ME-146

SEISMIC STRESS ANALYSIS REPORT

RHRSW PUMPS

DETROIT EDISON COMPANY

Enrico Fermi Plant

P.O. IE-92034

GOULDS PUMPS

Vertical Pump Division
Order # N301213

Analysis By

McDonald Engineering - Analysis Company

Birmingham, Alabama

Certification Statement

The RHRSW pumps covered by this report have been analyzed in accordance with Detroit Edison Specification 3071-25 and applicable industry codes. The pump meets all requirements for both Operating Basis and Design Basis Earthquakes.

Claudie K. McDonald

Claudie K. McDonald, Ph. D.

January 28, 1974

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1. SUMMARY OF RESULTS

A summary of the OBE stresses and allowable stresses for the pump are given below. The DBE stresses are not given because the OBE was the governing load in all cases.

	Actual	Allowable
Impeller Clearance	.0003"	.015"
Max. Column Stress		
Longitudinal	7,997	15,000
Circumferential	1,975	15,000
Support Bolting	4,567	25,000
Anchor Bolts		
Shear	7,307	10,000
Tensile	14,693	20,000
Column Flanges and Bolting		
Bolting (primary membrane)	9,741	25,000
Radial Flange Stress	10,827	12,600
Tangential Flange Stress	5,388	12,600
Bolting(Stress Due To Primary Bending)	31,095	37,500
Motor Bolting	1,205	10,000
Max. Shaft Combined Stress	13,889	15,000
Max. Coupling Combined Stress	13,894	15,000
Max. Shaft Deflection (in./foot)	.0067	.01

The OBE allowable stresses are from the ASME Code except for the shaft and coupling which are not covered by the Code and the stresses due to primary bending. The shaft and coupling allowable was established to be in general accord with the Code and the primary bending stresses are per the AEC Regulatory Guide 1.48.

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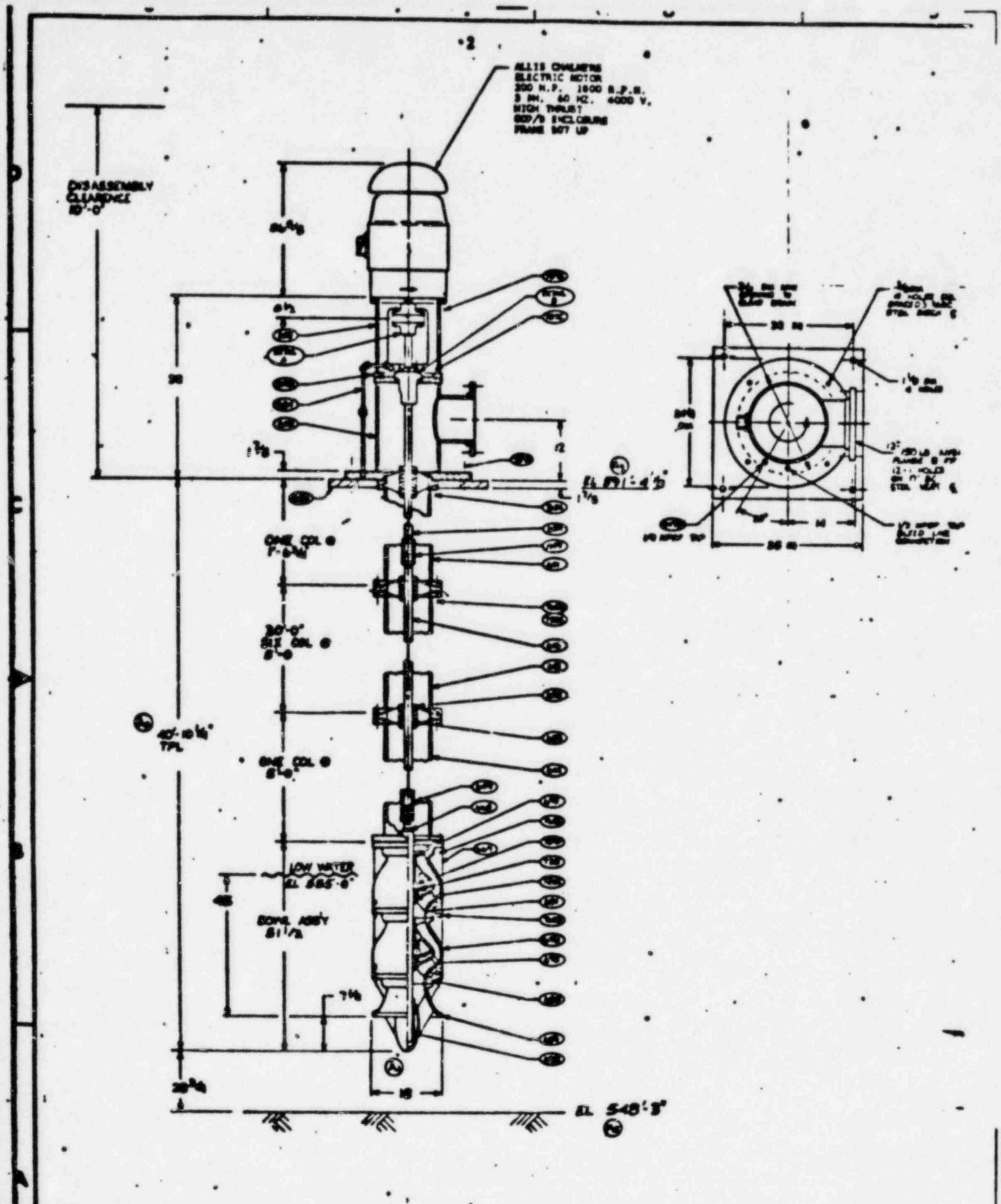

Figure 1 - Pump Outline Drawing

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2. SEISMIC ANALYSIS

A multidegree of freedom modal analysis is made using the computer program ICES-STRUDL developed at the Massachusetts Institute of Technology. Detailed data on the program, including users manuals, can be obtained from M. I. T. at very modest cost. The program is a general purpose type program and various segments are still under development and have not been checked out adequately. However, the parts of the program used for this analysis have been well checked out against hand solutions and classical results. These verification checks will be made available upon request(see Reference 1 in Appendix A).

2.1 Lateral Seismic Analysis

The computer model for the lateral analysis is shown in Figure 2. The joints and members are numbered to facilitate the computer input. Joint numbers are enclosed in circles. Masses are lumped at the flanges and the motor center of gravity. The results of the analysis show that this is an adequate number of mass points. The impeller masses are shown separately so that the impeller clearance can be easily checked.

The lateral analysis was made for both the high water level case and the low water level case. The detailed input data are included on pages 5 - 10. The input data are obtained from the model and pump detailed drawings. Interpretation of the data should be self explanatory in most cases but detailed comments will be made as follows.

Input for the high water level case is given first. The joint coordinates

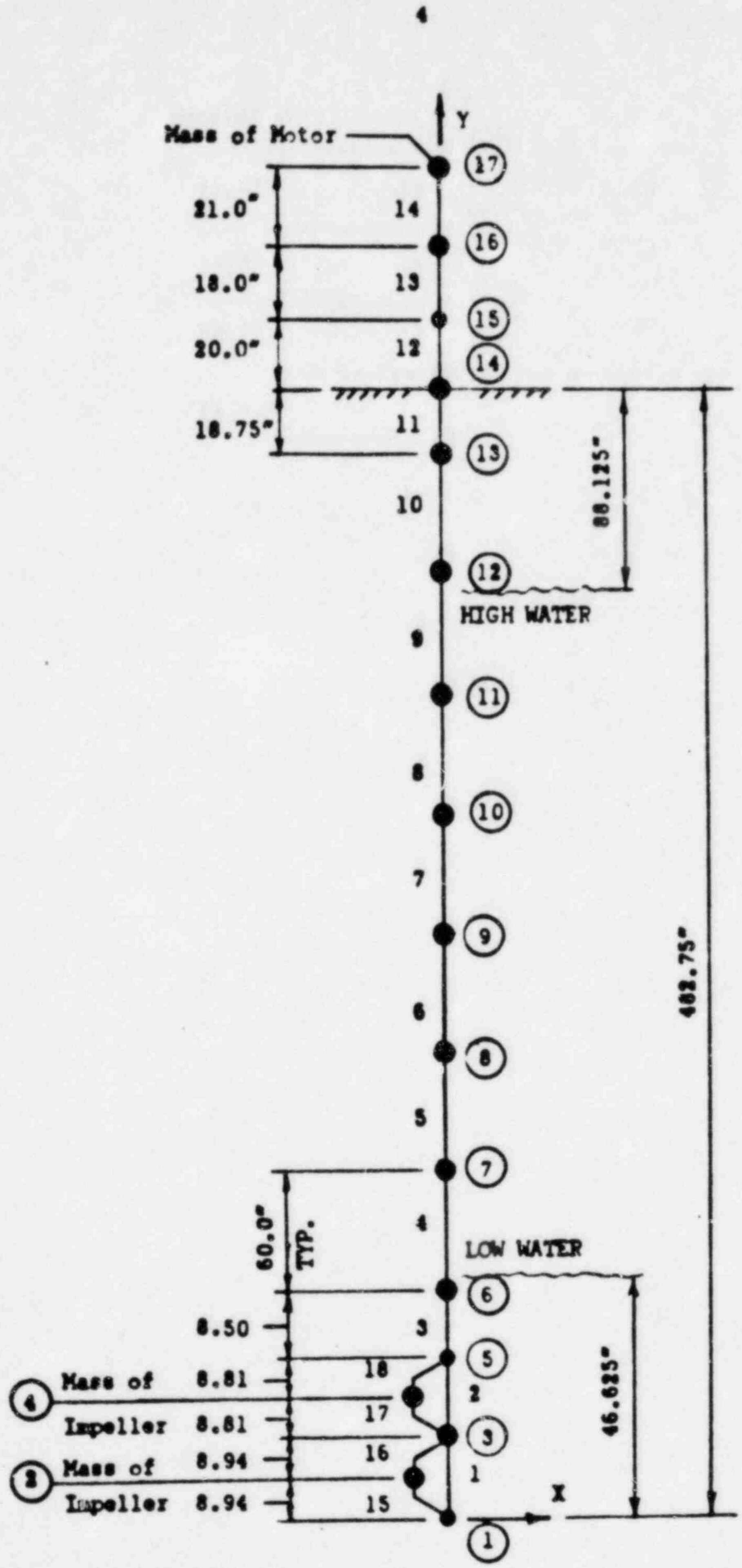

Figure 2 Dynamic Model for Lateral Analysis

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STRUDL '10P2' 'CONLOS RHRSW PUMP FOR DETROIT EDISON - HIGH WATER CONDITION'

            ************************************************
            *                                              *
            *              ICES STRUDL-II                  *
            *       THE STRUCTURAL DESIGN LANGUAGE         *
            *                                              *
            *    CIVIL ENGINEERING SYSTEMS LABORATORY      *
            *   MASSACHUSETTS INSTITUTE OF TECHNOLOGY      *
            *        CAMBRIDGE, MASSACHUSETTS              *
            *        V2 M2           JUNE, 1972            *
            *        16137125         1/25/74              *
            *                                              *
            ************************************************

TYPE PLANE FRAME
UNITS INCHES POUNDS
JOINT COORDINATES
 1    0.0     0.0
 2    0.0     8.94
 3    0.0    17.88
 4    0.0    26.69
 5    0.0    35.5
 6    0.0    44.0
 7    0.0   104.0
 8    0.0   164.0
 9    0.0   224.0
10    0.0   284.0
11    0.0   344.0
12    0.0   404.0
13    0.0   464.0
14    0.0   482.75        S
15    0.0   502.75
16    0.0   520.75
17    0.0   541.75
MEMBER INCIDENCES
 1    1    3
 2    3    5
```

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```
3 5 6
4 6 7
5 7 8
6 8 9
7 9 10
8 10 11
9 11 12
10 12 13
11 13 14
12 14 15
13 15 16
14 16 17
15 1 2
16 2 3
17 3 4
18 4 5
CONSTANTS
E 29000000. ALL
MEMBER PROPERTIES
1 PRIS AX 22.7 IZ 999.3
2 PRIS AX 22.7 IZ 999.3
3 PRIS AX 22.7 IZ 999.3
4 TO 11 PRIS AX 9.69 IZ 105.67
12 PRIS AX 16.05 IZ 373.
13 VARIABLE
SEGMENT 1 AX 16.05 AY 16.05 I' 373. L 2.5
SEGMENT 2  AX 14.64  IZ 56.412  L  39.5
SEGMENT 3 AX 16.05 AY 16.05 IZ 373. L 2.
14 PRIS AX 9.42 IZ 92.69
15 TO 16 PRIS AX 5.41 IZ 2.33
DYNAMIC DEGREES OF FREEDOM
JOINTS 1 TO 4 6 TO 14 16 17 DISP X
INERTIA OF JOINT 1       LINEAR ALL 2.021
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INERTIA OF JOINT 2 4      LINEAR ALL .291
INERTIA OF JOINT 3        LINEAR ALL 5.6429
INERTIA OF JOINT 6        LINEAR ALL 4.0910
INERTIA OF JOINT 7 TO 11 LINEAR ALL 2.5647
INERTIA OF JOINT 12       LINEAR ALL 2.0947
INERTIA OF JOINT 13       LINEAR ALL 1.3466
INERTIA OF JOINT 14       LINEAR ALL 3.4230
INERTIA OF JOINT 16       LINEAR ALL .5052
INERTIA OF JOINT 17       LINEAR ALL 9.3264
DUMP ORTHOGONALITY
DAMPING .02  15
UNITS CYCLES
STORE RESPONSE SPECTRA ACCELERATION VS FREQUENCY 'OBE'
DAMPING .02  FACTOR 386.
.05  .1
.05  .5147   .32  4.3545  1.43  6.2280  .26  13.253  .16  26.981
.16  45.249  .16  66.901
DYNAMIC LOADING 1  'OPERATING BASIS EARTHQUAKE'
SUPPORT ACCELERATION
DISP X FILE 'OBE'
DYNAMIC ANALYSIS MODAL
IHC210I PROGRAM INTERRUPT(P) OLD PSW IS    FF9500074006A07E
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STRUDL [illegible] ANNULUS [illegible] PUMP FOR DETROIT EDISON [illegible] WATER CONDITIONS

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****************************************************
*                                                  *
*               ICES STRUDL-II                     *
*       THE STRUCTURAL DESIGN LANGUAGE             *
*                                                  *
*   CIVIL ENGINEERING SYSTEMS LABORATORY           *
*   MASSACHUSETTS INSTITUTE OF TECHNOLOGY          *
*      CAMBRIDGE, MASSACHUSETTS                    *
*      V2 M2        JUNE, 1972                     *
*      13:39:40       1/25/74                      *
*                                                  *
****************************************************
```

TYPE PLANE FRAME

UNITS INCHES POUNDS

JOINT COORDINATES

1	0.0	0.0
2	0.0	8.94
3	0.0	17.88
4	0.0	26.69
5	0.0	35.5
6	0.0	44.0
7	0.0	104.0
8	0.0	164.0
9	0.0	224.0
10	0.0	284.0
11	0.0	344.0
12	0.0	404.0
13	0.0	464.0
14	0.0	482.75 S
15	0.0	502.75
16	0.0	520.75
17	0.0	541.75

MEMBER INCIDENCES

1	1	3
2	3	5

```
3  5  6
4  6  7
5  7  8
6  8  9
7  9  10
8  10 11
9  11 12
10 12 13
11 13 14
12 14 15
13 15 16
14 16 17
15 1  2
16 2  3
17 3  4
18 4  5
CONSTANTS
E 29000000. ALL
MEMBER PROPERTIES
1 PRIS AX 22.7 IZ 599.3
2 PRIS AX 22.7 IZ 599.3
3 PRIS AX 22.7 IZ 599.3
4 TO 11 PRIS AX 9.69 IZ 105.67
12 PRIS AX 16.05 IZ 373.
13 VARIABLE
SEGMENT 1 AX 16.05 AY 16.05 IZ 373. L 2.5
SEGMENT 2  AX 14.64  IZ 56.612  L  13.5
SEGMENT 3 AX 16.05 AY 16.05 IZ 373. L 2.
14 PRIS AX 9.42 IZ 52.69
15 TO 18 PRIS AX 5.41 IZ 2.33
DYNAMIC DEGREES OF FREEDOM
JOINTS 1 TO 4 6 TO 14 16 17 DISP X
INERTIA OF JOINT 1       LINEAR ALL 2.021
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```
INERTIA OF JOINT 2 4      LINEAR ALL .241
INERTIA OF JOINT 3        LINEAR ALL 5.6425
INERTIA OF JOINT 6 LINEAR ALL 3.6943
INERTIA OF JOINTS 7 TO 12 LINEAR ALL 1.8404
INERTIA OF JOINT 13       LINEAR ALL 1.3466
INERTIA OF JOINT 14       LINEAR ALL 3.4230
INERTIA OF JOINT 16       LINEAR ALL .5052
INERTIA OF JOINT 17       LINEAR ALL 9.3764
DUMP ORTHOGONALITY .
DYNAMIC ANALYSIS EIGENVALUE
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are obtained from the model and are entered in order X, Y. The member incidences are self explanatory. The area properties are for the simple beam type members except for the exceptions given as follows. The motor is modeled as an equivalent beam the properties of which are obtained from the motor reed frequency furnished by the manufacturer. The motor mount is modeled as a variable cross section beam to account for the holes cut out for access. The moment of inertia of the reduced section was obtained by assuming that the two pipe sectors act independently when the load is applied. This gives a lower moment of inertia than if the two sectors were assumed to bend as one beam. The preliminary analysis showed that the section at the cutouts was inadequate and stiffeners were added prior to the final analysis.

The pump lower bowl assembly is of complex cross sectional geometry. An equivalent beam was obtained to model the bowl assembly.

The lump masses include the water internal to the pump and also external water for the submerged portion of the pump. Both the high water level and low water level was checked to determine which was the worst case. The high water level case was the worst, thus only the frequencies for the low water case are included for reference only.

An inspection of the response spectra for the lateral case showed that the East-West earthquake gave the highest loads for this pump. The OBE also governs the design since the DBE seismic loads are only slightly higher than the OBE loads.

The output sheets for the computer analysis follow.

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ORTHOGONALITY WITH RESPECT TO MASS

ROW 1	0.100000000 01	-0.118637000-12	-0.459876970-14	-0.499066050-25	-0.230050140-16	-0.374154700-15
	-0.119360490-15	0.626465370-16	0.183131910-15	0.532127250-24	-0.324710550-15	0.519706640-15
	-0.289492380-16	0.309285590-15				
ROW 2	-0.118626540-12	0.100000000 01	0.453373030-14	0.352512390-26	0.158055270-14	0.329651670-15
	0.567574840-16	-0.242366500-15	0.725331250-16	-0.243331170-24	0.107552060-15	0.153031750-15
	0.120378800-15	0.139097710-15				
ROW 3	-0.459463330-14	0.454673390-14	0.100000000 01	0.656639610-23	-0.480301560-16	0.127556390-15
	0.975781960-17	-0.479759460-16	0.386518070-16	-0.474077480-24	0.302709250-15	0.182552540-15
	0.102638800-15	0.704264300-16				
ROW 4	-0.495066050-25	0.352512390-26	0.656639610-23	0.100000000 01	0.232617060-24	-0.879292920-27
	-0.480004470-24	0.252700280-24	0.473050930-24	0.416333630-16	0.207283490-24	-0.473775320-24
	0.162086600-24	0.398224540-24				
ROW 5	-0.110619500-16	0.157816130-14	-0.480301560-16	0.232617060-24	0.100000000 01	-0.382723370-15
	0.252402270-15	0.975781760-17	-0.181224390-15	-0.528697160-24	0.286229370-15	0.251331620-16
	0.240730160-15	0.633473840-16				
ROW 6	-0.375472470-15	0.329651670-15	0.113570180-15	-0.879292920-27	-0.368628740-15	0.100000000 01
	0.350414140-15	0.133573710-15	-0.177580770-15	-0.207627000-24	-0.563785130-16	0.717536910-16
	0.298020200-15	-0.775068230-16				
ROW 7	-0.119353720-15	0.573600690-16	0.992044990-17	-0.480004470-24	0.286009000-15	0.350414140-15
	0.100000000 01	0.134083410-15	-0.237223440-15	0.344681960-24	-0.111022300-15	-0.177267060-16
	0.324207100-15	-0.330152800-15				
ROW 8	0.452993220-16	-0.237223440-15	-0.757315220-16	0.252700280-24	0.981202970-17	0.134441070-15
	0.117093830-15	0.100000000 01	-0.623795720-15	0.142486170-24	0.277555760-16	-0.469459540-16
	0.516200500-15	-0.758510800-15				
ROW 9	0.142365510-15	0.725973350-16	0.247740200-16	0.473050930-24	-0.195102180-15	-0.173960240-15
	-0.250667540-15	-0.623934140-15	0.100000000 01	-0.795521430-24	-0.494396190-16	-0.997804810-17
	0.442536490-15	-0.747284120-15				
ROW 10	0.532127250-24	-0.243331170-24	-0.474077480-24	0.416333630-16	-0.528697160-24	-0.207627000-24
	0.344681960-24	0.142486170-24	-0.795521430-24	0.100000000 01	-0.295124000-22	0.253046490-22
	-0.198360450-24	-0.834056820-24				
ROW 11	-0.324881180-15	0.109287580-15	0.303107160-15	0.207283490-24	0.286229370-15	-0.581763430-16
	-0.124900090-15	0.277555760-16	-0.485722570-16	-0.295124000-22	0.100000000 01	-0.666206930-17
	-0.248180650-18	-0.115132950-17				
ROW 12	0.495744740-15	0.166801123-15	0.179025500-15	-0.473775320-24	0.226937070-16	0.855943730-16
	-0.169677660-16	-0.434765070-16	-0.726415460-17	0.253046490-22	-0.471627950-17	0.100000000 01
	-0.115663060-15	0.149750910-15				
ROW 13	-0.967081220-16	0.120283970-15	0.190481950-15	0.162086600-24	0.242401550-15	0.298020470-15
	0.320485660-15	0.515333150-15	0.492472620-15	-0.198360450-24	-0.247968900-18	-0.115679580-15
	0.100000000 01	0.982758870-15				
ROW 14	0.375434580-15	0.136452830-15	0.669631250-16	0.398224540-24	0.598777120-16	-0.801116750-16
	-0.303529220-15	-0.758507830-15	-0.749273330-15	-0.834056820-24	-0.125974980-17	0.122005090-15
	0.992636660-15	0.100000000 01				

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ORTHOGONALITY WITH RESPECT TO STIFFNESS

ROW 1	0.104573680D 02	-0.607506580D-09	0.604399510D-10	-0.349006600D-23	0.301063199D-09	0.818707990D-09
	0.130483820D-08	0.169026040D-08	0.132660990D-08	0.557065790D-23	-0.202931010D-10	0.151681090D-08
	-0.119203580D-08	-0.124863000D-08				
ROW 2	-0.619016700D-09	0.748574780D 03	0.119252340D-09	0.284172510D-22	-0.321053690D-10	-0.660265440D-11
	0.239285570D-09	0.344069660D-09	0.208277840D-09	-0.182195760D-21	0.782169440D-10	0.575756330D-09
	-0.628159210D-10	-0.873272430D-10				
ROW 3	0.215572750D-11	0.933887000D-10	0.693454440D 04	0.455943280D-19	-0.158720770D-10	-0.162120980D-09
	-0.215507610D-09	-0.925413060D-10	-0.574118530D-11	-0.328751910D-20	0.436557460D-10	0.758106470D-09
	0.319901440D-09	0.399041350D-09				
ROW 4	-0.349086630D-23	0.284172510D-22	0.455943280D-19	0.741355330D 04	0.178047520D-20	-0.[illegible]33181750D-22
	-0.336559510D-26	0.187006840D-20	0.350956810D-20	0.582076610D-10	0.153678160D-20	-0.[illegible]51307[illegible]80D-20
	0.120753490D-20	0.295239720D-20				
ROW 5	0.341024750D-09	-0.458083430D-10	-0.948085610D-11	0.178047520D-20	0.287403960D 05	-0.105583100D-09
	-0.399211330D-09	-0.459797530D-09	0.354113540D-11	-0.152237830D-19	0.582076610D-10	0.241527690D-09
	0.645059120D-09	0.134962730D-08				
ROW 6	0.765556080D-09	-0.268940537D-10	-0.165751420D-09	-0.183181750D-22	-0.131954490D-09	0.808305270D 05
	-0.394834140D-07	-0.516479330D-09	-0.139152690D-09	-0.167015140D-19	-0.582[illegible]5610D-10	0.403076680D-09
	0.114257070D-08	0.614409680D-09				
ROW 7	0.130193730D-08	0.208121590D-09	-0.230093720D-09	-0.356559510D-20	-0.410437910D-09	-0.402337720D-09
	0.176695490D 06	-0.611464660D-09	-0.708382690D-09	0.648839110D-19	-0.436557460D-10	-0.790123520D-11
	0.133992860D-08	-0.113237860D-09				
ROW 8	0.164286160D-08	0.321703520D-09	-0.105863800D-09	0.187006840D-20	-0.452760450D-09	-0.520762560D-09
	-0.588753470D-09	0.309654630D 06	-0.248583010D-06	0.371238920D-19	0.291038300D-10	-0.56786[illegible]D-10
	0.295283800D-08	-0.338016750D-08				
ROW 9	0.129039660D-08	0.212187060D-09	-0.265321100D-11	0.350956810D-20	0.293098080D-11	-0.161310960D-09
	-0.712569100D-09	-0.151726770D-08	0.426956710D 06	-0.365995780D-18	-0.261934470D-09	0.750901560D-10
	0.296979350D-08	-0.337226360D-08				
ROW 10	0.557065790D-23	-0.182195760D-21	-0.328751910D-20	0.310323150D-10	-0.152237830D-19	-0.167015140D-19
	0.648839110D-19	0.371238920D-19	-0.365995760D-18	0.338795680D 07	-0.107522020D-15	0.910874110D-16
	0.611229810D-19	-0.360574960D-17				
ROW 11	-0.199075290D-10	0.760813630D-10	0.420037340D-10	0.153678160D-20	0.424094080D-10	-0.554791770D-10
	-0.504317039D-10	0.472937240D-10	-0.292857290D-09	-0.107522020D-15	0.377071700D 07	-0.336513040D-10
	-0.560513420D-11	-0.666844360D-11				
ROW 12	0.172972060D-08	0.557592470D-09	0.711752090D-09	-0.351307100D-20	0.167589500D-09	0.293312710D-09
	-0.150520480D-09	-0.221244940D-09	-0.470521400D-10	0.910874110D-16	-0.354702930D-10	0.392909500D 07
	-0.133515310D-08	0.640803810D-09				
ROW 13	-0.101833090D-08	0.761213400D-10	0.381135760D-09	0.120750490D-20	0.711420610D-09	0.109585510D-08
	0.124404140D-08	0.269354700D-08	0.292507100D-08	0.611229810D-19	-0.671610160D-11	-0.157760000D-08
	0.954206070D 07	0.726610010D-08				
ROW 14	-0.103970230D-08	0.119554710D-09	0.539599210D-09	0.295239720D-20	0.119754010D-08	0.708391080D-09
	-0.644409530D-10	-0.306724150D-08	-0.332609370D-08	-0.360574960D-17	-0.733635210D-11	0.577675350D-09
	0.351920410D-08	0.102935430D 08				

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RESULTS OF LATEST ANALYSES

PROBLEM - GP2 TITLE - GOULDS [illegible] PUMP FOR DETROIT EDISON - HIGH WATER CONDITION

ACTIVE UNITS INCH LB CYC DEGF SEC

ACTIVE STRUCTURE TYPE PLANE FRAME

ACTIVE COORDINATE AXES X Y

LOADING - 1 OPERATING BASIS EARTHQUAKE

MEMBER FORCES

MEMBER	JOINT	RESPONSE TYPE	FORCE AXIAL	FORCE SHEAR-Y	FORCE SHEAR-Z	MOMENT TORSIONAL	MOMENT BENDING-Y	MOMENT BENDING-Z
1	1	RMS	0.0	162.1157932				127.4326963
		ABS SUM	0.0	298.2933109				557.0302734
1	3	RMS	0.0	162.1157932				2017.2133789
		ABS SUM	0.0	298.2933105				5178.2343750
2	3	RMS	0.0	372.5205645				2754.8208008
		ABS SUM	0.0	642.3352051				5043.0234375
2	5	RMS	0.0	372.5205645				9290.0664062
		ABS SUM	0.0	642.3352051				16360.9687500
3	5	RMS	0.0	322.0512695				9622.5859375
		ABS SUM	0.0	513.5774809				16964.0937500
3	6	RMS	0.0	322.0512695				12217.4296875
		ABS SUM	0.0	513.5778309				21329.5117187
4	6	RMS	0.0	438.0297852				12503.3906250
		ABS SUM	0.0	694.6696777				21888.9648437
4	7	RMS	0.0	438.0297852				34958.2304687
		ABS SUM	0.0	694.6696777				62040.7773437
5	7	RMS	0.0	401.1633301				38556.9257812
		ABS SUM	0.0	618.3581543				62038.6210937
5	8	RMS	0.0	401.1633301				61440.3906250
		ABS SUM	0.0	618.3581543				93168.1250000
6	8	RMS	0.0	379.9650879				61443.0273437
		ABS SUM	0.0	521.9218750				93169.0625000

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6	9	RMS	0.0	379.9656379	79624.3750000
		ABS SUM	0.0	521.9218750	112156.0750000
7	9	RMS	0.0	440.1833496	79625.4375000
		ABS SUM	0.0	693.0234375	112158.0625000
7	10	RMS	0.0	440.1833496	95647.8125000
		ABS SUM	0.0	693.0234375	129242.5000000
8	10	RMS	0.0	552.5378418	95646.1875000
		ABS SUM	0.0	835.8249512	129240.6250000
8	11	RMS	0.0	552.5378418	114383.6250000
		ABS SUM	0.0	835.8249512	131866.3125000
9	11	RMS	0.0	656.3015137	114383.6250000
		ABS SUM	0.0	1010.6044922	131866.3750000
9	12	RMS	0.0	656.3015137	139735.6875000
		ABS SUM	0.0	1010.6044922	160748.9375000
10	12	RMS	0.0	699.4265137	139735.9375000
		ABS SUM	0.0	1136.9533691	160749.2500000
10	13	RMS	0.0	699.4265137	171479.5000000
		ABS SUM	0.0	1136.9533691	223417.2500000
11	13	RMS	0.0	701.5971680	171479.6250000
		ABS SUM	0.0	1145.3569336	223417.5000000
11	14	RMS	0.0	701.5971680	182266.2500000
		ABS SUM	0.0	1145.3569336	244892.9375000
12	14	RMS	0.0	1003.4326172	58808.8233125
		ABS SUM	0.0	1003.4328613	58809.8 03125
12	15	RMS	0.0	1003.4326172	38740.1601562
		ABS SUM	0.0	1003.4328613	38740.1640625
13	15	RMS	0.0	1003.4299316	38740.1171875
		ABS SUM	0.0	1003.4299316	38740.1210937
13	16	RMS	0.0	1003.4299316	20678.3750000
		ABS SUM	0.0	1003.4299316	20678.3828125
14	16	RMS	0.0	984.6987305	20678.5234375
		ABS SUM	0.0	984.6989746	20678.5273437
14	17	RMS	0.0	984.6987305	0.1452111
		ABS SUM	0.0	984.6989746	0.1452112
15	1	RMS	0.0	4.9436121	24.6924286
		ABS SUM	0.0	8.6714363	43.5703583
15	2	RMS	0.0	4.9436121	19.5105896
		ABS SUM	0.0	8.6714363	33.9521790
16	2	RMS	0.0	6.3799105	20.6527405
		ABS SUM	0.0	11.3056774	35.8235779
16	3	RMS	0.0	6.3799105	36.4548798
		ABS SUM	0.0	11.3056774	65.2490082
17	3	RMS	0.0	2.9603196	28.3387909
		ABS SUM	0.0	4.6919603	44.9219818

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17	4	RMS	0.0	2.9609194	10.9740143
		ABS SUM	0.0	4.6917603	22.5710079
18	4	RMS	0.0	5.6991806	11.3200805
		ABS SUM	0.0	8.7943487	23.3591614
18	5	RMS	0.0	5.6991806	53.0396454
		ABS SUM	0.0	8.7943487	89.3054047

RESULTANT JOINT DISPLACEMENTS- SUPPORTS

JOINT		RESPONSE TYPE	X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
			/------------------ DISPLACEMENT	------------------//		------------------ ROTATION	------------------/	
14	GLOBAL	RMS	0.0	0.0				0.0
		ABS SUM	0.0	0.0				0.0

RESULTANT JOINT DISPLACEMENTS- FREE JOINTS

JOINT		RESPONSE TYPE	X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
			/------------------ DISPLACEMENT	------------------//		------------------ ROTATION	------------------/	
1	GLOBAL	RMS	2.2978334	0.0				0.0011032
		ABS SUM	2.3580179	0.0				0.0012849
2	GLOBAL	RMS	2.2364836	0.0				0.0011032
		ABS SUM	2.2858763	0.0				0.0012848
3	GLOBAL	RMS	2.1751691	0.0				0.0011031
		ABS SUM	2.2137070	0.0				0.0012845
4	GLOBAL	RMS	2.1147490	0.0				0.0011029
		ABS SUM	2.1427698	0.0				0.0012818
5	GLOBAL	RMS	2.0544605	0.0				0.0011025
		ABS SUM	2.0729451	0.0				0.0012827
6	GLOBAL	RMS	1.9963178	0.0				0.0011019
		ABS SUM	2.0061207	0.0				0.0012812
7	GLOBAL	RMS	1.5914783	0.0				0.0010678
		ABS SUM	1.6472472	0.0				0.0012341
8	GLOBAL	RMS	1.2051353	0.0				0.0010027
		ABS SUM	1.3020163	0.0				0.0010490
9	GLOBAL	RMS	0.8451028	0.0				0.0009017
		ABS SUM	0.9548747	0.0				0.0009185
10	GLOBAL	RMS	0.5363259	0.0				0.0007663
		ABS SUM	0.6314898	0.0				0.0008382
11	GLOBAL	RMS	0.2795697	0.0				0.0005925
		ABS SUM	0.3445011	0.0				0.0006910
12	GLOBAL	RMS	0.0963265	0.0				0.0003725
		ABS SUM	0.1237707	0.0				0.0004655
13	GLOBAL	RMS	0.0059318	0.0				0.0000960
		ABS SUM	0.0377611	0.0				0.0001298
15	GLOBAL	RMS	0.0009637	0.0				0.0000144
		ABS SUM	0.0009637	0.0				0.0000144
16	GLOBAL	RMS	0.0050053	0.0				0.0000549
		ABS SUM	0.0050053	0.0				0.0000549
17	GLOBAL	RMS	0.0142415	0.0				0.0000775
		ABS SUM	0.0142415	0.0				0.0000775

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RESULTS OF LATEST ANALYSES

PROBLEM - GP2 TITLE - GOULDS RHRSW PUMP FOR DETROIT EDISON - HIGH WATER CONDITION

ACTIVE UNITS INCH LB CYC DEGF SEC

ACTIVE STRUCTURE TYPE PLANE FRAME

ACTIVE COORDINATE AXES X Y

EIGENVALUES

MODE	EIGENVALUE	FREQUENCY	PERIOD
1	2.6498060D-01	5.1467330D-01	1.9429800 00
2	1.8461650 01	4.3544980 00	2.2964760-01
3	1.7565430 02	1.3253470 01	7.5451960-02
4	1.8778780 02	1.3703570 01	7.2973690-02
5	7.2800380 02	2.6981550 01	3.7062370-02
6	2.0474640 03	4.5248920 01	2.2099980-02
7	4.4757560 03	6.6901090 01	1.4947440-02
8	7.8436550 03	8.8564420 01	1.1291220-02
9	1.0914560 04	1.0447500 02	9.6158480-03
10	8.5818080 04	2.9294720 02	3.4135840-03
11	9.5513520 04	3.0905260 02	3.2356250-03
12	9.9525290 04	3.1547630 02	3.1698100-03
13	2.4130360 05	4.9123360 02	2.0340350-03
14	2.6066290 05	5.1055160 02	1.9586660-03

EIGENVECTORS

MODE 1

JOINT		DISPLACEMENT X DISP.	DISPLACEMENT Y DISP.	DISPLACEMENT Z DISP.	ROTATION X ROT.	ROTATION Y ROT.	ROTATION Z ROT.
1	GLOBAL	0.9999999	0.0				0.0029768
2	GLOBAL	0.9733880	0.0				0.0029768
3	GLOBAL	0.9467755	0.0				0.0029766
4	GLOBAL	0.9205548	0.0				0.0029761
5	GLOBAL	0.8943378	0.0				0.0029752
6	GLOBAL	0.8690512	0.0				0.0029740
7	GLOBAL	0.6924256	0.0				0.0028994
8	GLOBAL	0.5229432	0.0				0.0027338
9	GLOBAL	0.3664837	0.0				0.0024661
10	GLOBAL	0.2292098	0.0				0.0020885
11	GLOBAL	0.1181014	0.0				0.0015956
12	GLOBAL	0.0401108	0.0				0.0009842

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JOINT		X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
13	GLOBAL	0.0023911	0.0				0.0002531
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0000000	0.0				-0.0000000
16	GLOBAL	0.0000000	0.0				-0.0000000
17	GLOBAL	0.0000000	0.0				-0.0000000

MODE 2

JOINT		DISPLACEMENT X DISP.	DISPLACEMENT Y DISP.	DISPLACEMENT Z DISP.	ROTATION X ROT.	ROTATION Y ROT.	ROTATION Z ROT.
1	GLOBAL	-0.5154305	0.0				-0.0100616
2	GLOBAL	-0.4255208	0.0				-0.0100591
3	GLOBAL	-0.3355809	0.0				-0.0100519
4	GLOBAL	-0.2471159	0.0				-0.0100355
5	GLOBAL	-0.1587966	0.0				-0.0100080
6	GLOBAL	-0.0736813	0.0				-0.0099703
7	GLOBAL	0.4757262	0.0				-0.0080322
8	GLOBAL	0.8579661	0.0				-0.0044931
9	GLOBAL	0.9999999	0.0				-0.0002089
10	GLOBAL	0.8419635	0.0				0.0036279
11	GLOBAL	0.5478799	0.0				0.0058032
12	GLOBAL	0.2479610	0.0				0.0051605
13	GLOBAL	0.0172466	0.0				0.0017864
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0000000	0.0				-0.0000000
16	GLOBAL	0.0000000	0.0				-0.0000000
17	GLOBAL	0.0000000	0.0				-0.0000000

MODE 3

JOINT		DISPLACEMENT X DISP.	DISPLACEMENT Y DISP.	DISPLACEMENT Z DISP.	ROTATION X ROT.	ROTATION Y ROT.	ROTATION Z ROT.
1	GLOBAL	0.4759699	0.0				0.0160276
2	GLOBAL	0.3329914	0.0				0.0160062
3	GLOBAL	0.1899095	0.0				0.0159410
4	GLOBAL	0.0499991	0.0				0.0158159
5	GLOBAL	-0.0885406	0.0				0.0156137
6	GLOBAL	-0.2201633	0.0				0.0153443
7	GLOBAL	-0.8571184	0.0				0.0046399
8	GLOBAL	-0.7241633	0.0				-0.0064540
9	GLOBAL	0.0165318	0.0				-0.0145063
10	GLOBAL	0.7860252	0.0				-0.0092801
11	GLOBAL	0.9499998	0.0				0.0024532
12	GLOBAL	0.5738776	0.0				0.0103747
13	GLOBAL	0.0479196	0.0				0.0048522
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	-0.0000000	0.0				0.0000000
16	GLOBAL	-0.0000000	0.0				0.0000000
17	GLOBAL	-0.0000000	0.0				0.0000000

MODE 4

JOINT		DISPLACEMENT X DISP.	DISPLACEMENT Y DISP.	DISPLACEMENT Z DISP.	ROTATION X ROT.	ROTATION Y ROT.	ROTATION Z ROT.
1	GLOBAL	-0.0000000	0.0				-0.0000000
2	GLOBAL	-0.0000000	0.0				-0.0000000
3	GLOBAL	-0.0000000	0.0				-0.0000000
4	GLOBAL	-0.0000000	0.0				-0.0000000
5	GLOBAL	0.0000000	0.0				-0.0000000

JOINT		X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
7	GLOBAL	0.0000000	0.0				-0.0000000
8	GLOBAL	0.0000000	0.0				0.0000000
9	GLOBAL	-0.0000000	0.0				0.0000000
10	GLOBAL	-0.0000000	0.0				0.0000000
11	GLOBAL	-0.0000000	0.0				-0.0000000
12	GLOBAL	-0.0000000	0.0				-0.0000000
13	GLOBAL	-0.0000000	0.0				-0.0000000
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0676650	0.0				-0.0063323
16	GLOBAL	0.3514608	0.0				-0.0242311
17	GLOBAL	0.3599999	0.0				-0.0342086

MODE 5

JOINT		/----------DISPLACEMENT---------- X DISP.	Y DISP.	Z DISP.	//----------ROTATION---------- X ROT.	Y ROT.	Z ROT. /
1	GLOBAL	0.5182145	0.0				0.0231401
2	GLOBAL	0.3125073	0.0				0.0230518
3	GLOBAL	0.1066359	0.0				0.0227582
4	GLOBAL	-0.0923158	0.0				0.0222323
5	GLOBAL	-0.2842596	0.0				0.0214345
6	GLOBAL	-0.4522926	0.0				0.0204041
7	GLOBAL	-0.6440487	0.0				-0.0082924
8	GLOBAL	0.2079839	0.0				-0.0207483
9	GLOBAL	0.9599998	0.0				-0.0011669
10	GLOBAL	0.3025830	0.0				0.0206857
11	GLOBAL	-0.8857667	0.0				0.0127122
12	GLOBAL	-0.9137720	0.0				-0.0107173
13	GLOBAL	-0.0969472	0.0				-0.0093854
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	-0.0000000	0.0				0.0000000
16	GLOBAL	-0.0000000	0.0				0.0000000
17	GLOBAL	-0.0000000	0.0				0.0000000

MODE 6

JOINT		/----------DISPLACEMENT---------- X DISP.	Y DISP.	Z DISP.	//----------ROTATION---------- X ROT.	Y ROT.	Z ROT. /
1	GLOBAL	0.4666820	0.0				0.0249023
2	GLOBAL	0.2491146	0.0				0.0246575
3	GLOBAL	0.0294995	0.0				0.0239117
4	GLOBAL	-0.1774479	0.0				0.0226460
5	GLOBAL	-0.3677993	0.0				0.0208308
6	GLOBAL	-0.5356678	0.0				0.0185574
7	GLOBAL	-0.2009557	0.0				-0.0210672
8	GLOBAL	0.8853130	0.0				-0.0051376
9	GLOBAL	0.0931363	0.0				0.0239631
10	GLOBAL	-0.8956680	0.0				-0.0010656
11	GLOBAL	0.1840944	0.0				-0.0242987
12	GLOBAL	0.9599998	0.0				0.0034770
13	GLOBAL	0.1338766	0.0				0.0129017
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0000000	0.0				-0.0000000
16	GLOBAL	0.0000000	0.0				-0.0000000
17	GLOBAL	0.0000000	0.0				-0.0000000

MODE 7

JOINT	/----------DISPLACEMENT---------- X DISP.	Y DISP.	Z DISP.	//----------ROTATION---------- X ROT.	Y ROT.	Z ROT. /

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1	GLOBAL	-0.4386616	0.0				-0.0264363
2	GLOBAL	-0.2076952	0.0				-0.0259355
3	GLOBAL	0.0220194	0.0				-0.0244128
4	GLOBAL	0.2310134	0.0				-0.0219416
5	GLOBAL	0.4060068	0.0				-0.0185778
6	GLOBAL	0.5471291	0.0				-0.0144914
7	GLOBAL	-0.3441840	0.0				0.0223610
8	GLOBAL	-0.5561184	0.0				-0.0196901
9	GLOBAL	0.8624277	0.0				-0.0039513
10	GLOBAL	-0.3165320	0.0				0.0234158
11	GLOBAL	-0.5244293	0.0				-0.0203491
12	GLOBAL	0.9999999	0.0				-0.0078458
13	GLOBAL	0.1773769	0.0				0.0166421
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	-0.0000000	0.0				0.0000000
16	GLOBAL	-0.0000000	0.0				0.0000000
17	GLOBAL	-0.0000000	0.0				0.0000000

MODE 8

JOINT		/----------DISPLACEMENT----------		//----------ROTATION----------			/
		X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
1	GLOBAL	-0.4778611	0.0				-0.0317406
2	GLOBAL	-0.2036187	0.0				-0.0337845
3	GLOBAL	0.0657630	0.0				-0.0278814
4	GLOBAL	0.3029299	0.0				-0.0233412
5	GLOBAL	0.4740555	0.0				-0.0174457
6	GLOBAL	0.5936617	0.0				-0.0104937
7	GLOBAL	-0.9268777	0.0				0.0108694
8	GLOBAL	0.4047001	0.0				-0.0235456
9	GLOBAL	0.2425607	0.0				0.0248408
10	GLOBAL	-0.7941051	0.0				-0.0158673
11	GLOBAL	0.9999999	0.0				0.0007569
12	GLOBAL	-0.9353217	0.0				0.0200506
13	GLOBAL	-0.2169239	0.0				-0.0200130
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0000000	0.0				-0.0000000
16	GLOBAL	0.0000000	0.0				-0.0000000
17	GLOBAL	0.0000000	0.0				-0.0000000

MODE 9

JOINT		/----------DISPLACEMENT----------		//----------ROTATION----------			/
		X DISP.	Y DISP.	Z DISP.	X ROT.	Y ROT.	Z ROT.
1	GLOBAL	-0.3795905	0.0				-0.0268129
2	GLOBAL	-0.149767	0.0				-0.0257657
3	GLOBAL	0.0747536	0.0				-0.0225889
4	GLOBAL	0.2648063	0.0				-0.0177409
5	GLOBAL	0.3837045	0.0				-0.0116522
6	GLOBAL	0.4536935	0.0				-0.0046320
7	GLOBAL	-0.9697716	0.0				-0.0058188
8	GLOBAL	0.9999998	0.0				0.0005918
9	GLOBAL	-0.9714271	0.0				0.0035344
10	GLOBAL	0.3544185	0.0				-0.0074503
11	GLOBAL	-0.6554901	0.0				0.0134700
12	GLOBAL	0.4743202	0.0				-0.0155246
13	GLOBAL	0.1349578	0.0				0.0121061
14	GLOBAL	0.0	0.0				0.0
15	GLOBAL	0.0000000	0.0				-0.0000000
16	GLOBAL	0.0000000	0.0				-0.0000000
17	GLOBAL	0.0000000	0.0				-0.0000000

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LOW WATER CASE

ORTHOGONALITY WITH RESPECT TO MASS

ROW 1	0.100000000 01	-0.457417790-13	-0.442536480-25	-0.340750640-14	-0.578042390-15	-0.267713230-15
	-0.284731820-15	0.220845210-15	-0.348909810-16	0.421987450-24	-0.172171300-15	0.401914170-15
	-0.175573910-15	-0.871986280-16				
ROW 2	-0.457451940-13	0.100000003 01	-0.143477560-25	0.607654660-15	0.947592700-16	-0.277067870-15
	-0.410370520-16	-0.116551730-16	0.108094960-15	-0.227010730-24	-0.199493200-16	0.211822610-15
	0.851783550-16	0.197320950-16				
ROW 3	-0.442536440-25	-0.143477560-25	0.100000000 01	0.590952010-23	0.163717240-25	-0.277498830-25
	-0.535459120-24	0.837015160-24	0.482816190-25	0.416333630-16	-0.194763350-24	-0.390508430-25
	0.319275820-24	0.252478680-25				
ROW 4	-0.339110660-14	0.605916550-15	0.590952010-23	0.100000000 01	-0.797322280-15	0.376218150-15
	-0.333012700-15	-0.144632570-15	0.106034970-15	-0.397823200-24	0.187350140-15	0.108216930-15
	0.581126650-16	0.745264590-16				
ROW 5	-0.577175030-15	0.111239140-15	0.143717240-25	-0.797322280-15	0.100000000 01	0.319839640-15
	0.239251020-16	-0.220093040-15	0.118178040-16	-0.400283210-24	0.251534900-15	0.455669840-16
	0.234436960-15	0.128830030-15				
ROW 6	-0.271182680-15	-0.290745650-15	-0.277498810-25	0.362340370-15	0.319893850-15	0.100000000 01
	-0.273284950-15	-0.266280050-15	-0.129187690-15	-0.165180670-24	-0.164798730-16	0.535697520-16
	0.241088540-15	0.557704230-16				
ROW 7	-0.283861070-15	-0.384349670-16	-0.535459120-24	-0.318972280-15	0.363318390-16	-0.272351590-15
	0.100000000 01	-0.262813610-15	-0.222044600-15	0.189005620-24	-0.416333630-16	-0.518248640-16
	0.354082260-15	-0.192684090-15				
ROW 8	0.224314650-15	0.487690980-18	0.807035160-24	-0.144686780-15	-0.206161040-15	-0.266280050-15
	-0.277555760-15	0.100000000 01	-0.304443970-15	0.257399370-24	0.138777080-16	-0.134441070-16
	0.585924150-15	-0.695612440-15				
ROW 9	-0.391769680-16	0.803393810-16	0.482816190-25	0.106950540-15	0.118178040-16	-0.129236900-15
	-0.235922390-15	-0.304443970-15	0.100000000 01	-0.842228120-24	0.867361740-17	-0.466511870-16
	0.373939370-15	-0.336701170-15				
ROW 10	0.421987450-24	-0.227010730-24	0.416333630-16	-0.397823200-24	-0.400283210-24	-0.165180670-24
	0.189005620-24	0.257399370-24	-0.842228120-24	0.100000000 01	0.312095400-22	0.869295880-23
	-0.528169770-24	-0.133019040-24				
ROW 11	-0.172550730-15	-0.164798730-16	-0.194763350-24	0.181278600-15	0.256739070-15	-0.780625560-17
	-0.416333630-16	0.138777080-16	0.954097910-17	0.312095400-22	0.100000000 01	-0.504154010-17
	0.160724500-17	-0.314439810-17				
ROW 12	0.403665830-15	0.225697010-15	-0.390508430-25	0.106480980-15	0.430462140-16	0.397250450-16
	-0.370255040-16	-0.137336020-16	-0.648927460-16	0.869295880-23	-0.444522890-17	0.100000000 01
	0.112859790-15	0.429879110-16				
ROW 13	-0.168591560-15	0.625932490-16	0.319275820-24	0.572498720-16	0.231821110-15	0.238479900-15
	0.351541050-15	0.534193040-15	0.372187490-15	-0.528149790-24	0.167225480-17	0.129326330-15
	0.100000000 01	0.520254740-15				
ROW 14	-0.101076000-15	0.188659430-16	0.252498680-25	0.729541540-16	0.124496820-15	0.540325230-[illegible]
	-0.192684290-15	-0.695612650-15	-0.337568340-15	-0.133019040-24	-0.303280150-17	0.438584520-[illegible]
	0.520363170-15	0.100000000 01				

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LOW WATER CASE

ORTHOGONALITY WITH RESPECT TO STIFFNESS

ROW 1	0.112308750 02	-0.354007500-09	-0.579088960-24	0.511210310-09	0.971919880-09	0.112015090-08
	0.941675450-09	0.818609180-09	0.695365540-09	0.473945430-23	-0.171326060-09	0.177158000-08
	-0.167310320-08	-0.261166160-08				
ROW 2	-0.332422850-09	0.988400950 03	-0.308931690-22	0.213472130-09	-0.104699140-09	-0.413820090-10
	0.759108330-10	0.107304180-09	-0.785846010-09	-0.224383390-21	0.269210430-09	0.807968800-09
	0.530774560-09	-0.187583300-09				
ROW 3	-0.579088960-24	-0.308931693-22	0.761355330 04	0.444703370-19	0.118543700-21	-0.210594860-21
	-0.397718930-20	0.598060080-20	0.360044330-21	0.582076610-10	-0.144392200-20	-0.290301090-21
	0.236684750-20	0.187324700-21				
ROW 4	0.516493273-09	0.196210410-09	0.444703370-19	0.911340040 04	-0.138779650-09	-0.293795210-09
	-0.319914760-09	-0.547970560-10	-0.245790940-09	-0.362988940-20	0.291038300-09	0.244540390-09
	0.224063430-09	0.675852863-09				
ROW 5	0.942664970-09	-0.127525323-09	0.118543700-21	-0.154993130-09	0.364959050 05	-0.174306790-09
	-0.291777273-09	-0.323936960-09	-0.565023580-10	-0.146119590-19	0.291038300-10	-0.199179340-09
	0.149678830-08	0.111749390-08				
ROW 6	0.104473663-08	-0.224756930-10	-0.210594860-21	-0.322576190-09	-0.211926480-09	0.999348080 05
	-0.171212380-09	-0.259949030-09	0.410609480-10	-0.164404380-19	-0.189174900-09	-0.387899490-09
	0.206102020-08	0.433970190-09				
ROW 7	0.527231010-09	0.533893093-10	-0.397718930-20	-0.351796590-09	-0.280500960-09	-0.192414970-09
	0.219062447 06	-0.213333350-09	-0.901536620-10	0.484465500-19	0.218278730-09	-0.696616100-09
	-0.289563500-08	-0.157536340-08				
ROW 8	0.768974630-09	0.785210510-10	0.598060080-20	-0.805575610-10	-0.325474760-09	-0.315253600-09
	-0.202078350-09	0.396973861 06	-0.435022680-09	0.638611870-19	0.130967240-09	-0.498687310-09
	0.474473550-08	-0.589069680-08				
ROW 9	0.713362930-09	-0.184521223-09	0.360044330-21	-0.274259290-09	-0.489635000-10	0.129603000-10
	-0.890736370-10	-0.473344033-09	0.574544630 06	-0.489096290-18	-0.160071070-09	-0.375935530-09
	0.270196980-08	-0.197977430-08				
ROW 10	0.473945430-23	-0.224383390-21	0.310323150-10	-0.362988940-20	-0.146119590-19	-0.164404380-19
	0.484465530-19	0.638611873-19	-0.489096290-18	0.338795680 07	0.114522720-15	0.341934410-16
	-0.121008950-17	-0.135328340-17				
ROW 11	-0.170527510-09	0.264926060-09	-0.144392200-20	0.294029690-09	0.298427950-10	-0.185536920-09
	0.226466107-09	0.151945629-09	-0.152795110-09	0.114522720-15	0.378152000 07	-0.209183780-10
	-0.206767940-11	-0.237727170-10				
ROW 12	0.148579530-08	0.762321330-09	-0.290301090-21	[illegible]	-0.364609900-09	-0.631043660-09
	-0.686689830-09	-0.706846991-09	-0.473086460-09	[illegible]	-0.236468620-10	0.430158600 07
	-0.310672180-08	0.166002470-08				
ROW 13	-0.132318020-08	0.728322083-09	0.236689750-20	0.338093970-09	0.201603870-08	0.235316200-08
	0.267923313-09	0.459212755-08	0.267593810-08	-0.121008950-17	-0.248175090-11	-0.337961700-08
	0.934235522 07	0.121335460-08				
ROW 14	-0.224062360-08	-0.376322380-10	0.187324700-21	0.760789510-09	0.123577230-08	0.501030060-09
	-0.152421650-08	-0.595577523-09	-0.193807650-08	-0.105328340-17	-0.214117390-10	0.131030740-0
	-0.161642460-08	0.132907750-08				

FIRST DYNAMIC EIGENVECTORS EIGENVALUES

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LOW WATER CASE

RESULTS OF LATEST ANALYSES

PROBLEM - GP2 TITLE - GOULDS RHRSW PUMP FOR DETROIT EDISON -LOW WATER CONDITION

ACTIVE UNITS INCH LB RAD DEGF SEC

ACTIVE STRUCTURE TYPE PLANE FRAME

ACTIVE COORDINATE AXES X Y

EIGENVALUES

MODE	EIGENVALUE	FREQUENCY	PERIOD
1	1.1230880D 01	5.3336840D-01	1.8748770 00
2	9.6840090D 02	5.0036520 00	1.9985400D-01
3	7.4135530 03	1.3703570 01	7.2973690D-02
4	9.1134000 03	1.5193600 01	6.5817180D-02
5	3.6495910D 04	3.0404830 01	3.2889510D-02
6	9.5934810D 04	5.0312440D 01	1.9875640D-02
7	2.1906290 05	7.4491190 01	1.3424410D-02
8	3.9697380D 05	1.0027700 02	9.9723740D-03
9	5.7454460D 05	1.2063750 02	8.2892960D-03
10	3.3874570 06	2.9294720 02	3.4135840D-03
11	3.7615200 06	3.0949500 02	3.2310700D-03
12	4.0015460 06	3.1837320 02	3.1404670D-03
13	9.5629630 06	4.9165690 02	2.0339390-03
14	1.0240780 07	5.1055730 02	1.9586440D-03

EIGENVECTORS

MODE 1

JOINT		DISPLACEMENT X DISP.	Y DISP.	Z DISP.	ROTATION X ROT.	Y ROT.	Z ROT.
1	GLOBAL	0.9999938	0.0				0.0029919
2	GLOBAL	0.9732537	0.0				0.0029918
3	GLOBAL	0.9465084	0.0				0.0029916
4	GLOBAL	0.9201534	0.0				0.0029911
5	GLOBAL	0.8938046	0.0				0.0029902
6	GLOBAL	0.8681937	0.0				0.0029488
7	GLOBAL	0.6909860	0.0				0.0029099
8	GLOBAL	0.5210724	0.0				0.0027374
9	GLOBAL	0.3645329	0.0				0.0024629
10	GLOBAL	0.2276028	0.0				0.0020803
11	GLOBAL	0.1171445	0.0				0.0015854
12	GLOBAL	0.0397330	0.0				0.0009758

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Simple conservative checks were made to insure that it was not necessary to include separate mass points to account for the movement of the shaft relative to the bearings. The shaft is supported at sufficiently short intervals so that this is not necessary.

The response spectra must be input into the computer in order to perform the modal analysis. Experience has shown that STRUDL does a very poor job of interpolating between specified points of the spectra. Thus, in order to avoid interpolation errors, the analysis is performed and the frequencies obtained. Then the spectra is input paying particular attention to inputting points that coincide with the frequencies.

An orthogonality check is printed out to show that the mode shapes and frequencies are accurate. The off diagonal terms in this matrix should be zero.

The computer output shows that two frequencies (3rd and 4th) are very close to each other. This should not be interpreted to mean that the square root of the sum of the squares method is not applicable for these frequencies because one of these frequencies is for the lower part of the pump and the other is for the upper part. The support makes the lower and upper parts two separate independent cantilever beams.

The damping was taken to be 2% for the OBE.

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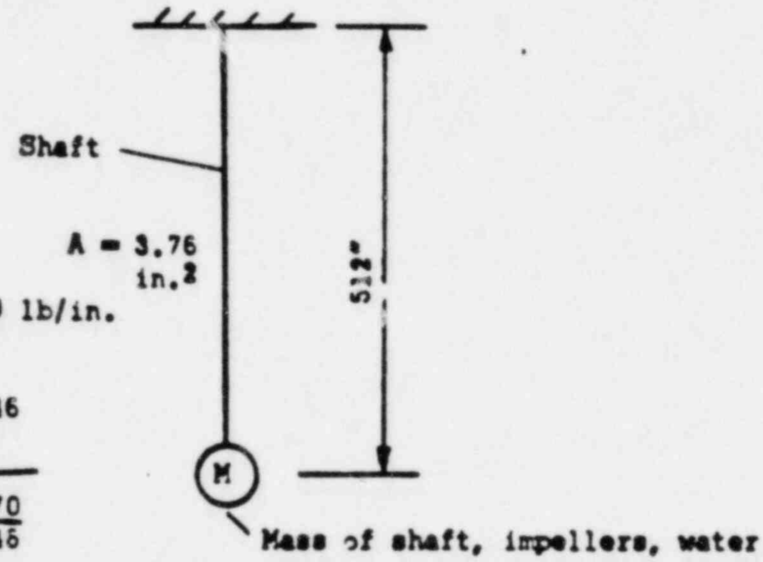
2.2 Vertical Seismic Analysis

The pump is obviously rigid in the vertical direction* except for the impeller-shaft assembly. The shaft is supported at short intervals in the lateral direction but is only supported near the motor in the vertical direction. In addition, some of the internal water is supported by the impeller. The exact amount of water supported by the impeller is difficult to determine due to friction effects, etc. Thus, in order to be conservative, the entire amount of water inside the pump is assumed to be supported by the impeller. The model is shown below.



$$K = \frac{EA}{L} = 212{,}969 \text{ lb/in.}$$

$$M = \frac{2681}{386} = 6.946$$

$$f = \frac{1}{6.283}\sqrt{\frac{212870}{6.946}}$$

$$= 27.86 \text{ cps}$$

From the response spectra curve for the OBE, the acceleration is 1.2 g for the impeller assembly and .2 g for the remainder of the pump.

* This has been proved many times in previous reports. This work will be made available upon request.

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3. STRESS ANALYSIS

3.1 Introduction

The seismic loads are combined with the normal operating loads and a stress analysis is made. Since the allowable stress for the DBE loading is approximately twice that for the OBE and the DBE seismic loads are only slightly more than the OBE and in some cases less, the OBE condition is the worst case.

The piping loads on the pump are estimated in accordance with the specification. These are:

$$M_t = 400,000 \text{ in-lbs}$$

$$M_c = M_l = 200,000 \text{ in-lbs}$$

$$P = 16,000 \text{ lbs}$$

$$V_c = V_L = 4,000 \text{ lbs}$$

The nomenclature used is that of Welding Research Council Bulletin 107. The above loads are much higher than expected on this pump because the thermal gradient will be low.

3.2 Stresses in Column

The highest stresses in the pump column occur at the support and are due to seismic, pressure, and dead load. These stresses are:

Lateral Seismic

$$S_l = 182266/30 = 6,076 \text{ psi}$$

where the moment is taken from the computer printout, page 15, and the section modulus is that of a 12" sch. 30 pipe in the corroded condition.

Vertical Seismic Plus Dead Load

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Total vertical load is $P = 1.2\ (7961) = 9553$ lbs

$S_2 = 9553/9.82 = 973$ psi

Pressure Stress

$S = PR/t + .6P$ (from ASME Code)

$= \frac{80.3(6)}{.25} + .6(80.3) = 1{,}975$ psi Circumferential

$S_L = \frac{1}{2}(PR/t - .4P) = \frac{1}{2}(80.3(6)/.25 - .4(80.3)) = 948$

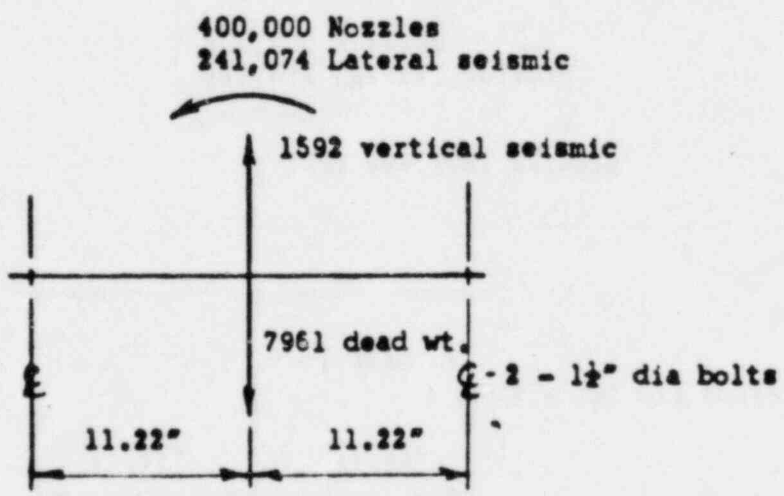
Total Circum. Stress = 1,975 psi

Total Longitudinal Stress = 948 + 973 + 6,076 = 7,997 psi

The ASME Code allowable stress for SA 106 Gr.B is 15,000 psi. Therefore the column is adequate.

3.3 Stress Analysis of Support Flange and Bolting

The pump is subjected to overturning moments due to seismic and nozzle loads. These are shown in the worst condition in the sketch below.



The overturning moment , $M = 400{,}000 + 241{,}074 - 11.22(7961 - 1592)$

$= 569{,}591$ in-lbs

The tensile stress in the bolts is:

$$S = \frac{569591}{2(22.44)(.9691)} = 13,096 \text{ psi}$$

The shearing loads are due to both seismic and nozzle loads. These are

$$V = 16,000 + 1704 = 17,704 \text{ lbs}$$

The shearing stress is:

$$S_s = 17,704/(4(.9691) = 4,567 \text{ psi}$$

The allowable stress for SA 193 Gr. B7 is 25,000 psi tensile. Thus the bolts are more than adequate.

3.4 Analysis of Anchor Bolts

The overturning moment on the anchor bolts is the same as for the bolts previously analyzed. The distance between the bolts is different and the bolts are different size. Thus the stress in tension is:

$$S = \frac{569591}{32(2)(.6057)} = 14,693 \text{ psi}$$

The shearing stress is:

$$S_s = 17,704/(4(.6057)) = 7,307 \text{ psi}$$

SA 307 anchor bolts will be more than adequate.

3.5 Column Flanges and Bolting

The column is subjected to both internal pressure and external forces and moments due to seismic. The external forces are converted to equivalent internal pressure by the method given on page 170, Ref. 3.

$$P_{eq} = \frac{16M}{3.142G^3} + \frac{4F}{3.142G^2}$$

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where:

M = external moment

F = external force

G = gasket diameter

$$P_{eq} = \frac{16(182266)}{3.152(15^3)} + \frac{4(7961)}{3.152(15^2)} = 320$$

The total design pressure is:

$P = 320 + 80.3 = 400.3$

This flange is also flat faced with metal to metal contact outside the bolt circle and is designed to ASME Section VIII, App. II, Part B.

$A = 16.6$, $B = 12.75$ $C = 15$, $t = 1.04$, $\ell = 3.71$, $r_E = 1$

$r_S = .5$ (assumed), $B_1 = 13.$ $a = 1.181$, $S_B = 25000$, $G = 15$

$h_D = 1.125''$ $h_G = 0$, $h_T = .5625''$ $H_D = .785(12.75)^2 (400.3) = 51{,}082$

$H_T = 19{,}630$ $H = .785(15)(400.3) = 70{,}712$

$M_p = 51082(1.125) + 19630(.5625) = 68509$ in-lbs

The value of h_c which governs in this case is: $h_c = (A - C)/2 = .8$

$H_c = 68509/.8 = 85{,}636$ lbs

The total bolt load is $85{,}636 + 70{,}712 = 156{,}348$ lbs

The above bolt load can be broken down into two types, that caused by primary loads(pressure plus dead load plus vertical seismic) and primary bending(lateral seismic). The ASME Code does not provide allowable stresses for the stresses due to bending but AEC Regulatory Guide 1.48 does. The loads are:

Bolt loads due to primary membrane stress in pipe = 48,978 lbs

Bolt loads due to primary bending stress in pipe = 107,370 lbs

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The allowable bolt loads are:

Loads due to primary membrane stress = 12(.419)(25000) = 125,700 lbs

Loads due to primary bending stress in the pipe plus primary membrane stress (AEC Reg. Guide 1.48) = 12(.419)(25000)(1.5) = 188,550 lbs

$$48{,}978 < 125{,}700$$

$$156{,}348 < 188{,}550$$

Thus, the bolts are adequate.

Flange Stresses

$$EO_A = \frac{(1)(.5)(25000)(3.68)}{16.6 - 15} - \frac{.29(16.6 - 15)(68509)}{13.(1.81)(1.04)^3}$$

$$= 27{,}549 \text{ psi}$$

$$S_R = \frac{6(68509)}{(1.04)^2(3.14(15)-12(1))} = 10{,}827 \text{ psi}$$

$$S_T = \frac{5.46(68509)}{12.75(1.04)^2}\left[.318\left(\left(\frac{2.25}{27.75}\right) + \frac{2(.8)}{31.6}\right) + .075\right] + \frac{27549(1.04)}{12.75}$$

$$= 5{,}418 \text{ psi}$$

The ASME Code allowable stress for SA 283 Gr. D is 12,600 psi. Thus the flanges are adequate.

3.6 Analysis of Motor Bolting

The motor is fastened to the mount by 4 - 5/8" screws of AISI C 1018 material on a 14.75" B. C. The moment caused by lateral seismic is 20,679 in-lbs from page 15.

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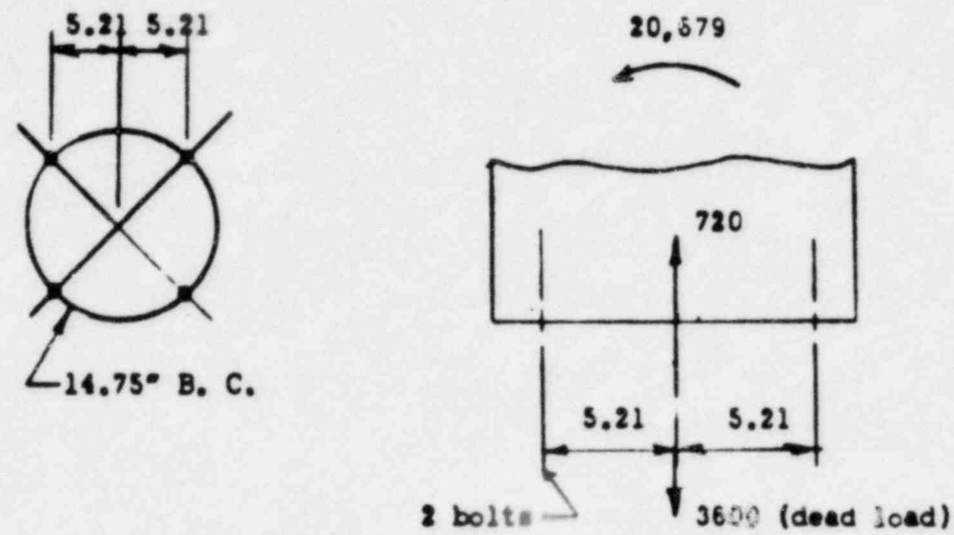

$M = 20{,}679 - 5.21(3600-720) = 5{,}674$ in-lbs

The tensile stress is:

$$S = \frac{5{,}674}{2(10.42)(.2260)} = 1{,}205 \text{ psi}$$

The shearing load from page 15 is 985 lbs.

Thus the shearing stress is:

$$S_s = \frac{985}{4(.226)} = 1{,}090 \text{ psi}$$

The AISI C 1018 bolts are more than adequate for these loads.

3.7 Stresses in Shaft

The stresses in the shaft are caused by normal torsion, normal downthrust, seismic bending due to lateral momement, and axial load due to vertical seismic. The shaft is weakest at the threaded end where it engages the coupling. The most highly stressed location is the coupling near where the moment is highest. This is near the support, thus the moment is 182,266 in-lbs from page 15. The minimum root diameter of the threads is 2.0792"

$$I = \frac{3.142(2.0792)^4}{64} = .9174 \qquad J = 2I = 1.835 \text{ in.}^4$$

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The torque T = $\frac{63000(300)}{1800}$ = 10,500 in-lbs

The shearing stress due to torque is:

$$S_1 = \frac{10500(2.0792)}{1.835\ (2)} = 5,949 \text{ psi}$$

The vertical seismic load on the shaft due to weight of the shaft plus internal fluid is:

1.2(2681) = 3217 lbs

The total axial load on the shaft, conservatively is:

Dead load	2681
seismic	3217
downthrust	15000
	20898

Axial stress is:

$$S_2 = 20898/(3.40) = 6,146 \text{ psi}$$

Bending stress in shaft:

$$S_3 = \frac{182,266}{185.67}(1.04) = 1,020 \text{ psi}$$

The total tensile stress is:

$$S = 6146 + 1020 = 7,166 \text{ psi}$$

The combined stress is:

$$S_c = \sqrt{(7166)^2 + (2(5949))^2} = 13,889 \text{ psi}$$

The maximum normal stress in the shaft is 13,889 psi and the maximum shearing stress is 5,949 psi. The ASME Code does not provide stress values to be used for the design of shafts. An allowable of 15000 psi is established for the A-582 TP 416 shaft, which is in accordance with the general stress limits of the Code.

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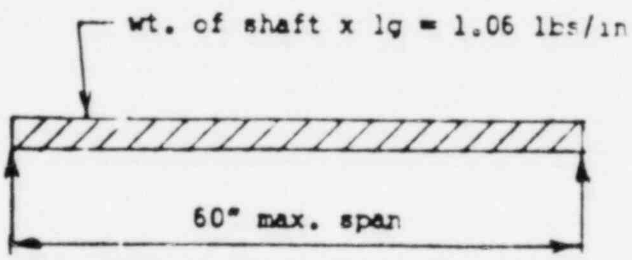
3.8 Deflections in Shaft

Good practice in transmission shaft design limits the maximum deflection to .01 inches per foot to prevent excessive wear on the bearings (see Ref. 5). As mentioned before, the shaft is supported such that it is rigid between the bearings insofar as the seismic analysis is concerned. However, the shaft will experience accelerations imposed by the bearing supports and must be checked for resulting deflections. It is clear that the maximum total acceleration of the bearings would be less than 1g. This analysis will be made for the conservative value of 1g and the shaft will be taken as simply supported at the bearings.



$$\text{Defl. @ midpoint} = \frac{5(1.06)(60)^4}{384(29000000)(.9174)} = .0067''$$

The above deflection is well within acceptable limits.

3.9 Stresses in Coupling

The maximum loads in the coupling are the same as those previously applied to the shaft (Article 3.5, page 27). The coupling has the following dimensions:

O.D. = 2.75" Length = 5.5" Root thd. dia. = 2.1875"

Therefore:

$$I = \frac{3.142((2.75)^4 - (2.1875)^4)}{64} = 1.6834 \text{ in.}^4$$

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$J = 2I = 3.3667$

$A = \frac{3.142((2.75)^2 - (2.1875)^2)}{4} = 2.181 \text{ in.}^2$

$S_1 = \frac{10500(1.375)}{3.3667} = 4288\text{psi}$

$S_2 = 20898/2.181 = 9582\text{psi}$

$S_3 = \frac{182266(1.375)}{185.67} = 1350 \text{ psi}$

$S = 9582 + 1350 = 10932\text{psi}$

$S_c = \sqrt{(10932))^2 + (2(4288))^2} = 13,894 \text{ psi}$

The allowable stress for ASTM A-582 TP 416 is 15000 psi. Thus, the coupling is adequate.

The thread engagement of the coupling is more than the diameter of the threads, thus the full strength of the coupling is developed.

3.10 Column Deflections

Excessive column deflections can cause wear on the solid bearings and must, therefore, be kept within tolerances. The most critical joint is 13 because the bearing located at the support cannot undergo rotation. Thus the deflection at joint 13 causes the shaft to bend at the bearing. The deflection of joint 13 is .0058"(from page 16). The span is 18.75", thus the deflection is less than the .01 inch/foot given by Ref. 5.

3.11 Nozzle Loads

s mentioned previously, the nozzle loads assumed for this purp in accordance ith the specification are fairly high. This is a low temperature system, erefore, the piping loads are expected to be much lower than those prev-usly assumed. The reinforcement of this nozzle due to internal pressure covered by the ASME Code, and no reinforcement is required. The ASME de does not cover the stresses in the nozzle caused by external loads. ere is no analysis method available at this time (known to this analyst) which these stresses. Welding Research Council Bulletin 107 is widely ed but it is limited to nozzles which do not exceed half the size of e vessel. Nevertheless, an estimate of the stresses can be made by WRC lletin 107.

$$\gamma = 6.87/.25 = 27.48 \qquad \beta = \frac{.875(6.25)}{6.87} = .796$$

is gives a longitudinal stress of:

$$S = 130,000 \text{ psi}$$

ich is much too high, of course. The Code does not give limits for a scontinuity stress of this type but 3S is often used, which in this se would be 45,000 psi. Thus, the nozzle will withstand loads of proximately one third of those specified without a reinforcing pad. A x 16" O.D. pad will be required for the loads given by the specifi-tion. However, it is recommended that this pad not be added until firm zle loads are received.

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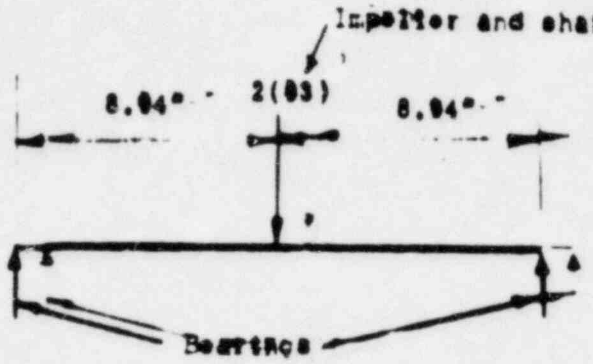
3.13 Impeller Clearance

The impeller clearance relative to the pump casing or wear ring is checked by assuming that the shaft is simply supported at the bearings and a 2g seismic load is applied. This a conservative approach.



The deflection is:

$$D = \frac{166(17.88)^3}{48(29000000)(2.33)} = .0003"$$

The impeller clearance is .015", thus o.k.

Appendix A - References

1. McDonald, C. K. , Course Notes for Short Course entitled "Dynamic Seismic Analysis of Nuclear Power Plant Components", The University of Alabama in Birmingham, 1973.
2. Fritz, R. J. , "The Effects of Liquids on the Dynamic Motions of Immersed Solids", Jr. of Engr. for Industry, ASME, Feb., 1972, pp 167-173.
3. ASME Boiler and Pressure Vessel Code, Sect. III, Nuclear Power Plant Components, 1971.
4. ASA B17.C, Code for Design for Transmission Shafting(being updated).
5. Machinery's Handbook, 15th Edition, 1956, p507.

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