Industry / NRC Meeting on Generic Letter 2008-01, “Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems”

December 5th, 2008

NEI
NUCLEAR ENERGY INSTITUTE

Agenda

- Welcome and Introductions
- Recent gas transport testing
  - Analysis methodology for gas transport
  - Bounding criteria for assessing gas transport and impact on pump performance,
- Break – 10 am
- Continuation
- Public Comment
- Lunch – 11:45 am

Agenda

- Generic aspects of initial staff assessments of Generic Letter 2008-01 responses
- Coordination of NRC / NEI / Owners Groups / Industry activities
  - 90 day letter template
  - Owners Groups reports supporting GL responses
  - GAT Long term plans
- Break – 2 PM
- Continuation
- Public Comment
- Adjourn – 4 PM

Welcome and Introductions

- Indroductions
- Web Cast Participant Instructions
  - Send participant names to David Beaulieu at David.Beaulieu@nrc.gov
  - Phones on mute please unless asking a question
  - Time will be allowed for web cast participant questions

Industry Presentations

Industry Overview of Recent gas transport testing

Analysis methodology for gas transport

Bounding criteria for assessing gas transport and impact on pump performance

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Long Term Plans

Long Term Plans

- TS Traveler to be developed to address appropriate surveillance requirements and bases
- Gas transport in pump suction piping
- Pump acceptance criteria
  - Decision analysis

Public comment

Next meeting schedule

Close

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Gas Transport Testing

Presenter – Steve Swantner

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Background

- Project aimed at filling gap in industry knowledge
  - Gas transport data in large diameter elbows and vertical pipes
- Project Objectives
  - Flow regime identification
  - Phenomenon identification
  - Empirically based scaling arguments
  - Guidance for plant specific gas transport in pump suction piping

Project Phases

- PWROG funded project
- Testing conducted at Purdue University
- Phase I (2005) – **PA-SEE-0217**
  - Examined gas transport in 6” and 8” piping
  - WCAP-16631 documented program and results
- Phase II (2008-2010) – **PA-SEE-0460**
  - Review APS Test Data
  - Examine gas transport in 4” and 12” piping
  - Determine temperature effects using 4” piping
  - Develop scaling methodology to cover 4” to 30” pipe

Status

- Project kick-off meeting was held at Purdue University
  - Lessons learned from 6” and 8” testing
  - Improvements to test loop identified
- 12” loop testing currently in progress

Schedule

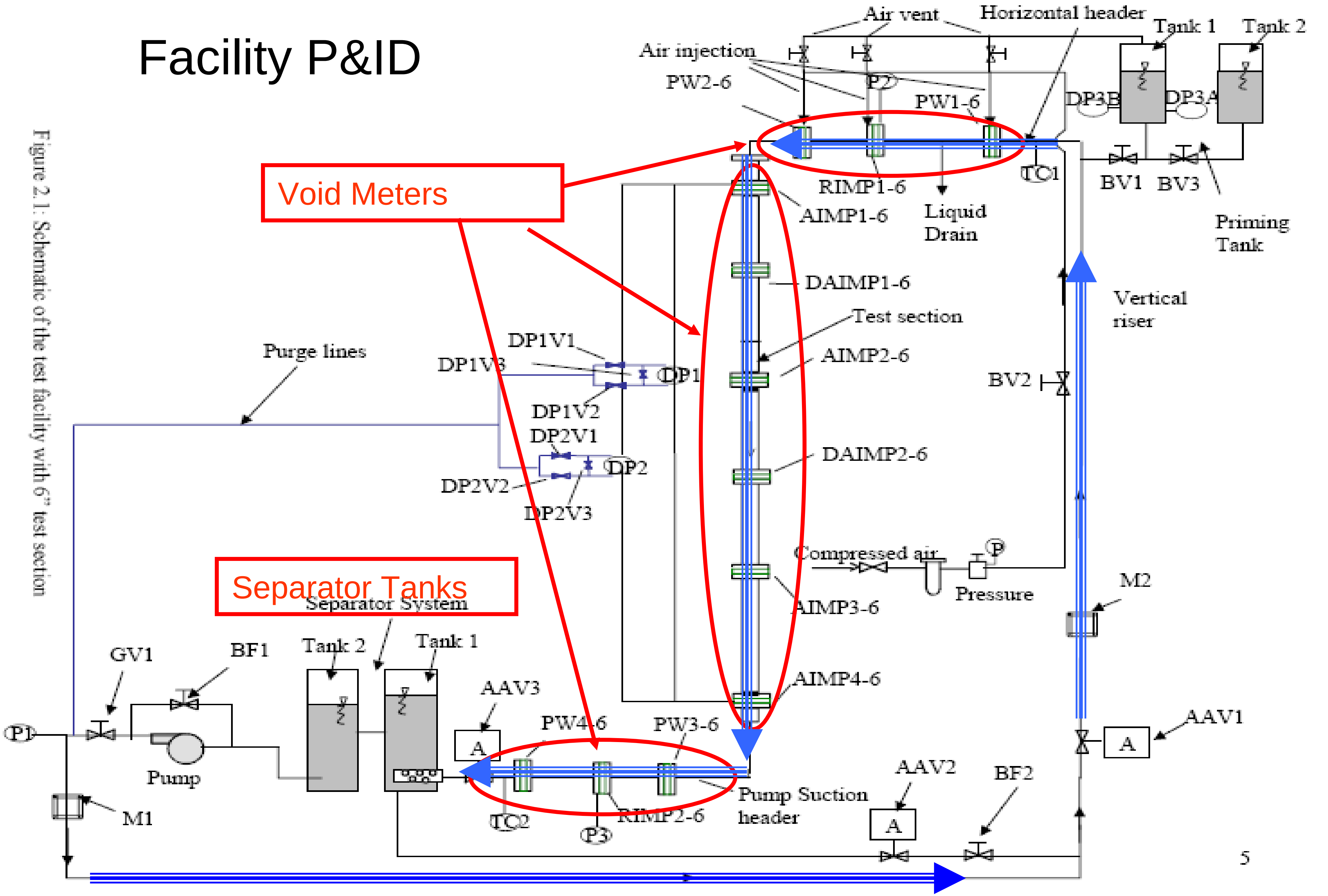
- 12” testing will be completed in 2008
- 4” loop construction, testing, and scaling will be completed in 2009
- Interim reports provided ASAP after testing phases, with final WCAP in 2010

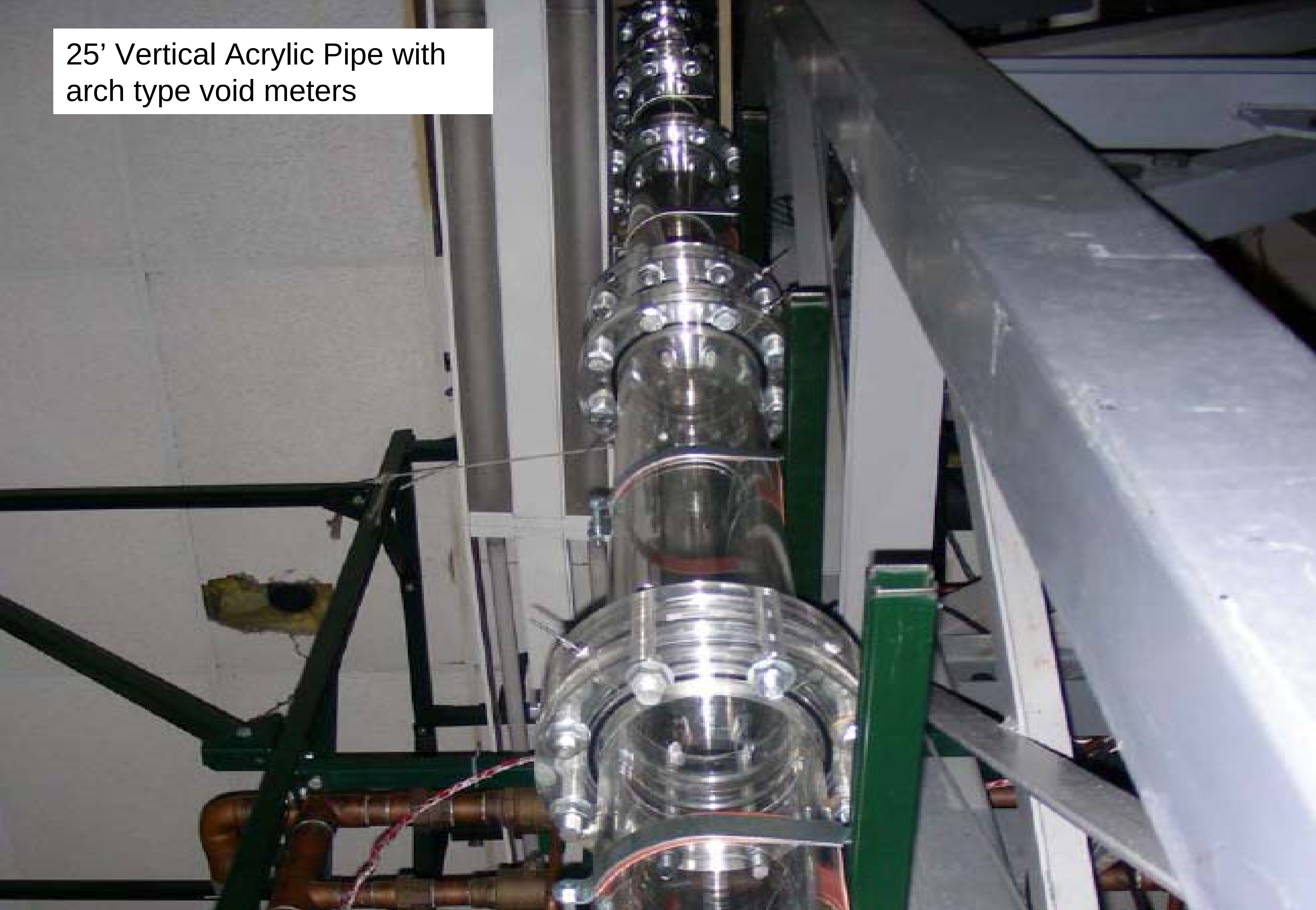
Overview of 6” and 8” Testing

Test Summary

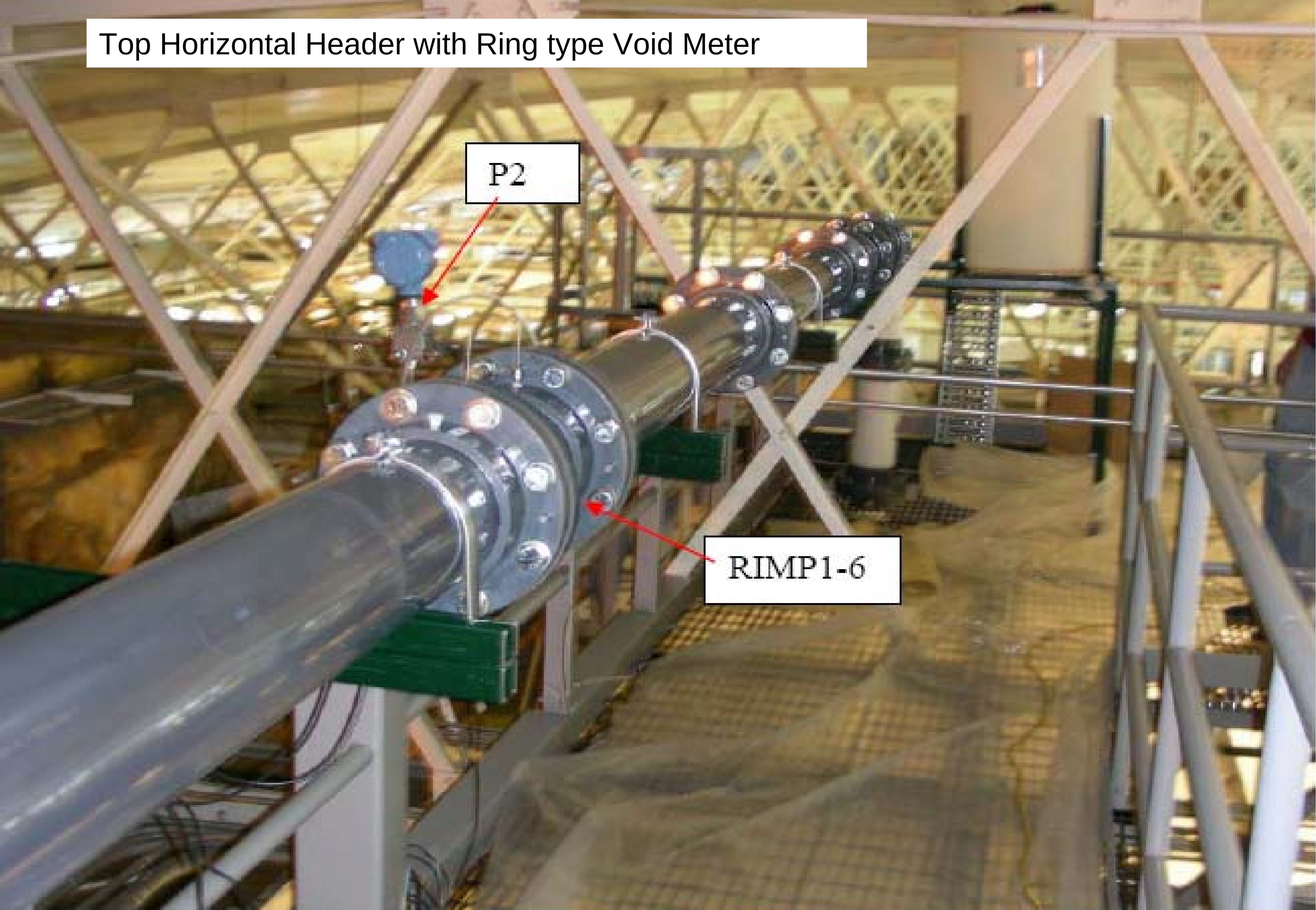
- Testing performed at Purdue University
- Full scale model of pump suction piping with 25' vertical drop
- Two pipe sizes tested
  - 6-inch and 8-inch diameter
- Acrylic pipe used to enhance visualization
  - Cameras at 4 locations
- Three types of gas volume fraction void meters used to quantify transport process

Facility P&ID





25’ Vertical Acrylic Pipe with arch type void meters



Top Horizontal Header with Ring type Void Meter

Test Parameters

- Range of Initial conditions
  - 75-80 test runs performed on each pipe size
  - Gas volume in upper horizontal piping
    - Range of 5% - 20% gas volume fraction
  - Liquid flow rate
    - Range of 200 – 900 gpm (6-inch)
    - Range of 400 – 1800 gpm (8-inch)
- Gas transport characteristics
    - Void fraction and flow regime were measured as function of location and time

Summary of Results

- Quantitative correlations developed to support plant specific assessments
  – Void fraction as a function of flowrate and vertical drop length
  – Objective identification of flow regime
- Qualitative Results from viewing acrylic pipe section
  – Top Horizontal Pipe
  – Vertical Pipe
  – Bottom Horizontal Pipe

Top Horizontal

- Air quickly transported to downstream end by the descending elbow
- Elbow acts as buffer to slow down the air transport into the vertical drop section
- Rate of air release from buffer increases with flow

Vertical

- Ability to pull air down from top elbow increases with flow velocity
- Air held up in top sections at lower flow rates
- Void fraction decreases with downward distance due to
  - Increase in static pressure
  - Buoyancy prolongs the transport time for a fixed volume of air
  - Bigger bubbles disperse into smaller bubbles

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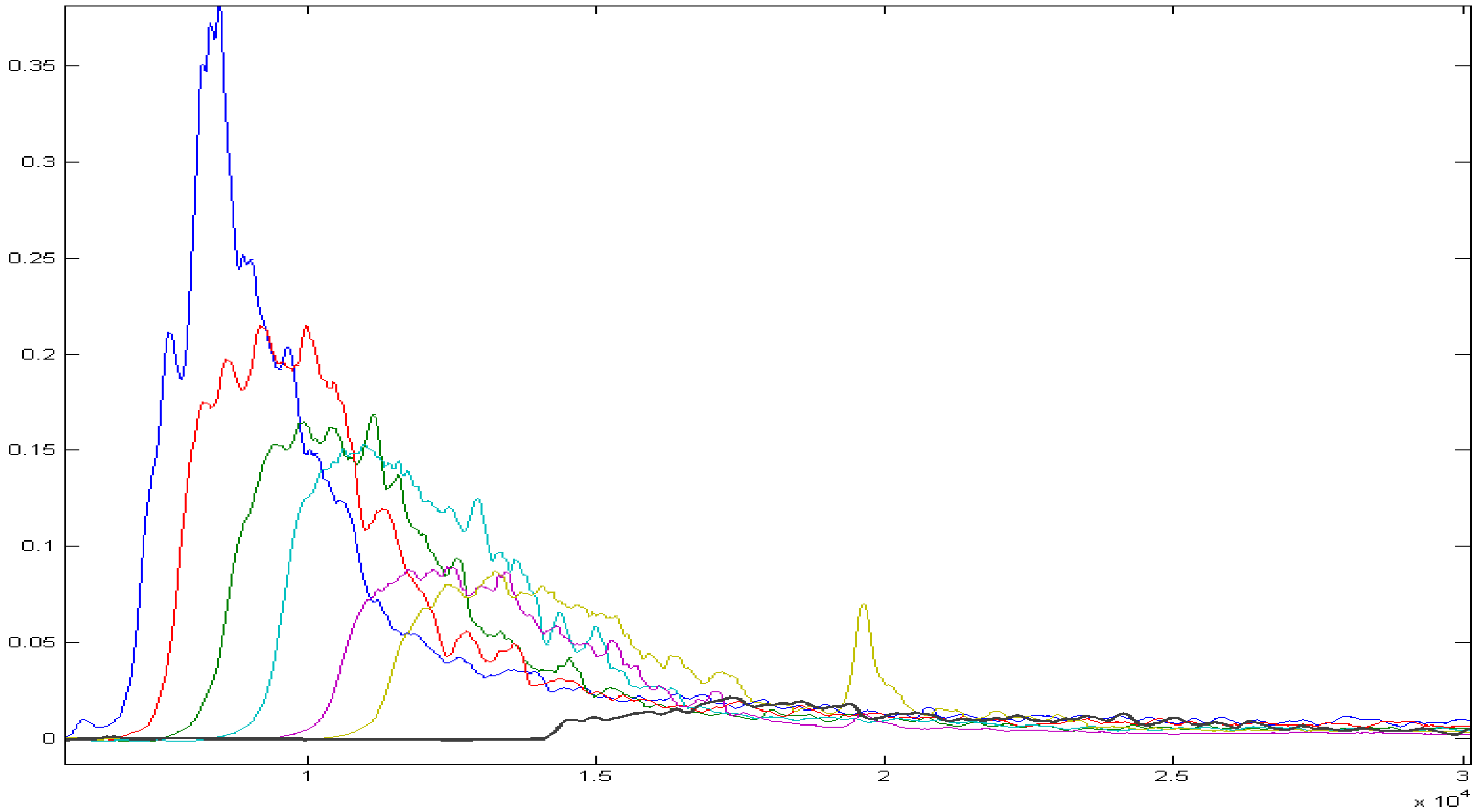
Bottom Horizontal

- Bottom elbow acts as buffer to store air as a layer on the top of the pipe
- Water slips under elongated air pockets immediately downstream of elbow
- Some elongated air pockets float back into the incoming vertical pipe (i.e., bubble-recirculation) resulting in less void to the pump
- Air is gradually entrained in liquid stream resulting in a reduction in void fraction to the pump

Typical Profile Variation during Transport



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Pump Response to Gas Ingestion

Presenter – Robert Becse

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Presentation Summary

- Background
- Basis of Interim Criteria
- Review of Draft Division of Safety Systems (DSS) Criteria
- Review of PWROG Interim Criteria
- Comparison of Criteria
- Future Efforts
- Take-aways

Background

- Every US licensee is required by GL-2008-01 to evaluate their Emergency Core Cooling System (ECCS), Decay Heat Removal (DHR) system and containment spray (CS) system design, operation and test procedures to assure that gas intrusion is minimized and monitored in order to maintain system operability and compliance with the requirements of 10 CFR 50 Appendices A and B.
- PWROG/BWROG include the development of interim pump criteria.
- PWROG funded PA-450 Task 2 to develop interim pump criteria.
- The interim pump criteria was published via V-EC-1866, Rev. 0

Basis of Interim Pump Criteria in V-EC-1866

- Comprehensive Literature Search
- Access to previous Industry OE
- Pump Test Data

DSS Pump Operation Interim Criteria (Draft)

Pump Operation Interim Criteria	Allowable Φ
Steady state (>20 sec following initiation of gas ingestion) with $40\% \leq Q/Q_{BEP} \leq 120\%$	2%
Steady state with $Q/Q_{BEP} < 40\%$ or $>120\%$	1%
Maximum during 5 second transient with $70\% \leq Q/Q_{BEP} \leq 120\%$	10% (peak)
Maximum during 5 second transient with $Q/Q_{BEP} < 70\%$ or $> 120\%$	5% (peak)

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V-EC-1866 Pump Interim Criteria (PWROG)

Pump Operation Interim Criteria	Allowable Φ
Steady state with 40% $\leq Q/Q_{BEP} \leq$ 120%	2%
Steady state with Q/Q_{BEP} < 40 % or >120%	Not specified
WDF (single stage) transient limit with 70% $\leq Q/Q_{BEP} \leq$ 120% for 20 sec.	5% (avg.)
CA (multi-stage, stiff shaft) transient limit with 70% $\leq Q/Q_{BEP} \leq$ 140% for 20 sec.	20% (avg.)
RLIJ, JHF (multi-stage, flexible shaft) transient limit with 70% $\leq Q/Q_{BEP} \leq$ 120% for 5 sec.	10% (avg.)

BWROG Criteria

BWROG Criteria	*Allowable Φ*
Steady state $Q/Q_{BEP} \leq 120\%$	**2%**
Steady state with $Q/Q_{BEP} > 120\%$	**1%**
Average during 5 second transient	**10%**

Differences Between DSS and V-EC-1866 (PWROG) Steady State Criteria

- DSS and V-EC-1866 in agreement for $40\% \leq Q/Q_{BEP} \leq 120\%$.
- DSS includes specific additional guidance at off-nominal conditions of < 40% and > 120% BEP.
- Basis of DSS
  - NUREG/CR-2792 and industry information state that outside of this range 2% may be inappropriate for some conditions.
  - Engineering judgment that 1% should accommodate most considerations.
    - DSS notes that even 1% may still pose concerns with gas accumulation in some pumps over time.

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Differences Between DSS and V-EC-1866 (PWROG) Steady State Criteria

- V-EC-1866 does not provide a specific limit for off-nominal conditions < 40% or > 120% BEP.
- Basis for V-EC-1866 (Per section 5.2 of the report)
  - Range of steady state limit based on review of existing data.
  - For operation at these off-nominal conditions and beyond, V-EC-1866 notes that input from vendor should be obtained.

Differences Between DSS and V-EC-1866 (PWROG) Steady State Criteria

- Considerations for obtaining vendor input for operation beyond 40% and 120% void fraction
  - Pump designs (e.g., blade angles) are optimized for performance at BEP. Performance at off-nominal conditions can vary between pump designs and conditions.
  - Larger unit – to – unit performance variability is expected at off-nominal conditions than at BEP.

Summary of Differences Between DSS and V-EC-1866 (PWROG) Steady State Criteria

- DSS and V-EC-1866 are in agreement with 2% void fraction for $40\% \leq Q/Q_{BEP} \leq 120\%$.
- DSS includes specific additional criteria of 1% void fraction at off-nominal conditions of < 40% and > 120% BEP.
- V-EC-1866 notes that outside of the above criteria vendor input is required.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- DSS criteria fashioned similar to V-EC-1866
  - Transient timeframe corresponds to the minimum of the times considered by V-EC-1866.
  - Flow range corresponds to most limiting range in V-EC-1866.
  - Similar to steady state, DSS provides specific criteria outside of 70% - 120% flow range.
  - Criteria represent peak values of void fraction.
  - Does not distinguish between single and multi-stage or stiff and flexible shaft.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- V-EC-1866 criteria
  - Based on test data for two different pumps.
    - Transient timespan based on testing.
    - Provides flexibility based on pump design.
    - Similar to steady state, does not provide specific guidance outside of the flow range.
    - Utilizes average values of void fraction vice peak value over timeframe.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- V-EC-1866 Transient Timespan
  - Timespan based on test data and adjusted via a safety factor of 10x (See Appendix C, section 1).

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- Transient Criteria established for multiple designs.
  - Test data shows that multi-stage pumps can tolerate higher void fractions with less degradation than a single stage pump. (See section 3.2)
    - For a single stage, if air bubbles are present in the vane passage up to a particular distance along the impeller blade, a corresponding percentage head degradation is expected.
    - For a multi-stage, if air bubbles are present in the vane passage up to a particular distance along the impeller blade, a corresponding percentage head degradation is expected for only the first stage. The remaining stages should not be impacted relative to head rise. As such, the overall head degradation for the pump is less.

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Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- Flexible vs. stiff shaft requirements (See Appendix C, section 3)
  - Both flexible and stiff shaft requirements assume that the pump is not air bound.
  - Flexible shaft needs a tighter criteria than a stiff shaft based on the imbalance applied to the impeller and the subsequent response of the rotor.
  - Both of the above statements assume that air binding is not occurring.
  - Flexible Rotor
    - Larger deflections resulting in possible contact or rub on seals resulting in removal of material and/or excessive loads on bearings.
    - Excessive loads can over-stress the rotor leading to cracked shafts.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- Flow range
  - Range of steady state limit based on review of existing data.
  - For operation at these off-nominal conditions and beyond, V-EC-1866 notes that input from vendor should be obtained.
  - Similar “considerations” as noted in steady state discussion.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- Significant Differences Between DSS and V-EC-1866
  - Requires that pump user make a comparison between actual pump and pump discussed in V-EC-1866 (pump attributes)
  - Requires that pump user contact pump manufacturer if outside of the criteria

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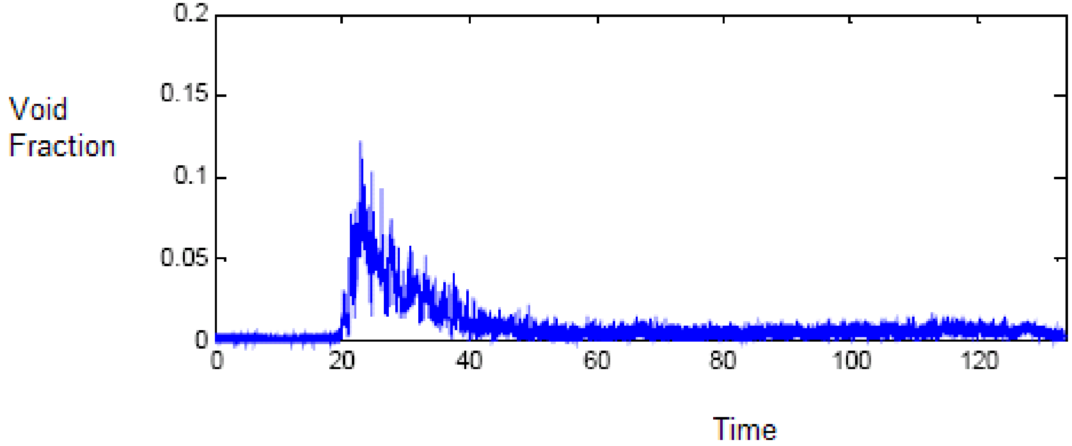
Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria

- Average allowable void fraction
  - Based on test data.
  - Conservative, as actual tests were performed for longer periods of time with no adverse impact on the tested pump.
  - From the previous presentation, the peak void fraction dampens out during transport down vertical pipe and transitions into the horizontal pipe.
- Peak void fraction
  - It is noted that based on gas transport data, void fraction as a function time is not a step function. A typical plot of void fraction versus time is presented on the next slide.
  - Peak void fraction is only present for a portion of the time interval.

Differences Between DSS and V-EC-1866 (PWROG) Transient Criteria



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NPSH Considerations

- NPSHR is part of steady state criteria.
- NPSHR testing is accomplished at stable test points. There is no "transient" NPSHR data.
- NPSHR criteria based on performance near BEP.
- NPSHR a/w = NPSHR w (1+0.5 (void fraction))

Future Efforts

- The Owners Groups are exploring future options relative to the applicability of the interim criteria.

Take-aways

- For flowrates less than 40% BEP, Froude number does not support significant gas transport to the pump.
- Base transient criteria on pump types/attributes vice a general criteria.
- NPSHR applicable to steady state not transient conditions.
- Use of average void fraction vice peak void fraction.
- Transient limits ensure that for the pumps tested, head breakdown did not occur ensuring no gas binding.
- Methods to determine gas void fraction at the pump inlet to be included in the draft DSS paper.

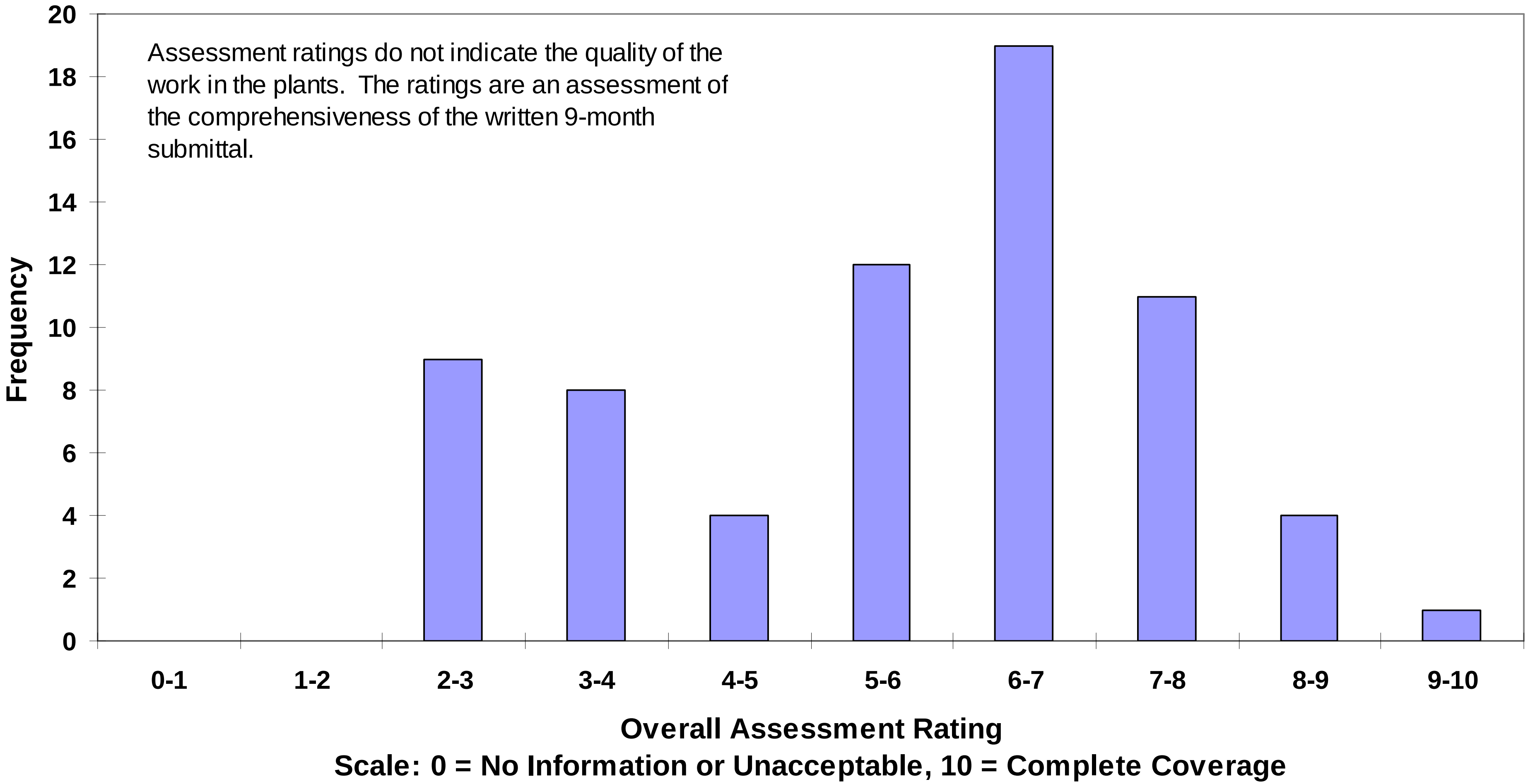
NRC Handout and Slides

December 5, 2008

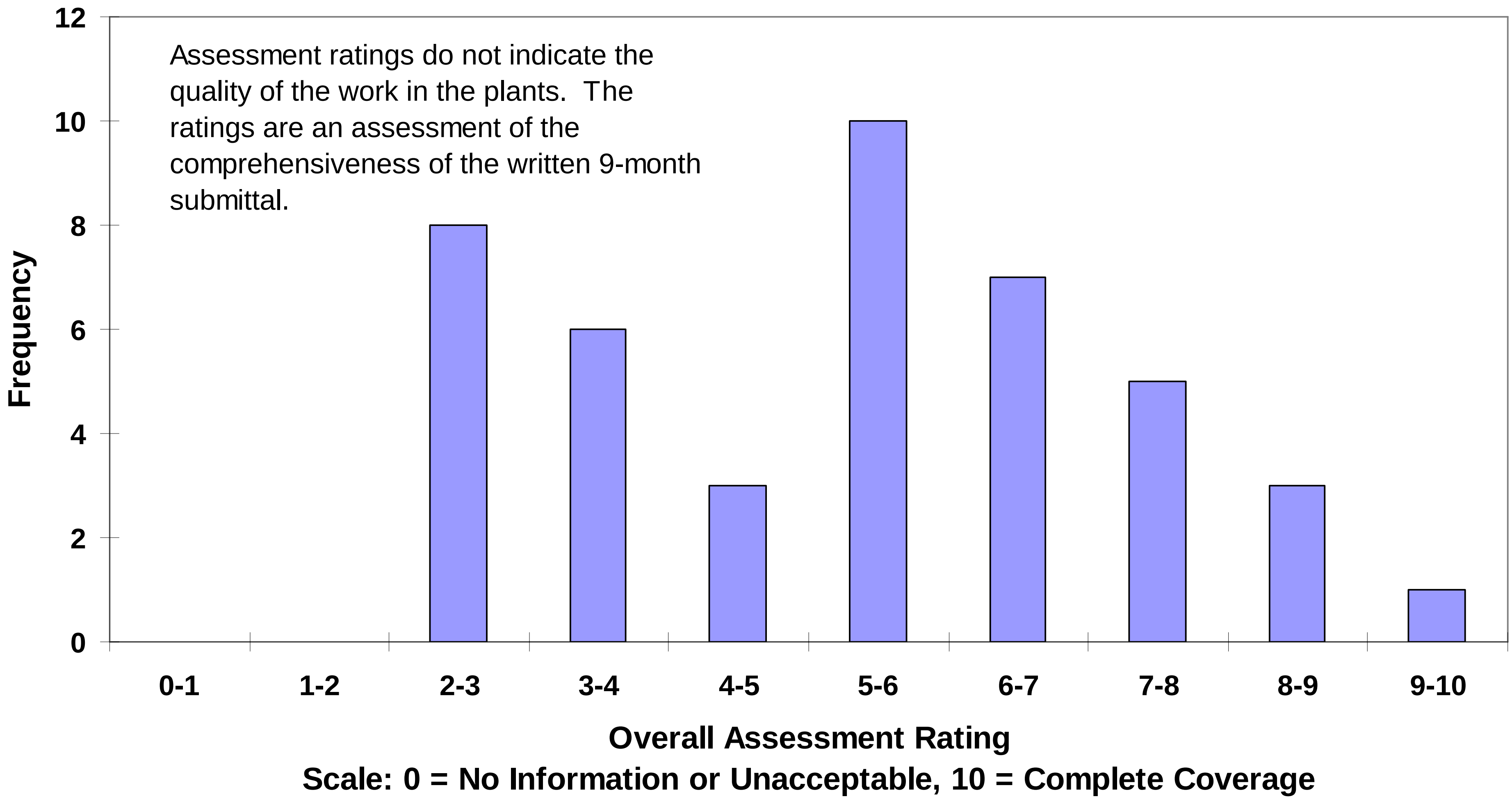
Generic Letter 2008-01 9-month Response
Rating Sheet for NRC Preliminary Assessment of Submittal Comprehensiveness

ENTER PLANT NAME HERE			
No.	**Item**	**Rating 0-10**	**Comments**
i	ECCS, DHR (RHR, SDC), & CSS identified if applicable?		
ii	History & background discussed?		
1	Licensing basis documents indentified & addressed including summary of review results such as applicability & weaknesses		
1.1	TS		
1.2	TS bases		
1.3	UFSAR		
1.4	Responses to NRC generic communications as applicable		
1.5	Regulatory commitments as applicable		
1.6	License conditions as applicable		
1.7	Identification of TSTF & other TS improvements		
2	Design evaluation		
2.1	Gas volume acceptance criteria vs. location. Include suction & discharge pipes, & (BWRs) GSI-193 (suppression pool gas)		
2.2	Pump acceptance criteria including qualifications for weakness in owners groups recommendations, recognition of potential start pulsations, ongoing data development efforts, NPSH		
2.3	Design basis document changes summarized		
2.4	P&ID & isometric drawing reviews		
2.5	Needed vent valve modifications accomplished or committed		
2.6	Walkdowns completed & results including acceptance criteria		
2.7	Walkdown plans for completion		Enter 10 if not needed
2.8	Potential gas intrusion mechanisms addressed		
2.9	List of incomplete items & completion schedule		
3	Testing evaluation		
3.1	Procedures reviews results addressed including venting history		
3.2	Procedures revisions to be accomplished addressed		
3.3	Gas void determination method & documentation addressed		
3.4	List of incomplete items & completion schedule		
4	Corrective actions		
4.1	Interim coverage of TS inadequacies by TRM or procedures to ensure meeting Appendix B requirements		
4.2	Corrective actions completed listed & summarized		
4.3	List of incomplete items & completion schedule, commitments		
	OVERALL RATING		

GL 2008-01 9-month Response
Initial Assessment Ratings of Submittal Comprehensiveness



GL 2008-01 9-month Response
Initial Assessment Ratings of Submittal Comprehensiveness
PWR Responses



GL 2008-01 9-month Response
Initial Assessment Ratings of Submittal Comprehensiveness
BWR Responses