Nuclear Purge Valve Stress Analysis

8007080 208

STRESS REPORT FOR

36 Inch NR1A
NUCLEAR CLASS __

PER SECTION III

ASME BOILER AND PRESSURE VESSEL CODE

PROJECT SITE Kewaunee Nuclear Power Plant

CUSTOMER Wisconsin Public Service Corp.

ENGINEER Pioneer Service & Engineering Copr.

ORIGINAL SPECIFICATION K-158

ORIGINAL PURCHASE ORDER K-158

ORIGINAL PRATT JOB NO. 7-4019-1 & 2

VALVE TAG NOS. CV-31123

CV-31124

CV-31125

CV-31126

General Arrangement Drawing E-1286 M Rev. 8

Cross Section Drawing C-1094 Rev. 1

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INDEX

I. Summary Data

II. Introduction

III. Considerations

IV. Method of Analysis

A. Torque Calculations

B. Valve Stress Analysis

C. Operator Evaluation

V. Conclusion

Attachment 1 Pressure vs. Time Graph

Attachment 2 36" NR1A Valve Stress Report

I. SUMMARY DATA

VALVE SIZE AND TYPE: 36" NR1A PRATT JOB NO.: D-028857

OPERATOR: T-516-SR3/Bettis

Standard Calculation Pressure (Design Pressure)	65	psig
Operating Pressure (Maximum)	42	psig
Acceleration Levels (Design)	5	gx
	5	gy
	5	gz
Acceleration Levels (Specified)	4	gx
	4	gy
	5	gz
Specific Design Pressure	42	psig
Minimum Valve Wall Thickness	2.25	inches
Code Required Wall Thickness	.49	inches

Form No. HPCo. 3.173

II. INTRODUCTION

This investigation has been made in response to a request by the Customer/Engineer for evaluation of the 36" containment isolation/purge valves originally furnished on Pratt Order Nos. 7-4019-1 & 2 regarding structural adequacy to withstand the dynamic torques which would occur during the faulted condition of a loss of coolant accident (LOCA) within the containment vessel. The valve assembly would be capable of closure during this event in a time equal to or less than that originally specified. Containment pressure-time data was furnished by the Customer/Engineer to identify the maximum differential pressure across the valve and to identify fluid dynamic torque coefficients. This is included as Attachment 1.

III. CONSIDERATIONS

The NRC guidelines for demonstration of operability of purge and vent valves, dated September 27, 1979 has been incorporated in this evaluation as follows:

A.

1. Valve closure time during a LOCA will be less than or equal to the no flow time demonstrated during shop tests, since fluid dynamic effects tend to close a butterfly valve.

2. In this analysis we have considered the direction of flow furnished by owner which is the direction resulting in higher torque. We have used differential pressure-time data furnished by owner. (See Attachments 1 and 2.)

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 since the same back pressure will also be present at the inlet side of the cylinder and the differential pressure will be the same during normal operation.

5. Purge valves supplied by Henry Pratt Co. do not normally include accumulators. Accumulators, when used, are for opening the valve rather than closing.

6. Torque limiting devices apply only to electric motor operators which were not furnished on purge valves for Kewaunee, Wisconsin Nuclear Plant.

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

8. For compressible fluid flow, the effects of valve orientation relative to the pipe line are considered to be insignificant.

B. This analysis consists of a static analysis of the valve components demonstrating that the stress levels under combined seismic and LOCA conditions are less than the 90% of yield strength of the materials used.

A valve operator structural evaluation is presented based on the operators ability to resist the reaction of LOCA induced fluid dynamic torques.

C. Sealing integrity can be evaluated as follows:

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 1×10^8 rads at a minimum incidence temperature of 350°F. It is recommended that seats be visually inspected every 18 months and be replaced periodically as required.

Valves at outside ambient temperatures below 0°F, if not properly adjusted, may have leakage due to thermal contraction of the elastomer; however, during a LOCA, 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.

ELBOW EFFECT ON FLOW AND MAXIMUM TORQUE

From the general (plan) drawing of containment piping and ducts installation supplied by Customer/Engineer, the shafts of purge valves are in a perpendicular plane to the inlet bend (of elbow). Closing of valves is clockwise if looked from operator end of valve which will reduce maximum torque value.

Based on theoretical limits and our test data, Δp with pipe-in inlet varies from .471 P_1 to about 0.407 P_1. With an elbow in the system this goes farther down to about 0.3 P_1 or about to 73% of the initial assumed Δp used in the computer program. Simply stated, the highest torque value will be direct valve inlet with rounded inlet throat-nozzle.

IV. METHOD OF ANALYSIS

Valve/Actuator evaluation is based on fluid dynamic torque calculation, valve stress analysis and operator evaluation.

A. Torque Calculation

The torque of any open butterfly valve is the summation of fluid dynamic torque and bearing friction torque at any given 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, in.

ΔP = Pressure differential, psi. (LIMITED TO ~ .47 P_1 MAX. AT SONIC FLOW.)

C_t = Torque coefficient.

Pratt has developed torque coefficients for different angles of disc opening based on experimental test data using 5" scale model valves with dry air as fluid medium. Such tests were performed using "on-center" disc designs at varying upstream/downstream pressure ratios of 1:1 to 4:1. Similar tests were performed for "off-center" discs at a pressure ratio of 1:1.

For the purpose of this analysis "off-center" disc torque coefficients have been derived by modification of experimentally determined "off-center" disc torque coefficients as described above, incorporating applicable pressure ratio factor.

The following computer table summarizes calculation data and torque results for valve opening angles of 0 to 90°.

The maximum valve torque due to flow under specified LOCA conditions occurs at the valve angle 75° from the closed position and is equal to 125752 in-lbs. (worst condition).

DRAFT

7-233857 TORQUE TABLE 1 5 / 30 / 80

DISC SIZE: 36 INCHES OFFSET ASYMMETRIC DISC
VALVE TYPE: R1A CLASS 75
SHAFT DIA.: 4 INCHES
BRG. COEF. OF FRCTN.: 5.00000E-03
SEATING FACTOR: 25
INLET PRESSURE: 47.7 PSIA
THROAT -SONIC PRESS.: 26.0941 PSIA-FULLY OPEN
OUTLET PRESSURE: 14.7 PSIA
MAX FLOW RATE: 288745. CFM; 667363. SCFM; 50943.7 LB/MIN
MINIMUM SONIC FLOW: 39227.3 LB/MIN
VALVE INLET DENSITY: .176432 LB/FT↑3
FULL OPEN DELTA P: 21.6059 PSI
SYSTEM CONDITIONS:
PIPE IN-PIPE OUT -AND- AIR SERVICE @ 270 DEG.F

	ANGLE	DELTA P PSI	PRESS. RATIO	THROAT (SONIC) FLOW (SCFM)	FLOW (LB/MIN)	TD	TB+TH	TO OPEN TD+TB+TH	TO CLOSE TD-TB-TH
(Closed)	0	33.00	3.245	0	0	-32400	335	32735	-32735
	5	24.70	2.074	4211	321	893	250	1143	642
	10	24.66	2.070	10744	820	2531	247	2773	2284
	15	24.60	2.065	22907	1743	4263	241	4505	4021
	20	24.52	2.058	40057	3058	8430	234	8664	8196
	25	24.42	2.049	64082	4892	12561	225	12787	12336
	30	24.29	2.038	93869	7165	21348	214	21562	21133
	35	24.15	2.025	126560	9634	33433	201	33640	33237
	40	23.98	2.011	162202	12332	47915	187	47102	46323
	45	23.38	1.996	204516	15613	61895	171	61467	61124
	50	23.60	1.979	245733	18764	74771	154	74925	74616
	55	23.39	1.962	303074	23137	84550	136	84686	84413
	60	23.16	1.944	375439	28665	95896	117	95214	94978
	65	22.92	1.925	454315	34683	101336	98	101935	101737
	70	22.67	1.906	542433	41410	112217	92	112309	112124
	75	22.41	1.886	632173	48261	125661	91	125752	125569
	80	22.15	1.867	648933	49534	111992	90	112082	111900
	85	21.88	1.847	663443	50649	93033	89	93077	92989
(Full Open)	90	21.61	1.828	667363	50943	62742	87	62830	62654

SEATING + BEARING + HUB SEAL TORQUE (M/A)= 32735 IN-LBS @ 0 DEG.
MAX.DYN. + BEARING + HUB SEAL TORQUE (M/A) = 125752 IN-LBS @ 75 DEG.

TD = Fluid Dynamic Torque

TB = Bearing Friction Torque

TH = Hub Torque

B. Valve Stress Analysis

The calculated maximum valve torque of 125752 in-lbs. resulting from LOCA conditions is less than the torque which was used for the original seismic stress analysis of the subject valve.

Since the stress levels in the analysis are below the design allowable, it is concluded that the valve assembly is structurally suitable for LOCA induced forces combined with seismic and other loads.

C. Operator Evaluation

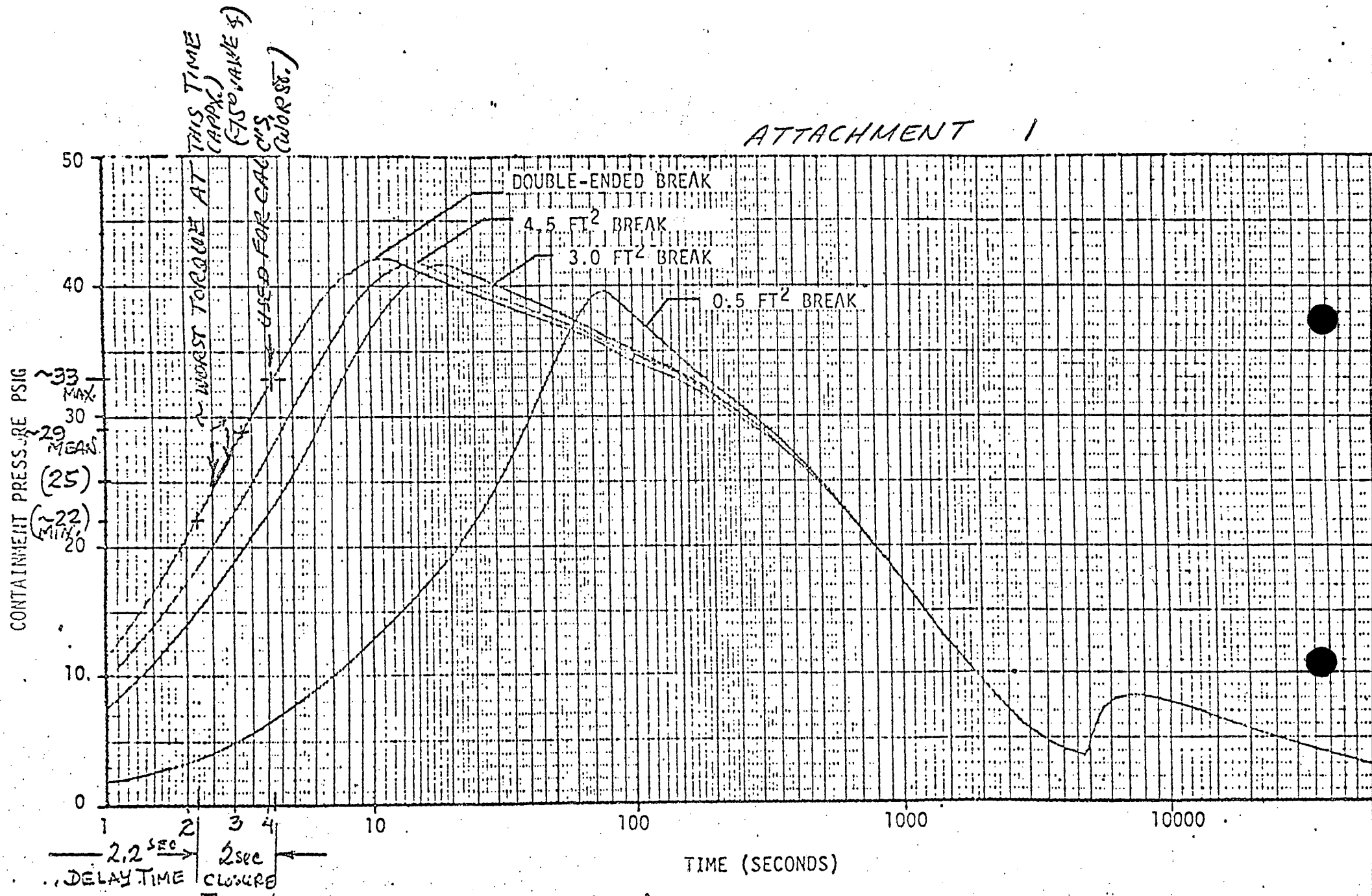
The maximum torque (125752 in-lbs.) generated during a LOCA induces reactive forces in the load carrying components of the actuator. The Bettis Model T-516-SR3 furnished has a rating of 197000 in-lbs. for these components at the full open or full closed positions.

The manufacturer has advised that the maximum torque absorption capability at any intermediate position between full open and full closed should be limited to 109000 in-lbs. Fluid dynamic torques generated by a LOCA were found to be lower than 109000 in-lbs. only for valve disc openings of 65° of less.

V. CONCLUSION

It is concluded that the valve structure during closure is adequate for the defined LOCA induced loads based on the calculated torques developed in their analysis, however, the calculated torques exceed the manufacturer's rating for the actuator except at valve disc opening angles of 65° or less.

ATTACHMENT 1



TIME 4.2 SEC. FROM "ZERO" TIME (LOCA)

Kewaunee

ATTACHMENT 2

36" NR1A VALVE STRESS REPORT

Summarized in the following two tables are valve stress intensities of primary concern. Essentially, Table I identifies body stresses and how they relate to the "Draft ASME Code for Pumps and Valves for Nuclear Power" dated Nov., 1968 and the March, 1970 Addendum. Table II identifies stresses in other elements of the butterfly valve assembly for which the pump and valve code provides no specific analysis procedure.

Depending upon the nature of the stress being considered, the allowable stress level is defined as one of the following:

1. For calculations based on code procedures, allowable stresses as specified in the code.

2. For calculations not based on code procedures, stress levels are kept below Sm for tensile stresses and .5 Sm for shear stresses. Sm is allowable stress level as specified in Tables A.1 and A.2 of the Pump and Valve Code for 300°F.

TABLE I - Body Stress Levels

Stress Name	Code Ref. Par.	Code Sym.	Analysis Ref. Pg.	Stress Level	Allowable Stress
Primary Membrane Stress Intensity	452.3	Pm	5	751	Sm 18,900
Primary & Secondary Stress due to internal pressure	452.4a	Qp	5	2,122	1.5 Sm 28,350
Secondary Stresses Due to Pipe Reaction	452.4b	Ped Peb Pet	6	1,721 4,704 3,367	1.5 Sm 28,350
Valve Body Secondary Stresses	452.4	Sn	6	7,100	3 Sm 59,700
Fatigue Stress ($N_a \geq 2,000$)	452.5	Sp	7	5,176	65,000
Primary & Secondary Stresses due to flange, pressure, and Seismic loads	Non Codified	Sa	7	1,181	1.5 Sm 28,350

Notes:

1. Seismic accelerations are 5 g's. simultaneously applied in each of three mutually perpendicular directions.
2. Analysis pressure is 65 psig.
3. Allowable stresses are at 300°F.
4. Body material is carbon steel per ASTM A516-Gr. 60.

TABLE II - Non-Codified Stress Levels

Valve Component	Stress Name	Analysis Ref. Pg.	Material	Stress Level	Allowable Stress
Trunnion Weldment Assy.	Combined Trunnion Weld Shear Stress	8	ASTM A-350 Gr. LF-1	2,150	.5 Sm 8,850
	Combined Tensile Stress in Trunnion	11	ASTM A-350 Gr. LF-1	1,635	Sm 17,700
	Combined Tensile Stress in Trunnion Base Weld	11	ASTM A-350 Gr. LF-1	1,635	Sm 17,700
	Local Bending Stress in Body	11	ASTM A-516 Gr. 60	13,000	Sm 18,900
Disc	Maximum Disc Stress	12	ASTM A-516 Gr. 60	11,740	Sm 18,900
Shaft	Maximum Shaft Stress	13	ASTM A-479 Type 304	15,730	Sm 19,800
Shaft Retainer Assembly	Retainer Shear Stress	14	ASTM A-240 Type 304	2,750	.5 Sm 9,900
	Retainer Bearing Stress	14	ASTM A-240 Type 304	14,000	Sm 19,800
	Bolt Tensile Stress	14	ASTM A-540 Cl.1,Gr.321	21,000	Sm 46,200
	Shaft Groove Shear Stress	14	ASTM A-479 Type 304	1,800	.5 Sm 9,900
Hub Block Assembly	Keyway Bearing Stress (SHEAR STR.)	15	ASTM A-350 Gr. LFI	31,438 (15,720)	.9Sm 36,000 (Sm 17,000)
	Max. Combined Bolt Stress	16	ASTM A-540 Cl.1,Gr.B21	26,565	Sm 46,200
Thrust Bearing Assembly	T. Washer Normal Bearing Stress	18	Silicon Lub Bronze	374	* 1,200
	T. Washer Seismic Bearing Stress	18	Silicon Lub Bronze	1,870	* 8,000
	Adjusting Screw Shear Stress	18	ASTM A-479 Type 316	6,240	.5 Sm 10,000
	Adjusting Screw Tensile Stress	18	ASTM A-479 Type 316	14,800	Sm 20,000
	Retaining Screw Tensile Stress	18	ASTM A-540 Cl.1,Gr.B21	17,700	Sm 46,200
	Cover Shear Stress	18	ASTM A-516 Gr. 60	2,600	15 Sm 9,450

*Not specified in pump and valve code.

NOTES:
1. Seismic accelerations are 5 g's. simultaneously applied in each of three mutually perpendicular directions.
2. Analysis pressure is 65 psig.
3. Allowable stresses are at 300° F.