NRC FORM 658
(9-1999)

U.S. NUCLEAR REGULATORY COMMISSION

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DATE OF MEETING
11/5/03

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Docket Number(s): 691

Plant/Facility Name: BWR Owners Group

TAC Number(s) (if available): MC0931

Reference Meeting Notice: ML032950574

Purpose of Meeting (copy from meeting notice): Meeting with the BWROG to discuss steam dryer integrity

| NAME OF PERSON WHO ISSUED MEETING NOTICE | TITLE |
|---|---|
| Alan Wang | Project Manager |

OFFICE: NRR/~~DLPM~~ DLPM

DIVISION: DLPM

BRANCH: PD IV-2

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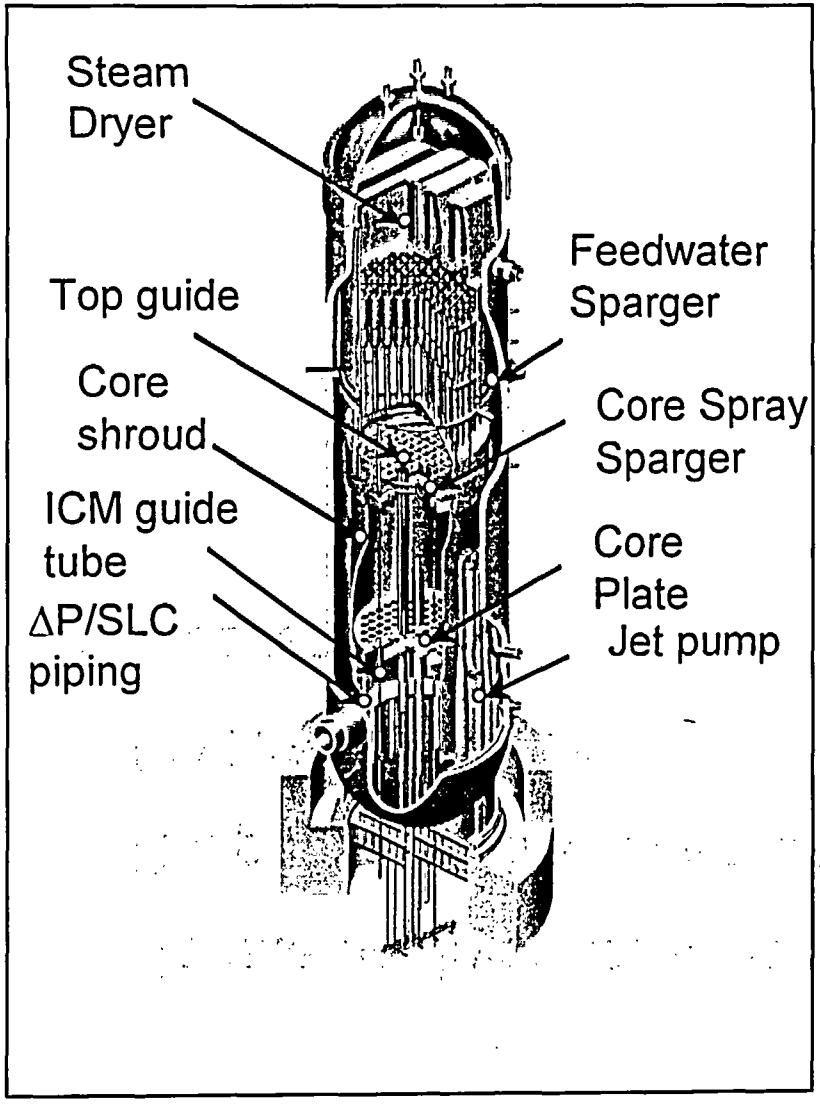


# BWR Steam Dryer Update

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GE Nuclear Energy

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Constellation Generation

November 5, 2003

# Agenda

- Update on dryer activities since last meeting with NRC
- Response to NRC questions on SIL 644 Supplement 1
- BWRVIP activities
- Discussion

# Update
# Steam Dryer Activities

- BWROG Ad Hoc steam dryer committee meeting
- SIL 644 Supplement 1 issued
- Recent inspections
- Extended Power Uprate analyses

# Update
# BWROG Ad Hoc Steam Dryer Committee

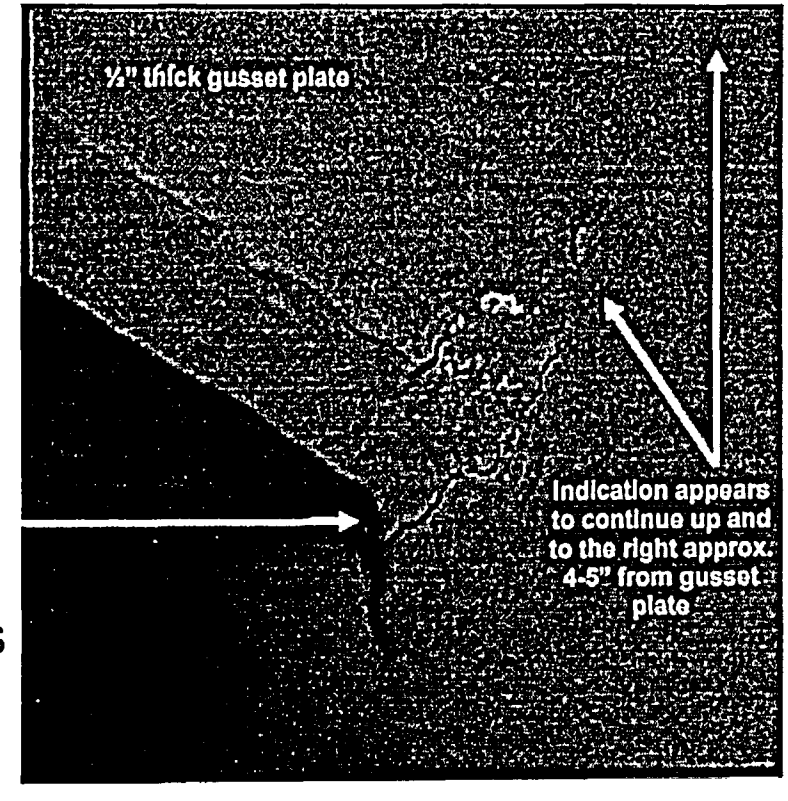
- BWROG Steam Dryer Committee formed to review recent steam dryer failures and develop action plan
  - Exelon and GE root cause evaluations
  - Fleet-wide dryer operating experience
  - GE screening matrix for ranking susceptibility
  - Potential impact of dryer failure on safety and operation
- Short and long term plans developed to address the steam dryer integrity concerns
  - Develop BWRVIP inspection and evaluation guidelines
  - Revisit BWRVIP safety assessment (BWRVIP-06)
  - Address broad reliability and performance issues

# Recent Steam Dryer Inspections

- Overseas BWR/4
  - Power uprate = 110%
  - Square hood design, no internal braces
  - High stress locations per SIL 644 Supp. 1
    - Accessible areas under the hood also inspected
- Peach Bottom 3
  - Power uprate = 105%
  - Slanted hood design, no internal braces
  - High stress locations per SIL 644 Supp. 1
- Duane Arnold
  - Power uprate = 112%
  - Slanted hood design, no internal braces
  - End panels, cover plates, tie bars, no vertical rib inspection (conducted prior to issuance of but consistent with SIL 644 Supp. 1)
- Results: no indications found in high stress locations

# Update
# Recent Steam Dryer Inspections

- Dresden 2
  - Power uprate = 117%
  - Square hood design, internal braces
  - dryer outer, interior hood welds per SIL 644 Supp. 1
    - Included interior of inner banks
  - Short fatigue cracks on inner surface of outer vertical hood panels at diagonal brace brackets
    - Location predicted by structural, loads analyses
    - Similar to Quad Cities 2 outer hood on 270° side
    - No cracking on inner banks



# Results of BWRVIP/BWROG Survey

- Responses received for 21 units (~2/3 of fleet)
- 19 units have uprated power or are planning future power uprates
- Most units will be monitoring moisture carryover
  - 8 units monitoring now
  - 6 units in process of implementing procedures
  - 2 units will implement monitoring with power uprate
  - Under evaluation for 3 units
- Regular dryer inspections
  - Dryers usually inspected every other outage
  - Inspections fairly thorough (monitoring previous indications, repairs)
  - Licensees may move up inspection in response to recent dryer issues
  - Almost all will inspect per SIL 644 S1 recommendations

# Extended Power Uprate Analyses

- EPU evaluations in progress or submitted for NRC review
  - Detailed structural evaluation for steam dryer
    - Reference load definition based on existing in-plant testing
    - Finite element analysis for entire dryer
    - Benchmark against current operating power
    - Recommend modifications as appropriate
  - Further evaluation for reactor internals in steam, feed flow path
    - Revisited original EPU FIV disposition for internals
    - Performed quantitative analyses for additional components
    - Update EPU process to include additional components as appropriate

# Extended Power Uprate Analyses (cont.)

- External components in steamline, feedwater flow paths
  - Additional recommendations for monitoring and inspections for steamline components
  - Feedwater components addressed by current EPU evaluations

# Response

# to

# NRC Questions on SIL 644 Supplement 1

# SIL 644 Supplement 1
# Question 1

- SIL No. 644, Supplement 1 does not appear to address all of the potential factors that could affect the susceptibility of a steam dryer to failure during operation of a BWR above the OLTP. For example, in addition to steam dryer design and maximum MSL steam velocity discussed in the SIL, the extent of the power level change from the OLTP, or the change in the MSL steam velocity, might also influence the susceptibility of a particular steam dryer to failure. Further, less stringent recommendations related to steam dryer integrity might be permissible where a BWR has only implemented or will only implement a minimum measurement uncertainty recapture power uprate. Please be prepared to discuss your criteria for establishing susceptible plants and the bases.

# SIL 644 Supplement 1
# Response to Question 1

- Susceptibility determined primarily by dryer design
- Steam flow, steamline velocity determine pressure loading
  - Steam flow rate is directly related to core power
  - Bounding flow rate (EPU vs OLTP) used in screening
- Other factors may affect susceptibility
  - Will be evaluated as part of BWRVIP activities
- Results from BWRVIP activities may justify relaxation in SIL recommendations

# SIL 644 Supplement 1 Question 2

- The recommendations in SIL No. 644, Supplement 1 focus on identifying steam dryer failure, such as by increased moisture content in the MSL steam flow and visual inspection of the steam dryer for cracks. However, these recommendations will only identify future failures of steam dryers after the fact. We believe that additional effort should be made to provide reasonable assurance that future steam dryer failures are highly unlikely, through such means as predictive analyses or instrumentation.

# SIL 644 Supplement 1
# Response to Question 2

- Goal of BWRVIP effort is successful operation of steam dryers
- GENE currently developing predictive analytical techniques for dryer structural evaluations
  - Load definition, evaluation based on measurements, experience from several instrumented dryers
  - Finite element model of entire dryer
  - Determine most likely failure modes
  - Identify vulnerable locations
- SIL inspection, monitoring recommendations intended to detect dryer cracking before large loose parts are generated
- Evaluation of plant experience will supplement analytical techniques

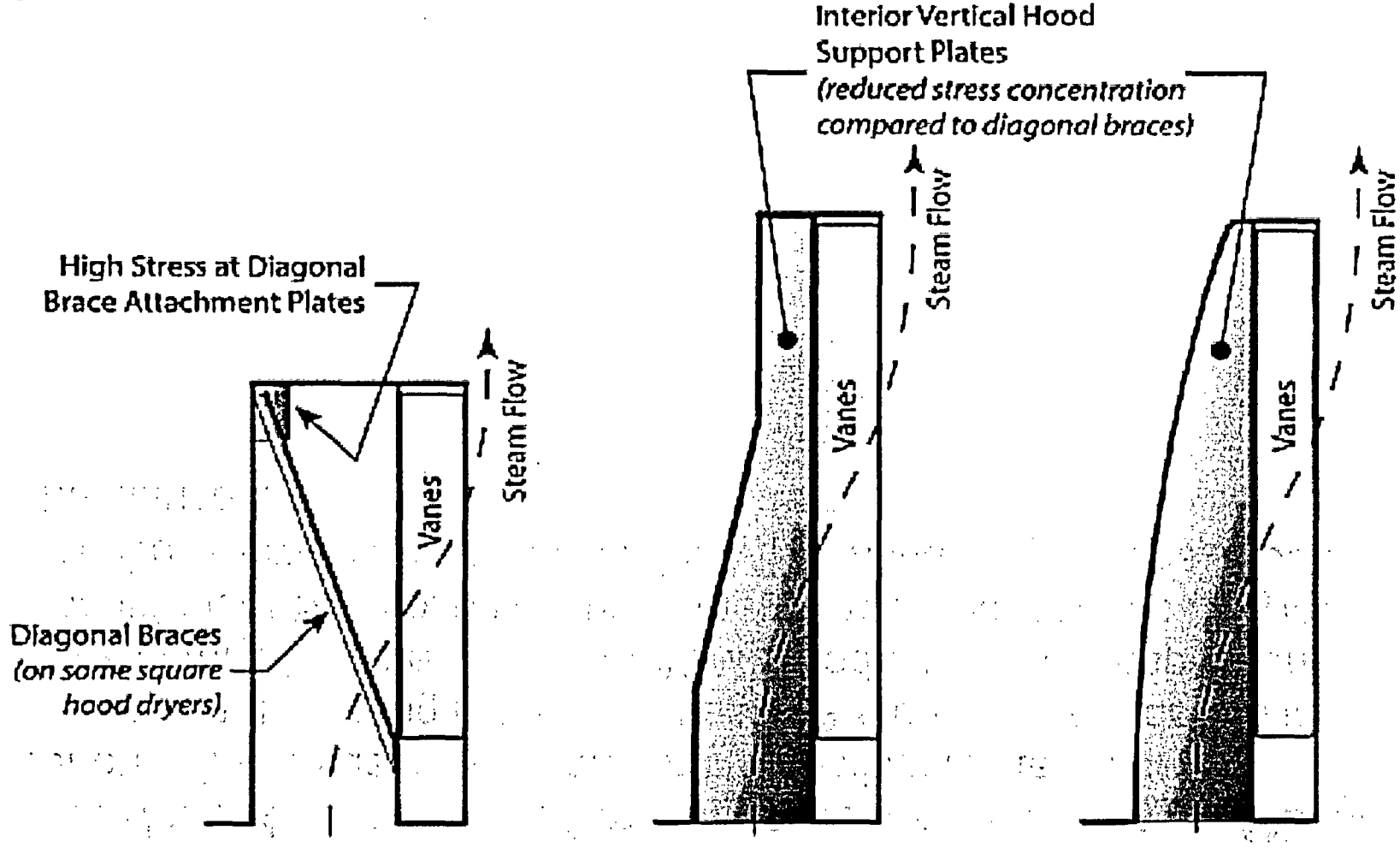
## SIL 644 Supplement 1 Question 3

- The basis for the applicability of internal steam dryer inspection recommendations in SIL No. 644, Supplement 1 only to the BWR/3 steam dryer design with internal braces is not apparent in that experience has suggested that cracking might initiate on the interior surface of the steam dryer.

# SIL 644 Supplement 1
# Response to Question 3

- Internal inspections recommended only for BWR/3 with internal diagonal braces
  - Interior brace attachment bracket forms localized stress concentration on inside surface of hood
  - Crack initiation observed at this location in two BWR/3s
  - Location predicted by structural analysis
- External inspections recommended for later dryer designs
  - No internal bracket forming stress concentration
  - Single-sided groove or fillet weld specified
  - Full weld penetration or backside welds not required
  - May be difficult to distinguish potential crack from crevice area in weld root

# SIL 644 Supplement 1
# Basic GE Steam Dryer Hood Types




**Square Hoods**
BWR/3 Style Design

**Slanted Hoods**
BWR/4 Style Design
Improved Steam Flow

**Curved Hoods**
BWR/5 Style Design
Optimized Steam Flow

# SIL 644 Supplement 1
# Question 4

- SIL No. 644, Supplement 1 recommends the performance of "best effort" VT-1 visual inspections of the applicable steam dryers during an upcoming refueling outage. Although steam dryers in BWRs might not be subject to ASME Code inservice inspections, the intent of SIL No. 644, Supplement 1 with respect to satisfying the Code provisions in performing VT-1 visual inspections should be clarified.

# SIL 644 Supplement 1
# Response to Question 4

- Previous dryer inspections used VT-3
  - Overview of general condition
  - Higher resolution if needed
- SIL recommended VT-1 to specify resolution needed to detect potential flaws
- "Best effort" used to allow flexibility in case standard cannot be met for all locations
  - Accessibility restrictions may make VT-1 difficult to meet requirements (angle, lighting, resolution)
  - Remote operated vehicle may be used (stability issues)
  - May be difficult to remove all bubbles for interior inspections

# SIL 644 Supplement 1
# Question 5

- SIL No. 644, Supplement 1 recommends inspection of BWR/4 and later steam dryer designs prior to initial operation above the OLTP, or within the next two scheduled refueling outages if already operating above the OLTP. This recommendation has the potential to allow the steam dryer at some BWRs operating above the OLTP not to be inspected for almost 4 years. Please discuss the basis for the timeliness of this recommendation.

# SIL 644 Supplement 1
# Response to Question 5

- Potential for fatigue cracking greatest early in plant life cycle, then during first power uprate operating cycle
- Inspection recommended prior to power uprate
  - Existing cracks and damage may reduce endurance limit
- If a plant has operated above OLTP for significant time, then it is past the initial vulnerable period
- Allow flexibility for scheduling inspections for plants with outages immediately following SIL issuance
- Two cycle schedule recommended only for lower stress dryer designs

# SIL 644 Supplement 1
# Question 6

- SIL No. 644, Supplement 1 discusses recent steam dryer failures at one BWR in the United States. Recommendations to address steam dryer integrity should also incorporate applicable experience from other BWRs in the U.S. and other countries. Please be prepared to discuss significant steam dryer failures in the U.S. and overseas.

# SIL 644 Supplement 1
# Response to Question 6

- Dryers have experienced IGSCC and fatigue cracking at OLTP and power uprate conditions
- IGSCC cracks primarily found in support ring, hood end plates
  - Monitored for growth
  - Weld repaired if necessary
- Fatigue cracks primarily found in drain channels, hood welds, tie bars
  - Repaired by replacement of failed part, weld reinforced, or added reinforcement plates
- Operating experience, repair history will be considered in developing BWRVIP I&E guidelines

# SIL 644 Supplement 1
# Dryer Component Indication History (partial)

| Component | Total | Fatigue | IGSCC | Other* |
|---|---|---|---|---|
| Support Ring | 33 | | 32 | 1 |
| Drain Channel | 20 | 15 | 4 | 1 |
| Hood | 17 | 13 | 1 | 3 |
| End Plate | 11 | | 10 | 1 |
| Tie Bar | 7 | 7 | | |
| Lifting Rod | 7 | 3 | 1 | 3 |
| Skirt | 6 | 1 | 1 | 4 |
| Guide Bracket | 3 | | | 3 |
| Leveling Screw | 2 | 1 | 1 | |
| Seismic Block | 2 | | 1 | 1 |
| Tie Rod | 2 | | 1 | 1 |
| Gusset Support | 2 | | | 2 |
| Cover Plate | 1 | 1 | | |
| Bottom Plate | 1 | | 1 | |
| Extension | 1 | | 1 | |
| Guide Rod | 1 | | | 1 |
| Guide Rod Brace | 1 | | | 1 |
| Guide Slot | 1 | | | 1 |
| Hold Down Ass'y | 1 | | | 1 |
| Plug Weld | 1 | | | 1 |

*Fabrication, bad weld, handling, etc.

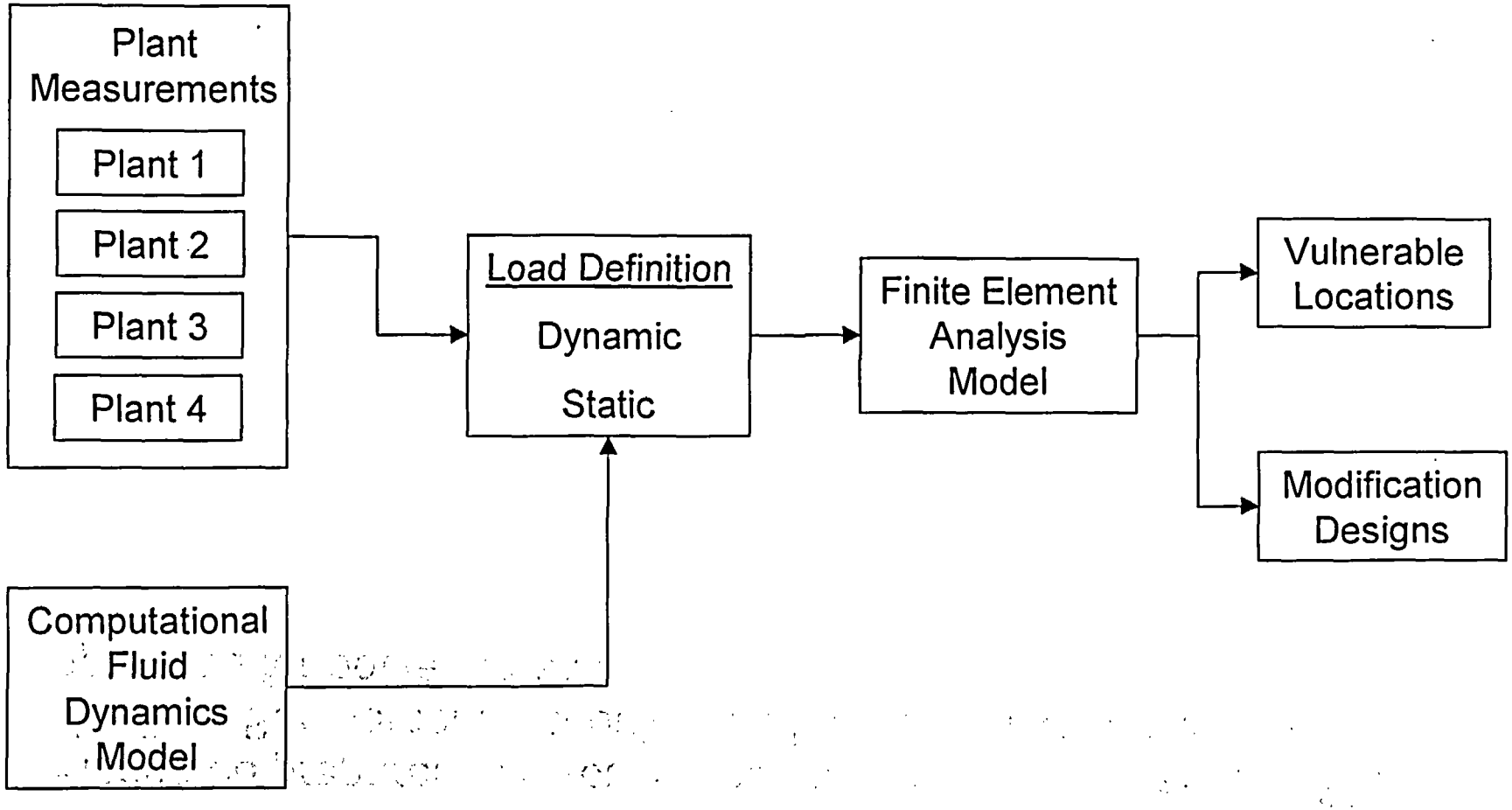
# SIL 644 Supplement 1 Question 7

- With regard to power uprates, please be prepared to discuss what actions you intend to propose for BWRs planning to apply for future power uprates (i.e., measurement uncertainty recapture, stretch, and extended).

# SIL 644 Supplement 1
# Response to Question 7

- GENE is developing predictive analytical techniques in support of future power uprates
  - Dynamic load definition based on in-plant measurements of several instrumented dryers
  - Computational fluid dynamics model for detailed static load distribution
  - Finite element structural analysis model of entire dryer
  - Benchmark against OLTP conditions
  - Identify vulnerable components
- Process applicable to any size power uprate
- Experience with initial EPU applications may justify simpler analysis for stretch, MUR uprates

# SIL 644 Supplement 1
# Dryer Structural Analysis Process



# SIL 644 Supplement 1
# Question 8

- Please be prepared to discuss what actions not addressed in SIL No. 644, Supplement 1 should be taken for BWRs previously approved for power uprates.

# SIL 644 Supplement 1
# Response to Question 8

- BWRs that have been previously approved for EPUs, but have not fully implemented may consider performing detailed structural evaluations
- Purpose of SIL to provide quick response
  - Monitoring recommendations
  - Inspection guidance for fall, spring outages
- BWRVIP is preparing I&E guidelines to ensure dryer integrity over life of plant
- I&E guidelines will consider factors such as
  - Dryer design
  - Fabrication
  - Operating experience
  - Plant power operating history, including power uprate conditions
- I&E guidelines will address additional actions beyond those identified in the SIL

# BWRVIP Steam Dryer Activities

# BWRVIP Steam Dryer I&E Guideline Goals

- Dryer designs and fabrication details understood
- Operating experience and repair history compiled and documented
- Loads understood and defined
- Reliable performance between inspection intervals
- Predictable life expectancy and maintenance needs
- Evaluation guidance for consistent disposition and repair
- Safety significance

# BWRVIP Steam Dryer I&E Guidelines

- Failure Consequence Analysis
  - Potential for component failure
  - Consequences of failure
  - Detectability of failure
  - Safety consequences of a failure (including FMEA)
  - Loose parts evaluation

# BWRVIP Steam Dryer I&E Guidelines

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

# BWRVIP Steam Dryer I&E Guidelines

- Flaw Evaluation methods
  - Analysis methods and sample evaluation
- Operational Guidance
- Repair Guidance (may result in a separate Repair Design Criteria report)

# Additional BWRVIP Activities

- Update the BWRVIP-06 based on the revised steam dryer Failure Modes and Effects Analysis
- Potential followup actions / testing to support refinement of GE load definition
- Potential BWRVIP Dryer repair / fabrication guidelines

# Conclusion

BWRVIP I&E guidelines are the recommended means for providing guidance to operational BWRs with respect to managing and maintaining steam dryer integrity over the lifetime of the plant