ENCLOSURE 4

BALANCE OF PLANT STRUCTURES
SEISMIC REEVALUATION PROGRAM

AS-BUILT REEVALUATION OF THE TURBINE BUILDING SOUTH EXTENSION

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(3805L)

1. INTRODUCTION

On April 30, 1982, the results of the seismic reevaluation of the turbine building and turbine generator pedestal were submitted to the NRC (Reference 1). The submittal identified conceptual modifications consisting of addition of structural steel bracing, foundation changes, and miscellaneous modifications to the north extension, south extension, west heater platform, and east heater platform of the turbine building. The summary of these modifications are given in Section 5 of Reference 1.

By mid-1983 all of the modifications to the north, east, and west extensions, as well as the majority of the modifications to the south extension were completed. On December 23, 1983 the "Return To Service" (RTS) plan was submitted to the NRC (Reference 2). The basis of the plan was to assure that structures, systems, and components necessary to achieve and maintain a hot standby condition have sufficient design margins to resist the postulated 0.67g modified Housner earthquake. Since the failure of the south extension would not prevent the plant from reaching a safe shutdown condition, the conceptual modifications remaining in the south extension were not implemented during the RTS.

Since seismic withstand capacity of the south extension has been substantially increased by the modifications constructed to date, an analysis of the adequacy of this condition to sustain required seismic loads was performed. This report describes of the as-built condition of the south extension, including the modifications constructed to date except one brace (No. 43) and one foundation (No. D). The analysis methodology for evaluating the as-built withstand capability and the results of this analysis are also presented. It is shown that the as-is condition of the south turbine extension satisfies the seismic reevaluation criteria (Reference 3).

2. SUMMARY OF MODIFICATIONS IMPLEMENTED

The following describe all of the proposed modifications to the south extension identified in Section 5.4 of Reference 1 and describe the current status of completion of each modification. Figure 1 shows the conceptual modifications identified in Reference 1. The as-built condition is depicted in Figure 2.

2.1 Structural Steel Bracing

a. A wide flange W12X120 diagonal brace was designed for installation between the top of column N-6 and the bottom of column M-6.

STATUS: Complete

b. A wide flange W12x120 diagonal brace was designed for installation between the top of column N-6 and the bottom of column P-6.

STATUS: Complete

c. A wide flange W12x120 "K" brace was designed for installation in the east-west direction between column M-6, M-7 and M-8.

STATUS: Complete

d. A wide flange W12x120 diagonal brace was designed for installation between the top of column N-8 and the bottom of column M-8.

STATUS: Complete

e. A wide flange W12x120 diagonal brace was designed for installation between the top of column P-8 and the bottom of column N-8.

STATUS: Complete

f. A wide flange W12x120 diagonal brace was designed for installation between the top of column P-7 and the bottom of column P-6.

STATUS: Complete

g. A wide flange W12x120 diagonal brace was designed for installation between the top of column P-6 to the concrete pier located east of column P-6.

STATUS: The as-built analysis of the south extension showed that this modification is not required to satisfy the design margins.

2.2 Foundations

a. Along column line 6 a combined footing approximately 20 feet x 12 feet x 6 feet deep was designed for installation. The existing footings for columns M-6 and N-6 were structurally connected to the modified footing using rock bolts.

STATUS: Complete

b. Along column line 8, a combined footing approximately 20 feet x 12 feet x 6 feet deep was designed for installation. The existing footings for the columns M-8 and N-8 were structurally connected to the modified footing using rock bolts.

STATUS: Complete

c. Along column lines P-6 to P-8 a combined footing was designed for installation. The existing footings for the columns P-6, P-7, and P-8 were structurally connected to the modified footing using rock bolts.

STATUS: The as-built analysis of the south extension showed that this modification is not required to satisfy the design margin.

d. A spread foundation was designed for installation east of column P-6.

STATUS: The as-built analysis of the south extension showed that this modification is not required to satisfy the design margins. (See item g in Section 2.1) of the deck slab. These shear plates were welded to the top flanges of the supporting beams and girders. Some of these welds were ground out and rewelded in order to assure transmitting of seismic forces to the structural frame.

STATUS: Complete

3. REEVALUATION CRITERIA AND METHODOLOGY

The criteria followed for the reevaluation of the south extension are given in References 1 and 3. The analysis considered the occurrence of a 0.67g modified Housner earthquake in combination with normal plant operating loads, including the presence of the turbine gantry crane.

The basis of the mathematical model used is the three-dimensional finite element model developed in Reference 1. The turbine building complex is basically a frame structure supported by individual footings. There are no structural elements connecting the north, south, east, and west extensions, therefore, there is no interaction between the extensions.

For this reason, for the reevaluation presented herein, the north, east, and west extensions are removed from the mathematical model. The models of the turbine generator and pedestal are included since some of the south extension footings rest on the pedestal basement. The gantry crane is assumed to be parked at its normal plant operating location, that is on the south end of the south extension. The finite element idealization is given in Figure 3.

Linear elastic analysis methods are used for the computation of the static and dynamic responses. For the dynamic analysis response spectrum method is utilized.

The procedure followed to account for the effects of soil-structure interaction is consistent with Reference 1. Soil-structure interaction effects were taken into account by lumped parameter representation of the soil medium stiffness and damping. In computing the soil parameters, the footing geometry, structure inertia, total structural embedment, strain dependent properties of the foundation medium and forcing frequencies were considered as discussed in Reference 3. Because the supporting medium is a San Mateo sand deposit which is uniform and extends to a depth of approximately 1000 feet below the site, a frequency independent representation of soil stiffness and damping values was used. In addition, the effects of soil backfill conditions are included in the computations of lumped parameter soil structure interaction values as described in Reference 4.

The soil medium is represented in the three-dimensional finite element model by including three translational and two rotational linear spring stiffness values and their corresponding damping values. Although the composite modal damping values computed were as high as 51 percent, the maximum composite modal damping was conservatively limited to 20 percent for the response spectrum analysis.

The resulting structural seismic responses obtained from the response spectrum analysis consist of moments, shears, and displacements for the various elements that comprise the finite element model. These responses are then combined with the static analysis results for the evaluation of the structural members, the connections and the column anchorages. The results of the calculations indicate that all structural elements in the as-built condition of the south extension satisfies the criteria set forth in References 1 and 3. Possible uplift in the footings are also evaluated.

4. DISCUSSION OF RESULTS

In the present reevaluation, the member forces are computed both for the lower bound and upper bound soil conditions. In the majority of the cases, the lower bound soil parameters, reflecting the interpreted extreme soil backfill conditions (Reference 5), govern the evaluation. The forces are then compared with the element forces presented in

Reference 1. When the computed forces are less than or equal to those in Reference 1, the structural element (beam, column, or a connection) satisfies the seismic evaluation criteria. The majority of the evaluations fall into this category. Additional computations are performed to demonstrate that the element with the as-built forces satisfies the evaluation criteria, when the calculated forces are higher than those given in Reference 1.

Tables 1 through 6 show the summary of the evaluations performed. For ease of reference the tables also contain the results of the member evaluations presented in Reference 1. The "remarks" column of each table describe the evaluation results of the as-built analysis described herein.

As is described in section 2.2, item c, the foundation modification combining footings P6, P7 and P8 is not constructed. Therefore the existing foundations were reviewed for the uplift loads from the newly installed bracing members. The dynamic analysis performed using the upperbound values of the soil parameters yielded forces on the footings which were less than the net downward forces in the columns. Therefore, the results of the upper bound analysis were acceptable for uplift considerations of the footings. The selected footing evaluation indicated they met the acceptance criteria.

The bracing member forces calculated from the dynamic analysis performed using lower bound values of the soil parameters were evaluated in the similar manner for uplift considerations. All the structural column locations reviewed met the acceptance criteria except column location P6. At column P6, the lower bound analysis yielded a total uplift load which was 4 percent greater than the total downward force on the footing. The effect of this unbalanced force on the rest of the structure was evaluated by performing a three dimensional static analysis. In this analysis the net unbalanced load of 7.8 kips at the column base was applied as an upward load to be redistributed and the resulting forces in the structural members were calculated. These members forces were superposed on the forces calculated from the dead load analysis and dynamic analyses. All the members evaluated using these forces were found to be acceptable. Therefore, all the structural column footings were considered acceptable.

It should be noted that a large portion of the uplift load on the bracing members during DBE is generated because of the conservative method of modeling of the gantry crane on the parking structure outside of the south extension on the southside. The gantry crane is free to roll on the crane girders. The wheels of the gantry crane are not structurally connected to the crane rail girder. However, for the finite element model the legs of the crane were modeled as pin connected to the crane rail girders. Because of this conservative way of modeling, the east-west rocking mode of the crane about the north-south axis generates a large portion of the tensile load in the bracing members. In reality, the gantry crane may lift up during an east-west excitation. An independent stability analysis of the gantry crane performed previously had indicated that large margins of safety exist against the crane overturning even if the crane legs lift up. Therefore, the column footing P6 is acceptable. The columns and footings of the parking structure, R6 and R8, were evaluated for the compressive loads only, since it was concluded that due to lifting of the legs of the crane, these columns can not be subjected to a tensile load.

The maximum lateral displacements of the south extension structure and the turbine/generator pedestal, as shown in Table 7, were calculated using the response spectrum analysis method. Two independent analyses were performed corresponding to the lowerbound and the upperbound values of the soil parameters. The lowerbound analysis yielded larger lateral displacements. As shown in Table 7 the maximum combined SRSS displacement of the Turbine/Generator Pedestal and the South Extension deck is 1.11 inches. This is smaller than the 1.50 inches of the seismic gap available between the two structures, therefore is acceptable.

5. CONCLUSIONS

Based on the results of the reevaluation of the south turbine building extension with the modifications installed, it is concluded that the existing south extension, satisfies the seismic reevaluation criteria without further modification. Therefore, the additional conceptual modifications identified in Reference 1 need not be implemented to satisfy the design margins.

REFERENCES

1. Enclosure 2 to the letter from K. P. Baskin to D. M. Crutchfield, dated April 30, 1982, "Balance of Plant Structures Seismic Reevaluation Program, Turbine Building and Turbine Generator Pedestal, San Onofre Nuclear Generating Station, Unit 1".

2. Enclosure to letter from M. O. Medford to D. M. Crutchfield, dated December 23, 1983, "Docket Number 50-206, Return to Service Plan, Seismic Reevaluation Program, San Onofre Nuclear Generating Station, Unit 1".

3. Enclosure to letter from K. P. Baskin to D. M. Crutchfield, dated February 23, 1981, "Balance of Plant Structures Seismic Reevaluation Criteria, San Onofre Nuclear Generating Station, Unit 1".

4. Enclosure to letter from K. P. Baskin to D. M. Crutchfield, dated April 18, 1983, "Soil Backfill Conditions, Chapters 1, 2, & 3". Enclosure to letter from R. W. Krieger to D. M. Crutchfield, dated September 1, 1983, "Soil Backfill Conditions, Chapters 4 & 5". Enclosure to letter from M. O. Medford to D. M. Crutchfield, "Addendum 3 to the Report on Soil Backfill Conditions; Shear Modulus Values used in Soil Structure Interaction Studies SONGS 1".

P6-P7	36
P6-N6	37
M6-N6	38
M6-M7-M8	39-40
M8-N8	41
N8-P8	42
P6 Outside	43

M6-N6 - "E"
M8-N8 - "F"
P6-P8 - "D"

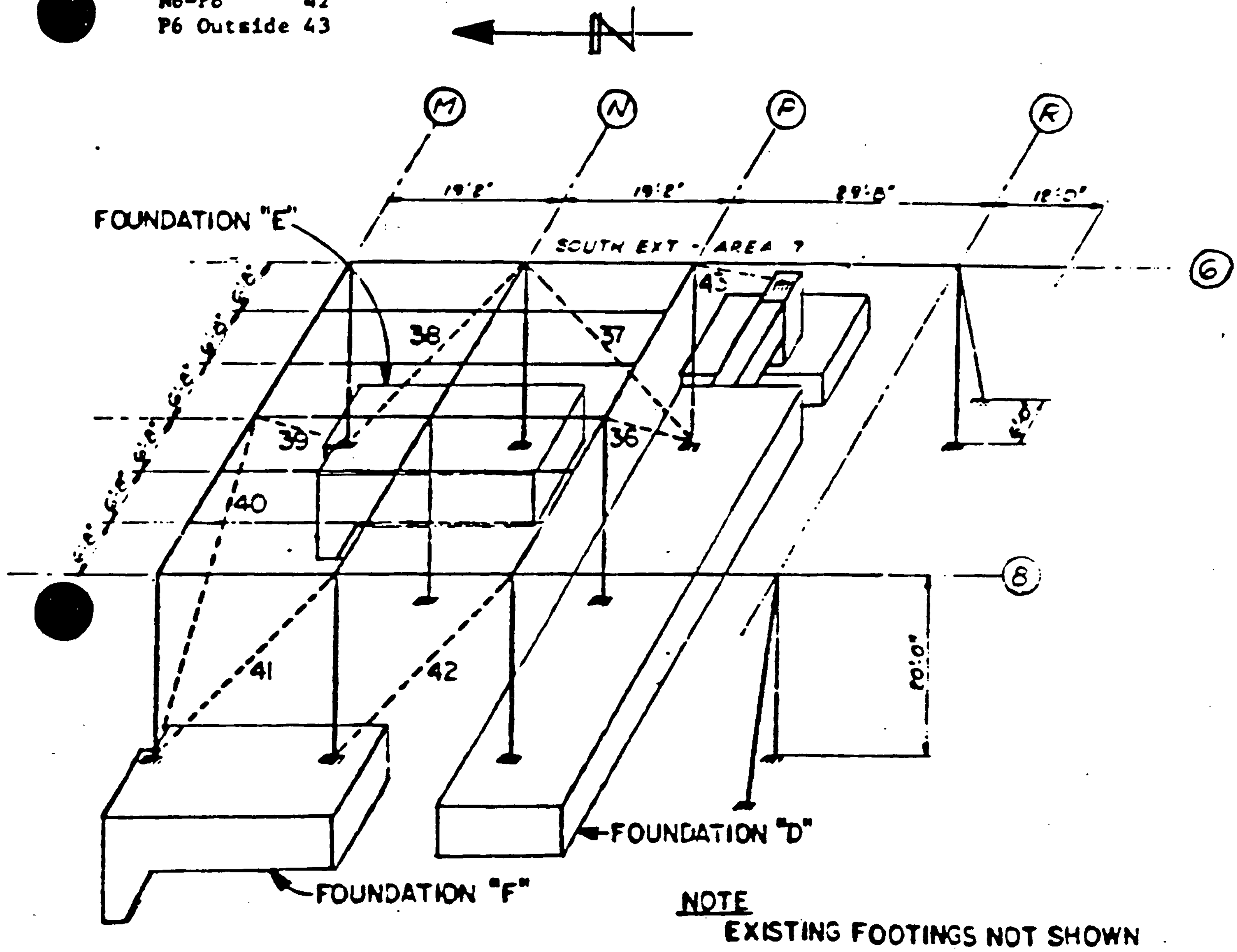

Figure 1. Conceptual and Foundation Modifications in South Extension of Turbine Building (Reference 1)

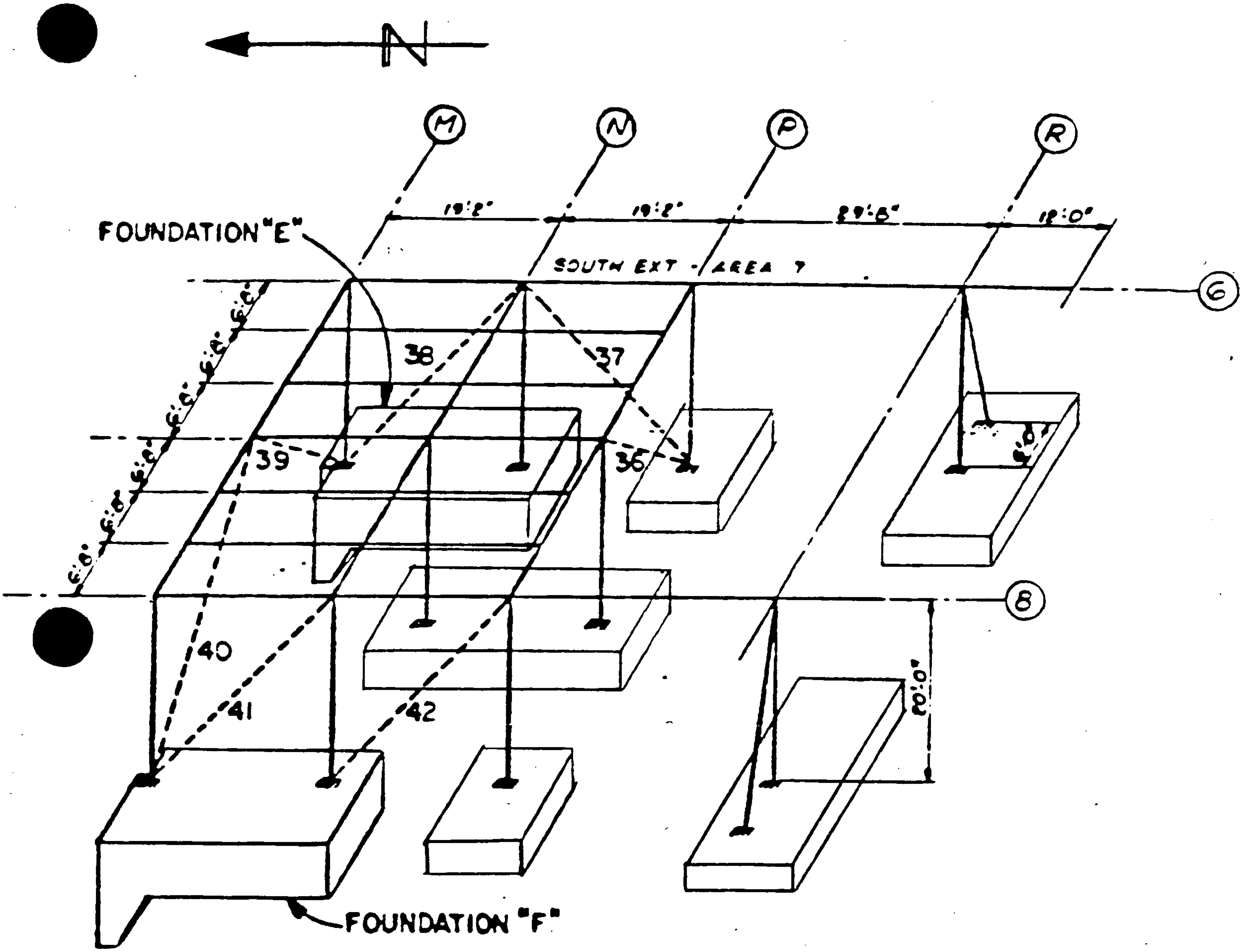

Figure 2. As-Built Bracing and Foundation Modifications in South Extension of Turbine Building

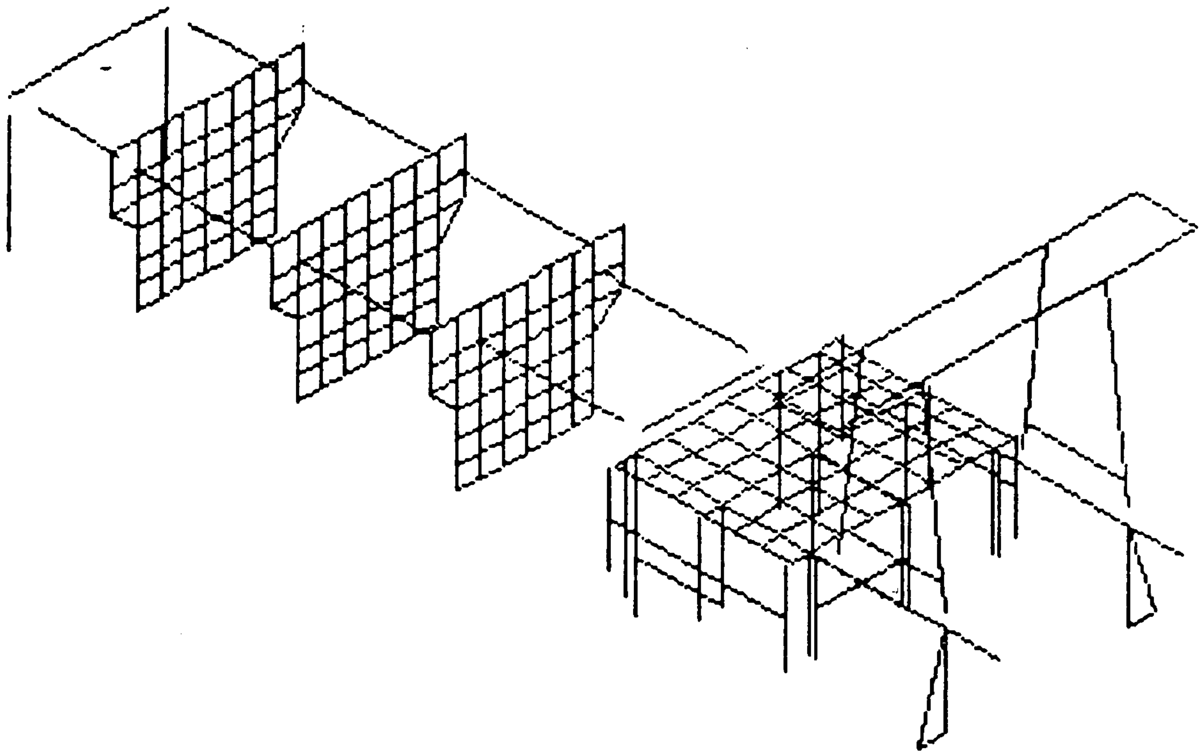

Figure 3. Mathematical Model used in the Analyses of
the South Extension of Turbine Building

TABLE 1 SOUTH EXTENSIO[illegible] BRACING STRESS EVALUATION

SEP EVALUATION FROM REFERENCE 1 TABLE 32 (1982)									PRESENT EVALUATION (1985)
NO.	DESCRIPTION	REF. FIGURE NO.	SIZE	fa	Fa	SF= Fa/fa	MEETS CRITERIA YES	NO	REMARKS
BR1	M6 - N6	41	W12x120	7.54	20.32	2.69	x		NOTE A
BR2	N6 - P6	41	W12x79	9.53	19.78	2.08	x		NOTE A
BR3	P8 - N8	41	W12x79	10.56	19.78	1.87	x		NOTE A
BR4	N8 - M8	41	W12x120	8.19	20.32	2.48	x		NOTE A
BR5	P6 - F7	41	W12x120	8.50	19.98	2.35	x		NOTE A
BR6	M8 - M7	41	W12x79	9.44	19.06	2.02	x		NOTE A
BR7	M7 - M6	41	W12x79	9.53	19.06	2.00	x		NOTE A
BR8	P6	41	W12x120	5.38	22.30	4.14	x		NOT CONSTRUCTED

NOTES:
1. fa = CALCULATED AXIAL STRESS, KSI
2. Fa = ALLOWABLE AXIAL STRESS, KSI
3. SF = SAFETY FACTOR FOR AXIAL COMPRESSION

NOTE A: SEP LOADS HIGHER, MEMBER OK.

TABLE 4 SOUTH EXTENSION - BOLTED CONNECTION EVALUATION

SEP EVALUATION FROM REFERENCE 1, TABLE 35 (1982)								PRESENT EVALUATION (1985)
IDENTIFICATION	REFERENCE FIGURE NO.	SIZE	V_C	V_A	SF_V V_A/V_C	MEETS CRITERIA		REMARKS
						YES	NO	
BC1	44	7 ROWS	263.3	414.4	1.57	X		NOTE A
BC2	44	6 ROWS	56.3	212.8	3.78	X		NOTE A
BC3	44	5 ROWS	36.1	106.0	2.94	X		NOTE A
BC4	44	4 ROWS	17.1	84.8	4.96	X		NOTE A
BC5	44	3 ROWS	6.4	36.7	5.73	X		NOTE B

NOTATION

1. V_C - CALCULATED SHEAR, KIPS
2. V_A - ALLOWABLE SHEAR, KIPS
3. SF_V - SAFETY FACTOR FOR SHEAR

NOTE A: SEP LOADS HIGHER, CONNECTION OK

NOTE B: AS-BUILT LOADS MARGINALLY HIGHER, CONNECTION OK BY INSPECTION

TABLE 5 SOUTH EXTENSION COLUMN EVALUATION

SEP EVALUATION FROM REFERENCE 1, TABLE 36 (1982)															PRESENT EVALUATION (1985)
IDEN'T	REF FIGURE NO	SIZE	DESCRIPTION	P OR f_a	Py OR F_a	Mx OR f_{bx}	Mpx OR F_{bx}	My OR f_{by}	Mpy OR F_{by}	(1) R_C, R_C^b	R_A	SF= R_A/R_C	MEETS CRITERIA YES	MEETS CRITERIA NO	REMARKS
M-6	45	W24x130		1.67	16.14	15.40	22.0	5.17	27.0	1.01	1.60	1.58	X		NOTE A
M-8	45	W24x130		1.67	16.14	15.40	22.0	5.17	27.0	1.01	1.60	1.58	X		NOTE A
N-6	45	W24x110		6.32	14.60	8.59	21.3	4.23	27.0	0.98	1.60	1.63	X		NOTE A
N-7	45	W24x130		4.69	15.99	9.06	22.0	4.74	27.0	0.84	1.60	1.90	X		NOTE B
N-8	45	W24x110		9.13	14.65	8.79	20.97	4.85	27.0	1.27	1.60	1.26	X		NOTE A
P-6	45	W24x100		271	1062	3655	10080	193	2059	0.62^b	1.0	1.61	X		NOTE C, S.F. = 1.14
P-7	45	W24x130		6.94	15.98	9.28	22.0	5.85	27.0	1.06	1.60	1.51	X		NOTE C, SF. = 1.48
P-8	45	W24x100		8.78	14.51	6.99	19.09	5.92	27.0	1.27	1.60	1.26	X		NOTE C, SF = 1.02
R-6	45	W24x130		9.43	16.10	12.89	22.0	0.71	27.0	1.15	1.60	1.39	X		NOTE A
R-8	45	W24x130		9.43	16.10	12.89	22.0	0.71	27.0	1.15	1.60	1.39	X		NOTE C, SF. = 1.23
R-6, R8 DIAGONALS	45	W14x74		238	785	702	4536	203	1462	0.52^b	1.0	1.92	X		NOTE C, SF. = 1.01

NOTATION

1. R_C - COMBINED STRESS FACTOR
2. R_A - ALLOWABLE COMBINED STRESS FACTOR
3. SF - OVERALL SAFETY FACTOR
4. f_a, F_a, F_{bx}, ETC. - SEE AISC ST'L CONSTRUCTION MANUAL 1980, ksi
   P, Py, Mpx ETC. ——— " ——— KIPS OR KIP-INCHES

FOOT NOTES (DESIGNATED BY SUPERSCRIPTS)

(1) INTERACTION EQS FOR STRUCTURAL STEEL:

$$R_C = \frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{(1 - f_a/F'_{ex}) F_{bx}} + \frac{C_{my} f_{by}}{(1 - f_a/F'_{ey}) F_{by}}, \text{ OR } \frac{f_a}{0.60 F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}}, \text{ OR } \frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}}; \quad R_C^b = \frac{P}{P_y} + \frac{1}{1.18}\frac{M_x}{M_{px}} + \frac{1}{1.67}\frac{M_y}{M_{py}}$$

NOTE A: SEP LOADS HIGHER, MEMBER OK BY INSPECTION
NOTE B: AS-BUILT LOADS MARGINALLY HIGHER, MEMBER OK BY INSPECTION
NOTE C: AS-BUILT LOADS HIGHER, MEMBER OK

TABLE 6 SOUTH EXTENSION - COLUMN ANCHORAGE EVALUATION

SEP EVALUATION FROM REFERENCE 1, TABLE 37 (1982) — PRESENT EVALUATION (1985)

IDENT	REF FIGURE NO.	DESCRIPTION	SIZE	f_t	F_t	SF_t F_t/f_t	f_b	F_b	R_C[7]	R_A[8]	SF_b[9]	MEETS CRITERIA YES	MEETS CRITERIA NO	REMARKS	REMARKS (PRESENT EVALUATION 1985)
M-6	45	ANCHOR BOLTS	1½"φ	169	101	0.60							x	SEE SECTION 5	NOTE
		BASE PL	2¼"				25.2	27.0	0.93	1.6	1.72	x			
M-8	45	ANCHOR BOLTS	1½"φ	170	101	0.60							x	SEE SECTION 5	NOTE
		BASE PL	2¼"				25.4	27.0	0.94	1.6	1.70	x			
N-6	45	ANCHOR BOLTS	1½"φ	34.6	101	2.92						x			NOTE
		BASE PL	2½"				27.3	27.0	1.01	1.6	1.58	x			
N-8	45	ANCHOR BOLTS	1½"φ	9.0	101	11.22						x			NOTE
		BASE PL	2¼"				27.4	27.0	1.02	1.6	1.57	x			
P-6	45	ANCHOR BOLTS	1¼"φ	148	101	0.68							x	SEE SECTION 5	NOTE C
		BASE PL	2¼"				54.4	27.0	2.02	1.6	0.79		x		
P-8	45	ANCHOR BOLTS	1¼"φ	3.8	101	26.6						x			NOTE
		BASE PL	2¼"				24.1	27.0	0.89	1.6	1.80	x			
P-7	45	ANCHOR BOLTS	1¼"φ	39.3	101	2.57						x			NOTE
		BASE PL	2½"				18.4	27.0	0.68	1.6	2.35	x			
N-7	45	ANCHOR BOLTS	1¾"φ	—	—	—						x		ADEQUATE BY COMPARISON TO P-7	NOTE
		BASE PL	2½"				—	—	—	—	—	x			
-6(COL)	45	ANCHOR BOLTS	1"φ	180	32	0.18							x	SEE SECTION 5	NOTE
		BASE PL	1¾"				[illegible]	27.0	1.42	1.6	1.13	x			
8(COL)	45	ANCHOR BOLTS	1"φ	197	32	0.16							x	SEE SECTION 5	NOTE
		BASE PL	1¾"				[illegible]	27.0	1.46	1.6	1.10	x			

NOTATION

1. SF_t - SAFETY FACTOR FOR TENSILE LOAD
2. SF_b - SAFETY FACTOR FOR BENDING
3. f_t, F_t, f_b, F_b - SEE AISC STEEL CONSTRUCTION MANUAL 1980, KSI
4. COMPUTED BENDING MOMENT K-IN
5. ALLOWABLE PLAST. MOM = $F_y \times Z$
6. SF_b = M PLASTIC/MC
7. $R_C = f_b/F_b$
8. $R_A = 1.6$
9. $SF_b = R_A/R_C$
10. SHEAR CONE CAPACITY OF BASE PL W/O ANC BOLTS (COL. WELDED TO BASE PL)

NOTE A: SEP LOADS HIGHER, ANCHORAGE OK
NOTE B: AS-BUILT LOADS MARGINALLY HIGHER, ANCHORAGE OK BY INSPECTION
NOTE C: AS-BUILT LOADS HIGHER, ANCHORAGE OK

TABLE 7 SOUTH EXTENSION - DISPLACEMENTS

LOCATION	DISPLACEMENT DIRECTION	MAXIMUM DISPLACEMENTS (INCHES)	REMARKS
Northwest Corner of the South Ext. Deck	North-South	0.582	Displacements O.K.
	East-West	0.328	
Northwest Corner of the South Ext. Deck	North-South	0.543	Displacements O.K.
	East-West	0.328	
Southeast Corner of the Turbine Pedestal Deck	North-South	0.946	Displacements O.K.
	East-West	0.608	
Southeast Corner of the Turbine Pedestal Deck	North-South	0.946	Displacements O.K.
	East-West	0.608	
SRSS Combined Displacement Turbine Pedestal Deck With South Ext. Deck	North-South	1.11	Displacements O.K.