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GE Nuclear Energy

Update on Steam Dryer Activities

Presentation to USNRC
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Agenda

- QC2 dryer failure overview
- Failure Mode Analysis and Safety assessment
- Extent of Condition
- Screening Matrix Evaluation
- SIL Recommendations (Preliminary)
- Plans for EPU

QC2 Steam Dryer Failure & Root Causes

- **2002 Event**
  - June 7: Identified degraded steam dryer conditions
  - July 11: Plant shutdown. Cover plate failed.
  - Root Cause: High cycle fatigue due to high frequency acoustic resonance (130 to 230 Hertz)
    - Increased loading due to EPU operation

- **2003 Event**
  - May 6: First indication of degraded dryer performance
  - May 28: Power reduced to pre-EPU level. Moisture carryover steady at 0.2%
  - June 10: Plant shutdown. Cracks in dryer hoods
  - Root Cause:High cycle fatigue due to low frequency pressure loading (0 to 50 Hertz)
    - Operation with failed cover plate caused accelerated fatigue in the hood area
    - Increased load due to PORV opening (April 16)

Function and Safety Considerations

- **The function of the steam dryer is to remove moisture from steam exiting the reactor by vanes and perforated plates**
- **The steam dryer does not perform a safety function**
  - The steam dryer is not required to prevent or mitigate the consequences of accidents
- **Failure Modes and Effects Analysis (FMEA) evaluated the likelihood and consequences for bounding loose parts**
- **For a degraded dryer, structural integrity is adequate if the safety consequences of any loose part that may be generated is analyzed to be acceptable**
  - FMEA demonstrates that loose parts will not interfere with the ability to shutdown the reactor, provide adequate core cooling, or isolate the main steam lines
- **Safe reactor operation is not compromised by a degraded steam dryer**

FMEA Example

		Probability of Failure				Consequence of Failure*			Detectability of Failure		
#	Dryer Part	Previous Failure History HCF (Yes, No)	High Freq Effects (~180 Hz) (H, M, L)	Low Freq Effects (~ 15-30 Hz) (H, M, L)	Occurance Rating	Failure Impact: Loose Part In MSL? (H, M or L)	Failure Impact: No MSIV Closure? (H, M or L)	Severity Rating	Failure Impact: Potential Large Bypass Area? (H, M or L)	Detectability Rating	Overall RPN**
15	Drain Channels	Yes	H	M	9	L or None	L	1	L to M	5	45
16	Drain Pipes & Elbows	No	L	L	1	L or None	L	1	L	9	9
17	Support Ring	No	L	L	1	L	L	1	M	5	5
18	Cross Beams	No	L	L	1	L	L	1	L	9	9
19	Lower Support Ring	Yes	L	L	1	None	L	1	None	9	9
20	Baffle Between Center Banks	Yes	L	M	5	L	L	1	None	9	45
21	Tie Bars	Yes	L	M	5	L	L	1	None	9	45
22	Channel for Steam Dryer Guide Rod	No	M	M	5	L	L	1	L	9	45
23	Lifting Rod & Lifting Eye	Yes	L	M	5	L	L	1	None	9	45
24	Manway covers	No	L	L	1	M	L	1	H	1	1
25	Channel for RPV Suppt Brkt	Yes	L	M	5	L	L	1	M	5	25

*Failures will result in large loose parts that cannot enter the core shroud region. Some small loose parts that can enter the core shroud may also be generated. These small parts have been evaluated to have no significant safety consequences.
**Risk Priority Number (RPN) value less than 125 is not risk significant.

QC-2 Extent of Condition Scope of Evaluation

- **Evaluated EPU changes to identify potentially impacted components**
  - Core power, FW and steam flow, FW temperature, RIPD and carryunder
- **Components included in review**
  - Reactor internals
    - Components instrumented during startup testing
    - Components in steam path, FW flow path
  - External steam path
    - Main steam line piping
    - Steam path components
- **Considered experience from**
  - Flow induced & acoustic vibration
  - Flow effect on pressure distribution

QC2 Extent of Condition Summary

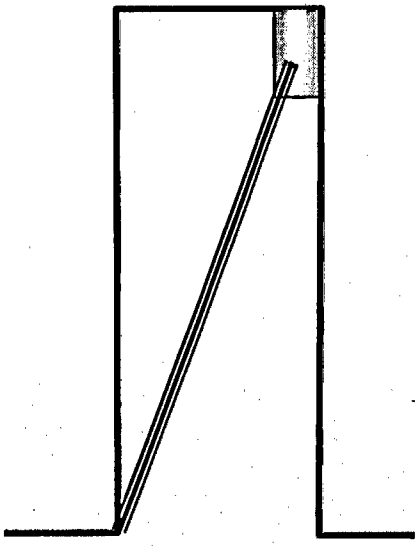
- **Additional analysis identified that components evaluated are acceptable at EPU conditions**
- **Considerations in EPU evaluation process**
  - Included additional dryer components
  - Included additional analysis elements (component FEA model, FIV loads, FIV stresses)

Extent condition evaluation did not identify new vulnerabilities for other components

Asset Management

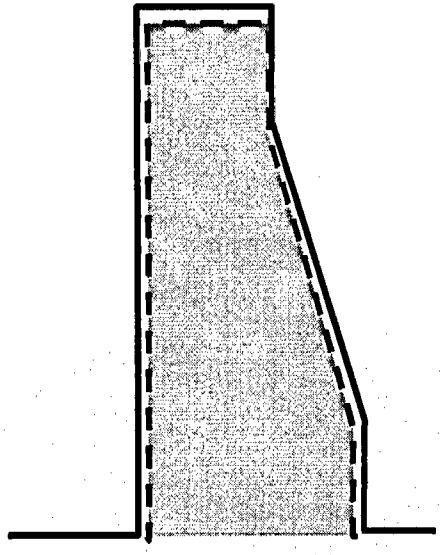
- **Completed dryer screening matrix and key attributes to analyze susceptibility across the BWR fleet**
- **Revise SIL 644**
- **Develop scope for dryer analysis for EPU**
  - Incorporated lessons learned from QC2 into analysis
- **BWROG Activities**

Basic Hood Types



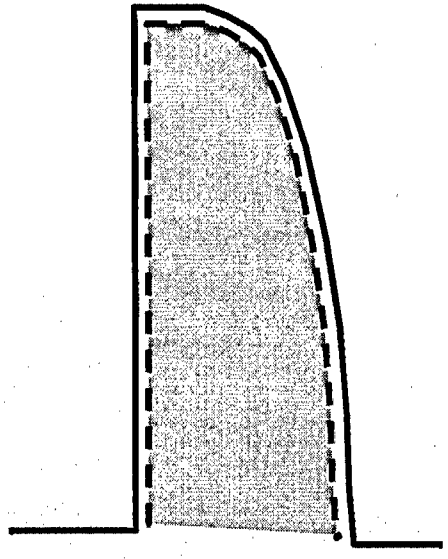
Square hoods

- BWR/3 Style Dryer
- Earliest Design
- Localized Top Hood Stress



Slanted hoods

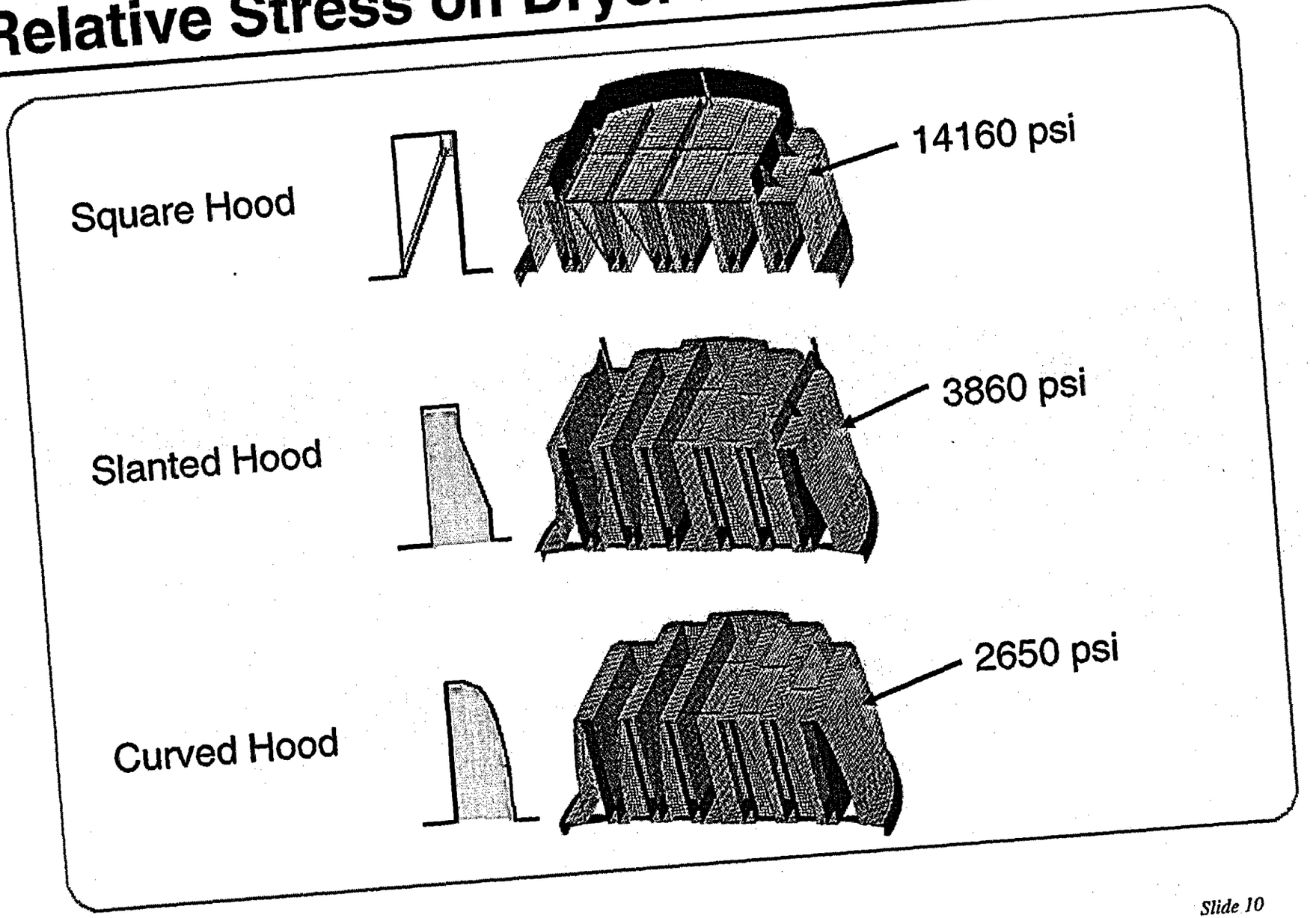
- Early BWR/4 Style Dryer
- Improved
  - Better Steam Flow
  - Reduced Stress Concentration



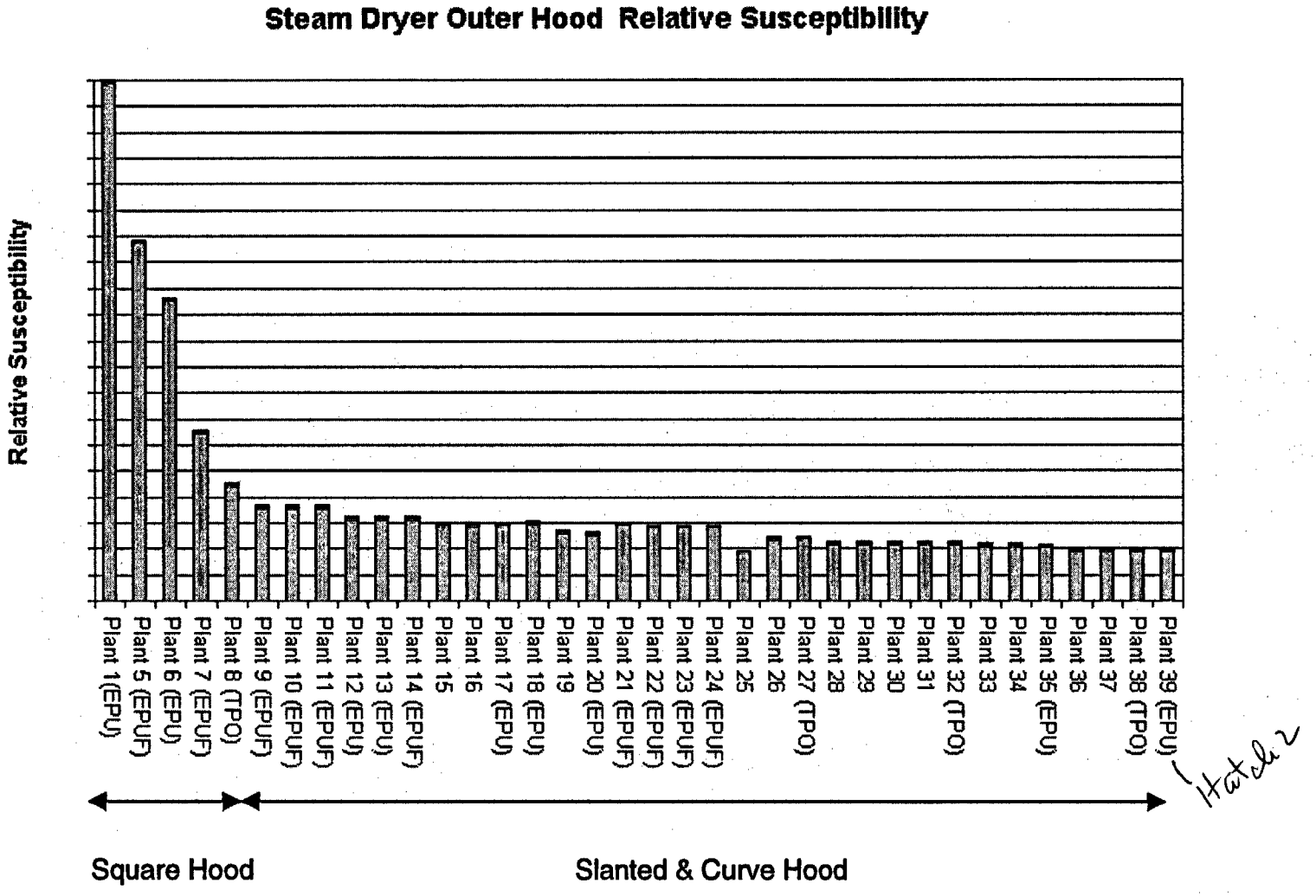
Curved hoods

- BWR/4 and Later
- Optimized for Steam Flow

Relative Stress on Dryer Hood



Screening Matrix Results



BWR/3-Style Steam Dryer is susceptible to dryer failure

Screening Matrix

- **Steam Velocity from Plant Data**
  - Pressure based on square of steam velocity
  - QC2 = Highest =10, Other plants: Based on velocity^2
- **Stress from Finite Element Analysis**
  - Based on uniform unit pressure loading
  - Square = 10, Slanted =3, Curved = 2

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

SIL Recommendations

- **SIL 644 issued 2002**
  - Recommendations based on the cover plate failure at QC2 in July 2002
    - Moisture carryover monitoring
    - Inspection
  - For BWR plants with square hood steam dryer
  - Focuses on the cover plate of the steam dryer
- **SIL 644 Rev. 1 will be issued August 2003**
  - Expands the scope to all dryer components of all BWR dryers

SIL Recommendations - Preliminary

- **Monitoring of main steam line moisture content:**
  - Establish base line for moisture content
  - Periodic monitoring, and
  - Following any transient that may induce pressure loads on the dryer
- **Inspections**
  - Baseline inspection for all high stress locations

Steam Dryer Evaluation

- **Generic**
  - Perform representative full FEA for each dryer type
- **Plant Specific Assessment**
  - Perform inspection
  - Confirm applicability of representative dryer type
  - Consider extent of conditions

Conclusion

- No safety concern due to degraded steam dryer
- Root cause of QC-2 dryer failure understood
- Square hood dryer more susceptible to failure
- Lessons learned incorporated in EPU evaluation process
- Industry communication planned for August