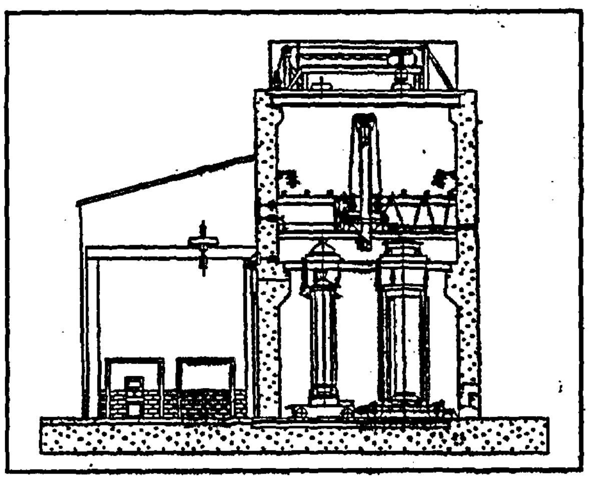
Dry Transfer System Topical Safety Analysis Report

Volume 3



U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

Printed with soy ink on recycled paper

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

CHAPTER 2
SITE CHARACTERISTICS

CHAPTER 3
PRINCIPAL DESIGN CRITERIA

CHAPTER 4
INSTALLATION DESIGN

CHAPTER 5
OPERATION SYSTEMS

APPENDIX 5A
TECHNICAL REPORT FOR THE CONTROL SUBSYSTEM OF THE DRY TRANSFER SYSTEM

CHAPTER 6
SITE GENERATED WASTE CONFINEMENT AND MANAGEMENT

CHAPTER 7
RADIATION PROTECTION

APPENDIX 7A
SHIELDING EVALUATION OF THE DRY TRANSFER SYSTEM

CHAPTER 8
ACCIDENT ANALYSIS

APPENDIX 8A.1
STRUCTURAL ANALYSIS OF DTS

APPENDIX 8A.2
CASK TRANSFER SUBSYSTEM ANALYSIS

APPENDIX 8A.3
RECEIVING AND SOURCE CASK MATING SUBSYSTEM

APPENDIX 8A.4
SHIELD PLUG AND SOURCE CASK LID HANDLING SUBSYSTEM ANALYSIS

APPENDIX 8A.5
FUEL HANDLING CRANE ANALYSIS

APPENDIX 8A.6
DOSE ASSESSMENT FROM OFF-NORMAL CONDITIONS

CHAPTER 9
CONDUCT OF OPERATIONS

CHAPTER 10
OPERATING CONTROLS AND LIMITS

CHAPTER 11
QUALITY ASSURANCE

APPENDIX 11A
TRANSNUCLEAR QUALITY ASSURANCE PROGRAM

LIST OF TABLES

TABLE PAGE

CHAPTER 1

CHAPTER 3

CHAPTER 4

CHAPTER 5

APPENDIX 5A

CHAPTER 6

CHAPTER 7

APPENDIX 7A

CHAPTER 8

APPENDIX 8A.1

APPENDIX 8A.2

APPENDIX 8A.4

APPENDIX 8A.5

APPENDIX 8A.6

CHAPTER 9

CHAPTER 10

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

CHAPTER 3

CHAPTER 4

CHAPTER 5

APPENDIX 5A

CHAPTER 7

APPENDIX 7A

CHAPTER 8

APPENDIX 8A.1

APPENDIX 8A.2

APPENDIX 8A.3

APPENDIX 8A.4

APPENDIX 8A.5

APPENDIX 11A

Appendix 8A.1 Structural Analysis of DTS

8A.1.1 Structural Specifications

The design bases for the DTS are described in Chapter 3.0. The structure will be constructed from reinforced concrete and structural steel work, the design of which complies with the following principle specifications:

- American Concrete Institute ACI 349-85: Code Requirements for Nuclear Safety Related Concrete Structures.
- American Concrete Institute ACI 318-89: Building Code Requirements for Reinforced Concrete with Commentary.
- American Institute of Steel Construction: AISC Specification for the Design, Fabrication and Erection of Structured Steel for Buildings. June, 1989.

8A.1.2 General Description of the DTS Structure

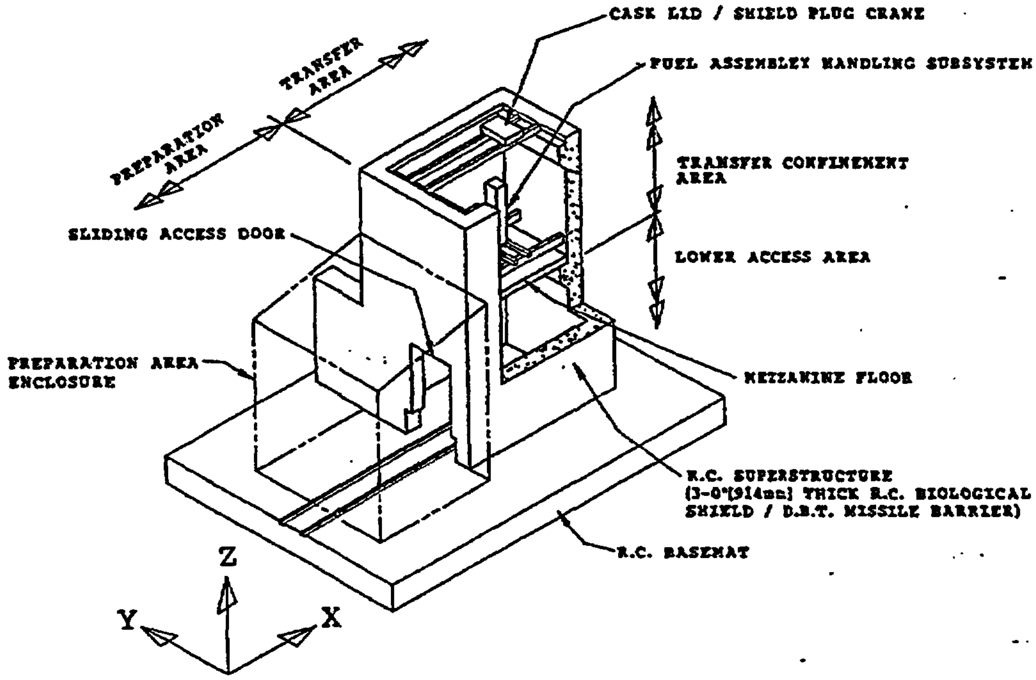
The primary functions of the DTS structure are to provide radiation shielding, tornado missile protection, and confinement of radioactive material. The Dry Transfer System Overview is shown on Figure 8A.1-1.

The DTS structure includes the following major elements:

- Reinforced concrete basemat;
- Reinforced concrete superstructure which encloses the Transfer Confinement Area and Lower Access Area, provides a radiation shield, tornado missile barrier, and primary confinement, and contains the fuel transfer equipment;
- Embedments for support of the fuel handling crane;
- Protective cover;
- Structural steel roof plate that supports the upper crane;
- Mezzanine plate that supports the Cask Mating Subsystem;
- Sliding door between the Lower Access Area and the Preparation Area; and
- Preparation Area Enclosure.

Figure 8A.1-1

Dry Transfer System Overview



8A.1.3 Design Loadings and Input Parameters

In preparing the design of the DTS, the loadings and other input parameters have been based upon the following principle codes and standards:

- American National Standards Institute, Design Criteria for an Independent Spent Fuel Storage Installation. ANSI/ANS 57.9-1992.
- American National Standards Institute, Minimum Design Loads for Buildings and Other Structures. ANSI/ASCE 7-88-1990.
- U.S. Nuclear Regulatory Commission, Regulatory Guide 1.60. Design Response Spectra for Seismic Design of Nuclear Power Plants, 1973.
- U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61. Damping Values for Seismic Design of Nuclear Power Plants, 1973.
- U.S. Nuclear Regulatory Commission, Regulatory Guide 1.76. Design Basis Tornado for Nuclear Power Plants, 1974.
- "Missile Generated by Natural Phenomena." U.S. Nuclear Regulatory Commission, NUREG-0800. Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, July 1981. Para. 3.5.1.4.

Since the design presented in this report is based on a non-site specific location, conservative assumptions have been made for the selection of input parameters (wind loading, seismic loading, soil conditions, missiles, etc.).

8A.1.4 Design Basis and Philosophy

The reinforced concrete structure forms a heavy rigid box structure with substantial stiff cross walls in both directions.

A. Seismic Analysis

The seismic analysis is performed assuming the structure is founded on a hard rock site. A response spectrum analysis was used to verify the structural design. The seismic input was taken from 10 CFR 72.102.

B. Tornado Missiles

The design of the structure has taken into account the missiles produced by the design basis tornado. The most damaging missiles are the automobile, wood utility pole and 12" (305 mm) diameter pipe. The automobile and utility pole impacts are limited to a height of no more than 30' (9.1 m) above grade.

The automobile does not create local damage since it is a "soft" missile and crushes on impact. It is considered with respect to overall barrier stability and energy absorption. Similarly, the wood utility pole is subject to considerable deformation and will not locally deform the structure. Thus, the 12" diameter (305 mm) Schedule 40 steel pipe is considered the missile that can produce the worst local damage effects.

The DTS wall thickness is primarily-dictated by shielding requirements. The massive walls adequately protect the DTS against tornado missiles and other adverse natural phenomena. The tornado generated missile impacts are considered to bound all other reasonable impact-type accidents.

8A.1.5 Normal Operation Structural Analysis

Table 8A.1-1 shows the normal operating loads for which the DTS structural components are designed. The table also lists the individual components which are affected by each loading. The magnitude and characteristics of each load are described in Section 8A.1.5.1.

The method of analysis and analytical results for each load are described in sections 8A.1.5.2 through 8A.1.5.6. The mechanical properties of materials employed in the structural analysis of the DTS system components are presented in Table 8A.1-2.

Table 8A.1-1

DTS Normal Operating Loads

Load Type	Affected Component				
	Reinforced Concrete Structure	Protective Cover	Roof Plate	Mezzanine Plate	Sliding Door
Dead Loads	X	X	X	X	X
Operational Handling Loads	X		X	X	
Live Loads	X	X	X	X	
Normal Thermal Loads	X	X	X	X	X
Internal Pressure	X	X	X	X	X
Design Basis Wind Pressure	X	X			

Table 8A.1-2A

Mechanical Properties of Material - Protective Cover & Roof Plate

Component	Material	Temp. (°F)	Yield Strength S_y (ksi)	Ultimate Strength S_u (ksi)	Remark
Protective Cover	A-36	70	36	58	
Protective Cover Beams	A-441(1)	70	50	70	
Protective Cover Bolts	A-193-B7	70	105	125	
Roof Plate	A-105	70	36	70	
Roof Plate Beams	A-441(2)	70	46	67	
Roof Plate Bolts	A-193-B7	70	105	125	
Roof Plate Corbel Connection Bolts	A-325(3)	70	56	73	

Notes:

1. For thickness 3/4 in. (19 mm) and under
2. For thickness over 3/4 in. to 1-1/2 in. (19 mm to 38 mm)
3. For 1 in. bolt

Table 8A.1-2B

Mechanical Properties of Material - Mezzanine Plate

Component	Material	Temp. (°F)	Yield Strength S_y (ksi)	Ultimate Strength S_u (ksi)	Remark
Mezzanine Plate	A-36	70	36	58	
Mezzanine Plate Beams	A-441[(1)]	70	50	70	
Mezzanine Plate Bolts	A-193-B7	70	105	125	
Mezzanine Plate Corbel Connection Bolts	A-325[(2)]	70	56	73	

Notes:

1. For thickness 3/4 in. (19 mm) and under
2. For 1 in. bolt

Table 8A.1-2C

Mechanical Properties of Material - Sliding Door

Component	Material	Temp. (°F)	Yield Strength S_y (ksi)	Ultimate Strength S_u (ksi)	Remark
Sliding Door	A-105	70	36	70	
Sliding Door Wheels	Drop Forged Steel	70	----	64	
Sliding Door wheel Axle	A-564 Type 630 H 1100	70	115	140	
Axle Bracket	A-514	70	100	110	
Axle Bracket Bearing	A-514	70	22	45	
Sliding Door Support Bracket	A-514	70	100	110	
Sliding Door Shear Pin	A-441(1)	70	42	63	
Sliding Door Rail	A-514	70	100	110	

Note:

1. For thickness over 3/4 in. to 1-1/2 in. (19 mm to 38 mm)

Table 8A.1-2D

Mechanical Properties of Reinforced Concrete and Rebar

Component	Material	Temp. (^{0}F)	Yield Strength S_y (ksi)	Ultimate Strength S_u (ksi)	Remark
Reinforcing Steel	A-615 Grade 60	70	60	90	

Component	Density (lbs/ft^3)	28 days Compress. Strength (ksi)	Modulus of Elasticity (ksi)	Remark
Reinforced Concrete	150	3	3000	

8A.1.5.1 Normal Operating Loads

The normal operating loads are described in detail in the following paragraphs.

A. Dead Loads

Table 8A.1-3 shows the weights of various components of the DTS. The dead weight of each component is determined based on nominal component dimensions.

B. Operational Handling Loads

The operational handling loads are included in the weight of the equipment presented in Table 8A.1-3.

C. Live Loads

As discussed in Chapter 4.0, a live load of 250 lbs/ft^2 (11,970 Pa) is conservatively selected to envelope all postulated live loads acting on the DTS, including the effects of snow and ice.

D. Normal Thermal Loads

The DTS is subject to thermal expansion loads associated with normal operating conditions. The range of normal operating temperature used for the design of the DTS is 60°F to 100°F (16°C to 38°C) in the Preparation Area and 40°F to 130°F (4°C to 54°C) in other areas.

E. Internal Pressure

The internal pressures (created by the HVAC system) during operation are as follows:

- TCA: 1 in (25.4 mm) H_20 less than ambient.
- Lower Access Area: 0.5 in (12.7 mm) H_20 less than ambient.
- Preparation Area: 0.25 in (6.4 mm) H_20 less than ambient.

F. Design Basis Wind Pressure

Design wind pressures for the structure have been determined at 25 ft (7.6 m), 50 ft (15.2 m) and 55 ft (16.8 m) above grade, and are summarized in Table 3.2-3.

Table 8A.1-3

DTS Component Weights

Component Description		Calculated Weight
Reinforced Concrete Structure		2,195,600 lbs (995,920 kg)
R. C. Basemat		2,200,000 lbs (997,920 kg)
Protective Cover & Beams		135,000 lbs (61,200 kg)
Roof Plate Level	Roof Plate	166,875 lbs (75,700 kg)
	Support Beam	56,741 lbs (25,700 kg)
	Equipment (including handling loads)	27,258 lbs (12,300 kg)
Fuel Handling Crane		22,000 lbs (10,000 kg)
Mezzanine Plate Level	Mezzanine Plate	25,230 lbs (11,400 kg)
	Support Beam	8,220 lbs (3,700 kg)
	Equipment (including handling loads)	49,500 lbs (22,400 kg)
Sliding Door		85,000 lbs (38,560 kg)

8A.1.5.2 Reinforced Concrete (Structure) Structural Analysis

Chapter 4, Section 4.2.3.1 provides the detailed description of the reinforced concrete structure. The configuration details including dimensions are shown on drawings 1051-12, 1051-16, and 1051-28. The structure is designed to withstand a number of different loads and combinations of loads. The relevant normal operating loads are as follows (Refer to Table 8A.1-1):

- Dead loads
- Operational handling loads
- Live loads
- Normal thermal loads
- Internal pressure
- Design basis wind pressure

The DTS reinforced concrete wall thickness is primarily dictated by shielding requirements. For calculation of stresses, the design is dominated by the design basis tornado (DBT) and safe shutdown earthquake (SSE) loads (Reference Section 8A.1.6.1). Other loads are much smaller; for example, the design basis wind pressure of 59 lb/ft^2 (2825 Pa) is much less than the design basis tornado wind, which is taken to be 447 lb/ft^2 (21,400 Pa). In general, loads which are clearly not limiting are not evaluated; brief checks are included on less obviously unimportant loads.

The compressive stress of the reinforced concrete wall due to dead weights and operating loads are calculated as:

Weight of reinforced concrete = 2,195,600 lbs (Table 8A.1-3)
Weight of equipments including handling loads = 575,824 lbs (Table 8A.1-3)

TOTAL WIGHT = 2,771,424 lbs

Cross section area: $A = ((379-72)(2) + (280-36) + (280-36-150)) \times 36 = 34{,}272 \text{ in.}^2$

S = compression stress = 2,771,424/34,272 = 81 psi

$S_{allow.} = \Phi \times 0.85\,(f'c) = 0.7 \times 0.85 \times 3000 = 1{,}785$ psi

The compressive stress is much less than the allowable compressive stress of 1,785 psi.

The thermal analysis of the concrete building is also evaluated. Thermal loads within the structure due to the presence of the fuel assemblies and operating equipment induce two effects in the concrete walls.

- Bending due to temperature gradients across the walls
- Expansion due to rise in bulk temperature above base (setting) temperature

Thermal loading is considered to induce horizontal forces/moments in the walls due to restraint provided by adjacent orthogonal walls.

Thermal loads are considered both:

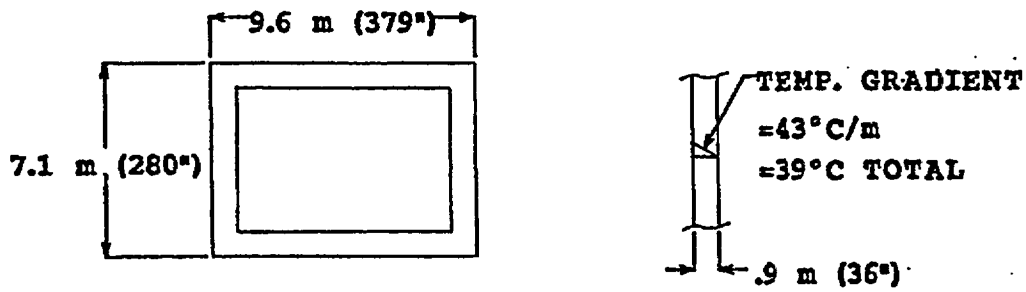
- Acting alone on uncracked sections.
- Acting in conjunction with other loads (Seismic/Tornado) on cracked sections.

Thermal loads are assessed in accordance with ACI-349-1R (Reference 8A.1.7-1) and are calculated in Tables 8A.1-4 and 8A.1-5. These calculated bending moments are to be combined with other loads for reinforced concrete wall design. The wall expansion due to bulk rise in temperature is found to be negligible.

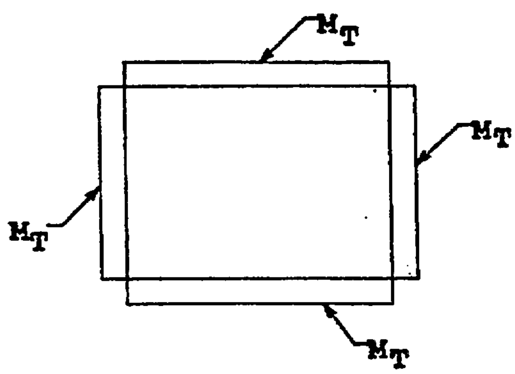
Table 8A.1-4

Bending Moment Calculation due to Thermal Load Only

(a) TEMPERATURE CROSS WALL EFFECTS



(b) BENDING MOMENT DIAGRAM DUE TO THERMAL LOAD



$$M_T = E \alpha \Delta T \frac{bd^2}{12}$$

$$E = 21 \times 10^9 N/m^2$$

$$\alpha = 9.9 \times 10^{-6}/°C$$

$$M_T = 21 \times 10^9 \times 9.9 \times 10^{-6} \times 39 \times \frac{1 \times 0.9^2}{12} \times 10^{-3}$$

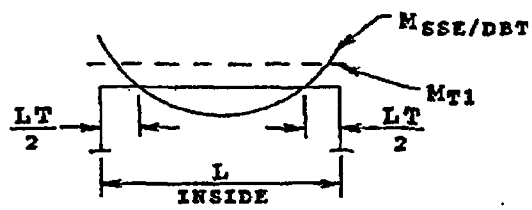
= 547 KNm

= 4,841 IN-KIPS

Table 8A.1-5

Bending Moment Calculation due to Thermal Load in Conjunction With Seismic/Tornado Loads

(a) BENDING MOMENT DIAGRAM-END CRACKED



$M_{T1} = M_T \times \frac{K1}{2}(1-CO_1)$

FROM ACI 349.1R-91, FIG. 2.6

$LT = 0.4L,\ a = 0.5LT$

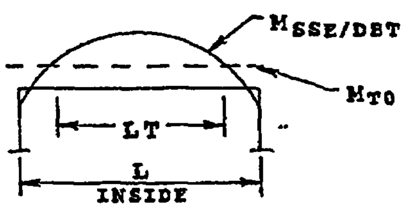
$\Rightarrow K1 = 2.0,\ CO_1 = 0.37$

$M_{T1} = 547 \times \frac{2}{2}(1-0.37)$

$= 345$ KNm

$= 3{,}054$ IN-KIPS

(b) BENDING MOMENT DIAGRAM-INTERIOR CRACKED



$M_{T0} = M_T \times \frac{K0}{2}(1-CO_0)$

FROM ACI 349.1R, FIG. 2.11

$LT = 0.6L,\ a = 0.5(L-LT)$

$\Rightarrow K0 = 2.8,\ CO_0 = 0.62$

$M_{T0} = 547 \times \frac{2.8}{2}(1-0.62)$

$= 291$ KNm

$= 2{,}576$ IN-KIPS

8A.1.5.3 Protective Cover Structural Analysis

Chapter 4, Section 4.2.3.2 provides the detailed description of the protective cover structure. The configuration details including dimensions are shown on drawing 1051-27. For normal operating conditions, a design load of 250 lbs/ft^2 (11,970 Pa) is conservatively used to calculate the stress in the protective cover roof plate. The shell stress in the plate is evaluated using Roark, page 225, case 36, conservatively assuming the plate is simply supported with a uniform load over the entire surface (Reference8A.1.7- 2).

$$S = \frac{\beta \; w \, b^2}{t^2}$$

where w = design load + dead load = 250 lbs/ft^2 +.29 (1.5) = 1.736 lbs/in^2 + 0.435 lbs/in^2
= 2.171 lbs/in^2
a = 120
b = 90
a/b = 1.33
β = 0.42

$$S = 0.42 \times \frac{2.171 \times 90^2}{1.5^2} = 3{,}283 \text{ psi}$$

The analysis results show a maximum stress of 3,283 psi (22.8 MPa) which is less than the allowable stress of 21,600 psi (149 MPa).

The protective cover is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

8A.1.5.4 Roof Plate Structural Analysis

Chapter 4, Section 4.2.3.3 provides the detailed description of the roof plate structure. The configuration details including dimensions are shown on drawing 1051-27. Normal operating loads on the roof plate and supporting beams are conservatively evaluated assuming all the weight (weight of roof plate, support beam and equipment loads) is supported by the five (5) W 14 x 550 beams only. An ANSYS (Reference 8A.1.7-3) finite element model was developed using stiff 4 3D beam element. The material properties for finite element analysis are calculated in Table 8A.1-7 and the finite element model, loading conditions, and boundary conditions are shown on Figure 8A.1-2. The analytical results and comparisons with the acceptance criteria defined in Chapter 3 are also presented in Table

8A.1-6. The maximum calculated stress in the beams is 8,850 psi (61 MPa) which is much less than the allowable stress of 25,200 psi (174 MPa).

Table 8A.1-6

Roof Plate Support Beam Stress Analysis Results Summary

Load Case	Location	Max. S.I. (psi)	Allow. Stress(1) (psi)	Remark
P_1	A	6,912	25,200	
P_2	B	5,775	25,200	
P_3	C	8,850	25,200	

Note: 1. The allowable is based on 0.6 S_y = 0.6 × 42,000 = 25,200 psi

The thermal expansion between the roof plate and reinforced concrete wall is calculated as follows:

Assume roof plate temperature = 130^0F
Assume concrete temperature = 70^0F

$\alpha_{steel} = 6.5 \times 10^{-6}$ in./^{0}F

$\delta_{steel} = 307\ (130\text{-}70) \times 6.5 \times 10^{-6} = 0.1197$ in.

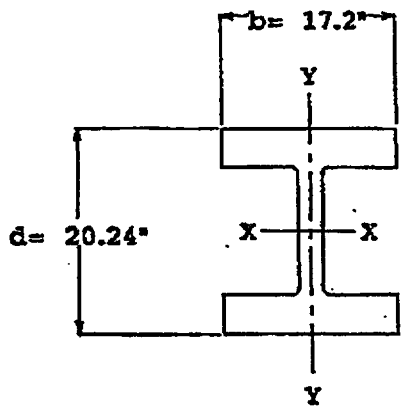
$\delta_{concrete} = 0$ (conservative)

Both the roof plate and beam are bolted to the reinforced concrete. 1-1/4 in. diameter oversized holes (1 in. bolt) are provided at the plate and beam connection points to allow free thermal expansion.

Table 8A.1-7

Material Properties for Finite Element Analysis - Roof Plate Support Beams

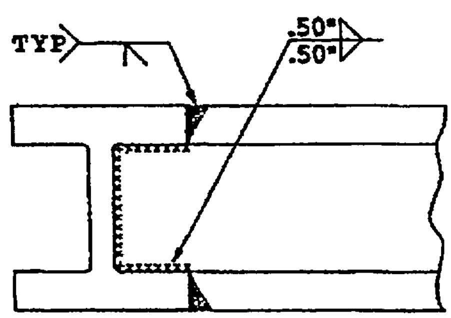
NUMBER AND SIZE OF SUPPORT BEAMS = 5- W14 x 550



$A = 162\ IN.^2$

$I_{X-X} = 9430\ IN.^4$

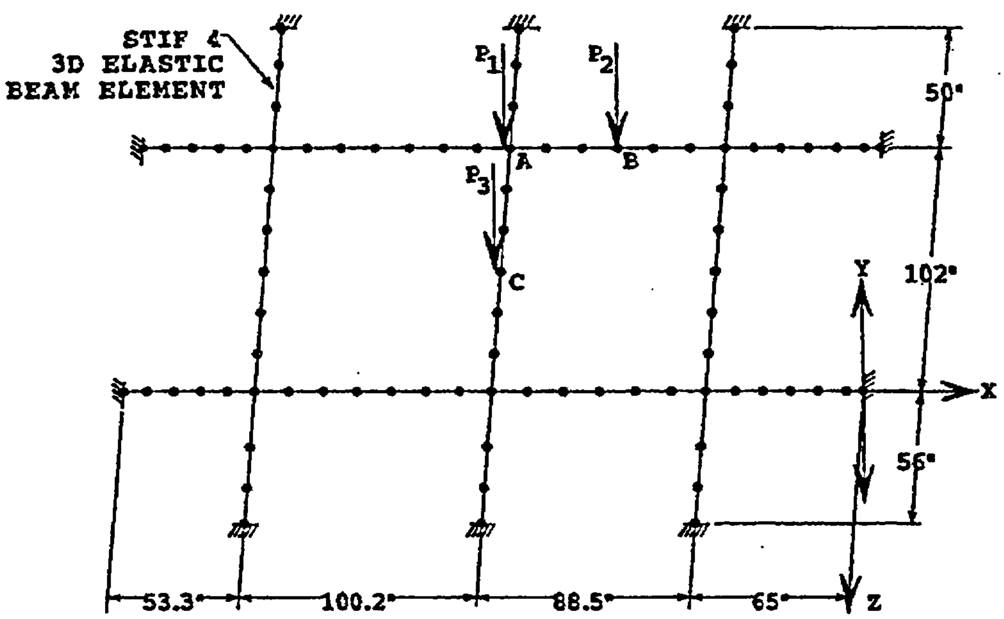
$I_{Y-Y} = 3250\ IN.^4$



BEAM CONNECTION DETAIL

Figure 8A.1-2

Finite Element Model, Loading and Boundary Conditions - Roof Plate Support Beams



LOAD CASE
$P_1 = P_2 = P_3$ = WEIGHT OF ROOF PLATE, BEAMS, AND EQUIPMENT
=166,875 + 56,741 + 27,258
=250,874 # (1,116 KN)

8A.1.5.5 Mezzanine Plate Structural Analysis

Chapter 4, Section 4.2.3.4 provides the detailed description of the mezzanine plate structure. The configuration details including dimensions are shown on drawing 1051-27. Normal operating condition loads on the mezzanine plate consist of the plate weight, the support beam dead weight, the Receiving and Source Cask Mating Subsystem dead weight, the Receiving and Source TC port cover weights, the receiving cask shield plug weight and the source cask lid weight. The analysis was performed conservatively assuming all the loads are supported by the beams only. A finite element (stiff 4) model of the assembly is utilized to evaluate the beam stress.

The material properties for finite element analysis are calculated in Table 8A.1-9 and the finite element model, loading conditions, and boundary conditions are shown on Figure 8A.1-3. The analytical results and comparisons with the acceptance criteria defined in Chapter 3 are also presented in Table 8A.1-8. The analysis shows a maximum stress of 22,500 psi (155 MPa) in the beams which is less than the allowable stress of 27,600 psi (190 MPa).

Table 8A.1-8

Mezzanine Plate Support Beam Stress Analysis Results Summary

Load Case	Location	Max. S.I. (psi)	Allow. Stress[1] (psi)	Remark
P_1	A	16,658	27,600	
P_2	B	16,916	27,600	
P_3	C	22,500	27,600	
P_4	D	17,488	27,600	

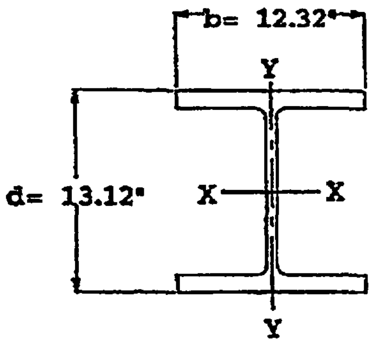
Note: 1. The allowable is based on $0.6\ S_y = 0.6 \times 46{,}000 = 27{,}600$ psi

For thermal expansion, the required minimum clearance between the end of the plate and the inside surface of the concrete wall is approximately 0.125"(3 mm) (Reference Section 8A.1.5.4). An adequate clearance is provided between the plate and the concrete wall to permit free thermal expansion under the maximum differential temperatures expected during normal operation. The mezzanine plates are bolted to the support beams and the beams are bolted to the reinforced concrete. The 1-1/4 in. diameter oversized hole has been provided in the support beams and will permit free thermal expansion of the support beams and thus minimize thermal stress.

Table 8A.1-9

Material Properties for Finite Element Analysis - Mezzanine Plate Support Beams

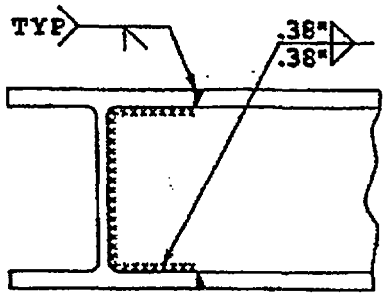
NUMBER AND SIZE OF SUPPORT BEAMS = 5- W12 x 120



$A = 35.3\ IN.^2$

$I_{X-X} = 1070\ IN.^4$

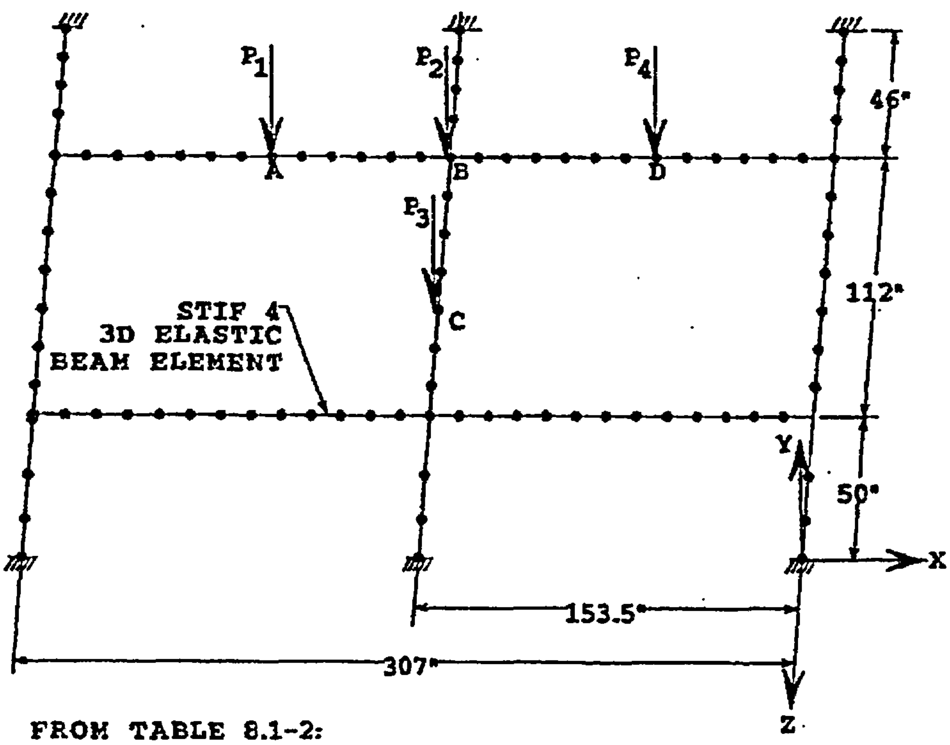
$I_{Y-Y} = 345\ IN.^4$



BEAM CONNECTION DETAIL

Figure 8A.1-3

Finite Element Model, Loading and Boundary Conditions - Mezzanine Plate Support Beams



FROM TABLE 8.1-2:

LOAD CASE

$P_1 = P_2 = P_3 = P_4 =$ WEIGHT OF PLATE, BEAMS, AND EQUIPMENT
=25,230 + 8,220 + 49,500
=82,950 # (369 KN)

8A.1.5.6 Sliding Door Structural Analysis

Chapter 4, Section 4.2.3.5 provides the detailed description of the sliding door structure. The configuration details including dimensions are shown on drawing 1051-5. The design of the sliding door is based on shielding requirements. For the dead load analysis, the most limiting conditions are considered. By considering the sliding door to be supported at the rails, the weight of the sliding door is conservatively increased by a factor of 1.5.

The weight of the sliding door is 85,000 lbs (Reference Table 8A.1-3). This load is increased by 1.5 to include the handling load. The total design load becomes:

$W = 85{,}000 \times 1.5 = 127{,}500$ lbs

S = Tension Stress = $127{,}500/(133.5 \times 9) = 106$ psi

This is much less than the allowable stress of $0.6 \times S_y = 0.6 \times 36{,}000 = 21{,}600$ psi. Other loads are much smaller; for example, the internal pressure is 2.59 lb/ft^2 (124 Pa), and is much less than the suction on the door due to the tornado wind, which is 419 lb/ft^2 (20,100 Pa). In general, loads which are clearly non-limiting are not considered explicitly; brief checks are included on less obviously unimportant loads. The stress calculations due to the DBT and SSE loads are described in Section 8A.1.6.5)

The sliding door is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

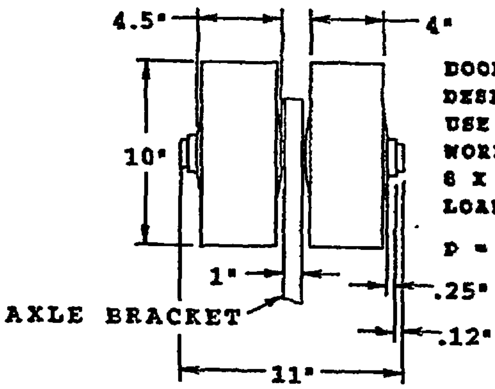
The other components of the sliding door affected by the normal handling loads are door wheels and door wheel axle, axle bracket, door rail, and support bracket. The stresses of these components are calculated in:

a. Door wheels and door wheel axle - Table 8A.1-10
b. Axle bracket - Table 8A.1-11
c. Door rail - Table 8A.1-12
d. Support bracket - Table 8A.1-13

The summary of the analytical results and comparisons with the acceptance criteria define in Chapter 3 are also presented in Table 8A.1-14.

Table 8A.1-10

Sliding Door Wheels and Axle Stress Calculations



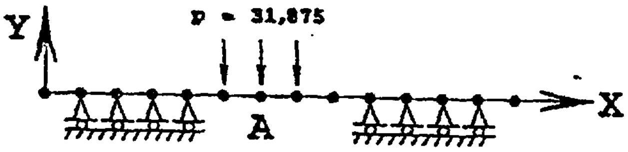
DOOR WEIGHT = 85,000 #
DESIGN WEIGHT = 1.5 X 85,000 = 127,500 #
USE 8" - 10" DROP FORGED STEEL WHEELS
WORKING CAPACITY = 20,000 #
8 X 20,000 # = 160,000 # > 127,500 #
LOAD AT EACH SET OF WHEELS

$$P = \frac{127,500}{4} = 31,875\ \#$$

(a) CALCULATE THE SHEAR STRESS - AXLE

$$S = \frac{31875}{2(\pi)\ (0.75)^2} = 9,019\text{psi} < 46,000\text{psi}$$

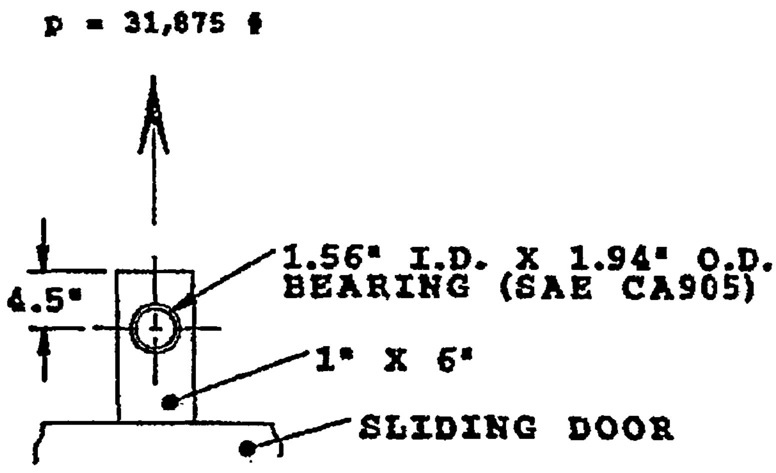
(b) CALCULATE THE BENDING STRESS - AXLE
A ANSYS FINITE ELEMENT MODEL WAS
DEVELOPED USING STIF 16



THE MAXIMUM BENDING STRESS AT LOCATION A
IS 18,108psi, WHICH IS LESS THAN
THE ALLOWABLE STRESS OF 69,000psi

Table 8A.1-11

Sliding Door Axle Bracket Stress Calculations



(a) CALCULATE THE BEARING STRESS

$$S = \frac{31875}{1 \times 1.5} = 21{,}250\text{psi} < 45{,}000\text{psi}$$

(b) CALCULATE THE SHEAR STRESS

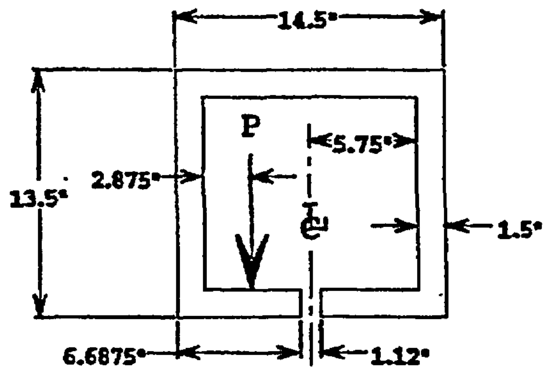
$$S = \frac{31875}{(4.5-2) \times 1 \times 2} = 6{,}375\text{psi} < 40{,}000\text{psi}$$

(c) CALCULATE THE TENSION STRESS

$$S = \frac{31875}{1 \times (6-2)} = 7{,}969\text{psi} < 60{,}000\text{psi}$$

Table 8A.1-12

Sliding Door Rail Stress Calculations



TOTAL LENGTH OF DOOR RAIL = 355" (REF. DWG. 1051-5)
ASSUME ONLY 133.5" (SAME AS THE WIDTH OF THE DOOR)
WILL SUPPORT THE WEIGHT OF THE DOOR.

$P = \frac{1.5 \times 85{,}000}{2} = 63{,}750$ #

M = BENDING MOMENT = 63,750 X (2.875 + 0.75) = 231,094 IN-#

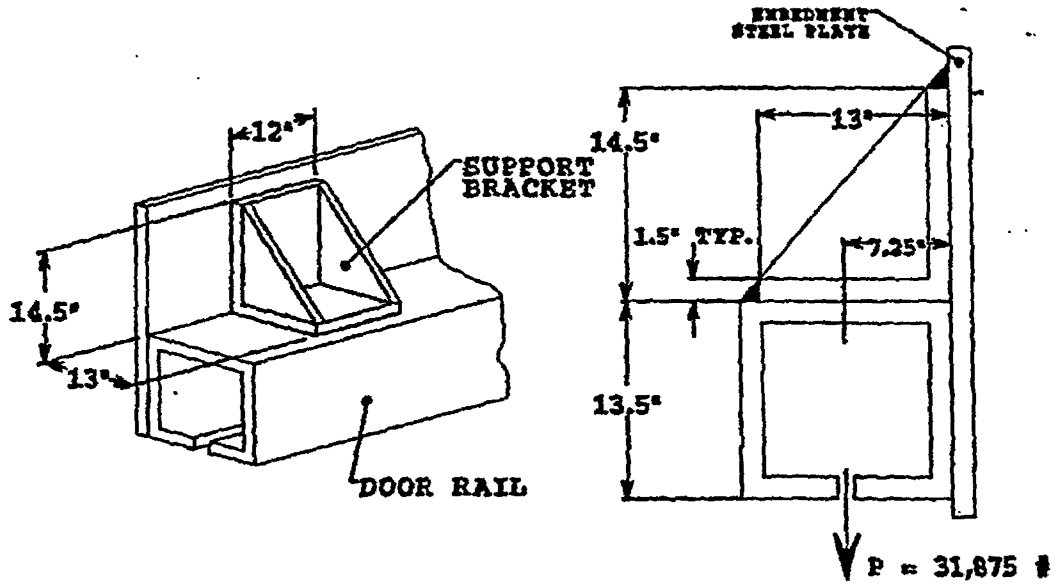
$I = \frac{bh^3}{12} = \frac{133.5\ (1.5)^3}{12} = 37.5\ IN^4$

S = BENDING STRESS $= \frac{Mc}{I} = \frac{231{,}094 \times 0.75}{37.5}$

$= 4{,}622psi < 69{,}000psi$

Table 8A.1-13

Sliding Door Support Bracket Stress Calculations



ASSUME EACH SET OF DOOR WHEELS WILL BE SUPPORTED BY ONE SET OF THE BRACKET

(a) TENSION STRESS AT WELD (3 SIDES) BETWEEN BASE PLATE AND DOOR RAIL

$$\sigma = \frac{31{,}875}{(13 \times 2 + 12) \times 1.5 \times 0.707} = 791\text{psi}$$

(b) SHEAR STRESS BETWEEN BRACKET AND EMBEDMENT STEEL PLATE

$$\sigma = \frac{31{,}875}{(14.5 \times 2 + 12) \times 1.5 \times 0.707} = 733\text{psi}$$

(b) BENDING STRESS AT SUPPORT BRACKET

$$I = I_1 + I_2 = \frac{12 \times 1.5^3}{12} + 2\left(\frac{1}{2} \times \frac{1.5 \times 13^3}{12}\right) = 278\ \text{IN}^4$$

$$\sigma = \frac{Mc}{I} = \frac{31{,}875 \times 7.25 \times 7.25}{278} = 6{,}027\text{psi} < 60{,}000\text{psi}$$

Table 8A.1-14

Sliding Door and Major Components Stress Analysis Results Summary (Dead Loads and Handling Loads)

Comp.	Calculated Stress			Allowable Stress		
	Tension	Bending	Shear	Tension	Bending	Shear
Door	106			21,600		
Door Wheel	127,500 (Load)			160,000 (Capacity)		
Wheel Axle		18,108	9,019		69,000	46,000
Axle Bracket	7,969		6,375	60,000		40,000
Bracket Bearing		21,250 (Bearing)			45,000 (Bearing)	
Support Bracket	791	6,027	733	60,000	60,000	40,000
Door Rail		4,622			69,000	

8A.1.6 Accident Loads Structural Analysis

Table 8A.1-15 shows the accident loads for which the DTS structural components are designed. The table also lists the individual components which are affected by each loading. In the following sections, each accident condition is analyzed to demonstrate that the requirements of the applicable codes are met and that adequate safety margins exist for the DTS design.

Table 8A.1-15

DTS Accident Loads Identification

	Affected Component				
Load Type	Reinforced Concrete Structure	Protective Cover	Roof Plate	Mezzanine Plate	Sliding Door
Seismic Load	X	X	X	X	X
Tornado Wind Load	X	X			X
Tornado Missiles	X	X			X

8A.1.6.1 Reinforced Concrete (Building) Structural Analysis

As described in Secti concrete structure is dominated by shielding requirement ed to evaluate the effects of tornado wind, tornado missiles and

8A.1.6.1.1 Tornad

The most seve neters corresponding to Region 1 in NRC Regulatory Guide 1.76 (Reference8A.1.7- 4) are assumed for the design basis tornado. The design parameters are specified in Section 3.2.1.1 and Table 3.2-4. These loads are applied to the exterior of the DTS structure.

The bending moments of the local wall due to the tornado wind pressure effect are calculated in Table 8A.1-16 and the results are:

$M_{sagging} = \pm 135$ KNm

$M_{hogging} = \pm 165$ KNm

Building Stability - Overturning

The global building effects including overturning moment at the base and base shear force are calculated in Table 8A.1-17 and the results are:

$M_{overturning\ moment} = 60{,}500$ KNm

$F_{base\ shear\ force} = 6{,}560$ KN

The stabilizing and overturning moments due to the tornado wind pressure are calculated in Table 8A.1-18 and the results are:

M_s = stabilizing moment = 138,225 KNm

M_o = overturning moment = 70,340 KNm

Factor of Safety = 138,225/70,340 = 1.98 > 1.5 OK

Since the overturning moment is smaller than the stabilizing moment, the DTS building will not overturn. The resulting factor of safety against overturning effects for Design Basis Tornado (DBT) wind loads is 1.98.

Building Stability - Sliding

First assume sliding resisted by base friction. Assumed reasonable friction angle between basemat and subsoil, 30^0.

Coefficient of Friction = Tan 30^0 = 0.58

Allowable Friction = 0.58/Factor of Safety = 0.58/1.1 = 0.53

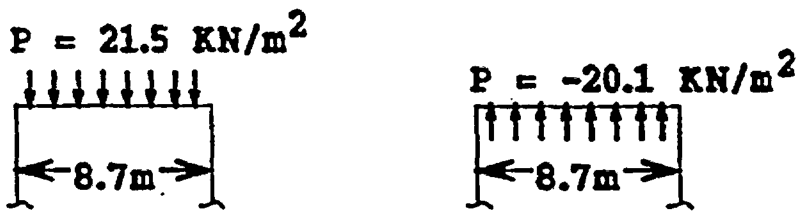
W_{min} = Weight of Concrete Superstructure +Weight of Basemat = 9828 + 8480 = 18,308 KN

F = Shear Force due to DBT = 6,560 KN

Required μ = 6560/18308 = 0.36 < 0.53   OK

Table 8A.1-16

Tornado Wind Pressure Effect - Local Wall Horizontal Bending



PLAN ON WALLS

MAX. PRESSURE = 21.5 KN/m^2
MAX. SUCTION = 20.2 KN/m^2

DESIGN HORIZONTAL BENDING MOMENTS

SAGGING (MIDDLE SPAN)

$$M = \frac{21.5 \times 8.7^2}{12} = \pm 135 \text{ KNm}$$

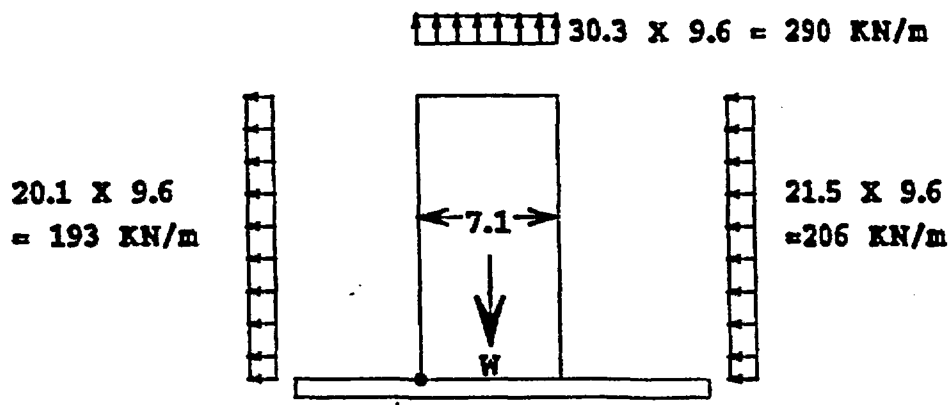
HOGGONG (SUPPORTS)

$$M = \frac{21.5 \times 8.7^2}{10} = \pm 165 \text{ KNm}$$

Table 8A.1-17

Tornado Wind Pressure Effect - Global Building Effect

CONSIDER DBT ACTING IN Y DIRECTION ON TRANSFER CONFINEMENT AND LOWER ACCESS AREA.



BUILDING WEIGHT = 12276 KN
BUILDING HEIGHT = 16.5 m
BUILDING LENGTH = 9.6 m

OVERTURNING MOMENT AT TOP OF THE BASE

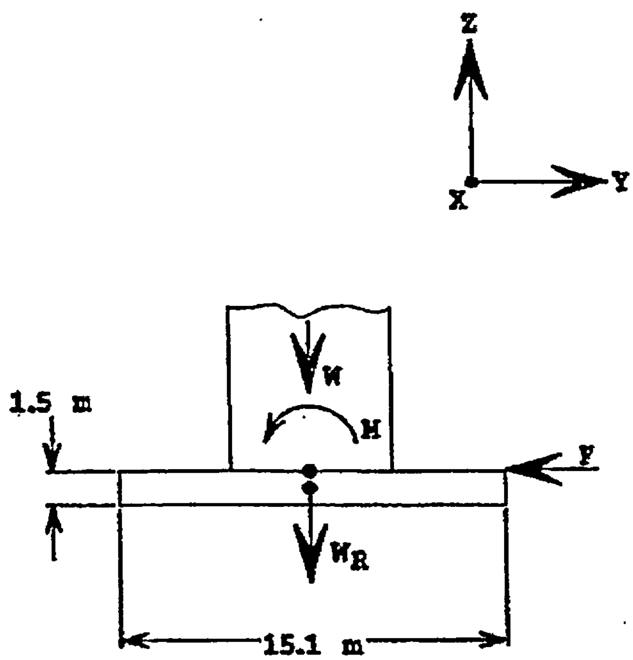
$$M = (206 + 193) \times \frac{16.5}{2} + \frac{290 \times 7.1^2}{2} = 60500 \text{ KNm}$$

BASE SHEAR FORCE

$$F = (206 + 193) \times 16.5 = 6560 \text{ KN}$$

Table 8A.1-18

DTS Superstructure Building Stability - DBT Wind Loading



BUILDING STABILITY-OVERTURNING

BY INSPECTION Y DIRECTION LOADING GOVERNS

F = 6560 KN (DUE TO HORIZONTAL ACCELERATION)

M = 60500 KNm

W = 12285 X 0.8 (TO ALLOW FOR MIN. EQUIP. WEIGHT) = 9828 KN

W_R = 8480 KN

$$\text{FACTOR OF SAFETY} = \frac{\text{STABILIZING MOMENT}}{\text{OVERTURNING MOMENT}}$$

$$= \frac{(9828 + 8480) \times 15.1(0.5)}{(60500 + 6560 \times 1.5)}$$

$$= \frac{138,225}{70,340} = 1.98 > 1.5 \quad \text{OK}$$

8A.1.6.1.2 Tornado Missiles

The side walls of the reinforced concrete are 36 inches thick (914 mm). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Chapter 3.0. Nevertheless, in order to demonstrate the adequacy of the DTS design for tornado missiles, detail analysis of the concrete wall has been performed and presented in Section 3.2.1.4. The items evaluated include the resistance to penetration, spalling, scabbing and perforation for a postulated missile impact.

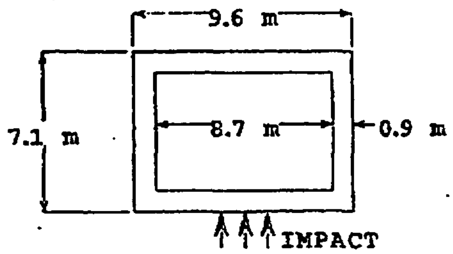
Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the structure cause only superficial damage. The structure thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the structure will not compromise their confinement capability. Local repair to the structure will be performed if required after a missile impact.

The concrete superstructure stability due to impact of the postulated DBT massive consisting of 1,800 Kg automobile, 28 sq. ft*. frontal area travelling at 59 m/sec., is evaluated at Table 8A.1-19.

*for calculating the bending moment in the structural wall, 21sq. ft. was conservatively used (see calculation in Table 8A.1-19).

Table 8A.1-19

Global Effect For Automobile Impacting "Head On" Into Center of Longer Wall

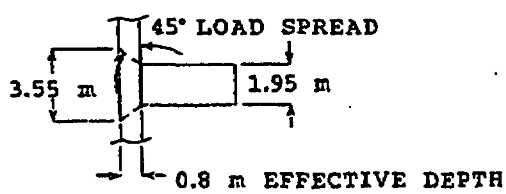


PLAN ON CONCRETE WALL

MISSLE (AUTOMOBILE)
FRONTAL AREA 21 FT^2 = 1.95 m^2
M = 1810 KG
V = 59 m/S
AVERAGE DYNAMIC FORCE
$F = 15.5\ M^{2/3}\ V^{1.62}$
$= 15.5(1810)^{2/3}\ (59)^{1.62}$
= 1700 KN

DYNAMIC INCREASED FACTOR AS ACI 349 APP. C FOR GRADE 60 REINFORCING STEEL
DIF = 1.1
⇒EQUIVALENT AVERAGE DYNAMIC FORCE $F = \frac{1700}{1.1} = 1545$ KN

CONSERVATIVELY USING DYNAMIC FORCE AS STATIC FORCE FOR BENDING MOMENT CALCULATION
⇒ EQUIVALENT STATIC FORCE = 1545 KN



SAGGING (MIDDLE SPAN)

$M = \frac{1545 \times 8.7}{6 \times 3.55} = 632$ KNm

HOGGING (SUPPORT)
M = 632 KNm

8A.1.6.1.3 Seismic Evaluation

A. Discussion of the Seismic Analysis

The design basis response spectra of NRC Regulatory Guide 1.60 (Reference 8A.1.7-6) is selected for the DTS design earthquake as defined in 10CFR72.102. From the Regulatory Guide 1.61 (Reference 8A.1.7- 7) Table 1, a damping value of seven (7) percent of critical damping is used for the reinforced concrete superstructure. The horizontal and vertical components of the response spectra (in Figures 1 and 2, respectively, of the NRC Regulatory Guide 1.60) correspond to a maximum horizontal and vertical ground acceleration of 1.0g. The maximum ground displacement is taken to be proportional to the maximum ground acceleration, and is set at 36 inches for a ground acceleration of 1.0g.

NRC regulatory Guide 1.60 also states that for sites with different acceleration values specified for the design basis earthquake, the response spectra used for design should be linearly scaled from Regulatory Guide 1.60, Figures 1 and 2, in proportion to the maximum specified horizontal grounding acceleration. The maximum horizontal ground acceleration component selected for design of the DTS superstructure is 0.25g. The maximum vertical acceleration component selected is two - thirds of the horizontal component which is 0.17g. These ground acceleration values comply with the recommendations of the 10CFR72.102 for sites underlaid by rock east of the Rocky Mountain front, except in the areas of known seismic activity. The input response spectrum for this analysis is shown on Figure 8A.1-4.

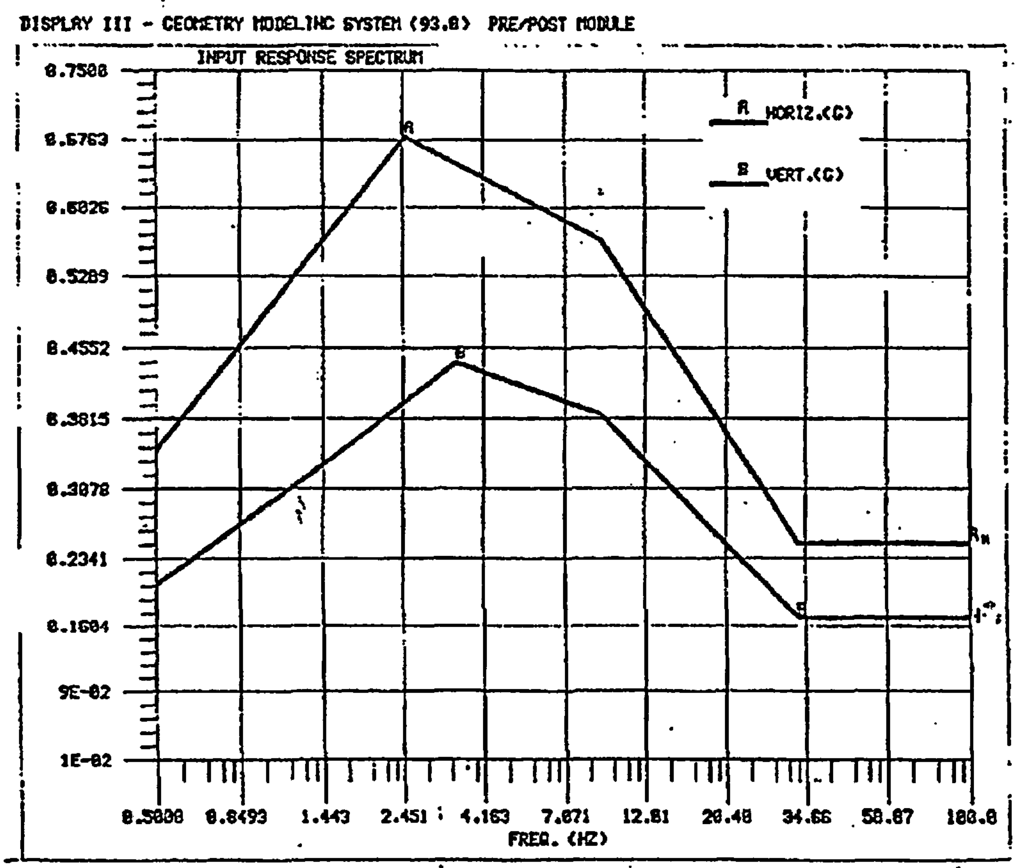
An appropriate design basis earthquake (also described as a Safe Shutdown Earthquake) can be represented by three orthogonal translational components (2 horizontal and 1 vertical) consisting of free field ground acceleration response spectra. These ground response spectra represent the maximum acceleration response to the earthquake motion of a series of single degree of freedom oscillators of natural frequency varying between 0.1 Hertz and 33 Hertz.

The seismic analysis of the DTS assumes that the structure founded on competent rock. In this circumstance, the phenomenon of Soil Structure Interaction (SSI) in which dynamic interaction between the structure and supporting soil medium need not be considered.

Furthermore the structure can be analyzed as fully fixed at the base of the shear walls at the top of the basement.

Figure 8A.1-4

Seismic Analysis - Input Response Spectrum



B. Model Generation

The structure has been modeled for seismic analysis purposes using the computer code ANSYS 4.4A.

The superstructure of the DTS facility comprises a relatively stiff shear wall structure in reinforced concrete supporting plant items and equipment on two flexible internal structural steel floors. In common with normal practice, equipment and internal structural steel floors are assumed not to contribute to the stiffness of the supporting reinforced concrete structure.

A three dimensional plate model of concrete superstructure above top of base, including plant masses was prepared. All reinforced concrete walls have been represented by four-node shell elements with elastic material properties based on gross uncracked concrete sections. Walls have been modeled at center locations throughout.

Rigid equipment is generally represented as lumped translational mass. Internal floors (including the roof level and mezzanine floor) which support major plant items and equipment are flexible in the vertical direction and have been represented as structural beam elements supporting vertical mass elements representing equipment, self weight, and floor imposed loading. The model generation and modeling assumption are shown in the following Figures:

Figure 8A.1-5: Finite element model of reinforced concrete structure
Figure 8A.1-6: Roof floor modeling assumptions
Figure 8A.1-7: Fuel assembly crane modeling assumptions
Figure 8A.1-8: Mezzanine floor modeling assumptions
Figure 8A.1-9: Sliding door and preparation area modeling assumptions

All concrete walls assumed 36" thick. Wall overall center line dimensions assumed 343" × 244" O/A in plan by 570.8" high.

Figure 8A.1-5

Finite Element Model of Reinforced Concrete Structure

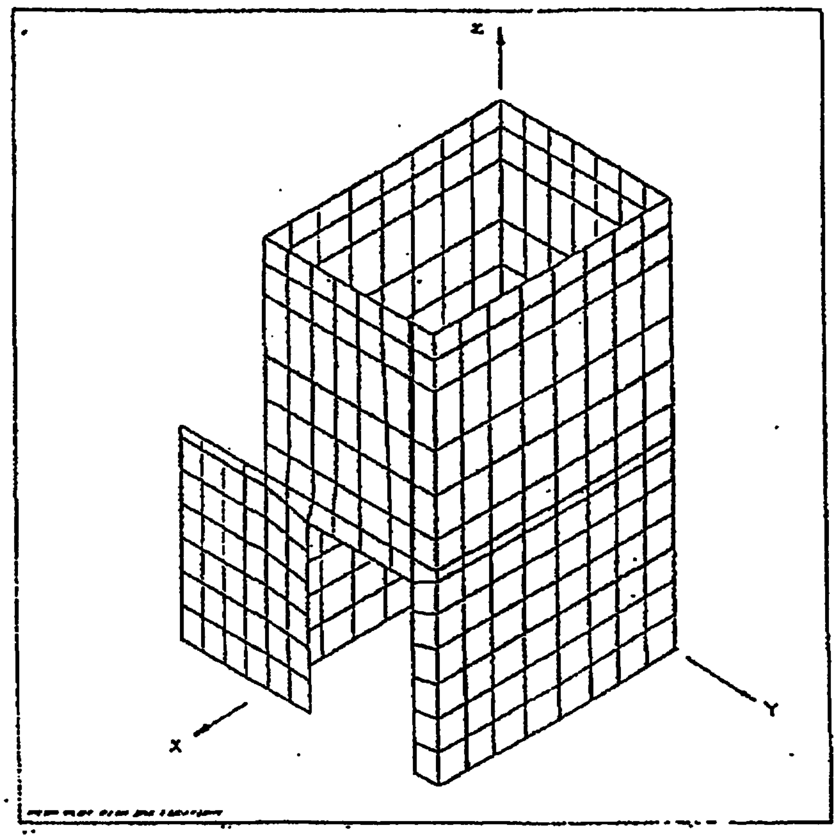
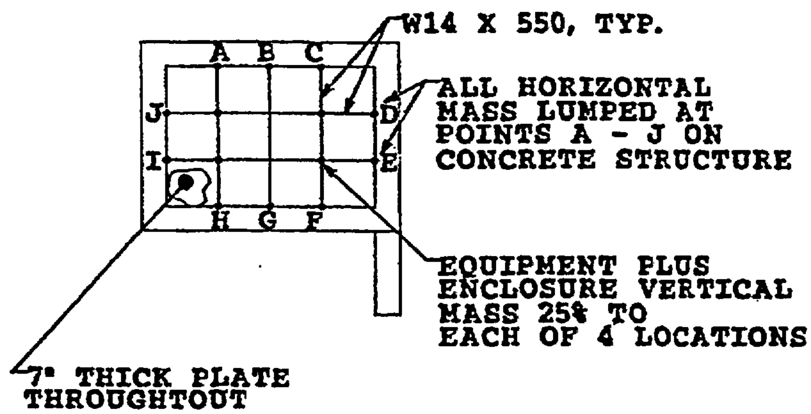


Figure 8A.1-6

Roof Floor Modeling Assumptions



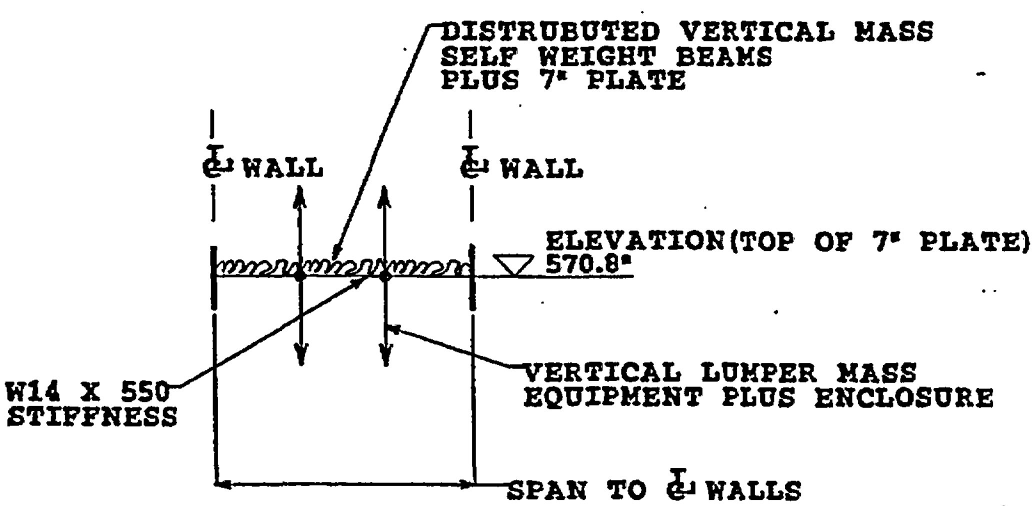
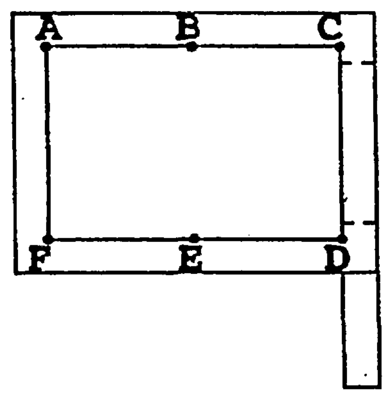


Figure 8A.1-7

Fuel Assembly Crane Modeling Assumptions



TOTAL EQUIPMENT MASS = 22,000 LB.
(FUEL ASSEMBLY CRANE)

MASS X,Y,Z DIRECTIONS (22000/6 = 3667 LB.)
APPLIED EQUALLY AT POINTS A-F

Figure 8A.1-8

Mezzanine Floor Modeling Assumptions

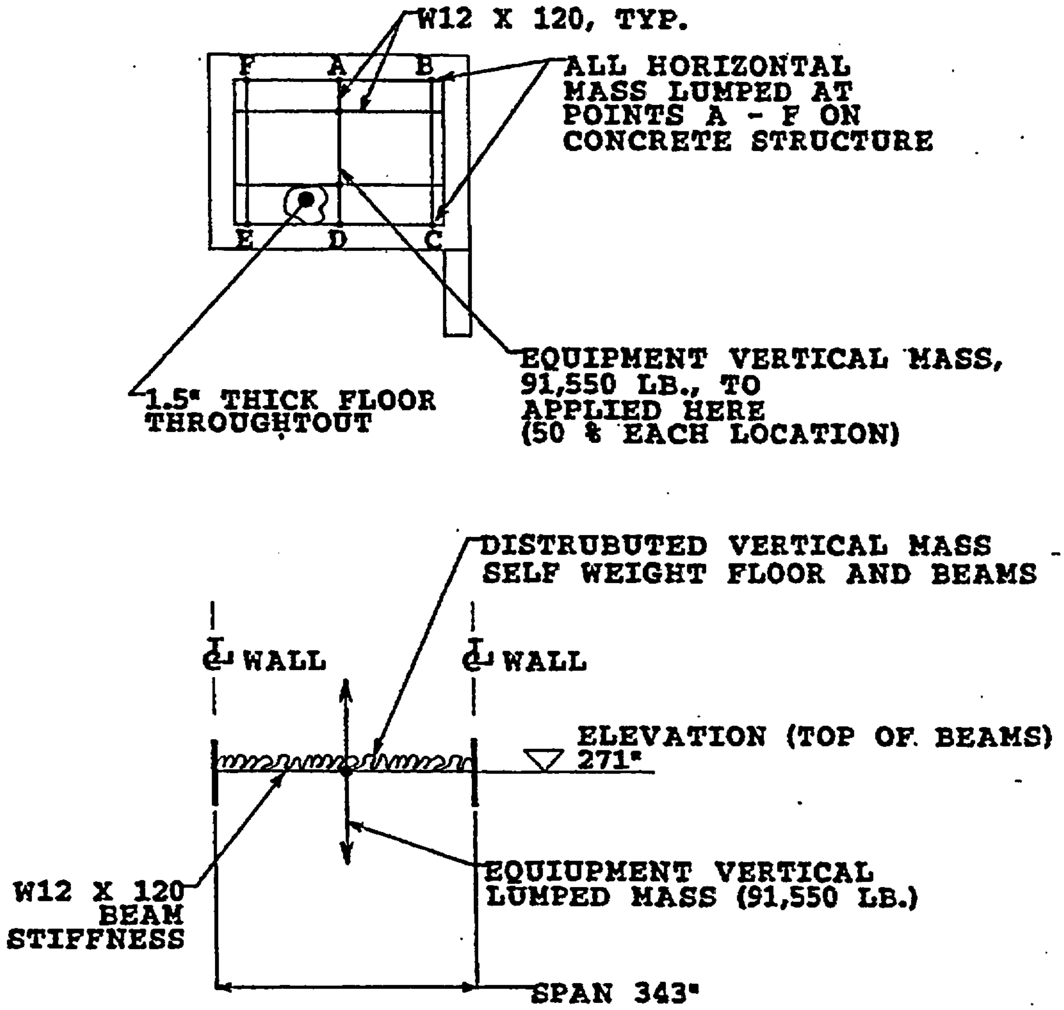
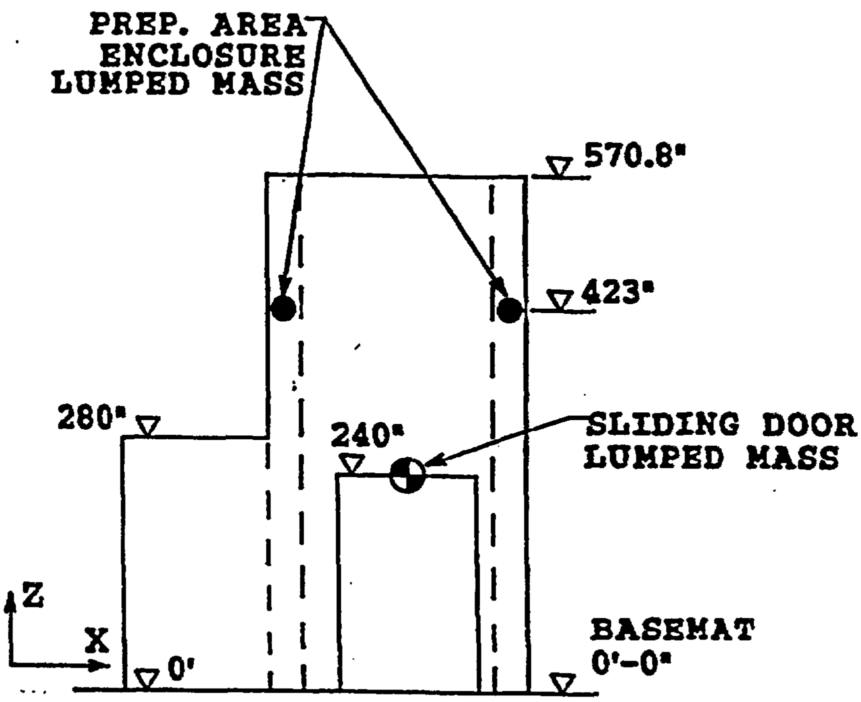


Figure 8A.1-9

Sliding Door and Preparation Area Modeling Assumptions



C. Analysis

A fixed base modal analysis technique was used to predict the structure response (in terms of acceleration) to the design earthquake input motion. A damping level of 7% was used which reflects the overall damping in a reinforced concrete structure stressed to levels approaching yield at the SSE.

A separate modal analysis has been carried out for each earthquake direction. The results from the 3 runs were combined using the square root sum of the squares method (SRSS). Results for individual earthquake direction analysis have been combined using the Complete Quadratic Combination technique (CQC).

Results from the modal analysis are as follows:

- Mode shapes, frequencies and mass participation factors for all structure modes of vibration up to approximately 50 Hertz.

- Zero Period Accelerations (also known as rigid body accelerations) at selected locations throughout the structure. These represent the maximum acceleration response at the locations in 2 horizontal and the vertical translational directions on the structure.

Zero Period Accelerations (ZPA)are subsequently adjusted manually by adding base input accelerations by SRSS to correct for:

- Dynamic mass missing from the modes considered and

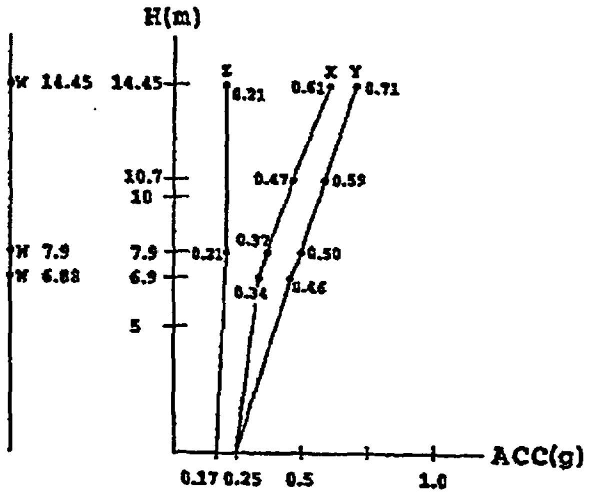
- Base input motion constant acceleration profile.

To produce design acceleration profiles due to global seismic effects it is necessary to combine output profiles with the ZPA values (0.25g horizontal, 0.17g vertical) using the SRSS method to account for fixed base analysis giving zero response at 0 m elevation, which should be ZPA value.

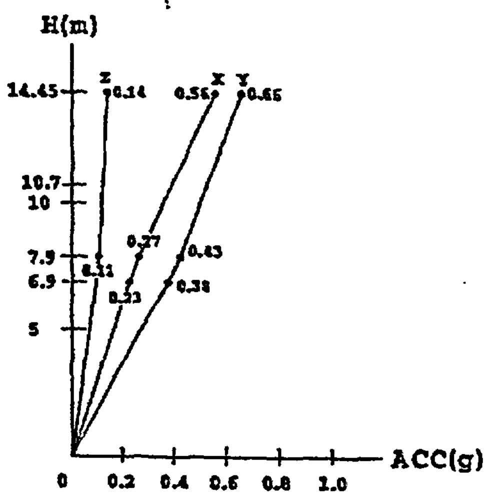
For global considerations, use acceleration values from "Middle Wall" positions. Figure 8A.1-10 shows both the global average seismic accelerations and global average seismic acceleration combined with ZPA. These accelerations are also listed in the Table 8A.1-20 and to be used for the reinforced concrete superstructure design.

Figure 8A.1-10

Wall Peak Accelerations - Global Seismic Effects



GLOBAL AV. SEISMIC ACCELERATION COMBINED WITH ZPA



GLOBAL AV. SEISMIC ACCELERATION

Table 8A.1-20

Global Average Seismic Accelerations Combined With ZPA

Location	Global Av. Seismic Acceleration Combined With ZPA			
	Acel X	Acel Y	Acel Z	
0 m	0.25g	0.25g	0.17g	
6.9 m	0.34g	0.46g	0.17g	
7.9 m	0.37g	0.50g	0.21g	
14.45m	0.61g	0.71g	0.21g	

D. Global Seismic Forces

First calculate total weights of structure and equipments (From Table 8A.1-3):

Roof Structure + Equipment (14.45m Level):

166,875 +56,741 + 27,258 = 250,874 lbs (286,600 lbs is used for calculation)
286,600 ÷ 2,240 × 9.81 = 1255 KN

Fuel Assembly Crane (7.9m Level):

22,000 ÷ 2,240 × 9.81 = 100 KN

Mezzanine Floor + Equipment (6.89m Level):

25,230 + 8,220 + 49,500 = 82,950 lbs (125,000 lbs is used for calculation)
125,000 ÷ 2,240 × 9.81 = 550 KN

Sliding Door (6.82m Level):

85,000 lbs (96,500 lbs is used for calculation)
96,500 ÷ 2,240 × 9.81 = 420 KN

Concrete Structure (CG at 7.9m Level):

2,234,624 ÷ 2,240 × 9.81 = 9,790 KN

Consider X - Direction:

Base Shear,
F_x = 1255 × 0.61 + 100 × 0.37 + 550 × 0.34 + 210 × 0.34 + 380 × 0.47 + 9790 × 0.34
= 766 + 37 + 187 + 72 + 179 + 3329 = 4,570 KN

Base Moment,
M_x = 766 × 14.45 + 37 × 7.9 + 187 × 6.89 + 72 × 8.82 + 179 × 10.7 + 3329 × 7.9
= 11069 + 292 + 1289 + 491 + 1915 + 26299
= 41,355KNm ≈ 41,360 KNm

Consider Y - Direction:

Base Shear,
$F_y = 1255 \times 0.71 + 100 \times 0.5 + 550 \times 0.46 + 210 \times 0.46 + 380 \times 0.59 + 9790 \times 0.46$
$= 891 + 50 + 250 + 97 + 225 + 4505$
$= 6{,}021 KN \approx 6050$ KN

Base Moment,
$M_y = 891 \times 14.45 + 50 \times 7.9 + 253 \times 6.89 + 97 \times 6.82 + 225 \times 10.7 + 4505 \times 7.9$
$= 12{,}875 + 395 + 1743 + 662 + 2408 + 35{,}590$
$= 53{,}673$ KNm $\approx 53{,}680$ KNm

Consider Z - Direction:

Vertical Force,
$F_z = (1255 + 100 + 550 + 210 + 380 + 9790) \times 0.2$
$= 12{,}285 \times 0.2$
$= 2{,}460$ KN

Base Moment, M_z
There are very small eccentricities in both directions, $M_z = 0$

The above calculated forces and moments are summarized in Table 8A.1-21.

Table 8A.1-21

Forces and Moments Analysis Results Summary - Global Seismic Effects

	X- Direction (Longitudinal)		Y - Direction (lateral)		Z- Direction (Vertical)	
	F_x(KN)	M_x(KNm)	F_y(KN)	M_y(KNm)	F_z(KN)	M_z(KNm)
Calculated at the Top of Basemat	4,570	41,360	6,050	53,680	2,460	0

F. Accelerations at Selected Locations on The Concrete Structure and Flexible Steel Floors.

Accelerations appropriate for a competent rock site are listed in the Table 8A.1-22 for selected locations on the concrete structure and flexible structural steel floors.

Table 8A.1-22

Acceleration For Selected Locations

Location	Equipment	ZPA Accelerations			
		Acel X	Acel Y	Acel Z	
0 m	Cask Trolley Base of Sliding Door	0.25g	0.25g	0.17g	
6.9 m	Mezz. Floor Top of Sliding Door	0.37g	0.5g	0.7g	
7.9 m	Fuel Crane Prep Area Roof Struc.	0.37g	0.50g	0.21g	
14.45 m	Roof Floor Lid Crane Shield Plug	0.69g	0.77g	0.40g	

G. Seismic Accelerations and Estimated Secondary Response Spectra For Design of support equipment.

Figures 8A.1-11 to 19 present the secondary response spectra which is to be used for equipment design. Spectra at 7% damping have been derived using the following data from the fixed base model analysis:

- Structure zero period accelerations at the location or area of interest.
- Structure mode shapes, frequencies and mass participation factors to identify modes of interest.
- Amplifications at important frequencies above zero period accelerations have been estimated using systems of single degree of freedom oscillators attached to locations in a separate finite element model.

Figure 8A.1-11

Secondary Response Spectra - X Direction (14.45m Level)

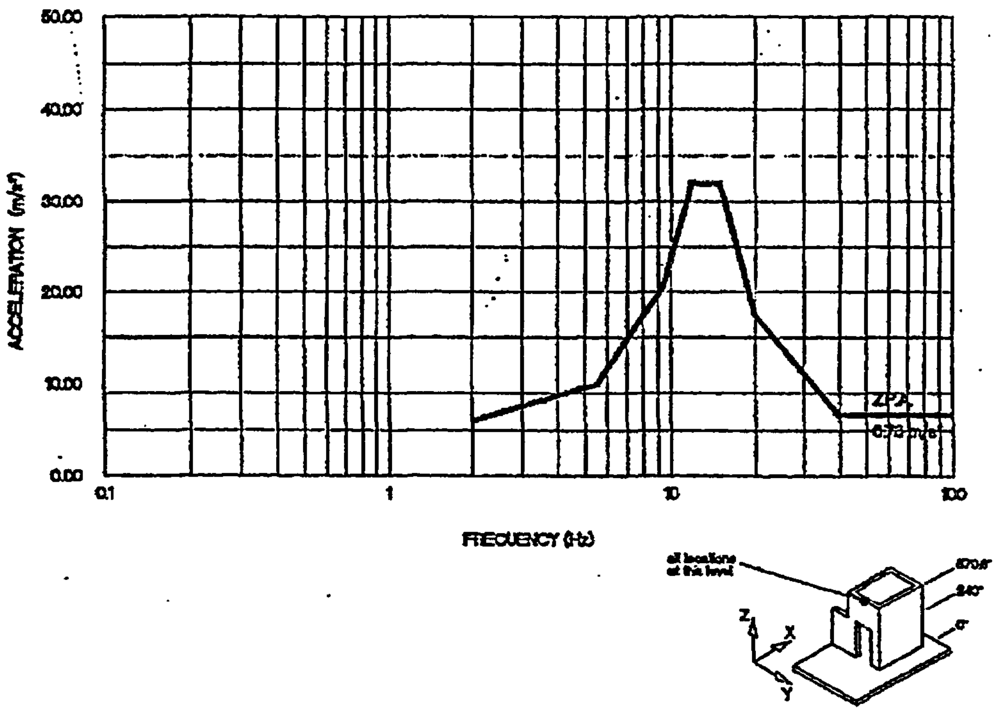


Figure 8A.1-12

Secondary Response Spectra - Y Direction (14.45m Level)

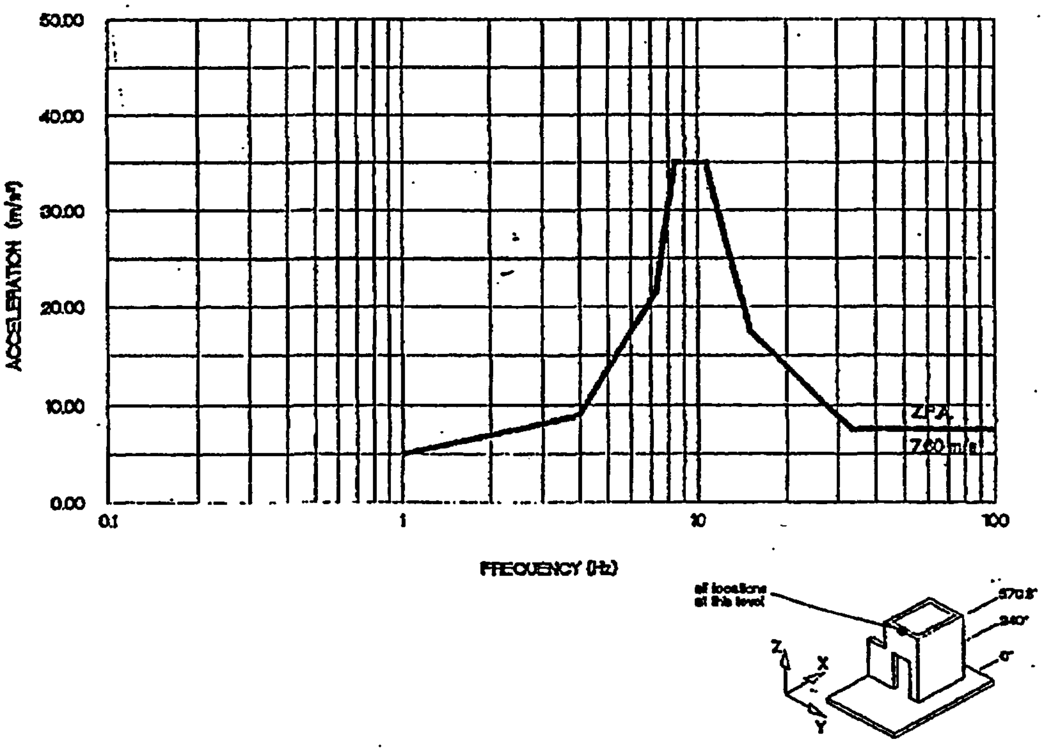


Figure 8A.1-13

Secondary Response Spectra - Z Direction (14.m Level)

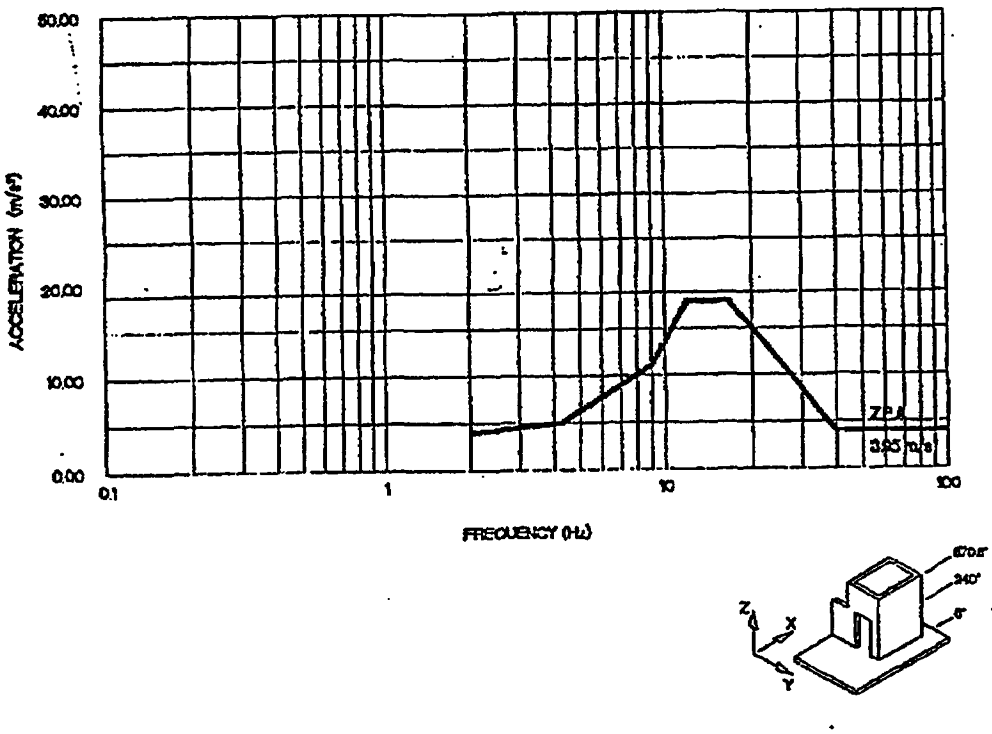


Figure 8A.1-14

Secondary Response Spectra - X Direction (7.9m Level)

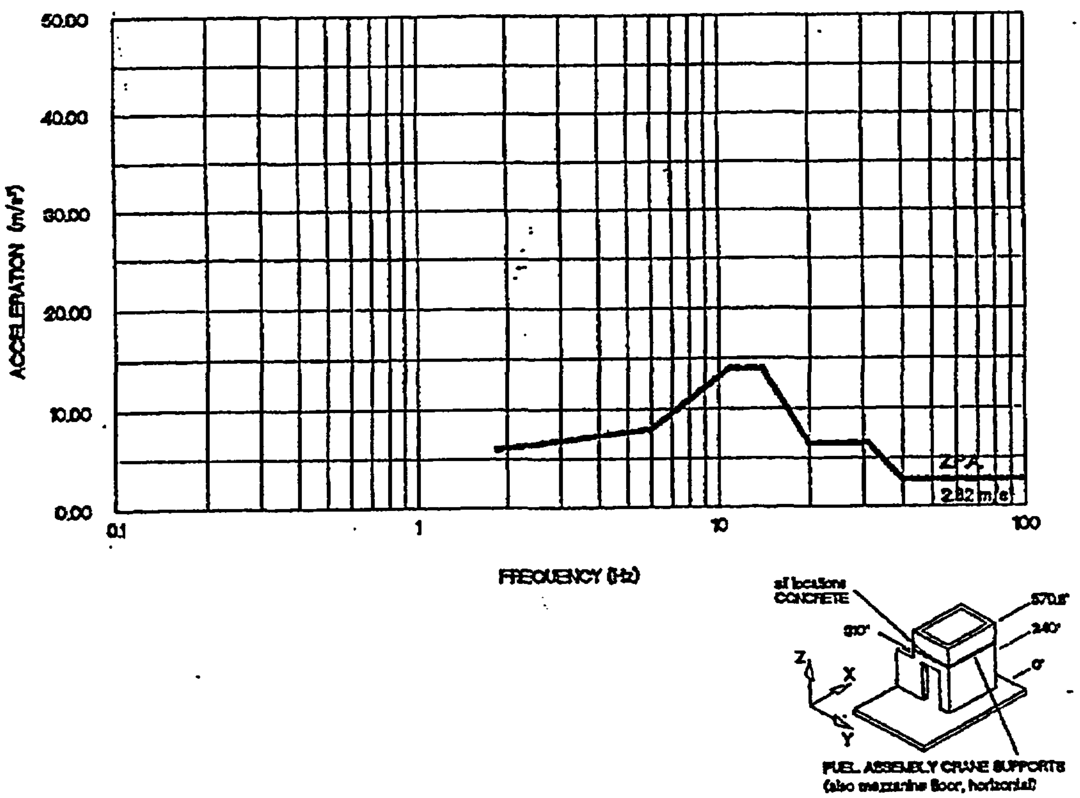


Figure 8A.1-15

Secondary Response Spectra - Y Direction (7.9m Level)

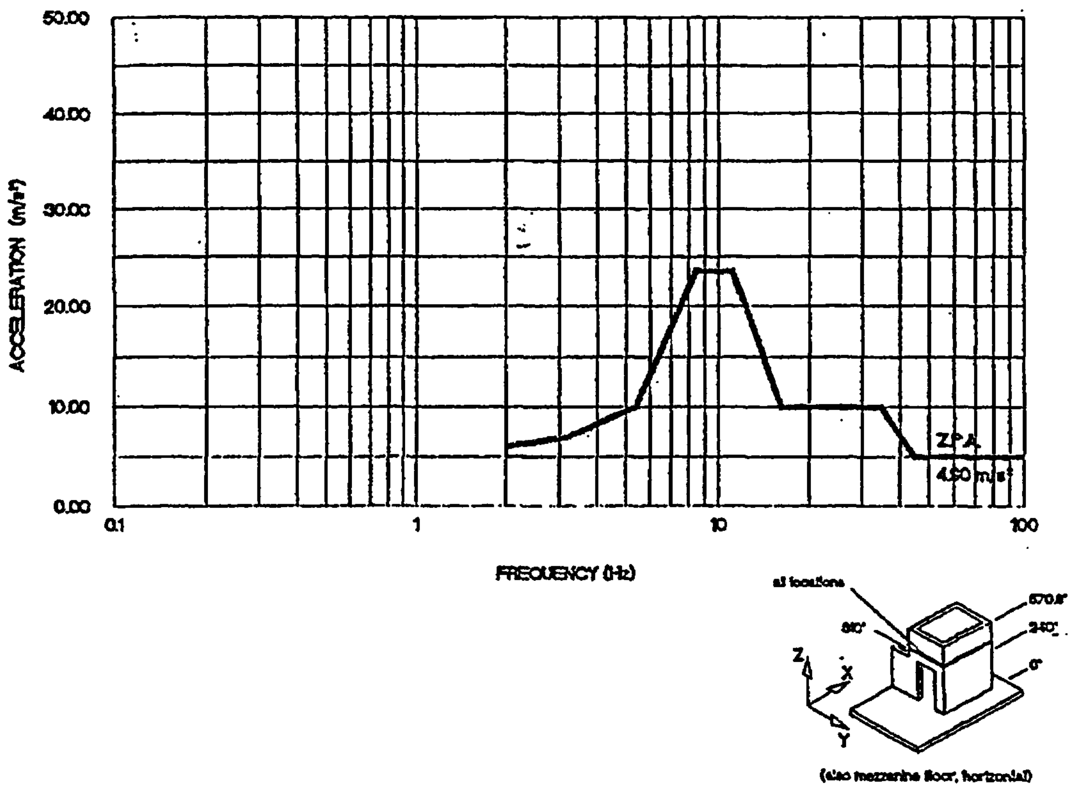


Figure 8A.1-16

Secondary Response Spectra - Z Direction (7.9m Level)

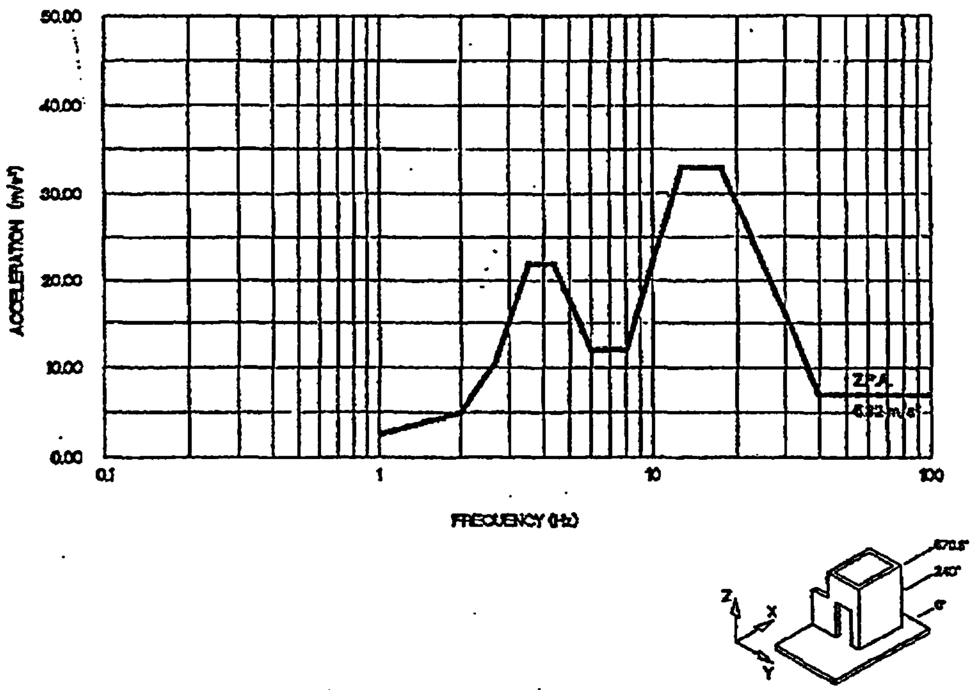


Figure 8A.1-17

Secondary Response Spectra - X Direction (6.0m Level)

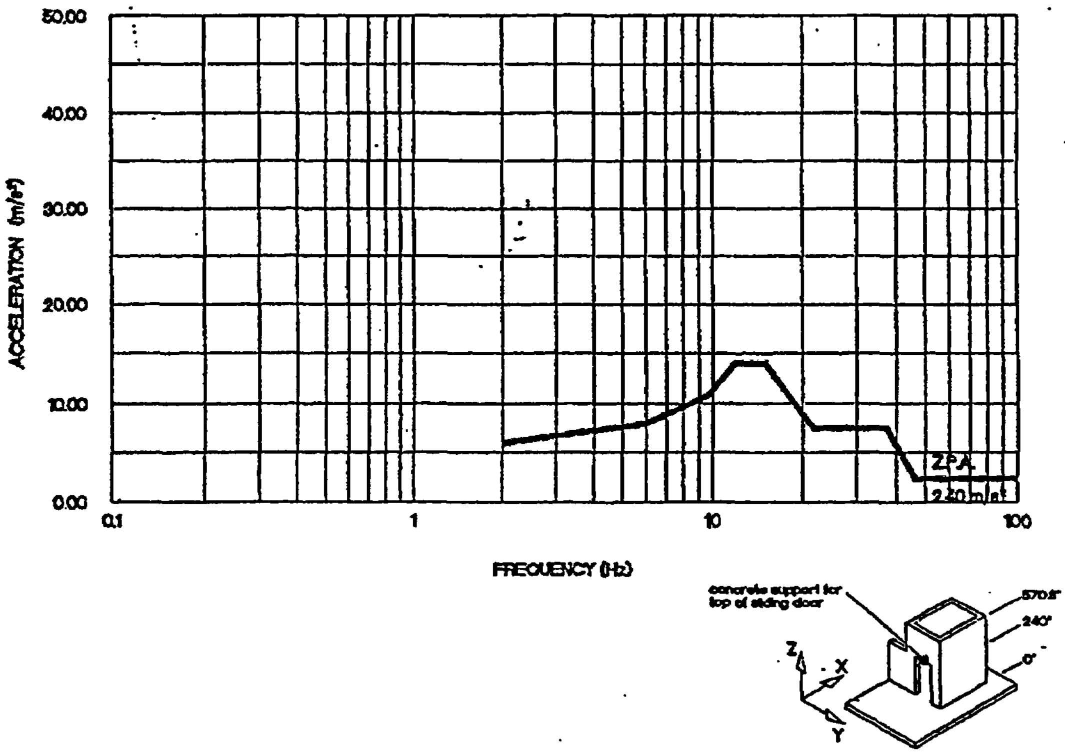


Figure 8A.1-18

Secondary Response Spectra - Y Direction (6.0m Level)

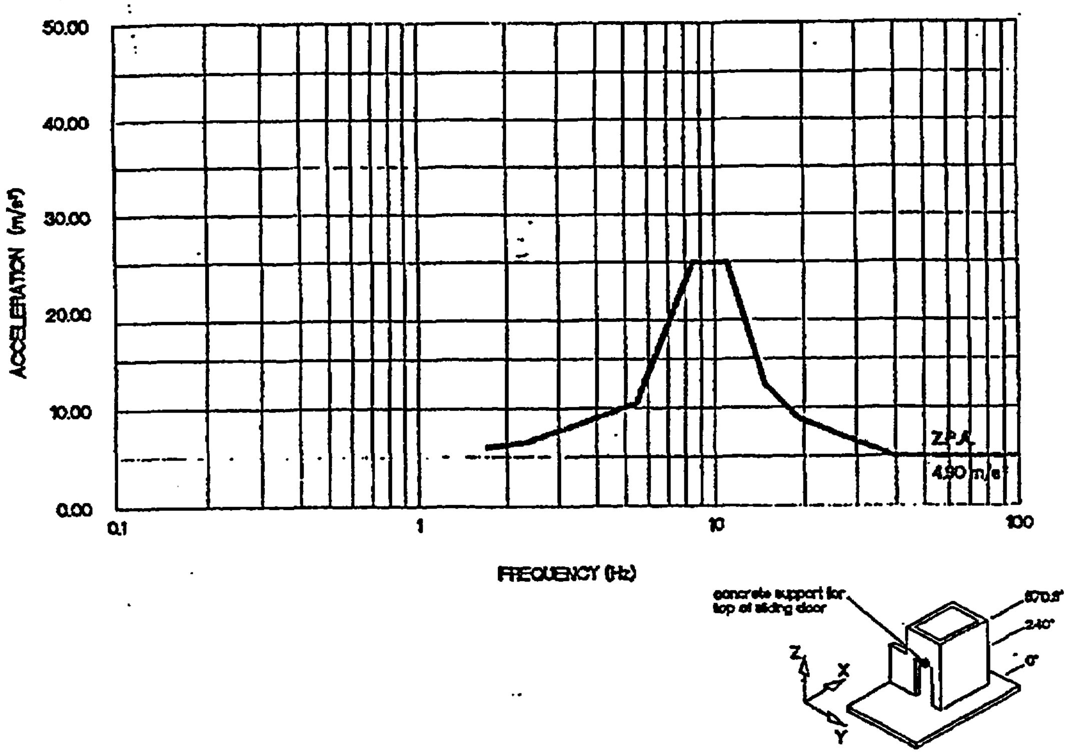
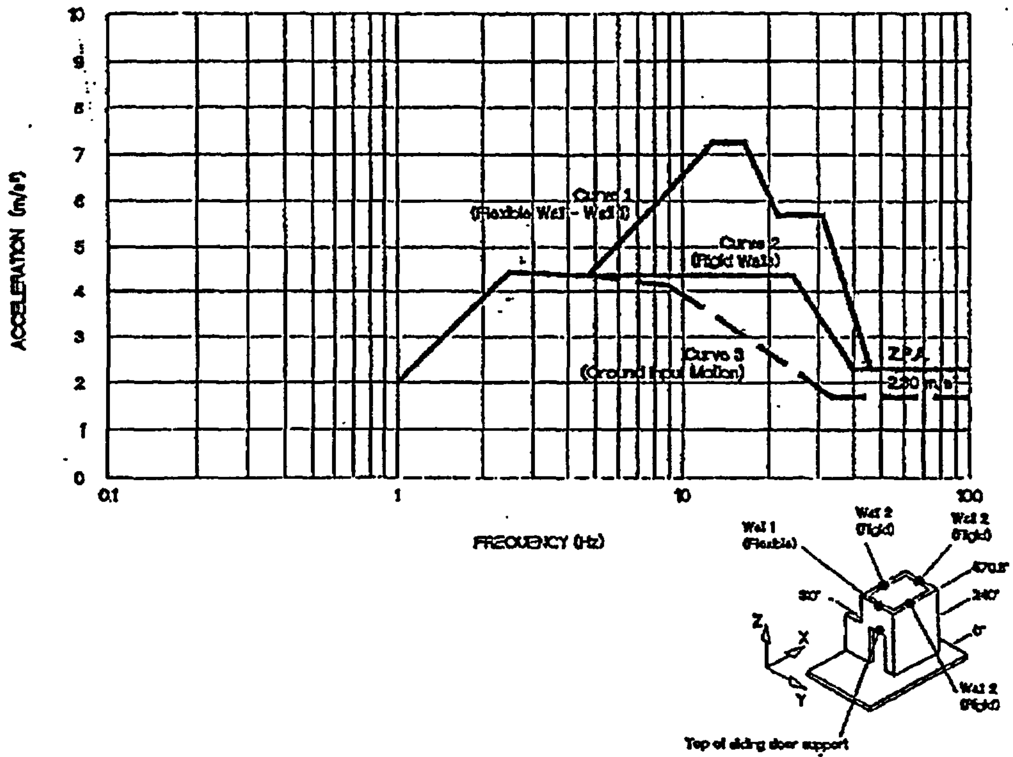


Figure 8A.1-19

Secondary Response Spectra - Z Direction (6.0m Level)



H. Basemat Design

The following are considered:

1. Building Stability (Overturning/Sliding):

Building stability due to DBT loading is discussed in Section 8A.1.6.1.1. The stability due to SSE is calculated as follow.

Stability and bearing pressure calculations based on area of basement local to TC/LA area only, ie. Area 15.5m × 15.1m. This approach is considered reasonal and conservative.

The stabilizing and overturning moments due to the SSE loading are calculated in Table 8A.1-23 and the results are:

M_s = stabilizing moment = 144,205 KNm

M_o = overturning moment = 62,755 KNm

Factor of Safety = 144,205/62,755 = 2.3 > 1.5 OK

Since the overturning moment is smaller than the stabilizing moment, the DTS building will not overturn. The resulting factor of safety against overturning effects for SSE loads is 2.3.

Building Stability - Sliding

First assume sliding resisted by base friction. Assumed reasonable friction angle between basemat and subsoil, 30^0.

Coefficient of Friction = Tan 30^0 = 0.58

Allowable Friction = 0.58/Factor of Safety = 0.58/1.1 = 0.53

Seismic Force (Reference Table 8A.1-21):

F_x = 4,570 KN
F_y = 6,050 KN
F_z = 2,460 KN

Horizontal Resultant = $(6050^2 + 4570^2)^{1/2}$ = 7582 KN

For minimum weight, use 40% of the vertical seismic component,

W_{min} = 12285 - 2460 (0.4) + 8480 × (1-0.4 × 0.2) = 19,103 KN

Required μ = 7582/19103 = 0.4 < 0.53 OK

2. Foundation Bearing Pressure

Foundation bearing pressures due to weight of concrete and equipment combined with SSE or DBT loads are calculated in Tables 8A.1-24 and 8A.1-25 and the results are:

P_{w+SSE} = 207 KN/m^2 < 225 KN/m^2 OK

P_{w+DBT} = 213 KN/m^2 < 225 KN/m^2 OK

3. Basemat Reinforced Concrete Design

External Cantilever - Design as one way spanning slab

Thickness - 1.50m
SSE loading govern, at root of cantilever ;

V = (207 + 115)/2 × 4 = 644 KN
Say effective depth = 1400 mm

$V_P = 644 \times 10^3 / 1400 \times 1000 = 0.46\ N/mm^2$

Allowable Pressure = $\Phi\ 2 \times (fc')^{1/2} = 0.85 \times 2 \times (3000)^{1/2}$ = 93psi = 0.64 N/mm^2 > 0.46 N/mm^2

Minimum reinforcement required = 0.0018 × 1500 × 1000 = 2700mm^2/m ⇒ 1.28^2/ft

$M_u = 115 \times 4^2/2 + (207 - 115)/2 \times 4^2 \times 2/3$ = 1910 KNm

$M_u / \Phi\ b\ d^2 = 1910 \times 10^6 / 0.9 \times 1000 \times 1400^2 = 1.08\ N/mm^2$

ρ = 0.0028

$\Rightarrow 0.0028 \times 1000 \times 1400 = 3920$ mm/m = 1.86 $in^2/ft \Rightarrow$ #10 at 8" (1.9 in^2 /ft)

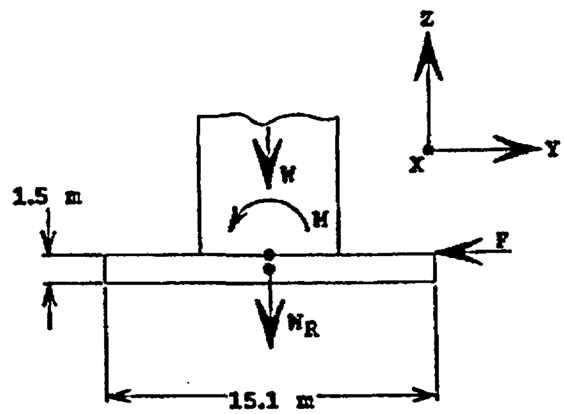
<u>Internal Slab</u>

By inspection, use minimum reinforcement.

ie. 1800 mm^2/m = 0.85 in^2/ft

Table 8A.1-23

DTS Superstructure Building Stability - SSE Loading



BUILDING STABILITY-OVERTURNING

IN Y DIRECTION	F_Y= 6050 KN	M_Y= 53680 KNm
IN X DIRECTION	F_X= 4570 KN	M_X= 41360 KNm
IN Z DIRECTION	F_Z= ± 2460 KN	

BUILDING WEIGHT = 12285 KN
BASEMAT AREA = 15.1 X 15.6 = 235 m^2

IN Y DIRECTION (Z DIRECTION RESPONSES-USE 40% RULE)

W = 12285 - 2460 X 0.4 = 11300 KN
M = My = 53680 KNm
F = Fy = 6050 KN
W_R= (15.1 X 15.6 X 1.5 X 24) X (1 - 0.2 X 0.4) = 7800 KN

$$\text{FACTOR OF SAFETY} = \frac{\text{STABILIZING MOMENT}}{\text{OVERTURNING MOMENT}}$$

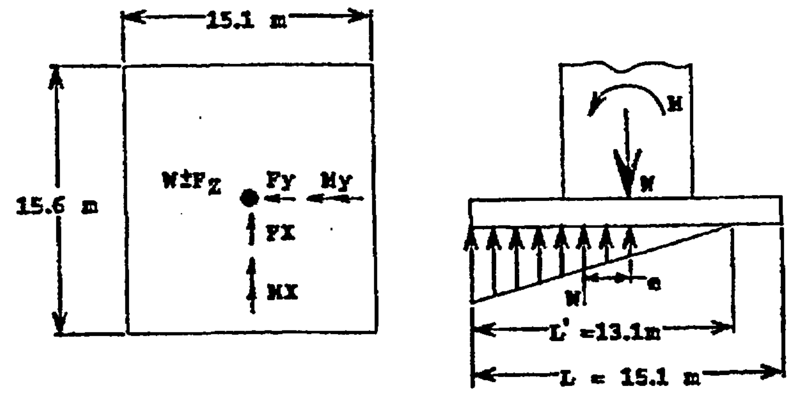
$$= \frac{(11300 + 7800) \times 15.1(0.5)}{(53680 + 6050 \times 1.5)}$$

$$= \frac{144,205}{62,755} = 2.3 > 1.5 \quad \underline{\text{OK}}$$

BY INSPECTION BUILDING STABILITY IN X DIRECTION OK

Table 8A.1-24

Basemat Bearing Pressure Calculation - Weight + SSE Load



(a) STATIC LOADING AND Y DIRECTION SEIMIC COMPONENT

$$\frac{W}{A} = \frac{12285 + 8480}{15.1 \times 15.6} = 88 \text{ KN/m}^2$$

APPLY RESULTANT OVERTURNING MOMENT ON WEAK AXIS:

$My = 53{,}680 + 6050 \times 1.5 = 62{,}755$ KNm

$MX = 41360 + 4570 \times 1.5 = 48215$ KNm

$$\text{RESULTANT } M = \sqrt{62755^2 + (48215 \times 0.4)^2} = 65650 \text{ KNm}$$

$$e = \frac{M}{W} = \frac{65{,}650}{20765} = 3.16 \text{ m} \qquad L' = \left(\frac{15.1}{2} - 3.16\right) \times 3 = 13.1 \text{ m}$$

$$\text{BEARING PRESSURE} = \frac{20765 \times 2}{15.6 \times 13.1} = 202 \text{ KN/m}^2$$

(b) Z DIRECTION COMPONENT

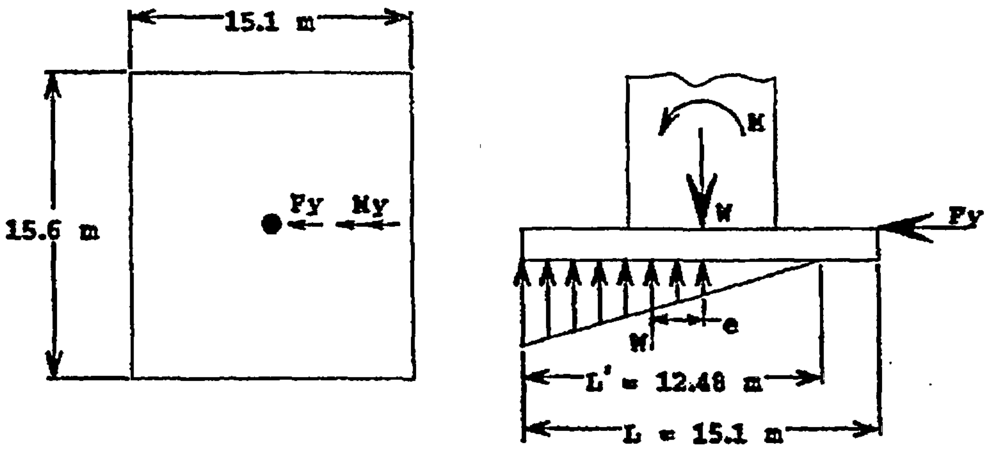
NOW APPLY 40% OF Z DIRECTION COMPONENT ON REDUCED WIDTH L'

$$\text{BEARING PRESSURE} = \frac{2460 \times 0.4}{15.6 \times 13.1} = 5 \text{ KN/m}^2$$

TOTAL BEARING PRESSURE = $202 + 5 = 207$ KN/m^2

Table 8A.1-25

Basemat Bearing Pressure Calculation - Weight + DBT Wind Loading



(a) STATIC LOADING AND DBT LOADING

$$\frac{W}{A} = \frac{12285 + 8480}{15.1 \times 15.6} = 88 \text{ KN/m}^2$$

DBT LOADING

Fy = 6560 KN (DUE TO HORIZONTAL ACCELERATION)

My = 60500 KNm

$$e = \frac{60500 + 6560 \times 1.5}{20765} = 3.39 \text{ m}$$

$$L' = \left(\frac{15.1}{2} - 3.39\right) \times 3 = 12.48 \text{ m}$$

$$\text{TOTAL BEARING PRESSURE} = \frac{20765 \times 2}{15.6 \times 12.48} = 213 \text{ KN/m}^2$$

I. Concrete Wall Above Mezzanine Floor at 6.9m Level

Horizontal Span

Horizontal Span	Moments (KNm)		Remark
	Hogging	Sagging	
SSE	742	721	
DBT (Pressure)	165	135	Table 8A.1-16
DBT (Missile)	632	632	Table 8A.1-19
Thermal (Alone)	547	-547	Table 8A.1-4
Thermal (± SSE/DBT)	345	-291	Table 8A.1-5

By inspection (SSE + Thermal) governs

$\Rightarrow M_{design}$/m width = 742 + 345 =1087 KNm

$M/\Phi bd^2 = 1087 \times 10^6 / 0.9 \times 1000 \times 800^2 = 1.89$ N/mm²

$\Rightarrow \varrho = 0.0048$

$A_s = 0.0048 \times 1000 \times 800 = 3840$ mm²/m = 1.82 in²/ft $\Rightarrow$ use # 10 at 8" C/C (1.90 in²/ft)(each face horizontal)

In Plan Shear

Total shears at 6.9m level in Y direction:

Load Case	Shear Force (F_y) (KN)	Remark
SSE	6050	
DBT (Wind Load)	3960	
DBT (Missile)	1140	

$\Rightarrow F_{y\,(design)} = 6050$ KN

In plan shear stress
$V_y = F/0.8 \times w \times t \times 2$ walls $= 6050 \times 10^3/0.8 \times 7100 \times 900 \times 2 = 0.59$ N/mm^2 = 85 psi

Allowable shear stress
$\Phi\, V_c = \Phi \times 2\, (f_c)^{1/2} = 0.85 \times 2 \times (3000)^{1/2} = 93$ psi   OK

Vertical Span

By inspection, use minimum reinforcement

$A_s = 0.0018 \times 1000 \times 900 = 1620$ mm^2/m = 0.76 in^2/ft $\Rightarrow$ use # 8 at 8" (1.18 in^2/ft)

Local to Equipment Anchorages

Check top of wall for roof beam horizontal seismic force F (Reference Table 8A.1-22):

F = (1255/2 No. beams) $\times$ 0.77g = 483 KN (Assume taken on one side only)

Check Shear at 14.45m Level;

$b_{eff} = 2 \times d$ (assume 45^0 load spread), d = 800mm, b_{eff} = 1600mm

$V = 483 \times 10^3/1600 \times 800 = 0.38$ N/mm^2 = 55 psi < 93 psi $\Rightarrow$ OK

Check flexural strength as vertical nib:

M = 483 KN × 575mm/2 = 138879 KN/mm

Maximum tension in vertical reinforcement;

T = 138870/800 × 2/3 = 262 mm^2 ⇒small ⇒ Minimum rebar are adequate

J. Walls Between Base and Mezzanine Floor

Horizontal Span: As above mezzanine floor

In Plan Shear

Load Case	Shear Force (KN)	Remark
SSE	$F_y = 6050$	Table 8A.1-21
SSE	$F_x = 4570$	Table 8A.1-21
DBT (Wind Load)	$F_y = 6560$	Table 8A.1-17

⇒ $F_{y\,(design)} = 6560$ KN

Allowable shear stress
$\Phi V_c = \Phi \times 2\,(f_c)^{1/2} = 0.85 \times 2 \times (3000)^{1/2} = 93$ psi

Y - direction:

Front wall
V_i = (6560/2 sides)/0.8 × (280" + 120" -150") × 25.4 × 900 = 0.71 N/mm^2 = 104 psi

Back wall

V_i = (6560/2 sides)/0.8 × 280"×25.4 × 900 = 0.64 N/mm^2 = 93 psi

Shear on front wall just over allowable, hence by inspection nominal reinforcement will be adequate. i.e. # 10 at 8" horizontal & # 8 at 8" vertical.

Calculate shear reinforcement required at corners of door opening.

With reference to ICE designers manual;

$A_s = V/\Phi\ f_y$ =6050/2 × 0.9 × 424 = 8158 mm^2 = 12.64 in^2
⇒use 10 - #10 at each corner A_s = 12.7 in^2 > 12.64 in^2

X - direction

V_i = 4570/2× 0.8 × 379" × 25.4 ×900 = 0.33 N/mm^2 = 48 psi < 93 psi OK

Axial stress due to tornado wind overturn moment

Reference Table 8A.1-17:

M_x = 60,500 KNm = 535,475 in-kips
M_y = 50,200 KNm = 444,311 in-kips

Check stress due to M_x:

F = 535,475/244 = 2194.57 kips
A = 343 × 36 = 12348 in^2
σ_x = 2194.57/12348 = 178 psi

Check stress due to weight:

W = 12285 KN = 2761668 lbs
A = ((379-72) × 2 + (280-36) + (280-36 -150)) × 36 = 34272 in^2
σ_w = 2761668/34272 = 81 psi

$\sigma_{Tension}$ = 178-81 = 97 psi
$\sigma_{Compression}$ = 178 + 81 = 259 psi < 1785 psi ($\Phi \times 0.85 \times f'_c$ = 0.7 × 0.85 × 3000 = 1785 psi)

Axial stress due to seismic load

From Table 8A.1-20:

M_y = 53680 KNm = 475,112 in-kips
M_x = 41360 KNm = 366,070 in-kips
F_z = 2460 KN = 553 kips

Check stress due to M_y:

F = 475112/244 = 1947 kips
A = 343 × 36 = 12348 in^2
σ_y = 1947/12348 = 158 psi

Check stress due to M_x:

F = 366070/343 = 1067 kips
A = (244-150+120) × 36 = 7704 in^2
σ_x = 1067/7704 = 138 psi

Check stress due to F_z:

F_z = 2460 KN = 553008 lbs
A = ((379-72) × 2 + (280-36) + (280-36 -150)) × 36 = 34272 in^2
σ_w = 553008/34272 = 16 psi

Check stress due to weight:

W = 12285 KN = 2761668 lbs
A = ((379-72) × 2 + (280-36) + (280-36 -150)) × 36 = 34272 in^2
σ_w = 2761668/34272 = 81 psi

$\sigma_{combined} = (158^2 + 138^2 + 16^2)^{1/2} = 210$ psi

$\sigma_{Tension}$ = 210 - 81 = 129 psi
$\sigma_{Compression}$ = 210 + 81 = 291 psi < 1785 psi ($\Phi \times 0.85 \times f'_c = 0.7 \times 0.85 \times 3000 = 1785$ psi)

$A_{required}$ = 129 × 36 ×12 / 0.9 × 60000 = 1.032 in^2/ft

⇒use #10 at 8" vertical up to mezzanine floor
⇒A = $\pi(1.25)^2/4$ × 1.5 = 1.84 in^2/ft > 1.032 in^2/ft

Allowable tension stress ⇒0.9 × 60000 = 54000 psi
Calculated tension stress 54000 × 1.032/1.84 = 30287 psi

K. Roof Plate/Beam Hold Down Arrangement

From Table 8A.1-22, seismic loads at roof floor are:

Acel X = 0.69g
Acel Y = 0.77g
Acel Z = 0.40g

Check for seismic load uplift on the roof:

Weight of roof plate = 166875 lbs (Table 8A.1-3)
Vertical seismic acceleration = 0.40g
By inspection, no uplift, small and nominal anchors would cater for it.
The hold down detail is shown in Figure 8A.1-20.

Check for seismic load uplift on the beam:

Floor steel beams are supported on two sides vertical and anchored on one side only horizontally (conservative assumption)

Weight of roof plate, beams and equipment = 286600 lbs = 1255 KN (Reference Section 8A.1.6.1.3- D).

By inspection, there is no seismic uplift occurring on the roof and beams, hence nominal hold down connection is adequate. The hold down detail is shown in Figure 8A.1-21.

Check for horizontal shear:

The horizontal shear force F_s = (1255/2) × 0.77 = 483 KN = 108,578 lbs
Allowable shear stress = 0.42 (S_u) = 0.42 × 73000 = 30,600 psi
Try 4 No. of bolts through the 900mm wall to take floor seismic shear in direct tension.

$A_{required}$ = $F_s/\Phi\ f_y$ = 108578/30600 = 3.54 in^2
i.e. use 4-1-1/4"dia. A-325 bolts (A= 4 × 0.969 = 3.876 in^2)

The hold down detail is shown in Figure 8A.1-21.

L. Mezzanine Plate/Beam Hold Down Arrangement

From Table 8A.1-21, seismic loads at roof floor are:

Acel X = 0.37g
Acel Y = 0.50g
Acel Z = 0.70g
By inspection use as roof details. The hold down detail is shown in Figure 8A.1-22.

Figure 8A.1-20

Roof Plate Hold Down Details

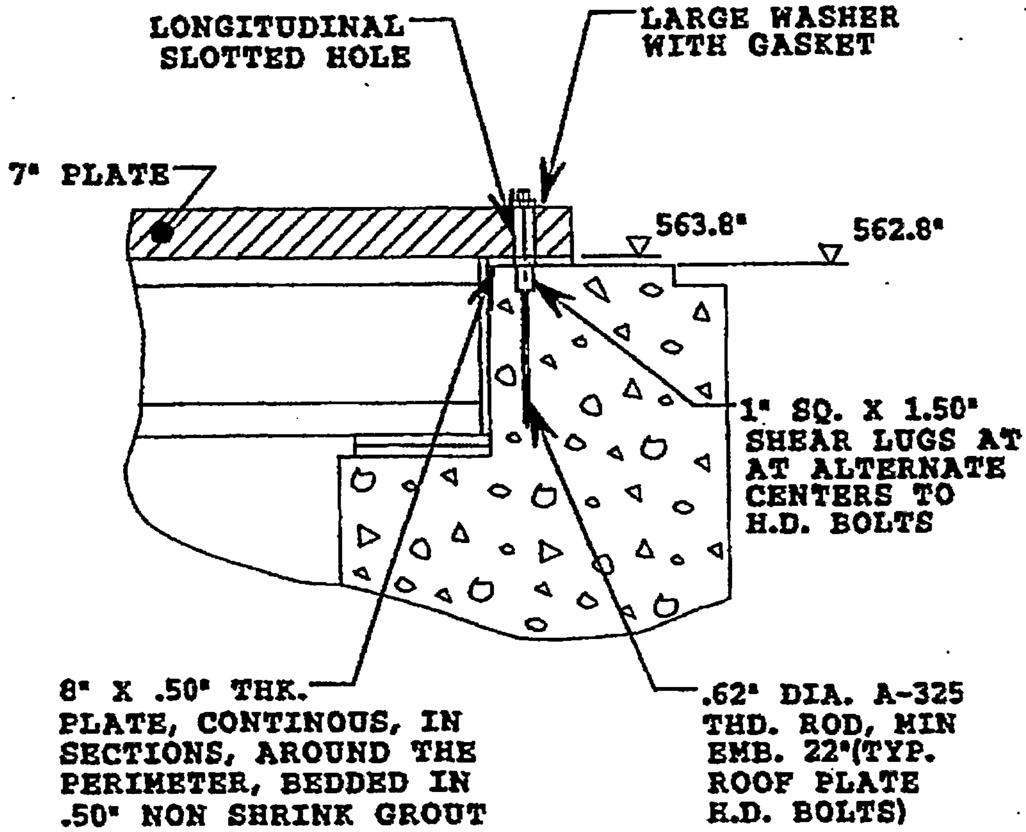


Figure 8A.1-21

Roof Plate Support Beam Connection Details

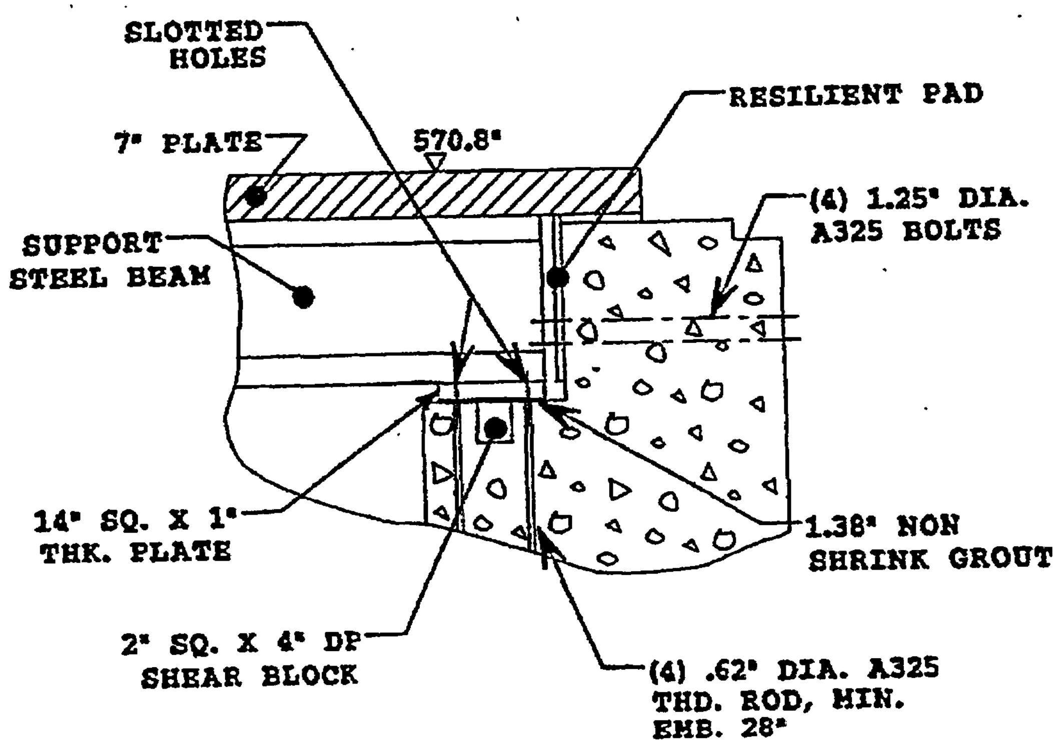
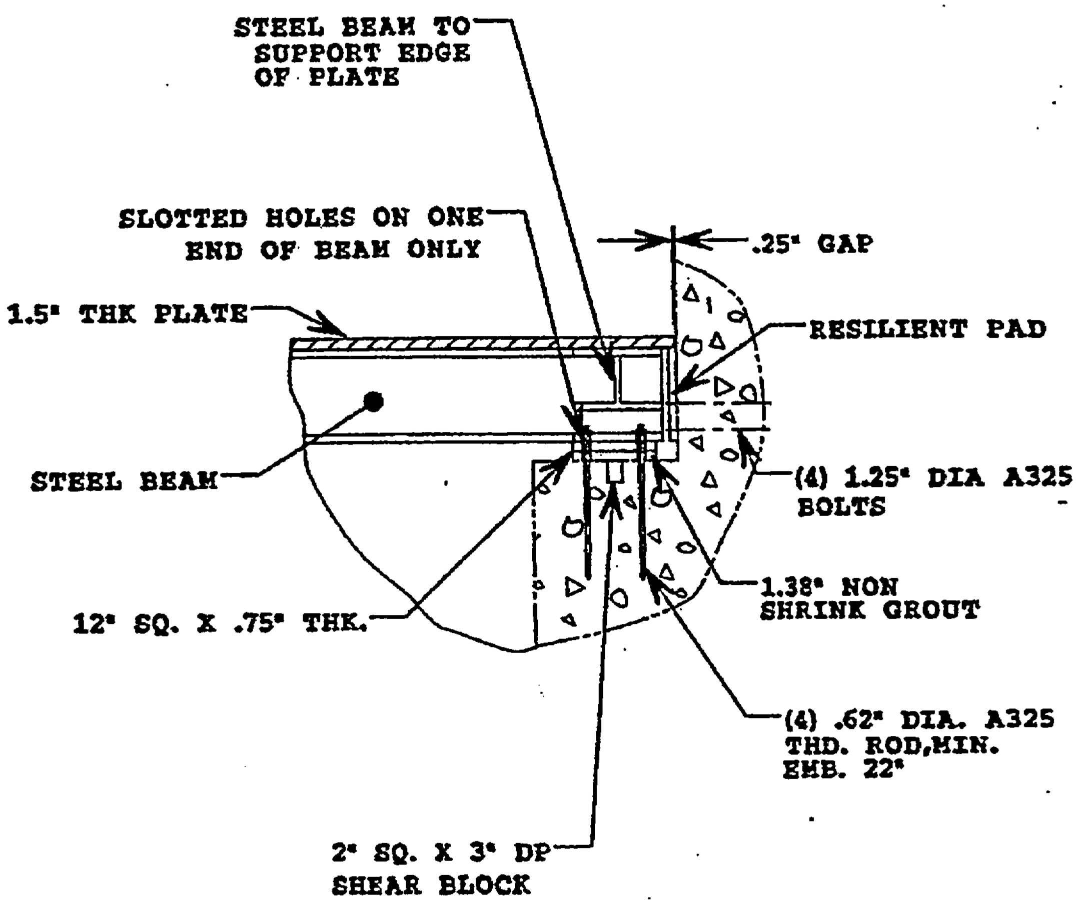


Figure 8A.1-22

Mezzanine Plate Support Beam Connection Details



M. Reinforced Concrete Superstructure Load Combination

The applicable loads for the DTS reinforced concrete superstructure include the dead weight, handling loads, tornado wind/missile loads, and seismic loads. The load combinations are based on ANSI - 57.9 as shown in Chapter 3. Table 8A.1-26 shows the maximum combined stress and are compared to AISC code allowables (Reference Chapte 3). Table 8A.1-27 summary the building shear stresses and are compared to the Code allowables. The results of the building stability analysis are also shown in Table 8A.1-28, The minimum margin of safety against overturning is 1.98.

Table 8A.1-26

DTS Reinforced Concrete Wall Enveloping Load Combination Results

Load	Calculated Stress			Allowable Stress		
	Compression (Concrete)	Tension (Rebar)	Bending (Rebar)	Compression (Concrete)	Tension (Rebar)	Bending (Rebar)
$D+L+E_{ss}$	291 psi (2.01 MPa)			1,785 psi (12.3 MPa)		
		30,287 psi (209 Mpa)			54,000 psi (372 MPa)	
$D+L+W_t$	259 psi (1.79 MPa)			1,785 psi (12.3 MPa)		
		22,774 psi (157 MPa)			54,000 psi (372 MPa)	
$D+L+T_o+E_{ss}$			51,726 psi (357 MPa)			54,000 psi (372 MPa)
$D+L+T_o+W_t$			37,515 psi (259 MPa)			54,000 psi (372 MPa)

Where:
D = Dead Loads
L = Live Loads and Handling Loads
E_{ss} = Seismic Loads
W_t = Tornado Wind/Missile Loads
T_o = Thermal Loads

Table 8A.1-27

DTS Reinforced Concrete Structure - Building Shear Stress

Component	Governing Load	Calculated Concrete Shear Stress	Allowable Concrete Shear Stress
Wall at Roof 540" Level	E_{ss}	55 psi (0.038 MPa)	93 psi (0.64 MPa)
Wall above Mezzanine Floor at 271" Level	E_{ss}	85 psi (0.59 MPa)	93 psi (0.64 MPa)
Walls Between Base and mezzanine Floor Front Wall	W_t	104 psi* (0.72 MPa)	93 psi (0.64 MPa)
Back Wall	W_t	93 psi (0.64 MPa)	93 psi (0.64 MPa)

* Shear Stress on the front concrete wall just over the allowable. Shear reinforcements are calculated per ACI-349, Section 11.5.6.
Required Rebar Area = 0.06 in^2/ft
Provide Rebar Area = 1.58 in^2/ft

Table 8A.1-28

DTS Reinforced Concrete Structure - Building Stability

Loading	Overturning moment	Stabilizing Moment	Factor of Safety
E_{ss}	62,755 kNm (555,434 in-kips)	144,205 kNm (1,276,333 in-kips)	2.3
W_t	70,340 kNm (622,567 in-kips)	138,225 kNm (1,223,409 in-kips)	1.98

8A.1.6.2 Protective Cover Structural Analysis

The protective cover is designed to withstand the following accident loads:

- Tornado winds,
- Tornado generated missiles, and
- Design basis earthquake.

Tornado Winds

The maximum DBT wind load pressure at protective cover is 630 lbs/ft^2. The maximum force applied to the wall of the protective cover is;

F = 379 × 107 × 630/144 = 177,419 lbs
$S_{allow.}$ = allowable bolt shear stress = 0.42 S_u = 0.42 × 125,000 =52,500 psi
$A_{req'd}$ = required area = 177,419/52,500 = 3.38 in^2
$N_{req'd}$ = no. of bolt required = 3.38/0.226 = 14.95 ⇒15 << 108
S_{shear} = bolt shear stress = 177,419/108 × 0.226 = 7,270 psi ≤ 0.42 S_u = 52,500 psi

The shear stress in the bolt is 7,270 psi (50.12 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa).

For calculating the tensile stress in the bolts, conservatively assuming the maximum lifting load is equal to the maximum horizontal force applied to the wall. This force is held by 32 bolts (one side), the maximum tensile stress is:

S = 177,419/32 × 0.226 = 24,532 psi ≤ 0.7 S_u = 87,500 psi (603 MPa)

Tornado Generated Missiles

The protective cover is analyzed to verify its adequacy for local barrier impingement of a DBT missile. Detail analysis of the protective cover has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, there is a adequate protection against local design basis tornado missile impact damage. Local bending and distortion to protective cover is acceptable, since the DTS will not be operated during a tornado watch or warning.

Design Basis Earthquake

The maximum calculated seismic accelerations for the roof plate are 0.77g horizontally and 0.4g vertically. With the protective cover plate bolted to the support beam, the beam stresses due to the resulting 0.4g vertical acceleration are calculated by factoring the normal operating condition load analysis results reported in Section 8A.1.5.3;

$$S = 3283 \times (1 + 0.4) = 4{,}596 \text{ psi}$$

This maximum combined stress of 4,596 psi (31.68 MPa) is much less than the allowable stress of 44,160 psi (304 MPa).

$$S_{allow.} = 1.6 \times 0.6 \times 46000 = 44{,}160 \text{ psi}$$

For the load evaluation of the protective cover plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.77g is assumed to be resisted by the one hundred and ten (108) - 5/8"(16 mm) bolts:

W = total weight = 135,000 lbs
F = horizontal force = 135,000 × 0.77 = 103,950 lbs
$S_{allow.}$ = allowable bolt shear stress = 0.42 S_u= 0.42 × 125,000 = 52,500 psi
$A_{req'd}$ = required area = 103,950/52,500 = 1.98 in^2
$N_{req'd}$ = no. of bolt required = 1.98/0.226 = 8.76 $\Rightarrow$9 << 110
S_{shear} = bolt shear stress = 103,950/110 × 0.226 = 4,184 psi

The shear stress in the bolt is 4,184 psi (28.84 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa).

8A.1.6.3 Roof Plate Structural Analysis

The maximum calculated seismic accelerations for the roof plate are 0.77g horizontally and 0.4g vertically. With the roof plate bolted to the support beam, the beam stresses due to the resulting 0.4g vertical acceleration are calculated by factoring the normal operating condition load analysis results reported in Section 8A.1.5.4;

$$S = 8850 \times (1 + 0.4) = 12{,}390 \text{ psi}$$

This maximum combined stress of 12,390 psi (85.4 MPa) is much less than the allowable stress of 44,160 psi (304 MPa).

$$S_{allow.} = 1.6 \times 0.6 \times 42000 = 40{,}320 \text{ psi (278 MPa)}$$

For the load evaluation of the roof plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.77g is assumed to be resisted by the one hundred and ten (110) - 5/8"(16 mm) bolts:

W = total weight = 250,874 lbs
F = horizontal force = 250,874 × 0.77 = 193,173 lbs
$S_{allow.}$ = allowable bolt shear stress = 0.42 (S_u) = 0.42 × 125,000 = 52,500 psi
$A_{req'd}$ = required area = 193,173/52,500 = 3.68 in^2
$N_{req'd}$ = no. of bolt required = 3.68/0.226 = 16.28 ⇒17 << 110
S_{shear} = bolt shear stress = 193,173/110 × 0.226 = 7,770 psi

The shear stress in the bolt is 7,770 psi (53.6 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa).

8A.1.6.4 Mezzanine Plate Structural Analysis

The maximum calculated seismic accelerations for the mezzanine plate are 0.5g horizontally and 0.7g vertically. With the mezzanine plate bolted to the support beam, the beam stresses due to the resulting 0.7g vertical acceleration are calculated by factoring the normal operating condition load analysis results reported in Section 8A.1.5.5.

$$S = 22{,}500 \times (1 + 0.7) = 38{,}250 \text{ psi}$$

$$S_{allow.} = 1.6 \times 0.6 \times 46{,}000 = 44{,}160 \text{ psi}$$

The maximum combined beam stress obtained from this analysis is 38,250 psi (264 MPa) which is less than the allowable stress of 44,160 psi (304 MPa).

For the load evaluation of the mezzanine plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.5g is assumed to be resisted by the sixty three (63) - 5/8" (16 mm) bolts:

W = total weight = 82,950 lbs
F = horizontal force = 82,950 × 0.5 = 41,475 lbs
$S_{allow.}$ = allowable bolt shear stress = 0.42 (S_u) = 0.42 × 125,000 = 52,500 psi
$A_{req'd}$ = required area = 41,475/52,500 = 0.79 in^2
$N_{req'd}$ = no. of bolt required = 0.79/0.226 = 3.5⇒4 << 63
S_{shear} = bolt shear stress = 41,475/63 × 0.226 = 2,913 psi

The shear stress in the bolt is 2,913 psi (20 Ma) which is less than the allowable shear stress of 52,500 psi (362MPa).

8A.1.6.5 Sliding Door Structural Analysis

The design of the sliding door is based on shielding requirements. Analyses are also performed to evaluate the effects of tornado wind, tornado missiles and seismic loads.

8A.1.6.5.1 Tornado Wind Load

The sliding door design is evaluated for the effects of tornado wind loads in accordance with the design criteria indicated in Section 3.0. The maximum stresses induced in the sliding door by DBT wind pressure loads are very conservatively calculated using the correlation presented in Roark, page 228, Case 48 (Reference 8A.1.7- 2). The wind pressure load, 419 lbs/ft^2, (0.02 Ma) is applied as a uniform load over the entire surface.

$$S = \frac{\beta w\, b^2}{t^2}$$

where $w = 419\ lbs/ft^2 = 2.91\ lbs/in^2$
$a = 240.$
$b = 109.5$
$a/b = 2.19$
$\beta = 0.792$

$$S = 0.792 \times \frac{2.91 \times 109.5^2}{7.0^2} = 564 \text{ psi}$$

$$S_{allow.} = 1.6 \times 0.6 \times 36000 = 34{,}560 \text{ psi}$$

The analysis results show a maximum stress of 564 psi (3.9 Ma) which is less than the allowable stress of 34,560 psi (238.3 Ma). Since the resulting sliding door stress is a small fraction of the code allowable, DBT wind loads are not considered further.

8A.1.6.5.2 Tornado Missiles

The thickness of the sliding door is 7" (bottom) and 9" (top) (178 mm and 229 mm, respectively). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Section 3.0. Detail analysis of the sliding door has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the sliding door cause only superficial damage. The sliding door

thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the sliding door will not compromise their confinement capability.

The maximum stress induced in the sliding door by the automobile impact load is calculated using the correlation presented in Roark, page 226, Case 38. The impact pressure, 196 psi (1.35 MPa) is applied as a uniform load over the impact area, 4029.4 in^2 (2.6 m^2). Substituting the sliding door physical dimensions and the pressure load into the correction, the maximum calculated stress is 8,704 psi (60 MPa) which is less than the allowable stress of 21,600 psi (148.9 MPa).

8A.1.6.5.3 Seismic Evaluation

The maximum calculated seismic accelerations for the sliding door are 0.7g vertically, 0.37g longitudinally, and 0.5g laterally. With the sliding door hanging on the support rails, the door stresses due to the resulting 0.7g vertical acceleration are calculated by factoring the dead load analysis results reported in Section 8A.1.5.6. Table 8A.1-29 summarized the combined stresses.

Table 8A.1-29

Sliding Door and Major Components Stress Analysis Results Summary (Dead Loads, Handling Loads, and seismic Load)

Comp.	Calculated Stress			Allowable Stress		
	Tension	Bending	Shear	Tension	Bending	Shear
Door	180			34,560		
Door Wheel	144,500 (Load)			160,000 (Capacity)		
Wheel Axle		30,784	15,332		110,400	64,400
Axle Bracket	13,547		10,838	96,000		56,000
Bracket Bearing		36,125 (Bearing)			45,000 (Bearing)	
Support Bracket	1,348	10,246	1,246	96,000	96,000	56,000
Door Rail		7,857			110,400	

For the stress evaluation of the sliding door due to seismic acceleration in the lateral direction, the resulting equivalent static acceleration of 0.5g is assumed to be resisted by four (4) - 2"(508 mm) dia. pin. The local bearing stresses of the sliding door at the support pin locations are calculated to be;

F = Lateral force = $85{,}000 \times 0.5 = 42{,}500$ lbs

A_b = Bearing area = $3.1416 \times 2/2 \times 7 \times 4 = 87.96$ in^2

A_s = shear area = $3.1414\ (1)^2 \times 2 \times 4 = 25$ in^2

$S_{bearing\ stress} = 42{,}500/87.96 = 483$ psi $< 1.6 \times 0.6 \times 42000 = 40{,}320$ psi

$S_{shear\ stress} = 42{,}500/25 = 1{,}700$ psi $< 1.4 \times 0.4 \times 42000 = 23{,}520$ psi

Since the resulting sliding door stress is a small fraction of the Code allowable, SSE load is not considered further.

8A.1.7 References

8A.1.7-1 American Concrete Institute ACI 349-1R: Code Requirements for Nuclear Safety Related Concrete Structures - Thermal effects.

8A.1.7-2 Formulas for Stress and Strain by R. Roark, Fourth Edition.

8A.1.7-3 ANSYS Engineering Analysis Systems User's Manual Volume 1 and 2, Revision 4.4A.

8A.1.7-4 NRC Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," April 1974.

8A.1.7-5 Guidelines for the Design and Assessment of Concrete Structures Subjected to Impact, UKAEA, SRDR439, Issue 3, May 1990.

8A.1.7-6 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.60. Design Response Spectra for Seismic Design of Nuclear Power Plants, 1973.

8A.1.7-7 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61. Damping Values for Seismic Design of Nuclear Power Plants, 1973.

8A.1.7-8 J.R. Mcdonald, K.C. Mehta, and J.E. Minor, "Design Guidelines for Wind Resistant Structures," Institute for Disaster Research and Department of Civil Engineering, Texas Tech University, Lubbock, Texas, June 1975.

8A.1.7-9 "Design of Structures for Missile Impact," Bechtel Topical Report, BC-TOP-9A (8.51).

Appendix 8A.2 Cask Transfer Subsystem Analysis

This appendix describes the analysis performed on the cask transfer subsystems. The Cask Transfer Subsystem accepts vertical casks at the entrance to the Preparation Area and moves it laterally in the X direction to the Lower Access Area, aligns it with the Cask Mating Subsystem and supports it during transfer of the spent fuel assembly.

The following calculations form a part of this appendix:

1. Analysis of the Locking Pins
2. Analysis of the Transmission Cradles
3. Analysis of the anti-derailing devices
4. Analysis of the guidance rollers and wheels.

The Cask Transfer Subsystem is designed to receive 157 shipments of PWR fuel or 133 shipments of BWR fuel per year (or approximately 53 shipments of PWR fuel or 44 shipments of BWR fuel per 100 day operating period).

The operating period is defined as the calendar year less the annual maintenance periods. The standard operating period is 300 days/year (24 hours/working day), with an average cycle of a 100 day operating period followed by a 21 - 22 day maintenance period.

The production period is defined as the operating period less the shutdown periods due to routine maintenance or due to equipment failure and the corresponding repair time.

The cask transfer subsystem is designed to operate at temperatures between 40°F to 130°F, or at temperatures between 20°F to 200°F for short periods of time.

8A2.1 Source Cask Transfer Subsystem General Description

The transfer of the source cask is performed by a motor driven trolley on rails. This trolley is designed to be loaded with the source cask. Centering guides ensure that the cask is properly positioned on the trolley.

The source cask is held onto the trolley by means of its lower trunnions. Single-piece devices, all-bolted on the trolley plate and above the trunnions, are removable and cask specific. The bolted plates weigh a maximum of 60 pounds (27 kg) and are manually removed.

The trolley structure and the cask holding system prevent the cask from falling due to any design event.

The cask is elevated 15.7 inches (400 mm) above the base of the trolley, to allow proper alignment with the source cask mating subsystem.

When the trolley is stopped in a specific position in the Preparation area or in the Lower Access Area, it is locked at its front by means of a vertical pin actuated by a jack, which penetrates into the concrete base mat of the DTS. The locking pin prevents the trolley from accidental forward and backward movement along the rails, and also prevents the trolley from moving due to a seismic event.

The general characteristics of the source cask transfer trolley are presented in Table 8A.2-1.

Table 8A.2-1
Source Cask Transfer Trolley Characteristics

	U.S. Units	Metric Units
Overall Dimensions	10.2 ft x 8.5 ft x 4.4 ft	3.1 m x 2.6 m x 1.3 m
Runway Length	49 ft	15 m
Span	9.1 ft	2.8 m
Wheelbase	6.6 ft	2 m
Maximum Design Load	30 tons	27.2 mtons
Material	Main components are painted carbon steel. Wheels are carbon steel. The beams and plates are A36. The bolts are A193-B7.	
Coating	Coating meets requirements of Category A - Service Level 1 coating as defined in ASME-NOG-1.	

The trolley moves along the X-axis through the use of an synchronous motor/brake with a manual brake disengagement. Two of the four trolley wheels (one on each side) are driven. The trolley has two speeds 0.7 ft/min (0.2 m/min) and 10 ft/min (3 m/min). The trolley has 2 braking systems: a service brake and an emergency brake. The emergency brake is used as a parking brake.

Trolley guidance is made by two sets of lateral rollers on one of the two runway rails. An anti-taking off device is implemented on both rails. See Figure 8A.2-1. Source cask guidance, during loading, is made by four centering guides.

A summary of the calculated dimensions, based on seismic and static loads is presented in Table 8A.2-2.

Figure 8A.2-1

Trolley Guidance and Anti-Taking Off Device

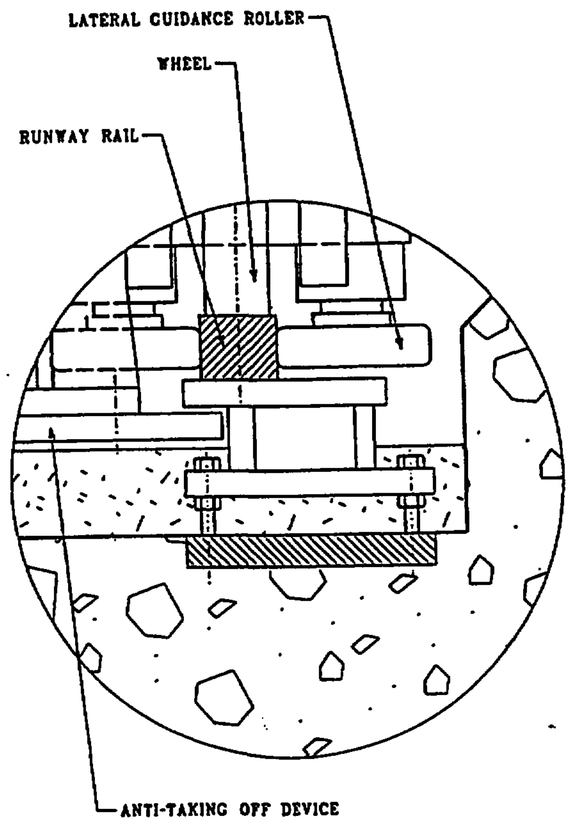


Table 8A.2-2

Calculated Dimensions of Source Cask Trolley

Part	Load	Calculated Size
Bolts of Cradle	Seismic	6 bolts M30 (1.2 in.)
Plate of anti-taking off device	Seismic	30 mm thick (1.2 in.)
Bolts of anti-taking off Device	Seismic	4 bolts M16 (0.6 in)
Diameter of the locking pin	Seismic	80 mm (3.2 in.)
Wheel diameter	Static	450 mm (17.7 in.)
Rail width minimum	Static	40 mm (1.6 in.)
Guidance roller	Static	150 mm (5.9 in.)
Rail height minimum	Static	30 mm (1.2 in.)

8A.2.2 Receiving Cask Transfer Subsystem General Description

The transfer of the receiving cask is performed by a motor driven trolley on rails. This trolley is designed to be loaded with the receiving cask. The structure of the trolley prevents the cask from tipping under all design events. Centering guides ensure that the cask is properly positioned on the trolley.

The receiving cask is held onto the trolley by means of its lower trunnions. Single-piece devices, all-bolted on the trolley plate and above the trunnions, are removable and cask specific. The bolted plates weigh a maximum of 60 pounds (27 kg) and are manually removed.

When the trolley is stopped in a specific position in the Preparation area or in the Lower Access Area, it is locked at its front by means of a vertical pin actuated by a jack, which penetrates into the concrete base mat of the DTS. The locking pin prevents the trolley from accidental forward and backward movement along the rails, and also prevents the trolley from moving due to a seismic event.

The general characteristics of the receiving cask transfer trolley are presented in Table 8A.2-3.

Table 8A.2-3

Receiving Cask Transfer Trolley Characteristics

	U.S. Units	Metric Units
Overall Dimensions	11.2 ft x 10.2 ft x 3.4 ft	3.4 m x 3.1 m x 1.0 m
Runway Length	49 ft	15 m
Span	9.2 ft	2.8 m
Wheelbase	8.9 ft	2.7 m
Maximum Design Load	125 tons	113.4 mtons
Material	Main components are painted carbon steel. Wheels are carbon steel. The beams and plates are A36. The bolts are A193-B7.	
Coating	Coating meets requirements of Category A - Service Level 1 coating as defined in ASME-NOG-1.	

The trolley moves along the X-axis through the use of an synchronous motor/brake with a manual brake disengagement. Two of the four trolley wheels (one on each side) are driven. The trolley has two speeds 0.7 ft/min (0.2 m/min) and 10 ft/min (3 m/min). The trolley has 2 braking systems: a service brake and an emergency brake. The emergency brake is used as a parking brake.

Trolley guidance is made by two sets of lateral rollers on one of the two runway rails. An anti-taking off device is implemented on both rails. See Figure 8A.2-1. Receiving cask guidance, during loading, is made by four centering guides.

A summary of the calculated dimensions, based on seismic and static loads is presented in Table 8A.2-4.

Table 8A.2-4

Calculated Dimensions of Receiving Cask Trolley

Part	Load	Calculated Size
Bolts of Cradle	Seismic	6 bolts M30 (1.2 in.)
Plate of anti-taking off device	Seismic	40 mm thick (1.6 in.)
Bolts of anti-taking off Device	Seismic	4 bolts M24 (1 in)
Diameter of the locking pin	Seismic	120 mm (4.8 in.)
Wheel diameter	Static	700 mm (27.6 in.)
Rail width minimum	Static	100 mm (3.9 in.)
Guidance roller	Static	180 mm (7.1 in.)
Rail height minimum	Static	50 mm (1.97 in.)

8A.2.3 Runway Rails - General Description

The same runway rails are used by the source and receiving cask transfer subsystems. The runway rail length is 49 feet (15 m). At the end of each runway, there is a bumper guard. The rail tolerances are shown in Table 8A.2-5.

At the attachment position (beneath the cask mating subsystems), the overall tolerance shall be, in the vertical direction (for rails + trolley on rails + cask on trolley) ± 5 mm/m (± 0.005 in/in).

The runway rails are shown in Figure 8A.2-2.

Table 8A.2-5

Rail Tolerances

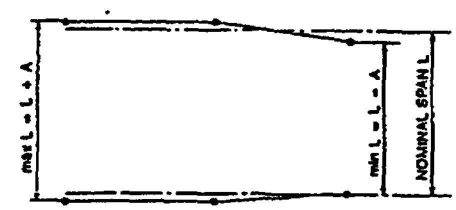
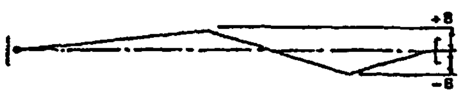
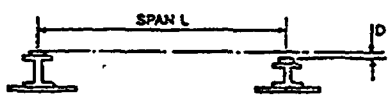
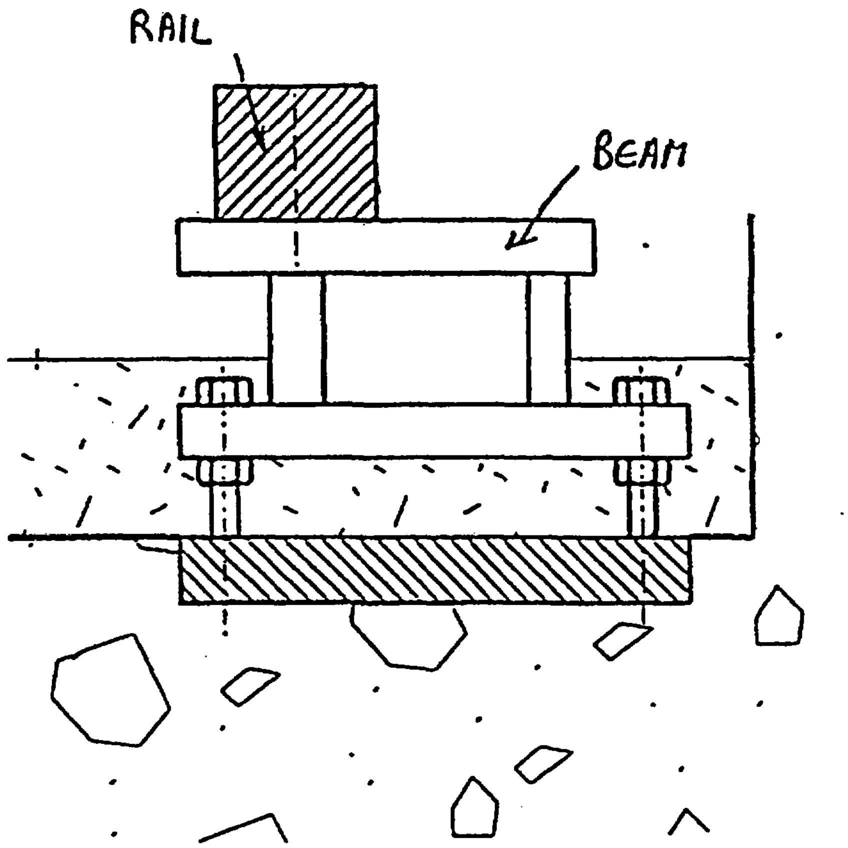
ITEM	FIGURE	OVERALL TOLERANCE	MAXIMUM RATE OF CHANGE
SPAN		L ≤ 50' A = 3/16"	1/4" in 20'-0"
Straightness		B = 3/8"	1/4" in 20'-0"
Elevation		C = 3/8"	1/4" in 20'-0"
Rail-to-rail elevation		L ≤ 50' D = ± 3/16"	1/4" in 20'-0"

Figure 8A.2-2

Runway Rails



8A.2.4 Source Cask Trolley Calculations

8A.2.4.1 Assumptions

It is assumed that the trolley is protected from environmental loads such as wind and snow by the DTS or the Preparation Area Roof. When the trolley is in the cask loading area, the cask is fully sealed and locked. It is assumed that damage due to the source cask during loading on to the trolley has been evaluated as part of the licensing process of the source cask.

The trunnion hold downs and the anti-derailing devices are calculated with the seismic load and the live load. The guiding roller wheels are calculated with the live load with motion.

The material properties used in the analysis are taken from NOG-1, Tables NOG 4211-1 and 4221-1 and are presented in Table 8A.2-6 below.

The trolley and casks are assumed to be rigid. The length of the source cask is 4,826 mm (190 inches). The outside diameter of the source cask is 1,028 mm (40.5 inches).

Table 8A.2-6

Properties of Materials

Material	**Yield Strength**	**Ultimate Strength**
A36	36 ksi (248 MPa)	58 ksi (399 MPa)
A193-B7	75 ksi (517 MPa)	100 ksi (689 MPa)

8A.2.4.2 Design Criteria

The design criteria are taken from ASME NOG-4300 and are repeated below. The nomenclature of NOG-4120 is used.

For beams subjected to axial tension and bending:

$$\sigma / \sigma_a + \sigma_{bx} / \sigma_{abx} + \sigma_{by} / \sigma_{aby} \leq 1.0 \qquad (1)$$

where $\sigma_a = \sigma_{abx} = \sigma_{aby} = 0.9$ Sy (for the seismic case)

σ_a is the axial stress

σ_{abx} and σ_{aby} are the stresses due to the bending moment.

The maximum allowable shear stress under seismic load is 0.5 σ_y.

An additional safety factor of 1.2 is used to take into account imprecision of the data.

For the beams, which are made from A36 steel:

The tensile stress allowable is:

$$F/A + M_{bx}x/ I_x + M_{by}y/ I_y < 0.9 \sigma_y/1.2 = 186 \text{ MPa} = 27.0 \text{ ksi} \quad (2)$$

The shear stress allowable is $0.5\sigma_y /1.2$ = 103 MPa = 15 ksi.

where A is the cross sectional area.
F is the axial force
M_{bx} and M_{by} are bending moments about the x and y axes
I_x and I_y are the moduli of inertia

The allowable stresses in the bolts are taken from NOG-4513. For seismic loading, the maximum allowable tensile load is 0.5 σ_u , and the maximum allowable shear stress is 0.26 σ_u. An additional safety factor of 1.2 is used to take into account imprecision of the data.

Therefore, the allowable tensile stress is 0.5 x 100 ksi / 1.2 = 287 MPa =41.6 ksi. The allowable shear stress is 149 MPa = 21.6 ksi.

8A.2.4.3 Seismic Loading

The source cask and source cask trolley are assumed to be rigid. Since the trolley and source cask are not perfectly rigid, an addition factor of 1.5 is used.

The trolley is analyzed for a horizontal g loading of 0.25 g x 1.5 = 0.375 g and a vertical g loading of 0.17 g x 1.5 = 0.255 g.

The trolley's response to each of the three components of seismic input are combined by taking the square root of the sum of the squares (SRSS) per NOG-4153.10:

$$SRSS = \sqrt{(Sx^2 + Sy^2 + Sz^2)}$$

The seismic analysis was performed for two load combinations: seismic loading + static loading and seismic loading - static loading. The static load is the live load of the cask and the trolley due to gravity.

U.S.

The acceleration due to gravity is $g = 9.81 \text{ m/sec}^2$.

8A.2.4.4 Operational Loading

The following operational loads are taken into account:

- The live load of the cask and trolley under gravity (Used for calculating the stresses on the wheels)
- The transverse horizontal load (5% of the live load of the cask and the trolley dead load in the transverse direction per NOG-4133(b)) This load is used to size the guiding rollers.

An isometric sketch of the cask on the trolley is shown in Figure 8A.2-3. A top view of the cask on the trolley is shown in Figure 8A.2-4. The bumpers are welded to the beams of the trolley.

8A.2.4.5 Evaluation of Bolts

The trunnion cradles are shown in Figure 8A.2-5. Six M30 (1.2 in. diameter) bolts are evaluated using the maximum vertical reaction in the + Z direction on the cradle. This reaction is obtained by subtracting the static load from the seismic load.

X direction seismic loading

The seismic load in the X direction is applied at the center of gravity of the cask, G. The load is reacted at the point C (Figure 8A.2-3) which is the center of the compression zone.

The seismic loading in the X direction is reacted by the trolley base at C and by the cradle supports.

The force in the x direction is the seismic acceleration in the x direction times the mass of the cask.

$$F_x = ma_x$$

The distance to the center of the compression zone is $L_1 = D/3$ where D is the diameter of the cask.

OG is the distance between the center of gravity and the base of the cask. Assuming that the cask weight is approximately equally distributed along its length, OG = L/2.

The reaction forces in the z direction due to the x axis seismic acceleration at the trunnion locations are equal due to symmetry :

$R_{BZX} = R_{AZX}$

Figure 8A.2-3

Isometric Sketch of Cask on Trolley

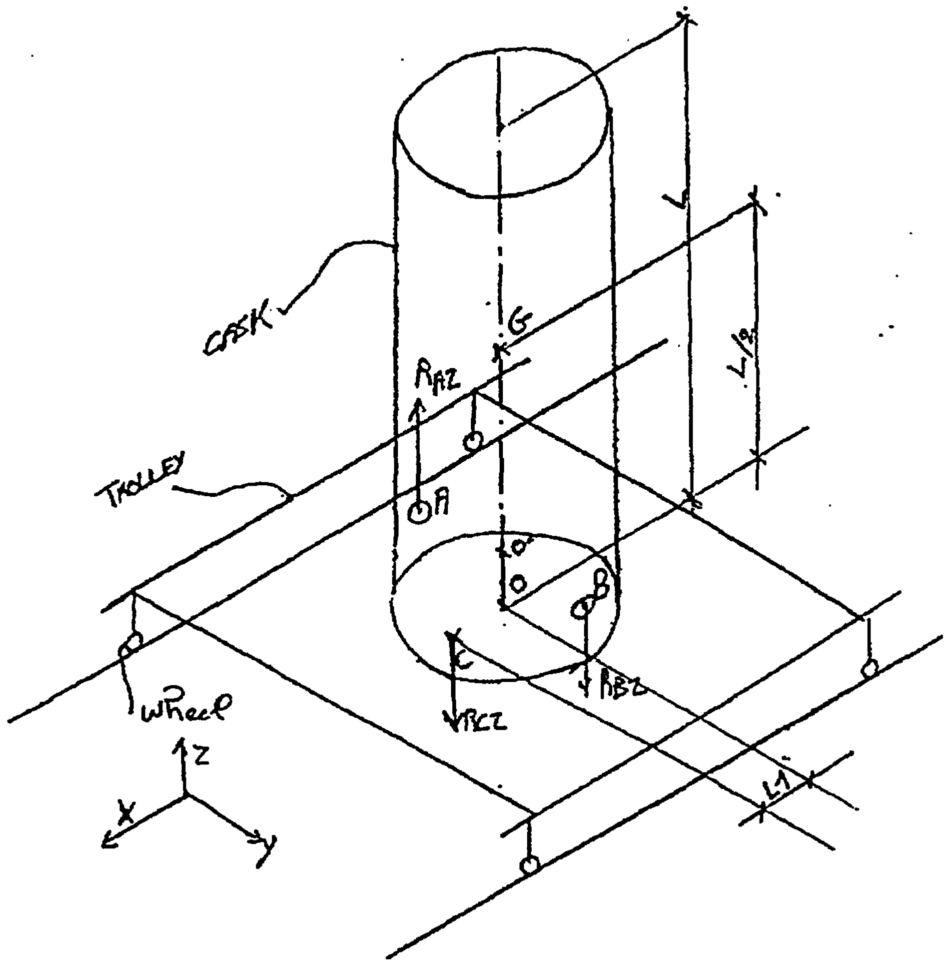


Figure 8A.2-4

Top View of Cask on Trolley

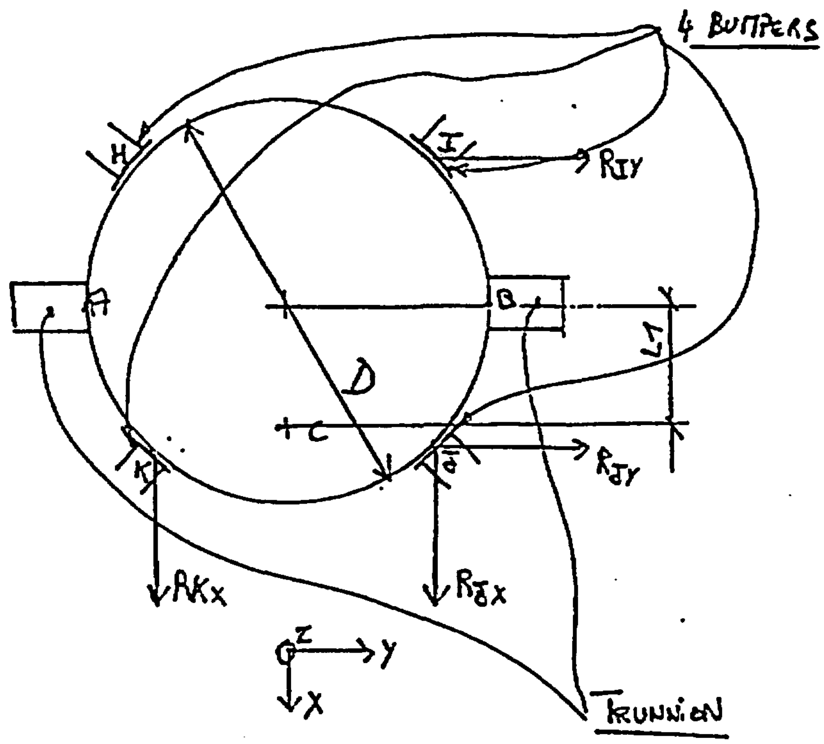
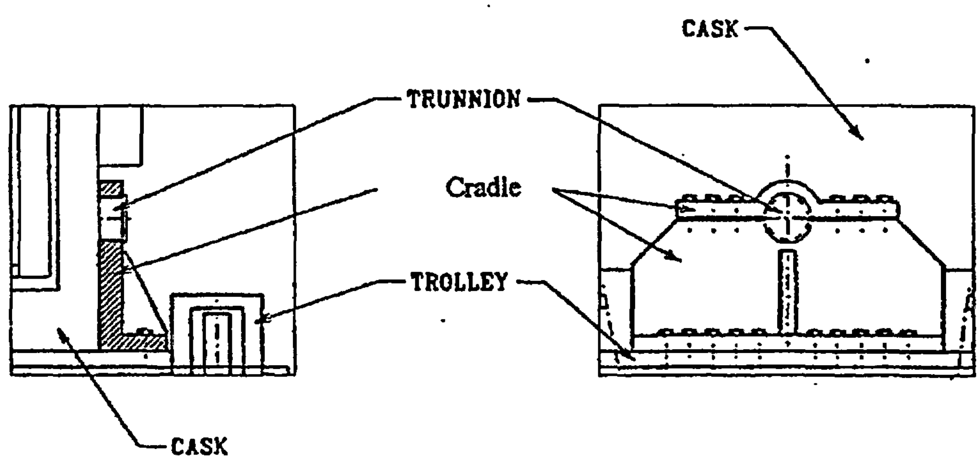


FIGURE 8A2-5

CASK TRANSFER SUBSYSTEM TRUNNION CRADLES



Then, summing the equations in the z direction:

$$R_{BZX} + R_{AZX} + R_{CZX} = 0$$

Therefore,

$$R_{AZX} = R_{BZX} = - R_{CZX} /2$$

Summing the moments about C to 0:

$$F_x \text{ x } OG - (R_{AZX} + R_{BZX})L_1 = 0 \text{ or}$$

$$R_{AZX} = R_{BZX} = F_x \text{ x } OG/2L_1 = ma_xL/2/(2D/3) = ma_x(3L/4D)$$

This reaction force is taken by the cradle.

The x axis reaction is equally taken by the two bumpers. Figure 8A.2-4)

$$R_{KX} = R_{JX} = ma_x/2$$

Y direction seismic loading

The seismic load in the Y direction is applied at the center of gravity of the cask, G. The load is reacted at the point B (Figure 8A.2-3) which is the center of the compression zone and by one cradle at location A.

The force in the y direction is the seismic acceleration in the y direction times the mass of the cask.

$$F_y = ma_y$$

OG is the distance between the center of gravity and the base of the cask. Assuming that the cask weight is approximately equally distributed along its length, OG = L/2.

AB is the distance between the two cradles. AB is approximately equal to D.

The static equations are:

$$F_yOG - R_{AZY}AB = 0$$

Therefore,

R_{AZY} = - R_{BZY} = F_yOG/AB = $ma_yL/2D$ (cradle reaction force)

Summing the forces in the Y direction:

$R_{IY} = R_{JY} = ma_y/2$ (bumper reaction forces)

Z direction Seismic Loading

The Z direction seismic loading is equally divided between the two cradles:

$F_z = ma_z$

$R_{AZZ} = R_{BZZ} = ma_z/2$ (cradle reaction loads)

Static Z direction loads

The weight of the cask is equally divided by the two cradles.

$P_z = -Mg$

The vertical reactions at the two cradle locations are R_{AZS} and R_{BZS}.

$R_{AZS} = R_{BZS} = -Mg/2$ (at the cradles)

Load Combination

Combining the results:

The maximum +Z reaction on the cradle is: (Seismic - Static)

$R_{AZ} = \sqrt{(R_{AZX}^2 + R_{AZY}^2 + R_{AZZ}^2)} + R_{AZS}$

The maximum X and Y reaction on the bumper is at J, where:

$R_{JX} = ma_x/2$

and $R_{JY} = ma_y/2$

Solving numerically:

$R_{AZX} = ma_x(3L/4D) = 388{,}577$ N

$R_{AZY} = ma_yL/2D = 259{,}052$ N

$R_{AZZ} = ma_z/2 = 37{,}524$ N

$R_{AZS} = -Mg/2 = -147{,}150$ N

$R_{JX} = ma_x/2 = 110{,}363$ N

$R_{JY} = ma_y/2 = 110{,}363$ N

Therefore, the maximum reaction force in the Z direction on the cradle is:

$$R_{AZ} = \sqrt{(R_{AZX}^2 + R_{AZY}^2 + R_{AZZ}^2)} + R_{AZS} = 321{,}366 \text{ N} = 72{,}293 \text{ lbf}$$

Six M30 bolts attach each cradle. The vertical force R_{AZ} is the tension in the bolts.

The cross sectional area for an M30 bolt is $A_B = 561$ mm^2

The tensile stress in the bolt is:

$$\sigma = R_{AZ}/6A_B = 96 \text{ MPa} = 13.9 \text{ ksi} \leq 287 \text{ MPa} = 41.6 \text{ ksi}$$

The safety factor in the bolts is SF = 287/96 = 3. Therefore the stresses in the bolts are acceptable.

8A.2.4.6 Evaluation of Anti-Taking Off Device and Locking Pin

The Anti-taking off device is shown in Figure 8A.2-1. The anti-taking off device prevents the trolley from tipping during a seismic event. This section calculates the stresses on the anti-taking off device. Figures 8A.2-6 through 8A.2-8 are used to perform this analysis.

The anti-taking off device is sized to withstand the maximum vertical force in the Z-direction. This force is obtained by combining the static and seismic loads. The reaction forces for each load step (x-direction seismic load, y-direction seismic load, z-direction seismic load and static load) are calculated and then combined to determine the maximum reaction force.

X direction Seismic Load

The seismic load on the trolley (M_t) is applied at G' shown in Figure 8A.2-8. The seismic load on the cask (M) is applied at G shown in Figure 8A.2-8. The seismic load is reacted by compression on the wheel at locations A & D and tension in the anti taking-off devices at locations B and C.

The vertical reaction forces due to the x direction seismic load at the anti-taking off devices are defined as R_{BZX} and R_{CZX}. From symmetry, $R_{BZX} = R_{CZX}$.

O'G is the vertical distance between the center of gravity of the cask and the base of the anti-taking off device.

Figure 8A.2-6

Cask on Trolley

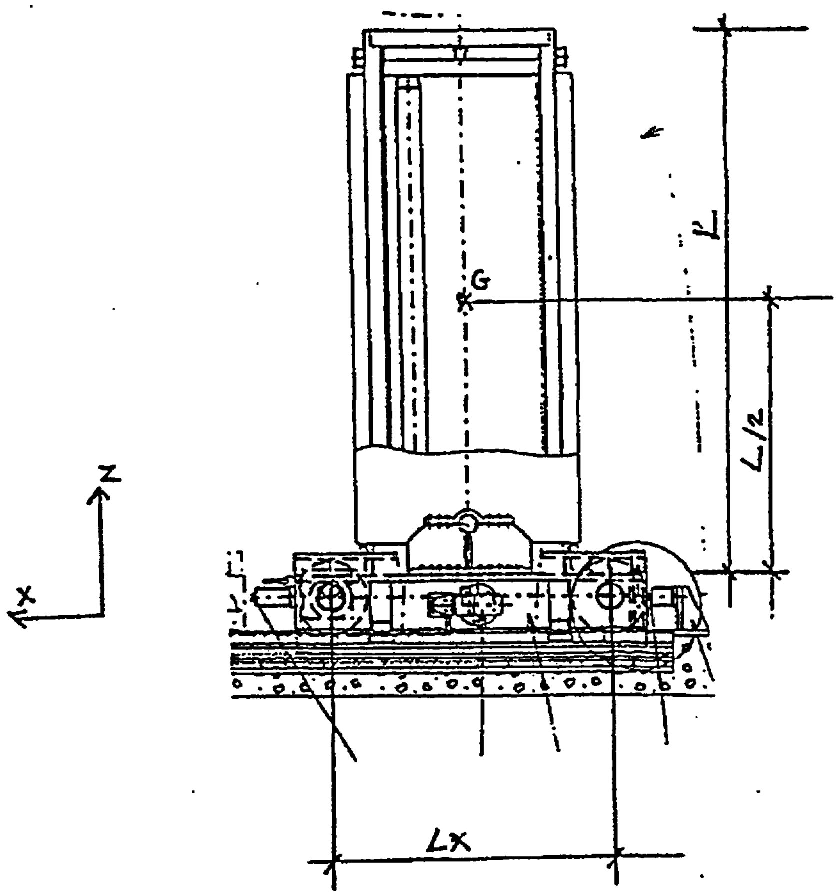


Figure 8A.2-7

Rails of Trolley

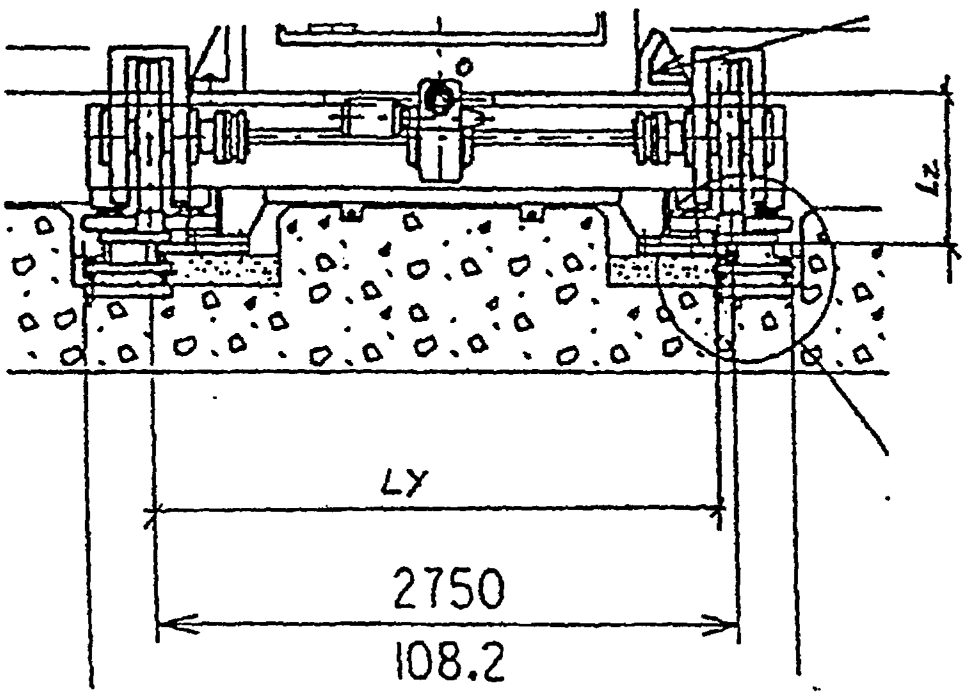
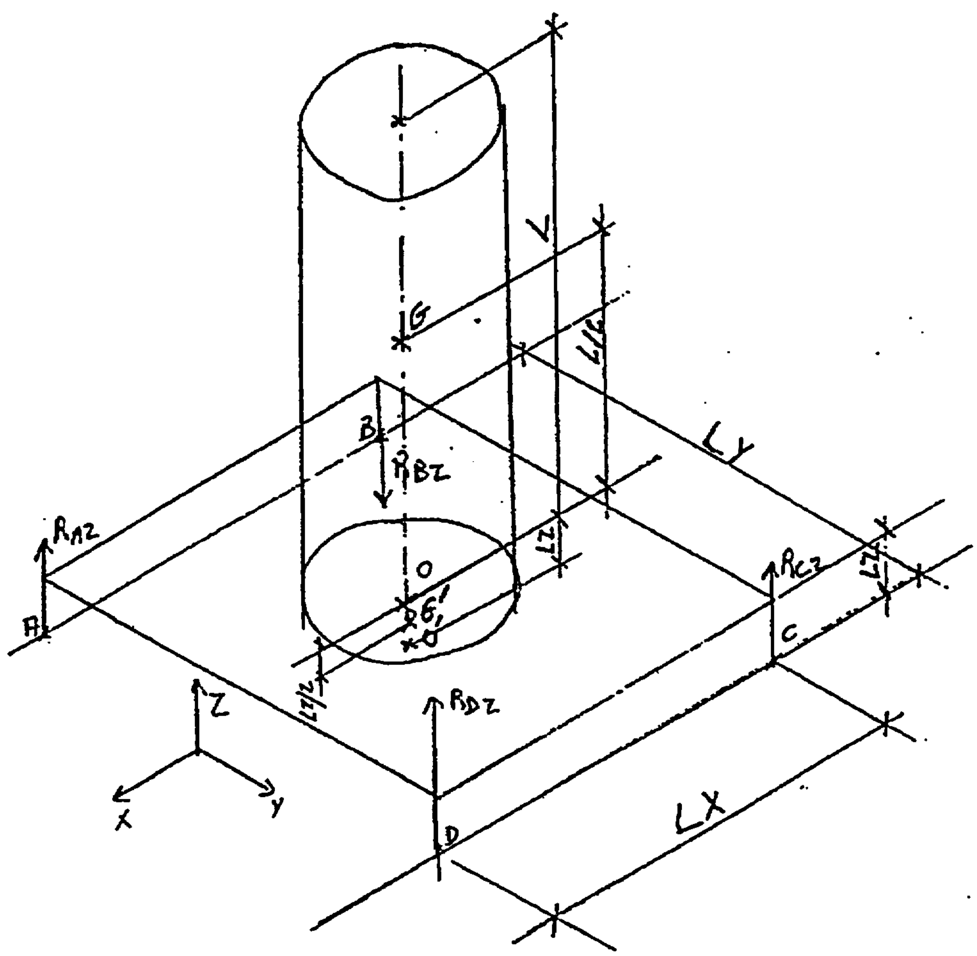


Figure 8A.2-8

**Cask on Trolley
Showing Distances between Reaction Forces**



From Figure 8A.2-8,

$$O'G = L/2 + L_Z.$$

O'G' is the vertical distance between the center of gravity of the trolley and the base of the anti-taking off device.

$$O'G' = L_Z /2.$$

Summing the moments to zero about AD:

$$M_t a_x O'G' + M a_x O'G - (R_{BZX} + R_{CZX})L_x = 0$$

Therefore,

$$R_{BZX} = (M_t a_x O'G' + M a_x O'G)/2L_x \quad \text{or}$$

$$R_{BZX} = (M_t a_x L_Z /2 + M a_x (L/2 + L_Z))/2L_x$$

The locking pin takes the force in the x direction:

$$R_X = (M + M_t)a_x$$

<u>Y direction Seismic Loading</u>

The seismic load on the trolley (M_t) is applied at G' shown in Figure 8A.2-8. The seismic load on the cask (M) is applied at G shown in Figure 8A.2-8. The seismic load is reacted by compression on the wheel at locations C & D and tension in the anti taking-off devices at locations A and B.

The vertical reaction forces due to the y direction seismic load at the anti-taking off devices are defined as RB_{AZY} and R_{BZY}. From symmetry, $R_{AZY} = R_{BZY}$.

O'G is the vertical distance between the center of gravity of the cask and the base of the anti-taking off device.

From Figure 8A.2-8,

$$O'G = L/2 + L_Z.$$

O'G' is the vertical distance between the center of gravity of the trolley and the base of the anti-taking off device.

$O'G' = L_Z/2.$

Summing the moments to zero about AD:

$$M_t a_y O'G' + M a_y O'G - (R_{AZY} + R_{BZY})L_y = 0$$

Therefore,

$$R_{BZY} = (M_t a_y O'G' + M a_y O'G)/ 2L_y \text{ or}$$

$$R_{BZY} = (M_t a_y L_Z/2 + M a_x (L/2 + L_Z))/ 2L_y$$

The y direction force is taken by the superior plate under the rail on the two anti-taking off devices at A and B.

$$R_{AY} = R_{BY} = (M + M_t)a_y / 2$$

Z Direction Seismic Loading

The z direction seismic loads are taken equally by the four anti-taking off devices:

$$R_{BZZ} = (M + M_t)a_z / 4$$

Static Z Direction Loading

The static compression load is taken equally by the four wheels. The dead load is:

$$P_Z = (M + M_t)g$$

The vertical compression at point B is:

$$R_{BZS} = -(M + M_t)g/4$$

Load Combination

Combining the results:

The maximum vertical force on the anti-taking off device is the combination of the static + seismic load:

$$R_{BZ} = \sqrt{(R_{BZX}^2 + R_{BZY}^2 + R_{BZZ}^2)} - R_{BZS}$$

The maximum force on the locking pin is:

$$R_X = (M + M_t)a_x$$

The maximum force in the Y direction on the anti-taking off device is:

$$R_{BY} = (M + M_t)a_y / 2$$

Solving numerically:

given $M = 30$ tons
$L = 4{,}826$ mm
$M_t = 15$ tons
$L_x = 2000$ mm
$L_Y = 2550$ mm
$L_z = 600$ mm
$a_x = 0.375$ g
$a_y = 0.375$ g

Then $R_{BZX} = 87{,}269$ N
$R_{BZY} = 68{,}446$ N
$R_{BZZ} = 28{,}142$ N
$R_{BZS} = -110{,}363$ N

The forces taken by the anti-taking off device are:

$R_{BZ} = 4{,}061$ N = 912 lbf
$R_{BY} = 82{,}772$ N = 18,694 lbf

The force on the locking pin is:

$R_x = 165{,}544$ N = 37,216 lbf

The dimensions of the Anti-Taking Off Device are shown in Figure 8A.2-9. The anti-taking off device is made from A36 carbon steel, with A193 B7 bolts.

The maximum bending moment in the plate is at bolt position 2:

$$M_{max} = R_{BZ}\, a = (4061 \text{ N})(50\text{mm}) = 203 \text{ mN}$$

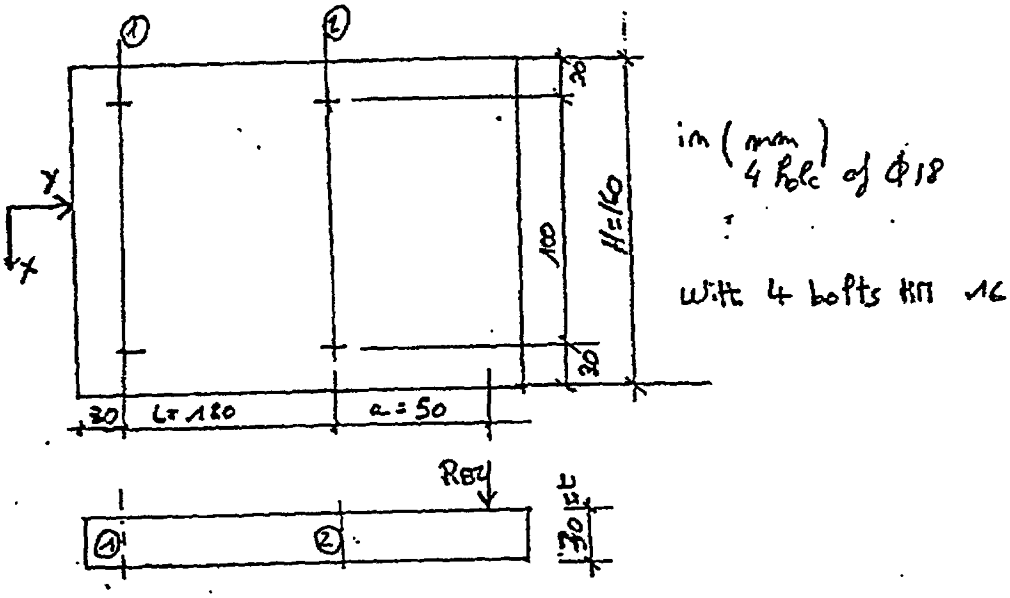
The maximum tension in a bolt occurs at position 2:

F = tension in bolt
A_b = bolt cross sectional area = 157 mm^2

Then $2FL - R_{BZ}(L + a) = 0$

Figure 8A.2-9

Source Cask Anti-Taking Off Device



Solving for F:

$$F = R_{BZ}\ (L + a)/2L = 2880\ N$$

The tensile stress in the bolt is:

$$\sigma = F/A_b = 2880/157 = 19\ MPa \leq\ 287\ MPa$$

The safety factor is:

$$SF = 287/19 = 15$$

The section modulus of the plate is:

$$S = (H\text{-}2*18)t^3/6t = 18{,}600\ mm^3$$

where t = the thickness of the plate = 30 mm and H = 160 mm.

The bending stress in the plate is:

$$\sigma = M_{max}/\ S = \ 11\ MPa = 1.6\ ksi \leq 186\ MPa = 27\ ksi$$

The safety factor is SF = 186/11 = 17.

The force R_{BY} is taken directly by the trolley.

The locking pin is shown in Figure 8A.2-10. The pin diameter is D = 2L = 80 mm.
The shear stress in the pin is $\tau = R_x / A = 33\ MPa \leq 103\ MPa = 15\ ksi$ where
$R_x = 165{,}544\ N = 37{,}216\ lbf$
and $A = \pi D^2/4 = 5{,}026\ mm^2$

The safety factor on the locking pin is SF = 103/33 = 3.1.

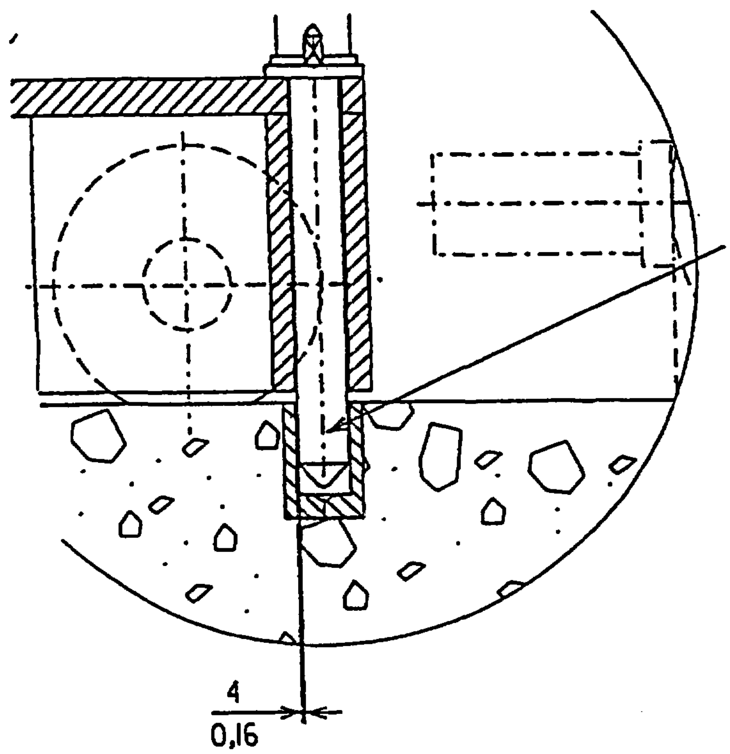
8A.2.4.7 Evaluation of Wheels

The wheels are sized based on static loads. The trolley wheels are 450 mm in diameter (17.7 in. The effective width of the rail head is 40 mm (1.6 in). The allowable wheel load is taken from NOG 5452.3:

$P_a = KbD$ (lbs)
where $K = 1300\ (BHN/260)^{0.333} = 1393$

Figure 8A.2-10

Locking Pin



The load is equally distributed between the four wheels. Therefore the load on each wheel is:

$F_z = (M + M_t)g/4 = 110,363$ N = 24,811 lbf

The allowable load is $P_a = KbD = 1393(1.6)(17.7) = 39,449$ lbf. Therefore the loads on the wheels are acceptable. The safety factor is SF = 39449/24811 = 1.5.

8A.2.4.8 Evaluation of the Guiding Rollers

The guiding rollers are calculated based on static loads. The rail width, b = 1.2 in. (30mm). The roller diameter, D, is 5.9 in (150 mm). The allowable load is taken from NOG 5452.3:

$P_a = KbD$ (lbs)
where $K = 1300\ (BHN/260)^{0.333} = 1393$

The total load is equally distributed between the 2 guidance rollers. From NOG 4133(b), the lateral load is taken as 5% of the vertical load:

P_y = 5% (trolley + cask) live load = $0.05\ (M + M_t)g = 22,073$ N

$F_y = P_y /2 = 11,037$ N = 2,481 lbf

The allowable load is $P_a = KbD = 1393(1.2)(5.9) = 9863$ lbf. Therefore the loads on the wheels are acceptable. The safety factor is SF = 9863/2481 = 3.9.

8A.2.4.9 Summary of Stresses - Source Cask Transfer Trolley

The sizes of the structural components of the source cask trolley, together with the calculated stresses and allowable stresses are presented in Table 8A.2-7.

Table 8A.2-7

Summary Source Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 MPa	96 MPa	6 bolts M30 (1.2 in dia.)	3
Plate of anti-taking off device	Seismic	186 MPa	11 MPa	30 mm thick (1.2 in)	17
Bolts of anti-taking off Device	Seismic	287 MPa	19 MPa	4 bolts M16 (0.6 in)	15
Diameter of the locking pin	Seismic	103 MPa	33 MPa	D = 80 mm (3.2 in)	3.1
Wheel diameter	Static	39,449 lbf	24,811 lbf	D = 450 mm (17.7 in)	1.5
Rail width minimum	Static	39,449 lbf	24,811 lbf	b = 40 mm (1.6 in)	1.5
Guidance roller	Static	9,863 lbf	2,481 lbf	D = 150 mm (5.9 in)	3.9
Rail height minimum	Static	9,863 lbf	2,481 lbf	b = 30 mm (1.2 in)	3.9

8A.2.5 Receiving Cask Trolley Calculations

8A.2.5.1 Assumptions

It is assumed that the trolley is protected from environmental loads such as wind and snow by the DTS or the Preparation Area Roof. When the trolley is in the cask loading area, the cask is fully sealed and locked. It is assumed that potential damage to the receiving cask during loading on to the trolley has been evaluated as part of the licensing process of the source cask.

The trunnion hold downs and the anti-derailing devices are calculated with the seismic load and the live load. The guiding roller wheels are calculated with the live load with motion.

The material properties used in the analysis are taken from NOG-1, Tables NOG 4211-1 and 4221-1 and are presented in Table 8A.2-6.

The trolley and casks are assumed to be rigid. The length of the receiving cask is 5,290 mm (208.3 inches). The outside diameter of the receiving cask is 1,855 mm (73.0 inches).

8A.2.5.2 Design Criteria

The design criteria are taken from ASME NOG-4300 and presented in Section 8A.2.4.

8A.2.5.3 Seismic Loading

The receiving cask and receiving cask trolley are assumed to be rigid. Since the trolley and source cask are not perfectly rigid, an addition factor of 1.5 is used.

The trolley is analyzed for a horizontal g loading of 0.25 g x 1.5 = 0.375 g and a vertical g loading of 0.17 g x 1.5 = 0.255 g.

The trolley's response to each of the three components of seismic input are combined by taking the square root of the sum of the squares (SRSS) per NOG-4153.10:

$$SRSS = \sqrt{(Sx^2 + Sy^2 + Sz^2)}$$

The seismic analysis was performed for two load combinations: seismic loading + static loading and seismic loading - static loading. The static load is the live load of the cask and the trolley due to gravity.

The acceleration due to gravity is $g = 9.81$ m/sec^2.

8A.2.5.4 Operational Loading

The following operational loads are taken into account:

- The live load of the cask and trolley under gravity (Used for calculating the stresses on the wheels)
- The transverse horizontal load (5% of the live load of the cask and the trolley dead

load in the transverse direction per NOG-4133(b)) This load is used to size the guiding rollers.

An isometric sketch of the cask on the trolley is shown in Figure 8A.2-3. A top view of the cask on the trolley is shown in Figure 8A.2-4. The bumpers are welded to the beams of the trolley.

8A.2.5.5 Evaluation of Bolts

Six M30 (1.2 in. diameter) bolts are evaluated using the maximum vertical reaction in the + Z direction on the cradle. This reaction is obtained by subtracting the static load from the seismic load.

X direction seismic loading

The seismic load in the X direction is applied at the center of gravity of the cask, G. The load is reacted at the point C (Figure 8A.2-3) which is the center of the compression zone.

The seismic loading in the X direction is reacted by the trolley base at C and by the cradle supports.

The force in the x direction is the seismic acceleration in the x direction times the mass of the cask.

$$F_x = ma_x$$

The distance to the center of the compression zone is $L_1 = D/3$ where D is the diameter of the cask.

OG is the distance between the center of gravity and the base of the cask. Assuming that the cask weight is approximately equally distributed along its length, OG = L/2.

The reaction forces in the z direction due to the x axis seismic acceleration at the trunnion locations are equal due to symmetry :

$$R_{BZX} = R_{AZX}$$

Then, summing the equations in the z direction:

$$R_{BZX} + R_{AZX} + R_{CZX} = 0$$

Therefore,

$$R_{AZX} = R_{BZX} = - R_{CZX}\ /2$$

Summing the moments about C to 0:

$$F_x \text{ x } OG - (R_{AZX} + R_{BZX})L_1 = 0 \text{ or}$$

$$R_{AZX} = R_{BZX} = F_x \text{ x } OG/2L_1 = ma_xL/2/(2D/3) = ma_x(3L/4D)$$

This reaction force is taken by the cradle.

The x axis reaction is equally taken by the two bumpers. Figure 8A.2-4)

$$R_{KX} = R_{JX} = ma_x/2$$

<u>Y direction seismic loading</u>

The seismic load in the Y direction is applied at the center of gravity of the cask, G. The load is reacted at the point B (Figure 8A.2-3) which is the center of the compression zone and by one cradle at location A.

The force in the y direction is the seismic acceleration in the y direction times the mass of the cask.

$$F_y = ma_y$$

OG is the distance between the center of gravity and the base of the cask. Assuming that the cask weight is approximately equally distributed along its length, OG = L/2.

AB is the distance between the two cradles. AB is approximately equal to D.

The static equations are:

$$F_yOG - R_{AZY}AB = 0$$

Therefore,

$$R_{AZY} = - R_{BZY} = F_yOG/AB = ma_yL/2D \text{ (cradle reaction force)}$$

Summing the forces in the Y direction:

$R_{IY} = R_{JY} = ma_y /2$ (bumper reaction forces)

Z direction Seismic Loading

The Z direction seismic loading is equally divided between the two cradles:

$F_z = ma_z$

$R_{AZZ} = R_{BZZ} = ma_z /2$ (cradle reaction loads)

Static Z direction loads

The weight of the cask is equally divided by the two cradles.

$P_z = -Mg$

The vertical reactions at the two cradle locations are R_{AZS} and R_{BZS}.

$R_{AZS} = R_{BZS} = -Mg/2$ (at the cradles)

Combining the results:

The maximum +Z reaction on the cradle is: (Seismic - Static)

$R_{AZ} = \sqrt{(R_{AZX}^2 + R_{AZY}^2 + R_{AZZ}^2)} + R_{AZS}$

The maximum X and Y reaction on the bumper is at J, where:

$R_{JX} = ma_x /2$

and $R_{JY} = ma_y /2$

Solving numerically:

$R_{AZX} = ma_x(3L/4D) = 983{,}520$ N

$R_{AZY} = ma_yL/2D = 655{,}682$ N

$R_{AZZ} = ma_z /2 = 156{,}348$ N

$R_{AZS} = -Mg/2 = -613{,}125$ N

$R_{JX} = ma_x /2 = 229{,}922$ N

$R_{JY} = ma_y /2 = 229{,}922$ N

Therefore, the maximum reaction force in the Z direction on the cradle is:

$$R_{AZ} = \sqrt{(R_{AZX}^2 + R_{AZY}^2 + R_{AZZ}^2)} + R_{AZS} = 579{,}215 \text{ N} = 130{,}300 \text{ lbf}$$

Six M30 bolts attach each cradle. The vertical force R_{AZ} is the tension in the bolts.

The cross sectional area for an M30 bolt is $A_B = 561$ mm^2

The tensile stress in the bolt is:

$$\sigma = R_{AZ}/6A_B = 172 \text{ MPa} = 25 \text{ ksi} \leq 287 \text{ MPa} = 41.6 \text{ ksi}$$

The safety factor in the bolts is SF = 287/172 = 1.6. Therefore the stresses in the bolts are acceptable.

8A.2.5.6 Evaluation of Anti-Taking Off Device and Locking Pin

The Anti-taking off device is shown in Figure 8A.2-1. The anti-taking off device prevents the trolley from tipping during a seismic event. This section calculates the stresses on the anti-taking off device. Figures 8A.2-6 through 8A.2-8 are used to perform this analysis.

The anti-taking off device is sized to withstand the maximum vertical force in the Z-direction. This force is obtained by combining the static and seismic loads. The reaction forces for each load step (x-direction seismic load, y-direction seismic load, z-direction seismic load and static load) are calculated and then combined to determine the maximum reaction force.

X direction Seismic Load

The seismic load on the trolley (M_t) is applied at G' shown in Figure 8A.2-8. The seismic load on the cask (M) is applied at G shown in Figure 8A.2-8. The seismic load is reacted by compression on the wheel at locations A & D and tension in the anti taking-off devices at locations B and C.

The vertical reaction forces due to the x direction seismic load at the anti-taking off devices are defined as R_{BZX} and R_{CZX}. From symmetry, $R_{BZX} = R_{CZX}$.

O'G is the vertical distance between the center of gravity of the cask and the base of

the anti-taking off device.

From Figure 8A.2-8,

$O'G = L/2 + L_Z$.

O'G' is the vertical distance between the center of gravity of the trolley and the base of the anti-taking off device.

$O'G' = L_Z /2$.

Summing the moments to zero about AD:

$M_t a_x O'G' + Ma_x O'G - (R_{BZX} + R_{CZX})L_x = 0$

Therefore,

$R_{BZX} = (M_t a_x O'G' + Ma_x O'G)/2L_x$ or

$R_{BZX} = (M_t a_x L_Z /2 + Ma_x(L/2 + L_Z))/2L_x$

The locking pin takes the force in the x direction:

$R_X = (M + M_t)a_x$

Y direction Seismic Loading

The seismic load on the trolley (M_t) is applied at G' shown in Figure 8A.2-8. The seismic load on the cask (M) is applied at G shown in Figure 8A.2-8. The seismic load is reacted by compression on the wheel at locations C & D and tension in the anti taking-off devices at locations A and B.

The vertical reaction forces due to the y direction seismic load at the anti-taking off devices are defined as RB_{AZY} and R_{BZY}. From symmetry, $R_{AZY} = R_{BZY}$.

O'G is the vertical distance between the center of gravity of the cask and the base of the anti-taking off device.

From Figure 8A.2-8,

$O'G = L/2 + L_Z$.

O'G' is the vertical distance between the center of gravity of the trolley and the base of the anti-taking off device.

$$O'G' = L_Z /2.$$

Summing the moments to zero about AD:

$$M_t a_y O'G' + M a_y O'G - (R_{AZY} + R_{BZY})L_y = 0$$

Therefore,

$$R_{BZY} = (M_t a_y O'G' + M a_y O'G)/ 2L_y \text{ or}$$

$$R_{BZY} = (M_t a_y L_Z /2 + M a_x (L/2 + L_Z))/ 2L_y$$

The y direction force is taken by the superior plate under the rail on the two anti-taking off devices at A and B.

$$R_{AY} = R_{BY} = (M + M_t) a_y / 2$$

Z Direction Seismic Loading

The z direction seismic loads are taken equally by the four anti-taking off devices:

$$R_{BZZ} = (M + M_t) a_z / 4$$

Static Z Direction Loading

The static compression load is taken equally by the four wheels. The dead load is:

$$P_Z = (M + M_t) g$$

The vertical compression at point B is:

$$R_{BZS} = - (M + M_t) g/4$$

Load Combination

Combining the results:

The maximum vertical force on the anti-taking off device is the combination of the static + seismic load:

$R_{BZ} = \sqrt{(R_{BZX}^2 + R_{BZY}^2 + R_{BZZ}^2)} - R_{BZS}$

The maximum force on the locking pin is:

$R_X = (M + M_t)a_x$

The maximum force in the Y direction on the anti-taking off device is:

$R_{BY} = (M + M_t)a_y / 2$

Solving numerically:

given $M = 125$ tons
$L = 5{,}290$ mm
$M_t = 20$ tons
$L_x = 2770$ mm
$L_Y = 2550$ mm
$L_z = 700$ mm
$a_x = 0.375$ g
$a_y = 0.375$ g

Then $R_{BZX} = 289{,}617$ N
$R_{BZY} = 306{,}654$ N
$R_{BZZ} = 90{,}683$ N
$R_{BZS} = -355{,}612$ N

The forces taken by the anti-taking off device are:

$R_{BZ} = 78{,}525$ N = 17,047 lbf
$R_{BY} = 266{,}710$ N = 59,960 lbf

The force on the locking pin is:

$R_x = 533{,}420$ N = 119,920 lbf

The dimensions of the Anti-Taking Off Device are shown in Figure 8A.2-11. The anti-taking off device is made from A36 carbon steel, with A193 B7 bolts.

The maximum bending moment in the plate is at bolt position 2:

$M_{max} = R_{BZ}\, a = (78{,}525\ N)(50mm) = 3{,}975$ mN

The maximum tension in a bolt occurs at position 2:

F = tension in bolt
A_b = bolt cross sectional area = 353 mm^2

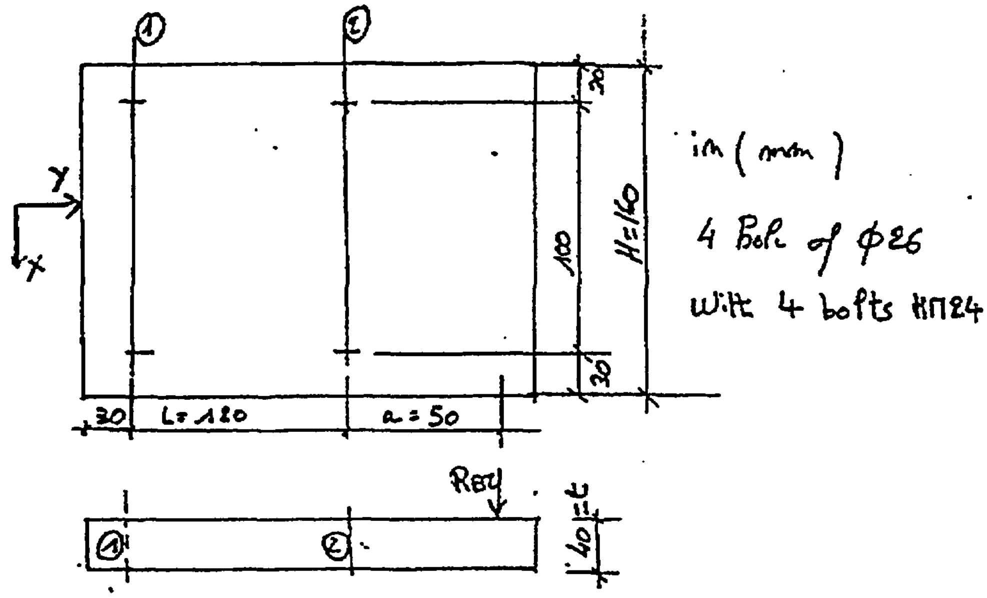
Then $2FL - R_{BZ}(L + a) = 0$

Solving for F:

$$F = R_{BZ}(L + a)/2L = 53{,}800 \text{ N per bolt}$$

Figure 8A.2-11

Receiving Cask Anti-Taking Off Device



The tensile stress in the bolt is:

$\sigma = F/A_b = 53{,}800/353 = 153$ MPa $\leq$ 287 MPa
The safety factor is:

SF = 287/153 = 1.8

The section modulus of the plate is:

$S = (H\text{-}2{*}26)t^3/6t = 28{,}800\ mm^3$

where t = the thickness of the plate = 40 mm and H = 160 mm.

The bending stress in the plate is:

$\sigma = M_{max}/ S =$ 138 MPa = 20 ksi $\leq$ 186 MPa = 27 ksi

The safety factor is SF = 186/138 = 1.3.

The force R_{BY} is taken directly by the trolley.

The locking pin is shown in Figure 8A.2-10. The pin diameter is D = 2L = 120 mm. The shear stress in the pin is $\tau = R_x / A = 47$ MPa $\leq$ 103 MPa = 15 ksi where

R_x = 533,420 N = 119,919 lbf

and $A = \pi D^2/4 = 11{,}310\ mm^2$

The safety factor on the locking pin is SF = 103/47 = 2.2.

8A.2.5.7 Evaluation of Wheels

The wheels are sized based on static loads. The trolley wheels are 700 mm in diameter (27.6 in). The effective width of the rail head is 100 mm (3.9 in). The allowable wheel load is taken from NOG 5452.3:

$P_a = KbD$ (lbs)

where $K = 1300\ (BHN/260)^{0.333} = 1393$

The load is equally distributed between the four wheels. Therefore the load on each wheel is:

$F_z = (M + M_t)g/4 = 355{,}612$ N = 79,946 lbf

The allowable load is $P_a = KbD$ = 1393(3.9)(27.6) = 151,141 lbf. Therefore the loads on the wheels are acceptable. The safety factor is SF =151141/79946 = 1.9.

8A.2.5.8 Evaluation of the Guiding Rollers

The guiding rollers are calculated based on static loads. The rail width, b = 1.97 in. (50mm). The roller diameter, D, is 7.1 in (180 mm). The allowable load is taken from NOG 5452.3:

$P_a = KbD$ (lbs)
where $K = 1300\ (BHN/260)^{0.333} = 1393$

The total load is equally distributed between the 2 guidance rollers. From NOG 4133(b), the lateral load is taken as 5% of the vertical load:

P_y = 5% (trolley + cask) live load = $0.05\ (M + M_t)g$ = 71,123 N

$F_y = P_y /2$ = 35,562 N = 7,995 lbf

The allowable load is $P_a = KbD$ = 1393(1.97)(7.1) = 19,490 lbf. Therefore the loads on the wheels are acceptable. The safety factor is SF = 19490/7995 = 2.4.

8A.2.5.9 Summary of Stresses - Receiving Cask Transfer Trolley

The sizes of the structural components of the source cask trolley, together with the calculated stresses and allowable stresses are presented in Table 8A.2-8.

Table 8A.2-8

Summary Receiving Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 MPa	172 MPa	6 bolts M30 (1.2 in dia.)	1.6
Plate of anti-taking off device	Seismic	186 MPa	138 MPa	40 mm thick (1.6 in)	1.3
Bolts of anti-taking off Device	Seismic	287 MPa	153 MPa	4 bolts M24 (1 in)	1.8
Diameter of the locking pin	Seismic	103 MPa	47 MPa	D = 120 mm (4.8 in)	2.2
Wheel diameter	Static	151,141 lbf	79,946 lbf	D = 700 mm (27.6 in)	1.9
Rail width minimum	Static	151,141 lbf	79,946 lbf	b = 100 mm (3.9 in)	1.9
Guidance roller	Static	19,490 lbf	7,995 lbf	D = 180 mm (7.1 in)	2.4
Rail height minimum	Static	19,490 lbf	7,995 lbf	b = 50 mm (1.97 in)	2.4

Appendix 8A.3 Receiving and Source Cask Mating Subsystem

This appendix describes the calculations performed to ensure that the Receiving and Source Cask Mating Subsystem functions safely. The only portion of the Cask Mating Subsystem which is important to safety is the lifting of the cask lid, through the use of the overlid. Calculations are presented which evaluate the thickness of the overlid pintle, the thickness of the shield plug pintle, and the size of the overlid gripping device.

The source cask lid pintle and the shield plug pintle are identical. The grapple for the source cask lid and the grapple for the shield plug are also identical. Since the source cask lid is lighter than the shield plug, the analysis is performed on the shield plug pintle.

The forces are taken from the ANSYS analysis of the upper crane presented in Appendix 8A4. There are 4 fingers on each grapple. Any two opposing fingers can accommodate the entire load. The vertical force Fz is taken from the ANSYS model and is 150,000 N. This is the maximum force at the finger location for all positions analyzed. The mass used in the ANSYS analysis is 7000 kg.

The following masses are taken into account:

m_p = 3000 kg = mass of the shield plug
m_o = 1500 kg = mass of the overlid

The fingers, pintle and axis are all made from A36 forged carbon steel, with the following minimum properties:

yield strength, σ_y	36 ksi (248 MPa)
ultimate strength, σ_u	58 ksi (399 MPa)

The mass of the plug and overlid is less than that used in the ANSYS analysis. Therefore, the force is corrected below.

$$F_z = F_z(\text{computed}) \times m/m_T$$

where m is the mass of the system and m_T is the mass used in the analysis (7000 kg).

Pintle of the plug

The maximum force on the pintle of the plug due to seismic loading is:

$$F_z = 150{,}000 \times m_p/m_T = 150{,}000 \times 3000/7000 = 64{,}300 \text{ N} = 14{,}454 \text{ lbs}$$

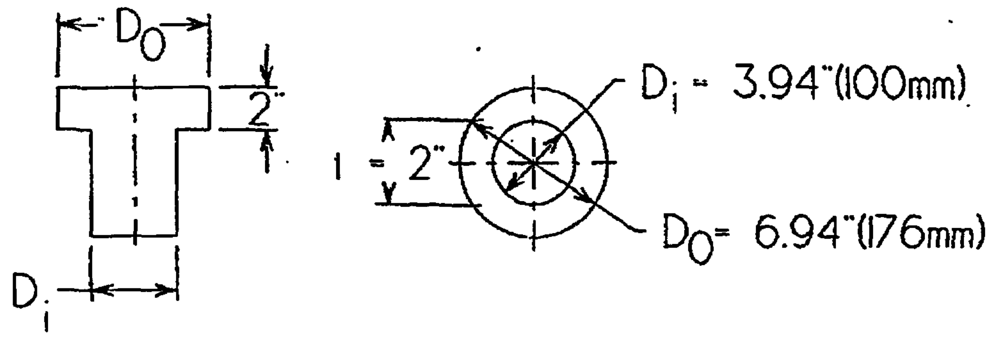
The maximum force in the static case (including a factor of 6 to yield for a nonredundant lift system) is:

$$F = 3000 \times 9.81 \times 6.0 = 1.77 \times 10^5 \text{ N} = 39{,}654 \text{ lbs}$$

Therefore the static case is limiting. The pintle of the plug is shown below:

FIGURE 8A.3-1

PINTLE OF THE PLUG



Using the loading from the static analysis, the force on one finger is:

$T = F_z / 2 = 19{,}827$ lbs

The contact length t is the width of the finger, 2" (50 mm). The modulus of inertia of the bending resistant section is:

$S = te^2/6$ where e is the thickness of the pintle, 2" (50 mm) and t is the width of the finger

$S = 2 \times 2^2 / 6 = 1.33$ in^3

The bending moment is $M = Td = 19{,}827 \times 1.5 = 29{,}741$ in- lbs

The bending stress is:

$\sigma = M/S = 29741/1.33 = 22{,}362$ psi $<$ 36,000 psi (6 to yield strength)

$\sigma = 22{,}362 \times 10/6 = 37{,}270$ psi $<$ 58,000 psi (10 to tensile strength)

Fingers and axis of the overlid

The axis of the grapple is 1 in. (25 mm).
The cross sectional area is therefore $A = 0.785$ in^2 (491 mm^2). The shear force in the pin for the static loading is:

$F = 19{,}827$ lbs

The shear stress is:

$\tau = T/2A = 19{,}827/2 \times 0.785 = 12{,}629$ psi $<$ 36,000 psi

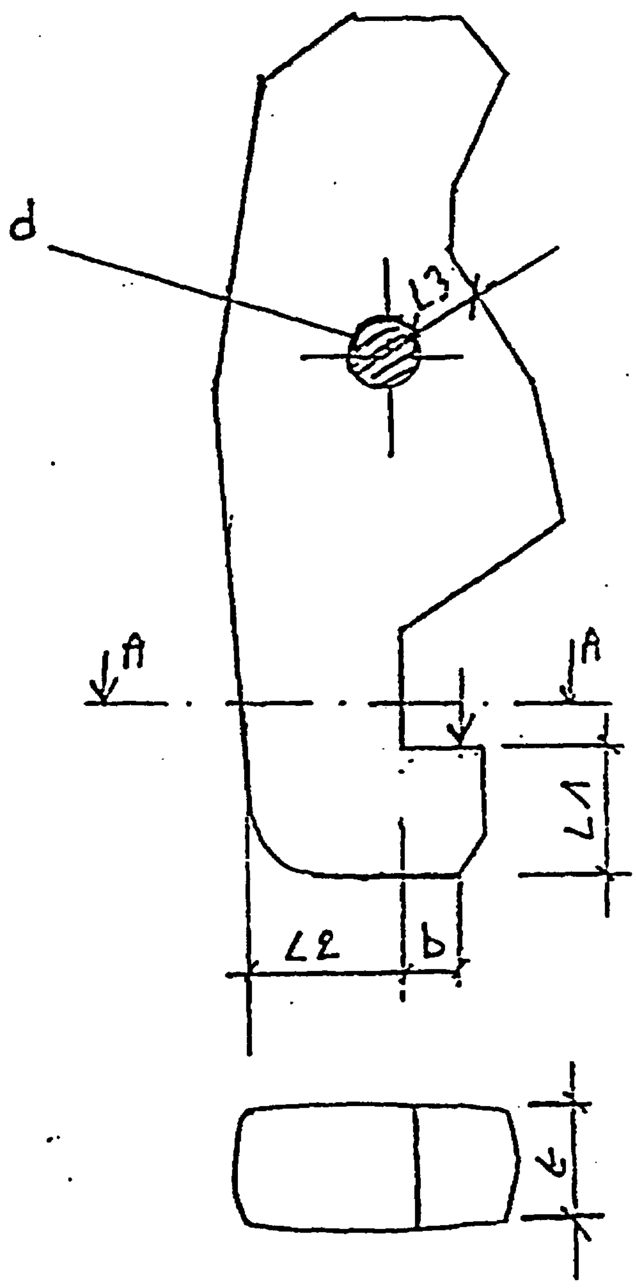
$\tau = 12{,}629 \times 10/6 = 21{,}048$ psi $<$ 58,000 psi

A sketch of a finger is shown below. The following dimensions are used for the finger:

L2 = 60 mm = 2.36 in
L1 = 50 mm = 2.0 in.
L3 = 20 mm = 0.8 in.
t = 50 mm = 2.0 in.
b ≈ 20 mm =0.8 in.
d = 25 mm = 1.0"

FIGURE 8A.3-2

FINGER



The shear stress in the L1 section is:

$\tau = T/L_1t = 19{,}827/2\times2 = 4{,}957$ psi $\prec$ 36,000 psi

$\tau = 4{,}957 \times 10/6 = 7{,}828$ psi $\prec$ 58,000 psi

The shear stress in the L3 section is:

$\tau = T/L_3t = 19{,}827/0.8 \times 2 = 12{,}392$ psi $\prec$ 36,000 psi

$\tau = 12{,}392\times 10/6 =20{,}653$ psi $\prec$ 58,000 psi

The tensile and bending stress in the L2 section is:

$\sigma = T/L_2t + M/S$

where $M = T(b + L_2 /2) = 19{,}827\ (0.8 + 2.36/2) = 39{,}257$ psi

and $S = tL_2^2/6 = 2 \times 2.36^2/6 = 1.86\ in^3$

Then $\sigma = 19{,}827/2.36 \times 2 + 39{,}257/1.86 = 4{,}200 + 21{,}106 = 25{,}306$ psi $\prec$ 36,000 psi

$\sigma = 25{,}306 \times 10/6 = 42{,}176$ psi $\prec$ 58,000 psi

Pintle of the Overlid

The maximum force based on the seismic analysis is:

$F_z = 150{,}000(m_p + m_o)/m_T = (150000)(4500)/7000 = 96{,}429\ N = 21{,}677$ lbs

The maximum force due to the static case using a safety factor of 6 for nonredundant loading is:

$F = 4500 * 9.81 * 6 = 2.65 \times 10^5\ N = 59{,}572$ lbs

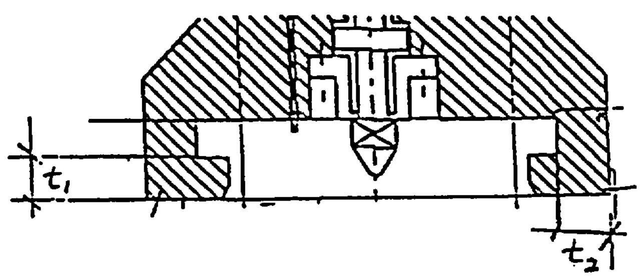
We conservatively assume that the load is handled by 2 fingers only. Then the maximum force applied to each finger is:

$T = F_z/2 = 29{,}786$ lbs

The pintle on the overlid is shown below:

FIGURE 8A.3-3

PINTLE ON THE OVERLID



t_1 = 40 mm =
1.6 in.
t_2 = 40 mm = 1.6 in.

The bending stress is:

$\sigma = M/S = 6T/\pi t_1^2 = 6 \times 29{,}786 / \pi \times 1.6^2 = 22{,}220$ psi i $<$ 36,000 psi

$\sigma = 22{,}220 \times 10/6 = 37{,}033$ psi $<$ 58,000 psi

The stress at t_2 is equal to the stress at t_1.

Summary of Results

The summary of the stresses in the cask mating subsystem are shown below.

Part	**Load**	**Allowable Value (ksi)**	**Calculated Value(ksi)**	**Calculated Size**
Axis for finger of the overlid diameter	Static	36 (yield) 58 (tensile)	12.6 (shear) 21.0 (shear)	25 mm (1.0 in)
Overlid finger thickness	Static	36 (yield) 58 (tensile)	25.3(bending) 42.2(bending)	50 mm (2 in.)
Plug Pintle thickness	Static	36 (yield) 58 (tensile)	22.3(bending) 37.2(bending)	50 mm (2 in.)
Overlid Pintle Thickness	Static	36 (yield) 58 (tensile)	22.2(bending) 37.0(bending)	40 mm (1.6 in.)

Appendix 8A.4 Shield Plug and Source Cask Lid Handling Subsystem Analysis

This appendix describes the analysis performed on the upper crane, TC port covers and upper shield port covers. The upper crane has been analyzed using the finite element analysis program ANSYS 4.4. Certain components of the crane, such as the grapple, have been evaluated using hand calculations.

The seismic analysis is performed on the crane to ensure retention of the load and the prevention of any component from becoming a missile that would be detrimental to the DTS's safety related equipment. Seismic evaluation is performed with and without the rated load.

8A.4.1 Positions Evaluated

The crane is analyzed with the rated load with the trolley in two positions: over the source cask and over the receiving cask. The crane is evaluated with the trolley at mid-span without the rated load. The length of the cable is calculated and introduced to have the vertical frequency at the maximum of the vertical spectrum. This position is more severe than the position with the hook in the full up or full down positions.

8A.4.2 Load Combinations

The following loads are used for the seismic evaluation. The symbols and nomenclature are taken from NOG-1.

P_{dt} = the trolley dead load
P_{db} = frame and rail dead load
P_{lr} = the rated load of the crane
P_{cs} = the credible critical load with safe shutdown earthquake
$P_{e'}$ = safe shutdown earthquake load

Note that the rated load of the crane is equal to the credible critical load, $P_{cs} = P_{lr}$.

The following load combinations were evaluated for the seismic event, as specified in NOG-4140(d):

$P_{c10} = P_{dt} + P_{db} + P_{cs} + P_{e'}$ (evaluated with trolley positioned over a cask - Load Combination 1)

$P_{c11} = P_{dt} + P_{db} + P_{e'}$ (evaluated with the trolley at mid-span - Load Combination 2)

$P = P_{dt} + P_{lr}$ (evaluated with trolley positioned over a cask -Load Combination 3)

$P = P_{dt}$ (evaluated with the trolley at mid-span - Load Combination 4)

The force in the cable is obtained from Load combination 1. The stresses in the supporting structure of the compensator and the support of pulleys #1 and #6 are obtained from this cable force. This is load combination 5.

Load combination 1 and 5 are combined to take into account the forces in the trolley induced by the cables in the seismic calculation. This is load combination 6.

Load combinations 2 and 6 are used to analyze the crane during a seismic event. Load combination 6 is used to analyze the supporting structure of the compensator and the support of pulleys #1 and #6 during a seismic event. Combinations 3 and 4 are used to verify the girder deflection.

8A.4.3 Material Properties

The properties for the structural components of the crane were taken from Tables NOG-4211-1 and NOG-4221-1 of NOG-1, and are summarized below:

The plates and beams will be constructed from A36 Steel, with a minimum yield strength of 36 ksi (248 MPa) and a minimum tensile strength of 58 ksi (399 MPa).

The structural connections will be constructed from A193 Grade B7, with a minimum yield strength of 75 ksi (517 MPa) and a minimum tensile strength of 100 ksi (689 MPa).

The cable minimum ultimate strength used in the analytical model is 256.7 ksi (1770 MPa). A shape factor including the strand factor of 0.57 is used in the analysis.

8A.4.4 Design Criteria

The design criteria for the crane are taken from NOG-4300 and are repeated following.

Allowable Stresses in the beams

For compression members with an equivalent slenderness ratio:

$$kl/r < C_c = \sqrt{(2\pi^2 E/\sigma_y)} \qquad (6)$$

where E = modulus of elasticity
σ_y = the yield point
k = effective length factor
l = length of compression member

r = radius of gyration of member
and C_c = column slenderness ratio separating elastic and inelastic buckling

The allowable axial compression stress shall not exceed the value:

$$\sigma_a = (1-((kl/r)^2 / 2C_c^2))(\sigma_y / FS) \qquad (7)$$

where FS = factor of safety and the other variables are as noted above.

The required factor of safety is equal to:

$$FS = N\{5/3 + (3/8)((kl/r)/C_c) - (1/8)((kl/r)/C_c)^3\} \qquad (8)$$

For severe environmental loads, the value of N is 0.67. For compression members with an equivalent slenderness ratio $kl/r > C_c$, the allowable axial compression stress shall not exceed the value:

$$\sigma_a = 12\pi^2 E / (23N(kl/r)^2) \qquad (9)$$

Members subjected to both axial compression and bending stresses shall satisfy the following requirements:

$$\sigma / \sigma_a + C_{mx}\sigma_{bx} / ((1 - \sigma/\sigma'_{ex})\sigma_{abx}) + C_{my}\sigma_{by} / ((1- \sigma/\sigma'_{ey})\sigma_{aby}) \leq 1.0 \qquad (10)$$

$$\sigma / \sigma_{ac} + \sigma_{bx} / \sigma_{abx} + \sigma_{by} / \sigma_{aby} \leq 1.0 \qquad (11)$$

where $$\sigma'_e = 12\pi^2 E / (23N(kl/r)^2) \qquad (12)$$

The subscripts x and y, combined with subscripts b, m, and e, indicate the axis of bending about which a particular stress or design property applies; and σ_a , σ_{ab} are the allowable axial and bending stresses respectively.

The l is the actual unbraced length in the plane of bending, r is the corresponding radius of gyration, K is the effective length factor in the plane of bending and N is the loading condition factor, 0.67 for extreme environmental loading.

C_m is a coefficient whose value is:

(a) $C_m = 0.85$ for compression members in frames subject to joint translation;
(b) $C_m = 0.6 - 0.4\ (M_1/M_2)$ but not less than 0.4 for restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending. M_1/M_2 is the ratio of the smaller to the larger moments at the ends of that portion of the member unbraced in the plane of bending under consideration.
(c) For compression members in frames braced against joint translation in the plane of loading and subjected to transverse loading between their supports, $C_m = 0.85$ for members whose ends are restrained, and $C_m = 1.0$ for members whose ends are unrestrained.

If $\sigma/\sigma_a \leq 0.15$, then only equation (11) needs to be evaluated.

Members subjected to both axial tension and bending stresses shall satisfy equation (11). The computed bending tensile stress, taken alone, shall not exceed the $0.9\sigma_y$.

The maximum allowable shear stress under seismic load is $0.5\ \sigma_y$.

An additional factor of 1.2 is applied to all stresses to account for uncertainties since the loading may change from site to site.

For the beams, which are made from A36 steel:

The tensile stress allowable is:

$$F/A + M_{bx}x/I_x + M_{by}y/I_y < 0.9\ \sigma_y/1.2 = 186 \text{ MPa} = 27.0 \text{ ksi} \quad (13)$$

The shear stress allowable is $0.5\sigma_y/1.2 = 103$ MPa = 15 ksi.

Allowable stresses in Bolts

The allowable stresses in the bolts are taken from NOG-4513. For seismic loading, the maximum allowable tensile load is $0.5\ \sigma_y$, and the maximum allowable shear stress is $0.26\ \sigma_y$. For bearing type joints, the stresses shall meet the following criteria:

$$\sigma \leq 0.6\ \sigma_y R - 1.6\ \tau \quad (14)$$

The maximum allowable tensile stress due to seismic loading, assuming an additional safety factor of 1.2 is therefore 41.6 ksi (287 MPa). The maximum allowable shear stress, assuming an additional safety factor of 1.2 is 21.6 ksi (149 MPa).

Allowable Deflections

The total vertical deflection of the girder during operational loading for the rated live load plus trolley ($P_{dt} + P_{lr}$), and not including impact or dead load of the girder, shall not exceed 1/1000 of the span.

Allowable stress for the Cables.

The maximum allowable stresses in the cables is governed by NOG-5425.1. The maximum critical load (without impact), plus the weight of the load block divided by the total number of parts of rope per system, shall not exceed 10% of the manufacturer's published breaking strength on the total system. The seismic load with all parts of rope intact shall not exceed 40% of the manufacturer's published breaking strength.

For the cables, $\sigma_u = 1770$ MPa = 256.7 ksi. For the static case,

$$F/KA < \sigma_u / 10 = 177 \text{ MPa} = 25.6 \text{ ksi} \qquad (15)$$

K is the shape coefficient, which is taken as 0.57. $A = \pi d^2/4$.

Then:

$$d_{MIN} = \sqrt{(40F/K\pi\sigma_u)} \qquad (16)$$

and

$$F = P_{cl} / n\eta \qquad (17)$$

where P_{cl} = the credible critical load and the weight of the load block
n = the number of parts of the rope
η = the efficiency, which is taken as 0.94 to start.

8A.4.5 Component Weights

The following masses were used in the model of the upper crane:

Live load: 7,000 kg (lifting capacity and grapple)
Trolley: 2,000 kg

8A.4.6 Upper Crane Model

A model of the upper crane was made to evaluate it under seismic loading. The response spectrum method was used according to the requirements of NOG 4153.1. The response of the crane to the input response spectra in three directions was determined on a

modal basis. An ANSYS model was used to perform the analysis. The program searches the frequency and the modal participation factor up to the cutoff frequency (around 33 Hz). If the sum of the participation of the mass is less than 90% in a direction, the program is completed with the equivalent static component in this direction. The residual mass is affected with the acceleration of the cutoff frequency in this direction.

The dynamic responses of the structure are combined using the "grouping method" in accordance with NOG 4153.10. The three directional components of the earthquake motion are combined by taking the square root of the sum of the squares of the maximum representation values of the codirectional responses caused by each of the three components of earthquake motion at each mode of the crane mathematical model.

The model consists of:

- a plate for the mezzanine and its beams
- a left support for the pulleys
- a right support for the pulleys
- a trolley with a cable and a mass
- rails and poles.

The finite element required 1,350 elements and 1,178 nodes.

Trolley and Cable Model

The trolley is represented by STIF 4 beams with corrected densities to simulate the weight of the trolley. A sketch of the trolley model is shown in Figure 8A.4-1. The dotted lines are rigid beams with nearly no mass (material density of 0.1×10^{-11} kg/m^3). The single solid lines represent rectangular structural tubing 12 in. x 18 in x 1/2 in with a density of 0.55×10^{-7} kg/mm^3. The double solid lines represent rectangular structural tubing 16 in. x 12 in. x 1/2 in. with a density of 0.347×10^{-7} kg/mm^3. These corrected densities give a total mass of 2.67 metric tons or 5,732 lbs.

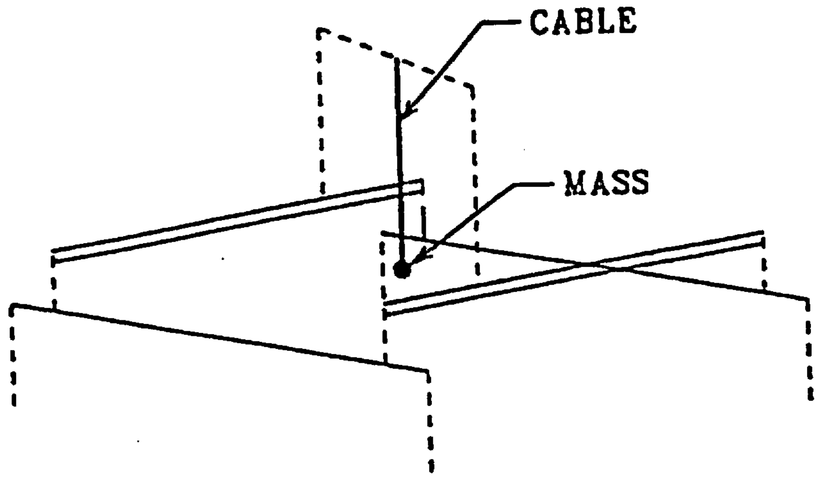
The cable is modeled as a spar element (LINK 8 of ANSYS) with a stiffness and a length which provides a vertical frequency of 10 Hz:

$$F = (1/2\pi)\sqrt{k/m} = 10 \text{ Hz}$$

The spring constant $k = EA/L$

Figure 8A.4-1

ANSYS Trolley Model



The truss element area and length are chosen to provide resonance at the spectrum peak of 10 Hz. The actual cable stiffness is much less than a truss. However, we are only interested in resonance at 10 Hz in order to obtain a peak load from the truss.

where
E = Young's Modulus = 201,000 MPa
A = cross sectional area
L = length of the cable = 1 m
m = mass = 7,000 kg

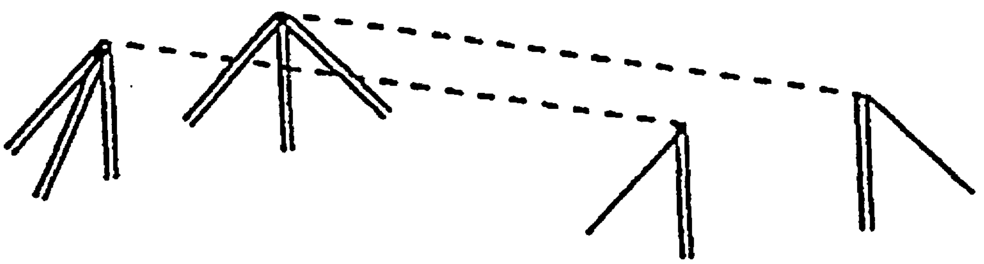
Solving for k: $k = (2 \pi F)^2 m = 2.77 \times 10^7$ N/m
Then solving for A = 137.8 mm^2

Model of Rails and Poles

The rails and poles are modeled as beam elements (ANSYS STIF 4). A sketch of the model is shown in Figure 8A.4-2. The dotted lines represent W 10 x 60 beams with 2 lateral shells reinforcing them. The double lines represent W10 x 60 beams. The single lines represent W 6 x 25 beams. The density used for the beams is 7,850 kg/m^3. All beams are made from A36 steel.

Figure 8A.4-2

Model of Rails and Poles



Link Between the Trolley and the Rails

The link between the trolley and the rails is shown in Figure 8A.4-3. STIF 14 spring dampers with a high degree of stiffness are used to model the coupled nodes. The node constraints are summarized in Table 8A.4-1.

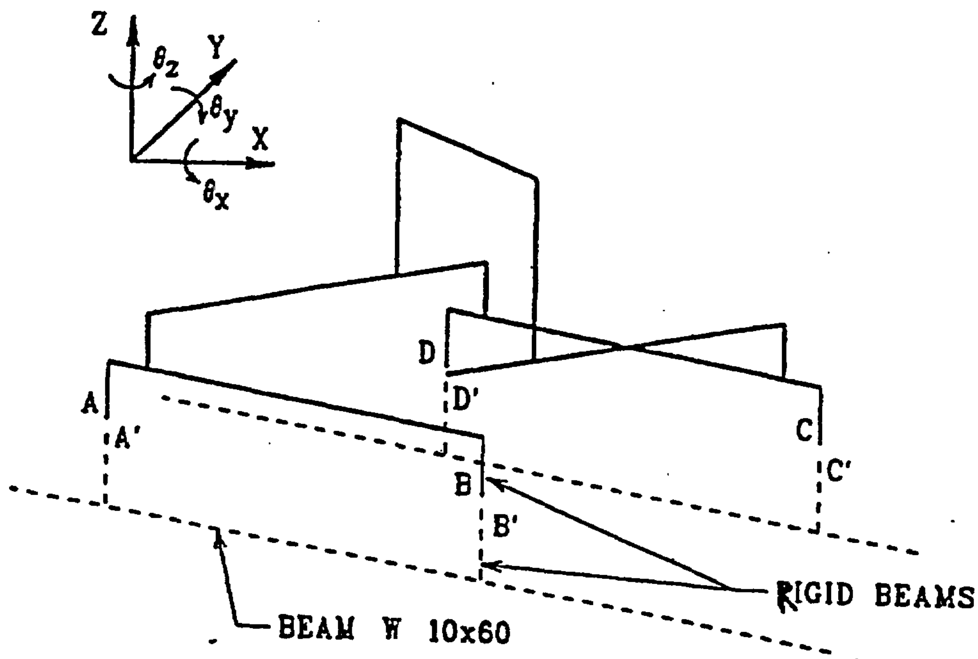
Table 8A.4-1

Node Constraints

	Translation			Rotation		
Nodes	X	Y	Z	θ_x	θ_y	θ_z
AA'	Free	Coupled	Coupled	FREE		
BB'	Coupled	Coupled	Coupled			
CC'	Coupled	Coupled	Coupled			
DD'	Free	Coupled	Coupled			

Figure 8A.4-3

Links Between the Trolley and the Rails

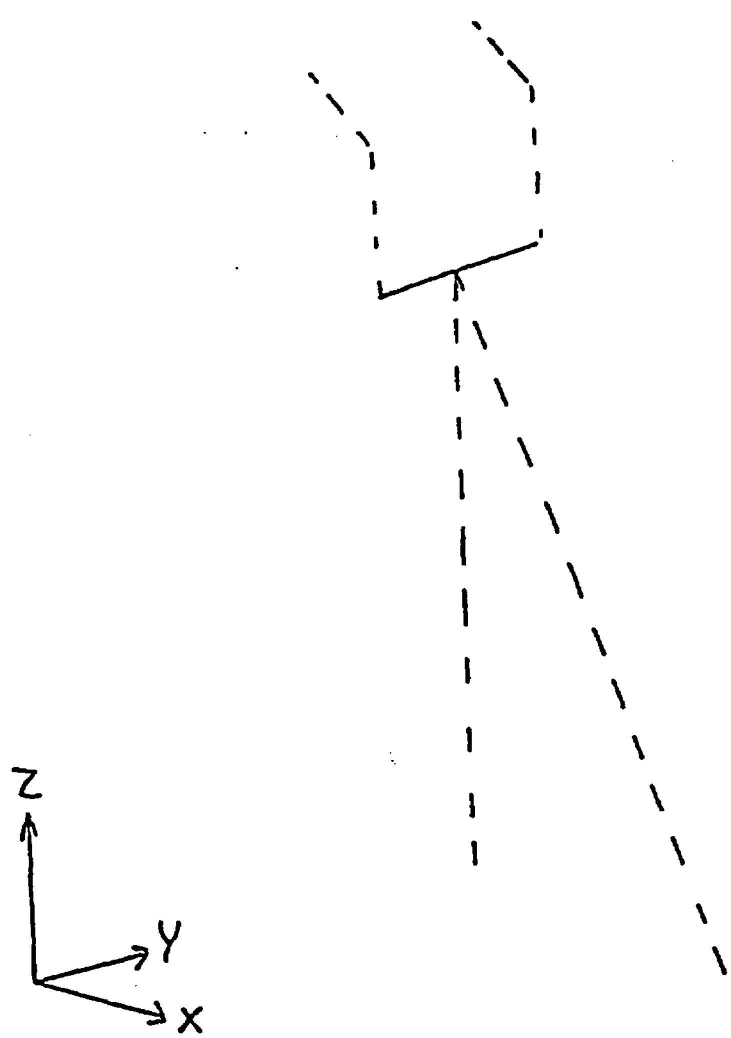


Left Support of the Pulleys

The left support of the pulleys is a beam structure modeled as shown in Figure 8A.4-4. The dotted lines represent W 10 x 60 beams (STIF4 ANSYS). The solid lines represent W10 x 60 beams reinforced by two lateral plates. The beams are made from A36 carbon steel, with a density of 7850 kg/m^3.

Figure 8A.4-4

Left Pulley Support

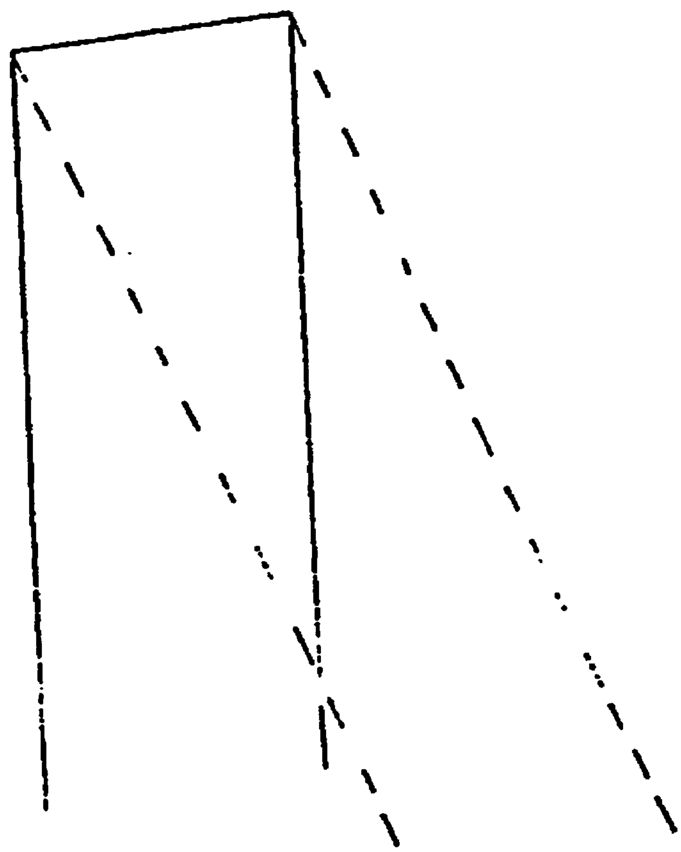


Right Support of the Pulleys

The right support of the pulleys is a beam structure modeled as shown in Figure 8A.4-5. The solid lines represent W 8 x 35 beams, and the dotted lines represent W6 x 25 beams. The beams are made from A36 carbon steel with a density of 7,850 kg/m^3.

Figure 8A.4-5

Right Pulley Support



Roof Plate

The roof plate is modeled using ANSYS shell element 43. The analysis was made using a 4 inch thick plate. Since the analysis was performed, the plate was increased to 7 inches to provide additional shielding. This analysis is expected to be conservative. The plate is made from A36 steel with a density of 7,850 kg/m^3. The plate is reinforced by 5 W14 x 550 beams.

The plate consists of 4 shells which are attached by bolts at the level of the fillets A, B and C. The boundary conditions are shown in Table 8A.4-2.

Table 8A.4-2
Restraint Conditions - Roof Plate

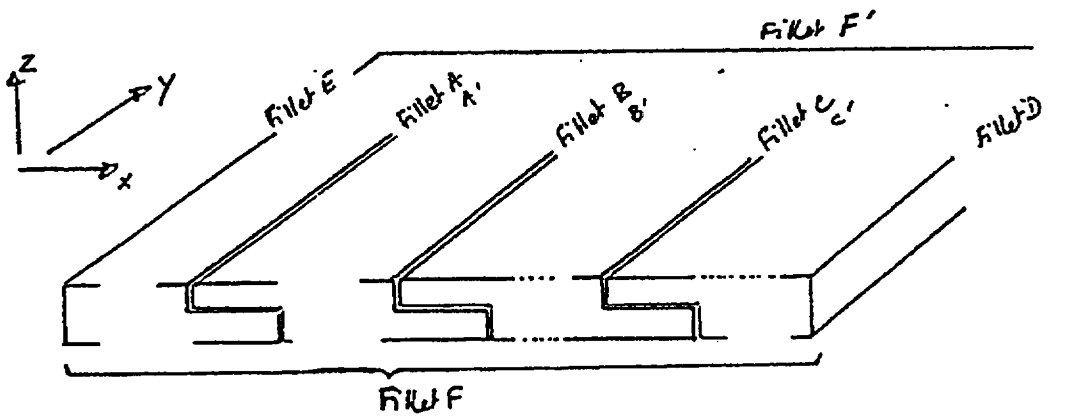
	Translation			Rotation		
Fillet	**X**	**Y**	**Z**	θ_x	θ_y	θ_z
AA'	Coupled	Free	Coupled	FREE		
BB'	Coupled	Free	Coupled			
CC'	Coupled	Free	Coupled			
E	Fixed	Free	Fixed			
F	Free	Fixed	Fixed			
D	Free	Free	Fixed			
F'	Free	Free	Fixed			

The coupling conditions between the 2 fillets are realized by coupled set equations. The fixed degrees of freedom are imposed by displacement constraints. (No displacement in the given degree of freedom).

The W14 x 550 beams are welded to the plates. Therefore, the nodes are coupled in all directions. For conservatism, the neutral axis of the beams are set coincident with those of the plate as shown in Figure 8A.4-6.

Figure 8A.4-6

W14 x 550 Beams and Roof Plate



Protective Cover

The protective cover is considered as a mass. The weight of the protective cover used in the analysis is 16 metric tons, or 35,274 lbs. The mass is uniformly distributed on the intersection of the plate and the protective cover. ANSYS mass elements 21 are used to represent the protective cover.

Link Between the Roof Plate and the Crane Supports

The crane supports and the roof plate are shown in Figure 8A.4-7. The node restraints are summarized in Table 8A.4-3.

Figure 8A.4-7

Upper Plate and Crane Supports

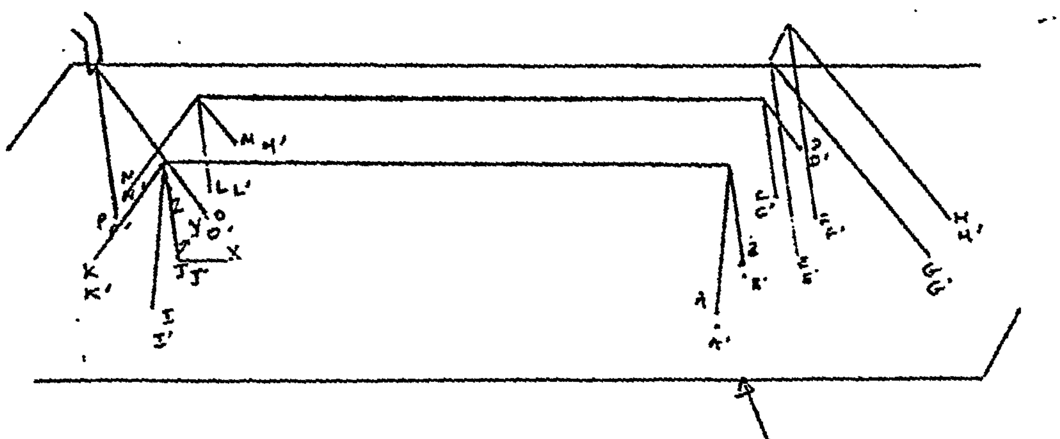


Table 8A.4-3

Restraint Conditions between the Roof Plate and the Crane Supports

	Translation			Rotation		
Nodes	**X**	**Y**	**Z**	θ_x	θ_y	θ_z
AA'	Coupled			Coupled		
BB'				Coupled		
CC'				Coupled		
DD'				Coupled		
EE'				Coupled	Free	Coupled
FF'				Coupled	Free	Coupled
GG'				Coupled	Free	Coupled
HH'				Coupled	Free	Coupled
II'				Free	Coupled	Coupled
JJ'				Coupled	Coupled	Coupled
KK'				Coupled	Free	Coupled
LL'				Coupled	Coupled	Coupled
MM'				Free	Coupled	Coupled
NN'				Coupled	Free	Coupled
OO'				Coupled		
PP'				Coupled		

The ANSYS model is shown in Figures 8A.4-8 through 8A.4-13.

Figure 8A.4-8

Model of Crane Supports

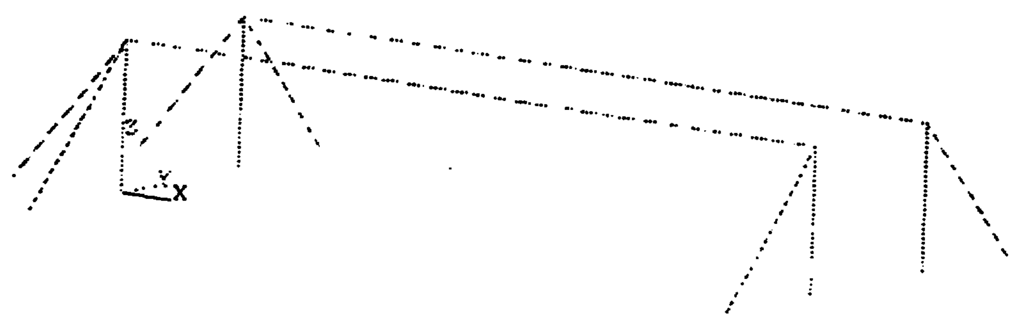


Figure 8A.4-9

Model of Left Pulley Support

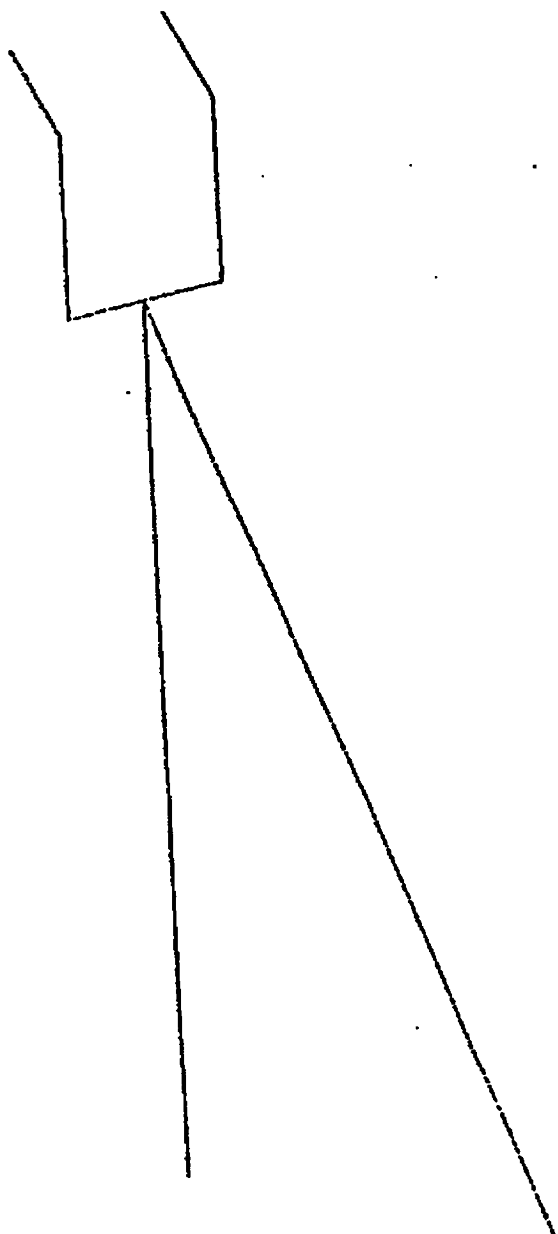


Figure 8A.4-10

Model of Right Pulley Support

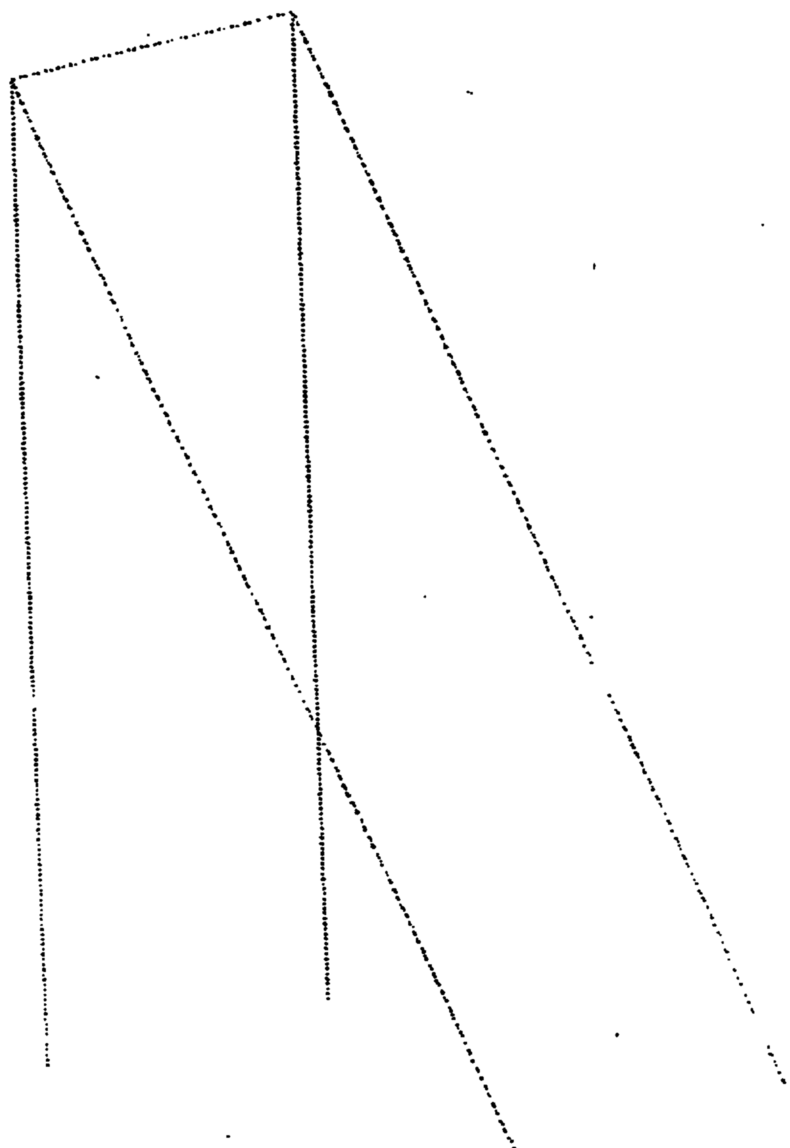


Figure 8A.4-11

Model of Trolley

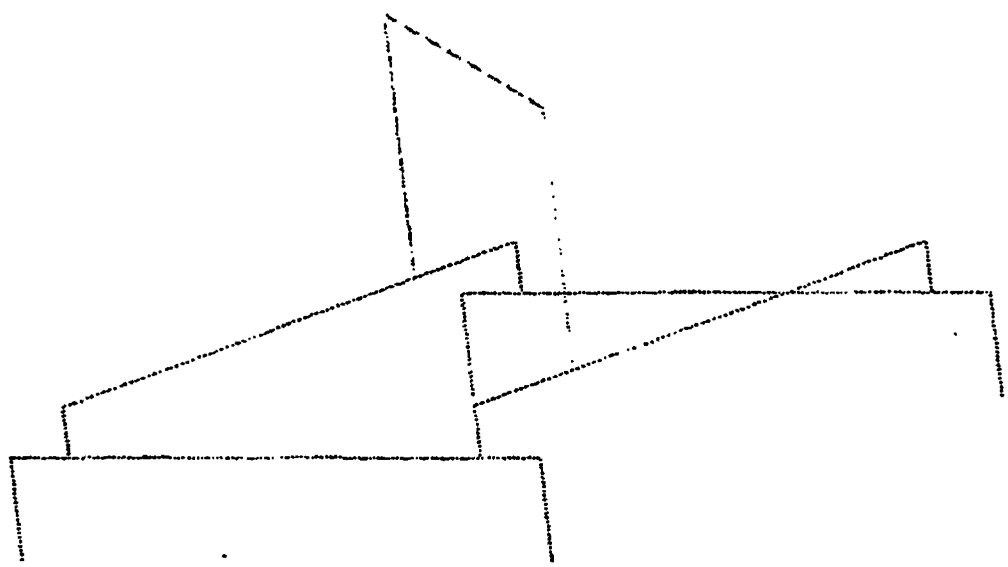


Figure 8A.4-12

Model of Trolley with Cable and Mass

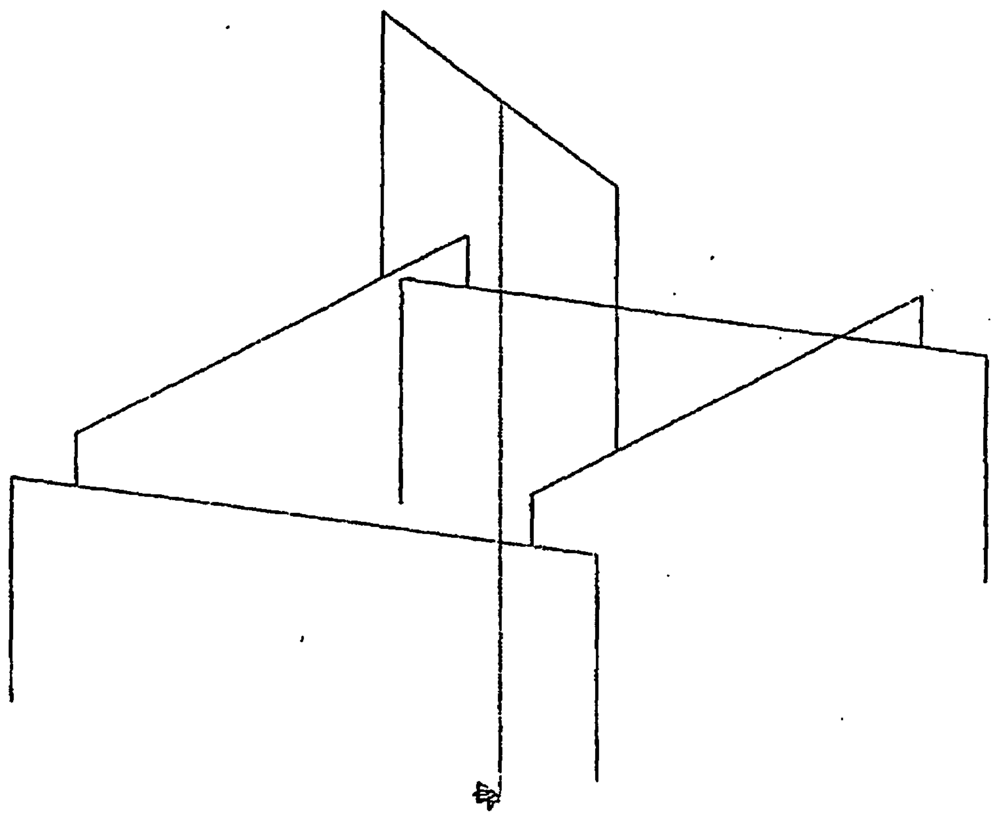
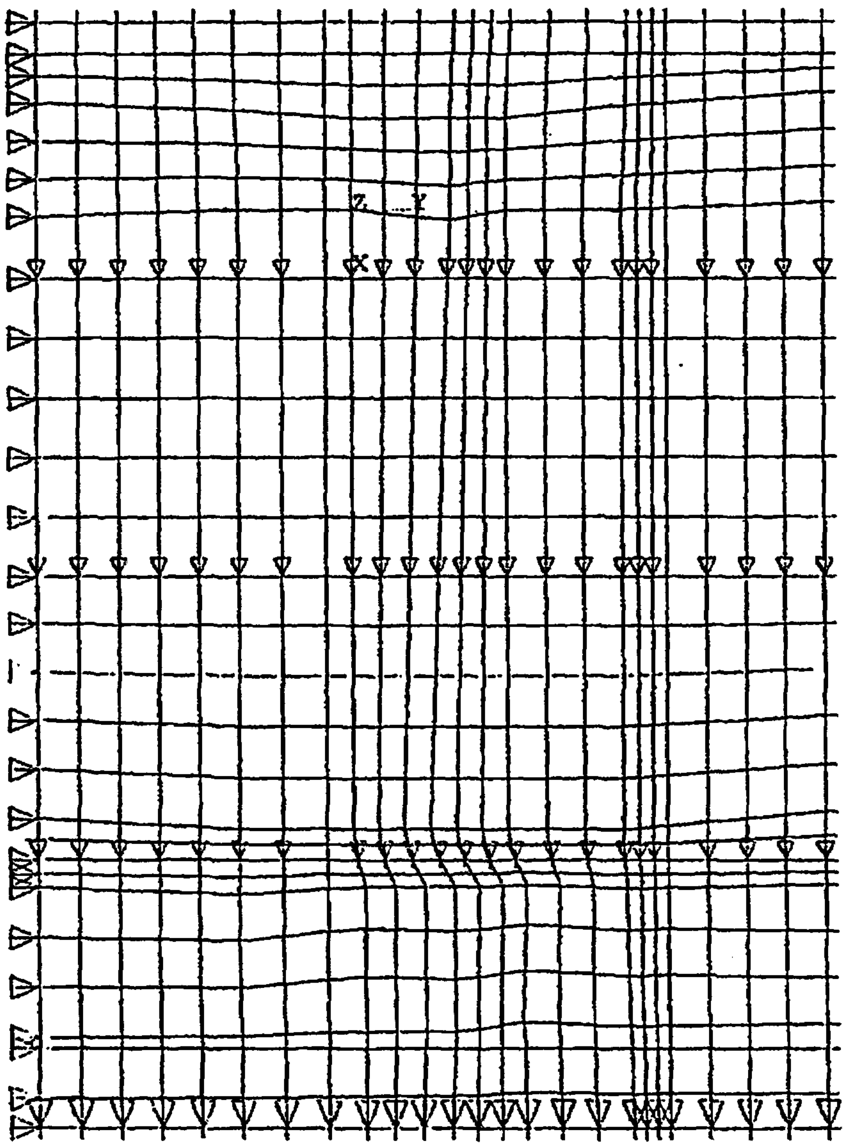


Figure 8A.4-13

Model of Roof Plate



8A.4.7 Input Spectra

The spectra is presented in Figures 8A.4-14 and 8A.4-15. The spectrum is based on a hard rock site (a basemat founded on competent bedrock with shear wave velocity > 1100 m/s. It is not valid for other site conditions such as sands, gravel, silt or clay. Note that the spectrum used for this analysis is slightly different from the spectrum determined in Appendix 8A.1. This analysis will be redone when a site location is determined with actual site spectrum. This analysis is only used to size the equipment and to be representative of the expected spectrum at the various potential DTS locations.

Figure 8A.4-14

Secondary Response Spectra, 46' Level, Y Direction

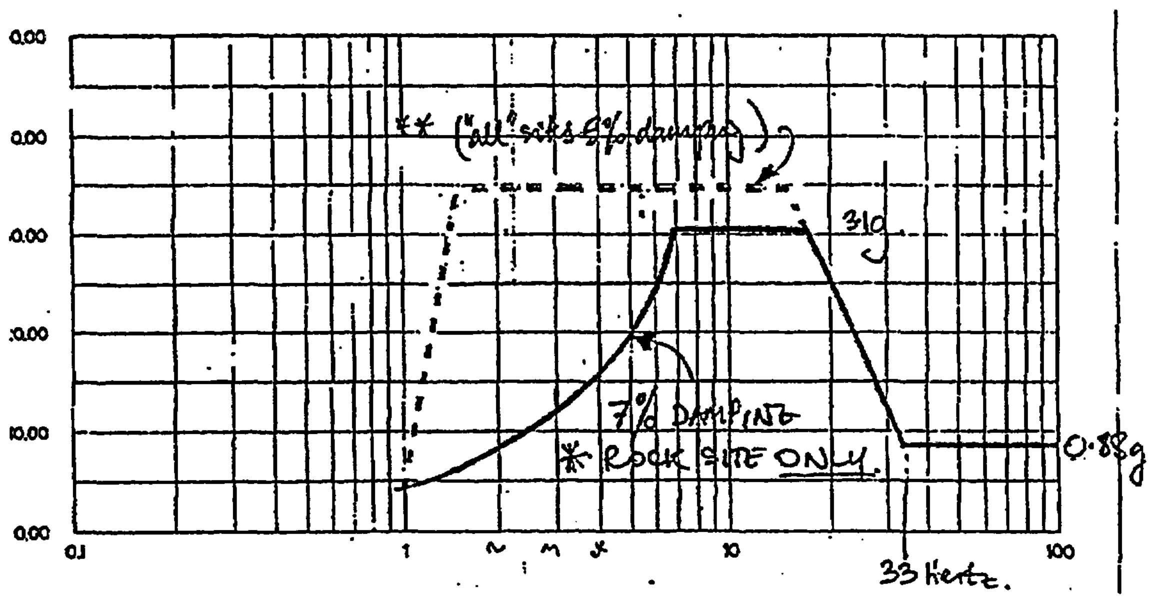
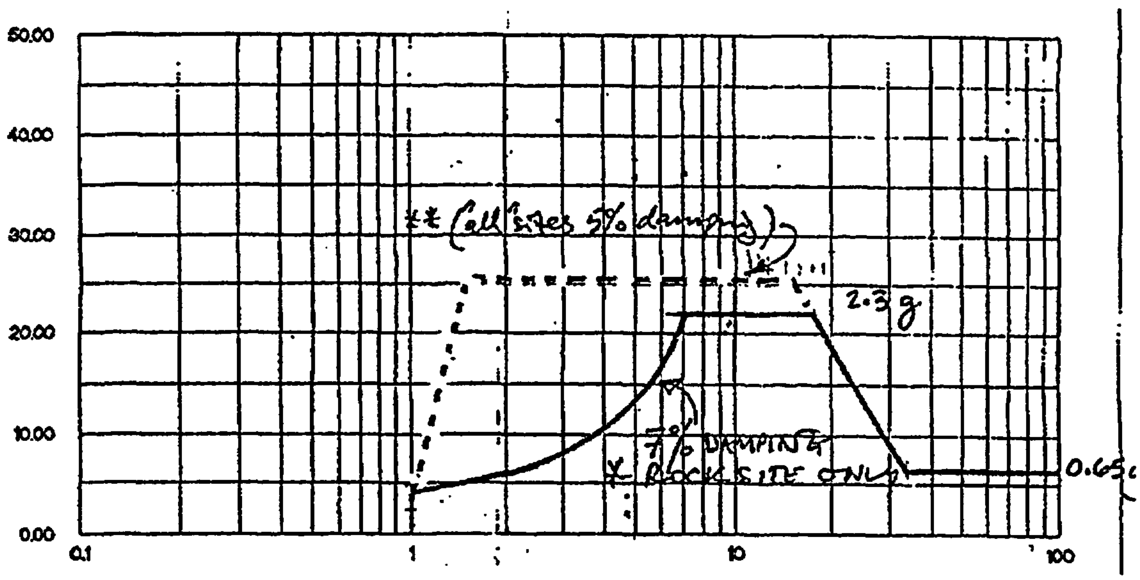


Figure 8A.4-15

Secondary Response Spectra, 46' Level, X Direction



8A.4.8 Seismic Results

The maximum stresses in the beams and plates due to load combination 1 are summarized in Table 8A.4-4. All the stresses are well below the allowable stress.

Table 8A.4-4

Seismic Stresses
Load Combination 1

Component	Maximum Tension		Maximum Shear	
	Calculated	Allowable	Calculated	Allowable
W10 x 60 with shell	25.5 MPa 3.7 ksi	186 MPa 27 ksi	18.6 MPa 2.7 ksi	103 MPa 15 ksi
W10 x 60	26 MPa 3.8 ksi	186 MPa 27 ksi	16 MPa 2.3 ksi	103 MPa 15 ksi
300 x 200 x 10	13.2 MPa 1.9 ksi	186 MPa 27 ksi	25.3 MPa 3.6 ksi	103 MPa 15 ksi
400 x 200 x 10	10.6 MPa 1.54 ksi	186 MPa 27 ksi	10.7 MPa 1.55 ksi	103 MPa 15 ksi
W 8 x 35	13.3 MPa 1.9 ksi	186 MPa 27 ksi	2.15 MPa 0.3 ksi	103 MPa 15 ksi
W 6 x 25	6.15 MPa 0.9 ksi	186 MPa 27 ksi	0.97 MPa 0.14 ksi	103 MPa 15 ksi
W14 x 550	18.7 MPa 2.7 ksi	186 MPa 27 ksi	2.5 MPa 3.5 ksi	103 MPa 15 ksi

The maximum stresses in the beams and plates due to load combination 2 are summarized in Table 8A.4-5. All the stresses are well below the allowable stress.

Table 8A.4-5

Seismic Stresses
Load Combination 2

Component	Maximum Tension		Maximum Shear	
	Calculated	Allowable	Calculated	Allowable
W10 x 60 with shell	53 MPa 7.62 ksi	186 MPa 27 ksi	8.88 MPa 1.3 ksi	103 MPa 15 ksi
W10 x 60	26 MPa 3.8 ksi	186 MPa 27 ksi	16 MPa 2.3 ksi	103 MPa 15 ksi
300 x 200 x 10	5.6 MPa 0.81ksi	186 MPa 27 ksi	11.3 MPa 1.64 ksi	103 MPa 15 ksi
400 x 200 x 10	5.22 MPa 0.75 ksi	186 MPa 27 ksi	2.56 MPa 0.37 ksi	103 MPa 15 ksi
W 8 x 35	12.9 MPa 1.87 ksi	186 MPa 27 ksi	2.07 MPa 0.3 ksi	103 MPa 15 ksi
W 6 x 25	5.96 MPa 0.86 ksi	186 MPa 27 ksi	0.94 MPa 0.13 ksi	103 MPa 15 ksi
W14 x 550	18.4 MPa 2.67 ksi	186 MPa 27 ksi	2.47 Pa .36 ksi	103 MPa 15 ksi

Combination 5 is obtained by applying the cable force from combination 1(150,000 N) to the 4 top nodes of the right and left pulley supports. These results are combined with load combination 1 to form load combination 6.

The maximum stresses in the beams and plates due to load combination 6 are summarized in Table 8A.4-6. All the stresses are well below the allowable stress.

Table 8A.4-6

Seismic Stresses
Load Combination 6

Component	Maximum Tension		Maximum Shear	
	Calculated	Allowable	Calculated	Allowable
W10 x 60 with shell	19.8 MPa 2.87 ksi	186 MPa 27 ksi	19.8 MPa 2.87 ksi	103 MPa 15 ksi
W10 x 60	39 MPa 5.6 ksi	186 MPa 27 ksi	17.1 MPa 2.48 ksi	103 MPa 15 ksi
300 x 200 x 10	13.9 MPa 2 ksi	186 MPa 27 ksi	28 MPa 4 ksi	103 MPa 15 ksi
400 x 200 x 10	10.33 MPa 1.5 ksi	186 MPa 27 ksi	4.09 MPa 0.6 ksi	103 MPa 15 ksi
W 8 x 35	21.5 MPa 3.1 ksi	186 MPa 27 ksi	2.2 MPa 0.32 ksi	103 MPa 15 ksi
W 6 x 25	21.6 MPa 3.1 ksi	186 MPa 27 ksi	0.96 MPa 0.14 ksi	103 MPa 15 ksi
W14 x 550	21 MPa 3 ksi	186 MPa 27 ksi	2.77 MPa 3.4 ksi	103 MPa 15 ksi

8A.4.9 Rail Deflection

The maximum deflection in the rails is obtained from combination 3 and 4. The maximum deflection with the trolley over a cask due to the trolley dead load and rated load (combination 3) is 1.063 mm. The maximum deflection from the trolley dead load only with the trolley positioned at midspan 0.08 mm. The allowable deflection, from NOG 4341 is 1/1000 of the length of the girder, or 4.9 mm. Therefore, the rail deflection is acceptable.

8A.4.10 Modal analysis

The results of the modal analysis are presented in the two following tables. Two cases are presented: the trolley at midspan and the trolley positioned over a cask.

The following information is provided:

- The first frequencies below the critical frequency
- The associated acceleration of the mode
- The dragged mass

TABLE 8A.4-7

TROLLEY WITH A MASS
(TROLLEY OVER A CASK)

Total Weight : 101.000

Nodes Reading (Direction X)

Load Step Number 1

MODE	FREQ.	ACCEL	WEIGHT	% WEIGHT CUM
	Hz	m.s-2	kg	
1	7.80	23.00	0.01	0.00
2	9.44	23.00	1.19	0.00
3	20.87	15.56	61.51	0.06
4	24.97	11.06	0.00	0.00
5	33.08	6.50	118.76	0.12
6	36.07	6.50	1280.14	1.27
7	41.55	6.50	1153.54	1.14

TABLE 8A.4-7 (Continued)

TROLLEY WITH A MASS
(TROLLEY OVER A CASK)

Total Weight : 101.000

Nodes Reading (Direction Y)

Load Step Number 2

MODE	FREQ. Hz	ACCEL m.s-2	WEIGHT kg	% WEIGHT CUM
1	7.80	31.00	300.29	0.30
2	9.44	31.00	0.05	0.00
3	20.87	21.00	0.07	0.00
4	24.97	14.94	341.31	0.34
5	33.08	8.80	3500.60	3.47
6	36.07	8.80	42.21	0.05
7	41.55	8.80	24.29	0.02

TABLE 8A.4-7 (Continued)

TROLLEY WITH A MASS
(TROLLEY OVER A CASK)

Total Weight : 101.000

Nodes Reading (Direction Z)

Load Step Number 3

MODE	FREQ.	ACCEL	WEIGHT	% WEIGHT CUM
	Hz	m.s-2	kg	
1	7.80	8.80	0.05	0.00
2	9.44	8.80	12103.00	11.98
3	20.87	4.99	61136.90	60.53
4	24.97	3.40	5.30	0.01
5	33.08	2.00	7.40	0.01
6	36.07	2.00	9.50	0.01
7	41.55	2.00	215.96	0.21

TABLE 8A.4-8

TROLLEY WITHOUT MASS (TROLLEY AT MID-SPAN)

Total Weight : 94.002

<u>Nodes Reading (Direction X)</u>

Load Step Number 1

MODE	FREQ.	ACCEL	WEIGHT	% WEIGHT CUM
	Hz	m.s-2	kg	
1	7.80	23.00	0.00	0.00
2	16.49	23.00	0.00	0.00
3	19.63	17.49	31.62	0.03
4	24.97	11.06	0.02	0.00
5	27.34	9.30	46.23	0.05
6	29.40	8.10	1.63	0.00
7	38.76	6.50	84.29	0.09

TABLE 8A.4-8 (Continued)

TROLLEY WITHOUT MASS
(TROLLEY AT MID-SPAN)

Total Weight : 94.002

Nodes Reading (Direction Y)

Load Step Number 2

MODE	FREQ.	ACCEL	WEIGHT	% WEIGHT CUM
	Hz	m.s-2	kg	
1	7.80	31.00	300.61	0.32
2	16.49	31.00	3875.72	4.12
3	19.63	23.00	0.09	0.00
4	24.97	14.94	315.64	0.34
5	27.34	12.57	0.45	0.00
6	29.40	10.96	55.28	0.06
7	38.76	8.80	0.09	0.00

TABLE 8A.4-8 (Continued)

TROLLEY WITHOUT MASS
(TROLLEY AT MID-SPAN)

Total Weight .: 94.002

Nodes Reading (Direction Z)

Load Step Number 3

MODE	FREQ.	ACCEL	WEIGHT	% WEIGHT CUM
	Hz	m.s-2	kg	
1	7.80	8.80	0.01	0.00
2	16.49	8.25	0.50	0.00
3	19.63	5.69	61370.60	65.29
4	24.97	3.40	0.99	0.00
5	27.34	2.80	4682.92	4.98
6	29.40	2.40	34.02	0.04
7	38.76	2.00	19.09	0.02

8A.4.11 Evaluation of the Cables and Pulleys

There are 8 parts to the cable.

The static load is the limiting case, due to the safety factor of 10 on ultimate strength. The maximum credible critical load, P_{cl}= Mg = 70,000 N.

The rope efficiency, η, is 0.94.

The number of parts to the rope is 2 x 4 = 8. The force on the rope is therefore:

$F = P_{cl} / n\eta = 9{,}308$ N
k = the shape factor = 0.57
σ_u = 1770 MPa
The minimum required cable diameter is:

$$d_{min} = \sqrt{(10F/(k\pi\sigma_u/4)} = \sqrt{(93{,}080)/((0.57)(1770)\ \pi/4)} = 10.7 \text{ mm}$$

The cable is 12 mm in diameter. Therefore, the cable is acceptable.

From NOG-5427.1, the pitch diameter of all sheaves except equalizer sheaves shall be not less than 24 times the diameter of the hoist rope. The sheave diameter is 300 mm (11.9 in) which is > 24 x 12 = 288. Therefore the sheave diameter is acceptable.

The allowable force in the cable $P = P_{cl}\ (12/10.7)^2 = 88{,}042$ N

The safety factor is:

$SF = P/P_{cl} = 1.25$

8A.4.12 Wheel Analysis

The wheels are sized using the static case plus the impact load during lifting. The bridge rail dimensions are shown in Figure 8A.5-16. The effective width of the rail head is 37 mm (1.45 in.) The diameter of the wheel is 139 mm (5.5 in.) The allowable wheel load is taken from from NOG-5452.3:

$$P_a = KbD \text{ (lbs)} \qquad (18)$$

where $K = 1300\ (BHN/260)^{0.333} = 1393$
b = the effective width of the rail head
D = diameter of the wheel.

Therefore P_a = (1393)(1.45)(5.5) = 11,109 lbs.

The actual load is $P = (M_t + 1.15\ M_l)g$ (19)

where M_t is the mass of the trolley and M_l is the mass of the rated load. G is 9.81 m/s^2.

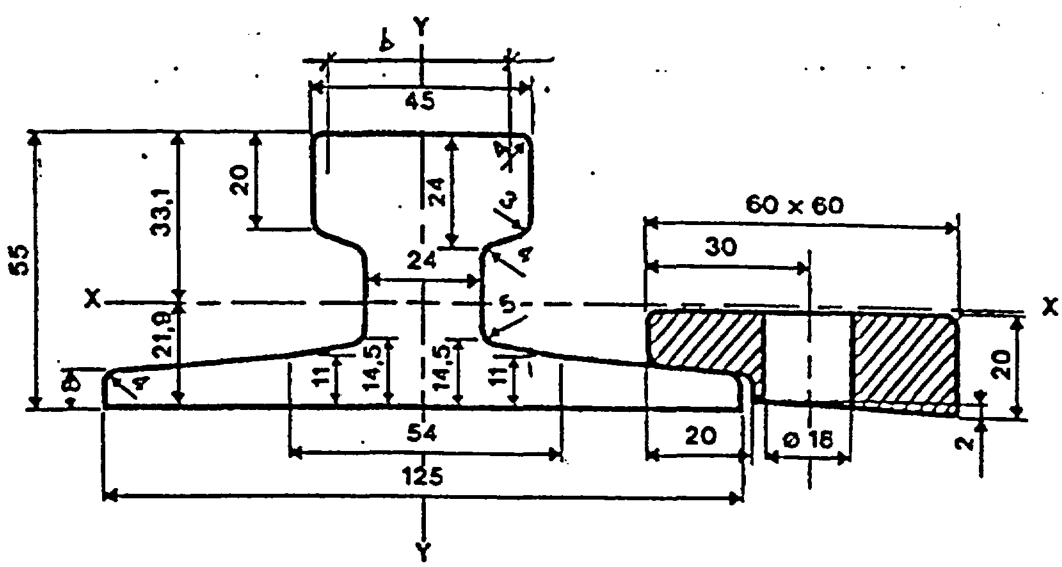
Then P = 100,500 N = 22,157 lbf.

The operational load is equally distributed between the four wheels. Therefore each wheel takes a load of P/4 = 25,125 N = 5,540 Lbf.

The safety factor is therefore 11,109/5,540 = 2.

Figure 8A.4-16

Rails BURBACH KS22-A45



8A.4.13 Evaluation of Guidance Rollers

The guidance rollers are calculated using the impact load in the transverse direction. The lateral rail width is 13 mm = 0.51 in. The roller diameter is 1.4 in (36 mm). The allowable load is taken from from NOG-5452.3:

$$P_a = KbD \text{ (lbs)}$$

where $K = 1300\ (BHN/260)^{0.333} = 1393$
b = the effective width of the rail side
D = diameter of the roller.

Therefore $P_a = (1393)(1.4)(0.51) = 994$ lbs.

The actual load is P = 5% (weight of trolley + rated load) = $0.05(M_t + M_l)g$
where M_t is the mass of the trolley and M_l is the mass of the rated load. G is the 9.81 m/s^2.

Then P = 4500 N = 992 lbf.

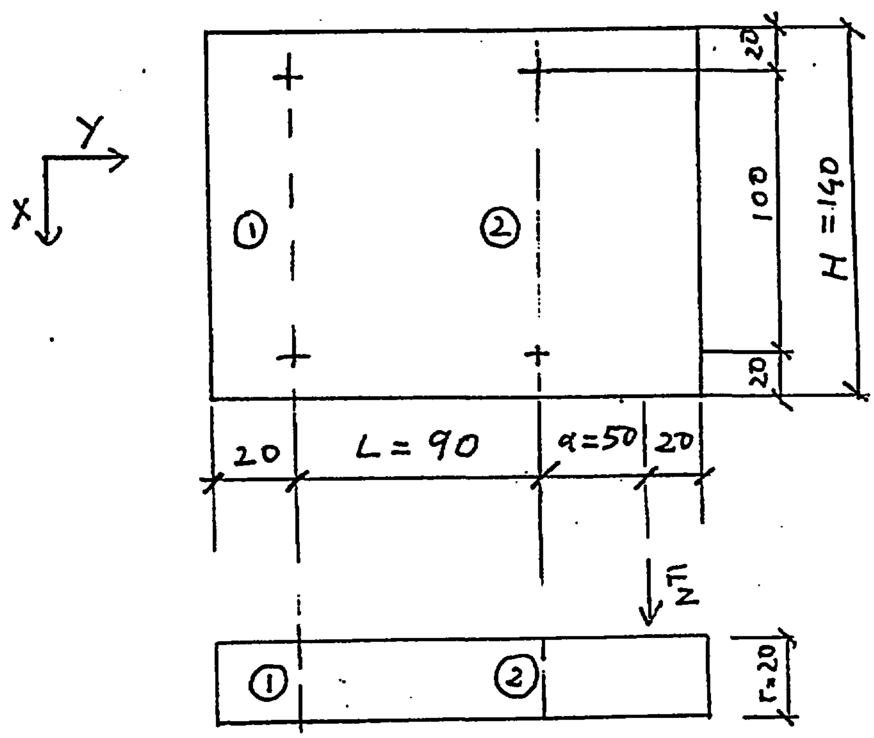
The operational load is equally taken by the two guidance rollers. Therefore for each roller Fx = p/2 = 2250 N = 496 lbf. The safety factor is therefore 994/496 = 2.0.

8A.4.14 Evaluation of the Anti-Taking Off Device (of the Bridge)

To evaluate the anti-taking off devices, the static and seismic reactions must be added. The maximum reaction force from the seismic analysis is used. This occurs for the load combination with the trolley above a cask opening. The force F_z = 3,731 N (Node 439). The maximum bending moment in the plate occurs along the plane 2-2 in Figure 8A.4-17. The bending moment = $F_z a$ = (3,731)(50 mm) = 187 N-m. The maximum bending moment in the plate is at the plane 2-2.

Figure 8A.4-17

Dimensions of Anti-Taking Off Device



The maximum bolt tension is on the two bolts at 2. The bolts are M16, made from A193 Gr B7 steel. The cross sectional area of each bolt is 157 mm^2. The force in each bolt is F_b:

$$F_b = F_z\,(L+a)/2L = (3{,}731)(140)/180 = 2{,}902\ N$$

The tensile stress in the bolt is therefore:

$$\sigma = F_b\,/A_b = 2902/157 = 19\ MPa \leq 0.5\,\sigma_u\,/1.2 = 287\ MPa = 41.6\ ksi$$

The safety factor is SF = 287/19 = 15.

The section modulus of the plate is: $S = (H\text{-}2{*}18)t^3/6t = 6{,}900\ mm^3$ where the thickness of the plate, t = 20 mm = 0.8 in.

The bending stress is $\sigma = M/S = 187\ mN/6{,}900\ mm^3 = 27\ MPa = 3.9\ ksi$. This is well below the allowable stress of 186 MPa. The safety factor is 186/27 = 6.8.

8A.4.15 Evaluation of the Anti-Derailing Devices

The anti-derailing device is the lateral stop on the rail and is fixed to the trolley. There are four anti-derailing devices on the trolley. To calculate the stresses on the anti-derailing device, the maximum lateral force is needed. This is obtained from the seismic analysis. The lateral force is extracted from the ANSYS output.

The maximum force is F_y = 59,848 lbs and is obtained from load combination 1 with the trolley positioned above the cask, at node 1178.

A sketch of the anti-derailing device is shown in Figure 8A.4-18.
The static equations are as follows:

$$R_A = F_Y$$
$$R_A\,(15/2) + F_Y * C - R_B{*}a/2 = 0 \quad \text{(Summing moments about 0')}$$

Therefore:

$$R_C = R_B = F_Y\,(C + 15/2)/(a/2) = 67{,}329\ N \text{ for } C = 60\ mm$$

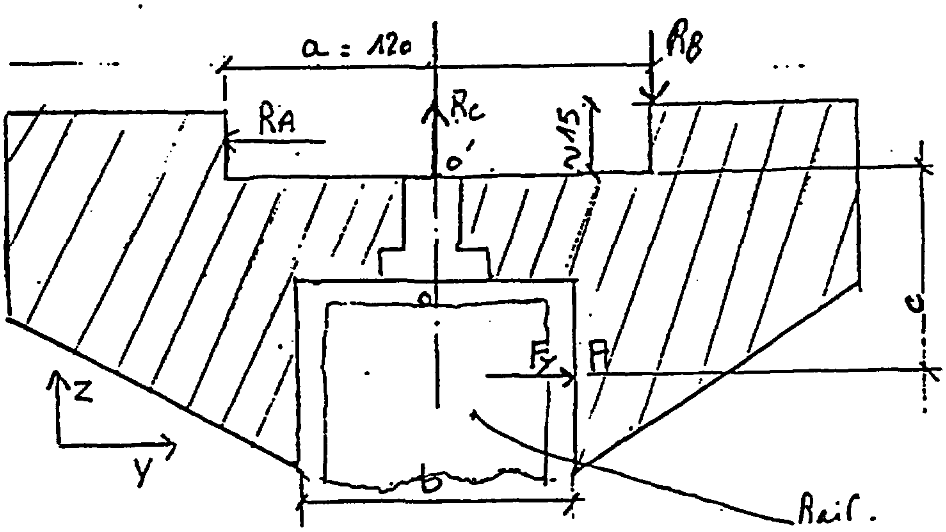
Two M16 bolts hold the anti-derailing device in place. The tensile force in each bolt is

$$F_b = R_C\,/2 = 33{,}665\ N$$

The tensile stress in each bolt is $\sigma_b = F_b/A_b = 215\ MPa = 31.1\ ksi < 287\ MPa = 41.6\ ksi$. The cross sectional area of each bolt is 157 mm^2. The safety factor is 287/215 = 1.3.

Figure 8A.4-18

Anti-Derailing Device



8A.4.16 Evaluation of the Fingers and Axis of the Grapple

Seismic Loads

The forces are taken from the ANSYS seismic analysis. For conservatism, the force is assumed to be carried by only two of the four fingers. The vertical force Fz is taken from the ANSYS model and is 150,000 N. This is the maximum force at the finger location for all positions analyzed. The mass used in the ANSYS analysis is 7000 kg.

The following masses are taken into account:

m_p = 3000 kg = mass of the shield plug
m_o = 1500 kg = mass of the overlid

The fingers and axis are all made from A36 forged carbon steel, with the following minimum properties:

yield strength, σ_y	36 ksi (248 MPa)
ultimate strength, σ_u	58 ksi (399 MPa)

The allowable stress is $0.9\ \sigma_y/1.2 = 186$ MPa = 27 ksi. Note that an additional safety factor of 1.2 has been added to allow for uncertainties in the dimensions. The shear stress allowable is $0.5\ \sigma_y/1.2 = 103$ MPa = 15 ksi.

The mass of the plug and overlid is less than that used in the ANSYS analysis. Therefore, the force is corrected below.

$$F_z = F_z(\text{computed}) \times m/m_T$$

where m is the mass of the system and m_T is the mass used in the analysis (7000 kg).

Pintle of the plug

The maximum force on the pintle of the plug due to seismic loading is:

$$F_z = 150{,}000 \times m_p/m_T = 150{,}000 \times 4500/7000 = 96{,}429 \text{ N}$$

Static Load

For a nonredundant lift, a safety factor of 6 to yield and 10 to ultimate is used. For this component, the ultimate strength is limiting.

The maximum force in the static case including a factor of 10 to ultimate strength for a nonredundant lift is:

$$F = 4500 \times 9.81 \times 10 = 4.41 \times 10^5 \text{ N}$$

Using the loading from the seismic analysis, and assuming that the load is handled by 2 fingers, the force on one finger is:

$$T = F_z / 2 = 2.2 \times 10^5 \text{ N}$$

The axis of the grapple is 30 mm.
The cross sectional area is therefore 707 mm^2. The shear force in the pin is:

$$F = T/2 = 1.1 \times 10^5 \text{ N (because the axis is a rod supported at the ends)}$$

The shear stress is:

$$\tau = F/A = 1.1 \times 10^5 / 707 = 156 \text{ MPa} = 22.6 \text{ ksi} \leq 200 \text{ MPa} = 29 \text{ ksi}$$

The safety factor is SF = (200/156)*10 = 12.8

A sketch of a finger is shown below. The following lengths are used for the finger:

L2 = 60 mm = 2.4 in
L1 = 30 mm = 1.2 in.
L3 = 30 mm = 1.2 in.
t = 60 mm = 2.4 in.
b ≈ 20 mm = 0.8 in.

The shear stress in the L1 section is:

$$\tau = T/L_1 t = (2.2 \times 10^5)/(30*50) = 147 \text{ MPa} = 21 \text{ ksi} \leq 200 \text{ MPa} = 29 \text{ ksi}$$

The shear stress in the L3 section is:

$$\tau = T/L_3 t = (2.2 \times 10^5)/(30*50) = 147 \text{ MPa} = 21 \text{ ksi} \leq 200 \text{ MPa} = 29 \text{ ksi}$$

The tensile and bending stress in the L2 section is:

$$\sigma = T/L_2 t + M/S$$

where $M = T(b + L_2 /2) = (2.2 \times 10^5)(20 + 30) = 1.1 \times 10^4$ mN

and $S = tL_2^2/6 = (60)(60)^2/6 = 36\ cm^3$

Then $\sigma = (2.2 \times 10^5)/(60*60) + 1.1 \times 10^4 / 36 =$ 367 MPa = 53.2 ksi ≤ 399 MPa = 58 ksi

The safety factor on the maximum stress is:

SF = 399 x 10 / 367 = 10.9

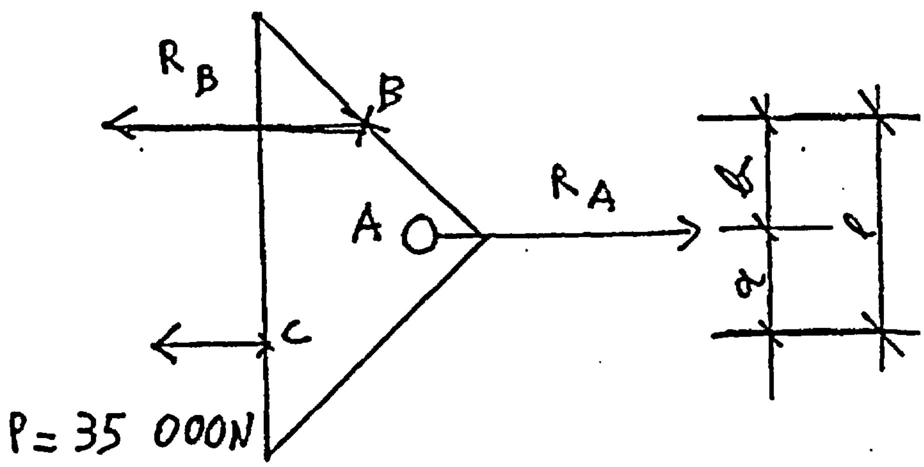
8A.4.17 Compensator Axis Analysis

The maximum force on the compensator axis occurs in the event of a cable breaking combined with the seismic load. The compensator is shown conceptually in Figure 8A.4-18.

R_A is the reaction on the compensator axis. R_B is the reaction at point B. P is the maximum force on the cable. It is exerted only at point C. The compensator is supported on B on the frame of the structure.

Figure 8A.4-19

Sketch of Compensator



Summing the forces:

$$R_A + R_B = P$$

Summing the moments:

$$P(a + b) - R_A b = 0$$

Then, $R_A = P(a + b)/b$

For the case of the broken cable:

$P = Mg/2 = 35{,}000$ N
where M is the mass of the rated load = 7,000 kg
$g = 10$ m/sec^2

Then R_A = 105,000 N = 23,147 lbf.

The diameter of the compensator axis D = 40 mm = 1.6 in.
The cross sectional area of the axis is 1,256 mm^2.

There are two shear areas on the axis. Therefore the shear stress is:

$$\tau = R_A/2S = 42 \text{ MPa} = 6.1 \text{ ksi} \leq 0.45\sigma_y/1.2 = 93 \text{ MPa} = 13.5 \text{ ksi}$$

The safety factor is SF = 93/42 = 2.2.

The force taken from the seismic analysis is 75,000N. Therefore, the static case is limiting.

8A.4.18 Analysis of the Locking Pins

Locking Pins of the Trolley

The maximum force on the locking pin is taken from the seismic analysis. The maximum force is from load combination 1 at node 1123, where F_x = 15,600 N and at node 1178, where F_x= 17,045 N. The force on the pin is the sum of the two reactions.

$$F_p = 15{,}600 + 17{,}045 = 32{,}645 \text{ N}.$$

The diameter of the pin is D = 30 mm = 1.2 in.
The cross sectional area is A = 707 mm^2.
The shear stress is $\tau = F/A$ = 47 MPa = 6.82 ksi < $0.5\sigma_y/1.2$ = 103 MPa = 15 ksi.

The safety factor is SF = 103/47 = 2.2.

Locking Pins of the Port Covers

The pin is used to stop the port cover in the direction of the port cover railway. The covers are assumed to be rigid. The horizontal acceleration in the Y direction is a_y = 0.74 x 9.81 x 1.5 = 10.9 m/sec^2 at the 27' level and a_y = 0.88 x 9.81 x 1.5 = 13 m/sec^2 at the 46' level. The forces in the Y direction due to seismic loading are shown in Table 8A.4-9.

Table 8A.4-9

Forces on the Locking Pins

	Mass		F_y	
	US Units	Metric Units	US Units	Metric Units
Upper Shield Port Cover	1.9 tons	1700 kg	4873 lbf	22,100 N
Receiving Cask TC Port Cover	9.3 tons	9500 kg	20426 lbf	92,650 N
Source Cask TC Port Cover	6 tons	5500 kg	13217 lbf	59,950 N

The locking pins are selected such that the distance between the lower part of the port cover and the plate is less than D/2 to ensure that there is no bending moment on the pin.

Upper Shield Port Cover

The diameter of the pin D = 24 mm = 0.95 in. The cross sectional area A = 452 mm^2. Therefore, the shear stress τ = F/A = 49 MPa = 7.1 ksi. The safety factor is SF = 103/49 = 2.1.

Receiving Cask TC Port Cover

The diameter of the pin D = 40 mm = 1.6 in. The cross sectional area A = 1256 mm^2. Therefore, the shear stress τ = F/A = 48 MPa = 7 ksi. The safety factor is SF = 103/48 = 2.1.

Source Cask TC Port Cover

The diameter of the pin D = 50 mm = 2 in. The cross sectional area A = 1963 mm^2. Therefore, the shear stress τ = F/A = 47 MPa = 6.85 ksi. The safety factor is SF = 103/47 = 2.2.

8A.4.19 Summary of Results

A summary of the analysis results on the Shield Plug and Source Cask Handling Subsystem is presented in Table 8A.4-10 below:

Table 8A.4-10

Summary of Results

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Cable Diameter	Static	88,042 N	70,000 N	12 mm (0.48 in.)	1.25
Trolley Wheel Diameter	Static	11,109 lbf	5,540 lbf	139 mm (5.5 in.)	2
Rail Width	Static	11,109 lbf	5,540 lbf	37 mm (1.45 in)	2
Guidance Roller Diameter	Static	994 lbf	496 lbf	36 mm (1.4 in)	2
Anti-Taking Off Device Bolt	Seismic	287 MPa	19 MPa	16 mm dia. (0.63 in)	15
Anti-Taking Off Device Plate Thickness	Seismic	186 MPa	27 MPa	20 mm (0.8 in)	6.8
Anti-Seismic Bumper Bolt Diameter	Seismic	287 MPa	215 MPa	16 mm dia. (0.63 in)	1.3
Finger of grapple axis diameter	Static	200 MPa	15.6 MPa	30 mm (1.2 in)	12.8

Table 8A.4-10 (Continued)

Summary of Results

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Grapple finger thickness	Static	399 MPa	36.7 MPa	60 mm (2.4 in)	10.9
Compensator axis diameter	Cable Breaking	93 MPa	42 MPa	40 mm (1.6 in.)	2.2
Trolley locking pin diameter	Seismic	103 MPa	47 MPa	30 mm (1.2 in)	2.2
Upper Shield Port locking pin diameter	Seismic	103 MPa	49 MPa	24 mm (1 in)	2.1
Receiving Cask TC port cover locking pin diameter	Seismic	103 MPa	48 MPa	40 mm (1.6 in.)	2.1
Source Cask TC port cover locking pin diameter	Seismic	103 MPa	47 MPa	50 mm (2 in)	2.2

Appendix 8A.5 Fuel Handling Crane Analysis

The fuel handling crane has been analyzed using the finite element analysis program ANSYS 4.4. Certain components of the crane, such as the grapple, have been evaluated using hand calculations.

The seismic analysis is performed on the crane to ensure retention of the load and the prevention of any component from becoming a missile that would be detrimental to the DTS's safety related equipment. Seismic evaluation is performed with and without the rated load.

8A.5.1 Positions Evaluated

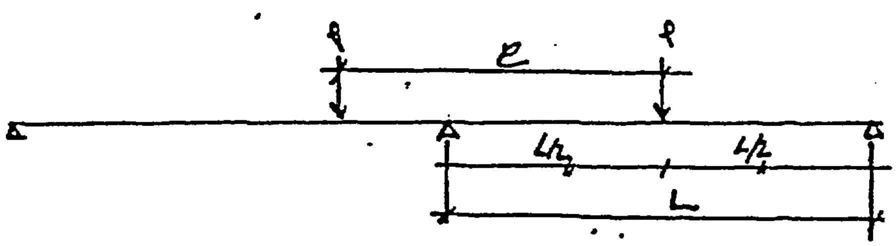
The crane and the trolley can have any position during the earthquake. This section evaluates the possible positions of the crane and trolley to determine the worst orientations for analysis.

A. Bridge Position

The bridge rails are each simply supported by three equally spaced supports, one on each end and one at the center of the beam. The position of the bridge which results in the maximum bending moment in the bridge rails is where one of the two bridge wheels is located at mid span between an end support and the center support. (See Figure 8A.5-1). This is also the position which results in the maximum force on the rail support. This position is possible provided that the distance between the 2 wheels of the bridge along the X-axis, e, is greater than or equal to 0.586L, where L is the span. For the DTS, e = 2400 mm and L = 2000 mm. Therefore, $e \geq 0.586L = 1{,}172$ mm. Therefore, the bridge is analyzed with one wheel at mid-span.

Figure 8A.5-1

Position of the Bridge Resulting in Maximum Bending



L = span

e = distance between the 2 wheels of the bridge along the X axis

B. Trolley Position

The beams supporting the trolley on the bridge are simply supported on two supports of span L. The distance between the two wheels of the trolley is e. A sketch of the forces imposed by the trolley on the beam is provided in Figure 8A.5-2. The forces applied by the trolley in any direction are approximately equally distributed. Then if $e < 0.586\ L$, for $a < b$, the maximum bending moment is at M2, where:

$$a = L/4(2-3e/L) \qquad (1)$$

and

$$M_{max} = (PL/2)(1-e/2L)^2 \qquad (2)$$

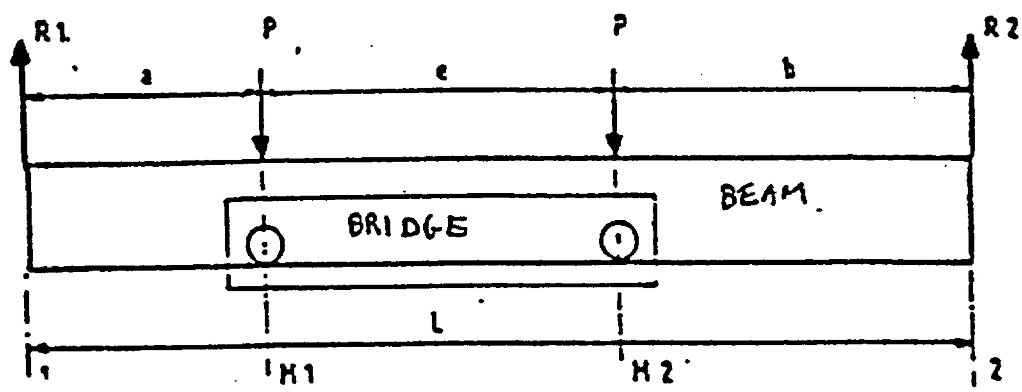
The distance between trolley wheels is e = 2.4 m = 94.5 inches. The span, L = 4.7 m = 185 in. Therefore, a = 0.55 m = 21.6 inches. The position which results in the maximum bending moment is at the position b = L - a - e = 1.75 m = 68.9 in.

The position which results in the maximum force at a support is where one wheel is at the end of the span.

Therefore, two positions of the trolley have been analyzed: a = 0.55 m = 21.6 in. and a = 0 (end of span).

Figure 8A.5-2

Forces Applied to the Trolley



C. Cable Position

The length of the cable, L, is selected such that the cable under load will have the first vertical frequency at the peak of the spectrum. This cable length will result in higher stresses than would occur if the hook were in the full up or full down position. The peak acceleration during the seismic event occurs at around 10 Hz. The weight of the load on the cable is 1500 kg = 3,300 lbs. The spring constant of the cable which would result in a natural frequency of 10 Hz is derived below:

$$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \qquad (3)$$

$$K = (2\pi f)^2 M = 5.92 \times 10^6 \text{ N/m} \qquad (4)$$

The length of the cable, L, which results in the first vertical frequency at 10 Hz is:

$$L = EA/K \qquad (5)$$

where E = the modulus of elasticity = 201,000 MPa = 29.2×10^6 psi and A = the cross sectional area of the cable. The cable is modeled as a spar element of length = 1 meter. To get a natural frequency of 10 Hz, the area of the spar is input as A = 29.46 mm^2 = 0.046 in^2.

8A.5.2 Load Combinations

The following loads are used for the seismic evaluation. The symbols and nomenclature are taken from NOG-1.

P_{dt} = the trolley dead load
P_{db} = the bridge dead load
P_{lr} = the rated load of the crane
P_{cs} = the credible critical load with safe shutdown earthquake
$P_{e'}$ = safe shutdown earthquake load

Note that the rated load of the crane is equal to the credible critical load, $P_{cs} = P_{lr}$.

The following load combinations were evaluated for the seismic event, as specified in NOG-4140(d):

$P_{c10} = P_{dt} + P_{db} + P_{cs} + P_{e'}$ (evaluated with the trolley at 0.55 m (21.6 in.) from the end and under load - Load Combination 1)

$P_{c10} = P_{dt} + P_{db} + P_{cs} + P_{e'}$ (evaluated with the trolley at the end under load - Load Combination 2)

$P_{c11} = P_{dt} + P_{db} + P_{e'}$ (evaluated with the trolley at 0.55 m (21.6 in.) from the end and no load - Load Combination 3)

$P_{c11} = P_{dt} + P_{db} + P_{e'}$ (evaluated with the trolley at the end with with no load - Load Combination 4)

The calculations were performed with the following:

- The length of the cable was fixed to have the vertical frequency at the peak of the spectrum.

- The position of the bridge for all cases was with one wheel at mid-span.

Additionally, the girder deflection was evaluated with the trolley at 0.55 m (21.6 in.) under the maximum rated load using the following load:

$$P = P_{dt} + P_{lr} \qquad \text{(Load Combination 5)}$$

8A.5.3 Material Properties

The properties for the structural components of the crane were taken from Tables NOG-4211-1 and NOG-4221-1 of NOG-1, and are summarized below:

The plates and beams will be constructed from A36 Steel, with a minimum yield strength of 36 ksi (248 MPa) and a minimum tensile strength of 58 ksi (399 MPa).

The structural connections will be constructed from A193 Grade B7, with a minimum yield strength of 75 ksi (517 MPa) and a minimum tensile strength of 100 ksi (689 MPa).

The cable minimum ultimate strength used in the analytical model is 256.7 ksi (1770 MPa). A shape factor including the strand factor of 0.57 is used in the analysis.

8A.5.4 Design Criteria

The design criteria for the crane are taken from NOG-4300 and are repeated following.

Allowable Stresses in the beams

For compression members with an equivalent slenderness ratio:

$$kl/r < C_c = \sqrt{(2\pi^2 E/\sigma_y)} \qquad (6)$$

where E = modulus of elasticity
σ_y = the yield point
k = effective length factor
l = length of compression member
r = radius of gyration of member
and C_c = column slenderness ratio separating elastic and inelastic buckling

The allowable axial compression stress shall not exceed the value:

$$\sigma_a = (1-((kl/r)^2 / 2C_c^2))(\sigma_y / FS) \quad (7)$$

where FS = factor of safety and the other variables are as noted above.

The required factor of safety is equal to:

$$FS = N\{5/3 + (3/8) ((kl/r)/C_c) - (1/8) ((kl/r)/C_c)^3 \} \quad (8)$$

For severe environmental loads, the value of N is 0.67. For compression members with an equivalent slenderness ratio $kl/r > C_c$, the allowable axial compression stress shall not exceed the value:

$$\sigma_a = 12\pi^2 E / (23N(kl/r)^2) \quad (9)$$

Members subjected to both axial compression and bending stresses shall satisfy the following requirements:

$$\sigma / \sigma_a + C_{mx} \sigma_{bx} / ((1 - \sigma/\sigma'_{ex})\sigma_{abx}) + C_{my}\sigma_{by} / ((1- \sigma/\sigma'_{ey})\sigma_{aby}) \leq 1.0 \quad (10)$$

$$\sigma / \sigma_{ac} + \sigma_{bx} / \sigma_{abx} + \sigma_{by} / \sigma_{aby} \leq 1.0 \quad (11)$$

where

$$\sigma'_e = 12\pi^2 E / (23N(kl/r)^2) \quad (12)$$

The subscripts x and y, combined with subscripts b, m, and e, indicate the axis of bending about which a particular stress or design property applies; and σ_a , σ_{ab} are the allowable axial and bending stresses respectively.

The l is the actual unbraced length in the plane of bending, r is the corresponding radius of gyration, K is the effective length factor in the plane of bending and N is the loading condition factor, 0.67 for extreme environmental loading.

C_m is a coefficient whose value is:

(a) $C_m = 0.85$ for compression members in frames subject to joint translation;
(b) $C_m = 0.6 - 0.4 (M_1 /M_2)$ but not less than 0.4 for restrained compression members in frames braced against joint translation and not subject to transverse

loading between their supports in the plane of bending. M_1/M_2 is the ratio of the smaller to the larger moments at the ends of that portion of the member unbraced in the plane of bending under consideration.

(c) For compression members in frames braced against joint translation in the plane of loading and subjected to transverse loading between their supports, $C_m = 0.85$ for members whose ends are restrained, and $C_m = 1.0$ for members whose ends are unrestrained.

If $\sigma/\sigma_a \leq 0.15$, then only equation (11) needs to be evaluated.

Members subjected to both axial tension and bending stresses shall satisfy equation (11). The computed bending tensile stress, taken alone, shall not exceed the $0.9\sigma_y$.

The maximum allowable shear stress under seismic load is $0.5\ \sigma_y$.

An additional factor of 1.2 is applied to all stresses to account for uncertainties since the loading may change from site to site.

For the beams, which are made from A36 steel:

The tensile stress allowable is:

$$F/A + M_{bx}x/I_x + M_{by}y/I_y < 0.9\ \sigma_y/1.2 = 186 \text{ MPa} = 27.0 \text{ ksi} \qquad (13)$$

The shear stress allowable is $0.5\sigma_y/1.2 = 103$ MPa = 15 ksi.

<u>Allowable stresses in Bolts</u>

The allowable stresses in the bolts are taken from NOG-4513. For seismic loading, the maximum allowable tensile load is $0.5\ \sigma_u$, and the maximum allowable shear stress is $0.26\ \sigma_u$. For bearing type joints, the stresses shall meet the following criteria:

$$\sigma \leq 0.6\ \sigma_y R - 1.6\ \tau \qquad (14)$$

The maximum allowable tensile stress due to seismic loading, assuming an additional safety factor of 1.2 is therefore 41.6 ksi (287 MPa). The maximum allowable shear stress, assuming an additional safety factor of 1.2 is 21.6 ksi (149 MPa).

Allowable Deflections

The total vertical deflection of the girder during operational loading for the rated live load plus trolley (P_{dt} + P_{lr}), and not including impact or dead load of the girder, shall not exceed 1/1000 of the span.

Allowable stress for the Cables.

The maximum allowable stresses in the cables is governed by NOG-5425.1. The maximum critical load (without impact), plus the weight of the load block divided by the total number of parts of rope per system, shall not exceed 10% of the manufacturer's published breaking strength on the total system. The seismic load with all parts of rope intact shall not exceed 40% of the manufacturer's published breaking strength.

For the cables, σ_u = 1770 MPa = 256.7 ksi. For the static case,

$$F/KA < \sigma_u / 10 = 177 \text{ MPa} = 25.6 \text{ ksi} \quad (15)$$

K is the shape coefficient, which is taken as 0.57. $A = \pi d^2/4$.

Then:

$$d_{MIN} = \sqrt{(40F/K\pi\sigma_u)} \quad (16)$$

and

$$F = P_{cl} / n\eta \quad (17)$$

where P_{cl} = the credible critical load and the weight of the load block
n = the number of parts of the rope
η = the efficiency, which is taken as 0.94 to start.

8A.5.5 Component Weights

The following loads were used in the model of the fuel handling crane:

Beams and Rails	4000 kg	4.4 tons
Bridge	4000 kg	4.4 tons
Trolley	1500 kg	1.7 tons
Rotating Platform + Roller	4000 kg	4.4 tons
Crane Rated Load	1500 kg	1.7 tons
Total load	**15,000 kg**	**16.6 tons**

8A.5.6 Fuel Handling Crane Model

A model of the fuel handling crane was made to evaluate the crane under seismic loading. The response spectrum method was used according to the requirements of NOG 4153.1. The response of the crane to the input response spectra in three directions was determined on a modal basis. An ANSYS model was used to perform the analysis. The program searches the frequency and the modal participation factor up to the cutoff frequency (around 33 Hz). If the sum of the participation of the mass is less than 90% in a direction, the program is completed with the equivalent static component in this direction. The residual mass is affected with the acceleration of the cutoff frequency in this direction.

The dynamic responses of the structure are combined using the "grouping method" in accordance with NOG 4153.10. The three directional components of the earthquake motion are combined by taking the square root of the sum of the squares of the maximum representation values of the codirectional responses caused by each of the three components of earthquake motion at each mode of the crane mathematical model.

The model consists of 900 elements and 680 nodes. The model is made up of a trolley, a vertical beam with a cable and a mass, a bridge, and rails.

Trolley Model

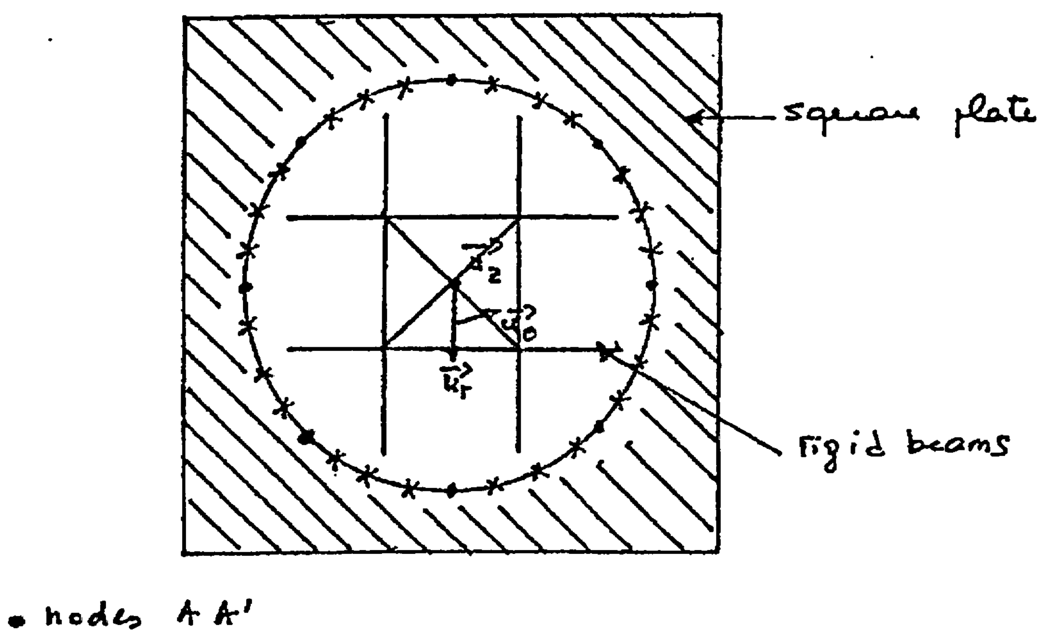
The trolley is made up of frame of beams W12 x 12 x 0.5 linked with rigid beams to a square plate with a circular centered hole receiving a rotating circular plate. See Figure

8A.5-3. The link between the circular plate and the square one is made with spring elements as shown in the figure. The circular plate is reinforced by rigid beams.

The nodes identified as AA' are coupled in the radial and vertical directions, and are free in the rotational direction. The nodes identified as BB' are coupled in the radial direction, and free in all other directions. The square plate is 3.0 inches thick and the circular plate is 3.0 inches thick.

Figure 8A.5-3

Trolley Model



Vertical Beam

The vertical beam is a square beam of 400 x 400 x 15 mm (15.75 in x 15.75 in. x 0.6 inch). It is linked with the circular plate in all degrees of freedom. The additional weight of the equipment supported by the vertical beam (crud catcher, pulleys, etc. are modeled by mass elements all along the length of the beam to get a total weight of 1.5 tons in the x and y directions. The model consists of 25 mass elements, each 57.7 kg.)

A cable with a mass of 1.5 metric tons is fixed to the beam. Since we want the cable and the mass to have a vertical frequency of 10 Hz, we model the cable using a spar element with a length of 1 meter. The cross sectional area is calculated below:

$$F = (1/2\pi)\sqrt{(k/m)} = 10 \text{ Hz} \qquad (18)$$

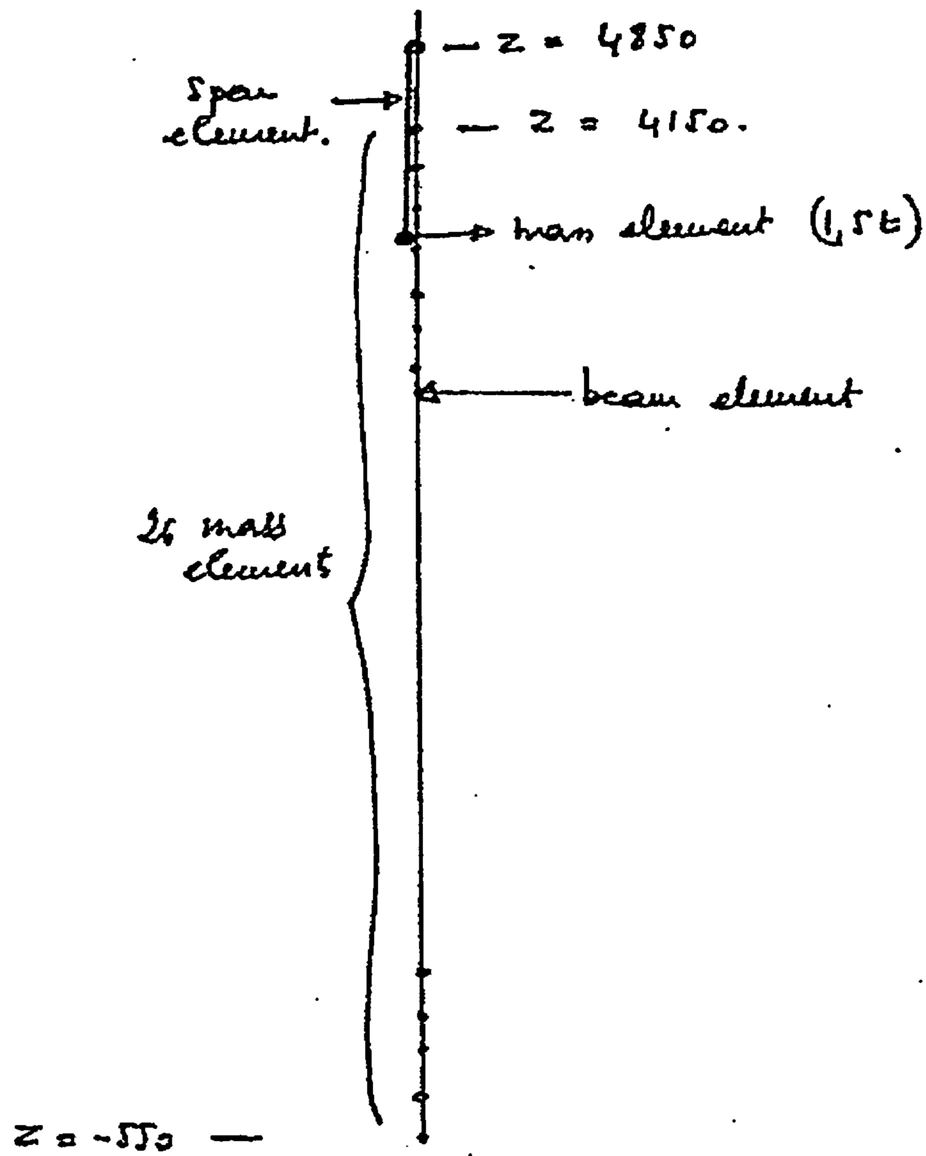
where k = EA/L
E is the modulus of elasticity of the cable
A is the cross sectional area
L is the length of the cable
and m is the mass = 1.5 metric tons
Solving equation (18) for k results in $k = 5.922 \times 10^6$ kg.

The cable has an elastic modulus, E of 201,000 MPa. Therefore the cross sectional area which results in a frequency of 10 Hz is 29.46 mm^2.

The model of the vertical beam is shown in Figure 8A.5-4.

Figure 8A.5-4

Model of Vertical Beam



Bridge

The bridge is modeled by two kinds of beams (W12 x 8 x 0.5 and W14 x 82) reinforced by 2 lateral shells.

Rails

The rails are modeled by W 12 x 96 beams reinforced by 2 lateral shells.

Material Densities

The material densities used in the model are corrected to have the following mass:

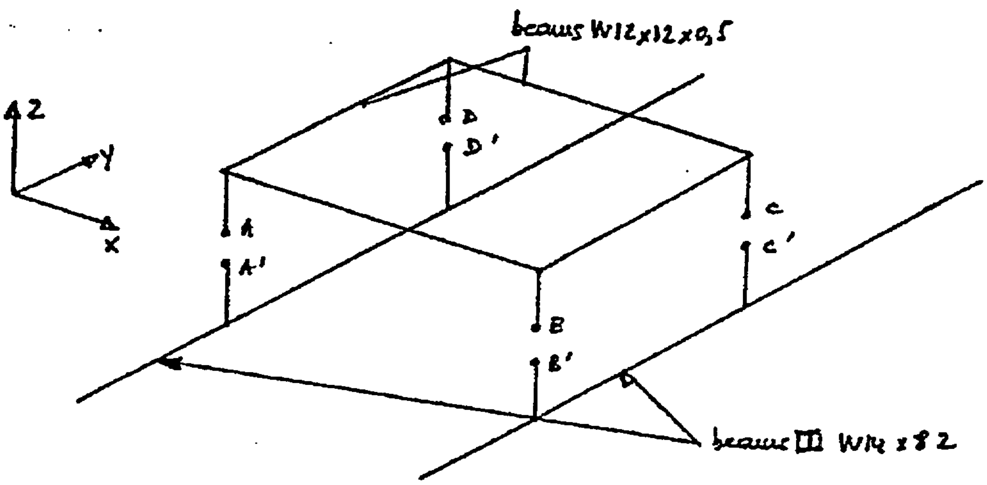
Component	**mass (kg)**
4 bridge beams	4000
Cable	negligible
Frame of the trolley	1500 kg
Rails	4000 kg
Plates (circular and square)	2000 kg
Vertical Beam	2000 kg
Mass elements	1500 kg.
Total mass	15000 kg

8A.5.7 Boundary Conditions

The bridge rails are supported by brackets. The rail nodes which contact the bracket are fixed in the x, y z and θ_x directions. To ensure that there is no instability, the mass element at the end of the cable is fixed in the x and y directions. The connection between the trolley and bridge is shown in Figure 8A.5-5.

Figure 8A.5-5

Link Between Trolley and Bridge



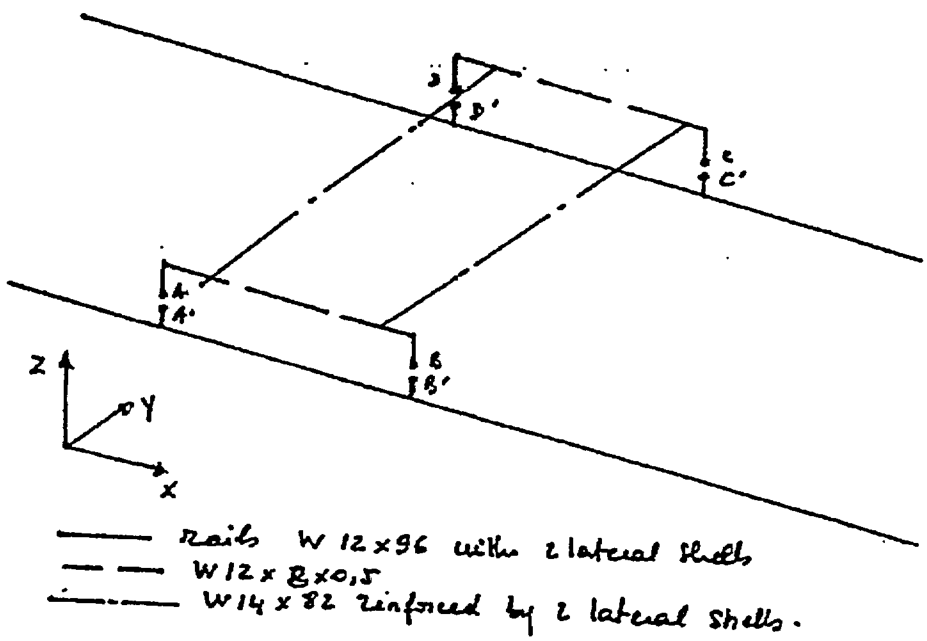
The coupled degrees of freedom are provided below:

Restraint Conditions - Trolley and Bridge Connection						
Nodes	X	Y	Z	θ_x	θ_y	θ_z
AA'	Coupled	Coupled	Coupled	Free	Free	Free
BB'	Coupled	Coupled	Coupled	Free	Free	Free
CC'	Coupled	Free	Coupled	Free	Free	Free
DD'	Coupled	Free	Coupled	Free	Free	Free

The connection between the bridge and the rails is shown in Figure 8A.5-6.

Figure 8A.5-6

Link Between Bridge and Rails



The node coupling between the bridge and the rails is summarized below:

Restraint Conditions - Bridge and Rail Connection						
Nodes	X	Y	Z	θ_x	θ_y	θ_z
AA'	Free	Coupled	Coupled	Free	Free	Free
BB'	Coupled	Coupled	Coupled	Free	Free	Free
CC'	Coupled	Free	Coupled	Free	Free	Free
DD'	Free	Free	Coupled	Free	Free	Free

The model and boundary conditions of the trolley positioned at 550 mm is shown in Figures 8A.5-7 and 8A.5-11. The model of the trolley positioned at the end is shown in Figures 8A.5-12 through 8A.5-14. The boundary conditions for this case are identical to those for the trolley positioned at 550 mm.

The accelerations due to the seismic event used for evaluation of the fuel handling crane are presented in Figures 8A.5-15 and 8A.5-16. The spectrum is based on a hard rock site (a basemat founded on competent bedrock with shear wave velocity > 1100 m/s. It is not valid for other site conditions such as sands, gravel, silt or clay. Note that the spectrum used for this analysis is slightly different from the spectrum determined in Appendix 8A1. The analysis will be redone when a site location is determined with actual site spectrum. This analysis is only used to size the equipment and to be representative of the expected spectrum at the various potential DTS locations.

Figure 8A.5-7
ANSYS Model & Boundary Conditions Trolley Positioned at 550 mm
Top View

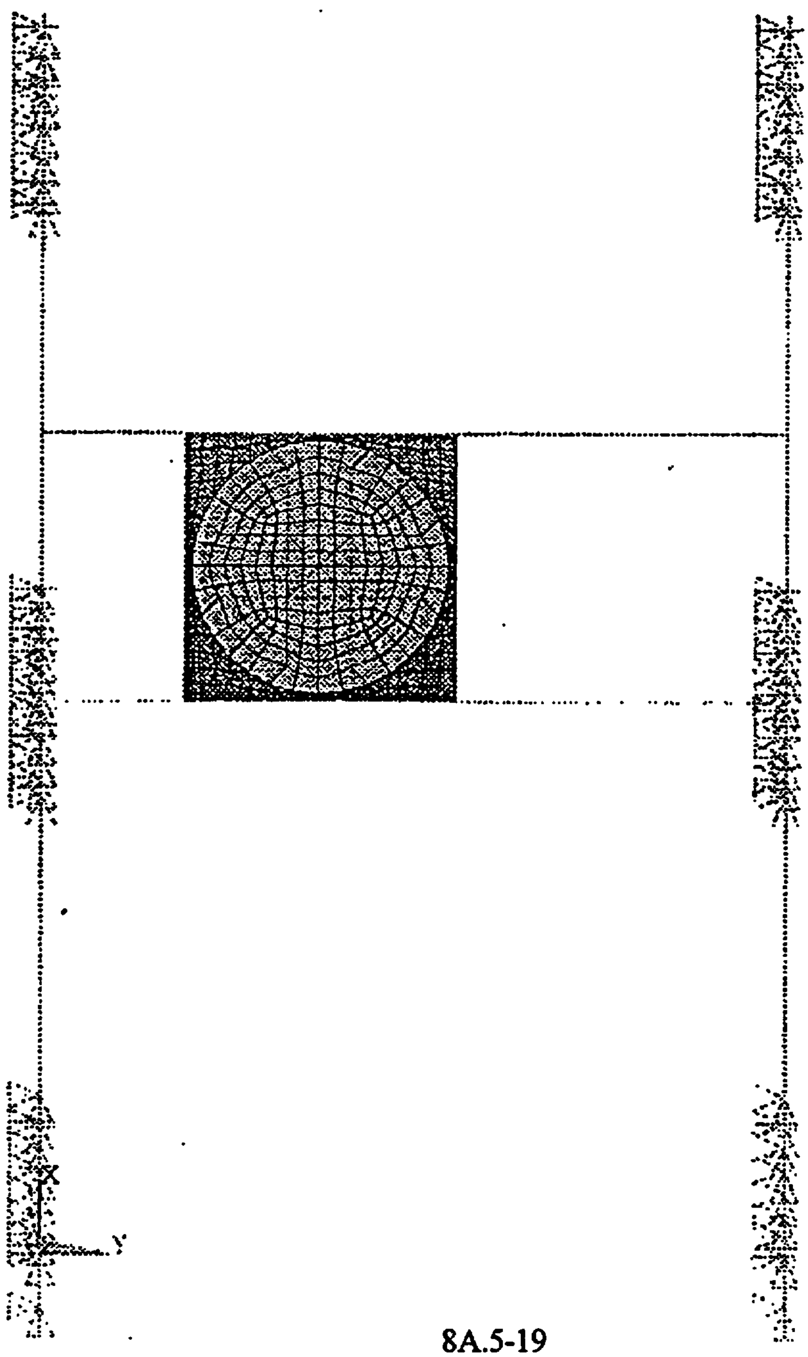


Figure 8A.5-8
ANSYS Model & Boundary Conditions
Trolley Positioned at 550 mm
Isometric View

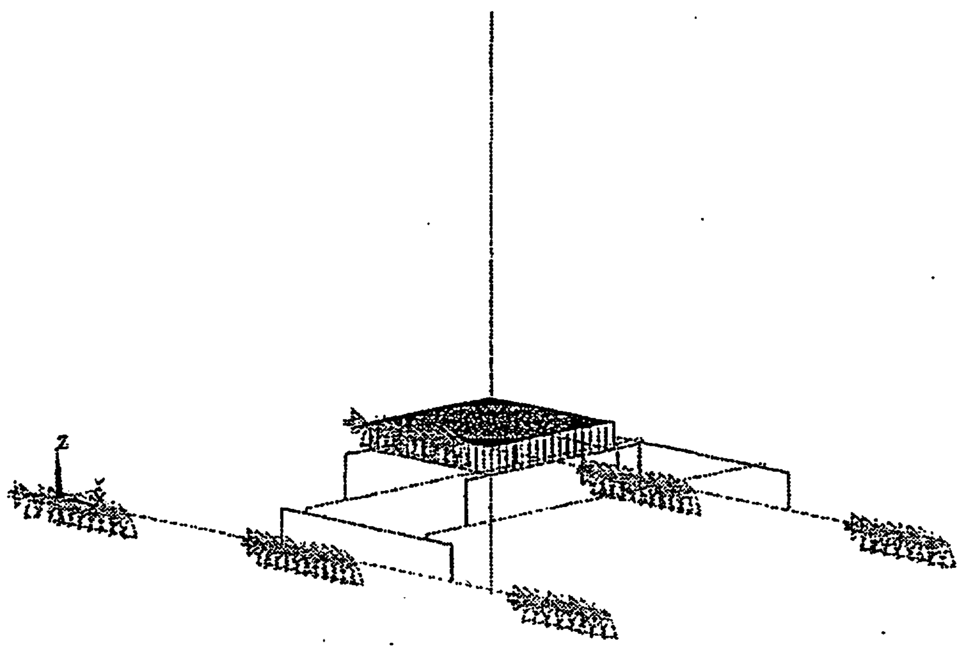


Figure 8A.5-9
ANSYS Model & Boundary Conditions
Trolley Positioned at 550 mm
SideView

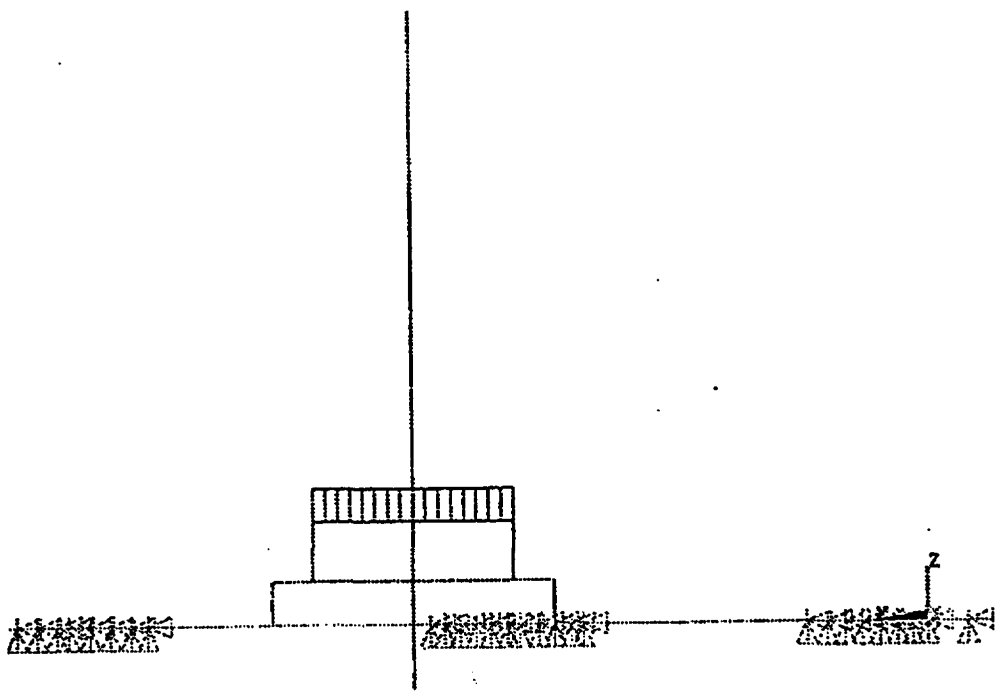


Figure 8A.5-10
ANSYS Model & Boundary Conditions
Trolley Positioned at 550 mm
End View

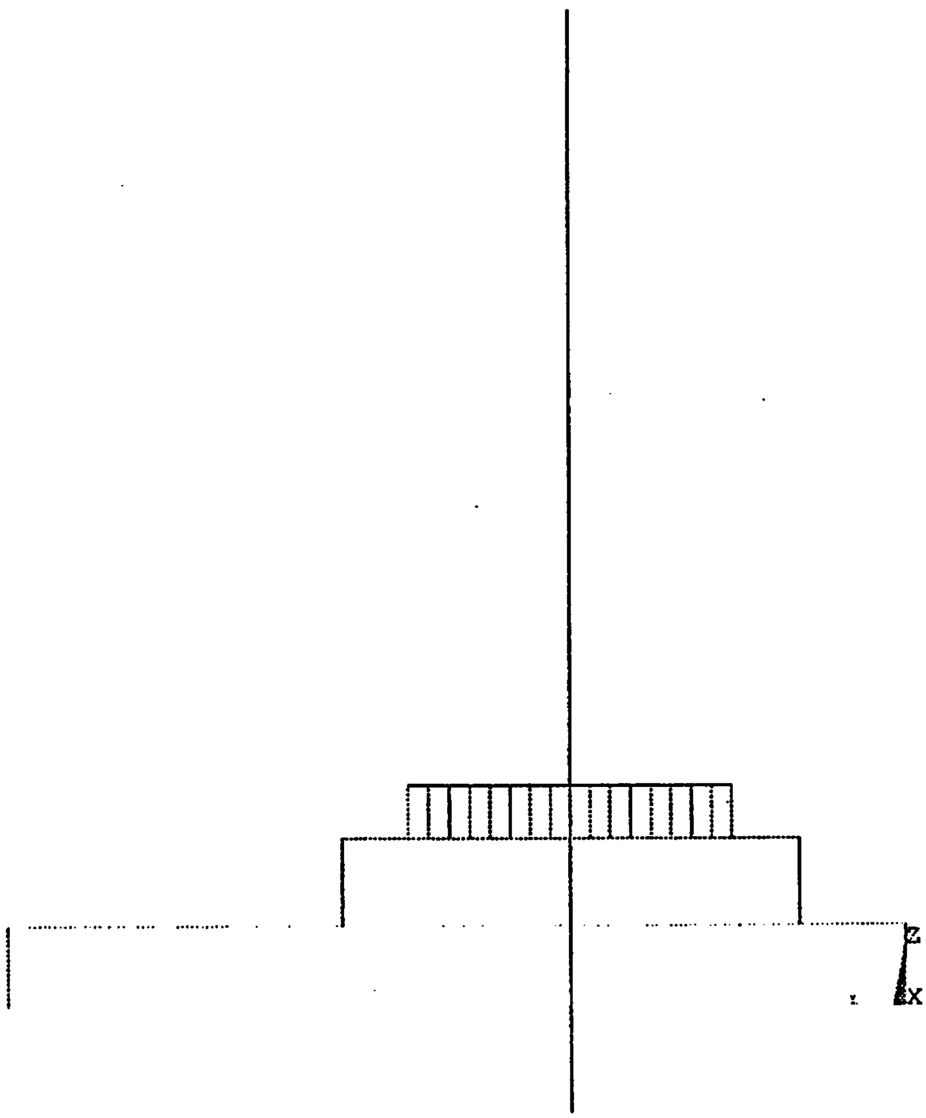


Figure 8A.5-11
ANSYS Model & Boundary Conditions
Trolley Positioned at 550 mm
Second Isometric View

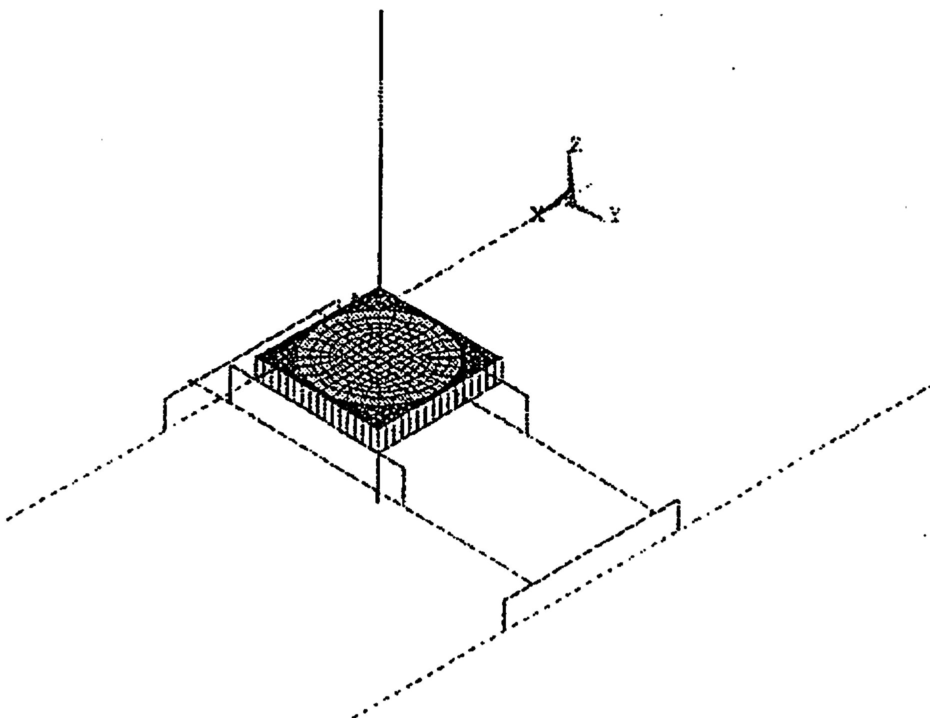


Figure 8A.5-12
ANSYS Model
Trolley Positioned at End
Isometric View from Top

1

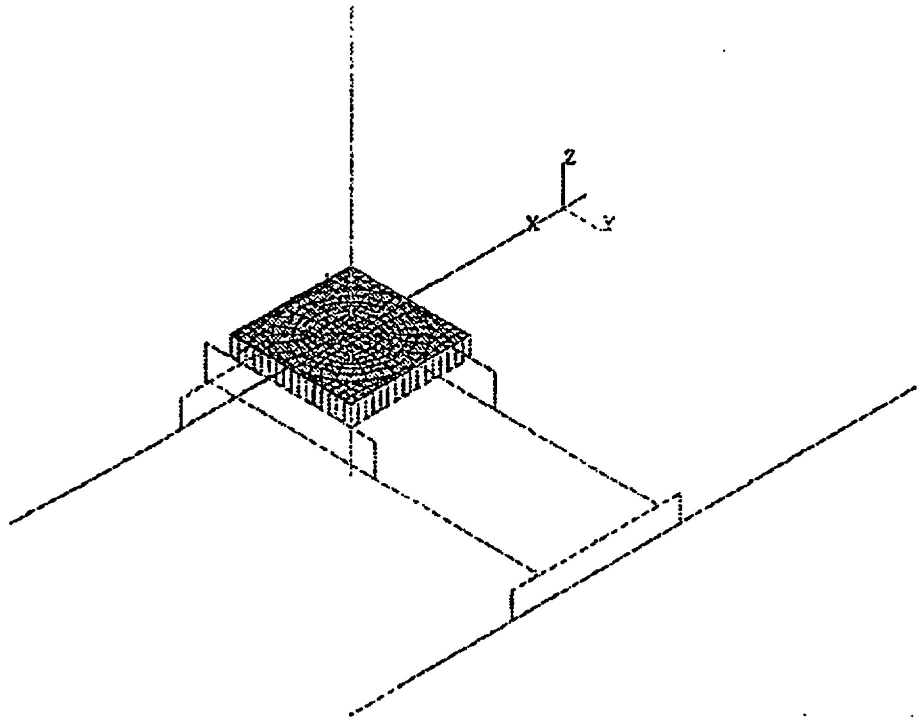


Figure 8A.5-13
ANSYS Model
Trolley Positioned at End
Isometric View from Side

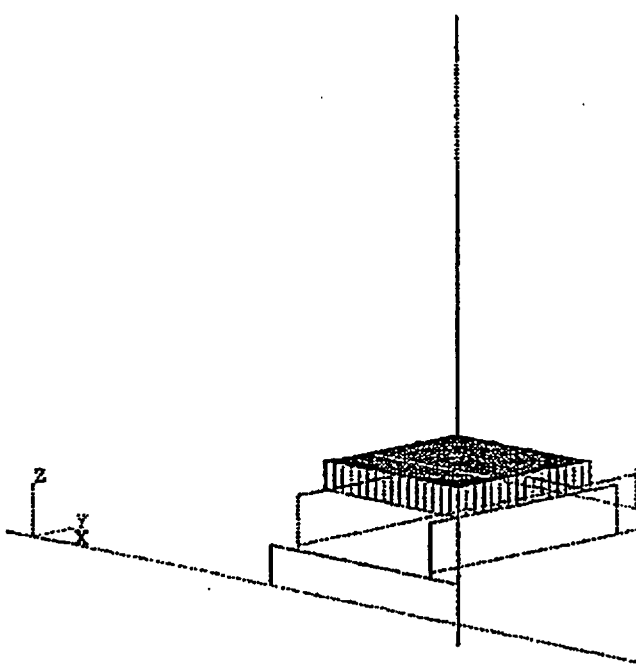


Figure 8A.5-14
ANSYS Model & Boundary Conditions Trolley Positioned at End
End View

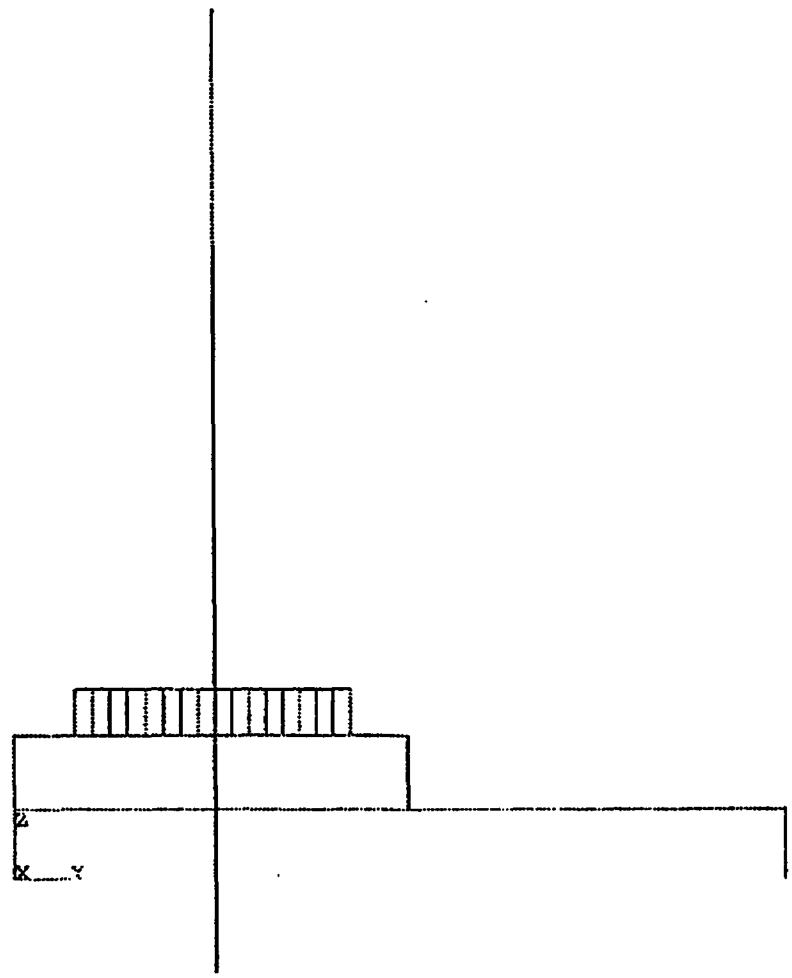


Figure 8A.5-15
Secondary Response Spectra
27" 0" Level, Y direction 7% Damping

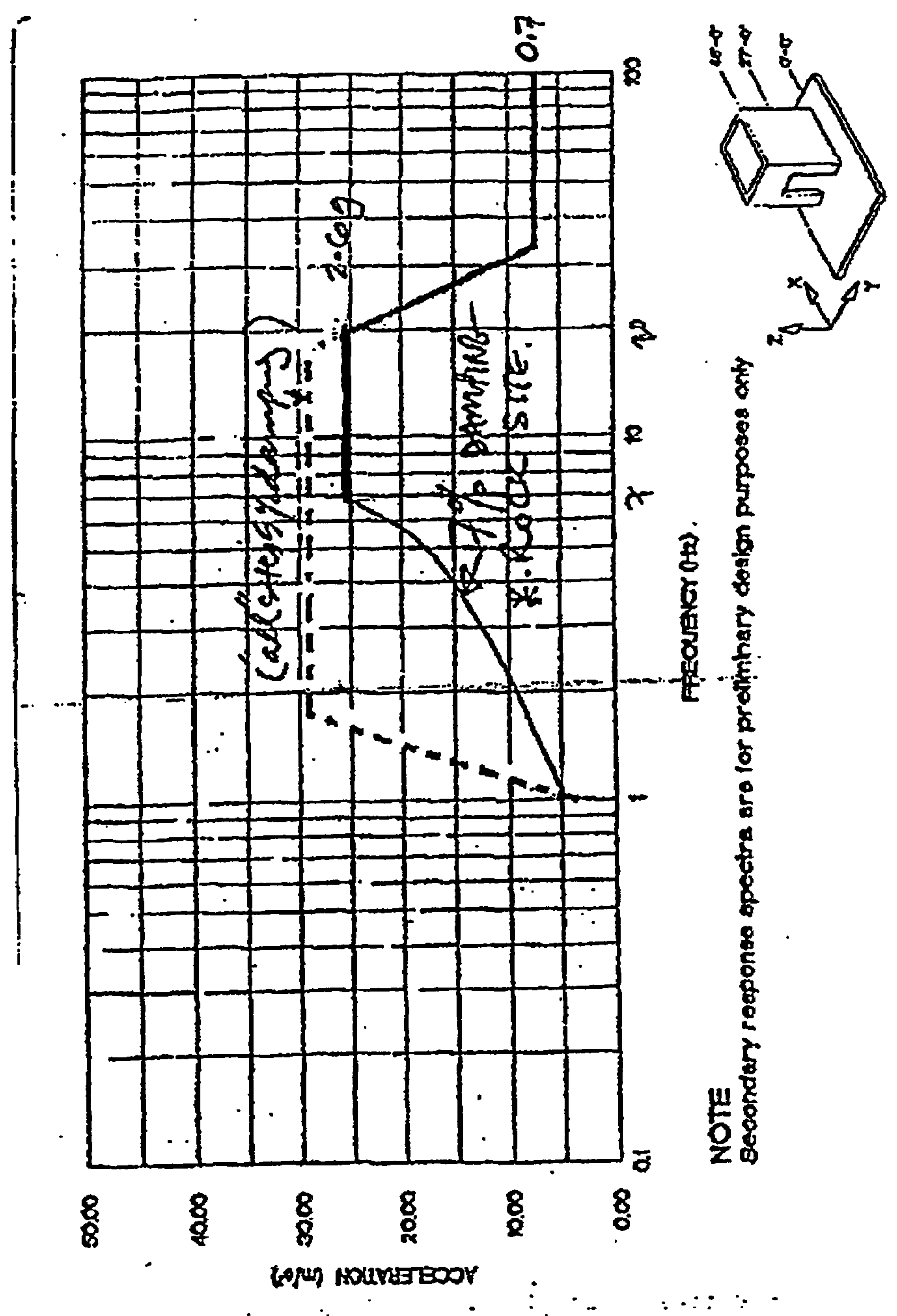
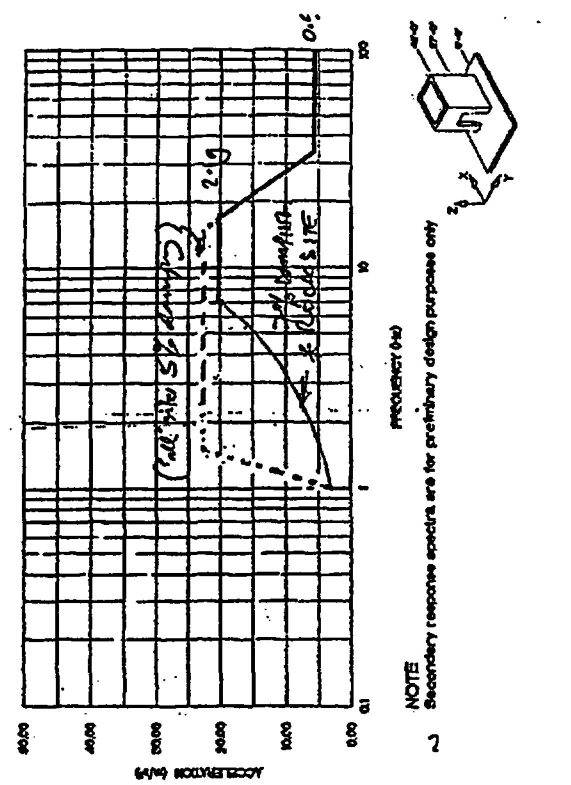


Figure 8A.5-16
Secondary Response Spectra
27" 0" Level, X direction 7% Damping



8A.5.8 Results

The stresses in the main beams due to load combination 1 are presented below in Table 8A.5-1:

Table 8A.5-1

Beam Stresses Load Combination 1
(Seismic Analysis)

Beams	**Maximum Tension**		**Maximum Shear**		**Conclusion**
	Calculated	Allowable	Calculated	Allowable	
W 14 x 82 with shell (bridge)	48.2 MPa 7 KSI	186 MPa 27 KSI	20.5 MPa 3 KSI	103 MPa 15 KSI	Acceptable
W 12 x 96 with shell (rails)	34.8 MPa 5 KSI	186 MPa 27 KSI	9.8 MPa 1.4 KSI	103 MPa 15 KSI	Acceptable
12 x 8 x 0.5 (bridge)	62 MPa 9 KSI	186 MPa 27 KSI	35.8 MPa 5.2 KSI	103 MPa 15 KSI	Acceptable
12 x 12 x 0.5 (trolley)	32.8 MPa 4.7 KSI	186 MPa 27 KSI	23.1 MPa 3.3 KSI	103 MPa 15 KSI	Acceptable
400 x 400 x 15 (fuel tube)	65.6 MPa 9.52 KSI	186 MPa 27 KSI	5 MPa 0.7 KSI	103 MPa 15 KSI	Acceptable

As shown in the Table, the stresses in the beams are well below the allowable stresses.

The forces in the links are presented in Section 8A.5.9-1. All units are metric.

The maximum stress in the plates (both the rotational table and the trolley plates) is 101 MPa (14.4 ksi). This value is well below the allowable stress of 186 MPa (27 ksi). A plot of the stresses in the plates is shown in Figures 8A.5-17 through 8A.5-20. The stresses are plotted in metric (MPa).

The reaction forces at the brackets are presented in Section 8A.5.10-1. Metric units are used. In Section 8A.5.11, the first frequencies below the critical frequency are presented.

Figure 8A.5-17

Plate Stresses
Top of Plate
Load Combination 1
Primary + Secondary Stresses

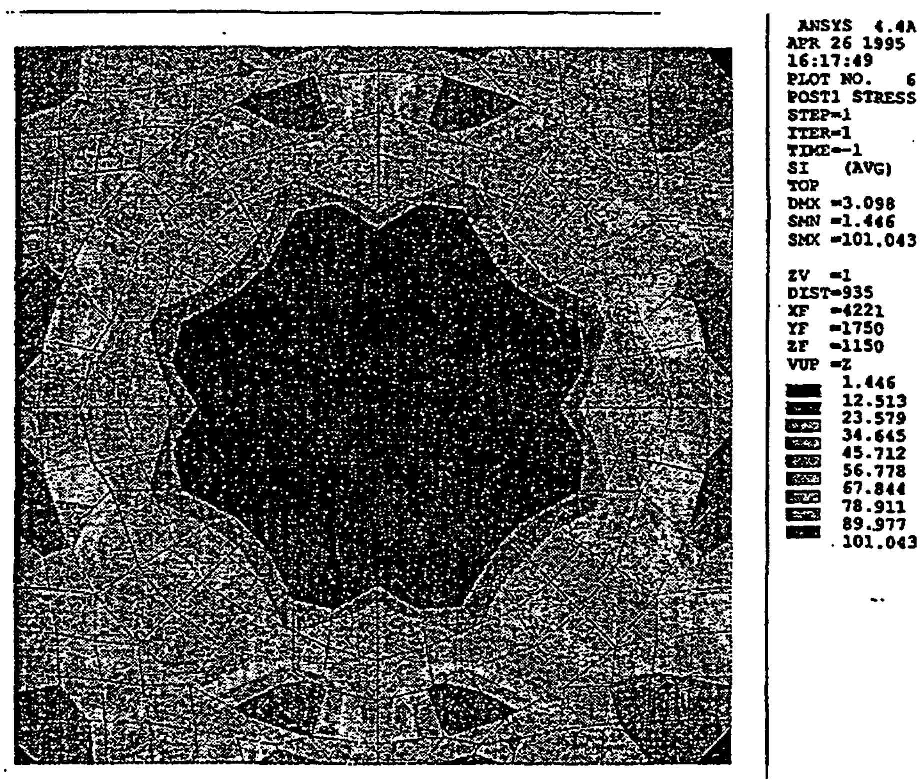


Figure 8A.5-18

Plate Stresses
Middle of Plate
Load Combination 1
Primary + Secondary Stresses

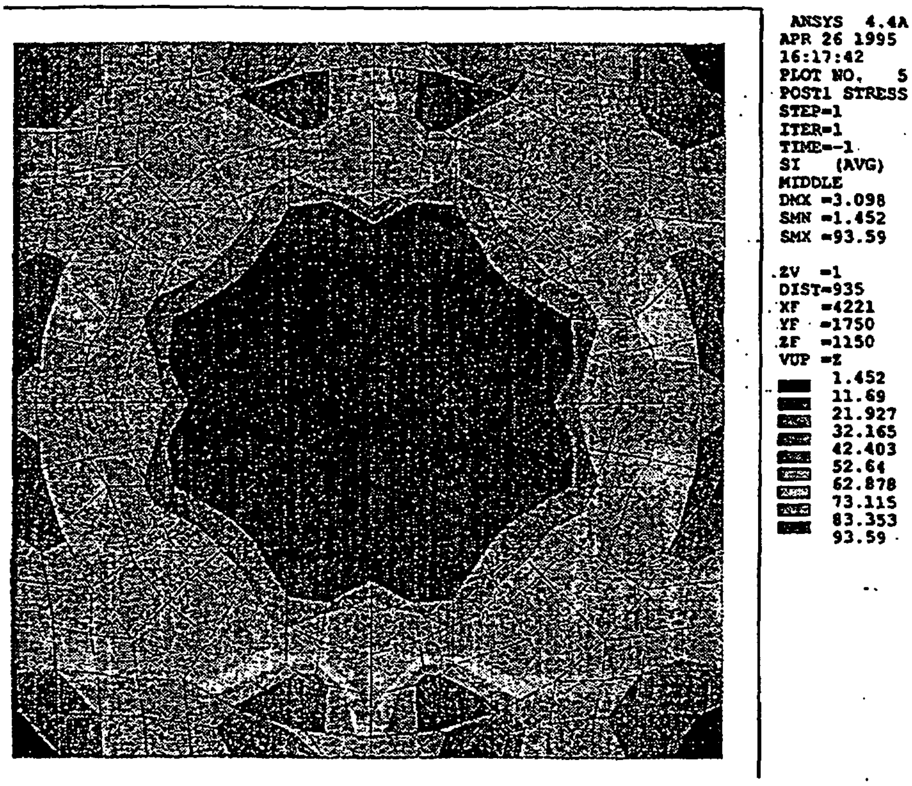


Figure 8A.5-19

Plate Stresses
Middle of Plate
Load Combination 1
Primary - Secondary Stresses

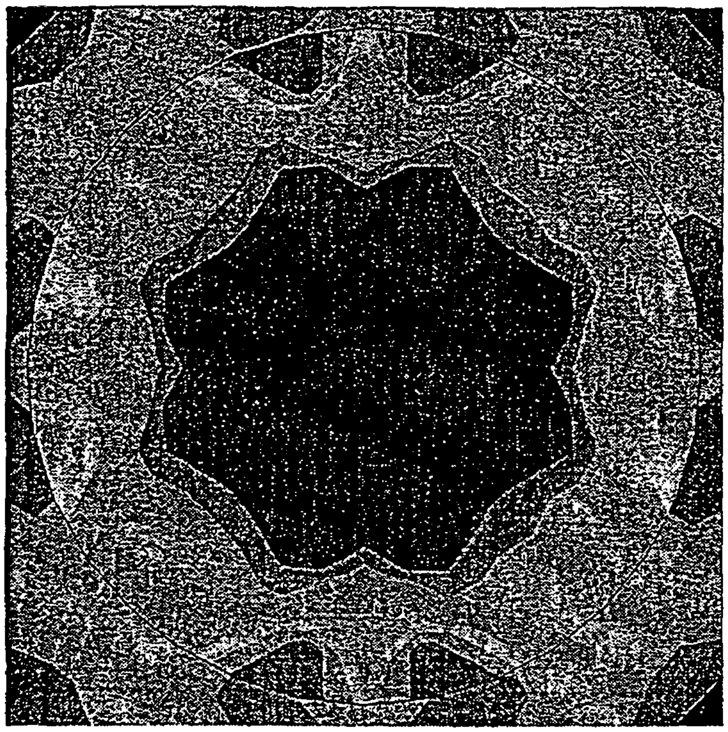
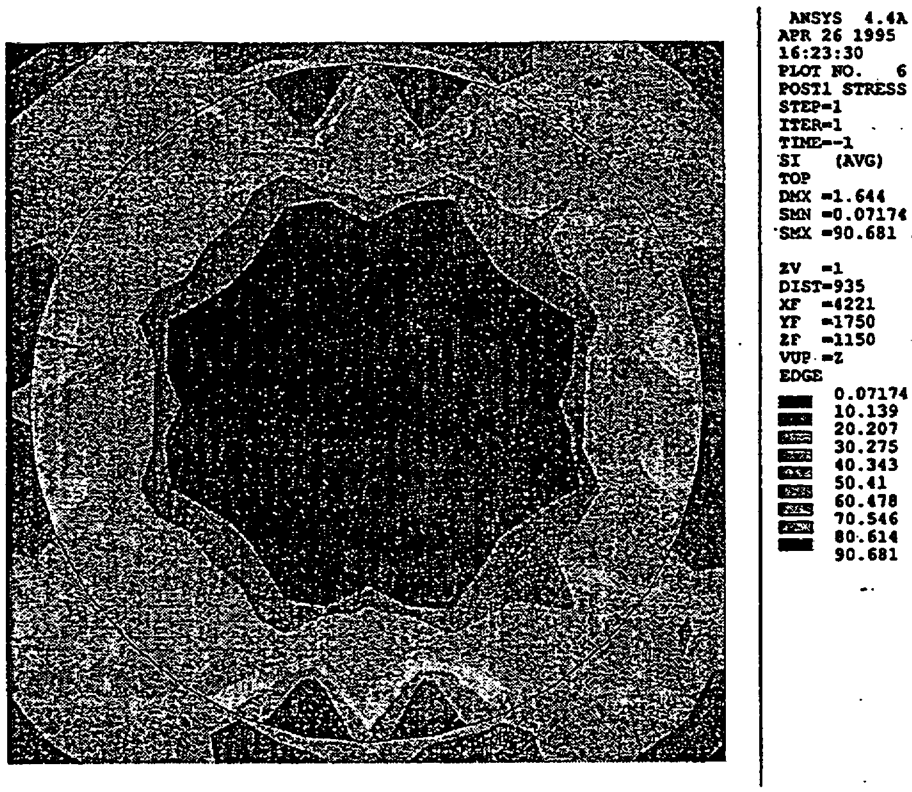


Figure 8A.5-20

Plate Stresses
Top of Plate
Load Combination 1
Primary - Secondary Stresses



The stresses in the beams due to load combination 2 are presented in the table 8A.5-2 below.

Table 8A.5-2

Beam Stresses Load Combination 2
(Seismic Analysis)

Beams	**Maximum Tension**		**Maximum Shear**		**Conclusion**
	Calculated	Allowable	Calculated	Allowable	
W 14 x 82 with shell (bridge)	50.7 MPa 7.35 KSI	186 MPa 27KSI	6.4 MPa 0.92 KSI	103 MPa 15 KSI	Acceptable
W 12 x 96 with shell (rails)	33.3 MPa 4.83 KSI	186 MPa 27 KSI	9.5 MPa 1.37 KSI	103 MPa 15 KSI	Acceptable
12 x 8 x 0.5 (bridge)	61.8 MPa 8.96 KSI	186 MPa 27 KSI	36.2 MPa 5.2 KSI	103 MPa 15 KSI	Acceptable
12 x 12 x 0.5 (trolley)	35.1 MPa 5.1 KSI	186 MPa 27 KSI	23.5 MPa 3.4 KSI	103 MPa 15 KSI	Acceptable
400 x 400 x 15 (fuel tube)	78MPa 11.3 KSI	186 MPa 27 KSI	5.9 MPa 0.8 KSI	103 MPa 15 KSI	Acceptable

As shown in the Table, the stresses in the beams are well below the allowable stresses.

The forces in the links are presented in Section 8A.5.9-2. All units are presented in metric.

The reaction forces at the brackets are presented in Section 8A.5.10-2.

In Section 8A.5.11, the first frequencies below the critical frequency are presented. The maximum stress in the plates (both the rotational table and the trolley plates) is 102 MPa (14.8 ksi). This value is well below the allowable stress of 186 MPa (27 ksi). A plot of the stresses in the plates due to this load is shown in Figures 8A.5-21 through 8A.5-24.

The maximum deflection of the bridge rails under normal loads (Load combination 5) is 1.065 mm. This is below the allowable deflection of 1/1000 (span) = 1/1000 x 4700 mm = 4.7 mm. Therefore the deflection is acceptable.

Figure 8A.5-21

Plate Stresses
Top of Plate
Load Combination 2
Primary + Secondary Stresses

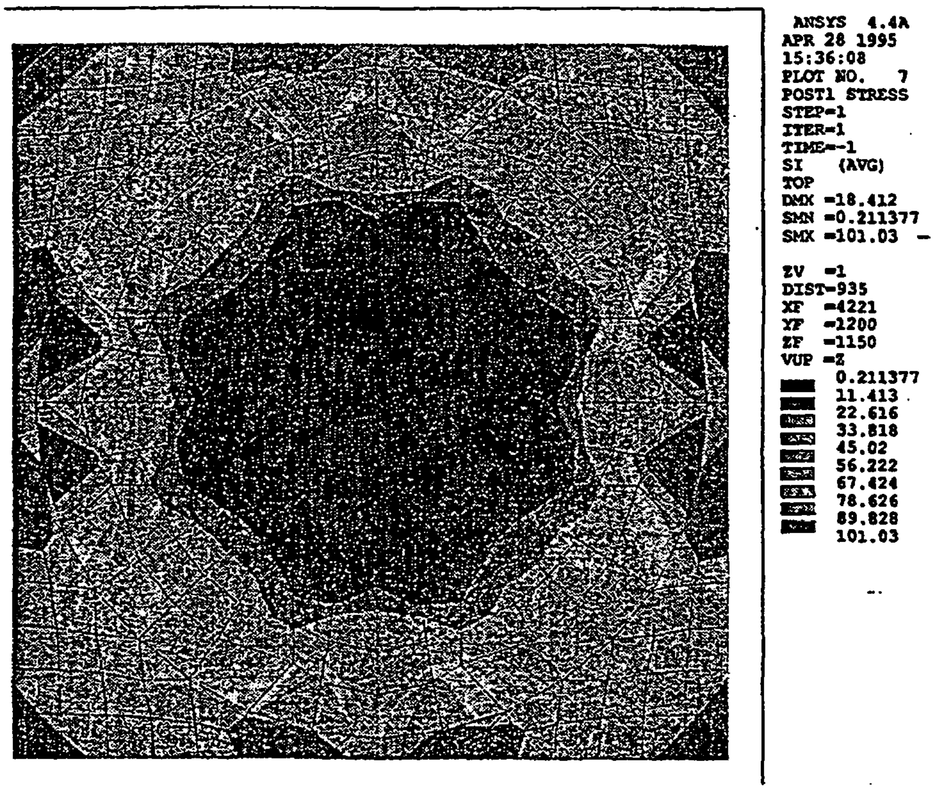


Figure 8A.5-22

Plate Stresses
Middle of Plate
Load Combination 2
Primary + Secondary Stresses

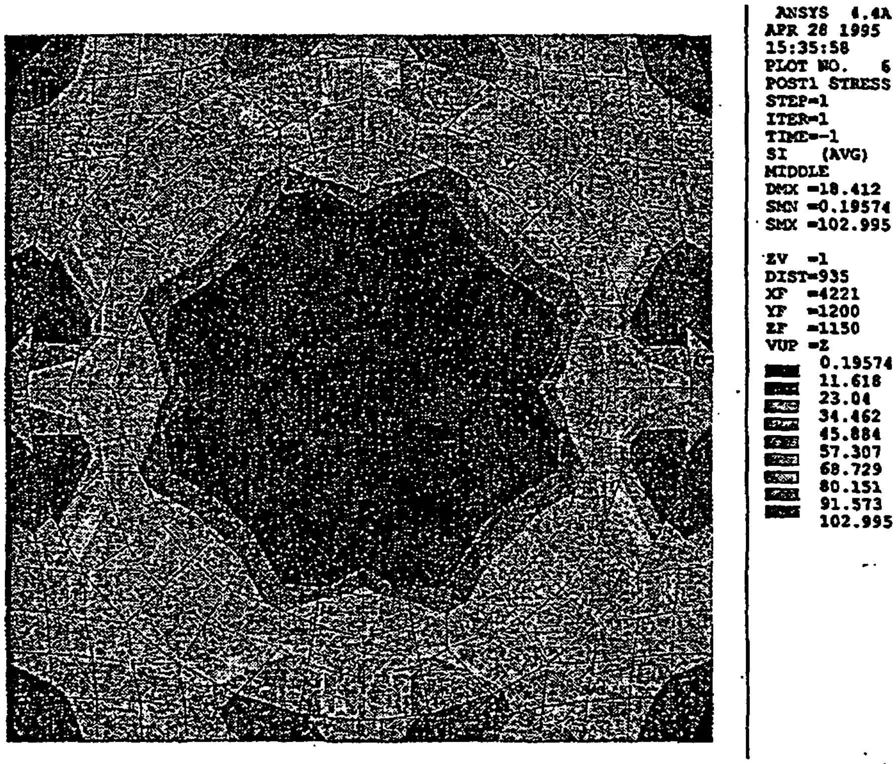


Figure 8A.5-23

Plate Stresses
Middle of Plate
Load Combination 2
Primary - Secondary Stresses

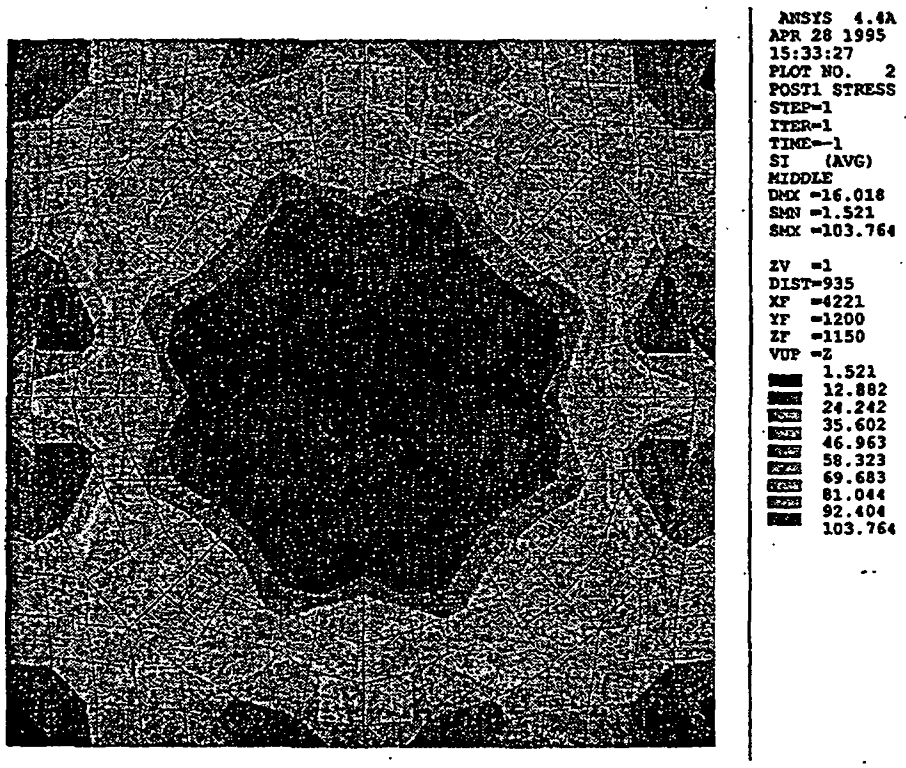
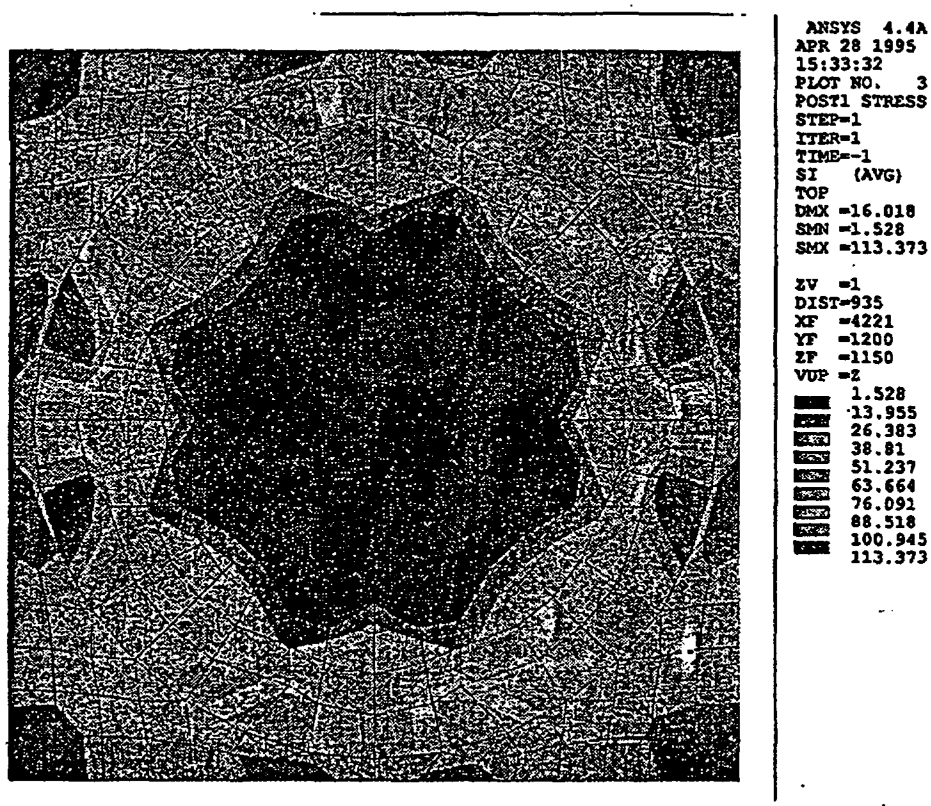


Figure 8A.5-24

Plate Stresses
Top of Plate
Load Combination 2
Primary - Secondary Stresses



8A.5.9 Reaction Forces

The reaction forces for Load Combinations 1 and 2 are provided in the following pages. All units are metric.

8A.5.10 Static Calculations

Cables and Pulleys

A cable with a minimum diameter of 12 mm (0.48 inches) and an ultimate strength of 1770 MPa (256.7 ksi) has been selected. A factor of 10 is required on breaking strength. Therefore the maximum credible load is 10 x the lifting load. Using an efficiency factor η = 0.94 and 2 rope parts, the force on the rope is:

F = 15000 N/(0.94*2) = 7979 N

The allowable force on the cable is $P = P_{cl}$ (12/1904)2 = 21,428 N

Therefore the safety factor is $P/P_{cl} = 1.4$.

The sheave to rope ratio is 24 in accordance with NOG-5427.1. The minimum sheave diameter is therefore 24 x 12 = 288 mm. A sheave diameter of 300 mm has been selected.

Wheels of the Bridge

The wheels are sized using the static case plus the impact load during lifting. The bridge rail dimensions are shown in Figure 8A.5-25. The effective width of the rail head is 37 mm (1.45 in.) The diameter of the wheel is 153 mm (6.1 in.) The allowable wheel load is taken from from NOG-5452.3:

$$P_a = KbD \text{ (lbs)}$$

where $K = 1300\ (BHN/260)^{0.333} = 1393$
b = the effective width of the rail head
D = diameter of the wheel.

Therefore P_a = (1393)(1.45)(6.1) = 12,321 lbs.

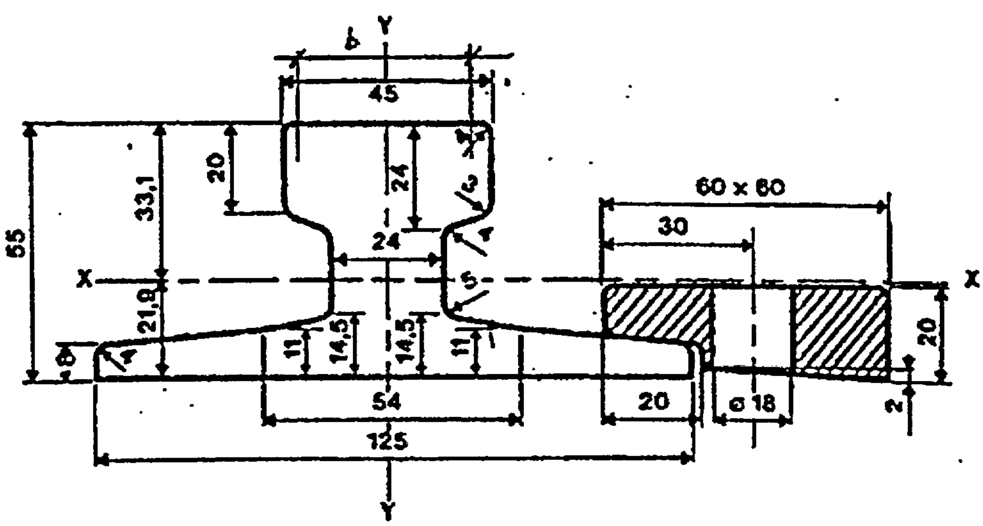
The actual load P = ((Mt + Mb + Mr) + 1.15 Ml)g
where Mt is the mass of the trolley, Mb is the mass of the bridge, Mr is the mass of the rotating platform and Ml is the mass of the rated load. G is the 9.81 m/s^2.

Then P = 220,228 N = 24,278 lbf.

The operational load is equally distributed between the four wheels. Therefore each wheel takes a load of P/4 = 27,530 N = 6,070 Lbf.
The safety factor is therefore 12321/6070 = 2.03

Figure 8A.5-25

Bridge Rails BURBACH KS22-A45



Wheels of the Trolley

The wheels are sized using the static case plus the impact load during lifting. The trolley rails are identical to the bridge rails. The effective width of the rail head is 37 mm (1.45 in.) The diameter of the wheel is 99 mm (3.9 in.) The allowable wheel load is taken from from NOG-5452.3:

$$P_a = KbD \text{ (lbs)}$$

where $K = 1300\ (BHN/260)^{0.333} = 1393$
b = the effective width of the rail head
D = diameter of the wheel.

Therefore P_a = (1393)(1.45)(3.9) = 7878 lbs.

The actual load P = $((M_t + M_r) + 1.15\ M_l)g$

where M_t is the mass of the trolley, M_r is the mass of the rotating platform and M_l is the mass of the rated load. G is the 9.81 m/s^2.

Then P = 70 N = 24,278 lbf.

The operational load is equally distributed between the four wheels. Therefore each wheel takes a load of P/4 = 27,530 N = 6,070 Lbf.

The safety factor is therefore 12321/6070 = 2.03

Evaluation of Guidance Rollers

The guidance rollers are calculated using the impact load in the transverse direction. The lateral rail width is 13 mm = 0.51 in. The roller diameter is 1.1 in (28 mm). The allowable load is taken from from NOG-5452.3:

$$P_a = KbD \text{ (lbs)}$$

where K = 1300 $(BHN/260)^{0.333}$ = 1393
b = the effective width of the rail side
D = diameter of the roller.

Therefore P_a = (1393)(1.1)(0.51) = 781 lbs. lbs.

The actual load P = 5% (weight of trolley + rotating platform + rated load) = 0.05(Mt +Mr +Ml)g
where Mt is the mass of the trolley, Mr is the mass of the rotating platform and Ml is the mass of the rated load. G is the 9.81 m/s^2.

Then P = 3434 N = 758 lbf.

The operational load is equally taken by the two guidance rollers. Therefore for each roller Fx = p/2 = 1717 N = 379 lbf. The safety factor is therefore 781/379 = 2.06.

Evaluation of the Anti-Taking Off Device (of the Bridge)

To evaluate the anit-taking off devices, the static and seismic reactions must be added. The maximum reaction force from the seismic analysis is used. This occurs for the load combination with the trolley at 550 mm. The force F_z = 35,638 N (Node 526). The

maximum bending moment in the plate occurs along the plane 2-2 in Figure 8A.5-26. The beinding moment = $F_z a$ = (35,638)(50 mm) = 1782 N-m.

The two bolts on the plane 2-2 see the maximum tension. The cross sectional area of each bolt is 157 mm^2. The Tensile force in each bolt is:

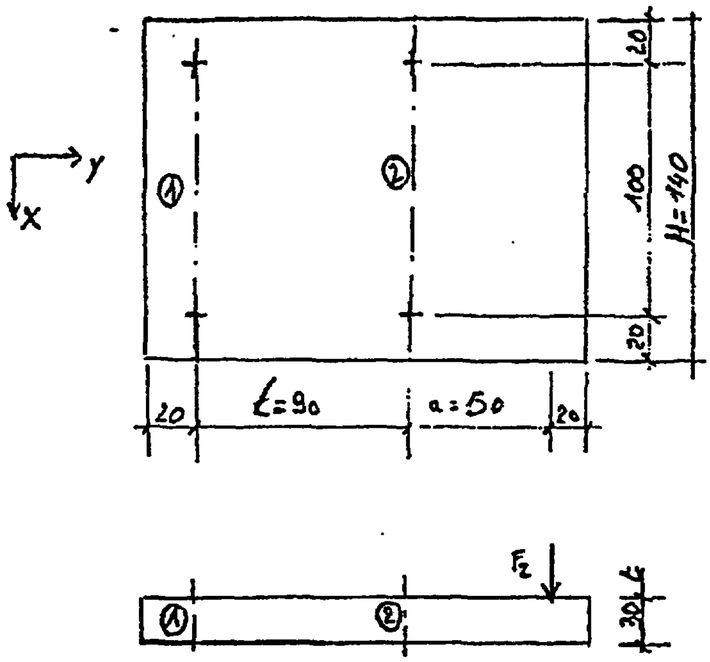
$F_b = F_z(L+a)/2L$ = 27,719 N per bolt.

This results in a tensile stress in each bolt of $\sigma = F_b/A$ = 177 MPa. The bolt allowable stress is 287 MPa. Therefore the safety factor is SF = 287/177 = 1.6.

The plate stress is evaluated below. The section modulus = S = $(H-2x18)t^3/6t$ = 15,600 mm^3. The bending stress is $\sigma = M/S$ = 1782 mN/15,600 mm^3 = 114 MPa = 16.6 ksi. This is well below the allowable stress of 189 MPa. The safety factor is 186/114 = 1.6.

Figure 8A.5-26

Dimensions of Bridge Anti-Taking Off Device



in mm.

4 holes of Ø 18 with 4 bolts M16.

Evaluation of the anti-taking off of the trolley

The trolley anti-taking off device is identical to the bridge anti-taking off device shown in Figure 8A.5-26. The maximum reaction force from the seismic analysisis taken from the case with the trolley at the end. The maximum force F_z = 46,973 N (Node 439). The maximum bending moment in the plate occurs along the plane 2-2 in Figure 8A.5-26. The bending moment = $F_z a$ = (46,973)(50 mm) = 2,349 N-m.

The two bolts on the plane 2-2 see the maximum tension. The cross sectional area of each bolt is 157 mm^2. The tensile force in each bolt is:

$F_b = F_z(L+a)/2L$ = 36,535 N per bolt.

This results in a tensile stress in each bolt of $\sigma = F_b/A$ = 233 MPa. The bolt allowable stress is 287 MPa. Therefore the safety factor is SF = 287/233 = 1.2.

The plate stress is evaluated below. The section modulus = $S = (H\text{-}2x18)t^3/6t$ = 15,600 mm^3. The bending stress is $\sigma = M/S$ = 2349 mN/15,600 mm^3 = 150 MPa = 21.8 ksi. This is below the allowable stress of 189 MPa. The safety factor is 186/150 = 1.2.

Anti-Taking Off device of the Rotating Platform

The anti-taking off device of the rotating platform is shown in figure 8A.5-27. The vertical force is taken from the results of the ANSYS analysis. The maximum vertical force is 41,445 N (element 396) and occurs with the trolley at 550 mm.

The cross sectional area of each bolt is 157 mm^2. The Tensile force in each bolt is:

$F_b = F_z(C-A/2)/2A$ = 20,728 N per bolt.

A = 200 mm
B = 200 mm
C= 300 mm
Bolt cross sectional area = 157 mm^2

This results in a tensile stress in each bolt of $\sigma = F_b/A$ =132 MPa. The bolt allowable stress is 287 MPa. Therefore the safety factor is SF = 287/132 = 2.1.

The plate stress is evaluated below. The plate thickness , t, is 25 mm, and section modulus = $S = \pi dt^3/6t$ = 13.08 cm^3.

Figure 8A.5-27a

Rotating Platform Anti-Taking Off Device

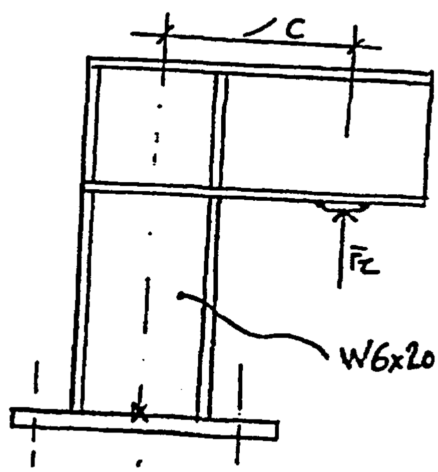
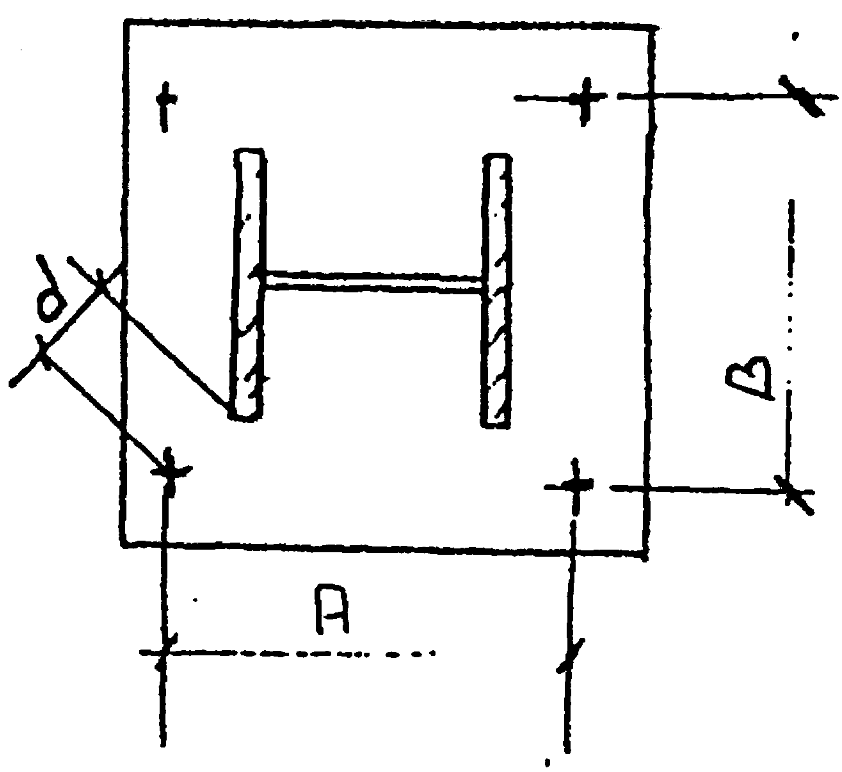


Figure 8A.5-27b

Rotating Platform Anti-Taking Off Device

Four bolts M16.



The bending moment on the plate is M = Fd = 829 mN. The bending stress is therefore

$$\sigma = M/S = 64 \text{ MPa} = 9.2 \text{ ksi} \leq 0.5\ \sigma_u / 1.2 = 186 \text{ MPa} = 27 \text{ ksi}$$

The safety factor SF = 186/64 = 2.9.

The bending moment in the W 6 x 20 beams is

$$F_z\ C = M = 12{,}437 \text{ mN}$$

The section modulus of inertia of the beam is 219 cm^3. The cross sectional area A = 37.8 cm^2. The tensile stress in the beam is therefore:

$$\sigma = (F_z/A + M/S) = 68 \text{ MPa} = 9.9 \text{ ksi} < 0.9\ vy/2 = 186 \text{ MPa} = 27 \text{ Ksi}$$

The safety factor is SF = 186/68 = 2.7.

Anti-Seismic Transverse Bumpers

Thc transverse bumpers are the lateral end stops on the rails. They are fixed on the bridge and the trolley. There are four bumpers on the bridge and four bumpers on the trolley. The lateral forees exerted due to the seismic event, taken from the ANSYS runs are used for this analysis.

Bridge Anti-Seismic Transverse Bumpers

The anti-seismic bumpers used on the bridge and trolley are shown in Figure 8A.5-28. They are made of A36 steel and held in place using two A193 Gr B7 bolts. The maximum transverse force due to the seismic loading, F_y is taken from node 526 from the case with the trolley located at 550 mm.

The equations of static equilibrium are:

$R_A = F_y$ and

$R_A \times 15/2 + F_y \times C - R_B \text{ X } a/2 = 0$ (at o')

Solving the equations $R_C = R_B = F_y (C + 15/2)/ (a/2) = 69{,}964$ N with C = 60 mm

The tensile force on cach of the two bolts is $F_{bolt} = R_c / 2 = 34{,}982$ N

The bolt diameter is 16 mm = 0.63 in. Therefore A = 157 mm^2.

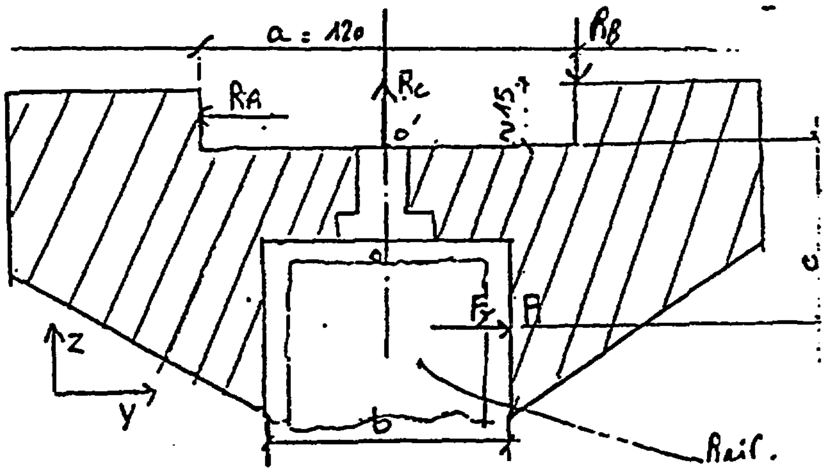
The tensile stress in each bolt is therefore:

$a = F_{bolt}/A = 223$ MPa= 31.1 ksi $< 0.5\ \sigma_u / 1.2 = 287$ MPa = 41.6 ksi

The safety factor is SF = 287/223 = 1.2.

Figure 8A.5-28

Anti-Seismic Transverse Bumpers



Trolley Anti-Seismic Transverse Bumpers

The bumpers on the trolley are identical to those used on the bridge. The maximum transverse loading on the trolley due to the seismic event is F_x = 62k,886 N taken from node 442 from the case where the trolley is located at the end.

The equations of static equilibrium are:

$R_A = F_x = 62{,}886$ N and

$R_A \times 15/2 + F_x \times C - R_B \times a/2 = 0$ (at o')

Solving the equations $R_C = R_B = F_x\ (C + 15/2)/(a/2) = 70{,}747$ N with $C = 60$ mm

The tensile force on each of the two bolts is $F_{bolt} = R_C/2 = 35{,}374$ N

The bolt diameter is 16 mm = 0.63 in. Therefore A = 157 mm^2.

The tensile stress in each bolt is therefore:

$\sigma = F_{bolt} / A = 226$ MPa = 32.7 ksi $< 0.5\ \sigma_u / 1.2 = 287$ MPa = 41.6 ksi

The safety factor is SF = 287/226 = 1.2.

Grapple, Axis, Pins and Head

For a mass of M = 1500 kg, the maximum force on the cables during a seismic event is F_z = 43,580 N. There will be four fingers on each grapple for a PWR and 2 fingers on each grapple for a BWR. Therefore, for the following calculations, the force F_z is exerted on 2 fingers on the PWQR and one finger on the BWR.

The vertical force F_z is taken from the output of the ANSYS seismic analysis. It is the maximum vertical force for all load comibinations.

PWR Grapple

The mass for a PWR fuel assembly is M_F = 780 kg. The grapple pivot axis, fingers and pintle will be made from A36 forged carbon steel. The properties of this material are provided below:

Yield Strength, σ_y	36 ksi	348 MPa
Tensile Strength, σ_u	58 ksi	399 MPa

The weight of the fuel assembly is less than the nu,mber used to evaluate the seismic event using ANSYS. (M_T = 1500 kg was used for the ANSYS analysis). Therefore the force exerted on the grapple (corrected) is:

$F_z = F_z$(computed) x M_F/M_T = 43,580 x 780/1500 = 22,661 N = 5,094 lbs.

The maximum force in the static case (including a factor of 6 to yield for a nonredundant lift system) is:

F_z = 780 x 6 = 4680 kg = 10,317 lbs.

Therefore the maximum stress is found from the static case:

F(per finger) = 10,317/2 = 5,159 lbs.

Stresses on the Pivot Axis

The diameter of the pivot axis is 18 mm = 0.7 in.

The cross sectional area is 254 mm^2 (0.385 in^2)

The shear force is T = 5,159 lbs.

The shear stress is τ = T/2A = 5159/(2 x 0.385)= 6,700 psi < 36,000 psi (6 to yield strength)

or τ = 6,700 x 10/6 = 11,170 psi < 58,000 psi (10 to Ultimate Strength)

Stresses in the Grapple Finger

The grapple finger is shown in Figure 8A.5-29. The shear stress in the L1 section is:

$\tau = F/(L_1 t)$ = 5159/(0.6x 0.8) = 10,748 psi < 36,000 psi

$\tau = F/(L_1 t)$ = 10,748 x 10/6 = 17,913 psi < 58,000 psi

The horizontal force F_x at the pivot point is $F_x = FH_2/H_1$

Since $H_2 < H_1$, , $F_x < F$. Then the shear stress in the L3 section is

$\tau = F/(L_3t) = 5159/(0.4 \times 0.8) = 16{,}122$ psi $< 36{,}000$ psi

$\tau = F/(L_3t) = 16{,}122 \times 10/6 = 26{,}870$ psi $< 58{,}000$ psi

The tensile and bending stress in the L2 section is

$\sigma = F/(L_2t) + M/S$

where $M = F(b + L_2/2) = 5{,}159\ (0.4 + 1.25/2) = 5{,}288$ in-lbs

and $S = tL_2^2/6 = 0.8(1.25)^2/6 = 0.2083$ in^3

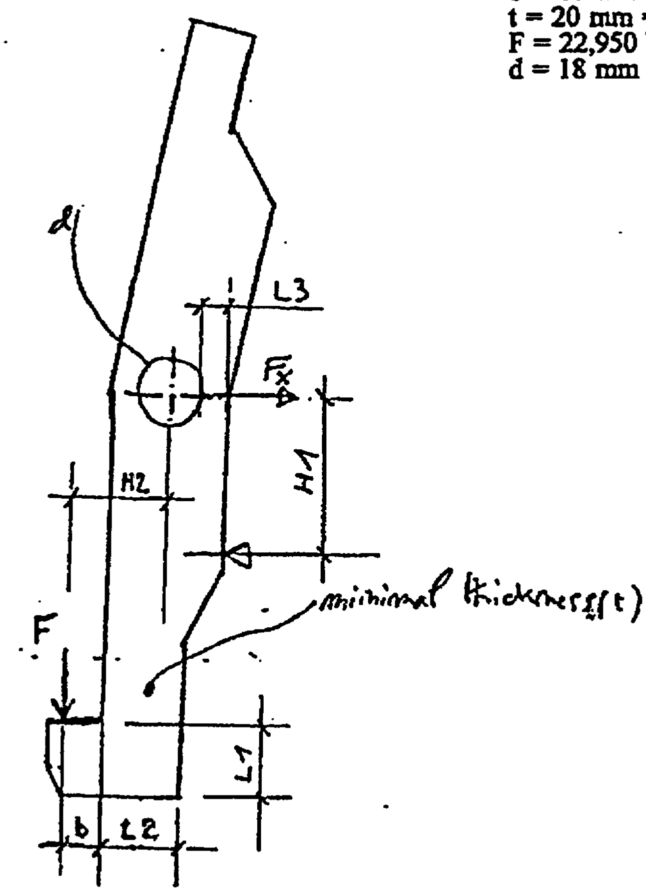
then $\sigma = 5150/(1.25 \times 0.8) + 5288/0.2083 = 30{,}545$ psi $< 36{,}000$ psi to yield strength

and $\sigma = 30545 \times 10/6 = 50{,}908$ psi $< 58{,}000$ psi to ultimate strength

Figure 8A.5-29

Grapple Finger

The following lengths are used in the analysis:
L2 = 32 mm = 1.25 in.
L1 = 15 mm = 0.6 in.
L3 = 10 mm = 0.4 in.
b = 10 mm = 0.4 in.
t = 20 mm = 0.8 in.
F = 22,950 N = 5,159 lbs.
d = 18 mm = 0.7 in.



BWR Grapple

The mass for a BWR fuel assembly is M_F = 330 kg. The grapple pivot axis, fingers and pintle will be made from A36 forged carbon steel. The properties of this material are provided below:

Yield Strength, σ_y	36 ksi	348 MPa
Tensile Strength, σ_u	58 ksi	399 MPa

The weight of the fuel assembly is less than the nu,mber used to evaluate the seismic event using ANSYS. (M_T = 1500 kg was used for the ANSYS analysis). Therefore the force exerted on the grapple (corrected) is:

$F_z = F_z(\text{computed}) \times M_F/M_T = 43{,}580 \times 330/1500 = 9{,}588$ N = 2,155 lbs.

The maximum force in the static case (including a factor of 6 to yield for a nonredundant lift system) is:

$F_z = 330 \times 6 = 1{,}980$ kg = 4,365 lbs.

Therefore the static case is limiting. The force per finger is 4,365 lbs (The force is exerted on one finger only).

Stresses on the Pivot Axis

The diameter of the pivot axis is 18 mm = 0.7 in.

The cross sectional area is 254 mm^2 (0.385 in^2)

The shear stress is $\tau = T/2A = 4365/(2 \times 0.385) = 5{,}670$ psi < 36,000 psi (6 to yield strength)

or $\tau = 5{,}670 \times 10/6 = 9{,}450$ psi < 58,000 psi (10 to Ultimate Strength)

Stresses in the Grapple Finger

Since the forces are lower in the BWR case than in the PWR case, the stresses are acceptable.

8A.5.11 Summary of Results

The results of the analyses on the Fuel Handling Crane are summarized in Table 8A.5-3. All the stresses are below the allowable stresses, and are therefore acceptable.

Table 8A.5-3

Fuel Handling Crane Results

Part	**Load**	**Allowable Value**	**Calculated Value**	**Calculated Size**	**Safety Factor**
Cable Diameter	Static	21,420 N	15,000 N	12 mm (0.48 in.)	1.4
Bridge wheel diameter	Static	12,321 lbf	6,070 lbf	153 mm (6.1 in.)	2
Bridge Rail Width	Static	12,321 lbf	6,070 lbf	37 mm (1.45 in)	2
Trolley Wheel Diameter	Static	7,878 lbf	3,906 lbf	99 mm (3.9 in)	2
Trolley rail width	Static	7,878 lbf	3,906 lbf	37 mm (1.45 in.)	2
Guidance roller diameter	Static	781 lbf	379 lbf	28 mm (1.1 in)	2
Bolt of Bridge anti-taking off device	Seismic	287 MPa	177 MPa	16 mm (0.63 in)	1.6
Plate of Bridge anti-taking off Device	Seismic	186 MPa	114 MPa	t = 30 mm (1.2 in.)	1.6

Table 8A.5-3 (Continued)

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Bolt of Trolley anti-taking off Device	Seismic	287 MPa	233 MPa	16 mm (0.63 in.)	1.2
Plate of Trolley anti-Taking Off Device	Seismic	186 MPa	150 MPa	t= 30 mm (1.2 in)	1.2
Bolts of Rotating Platform anti-taking Off Device	Seismic	287 MPa	1321 MPa	16 mm (0.63 in.)	2.1
Plate of Rotating Device Anti-Taking Off Device	Seismic	186 MPa	64 MPa	t = 25 mm (1 in)	2.9
W 6 x 20 Beam of the Platform Anti-taking Off Device	Seismic	186 MPa	68 MPa	W 6 x 20	2.7
Bolts of Bridge anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia. (0.63 in)	1.2

Table 8A.5-3 (Continued)

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Bolts of Trolley anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia (0.63 in.)	1.2
PWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	6.7 ksi (shear) 11.2 ksi (shear)	18 mm dia. (0.7 in.)	>6 to yield >10 to ultimate
BWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	5.7 ksi (shear) 9.4 ksi (shear)	18 mm dia. (0.7 in)	>6 to yield >10 to ultimate
Grapple Finger (PWR and BWR)	Static	36 ksi yield 58 ksi tensile	30.5 ksi (bending) 50.9 ksi (bending)	t = 20 mm (0.8 in)	>6 to yield >10 to ultimate

Appendix 8A.6 Dose Assessment from Off-Normal Conditions

8A.6 .1 Introduction

For the dose assessment for off-normal conditions, the worst scenario considered is that the HEPA filters are inoperable while the receiving cask is open and filled with 21 fuel assemblies.

8A.6.2 Source Evaluation

For this analysis, the irradiation is performed on a per MTU basis using a Westinghouse 17 x 17 assembly. For the Curie content of burned fuel, the values calculated from a B&W 15x15 assembly will be similar to the Westinghouse 17x17. The Westinghouse 17x17 assembly will lead to slightly more conservative results.

The Westinghouse 17x17 assembly described in Reference 8A.6 -2 is utilized as the model. The assembly is assumed to have a 3.85w% enrichment. The fuel is irradiated with a typical specific power of 37.5 MW/MTU to a total burnup of 40,000 MWD/MTU. Three cycles will be used with a down time of 30 days between cycles.

Material compositions are taken from Reference 8A.6-2 and adjusted for 3.85 w% enrichment. Of particular interest is the amount of Co-59 in each material. From Table 4.3:

Zr-4	0.001 w%
Inconel-718	0.4694 w%
SS304	0.08 w%

For the irradiation of the materials outside of the fuel region, the methodology of Reference 8A.6-2 is used; i.e., to account for the axial flux variation and the neutron spectrum, the flux and material quantities are modified as follows. The flux for the end fittings and plenum are multiplied by 0.011 and 0.042, respectively. The quantity of Mn, Co, and Zr in these regions is multiplied by 0.8, 0.67 and 0.40, respectively.

Materials (Reference 8A.6-2, Table 4.4)

Region	Material	Kg/MTU
Fuel Zone		
Cladding	Zircaloy-4	223.0
Grid Spacers & Springs	Inconel 718	12.8
Grid Brazing	Nicrobraze 50	2.6
Miscellaneous	SS 304	9.9
Plenum Zone		
Cladding	Zircaloy-4	12.0
Spring	SS 302	4.2
End Fitting Zone		
Top Fitting	SS 304	14.8
Bottom Fitting	SS 304	12.4

As previously mentioned, the elemental compositions of each of the materials listed above is taken from Table 4.3 of Reference 8A.6-2, as modified in the plenum and end zones.

From the ORIGEN2 run, fission gases and volatile nuclides were selected. The following values were calculated:

Table 8A.6-1

Fission Gas and Volatile Nuclides Inventory (Curies/Assembly) Westinghouse 17x17 3.85 w% U-235, 40,000 MWD/MTU

Nuclide	Ci/MTU	Ci/assy {x0.461(MTU/assy)}
H-3	2.084E+2 + 4.922E+2	323
Co-60	4.493E+03	2,070
Kr-85	8.235E+03	3,800
Sr-90	7.948E+04	36,600
Ru-106	1.937E+04	8,930
I-129	3.722E-02	0.0172
Cs-134	3.698E+04	17,000
Cs-137	1.117E+05	51,500

8A.6.3 Off-Normal Release Analysis

The concentration of gaseous nuclides at a given distance from the DTS is determined by the method of Reference 8A.6-3, Section 1.3, assuming stable (Pasquill F) conditions and a wind speed of 1 m/s.

This method provides short term relative concentrations (χ/Q) for releases at a low height above ground level. Unlike stack releases, ground level release relative concentration declines monotonically with distance from the release point; so a maximum need not be found. Short term relative concentrations are conservative because they do not account for the fluctuations in wind speed and direction and atmospheric conditions which occur over a longer time.

The dose is calculated according to Reference 8A.6-4, assuming that the major dose components are from immersion in a semi-infinite gas cloud and from inhalation. The dose conversion factors are taken from references 8A.6-5 and 8A.6-6. The gaseous radionuclide inventory is taken from ORIGEN2 runs for 5 years decay time. The only gaseous radioisotopes of significance are H-3, Kr-85 and I-129. Tritium occurs both as a fission products and from activation in the cladding.It is assumed that 30% of the Kr-85 escapes from the pellet into the fuel rod plenum as a free gas and that 10% of other noble gases become free gas.

8A.6.4 Air Dispersion Evaluation

The worst scenario considered is that the HEPA filters are inoperable while the receiving cask is open and filled with 21 fuel assemblies. Two distances from DTS are considered; 100 m (minimum controlled boundary distance) and 500 m.

χ/Q Calculation

The atmospheric diffusion from vents and other building penetrations at 100 meters (Reference 8A.6-3, Section 1.3.1) is calculated below:

$$\frac{\chi}{Q} = \frac{1}{U(\pi\sigma_y\sigma_z + \frac{A}{2})} \qquad (1)$$

$$\frac{\chi}{Q} = \frac{1}{U(3\pi\sigma_y\sigma_z)} \qquad (2)$$

$$\frac{\chi}{Q} = \frac{1}{U\pi\Sigma_y\sigma_z} \qquad (3)$$

where:

- χ/Q is the relative concentration, in sec/m^3
- U is wind speed at 10 meters above plant grade, in m/sec
- σ_y is lateral plume spread , in m, a function of atmospheric stability and distance (see Figure 1 from Regulatory Guide 1.145)
- σ_z is the vertical plume spread, in m, a function of atmospheric stability and distance (see Figure 2 from Regulatory Guide 1.145)
- M Correction factors for σ_y values by atmospheric stability class (see Figure 3 from Regulatory Guide 1.145)
- Σ_y is lateral plume spread with meander and building wake effects, in m, a function of atmospheric stability, wind speed, U, and distance. $\Sigma_y = M\sigma_y$ for

distances less than 800 meters.

A is the smallest vertical-plane cross-sectional area of the DTS building, in m^2.

Calculating:

$A = 7.11 \text{ m} \times 13.8 \text{ m} = 98.1 \text{ m}^2$

From Regulatory Guide 1.145, Figure 1

σ_y at 100 meters, Pasquill Stability Category F = 4 meters

σ_y at 500 meters, Pasquill Stability Category F = 20 meters

From Regulatory Guide 1.145, Figure 2

σ_z at 100 meters, Pasquill Stability Category F = 2.3 meters

σ_z at 500 meters, Pasquill Stability Category F = 8.4 meters

From Regulatory Guide 1.145, Figure 3

M at U = 1 m/sec, Pasquill Stability Category F = 4

therefore, Σ_y at 100 meters, Pasquill Stability Category F = 4 * 4 m = 16 m

therefore, Σ_y at 500 meters, Pasquill Stability Category F = 4 * 20 m = 80 m

For 100 m, substituting into Equations (1), (2), and (3) yields:

(1) $\chi/Q = 1 / 1(\pi * 4 * 2.3 + 98.1/2) = 1.28\text{E-}2 \text{ sec/m}^3$
(2) $\chi/Q = 1 / 1(\pi * 3 * 4 * 2.3) = 1.15\text{E-}2 \text{ sec/m}^3$
(3) $\chi/Q = 1 / 1(\pi * 16 * 2.3) = 8.65\text{E-}3 \text{ sec/m}^3$

Choosing the larger of calculations (1) and (2), and the lesser of that selection and (3) yields:

$\underline{\chi/Q = 8.65\text{E-}3 \text{ sec/m}^3}$, which includes wake and meander effects.

Similarly, substituting for 500 meters

(1) $\chi/Q = 1 / 1(\pi * 20 * 8.4 + 98.1/2) = 1.73E\text{-}03$ sec/m^3
(2) $\chi/Q = 1 / 1(\pi * 3 * 20 * 8.4) = 6.32E\text{-}04$ sec/m^3
(3) $\chi/Q = 1 / 1(\pi * 80 * 8.4) = 4.74E\text{-}04$ sec/m^3

Choosing the larger of calculations (1) and (2), and the lesser of that selection and (3) yields:

χ/Q = 4.74E-04 sec/m^3, which includes wake and meander effects.

8A.6.5 Radioactive Gas Inventory

The radioactive gas inventory was taken from the ORIGEN2 results. From Reference 8A.6-7, for assumptions related to the release of radioactive material from a fuel handling accident "the gap activity in the damaged rods released consists of 10% of the total noble gases other than Kr-85, 30% of Kr-85." Therefore a 30% release is assumed for the Kr-85 and 10% release is assumed for the I-129.

The tritium was assumed that of the gap activity, 10% is released. Cs-134 and Cs-137 are not typically considered volatile nuclide following a fuel handling accidents (Reg Guide 1.25 considers the release of noble gases and radioactive iodine following a fuel handling accident. Other nuclides are not considered). As an estimate, these gases are considered volatile and available for release. These are assumed to release 10% of the activity. (Table 8A.6-2)

Table 8A.6-2

Fission Gas Inventory
(Curies/Assembly)
Westinghouse 17x17 3.85 w% U-235, 40,000 MWD/MTU

Nuclide	Ci/MTU	Ci/assy (*0.461mtu/assy)	Ci/21 assy	Fraction Released (μCi)
H-3	2.084E+02 + 4.922E+02	323	6,780	6.78E+08
Kr-85	8.235E+03	3,800	79,800	2.39E+10
I-129	3.722E-02	0.0172	0.361	3.61E+04

8A.6.6 Exposure to Dose Conversion Factors

The exposure-to-dose conversion factors for inhalation effects are taken from Reference 8A6-5 and for air immersion are taken from Reference 8A6-6.

Table 8A.6-3

Exposure to Dose Conversion Factors for Inhalation

Isotope	Effective DCF Inhalation (mrem/μCi)	Effective DCF Air Immersion (mrem/yr per μCi/cm^3)
H-3	6.401E-02	3.866E+04
Kr-85	---	2.57E+07
I-129	5772	7.78E+07

8A.6.6.1 Dose Calculations at 100 meters from the source:

Dose From Inhalation of Non-Noble Radionuclides

$$Dose_{isotope} = R * \chi * DCF_{inhalation\text{-}isotope}$$
$$Dose_{isotope} = R * \chi/Q * Q * DCF_{inhalation\text{-}isotope}$$

where:

R is the inhalation rate, 8000 m^3/yr (from Reference 8A.6-9)
χ/Q is the atmospheric dispersion value dependent on distance (sec/m^3)
Q is the amount of material released (μCi)
$DCF_{inhalation\text{-}isotope}$ is the exposure dose conversion faction by isotope (mrem/μCi)

Substituting for H-3:

$$Dose_{isotope} = (8000\ m^3/yr)*(8.65E\text{-}03\ sec/m^3)*(6.78E+08\ \mu Ci)*(0.0641\ mrem/\mu Ci)*(3.1706E\text{-}08\ yr/sec)$$
$$Dose_{isotope} = 95.2\ mrem$$

Similarly for other isotopes:

Isotope	chi (uCi-yr/m^3)	Breath Rate (m^3/yr)	DCF-inhalation (mrem/uCi)	Dose (mrem)
H-3	1.86e-01	8000	0.06401	9.52E+01
Kr-85	6.57E+00	8000	---	---
I-129	9.90e-06	8000	5772	4.57E+02
	Subtotal (Fission Gases):			552

8A.6.6.2 Dose from Exposure to Semi-Infinite Cloud Effective Dose from Air Immersion

$Dose_{air\ immersion} = \chi * DCF_{air\ immersion} = Q * \chi/Q * DCF_{air\ immersion}$

For Kr-85:

$Dose_{Kr\text{-}85} =$ (6.57E-06 μCi)*(8.65E-03 sec/m^3)*{2.57E+07 (mrem/yr)/(μCi/cm^3)}*(3.1706E-08 yr/sec)*(1E-06 m^3/cm^3) = 169 mrem

Similarly for other isotopes:

Isotope	chi (uCi-yr/cm^3)	DCF-immersion (mrem/yr)/(uCi/cm^3)	Dose (mrem)
H-3	1.86e-07	3.87E+04	7.19e-03
Kr-85	6.57e-06	2.57E+07	1.69E+02
I-129	9.90e-12	7.78E+07	7.70e-04
	Subtotal (Fission Gases):		169

8A.6.7 Dose Calculations at 500 meters from the Source

8A.6.7.1 Doses from Inhalation

Isotopes	χ (μCi-yr/m^3)	Breath Rate (m^3/yr)	DCF-inhalation (mrem/μCi)	Dose (mrem)
H-3	1.02E-02	8000	0.06401	5.22E+00
Kr-85	3.60E-01	8000	---	---
I-129	5.43E-07	8000	5772	2.51E+01
	Subtotal (Fission Gases):			30.3

8A.6.7.2 Doses from Immersion

Isotope	χ (μCi-yr/cm^3)	DCF-immersion (mrem/yr)/(μCi/cm^3)	Dose (mrem)
H-3	1.02E-08	3.87E+04	3.94E-04
Kr-85	3.60E-07	2.57E+07	9.25E+00
I-129	5.43E-13	7.78E+07	4.22E-05
	Subtotal (Fission Gases):		9

8A.6.8 Estimated Doses from Off-normal Conditions

A summary of the estimated doses are presented in Table 8A.6-4.

Table 8A.6-4

Estimated Doses from Off-Normal Conditions

Complete Failure	at 100 meters	
Isotope	Inhalation Dose (mrem)	Immersion Dose (mrem)
H-3	95.2	7.19E-03
Kr-85	---	169
I-129	457	7.70E-04
Total	552	169
Complete Failure	at 500 meters	
H-3	5.22	3.94E-04
Kr-85	---	9.25
I-129	25.1	4.22E-05
Total	30.3	9.25

At 100 meters, the total inhalation plus immersion dose is 721 mrem.
At 500 meters, the total inhalation plus immersion dose is 39.6 mrem.

8A.6.9 References

8A.6-1 ORIGEN2 Users Manual

8A.6-2 Croff, et al, "Revised Uranium - Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, September 1978.

8A.6-3 Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1, 1983.

8A.6-4 Nuclear Regulatory Commission, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I" Revision 1, October 1977.

8A.6-5 Environmental Protection Agency Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion," EPA-520/1-88-020, September, 1988.

8A.6-6 Environmental Protection Agency Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil" EPA-402-R-93-081, September, 1993.

8A.6-7 Nuclear Regulatory Commission, Regulatory Guide 1.25, (Safety Guide 25) " Assumptions used for evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors," March, 23, 1972.

8A.6-9 TN & Westinghouse, Extended Fuel Burnup Demonstration, Topical Report, DOE/ET 34014-11.

CHAPTER 9

CONDUCT OF OPERATIONS

9.1 Organizational Structure

The organizational structure for the DTS is site specific and will be addressed in the site specific license application.

9.2 Preoperational Testing and Operation

The detailed pre-operational testing program will be submitted as part of the site-specific application. The testing shall prove compliance with the capabilities, features and parameters presented in this Topical Report and the site-specific design and specifications upon which approval of a specific installation is based. Testing shall progressively include components, subsystems and complete systems. Testing shall include compliance in manufacturing, shop and field fabrication and processes, assembly operations and interfaces with other systems.

The anticipated off-normal operation scenarios shall be tested to validate operation safety and function.

The monitoring function of the Control Subsystem shall be validated during the system testing as well as all the interlocks between the equipment. Bypasses can be used to set equipment status or conditions linked indirectly with the control (HVAC with sliding door position for example). Bypasses can not be used to test alarms.

Structural Subsystem

The structural subsystem shall undergo the following testing:

Normal operations:

Test the opening and closing functions of the sliding door. Test the inflating of the seal. Process the locking operation.

The interface with the HVAC Subsystem (including sealing effectiveness) and the TC Cask Mating Subsystem (for HVAC) shall be tested during HVAC tests.

Interlock testing:

The opening of the sliding door is interlocked with the closed position of the two TC port covers and the radiation monitoring information. The TC port covers shall be placed in the "not closed" position to test the interlocks. The radiation monitoring interface shall be tested by manually generating a radiation alarm.

HVAC Subsystem

The following tests shall be performed on the HVAC Subsystem:

All components of the HVAC Subsystem shall be factory tested to ensure that design

specifications are met. Prior to operation, the exhaust fans will be run to verify proper operation. The heat pump and cooling units will also be run to verify that they are operating properly.

The temperature monitoring equipment will be calibrated. The temperture sensors and alarms will be checked by locally cooling and heating the sensors.

The temperature of the DTS will be monitored for at least 96 hours to ensure that the system is operating properly.

Check the proper monitoring of the temperature in each room.

Pressure Differential Control:

Test the capability of the HVAC Subsystem to establish the pressure differential between the three areas. Check the proper monitoring of the pressure in each room. After establishment of the proper pressure differential between the three areas, bypass automatic damper and fan control and check that alarms corresponding to the incapability of the HVAC to maintain the proper pressure differential are generated.

Test the automatic switching from lead to backup fan by shutting off the lead exhaust fan power. Test the monitoring and alarms linked to this status. Shut off the backup exhaust fan (loss of double confinement). Check that proper alarms are activated. Check that in each case the damper associated with the fan is closed.

Check that each damper failure (detected by the equipment) triggers an alarm and that the failing equipment can be identified (monitoring display).

Interface with Sliding Door & Cask Mating Subsystem

With the sliding door closed, the source and receiving cask mated, the pressure differential between areas established, open the sliding door or disengage one or the other cask and check that in each case the exhaust fan speed is kept constant. Reestablish the conditions and check that the pressure differential is reestablished. Bypasses can be used to change the conditions.

Cask Transfer Subsystem

Test the positioning of the transfer trolleys, generate off-normal operations activating different sensors (over travel, collision...) while the trolleys are running.

Test the locking operation. Check that the monitoring system displays the locking information.

Transfer Confinement Casks Mating Subsystem

Mating:

With the casks (or a mockup of a cask) in position, test the mating operations under normal conditions. Visually check the platform position. Check that the vertical positioning of the three electrical jacks and the mating status are displayed in the Control Center.

Disengagement:

Verify that the Cask Mating Subsystem moves to the full up position without binding.

Transfer Confinement Port Covers

Positioning:

Test the positioning of each TC port cover. Check the proper alignment of the port covers with lines drawn on the mezzanine plate. Test off-normal operations (over travel).

Test the locking operation when the TC port cover is open. Test the time-out detection. Test inconsistencies between lock and port cover positions as shown in Tables 9.2-1 and 9.2-2.

Table 9.2-1
Receiving Cask TC Port Cover Instrumentation Logic Table

	Open	Closed	Off Centered	Locked	Unlocked
Open		X	X	O	O
Closed	X		X	X	O
Off Centered	X	X		X	O
Locked	O	X	X		X
Unlocked	O	O	O	X	

Table 9.2-2

Source Cask TC port cover instrumentation logic table

Information	Open	Closed	Locked	Unlocked
Open		X	O	O
Closed	X		X	O
Locked	O	X		X
Unlocked	O	O	X	

Test the interlocks between the positioning and locking operations.

Verify proper operation of manual backup system for TC port covers, including moving platforms from worst condition positions.

<u>Source Cask Lid and Receiving Cask Shield Plug Handling Subsystem</u>

The two upper shield port covers opening, closing and locking functions shall be tested independently.

Test the positioning of the upper shield port. Test off-normal operations (over travel).

Test the locking operation when the upper shield port is closed. Test the time-out detection. Test inconsistencies between lock and shield port positions as shown in Table 9.2-3.

Table 9.2-3
Source and Receiving Cask Upper Shield Ports Instrumentation Logic Table

Information	Open	Closed	Locked	Unlocked
Open		X	X	O
Closed	X		O	O
Locked	X	O		X
Unlocked	O	O	X	

Test the interlocks on the positioning and locking operations.

Preoperational testing of the upper crane shall be performed in accordance with NOG-7420. Inspections prior to performance testing shall be in accordance with NOG-7520. A load test of the hoist and grapple will be performed at 125% of the rated load in accordance with NOG-7523.

Perform an operation functional check on the hoist lowering and lifting. Verify that the positions of the hoist do not result in any interferences. Verify that the grapple engages and disengages properly. Verify that the gripping device engages and disengages properly. Verify that all sensors are functioning including verification of proper position and function of limit switches for positioning trolley and function of the over travel limit switches. Verify absolute positioning of the hoist with and without load. Verify functionality of all limit switches and associated instrumentation.

Verify that the load cell is reading correctly by lifting known loads.

Verify that the upper crane hoist can not operate of the lid/shield plug handling grapple is not stopped in its upper z position. Verify that the upper crane trolley can not be operated unless the upper shield ports are closed.

Verify that the upper shield ports cannot be closed unless the lid/shield plug grapple is in the upper z position or if the hoist is loaded.

Verify that the upper shield port covers cannot be opened if the opposite TC port cover is not closed.

Verify that the upper shield ports cannot be unlocked if the fuel handling system is in operation.

Verify that only one upper shield port can be open at one time.

Verify that the upper shield ports cannot be locked in the closed position.

Verify that motion of the hoist is stopped when the cables are under loaded during lowering.

Verify that the motion of the hoist is automatically stopped when the grapple reaches the upper position (with no load) and the position above the TC port cover when the cables are loaded.

Verify that the hoist cannot be operated unless the fuel assembly handling crane carriage is stopped in the parking position.

Verify that the hoist cannot be used for lifting unless the grapple is totally disengaged from the overlid or unless both the gripping device and grapple are fully engaged.

Verify that the grapple can not be disengaged if the cables are loaded or if the grapple is not in its proper z position.

Fuel Assembly Handling Subsystem

Inspections of the Fuel Handling Subsystem prior to performance testing shall be in accordance with NOG-7520. Preoperational testing of the upper crane shall be performed in accordance with NOG-7420 A load test will be performed on the system at 125% of the rated load in accordance with NOG-7523.

Perform a functional test to ensure that the crane carriage and the rotating platform can move to locate the fuel transfer tube above all locations in both the source and receiving casks.

Perform a complete checkout of the positioning system to ensure that the gross positioning is programmed correctly. Verify that all operations can be monitored visually with the assistance of the CCTV's.

Verify that the crane carriage and the rotating platform will not move unless the fuel assembly grapple is in the upper z position.

Verify that the crane carriage and the rotating platform cannot be moved if the crud catcher is not closed.

Verify that the crane carriage cannot be moved unless the two upper shield ports are locked in the closed position. Verify that the crane carriage cannot be moved unless the two TC port covers are locked in the open position.

Verify that the crud catcher cannot be opened unless the crane carriage is stopped in both the x and y directions and the rotating platform is also stopped.

Verify that the crud catcher cannot be closed unless the grapple is in the upper z position.

Verify that the hoist operates properly under load and without load. Verify, using a dummy fuel assembly that the pass through to the fuel transfer tube is smooth and no binding

results.

Verify that the grapple fully engages and disengages. Verify that disengagement will not occur if the cable is loaded or if the grapple is not stopped in the proper position.

Verify proper operation of all sensors including verification of grapple fingers closed and open and fuel assembly presence. Verify proper operation and readout of the load cell.

Verify proper operation of all manual backup positioning equipment and verify proper operation of all electrical backup equipment.

Verify proper operation of backup power supply.

Fire Suppression System

Verify proper operation of smoke and fire detection systems.

Radiation Monitoring System

The Radiation Monitoring System shall be calibrated and functionally tested prior to operation. It is expected that these tests will be incorporated into the reactor's instrumentation maintenance program.

Cameras and Lighting

Verify proper positioning of all cameras and lights. Verify that all operations which require visual monitoring can be seen using the cameras and monitors.

9.3 Training Program

The training program plans for the DTS are site specific and will be submitted with the site-specific license applications.

9.4 Normal Operations

9.4.1 Procedures

Detailed written procedures for all normal operating, maintenance, and testing procedures will be prepared and in effect prior to operation of the DTS. These procedures are briefly described in the following subsections.

These procedures will be expanded in detail, presented on a site specific format and included in the submission of the

9.4.1.1 Administrative Procedures

Administrative procedures will provide rules and instructions to DTS personnel to provide a clear understanding of operating philosophy and management policies. These procedures included instructions pertaining to personnel conduct and control, including consideration of job-related factors which influence the effectiveness of operating and maintenance personnel, e.g. work hours, entering and exiting the DTS, organization, and responsibility, etc.

9.4.1.2 Annunciator Response Guides

Annunciator response guides will provide information relative to each alarm annunciator which monitors cask and fuel parameters. The procedures will provide alarm set points and appropriate corrective action.

9.4.1.3 Radiation Protection Procedures

Radiation protection procedures are used to implement a radiation control program. The radiation control program will involve the acquisition of data and provision of equipment to perform necessary radiation surveys, measurements, and evaluations for the assessment and control of radiation hazards associated with the operation of the DTS. Procedures will be developed and implemented for: monitoring exposures of employees; radiation surveys of work areas; and radiation monitoring of maintenance activities.

Regularly scheduled surveillance will be required, but calculations show that dose received by personnel from anticipated activities are within the guidelines set forth in 10 CFR 20. There are no credible events during normal operations that could lead to high radiation releases. Accident analyses in Chapter 8 also show no credible event leading to high radiation releases.

9.4.1.4 Maintenance Procedures

Maintenance procedures will be established for performing preventative and corrective maintenance on the DTS equipment. Preventive maintenance will be performed on a periodic basis to preclude the degradation of DTS systems, equipment and components. Corrective maintenance is that performed to rectify any unexpected system, equipment, or component malfunction, and is initiated as necessary.

9.4.1.5 Operating Procedures

Operating procedures will provide instructions for the use of DTS subsystems.

9.4.1.6 Test Procedures

Periodic test procedures will be developed to ensure that DTS subsystems, equipment, and components are observed on a routine basis to verify operability.

9.4.1.7 Pre-operational Test Procedures

Pre-operational test procedures will be established to ensure that DTS structures, systems, and components satisfactorily perform their required functions. These test procedures will further ensure that the DTS has been properly designed and constructed and is ready to operate in a manner that will not endanger the health and safety of the public.

9.4.1.8 Quality Assurance Procedures

Quality assurance procedures will be established to ensure that the operation and maintenance of the DTS is performed in accordance with 10CFR72 Subpart G or 10CFR50 Appendix B, as applicable.

9.4.2 Records

Records will be maintained in accordance with the site specific program and will be described in the site specific license application.

9.5 Emergency Planning

The site specific Emergency Plan will describe the organization , assessment actions, conditions for activation of the emergency organization, notification procedures, emergency facilities and equipment, training, provisions for maintaining emergency preparedness, and recovery criteria used at the site utilizing the DTS.

Portions of the Emergency Plan and applicable implementing procedures will be modified to reflect the actions to be taken during off-normal and accident conditions. Design Event III will require the declaration of a Notification of Unusual Event. Design Event IV will require declaration of an Alert.

A comprehensive analysis of the DTS due to various accidents has been performed and is presented in Chapter 8. For each postulated accident, appropriate corrective action and recovery procedures, which would minimize the consequences of the accident, have been described.

Detailed emergency plans will rely heavily on the emergency services and organizations available at the on-site reactor. Details of how the DTS will be incorporated into the Emergency Plans will be provided by the utility applying for certification of a specific site.

9.6 Decommissioning Plan

The DTS is designed so that the major components can be disassembled and transported as LSA material to a new site for reuse. The concrete structure, interior walls and floor, can be decontaminated and disposed of as either low level waste, or preferably, as normal debris, minor equipment items will be disposed as low level waste.

9.6.1 Decommissioning Program

The DTS is designed to confine contamination within its three areas. After each completed dry transfer, equipment and structure surfaces of the DTS are decontaminated to levels that permit maintenance activities. The level of radiation and the contamination in the three areas is expected to be low. This approach facilitates decontamination at the termination of the DTS use.

All three areas will be vacuumed to remove any loose contamination. Each equipment item will be wiped with damp cloths, surveyed and removed to appropriate disposition. The only equipment which is expected to present high contamination levels is the fuel transfer tube and its associated crud catcher. Efforts will be taken to decontaminate the fuel transfer tube. If unsuccessful, the fuel transfer tube may be disposed of. All other major equipment which is decontaminated on site will be packed and transported to the next location. This equipment includes: upper crane, CCTV and lighting, fuel assembly handling, cask mating, upper shield cover, roof plate, cask mating, TC port cover handling, mezzanine plate, cask transfer, cask, lid handling, HVAC. Only the sliding door, the protective cover, and concrete structure will not be removed.

Once only the shell of the DTS remains, the inside walls of will be cleaned as required. The walls of the DTS are painted to facilitate decontamination and to prevent the need for scabbling the concrete.

No residual contamination is expected to be left behind outside the DTS. The rails and peripheral utility structure will be decommissioned when all equipment inside the DTS building is removed.

Decommissioning is estimated to use a 5 member crew and last for 60 days. Waste from decontamination and decommissioning will consist of cloths, protective clothing from workers, HEPA filters, and minor equipment.

9.6.2 Cost of Decommissioning

The amount of material expected to be disposed of as low level waste is expected to be negligible. The primary source of contamination is the spalled material from the fuel assembly (crud), however, the fuel assembly is enclosed by the transfer tube through most of the fuel transfer process. This tube is the only piece of equipment that potentially will not be decontaminated. All other major equipment items and the walls of the DTS will be decontaminated. The volume is estimated to be 20-40 55-gallon drums (Approximately, 2-4 55-gallon drums per week). These are expected to be easily incorporated into the waste streams from other site operations.

Demolition of the DTS structure is not included in this waste volume estimate. The DTS building is not expected to be contaminated following cleaning and it will be demolished and disposed of through standard construction methods.

9.6.3 Decommissioning Facilitation

The DTS is designed for its ease of decontamination. The fuel during the fuel transfer process is enclosed in a steel tube with a crud catcher. The majority of crud from a fuel assembly is expected to be captured by this crud catcher. When the fuel is lowered into the receiving cask, this spalled material is expected to fall into the receiving cask. Therefore, the amount of loose contamination in the DTS is expected to be minimal.

The concrete walls are coated with paint to eliminate the need to scabble the concrete. The painted walls will only require wiping with damp cloths or at most high pressure water cleaning for decontamination.

Due to the design features of the DTS, the amount of material requiring disposal generated from decontamination is minimal.

9.6.4 Recordkeeping of Decommissioning

Recordkeeping in support of decommissioning will consist of the source cask records, the receiving cask records, the fuel transferred records, and facility records (operating procedures, maintenance, incident reports, decontamination, etc.). These will be kept in a secure storage area at the host facility.

9.7 Physical Security and Safeguards and Contingency Plans

The physical security and safeguards and contingency plans are site specific and will be discussed in the site specific license applications.

10. OPERATING CONTROLS AND LIMITS

10.1 Proposed Operating Controls and Limits

The general areas where controls and limits are necessary for safe operations of the DTS system are shown in Table 10.1-1. The conditions and other items to be controlled have been selected based on the safety assessments for normal and accident conditions provided mainly in Chapter 8.

In addition to the operating controls and limits proposed herein, there will be specific operating controls related to welding of the receiving cask lids, inerting of the receiving cask, and site specific controls. These controls and limits will be specified in the site application.

Table 10.1-1
General Areas Where Controls and Limits are Necessary

AREAS FOR OPERATING CONTROLS AND LIMITS	CONDITIONS OR OTHER ITEMS TO BE CONTROLLED
1. Cask Characteristics	Surface Dose Rates, Alignment with the TCS, Dimensional characteristics of lid opening, weight of lid and shield plug, compatibility with lifting pintle
2. IFA Characteristics	Type and physical condition, burnup, initial enrichment, total weight, gamma source strength, neutron source strength, decay heat power, post irradiation time
3. Cask Transfer Trolleys	Security of Load Locking Mechanism
4. Upper Crane	Load testing Grapple operation Sensor operation
5. Fuel Handling Subsystem	Load testing Sensor operation Operation of grapple Crud catcher operation
6. Cask Mating Subsystem	Mating of Cask with Cask Mating Subsystem Sensor Operation Operation of gripping device
7. Sliding Door	Interlocks
8. Health Physics	Radiation Detection Radioactivity Detection Health Physics Surveys
9. HVAC System	Operability Radioactivity Monitoring HEPA filter pressure differences HEPA filter testing

10.2 Development of Operating Controls and Limits

This section provides a description and discussion of the operating controls and limits specified in this Topical Report. These specifications cover generic issues associated with the operation of the DTS so as to ensure the protection of operators, the environment and the public's health and safety. Any additional operating controls and limits on site specific issues will be supplied by site license applicants.

10.2.1 Functional and Operational Limits, Monitoring Instruments and Limiting Control Settings

This category of operating controls and limits applies to operating variables that are observable and measurable during operation of the DTS.

10.2.1.1 Surface Dose Rate of Source Cask

Title: Surface Dose Rate of Source Cask

Specification: The source cask shall provide shielding for the design basis fuel at least as well as the design basis fuel. The maximum contact dose rate at axial midpoint on the top of the cask shall not exceed 250 mrem/hr. The maximum contact dose rate at the radial midpoint at the side of the cask shall not exceed 300 mrem/hr. (Gamma and Neutron)

Applicability: All source casks

Objective: Ensure that the operational dose rates to workers are within site acceptance criteria and ALARA.

Action: Casks with higher surface dose rates will not be permitted inside the DTS.

Surveillance: Surface dose rates on all incoming source casks will be surveyed.

Basis: Shielding analysis of Chapter 7.

10.2.1.2 Alignment of the Source Cask or Receiving Cask with the TCS

Title: Cask Alignment

Specification: All source casks and receiving casks must mate properly with the cask mating system.

Applicability: All casks.

Objective: Maintain confinement between the Lower Access Area and the TCS to minimize the spread of contamination and ensure proper alignment.

Action: If cask will not fitup properly, operators can investigate the cask mating system by entering the lower access area after verification that both casks are closed, and that radiation levels within the Lower Access Area are low enough to permit entry.

Surveillance: The mating of the casks with the cask mating subsystem will be verified by video camera from the Control Center. Shield plug or source cask lid removal will not be performed prior to verification of proper fitup.

Basis: ALARA

10.2.1.3 Cask Characteristics

Title: Cask Characteristics

Specification: All source casks and receiving casks must interface with the DTS to ensure proper operation.

Applicability: All casks.

Objective: Ensure that the DTS will properly function, and prevent operational interference.

Action: All cask designs shall be verified to ensure that the cask height, diameter, inside diameter, lid diameter, shield plug diameter, fuel cell opening, trunnion sizes and locations and pintle dimensions are acceptable for proper interface with the DTS.

Surveillance: Design verification.

Bases: Section 3.1.2

10.2.1.4 Spent Fuel Specifications

Title: Fuel Specifications

Specifications: Type Intact PWR fuel assemblies

Weight	1720 lbs. max.
Burnup	≤ 40,000 MWD/MTU
Initial Enrichment	≤ 3.75 w/o U-235
Cooling Time	minimum 5 years
Decay Heat / Fuel Assembly	≤ 0.74 kW
Neutron Source per assembly	≤ 2.4E+08 n/sec with spectrum bounded by Table 3.1-3
Gamma Source per assembly	≤ 7.8E15 photon/sec with spectrum bounded by Table 3.1-2

Applicability: All fuel.

Objective: To avoid exceeding the ranges for which the thermal, shielding, criticality and release calculations are valid.

Action: Spent Fuel which do not meet these specifications may not be transferred in the DTS.

Surveillance: Each spent fuel assembly will be demonstrated to meet these specifications by reactor staff, using site-specific procedures, before fuel transfer within the DTS.

Basis: The basic design of the DTS against the physical and radiological parameters specified.

10.2.1.5 <u>Cask Transfer Trolley Locking</u>

Title: Locking of Source Cask and Receiving Cask Trolleys in the Preparation Area and the Lower Access Area.

Applicability: Source Cask and Receiving Cask Trolleys

Objective: Prevention of inadvertent movement of the trolleys during a seismic event.

Action: The cask trolleys will be locked in place in the Preparation Area prior to removing the lid bolts of the source cask and prior to initiating closure operations on the receiving cask. Both cask trolleys will be locked in place in the Lower Access Area after positioning of the cask below the opening in the Mezzanine plate.

Surveillance: Interlock of locking pin and TC port cover opening.

Basis: Prevention of movement of the trolleys during a seismic event.

10.2.1.6 Tiedown of Casks on Trolleys

Title: Tiedown of Casks on Trolleys

Applicability: Source cask and receiving cask trolleys.

Objective: Prevention of cask tipover during tornado or seismic event.

Action: Cask shall be securely fastened to the trolley prior to movement of the trolley into the Preparation Area.

Surveillance: Operational Procedure.

Basis: Prevention of cask tipover due to tornado or seismic event.

10.2.1.7 Load Testing of Upper Crane and Fuel Handling Crane

Title: Pre-Operational Testing of Upper Crane and Fuel Handling Crane

Applicability: Cranes

Objective: Prevention of loss of load.

Action: Cranes shall be inspected and tested in accordance with NOG-7000.

Surveillance: Testing and inspections shall be verified by appropriate site personnel. Documentation shall be in accordance with NOG-7600.

Basis: Prevention of loss of load.

10.2.1.8 Operational Testing of Grapples and Gripping Devices

Title: Grapples and Gripping Devices Operational Testing

Applicability: Fuel Handling Crane Grapple, Cask Mating Subsystem Gripping Device and Upper Crane Grapple

Objective: Ensure grapples stay engaged while under load, can be easily disengaged with no load, and all sensors operate properly.

Action: Full check out of grapple and gripping device operations including operational testing of all sensors, load indicators, and grapple movements prior to first use and during each scheduled maintenance period.

Surveillance: Full operational testing.

Basis: Prevention of loss of load, and prevent need for maintenance on equipment located in high radiation environment.

10.2.1.9 Sensor Functional Testing

Title: Sensor Functional Testing

Applicability: Fuel Handling Crane, Cask Mating Subsystem, Shield Plug and Source Cask Lid Handling Subsystem, Cask Transfer Subsystems

Objective: Verification of proper function of all sensors.

Action:

1. Prior to first use of the DTS, all equipment shall go through complete system functional testing including verification of proper positioning of all sensors, proper indications, proper activation of interlocks, proper disengagement of interlocks through the use of bypasses. This shall include functional testing of all backup instrumentation.

2. During each scheduled maintenance period, all equipment shall be functionally checked to ensure that all instrumentation is in good working order.

Surveillance: See action above.

Basis: Assurance that operators and the control system are provided with accurate information from the equipment.

10.2.1.10 Port Cover Locking

Title: Port Cover Locking.

Applicability: Upper shield port cover locking in closed position and TC port cover locking in open position.

Objective: Upper shield port covers: Ensure that radiation dose rates on the roof of the DTS are within calculated values, thus ensuring that off-site dose rates are within allowable limits.

TC port covers: Prevention of collision with fuel handling machine and ensuring that the opening to the casks is clear for fuel transfer.

Action: The upper shield port cover will be locked in the closed position during fuel transfer. The TC port covers will be locked in the open position during fuel transfer.

Surveillance: Verification that sensors and interlocks are working properly prior to first use and during scheduled maintenance periods. Verification of proper operation and fitup of locking devices prior to first use.

Basis: Shielding evaluation presented in Section 7 and proper operation.

10.2.1.11 Upper Crane Alignment

Title: Upper Crane Alignment

Specification: Upper crane must align with the lifting pintle on the cask mating subsystem.

Applicability: Upper Crane

Objective: Ensure proper fitup and operability of grapple and gripping device.

Action: Locate crane above each cask opening and engage and disengage with overlid pintle.

Surveillance: Verify proper engagement, disengagement and operation prior to first use and during scheduled maintenance periods.

Basis: Ensure that source cask lid and shield plug can be removed and

replaced during operations.

10.2.1.12 Upper Crane Operations

Title: Upper Crane Vertical Positioning

Specification: Upper crane must be capable of proper positioning in full up position, above TC port cover with lid (or shield plug), above TC port cover with lid (or shield plug) disengaged, and at location of overlid gripping device in the cask mating subsystem.

Applicability: Upper Crane

Objective: Ensure proper fitup and operability of grapple and gripping device.

Action: Locate grapple in vertical orientation in positions specified in the operating procedures.

Surveillance: Preoperational testing of sensors and crane prior to first use.

Basis: Ensure proper functioning of crane hoist.

10.2.1.13 Fuel Handling Subsystem Operation

Title: Fuel Handling Subsystem Operation

Specification: Fuel Handling Subsystem must be able to safely lift one fuel assembly out of the source cask and place it into a specified location in the receiving cask.

Applicability: Fuel Handling Subsystem

Objective: Ensure safe handling of the fuel assembly.

Action: Demonstrate using a dummy fuel assembly that the fuel handling subsystem works properly prior to first use of the DTS. Full operational testing would include verification of crud catcher operation, full operation of bridge, trolley and rotating platform and all sensors. Verification of all computer assisted positioning.

Surveillance: Proper alignment and positioning is continuously checked during operation using video cameras.

Basis: The fuel handling subsystem must transfer fuel from the source cask to the receiving cask.

10.2.1.14 Sliding Door

Title: Operation of Sliding Door

Specification: The sliding door must properly shield the preparation area from radiation during fuel transfer.

Applicability: Sliding Door

Action: Sliding Door must interlock with radiation monitoring system to ensure that door will not be opened during fuel transfer. Sliding door must provide adequate shielding during fuel transfer.

Surveillance: Continuous radiation monitoring in the Preparation Area during DTS operation. Check out of interlocks prior to first use of DTS, and periodic testing of interlocks during scheduled maintenance periods.

Basis: Radiation safety.

10.2.2 Limiting Conditions for Operation

Limiting conditions for operation of equipment, systems and components (in terms of lowest acceptable level of performance, minimum number of components available, etc.) will be concerned with operating systems.

Technical conditions and characteristics are provided in terms of allowable levels of operating variables which are measured before operation of the equipment is permitted. Also included in this section are interlocks which automatically inhibit operations unless certain conditions are met.

10.2.2.1 HVAC Subsystem Operational Checks

10.2.2.1.1 Ventilation System Pre-shift Checks

Title: Ventilation System Pre-shift Checks

Specification: Fans are running. Pressure differences across HEPA filters within range, typically 1-4 in. wg. Pressures in each of the DTS areas (TCA, Lower Access Area, and Preparation Area) are within range.

Applicability: HVAC Subsystem

Objective: To minimize spread of contaminated material.

Action: If fans are not running, shift to backup system. Investigate cause of problem and repair. Adjust flow rates to ensure pressure differentials.

Surveillance: Check flows, pressure differentials and operation of fans before starting each shift. Replace filters when casks are moved out of Lower Access Area if required, and as part of scheduled maintenance.

Basis: HEPA filters are typically designed for pressure differentials of 1 - 4 in wg, depending on dust load and flow. Actual values are site-specific, depending on type and make of filters used. High pressure differences indicate filters need changing. Radiation levels in the Lower Access Area may also indicate need for filter change.

10.2.2.1.2 HEPA Filter Leak Detection

Title: HEPA filter leak detection

Specification: Filters must pass DOP, sodium flame or similar test.

Applicability: All HEPA filters

Objective: To ensure that exhaust air is adequately filtered.

Action: If filters fail test, change them. Also change filters as part of scheduled maintenance.

Surveillance: Perform test after installing filters.

Basis: Filters will be tested in accordance with ANSI/ASME N509.

10.2.2.1.3 Air Particulate Check

Title: Air Particulate Check

Specification: Air samples from the exhaust stack shall be monitored and meet site specific limits.

Applicability: This will be addressed in the site-specific Health Physics Control

procedure. See also Section 7.3.4.2.

Objective: Ensure particulate release is within allowable values.

Action: The exhaust stack will be equipped with a continuous air monitor, which collects and monitors airborne particulate, iodine and noble gases.

Surveillance: Continuous monitoring.

Basis: Off Site Dose rates.

10.2.2.2 Cask Handling

10.2.2.2.1 Health Physics Surveys on the Receiving Cask

This will be addressed in the sit e specific health physics control procedure.

10.2.2.2.2 Security of Casks on Cask Trolleys

Title: Security of Casks on Cask Trolleys

Specification: Casks must be secured on the casks.

Applicability: Source Cask and Receiving Cask and their trolleys.

Objective: Prevention of cask tipover due to seismic event.

Action: Loaded trolleys will not be moved until casks are securely fastened.

Surveillance: Bolt torques shall be verified prior to moving trolley.

Basis: The cask holddown devices are designed against the design basis earthquake loadings assuming that they are securely fastened.

10.2.2.2.3 Interlocks

Title: Interlocks

Specification: Interlocks prevent operators from incorrectly performing operations which would affect the safety of the DTS, such as lifting a load without proper engagement, or opening the sliding door during fuel transfer.

Applicability: Control System

Objective: Prevention of inadvertent incorrect operations.

Action: Interlocks are provided per Table 5.4-1 which prevent the operator from performing operations which would result in an unsafe condition.

Surveillance: Interlocks cannot be bypasses without supervisory password or key.

Basis: DTS is designed so that operators cannot render the system unsafe by incorrect commands.

10.2.3 Surveillance Requirements

This section addresses the routine checking or continuous monitoring carried out to ensure that no undetected radiation or gas leak may occur tend to ensure no degradation of air flow through the DTS.

Tests and inspections of equipment necessary to maintain limits are addressed in Section 10.2.1 and 10.2.2.

10.2.3.1 Area Gamma Radiation Monitoring

Title: Area Gamma Radiation Monitoring

Specification: Alarm if in excess of limits specified in Chapter 7.

Applicability: Monitors specified in 7.3.4.1.

Objective: To warn operators of high radiation fields where they might otherwise be working.

Action: If alarm triggered, evacuate/do not enter affected area. Supervisor will arrange to find source of radiation and correct fault under health physics control.

Surveillance: Permanent monitoring with alarms locally, in the Control Center and repeated as a general alarm in the on-site Reactor Control Room.

Basis: See Chapter 7.

10.2.3.2 Portable Radiation Detection

Title:	Portable Radiation Detection
Specification Applicability Objective Action Surveillance	These will be addressed in the site specific Health Physics Procedure

10.2.3.3 Ventilation Systems Radioactivity Monitoring

Title:	Ventilation Systems Radioactivity Monitoring
Specification:	Alarm if radioactivity exceeds instrument set points
Applicability:	Ventilation systems radioactivity monitor at exhaust stack
Objective:	To measure, record and alarm radioactivity which may be discharged to atmosphere
Action:	If radioactivity is detected, return fuel to casks,and install source cask lid and receiving cask shield plug. Supervisor will arrange to find source of radiation and correct fault under health physics control.
Surveillance:	Permanent Monitoring Periodically check that sampling method is accurate.
Basis:	To ensure that discharges are maintained at ALARA levels in accordance with 10CFR20.

10.2.3.4 Shut down during Tornado Watch or Warning

Title:	Tornado Watch or Warning Shutdown
Specification:	If a tornado watch or warning is issued for the vicinity of the DTS, the DTS will be shut down.
Applicability:	Any tornado watch or warning within a specified radius of the DTS.
Objective:	To ensure recovery of the fuel assemblies after a tornado.

Action: Fuel assembly being transferred will be installed in nearest cask. Source cask lid and receiving cask shield plug will be installed on the casks. TC port covers and upper shield port covers will be closed. Control center may be moved to a sheltered area. Casks which are not fully closed (partially welded or bolted) will be moved into the Lower Access Area and the sliding door will be closed.

Surveillance: Weather shall be monitored on site or from a weather tower within 10 miles of the DTS.

Basis: Ensure that the fuel assemblies can be removed from the DTS safely after the DTS is struck by a tornado missile.

10.2.4 Design Features

Any minor changes in the design of essential equipment to suit specific site requirements will be covered in site-specific license applications. Control of further changes will be addressed then, and therefore no design controls are provided in this Topical Report.

10.2.5 Administrative Controls

Site specific license applications will contain a full description and discussion of organization and administrative systems and procedures, record keeping, review, audit and reporting necessary to ensure that the operation of the DTS is performed in a safe manner. Therefore, no administrative controls are provided in this report.

CHAPTER 11

QUALITY ASSURANCE PROGRAM

This chapter describes the quality assurance controls which apply to activities that affect the components and systems important to safety. "Quality Assurance" includes quality control, which comprises those quality assurance actions related to control of the physical characteristics and quality of the material or components to predetermined requirements.

The design of the DTS was performed in accordance with Transnuclear Quality Assurance Program that has been established in conformance with the requirements of 10 CFR 72, Subpart G. Likewise, the organizations that select the site, construct the facility , fabricate and install the equipment, test the systems, operate the systems and decommission the facility and site shall have a Quality Assurance Program appropriate to these activities. The QA programs shall be implemented for all activities which are important to safety including those that are subcontracted for this project. The components and systems important to safety are listed in Section 3.4, "Classification of Structures, Components and Systems."

Supplier organizations and their subcontractors shall be made aware of the mandatory QA requirements including the applicability of Codes and Standards by identifying such in procurement documents. These requirements must cover the activities identified throughout the life of the activity.

The eighteen (18) criteria described in Subpart G are as follows:

1. Quality Assurance Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures and Drawings
6. Document Control
7. Control of Purchased Material, Equipment and Services
8. Identification and Control of Materials, Parts and Components
9. Control of Special Processes
10. Licensee Inspection
11. Test Control
12. Control of Measuring and Test Equipment
13. Handling, Storage, and Shipping Control
14. Inspection, Test and Operating Status

15. Nonconforming Materials, Parts or Components
16. Corrective Action
17. Quality Assurance Records
18. Audits

A copy of TN's Quality Assurance Program for Design, Fabrication, Inspection and Testing of Storage Systems for Spent Fuel and Associated Radioactive Materials (E-9213) is enclosed attached as Appendix 11A.1 for reference.

E-9213
Rev 2

QUALITY ASSURANCE PROGRAM

FOR

DESIGN, FABRICATION, INSPECTION, MODIFICATION AND TESTING OF

STORAGE SYSTEMS FOR SPENT FUEL AND RADIOACTIVE MATERIALS

Transnuclear, Inc.
Two Skyline Drive
Hawthorne, NY 10532

TABLE OF CONTENTS

INTRODUCTION

The Code of Federal Regulations, Title 10, Part 72 "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation" (ISFSI), requires in Subpart G that a quality assurance program based on the criteria in Appendix B of 10 CFR 50 be established and implemented for the structures, systems and components of an ISFSI that are important to safety. This document describes how Transnuclear, Inc. (TN) intends to satisfy these requirements as a supplier of storage systems* for spent fuel and associated radioactive materials.

As a supplier, TN has QA responsibility for all phases of design, fabrication, inspection and testing of storage systems, which TN delivers to an ISFSI for storage of licensed material. This QA responsibility exists whether TN has contractual responsibility for each of the individual phases or not.

For example, if TN intends to deliver equipment which was constructed by others without TN involvement, TN shall assure itself that activities associated with its construction were performed, where applicable, in accordance with the quality assurance requirements of 10 CFR 72, Subpart G. On the other hand, if a storage system is designed, fabricated, inspected and tested by TN or under contract to TN, TN shall assure that the QA Program, as described herein, is implemented during these phases. Organizations that perform such work under direct contract to TN are identified herein as major participating organizations. They may provide hardware, services or both.

This document describes TN's generic QA Program for the design, fabrication, inspection, modification and testing of storage systems in accordance with 10 CFR 72, Subpart G. Additionally, TN's Topical Safety Analysis Report (TSAR) for a storage system shall contain specific provisions as required. These specific provisions shall consider the complexity and the proposed use of the structures, systems and components.

The organization of this document follows that of Appendix B of 10 CFR 50, in that sections are numbered and titled the same as the corresponding 18 criteria of Appendix B.

* A storage system consists of a storage module and any associated equipment which may be required for loading and unloading at the ISFSI.

1. ORGANIZATION

The organizational structure which has been set up at TN to establish and implement its QA Programs is shown in Fig. 1. The authority and duties of the personnel performing activities affecting the safety related functions are described below.

The Chief Engineer is the person responsible for establishing the QA Program. He reports to the President of TN. The President shall approve the QA Program and any revisions thereto. The Chief Engineer shall approve Corporate QA Procedures and any revisions thereto. The minimum qualification requirements for the position of Chief Engineer are a bachelor's degree in engineering from an accredited institution and ten years of experience in engineering and quality assurance activities.

For each project, a person shall be assigned as the QA Engineer for that project. In his capacity as Project QA Engineer he reports directly to the Office of the President, as shown by the solid line in Fig. 1. The person who is assigned as the QA Engineer for a particular project shall have no other responsibilities on that project. He shall be functionally independent of any group or individual directly responsible for the activities which he monitors. He shall also be sufficiently independent of undue influences and responsibilities for schedules and costs. He shall have the authority and organizational freedom to enforce QA requirements, to identify problem areas, to recommend or provide solutions to QA problems, and to verify the effectiveness of the solutions. The minimum qualification requirements for the position of Project QA Engineer are a bachelor's degree in engineering, physical sciences or mathematics from an accredited institution and five years of experience in engineering activities with at least one year of experience in quality assurance activities.

The services of a Quality Assurance consultant may be utilized. The minimum qualification requirements for the QA consultant shall be the same as those for a Project QA Engineer. The consultant may provide auditing and oversight services to assure that quality assurance requirements are fulfilled in accordance with this document and applicable procedures. The QA consultant may serve as the QA Engineer on specific projects.

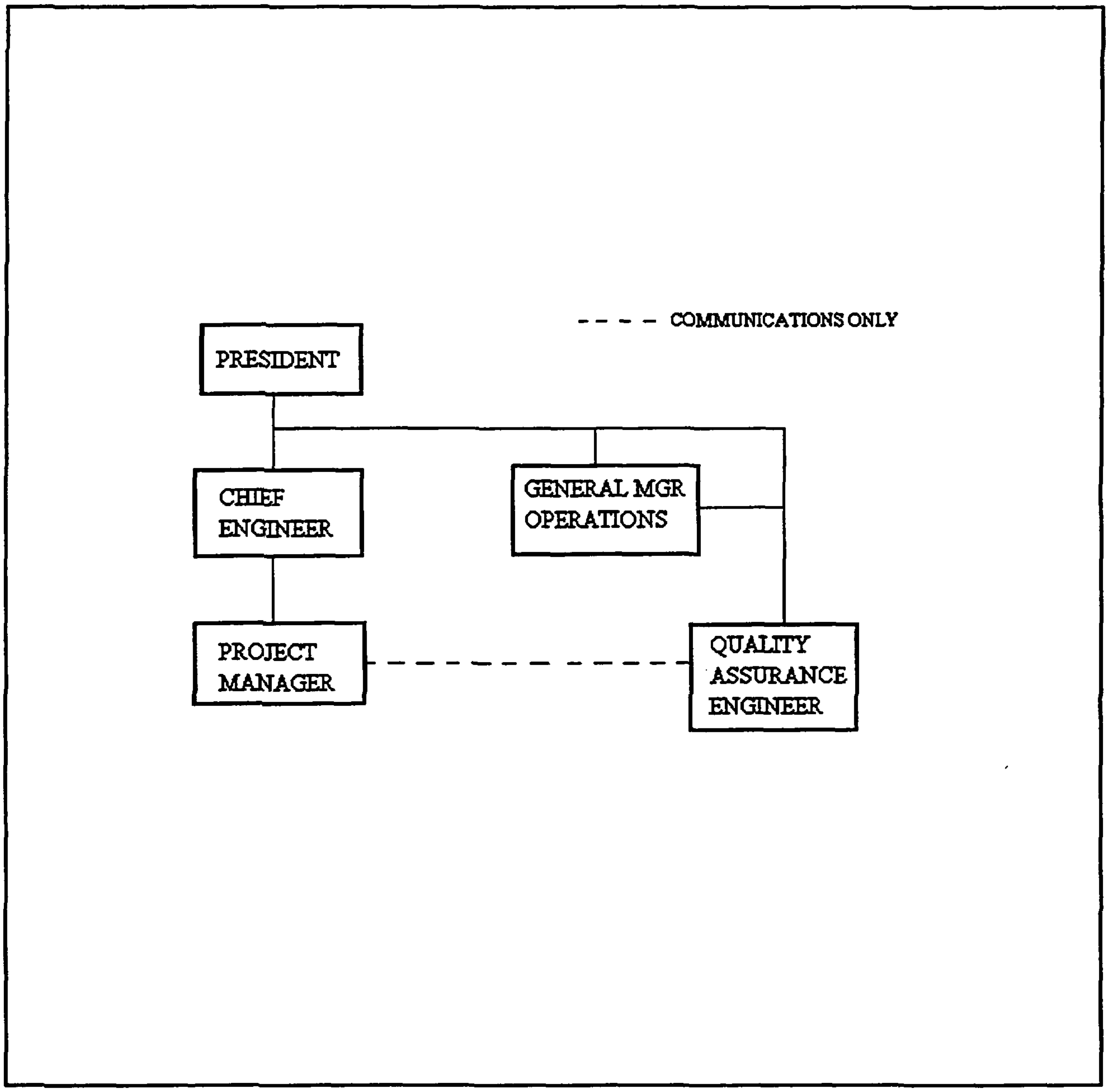


FIG. 1 TNY ORGANIZATION CHART

The Project QA Engineer has the following typical responsibilities:

a. Prepare TN's QA Program Plans and QA Procedures for specific projects.

b. Verify that major participating organizations have approved QA Programs, as required.

c. Approve QA Program Plans of participating organizations for a project for which he has been assigned as the QA Engineer.

d. Verify that major participating organizations have QA procedures, as required.

e. Assure that TN design documents contain applicable QA requirements.

f. Approve TN safety related procurement specifications, instructions, procedures and drawings.

g. Assure that further processing, delivery, installation or use of non-conforming items is controlled until proper disposition has occurred.

h. Perform audits to verify that QA requirements are being met,(if qualified as a lead auditor).

The Project QA Engineer may delegate the performance of one or more of these functions to other qualified individuals at TN, or from contractor organizations, who do not have direct responsibility for performing the work being monitored.

A Project Manager or Project Engineer shall be responsible to the Chief Engineer for all technical aspects of a project including design, issuing of procurement documents, preparation of TSAR's, construction and delivery of storage systems, as applicable.

A possible interrelationship between TN and another major participating organization is shown in Fig. 2. The other organization could be a design agent, manufacturer, supplier or sub-contractor. The chart is provided to establish that any organization performing functions affecting quality must have a QA position with the required authority and organizational freedom as well as direct access to upper levels of management. The chart also shows the requirement for direct communication between Quality Assurance of TN and the other organization. However, TN shall retain overall responsibility for the QA program.

Specific organization charts of major participating organizations shall be detailed in their respective QA documents, and shall be in full compliance with the QA requirements of 10 CFR Part 72.

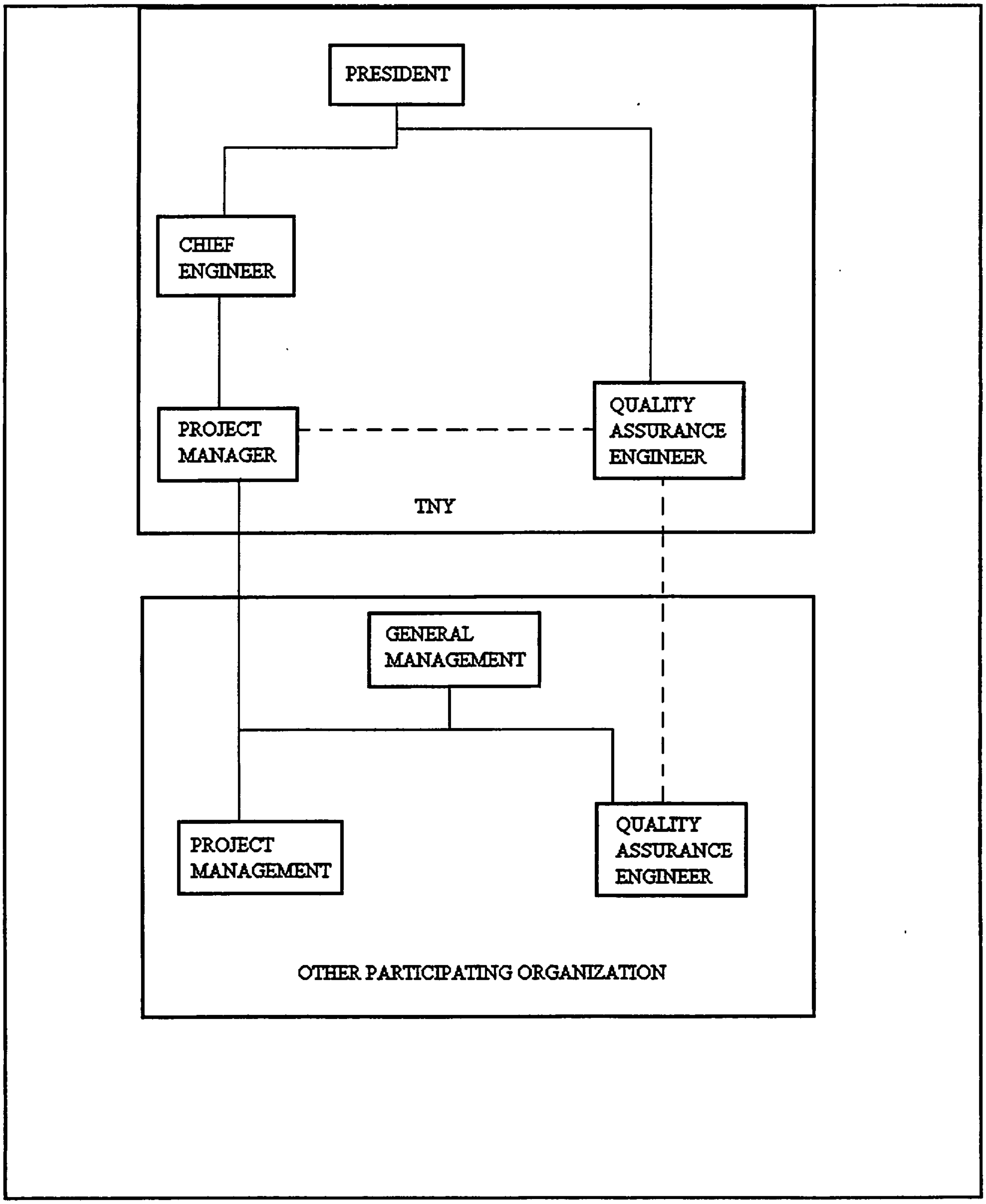


FIG. 2 TYPICAL OVERALL ORGANIZATION CHART

2. QUALITY ASSURANCE PROGRAM

The program described herein is a generic program which shall be implemented by TN as a supplier of storage systems. The program is intended to be in full compliance with the requirements of Subpart G of 10 CFR 72.

It is the policy of TN to establish and maintain an integrated quality assurance system which governs the design, fabrication, inspection, modification and testing of structures, systems and components for storage of spent fuel and associated radioactive materials. This system applies to all safety related activities performed by TN, or its' contractors, to assure that the storage systems meet the required high standards of reliability and safety. The quality assurance system utilizes Project QA Program Plans, Corporate QA Procedures and Project QA Procedures to define specific quality assurance requirements for implementation of the generic QA Program at TN. Comparable plans and procedures shall be utilized by TN contractors.

Specific QA Program Plans shall be prepared to detail the actual measures which are to be established and implemented for a particular project or portion of a project. Each specific project QA Program Plan shall identify the participating organizations, their inter-relationships, and the responsibilities of each of the participants. The scope of specific QA Program Plans will differ based upon the type and complexity of the quality affected activities to be performed.

QA Program Plans for new projects shall be established at the earliest time consistent with the schedule for accomplishing activities on such projects. Specific measures shall be established in the QA Program Plans directly or by reference to Corporate QA Procedures, which are applicable to all TN projects, or to Project QA Procedures which are only applicable to specific projects. The Corporate QA Procedures are used for activities such as Drawing Control, Procedure Format, Document Transmittals, etc. Project QA Procedures are used for specific project activities unique to a particular project. The TN Project QA Engineer shall identify all QA procedures required during a particular phase of a project during the development of the QA Program Plan. If QA procedures so identified do not yet exist, they shall be prepared as either Corporate or Project QA Procedures, approved, and issued prior to the performance of the activities covered by the procedures. Appendix A to this Program lists the Corporate QA Procedures presently applicable to TN QA activities against a matrix of the 18 criteria of Appendix B of 10 CFR 50.

Preparation of the QA Program, and subsequent revisions thereto, are the responsibility of the Chief Engineer. The President of TN shall approve the original QA Program and any subsequent revisions. QA Program Plans for specific projects and any revisions thereto, shall be approved by the Project QA Engineer. Corporate QA Procedures shall be approved by the Chief Engineer. Project QA Procedures shall be approved by the Project QA Engineer.

The distribution of the generic QA Program is controlled by TN's Chief Engineer. He is also responsible for the distribution of Corporate QA Procedures. The Project QA Engineer is responsible for the distribution of Project QA Procedures. He assures that responsible organizations and individuals are aware of all mandatory QA requirements for project activities under their cognizance and that copies of the general and specific QA program, plans and procedures are distributed to them, as applicable.

Major organizations participating in a project shall have approved quality assurance programs including written procedures and instructions to implement their respective programs. Their programs, procedures and instructions shall be in full compliance with the applicable criteria of Appendix B of 10 CFR 50. These QA programs shall be formally reviewed and accepted for use by the TN Project QA Engineer prior to the initiation of activities affecting quality.

Specific project QA Program Plans prepared by major participating organizations shall be approved by the TN Project QA Engineer. Audits and/or overchecks shall be performed to assure that these programs and procedures are properly implemented by the participating organizations.

The Project QA Engineer is responsible for verifying on a particular project that all activities on safety-related structures, systems and components are controlled by the QA program. In case of disputes with the TN Project Manager or others over quality matters, he can request resolution by TN's President.

Safety related items shall be identified by the Project Engineer for each specific design. The complexity and importance of these items shall be defined and any special requirements shall be described.

TN shall hold annual QA Review Meetings to assess the adequacy and effectiveness of the generic and specific Project QA Programs. These review meetings shall be chaired by the President. The Chief Engineer, Project Engineers and QA Engineers for ongoing projects shall attend. These reviews shall be documented and shall include a list of follow-up action items, designating responsibilities and schedules for implementation.

TN and major participating organizations shall provide suitable conditions, environment and equipment for activities affecting quality. Special controls, tools, equipment, etc. shall be provided to attain the appropriate level of quality. Inspections, tests and other controls shall be implemented to assure that the appropriate levels of quality are attained.

Personnel performing activities affecting quality shall be properly trained and indoctrinated as to the purpose, scope and proper implementation of the QA Program, the specific QA Program Plan, and QA Procedures to assure that they recognize that the implementation of the QA Program is mandatory for safety related items and to assure proficiency for the tasks which they are to perform. The proficiency of TN personnel performing activities affecting quality shall be maintained through a program of on-the-job training and indoctrination meetings as required. Meeting reports shall identify the subject matter, attending personnel and dates for training and indoctrination sessions.

3. DESIGN CONTROL

TN shall establish measures to assure that regulatory requirements and storage system designs have been or are correctly translated into drawings, specifications, procedures and instructions. The design shall consider, but shall not be limited to the following designs aspects: criticality, shielding, stresses, thermal and hydraulic performance, accident conditions, compatibility of materials, accessibility for in-service inspection, maintenance and repair.

Measures shall be established for the selection of suitable materials, parts, equipment, and processes for safety-related structures, systems and components. Valid industry standards and specifications shall be utilized to the greatest practical extent.

Written instructions, procedures and/or plans shall identify the methods of control for the design of the storage system. These documents shall identify the safety related items, regulatory requirements, applicable codes or standards, design criteria and measures for coordination and control of design interfaces, and appropriate quality standards. Deviations from applicable codes and standards shall be identified and controlled.

Design calculations and drawings shall be prepared and checked in accordance with approved procedures. Materials, parts and equipment which are standard, commercial (off the shelf) or which have been previously approved for a different application shall be reviewed for suitability prior to selection. The Project Manager and Project QA Engineer shall review design documents to assure that the design characteristics of the storage module can be controlled, inspected, and tested and that appropriate inspection and test criteria have been identified.

The adequacy of the design shall be verified by individuals or groups, other than those who performed the original design based on reviews of design documents, supplemented, as appropriate, by test data from prototype or scale model tests. These reviews shall culminate in formal Design Review Meetings. The Project Manager shall schedule and chair such meetings. The meetings shall be held to confirm that various aspects of the design have been properly considered, including conformance to licensing requirements when applicable. The Design Review Meetings shall also assure that there has been, is and will be appropriate coordination between organizations participating in the design, fabrication, inspection and testing of the storage system.

Questions and concerns expressed at a design review meeting that require resolution shall be identified as action items in the design review meeting report which is issued by the Project Engineer. The report assigns an individual and due date for the resolution of each item.

After satisfactory completion of action items, a memorandum shall be prepared by the Project Engineer documenting the fact that the design review verification process has been completed. If testing is used to verify design, the test program and results will in addition be subjected to the design review process. Design verification tests may be conducted with appropriately scaled models or full size components. The tests would be conducted under the most adverse design conditions.

Any errors or deficiencies in the design or design documents, including the design process, that could adversely affect safety-related structures, systems or components shall be documented, and corrective action shall be taken in accordance with Section 16 of this Program.

TN shall assure that measures are established and implemented to verify that the fabrication and assembly drawings, prepared by the Fabricator are consistent with design documents. For storage systems of TN design, TN shall review all fabrication drawings, approve design changes and establish procedures for the documentary control of design changes.

All design changes, including field changes, shall be subject to the same or equivalent design control measures as are applicable to the original design.

TN shall establish measures to assure that the approved design and operating conditions are not changed unless the effect of the changes on the design are evaluated and approved. For any change which affects the basis for a license to use a storage system at an ISFSI, approval for the change shall be obtained from the Nuclear Regulatory Commission prior to its use under the modified conditions.

4. PROCUREMENT DOCUMENT CONTROL

Procurement documents shall be prepared which clearly define all design requirements including quality assurance requirements, and shall reference all applicable documents, including codes, standards, regulatory requirements and the storage system design. These documents shall serve as the principal technical documents for the procurement of structures, systems and components and related services to be used in the design, fabrication, inspection and testing of the storage systems.

These documents may be prepared by TN or by one or more major participating organizations, e.g. Design Agent, Manufacturer, etc. Each of these organizations shall have a documented, approved quality assurance program which shall be supplemented by detailed procedures and instructions as required to assure adequate control for preparing safety related procurement documents. Changes and revisions to these documents shall be reviewed and approved in an equivalent manner as the original document in accordance with documented procedures. These programs shall also include measures to qualify/accept the quality assurance programs of their suppliers and subcontractors for safety related equipment, materials or services.

Procurement documents shall also address the applicability of the provisions of 10 CFR 21, Reporting of Defects and Noncompliance.

Safety related procurement specifications prepared and/or issued by TN shall be reviewed by the Project QA Engineer to determine that appropriate quality requirements are correctly stated, inspectable and controllable. The QA Engineer shall also verify that adequate acceptance and rejection criteria are identified and that the procurement specification was prepared, reviewed and approved in accordance with the applicable procedures. The QA Engineer's written approval of the procurement specification shall signify that he has verified these items prior to release.

TN's safety related procurement specifications shall identify which documents (e.g. drawings, specifications, procedures, inspection and fabrication plans, inspection and test records, personnel and procedure qualifications, and chemical and physical test results of materials) are to be prepared by a supplier and which documents are to be submitted to TN or its agents for review, information and/or approval. They shall also specify which documents are to be retained, controlled and maintained by the supplier for specified periods and which records shall be transmitted to TN prior to use of the storage system. Duplicate records may be maintained for specified periods by both the supplier and TN to facilitate permanent record storage.

Procurement specifications shall also include requirements to insure that TN or its agents have reasonable rights of access to the supplier's facility and records for source inspection and audit prior to contract award, and inspection and audits during and after completion of fabrication.

Purchase Orders may be prepared by TN management and shall be in compliance with the technical and quality assurance requirements identified in the procurement specifications.

5. INSTRUCTIONS, PROCEDURES AND DRAWINGS

Methods for complying with each of the applicable 18 criteria of Appendix G of 10 CFR 72, for activities affecting quality during design, fabrication, inspection and testing shall be specified in instructions, procedures and/or drawings. They shall be prepared, reviewed, approved and controlled in accordance with written document control procedures.

These instructions, procedures and drawings shall include quantitative and/or qualitative acceptance criteria to permit verification that activities affecting quality have been satisfactorily accomplished.

The QA Engineer on a project shall review and approve Project instructions, procedures and drawings which are prepared by TN. These documents may include, but are not limited to specifications, drawings, special process, calibration, test, operating, maintenance and repair instructions and procedures and any changes thereto.

6. DOCUMENT CONTROL

TN shall establish and implement procedures to control the issuance of TN documents which prescribe activities affecting quality. These procedures shall define document control measures to assure adequate review, approval, release and distribution of original documents and subsequent revisions. These documents may include, but are not limited to design specifications, drawings, procurement specifications, and special process, test and operating procedures. A specific QA Plan for each project shall identify the persons, groups and/or organizations responsible for reviewing and approving documents and their revisions for that project.

Major participating organizations shall establish and implement document control procedures in accordance with their approved QA program.

Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless otherwise delegated by TN or a major participating organization. Approved changes shall be included in the applicable drawings, procedures, instructions or other documents prior to the implementation of the change.

The Project Manager shall be responsible for the control of Project documents which are issued by TN. He shall also be responsible for the receipt and distribution of Project documents to and from participating organizations. He shall distribute controlled documents in accordance with TN's established QA procedures to prevent the inadvertent use of obsolete/superseded documents. He shall maintain an up-to-date file of all Project records.

The originals of documents which require distribution control to prevent their inadvertent use shall be stamped on the cover sheet with the TN Document Control stamp. All copies made from the original shall be identified as "controlled" or "uncontrolled" as determined by the individual who is responsible for the distribution of that document. All controlled copies shall be entered on a controlled copy log which is filed with the original document. Individual recipients are required to acknowledge receipt of the document by initialling the log. When a controlled copy is transmitted to an outside user, it shall be accompanied by a TN Document Transmittal Form which the recipient signs and returns to Transnuclear verifying that he has received the document and carried out the instructions indicated thereon. These receipts shall be filed with the original document.

When a document is changed, revised copies shall be distributed in the same manner to the users identified on the controlled copy log. The recipient shall be required to void the superseded document or return it for destruction.

Documents shall be available at the location where activities affecting quality are performed prior to commencing the work.

For certain types of documents which are issued by TN, the Project Engineer shall maintain Master Lists to identify current revisions. He shall update and distribute these lists to responsible personnel to preclude the use of superseded documents. Major participating organizations shall utilize the same or equivalent measures.

7. CONTROL OF PURCHASED MATERIAL, EQUIPMENT AND SERVICES

Measures shall be established and implemented to assure that all purchased material, equipment, and services conform to procurement documents.

An engineering source evaluation of prospective supplier's facilities shall be performed by the TN Project Engineer to confirm that the organization has the technical capability to supply safety related equipment, materials or services in accordance with the project's design, manufacturing, quality assurance and procurement requirements.

The TN Project QA Engineer shall assure that source evaluation audits of potential suppliers are performed in accordance with TN Corporate QA Procedures to verify that they can comply with the criteria of Appendix G of 10 CFR 72 that are applicable to the material, equipment, or service being procured.

The resultant reports of the engineering source evaluations and source evaluation audits shall be filed and retained in accordance with Section 17 and the applicable QA procedures.

Contractors and sub-contractors shall be inspected and audited at planned intervals to verify that they comply with quality requirements and to assess the effectiveness of their QA program. The inspections and audits shall be performed as described in Sections 10 and 18, respectively.

Suppliers shall provide objective evidence that storage modules and associated items, including repaired or spare parts, meet all quality requirements. All items shall be properly identified. Appropriate records shall be available prior to use or installation to permit verification of conformance with procurement documents. These records shall be retained accessibly (See Section 17). The supplier shall furnish to TN all documentation which identifies all procurement requirements which have not been met together with nonconformance reports dispositioned "accept as is" or "repair". These documents shall be reviewed by the Project Engineer, Project QA Engineer and TN's design agent (if applicable) to assure conformance with procurement document requirements. The Project Engineer shall accept these documents in writing.

Supplier's certificates of conformance for safety related structures, systems and components furnished to TN shall be periodically evaluated by audits, independent inspections or tests to verify that they are valid. The frequency and extent of these evaluations shall be related to the safety importance of the procured material or equipment. An acceptance test program approved by TN shall be performed for each storage system in accordance with the requirements of the procurement documents.

TN or its agent(s) shall perform receiving inspections on safety related structures, systems and components furnished to TN, to assure that they are properly identified and correspond to the receiving documentation. These receiving inspections may be performed at a supplier's facility, if appropriate. The inspections shall verify that the material or equipment conforms to the requirements specified in procurement documents. Nonconforming materials, parts or components shall be controlled in accordance with Section 15. These inspections shall be performed utilizing previously established inspection instructions. Fabrication records, acceptance test records and certificates of conformance shall be made available by TN at the ISFSI prior to first use of a storage system.

8. IDENTIFICATION AND CONTROL OF MATERIALS, PARTS AND COMPONENTS

Measures shall be established and implemented to identify and control materials, parts, and components. These measures shall assure identification of an item by an appropriate means during the fabrication, installation and use of the item and shall prevent the inadvertent use of incorrect or defective items. The requirements for identification shall be established during the preparation of procurement specifications and design drawings. The methods and location of identification information shall be selected so as to not adversely affect the fit, function or quality of the items being identified.

The identification and control of safety-related items shall be traceable through procurement, fabrication, inspection and test records. Correct identification of materials, parts and components shall be verified and documented prior to their release for fabrication, assembly, shipping and installation.

9. CONTROL OF SPECIAL PROCESSES

Measures shall be established and implemented for the control of special processes used in the fabrication and inspection of storage systems. These processes include welding, non-destructive examinations and other processes special to a specific component as identified in the procurement specifications.

System suppliers shall prepare and qualify procedures for special processes. These procedures shall be approved by TN.

Special processes shall be performed in accordance with approved written procedures. Personnel who perform special processes shall be formally trained and qualified in accordance with applicable codes, standards or specifications. Qualification records of procedures and personnel shall be filed and kept current by the organization which performs the special process.

10. INSPECTION

Measures shall be established and implemented to inspect materials, parts, processes or other activities affecting quality to verify conformance with documented instructions, procedures, specifications, drawings, or other procurement documents. These inspections shall be performed by personnel other than those who performed the activity being inspected. Inspectors shall be qualified in accordance with the applicable codes, standards, and the training programs of TN or its contractors. Inspector qualifications and certifications shall be maintained current and these records shall be retained in accordance with Section 17 of this Program.

Inspections shall be performed in accordance with approved, written instructions and procedures. The instructions and procedures shall include and address acceptance criteria; identify the characteristics and activities to be inspected; describe the method of inspection; record evidence of completion and verifying of a manufacturing, inspection or test operation; and record the identity of the recording inspector or data recorder and the results of the inspection operation. When direct inspection is not possible, provisions shall be established for indirect control by monitoring processing methods, equipment, and personnel.

Mandatory hold points shall be established for inspections or witnessing of those items or activities whose conformance to requirements can not be determined subsequently. Work shall not proceed beyond a hold point without the consent of the designated inspector.

Modifications and/or repairs to and replacements of safety related structures, systems and components shall be inspected in accordance with the original design and inspection requirements or acceptable alternatives.

11. TEST CONTROL

A program shall be established and implemented to perform required proof, acceptance and operational tests, as identified in procurement specifications.

The tests shall be performed by qualified personnel in accordance with approved, written instructions, procedures and/or checklists. Test procedures shall incorporate or reference the applicable requirements and acceptance limits contained in the design and procurement documents; instructions for performance of the test; test prerequisites such as test equipment requirements, personnel qualification requirements, fabrication or operational status of the item to be tested, and the provisions for data recording and retention; and mandatory inspection hold points to allow witnessing by TN or it's agents.

Test results shall be documented and evaluated. They shall demonstrate that acceptance criteria have been met. Acceptance of test results for a specific project shall be acknowledged in writing by the TN Project Engineer for that project or his designee. Tests performed after modifications, repairs or replacements of safety related structures, systems or components shall be performed in accordance with the original design and testing requirements or acceptable alternatives.

12. CONTROL OF MEASURING AND TEST EQUIPMENT

Measures shall be established and implemented to assure that tools, gages, instruments and other measuring and testing devices used in activities affecting quality are properly controlled, calibrated and adjusted to maintain accuracy within required limits. These measuring devices shall be calibrated at scheduled intervals against certified standards having known, valid relationships to national standards. Intervals are based on required accuracy, precision, purpose, amount of use, stability characteristics and other conditions which could affect the measurements. All calibrations shall be performed in accordance with approved written procedures.

Measuring and test equipment shall be identified and traceable to the calibration records, and shall be labeled or tagged indicating the next required calibration date. Standards utilized for calibration of measuring and test equipment shall have an uncertainty requirement of no greater than one-fourth of the tolerance of the equipment being calibrated, unless limited by the state of the art of the equipment or calibrating standard.

When measuring and test equipment is found to be out of calibration, measures shall be taken and documented to determine the validity of inspections performed during the period the equipment was out of calibration. The complete status of all measuring and test equipment under the calibration system shall be recorded and maintained.

Test equipment shall be subjected to a proof test to demonstrate that it performs its intended function prior to its use.

Operational checks shall be performed on test equipment, as required, to assure that the equipment is still functioning properly prior to actual testing.

13. HANDLING, STORAGE AND SHIPPING

Measures shall be established and implemented to assure that all materials, parts, assemblies, spare parts, special tools, and equipment are handled, stored, packaged and shipped in a manner which prevents damage, loss of identity or deterioration. These activities shall be carried out in accordance with written approved procedures.

When necessary, storage procedures shall address special requirements for environmental protection such as inert gas atmospheres, moisture, temperature levels, etc.

14. INSPECTION, TEST AND OPERATING STATUS

Measures shall be established and implemented to assure that the status of required inspections and tests are clearly indicated by some suitable means, e.g. tags, labels, cards, form sheets, check lists, etc. The status of nonconforming items is of particular concern (see Section 15).

By-passing of required inspections, tests, or other critical operations shall be controlled in accordance with written procedures or instructions by the TN QA Engineer and/or TN's inspection agent.

Where appropriate, the operating status of components of a storage system e.g. valves, switches, etc. shall be indicated to prevent inadvertent operation.

The application and removal of status indicators shall be in accordance with approved written instructions and procedures.

15. NONCONFORMING MATERIALS, PARTS OR COMPONENTS

Measures shall be established and implemented to control materials, parts, and components which do not conform to requirements so as to prevent their inadvertent use in manufacturing operations or during service.

These measures shall be described in approved written instructions and procedures. The nonconforming items shall include items which do not meet specification or drawing requirements, as well as items which are not fabricated or tested in accordance with approved written procedures or by qualified processes or by qualified personnel, where the use of such procedures, processes or personnel is required by the fabrication, test, inspection or quality control documents.

Nonconforming items shall be identified and segregated to prevent their inadvertent use. Nonconformance reports shall be utilized for the procedural control of nonconformances. They shall describe the nonconformances and provide for their disposition. Inspection requirements for nonconforming items following rework, repair or modification shall be detailed in the nonconformance reports which shall be approved and signed following completion of the disposition. The acceptability of the rework or repair of nonconforming materials, parts, and components shall be verified by reinspecting and/or retesting the reworked or repaired item to the original requirements, or by a method which is at least equal to the original inspection and/or testing method. Inspection, testing, rework, and repair procedures shall be documented and controlled.

Nonconformance reports shall be utilized to notify other affected organizations. Items which are not in conformance with TN approved documents shall be reviewed by TN's Project Manager and QA Engineer. Their disposition shall be approved by TN's QA Engineer. Nonconformances with documents such as fabrication details, which may not require TN approval, may be resolved without TN approval by major participating organizations, as appropriate, in accordance with their approved QA programs.

Nonconformance reports shall be made part of the inspection records and shall be forwarded by TN to the purchaser of a storage system prior to its use. Nonconformance reports shall also be reviewed periodically to identify quality trends. The results of these reviews shall be reported to management for their assessment.

Procedures shall be established and implemented to report defects and noncompliance in accordance with the provisions of 10 CFR 21.

16. CORRECTIVE ACTION

All conditions adverse to quality are documented in nonconformance reports in accordance with established TN QA Procedures. The cause for the condition is identified and a disposition is recommended, justified and approved. If the condition is significant, corrective actions to preclude recurrence are identified and implemented.

TN nonconformance reports require approvals by the Project Engineer and Project QA Engineer. Nonconformance reports are reviewed annually to identify trends which may require further corrective actions. Such actions are then implemented by the Chief Engineer or his designee.

17. QUALITY ASSURANCE RECORDS

For each storage system a program shall be established and implemented to assure that sufficient written records are maintained to furnish evidence of activities affecting quality. These records include, but are not limited to, design records, procurement records, results of reviews, inspections, tests, audits, monitoring of work performance, materials analyses, and related procedures such as qualifications of personnel and equipment.

Quality assurance records shall be collected by the originating organization as the documents are completed. They shall be stored by these organization(s) until delivery of the storage system. The requirements and responsibilities for record transmittals, record retention, and maintenance by the originating organization(s) prior to completion of the work shall be in accordance with the applicable codes, standards, procurement specifications, and the organizations' QA program. Approved, written procedures shall be utilized to control and maintain QA records.

Inspection and test records shall contain, where applicable, the description of the type of observation; evidence of the completion and verification of a fabrication, inspection, or test operation; the date and results of the inspection or test; any information related to conditions adverse to quality; the identification of the inspector, data recorder, or test operator; and evidence of the acceptability of the test or inspection results.

The records program shall identify which types of records are to be transmitted to TN for retention at TN and which ones shall be retained by the originating organization in accordance with procurement specification requirements, Section 4. "Lifetime" records shall be retained by TN, the fabricator, or TN's customer, as appropriate. The records shall be identified, indexed and stored in accessible locations. The record storage facility shall be constructed, located and secured in accordance with written procedures to prevent destruction of the records by fire, flooding, theft, and deterioration by environmental conditions such as temperature and humidity. Alternatively, duplicate storage of records at two separate locations may be utilized to prevent loss or destruction.

Maintenance of records at TN shall be in accordance with written approved procedures. These procedures shall address duration of storage, responsibilities for safekeeping, preservation, and disposition of nonpermanent records. Maintenance of records at participating organizations shall be in accordance with their approved program.

18. AUDITS

A comprehensive program of planned and periodic audits shall be established and implemented by TN to verify compliance with all aspects of the TN QA Program and to determine its effectiveness. The audit program shall include audits by TN of it's suppliers' QA programs, procedures and activities to verify and evaluate that the suppliers' procedures and activities are meaningful and comply with the overall QA Program. Suppliers of safety related equipment, material or services to TN shall implement a program to verify compliance with all aspects of their QA program and to determine its effectiveness.

The audit program shall describe the areas to be audited, such as design activities, procurement, fabrication, inspection and testing of storage systems. The schedule for such audits shall be based upon the safety importance of the activities being audited.

The audits shall be performed by qualified personnel not having direct responsibilities in the areas being audited. The audits shall be conducted in accordance with written approved procedures and/or check lists. Audit results shall be documented, and shall be reviewed with personnel having responsibility for the area audited. Corrective actions and schedules for implementation shall be established and recorded. Reaudits of deficient areas shall be scheduled on a timely basis to verify implementation of agreed upon corrective actions. Audit reports shall include an objective evaluation by the auditor of the quality related practices, procedures and instructions for the area or activity being audited and the effectiveness of their implementation.

Audit reports shall be distributed to management. The reports shall be reviewed for indications of adverse trends which could affect quality. If the results of such assessments so indicate, pertinent sections of the QA program shall be revised.

Audits of project activities for which TN has direct responsibility shall be performed by a qualified lead auditor.

APPENDIX A

MATRIX OF EXISTING QA PROCEDURES AGAINST THE APPLICABLE CRITERIA OF APPENDIX B OF 10 CFR 50

Corporate QA Procedures	Title	10 CFR 50 Appendix B Criteria																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.2	Personnel Training and Project Responsibility	X	X																
2.1	Qualification of Inspection and Test Personnel		X			X	X	X		X	X	X	X	X	X	X	X	X	
2.2	Q/A Procedure Format		X			X	X												
2.3	Qualification of QA Program Audit Personnel		X			X	X	X		X				X				X	X
2.4	Qualification of Operations Personnel		X			X	X	X		X	X			X				X	
3.1	Control of Engineering Calculations	X	X	X		X	X											X	
3.2	Design Control	X	X	X	X		X	X										X	
3.3	Computer Program Control	X	X	X	X	X	X	X				X				X	X	X	
4.1	Procurement Specification Preparation and Control for Special Equipment	X	X	X	X		X	X										X	X
4.2	Procurement Document Preparation and Control of Commercial Grade Items	X	X	X	X	X	X	X	X		X	X		X	X	X		X	
5.1	Drawing Control	X	X	X		X	X											X	

APPENDIX A

MATRIX OF EXISTING QA PROCEDURES AGAINST THE APPLICABLE CRITERIA OF APPENDIX B OF 10 CFR 50

Corporate Q Procedures	Title	10 CFR 50 Appendix B Criteria																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5.2	Control of Operating Manuals	X	X			X	X											X	
5.3	Preparation and Control of Test, Inspection, Maintenance and Operations Procedures	X	X			X	X				X	X	X					X	
6.1	Document Transmittals	X	X	X	X	X	X											X	
6.2	Identification & Distribution of Controlled Documents	X	X	X	X	X	X											X	
7.1	Procurement Source Evaluation	X	X			X	X	X										X	X
7.2	Receipt Inspection		X		X	X	X	X			X	X	X		X	X	X	X	
7.3	Procurement Planning	X	X		X		X	X				X		X				X	
8.1	Identification and Control of Parts and Equipment	X	X					X	X		X			X	X	X			
10.1	Procedure for Visual Method Non Destructive Examination		X			X				X	X				X	X		X	
10.2	Personnel Qualification for Non Destructive Examination (V.T.)		X			X					X							X	
11.1	Test Control		X	X		X	X		X		X	X	X		X	X		X	

APPENDIX A

MATRIX OF EXISTING QA PROCEDURES AGAINST THE APPLICABLE CRITERIA OF APPENDIX B OF 10 CFR 50

Corporate QA Procedures	Title	10 CFR 50 Appendix B Criteria																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
12.1	Control of Measuring and Test Equipment		X			X	X		X		X	X	X	X	X	X	X	X	X
13.1	Handling, Storage & Shipping	X	X			X	X		X		X			X	X			X	
15.1	Reporting of Defects and Noncompliance	X	X								X					X	X	X	
15.2	Nonconformance Control	X	X		X	X	X	X	X		X	X				X	X	X	
16.1	Corrective Action		X			X	X				X					X	X	X	
17.1	Temporary Working Files-Design and Procurement	X	X	X	X	X	X											X	
17.2	Permanent Storage and Maintenance of Design and Procurement Records	X	X	X	X	X	X				X							X	X
17.3	Project Close-Out Procedure	X	X	X		X	X											X	
18.1	Source Evaluation Overchecks	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
18.2	Audits of Agent for Design and Procurement	X	X	X	X	X	X	X										X	X
18.3	QA Audits	X	X	X		X	X									X	X	X	X