Soil Structure Interaction Analysis for the Hanford Site 241-SY-101 Double-Shell Waste Storage Tanks

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Date Published
September 1991

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and Waste Management

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Hanford Operations and Engineering Contractor for the U.S. Department of Energy under Contract DE-AC06-87RL10930

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Document Title: SOIL-STRUCTURE INTERACTION ANALYSIS FOR THE HANFORD SITE
241-SY-101 DOUBLE-SHELL STORAGE TANK

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ABSTRACT

The 241-SY-101 tank is a double-shell waste storage tank buried in the 241-SY tank farm in the 200 West Area of the Hanford Site. This analysis addresses the effects of seismic soil-structure interaction on the tank structure and includes a parametric soil-structure interaction study addressing three configurations: two-dimensional soil-structure, a two-dimensional structure-soil-structure, and a three-dimensional soil-structure interaction. This study was designed to determine an optimal method for addressing seismic-soil effects on underground storage tanks. The computer programs calculate seismic-soil pressures on the double-shell tank walls and seismic acceleration response spectra in the tank.

The results of this soil-structure interaction parametric study as produced by the computer programs are given in terms of seismic soil pressures and response spectra. The conclusions of this soil-structure interaction evaluation are that dynamically calculated soil pressures in the 241-SY-101 tank are significantly reduced from those using standard hand calculation methods and that seismic evaluation of underground double-shell waste storage tanks must consider soil-structure interaction effects in order to predict conservative structural response. Appendixes supporting this study are available in Volume 2 of this report.
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EXECUTIVE SUMMARY

The 241-SY-101 double-shell tank (DST) is a waste storage tank buried in the 241-SY tank farm in the 200 West Area of the Hanford Site. This DST has been analyzed in the past for seismic loads in three separate analyses for three different liquid levels. This analysis addresses the effects of seismic soil-structure interaction (SSI) on the tank structure. This SSI analysis is an evaluation of DST 241-SY-101 with a liquid level capacity of 4,656 m$^3$ (1.23 Mgal), the largest capacity analyzed to date.

The present effort includes a parametric SSI study addressing three configurations: a two-dimensional soil structure, a two-dimensional structure-soil-structure, and a three-dimensional soil-structure interaction. This study was designed to determine an optimal method for addressing seismic-soil effects on underground storage tanks. The computer programs calculate seismic-soil pressures on the DST walls and seismic acceleration response spectra in the tank. The objective is to calculate seismic SSI effects on an underground storage tank using two-dimensional methods, two-dimensional methods including the effects of adjacent tank, and three-dimensional effects to determine which method is adequate to predict SSI effects.

This seismic SSI parametric study of DST 241-SY-101 used the finite-element computer codes ANSYS, SHAKE, FLUSH, and SASSI. The ANSYS

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1ANSYS is a proprietary code, but a user’s license is commercially available from Swanson Analysis Systems, Inc., Houston, Pennsylvania.

2SHAKE is a computer program developed by the University of California, Berkeley, California.

3FLUSH is a computer program developed by the University of California, Berkeley, California.
computer code calculates the tank's liner and fluid natural frequency for input modeling to the SSI programs. The SHAKE and FLUSH codes calculate the seismic free-field soil properties for use in the SSI programs. The FLUSH two-dimensional SSI program, with a simulated three-dimensional effect, calculates soil pressures and seismic responses for one- and two-tank models. The FLUSH results then are compared to the three-dimensional SASSI results for a single tank. The SASSI three-dimensional program calculates the seismic response, which is then compared to the FLUSH two-dimensional and the Standard Design Criteria 4.1 response spectra.

The results of the SSI parametric study are given in terms of seismic soil pressures and response spectra, which are provided in Sections 3.1.2 and 3.1.3 and Appendix C (provided in Volume 2 of this report). The soil pressure results of this SSI evaluation, when compared to previous calculations\(^5\) show that using American Society of Civil Engineers (ASCE) methodology\(^6\) to determine SSI effects is highly conservative. The SSI dynamically calculated soil pressures are approximately 40 percent of the ASCE hand-calculated values.

\(^4\)SASSI is a computer program developed by the University of California, Berkeley, California.


The response spectra results indicate that the buried tank will incur some amplification in the 1- to 2-Hz range. The amplified acceleration is above the SDC 4.1 free-field surface response spectra. The conclusion of this SSI evaluation is that the seismic evaluation of underground tanks must consider SSI effects to accurately predict structural response. When multiple tank configurations are considered, accelerations in the 1- to 2-Hz range were decreased while accelerations in the 7- to 10-Hz were increased. The three-dimensional single-tank case also produced much lower response in the 1- to 2-Hz range than the two-dimensional single-tank case but higher response in the 7- to 10-Hz.
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<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society of Testing and Materials</td>
</tr>
<tr>
<td>DST</td>
<td>double-shell tank</td>
</tr>
<tr>
<td>SSE</td>
<td>Safe Shutdown Earthquake</td>
</tr>
<tr>
<td>SSI</td>
<td>soil-structure interaction</td>
</tr>
<tr>
<td>SST</td>
<td>single-shell tank</td>
</tr>
<tr>
<td>WHC</td>
<td>Westinghouse Hanford Company</td>
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</tbody>
</table>
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Double-shell tank (DST) 241-SY-101 is one of three radioactive waste storage tanks buried in the 241-SY tank farm in the 200 West Area and is a representative DST on the Hanford Site. This DST has been structurally evaluated at liquid levels of 9.22 m (363 in.) (URS/Blume 1974), 10.72 m (422 in.) (URS/Blume 1981), and 11.43 m (450 in.) (WHC 1991). Figure 1 provides the waste tank profile, and Figure 2 provides pool height locations relative to the DST profile. Neither the DSTs nor any of the single-shell tanks (SST) at the Hanford Site have been analyzed for soil-structure interaction (SSI) effects. Without an SSI evaluation, accurate seismic response cannot be guaranteed. High-hazard facilities are required by Hanford Plant Standard Arch-Civil Standard Design Criteria (SDC) 4.1, Rev. 11 (Conrads 1989), to be evaluated for SSI effects.

1.1 PURPOSE

This structural assessment evaluates DST 241-SY-101 for the effects of seismic SSI loads and considers cases for two-dimensional single-tank, three-dimensional single-tank, and two-dimensional multitank situations. The intent is to determine the influence that SSI has on the seismic response of buried tanks. The results of these analyses are reported in the form of dynamic soil pressures and acceleration response spectra. Comparison between two-dimensional, three-dimensional, and multitank spectra results show the influence of SSI effects in various areas of the structure. From these results, conclusions and recommendations can be made on how future tank structural evaluations should be performed.

1.2 BACKGROUND

Tank 241-SY-101 was constructed between 1974 and 1976, and filling was initiated in early 1977. The original capacity of the tank was defined as 3,785 m³ (1 Mgal), and the first design verification analysis was performed by URS/John A. Blume and Associates, Engineers (URS/Blume 1974). Subsequently, the operational specifications were modified to allow operation of the tank at a capacity of 4,315 m³ (1.14 Mgal). Design verification analysis was performed and reported (URS/Blume 1981). In July 1991, a Westinghouse Hanford Company (Westinghouse Hanford) analysis evaluated DST 241-SY-101 for 4,656 m³ (1.23 Mgal). The initial specifications for the operation of this tank defined a uniform specific gravity of 1.7 for the waste, a uniform maximum waste operating temperature of 121 °C (250 °F), and the design capacities as discussed above. All analyses (URS/Blume 1974, 1981; WHC 1991) used the above specific gravity and waste temperature and the appropriate liquid depths.
Figure 1. Typical Tank Cross Section.

Spring Line Primary Steel Tank
Secondary Steel Tank
Primary Steel Tank
Insulating Concrete
Concrete Tank

EL-188.27 m
EL-197.97 m
EL-188.11 m
EL-204.90 m
Figure 2. Liquid Pool Height.

New Pool Height
11.43 m EL = 199.72 m

URS/Blume, 1981
Pool Height
10.72 m EL = 199.01 m

Spring Line Primary
Steel Tank
EL-198.99 m

Original Pool Height 9.22 m
EL-197.51 m

EL-198.27 m
2.0 DISCUSSION

2.1 TANK DESCRIPTION

Tank 241-SY-101 is a reinforced-concrete, cylindrical, domed-roof, buried tank that contains an inner primary steel tank and a secondary steel liner. The tank has an overall outside diameter of 25.30 m (83 ft), an overall height of approximately 15.24 m (50 ft), and a minimum depth of soil burden at the dome of 1.98 m (6.5 ft). The annulus between the inner and outer liners is 0.76 m (30 in.). Dimensional details of the tank are presented in Figure 1. Table 1 lists the drawings that define the structural details and control dimensions of the buried tank.

<table>
<thead>
<tr>
<th>Drawing</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>H-2-37704</td>
<td>&quot;Structural Concrete Tank Foundation - Plan and Details,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 2, 1976</td>
</tr>
<tr>
<td>H-2-37705</td>
<td>&quot;Structural Insulating Concrete - Plan and Details,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 2, 1975</td>
</tr>
<tr>
<td>H-2-37706</td>
<td>&quot;Concrete - Tank Sections and Haunch Reinforcement,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 2, 1976</td>
</tr>
<tr>
<td>H-2-37707</td>
<td>&quot;Concrete - Dome Reinforcement Plan and Details,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 1, 1976</td>
</tr>
<tr>
<td>H-2-37708</td>
<td>&quot;Concrete - Haunch Reinforcement at Annulus Access,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 1, 1976</td>
</tr>
<tr>
<td>H-2-37772</td>
<td>&quot;Tank Cross Section, 241-SY Tank Farm,&quot;</td>
</tr>
<tr>
<td></td>
<td>Rev. 2, 19</td>
</tr>
</tbody>
</table>

The reinforced-concrete dome varies in thickness from 0.38 m (15 in.) at the crown to about 0.76 m (30 in.) at the haunch. The dome's inner surface is ellipsoidal with a major diameter of 24.38 m (80 ft) and a minor diameter of 9.14 m (30 ft). The dome outer surface has two radii, the first is 30.43 m (99 ft 10 in.) over the center portion of the dome covering an arc of about 11.5 degrees, and the second is 20.88 m (68 ft 6.25 in.) over the remaining outer portion of the dome. The cylindrical wall has a constant thickness of 0.46 m (18 in.) from the haunch to the base. The cylindrical concrete encasement rests on the concrete basemat, but is not structurally connected.

The tank is of dual steel-wall construction. The primary tank is a welded assembly fabricated of American Society of Testing and Materials (ASTM 1972) A516 Gr 65 mild steel with a minimum specified yield of 241,000 Kpa (35 kip/in²). The diameter of the cylindrical portion of the tank is 22.86 m (75 ft) (measured from the centerline of the plate). The cylindrical section is nominally 9.75 m (32 ft) high, and the rise of the
The minimum plate thickness of 10 mm (0.375 in.) occurs over the tank dome from about the dome tangent line to near the center of the dome. The thickness increases to 13 mm (0.5 in.) at the dome center region. The upper tank wall and tank bottom are 13 mm (0.5 in.) thick. The radius in the lower knuckle region is 0.30 m (12 in.) with a thickness of 22 mm (0.875 in.) decreasing to 19 mm (0.75 in.) for about the first 3.05 m (10 ft) of wall height. The primary steel tank sits on an 0.20-m (8-in.)-thick layer of insulating refractory concrete. The secondary liner is located between the concrete basemat and the refractory concrete. The primary steel tank is attached structurally to the reinforced-concrete tank dome. The interconnecting J-bolts are threaded into studs that are welded to the liner at a spacing of 0.61 m (24 in). The concrete tank dome was cast in place with the dome liner as the inner surface form. About 10.67 m (35 ft) above the tank bottom, the primary liner curves inward to a point of tangency with the secondary steel liner. There is no structural attachment between the primary tank and secondary liner.

The secondary liner is a welded assembly fabricated from ASTM A516 Gr 65 mild steel with a minimum tensile yield strength of 241,000 Kpa (35 kip/in²). The liner rests on the concrete basemat and has a uniform thickness of 10 mm (0.375 in.), except at the bottom knuckle region where the thickness increases to 13 mm (0.5 in.). The knuckle radius is 0.30 m (12 in.). The cylindrical portion of the secondary liner extends to a point of tangency with the primary liner. At that location, the secondary liner terminates. The secondary liner is structurally independent from the primary tank and is connected to the cylindrical portion of the concrete tank wall by tie rods that are threaded into studs welded to the liner. The concrete cylindrical wall was cast in place with the secondary liner as a form for the inner surface.

The excavation design was backfilled after the tank was completed. The excavation design was a 20.12-m (66-ft)-radius area at the foundation, which then sloped up at a run of 1.5 and a rise of 1. The soil profile, according to the URS/Blume report (1974), is sandy-gravel graded down to 47.24 m (155 ft), where a bedrock layer is encountered. Table 2 and Figure 3 provide soil properties and layers in relation to the tank.

### 2.2 LOADING CONDITIONS

The seismic SSI analysis results are shown in terms of soil pressures, response spectra, and member-force time histories at nodes on the structure. This analysis is performed in two steps. Step one iterates soil properties under seismic time history loads. Step two uses the soil property results to determine SSI structure acceleration versus frequency results for model nodes. The run stream to the free-field computer program include soil properties and a seismic time history that meet the SDC 4.1 7-percent damped seismic criteria for Safety Class 1 structures. The run stream to the SSI programs includes the soil properties after the free-field iterations, the structure elements and their properties, and the acceleration time history.

Soil layers and properties for the 241-SY tank farm are given in the URS/Blume report (1974). Table 2 presents the soil properties, and Figure 3 presents the soil layering associated with the soil properties.
### Table 2. Soil-Tank Model Properties.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass density (kg·s²/m⁴)</th>
<th>Modulus of elasticity (Kpa)</th>
<th>Poison's ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>799.7</td>
<td>2.735 E-10</td>
<td>0.300</td>
</tr>
<tr>
<td>Concrete</td>
<td>224.8</td>
<td>3.773 E-9</td>
<td>0.150</td>
</tr>
<tr>
<td>Insulating Concrete</td>
<td>49.0</td>
<td>1.986 E-8</td>
<td>0.150</td>
</tr>
<tr>
<td>Backfill Layer 1</td>
<td>195.9</td>
<td>3.145 E-7</td>
<td>0.200</td>
</tr>
<tr>
<td>Backfill Layer 2</td>
<td>195.9</td>
<td>3.365 E-7</td>
<td>0.200</td>
</tr>
<tr>
<td>Backfill Layer 3</td>
<td>195.9</td>
<td>5.879 E-7</td>
<td>0.200</td>
</tr>
<tr>
<td>Backfill Layer 4</td>
<td>195.9</td>
<td>8.273 E-7</td>
<td>0.200</td>
</tr>
<tr>
<td>Soil Layer 5</td>
<td>186.0</td>
<td>3.278 E-7</td>
<td>0.230</td>
</tr>
<tr>
<td>Soil Layer 6</td>
<td>192.6</td>
<td>3.580 E-7</td>
<td>0.180</td>
</tr>
<tr>
<td>Soil Layer 7</td>
<td>176.3</td>
<td>8.625 E-7</td>
<td>0.270</td>
</tr>
<tr>
<td>Soil Layer 8</td>
<td>207.3</td>
<td>9.203 E-7</td>
<td>0.390</td>
</tr>
<tr>
<td>Soil Layer 9</td>
<td>187.7</td>
<td>9.498 E-7</td>
<td>0.420</td>
</tr>
<tr>
<td>Soil Layer 10</td>
<td>176.3</td>
<td>1.033 E-8</td>
<td>0.435</td>
</tr>
<tr>
<td>Soil Layer 11</td>
<td>176.3</td>
<td>--</td>
<td>0.440</td>
</tr>
</tbody>
</table>
Figure 3. Assumed Soil Layering in URS-Blume Soil-Tank Model.
The tank concrete walls, dome, and foundation sections have a density of 2,403 kg/m$^3$ (150 lb/ft$^3$). The dimensions of these sections are calculated and shown in Appendix A (provided in Volume 2 of this report).

The primary tank and liquid contents are proportioned and applied to the tank structure to produce the same natural frequency and effective mass as calculated by the ANSYS$^1$ computer model. Figure 4 displays the ANSYS tank liner and liquid contents model.

2.3 PREVIOUS ANALYSES

Tank 241-SY-101 has been analyzed three times (URS/Blume 1974, 1981; WHC 1991). The scope of the first analysis determined the combined effects of long-term dead, thermal loads with short-term live loads, and the Safe Shutdown Earthquake (SSE) ground motions on the 241-SY-101 waste storage tank structure. The liquid capacity was 3,785 m$^3$ (1 Mgal), which translates into a liquid waste depth of 9.22 m (363 in.). The soil elements used were not iterated elements and are shown in Figure 3.

The defined scope of work of the second analysis (URS/Blume 1981) determined the primary steel tank structure for the following load cases:

- The hydrostatic loads and hydrodynamic loads resulting from the SSE for a liquid depth of 10.72 m (422 in.) and a maximum specific gravity of 1.7.
- The thermal loads resulting from a liquid level of 10.72 m (422 in.) and a maximum uniform liquid temperature of 121 °C (250 °F).
- The loads from relative displacement at the top and bottom supports of the primary steel structure induced by thermal-creep displacement in the tank's concrete structure.
- The loads from internal negative pressure (vacuum loading).

The third analysis (WHC 1991) was similar in scope to the first; an equivalent static method was used to evaluate the design-basis earthquake and soil pressures instead of soil elements were used.

2.4 ANALYSIS METHOD

Four computer programs were used to evaluate DST 241-SY-101 for SSI effects. First, the ANSYS computer code was used to calculate the natural frequency and effective mass of the primary tank liner and fluid contents during a seismic event. The ANSYS results then were used to model a mass

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$^1$ANSYS is a proprietary code, but a user's license is commercially available from Swanson Analysis Systems, Inc., Houston, Pennsylvania.
Figure 4. "ANSYS" Elements.
spring system for use in the SSI computer programs. The SHAKE\(^1\) program was used to find the strain-dependent soil properties that were used in the SSI programs. Finally the FLUSH\(^2\) and SASSI\(^3\) SSI programs were used to calculate the seismic soil pressures and response spectra for the two-dimensional single-tank, two-dimensional double-tank, and three-dimensional single-tank cases. The data required to begin this analysis included tank dimensions, weight, the soil layers and properties, and the seismic input time history.

The ANSYS STIF 81 axisymmetric fluid elements and STIF 61 axisymmetric steel-plate elements were used to model the liquid waste and the primary tank. It should be noted that the primary tank is attached to the concrete outer tank only at the top and bottom. From this model, the natural frequency and the effective fluid mass were calculated (see Figure 4 for element plot and tank natural frequency). The first 29 modes of the ANSYS model were fluid circulation modes with no effective mass; mode 30 was the first significant mode with an effective impulsive mass of 55 percent of the total mass and a natural frequency of 6.457 \(\text{Hz}\). The remaining 45 percent of the mass is in the sloshing mode at about 0.2 \(\text{Hz}\), where it is considered to have no effect on the tank as a whole.

The SHAKE program and the initial mode of the FLUSH program involve a soil-strain iteration process for the free field that produces the final soil properties. Soil elastic modulus and shear modulus are not linear with respect to strain, as in the case of steel and concrete. As the strain increases in soil, the shear modulus decreases. Calculating the shear modulus at the seismic strain level for dynamic analysis requires an iteration process. Five iterations usually are required to get less than a 5 percent change in shear modulus from the previous iteration. This process is typical of both the SHAKE and FLUSH programs. In addition to soil properties, the SHAKE and FLUSH programs produce the free-field soil response spectra for comparison to the site design criteria spectra. See Figures 5 and 6 for a view of these spectra plots. The degree to which these two spectra match is a measure of the adequacy of the input time history.

The iterated soil properties were then used in the two-dimensional FLUSH SSI program to calculate soil pressures and response spectra. The FLUSH program is basically a two-dimensional program with simulated three-dimensional effects. The model was set up as a two-dimensional plate model, then given a thickness to match the structure's width. A viscous dash-pot-type boundary condition was applied along the two side surfaces to simulate radiation damping in the third dimension. (See Figures 7 and 8 for element plots.) Both single- and double-shell tank models were created in the

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\(^1\)SHAKE is a computer program developed by the University of California, Berkeley, California.

\(^2\)FLUSH is a computer program developed by the University of California, Berkeley, California.

\(^3\)SASSI is a computer program developed by the University of California, Berkeley, California.
Figure 5. "FLUSH" Free Field Spectra.

Abs. Acc. (G/S) vs. Freq. (HZ)

- SURFACE
- SDC-4.1
- CROWN
- HAUNCH
- MID WALL
- BASE

Damping = .07
Figure 6. "SHAKE" Free Field Spectra.

Free Field Response, .20g Zpa
Figure 7. "FLUSH" Single Tank Elements.
Figure 8. "FLUSH" Double Tank Elements.
FLUSH program with strain-dependent soil elements, elastic steel, and concrete elements. The two models produced soil pressures and seismic response spectra that can be compared to each other, the three-dimensional SASSI results, and the SDC 4.1 criteria ground surface spectra.

The iterated soil properties are also used in the three-dimensional SASSI SSI program in the same manner as in the FLUSH program. The SASSI program is run in a segmented fashion with the free-field layered soil system input first and saved; then the embedded structure and structure-soil interaction nodes and elements are input. The final SASSI program analysis produces the same type of results as the FLUSH program response spectra at any mode in the tank model (see Figures 9 and 10).

3.0 RESULTS AND CONCLUSIONS

3.1 RESULTS

3.1.1 Free-Field Results

The results of the free-field soil response spectra for both the FLUSH and SHAKE programs are provided in Appendix C. The spectra curves for the soil surface and other important layers in the soil column are plotted along with the site design criteria spectra of SDC 4.1. Figure 5 presents the FLUSH free-field spectra data plots, and Figure 6 presents the SHAKE free-field data plots. The SHAKE free-field output yields data that are much closer to the design criteria spectra than those of the FLUSH program. The FLUSH free-field output plotted in Figure 5 has been scaled upward by 10 percent to account for under-predicting the input spectra.

3.1.2 FLUSH Results

The soil pressure and response spectra results recorded by the FLUSH computer program are provided in Appendix C. The soil pressures, calculated by the FLUSH program and applied to the tank side walls, give a total force of 29,223 kg/m-width (19,637 lb/ft-width) of DST 241-SY-101. Previous analysis of DST 241-SY-101 (WHC 1991) that used the American Society of Civil Engineers (ASCE) methodology (ASCE 1986) to calculate the soil properties resulted in a total force of 75,352 kg/m-width (50,634 lb/ft-width), 258 percent higher than the dynamically calculated SSI pressures.

The tank response spectra calculated by the FLUSH program for SST and DST arrangements are shown in Figures 11 and 12. These response spectra show some amplification over the input response spectra in the 1- to 2-Hz range for all locations in the tank structure. The tank structure nodes located in the lower portions of the tank have a significant second amplification in the 7- to 10-Hz range. This mode most likely reflects the influence of the tank liner and fluid mode and the free-field mode. The spectrum peak, in the 1- to 2-Hz range of the upper portions of the tank, is greater than that of the site
Figure 9. "SASSI" Soil-Tank Elements.
SY-101 Quarter Model - house

Figure 10. "SASSI" Fluid-Liner Elements.
Figure 11. "FLUSH" Single Tank Spectra.
Figure 12. "FLUSH" Double Tank Spectra.
criteria spectra of SDC 4.1 and is consistent in both the SST and DST models. In the tank wall of the DST model only, there also is a spectra peak in the 7- to 10-Hz range that exceeds the SDC 4.1 spectra criteria.

3.1.3 SASSI Results

Data for the response spectra curves produced by the three-dimensional SASSI program are provided in Appendix C, and the curves are shown in Figure 13. The response curves generated by SASSI have the same amplification (in the 1- to 2-Hz range) and spectra peaks (in the 7- to 10-Hz range) as those in the two-dimensional FLUSH runs. The spectra peak in the 1- to 2-Hz range for upper tank locations is lower than that in the two-dimensional FLUSH models but still slightly above the site design criteria spectra found in SDC 4.1. In the secondary 7- to 10-Hz mode, the SASSI program registers a peak at the tank base that exceeds SDC 4.1 criteria.

3.2 CONCLUSIONS

This SSI evaluation compares two-dimensional and three-dimensional seismic SSI evaluations to the static seismic analysis method used in the past (WHC 1991). The soil pressure calculations performed by the ASCE method (ASCE 1986) are conservative and can be reduced by a significant amount by SSI analysis. The tank response spectra produced by the two-dimensional and three-dimensional SSI programs yield amplified accelerations in excess of the Hanford Site free-field design spectra for Safety Class 1 structures at some frequencies. This shows that the SSI analyses are required to determine accurate seismic response of this type of underground tank. However, the broad attenuation of the seismic loading at depth is expected to produce considerably smaller stresses than the previous equivalent static analysis. It should be noted that these conclusions are based on a Building 234-52 input time history that had to be scaled up by 10 percent to meet SDC 4.1 criteria. A better fitted time history could possibly reduce the seismic SSI acceleration below the SDC 4.1 criteria spectra. The fact that the SASSI results did not produce amplifications in the 1-2 Hz range should lead to its use in tank-to-tank interaction studies. The SASSI program is able to incorporate the detailed three-dimensional aspects of the tank configuration.

3.3 RECOMMENDATIONS

This SSI evaluation indicates that, in general, the buried tanks move with the soil with some minor soil-structure interaction. These results also indicate that the two-dimensional SSI results are slightly more conservative than the three-dimensional results, and because of their simpler modeling, could be more cost effective to perform than three-dimensional analysis. The two-dimensional SSI evaluations should also consider multiple tank arrangements in order to obtain conservative responses at all locations in the structure. All elements of this SSI evaluation have not been fully developed for their effects on buried tanks. These elements include SST seismic responses, multiple three-dimensional tank arrays, a range of time
Figure 13. "SASSI" Single Tank Spectra.
histories and damping values, and the influence of non-linear cracked section properties. Further parametric studies need to explore these elements and their effects on SSI analyses for buried tanks.

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