance Criteria for dryer measurements (Go/No-Go decision)
- Will then raise to EPU power level over 29-hour period (TCs 34-41)

Startup Test Plan
Approach (cont.)

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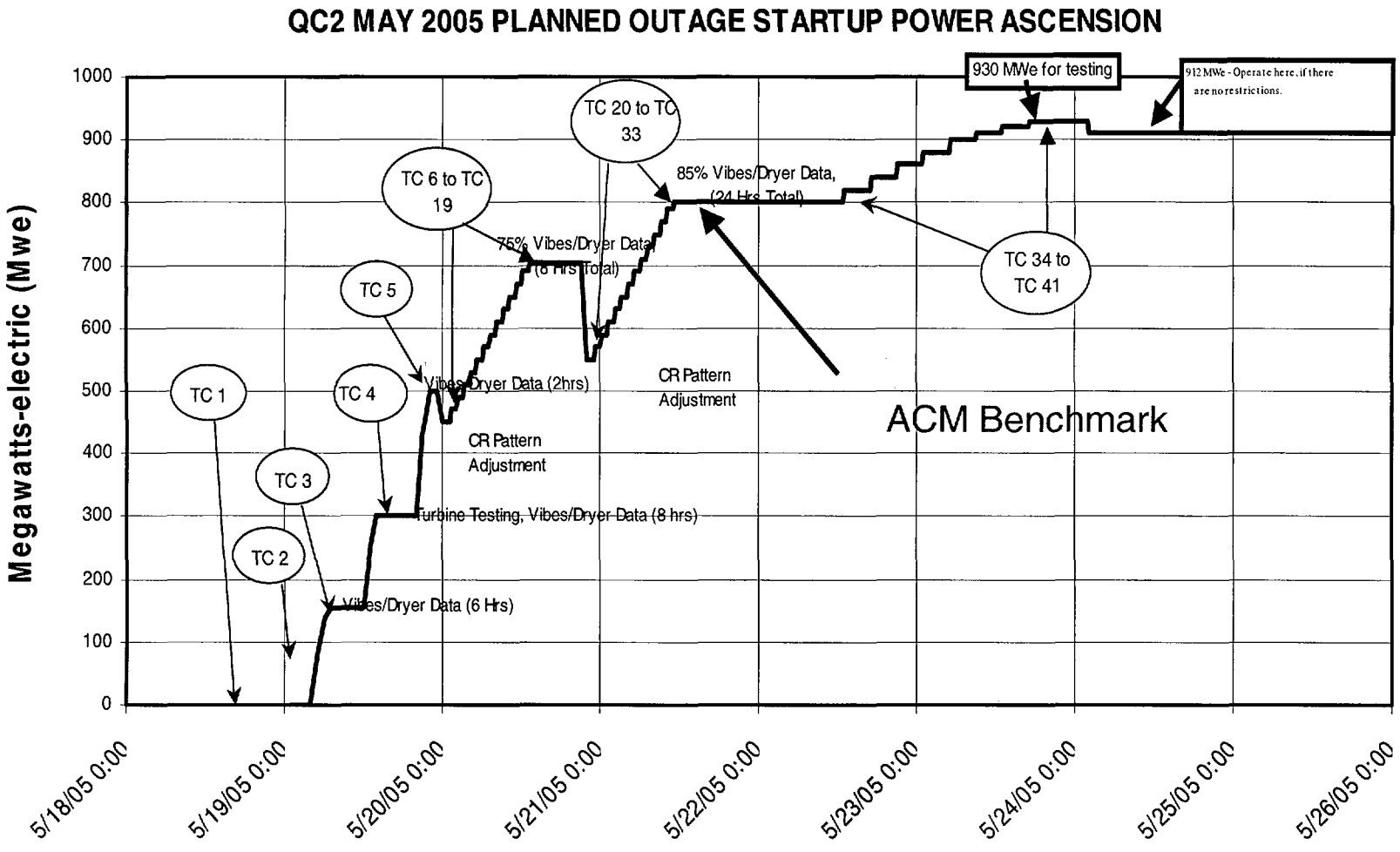

Startup Test Plan
Approach (cont.)

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- Planned data measurements
  - 42 dryer sensors recorded on GE data acquisition system (DAS)
  - 3 reactor steam dome pressure sensors and 4 pressure measurements at the MSL flow venturis recorded on high speed recorders
  - 4 control valve positions recorded on high speed recorder
  - 56 strain gauges on MSLs in drywell/heater bay recorded on DAS
  - 33 accelerometers on MSLs in drywell recorded on tape drives
  - System equipment parameters recorded by computer points and by Operator rounds (approximately 1000 data points)
  - Hand held measurements for vibration levels and local temperatures

Startup Test Plan
Dryer Acceptance

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- The dryer will have four Acceptance Criteria:
  - Criterion A – Dryer strain gauges indicate that the peak dryer stress levels have reached ASME Fatigue Curve "B" (16,500 psi)
  - Criterion B – Dryer strain gauges indicate that the peak dryer stress levels have reached 10,800 psi for outside dryer components, or 13,600 psi for inside dryer components
  - Criterion C – Six pressure gauges on the steam dryer (actual plant pressure data) will be compared to two load case frequencies and amplitudes; load cases are the SMT and QC2 data from power accession to EPU power levels in August 2004
  - Criterion D – If less than the minimum number of strain gauges are functioning, then accelerometer criteria will be used as a backup

Startup Test Plan
Dryer Acceptance (cont.)

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- Criterion C will be implemented above 2511 MWt and when the strain gauges reach 50% of Criterion A
- In addition, strain gauge and accelerometer results will be trended during power ascension based on direct readings and FFT analysis
- Moisture carryover will be sampled and trended during the approach to full power; the dryer design criterion of 0.1% will be a Level 1 Criterion

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Startup Test Plan Update

Keith Moser
Asset Management Engineer

Startup Test Plan Update

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- Incorporated comments from NRC meeting April 11 - 13, 2005, into startup plan
  - Trending strain gauge from previous power levels
    - Direct reading
    - FFT
  - Trending accelerometers
    - Direct reading
    - FFT
  - Added Level D acceptance criteria for accelerometers in the event that strain gauges fail

Applying Acceptance Criteria

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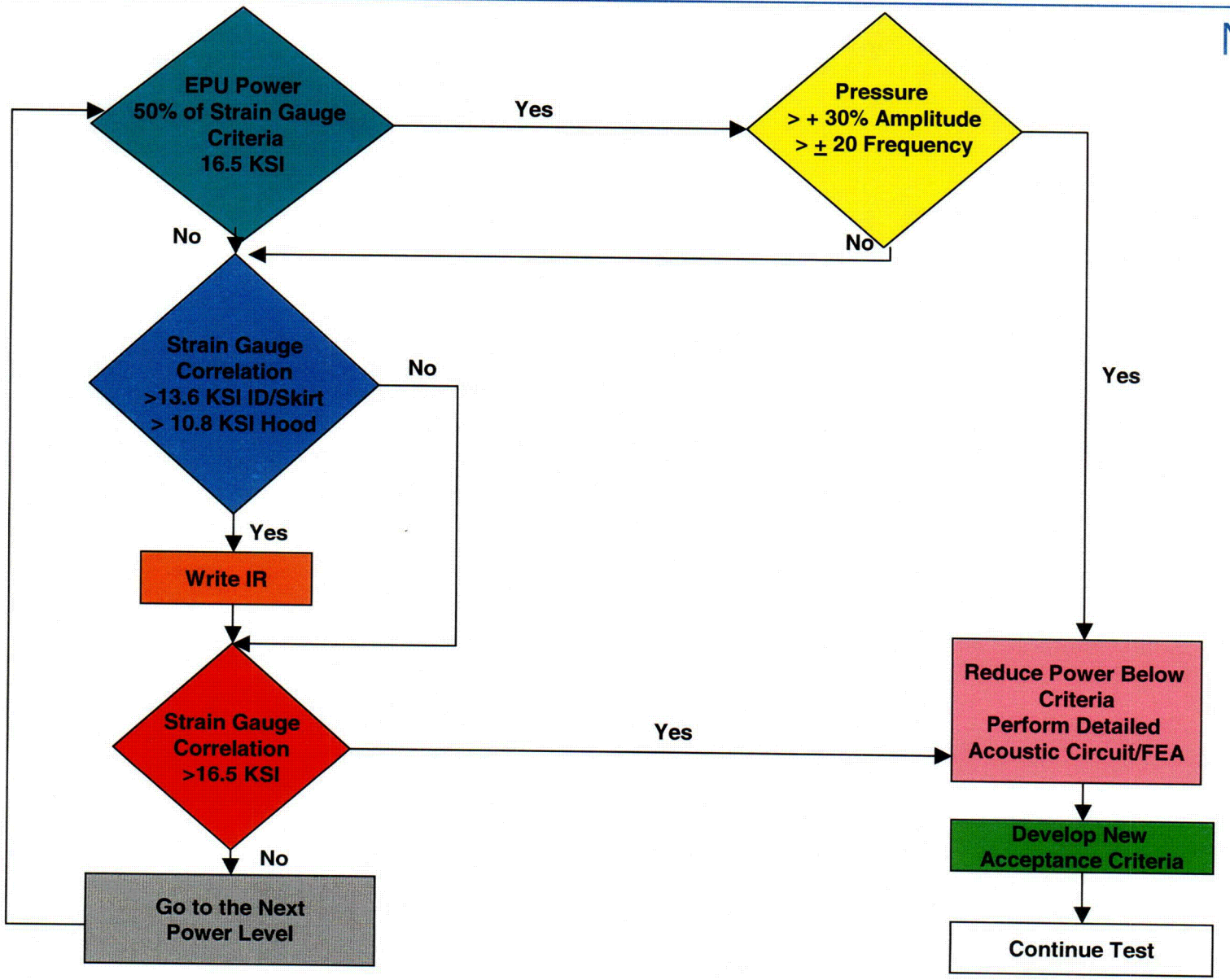

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Operational Plans for QC2 and Basis

Roman Gesior
Director – Asset Management

QC2 Operational Plan

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- Shutdown for QC2 dryer replacement outage on May 9, 2005
  - Outage duration expected to be 10 days
  - Upgrade Target Rock S/RVs
  - Replace dryer
  - Install dryer instrumentation, cabling, and data acquisition system (DAS)
  - Install steam line strain gauges
  - Confirm instrumentation operation prior to restart

QC2 Operational Plan (cont.)

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- Execute Startup Test Plan
  - Expect to be at full pre-EPU power (2511 MWt) ~ May 21
  - Expect to reach full EPU power (2957 MWt or 930 MWe) ~ May 23
    - Operate at this level 5 – 8 hours to collect data
  - Return to 912 MWe ~ May 24
  - Confirm acoustic circuit analysis results demonstrate reasonable loads
  - Confirm dryer qualification through FEA of instrumented dryer pressure gauge information
- Operate remainder of cycle at 912 MWe
    - Within any limitations identified during startup test
  - Continue to monitor strain gauge data throughout the cycle as thermal power increases due to environmental factors to confirm dryer stress is bound by predictions

QC2 Operational Plan Basis

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- Rigorous steam dryer qualification provides confidence in integrity at EPU operation
  - Design philosophy that minimizes FIV susceptibility
  - Diverse loads applied to conservatively bound uncertainty
    - QC1 SMT
    - QC2 In-plant loads
  - Diverse and comprehensive FEMs conservatively bound analysis uncertainty
    - Solid models
    - Weld evaluations
  - Load frequency sensitivity analysis to address model uncertainties
    - Each model run with nominal and +/- 10% shift in time step
  - Hammer test reduces uncertainty in as-built dryer frequency and damping

QC2 Operational Plan Basis (cont.)

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- Startup test plan
  - Instrumented dryer data to confirm analysis load inputs (e.g., frequency and amplitude)
  - Dryer strain gauge data to confirm stress levels remain bounded by predictions
  - MSL strain gauges will be used to confirm acoustic circuit loads are reasonable
  - Dryer data will be trended to address unexpected change in key monitored parameters (e.g., pressure and strain)
  - If Criteria A are exceeded, power will be reduced

QC2 Operational Plan Basis (cont.)

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- Startup test plan (cont.)
  - Monitoring of reactor parameters for timely identification of issues
  - Other plant equipment will also be monitored to identify adverse conditions (e.g., ERVs, Target Rock S/RV, B MSL, B MSIV, High Pressure Coolant Injection (HPCI) valve actuator)
  - Moisture carryover

QC2 Operational Plan Basis (cont.)

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- Conclusions
  - Conservative design
  - Extensive evaluations
  - Detailed startup test plan
- Exelon has taken the necessary steps for safe EPU operation of QC2

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Operational Plans for QC1 and Bases

Roman Gesior
Director – Asset Management

QC1 Operational Plan

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- Outage to replace steam dryer expected last week of May 2005
  - Outage duration expect to be ~6 days
- Expect to execute a startup test plan similar to QC2 without dryer instrumentation
  - Power ascension to 912 MWe
  - No dryer instrumentation installed
  - MSL strain gauges will be installed to confirm, using acoustic circuit analysis, that dryer loads remain reasonable
- Power operation for remainder of cycle at 912 MWe if no limitations identified during startup test or from QC2 instrumented dryer results

QC1 Operational Plan Basis

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- QC1 dryer qualification is equally as robust as QC2
- Same design as QC2
- No evidence that QC1 loads are greater than QC2
- SMT loads obtained with QC1 configuration
- MSL strain gauge data will be acquired
  - Acoustic circuit analysis will be performed to confirm dryer loads are consistent with those used in FEA
  - Acoustic circuit analysis method will be evaluated during startup testing of QC2

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Summary of Commitments for EPU Operation

Patrick Simpson
Manager – Licensing

Regulatory Commitments – QC2

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- After dryer replacement, operation at EPU power levels will continue while detailed evaluations of the instrumented data are performed, if the Startup Test Plan acceptance criteria (i.e., go/no-go decision) are met
  - If the detailed evaluations are not completed within 60 days of data collection at 930 MWe, power will be reduced to OLTP until the evaluations are completed
- EGC will obtain NRC approval for long-term EPU operation of QC2
- EGC will conduct daily monitoring of MCO and other key reactor and plant parameters while operating at full power
  - If indications of dryer damage or structural integrity concerns are identified, power will be reduced to OLTP and the issue will be evaluated in accordance with the corrective action process
- During the Spring 2006 refueling outage for QC2:
  - EGC will perform a general visual inspection of the RPV internals, steam, and feedwater systems, including inspection and disassembly if needed of the most susceptible components, which include ERVs
  - EGC will conduct an inspection of the QC2 dryer using BWRVIP inspection guidance

Regulatory Commitments – QC1

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- After dryer replacement, operation at EPU power levels will continue while detailed evaluations of the QC2 instrumented data are performed
  - If the QC2 detailed evaluations are not completed within 60 days of data collection at 930 MWe, QC1 power will be reduced to OLTP until the evaluations are completed
- EGC will obtain NRC approval for long-term EPU operation of QC1
- EGC will conduct daily monitoring of MCO and other key reactor and plant parameters while operating at full power
  - If indications of dryer damage or structural integrity concerns are identified, power will be reduced to OLTP and the issue will be evaluated in accordance with the corrective action process
- During the Spring 2007 refueling outage for QC1, EGC will conduct an inspection of the QC1 dryer using BWRVIP inspection guidance

Regulatory Commitments – DNPS

Exelon SM
Nuclear

- EGC will conduct daily monitoring of MCO and other key reactor and plant parameters while operating at full power
  - If indications of dryer damage or structural integrity concerns are identified, power will be reduced to OLTP and the issue will be evaluated in accordance with the corrective action process
- During the Fall 2005 refueling outage for D2:
  - EGC will perform a general visual inspection of the RPV internals, steam, and feedwater systems, including inspection and disassembly if needed of the most susceptible components, which include ERVs
  - EGC will conduct an inspection of the D2 dryer using BWRVIP inspection guidance
    - Results will be evaluated, considering the analytical work done to date, to determine appropriate action for D3
    - Evaluation results and plans for D3 (e.g., potential need for mid-cycle outage) will be shared with the NRC within one month of completion of the Fall 2005 refueling outage for D2
  - EGC will attempt to locate and retrieve the lost D2 feedwater sample probe

Regulatory Commitments

Exelon SM
Nuclear

- EGC will evaluate the AC model using the MSL strain gauge data without bias from the QC2 instrumented dryer test data, and take appropriate action in response to the application of the test results to the DNPS dryers. EGC will share the predicted QC2 dryer loads based on the AC model using the MSL strain gauge data with the NRC for comparison to the actual QC2 loads obtained from the instrumented dryer. EGC will meet with the NRC technical staff in late June 2005 to discuss:
  - Results of the collected QC2 instrumented dryer data evaluations,
  - Results of SMT of the QC1 steam dryer, and
  - The decision and its basis regarding SMT of the D2 and D3 dryers.
- EGC will meet with NRC management in mid-July 2005 to present and summarize the information above as it applies to operation of D2 and D3 at EPU conditions