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BYRON JACKSON REPORT DC-1102

SEISMIC ANALYSIS

Auxiliary Feedwater Pumps
Southern California Edison Company
San Onofre Nuclear Generating Station
Units 2 and 3

Specification Number:	S023-405-6
Purchase Order Number:	N-4140791
Byron Jackson Job Numbers:	751-L-0091
	751-L-0092
	751-L-0093
	751-L-0094

Prepared by: Paul Hogas — Design Engineer — Date 10 Nov. 78

Approved By: Larry B. Boswell — Section Head - Nuclear Auxiliary Pumps — Date 28 Nov 78

BYRON JACKSON PUMP DIVISION
BORG-WARNER CORPORATION
Los Angeles, California

SCE # 4079
SØ23-[redacted]
405-6-81-2

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BYRON JACKSON REPORT DC-1102 Revision B

SEISMIC ANALYSIS

Auxiliary Feedwater Pumps
Southern California Edison Company
San Onofre Nuclear Generating Station
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	751-L-0094

Prepared by: ______________________ Date 2 June 78
Design Engineer

Approved By: ______________________ Date 2 Jun 78
Section Head - Nuclear
Auxiliary Pumps

BYRON JACKSON PUMP DIVISION
BORG-WARNER CORPORATION
Los Angeles, California

405-6-81-2

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BYRON JACKSON REPORT DC-1102   Revision A

SEISMIC ANALYSIS

Auxiliary Feedwater Pumps
Southern California Edison Company
San Onofre Nuclear Generating Station
Units 2 and 3

Specification Number:	S023-405-6
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	751-L-0093
	751-L-0094

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BYRON JACKSON PUMP DIVISION
BORG-WARNER CORPORATION
Los Angeles, California

405-6-81-0

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BYRON JACKSON REPORT DC-1102 Revision 0

SEISMIC ANALYSIS

Auxiliary Feedwater Pumps
Southern California Edison Company
San Onofre Nuclear Generating Station
Units 2 and 3

Specification Number:	S023-405-6
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	751-L-0093
	751-L-0094

Prepared By: Paul Fyogas Date 4 Apr. 77
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BORG-WARNER CORPORATION
Los Angeles, California

405-6-81-2

REVISION LIST

Ø	4 Apr.77	Original submittal
A	27 Feb.78	Changed Page 1 from Scope to Certification. Added the symbol π to the denominator of all frequency formulas. Incorporated new response spectra and nozzle loads. Revised pump and turbine weights.
B	2 June 78	Added turbine nozzle loads to foundation bolt analysis.
C	3 Nov. 78	Verified frequency model in 4.1, added 7.0 shaft deflection analysis, revised turbine inlet nozzle loads for tables 16 & 18, added driver torque to operating loads in tables 15 & 17.

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1.0 CERTIFICATION

This report summarizes the seismic analysis performed on a 4 x 6 x 9D 8-Stage DVMX and is certified to be in compliance with Bechtel Specification No. S023-405-6.

Revision Ø
Revision A

Leong Pok Kuah DATE 6 MAR. 1978

Registration No. CAL. # ME 18729

Revision B

Leong Pok Kuah DATE 2 JUNE 1978

Registration No. CAL. # ME 18729

Revision C

Leong Pok Kuah

Registration No. CAL. # ME 18729 DATE 14 NOV. 1978

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2.0 METHOD OF ANALYSIS

The natural frequency of vibration was determined for the pump and driver supports so that the seismic accelerations could be determined using the frequency response spectrums supplied by Bechtel.

The hold-down bolts, alignment dowels and foundation bolts were investigated to determine if they were adequate size to withstand gravitational, nozzle, and seismic loads.

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3.0 MATERIALS

	PUMP HOLD DOWN BOLTS	PUMP ALIGNMENT DOWELS	FOUNDATION BOLTS
Size	1" - 8 NC	1/2" Dia.	1" - 8 NC
Material	ASME-SA 193 GR. B7	ASME-SA 193 GR. B7	Note 1
Allowable Tensile Stress *(psi)	25,000	25,000	
Minimum Yield Stress *(psi)	105,000	105,000	

TABLE 1

*Stress values are taken from Ref. 2

Note 1: Foundation bolts are to be supplied by others.

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4.0 CALCULATION OF NATURAL FREQUENCIES OF VIBRATION

4.1 Introduction

The determination of seismic effects on a structure using dynamic methods requires simplifying assumptions and idealization to formulate the problem that lies within the capability of known methods of solution. These simplifications, in effect, involve the substitution of a model for the structure and the response determined is that of the model. To calculate the natural frequencies we assume the pump, drivers and their pedestals to be an equivalent spring-mass system where we use conventional strength of materials to determine the spring constants.

Although this calculated frequency is approximate it has been shown to be adequate by test data. Actual testing for natural frequency has been done on a similar pump of this size. The results are summarized in Byron Jackson Engineering Report No. 247-30352. The minimum natural frequency tested for any direction was significantly higher than 33 Hz.

In this section and in subsequent sections the following coordinate system will be used: The x-axis is parallel to the pump shaft and is positive toward the driver. The y-axis is vertical and is positive upward. The z-axis is perpendicular to the pump shaft and the positive direction is such that a right-handed coordinate system is defined.

4.2 Computation Procedure - Vertical Frequencies

It has been established for many structural materials that within certain limits the elongation of the pedestals is proportion to the force. This simple linear relationship is given by

$$\delta = \frac{Fl}{AE} \tag{1}$$

Rearranging Eq. (1) we define a spring constant as

$$K = \frac{F}{\delta} = \frac{EA}{l} \tag{2}$$

where

E = modulus of elasticity (psi)

A = cross-sectional area of the pedestal (in^2)

l = height of the pedestal

For equipment mounted on more than one pedestal the combined spring constant is just the algebraic sum of the individual spring constants. Having obtained the combined spring constant the natural frequency is then given by

$$f = \frac{1}{2\pi}\left(\frac{K}{M}\right)^{\frac{1}{2}} \tag{3}$$

where M is the mass of the equipment on the pedestals.

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4.2.1 Vertical Frequencies - Turbine Driven Unit

Tabulated below are geometric and material properties for the pump and turbine pedestals. (Refer to Figure 1 for the general arrangement.)

	PUMP	TURBINE*	
E (psi)	29×10^6	29×10^6	29×10^6
A (in^2)	13.75	26.88	10.00
L (in)	12.25	7.25	7.25
M (lbs - sec^2/in)	8.41	10.21	

TABLE 2

Using the formulas generated previously the combined spring constant for the pump pedestals is

$$K = \frac{4 \times 29 \times 10^6 \times 13.75}{12.25} = 130.20 \times 10^6 \text{ lb/in}$$

and the natural frequency is

$$f = \frac{1}{2\pi} \left(\frac{130.20 \times 10^6}{8.41} \right)^{1/2} = 626 \text{ Hz}$$

*The turbine has two different types of pedestals.

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Similarly the combined spring constant for the turbine pedestals is

$$K = \frac{29 \times 10^6 \times 26.88}{7.25} + \frac{2 \times 29 \times 10^6 \times 10.00}{7.25}$$

$$K = 107.52 \times 10^6 + 80 \times 10^6$$

$$K = 187.52 \times 10^6 \text{ lb/in}$$

and the natural frequency is

$$f = \frac{1}{2\pi}\left(\frac{187.52 \times 10^6}{10.21}\right)^{1/2} = 682 \text{ Hz}$$

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4.2.2 Vertical Frequencies - Motor Driven Unit

Tabulated below are the geometric and material properties for the pump and motor pedestals (refer to Figure 2 for the general arrangement).

	PUMP	MOTOR
E (psi)	29×10^6	29×10^6
A (in^2)	13.75	338.00
L (in)	17.25	1.75
M ($lb\text{-}sec^2/in$)	8.41	25.10

TABLE 3

The combined spring constant for pump pedestals is

$$K = \frac{4 \times 29 \times 10^6 \times 13.75}{17.25} = 92.46 \times 10^6 \text{ lb/in}$$

and the natural frequency is

$$f = \frac{1}{2\pi}\left(\frac{92.46 \times 10^6}{8.41}\right)^{\frac{1}{2}} = 528 \text{ Hz}$$

Similarly the combined spring constant for the motor pedestals is

$$K = \frac{2 \times 29 \times 10^6 \times 338.00}{1.75} = 11202.29 \times 10^6 \text{ lb/in}$$

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and the natural frequency is

$$f = \frac{1}{2\pi}\left(\frac{11202.29 \times 10^6}{25.10}\right)^{\frac{1}{2}} = 3362 \text{ Hz}$$

This large frequency is due to the fact that the motor pedestals are 1-3/4" thick plate whereas the other pedestals are hollow. Therefore, these motor pedestals would be expected to be very rigid.

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4.3 Computation Procedure - Horizontal Frequencies

The calculation of the horizontal frequencies is analogous to the vertical frequencies. The pedestals are assumed to be cantilevered beams and the deflection is given by

$$\delta = \frac{1}{3}\frac{Fl^3}{EI} \qquad (4)$$

Rearranging Eq. (3) the spring constant is defined as

$$K = \frac{F}{\delta} = \frac{3EI}{l^3} \qquad (5)$$

where I is the area moment of inertia (in^4).

4.3.1 Horizontal Frequencies - Turbine Driven Unit

Tabulated below are the geometric and material properties of the pump and turbine pedestals.

	PUMP	TURBINE	
E (psi)	29×10^6	29×10^6	29×10^6
I (in^4)*	123.65, 94.13	433.75, 1186.07	48.33, 35.83
l (in)	12.25	7.25	7.25
M ($lb\text{-}sec^2/in$)	8.41	10.21	

TABLE 4

*Since the pedestals have a rectangular cross-section there are two values for the area moment of inertia.

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The spring constants for the pump pedestals are

$$K = \frac{4 \times 3 \times 29 \times 10^6 \times 123.65}{(12.25)^3} = 23.41 \times 10^6 \text{ lb/in (x-direction)}$$

and

$$K = \frac{4 \times 3 \times 29 \times 10^6 \times 94.13}{(12.25)^3} = 17.82 \times 10^6 \text{ lb/in (z-direction)}$$

The natural frequencies are

$$f = \frac{1}{2\pi}\left(\frac{23.41 \times 10^6}{8.41}\right)^{\frac{1}{2}} = 266 \text{ Hz (x-direction)}$$

$$f = \frac{1}{2\pi}\left(\frac{17.82 \times 10^6}{8.41}\right)^{\frac{1}{2}} = 232 \text{ Hz (z-direction)}$$

Similarly the spring constants for the turbine pedestals are

$$K = \frac{3 \times 29 \times 10^6 \times 433.75}{(7.25)^3} + \frac{2 \times 3 \times 29 \times 10^6 \times 48.33}{(7.25)^3} =$$

$$K = 99.02 \times 10^6 + 22.07 \times 10^6 = 121.09 \times 10^6 \text{ lb/in (x-direction)}$$

and

$$K = \frac{3 \times 29 \times 10^6 \times 1186.07}{(7.25)^3} + \frac{2 \times 3 \times 29 \times 10^6 \times 35.83}{(7.25)^3} =$$

$$K = 270.78 \times 10^6 + 16.36 \times 10^6 = 287.14 \times 10^6 \text{ lb/in (z-direction)}$$

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The natural frequencies of the turbine pedestals are

$$f = \frac{1}{2\pi}\left(\frac{121.09 \times 10^6}{10.21}\right)^{\frac{1}{2}} = 548 \text{ Hz (x-direction)}$$

and

$$f = \frac{1}{2\pi}\left(\frac{287.14 \times 10^6}{10.21}\right)^{\frac{1}{2}} = 844 \text{ Hz (z-direction)}$$

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4.3.2 Horizontal Frequencies - Motor Driven Unit

Tabulated below are the geometric and material properties of the pump and motor pedestals

	PUMP	MOTOR
E (psi)	29×10^6	29×10^6
I (in^4)	123.65, 94.13	50279.26, 1802.67
l (in)	17.25	1.75
M ($lb\text{-}sec^2/in$)	8.41	25.10

TABLE 5

The spring constants for the pump pedestals are

$$K = \frac{4 \times 3 \times 29 \times 10^6 \times 123.65}{(17.25)^3} = 8.38 \times 10^6 \text{ lb/in (x-direction)}$$

and

$$K = \frac{4 \times 3 \times 29 \times 10^6 \times 94.13}{(17.25)^3} = 6.38 \times 10^6 \text{ lb/in (z-direction)}$$

The natural frequencies are

$$f = \frac{1}{2\pi}\left(\frac{8.38 \times 10^6}{8.41}\right)^{\frac{1}{2}} = 159 \text{ Hz (x-direction)}$$

and

$$f = \frac{1}{2\pi}\left(\frac{6.38 \times 10^6}{8.41}\right)^{\frac{1}{2}} = 139 \text{ Hz (z-direction)}$$

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Similarly the spring constants for the motor pedestals are

$$K = \frac{2 \times 3 \times 29 \times 10^6 \times 50279.26}{(1.75)^3} = 1632390.20 \times 10^6 \text{ lb/in (x-direction)}$$

and

$$K = \frac{2 \times 3 \times 29 \times 10^6 \times 1802.67}{(1.75)^3} = 58526.34 \times 10^6 \text{ lb/in (z-direction)}$$

and the natural frequencies are

$$f = \frac{1}{2\pi}\left(\frac{1632390.20 \times 10^6}{25.10}\right)^{1/2} = 40588 \text{ Hz (x-direction)}$$

and

$$f = \frac{1}{2\pi}\left(\frac{58526.34 \times 10^6}{25.10}\right)^{1/2} = 7685 \text{ Hz (z-direction)}$$

Again these high frequencies are due to the fact that these pedestals are 1-3/4" thick solid plate.

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4.4 Summary

All of the calculated frequencies are very high and well in excess of 30 Hz. Therefore, the accelerations will be taken from the zero period acceleration part of response spectrums Sketch No. S023-SK-S-986 Rev. A, S023-SK-S-987 Rev A, S023-SK-988 Rev. A, and S023-SK-989 Rev. A and are tabulated below.

	OBE	DBE
Horizontal (g's)	0.6	1.2
Vertical (g's)	0.7	1.3

TABLE 6

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5.0 CALCULATION OF STRESSES IN PUMP MOUNTING

5.1 Introduction

Shown in Figure 3 is a typical pump foot with a hold down bolt hole and a locating dowel hole. The maximum stresses of the pump mounting are found in the hold down bolts and dowels because their tensile and shear area is much less than the area of attachment between the foot and the case.

5.2 Computation Procedure

Since the dowels are located in tight fitting holes which permit vertical motion and the bolts are installed in clearance holes the shear forces are transmitted only to the dowels and tensile forces are transmitted only to the bolts. After determining the forces and moments on the pump we translate them from their point of application to the center of the bolting shear plane, which is the center of the rectangle formed by the hold down bolts. The vertical force and the moments about the horizontal axis contribute only to the tensile load. Similarily, the horizontal forces and the moment about the vertical axis contribute only to the shear load.

The vertical force, F_y, is divided equally between the bolts. The moments about the horizontal axis, M_x and M_y, are each assumed to be a couple consisting of two forces of equal

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magnitude and opposite direction. The sum of the three tensile forces acting at each bolt is evaluated and the largest is divided by the root area of the bolt to obtain the tensile stress.

The horizontal forces F_x and F_z are divided equally between the dowels. The moment about the vertical axis, M_y, is also assumed to be a couple. The forces comprising this couple are added vectorially to the other shear forces. The resultant forces are evaluated and the largest one is divided by the cross-sectional area of the dowel to obtain the shear stress.

5.3 Determination of Seismic Loads

In general the horizontal and vertical seismic forces are given by

$$Fh = \frac{W}{g} ah \qquad (6)$$

and

$$Fv = \frac{W}{g} av - W \qquad (7)$$

where
Fh = horizontal force
Fv = vertical force
W = component weight
g = acceleration due to gravity
ah = horizontal seismic acceleration
av = vertical seismic acceleration

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Using the accelerations given in Table 6 the seismic forces acting at the C.G. of the pump are

	OBE	DBE
Horizontal (lbs)	1950	3900
Vertical (lbs)	-975	975

TABLE 7

5.4 Seismic Stresses

The shear stress in the dowels and the tensile stress in the bolts were calculated using the previously outline methodology. The horizontal forces were taken in the direction that maximized the stresses. The results are tabulated in Table 8.

SEISMIC LOADS	BOLTS (Tensile) psi	DOWELS (Shear) psi
OBE	46	9558
DBE	1402	19116

TABLE 8

5.5 Nozzle Load Stresses

The shear stress in the dowels and the tensile stress in the bolts were calculated due to the nozzle loads for the operating, OBE and DBE condition. The methodology used in Section 5.4 is again used in this section with the results given in Table 9.

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NOZZLE LOADS	TURBINE DRIVEN PUMP		MOTOR DRIVEN UNIT	
	Tensile psi	Shear psi	Tensile psi	Shear psi
Operating	479	3685	133	1635
OBE	604	3541	546	1749
DBE	1209	7082	1092	3497

TABLE 9

5.6 Summary

The total stresses are obtained by combining Tables 8 and 9 and comparing with the stress criteria.

Examination of Table 10 shows that in all cases the calculated stress values are less than the stress criteria and therefore the hold down bolting and doweling are of sufficient strength.

	TURBINE DRIVEN UNIT			
	Tensile		Shear	
	Calculated Stress psi	Stress Criteria psi	Calculated Stress psi	Stress Criteria psi
OBE(5)	1129	25000(1)	16784	20000(2)
DBE	3090	94500(3)	29883	75600(4)

	MOTOR DRIVEN UNIT			
	Tensile		Shear	
	Calculated Stress psi	Stress Criteria psi	Calculated Stress psi	Stress Criteria psi
OBE(5)	725	25000	12942	20000
DBE	2627	94500	24248	75600

TABLE 10

See Page 20 for Footnotes

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FOOTNOTES - TABLE 10 (Page 19)

(1) Stress Criteria = allowable tensile stress

(2) Stress Criteria = 0.8 x allowable tensile stress

(3) Stress Criteria = 0.9 x yield stress

(4) Stress Criteria = 0.8 x 0.9 x yield stress

(5) The calculated stresses for the OBE and DBE includes the operating nozzle loads.

6.0 CALCULATION OF STRESSES IN THE FOUNDATION BOLTS

6.1 Introduction

In this section the stresses in the baseplate foundation bolts of the turbine and motor driven units are calculated. The computational procedure used previously in this report is used again in this section. The foundation bolt patterns are shown in Figures 1 and 2. The foundation bolts are one inch in diameter, have eight threads per inch with a root area of 0.551 in^2. The coordinate system is similar to that used in the previous section except that the origin is at the center of the rectangle formed by the foundation bolts.

6.2 Seismic Stress (Turbine Driven Unit)

Using the accelerations from Table 6 and Eqs. (6) and (7) the loads acting at the C.G. of the pump, turbine, baseplate system are:

	OBE	DBE
Horizontal (lbs)	6117	12234
Vertical (lbs)	-3059	3059

405-6-81-2 TABLE 11

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The loads and stresses were calculated using the previously outline procedure and were found to be:

	OBE		DBE	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
Tension	596	1081	2289	4154
Shear	766	1390	1532	2780

TABLE 12

6.3 Seismic Stresses (Motor Driven Unit)

Using the accelerations from Table 6 and Eqs. (6) and (7) the loads acting at the C.G. of the pump, motor, and baseplate system are:

	OBE	DBE
Horizontal (lbs)	10170	20340
Vertical (lbs)	-5085	5085

TABLE 13

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The loads and stresses were found to be

	OBE		DBE	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
Tension	1246	2262	4123	7483
Shear	1757	3188	3514	6377

TABLE 14

6.4 Nozzle Loads (Turbine Driven Unit)

In this section the foundation bolt stresses are calculated due to the normal operating, OBE and DBE nozzle loads acting on the pump and the turbine. Tabulated below in Tables 15 and 16 are the foundation bolt loads and stresses from the pump and turbine respectively.

Pump Nozzle Loads	TENSILE		SHEAR	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
Operating	313	568	356	646
OBE	137	248	220	398
DBE	274	497	439	797

TABLE 15

Turbine Nozzle Loads	TENSILE		SHEAR	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
Operating	15	27	91	165
OBE	11	20	30	55
DBE	20	36	63	114

TABLE 16

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6.5 Nozzle Loads (Motor Driven Unit)

This section contains the foundation bolt stresses for the motor driven unit due to the operating, OBE and DBE nozzle loads.

	TENSILE		SHEAR	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
Operating	126	230	139	252
OBE	-3	-6	52	95
DBE	-6	-12	105	191

TABLE 17

6.6 Summary

In this section the loads and stresses from the previous four sections are combined with the resulting loads and stresses given below in Table 18.

	TURBINE DRIVEN UNIT			
	Tensile		Shear	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
OBE	1072	1945	1463	2655
DBE	2911	5283	2481	4502

	MOTOR DRIVEN UNIT			
	Tensile		Shear	
	Load (lbs)	Stress (psi)	Load (lbs)	Stress (psi)
OBE	1369	2485	1948	3535
DBE	4243	7701	3758	6820

TABLE 18

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It should be noted that the loads and stresses from the normal operating conditions are included in the total stresses given in Table 18. Although the foundation bolts are beyond the scope of Byron Jackson's supply, these loads and stresses are low and should be well within the capability of standard foundation bolt material.

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7.0 SHAFT DEFLECTION ANALYSIS

The rotor displacement due to seismic loading under DBE conditions is calculated and compared to the allowable rotor clearance. The pump shaft has been sag-bored to allow for shaft deflection due to dead weight.

The shaft is modeled as a beam with pinned supports at the two end bearings and with a spring support at the center stage piece. The shaft model is shown in Fig. 4. The reactions at the pinned supports and deflections on the shaft are determined by the program MULTISPAN. (Reference 5) The output is shown on pages 26 and 27.

The deflection of the spring support at the center stage piece is calculated by using the spring constant,

$$K = 1.32\ (10^5)\ \text{lbs./in.}$$

obtained by the Byron Jackson computer program Lomakin *. The output is shown on page 28. The reaction force at the center stage piece from the MULTISPAN run is,

$$F_R = 296\ \text{lbs.}$$

The deflection at this point is,

$$S = \frac{FR}{K} = .00224\ \text{in.}$$

The deflection of the spring is added to the deflections of the shaft determined by MULTISPAN. This is a conservative assumption since the deflection will not exceed the valve determined but can be less.

Max. deflection = .00261, minimum rotor clearance = .006

The resulting maximum shaft deflection is less than the minimum rotor clearance.

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**** MULTISPAN VERS. 1.2 ****

PERFORMS THE BENDING ANALYSIS OF MULTI-SPAN BEAMS

- O U T P U T -

* * * * * * * * * * * * * * *

*** INPUT DATA SUMMARY ***

- GEOMETRY -

LEFT END = PINNED
RIGHT END = PINNED

SPAN NUMBER	FROM X-STATION (IN)	TO X-STATION (IN)
1	0.	3.540E+01
2	3.540E+01	7.160E+01

X-STATION (IN)	E (PSI)	I (IN**4)
7.160E+01	2.900E+07	5.070E+00

- CONCENTRATED LOADS -

X-STATION (IN)	MAGNITUDE (LBS)
1.620E+01	4.100E+01
2.370E+01	2.050E+01
2.820E+01	2.050E+01
3.270E+01	2.050E+01
3.820E+01	2.750E+01
4.270E+01	2.050E+01
4.720E+01	2.050E+01
5.170E+01	2.050E+01

- DISTRIBUTED LOADS -

START X-STATION (IN)	START MAGNITUDE (LBS/IN)	END X-STATION (IN)	END MAGNITUDE (LBS/IN)
0.	2.960E+00	7.160E+01	2.960E+00

*** REACTIONS ***

X-STATION (IN)	VERTICAL REACTION (LBS)	INTERNAL MOMENT (IN-LBS)
0.	-5.954E+01	0.
3.540E+01	-2.951E+02	9.768E+02
7.160E+01	-4.877E+01	0.

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*** INTERNAL FORCES AND DISPLACEMENTS ***

X-STATION (IN)	SHEAR (LBS)	MOMENT (IN-LBS)	ROTATION (RAD)	Y-DISPL (IN)
- SPAN NUMBER 1 -				
0.	-5.954E+01	0.	3.677E-05	0.
2.500E+00	-5.214E+01	-1.396E+02	3.556E-05	9.090E-05
5.000E+00	-4.474E+01	-2.607E+02	3.213E-05	1.759E-04
7.500E+00	-3.734E+01	-3.633E+02	2.680E-05	2.500E-04
1.000E+01	-2.994E+01	-4.474E+02	1.988E-05	3.086E-04
1.250E+01	-2.254E+01	-5.131E+02	1.168E-05	3.483E-04
1.500E+01	-1.514E+01	-5.602E+02	2.534E-06	3.662E-04
1.620E+01	-1.159E+01	-5.762E+02	-2.106E-06	3.665E-04
1.620E+01	2.941E+01	-5.762E+02	-2.106E-06	3.665E-04
1.750E+01	3.326E+01	-5.355E+02	-7.024E-06	3.605E-04
2.000E+01	4.066E+01	-4.431E+02	-1.537E-05	3.322E-04
2.250E+01	4.806E+01	-3.322E+02	-2.199E-05	2.851E-04
2.370E+01	5.161E+01	-2.724E+02	-2.446E-05	2.572E-04
2.370E+01	7.211E+01	-2.724E+02	-2.446E-05	2.572E-04
2.500E+01	7.596E+01	-1.762E+02	-2.644E-05	2.240E-04
2.750E+01	8.336E+01	2.298E+01	-2.777E-05	1.555E-04
2.820E+01	8.543E+01	8.205E+01	-2.752E-05	1.362E-04
2.820E+01	1.059E+02	8.205E+01	-2.752E-05	1.362E-04
3.000E+01	1.113E+02	2.775E+02	-2.533E-05	8.824E-05
3.250E+01	1.187E+02	5.649E+02	-1.820E-05	3.282E-05
3.270E+01	1.192E+02	5.887E+02	-1.741E-05	2.925E-05
3.270E+01	1.397E+02	5.887E+02	-1.741E-05	2.925E-05
3.500E+01	1.466E+02	9.179E+02	-5.648E-06	1.749E-06
3.540E+01	1.477E+02	9.768E+02	-3.070E-06	1.388E-17
- SPAN NUMBER 2 -				
3.540E+01	-1.474E+02	9.768E+02	-3.070E-06	1.388E-17
3.750E+01	-1.412E+02	6.738E+02	8.702E-06	6.670E-06
3.820E+01	-1.391E+02	5.757E+02	1.168E-05	1.383E-05
3.820E+01	-1.116E+02	5.757E+02	1.168E-05	1.383E-05
4.000E+01	-1.063E+02	3.796E+02	1.751E-05	4.046E-05
4.250E+01	-9.887E+01	1.232E+02	2.176E-05	9.047E-05
4.270E+01	-9.828E+01	1.035E+02	2.192E-05	9.483E-05
4.270E+01	-7.778E+01	1.035E+02	2.192E-05	9.483E-05
4.500E+01	-7.097E+01	-6.755E+01	2.218E-05	1.461E-04
4.720E+01	-6.446E+01	-2.165E+02	2.004E-05	1.929E-04
4.720E+01	-4.396E+01	-2.165E+02	2.004E-05	1.929E-04
4.750E+01	-4.307E+01	-2.296E+02	1.958E-05	1.988E-04
5.000E+01	-3.567E+01	-3.280E+02	1.481E-05	2.422E-04
5.170E+01	-3.064E+01	-3.844E+02	1.069E-05	2.640E-04
5.170E+01	-1.014E+01	-3.844E+02	1.069E-05	2.640E-04
5.250E+01	-7.770E+00	-3.915E+02	8.575E-06	2.717E-04
5.500E+01	-3.695E-01	-4.017E+02	1.806E-06	2.847E-04
5.750E+01	7.030E+00	-3.934E+02	-4.980E-06	2.807E-04
6.000E+01	1.443E+01	-3.665E+02	-1.147E-05	2.600E-04
6.250E+01	2.183E+01	-3.212E+02	-1.734E-05	2.239E-04
6.500E+01	2.923E+01	-2.574E+02	-2.229E-05	1.741E-04
6.750E+01	3.663E+01	-1.751E+02	-2.599E-05	1.135E-04
7.000E+01	4.403E+01	-7.424E+01	-2.813E-05	4.545E-05
7.160E+01	4.877E+01	0.	-2.854E-05	-1.249E-16

PROGRAM LOMAKIN *

RELEASE 1.0

```
DETAILS?   (YES=1, NO=0)
?0

ENTER JOB IDENTIFICATION. (2 LINES, 50 CHAR/LINE)
?SAN ONOFRE
?CENTER STAGE PIECE

ENTER  B , L , D , P , Q , R , T .
?.006,3.56,4.75,611,5.18,.00224,100


REYNOLDS NUMBER = 0.252E+04

USING WELDONS CHART OF REYNOLDS NUMBER VS. FRICTION COEFFICIENT,
ENTER FC. (PLAIN OR GROOVED SLEEVE WITH OR OPPOSITE TO FLUID FLOW).
?.062
```

SAN ONOFRE
CENTER STAGE PIECE

INPUT VARIABLES

```
RADIAL CLEARANCE ......=     0.006 IN
BUSHING LENGTH ........=     3.560 IN
BUSHING DIAMETER ......=     4.750 IN
PRESSURE DROP .........=   611.000 PSI
FLUID LEAKAGE .........=     5.180 GPM
ROTOR RADIAL DISPL ....=     0.002 IN
TEMPERATURE (WATER) ...=   100.000 DEGF
KINEMATIC VISCOSITY ...= 0.737E-05 FT-SQ/SEC
FRICTION COEFFICIENT ..=     0.062
```

RESULTS

```
LABYRINTH RATIO(MU) ...=     0.227
ECCENTRICITY RATIO(EP).=     0.373
FLUID VELOCITY ........=   222.655 IN/SEC
REYNOLDS NUMBER .......= 0.252E+04
FORCE .................= 0.296E+03 LB
BEARING STIFFNESS .....= 0.132E+06 LB/IN
```

405-6-81-2

8.0 REFERENCES

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2. ASME Boiler and Pressure Vessel Code, Section III, 1974 Edition including Winter 1974 Addenda.

3. Den Hartog, J.P., Mechanical Vibrations, McGraw-Hill Book Company, Inc., (1940).

4. DeLaval Engineering Handbook, Third Edition, Edited by H. Gartman, McGraw-Hill Book Company (1970).

5. Program Multispan, Strupak Instruction Guides, TRW Systems Group, Redondo Beach, California, 90278.

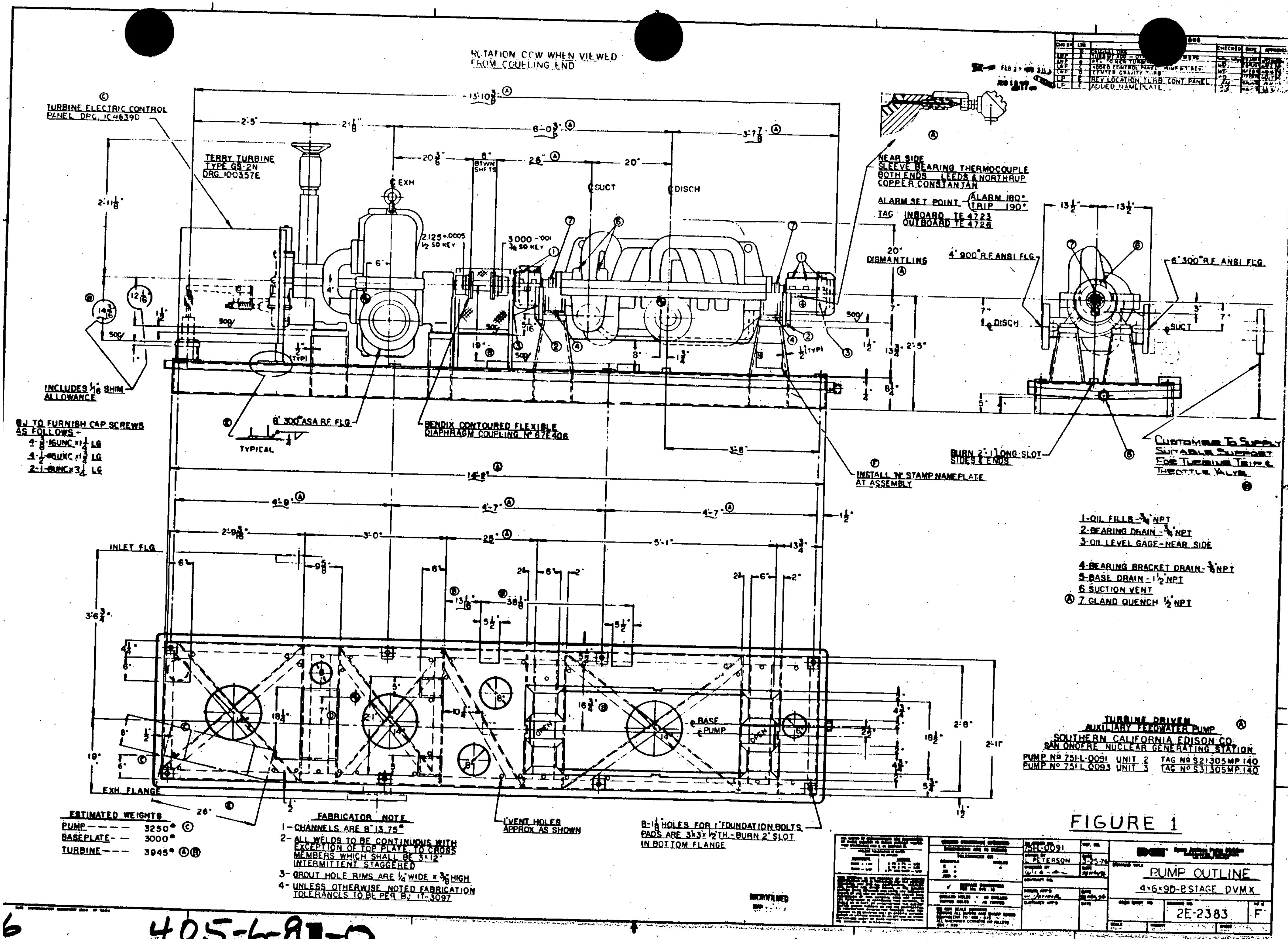
405-6-81-2

2U

FIGURES

405-6-81-9

25



ROTATION CCW WHEN VIEWED FROM COUPLING END
TURBINE ELECTRIC CONTROL PANEL DPG. 1C46390
TERRY TURBINE TYPE GS-2N DRG 100357E
NEAR SIDE SLEEVE BEARING THERMOCOUPLE BOTH ENDS LEEDS & NORTHRUP COPPER CONSTANTAN
ALARM SET POINT - ALARM 180° TRIP 190°
TAG INBOARD TE 4723 OUTBOARD TE 4726
20" DISMANTLING
4" 900# R.F. ANSI FLG
6" 300# R.F. ANSI FLG
℄ EXH
℄ SUCT
℄ DISCH
INCLUDES 1/16 SHIM ALLOWANCE
BJ TO FURNISH CAP SCREWS AS FOLLOWS -
8" 300 ASA RF FLG
BENDIX CONTOURED FLEXIBLE DIAPHRAGM COUPLING Nº 67E406
TYPICAL
BURN 2"-1 LONG SLOT SIDES & ENDS
INSTALL 'N' STAMP NAMEPLATE AT ASSEMBLY
CUSTOMER TO SUPPLY SUITABLE SUPPORT FOR TURBINE TRIP & THROTTLE VALVE
1-OIL FILLS-3/4" NPT
2-BEARING DRAIN-3/4" NPT
3-OIL LEVEL GAGE-NEAR SIDE
4-BEARING BRACKET DRAIN-3/4" NPT
5-BASE DRAIN-1 1/2" NPT
6 SUCTION VENT
7 GLAND QUENCH 1/2" NPT
INLET FLG
EXH. FLANGE
℄ BASE
℄ PUMP
OPEN
TURBINE DRIVEN AUXILIARY FEEDWATER PUMP
SOUTHERN CALIFORNIA EDISON CO.
SAN ONOFRE NUCLEAR GENERATING STATION
PUMP Nº 751-L-0091 UNIT 2 TAG Nº S21305MP140
PUMP Nº 751-L-0093 UNIT 3 TAG Nº S31305MP140
ESTIMATED WEIGHTS
PUMP ---- 3250#
BASEPLATE --- 3000#
TURBINE --- 3945#
FABRICATOR NOTE
1- CHANNELS ARE 8" 13.75#
2- ALL WELDS TO BE CONTINUOUS WITH EXCEPTION OF TOP PLATE TO CROSS MEMBERS WHICH SHALL BE 3"-12" INTERMITTENT STAGGERED
3- GROUT HOLE RIMS ARE 1/4 WIDE x 3/8 HIGH
4- UNLESS OTHERWISE NOTED FABRICATION TOLERANCES TO BE PER BJ IT-3097
VENT HOLES APPROX AS SHOWN
8-1 1/8 HOLES FOR 1" FOUNDATION BOLTS PADS ARE 3x3x1/2 TH.-BURN 2" SLOT IN BOTTOM FLANGE
MICROFILMED
FIGURE 1
L. PETERSON
PUMP OUTLINE
4x6x9D-8STAGE DVMX
2E-2383
F

405-681-0

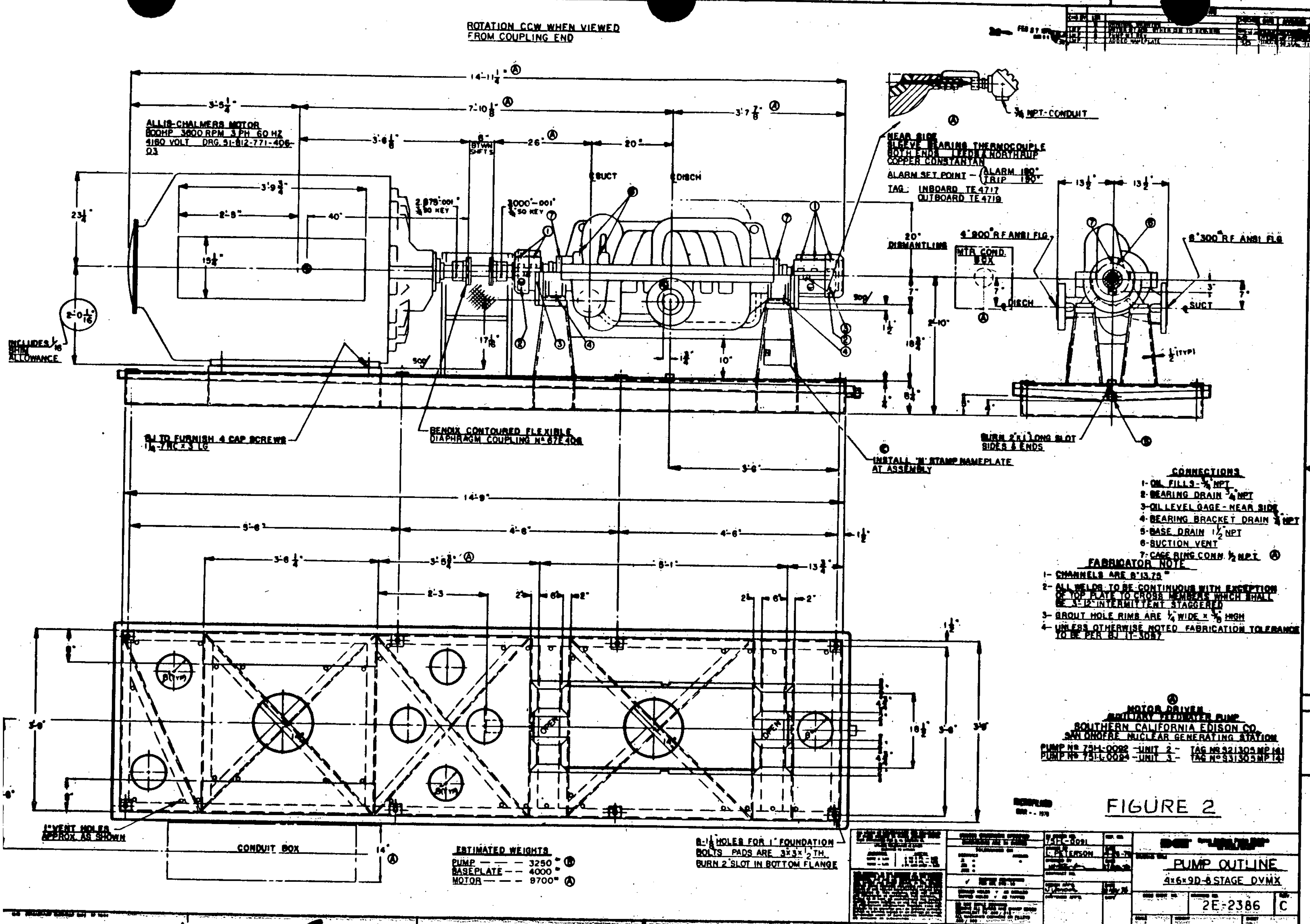


FIGURE 2

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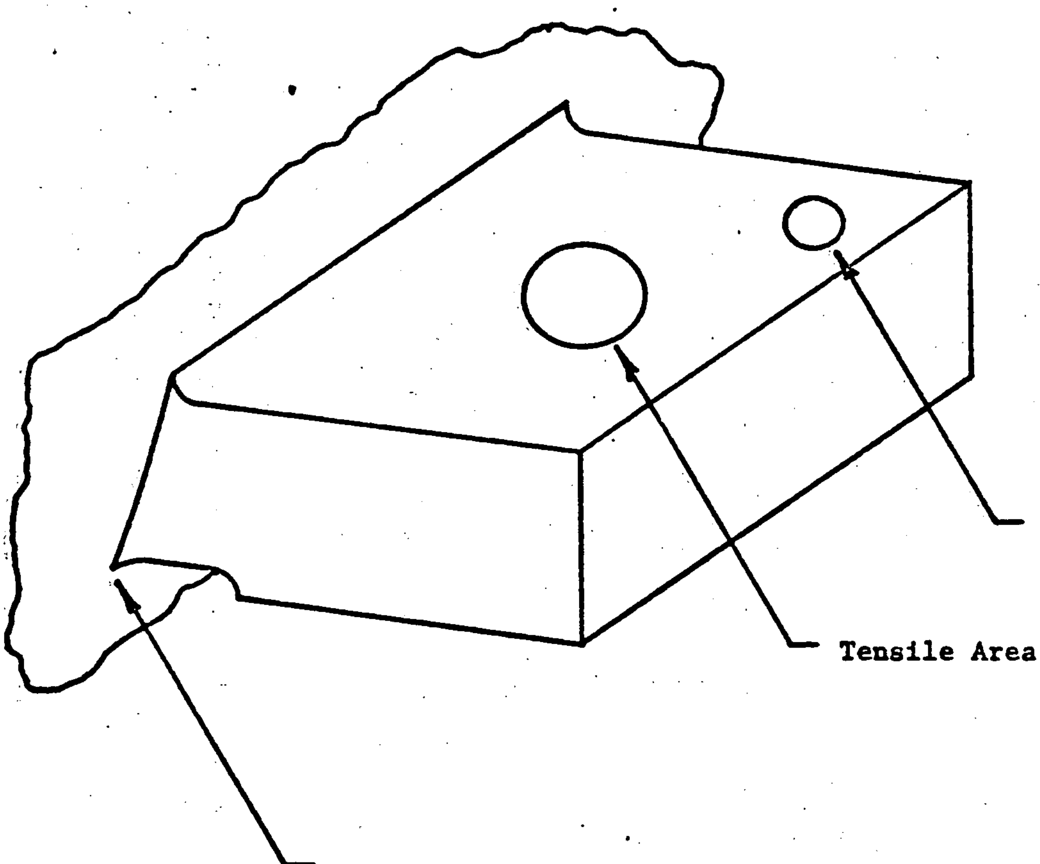
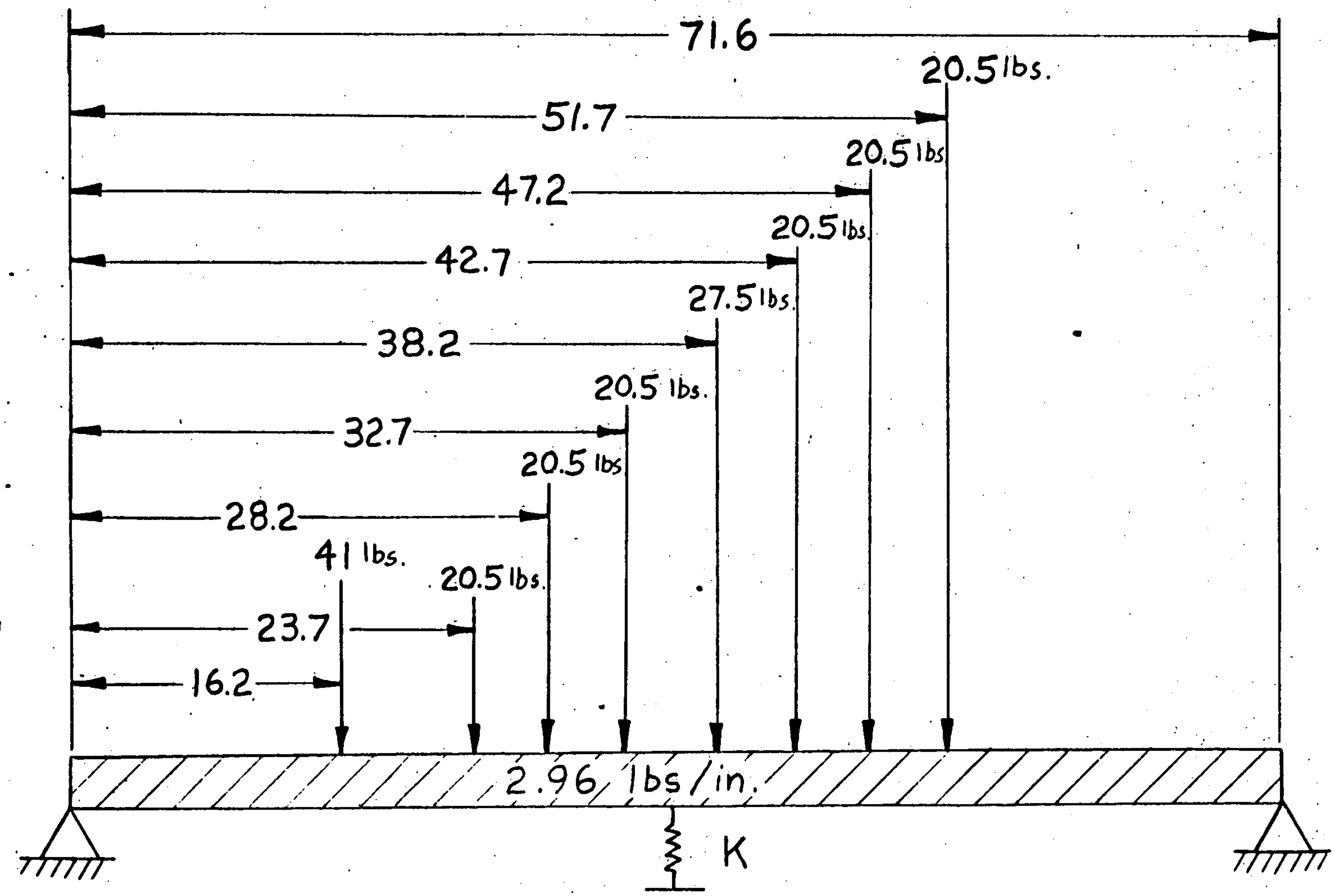


FIGURE 3 TYPICAL PUMP FOOT

405-6-8II-2



SHAFT MODEL

FIGURE 4

ADDENDUM I TO DC-1102

BECHTEL NOZZLE LOADS

405-6-81-2

WD

AUXILIARY FEEDWATER PUMP P-141 UNIT 2
MOTOR DRIVEN
6" Ø SUCTION

	THERMAL EXPANSION	WEIGHT (PIPE, FLUID & INSULATION)	OPERATING BASIS EARTHQUAKE O.B.E.	DESIGN BASIS EARTHQUAKE D.B.E.
F_X	+ 558	- 14	± 42	± 84
F_Y	+ 117	- 235	± 29	± 58
F_Z	- 200	+ 11	± 25	± 50
M_X	- 180	+ 358	± 205	± 410
M_Y	+ 1053	- 39	± 41	± 82
M_Z	+ 287	+ 46	± 67	± 134

4" Ø Discharge

	THERMAL EXPANSION	WEIGHT (PIPE, FLUID & INSULATION)	OPERATING BASIS EARTHQUAKE O.B.E.	DESIGN BASIS EARTHQUAKE D.B.E.
F_X	+ 499	+ 22	± 135	± 270
F_Y	+ 66	- 108	± 127	± 254
F_Z	+ 35	- 7	± 175	± 350
M_X	+ 80	- 100	± 246	± 492
M_Y	- 792	- 16	± 163	± 326
M_Z	- 13	+ 11	± 115	± 230

405-6-81-2

AUXILIARY FEEDWATER PUMP P-140 UNIT 2
TURBINE DRIVEN
6" Ø SUCTION

	THERMAL EXPANSION	WEIGHT (PIPE, FLUID & INSULATION)	OPERATING BASIS EARTHQUAKE O.B.E.	DESIGN BASIS EARTHQUAKE D.B.E.
F_X	+ 690	0	± 89	± 178
F_Y	+ 13	+20	± 97	± 194
F_Z	− 196	0	± 138	± 276
M_X	-13	-175	± 124	± 248
M_Y	+ 1327	0	± 110	± 220
M_Z	+ 49	-11	± 115	± 230

4"Ø DISCHARGE

	THERMAL EXPANSION	WEIGHT (PIPE, FLUID & INSULATION)	OPERATING BASIS EARTHQUAKE O.B.E.	DESIGN BASIS EARTHQUAKE D.B.E.
F_X	+ 964	+ 29	± 412	± 824
F_Y	-76	-125	± 87	± 174
F_Z	-170	-11	± 166	± 332
M_X	-143	-131	± 378	± 756
M_Y	-1148	-28	± 459	± 918
M_Z	+ 22	+ 18	± 154	± 308

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AUXILIARY FEEDWATER TURBINE

8" Outlet Nozzle *

	THERMAL EXPANSION	WEIGHT (PIPE, FLUID & INSULATION)	OPERATING BASIS EARTHQUAKE O.B.E	DESIGN BASIS EARTHQUAKE D.B.E.
F_X	180	0	± 25	± 40
F_Y	-5	-33	± 25	± 40
F_Z	30	0	± 25	± 40
M_X	10	0	0	0
M_Y	-53	0	0	0
M_Z	0	0	0	0

4" Inlet Nozzle

F_X	-141	-6	± 37	± 74
F_Y	32	-55	± 104	± 208
F_Z	- 12	0	± 82	± 164
M_X	- 16	82	± 159	± 308
M_Y	-101	- 5	± 44	± 88
M_Z	244	5	± 24	± 48

* There is an additional 100 lbs. of thrust due to an untied expansion joint in the F_Z direction.

405-6-81-2

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