AP1000 CONTAINMENT VESSEL EXTERNAL PRESSURE ANALYSIS AND DESIGN

AGENDA

- Introductions
- Executive Summary (Mike Corletti)
- Transient Analysis (Tom Kindred)
- Vacuum Relief System Design (Dave Kanuch)
- Containment Vessel (Kevin Moore)
- Questions/Comments

EXECUTIVE SUMMARY

- Westinghouse identified discrepancy in Chapter 6 regarding the containment external pressure analysis
- In addition it has been noted that there is a discrepancy between the negative pressure analysis in Chapter 6 and the containment service limits in Chapter 3
- In response Westinghouse has performed a new safety analysis and is implementing a design change to incorporate a vacuum relief system that demonstrates acceptable containment design
- The containment differential pressure is changed to 1.7 psid
- As a result of changes the containment vessel and vacuum relief system are in compliance with all requirements

TRANSIENT ANALYSIS

PURPOSE

- The purpose of the analysis is to evaluate the bounding transient that generates the maximum pressure differential for the purposes of the Ch. 6 safety analysis
- The most limiting event is a complete loss of AC power (station blackout) at hot no load conditions with no decay heat

REVISED CH. 6 SAFETY ANALYSIS

- Ch. 6 Safety Analysis is being revised and will be included in DCD Rev. 18
  - Safety Analysis Methodology is the same as prior analysis (Rev. 15 of DCD)
  - Revised analysis includes revised bounding assumptions
  - New transient analysis evaluation will not credit operator action to mitigate the event
    - Vacuum relief system added to mitigate event

TRANSIENT DESCRIPTION

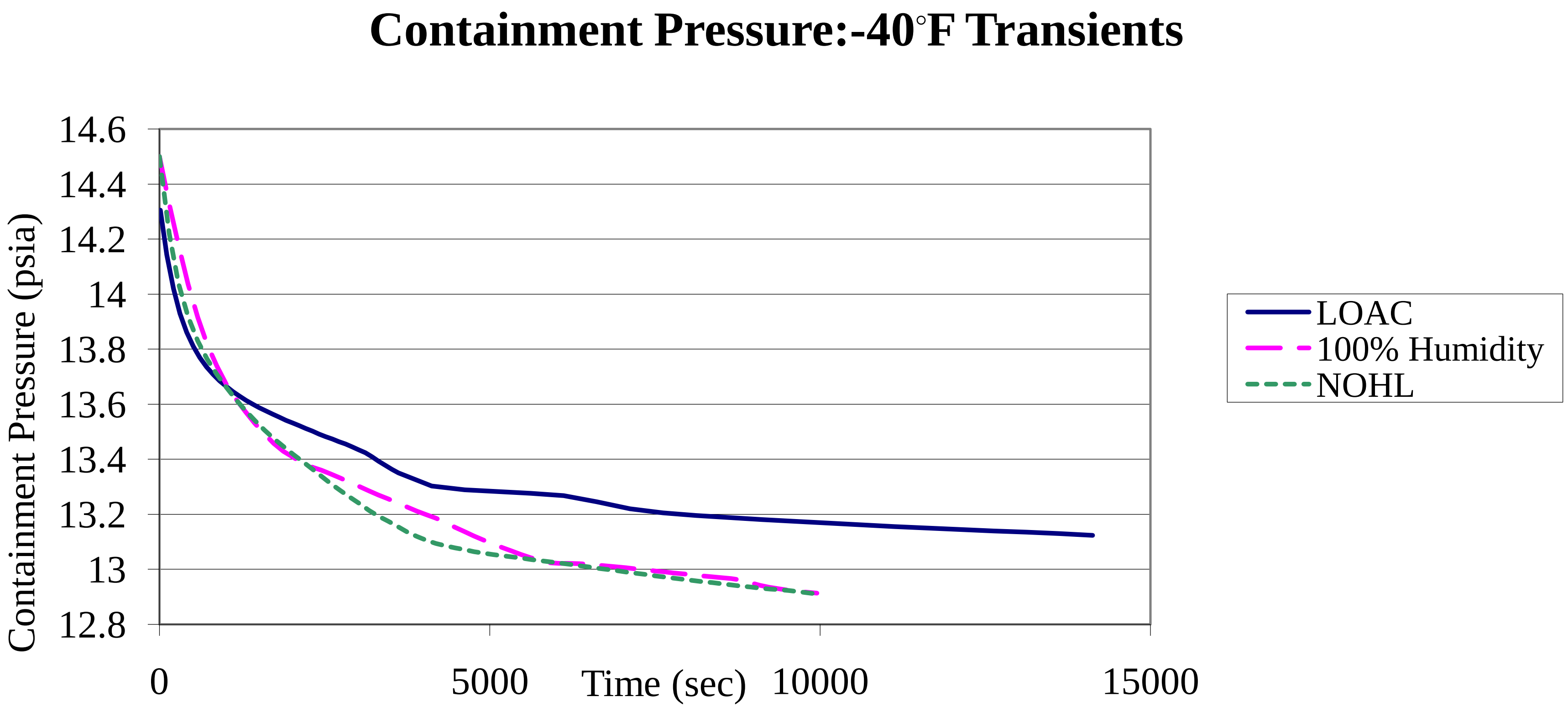
- Transients were performed at three different external/internal temperatures

Int. Temp (°F)	Ext. Temp (°F)	ΔT (°F)
78.6	-40	-118.6
104.9	8	96.9
121.4	33	88.4

TRANSIENT DESCRIPTION (CONT'D)

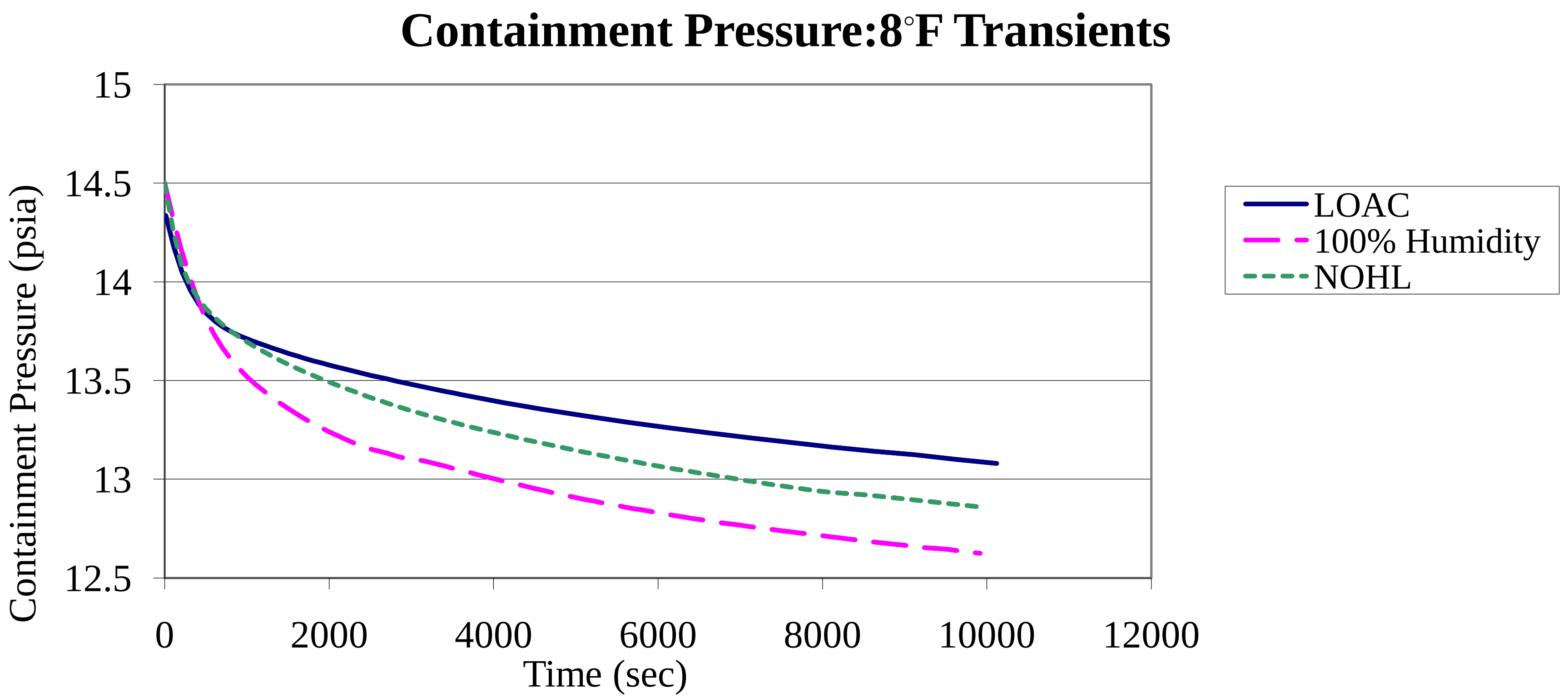
- For each external temperature, three different transients were analyzed:
  - Initial equilibrium conditions
  - Humidity (50%, 100%)
  - Heat loads (Mode 3 NOP/NOT, zero decay heat)
- To determine the bounding negative pressure scenario

-40°F TRANSIENTS



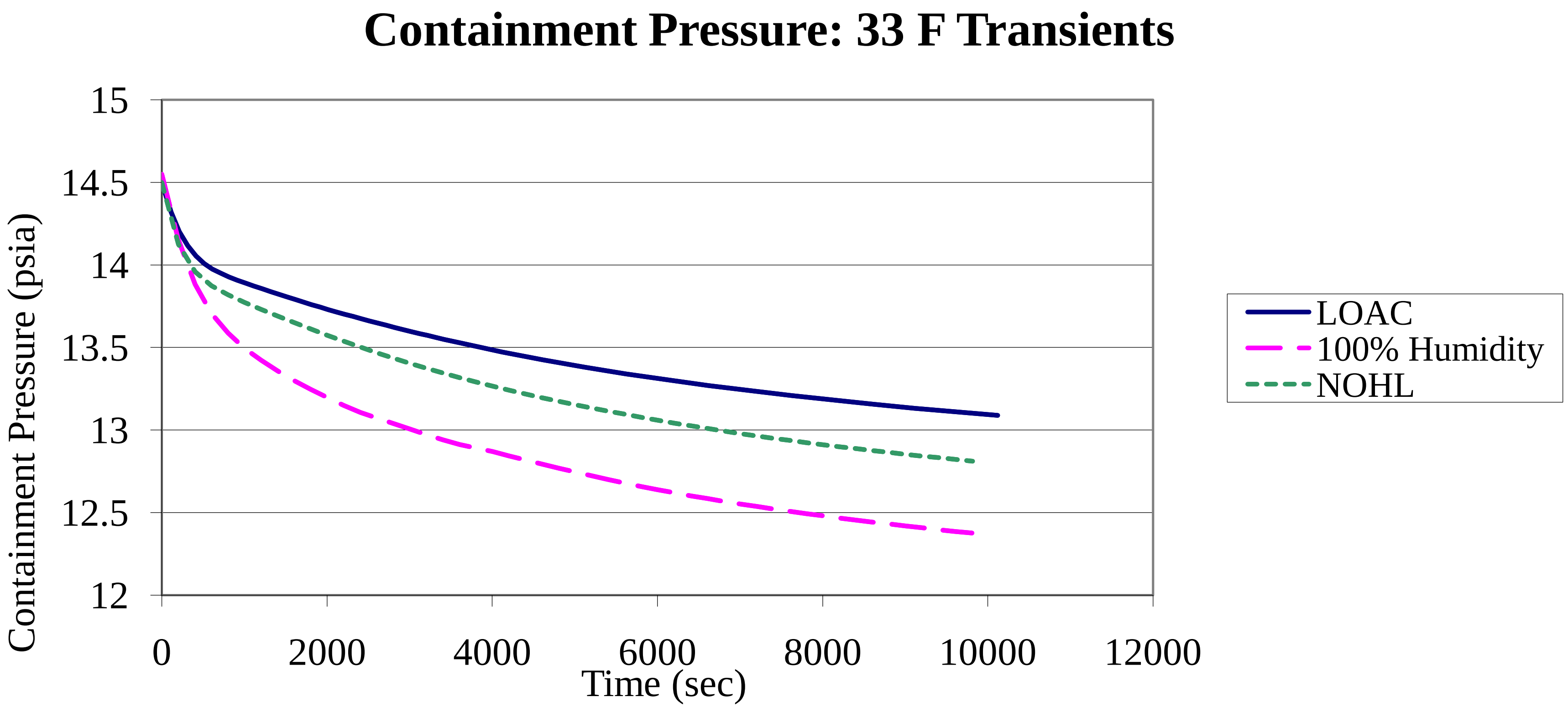
*Vacuum relief system not credited

8°F TRANSIENTS



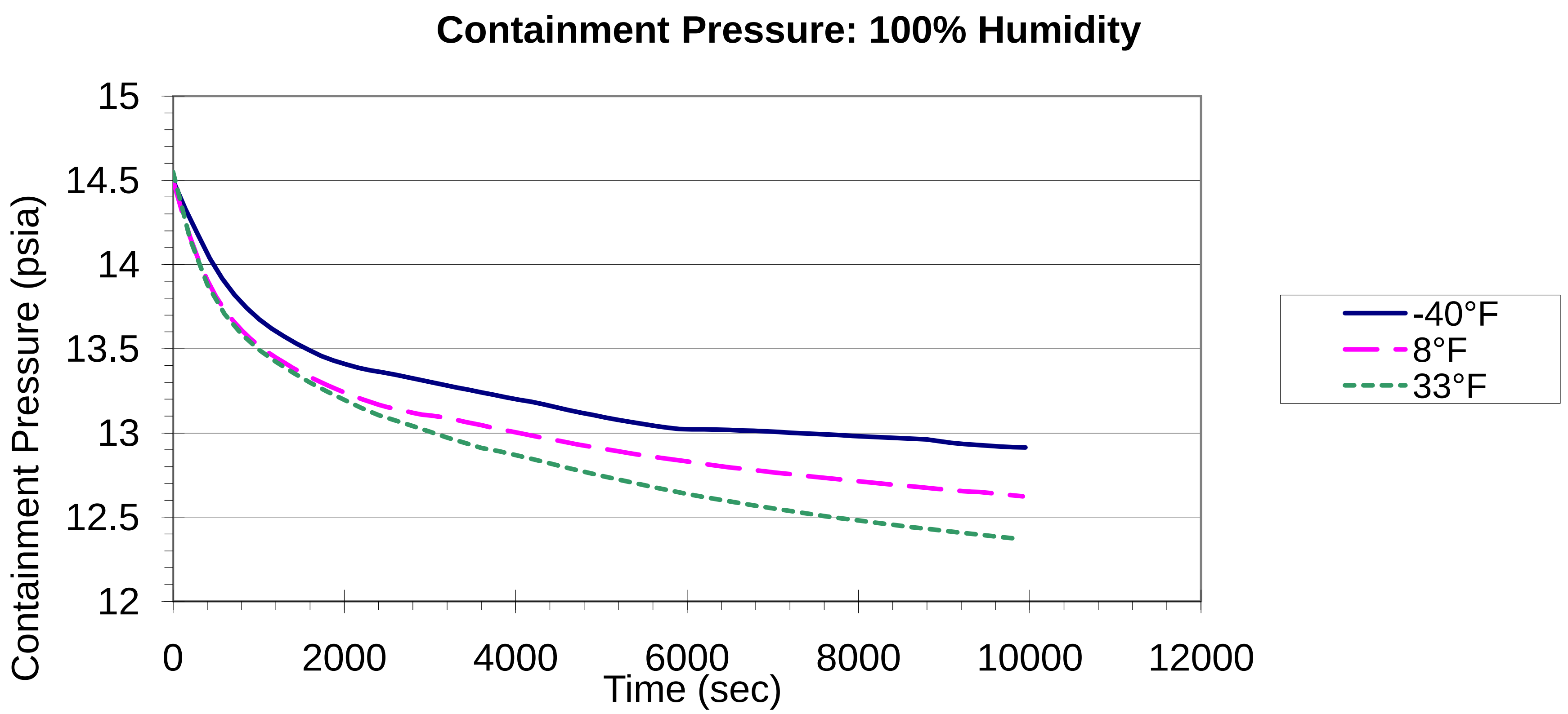
*Vacuum relief system not credited

33°F TRANSIENT



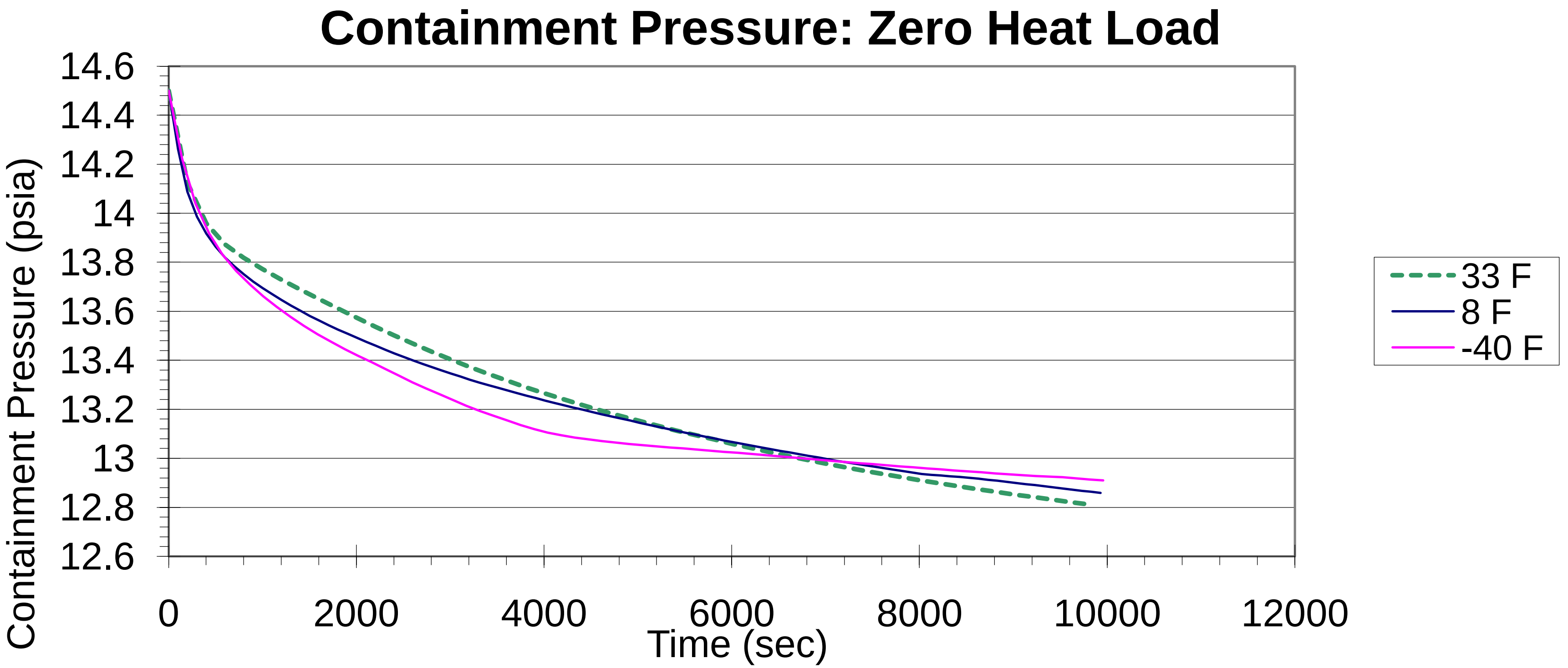
*Vacuum relief system not credited

100% HUMIDITY TRANSIENTS



*Vacuum relief system not credited

ZERO HEAT LOAD TRANSIENTS



*Vacuum relief system not credited

PRESSURE RESPONSE MAGNITUDE VALUES

The table below shows the peak external pressure at t=3600 seconds post-transient

(psia)	H100%	NOHL
P8	13.04	13.28
P33	12.91	13.32
N40	13.24	13.16

PHENOMENA RANKING

- Based on the table and the plots on the previous slides it was determined that the dominant phenomena for a negative pressure excursion in order of rank is:
  1. Humidity
  2. Heat load

KEY ASSUMPTIONS

- Humidity is maximized (100%) to the highest possible value
  - Maximizes the contribution of the partial pressure of water
  - Shell temperature always below dew point
- The heat transfer gradient to the exterior was maximized
  - No active containment cooling was modeled
  - Design basis sensible heat loads were used to maximize containment internal temperature
  - Containment equilibrated with PCS in natural convection
  - At transient initiation instantaneous step change to force flow convection (24.8 ft/s)

KEY ASSUMPTIONS (CONT'D)

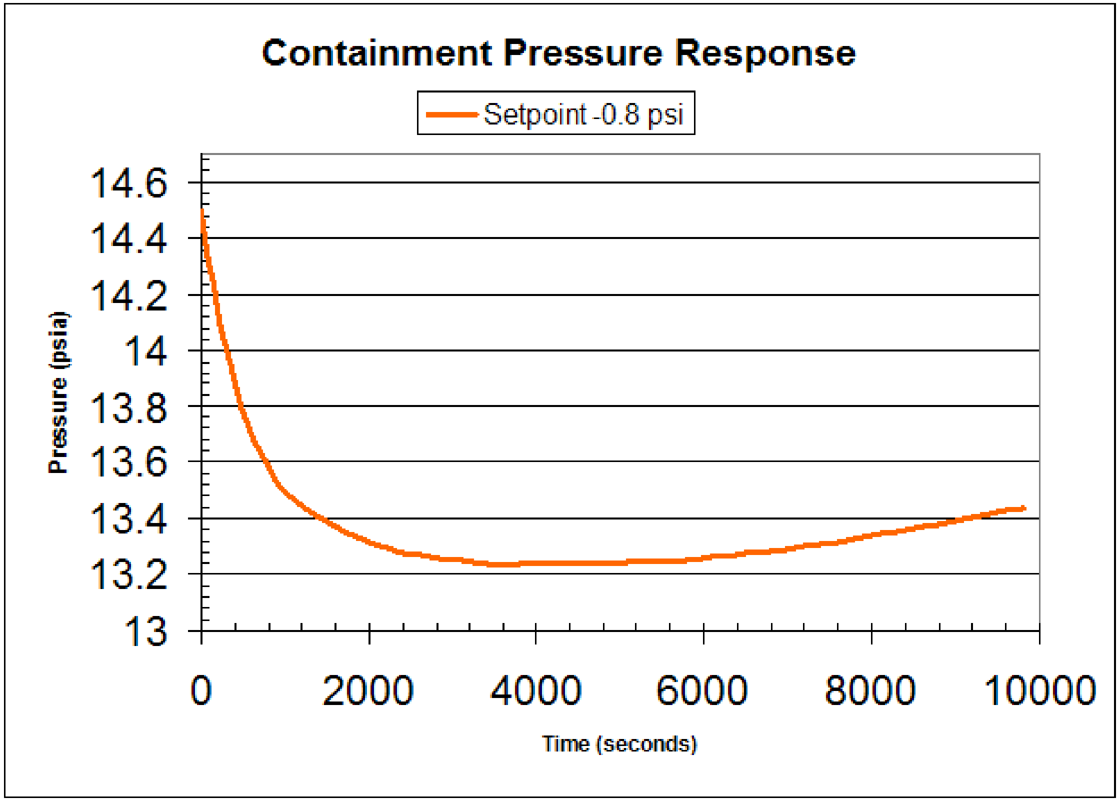
- Transient initiation external temperature was decreased 20°F according to chopped cosine distribution with a periodicity of 24 hours
- Conservative RCS sensible heat loss to containment was modeled
  - Assumed instantaneous step change to approximately 1/5th of the design value
- Zero decay heat was assumed

CONCLUSION

- The 33°F/120°F case with 100% humidity yielded the bounding negative depressurization rate
  - Used to confirm the vacuum relief design to mitigate the bounding external pressure excursion
- Next step is to demonstrate transient performance with vacuum relief

CONTAINMENT PRESSURE RESPONSE WITH VACUUM RELIEF

Containment design pressure differential is 1.7 psi

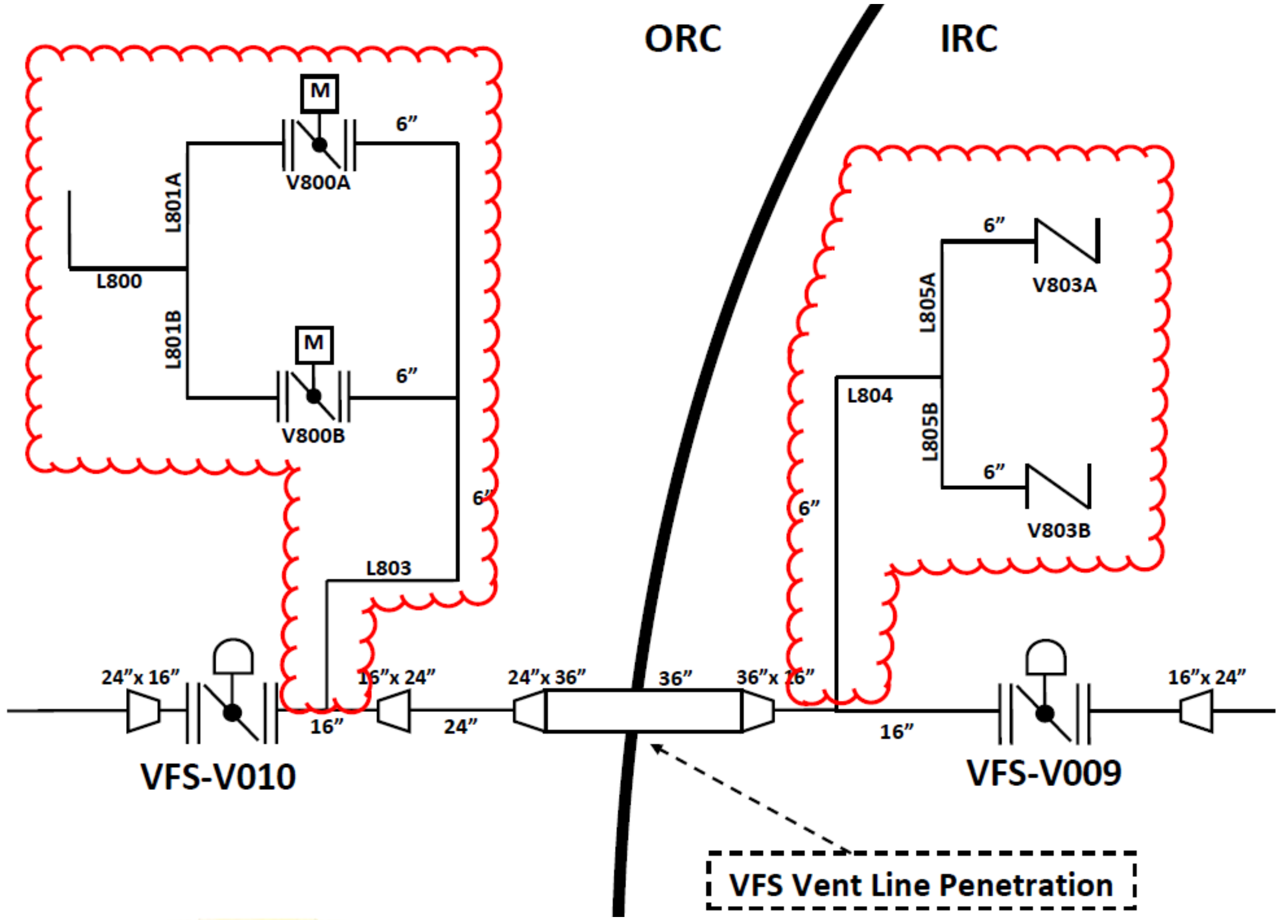


VACUUM RELIEF SYSTEM DESIGN

DESCRIPTION

- Vacuum relief is required based on 6.2.1.1.4 containment external pressure analysis
- Current AP1000 Containment has no provision for containment vacuum relief
- Design change is being developed to resolve this issue

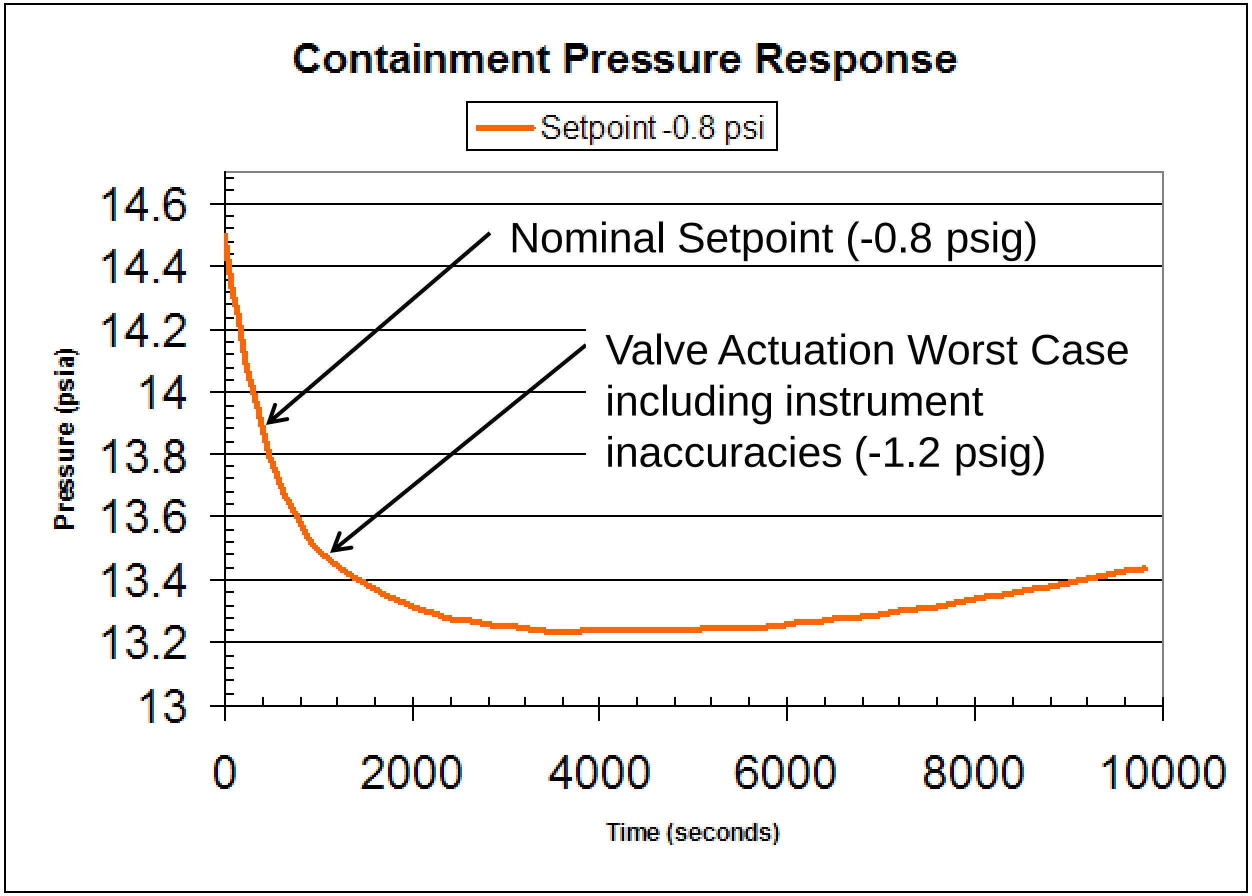
PROPOSED DESIGN CHANGE



SIZING CONSIDERATIONS

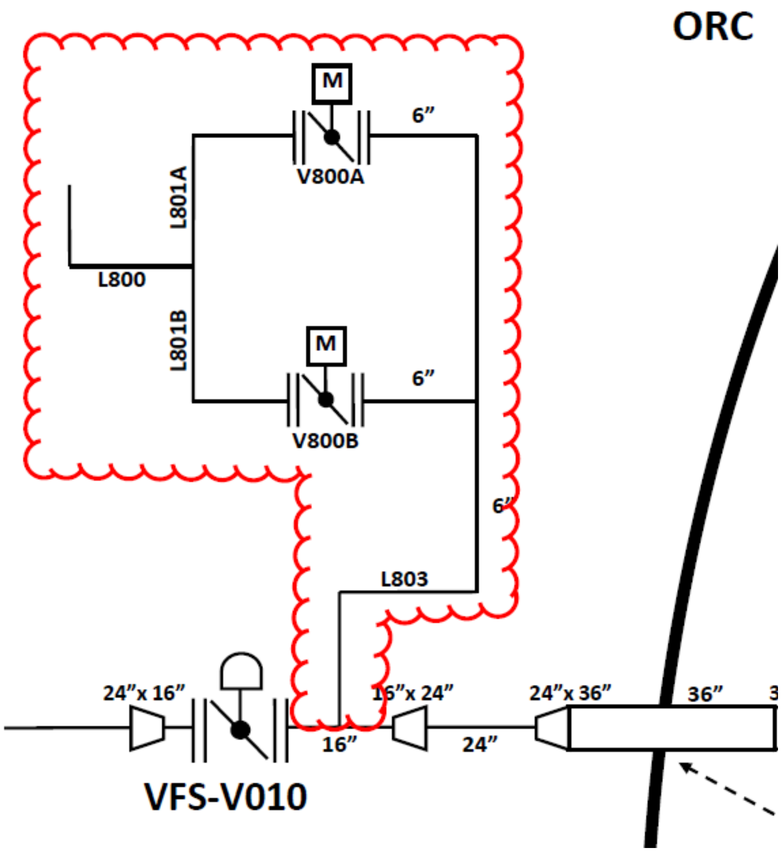
- 6” System based on the following:
  - Revised transient analysis results
  - -0.8 psig setpoint
  - ±0.4 psi instrument accuracy for pressure measurement
  - Valve opening time (20 secs)
  - Mitigates the transient and supports the -1.7 psig containment vessel design external pressure
- Includes significant margin in hydraulic resistance

SIZING CONSIDERATIONS



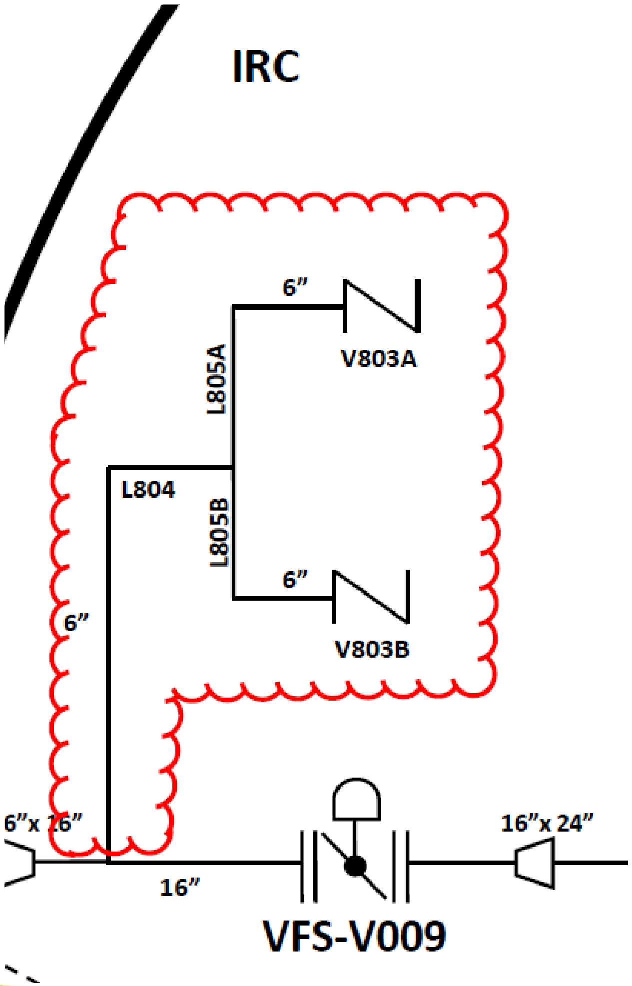
VALVE SELECTION – ORC

- Motor operated butterfly valve selected for outboard relief
- High Cv (low resistance)
- Powered by 1E batteries
- Meets Code compliance
  - ASME Section III, ANSI 56.2, OM Code



VALVE SELECTION – IRC

- Self actuated swing check valve selected for inboard relief
- Simple design
- Horizontally Installed
- Balanced and Adjustable
- Soft-seated steel valve
- Meets Code compliance
  - ASME Section III, ANSI 56.2, OM Code



ASME CODE COMPLIANCE

- ASME Section III, Article NE-7000
  - NE-7110 (Scope)
    - Applicability of the vacuum relief system to the CV design
  - NE-7120(a) (Integrated Overpressure Protection)
    - Defines method use for overpressure protection
  - NE-7142 (Provisions when Stop Valves are Used)
    - No stop valves placed at the inlet or discharge lines of the relief device

ASME CODE COMPLIANCE (CONT'D)

- NE-7152 (Vacuum Relief Devices)
  - (a) Vacuum relief system is designed to Class 2
  - (b) Inboard check valve is compliant
  - (c)(1) Two independent external power operated valves (POV)
  - (c)(2) Two parallel self actuating relief devices in series with each POV

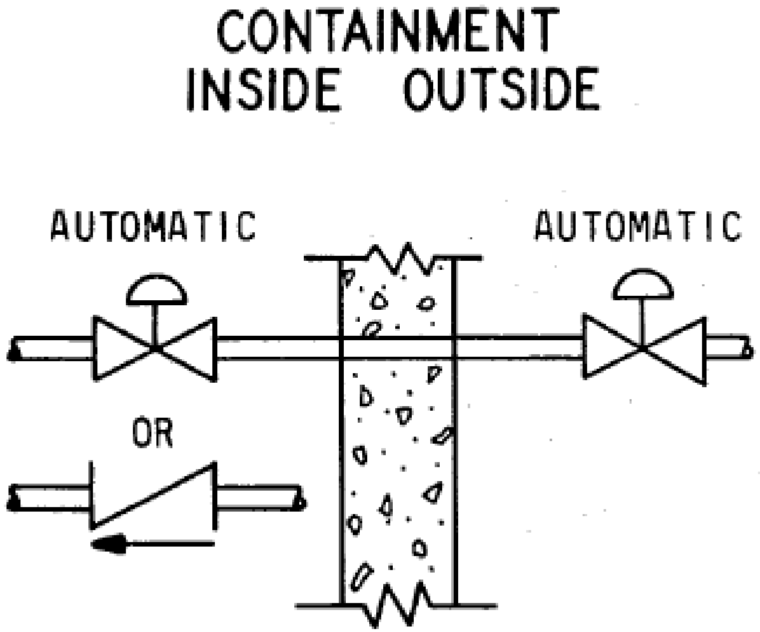
ASME CODE COMPLIANCE (CONT'D)

- NE-7220 (Content of Report)
  - Vacuum relief system design uses redundancy and diversity consistent with single failure analysis to maintain system function
- NE-7311 (Relieving Capacity)
  - Each independent relief path provides system capacity to prevent the CV design pressure from being exceeded

CONTAINMENT ISOLATION CONSIDERATIONS

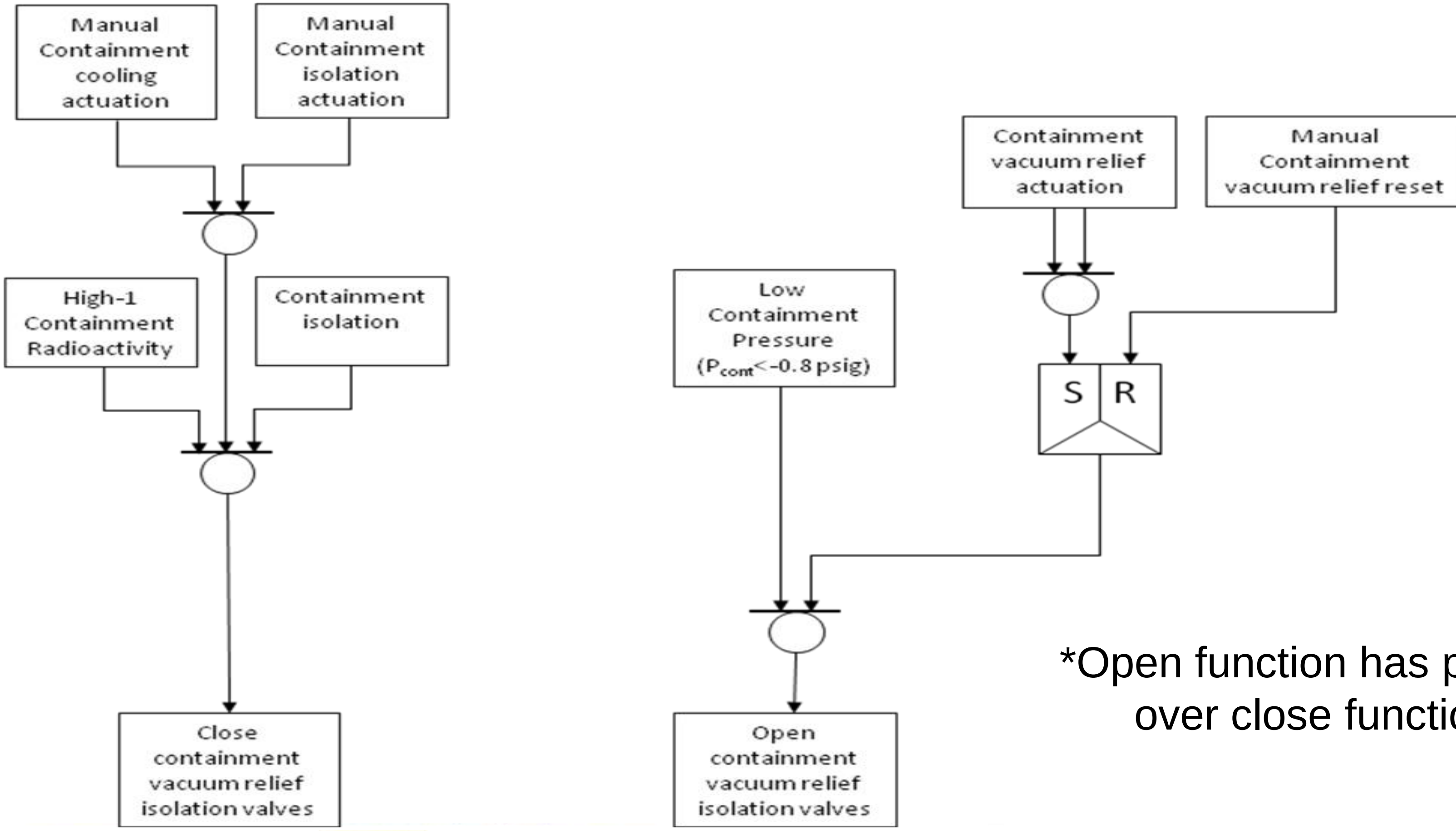
- ANSI 56.2 and ANSI 56.8
  - GDC 54 (Test Ability)
    - Spool pieces and temporary test connections to be used for leakage rate testing
  - GDC 55 (RCS Boundary)
    - N/A
  - GDC 56 (Containment Isolation)
    - Automatic valve outside and inside containment
  - GDC 57 (Closed Systems)
    - N/A

CONTAINMENT ISOLATION CONSIDERATIONS



ANSI 56.2

MOV CONTROL LOGIC



*Open function has priority over close function

CONTAINMENT VESSEL DESIGN

CHANGES TO CV DESIGN DUE TO ADDITION OF VACUUM RELIEF SYSTEM

- The CV design external pressure is selected to be 1.7 psid
- Chapter 6 safety analysis demonstrates that the system precludes pressures exceeding the design external pressure

CHANGES TO DCD CHAPTER 3.8.2

- DCD Section 3.8.2.4.1.1
  - Removed all descriptions of transients used as basis for design external pressure analysis
  - Added statement defining design external pressure based on vacuum relief system actuation point
- DCD Table 3.8.2-1
  - CV design external pressure is now evaluated in Service Levels A and D as well as design case 2
  - To meet N-284 requirements, thermal loads were added to the external pressure design load combination

RAI TR09-008 REVISION 6

- Changes to TR09:
  - Use of P_e combined with normal operation in cold weather
  - Update of Load Combinations based on Table 3.8.2-1 revision
  - Re-evaluation of CV stability in the vicinity of large penetrations
  - More conservative ASME service level evaluations are now performed for CV external pressure cases

CV STRUCTURAL ANALYSIS SUMMARY

- DCD Revision 15 contained CV design external pressure of 2.9 psid and was included in Load Combinations Level A and D
- Potential buckling was seen when cold weather thermal case was considered (original non-mechanistic assumptions)
  - If thermal loads are not considered in this case, the CV design meets NE-3133 for buckling
- Chapter 6 analysis was then refined with more realistic assumptions to define design external pressure (0.9 psid)
- This resulted in a dual design external pressure in Table 3.8.2-1, which was found to be in conflict with the ASME Code Section NE-3113
- The optimum design external pressure is now defined by the Chapter 6 safety analysis while still providing acceptable results in all load combinations to meet N-284 at 1.7 psid

CV STRUCTURAL ANALYSIS SUMMARY (CONT'D)

- Stability analysis has been performed for the containment vessel for load combination service levels A and D at 1.5 psid
  - N-284 requirements are met for global and local instability
  - All requirements of NE-3000 for allowable stress intensities are also met
  - These are the only 2 service level cases that contain external pressure – design case Des2 for external pressure is the same as service level A
- Currently performing the analysis to verify 1.7 psid design external pressure

FINAL SUMMARY

- Westinghouse has described design and analysis changes to address the containment vessel external pressure issue
- Westinghouse will submit formal change notice describing these changes and DCD impacts on July 30
- Westinghouse will support the staff to reach their final safety determination on this issue