MULTIPLE SUBSEQUENT SAFETY/RELIEF VALVE ACTUATION EVALUATION

FOR

E. I. HATCH
NUCLEAR PLANT UNIT 2
MARK I CONTAINMENT
DOCKET NO. 50-366

PREPARED

FOR

GEORGIA POWER COMPANY
SOUTHERN COMPANY SERVICES, INC.

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1.0 INTRODUCTION

In July 1978, the torus and support system for the Hatch Nuclear Plant Unit 2 were evaluated for effects of a multiple subsequent Safety-Relief valve(SRV)actuation due to isolation event (Reference 1). The evaluation was performed by extrapolating data from an SRV discharge test performed at the Peach Bottom Unit 2 plant. Subsequent to the evaluation, an SRV discharge test was performed at the Hatch Unit 2 plant in October, 1978. Thus the present report represents a revision of Reference 1, wherein the evaluation of the torus for multiple subsequent SRV actuation has been repeated, based on the plant unique data taken in the Hatch Unit 2 SRV test.

In the evaluation, the Hatch Unit 2 test data has been extrapolated to account for differences between test and setpoint pressure, for the higher loading which would occur in the subsequent actuation condition, and for the superposition of multiple valves actuating simultaneously. Two cases have been considered in the evaluation: Subsequent simultaneous actuation of the four lowest setpoint valves, and subsequent simultaneous actuation of all eleven valves (see Figure 1). The extrapolation of data from the test conditions to the two cases evaluated has been carried out using procedures specified by General Electric in Reference 3.

The evaluation included general membrane stresses in the torus shell, torus column loads, and stresses in the column to torus welds. The calculated stresses were compared with acceptance criteria for the Mark I Short Term Program (STP). The evaluation procedure and results are described herein.

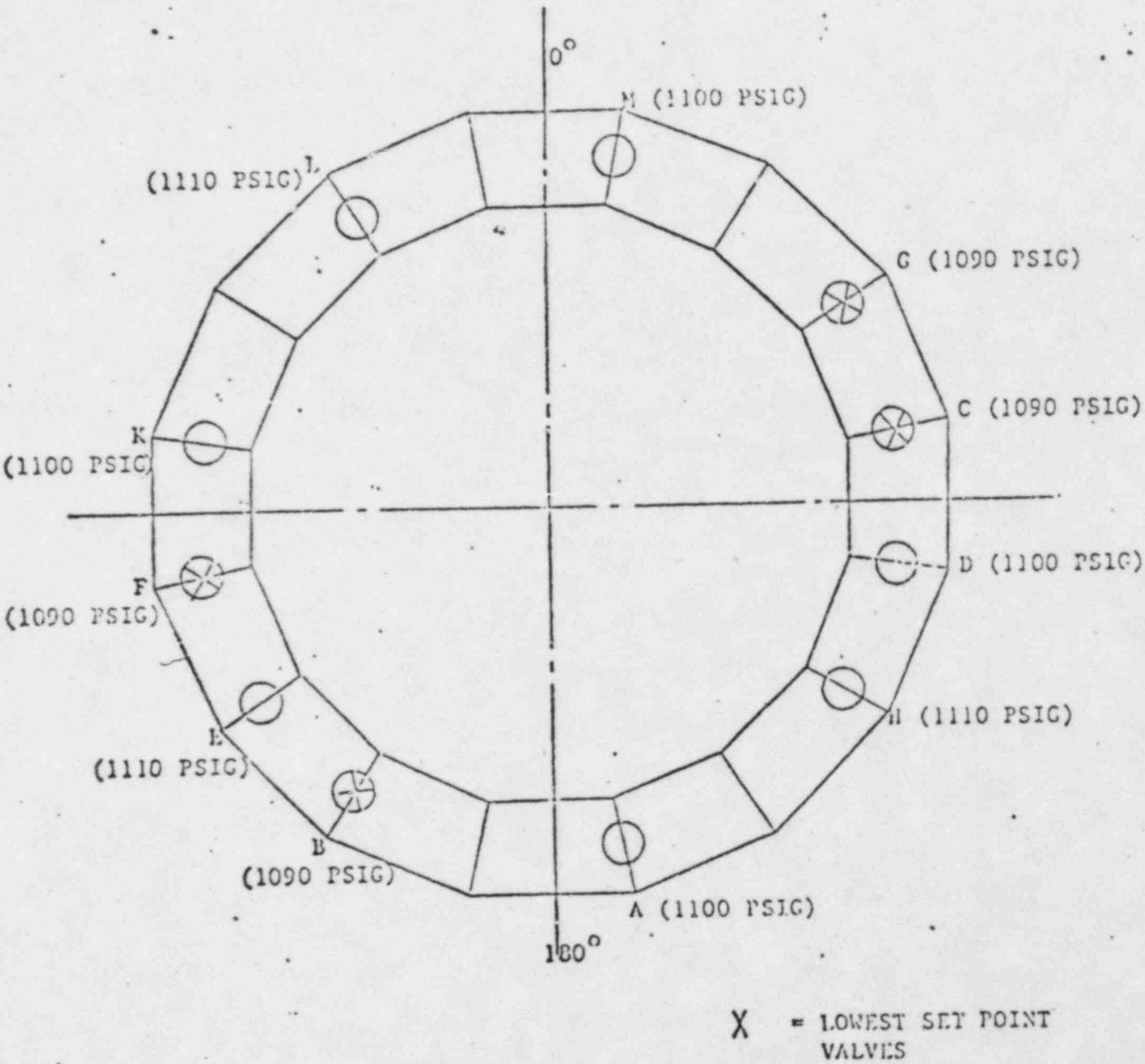

FIGURE 1: SAFETY RELIEF VALVE RAMSHEAD LOCATIONS AND SET POINTS FOR HATCH UNIT 2

2.0 EVALUATION PROCEDURE

Based on the information available from the ongoing Mark I program, the Hatch 2 torus support system would experience the highest loads following the actuation of the safety relief valve D. Thus, the evaluation was based on the preliminary information measured for a single actuation of safety relief valve D in the cold condition. The measured data on maximum shell stress and outside column load formed the baseline for the evaluation. The approach used in the evaluation is consistent with Reference 3.

The baseline data was extrapolated to predict response for the multiple valve second actuation cases. Consecutive valve actuation factors obtained from Reference 3 were applied to account for the "Hot Pop" effect. Since the Hatch Unit 2 SRV test data was obtained at reactor pressures slightly lower than the SRV setpoint pressures, a multiplier was applied to account for the "pressure difference" effect.

The procedures in Reference 3 were used to determine the effect of simultaneous actuations of multiple valves. Attenuation curves were applied to determine shell stress and column load in the test bay based on position of each valve in the multiple actuation. The attenuation curves were derived from results of testing at Monticello(Reference 3) and Peach Bottom (Reference 2), which included actuations of various valves outside the test bay. Peach Bottom was selected as a reference since it has eleven (11) SRV's in 4-4-3 setpoint grouping, SRV ramsheads located on torus ring girders, and full saddle supports for the torus, all similar to Hatch 2.

The evaluation was performed for general membrane stresses in the torus shell, column loads, and stresses in the column-to-torus weld connections. The results were compared against acceptance criteria for the Mark I Short Term Program. The procedure is described below.

2.1 Consecutive actuation Factors

Consecutive actuation factors of 2.37 for torus shell stress and 1.96 for column load, as recommended by General Electric in Reference 3, were applied to account for the higher discharge loading in the hot condition.

2.2 SRV Setpoint Pressure to Reactor Pressure Multiplier

The test data for the Hatch Unit 2 was obtained for a cold actuation of Valve D, with reactor pressure at approximately 973 psig. The SRV pressure setpoints are at 1090-1110 psig. Therefore, the data must be corrected to setpoint pressure. The reactor pressure to setpoint pressure multipliers were calculated by applying the analytical methods described in Reference 5. The multipliers were found to be 1.09 for the four valve case (extrapolation to lowest setpoint pressure) and 1.10 for the eleven valve case (extrapolation to highest setpoint pressure).

2.3 Shell Stress Multiplier

In the Hatch Unit 2, all shell stresses were measured using strain gages on the outside of the torus shell. The measured stresses thus reflect membrane and bending components, while the shell structural integrity is judged relating to the membrane component. In accordance with the General Electric recommendation in Reference 3, the measu-ed shell stresses were divided by a factor of 1.17 to obtain the shell membrane stresses.

2.4 Structural Response Attenuation

Figure 2 and 3 show the attenuation curves for the torus shell stress and column load. The shell stress attenuation curve in Figure 2 was obtained from the results of Peach Bottom SRV discharge test (Reference 2). The column load attenuation curve in Figure 3 was given by General Electric in Reference 3. The Peach Bottom data is indicated on Figure 3 for comparison. Multipliers were taken from the curves for each valve included in the combination, based on location in the torus.

2.5 Acceptance Criteria

Dead weight, hydrostatic pressure and seismic effects were added to shell stresses and column loads calculated as above. In accordance with the NRC requirements for the evaluation (Reference 6), the results were compared with the STP acceptance criteria. The STP criteria were defined in terms of strength ratio. The strength ratio for an element is the stress (or strain) in the element for a given applied load divided by the lower bound of the value of stress (or strain) for which one would predict failure of the element. The STP criteria, described in Reference 7, require that a strength ratio of 0.5 may not be exceeded for any component.

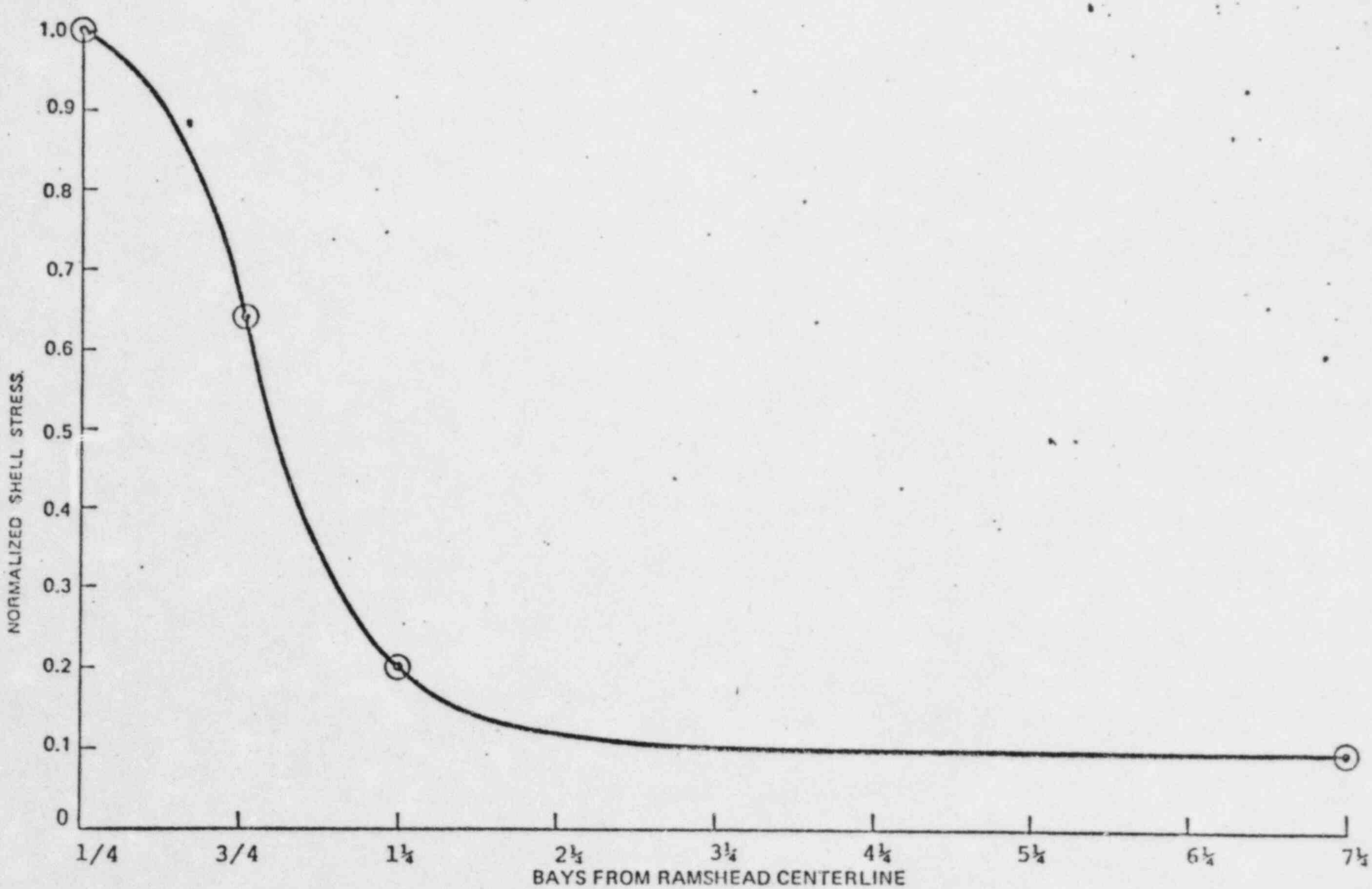

FIGURE 2 TORUS SHELL STRESS ATTENUATION
RING GIRDER DISCHARGES
(FROM PEACH BOTTOM TEST DATA IN REFERENCE 2)

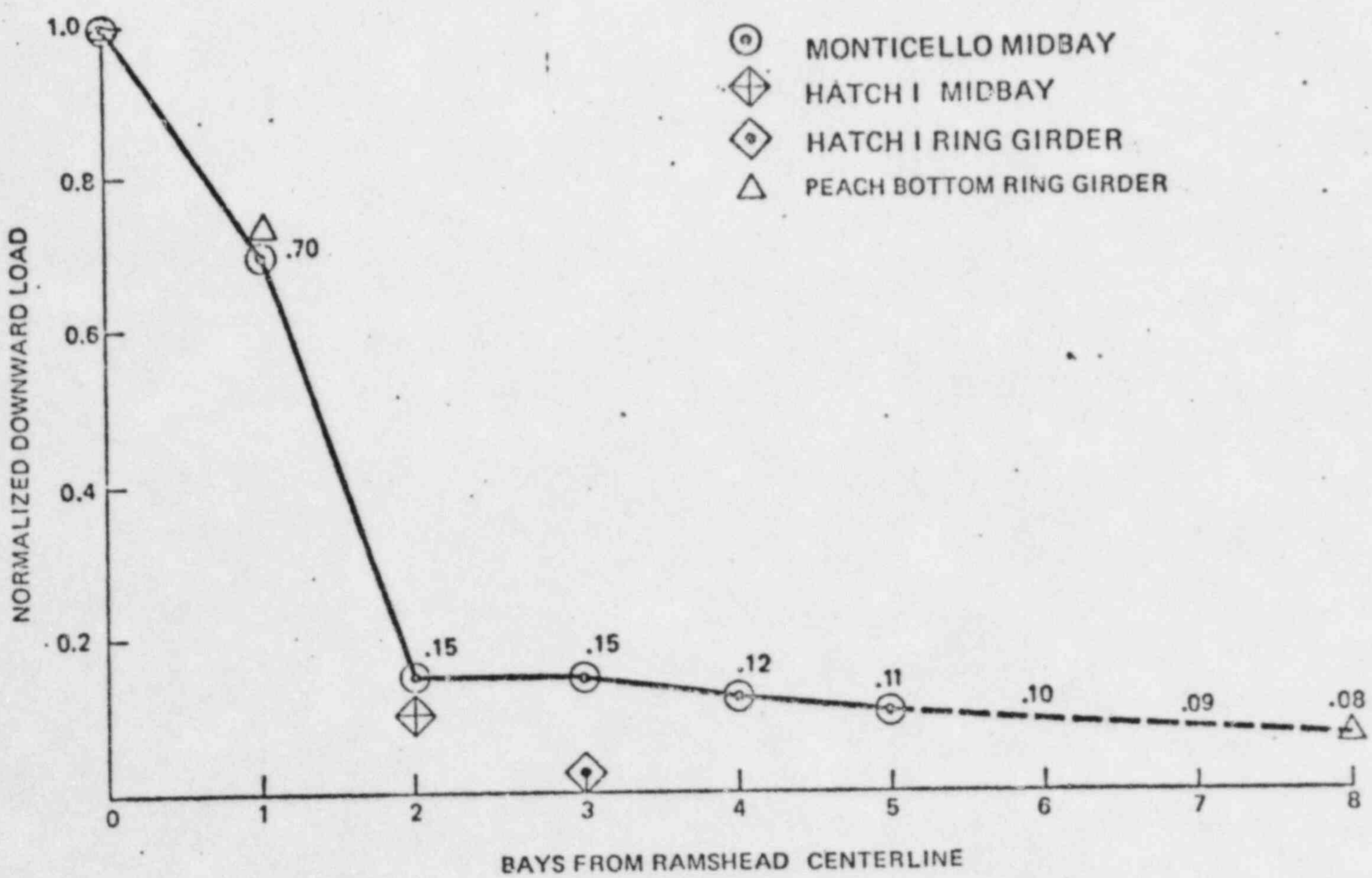

FIGURE 3 TORUS COLUMN LOAD ATTENUATION
(FROM GENERAL ELECTRIC REFERENCE 3 REPORT)

3.0 CALCULATIONS

The actual calculations to determine strength ratios for the torus shell, columns, and column-to-torus connections are given below. Calculations are presented for a four valve case and an eleven valve case.

3.1 Four Valve Case

In the first case, the four lowest setpoint valves were assumed to undergo subsequent simultaneous actuation. Referring to Figure 1, the lowest setpoint valves are G, C, B and F. The evaluation follows.

3.1.1 Torus Shell

The highest measured shell stress for single valve cold actuation occurred at torus quarter span, along the axis of the ramshead discharge. Based on preliminary data, this measured value was estimated to be 7.7 ksi (Reference 9). The calculations for multiple second actuation follow:

Maximum shell membrane stress for single valve cold actuation $= 7.7/1.17 = 6.6$ ksi

Factor for multiple actuation:

From Figure 2

Multiplier for Valve C = 1.0

Multiplier for Valve G = 0.64

Multiplier for Valve B = 0.11

Multiplier for Valve F = 0.10

Net multiplier

$$= 1.2 \sqrt{(1.0)^2 + (0.64)^2 + (0.11)^2 + (0.10)^2} = 1.44$$

Consecutive actuation factor = 2.37

SRV setpoint pressure to reactor pressure multiplier = 1.09

Resultant shell stress due to SRV discharge

$$= (1.44)(2.37)(1.09)(6.6) = 24.6 \text{ ksi}$$

Shell stress due to dead weight, hydrostatic pressure and earthquake was taken from Reference 8, = 1.4 ksi.

Total shell stess = 24.6 + 1.4 = 26.0 ksi

The yield stress for the SA 516 Grade 70 torus material is 38 ksi. Since the calculated stress is within yield and the strength ratio is about 0.34, it satisfies the Short Term Program Acceptance Criteria.

3.1.2 Columns

The maximum column load measured at Hatch Unit 2 for a single valve cold actuation was 84 kips (Reference 9). This value was measured near the top of the outside column. In a torus with saddle supports, column load is greater at the bottom than at the top, due to load transfer by shear from the web

of the saddle. In the Peach Bottom SRV test (Reference 2), load measured at the top of the column was approximately 80% of that at the bottom. This ratio was applied for Hatch Unit 2, since the saddle design is similar to Peach Bottom, resulting in a baseline outside column load of 84/.80 = 105 kips. Inside column loads were conservatively taken equal to the outside column loads. The calculations for multiple valve second actuation follow:

Factor for multiple actuation:

From Figure 3, reading abscissa for ring girder discharge

Multiplier for Valve C = 1.0

Multiplier for Valve G = 0.70

Multiplier for Valve B = 0.10

Multiplier for Valve F = 0.08

Net multiplier = 1.0 + 0.70 + 0.10 + 0.08 = 1.88

Consecutive actuation factor = 1.96

SRV setpoint pressure to reactor pressure multiplier = 1.09

Resultant compressive column load

Outside column = (1.88)(1.96)(1.09)(105) = 422 kips

Inside colum = (1.88)(1.96)(1.09)(105) = 422 kips

Column loads due to dead weight, hydrostatic pressure and earthquake were taken from Reference 8.

Outside column = 92 kips

Inside column = 74 kips

Total column load

Outside column = 422 + 92 = 514 kips

Inside column = 422 + 74 = 496 kips

To calculate strength ratio for the columns, capacity was taken as 1.6 times CRC static capacity (Reference 7).

On this basis:

Outside column SR $= \frac{514}{3120} = 0.16 \leq 0.5$

Inside column SR $= \frac{496}{1970} = 0.25 \leq 0.5$

3.1.3 Column-to-Torus Connection

The maximum load measured near the top of the outside column, for a single valve cold actuation was 84 kips (Reference 9). The load on the inside column was conservatively assumed equal to that on the outside column. Calculations for multiple valve second actuation follow:

Factor for multiple actuation:

From Figure 3, reading absicissa for ring girder discharge

Multiplier for Valve C = 1.0

Multiplier for Valve G = 0.70

Multiplier for Valve B = 0.10

Multiplier for Valve F = 0.08

Net multiplier = 1.0 + 0.70 + 0.10 + 0.08 = 1.88

Consecutive actuation factor = 1.96

SRV setpoint pressure to reactor pressure multiplier = 1.09

Resultant column-to-torus connection force:

Outside column connection

$$= (1.88)(1.96)(1.09)(84) = 337 \text{ kips}$$

Inside column connection

$$= (1.88)(1.96)(1.09)(84) = 337 \text{ kips}$$

Column-to-torus connection forces due to dead weight, hydrostatic pressure and earthquake were taken from Reference 8.

Outside column connection = 74 kips

Inside column connection = 58 kips

Total column-to-torus connection loads:

Outside column connection = 337 + 74 = 411 kips

Inside column connection = 337 + 58 = 395 kips

The capacity of the connection was calculated in accordance with Reference 7, Appendix A. On this basis:

Strength ratios are:

Outside column connection $= \frac{411}{2810} = 0.15 \leq 0.5$

Inside column connection $= \frac{395}{2119} = 0.19 \leq 0.5$

3.2 Eleven Va[illegible]e Case

In the second case, all eleven valves were assumed to undergo subsequent simultaneous actuation. The evaluation follows.

3.2.1 Torus Shell

As described above, the highest measured shell stress was 7.7 ksi at quarter span. The procedure is as before.

Maximum shell membrane stress for single valve cold actuation

= 7.7/1.17 = 6.6 ksi

Factor for multiple actuation:

From Figure 2

Multiplier for Valve C = 1.0

Multiplier for Valve G = 0.64

Multiplier for Valve D = 0.20

Multiplier for Valve H = 0.13

Multiplier for Valve M = 0.12

Multiplier for Valve L = 0.11

Multiplier for Valve A = 0.11

Multiplier for Valve K = 0.11

Multiplier for Valve B or Valve E = 0.11

Multiplier for Valve F = 0.10

Net multiplier

$= 1.2 \sqrt{(1.0)^2+(0.64)^2+(0.20)^2+(0.13)^2+(0.12)^2+(5)(0.11)^2+(0.10)^2}$

= 1.49

Consecutive actuation factor = 2.37

SRV setpoint pressure to reactor pressure multiplier = 1.10

Resultant shell stress due to SRV discharge

= (1.49)(2.37)(1.10)(6.6) = 25.6 ksi

Shell stress due to dead weight, hydrostatic pressure and earthquake was taken from Reference 8, = 1.4 ksi

Total shell stress = 25.6 + 1.4 = 27.0 ksi

The yield stress for the SA 516 Grade 70 torus material is 38 ksi. Since the calculated stress is within yield, and the strength ratio is about 0.36, it satisfies Short Term Program Acceptance Criteria.

3.2.2 Columns

From Section 3.1.2, the maximum column loads for a single valve cold actuation were:

Outside column = 105 kips

Inside column = 105 kips

Factor for multiple actuation:

From Figure 3, reading abscissa for ring girder discharge

Multiplier for Valve C = 1.0

Multiplier for Valve G or D = 0.70

Multiplier for Valve H = 0.15

Multiplier for Valve M = 0.15

Multiplier for Valve L = 0.11

Multiplier for Valve A = 0.12

Multiplier for Valve K or E = 0.09

Multiplier for Valve B = 0.10

Multiplier for Valve F = 0.08

Net multiplier = 1.0 + (2)(0.70) + (2)(0.15) + 0.12 + 0.11 + 0.10 +(2)(0.09) + 0.08 = 3.29

Consecutive actuation factor = 1.96

SRV setpoint pressure to reactor pressure multiplier = 1.10

Resultant compressive column load

Outside column = (3.29)(1.96)(1.10)(105) = 745 kips

Inside column = (3.29)(1.96)(1.10)(105) = 745 kips

Column loads due to dead weight, hydrostatic pressure and earthquake were taken from Reference 8.

Outside column = 92 kips

Inside column = 74 kips

Total column load

Outside column = 745 + 92 = 837 kips

Inside column = 745 + 74 = 819 kips

To calculate strength ratio for the columns, capacity was taken as 1.6 times CRC static capacity (Reference 7). On this basis:

Outside column SR = $\frac{837}{3120} = 0.27 \leq 0.5$

Inside column SR = $\frac{819}{1970} = 0.42 \leq 0.5$

3.2.3 Column-to-Torus Connection

The maximum loads measured near the tops of the columns, for a single valve cold actuation, were:

Outside column connection = 84 kips

Inside column connection = 84 kips

Factor for multiple actuation:

From Figure 3, reading abscissa for ring girder discharge

Multiplier for Valve C = 1.0

Multiplier for Valve G or D = 0.70

Multiplier for Valve H = 0.15

Multiplier for Valve M = 0.15

Multiplier for Valve L = 0.11

Multiplier for Valve A = 0.12

Multiplier for Valve K or E = 0.09

Multiplier for Valve B = 0.10

Multiplier for Valve F = 0.08

Net multiplier

= 1.0 + (2)(0.70) + (2)(0.15) + 0.12 + 0.11 + 0.10 + (2)(0.09) + 0.08 = 3.29

Consecutive actuation factor = 1.96

SRV setpoint pressure to reactor pressure multiplier = 1.10

Resultant column-to-torus connection force

Outside column connection

= (3.29)(1.96)(1.10)(84) = 596 kips

Inside column connection

= (3.29)(1.96)(1.10)(84) = 596 kips

Column-to-torus connection forces due to dead weight and earthquake were taken from Reference 8

Outside column connection = 74 kips

Inside column connection = 58 kips

Total column connection load

Outside column connection = 596 + 74 = 670 kips

Inside column connection = 596 + 58 = 654 kips

The capacity of the connection was calculated in accordance with Reference 7, Appendix A. On this basis:

Strength ratios are:

$$\text{Outside column connection} = \frac{670}{2810} = 0.24 \leq 0.5$$

$$\text{Inside column connection} = \frac{654}{2119} = 0.31 \leq 0.5$$

4.0 RESULTS AND CONCLUSIONS

The results of the evaluation for the four valve case are summarized in Table 1. The maximum primary membrane stress intensity calculated for the torus shell was about 26.0 ksi, which is within yield strength of the material, and thus, well within the required margin of two against failure. The worst case strength ratio for support system components was found to be that for the inside column. The calculated strength ratio for the inside column was 0.25, which satisfies the STP acceptance criteria of 0.5.

The results of the evaluation for the eleven valve case are summarized in Table 2. The maximum primary membrane stress intensity calculated for the torus shell was about 27.0 ksi, which is also within yield strength of the material. The worst case strength ratio for support system components was again found to be that for the inside column. The calculated strength ratio for the inside column was 0.42, which satisfies the STP acceptance criteria of 0.5.

TABLE 1

SUMMARY OF RESULTS

FOR HATCH UNIT 2

SUBSEQUENT SIMULTANEOUS ACTUATION OF FOUR LOWEST SETPOINT VALVES

EVALUATION AGAINST STP CRITERIA

LOCATION	STRESS CATEGORY OR LOAD	EXTRAPOLATED FOUR VALVE HOT POP	STRENGTH RATIO
DISCHARGE ℄ AT ½ SPAN	SHELL P_m	26.0 ksi	0.34
OUTER COLUMN	AXIAL FORCE AT BOTTOM	514 kips	0.16
OUTER COLUMN-TORUS CONNECTION	AXIAL FORCE AT TOP	411 kips	0.15
INNER COLUMN	AXIAL FORCE AT BOTTOM	496 kips	0.25
INNER COLUMN-TORUS CONNECTION	AXIAL FORCE AT TOP	395 kips	0.19

TABLE 2

SUMMARY OF RESULTS

FOR HATCH UNIT 2

SUBSEQUENT SIMULTANEOUS ACTUATION OF ELEVEN VALVES

EVALUATION AGAINST STP CRITERIA

LOCATION	STRESS CATEGORY OR LOAD	EXTRAPOLATED ELEVEN VALVE HOT POP	STRENGTH RATIO
DISCHARGE ¢ AT ¼ SPAN	SHELL P_m	27.0 ksi	0.36
OUTER COLUMN	AXIAL FORCE AT BOTTOM	837 kips	0.27
OUTER COLUMN-TORUS CONNECTION	AXIAL FORCE AT TOP	670 kips	0.24
INNER COLUMN	AXIAL FORCE AT BOTTOM	819 kips	0.42
INNER COLUMN-TORUS CONNECTION	AXIAL FORCE AT TOP	654 kips	0.31

5.0 REFERENCES

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