GPU Nuclear

TECHNICAL DATA REPORT

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PROJECT: Oyster Creek Nuclear Station	DEPARTMENT/SECTION E&D/Engineering Mechanics
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DOCUMENT TITLE: Stress Analysis for Demonstration of Operability of Purge and Vent Valves During Design Basis Accidents

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ABSTRACT:

a. Brief Statement of Problem

The subject analysis has been consequently performed per References 6.7 and 6.18 to verify that when containment purge and vent valves, greater than 3" nominal diameter, are 30° open or less, they will be capable of performing their intended function without damage to critical valve components under combined seismic and DBA-LOCA conditions, and that it is available to close these valves from 30° open when fluid dynamic torques are introduced.

Per Robert E. Weltman's letter to John L. Sullivan, Jr., dated May 16, 1980 (Reference 6.6), the valves analyzed were:

1. Drywell Purge Valves V-23-13 and V-23-14.
2. Torus Purge Valves V-23-15 and V-23-16.
3. Torus Vent Valves V-28-17 and V-28-18.
4. Drywell Vent VAlves V-27-1 and V-27-2.
5. Drywell Purge Valves V-27-3 and V-27-4.

The torque and stress analysis results for demonstration of operability of purge and vent valves per NRC guidelines as shown in References 6.8 and 6.17 are documented in Section 3.0 of this TDR.

b. Summary of Key Results

The following results were obtained when valves are 30° open or less during LOCA:

1. Each valve operator is able to restrain the total valve torque which is the sum of seating torque and fluid dynamic torque (See Table 3 in Appendix).

2. The calculated stress levels of the valve components under combined seismic and LOCA conditions are less than the LOCA allowable limits of 90 percent of the yield strength of the material used (See Table 5 in Appendix).

c. Conclusion

1. Each valve operator can overcome the total valve torque when opening the valve and restrain the total valve torque when closing the valve.

2. The structural integrity of the valves is assured if the valve openings are limited to 30° or less.

d. Recommendations

1. To ensure structural integrity, the valve opening must be limited to 30° open or less.

2. To ensure sealing integrity, the valve seats must be visually inspected and be replaced as required.

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TITLE Stress Analysis for Demonstration of Operability of Purge and Vent Valves During Design Basis Accident.

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	The conservatism of the calculated valve torques was eliminated by using 1. The curves of drywell and torus pressure transients during DBA as shown in Figure 2, 2. The valve response time following a LOCA and each valve closing time as indicated in References 6.13 and 6.14 respectively, as well as, 3. Mass and momentum equations to solve for velocity and pressure drop across each valve. The valve torques are compared with the allowable operator torques in terms of available safety factors. They are in turn compared with the NRC required safety factors as shown in Table 3. In addition, more references have been added in Section 6.	[signature] J. Shen [signature]	5/10/85 5/10/85

OYSTER CREEK NUCLEAR STATION
STRESS ANALYSIS FOR DEMONSTRATION OF OPERABILITY OF PURGE AND VENT VALVES DURING DESIGN BASIS ACCIDENTS

Table of Contents

1.0 PURPOSE AND SUMMARY

The purpose of this TDR is to document the results of the analysis for the containment purge and vent valves regarding structural adequacy to withstand the fluid dynamic torques which would occur during the faulted condition of a loss of coolant accident (LOCA) within the containment vessel (References 6.10, 6.11 and 6.12), and the design basis seismic loads per design specification (Reference 6.4).

Per Reference 6.6, valves V-23-13 and V-23-14 (Drywell Purge), V-23-15 and V-23-16 (Torus Purge), V-28-17 and V-28-18 (Torus Vent), V-27-1 and V-27-2 (Drywell Vent), and V-27-3 and V-27-4 (Drywell Purge), as shown in Figure 1, were analyzed.

The NRC guidelines for demonstration of operability of purge and vent valves dated 9/27/79 (Reference 6.8) and the NRC comments made during the meeting held on 2/13/85 in Bethesda, Maryland (Reference 6.17) have been incorporated in this evaluation.

A. Considerations

Per NRC guidelines (References 6.8 and 6.17) the following items have been considered:

1. Valve closure rate is constant per Reference 6.5. The valve response time following a LOCA and each valve closing time may be obtained from Reference 6.13 and 6.14 respectively. The fluid dynamic torques tend to close the valve and the bearing friction torques always resist the operator.
2. To qualify valve from an opening of 30° to the fully closed position, the fluid velocity and differential pressure across the valve at a specified disc position may be generated from mass conservation and momentum equations (Reference 6.15).
3. The subject valves do not use accumulators.
4. There are no torque limiting devices for the air operated valves at Oyster Creek Nuclear Station.
5. Friction losses at fittings and valves in the piping systems were considered in the analysis.

6. The required safety factors are 1.5 and 3.0 for valve shaft in plane and out of plane respectively as long as the valve is located within five pipe diameters after the elbow (Reference 6.17).

7. The drywell and torus pressure transients during DBA-LOCA were obtained from Reference 6.12 and shown in Figure 2.

B. Operator Evaluation

In evaluating the structural integrity of the valve operator, the calculated torque during LOCA was compared with the allowable torque rating of the operator per manufacturer's data to see if the available safety factor is higher than the required per Reference 6.17.

C. Stress Analysis

Based on the valve torque data (Ref. 6.9) even more conservative than those shown in Table 3, stresses generated at valve components under combined seismic and LOCA conditions were analyzed using the design rules for Class 1 valves as detailed in Paragraph NB-3540 of Section III of the ASME Boiler and Pressure Vessel Code (Reference 6.1, hereafter referred to as the Code). The calculated stress levels were compared to the code allowables, if possible, or the LOCA allowables of 90% of the yield strength of the material used.

D. Sealing Integrity

The EPDM seats for valves V-27-1, V-27-2, V-27-3, and V-27-4 have the maximum cumulative radiation resistance of 5×10^7 rads, and the Nitron seats for V-28-17, V-28-18, V-23-13, V-23-14, V-23-15, and V-23-16 have 1×10^5 rads per manufacturer's information. Decontamination chemicals have very little effect on these valve seats.

Valves at outside ambient temperature below 0°F, if not properly adjusted, may have leakage due to thermal contraction of the elastomer. However, during LOCA, the valve internal temperature would be expected to be higher than the ambient, which tends to increase sealing capability after valve closure. Since the presence of debris or damage to the seats would impair sealing, the seats must be visually inspected and be replaced as required to ensure sealing integrity.

2.0 METHODS

This study consists of fluid dynamic torque calculations, valve stress analysis, and operator evaluation. Methods are depicted as follows:

2.1 Torque Calculations

The method described in Reference 6.3 for calculating torques of butterfly valves is employed in this analysis.

The valve torques are calculated using the following formulas:

$$T_s = C_s D^2 \quad (1)$$

$$T_b = 4.71 D^2 d f \Delta p \quad (2)$$

$$T_d = C_t D^3 \Delta p \quad (3)$$

$$T_h = 3.06 D^4 \quad (4)$$

where:

T_s = seating torque in ft.-lbs.

T_b = bearing torque in ft.-lbs.

T_d = fluid dynamic torque ft.-lbs.

T_h = hydrostatic torque in ft.-lbs.

D = diameter of valve in ft.

d = diameter of shaft in inches.

Δp = pressure drop across valve in psi.

C_s = coefficient of seating torque.

C_t = coefficient of dynamic torque.

f = bearing friction coefficient = 0.25

The torque coefficients may be obtained from the valve manufacturers (Ref. 6.5). With the given drywell and torus pressure transients during DBA and valve closing characteristics, the fluid velocity and the pressure drop across each valve at a specified disc opening angle between 0° and 30°, can be generated from mass conservation and momentum equations. The total valve torque is either a combination of bearing, seating and hydrostatic torques when valve is closed or a combination of bearing and fluid dynamic torques when valve is open.

$(Tc)_1 = T_b + T_s + T_h$ (disc in the closed position) (5)

$(Tc)_2 = 1.2\ T_b + T_d$ (disc in the open position) (6)

The NRC required safety factors are 1.5 and 3 for valve shaft in plane and out of plane respectively as long as the valve is located within 5 pipe diameters after the elbows (Reference 6.17). The detailed torque calculations and available safety factors were documented in Reference 6.15.

2.2 Valve Stress Analysis

This analysis used the design rules for class 1 valves as described in paragraph NB-3540 of Section III of the ASME Boiler and Pressure Vessel Code (Reference 6.1). The requirements for class 1 valves are much more explicit than those for either class 2 or 3 valves. The analysis is conservative since the design rules for class 2 and 3 valves are exceeded by those for class 1 valves.

Valve components were analyzed based on the conservative torques obtained by considering the maximum containment design pressure as the pressure immediately in front of the valve during LOCA (Reference 6.9). The SSE seismic accelerations were simultaneously applied in each of three mutually perpendicular directions.

Seismic loads were conservatively taken as 1.5 times of the acceleration levels given in Reference 6.4. The acceleration constants gx, gy, and gz represent accelerations in the x, y, z directions respectively. In the coordinate system the x axis is defined along the pipe axis, the z axis along the shaft axis, and the y axis mutually perpendicular to the x and z axes. Valve orientation with respect to gravity was taken into account by adding an equivalent 1g load to the seismic load in the proper direction. The acceleration constants used are summarized in Table 1 in Appendix.

As shown in Reference 6.9, the calculated stress values were compared with the code allowables, if possible, or the LOCA allowables of 90% of the yield strength of the materials used. Code allowable stress levels are Sm for tensile stresses and 0.6 Sm for shear stresses. Where Sm is the design stress intensity value as defined in Appendix I, Table I-1.1 of Section III of the Code. The valve component materials are listed in Table 2 in Appendix.

2.3 Operator Evaluation

To evaluate the structural adequacy of the valve operators, the LOCA induced operating torques for valves at different disc positions have to be compared with the allowable torques for operators to see if the available safety factors are higher than the required.

3.0 RESULTS

The calculated torques and the available safety factors are summarized in Table 3 in Appendix. The maximum torque absorption capability based on manufacturer's data is also presented in the same Table. It shows that the operators are structurally adequate for valve closing from 30° open.

Table 4 in Appendix compares the minimum valve body wall thicknesses with the code required minimum thicknesses. All the valves satisfy the minimum wall thickness requirement of the Code.

The calculated stress levels of the main elements of the valves are listed in Table 5 in Appendix. Results indicate that all the valve components stresses meet the code allowable stress limits, or the LOCA allowable limits of 90% of the yield strength.

4.0 CONCLUSION

All ten (10) valves are structurally adequate if the valve opening angles are limited to 30° or less under combined LOCA, pressure, and DBA seismic loads. Structural adequacy is assured for the operators and the valve components.

5.0 RECOMMENDATIONS

1. To ensure structural integrity, the valve openings must be limited to 30° open or less from the closed position.

2. To ensure sealing integrity, the valve seats must be visually inspected and be replaced as required.

6.0 REFERENCES

6.1 ASME Boiler and Pressure Vessel Code, Section III, 1980 Edition.

6.2 Steel Valves, ANSI B16. 34-1977.

6.3 AWWA Standard for Rubber-Seated Butterfly Valves, ANSI/AWWA C504-80.

6.4 Procurement Specification No. 492-7, Air Operated Butterfly Valves, Non-N Stamped ASME III, Nuclear Safety Related - Class 1EW, Oyster Creek Nuclear Generating Station, Revision 1, Date 4/8/81.

6.5 Valve, Applicable Data from Manufacturers, A.C. Shiau letter to A. P. Rochino dated 5/15/81.

6.6 Robert E. Weltman letter to John L. Sullivan, Jr. dated May 16, 1980.

6.7 Jim Knubel letter to D. K. Croneberger dated 11/1/80.

6.8 The NRC Guidelines for Demonstration of Operability of Purge and Vent Valves, dated 9/27/79.

6.9 Oyster Creek Purge and Vent Valve Analysis Calculation Book, Calculation No. 1302X-322C-A07.

6.10 OC-Plant Description Manual, Section 2.1.9 by GE and B&R, dated December 1972.

6.11 OC-Specification S-2299-66, By B&R.

6.12 MPR-733, OC Nuclear Generating Station, Mark 1 Containment Long - Term Program, Plant Unique Analysis Report, Suppression Chamber and Vent System, August 1982.

6.13 Telecon between S. R. Deshmukh & T. G. Manning, April 1985.

6.14 OC Nuclear Generating Station Procedure No. 678.4.001, Rev. 1, 10/16/84.

6.15 GPUN Calculation No. C-1302-822-5320-009.

6.16 Operability of OC Purge and Vent Valve During Design Basis Accident, T. G. Manning letter to R. L. Lorenzo, dated 4/19/85 (EM-85-1401).

6.17 Minutes of NRC/GPUN meeting on OCNGS Containment Vent and Purge System, P. F. Wells letter to M. W. Laggart, dated 2/21/85.

6.18 GPUN TR No. AT 4269.

7.0 APPENDIX

Figures 1 and 2, as well as Tables 1 through 5 are presented in this Appendix.

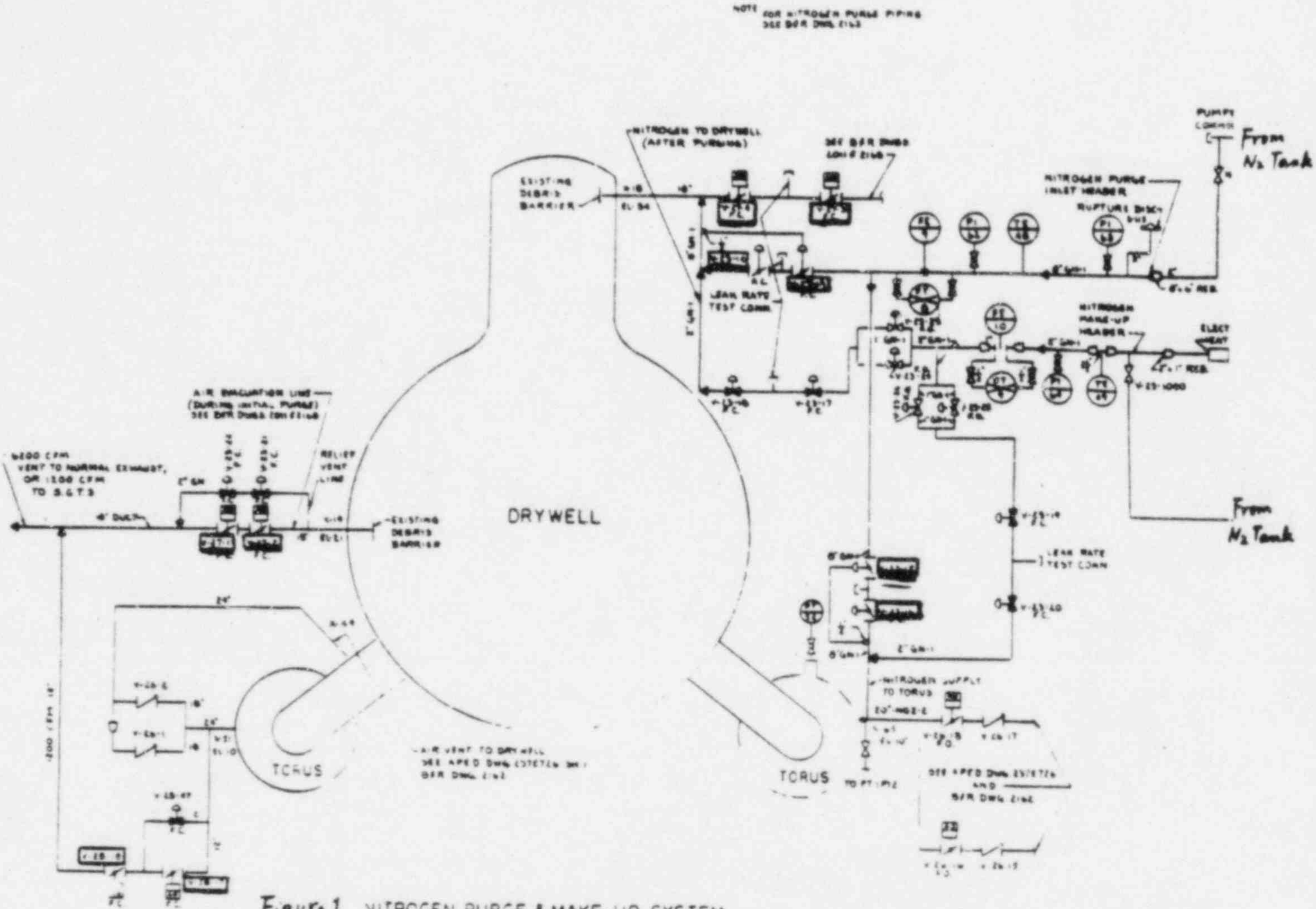

Figure 1 NITROGEN PURGE & MAKE-UP SYSTEM
(Stone & Webster Drawing No. 13432.19-1, Rev. 1.)

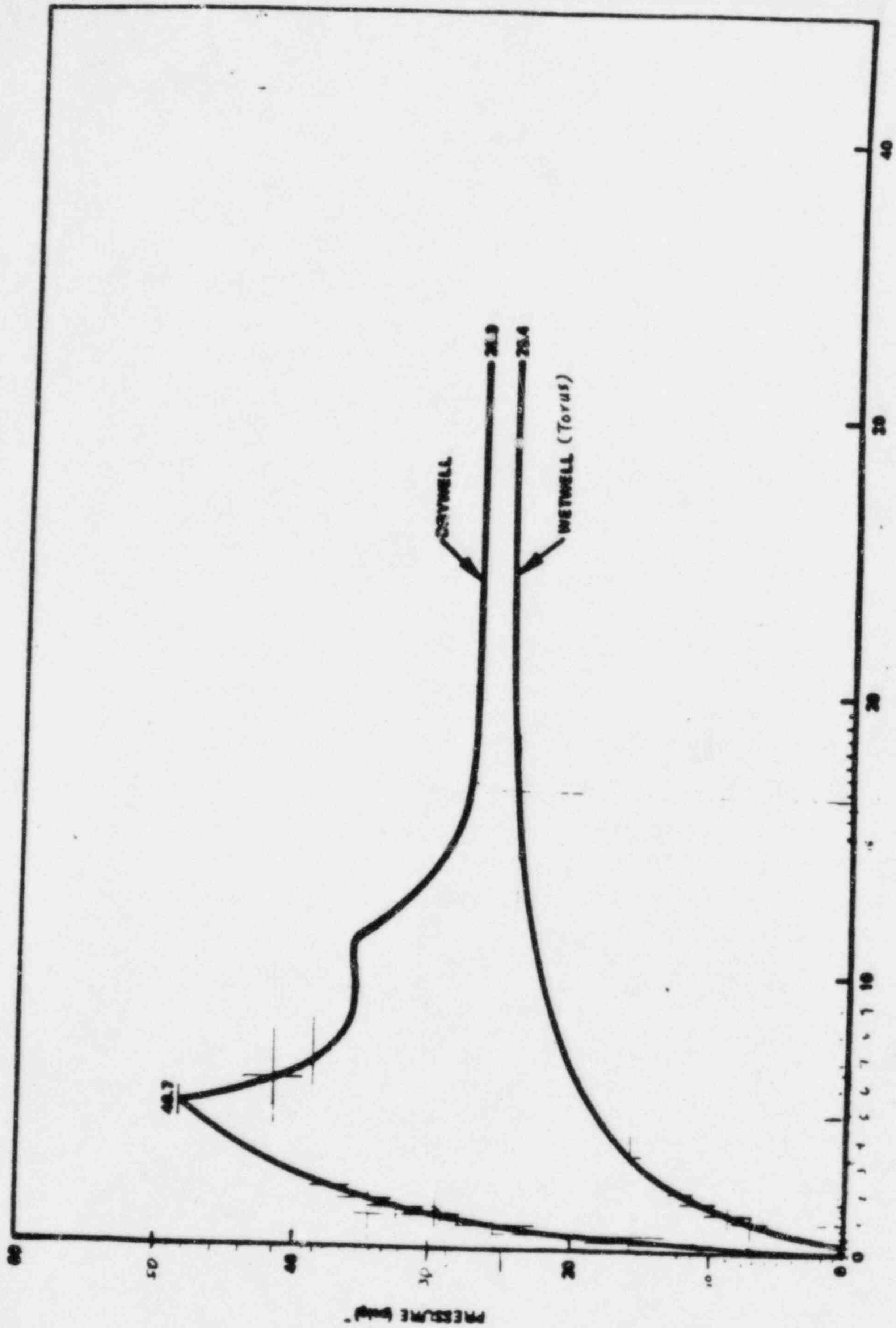

Figure 2
Figure OC 4.1.1-1b. DBA Containment Pressure Response (Zero ΔP). 4.06 ft Submergence

TABLE 1 SEISMIC LOADS

DIRECTION OF ACCELERATION	ACCELERATION LEVELS			
	Shaft Axis is Vertical		Shaft axis is horizontal	
	Values given in Reference 6.4	Values used in the Analysis	Values given in Reference 6.4	Values used in the Analysis
g_x (pipe axis)	3g	4.5g	3g	4.5g
g_y	3g	4.5g	(3+1)g	(4.5+1)g
g_z (shaft axis)	(3+1)g	(4.5+1)g	3g	4.5g

TABLE 2 MATERIALS FOR VALVE COMPONENTS

VALVE COMPONENTS	MATERIALS		
	Group A (1) Valves	Group B (2) Valves	Group C (3) Valves
Body	ASTM-A126 Class B	ASTM-A126 Class B	Carbon Steel - Plate
Disc	ASTM-A536	SA351 CF8M	Ni-resist No. 2
Shaft	ASTM-A582	17-4 PH condition 1075, SA564	316 S.S.
Shaft Key	ASTM-A582	ASTM-A304, Grade 86-30H	SAE1035
Bushings	ASTM-B438, Type 2	Teflon	Teflon
Disc Pins	304 S.S.	17-4 PH condition 1075, SA564	316 S.S.
Operator Bolts	Carbon Steel	SAE Grade 2	SAE Grade 2

Note: (1) Group A valves are V-27-1, V-27-2, V-27-3, and V-27-4, the centerline 18" valves.

(2) Group B valves are V-28-17 and V-28-18, the Fisher Controls 12" valves.

(3) Group C valves are V-23-13, V-23-14, V-23-15, and V-23-16, the Fisher Controls 8" valves.

Valve Group	Valve Designation	Valve Size (in)	Disc at 30°				Disc at 15°				Disc at 5°				Disc at 1°			
			Total Valve Torque (in-lb)	Allowable Torque for Operator (in-lb)	Safety Factor Available	Safety Factor Required	Total Valve Torque (in-lb)	Allowable Torque for Operator (in-lb)	Safety Factor Available	Safety Factor Required	Total Valve Torque (in-lb)	Allowable Torque for Operator (in-lb)	Safety Factor Available	Safety Factor Required	Total Valve Torque (in-lb)	Allowable Torque for Operator (in-lb)	Safety Factor Available	Safety Factor Required
A	V-27-1 V-27-2	18	783	16,223	20.7	3	2,004	16,223	8.1	3	2,481	16,223	6.5	3	2,762	16,223	5.9	3
	V-27-3 V-27-4	18	794	16,223	20.4	3	2,481	16,223	6.5	3	3,043	16,223	5.3	3	3,387	16,223	4.8	3
B	V-28-17 V-28-18	12	78	4,800	61.5	3	1,162	4,800	4.1	3	1,297	4,800	3.7	3	1,303	4,800	3.7	3
C	V-23-13 V-23-14	8	671	4,800	7.2	3	671	4,800	7.2	3	671	4,800	7.2	3	671	4,800	7.2	3
	V-23-15 V-23-16	8	671	4,800	7.2	3	671	4,800	7.2	3	671	4,800	7.2	3	671	4,800	7.2	3

Valve Group	Valve Designation	Valve Size (in)	Disc Completely Closed			
			Total Valve Torque (in-lb)	Allowable Torque for Operator (in-lb)	Safety Factor Available	Safety Factor Required
A	V-27-1 V-27-2	18	3,243	12,058	3.7	1
	V-27-3 V-27-4	18	3,476	12,058	3.5	1
B	V-28-17 V-28-18	12	1153.1	4,800	4.2	1
C	V-23-13 V-23-14	8	555	4,800	8.6	1
	V-23-15 V-23-16	8	555	4,800	8.6	1

Table 3 Each Valve Torque and Safety Margin at Different Disc Positions.

TABLE 4 - MINIMUM BODY WALL THICKNESS

VALVE GROUP	VALVE DESIGNATION	VALVE SIZE (in.)	ACTUAL MINIMUM BODY WALL THICKNESS (in.)	CODE REQUIRED MIN. THICKNESS PER ANSI 16.34 (in.)
A	V-27-1, V-27-2 V-27-3, V-27-3	18	0.728	0.48
B	V-28-17, V-28-18	12	1.0	0.38
C	V-23-13, V-23-14 V-23-15, V-23-16	8	0.75	0.31

TABLE 5 SUMMARY OF STRESS ANALYSIS

VALVE GROUP	VALVE COMPONENT	STRESS NAME AND SYMBOL			STRESS LEVEL (PSI)	ALLOWABLE STRESS (PSI)
A (V-27-1, V-27-2, V-27-3, V-27-4)	Body	Primary Membrane		Pm	2423	Sm 12600 , $0.9\sigma_y$ 27000
		Primary plus secondary stress due to internal pressure		Qp	7012	Sm 12600 , $0.9\sigma_y$ 27000
		pipe reaction stress	Axial	Ped	4574	1.5 Sm 18900 , $0.9\sigma_y$ 27000
			Bending	Peb	16631	1.5 Sm 18900 , $0.9\sigma_y$ 27000
			Torsion	Pet	8648	1.5 Sm 18900 , $0.9\sigma_y$ 27000
		Thermal secondary Stress		Qt	444	Sm 12600 , $0.9\sigma_y$ 27000
		Primary plus secondary stress		Sn	23885	3 Sm 37800 , $0.9\sigma_y$ 27000
	Disc	Combined Bending Stress on disc centerline		S(1)	4032	$0.9\sigma_y$ 40500
	Shaft	Torsional shear Stress		S(9)	5341	$0.9\sigma_y$ 36000
		Combined Shear stress		S(6)	6030	$0.9\sigma_y$ 36000
		Combined bending stress		S(5)	8884	$0.9\sigma_y$ 36000
		Combined stress (shear and bending)		S(4)	11931	$0.9\sigma_y$ 36000
	Shaft Key	Shear stress on key		S(16)	11664	$0.9\sigma_y$ 36000
	Disc tapper pins	Shear stress in pins		S(17)	23999	$0.9\sigma_y$ 40500
	Bushings (shaft bearing)	Bearing stress in bushings		S(21)	2191	Compressive allowable 4000
	Operator Mounting	Tension in bolts		S(54) +S(55)	1530	$0.9\sigma_y$ 51300
		Shear due to Torque on bolts		S(57)	4308	$0.9\sigma_y$ 51300
		Combined stress in bolts		S(53)	5463	$0.9\sigma_y$ 51300

TABLE 5 (Cont'd)

VALVE GROUP	VALVE COMPONENT	STRESS NAME AND SYMBOL			STRESS LEVEL (PSI)	ALLOWABLE STRESS (PSI)
B (V-28-17, V-28-18)	Body	Primary Membrane		Pm	1360	Sm 12600, 0.9 σ_y 27000
		Primary plus secondary stress due to internal pressure		Qp	3825	Sm 12600, 0.9 σ_y 27000
		pipe reaction stress	Axial	Ped	3820	1.5 Sm 18900, 0.9 σ_y 27000
			Bending	Peb	9050	1.5 Sm 18900, 0.9 σ_y 27000
			Torsion	Pet	7211	1.5 Sm 18900, 0.9 σ_y 27000
		Thermal secondary Stress		Qt	468	Sm 12600, 0.9 σ_y 27000
		Primary plus secondary stress		Sn	13237	3 Sm 37800, 0.9 σ_y 27000
	Disc	Combined Bending Stress on disc centerline		S(1)	2822	Sm 17900
	Shaft	Torsional shear Stress		S(9)	9869	0.6 Sm 27600
		Combined Shear stress		S(6)	10134	0.6 Sm 27600
		Combined bending stress		S(5)	6747	Sm 46000
		Combined stress (shear and bending)		S(4)	14054	Sm 46000
	Shaft Key	Shear stress on key		S(16)	21531	0.9 σ_y 90000
	Disc tapper pins	Shear stress in pins		S(17)	27483	0.6 Sm 27600
	Bushings (shaft bearing)	Bearing stress in bushings		S(21)	1349	Compressive allowable 10000
	Operator Mounting	Tension in bolts		S(54) +S(55)	27921	0.9 σ_y 51300
		Shear due to Torque on bolts		S((57)	21899	0.9 σ_y 51300
		Combined stress in bolts		S(53)	45613	0.9 σ_y 51300

TABLE 5 (Cont'd)

VALVE GROUP	VALVE COMPONENT	STRESS NAME AND SYMBOL			STRESS LEVEL (PSI)	ALLOWABLE STRESS (PSI)
C (V-23-13, V-23-14, V-23-15, V-23-16)	Body	Primary Membrane		Pm	1394	Sm 14500
		Primary plus secondary stress due to internal pressure		Qp	3927	Sm 14500
		pipe reaction stress	Axial	Ped	7937	1.5 Sm 21750
			Bending	Pcb	21476	1.5 Sm 21750
			Torsion	Pet	16440	1.5 Sm 21750
		Thermal secondary Stress		Qt	419	Sm 14500
		Primary plus secondary stress		Sn	25629	3 Sm 43500
	Disc	Combined Bending Stress on disc centerline		S(1)	3246	$0.9\sigma_y$ 27000
	Shaft	Torsional shear Stress		S(9)	11988	0.6 Sm 13320
		Combined Shear stress		S(6)	12296	0.6 Sm 13320
		Combined bending stress		S(5)	14599	Sm 22200
		Combined stress (shear and bending)		S(4)	21599	Sm 22200
	Shaft Key	Shear stress on key		S(16)	22318	$0.9\sigma_y$ 50500
	Disc tapper pins	Shear stress in pins		S(17)	30308	$0.9\sigma_y$ 31500
	Bushings (shaft bearing)	Bearing stress in bushings		S(21)	1612	Compressive allowable 10000
	Operator Mounting	Tension in bolts		S(54) +S(55)	24010	$0.9\sigma_y$ 51300
		Shear due to Torque on bolts		S(57)	30049	$0.9\sigma_y$ 51300
		Combined stress in bolts		S(53)	50484	$0.9\sigma_y$ 51300