ATTACHMENT 2

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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

In accordance with Reference 6.3 it is requested that the analysis be performed to verify that containment purge and vent valves are capable of performing their intended function without damage to critical valve components during the Design Basis Accident - Loss of Coolant Accident (DBA-LOCA) loads and that the valves will close when fluid dynamic torques are introduced.

According to Reference 6.6, the valves to be analyzed are:

1. Spring Closed valves AH-V-1A and AH-V-1D (Reference 6.7).

2. Motor operated valves AH-V-1B and AH-V-1C (Reference 6.7).

The stress analysis results for demonstration of operability of purge and vent valves per NRC guidelines dated 9/27/79 (Reference 6.8) are documented in Section 3.0 of this TDR.

b. Summary of Key Results

1. The valve operators are able to resist the reaction of LOCA induced fluid dynamic torques for valve opening angle up to 30° from closed position (see Table 3 in Appendix).

2. The calculated stress levels of the valve components under combined seismic and LOCA conditions meet the code allowable stress limits, or the LOCA allowable limits of 90% of the yield strength except the stress

in the shaft. The calculated shaft stress is 2% over the code allowable stress limit (See Table 5 in Appendix).

Our engineering judgement is that this slight overstress in the shaft would not create a failure situation.

c. Conclusion

1. The actuator works in cooperation with the fluid dynamic torque to close the valve. Bearing friction and seat/disc friction are the only significant effects which restrain valve closure except that, for AH- V1B/1C, the motor operator speed limits the closure rate.

2. The closing ability of the spring closed valves is assured if the valve opening is limited to 30° plus 1.75° tolerance or less, (AH-V-1A and AH-V-1D).

   The closing ability of the motor operated valves is assured if the valve opening is limited to 30° plus 3.29° tolerance or less (AH-V-1B and AH-V-1C).

d. Recommendations

Pending any further analysis and NRC acceptance the valves should be limited as follows:

1. 30° plus 1.75° tolerance open or less from the closed position for AH-V-1A and AH-V-1D.

2. 30° plus 3.29° tolerance open or less from closed position for AH-V-1B and AH-V-1C.

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REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	Page 1a - Valve angle opening tolerances added.		11/11/81
1	Page 3 - Wording changes in Paragraph D.		11/11/81
1	Page 6 - Conservative assumptions added.		11/11/81
1	Page 7 - Valve angle opening tolerances added		11/11/81
1	Page 8 - Valve angle opening tolerances added		11/11/81

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REV	SUMMARY OF CHANGE	APPROVAL	DATE
2	Page 1a - Wording changes in paragraphs "c" and "d" per plant engineering request. wlw.	[signature]	3/4/82

Three Mile Island Unit 1
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 and the design basis seismic loads.

According to Reference 6.6, the valves to be analyzed are the air operated valves AH-V-1A and AH-V-1D (Reference 6.7), and the motor operated valves AH-V-1B and AH-V-1C (Reference 6.7). These valves are Pratt 48 inch butterfly valves, model R1A. Stress analysis is performed to show the structural adequacy for a valve opening of 30° or less from the closed position.

In summary, the NRC guidelines for demonstration of operability of purge and vent valves dated 9/27/79 (Reference 6.8) has been incorporated in this evaluation.

A. Considerations

Per NRC guidelines (Reference 6.8) the following considerations have been addressed.

1. Valve closure time during a LOCA will be less than or equal to the no flow time demonstrated during shop tests, since the fluid dynamic effects tend to close the valve.
2. To qualify valves for an opening of 30° or less from the closed position, the maximum differential pressure across the valve per Reference 6.6 are used in the analysis.
3. Worst case is determined as a single valve closure with containment pressure on one side of the valve and atmospheric pressure further downstream.
4. Containment back pressure will have no effect on closing the valve.
5. The subject valves do not use accumulators.
6. There are no torque limiting devices for the air operated valves AH-V-1A and AH-V-1D. The settings of the torque limiting devices for the electric motor operated valves AH-V-1B and AH-V-1C are compatible with the torques required to operate the valve during the design basis conditions.

7. The effect of upstream piping is ignored as a conservative approach.

8. The valve disc and shaft orientation does not affect torque calculations.

B. Stress Analysis

Stress analysis of the valve components under combined seismic and LOCA conditions is performed 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 are compared to code allowables, if possible, or the LOCA allowables of 90% of the yield strength of the material used.

C. Operator Evaluation

In evaluating the structural integrity of the valve operators, the calculated torque during LOCA is compared with the maximum torque rating of the operator per manufacturer's data.

D. Sealing Integrity

Decontamination chemicals have very little effect on EPT and stainless steel seats. Molded EPT seats are generically known to have a maximum cummulative radiation resistance of 1×10^{o} rads at a maximum incidence temperature of 350°F.

Valves at outside ambient temperature below 60°F, if not properly adjusted, may have leakage due to thermal contraction of the elastomer, however, during LOCA conditions, the valve internal temperature would be expected to be higher than ambient which tends to increase sealing capability after valve closure. The presence of debris or damage to the seats would obviously impair sealing. To ensure sealing integrity, the TMI-1 preventive maintenance program requires that the valve seats be cleaned and inspected periodically for damage and deterioration and replace if required. The valves being containment isolation valves are also required to pass the Local and Integrated Leak Rate Tests.

The seats on three of the four valves were replaced prior to performing and passing the Integrated Leak Rate Test on July 5, 1981.

2.0 METHODS

This investigation consists of fluid dynamic torque calculations, valve stress analysis, and operator evaluation.

2.1 Torque Calculations

The torque of butterfly valve at any opening position is the summation of fluid dynamic torque and bearing friction torque at any given disc opening angle.

Bearing friction torque is calculated from the following equation:

$$T_B = \Delta P(A)\ (U)\ (.5d)$$

Where,

ΔP = Pressure differential, psi.

A = Projected disc area normal to flow, in^2.

U = Bearing coefficient of friction.

d = Shaft diameter, in.

Fluid dynamic torque is calculated from the following equation:

$$T_D = C_t D^3 \Delta P$$

Where,

D = Valve diameter, inches.

ΔP = Pressure differential, psi.

C_t = Torque coefficient.

The detailed torque calculations are documented in Reference 6.9.

2.2 Valve Stress Analysis

This analysis used the design rules for class 1 valves 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 for either class 2 or 3 design rules. The analysis is conservative since the design rules for class 2 and 3 valves are exceeded by the rules for class 1 valves.

Valve components are analyzed by hand caculations under the assumption that the valve is either at maximum fluid dynamic torque or seating torque during the LOCA conditions against the maximum design pressure or the maximum differential pressure across the valve per Reference 6.6. The SSE seismic accelerations are simultaneously applied in each of three mutually perpendicular directions.

A natural frequency analysis is performed for valve components in Reference 6.9. Based on the frequency results, the seismic loads are conservatively taken as 1.5 times of the acceleration levels given in Reference 6.4. The acceleration constants g_x, g_y and g_z represent accelerations in the x,y and z directions respectively. The coordinate system is defined as the x axis 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 is 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.

The detailed stress analysis is given in Reference 6.9. The calculated stress values are compared to code allowables, if possible, or 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. 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

The maximum operating torque for valve due to flow under specified LOCA conditions as calculated in Section 2.1 is used to verify the structural adequacy of the operator. The valve operator structural evaluation is based on a comparison of the calculated torque against the operator ability to resist the reaction of LOCA induced fluid dynamic torques per manufacturer's data (Reference 6.5).

3.0 RESULTS

The results for torque calculations are summarized in Table 3 in Appendix. The maximum torque absorption capability based on manufacturer's advice is also presented in the Table. The evaluation shows that the operators are structurally adequate for valve opening angle up to 30° from closed position. Table 4 in Appendix shows the minimum valve body wall thicknesses versus 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. The results indicate that the valve components stresses meet the code allowable stress limits, or the LOCA allowable limits of 90% of the yield strength except the shaft stress. The shaft stress is 2% over the code allowable stress limit (see Table 5 in Appendix). However, based on our engineering judgment, the 2% overstress in the shaft will not create failure situation.

The following conservative assumptions were made in the analysis:

1. It was assumed to have an instantaneous reactor building pressure of 50.5 psig maximum. However, the magnitude of the actual dynamic torque will be substantially less than was used in the analysis because the air-operated valves AH-V1A and AH-V1D will close in less than 2 seconds and the motor-operated valves AH-V1B and AH-V1C will close in less than 5 seconds long before the reactor building pressure of 50.5 psig is attained in approximately 10 seconds after a LOCA event. The pressure buildup in containment after 2 seconds is approximately 16 psig and after 5 seconds is approximately 35 psig.

2. Even though it is highly unlikely that both the seismic and LOCA conditions happen simultaneously, the analysis was based on the worst case of having two abnormal conditions occurred together.

3. Throttling effects from the inside containment valves AH-V1B and AH-V1C were not used. The analysis assumes that the inner valves fail wide open and that the outer valves AH-V1A and AH-V1D will have to close against the fluid dynamic forces.

4.0 CONCLUSION

All the valves are structually adequate if the valve opening angle is limited to 30^{o} plus 1.75^{o} tolerance or less for AH-V-1A and AH-V-1D valves and 30^{o} plus 3.29^{o} tolerance or less for AH-V-1B and AH-V-1C valves from closed postion. This is based on consideration of combined effects of LOCA, pressure load, 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 opening must be limited to 30° plus 1.75° tolerance open or less from the closed position for AH-V-1A and AH-V-1D valves.

2. To ensure structural integrity, the valve opening must be limited to 30° plus 3.29° tolerance open or less from closed position for AH-V-1B and AH-V-1C valves.

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 R. F. Evers' letter to D. K. Croneberger dated October 21, 1980.

6.4 Letter from R. M. Rogers of Gilbert Associates, Inc. to D. G. Slear dated July 16, 1980. "Seismic Response Curves for the Reactor Building Shell for TMI Unit 1."

6.5 Valve Applicable Data from Manufcturers, A. C. Shiau letter to A. P. Rochino dated 9/16/81.

6.6 J. F. Fritzen's letter to J. R. Holstrom of Henry Pratt Company, dated May 4, 1979.

6.7 Gilbert Associates, Inc. drawing #4192, E-311-861 Rev. 10, and drawing #4192, E-311-833, Rev. 19.

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

6.9 TMI-1 Purge and Vent Valve Analysis Calculation Book, Calculation No. 1302X-322C-A44.

7.0 APPENDIX

Tables 1 through 5 are presented in this Appendix.

TABLE 1 SEISMIC LOADS

DIRECTION OF ACCELERATION	ACCELERATION LEVELS			
	Shaft Axis is Vertical (AH-V-1B and AH-V-1C)		Shaft Axis is Horizontal (AH-V-1A and AH-V-1D)	
	Values Given in Ref. 6.4	Values Used in the Analysis	Values Given in Ref. 6.4	Values Used in the Analysis
g_x (pipe axis)	0.5g	0.75g	0.5g	0.75g
g_y	0.5g	0.75g	(0.25+1)g	(0.375+1)g
g_z (shaft axis)	(0.25+1)g	(0.375+1)g	0.5g	0.75g

TABLE 2 MATERIALS FOR VALVE COMPONENTS

VALVE COMPONENTS	MATERIALS FOR ALL VALVES
Body	ASTM A-36
Disc	ASTM A-36
Shaft	ASTM A-276, Type 316, Condition A
Shaft Key	AISI C1045, C.D. Stl.
Disc Pins	ASTM A-276, Type 316
Bottom Cover Plate	ASTM A-36
Thrust Bearing	ASTM B-164, Condition A
Operator Bolts	SAE Gr. 2
Trunnion Body	ASTM A-36
Trunnion Bolts	SAE Gr. 2

TABLE 3 SUMMARY OF TORQUE ANALYSIS FOR ALL VALVES

VALVE OPENING ANGLE (°)	TOTAL OPERATING TORQUE (in-lb.)	Max. Allowable Torque for Operator (in-lb.) Air Operator (AH-V-1A & AH-V-1D)	Max. Allowable Torque for Operator (in-lb.) Motor Operator (AH-V-1B & AH-V-1C)
0 (Fully Closed)	64111	70000	153600
5	2667	↑	↑
10	5901		
15	9335		
20	15033		
25	23570		
30	35069	42500	49000
35	56212		
40	79816		
45	102067		
50	117064		
55	138457		
60	174535		
65	209803		
70	257926		
75	307347		
80	248970		
85	155583	↓	↓
90 (Fully Open)	104	70000	153600

TABLE 4 MINIMUM BODY WALL THICKNESS

VALVE DESIGNATION	VALVE SIZE (in.)	ACTUAL MINIMUM BODY WALL THICKNESS (in.)	CODE REQUIRED MIN. THICKNESS PER ANSI 16.34 (in.)
AH-V-1A, AH-V-1B AH-V-1C, AH-V-1D	48	2.125	0.49

TABLE 5 SUMMARY OF STRESS ANALYSIS

VALVE COMPONENT	STRESS NAME AND SYMBOL			STRESS LEVEL (psi) AH-V-1A&AH-V-1D	STRESS LEVEL (psi) AH-V-1B&AH-V-1C	ALLOWABLE STRESS (psi)
Body	Primary Membrane		Pm	990	990	Sm 12600 , 0.9 σ_y 27000
	Primary plus secondary stress due to internal pressure		Qp	2970	2970	Sm 12600 , 0.9 σ_y 27000
	Pipe reaction stress	Axial	Ped	2542	2542	1.5 Sm 18900 , 0.9 σ_y 27000
		Bending	Peb	9164	9164	1.5 Sm 18900 , 0.9 σ_y 27000
		Torsion	Pet	4773	4773	1.5 Sm 18900 , 0.9 σ_y 27000
	Thermal secondary Stress		Qt	1197	1197	Sm 12600 , 0.9 σ_y 27000
	Primary plus secondary stress		Sn	13428	13428	3 Sm 37800 , 0.9 σ_y 27000
Disc	Combined Bending Stress on disc centerline		S(1)	4643	4643	Sm 12600
Shaft	Torsional Sheer Stress		S(9)	5102	5102	0.6 Sm 12000
	Combined Shear Stress		S(6)	6983	6960	0.6 Sm 12000
	Combined stress (shear and bending)		S(4)	30748	30734	1.5Sm 30000
Shaft Key	Shear stress on key		S(16)	10467	10467	0.9 81000
Disc Pins	Shear stress in pins		S(17)	13890	13890	0.9 27000

TABLE 5 (CONT'D)

VALVE COMPONENT	STRESS NAME AND SYMBOL		STRESS LEVEL (psi)		ALLOWABLE STRESS (psi)
			AH-V-1A&AH-V-1D	AH-V-1B&AH-V-1C	
Thrust Bearing	Bearing stress on thrust collar	S(22)	92	169	Sm 13600
	Shear stress in adjusting screw	S(27)	460	843	0.6 Sm 8160
	Combined stress in retainer bolts	S(28)	3325	6096	Sm 13600
	Shear tear-out of thrust retainer bolts	S(31)	472	866	0.6 Sm 8160
Bottom Cover Plate	Shear tear-out of cover bolts thru tapped holes	S(33)	1097	1237	0.6 Sm 7560
	Shear tear-out of cover bolt head thru cover	S(34)	818	922	0.6 Sm 7560
	Combined stress in cover	S(38)	673	942	Sm 12600
Operator Mounting	Shear tear-out of trunnion bolts in top trunnion tapped holes	S(42)	962	751	0.6 Sm 7560
	Bearing stress of trunnion bolt on tapped hole in trunnion	S(43)	3069	2213	Sm 12600
	Tension in bolt on top trunnion	S(47) + S(48)	5452	4259	Sm 12600
	Shear due to torque on trunnion bolts	S(50)	5364	4252	0.6 Sm 7560
	Combined stress in trunnion bolts	S(46)	10021	7454	Sm 12600
	Combined stress in operator bolts	S(53)	10198	8037	Sm 12600