Attachment J

This Attachment addresses:

Condenser Seismic Evaluation

EQE Calculation 200621-C-009

CALCULATION COVER SHEET

EQE INTERNATIONAL

Calculation No. 200621-C-009

Project: TVA BFN-3 MSIV OUTLIER RESOLUTION

Calculation Title: CONDENSER SEISMIC EVALUATION

References: SEE SECTION 3.0

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1.0 PURPOSE AND SCOPE

The purpose of this calculation is to verify the Browns Ferry (BFN) condenser seismic capacity and resolve Outlier 13-1, as identified during the BFN-3 MSIV Seismic Verification Walkdown (Reference 2).

2.0 METHODOLOGY

The BFN Unit 3 condenser is evaluated using seismic experience data from past earthquakes and engineering analysis. Seismic capacity versus demand is evaluated by comparing the BFN Unit 3 condenser with condensers in the seismic experience database that have experienced strong ground motions in excess of the BFN-3 Design Basis Earthquake (DBE). Condenser size, construction, design and anchorage characteristics are summarized and compared with parameters of earthquake experience condensers.

Anchorage evaluation methodology used is consistent with that described in the Generic Implementation Procedure (GIP, Reference 1) and standard structural engineering practices.

3.0 REFERENCES

1. "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment", Rev. 2A, March 1993, prepared by Winston & Strawn, EQE, et al., for the Seismic Qualification Utility Group (SQUG).

2. "BFNP - Unit 3 MSIV Seismic Verification Walkdown Report", EQE Report No 50147.08-R-001, Draft, September 30, 1995.

3. BWROG Report for Increasing MSIV Leakage Rate Limits and Elimination of Leakage Control Systems, General Electric NEDC-31858P, Rev. 2, September 1993.

4. AISC Manual of Steel Construction, 8th Edition

5. Seismic Verification of Nuclear Plant Equipment Anchorage (Revision 1), Volume 1 : Development of Anchorage Guidelines, EPRI NP-5228-SL, June 1991.

6. TVA and Vendor Documents:

a. Misc. Steel Turbine Foundation Embedded Parts Sheet 2	48N840 R12
b. Outline of Shell 3A for 666,000 Sq. Ft. ...Surface Condenser	3-93-621-5-1A
c. Outline of Shell 3B for 666,000 Sq. Ft. ...Surface Condenser	3-93-621-5-2A
d. Outline of Shell 3 for 666,000 Sq. Ft. .....Surface Condenser	3-93-621-5-3A
e. Instructions for the Care & Operation of Surface Condenser & Accessories	BFN-VTD- F175-0050
f. Arrangement of Condenser Supports & Anchor	93-505-3-190 Rev E

7. TVA Browns Ferry Nuclear Plant Final Safety Analysis Report (FSAR).

8. TVA Calculation No. CD-N0001-980039, "Main Steam Seismic Ruggedness Verification".

4.0 TURBINE CONDENSER CHARACTERISTICS COMPARISON

The High Pressure condenser has a heat transfer surface area of 222,000 ft^2. In Table 3-1, the design attributes of the condenser is compared with the two sites in the earthquake experience database that have condensers most representative of BWR type condensers: Moss Landing Units 6 & 7, and Ormond Beach Units 1 & 2.

The shell of the condenser is constructed of ASTM A-285 Gr. C steel plate. The database condenser shells are ASTM A-285 Gr. C steel plate. Some of the overall heat transfer area, weight, and footprint of the condenser are enveloped by the database condensers, as shown in Figures 4-1 through 4-4.

In summary, the condenser design and anchorage are similar to those at facilities in the earthquake experience database that have experienced earthquakes in excess of the Browns Ferry design basis DBE (See Figure 4-8). Appendix D, Section 4.1, of NEDC -31858P (Reference 3) contains details of the earthquake experience for condensers. Specific data used in the evaluation are as follows:

4.1 BFNP-Unit 3 Condenser Design Basis

4.1.1 Design Code

Heat Exchanger Institute (HEI) Standards

4.1.2 Hydrostatic Test Requirements

Shell - Completely filled with water

4.1.3 Anchorage

The condenser anchorage is shown schematically in Figure 4-5. The condenser has six plate supports with (2 or 3) 2" or 2½ " diameter anchor bolts each. Each anchor bolt has greater than 5' nominal length with approximately 48" embedment in the turbine building foundation. The supports are designed to resist vertical operating loads. Thermal growth of the condenser occurs from the fixed point near the center of the base. The sliding plate supports have slotted holes allowing thermal growth radial to a fixed center support pad. The center support consists of a built-up H section, embedded 4' into the turbine base mat and welded to the condenser bottom.

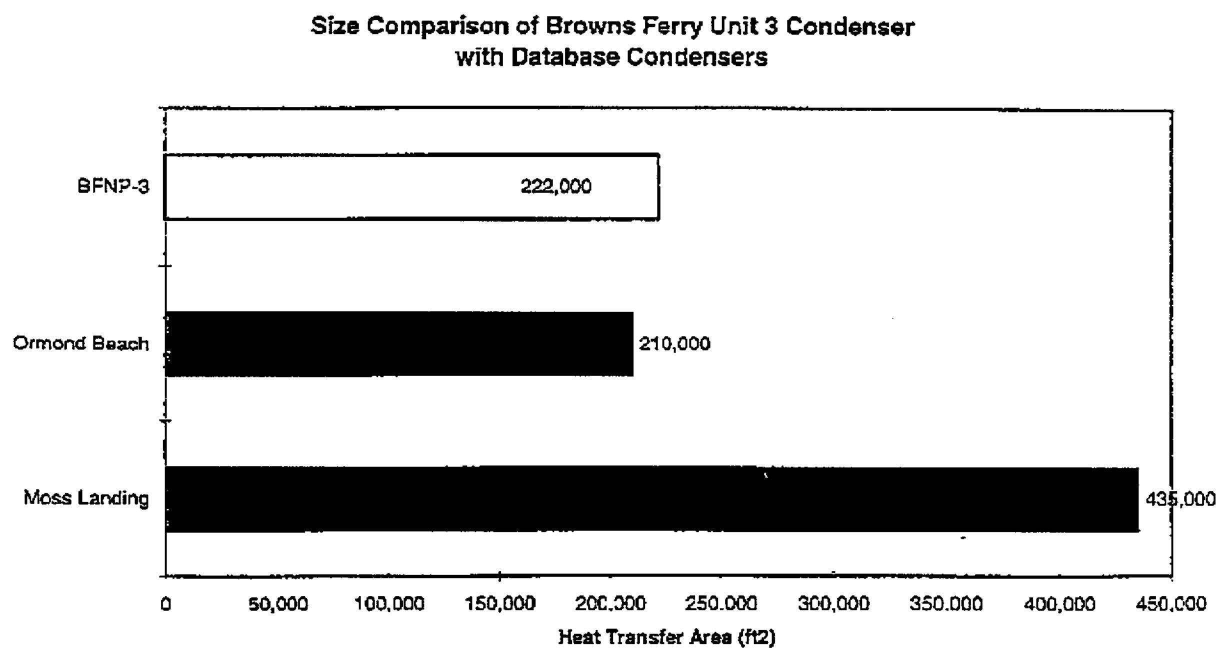


Figure 4-1 Size Comparison of Browns Ferry Unit 3 Condenser with Database Condensers

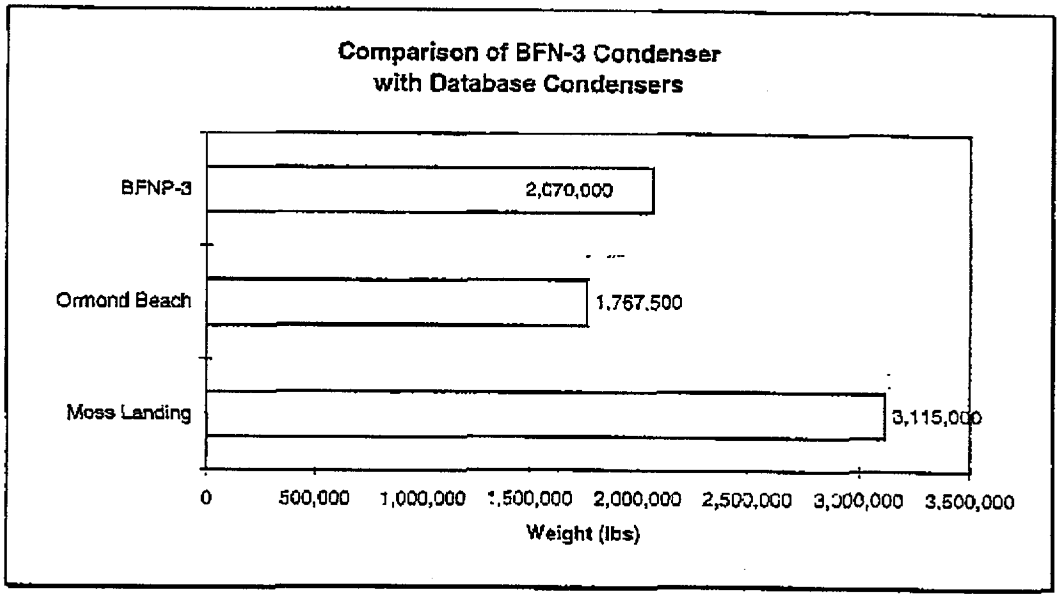


Figure 4-2 Weight Comparison of BFN-3 Condenser with Database Condensers

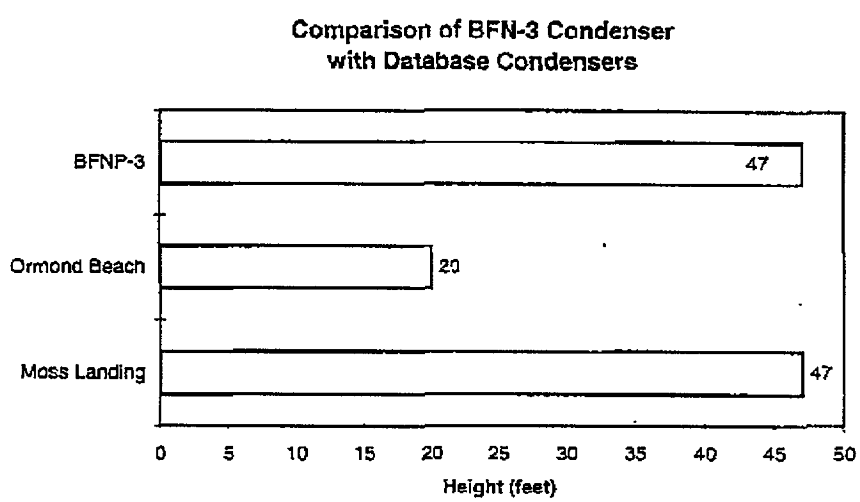


Figure 4-3 Height Comparison of BFN-3 Condenser with Database Condensers

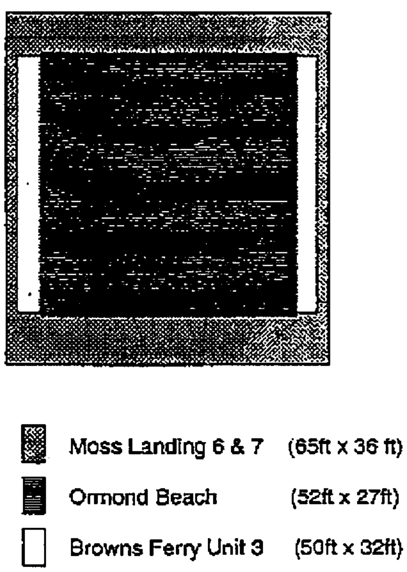


Figure 4-4
Comparison of Browns Ferry Unit 3 Condenser Plan Dimensions with Database Condensers

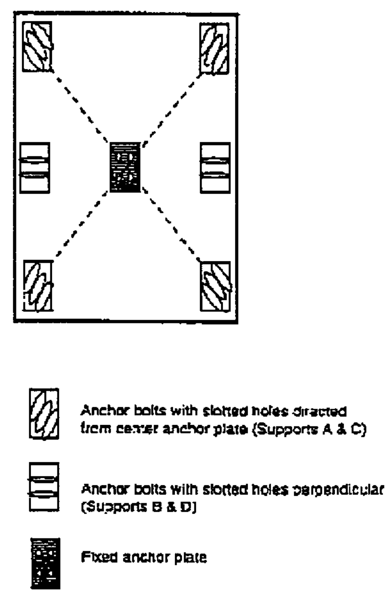
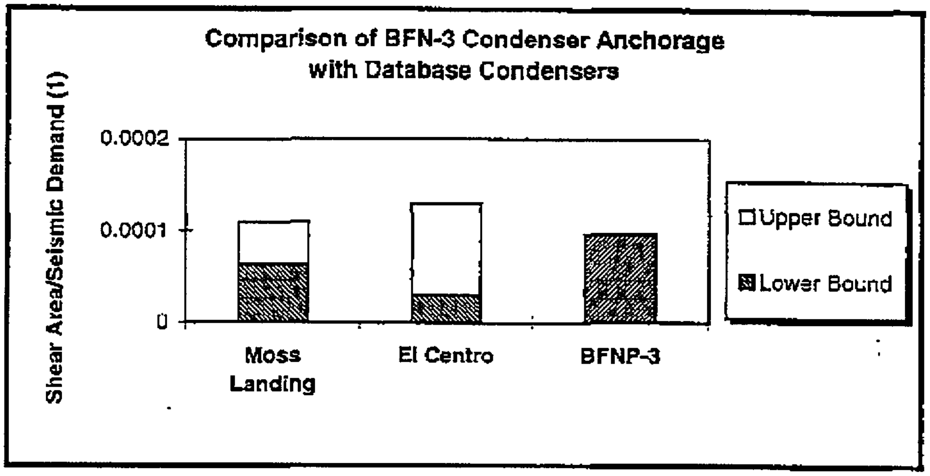
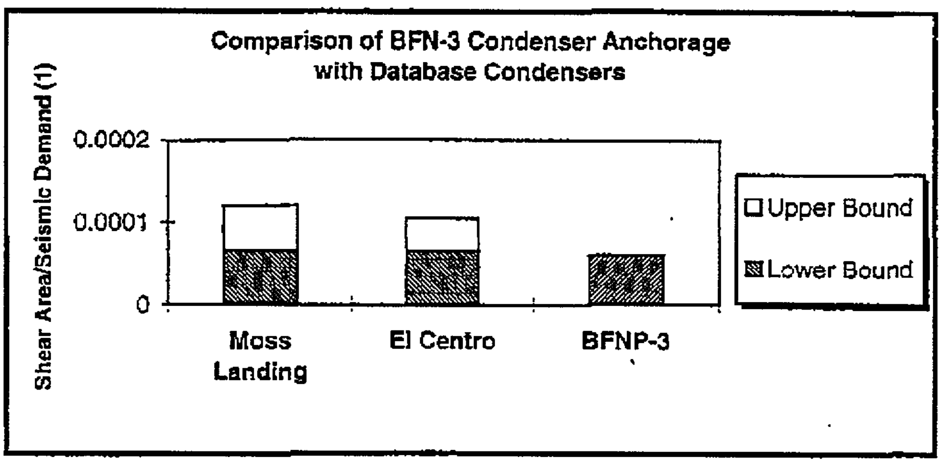


Figure 4-5
Schematic Plan View of Browns Ferry Unit 3 Condenser Anchorage





Note (1): Shear Area(in^2)/Demand(condenser weight x g level)

Figure 4-6 and 4-7 Comparison of BFN-3 Condenser Anchorage with Database Condensers

The condenser anchorage was compared with the performance of similar condenser in the earthquake experience database. The shear area of the condenser anchorages, divided by the seismic demand was used to compare condenser anchorage with condensers in the earthquake experience database (See Figures 4-6 and 4-7). The values for the BFN-Unit 3 condenser are as follows:

	Shear Area (in^2)/Seismic Demand
	Lower Bound
Parallel to Turbine Generator Axis	0.0000604
Transverse to Turbine Generator Axis	0.0000966

The condenser anchorage shear area to seismic demand is substantially greater than the selected database sites (see NEDC 31858P, Reference 3, Figures 4-10 and 4-11 of Appendix D)

4.1.4 Manufacturer: Foster Wheeler

4.1.5 Surface Area, Weight, Dimensions

Surface Area: condenser has 222,000 ft^2

Weight: condenser weighs 2,070,000 lbs operating.

Dimensions: condenser is 50' long, 32' wide and 47½ ' high.

4.1.6 Type: Base supported, rectangular.

4.1.7 Shell Material

Material: ASTM A-285 Gr. C steel 7/8" thick

4.1.8 Tube Design

Material: ASTM B-111 Inhibited Admiralty

Tubes: ASTM B-111 Inhibited Admiralty, 7/8"-18 BWG.

The effective tube length is 49' 9¼".

The condenser design and anchorage are similar to those at facilities in the earthquake experience database that have experienced earthquakes in excess of the BFN design basis DBE and the BFN condenser is bounded by the comparable attributes of the database condensers.

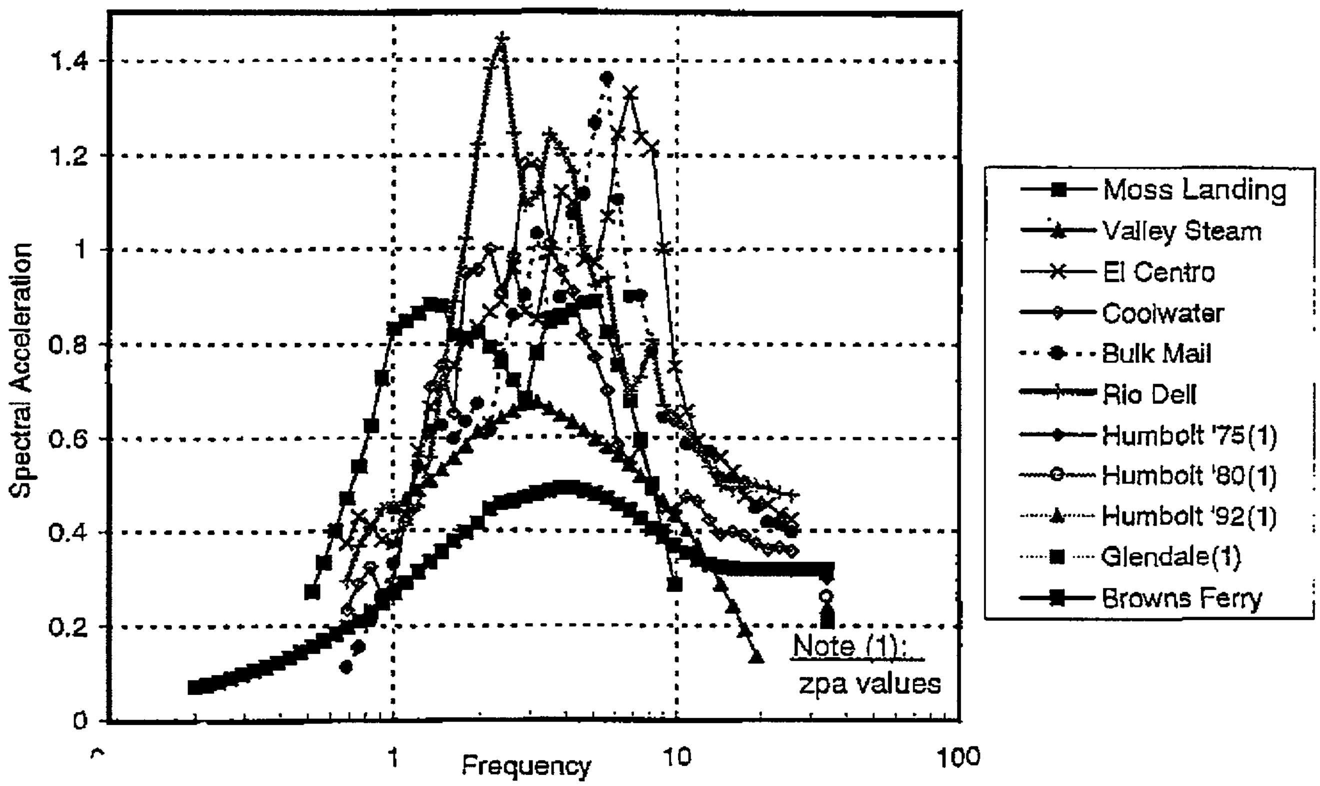


Figure 4-8
Comparisons of Database Site Spectra
to Browns Ferry Unit 3 DBE Ground Spectra

5.0 ANCHORAGE EVALUATION

Determine Input Seismic Accelerations

An evaluation of the condenser support system was performed using seismic demand determined by the GIP method for the turbine building at the condenser foundation elevation.

Condensers are large structures that are by design very stiff to withstand operating vacuum and hydro-static test loads. The condenser shell design utilizes a steel shell, stiffened with integral plate stiffeners and structural members. The predominant seismic response of the condenser is expected to be rigid body dynamics. The calculations are performed for the frequency range of the zero period acceleration (ZPA).

The condenser is mounted on the base mat at elevation 562 feet. Design spectra were not available for the Turbine Building at this elevation. Accelerations for the condenser analysis were based on the site design spectra zero period acceleration of 0.2g. This value was increased by a factor of 1.6 in accordance with the BFN FSAR (Reference 7) to account for site amplification for soil-founded structures (see also Reference 8).

Determine Overturning Moments and Base Shears

Established weights, center of gravity, overturning moments and base shears for the condenser are calculated and shown in Table 5-1. Overturning moments and base shears are established using conservative methods for combination of directional and load components. The condenser is symmetric about two axes and eccentricities are expected to be very small.

Dynamic frequencies for the condenser are complex due to the stiffened plate nature of the construction and the complicated internals, and are not known. The condenser was assumed to behave in a rigid manner and respond to the ZPA.

Overturning moments are calculated assuming that plane section remain plane and materials are assumed to be elastic. Moments and base shears are shown in Table 5-2.

Support Forces and Capacities

Support forces and capacities are calculated and shown in Table 5-2. Total tension forces due to overturning moments in N-S and E-W directions of earthquake excitation are combined by the Square Root of the Sum of the Squares (SRSS) rule and are added absolutely to the operating loads. Operating loads are taken as the sum of vacuum loads and dead load forces on the anchor pads from Reference 6f. Tension forces are resisted by the six support pads around the condenser perimeter. Base shears are calculated separately for N-S and E-W directions of earthquake excitation and compared with shear capacities. Base shear is resisted by the anchor support at the condenser center.

Bolt Capacity - Tension Supports A, B, C & D

The condenser anchorage is shown schematically in Figure 4-5. The condenser has six plate supports with (2 or 3) 2" or 2½ " diameter anchor bolts each. The supports are designed to resist vertical operating loads. Thermal growth of the condenser occurs from the fixed point near the center of the base. The sliding plate supports have slotted holes allowing thermal growth radial to a fixed center support pad.

Each of the six perimeter bolted anchorages (Supports A, B, C & D), located at around the condenser perimeter, consists of either (2 or 3) 2- or 2½-inch bolts. Each anchor bolt has greater than 5' nominal length with approximately 48" embedment in the turbine building foundation per Reference 6a. The bolts are in slotted holes on 15 inch centers.

The ACI allowable pullout on a cast-in-place anchor is based on the area of the bolt, the bolt material, the concrete strength, and the embedment length. Bolt material is assumed to be A-36 steel and the allowable tensile load is based on the nominal bolt area times an allowable stress. The allowable stress is 1.7 times the working stress design allowable given in Part 1 of the AISC (Reference 4) and is equal to 34,000 psi. Some of the bolts are 2", some are 2½". The pullout capacity of all the bolts is calculated assuming a 2" nominal. The pullout capacity of the bolts is as follows:

Bolt Diameter, D = 2.0 inch

Bolt Area, A = 3.14 inch ^{2}

Bolt Capacity, C = (4) 3.14 x 34ksi = 427 Kips

The ACI code formula for pullout capacity of cast-in-place bolts due to failure of concrete is:

$C = 4\phi\sqrt{f'c}\ \pi(L+D)L$

where: L = 48 inches (min assumed)

$\phi = 0.65$

f'c = 3,500 psi; concrete compressive strength

D = 2 inches

C = 1,159 Kips per bolt minimum (greater for 2½" bolts)

The projected shear cone for a bolt with 48 inch of embedment is as follows:

$A_{cone} = \frac{\pi(2 \times L + D)^2}{4}$ $A_{cone} = 7{,}543\ in^2$

The installed anchorage configuration has only 15 inch spacing between the bolts. Using the GIP Tension bolt reduction formula (Reference 1):

$A'cone = \pi\ r^2 - ½ \{ r^2\theta - r\,s' \sin(\theta/2)\}$

where:

L = bolt embedment = 48 in.

D = bolt diameter = 2 in.

s' = actual bolt spacing = 15 in.

r = (2L+D)/2 = 49 in.

$\theta = 2 \cos^{-1} (s'/(2L+D)) = 2.8343$ rad.

:A'cone = 4,504 in^2

$C' = (A'/A_{cone}) \times C$ C'= 692 Kips > **427 Kips per bolt minimum**

Bolt strength controls

The perimeter supports are primarily designed for tensile loads but can carry some shear loads once small bolt hole gaps are overcome.

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Center Anchor Support Capacity - Shear

The center support consists of a built-up H section, embedded 4' into the turbine base mat and welded to the condenser bottom as shown in Figure 5-1. All seismic shears are assumed to be resisted by the H section.

$F_v = 0.4\ F_y \times 4/3$ (AISC earthquake increase) = 19.2 Ksi for A-36 steel

$A_v = 20 \times 2 = 40\ in^2$ N-S

$A_v = 16 \times 2 \times 2 = 64\ in^2$ E-W

$V_{all} = 40 \times 19.2 = 768$ Kips N-S (Transverse)

$V_{all} = 64 \times 19.2 = 1{,}229$ Kips E-W (Longitudinal)

The existing condenser anchorage system capacity is substantially greater than the demand of combined operational and lateral seismic DBE forces.

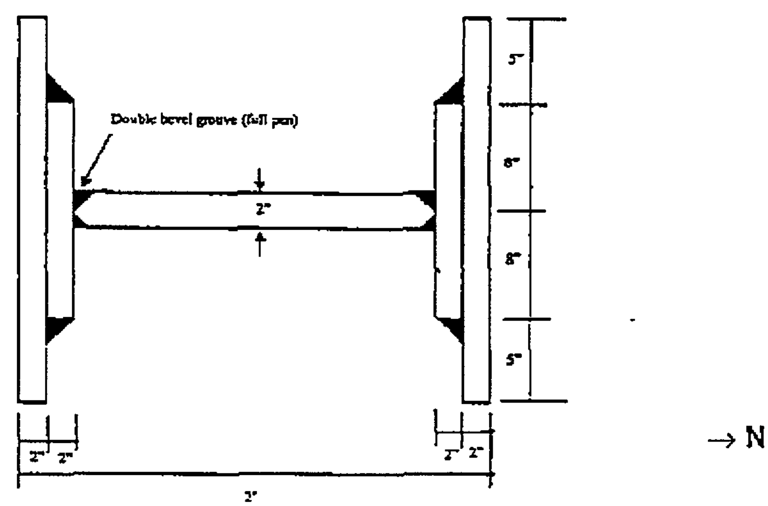

Figure 5-1 Anchor Design

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Table 5-1

BFNP Condenser Weight & C.G.

Section No.	No. of Sections	Weight Each (lb)	Weight (lb)	y C.G. (in)	W*y
Condenser Shell	1	1,500,000	1,500,000	190	285,000,000
Water in Tubes	1	327,946	327,946	81	26,563,610
Water in Hot Well	1	242,575	242,575	18	4,366,343
		Totals	2,070,520		315,929,952
			C.G.	12.72 (ft)	

Operating wt from Foster Wheeler Dwg. No. 0-93-505-3-190 Rev. E (Ref. 6f) 2,070,000 (lbs)

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Table 5-2

Condenser Loads

*Vertical Loads: "+" = Tension

Lateral Earthquake Accelerations												Vertical Earthquake Accel.		
DBE Acc.horizontal:	0.32	"="	0.2	x	1.6	Soil Amplification	Moment:	kip-ft				DBE Acc. vertical	0.20	g
Total Wt	2070	kips		Arm:	12.72	ft.	8426	kip-ft						
								kip-ft						
Total: Wtotal:	2070	kips										Total: Wtotal:	2070	kips
DBE Shear:	**662.4**	**kips**		**DBE Moment:**			**8426**	**kip-ft**				**Total Uplift:**	**414**	**kips**

Support Location	Longitudinal "1" = Active Support	Bolt Load (kips)	Anchor Load (kips)	"1" = Active Support	Bolt Load (kips)	Anchor Load (kips)	Max Bolt Load (kips)		Transverse "1" = Active Support	Bolt Load (kips)	Anchor Load (kips)	"1" = Active Support	Anchor Load (kips)	Max Bolt Load (kips)	Anchor Load (kips)	Total SRSS Bolt Load (kips)
X1		0			0		0			0				0		0
Y1		0			0		0			0				0		0
Z1		0			0		0			0				0		0
X2		0			0		0			0				0		0
Y2		0			0		0			0				0		0
Z2		0			0		0			0				0		0
F1	1		662	1		662	0	662	1		662	1	662		662	
Totals:	1.00	0		1.00	0				1.00	0		1.00				

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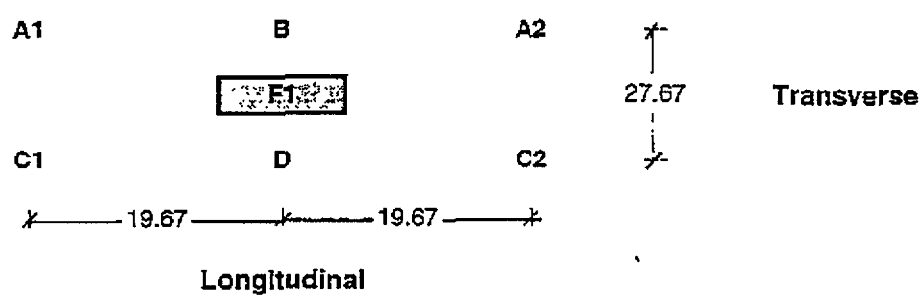
Table 5-2 (Cont.)

Support Location	OP Operating Load (kips)	Tension Due to Seismic Overturning						Tension Due to Vert	
		Longitudinal			Transverse			Vertical	
		Arm (ft)	"1" = Active Support	Tension (kips)	Arm (ft)	"1" = Active Support	Tension (kips)	"1" = Active Support	Tension (kips)
A1	-70	39.34	1	86	27.67	1	203	1	69
B	-70	39.34	1	43	27.67	1	203	1	69
A2	-70	39.34		0	27.67	1	203	1	69
C1	-70	39.34	1	86	27.67		0	1	69
D	-70	39.34	1	43	27.67		0	1	69
C2	-70	39.34		0	27.67		0	1	69
F1									
Totals:	-420		4			3		6	414

Support Location Diagram



Assumptions:
Anchors A, B, C & D take no shear. All seismic shear is taken by the fixed support F
Anchors A, B, C & D take tension/compression from rocking and operating loads

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Table 5-3

Anchor Demands

Support	DBE Loads		Per Bolt Load			Bolt Stress			
	Shear (kips)	Tension (kips)	# of Bolts	Shear (k/bolt)	Tension (k/bolt)	Bolt Size	Bolt Area	Bolt Stress Ksi	For A-36 steel, Allowable is 34ksi
A1	0	80	3	0	27	2	3.14	17.08	ok
B	0	60	2	0	30	2	3.14	23.67	ok
A2	0	53	3	0	18	2	3.14	15.33	ok
C1	0	80	3	0	27	2.5	4.91	2.72	ok
D	0	60	2	0	30	2.5	4.91	1.14	ok
C2	0	53	3	0	18	2.5	4.91	0	ok
F1	662	0							

All bolt tension loads are much less than 427 Kip capacity (minimum 2" Diameter)

Anchor shear load is less than minimum 768 Kip (N-S) capacity

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6.0 CONCLUSIONS

Analyses of the BFN Unit 3 condenser and comparisons with database condensers were performed. The condenser design and anchorage are shown to be similar to those at facilities in the earthquake experience database that have experienced earthquakes in excess of the BFN design basis DBE. The BFN condenser is bounded by the comparable attributes of the database condensers. Anchorage calculations performed for the BFN Unit 3 condenser indicate that the imposed seismic and operational demand of the design basis DBE is less than the anchorage capacity.