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DATE OF MEETING

2/3/04

The attached document(s), which was/were handed out in this meeting, is/are to be placed in the public domain as soon as possible. The minutes of the meeting will be issued in the near future. Following are administrative details regarding this meeting:

Docket Number(s) 50-691

Plant/Facility Name BWROG

TAC Number(s) (if available) ML0931

Reference Meeting Notice ML040230340

Purpose of Meeting  
(copy from meeting notice) Meeting with the BWROG  
to discuss effects of  
extended power updates on  
plant operation.

NAME OF PERSON WHO ISSUED MEETING NOTICE

Alan Wang

TITLE

PM X1445

OFFICE

NRR

DIVISION

DLPM

BRANCH

PD IV

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DFOI

	June 2002	Dec 2002	April 2003	June 2003	July 2003	August 2003
Plant	Quad Cities 2		Quad Cities 2	Quad Cities 2		
Component Failure	Steam dryer cover plate		PORV stuck open	- Dryer outer bank hood - Internal bracing		
Root Cause	High cycle fatigue: Cover plate Hz aligns with vortex shedding Hz and acoustic vibration ~180Hz			High-cycle fatigue driven by low Hz pressure pulsations @ EPU steam velocities ~24 Hz (exacerbated by PORV discharge)		
Corrective Action	Repair and modify QC2 cover plate			- repair/modify hood - eliminate internal bracing		
Extent of Condition	Quad Cities 2 only (cover plate)			Quad Cities 1&2 Dresden 2&3 (dryer susceptibility)		
Licensee Generic Action		Dresden 3 modifies cover plate (Fall 2002 outage)	Quad Cities 1 modifies cover plate (Spring 2003 outage)			
NRC Action	Monitors licensee actions (moderate) Issues IN 2002-26 (9/11/02)			Monitors licensee actions (extensive) Sends SIT to QC2	Issue IN 2002-26 Supp 1 (7/21/03) Meeting with Exelon/GE/BWROG (7/25/03)	
Industry Action	GE issues SIL No. 644 (8/21/02)					

	Sept 2003	Oct 2003	Nov 2003	Dec 2003	Jan 2004
Plant		Dresden 2	Quad Cities 1	Dresden 3	
Component Failure		- FW sampling probe - FW sparger (3 holes) - cracks in dryer hood	- outer bank hood (lost part) - ERV actuator - degraded MS line subcomponents	- FW sampling probe - cracks in dryer hood	
Root Cause		FW probe HZ aligns with vortex shedding Hz @ EPU conditions	High cycle fatigue caused by fluctuating pressure loading with acoustic component at EPU	FW probe Hz aligns with vortex shedding Hz @ EPU conditions	
Corrective Action		- repair FW sparger - retrieve FW probe <div style="border: 1px solid black; padding: 2px;">1 probe still missing</div>	- repair/modify dryer hood - eliminate bracing - lost part analysis <div style="border: 1px solid black; padding: 2px;">Steam dryer pieces still missing</div> - repair ERV actuator - perform EPU vibration assessment	- retrieves 2 FW probes from FW sparger	
Extent of Condition		Dresden 2 (FW probe)	Quad Cities 1&2 Dresden 2&3 (MS line subcomponents) <div style="border: 1px solid black; padding: 2px;">EPU impact on MS line subcomponents for other BWRs not addressed</div>	Dresden 2 & 3 sampling probes <div style="border: 1px solid black; padding: 2px;">EPU impact on FW components for other BWRs not addressed</div>	
Licensee Generic Action		Dresden 2 modifies - cover plate - dryer hood/bracing (Fall 2003 outage)		Dresden 3 (mid-cycle outage) - modify cover plate - modify dryer hood/bracing  Quad Cities 1 conducts vibration assessment for EPU	Licensee returns QC1 to pre-EPU level due to EPU effect on ERVs
NRC Action		NRC sends letter to BWROG commenting on GE SIL Supp 1 (9/26/03)	NRC meets with BWROG (11/4/03) - NRC comments on SIL - generic steam dryer issues		Issues IN 2002-26 Supp 2 (1/9/04)
Industry Action		GE issues SIL No. 644 Supp 1 (9/5/03)	BWROG tasks BWRVIP to address steam dryer issues	Develops survey on BWR steam dryer inspections	

CONCERNS RELATED TO  
POTENTIAL ADVERSE FLOW EFFECTS  
FROM POWER UPRATES

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Mechanical and Civil Engineering Branch  
Office of Nuclear Reactor Regulation  
U.S. Nuclear Regulatory Commission

February 3, 2004

## DISCUSSION TOPICS

- Scope of failures
- Cause of failures
- Action taken (plant specific)
- Further actions needed (generic)

1. Scope of failures under power uprate conditions has expanded.

June 2002: After operating a few months at EPU conditions, Quad Cities Unit 2 experiences failure of steam dryer cover plate with pieces found in main steamline flow venturi and turbine stop valve strainer.

June 2003: Following restart from steam dryer repairs in 2002, Quad Cities Unit 2 experiences additional failures of steam dryer outer bank hood, internal braces, and tie bars.

October 2003: After 2 years of EPU operation, Dresden Unit 2 finds 4-inch fatigue cracks on inner surface of outer vertical hood panels at diagonal brace brackets of steam dryer. Dresden Unit 2 also finds three holes in FW sparger caused by broken FW sampling probe that was retrieved from sparger.

November 2003: After 9 months of EPU operation, Quad Cities Unit 1 experiences failure of steam dryer with missing pieces, main steam relief valve (including actuator, drain line, and support), and main steamline supports. During January 16 telecon, degradation of limit switch in HPCI steam supply MOV attributed to vibration.

December 2003: Following shutdown in response to Quad Cities failures, Dresden Unit 3 finds two 4-inch through-wall cracks in steam dryer hood. Dresden Unit 3 also finds two sampling probes in FW sparger that had broken loose in FW system.

December 2003: Dresden Unit 2 identifies failure of a second FW sampling probe that remains lost in FW system.

2. Cause of failures attributed to EPU conditions; but load definition has not been firmly established.

July 2002: Licensee states that root cause of Quad Cities Unit 2 steam dryer cover plate failures in 2002 was high-cycle fatigue due to high frequency acoustic resonance (130 to 230 Hertz). Licensee attributed failure to increased loading due to EPU operation.

July 2003: Licensee states that root cause of Quad Cities Unit 2 steam dryer failure in 2003 was high-cycle fatigue due to low frequency pressure loading (0 to 50 Hertz). Licensee indicated that failure was due to operation with failed cover plate which caused accelerated fatigue in hood area, and increased loading due to PORV opening.

December 2003: Licensee's root cause evaluation of Dresden FW probe failures indicates that original probes were susceptible to failure mechanisms of Transgranular Stress Corrosion Cracking and fatigue failure resulting from flow-induced vibration, and that the more recent replacement probes are susceptible to fatigue failure from flow-induced vibration.

January 22, 2004: GE indicates during a telephone conference that a previously unevaluated fluctuating pressure load in the acoustic range is believed to be contributing to adverse vibration effects during power uprates.

TBD: NRC plans to review GE load definition and steam dryer analysis methodology in conjunction with Vermont Yankee EPU submittal.

3. Industry actions respond to failures “after the fact,” and do not resolve plant-specific susceptibility and future failures of other components.

July 2002: Licensee repaired Quad Cities Unit 2 steam dryer by installing 0.5-inch cover plate and increasing weld size to 0.5 inches.

August 2002: In SIL 644, GE recommended that BWRs with BWR/3 steam dryers with 0.25-inch cover plates consider reviewing inspection records, monitoring plant parameters, and increasing frequency of moisture content measurements, and BWRs with BWR/3 steam dryers operating or planning to operate above OLP should perform VT-1 examination of cover plates and welds at next RFO.

July 2003: Licensee repaired Quad Cities Unit 2 steam dryer by replacing 0.5-inch outer hood plates with 1-inch plates, removing internal braces, and adding gussets and stiffeners.

September 5, 2003: In Supplement 1 to SIL 644, GE recommended that all BWRs operating or planning to operate above OLTP consider reviewing inspection records, monitoring plant parameters, increasing frequency of moisture content measurements, and conducting steam dryer inspections based on their specific design to identify failures that have occurred in the steam dryer.

September 26, 2003: In a letter to BWROG, NRC provides numerous concerns regarding provisions in SIL 644, Supplement 1, such as the lack of proactive measures to avoid adverse flow effects from power uprates.

November 4, 2003: In a public meeting, BWRVIP discusses plans to develop guidelines for inspecting, monitoring, and evaluating steam dryers.



November 5, 2003: In a public meeting, BWROG discusses NRC comments on SIL 644, Supplement 1, but has not resolved those concerns. GE indicates that "subcomponents" not evaluated for potential adverse flow effects during initial power uprate reviews.

November 2003: Licensee performs repairs of steam dryer and steamline components at Quad Cities Unit 1 that are more extensive than previously performed at Quad Cities Unit 2. Licensee is unable to locate lost dryer parts, but justifies startup with lost parts evaluation.

December 2003: Dresden Unit 2 justifies restart with lost parts evaluation for missing FW sampling probe.

January 16, 2004: Licensee states during telecon that electromatic relief valves at Quad Cities Unit 1 justified for EPU operation for only a limited time period. Licensee subsequently decides to remain at pre-EPU power levels until further modifications completed.

January 22, 2004: GE states during a telecon that previously unevaluated fluctuating pressure load can be considered generically only for the steam dryer, and that potential adverse flow effects on steam and feedwater lines and their components must be evaluated on plant-specific basis.

4. Lack of specific industry organization coordinating response to potential adverse flow effects from power uprates.

November 5, 2003: BWROG indicates that BWRVIP tasked to develop inspection guidelines but apparently only for steam dryer. BWROG states that survey to be performed of power uprate experience at BWR plants. Not clear which industry organization intends to resolve NRC concerns with Supplement 1 to SIL 644.

January 15, 2004: During a telecon with NRC, licensee of Vermont Yankee points to its planned response to Supplement 1 to SIL 644 on steam dryers as part of initial support for NRC approval of its proposed EPU operation without clear indication of plan to resolve overall issue.

January 20, 2004: In a telephone conference with NEI, the NRC staff discusses the apparent lack of coordination among BWR owners in addressing the extent of condition and generic impact of power uprates on BWRs. During the telecon, NEI commits to contact INPO to discuss what they have found with respect to the impact of power uprates on plant performance.

January 22, 2004: In a telecon with NRC staff, GE indicates that its new fluctuating pressure loading evaluation only addresses steam dryers, and that plant-specific review is necessary for steam and feedwater flow effects.

## NRC QUESTIONS

- Extent of condition / What else can fail?
- Safety significance / What are the potential adverse impacts of failures?
- Susceptibility and applicability / Which plants are vulnerable and why (e.g., all BWRs, all power uprates, all EPU's, all plants)?
- Remedies / What are the options and associated advantages, disadvantages, and impacts?
- Next steps / What actions should be taken by industry and NRC for current power uprates and future uprates?
- Schedule / What is the urgency of the issue?

***Industry Plan/Status Update  
for  
Resolution of BWR Steam Dryer  
Integrity and Other  
Extended Power Uprate Concerns***

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Presentation for BWROG/NRC Meeting  
February 3, 2004  
Rockville, MD

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# BWR Extended Power Uprate Issues

## Introduction

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### ✦ BWROG Goals

- ✦ Ensure that operating experience and lessons learned are incorporated into power uprate programs to assure safe and reliable operations
- ✦ Provide executive oversight for a broad range of industry efforts related to BWR power uprates

# BWR Extended Power Uprate Issues

## Introduction

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- \* EPU's implemented at 11 BWRs
- \* EPU's planned at 6 BWRs in near term
- \* Approximately 100 uprates have been implemented in the industry
- \* Number of industry events have not significantly increased as a result of power uprate

# BWR Extended Power Uprate Issues

## Introduction

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- \* Due to recent failures of BWR 3 steam dryers and other components, the BWR industry has increased its attention to operational reliability at EPU conditions
- \* Industry has initiated systematic efforts to better predict and prevent component failures caused by BWR EPU conditions

# BWR Extended Power Uprate Issues

## Introduction

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### \* Ongoing EPU-related work includes

- ◆ BWRVIP development of steam dryer inspection and evaluation guidelines
- ◆ Vibration monitoring at a BWR 3 to identify additional areas for analytical and operational improvements
- ◆ GE and Exelon conducting detailed EPU extent of condition review of BWR 3 components and subcomponents
- ◆ BWROG thorough review of industry data to better understand problem areas and component failures related to operation under EPU conditions



## Steam Dryer Integrity Background

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- ✦ Dryer failures at Quad Cities and discovery of cracks on Dresden dryers (BWR 3s) related to power uprate conditions
  - ✦ GE screening matrix ranks susceptibility of other BWR dryers for similar damage
  - ✦ Design modifications and repairs implemented on Dresden and Quad Cities units
  - ✦ GE SIL 644 and 644 supplement 1 provides inspection recommendations

## Steam Dryer Integrity Industry Objective

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- ✦ Resolve BWR steam dryer integrity issues to preclude:
  - ✦ Adverse impact on plant safety
  - ✦ Significant forced outages and extended refueling outages caused by dryer failure
  - ✦ Increased secondary side radiation dose due to dryer failures

# Steam Dryer Integrity

## GENE Workscope

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- ✧ SIL 644 Supplement 1 issued on September 5, 2003 provides detailed dryer inspection recommendations
- ✧ Revision to SIL 644 underway to capture recent experience
  - ◆ Monitoring trends more important than absolute thresholds
  - ◆ Dryer workmanship can be significant variable
- ✧ Steam dryer load definition
  - ◆ Original design did not include flow induced vibration and acoustic loads
- ✧ Detailed steam dryer structural evaluations for EPU submittals

# Steam Dryer Integrity

## Recent Steam Dryer Inspection Experience

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✱ Quad Cities 1 outer hood failure (Nov. 2003)

- ◆ Failure, root cause similar to Quad Cities 2
- ◆ Fatigue cracks on inner bank braces
  - Root cause – configuration, weld quality

✱ Dresden 3 preemptive repair (Dec. 2003)

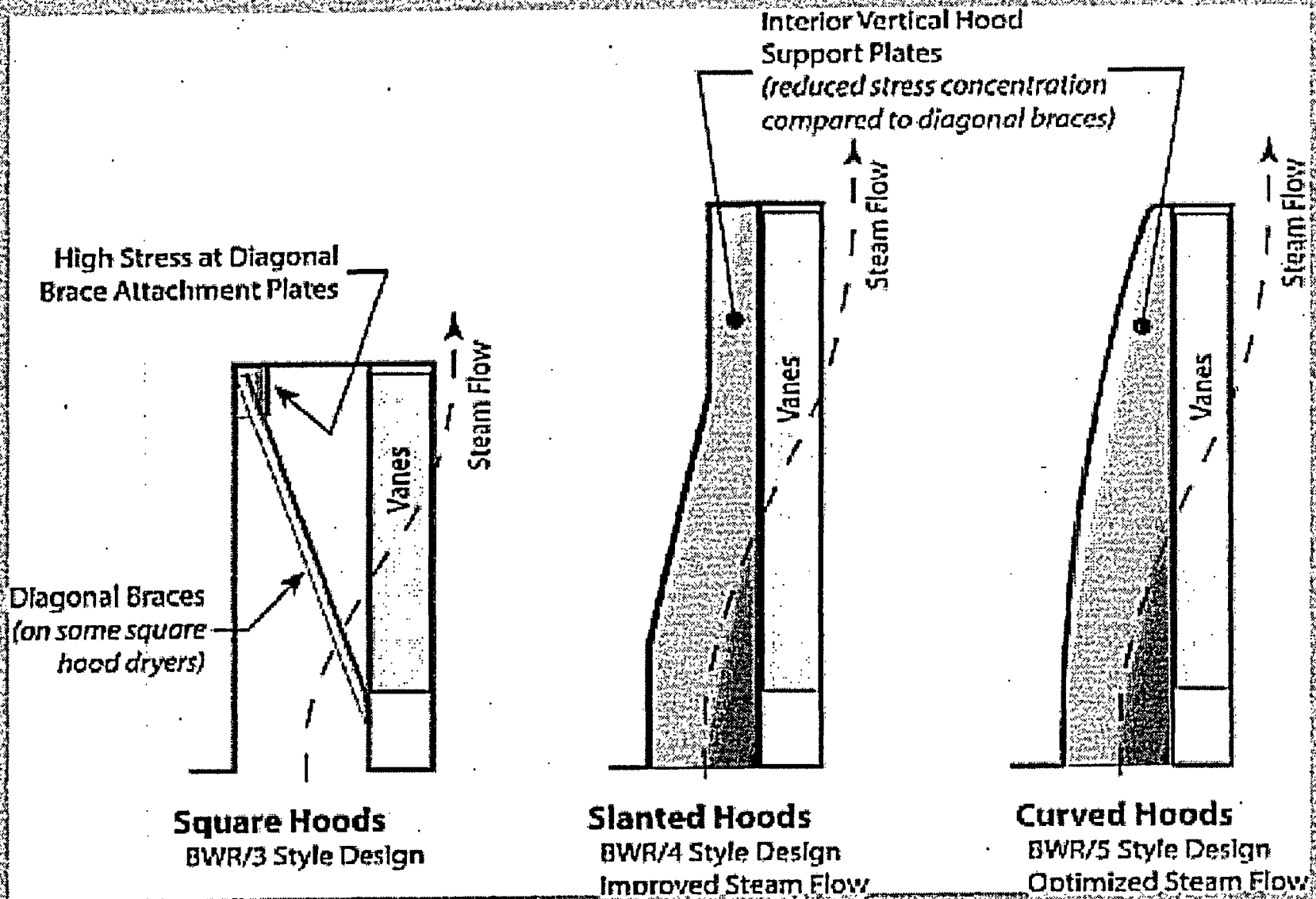
- ◆ Short fatigue cracks on vertical hood panels
- ◆ Location similar to Dresden 2

# Steam Dryer Integrity

## Summary of Key Design Factors

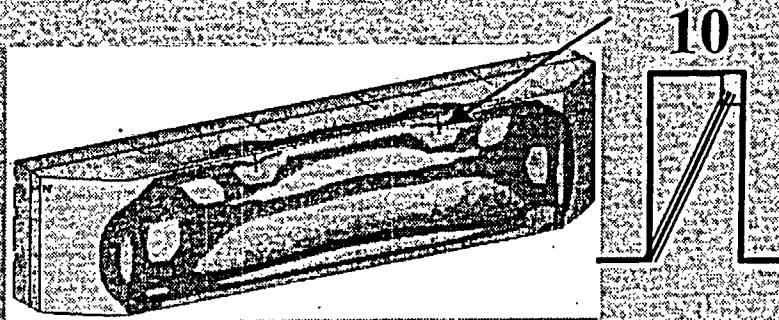
- \* BWR 3; square hood and internal braces
  - High stresses where braces attach to hood
  - Some BWR 3 dryers do not have internal braces
- \* BWR 4; slanted hoods, internal braces replaced with plates that reduce the maximum stress
- \* BWR 5 and later; curved hoods to optimize steam flow, retained the internal plates; even lower maximum stress
- \* Higher MSL velocities increases the amplitude of flow induced and acoustic load forcing functions that lead to high cycle fatigue
  - Quad Cities and Dresden have small 20" diameter steam lines

# Basic GE Steam Dryer Hood Types

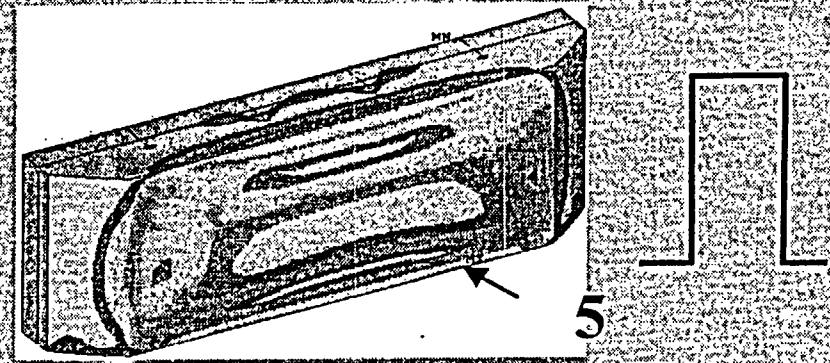


# Relative Stress on GE Steam Dryer Hoods

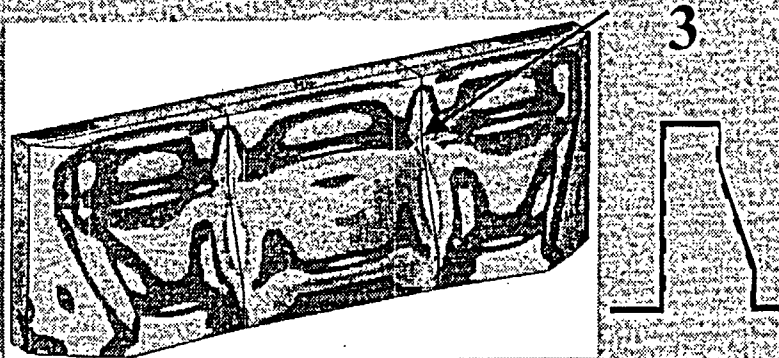
Square Hood w/Struts



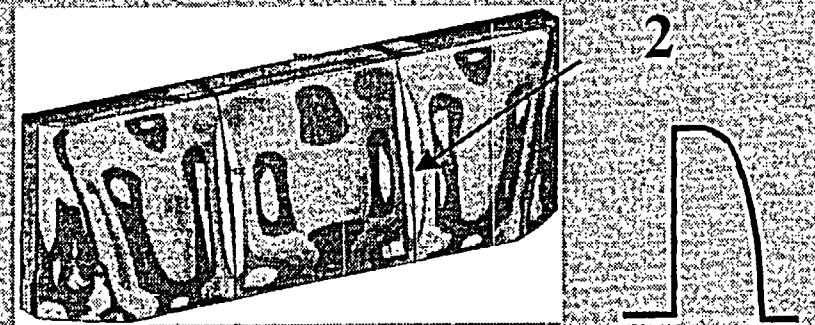
Square Hood w/o Struts



Slanted Hood



Curved Hood



# GE Steam Dryer Screening Matrix

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- \* Relative steam dryer failure probability function of:
    - Square of steam velocity
    - Relative stress on steam dryer hoods from finite element analysis

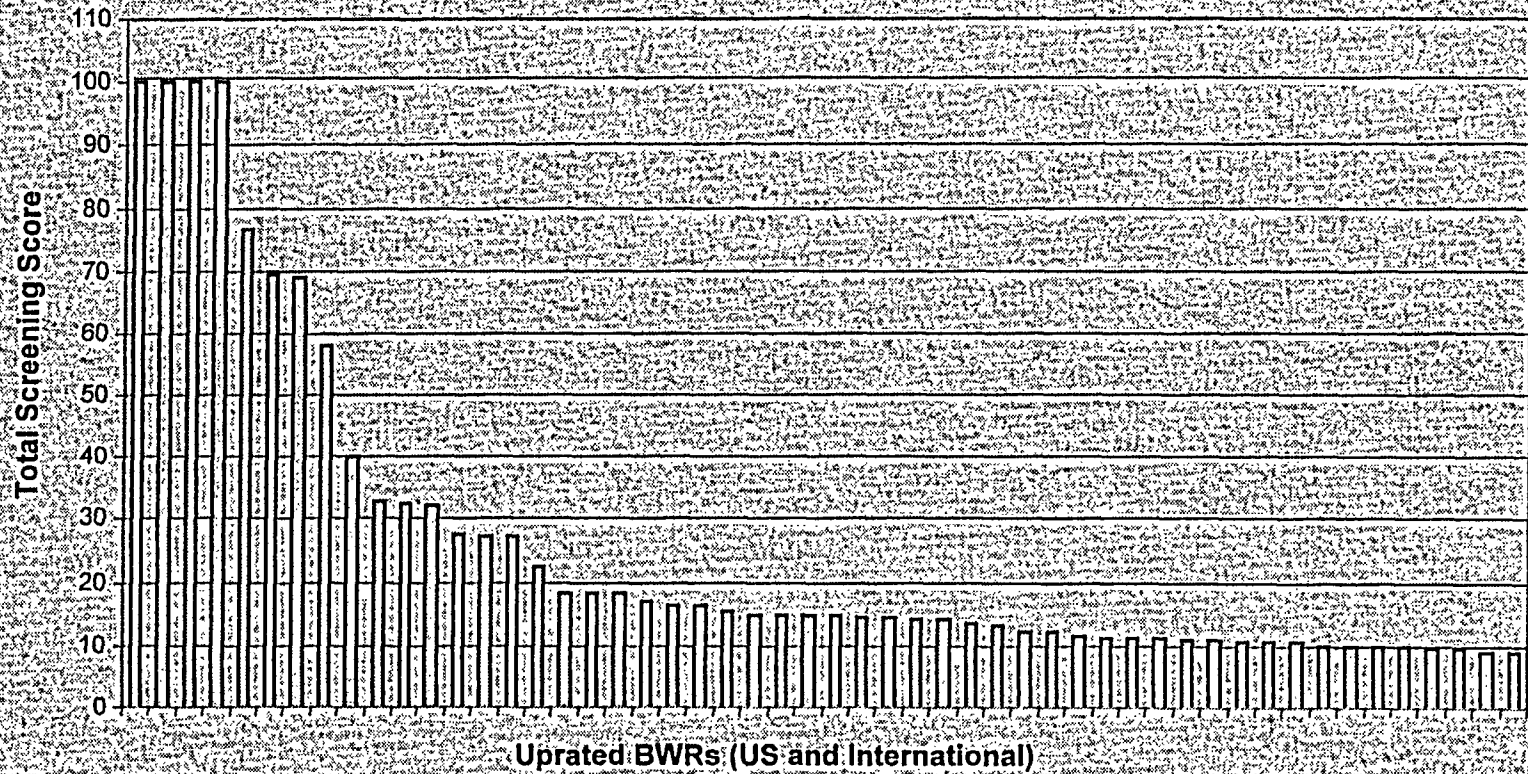


# GE Steam Dryer Screening Matrix

## Example Results

<b>Plant</b>	<b>Average Flow Vel. / Line (ft/sec)</b>	<b>Pressure Load Score</b>	<b>Hood Type</b>	<b>Stress Score</b>	<b>Relative Score</b>
Plant 4	202	10.00	Flat	10	100
Plant 5	168	6.90	Flat	10	69
Plant 17	141	4.87	Slanted	3	15
Plant 20	134	4.43	Slanted	3	13
Plant 22	172	7.23	Curved	2	14
Plant 14	181	8.03	Curved	2	16

# SCREENING MATRIX RESULTS



**75% of updated U.S. BWR dryer failure probabilities are less than 20% of highest screening matrix results (BWR 3s are highest risk)**

# Steam Dryer Integrity

## BWRVIP – Inspection and Evaluation Guidelines

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### ✧ Steam Dryer Configurations

- ◆ Dryer Design and Fabrication
- ◆ Inspection History and Results
- ◆ Areas of Susceptibility

### ✧ Consequence Analysis

- ◆ Detectability of failure
- ◆ Safety consequences of a failure (including FMEA)

### ✧ Inspection Guidelines

- ◆ Categorization by design type, model, susceptibility, etc.
- ◆ Inspection methods
- ◆ Locations and frequency of inspections

# Steam Dryer Integrity

## BWRVIP – Inspection and Evaluation Guidelines

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- ✱ Flaw Evaluation methods
  - ◆ Analysis methods and sample evaluation
- ✱ Operational Guidance
- ✱ Repair Guidance
- ✱ September 2004 Submittal to NRC

# Steam Dryer Integrity BWRVIP – Additional Activities

- ✱ Update the BWRVIP-06 based on the revised steam dryer Failure Modes and Effects Analysis
  - ◆ Includes updated assessment of loose parts
  - ◆ September 2004 Submittal to NRC
- ✱ Follow-up actions as appropriate

# Steam Dryer Integrity BWROG Workscope

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- ✱ Develop best practices for parameter monitoring including possible responses to observed increases
  - Moisture carryover
  - Steam line flow mismatch
- ✱ Identify key parameters besides dryer failure that influence moisture carryover
- ✱ Improve ability to understand parameter changes and take appropriate action

# Extended Power Uprate Background

- \* NRC senior management have expressed concern with respect to recent incidents of degraded hardware resulting from EPU at BWRs
- \* GE and Exelon jointly performing detailed Extent Of Condition review for Extended Power Uprate for Dresden and Quad Cities
- \* BWROG committee formed in December 2003 to review the operating experience associated with EPU and determine if there are additional actions our members should be considering
  - ◆ Committee working with GE and Exelon on Extent of Condition review

# Extended Power Uprate Exelon Vibration Program

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- ✧ Accelerometers installed on QC Unit 1 MSL components chosen due to potential vulnerability to accelerated aging from vibration
  - ERVs
  - Main Steam Isolation Valve (MSIV)
  - Target Rock Safety/Relief Valve
  - High Pressure Coolant Injection (HPCI) steam supply valve
- ✧ Collected vibration data over a range of power levels from pre-EPU to EPU
- ✧ Evaluated major components and subcomponents to determine their vulnerability to near term structural failures or accelerated aging due to EPU related increased vibration levels



## Extended Power Uprate Exelon Vibration Program-Assessment Conclusion

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- \* MSL components are acceptable for full cycle operation at EPU power, with the exception of the ERV actuators which are identified as having some potential for accelerated aging at EPU power levels
- \* Additional testing to be performed will determine any further actions required to ensure acceptable operation of the ERVs

## Extended Power Uprate GE / Exelon Workscope

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- ✱ Review operating history for QC, Dresden, and incorporate BWR industry lessons learned
- ✱ Review operational and reliability considerations for systems, components, and subcomponents affected by EPU
- ✱ Assess critical systems component design limitations versus EPU projected and actual performance and evaluate adequacy of engineering margin

## Extended Power Uprate GE / Exelon Workscope

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✱ Develop analytical and operational improvement recommendations to preclude component failures following implementation of EPU

- Evaluate margin of critical operating parameters with respect to design limits
- Identify and mitigate potential vulnerabilities
  - ◊ Revised operational strategies
  - ◊ Enhanced maintenance requirements
  - ◊ Analysis enhancements

✱ May 2004 scheduled completion

# Extended Power Uprate GE Workscope

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- ✱ Resolve problems associated with known failures
  - ◆ Detailed steam dryer structural evaluation
  - ◆ Inspection, monitoring recommendations for external components susceptible to piping vibration (ERVs, sample probes, etc.)
- ✱ Steam and feedwater flow path component evaluations for EPU submittals
- ✱ Update EPU evaluation process based on Extent of Condition review results
  - ◆ Recommend additional modifications to plants and operating strategies
- ✱ June 2004 scheduled completion

## Extended Power Uprate Current BWROG Workscope

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✱ Survey BWRs with EPU operating experience to determine

- Extent of component and subcomponent failures
- Increased component wear/maintenance
- Forced outage and plant unavailability changes due to EPU
- EPU operational impacts (water chemistry changes, area temperatures, area dose rates, etc)

✱ Survey issued on January 12, 2004

✱ Survey responses due February 12, 2004

## Extended Power Uprate Current BWROG Workscope

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- ✱ Review of INPO Power Uprate Database in process
  - ◆ Target completion February 24, 2004
- ✱ Review of component failure evaluation developed by GE/Exelon
  - ◆ Scheduled completion February 16, 2004

## Extended Power Uprate Current BWROG Workscope

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- ✧ Review of GE self-assessment and actions taken with respect to flow induced vibration
- ✧ Development of recommendations if any further actions are needed by the BWROG or its members
- ✧ Issue letter to NRC detailing the results of the BWROG extended power uprate operating survey and review of the INPO Power Uprate Database
- ✧ May 2004 scheduled completion

## Extended Power Uprate Summary

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- \* BWROG has increased its attention to operational reliability at EPU conditions
- \* BWR industry has initiated systematic efforts to better predict and prevent component failures caused by EPU conditions