Hanford Double-Shell Tank Thermal and Seismic Project - Increased Liquid Level Analysis for 241-AP Tank Farms

Author: TC Mackey

WRPS

Richland, WA 99352

U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/ECN: ECN-725881 -R0 UC:
Cost Center: Charge Code:
B&R Code: Total Pages: 521

Key Words: DST, Double-Shell Tanks, dynamic response, waste elastic properties, increased fluid level, sludge level, DST comments

Abstract: The essential difference between Revision 1 and the original issue of this report is in the analysis of the anchor bolts that tie the steel dome of the primary tank to the concrete tank dome. The reevaluation of the AP anchor bolts showed that (for a given temperature increase) the anchor shear load distribution did not change significantly from the initially higher stiffness to the new secant shear stiffness. Therefore, the forces and displacements of the other tank components such as the primary tanks stresses, secondary liner strains, and concrete tank forces and moments also did not change significantly. Consequently, the revised work in Revision 1 focused on the changes in the anchor bolt responses, and a full reevaluation of all tank components was judged to be unnecessary..

TRADEMARK DISCLAIMER: Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Release Approval

1/14/2009
Date

Release Stamp

Approved For Public Release

Tank Farm Contractor (TFC) RECORD OF REVISION		(1) Document Number: RPP-RPT-32237	Page 1
(2) Title: Increased Liquid Level Analysis for 241-AP Tank Farms			
Change Control Record			
(3) Revision	(4) Description of Change – Replace, Add, and Delete Pages	Authorized for Release	
		(5) Resp. Engr. (print/sign/date)	(6) Resp. Mgr. (print/sign/date)
1 RS	Incorporate ECN 725881 Rev. 0	T.C. Mackey 1/8/09	D.J. Washenfelder 01/08/2009

**Pacific Northwest
National Laboratory**

Operated by Battelle for the
U.S. Department of Energy

Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms

J. E. Deibler
K. I. Johnson
N. K. Karri
K. L. Stoops

M. W. Rinker
S. P. Pilli
F. G. Abatt

September 2008

Prepared for
CH2M HILL Hanford Group, Inc.
in Support of the
Double-Shell Tank Integrity Program

Sponsored by the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

This document was printed on recycled paper.

Hanford Double-Shell Tank Thermal and Seismic Project – Increased Liquid Level Analysis for 241-AP Tank Farms

J. E. Deibler	M. W. Rinker
K. I. Johnson	S. P. Pilli
N. K. Karri	F. G. Abatt ^(a)
K. L. Stoops ^(a)	

January 2008

Prepared for
CH2M HILL Hanford Group, Inc.
in Support of the Double-Shell Tank Integrity Program

Pacific Northwest National Laboratory
Richland, Washington 99352

(a) M&D Professional Services, Richland, Washington.

Intentionally left blank.

Executive Summary

This report summarizes the results of the Double-Shell Tank Increased Liquid Level Analysis. This combined analysis provides a thorough, defensible, and documented analysis that will become part of the overall analysis of record for the proposed liquid level increase in the Hanford 241-AP Double-Shell Tank (DST) Farms.

The bases of the analytical work presented herein are two ANSYS^{®1} finite element models that were modified from the previous DST structural integrity analyses to represent the AP tank design. The current analysis conservatively assumes that the AP tanks are operating with 460 inches of liquid waste, at a temperature of 210°F, and a specific gravity of 1.83. The Thermal and Operating Loads Analysis (TOLA) model includes the effects of temperature on material properties, creep, concrete cracking, and various waste and annulus pressure-loading conditions. The seismic model considers the interaction of the tanks with the surrounding soil including a range of soil properties, and the effects of the waste contents during a seismic event.

The structural evaluations completed with the AP tank models do not reveal any structural deficiencies with the integrity of the DSTs under these increased waste level operating conditions. The analyses represent 60 years of waste storage in the AP tanks. Bounding material properties were selected to provide the most severe combinations.

The reinforced concrete structure was evaluated according to the American Concrete Institute (ACI) code requirements for nuclear safety-related structures (ACI 1990). The demand was demonstrated to be lower than the capacity at all locations.

The primary tank was evaluated using the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section III, Division 1, Service Level D capacities for combined seismic plus non-seismic loading as prescribed in Day et al. (1995) and Bandyopadhyay et al. (1995). It was demonstrated that the general primary membrane stress intensity in the primary tank remained well below the material yield stress for combined seismic and non-seismic loading. Similarly, the combined non-seismic and seismic demands for local membrane, plus bending as well as local membrane, plus bending, plus thermal loading, remained well below the capacities defined by the code. The primary tank is acceptable according to the established criteria.

The concrete and steel structures are demonstrated to meet the requirements of the International Building Code 2003 (IBC 2003). While the IBC does not explicitly address underground tanks, provision is made within the code to satisfy its requirements by demonstrating compliance with the requirements of the ACI code for concrete structures. Similarly, the IBC references the ASCE code for steel structures, which in turn requires compliance with the ASME B&PV code. Consequently, by demonstrating compliance with the ACI and ASME codes, the DSTs are shown to satisfy the requirements of the IBC.

The primary tank buckling evaluation demonstrated that the current limit on the maximum vacuum level of 12 inches water gauge is acceptable given the current lack of corrosion in the tanks and the expectation that the maximum waste temperature will not exceed 210°F. For this analysis, the occurrence of the maximum tank vacuum was classified as a service level C, emergency load condition. This limit is

¹ ANSYS is a registered trademark of ANSYS, Inc., Canonsburg, Pennsylvania.

predicated on maintaining the minimum allowable waste level at 12 inches to preclude bottom uplift from occurring.

The potential for stress corrosion cracking (SCC) of the primary tank, particularly in the lower knuckle, was assessed. Based on the recent analysis, current testing, and the historical operational records dating back to 1971, we conclude that SCC is unlikely if the present operating requirements are maintained.

The concrete-backed steel liner was evaluated to ASME Section III, Division 2 requirements (ASME 1992b). The liner strain was determined to be less than the maximum allowable levels for all load cases.

The essential difference between Revision 1 and the original issue of this report is in the analysis of the anchor bolts that tie the steel dome of the primary tank to the concrete tank dome. An independent review of Revision 0 of this report raised concerns about the anchor bolt capacity (see Appendix A.2). Further analysis resulted in changes to the anchor bolt modeling and the evaluation method. A detailed anchor bolt analysis of the AP welded stud and threaded stud configuration was conducted (Appendix A.3) to establish allowable anchor shear loads and the secant shear stiffness for calculating the distribution of anchor bolt loads in the global tank model. An ultimate shear capacity of 14.3 kips and a secant shear stiffness of 65,000 lbf/inch were the result of this work. Reevaluation of the anchor bolt forces with the above secant stiffness showed adequate safety margin for a maximum bulk waste temperature of 135°F with a concrete curing temperature of 80°F (the stress-free baseline temperature). Note that to date, the average bulk waste temperatures in the AP tanks have not reached 135°F, even during evaporator campaigns. An increased margin of safety is assured in that no evaporator discharges will be made to tanks certified to operate with waste at a level of 460 inches. The reevaluation of the AP anchors has been reviewed externally (Appendix A.4, A.5, A.8 and A.9).

The reevaluation of the AP anchor bolts showed that (for a given temperature increase) the anchor shear load distribution did not change significantly from the initially higher stiffness to the new secant shear stiffness. Therefore, the forces and displacements of the other tank components such as the primary tanks stresses, secondary liner strains, and concrete tank forces and moments also did not change significantly. Consequently, the revised work in Revision 1 focused on the changes in the anchor bolt responses, and a full reevaluation of all tank components was judged to be unnecessary.

Acronyms

ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials Standards
AWS	American Welding Society
BEC	Best-estimate concrete
BES	Best-estimate soil
B&PV	Boiler and Pressure Vessel
COF	Coefficient of friction
CTE	Coefficient of thermal expansion
DOE	Department of Energy
DSA	Documented Safety Analysis
DST	Double-Shell Tank
FCC	Fully cracked concrete
FE	Finite element
IBC	International Building Code
K_{ISCC}	Threshold stress intensity factor
LBS	Lower bound soil
MCE	Maximum considered earthquake
ν	Poisson's ratio
NUREG	U.S. Nuclear Regulatory Commission Regulation
PC	Performance Category
PNNL	Pacific Northwest National Laboratory
PSHA	Probabilistic Seismic Hazard Analysis
PWHT	Post weld heat treatment
SCC	Stress corrosion cracking
SpG	Specific gravity
SRS	Savannah River Site
TOLA	Thermal and Operating Loads Analysis
UBS	Upper bound soil
USGS	U.S. Geological Survey
Wg	Water gauge
WTP	Waste Treatment Plant

Intentionally left blank.

Units

°F	degree Fahrenheit
ft	foot/feet
g	gravitational acceleration
in	inch
kip	1000 pounds
ksf	1000 pounds per square foot
ksi	1000 pounds per square inch
ksi in ^{1/2}	1000 pounds per square inch square root inch
lb	pound
mil	1/1000 inch
psi	pounds per square inch
yr	year

Intentionally left blank.

Contents

Executive Summary	iii
Acronyms	v
Units	vii
1.0 Introduction	1.1
1.1 Purpose of the DST Increased Liquid Waste Level Analysis	1.1
1.2 Impact of Analysis	1.2
1.3 Analysis Methodology	1.2
1.4 Double-Shell Tank Design	1.3
1.4.1 Thermal Characteristics	1.4
1.4.2 Ventilation System	1.4
1.4.3 Primary Tank	1.4
1.4.4 Secondary Liner	1.4
1.4.5 Concrete Shell	1.4
1.4.6 Insulating Concrete	1.5
1.5 Organization of the Increased Liquid Level Analysis Report	1.5
2.0 TOLA Model	2.1
2.1 Introduction	2.1
2.2 241-AY Finite Element Model	2.1
2.2.1 241-AY Tank Model Geometry	2.1
2.2.2 241-AP Tank Model Modifications	2.2
2.2.3 ANSYS® Model Construction	2.2
2.2.4 Real Constants	2.8
2.3 Material Properties	2.10
2.3.1 Structural Concrete	2.11
2.3.2 Insulating Concrete	2.13
2.3.3 Structural Steel	2.13
2.3.4 Reinforcing Steel	2.14
2.3.5 Soils	2.14
2.3.6 Coefficients of Friction at Material Interfaces	2.17
2.4 Loads	2.18
2.4.1 Thermal Loads	2.18
2.4.2 Mechanical Loads	2.32
2.4.3 ACI Load Factors	2.33
2.4.4 Load Step Procedure	2.34

3.0 Seismic Model.....	3.1
3.1 Introduction.....	3.1
3.2 Finite Element Model.....	3.1
3.2.1 Model Description.....	3.1
3.2.2 Concrete Model.....	3.3
3.2.3 Primary Tank.....	3.9
3.2.4 Insulating Concrete.....	3.13
3.2.5 Anchor Bolts.....	3.13
3.2.6 Secondary Liner.....	3.14
3.2.7 Waste.....	3.16
3.2.8 Primary Tank/Concrete Dome Interface.....	3.17
3.2.9 Primary Tank/Insulating Concrete Interface.....	3.18
3.2.10 Insulating Concrete/Secondary Liner Interface.....	3.19
3.2.11 Soil/Concrete Tank Interface.....	3.19
3.2.12 Excavated/Native Soil Interface.....	3.20
3.2.13 Waste/Primary Tank Interface.....	3.21
3.2.14 Concrete Wall/Footing Interface.....	3.22
3.2.15 Surface Loads.....	3.22
3.3 Soil Model.....	3.23
3.3.1 Soil Properties.....	3.23
3.3.2 Excavated Soil.....	3.25
3.3.3 Native Soil.....	3.27
3.4 Boundary Conditions.....	3.28
3.4.1 Soil Boundary Conditions.....	3.28
3.4.2 Tank Boundary Conditions.....	3.30
3.5 Seismic Input.....	3.32
3.6 Load Cases.....	3.35
3.6.1 Acceptance Criteria for Response Spectra.....	3.35
3.6.2 Modification to ANSYS® Base Time Histories.....	3.37
3.6.3 ANSYS® Base Acceleration Time Histories.....	3.37
3.7 Model Excitation.....	3.41
4.0 Model Reconciliation.....	4.1
5.0 Structural Acceptance Criteria.....	5.1
5.1 Introduction.....	5.1
5.2 Design and Construction Specifications for 241-AP Tanks.....	5.1
5.3 Applicable Codes.....	5.2

5.3.1	Design Codes of Record for the DSTs	5.2
5.3.2	Steel Design Codes of Record.....	5.2
5.3.3	Concrete Design Codes of Record	5.4
5.3.4	Contemporary Codes for Structural Evaluation of the DSTs.....	5.5
6.0	Analysis Results	6.1
6.1	ACI Structural Concrete Evaluation.....	6.1
6.1.1	Best-Estimate Soil, Best-Estimate Concrete	6.2
6.1.2	Upper Bound Soil, Best-Estimate Concrete.....	6.8
6.1.3	Lower Bound Soil, Best-Estimate Concrete.....	6.8
6.1.4	Best-Estimate Soil, Fully Cracked Concrete	6.8
6.2	ASME Primary Tank Evaluation	6.18
6.2.1	Primary Tank Results	6.18
6.2.2	Evaluation Criteria Discussion.....	6.19
6.2.3	ANSYS® Seismic Sloshing Concerns	6.19
6.2.4	Best-Estimate Soil, Best-Estimate Concrete	6.19
6.2.5	Upper Bound Soil, Best-Estimate Concrete.....	6.19
6.2.6	Lower Bound Soil, Best-Estimate Concrete.....	6.19
6.2.7	Best-Estimate Soil, Fully Cracked Concrete.....	6.20
6.3	Primary Tank Stress Corrosion Cracking Evaluation	6.30
6.3.1	Analytical Evaluation.....	6.30
6.3.2	DST Operating Experience	6.32
6.3.3	Seismic Considerations	6.33
6.4	Primary Tank Buckling Evaluation.....	6.34
6.4.1	Evaluation Method.....	6.34
6.4.2	Evaluation Criteria	6.38
6.4.3	Buckling Results	6.39
6.5	ASME Concrete-Backed Steel Evaluation.....	6.40
6.5.1	Best-Estimate Soil, Best-Estimate Concrete	6.40
6.5.2	Upper Bound Soil, Best-Estimate Concrete.....	6.40
6.5.3	Lower Bound Soil, Best-Estimate Concrete.....	6.40
6.5.4	Best-Estimate Soil, Fully Cracked Concrete	6.41
6.6	Anchor Bolt Evaluation.....	6.53
6.7	The Effect of Waste Model Uncertainties on Anchor Bolt Evaluation.....	6.56
7.0	Conclusions and Recommendations	7.1
7.1	Reinforced Concrete.....	7.1
7.2	Primary Tank.....	7.1

7.3 Stress Corrosion Cracking.....	7.1
7.4 Primary Tank Buckling	7.1
7.5 Concrete-Backed Liner	7.2
7.6 Anchor Bolts	7.2
8.0 References.....	8.1
Appendix A – Reviewer Comments and Resolution	A.1
Appendix B – Software Acceptance	D.1
Appendix C – ANSYS® Model Files	E.1

Figures

1-1 Cross Section of a Typical Double-Shell Tank	1.3
1-2 Typical Double-Shell Tank Configuration.....	1.3
2-1 Comparison of 241-AP and TOLA Models	2.2
2-2 Finite Element Mesh of Full Model	2.3
2-3 Close-Up Showing Finite Element Mesh of Tank.....	2.3
2-4 Close-Up Showing Mesh of Haunch.....	2.4
2-5 Close-Up Showing Mesh of Tank Base	2.4
2-6 Concrete Elastic Modulus.....	2.11
2-7 Concrete Strength Used for Finite Element Analysis.....	2.12
2-8 Structural Steel Elastic Modulus	2.13
2-9 Structural Steel Coefficient of Thermal Expansion.....	2.14
2-10 Steel Reinforcing Bar Stress-Strain Curves: a) Grade 40 Rebar, b) Grade 60 Rebar.....	2.15
2-11 Soil Configuration Adjacent to DSTs.....	2.16
2-12 Distribution of Soil Properties in the DST Finite Element Model	2.16
2-13 Undisturbed Soil Elastic Modulus and Poisson's Ratio	2.17
2-14 Backfill Soil Elastic Modulus.....	2.17
2-15 Temperature Distribution at Step 2 in the Design Basis Transient.....	2.20
2-16 Temperature Distribution at Step 3 in the Design Basis Transient.....	2.21
2-17 Temperature Distribution at Step 4 in the Design Basis Transient.....	2.22
2-18 Temperature Distribution at Step 5 in the Design Basis Transient.....	2.23
2-19 Temperature Distribution at Step 6 in the Design Basis Transient.....	2.24
2-20 Steady-State Temperature Distribution at Steps 7 and 8 in the Design Basis Transient.....	2.25
2-21 Temperature Distribution at Step 9 in the Design Basis Transient.....	2.26
2-22 Temperature Distribution at Step 10 in the Design Basis Transient.....	2.27
2-23 Temperature Distribution at Step 11 in the Design Basis Transient.....	2.28

2-24	Temperature Distribution at Step 12 in the Design Basis Transient.....	2.29
2-25	Temperature Distribution During Heat up in the Anchor Bolt Design Basis Transient.....	2.30
2-26	Temperature Distribution at Steady State in the Anchor Bolt Design Basis Transient.....	2.31
2-27	Temperature Distribution During Cool Down in the Anchor Bolt Design Basis Transient....	2.32
2-28	Analysis Flow Plan.....	2.34
3-1	AY Primary Tank Dimensions	3.2
3-2	Composite Tank Model Detail	3.2
3-3	Concrete Tank Profile, Including Shell Thickness	3.9
3-4	Concrete Tank Model Detail	3.9
3-5	Primary/Concrete Tank Node Geometry.....	3.10
3-6	Primary Tank Model Detail.....	3.12
3-7	Primary Tank Model Detail – Knuckle Region.....	3.12
3-8	Insulating Concrete Model Detail.....	3.13
3-9	Anchor Bolt Model Detail	3.15
3-10	Spring Elements – Anchor Bolts to Primary Tank	3.15
3-11	Secondary Liner Model Detail	3.16
3-12	Waste Model Detail.....	3.17
3-13	Waste Model Detail, Interface with Tank Dome.....	3.18
3-14	Contact Elements – Primary Tank to Concrete Dome.....	3.18
3-15	Contact Elements –Insulating Concrete Top and Bottom	3.19
3-16	Contact Elements – Soil to Concrete Tank.....	3.20
3-17	Spring Elements – Concrete Footing to Soil	3.20
3-18	Contact Elements – Near Soil to Far Soil	3.21
3-19	Contact Elements – Waste to Primary Tank.....	3.21
3-20	Contact Elements – Concrete Wall to Footing	3.22
3-21	Mass Elements – Soil Surface	3.22
3-22	Excavated Soil Model Detail	3.26
3-23	Excavated Soil – Softened Soil Zones.....	3.26
3-24	Model Detail.....	3.27
3-25	Far-Field Soil Model Detail.....	3.27
3-26	Link Elements – Edges of Soil Model.....	3.28
3-27	Boundary Conditions – Soil Base.....	3.29
3-28	Boundary Conditions – Typical Soil Layer.....	3.29
3-29	Boundary Conditions – Slaved Boundary Conditions.....	3.30
3-30	Boundary Conditions – Symmetry Plane	3.30
3-31	Boundary Conditions – Concrete Tank.....	3.31

3-32	Boundary Conditions – Primary Tank.....	3.31
3-33	Boundary Conditions – Secondary Liner	3.32
3-34	Comparison of Horizontal Surface Spectra at 5% Spectral Damping.....	3.33
3-35	Comparison of Vertical Surface Spectra at 5% Spectral Damping.....	3.33
3-36	Horizontal and Vertical Surface Acceleration Time History	3.34
3-37	Horizontal and Vertical Surface Displacement Time History.....	3.34
3-38	Ratio of the ANSYS® Tank Foundation Level Spectra to the SHAKE Surface Spectrum for Horizontal Excitation.....	3.36
3-39	Envelope of the Ratio of the ANSYS® Tank Foundation-Level Spectra to the SHAKE Surface Spectrum for Vertical Excitation	3.36
3-40	Ratio of the ANSYS® Tank Foundation Level Spectra to the SHAKE Surface Spectrum for Modified Horizontal Excitation.....	3.37
3-41	Envelope of the Ratio of the Tank Foundation Level Spectra to the Surface Spectra for Modified Vertical Excitation	3.38
3-42	Horizontal and Vertical Base Acceleration Time History, –266 feet, Lower Bound Soil.....	3.38
3-43	Horizontal and Vertical Base Displacement Time History, –266 feet, Lower Bound Soil.....	3.39
3-44	Horizontal and Vertical Base Acceleration Time History, –266 feet, Best-Estimate Soil	3.39
3-45	Horizontal and Vertical Base Displacement Time History, –266 feet, Best-Estimate Soil	3.40
3-46	Horizontal and Vertical Base Acceleration Time History, –266 feet, Upper Bound Soil.....	3.40
3-47	Horizontal and Vertical Base Displacement Time History, –266 feet, Upper Bound Soil.....	3.41
6-1	Reinforced Concrete Sections – Dome and Haunch Area.....	6.2
6-2	Reinforced Concrete Sections – Wall.....	6.3
6-3	Reinforced Concrete Sections – Slab	6.3
6-4	BES-BEC, Load Combination 1.....	6.4
6-5	BES-BEC, Load Combination 4, Meridional.....	6.4
6-6	BES-BEC, Load Combination 4, Circumferential	6.5
6-7	BES-BEC, Load Combination 4, Shear.....	6.5
6-8	BES-BEC, Load Combination 4, In-Plane Shear.....	6.6
6-9	BES-BEC, Load Combination 9, Meridional	6.6
6-10	BES-BEC, Load Combination 9, Circumferential	6.7
6-11	BES-BEC, Load Combination 9, Shear.....	6.7
6-12	UBS-BEC, Load Combination 1	6.8
6-13	UBS-BEC, Load Combination 4, Meridional	6.9

6-14	UBS-BEC, Load Combination 4, Circumferential	6.9
6-15	UBS-BEC, Load Combination 4, Shear	6.10
6-16	UBS-BEC, Load Combination 4, In-Plane Shear.....	6.10
6-17	UBS-BEC, Load Combination 9', Meridional	6.11
6-18	UBS-BEC, Load Combination 9', Circumferential.....	6.11
6-19	UBS-BEC, Load Combination 9', Shear.....	6.12
6-20	LBS-BEC, Load Combination 1.....	6.12
6-21	LBS-BEC, Load Combination 4, Meridional.....	6.13
6-22	LBS-BEC, Load Combination 4, Circumferential	6.13
6-23	LBS-BEC, Load Combination 4, Shear.....	6.14
6-24	LBS-BEC, Load Combination 4, In-Plane Shear.....	6.14
6-25	LBS-BEC, Load Combination 9', Meridional.....	6.15
6-26	LBS-BEC, Load Combination 9', Circumferential	6.15
6-27	LBS-BEC, Load Combination 9', Shear	6.16
6-28	BES-FCC, Load Combination 4, Meridional	6.16
6-29	BES-FCC, Load Combination 4, Circumferential.....	6.17
6-30	BES-FCC, Load Combination 4, Shear.....	6.17
6-31	LBS-FCC, Load Combination 4, In-Plane Shear	6.18
6-32	Relative Magnitude of TOLA and Seismic Primary Membrane Stress Intensity.....	6.20
6-33	BES-BEC Primary Membrane Stress Intensity	6.21
6-34	BES-BEC Primary Membrane + Bending Stress Intensity	6.21
6-35	BES-BEC Primary Membrane + Bending Stress Intensity	6.21
6-36	BES-BEC Primary + Secondary Stress Intensity Range	6.22
6-37	BES-BEC Primary + Secondary Stress Intensity Range	6.22
6-38	UBS-BEC Primary Membrane Stress Intensity.....	6.23
6-39	UBS-BEC Primary Membrane + Bending Stress Intensity.....	6.23
6-40	UBS-BEC Primary Membrane + Bending Stress Intensity	6.24
6-41	UBS-BEC Primary + Secondary Stress Intensity Range.....	6.24
6-42	UBS-BEC Primary + Secondary Stress Intensity Range.....	6.25
6-43	LBS-BEC Primary Membrane Stress Intensity	6.25
6-44	LBS-BEC Primary Membrane + Bending Stress Intensity	6.26
6-45	LBS-BEC Primary Membrane + Bending Stress Intensity	6.26
6-46	LBS-BEC Primary + Secondary Stress Intensity Range	6.27
6-47	LBS-BEC Primary + Secondary Stress Intensity Range	6.27
6-48	BES-FCC Primary Membrane Stress Intensity	6.28
6-49	BES-FCC Primary Membrane + Bending Stress Intensity.....	6.28

6-50	BES-FCC Primary Membrane + Bending Stress Intensity	6.29
6-51	BES-FCC Primary + Secondary Stress Intensity Range	6.29
6-52	BES-FCC Primary + Secondary Stress Intensity Range	6.30
6-53	Comparison of TOLA and AN-107 Lower Knuckle Principal Stress	6.31
6-54	Effect of Applied Bending Stress on Calculated Stress Intensity Factor for the Lower Knuckle of Tank AN-107	6.32
6-55	Buckling Model	6.35
6-56	Buckling Model Loads	6.35
6-57	Buckling Load Deflection Curve	6.36
6-58	Model Displaced Shape at Vacuum Limit	6.37
6-59	BES-BEC, Principal Membrane Strain – Tension	6.41
6-60	BES-BEC, Principal Membrane Strain – Compression	6.41
6-61	BES-BEC, Principal Membrane + Bending Strain Outer Surface – Tension	6.42
6-62	BES-BEC, Principal Membrane + Bending Strain Outer Surface – Compression	6.42
6-63	BES-BEC, Principal Membrane + Bending Strain Inner Surface – Tension	6.43
6-64	BES-BEC, Principal Membrane + Bending Strain Inner Surface – Compression	6.43
6-65	UBS-BEC, Principal Membrane Strain – Tension	6.44
6-66	UBS-BEC, Principal Membrane Strain – Compression	6.44
6-67	UBS-BEC, Principal Membrane + Bending Strain Outer Surface – Tension	6.45
6-68	UBS-BEC, Principal Membrane + Bending Strain Outer Surface – Compression	6.45
6-69	UBS-BEC, Principal Membrane + Bending Strain Inner Surface – Tension	6.46
6-70	UBS-BEC, Principal Membrane + Bending Strain Inner Surface – Compression	6.46
6-71	LBS-BEC, Principal Membrane Strain – Tension	6.47
6-72	LBS-BEC, Principal Membrane Strain – Compression	6.47
6-73	LBS-BEC, Principal Membrane + Bending Strain Outer Surface – Tension	6.48
6-74	LBS-BEC, Principal Membrane + Bending Strain Outer Surface – Compression	6.48
6-75	LBS-BEC, Principal Membrane + Bending Strain Inner Surface – Tension	6.49
6-76	LBS-BEC, Principal Membrane + Bending Strain Inner Surface – Compression	6.49
6-77	BES-FCC, Principal Membrane Strain – Tension	6.50
6-78	BES-FCC, Principal Membrane Strain – Compression	6.50
6-79	BES-FCC, Principal Membrane + Bending Strain Outer Surface – Tension	6.51
6-80	BES-FCC, Principal Membrane + Bending Strain Outer Surface – Compression	6.51
6-81	BES-FCC, Principal Membrane + Bending Strain Inner Surface – Tension	6.52
6-82	BES-FCC, Principal Membrane + Bending Strain Inner Surface – Compression	6.52
6-83	BES-BEC, Anchor Bolt Displacement Evaluation	6.54
6-84	UBS-BEC, Anchor Bolt Displacement Evaluation	6.55
6-85	LBS-BEC, Anchor Bolt Displacement Evaluation	6.55

6-86	BES-FCC, Anchor Bolt Displacement Evaluation	6.56
6-87	Comparison of Maximum Waste from the ANSYS® Primary Tank Sub-Model for Waste Elements at $\theta=0^\circ$ Subjected to Horizontal Seismic Excitation Only to Maximum Waste Pressures for the 100% Impulsive Case	6.59

Tables

1-1	DST 241-AP Required Load Conditions for Analysis	1.2
2-1	Double-Shell Tank 241-AY Design Drawings	2.1
2-2	Foundation Concrete Rebar Volume Ratios	2.9
2-3	Wall Concrete Rebar Volume Ratios	2.9
2-4	Dome Concrete Rebar Volume Ratios	2.10
2-5	Haunch Concrete Rebar Volume Ratios	2.10
2-6	Coefficients for the ANSYS® Creep Law	2.12
2-7	Structural Properties for the Insulating Concrete	2.13
2-8	Coefficients of Friction	2.18
2-9	Temperature States that Define the Design Basis Annual Thermal Cycle for the ANSYS® Structural Model	2.19
2-10	DST 241-AP Load Conditions for Analysis	2.33
3-1	ANSYS® Model Input File Description	3.3
3-2	Concrete Tank Centerline Coordinates	3.4
3-3	Best-Estimate Concrete Properties, 250°F	3.6
3-4	Fully Cracked Concrete Properties	3.7
3-5	Primary Tank Dome Coordination Calculation	3.11
3-6	Anchor Bolt Area Calculation	3.14
3-7	Best-Estimate Native Soil Iterated Soil Properties	3.23
3-8	Best-Estimate Excavated Soil Iterated Soil Properties	3.24
3-9	Upper Bound Native Soil Iterated Soil Properties	3.24
3-10	Upper Bound Excavated Soil Iterated Soil Properties	3.24
3-11	Lower Bound Native Soil Iterated Soil Properties	3.25
3-12	Lower Bound Excavated Soil Iterated Soil Properties	3.25
4-1	Element Correlation for ACI Evaluation	4.2
4-2	Element Correlation for Primary Tank Evaluation	4.3
4-3	Element Correlation for Concrete-Backed Liner Evaluation	4.4
4-4	Element Correlation for Anchor Bolt Evaluation	4.4
5-1	Summary of the S_m Allowables that were Specified for Each of the DST Designs	5.3

5-2	Summary of Hanford Double-Shell Tank Structural Concrete Design Basis	5.4
5-3	Summary of the Local and Global Significance of Failure of the Various DST Components	5.7
5-4	Stress Intensity Classification.....	5.7
6-1	Comparison of TOLA and AN-107 Analyses	6.31
6-2	Primary Tank Buckling Evaluation.....	6.39
6-3	Summary of Primary Tank Buckling Evaluation	6.40

1.0 Introduction

As provided in the CH2M HILL Hanford Group, Inc. (CH2M HILL) statement of work to the Pacific Northwest National Laboratory (PNNL) entitled *Double-Shell Tank (DST) Integrity Project – DST Thermal and Seismic Analyses, Revision 2*, the overall scope of this project was to complete an analysis of record of the DST system at Hanford. The analysis was conducted to provide analytical documentation of the DST system's structural integrity and to support programmatic decisions toward the continued operations of these tanks during waste cleanup operations at the Hanford Site. This work establishes a defensible basis for operating specifications for continued use of the DSTs as well as providing an estimate of the remaining DST useful life.

The overall scope of the project was defined by seven activities that were completed over a 4-year period. The primary activities were:

- Thermal and Operating Loads Analysis (TOLA)
- Evaluation of Alternative Liquid Waste Levels in the DSTs
- Seismic Analysis
- Minimum Allowable Wall Thickness Analysis
- Buckling Analysis

Reports have been published documenting the Thermal and Operating Loads (TOLA) Analysis (Rinker et al. 2004), the Seismic Analysis (Rinker et al. 2006c), the Buckling Analysis (Johnson et al. 2006), and the Combined TOLA + Seismic Analysis (Rinker et al. 2006d). This report documents the evaluation of the proposed increased liquid level in the 241-AP Tank Farms.

1.1 Purpose of the DST Increased Liquid Waste Level Analysis

Ensuring adequate waste storage volume is critical to the success of the U.S. Department of Energy's (DOE's) mission to retrieve, treat and dispose of the radioactive waste in the Hanford Tank Farms. Increasing the available waste storage volume in the existing DSTs is an attractive option compared to the construction of new tanks. The purpose of the DST Increased Liquid Level Analysis is to demonstrate the structural integrity of the DSTs under the loading imposed by an increase in the liquid waste level above the current design limits. Review of tank design and operating parameters limited the DSTs under consideration for an increase in waste level to the 241-AP tanks.

The previous analyses (TOLA, Seismic, Buckling and Combined) developed and analyzed a tank model for a set of bounding thermal and operating load cases and bounding geometry of the 241-AY tank design. These nonlinear time-dependent analyses calculated the effects of heating the tank to the maximum operating temperature, long-term operation at elevated temperatures, and operating temperature cycles. These analyses also accounted for the degradation of modulus of elasticity, compressive strength, etc., in the concrete with extended exposure to elevated temperatures. The results predict time-dependent creep, cracking, stresses, strains, and deformations for the entire structure.

The seismic analysis considers the interaction of the tank with the surrounding soil, and the effects of the primary tank contents. The DST and the surrounding soil are modeled as a system of finite elements. The depth and width of the soil incorporated into the analysis model are sufficient to obtain accurate

analytical results. The analysis includes the soil-structure interaction (SSI) model represented by several (nonlinear) contact surfaces in the tank structure. The contained waste was modeled explicitly in order to capture the fluid-structure interaction behavior between the waste and the primary tank. Detailed analyses of the increased interaction between the contained waste and the curved dome area of the primary tank resulting from the increased liquid waste level are described in the Increased Liquid Level Seismic report (Abatt and Rinker 2008).

The previous analyses addressed bounding load cases and geometry and do not consider conditions that would apply to specific tanks. The objective of this work was to perform an analysis for the AP tanks that are the only tanks being considered for the increase waste level. The previously developed models were used with only minor modifications to represent the AP tanks. The load conditions for this analysis are summarized in Table 1-1. The work is documented (including analysis input files) in such a manner to expedite potential future sensitivity calculation and other tank-specific calculations as required by future needs.

Table 1-1. DST 241-AP Required Load Conditions for Analysis

Design Load	Value	Notes
Design life	>50 years	A 60-year design life is used
Maximum corrosion rate	1 mil/yr	A total corrosion allowance of 0.060 inch is applied to the specified nominal thicknesses
Soil cover	8.5 ft @ 125 lb/ft ³	Relative to dome apex
Hydrostatic	460 inches @ 1.83 SpG	Current tank contents are below 1.5 SpG
Pressure	-12 in. w.g. (water gauge)	Primary Tank
	-20 in. w.g.	Annulus
Pressure	40 lb/ft ²	Uniform
	200,000 lb	Concentrated
Live load	210°F	Maximum bulk temperature of waste for calculational purposes

1.2 Impact of Analysis

The primary impact of the Increased Liquid Level analysis is to allow for increased waste storage volume in the DSTs. Raising the level in 241-AP Tank Farm by approximately 40 inches will increase the storage volume in each of the eight tanks by roughly 100,000 gallons. The impacts of the additional storage volume on Hanford Site operations are the responsibility of DOE and the Contractor.

1.3 Analysis Methodology

The analysis was conducted with two separate and distinct ANSYS^{®1} finite element models. The normal thermal and operating loads are considered in the TOLA model, which is described in detail by Rinker et al. (2004). The seismic loads are considered in the seismic model, which is described in detail by Rinker et al. (2006c). Results from the separate TOLA and seismic analyses are combined as necessary in various Excel spreadsheets for the appropriate code evaluation. The Combined Summary report

¹ ANSYS is a registered trademark of ANSYS, Inc., Canonsburg, Pennsylvania.

(Rinker et al. 2006d) outlines the method of combining results. Details for each model are given in Chapters 2 and 3 of this report. The combined results are presented in Chapter 6.

1.4 Double-Shell Tank Design

Figure 1-1 is a simplified diagram of a typical DST structure, showing an inner primary tank and an outer secondary tank covered by a reinforced-concrete shell. The primary and secondary tanks are made of carbon steel plate varying from 3/8 to 1 inch thick. The top of the concrete dome is 15 inches thick and it becomes thicker toward the wall. The walls are 18 inches thick. The entire tank structure is buried at a depth of 6 to 8 feet, measured from the top of the tank dome (Han 1996). Figure 1-2 shows the configuration in 3-dimensional cross section.

The 241-AP Tank Farm was constructed over a period of about 4 years (from 1983 to 1986), with a design life of 50 years. These tanks have been in service for approximately 21 years.

Figure 1-1. Cross Section of a Typical Double-Shell Tank

Figure 1-2. Typical Double-Shell Tank Configuration

1.4.1 Thermal Characteristics

The bounding analyses reported in the Combined TOLA and Seismic Analysis (Rinker et al. 2006d) used the design thermal load from 422 inches of 350°F waste. That report describes the historical review of actual operating temperatures for all the DSTs. While that review did not indicate any waste temperatures in the AP tanks approaching the design limit of 210°F, a maximum waste temperature of 210°F was assumed for each thermal cycle for the Increased Liquid Level analysis. The ANSYS® thermal model described in the Buckling report (Johnson et al. 2006) was used to develop the thermal profiles for use in the thermal cycle.

1.4.2 Ventilation System

The annulus ventilation systems for the DSTs are designed to perform three functions: 1) provide primary tank leak detection through continuous radiation monitoring of the annulus exhaust air, 2) limit temperature build-up in the secondary tank concrete, and 3) remove heat and moisture from the annulus space. The primary tank ventilation systems perform similar functions: 1) limit flammable gas accumulation, 2) limit temperature build-up in the primary tank and secondary tank concrete, 3) maintain a vacuum on the primary tank, and 4) remove heat and moisture from the primary tank in order to minimize vapor space corrosion (Duncan 2003).

1.4.3 Primary Tank

The 75-foot-diameter primary steel tank provides containment for the stored waste. The primary tank varies in thickness from a minimum of 3/8 inch in the dome to a maximum of 1 inch at the bottom center of the tank. The primary tank is constructed from a series of formed segmented plates welded in a staggered arrangement. All butt welds on the primary tank received 100% radiographic examination during construction. The tanks were also post-weld heat treated to stress relieve the welds. The primary tank resists the hydrostatic and hydrodynamic waste loads and the internal pressure.

1.4.4 Secondary Liner

The secondary steel tank, or liner, lies beneath the insulating concrete and is built directly on top of the concrete foundation. The secondary tanks are about 5 feet larger in diameter than the primary tanks, resulting in a 2.5-foot-wide annular space between the primary and secondary tanks. The secondary liner is joined to the primary tank dome at the upper haunch area, and the two tanks are enclosed in a reinforced concrete shell. The secondary liner provides a second confinement barrier for potential primary tank leaks, thus preventing uncontrolled releases of waste to the environment.

1.4.5 Concrete Shell

On the outside of the secondary tank is a reinforced concrete shell. The exterior concrete shell comprises a foundation, walls, and a dome that completely enclose the secondary tank and primary tank dome. The structural concrete foundations are about 88 feet in diameter and are designed to distribute all weight loads to the ground below. The structural foundation contains drain lines and leak-detection wells to collect any leakage from the secondary liner. The top of the concrete foundation also contains slots to drain any liquid that might leak from the secondary tank.

The concrete shell wall is constructed of steel-reinforced concrete. The shells are about 83 feet in outside diameter and about 18 inches thick and rest on steel slide plates supported by the tank foundation. The concrete shells were poured directly against the secondary liner (i.e., the secondary liner was used as a casting form for the concrete shell). Construction form ties welded to the outside of the secondary tank attach the steel to the concrete walls. The dome is 15 inches thick and is constructed of steel-reinforced concrete. The primary tank is attached to the concrete dome by welded studs and threaded anchor bolts that are cast into the concrete dome.

Steel riser pipes penetrate the concrete dome and the top of the primary and secondary tanks. The risers provide access to the primary tank and the annulus space for waste transfer operations, equipment installation, and monitoring. The risers are located in covered pits or are located at grade at specific locations above the pits.

1.4.6 Insulating Concrete

The primary tank rests on an 8-inch-thick insulating concrete support pad, located between the primary and secondary tank floors. The concrete pad includes air distribution and drain slots in a radial pattern, which are designed to maintain a uniform tank bottom temperature, to provide a means of heat removal and leak detection, and to help eliminate pockets of water condensation. To provide supplemental cooling, air can be routed through the drain slots via the annulus ventilation system. The drain slots allow any leakage from the primary tank to drain into the annular space, where leak-detection instrumentation is installed.

1.5 Organization of the Increased Liquid Level Analysis Report

The organization and content of this report are described briefly as follows:

- Chapter 1 – Introduction: Provides the background and overall purpose of the Double-Shell Tank Thermal and Seismic Analysis. The scope of the Increased Liquid Level analyses is described. Basic DST information is also included in this chapter.
- Chapter 2 – TOLA Model: Describes the ANSYS® finite element model used for the thermal and operating loads analyses. Summarizes the material properties, loads and load case combinations.
- Chapter 3 – Seismic Model: Describes the ANSYS® finite element model used for the seismic analyses. Summarizes the material properties, boundary conditions and acceleration time-histories.
- Chapter 4 – Model Reconciliation: Discusses the differences between the TOLA and seismic models and the methods for combining results.
- Chapter 5 – Structural Acceptance Criteria: Describes the code-based acceptance criteria used to evaluate the combined results.
- Chapter 6 – Analysis Results: Provides a summary of the increased liquid level results. The ACI concrete evaluation for each run is presented and followed by the ASME primary tank evaluation. The stress-corrosion cracking criteria for the primary tank are considered next, followed by buckling analyses of the primary tank. Finally, the evaluation of the anchor bolts and the secondary liner are assessed.
- Chapter 7 – Conclusions and Recommendations: Summarizes the increased liquid level analysis with conclusions regarding DST structural integrity based on the evaluations conducted.

- Chapter 8 – References: Lists the references used in the study.
- Appendix A – Reviewer Comments and Resolution: Independent reviewer comments on Rev. 0.
- Appendix B – Software Acceptance.
- Appendix C – ANSYS® Model Files: Documents the TOLA model input and post-processing files.

2.0 TOLA Model

2.1 Introduction

This chapter describes the ANSYS® finite element (FE) model, material properties, and loads used for the double-shell tank (DST) Increased Liquid Level analysis. Complete documentation of the model is found in the TOLA report (Rinker et al. 2004). The current report contains summaries of the model, material properties, and loads. The TOLA report should be referenced for complete model description and background information.

The TOLA analysis was conducted on a model of the 241-AY tank that was selected as the bounding DST geometry. However, only the 241-AP tanks are being considered for the increase in waste liquid level. It is recognized that significant differences (as summarized in Table 2.4 of the TOLA report) exist between the AP tanks and the TOLA model. These include higher strength structural steel, higher strength concrete, higher strength reinforcing steel, increased thickness foundation, and increased amounts of reinforcing steel. The only modifications to the TOLA model used for the increase liquid level analysis to accommodate the differences in the AP tank design were to the primary tank wall thickness. The use of the TOLA model with the lower strength and thinner materials ensures an additional conservatism to the analysis.

2.2 241-AY Finite Element Model

This section describes the geometry and construction of the ANSYS® finite element model. A comprehensive description of the FE model is found in the TOLA report (Rinker et al. 2004). The TOLA report should be referenced for complete model description and background information. As noted above, these sections will describe the TOLA model of the 241-AY tank.

2.2.1 241-AY Tank Model Geometry

The TOLA report provided the rationale for choosing the 241-AY tank as the basis for the bounding model for the DST analyses. The geometry for this tank was taken from the design drawings listed in Table 2-1. A limited number of construction drawings, relating primarily to the steel tank construction, also were referred to for confirmation of dimensions.

It was helpful to review the other tank drawings, particularly 241-SY, because of its similarity to the 241-AY tank. In addition, the newer tank drawings, such as 241-AP, provided valuable insight to the reinforcing steel details.

Table 2-1. Double-Shell Tank 241-AY Design Drawings

Drawing #	Title
H-2-64306	Tank foundation plan
H-2-64307	Structural insulating concrete plan and details
H-2-64310	Concrete tank section and details
H-2-64311	Concrete dome reinforcement plan and details
H-2-64449	Tank elevation and details

2.2.2 241-AP Tank Model Modifications

As noted above, modifications to the TOLA model were limited to changes to the primary tank wall thickness. Figure 2-1 illustrates the differences in the wall thickness between the TOLA model and the AP modifications. The difference in waste depth is also depicted in this figure.

Figure 2-1. Comparison of 241-AP and TOLA Models

2.2.3 ANSYS® Model Construction

ANSYS® Version 7.0 was used for the TOLA analyses. The FE model was developed using ANSYS® APDL macros that build the geometry in 2-D and sweep the cross section about the tank central axis. The macros are listed in Appendix C and also are available electronically. A 2.9-degree section of the tank was modeled with symmetry boundary conditions. This gives an element length of 24 inches in the circumferential direction at the concrete tank inside diameter, which is equal to the anchor bolt spacing. Figures 2-2 through 2-5 show various aspects of the model.

Figure 2-2. Finite Element Mesh of Full Model

Figure 2-3. Close-Up Showing Finite Element Mesh of Tank

Figure 2-4. Close-Up Showing Mesh of Haunch

Figure 2-5. Close-Up Showing Mesh of Tank Base

The model was constructed with a nominal soil overburden of 8.3 feet. The subgrade undisturbed soil depth extends to a depth of 168 feet below the foundation. The lateral soil dimension is 240 feet and includes a “stair step” boundary to distinguish between undisturbed soil and compacted backfill.

SOLID65 elements are used to represent the reinforced concrete regions. The tank liners, insulating concrete confinement ring, liner construction stiffeners, and the anchors use SHELL181 elements with full integration. The anchor bolts use COMBIN40 elements. Nonlinear contacts between various surfaces use the TARGET170 and CONTACT173 elements. SOLID45 elements are used to explicitly represent the soil.

The reinforced concrete is divided into regions that have different steel reinforcement ratios, where it is assumed that the thickness of each rebar layer is 1 inch. The rebar capabilities of the SOLID65 concrete elements were used to represent the reinforcing steel. For regions with nonzero reinforcement ratios, the element attributes include an element coordinate system and two rotation angles that identify the rebar orientation. The element x-axis is parallel to the radial direction, the y-axis is parallel to the circumferential direction, and the z-axis is parallel to the vertical direction. The dome uses the z-axis for the vertical/radial direction. The haunch region uses a spherical coordinate system to define the local x-direction (radially outward from the global origin at the bottom/center of the primary tank) to represent the diagonal ties. Note that the directions used for the rebar's three volume ratios specified as real constants are not in the element coordinate system x-, y-, or z-directions (ESYS), but rather the element x-direction for x, rotation angle theta for y, and rotation angle phi for z. See the ANSYS® Elements Manual and Theory Manual for SOLID65 for more detail.

The ANSYS® concrete material model has no provision for representing the post-cracking tension stiffening behavior of reinforced concrete. The stiffness of an element becomes zero immediately upon cracking. As a consequence, achieving convergence proved nearly impossible during the large-scale cracking that occurs in the model during a thermal cycle. Previous DST analytical reports describe similar difficulties and relate the use of "glue elements" to stabilize the solution. For this analysis, a set of SOLID45 elements was superimposed over the SOLID65 concrete elements to provide numerical stability to the model. These elements were assigned a low modulus (approximately 0.5% of the nominal concrete modulus). The use of these augmented stiffness elements greatly facilitated the model convergence and was demonstrated to have no significant impact on the resulting forces, moments, stress, or strain.

The program flow for the model, including a brief description of each macro, is as follows:

SET_SLICE.MAC

- PNNLA.MAC – basic tank parameters and 2-D geometry, no soil geometry. Geometry divided to accommodate rebar, anchor bolts, and construction stiffeners later. Many area components created.
 - SET_PARMS – sets model parameters that may change (e.g., loads, material properties, overburden depth)
- PNNLA2.MAC – element attribute (real, type, mat, esys) assignments (not values) to geometry (not soil)
 - SET_RX.MAC – selects areas within a range of x
 - SET_REAL.MAC – assigns real constant attribute to each area
 - SET_RY.MAC – selects areas within a range of y
 - SET_REAL.MAC – assigns real constant attribute to each area

- SET_REAL.MAC – assigns real constant attribute to each area
- PNNLA3.MAC – identify as components: anchor bolt lines (line_bolt), stiffener lines (line_stiff), anchor lines (line_anch in haunch), primary tank lines (line_prim), secondary liner lines (line_secon), bottom anchor lines (line_botanch)
- PNNLA4.MAC – 2-D soil geometry, 2-D mesh of soil and the other 2-D solids, rotate to create 3-D geometry/mesh for slice model (no 3-D shell elements), note that soil geometry/mesh is later redefined in set_soil.mac
 - MESH_SIZE.MAC – sets default element size for rebar and soil elements, sets sweep angle, and sets number of divisions per quadrant
- PNNLA5.MAC – merges nodes/keypoints at slab/rebar and tank/rebar; couples all soil nodes to corresponding structural nodes and top of slab to bottom of wall and top of slab to bottom of insulating concrete (note that all coupling is later deleted)
- PNNLA6.MAC – generates anchor bolts, studs, wall base plate, confining ring below secondary liner, confining ring for insulating concrete, wall, and dome stiffeners.
- PNNLA7.MAC – generate primary tank geometry and mesh, define values for all tank real constants, couple vertical displacements at liner bottom
- PNNLA8.MAC – generates secondary liner geometry and mesh, couples vertical displacements at liner bottom, couples shell horizontal displacements to sidewall, couples shell vertical displacements to dome, merges secondary liner nodes with slab top nodes
- PNNLA9.MAC – merges liner to anchor bolts/studs/anchor nodes, applies constraints
 - SET_MATERIALS.MAC – sets all material properties
 - SET_OPTIONS.MAC – includes/excludes certain nonlinear material models (e.g., nonlinear concrete, creep, nonlinear steel liner, nonlinear rebar, nonlinear soil)
 - SET_SOIL.MAC – creates soil geometry and mesh; couples to concrete
- Delete all coupled sets
- SET_AREAS_SLICE.MAC – defines area components for contact definition
- Add steel plate below wall (on slab)
- Add nonlinear contact with appropriate friction coefficients per Section 3.6.2 between soil/concrete, secondary liner/concrete wall, primary tank/dome, primary tank/insulating concrete, slab top/insulating concrete, and wall/slab
- Merge insulating concrete bottom/secondary liner nodes, liner/concrete nodes at centerline
- SET_ESYS_3D.MAC – define all rebar elements real, modify secondary liner elements above 357.5 inch to be 3/8 inch thick
- APPLY_LOADS_SLICE.MAC – reverse area normal of radiused section of secondary liner, apply parametric loads
 - MESH_SIZE.MAC – sets default element size for rebar and soil elements, sets sweep angle, and sets number of divisions per quadrant

- Apply axisymmetric boundary conditions
- Copy anchor bolts, etc. for slice model; divide anchor bolt/bottom anchors by 2 for slice model
- Couple nodes at primary/secondary liner intersection
- Define soil layers including elevation and material properties
 - SET_SLAYER.MAC – applies soil material properties to a layer
- SET_BACKFILL.MAC – defines backfill region and sets linear and nonlinear material properties
- Define augmented stiffness elements
- Merge duplicate contact elements/nodes
- Apply gravity, waste depth, surface loads, annulus and primary tank pressures
- SET_SLICEB.INP runs the thermal cycling for years 1 through 5
- Extended13yr.INP runs the thermal cycling and creep for years 6 through 18
- TwoYrCycle.INP runs the thermal cycling for years 19 and 20
- TwoYrCycleWith460wh.INP increases the waste level to 460 inches and runs the thermal cycling for year 21 and 22
- Extended36yr.INP runs the thermal cycling and creep for years 23 through 58
- TwoYrCycTo60Yr.INP runs the thermal cycling for year 59 and 60
- SET_SLICED6.INP runs ACI load combination 4
- SET_SLICEH.INP runs the thermal cycle for load combination 9

The ANSYS® concrete material model is used for the SOLID65 elements. This model allows for cracking and crushing, as well as variable shear transfer for open/closed cracks. In addition, the implicit creep material model for concrete was used. ANSYS® allows for the concrete cracking/crushing material model and creep material model to be used simultaneously.

The soil elements use the Drucker-Prager constitutive model, which has an internal friction angle, cohesion, and a dilatancy angle as material properties (see Section 2.3.5). A small positive value of cohesion is used to represent the Hanford cohesionless soils, and the dilatancy angle is assumed to be equal to the friction angle (this parameter induces volume changes as a function of element shear stress).

The soil region surrounding the concrete tank and foundation is coupled to the concrete using nonlinear surface-to-surface contact elements, where the sliding friction coefficient is as specified in Section 2.3.6.

The tank liners are coupled to the structural and nonstructural concrete in a similar manner, i.e., with nonlinear contact elements. A friction coefficient is used for these surfaces as well, as specified in Section 2.3.6. These include contact between the following surfaces:

- secondary liner and tank
- primary tank and dome
- bottom of primary tank and top of insulating concrete

- top of slab and bottom of insulating concrete
- bottom of secondary liner and top of slab
- bottom of tank wall and top of slab.

2.2.4 Real Constants

ANSYS® uses real constants to define element properties for certain element types, e.g., thickness for shell elements. The thicknesses of the different regions of the steel liners are defined in SET_PARMS.MAC and assigned in PNNLA7.MAC. The thickness of the primary tank that is in contact with the waste was given a 0.001 inch/year corrosion allowance for the desired 60-year design life for a total reduction of 0.060 inch at the beginning of the analysis. Real constants for the wall and dome stiffeners are defined in PNNLA6.MAC.

2.2.4.1 Reinforcing Steel

The concrete reinforcing steel is modeled by using the rebar capabilities of the ANSYS® SOLID65 element. Elements of 1-inch thickness were defined in the appropriate locations in the dome, haunch, wall, and foundation. The real constants for the rebar elements include the following for each of three possible rebar directions:

- the rebar material ID
- steel volume ratio
- two angles used to orient the rebar directions relative to the element coordinate system.

Tables 2-2 through 2-5 show the calculations for the steel volume ratios required for the concrete rebar elements. The geometry of the rebar, including the locations of transition between rebar volumes, is defined in PNNLA.MAC. Real constants are initially assigned by location in PNNLA2.MAC. The volume ratios and rebar orientation are defined in SET_ESYS_3D.MAC.

2.2.4.2 Anchor Bolts

The tank design drawings listed in Table 2-1 specify an anchor bolt spacing of 2 feet by 2 feet. The 3-D finite element model was constructed as a 2.9-degree wedge that gives the correct 24-inch spacing at the concrete wall (480 feet). The anchor bolts were modeled with two sets of springs: one normal to the primary tank surface to represent the axial stiffness of the anchor bolt, and one tangent to the surface to represent the shear stiffness.

Rev. 0 of this report utilized beam elements for the anchor bolts. The independent reviewers raised concerns over the anchor bolt capacity used in the evaluation (Appendix A.2). They also suggested accounting for the nonlinear shear response of the anchor bolts that has been well documented in Ollgaard et al. (1971) and Lam and El-Lobody (2005). Detailed finite element models (described in Appendix A.3) were developed and the nonlinear response of the AP anchor bolt design was determined. The appropriate secant modulus was identified and used in the DST model. The secant stiffness is a function of the radial location of the anchor bolt.

Table 2-2. Foundation Concrete Rebar Volume Ratios

Description	Slab Bottom		Meridional Spacing ^(a)	# Bars ^(a)	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
Elevation (in.)	Radius (in.)	Bar Size							
NA	75	5	12	NA	0.0256	5	12	0.0256	101
	115	5	NA	48	0.0258	5	12	0.0256	102
	202	5	NA	95	0.0316	5	12	0.0256	103
	350	5	NA	189	0.0360	5	12	0.0256	104
	369	5	NA	240	0.0326	5	12	0.0256	105
	435	5	NA	240	0.0293	5	12	0.0256	106
	444	5	NA	240	0.0267	6	8	0.0552	107
	528	7	NA	512	0.1016	6	8	0.0552	108
Description	Slab Top		Meridional Spacing	# Bars	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
Elevation (in.)	Radius (in.)	Bar Size							
NA	75	5	12	NA	0.0256	5	12	0.0256	111
	115	5	NA	45	0.0242	5	12	0.0256	112
	202	5	NA	99	0.0330	5	12	0.0256	113
	350	5	NA	198	0.0377	5	12	0.0256	114
	369	5	NA	198	0.0269	5	12	0.0256	115
	435	5	NA	256	0.0313	5	12	0.0256	116
	444	5	NA	256	0.0284	6	8	0.0552	117
	528	5	NA	256	0.0259	6	8	0.0552	118
(a) The drawings used to obtain this information specify rebar by spacing or # bars; therefore, where a measurement for Meridional spacing is given, information for # bars is not recorded, and vice versa. NA = Not applicable.									

Table 2-3. Wall Concrete Rebar Volume Ratios

Description	Wall		Meridional Spacing ^(a)	# Bars ^(a)	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
Elevation (in.)	Radius (in.)	Bar Size							
147	75	6	12	NA	0.0368	8	8	0.0982	201/206
204	115	6	9	NA	0.0491	8	8	0.0982	202/207
303	202	6	9	NA	0.0491	8	12	0.0654	203/208
339.5	350	8	12	NA	0.0654	8	12	0.0654	204/209
381.5	369	8	12	NA	0.0654	8	12	0.0654	205/210
(a) The drawings used to obtain this information specify rebar by spacing or # bars; therefore, where a measurement for Meridional spacing is given, information for # bars is not recorded, and vice versa. NA = Not applicable.									

Table 2-4. Dome Concrete Rebar Volume Ratios

Description	Dome	Bar	Meridional			Bar	Hoop		Real
Elevation (in.)	Radius (in.)	Size	Spacing ^(a)	# Bars ^(a)	Volume Ratio	Size	Spacing	Volume Ratio	Constant
NA	120	6	NA	51	0.0453	6	12	0.0368	301
	183	6	NA	101	0.0490	6	12	0.0368	302
	270	6	NA	202	0.0651	6	12	0.0368	303
	304.5	6	NA	202	0.0496	8	6	0.1309	304
	314	8	NA	346	0.1399	8	6	0.1309	305
	354	8	NA	346	0.1300	9	6	0.1657	306
	368.9	8	NA	346	0.1197	9	4	0.2485	307
	391	8	NA	346	0.1139	9	4	0.2485	308
(a) The drawings used to obtain this information specify rebar by spacing or # bars; therefore, where a measurement for Meridional spacing is given, information for # bars is not recorded, and vice versa. NA = Not applicable.									

Table 2-5. Haunch Concrete Rebar Volume Ratios

Elevation (in.)	Haunch External Radius (in.)	Bar Size	Meridional Spacing ^(a)	# Bars ^(a)	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
NA	450	8	NA	519	0.1534	9	4.5	0.2209	401
NA	496	8	NA	519	0.1375	9	4.5	0.2209	402
NA	496	8	4	NA					
408	NA	6	6	NA	0.2700	8	6	0.1309	404
452	NA	8	6	NA	0.1309	9	4	0.2485	403
Elevation (in.)	Internal Radius (in.)	Bar Size	Meridional Spacing ^(a)	# Bars ^(a)	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
NA	480	8	NA	519	0.1489	9	4.5	0.2209	406
408	NA	8	6	NA	0.1309	8	6	0.1309	405
Elevation (in.)	Middle Radius (in.)	Bar Size	Meridional Spacing ^(a)	# Bars ^(a)	Volume Ratio	Bar Size	Hoop Spacing	Volume Ratio	Real Constant
NA	486.5	6	NA	163	0.0261	9	4.5	0.2209	502
435	487	6	NA	163	0.0235	9	8	0.1243	500
451	NA	4	18	NA	0.0109	9	8	0.1243	501
	Ties	Bar Size	Meridional Spacing	Hoop Space	Volume Ratio				
NA		4	16	18	0.0007	NA	NA	NA	NA
(a) The drawings used to obtain this information specify rebar by spacing or # bars; therefore, where a measurement for Meridional spacing is given, information for # bars is not recorded, and vice versa. NA = Not applicable.									

2.3 Material Properties

This section summarizes the material properties used in the TOLA finite element model. A comprehensive description of the structural and thermal properties is found in the TOLA report (Rinker et al, 2004). The TOLA report should be referenced for complete material property description and background information. The lower concrete and steel strengths of the TOLA analysis were maintained in the

Increased Liquid Level finite element model. The higher strength of the A537 steel used in the AP tanks was used for the allowable stress evaluation of the primary steel tank.

2.3.1 Structural Concrete

This section summarizes the structural properties of reinforced concrete that were used in the finite element analysis. The concrete properties listed here represent Hanford batch concrete with a 3-ksi specified minimum compressive strength, as specified for the 241-AY tank design. The properties are summarized in figures and tables in this section.

The concrete elastic modulus was prescribed to be temperature-dependent, as shown in Figure 2-6. The concrete compressive and tensile strengths are shown in Figure 2-7. These are the mean strengths as described in the TOLA report (Rinker et al. 2004). These values are used in the ANSYS® cracking algorithm employed with the SOLID65 concrete elements. The crushing capabilities of the SOLID65 elements were not used. The ACI code evaluation (see Section 6.1 of Chapter 6) used the lower bound compressive strengths of 4.5 ksi specified minimum strength concrete to determine the load and moment capacities of the reinforced concrete tank structure. Thus the analysis conservatively used the mean strength properties to determine the demand and the lower bound properties to establish the concrete section capacity. The TOLA report (Rinker et al. 2004) describes the basis for the concrete strength degradation as a function of temperature.

The coefficient of thermal expansion (CTE) of concrete was taken to be 0.37×10^{-6} in./in./°F. Poisson's ratio was specified to be 0.15.

Figure 2-6. Concrete Elastic Modulus

Figure 2-7. Concrete Strength Used for Finite Element Analysis

Previous DST analyses have identified concrete creep as being an important material parameter. The TOLA report (Rinker et al. 2004) describes the procedure and data used for defining the concrete creep material model. The time-hardening creep algorithm in ANSYS® is defined as

$$\dot{\epsilon}_{cr} = C_1 \sigma^{C_2} t^{C_3} e^{-C_4/T} \quad (2.1)$$

The coefficients used for the ANSYS® time-hardening implicit creep law are given in Table 2-6. The creep law parameters are provided to ANSYS® via the TBDATA command found in SET_PARMS.MAC.

Table 2-6. Coefficients for the ANSYS® Creep Law

Coefficient	Value
C1	0.2545×10^{-6}
C2	1
C3	-0.838
C4	320

2.3.1.1 Degraded Concrete Properties

It was necessary to develop a method to prevent the concrete modulus and strength from “recovering” during subsequent thermal cycles after the initial degradation due to elevated temperature. This was accomplished by redefining the concrete material properties in their degraded condition at the end of the first year at 210°F. Because the degradation is temperature dependent, this definition required segregating the concrete elements into groups of 10-degree increments based on their maximum

temperature (steady-state). A modified set of concrete properties in the degraded condition was defined. At the conclusion of the first year of creep, the properties of each 10-degree group of concrete elements were changed using the ANSYS® **mpch** command to redefine these elements with the degraded properties.

2.3.2 Insulating Concrete

A linear elastic material model was prescribed for the insulating concrete. Table 2-7 lists the structural properties that were used. The compressive strength was not used in the finite element analysis, but was employed in the evaluation of the insulating concrete stress level.

Table 2-7. Structural Properties for the Insulating Concrete

Material Property	Units	Value – Tank AY
Compressive strength	psi	200
Elastic modulus	psi	165,000
Poisson's ratio		0.15
Density	lb/ft ³	50
Coefficient of thermal expansion	in./in.-°F	3.7

2.3.3 Structural Steel

The elastic modulus of the primary tank and the secondary liner structural steels was defined to be temperature-dependent, as shown in Figure 2-8. An elastoplastic material model was defined with a yield of 36,000 psi and a tangent modulus of 1% the nominal elastic modulus. The density of steel was taken as 490 lb/ft³. Poisson's ratio was taken as 0.30. The steel CTE was defined to be temperature dependent as shown in Figure 2-9.

Figure 2-8. Structural Steel Elastic Modulus

Figure 2-9. Structural Steel Coefficient of Thermal Expansion

2.3.4 Reinforcing Steel

Two grades of reinforcing steel were used in the construction of the 241-AY DST. Rebar with 40,000 psi yield strength was used in the slab, and steel with 60,000 psi yield strength was used in the wall and dome. The nonlinear stress-strain curves shown in Figure 2-10 for both grades of rebar were implemented in the ANSYS® model. The density was specified to be 490 lb/ft³. Poisson's ratio was taken as 0.3 and the mean CTE was specified as 6×10^{-6} in./in.-°F.

2.3.5 Soils

Distinction was made between the undisturbed soil and the compacted backfill, as shown Figure 2-11. The DST foundation is supported by the undisturbed native soil. The backfill applies radial pressure and axial frictional force to the tank walls and a dead load to the dome. The FE soil properties were distributed accordingly, as depicted in Figure 2-12.

The soil dimensions are:

Soil depth below foundation:	168 feet
Overburden depth:	8.3 feet
Radial extent (from center of tank):	240 feet
Excavation slope:	Stair-stepped approximation with 1.5:1 slope

(a)

(b)

Figure 2-10. Steel Reinforcing Bar Stress-Strain Curves: a) Grade 40 Rebar (slab), b) Grade 60 Rebar (wall and dome)

Figure 2-11. Soil Configuration Adjacent to DSTs

Figure 2-12. Distribution of Soil Properties in the DST Finite Element Model

The soil constitutive model used for the DST analysis was the ANSYS® Drucker-Prager elastoplastic model. The elastic response is determined by the elastic modulus (E) and the Poisson's ratio (ν). The elastic modulus and Poisson's ratio must be assigned according to the soil depth because the Drucker-Prager model does not adjust the stiffness for confining pressure. The undisturbed soil elastic modulus and Poisson's ratio are shown in Figure 2-13. The compacted backfill soil modulus is shown in Figure 2-14. The backfill Poisson's ratio was constant at 0.27.

The Drucker-Prager plasticity parameters were defined to be constant with soil depth and temperature. The values used are: cohesion = 1.0 psi, friction angle = 35° , and dilatancy angle = 8° . The undisturbed soil density was 110 lb/ft³ and the compacted backfill density was 125 lb/ft³. A detailed discussion is presented in the TOLA report (Rinker et al. 2004).

Figure 2-13. Undisturbed Soil Elastic Modulus and Poisson's Ratio

Figure 2-14. Backfill Soil Elastic Modulus

2.3.6 Coefficients of Friction at Material Interfaces

The DST finite element model includes several contact interfaces where friction forces must be accounted for. Table 2-8 summarizes the coefficients of friction (COF) that are used in the DST model. The basis for these values is given in Rinker et al. (2004).

Table 2-8. Coefficients of Friction

Material Interface Description	Coefficient of Friction
Soil-to-concrete: Dome	0.3
Side walls	0.05
Base mat	0.6
Concrete-to-steel (concrete cast against steel)	0.4
Concrete-to-steel (insulating concrete-to-primary tank)	0.3
Steel-to-steel (graphite-lubricated)	0.2

2.4 Loads

This section describes the loads used in the thermal and operating load analysis. A comprehensive description of the load and boundary conditions is found in the TOLA report (Rinker et al. 2004). The TOLA report should be referenced for complete load description and background information.

The load parameters are defined in SET_PARMS.MAC and are applied in APPLY_LOADS_SLICE.MAC. The loading sequence is defined in SET_SLICE.MAC and subsequent input files.

2.4.1 Thermal Loads

The temperature distributions described in the TOLA report (Rinker et al. 2004) were applied as thermal loads. The temperature profiles represented a yearly thermal cycle that includes the design basis heat up transient, a steady-state dwell time at the maximum design waste temperature, followed by the design basis temperature cool down transient. Table 2-9 presents the time and waste temperatures that define the cycle. Multiple temperature distributions were solved during the waste heating and cooling segments of the transient to ensure that the maximum effect of the transient temperature gradients was captured in the structural evaluations of the concrete and steel sections. It was also conservatively assumed that the steady-state temperature distribution corresponding to a maximum waste temperature of 210°F was achieved at the end of the high-temperature segment of the transient. This approach ensures that the maximum concrete temperatures and the maximum thermal degradation in the concrete strength and stiffness are considered. At the low waste temperature of 50°F it was also assumed that the transient ended with the tank and surrounding soil returning to the uniform 50°F initial temperature. The mechanical analyses assume 50°F as the initial stress-free temperature for the soil, steel, and concrete.

The DST model temperatures are used in the analysis for including the effects of concrete thermal degradation, temperature-dependent steel properties, and differential thermal expansion between the steel and the concrete. The different temperature fields corresponding to the mechanical solution (steps 2 through 12 in Table 2-9) are shown in Figures 2-15 through 2-24. (Note that solution steps 7 and 8 are the same temperature state and only plotted once.) Data files for the temperature distributions are prohibitively large for inclusion in this report as appendices but are available on the electronic media version of this report.

Table 2-9. Temperature States that Define the Design Basis Annual Thermal Cycle for the ANSYS® Structural Model

Step No.	Comment	Days	Waste Temp., °F	Plot Label
1	Initial temperature = 50°F uniform	0	50	
2	Fast heat to 125°F (@ 10°F/hour)	0.3	125	h1
3	First step to 210°F (@ 20°F/day)	2.4	167.5	h2
4	Second step to 210°F	4.6	210	h3
5	Intermediate step toward steady-state	23	210	h4
6	Steady-state @ 210°F	38	210	Ss
7	H _{old} – steady-state @ 210°F	350	210	H _{old}
8	Material property change	351	210	
9	First step to 125°F cool down (@ 20°F/day)	353	167.5	c1
10	Second step to 125°F	355	125	c2
11	Fast cool down to 50°F (@ 10°F/day)	355.6	50	c3
12	Tank cool down transient to 50°F	356.6	50	c4
13	Uniform 50°F	365	50	

The service life of the 241-AP Tank Farm is 50 years. For the purpose of this analysis, a life of 60 years was selected. This value was chosen based on the number of years already in service and the anticipated continuing waste storage. While the historical data suggest a three-year full-temperature cycle, an annual cycle was conservatively specified for the thermal loading. However, the completion of an analysis with 60 thermal cycles proved problematic with the model convergence issues. Review of the preliminary results demonstrated little change in the concrete cracking, concrete force and moments and tank stress beyond the first several cycles. In addition, the creep rate decreases over time (see the TOLA report Chapter 3). Accordingly, analyses consisted of one thermal cycle per year of 422 inches of waste for five years followed by 13 years of creep at elevated temperature followed by two annual thermal cycles. The waste level was then increased to 460 inches. Two annual thermal cycles were conducted at this waste level followed by 36 years of creep at elevated temperature, concluding with two final thermal cycles as described in Section 2.4.4.

The concerns raised by the independent reviewers (Appendix A) regarding the capacity of the anchor bolts resulted in modifications to the anchor bolt modeling as described in Chapter 2.2.4.2 and Appendix A.3. However, evaluation of the anchor bolts continued to be problematic at the higher waste temperatures. Accordingly, as described in Appendix A.3, a separate, distinct 60-year analysis was conducted at a reduced waste temperature of 135°F. This temperature corresponded to the anchor bolt limit load, and it is still higher than the temperatures expected for future AP tank operations. The DST thermal cycle ranged from a uniform 80°F to the steady state temperature distribution corresponding to the 135°F waste temperature. Only one intermediate heat up and cool down load step was required. The temperature distribution for these load steps and the steady state waste condition are shown in Figures 2-25 through 2-27.

Figure 2-15. Temperature (°F) Distribution at Step 2 (Table 2-9) in the Design Basis Transient (waste temperature = 125°F)

Figure 2-16. Temperature (°F) Distribution at Step 3 (Table 2-9) in the Design Basis Transient (waste temperature = 167.5°F)

Figure 2-17. Temperature (°F) Distribution at Step 4 (Table 2-9) in the Design Basis Transient (waste temperature = 210°F)

Figure 2-18. Temperature (°F) Distribution at Step 5 (Table 2-9) in the Design Basis Transient (waste temperature = 210°F)

Figure 2-19. Temperature (°F) Distribution at Step 6 (Table 2-9) in the Design Basis Transient (waste temperature = 210°F)

Figure 2-20. Steady-State Temperature (°F) Distribution at Steps 7 and 8 (Table 2-9) in the Design Basis Transient (waste temperature = 210°F)

Figure 2-21. Temperature (°F) Distribution at Step 9 (Table 2-9) in the Design Basis Transient (waste temperature = 167.5°F)

Figure 2-22. Temperature (°F) Distribution at Step 10 (Table 2-9) in the Design Basis Transient (waste temperature = 125°F)

Figure 2-23. Temperature (°F) Distribution at Step 11 (Table 2-9) in the Design Basis Transient (waste temperature = 50°F)

Figure 2-24. Temperature (°F) Distribution at Step 12 (Table 2-9) in the Design Basis Transient (waste temperature = 50°F)

Figure 2-25. Temperature (°F) Distribution During Heat up in the Anchor Bolt Design Basis Transient (waste temperature = 135°F)

Figure 2-26. Temperature (°F) Distribution at Steady State in the Anchor Bolt Design Basis Transient (waste temperature = 135°F)

Figure 2-27. Temperature (°F) Distribution During Cool Down in the Anchor Bolt Design Basis Transient (waste temperature = 80°F)

2.4.2 Mechanical Loads

Table 2-10 lists the non-seismic loading conditions that are specified in the statement of work for this project. The list contains both structural and thermal operating loads that are both static and transient in nature. The concentrated live load was increased at the end of the nominal 60-year analysis.

Table 2-10. DST 241-AP Load Conditions for Analysis

Design Load	Value	Notes
Design life	> 50 years	A 60-year design life is used.
Maximum corrosion rate	1 mil/yr	A total corrosion allowance of 0.060 inch is applied to the specified nominal thicknesses.
Soil cover	8.3 ft @ 125 lb/ft ³	Relative to dome apex.
Hydrostatic Pressure	460 inches @ 1.83 SpG	Current tank contents are below 1.5 SpG
	-12 in. w.g. (water gauge) $\leq P_{\text{primary}}$ $\leq +60$ in. w.g.	Primary tank
	-20 in. w.g. $\leq P_{\text{annulus}} \leq +60$ in. w.g.	Annulus
	-12 in. w.g. $\leq P_{\text{primary}} - P_{\text{annulus}}$	Differential
Live load	40 lb/ft ²	Uniform
	200,000 lb. nominal	Concentrated
Thermal	210°F	Maximum bulk temperature of waste
	20°F/day	Waste maximum heatup/cooldown rate
	1/yr	Cyclic rate

2.4.3 ACI Load Factors

The load factors required by ACI 349-90 (ACI 1990) were achieved by directly applying them to the relevant load in a separate load step. The load factors to be applied in this analysis are a subset of the possible combinations specified in ACI 349, Section 9.2 (ACI 1990). The subset is defined by WHC-SD-WM-DGS-003 (Day et al. 1995). The normal operating and thermal loads specified for analysis are:

- U = Demand Load (comprised of combinations of the following):
- D = Dead Load (tank + overburden + concentrated dead load + piping and equipment)
- L = Live Loads
- L1 = uniform live load
- L2 = concentrated live load
- F = Hydrostatic waste pressure
- V = Vapor pressure loading (annulus and vapor space)
- H = Lateral soil pressure
- T = Thermal load (internal forces and moments caused by temperature distribution within the concrete). Normal (T_o) and abnormal (T_{abnormal}) cases are specified. As described in Chapter 4, the abnormal temperature cases are bounded by the design thermal transient that is applied in the thermal and operating loads analysis.
- R_o = Piping and equipment reactions¹

The credible but improbable extreme environmental load is:

$$E_{ss} = \text{Safe Shutdown Earthquake (SSE) effects} - \text{Design Basis Earthquake effects}$$

WHC-SD-WM-DGS-003 does not distinguish L1 from L2, or V from F. Those items are combined into L and F. We chose to maintain a distinction and combine them algebraically as a matter of form.

¹ R_o is not considered in this analysis.

The applicable ACI load combinations reduce to:

$$\text{Load Combination 1: } U = 1.4(D + F + V) + 1.7(H + L1 + L2)$$

$$\text{Load Combination 4: } U = D + F + V + H + L1 + L2 + T + E_{ss}$$

$$\text{Load Combination 9: } U = 1.05D + 1.05(F + V) + 1.3(L1 + L2 + H) + 1.05T_o$$

Load Combination 9 is, in terms of load factors, intermediate between Load Combination 1 and Load Combination 4. Instead of applying Load Combination 9, we conservatively applied Load Combination 1 then added the thermal loads with the temperatures increased by 5% as discrete load steps; that is, Load Combination 9': $U = 1.4(D + F + V) + 1.7(H + L1 + L2) + 1.05T$.

2.4.4 Load Step Procedure

Figure 2-28 shows the flow plan used to model the 61 years of thermal cycles. The analysis is divided into several distinct analyses to facilitate a restart in the event of convergence difficulties. The time spans from years 5 to 18 and from 22 to 58 are single thermal cycles held at the steady state temperature for nominally 13 and 53 years, respectively. These are followed by 2 thermal cycles to capture any effect the long term creep may have had on the cracking of the concrete and subsequent load distribution. The waste level was increased from 422 inches to 460 inches following year 20. The ASME and ACI load combinations 1 and 4 evaluations are carried out at the end of or during year 60. An additional thermal cycle (year 61) is completed with the temperatures increased by 5% to provide a conservative evaluation of ACI load combination 9.

Figure 2-28. Analysis Flow Plan

3.0 Seismic Model

3.1 Introduction

This chapter describes the ANSYS® finite element (FE) model, material properties, and loads used for the double-shell tank (DST) seismic analysis. Complete documentation of the seismic model supporting the proposed liquid level increase in the AP Tank Farms may be found in the Seismic Analysis report (Abatt and Rinker 2008). The current report contains summaries of the model, material properties and loads. The Seismic Analysis report should be referenced for complete model description and background information.

3.2 Finite Element Model

The model used for the evaluation of the AP tank configuration and increased liquid level is based on the model developed for the AY tank and a liquid level of 422 inches (Rinker et al. 2006c). Key differences in the increased liquid level and the AY model are as follows:

- AP tank geometry used (geometry and wall thicknesses)
- Waste level increased to 460 inches
- Waste specific gravity increased to 1.83
- Number of contact areas used for waste/primary tank interface increased

For completeness, a detailed description of the model development is provided below.

3.2.1 Model Description

A model of a Hanford double-shell tank was created and analyzed using version 8.1 of the general purpose finite element program ANSYS®. A half-symmetry model of the DST, including the concrete tank, primary tank, secondary liner, anchor bolts, waste, and surrounding soil was developed to evaluate the seismic loading on the DST.

The tank model geometry was based on the AP tank configuration shown in Hanford Drawing H-2-90534. The primary tank has a 450-inch radius and the height of the vertical wall is 422.3 inches. The nominal dome apex is 561.5 inches above the bottom of the tank. The models were run using waste depths of 460 inches. An excerpt from Drawing H-2-90534 is shown as Figure 3-1. Figure 3-2 shows the complete model. Details for each part of the model are discussed in the following sections.

The detailed ANSYS® model was developed based on coordinates used in the TOLA model. A series of input files were used to break the model creation into manageable parts. The files used, and a short description is provided in Table 3-1. Files that are common to all load cases are provided in Appendix E of the Increased Liquid Level Seismic report (Abatt and Rinker 2008). Files that are unique to a specific load case are provided in the appendix of that report for each load case.

Figure 3-1. AY Primary Tank Dimensions

Figure 3-2. Composite Tank Model Detail

Table 3-1. ANSYS® Model Input File Description

File Name	Description
Run-tank.txt	Calls each input for development of model
Tank-coordinates-AY.txt	Defines key geometry and model parameters. Concrete geometry set to match PNNL section cut locations.
Tank-props-###.txt	Defines concrete material and real properties for model. Uses properties based on best-estimate or fully cracked conditions. Each tank layer can be assigned unique properties
Tank-mesh1.txt	Creates concrete tank mesh. Foundation and wall are separate entities
Primary-props-AY.txt	Defines primary tank material and real properties.
Primary.txt	Creates primary tank mesh. Primary tank is not connected to concrete tank.
Insulate.txt	Creates insulating concrete mesh. Uses existing geometry from concrete and primary tanks, but is not connected.
Waste-solid-AY.txt	Creates model of waste. Uses Solid 45 elements with low shear modulus. Uses primary tank geometry.
Interface1.txt	Creates interface connections or contacts between pieces of model
Interface-gap1.txt	Creates interface connections or contacts between pieces of model
Bolts-friction.txt	Creates elements for anchor bolts and contact surface between the primary tank and concrete tank in the dome
Liner.txt	Creates elements for Secondary Liner
Near-soil-1.txt	Creates soil model for excavated region around tank. Merges coincident nodes with concrete tank.
Soil-props-###-geo.txt	Defines all soil geometry and material properties. Excavated region and native soil have different material properties. Unique files are used for each soil condition (UB, BE, LB).
Far-soil.txt	Creates far-field/native soil to a radius of 320 ft and depth of 266 ft. Merges coincident nodes with near soil and concrete tank. Places large mass at bottom of model for excitation force.
Fix-soil.txt	Creates the contact interface between the excavated soil and native soil portions of the model
Slave.txt	Creates slaved boundary conditions around exterior of model.
Boundary.txt	Creates boundary conditions for symmetry. Does not set boundary conditions for solution phase.
Live_load.txt	Applies surface concentrated load over center of dome
Outer-spar.txt	Creates spar elements at edge of soil model to control shear behavior.
(a) Unique files are used for each concrete and soil condition – best-estimate, lower bound, upper bound soils and fully cracked concrete.	

All components of the model are based on 9-degree slices over the half model, for a total of twenty slices. The model description will address the tank components first, then the surrounding soil.

3.2.2 Concrete Model

The first component developed in the model is the concrete tank shell and footing. Thirty-three sections are used between the dome and center of the floor for each 9-degree slice. In the detailed TOLA slice model, seventy sections were identified and used for extracting forces and moments. Using the profile coordinates for these seventy sections, a subset of 33 sections was developed for the profile of the ANSYS® seismic model (see Figure 3-3). Based on the need to allow for connecting other portions of the full model, some coordinates were adjusted relative to the TOLA slice model.

The geometry of the concrete tank is based on a combination of data from drawings and TOLA slice model. The basic geometry is based on drawings H-2-90439 and H-2-90442. Nodal locations were selected to correspond reasonably well to the TOLA model. This placement was done to simplify load combinations. Table 3-2 provides a listing comparison of nodal coordinates for the ANSYS® seismic model and TOLA slice model.

Input file "Tank-Coordinates-AY.txt" is used to read coordinate data for the concrete tank.

Table 3-2. Concrete Tank Centerline Coordinates

	Section	Coordinates			ANSYS®		
		R (inch)	H (inch)	T (inch)	X	Z	Set #
		0	568.6	15	0	568.8	1
Dome	1	30.2	568.6	15			
				15	45	568	2
Dome	2	61.4	567.5	15			
Dome	3	90.4	565.8	15	90.4	565.8	3
Dome	4	120.72	563.21	15	120.72	563.21	4
Dome	5	152.9	559.7	15	152.9	559.7	5
Dome	6	184.14	555.34	15			
Dome	7	211.4	550.7	15	211.4	550.7	6
Dome	8	239.1	545.2	15	239.1	545.2	7
Dome	9	271.85	537.45	15			
Dome	10	306.63	527.68	15	306.63	527.68	8
Dome	11	316.22	524.68	15			
Dome	12	335.6	518.2	15	335.6	518.2	9
Dome	13	356.7	510.37	15			
Dome	14	371.86	504.24	15			
Dome	15	393.7	494.5	15	393.7	494.5	10
Dome	16	404.5	489.3	18.92			
Haunch	17	415.2	483.7	20.31			
Haunch	18	428.7	476.2	22.58	428.7	476.2	11
Haunch	19	441.8	468.2	25.56			
Haunch	20	454.5	459.5	29.46			
Haunch	21	469.9	447.4	36.36	469.9	447.4	12
Haunch	22	483.8	423.18	29.71			
Haunch	23	486.9	407.1	22.52	486.9	407.1	13
Haunch	24	488.47	393.5	19.07			
Wall	25	489	382.1	18	489	382.1	14
Wall	26	489	360.8	18			
Wall	27	489	345.6	18			
Wall	28	489	335	18	489	335	15
Wall	29	489	321	18			
Wall	30	489	306	18			
Wall	31	489	300	18			
Wall	32	489	281	18	489	281	16
Wall	33	489	260.5	18			
Wall	34	489	236	18	489	236.5	17
Wall	35	489	210.5	18			
Wall	36	489	201	18			
Wall	37	489	186.8	18	489	186.8	18
Wall	38	489	171	18			

Table 3-2. (contd)

	Section	Coordinates			ANSYS®		
		R (inch)	H (inch)	T (inch)	X	Z	Set #
Wall	39	489	150.5	18			
Wall	40	489	145.5	18	489	145.5	19
Wall	41	489	120.5	18			
Wall	42	489	100.5	18			
Wall	43	489	80	18			
Wall	44	489	60	18	489	70.0	20
Wall	45	489	39.9	18			
Wall	46	489	21	18	489	20	21
Wall	47	489	-4.5	18			
					489	-4.0	22
					531	-4.0	23
Slab	48	517	-18.4	23.5			
Slab	49	508.5	-18.4	23.5			
Slab	50	503	-18.4	23.5			
Slab	51	496.8	-19.1	23.5			
Slab	52	493	-19.1	23.5			
Slab	53	489	-19.1	22	489	-4.0	24
Slab	54	485.1	-19.1	22			
Slab	55	481	-19.1	22			
Slab	56	477	-19.1	22			
Slab	57	471	-19.1	22			
Slab	58	465	-19.1	22			
Slab	59	440	-19.1	19.38	438	-4.0	25
Slab	60	421.4	-17.9	17.05			
Slab	61	390	-15.9	13.12			
					410	-4.0	26
Slab	62	358	-13.9	9.13	358	-4.0	27
Slab	63	338	-13.4	8			
Slab	64	277.7	-13.4	8	277.7	-4.0	28
Slab	65	218.5	-13.4	8	218.5	-4.0	29
Slab	66	180	-13.4	8	180	-4.0	30
Slab	67	129.9	-13.4	8	129.9	-4.0	31
Slab	68	95.7	-13.4	8	95.7	-4.0	32
Slab	69	54	-17.1	15.43			
					36	-4.0	33
Slab	70	20	-20.1	21.5			
					0	-4.0	34

Note: The concrete tank wall is 8 inches short due to modeling error.

Element stiffnesses are also based on the TOLA slice model for best-estimate concrete conditions for a maximum temperature of 250°F. Common properties for all concrete sections are provided below.

$\nu = 0.18$

Damping – 7%

Input file “Tank-Props-BEC-250.txt” defines the concrete tank material properties and real constants (thickness) for the best-estimate concrete. Input file “Tank-Props-BEC-Crack.txt” defines the concrete tank material properties and real constants (thickness) for the fully cracked concrete. Table 3-3 provides a complete listing of section properties based on the TOLA model. Table 3-4 provides concrete section properties assuming all sections are cracked.

Table 3-3. Best-Estimate Concrete Properties, 250°F

Cracked Y/N	Eshl (psi)	Shell Thickness t-shl (ksf)	(in.)	Shell Density, Rho-shl (ft)	(lb/in ³)	M&D Section (lb/ft ³)	No.	PNNL Section No.
N	4.502E+06	648,297	15.35	1.28	0.08484	147		1
N	4.352E+06	626,754	15.18	1.26	0.08578	148	1	2
N	4.306E+06	620,114	15.12	1.26	0.08609	149	2	3
N	4.282E+06	616,594	15.09	1.26	0.08627	149	3	4
N	4.262E+06	613,774	15.15	1.26	0.08595	149		5
N	4.243E+06	610,922	15.13	1.26	0.08609	149	4	6
N	4.315E+06	621,305	15.21	1.27	0.08559	148	5	7
N	4.295E+06	618,475	15.19	1.27	0.08572	148		8
N	4.216E+06	607,093	15.17	1.26	0.08583	148	6	9
N	4.201E+06	604,939	15.15	1.26	0.08594	148		10
N	4.439E+06	639,237	15.39	1.28	0.08463	146	7	11
N	4.425E+06	637,265	15.34	1.28	0.08487	147		12
N	4.405E+06	634,338	15.32	1.28	0.08497	147	8	13
N	4.392E+06	632,441	15.31	1.28	0.08504	147		14
N	4.316E+06	621,503	15.30	1.28	0.08510	147		15
N	4.406E+06	634,531	19.32	1.61	0.08499	147		16
N	4.366E+06	628,756	20.73	1.73	0.08505	147	9	17
N	4.323E+06	622,528	22.99	1.92	0.08527	147		18
Y	1.655E+06	238,350	26.72	2.23	0.08302	143		19
Y	1.345E+06	193,677	26.78	2.23	0.09548	165	10	20
N	4.000E+06	575,959	37.86	3.15	0.08337	144	11	21
N	3.960E+06	570,283	30.93	2.58	0.08339	144		22
Y	1.264E+06	182,025	21.60	1.80	0.09052	156		23
Y	1.409E+06	202,953	18.00	1.50	0.09197	159	12	24
Y	1.120E+06	161,221	15.28	1.27	0.10227	177		25
Y	1.093E+06	157,426	15.36	1.28	0.10170	176	13	26
Y	1.076E+06	155,010	15.42	1.28	0.10133	175		27
Y	1.068E+06	153,784	14.00	1.17	0.11163	193		28
Y	1.068E+06	153,784	14.00	1.17	0.11163	193		29
Y	1.068E+06	153,784	14.00	1.17	0.11163	193	14	30
Y	9.490E+05	136,651	13.53	1.13	0.11552	200		31
Y	9.490E+05	136,651	13.53	1.13	0.11552	200		32
Y	9.490E+05	136,651	13.53	1.13	0.11552	200	15	33
Y	9.490E+05	136,651	13.53	1.13	0.11552	200		34
Y	9.490E+05	136,651	13.53	1.13	0.11552	200	16	35
Y	9.490E+05	136,651	13.53	1.13	0.11552	200		36
Y	9.490E+05	136,651	13.53	1.13	0.11552	200		37
N	9.589E+05	138,084	14.89	1.24	0.10496	181	17	38
N	3.467E+06	499,310	18.08	1.51	0.08644	149		39
Y	3.435E+06	494,646	18.06	1.50	0.08652	150		40
Y	8.568E+05	123,378	12.89	1.07	0.12123	209	18	41
Y	8.568E+05	123,378	12.89	1.07	0.12123	209		42
Y	8.655E+05	124,633	14.21	1.18	0.10997	190	19	43
Y	8.655E+05	124,633	14.21	1.18	0.10997	190		44
Y	8.568E+05	123,378	12.89	1.07	0.12123	209		45
Y	8.638E+05	124,388	12.86	1.07	0.12149	210	20	46
Y	8.871E+05	127,746	14.12	1.18	0.11067	191		47
N	3.810E+06	548,683	23.64	1.97	0.09606	166	21	48
N	3.764E+06	542,010	23.65	1.97	0.09604	166		49
Y	1.038E+06	149,405	20.05	1.67	0.10680	185		50
Y	1.054E+06	151,733	20.06	1.67	0.10674	184		51
Y	1.075E+06	154,870	20.12	1.68	0.10643	184	22	52
Y	7.157E+05	103,055	14.04	1.17	0.13627	235		53

Table 3-3. (contd)

Cracked Y/N	Eshl	Shell Thickness t-shl		Shell Density, Rho-shl		M&D Section		PNNL Section
	(psi)	(ksf)	(in.)	(ft)	(lb/in ³)	(lb/ft ³)	No.	No.
N	3.571E+06	514,287	17.19	1.43	0.09959	172	23	54
N	3.570E+06	514,043	13.20	1.10	0.10383	179		55
Y	1.140E+06	164,113	6.14	0.51	0.16690	288	24	56
N	3.632E+06	522,946	7.94	0.66	0.11656	201	25	57
Y	1.349E+06	194,254	4.96	0.41	0.18649	322	26	58
Y	1.387E+06	199,783	7.02	0.58	0.16289	281	27	59
Y	1.129E+06	162,553	6.61	0.55	0.17280	299	28	60
Y	1.393E+06	200,531	5.01	0.42	0.22800	394	29	61
Y	1.163E+06	167,538	4.81	0.40	0.23765	411	30	62
Y	8.719E+05	125,560	12.28	1.02	0.14557	252		63

Table 3-4. Fully Cracked Concrete Properites

Is Section Cracked?	Eshl		Shell Thickness t-shl		Shell Density, Rho-shl		M&D Section	PNNL Section
	(psi)	(ksf)	(in.)	(ft)	(lb/in ³)	(lb/ft ³)	No.	No.
Y	1.435E+06	206,708	14.64	1.22	0.08893	154		1
Y	1.084E+06	156,131	13.21	1.10	0.09854	170	1	2
Y	9.438E+05	135,907	12.40	1.03	0.10504	182	2	3
Y	8.552E+05	123,148	11.78	0.98	0.11053	191	3	4
Y	9.951E+05	143,289	12.81	1.07	0.10168	176		5
Y	9.318E+05	134,181	12.41	1.03	0.10491	181	4	6
Y	1.141E+06	164,239	13.58	1.13	0.09590	166	5	7
Y	1.089E+06	156,781	13.32	1.11	0.09774	169		8
Y	1.029E+06	148,115	13.08	1.09	0.09951	172	6	9
Y	9.768E+05	140,657	12.53	1.04	0.10391	180		10
Y	1.512E+06	217,769	14.64	1.22	0.08897	154	7	11
Y	1.482E+06	213,340	14.39	1.20	0.09048	156		12
Y	1.443E+06	207,751	14.28	1.19	0.09119	158	8	13
Y	1.417E+06	204,062	14.20	1.18	0.09168	158		14
Y	1.371E+06	197,485	14.12	1.18	0.09219	159		15
Y	1.544E+06	222,339	18.42	1.53	0.08916	154		16
Y	1.474E+06	212,206	19.67	1.64	0.08962	155	9	17
Y	1.394E+06	200,772	21.66	1.81	0.09047	156		18
Y	1.531E+06	220,469	27.13	2.26	0.08177	141		19
Y	1.240E+06	178,532	27.37	2.28	0.09343	161	10	20
Y	1.046E+06	150,644	34.88	2.91	0.09050	156	11	21
Y	1.270E+06	182,924	32.31	2.69	0.07982	138		22
Y	1.163E+06	167,483	22.03	1.84	0.08873	153		23
Y	1.302E+06	187,438	18.31	1.53	0.09041	156	12	24
Y	1.028E+06	147,988	15.59	1.30	0.10025	173		25
Y	1.004E+06	144,559	15.67	1.31	0.09972	172	13	26
Y	9.887E+05	142,377	15.72	1.31	0.09937	172		27
Y	9.808E+05	141,234	14.29	1.19	0.10936	189		28
Y	9.808E+05	141,234	14.29	1.19	0.10936	189		29
Y	9.808E+05	141,234	14.29	1.19	0.10936	189	14	30
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		31
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		32
Y	8.690E+05	125,131	13.83	1.15	0.11297	195	15	33

Table 3-4. (contd)

Is Section Cracked?	Eshl		Shell Thickness t-shl		Shell Density, Rho-shl		M&D Section	PNNL Section
	(psi)	(ksf)	(in.)	(ft)	(lb/in ³)	(lb/ft ³)	No.	No.
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		34
Y	8.690E+05	125,131	13.83	1.15	0.11297	195	16	35
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		36
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		37
Y	8.782E+05	126,463	15.21	1.27	0.10273	178	17	38
Y	8.690E+05	125,131	13.83	1.15	0.11297	195		39
Y	7.828E+05	112,717	13.20	1.10	0.11839	205		40
Y	7.828E+05	112,717	13.20	1.10	0.11839	205	18	41
Y	7.828E+05	112,717	13.20	1.10	0.11839	205		42
Y	7.908E+05	113,881	14.54	1.21	0.10747	186	19	43
Y	7.908E+05	113,881	14.54	1.21	0.10747	186		44
Y	7.828E+05	112,717	13.20	1.10	0.11839	205		45
Y	7.891E+05	113,629	13.17	1.10	0.11864	205	20	46
Y	8.104E+05	116,693	14.45	1.20	0.10813	187		47
Y	9.322E+05	134,235	21.54	1.79	0.10546	182	21	48
Y	9.324E+05	134,263	21.66	1.80	0.10488	181		49
Y	9.504E+05	136,857	20.46	1.71	0.10463	181		50
Y	9.659E+05	139,096	20.46	1.71	0.10465	181		51
Y	9.861E+05	141,998	20.52	1.71	0.10436	180	22	52
Y	6.510E+05	93,743	14.43	1.20	0.13263	229		53
Y	7.229E+05	104,097	14.13	1.18	0.12109	209	24	54
Y	8.420E+05	121,245	11.21	0.93	0.12227	211		55
Y	1.048E+06	150,866	6.25	0.52	0.16372	283	24	56
Y	1.147E+06	165,097	4.93	0.41	0.18777	324	25	57
Y	1.246E+06	179,441	5.05	0.42	0.18346	317	26	58
Y	1.283E+06	184,804	7.11	0.59	0.16072	278	27	59
Y	1.038E+06	149,438	6.73	0.56	0.16977	293	28	60
Y	1.288E+06	185,420	5.09	0.42	0.22441	388	29	61
Y	1.070E+06	154,101	4.90	0.41	0.23326	403	30	62
Y	7.964E+05	114,687	12.57	1.05	0.14218	246		63

Input file "Tank-Mesh1.txt" develops the concrete tank model. Element type SHELL143 is used for the concrete tank to be able to extract through-wall shear forces.

Figures 3-3 and 3-4 show the profile and full concrete tank model, respectively.

Figure 3-3. Concrete Tank Profile, Including Shell Thickness

Figure 3-4. Concrete Tank Model Detail

3.2.3 Primary Tank

The geometry of the primary tank is based on drawing H-2-90534. To ensure that the anchor bolt elements are perpendicular to the primary tank, the primary tank dome coordinates were calculated based on the location of the corresponding concrete tank coordinate, taking into account the concrete shell thickness, and normal to the primary tank (see Figure 3-5). The concrete shell thickness used is based on the nominal concrete thickness.

Figure 3-5. Primary/Concrete Tank Node Geometry

The location of the primary tank nodes were iteratively determined as follows:

Select a value for x (radial distance from center of the tank).

Calculate the respective location for y' based on the defined shape of the primary tank. The primary tank is an ellipse with a major axis of 80 feet and minor axis of 30 feet. The equation for location of y' is as follows:

$$y' = a\sqrt{1 - \frac{x^2}{b^2}} - a, \text{ where} \quad (3.1)$$

$a = \text{Minor Radius} = 180 \text{ in}$

$b = \text{Major Radius} = 480 \text{ in}$

$x = \text{Test Location for } x$

$$\text{For } x = 61.0398, y' = 180\sqrt{1 - \frac{61.0398^2}{480^2}} - 180 = -1.46 \quad (3.2)$$

The slope of the ellipse can be calculated by taking the derivative of the equation for y' .

$$\frac{d}{dx} \left(a\sqrt{1 - \frac{x^2}{b^2}} \right) = -\frac{x \frac{a}{b}}{\sqrt{b^2 - x^2}} \quad (3.3)$$

For $x = 61.0398$, the slope of the ellipse is -0.048 . The corresponding angle is the arctangent of the slope, or in this case, -0.048 . The length of line connecting the centerline of the concrete to the primary tank is half the thickness of the tank at that point. Therefore, to check the accuracy of the assumed x location of the primary tank, back-calculate the location of the concrete coordinates. If the back-calculated concrete location is the same as the known location, the x location of the primary tank must be correct, otherwise, reselect x until it is correct. The primary tank dome coordinate calculations are summarized in Table 3-5.

Following the example, for concrete location of (60.4), the x location of the primary tank is 61.0398. y' was determined to be -1.46. Adjusting this to value for the vertical location of the center of the ellipse, add 561.45 (elevation of the primary tank at the apex). For this case, $y=559.99$. The check is as follows:

$$X_{conc} = X_{primary} + \frac{t}{2} \sin(\theta), \text{ where } \theta \text{ is the angle of the slope from horizontal} \quad (3.4)$$

$$X_{conc} = 61.0398 + \frac{15}{2} \sin(0.048) = 61.39966 \approx 61.4 \quad (3.5)$$

$$Y_{conc} = Y_{primary} + \frac{t}{2} \cos(\theta) = 559.99 + \frac{15}{2} \cos(0.048) = 567.48136 \approx 567.5 \quad (3.6)$$

Table 3-5. Primary Tank Dome Coordination Calculation

Concrete				Primary Tank							
X	y	T	Error	x	y	y'	Slope	Angle (rad)	Angle (Deg)	Y Offset	X Offset
0	568.95	15	0%	0	561.45	0.00	0.000	0.000	0.000	7.500	0.000
30.2	568.6	15	0%	30.0238	561.10	-0.35	-0.024	-0.023	-1.346	7.498	-0.176
45	568.2	15	0%	44.7369	560.67	-0.78	-0.035	-0.035	-2.010	7.495	-0.263
61.4	567.5	15	0%	61.0398	559.99	-1.46	-0.048	-0.048	-2.753	7.491	-0.360
120.72	563.21	15	0%	119.9972	555.73	-5.72	-0.097	-0.097	-5.530	7.465	-0.723
152.9	559.7	15	0%	151.9685	552.19	-9.26	-0.125	-0.125	-7.134	7.442	-0.931
211.4	550.7	15	0%	210.0535	543.30	-18.15	-0.183	-0.181	-10.343	7.378	-1.347
239.1	545.2	15	0%	237.5336	537.86	-23.59	-0.214	-0.210	-12.055	7.335	-1.566
306.63	527.68	15	0%	304.4248	520.62	-40.83	-0.308	-0.298	-17.099	7.169	-2.205
335.6	518.2	15	0%	333.0513	511.07	-50.38	-0.361	-0.347	-19.866	7.054	-2.549
393.7	494.5	15	0%	390.2214	486.27	-75.18	-0.524	-0.482	-27.633	6.645	-3.479
428.7	476.2	22.58	0%	422.2643	467.04	-94.41	-0.694	-0.607	-34.752	9.276	-6.436
				432	459.91	-101.54	-0.774	-0.659	-37.750	0.000	0.000
				440	453.39	-108.06	-0.860	-0.710	-40.700	0.000	0.000
A	180										
B	480										

Element thicknesses are based on the drawing H-2-90534 but reduced by 0.06 inches for the corrosion allowance (see Section 2.2.4). General steel properties are used and are as follows:

Elastic Modulus (E) = 4,176,000 kip/ft²

Poisson's Ratio (ν) = 0.30

Mass Density (ρ) = 0.001522 kip-sec²/ft⁴ = (0.490 kip/ft³)/(32.2 ft/sec²)

Damping = 2%

Tank coordinates are developed in the model from input file "Tank-Coordinates-AY.txt." Tank element properties are from input file "Primary-Props-AY." The tank mesh is generated using "Primary.txt" and uses SHELL143 elements.

Figure 3-6 shows the full primary tank model and Figure 3-7 shows the detail in the knuckle region at the bottom of the tank.

Figure 3-6. Primary Tank Model Detail

Figure 3-7. Primary Tank Model Detail – Knuckle Region

3.2.4 Insulating Concrete

The insulating concrete uses the geometry defined for the concrete and primary tanks and fills in the open volume with solid element (SOLID45). Concrete properties are taken as follows Rinker et al. (2004).

Elastic Modulus (E) = 23,760 kip/ft²

Poisson's Ratio (ν) = 0.15

Mass Density (ρ) = 0.00155 kip-sec²/ft⁴ = (0.050 kip/ft³)/(32.2 ft/sec²)

Damping = 7%

Material properties for the insulating concrete are in the file "Tank-Props-BEC-250.txt." The element mesh is generated using "Insulate.txt." Figure 3-8 shows the insulating concrete elements.

Figure 3-8. Insulating Concrete Model Detail

3.2.5 Anchor Bolts

The anchor bolts connecting the primary tank to the concrete shell are modeled using beam elements (BEAM4) and spring elements (COMBIN14). Based on drawing H-2-64310 the anchor bolts are spaced on an average of 2 ft in each direction. Therefore, the contributing area of the bolts in the model is based on the number of 4 ft² areas associated with the element. The required area is calculated based on the number of bolts to be represented and the thickness of the concrete at the bolt location.

Table 3-6. Anchor Bolt Area Calculation

Ring No.	1	2	3	4	5	6	7	8	9	10	11
x	0.00	44.72	89.87	120.00	151.97	210.05	237.53	304.42	333.05	390.22	422.26
y	561.45	560.77	558.37	555.83	552.29	543.40	537.96	520.72	511.17	486.37	467.14
	0.00	0.68	3.08	5.62	9.16	18.05	23.49	40.73	50.28	75.08	94.31
Delta Y	0.00	0.68	2.40	2.53	3.54	8.89	5.43	17.25	9.55	24.80	19.23
x'	0.00	44.72	89.92	120.13	152.24	210.83	238.69	307.14	336.83	397.38	432.67
x''	0.00	44.72	89.93	120.17	152.34	211.10	239.11	308.19	338.37	400.69	438.06
Horizontal midpoint	22.36	67.33	105.05	136.26	181.72	225.11	273.65	323.28	369.53	419.37	443.88
Ring area	785.52	6335.32	10214.81	11827.27	22708.34	27726.13	38033.10	46534.03	50329.54	61766.66	41420.22
Number of bolts in ring	1.36	11.00	17.73	20.53	39.42	48.14	66.03	80.79	87.38	107.23	71.91
Bolts per element (20 sections)	1.36	0.55	0.89	1.03	1.97	2.41	3.30	4.04	4.37	5.36	3.60

The BEAM4 elements are modeled as essentially rigid, and are oriented normal to the tank dome. Attached to the base of each beam element are three orthogonal springs oriented in the directions of the global coordinate system. Because the beams are rigid, the springs define the response of the anchor bolts in the model.

The stiffness of a single anchor bolt was set to 780 kip/ft (65,000 lbf/in.) in all three directions. This formulation will underestimate the axial stiffness of an anchor bolt and thus conservatively overestimate the total deformation of the bolt. Not only does this modeling assumption err on the conservative side, but the axial response of the anchor bolts in the seismic model is essentially inconsequential when combined with the results of the TOLA model.

The anchor bolt model is developed using input file "Bolt-Friction.txt." See Figure 3-9 for the distribution of anchor bolts. Figure 3-10 shows the locations of spring elements connecting the end of each anchor bolt to the primary tank.

3.2.6 Secondary Liner

The secondary liner is modeled using SHELL143 elements and its geometry is taken from H-2-90534. The steel thickness is 0.375 inch in the floor transitioning to 0.5625 inch in the knuckle and 0.5 inch in the lower wall. The model stops after the 1st full wall element coincident with the liner. The secondary liner is shown in Figure 3-11.

Input file "Liner.txt" develops the model for the liner using the geometry defined for the concrete tank in "Tank-Coordinates.txt." The following material properties are used for the steel liner.

Elastic Modulus (E) = 4,176,000 kip/ft²

Poisson's Ratio (ν) = 0.30

Mass Density (ρ) = 0.001522 kip-sec²/ft⁴ = (0.490 kip/ft³)/(32.2 ft/sec²)

Damping = 2%

Figure 3-9. Anchor Bolt Model Detail

Figure 3-10. Spring Elements – Anchor Bolts to Primary Tank

Figure 3-11. Secondary Liner Model Detail

3.2.7 Waste

The waste is modeled using solid elements (SOLID45) with material properties defined to emulate a liquid. The waste elements are meshed such that there are no common nodes with the primary tank; however, those on the exterior (at the primary tank) are coincident with the primary tank nodes. Contact elements are used for the interface between the waste and the primary tank. The material properties are as follows:

Elastic Modulus (E) = 25.92 kip/ft²

Poisson's Ratio (ν) = 0.4999

Mass Density (ρ) = 0.003294 kip-sec²/ft⁴ = (1.7*0.0624 kip/ft³)/(32.2 ft/sec²)

Damping = 0

Shear Modulus (G) = 0.216 kip/ft²

The elastic modulus, E was calculated based on the Bulk Modulus of water (~300,000 psi). Using a value of ν close to 0.5 (0.49999), the value of E can be calculated.

$$B = E/[3(1 - 2\nu)] \text{ or} \quad (3.10)$$

$$E = B[3(1 - 2\nu)] = 300,000[3(1 - 2(0.49999))] = 18\text{lb/in}^2 = 2.592\text{kip/ft}^2 \quad (3.11)$$

The shear modulus, G can then be calculated based on E and ν , $G=E/[2(1+\nu)]$. For the values shown above, this gives a value for G of 0.864 kip/ft². However, because a fluid cannot carry shear, a smaller value is used. The value was selected such that the solution remains mathematically stable.

Figure 3-12 shows the waste elements.

Figure 3-12. Waste Model Detail

Two benchmarking studies were performed to assess the fluid-structure interaction behavior of the primary tank and contained waste under seismic excitation. In the study documented in Rinker et al. (2006b), the fluid-structure interaction was simulated in ANSYS®. In the studies documented in Rinker and Abatt (2006a, 2006b), the fluid-structure interaction was simulated using MSC.Dytran®¹ (Dytran®). The studies showed that the modeling approach used in ANSYS® adequately predicts the total hydrodynamic reaction force and pressure distribution both vertically and circumferentially, but that the model was deficient in predicting the convective response of the waste.

The fundamental difference between the current increased liquid level analysis and the earlier analysis at the baseline liquid level of 422 inches (Rinker et al. 2006c) is increased interaction between the contained waste and the curved dome area of the primary tank (see Figure 3-13). Thus, the stresses induced by the interaction of the liquid and the dome are of particular concern. The results from the Dytran® sub-model analysis are compared to the results of a similar ANSYS® sub-model of a primary tank, as well as to the results from the global ANSYS® models in the Increased Liquid Level Seismic report (Abatt and Rinker 2008).

3.2.8 Primary Tank/Concrete Dome Interface

A combination of TARGET170 and CONTA173 elements are used to model the interface between the top of the primary tank and the inside face of the concrete dome. Key-Option controls are used to place the interface location at the inside face of the concrete (or bottom of the concrete shell element). A coefficient of friction of 0.01 was used for the contact surface. The low friction value results in the anchor bolts being the primary load path for shear between the primary tank and the dome. A small value is used instead of zero to improve model solution stability.

¹ Dytran is a registered trademark of MSC Software Corporation, Santa Ana, California.

Figure 3-13. Waste Model Detail, Interface with Tank Dome

The contact surface is developed using input file “bolt-friction.txt.” Figure 3-14 shows the contact and target elements comprising the dome contact surface.

Figure 3-14. Contact Elements – Primary Tank to Concrete Dome

3.2.9 Primary Tank/Insulating Concrete Interface

A combination of TARGET170 and CONTA173 elements are used to model the interface between the bottom of the primary tank and the top of the insulating concrete. The contact and target surfaces are modeled as coincident (i.e., no offsets are included for shell thicknesses). A coefficient of friction of 0.4 was used for the contact surface. The contact surface is developed using input file “interface1.txt.” Figure 3-15 shows the contact elements (top layer of elements).

3.2.10 Insulating Concrete/Secondary Liner Interface

A combination of TARGE170 and CONTA173 elements are used to model the interface between the bottom of the primary tank and the top of the insulating concrete. The contact and target surfaces are modeled as coincident (i.e., no offsets are included for shell thicknesses). A coefficient of friction of 0.4 was used for the contact surface. The contact surface is developed using input file "interface1.txt." Figure 3-15 shows the contact elements (bottom layer of elements).

3.2.11 Soil/Concrete Tank Interface

A combination of TARGE170 and CONTA173 elements are used to model the interface between the soil and the concrete tank, and for the interface plane between the native and excavated soils. A coefficient of friction of 0.2 was used for the contact surface between the soil and the concrete tank during the gravity loading solution phase (static case) to realistically simulate the distribution of geostatic loads. The friction coefficient was then increased to 0.6 for the transient portion of the solution to simulate the dynamic frictional response at this interface. Rinker et al. (2006c) describes the soil friction model in complete detail. See Figure 3-16 for the contact surface model.

For the interface between the bottom of the footing and the native soil, COMBIN14 (spring) elements were used. Arbitrary high stiffness values were applied to these springs because the flexibility at the interface is already included in the material properties for the concrete and soil. See Figure 3-17 for the location of the interface springs.

Figure 3-15. Contact Elements –Insulating Concrete Top and Bottom

Figure 3-16. Contact Elements – Soil to Concrete Tank

Figure 3-17. Spring Elements – Concrete Footing to Soil

3.2.12 Excavated/Native Soil Interface

A combination of TARGE170 and CONTA173 elements are used to model the interface between the native and excavated soils. An initial coefficient of friction of 0.3 is used for the gravity (static) analysis. The coefficient of friction is changed to 0.7 for the transient analysis. This surface is included to improve the initial conditions for the transient analysis by allowing an initial displacement between the native and excavated soil but located far enough away that it does not have a significant effect on the tank behavior. Figure 3-18 shows the contact elements constituting the soil interface.

This surface is developed using the input file “fix-soil.txt”

Figure 3-18. Contact Elements – Near Soil to Far Soil

3.2.13 Waste/Primary Tank Interface

A combination of TARGE170 and CONTA173 elements are used to model the interface between waste and primary tank. No friction is included for this surface. A high stiffness was defined for this contact to obtain the correct hydrostatic pressure on the tank. The high stiffness of the contact was needed because the waste model was very soft. Excessive displacements occur without modifying the contact stiffness. The contact surface is divided into multiple zones to enhance the performance of the contacts. This approach captures more realistic waste pressures in areas of higher curvature (dome and knuckle regions). The contact surface is developed using input file “Waste-Soild-AY.txt.” The interface between the waste and primary tank is shown in Figure 3-19.

Figure 3-19. Contact Elements – Waste to Primary Tank

3.2.14 Concrete Wall/Footing Interface

The contact at the bottom of the wall was modeled using CONTA178 elements. A friction coefficient of 0.2 was used for this contact to reflect the steel on steel interface. Use of contact elements for this interface will be used to determine if displacement can occur during a seismic event. The contact elements allow only normal and shear forces (no moments) to be transferred to the footing. The contact between the bottom of the wall and the footing is shown in Figure 3-20.

Figure 3-20. Contact Elements – Concrete Wall to Footing

3.2.15 Surface Loads

MASS21 elements were added to the soil surface over the center of the dome to create a “live load” over the tank dome. The mass provides an equivalent weight of 200,000 lbf. Mass elements were used in lieu of forces to capture the dynamic participation of equipment that creates this load. Figure 3-21 illustrates the placement of the mass elements.

Figure 3-21. Mass Elements – Soil Surface

3.3 Soil Model

This section describes the geometry and construction of the ANSYS® finite element model of the soil surrounding the DST. A comprehensive description of the FE model is found in the Seismic Analysis report (Rinker et al. 2006c). The Seismic Analysis report should be referenced for complete model description and background information.

3.3.1 Soil Properties

The soil surrounding the tank is modeled in two groups, the excavated soil, and the far-field soil. The excavated soil fills the volume outside the concrete tank and bounded by the slope matching the soil removed during construction. The far-field soil is comprised of all other soil out to a radius of 320 feet and a depth of 266 feet. Both regions are modeled using SOLID45 elements.

Two SHAKE analyses were performed for each soil condition to obtain soil properties for the layering used in the model (Rinker et al. 2006a). One run used the native soil properties and is used for the far-field soil material properties. The second run used material properties associated with structural backfill and the results are used for the material properties in the excavated soil region.

Soil properties used for the model are listed in Tables 3-7 through 3-12.

Table 3-7. Best-Estimate Native Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.017	6622.3	0.24	16,423	110	901
9.2	0.025	6241.7	0.24	15,479	110	902
16.4	0.034	5839.1	0.24	14,481	110	903
22.1	0.028	5930.4	0.24	14,707	110	904
29	0.032	5724.9	0.19	13,625	110	905
37.2	0.033	6494.2	0.19	15,456	110	906
44.7	0.033	7366.4	0.19	17,532	110	907
52.9	0.025	8811.9	0.19	20,972	110	908
65.5	0.026	9851.5	0.19	23,447	110	909
82	0.027	9721.9	0.19	23,138	110	910
98.8	0.029	9560.1	0.19	22,753	110	911
115.5	0.033	9272.5	0.19	22,069	110	912
132	0.025	10,831.8	0.19	25,780	110	913
148.3	0.027	10,644	0.19	25,333	110	914
167.5	0.022	13,867.4	0.28	35,501	120	915
189.5	0.021	15,416	0.28	39,465	120	916
211.5	0.023	15,064.3	0.28	38,565	120	917
233.5	0.025	14,732.5	0.28	37,715	120	918
255.5	0.024	16,209.2	0.28	41,496	120	919

Table 3-8. Best-Estimate Excavated Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.019	3920.4	0.27	9958	125	801
9.2	0.035	3463.4	0.27	8797	125	802
16.4	0.048	3088.5	0.27	7845	125	803
22.1	0.039	3231.8	0.27	8209	125	804
29	0.048	3005.6	0.27	7634	125	805
37.2	0.055	2829.8	0.27	7188	125	806
44.7	0.059	2729.6	0.27	6933	125	807
52.9	0.045	3018.4	0.27	7667	125	808

Table 3-9. Upper Bound Native Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.016	10,004.3	0.24	24,811	110	901
9.2	0.022	9607.3	0.24	23,826	110	902
16.4	0.027	9268.4	0.24	22,986	110	903
22.1	0.022	9383.3	0.24	23,271	110	904
29	0.026	9068.8	0.19	21,584	110	905
37.2	0.027	10,289.2	0.19	24,488	110	906
44.7	0.028	11,649.1	0.19	27,725	110	907
52.9	0.022	13,709.7	0.19	32,629	110	908
65.5	0.022	15,284.2	0.19	36,376	110	909
82	0.024	15,035.4	0.19	35,784	110	910
98.8	0.025	14,863.1	0.19	35,374	110	911
115.5	0.026	14,746.3	0.19	35,096	110	912
132	0.02	16,982.4	0.19	40,418	110	913
148.3	0.021	16,838.8	0.19	40,076	110	914
167.5	0.019	21,821.5	0.28	55,863	120	915
189.5	0.019	23,910.6	0.28	61,211	120	916
211.5	0.02	23,673.5	0.28	60,604	120	917
233.5	0.02	23,525	0.28	60,224	120	918
255.5	0.019	25,917.8	0.28	66,350	120	919

Table 3-10. Upper Bound Excavated Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.017	5956.9	0.27	15,131	125	801
9.2	0.027	5554.3	0.27	14,108	125	802
16.4	0.039	5041.9	0.27	12,806	125	803
22.1	0.031	5191.5	0.27	13,186	125	804
29	0.035	5005.7	0.27	12,714	125	805
37.2	0.042	4747.8	0.27	12,059	125	806
44.7	0.047	4551.9	0.27	11,562	125	807
52.9	0.037	4864.9	0.27	12,357	125	808

Table 3-11. Lower Bound Native Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.018	4382.9	0.24	10,870	110	901
9.2	0.03	4004	0.24	9,930	110	902
16.4	0.043	3590.3	0.24	8,904	110	903
22.1	0.034	3739.6	0.24	9,274	110	904
29	0.04	3551.3	0.19	8,452	110	905
37.2	0.042	4004.4	0.19	9,530	110	906
44.7	0.042	4561.5	0.19	10,856	110	907
52.9	0.03	5629.7	0.19	13,399	110	908
65.5	0.03	6331	0.19	15,068	110	909
82	0.035	6066.4	0.19	14,438	110	910
98.8	0.039	5831.4	0.19	13,879	110	911
115.5	0.043	5633.7	0.19	13,408	110	912
132	0.032	6786.7	0.19	16,152	110	913
148.3	0.032	6763.3	0.19	16,097	110	914
167.5	0.028	8619.5	0.28	22,066	120	915
189.5	0.028	9445.3	0.28	24,180	120	916
211.5	0.029	9314.8	0.28	23,846	120	917
233.5	0.029	9320.7	0.28	23,861	120	918
255.5	0.026	10588.1	0.28	27,106	120	919
279	0.014	29929.7	0.3	77,817	125	920
304	0.014	29856.3	0.3	77,626	125	921
329	0.015	29714.3	0.3	77,257	125	922
354	0.015	29602.2	0.3	76,966	125	923

Table 3-12. Lower Bound Excavated Soil Iterated Soil Properties

Layer Depth	Damping	G	Poisson's Ratio	E	Density	Material Property No.
2.5	0.023	2547.2	0.27	6,470	125	801
9.2	0.044	2126.7	0.27	5,402	125	802
16.4	0.066	1782.2	0.27	4,527	125	803
22.1	0.053	1910.9	0.27	4,854	125	804
29	0.061	1777	0.27	4,514	125	805
37.2	0.067	1689.3	0.27	4,291	125	806
44.7	0.07	1628.4	0.27	4,136	125	807
52.9	0.056	1815.9	0.27	4,612	125	808

3.3.2 Excavated Soil

The excavated soil portion of the soil is developed using the input file "Near-Soil-1.txt." Figures 3-22 through 3-24 show the detail of the excavated region of soil. Two zones in the soil above the dome are softened to break the potential arching that can occur in the soil model. This arching effect can occur because linear elastic properties are used for soil, which means that the soil as modeled can carry tension. The development of the softened regions of the soil over the tank dome is discussed in detail in the Seismic Analysis report (Rinker et al. 2006c).

Figure 3-22. Excavated Soil Model Detail

Figure 3-23. Excavated Soil – Softened Soil Zones

Figure 3-24. Model Detail

3.3.3 Native Soil

The native soil region of the model is developed using input file "Far-Soil.txt." SOLID45 elements are used and the material properties are discussed above. Figure 3-25 shows the native soil portion of the model.

Figure 3-25. Far-Field Soil Model Detail

LINK8 elements are used to connect the native soil slaved nodes on each layer to the symmetry plane. These are required because the slaved node of a couple cannot have a boundary condition applied to it. Therefore, to maintain the desired soil behavior, the link elements effectively complete the coupling of the outside soil node at each layer. Figure 3-26 shows the locations of the link elements. Input file "Outer-Spar.txt" develops these elements.

Figure 3-26. Link Elements – Edges of Soil Model

3.4 Boundary Conditions

This section describes the boundary conditions applied to the ANSYS® seismic finite element model. A comprehensive description of the FE model is found in the Seismic Analysis report (Rinker et al. 2006c). The Seismic Analysis report should be referenced for complete model description and background information.

3.4.1 Soil Boundary Conditions

All nodes on the outside edge (radius = 320 feet) have been “slaved” to a single node at each layer. Couples are used in each of the three translations to force the soil to behave essentially as a shear beam. This approach is used to create the appropriate conditions for vertical and horizontal waves to pass through the model (see Figures 3-28 and 3-29). The effectiveness of this approach is documented in Rinker et al. (2006a). All nodes on the bottom of the model (-266 ft) are coupled together to create a rigid foundation (see Figure 3-27). The symmetry plane for the soil has all nodes fixed for Y translation, see Figure 3-30.

Figure 3-27. Boundary Conditions – Soil Base

Figure 3-28. Boundary Conditions – Typical Soil Layer

Figure 3-29. Boundary Conditions – Slaved Boundary Conditions

Figure 3-30. Boundary Conditions – Symmetry Plane

3.4.2 Tank Boundary Conditions

The tank model has all nodes on the symmetry plane fixed to the Y translation, X rotation, and Z rotation (see Figures 3-31 and 3-32). Couples have been used between some components to ensure compatible

displacements occur. Where no common nodes exist between the concrete tank and secondary liner, couples are used to control the deformation of the secondary liner where it is in contact with the concrete tank. This ensures that the secondary liner does not “pass through” the concrete on the footing and on the walls (see Figure 3-33).

Figure 3-31. Boundary Conditions – Concrete Tank

Figure 3-32. Boundary Conditions – Primary Tank

Figure 3-33. Boundary Conditions – Secondary Liner

3.5 Seismic Input

The seismic analysis of the DSTs requires appropriate acceleration time-history records representing the required seismic excitation. Time history records must be available for both the horizontal and vertical directions. Typically, the required seismic input is specified in terms of design spectra. If time-histories are required, such time histories are often synthesized numerically subject to certain requirements related to the proper representation of the design spectra (ASCE 1998; NUREG-0800). The time-history records used in this analysis of the DSTs were existing time-histories that were used on the Hanford Waste Treatment Project (WTP). The justification for the use of existing time-histories is presented below.

The Hanford Tank Farms Documented Safety Analysis or DSA (Tomaszewski 2004) designates the DSTs as Performance Category 2 (PC-2) structures. DOE-STD-1020-2002, Section 2, states that the ground motions for PC-2 shall be developed following IBC (2000), in which the surface response spectra are specified to be 2/3 of the Maximum Considered Earthquake (MCE) ground motions. The MCE ground motions are defined as the ground motions with a mean annual frequency of exceedance of 4×10^{-4} (2% probability of exceedance in 50 years). The MCE motions may be defined based on either the USGS National Hazard Mapping results, adjusted for the appropriate site classification, or from a site-specific Probabilistic Seismic Hazard Analysis (PSHA). If the MCE response spectrum is to be defined from a site-specific PSHA, it cannot be less than 80% of the spectrum defined from the USGS National Hazard Mapping results. The PC-2 ground motions used in the DST analysis are based on a site-specific PSHA. The detailed development of the PC-2 spectra for the DST Farms is documented in Rinker and Youngs (2006).

Acceleration time-histories for two horizontal components and one vertical component of seismic motion were synthesized for the seismic design and evaluation of the Hanford Site WTP (BNFL 2000). The horizontal design spectrum for the WTP is anchored at 0.257g (peak ground acceleration (PGA)), and the vertical design spectrum is anchored at 0.175g PGA. The time-histories generated to match the WTP design spectra were previously used by M&D in the preliminary soil-structure interaction analysis of the WTP high-level waste and pretreatment facilities, and were readily available (M&D 2001a; 2001b).

The Hanford Double-Shell Tank Farms horizontal design spectrum for 5% spectral damping is shown in Figure 3-34. Also shown in Figure 3-35 are the horizontal control motion spectra for the WTP project. All reference or control motions are defined at the soil surface. Similar plots for the vertical direction are shown in Figure 3-35.

The relationships between the design spectra and the control motion response spectra show that it is acceptable to use the acceleration time-histories from the WTP for the analysis of the DSTs.

Figure 3-34. Comparison of Horizontal Surface Spectra at 5% Spectral Damping

Figure 3-35. Comparison of Vertical Surface Spectra at 5% Spectral Damping

Acceleration and displacement time histories for horizontal and vertical input are shown in Figures 3-36 and 3-37, respectively.

Figure 3-36. Horizontal and Vertical Surface Acceleration Time History

Figure 3-37. Horizontal and Vertical Surface Displacement Time History

3.6 Load Cases

Four separate load cases have been considered in this analysis. These cases are:

- Lower Bound Soil, Best-Estimate Concrete (LBS-BEC) Properties
- Best-Estimate Soil, Best-Estimate Concrete (BES-BEC) Properties
- Upper Bound Soil, Best-Estimate Concrete (UBS-BEC) Properties
- Best-Estimate Soil, Fully Cracked Concrete (BES-FCC) Properties

These four cases are intended to cover the most significant areas of uncertainty for response of the DSTs to seismic loading. The three variations in soil properties address the variability and uncertainty in soil properties. The fully cracked concrete case covers the additional uncertainty of expected concrete condition.

Each load case consists of two analyses. First a gravity case is analyzed. Results from the gravity only case will be used to determine the seismic only results from the non-linear transient analysis. The second analysis for each case is a non-linear time history analysis. Two input motions (horizontal and vertical) have been defined as acceleration time histories consisting of 2048 time steps. Acceleration time histories were developed for each of the three soil conditions at the -266-foot level.

3.6.1 Acceptance Criteria for Response Spectra

The following acceptance or screening criteria were applied to the tank foundation-level response spectra generated by the ANSYS® column model:

1. The envelope of the best-estimate, lower bound, and upper bound response spectra at the tank foundation level (-57.6 feet) should be at least 60% of the surface control motion. This criterion applies to both horizontal and vertical motion.
2. The envelope of the best-estimate, lower bound, and upper bound ANSYS® and Dytran® response spectra at the tank foundation level (-57.6 feet) should be at least 90% of the SHAKE response spectrum.
3. The envelope of the best-estimate, lower bound, and upper bound ANSYS® and Dytran® response spectra at the tank foundation level (-57 feet) should be greater than or equal to the SHAKE response spectrum over any $\pm 15\%$ bandwidth.

The above criteria should be met for both horizontal and vertical spectra. Additional criteria were evaluated for these input motions and response spectra. The additional criteria are discussed in Rinker et al. (2006a). The first condition is intended to minimize the dip that can occur in deconvolved response spectra at moderate depth at the frequency of the overlying soil column. Such a dip appears in the foundation level SHAKE spectrum shown in Figure 3-38 as well as in other plots.

The tests of the first criterion are shown graphically for both horizontal and vertical input as shown in Figures 3-38 and 3-39, respectively. The results indicate that the first condition is not met at all frequencies. Modifications to ensure that the condition is met will be discussed in Section 3.6.2.

Figure 3-38. Ratio of the ANSYS® Tank Foundation Level Spectra to the SHAKE Surface Spectrum for Horizontal Excitation

Figure 3-39. Envelope of the Ratio of the ANSYS® Tank Foundation-Level Spectra to the SHAKE Surface Spectrum for Vertical Excitation

3.6.2 Modification to ANSYS® Base Time Histories

Comparison of the ANSYS® soil column spectra at the tank foundation level to the SHAKE surface spectra for horizontal and vertical excitation (Figures 3-39 and 3-40) showed that the tank foundation spectra do not meet the first criterion. The envelope of the best-estimate, lower bound, and upper bound response spectra at the tank foundation level (-57.6 feet) should be at least 60% of the surface control motion. This applies to both horizontal and vertical motion. To ensure that the envelope of the tank foundation level spectra is at least 60% of the SHAKE surface spectrum, the horizontal lower and upper bound base time histories used as input to the ANSYS® soil column model were scaled up by factors of 1.175 and 1.12, respectively. The vertical lower and upper bound base time histories were scaled up by factors of 1.12 and 1.19, respectively. Comparisons of the tank foundation-level spectra to the SHAKE surface spectra for the modified base time histories are shown in Figures 3-40 and 3-41. Increasing the base time histories by the above factors results in the ratio of the tank foundation-level spectra to SHAKE surface spectra meeting the 60% criterion.

Figure 3-40. Ratio of the ANSYS® Tank Foundation Level Spectra to the SHAKE Surface Spectrum for Modified Horizontal Excitation

3.6.3 ANSYS® Base Acceleration Time Histories

Individual time histories are applied for each different soil condition. Lower Bound, Best-Estimate, and Upper Bound soil horizontal and vertical acceleration time histories are shown in Figures 3-42, 3-44, and 3-46, respectively. Lower Bound, Best-Estimate, and Upper Bound soil horizontal and vertical displacement time histories are shown in Figures 3-43, 3-45, and 3-47, respectively.

Figure 3-41. Envelope of the Ratio of the Tank Foundation Level Spectra to the Surface Spectra for Modified Vertical Excitation

Figure 3-42. Horizontal and Vertical Base Acceleration Time History, -266 feet, Lower Bound Soil

Figure 3-43. Horizontal and Vertical Base Displacement Time History, -266 feet, Lower Bound Soil

Figure 3-44. Horizontal and Vertical Base Acceleration Time History, -266 feet, Best-Estimate Soil

Figure 3-45. Horizontal and Vertical Base Displacement Time History, -266 feet, Best-Estimate Soil

Figure 3-46. Horizontal and Vertical Base Acceleration Time History, -266 feet, Upper Bound Soil

Figure 3-47. Horizontal and Vertical Base Displacement Time History, -266 feet, Upper Bound Soil

3.7 Model Excitation

An acceleration time history extracted from SHAKE at the -266-foot level is used for the excitation of the full model. A very large mass element is located at the bottom of the soil model (-266 feet) and a force is applied to that node. The force is the product of the point mass and the acceleration for that time step of the time history. The point mass used is greater than 100 times the mass of the full model to faithfully simulate the seismic excitation.

Intentionally left blank.

4.0 Model Reconciliation

The finite element models used in the TOLA and seismic analyses are significantly different. Reviewing the figure and model description in Chapters 2 and 3 readily demonstrates the dissimilarities (e.g., the TOLA model represents a 2.9° section of the tank and the seismic model represents a 180° section of the tank). The non-axisymmetric nature of the earthquake load requires the seismic model to encompass at least 180°. The acceleration time history used to represent the earthquake comprised 2048 load steps to achieve the 20.48 seconds of the transient analysis. Minimizing the model size was important in achieving a reasonable solution run time on the computer. Consequently, the element size is quite large in comparison to the TOLA model.

In contrast, the TOLA analysis has no inherent non-axisymmetric features. The 3-D model was made necessary only by the desire to use SOLID65 concrete element in ANSYS®. A refined mesh was implemented to obtain better resolution of stress throughout the model, particularly in the knuckle region.

The disparity between models required a mapping procedure in order to combine the TOLA and seismic results. This section summarizes the mapping for the different evaluations.

- Table 4-1 shows the element correlation for the ACI evaluation.
- Table 4-2 shows the element correlation for the ASME primary tank evaluation
- Table 4-3 shows the element correlation for the ASME concrete-backed liner evaluation. As shown in Figure 3-12, the secondary liner in the seismic model extended only across the floor and up to the second element in the tank wall. Consequently, seismic strain in the wall and haunch was taken from the concrete shell elements representing the wall. Strain in the dome was taken from the steel liner.
- Table 4-4 shows the correlation for the anchor bolts.

Table 4-1. Element Correlation for ACI Evaluation

Seismic Element #	R (in.)	Z (in. up)	TOLA Section #
7	22.5		
57	67.6998		2
77	105.5598		3
97	136.812		4
117	182.154		6
137	225.252		8
157	272.862		9
177	321.114		11
197	364.65		13
217	411.198		17
237	449.298		20
257	478.398	431.244	21
277	487.95	398.598	24
297	489	362.55	26
317	489	312	30
337	489	262.746	33
357	489	215.646	35
377	489	170.148	38
397	489	111.744	41
417	489	48.996	43
437	489	12	46
457	510		48
477	463.5		52
497	424.002		54
517	384		55
537	317.85		57
557	248.1		59
577	199.248		60
597	154.95		61
617	112.8		62
637	65.85		63

Table 4-2. Element Correlation for Primary Tank Evaluation

Seismic Element #		R (in.)	Z (in.)	TOLA Element #
762	dome	44.74	560.50	15276
782		89.87	558.32	15264
802		120.00	555.74	15303
822		151.97	552.26	15258
842		210.05	543.32	15247
862		237.53	537.87	15227
882		304.42	520.51	15211
902		333.05	511.15	15185
922	dome	390.22	487.86	15197
942	haunch	422.26	466.92	15180
962		432.00	460.00	15176
982		444.36	448.70	15172
1002	haunch	448.66	437.40	15168
1022	wall	450.00	426.13	15162
1042		450.00	402.13	15156
1062		450.00	378.13	15150
1082		450.00	354.13	15144
1102		450.00	329.88	15138
1122		450.00	306.78	15132
1142		450.00	283.68	15126
1162		450.00	260.58	15120
1182		450.00	237.38	15115
1202		450.00	214.28	15109
1222		450.00	191.18	15103
1242		450.00	168.08	15097
1262		450.00	144.88	15092
1282		450.00	123.28	15086
1302		450.00	101.68	15081
1322		450.00	80.08	15076
1342		450.00	58.48	15070
1362		450.00	37.00	15064
1382	wall	450.00	12.00	15061
1402	knuckle	446.49	3.51	15056
1422	knuckle	438.00	0.00	15050
1442	floor	423.00	0.00	15037
1462		400.00	0.00	15018
1482		340.00	0.00	15000
1502		280.00	0.00	14981
1522		220.00	0.00	14962
1542		160.00	0.00	14943
1562	floor	100.00	0.00	14927

Table 4-3. Element Correlation for Concrete-Backed Liner Evaluation

Seismic Element #		R (in.)	Z (in. up)	TOLA Element #
762	dome	68.02		15276
782		105.91		15264
802		136.01		15324
822		180.6		15303
842		224.26		15258
862		272.27		15247
882		318.015		15227
902		362.525		15211
922		405.475		15185
237		448.92		15804
257		471.63		15814
277		479.165		15798
297	wall	480	353.5	15912
317		480	302.5	15897
337		480	254.5	15877
357		480	206.5	15866
377		480	161.5	15851
397		480	107.5	15837
2062		480	41.5	15819
2052	wall	480	8.4125	15953
2042	knuckle	478.99	7.752	15785
2032	knuckle	472.555	1.752	15788
477	floor	448.5	0	15795
497		416.665		15654
517		378.355		15666
537		311.305		15687
557		244.255		15708
577		196.36		15723
597		151.66		15737
617		110.155		15750
637		65.4535		15764

Table 4-4. Element Correlation for Anchor Bolt Evaluation

Seismic J-Bolt	Seismic Radius	TOLA Radius	TOLA scale factor
Radius 4	120.0	107.5	4.465
Radius 5	152.0	167.6	2.864
Radius 6	210.1	208.5	2.302
Radius 7	237.5	243.3	1.973
Radius 8	304.4	300.5	1.597
Radius 9	333.1	325.2	1.476
Radius 10	390.2	391.7	1.225
Radius 11	422.3	413.4	1.161

5.0 Structural Acceptance Criteria

5.1 Introduction

This chapter describes the code-based acceptance criteria that are used to evaluate the AP tanks for the Increased Liquid Level Analysis. A complete description of the evaluation criteria is found in the Thermal and Operating Loads Analysis report (Rinker et al. 2004).

Day et al. (1995) provides a definitive summary of code-based structural acceptance criteria that govern the current and future uses of the Hanford DSTs. The document covers the primary objectives of any reevaluation of the existing waste storage tanks for continued operation or remediation, namely: 1) to show that the tank structures remain within code-based limits for the original design-based loads, 2) to evaluate if the actual service conditions or changes in requirements will exceed the design conditions, or 3) to evaluate current operating loads and future remediation activity loads.

The structural acceptance criteria document by Day et al. (1995) describes the tank designs, loads that must be sustained, potential failure modes, and the recommended approaches to protect against such failure. The application of code-based evaluation methods is discussed in detail. Alternate methods to the code-based approach are recommended to account for localized overstressing, load redistribution, and reduction in section capacities due to material degradation. Code reconciliation issues and material degradation under aging conditions also are addressed.

The purpose of this chapter is to identify a) the design and construction standards that were used for the double-shell tank designs, b) the allowable stresses for the steels and the minimum specified strengths of the concrete that were specified in the design, and c) the analysis methods that will be used to evaluate the structural adequacy of the AP tank design. Because Day et al. (1995) specifically identifies the recommended code-based methods for tank evaluation, they are not reproduced in this document.

5.2 Design and Construction Specifications for 241-AP Tanks

The 241-AP Tank Farm was constructed as part of Project B-340, 241-AP Tank Farm Project. For that project, the design and construction specifications list the standards that were used in the design and construction of the 241-AP tank farm. Specifications that are pertinent to the steel and concrete structure include:

- B-340-C4, Primary and Secondary Steel Tanks
- B-340-C3, Tank Foundations
- B-340-C5, Side Walls and Dome.

B-340-C4 documents that the 241-AP tanks were designed, fabricated, and inspected to the intent of the 1980 ASME Boiler and Pressure Vessel Code, Section VIII, Division 2. (Note: Although the ASME code standards were followed, the tanks were not registered as ASME vessels due to the non-standard nature of their design, use, and contents.) The steel plate used to construct the primary and secondary liners is specified as ASTM A537 Class 1 (ASTM 1965). Abatt (1996) lists the ASME S_m allowables that were specified for the pressure vessel steels for each of the DST designs (see Table 5-1).

B-340-C3 and B-340-C5 document that the 241-AP tanks were constructed to the 1977 ACI 318 building code requirements for reinforced concrete (ACI 1977). In addition, structural concrete for the foundation was required to have a minimum allowable compressive strength of 4500 psi at 28 days. The concrete in the walls and dome was specified at 5000 psi.

5.3 Applicable Codes

5.3.1 Design Codes of Record for the DSTs

Abatt (1996) identifies SDC 4.1, *Standard Arch-Civil Design Criteria - Design Loads for Facilities*, as the standard for the design of tanks at the Hanford Site. This standard has been in existence since the original document was published in April 1957, and it has been revised since then to comply with current DOE orders. More recently, SDC 4.1 was superseded by HNF-PRO-097, *Engineering Design and Evaluation (Natural Phenomena Hazard)* (HNF-PRO-097 2002). However, HNF-PRO-097 (2002) is a more general standard in use by the Project Hanford Management Contractor and a similar standard, TFC-ENG-STD-06, *Design Loads for Tank Farm Facilities* (Mackey 2004) is used by the Tank Farm Contractor.

5.3.2 Steel Design Codes of Record

Abatt (1996) summarized the codes of record that were used during the design of the various DST farms. The codes pertaining to the steel liner and tank components are listed in Table 5-1.

Table 5-1. Summary of the S_m Allowables that were Specified for Each of the DST Designs (Abatt 1996)

Tank Farm 241-	Construction Years	Max. Temp, °F	Primary Tank Design Code	ASTM Plate Spec.	Minimum Specification	Temperature, °F					
						100	200	250	300	350	400
AY	1968-1970	350	ASME Section VIII, Div 2 (1965)	A515	S_u (ksi) = 32	32	29.2	28.8	28.3	27.9	27.4
				Gr 60	S_{ut} (ksi) = 60	60	60	60	60	60	60
					S_m (ksi)	20	19.5	19.2	18.9	18.6	18.3
AZ	1971 & 1977	350	ASME Section III, (1968)	A515	S_u (ksi) = 32	32	29.2	28.8	28.3	27.9	27.4
				Gr 60	S_{ut} (ksi) = 60	60	60	60	60	60	60
					S_m (ksi)	20	19.5	19.2	18.9	18.6	18.3
SY	1974-1976	250	ASME Section III, Div 1 (1971 & 1973 addenda)	A516	S_u (ksi) = 35	35	31.9	31.5	31.0	30.5	30.0
				Gr 65	S_{ut} (ksi) = 65	65	65	65	65	65	65
					S_m (ksi)	21.7	21.3	21.0	20.7	20.3	20.0
AW	1978-1980	350	ASME Section VIII, Div 2 (1974 & summer 1975 addenda)	A537	S_u (ksi) = 50	50	44.1	42.3	40.5	39.0	37.5
				Class 1	S_{ut} (ksi) = 70	70	70	70	70	70	70
					S_m (ksi)	23.3	23.3	23.1	22.9	22.9	22.9
AN	1980-1981	350	ASME Section VIII, Div 2 (1974 & 1976 addenda)	A537	S_u (ksi) = 50	50	44.1	42.3	40.5	39.0	37.5
				Class 1	S_{ut} (ksi) = 70	70	70	70	70	70	70
					S_m (ksi)	23.3	23.3	23.1	22.9	22.9	22.9
AP	1983-1986	210	ASME Section VIII, Div 2 (1980 & winter 1981 addenda)	A537	S_u (ksi) = 50	50	44.1	42.3	40.5	39.0	37.5
				Class 1	S_{ut} (ksi) = 70	70	70	70	70	70	70
					S_m (ksi)	23.3	23.3	23.1	22.9	22.9	22.9

5.3.3 Concrete Design Codes of Record

Abatt (1996) also summarized the codes of record that pertain to the reinforced concrete structure of the tanks. These codes are listed in Table 5-2. Table 5-2 shows that the 241-AY tanks were designed to the standards of the 1963 revision of ACI 318 (ACI 1963).

Table 5-2. Summary of Hanford Double-Shell Tank Structural Concrete Design Basis (Abatt 1996)

Tank Farm 241-	Const. Years	Design Code				Reinforcing Steel		
		Specified 28-day Compressive Strength (10 ³ lbf/in ²)						
		Dome & Haunch	Wall	Basemat Foundation	Insulation Concrete ^(a)	Rebar (ASTM)	Cross-Ties (ASTM)	Welds
AY	1968-70	ACI 318 (1963)				A15-65 FDN Gr. 40 A432-66 Shell Gr. 60	A432-66 Gr. 60	NA
		3 (Type III)	3 (Type II)	3	0.200			
AZ	1971 & 77	ACI 318 (1963)				A615-68 Gr. 60	A615-72 Gr. 60	NA
		3	3	3 (Type V)	0.200			
SY	1974-76	ACI 318 (1971)				A615-72 Gr. 60	A615-72 Gr. 40	AWS D12.1
		4.5 (Type III)	4.5 (Type II)	3(4.5) ^(b) (Type V)	0.130			
AW	1978-80	ACI 318 (1971)				A615-76a Gr. 60	A615-76a Gr. 40	AWS D12.1 HPS-220-W
		5 (Type III)	5 (Type II)	4.5 (Type II)	0.130			
AN	1980-81	ACI 318 (1971)				A615-75 Gr. 60	A615-75 Gr. 40	AWS D12.1 HPS-220-W
		5 (4.5) ^(c) (Type III)	5 (4.5) ^(c) (Type II)	4.5 (Type II)	0.130			
AP	1983-86	ACI 349 (1976)				A615-81a Gr. 60	A615-81a Gr. 60	AWS D1.4
		5	5	4.5 (Type II)	0.130			

(a) The insulating concrete material is a cast-in-place lightweight refractory concrete material.
(b) From H-2-37704.
(c) From H-2-71907.

Type II = Low-alkali Portland cement – used where moderate exposure to sulfate attack is anticipated. Type II cement is in common use in western United States. Type II cement gains strength a little more slowly than general-purpose Type I cement but ultimately attains strength of Type I cement.
Type III – High-early-strength cement – develops in 7 days the same strength that is achieved at 28 days for concrete made from Types I or II cement, but may not achieve the long-term strength of Types I or II.
Type V = Sulfate-resisting cement – strength characteristics are equivalent to Type II.

ACI = American Concrete Institute.
ASTM = American Society of Testing and Materials.
AWS = American Welding Society.
FDN = Foundation (basemat).
HPS = Hanford Plant Standard.
NA = Not applicable.

5.3.4 Contemporary Codes for Structural Evaluation of the DSTs

Day et al. (1995) lists the following DOE orders as applicable to the analysis and structural qualification of the existing DSTs for continued operation:

- DOE Order 6430.1A, *General Design Criteria* (DOE 1989)
- DOE Order 5480.28, *Natural Phenomena Hazard Mitigation* (DOE 1993)

Note that DOE Order 420.1, *Facility Safety*, Section 4.4, Natural Phenomena Hazard Mitigation (DOE 2000), superseded DOE Order 5480.28. In addition, DOE Order 6430.1A has been cancelled.

Day et al. (1995) further states that the analysis and structural qualification of the existing DSTs for continued operation must be performed using the following codes and standards as guidance:

- BNL 52527, *Guidelines for Development of Structural Integrity, Programs for DOE High-Level Waste Storage Tanks* (Bandyopadhyay 1997)
- U.S. DOE Report UCRL 15910, *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards* (UCRL 1990) (superseded by DOE-STD-1020-2002)
- ASCE Standard 4-86, *Seismic Analysis of Safety Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures* (ASCE 1986)
- Hanford Plant Standards, HPS-SDC-4.1, Rev. 12, *Standard Arch-Civil Design Criteria, Design Loads for Facilities* (SDC-4.1 1993) (superseded by TFC-ENG-STD-06)
- TFC-ENG-STD-06, *Design Loads for Tank Farm Facilities*, CH2M Hill Hanford Group, Inc. (Mackey 2004)
- BNL 52361, *Seismic Design and Evaluation Guidelines for the Department of Energy High Level Waste Tanks and Appurtenances* (Bandyopadhyay et al. 1995)

Specific guidance is given by Day et al. (1995) on the code analysis methods to be used in evaluating the major components of the tank, namely:

Primary Tank: The primary tank shall be evaluated against the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC, Article NC-3200 (ASME 1992a). (Note: The design by analysis methods of Section III, Article XIII-1000, "Design Based on Stress Analysis," are equivalent to the analysis requirements of Section VIII, Division 2 (ASME 1992d). The primary difference between Section III (nuclear vessels and piping) and Section VIII (non-nuclear vessels and piping) involves the increased level of material qualification and fabrication inspection required by Section III.

Secondary Concrete Structure: The secondary concrete structure shall be evaluated against the requirements of ACI 349-90, *Code Requirements for Nuclear Safety Related Concrete Structures* (ACI 1990). While the AY tanks were designed to ACI 318 (ACI 1963), ACI 349 provides essentially the same technical design provisions. Mackey (2004a) notes that using ACI 349 as the evaluation criteria would not change the calculation results.

Secondary Tank Liner: The secondary tank liner shall be evaluated using the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 2, Subsection CC (ASME 1992c). Those portions of the liner that are not backed by concrete shall be evaluated to the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NC (ASME 1992a). (Note: The evaluation methods of Section III, Division 2, Subsection CC are recommended because the steel-lined, reinforced concrete tanks are similar in construction to concrete nuclear containment vessels, which Subsection CC covers. Section VIII does not provide specific guidance on the evaluation of steel liners backed by concrete. Therefore, the analysis methodology recommended in Section III will be adopted [as recommended by Day et al. (1995)], even though the tanks were not strictly designed, constructed, and inspected to Section III standards.)

Insulating Concrete Pad: The insulating concrete pad shall be evaluated against the bearing stress requirements of ACI 349-90, *Code Requirements for Nuclear Safety Related Concrete Structures* (ACI 1990).

Primary Tank Dome and Secondary Liner Anchorage System: The anchorage systems for that portion of the tank steel which is backed by concrete shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 2, Subsection CC (ASME 1992c).

Abatt (1996) presents a compilation of the ASME allowable stresses and the load factor combinations that were used in performing "design by analysis" evaluations of the DST primary tanks. Later sections of Day et al. (1995) give detailed guidance on how to apply these codes to analyze the tanks. Section 2 of Day et al. (1995) provides guidance on defining the tank loads (normal, abnormal, and extreme loads) for consideration in the analysis.

Potential failure modes are identified and discussed in detail in Section 3 of Day et al. (1995) for specific tank components as summarized here in Table 5-3.

Section 4 of Day et al. (1995) presents detailed discussion of the ASME code methods for evaluating the above failure modes in the primary tanks, secondary liner, and the anchor bolts. For anchor bolts, Section 4 gives specific guidance on the appropriate liner anchor allowables to use in the code evaluation (see Tables 4.1.4-1, 4.1.4-2, and 4.1.4-3 in Day et al. 1995). Section 4 also presents a similarly detailed discussion of the ACI code methods for evaluating the reinforced concrete tank walls and dome. This includes examples of the load combinations and load scaling factors required by the code.

Section 5 of Day et al. (1995) gives guidance on what to consider in reconciling differences in the current versions of the ASME and ACI codes when reanalyzing the double-shell tanks. The "design by analysis" methods recommended by the ASME code have not changed in their application since the design of the 241-AY tanks. Therefore, the primary and secondary tank steels will be evaluated to the current methods using the S_m allowables and stress intensity classifications listed in Tables 5-1 and 5-4.

Table 5-3. Summary Table of the Local and Global Significance of Failure of the Various DST Components (Day et al. 1995)

Failure Mode	Steel Tank or Liner	Steel Reinforcement	Concrete	Soil
Buckling	L→L		G	
Collapse			G	
Fatigue	L→L	L→G	L→G	
Fracture	L→L			
Bond-slip		L→G		
Plastic failure	L→L	L→G	L→G	
Bearing failure			L→L	L→L
L→L Local failure that could lead to leakage.				
L→G Local failure that could lead to a global instability failure.				
G Global instability failure.				

Table 5-4. Stress Intensity Classification (Abatt 1996)

Vessel Component	Location	Origin of Stress	Type of Stress	Classification
Cylindrical or spherical shell	Shell plate remote from discontinuity	Internal pressure	General membrane gradient through plate thickness	P_m
		Axial thermal gradient	Membrane bending	Q
	Junction with head or flange	Internal pressure	Membrane bending	P_L
Any shell or head	Any section across entire vessel	External load or moment, or internal pressure	General membrane averaged across full section	P_m
		External load or moment	Bending across full section	P_m
	Near nozzle or other openings	External load or moment, or internal pressure	Local membrane bending	P_L
	Any location	Temperature difference between shell and head	Membrane bending	Q
Dished head or conical head	Crown	Internal pressure	Membrane bending	P_m
	Knuckle or injection to shell	Internal pressure	Membrane bending	$P_L^{(a)}$
P_m = Primary membrane. P_L = Local membrane. Q = Secondary. (a) Consideration shall also be given to the possibility of wrinkling and excessive deformation in vessels with large diameter-to-thickness ratio.				

Intentionally left blank.

6.0 Analysis Results

6.1 ACI Structural Concrete Evaluation

The Structural Acceptance Criteria document, WHC-SD-WM-DGS-003 (Day et al. 1995), specifies that the reinforced concrete structure of the tanks shall be evaluated to the standards of ACI 349-90, Section 9.2 (ACI 1990). The requirements of the IBC are satisfied by virtue of meeting the standards of ACI 349. Chapter 19 of the IBC states that structural concrete shall be designed in accordance with the requirements of ACI 318 (ACI 1977). The commentary on ACI 349 describes the additional conservatism for nuclear structures that exceed those in ACI 318. Accordingly, a structure that is shown to conform to ACI 349 satisfies the IBC.

The load factors to be applied in the DST analyses are a subset of the possible combinations specified in ACI 349, that subset being defined by and, further, reduced by the definition of the current work scope. Chapter 7 of the TOLA report (Rinker et al. 2004) indicates that load combinations 1, 4, and 9 are relevant for this study. The seismic loads are considered in load combination 4.

As noted previously, the seismic model contains larger elements than the TOLA model. Accordingly, the ACI evaluation of combined TOLA + seismic loads was conducted at 30 locations in the secondary concrete tank rather than the 63 locations recorded in the TOLA report. Figures 6-1 through 6-3 show the locations of these 30 sections.

The peak loads and moments from the seismic analysis were combined with the loads and moments from each load step of the thermal cycle in such a way as to maximize the demand/capacity ratio. In other words, the direction of the seismic loads and moments was ignored and the results were summed so as to give the worst possible combination of force and moments for that section. The peak seismic loads and moments were extracted from the seismic time history results without regard to location in the tank or time during the seismic event. This simplified the combination of seismic and TOLA demands while maintaining a conservative evaluation.

The capacity of each section was determined according to the reinforcing steel and concrete geometry and properties specified on the 241-AP tank drawings. In other words, the section capacities were increased from the TOLA analysis (Rinker et al. 2004), which was based on the 241-AY Tank Farm design. The 241-AP tanks have more and larger rebar (in some locations), higher strength rebar (foundation), higher concrete nominal strength, and the lower operating temperatures also results in higher concrete strength.

The 3-D seismic analysis generates non-axisymmetric response that requires evaluation of the in-plane shear forces in addition to the cross-section shear forces. The method of ACI 349, Section 11.10 was applied to the in-plane shear force (ACI 1990).

The concrete in the TOLA analyses is allowed to crack; therefore there are no distinct Fully Cracked Concrete (FCC) TOLA results. Accordingly, results are presented for the three ACI load combinations for the Best-Estimate Soil, Best-Estimate Concrete (BES-BEC); Lower Bound Soil (LBS)-BEC; and Upper Bound Soil (UBS)-BEC soil – concrete cases. Only load combination 4 results are presented for the BES-FCC case.

Figure 6-1. Reinforced Concrete Sections – Dome and Haunch Area

6.1.1 Best-Estimate Soil, Best-Estimate Concrete

Figure 6-4 shows the demand/capacity ratios for load combination 1 of the Best-Estimate Soil, Best-Estimate Concrete (BES-BEC) material combination. Load combination 4 is shown in Figures 6-5–6-8. Load combination 9 is shown in Figures 6-9–6-11. The demand/capacity ratios are all less than 1.0 in the meridional, circumferential, and shear directions.

Figure 6-2. Reinforced Concrete Sections – Wall

Figure 6-3. Reinforced Concrete Sections – Slab

ACI-349 Demand/Capacity Ratios - LC 1,
AP, 460", BES-BEC, TOLA

Figure 6-4. BES-BEC, Load Combination 1

ACI-349 Demand/Capacity Ratios - LC 4
BES-BEC, TOLA + Seismic, Meridional

Figure 6-5. BES-BEC, Load Combination 4, Meridional

ACI-349 Demand/Capacity Ratios - LC 4
BES-BEC, TOLA + Seismic, Circumferential

Figure 6-6. BES-BEC, Load Combination 4, Circumferential

ACI-349 Demand/Capacity Ratios - LC 4
BES-BEC, TOLA + Seismic, Shear

Figure 6-7. BES-BEC, Load Combination 4, Shear

Figure 6-8. BES-BEC, Load Combination 4, In-Plane Shear

Figure 6-9. BES-BEC, Load Combination 9, Meridional

Figure 6-10. BES-BEC, Load Combination 9, Circumferential

Figure 6-11. BES-BEC, Load Combination 9, Shear

6.1.2 Upper Bound Soil, Best-Estimate Concrete

Figures 6-12 through 6-19 show the demand/capacity ratios for load combinations 1, 4, and 9 of the Upper Bound Soil, Best-Estimate Concrete (UBS-BEC) material combination. The demand/capacity ratios are all less than 1.0 in all directions.

6.1.3 Lower Bound Soil, Best-Estimate Concrete

Figures 6-20 through 6-27 show the demand/capacity ratios for load combinations 1, 4, and 9 of the Lower Bound Soil, Best-Estimate Concrete (LBS-BEC) material combination. The demand/capacity ratios are all less than 1.0 in all directions.

6.1.4 Best-Estimate Soil, Fully Cracked Concrete

Figures 6-28 through 6-31 show the demand/capacity ratios for load combination 4 of the Best-Estimate Soil, Fully Cracked Concrete (BES-FCC) material combination. The demand/capacity ratios are all less than 1.0 in all directions.

Figure 6-12. UBS-BEC, Load Combination 1

ACI-349 Demand/Capacity Ratios - LC 4
UBS-BEC, TOLA + Seismic, Meridional

Figure 6-13. UBS-BEC, Load Combination 4, Meridional

ACI-349 Demand/Capacity Ratios - LC 4
UBS-BEC, TOLA + Seismic, Circumferential

Figure 6-14. UBS-BEC, Load Combination 4, Circumferential

ACI-349 Demand/Capacity Ratios - LC 4
UBS-BEC, TOLA + Seismic, Shear

Figure 6-15. UBS-BEC, Load Combination 4, Shear

ACI-349 Demand/Capacity Ratios - LC 4
UBS-BEC, TOLA + Seismic, In Plane Shear

Figure 6-16. UBS-BEC, Load Combination 4, In-Plane Shear

**ACI-349 Demand/Capacity Ratios - LC 9
UBS-BEC, TOLA, Meridional**

Figure 6-17. UBS-BEC, Load Combination 9', Meridional

**ACI-349 Demand/Capacity Ratios - LC 9
UBS-BEC, TOLA, Circumferential**

Figure 6-18. UBS-BEC, Load Combination 9', Circumferential

**ACI-349 Demand/Capacity Ratios - LC 9
UBS-BEC, TOLA, Shear**

Figure 6-19. UBS-BEC, Load Combination 9', Shear

**ACI-349 Demand/Capacity Ratios - LC 1,
AP, 460", LBS-BEC, TOLA**

Figure 6-20. LBS-BEC, Load Combination 1

ACI-349 Demand/Capacity Ratios - LC 4
LBS-BEC, TOLA + Seismic, Meridional

Figure 6-21. LBS-BEC, Load Combination 4, Meridional

ACI-349 Demand/Capacity Ratios - LC 4
LBS-BEC, TOLA + Seismic, Circumferential

Figure 6-22. LBS-BEC, Load Combination 4, Circumferential

Figure 6-23. LBS-BEC, Load Combination 4, Shear

Figure 6-24. LBS-BEC, Load Combination 4, In-Plane Shear

Figure 6-25. LBS-BEC, Load Combination 9¹, Meridional Figure 6-26. LBS-BEC, Load Combination 9¹, Circumferential

**ACI-349 Demand/Capacity Ratios - LC 9
LBS-BEC, TOLA, Shear**

Figure 6-27. LBS-BEC, Load Combination 9, Shear

**ACI-349 Demand/Capacity Ratios - LC 4
BES-FCC, TOLA + Seismic, Meridional**

Figure 6-28. BES-FCC, Load Combination 4, Meridional

Figure 6-29. BES-FCC, Load Combination 4, Circumferential

Figure 6-30. BES-FCC, Load Combination 4, Shear

Figure 6-31. LBS-FCC, Load Combination 4, In-Plane Shear

6.2 ASME Primary Tank Evaluation

The primary tank was evaluated against the requirements of ASME B&PV Code, Section III, Division 1, Subsection NC, Article NC-3200 (ASME 1992a). Section 1622 of the IBC mandates that nonbuilding structures comply with the requirements of Section 9.14 of ASCE 7. That document, in turn, references the ASME B&PV Code as the applicable standard. Therefore, while the DST primary tank structure is not specifically addressed in IBC, they can be shown to meet the requirements of IBC by demonstrating their compliance with the ASME code.

The Evaluation Criteria document (Day et al. 1995) states that earthquake loads may be considered as Service Level D loading. The Seismic Design and Evaluation document (Bandyopadhyay et al. 1995) also states that load combinations including the design basis earthquake should use Service Level D capacities.

6.2.1 Primary Tank Results

Appendix A.7 of this report describes a study of the mesh refinement of the lower knuckle of the primary tank in the seismic FE model. That study concluded that the seismic stress intensities in the primary tank lower knuckle should be multiplied by a factor of at least 2.0 before being combined with the TOLA results. Given the uncertainties in the interpretation of the study results, a conservative factor of 3.0 was applied to the lower knuckle elements in the spreadsheets used to combine the primary tank stress intensities. The general primary membrane stress intensity, the general primary membrane plus bending stress intensity and the primary plus secondary stress intensity range are shown in Figures 6-33 through 6-52. The demands are well within the allowable capacity for each of the four material combinations.

6.2.2 Evaluation Criteria Discussion

The evaluation of the primary tank capacity was in accord with ASME Section III, Division 1, Service Level D as specified by the Structural Acceptance Criteria document (Day et al. 1995) and the guidance of the Seismic Evaluation document (Bandyopadhyay et al. 1995). The ASME code specifies the following load combinations and capacities for an elastic analysis:

$$\text{General primary membrane stress intensity} \quad P_m \leq kS_m \quad (6.1)$$

$$\text{Local primary membrane stress intensity} \quad P_L \leq 1.5kS_m \quad (6.2)$$

$$\text{Primary membrane + bending stress intensity} \quad (P_m \text{ or } P_L) + P_b \leq 1.5kS_m \quad (6.3)$$

$$\text{Primary + secondary stress intensity} \quad (P_m \text{ or } P_L) + P_b + Q \leq 3S_m \quad (6.4)$$

In these equations, P_m is the primary membrane stress, P_L is the local primary stress, P_b is the primary bending stress, and Q is a secondary stress (thermal in the case of the DSTs). The factor k is equal to 2.0 for Service Level D capacities.

The general primary membrane stress in the DST primary tank is dominated by hoop tension. Section 5.5 of the Seismic Evaluation document (Bandyopadhyay et al. 1995) imposes the additional condition that the hoop membrane stress capacity should be taken as the ASME Section III, Division 1, Service Level D limit of $2S_m$, or the yield strength, whichever is less. The intent of the additional condition is that kS_m should be limited to the yield strength if credit is taken for inelastic energy absorption in the computation of demands. Accordingly, the general primary membrane stress intensity criterion becomes:

$$P_m \leq \min(kS_m, S_y) \quad (6.5)$$

While the factored inelastic demand was not used, the additional conservatism afforded by the yield strength was maintained for each of the DST evaluations as shown in Figures 6-24, 6-29, 6-34, and 6-39.

The allowable stresses, S_m and S_y were conservatively taken at 250°F for the A537 steel used in the AP tanks as 23.1 ksi and 42.3 ksi, respectively.

6.2.3 Best-Estimate Soil, Best-Estimate Concrete

Figures 6-33–6-37 show the demand/capacity ratios for the primary tank for the BES-BEC material combination. All demand/capacity ratios are all less than 1.0.

6.2.4 Upper Bound Soil, Best-Estimate Concrete

Figures 6-38–6-42 show the demand/capacity ratios for the primary tank for the UBS-BEC material combination. All demand/capacity ratios are all less than 1.0.

6.2.5 Lower Bound Soil, Best-Estimate Concrete

Figures 6-43–6-47 show the demand/capacity ratios for the primary tank for the LBS-BEC material combination. All demand/capacity ratios are all less than 1.0.

6.2.6 Best-Estimate Soil, Fully Cracked Concrete

Figures 6-48–6-52 show the demand/capacity ratios for the primary tank for the BES-FCC material combination. All demand/capacity ratios are all less than 1.0.

Figure 6-32. Relative Magnitude of TOLA and Seismic Primary Membrane Stress Intensity

Figure 6-33. BES-BEC Primary Membrane Stress Intensity

Figure 6-34. BES-BEC Primary Membrane + Bending (inside) Stress Intensity

Figure 6-35. BES-BEC Primary Membrane + Bending (outside) Stress Intensity

Figure 6-36. BES-BEC Primary + Secondary (inside) Stress Intensity Range

Figure 6-37. BES-BEC Primary + Secondary (outside) Stress Intensity Range

Figure 6-38. UBS-BEC Primary Membrane Stress Intensity

Figure 6-39. UBS-BEC Primary Membrane + Bending (inside) Stress Intensity

Figure 6-40. UBS-BEC Primary Membrane + Bending (outside) Stress Intensity

Figure 6-41. UBS-BEC Primary + Secondary (inside) Stress Intensity Range

Figure 6-42. UBS-BEC Primary + Secondary (outside) Stress Intensity Range

Figure 6-43. LBS-BEC Primary Membrane Stress Intensity

Figure 6-44. LBS-BEC Primary Membrane + Bending (inside) Stress Intensity

Figure 6-45. LBS-BEC Primary Membrane + Bending (outside) Stress Intensity

Figure 6-46. LBS-BEC Primary + Secondary (inside) Stress Intensity Range

Figure 6-47. LBS-BEC Primary + Secondary (outside) Stress Intensity Range

Figure 6-48. BES-FCC Primary Membrane Stress Intensity

Figure 6-49. BES-FCC Primary Membrane + Bending (inside) Stress Intensity

Figure 6-50. BES-FCC Primary Membrane + Bending (outside) Stress Intensity

Figure 6-51. BES-FCC Primary + Secondary (inside) Stress Intensity Range

Figure 6-52. BES-FCC Primary + Secondary (outside) Stress Intensity Range

6.3 Primary Tank Stress Corrosion Cracking Evaluation

The Structural Acceptance Criteria document (Day et al. 1995) raised the issue of primary tank fracture by stress corrosion cracking (SCC) as a potential failure mode. However, the report does not set forth a criterion by which to assess the limits on stress, temperature, or waste chemistry to preclude such failure. The TOLA report (Rinker et al. 2004) used the previously postulated limit on the primary tank principal stress on the inner surface to 90% of the yield strength of the tank steel. Perhaps the earliest appearance of this criterion is the AP Tank Farm Functional Design Criteria (Garfield and Guenther 1981). Other indications are that the criterion was “less than yield” prior to construction of the AZ farm, but was changed to “90% of yield” beginning with the AZ tanks.

Intervening analyses, particularly the Expert Panel discussions regarding waste chemistry (Terry et al. 2004) raised concerns regarding the validity of this criterion. The subsequent evaluation of the stress criteria for stress corrosion cracking (Rinker et al. 2005) was unable to establish a technical basis for the 90% yield criterion. That report also observed that while other industries and other design codes are concerned about SCC, they do not address the issue solely on the basis of a stress limit. Other approaches to addressing SCC include reduction of tensile residual stress by post weld heat treatment (PWHT), control of environmental conditions (chemistry and temperature), in-service inspection to confirm the lack of stress corrosion cracks, and fracture mechanics calculations to assess the possibility of crack growth.

6.3.1 Analytical Evaluation

The SCC report (Rinker et al. 2005) developed a damage tolerance approach based on fracture mechanics methods as an alternative means of evaluation. That report focused specifically on Tank AN-107 because

of the historical difficulty of maintaining the desired pH levels in the waste. The fracture mechanics calculations referenced crack growth rate data being developed concurrently (Brongers et al. 2005).

Earlier crack growth testing (Blackburn 1995a, 1995b) in highly aggressive solutions has demonstrated relatively high crack growth rates. It was recognized, however, that these test conditions were very conservative in comparison to the lower temperatures and less aggressive chemical conditions of past and current tank operations. This conservatism was confirmed by the recent test results (Brongers et al. 2005) which showed no propensity to crack at equilibrium corrosion potentials, and one to two orders of magnitude lower crack growth rates with an induced voltage to bring the system into the SCC sensitivity range. Only insignificant crack growth was predicted over the projected life of tank operations. Accordingly, conservative values of K_{ISCC} were assigned to facilitate the fracture mechanics calculations.

Application of the fracture mechanics method to Tank AN-107 showed a very low potential for stress corrosion crack growth. There are, however, differences between the loads and tank geometry (wall thickness) of the AN-107 and bounding TOLA analysis described herein. The differences in load are summarized in Table 6-1.

Table 6-1. Comparison of TOLA and AN-107 Analyses

Feature	TOLA	AN-107
Soil overburden (ft)	8.3	7.4
Overburden density (lb/ft ³)	125	120
Waste height (in.)	422	388
Waste specific gravity	1.70	1.43
Waste temperature (°F)	350	110

The effect of these differences on the lower knuckle inner surface principal stress is shown in Figure 6-53.

Figure 6-53. Comparison of TOLA and AN-107 Lower Knuckle Principal Stress

A parametric study on the effect of the applied bending stress to the sensitivity to crack growth was conducted as part of the SCC study (Rinker et al. 2005). Figure 5-5 from that report is reproduced here as Figure 6-54. Interpolation of the results to the TOLA bending stress of ± 27 ksi suggest that crack growth is unlikely for an existing 0.10 inch crack unless K_{ISCC} is less than $21 \text{ ksi-in}^{1/2}$. These results are predicated on the assumption of the lower knuckle steel temperature being more moderate ($\leq 150^\circ\text{F}$) than was historically recorded in the AY/AZ tanks.

Figure 6-54. Effect of Applied Bending Stress on Calculated Stress Intensity Factor for the Lower Knuckle of Tank AN-107

6.3.2 DST Operating Experience

Appendix C of the SCC report (Rinker et al. 2005) summarized the operating experience with DSTs at both the Hanford Site and the Savannah River Site (SRS). Stress corrosion cracking occurred with some early waste tank designs, without PWHT, at Savannah River. These tanks were constructed of carbon steel but, unlike the Hanford DSTs, were not given post-weld heat treatments to reduce welding residual stresses. The SRS tanks with confirmed SCC were exposed to relatively high-temperature wastes with adverse waste chemistries that were outside the current limits imposed on both Savannah River and Hanford tanks. Other early Savannah River tanks (also of low carbon steels and without PWHT) were operated at less severe waste chemistries and temperatures without reported SCC.

Savannah River initiated research programs in response to the early cracking incidents. Results of this research showed the benefits of PWHTs and improved specifications for waste chemistry. Implementation of these mitigative measures has evidently been effective because there has been no further SCC either in the older tanks (without PWHT) or in newer tanks that used PWHT.

Hanford waste storage tanks have experienced leaks from the older single-shell tanks (no PWHT) but also achieved a record of no leakage from the newer DSTs with PWHT. It is not possible to examine failed liners of single-shell tanks which precludes the detailed analyses needed to determine whether the failures were caused by corrosion, wall thinning, pitting, or cracking. It is likely that SCC was a factor because none of the older tanks were given PWHT to reduce welding residual stresses. Furthermore, the past service conditions included storage of wastes at high temperatures with chemical compositions known to contribute to SCC.

In contrast, no SCC has been observed in any of the 28 Hanford DSTs over periods of operation that date back to 1971. Detection methods include observation of leakage from through-wall cracks, visual inspections of the outer surface of the tanks, and monitoring for moisture and the increased radiation levels caused by leakage from the primary tank into the outer annulus. Ultrasonic (UT) examinations have been used to look for cracks with less than through-wall depths (present sensitivity can detect very small defects but can only dimension them to 0.050 inch depth), and none have been detected in the lower knuckle region. These crack inspections are done on a 30 inch wide top-to-bottom vertical pass (~40 feet), as well as a 20-foot long segment of the lower knuckle region. However, these UT examinations have covered only a fraction of the tank wall, and depend on the covered fractions being representative of entire tank conditions. Uncertainties aside, it can nevertheless be concluded that the Hanford DSTs appear to have experienced no significant SCC degradation.

There has been no stress corrosion cracking observed in the Hanford DSTs under the present chemistry controls and operating parameters. Recent corrosion testing and analysis overseen by the Expert Panel (Terry et al. 2004), when coupled with the historical operational record dating back to 1971, shows that SCC is unlikely if the present operating requirements are maintained. Temperature limits are lower and waste chemistry is much less aggressive than those that have caused cracking incidents in laboratory experiments and SRS waste storage tanks.

6.3.3 Seismic Considerations

Implicit in the definition of stress corrosion cracking is the presence of a static tensile stress. A seismic event is by definition a transient event, lasting a much shorter duration than that required to produce SCC. However, it has been posited that seismically induced stresses, when added to the baseline stresses from the thermal and operating loads, may exceed the yield strength of the primary tank steel. Consequently, the stress state following the earthquake may be higher thus possibly promoting the development of SCC.

A simplified stress analysis of the lower knuckle was conducted to evaluate this scenario. A model of the lower knuckle was loaded with a downward displacement of the wall sufficient to achieve an inside surface stress just below the yield strength (32 ksi) of the steel. This load condition was selected to conservatively represent the nominal operating loads. The displacement was then increased to give an additional 10 ksi compressive stress resulting in yielding of the knuckle such as might occur in an earthquake. The wall stress was then evaluated after returning the load to the nominal operating level. It was observed that the maximum inside surface stress was decreased by nearly 5 ksi following this overstress event.

This analysis demonstrates that yielding of the lower knuckle due to increased meridional compression such as might result from an earthquake does not increase the inside surface stress after the transient event has passed. The model predicts that such an overstress condition may actually decrease the subsequent surface stress due to the load reversal effect in going from the over stress state back to the normal operating condition.

6.4 Primary Tank Buckling Evaluation

Buckling of the primary tank was considered in Section 8.5 of the TOLA report (Rinker et al. 2004). The evaluation method was based on the method defined in Code Case N-284-1 of the ASME B&PV Code, Section III, Division 1 (ASME 1992a). The buckling evaluation for service Level D was conducted using seismic demands from the original design calculations (Blume and Associates 1974). A separate task of the *DST Integrity Project* was to conduct detailed buckling analyses, in part to “develop an approximate influence function to estimate the effect of changes between the finite element analysis parameters and the tank specific conditions.” Accordingly, a new finite element model was developed, distinct from the TOLA model, and buckling evaluations were performed incorporating the results from the current seismic analysis. Complete documentation of the TOLA buckling evaluation is found in the Buckling Analysis report (Johnson et al. 2006).

6.4.1 Evaluation Method

Large displacement finite element analyses were used to predict the limiting vacuum load for the DST primary tanks under combined axial and vacuum loads. Figure 6-55 shows the model of the primary tank used in this analysis. A downward deflection was applied to the dome of the tank (the area in contact with the concrete tank structure) to simulate the displacement controlled axial compression of the tank wall that occurs due to concrete thermal degradation and creep, plus the confined thermal expansion of the steel tank inside the concrete shell. The model includes a geometric imperfection to initiate the buckling instability under the radially symmetric vacuum load. The imperfection was sized to the maximum out of roundness (1-inch deviation in a 7-foot arc length) allowed in the AY tank farm construction specifications (HWS-7789 Hanford Engineering Services 1968). Additional loads on the model include gravity and hydrostatic pressure of the waste at height, h , and specific gravity, SpG (see Figure 6-56).

The onset of the buckling instability was predicted by applying an increasing vacuum load on the inside surface of the tank while monitoring the maximum radial displacement of the tank wall as a function of the increasing vacuum load. The onset of instability is signaled by an increasing rate of radial deflection for a constant increment in the applied vacuum load. Figure 6-57 shows an example load deflection curve from one of the cases that were analyzed. Because vacuum is a primary load, the stresses are not self limiting and the model eventually fails to converge (numerically) as the physical load carrying capacity of the tank is reached. However, using the final converged vacuum load as the buckling limit is not a reliable measure of the onset of instability because the final convergence is sensitive to non-physical factors including the load step size, the convergence tolerance, and the numerical precision of the computer. Therefore, the ASME code was reviewed to find an appropriate method for defining the limiting vacuum load.

Figure 6-55. Buckling Model

Figure 6-56. Buckling Model Loads

Figure 6-57. Buckling Load Deflection Curve

The ASME Boiler and Pressure Vessel Code, Section III, NB-3213.25, provides guidance on establishing a reasonable collapse load for a structure undergoing controlled plastic deformation (ASME 1992a). Although an elastic buckling phenomenon is being evaluating (the buckling models predict that the tank membrane stresses are well below the elastic limit), the increasing rate of distortion in the tank wall (for a constant increasing vacuum load) represents a gradual decrease in structural stiffness that is similar to a structure undergoing progressive plastic deformation. In the former case, the stiffness reduction is due to the large deformations of the tank geometry that progressively decrease the load carrying capacity of the tank. In the latter case, it is due to plastic softening. The ASME code method establishes the collapse load by limiting the reduction in structural stiffness under increasing load.

NB-3213.25 Plastic Analysis — Collapse Load. *A plastic analysis may be used to determine the collapse load for a given combination of loads on a given structure. The following criterion for determination of the collapse load shall be used. A load-deflection or load-strain curve is plotted with load as the ordinate and deflection or strain as the abscissa. The angle that the linear part of the load-deflection or load-strain curve makes with the ordinate is called θ . A second straight line, hereafter called the collapse limit line, is drawn through the origin so that it makes an angle of $\tan^{-1}(2 \tan \theta)$ with the ordinate. The collapse load is the load at the intersection of the load-deflection or load-strain curve and the collapse limit line. If this method is used, particular care should be given to ensure that the strains or deflections that are used are indicative of the load carrying capacity of the structure.*

Figure 6-57 graphically illustrates the ASME code method based on the factor of two stiffness reduction. The radial displacement is offset from zero (at zero vacuum) because the initial loads (axial compression, hydrostatic pressure, and gravity) cause an initial radial deflection in the tank wall. The initial load/deflection slope was calculated and a second line was drawn at an angle with twice the tangent measured from the vertical axis. The vacuum limit was then calculated by interpolating to find the vacuum load

where the second line crossed the load/deflection curve (Figure 6-57). In this case, the ASME collapse load is about 62% of the last converged vacuum load. Figure 6-58 shows the displaced shape of the tank model at the ASME collapse load. The displacements are magnified by a factor of 50 for visual effect. For the tank geometry, the ASME method results in a minor amount of tank distortion.

A matrix of tank models was run to develop equations for the tank vacuum limit as a function of waste height, specific gravity, wall thickness, and axial compressive load. Influence functions were developed to estimate the applied axial force in the primary tank wall that is required for evaluating buckling of the primary tank. The axial force contributions from the applied loads were evaluated, giving the total axial force as the sum of the following loads:

- Differential thermal expansion,
- Gravity,
- Surface loads,
- Concrete thermal degradation and creep,
- Seismic excitation, and the
- Effect of hydrostatic waste pressure on the confined axial force.

Once the unfactored axial force and vacuum limits are calculated, then the safety factors for the ASME Section III service levels are applied to calculate the allowable tank vacuum limits.

Figure 6-58. Model Displaced Shape at Vacuum Limit

6.4.2 Evaluation Criteria

The buckling calculations are conducted for the four different service levels defined in ASME Section III, each with required factors of safety for local and global buckling:

	Factors of Safety	
	Local Buckling	Global Buckling
Level A = Normal operating conditions	2.0	2.4
Level B = Upset conditions	2.0	2.4
Level C = Emergency conditions	1.67	2.0
Level D = Faulted conditions	1.34	1.61

Attachment B of Julyk (2002) makes the argument that axial compression in the tank cylinder will be relieved by local bowing of the wall before the onset of general instability. This position is justified since the meridional (axial) compressive stresses are displacement controlled as a result of differential thermal expansion and concrete creep induced loads on the primary tank. The load deflection response of the large displacement finite element models using in the current buckling analysis confirm that the axial stress in the tank is self-limited by the deformation of the primary tank geometry. This rational leads to the following buckling criteria when combining the effects of axial and hoop loads on the allowable vacuum:

The allowable vacuum (net negative pressure) in the double shell tanks is controlled by the minimum of two cases,

- A. Local Buckling (with local buckling safety factors imposed) evaluated considering the interaction of the net internal vacuum load (Δp) combined with the meridional compressive stress (σ_ϕ).
- B. General Instability (with global buckling safety factors imposed) evaluated considering the net internal vacuum load (Δp) acting alone. No interaction with the meridional compressive stress shall be considered ($\sigma_\phi = 0$).

These criteria were used by Julyk (2002) are they also used in the current buckling evaluation.

Julyk (2002) states that activation of the tank relief valves at the limiting vacuum load should be classified as a Level C (emergency) load condition. This is justified because the normal vacuum imposed by the tank ventilation systems is about 3 inches w.g. compared to the vacuum limit of 6.6 inches w.g. for the AY, SY, AN, AW, and AZ tanks and 12 inches w.g. for the AP primary tank. The relief valves (set at the limit values) are not expected to activate over the operating life of the tanks and at worst this would occur no more than 25 times. Therefore, activation of the relief valves would be an off-normal occurrence, which is consistent with the ASME Service Load Classification for Level C events.

It is assumed in this analysis that the design basis loads used in the thermal and operating loads analysis conservatively represent Service Levels A, B, and C. This is consistent with the loading conditions assumed by Julyk (2002). Service Level D, however, requires that the incremental seismic stresses be added to the design basis stresses for evaluating the faulted condition.

6.4.3 Buckling Results

An Excel™ spreadsheet was constructed using the relationships documented in detail in the Buckling report (Johnson et al. 2006) and it applies the Section III service level safety factors to calculate the vacuum allowable for the primary tanks. Table 6-2 shows a summary of the allowable vacuum calculations that are based on the current 210°F operating limits for waste temperature, 460 inch waste height, and waste specific gravity of 1.83. A corrosion allowance of 0.060 inch was assumed in these calculations. Table 6-2 shows the specified vacuum limit of 12 inches w.g. is greater than the current vacuum allowable to prevent buckling of 10.46 inch w.g.

Table 6-3 summarizes the additional analyses that showed that the allowable vacuum was above the 12-inch limit for corrosion allowances less than 0.025 inch. Little or no corrosion has been observed in the primary tanks (Jensen 2003, 2005) such that this wall thickness is appropriate for the buckling calculation. With this assumption, the AP tank passes the buckling criteria. Additional consideration may be given to the operational capabilities of the ventilation equipment.

Table 6-2. Primary Tank Buckling Evaluation

	AP
Approx. Operating History	
Temp, F	120
Hwaste, inch	422
Operating Limits	
Temp, F	210
Hwaste, inch	460
SpG	1.83
Corrosion Allowance, inch	0.060
Yield at Temp, ksi	43.8
Calculated Axial Forces	
Operating Axial Force, kip/inch	-0.355
Oper+Seismic Force, kip/inch	-0.869
Axial Force Limit, kip/inch	-2.842
Calculated Allowable Vacuum Limits, inches w.g.	
Local Buckling	
Service Level A&B	9.61
Service Level C	11.51
Service Level D	13.37
Global Buckling	
Service Level A&B	8.71
Service Level C	10.46
Governing	
Allowable Vacuum, inch w.g.	8.71
Governing Allowable when vacuum = Level C load	
	10.46
Current Vacuum Limit, inches w.g.	
	12

Table 6-3. Summary of Primary Tank Buckling Evaluation

	AP
Approx. Operating History	
Temp, F	120
Hwaste, inch	422
Maximum Expected Future Operating Conditions	
Temp, F	210
Hwaste, inch	460
SpG	1.83
Yield at Temp, ksi	43.80
Corrosion Allowance, inch	0.000
Level C Vacuum Limit, inch w.g.	13.35
Corrosion Allowance, inch	0.010
Level C Vacuum Limit, inch w.g.	12.85
Corrosion Allowance, inch	0.025
Level C Vacuum Limit, inch w.g.	12.11
Corrosion Allowance, inch	0.060
Level C Vacuum Limit, inch w.g.	10.46

6.5 ASME Concrete-Backed Steel Evaluation

The evaluation criteria for the concrete-backed steel liner (both primary and secondary liner) are specified by Day et al. (1995) in WHC-SD-WM-DGS-003. These requirements were taken from the ASME B&PV Code, Section III, Division 1, Subsection NC-3700 (ASME 1992a). The seismic load component is added to the factored load combination under the abnormal/extreme environmental category.

6.5.1 Best-Estimate Soil, Best-Estimate Concrete

Figures 6-59–6-64 show the demand/capacity ratios for the primary tank for the BES-BEC material combination. All demand/capacity ratios are less than 1.0.

6.5.2 Upper Bound Soil, Best-Estimate Concrete

Figures 6-65–6-70 show the demand/capacity ratios for the primary tank for the UBS-BEC material combination. All demand/capacity ratios are less than 1.0.

6.5.3 Lower Bound Soil, Best-Estimate Concrete

Figures 6-71–6-76 show the demand/capacity ratios for the primary tank for the LBS-BEC material combination. All demand/capacity ratios are less than 1.0.

6.5.4 Best-Estimate Soil, Fully Cracked Concrete

Figures 6-77–6-82 show the demand/capacity ratios for the primary tank for the LBS-FCC material combination. All demand/capacity ratios are less than 1.0.

Figure 6-59. BES-BEC, Principal Membrane Strain – Tension (ϵ_1)

Figure 6-60. BES-BEC, Principal Membrane Strain – Compression (ϵ_3)

Figure 6-61. BES-BEC, Principal Membrane + Bending Strain Outer Surface – Tension (ϵ_1) Figure 6-62. BES-BEC, Principal Membrane + Bending Strain Outer Surface – Compression (ϵ_3)

Figure 6-63. BES-BEC, Principal Membrane + Bending Strain Inner Surface – Tension (ϵ_1) Figure 6-64. BES-BEC, Principal Membrane + Bending Strain Inner Surface – Compression (ϵ_3)

Figure 6-65. UBS-BEC, Principal Membrane Strain – Tension (ϵ_t) Figure 6-66. UBS-BEC, Principal Membrane Strain – Compression (ϵ_c)

Figure 6-67. UBS-BEC, Principal Membrane + Bending Strain Outer Surface – Tension (ϵ_1)

Figure 6-68. UBS-BEC, Principal Membrane + Bending Strain Outer Surface – Compression (ϵ_3)

Figure 6-69. UBS-BEC, Principal Membrane + Bending Strain Inner Surface – Tension (ϵ_1) Figure 6-70. UBS-BEC, Principal Membrane + Bending Strain Inner Surface – Compression (ϵ_3)

Figure 6-71. LBS-BEC, Principal Membrane Strain – Tension (ϵ_1) Figure 6-72. LBS-BEC, Principal Membrane Strain – Compression (ϵ_3)

Figure 6-73. LBS-BEC, Principal Membrane + Bending Strain Outer Surface – Tension (ϵ_1) Figure 6-74. LBS-BEC, Principal Membrane + Bending Strain Outer Surface – Compression (ϵ_3)

Figure 6-75. LBS-BEC, Principal Membrane + Bending Strain Inner Surface – Tension (ϵ_1) Figure 6-76. LBS-BEC, Principal Membrane + Bending Strain Inner Surface – Compression (ϵ_3)

Figure 6-77. BES-FCC, Principal Membrane Strain – Tension (ϵ_1) Figure 6-78. BES-FCC, Principal Membrane Strain – Compression (ϵ_3)

Figure 6-79. BES-FCC, Principal Membrane + Bending Strain Outer Surface – Tension (ϵ_1)

Figure 6-80. BES-FCC, Principal Membrane + Bending Strain Outer Surface – Compression (ϵ_3)

Figure 6-81. BES-FCC, Principal Membrane + Bending Strain Inner Surface – Tension (ϵ_1) Figure 6-82. BES-FCC, Principal Membrane + Bending Strain Inner Surface – Compression (ϵ_3)

6.6 Anchor Bolt Evaluation

The initial evaluation of the primary tank dome anchor bolts documented in Rev. 0 of this report was conducted in accordance with the ASME B&PV Code per (Day et al 1995). In July 2007, independent reviewers raised concerns regarding the anchor bolt capacity used in that evaluation (Appendix A.2). In response to the reviewer comments, the anchor bolts were re-evaluated using an approach based on a combination of test data and analytical modeling.

Because the DST configuration of an internally threaded weld stud with a threaded anchor bolt is not supported directly by test data, detailed finite element models were developed to establish an equivalent diameter for the shear response of the anchors. Once the equivalent diameter was established, test data were used to determine the ultimate shear deformation for the anchors. The models and incorporation of the test data are described in Appendix A.3.

Test data on similar anchors show ductile responses represented by highly nonlinear load-deformation curves in both shear and tension. The known nonlinear response of the DST anchors was characterized by consistent linearizations of the shear and tensile load-deformation curves using a secant modulus approach as described in Chapter 2.2.4.2 and Appendix A.3.

The reviewer comments on the anchor re-evaluation are provided in Appendixes A.4 and A.5. The follow-up review documented in Appendix A.5 questioned the use of a single shear stiffness for all the anchor bolts in the tank dome. Subsequent analyses described in Appendix A.6 demonstrated the validity of this approach.

An additional review of the anchor bolt modeling and evaluation is documented in Appendix A.9. In addition to finding the anchor bolt modeling and evaluation methods used in the DST structural evaluation to be appropriate, an important development in this review was the procedure for combining thermal and non-thermal demands. Because the evaluation of the DST anchor bolts did not reduce the thermal demands on the anchor bolts in accordance with the given procedure, that aspect of the anchor bolt evaluation was considered by the reviewer to be very conservative.

A conservatism identified during the July 2007 review was the use of the 0.5 strength reduction factor specified by the ASME code compared to the 0.75 factor specified by both the ACI (2001) and AISC (2005). The ASME B&PVC criteria are intended for the design of concrete containments in nuclear facilities. Since 1995, the DSTs have been downgraded from PC-3 to PC-2 structures, and the application of the concrete containment code to the anchor bolt evaluation is viewed as unnecessarily restrictive. Consequently, the current evaluation of the AP anchors follows the procedure given in ACI-349-01 (ACI 2001). The change of criteria from ASME to ACI 349-01 has the effect of increasing the capacity of the AP anchors by 50%.

By comparing AP anchor bolt model results with the available test data on anchor ultimate shear forces and displacement, it was determined that an ultimate shear displacement $\delta_{UN} = 0.22$ inch is appropriate for the welded stud and threaded anchor configuration used in the AP tanks. The corresponding ultimate shear force is $V_{UN} = 14.34$ kips. The secant shear modulus, k_s , is calculated as:

$$k_s = \frac{V_{UN}}{\delta_{UN}} = \frac{14.34 \text{ kips}}{0.22 \text{ inch}} = 65,187 \text{ lbf/in}$$

The value of 65,000 lbf/in. was selected for the TOLA and seismic models in both shear and tension.

The demands from the combination of the 210°F waste thermal load with the seismic loads exceed the anchor bolt capacity. A review of historical tank operation data indicated maximum dome temperatures of approximately 100°F. Discussions with Tank Operations confirmed that a bulk waste temperature of 135°F was sufficient to accommodate expected future operations. Additionally, the stress-free concrete curing temperature was identified as 80°F rather than the previously assumed, more conservative 50°F. Four (one for each soil – concrete combination) full 60-year analyses were conducted with the thermal cycle ranging from 80°F to 135°F. These analyses were used only for the evaluation of the anchor bolts. The anchor bolt demands from the thermal and operating loads were combined with the seismic demands. The anchor bolt evaluations are shown in Figures 6-83 through 6-86.

The primary tank dome anchor bolt forces and displacements are within the allowable limit for all combinations of soil and concrete with a maximum waste temperature of 135°F.

Figure 6-83. BES – BEC, Anchor Bolt Displacement Evaluation

Figure 6-84. UBS – BEC, Anchor Bolt Displacement Evaluation

Figure 6-85. LBS – BEC, Anchor Bolt Displacement Evaluation

Figure 6-86. BES – FCC, Anchor Bolt Displacement Evaluation

6.7 The Effect of Waste Model Uncertainties on Anchor Bolt Evaluation

In the Dytran[®] analysis of the AP Tanks, the waste was modeled as a homogeneous, nearly incompressible, inviscid liquid with a bulk specific gravity of 1.83. In the ANSYS[®] analysis, the waste is modeled as a homogeneous, nearly incompressible deformable solid with very low shear resistance, also with a bulk specific gravity of 1.83. During a project review meeting held in June 2007, one review comment stated that there are fundamental uncertainties in idealizing the tank waste as a homogeneous liquid (Appendix A). The technical issue of concern is that hydrodynamic effects for a tank storing a solid-like material may be larger than for a liquid-containing tank.

The potential for an increased response from a tank containing a solid-like material relative to a tank containing a liquid arises from two mechanisms. First, the solid-like material will have reduced sloshing response relative to a liquid, so a higher portion of the mass responds impulsively, thereby increasing some response parameters. Second, depending on the excitation as well the structural characteristics and geometrical configuration of the tank and contained waste, it is possible for the response of the tank to amplify the response of the tank walls (Veletsos and Younan [1998]).

The second phenomenon can occur when the natural frequencies of contained material are “in tune” with the natural frequencies of the tank. This also depends on the ratio of the waste height to the tank radius (slenderness ratio), and the characteristics of the forcing function. For this to occur, the contained material must be “solid” in the sense that it has structural frequencies and mode shapes independent of the tank itself. This characterization appears to be inconsistent with Hanford DST waste properties and will

not be discussed further. Depending on the DST waste composition, the first phenomenon may occur to some degree.

Based on the current waste composition data for the AP tanks reported in the Tank Waste Information Network System (TWINS) database (TWINS 2008), the waste composition in the AP tanks includes a sludge-like material with depths less than the bottom one-third of the total waste height. The waste is similar in consistency to over-saturated soil with a low angle of repose and a specific gravity of 1.5 to 1.83. More than two-thirds of the waste is a liquid with a specific gravity of 1.3 to 1.5 that covers the sludge layer. Increasing the liquid level to 460 inches will not exceed the current assumption of 1/3 sludge and 2/3 liquid.

When the waste is completely liquid, the mass of the waste in the DSTs that responds in the impulsive and convective modes is roughly the same, with somewhat greater than half the waste mass responding in the impulsive mode (BNL 1995).

If it is assumed conservatively that the lower one-third of the waste is a sludge layer of specific gravity of 1.83 that responds 100% impulsively, and that the upper two-thirds of the waste is liquid with specific gravity of 1.83, which responds equally in the impulsive and convective modes, then two-thirds of the total waste mass responds impulsively. This gives an approximate increase of 1/6 (16.7%) in the portion of the waste responding impulsively. The increase in impulsive mass will affect both the demands on the anchor bolts, and the waste pressures in the primary tank.

Some simple conservative estimates of the effects of a sludge layer at the bottom of the tank can be made based on the equations in Chapter 4 of BNL (1995) and Rinker and Abatt (2006a).

As a first approximation, it is assumed that the increase in the maximum horizontal hydrodynamic reaction force is proportional to the increase in the impulsive mass of the waste. That is, the increase in the maximum horizontal reaction force is estimated to be 16.7%. The increased shear reaction is split between the bottom of the primary tank (contact interface with the insulating concrete) and the top of the primary tank (anchor bolts and normal and shear forces between steel and concrete dome).

With several load paths available to accommodate the increased shear force, not all of the additional shear will be reacted by the anchor bolts. Moreover, a significant portion of the anchor bolt demand (roughly 1/3) is from thermal and operating loads, which are largely unaffected by the presence of a sludge layer. With the above considerations in mind, the increase in the anchor bolt demands from this conservative estimate appears to be less than 10%. This upper bound estimate of the increase in anchor bolt loads is exclusive of several other notable conservative factors in the analysis including the following:

- The most recent site response analyses performed at the Hanford Site Waste Treatment Plant (WTP) show that the currently published design spectra for the WTP Site are significantly lower than the interim spectra published in 2005 (Youngs 2007). This indicates that the governing spectra being used for the DST analysis are likely to be conservative.
- The TOLA and seismic demands reported for the AP tanks do not credit any friction between the concrete dome and the steel tank. Initial indications are that the benefit of friction may reduce the demands by approximately 5%.

- So far, a simplified routine that smears spatial and temporal results has been used to calculate peak seismic demands. Use of a more refined methodology is estimated to reduce the seismic demand by approximately 5-10%.
- The assumption of a bulk modulus of 1.83 is conservative.

In lieu of further more detailed analysis, it appears that for a sludge height not exceeding one-third of the primary tank height, the potential increase in anchor bolt loads due to increased impulsive response is offset by the increase in capacity associated with the conservatism inherent to the analysis.

Due to the margins available in the primary tank stresses that are shown in Section 6.2, an even more conservative argument suffices to show that the increased dynamic pressures in the primary tank are acceptable. For this estimate, assume that *all of the tank waste responds impulsively*. In this case, the peak hydrodynamic wall pressure is independent of the vertical position along the tank wall and is given by

$$P_{wall}(\theta) = \rho_w \cdot R \cdot (S_A)_1 \cdot \cos(\theta).$$

The spectral acceleration for the impulsive mode of the primary tank and waste can be estimated from the impulsive mode frequency and in-structure response spectrum at the base of the primary tank.

The ANSYS® simulation for the increased liquid level shows an impulsive frequency of 5.78 Hz. The Dytran® simulations show 5.7 and 5.88 Hz depending on whether the input is single- or two-component motion. The effective impulsive damping from either model is in the range of 4% of critical damping. Based on the horizontal response spectrum shown in Figure 3-21 of Abatt and Rinker (2008), an upper bound estimate of the spectral acceleration for the impulsive mode of the primary tank is 0.35g. The corresponding peak dynamic wall pressure along the plane of excitation ($\theta=0$) is 10.4 lbf/in².

Figure 6-87 below is a reproduction of Figure 6-6 in Abatt and Rinker (2008) that includes the predicted waste pressures for the 100% impulsive response. In the critical middle third of the primary tank, the increase in *total gage pressure* (stress producing pressure) is 10-15%. Although the percentage increase in the dynamic pressure is higher, the waste pressures are dominated by the gravity-induced hydrostatic pressure over the majority of the tank. The increase in dynamic pressures associated with the increase in the impulsive response is mitigated by the superimposed static pressure. Thus, even with highly conservative assumptions, increases in the AP tank waste pressures and tank stresses are easily accommodated with the present analysis.

Figure 6-87. Comparison of Maximum Waste from the ANSYS® Primary Tank Sub-Model for Waste Elements at $\theta=0^\circ$ Subjected to Horizontal Seismic Excitation Only to Maximum Waste Pressures for the 100% Impulsive Case

Intentionally left blank.

7.0 Conclusions and Recommendations

The code evaluations reported in Chapter 6 for the AP tank model with 460 inches of 1.83 SpG waste do not reveal any structural deficiencies with the integrity of the DST. The analyses represent 60 years of use, which corresponds to an additional 40 years of use beyond the current date. The loads imposed on the model for the finite element analyses are significantly more severe than any service to date or proposed for the future. The material properties were selected to be lower bound and in the most severe combinations.

7.1 Reinforced Concrete

The reinforced concrete structure was evaluated in the manner required by ACI 349 (ACI 1990). Load combinations 1, 4 (which includes the seismic load), and 9 of the ACI code were evaluated for each combination of soil and concrete properties. The axial load and moment were evaluated on the load-moment interaction diagram for each individual cross section. The demand was demonstrated to be lower than the capacity at all locations for all load combinations. The cross-section shear demand was less than the capacity for all sections. The in-plane shear demand/capacity ratios were evaluated for the seismic loads and showed low values.

7.2 Primary Tank

The primary tank is governed by ASME B&PV Code, Section III, Division 1 (ASME 1992a). The allowable stress value, S_m , is provided by the code at operating temperature, which is defined to be 210°F for operating loads. This value at this temperature was used for all the stress intensity code checks regardless of temperature. All sections of the primary tank were checked to Service Level D requirements with $k = 2.0$. In all instances the factored inelastic general primary membrane stress intensity remained below the yield stress (which is lower than the allowable $2S_m$). The primary local membrane plus bending stress intensity remained below the code allowable value of $1.5 kS_m$, and the primary + secondary (thermal) stress intensity range remained below the code allowable value of $3.0 S_m$. Therefore, the primary tank is acceptable according to the established criteria.

7.3 Stress Corrosion Cracking

The use of the criterion limiting the primary tank principal stress on the inside surface to 90% of the yield strength of the steel to prevent stress corrosion cracking was discontinued with this analysis. The SCC report (Rinker et al. 2005) discouraged further use of this criterion, citing the lack of a technical basis. The fracture mechanics method developed in that report was extended to evaluate the bounding tank under the thermal and operating loads. The results when considered with the current crack growth rate testing show that SCC is unlikely if the present operating requirements are maintained. Analysis also showed that the propensity for SCC would not be increased after a seismic event.

7.4 Primary Tank Buckling

A large displacement finite element analysis method was developed to evaluate the potential for buckling of the primary tank. The method was shown to have good correlation with the ASME code case N-284 method. The primary tank buckling evaluation showed the current limit on demand of 12 inch w.g.

vacuum to exceed the ASME allowable of 10.4 inch. This determination was based on analysis at the full 60-year corrosion allowance on the tank wall of 0.060 inch. However, analysis at a corrosion allowance of 0.025 inch results in an acceptable demand/capacity ratio. Therefore, the current limit of 12 inches w.g. for the AP tanks is acceptable given the current lack of corrosion in the tanks. It should be noted that, as a result of the anchor bolt analysis, the maximum tank waste bulk temperature is reduced to 135°F. Therefore, the buckling analysis is now more conservative, which would allow for a corrosion allowance higher than 0.025 inch.

7.5 Concrete-Backed Liner

The evaluation criteria for the secondary steel liner are strain-based and taken from the ASME B&PV Code, Section III, Division 2, Subsection NC (ASME 1992a) for normal service loads. The results in all cases demonstrate that the secondary liner strains are all well below the allowable strain levels. Therefore, the secondary liner is judged to be adequate.

7.6 Anchor Bolts

Evaluation of the anchor bolts in the dome was conducted with the ACI/AISC strength reduction factor of 0.75. The combination of thermal and seismic loads was evaluated using a displacement-based criterion. In all cases the anchor bolts were within the allowable range for an operating waste temperature range of 80°F to 135°F. Therefore, the dome anchor bolts are considered to be satisfactory.

8.0 References

- Abatt FG. 1996. *Double-Shell Tank Useful Life Analysis*. WHC-SD-WM-ER-556, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Abatt FG and MW Rinker. 2008. *Hanford Double-Shell Tank Thermal and Seismic Project – Seismic Analysis of Increased Liquid Level for 241-AP Tank Farms*. RPP-RPT-32239, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.
- ACI. 1977. *American Concrete Institute Building Code Requirements for Structural Concrete*. ACI 318-77, American Concrete Institute, Detroit, Michigan.
- ACI. 1990. *American Concrete Institute Code Requirements for Nuclear Safety Related Concrete Structures*. ACI 349-90, American Concrete Institute, Detroit, Michigan.
- ACI. 2001. *American Concrete Institute Code Requirements for Nuclear Safety Related Concrete Structures*. ACI 349-01, American Concrete Institute, Detroit, Michigan.
- AISC. 2005. *Steel Construction Manual*, American Institute of Steel Construction, New York, New York.
- American Society of Mechanical Engineers (ASME). 1995. Code Case N-284-1, 1995, Metal Containment Shell Buckling Design Method, Class MC, Section III, Division 1. *ASME Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York.
- American Society of Mechanical Engineers (ASME). 1992a. Section III, Division 1, Subsection NC. “Class 2 Components.” *ASME Boiler and Pressure Vessel Code*. ASME, New York.
- American Society of Mechanical Engineers (ASME). 1992b. Section III, Division 2, “Rules for Construction of Nuclear Power Plant Components.” *ASME Boiler and Pressure Vessel Code*. ASME, New York.
- American Society of Mechanical Engineers (ASME). 1992c. Section III, Division 2, Subsection CC. “Concrete Containment.” *ASME Boiler and Pressure Vessel Code*. ASME, New York.
- American Society of Mechanical Engineers (ASME). 1992d. Section VIII, Division 2, “Pressure Vessels – Alternative Rules.” *ASME Boiler and Pressure Vessel Code*. ASME, New York.
- ASCE. 1986. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures*. ASCE Standard 4-86, American Society of Civil Engineers, New York, New York.
- ASCE. 1998. *Seismic Analysis of Safety-Related Nuclear Structures and Commentary*. ASCE 4-98, American Society of Civil Engineers, Reston, Virginia.
- ASTM. 1965. *American Society for Testing and Materials Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*. American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Bandyopadhyay K, A Cornell, C Costantino, R Kennedy, C Miller, and A Veletsos. 1995. *Seismic Design and Evaluation Guidelines for the Department of Energy High Level Waste Tanks and Appurtenances*. BNL 52361, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York.

Bandyopadhyay K. 1997. *Guidelines for Development of Structural Integrity, Programs for DOE High-Level Waste Storage Tanks*. BNL 52527, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York.

Blackburn LD. 1995a. *Recommended Test Program to Determine Crack Growth Rate in Double-Shell Tank Materials*. WHC-SD-WM-ETP-137 Rev. 0, prepared by ICF Kaiser Hanford Company for Westinghouse Hanford Company, Richland, Washington.

Blackburn LD. 1995b. *Nitrate Stress Corrosion Crack Growth Rate in Plain Carbon Steels*. WHC-SD-WM-ES-349 Rev. 0, prepared by ICF Kaiser Hanford Company for Westinghouse Hanford Company, Richland, Washington.

Blume and Associates. 1974. *Analysis of Underground Waste Storage Tanks 241-SY at Hanford, Washington*. ARH-R-172, URS/John A. Blume and Associates, Atlantic-Richfield Hanford Company, Richland, Washington.

BNFL. 2000. *Free-Field Analysis of HLW Vitrification Building*. CALC-W375HV-ST000004, Rev. 0, BNFL, Inc., Richland, Washington.

Brongers MP, CS Brossia, and C Mendez. 2005. *Investigation of Chemistry Factors Influencing Stress Corrosion Cracking Susceptibility of High-Level Waste in Double Shell Tank 241-AN-107*. RPP-RPT-28063, Rev. 0, prepared by CC Technologies Laboratories, Dublin, Ohio for ARES Corporation, Richland, Washington.

BNL. 1995. *Seismic Design and Evaluation Guidelines for the Department of Energy High Level Waste Storage Tanks and Appurtenances*. Report No. 52361, Engineering Research and Applications Division, Department of Advanced Technology, Brookhaven National Laboratory, Associated Universities, Inc. Upton, New York.

Day JP, AD Dymess, LJ Julyk, CJ Moore, WS Peterson, MA Scott, HP Shrivastava, JS Shulman, and TN Watts. 1995. *Structural Acceptance Criteria for the Evaluation of Existing Double-Shell Waste Storage Tanks Located at the Hanford Site, Richland, Washington*. WHC-SD-WM-DGS-003. Westinghouse Hanford Company, Richland, Washington.

DOE. 1989. *General Design Criteria*. DOE Order 6430.1A, U.S. Department of Energy, Washington, D.C.

DOE. 1993. *Natural Phenomena Hazards Mitigation*. DOE Order 5480.28, U.S. Department of Energy, Washington, D.C.

DOE. 2000. *Facility Safety*. DOE Order 420.1, U.S. Department of Energy, Washington, D.C.

DOE STD. 2002. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. DOE-STD-1020-2002, U.S. Department of Energy, Washington, D.C.

Duncan GP. 2003. *Double-Shell Tank Integrity Program Plan*, RPP-7574, Rev. 1A, CH2M HILL Hanford Group, Inc., Richland, Washington.

Garfield JS and RB Guenther. 1981. *Functional Design Criteria 214-AP Tank Farm Project B-340 Line Item FY-1983*. RHO-CK951-FDC-1, Rockwell Hanford Operations, Richland, Washington.

Han FC. 1996. *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks*. WHC-SD-TWR-RPT-002, Revision 0A, Westinghouse Hanford Company, Richland, Washington.

Hanford Engineering Services. 1968. *Specification for Primary and Secondary Steel Tanks*. HWS-7789, Hanford Engineering Services, Richland, Washington.

HNF-PRO-097. 2002. *Engineering Design and Evaluation (Natural Phenomena Hazard)*. Project Hanford Management System, Fluor Hanford Company, Richland, Washington.

IBC. 2000. *International Building Code 2003*. International Code Council, Inc.

Jensen CE. 2003. *Supplement 2 to Inspection Results for Double Shell Tank 241-AY-101 FY2003*. RPP-15763, CH2M HILL Hanford Group, Inc., Richland, Washington.

Jensen CE. 2005. *Ultrasonic Inspection Results for DST 241-AP-106 FY2005*. RPP-RPT-23205, CH2M HILL Hanford Group, Inc., Richland, Washington.

Johnson KI, SP Pilli, NK Karri, JE Deibler, and MW Rinker. 2006. *Hanford Double-Shell Tank Thermal and Seismic Project – Buckling Evaluation Methods and Results for the Primary Tanks*. RPP-RPT-28967, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Julyk LJ. 2002. *Assessment of Double-Shell Tank Internal Vacuum Specification Limits on Primary Tanks*. HNF-1838 Rev. 0-A, CH2M HILL Hanford Group, Inc., Richland, Washington.

Lam D and E El-Lobody. 2005. "Behavior of Headed Stud Shear Connectors in Composite Beam." *Journal of Structural Engineering* 31:1.

M&D. 2001a. *SASSI Analysis – HLW Preliminary SSI Evaluation*. Rev. 0, M&D Calculation No. 01-0010-HLW-2, M&D Professional Services, Richland, Washington.

M&D. 2001b. *SASSI Analysis – PT Preliminary SSI Evaluation*. Rev. 0, M&D Calculation No. 01-0010-PT-2, M&D Professional Services, Richland, Washington.

Mackey TC. 2004. *Design Loads for Tank Farm Facilities*. TFC-ENG-STD-06, CH2M HILL Hanford Group, Inc., Richland, Washington.

NUREG-0800. USNRC Standard Review Plan 3.7.1, Seismic Design Parameters, Revision 2, August 1989. U.S. Nuclear Regulatory Commission, Washington, D.C.

Ollgaard JG, RG Slutter, and JW Fisher. 1971. "Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete." *AISC Engineering Journal* 8:2.

Rinker MW and FG Abatt. 2006a. *Hanford Double Shell Tank Thermal and Seismic Project - Dytran Benchmark Analysis of Seismically Induced Fluid-Structure Interaction in a Hanford Double Shell Primary Tank*. RPP-RPT-28963, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW and FG Abatt. 2006b. *Hanford Double Shell Tank Thermal and Seismic Project - Dytran Benchmark Analysis of Seismically Induced Fluid-Structure Interaction Analysis in Flat-Top Tanks*. RPP-RPT-30807, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW, FG Abatt, BG Carpenter, and CA Hendrix. 2006a. *Hanford Double Shell Tank Thermal and Seismic Project - Establishment of Methodology for Time Domain Soil-Structure Interaction Analysis of a Hanford Double Shell Tank*. RPP-RPT-28964, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW, BG Carpenter, and FG Abatt. 2006b. *Hanford Double Shell Tank Thermal and Seismic Project - ANSYS Benchmark Analysis of Seismically Induced Fluid-Structure Interaction in a Hanford Double Shell Primary Tank*. RPP-RPT-28965, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW, BG Carpenter, C Hendrix, and FG Abatt. 2006c. *Hanford Double Shell Tank Thermal and Seismic Project - ANSYS Seismic Analysis of Hanford Double Shell Primary Tank*. RPP-RPT-28966, Rev. 0, M&D Professional Services, Richland, Washington.

Rinker MW, JE Deibler, KI Johnson, NK Karri, SP Pilli, FG Abatt, BG Carpenter, and CA Hendrix. 2006d. *Hanford Double-Shell Tank Thermal and Seismic Project – Summary of Combined Thermal and Operating Loads with Seismic Analysis*. RPP-RPT-28968, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW, JE Deibler, KI Johnson, SP Pilli, CE Guzman-Leong, and OD Mullen. 2004. *Hanford Double-Shell Tank Thermal and Seismic Project – Thermal and Operating Load Analysis*. RPP-RPT-23308, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW, FA Simonen, JE Deibler, KI Johnson, SR Gosselin, SP Pilli, and AB Johnson. 2005. *Evaluation and Recommendation of Stress Criteria for Stress Corrosion Cracking of Hanford Double-Shell Tanks*. RPP-RPT-27574, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW and RR Youngs. 2006. *Development of PC2 Surface Spectra for Double-Shell Tank Facilities, DOE Hanford Site in Washington State*. RPP-RPT-27570, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

SDC-4.1. 1993. *Standard Arch-Civil Design Criteria, Design Loads for Facilities*. Hanford Plant Standards, HPS-SDC-4.1, Rev. 12, U.S. Department of Energy, Richland, Washington.

Terry M, J Beavers, C Czajkowski, G Frankel, B Gordon, T Jones, R Jones, L Stock, B Wiersma, and P Zapp. 2004. *Expert Panel Workshop for Hanford Site Double-Shell Tank Waste Chemistry Optimization*. RPP-RPT-22126 Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

TWINS. 2008. Tank Waste Information Network System (TWINS) database. Data Source Selection Forms, Best Basis Inventory, Tank Density and Percent Water sub-directory.
<http://twins.pnl.gov/twins.htm>.

Tomaszewski TA. 2004. *Tank Farms Documented Safety Analysis, Rev. 1*. RPP-13033, Rev. 1, CH2M HILL Hanford Group, Inc., Richland, Washington.

UCRL. 1990. *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards*. U.S. DOE Report UCRL 15910, Lawrence Livermore National Laboratory, Livermore, California.

Youngs RR. 2007. *Updated Site Response Analyses for the Waste Treatment Plant, DOE Hanford Site, Washington*. PNNL-16653, GMX-9995.002-001, prepared by Geomatrix Consultants, Inc. for the Pacific Northwest National Laboratory.

Veletsos AS and AH Younan. 1998. *Dynamics of Solid-Containing Tanks. II: Flexible Tanks*. Journal of Structural Engineering.

Intentionally left blank.

Appendix A

Reviewer Comments and Resolution

Intentionally left blank.

Appendix A

A.1 Introduction

A series of project technical reviews were conducted subsequent to the initial Rev. 0 release of this report. These reviews raised a number of issues, including the anchor bolt evaluation and the primary tank lower knuckle mesh resolution. This appendix provides a chronological account of the reviewer comments and analytical responses.

At the June 2007 review meeting of the analyses on the Effect of Increased Liquid Level in 241-AP Tank Farms, the reviewers (RP Kennedy and AS Veletsos) raised concerns primarily with the anchor bolt evaluation. Changes to the anchor bolt modeling and evaluation were suggested and subsequently implemented. Further questions regarding the new anchor bolt modeling were raised at the March 2008 review. These comments were addressed and a further review was conducted by RE Klingner.

A.2 Reviewer Comments – Kennedy and Veletsos, July 2007

Comments Regarding Seismic Evaluation of Hanford Double-Shell Tanks and Effect of Increased Liquid Level in 241-AP Tank Farms

by

R. P. Kennedy and A. S. Veletsos
July 2007

A.2.1 Introduction

Based on our review of the seismic response analyses of the Hanford Double-Shell Tanks (DSTs) reported through February 2006, we provided in Ref. A.2.1 comments on the reported information and recommendations for requisite additional studies. In response to this input, previously reviewed reports (Refs. A.2.2, A.2.4, and A.2.5) have been modified and comprehensive Appendices have been added to them. In addition, a benchmark study (Ref. A.2.3) of seismically induced fluid-structure interaction in flat-top tanks has been performed using the DYTRAN computer program. Lastly, two reports (Refs. A.2.6 and A.2.7) evaluating the effects of increasing the waste in the 241-AP tanks to the 460-inch level have been prepared.

Our present input refers to the additional studies conducted since then, and it is based on:

- Our review of Refs. A.2.2 through A.2.7; and

- The presentations and ensuing discussions at the Review Meeting of June 7 and 8, 2007, in which we participated to provide an independent oversight and comment on the adequacy and completeness of the approach being used.

Our views and recommendations are presented under the following six topic headings.

A.2.2 Fluid-Structure Interaction Analyses of Primary Tanks

A.2.2.1 DYTRAN Analyses

Refs. A.2.2 and A.2.3 present a series of fluid-structure interaction analyses performed using computer program DYTRAN. The problem with the DYTRAN solution identified in Section 3.3 of Ref. A.2.1 has been addressed by using a more refined mesh in the tank region for which the fluid comes in contact with the roof.

We consider the DYTRAN fluid-structure interaction solutions obtained with the refined mesh to represent a good representation of the behavior of a homogeneous, incompressible, practically inviscid liquid in the tanks.

A.2.2.2 ANSYS Analyses

The ANSYS model continues to be used for the combined soil-structure-fluid interaction seismic evaluation of the tanks. As previously noted in Section 3.1 of Ref. A.2.1, this model conservatively overestimates the impulsive mode component of the hydrodynamic effects on the primary tank and underestimates the convective component of the effects. Because the impulsive mode of response dominates the fluid effects on the primary tank and because the ANSYS results are generally slightly higher than the DYTRAN results, we concur that the ANSYS model can continue to be used for the seismic evaluation of the soil-structure-fluid system. However, wherever critical, the convective and dome constrained fluid pressures near the surface of the liquid should be obtained from the DYTRAN solutions.

A.2.2.3 Modeling of Waste

In the seismic analyses of the Hanford DSTs conducted so far – as in all previous analyses of waste-containing tanks that we are aware of – the waste was effectively modeled as a homogeneous, incompressible, practically inviscid liquid. There are fundamental uncertainties in this idealization, and it would be highly desirable to assess their effect on critical responses.

We recommend that, as a minimum, a qualitative discussion be provided as to why it is considered acceptable to model the waste as a homogeneous liquid. From discussions on this issue during the June 7 and 8 meetings, we understand that the waste may appropriately be represented as:

1. Liquid with a specific gravity (SG) of 1.3 to 1.5 over at least the upper 2/3 of the waste height; and

2. Sludge with the consistency of over-saturated soil with a low angle of repose and a SG of 1.5 to 1.83 over the lower portion of the tank.

Based on this description, we concur that it is probably reasonable, as a first approximation, to model the waste as an incompressible liquid with a SG of at least 1.7. However, this aspect of the system modeling is likely to continue being of concern to some, especially in light of the currently available computational capabilities.

In defense of criticism that may legitimately be voiced on this issue, it is recommended that the critical responses of a simplified model of the tank-waste system (for example, one that does not provide for the effects of soil-structure interaction or the impact effects of the sloshing surface of the waste with the superimposed dome) be evaluated by representing the waste as a uniform, deformable solid with the properties of the lower portion of the waste. The computed responses must then be compared with those obtained for the liquid-like idealization of the waste.

A more realistic modeling of the waste and of the tank itself would be warranted only if the differences in the critical responses computed for the liquid-like and proposed representations of the waste are shown to be of practical significance.

A.2.2.4 Comparison of DYTRAN Results With Approximate Results Obtained Using Method of BNL Tank Report (Ref. A.2.8)

For the condition under which the sloshing liquid impacts the tank roof, Refs. A.2.2 and A.2.3 compare the DYTRAN-computed pressures and reactions with those estimated by the approximate method presented in Appendix D of the BNL tank report (Ref. A.2.8). However, both in Refs. A.2.2 and A.2.3, this appendix, particularly in sections dealing with wall pressures, has been misinterpreted.

Appendix D of Ref. A.2.8 provides the following equations for estimating the hydrodynamic pressures induced on the tank wall:

- Constrained impulsive pressure p_{ic} , defined by Equation (D.5)
- Unconstrained impulsive pressure p_{iu} , defined by Equation (D.6)
- Unconstrained convective pressure p_{cu} , defined by Equation (D.7)

For liquid that is constrained by the roof within the angle $|\theta| \leq \theta_c$, Appendix D approximates the hydrodynamic wall pressure p by:

$$\begin{array}{l} \text{for } |\theta| \leq \theta_c \\ p = p_{ic} \end{array} \quad (A.2.1)$$

$$\begin{array}{l} \text{for } |\theta| > \theta_c \\ p = \left[p_{iu}^2 + p_{cu}^2 \right]^{0.5} \end{array} \quad (A.2.2)$$

Instead, Refs. A.2.2 and A.2.3 have incorrectly used the expression:

$$\text{for } |\theta| \leq \theta_0$$

$$p = p_{ic} + p_{iu} + p_{cu} \quad (\text{A.2.3})$$

which leads to a substantial overestimation of the wall pressures.

For example, for the 480-inch liquid level results shown in Figure 4-9 of Ref. A.2.3, the correct values of the maximum absolute pressures determined by the approach of Appendix D of Ref. A.2.8 vary from 54.3 psi at the bottom to 23.9 psi at the top of the waste height. Similarly, the maximum gage pressure on the wall determined by this approach is 39.6 psi, which is in close agreement with the DYTRAN result of 37.8 psi. These results are only slightly greater than the DYTRAN computed maximum pressures.

Ref. A.2.3 also incorrectly computes the minimum pressures corresponding to $\theta = 180^\circ$ by subtracting the incorrectly defined pressure p obtained by application of Equation (A.2.3) from the hydrostatic pressure. The correct hydrodynamic pressure that must be subtracted from the static pressure is given by Equation (A.2.2). The resulting minimum pressure determined by the approach of Appendix D of Ref. A.2.8 is identical to the open top minimum pressure. Again, there is close agreement between the results computed by DYTRAN and those obtained by the approach of Appendix D.

A lesser problem exists with the peak horizontal reaction forces P reported in Refs. A.2.2 and A.2.3 based on the approach of Appendix D of Ref. A.2.8. The reaction forces, in the later approach should be determined from the expressions:

$$P_{ic} = \varepsilon \left(\frac{H_t}{H_\ell} \right) m_\ell (S_A)_i \quad (\text{A.2.4})$$

$$P_{iu} = (1 - \varepsilon) P_i \quad (\text{A.2.5})$$

$$P_{cu} = (1 - \varepsilon) P_c \quad (\text{A.2.6})$$

$$P = \left[(P_{ic} + P_{iu})^2 + P_{cu}^2 \right]^{0.5} \quad (\text{A.2.7})$$

where m_ℓ is the total liquid mass, $(S_A)_i$ is the spectral acceleration for the impulsive mode of response, H_t is the roof height, H_ℓ is the liquid height, ε is the fraction of the liquid that is constrained by the roof, and P_i and P_c are respectively the impulsive and convective components of the reactions for an open top (unconstrained) liquid surface.

For example, for the 480-inch liquid level, the peak horizontal reaction force P obtained by the approach of Appendix D should be 4.14×10^6 lbs as opposed to the 4.47×10^6 lbs reported in Figure 4.1 and Table 4.1 of Ref. A.2.3.

Furthermore, Appendix D of Ref. A.2.8 does not provide a method for estimating the peak value of the convective component of the reaction following the decay of the impulsive component. Neither P_{cu} (shown in Refs. A.2.2 and A.2.3) nor P_c are intended to represent the peak horizontal convective reaction

force. It is therefore recommended that no results be reported in tables such as Table 4-1 and figures such as Figure 4-2 of Ref. A.2.3 for the peak value of the convective component of the horizontal force obtained by the approach of Appendix D.

The maximum roof pressure of 16.2 psi gage reported in Table 4-1 of Ref. A.2.3 for the DYTRAN results is believed to be for the midheight of the top outermost fluid element closest to the wall-roof junction. However, in Figure 4-9 of Ref. A.2.3, the corresponding wall pressure for the same element is only about 26.7 psi absolute (corresponding to about 12.0 psi gage). Please explain why there is such a large difference between the roof pressure and wall pressure for this same fluid element.

We recommend that the results obtained by the approach of Appendix D of Ref. A.2.8 shown in Sections 4 and 5 and Appendix B of Ref. A.2.3, and in Appendices C and D of Ref. A.2.2 be corrected so as not to lead others astray when using the approximate method. Correcting these results will also help to demonstrate the reasonableness of the DYTRAN results.

A.2.3 Anchorage of Primary Tank Steel Dome to Concrete Vault Dome

Shearing forces and tensile forces between the primary tank steel dome and the concrete vault dome are transferred by ½-inch diameter anchors. These anchors consist of either 6-inch long headed anchor bolts or 6-inch long J-bolts with a 180° J-hook at their upper end. These anchor bolts are screwed into ¾-inch diameter by 1.375-inch high Nelson tapped welding studs welded to the steel dome.

The tensile loads on these anchors are small. However, the shear loads are significant.

In Ref. A.2.1 we stated that:

Neither of us is familiar with the basis of the acceptance criteria for the reported allowables. Furthermore, we do not have sufficient information regarding the Nelson Internally Threaded Studs used to attach the J-bolts to the steel tank so that we may assess the appropriateness of the indicated allowables.

The basis for the tension and shear allowables for these anchors has now been provided in Section 6.1 of Ref. A.2.4 and Section E.3 of Ref. A.2.5.

Based on our review of these sections, we have concerns about the allowable capacities assigned to the anchors. We also wish to comment on the demands computed for these anchors.

A.2.3.1 Allowable Anchor Bolt Capacities

From Table 6-3 of Ref. A.2.4, the allowable anchor tension T_a and shear V_a are defined by the following expressions:

For Normal (Operating) Loads

$$T_a = 0.33 T_u \quad (A.2.8a)$$

$$V_a = 0.33 V_u \quad (A.2.8b)$$

For Abnormal (Operating + Seismic) Loads

$$T_u = 0.5 T_u \quad (\text{A.2.9a})$$

$$V_u = 0.5 V_u \quad (\text{A.2.9b})$$

where T_u and V_u represent the nominal ultimate tensile and shear capacities of the anchors, respectively. We understand that the tank criteria document specifies the use of these ASME code factors of 0.33 and 0.5. These factors are lower (more conservative) than the strength reduction factors ϕ in both the AISC Code (Ref. A.2.9) for steel and the ACI Code (Ref. A.2.10) for concrete.

A.2.3.1.1 Nominal Ultimate Tensile Strength for Headed Bolts

Table 6-3 of Ref. A.2.4 bases the nominal ultimate tensile capacity of the anchors on:

$$T_u = (2/3) A_b f_u \quad (\text{A.2.10})$$

where $A_b = 0.1963 \text{ inch}^2$ is the cross-sectional area of the bolt shank, and $f_u = 60 \text{ ksi}$ is the ultimate strength of the bolt material. Thus:

$$T_u = 7.85 \text{ kips} \quad (\text{A.2.11})$$

which is slightly less (more conservative) than the nominal T_u computed in accordance with AISC (Ref. A.2.9) or ACI (Ref. A.2.10).

However, Refs. A.2.4 and A.2.5 do not check the anchor tensile capacity as governed by the concrete breakout strength T_{ub} :

$$T_{ub} = 24(f'_c)^{0.5} h^{1.5} \quad (\text{A.2.12})$$

where $f'_c = 4860 \text{ psi}$ is the concrete strength, and $h = 6 \text{ inches}$ is the bolt length. Neither is the concrete pullout strength, T_{up} , defined by:

$$T_{up} = 8f'_c A_{brg} \quad (\text{A.2.13})$$

checked, where $A_{brg} = 0.2959 \text{ inch}$ is the bearing area of the head on a $1/2 \text{ inch}$ bolt. The values obtained from Equations (A.2.12) and (A.2.13) are:

$$T_{ub} = 24.6 \text{ kips} \quad (\text{A.2.14})$$

$$T_{up} = 11.5 \text{ kips} \quad (\text{A.2.15})$$

These concrete failure modes do not control the nominal ultimate tensile capacity T_u for the headed anchor bolts. Even so, these concrete failure mode tensile capacities should be computed.

In conclusion, the tensile capacity $T_u=7.85$ kips presented in Table 6-3 of Ref. A.2.4 is considered to be reasonable for the headed anchor bolts.

A.2.3.1.2 Nominal Ultimate Tensile Strength for J-Bolt Anchors

J-Bolt anchors are not permitted by either AISC or ACI for positive tensile anchorage. See, for example, page 14-10 of Ref. A.2.9. Therefore, no approach is provided in either Ref. A.2.9 or A.2.10 for computing the ultimate tension capacity of J-Bolt anchors.

A criterion for determining the nominal ultimate capacity of J-Bolt anchors is provided in older versions of the British Standard CP110 (Ref. A.2.11). Based on this Standard, the ultimate bond tensile capacity T_{ub} for J-Bolt anchors is defined by:

$$T_{ub} = \pi d_b f_{bs} \ell_e \quad (A.2.16)$$

where d_b is the bar diameter, f_{bs} is the concrete bond strength for a smooth-bar, and ℓ_e is the effective bar length given by:

$$\ell_e = \ell_s + \ell_h \quad (A.2.17)$$

$$\ell_h \leq 24 d_b \quad (A.2.18)$$

where ℓ_s is the straight bar length to the start of the hook, and ℓ_h is the inside radius length of the hook plus any straight extension beyond the hook, provided ℓ_h is limited to not more than $24 d_b$. For concrete with f'_c greater than 4600 psi, CP110 limits the smooth-bar bond-strength to:

$$f_{bs} = 275 \text{ psi} \quad (A.2.19)$$

We suggest that the bond-slip capacity of the J-Bolt anchors might control their ultimate tensile capacity T_u rather than the steel bolt shank capacity $T_u=7.85$ kips given by Equation (A.2.11). One possible approach for estimating the bond-slip capacity is to use Equations (A.2.16) through (A.2.19).

A.2.3.1.3 Nominal Ultimate Shear Strength for Anchor Bolts

In Table 6-3 of Ref. A.2.4, ultimate shear strength values V_u based both on a steel failure limit and on a concrete failure limit were computed using the following expressions:

For Steel Failure Limit

$$V_{us} = 0.9 A_s f_u \quad (A.2.20)$$

For Concrete Failure Limit

$$V_{uc} = 5.66 A_s f_c^{0.3} E_c^{0.44} \quad (A.2.21)$$

In Table 6-3 of Ref. 4 the full cross-sectional area $A_s=0.442 \text{ in}^2$ of the $\frac{3}{4}$ -inch diameter Nelson tapped welding stud was used in both Equations (A.20) and (A.21) to obtain:

$$V_{us} = 23.86 \text{ kips} \quad (A.2.22)$$

$$V_{uc} = 23.42 \text{ kips} \quad (A.2.23)$$

In our judgment, it is inappropriate to use $A_s=0.442 \text{ in}^2$ in Equation (A.2.21) for the concrete failure limit V_{uc} . This equation was based on extensive test data for headed studs with a length of at least four stud diameters and is unconservative for lesser bearing lengths. For a $\frac{3}{4}$ -inch diameter stud, the required length is 3.0 inches. However, the Nelson tapped welding stud is only 1.375 inch long. Over the remainder of the required 3.0 inch length, the concrete bears against a $\frac{1}{2}$ inch bolt instead of a $\frac{3}{4}$ inch stud.

The required bearing area A_{bear} to obtain the V_{uc} capacity is:

Required

$$A_{bear} = 4\left(\frac{3}{4} \text{ in}\right)^2 = 2.25 \text{ in}^2 \quad (\text{A.2.24})$$

However, the available bearing area in the 3 inch length is only:

Available

$$A_{bear} = 1.375 \text{ in} \left(\frac{3}{4} \text{ in}\right) + 1.625 \text{ in} \left(\frac{1}{2} \text{ in}\right) = 1.844 \text{ in}^2 \quad (\text{A.2.25})$$

Conservatively assuming a uniform bearing pressure over the required 3 inch length, V_{uc} should be reduced to:

$$V_{uc} = (1.844/2.25)(23.42) = 19.19 \text{ kips} \quad (\text{A.2.26})$$

for an average bearing pressure on the concrete of:

$$f_{bear} = \frac{19.19}{1.844} = 10.4 \text{ ksi} \quad (\text{A.2.27})$$

It is undoubtedly conservative to assume a uniform bearing pressure over the 3-inch length. In reality, bearing pressure will be concentrated closer to the base and this concentration will lead to a higher V_{uc} than that given by Equation (A.2.26). However, for a 4.86 ksi concrete, it is not clear how much higher than 10.4 ksi the bearing pressure can become without crushing the concrete.

It is also not appropriate to use the full $A_s=0.442 \text{ in}^2$ to determine the steel failure limit V_{us} . Immediately above the base, the cross-sectional area of the $\frac{3}{4}$ -inch Nelson tapped welding stud is reduced by the tapped threaded hole. Using the diameter midway between the minor and pitch diameter of the threaded hole, the reduction in cross-sectional area becomes 0.1416 inch. Thus, the effective shear area A_{se} of the welding stud is:

$$A_{se} = 0.4418 - 0.1416 = 0.300 \text{ in}^2 \quad (\text{A.2.28})$$

and with $f_u=60 \text{ ksi}$, Equation (A.2.20) yields:

$$V_{us} = 0.9(0.300)(60) = 16.2 \text{ kips} \quad (\text{A.2.29})$$

Another location that might control the ultimate shear capacity of the anchorage is the $\frac{1}{2}$ inch anchor bolt shaft at its junction with the Nelson tapped welding stud. Based on Equation (A.2.20), the shear capacity V_{ub} for the bolt shank is:

$$V_{ub} = 0.9(0.1963 \text{ in}^2)(60 \text{ ksi}) = 10.60 \text{ kips} \quad (\text{A.2.30})$$

Conservatively assuming a uniform bearing pressure $f_{bear} = 10.4 \text{ ksi}$ and a bearing area $A_{bear} = 1.375(3/4) = 1.031 \text{ in}^2$ for the welding stud, the corresponding ultimate shear capacity at the base of the welding stud is:

$$V_{usb} = V_{ub} + f_{bear} A_{bear} = 21.3 \text{ kips} \quad (\text{A.2.31})$$

which is not the controlling capacity.

The ultimate shear capacity, V_u , of the anchors seems to be controlled by the V_{us} value determined from Equation (A.2.20). Thus:

$$V_u = 16.2 \text{ kips} \quad (\text{A.2.32})$$

which is only 69% of the value reported in Table 6-3 of Ref. 4 for these anchors.

A.2.3.2 Recommendation for Finite Element Analysis of Anchor Bolts

We recommend that a detailed nonlinear finite element model be developed for an anchor in the concrete dome so as to determine its load-deformation relationship in shear. The model must include: (1) a realistic stress-strain relationship for the Nelson welding stud and stud bolt, (2) realistic nonlinear constitutive properties for compression, shear, and tension in the concrete, (3) a bond shear limit between the anchor and concrete of no more than 250 psi, and (4) a coefficient of friction between the anchor and concrete of no more than 0.2, with friction induced stresses not being additive to the bond induced stresses since friction activates after the bond is broken.

It is unlikely that this finite element analysis would justify the use of an ultimate shear strength higher than the 16.2 kips value, since the shear area is reduced by the tapped hole in the Nelson welding stud and the bolt does not extend to the bottom of this tapped hole. However, the analysis is likely to show significant shear distortions at an allowable shear load $V_a = 0.5V_u = 8.1 \text{ kips}$. The results of this analysis could be then used to determine if a lower shear stiffness than that currently considered for the anchors would be appropriate to use in the demand analyses.

As shown in Figures 6-25 and 6-26 of Ref. 4, the reported demand analyses indicate the total shear between the primary tank steel dome and the concrete vault roof is heavily concentrated on the outermost anchor bolts. We expect that reducing the shear stiffness of the anchors below the level used in the demand evaluations presented so far will redistribute the shear to more anchors and will reduce the shear demands on the outermost anchors.

A.2.3.3 Other Comments on Anchor Bolt Demand

A.2.3.3.1 Anchor Bolt Demand for 422 Inch Waste Level

In Ref. 12, the shear demand in the outermost anchor bolts for the combination of gravity and seismic loads was reported to be:

$$V_{bs} = 5.4 \text{ kips/bolt} \quad (\text{A.2.33})$$

for the 'Best Estimate Soil-Fully Cracked Concrete' (BES-FCC) Case. This value was obtained from an analysis in which the coefficient of friction, COF, between the steel and concrete was taken as 0.4.

In Ref. 1 we commented that a COF value of 0.4 was too high to use once sliding was initiated and the anchor bolts begin to pick-up shear load. Therefore, the seismic analysis was rerun with COF=0 for 'Best-Estimate Soil-Best Estimate Concrete' (BES-BEC) Case which is not the critical BES-FCC Case that we had recommended to be considered. For the BES-BEC Case, the shear V_{bs} increased from 4.052 kips for COF=0.4 to 4.591 kips for COF=0, or by a factor of 1.133. Applying the same amplification factor to the BES-FCC Case leads to:

BES-FCC Case (COF=0)

$$V_{bs} = 5.4(1.133) = 6.1 \text{ kips} \quad (\text{A.2.34})$$

However, in Section 6.3 of Ref. 4 the seismically induced shear demand $V_{bs}=4.6$ kips was used to evaluate the Demand to Capacity ratio (D/C) of the anchors. We believe that the appropriate seismic shear demand should have been $V_{bs}=6.1$ kips.

The seismic shear demand $V_{bs}=4.6$ kips in Ref. 4 was then combined with the shear demand V_{bc} on the outermost anchor induced by axial compression in the tank wall resulting from thermal expansion of the steel tank and axial shortening of the concrete vault due to concrete creep. The maximum permissible axial compressive force was then determined from the permissible $V_{bc}=V_a-V_{bs}=11.7 \text{ kips}-4.6 \text{ kips}=7.1 \text{ kips}$.

Increasing V_{bs} from 4.6 kips to 6.1 kips and decreasing V_a from 11.7 kips to 8.1 kips will substantially reduce the allowable axial compression in the tank wall due to temperature and creep effects since V_{bc} is reduced to $8.1 \text{ kips}-6.1 \text{ kips}=2.0 \text{ kips}$.

However, the temperature and creep induced axial compression in the tank wall occurs only when significant compressive normal forces exist between the primary tank dome and the concrete vault roof. Under these conditions, even a low COF value of 0.2, which we previously accepted in Ref. 1, is likely to reduce the V_{bc} demand.

In summary, we do not concur with the D/C evaluation of the J-Bolt anchors presented in Sections 6.1 through 6.3 of Ref. 4 and summarized in Section 6.6 of Ref. 5 because:

1. The reported ultimate shear capacity V_u of the anchors appears to be significantly unconservative; and
2. Both conservative and unconservative aspects appear to exist in the anchorage demand evaluations.

A.2.3.3.2 Anchor Bolt Demand for 460 Inch Waste Level

For the anchorage of the steel dome to the concrete roof and the combination of gravity and seismic loads, Ref. 6 reports a shear demand V_{bs} in the outermost anchors of 9.0 kips. This V_{bs} represents an approximate factor of 1.5 increase resulting from increasing the waste height from 422 inches to 460 inches and increasing the waste SG from 1.7 to 1.83. This increase seems reasonable, because with the increased waste level, a greater fraction of the total seismically induced horizontal reaction gets transferred to the concrete vault roof.

For the waste level considered, it is not clear how the temperatures and creep induced shear, V_{bc} , is combined with V_{bs} in Section 6.6 of Ref. 7. No explanation is provided on how the total shear demand V_b on the outermost anchor bolts was obtained. However, based on an allowable $V_a=11.7$ kips, the maximum D/C ratio is shown in Figure 6-86 of Ref. 7 to be about 0.88, which would correspond to a combined total shear demand:

$$V_b = 0.88(11.71 \text{ kips}) = 10.3 \text{ kips} \quad (\text{A.2.35})$$

This combined shear demand is only 1.3 kips higher than the value of $V_{bs}=9.0$ kips obtained for gravity and seismic loads only. The small effect of the V_{bc} in this case does not appear to be consistent with the result reported in Section 6.3 of Ref. 4 for the 422 inch waste level.

A seismic shear demand of $V_{bs}=9.0$ kips compounds the issues that arise if the ultimate shear capacity V_u is reduced to 16.2 kips and the allowable shear capacity V_a is reduced to 8.1 kips. The computed seismic shear demand alone for the outermost anchor exceeds this allowable shear capacity.

One should reconsider whether it is really necessary to define the allowable shear:

$$V_a = 0.5 V_u \quad (\text{A.2.36})$$

as is currently required by the project criteria for Abnormal (Operating + Seismic) Loads. Both AISC (Ref. 9) and ACI (Ref. 10) would permit the use of a strength reduction factor $\phi=0.75$, which would increase the allowable V_a for a given V_u by a factor of 1.5.

A.2.4 Buckling Evaluations

We concur with the approach for the buckling evaluation of the tank wall presented in Ref. 4 and summarized in Section 6.4 of Ref. 5 for a generic tank. The same approach and results are summarized in Section 6.4 of Ref. 7 for the AP tanks with the increased waste height.

A.2.5 Seismic Induced Stressed in Lower Knuckle of Primary Tank

The lower knuckle of the primary tank is too crudely modeled in the global analysis of the soil-structure-waste system to accurately define the peak values of the stresses induced in it. To provide for this inadequacy, the maximum values of the stresses determined in the global analysis for this region were increased by a factor of 2.0. We understand that this factor was based on the increase in maximum stresses determined for a refined model of the knuckle considering the effects of the hydrostatic pressures only.

While this amplification factor may indeed be adequate for the hydrostatic effects, we are concerned that it may not be adequate for the seismically induced effects. As the seismic loading, unlike the hydrostatic, induces a substantive axial force in the tank-wall, we expect the increase of the bending stresses in the knuckle to be larger for the seismic loading than for the hydrostatic.

We recommend that the stresses in the refined local model of the lower knuckle be determined using the maximum values of the boundary forces and of the associated pressures computed in the seismic analysis of the global model. A comparison of the absolute maximum values of the resulting stresses with those obtained by the global model would then provide a more defensible estimate of the amplification factor that should be applied to the seismically induced effects determined with the global model.

Alternatively – although this option is not as desirable – an approximate estimate of the requisite amplification factor may be determined by a static analysis similar to the one used, provided the vertical and circumferential distributions of the pressures considered are representative of those of the impulsive component of the seismically induced pressures.

Considering that some of the reported analyses indicate the absolute maximum stresses to occur in the base plate, slightly beyond the lower end of the knuckle, it is important that the local model does include this region.

A.2.6 Comments in Inelastic Factor and Nonlinear Response

So long as these tanks are considered to be PC#2 structures, we concur with the use of a Response Modification Factor $R=2.5$ coupled with an Importance Factor $I=1.5$ which results in an Inelastic Factor:

$$F_{\mu} \frac{R}{I} = 1.67 \quad (\text{A.2.37})$$

For ductile failure modes, the computed seismic demands can be reduced by $F_u=1.67$ before being combined with non-seismic demands. For brittle failure modes such as J-bolt anchorage failure and buckling, no credit should be taken for the Inelastic Factor (i.e., $F_u=1.0$).

In addition, wherever credit is taken for the Inelastic Factor $F_u=1.67$, the ASME Code allowable stresses defined by Equations (A.37) through (A.40) of Ref. 5 should be limited to:

$$kS_m \leq S_y \quad (\text{A.2.38})$$

$$1.5k S_m \leq 1.5 S_y \quad (\text{A.2.39})$$

$$3S_m \leq 1.5 S_y \quad (\text{A.2.40})$$

where S_y is the yield stress. These limits should be applied to insure that the effect of inelastic behavior is not double-counted.

However, we are concerned with the statements on Pages i, 6.16, and 7.1 that primary stresses remain below yield, and that gross plastic deformation does not occur. The use of $F_u=1.67$ automatically implies that gross plastic deformation has occurred during the transient seismic response. In fact, in order to develop an F_u of 1.67, the gross deformation (elastic + plastic) during transient seismic response needs to be about 1.5 to 2.0 times the yield deformation of the structure (i.e., transient gross plastic deformations are about 0.5 to 1.0 times the yield deformation). At the end of the seismic event some residual stresses will remain in the yielding elements of the structure. However, it is not expected that the further operability or future seismic margin will appreciably be impaired by this level of inelastic response, although the potential for future stress-controlled cracking may increase.

If it is necessary to prevent gross plastic deformation, a value of $F_u=1.0$ should be used. In this case, the limits imposed by Equations (A.2.38) through (A.2.40) would no longer be necessary.

Lastly, we do not recommend the use of the $R=3$ factor discussed in the second paragraph on Page 6.17 of Ref. 5. We consider $R=2.5$ to be reasonable, but not conservative. We further believe that it would be difficult to defend the view that there is sufficient inelastic energy dissipation capability in these tanks so as to justify the use of $R=3$ (i.e., $F_u=2.0$).

A.2.7 References

Kennedy RP and AS Veletsos. 2006. *Additional Comments and Recommendations Concerning Seismic Evaluation of Hanford Double-Shell Tanks*.

Rinker MW and FG Abatt. 2006. *Hanford Thermal and Seismic Project-DYTRAN Analysis of Seismically Induced Fluid-Structure Interaction on a Hanford Double-Shell Primary Tank*. RPP-RPT-28963, Rev. 0A, Pacific Northwest National Laboratory, Richland, Washington.

Abatt FG and MW Rinker. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-DYTRAN Benchmark Analysis of Seismically Induced Fluid-Structure Interaction in Flat-Top Tanks*. RPP-RPT-30807, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Johnson KI et al. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Buckling Evaluation Methods and Results for the Primary Tanks*. RPP-RPT-28967, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Deibler JE et al. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Summary of Combined Thermal and Operating Loads with Seismic Analysis*. RPP-RPT-28968, Rev. 0-A, Pacific Northwest National Laboratory, Richland, Washington.

Abatt FG, BG Carpenter, and MW Rinker. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Seismic Analysis in Support of Increased Liquid Level in 241-AP Tank Farms*. RPP-RPT-32239, Rev.0, Pacific Northwest National Laboratory, Richland, Washington.

Deibler JE et al. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Increased Liquid Level Analysis for 241-AP Tank Farms*. RPP-RPT-32237, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Bandyopadhyay K et al. 1995. *Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances*. BNL 52361, Brookhaven National Laboratory, Upton, New York.

AISC, *Steel Construction Manual*, Thirteenth Edition, 2005.

ACI 349-01, *Code Requirements for Nuclear Safety Related Concrete Structures*, 2001.

British Standards Institution, *The Structural Use of Concrete Part 1: Design, Materials, and Workmanship*, London, CP110 Part 1, 1972, as amended in November 1980.

Carpenter BG, C Hendrix, and GG Abatt. 2006. *ANSYS Seismic Analysis of Hanford Double-Shell Primary Tank*. M&D-2008-004-CALC-001, Rev. 0A, Draft, M&D Professional Services, Inc.

A.3 Anchor Bolt Modeling and Evaluation

Reevaluation of the DST Anchor Bolts for the Increased Waste Level in AP Tanks

by

M. W. Rinker, J. E. Deibler, K. I. Johnson, and F. G. Abatt
 PNNL and M&D
 December 17, 2007

A.3.1 Introduction

At the June 2007 review meeting of the PNNL analyses on the Effect of Increased Liquid Level in 241-AP Tank Farms, the reviewers raised concerns with the anchor bolt evaluation. In particular, *"we do not concur with the D/C evaluation of the J-bolt anchors presented in Sections 6.1 through 6.3 of Ref. 4 and summarized in Section 6.6 of Ref. 5 because:*

3. *The reported ultimate shear capacity V_u of the anchors appears to be significantly unconservative; and*
4. *Both conservative and unconservative aspects appear to exist in the anchorage demand evaluations."*

The reviewers' recommendation and arguments are as follows:

"We recommend that a detailed nonlinear finite element model be developed for an anchor in the concrete dome so as to determine its load-deformation relationship in shear. The model must include: (1) a realistic stress-strain relationship for the Nelson welding stud and stud bolt, (2) realistic nonlinear constitutive properties for compression, shear, and tension in the concrete, (3) a bond shear limit between the anchor and concrete of no more than 250 psi, and (4) a coefficient of friction between the anchor and concrete of no more than 0.2, with friction induced stresses not being additive to the bond induced stresses since friction activates after the bond is broken.

It is unlikely that this finite element analysis would justify the use of an ultimate shear strength higher than the 16.2 kips value, since the shear area is reduced by the tapped hole in the Nelson welding stud and the bolt does not extend to the bottom of this tapped hole. However, the analysis is likely to show significant shear distortions at an allowable shear load $V_a = 0.5V_u = 8.1$ kips. The results of this analysis could be then used to determine if a lower shear stiffness than that currently considered for the anchors would be appropriate to use in the demand analyses.

As shown in Figs. 6-25 and 6-26 of Ref. 4, the reported demand analyses indicate the total shear between the primary tank steel dome and the concrete vault roof is heavily concentrated on the outermost anchor bolts. We expect that reducing the shear stiffness of the anchors below the level used in the demand evaluations presented so far will redistribute the shear to more anchors and will reduce the shear demands on the outermost anchors.”

This document summarizes our responses to the reviewer’s comments regarding the anchor integrity and describes the resolution to the issues raised. Briefly, we concur that the anchor shear capacity used in the previous analyses is unconservative. However, we will demonstrate that by

- 1) adopting the ACI 349 evaluation criteria for the AP tanks
- 2) limiting the temperature range (ΔT) to 55°F based on reduced tank temperature ranges and an anchor bolt stress-free temperature of 80°F
- 3) using an equivalent linear shear stiffness (secant modulus) to represent the shear response of the anchor bolts in the finite element models to allow limited shear deformation,

the anchor bolt capacity is greater than the demand for the AP tanks at the 460 inch waste depth.

A.3.2 Background

The anchor bolts are used to attach the steel primary tank in the tank dome and the steel secondary liner in the wall to the secondary concrete tank. The anchor bolts take several different forms, depending on the tank family. The AY, AZ, and SY tanks use J-bolts (or hooked bolts with 180 degree bend to use the terminology of ACI-318). The AN and AW tanks use L-bolts (hooked bolts with 90 degree bend). The AP tanks use headed studs. The original thermal and operating loads analysis (TOLA) report (RPP-RPT-23308) appropriately used the terminology “J-Bolts” as that model was largely based on the AY tank. However, that nomenclature was inadvertently preserved in the 241-AP Increased Liquid Level reports. This will be corrected in the future revision to these reports.

Common to all the tanks is the use of a 3/4 inch external diameter by 1-3/8 inch long internally threaded weld stud (Nelson TBL shown in Figure A.3-1) that is welded onto the steel tank or liner. The 1/2 inch anchor bolt, whether J, L, or headed stud is then threaded into this stud. A cursory review of the stud geometry as shown in Figure A.3-1 suggests that there may be adequate material at the 3/4 inch diameter at the base of the stud to transfer the shear load.

Figure A.3-1. Nelson TBL Internally Threaded Stud

Table A.3-1a. Nelson TBL Weld Stud Dimensions

Stud Diameter	Maximum Tap Size C	Minimum Values				Burn Off	E	F	Flash Clearance
		D	A	L	S				
3/4	5/8-11	0.750	0.937	0.406	0.250	0.187	1.062	0.250	1.125

Table A.3-1b. Nelson TBL Thread Dimensions

Thread Size	Minimum OD	Length of Engagement for Full Strength	Imperfect Thread Depth	Solid Weld Base
1/2 - 13	0.625	0.750	0.319	0.218

The nominal 3/4 inch diameter stud dimensions listed in Table A.3-1a were extracted from the Nelson Stud Welding (NSW) catalog. The additional thread dimensions listed in Table A.3-1b were obtained from NSW in response to questions arising from the initial uncertainty in the dimensions of the as-installed stud. The 1-3/8 inch (1.375) length TBL stud with a 1/2-13 thread requires 0.75 inch thread length. The remaining 0.625 inch length also includes 0.319 inch imperfect thread length. The final 0.306 inch length of the solid weld base exceeds the NSW specified minimum of 0.218 inch. The welding process consumes 0.187 inch of the base leaving 0.119 inch solid material. These dimensions formed the basis of the finite element model described below.

A.3.2.1 Correlation of Finite Element Models with Anchor Bolt Shear Tests

A combined experimental and modeling study (Lam and El-Lobody 2005) by the University of Leeds provided a convenient benchmark for developing finite element models of anchor bolts loaded in shear. An ANSYS model of the Leeds anchor bolt test was constructed and compared with the experimental and ABAQUS results reported in the Leeds paper. This comparison validates the selection of element type, mesh resolution and material models. Once confidence in the method was obtained, a model of a standard 3/4 inch headed stud was constructed. This was followed by a model of the AP configuration anchor bolt with the internally threaded weld stud and headed anchor bolt.

The shear strength predicted by the model was compared with the values recommended by the reviewers. The load-displacement response of the ANSYS model established the shear stiffness response of the anchor bolt. As suggested by the reviewers, this nonlinear stiffness can be used in the TOLA and seismic models to evaluate the potential redistribution of shear loads.

The ABAQUS model from the Leeds paper is shown in Figure A.3-2. The corresponding ANSYS model is shown in Figure A.3-3. The shear connector (anchor) is 19 mm (3/4 inch) diameter and 100 mm (4 inch) length. The push-off test specimen is similar to the standard test established by the British Standards Institution.

Figure A.3-2. ABAQUS Model

Figure A.3-3. ANSYS Model

A key feature of the ABAQUS analysis is the use of a simple elastic-plastic material model for the concrete. The yield strength was taken as the compressive strength of the concrete. The Leeds paper mentions 3 different concrete strengths: cube strength, compressive strength and cylinder compressive strength. The interplay between the different strengths was not precisely defined, but running the model with the various values helped narrow the definition. Four different concrete slab strengths were tested.

Figure A.3-4 shows the load-displacement curve for the SP-3 concrete, which is closest in strength to the Hanford AP concrete ($f_c = 5$ ksi). The plot includes curves for the experimental tests, the ABAQUS results and the ANSYS results. Note that quite good correlation is achieved between the experimental test, the ABAQUS results and the ANSYS results. Results from the other models with different concrete strengths showed similar good correlation.

Figure A.3-4. SP-3 Load-Displacement Results

With satisfactory results from the comparison to the Leeds experimental and modeling results, the FE modeling progressed to a standard 3/4 inch Nelson headed stud for which published test data exists. A standard 3/4 inch headed anchor bolt model is shown in Figure A.3-5. The length was taken as the minimum required of 4 times the diameter, or 3 inches. Figure A.3-6 shows the comparison with the Ollgaard (1971) data.

Figure A.3-5. 3/4 Inch Headed Stud Anchor Bolt Model

Figure A.3-6. 3/4 Inch Headed Stud Load-Displacement Results

Figure A.3-7 shows the AP anchor bolt model. As described earlier, the solid region at the base of the stud is defined to be 0.119 inch high. The annular region is defined to be 0.406 inch high. The dimensions of the weld flash are taken from NSW specifications.

Figure A.3-7. AP Anchor Bolt Model

Figure A.3-8 shows the load-displacement response. The annular area of the TBL stud results in a lower strength than the full 3/4 inch stud. Figure A.3-9 shows the shear deformation that occurs in the TBL stud.

Figure A.3-10 shows results from several additional analyses that were conducted to gain an understanding of the effect of the length of the solid section at the base of the weld stud. The AP 1" curve and AP 2" curve are models with the solid base height increased to 1 inch and 2 inches, respectively. The overall anchor bolt embedment was maintained at 6 inches. Note that the load carrying ability increases but remains below the standard 3/4 inch headed stud even with a 2 inch base. The conclusion from the finite element anchor bolt study is that an ultimate shear load, $V_{UN} = 14.3$ kips, is appropriate for the welded/threaded anchor studs used in the AP tanks. This is compared to the 16.2 kip shear strength that was estimated by the reviewers. The more conservative 14.3 kip value is used later in this section to calculate the equivalent secant modulus for the equivalent linear modulus of the anchor studs.

Figure A.3-8. AP – 3/4 Inch Headed Stud Comparison

Figure A.3-9. Anchor Bolt Shear Deformation

Figure A.3-10. Load-Displacement Results

A.3.2.2 AP Anchor Bolt Shear Displacement Allowable and Secant Modulus Stiffness

In discussions held with the reviewers subsequent to the June review meeting, it was suggested that consideration be given to using an anchor bolt shear stiffness corresponding to a secant modulus that credits the finite shear deformation that occurs under higher load. The finite element anchor bolt modeling (Figures A.3-8 through A.3-10) and experimental data (Ollgaard et al. 1971; Lam and El-Lobody 2005) clearly shows the expected nonlinear response with significant softening prior to reaching the ultimate load.

The ASME evaluation makes a distinction between an anchor bolt force allowable and a displacement allowable based on the different response to force limited and displacement limited loading configurations. Use of the linear secant makes the anchor shear force and displacement allowables equivalent because the secant stiffness is defined as the ultimate anchor shear force divided by the corresponding anchor shear displacement. The secant stiffness also softens the initial portion of the load-deflection curve allowing some shear load redistribution between the anchors.

The DST Evaluation Criteria document (Day et al. 1995) specifies Ultimate Displacements for Nelson Studs (Table 4.1.4-3). The recommended allowable shear displacements for 1/2 inch and 5/8 inch Headed-Threaded Studs are 0.167 inch and 0.22 inch, respectively. The footnote states that test data are not available for this configuration, and that the recommended values are conservative. Indeed, the local nonlinear anchor bolt model that was calibrated against test data shows that the effective diameter of the anchor bolt and welded stud combination is greater than the nominal 1/2 inch diameter of the headed studs, indicating an ultimate shear displacement greater than 0.167 inch.

The ultimate shear displacement for the AP anchor bolts was established using the experimentally determined anchor bolt slip capacities reported by Oehlers and Sved (1995) and the experimentally determined load-slip relationship documented by Ollgaard et al. (1971). Oehlers reported good correlation with the following equation of slip capacity:

$$S_f/d_s = 0.45 - 0.0021f_c \quad (\text{A.3.1})$$

where S_f is the slip at fracture, d_s is the anchor bolt shank diameter and f_c is the concrete strength in N/mm^2 . This gives an allowable shear displacement of 0.285 inch for a 3/4 inch anchor bolt and 0.188 inch for a 1/2 inch anchor bolt.

Ollgaard (1971) reported an empirical formula for shear load-slip response as:

$$Q = Q_u(1 - e^{-18\Delta})^{0.4} \quad (\text{A.3.2})$$

The load-slip curves for 1/2 and 3/4 inch anchor bolts defined by this relationship are shown in Figure A.3-11. The displacement capacity of these size anchor bolts is also identified on the plot. The AP anchor bolt response as determined by the finite element model is also shown in this figure. The AP anchor bolt ultimate shear displacement is established as 0.22 inch, which is the intersection of the line joining the 1/2 and 3/4 inch capacities with the AP response. The corresponding ultimate shear force is $V_{UN} = 14.34$ kips for the AP anchors.

Figure A.3-11. AP Anchor Bolt Secant Modulus and Allowable Displacement

This point also defines the secant modulus for use in the TOLA and seismic finite element models. The secant shear modulus, k_s , is calculated as:

$$k_s = \frac{V_{UN}}{\delta_{UN}} = \frac{14.34 \text{ kips}}{0.22 \text{ inch}} = 65,187 \text{ lbf/in} \quad (\text{A.3.3})$$

The value of 65,000 lbf/in was selected for both the TOLA and seismic models.

A.3.2.3 Establishing Rational Concrete Curing and Tank Operating Temperatures from the Available Tank Data Records

The primary contributor to the anchor bolt demand from the thermal and operating loads analysis (Deibler et al. 2007) is the mismatch between thermal expansion coefficients of the concrete and steel liner in conjunction with the specified temperature range. The original analysis very conservatively defined the maximum waste temperature at the design limit of 210°F even though the maximum waste temperatures had never come close to the design limit. In addition, the stress-free temperature for the differential thermal expansion stresses was taken as 50°F, which is conservatively low considering the natural heat of hydration that occurs during concrete curing. Therefore, the available data records on concrete curing temperatures and the historical waste temperature in the AP tanks were reviewed to define more realistic values for the stress-free and maximum waste temperature limits.

A review of the construction records found only one example of curing temperatures. It was for tank 241-AP-104, which had temperature of 81°F, 78°F, and 64°F for thermocouples embedded in the haunch during the pour. This pour coincided with coldest temperatures experienced in the 241-AP during construction. All three thermocouples showed a similar temperature rise during curing. Based on this information, the baseline (stress-free) temperature for the anchor bolts was selected as 80°F.

A review of the operating temperatures back to completion of the 241-AP Tank Farm in 1986 showed that the tanks normally operated at 80°F ± 10°F. Two exceptions to this temperature range were 241-AP-104 and 241-AP-108 when the received waste from the 242-A Evaporator raised the temperature in the lower portions of the tank to between 120°F and 130°F and the dome temperature to approximately 100°F. The heat from these transfers quickly dissipated from the tank with the temperatures returning to the previously stated range. From this review it was estimated that a maximum dome temperature of 110°F conservatively bounds the operating history of all the AP tanks.

Discussions were also held with tank farm operations staff to determine if the current operating temperature (210°F) could be reduced without impacting the future waste retrieval and treatment operations. It was concluded that a maximum waste temperature limit of 135°F is sufficiently high to not limit operations.

A.3.2.4 Thermal and Operating Loads Analysis

The primary contributor to the anchor bolt demand from the thermal and operating loads analysis (Deibler et al. 2007) is the mismatch between thermal expansion coefficients of the concrete and steel liner in conjunction with the specified temperature range $\Delta T = 160^\circ\text{F} = (210^\circ\text{F} - 50^\circ\text{F})$. The review of construction records and operational data suggests a more historically realistic range to be $\Delta T = 30^\circ\text{F}$ (110°F–80°F). A 60-year analysis was conducted with this temperature range.

The apparent margin for the anchor bolts with this temperature range suggested there is sufficient capacity to accommodate a wider temperature range. Another analysis, based on more realistic yet conservative tank bulk waste temperature of 135°F yielding the following $\Delta T = 55^\circ\text{F} = (135^\circ\text{F} - 80^\circ\text{F})$, was conducted.

All the other model parameters – loads and material models (including concrete creep and cracking) are as documented in the Increased Liquid Level report (Deibler et al. 2007).

The secant stiffness of 65,000 lbf/in was used for the spring elements that represent the anchor bolts in shear.

A.3.2.5 Seismic Analysis

The earlier reported anchor evaluation was based on a shear response that did not credit the finite shear deformation that is known to occur in such anchor bolts under higher loads. The current approach uses the secant modulus of 65,000 lbf/in in both the TOLA and seismic analyses.

The same combinations of soil properties and concrete properties used for the initial AP level rise and baseline analysis were used for the re-analysis of the anchor bolts. That is, the four combinations to be evaluated are BES-BEC, UBS-BEC, LBS-BES, and BES-FCC.

A.3.2.6 Shift from ASME to ACI 349 Evaluation Criteria for the AP Tank Anchor Bolts

The current evaluation of the AP anchor bolts follows the procedure given in ACI 349-01, which was the original concrete code of record for the AP tanks. The initial evaluation of the AP anchor bolts was performed using ASME B&PVC evaluation criteria as recommended in Day et al. (1995). The ASME B&PVC criteria are intended for the design of concrete containments in nuclear facilities. Since 1995, the DSTs have been downgraded from PC-3 to PC-2 structures, and the application of the concrete containment code to the anchor bolt evaluation is viewed as unnecessarily restrictive. The change of criteria from ASME (specifying a 0.50 load reduction factor on ultimate) to ACI 349-01 (0.75 load reduction factor) has the effect of increasing the capacity of the AP anchors by 50%.

A.3.2.7 Combined TOLA and Seismic Results:

The maximum anchor shear deflections in both the TOLA and seismic analyses occur at the outer-most row of anchors near the transition between the dome and the haunch regions of the tank. The anchor shear deflections from the TOLA and seismic analyses were added and compared against shear displacement allowables based on both the ASME and ACI evaluation criteria. The TOLA results (with 55°F temperature range) were combined with full time history seismic results. Based on the ultimate shear deformation of 0.22 inch (Figure A.3-11), the allowable shear deformation per the ASME and ACI 349 criteria are $(0.5)(0.22 \text{ inch}) = 0.11 \text{ inch}$, and $(0.75)(0.22 \text{ inch}) = 0.165 \text{ inch}$, respectively. Table A.3-2 shows demand-to-capacity ratios using the ASME and ACI 349 criteria for the worst case Upper Bound Soil analysis. Using the ACI criteria, the demand-to-capacity ratios are below 1.0 for each of the 4 soil/concrete cases.

Table A.3-2. The Combined TOLA and Seismic Anchor Shear Demands Compared to the ACI and ASME Displacement Allowables

Run	Maximum Deflection (in)
TOLA – 55 °F temp. range	0.068
Seismic – full time history UBS/BEC	0.096
Total Shear Deformation	0.164
ACI 349 D/C Ratio	0.99
ASME D/C Ratio	1.49

A.3.2.8 Sources of Analytical Conservatism

- So far, a simplified routine that smears spatial and temporal results has been used to calculate peak seismic demands. Use of a more refined methodology is estimated to reduce the seismic demand by approximately 5-10%.

- The TOLA and seismic demands reported for the AP tanks do not credit any friction between the concrete dome and the steel tank. Initial indications are that the benefit of friction may reduce the demands by approximately 5%.
- The use of the nonlinear load-displacement response of the anchor bolt as predicted by the ANSYS finite element model resulted in an allowable ultimate shear load of 14.5 kip. This is conservative in comparison to the 16.2 kip load based on the annular region of the anchor bolt as recommended by the reviewers.
- The most recent site response analyses performed at the Hanford Site Waste Treatment Plant (WTP) Site show that the currently published design spectra for the WTP Site are significantly lower than the interim spectra published in 2005 (PNNL 2007). This indicates that the governing spectra being used for the DST analysis are likely to be conservative.

A.3.2.9 Additional Considerations

- The project team has sought technical support from ACI 349 Code Committee member Richard E. Klingner. Professor Klingner is an expert in anchorage to concrete and will be contracted to assist in questions of ACI code interpretation and treatment of thermal demands on the anchor bolts. In the interim, the evaluation of the AP Tanks will proceed using conservative assumptions for the treatment of thermal demands on the anchor bolts.
- The focus so far has been on calculating the demand-to-capacity ratios for the anchor bolts. The larger question of the safety function that is performed by the anchor bolts and the degree of structural stability provided by the anchor bolts has not been addressed. If it can be shown that the system remains stable with some or all of the anchor bolts removed from the load path, this will add defense-in-depth to the arguments supporting the evaluation of the anchor bolts.

A.3.3 Conclusion

1. Due to the lower temperature ranges used to calculate the thermal demands and the switch to the ACI 349-01 code criteria the anchor bolts in the AP tank farm have adequate capacity at the 460 inch waste level.

A.3.4 References

- Champney C. 1994. *TBL Internally Threaded Stud Minimum Length Calculation*, Bulletin 1994-2, Nelson Stud Welding.
- Day JP et al. 1995. *Structural Acceptance Criteria for the Evaluation of Existing Double-Shell Waste Storage Tanks Located at the Hanford Site, Richland, Washington*. WHC-SD-WM-DGS-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Deibler JE et al. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Increased Liquid Level Analysis for 241-AP Tank Farms*. RPP-RPT-32237, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Kennedy RP and AS Veletsos. 2007. *Comments Regarding Seismic Evaluation of Hanford Double-Shell Tanks and Effect of Increased Liquid Level in 241-AP Tank Farms.*

Lam D and E El-Lobody. 2005. "Behavior of Headed Stud Shear Connectors in Composite Beam." *Journal of Structural Engineering* 131:1.

Oehlers DJ and G Sved. 1995. "Composite Beams with Limited-Slip-Capacity Shear Connectors." *Journal of Structural Engineering* 121:6.

Ollgaard JG, RG Slutter, and JW Fisher. 1971. "Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete." *AISC Engineering Journal* 8:2.

PNNL. 2007. *Updated Site Response Analysis for the Waste Treatment Plant, DOE Hanford Site, Washington.* Prepared by Geomatrix Consultants, for Pacific Northwest National Laboratory, Richland, Washington.

Rinker MW et al. 2004. *Hanford Double-Shell Tank Thermal and Seismic Project-Thermal and Operating Loads Analysis.* RPP-RPT-23308, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

A.4 Reviewer Comments – Kennedy, December 2007

Comments Regarding Revised Anchor Bolt Evaluation for 241-AP Tanks with Increased Liquid Level

by

R. P. Kennedy
December 2007

A.4.1 Introduction

I have reviewed Sections 3 (*Seismic Model*) and 6 (*Analysis Results*), and Appendix B (*Anchor Bolt Evaluation*) of the revised Diebler, J.E., et al., *Hanford Double-Shell Tank Thermal and Seismic Project-Increased Level Analysis for 241-AP Tank Farms*, RPP-RPT-32237, Rev. 1, Pacific Northwest National Laboratory, December 2007. The purpose of my review was to review the revised anchor bolt evaluation of the 241-AP tanks with increased liquid level.

A.4.2 Overall Comment

I concur with the revised anchor bolt evaluation. Therefore, I concur that the Demand/Capacity (D/C) ratio for the 241-AP tank anchor bolts does not exceed unity so long as:

- (1) Liquid level does not exceed 460 inches,
- (2) Thermal increase (ΔT) of primary tank in dome region does not exceed 55°F, and
- (3) Seismic input does not exceed the level defined in Section 3.5 of the reviewed report

A few specific comments follow.

A.4.3 Specific Comments

A.4.3.1 Comment on Section 3.2.5 of Reviewed Report

No basis is presented on Page 3.14 for the use of an anchor bolt stiffness of 65.0 kips/inch in the seismic and thermal evaluations. This section should refer to Page B.11 of Appendix B where this shear stiffness is defined. I concur that the secant shear stiffness of 65.0 kips/inch defined on Page B.11 is reasonable.

A.4.3.2 Comment on Section 6.6 of Reviewed Report

Section 6.6 of the reviewed report does not define either the nominal ultimate shear capacities or the factored ultimate shear capacities used for the anchor bolt D/C ratios reported in this section. Based on

my understanding of Appendix B, I believe that the nominal ultimate shear displacement, δ_{UN} , and the nominal ultimate shear capacity, V_{UN} , used are:

$$\delta_{UN} = 0.22 \text{ inch} \quad (\text{A.4.1})$$

$$V_{UN} = (65 \text{ kip/in})(0.22 \text{ inch}) = 14.3 \text{ kips} \quad (\text{A.4.2})$$

Thus, based on a strength reduction factor $\phi=0.75$, the factored δ_{UF} and V_{UF} are:

$$\delta_{UF} = 0.165 \text{ inch} \quad (\text{A.4.3})$$

$$V_{UF} = 10.7 \text{ kips} \quad (\text{A.4.4})$$

I consider these values of δ_{UN} , V_{UN} , δ_{UF} , and V_{UF} to be reasonable based upon the material presented in Appendix B.

Section 6.6 should explicitly define the factored δ_{UF} and V_{UF} used in the anchor bolt D/C ratios presented in this sections. Furthermore, Section 6.6 should refer to the sections in Appendix B where the basis for δ_{UN} , V_{UN} , δ_{UF} , and V_{UF} are explicitly presented.

A.4.3 Comments on Appendix A.3

I concur with the anchor bolt model shown in Figure A.3-7 which was used in the finite element analysis to determine the nominal ultimate capacity of the AP anchor bolts.

I concur that the nominal ultimate shear displacement, δ_{UN} , of 0.22 inch reported on Page B.11 is reasonable.

I concur that the use of the strength reduction factor $\phi=0.75$ discussed on Pages B.13 and B.14 is appropriate for defining the factored load capacity.

However, I found the last paragraph on Page B.7 discussing the nominal ultimate shear capacity, V_{UN} , and the last paragraph on Page B.11 defining the secant stiffness k_S , to be confusing and mutually contradictory.

Page B.7 reports a 14 kip "plateau" shear strength which is then increased by a factor of 1.17 to obtain a shear strength of 16.4 kips. The basis for the 1.17 increase factor is not convincingly discussed. I presume that this increase is to account for strain hardening effects. Lastly, what is the V_{UN} being defined at the end of the last paragraph on Page B.7?

The secant stiffness, k_S , defined on Page B.11 should be based on:

$$k_S = \frac{V_{UN}}{\delta_{UN}} \quad (\text{A.4.5})$$

If $V_{UN}=16.4$ kips and $\delta_{UN}=0.22$ inch, then:

$$k_s = \frac{16.4 \text{ kips}}{0.22 \text{ inch}} = 74.5 \text{ kips / inch} \quad (\text{A.4.6})$$

which is larger than the k_s reported on Page B.11. If $k_s=65$ kip/inch and $\delta_{UN}=0.22$ inch, then:

$$V_{UN} = (65 \text{ kips/inch})(0.22 \text{ inch}) = 14.3 \text{ kips} \quad (\text{A.4.7})$$

The problem is that V_{UN} , δ_{UN} , and k_s need to be mutually consistent in accordance with Equation (C.5). Since $k_s=65$ kips/inch was used in the Demand analyses, I recommend that V_{UN} be taken as 14.3 kips in accordance with Equation (C.7). Otherwise, if $V_{UN}=16.4$ kips then $k_s=74.5$ kips/inch in accordance with Equation (C.6) and the Demand analyses should be revised using this revised k_s .

Finally, a consistent set of V_{UN} , δ_{UN} , and k_s should be defined in Appendix B and repeated in Section 6.6.

A.5 Reviewer Comments – Veletsos, March 2008

Comments Regarding Revised Anchor Bolt Evaluation for 241-AP Tanks with Increased Liquid Level

by

A.S. Veletsos
March 2008

A.5.1 Scope of Comments

The following comments relate mainly to Sections 2.2.4.2, 2.4.1, 3.2.5, 3.5, 6.6 and Appendices A.3 and A.4 of the report by Deibler, J.E. et al, *Hanford Double-Shell Tank Thermal and Seismic Project, Increased Level Analysis for 241-AP Tank Farms*, RPP-RPT-32237, Rev. 1, Pacific Northwest National Laboratory, January 2008. These are the sections that deal with the demand and capacity evaluation of the anchor bolts connecting the primary tank to the concrete dome. The remaining sections of the Report are identical to those of its initial version, Rev. 0, and, with one exception, are not commented on.

A.5.2 General Comments

As previously indicated, I cannot claim any in-depth expertise on the characteristics and behavior of the type of anchor bolts used in this project. The comments that follow represent simply my best effort and judgment on the issues involved.

I concur with Dr. Kennedy's conclusion in Appendix A.4 of the Report to the effect that the revised anchor bolt evaluation is acceptable subject to the conditions enumerated in Section A.4.2. I further concur with the view that the basis and values of the ultimate shear strength and displacement of the bolts, and of the associated stiffness used in the evaluation of their demand/capacity ratio should clearly be identified in Section 6.6 of the Report.

A.5.3 Additional Comments

A.5.3.1. On the third paragraph of p. 6.54 of the Report, the strength reduction factor specified by ACI 349 is incorrectly listed as 0.50 rather than 0.75, the latter value being correctly reported on p. 13 of Appendix A.3. This typographical error should be corrected.

A.5.3.2. The nonlinear, hysteretic, nearly elastoplastic resistance-deformation diagram of the anchor bolts in the reported analyses was approximated by a linear relationship with a stiffness equal to the secant stiffness of the actual diagram corresponding to the maximum resisting force and permissible deformation. In the evaluation of the seismic effects, I would have definitely preferred the use of the actual, nonlinear relationship. I would also have liked to see the relevant resistance-deformation diagram presented for both increasing and decreasing cycles of loading. I do realize, of course, that the analysis of

the nonlinear, hysteretic system would have been considerably more involved than of its linearized approximation.

A.5.3.3. The information regarding the maximum force and deformation demands for the anchor bolts presented in the Report is not sufficiently detailed in my view. I strongly recommend that the relevant demands for both the seismic effect and the combination of the seismic and other effects be identified for at least the most highly deformed bolts at the bottom and next to the bottom rings of the dome. Additionally, to provide some insight into the sensitivity of these demands to the stiffness of the linearized version of the resistance-deformation relationship of the bolts, it is recommended that they are also evaluated and reported for a higher bolt stiffness, such as their low-amplitude, initial stiffness.

A.5.3.4. It is not clear if the value of approximately 65 kips/in for the stiffness of the linearized version of the resistance-deformation relationship of the anchor bolts was used for all bolts, or only for those on the bottom ring of the dome which will experience the largest deformations. This issue needs to be clarified. The use of the secant stiffness for all bolts has the undesirable effect of underestimating the force and deformation demands for the bolts at or near the bottom rings of the dome.

A.5.3.5. I am perplexed by the comments on pages A.4.2 and A.4.3 of Dr. Kennedy's review regarding the shear strength and secant stiffness values of the bolts used in the reported analyses. My own understanding is that the reported solutions are indeed for an ultimate shearing strength of 14.3 kips (as noted on page 10 of Appendix A.3) and for a secant stiffness of $780 \text{ kips/ft} = 65 \text{ kips/in}$ (as noted on pages 3.14 and A.3.11 of the Report). It appears that this information needs to be emphasized, preferably in the body of the Report. If, however, my interpretation is not correct, I would concur with Dr. Kennedy's recommendation.

A.5.3.6. On the issue of the uncertainties and potential conservatism involved in the reported analyses (listed on pages 6.58 and A.3.14 of the Report), I wish to note that I fully agree that the design response spectra used in the study are likely to be conservative. As previously indicated, this is expected to be especially true of the spectrum for the vertical component of shaking, the peak segment of which is considered to be much broader than that for the horizontal component (see Figs. 3-34 and 3-35 of the Report).

A.5.4 Comment on Another Issue

In Section A.5 of the Reviewer Comments presented in Appendix A of the Report, concern was expressed about the accuracy of the maximum seismic stresses reported previously for the lower knuckle of the primary tank, and some additional studies were recommended to clarify matters. Based on the information presented in Section 6.2.1 of the Report, however, this concern does not appear to have yet been addressed. If this is indeed true, it is strongly recommended that it be given the appropriate attention.

A.6 Anchor Bolt Modeling and Evaluation

DST Anchor Bolt Modeling and Evaluation

July 14, 2008

PNNL and M&D

MW Rinker, JE Deibler, KI Johnson and FG Abatt

A.6.1 Introduction

At the June 2007 review of the DST analyses, the reviewers raised concerns with the anchor bolt evaluation. The ultimate shear capacity used in the original evaluation reported in Deibler et al. (2007) was judged to be unconservative. In response, the secant stiffness representation of the anchor bolts was developed and an evaluation method based on allowable shear displacements was identified. Complete details are given in Appendix A.3 of the Increased Liquid Level report, Rev. 1 (Deibler et al. 2008).

Additional comments by the reviewers in March 2008 raised concerns over the use of a uniform anchor bolt shear stiffness over the entire radius of the dome. It was postulated that in some locations, credit was being taken for unrealized ductility. An iterative procedure that converges on matching the secant stiffness to the actual shear displacement was recommended. A representative analysis that demonstrates the use of location specific shear stiffness anchor bolts is described in this report.

A.6.2 Location Specific Anchor Bolt Stiffness

The 65 kip/in value of the secant shear stiffness of the AP anchor bolts reported in Rev. 1 of the Increased Liquid Level report (Deibler et al. 2008) was based on the estimated failure point on the shear load-deformation diagram and is a lower bound for possible secant shear moduli. Generally, the shear demand on the DST anchor bolts in the dome increases as radial distance from the dome apex increases. The use of a uniform value of the secant shear modulus that is based on the failure point of the anchors means that all anchors are assigned a lower bound shear stiffness. The difference between the assigned value of 65 kip/in and the expected value based on realized shear deformations increases for anchors closer to the dome apex.

During the March 2008 review a question was raised as to whether the above approach would provide conservative estimates of the anchor shear displacements. From a static point of view, lower shear stiffnesses will produce higher shear displacements that conservatively bound the actual displacements. However, the concern raised during the review was if an increase in anchor bolt stiffness could cause a frequency shift in the system dynamic response that could amplify the anchor bolt response.

To investigate this possibility, the reviewers recommended an iterative procedure to more accurately match the shear stiffness with the actual shear deformation in the anchor bolts on a row-by-row basis.

One iteration towards the radial location specific anchor stiffness was conducted to evaluate the use of uniform stiffness anchor bolts. The combined TOLA + seismic shear displacements for each row of

anchor bolts from the uniform 65 kips/in stiffness analysis of the Upper-Bound Soil, Best Estimate Concrete were overlaid on the predicted shear load-displacement curve for the AP anchor bolts. The secant modulus for each point is then used as the shear stiffness at that location for the next iteration of the analysis. Figure A.6-1 illustrates the procedure graphically.

Figure A.6-1. Location Specific Anchor Bolt Stiffness Determination

The stiffness at each location is greater than the nominal 65 kips/in. As expected, the resulting combined shear displacements decrease. This procedure could be repeated until convergence of the anchor bolt stiffness is achieved at each specific location. However, a demand/capacity evaluation at the end of this first iteration demonstrates the conservative results given by the uniform 65 kips/in shear stiffness. Figure A.6-2 shows the demand/capacity evaluation for the nominal and first iteration shear stiffness. The anchor bolts pass the evaluation at the nominal 65 kips/in shear stiffness (D/C ratio equal to 0.99 at the outer-most anchor). The more refined analysis gives a maximum D/C ratio of 0.53. If a second iteration were analyzed this ratio would drop even further.

Figure A.6-2. Location Specific Anchor Bolt Demand/Capacity Evaluation

A.6.3 Conclusion

The secant modulus anchor bolt modeling is a viable method of accommodating the nonlinear load-displacement response. The assignment of a uniform lower bound secant shear modulus to all of the anchor bolts provided a very conservative estimate of the shear deformations relative to a more refined row-by-row assignment of shear stiffnesses based on actual deformations. The higher location specific shear stiffnesses resulted in a decrease in shear deformation under dynamic seismic loading.

A.6.4 References

Deibler JE, MW Rinker, KI Johnson, FG Abatt, SP Pilli, BJ Carpenter, and NK Karri. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project - Increased Liquid Level Analysis for 241-AP Tank Farms*. RPP-RPT-32237, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Deibler JE, MW Rinker, KI Johnson, FG Abatt, SP Pilli, and NK Karri. 2008. *Hanford Double-Shell Tank Thermal and Seismic Project - Increased Liquid Level Analysis for 241-AP Tank Farms*. RPP-RPT-32237, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

A.7 Seismic Model Primary Tank Lower Knuckle Mesh Resolution

Seismic Model Primary Tank Knuckle Stress Evaluation

May 15, 2008

M&D Professional Services, Inc

KL Stoops, FG Abatt, M Meyer

A.7.1 Introduction and Purpose

The complexity of the global DST seismic model required that some mesh resolution be sacrificed in the lower knuckle region of the primary tank. The purpose of this appendix is to establish a factor that will be applied to the global seismic model lower knuckle stress components to account for loss of accuracy due to the limited mesh resolution (discretization error). This factor can be applied to the lower knuckle stress components from the global seismic model before combining the results with the TOLA model stresses and performing the primary tank ASME code evaluation. Although this Appendix focuses on the AY configuration, both AY and AP tank are addressed using a common methodology.

A.7.2 Background

A study of the effect of mesh resolution on the stresses in the lower knuckle of the primary tank in the seismic model was documented in Appendix A of Deibler et al. (2008). The important conclusions of that study were that increasing the mesh resolution in the lower knuckle from two elements to eight elements produced sufficiently accurate stresses, and that a single factor of 2.0 applied to the meridional and hoop stress components was more than enough to account for loss of mesh resolution in the global model.

Further investigation was motivated by a comment from reviewers R.P. Kennedy and A.S. Veletsos during a July 2007 project review meeting. The text of the comment appears below in italics.

The lower knuckle of the primary tank is too crudely modeled in the global analysis of the soil-structure-waste system to accurately define the peak values of the stresses induced in it. To provide for this inadequacy, the maximum values of the stresses determined in the global analysis for this region were increased by a factor of 2.0. We understand that this factor was based on the increase in maximum stresses determined for a refined model of the knuckle considering the effects of the hydrostatic pressures only.

While this amplification factor may indeed be adequate for the hydrostatic effects, we are concerned that it may not be adequate for the seismically induced effects. As the seismic loading, unlike the hydrostatic, induces a substantive axial force in the

tank-wall, we expect the increase of the bending stresses in the knuckle to be larger for the seismic loading than for the hydrostatic.

We recommend that the stresses in the refined local model of the lower knuckle be determined using the maximum values of the boundary forces and of the associated pressures computed in the seismic analysis of the global model. A comparison of the absolute maximum values of the resulting stresses with those obtained by the global model would then provide a more defensible estimate of the amplification factor that should be applied to the seismically induced effects determined with the global model.

Alternatively – although this option is not as desirable – an approximate estimate of the requisite amplification factor may be determined by a static analysis similar to the one used, provided the vertical and circumferential distributions of the pressures considered are representative of those of the impulsive component of the seismically induced pressures.

Considering that some of the reported analyses indicate the absolute maximum stresses to occur in the base plate, slightly beyond the lower end of the knuckle, it is important that the local model does include this region.

The approach to the evaluation differs from that reported in Revision 0 of this Appendix in the following important aspects:

1. The focus of the evaluation is the differences in results between the global seismic model (with two elements in the knuckle) and the results the global seismic model *would have* if a more accurate eight element mesh had been used in the knuckle.
2. The axisymmetric study model used in Revision 0 was abandoned in favor of a slice model so that the global model and study model used the same element types. The slice study model is based directly on the global seismic model.
3. The adjustment factor is based on the differences in results between the slice study model with two elements in the knuckle vs. with eight elements in the knuckle. The previous approach compared the results from two different models: the global seismic model, and the TOLA model.
4. Because the slice study model is based directly on the global seismic model and uses the same element types, it was judged to be unnecessary to “benchmark” the study model against the thermal and operating loads analysis (TOLA) model. Thus, the TOLA model is no longer referenced in this evaluation.
5. Based on the results from Revision 0 and the mesh refinement in the thermal and operating loads analysis (TOLA) model, it was determined that having eight elements in the knuckle provides sufficient mesh refinement.
6. The comparisons between the global seismic model and slice study model are performed using loads representative of seismic loads only in the absence of gravity, since these are the loads that will be combined with the TOLA results.
7. The effects of axial loads in the tank will be included in the evaluation.
8. The configuration of the AP tanks as well as the AY-based baseline model will be addressed in this evaluation.

A.7.3 References

Abatt, F.G., 2008, *Establishment of Methodology for Time Domain Soil-Structure Interaction Analysis of a Hanford Double Shell Tank*, M&D-2008-004-RPT-01, Rev. 1, prepared by M&D Professional Services, Inc. for Pacific Northwest National Laboratory, Richland, Washington.

Deibler J.E. et al. 2007. *Hanford Double-Shell Tank Thermal and Seismic Project-Increased Liquid Level Analysis for 241-AP Tank Farms*. RPP-RPT-32237, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.

Deibler J.E. et al. 2008. *Hanford Double-Shell Tank Thermal and Seismic Project-Summary of Combined Thermal and Operating Loads with Seismic Analysis*. RPP-RPT-28968, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

A.7.4 Methodology

A set of load cases will be identified to satisfy the comments (above). The load cases will apply representative seismic axial force and waste pressure loads. To speed runtime and reduce postprocessing, the loads will be applied statically to a simplified model. The seismic only results will be obtained through the same procedure as for the global seismic model, which is to solve with combined gravity + seismic and then subtract the gravity portion (solved independently) via postprocessing. The differences in the results between the different mesh densities will be examined and an adjustment factor (ratio) will be determined. The method of combination of the global seismic model results to the TOLA model results will be prescribed, and a single bounding adjustment factor will be determined for use in the combination.

A.7.5 Model Descriptions

A.7.5.1 DST Primary Tank Knuckle Geometry

The DST primary tanks have a 12-inch radius knuckle region that joins the tank cylindrical sidewalls to the tank bottom plates. The bottom of the primary tank is supported below by insulating concrete. The insulating concrete extends past the bottom tangent of the knuckle, although the knuckle will not contact the insulating concrete outside of the tangent unless significant deflection occurs. Typical knuckle geometry is shown in Figure 0.7-3.

Figure 0.7-3. Knuckle Detail from Drawing AY H-2-64307.

A.7.5.2 Global Seismic Model Description

A complete description of the AY-based generic seismic model can be found in Section 3.0 of Abatt (2008). A view of the primary tank knuckle and insulating concrete from the global model is shown as Figure 0.7-4.

Figure 0.7-4. Primary Tank Knuckle and Insulating Concrete from Global Seismic Model.

The property configuration used for this evaluation is AY tank Best Estimate Soil, Best Estimate Concrete, Lower Bound Anchor Bolt Secant Modulus (AY-BES-BEC-LBmod).

A.7.5.3 Slice Study Model

The slice model is based directly on the global seismic model, but with the following simplifications and modifications:

- To create the study model, the global seismic model is generated, and then a 1 element wide slice is selected for the solution.
- To improve element aspect ratios in the primary tank knuckle at higher mesh resolutions, the mesh is modified to provide an element width of 2 degrees, instead of 9 degrees. The free mesh in the center region of the model is also adjusted to accommodate the narrower slice. Other than the knuckle itself, this is the only mesh change.
- The waste is removed from the study model. Loads from the waste will be simulated as pressures on the inner surface of the primary tank.
- Symmetry boundary conditions are applied at the slice sides (circumferential) and at the center of the tank (radial).
- The soil boundary conditions are distributed among nodes that were previously coupled to a master node.
- The solution is performed statically.

The purpose of this investigation is to address the local response of the knuckle, not global behavior of the tank. Although the slice model does not capture full three-dimensional effects, it is sufficient for studying the effects of mesh resolution in the lower knuckle.

Figure 0.7-5 shows a full element plot of the study model, and Figure 0.7-6 shows a close-up view of the knuckle region of the study model.

Figure 0.7-5. Study Model Shown Without Soil Elements

Figure 0.7-6. Primary Tank Knuckle Region of Study Model (8 element knuckle mesh).

A.7.6 Load Application and Load Case Definition

Per the comments made by Kennedy and Veletsos (see 0), seismically induced axial and waste pressure loads on the primary tank will be addressed. These loads will be addressed in the following load cases:

- 1) Seismic waste pressure on primary tank. Waste pressure is taken from the tables of theoretical waste pressure found in Section 8.2 of Abatt (2008). The theoretical values are used for simplicity (e.g. actual results are non-uniform and harder to apply). The theoretical values are compared to the global seismic model results in Abatt (2008), and are found to be similar to the global seismic model FEA results.
- 2) Axial loads in the primary tank wall. The axial load is applied to the model based on the meridional midplane stress values found in Deibler et al (2007). A vertical force will be applied at approximately half height on the primary tank wall such that the resulting stress in the primary tank wall is similar to the meridional midplane stress values found in Deibler et al (2007). The meridional stress is assumed to be completely caused by the seismic structural forces (e.g. overturning). The values reported in Deibler et al (2007) are absolute value; therefore the range of loads is potentially reversing. Two opposing axial load subcases will be considered:
 - a. Axial up, based on positive maximum global seismic model stress results (Abatt 2008) from the primary tank wall.
 - b. Axial down, based on negative maximum global seismic model stress results (Abatt 2008) from the primary tank wall.

An additional gravity case considering dead weight with waste hydrostatic fluid effects due to gravity will be run as a non-seismic baseline. The load cases will be run with gravity effects (dead weight and waste

hydrostatic fluid effects due to gravity) included, and the results of the gravity case will be subtracted from the seismic results. This methodology is the same approach used for producing the global seismic results.

All loads will be applied statically as either a surface pressure or point forces resulting in membrane stress.

A.7.6.1 Limit of Knuckle Mesh Influence

Results will be presented in the knuckle region and adjacent elements. The limits of influence from the knuckle mesh will be demonstrated by convergence in the results. Convergence is defined as when the relative difference is small, or the overall magnitude is small compared to the maximum values used for calculation of the factor. Beyond the zone of influence no adjustment factor is required.

A.7.6.2 Methodology Differences and Sensitivity to Applied Loading

The global seismic model is evaluated with dynamic loading, and the study model is evaluated with statically applied loads. For a single load state (as defined by the load cases above), a set of static solutions provide sufficient data on the response of the model to determine the relative differences due to the knuckle mesh.

The loads used in the study model are based on the results provided in Abatt (2008). Those results are maximum absolute values taken from the global seismic model time history analysis. Therefore, the following variations are inherent to this bounding value approach:

- The tank experiences a range of loads that are not reported in detail (absolute maximums only)
- Co-existence of multiple loads (e.g. waste pressure and axial loading) at any place or time cannot be determined without more extensive investigation and correlation

The variations are addressed by determining the sensitivity of the model to the loading. The load will be varied to demonstrate the applicability of the adjustment factor over the expected range of magnitude for the given load type. If the response to the applied loads is nearly linear then the adjustment factor is largely independent of the applied load magnitude. The adjustment factor may then be applied to a range of loads, encompassing the variations.

A.7.7 Definition of Adjustment Factor

The global seismic model has inadequate mesh resolution in the primary tank knuckle. In order to make sure that conservative stresses are presented for the seismic analyses, a scaling factor needs to be determined to account for the lower mesh resolution in the global seismic model.

In Deibler et al 2008, the seismic results from the 2 element global seismic model are combined with the results from the 8 element TOLA model to perform an ASME code evaluation of the primary tank. In this process, an adjustment factor must be applied to the global seismic model results to compensate for the lack of mesh resolution in the global seismic model.

A.7.7.1 Calculation of the adjustment factor

The factor is based on the maximum of the absolute values of meridional and hoop stresses from the study model with 2 and 8 element meshes. The factor is determined by the following steps (performed in a spreadsheet):

1. List stress results by element
2. The knuckle zone of influence is determined by reviewing convergence of the different mesh results.
3. Only results within the zone of influence are applicable for factor use. However, to compare the full range of knuckle results, calculation of the factor must include an element at a common location on each end, regardless of the elements to which the factor is to be applied. See the example below for further explanation.
4. Take the absolute value of the results.
5. Find the maximum of the absolute values for both 2 element and 8 element results (independent of location)
6. Divide the pair of results found above: 8 element divided by 2 element (independent of location)

It is also recognized that other comparison algorithms could be used, but this recommendation uses the method described here.

The calculation of the adjustment factors for each load case is summarized in a table following the graphical presentation of the results.

The adjustment factor and the zone of influence will be determined for each load case. After that, a single bounding factor and zone of influence will be concluded.

A.7.7.2 Example factor calculation using identical results:

In this example, and in the actual results following, the results used are obtained from elements, and therefore located at the element centroid. The plots will show straight line interpolation between data points to aid comparison and reveal trends. The X-axis on all plots is an arbitrary sequence that indicates the progression of elements from the wall to the floor, where the knuckle extends from element 1 to 8. Additional data points on either side of the knuckle are included to show the limits of the knuckle mesh influence.

Knuckle elements are highlighted. The 2 element mesh does not align with the 8 element mesh, therefore the location is noninteger. Elements 0 and 9 (and beyond) have the same location.

8 element			2 element		
element	Stress		element	stress	
0	0		0	0	
1	1		2.50	2.5	
2	2		6.50	6.5	
3	3		9	9	<- max
4	4				
5	5				
6	6				
7	7				
8	8				
9	9	<- max			
Max abs value	9.00		Max abs value	9.00	
					Factor
					1.00

The factor is $8e/2e = 9/9 = 1.0$.

Note that if the common element at each end is not included, the factor is $8/6.5 = 1.23$, which is clearly incorrect, since the data trend is identical. The common element must be included to ensure that no difference in *alignment* of the element centroids inadvertently leads to a different *range* of data being considered (in this example 1 to 8 vs 2.5 to 6.5).

A.7.7.3 Application of the adjustment factor

The method of combining the results must be consistent with the method of calculating the adjustment factor. The adjustment factor must be applied to the global seismic model results within the knuckle zone of influence. The single bounding factor and zone of influence must be used when the loading involves an indeterminate combination of the load types addressed in the load cases.

The dead weight portion of the seismic load from the global seismic model is subtracted from the results before combination; therefore an adjustment factor is applied to seismic loads for a consistent approach.

The recommended method for mapping the global seismic model results to the TOLA model is outlined below. This simplified, conservative method is consistent with the use of a single bounding factor. Follow the process for each stress component (hoop, meridional, top/bottom/membrane, etc.)

1. List the results for the global seismic model elements
2. Determine the maximum stress within the given zone of influence
3. Multiply the above maximum stress by the adjustment factor
4. Add the resulting single value to the TOLA model elements within a location range equal to the zone of influence.

A.7.8 Results

A.7.8.1 Format for presentation of results

Results will be summarized and presented in plots showing primary tank meridional and hoop stresses in the knuckle region. Meridional and hoop stresses will be labeled SM and SH, respectively. The top, middle, and bottom shell surface from which the results are retrieved will be identified by _T, _M, and _B respectively. The stress label will be followed by an indicator of the number of elements (e.g. "2e") and a label for the load case. Finally, an additional number (if present) at the end indicates a multiplier on the nominal load. For example, the label "SM_T 8e Pseis_AY 2" represents meridional stress at the top surface on a model with a 8 element mesh, under seismic waste pressure for the AY configuration, using twice the nominal load.

A.7.8.2 Load Case 1: Pressure Loading

The study model was subjected to a pressure load to simulate the effect of the waste during a seismic event. The pressures are taken from the tables of theoretical waste pressure found in Section 8.2 of Abatt (2008). The pressures used the AY tank waste depth of 422 inches with a specific gravity of 1.7. The pressure is applied to the primary tank as a pressure gradient over the depth of the waste. To show the sensitivity of the model to the load, additional loads of one-half and double the nominal loading are applied to the study model. The load case also includes gravity effects (dead weight and waste hydrostatic fluid effects due to gravity), which will be subtracted in post processing.

Table A.7 -1. Theoretical Waste Pressures, BES-BEC (copied from Section 8.2 of Abatt (2008))

Waste Height Ratio	Waste Height	Hydro static (psi)	Imp (psi)	Conv (psi)	Vert (psi)	Dyn (psi)	Dyn (SRSS) (psi)	Theor Max	Theor Min	Theor Max (SRSS)	Theor Min (SRSS)
0.97	410.75	0.69	1.08	1.38	0.26	2.01	1.77	2.70	-1.32	2.46	-1.08
0.92	386.5	2.18	2	1.25	0.82	3.18	2.50	5.36	-1.00	4.68	-0.32
0.85	359.5	3.84	2.86	1.13	1.43	4.51	3.39	8.34	-0.67	7.23	0.45
0.79	332	5.53	3.59	1.02	2.05	5.78	4.26	11.31	-0.26	9.78	1.27
0.72	305	7.18	4.2	0.93	2.63	6.93	5.04	14.11	0.25	12.22	2.14
0.66	278	8.84	4.73	0.85	3.18	7.99	5.76	16.83	0.85	14.60	3.08
0.59	251	10.50	5.17	0.77	3.7	8.93	6.40	19.42	1.57	16.90	4.09
0.53	225.65	12.05	5.53	0.72	4.15	9.73	6.95	21.78	2.33	19.01	5.10
0.48	202.3	13.49	5.81	0.67	4.54	10.39	7.40	23.88	3.10	20.89	6.08
0.42	179.3	14.90	6.05	0.63	4.89	10.97	7.80	25.87	3.93	22.70	7.09
0.37	156.35	16.31	6.26	0.6	5.2	11.49	8.16	27.80	4.82	24.47	8.15
0.31	131.45	17.84	6.44	0.56	5.49	11.95	8.48	29.79	5.88	26.32	9.36
0.25	104.5	19.49	6.6	0.54	5.76	12.38	8.78	31.87	7.11	28.27	10.71
0.18	77.6	21.15	6.73	0.52	5.97	12.72	9.01	33.87	8.43	30.16	12.14
0.12	50.6	22.81	6.81	0.5	6.11	12.94	9.16	35.74	9.87	31.97	13.64
0.06	24.5	24.40	6.86	0.49	6.2	13.08	9.26	37.48	11.32	33.66	15.14

Figure 0.7-5. Element Plot Showing Applied Loads

A.7.8.3 Results

The meridional and hoop stresses for the study model with several mesh refinements are presented in Figure 0.7-7 through Figure 0.7-12.

Figure 0.7-7. Knuckle Meridional Stress – Outside Surface (Away from Waste)

Figure 0.7-8. Knuckle Meridional Stress – Mid-plane Surface

Figure 0.7-9. Knuckle Meridional Stress – Inside Surface (Near Waste)

Figure 0.7-10. Knuckle Hoop Stress – Outside Surface (Away from Waste)

Figure 0.7-11. Knuckle Hoop Stress – Mid-plane Surface

Figure 0.7-12. Knuckle Hoop Stress – Inside Surface (Near Waste)

A.7.8.4 Seismic Pressure Stress Factors

As shown in Figure 0.7-7 through Figure 0.7-12, the results converge at the first element outside the knuckle. The zone of influence is thus limited to the knuckle itself.

Table A.7-2. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Pseis_AY 2	2883.80	43.96	2795.90	2895.90	2482.30	2068.80
8e Pseis_AY 2X (scaled)	2883.60	43.99	2795.80	2895.20	2481.40	2067.60
Scale factor	1.00	1.00	1.00	1.00	1.00	1.00

Table A.7-3. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Pseis_AY .5	720.90	10.98	699.00	724.20	620.80	517.50
8e Pseis_AY .5X (scaled)	720.90	11.00	698.95	723.80	620.35	516.90
Scale factor	1.00	1.00	1.00	1.00	1.00	1.00

The stress scales linearly with the load. Thus, a single adjustment factor may be used, according to methodology described in 0.

Table A.7-4. List of results with adjustment factor calculation

Study 2e Pseis_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	71.08	21.197	-28.688	378.6	363.8	348.8
2.50	7917	997.6	20.984	-955.6	1091.5	778.4	465.2
6.50	8007	1395.3	21.013	-1353.3	551.6	110.34	-330.95
9	8097	186.58	-7.58	-201.75	666.5	18.877	-628.8
	Max abs value	1395.30	21.20	1353.30	1091.50	778.40	628.80
Study 8e Pseis_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	69.022	2.10E+01	-26.928	382.7	368.4	354
1	7917	687.9	19.58	-648.7	1447.6	1240.7	1033.8
2	7962	939.1	21.304	-896.5	1206.4	914.4	622.4
3	8007	1107.4	21.603	-1064.2	978.6	628.8	279
4	8052	1220.4	21.463	-1177.6	783.6	394.7	5.88
5	8277	1296.5	21.321	-1253.9	633	218.71	-195.53
6	8322	1351.5	21.298	-1308.9	529.6	99.9	-329.87
7	8367	1398.9	21.542	-1355.8	470.5	30.3	-410
8	8412	1441.8	21.995	-1397.9	447.9	0.37	-447.2
9	8637	181.81	-8.13	-198.04	651.9	18.424	-615.1
	Max abs value	1441.80	22.00	1397.90	1447.60	1240.70	1033.80
		Pseis_AY factors (max)	Pseis_AY factors (max)	Pseis_AY factors (max)	Pseis_AY factors (max)	Pseis_AY factors (max)	Pseis_AY factors (max)
		1.03	1.04	1.03	1.33	1.59	1.64

For seismic meridional stresses in the knuckle, the ratio of the 8 element mesh to the 2 element mesh produces a correction factor of 1.04. For seismic hoop stresses in the knuckle, the ratio of 8 element mesh to the 2 element mesh produces a correction factor of 1.64. To ensure conservative analyses, the primary tank knuckle seismic meridional and hoop stresses should both receive a stress factor of at least 1.64.

A.7.8.5 Load Case 2: Upward Axial Force

A positive vertical force will be applied at approximately midway up the primary tank wall such that the resulting stress in the primary tank wall is similar to the meridional midplane stress values found in

Deibler et al 2008. To show the sensitivity of the model to the load, additional loads of one-half and double the nominal loading are applied to the study model. The load case also includes gravity effects (dead weight and waste hydrostatic fluid effects due to gravity), which will be subtracted in post processing.

The wall extends from path location 508" to 851". At the nominal load magnitude, the meridional midplane stress in the five primary tank wall elements above the knuckle in the study model is 90 ksf, which is a reasonable match within the range of values shown in Table A.7-5 for that location.

Table A.7-5. Excerpt from Appendix F AY-2D-NL-BES-BEC Pri Tank Stress Seismic Only.xls

ANSYS MAXIMUMS BY PATH

M&D Starting Element No.	Path (in.)	Shell Mid-Plane PNNL-AY-2D-NL- BES-BEC Meridional Stress (kip/ft²) Mid
981	503.51	137.84
1001	527.76	151.25
1021	554.76	122.92
1041	582.26	131.39
1061	609.26	140.18
1081	636.26	144.67
1101	663.26	146.55
1121	688.61	144.30
1141	711.96	139.56
1161	734.96	132.39
1181	757.91	125.60
1201	782.81	73.49
1221	809.76	65.13
1241	836.76	56.71
1261	863.76	47.75

Figure 0.7-13. Element Plot Showing Applied Loads

A.7.8.6 Results

The meridional and hoop stresses for the study model with several mesh refinements are presented in Figure 0.7-14 through Figure 0.7-19.

Figure 0.7-14. Knuckle Meridional Stress – Outside Surface (Away from Waste)

Figure 0.7-15. Knuckle Meridional Stress – Mid-plane Surface

Figure 0.7-16. Knuckle Meridional Stress – Inside Surface (Near Waste)

Figure 0.7-17. Knuckle Hoop Stress – Outside Surface (Away from Waste)

Figure 0.7-18. Knuckle Hoop Stress – Mid-plane Surface

Figure 0.7-19. Knuckle Hoop Stress – Inside Surface (Near Waste)

A.7.8.7 Seismic Axial Force Stress Factors

As shown in Figure 0.7-14 through Figure 0.7-19, the results converge at the first element outside the knuckle. The zone of influence is thus limited to the knuckle itself.

Table A.7-6. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc+_AY 2	5855.41	163.78	6045.88	2944.50	3411.31	3878.14
8e Forc+_AY 2X (scaled)	6093.20	165.26	6282.00	2912.60	3374.00	3835.20
Scale factor	1.04	1.01	1.04	0.99	0.99	0.99

Table A.7-7. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc+_AY .5	1525.20	41.32	1572.30	727.50	842.80	958.00
8e Forc+_AY .5X (scaled)	1523.30	41.32	1570.50	728.15	843.50	958.80
Scale factor	1.00	1.00	1.00	1.00	1.00	1.00

The stress scales approximately linearly with the load. Thus, a single adjustment factor may be used, according to methodology described in 0.

Table A.7-8. List of results with adjustment factor calculation

Study 2e Forc+_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	311.44	92.511	-126.418	-153.84	-219.43	-285.13
2.50	7917	521.8	82.169	-357.5	-1064.7	-1170.6	-1276.63
6.50	8007	-1591.4	65.392	1722.2	-742	-191.74	358.48
9	8097	-399.46	21.04	441.56	-1368.2	27.208	1422.57
	Max abs value	1591.40	92.51	1722.20	1368.20	1170.60	1422.57
Study 8e Forc+_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	292.632	9.21E+01	-108.43	-148.9	-208.99	-269.18
1	7917	868.5	79.112	-710.3	-1456.3	-1687	-1917.6
2	7962	914.2	81.269	-751.6	-1117.6	-1349	-1580.52
3	8007	811.9	82.631	-646.6	-822.4	-1010.3	-1198.25
4	8052	520.9	81.928	-357.2	-600.3	-688.59	-776.81
5	8277	-11.5	77.608	166.7	-490.3	-408.75	-327.16
6	8322	-800.8	70.353	941.5	-514.4	-192.38	129.65
7	8367	-1820.8	60.475	1941.7	-675	-51.07	572.83
8	8412	-3046.6	47.224	3141	-966.06	12.43	990.88
9	8637	-407.8	20.54	448.87	-1394.9	26.66	1448.2
	Max abs value	3046.60	92.11	3141.00	1456.30	1687.00	1917.60
		Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)
		1.91	1.00	1.82	1.06	1.44	1.35

For seismic meridional stresses in the knuckle, the ratio of the 8 element mesh to the 2 element mesh produces a correction factor of 1.91. For seismic hoop stresses in the knuckle, the ratio of 8 element mesh to the 2 element mesh produces a correction factor of 1.44. To ensure conservative analyses, the primary tank knuckle seismic meridional and hoop stresses should both receive a stress factor of at least 1.91.

A.7.8.8 Load Case 3: Downward Axial Force

The loading is the same as for upward axial force, except the sign of the vertical force is negative.

Figure 0.7-20. Element Plot Showing Applied Loads

A.7.8.9 Results

The meridional and hoop stresses for the study model with several mesh refinements are presented in Figure 0.7-14 through Figure 0.7-19.

Figure 0.7-21. Knuckle Meridional Stress – Outside Surface (Away from Waste)

Figure 0.7-22. Knuckle Meridional Stress – Mid-plane Surface

Figure 0.7-23. Knuckle Meridional Stress – Inside Surface (Near Waste)

Figure 0.7-24. Knuckle Hoop Stress – Outside Surface (Away from Waste)

Figure 0.7-25. Knuckle Hoop Stress – Mid-plane Surface

Figure 0.7-26. Knuckle Hoop Stress – Inside Surface (Near Waste)

A.7.8.10 Seismic Axial Force Stress Factors

As shown in Figure 0.7-21 through Figure 0.7-26, the results converge at the first element outside the knuckle. The zone of influence is thus limited to the knuckle itself.

Table A.7-9. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc-_AY 2	6079.50	165.20	6269.10	2915.00	3376.90	3838.70
8e Forc-_AY 2X (scaled)	6102.00	184.21	6290.80	2908.80	3369.60	3830.40
Scale factor	1.00	1.12	1.00	1.00	1.00	1.00

Table A.7-10. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc-_AY .5	1528.20	41.31	1575.40	726.60	841.60	956.60
8e Forc-_AY .5X (scaled)	1525.50	46.05	1572.70	727.20	842.40	957.60
Scale factor	1.00	1.11	1.00	1.00	1.00	1.00

The stress scales linearly with the load. Thus, a single adjustment factor may be used, according to methodology described in 0.

Table A.7-11. List of results with adjustment factor calculation

Study 2e Forc-_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	-311.44	-92.505	126.432	153.7	219.5	285.1
2.50	7917	-521.5	-82.164	357.2	1063.9	1169.8	1275.6
6.50	8007	1592.2	-65.36	-1723	741.1	190.7	-359.75
9	8097	397.58	-22.3	-442.15	1365.1	-27.788	-1420.7
	Max abs value	1592.20	92.51	1723.00	1365.10	1169.80	1420.70
Study 8e Forc-_AY							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
0	7827	-292.508	-9.21E+01	108.292	148.6	208.8	268.9
1	7917	-867.8	-79.114	709.55	1454.4	1684.8	1915.2
2	7962	-913	-81.263	750.5	1115.9	1347	1578.1
3	8007	-810.3	-82.617	645	820.9	1008.4	1196
4	8052	-518.7	-81.901	354.8	599.4	686.9	774.43
5	8277	14.5	-77.566	-169.6	489.7	407.21	324.83
6	8322	804.5	-70.299	-945	514.1	191.1	-131.94
7	8367	1824.9	-60.41	-1945.7	674.9	49.95	-575.1
8	8412	3051	-47.149	-3145.4	966.2	-13.44	-993.1
9	8637	404.71	-21.75	-448.19	1387.7	-27.261	-1442.2
	Max abs value	3051.00	92.11	3145.40	1454.40	1684.80	1915.20
		Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)	Forc_AY factors (max)
		1.92	1.00	1.83	1.07	1.44	1.35

For seismic meridional stresses in the knuckle, the ratio of the 8 element mesh to the 2 element mesh produces a correction factor of 1.92. For seismic hoop stresses in the knuckle, the ratio of 8 element mesh to the 2 element mesh produces a correction factor of 1.44. To ensure conservative analyses, the primary tank knuckle seismic meridional and hoop stresses should both receive a stress factor of at least 1.92.

A.7.9 AY vs. AP

The AP tank configuration is examined using the same methodology as AY tank. The applied loads are derived from AP tank waste properties (Abatt 2008) and AP tank global seismic model results (Abatt

2008). In the interest of brevity, only tabular results with adjustment factor calculation are presented for the AP tank configuration.

A.7.9.1 Load Case 1: Pressure Loading

Table A.7-12. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Pseis_AP 2	671.90	51.52	568.92	889.80	907.10	924.40
8e Pseis_AP 2X (scaled)	691.50	51.47	588.56	888.80	906.00	923.00
Scale factor	1.03	1.00	1.03	1.00	1.00	1.00

Table A.7-13. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Pseis_AP .5	182.84	12.88	157.08	221.50	225.80	230.00
8e Pseis_AP .5X (scaled)	172.88	12.87	147.14	222.20	226.50	230.75
Scale factor	0.95	1.00	0.94	1.00	1.00	1.00

Table A.7-14. List of results with adjustment factor calculation

Study 2e Pseis_AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	-148.08	26.6866	201.45	724.6	777.1	829.6
0	7925	-6.35	22.5931	51.53	436.6	445.4	454
2.50	8015	128.7	23.0091	-82.7	156.79	122.02	87.2
6.50	8105	335.4	25.103	-285.2	124	26.96	-70.067
9	8195	51.22	13.58	-24.05	152.9	25.125	-102.7
10	8285	-18.8349	12.77	44.38	-79.76	24.763	129.28
	Max abs value	335.40	26.69	285.20	724.60	777.10	829.60

Study 8e Pseis _AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	-144.36	26.444	197.24	725.6	776.7	828
0	7925	-6.2	22.3883	50.97	444.4	453	461.5
1	8015	-48	21.7304	91.4	172.02	192	212
2	8060	87.4	23.2094	-41	167.11	145.2	123.3
3	8105	195.3	24.2348	-146.8	157.58	102.33	47.1
4	8150	276.64	25.0275	-226.58	147.17	66.99	-13.2
5	8375	326.682	25.5591	-275.561	136.45	41.29	-53.88
6	8420	345.75	25.735	-294.28	125.38	25.18	-75.019
7	8465	340.3	25.67	-289	114.34	16.85	-80.64
8	8510	311.5	25.345	-260.8	101.4	13.79	-73.82
9	8735	46.37	12.83	-20.71	138.9	24.585	-89.7
10	8825	-17.5954	12.01	41.61	-73.68	24.208	122.09
	Max abs value	345.75	26.44	294.28	725.60	776.70	828.00
		Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)
		1.03	0.99	1.03	1.00	1.00	1.00

A.7.9.2 Load Case 2: Upward Axial Force

Table A.7-15. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc+ _AP 2	5260.20	193.48	4873.20	3016.70	1611.36	3208.70
8e Forc+ _AP 2X (scaled)	5067.34	218.97	4634.68	2899.75	1562.56	3064.96
Scale factor	0.96	1.13	0.95	0.96	0.97	0.96

Table A.7-16. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc+ _AP .5	1267.22	56.44	1225.90	721.36	387.75	761.15
8e Forc+ _AP .5X (scaled)	1266.84	54.74	1158.67	724.94	390.64	766.24
Scale factor	1.00	0.97	0.95	1.00	1.01	1.01

Table A.7-17. List of results with adjustment factor calculation

Study 2e Forc+_AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	-153.95	78.9456	311.84	-91	-21.1	48.8
0	7925	342.582	66.8371	-208.91	-314	-396.6	-479.4
2.50	8015	1291.819	66.8811	-1158.05	20.3	-341.52	-703.36
6.50	8105	-194.53	50.699	295.93	-164.27	-68.22	27.847
9	8195	-237.18	18.05	273.278	-799.1	24.261	847.62
10	8285	64.6951	16.13	-32.43	176.74	18.684	-139.37
	Max abs value	1291.82	78.95	1158.05	799.10	396.60	847.62
Study 8e Forc+_AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	-243.94	128.497	500.93	-135.4	-23.7	88.1
0	7925	478.65	108.7953	-261.064	-537	-647.9	-758.9
1	8015	2277	104.2084	-2068.61	-130.18	-781.28	-1432.37
2	8060	2533.67	108.1724	-2317.34	4.86	-717.51	-1439.88
3	8105	2520.9	109.4848	-2301.97	107.02	-602.71	-1312.456
4	8150	2220.92	107.5485	-2005.86	158.66	-450.01	-1058.68
5	8375	1597.17	100.8981	-1395.37	125.48	-285.07	-695.62
6	8420	650.5	90.721	-469.01	-17.28	-136.97	-256.651
7	8465	-577.33	77.531	732.41	-278.1	-29.49	219.127
8	8510	-2051.47	60.219	2171.9	-659.54	21.93	703.399
9	8735	-435.87	29.05	493.99	-1449.873	41.28	1532.48
10	8825	81.4976	24.95	-31.59	211.14	29.039	-153.07
	Max abs value	2533.67	128.50	2317.34	1449.87	781.28	1532.48
		Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)
		1.96	1.63	2.00	1.81	1.97	1.81

A.7.9.3 Load Case 3: Downward Axial Force

Table A.7-18. List of results for 2x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc-_AP 2	5131.70	223.82	4689.00	2983.10	1573.70	3152.40
8e Forc-_AP 2X (scaled)	5133.00	223.85	4690.20	2992.40	1574.80	3161.40
Scale factor	1.00	1.00	1.00	1.00	1.00	1.00

Table A.7-19. List of results for 0.5x load with scale factor calculation

	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
8e Forc- _AP .5	1283.10	55.97	1172.40	748.10	393.90	790.00
8e Forc- _AP .5X (scaled)	1283.25	55.96	1172.55	748.10	393.70	790.35
Scale factor	1.00	1.00	1.00	1.00	1.00	1.00

Table A.7-20. List of results with adjustment factor calculation

Study 2e Forc- _AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	157.65	-77.9584	-313.565	91.4	20.8	-49.8
0	7925	-341.04	-66.0009	209.04	319.5	402	484.5
2.50	8015	-1320	-66.2949	1187.4	-19.51	350.92	721.3
6.50	8105	115.9	-50.866	-217.6	145.65	72.07	-1.506
9	8195	246.28	-20.04	-286.36	830.4	-25.588	-881.6
10	8285	-51.0679	-18.8	13.48	-123.87	-22.276	79.31
	Max abs value	1320.00	77.96	1187.40	830.40	402.00	881.60
Study 8e Forc- _AP							
	Element	SM_T	SM_M	SM_B	SH_T	SH_M	SH_B
-1	7835	245.621	-131.673	-508.97	137.6	24.4	-88.7
0	7925	-489.49	-111.4747	266.53	542.3	655.8	769.1
1	8015	-2311	-106.7366	2097.5	126.83	787.4	1447.9
2	8060	-2566.5	-110.6976	2345.1	-9.56	721.8	1453.1
3	8105	-2545.5	-111.9252	2321.6	-111.44	604.67	1320.8
4	8150	-2229.88	-109.8015	2010.24	-160.86	449.47	1059.69
5	8375	-1582.93	-102.8459	1377.23	-122.97	282.25	687.52
6	8420	-606.166	-92.305	421.555	27.14	132.66	238.189
7	8465	656.9	-78.692	-814.3	297.6	24.62	-248.35
8	8510	2170.4	-60.896	-2292.2	690.35	-26.67	-743.69
9	8735	443.9	-33.858	-511.62	1496.2	-42.245	-1580.7
10	8825	-102.4654	-32.56	37.34	-262.04	-39.382	183.27
	Max abs value	2566.50	131.67	2345.10	1496.20	787.40	1580.70
		Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)	Forc_AP factors (max)
		1.94	1.69	1.97	1.80	1.96	1.79

A.7.9.4 Summary of AP tank configuration

The general trend for AP tank results is similar to AY tank. The AP tank does not reach convergence of the 2 element and 8 element results until the second element outside of the knuckle.

The stress scales approximately linearly with the load. Thus, a single adjustment factor may be used, according to methodology described in 0.

For seismic meridional stresses in the knuckle, the ratio of the 8 element mesh to the 2 element mesh produces a correction factor of 2.0. For seismic hoop stresses in the knuckle, the ratio of 8 element mesh to the 2 element mesh produces a correction factor of 1.97. To ensure conservative analyses, the primary tank knuckle seismic meridional and hoop stresses should both receive a stress factor of at least 2.0.

A.7.10 Summary and Conclusion

This appendix establishes a factor that will be applied to the global seismic model lower knuckle stress components to account for loss of accuracy due to the limited two element mesh resolution. This factor will be applied to the lower knuckle stress components from the global seismic model before combining the results with the TOLA model stresses, which uses a more accurate eight element mesh resolution.

In comments on the previous revision of this appendix, reviewers R.P. Kennedy and A.S. Veletsos recommended that the adjustment factor consider seismically-induced effects, specifically seismic waste pressure and axial loads in the primary tank wall. This revision is substantially rewritten based upon the comments.

The effects of the knuckle mesh and seismic loading are evaluated using a simplified slice model based directly on the global seismic model. Two instances of the study model were used; a two element and an eight element knuckle mesh resolution. Three load cases were defined to evaluate the load conditions indicated in the above comments. The load cases are run with a range of load magnitudes found in the global seismic model.

The results of the evaluation showed:

- The knuckle zone of influence is limited to the knuckle itself (AY) or within 1 element of the knuckle (AP). Thus, the effect of the knuckle mesh resolution (and the adjustment required) is localized.
- The stress scales approximately linearly with the load. Thus, a single adjustment factor may be used because the single factor is applicable over the entire range considered. The broad applicability of the factor covers uncertainties in the magnitude of the load.

The adjustment factor is based on the maximum of the absolute values of meridional and hoop stresses from the study model with 2 and 8 element meshes.

An adjustment factor of at least 2.0 is recommended to be applied to the meridional and hoop stresses for the primary tank lower knuckle of the global seismic model. The adjustment factor need only be applied

to the knuckle zone of influence elements, which is at most one element beyond the knuckle. The applicable elements are list below:

Table 0.7-21. List of AY global seismic model elements requiring adjustment factor

1302	1307	1312	1317	1322	1327	1332	1337
1303	1308	1313	1318	1323	1328	1333	1338
1304	1309	1314	1319	1324	1329	1334	1339
1305	1310	1315	1320	1325	1330	1335	1340
1306	1311	1316	1321	1326	1331	1336	1341

Table 0.7-22. List of AP global seismic model elements requiring adjustment factor

1362	1372	1382	1392	1402	1412	1422	1432
1363	1373	1383	1393	1403	1413	1423	1433
1364	1374	1384	1394	1404	1414	1424	1434
1365	1375	1385	1395	1405	1415	1425	1435
1366	1376	1386	1396	1406	1416	1426	1436
1367	1377	1387	1397	1407	1417	1427	1437
1368	1378	1388	1398	1408	1418	1428	1438
1369	1379	1389	1399	1409	1419	1429	1439
1370	1380	1390	1400	1410	1420	1430	1440
1371	1381	1391	1401	1411	1421	1431	1441

A.7.11 Application to Increased Liquid Level Analysis for AP Tanks

There are differences in the interpretation of the results of the primary tank lower knuckle study. While the study concluded that “An adjustment factor of at least 2.0 is recommended to be applied” to the seismic results of the primary tank stress in the lower knuckle, a factor of 3.0 was used for combining with the TOLA results for the subsequent ASME evaluation.

A.8 Reviewer Comments – Veletsos, August 2008

Comments Regarding Revised Anchor Bolt Evaluation for 241-AP Tanks with Increased Liquid Level

by

A.S. Veletsos
Via e-mail
August 12 2008

Following, at long last, are my comments on the report on Anchor Bolts Modeling.

The issuance of this report in its present form would be totally acceptable to me. I would, however, like to add the following remarks, and leave it up to you and your associates to decide if any adjustments would be desirable in response to them.

There were two issues mentioned on this topic in our teleconference of March 25, 2008. First, that increasing the flexibility of the anchor bolts may decrease rather than increase their maximum dynamic deformations; and second, that considering the stiffness or flexibility of all bolts to be the same is likely to underestimate the maximum deformations of those in the lower rows compared to those in the upper rows.

For reasons that I do not quite understand but I fully accept, the results of the more extensive study of anchor bolts had already demonstrated that, at least for the conditions relevant to the project, my view on the first issue was not correct. On the other hand, the view on the second issue is demonstrated to have been right by the results of the present study. It is worth noting in this regard that, although of significantly lower values, the ordinates of the curve in Fig. 2 of the Report for bolts with the realistic, differing effective stiffness increase much more rapidly with increasing distance from the crown than do those of the curve for bolts of the same stiffness. Specifically, whereas the ratio of the ordinates of the curves for bolts of the same effective stiffness at distances of roughly 260 in. and 50 in. from the crown is approximately $0.38 / 0.12 = 3.2$, for the bolts of variable stiffness, it is $0.1 / 0.02 = 5$. More importantly, at the distances of about 440 in. and 50 in. from the crown, the corresponding ratios are approximately $1.0 / 0.12 = 8.3$ and $0.52 / 0.02 = 26$, respectively.

I hope that these brief comments prove helpful.

A.9 Reviewer Comments – Klingner, September 2008

COMMENTS ON THE TREATMENT OF ANCHORS IN ANALYSES OF HANFORD DOUBLE-SHELL TANKS

**Richard E. Klingner, PE
Austin, TX
September 2008**

A.9.1 Introduction

Pacific Northwest National Laboratories (PNNL) and M&D Professional Services (M&D) are conducting analyses of the Hanford Site Double-Shell Tanks (DSTs) as part of the DST Integrity Project. The thermal and operating loads (TOLA) analysis is being performed by PNNL and the seismic analysis is being performed by M&D. The computer models used for the seismic analyses are distinct from the computer models used for the TOLA analyses, and results from the two models have been superposed.

Among the critical components of the DST structure are the anchors that connect the steel dome of the primary tank to the concrete dome of the vault. For the analyses noted above, the nonlinear response of these embedded anchors has been simulated using an equivalent linear elastic modulus (secant modulus) that is based on the estimated maximum deformation capacity of the anchors. Of particular interest is the development of the equivalent linear elastic modulus representing the shear response of the anchors.

The equivalent linear elastic moduli in shear and tension that were used in the evaluation of the DST anchor bolts were developed based on a combination of test results, extrapolations of test results, and analytical predictions. This paper has three purposes. The first is to review and assess the underlying technical justification for the combination of TOLA and seismic demands on the anchors when those anchors are simulated using an equivalent linear modulus in the separate models. The second is to assess the ultimate shearing deformation capacity used in the DST anchor evaluation. The third is to comment on the relationship between the approach used in the DST anchor evaluation and the current activity of ACI Committee 349 (Concrete Nuclear Structures).

A.9.2 Superposition of Seismic and TOLA Results

Because the goals and technical constraints of the seismic and TOLA models were significantly different, the two analyses have been conducted separately using distinct models and the results then combined. Such superposition is convenient because it reduces computational effort. It also eliminates the possibility of numerical instability associated with spurious coupling of seismic and TOLA solutions that might in fact be uncoupled.

Such superposition is valid, provided that the following conditions are met:

- 1) The seismic and TOLA responses must each be essentially linear elastic;
- 2) The secant stiffnesses used for the anchor bolts in the seismic and TOLA analyses must be consistent with the range of deformations experienced by those anchor bolts in the seismic and the TOLA responses; and
- 3) The secant stiffnesses used for the anchors in the seismic and TOLA analyses must be consistent with the ranges of deformations experienced by those anchors in the superposed seismic and TOLA analyses.

The above assertion is clearly valid if each anchor remains linear elastic throughout the seismic and TOLA responses, and also throughout the superposition of those responses. The assertion remains reasonable provided that each of the seismic and TOLA responses, as well as their superposition, is essentially represented by the equivalent linearization. This particular point is addressed below.

A.9.3 Technical Justification for Equivalent Linear Analyses

The biggest question regarding the use of equivalent linear models in the seismic and TOLA analyses for elements whose behavior is actually nonlinear is, "Is equivalent linearization safe?" This question becomes especially complex when the loading comes from restrained thermal deformations in addition to applied gravity loads or seismic inertial forces.

A fundamental approach to this question is probably best. The solution to a structural analysis problem must satisfy equilibrium, constitutive relationships, and kinematics. The collapse load predicted by such a solution is in principle exact if the model is correct. According to the lower-bound theorem of structural mechanics (Hodge 1958, Neal 1963), a collapse load predicted using a solution that satisfies equilibrium and constitutive relationships, but not necessarily kinematics, is a lower bound to the true collapse load. Analytical solutions that satisfy the lower-bound theorem are therefore in principle safe for the design, because the true collapse load is always greater than or equal to that predicted.

In structural design for applied loads, the lower-bound theorem is applied by selecting a force path from the point of load application to the foundation, and by providing along that force path sufficient strength to resist the resulting actions, under the deformations associated with those actions. The force path does not have to be that corresponding to elastic analysis. Examples of the lower-bound approach to structural design are the idealization of reinforced concrete slabs with plan dimensional ratios of 2:1 or greater as one-way slabs spanning in the shorter direction, and the idealization of complex reinforced concrete assemblages using strut-and-tie models. Lower-bound models satisfy equilibrium of applied forces and corresponding internal actions, and they satisfy constitutive relationships because yield is not exceeded along the designated load path.

Under applied loads from gravity or ground shaking, an analytical approach that uses equivalent linearization with a secant modulus based on a deformation greater than or equal to the calculated deformation, is in principle consistent with the lower-bound theorem of structural mechanics, and is in principle therefore safe.

To see why this is so, consider the hypothetical structural system whose force-deformation behavior is shown in Figure 27. Units of load and displacement are arbitrary. For discussion purposes, the curve on the figure represents the system's true force-deformation behavior, while the upper and lower straight lines represent equivalent linearizations of that behavior using secant stiffnesses evaluated between zero and a deformation of 0.01, and between zero and a deformation of 0.02, respectively.

Figure 27 Hypothetical structural system

Suppose that the system is analyzed using an equivalent linearization with the secant stiffness evaluated between zero and a deformation of 0.01. Provided that the deformation experienced by the system is less than or equal to 0.01, the results of the analysis will satisfy the lower-bound theorem: equilibrium is satisfied, and so are constitutive relationships, because the force consistent with the secant stiffness is always less than or equal to the true force.

If the calculated deformation exceeds 0.01, then constitutive relationships are no longer necessarily satisfied, and the analysis should be repeated using a secant stiffness evaluated between zero and a greater deformation (for example, 0.02).

This logic is valid provided that the system is a softening system, and provided that its behavior is ductile rather than brittle, so that there is no sudden release of energy at failure. It also applies to the seismic response, which is essentially elastic.

The logic remains valid even when the load on the system comes from restrained internal deformations, because any such load case can be interpreted as the summation of two load cases: the first is the combination of thermal deformations plus the external loads (nodal loads) necessary to give zero nodal displacements; and the second is the opposite of those nodal loads. In addition, it is useful to remember that in principle, a ductile anchor embedded in concrete that is subjected to thermal deformations cannot

fail as a result of those deformations, because as the stiffness of the anchor approaches zero, so does the change in anchor force resulting from thermal deformations of the concrete. This presumes, of course, that the deformation limit of the anchor is not exceeded.

Finally, it is worthwhile to discuss briefly the probable effects of two other possible behaviors in the concrete surrounding the anchors: tensile cracking and creep (or relaxation). Both of these decrease the effective elastic modulus of the concrete, and therefore decrease the forces imposed on the anchors by restrained thermal deformations. Provided that cracking of the concrete does not degrade the performance of the tank in other ways, it does not affect the validity of the lower-bound approach presented above.

A.9.4 Development of Equivalent Linear Elastic Models for Anchors

In terms of the above example, it is necessary to have a reliable force-deformation curve in order for the equivalent secant linearization to satisfy the lower-bound theorem. Such force-deformation curves can be obtained by test or by analysis. The process used to develop them in this case is reported in pp. 10-13 of Appendix B of Deibler (2008), and is corroborated by Figure 28 (Nelson 1961), which shows force-deformation curves for plain headed bolts loaded in shear. Behavior is ductile, and the maximum deformations reported in Nelson (1961) for 1/2-, 5/8-, and 3/4-in. diameter studs are 0.167 in., 0.299 in., and 0.341 in., respectively. The reported deformations are for concrete compressive strengths between approximately 3,800 and 4,200 psi. The deformations at failure are consistent with those reported by Hungerford (2004) in tests of single welded studs embedded in concrete and loaded in shear. Hungerford reports deformations at failure of 0.6 in. for 3/4-in. welded studs.

FIG. 13 LOAD-SLIP vs. LOAD DISPLACEMENT CURVES FOR HEADED STUDS

Figure 28 Force-deformation curves for headed bolts (Figure 13 of Nelson [1961])

Figure 29 and Figure 30, taken from Hungerford (2004), show a load-slip curve for a cast-in-place, 3/4-in. diameter welded stud, 5-in. long, loaded in shear. The concrete in that test series had a strength of 3,500 psi at time of test, and showed some hairline cracks.

Figure 29 Load-slip curve for 3/4-in., cast-in-place welded stud, 0 to 0.8 in. (Hungerford 2004)

Figure 30 Load-slip curve for 3/4-in., cast-in-place welded stud, 0 to 0.3 in. (Hungerford 2004)
Deformations at failure will be less for smaller studs, but are still expected to be considerably above 0.2 in. for studs with an effective diameter of at least 9/16 in., which was shown in Appendix B of Deibler *et al.* (2008) to be the effective diameter of the DST anchor bolts.

A.9.5 The Proposed Approach and ACI349 Loading Combinations

This paper is the work of an individual, and does not represent an official interpretation of any document authored by ACI Committee 349 (Concrete Nuclear Structures). Nevertheless, the approach discussed here (equivalent linearization, direct combination of thermal and seismic effects, and a check that the calculated anchor deformations do not exceed the limits of the experimental and analytical results used to establish the linearization) is consistent with the current work of ACI349. Also, the procedure used to combine non-thermal and thermal effects is consistent and conservative. In this section, each of these points is discussed further.

As discussed in Deibler *et al.* (2008), the DST anchor bolts were evaluated according to ACI349-01 (ACI 2001). That standard treats combinations of thermal and seismic loads quite briefly. Of the eleven factored loading combinations given in Section 9.2.1 of that document, only two address combinations of thermal loads and design-basis earthquake; both combinations simply add their effects. This point is discussed further below.

Further guidance is given in that Committee's *Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures* (ACI349.1R-07). As stated in Section 1.3 (General Guidelines) of that document,

Stresses resulting from thermal effects are generally self-relieving, that is thermal forces and moments are greatly reduced or completely relieved once concrete cracks or reinforcement yields; as a result, thermal effects do not reduce the strength of a section for mechanical loads.

Informal Committee discussions reflect agreement that thermal loads cannot produce failure of an element, provided that deformation limits are not exceeded.

Given the limited guidance from ACI349 regarding appropriate combinations of thermal and earthquake effects, it is necessary to use professional judgment to establish appropriate combinations of thermal and seismic effects from consistent linearizations, and to establish appropriate ways of comparing those combinations against available capacities.

Of the loading combinations given in Section 9.2.1 of ACI349-01, only one (Loading Combination 4) involves thermal effects plus design-basis earthquake. That combination is repeated below in Eq. (1), with the factored loading combination (U) on the right-hand side of the equation:

$$D + F + L + H + T_o + R_o + E_{ss} = U \quad \text{Eq. (1)}$$

Consider first a combination of load effects not involving thermal effects. The design criterion is given in Eq. (2):

$$\sum_{i=1}^N \text{Non-thermal Effect}_i = U \leq \phi (\text{nominal resistance}) \quad \text{Eq. (2)}$$

If consistent linearizations are used, so that deformations are proportional to actions, then for the case of shearing loads and deformations, this design criterion can be expressed directly in terms of deformations, as in Eq. (3):

$$\sum_{i=1}^N (\Delta_{non-thermal})_i \leq \phi (\Delta_{ultimate}) \quad Eq. (3)$$

where

$\Delta_{non-thermal}$ = shearing deformations from non-thermal effects; and
 $\Delta_{ultimate}$ = ultimate shearing deformation capacity

The ϕ -factor is intended to address the statistical dispersion of load effects, and possibly the statistical dispersion of ultimate shearing deformations. The ultimate shearing deformations used in the evaluation of the DST anchor bolts are based on the ultimate deformations reported in Oehlers and Sved (1995), which have a coefficient of variation of only 0.048. Thus, in the case of the DST anchor bolts, the primary purpose of the ϕ -factor is to address the statistical dispersion of load effects.

According to Appendix B4.4 of ACI349-01, the ϕ -factor corresponding to failure of a ductile steel element is 0.75 in shear. Based on this evaluation, it would be justifiable to use a ϕ -factor of 0.75 in Eq. (3), leading to Eq. (4):

$$\sum_{i=1}^N (\Delta_{non-thermal})_i \leq 0.75 (\Delta_{ultimate}) \quad Eq. (4)$$

Now consider combinations of loads involving thermal loads only. Because thermal loads cannot in principle produce failure provided that the ultimate shearing deformation is not exceeded, there is no need to use a ϕ -factor to account for the statistical dispersion of thermal effects. The appropriate loading combination is therefore as shown in Eq. (5):

$$\sum_{i=1}^N (\Delta_{thermal})_i \leq 1.0 (\Delta_{ultimate}) \quad Eq. (5)$$

where

$\Delta_{thermal}$ = shearing deformations from thermal effects; and
 $\Delta_{ultimate}$ = ultimate shearing deformation capacity

Finally, consider combinations of non-thermal and thermal effects. To combine those appropriately, both sides of the above equation involving thermal effects only should be factored by 0.75. The equation

involving non-thermal effects only and the factored equation involving thermal effects only can then be combined as in Eq. (6).

$$\sum_{i=1}^N (\Delta_{non-thermal}) + 0.75 (\Delta_{thermal})_i \leq 0.75 (\Delta_{ultimate}) \quad Eq. (6)$$

If desired, Eq. (6) can be simplified (very conservatively) as Eq. (7):

$$\sum_{i=1}^N (\Delta_{non-thermal}) + (\Delta_{thermal})_i \leq 0.75 (\Delta_{ultimate}) \quad Eq. (7)$$

A.9.6 Concluding Remarks

These “Comments” have three purposes. The first is to review and assess the underlying technical justification for the combination of TOLA and seismic demands on the anchors when those anchors are simulated using an equivalent linear modulus in the separate models. The second is to assess the value of the ultimate shearing deformation used to evaluate the DST anchors. The third is to comment on the relationship between the approach used in the DST anchor evaluation and the current activity of ACI Committee 349 (Concrete Nuclear Structures), particularly with respect to loading combinations involving non-thermal plus thermal effects.

In the above sections, that underlying technical justification is assessed, and is judged valid, because the following conditions are met:

- 1) The seismic and TOLA responses are each essentially linear elastic;
- 2) The secant stiffnesses used for the anchor bolts in the seismic and TOLA analyses are consistent with the range of deformations experienced by those anchor bolts in the seismic and the TOLA responses; and
- 3) The secant stiffnesses used for the anchors in the seismic and TOLA analyses are consistent with the ranges of deformations experienced by those anchors in the superposed seismic and TOLA analyses.

In the above sections, the probable ultimate shear deformation capacity of the DST anchors is shown to considerably exceed the approximately 0.2 in. used in the DST evaluation.

Although ACI Committee 349 (Concrete Nuclear Structures) gives little direct guidance on how to combine thermal effects with those from design-basis earthquakes, it does give general guidance on the interaction of thermal and seismic effects. That guidance is consistent with the general approach used here. Because thermal effects cannot in principle produce failure provided that the ultimate deformation

capacity is not exceeded, it is appropriate to compute the summation of shearing deformations from non-thermal effects, plus 0.75 times the shearing deformations from thermal effects, and to compare that summation with 0.75 times the ultimate deformation capacity. In this case, shearing deformations from non-thermal and thermal effects were summed directly, and were compared with 0.75 times the ultimate deformation capacity. This is very conservative.

I therefore conclude that the methodology used to evaluate the DST anchor bolts is technically justified, safe, and consistent with the current activity of ACI Committee 349.

A.9.7 References

ACI 2001, *Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01) and Commentary (ACI 349R-01)*, American Concrete Institute, Farmington Hills, Michigan.

Deibler, J.E, K.I. Johnson, S.P. Pilli, M.W. Rinker, F.G. Abatt, and N.K. Karri, 2008, *Hanford Double-Shell Tank Thermal and Seismic Project – Increase Liquid Level Analysis for 241-AP Tank Farms*, RPP-RPT-32237, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Hodge, P.H., 1959, *Plastic Analysis of Structures*, McGraw-Hill, New York, NY.

Hungerford, B., 2004, *Methods to Develop Composite Action in Non-Composite Bridge Floor Systems: Part II*, MS Thesis, The University of Texas at Austin, May 2004.

Neal, B.G., 1963, *The Plastic Methods of Structural Analysis*, Chapman and Hall, London.

Nelson, 1961, *Design Data: Nelson Concrete Anchor Studs for Securing Steel to Concrete*, Design Manual #21, Nelson Stud Welding Co., Elyria, Ohio.

Oehlers, Deric John, and George Sved, 1995, *Composite Beams with Limited-Slip-Capacity Shear Connectors*, *Journal of Structural Engineering*: 932-938.

Appendix B

Software Acceptance

Intentionally left blank.

Appendix B

Software Acceptance

- 1) Project Title and Number: DST Thermal and Seismic Analyses 48971
- 2) Software Name and Version: ANSYS 7.0 (Rev. 11)
- 3) Computer and Property Number: Dell PWS 530 WD39892
- 4) Operating System: Windows XP Professional Version 2002 Service Pack 2
- 5) Scope of Testing: Software reinstallation (XP SP2)
- 6) Tests: Execute ANSYS Verification Testing Package
- 7) Discrepancies:
 - a) c0231. These differences are acceptable per the ANSYS Verification Package User's Guide – ANSYS Release 7.0 (AVPUG).
 - b) vm184. These differences occur at the 5th significant figure.
 - c) vm198. This difference is the reporting of the customer number for this installation.
 - d) vmc8. These differences are acceptable as noted in the output because of the difference in number of iterations and accuracy.
 - e) cyc-177s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - f) cyc-178s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - g) dds-13s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - h) dds-17s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - i) ev173-53s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - j) ev175-20s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - k) ev175-21s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.

- l) inrt-16s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - m) sx120-1s. This test case requires the "Frequency Sweep Module" which is not part of this software installation and is not required for the DST analyses.
- 8) Finding: This installation of ANSYS is acceptable

Certified by:

JE Deibler 2/24/05
Code Custodian

Reviewed by:

KI Johnson 4/16/05
Lead Engineer

Notes for test case cO231

Test case cO231 may show considerable differences for the Phase Angle value that is part of the Post1 Nodal Degree of Freedom Listing (PRNS command) output. Any such differences do not indicate a problem with this test case's results and should be considered acceptable. The output items of significance for this test case are the UZ values in the Post1 Nodal Degree of Freedom Listing. Machine precision differences in the form of small numerical differences that are trivial with respect to the test's output items of significance may also show for this test case in the compare output for this test. Please see *Verifying ANSYS and Evaluating COMPARE Differences* in Chapter 2 of the *ANSYS Verification Testing Package User's Guide* for more information on evaluating COMPARE differences. The following is an example of acceptable COMPARE differences for test case cO231:

```
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.7700 22. T= VALUE -9.8119 -3.7693 22.
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.7579 -3.9649 22. T= VALUE -9.7581 -3.9643 22.

COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= 8 0.53291 0.39425 10 T= 8 0.53293 0.39419 10
COMPARE DIFFERENCE FOUND AT G= 10 0.52495 0.39568 9. T= 10 0.52497 0.39562 9.
COMPARE DIFFERENCE FOUND AT NG= 259 NT= 259 G= 12 0.50433 0.40282 8.6482 8.6722 T= 12 0.50435 0.40276 8.6471
8.6711
COMPARE DIFFERENCE FOUND AT NG= 260 NT= 260 G= 14 0.48186 0.41201 7.8710 7.8965 T= 14 0.48188 0.41196 7.8700
7.8955
COMPARE DIFFERENCE FOUND AT NG= 261 NT= 261 G= 16 0.45505 0.42479 7.0719 7.0992 T= 16 0.45507 0.42473 7.0710
7.0983
COMPARE DIFFERENCE FOUND AT NG= 262 NT= 262 G= 18 0.42339 0.44092 6.2424 6.2723 T= 18 0.42341 0.44086 6.2417
6.2715
COMPARE DIFFERENCE FOUND AT NG= 263 NT= 263 G= 20 0.38501 0.46124 5.3732 5.4067 T= 20 0.38502 0.46118 5.3726
5.4061
COMPARE DIFFERENCE FOUND AT NG= 267 NT= 267 G= VALUE -9.6034 -3.9649 18.806 21.413 T= VALUE -9.6036 -3.9643
18.805 21.412
NG= 271 NT= 271 22.469 24.766 22.469 24.766
NG= 192 NT= 192 1 -PHASE ANGLE = 1- PHASE ANGLE =
NG= 213 NT= 213 469 24.766 469 24.766
NG= 219 NT= 219 2- PHASE ANGLE = 2- PHASE ANGLE =
NG= 240 NT= 240 440 24.710 440 24.710
NG= 246 NT= 246 3- PHASE ANGLE = 3- PHASE ANGLE =
NG= 257 NT= 257 161 10.183 160 10.181
NG= 4080 4068

258 NT= 258 9.4309 9.4297
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.9649 T= VALUE -9.8119 -3.9643
30.580 306.570
30.580 306.570
30.580 306.570
```

Notes for Test Case vm212

Test case vm212 may produce an expected compare difference due to an inconsequential warning message that appears in the ANSYS, Inc. supplied output file that may not appear in the output file generated by your system for this test case. This compare difference should be considered acceptable. The following is an example of this compare difference.

```
COMPARE DIFFERENCE FOUND AT      NG= 445 NT= 436
G= NUMBER OF WARNING MESSAGES ENCOUNTERED= 1
T= NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
```

Notes for Test Cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s

Test cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s may produce expected compare differences due to the use of a macro named qaend. The method that is used in the verification procedure (runqa) to handle this macro may cause one or more comparison differences. Any such compare differences are inconsequential and should be considered acceptable. The following is an example of such a compare difference.

```
EXTRA DATA SKIPPED ON TEST FILE      NG= 1033 NT= 1030
T= USE COMMAND MACRO qaend
T= ARGS= 137.00
END OF SKIPPED DATA                  NG= 1033 NT= 1033
```

Notes for test Cases dds-13s, dds-17s, and ev175-21 s

The test cases dds-13s, dds-17s, and ev175-21 s will run to completion only if the "Parallel Performance for ANSYS" product (DDS and AMG solvers) is included in your ANSYS installation.

c0211r2	7020021010	70SP20030909	0	0	605	605	81%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0212	7020021010	70SP20030909	0	0	223	223	45%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0213	7020021010	70SP20030909	0	0	197	197	41%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0214	7020021010	70SP20030909	0	0	409	409	67%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0215	7020021010	70SP20030909	0	0	648	648	81%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0216	7020021010	70SP20030909	0	0	510	510	74%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0217	7020021010	70SP20030909	0	0	332	332	66%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0218	7020021010	70SP20030909	0	0	1627	1627	93%	02/12/2005	11:02	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0219	7020021010	70SP20030909	0	0	2732	2732	95%	02/12/2005	11:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0220	7020021010	70SP20030909	0	0	494	494	76%	02/12/2005	11:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0221	7020021010	70SP20030909	0	0	1265	1265	90%	02/12/2005	11:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0222	7020021010	70SP20030909	0	0	1543	1543	92%	02/12/2005	11:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0223	7020021010	70SP20030909	0	0	362	362	66%	02/12/2005	11:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0224	7020021010	70SP20030909	0	0	307	307	59%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0225	7020021010	70SP20030909	0	0	420	420	70%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0226	7020021010	70SP20030909	0	0	521	521	74%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227	7020021010	70SP20030909	0	0	380	380	65%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227a	7020021010	70SP20030909	0	0	380	380	65%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0228	7020021010	70SP20030909	0	0	236	236	50%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0229	7020021010	70SP20030909	0	0	715	715	81%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0230	7020021010	70SP20030909	0	0	2513	2513	94%	02/12/2005	11:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

c0231	7020021010	70SP20030909	3	0	304	304	61%	02/12/2005	11:05	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0232	7020021010	70SP20030909	0	0	517	517	79%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0233	7020021010	70SP20030909	0	0	542	542	75%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0234	7020021010	70SP20030909	0	0	420	420	68%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm1	7020021010	70SP20030909	0	0	474	474	72%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm2	7020021010	70SP20030909	0	0	667	667	81%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm3	7020021010	70SP20030909	0	0	499	499	73%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm4	7020021010	70SP20030909	0	0	434	434	69%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm5	7020021010	70SP20030909	0	0	884	884	85%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm6	7020021010	70SP20030909	0	0	854	854	83%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm7	7020021010	70SP20030909	0	0	2176	2176	93%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm8	7020021010	70SP20030909	0	0	346	346	64%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm9	7020021010	70SP20030909	0	0	851	851	85%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm10	7020021010	70SP20030909	0	0	437	437	69%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm11	7020021010	70SP20030909	0	0	885	885	85%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm12	7020021010	70SP20030909	0	0	444	444	70%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm13	7020021010	70SP20030909	0	0	464	464	71%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm14	7020021010	70SP20030909	0	0	537	537	76%	02/12/2005	11:06	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm15	7020021010	70SP20030909	0	0	1356	1356	91%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm16	7020021010	70SP20030909	0	0	740	740	82%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm17	7020021010	70SP20030909	0	0	546	546	76%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

vm18	7020021010	70SP20030909	0	0	450	450	71%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm19	7020021010	70SP20030909	0	0	725	725	80%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm20	7020021010	70SP20030909	0	0	449	449	70%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm21	7020021010	70SP20030909	0	0	805	805	82%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm22	7020021010	70SP20030909	0	0	398	398	66%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm23	7020021010	70SP20030909	0	0	1043	1043	88%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm24	7020021010	70SP20030909	0	0	766	766	82%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm25	7020021010	70SP20030909	0	0	2350	2350	95%	02/12/2005	11:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm26	7020021010	70SP20030909	0	0	1829	1829	89%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm27	7020021010	70SP20030909	0	0	910	910	85%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm28	7020021010	70SP20030909	0	0	418	418	70%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm29	7020021010	70SP20030909	0	0	683	683	80%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm30	7020021010	70SP20030909	0	0	449	449	70%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm31	7020021010	70SP20030909	0	0	551	551	76%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm32	7020021010	70SP20030909	0	0	881	881	84%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm33	7020021010	70SP20030909	0	0	902	902	85%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm34	7020021010	70SP20030909	0	0	1380	1380	90%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm35	7020021010	70SP20030909	0	0	594	594	77%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm36	7020021010	70SP20030909	0	0	1086	1086	88%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm37	7020021010	70SP20030909	0	0	690	690	81%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm38	7020021010	70SP20030909	0	0	1667	1667	92%	02/12/2005	11:08	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm39	7020021010	70SP20030909	0	0	819	819	84%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm40	7020021010	70SP20030909	0	0	876	876	86%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm41	7020021010	70SP20030909	0	0	829	829	83%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm42	7020021010	70SP20030909	0	0	607	607	77%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm43	7020021010	70SP20030909	0	0	860	860	85%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm44	7020021010	70SP20030909	0	0	1198	1198	90%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm45	7020021010	70SP20030909	0	0	416	416	67%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm46	7020021010	70SP20030909	0	0	794	794	82%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm47	7020021010	70SP20030909	0	0	416	416	67%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm48	7020021010	70SP20030909	0	0	421	421	68%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm49	7020021010	70SP20030909	0	0	700	700	80%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm50	7020021010	70SP20030909	0	0	500	500	72%	02/12/2005	11:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm51	7020021010	70SP20030909	0	0	531	531	77%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm52	7020021010	70SP20030909	0	0	520	520	74%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm53	7020021010	70SP20030909	0	0	789	789	82%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm54	7020021010	70SP20030909	0	0	564	564	75%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm55	7020021010	70SP20030909	0	0	995	995	87%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm56	7020021010	70SP20030909	0	0	1577	1577	91%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm57	7020021010	70SP20030909	0	0	737	737	81%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm58	7020021010	70SP20030909	0	0	580	580	76%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm59	7020021010	70SP20030909	0	0	833	833	84%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm60	7020021010	70SP20030909	0	0	537	537	72%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm61	7020021010	70SP20030909	0	0	402	402	66%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm62	7020021010	70SP20030909	0	0	755	755	82%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm63	7020021010	70SP20030909	0	0	1280	1280	89%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm64	7020021010	70SP20030909	0	0	510	510	74%	02/12/2005	11:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm65	7020021010	70SP20030909	0	0	3323	3323	96%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm66	7020021010	70SP20030909	0	0	516	516	74%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm67	7020021010	70SP20030909	0	0	591	591	76%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm68	7020021010	70SP20030909	0	0	739	739	80%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm69	7020021010	70SP20030909	0	0	553	553	75%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm70	7020021010	70SP20030909	0	0	940	940	86%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm71	7020021010	70SP20030909	0	0	1307	1307	87%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm72	7020021010	70SP20030909	0	0	2161	2161	90%	02/12/2005	11:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm73	7020021010	70SP20030909	0	0	4189	4189	97%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm74	7020021010	70SP20030909	0	0	855	855	81%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm75	7020021010	70SP20030909	0	0	1129	1129	84%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm76	7020021010	70SP20030909	0	0	1187	1187	89%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm77	7020021010	70SP20030909	0	0	876	876	82%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm78	7020021010	70SP20030909	0	0	872	872	86%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm79	7020021010	70SP20030909	0	0	954	954	83%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm80	7020021010	70SP20030909	0	0	2205	2205	92%	02/12/2005	11:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm81	7020021010	70SP20030909	0	0	2015	2015	93%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm82	7020021010	70SP20030909	0	0	2144	2144	94%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm83	7020021010	70SP20030909	0	0	2191	2191	94%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm84	7020021010	70SP20030909	0	0	821	821	82%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm85	7020021010	70SP20030909	0	0	858	858	84%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm86	7020021010	70SP20030909	0	0	428	428	68%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm87	7020021010	70SP20030909	0	0	434	434	69%	02/12/2005	11:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm88	7020021010	70SP20030909	0	0	450	450	70%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm89	7020021010	70SP20030909	0	0	480	480	72%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm90	7020021010	70SP20030909	0	0	761	761	82%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm91	7020021010	70SP20030909	0	0	2102	2102	94%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm92	7020021010	70SP20030909	0	0	501	501	73%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm93	7020021010	70SP20030909	0	0	436	436	69%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm94	7020021010	70SP20030909	0	0	508	508	73%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm95	7020021010	70SP20030909	0	0	1044	1044	86%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm96	7020021010	70SP20030909	0	0	633	633	78%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm97	7020021010	70SP20030909	0	0	809	809	83%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm98	7020021010	70SP20030909	0	0	703	703	80%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm99	7020021010	70SP20030909	0	0	482	482	72%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm100	7020021010	70SP20030909	0	0	642	642	79%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm101	7020021010	70SP20030909	0	0	720	720	81%	02/12/2005	11:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

vm102	7020021010	70SP20030909	0	0	761	761	82%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm103	7020021010	70SP20030909	0	0	782	782	84%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm104	7020021010	70SP20030909	0	0	1822	1822	93%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm105	7020021010	70SP20030909	0	0	589	589	77%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm106	7020021010	70SP20030909	0	0	432	432	69%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm107	7020021010	70SP20030909	0	0	476	476	72%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm108	7020021010	70SP20030909	0	0	437	437	69%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm109	7020021010	70SP20030909	0	0	1025	1025	87%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm110	7020021010	70SP20030909	0	0	743	743	82%	02/12/2005	11:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm111	7020021010	70SP20030909	0	0	3511	3511	96%	02/12/2005	11:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm112	7020021010	70SP20030909	0	0	726	726	81%	02/12/2005	11:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm113	7020021010	70SP20030909	0	0	732	732	82%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm114	7020021010	70SP20030909	0	0	693	693	80%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm115	7020021010	70SP20030909	0	0	604	604	78%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm116	7020021010	70SP20030909	0	0	830	830	84%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm117	7020021010	70SP20030909	0	0	1048	1048	86%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm118	7020021010	70SP20030909	0	0	918	918	85%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm119	7020021010	70SP20030909	0	0	1225	1225	89%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm120	7020021010	70SP20030909	0	0	485	485	72%	02/12/2005	11:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm121	7020021010	70SP20030909	0	0	811	811	83%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm122	7020021010	70SP20030909	0	0	422	422	68%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm123	7020021010	70SP20030909	0	0	467	467	71%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm124	7020021010	70SP20030909	0	0	591	591	77%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm125	7020021010	70SP20030909	0	0	762	762	82%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm126	7020021010	70SP20030909	0	0	661	661	80%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm127	7020021010	70SP20030909	0	0	625	625	79%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm128	7020021010	70SP20030909	0	0	815	815	83%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm129	7020021010	70SP20030909	0	0	373	373	66%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm130	7020021010	70SP20030909	0	0	553	553	78%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm131	7020021010	70SP20030909	0	0	448	448	70%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm132	7020021010	70SP20030909	0	0	1827	1827	93%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm133	7020021010	70SP20030909	0	0	1701	1701	92%	02/12/2005	11:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm134	7020021010	70SP20030909	0	0	1808	1808	93%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm135	7020021010	70SP20030909	0	0	561	561	77%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm136	7020021010	70SP20030909	0	0	1909	1909	93%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm137	7020021010	70SP20030909	0	0	1395	1395	91%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm138	7020021010	70SP20030909	0	0	528	528	75%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm139	7020021010	70SP20030909	0	0	1132	1132	88%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm140	7020021010	70SP20030909	0	0	1184	1184	89%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm141	7020021010	70SP20030909	0	0	2040	2040	93%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm142	7020021010	70SP20030909	0	0	879	879	85%	02/12/2005	11:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm143	7020021010	70SP20030909	0	0	1672	1672	91%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm144	7020021010	70SP20030909	0	0	2164	2164	94%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm145	7020021010	70SP20030909	0	0	532	532	75%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm146	7020021010	70SP20030909	0	0	883	883	86%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm147	7020021010	70SP20030909	0	0	588	588	77%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm148	7020021010	70SP20030909	0	0	588	588	78%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm149	7020021010	70SP20030909	0	0	520	520	74%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm150	7020021010	70SP20030909	0	0	657	657	79%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm151	7020021010	70SP20030909	0	0	1058	1058	87%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm152	7020021010	70SP20030909	0	0	1211	1211	88%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm153	7020021010	70SP20030909	0	0	507	507	74%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm154	7020021010	70SP20030909	0	0	814	814	82%	02/12/2005	11:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm155	7020021010	70SP20030909	0	0	1255	1255	89%	02/12/2005	11:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm156	7020021010	70SP20030909	0	0	2047	2047	94%	02/12/2005	11:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm157	7020021010	70SP20030909	0	0	952	952	85%	02/12/2005	11:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm158	7020021010	70SP20030909	0	0	955	955	87%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm159	7020021010	70SP20030909	0	0	1524	1524	91%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm160	7020021010	70SP20030909	0	0	600	600	78%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm161	7020021010	70SP20030909	0	0	539	539	75%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm162	7020021010	70SP20030909	0	0	548	548	76%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm163	7020021010	70SP20030909	0	0	563	563	76%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm164	7020021010	70SP20030909	0	0	556	556	76%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm165	7020021010	70SP20030909	0	0	703	703	80%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm166	7020021010	70SP20030909	0	0	700	700	80%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm167	7020021010	70SP20030909	0	0	1138	1138	88%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm168	7020021010	70SP20030909	0	0	687	687	81%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm169	7020021010	70SP20030909	0	0	777	777	82%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm170	7020021010	70SP20030909	0	0	436	436	69%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm171	7020021010	70SP20030909	0	0	759	759	82%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm172	7020021010	70SP20030909	0	0	1528	1528	90%	02/12/2005	11:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm173	7020021010	70SP20030909	0	0	545	545	75%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm174	7020021010	70SP20030909	0	0	602	602	77%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm175	7020021010	70SP20030909	0	0	855	855	84%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm176	7020021010	70SP20030909	0	0	999	999	86%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm177	7020021010	70SP20030909	0	0	1127	1127	87%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm178	7020021010	70SP20030909	0	0	679	679	80%	02/12/2005	11:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm179	7020021010	70SP20030909	0	0	768	768	82%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm180	7020021010	70SP20030909	0	0	651	651	79%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm181	7020021010	70SP20030909	0	0	484	484	71%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm182	7020021010	70SP20030909	0	0	973	973	87%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm183	7020021010	70SP20030909	0	0	722	722	81%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm184	7020021010	70SP20030909	1	5	3162	3162	95%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm185	7020021010	70SP20030909	0	0	738	738	81%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm186	7020021010	70SP20030909	0	0	1392	1392	91%	02/12/2005	11:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm187	7020021010	70SP20030909	0	0	1489	1489	90%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm188	7020021010	70SP20030909	0	0	658	658	79%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm189	7020021010	70SP20030909	0	0	1067	1067	87%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm190	7020021010	70SP20030909	0	0	715	715	81%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm191	7020021010	70SP20030909	0	0	3075	3075	95%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm192	7020021010	70SP20030909	0	0	645	645	80%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm193	7020021010	70SP20030909	0	0	411	411	68%	02/12/2005	11:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm194	7020021010	70SP20030909	0	0	821	821	83%	02/12/2005	11:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm195	7020021010	70SP20030909	0	0	824	824	84%	02/12/2005	11:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm196	7020021010	70SP20030909	0	0	505	505	73%	02/12/2005	11:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm197	7020021010	70SP20030909	0	0	509	509	74%	02/12/2005	11:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm198	7020021010	70SP20030909	2	0	1208	1208	88%	02/12/2005	11:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm199	7020021010	70SP20030909	0	0	835	835	84%	02/12/2005	11:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm200	7020021010	70SP20030909	0	0	1258	1258	89%	02/12/2005	11:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm201	7020021010	70SP20030909	0	0	3072	3072	95%	02/12/2005	11:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm202	7020021010	70SP20030909	0	0	604	604	77%	02/12/2005	11:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm203	7020021010	70SP20030909	0	0	1020	1020	87%	02/12/2005	11:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm204	7020021010	70SP20030909	0	0	621	621	79%	02/12/2005	11:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm205	7020021010	70SP20030909	0	0	652	652	79%	02/12/2005	11:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm206	7020021010	70SP20030909	0	0	903	903	84%	02/12/2005	11:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm207	7020021010	70SP20030909	0	0	1079	1079	87%	02/12/2005	11:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm208	7020021010	70SP20030909	0	0	701	701	82%	02/12/2005	11:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm209	7020021010	70SP20030909	0	0	3159	3159	96%	02/12/2005	11:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm210	7020021010	70SP20030909	0	0	1426	1426	90%	02/12/2005	11:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm211	7020021010	70SP20030909	0	0	2658	2658	94%	02/12/2005	11:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm212	7020021010	70SP20030909	0	0	1041	1041	86%	02/12/2005	11:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm213	7020021010	70SP20030909	0	0	687	687	80%	02/12/2005	11:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm214	7020021010	70SP20030909	0	0	557	557	76%	02/12/2005	11:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm215	7020021010	70SP20030909	0	0	637	637	80%	02/12/2005	11:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm216	7020021010	70SP20030909	0	0	1111	1111	87%	02/12/2005	11:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm217	7020021010	70SP20030909	0	0	873	873	84%	02/12/2005	11:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm218	7020021010	70SP20030909	0	0	744	744	82%	02/12/2005	11:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm219	7020021010	70SP20030909	0	0	698	698	81%	02/12/2005	11:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm220	7020021010	70SP20030909	0	0	477	477	75%	02/12/2005	11:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm221	7020021010	70SP20030909	0	0	605	605	80%	02/12/2005	11:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm222	7020021010	70SP20030909	0	0	1536	1536	91%	02/12/2005	11:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm223	7020021010	70SP20030909	0	0	484	484	74%	02/12/2005	11:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm224	7020021010	70SP20030909	0	0	577	577	79%	02/12/2005	11:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm225	7020021010	70SP20030909	0	0	496	496	73%	02/12/2005	11:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm226	7020021010	70SP20030909	0	0	1622	1622	91%	02/12/2005	11:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm227	7020021010	70SP20030909	0	0	957	957	87%	02/12/2005	11:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm228	7020021010	70SP20030909	0	0	5849	5849	98%	02/12/2005	11:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm229	7020021010	70SP20030909	0	0	3944	3944	97%	02/12/2005	11:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm230	7020021010	70SP20030909	0	0	26798	26798	99%	02/12/2005	12:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm231	7020021010	70SP20030909	0	0	528	528	76%	02/12/2005	12:03	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm232	7020021010	70SP20030909	0	0	14057	14057	98%	02/12/2005	12:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm233	7020021010	70SP20030909	0	0	583	583	80%	02/12/2005	12:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm234	7020021010	70SP20030909	0	0	1468	1468	92%	02/12/2005	12:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm235	7020021010	70SP20030909	0	0	769	769	81%	02/12/2005	12:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm236	7020021010	70SP20030909	0	0	1760	1760	92%	02/12/2005	12:18	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc1	7020021010	70SP20030909	0	0	643	643	81%	02/12/2005	12:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc2	7020021010	70SP20030909	0	0	1692	1692	90%	02/12/2005	12:19	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc3	7020021010	70SP20030909	0	0	426	426	72%	02/12/2005	12:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc4	7020021010	70SP20030909	0	0	773	773	85%	02/12/2005	12:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc5	7020021010	70SP20030909	0	0	513	513	78%	02/12/2005	12:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc6	7020021010	70SP20030909	0	0	433	433	74%	02/12/2005	12:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc7	7020021010	70SP20030909	0	0	337	337	67%	02/12/2005	12:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc8	7020021010	70SP20030909	2	0	1894	1894	92%	02/12/2005	12:56	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd1	7020021010	70SP20030909	0	0	816	816	86%	02/12/2005	12:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd2	7020021010	70SP20030909	0	0	337	337	67%	02/12/2005	12:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd3	7020021010	70SP20030909	0	0	608	608	82%	02/12/2005	12:59	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
cyc-177s	7020021010	70SP20030909	1	0	1219	1222	91%	02/12/2005	13:01	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

cyc-178s	7020021010	70SP20030909	1	0	1219	1222	91%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
dds-13s	7020021010	NO_UPDATE	-88	0	402	146	49%	02/12/2005	13:04	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
dds-17s	7020021010	NO_UPDATE	-88	0	746	146	67%	02/12/2005	13:04	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-112s	7020021010	70SP20030909	0	0	279	279	58%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-124s	7020021010	70SP20030909	0	0	392	392	66%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-127s	7020021010	70SP20030909	0	0	527	527	75%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ess-26s	7020021010	70SP20030909	0	0	1846	1846	92%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ess-97s	7020021010	70SP20030909	0	0	1378	1378	90%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev117-106s	7020021010	70SP20030909	0	0	1333	1333	91%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev119-35s	7020021010	70SP20030909	0	0	506	506	74%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev120-85s	7020021010	70SP20030909	0	0	411	411	71%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev141-208s	7020021010	70SP20030909	0	0	341	341	66%	02/12/2005	13:04	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev144-13s	7020021010	70SP20030909	0	8	8804	8804	98%	02/12/2005	13:07	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev144-23s	7020021010	70SP20030909	0	0	1740	1740	92%	02/12/2005	13:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev154-23s	7020021010	70SP20030909	0	0	1259	1259	89%	02/12/2005	13:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev154-25s	7020021010	70SP20030909	0	0	587	587	76%	02/12/2005	13:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev171-57s	7020021010	70SP20030909	0	0	542	542	79%	02/12/2005	13:10	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev173-53s	7020021010	70SP20030909	1	0	1426	1429	92%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev174-46s	7020021010	70SP20030909	0	0	562	562	80%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev175-20s	7020021010	70SP20030909	1	0	538	541	79%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev175-21s	7020021010	NO_UPDATE	-88	0	566	146	64%	02/12/2005	13:11	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

ev175-38s	7020021010	70SP20030909	0	0	808	808	85%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev182-zbdpg11s	7020021010	70SP20030909	0	0	660	660	83%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev183-zdp120s	7020021010	70SP20030909	0	0	577	577	80%	02/12/2005	13:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-02s	7020021010	70SP20030909	0	0	267	267	56%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-07s	7020021010	70SP20030909	0	0	661	661	80%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev35-23s	7020021010	70SP20030909	0	0	293	293	61%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev95-45s	7020021010	70SP20030909	0	0	892	892	85%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev97-73s	7020021010	70SP20030909	0	0	621	621	82%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
f1o-136s	7020021010	70SP20030909	0	0	419	419	73%	02/12/2005	13:12	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
f1o-138s	7020021010	70SP20030909	0	0	352	352	68%	02/12/2005	13:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-16s	7020021010	70SP20030909	1	0	484	486	77%	02/12/2005	13:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-9s	7020021010	70SP20030909	0	0	421	421	73%	02/12/2005	13:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-bk501	7020021010	70SP20030909	0	0	536	536	78%	02/12/2005	13:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-gt202	7020021010	70SP20030909	0	0	780	780	84%	02/12/2005	13:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr003	7020021010	70SP20030909	0	0	328	328	65%	02/12/2005	13:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr804	7020021010	70SP20030909	0	0	329	329	65%	02/12/2005	13:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-1s	7020021010	70SP20030909	0	0	400	400	72%	02/12/2005	13:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-20s	7020021010	70SP20030909	0	0	879	879	85%	02/12/2005	13:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
sx120-1s	7020021010	NO_UPDATE	-08	0	248	146	30%	02/12/2005	13:16	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
tbc-155s	7020021010	70SP20030909	0	0	351	351	64%	02/12/2005	13:16	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=c0231 10:37:04 OCT 15, 2002 CP=      0.219
T= CURRENT JOBNAME=c0231 11:04:48 FEB 12, 2005 CP=      0.156

```

```

0 /verify,c0231

```

```

0 /title, c0231 {fsk} Unmatched nodes mapping

```

```

COMPARE DIFFERENCE FOUND AT      NG= 192 NT= 192
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE =     237.330

```

```

COMPARE DIFFERENCE FOUND AT      NG= 219 NT= 219
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE =     237.330

```

```

COMPARE DIFFERENCE FOUND AT      NG= 246 NT= 246
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE =     237.330

```

```

BOTTOM OF GOOD FILE REACHED AT LINE      289
G= |                                ANSYS RUN COMPLETED                                |

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT      -      0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT      -      0
~~~~~

```

```

*****
COMPARE ERRORS =      3      *
*****

```

```

=====
PROBLEM: c0231      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)   = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)   = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  - 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN  (# OF KNOWN ERRS)= 0

```

GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 304

LINES ON TEST FILE = 304

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAM=vm184  20:46:18  OCT 15, 2002 CP=          0.250
T= CURRENT JOBNAM=vm184  11:27:32  FEB 12, 2005 CP=          0.297

      0 /VERIFY,VM184
      0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM
      0 /style,1,Reason COMPARE differences are acceptable:
      0 /style,2, mesher accuracy - element number on warning; near-
zero values
      0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 926 NT= 926
G= VALUE -0.24849E-01 0.98917 -0.43496E-05 0.98948
T= VALUE -0.24849E-01 0.98917 0.43497E-05 0.98948

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 982 NT= 982
G= VALUE -0.53544E-02-0.26671E-05 0.42554 0.42557
T= VALUE -0.53544E-02 0.26671E-05 0.42554 0.42557

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 1011 NT= 1011
G= VALUE -0.12394E-01-0.61739E-05 0.98504 0.98511
T= VALUE -0.12394E-01 0.61739E-05 0.98504 0.98511

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

COMPARE DIFFERENCE FOUND AT  NG= 1580 NT= 1580
G= VALUE 0.24811E-01 0.98813 -0.43696E-05 0.98844
T= VALUE 0.24811E-01 0.98813 0.43701E-05 0.98844

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 1639 NT= 1639
G= VALUE -0.53533E-02-0.30755E-05 0.42553 0.42556

```

RPP-RPT-32237, Rev. 1

T= VALUE -0.53533E-02 0.30756E-05 0.42553 0.42556

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 1673 NT= 1673

G= VALUE -0.12392E-01-0.71193E-05 0.98502 0.98510

T= VALUE -0.12392E-01 0.71194E-05 0.98502 0.98510

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

BOTTOM OF GOOD FILE REACHED AT LINE 3147
G= | ANSYS RUN COMPLETED |

~~~~~  
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
~~~~~

COMPARE ERRORS = 1 *

WARNING - 5 ABSOLUTE VALUE DIFFERENCE(S) FOUND.

NOTE - 1 summary line(s) contained absolute value differences.

```
=====
PROBLEM: vml84          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KABSPP (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN  (# OF KNOWN ERRS)= 0
```


GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 3162

LINES ON TEST FILE = 3162

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=vm198 20:50:49 OCT 15, 2002 CP= 0.266
T= CURRENT JOBNAME=vm198 11:29:13 FEB 12, 2005 CP= 0.172

      0 /VERIFY,VM198

      0 /TITLE, VM198, LARGE STRAIN IN-PLANE TORSION TEST {%EL%}

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 618 NT= 618
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 907 NT= 907
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

```

BOTTOM OF GOOD FILE REACHED AT LINE 1193
 G= | ANSYS RUN COMPLETED |

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 2 *
*****

```

```

=====
PROBLEM: vm198          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS
ALMOST ZERO (GOOD)     = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)     = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE    = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)- 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1208
LINES ON TEST FILE = 1208
=====

```

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNOME=vmc8 21:52:06 OCT 15, 2002 CP= 0.219
T= CURRENT JOBNOME=vmc8 12:22:49 FEB 12, 2005 CP= 0.188

0 /VERIFY,VMC8
0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY
0 /style,1,Reason COMPARE differences are acceptable:
0 /style,2, number of iterations, accuracy
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE2
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE42
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE82
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
VISCO106
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
SOLID45
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
SOLID95
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
VISCO107
0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

COMPARE DIFFERENCE FOUND AT          NG= 880 NT= 880
G= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3255
T= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3240

```

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

COMPARE DIFFERENCE FOUND AT

NG= 1227 NT= 1227

G=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.7401E-16	0.000	3.410	0.000
T=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.2694E-35	0.000	3.422	0.000

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** TIME-HISTORY POSTPROCESSOR (POST26)

BOTTOM OF GOOD FILE REACHED AT LINE 1879
 G= | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 2 *

PROBLEM: vmc8		COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1	
ALMOST ZERO (TEST)	= 1.0000E-006	KASPR (0-SUMMARY 1-ALL)-	1	
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP (SKIP=ERR 0=Y, 1=N)=	0	
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100	
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6	
		KNOWN (# OF KNOWN ERRS)=	0	
		GREAD, TREAD =	1, 1	

~~~~~  
 LINES ON GOOD FILE = 1894  
 LINES ON TEST FILE = 1894  
 ~~~~~


1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-177s  11:45:34  OCT 15, 2002 CP=      0.219
T= CURRENT JOBNAME=cyc-177s  12:59:19  FEB 12, 2005 CP=      0.266

```

```

0 /verify,cyc-177s
0 /TITLE, ceb,cyc-177s, Test cyc symm Buckling element 42
0 /title,1,Full Results to Sector Results!
0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-177s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010     KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004     MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006     MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

LINEs ON GOOD FILE = 1219
LINEs ON TEST FILE - 1222

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-178s 11:48:41 OCT 15, 2002 CP= 0.250
T= CURRENT JOBNAME=cyc-178s 13:01:42 FEB 12, 2005 CP= 0.234

```

```

0 /verify,cyc-178s
0 /TITLE, ceb,cyc-178s, Test cyc symm Buckling element 182
0 /title,1,Full Results to Sector Results!
0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-178s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010     KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004     MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006     MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
                                   GREAD, TREAD = 1, 1
=====

```

LINE# ON GOOD FILE = 1219
LINE# ON TEST FILE - 1222

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-13s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 402
 LINES ON TEST FILE = 146

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-17s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 746
 LINES ON TEST FILE = 146

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=ev173-53s  14:02:31 OCT 15, 2002 CP=      0.234
T= CURRENT JOBNAME=ev173-53s  13:10:45 FEB 12, 2005 CP=      0.172

```

```

0 /verify,ev173-53s

```

```

0 /title,ev173-53s,mfquresh,Test to verify PSOVLE,ELFORM for 171-
175 (3D) with PENE

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1409 NT= 1401
T= USE COMMAND MACRO QAEND
T= ARGS= 20.000
END OF SKIPPED DATA                  NG= 1409 NT= 1406

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1411
G= |                                ANSYS RUN COMPLETED

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
~~~~~

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: ev173-53s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1426
LINES ON TEST FILE - 1429

```

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=ev175-20s  14:22:03  OCT 15, 2002 CP=      0.250
T= CURRENT JOBNAME=ev175-20s  13:11:18  FEB 12, 2005 CP=      0.156

```

```

0 /verify,ev175-20s

```

```

0 /title,ev175-20s,mfq, Check real constant FKN and FTOLN and
KEYOPT(2)=0,1

```

```

NOW COMPARING LINES FROM      ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 521 NT= 513
T= USE COMMAND MACRO QAEND
T= ARGS= 3.0000
END OF SKIPPED DATA      NG= 521 NT= 518

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 523
G- |      ANSYS RUN COMPLETED      |

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: ev175-20s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)      = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)      = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL      = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE     = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
                                   GREAD, TREAD = 1, 1
=====

```

LINE# ON GOOD FILE = 538
LINE# ON TEST FILE - 541

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: ev175-21s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD) = 1.0000E-006	KROUND (DROP LAST DIGIT)= 1		
ALMOST ZERO (TEST) = 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)= 1		
ABSOLUTE VALUE TOL = 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)= 0		
FRACTIONAL DIFFERENCE= 1.0000E-004	MAXERR (STOP WHEN ERRS)= 100		
ABSOLUTE DIFFERENCE = 1.0000E-006	MAXBUF (# LINES TO SCAN)= 6		
	KNOWN (# OF KNOWN ERRS)= 0		
	GREAD, TREAD = 1, 1		

=====

LINES ON GOOD FILE = 566
 LINES ON TEST FILE = 146

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=inrt-16s 16:14:59 OCT 15, 2002 CP=      0.219
T= CURRENT JOBNAME=inrt-16s 13:13:40 FEB 12, 2005 CP=      0.188

```

```

0 /VERIFY, INRT-16S

```

```

0 /TITLE, INRT-16S, ceb, component omega loading and layer
elements

```

```

0 /TITLE, INRT-16S, BENDING OF A COMPOSITE BEAM

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 462 NT= 459
T= USE COMMAND MACRO QAEND
END OF SKIPPED DATA                  NG= 462 NT= 463

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 469
G= |                                ANSYS RUN COMPLETED

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 1
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 1
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
~~~~~

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: inrt-16s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 484
LINES ON TEST FILE - 486

```

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: sx120-1s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 248
 LINES ON TEST FILE = 146

Software Acceptance

- 1) Project Title and Number: DST Thermal and Seismic Analyses 48971
- 2) Software Name and Version: ANSYS 7.0 (Rev. 11)
- 3) Computer and Property Number: Dell DHM WD44879
- 4) Operating System: Windows XP Professional Version 2002 Service Pack 2
- 5) Scope of Testing: Software reinstallation (XP SP2)
- 6) Tests: Execute ANSYS Verification Testing Package
- 7) Discrepancies:
 - n) c0231. These differences are acceptable per the ANSYS Verification Package User's Guide – ANSYS Release 7.0 (AVPUG).
 - o) vm184. These differences occur at the 5th significant figure.
 - p) vm198. This difference is the reporting of the customer number for this installation.
 - q) vmc8. These differences are acceptable as noted in the output because of the difference in number of iterations and accuracy.
 - r) cyc-177s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - s) cyc-178s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - t) dds-13s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - u) dds-17s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - v) ev173-53s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - w) ev175-20s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - x) ev175-21s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - y) inrt-16s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - z) sx120-1s. This test case requires the "Frequency Sweep Module" which is not part of this software installation and is not required for the DST analyses.
- 8) Finding: This installation of ANSYS is acceptable

Certified by:

JE Deibler John E Deibler 2/24/05
Code Custodian

Reviewed by:

KI Johnson Kenneth L Johnson 4/16/05
Lead Engineer

12/1 0/2002 Page 1 of 1 Addendum to ANSYS Verification Testing Package User's Guide -ANSYS Release 7.0

Notes for test case cO231

Test case cO231 may show considerable differences for the Phase Angle value that is part of the Post1 Nodal Degree of Freedom Listing (PRNS command) output. Any such differences do not indicate a problem with this test case's results and should be considered acceptable. The output items of significance for this test case are the UZ values in the Post1 Nodal Degree of Freedom Listing. Machine precision differences in the form of small numerical differences that are trivial with respect to the test's output items of significance may also show for this test case in the compare output for this test. Please see *Verifying ANSYS and Evaluating COMPARE Differences* in Chapter 2 of the *ANSYS Verification Testing Package User's Guide* for more information on evaluating COMPARE differences. The following is an example of acceptable COMPARE differences for test case cO231:

```
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.7700 22. T= VALUE -9.8119 -3.7693 22.
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.7579 -3.9649 22. T= VALUE -9.7581 -3.9643 22.

COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= 8 0.53291 0.39425 10 T= 8 0.53293 0.39419 10
COMPARE DIFFERENCE FOUND AT G= 10 0.52495 0.39568 9. T= 10 0.52497 0.39562 9.
COMPARE DIFFERENCE FOUND AT NG= 259 NT= 259 G= 12 0.50433 0.40282 8.6482 8.6722 T= 12 0.50435 0.40276 8.6471 8.6711
COMPARE DIFFERENCE FOUND AT NG= 260 NT= 260 G= 14 0.48186 0.41201 7.8710 7.8965 T= 14 0.48188 0.41196 7.8700 7.8955
COMPARE DIFFERENCE FOUND AT NG= 261 NT= 261 G= 16 0.45505 0.42478 7.0719 7.0992 T= 16 0.45507 0.42473 7.0710 7.0983
COMPARE DIFFERENCE FOUND AT NG= 262 NT= 262 G= 18 0.42339 0.44092 6.2424 6.2723 T= 18 0.42341 0.44086 6.2417 6.2715
COMPARE DIFFERENCE FOUND AT NG= 263 NT= 263 G= 20 0.38501 0.46124 5.3732 5.4067 T= 20 0.38502 0.46118 5.3726 5.4061
COMPARE DIFFERENCE FOUND AT NG= 267 NT= 267 G= VALUE -9.6034 -3.9649 18.806 21.413 T= VALUE -9.6036 -3.9643 18.805 21.412
NG= 271 NT= 271 22.469 24.766 22.469 24.766

NG= 192 NT= 192 1- PHASE ANGLE = 1- PHASE ANGLE =
NG= 213 NT= 213 469 24.766 469 24.766
NG= 219 NT= 219 2- PHASE ANGLE = 2- PHASE ANGLE =
NG= 240 NT= 240 440 24.710 440 24.710
NG= 246 NT= 246 3- PHASE ANGLE = 3- PHASE ANGLE =
NG= 257 NT= 257 161 10.183 160 10.181
NG= 4080 4060

258 NT= 258 9.4309 9.4297
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.9649 T= VALUE -9.8119 -3.9643
30.580 306.570
30.580 306.570
30.580 306.570
```

Notes for Test Case vm212

Test case vm212 may produce an expected compare difference due to an inconsequential warning message that appears in the ANSYS, Inc. supplied output file that may not appear in the output file generated by your system for this test case. This compare difference should be considered acceptable. The following is an example of this compare difference.

```
COMPARE DIFFERENCE FOUND AT      NG= 445 NT= 436
G= NUMBER OF WARNING MESSAGES ENCOUNTERED= 1
T= NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
```

Notes for Test Cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s

Test cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s may produce expected compare differences due to the use of a macro named qaend. The method that is used in the verification procedure (runqa) to handle this macro may cause one or more comparison differences. Any such compare differences are inconsequential and should be considered acceptable. The following is an example of such a compare difference.

```
EXTRA DATA SKIPPED ON TEST FILE      NG= 1033 NT= 1030
T= USE COMMAND MACRO qaend
T= ARGS= 137.00
END OF SKIPPED DATA                  NG= 1033 NT= 1033
```

Notes for test Cases dds-13s, dds-17s, and ev175-21 s

The test cases dds-13s, dds-17s, and ev175-21 s will run to completion only if the "Parallel Performance for ANSYS" product (DDS and AMG solvers) is included in your ANSYS installation.

c0211r2	7020021010	70SP20030909	0	0	605	605	81%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0212	7020021010	70SP20030909	0	0	223	223	45%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0213	7020021010	70SP20030909	0	0	197	197	41%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0214	7020021010	70SP20030909	0	0	409	409	67%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0215	7020021010	70SP20030909	0	0	648	648	81%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0216	7020021010	70SP20030909	0	0	510	510	74%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0217	7020021010	70SP20030909	0	0	332	332	66%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0218	7020021010	70SP20030909	0	0	1627	1627	93%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0219	7020021010	70SP20030909	0	0	2732	2732	95%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0220	7020021010	70SP20030909	0	0	494	494	76%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0221	7020021010	70SP20030909	0	0	1265	1265	90%	02/12/2005	21:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0222	7020021010	70SP20030909	0	0	1543	1543	92%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0223	7020021010	70SP20030909	0	0	362	362	66%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0224	7020021010	70SP20030909	0	0	307	307	59%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0225	7020021010	70SP20030909	0	0	420	420	70%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0226	7020021010	70SP20030909	0	0	521	521	74%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227	7020021010	70SP20030909	0	0	380	380	65%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227a	7020021010	70SP20030909	0	0	380	380	65%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0228	7020021010	70SP20030909	0	0	236	236	50%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0229	7020021010	70SP20030909	0	0	715	715	81%	02/12/2005	21:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0230	7020021010	70SP20030909	0	0	2513	2513	94%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

c0231	7020021010	70SP20030909	3	0	304	304	61%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0232	7020021010	70SP20030909	0	0	517	517	79%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0233	7020021010	70SP20030909	0	0	542	542	75%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
c0234	7020021010	70SP20030909	0	0	420	420	68%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm1	7020021010	70SP20030909	0	0	474	474	72%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm2	7020021010	70SP20030909	0	0	667	667	81%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm3	7020021010	70SP20030909	0	0	499	499	73%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm4	7020021010	70SP20030909	0	0	434	434	69%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm5	7020021010	70SP20030909	0	0	884	884	85%	02/12/2005	21:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm6	7020021010	70SP20030909	0	0	854	854	83%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm7	7020021010	70SP20030909	0	0	2176	2176	93%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm8	7020021010	70SP20030909	0	0	346	346	64%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm9	7020021010	70SP20030909	0	0	851	851	85%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm10	7020021010	70SP20030909	0	0	437	437	69%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm11	7020021010	70SP20030909	0	0	885	885	85%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm12	7020021010	70SP20030909	0	0	444	444	70%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm13	7020021010	70SP20030909	0	0	464	464	71%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm14	7020021010	70SP20030909	0	0	537	537	76%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm15	7020021010	70SP20030909	0	0	1356	1356	91%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm16	7020021010	70SP20030909	0	0	740	740	82%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm17	7020021010	70SP20030909	0	0	546	546	76%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

vm18	7020021010	70SP20030909	0	0	450	450	71%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm19	7020021010	70SP20030909	0	0	725	725	80%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm20	7020021010	70SP20030909	0	0	449	449	70%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm21	7020021010	70SP20030909	0	0	805	805	82%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm22	7020021010	70SP20030909	0	0	398	398	66%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm23	7020021010	70SP20030909	0	0	1043	1043	88%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm24	7020021010	70SP20030909	0	0	766	766	82%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm25	7020021010	70SP20030909	0	0	2350	2350	95%	02/12/2005	21:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm26	7020021010	70SP20030909	0	0	1829	1829	89%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm27	7020021010	70SP20030909	0	0	910	910	85%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm28	7020021010	70SP20030909	0	0	418	418	70%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm29	7020021010	70SP20030909	0	0	683	683	80%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm30	7020021010	70SP20030909	0	0	449	449	70%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm31	7020021010	70SP20030909	0	0	551	551	76%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm32	7020021010	70SP20030909	0	0	881	881	84%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm33	7020021010	70SP20030909	0	0	902	902	85%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm34	7020021010	70SP20030909	0	0	1380	1380	90%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm35	7020021010	70SP20030909	0	0	594	594	77%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm36	7020021010	70SP20030909	0	0	1086	1086	88%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm37	7020021010	70SP20030909	0	0	690	690	81%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm38	7020021010	70SP20030909	0	0	1667	1667	92%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm39	7020021010	70SP20030909	0	0	819	819	84%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm40	7020021010	70SP20030909	0	0	876	876	86%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm41	7020021010	70SP20030909	0	0	829	829	83%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm42	7020021010	70SP20030909	0	0	607	607	77%	02/12/2005	21:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm43	7020021010	70SP20030909	0	0	860	860	85%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm44	7020021010	70SP20030909	0	0	1198	1198	90%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm45	7020021010	70SP20030909	0	0	416	416	67%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm46	7020021010	70SP20030909	0	0	794	794	82%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm47	7020021010	70SP20030909	0	0	416	416	67%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm48	7020021010	70SP20030909	0	0	421	421	68%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm49	7020021010	70SP20030909	0	0	700	700	80%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm50	7020021010	70SP20030909	0	0	500	500	72%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm51	7020021010	70SP20030909	0	0	531	531	77%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm52	7020021010	70SP20030909	0	0	520	520	74%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm53	7020021010	70SP20030909	0	0	789	789	82%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm54	7020021010	70SP20030909	0	0	564	564	75%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm55	7020021010	70SP20030909	0	0	995	995	87%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm56	7020021010	70SP20030909	0	0	1577	1577	91%	02/12/2005	21:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm57	7020021010	70SP20030909	0	0	737	737	81%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm58	7020021010	70SP20030909	0	0	580	580	76%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm59	7020021010	70SP20030909	0	0	833	833	84%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm60	7020021010	70SP20030909	0	0	537	537	72%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm61	7020021010	70SP20030909	0	0	402	402	66%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm62	7020021010	70SP20030909	0	0	755	755	82%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm63	7020021010	70SP20030909	0	0	1280	1280	89%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm64	7020021010	70SP20030909	0	0	510	510	74%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm65	7020021010	70SP20030909	0	0	3323	3323	96%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm66	7020021010	70SP20030909	0	0	516	516	74%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm67	7020021010	70SP20030909	0	0	591	591	76%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm68	7020021010	70SP20030909	0	0	739	739	80%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm69	7020021010	70SP20030909	0	0	553	553	75%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm70	7020021010	70SP20030909	0	0	940	940	86%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm71	7020021010	70SP20030909	0	0	1307	1307	87%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm72	7020021010	70SP20030909	0	0	2161	2161	90%	02/12/2005	21:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm73	7020021010	70SP20030909	0	0	4189	4189	97%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm74	7020021010	70SP20030909	0	0	855	855	81%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm75	7020021010	70SP20030909	0	0	1129	1129	84%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm76	7020021010	70SP20030909	0	0	1187	1187	89%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm77	7020021010	70SP20030909	0	0	876	876	82%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm78	7020021010	70SP20030909	0	0	872	872	86%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm79	7020021010	70SP20030909	0	0	954	954	83%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm80	7020021010	70SP20030909	0	0	2205	2205	92%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm81	7020021010	70SP20030909	0	0	2015	2015	93%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm82	7020021010	70SP20030909	0	0	2144	2144	94%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm83	7020021010	70SP20030909	0	0	2191	2191	94%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm84	7020021010	70SP20030909	0	0	821	821	82%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm85	7020021010	70SP20030909	0	0	858	858	84%	02/12/2005	21:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm86	7020021010	70SP20030909	0	0	428	428	68%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm87	7020021010	70SP20030909	0	0	434	434	69%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm88	7020021010	70SP20030909	0	0	450	450	70%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm89	7020021010	70SP20030909	0	0	480	480	72%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm90	7020021010	70SP20030909	0	0	761	761	82%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm91	7020021010	70SP20030909	0	0	2102	2102	94%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm92	7020021010	70SP20030909	0	0	501	501	73%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm93	7020021010	70SP20030909	0	0	436	436	69%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm94	7020021010	70SP20030909	0	0	508	508	73%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm95	7020021010	70SP20030909	0	0	1044	1044	86%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm96	7020021010	70SP20030909	0	0	633	633	78%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm97	7020021010	70SP20030909	0	0	809	809	83%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm98	7020021010	70SP20030909	0	0	703	703	80%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm99	7020021010	70SP20030909	0	0	482	482	72%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm100	7020021010	70SP20030909	0	0	642	642	79%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm101	7020021010	70SP20030909	0	0	720	720	81%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm102	7020021010	70SP20030909	0	0	761	761	82%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm103	7020021010	70SP20030909	0	0	782	782	84%	02/12/2005	21:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm104	7020021010	70SP20030909	0	0	1822	1822	93%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm105	7020021010	70SP20030909	0	0	589	589	77%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm106	7020021010	70SP20030909	0	0	432	432	69%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm107	7020021010	70SP20030909	0	0	476	476	72%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm108	7020021010	70SP20030909	0	0	437	437	69%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm109	7020021010	70SP20030909	0	0	1025	1025	87%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm110	7020021010	70SP20030909	0	0	743	743	82%	02/12/2005	21:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm111	7020021010	70SP20030909	0	0	3511	3511	96%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm112	7020021010	70SP20030909	0	0	726	726	81%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm113	7020021010	70SP20030909	0	0	732	732	82%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm114	7020021010	70SP20030909	0	0	693	693	80%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm115	7020021010	70SP20030909	0	0	604	604	78%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm116	7020021010	70SP20030909	0	0	830	830	84%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm117	7020021010	70SP20030909	0	0	1048	1048	86%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm118	7020021010	70SP20030909	0	0	918	918	85%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm119	7020021010	70SP20030909	0	0	1225	1225	89%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm120	7020021010	70SP20030909	0	0	485	485	72%	02/12/2005	21:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm121	7020021010	70SP20030909	0	0	811	811	83%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm122	7020021010	70SP20030909	0	0	422	422	68%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm123	7020021010	70SP20030909	0	0	467	467	71%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm124	7020021010	70SP20030909	0	0	591	591	77%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm125	7020021010	70SP20030909	0	0	762	762	82%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm126	7020021010	70SP20030909	0	0	661	661	80%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm127	7020021010	70SP20030909	0	0	625	625	79%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm128	7020021010	70SP20030909	0	0	815	815	83%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm129	7020021010	70SP20030909	0	0	373	373	66%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm130	7020021010	70SP20030909	0	0	553	553	78%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm131	7020021010	70SP20030909	0	0	448	448	70%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm132	7020021010	70SP20030909	0	0	1827	1827	93%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm133	7020021010	70SP20030909	0	0	1701	1701	92%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm134	7020021010	70SP20030909	0	0	1808	1808	93%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm135	7020021010	70SP20030909	0	0	561	561	77%	02/12/2005	21:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm136	7020021010	70SP20030909	0	0	1909	1909	93%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm137	7020021010	70SP20030909	0	0	1395	1395	91%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm138	7020021010	70SP20030909	0	0	528	528	75%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm139	7020021010	70SP20030909	0	0	1132	1132	88%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm140	7020021010	70SP20030909	0	0	1184	1184	89%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm141	7020021010	70SP20030909	0	0	2040	2040	93%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm142	7020021010	70SP20030909	0	0	879	879	85%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm143	7020021010	70SP20030909	0	0	1672	1672	91%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm144	7020021010	70SP20030909	0	0	2164	2164	94%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm145	7020021010	70SP20030909	0	0	532	532	75%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm146	7020021010	70SP20030909	0	0	883	883	86%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm147	7020021010	70SP20030909	0	0	588	588	77%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm148	7020021010	70SP20030909	0	0	588	588	78%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm149	7020021010	70SP20030909	0	0	520	520	74%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm150	7020021010	70SP20030909	0	0	657	657	79%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm151	7020021010	70SP20030909	0	0	1058	1058	87%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm152	7020021010	70SP20030909	0	0	1211	1211	88%	02/12/2005	21:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm153	7020021010	70SP20030909	0	0	507	507	74%	02/12/2005	21:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm154	7020021010	70SP20030909	0	0	814	814	82%	02/12/2005	21:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm155	7020021010	70SP20030909	0	0	1255	1255	89%	02/12/2005	21:46	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm156	7020021010	70SP20030909	0	0	2047	2047	94%	02/12/2005	21:46	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm157	7020021010	70SP20030909	0	0	952	952	85%	02/12/2005	21:46	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm158	7020021010	70SP20030909	0	0	955	955	87%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm159	7020021010	70SP20030909	0	0	1524	1524	91%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm160	7020021010	70SP20030909	0	0	600	600	78%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm161	7020021010	70SP20030909	0	0	539	539	75%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm162	7020021010	70SP20030909	0	0	548	548	76%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm163	7020021010	70SP20030909	0	0	563	563	76%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm164	7020021010	70SP20030909	0	0	556	556	76%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm165	7020021010	70SP20030909	0	0	703	703	80%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm166	7020021010	70SP20030909	0	0	700	700	80%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm167	7020021010	70SP20030909	0	0	1138	1138	88%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm168	7020021010	70SP20030909	0	0	687	687	81%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm169	7020021010	70SP20030909	0	0	777	777	82%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm170	7020021010	70SP20030909	0	0	436	436	69%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm171	7020021010	70SP20030909	0	0	759	759	82%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm172	7020021010	70SP20030909	0	0	1528	1528	90%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm173	7020021010	70SP20030909	0	0	545	545	75%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm174	7020021010	70SP20030909	0	0	602	602	77%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm175	7020021010	70SP20030909	0	0	855	855	84%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm176	7020021010	70SP20030909	0	0	999	999	86%	02/12/2005	21:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm177	7020021010	70SP20030909	0	0	1127	1127	87%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm178	7020021010	70SP20030909	0	0	679	679	80%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm179	7020021010	70SP20030909	0	0	768	768	82%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm180	7020021010	70SP20030909	0	0	651	651	79%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm181	7020021010	70SP20030909	0	0	484	484	71%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm182	7020021010	70SP20030909	0	0	973	973	87%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm183	7020021010	70SP20030909	0	0	722	722	81%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm184	7020021010	70SP20030909	1	5	3162	3162	95%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm185	7020021010	70SP20030909	0	0	738	738	81%	02/12/2005	21:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm186	7020021010	70SP20030909	0	0	1392	1392	91%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm187	7020021010	70SP20030909	0	0	1489	1489	90%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm188	7020021010	70SP20030909	0	0	658	658	79%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm189	7020021010	70SP20030909	0	0	1067	1067	87%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm190	7020021010	70SP20030909	0	0	715	715	81%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm191	7020021010	70SP20030909	0	0	3075	3075	95%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm192	7020021010	70SP20030909	0	0	645	645	80%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm193	7020021010	70SP20030909	0	0	411	411	68%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm194	7020021010	70SP20030909	0	0	821	821	83%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm195	7020021010	70SP20030909	0	0	824	824	84%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm196	7020021010	70SP20030909	0	0	505	505	73%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm197	7020021010	70SP20030909	0	0	509	509	74%	02/12/2005	21:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm198	7020021010	70SP20030909	2	0	1208	1208	88%	02/12/2005	21:50	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm199	7020021010	70SP20030909	0	0	835	835	84%	02/12/2005	21:50	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm200	7020021010	70SP20030909	0	0	1258	1258	89%	02/12/2005	21:51	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm201	7020021010	70SP20030909	0	0	3072	3072	95%	02/12/2005	21:51	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm202	7020021010	70SP20030909	0	0	604	604	77%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm203	7020021010	70SP20030909	0	0	1020	1020	87%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm204	7020021010	70SP20030909	0	0	621	621	79%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm205	7020021010	70SP20030909	0	0	652	652	79%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
vm206	7020021010	70SP20030909	0	0	903	903	84%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

vm207	7020021010	70SP20030909	0	0	1079	1079	87%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm208	7020021010	70SP20030909	0	0	701	701	82%	02/12/2005	21:52	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm209	7020021010	70SP20030909	0	0	3159	3159	96%	02/12/2005	21:53	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm210	7020021010	70SP20030909	0	0	1426	1426	90%	02/12/2005	21:53	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm211	7020021010	70SP20030909	0	0	2658	2658	94%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm212	7020021010	70SP20030909	0	0	1041	1041	86%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm213	7020021010	70SP20030909	0	0	687	687	80%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm214	7020021010	70SP20030909	0	0	557	557	76%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm215	7020021010	70SP20030909	0	0	637	637	80%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm216	7020021010	70SP20030909	0	0	1111	1111	87%	02/12/2005	21:55	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm217	7020021010	70SP20030909	0	0	873	873	84%	02/12/2005	21:56	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm218	7020021010	70SP20030909	0	0	744	744	82%	02/12/2005	21:56	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm219	7020021010	70SP20030909	0	0	698	698	81%	02/12/2005	21:56	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm220	7020021010	70SP20030909	0	0	477	477	75%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm221	7020021010	70SP20030909	0	0	605	605	80%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm222	7020021010	70SP20030909	0	0	1536	1536	91%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm223	7020021010	70SP20030909	0	0	484	484	74%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm224	7020021010	70SP20030909	0	0	577	577	79%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm225	7020021010	70SP20030909	0	0	496	496	73%	02/12/2005	21:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm226	7020021010	70SP20030909	0	0	1622	1622	91%	02/12/2005	21:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm227	7020021010	70SP20030909	0	0	957	957	87%	02/12/2005	21:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm228	7020021010	70SP20030909	0	0	5849	5849	98%	02/12/2005	21:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm229	7020021010	70SP20030909	0	0	3944	3944	97%	02/12/2005	21:59	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm230	7020021010	70SP20030909	0	0	26798	26798	99%	02/12/2005	22:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm231	7020021010	70SP20030909	0	0	528	528	76%	02/12/2005	22:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm232	7020021010	70SP20030909	0	0	14057	14057	98%	02/12/2005	22:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm233	7020021010	70SP20030909	0	0	583	583	80%	02/12/2005	22:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm234	7020021010	70SP20030909	0	0	1468	1468	92%	02/12/2005	22:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm235	7020021010	70SP20030909	0	0	769	769	81%	02/12/2005	22:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm236	7020021010	70SP20030909	0	0	1760	1760	92%	02/12/2005	22:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc1	7020021010	70SP20030909	0	0	643	643	81%	02/12/2005	22:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc2	7020021010	70SP20030909	0	0	1692	1692	90%	02/12/2005	22:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc3	7020021010	70SP20030909	0	0	426	426	72%	02/12/2005	22:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc4	7020021010	70SP20030909	0	0	773	773	85%	02/12/2005	22:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc5	7020021010	70SP20030909	0	0	513	513	78%	02/12/2005	22:50	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc6	7020021010	70SP20030909	0	0	433	433	74%	02/12/2005	22:51	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc7	7020021010	70SP20030909	0	0	337	337	67%	02/12/2005	22:51	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc8	7020021010	70SP20030909	2	0	1894	1894	92%	02/12/2005	23:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd1	7020021010	70SP20030909	0	0	816	816	86%	02/12/2005	23:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd2	7020021010	70SP20030909	0	0	337	337	67%	02/12/2005	23:09	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd3	7020021010	70SP20030909	0	0	608	608	82%	02/12/2005	23:11	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
cyc-177s	7020021010	70SP20030909	1	0	1219	1222	91%	02/12/2005	23:13	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

cyc-178s	7020021010	70SP20030909	1	0	1219	1222	91%	02/12/2005	23:14	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
dds-13s	7020021010	NO_UPDATE	-88	0	402	146	49%	02/12/2005	23:14	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
dds-17s	7020021010	NO_UPDATE	-88	0	746	146	67%	02/12/2005	23:14	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-112s	7020021010	70SP20030909	0	0	279	279	58%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-124s	7020021010	70SP20030909	0	0	392	392	66%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
esp-127s	7020021010	70SP20030909	0	0	527	527	75%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ess-26s	7020021010	70SP20030909	0	0	1846	1846	92%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ess-97s	7020021010	70SP20030909	0	0	1378	1378	90%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev117-106s	7020021010	70SP20030909	0	0	1333	1333	91%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev119-35s	7020021010	70SP20030909	0	0	506	506	74%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev120-85s	7020021010	70SP20030909	0	0	411	411	71%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev141-208s	7020021010	70SP20030909	0	0	341	341	66%	02/12/2005	23:15	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev144-13s	7020021010	70SP20030909	0	8	8804	8804	98%	02/12/2005	23:17	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev144-23s	7020021010	70SP20030909	0	0	1740	1740	92%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev154-23s	7020021010	70SP20030909	0	0	1259	1259	89%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev154-25s	7020021010	70SP20030909	0	0	587	587	76%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev171-57s	7020021010	70SP20030909	0	0	542	542	79%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev173-53s	7020021010	70SP20030909	1	0	1426	1429	92%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev174-46s	7020021010	70SP20030909	0	0	562	562	80%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev175-20s	7020021010	70SP20030909	1	0	538	541	79%	02/12/2005	23:20	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				
ev175-21s	7020021010	NO_UPDATE	-88	0	566	146	64%	02/12/2005	23:20	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8		UP20020121	WINDOWS				

ev175-38s	7020021010	70SP20030909	0	0	808	808	85%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev182-zbdpg11s	7020021010	70SP20030909	0	0	660	660	83%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev183-zdp120s	7020021010	70SP20030909	0	0	577	577	80%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-02s	7020021010	70SP20030909	0	0	267	267	56%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-07s	7020021010	70SP20030909	0	0	661	661	80%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev35-23s	7020021010	70SP20030909	0	0	293	293	61%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev95-45s	7020021010	70SP20030909	0	0	892	892	85%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev97-73s	7020021010	70SP20030909	0	0	621	621	82%	02/12/2005	23:21	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
f1o-136s	7020021010	70SP20030909	0	0	419	419	73%	02/12/2005	23:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
f1o-138s	7020021010	70SP20030909	0	0	352	352	68%	02/12/2005	23:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-16s	7020021010	70SP20030909	1	0	484	486	77%	02/12/2005	23:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-9s	7020021010	70SP20030909	0	0	421	421	73%	02/12/2005	23:22	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-bk501	7020021010	70SP20030909	0	0	536	536	78%	02/12/2005	23:23	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-gt202	7020021010	70SP20030909	0	0	780	780	84%	02/12/2005	23:23	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr003	7020021010	70SP20030909	0	0	328	328	65%	02/12/2005	23:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr804	7020021010	70SP20030909	0	0	329	329	65%	02/12/2005	23:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-1s	7020021010	70SP20030909	0	0	400	400	72%	02/12/2005	23:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-20s	7020021010	70SP20030909	0	0	879	879	85%	02/12/2005	23:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
sx120-1s	7020021010	NO_UPDATE	-08	0	248	146	30%	02/12/2005	23:24	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
tbc-155s	7020021010	70SP20030909	0	0	351	351	64%	02/12/2005	23:24	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=c0231 10:37:04 OCT 15, 2002 CP=      0.219
T= CURRENT JOBNAME=c0231 21:33:01 FEB 12, 2005 CP=      0.094

```

```

0 /verify,c0231

```

```

0 /title, c0231 {fsk} Unmatched nodes mapping

```

```

COMPARE DIFFERENCE FOUND AT      NG= 192 NT= 192
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE =     237.330

```

```

COMPARE DIFFERENCE FOUND AT      NG= 219 NT= 219
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE =     237.330

```

```

COMPARE DIFFERENCE FOUND AT      NG= 246 NT= 246
G= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE =      30.580
T= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE =     237.330

```

```

BOTTOM OF GOOD FILE REACHED AT LINE      289
G= |                                ANSYS RUN COMPLETED                                |

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT      -      0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT      -      0
~~~~~

```

```

*****
COMPARE ERRORS =      3      *
*****

```

```

=====
PROBLEM: c0231      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)   = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)   = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  - 1.0000E-006      MAXBUF (# LINES TO SCAN)- 6
                                   KNOWN  (# OF KNOWN ERRS)= 0

```

GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 304

LINES ON TEST FILE = 304

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=vm184  20:46:18  OCT 15, 2002 CP=          0.250
T= CURRENT JOBNAME=vm184  21:48:44  FEB 12, 2005 CP=          0.109

      0 /VERIFY,VM184
      0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM
      0 /style,1,Reason COMPARE differences are acceptable:
      0 /style,2, mesher accuracy - element number on warning; near-
zero values
      0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 926 NT= 926
G= VALUE -0.24849E-01 0.98917 -0.43496E-05 0.98948
T= VALUE -0.24849E-01 0.98917 0.43497E-05 0.98948

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 982 NT= 982
G= VALUE -0.53544E-02-0.26671E-05 0.42554 0.42557
T= VALUE -0.53544E-02 0.26671E-05 0.42554 0.42557

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 1011 NT= 1011
G= VALUE -0.12394E-01-0.61739E-05 0.98504 0.98511
T= VALUE -0.12394E-01 0.61739E-05 0.98504 0.98511

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

COMPARE DIFFERENCE FOUND AT          NG= 1580 NT= 1580
G= VALUE 0.24811E-01 0.98813 -0.43696E-05 0.98844
T= VALUE 0.24811E-01 0.98813 0.43701E-05 0.98844

ABSOLUTE VALUE DIFFERENCE FOUND AT  NG= 1639 NT= 1639
G= VALUE -0.53533E-02-0.30755E-05 0.42553 0.42556

```

T= VALUE -0.53533E-02 0.30756E-05 0.42553 0.42556

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 1673 NT= 1673

G= VALUE -0.12392E-01-0.71193E-05 0.98502 0.98510

T= VALUE -0.12392E-01 0.71194E-05 0.98502 0.98510

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

BOTTOM OF GOOD FILE REACHED AT LINE 3147
G= | ANSYS RUN COMPLETED |

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

*****
WARNING - 5 ABSOLUTE VALUE DIFFERENCE(S) FOUND.
*****

```

```

*****
NOTE - 1 summary line(s) contained absolute value differences.
*****

```

```

=====
PROBLEM: vml84          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006          KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006          KABSPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010          KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004          MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006          MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN  (# OF KNOWN ERRS)= 0

```

GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 3162

LINES ON TEST FILE = 3162

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=vm198  20:50:49  OCT 15, 2002 CP=          0.266
T= CURRENT JOBNAME=vm198  21:49:55  FEB 12, 2005 CP=          0.094

      0 /VERIFY,VM198

      0 /TITLE, VM198, LARGE STRAIN IN-PLANE TORSION TEST {%EL%}

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 618 NT= 618
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 907 NT= 907
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

```

BOTTOM OF GOOD FILE REACHED AT LINE 1193
 G= | ANSYS RUN COMPLETED |

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 2 *
*****

```

```

=====
PROBLEM: vm198          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS
ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS)= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1208
LINES ON TEST FILE = 1208
=====

```

1

00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 113 NT= 113
 G= 00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010
 T= 00292062 VERSION=INTEL NT RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 114 NT= 114
 G= CURRENT JOBNAM=vmc8 21:52:06 OCT 15, 2002 CP= 0.219
 T= CURRENT JOBNAM=vmc8 22:51:25 FEB 12, 2005 CP= 0.125

0 /VERIFY,VMC8
 0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY
 0 /style,1,Reason COMPARE differences are acceptable:
 0 /style,2, number of iterations, accuracy
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 PLANE2
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 PLANE42
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 PLANE82
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 VISCO106
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 SOLID45
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 SOLID95
 0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
 VISCO107
 0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

COMPARE DIFFERENCE FOUND AT NG= 880 NT= 880
 G= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3255
 T= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3240

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

COMPARE DIFFERENCE FOUND AT

NG= 1227 NT= 1227

G=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.7401E-16	0.000	3.410	0.000
T=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.2694E-35	0.000	3.422	0.000

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** TIME-HISTORY POSTPROCESSOR (POST26)

BOTTOM OF GOOD FILE REACHED AT LINE 1879
 G= | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 2 *

PROBLEM: vmc8		COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1	
ALMOST ZERO (TEST)	= 1.0000E-006	KASPR (0-SUMMARY 1-ALL)-	1	
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP (SKIP=ERR 0=Y, 1=N)=	0	
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100	
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6	
		KNOWN (# OF KNOWN ERRS)=	0	
		GREAD, TREAD =	1, 1	

~~~~~  
 LINES ON GOOD FILE = 1894  
 LINES ON TEST FILE = 1894  
 ~~~~~

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-177s  11:45:34  OCT 15, 2002 CP=      0.219
T= CURRENT JOBNAME=cyc-177s  23:11:09  FEB 12, 2005 CP=      0.109

```

```

0 /verify,cyc-177s

0 /TITLE, ceb,cyc-177s, Test cyc symm Buckling element 42

0 /title,1,Full Results to Sector Results!

0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-177s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010     KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004     MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006     MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```


LINEs ON GOOD FILE = 1219
LINEs ON TEST FILE - 1222

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-178s  11:48:41  OCT 15, 2002 CP=      0.250
T= CURRENT JOBNAME=cyc-178s  23:13:04  FEB 12, 2005 CP=      0.125

```

```

0 /verify,cyc-178s
0 /TITLE, ceb,cyc-178s, Test cyc symm Buckling element 182
0 /title,1,Full Results to Sector Results!
0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-178s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE    = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
                                   GREAD, TREAD = 1, 1
=====

```

LINEs ON GOOD FILE = 1219
LINEs ON TEST FILE - 1222

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-13s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 402
 LINES ON TEST FILE = 146

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-17s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD) = 1.0000E-006	KROUND (DROP LAST DIGIT)= 1		
ALMOST ZERO (TEST) = 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)= 1		
ABSOLUTE VALUE TOL = 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)= 0		
FRACTIONAL DIFFERENCE= 1.0000E-004	MAXERR (STOP WHEN ERRS)= 100		
ABSOLUTE DIFFERENCE = 1.0000E-006	MAXBUF (# LINES TO SCAN)= 6		
	KNOWN (# OF KNOWN ERRS)= 0		
	GREAD, TREAD = 1, 1		

=====

~~~~~  
 LINES ON GOOD FILE = 746  
 LINES ON TEST FILE = 146  
 ~~~~~

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=ev173-53s  14:02:31 OCT 15, 2002 CP=      0.234
T= CURRENT JOBNAME=ev173-53s  23:20:30 FEB 12, 2005 CP=      0.094

```

```

0 /verify,ev173-53s

```

```

0 /title,ev173-53s,mfquresh,Test to verify PSOVLE,ELFORM for 171-
175 (3D) with PENE

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1409 NT= 1401
T= USE COMMAND MACRO QAEND
T= ARGS= 20.000
END OF SKIPPED DATA                  NG= 1409 NT= 1406

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1411
G= |                                ANSYS RUN COMPLETED

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
~~~~~

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: ev173-53s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)      = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)      = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL       = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE     = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1426
LINES ON TEST FILE - 1429

```

1

```

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=ev175-20s  14:22:03  OCT 15, 2002 CP=          0.250
T= CURRENT JOBNAME=ev175-20s  23:20:55  FEB 12, 2005 CP=          0.094

```

```

0 /verify,ev175-20s

```

```

0 /title,ev175-20s,mfq, Check real constant FKN and FTOLN and
KEYOPT(2)=0,1

```

```

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

```

```

EXTRA DATA SKIPPED ON TEST FILE          NG= 521 NT= 513
T= USE COMMAND MACRO QAEND
T= ARGS= 3.0000
END OF SKIPPED DATA          NG= 521 NT= 518

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 523
G- |          ANSYS RUN COMPLETED          |

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: ev175-20s          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)   = 1.0000E-006          KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)   = 1.0000E-006          KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010          KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004          MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  = 1.0000E-006          MAXBUF (# LINES TO SCAN)= 6
                                          KNOWN (# OF KNOWN ERRS)= 0
                                          GREAD, TREAD = 1, 1
=====

```

LINE# ON GOOD FILE = 538
LINE# ON TEST FILE - 541

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: ev175-21s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
--------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 566
 LINES ON TEST FILE = 146

1

00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 113 NT= 113
 G= 00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010
 T= 00292062 VERSION=INTEL NT RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 114 NT= 114
 G= CURRENT JOBNAM=intr-16s 16:14:59 OCT 15, 2002 CP= 0.219
 T= CURRENT JOBNAM=intr-16s 23:22:50 FEB 12, 2005 CP= 0.109

0 /VERIFY, INRT-16S

0 /TITLE, INRT-16S, ceb, component omega loading and layer
 elements

0 /TITLE, INRT-16S, BENDING OF A COMPOSITE BEAM

EXTRA DATA SKIPPED ON TEST FILE NG= 462 NT= 459
 T= USE COMMAND MACRO QAEND
 END OF SKIPPED DATA NG= 462 NT= 463

BOTTOM OF GOOD FILE REACHED AT LINE 469
 G= | ANSYS RUN COMPLETED

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE (BLANK LINES EXCLUDED) - 1  
 NUMBER OF LINES SKIPPED IN TEST FILE (BLANK LINES EXCLUDED) - 1  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 1 *

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: sx120-1s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
-------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 248
 LINES ON TEST FILE = 146

Software Acceptance

- 1) Project Title and Number: DST Thermal and Seismic Analyses 48971
- 2) Software Name and Version: ANSYS 7.0 (Rev. 11)
- 3) Computer and Property Number: Generic PC WD44903
- 4) Operating System: Windows XP Professional Version 2002 Service Pack 2
- 5) Scope of Testing: Hardware replacement and Software reinstallation (XP SP2)
- 6) Tests: Execute ANSYS Verification Testing Package
- 7) Discrepancies:
 - aa) c0231. These differences are acceptable per the ANSYS Verification Package User's Guide – ANSYS Release 7.0 (AVPUG).
 - bb) vm33. These differences are acceptable due to the unused degree of freedom (see AVPUG).
 - cc) vm176. These differences are acceptable due to the unused degree of freedom (see AVPUG).
 - dd) vm184. These differences occur at the 5th significant figure.
 - ee) vm198. This difference is the reporting of the customer number for this installation.
 - ff) vmc8. These differences are acceptable as noted in the output because of the difference in number of iterations and accuracy.
 - gg) cyc-177s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - hh) cyc-178s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - ii) dds-13s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - jj) dds-17s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.
 - kk) ev173-53s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - ll) ev175-20s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).
 - mm) ev175-21s. This test case requires the "Parallel Performance Module" which is not part of this software installation and is not required for the DST analyses.

nn) inrt-16s. This difference is acceptable due to the handling of the QAEND macro (see AVPUG).

8) Finding: This installation of ANSYS is acceptable

Certified by:

JE Deibler John E Deibler 11/11/05
Code Custodian

Reviewed by:

SP Pilli Siva prasad P 02/03/06
Staff Engineer

12/1 0/2002 Page 1 of 1 Addendum to ANSYS Verification Testing Package User's Guide -ANSYS Release 7.0

Notes for test case cO231

Test case cO231 may show considerable differences for the Phase Angle value that is part of the Post1 Nodal Degree of Freedom Listing (PRNS command) output. Any such differences do not indicate a problem with this test case's results and should be considered acceptable. The output items of significance for this test case are the UZ values in the Post1 Nodal Degree of Freedom Listing. Machine precision differences in the form of small numerical differences that are trivial with respect to the test's output items of significance may also show for this test case in the compare output for this test. Please see **Verifying ANSYS and Evaluating COMPARE Differences** in Chapter 2 of the *ANSYS Verification Testing Package User's Guide* for more information on evaluating COMPARE differences. The following is an example of acceptable COMPARE differences for test case cO231 :

```
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.7700 22. T= VALUE -9.8119 -3.7693 22.
COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= VALUE -9.7579 -3.9649 22. T= VALUE -9.7581 -3.9643 22.

COMPARE DIFFERENCE FOUND AT G= NODAL RESULTS ARE FOR CYCLIC SECTOR T= NODAL RESULTS ARE FOR CYCLIC SECTOR
COMPARE DIFFERENCE FOUND AT G= 8 0.53291 0.39425 10 T= 8 0.53293 0.39419 10
COMPARE DIFFERENCE FOUND AT G= 10 0.52495 0.39568 9. T= 10 0.52497 0.39562 9.
COMPARE DIFFERENCE FOUND AT NG= 259 NT= 259 G= 12 0.50433 0.40282 8.6482 8.6722 T= 12 0.50435 0.40276 8.6471
8.6711
COMPARE DIFFERENCE FOUND AT NG= 260 NT= 260 G= 14 0.48186 0.41201 7.8710 7.8965 T= 14 0.48188 0.41196 7.8700
7.8955
COMPARE DIFFERENCE FOUND AT NG= 261 NT= 261 G= 16 0.45505 0.42478 7.0719 7.0992 T= 16 0.45507 0.42473 7.0710
7.0983
COMPARE DIFFERENCE FOUND AT NG= 262 NT= 262 G= 18 0.42339 0.44092 6.2424 6.2723 T= 18 0.42341 0.44086 6.2417
6.2715
COMPARE DIFFERENCE FOUND AT NG= 263 NT= 263 G= 20 0.38501 0.46124 5.3732 5.4067 T= 20 0.38502 0.46118 5.3726
5.4061
COMPARE DIFFERENCE FOUND AT NG= 267 NT= 267 G= VALUE -9.6034 -3.9649 18.806 21.413 T= VALUE -9.6036 -3.9643
18.805 21.412
NG= 271 NT= 271 22.469 24.766 22.469 24.766

NG= 192 NT= 192 1 -PHASE ANGLE - 1- PHASE ANGLE -
NG= 213 NT= 213 469 24.766 469 24.766
NG= 219 NT= 219 2- PHASE ANGLE - 2- PHASE ANGLE -
NG= 240 NT= 240 440 24.710 440 24.710
NG= 246 NT= 246 3- PHASE ANGLE - 3- PHASE ANGLE -
NG= 257 NT= 257 161 10.183 160 10.181
NG= 4080 4060

258 NT= 258 9.4309 9.4297
COMPARE DIFFERENCE FOUND AT G= VALUE -9.8117 -3.9649 T= VALUE -9.8119 -3.9643
30.580 306.570
30.580 306.570
30.580 306.570
```

Notes for Test Case vm33 and vm176

Test case vm33 and vm176 will produce a number of expected compare differences due to product restrictions in the PLANE13 element's functionality. The expected compare differences are the result of the MAG degree of freedom being absent in the test case's output when it is run with the ANSYS/ Mechanical product. Since the MAG degree of freedom is unused in these test cases, these compare differences should be considered acceptable.

3-1 *ANSYS Verification Testing Package User's Guide* . ANSYS Release 7.0. 001767. @ SAS If, Inc.

Notes for Test Case vm212

Test case vm212 may produce an expected compare difference due to an inconsequential warning message that appears in the ANSYS, Inc. supplied output file that may not appear in the output file generated by your system for this test case. This compare difference should be considered acceptable. The following is an example of this compare difference.

```
COMPARE DIFFERENCE FOUND AT          NG= 445 NT= 436
G= NUMBER OF WARNING MESSAGES ENCOUNTERED= 1
T= NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
```

Notes for Test Cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s

Test cases cyc-177s, cyc-178s, ev-173-53s, ev-175-20s, inrt-16s, and inrt-9s may produce expected compare differences due to the use of a macro named qaend. The method that is used in the verification procedure (runqa) to handle this macro may cause one or more comparison differences. Any such compare differences are inconsequential and should be considered acceptable. The following is an example of such a compare difference.

```
EXTRA DATA SKIPPED ON TEST FILE      NG= 1033 NT= 1030
T= USE COMMAND MACRO qaend
T= ARGS= 137.00
END OF SKIPPED DATA                  NG= 1033 NT= 1033
```

Notes for test Cases dds-13s, dds-17s, and ev175-21 s

The test cases dds-13s, dds-17s, and ev175-21 s will run to completion only if the "Parallel Performance for ANSYS" product (DDS and AMG solvers) is included in your ANSYS installation.

3-6 *ANSYS Verification Testing Package User's Guide* . ANSYS Release 7.0. 001767. @ SAS If, Inc.

c0211r2	7020021010	70SP20030909	0	0	605	605	81%	11/10/2005	17:25	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0212	7020021010	70SP20030909	0	0	223	223	45%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0213	7020021010	70SP20030909	0	0	197	197	41%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0214	7020021010	70SP20030909	0	0	409	409	67%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0215	7020021010	70SP20030909	0	0	648	648	81%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0216	7020021010	70SP20030909	0	0	510	510	74%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0218	7020021010	70SP20030909	0	0	1627	1627	93%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0219	7020021010	70SP20030909	0	0	2732	2732	95%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0220	7020021010	70SP20030909	0	0	494	494	76%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0221	7020021010	70SP20030909	0	0	1265	1265	90%	11/10/2005	17:26	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0222	7020021010	70SP20030909	0	0	1543	1543	92%	11/10/2005	17:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0223	7020021010	70SP20030909	0	0	362	362	66%	11/10/2005	17:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0224	7020021010	70SP20030909	0	0	307	307	59%	11/10/2005	17:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0225	7020021010	70SP20030909	0	0	420	420	70%	11/10/2005	17:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0226	7020021010	70SP20030909	0	0	521	521	74%	11/10/2005	17:27	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227	7020021010	70SP20030909	0	0	380	380	65%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0227a	7020021010	70SP20030909	0	0	380	380	65%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0228	7020021010	70SP20030909	0	0	236	236	50%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0229	7020021010	70SP20030909	0	0	715	715	81%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0230	7020021010	70SP20030909	0	0	2513	2513	94%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0231	7020021010	70SP20030909	3	0	304	304	61%	11/10/2005	17:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

c0232	7020021010	70SP20030909	0	0	517	517	79%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0233	7020021010	70SP20030909	0	0	542	542	75%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
c0234	7020021010	70SP20030909	0	0	420	420	68%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm1	7020021010	70SP20030909	0	0	474	474	72%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm2	7020021010	70SP20030909	0	0	667	667	81%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm3	7020021010	70SP20030909	0	0	499	499	73%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm4	7020021010	70SP20030909	0	0	434	434	69%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm5	7020021010	70SP20030909	0	0	884	884	85%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm6	7020021010	70SP20030909	0	0	854	854	83%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm7	7020021010	70SP20030909	0	0	2176	2176	93%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm8	7020021010	70SP20030909	0	0	346	346	64%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm9	7020021010	70SP20030909	0	0	851	851	85%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm10	7020021010	70SP20030909	0	0	437	437	69%	11/10/2005	17:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm11	7020021010	70SP20030909	0	0	885	885	85%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm12	7020021010	70SP20030909	0	0	444	444	70%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm13	7020021010	70SP20030909	0	0	464	464	71%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm14	7020021010	70SP20030909	0	0	537	537	76%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm15	7020021010	70SP20030909	0	0	1356	1356	91%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm16	7020021010	70SP20030909	0	0	740	740	82%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm17	7020021010	70SP20030909	0	0	546	546	76%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm18	7020021010	70SP20030909	0	0	450	450	71%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm19	7020021010	70SP20030909	0	0	725	725	80%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm20	7020021010	70SP20030909	0	0	449	449	70%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm21	7020021010	70SP20030909	0	0	805	805	82%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm22	7020021010	70SP20030909	0	0	398	398	66%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm23	7020021010	70SP20030909	0	0	1043	1043	88%	11/10/2005	17:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm24	7020021010	70SP20030909	0	0	766	766	82%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm25	7020021010	70SP20030909	0	0	2350	2350	95%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm26	7020021010	70SP20030909	0	0	1829	1829	89%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm27	7020021010	70SP20030909	0	0	910	910	85%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm28	7020021010	70SP20030909	0	0	418	418	70%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm29	7020021010	70SP20030909	0	0	683	683	80%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm30	7020021010	70SP20030909	0	0	449	449	70%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm31	7020021010	70SP20030909	0	0	551	551	76%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm32	7020021010	70SP20030909	0	0	881	881	84%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm33	7020021010	70SP20030909	6	0	902	896	85%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm34	7020021010	70SP20030909	0	0	1380	1380	90%	11/10/2005	17:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm35	7020021010	70SP20030909	0	0	594	594	77%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm36	7020021010	70SP20030909	0	0	1086	1086	88%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm37	7020021010	70SP20030909	0	0	690	690	81%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm38	7020021010	70SP20030909	0	0	1667	1667	92%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm39	7020021010	70SP20030909	0	0	819	819	84%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm40	7020021010	70SP20030909	0	0	876	876	86%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm41	7020021010	70SP20030909	0	0	829	829	83%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm42	7020021010	70SP20030909	0	0	607	607	77%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm43	7020021010	70SP20030909	0	0	860	860	85%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm44	7020021010	70SP20030909	0	0	1198	1198	90%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm45	7020021010	70SP20030909	0	0	416	416	67%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm47	7020021010	70SP20030909	0	0	416	416	67%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm48	7020021010	70SP20030909	0	0	421	421	68%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm50	7020021010	70SP20030909	0	0	500	500	72%	11/10/2005	17:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm52	7020021010	70SP20030909	0	0	520	520	74%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm53	7020021010	70SP20030909	0	0	789	789	82%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm54	7020021010	70SP20030909	0	0	564	564	75%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm55	7020021010	70SP20030909	0	0	995	995	87%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm56	7020021010	70SP20030909	0	0	1577	1577	91%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm57	7020021010	70SP20030909	0	0	737	737	81%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm58	7020021010	70SP20030909	0	0	580	580	76%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm59	7020021010	70SP20030909	0	0	833	833	84%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm60	7020021010	70SP20030909	0	0	537	537	72%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm61	7020021010	70SP20030909	0	0	402	402	66%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm62	7020021010	70SP20030909	0	0	755	755	82%	11/10/2005	17:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm63	7020021010	70SP20030909	0	0	1280	1280	89%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm64	7020021010	70SP20030909	0	0	510	510	74%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm65	7020021010	70SP20030909	0	0	3323	3323	96%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm66	7020021010	70SP20030909	0	0	516	516	74%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm67	7020021010	70SP20030909	0	0	591	591	76%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm68	7020021010	70SP20030909	0	0	739	739	80%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm69	7020021010	70SP20030909	0	0	553	553	75%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm70	7020021010	70SP20030909	0	0	940	940	86%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm71	7020021010	70SP20030909	0	0	1307	1307	87%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm72	7020021010	70SP20030909	0	0	2161	2161	90%	11/10/2005	17:34	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm73	7020021010	70SP20030909	0	0	4189	4189	97%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm74	7020021010	70SP20030909	0	0	855	855	81%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm75	7020021010	70SP20030909	0	0	1129	1129	84%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm76	7020021010	70SP20030909	0	0	1187	1187	89%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm77	7020021010	70SP20030909	0	0	876	876	82%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm78	7020021010	70SP20030909	0	0	872	872	86%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm79	7020021010	70SP20030909	0	0	954	954	83%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm80	7020021010	70SP20030909	0	0	2205	2205	92%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm81	7020021010	70SP20030909	0	0	2015	2015	93%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm82	7020021010	70SP20030909	0	0	2144	2144	94%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm83	7020021010	70SP20030909	0	0	2191	2191	94%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm84	7020021010	70SP20030909	0	0	821	821	82%	11/10/2005	17:35	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm85	7020021010	70SP20030909	0	0	858	858	84%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm86	7020021010	70SP20030909	0	0	428	428	68%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm87	7020021010	70SP20030909	0	0	434	434	69%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm88	7020021010	70SP20030909	0	0	450	450	70%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm89	7020021010	70SP20030909	0	0	480	480	72%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm90	7020021010	70SP20030909	0	0	761	761	82%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm91	7020021010	70SP20030909	0	0	2102	2102	94%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm92	7020021010	70SP20030909	0	0	501	501	73%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm93	7020021010	70SP20030909	0	0	436	436	69%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm94	7020021010	70SP20030909	0	0	508	508	73%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm95	7020021010	70SP20030909	0	0	1044	1044	86%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm96	7020021010	70SP20030909	0	0	633	633	78%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm97	7020021010	70SP20030909	0	0	809	809	83%	11/10/2005	17:36	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm98	7020021010	70SP20030909	0	0	703	703	80%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm99	7020021010	70SP20030909	0	0	482	482	72%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm100	7020021010	70SP20030909	0	0	642	642	79%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm101	7020021010	70SP20030909	0	0	720	720	81%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm102	7020021010	70SP20030909	0	0	761	761	82%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm103	7020021010	70SP20030909	0	0	782	782	84%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm104	7020021010	70SP20030909	0	0	1822	1822	93%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm105	7020021010	70SP20030909	0	0	589	589	77%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm106	7020021010	70SP20030909	0	0	432	432	69%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm107	7020021010	70SP20030909	0	0	476	476	72%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm108	7020021010	70SP20030909	0	0	437	437	69%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm109	7020021010	70SP20030909	0	0	1025	1025	87%	11/10/2005	17:37	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm110	7020021010	70SP20030909	0	0	743	743	82%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm111	7020021010	70SP20030909	0	0	3511	3511	96%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm112	7020021010	70SP20030909	0	0	726	726	81%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm113	7020021010	70SP20030909	0	0	732	732	82%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm114	7020021010	70SP20030909	0	0	693	693	80%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm115	7020021010	70SP20030909	0	0	604	604	78%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm116	7020021010	70SP20030909	0	0	830	830	84%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm118	7020021010	70SP20030909	0	0	918	918	85%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm119	7020021010	70SP20030909	0	0	1225	1225	89%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm122	7020021010	70SP20030909	0	0	422	422	68%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm123	7020021010	70SP20030909	0	0	467	467	71%	11/10/2005	17:38	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm124	7020021010	70SP20030909	0	0	591	591	77%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm125	7020021010	70SP20030909	0	0	762	762	82%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm126	7020021010	70SP20030909	0	0	661	661	80%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm127	7020021010	70SP20030909	0	0	625	625	79%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm128	7020021010	70SP20030909	0	0	815	815	83%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm129	7020021010	70SP20030909	0	0	373	373	66%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm130	7020021010	70SP20030909	0	0	553	553	78%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm131	7020021010	70SP20030909	0	0	448	448	70%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm132	7020021010	70SP20030909	0	0	1827	1827	93%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm133	7020021010	70SP20030909	0	0	1701	1701	92%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm134	7020021010	70SP20030909	0	0	1808	1808	93%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm135	7020021010	70SP20030909	0	0	561	561	77%	11/10/2005	17:39	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm136	7020021010	70SP20030909	0	0	1909	1909	93%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm137	7020021010	70SP20030909	0	0	1395	1395	91%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm138	7020021010	70SP20030909	0	0	528	528	75%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm139	7020021010	70SP20030909	0	0	1132	1132	88%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm140	7020021010	70SP20030909	0	0	1184	1184	89%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm141	7020021010	70SP20030909	0	0	2040	2040	93%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm142	7020021010	70SP20030909	0	0	879	879	85%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm143	7020021010	70SP20030909	0	0	1672	1672	91%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm144	7020021010	70SP20030909	0	0	2164	2164	94%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm145	7020021010	70SP20030909	0	0	532	532	75%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm146	7020021010	70SP20030909	0	0	883	883	86%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm147	7020021010	70SP20030909	0	0	588	588	77%	11/10/2005	17:40	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm148	7020021010	70SP20030909	0	0	588	588	78%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm149	7020021010	70SP20030909	0	0	520	520	74%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm150	7020021010	70SP20030909	0	0	657	657	79%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm151	7020021010	70SP20030909	0	0	1058	1058	87%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm152	7020021010	70SP20030909	0	0	1211	1211	88%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm153	7020021010	70SP20030909	0	0	507	507	74%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm154	7020021010	70SP20030909	0	0	814	814	82%	11/10/2005	17:41	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm155	7020021010	70SP20030909	0	0	1255	1255	89%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm156	7020021010	70SP20030909	0	0	2047	2047	94%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm157	7020021010	70SP20030909	0	0	952	952	85%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm158	7020021010	70SP20030909	0	0	955	955	87%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm159	7020021010	70SP20030909	0	0	1524	1524	91%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm160	7020021010	70SP20030909	0	0	600	600	78%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm161	7020021010	70SP20030909	0	0	539	539	75%	11/10/2005	17:42	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm162	7020021010	70SP20030909	0	0	548	548	76%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm163	7020021010	70SP20030909	0	0	563	563	76%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm164	7020021010	70SP20030909	0	0	556	556	76%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm170	7020021010	70SP20030909	0	0	436	436	69%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm171	7020021010	70SP20030909	0	0	759	759	82%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm173	7020021010	70SP20030909	0	0	545	545	75%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm174	7020021010	70SP20030909	0	0	602	602	77%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm175	7020021010	70SP20030909	0	0	855	855	84%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm176	7020021010	70SP20030909	22	0	999	970	86%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm177	7020021010	70SP20030909	0	0	1127	1127	87%	11/10/2005	17:43	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm179	7020021010	70SP20030909	0	0	768	768	82%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm180	7020021010	70SP20030909	0	0	651	651	79%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm181	7020021010	70SP20030909	0	0	484	484	71%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm182	7020021010	70SP20030909	0	0	973	973	87%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm183	7020021010	70SP20030909	0	0	722	722	81%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm184	7020021010	70SP20030909	1	5	3162	3162	95%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm187	7020021010	70SP20030909	0	0	1489	1489	90%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm191	7020021010	70SP20030909	0	0	3075	3075	95%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm192	7020021010	70SP20030909	0	0	645	645	80%	11/10/2005	17:44	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm193	7020021010	70SP20030909	0	0	411	411	68%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm194	7020021010	70SP20030909	0	0	821	821	83%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm195	7020021010	70SP20030909	0	0	824	824	84%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm196	7020021010	70SP20030909	0	0	505	505	73%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm197	7020021010	70SP20030909	0	0	509	509	74%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm198	7020021010	70SP20030909	2	0	1208	1208	88%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm199	7020021010	70SP20030909	0	0	835	835	84%	11/10/2005	17:45	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm200	7020021010	70SP20030909	0	0	1258	1258	89%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm201	7020021010	70SP20030909	0	0	3072	3072	95%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm202	7020021010	70SP20030909	0	0	604	604	77%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm203	7020021010	70SP20030909	0	0	1020	1020	87%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm204	7020021010	70SP20030909	0	0	621	621	79%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vm205	7020021010	70SP20030909	0	0	652	652	79%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm210	7020021010	70SP20030909	0	0	1426	1426	90%	11/10/2005	17:47	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm211	7020021010	70SP20030909	0	0	2658	2658	94%	11/10/2005	17:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm215	7020021010	70SP20030909	0	0	637	637	80%	11/10/2005	17:48	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm216	7020021010	70SP20030909	0	0	1111	1111	87%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm217	7020021010	70SP20030909	0	0	873	873	84%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm218	7020021010	70SP20030909	0	0	744	744	82%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm222	7020021010	70SP20030909	0	0	1536	1536	91%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm224	7020021010	70SP20030909	0	0	577	577	79%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm225	7020021010	70SP20030909	0	0	496	496	73%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm227	7020021010	70SP20030909	0	0	957	957	87%	11/10/2005	17:49	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm228	7020021010	70SP20030909	0	0	5849	5849	98%	11/10/2005	17:50	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm229	7020021010	70SP20030909	0	0	3944	3944	97%	11/10/2005	17:53	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm230	7020021010	70SP20030909	0	0	26798	26798	99%	11/10/2005	17:54	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm231	7020021010	70SP20030909	0	0	528	528	76%	11/10/2005	17:54	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm232	7020021010	70SP20030909	0	0	14057	14057	98%	11/10/2005	17:56	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vm234	7020021010	70SP20030909	0	0	1468	1468	92%	11/10/2005	17:57	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc1	7020021010	70SP20030909	0	0	643	643	81%	11/10/2005	17:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc2	7020021010	70SP20030909	0	0	1692	1692	90%	11/10/2005	17:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc3	7020021010	70SP20030909	0	0	426	426	72%	11/10/2005	17:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc4	7020021010	70SP20030909	0	0	773	773	85%	11/10/2005	17:58	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

vmc5	7020021010	70SP20030909	0	0	513	513	78%	11/10/2005	17:59	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc6	7020021010	70SP20030909	0	0	433	433	74%	11/10/2005	17:59	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc7	7020021010	70SP20030909	0	0	337	337	67%	11/10/2005	17:59	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmc8	7020021010	70SP20030909	2	0	1894	1894	92%	11/10/2005	18:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd1	7020021010	70SP20030909	0	0	816	816	86%	11/10/2005	18:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd2	7020021010	70SP20030909	0	0	337	337	67%	11/10/2005	18:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
vmd3	7020021010	70SP20030909	0	0	608	608	82%	11/10/2005	18:28	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
cyc-177s	7020021010	70SP20030909	1	0	1219	1222	91%	11/10/2005	18:29	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
cyc-178s	7020021010	70SP20030909	1	0	1219	1222	91%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
dds-13s	7020021010	NO_UPDATE	-88	0	402	146	49%	11/10/2005	18:30	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
dds-17s	7020021010	NO_UPDATE	-88	0	746	146	67%	11/10/2005	18:30	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
esp-112s	7020021010	70SP20030909	0	0	279	279	58%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
esp-124s	7020021010	70SP20030909	0	0	392	392	66%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
esp-127s	7020021010	70SP20030909	0	0	527	527	75%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ess-26s	7020021010	70SP20030909	0	0	1846	1846	92%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ess-97s	7020021010	70SP20030909	0	0	1378	1378	90%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev154-23s	7020021010	70SP20030909	0	0	1259	1259	89%	11/10/2005	18:30	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev154-25s	7020021010	70SP20030909	0	0	587	587	76%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev171-57s	7020021010	70SP20030909	0	0	542	542	79%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev173-53s	7020021010	70SP20030909	1	0	1426	1429	92%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev175-20s	7020021010	70SP20030909	1	0	538	541	79%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

ev175-21s	7020021010	NO_UPDATE	-88	0	566	146	64%	11/10/2005	18:31	INTEL_NT
NOT_AVAILABLE	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev175-38s	7020021010	70SP20030909	0	0	808	808	85%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev182-zbdpg11s	7020021010	70SP20030909	0	0	660	660	83%	11/10/2005	18:31	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev183-zdpl20s	7020021010	70SP20030909	0	0	577	577	80%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-02s	7020021010	70SP20030909	0	0	267	267	56%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev184-07s	7020021010	70SP20030909	0	0	661	661	80%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev35-23s	7020021010	70SP20030909	0	0	293	293	61%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
ev95-45s	7020021010	70SP20030909	0	0	892	892	85%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-16s	7020021010	70SP20030909	1	0	484	486	77%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
inrt-9s	7020021010	70SP20030909	0	0	421	421	73%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-bk501	7020021010	70SP20030909	0	0	536	536	78%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvhy-gt202	7020021010	70SP20030909	0	0	780	780	84%	11/10/2005	18:32	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr003	7020021010	70SP20030909	0	0	328	328	65%	11/10/2005	18:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
mvve-cr804	7020021010	70SP20030909	0	0	329	329	65%	11/10/2005	18:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-1s	7020021010	70SP20030909	0	0	400	400	72%	11/10/2005	18:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					
se-20s	7020021010	70SP20030909	0	0	879	879	85%	11/10/2005	18:33	INTEL_NT
INTEL_NT	QA70-1	COMPARE_REL	3.8	UP20020121	WINDOWS					

1

00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 113 NT= 113
 G= 00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010
 T= 00292062 VERSION=INTEL NT RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 114 NT= 114
 G= CURRENT JOBNAME=c0231 10:37:04 OCT 15, 2002 CP= 0.219
 T= CURRENT JOBNAME=c0231 17:28:23 NOV 10, 2005 CP= 0.375

0 /verify,c0231

0 /title, c0231 {fsk} Unmatched nodes mapping

COMPARE DIFFERENCE FOUND AT NG= 192 NT= 192
 G= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE = 30.580
 T= NODAL RESULTS ARE FOR CYCLIC SECTOR 1 - PHASE ANGLE = 237.330

COMPARE DIFFERENCE FOUND AT NG= 219 NT= 219
 G= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE = 30.580
 T= NODAL RESULTS ARE FOR CYCLIC SECTOR 2 - PHASE ANGLE = 237.330

COMPARE DIFFERENCE FOUND AT NG= 246 NT= 246
 G= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE = 30.580
 T= NODAL RESULTS ARE FOR CYCLIC SECTOR 3 - PHASE ANGLE = 237.330

BOTTOM OF GOOD FILE REACHED AT LINE 289
 G= | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 3 *

```
=====
PROBLEM: c0231            COMPARE OPTIONS    COMPARE_REL 3.8 UP20020121    WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006            KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006            KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010           KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004           MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006           MAXBUF (# LINES TO SCAN)= 6
                                             KNOWN (# OF KNOWN ERRS)= 0
=====
```

GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 304

LINES ON TEST FILE = 304

B.102

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) -      0
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT      -      0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT      -      0
=====

```

```

*****
COMPARE ERRORS =          6                      *
*****

```

```

=====
PROBLEM:  vm33              COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS
ALMOST ZERO (GOOD)   = 1.0000E-006           KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)   = 1.0000E-006           KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL   = 1.0000E-010           KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004           MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE  = 1.0000E-006           MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN  (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE -      902
LINES ON TEST FILE =      896

```

```

*****

```


RPP-RPT-32237, Rev. 1

G= Element 16 references undefined MURX or BH table for material 2.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
G= Element 16 references undefined KXX for material 2.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
END OF SKIPPED DATA NG= 653 NT= 648

COMPARE DIFFERENCE FOUND AT NG= 731 NT= 720
G= Element 1 references undefined MURX or BH table for material 3.
T= Element 1 references undefined KXX for material 3.

EXTRA DATA SKIPPED ON GOOD FILE NG= 734 NT= 725
G= Element 1 references undefined KXX for material 3.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
END OF SKIPPED DATA NG= 737 NT= 725

COMPARE DIFFERENCE FOUND AT NG= 742 NT= 728
G= Element 11 references undefined MURX or BH table for material 4.
T= Element 11 references undefined KXX for material 4.

COMPARE DIFFERENCE FOUND AT NG= 745 NT= 731
G= Element 11 references undefined KXX for material 4.
T= Element 11 references undefined RSVX or PERX for material 4.

COMPARE DIFFERENCE FOUND AT NG= 748 NT= 734
G= Element 11 references undefined RSVX or PERX for material 4.
T= Element 16 references undefined KXX for material 2.

EXTRA DATA SKIPPED ON GOOD FILE NG= 751 NT= 742
G= Element 16 references undefined MURX or BH table for material 2.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
G= Element 16 references undefined KXX for material 2.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
END OF SKIPPED DATA NG= 757 NT= 742

COMPARE DIFFERENCE FOUND AT NG= 784 NT= 764
G= Element 1 references undefined MURX or BH table for material 3.
T= Element 1 references undefined KXX for material 3.

EXTRA DATA SKIPPED ON GOOD FILE NG= 787 NT= 769
G= Element 1 references undefined KXX for material 3.
G= *** WARNING *** CP= 0.000 TIME= 00:00:00
END OF SKIPPED DATA NG= 790 NT= 769

COMPARE DIFFERENCE FOUND AT NG= 795 NT= 772
G= Element 11 references undefined MURX or BH table for material 4.
T= Element 11 references undefined KXX for material 4.

COMPARE DIFFERENCE FOUND AT NG= 798 NT= 775
G= Element 11 references undefined KXX for material 4.
T= Element 11 references undefined RSVX or PERX for material 4.

COMPARE DIFFERENCE FOUND AT NG= 801 NT= 778
G= Element 11 references undefined RSVX or PERX for material 4.
T= Element 16 references undefined KXX for material 2.

EXTRA DATA SKIPPED ON GOOD FILE NG= 804 NT= 786
G= Element 16 references undefined MURX or BH table for material 2.

RPP-RPT-32237, Rev. 1

G= *** WARNING *** CP= 0.000 TIME= 00:00:00
 G= Element 16 references undefined KXX for material 2.
 G= *** WARNING *** CP= 0.000 TIME= 00:00:00
 END OF SKIPPED DATA NG= 810 NT= 786

NOW COMPARING LINES FROM ***** TIME-HISTORY POSTPROCESSOR (POST26)

COMPARE DIFFERENCE FOUND AT NG= 978 NT= 949
 G= NUMBER OF WARNING MESSAGES ENCOUNTERED= 32
 T= NUMBER OF WARNING MESSAGES ENCOUNTERED= 23

BOTTOM OF GOOD FILE REACHED AT LINE 984
 G= | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 22 *

=====

PROBLEM: vm176	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD) = 1.0000E-006	KROUND (DROP LAST DIGIT)=	1	
ALMOST ZERO (TEST) = 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1	
ABSOLUTE VALUE TOL = 1.0000E-010	KSKIP (SKIP-ERR 0=Y, 1=N)=	0	
FRACTIONAL DIFFERENCE= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100	
ABSOLUTE DIFFERENCE = 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6	
	KNOWN (# OF KNOWN ERRS)=	0	
	GREAD, TREAD =	1, 1	

=====

LINES ON GOOD FILE = 999
 LINES ON TEST FILE = 970

1

00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 113 NT= 113
 G= 00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010
 T= 00292062 VERSION=INTEL NT RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 114 NT= 114
 G= CURRENT JOBNAM=vm184 20:46:18 OCT 15, 2002 CP= 0.250
 T= CURRENT JOBNAM=vm184 17:44:26 NOV 10, 2005 CP= 0.375

0 /VERIFY,VM184

0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM

0 /style,1,Reason COMPARE differences are acceptable:

0 /style,2, mesher accuracy - element number on warning; near-zero values

0 /TITLE, VM184, STRAIGHT CANTILEVER BEAM

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1) *****

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 926 NT= 926
 G= VALUE -0.24849E-01 0.98917 -0.43496E-05 0.98948
 T= VALUE -0.24849E-01 0.98917 0.43497E-05 0.98948

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 982 NT= 982
 G= VALUE -0.53544E-02-0.26671E-05 0.42554 0.42557
 T= VALUE -0.53544E-02 0.26671E-05 0.42554 0.42557

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 1011 NT= 1011
 G= VALUE -0.12394E-01-0.61739E-05 0.98504 0.98511
 T= VALUE -0.12394E-01 0.61739E-05 0.98504 0.98511

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1) *****

COMPARE DIFFERENCE FOUND AT NG= 1580 NT= 1580
 G= VALUE 0.24811E-01 0.98813 -0.43696E-05 0.98844
 T= VALUE 0.24811E-01 0.98813 0.43701E-05 0.98844

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 1639 NT= 1639
 G= VALUE -0.53533E-02-0.30755E-05 0.42553 0.42556

RPP-RPT-32237, Rev. 1

T= VALUE -0.53533E-02 0.30756E-05 0.42553 0.42556

ABSOLUTE VALUE DIFFERENCE FOUND AT NG= 1673 NT= 1673

G= VALUE -0.12392E-01-0.71193E-05 0.98502 0.98510

T= VALUE -0.12392E-01 0.71194E-05 0.98502 0.98510

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM ***** ANSYS RESULTS INTERPRETATION (POST1)

BOTTOM OF GOOD FILE REACHED AT LINE 3147
G= | ANSYS RUN COMPLETED |

~~~~~  
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
~~~~~

COMPARE ERRORS = 1 *

WARNING - 5 ABSOLUTE VALUE DIFFERENCE(S) FOUND.

NOTE - 1 summary line(s) contained absolute value differences.

```
=====
PROBLEM: vml84          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)     = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)     = 1.0000E-006      KABSPP (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL     = 1.0000E-010      KSKIP (SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE - 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
```

GREAD, TREAD = 1, 1

LINES ON GOOD FILE = 3162

LINES ON TEST FILE = 3162

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=vm198 20:50:49 OCT 15, 2002 CP=          0.266
T= CURRENT JOBNAME=vm198 17:45:25 NOV 10, 2005 CP=          0.344

      0 /VERIFY,VM198

      0 /TITLE, VM198, LARGE STRAIN IN-PLANE TORSION TEST {%EL%}

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 618 NT= 618
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

COMPARE DIFFERENCE FOUND AT          NG= 907 NT= 907
G= RELEASE 0.0          UPDATE          0 CUSTOMER 00000000
T= RELEASE 0.0          UPDATE          0 CUSTOMER 00292062

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

NOW COMPARING LINES FROM          ***** TIME-HISTORY POSTPROCESSOR (POST26)
*****

```

BOTTOM OF GOOD FILE REACHED AT LINE 1193
 G= | ANSYS RUN COMPLETED |

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 2 *
*****

```

```

=====
PROBLEM: vm198          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS
ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)- 0
                                   GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1208
LINES ON TEST FILE = 1208
=====

```

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNOME=vmc8 21:52:06 OCT 15, 2002 CP= 0.219
T= CURRENT JOBNOME=vmc8 17:59:57 NOV 10, 2005 CP= 0.375

0 /VERIFY,VMC8
0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY
0 /style,1,Reason COMPARE differences are acceptable:
0 /style,2, number of iterations, accuracy
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE2
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE42
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
PLANE82
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
VISCO106
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
SOLID45
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
SOLID95
0 /title, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY -
VISCO107
0 /TITLE, VMC8, ALUMINUM BAR IMPACTING A RIGID BOUNDARY

NOW COMPARING LINES FROM          ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM          ***** ANSYS RESULTS INTERPRETATION (POST1)
*****

COMPARE DIFFERENCE FOUND AT          NG= 880 NT= 880
G= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3255
T= SET COMMAND GOT LOAD STEP= 2 SUBSTEP= 320 CUMULATIVE ITERATION= 3240

```

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

COMPARE DIFFERENCE FOUND AT

NG= 1227 NT= 1227

G=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.7401E-16	0.000	3.410	0.000
T=	3	ESOL	1	EPPL	EQV	EPPLEQV	0.2694E-35	0.000	3.422	0.000

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM

***** TIME-HISTORY POSTPROCESSOR (POST26)

NOW COMPARING LINES FROM

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

NOW COMPARING LINES FROM

***** ANSYS RESULTS INTERPRETATION (POST1)

NOW COMPARING LINES FROM ***** TIME-HISTORY POSTPROCESSOR (POST26)

BOTTOM OF GOOD FILE REACHED AT LINE 1879
 G= | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE (BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 2 *

PROBLEM: vmc8		COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1	
ALMOST ZERO (TEST)	= 1.0000E-006	KASPR (0-SUMMARY 1-ALL)-	1	
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP (SKIP=ERR 0=Y, 1=N)=	0	
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100	
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6	
		KNOWN (# OF KNOWN ERRS)=	0	
		GREAD, TREAD =	1, 1	

~~~~~  
 LINES ON GOOD FILE = 1894  
 LINES ON TEST FILE = 1894  
 ~~~~~

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-177s 11:45:34 OCT 15, 2002 CP= 0.219
T= CURRENT JOBNAME=cyc-177s 18:28:58 NOV 10, 2005 CP= 0.359

```

```

0 /verify,cyc-177s
0 /TITLE, ceb,cyc-177s, Test cyc symm Buckling element 42
0 /title,1,Full Results to Sector Results!
0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-177s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
                                   GREAD, TREAD = 1, 1
=====

```

LINEs ON GOOD FILE = 1219
LINEs ON TEST FILE - 1222

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=cyc-178s 11:48:41 OCT 15, 2002 CP= 0.250
T= CURRENT JOBNAME=cyc-178s 18:29:39 NOV 10, 2005 CP= 0.359

```

```

0 /verify,cyc-178s
0 /TITLE, ceb,cyc-178s, Test cyc symm Buckling element 182
0 /title,1,Full Results to Sector Results!
0 /stitle,Reason Compare differences are acceptable:

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1202 NT= 1194
T= USE COMMAND MACRO QAEND
T= ARGS= 289.00
END OF SKIPPED DATA                  NG= 1202 NT= 1199

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1204
G- |                                ANSYS RUN COMPLETED

```

```

=====
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
=====

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: cyc-178s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)    = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)    = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL    = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE   = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                   KNOWN (# OF KNOWN ERRS)= 0
                                   GREAD, TREAD = 1, 1
=====

```

LINEs ON GOOD FILE = 1219
LINEs ON TEST FILE - 1222

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-13s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 402
 LINES ON TEST FILE = 146

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: dds-17s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 746
 LINES ON TEST FILE = 146

1

```

00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000      VERSION=INTEL NT      RELEASE= 7.0      UP20021010
T= 00292062      VERSION=INTEL NT      RELEASE= 7.0SP11 UP20030909

```

```

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=ev173-53s  14:02:31 OCT 15, 2002 CP=      0.234
T= CURRENT JOBNAME=ev173-53s  18:31:16 NOV 10, 2005 CP=      0.406

```

```

0 /verify,ev173-53s

```

```

0 /title,ev173-53s,mfquresh,Test to verify PSOVLE,ELFORM for 171-
175 (3D) with PENE

```

```

EXTRA DATA SKIPPED ON TEST FILE      NG= 1409 NT= 1401
T= USE COMMAND MACRO QAEND
T= ARGS= 20.000
END OF SKIPPED DATA                  NG= 1409 NT= 1406

```

```

BOTTOM OF GOOD FILE REACHED AT LINE 1411
G= |                                ANSYS RUN COMPLETED

```

```

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
~~~~~

```

```

*****
COMPARE ERRORS = 1 *
*****

```

```

=====
PROBLEM: ev173-53s      COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)      = 1.0000E-006      KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)      = 1.0000E-006      KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL      = 1.0000E-010      KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004      MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE    = 1.0000E-006      MAXBUF (# LINES TO SCAN)= 6
                                           KNOWN (# OF KNOWN ERRS)= 0
                                           GREAD, TREAD = 1, 1
=====

```

```

LINES ON GOOD FILE = 1426
LINES ON TEST FILE - 1429

```

1

00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 113 NT= 113
 G= 00000000 VERSION=INTEL NT RELEASE= 7.0 UP20021010
 T= 00292062 VERSION=INTEL NT RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT NG= 114 NT= 114
 G= CURRENT JOBNAM=ev175-20s 14:22:03 OCT 15, 2002 CP= 0.250
 T= CURRENT JOBNAM=ev175-20s 18:31:34 NOV 10, 2005 CP= 0.328

0 /verify,ev175-20s

0 /title,ev175-20s,mfq, Check real constant FKN and FTOLN and
 KEYOPT(2)=0,1

NOW COMPARING LINES FROM ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

EXTRA DATA SKIPPED ON TEST FILE NG= 521 NT= 513
 T= USE COMMAND MACRO QAEND
 T= ARGS= 3.0000
 END OF SKIPPED DATA NG= 521 NT= 518

BOTTOM OF GOOD FILE REACHED AT LINE 523
 G- | ANSYS RUN COMPLETED |

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 2  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 2  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = 1 *

PROBLEM: ev175-20s		COMPARE OPTIONS	COMPARE_REL 3.8	UP20020121	WINDOWS
ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1		
ALMOST ZERO (TEST)	= 1.0000E-006	KASPR (0=SUMMARY 1=ALL)=	1		
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0		
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100		
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6		
		KNOWN (# OF KNOWN ERRS)=	0		
		GREAD, TREAD =	1, 1		

LINE# ON GOOD FILE = 538
LINE# ON TEST FILE - 541

1

*** ERROR -- (VERSION=) was not found anywhere in the "TEST" file. ***
 *** Comparison was supposed to start at this string, specified in CMFOPT. ***

~~~~~  
 NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED  
 NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 0  
 NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0  
 NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0  
 ~~~~~

 COMPARE ERRORS = -88 *

=====

PROBLEM: ev175-21s	COMPARE OPTIONS	COMPARE_REL 3.8 UP20020121	WINDOWS
--------------------	-----------------	----------------------------	---------

ALMOST ZERO (GOOD)	= 1.0000E-006	KROUND (DROP LAST DIGIT)=	1
ALMOST ZERO (TEST)	= 1.0000E-006	KABSPR (0=SUMMARY 1=ALL)=	1
ABSOLUTE VALUE TOL	= 1.0000E-010	KSKIP(SKIP=ERR 0=Y, 1=N)=	0
FRACTIONAL DIFFERENCE	= 1.0000E-004	MAXERR (STOP WHEN ERRS)=	100
ABSOLUTE DIFFERENCE	= 1.0000E-006	MAXBUF (# LINES TO SCAN)=	6
		KNOWN (# OF KNOWN ERRS)=	0
		GREAD, TREAD =	1, 1

=====

LINES ON GOOD FILE = 566
 LINES ON TEST FILE = 146

1

```

*****

00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 113 NT= 113
G= 00000000          VERSION=INTEL NT          RELEASE= 7.0          UP20021010
T= 00292062          VERSION=INTEL NT          RELEASE= 7.0SP11 UP20030909

EXPECTED COMPARE DIFFERENCE FOUND AT  NG= 114 NT= 114
G= CURRENT JOBNAME=inrt-16s 16:14:59 OCT 15, 2002 CP= 0.219
T= CURRENT JOBNAME=inrt-16s 18:32:29 NOV 10, 2005 CP= 0.391

      0 /VERIFY, INRT-16S

      0 /TITLE, INRT-16S, ceb, component omega loading and layer
elements

      0 /TITLE, INRT-16S, BENDING OF A COMPOSITE BEAM

EXTRA DATA SKIPPED ON TEST FILE          NG= 462 NT= 459
T= USE COMMAND MACRO QAEND
END OF SKIPPED DATA                      NG= 462 NT= 463

BOTTOM OF GOOD FILE REACHED AT LINE 469
G= |                                     ANSYS RUN COMPLETED |

~~~~~
NOTE- NONSTANDARD COMPARE - DIFOPT NAME QA70-1 HAS BEEN USED
NUMBER OF LINES SKIPPED IN GOOD FILE(BLANK LINES EXCLUDED) - 1
NUMBER OF LINES SKIPPED IN TEST FILE(BLANK LINES EXCLUDED) - 1
NUMBER OF LINES ON GOOD FILE WITH STRINGS CONDENSED OUT - 0
NUMBER OF LINES ON TEST FILE WITH STRINGS CONDENSED OUT - 0
~~~~~

*****
COMPARE ERRORS = 1 *
*****

=====
PROBLEM: inrt-16s          COMPARE OPTIONS  COMPARE_REL 3.8 UP20020121  WINDOWS

ALMOST ZERO (GOOD)      = 1.0000E-006          KROUND (DROP LAST DIGIT)= 1
ALMOST ZERO (TEST)      = 1.0000E-006          KASPR (0=SUMMARY 1=ALL)= 1
ABSOLUTE VALUE TOL      = 1.0000E-010          KSKIP(SKIP=ERR 0=Y, 1=N)= 0
FRACTIONAL DIFFERENCE= 1.0000E-004          MAXERR (STOP WHEN ERRS )= 100
ABSOLUTE DIFFERENCE = 1.0000E-006          MAXBUF (# LINES TO SCAN)= 6
                                          KNOWN (# OF KNOWN ERRS)= 0
                                          GREAD, TREAD = 1, 1
=====

LINES ON GOOD FILE = 484
LINES ON TEST FILE - 486
*****

```


Intentionally left blank.

Appendix C

ANSYS Model Files

Appendix C

ANSYS Model Files

C.1 Introduction

This appendix contains the ANSYS model input files for the thermal and operating load analyses. The input files for the seismic analyses are available in the seismic report (Rinker et al. 2007). To conserve space and avoid duplication of the same data multiple times, some of the files listed will be used multiple times, but they are only included one time in this document.

There are twenty-six files needed to actually build the model and run the initial mechanical loads. The key file for this phase of the analysis is the "set_slicea.mac" macro file. The set_slicea.mac file calls all of the other necessary files for the actual ANSYS run. At the end of this initial phase, the ANSYS database file is copied into a new subdirectory along with the eighteen temperature distribution macro files that apply the temperatures via body forces to each node point in the model and a short input macro file to re-start the ANSYS run. The actual nodal temperature values are not included in this appendix, as it would take over three thousand pages to do so. The actual nodal temperatures are included separately on electronic media. The ACI load factors are applied at the end of the 60 years of thermal cycling in a separate restart analysis. Section D.2 contains all the input files needed for the Best Estimate Soil – Best Estimate Concrete (BES-BEC) analysis. Sections D.3 and D.4 contain only the files that are different to run the Lower Bound Soil – Best Estimate Concrete and Upper Bound Soil – Best Estimate Concrete analyses.

Section D.5 contains the input files for the BES-BEC analysis with the anchor bolts modeled as springs. In addition to the secant stiffness spring model described in "set_slicea.mac", this analysis required fewer load steps for the thermal transient because of the lower (135°F) steady state waste temperature. These input files are also listed in this section.

The post-processing files required to extract the results from the TOLA model in preparation for combination with the seismic results are shown in Section D.6.

The input file for the detailed AP anchor bolt study described in Appendix B is listed in Section D.7.

C.2 Best Estimate Soil Model Input Files

C.2.1 Model Files

Input file: set_slicea.mac

```

**** AP 210F, Waste Height=422 SpG =1.83 for 20 years
10/11/2006
**** AP 210F, Waste Height=460 SpG =1.83 for 40 years
10/11/2006

**** AP modifications 8/9/04
****Liquid level 460", SpG 1.83 8/11/04
****Liquid level 460", SpG 2.0 7/26/04
****Liquid level 460", SpG 1.7 7/19/04
****2nd liner extension 0.25 thick 7/21/04
****2nd liner extension contact <> concrete 7/21/04
**** Augmented stiffness 5% Econc (350) 7/19/04
****5% pivot, bcs0,mmd 6/25/04
****Use nsub 6/24/04
****cnvtol,f(m),.005,0 6/16/04
**** Augmented stiffness 2% Econc (350) 6/14/04
**** Augmented stiffness 30000 6/11/04
****6/10/04 changes
**** Do not merge insulating concrete <> 2nd liner @ OD
of concrete
**** Add 1st radius element to contact of 1st liner <> ins
conc
**** Add contact 2nd liner <> slab concrete
****Correct node select for type,61 real,70 6/9/04
****Reorient Beam188 on z/= 0 face
****Fix Liner-Dome common nodes 5/6/04
****Delete "j-bolts" in wall 5/6/04
****Move j-bolt real definition to pnnla6.mac 3/30/04

```

```

****Changed Liner Coupling per J. Deibler 3/29/04
**** Augmented stiffness 15000 3/24/04
****Default convergence criteria 3/22/04
****Best estimate soil properties 3/19/04
****Soil-Concrete - 5 regions 2/23/04
****Correct Drucker-Prager - soil
****Correct mat,1 temperature dependent modulus
****Replace shell64 with shell181
****Primary tank pressure -12" H2O (was -6)
****125 pcf overburden, 110 pcf undisturbed soil
****10/30/03
****Define additional soils for load factor restart
****No cracking insulating concrete
****fix mpch (esel,r,mat,,2)
****1 yr + 15 day creep 5/14/03
**** Load step 5 creep for 330 days
****New load step 6 => mpch +5 days
**** "sets" degraded concrete properties
****
**** Turn off concrete crushing 5/5/03
****
**** Run 2, Load Step 1, 2 & thermal
**** (8.3' soil, 125 lb/ft3)
**** (0.06" primary tank corrosion wall, floor)
**** 4/16/03
****
****
**** JED mods 3/29/03
****

i_rebuild=1
*if,i_rebuild,eq,1,then
pnnla

```

```

pnnla2
pnnla3
pnnla4
pnnla5
pnnla6
pnnla7
pnnla8
pnnla9
*else
  resume,pnnla9,db
*endif

```

```

/prep7

```

```

allsel
epdelete,all,all

```

```

!get misc area components for applying loads, etc.
/input,set_areas_slice,mac

```

```

!add steel plate below wall (on slab)

```

```

r,45,1/4
csys,22
vsel,s,mat,,2
aslv
asel,r,loc,z,-8.125
asel,r,loc,x,480,498
aatt,1,45,22
mat,1
real,45
amesh,all

```

```

!define contact elements (all have default friction of 0.3)

```

```

et,60,170
et,61,173
mp,mu,61,,.3      !Soil-concrete dome
,mu,62,.4
,mu,63,.4
,mu,64,.4
,mu,65,.3
,mu,66,.2
,mu,67,.05        !soil-concrete wall
,mu,68,.3         !soil-concrete footing/top
,mu,69,.05        !soil-concrete footing/side
,mu,70,.6         !soil-concrete foundation
,mu,71,.4         !2nd liner-insulating concrete
6/10/04

```

```

!soil_concrete contact - dome

```

```

r,61,,,1,.1
real,61
type,61
mat,61
cmsel,s,aconc_soil
nsla,,1
nset,r,loc,z,452,600
esln
esurf
type,60
cmsel,s,asoil
nsla,,1
nset,r,loc,z,452,600
esln
esurf

```

```

!soil_concrete contact - wall

```

```

r,67,,,1,,1
real,67
type,61
mat,67
cmisel,s,aconc_soil
nsla,,1
nsel,r,loc,z,-3,453
esln
esurf
type,60
cmisel,s,asoil
nsla,,1
nsel,r,loc,z,-3,453
esln
esurf

```

```

!soil_concrete contact - Footing - top
r,68,,,1,,1
real,68
type,61
mat,68
cmisel,s,aconc_soil
nsla,,1
nsel,r,loc,z,-7,-6
esln
esurf
type,60
cmisel,s,asoil
nsla,,1
nsel,r,loc,z,-7,-6
,r,loc,x,496,530
esln
esurf

```

```
!soil_concrete contact - Footing - side
```

```

r,69,,,1,,1
real,69
type,61
mat,69
cmisel,s,aconc_soil
nsla,,1
nsel,r,loc,x,531
esln
esurf
type,60
cmisel,s,asoil
nsla,,1
nsel,r,loc,x,531
esln
esurf

```

```
!soil_concrete contact - Foundation
```

```

r,70,,,1,,1
real,70
type,61
mat,70
cmisel,s,aconc_soil
nsla,,1
nsel,r,loc,z,-31,-30
,r,loc,x,440,531
cm,foundconc,node
nsla,,1
nsel,r,loc,x,,440
,r,loc,z,-33,-8
cmse,a,foundconc
esln

```

```
!*** was -32 6/9/04
```



```

esurf
type,60
cmsel,s,asoil
nsla,,1
nsel,r,loc,z,-31,-30
r,loc,x,440,531
cm,foundsoil,node
nsla,,1
nsel,r,loc,x,,440
r,loc,z,-33,-8
cmsec,a,foundsoil
esln
esurf

!secondary liner contact
r,62,,,1,.1
real,62
type,60
mat,62
cmsel,s,aconc_shell
csys,0
asel,u,loc,y,459,99999
nsla,,1
esln
esel,r,mat,,2
esurf
type,61
cmsel,s,area_secon
csys,0
asel,u,loc,y,-99999,3.87
nsla,,1
esln

```

```

esurf

!primary liner contact with dome
r,63,,,1,.1
real,63
type,60
mat,63
cmsel,s,aconc_shell
asel,r,loc,y,459,99999
nsla,,1
esln
esel,r,mat,,2
esurf
type,61
cmsel,s,area_prim
asel,r,loc,y,459,99999
nsla,,1
esln
esurf

!primary liner contact with insulating concrete
r,64,,,1,.1
real,64
type,60
mat,64
cmsel,s,area_insul_top
nsla,,1
esln
esel,r,mat,,4
esurf
type,61
cmsel,s,area_prim
csys,0

```

```

asel,r,loc,y,0
nsla,,1
esln
nsle      !*6/10/04
esurf

```

```

!secondary liner contact with foundation concrete 6/10/04

```

```

r,71,,,1,.1
real,71
type,60
mat,71
cmse,,slab_top
asel,r,loc,x,-480,-440
nsla,,1
esln
esurf
type,61
cmse,,area_secon
asel,r,loc,x,-470,-440
,r,loc,y,-9,-8
nsla,,1
esln
nsle
esurf

```

```

!merge insulating concrete bottom nodes and secondary liner
nodes

```

```

cmse,s,area_insul_bot
cmse,a,area_secon
csys,0
asel,u,loc,y,20,9999
nsla,,1
cpintf,uz,.1

```

```

!slab top/insulating concrete

```

```

r,65,,,1,.1
real,65
type,60
mat,65
cmse,s,slab_top
nsla,,1
esln
esurf
type,61
cmse,s,area_insul_bot
nsla,,1
esln
esurf

```

```

!wall/slab contact

```

```

r,66,,,1,.1
real,66
type,60
mat,66
asel,,,,986,992
cm,slab_top_wall,area
nsla,,1
esln
esel,r,mat,,2
esurf
type,61
asel,,,,214
,a,,,706
,a,,,913,918,5
,a,,,934
cm,wall_bot,area

```

```

nsla,,1
esln
esel,r,mat,,2
esurf

```

```

allsel
!esel,s,type,,60
!nsle
!nummrg,node
!nummrg,elem
!esel,s,type,,61
!nsle
!nummrg,elem

```

```

max_mat=100
max_real=1000

```

```

!define the local coordinate systems and rebar orientations
/input,set_esys_3d,mac

```

```

!apply loads
/input,apply_loads_slice,mac
allsel

```

```

!apply axisymmetric boundary conditions
csys,22
nset,s,loc,y,180
nset,a,loc,y,180+swp_th-.001,183
csys,0
nset,a,loc,x,0
d,all,uy,0
d,all,rotx,0
d,all,roty,0

```

```

allsel

```

```

nset,s,loc,x,0
d,all,roty,0

```

```

!merge liner/concrete nodes at dome centerline
ksel,s,,2
ksel,a,,,329
nslk
nummrg,node
allsel

```

```

!copy jbolts, etc for slice model
csys,22
esel,s,type,,20,21
cm,c_bolt0,elem
egen,2,500000,all,,,0,0,0,0,0,swp_th
esel,s,mat,,1
esel,u,real,,45
nsle
nset,u,,,22789,22790 **** 5/6/04
,u,,,20260,20261 **** 6/10/04
nummrg,node

```

```

!divide jbolt/bottom anchors properties by 2 for slice model
r,30,.19635/2,.3068e-2/2,.3068e-2/2,.5,.5

```

```

esel,s,type,,20,21
cmset,u,e_bolt0
nsle
nset,r,,,500000,999999
cm,ntemp,node

```

```

vsel,s,mat,,2
vsel,a,mat,,6
csys,0
vsel,u,loc,y,-9999,-8.12
cm,vtemp,volu
*get,nv,volu,,count
*do,i,1,nv
*get,iv,volu,,num,min
eslv
nsle
cmsel,a,ntemp
nummrg,node
cm,ntemp,node
cmsel,s,vtemp
vsel,u,,,iv
cm,vtemp,volu
*enddo

```

```

****
**** Delete primary-secondary tank coupling at tangent
**** JED 3/31/03
****

```

```

r,41,3/16      !insulating concrete confining ring
thickness

```

```

/prep7

```

```

esel,s,mat,,5
nsle,,1
csys,0
*get,top_elev,node,,mxloc,y
cm,soil_elem,elem

```

```

*do,i,1,16
set_slayer,soil_z0(i),soil_z1(i),soil_emod(i),soil_pr(i)
*enddo

```

```

max_mat=100
!set backfill/overburden material
*do,i,1,8
set_backfill,bf_z0(i),bf_z1(i),bf_emod(i),bf_pr
*enddo

```

```

!Don't do this!! 5/6/04
!make sure anchors/jbolts/studs etc are merged with concrete
!esel,,type,,12,13
!,a,type,,20,21
!,a,type,,24,25
!nsle
!nsel,u,,,22789,22790      !*** 3/26/04
!numm,node

```

```

****
**** Augmented Stiffness 2/27/04
****
et,32,45
*get,cc350,ex,2,temp,350
mp,ex,12,cc350*0.05      !7/19/04
,prxy,12,,15
esel,,type,,12,15
egen,2,0,all,,,10
esel,,mat,,12
emod,all,type,32

```

```

/fil,set_slice_0
save

!***
!***Redefine j-bolts 4/1/04
!***

alls
csys
nod0k=node(-550,575,0)
nod1k=node(-550,575,27)
et,30,188          !New j-bolts
type,30
mat,1
real,20
secn,2
sect,2,beam,csolid
secd,.25/(2*.5),1,1    !Use 1/2 area for symmetry
esel,type,,20
nsle
nsel,r,loc,z
esln,,1
*get,jb0,elem,,count
*do,i,1,jb0
*get,jb1,elem,,num,min
*get,jn1,elem,jb1,node,1
*get,jn2,elem,jb1,node,2
e,jn1,jn2,nod0k
csel,u,,,jb1
*enddo

esel,type,,20
nsle

```

```

nsel,u,loc,z
esln,,1
*get,jb2,elem,,count
*do,i,1,jb2
*get,jb3,elem,,num,min
*get,jn3,elem,jb3,node,1
*get,jn4,elem,jb3,node,2
e,jn3,jn4,nod1k
csel,u,,,jb3
*enddo

allsel

!*** 2nd liner extension issues 7/21/04
asel,,,928,,,1
egen,2,100000,all,,,,,4,,,0,0,0
modm,nocheck
alls
emod,15784,-1,114183,104465
,15955,-3,104465,114183
,28878,-3,104465,114183
acle,928
real,62
type,60
mat,62
asel,,,928,,,1
esln
esel,r,type,,12
csurf
type,61
esel,type,,23
,r,real,,45
nsle

```

esurf
dsym,symm,y,5
alls

**** AP modifications 8/9/04
**** Thickness from set_parms.mac
!* r50=1-.06 !shell thickness (in) (R1 of Figure 11 in
RPP-13990)
!* r51=3/8-.06 !shell thickness (in) (R2,R6,R7,R9 of
Figure 11 in RPP-13990)
!* r52=7/8-.06 !shell thickness (in) (R3 of Figure 11 in
RPP-13990)
!* r53=3/4-.06 !shell thickness (in) (R4 of Figure 11 in
RPP-13990)
!* r54=1/2-.06 !shell thickness (in) (R5,R8 of Figure 11 in
RPP-13990)
!* r55=1/4 !shell thickness (in) (R10 of Figure 11 in RPP-
13990)
!* r56=3/8 !shell thickness (in) of secondary liner above
357.5 in

**** Additional liner thickness
r,57,9/16-.06
,58,15/16-.06
**** Redefine secondary liner thickness
r,55,3/8
,56,1/2
,59,9/16

**** Primary liner
csys
esel,,real,,51
nsle

nsel,r,loc,y,380,468.5
esln,,1
esel,r,real,,51
emod,all,real,54
esel,,real,,54
nsle
nsel,r,loc,y,142,238
esln,,1
esel,r,real,,54
emod,all,real,57
esel,,real,,52
nsle
nsel,r,loc,y,,12
,r,loc,x,-450,-437
esln,,1
esel,r,real,,52
emod,all,real,58
esel,,real,,51
nsle
nsel,r,loc,y,-1,1
esln,,1
esel,r,real,,51
emod,all,real,54
**** Secondary liner
esel,,real,,55,56
nsle
nsel,r,loc,y,24,460
esln,,1
esel,r,real,,55,56
emod,all,real,55
esel,,real,,55
nsle
nsel,r,loc,y,3.875,24


```

esln,,1
esel,r,real,,55
emod,all,real,56
esel,,real,,55
nsle
nsl,r,loc,y,-9,3.875
,r,loc,x,-480,-467
esln,,1
esel,r,real,,55
emod,all,real,59
esel,,real,,55
nsle
nsl,r,loc,x,-468,-420
esln,,1
esel,r,real,,55
emod,all,real,56

```

```

****
**** Temperatures
**** Uniform 50F (4/17/03)
****
tref,50
tnif,50

finish
/filnam,set_slice_0
/sol
!solcontrol,off
neqit,50
time,1
nlgeom,on
nrop,unsym

```

```

cnvt,f,,005,0      !6/16/04
,m,,.005,0        !6/16/04
crpl,.05
nsub,10,100,5
!delt,.1,.01,.2
!outres,all,all
!ntre,on,250
eqsl,sparse,.05,-1
hcs0,mmd
allsel
save
solve

```

```

time,2
****
**** Add waste and pressure loads
****
pres_surf=0      !ground surface uniform pressure psf
point_cent=0     !point load at center lb
pres_annulus=-20 !annulus pressure inches h2o
pres_int=-12     !annulus internal pressure inches
h2o
hwaste=422       !total waste height
height_waste1=hwaste/3 !height of waste 1 inches
gamma_waste1=1.83 !specific gravity of waste 1
height_waste2=hwaste/3 !height of waste 2 inches
gamma_waste2=1.83 !specific gravity of waste 2
height_waste3=hwaste/3 !height of waste 3 inches
gamma_waste3=1.83 !specific gravity of waste 3

/inp,apply_loads_slice,mac

delt,.1,.01,.25

```

```

solv

time,3
****
**** Add surface loads
****

pres_surf=40                !ground surface
uniform pressure psf
point_cent=200000           !point load at center
lb
pres_annulus=-20            !annulus pressure
inches h2o
pres_int=-12                !annulus internal
pressure inches h2o
hwaste=422                  !total waste height
height_waste1=hwaste/3      !height of waste 1
inches
gamma_waste1=1.83           !specific gravity of
waste 1
height_waste2=hwaste/3      !height of waste 2
inches
gamma_waste2=1.83           !specific gravity of
waste 2
height_waste3=hwaste/3      !height of waste 3
inches
gamma_waste3=1.83           !specific gravity of
waste 3

/inp,apply_loads_slice,mac

save
solv

```

Input file: apply_loads_slice.mac

```

****
**** Eliminate in-plane pressure 2nd liner
**** Add pressure 1st liner @ connection
**** 12/4/03
****

allsel
sfdele,all,all
sfedele,all,all,all
sfgrad,pres
fdele,all,all
esel,s,type,,59
edele,all

!40 psf pressure on ground surface
****
**** No pressure - Phase II, Load Case S5
csys,0
*get,ymx,kp,,mxloc,y
asel,s,loc,y,ymx
lsla
nsla,,1
esel,all
sf,all,pres,pres_surf/144

!200K point load at center
****
**** No concentrated load - Phase II, Load Case S5
csys,22
nset,r,loc,x,0,clr
*get,nnode,node,,count
f,all,fz,-point_cent/nnode*swp_th/360

```

```
!liner pressure loads
p_annulus=pres_annulus/12*62.4/144
p_internal=pres_int/12*62.4/144
```

```
!waste depth and unit weight
hw1=height_waste1
gammaw1=gamma_waste1
hw2=height_waste2
gammaw2=gamma_waste2
hw3=height_waste3
gammaw3=gamma_waste3
```

```
*if,abs(gammaw1),lt,1e-3,then
  gammaw1=1e-6
*else
  gammaw1=gammaw1*62.4/1728
*endif
*if,abs(gammaw2),lt,1e-3,then
  gammaw2=1e-6
*else
  gammaw2=gammaw2*62.4/1728
*endif
*if,abs(gammaw3),lt,1e-3,then
  gammaw3=1e-6
*else
  gammaw3=gammaw3*62.4/1728
*endif
```

```
zz4=0
zz3=hw1
zz2=zz3+hw2
zz1=zz2+hw3
```

```
zz0=460
pp0=p_internal
pp1=p_internal-p_annulus
pp2=pp1+hw3*gammaw3
pp3=pp2+hw2*gammaw2
pp4=pp3+hw1*gammaw1
```

```
allsel
```

```
!primary liner
esel,s,real,,50,54
nsle
cm,nliner,node
```

```
!top reaches of dome
allsel
csys,0
cmsel,s,nliner
nsel,r,loc,y,zz0-.03,9999
sfgrad,pres
sf,all,pres,pp0
```

```
!space between top of fluid and prim/secon liner intersection
cmsel,s,nliner
nsel,r,loc,y,zz1,zz0
sf,all,pres,pp1
```

```
!waste region 3
cmsel,s,nliner
nsel,r,loc,y,zz2,zz1
esln
esel,r,type,,1
nsle,,1
```

```
sfgrad,pres,0,y,zz1,(pp1-pp2)/hw3
sf,all,pres,pp1
```

```
!waste region 2
cmsel,s,nliner
nsl,r,loc,y,zz3,zz2
esln
esel,r,type,,1
nsle,,1
sfgrad,pres,0,y,zz2,(pp2-pp3)/hw2
sf,all,pres,pp2
```

```
!waste region 1
cmsel,s,nliner
nsl,r,loc,y,zz4,zz3
esln
esel,r,type,,1
nsle,,1
sfgrad,pres,0,y,zz3,(pp3-pp4)/hw1
sf,all,pres,pp3
```

```
!annulus
esel,s,type,,1
nsle,,1
cmsel,u,nliner
nsl,u,loc,y,-9999,-8.124
esln
esel,r,type,,1
nsle,,1
cm,nsecon,node
esln
esel,r,real,,55,56
sfgrad,pres
```

```
sf,all,pres,p_annulus
```

```
alls
```

Input file: mesh_size.mac

```
eesize=3.2           !default element size for
rebar [in]
soil_size=14         !default element size for soil
elements [in]
swp_th=24/(2*pi*480)*360 !single element sweep angle
[deg]
num_div=6            !number of divisions per
quadrant
```

Input file: PNNLA.mac

```
set_parms
/prep7
! 3/28/03
! DST - AY

*afun,deg

k,1,0,h6
k,2,0,h5
k,3,0,0
k,4,-ir2,0
k,5,ir2,h3+36+6+13/16
k,6,-r1*sin(th1),h6-r1+r1*cos(th1) !Intersection of exterior
dome radii
larc,6,1,3,r1           !Exterior dome radius - center

rectng,-ir2,0,h2,h1
rectng,-or,-ir,h2,h3    !Wall to tangent point
```

rectng,-or,-ir,h3,h4

lare,18,6,3,r2

!Exterior dome radius - outer

local,11,1,0,h3,0,,,,3/8

l,13,2

!Interior dome ellipse

csys,0

l,1,2

k,19,-ir2,0

k,20,-ir2,h4+5

l,19,20

lcsl,15,17

lfil,18,20,r3

!Radius primary tank to

dome

csys,11

l,21,22

nummrg,kp

csys,0

lfil,20,4,12

!Corner radius primary tank

floor

l,7,12

lfil,23,7,12

!Corner radius secondary

tank floor

wpcs,-1

wpro,,,90

wpof,,,icr

asbw,1

!Insulating concrete

al,8,19,17,18,16,1,14,13 !Haunch & dome concrete

adel,3,4

alls

numc,all

!Tank Foundation

*get,ik,kp,,num,max

k,ik+1,0,h2-24

k,ik+2,-36,h2-24

k,ik+3,-76,h2-10.5

k,ik+4,-29*12-1,h2-10.5

k,ik+5,-36*12-9,ky(ik+4)-11.5

k,ik+6,-44*12-3,ky(ik+5)

k,ik+7,kx(ik+6),ky(ik+6)+12+11.5

k,ik+8,-or-1,ky(ik+7)

k,ik+9,kx(ik+8),ky(ik+8)-1.5

k,ik+10,-or,ky(ik+9)

k,ik+11,-ir,ky(ik+9)

k,ik+12,-ir+1,ky(ik+9)

a,ik+1,ik+2,ik+3,ik+4,ik+5,ik+6,ik+7,ik+8,ik+9,ik+10,ik+11,
ik+12,8

!Dome & wall rebar

!Outer rebar

k,37,kx(11)+covext,ky(11)

!Outer edge wall outer

rebar - bottom

k,38,kx(37)+1,ky(37)

!Inner edge wall outer rebar -

bottom

k,39,kx(18)+covext,ky(18)-.707

!Outer edge wall outer

rebar - top

k,40,kx(39)+1,ky(39)-.707

!Inner edge wall outer

rebar - top

k,41,kx(6),ky(6)-covext

!Outer dome rebar radius

intersection

```

k,42,kx(41),ky(41)-1      !Outer dome rebar radius
intersection
k,43,kx(1),ky(1)-covext    !Outer dome rebar -
centerline outer
k,44,kx(1),ky(43)-1        !Outer dome rebar - centerline
inner
larc,39,41,3,r2-covext     !Outer edge of outer rebar,
outer radius
larc,41,43,3,r1-covext     !Outer edge of outer rebar,
center radius
larc,40,42,3,r2-covext-1   !Inner edge of outer rebar,
outer radius
larc,42,44,3,r1-covext-1   !Inner edge of outer rebar,
center radius
a,37,38,40,42,44,43,41,39  !Dome outer rebar

!Dome & wall rebar
!Inner rebar
k,45,kx(12)-covint1,ky(12)
,46,kx(45)-1,ky(45)
,47,kx(13)-covint1,ky(13)
,48,kx(47)-1,ky(47)
,55,0,ky(2)+covint2
,56,0,ky(55)+1
loca,12,1,,h3,,,(30*12+1.5)/(80*12+1.5)
k,49,ir+1.72,164
,53,ir+2.21,144
1,53,55
loca,13,1,,h3,,,(30*12+2.5)/(80*12+2.5)
k,50,ir+2.86,163.9
,54,ir+3.68,143.85
1,54,56
loca,14,1,,h3,,,(30*12+4)/(80*12+4)

```

```

k,51,ir+5.2,154.8          !Want 4" cover & 7-1/2"
from tangent
loca,15,1,,h3,,,(30*12+5.5)/(80*12+5.5)
k,52,ir+6.4,154.65
csys,0
1,45,47
,46,48
csys,11
a,45,47,49,51,53,55,56,54,52,50,48,46
csys,0

!Foundation rebar
covtop=3.5
covbot=3
ssli=(ky(27)-ky(26))/(kx(27)-kx(26))
sslo=(ky(28)-ky(29))/(kx(28)-kx(29))
k,60,kx(30)+3,ky(30)+covbot
k,61,kx(60),ky(60)+1
k,62,kx(31)+3,ky(8)-covtop
k,63,kx(62),ky(62)-1
k,64,0,ky(8)-covtop
k,65,0,ky(64)-1
k,74,0,ky(25)+covbot+1
k,75,0,ky(25)+covbot
k,66,kx(26)-ssli*covbot,ky(26)+covbot
k,67,kx(66)-ssli,ky(66)+1
k,68,kx(27)-ssli*covbot,ky(27)+covbot
k,69,kx(68)-ssli,ky(68)+1
k,70,kx(28)-sslo*covbot,ky(28)+covbot
k,71,kx(70)-sslo,ky(70)+1
k,72,kx(29)-sslo*covbot,ky(29)+covbot
k,73,kx(72)-sslo,ky(72)+1
a,60,61,73,71,69,67,74,75,66,68,70,72

```


a,62,64,65,63

!Haunch mid section rebar

k,80,kx(14)+11+.5,ky(14)+36

k,81,kx(80),ky(40)

k,82,kx(80),.5*(ky(80)+ky(81))

k,83,kx(14)+72,ky(14)+98

k,84,kx(14)+103,ky(14)+113

k,85,kx(84),ky(84)+1

k,86,kx(83),ky(83)+1

k,87,kx(82),ky(82)+1

k,88,kx(81)-1,ky(81)

k,89,kx(80)-1,ky(80)

a,80,82,87,81,88,89

a,82,83,84,85,86,87

ldiv,13,.34

csys,0

wpcs,-1

kwpa,57

wpro,-90

wpro,,60

asel,,,1

asbw,all

wpcs,-1

kwpa,14

wpof,,12

wpro,-90

asbw,all

allsel

aovlap,all

!divide bottom slab rebar at radial locations

*dim,bsr,,4

dl5=27.4

bsr(1)=(7+7.5)/2*12+dl5,(14+15)/2*12+dl5,31*12+6-9,435

asel,s,,,7

csys,0

wpcs,-1

wpro,-90

*do,i,1,4

wpoff,,,bsr(i)

asbw,all

wpoff,,,bsr(i)

*enddo

wpcs,-1

wpoff,kx(68),ky(68)

wpro,-90

wpro,,atan(ssli)

asbw,2

wpcs,-1

wpoff,kx(70),ky(70)

wpro,-90

wpro,,atan(sslo)

asbw,1

wpcs,-1

wpoff,kx(72),ky(72)

wpro,-90

wpro,,atan(sslo)

asbw,7

!divide top slab rebar at radial locations

*dim,tsr,,7

tsr(1)=kx(69),kx(35),kx(98),kx(71),kx(100),kx(102),kx(73)

```

asel,s,,,8
csys,0
wpcsys,-1
wprot,,,90
*do,i,1,7
wpoff,,,tsr(i)
asbw,all
wpoff,,, -tsr(i)
*enddo

```

```

!divide wall rebar
*dim,wr,,4
wr(1)=10*12+19+h2,17*12,23*12+19+h2,h3-42
asel,s,,,15,16
csys,0
wpcsys,-1
wprot,,, -90
kwpave,3
*do,i,1,4
wpoff,,,wr(i)
asbw,all
wpoff,,, -wr(i)
*enddo

```

```

!divide dome rebar
*dim,dr,,7
dl6=32.9
dr(1)=7*12+3+dl6,12*12+6+dl6,22*12+6,(24+26.75)/2*12,2
6*12+2,29*12+6,28*12+dl6,
asel,s,,,18,28,10
csys,0
wpcsys,-1
wpro,,, -90

```

```

kwpa,3
jdcr=h6-3-95*12
*do,i,1,7
wpof,,jdcr+95*12*cos(asin(dr(i)/(95*12))),dr(i)
wpro,,,asin(dr(i)/(95*12))
asbw,all
wpro,,, -asin(dr(i)/(95*12))
wpof,,, -(jdcr+95*12*cos(asin(dr(i)/(95*12)))), -dr(i)
*enddo

```

```

!divide bent bar, top of haunch
wpcsys,-1
kwpave,17
wpoff,48*cos(30)
wprot,,, -90
asel,s,,,29
asbw,all
allsel
1,40,39
asbl,28,127

```

```

allsel
nummrg,all
numcmp,all

```

```

!J-bolts
! 32-35 are tank wall stiffeners
*dim,jx,,35
*dim,jy,,35
*dim,jdeg,,35
jx(1)=479,479,479,479,479,479,479,479,479,479
jx(11)=479,479,479,479,479,479,479,479,479,479
jx(21)=412,391,369,347,324,299,272,241,206,165

```

```

jx(31)=107,479,479,479,479
jy(1)=19,43,67,91,115,139,163,187,211,235
jy(11)=259,283,307,331,355,379,402,424,442,460
jy(21)=474,486,496,504,511,515,518,522,525,527
jy(31)=529,89.5,89.5*2,89.5*3,89.5*4
jdeg(1)=90,90,90,90,90,90,90,90,90,90
jdeg(11)=90,90,90,90,90,90,75,55,45,40
jdeg(21)=35,30,25,20,15,10,9,8,7,6,5
jdeg(31)=1,90,90,90,90

```

```

csys
asel,,,24,29,5
,a,,,42,46,4
,a,,,14,16,2
,a,,,19,21,2
,a,,,30,51,21
,a,,,45,49,2
,a,,,50,56,2
,a,,,60,62,2

```

```

*do,i,1,35
wpcsys,-1
wpave,-jx(i),jy(i)
wprot,jdeg(i)
wprot,,,90
asbw,all
*enddo

```

```

!bottom anchors
lanch=5+3/16
ldiv,228,,14
kgen,2,38,,,0,lanch,0
a,12,268,269,38

```

```

allsel
aovlap,all

```

```

!flange of wall stiffeners - 6"
lsel,,,175,246,71
,a,,,266,303,37
*do,i,32,35
wpcsys,-1
wpave,-jx(i),jy(i)
wprot,jdeg(i)
wprot,,,90
wpoff,,,6
lsbw,all
*enddo
lsel,all

```

```

! dome stiffener (detail 9)
lang,16,51,90,.8
lsel,,,414
lsum
lsel,all
*get,stang,line,,jxv,x
wpc,-1
kwpa,51
wpro,,,90
wpro,,acos(stang)
wpof,,,6
lsbw,324
asbl,106,414

```

```

! line for concentrated load
wpc,-1
kwpa,1

```

wpro,,,90
wpof,,,clr
lsbw,1

!Identify areas
!inside layer of rebar
asel,,loc,x,-485,-484
,u,,,33,34
,a,,,21,91,70
,a,,,30,100,70
,a,,,104,105
,a,,,102,110,8
,a,,,107,111,4
,a,,,19,62,43
,a,,,51,60,9
,a,,,112,116,2
,a,,,118,120,2
,a,,,50,56,2
,a,,,122,127,5
,a,,,47
cm,as1,area

!outside layer of rebar
asel,,loc,x,-496,-495
,a,,,18,64,46
,a,,,57,59
,a,,,61,63,2
,a,,,53,55,2
,a,,,28,43,15
cm,as2,area

!bottom layer of slab
asel,,,1,2

,a,,,4,6
,a,,,11,13,2
,a,,,33
cm,as3,area

!top layer of slab
asel,,loc,y,-13,-11
cm,as4,area

!haunch
asel,s,,,32
cm,haunch,area

!concrete insulation
asel,s,,,3
cm,cinsul,area

!slab
asel,s,,,31
cm,slab,area

!haunch vertical steel
asel,s,,,9
cm,hvert,area

!haunch radial
asel,s,,,10
cm,hrad,area

!concrete
allsel
cmsel,u,hrad
cmsel,u,hvert

```

cm,sel,u,slab
cm,sel,u,cinsul
cm,sel,u,haunch
cm,sel,u,as4
cm,sel,u,as3
cm,sel,u,as2
cm,sel,u,as1
cm,conc,area

allsel
save,pnnla,db

```

Input file: PNNLA2.mac

```

mat_liner=1
mat_conc=2
mat_rebar=3
mat_insul=4
mat_soil=5
mat_haunch=6

```

```

type_liner=1      !liner shells
type_tank=2       !tank concrete
type_haunch=3     !haunch concrete
type_slab=4       !slab concrete
type_rebar=5      !rebar
type_insul=6      !insulating concrete
type_soil=7       !soil

```

```

et,type_liner,181
et,type_tank,181
et,type_haunch,181
et,type_slab,181
et,type_rebar,181

```

```

et,type_insul,181
et,type_soil,181

```

```

et,type_liner+10,65
et,type_tank+10,65
et,type_haunch+10,65
et,type_slab+10,65
et,type_rebar+10,65
et,type_insul+10,65
et,type_soil+10,45

```

!define local element coordinate systems for rebar regions

```

cm,sel,s,as1
cm,sel,a,as2
cm,sel,a,as3
cm,sel,a,as4
cm,sel,a,hvad
cm,sel,a,hvrt
*get,narea,area,,count
cm,atemp,area

```

```

*afun,deg
ics=100
*do,i,1,narea
  *get,ia,area,,num,min
  asel,s,,,ia
  !sla
  !sll
  csys,0
  *get,minx,kp,,mnloc,x
  *get,maxx,kp,,mxloc,x
  *get,miny,kp,,mnloc,y
  *get,maxy,kp,,mxloc,y

```

```

theta=90
*if,minx,ne,maxx,then
    theta=atan((maxy-miny)/(maxx-minx))
*endif
wpcsys,-1
kwpave,all
wprot,theta
cswplan,ics,0
aatt,mat_rebar,,type_rebar,ics
cmsel,s,atemp
asel,u,,,ia
cm,atemp,area
ics=ics+1
*enddo

```

```

!define spherical coordinate system for haunch, with center at
global origin
csys,0
wpcsys,-1
local,ics,2
asel,s,,,32
aatt,mat_conc,604,type_haunch,ics

```

```

!set real constants for rebar
csys,0
wpcsys,-1
!wall external
set_ry,-8,131,201,'as2'
set_ry,131,204,202,'as2'
set_ry,204,287,203,'as2'
set_ry,287,339,204,'as2'
set_ry,339,382,205,'as2'

```

```

!wall internal
csys,0
wpcsys,-1
set_ry,-8,131,206,'as1'
set_ry,131,204,207,'as1'
set_ry,204,287,208,'as1'
set_ry,287,339,209,'as1'
set_ry,339,382,210,'as1'

```

```

!slab bottom
csys,0
wpcsys,-1
set_rx,-75,0,101,'as3'
set_rx,-115,-75,102,'as3'
set_rx,-202,-115,103,'as3'
set_rx,-350,-202,104,'as3'
set_rx,-369,-350,105,'as3'
set_rx,-435,-369,106,'as3'
set_rx,-442,-435,107,'as3'
set_rx,-531,-442,108,'as3'

```

```

!slab top
csys,0
wpcsys,-1
set_rx,-75,0,111,'as4'
set_rx,-115,-75,112,'as4'
set_rx,-202,-115,113,'as4'
set_rx,-350,-202,114,'as4'
set_rx,-369,-350,115,'as4'
set_rx,-435,-369,116,'as4'
set_rx,-442,-435,117,'as4'
set_rx,-531,-442,118,'as4'

```



```
!dome external
csys,0
wpcsys,-1
set_rx,-120,0,301,'as2'
set_rx,-183,-120,302,'as2'
set_rx,-270,-183,303,'as2'
set_rx,-305,-270,304,'as2'
set_rx,-314,-305,305,'as2'
set_rx,-354,-314,306,'as2'
set_rx,-369,-354,307,'as2'
set_rx,-400,-369,308,'as2'
```

```
!dome internal
csys,0
wpcsys,-1
set_rx,-120,0,301,'as1'
set_rx,-183,-120,302,'as1'
set_rx,-270,-183,303,'as1'
set_rx,-305,-270,304,'as1'
set_rx,-314,-305,305,'as1'
set_rx,-354,-314,306,'as1'
set_rx,-369,-354,307,'as1'
set_rx,-400,-369,308,'as1'
```

```
!haunch external
csys,5
wpcsys,-1
cmse,s,as2
asel,r,loc,x,396,450
set_real,401
cmse,s,as2
asel,r,loc,x,450,504
,r,loc,z,381,999
```

```
set_real,402
cmse,s,as2
asel,r,loc,z,408,450
set_real,403
cmse,s,as2
asel,r,loc,z,372,410      !Problem??
set_real,404
```

```
!haunch internal
cmse,,as1
set_ry,381,408,405,'as1'
set_ry,408,488,406,'as1'
```

```
! Split haunch vertical at top of radial intersection
lsl,all
ksl,all
asel,s,,,9
ldiv,82,,47
1,278,87
*get,ics,area,9,attr,esys
asbl,9,418
cm,hvert,area
aatt,mat_rebar,,type_rebar,ics
```

```
!haunch middle (vertical)
asel,,,67
set_real,500      !Lower
asel,,,65
set_real,501      !Upper
!haunch middle (radial)
asel,s,,,10
set_real,502
```

```
!insulating concrete
asel,s,,,3
aatt,mat_insul,600,type_insul,0

!haunch concrete
asel,s,,,32
aatt,mat_haunch,503,type_haunch,ics
```

```
allsel
asel,u,mat,,mat_insul
asel,u,mat,,mat_rebar
asel,u,mat,,mat_haunch
aatt,mat_conc,700,type_tank,0
cm,atemp,area
asel,r,loc,y,-999,-8.125
aatt,mat_conc,700,type_slab,0
cmsel,s,atemp
asel,u,type,,type_slab
aatt,mat_conc,700,type_tank,0
```

```
asel,s,,,27      Outer cover haunch
l,39,18
asbl,27,419
aatt,mat_conc,700,type_tank,0
```

```
allsel
save,pnnla2,db
```

Input file: PNNLA3.mac

```
!identify jbolt lines
!*** Remove jbolts from wall 5/6/04
lsel,,,315,322,7
,a,,,318,327,9
```

```
,a,,,92,332,240
,a,,,326,337,11
,a,,,335,342,7
,a,,,209,349,140
,a,,,345,375,5
,a,,,354,379,5
,a,,,382
cm,line_bolt,line
```

```
lsel,,,229,389,160
,a,,,310,394,84
,a,,,399,407,8
,a,,,287,288
,a,,,413
cm,line_wstiff,line
```

```
lsel,,,414,415
cm,line_hstiff,line
```

```
lsel,,,3,9,6
,a,,,14,19,5
,a,,,330
,a,,,58,59
,a,,,339,341,2
,a,,,348,373,5
,a,,,380,381
,a,,,385
cm,line_prim,line
```

```
ksel,,loc,x,-480
,r,loc,y,,382
lslk,,1
lsel,a,,,16,17
```

```
,a,,,21,22
,a,,,25,27,2
,a,,,314,323,9
,a,,,96
,a,,,291,303,12
cm,line_secon,line
```

```
lsel,s,,,309
,a,,,406
cm,line_botanch,line
```

```
allsel
```

```
save,pnnla3,db
```

Input file: PNNLA4.mac

```
!copy areas for overlapping with soil
cm,a_orig,area
agen,2,all
cmsel,u,a_orig
cm,a_new,area
```

```
csys,0
ksel,s,loc,s,0
cm,ktemp,kp
*get,ymx,kp,,mxloc,y
*get,ymn,kp,,mnloc,y
ksel,r,loc,y,ymx
*get,iktop,kp,,num,min
cmsel,s,ktemp
ksel,r,loc,y,ymn
*get,ikbot,kp,,num,min
```

```
htop=12
radsoil=550
depthsoil=60
csys,0
wpcsys,-1
asel,none
rectng,-radsoil,0,ymn-depthsoil,ymx+htop
cm,as0,area
allsel
asba,as0,a_new
asel,s,,,283
adele,all,,,1
asel,s,,,282
cm,soil,area
aatt,mat_soil,1,type_soil
```

```
/input,mesh_size,mac
```

```
!***
!*** Clean up mesh 4/1/03
!***
```

```
lesl,385,,,20
,380,,,14
,89,,,76
,339,,,4
,246,,,1
,129,,,19
,175,,,3
,177,,,1
,178,,,1
,171,,,2
```

```
,172,,,2
,34,,,9
asel,s,type,,type_rebar
esize,eesize
amesh,all
acle,10
amap,10,82,84,85,87
asel,invert
asel,u,type,,type_soil
esize,eesize
amesh,all
asel,s,type,,type_soil
asel,a,mat,,mat_conc
lsla
ksll
nummrg,kp
```

```
asel,s,mat,,mat_soil
smrsize,8
lsel,s,,,832          !vertical line above dome center
lesize,all,,,4
lsel,s,,,833          !vertical line below dome center
lesize,all,,,8
esize,soil_size !20
amesh,all
```

```
extopt,esize,1
type,17
vrotat,all,,,,,ikbot,iktop,swp_th,1
```

```
asel,s,type,,type_slab
asel,a,type,,type_insul
cm,atemp,area
```

```
agen,2,all
cm,aaa,area
cmsel,s,atemp
aclear,all
adele,all,,,1
```

```
allsel
aslv,u
*get,na,area,,count
cm,atemp,area
*do,i,1,na
*get,ia,area,,num,min
asel,s,,,ia
*get,imat,area,ia,attr,mat
*get,ireal,area,ia,attr,real
*get,itype,area,ia,attr,type
*get,isis,area,ia,attr,esys
mat,imat
real,ireal
type,itype+10
esys,isis
ksel,all
vrotat,ia,,,,,ikbot,iktop,swp_th,1
cmsel,s,atemp
asel,u,,,ia
cm,atemp,area
*enddo
```

```
allsel
aclear,all
save,pnnla4,db
```

Input file: PNNLA5.mac

```

vsel,s,mat,,1
cm,vtemp,volu
vgen,2,all
cm,vvv,volu
cmsel,s,vtemp
vclear,all
vdelete,all,,1
cmsel,s,vvv
eslv
emodif,all,mat,mat_soil

```

!rotate all nodes to cylindrical coordinate system (22)

```

csys,0
wpcsys,-1
wprot,, -90
cswplan,22,1
allsel
nrotate,all

```

```

csys,0
!merge slab/rebar nodes/kps
vsel,s,type,,type_rebar+10
vsel,r,loc,y,-999,-11
vsel,a,type,,type_slab+10
vsel,u,mat,,1
eslv
nsle
aslv
lsla
ksll
nummrg,node
nummrg,kp

```

```

!merge tank/rebar nodes/kps
vsel,s,type,,type_rebar+10
vsel,r,loc,y,-8,999
vsel,a,type,,type_tank+10
vsel,a,type,,type_haunch+10
vsel,u,mat,,1
aslv
lsla
ksll
nsla,,1
nummrg,node
nummrg,kp

```

!couple soil to concrete exterior

```

esel,s,mat,,mat_soil
nsle
ksln
lslk,,1
asll,,1
cm,asoil,area
vsel,s,type,,type_tank+10
aslv
asel,r,ex1
cm,atank,area
vsel,s,type,,type_slab+10
aslv
asel,r,ex1
cm,aslab,area
vsel,s,type,,type_insul+10
aslv
cm,ainsul,area

```

!top of dome

```

csys,0
cmisel,s,atank
cmisel,a,asoil
asel,r,loc,y,452,999
!sla
nsla,,1
cpintf,uz,.1

!side of tank
cmisel,s,atank
cmisel,a,asoil
asel,r,loc,y,-8.125,452
!sla
nsla,,1
cpintf,ux,.1

!top of slab
cmisel,s,aslab
cmisel,a,asoil
asel,r,loc,y,-6.7,-6.6
!sla
nsla,,1
cpintf,uz,.1

!side of slab
cmisel,s,aslab
cmisel,a,asoil
asel,r,loc,y,-31,-6.7
asel,r,loc,x,-999,-529
!sla
nsla,,1
cpintf,ux,.1

```

```

!bottom of slab
cmisel,s,aslab
cmisel,a,asoil
asel,r,loc,x,-530,0
asel,r,loc,y,-999,-18.5
!sla
nsla,,1
cpintf,uz,.1

```

```

!couple top of slab / bottom of wall
cmisel,s,aslab
cmisel,a,atank
!sla
nsla,,1
cpintf,uz,.1

```

```

!couple top of slab / bottom of insulating concrete
vsel,s,mat,,mat_insul
cm,vtemp,volu
vgen,2,all
cm,volu_insul,volu
cmisel,s,vtemp
veclear,all
vdelete,all,,1
cmisel,s,volu_insul
aslv
cm,ainsul,area
cmisel,s,aslab
cmisel,a,ainsul
!sla
nsla,,1
cpintf,uz,.1

```


save,pnnla5.db

Input file: PNNLA6.mac

!*** mesh J-bolt @ liner w/separate node 5/6/04

!*** Use mesh200 for J-bolts 4/1/04

!*** redefine as beam188 in set_slicea.mac

resu,pnnla5.db

!generate J-bolts

type_bolt=20

et,type_bolt,200,2

mat,mat_liner

type,type_bolt

csys,0

cmse1,s,line_bolt

csys,11

lsl,r,loc,x,480,483

lgen,2,all,,,,,3000

ksll

ksel,r,loc,x,481,486

numm,kp

cmse,,line_bolt

lsl,u,loc,x,480,483

,a,,,423,435

lmesh,all

csys

!generate studs

type_stud=21

et,type_stud,4

area_stud=pi*.5**2/4

iy=pi*.5**4/64

iz=iy

ty=.5

tz=.5

r,30,area_stud,iy,iz,ty,tz

cmse1,s,line_botanch

real,30

mat,mat_liner

type,type_stud

lmesh,all

!generate wall base plate

asel,s,,,214

,a,,,706

,a,,,913,918,5

,a,,,934

cm,baseplate,area

type_baseplate=22

et,type_baseplate,63

r,40,.375

mat,mat_liner

type,type_baseplate

real,40

amesh,all

!generate confining ring below 12" secondary liner fillet

ksel,s,loc,x,-480-.01,-480+.01

ksel,r,loc,y,-8.2,6.9

ls1k,,1

asll

asel,u,loc,z,0

cm,confineplate,area

type_confine=23

et,type_confine,63

r,41,3/16

```

type,type_confine
real,41
mat,mat_liner
amesh,all

```

```

!generate confining ring for insulating concrete
csys,0
ksel,s,loc,x,-447
lslk,,1
asll,,1
cm,confinering,area
type_confine=23
type,type_confine
real,41
mat,mat_liner
amesh,all

```

```

!generate construction stiffeners
cmsel,s,line_wstiff
asll
asel,u,loc,z,0
cm,stiff_area,area
type_stiff=24
et,type_stiff,63
type,type_stiff
r,42,,5
real,42
mat,mat_line
amesh,all

```

```

!generate detail #9
cmse,,line_hstiff
asll

```

```

asel,u,loc,z,0
cm,detail9,area
type_anchor=25
et,type_anchor,63
type,type_anchor
r,43,,375*1.1
real,43
mat,mat_liner
amesh,all

```

```

allsel
save,pnnla6,db

```

Input file: PNNLA7.mac

```

!primary liner
allsel
aslv
lsla
cmsel,s,line_prim
lsel,a,,,34
cm,ltemp,line

asll
asel,u,loc,z,0
ksll
nummrg,kp
cm,line_prim,line
cm,area_prim,area
! Reverse normals - dome
asel,r,loc,y,459,999
arev,all
asel,none
ksel,s,loc,x,0

```

```

ksel,r,loc,y,ymx
*get,iktop,kp,,num,min
ksel,s,loc,x,0
ksel,r,loc,y,ymn
*get,ikbot,kp,,num,min
ksel,all
cmsel,s,ltemp
cmsel,s,area_prim
lsla,u
arotat,all,,,,,ikbot,iktop,swp_th,1
lsla
ksll
nummrg,kp
aatt,mat_liner,,type_liner
esize,4
smrt,off
lsl,s,,,9,436,427!radiusd part of primary liner
lesi,all,,,8,,1
lsl,s,,,440,441
lesize,all,,,1,,1
amesh,all

cm,atemp,area
agen,2,all
cm,area_liner_prim,area
cmsel,s,atemp
aclear,all
vsel,all
aslv,u
adele,all,,,1

r,50,r50
r,51,r51

```

```

r,52,r52
r,53,r53
r,54,r54
r,55,r55

```

```

!1" lid at tank bottom
cmsel,s,area_liner_prim
esla
cm,etemp,elem
nsla,,1
cm,ntemp,node
nsel,r,loc,x,-24,0
nsel,r,loc,y,-999,10
esln
cmsel,r,etemp
emodif,all,real,50

```

```

!3/8" bottom (on top of insulating concrete)
cmsel,s,ntemp
nsel,r,loc,x,-450+48,-24
nsel,r,loc,y,-999,10
esln
cmsel,r,etemp
emodif,all,real,51

```

```

!7/8" at fillet
cmsel,s,ntemp
nsel,r,loc,x,-450,-450+48
nsel,r,loc,y,-999,36.89
esln
cmsel,r,etemp
emodif,all,real,52

```

```
!3/4" vertical run
cmisel,s,ntemp
nsel,r,loc,x,-450
nsel,r,loc,y,36.88,144.89
esln
cmisel,r,etemp
emodif,all,real,53
```

```
!1/2" vertical run
cmisel,s,ntemp
nsel,r,loc,x,-450
nsel,r,loc,y,144.88,381.5
esln
cmisel,r,etemp
emodif,all,real,54
```

```
!3/8" upper reaches of liner
cmisel,s,ntemp
nsel,r,loc,x,-450,-72.1
nsel,r,loc,y,381.6,999
esln
cmisel,r,etemp
emodif,all,real,51
```

```
!1/2" at top/center
cmisel,s,ntemp
nsel,r,loc,x,-72,0
nsel,r,loc,y,381.6,999
esln
cmisel,r,etemp
emodif,all,real,54
```

```
!couple vertical displacements at liner bottom
```

```
!(first rotate the shell nodes)
esel,s,type,,type_liner
nsle
csys,22
nrotate,all
csys,0
asel,s,loc,y,0
nsla,,1
cpintf,uz,.1
cm,liner_insul_cp_z,node

allsel
save,pnnla7.db
```

Input file: PNNLA8.mac

```
!create shell elements for secondary liner
cmisel,s,line_secon
asll
asel,u,loc,z,0
cm,atemp,area
! Reverse normals - upper section
asel,r,loc,y,381,999
arev,all
lsl,,21,22
,a,,25
arotat,all,,,,,ikbot,iktop,swp_th,1
cmisel,a,atemp
asel,a,,27
cm,area_secon,area
lsla
ksll
nummrg,kp
```

```
lesi,437,,1
,438,,1
,9,,6
,22,,6
aatt,mat_liner,55,type_liner
amesh,all
```

```
cm,atemp,area
agen,2,all
cm,area_secon,area
cmsel,s,atemp
aclear,all
aslv,u
adele,all,,1
```

```
kset,s,loc,x,0
kset,r,loc,y,ymx
*get,iktop,kp,,num,min
kset,s,loc,x,0
kset,r,loc,y,ymn
*get,ikbot,kp,,num,min
kset,all
```

```
!couple vertical displacements at liner bottom
!(first rotate the shell nodes)
esel,s,type,,type_liner
nsle
csys,22
nrotate,all
```

```
csys,0
```

```
!couple shell horizontal displacements to sidewall
```

```
esel,s,type,,type_liner
nsle
cm,ntemp,node
esel,s,mat,,mat_conc
nsle
cmsel,a,ntemp
cm,ntemp,node
nsel,r,loc,y,-2,460
cpintf,ux,.1
cm,liner_wall_cp_x,node
```

```
!couple shell vertical displacement to dome
cmsel,s,ntemp
nsel,r,loc,y,460,999
cpintf,uz,.1
cm,liner_dome_cp_z,node
```

```
!merge secondary liner nodes with slab top nodes
asel,,loc,y,-8.125
,r,loc,x,-465,1
!sla
nsl,,1
cpdel,all,all
cpintf,uz,.1
```

```
allsel
save,pnnla8,db
```

Input file: PNNLA9.mac

```
!*** Do not common node intersection of
!*** primary & secondary liner JED 3/19/04
```

```

allsel
mpdelete,all,all
ibdelete,all,all
set_materials
set_options

```

```

acel,0,1,0

```

```

allsel

```

```

!merge coincident nodes between liners and
jbolts/studs/anchors

```

```

esel,s,type,,type_bolt
esel,a,type,,type_stiff
esel,a,type,,type_anchor
esel,a,type,,type_stud
esel,a,type,,type_liner
nsle,,1

```

```

nsel,u,,22789,22790      !*** 3/19/04
nummrg,node

```

```

set_soil

```

```

allsel
ddelete,all,all

```

```

!constrain boundaries

```

```

csys,0
nsel,s,loc,x,0
d,all,ux,0
d,all,uy,0

```

```

allsel

```

```

*get,xmn,node,,mnloc,x
*get,ymn,node,,mnloc,y
*get,ymx,node,,mxloc,y

```

```

nsel,s,loc,y,ymn
d,all,ux,0,,,uy,uz

```

```

ksel,s,loc,x,xmn
ksel,r,loc,z,0
lslk,,1

```

```

asll
asel,u,loc,z,0
nsla,,1
d,all,ux,0
d,all,uy,0
asel,s,loc,y,ymn
nsla,,1
d,all,ux,0,,,uy,uz

```

```

csys,22
nsel,s,loc,y,180-.01,180+.01
nsel,a,loc,y,180+swp_th-.01,180+swp_th+.01
d,all,uy,0
allsel

```

```

save,pnnla9,db

```

Input file: set_areas_slice.mac

```

asel,,,150,161
,a,,,177,179,2
,a,,,184,212,28
,a,,,224,226,2
cm,area_prim,area

```

```

vsel,,,1,199,,1
asel,inve
cmse,u,area_prim
cm,area_secon,area

```

```

cmsel,a,area_prim
nsla,,1
esln
sfdele,all,all
sfedele,all,all,all

```

```

asel,s,,,239
nsla,,1
esln
arev,all

```

```

cmse,,avert
,a,ahorz
cm,asoil,area

```

```

asel,,,314,316
,a,,,700
,a,,,196
,a,,,221,261,40
,a,,,978,984
cm,aconc_soil,area

```

```

asel,s,,,993,994
cm,slab_top,area

```

```

asel,,,929
,a,,,552,563,11

```

```

,a,,,870,876,6
,a,,,583,593,10
,a,,,605,625,20
,a,,,881,887,6
,a,,,636,646,10
,a,,,892,898,6
,a,,,671,677,6
,a,,,651,693,42
,a,,,641,656,15
,a,,,231,238,7
,a,,,710
,a,,,333
,a,,,243,244
,a,,,190,191
,a,,,723,733,10
,a,,,756,762,6
,a,,,784,796,12
,a,,,806,818,12
,a,,,828,839,11
,a,,,853,864,11
,a,,,844
cm,aconc_shell,area

asel,,,106,143,37
cm,area_insul_top,area

asel,s,,,27
cm,area_insul_bot,area

```

Input file: set_backfill.mac

```

!***
!***Dilation angle 8 6/4/04
!*** Add materials for load factor restart 8/2/03

```



```

**** JED mod 4/1/03
**** Define backfill/overburden
****
max_mat=max_mat+1
cmse,,soil_elem
nsle
hsub=top_elev-arg2-h2+24
rsub=-(68*12+hsub/1.5)
nsel,r,loc,y,top_elev-arg1,top_elev-arg2
,r,loc,x,rsub,0
esln
esel,r,mat,,max_mat
emod,all,mat,max_mat+20

soil_ex=arg3          !elastic modulus [psi]
soil_prxy=arg4        !Poisson ratio
soil_alpx=0           !thermal expansion
coefficient [me/F]
soil_cohesion=1       !drucker-prager constant
(assume small number) [psi]
soil_friction=35      !internal friction angle [deg]
soil_dilat=8          !dilatancy angle [deg]

soil_alpx=soil_alpx*1e-6  !in/in/F
soil_dens=b_gam/1728      !lb/in^3

mp,ex,max_mat+20,soil_ex
mp,dens,max_mat+20,soil_dens
mp,prxy,max_mat+20,soil_prxy
mp,alpx,max_mat+20,soil_alpx
tb,dp,max_mat+20
tbdata,1,soil_cohesion,soil_friction,soil_dilat

```

```

**** materials max_mat+70 for load factor restart

```

```

mp,ex,max_mat+70,soil_ex
mp,dens,max_mat+70,soil_dens*1.7/1.4
mp,prxy,max_mat+70,soil_prxy
mp,alpx,max_mat+70,soil_alpx
tb,dp,max_mat+70
tbdata,1,soil_cohesion,soil_friction,soil_dilat

```

Input file: set_csys.mac

```

*get,ia,area,,num,min
*get,iareal,area,ia,attr,real
*get,iamat,area,ia,attr,mat
*get,iatype,area,ia,attr,type
aatt,iamat,iareal,iatype,arg1

```

Input file: set_esys.mac

```

****
**** Set wall & dome rebar to material 3 6/4/04
****

/prep7
!define reinforced concrete real constants

!—Create local coordinate systems for esys
!—spherical 1
wpcsys,-1,0          !spherical
kwpave,1
wpoff,-1260
cswpla,200,2

wpcsys,-1,0          !spherical
kwpave,1

```

wpoff,-892
cswpla,201,2

csys,0 !ellipcal coordinate
wpcsys,-1
rat=40/15
k,10000,0,h3,0
kwpave,10000
wprot,90
cswplan,202,2,rat,rat

esel,s,real,,100,118 !slab
esel,r,type,,15
emodif,all,esys,22

esel,s,real,,200,210 !vertical wall
esel,r,type,,15
emodif,all,esys,22

esel,s,real,,300,308 !inner exterior dome
esel,r,type,,15
nsle
csys,22
nset,r,loc,x,0,170
esln
esel,r,type,,15
emodif,all,esys,200

esel,s,real,,300,308 !outer exterior dome
esel,r,type,,15
nsle
csys,22
nset,r,loc,x,170,9999

esln
esel,r,type,,15
emodif,all,esys,201

esel,s,real,,401,402 !exterior haunch
esel,r,type,,15
emodif,all,esys,201

esel,s,real,,403,404 !vertical haunch
esel,r,type,,15
emodif,all,esys,22

esel,s,real,,405,406 !interior haunch
esel,r,type,,15
emodif,all,esys,202

esel,s,real,,500,501 !vertical mid haunch
esel,r,type,,15
emodif,all,esys,22

esel,s,real,,502 !spherical mid haunch
esel,r,type,,15
emodif,all,esys,201

esel,s,real,,503 !tie bar haunch
emodif,all,esys,ics

! Slab bottom
r,101,6,.0256,,6,.0256 ! Center to 6'3"
rmor,90,,,90,90
r,102,6,.0258,,6,.0256 ! 6'3" to 7'6"+ld
rmor,90,,,90,90

r,103,6,.0316,,,6,.0256	! 7'6"+ld to 14'6"+ld
rmor,90,,,,90,90	
r,104,6,.0360,,,6,.0256	! 14'6"+ld to 29'2"
rmor,90,,,,90,90	
r,105,6,.0326,,,6,.0256	! 29'2" to 30'9"
rmor,90,,,,90,90	
r,106,6,.0293,,,6,.0256	! 30'9" to 36'3"
rmor,90,,,,90,90	
r,107,6,.0267,,,6,.0552	! 36'3" to 37'
rmor,90,,,,90,90	
r,108,6,.1016,,,6,.0552	! 37' to OD
rmor,90,,,,90,90	
! Slab top	
r,111,6,.0256,,,6,.0256	! Center to 6'3"
rmor,90,,,,90,90	
r,112,6,.0242,,,6,.0256	! 6'3" to 7'6"+ld
rmor,90,,,,90,90	
r,113,6,.0330,,,6,.0256	! 7'6"+ld to 14'6"+ld
rmor,90,,,,90,90	
r,114,6,.0377,,,6,.0256	! 14'6"+ld to 29'2"
rmor,90,,,,90,90	
r,115,6,.0269,,,6,.0256	! 29'2" to 30'9"
rmor,90,,,,90,90	
r,116,6,.0313,,,6,.0256	! 30'9" to 36'3"
rmor,90,,,,90,90	
r,117,6,.0284,,,6,.0552	! 36'3" to 37'
rmor,90,,,,90,90	
r,118,6,.0259,,,6,.0552	! 37' to OD
rmor,90,,,,90,90	
! Wall external	
r,201,,,,,3,.0982	! Base to 10'3" + 1/2 splice

rmor,90,,3,.0368,90,90	
r,202,,,,,3,.0982	! 10'3" to 17'
rmor,90,,3,.0491,90,90	
r,203,,,,,3,.0655	! 17' to 23'3" + 1/2 splice
rmor,90,,3,.0491,90,90	
r,204,,,,,3,.0655	! 23'3" to 28'3-1/2"
rmor,90,,3,.0655,90,90	
r,205,,,,,3,.0655	! 28'3-1/2" to tangent height
rmor,90,,3,.0655,90,90	
! Wall internal	
r,206,,,,,3,.0982	! Base to 10'3" + 1/2 splice
rmor,90,,3,.0368,90,90	
r,207,,,,,3,.0982	! 10'3" to 17'
rmor,90,,3,.0491,90,90	
r,208,,,,,3,.0655	! 17' to 23'3" + 1/2 splice
rmor,90,,3,.0491,90,90	
r,209,,,,,3,.0655	! 23'3" to 28'3-1/2"
rmor,90,,3,.0655,90,90	
r,210,,,,,3,.0655	! 28'3-1/2" to tangent height
rmor,90,,3,.0655,90,90	
! Dome top & bottom	
r,301,,,,,3,.0453	! Center to 7'3"
rmor,90,,3,.0368,90,90	
r,302,,,,,3,.0490	! 7'3" to 12'6" +
rmor,90,,3,.0368,90,90	
r,303,,,,,3,.0661	! 12'6" to 22'9"
rmor,90,,3,.0368,90,90	
r,304,,,,,3,.0496	! 22'9" to 25'4-1/2"
rmor,90,,3,.1309,90,90	
r,305,,,,,3,.1399	! 25'4-1/2" to 26'2"
rmor,90,,3,.1309,90,90	

```

r,306,,,,,3,,1300      ! 26'2" to 29'9
r,307,,,,,3,,1197      ! 28' to 29'6"
r,308,,,,,3,,1139      ! 29'6" to 32'6"
r,309,,,,,3,,2485,90,90

! Haunch external
! Dome (csys,201)
r,401,,,,,3,,2209      ! 33'3" to 37'6"
r,402,,,,,3,,1534,90,90
r,403,,,,,3,,2209      ! 37'6" to 41'4"
r,404,,,,,3,,1375,90,90
! Wall (csys,22)
r,405,,,,,3,,2485      ! Height: 34' to corner
r,406,,,,,3,,2045,90,90
r,407,,,,,3,,1309      ! Height: tangent to 34'
r,408,,,,,3,,2700,90,90

! Haunch internal
! (csys,202)
r,409,,,,,3,,1309      ! Height: tangent to 34'
r,410,,,,,3,,1309,90,90
r,411,,,,,3,,2209      ! 33'3" radius to 34' height
r,412,,,,,3,,1489,90,90

!haunch middle
! (csys,202)
r,502,3,,0007,,,,,3,,0261      ! 33'3" to vertical
r,503,3,,2209,90,90
! (csys,22)
r,504,3,,0007,,,,,3,,1243      ! lower vertical
r,505,3,,0236,90,90

```

```

r,501,3,,0007,,,,,3,,1243      ! upper vertical
r,502,3,,0109,90,90

!haunch ties
r,503,3,,0006
r,504,90,,,,,90,90

!secondary liner above 357.5"
r,505,r56
esel,s,real,,55
nsle,,1
csys,0
nsel,r,loc,y,357.5,99999
esln,,1
esel,r,type,,1
emodif,all,real,56

```

Input file: set_mat.mac

```

*get,ia,area,,num,min
*get,iareal,area,ia,attr,real
*get,iatype,area,ia,attr,type
*get,iacsys,area,ia,attr,esys
aatt,arg1,iareal,iatype,iacsys

```

Input file: set_materials.mac

```

!***
!***6/7/04 Add 205F & 215F degraded concrete
!***6/4/04 MISO rebar (mats 3 & 6)
!***10/9/03 Fill out temperature dependent steel modulus
table
!***7/23/03 Elastic insulating concrete (no cracking)
!***6/17/03 Correct alpx,mat_liner
!***

```

```

****      5/14/03
**** Add 6 concrete materials: mats 21 - 26
****      Constant (degraded) properties @
230,250,270,290,310,330
****      to be used after t=3+15+330 days
****
**** Remove concrete crushing 5/5/03
****
**** Temperature dependent Materials
****      Best estimate = mean values
****      All steel elastic
****      Run 2 (nocreep) 4/16/03
****
!specify all material properties
/prep7

![1]          steel (for liner, jbolts, studs, anchors,
bearing plates)
steel_alpx=steel_alpx*1e-6          !in/in/F
steel_dens=steel_gamma/1728         !lb/in^3

mpte
mpte,1,50,70,100,125,150,175
mpte,7,200,225,250,275,300,325
mpte,13,350
mpda,ex,mat_liner,1,29.5e6,29.5e6,29.34e6,29.20e6,29.07e6,
28.93e6
mpda,ex,mat_liner,7,28.8e6,28.68e6,28.55e6,28.43e6,28.3e6,
28.15e6
mpda,ex,mat_liner,13,28.0e6
mp,dens,mat_liner,steel_dens
mp,prxy,mat_liner,steel_prxy

```

```

mpda,alpx,mat_liner,1,5.73e-6,5.73e-6,5.73e-6,5.82e-
6,5.91e-6,6.0e-6
mpda,alpx,mat_liner,7,6.09e-6,6.18e-6,6.27e-6,6.35e-
6,6.43e-6,6.51e-6
mpda,alpx,mat_liner,13,6.59e-6
tb,biso,mat_liner
tbdata,1,steel_yield,steel_tan*steel_ex

![2]          structural concrete
conc_alpx=conc_alpx*1e-6          !in/in/F
conc_dens=conc_gamma/1728         !lb/in^3

mp,ex,mat_conc,7.434e6,-30.09e3,71.16,-.0709
mpda,ex,mat_conc,1,5.083e6,5.083e6,5.083e6
mp,dens,mat_conc,conc_dens
mp,prxy,mat_conc,conc_prxy
mp,alpx,mat_conc,conc_alpx
tb,concr,mat_conc,5
tbte,50,1
tbda,1,.1,.98,519,-1
tbte,200,2
tbda,1,.1,.98,519,-1
tbte,225,3
tbda,1,.1,.98,427,-1
tbte,250,4
tbda,1,.1,.98,335,-1
tbte,350,5
tbda,1,.1,.98,335,-1

tb,creep,mat_conc
tbda,1,.2545e-6,1,-.838,320,,1

![21]         degraded structural concrete (205F)

```

```

mp,ex,21,3.652e6
,dens,21,conc_dens
,prxy,21,conc_prxy
,alpx,21,conc_alpx
tb,concr,21
tbda,1,1,.98,501,-1
tb,creep,21
tbda,1,.2545e-6,1,-.838,320,,1

```

![22] degraded structural concrete (215F)

```

mp,ex,22,3.557e6
,dens,22,conc_dens
,prxy,22,conc_prxy
,alpx,22,conc_alpx
tb,concr,22
tbda,1,1,.98,465,-1
tb,creep,22
tbda,1,.2545e-6,1,-.838,320,,1

```

![23] degraded structural concrete (225F)

```

mp,ex,23,3.467e6
,dens,23,conc_dens
,prxy,23,conc_prxy
,alpx,23,conc_alpx
tb,concr,23
tbda,1,1,.98,427,-1
tb,creep,23
tbda,1,.2545e-6,1,-.838,320,,1

```

![24] degraded structural concrete (235F)

```

mp,ex,24,3.380e6
,dens,24,conc_dens
,prxy,24,conc_prxy

```

```

,alpx,24,conc_alpx
tb,concr,24
tbda,1,1,.98,390,-1
tb,creep,24
tbda,1,.2545e-6,1,-.838,320,,1

```

![25] degraded structural concrete (245F)

```

mp,ex,25,3.297e6
,dens,25,conc_dens
,prxy,25,conc_prxy
,alpx,25,conc_alpx
tb,concr,25
tbda,1,1,.98,354,-1
tb,creep,25
tbda,1,.2545e-6,1,-.838,320,,1

```

![26] degraded structural concrete (255F)

```

mp,ex,26,3.217e6
,dens,26,conc_dens
,prxy,26,conc_prxy
,alpx,26,conc_alpx
tb,concr,26
tbda,1,1,.98,335,-1
tb,creep,26
tbda,1,.2545e-6,1,-.838,320,,1

```

![27] degraded structural concrete (265F)

```

mp,ex,27,3.141e6
,dens,27,conc_dens
,prxy,27,conc_prxy
,alpx,27,conc_alpx
tb,concr,27
tbda,1,1,.98,335,-1

```

tb,creep,27
tbda,1,.2545e-6,1,-.838,320,,1

![28] degraded structural concrete (275F)
mp,ex,28,3.067e6
,dens,28,conc_dens
,prxy,28,conc_prxy
,alpx,28,conc_alpx
tb,concr,28
tbda,1,.1,.98,335,-1
tb,creep,28
tbda,1,.2545e-6,1,-.838,320,,1

![29] degraded structural concrete (285F)
mp,ex,29,2.996e6
,dens,29,conc_dens
,prxy,29,conc_prxy
,alpx,29,conc_alpx
tb,concr,29
tbda,1,.1,.98,335,-1
tb,creep,29
tbda,1,.2545e-6,1,-.838,320,,1

![30] degraded structural concrete (295F)
mp,ex,30,2.927e6
,dens,30,conc_dens
,prxy,30,conc_prxy
,alpx,30,conc_alpx
tb,concr,30
tbda,1,.1,.98,335,-1
tb,creep,30
tbda,1,.2545e-6,1,-.838,320,,1

![31] degraded structural concrete (305F)
mp,ex,31,2.860e6
,dens,31,conc_dens
,prxy,31,conc_prxy
,alpx,31,conc_alpx
tb,concr,31
tbda,1,.1,.98,335,-1
tb,creep,31
tbda,1,.2545e-6,1,-.838,320,,1

![32] degraded structural concrete (315F)
mp,ex,32,2.796e6
,dens,32,conc_dens
,prxy,32,conc_prxy
,alpx,32,conc_alpx
tb,concr,32
tbda,1,.1,.98,335,-1
tb,creep,32
tbda,1,.2545e-6,1,-.838,320,,1

![33] degraded structural concrete (325F)
mp,ex,33,2.734e6
,dens,33,conc_dens
,prxy,33,conc_prxy
,alpx,33,conc_alpx
tb,concr,33
tbda,1,.1,.98,335,-1
tb,creep,33
tbda,1,.2545e-6,1,-.838,320,,1

![34] degraded structural concrete (335F)
mp,ex,34,2.673e6
,dens,34,conc_dens


```
,prxy,34,conc_prxy
,alpx,34,conc_alpx
!b,concr,34
!bda,1,1,.98,335,-1
!b,creep,34
!bda,1,2545e-6,1,-.838,320,,1
```

```
! [35]      degraded structural concrete (345F)
```

```
mp,ex,35,2.615e6
,dens,35,conc_dens
,prxy,35,conc_prxy
,alpx,35,conc_alpx
!b,concr,35
!bda,1,1,.98,335,-1
!b,creep,35
!bda,1,2545e-6,1,-.838,320,,1
```

```
! [3]      rebar
```

```
rebar_alpx=rebar_alpx*1e-6      !in/in/F
rebar_dens=rebar_gamma/1728      !lb-sec^2/in^4
```

```
mp,ex,mat_rebar,rebar_ex
mp,dens,mat_rebar,rebar_dens
mp,prxy,mat_rebar,rebar_prxy
mp,alpx,mat_rebar,rebar_alpx
!b,miso,mat_rebar,4,4
!bte,100,1
!bpt,,2069e-6,60000
,,3770e-6,67331
,,9555e-6,73035
,,20129e-6,76967
!bte,200,2
!bpt,,1896e-6,54978
```

```
,,3770e-6,61720
,,9555e-6,66882
,,20129e-6,70582
!bte,300,3
!bpt,,1896e-6,53304
,,3770e-6,59850
,,9555e-6,64831
,,20129e-6,68453
!bte,400,4
!bpt,,1780e-6,51630
,,3770e-6,57979
,,9555e-6,62780
,,20129e-6,66325
```

```
! [4]      insulating concrete
```

```
insul_alpx=insul_alpx*1e-6      !in/in/F
insul_dens=insul_gamma/1728      !lb/in^3
```

```
mp,ex,mat_insul,insul_ex
mp,dens,mat_insul,insul_dens
mp,prxy,mat_insul,insul_prxy
mp,alpx,mat_insul,insul_alpx
!b,concr,mat_insul
!bda,1,insul_open,insul_closed,insul_crack,-1
```

```
! [5]      soil
```

```
! These soil properties for material 5 are overwritten later
```

```
!soil_ex=575000      !elastic modulus [psi]
!soil_prxy=0.1      !Poisson ratio
!soil_alpx=0      !thermal expansion coefficient
[me/F]
!soil_gamma=125      !unit weight [lb/ft^3]
```

```

!soil_cohesion=0      !drucker-prager constant (assume
small number) [psi]
!soil_friction=35.4    !internal friction angle [deg]
!soil_dilat=35.4      !dilatancy angle [deg]

```

```

!soil_alpx=soil_alpx*1e-6    !in/in/F
!soil_dens=soil_gamma/1728    !lb/in^3

```

```

!mp,ex,mat_soil,soil_ex
!mp,dens,mat_soil,soil_dens
!mp,prxy,mat_soil,soil_prxy
!mp,alpx,mat_soil,soil_alpx
!tb,dp,mat_soil
!tbdata,1,soil_cohesion,soil_friction,soil_dilat

```

```

!set mat_haunch materials equal to mat_conc material
vsel,s,mat,,mat_haunch
eslv
emodif,all,mat,mat_conc
mpdele,all,mat_haunch

```

```

!set slab rebar material properties
vsel,s,mat,,mat_rebar
eslv
nsle
nsel,r,loc,y,-999,-8.125
esln,,1
esel,r,mat,,mat_rebar
mat_srebar=6
emodif,all,mat,mat_srebar

```

```

!{6}      slab rebar
srebar_alpx=srebar_alpx*1e-6    !in/in/F

```

```

srebar_dens=srebar_gamma/1728    !lb/in^3

```

```

mp,ex,mat_srebar,srebar_ex
mp,dens,mat_srebar,srebar_dens
mp,prxy,mat_srebar,srebar_prxy
mp,alpx,mat_srebar,srebar_alpx
tb,miso,mat_srebar,4,4
tbte,100,1
tbpt,,1379e-6,40000
,,2513e-6,44887
,,6370e-6,48690
,,13419e-6,51311
tbte,200,2
tbpt,,1264e-6,36652
,,2513e-6,41147
,,6370e-6,44588
,,13419e-6,47055
tbte,300,3
tbpt,,1225e-6,35536
,,2513e-6,39900
,,6370e-6,43221
,,13419e-6,45636
tbte,400,4
tbpt,,1187e-6,34420
,,2513e-6,38653
,,6370e-6,41853
,,13419e-6,44217

```

```

allsel
esel,s,mat,,3
esel,a,mat,,6
emodif,all,mat,2

```

allsel

Input file: set_options.mac

!***Turn on creep, turn on steel plasticity 6/8/04

/prep7

!remove structural concrete CONCR material model

!tbdele,concr,mat_conc

!remove concrete CREEP material model

!tbdele,creep,mat_conc

!remove insulating concrete CONCR material model

!tbdele,concr,mat_insul

!remove insulating concrete CREEP material model

!tbdele,creep,mat_insul

!remove liner BISO material model

!tbdele,BISO,mat_liner

!remove rebar BISO material model

!tbdele,BISO,mat_rebar

!tbde,biso,mat_srebar

!remove soil DP material model

!tbdele,DP,mat_soil

Input file: set_parms.mac

!***

!*** Best estimate soil properties 3/19/04

!***

!*** Run 2, Load Case 1 - 4

!*** (8.3' soil, 125 lb/ft3)

!*** (0.06" primary tank corrosion)

!*** 4/16/03

!***

!***

!*** JED mods 3/20/03

!*** add clr - concentrated load radius

!*** add backfill properties 3/24

!*** backfill properties f(depth) 4/1

finish

/clear

/fil,pnmla

/prep7

/titl,AP 422"(20yr)/460"(40yr), 210F, 1.83SpG, BES

!

! DST - AY

pi=acos(-1)

clr=10*12

!Concentrated load radius

or=12*41.5

!Outside radius concrete wall

ir=12*40

!Inside radius concrete wall

ir2=12*37.5

!Radius primary tank

icr=37*12+3

!Radius insulating concrete

h1=0

h2=-8.125

h3=381.5

!Height dome tangent (31'9-1/2")

h4=h3+70.875

!Height exterior corner (+ 5'10-7/8" =

37'8-3/8")

h5=h3+15*12

!Height interior center dome

h6=h5+15

!Height exterior center dome

```
covext=2      !Concrete cover - exterior dome
covint1=4     !Concrete cover - wall
covint2=1.5   !Concrete cover - interior dome
```

```
r1=105*12+.25    !Exterior dome radius - center
th1=7+(45+14/60)*60 !Angle at tangent of external radii
r2=74*12+4       !Exterior dome radius - outer
r3=3*12+8.375    !Radius primary tank to dome
```

! This file sets the values of all parameters that may be changed

! These were originally defined in define_soil_layers.mac:

```
overburden=8.3*12 !overburden height above dome apex (ft)
subdepth=168*12  !subgrade soil depth (ft)
totalwidth=240*12 !total soil width (radius) from tank centerline
to edge (ft)
```

! These were originally defined in dstay7.mac:

```
r50=1-.06    !shell thickness (in) (R1 of Figure 11 in RPP-
13990)
r51=3/8-.06  !shell thickness (in) (R2,R6,R7,R9 of Figure 11 in
RPP-13990)
r52=7/8-.06  !shell thickness (in) (R3 of Figure 11 in RPP-
13990)
r53=3/4-.06  !shell thickness (in) (R4 of Figure 11 in RPP-
13990)
r54=1/2-.06  !shell thickness (in) (R5,R8 of Figure 11 in RPP-
13990)
```

```
r55=1/4      !shell thickness (in) (R10 of Figure 11 in RPP-13990)
```

! This was originally defined in set_esys_3d.mac:

```
r56=3/8      !shell thickness (in) of secondary liner above 357.5 in
```

! These were originally defined in set_materials.mac:

```
! [1]      steel (for liner, jbolts, studs, anchors, bearing plates)
steel_ex=27.7e6      !elastic modulus [psi]
steel_pxy=0.3        !Poisson ratio
steel_alpx=6.38      !thermal expansion coefficient
[microstrain/degree F]
steel_gamma=490      !unit weight [lb/ft^3]
steel_yield=36000     !yield strength [psi]
steel_tan=0.01       !rebar tangent modulus [% of elastic
modulus]
```

```
! [2]      structural concrete
conc_ex=3.8e6        !elastic modulus [psi]
conc_pxy=0.15        !Poisson ratio
conc_alpx=3.7        !thermal expansion coefficient
[microstrain/degree F]
conc_gamma=145       !unit weight [lb/ft^3]

conc_open=0.1        !shear transfer coefficient for open
crack
conc_closed=0.98     !shear transfer coefficient for closed
crack
conc_crush=3000       !uniaxial crushing stress [psi]
conc_crack=0.1*conc_crush !tensile cracking stress [psi]
```

```

! [3]      rebar
rebar_ex=29.0e6      !elastic modulus [psi]
rebar_prxy=0.3      !Poisson ratio
rebar_alpx=6.      !thermal expansion coefficient
[microstrain/degree F]
rebar_gamma=490      !unit weight [lb/ft^3]
rebar_yield=71000      !yield strength [psi]
rebar_tan=0      !rebar tangent modulus [psi]

! [4]      insulating concrete
insul_ex=165e3      !elastic modulus [psi]
insul_prxy=0.15      !Poisson ratio
insul_alpx=3.7      !thermal expansion coefficient
[me/F]
insul_gamma=50      !unit weight [lb/ft^3]

insul_open=0.1      !shear transfer coefficient for open
crack
insul_closed=0.98      !shear transfer coefficient for closed
crack
insul_crush=200      !uniaxial crushing stress [psi]
insul_crack=20      !tensile cracking stress [psi]

! [6]      slab rebar
srebar_ex=29.0e6      !elastic modulus [psi]
srebar_prxy=0.3      !Poisson ratio
srebar_alpx=6.      !thermal expansion coefficient
[microstrain/degree F]
srebar_gamma=490      !unit weight [lb/ft^3]
srebar_yield=49000      !yield strength [psi]
srebar_tan=0      !rebar tangent modulus [psi]

```

```

!*** Backfill
! These were originally defined in define_loads.mac:
! [5]      backfill soil
backfill_phi=34.5      !soil friction angle deg
backfill_dil=34.5      !backfill dilatancy angle deg
backfill_cte=0      !thermal expansion coef me/f

!*** No waste, pressures or ext. load
pres_surf=0      !ground surface uniform pressure
psf
point_cent=0      !point load at center lb
pres_annulus=0      !annulus pressure inches h2o
pres_int=0      !annulus internal pressure inches
h2o
hwaste=35.17*12      !total waste height
height_waste1=hwaste/3      !height of waste 1 inches
gamma_waste1=0      !specific gravity of waste 1
height_waste2=hwaste/3      !height of waste 2 inches
gamma_waste2=0      !specific gravity of waste 2
height_waste3=hwaste/3      !height of waste 3 inches
gamma_waste3=0      !specific gravity of waste 3

!define soil layers
*dim,soil_emo,,16
*dim,soil_pr,,16
*dim,soil_z0,,16
*dim,soil_z1,,16
*dim,bf_emo,,8
!*dim,bf_pr,,8
*dim,bf_z0,,8
*dim,bf_z1,,8

```

```

bfdinc=(h6+overburden+18.5)/8
sdinc=(subdepth+60)/8

*do,i,1,8
soil_z0(i)=i*bfdinc !vertical distance from surface
soil_z1(i)=(i-1)*bfdinc
soil_z0(i+8)=i*sdinc+bfdinc*8
soil_z1(i+8)=(i-1)*sdinc+bfdinc*8
bf_z0(i)=i*bfdinc
bf_z1(i)=(i-1)*bfdinc
*enddo

!Elastic modulus
soil_emod(1)=58000,62000,64618,67236,69563,72180,74798,77
125,82117,90000
soil_emod(11)=109697,129650,151456,172835,191000,200000
bf_emod(1)=12000,15000,19500,24000,28000,32500,37000,400
00

!Poisson's ratio
soil_pr(1)=.24,.24,.24,.24,.19,.19,.19,.19,.19,.19
soil_pr(11)=.19,.19,.28,.28,.28,.28
bf_pr=.27

!*** Soil 110 pcf - undisturbed
!*** Soil 125 pcf - backfill/overburden
s_gam=110 !lbf/ft3 density of soil layers
(excluding backfill)
b_gam=125 !lbf/ft3 density of soil layers
(excluding backfill)

save

```

Input file: set_real.mac

```

*get,ia,area,,num,min
*get,iamat,area,ia,attr,mat
*get,iatype,area,ia,attr,type
*get,iacsys,area,ia,attr,esys
aatt,iamat,arg1,iatype,iacsys

```

Input file: set_rx.mac

```

cmsel,s,arg4
csys,0
asel,r,loc,x,arg1,arg2
set_real,arg3

```

Input file: set_ry.mac

```

cmsel,s,arg4
csys,0
asel,r,loc,y,arg1,arg2
set_real,arg3

```

Input file: set_slayer.mac

```

!***
!*** Dilation angle 8 6/4/04
!*** Add materials for load factor restart 8/2/03
!*** JED mod 3/24/03
!*** Define soil
!*** (redefine backfill/overburden in set_backfill)
!***
max_mat=max_mat+1

/prep7

cmsel,s,soil_elem
nslc

```

```

csys,0
hsub=top_elev-arg2-h2+24
nsel,r,loc,y,top_elev-arg1,top_elev-arg2
esln,
esel,r,mat,,5
emodif,all,mat,max_mat
emodif,all,real,7

```

```

soil_ex=arg3      !elastic modulus [psi]
soil_prxy=arg4    !Poisson ratio
soil_alpx=0       !thermal expansion coefficient
[me/F]
soil_cohesion=1   !drucker-prager constant [psi]
soil_friction=35  !internal friction angle [deg]
soil_dilat=8      !dilatancy angle [deg]

```

```

soil_alpx=soil_alpx*1e-6    !in/in/F
soil_dens=s_gam/1728        !lb/in^3

```

```

mp,ex,max_mat,soil_ex
mp,dens,max_mat,soil_dens
mp,prxy,max_mat,soil_prxy
mp,alpx,max_mat,soil_alpx
tb,dp,max_mat
tbdata,1,soil_cohesion,soil_friction,soil_dilat

```

```

!*** materials max_mat+50 for load factor restart

```

```

mp,ex,max_mat+50,soil_ex
mp,dens,max_mat+50,soil_dens*1.7/1.4
mp,prxy,max_mat+50,soil_prxy

```

```

mp,alpx,max_mat+50,soil_alpx
tb,dp,max_mat+50
tbdata,1,soil_cohesion,soil_friction,soil_dilat

```

Input file: set_soil.mac

```

!***
!*** JED mod 3/24/03
!*** define subdepth (depth of soil below foundation)
!***
/prep7

```

```

csys,0
vsel,s,mat,,1
aslv
asel,u,loc,z,0
cm,aold,area
aslv
asel,r,loc,z,0
cm,anew,area
eslv
nsle
cpdel,all,all
vclear,all
vdel,all
cmsel,s,aold
adele,all,,1
cmsel,s,anew
lsla
lsize,all,,-1,,1
esize,16

```

```

adrag,1986,,,,,1989
aovlap,all

```



```

cm,asoil,area
asel,s,,,147
adele,all,,,1
cmsel,s,asoil
lcomb,14,1983
aatt,mat_soil,,type_soil
amesh,all

```

```

allsel
*get,km,kp,,num,max
dy=overburden-12

```

```

k,km+1,kx(1112)-dy,ky(1110)+dy
k,km+2,kx(1075)-dy,ky(1075)-dy
k,km+3,0,ky(km+2)
k,km+4,kx(km+2),ky(1077)-subdepth
k,km+5,0,ky(km+4)
k,km+6,0,ky(km+1)
k,km+7,-totalwidth,ky(km+1)
k,km+8,kx(km+7),ky(km+2)
k,km+9,kx(km+8),ky(km+4)
k,km+10,-c1r,ky(km+1)
asel,none
a,1112,1110,km+6,km+10,km+1
a,km+1,km+2,1075,1112
a,km+2,km+3,1077,1075
a,km+2,km+4,km+5,km+3
a,km+1,km+7,km+8,km+2
a,km+2,km+8,km+9,km+4
!sla
!sel,r,loc,x,kx(km+7)+1,kx(km+1)-1
!esize,all,,,40,1/10
!sel,r,loc,y,ky(km+1)

```

```

!esize,all,,,40,10,1
!sla
!sel,r,loc,y,ky(km+9)+1,ky(km+8)-1
!esize,all,,,40,10
!sel,r,loc,x,0
!esize,all,,,40,.1,1
!sla
aatt,mat_soil,,type_soil
amap,147,1112,1110,3261,3256
asel,u,,,147
mshkey,1
amesh,all

```

```

asel,s,mat,,mat_soil
type,type_soil+10
mat,mat_soil
ksel,all
vsel,none
vrotat,all,,,,,ikbot,iktop,swp_th,1
aclear,all

```

```

csys,22
nrotate,all

```

```

!couple to concrete DOFs
asel,,,462,466,4
,a,,,473
,a,,,469,471
,a,,,482,483
,a,,,488,491,3
cm,avert,area
asel,,,472,481,9
,a,,,478,479

```

```
cm,ahorz,area
```

```
esel,s,mat,,2
```

```
nsle
```

```
nsel,r,ext
```

```
cm,nconc,node
```

```
cmsel,s,avert
```

```
nsla,,1
```

```
cm,nsoil,node
```

```
*get,nnode,node,,count
```

```
*do,i,1,nnode
```

```
*get,inode,node,,num,min
```

```
cmsel,s,nconc
```

```
incoup=node(nx(inode),ny(inode),nz(inode))
```

```
nsel,s,,,incoup
```

```
nsel,a,,,inode
```

```
cp,next,uz,all
```

```
cmsel,s,nsoil
```

```
nsel,u,,,inode
```

```
cm,nsoil,node
```

```
*enddo
```

```
cmsel,s,ahorz
```

```
nsla,,1
```

```
cm,nsoil,node
```

```
*get,nnode,node,,count
```

```
*do,i,1,nnode
```

```
*get,inode,node,,num,min
```

```
cmsel,s,nconc
```

```
incoup=node(nx(inode),ny(inode),nz(inode))
```

```
nsel,s,,,incoup
```

```
nsel,a,,,inode
```

```
cp,next,ux,all
```

```
cmsel,s,nsoil
```

```
nsel,u,,,inode
```

```
cm,nsoil,node
```

```
*enddo
```

```
/eof
```

```
csys,22
```

```
nsel,s,loc,y,180-.01,180+.01
```

```
nsel,a,loc,y,180+swp_th-.01,180+swp_th+.01
```

```
nrotate,all
```

```
d,all,uy,0
```

```
allsel
```

Input file: set_type.mac

```
*get,ia,area,,num,min
```

```
*get,iareal,area,ia,attr,real
```

```
*get,iamat,area,ia,attr,mat
```

```
*get,iacsys,area,ia,attr,esys
```

```
aatt,iamat,iareal,arg1,iacsys
```

C.2.2 Thermal Cycling Files

There are six input files required to run the full 60 years of thermal cycling and creep. These are listed sequentially below.

Input file: set_slice.inp

```
/fil,set_slice_0
```

```
resu
```

```
/sol
```

```
antv,,rest
```

```
!*** Thermal load - Initial ramp
```

fhr1=7.5/24

time,3+fhr1 !LS 4

**** Fast heat to 125F

/nopr

/inp,fth,temp

/inp,bkh,temp

/gopr

nsub,3,10,2

solv

time,2.125+3+fhr1 !LS 4

**** One of Two steps to 210F

/nopr

/inp,fth1,temp

/inp,bkh1,temp

/gopr

nsub,3,10,2

solv

time,4.25+3+fhr1 !LS 4

**** Two of Two steps to 210F

/nopr

/inp,fth2,temp

/inp,bkh2,temp

/gopr

nsub,3,10,2

solv

time,26 !LS 9

**** 150F

/nopr

/inp,frss,temp

/inp,bkss,temp

/gopr

nsub,150,1000,10

solv

time,41 !LS 10

**** Steady state @ 210F

/nopr

/inp,frss1,temp

/inp,bkss1,temp

/gopr

nsub,150,1000,15

solv

time,353 !LS 11

**** Hold for 1 Year

nsub,300,10000,10

save

solv

time,353+1 !LS 12

**** mpchg and 1.0 days

*do,i,1,14

escl,type,,12,15

nsle

nsel,r,bf,temp,190+i*10,200+i*10

esln

escl,r,mat,,2

```

mpch,20,i,all
*enddo
esel,type,,12,15
nsle
nsel,r,bf,temp,330,345
esln
esel,r,mat,,2
mpch,35,all
esel,all
nsel,all
nsub,10,100,2
solv

```

```

time,354+2.125          !LS 13

```

```

!*** Cool to ambient

```

```

!***

```

```

!*** First of Two steps to 125F

```

```

!***

```

```

/nopr

```

```

/inp,frs1,temp

```

```

/inp,bkc1,temp

```

```

/gopr

```

```

nsub,15,200,5

```

```

solv

```

```

time,354+4.25          !LS 14

```

```

!***

```

```

!*** Second of two steps to 125F

```

```

!***

```

```

/nopr

```

```

/inp,frs2,temp

```

```

/inp,bkc2,temp

```

```

/gopr

```

```

nsub,15,200,5

```

```

solv

```

```

time,354+4.25+fhrt      !LS 17

```

```

!***

```

```

!*** Fast cool down to 50F

```

```

!***

```

```

/nopr

```

```

/inp,frs3,temp

```

```

/inp,bkc3,temp

```

```

/gopr

```

```

nsub,7,100,3

```

```

solv

```

```

time,354+4.25+fhrt+1    !LS 18

```

```

!***

```

```

!*** Tank cool down transient to 50F

```

```

!***

```

```

/nopr

```

```

/inp,frs4,temp

```

```

/inp,bkc4,temp

```

```

/gopr

```

```

nsub,5,100,2

```

```

solv

```

```

time,368                !LS 19

```

```

!**** Uniform 50F

```

```

nsub,47,150,20

```

```

bf,all,temp,50

```

```

solv

```

```

!*** Cycle 4 More Years

```

```

*do,i,1,4

```

time,3+fhr+365*i !LS 20

**** Thermal load - Initial ramp

/nopr

/inp,fth,temp

/inp,bkh,temp

/gopr

nsub,3,10,2

solv

time,3+2.125+fhr*365*i !LS 21

**** First of two steps to 210F

/nopr

/inp,fth1,temp

/inp,bkh1,temp

/gopr

nsub,20,100,6

solv

time,3+4.25+fhr+365*i !LS 22

**** Second of two steps to 210F

/nopr

/inp,fth2,temp

/inp,bkh2,temp

/gopr

nsub,20,100,6

solv

time,3+23+365*i !LS 25

**** 350F

/nopr

/inp,frss,temp

/inp,bkss,temp

/gopr

nsub,150,1000,10

solv

time,3+38+365*i !LS 26

**** Steady state @ 210F

/nopr

/inp,frss1,temp

/inp,bkss1,temp

/gopr

nsub,150,1000,30

solv

time,3+351+365*i !LS 27

**** Creep for 1 Year

nsub,300,10000,6

solv

**** Cool to ambient

time,3+351+2.125+365*i

!LS 28

!*** First of two steps to 125F

!***

/nopr

/inp,fr1,temp

/inp,bkc1,temp

/gopr

nsub,15,200,5

solv

time,3+351+4.25+365*i !LS 29

!***

!*** Second of two steps to 125F

!***

/nopr

/inp,fr2,temp

/inp,bkc2,temp

/gopr

nsub,15,200,5

solv

time,3+351+4.25+fhrt+365*i !LS 32

!***

!*** Fast cool down to 50F

!***

/nopr

/inp,fr3,temp

/inp,bkc3,temp

/gopr

nsub,7,100,3

solv

time,3+351+4.25+fhrt+1+365*i !LS 33

!***

!*** Tank cool down transient to 50F

!***

/nopr

/inp,fr4,temp

/inp,bkc4,temp

/gopr

nsub,5,100,2

solv

time,3+365+365*i !LS 34

!***

!*** Uniform 50F

!***

nsub,47,150,20

bf,all,temp,50

save

solv

*enddo

! End of 5 Year Thermal Cycles

Input file: Extended13yr.Inp

/fil,set_slice_0

resu

/sol

anty,,rest

!*** Thermal load - Initial ramp

!***

fhrt=7.5/24

time,3+fhrt+365*5

!***

!*** Fast heat to 125F

!***

```

/nopr
/inp,frh,temp
/inp,bkh,temp
/gopr
nsub,3,10,2
solv

```

```

time,2.125+3+fhrt+365*5
****
**** One of Two steps to 210F
****
/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr
nsub,3,10,2
solv

```

```

time,4.25+3+fhrt+365*5
****
**** Two of Two steps to 210F
****
/nopr
/inp,frh2,temp
/inp,bkh2,temp
/gopr
nsub,3,10,2
solv

```

```

time,26+365*5
**** Steady State @ 210
/nopr
/inp,frss,temp
/inp,bkss,temp

```

```

/gopr
nsub,150,1000,10
solv

```

```

time,41+365*5
**** Steady state @ 210F
/nopr
/inp,frss1,temp
/inp,bkss1,temp
/gopr
nsub,150,1000,15
solv

```

```

time,354+365*17
**** Hold for 13 Years
nsub,300,10000,10
save
solv

```

```

time,354+2.125+365*17
**** Cool to ambient
****
**** First of Two steps to 125F
****
/nopr
/inp,fr1,temp
/inp,bk1,temp
/gopr
nsub,15,200,5
solv

```

```

time,354+4.25+365*17
****

```


!*** Second of two steps to 125F

!***

/nopr

/inp,fr2,temp

/inp,bk2,temp

/gopr

nsub,15,200,5

solv

time,354+4.25+fhr+365*17

!***

!*** Fast cool down to 50F

!***

/nopr

/inp,fr3,temp

/inp,bk3,temp

/gopr

nsub,7,100,3

solv

time,354+4.25+fhr+1+365*17

!***

!*** Tank cool down transient to 50F

!***

/nopr

/inp,fr4,temp

/inp,bk4,temp

/gopr

nsub,5,100,2

solv

time,368+365*17

!**** Uniform 50F

nsub,47,150,20

bf,all,temp,50

solv

Input file: TwoYrCycle.inp

/fil,set_slice_0

resu

/sol

antl,,rest

!*** Thermal load - Initial ramp

!***

fhr=7.5/24

!*** Cycle

*do,i,18,19

time,3+fhr+365*i

!***

!*** Thermal load - Initial ramp

!***

/nopr

/inp,frh,temp

/inp,bkh,temp

/gopr

nsub,3,10,2

solv

time,3+2.125+fhr*365*i

!***

!*** First of two steps to 210F

!***

/nopr

/inp,frh1,temp

```

/inp,bkh1,temp
/gopr
nsub,20,100,6
solv

```

```

time,3+4.25+fhrt+365*i
****
**** Second of two steps to 210F
****
/nopr
/inp,ftt2,temp
/inp,bkh2,temp
/gopr
nsub,20,100,6
solv

```

```

time,3+23+365*i
****
**** 350F
****
/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr
nsub,150,1000,10
solv

```

```

time,3+38+365*i
****
**** Steady state @ 210F
****
/nopr
/inp,frss1,temp

```

```

/inp,bkss1,temp
/gopr
nsub,150,1000,30
solv

```

```

time,3+351+365*i
****
**** Creep for 1 Year
****
nsub,300,10000,6
solv

```

```

**** Cool to ambient
time,3+351+2.125+365*i
****
**** First of two steps to 125F
****
/nopr
/inp,frt1,temp
/inp,bkt1,temp
/gopr
nsub,15,200,5
solv

```

```

time,3+351+4.25+365*i
****
**** Second of two steps to 125F
****
/nopr
/inp,frt2,temp
/inp,bkt2,temp
/gopr
nsub,15,200,5

```

```

solv

time,3+351+4.25+fhrt+365*i
****
**** Fast cool down to 50F
****
/nopr
/inp,frc3,temp
/inp,bkc3,temp
/gopr
nsub,7,100,3
solv

time,3+351+4.25+fhrt+1+365*i
****
**** Tank cool down transient to 50F
****
/nopr
/inp,frc4,temp
/inp,bkc4,temp
/gopr
nsub,5,100,2
solv

time,3+365+365*i
****
**** Uniform 50F
****
nsub,47,150,20
bf,all,temp,50
save
solv

```

```

*enddo
! End of 20 Year Thermal Cycles

```

Input file: TwoYrCycleWith460wh.inp

```

/fil,set_slice_0
resu
/sol
anty,,rest

time,365*20+3+1
****
**** Add waste, pressure and surface loads
****

pres_surf=40          !ground surface uniform pressure
psf
point_cent=200000     !point load at center lb
pres_annulus=-20      !annulus pressure inches h2o
pres_int=-12          !annulus internal pressure inches
h2o
hwaste=460            !total waste height
height_waste1=hwaste/3 !height of waste 1 inches
gamma_waste1=1.83      !specific gravity of waste 1
height_waste2=hwaste/3 !height of waste 2 inches
gamma_waste2=1.83      !specific gravity of waste 2
height_waste3=hwaste/3 !height of waste 3 inches
gamma_waste3=1.83      !specific gravity of waste 3

/inp,apply_loads_slice,mac
solv

**** Thermal load - Initial ramp
****
fhrt=7.5/24

```

```

**** Cycle
*do,i,20,21

time,3+1+fhr+365*i
****
**** Thermal load - Initial ramp
****
/nopr
/inp,frh,temp
/inp,bkh,temp
/gopr
nsub,3,10,2
solv

time,3+1+2.125+fhr*365*i
****
**** First of two steps to 210F
****
/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr
nsub,20,100,6
solv

time,3+1+4.25+fhr+365*i
****
**** Second of two steps to 210F
****
/nopr
/inp,frh2,temp
/inp,bkh2,temp

```

```

/gopr
nsub,20,100,6
solv

time,3+1+23+365*i
****
**** 350F
****
/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr
nsub,150,1000,10
solv

time,3+1+38+365*i
****
**** Steady state @ 210F
****
/nopr
/inp,frss1,temp
/inp,bkss1,temp
/gopr
nsub,150,1000,30
solv

time,3+1+351+365*i
****
**** Creep for 1 Year
****
nsub,300,10000,6
solv

**** Cool to ambient

```

```

time,3+1+351+2.125+365*i
****
**** First of two steps to 125F
****
/nopr
/inp,frt1,temp
/inp,bkc1,temp
/gopr
nsub,15,200,5
solv

time,3+1+351+4.25+365*i
****
**** Second of two steps to 125F
****
/nopr
/inp,frt2,temp
/inp,bkc2,temp
/gopr
nsub,15,200,5
solv

time,3+1+351+4.25+flrt+365*i
****
**** Fast cool down to 50F
****
/nopr
/inp,frt3,temp
/inp,bkc3,temp
/gopr
nsub,7,100,3
solv

```

```

time,3+1+351+4.25+flrt+1+365*i
****
**** Tank cool down transient to 50F
****
/nopr
/inp,frt4,temp
/inp,bkc4,temp
/gopr
nsub,5,100,2
solv

time,3+1+365+365*i
****
**** Uniform 50F
****
nsub,47,150,20
bf,all,temp,50
save
solv

*enddo

! End of 22 Year Thermal Cycles with 460" waste height
from 20 years

Input file: Extended38yr.inp
/fil,set_slice_0
resu
/sol
anty,,rest

**** Thermal load - Initial ramp
****

```

fhr=7.5/24

time,4+fhr+365*20

**** Fast heat to 125F

/nopr

/inp,fth,temp

/inp,bkh,temp

/gopr

nsub,3,10,2

solv

time,2.125+4+fhr+365*20

**** One of Two steps to 210F

/nopr

/inp,fth1,temp

/inp,bkh1,temp

/gopr

nsub,3,10,2

solv

time,4.25+4+fhr+365*20

**** Two of Two steps to 210F

/nopr

/inp,fth2,temp

/inp,bkh2,temp

/gopr

nsub,3,10,2

solv

time,26+1+365*20

**** Steady State @ 210

/nopr

/inp,frss,temp

/inp,bkss,temp

/gopr

nsub,150,1000,10

solv

time,41+1+365*20

**** Steady state @ 210F

/nopr

/inp,frss1,temp

/inp,bkss1,temp

/gopr

nsub,150,1000,15

solv

time,354+365*57

**** Hold for 38 Years

nsub,300,10000,10

save

solv

time,354+2.125+365*57

**** Cool to ambient

**** First of Two steps to 125F

/nopr

/inp,frc1,temp

/inp,bkc1,temp

```
/gopr
nsub,15,200,5
solv
```

```
time,354+4.25+365*57
```

```
****
```

```
**** Second of two steps to 125F
```

```
****
```

```
/nopr
```

```
/inp,fr2,temp
```

```
/inp,bk2,temp
```

```
/gopr
```

```
nsub,15,200,5
```

```
solv
```

```
time,354+4.25+fhrt+365*57
```

```
****
```

```
**** Fast cool down to 50F
```

```
****
```

```
/nopr
```

```
/inp,fr3,temp
```

```
/inp,bk3,temp
```

```
/gopr
```

```
nsub,7,100,3
```

```
solv
```

```
time,354+4.25+fhrt+1+365*57
```

```
****
```

```
**** Tank cool down transient to 50F
```

```
****
```

```
/nopr
```

```
/inp,fr4,temp
```

```
/inp,bk4,temp
```

```
/gopr
nsub,5,100,2
solv
```

```
time,368+365*57
```

```
***** Uniform 50F
```

```
nsub,47,150,20
```

```
bf,all,temp,50
```

```
solv
```

```
! End of 58 year cycle
```

Input file: TwoYrCycTo60Yr.inp

```
/fil,set_slice_0
```

```
resu
```

```
/sol
```

```
anty,,rest
```

```
**** Thermal load - Initial ramp
```

```
****
```

```
fhrt=7.5/24
```

```
**** Cycle
```

```
*do,i,58,59
```

```
time,3+fhrt+365*i
```

```
****
```

```
**** Thermal load - Initial ramp
```

```
****
```

```
/nopr
```

```
/inp,frh,temp
```

```
/inp,bkh,temp
```

```
/gopr
```



```

nsub,3,10,2
solv

```

```
time,3+2.125+fhrt*365*i
```

```
****
```

```
**** First of two steps to 210F
```

```
****
```

```
/nopr
```

```
/inp,frh1,temp
```

```
/inp,bkh1,temp
```

```
/gopr
```

```
nsub,20,100,6
```

```
solv
```

```
time,3+4.25+fhrt*365*i
```

```
****
```

```
**** Second of two steps to 210F
```

```
****
```

```
/nopr
```

```
/inp,frh2,temp
```

```
/inp,bkh2,temp
```

```
/gopr
```

```
nsub,20,100,6
```

```
solv
```

```
time,3+23+365*i
```

```
****
```

```
**** 210F
```

```
****
```

```
/nopr
```

```
/inp,frss,temp
```

```
/inp,bkss,temp
```

```
/gopr
```

```
nsub,150,1000,10
```

```
solv
```

```
time,3+38+365*i
```

```
****
```

```
**** Steady state @ 210F
```

```
****
```

```
/nopr
```

```
/inp,frss1,temp
```

```
/inp,bkss1,temp
```

```
/gopr
```

```
nsub,150,1000,30
```

```
solv
```

```
time,3+351+365*i
```

```
****
```

```
**** Creep for 1 Year
```

```
****
```

```
nsub,300,10000,6
```

```
solv
```

```
**** Cool to ambient
```

```
time,3+351+2.125+365*i
```

```
****
```

```
**** First of two steps to 125F
```

```
****
```

```
/nopr
```

```
/inp,fr1,temp
```

```
/inp,bkc1,temp
```

```
/gopr
```

```
nsub,15,200,5
```

```
solv
```

```

time,3+351+4.25+365*i
****
**** Second of two steps to 125F
****
/nopr
/inp,frc2,temp
/inp,bkc2,temp
/gopr
nsub,15,200,5
solv

time,3+351+4.25+fhrt+365*i
****
**** Fast cool down to 50F
****
/nopr
/inp,frc3,temp
/inp,bkc3,temp
/gopr
nsub,7,100,3
solv

time,3+351+4.25+fhrt+1+365*i
****
**** Tank cool down transient to 50F
****
/nopr
/inp,frc4,temp
/inp,bkc4,temp
/gopr
nsub,5,100,2
solv

```

```

time,3+365+365*i
****
**** Uniform 50F
****
nsub,47,150,20
bf,all,temp,50
save
solv

*enddo

```

! End of 60 Year Thermal Cycles with 460" waste height
from 20 years

C.2.3 ACI Load Factors

Input file: set_sliced6a.inp

```

****
**** Load factors 12/19/06
**** 1.4 g
**** 1.4 pressures
**** 1.4 waste
**** 1.83*1.4 soil density
**** 1.7 distributed & concentrated load
****

/fil,set_slice_0
resu

/sol
anty,,rest

****

```

!***

time,365*61+4

nsub,10,100,5

acel,,1.4

pres_surf=40*1.7 !ground surface uniform pressure

psf

point_cent=200000*1.7 !point load at center lb

pres_annulus=-20*1.4 !annulus pressure inches h2o

pres_int=-12*1.4 !annulus internal pressure inches

h2o

hwaste=35.17*12 !total waste height

height_waste1=hwaste/3 !height of waste 1 inches

gamma_waste1=1.83*1.4 !specific gravity of waste 1

height_waste2=hwaste/3 !height of waste 2 inches

gamma_waste2=1.83*1.4 !specific gravity of waste 2

height_waste3=hwaste/3 !height of waste 3 inches

gamma_waste3=1.83*1.4 !specific gravity of waste 3

/inp,apply_loads_slice,mac

!***

!*** mpch to change density of soils

!***

*do,i,1,16

esel,,mat,,100+i

mpch,150+i,all

*enddo

*do,i,1,8

esel,,mat,,120+i

mpch,170+i,all

*enddo

esel,all

save

solv

Input file: set_slice.inp

!***

!*** Year 60 10/19/06 1.4D+1.7L+1.05T

!*** Adjust mpch (new SS temps) & Day 48 Steady State

6/8/04

!*** Adjust substeps 6/7/04

!*** 2 year thermal cycle *****inp modified*****5/19/04

!*** multiple heating and cooling load steps

!***

/fil,set_slice_0

resu

/sol

anty,,rest

!*** Thermal load - Initial ramp

!***

fhr=7.5/24

time,3+flut+365*60+1

!***

!*** Fast heat to 125F

!***

/nopr

/inp,fhr,temp

/inp,bkh,temp

/gopr

```
bfsc,temp,1.05,50
nsub,3,10,2
solv
```

```
time,3+2.125+flrt*365*60+1
```

```
!***
```

```
!*** First of two steps to 210F
```

```
!***
```

```
/nopr
```

```
/inp,frh1,temp
```

```
/inp,bkh1,temp
```

```
/gopr
```

```
bfsc,temp,1.05,50
```

```
nsub,20,100,6
```

```
solv
```

```
time,3+4.25+flrt+365*60+1
```

```
!***
```

```
!*** Second of two steps to 210F
```

```
!***
```

```
/nopr
```

```
/inp,frh2,temp
```

```
/inp,bkh2,temp
```

```
/gopr
```

```
bfsc,temp,1.05,50
```

```
nsub,20,100,6
```

```
solv
```

```
time,3+23+365*60+1
```

```
!***
```

```
!*** 210F
```

```
!***
```

```
/nopr
```

```
/inp,frss,temp
```

```
/inp,bkss,temp
```

```
/gopr
```

```
bfsc,temp,1.05,50
```

```
nsub,180,2000,40
```

```
solv
```

```
time,3+38+365*60+1
```

```
!***
```

```
!*** Steady state @ 210F
```

```
!***
```

```
/nopr
```

```
/inp,frss1,temp
```

```
/inp,bkss1,temp
```

```
/gopr
```

```
bfsc,temp,1.05,50
```

```
nsub,150,1000,25
```

```
solv
```

```
!*** Hold for 1 Year
```

```
time,354+365*60+1
```

```
nsub,300,10000,6
```

```
solv
```

```
!*** Cool to ambient
```

```
time,3+351+2.125+365*60+1
```

```
!***
```

```
!*** First of two steps to 125F
```

```
!***
```

```

/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr
bfsc,temp,1.05,50
nsub,15,200,5
solv

time,3+351+4.25+365*60+1
!***
!*** Second of two steps to 125F
!***
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr
bfsc,temp,1.05,50
nsub,15,200,5
solv

time,3+351+4.25+flut+365*60+1
!***
!*** Fast cool down to 50F
!***
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr
bfsc,temp,1.05,50
nsub,7,100,3
solv

time,3+351+4.25+flut+1+365*60+1

```

```

!***
!*** Tank cool down transient to 50F
!***
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr
bfsc,temp,1.05,50
nsub,5,100,2
solv

time,3+365+365*60+1
!***
!*** Uniform 50F
!***
nsub,47,150,20
bf,all,temp,50
save
solv

```

C.3 Lower Bound Soil Model Input Files

There is only one input file that is unique to the Lower Bound Soil analysis. It is listed below.

Input file: set_parms.mac

```

!***
!*** Low Bound soil properties 7/14/04
!***
!*** Run 2, Load Case 1 - 4
!*** (8.3' soil, 125 lb/ft3)
!*** (0.06" primary tank corrosion)
!*** 4/16/03

```

```

!***
!***
!*** JED mods 3/20/03
!*** add clr - concentrated load radius
!*** add backfill properties 3/24
!*** backfill properties f(depth) 4/1

```

```

finish
/clear
/fil,pnnla
/prop7
/titl,5% K; low soil E, high concrete E with no Creep"
!
! DST - AY

```

```

pi=acos(-1)

```

```

clr=10*12      !Concentrated load radius
or=12*41.5     !Outside radius concrete wall
ir=12*40       !Inside radius concrete wall
ir2=12*37.5    !Radius primary tank
icr=37*12+3    !Radius insulating concrete
h1=0
h2=-8.125
h3=381.5       !Height dome tangent (31'9-1/2")
h4=h3+70.875   !Height exterior corner (+ 5'10-7/8" =
37'8-3/8")
h5=h3+15*12    !Height interior center dome
h6=h5+15       !Height exterior center dome

covext=2       !Concrete cover - exterior dome
covint1=4      !Concrete cover - wall
covint2=1.5    !Concrete cover - interior dome

```

```

r1=105*12+.25  !Exterior dome radius - center
th1=7+(45+14/60)/60 !Angle at tangent of external radii
r2=74*12+4     !Exterior dome radius - outer
r3=3*12+8.375  !Radius primary tank to dome

```

! This file sets the values of all parameters that may be changed

! These were originally defined in define_soil_layers.mac:

```

overburden=8.3*12 !overburden height above dome apex (ft)
subdepth=168*12  !subgrade soil depth (ft)
totalwidth=240*12 !total soil width (radius) from tank
centerline to edge (ft)

```

! These were originally defined in dstay7.mac:

```

r50=1-.06      !shell thickness (in) (R1 of Figure 11 in RPP-
13990)
r51=3/8-.06    !shell thickness (in) (R2,R6,R7,R9 of Figure 11
in RPP-13990)
r52=7/8-.06    !shell thickness (in) (R3 of Figure 11 in RPP-
13990)
r53=3/4-.06    !shell thickness (in) (R4 of Figure 11 in RPP-
13990)
r54=1/2-.06    !shell thickness (in) (R5,R8 of Figure 11 in RPP-
13990)
r55=1/4        !shell thickness (in) (R10 of Figure 11 in RPP-
13990)

```

! This was originally defined in set_esys_3d.mac:

r56=3/8 !shell thickness (in) of secondary liner above 357.5 in

! These were originally defined in set_materials.mac:

! [1] steel (for liner, jbolts, studs, anchors, bearing plates)

steel_ex=27.7e6 !elastic modulus [psi]

steel_prxy=0.3 !Poisson ratio

steel_alpx=6.38 !thermal expansion

coefficient [microstrain/degree F]

steel_gamma=490 !unit weight [lb/ft^3]

steel_yield=36000 !yield strength [psi]

steel_tan=0.01 !rebar tangent modulus [%

of elastic modulus]

! [2] structural concrete

conc_ex=3.8e6 !elastic modulus [psi]

conc_prxy=0.15 !Poisson ratio

conc_alpx=3.7 !thermal expansion

coefficient [microstrain/degree F]

conc_gamma=145 !unit weight [lb/ft^3]

conc_open=0.1 !shear transfer coefficient for open crack

conc_closed=0.98 !shear transfer coefficient for closed

crack

conc_crush=3000 !uniaxial crushing stress

[psi]

conc_crack=0.1*conc_crush !tensile cracking stress [psi]

! [3] rebar

rebar_ex=29.0e6 !elastic modulus [psi]

rebar_prxy=0.3

!Poisson ratio

rebar_alpx=6.

!thermal expansion

coefficient [microstrain/degree F]

rebar_gamma=490

!unit weight [lb/ft^3]

rebar_yield=71000

!yield strength [psi]

rebar_tan=0

!rebar tangent modulus [psi]

! [4] insulating concrete

insul_ex=165e3

!elastic modulus [psi]

insul_prxy=0.15

!Poisson ratio

insul_alpx=3.7

!thermal expansion

coefficient [me/F]

insul_gamma=50

!unit weight [lb/ft^3]

insul_open=0.1

!shear transfer coefficient

for open crack

insul_closed=0.98

!shear transfer coefficient for closed

crack

insul_crush=200

!uniaxial crushing stress

[psi]

insul_crack=20

!tensile cracking stress [psi]

! [6] slab rebar

srebar_ex=29.0e6

!elastic modulus [psi]

srebar_prxy=0.3

!Poisson ratio

srebar_alpx=6.

!thermal expansion

coefficient [microstrain/degree F]

srebar_gamma=490

!unit weight [lb/ft^3]

srebar_yield=49000

!yield strength [psi]

srebar_tan=0

!rebar tangent modulus [psi]

!*** Backfill

! These were originally defined in define_loads.mac:

! [5] backfill soil

backfill_phi=34.5 !soil friction angle deg

backfill_dil=34.5 !backfill dilatancy angle deg

backfill_cte=0 !thermal expansion coef me/f

!*** No waste, pressures or ext. load

pres_surf=0 !ground surface uniform pressure

psf

point_cent=0 !point load at center lb

pres_annulus=0 !annulus pressure inches h2o

pres_int=0 !annulus internal pressure inches

h2o

hwaste=35.17*12 !total waste height

height_waste1=hwaste/3 !height of waste 1 inches

gamma_waste1=0 !specific gravity of waste 1

height_waste2=hwaste/3 !height of waste 2 inches

gamma_waste2=0 !specific gravity of waste 2

height_waste3=hwaste/3 !height of waste 3 inches

gamma_waste3=0 !specific gravity of waste 3

!define soil layers

*dim,soil_emod,,16

*dim,soil_pr,,16

*dim,soil_z0,,16

*dim,soil_z1,,16

*dim,bf_emod,,8

!*dim,bf_pr,,8

*dim,bf_z0,,8

*dim,bf_z1,,8

bfdinc=(h6+overburden+18.5)/8

sdinc=(subdepth+60)/8

*do,i,1,8

soil_z0(i)=i*bfdinc!vertical distance from surface

soil_z1(i)=(i-1)*bfdinc

soil_z0(i+8)=i*sdinc+bfdinc*8

soil_z1(i+8)=(i-1)*sdinc+bfdinc*8

bf_z0(i)=i*bfdinc

bf_z1(i)=(i-1)*bfdinc

*enddo

!Elastic modulus

soil_emod(1)=44000,46000,48711,51423,53833,56544,59255,6
1665,66835,75000

soil_emod(11)=78900,82851,87169,91403,95000,99000

bf_emod(1)=8000,10000,12864,15727,18273,21136,24000,260
00

!Poisson's ratio

soil_pr(1)=.24,.24,.24,.24,.19,.19,.19,.19,.19,.19

soil_pr(11)=.19,.19,.28,.28,.28,.28

bf_pr=.27

!*** Soil 110 pcf - undisturbed

!*** Soil 125 pcf - backfill/overburden

s_gam=110 !lb/ft³ density of soil layers
(excluding backfill)

b_gam=125 !lb/ft³ density of soil layers
(excluding backfill)

save

C.4 Upper Bound Soil Model Input Files

There is only one input file that is unique to the Upper Bound Soil analysis. It is listed below.

Input file: set_parms.mac

```
****
**** Upper bound soil 11/21/05
**** Best estimate soil properties 3/19/04
****
**** Run 2, Load Case 1 - 4
**** (8.3' soil, 125 lb/ft3)
**** (0.06" primary tank corrosion)
**** 4/16/03
****
****
**** JED mods 3/20/03
**** add clr - concentrated load radius
**** add backfill properties 3/24
**** backfill properties f(depth) 4/1

finish
/clear
/fil,pnnla
/prep7
/titl,Baseline, Upper Bound Soil
!
! DST - AY

pi=acos(-1)

clr=10*12      !Concentrated load radius
or=12*41.5     !Outside radius concrete wall
ir=12*40       !Inside radius concrete wall
ir2=12*37.5    !Radius primary tank
```

```
icr=37*12+3    !Radius insulating concrete
h1=0
h2=-8.125
h3=381.5       !Height dome tangent (31'9-1/2")
h4=h3+70.875   !Height exterior corner (+ 5'10-7/8" =
37'8-3/8")
h5=h3+15*12    !Height interior center dome
h6=h5+15       !Height exterior center dome

covext=2       !Concrete cover - exterior dome
covint1=4      !Concrete cover - wall
covint2=1.5    !Concrete cover - interior dome

r1=105*12+.25  !Exterior dome radius - center
th1=7+(45+14/60)*60 !Angle at tangent of external radii
r2=74*12+4     !Exterior dome radius - outer
r3=3*12+8.375  !Radius primary tank to dome

! This file sets the values of all parameters that may be changed

! These were originally defined in define_soil_layers.mac:

overburden=8.3*12 !overburden height above dome apex (ft)
subdepth=168*12  !subgrade soil depth (ft)
totalwidth=240*12 !total soil width (radius) from tank centerline
to edge (ft)

! These were originally defined in dstay7.mac:

r50=1-.06       !shell thickness (in) (R1 of Figure 11 in RPP-
13990)
```

r51=3/8-.06 !shell thickness (in) (R2,R6,R7,R9 of Figure 11 in RPP-13990)

r52=7/8-.06 !shell thickness (in) (R3 of Figure 11 in RPP-13990)

r53=3/4-.06 !shell thickness (in) (R4 of Figure 11 in RPP-13990)

r54=1/2-.06 !shell thickness (in) (R5,R8 of Figure 11 in RPP-13990)

r55=1/4 !shell thickness (in) (R10 of Figure 11 in RPP-13990)

! This was originally defined in set_esys_3d.mac:

r56=3/8 !shell thickness (in) of secondary liner above 357.5 in

! These were originally defined in set_materials.mac:

! [1] steel (for liner, jbolts, studs, anchors, bearing plates)
steel_ex=27.7e6 !elastic modulus [psi]
steel_pxy=0.3 !Poisson ratio
steel_alpx=6.38 !thermal expansion

coefficient [microstrain/degree F]

steel_gamma=490 !unit weight [lb/ft^3]
steel_yield=36000 !yield strength [psi]
steel_tan=0.01 !rebar tangent modulus [%
of elastic modulus]

! [2] structural concrete
conc_ex=3.8e6 !elastic modulus [psi]
conc_pxy=0.15 !Poisson ratio
conc_alpx=3.7 !thermal expansion
coefficient [microstrain/degree F]
conc_gamma=145 !unit weight [lb/ft^3]

conc_open=0.1 !shear transfer coefficient for open crack
conc_closed=0.98 !shear transfer coefficient for closed crack

conc_crush=3000 !uniaxial crushing stress [psi]

conc_crack=0.1*conc_crush !tensile cracking stress [psi]

! [3] rebar

rebar_ex=29.0e6 !elastic modulus [psi]

rebar_pxy=0.3 !Poisson ratio

rebar_alpx=6. !thermal expansion

coefficient [microstrain/degree F]

rebar_gamma=490 !unit weight [lb/ft^3]

rebar_yield=71000 !yield strength [psi]

rebar_tan=0 !rebar tangent modulus [psi]

! [4] insulating concrete

insul_ex=165e3 !elastic modulus [psi]

insul_pxy=0.15 !Poisson ratio

insul_alpx=3.7 !thermal expansion coefficient

[me/F]

insul_gamma=50 !unit weight [lb/ft^3]

insul_open=0.1 !shear transfer coefficient for open crack

insul_closed=0.98 !shear transfer coefficient for closed crack

insul_crush=200 !uniaxial crushing stress [psi]

insul_crack=20 !tensile cracking stress [psi]

! [6] slab rebar

srebar_ex=29.0e6 !elastic modulus [psi]

srebar_pxy=0.3 !Poisson ratio

```

srebar_alpx=6.          !thermal expansion coefficient
[microstrain/degree F]
srebar_gamma=490        !unit weight [lb/ft^3]
srebar_yield=49000       !yield strength [psi]
srebar_tan=0            !rebar tangent modulus [psi]

!*** Backfill
! These were originally defined in define_loads.mac:
! [5]      backfill soil
backfill_phi=34.5       !soil friction angle deg
backfill_dil=34.5       !backfill dilatancy angle deg
backfill_cte=0          !thermal expansion coef me/f

!*** No waste, pressures or ext. load
pres_surf=0             !ground surface uniform pressure
psf
point_cent=0            !point load at center lb
pres_annulus=0          !annulus pressure inches h2o
pres_int=0              !annulus internal pressure inches
h2o
hwaste=35.17*12         !total waste height
height_waste1=hwaste/3  !height of waste 1 inches
gamma_waste1=0          !specific gravity of waste 1
height_waste2=hwaste/3  !height of waste 2 inches
gamma_waste2=0          !specific gravity of waste 2
height_waste3=hwaste/3  !height of waste 3 inches
gamma_waste3=0          !specific gravity of waste 3

!define soil layers
*dim,soil_emod,,16
*dim,soil_pr,,16

```

```

*dim,soil_z0,,16
*dim,soil_z1,,16
*dim,bf_emod,,8
!*dim,bf_pr,,8
*dim,bf_z0,,8
*dim,bf_z1,,8
bfdinc=(h6+overburden+18.5)/8
sdinc=(subdepth+60)/8

*do,i,1,8
soil_z0(i)=i*bfdinc !vertical distance from surface
soil_z1(i)=(i-1)*bfdinc
soil_z0(i+8)=i*sdinc+bfdinc*8
soil_z1(i+8)=(i-1)*sdinc+bfdinc*8
bf_z0(i)=i*bfdinc
bf_z1(i)=(i-1)*bfdinc
*enddo

!Elastic modulus
soil_emod(1)=75000,78000,80524,83049,85292,87817,90341,92
585,97398,105000
soil_emod(11)=140494,176448,215742,254268,287000,315000
bf_emod(1)=16000,20000,26136,32273,37727,43864,50000,540
00

!Poisson's ratio
soil_pr(1)=.24,.24,.24,.24,.19,.19,.19,.19,.19,.19
soil_pr(11)=.19,.19,.28,.28,.28,.28
bf_pr=.27

!*** Soil 110 pcf - undisturbed
!*** Soil 125 pcf - backfill/overburden

```

```

s_gam=110          !lb/ft^3 density of soil layers
(excluding backfill)
b_gam=125          !lb/ft^3 density of soil layers
(excluding backfill)

save

```

C.5 Modified Anchor Bolt Files

Input file: set_slicea.mac

```

!*** Secant modulus anchor bolt springs      8/8/07
!*** Stiff anchor bolt springs      8/6/07
!*** AP 210F, Waste Height=422 SpG =1.83 for 20 years
10/11/2006
!*** AP 210F, Waste Height=460 SpG =1.83 for 40 years
10/11/2006

!*** AP modifications 8/9/04
!*** Liquid level 460", SpG 1.83      8/11/04
!*** Liquid level 460", SpG 2.0      7/26/04
!*** Liquid level 460", SpG 1.7      7/19/04
!*** 2nd liner extension 0.25 thick      7/21/04
!*** 2nd liner extension contact <> concrete 7/21/04
!*** Augmented stiffness 5% Econc (350) 7/19/04
!*** 5% pivot, bcso,mmd      6/25/04
!*** Use nsub      6/24/04
!*** cnvtol,f(m),.005,0      6/16/04
!*** Augmented stiffness 2% Econc (350) 6/14/04
!*** Augmented stiffness 30000 6/11/04
!*** 6/10/04 changes
!*** Do not merge insulating concrete <> 2nd liner @ OD of
concrete
!*** Add 1st radius element to contact of 1st liner <> ins conc

```

```

!*** Add contact 2nd liner <> slab concrete
!*** Correct node select for type,61 real,70 6/9/04
!*** Reorient Beam188 on z/= 0 face
!*** Fix Liner-Dome common nodes 5/6/04
!*** Delete "j-bolts" in wall 5/6/04
!*** Move j-bolt real definition to pmula6.mac 3/30/04
!*** Changed Liner Coupling per J. Deibler 3/29/04
!*** Augmented stiffness 15000 3/24/04
!*** Default convergence criteria 3/22/04
!*** Best estimate soil properties 3/19/04
!*** Soil-Concrete - 5 regions 2/23/04
!*** Correct Drucker-Prager - soil
!*** Correct mat,1 temperature dependent modulus
!*** Replace shell64 with shell181
!*** Primary tank pressure -12" H2O (was -6)
!*** 125 pcf overburden, 110 pcf undisturbed soil
!*** 10/30/03
!*** Define additional soils for load factor restart
!*** No cracking insulating concrete
!*** fix mpch (esel,r,mat,,2)
!*** 1 yr + 15 day creep 5/14/03
!*** Load step 5 creep for 330 days
!*** New load step 6 => mpch +5 days
!*** "sets" degraded concrete properties
!***
!*** Turn off concrete crushing 5/5/03
!***
!*** Run 2, Load Step 1, 2 & thermal
!*** (8.3' soil, 125 lb/ft3)
!*** (0.06" primary tank corrosion wall, floor)
!*** 4/16/03
!***
!***

```

```
!*** JED mods 3/29/03
!***
```

```
i_rebuild=1
*if,i_rebuild,eq,1,then
  pnnla
  pnnla2
  pnnla3
  pnnla4
  pnnla5
  pnnla6
  pnnla7
  pnnla8
  pnnla9
*else
  resume,pnnla9,db
*endif
```

```
/prep7
```

```
allsel
cpdele,all,all
```

```
!get misc area components for applying loads, etc.
/input,set_areas_slice,mac
```

```
!add steel plate below wall (on slab)
r,45,1/4
csys,22
vsel,s,mat,,2
aslv
asel,r,loc,z,-8.125
asel,r,loc,x,480,498
```

```
aatt,1,45,22
mat,1
real,45
amesh,all
```

```
!define contact elements (all have default friction of 0.3)
et,60,170
et,61,173
mp,mu,61,,3          !Soil-concrete dome
,mu,62,.01
,mu,63,.01
,mu,64,.4
,mu,65,.3
,mu,66,.2
,mu,67,.05          !soil-concrete wall
,mu,68,.3          !soil-concrete footing/top
,mu,69,.05          !soil-concrete footing/side
,mu,70,.6          !soil-concrete foundation
,mu,71,.4          !2nd liner-insulating concrete 6/10/04
```

```
!soil_concrete contact - dome
r,61,,,1,.1
real,61
type,61
mat,61
cmset,s,aconc_soil
nsla,,1
nset,r,loc,z,452,600
esln
esurf
type,60
cmset,s,asoil
nsla,,1
```

```

nsl,r,loc,z,452,600
esln
esurf

```

```
!soil_concrete contact - wall
```

```

r,67,,,1,.1
real,67
type,61
mat,67
cmset,s,aconc_soil
nsla,,1
nsl,r,loc,z,-3,453
esln
esurf
type,60
cmset,s,asoil
nsla,,1
nsl,r,loc,z,-3,453
esln
esurf

```

```
!soil_concrete contact - Footing - top
```

```

r,68,,,1,.1
real,68
type,61
mat,68
cmset,s,aconc_soil
nsla,,1
nsl,r,loc,z,-7,-6
esln
esurf
type,60
cmset,s,asoil

```

```

nsla,,1
nsl,r,loc,z,-7,-6
,r,loc,x,496,530
esln
esurf

```

```
!soil_concrete contact - Footing - side
```

```

r,69,,,1,.1
real,69
type,61
mat,69
cmset,s,aconc_soil
nsla,,1
nsl,r,loc,x,531
esln
esurf
type,60
cmset,s,asoil
nsla,,1
nsl,r,loc,x,531
esln
esurf

```

```
!soil_concrete contact - Foundation
```

```

r,70,,,1,.1
real,70
type,61
mat,70
cmset,s,aconc_soil
nsla,,1
nsl,r,loc,z,-31,-30
,r,loc,x,440,531
cm,foundconc,node

```



```

nsla,,1
nsl,r,loc,x,,440
,r,loc,z,-33,-8      !** was -32 6/9/04
cmse,a,foundconc
esln
esurf
type,60
cmse,s,asoil
nsla,,1
nsl,r,loc,z,-31,-30
,r,loc,x,440,531
cm,foundsoil,node
nsla,,1
nsl,r,loc,x,,440
,r,loc,z,-33,-8
cmse,a,foundsoil
esln
esurf

!secondary liner contact
r,62,,,1,,1
real,62
type,60
mat,62
cmse,s,aconc_shell
csys,0
asel,u,loc,y,459,99999
nsla,,1
esln
esel,r,mat,,2
esurf
type,61
cmse,s,area_secon

```

```

csys,0
asel,u,loc,y,-99999,3.87
nsla,,1
esln
esurf

!primary liner contact with dome
r,63,,,1,,1
real,63
type,60
mat,63
cmse,s,aconc_shell
asel,r,loc,y,459,99999
nsla,,1
esln
esel,r,mat,,2
esurf
type,61
cmse,s,area_prim
asel,r,loc,y,459,99999
nsla,,1
esln
esurf

!primary liner contact with insulating concrete
r,64,,,1,,1
real,64
type,60
mat,64
cmse,s,area_insul_top
nsla,,1
esln
esel,r,mat,,4

```

```

esurf
type,61
cmse,s,area_prim
csys,0
asel,r,loc,y,0
nsla,,1
esln
nsle !*6/10/04
esurf

```

```

!secondary liner contact with foundation concrete 6/10/04
r,71,,,1,,1
real,71
type,60
mat,71
cmse,,slab_top
asel,r,loc,x,-480,-440
nsla,,1
esln
esur
type,61
cmse,,area_secon
asel,r,loc,x,-470,-440
,r,loc,y,-9,-8
nsla,,1
esln
nsle
esur

```

```

!merge insulating concrete bottom nodes and secondary liner nodes
cmse,s,area_insul_bot
cmse,a,area_secon
csys,0

```

```

asel,u,loc,y,20,9999
nsla,,1
cpintf,uz,,1

```

```

!slab top/insulating concrete
r,65,,,1,,1
real,65
type,60
mat,65
cmse,s,slab_top
nsla,,1
esln
esurf
type,61
cmse,s,area_insul_bot
nsla,,1
esln
esurf

```

```

!wall/slab contact
r,66,,,1,,1
real,66
type,60
mat,66
asel,,,986,992
cm,slab_top_wall,area
nsla,,1
esln
cse1,r,mat,,2
esurf
type,61
asel,,,214
,a,,,706

```

```
,a,,913,918,5
,a,,934
cm,wall_bot,area
nsla,1
esln
esel,r,mat,,2
esurf
```

```
allsel
!esel,s,type,,60
!nsle
!nummrg,node
!nummrg,elem
!esel,s,type,,61
!nsle
!nummrg,elem
```

```
max_mat=100
max_real=1000
```

```
!define the local coordinate systems and rebar orientations
/input,set_esys_3d,mac
```

```
!apply loads
/input,apply_loads_slice,mac
allsel
```

```
!apply axisymmetric boundary conditions
csys,22
nsl,s,loc,y,180
nsl,a,loc,y,180+swp_th-.001,183
csys,0
nsl,a,loc,x,0
```

```
d,all,uy,0
d,all,rotx,0
d,all,rotz,0
allsel
```

```
nsl,s,loc,x,0
d,all,roty,0
```

```
!merge liner/concrete nodes at dome centerline
ksel,s,,2
ksel,a,,329
nslk
nummrg,node
allsel
```

```
!copy jbolts, etc for slice model
csys,22
esel,s,type,,20,21
cm,e_bolt0,elem
egen,2,500000,all,,0,0,0,0,,swp_th
esel,s,mat,,1
esel,u,real,,45
nsle
nsl,u,,22789,22790 **** 5/6/04
,u,,20260,20261 **** 6/10/04
nummrg,node
```

```
!divide jbolt/bottom anchors properties by 2 for slice model
r,30,.19635/2,.3068e-2/2,.3068e-2/2,.5,.5
```

```
esel,s,type,,20,21
cmset,u,e_bolt0
nsle
```

```

nsl,r,,,500000,999999
cm,ntemp,node

vsel,s,mat,,2
vsel,a,mat,,6
csys,0
vsel,u,loc,y,-9999,-8.12
cm,vtemp,volu
*get,nv,volu,,count
*do,i,1,nv
  *get,iv,volu,,num,min
  eslv
  nsle
  cmsel,a,ntemp
  nummrg,node
  cm,ntemp,node
  cmsel,s,vtemp
  vsel,u,,,iv
  cm,vtemp,volu
*enddo

!***
!*** Delete primary-secondary tank coupling at tangent
!*** JED 3/31/03
!***

r,41,3/16      !insulating concrete confining ring thickness

/prep7

esel,s,mat,,5
nsle,,1
csys,0

```

```

*get,top_elev,node,,mxloc,y
cm,soil_elem,elem

*do,i,1,16
  set_slayer,soil_z0(i),soil_z1(i),soil_emod(i),soil_pr(i)
*enddo

max_mat=100
!set backfill/overburden material
*do,i,1,8
  set_backfill,bf_z0(i),bf_z1(i),bf_emod(i),bf_pr
*enddo

!Don't do this!! 5/6/04
!make sure anchors/jbolts/studs etc are merged with concrete
!esel,,type,,12,13
!,a,type,,20,21
!,a,type,,24,25
!nsle
!nsl,u,,,22789,22790   !*** 3/26/04
!numm,node

!***
!*** Augmented Stiffness 2/27/04
!***

et,32,45
*get,ec350,ex,2,temp,350
mp,ex,12,ec350*0.05      17/19/04
,prxy,12,,15
esel,,type,,12,15
egen,2,0,all,,,10
esel,,mat,,12
emod,all,type,32

```

```

****
**** Use springs for anchor bolts 8/9/07
****

alls
csys
et,35,40,,,2          !Anchor bolt axial
,36,40,,,1            !Anchor bolt shear
r,21,29e6*(pi*.5**2/4)/6      !Axial stiffness
*do,i,1,18
r,i,i*24*2*pi/24*swp_th/360*65000/2
*enddo

csys,11
nse1,,loc,x,480-.5,480+.5
cm,anch,node
loca,99,,,,,,swp_th
csys
*do,i,1,15
cmse,,anch
csys
nse1,r,loc,z
,r,loc,x,-i*24-1.5,-i*24+1.5
type,35
real,21
drot=atan(-nx(ndnext(1))*180/480/(480**2-nx(ndnext(1))**2)**.5)
loca,50+i,,nx(ndnext(1)),ny(ndnext(1)),,drot
nrot,all
e,ndnext(0),ndnext(ndnext(0))
type,36
real,i
e,ndnext(0),ndnext(ndnext(0))

*enddo
*do,i,16,18
cmse,,anch
csys
nse1,r,loc,z
,r,loc,x,-i*24-1.5,-i*24+1.5
type,35
real,21
drot=atan(-nx(ndnext(1))*180/480/(480**2-nx(ndnext(1))**2)**.5)
loca,50+i,,nx(ndnext(1)),ny(ndnext(1)),,drot
nrot,all
e,ndnext(0),ndnext(ndnext(0))
type,36
real,i
e,ndnext(0),ndnext(ndnext(0))

*enddo
*do,i,16,18
cmse,,anch
csys
nse1,r,loc,z
,r,loc,x,-i*24-1.5,-i*24+1.5
type,35
real,21
drot=atan(-nx(ndnext(1))*180/480/(480**2-nx(ndnext(1))**2)**.5)
loca,50+i,,nx(ndnext(1)),ny(ndnext(1)),,drot
nrot,all
e,ndnext(0),ndnext(ndnext(0))
type,36
real,i
e,ndnext(0),ndnext(ndnext(0))

*enddo
*do,i,16,18
cmse,,anch
csys
nse1,u,loc,z
,r,loc,x,-i*24-1.4,-i*24+1.5
type,35
real,21
drot=atan(-nx(ndnext(1))*180/480/(480**2-nx(ndnext(1))**2)**.5)
csys,99
cloc,70+i,,nx(ndnext(1)),ny(ndnext(1)),,drot
nrot,all
e,ndnext(0),ndnext(ndnext(0))
type,36
real,i
e,ndnext(0),ndnext(ndnext(0))

*enddo
*do,i,16,18

```

```

cmse,,anob
csys
nse1,u,loc,z
,r,loc,x,-i*24,-i*24+2
type,35
real,21
drot=atan(-nx(ndnext(1))*180/480/(480**2-nx(ndnext(1))**2)**.5)
csys,99
cloc,70+i,,nx(ndnext(1)),ny(ndnext(1)),,drot
nrot,all
e,ndnext(0),ndnext(ndnext(0))
type,36
real,i
e,ndnext(0),ndnext(ndnext(0))
*enddo
**** Fix BC
esel,,type,,35
nsle
ddel,all,all
d,all,uz
,all,rotx
,all,roty
allsel

**** 2nd liner extension issues 7/21/04
asel,,,928,,,1
egen,2,100000,all,,,,4,,,0,0,0
modm,nocheck
alls
emod,15784,-1,114183,104465
,15955,-3,104465,114183
,28878,-3,104465,114183
acle,928

```

```

real,62
type,60
mat,62
asel,,,928,,,1
esln
esel,r,type,,12
esurf
type,61
esel,,type,,23
,r,real,,45
nsle
esurf
dsym,sym,y,5
alls

**** AP modifications 8/9/04
**** Thickness from set_parms.mac
!* r50=1-.06 !shell thickness (in) (R1 of Figure 11 in RPP-
13990)
!* r51=3/8-.06 !shell thickness (in) (R2,R6,R7,R9 of Figure 11 in
RPP-13990)
!* r52=7/8-.06 !shell thickness (in) (R3 of Figure 11 in RPP-
13990)
!* r53=3/4-.06 !shell thickness (in) (R4 of Figure 11 in RPP-
13990)
!* r54=1/2-.06 !shell thickness (in) (R5,R8 of Figure 11 in RPP-
13990)
!* r55=1/4 !shell thickness (in) (R10 of Figure 11 in RPP-13990)
!* r56=3/8 !shell thickness (in) of secondary liner above 357.5 in

**** Additional liner thickness
r,57,9/16-.06
,58,15/16-.06

```

!*** Redefine secondary liner thickness

r,55,3/8

,56,1/2

,59,9/16

!*** Primary liner

csys

esel,,real,,51

nsle

nsel,r,loc,y,380,468.5

esln,,1

esel,r,real,,51

emod,all,real,54

esel,,real,,54

nsle

nsel,r,loc,y,142,238

esln,,1

esel,r,real,,54

emod,all,real,57

esel,,real,,52

nsle

nsel,r,loc,y,,12

,r,loc,x,-450,-437

esln,,1

esel,r,real,,52

emod,all,real,58

esel,,real,,51

nsle

nsel,r,loc,y,-1,1

esln,,1

esel,r,real,,51

emod,all,real,54

!*** Secondary liner

esel,,real,,55,56

nsle

nsel,r,loc,y,24,460

esln,,1

esel,r,real,,55,56

emod,all,real,55

esel,,real,,55

nsle

nsel,r,loc,y,3.875,24

esln,,1

esel,r,real,,55

emod,all,real,56

esel,,real,,55

nsle

nsel,r,loc,y,-9,3.875

,r,loc,x,-480,-467

esln,,1

esel,r,real,,55

emod,all,real,59

esel,,real,,55

nsle

nsel,r,loc,x,-468,-420

esln,,1

esel,r,real,,55

emod,all,real,56

!***

!*** Temperatures

!*** Uniform 80F (8/29/07)

!***

tref,80

tunif,80


```

finish
/filnam,set_slice_0
/sol
!solcontrol,off
neqit,50
time,1
nlgeom,on
nrop,unsym
cmvt,f,,.005,0      !6/16/04
,m,,.005,0      !6/16/04
crpl,.05
nsub,10,100,5
!delt,.1,.01,.2
!outres,all,all
!nrre,on,250
eqsl,sparse,.05,-1
bcs0,mmd
allsel
save
solve

time,2
!***
!*** Add waste and pressure loads
!***
pres_surf=0          !ground surface uniform pressure
psf
point_cent=0          !point load at center lb
pres_annulus=-20      !annulus pressure inches
h2o
pres_int=-12          !annulus internal pressure
inches h2o
hwaste=422            !total waste height

```

```

height_waste1=hwaste/3      !height of waste 1
inches
gamma_waste1=1.83           !specific gravity of waste 1
height_waste2=hwaste/3      !height of waste 2
inches
gamma_waste2=1.83           !specific gravity of waste 2
height_waste3=hwaste/3      !height of waste 3
inches
gamma_waste3=1.83           !specific gravity of waste 3

/inp,apply_loads_slice,mac

delt,.1,.01,.25
solv

time,3
!***
!*** Add surface loads
!***
pres_surf=40            !ground surface uniform
pressure psf
point_cent=200000        !point load at center lb
pres_annulus=-20        !annulus pressure inches
h2o
pres_int=-12            !annulus internal pressure
inches h2o
hwaste=422              !total waste height
height_waste1=hwaste/3   !height of waste 1
inches
gamma_waste1=1.83        !specific gravity of waste 1
height_waste2=hwaste/3   !height of waste 2
inches
gamma_waste2=1.83        !specific gravity of waste 2

```

```

height_waste3=hwaste/3           !height of waste 3
inches
gamma_waste3=1.83                 !specific gravity of waste 3

/inp,apply_loads_slice,mac

save
solv

Input file: set_slice7.mac
!Removed temperature scaling NK 11/29/2007

/fil,set_slice_0
resu
/titl,AP, secant modulus, 80-150F

/sol
anty,,rcst

time,18          !LS 4
!*** Intermediate heating step
/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr

delt,.5,.01,2
solv

time,33          !LS 5
!*** Steady state @ 150F
/nopr
/inp,frss,temp

```

```

/inp,bkss,temp
/gopr

delt,.5,.01,2
solv

time,358          !LS 6
!*** Hold for 1 Year
delt,.5,.01,150
solv

time,363          !LS 7
!*** Intermediate cooling step
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr

delt,.5,.01,2
solv

time,368          !LS 8
!*** Uniform 80F
bf,all,temp,80
delt,.5,.01,2
solv

!*** Cycle once

time,383          !LS 9
!*** Intermediate heating step
/nopr
/inp,frh1,temp

```

```

/inp,bkh1,temp
/gopr

delt,.5,.01,2
solv

time,3+30+365      !LS 10
!***
!*** Steady state @ 150F
!***
/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr

delt,.5,.01,2
solv

time,358+365      !LS 11
!***
!*** Creep for 1 Year
!***
delt,.5,.01,150
solv

time,363+365      !LS 12
!*** Intermediate cooling step
/nopr
/inp,frs1,temp
/inp,bks1,temp
/gopr

delt,.5,.01,2

```

```

solv

!*** Cool to ambient

time,3+365+365      !LS 13
!***
!*** Uniform 80F
!***
bf,all,temp,80
delt,.5,.01,2
save
solv

time,383+365      !LS 14
!*** Intermediate heating step
/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr

delt,.5,.01,2
solv

time,3+30+730      !LS 15
!***
!*** Steady state @ 150F
!***
/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr

delt,.5,.01,2

```

solv

time,358+19*365 !LS 16

!***

!*** Creep for 18 Years

!***

delt,.5,.01,1000

solv

time,363+19*365 !LS 17

!*** Intermediate cooling step

/nopr

/inp,frc1,temp

/inp,bkc1,temp

/gopr

delt,.5,.01,2

solv

!*** Cool to ambient

time,3+20*365 !LS 18

!***

!**** Uniform 80F

!***

bf,all,temp,80

delt,.5,.01,2

save

solv

Input file: set_sliceb8.mac

! Increase waste to 460"

/fil,set_slice_0

resu

/sol

anty,,rest

time,365*20+1

!***

!*** Add waste, pressure and surface loads

!***

pres_surf=40

!ground surface uniform

pressure psf

point_cent=200000

!point load at center lb

pres_annulus=-20

!annulus pressure inches

h2o

pres_int=-12

!annulus internal pressure

inches h2o

hwaste=460

!total waste height

height_waste1=hwaste/3

!height of waste 1

inches

gamma_waste1=1.83

!specific gravity of waste 1

height_waste2=hwaste/3

!height of waste 2

inches

gamma_waste2=1.83

!specific gravity of waste 2

height_waste3=hwaste/3

!height of waste 3

inches

gamma_waste3=1.83

!specific gravity of waste 3

/inp,apply_loads_slice,mac

solv

time,365*20+15

!LS 19

!*** Intermediate heating step

```

/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr

```

```

delt,.5,.01,2
solv

```

```

time,20*265+30          !LS 20
!*** Steady state @ 135F

```

```

/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr

```

```

delt,.5,.01,2
solv

```

```

time,20*365+355          !LS 21
!*** Hold for 1 Year

```

```

delt,.5,.01,150
solv

```

```

time,20*365+360          !LS 22
!*** Intermediate cooling step

```

```

/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr

```

```

delt,.5,.01,2
solv

```

```

time,21*365              !LS 23

```

```

!*** Uniform 80F
bf,all,temp,80
delt,.5,.01,2
solv

```

```

!*** Cycle once

```

```

time,21*365+15           !LS 24
!*** Intermediate heating step

```

```

/nopr
/inp,frh1,temp
/inp,bkh1,temp
/gopr

```

```

delt,.5,.01,2
solv

```

```

time,30+21*365           !LS 25
!***

```

```

!*** Steady state @ 135F
!***

```

```

/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr

```

```

delt,.5,.01,2
solv

```

```

time,355+21*365          !LS 26
!***

```

```

!*** Creep for 1 Year

```

```

!***
delt,.5,.01,150
solv

time,360+21*365      !LS 27
!*** Intermediate cooling step
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr

delt,.5,.01,2
solv

!*** Cool to ambient

time,22*365          !LS 28
!***
!**** Uniform 80F
!***
bf,all,temp,80
delt,.5,.01,2
solv

time,22*365+15       !LS 29
!*** Intermediate heating step
/nopr
/inp,frhl,temp
/inp,bkhl,temp
/gopr

delt,.5,.01,2
solv

```

```

time,30+22*365      !LS 30
!***
!*** Steady state @ 135F
!***
/nopr
/inp,frss,temp
/inp,bkss,temp
/gopr

delt,.5,.01,2
solv

time,355+59*365     !LS 31
!***
!*** Creep for 38 Year
!***
delt,.5,.01,2000
solv

time,360+59*365     !LS 32
!*** Intermediate cooling step
/nopr
/inp,frcl,temp
/inp,bkcl,temp
/gopr

delt,.5,.01,2
solv

!**** Cool to ambient

time,60*365         !LS 33

```

```

!***
!**** Uniform 80F
!***
bf,all,temp,80
delt,5,.01,2
save
solv

```

C.6 Postprocessing Files

There are five postprocessing files associated with the ACI evaluation, the ASME evaluation of the primary and secondary liner, and the anchor bolts. They are listed below.

Input file: paci11.inp

```

!***
!*** ACI postprocessing
!*** 9/2/04 Automate for year 61
!*** 8/3/04 Delete section 64
!*** 1/15/04 Revised
!*** 9/8/03 Add 6 locations to foundation
!*** 9/4/03 Use pcal,intg for hoop direction
!*****
!*** 9/3/03 Add titles - change as necessary!!
!*****
!*** 8/23/03 (FSUM)
!***

*dim,dox,,15
dox(1)=30,61,90,120,152,183,210,237.5,270,304.5
dox(11)=314,334,354,368.9,390.2
*dim,thx,,9

```

```

thx(1)=146.6,148.9,152.0,154.91,158.75,163.9,168.1,172.35,176
.177
*dim,wh,,23
wh(1)=382.1,361.5,346.1,335,321,306,300,281,260.5,236
wh(11)=212.7,200,186.8,171,151.6,145.5,120.5,100.5,80,60
wh(21)=39.9,21,-4.5
*dim,dxx,,16
dxx(1)=514,503,489,477,461.5,440,421.4,390,358,338
dxx(11)=277.7,218.5,180,129.9,95.7,54

```

```

*do,m,138,147
set,m

```

```

*cfo,ls% m%,aci
*afun,deg
!*** Titles
tt1='Baseline'
tt2='Year 61'
tt3='ls% m%'
tt4a='40 psf uniform,'
tt4b='100 ton concentrated,'
tt4c='-20 in. annulus,'
tt4d='-6 in. vapor space'
!tt4d='None'
!tt5='1.4(D + F) + 1.7(L + H)'
tt5='None'
!*** Column headings
ct1='Section'
ct2=' shear'
ct3='F-merid '
ct4='M-merid '
ct5='F-hoop '
ct6='M-hoop '

```



```

ct7='Tmin '
ct8='Tmax '
ct9='Tave '
ct10='xbar '
ct11='ybar '
ct12='sect thk'
ttb=' '

*vwni,tt1
%c
*vwni,tt2
%c
*vwni,tt3
%c
*vwni,tt4a,tt4b,tt4c,tt4d
%c %c %c %c
*vwni,tt5
%c
*vwni,ttb
(a8)
*vwni,ttb
(a8)
*vwni,ct1,ct2,ct3,ct4,ct5,ct6,ct7,ct8,ct9,ct10,ct11,ct12
(12a8)
*vwni,ttb
(a8)

!***
!*** Dome

k=0

```

```

csys
esel,,type,,12,15
nsle

!*** Find center of outer arc
cdl=distkp(6,18)
cda=asin(cdl/(2*r2))
ctheta=atan((ky(6)-ky(18))/(kx(6)-kx(18)))
cgam=90-cda-ctheta
cdelx=r2*cos(cgam)
cdely=r2*sin(cgam)
orcirx=kx(18)+cdelx
orciry=ky(18)-cdely

*do,i,1,15
k=k+1
esel,,type,,12,15
nsle
csys
x1=dox(i)
thd1=acos(x1/480)
y1=h5-180+180*sin(thd1)
*if,i,le,5,then
thd1=asin(x1/(r1-15))
x2=r1*sin(thd1)
y2=h6-r1+r1*cos(thd1)
*else
thd1=atan((y1-orciry)/(x1+orcirx))
x2=r2*cos(thd1)-orcirx
y2=r2*sin(thd1)+orciry
thd1=90-thd1
*endif

```

```
path,sect %k%,2,,200
ppat,1,,-x1,y1
,2,,-x2,y2
```

```
nset,r,loc,y,400,599
loca,45,,-x1,y1,,thd1-90
nset,r,loc,y,-3,500
esln,,1
esel,r,type,,12,15
*if,i,eq,8,then
esel,a,,,8995
*elseif,i,eq,9,then
esel,a,,,9181
*elseif,i,eq,11,then
esel,a,,,9200
*elseif,i,eq,12,then
esel,a,,,8941
*elseif,i,eq,13,then
esel,a,,,8825
*elseif,i,eq,14,then
esel,a,,,8999
*endif
cm,upper,elem
```

```
pdef,temp,bfe,temp
pcalc,intg,itemp,temp,s
*get,delt,path,,last,s
```

```
nset,r,loc,y,-3,0
,r,loc,z
*if,i,eq,10,then
nset,u,,,2990
*endif
```

```
*get,ncount,node,,count
cm,sectn,node
slocxt=0
slocyt=0
secx=0
secy=0
csys
rsys
*do,j,1,ncount
ncur=ndnext(j)
slocxt=slocxt+nx(ncur)+ux(ncur)
slocyt=slocyt+ny(ncur)+uy(ncur)
secx=secx+nx(ncur)
secy=secy+ny(ncur)
nset,u,,,ncur
*enddo
rsys,45
slocx=slocxt/ncount
slocy=slocyt/ncount
xbar=-secx/ncount
ybar=secy/ncount
```

```
secw=xbar*swp_th/2*pi/180
cmse,,sectn
rsys,45
spoi,,slocx,slocy
fsum,rsys
*get,smeru,fsum,,item,fx
*get,pmceru,fsum,,item,fy
*get,nmeru,fsum,,item,mz
*get,tmin,path,,min,temp
*get,tmax,path,,max,temp
*get,ttoi,path,,last,itemp
```

```

esel,,type,,12,15
cmse,u,upper
fsum
*get,smerl,fsum,,item,fx
*get,pmerl,fsum,,item,fy
*get,mmerl,fsum,,item,mz
smer=(smeru-smerl)/2
pmer=(pmeru-pmerl)/2
mmer=(mmeru-mmerl)/2

!** Calculate hoop area
esln
esel,r,type,,12,15
*if,i,eq,8,then
esel,u,,,8996
*elseif,i,eq,9,then
esel,u,,,9182
*elseif,i,eq,10,then
esel,u,,,9203
*elseif,i,eq,11,then
esel,u,,,9199
*elseif,i,eq,12,then
esel,u,,,8942
*elseif,i,eq,13,then
esel,u,,,8824
*elseif,i,eq,14,then
esel,u,,,8998
*endif
nsle
nsel,r,loc,z
*get,ecount,elem,,count
hparea=0
*do,j,1,ecount

```

```

ecur=elnext(j)
hparea=hparea+arface(ecur)
esel,u,,,ecur
*enddo
hparea=hparea/2
hpw=hparea/delt

```

```

esel,,type,,12,15
cmse,,sectn
fsum,rsys
*get,php,fsum,,item,fz
*get,mhp,fsum,,item,my

```

```

tave=ttot/delt
smer=smer/secw*12/1000
pmer=pmer/secw*12/1000
mmer=-mmer/secw/1000
php=php/hpw*12/1000
mhp=mhp/hpw/1000

```

```

*vwi,k,smer,pmer,mmer,php,mhp,tmin,tmax,tave,xbar,ybar,delt
(11f8.1,f8.2)
*enddo

```

```

!*** Haunch

```

```

csys
esel,,type,,12,15
nsle

```

```

!**** Find center of outer arc
csys
cdl=distkp(6,18)

```

```

cda=asin(cdl/(2*r2))
ctheta=atan((ky(6)-ky(18))/(kx(6)-kx(18)))
cgam=90-cda-ctheta
cdelx=r2*cos(cgam)
cdely=r2*sin(cgam)
orcirx=kx(18)+cdelx
orciry=ky(18)-cdely

```

```

*do,i,1,9
k=k+1
esel,type,,12,15
nsle
csys
x1=480*cos(thx(i))
y1=480*sin(thx(i))*375+h3
*if,i,le,4,then
thd1=atan((y1-orciry)/(x1-orcirx))
x2=orcirx-r2*cos(thd1)
y2=orciry-r2*sin(thd1)
*elseif,i,eq,5,then
thd1=atan((y1-orciry)/(x1-orcirx))+5
x2=orcirx-r2*cos(thd1-4.85)
y2=orciry-r2*sin(thd1-4.85)
*elseif,i,eq,6,then
thd1=atan((y1-orciry)/(x1-orcirx))+11
x2=orcirx-r2*cos(thd1-10.5)
y2=orciry-r2*sin(thd1-10.5)
*elseif,i,eq,7,then
x2=-498
y2=427.6
thd1=atan((y2-y1)/(x2-x1))
*elseif,i,eq,8,then
x2=-498

```

```

y2=408.8
thd1=atan((y2-y1)/(x2-x1))
*else
x2=-498
y2=393.5
*endif

```

```

path,sect %%k%,2,,200
ppat,1,,x1,y1
,2,,x2,y2

```

```

nset,r,loc,y,380,599
loca,45,,x1,y1,thd1
nset,r,loc,y,-3,500
esln,,1
esel,r,type,,12,15
*if,i,eq,4,then
esel,u,,,8475
*elseif,i,eq,6,then
esel,a,,,9403,9434,31
,a,,,9480,9640,160
*elseif,i,eq,7,then
esel,u,,,9455
*endif
cm,upper,elem

```

```

rsys,45
pdef,temp,bfe,temp
pcalc,intg,itemp,temp,s
*get,delt,path,,last,s

```

```

nset,r,loc,y,-3,0
,r,loc,z

```

```

*if,i,eq,4,then
nse1,u,,,2692,2694,2
*elseif,i,eq,6,then
nse1,a,,,3807,3820,13
*elseif,i,eq,7,then
nse1,u,,,3822,3824,2
,u,,,2707
*endif
*get,ncount,node,,count
cm,sectn,node
slocxt=0
slocyt=0
secx=0
secy=0
csys
rsys
*do,j,1,ncount
ncur=ndnext(j)
slocxt=slocxt+nx(ncur)+ux(ncur)
slocyt=slocyt+ny(ncur)+uy(ncur)
secx=secx+nx(ncur)
secy=secy+ny(ncur)
nse1,u,,,ncur
*enddo
rsys,45
slocx=slocxt/ncount
slocy=slocyt/ncount
xbar=-secx/ncount
ybar=secy/ncount
cmse,,sectn

spoi,,slocx,slocy
fsum,rsys

```

```

!*** Sum moments about neutral axis
*if,k,gt,18,and,k,l1,23,then
*get,mzn,fsum,,item,mz
flag=1
*if,mzn,gt,0,then
flag=-1
*endif
*if,k,eq,19,then
slocx=slocx+flag*.85*cos(thd1)
slocy=slocy+flag*.85*sin(thd1)
*elseif,k,eq,20
slocx=slocx+flag*.8*cos(thd1)
slocy=slocy+flag*.8*sin(thd1)
*elseif,k,eq,21
slocx=slocx+flag*.82*cos(thd1)
slocy=slocy+flag*.82*sin(thd1)
*else
slocx=slocx+flag*.77*cos(thd1)
slocy=slocy+flag*.77*sin(thd1)
*endif
*endif
spoi,,slocx,slocy
fsum,rsys

*get,smeru,fsum,,item,fx
*get,pmeru,fsum,,item,fy
*get,mmeru,fsum,,item,mz
*get,tmin,path,,min,temp
*get,tmax,path,,max,temp
*get,ttot,path,,last,itemp
esel,,type,,12,15
cmse,u,upper
fsum

```

```

*get,smerl,fsum,,item,fx
*get,pmerl,fsum,,item,fy
*get,mmerl,fsum,,item,mz
smer=(smeru-smerl)/2
pmer=(pmeru-pmerl)/2
mmmer=(mmmeru-mmerl)/2

!*** Calculate hoop area
esln
esel,r,type,,12,15
*if,i,eq,4,then
esel,a,,,8478
*elseif,i,eq,6,then
esel,u,,,9378,9479,101
*endif
nsle
nsel,r,loc,z
*get,ecount,elem,,count
hparea=0
*do,j,1,ecount
ecur=elnext(j)
hparea=hparea+arface(ecur)
esel,u,,,ecur
*enddo
hparea=hparea/2
hpw=hparea/delt

esel,,type,,12,15
cmse,,sectn
fsum,rsys
*get,php,fsum,,item,fz
*get,mhp,fsum,,item,my

```

```

secw=xbar*swp_th/2*pi/180
tave=ttot/delt
smer=smer/secw*12/1000
pmer=pmer/secw*12/1000
mmmer=-mmmer/secw/1000
php=php/hpw*12/1000
mhp=mhp/hpw/1000

*vwri,k,smer,pmer,mmmer,php,mhp,tmin,tmax,tave,xbar,ybar,delt
(11f8.1,f8.2)
*enddo

!***
!*** Wall

csys
esel,,type,,12,15
nsle

*do,i,1,23
k=k+1
esel,,type,,12,15
,u,type,,14
nsle
csys
x1=-480
y1=wh(i)
x2=-498
y2=wh(i)

path,sect %k%,2,,200
ppat,1,,x1,y1
,2,,x2,y2

```

```

nse1,r,loc,y,h2,599
nse1,r,loc,y,wh(i)-3,599
esln,,1
esel,r,type,,12,15
*if,i,eq,2,then
esel,a,,,11133
*elseif,i,eq,3,then
esel,a,,,8559,11138,2579
*elseif,i,eq,4,then
esel,a,,,10972
*elseif,i,eq,8,then
esel,a,,,8590
*elseif,i,eq,9,then
esel,a,,,11091,11257,166
*elseif,i,eq,10,then
esel,a,,,8604,11098,2494
*elseif,i,eq,11,then
esel,a,,,11242
*elseif,i,eq,12,then
esel,a,,,11238
*elseif,i,eq,14,then
esel,a,,,11087,11229,142
*elseif,i,eq,15,then
esel,a,,,11156,11223,67
*elseif,i,eq,16,then
esel,a,,,11158,11221,63
*elseif,i,eq,17,then
esel,a,,,11213
*elseif,i,eq,18,then
esel,a,,,11173
*elseif,i,eq,19,then
esel,a,,,10931,11048,117

```

```

*elseif,i,eq,20,then
esel,a,,,11194
*endif
cm,upper,elem

```

```

rsys
pdef,temp,bfe,temp
pcalc,intg,itemp,temp,s
*get,delt,path,,last,s

```

```

nse1,r,loc,y,wh(i)-3,wh(i)
,r,loc,z
,r,loc,x,-498,-480
*get,ncount,node,,count
cm,sectn,node
slocxt=0
slocyt=0
secx=0
secy=0
csys
rsys
*do,j,1,ncount
ncur=ndnext(j)
slocxt=slocxt+nx(ncur)+ux(ncur)
slocyt=slocyt+ny(ncur)+uy(ncur)
secx=secx+nx(ncur)
secy=secy+ny(ncur)
nse1,u,,,ncur
*enddo
slocx=slocxt/ncount
slocy=slocyt/ncount
xbar=-secx/ncount
ybar=secy/ncount

```



```
cmse,,sectn
secw=xbar*swp_th/2*pi/180
```

```
spoi,,slocx,slocy
fsum,rsys
*get,smeru,fsum,,item,fx
*get,pmeru,fsum,,item,fy
*get,mmeru,fsum,,item,mz
*get,tmin,path,,min,temp
*get,tmax,path,,max,temp
*get,ttoi,path,,last,itemp
esel,,type,,12,15
cmse,u,upper
fsum
*get,smerl,fsum,,item,fx
*get,pmerl,fsum,,item,fy
*get,mmerl,fsum,,item,mz
smer=(smeru-smerl)/2
pmer=(pmeru-pmerl)/2
mmer=(mmeru-mmerl)/2
```

```
! ** Calculate hoop area
esln
esel,r,type,,12,15
*if,i,eq,2,then
esel,u,,11134
*elseif,i,eq,3,then
esel,u,,8558,11139,2581
*elseif,i,eq,4,then
esel,u,,10973
*elseif,i,eq,8,then
esel,u,,8591
*elseif,i,eq,9,then
```

```
esel,u,,11092,11256,164
*elseif,i,eq,10,then
esel,u,,8605,11106,2501
*elseif,i,eq,11,then
esel,u,,11241
*elseif,i,eq,12,then
esel,u,,11237
*elseif,i,eq,14,then
esel,u,,11086,11228,142
*elseif,i,eq,15,then
esel,u,,11157,11222,65
*elseif,i,eq,16,then
esel,u,,11159,11220,61
*elseif,i,eq,17,then
esel,u,,11212
*elseif,i,eq,18,then
esel,u,,11174
*elseif,i,eq,19,then
esel,u,,10930,11049,119
*elseif,i,eq,20,then
esel,u,,11193
*endif
nslc
nslc,r,loc,z
*get,ecount,elem,,count
hparea=0
*do,j,1,ecount
ecur=elnext(j)
hparea=hparea+arface(ecur)
esel,u,,ecur
*enddo
hparea=hparea/2
hpw=hparea/delt
```

```

esel,,type,,12,15
cmse,,sectn
fsum,rsys
*get,php,fsum,,item,fz
*get,mhp,fsum,,item,my

```

```

secw=xbar*swp_th/2*pi/180
tave=ttot/delt
smer=smer/secw*12/1000
pmer=pmer/secw*12/1000
mmer=-mmer/secw/1000
php=php/hpw*12/1000
mhp=mhp/hpw/1000

```

```

*vwri,k,smer,pmer,mmer,php,mhp,tmin,tmax,tave,xbar,ybar,delt
(11f8.1,f8.2)
*enddo

```

```

!***
!*** Found

```

```

csys
esel,,type,,12,15
nsle
*do,i,1,16
k=k+1
esel,,type,,12,15
nsle
csys
x1=dsx(i)
*if,i,le,5,then
y1=30.125

```

```

*elseif,i,le,9,then
y1=(ky(305)-ky(304))/(kx(305)-kx(304))*(-dsx(i)-
kx(304))+ky(304)
*elseif,i,le,15,then
y1=-18.625
*elseif,i,eq,16,then
y1=(ky(303)-ky(302))/(kx(303)-kx(302))*(-dsx(i)-
kx(302))+ky(302)
*endif
x2=dsx(i)
y2=h2
*if,i,le,2,then
y2=-6.625
*endif
path,sect %k%,2,,200
ppat,1,,x1,y1
,2,,x2,y2
nset,r,loc,y,-40,y2
nset,r,loc,x,-dsx(i)-3,1
esln,,1
esel,r,type,,12,15
*if,i,eq,7,then
esel,a,,,12008
*elseif,i,eq,13,then
esel,a,,,12088
*elseif,i,eq,16,then
esel,a,,,11793,12283,490
*endif
cm,lower,clem

pdef,temp,bfe,temp
pcalc,intg,itemp,temp,s
*get,delt,path,,last,s

```

```

nsle
nsl,r,loc,x,-dsx(i)-3,-dsx(i)
,r,loc,z
*if,i.eq,6,then
nsl,u,,9483
*elseif,i.eq,7,then
nsl,u,,9344
*elseif,i.eq,16,then
nsl,a,,281
*endif
*get,ncount,node,,count
cm,sectn,node
slocxt=0
slocyt=0
secx=0
secy=0
csys
rsys
*do,j,1,ncount
ncur=ndnext(j-1)
slocxt=slocxt+nx(ncur)+ux(ncur)
slocyt=slocyt+ny(ncur)+uy(ncur)
secx=secx+nx(ncur)
secy=secy+ny(ncur)
nsl,u,,ncur
*enddo
slocx=slocxt/ncount
slocy=slocyt/ncount
xbar=-secx/ncount
ybar=secy/ncount
cmse,,sectn
secw=xbar*swp_th/2*pi/180

```

```

spoi,,slocx,slocy
fsum
*get,smerl,fsum,,item,fy
*get,pmerl,fsum,,item,fx
*get,mmerl,fsum,,item,mz
*get,tmin,path,,min,temp
*get,tmax,path,,max,temp
*get,ttoi,path,,last,itemp
esel,,type,,12,15
cmse,u,lower
fsum
*get,smeru,fsum,,item,fy
*get,pmeru,fsum,,item,fx
*get,mmeru,fsum,,item,mz
smer=(smerl-smeru)/2
pmer=(pmerl-pmeru)/2
mmer=(mmeru-mmerl)/2

!** Calculate hoop area
esln
esel,r,type,,12,15
*if,i.eq,6,then
esel,u,,12148
*elseif,i.eq,7,then
esel,u,,11797,12007,210
*elseif,i.eq,13,then
esel,u,,12101
*endif
nsle
nsl,r,loc,z
*get,ecount,elem,,count
hparea=0

```

```

*do,j,1,ecount
ecur=elnext(j)
hparea=hparea+arface(ecur)
esel,u,,,ecur
*enddo
hparea=hparea/2
hpw=hparea/delt

```

```

esel,,type,,12,15
cmse,,sectn
fsum,rsys
*get,php,fsum,,item,fz
*get,mhp,fsum,,item,mx

```

```

tave=ttot/delt
smer=smer/secw*12/1000
pmer=pmer/secw*12/1000
mmer=-mmer/secw/1000
php=php/hpw*12/1000
mhp=mhp/hpw/1000

```

```

*vwri,k,smer,pmer,mmer,php,mhp,tmin,tmax,tave,xbar,ybar,delt
(11f8.1,f8.2)
*enddo

```

```

*cfc
*enddo

```

Input file: postprimcomb.inp

```

/post1
set,148
lcwr,1

```

```

loca,199,1,,280.75,,90
esel,,,14927,14943,16
,a,,,14962,15000,19
,a,,,15018,15037,19
,a,,,15050,15056,6
,a,,,15061,15064,3
,a,,,15070,15076,6
,a,,,15081,15086,5
,a,,,15092,15097,5
,a,,,15103,15115,6
,a,,,15120,15168,6
,a,,,15172,15180,4
,a,,,15185,15197,12
,a,,,15211,15227,16
,a,,,15247,15258,11
,a,,,15264,15276,12
,a,,,15303,15324,21
rsys,solu

```

```

*do,k,138,147
set,k
lcp,sub,1
shel,top
ETAB,sintt,s,int
ETAB,loey,cent,y
shel,bot
ETAB,sintb,s,int
ETAB,loey,cent,y
esor,ctab,loey,1
/out,primsec%k%,lis
PRET,loey,sintt,sintb
/out
*enddo

```

Input file: postprimcomb1.inp

```
/post1
set,148
```

```
loca,199,1,,280.75,,90
esel,,,14927,14943,16
,a,,,14962,15000,19
,a,,,15018,15037,19
,a,,,15050,15056,6
,a,,,15061,15064,3
,a,,,15070,15076,6
,a,,,15081,15086,5
,a,,,15092,15097,5
,a,,,15103,15115,6
,a,,,15120,15168,6
,a,,,15172,15180,4
,a,,,15185,15197,12
,a,,,15211,15227,16
,a,,,15247,15258,11
,a,,,15264,15276,12
,a,,,15303,15324,21
rsys,solu
shel,mid
etab,sxm,s,x
ETAB,sym,s,y
ETAB,sxym,s,xy
ETAB,sintm,s,int
ETAB,locy,cent,y
shel,top
etab,sxt,s,x
ETAB,syt,s,y
ETAB,sxyt,s,xy
```

```
ETAB,sintt,s,int
ETAB,locy,cent,y
shel,bot
etab,sxb,s,x
ETAB,syb,s,y
ETAB,sxyb,s,xy
ETAB,sintb,s,int
ETAB,locy,cent,y
pret,locy,sxm,sym,sxym,sintm
PRET,locy,sxt,syt,sxyt,sintt
PRET,locy,sxb,syb,sxyb,sintb
```

Input file: postseccomb.inp

```
/post1
c8y8
```

```
esel,,,15185,15211,26
,a,,,15227,15247,20
,a,,,15258,15264,6
,a,,,15276,15298,522
,a,,,15303,15324,21
,a,,,15804,15814,10
,a,,,15654,15666,12
,a,,,15687,15708,21
,a,,,15723,15737,14
,a,,,15750,15953,203
,a,,,15785,15788,3
,a,,,15819,15837,18
,a,,,15851,15866,15
,a,,,15877,15897,20
,a,,,15795,15912,117
,a,,,15764
```

```
loca,199,1,,280.75,,90
```

```
*do,k,138,148
set,k
ctab,loey,cent,y
shel,mid
ctab,epstm,epto,1
,epscm,epto,3
sadd,epscm,epscm,,-1
shel,top
ctab,epstbt,epto,1
,epscbt,epto,3
sadd,epscbt,epscbt,,-1
shel,bot
ctab,epstbb,epto,1
,epscbb,epto,3
sadd,epscbb,epscbb,,-1
esor,ctab,loey,1
/out,combs1%k%,lis
pret,loey,epstm,epscm,epstbt,epscbt,epstbb,epscbb
/out
*enddo
```

Input file: jbolt2.inp

```
!*** J-bolts
!*** 6/1/04
!***

!*** writes data for all load steps in a single file! modified
09/02/04 - Siva!
!*** NB!! 6/1/04
!*** This version uses (sfyi**2+sfzi**2)**1/2
!*** because beams on z <= 0 face are
```

```
!*** incorrectly oriented (should use nod1k in set_slicea.mac)
!***
```

```
/fil,set_slice_0
resu
/post1
```

```
*do,k,138,148
```

```
set,k
*cfo,1steps,asme,,append
tt1='Load Step'
*vwr1,tt1
%oc
```

```
*vwr1,k
(11f8.1,f8.1)
```

```
ct='J-bolt pos'
ct1='F-axial'
ct2='F-shear'
ct3='U-axial'
ct4='U-shear'
```

```
*vwr1,ct,ct1,ct2,ct3,ct4
(12a12)
```

```
esel,,real,,50,56
nsle
esln
esel,r,type,,30
nsle
ctab,fxi,smisc,1
```

```

,sfyi,smisc,6
,sfzi,smisc,5
,exi,smisc,7
,esyi,smisc,12
,eszi,smisc,11
csys,1
etab,jloc,cent,y
esor,etab,jloc,1
*dim,faxial,,13
,fshear,,13
,uaxial,,13
,ushear,,13
*do,i,1,13
*get,e1,sort,,imin
*get,fx1,elem,e1,etab,fxi
*get,fsheary1,elem,e1,etab,sfyi
*get,fshearz1,elem,e1,etab,sfzi
*get,ex1,elem,e1,etab,exi
*get,esheary1,elem,e1,etab,esyi
*get,eshearz1,elem,e1,etab,eszi
esel,u,,e1
esor,etab,jloc,1
*get,e2,sort,,imin
*get,fx2,elem,e2,etab,fxi
*get,fsheary2,elem,e2,etab,sfyi
*get,fshearz2,elem,e2,etab,sfzi
*get,ex2,elem,e2,etab,exi
*get,esheary2,elem,e2,etab,esyi
*get,eshearz2,elem,e2,etab,eszi
faxial(i)=fx1+fx2
fsheary=(fsheary1**2+fshearz1**2)**0.5
fshearz=(fsheary2**2+fshearz2**2)**0.5
fshear(i)=fsheary+fshearz

```

```

uaxial(i)=(ex1*4+ex2*4)/2      !** 4" J-bolt length
usheary=(esheary1**2+eshearz1**2)**0.5
ushearz=(esheary2**2+eshearz2**2)**0.5
ushear(i)=(usheary*4+ushearz*4)/2
esel,u,,e2
esor,etab,jloc,1

fax=faxial(i)
fsh=fshear(i)
uax=uaxial(i)
ush=ushear(i)

*vwr,i,fx,fsh,uax,ush
(12g12.5,g12.5)

*enddo
*cfc
*enddo

```

C.7 Detailed Anchor Bolt Model File

```

! Same as C2 with more divisions for bolt circumference.
! Coarse Model
! Without using VSYMM for symmetry KNK 11/06/07
! Quarter model with symmetry KNK 11/05/07
! Bolt, Stud, Plate and Concrete dimensions from m7c.inp and
Weld flash dimensions from m2.inp
! Detailed anchor bolt model

finish
/clear

```



```
/fil,APAnchorBoltC8
/tit,AP anchor-bolt with Weld Flash
/prep7
```

```
!=====PARAMETERS=====
```

```
!-----Nelson 3/4" Stud-----
```

```
D=3/4          ! Stud Diameter
S=0.119        ! Depth of Solid Weld Base
I=0.406        ! The Imperfect Thread
Depth
E=1.062        ! Weld Diameter
F=0.25         ! Height of Weld Flash
A=0.937
BurnOff=0.187
```

```
!---Anchor Bolt-----
```

```
D1=0.5         ! Bolt Diameter
```

```
!---Other Constants-----
```

```
pi=22.0/7.0
```

```
!=====ELEMENT TYPES=====
```

```
et,1,45        !Stud(TBL)
et,2,45        !Bolt
et,3,45        !Plate
et,4,45        !Concrete
et,5,45        !Weld Flash
```

```
et,7,TARGE170
```

```
et,8,CONTA174
```

```
et,9,MESH200,6
```

```
!=====MATERIALS=====
```

```
!**TBL STUD and Weld Flash
```

```
mp,ex,1,29.0e6
,nuxy,1,0.29
!,dens,1,490/12**3
tb,bkin,1
tbda,,68300
```

```
!**Bolt
```

```
mp,ex,2,29.0e6
mp,nuxy,2,.29
!,dens,1,490/12**3
tb,bkin,2
tbda,,68300
```

```
!**Plate
```

```
mp,ex,3,29.0e6
,nuxy,3,.29
!,dens,1,490/12**3
tb,bkin,3
tbda,,68300
```

```
!**Concrete
```

```
mp,ex,4,5.083e6
,nuxy,4,.15
!,dens,1,145/12**3
tb,bkin,4
tbda,,5000*5889/3000
```

```
!===== FE MODEL=====
```

```
pcir,D1/2,,90
```

,D/2,E/2,,90
 A,1,7,6,2
 adele,all
 blc4,0,0,8,8
 asbl,1,all
 nummrg,KP
 numcmp,AREA

type,9
 asel,,,1
 lsla
 lsize,all,,8
 amesh,1
 asel,,,2
 amap,2,6,2,1,7

type,1
 mat,1
 esiz,,3
 asel,,,1,2
 vext,all,,,,,S

asel,,,9
 esiz,,3
 vext,9,,,,,F-S ! Height of Weld Flash= 0.25
 esiz,,5
 vext,13,,,,,I

asel,,,5
 agen,2,all,,,,,I+F-S,,0
 asel,,,18
 type,1
 mat,1

esiz,,8
 vext,18,,,,,1.094
 asel,,,23
 type,9
 amesh,all
 type,2
 mat,2
 vext,23,,,,,1.094

asel,,,29
 type,2
 esize,,20
 vext,29,,,,,6-0.312-1.75
 wpoffs,,kz(35)
 pcir,D1/2,D/2,90
 ,D/2,D1,,90
 asel,,loc,z,kz(35)
 numm,kp
 type,9
 esize
 amap,37,34,37,38,36
 amap,38,37,41,42,38
 asel,,loc,z,kz(35)
 type,2
 esize,,2
 vext,all,,,,,312

wpstyl,defa
 wprotat,,-90
 wpstyl,,,,,,0
 larc,4,17,7,.3
 lsel,all
 al,7,86,30,23

```
lesize,7,,,4
lesize,86,,,8
asel,,,,51
lsla
type,9
ames,51
type,5
mat,1
vdra,51,,,,,6
```

```
nummrg,node
```

```
asel,,loc,z,kz(40)
```

```
agen,2,all
ksel,,,,9,11
kgen,2,all,,,,kz(40)
ksel,,,,57,61
a,57,59,60,61,58
```

```
asel,,,,57,59
type,9
amesh,all
```

```
lesize,104,,,16,6
lesize,107,,,16,1/6
lsl,,,,105,106
lesize,all,,,12
```

```
asel,,,,60
lsla
type,9
amesh,all
```

```
asel,,,,57,60
esize,,2
type,4
mat,4
vext,all,,,,,1
```

```
asel,,,,60
esize,,2
vext,all,,,,,-0.312
```

```
asel,,,,37,38
agen,2,all
```

```
asel,,,,78
asel,a,,,84,85
esize,,20
vext,all,,,,,-1*(6-0.312-1.75)
```

```
asel,,,,97
agen,2,all
type,9
asel,,,,101
amesh,all
esize,,8
type,4
mat,4
asel,,,,86,101,101-86
vext,all,,,,,-1.094
esize,,5
asel,,,,102,108,6
vext,all,,,,,-1*I
```

asel,,,55
 agen,2,all
 wpstyl,defa
 k,,E/2+D/2-D1/2
 l,116,120
 wprot,,90
 larc,112,120,116,0.3

lsel,,,,215,216
 adrag,all,,,,,212

asel,,,124,126
 asel,a,,,119
 lsia
 ksl
 nummrg,kp
 al,215,216,206,211
 al,217,213,204,220

asel,,,124,128
 asel,a,,,119
 va,125,126,119,124,127,128
 vsweep,24,119,125

esel,,type,,4
 nslc
 ksln
 nummrg,node
 nummrg,kp

ksel,,,9,11
 kgen,2,all
 allsel

a,120,81,82,92,122
 a,120,81,108,107
 a,81,82,109,108
 a,82,92,110,109
 a,92,122,111,110
 allsel

va,101,109,120,129,126,98,113
 vsweep,25,113,98

asel,,,1,2
 asel,a,,,52
 asel,a,,,98
 asel,a,,,125

agen,2,all

asel,,,130,134
 lsia
 ksl
 nummrg,kp

type,9
 amesh,132,134,2
 asel,,,133
 lsia
 lesize,222,,,16,6
 lesize,225,,,16,1/6
 lsel,,,223,224
 lesize,all,,,12
 amesh,133
 asel,,,130,134
 esize,,2

```

type,3
mat,3
vext,all,,,,,-0.375
allsel

```

```

!-----End of Quarter Model-----

```

```

esel,,type,,1,8
nsle
nsym,X,100000,all
esym,,100000,all

```

```

*do,EIType,1,5
esel,,type,,EIType
nsle
ksln
nummrg,node
nummrg,kp
*enddo

```

```

esel,,type,,1,5
esel,u,type,,4
nsle
ksln
nummrg,node
nummrg,kp

```

```

!allsel
!numcmp,node
!numcmp,kp

```

```

!=====CONTACT DEFINITIONS=====

```

```

!*** Plate <> Concrete

```

```

esel,,type,,3
nsle
csys,1
nsel,r,loc,z
,r,loc,x,0.53,20
type,7
real,10
esurf      !Plate
esel,,type,,4
nsle
nsel,r,loc,z
,r,loc,x,0.53,20
type,8
esurf      !Concrete

```

```

!*** TBL <> Concrete - radial
esel,,type,,1
nsle
csys,1
nsel,r,loc,x,D/2
,r,loc,z,F,1.75
type,7      ! Convex surface---->Contact
real,11
esurf      !TBL
esel,,type,,4
nsle
nsel,r,loc,x,D/2
,r,loc,z,F,1.75
type,8
esurf      !Concrete

```

```

!*** TBL <> Concrete - axial
esel,,type,,1

```

```

nsle
nsel,r,loc,z,1.75
,r,loc,x,0.25,0.375
type,7      ! Flat, Stiffer----->Target
real,12
esurf      !TBL
esel,,type,,4
nsle
nsel,r,loc,x,0.25,0.375
,r,loc,z,1.75
type,8      !Concrete
esurf

!*** Shank <> Concrete
esel,,type,,2
nsle
nsel,r,loc,x,0.25
,r,loc,z,1.75,6-0.312
type,7      ! Convex surface----->Contact
real,13
esurf      !Shank
esel,,type,,4
nsle
nsel,r,loc,x,0.25
,r,loc,z,1.75,6-0.312
type,8
esurf      !Concrete

!*** Bolt - under <> Concrete
esel,,type,,2
nsle
nsel,r,loc,x,.25,0.5
,r,loc,z,6.0-0.312

```

```

type,7      ! Flat, Stiffer----->Target
real,14
esurf      !Bolt Head Bot
esel,,type,,4
nsle
nsel,r,loc,x,.25,0.5
,r,loc,z,6.0-0.312
type,8
esurf      !Concrete

!*** Bolt - radial <> Concrete
esel,,type,,2
nsle
nsel,r,loc,x,0.5
,r,loc,z,6.0-0.312,6.0
type,7      ! Convex surface----->Contact
real,15
esurf      !Bolt Head Side
esel,,type,,4
nsle
nsel,r,loc,x,.5
,r,loc,z,6.0-0.312,6.0
type,8
esurf      !Concrete

!*** Bolt - axial <> Concrete
esel,,type,,2
nsle
nsel,r,loc,x,0,0.5
nsel,r,loc,z,6.0
type,7      ! Flat, Stiffer----->Target
real,16
esurf      !Bolt Head Top

```

```

esel,,type,,4
nsle
nsel,r,loc,x,0,0.5
,r,loc,z,6.0
type,8
esurf      ! Concrete

```

```

!*** Weld Flash <> Concrete

```

```

!----Code for Selecting Nodes on the Surface of Weld Flash
asel,,,55,,,1
cm,A55Nodes,node
*get,NdCt,NODE,0,COUNT
*dim,WFnodes1,,NdCt
*dim,WFnodes2,,NdCt
*do,indx,1,NdCt
*get,NdNum,NODE,0,NUM,MIN
WFnodes1(indx)=NdNum
nsel,u,,,NdNum
*enddo
CSYS
esel,,type,,5
nsle
*do,indx,1,NdCt
WFnodes2(indx)=NODE(-
1*NX(WFnodes1(indx)),NY(WFnodes1(indx)),NZ(WFnodes1(
indx)))
*enddo
nsel,none
*do,indx,1,NdCt
nsel,a,,,WFnodes1(indx)
nsel,a,,,WFnodes2(indx)
*enddo

```

```

type,7      ! Convex surface---->Contact
real,17
esurf      !Weld Flash
!----Code for Selecting Nodes on Concrete Touching the
Surface of Weld Flash
asel,,,124,,,1
cm,A124Nodes,node
*get,NdCt2,NODE,0,COUNT
*dim,WFnodes1b,,NdCt2
*dim,WFnodes2b,,NdCt2
*do,indx,1,NdCt2
*get,NdNum,NODE,0,NUM,MIN
WFnodes1b(indx)=NdNum
nsel,u,,,NdNum
*enddo
CSYS
esel,,type,,4
nsle
*do,indx,1,NdCt2
WFnodes2b(indx)=NODE(-
1*NX(WFnodes1b(indx)),NY(WFnodes1b(indx)),NZ(WFnodes
1b(indx)))
*enddo
nsel,none
*do,indx,1,NdCt2
nsel,a,,,WFnodes1b(indx)
nsel,a,,,WFnodes2b(indx)
*enddo
type,8
esurf      !Concrete

!=====BOUNDARY CONDITIONS=====

```

```

CSYS
!*** Symmetry BC
nse1,,loc,y
d,all,uy
!*** UX
esel,,type,,4
nsle
nse1,r,loc,x,8
d,all,ux
!*** UZ
nse1,,loc,z,-0.375
d,all,uz

!=====LOADS=====

!*** Load
esel,,type,,3
nsle
nse1,r,loc,x,-8
d,all,ux,-0.5

allsel
esel,,type,,1,8
nsle
save

!=====SOLUTION=====

/sol
auto,on
delt,.01,.0001
out,all,all
solv

```