JOB NO. 97019

FILE NO. 97019.1.1, REV. 0
FILE NO. C97019.1.1, REV. 0

PRIVATE UTILITY FUEL STORAGE PROJECT CASK

SEISMIC TIPOVER ANALYSIS

PREPARED FOR
SIERRA NUCLEAR CORPORATION

(VOLUME 1)

PREPARED BY

ADVENT Engineering Services, Inc.
17 Crow Canyon Court, Suite 100
San Ramon, CA 94583
(510) 743-7777

CALCULATION COVER SHEET

PROJECT	JOB NO.	FILE NO.
Sierra Nuclear Corporation TranStor Cask	97019	97019.1.1
CLIENT Sierra Nuclear Corporation	CLIENT CALC. NO. --	NO. OF SHEETS 16 (including cover)

SUBJECT

Private Utility Fuel Storage Project Cask
Seismic Tipover Analysis

PURPOSE

To perform non-linear transient analysis of the TranStor cask to demonstrate stability of the cask for site-specific horizontal and vertical seismic acceleration time histories.

SOURCES OF DATA & REFERENCES

See Section 7.0 of calculation.

PURPOSE FOR REVISION

Originators	Reviewers	Design Verified by	Date	Approved By	Date
K. Choi	J. Shulman		7/18/97		7/18/97
		Revision No. 0		Project Distribution Project File Sierra Nuclear Corporation	
		Supersedes Calc. No.			

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 1	Rev. No.	0

TABLE OF CONTENTS

1.0 PURPOSE 2

2.0 CALCULATION METHODOLOGY 3

2.1 Time History Input 3
2.2 Displacement Time History Development 4
2.3 Model Development 5

3.0 ASSUMPTIONS 10

4.0 ANALYSIS 11

5.0 RESULTS 12

6.0 CONCLUSION 16

7.0 REFERENCES 17

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Kay Hsu	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By: [signature]	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 2	Rev. No.	0

1.0 PURPOSE

The purpose of this calculation is to evaluate the stability, determined by non-linear dynamic time-history analysis, of the TranStor Cask for site-specific seismic time history input motions. Seismic input was defined in Sierra Nuclear Corporation Purchase Order No. 97-019 (Reference 7.1) via its reference to the acceleration time histories provided by Sierra Nuclear Corporation letter PFS01-97-029, dated May 20, 1997 (Reference 7.2), with the horizontal time history increased by a factor of 1.077 to account for the three-dimensionality of the seismic input in the two-dimensional analysis. The non-linear characteristics of the interface between the cask and the ground required the application of a non-linear time history analysis. Cask stability is demonstrated for these time histories, with the 1.077 horizontal motion increase factor.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Ken 4. d	Date 7/18/97	
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By: J Sterling	Date 7/18/97	
System	Job No. 97019	File No. 97019.1.1	
Client Calc. No.	Sheet No. 3	Rev. No. 0	

2.0 CALCULATION METHODOLOGY

2.1 Time History Input

Figure 2.1 contains a plot of the input acceleration time history used as the basis for the horizontal seismic input, including the 1.077 increase factor. Figure 2.2 contains a plot of the input acceleration time history used as the basis for the vertical seismic input.

2.2 Displacement Time History Development

The non-linear time history analysis of the cask was performed using the ANSYS general purpose finite element code (Reference 7.3 and 7.4). Vertical seismic excitation of the cask (including the effect of the cask's deadweight) was applied via an acceleration time history, which acted directly upon the cask's lumped mass. Horizontal seismic input was most appropriately addressed via the application of a displacement time history at the cask's base. The horizontal seismic displacement time history was determined by double integration of the "horizontal" acceleration time history (as described in Section 2.1) using the ANSYS PREP 6 Preprocessor (Reference 7.3).

File C97019.1.1 contains the computer input and output files associated with this phase of the analysis.

2.3 Model Development

The ANSYS finite element model of the cask is depicted in Figure 2.3. The two-dimensional model addressed the cask as rigid with its center of gravity located 114.5 inches above its base.

The cask structure was represented by an assembly of massless ANSYS BEAM4 3-D Elastic Beam elements; one orientated vertically with a length of 114.5", representing the distance to the center of gravity from the base, and two orientated horizontally each with a length of 65" to represent the 130" bottom diameter of the cask. Each of the beam elements were assigned real properties which assured that the cask was rigid, i.e. that the fundamental frequencies of the cask, as modeled, were above 33 Hz (the minimum frequency at which the structure sees the input motion as static). The BEAM4 element is an uniaxial element with tension, compression, torsion,

and bending capabilities. The element has six degrees of freedom at each node: translations in the nodal x, y and z directions and rotations about the nodal x, y and z axes.

The inertia of the cask was represented by an ANSYS MASS21 Structural Mass element located 114.5" above the base and assigned a mass of 737.58 lbf-sec^2/in., corresponding to its weight of 285,000 lbs and a rotary inertia of 3,895,531 lbf-in-sec^2. The rotary inertia was derived from the expression $I = 1/12\ m\ (3a^2 + L^2)$, where m is the total mass of the cask, a is the radius of the cask and L is the height of the cask. The MASS21 element is a point element having up to six degrees of freedom: translations in the nodal x, y and z directions and rotations about the nodal x, y and z axes.

The interface between the cask base and the ground was represented via an ANSYS CONTAC52 3-D Point-to-Point Contact element. Three such elements were defined, one at each end of the horizontal beams representing the cask base and one at the center of the cask. For each of the three elements, the GAP was initially assumed to be zero and START was taken as 1.0 (gap initially closed and not sliding). In selecting the normal stiffness for each element, KN, it is important to note that unreasonably high stiffness values should be avoided. The normal stiffness for each element was set as 3 E7 lbs/in order to assure sufficient rigidity of the cask in the vertical direction. The CONTAC52 element represents two surfaces which may maintain or break physical contact and may slide relative to each other. The element is capable of supporting only compression in the direction normal to the surfaces and shear (Coulomb friction) in the tangential direction. The element has three degrees of freedom in the nodal x, y and z directions.

File C97019.1.1 contains the computer input file associated with the model development state of the analysis.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Key L. Lu	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By: [signature]	Date	7/18/97
	Job No. 97019	File No.	97019.1.1
System	Sheet No. 5	Rev. No.	0
Client Calc. No.			

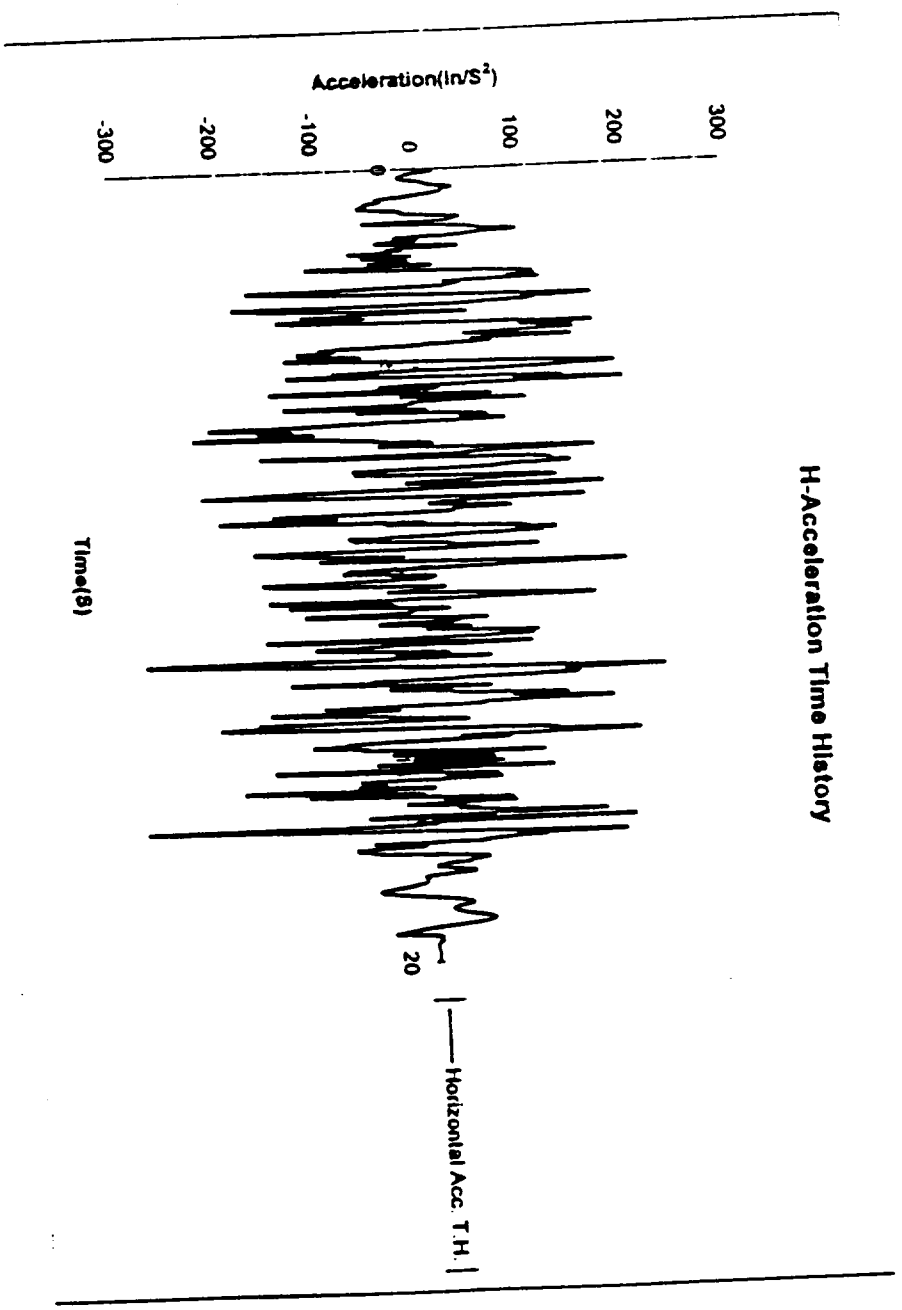

Figure 2.1

ADVENT
ENGINEERING SERVICES, INC.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date 7/18/97	
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date 7/18/97	
System	Job No. 97019	File No. 97019.1.1	
Client Calc. No.	Sheet No. 6	Rev. No. 0	

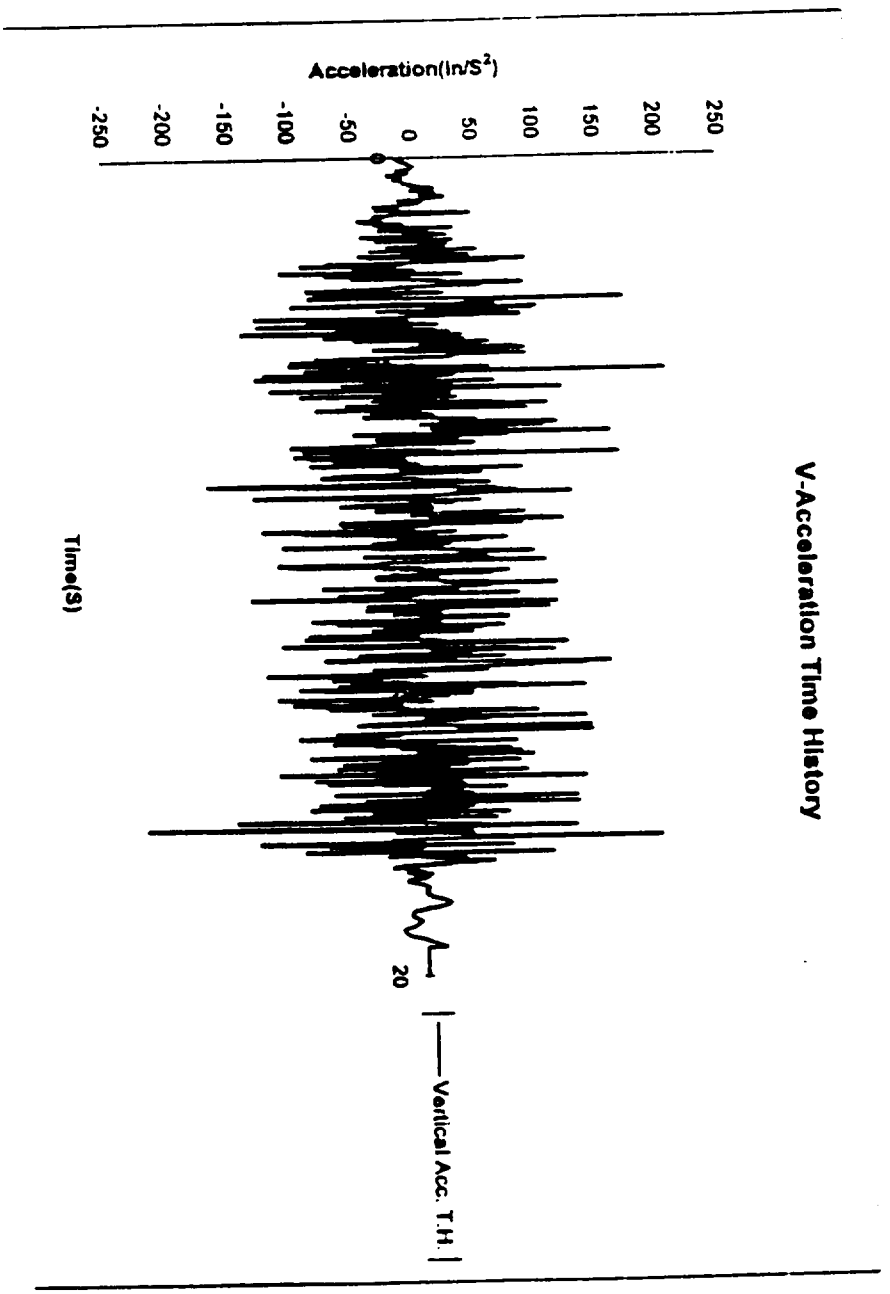

Figure 2.2

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Key Y. Li	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By: [signature]	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 7	Rev. No.	0

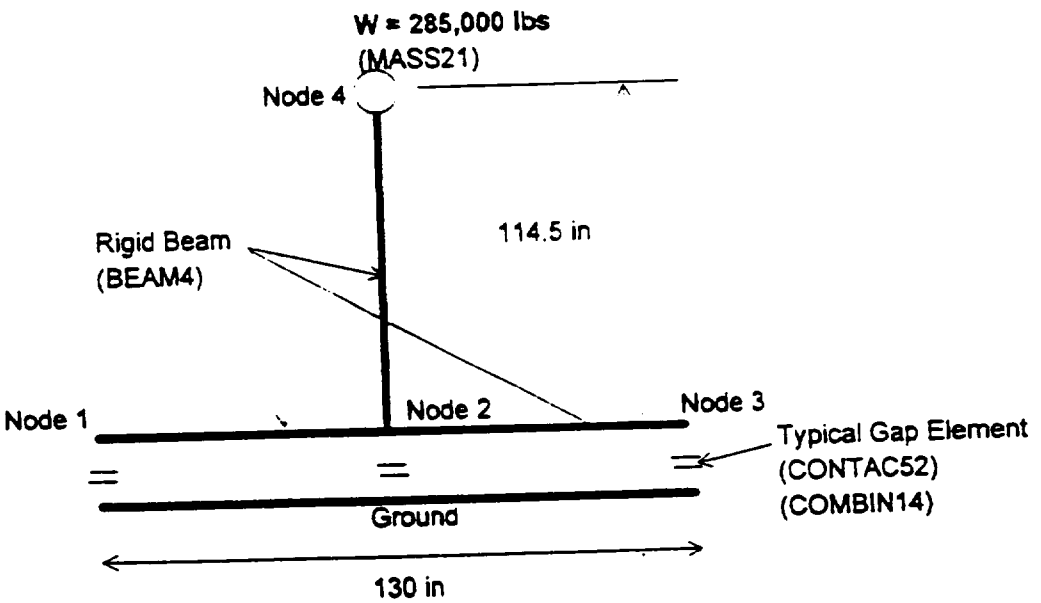

Figure 2.1

ADVENT
ENGINEERING SERVICES, INC.

3.0 ASSUMPTIONS

The following assumptions were made in the performance of the seismic cask tipover analysis:

- The cask was assumed to be a rigid cylinder.
- A horizontal seismic displacement time history was applied at the base of the cask; which is consistent with the assumption that there was no potential for sliding between the cask and the ground, an assumption which is conservative for the assessment of tipover.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Kay 4. Ce	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 9	Rev. No.	0

4.0 ANALYSIS

The ANSYS Revision 5.1 (Reference 7.4) TRANS analysis type was utilized in the non-linear transient analysis of the cask for seismic tipover. The analysis invoked the inclusion of large deformation effects. The full Newton-Raphson option was used to solve the non-linear equations in the full transient analysis.

The acceleration and displacement time histories defined in Section 2.1 and 2.2 established design basis input motions. The acceleration and displacement time histories were defined at second intervals, which was the load step interval utilized in the transient analysis. For each load step, [ ] substeps were specified, resulting in an integration time step of [ ] seconds. A convergence value was set at [ ]% for the out-of-balance load for any active degree of freedom.

Boundary conditions were imposed to transform the problem to a two-dimensional one. All translations in the y-direction and all rotations about the x and z axes were set to zero. The displacement time history was applied at the center of the cask base [ ]. The application of the displacement time history at the cask base eliminates the need to address the extent of sliding and the action of friction at the cask base, i.e. the cask is not free to slide.

File C97019.1.1 contains the computer input and output files associated with the transient analysis.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Kenneth A. Dr	Date 7/18/97	
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By: [signature]	Date 7/18/97	
System	Job No. 97019	File No. 97019.1.1	
Client Calc. No.	Sheet No. 10	Rev. No. 0	

5.0 RESULTS

Results of the analysis for a horizontal displacement time history corresponding to the acceleration time history defined by Figure 2.1 and the vertical acceleration time history defined by Figure 2.2 are shown in Figures 5.1 through 5.3.

Figure 5.1 depicts the absolute horizontal displacements of the input node [ ] and the responding center of gravity node [ ]. The maximum horizontal displacement of the input node is 93.67 inches. The maximum horizontal displacement of the center of gravity node is 112.4 inches.

Figure 5.2 depicts the horizontal displacement of the responding center of gravity node relative to the horizontal displacement of the input node. The maximum relative horizontal displacement of the responding center of gravity node is 27.0 inches; a value that is well within the tipover threshold of 56.5 inches.

Figure 5.3 depicts the rotation of the input node and confirms that the relative displacement of the responding center of gravity node is due strictly to rigid body effects.

File C97019.1.1 contains the computer input and output files associated with the postprocessing of the transient analysis results.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 11	Rev. No.	0

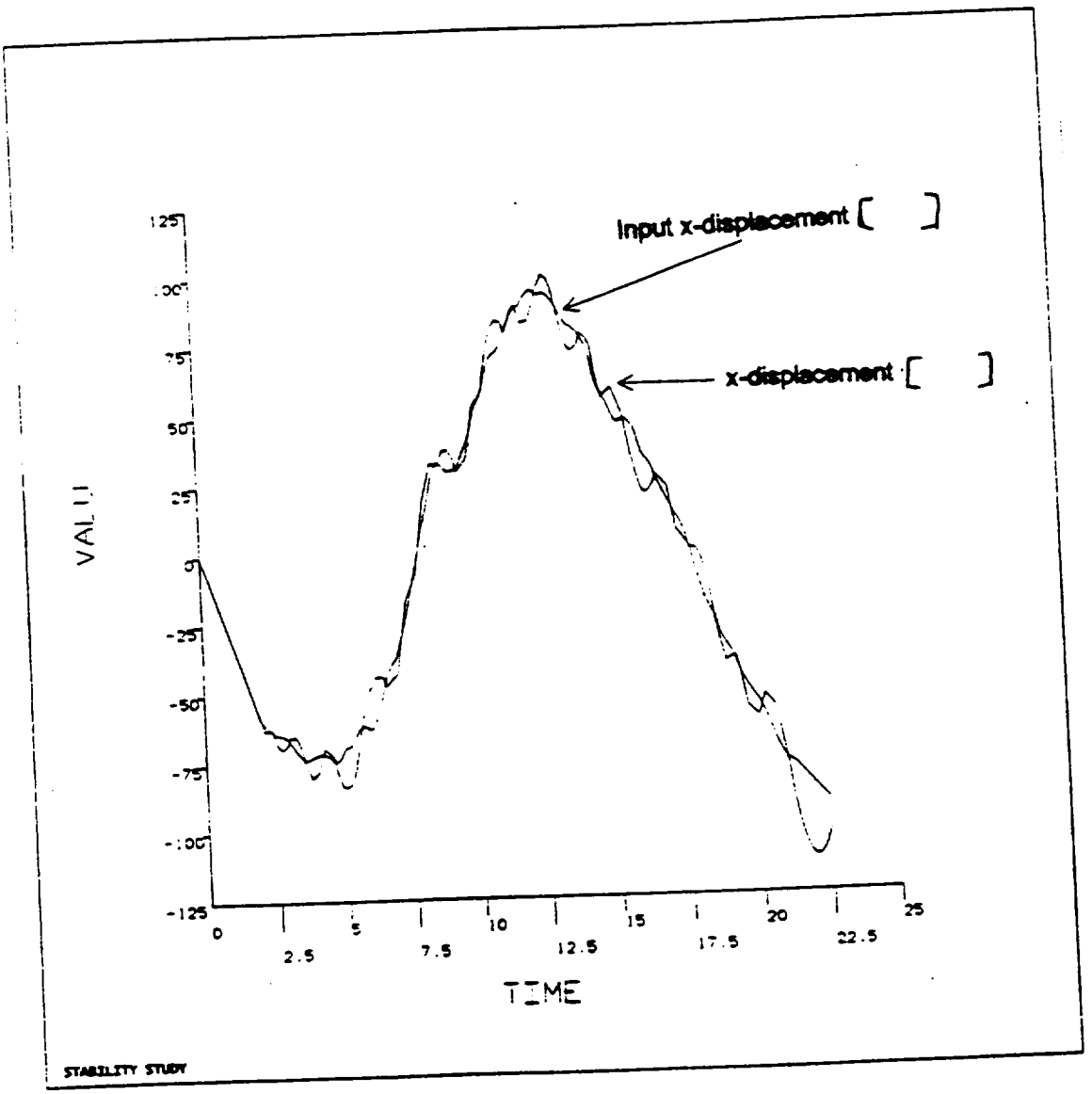

Figure 5.1

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 12	Rev. No.	0

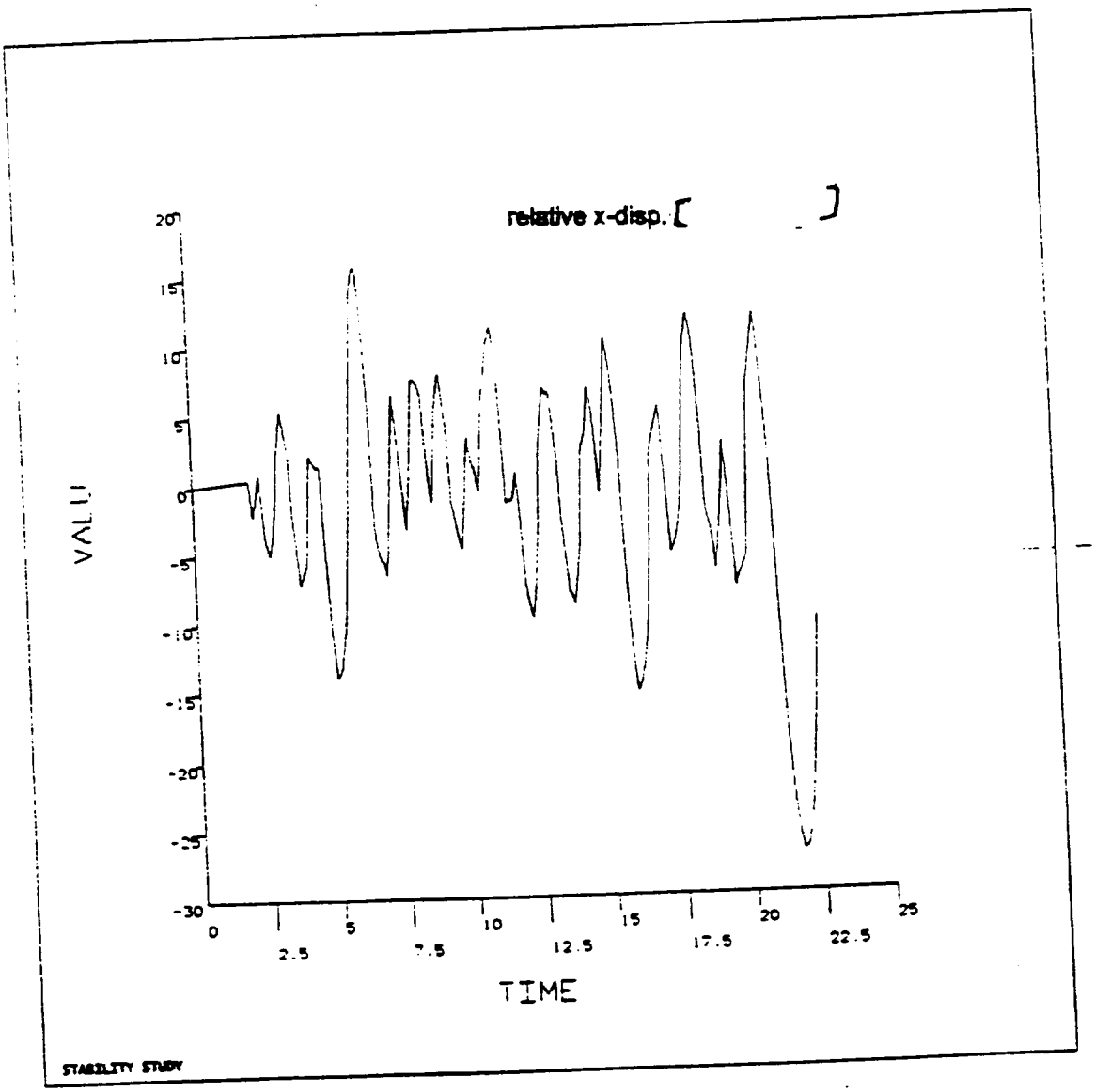

Figure 5.2

Project Sierra Nuclear Corporation TranStor Cask	Prepared By: Keyh. Ch	Date 7/18/97	
Subject Private Utility Fuel Storage Project Cask: Seismic Tipover Analysis	Reviewed By: [signature]	Date 7/18/97	
System	Job No. 97019	File No. 97019.1.1	
Client Calc. No.	Sheet No. 13	Rev. No. 0	

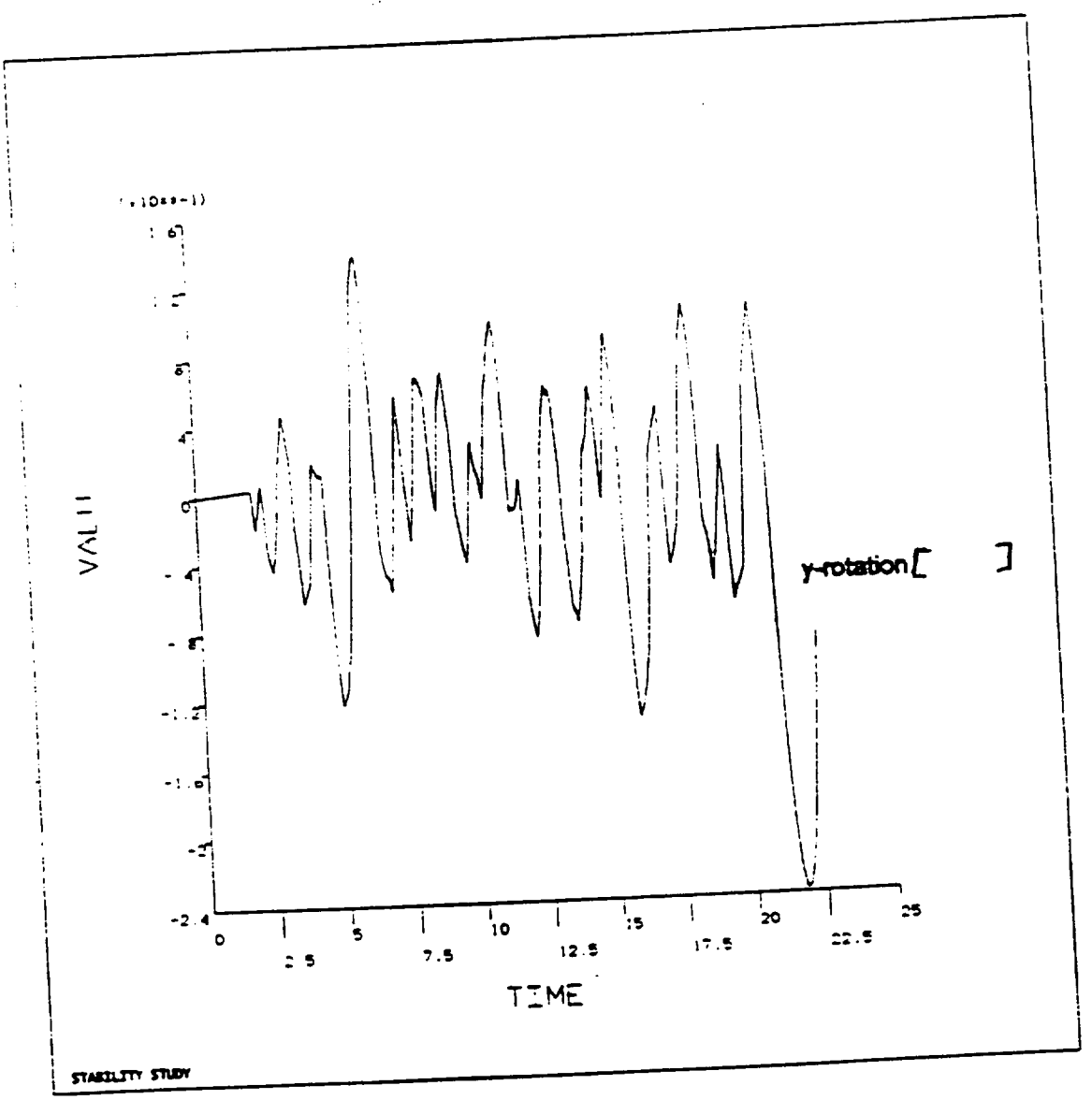

Figure 5.3

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 14	Rev. No.	0

6.0 CONCLUSION

Seismic stability of the TranStor cask has been demonstrated for two site-specific time histories; one representing seismic input in the horizontal direction and the other representing seismic input in the vertical direction.

Project Sierra Nuclear Corporation TranStor Cask	Prepared By:	Date	7/18/97
Subject Private Utility Fuel Storage Project Cask Seismic Tipover Analysis	Reviewed By:	Date	7/18/97
System	Job No. 97019	File No.	97019.1.1
Client Calc. No.	Sheet No. 15	Rev. No.	0

7.0 REFERENCES

7.1 Sierra Nuclear Corporation Purchase Order No. 97-019, Rev. No. 0, July 14, 1997.

7.2 Sierra Nuclear Corporation Letter No. PFS01-97-029, May 20, 1997.

7.3 Swanson Analysis Systems, Inc., ANSYS Engineering Analysis System User's Manual for ANSYS Revision 4.4, May 1, 1989.

7.4 Swanson Analysis Systems, Inc., ANSYS User's Manual for Revision 5.1, February 15, 1994.

COMPUTER BINDER INDEX

FILE NUMBER	Rev.	MODEL	RUN DESCRIPTION	PROGRAM/ VERSION	VOL UME
C97019.1.1.A	0	Cask	Dynamic Non-linear Transient Analysis	ANSYS 5.2 FULL	1 of 1
C97019.1.1.B	0	N/A (ANSYS PREP6)	Displacement Conversion	ANSYS4.4A FULL	1 of 1

continued

Appendices

The four appendices which contain the input and output files are proprietary.

Appendix 1	File No. C97019.1.1.A, Rev 0, 61 pages
Appendix 2	Output File For NSRA2.INP, 155 pages
Appendix 3	File No. C97019.1.1.B, Rev 0, 2 pages
Appendix 4	Output File For PEE6X.OUT, 74 pages