AP1000 Containment Vessel Design

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Introduction

- Purpose: Review of the Design and Analysis of the AP1000 Containment Vessel
- Design and Analysis performed by CB&I
- CB&I has worked with Westinghouse on AP600 and AP1000
- Current Work on AP1000 Began May, 2001

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Overview of Discussion

- AP1000 Containment Vessel Design Requirements & Geometry
- Sizing Studies
- Stress Analysis
- Dynamic Analysis
- Combination of Stresses
- Stress Evaluation Results
- Conclusions

AP1000 Containment Vessel Design Specification

- Westinghouse Specification: APP-MV50-Z0-001
- Meets requirements of the AP1000 Design Certification Document
- Design Specification reviewed by CB&I
- Design Code: ASME Section III, Class MC, 2001 Ed. 2002 Add
- Code Case N-284-1 Metal Containment Shell Buckling Design Methods
- NQA-1 Edition thru NQA-1b-1991 Add

AP1000 Containment Vessel Design Inputs

- Design Internal Pressure: 59 psig at Design Temperature of 300°F
- Design External Pressure: 2.9 psig at Design Temperature of 70 °F
- Design Temperature: 300°F
- Minimum Service Temperature: -15°F
- Shell Thickness: 1.75 inch (Cylinder)
- Head Thickness: 1.625 inch
- Corrosion Allowance: Zero (except Ring 1)

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AP1000 Containment Vessel Design Inputs

- Inside Diameter: 130'-0"
- Overall Height: 215'-4"
- Tan-to-Tan Length: 140'-1"
- Material: SA738 Grade B
- Design Code:
  ASME Section III Division 1, Subsection NE, Class MC Components,
  2001 Edition with 2002 Addenda

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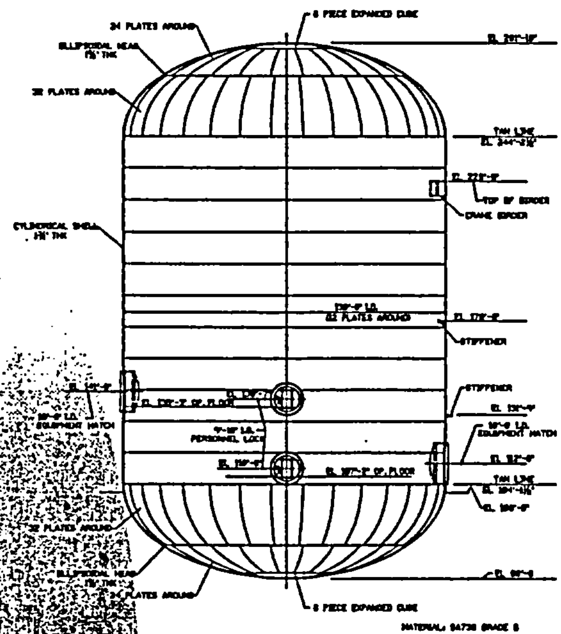

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Phase I: Sizing Studies

- Review of Increased Polar Crane Loads on Polar Crane Girder
- Review of Increased Polar Crane Loads on the Lower Shell
- SA 738 Grade B Material Evaluation and Approval to use by ASME
- Reinforcement of Equip. Hatch and Personnel Lock Penetrations
- Confirmation of Top and Bott. Head Thickness

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Phase II: Vessel Design for Internal and External Pressure

- Westinghouse Doc.: APP-MV50-S2C-002
- NE-3300 "Design by Formula"
- NE-3133 "Components Under External Loading"
- Equipment Hatch Cover Thickness
- NE-3200 "Design by Analysis" Axisymmetric Stress Analysis for Internal Pressure

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Axisymmetric Analysis for Internal Pressure

- ANSYS Version 5.7.1 Finite Element Computer Program
- Linear-elastic static analysis for an internal design pressure of 59 psig.
- Shell, head, stiffeners and crane girder modeled using ANSYS Shell61 elements.
- Maximum membrane stress intensity away from discontinuities is 26.30 ksi.
- Maximum surface stress intensity anywhere in the shell or heads is 35.49 ksi.

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Phase II: Containment Vessel Pressure Capabilities

- Westinghouse Doc.: APP-MV50-S2C-003
- Basis: Stress Intensity Limits for Service Level C or 60% of Critical Buckling Pressure
- Ultimate Pressure Capacity based on failure of a component.
- Axisymmetric Stress Analysis of Containment Vessel for Service Level C Loads.

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Phase II: Dynamic Analysis of Containment Vessel

- Westinghouse Doc.: APP-MV50-S2C-001
- Development of the Lumped Mass Stick Model
- Dynamic Behavior of the Stick and the Axisymmetric Models are the same.
- Spring Constants developed that represent the local stiffness of the shell/ crane girder system at the interface with the polar crane.

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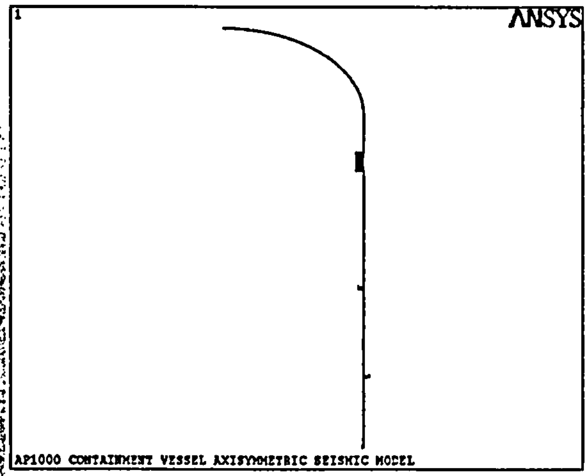
Axisymmetric Analysis Model



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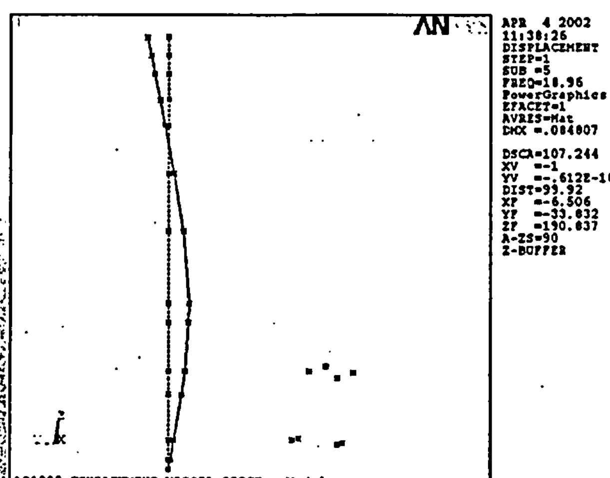
Containment Vessel Stick Model



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Phase II: Polar Crane Load Stress Analysis

- Westinghouse Doc.: APP-MV50-S2C-004: Consider:
  - Polar Crane Dead Loads
  - Polar Crane Lift Load
  - Polar Crane Seismic Loads
- 18 Polar Crane Loading Cases
- Shell of Revolution Analysis for Stresses using crane loading from AP1000 CV Specification
- Stresses and displacements for the polar crane loads are summarized in this document.

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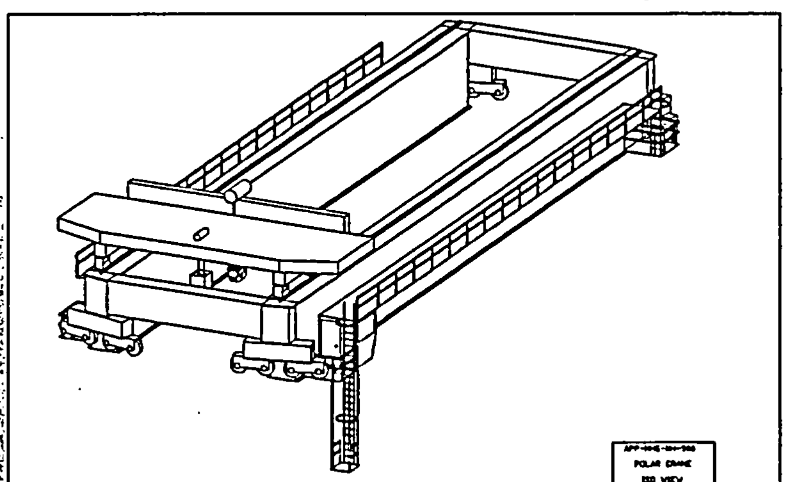
Polar Crane & Trolley



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Phase II: Analysis Using Equivalent Static Seismic Accelerations Without Polar Crane System

- Westinghouse Doc.: APP-MV50-S2C-005
- Purpose: To study the response of the stiffened containment vessel configuration to equivalent static seismic accelerations.
- Analysis did not include the polar crane system; rails, crane, bridge and trolley.
- Analysis used ANSYS 6.0
- Heads and shell modeled using shell elements ANSYS SHELL61
- Stresses and displacements for seismic loads were summarized in Section 9.
- Results were later added to the results of the polar crane seismic load analysis

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Phase III: Compile Stresses from Analysis Results and Evaluate Stresses

- Westinghouse Doc.: APP-MV50-S2C-006: Perform and Verify Stress Evaluation of the Calculated Specified Load Combination Stresses
- Prepare and Verify Calculations Combining the Stresses From:

Containment Vessel Seismic Loads

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Parked Polar Crane Seismic Loads

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Stress Evaluation for Load Combinations

- Evaluated the combined stresses from the specified service load combinations.
- The evaluation was performed on areas away from penetrations or insert plates.
- Lowest course of the containment vessel has an additional corrosion allowance of 0.125". This additional thickness was not used in the calculations.
- Load Combinations and Service Levels in accordance with ASME Code Section III, Class MC

Containment Vessel Load Combinations and Load Factors

Load	Level A Service Limit	Level C Service Limit	Level C Service Limit	Level D Service Limit
DLCV	1.0	1.0	1.0	1.0
DLPCP	1.0	1.0	1.0	1.0
P_i	1.0	1.0		
P_e				1.0
±E,P1 thru ±E,P4		1.0	1.0	1.0
Load Comb. No.	LA1.1	LC1.1.1 thru LC1.1.4	LC1.2.1 thru LC1.2.4	LD2.0.1 thru LD2.0.4
Evaluation Criteria	Stress Intensity for Surface and Membrane Stresses and Buckling for Membrane Stresses	Stress Intensity for Surface and Membrane Stresses and Buckling for Membrane Stresses	Stress Intensity for Surface and Membrane Stresses and Buckling for Membrane Stresses	Stress Intensity for Surface and Membrane Stresses and Buckling for Membrane Stresses

Source of Stresses

- Containment Vessel Dead Load
- Polar Crane Dead Load (parked at 0°)
- Design Internal Pressure of 59 psig
- Design External Pressure of –2.9 psig
- SSE Containment Vessel Seismic Loads
- SSE Polar Crane Seismic Loads
- SSE Seismic Eccentricity of Masses
- SSE CV plus Polar Crane Parked for Membrane Stresses
- SSE CV plus Polar Crane Parked for Surface Stresses

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Accidental Torsion

- This section calculates the SSE seismic stresses due to torsion caused by eccentricity of the masses.
- The stresses from this loading are combined with other SSE seismic stresses for the total SSE seismic stresses.
- Sources producing the torsion are:
  - Accidental torsion due to an eccentricity equal to 5% of the CV diameter at the Elev. of the mass.
  - Torsional response from the time-history analyses of the nuclear island seismic analysis stick model.

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Stress Acceptance Criteria

- Acceptance Criteria: ASME NE-3220 and 3221-1
- Buckling Acceptance Criteria ASME Code Case N-284 Rev. 1
- Buckling allowables calculated on a case by case basis depending on the nature and magnitude of stresses.
- Evaluation for buckling made using an interaction check.

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Five Vessel Regions That Required Additional Buckling Evaluation

- Bottom Head in the Vicinity of the Base (Elev. 100'-0)
- Shell at the Bottom Tangent Line (Elev. 104'-1 ½)
- Shell in the Vicinity of the Crane Girder
- Cylindrical Shell Beyond the Crane Girder Region
- Top Head in the Vicinity of the Top Head Knuckle

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Conclusion

- The stresses in the containment vessel shell and heads meet the design requirements of the AP1000 Spec. for the load cases considered.
- The stresses in the containment vessel shell and heads meet the design requirements of the ASME Code Section III, Class MC.

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