U.S. Department of Energy
Office of River Protection
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

0099070

11-TPD-064

SEP 15 2011

Ms. Jane A. Hedges, Program Manager
Nuclear Waste Program
State of Washington
Department of Ecology
3100 Port of Benton Blvd
Richland, Washington 99352

Dear Ms. Hedges:

COMPLETION OF HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER (HFFACO) TARGET DATE M-045-91G-T01, DUE SEPTEMBER 30, 2011

This letter documents completion of the HFFACO Target Date M-045-91G-T01. This target date requires that the U. S. Department of Energy, Office of River Protection (ORP) provide to the Washington State Department of Ecology (Ecology) the Structural Analyses of Record final documentation of single-shell tanks (SSTs) for 530,000 gallon tanks (B, C, T, and U Farms). 0098440 RPP-RPT-49989, *Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis,* satisfies these requirements. RPP-RPT-49989 was delivered in electronic format to Ecology on August 23, 2011, when Ecology received a presentation (Enclosure 1) on the results of the analysis. A hard copy of the document was also delivered to Ecology on August 26, 2011, and a copy has been added to the Tri-Party Agreement Administrative Record (Record # 0093723). Due to the size of the document, only the cover page of the document is attached to this letter (Enclosure 2).

If you have any questions, please contact me, or your staff may contact Mr. Jeremy M. Johnson, at (509) 376-1866.

Sincerely,

Scott L. Samuelson, Manager
Office of River Protection

TPD: JMJ

Enclosures (2)

cc w/encls: See Page 2

SEP 1 5 2011

cc w/encls:
S. Harris, CTUIR
M. W. Barnes, Ecology
M. L. Hendrickson, Ecology
J. J. Lyon, Ecology
J. B. Price, Ecology
C. L. Whalen, Ecology
D. A. Faulk, EPA
S. L. Leckband, HAB
J. F. Oilero, MSA
R. E. Piippo, MSA
J. G. Vance, MSA
G. Bohnee, NPT
K. Niles, ODOE
K. D. Boomer, WRPS
Jim Castleberry, WRPS
W. T. Dixon, WRPS
J. W. Donnelly, WRPS
A. M. Hopkins, WRPS
S. E. Killoy, WRPS
J. J. Luke, WRPS
F. R. Miera, WRPS
D. J. Washenfelder, WRPS
R. Jim, YN
Administrative Record
Environmental Portal, LMSI
TPA Administrative Record (S-2-4)
WRPS Correspondence

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Enclosure 1

11-TPD-064

Single-Shell Tank Analysis of Record Project

Consisting of 34 pages, including coversheet.

PNNL-SA-82443

Single-Shell Tank Analysis of Record Project

Overview and Results of the Type II Tank Analysis of Record

Presented to Washington Department of Ecology

Mike Rinker

August 23, 2011

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Motivation for the Single-Shell Tank Analysis of Record

- Single-Shell Tank (SST) Analysis of Record (AOR) was recommended by the SST Integrity Panel (Terry and Boomer, 2009)
  - Modern structural analysis of SSTs
  - All the SSTs are well beyond their estimated design life (25 years)
  - Determine the current load carrying capacities
    - estimate any structural damage from past operations
    - thermal degradation of concrete structural properties
    - concrete creep
    - seismic loads
- Provide a technical basis for the allowable structural loads that govern day-to-day operations of the SSTs
- Ensure adequate margin remains against dome limit loads through period of waste retrieval and closure
- Analysis performed to NQA-1 requirements

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Our Team

- WRPS manages the tank farms and the AOR for the DOE in their role as prime contractor
  - Provide oversight, guidance, and direction to the Single-Shell Tank Analysis of Record project
  - Provide historical documents and technical/operational perspective
- PNNL subcontracted to perform the Single-Shell Tank AOR
  - Performed the previous Double-Shell Tank AOR
  - Responsible for evaluation criteria, Thermal and Operating Loads analysis, load combination/code evaluation, and project management
- M&D Professional Services
  - Responsible for the seismic analysis
- AMEC/Geomatrix
  - Seismic response spectra input

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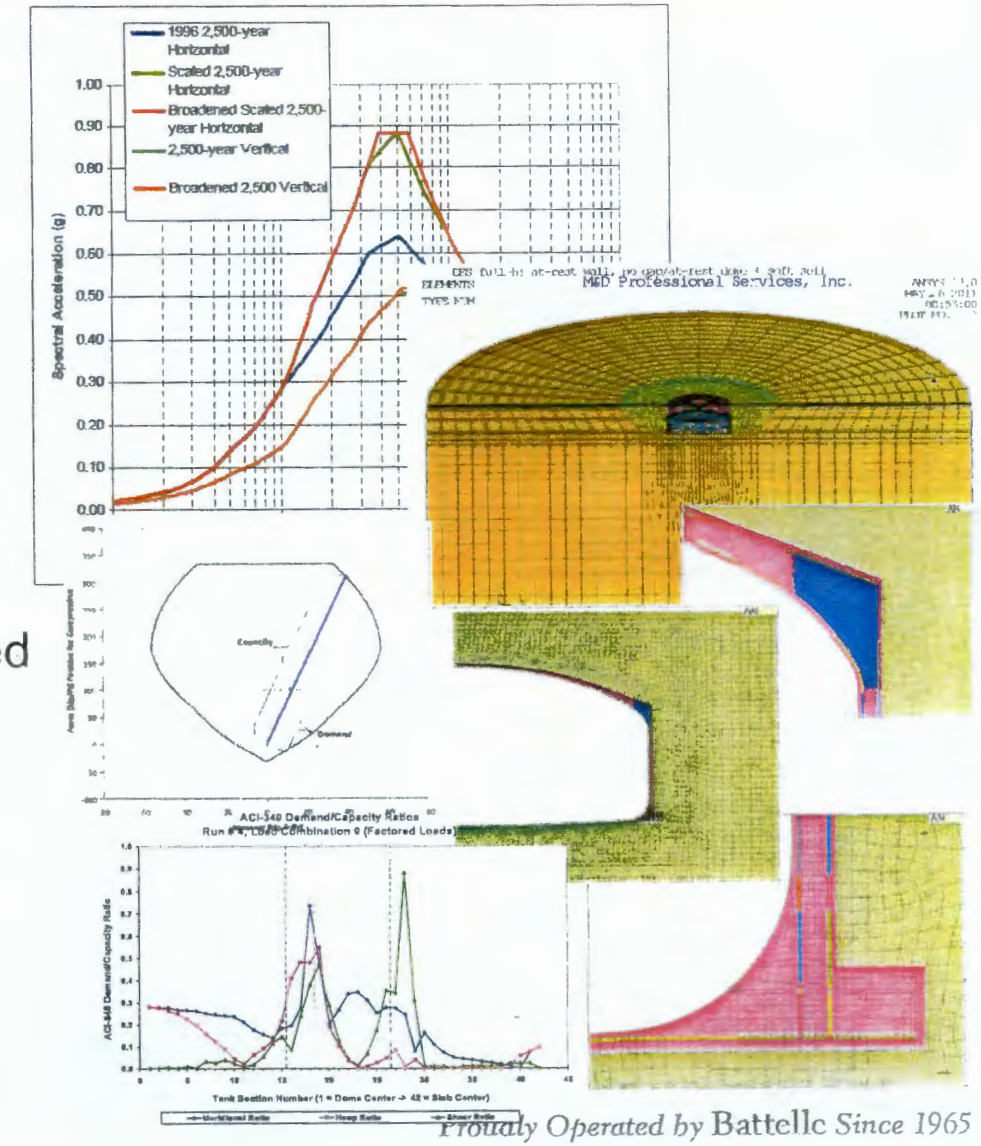
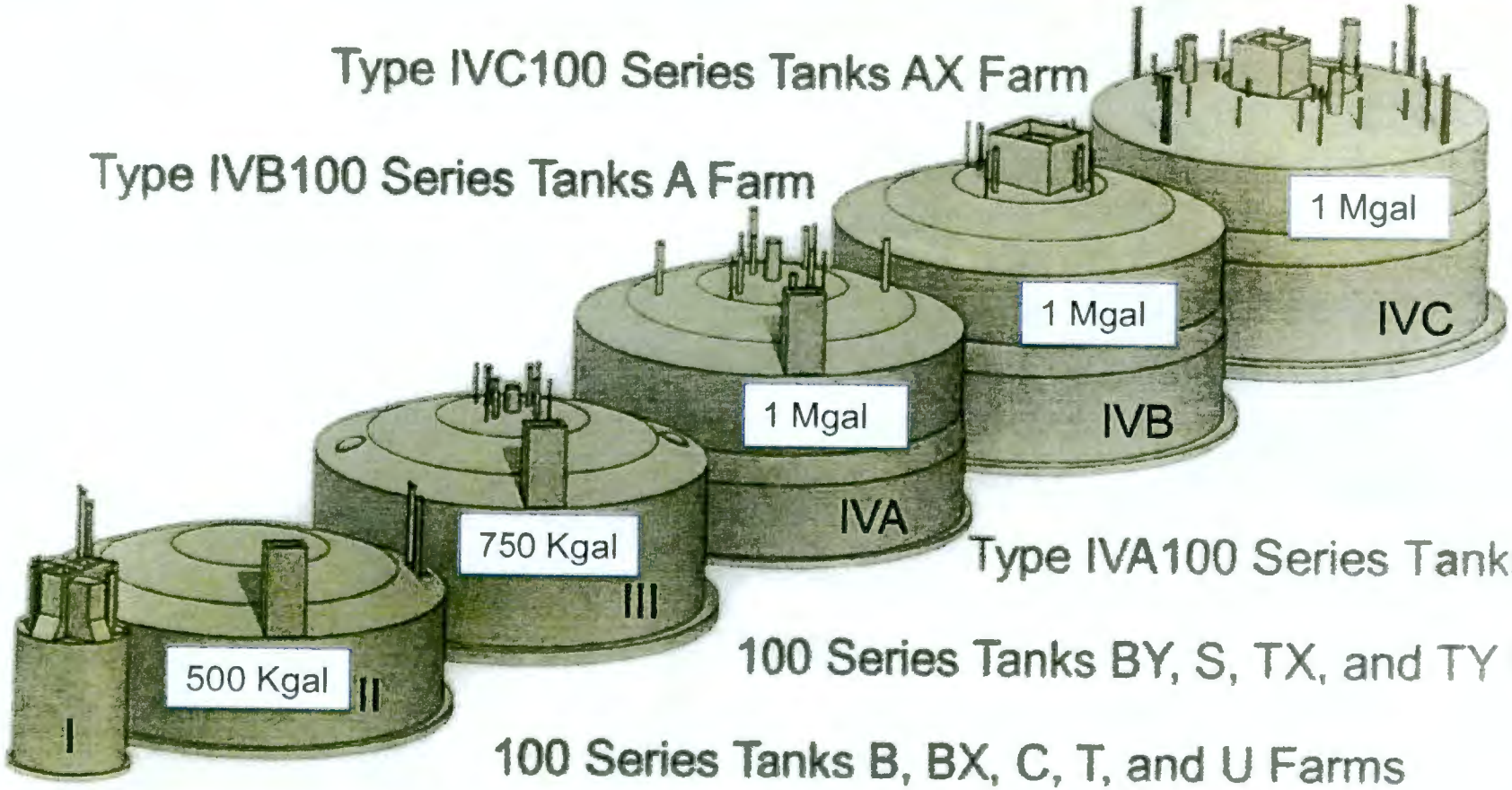
Our Approach to SST Integrity Evaluation

- Determine structural evaluation criteria based upon current codes
- Review concrete and soil properties based upon available data
- Define the seismic analysis input based upon available geotechnical data
- Define tank loading scenarios – operating loads, seismic loads, thermal loads
- Develop and execute computer-based engineering models of the tanks
- Assess tank integrity using the structural evaluation criteria
- Interpret analysis results regarding potential impacts on operations



Layout and Classification of Single-Shell Tanks



Type IVA100 Series Tanks SX Farm

100 Series Tanks BY, S, TX, and TY Farms

100 Series Tanks B, BX, C, T, and U Farms

200 Series Tank
B, C, T, and U Farms

External Review is an Important Aspect of this Work

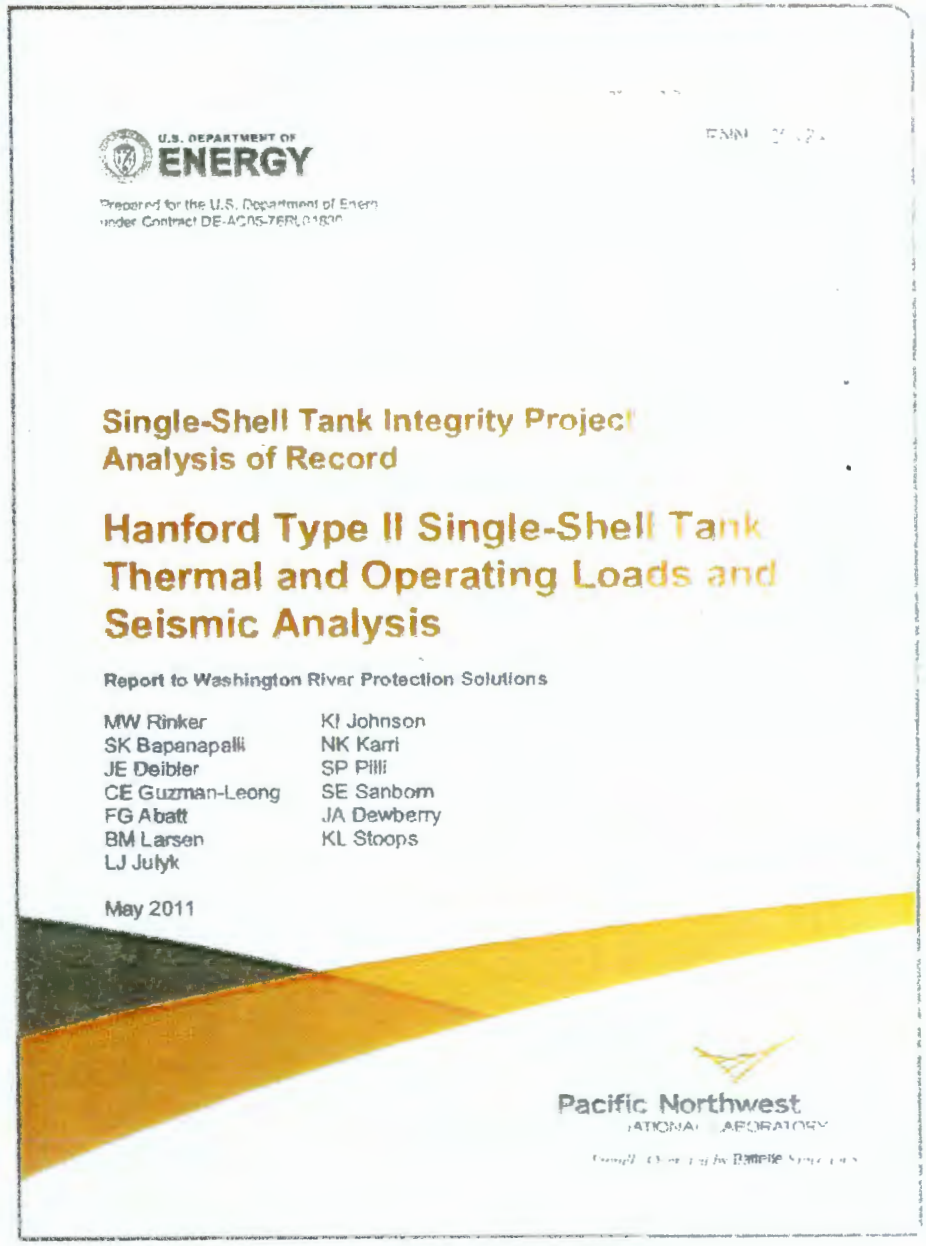
- Preliminary external review occurred in August, 2010
  - Comments provided by Dr Andy Veletsos and Dr Robert Kennedy documented in a letter to WRPS
    - 13 comments were documented in Appendix A of the Type II Report
    - Several studies were performed and responses were included in Appendix A, other Appendices, and the body of the report as required. (Also, see section 2.1 "Roadmap"
- Thermal and Operating Loads Analysis (TOLA) model completed
- Seismic model completed
- Appurtenance Models for TOLA and Seismic completed
- Thermal loads, Dead Loads, Live Loads, Loads due to waste and soil, and Seismic Loads generated

External Review is an Important Aspect of this Work (Cont)

- Developed Seismic input for SSI model
- TOLA and Seismic Models have been run for a variety of cases
- Appurtenance Models have been run for several cases
- Limit Load and Buckling Analyses completed
- A second external technical review by Drs Veletsos and Kennedy was held in May, 2011 – ***No negative findings***
  - Overall, analyses are comprehensive and insightful and are responsive to September 2010 comments and recommendations.
  - The concrete and steel properties used in the analyses show the SSTs satisfy ACI design strength requirements.
  - Another on-site review is not required but a final "sanity check" of the report by the reviewers is recommended.

Final Report Delivered and Released

The Type II Analysis Report has been completed, reviewed, and released by WRPS in August, 2011



U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

Single-Shell Tank Integrity Project
Analysis of Record

Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis

Report to Washington River Protection Solutions

MW Rinker
SK Bapanapalli
JE Deibler
CE Guzman-Leong
FG Abatt
BM Larsen
LJ Julyk
KI Johnson
NK Karri
SP Pilli
SE Sanborn
JA Dewberry
KL Stoops

May 2011

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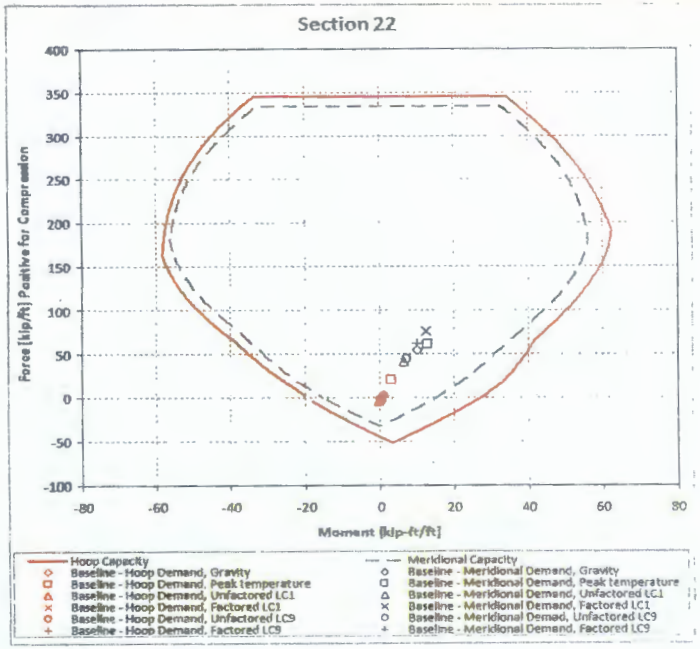
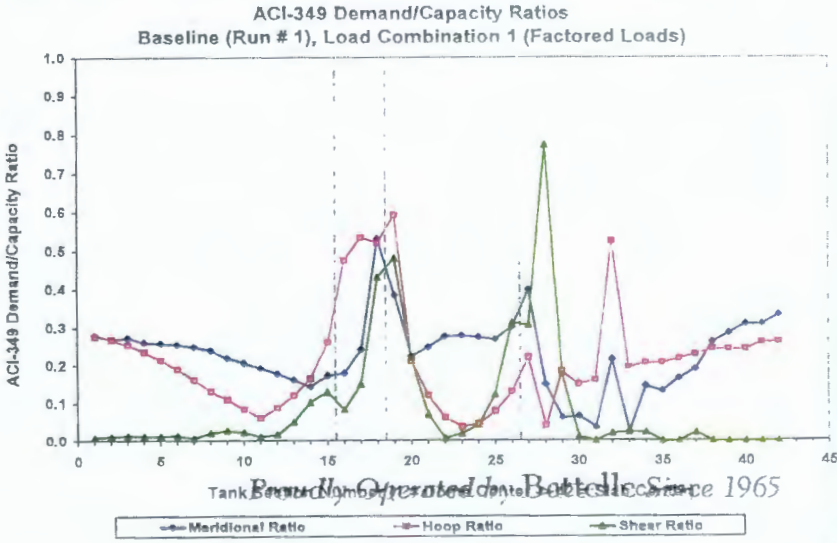
Evaluation Criteria for the SSTs – Reinforced Concrete – ACI-349 (2006)

- Structural Demand Calculations
  - Ultimate strength analysis using factored load combinations
    1. U = I.4D + 1.4F + 1.7L + 1.7H
    4. U = D + F + L + H + To + Ess
    9. U = 1.05D + 1.05F + 1.3L + 1.3H +1.05To
  - Factored loads are applied to the nonlinear finite element model
- Models include concrete cracking, soil plasticity and interface contact with friction.
- Model results are section Force, Moment, and Shear loads.
- Structural Capacity Calculations
  - Tank section demands are evaluated against ACI-349 section capacities.





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Evaluation Criteria – Buckling and Limit Analysis

- Buckling Analyses
  - Dome buckling => distributed + concentrated loads
  - Cylindrical wall buckling => axial force + external pressure
  - Imperfection buckling load reduction factors are recommended from ACI SP-67, Concrete Shell Buckling

$$P_b^{Allow} = \alpha_1 \alpha_2 \alpha_3 \alpha_4 P_b^{lin} \frac{1}{SF_b}$$

- Limit Analysis
  - Tank Models use nonlinear, large strain finite element analysis with concrete cracking and rebar yielding
  - SST scale model test results available for model validation
  - Model is run to allow for concrete crushing as well as re-bar yielding
  - When the non-linear analysis fails to converge, the tank is assumed to have failed and the limit loads reached.

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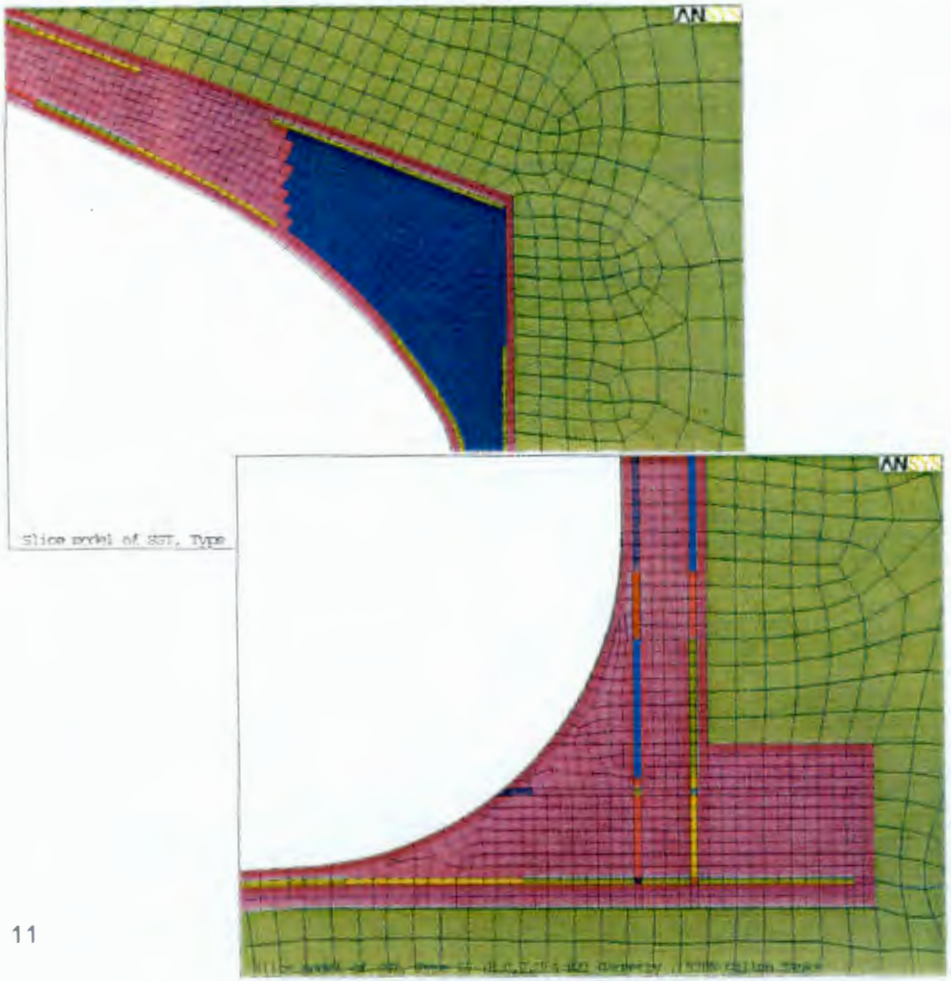
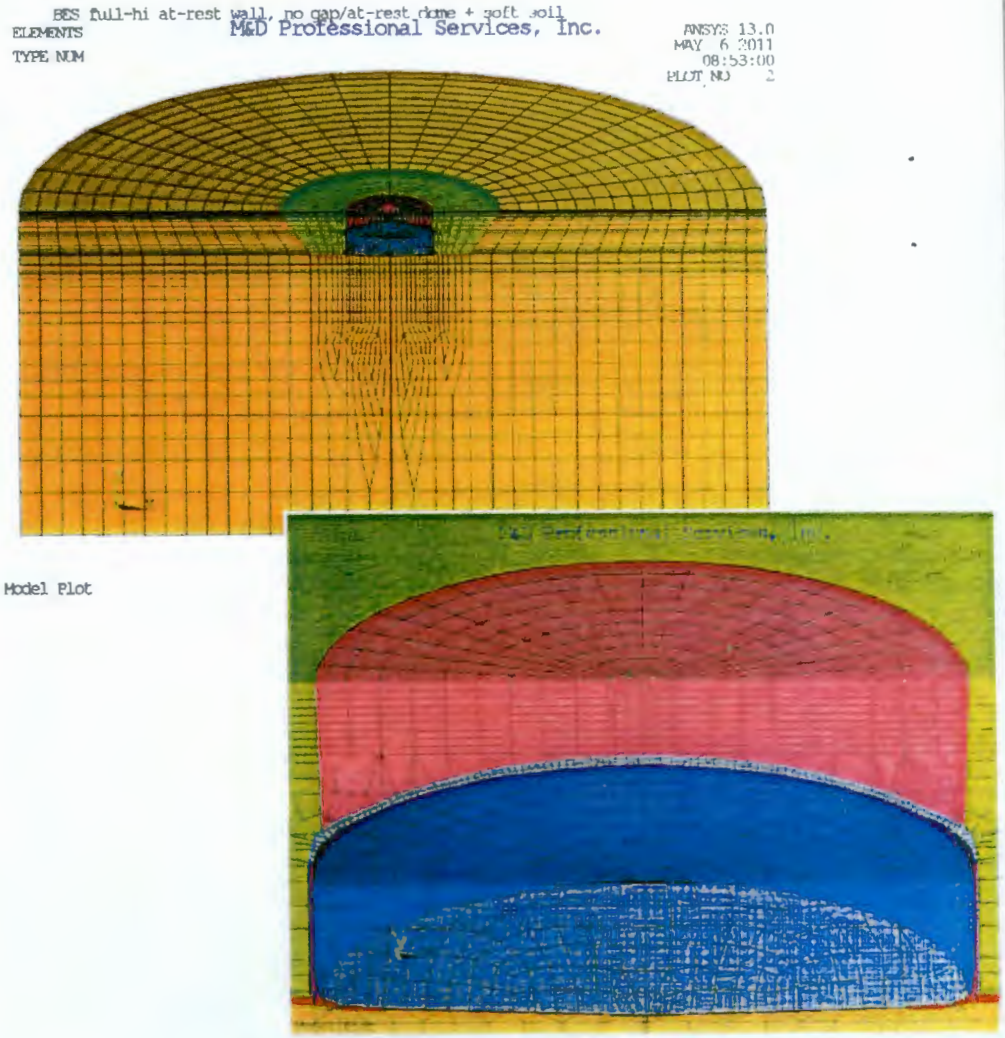
Finite Element Model Used for TOLA and Seismic Models

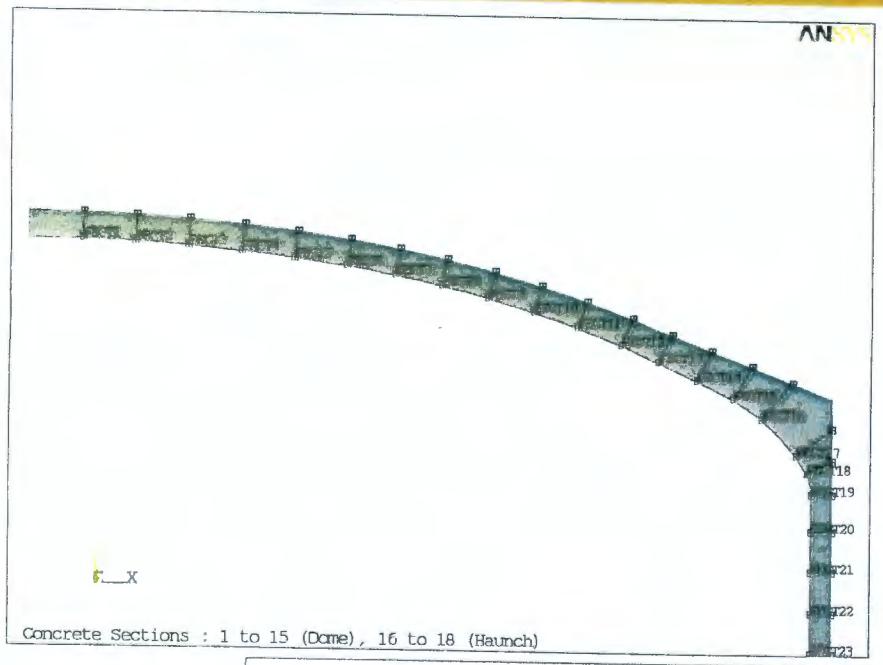
TOLA Model

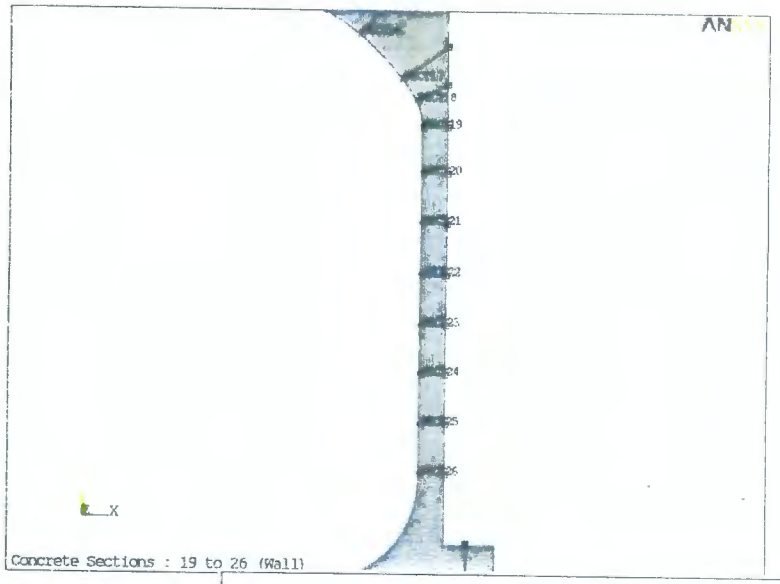


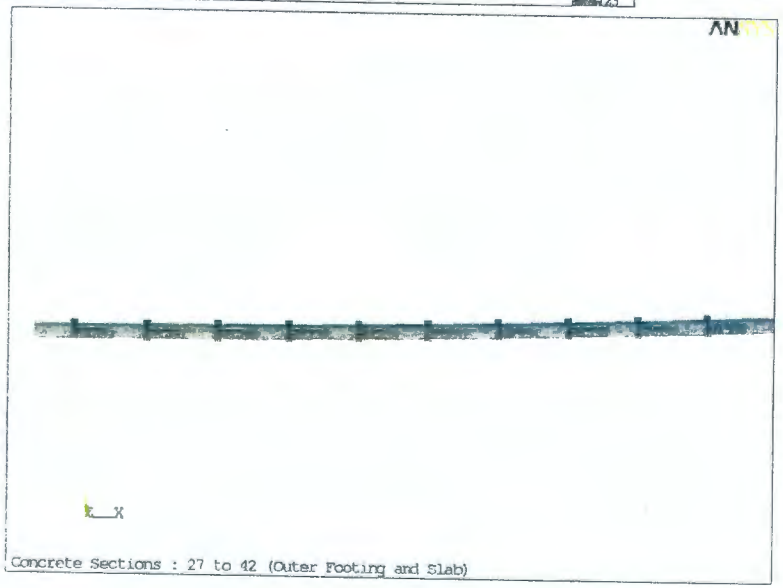
Seismic Model

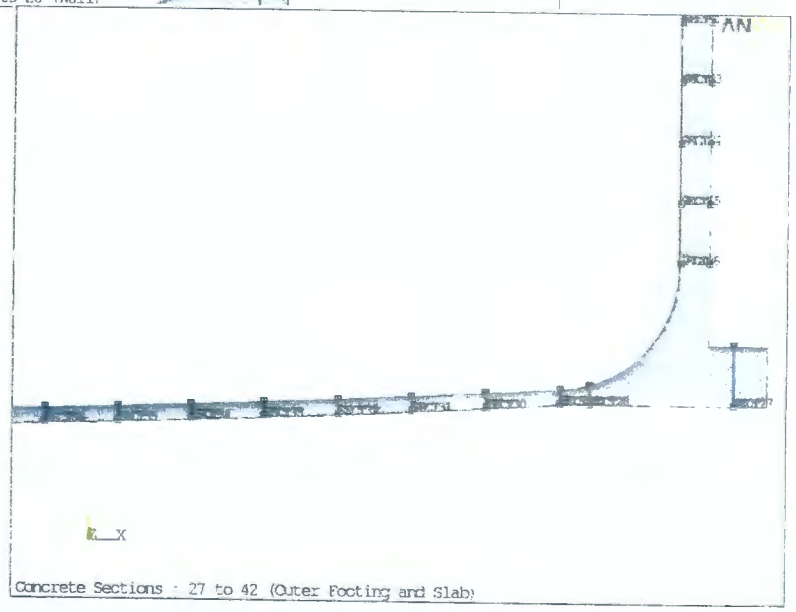


Sections for Demand/Capacity Calculations

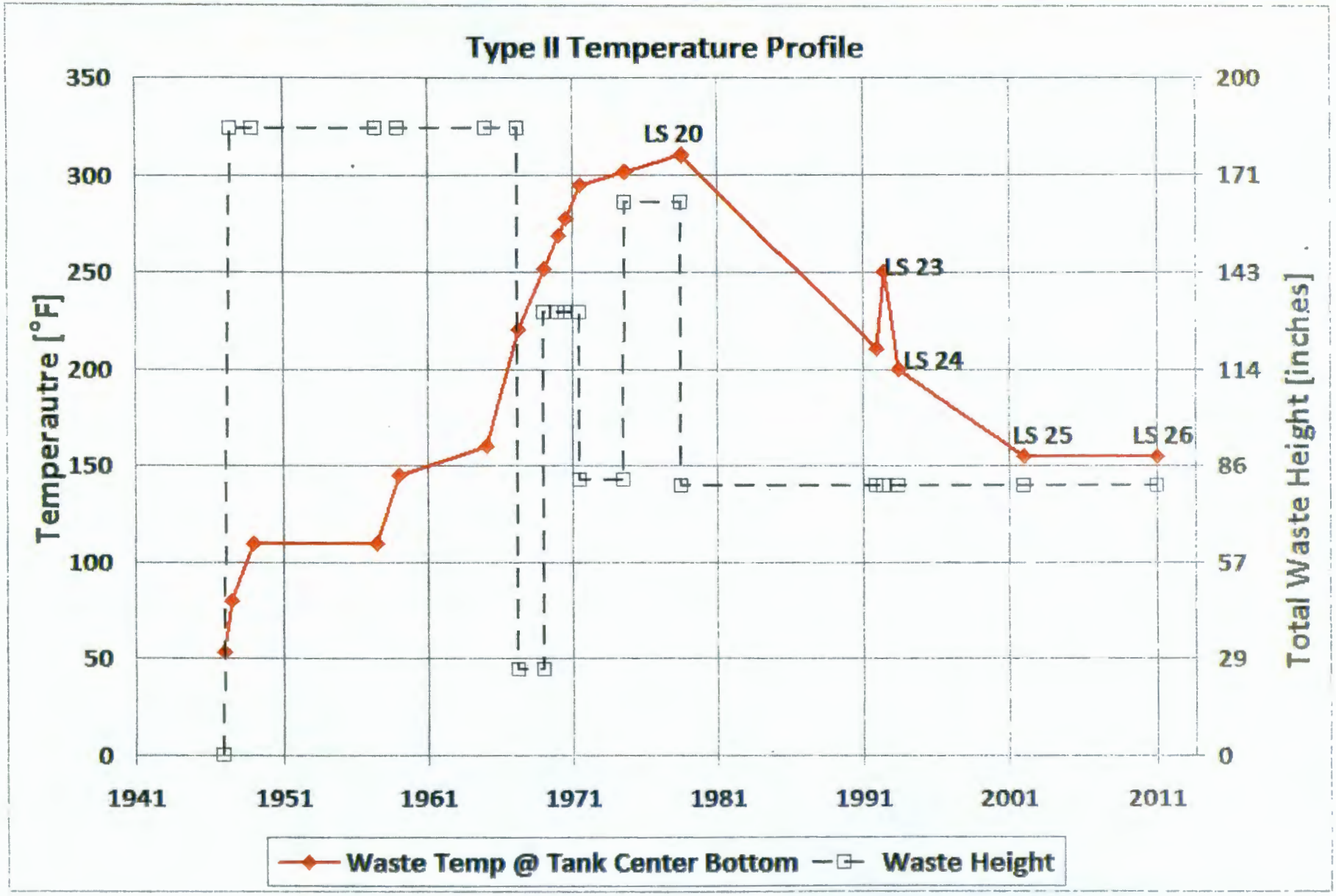






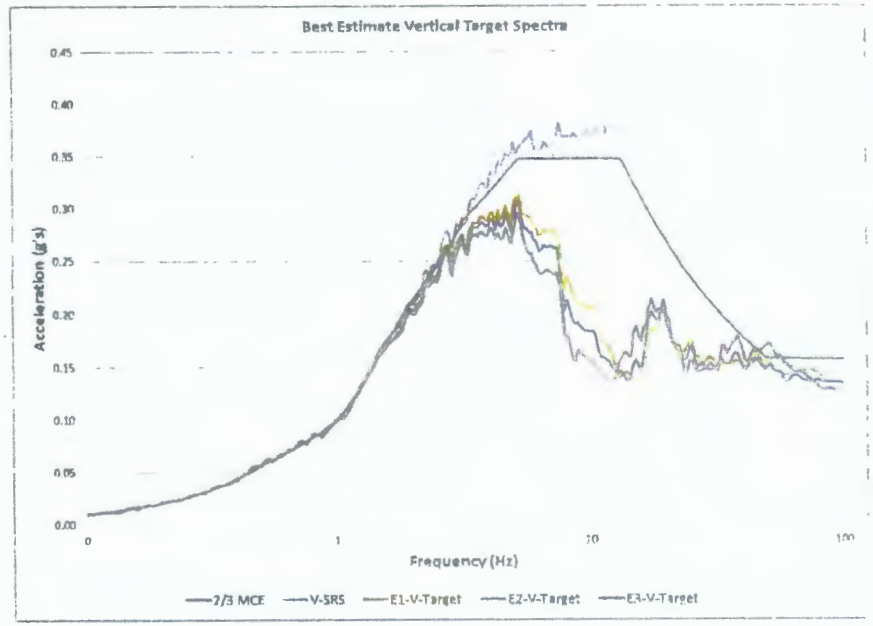


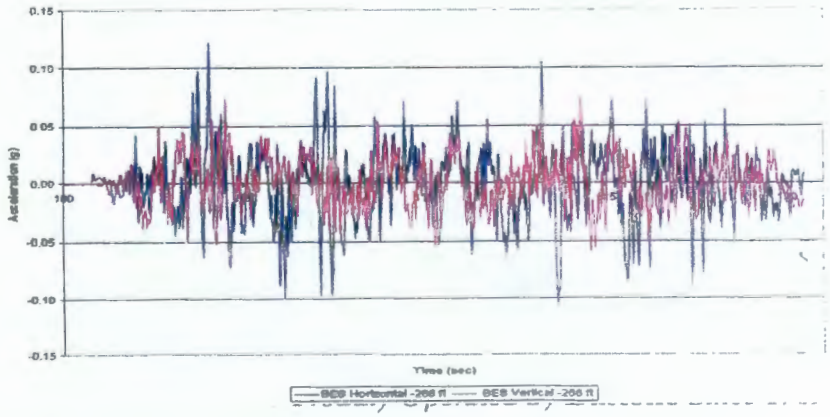
Thermal Loads – Profile used for Type II Tank Analysis



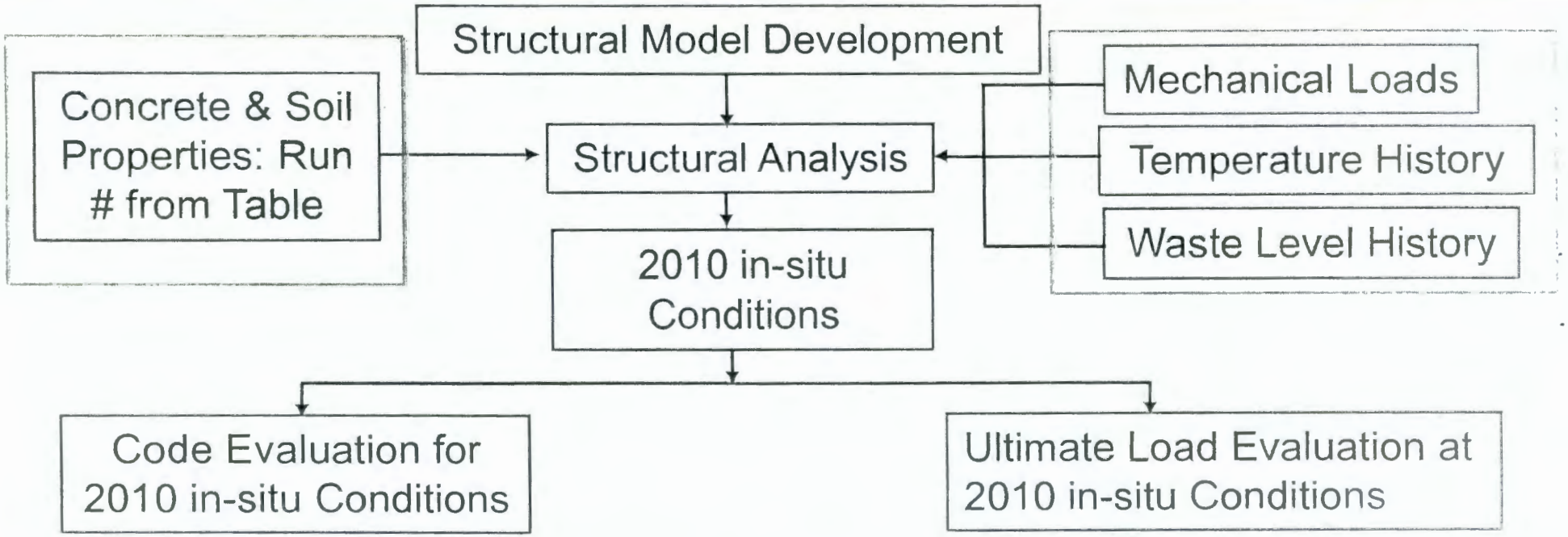
Response Spectra and Time History Development

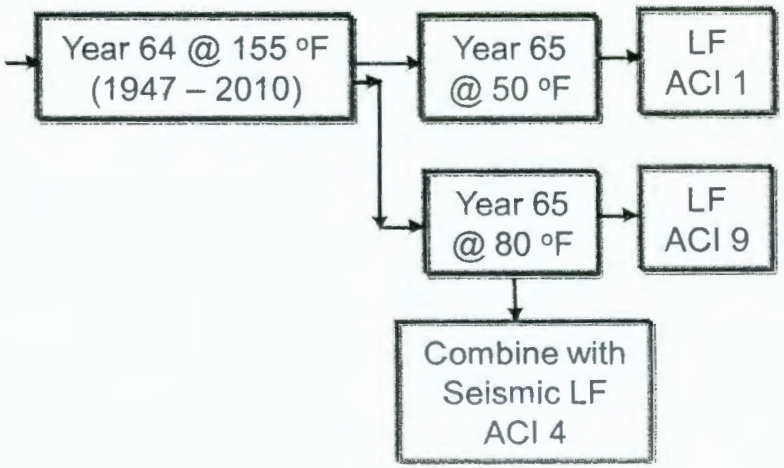
- Seismic Demand
  - Benchmarks completed against TOLA Model
  - Response Spectra and Time Histories developed by Geomatrix
  - Spectral matching completed by M&D and Geomatrix through an iterative process
  - Time Histories used for Seismic Model based upon completion of spectral matching.





Overall Model Flow for Analyses





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SST Run Matrix: Load Combinations 1 and 9

SST TOLA Run Matrix:

Run	Soil Modulus	Concrete		
		Modulus	Tensile Strength	Creep
1	Nominal	Nominal	Near Zero	Yes
2	Nominal	Nominal	Near Zero	No
3	Nominal	High	Near Zero	No
4	Low	High	Near Zero	No
5	Low	Nominal	Near Zero	No

SST TOLA Run Matrix used for Load Combinations 1 and 9 (Non-Seismic)

Results: Load Combinations 1 and 9: Meridional

Summary of LC1, LC9 Demand/Capacity Ratios

Meridional ACI Demand/Capacity Ratio Range

	Run Matrix	Load Step	Dome 1 to 15	Haunch 16 to 18	Wall 19 to 26	Slab 27 to 42
Best estimate	Run 1	LS 21 (Peak temperature)	0.11–0.21	0.15–0.41	0.18–0.28	0.08–0.82
		LS 27 (LC 1 - unfactored)	0.10–0.19	0.12–0.33	0.12–0.22	0.01–0.49
		LS 28 (LC 1 - factored)	0.14–0.28	0.18–0.53	0.22–0.39	0.02–0.40
		LS 27 (LC 9 - unfactored)	0.10–0.20	0.13–0.35	0.13–0.23	0.00–0.21
		LS 28 (LC 9 - factored)	0.13–0.25	0.17–0.47	0.19–0.33	0.00–0.20
"Worst-case combinations" using available material property bounds	Run 2	LS 21 (Peak temperature)	0.11–0.22	0.17–0.49	0.18–0.31	0.08–1.01
		LS 27 (LC 1 - unfactored)	0.11–0.21	0.14–0.49	0.13–0.29	0.02–0.41
		LS 28 (LC 1 - factored)	0.14–0.30	0.20–0.69	0.23–0.45	0.01–0.34
		LS 27 (LC 9 - unfactored)	0.11–0.21	0.15–0.50	0.14–0.29	0.00–0.24
		LS 28 (LC 9 - factored)	0.14–0.27	0.19–0.62	0.21–0.38	0.00–0.21
	Run3	LS 21 (Peak temperature)	0.11–0.22	0.17–0.48	0.18–0.32	0.09–1.13
		LS 27 (LC 1 - unfactored)	0.11–0.22	0.14–0.48	0.13–0.26	0.02–0.39
		LS 28 (LC 1 - factored)	0.14–0.30	0.20–0.68	0.23–0.43	0.01–0.33
		LS 27 (LC 9 - unfactored)	0.11–0.22	0.15–0.48	0.14–0.27	0.00–0.25
		LS 28 (LC 9 - factored)	0.13–0.27	0.19–0.61	0.19–0.36	0.00–0.21
	Run 4	LS 21 (Peak temperature)	0.11–0.23	0.16–0.53	0.18–0.33	0.07–1.03
		LS 27 (LC 1 - unfactored)	0.11–0.23	0.14–0.50	0.14–0.30	0.00–0.43
		LS 28 (LC 1 - factored)	0.15–0.31	0.20–0.72	0.24–0.47	0.00–0.36
		LS 27 (LC 9 - unfactored)	0.11–0.23	0.15–0.51	0.15–0.30	0.00–0.29
		LS 28 (LC 9 - factored)	0.14–0.28	0.20–0.73	0.20–0.47	0.00–0.27
	Run 5	LS 21 (Peak temperature)	0.11–0.23	0.16–0.52	0.18–0.32	0.07–0.92
		LS 27 (LC 1 - unfactored)	0.11–0.22	0.14–0.50	0.15–0.31	0.03–0.46
		LS 28 (LC 1 - factored)	0.15–0.31	0.2–0.73	0.25–0.48	0.02–0.39
		LS 27 (LC 9 - unfactored)	0.11–0.23	0.15–0.51	0.15–0.30	0.00–0.29
		LS 28 (LC 9 - factored)	0.14–0.29	0.19–0.65	0.22–0.41	0.00–0.31

Results: Load Combinations 1 and 9: Circumferential

Summary of LC1, LC9 Demand/Capacity Ratios

Circumferential/Hoop ACI Demand/Capacity Ratio Range

	Run Matrix	Load Step	Dome 1 to 15	Haunch 16 to 18	Wall 19 to 26	Slab 27 to 42
Best estimate	Run 1	LS 21 (Peak temperature)	0.01–0.21	0.03–0.11	0.01–0.1	0.23–0.82
		LS 27 (LC 1 - unfactored)	0.05–0.21	0.39–0.43	0.05–0.48	0.07–0.22
		LS 28 (LC 1 - factored)	0.06–0.28	0.47–0.53	0.04–0.59	0.04–0.53
		LS 27 (LC 9 - unfactored)	0.04–0.19	0.31–0.36	0.01–0.37	0.00–0.09
		LS 28 (LC 9 - factored)	0.04–0.25	0.38–0.43	0.01–0.46	0.00–0.11
"Worst-case combinations" using available material property bounds	Run 2	LS 21 (Peak temperature)	0.00–0.22	0.02–0.11	0.01–0.08	0.19–1.00
		LS 27 (LC 1 - unfactored)	0.04–0.21	0.37–0.42	0.08–0.48	0.00–0.23
		LS 28 (LC 1 - factored)	0.05–0.29	0.46–0.53	0.06–0.59	0.00–0.26
		LS 27 (LC 9 - unfactored)	0.01–0.21	0.30–0.35	0.00–0.37	0.00–0.09
		LS 28 (LC 9 - factored)	0.01–0.26	0.36–0.43	0.00–0.45	0.00–0.09
	Run3	LS 21 (Peak temperature)	0.00–0.22	0.02–0.11	0.01–0.08	0.14–1.12
		LS 27 (LC 1 - unfactored)	0.03–0.22	0.37–0.42	0.08–0.48	0.00–0.24
		LS 28 (LC 1 - factored)	0.06–0.29	0.45–0.52	0.07–0.61	0.00–0.31
		LS 27 (LC 9 - unfactored)	0.02–0.22	0.29–0.34	0.00–0.38	0.00–0.11
		LS 28 (LC 9 - factored)	0.02–0.27	0.36–0.42	0.00–0.46	0.00–0.11
	Run 4	LS 21 (Peak temperature)	0.00–0.23	0.11–0.23	0.01–0.24	0.07–1.02
		LS 27 (LC 1 - unfactored)	0.04–0.22	0.39–0.45	0.07–0.55	0.00–0.24
		LS 28 (LC 1 - factored)	0.06–0.31	0.50–0.58	0.05–0.70	0.01–0.28
		LS 27 (LC 9 - unfactored)	0.02–0.22	0.33–0.39	0.00–0.47	0.00–0.11
		LS 28 (LC 9 - factored)	0.02–0.28	0.41–0.48	0.00–0.55	0.00–0.09
	Run 5	LS 21 (Peak temperature)	0.00–0.23	0.11–0.23	0.01–0.23	0.11–0.91
		LS 27 (LC 1 - unfactored)	0.05–0.22	0.39–0.45	0.07–0.54	0.04–0.23
		LS 28 (LC 1 - factored)	0.05–0.30	0.50–0.58	0.04–0.69	0.06–0.26
		LS 27 (LC 9 - unfactored)	0.01–0.23	0.33–0.39	0.00–0.46	0.00–0.09
		LS 28 (LC 9 - factored)	0.02–0.28	0.41–0.49	0.00–0.57	0.00–0.07

Results: Load Combinations 1 and 9: Shear

Summary of LC1, LC9 Demand/Capacity Ratios

Shear ACI Demand/Capacity Ratio Range

"Worst-case combinations" using available material property bounds

	Run Matrix	Load Step	Dome 1 to 15	Haunch 16 to 18	Wall 19 to 26	Slab 27 to 42
Best Estimate	Run 1	LS 21 (Peak temperature)	0.00–0.12	0.08–0.25	0.00–0.44	0.00–1.00
		LS 27 (LC 1 - unfactored)	0.00–0.08	0.04–0.18	0.01–0.34	0.00–0.38
		LS 28 (LC 1 - factored)	0.01–0.13	0.08–0.43	0.01–0.48	0.00–0.77
		LS 27 (LC 9 - unfactored)	0.00–0.09	0.06–0.19	0.01–0.37	0.00–0.34
		LS 28 (LC 9 - factored)	0.00–0.12	0.06–0.31	0.00–0.43	0.00–0.58
	Run 2	LS 21 (Peak temperature)	0.00–0.12	0.07–0.28	0.01–0.48	0.00–1.16
		LS 27 (LC 1 - unfactored)	0.00–0.10	0.05–0.17	0.01–0.37	0.00–0.57
		LS 28 (LC 1 - factored)	0.00–0.15	0.09–0.43	0.01–0.53	0.00–0.93
		LS 27 (LC 9 - unfactored)	0.00–0.10	0.05–0.18	0.02–0.45	0.00–0.59
		LS 28 (LC 9 - factored)	0.00–0.13	0.07–0.31	0.01–0.50	0.00–0.76
	Run3	LS 21 (Peak temperature)	0.00–0.12	0.07–0.27	0.01–0.49	0.00–1.24
		LS 27 (LC 1 - unfactored)	0.00–0.10	0.05–0.16	0.01–0.39	0.00–0.61
		LS 28 (LC 1 - factored)	0.00–0.15	0.09–0.42	0.01–0.53	0.00–0.99
		LS 27 (LC 9 - unfactored)	0.00–0.10	0.05–0.16	0.01–0.42	0.00–0.60
		LS 28 (LC 9 - factored)	0.00–0.14	0.08–0.29	0.02–0.50	0.00–0.78
	Run 4	LS 21 (Peak temperature)	0.00–0.12	0.07–0.30	0.02–0.50	0.00–1.21
		LS 27 (LC 1 - unfactored)	0.00–0.11	0.06–0.23	0.01–0.41	0.00–0.70
		LS 28 (LC 1 - factored)	0.00–0.16	0.10–0.51	0.03–0.55	0.00–1.10
		LS 27 (LC 9 - unfactored)	0.00–0.11	0.06–0.23	0.01–0.43	0.00–0.69
		LS 28 (LC 9 - factored)	0.00–0.15	0.08–0.38	0.01–0.47	0.00–0.88
	Run 5	LS 21 (Peak temperature)	0.00–0.12	0.07–0.30	0.01–0.47	0.00–1.12
		LS 27 (LC 1 - unfactored)	0.00–0.10	0.06–0.24	0.01–0.40	0.00–0.66
		LS 28 (LC 1 - factored)	0.00–0.16	0.10–0.52	0.02–0.53	0.00–1.06
		LS 27 (LC 9 - unfactored)	0.00–0.11	0.06–0.24	0.01–0.42	0.00–0.67
		LS 28 (LC 9 - factored)	0.00–0.14	0.08–0.37	0.02–0.52	0.00–0.85

SST Load Combination 4 – Run Matrix

#	Seismic Properties			TOLA
	Soil	Waste		
		Properties	Height	Run Used
1	BES	High	Full	1
2	BES	Low	Full	1
3	BES	-	Empty	1
4	LBS	High	Full	5**
5	LBS	Low	Full	5**
6	LBS	-	Empty	5**
7	UBS	High	Full	UBS*
8	UBS	Low	Full	UBS*
9	UBS	-	Empty	UBS*

SST TOLA Run Matrix for Reference:

Run	Soil Modulus	Concrete		
		Modulus	Tensile Strength	Creep
1	N	N	Near Zero	Yes
2	N	N	Near Zero	No
3	N	H	Near Zero	No
4	L	H	Near Zero	No
5	L	N	Near Zero	No

L – Low, N –Nominal/Mean (Best Estimate), H – High

Notes :

- For (*)
  - UBS is not a part of TOLA run matrix; UBS TOLA run added for LC4 combination
- For (**)
  - Run 5 with creep is not available, so use run 5 with no creep. In general no creep case is conservative

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Results: Load Combination 4, Meridional, Circumferential, and Shear

Summary of LC4 – Seismic Demand/Capacity Ratios

Combined ACI Demand/Capacity Ratio Range

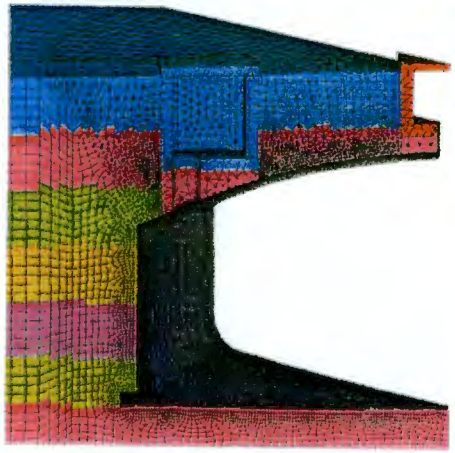
Combined Run		Dome 1 to 15	Haunch 16 to 18	Wall 19 to 26	Slab 27 to 42
Run 1 Seismic: BES G_{high} TOLA: BES	Meridional	0.12–0.24	0.18–0.73	0.15–0.40	0.12–1.51
	Hoop	0.13–0.80	0.49–0.53	0.17–0.66	0.19–0.28
	Shear	0.01–0.13	0.22–0.30	0.06–0.75	0.00–0.64
Run 2 Seismic: BES G_{low} TOLA: BES	Meridional	0.12–0.25	0.17–0.60	0.15–0.33	0.08–1.03
	Hoop	0.11–0.70	0.48–0.53	0.11–0.48	0.04–0.28
	Shear	0.01–0.12	0.19–0.30	0.05–0.50	0.00–0.46
Run 3 Seismic: BES empty TOLA: BES	Meridional	0.12–0.25	0.17–0.65	0.15–0.33	0.04–0.60
	Hoop	0.11–0.70	0.49–0.53	0.11–0.48	0.06–0.28
	Shear	0.01–0.13	0.19–0.30	0.04–0.51	0.00–0.47
Run 4 Seismic: LBS G_{high} TOLA: LBS	Meridional	0.13–0.28	0.20–0.81	0.17–0.47	0.10–1.08
	Hoop	0.14–0.54	0.51–0.56	0.20–0.70	0.17–0.28
	Shear	0.01–0.14	0.16–0.32	0.03–0.87	0.00–1.17
Run 5 Seismic: LBS G_{low} TOLA: LBS	Meridional	0.13–0.27	0.20–0.73	0.17–0.46	0.04–0.61
	Hoop	0.14–0.54	0.50–0.55	0.11–0.54	0.00–0.28
	Shear	0.01–0.14	0.16–0.32	0.03–0.81	0.00–1.04
Run 6 Seismic: LBS empty TOLA: LBS	Meridional	0.13–0.27	0.21–0.73	0.17–0.42	0.02–0.61
	Hoop	0.14–0.54	0.50–0.55	0.09–0.54	0.17–0.28
	Shear	0.01–0.14	0.16–0.32	0.03–0.75	0.00–0.98
Run 7 Seismic: UBS G_{high} TOLA: UBS	Meridional	0.12–0.23	0.23–0.63	0.14–0.36	0.21–2.16
	Hoop	0.09–0.38	0.45–0.52	0.19–0.71	0.19–0.47
	Shear	0.01–0.18	0.15–0.26	0.06–0.72	0.00–0.82
Run 8 Seismic: UBS G_{low} TOLA: UBS	Meridional	0.12–0.23	0.24–0.63	0.14–0.31	0.15–1.44
	Hoop	0.09–0.34	0.45–0.50	0.10–0.43	0.07–0.29
	Shear	0.01–0.13	0.15–0.26	0.04–0.60	0.00–0.56
Run 9 Seismic: UBS empty TOLA: UBS	Meridional	0.12–0.23	0.24–0.58	0.14–0.31	0.02–0.84
	Hoop	0.10–0.38	0.45–0.50	0.10–0.42	0.19–0.29
	Shear	0.01–0.18	0.15–0.25	0.04–0.60	0.00–0.52

Results Summary – Detailed Analysis

- For all runs with "Best Estimate" properties, the tank dome, haunch, and wall demands were below the capacity.
- For all runs with variations in soil and concrete properties, the tank dome, haunch, and wall, demands were below the capacity
- Several locations in the slab showed higher demands than capacity
  - Additional runs were made isolating the slab from the rest of the tank, and those results show that the dome, haunch, and wall maintain structural integrity
  - The slab is displacement controlled

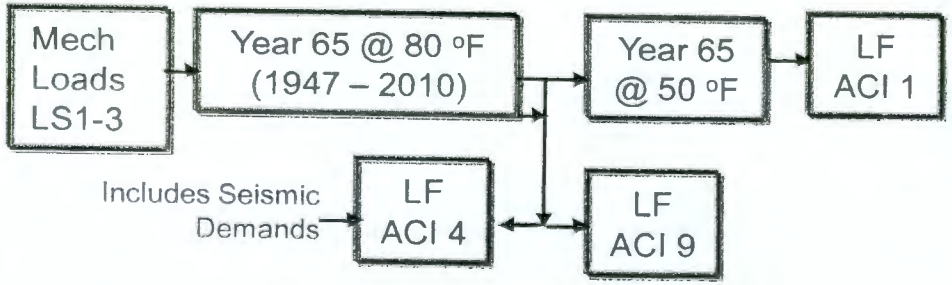
Modeling of Appurtenances

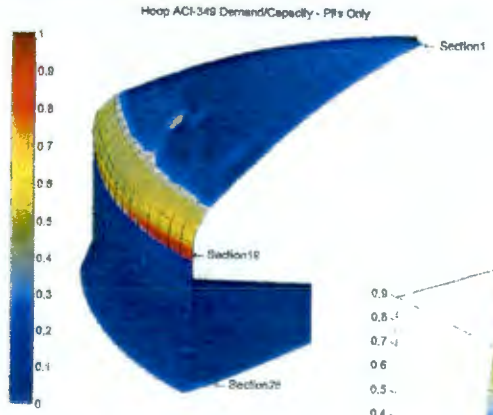
- Determine the impacts of Appurtenances
  - Pump pits Alone
  - Pits and Penetrations

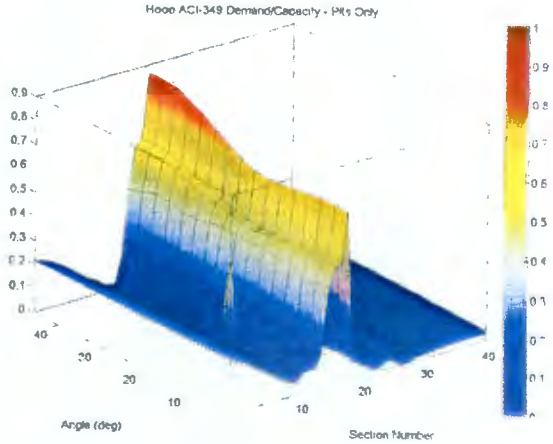


Type II Tank Appurtenances

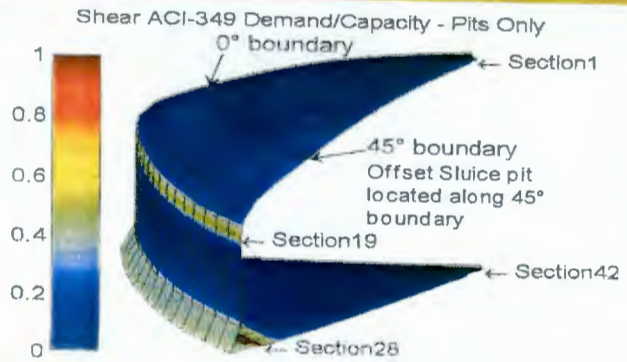
- Check ACI D/C at:
  - Peak temperature
  - ACI load combinations 1, 4, and 9

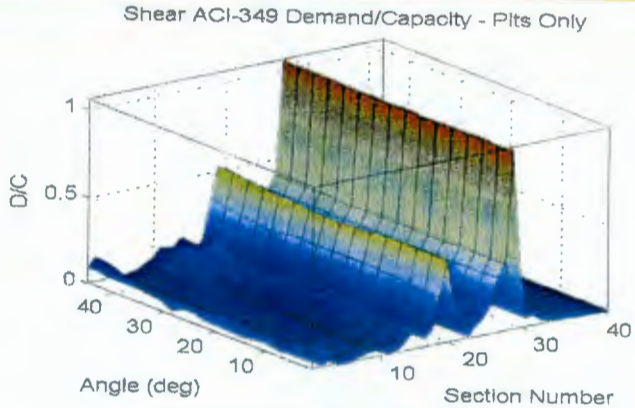


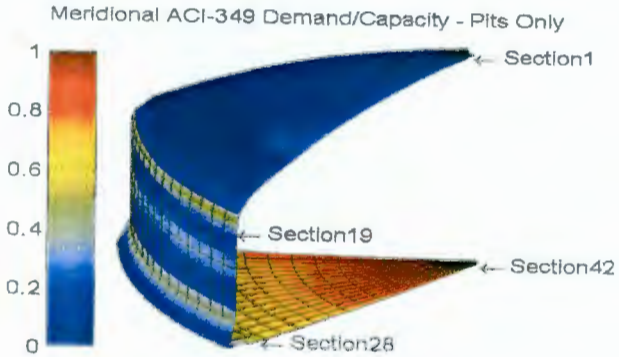


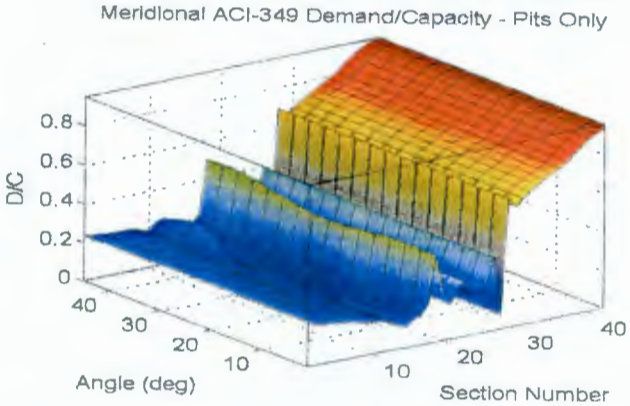


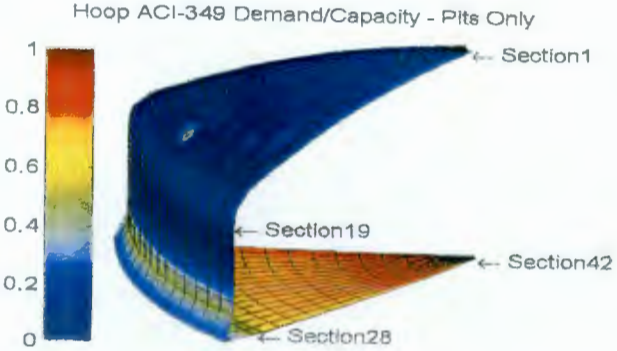
Appurtenance Results – Pits – Peak Temp

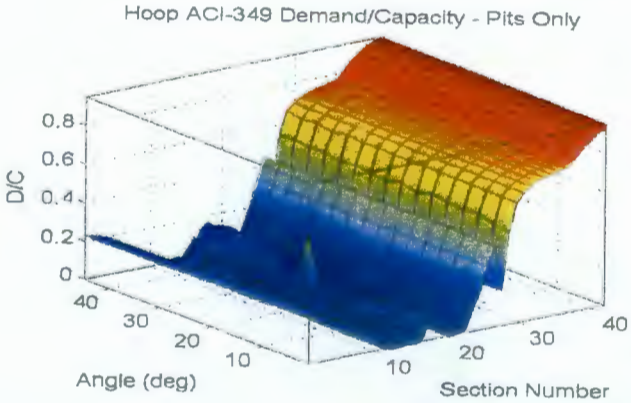












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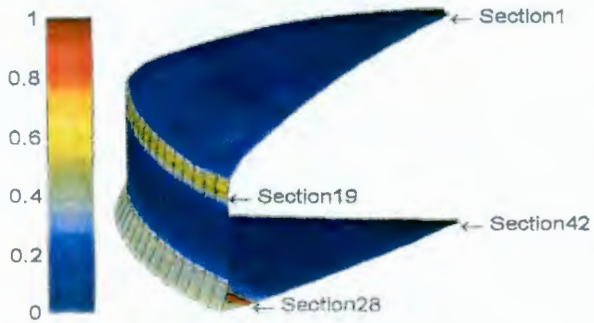
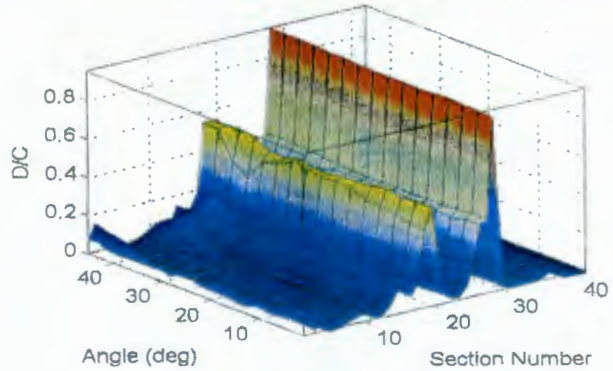
Appurtenance Results – Pits – Load Combination 1

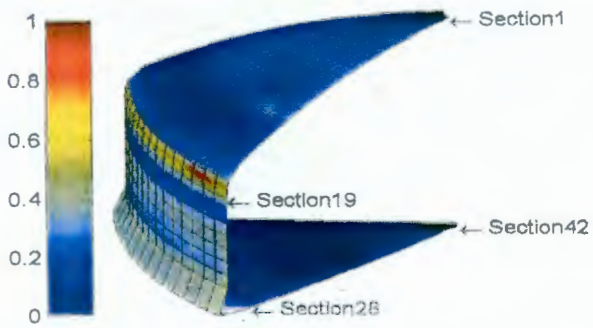
Shear ACI-349 Demand/Capacity - Pits Only



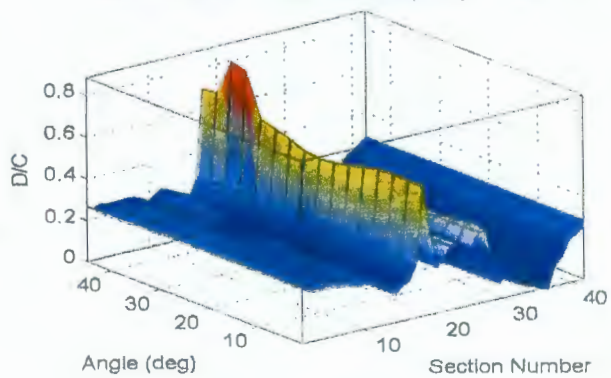
Shear ACI-349 Demand/Capacity - Pits Only



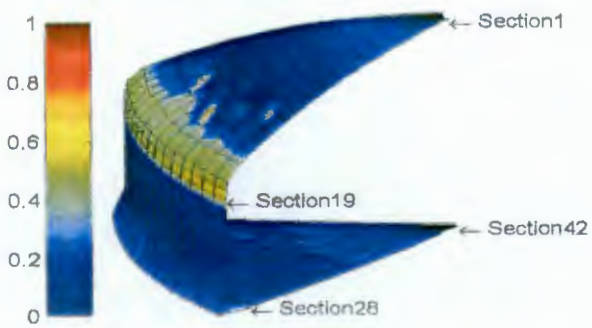
Meridional ACI-349 Demand/Capacity - Pits Only



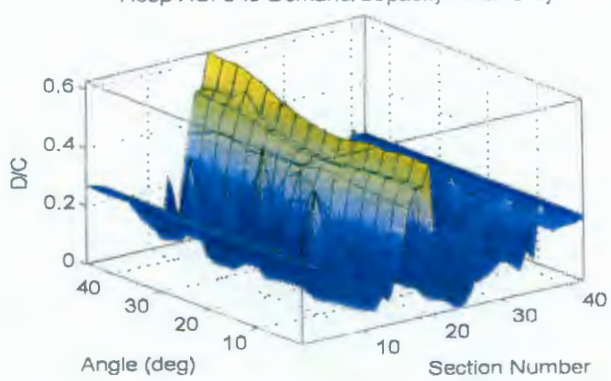
Meridional ACI-349 Demand/Capacity - Pits Only



Hoop ACI-349 Demand/Capacity - Pits Only



Hoop ACI-349 Demand/Capacity - Pits Only



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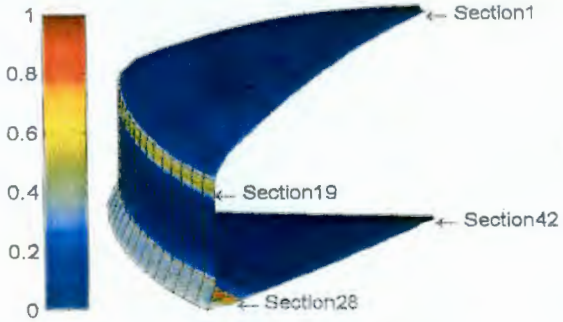
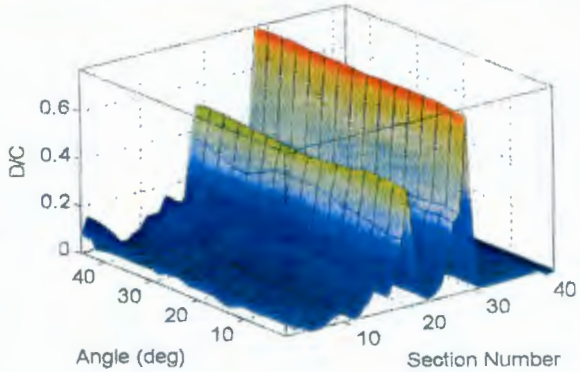
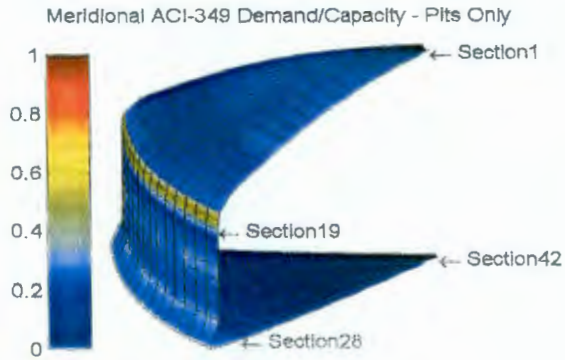
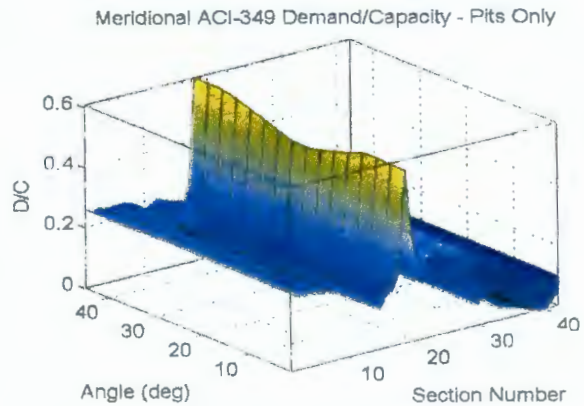
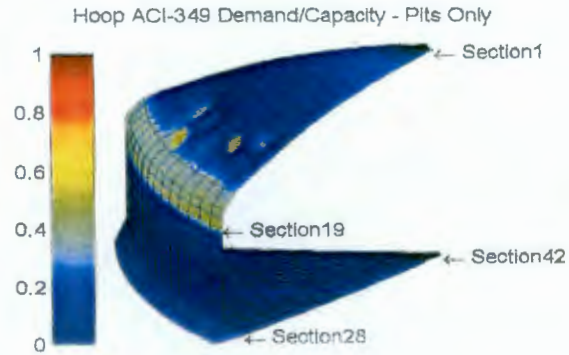
Appurtenance Results – Pits – Load Combination 9

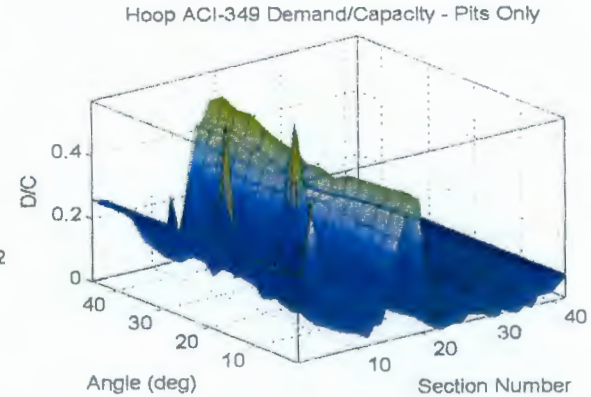












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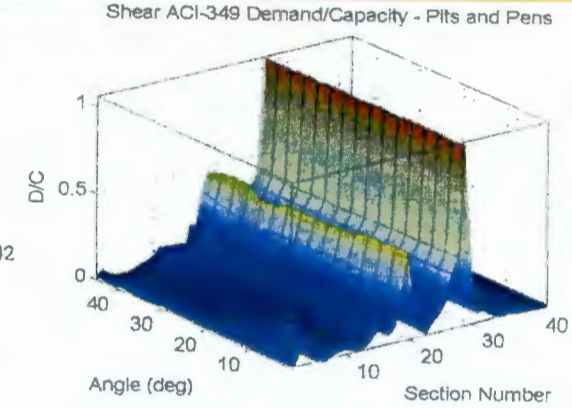
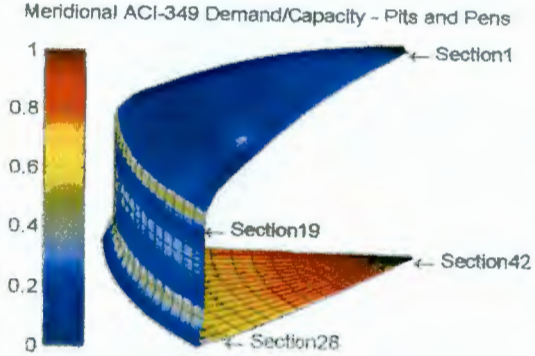
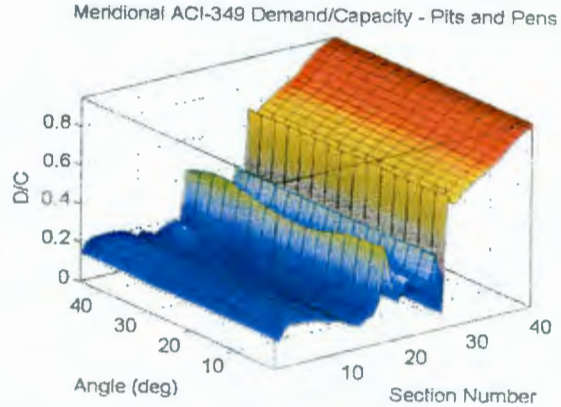
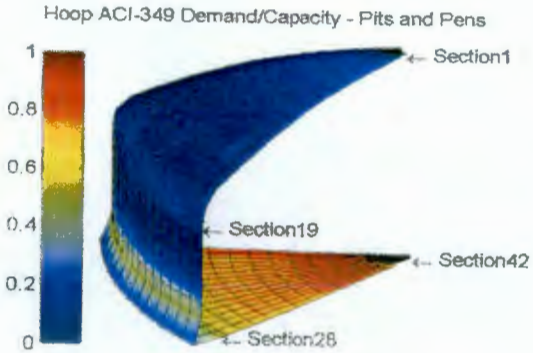
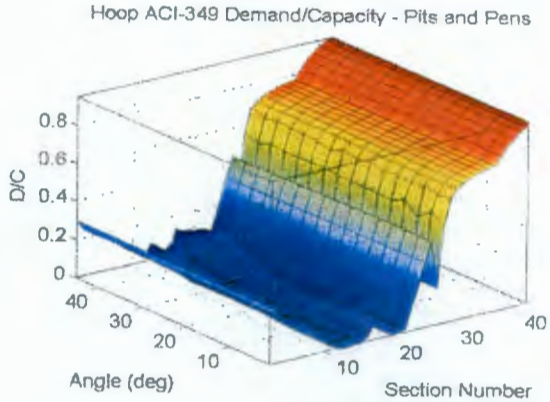
Pits and Penetrations – Peak T











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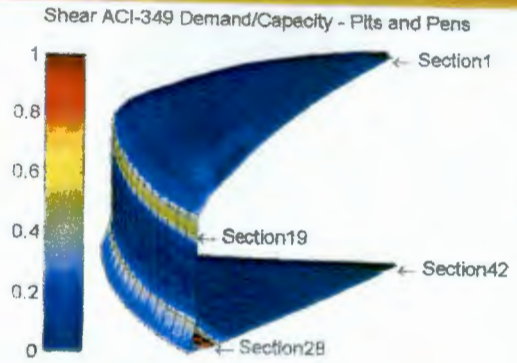
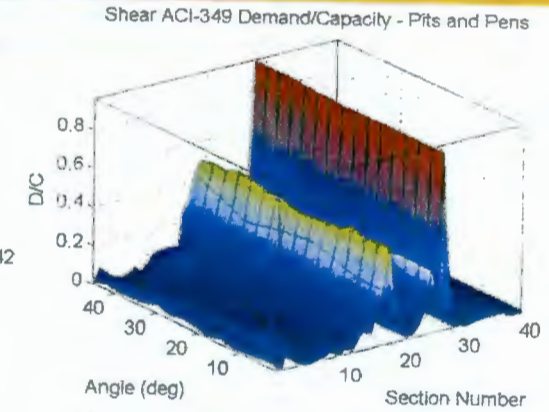
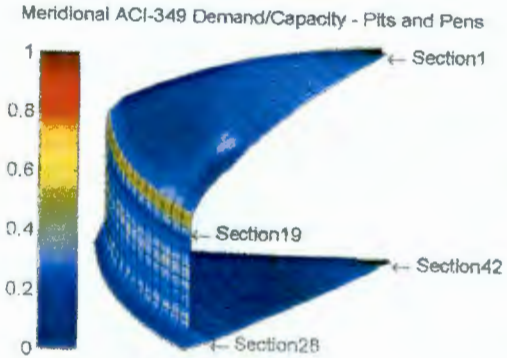
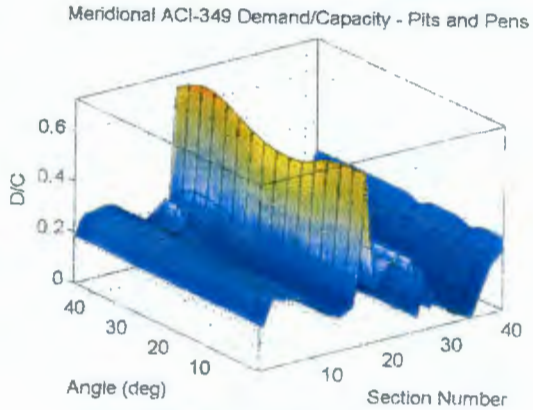
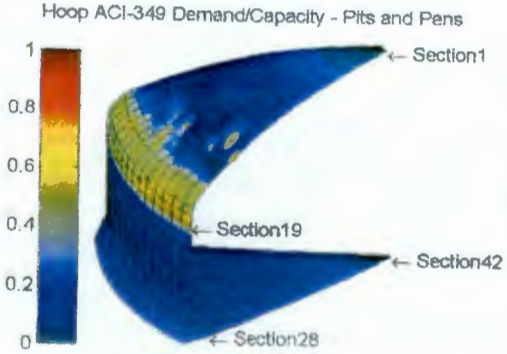
Pits and Penetrations – Load Combination 1

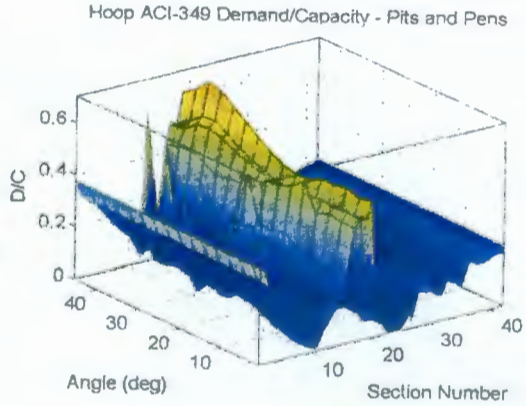












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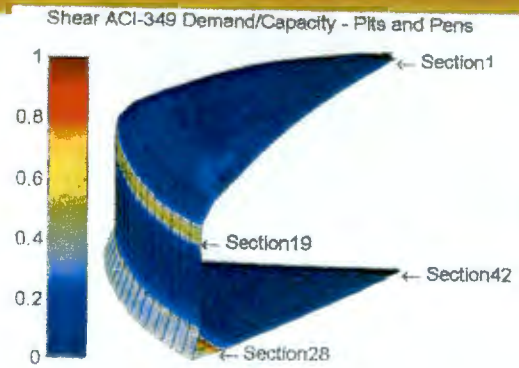
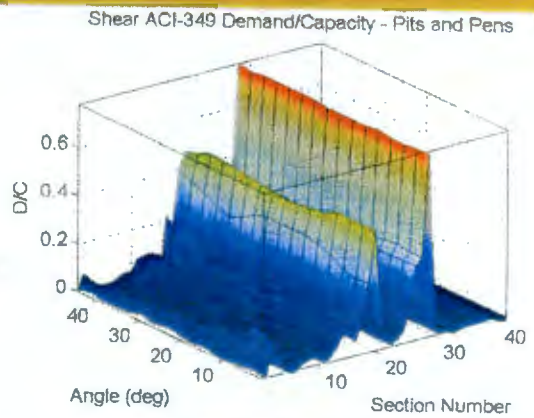
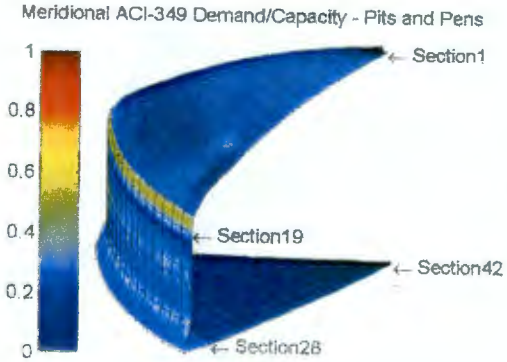
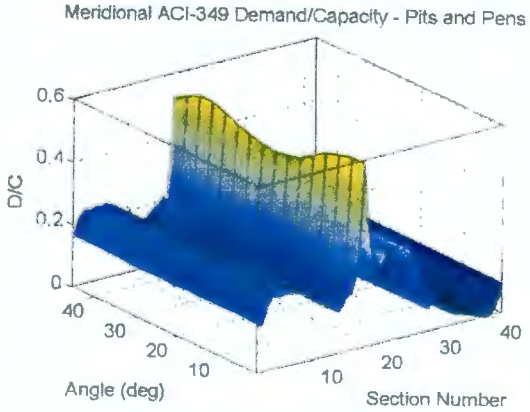
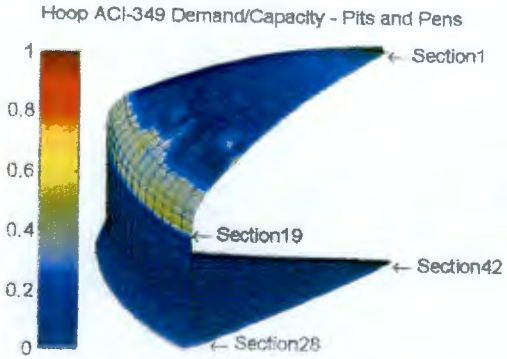
Pits and Penetrations – Load Combination 9

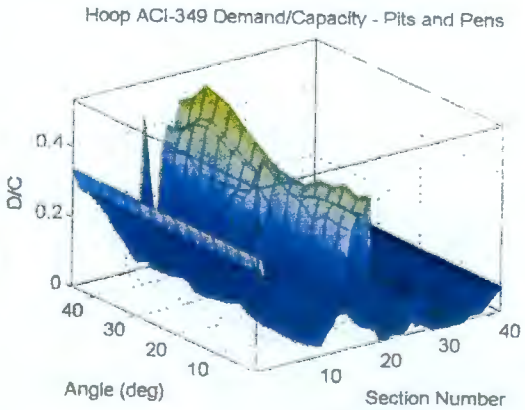












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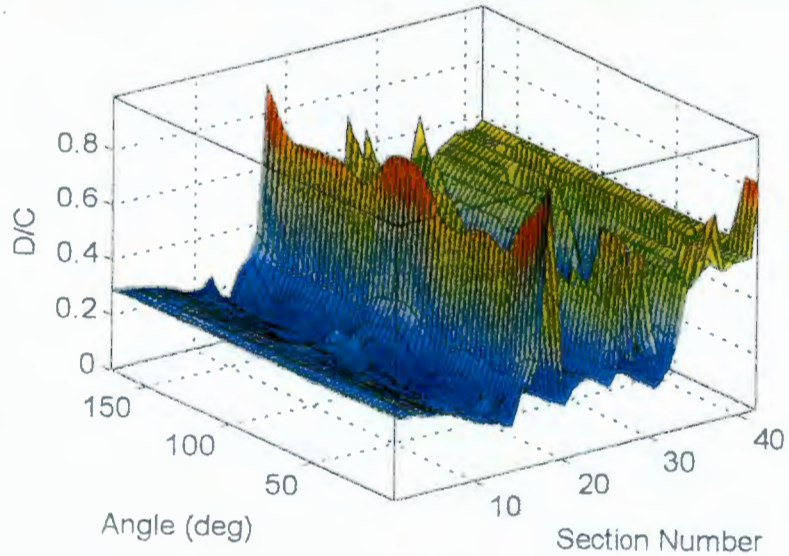
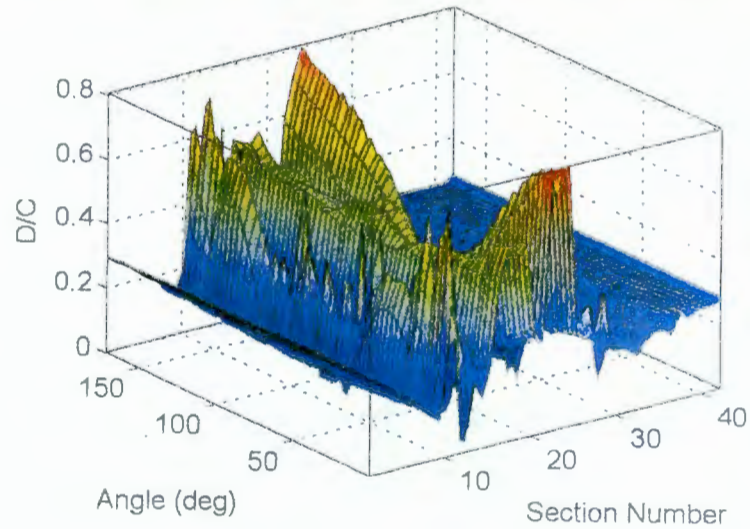
Pits – Load Combination 4

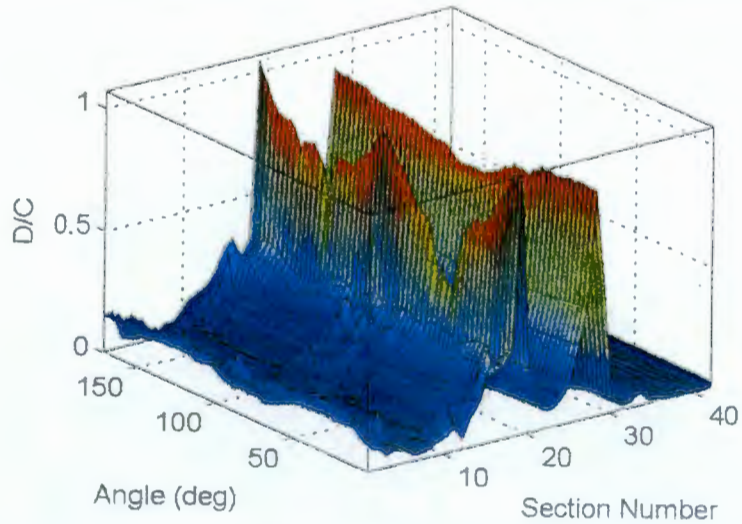
Merid. ACI-349 LC4 Demand/Capacity - Pits Only



Hoop ACI-349 LC4 Demand/Capacity - Pits Only



Shear ACI-349 LC4 Demand/Capacity - Pits Only



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Results Summary of Pits and Penetrations

- For load combinations 1 and 9, demands were less than capacity for all locations in the dome, haunch, and wall.
- For load combination 4 (seismic), the shear demand at section 19 (top of the wall) exceeded capacity in a localized area
  - Appurtenance model includes combination of pit weight and soil overburden that is conservative.

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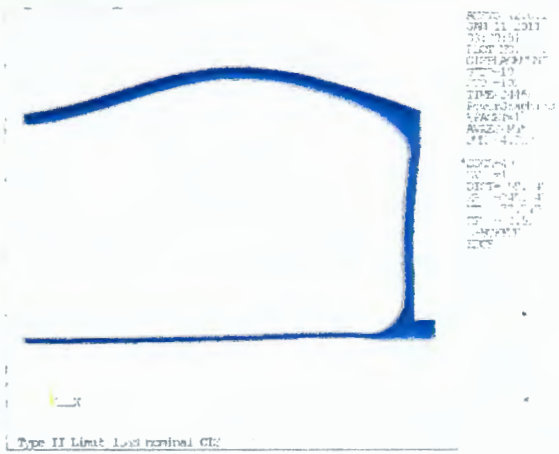
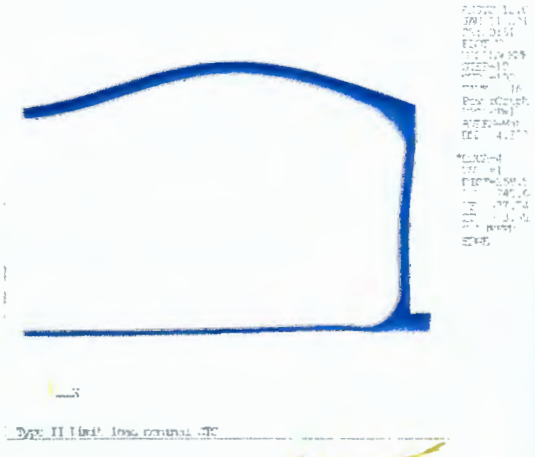
Results Summary of Limit Loads and Buckling Analyses

- **Tank Limit Analysis safety factors**
  - Safety Factors all greater than 3.0 recommended in evaluation criteria

Concrete	Limit Load - uniform (psi)	Limit Load - local (kips)	Equiv load - uniform (psi)	Equiv load - local (kips)	Safety Factor (uniform)	Safety Factor (local)
10' Soil LB	38	5000	10.2	1100	4.7	5.5
10' Soil Nom.	43	5700	10	1060	5.3	6.4
5.8' Soil LB	38	3700	6	510	7.3	8.3
5.8' Soil Nom.	44	4400	6	510	8.3	9.6



- **Buckling analyses**
  - Dome buckling safety factor of 3.15 slightly below recommended values 3.5
  - For realistic temperature and soil depth, dome safety factors of 4.0 exceeded requirements
  - For high soil depth, safety factors was 3.43 which is just under the recommended value.
  - Wall buckling analyses showed safety factors that significantly exceeded recommended values in all cases.



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Overall Conclusions

- Analysis conducted did not show any structural deficiencies in the dome or wall of the Type II SSTs
- The floor of the SSTs shows deficiencies due to low tension demands and low capacity of the concrete, but the floor has no impact on the structural integrity of the dome and wall
- Appurtenances in the Type II SSTs show that a localized area exceeded the D/C ratios for a conservative case
- The limit loads and buckling loads did not uncover any deficiencies.

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Enclosure 2

11-TPD-064

RPP-RPT-49989, Rev. 0
Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis

Consisting of 2 pages, including coversheet.

Single-Shell Tank Integrity Project Analysis of Record Hanford Type II Single-Shell Tank Thermal and Operating Loads and Seismic Analysis

Author Name: R.S. Rast
Washington River Protection Solutions

Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

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Key Words: Single Shell Tank, SST, 530000 gallon, structural, analysis of record, dome, concrete, rebar, thermal, operating, seismic, soil structure interaction, finite element analysis, ANSYS

Abstract: This report documents the structural analysis of record of Hanford 530,000 gallon (Type II) Single-Shell Tanks. The analysis concludes that for the imposed loading, the reinforced concrete tank structure meets the requirements of the American Concrete Institute (ACI) 349 code and thereby the International Building Codes (IBC). Analyses include the effects and combinations of seismic, dead, live, soil, thermal, hydrostatic, concentrated loads. The analysis also addresses the effects of concrete pits and associated penetrations. Limit load and buckling analyses are also performed to provide insight as to the response of the tank structure to increased concentrated and distributed loads applied at the ground surface. The analysis of record has been peer reviewed by recognized industry experts.

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