ME-991

(FP #55927-01)

PRESSURE BOUNDARY CALCULATIONS

OF

HORIZONTAL PUMPS

SIZE & TYPE: 6x10x14B-CD

S.O. NO.: 14210477/80

CUSTOMER: UNITED ENGINEERS AND CONSTRUCTORS INC.

PLANT: PUBLIC SERVICE CO. OF NEW HAMPSHIRE

CUSTOMER P.O. NO.: SNH-13-9763-006-283-3

SERVICE: CONTAINMENT SPRAY PUMPS

Manufactured By

BINGHAM-WILLAMETTE COMPANY

PORTLAND, OREGON

Analysis By

McDONALD ENGINEERING ANALYSIS COMPANY, INC.

Birmingham, Alabama

CERTIFICATION STATEMENT

The pressure boundary design calculations have been made in accordance with the ASME Code Section III Class 2 1974 Edition including Winter '75 Addenda. The design conditions are 300 psig internal pressure at 300° F for the pump. The design conditions for the cooling water are 150 psig and 200° F.

The seismic analysis for this pump is contained in Bingham-Willamette Company Report No. 14210477-05.

C. K. McDonald, Ph.D., P. E.

Alabama Registration No. 9586

February 9, 1983

ALABAMA
REGISTERED
No. 9586
PROFESSIONAL
ENGINEER
CLAUDIE KENNETH McDONALD

TABLE OF CONTENTS

1. INTRODUCTION

This report includes the pressure boundary design calculations for the pump and cooling water system.

The pressure boundary calculations are contained in Section 4 of this report. A summary of results is given in Section 2.

The following procedures were used for the analysis:

(a) Nozzle Flanges

The nozzle flanges are analyzed by the procedures given in Appendix XI of the ASME Code. The nozzle flanges were analyzed for both internal pressure only and internal pressure plus external nozzle load cases. The external loads were applied to the flanges in accordance with the procedures outlined in Paragraph NC-3647 of the ASME Code.

(b) Nozzles

The stress in the nozzles at the junction of the nozzle/casing is obtained by the procedure given in the ASME Code Paragraph NC-3652, where the nozzle/casing is treated as an equivalent tee.

(c) Casing

The stress in the casing is obtained by the method in Paragraph NC-3324.3 of the ASME Code.

(d) End Cover and Bolting

The bolting is analyzed per the procedures given in Appendix XI. The end cover is analyzed as a flat head per Paragraph NC-3325.

(e) Nozzle and End Cover Reinforcement

The nozzle and end cover reinforcement is checked per ASME Code Paragraphs NC-3332 and NC-3335.

(f) Piping and Cooling Coils

The piping and cooling coils are analyzed per ASME Code Paragraphs NC-3641.

The cooling water system calculations are not usually included in the ASME Code Pressure Boundary calculations but are included herein since the design conditions were included in the specification.

2. SUMMARY OF RESULTS

The actual stress is compared to the allowable stress or the required thickness is compared to the actual thickness below.

Component	Actual	Allowable
Discharge Nozzle Stress, PSI	6,720	19,800
Suction Nozzle Stress, PSI	5,991	19,800
End Cover Bolting Stress, PSI	7,192	13,600
Mechanical Seal Bolting Stress, PSI	7,018	13,600
Discharge Flange Stress, PSI	15,958	19,800
Suction Flange Stress, PSI	15,792	19,800

Component	Actual	Required
Casing Thickness, Inches	1.125	.216
Nozzle Reinforcement, Square Inches	9.09	1.08
End Cover Thickness, Inches	1.75	1.22
End Cover Reinforcement, Square Inches	5.44	5.185
3/4" Sch. 40 Pipe Thickness, Inches	.099	.005
5/8" O.D. Tubing Thickness, Inches	.065	.003
Cooling Coil Thickness, Inches	.125	.010
Heat Exchanger Coil Thickness, Inches	.025	.006

3. LOADINGS ON PUMP

3.1 Nozzle Loads

The nozzle loads applied to the individual pump nozzles and flanges are given in Appendix B.

3.2 Internal Pressure Loading

The design pressure conditions are 300 psig at 300° F for the pump. The cooling water design conditions are 150 psig at 200° F.

4. DETAILED CALCULATIONS

4.1 Nozzle Analysis

The discharge and suction nozzle-casing intersection is approximated as a tee and analyzed per ND-3652. The nozzles have a smooth transition into the casing and thus approach a welding tee. However, the contour is not exactly the same as a welding tee. Thus, to be conservative, a stress intensification factor will be used which is that of a fabricated tee. The mean diameter of the casing is 17.625". The material is SA-351-CF8M with a casing factor of 0.8. The thickness of the casing is 1.125" minimum.

Fabricated tee: $h = \frac{1.125}{8.81} = .1277$ $\quad i = \frac{.9}{(.1277)^{2/3}} = 3.55$

(a) Discharge Nozzle

$M_x = 2600(12) + 1500(20) = 61{,}200$ in-lbs.

$M_y = 2900(12) = 34{,}800$ in-lbs.

$Z = 3.1416(3.56)^2(1.125) = 44.79$ in.^{3}

$M_z = 2600(12) + 1500(20) = 61{,}200$ in-lbs.

$M = \sqrt{(61200)^2 + (34800)^2 + (61200)^2} = 93{,}284$ in-lbs.

NC-3652.1 Equation (8)

$$S = \frac{300(17.625)}{4(1.125)} + \frac{.75(3.55)(93284)}{44.79} = 6{,}720 \text{ psi} < 1.5(.8)(16500) = 19{,}800 \text{ psi}$$

(2) Suction Nozzle

M_x = 6700(12) + 2200(20) = 124,400 in-lbs.

M_z = 6700(12) + 2200(20) = 124,400 in-lbs.

M_y = 7500(12) = 90,000 in-lbs.

$M = \sqrt{(124400)^2 + (124400)^2 + (90000)^2}$ = 197,613 in-lbs.

$Z = 3.1416(5.56)^2(1.125)$ = 109.26 $in.^3$

NC-3652.1 Equation (8)

$$S = \frac{300(17.625)}{4(1.125)} + \frac{.75(3.55)(197613)}{109.26} = 5{,}991 < 19{,}800$$

4.2 Casing Thickness

The required casing thickness per NC-3324.3 is:

$$t = \frac{PR}{S - .6P}$$

P = 300 psig

R = 9.375"

S = 16500(.8) = 13,200 psi including casting factor of .8

Thus:

$$t = \frac{300(9.375)}{13200-.6(300)} = .216"$$

The actual thickness is 1.125" minimum.

4.3 Nozzle Reinforcement

The required nozzle reinforcement (suction nozzle is worst case) per NC-3333 is:

$A = .5dt_r$

$d = 10''$ for suction nozzle

$t_r = .216''$ from Section 4.2

Thus:

$A = .5(10)(.216) = 1.08 \text{ in.}^2$

The metal available per NC-3335 is:

$A_1 = (t-t_r)d$

$t = 1.125''$

Thus:

$A1 = (1.125-.216)(10) = 9.09 \text{ in.}^2$

Therefore, the metal area available for reinforcement is greater than the required area.

4.4 Nozzle Flanges

The nozzle flanges are analyzed per ASME Code Appendix XI and NC-3647. The analyses are made by computer and are included in Appendix A.

4.5 End Cover and Bolting Analysis

Per ASME Code Appendix XI, the bolt loads are:

$Wm_1 = .785G^2P + (2b)(3.14(GmP))$

$Wm_2 = 3.14bGy$

$G = 14.75"$, mean gasket diameter

$b = .219"$, gasket seating width

$m = 2$ for 1/8" asbestos gasket

$P = 300$ psig

$y = 1600$ for 1/8" asbestos gasket

Thus:

$Wm_1 = .785(14.75)^2(300) + 2(.219)(3.14)(14.75)(2)(300) = 63,408$ lbs.

$Wm_2 = 3.14(.219)(14.75)(1600) = 16,229$ lbs.

There are 16 - 1" bolts, thus the bolt stresses are:

$S = \frac{63408}{16(.551)} = 7,192$ psi operating

$= \frac{16229}{16(.551)} = 1,841$ psi bolt up

The allowable bolt stresses for SA-193 B8M are 13,600 psi operating and 15,000 psi bolt up.

The required cover thickness per NC-3325.2 is:

$t_r = d\sqrt{CP/S + 1.9Wh_g/Sd^3}$

$d = G = 14.75$

$P = 300$ psig

$S = 18,400$ psi for SA-182 F 316

$C = .3$

$h_g = .9375"$ per Appendix XI of ASME Code

$$W = W_{m1} = 63{,}408 \text{ lbs.}$$

Thus:

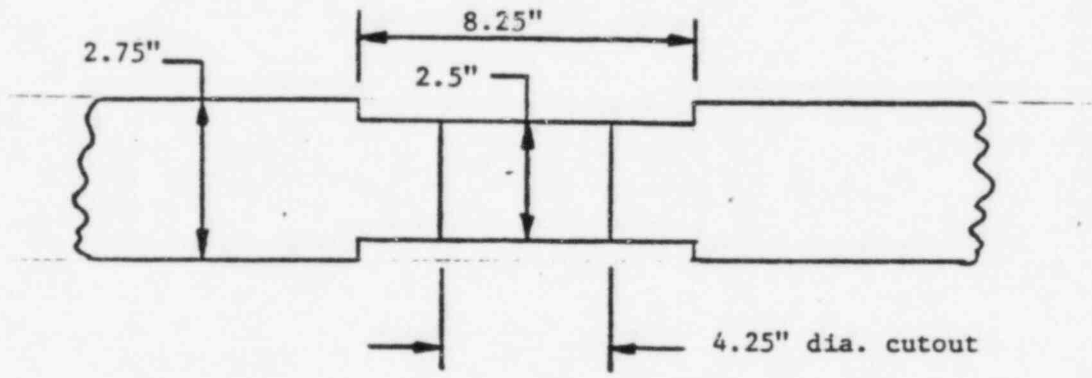
$$t_r = 14.75\sqrt{\frac{.3(300)}{18400} + \frac{1.9(63408)(.9375)}{18400(14.75)^3}}$$

$$= 1.22"$$

The actual minimum thickness of the cover is 1.75".

4.6 End Cover Reinforcement

The end cover has a cutout as shown below:



t_r = 1.22" from Section 4.5.

The required area is, per NC-3332.2:

$$A = 4.25(1.22) = 5.185 \text{ in.}^2$$

The available area per NC-3335 is:

$$A_1 = (2.5 - 1.22)(4.25) = 5.44 \text{ in.}^2$$

The available area is larger than the required area and the cover is adequate.

4.7 Mechanical Seal Assembly Bolting

The mechanical seal assembly is bolted to the end cover by 4 - 3/4" diameter studs. The gasket is "O" ring type. Thus, per Appendix XI:

$$Wm_1 = .785G^2P$$

$$P = 300 \text{ psig}$$

$$G = 6''$$

$$Wm_1 = .785(6)^2(300) = 8,478 \text{ lbs.}$$

$$S = \frac{8478}{4(.302)} = 7,018 \text{ psi}$$

The allowable for SA-193 B8M bolts is 13,600 psi.

4.8 Seal Cooling Water Piping

This piping and tubing are analyzed per NC-3641.

$$t = \frac{PD}{2(SE + .4P)}$$

D = outside diameter

t = required thickness

P = 150 psig

S = 18,800 psi for SA-312 Tp 316

E = .85 for welded pipe or tubing

Thus:

(a) 3/4" Sch. 40 Pipe

$$t = \frac{150(1.05)}{2(18800(.85) + .4(150))} = .005"$$

The actual minimum thickness is .099".

(b) 5/8" O. D. Tubing

$$t = \frac{150(.625)}{2(18800(.85) + .4(150))} = .003"$$

The actual thickness is .065".

4.9 Cooling Coil

The cooling coil is analyzed per the same equation as used in Section 4.8 except:

S = 12,000 psi for stainless steel

E = .8, casting factor

D = 1.25" maximum

$$t = \frac{150(1.25)}{2(12000(.8) + .4(150))} = .010"$$

The actual thickness is .125".

4.10 Heat Exchanger Coil

The coil is a 5/8" O.D. tube. The same equation used in Section 4.8 is used here except the pressure is 300 psig and S = 18400 psi.

$$t = \frac{300(.625)}{2(18400(.85) + .4(300))} = .006"$$

The minimum thickness is at least .025".

APPENDIX A - EXTERNAL FLANGES AND END COVER ANALYSIS

(a) Discharge Flange (Internal Pressure Only)

FLANGE INPUT DATA (SEE ASME CODE FOR NOMENCLATURE)

A = 12.5 B = 6 C = 10.62 N = 12 DB = .75
G = 7.81443454 AB = .302 T = 1.375 G1 = 1.125
G0 = 1.125 M = 3 Y = 10000 P = 300
MOM = 0 F = 0 TEMP = 300 SMALL B = .34278273

OPERATING STRESSES, PSI

	ACTUAL	ALLOWABLE
LONGITUDINAL HUB STRESS, SH	4554	19800
RADIAL STRESS, SR	5937	13200
TANGENTIAL STRESS, ST	2122	13200
(SH+SR)/2	5246	13200
(SH+ST)/2	3338	13200
OPERATING BOLT STRESS	8145	BY OTHERS
BOLT-UP BOLT STRESS	23209	BY OTHERS

FLANGE SHAPE CONSTANTS

K = 2.08333333 T = 1.47610161 Z = 1.5987526 U = 3.079947
Y = 2.80275764 V = .550103
F = .90892 SMALL F = 1
G1/G0 = 1 H/H0 = 0

FLANGE STRESS FACTORS

SMALL D = 18.4101006 SMALL E = .349843471 L (OR LAMBDA) = 1.14454763

EQUIVALENT PRESSURES

PE = 0 PFD = 300

FLANGE MOMENT ARMS, INCHES

HD= 1.7475 HG= 1.40278273 HT = 1.85639136

FLANGE LOADS, POUNDS

WM1 = 29520 WM2 = 84109

FLANGE MOMENTS, IN-LBS

MD = 14815 MG = 21237 MT = 10958 MD+MG+MT = 47010

(b) Discharge Flange (Internal Pressure + External Nozzle Loads)

FLANGE INPUT DATA (SEE ASME CODE FOR NOMENCLATURE)

A = 12.5 B = 6 C = 10.62 N = 12 DB = .75
G = 7.81443454 AB = .302 T = 1.375 G1 = 1.125
GO = 1.125 M = 3 Y = 10000 P = 300
MOM = 44123 F = 1700 TEMP = 300 SMALL B = .34278273

OPERATING STRESSES, PSI

	ACTUAL	ALLOWABLE
LONGITUDINAL HUB STRESS, SH	12642	19800
RADIAL STRESS, SR	15958	19800
TANGENTIAL STRESS, ST	5706	19800
(SH+SR)/2	14300	19800
(SH+ST)/2	9174	19800
OPERATING BOLT STRESS	21895	BY OTHERS
BOLT-UP BOLT STRESS	23209	BY OTHERS

FLANGE SHAPE CONSTANTS

K = 2.08333333 T = 1.47610161 Z = 1.5987526 U = 3.079947
Y = 2.80275764 V = .550103
F = .90892 SMALL F = 1
G1/GO = 1 H/HO = 0

FLANGE STRESS FACTORS

SMALL D = 18.4101006 SMALL E = .349843471 L (OR LAMBDA) = 1.14454763

EQUIVALENT PRESSURES

PE = 506.3 PFD = 806.3

FLANGE MOMENT ARMS, INCHES

HD= 1.7475 HG= 1.40278273 HT = 1.85639136

FLANGE LOADS, POUNDS

WM1 = 79347 WM2 = 84109

FLANGE MOMENTS, IN-LBS

MD = 39821 MG = 57084 MT = 29453 MD+MG+MT = 126358

(c) Suction Flange (Internal Pressure Only)

FLANGE INPUT DATA (SEE ASME CODE FOR NOMENCLATURE)

A = 17.5 B = 10 C = 15.25 N = 16 DB = 1
G = 12.0428932 AB = .551 T = 1.81 G1 = 1.125
GO = 1.125 M = 3 Y = 10000 P = 300
MOM = 0 F = 0 TEMP = 300 SMALL B = .353553391

OPERATING STRESSES, PSI

	ACTUAL	ALLOWABLE
LONGITUDINAL HUB STRESS, SH	6943	19800
RADIAL STRESS, SR	4931	13200
TANGENTIAL STRESS, ST	2469	13200
(SH+SR)/2	5937	13200
(SH+ST)/2	4706	13200
OPERATING BOLT STRESS	6603	BY OTHERS
BOLT-UP BOLT STRESS	15165	BY OTHERS

FLANGE SHAPE CONSTANTS

K = 1.75 T = 1.60463733 Z = 1.96969697 U = 4.00224229
Y = 3.64204801 V = .550103
F = .90892 SMALL F = 1
G1/GO = 1 H/HO = 0

FLANGE STRESS FACTORS

SMALL D = 30.8845068 SMALL E = .270987587 L (OR LAMBDA) = 1.12085983

EQUIVALENT PRESSURES

PE = 0 PFD = 300

FLANGE MOMENT ARMS, INCHES

HD= 2.0625 HG= 1.60355339 HT = 2.1142767

FLANGE LOADS, POUNDS

WM1 = 58219 WM2 = 133695

FLANGE MOMENTS, IN-LBS

MD = 48571 MG = 38589 MT = 22421 MD+MG+MT = 109581

(d) Suction Flange (Internal Pressure + External Nozzle Loads)

FLANGE INPUT DATA (SEE ASME CODE FOR NOMENCLATURE)

A = 17.5 B = 10 C = 15.25 N = 16 DB = 1
G = 12.0428932 AB = .551 T = 1.81 G1 = 1.125
GO = 1.125 M = 3 Y = 10000 P = 300
MOM = 113703 F = 2500 TEMP = 300 SMALL B = .353553391

OPERATING STRESSES, PSI

	ACTUAL	ALLOWABLE
LONGITUDINAL HUB STRESS, SH	15792	19800
RADIAL STRESS, SR	10741	19800
TANGENTIAL STRESS, ST	5379	19800
(SH+SR)/2	13266	19800
(SH+ST)/2	10586	19800
OPERATING BOLT STRESS	14385	BY OTHERS
BOLT-UP BOLT STRESS	15165	BY OTHERS

FLANGE SHAPE CONSTANTS

K = 1.75 T = 1.60463733 Z = 1.96969697 U = 4.00224229
Y = 3.64204801 V = .550103
F = .90892 SMALL F = 1
G1/GO = 1 H/HO = 0

FLANGE STRESS FACTORS

SMALL D = 30.8845068 SMALL E = .270987587 L (OR LAMBDA) = 1.12085983

EQUIVALENT PRESSURES

PE = 353.4 PFD = 653.4

FLANGE MOMENT ARMS, INCHES

HD= 2.0625 HG= 1.60355339 HT = 2.1142767

FLANGE LOADS, POUNDS

WM1 = 126822 WM2 = 133695

FLANGE MOMENTS, IN-LBS

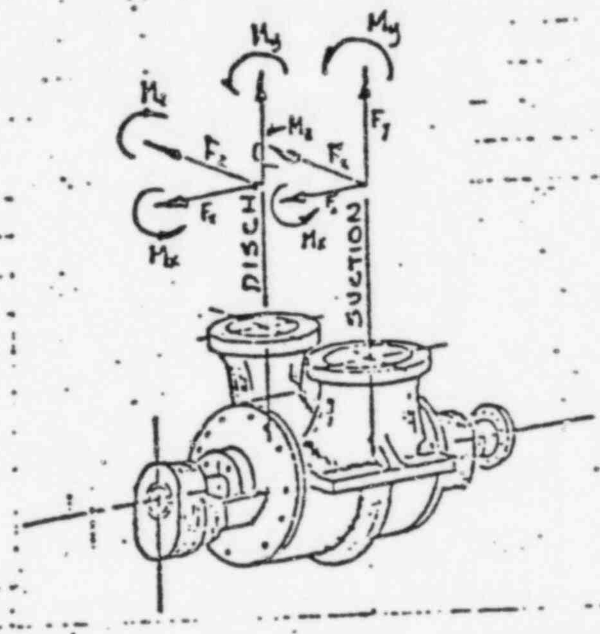
MD = 105805 MG = 84061 MT = 48841 MD+MG+MT = 238707

MAXIMUM ALLOWABLE NOZZLE LO[illegible]

DOUBLE BEARING TOP SUCTION AND DISCHARGE PUMP

APPENDIX B

FIGURE 1
SPEC. NO. 9763-006-238-3



P = 300 psig
T = 300 °F

	F_X	F_Y	F_Z	F_R	M_X	M_Y	M_Z	M_R	
SUCTION	2200	2500	2200	2750	6700	7500	6700	8400	113703
DISCHARGE	1500	1700	1500	1900	2600	2900	2600	3250	44123

FORCES IN (LB.) MOMENTS IN (FT.-LB.)

~~P = 2200~~ 2500
1700

THE RELATIONSHIP OF ACTUAL COMPONENT LOADS TO THE ALLOWABLE RESULTANT LOAD, MUST SATISFY THE EXPRESSIONS:

$$\sqrt{(F_{X\,actual})^2 + (F_{Y\,actual})^2 + (F_{Z\,actual})^2} \le F_{R\,allowable}$$

AND $$\sqrt{(M_{X\,actual})^2 + (M_{Y\,actual})^2 + (M_{Z\,actual})^2} \le M_{R\,allowable}$$

WP-

Bingham-Willamette Company	PORTLAND, OR. SHREVEPORT, LA. VANCOUVER, B.C.	United Engineers / Public Service of N.H. [illegible]	DATE: 1-27-7[illegible] CONTAINMENT SPRAY [illegible] FM-[illegible]