ANALYSIS OF 42" - R1A8
CLASS 75 BUTTERFLY VALVES
AT ZION NUCLEAR STATION
FOR
COMMONWEALTH EDISON COMPANY

Final Report

Volume No. 1

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CYGNA

Calculation Cover Sheet

Project	Zion Units 1 & 2	Job No.	83003
		File No.	83003/1/F
Client	Commonwealth Edison	Calc. Set No.	1008
		No. of Sheets	404 (W/Appendices)

Subject

Dynamic Torque Analysis of 42" - R1A8 Butterfly Valves for Zion Units 1 & 2

Statement of Problem

To determine the dynamic torque and resulting component stresses for the subject valves due to Containment Back-pressure Effects (CBE).

Sources of Data

1. Drawing Set by H. PRATT, supplied by Commonwealth Edison. (Input Document No. 83003-DID-001)
2. Flow coefficient data supplied by H. PRATT. (Input Document No. 83003-DID-002)

Sources of Formulae & References

1. See Section 7.0 of Report.
2. Cygna computer binder 83003/1/F.

Remarks

All components satisfy the stress analysis criteria.

Originators	Checkers	Distribution	Revision No. 0
J. M. Foley	R. P. Casassa		Supersedes Calculation Set No. N/A
B. A. Bouton	J. M. Foley		
A. D. Ho	D. A. Ferg		Approved By [signature] Date 12-16-82

1005.00

Calculation Sheet	Prepared By [signature]	Date 12/15/82
Project Commonwealth Edison	Checked By R P Carana	Date 12/16/82
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EXECUTIVE SUMMARY

This analysis was performed to qualify the 42" R1A8 Class 75 containment purge valves for Commonwealth Edison's Zion Station Units 1 and 2. The analysis was to determine whether or not the butterfly purge valves, when subjected to a worst-case containment pressure transient, will close within a specified time interval and therefore accomplish their intended safety function. The time dependent torque profile developed on the valve stem due to the containment pressure transient was calculated for valve closing times of 5 seconds and 8 seconds after the onset of the postulated containment pressure.

The dynamic torque profiles were applied to a mathematical model of the valve consisting of beam and plate finite elements to represent the mass and stiffness of the valve disc and valve stem. The resultant stresses in the valve stem and valve disc were calculated using the ANSYS code and compared with the ASME code allowables.

Based on an acceptance criteria that the calculated stresses remain below code-allowable yield stresses at all times during the containment pressure trainsient, the results of this conservative analysis indicate the purge valves would have sufficient strength and integrity to close from a full-open position even under design-basis accident conditions.

1.0 INTRODUCTION

This report will examine the effects of the flow induced dynamic torque on the 42" R1A8 containment isolation/purge butterfly valves. First, the flow time history for both the 5 second and 8 second closing times is determined. This analysis will be based primarily on the containment pressure vs. time curve for all available energies (Ref. 13) and a set of general equations relating the piping system configuration to the flow rate. From the flow analysis, the maximum torque on the system will be calculated and applied to the finite element model of the disk assembly. Critical stresses for both closing times can be extracted from the finite element analyses. These stresses will then be compared to appropriate allowables from the ASME Boiler and Pressure Vessel Code.

The following Valve Tag Numbers are covered by the report:

1AOV-RV0001	2AOV-RV0001
1AOV-RV0002	2AOV-RV0002
1AOV-RV0003	2AOV-RV0003
1AOV-RV0004	2AOV-RV0004

A number of conservative assumptions were used in performing the calculation. These assumptions are clearly identified and summarized in Section 3.1. In addition, justification supporting the reasonableness of each major assumption is also provided.

The analysis performed here is based on the pressure time history for faulted conditions due to a Loss of Coolant Accident (LOCA).

2.0 SUMMARY OF RESULTS

TORQUE RESULTS

From Section 4.7 the maximum dynamic torque and corresponding opening angle (θ) for each closing time are:

5 Sec. Closing

θ CRIT = 65.63°

T_D (max) = 167,431 IN-LB

8 Sec. Closing

θ CRIT = 66.43°

T_D (max) = 189,576 IN-LB

STRESS RESULTS

The following tables summarizes the maximum stresses and allowables for the components considered in Section 6. Note that the maximums from all load cases (1, 1A & 2) are summarized.

LOAD CASE #1 - 8 SECOND CLOSING

COMPONENT	STRESS TYPE	STRESS (KSI)	ALLOWABLE (KSI)	FACTOR OF SAFETY
Dome	Bend	10.6	30.7	2.90
Stem	Shear	15.2	16.0	1.05
Shaft	Bend	9.3	28.8	3.10
Top Hub	Bend	8.6	28.8	3.35
Bottom Hub	Bend	9.0	28.8	3.20
Shear Pins	Shear	14.3	16.0	1.12

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SUMMARY OF RESULTS (Con't)

LOAD CASE #1A - 5 SECOND CLOSING

COMPONENT	STRESS TYPE	STRESS (KSI)	ALLOWABLE (KSI)	FACTOR OF SAFETY
Dome	Bend	9.4	30.7	3.27
Stem	Shear	13.4	16.0	1.19
Shaft	Bend	9.7	28.8	2.97
Top Hub	Bend	7.6	28.8	3.79
Bottom Hub	Bend	1.4	28.8	20.6
Shear Pins	Shear	12.6	16.0	1.27

LOAD CASE #2 - MAX. PRESSURE

COMPONENT	STRESS TYPE	STRESS (PSI)	ALLOWABLE (PSI)	FACTOR OF SAFETY
Dome	Bend	12.5	30.7	2.46
Stem	Shear	7.6	24.0	3.16
Shaft	Bend	3.4	28.8	8.47
Top Hub	Bend	3.0	28.8	9.60
Bottom Hub	Bend	3.1	28.8	9.29
Shear Pins	*	*	*	*

*In the closed position the shear pins are parallel to the pressure load and therefore do not experience any significant load.

SUMMARY OF RESULTS (Con't)

CONCLUSIONS

Based on the stresses summarized above, the disc assembly is acceptable for the flow induced loads.

3.0 METHOD OF ANALYSIS

The analysis performed in this report consists of two sections. First, based on the containment pressure time history and valve flow factors, the dynamic torque time history is developed. This includes the calculation of the weight flow rate, pressure drop across the valve, and critical pressure ratio, as well as the torque at various points in the closing cycle. The equations governing the time-flow-torque relationship and the relevent flow coefficients are developed, derived or summarized in Section 4. These equations and coefficients are then incorporated into a Fortran IV computer program and solved for both the 5 second and 8 second closing times. Solutions are obtained at increments of 0.05 seconds. Results are summarized on Pages 31 & 32 of Section 4. A listing of the output is included in Appendix A and a listing of the computer program is included in Appendix D.

The second phase of the analysis consists of applying the torque and pressure loads to a finite element model of the disc assembly. Two cases are considered. First, loads representing the shear and torque loads on the shaft are applied. Then, a second static analysis applying the maximum possible upstream pressure to the surface of the dome is performed. This is required because the upstream pressure continues to increase after the valve is closed. The maximum static pressure at t=50 seconds is used. (See Figure 4-2). The analyses are performed using the ANSYS Finite Element Model described in Section 5 of this report. The maximum stress results for the dome, shaft, stem and hubs are summarized and compared to appropriate allowables in Section 6. The allowables are based on the ASME Boiler and Pressure Vessel Code and the AISC Manual of Steel Construction (Ref.'s 7 & 8). The detailed ANSYS results are included in Appendix B and C.

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3.1 ASSUMPTIONS

Below is a list of the major assumptions used to perform this analysis. Each item includes a reference either to a document or text which supports the assumption; or to a section in this report which discusses the assumption and its justification in detail.

1. The line is assumed to dump into an environment at atmospheric pressure. (14.7 PSIA) (Ref. 12)

2. Temperature is assumed constant at 283·F (743·R). (Ref. 1 & 4)

3. The resistance coefficients used to determine the head loss due to the piping, elbows, mitres, etc. have been derived or extrapolated from Appendix A of the Crane Catalog. (Ref. 2)

4. The dynamic torque coefficient (C_t) as a function of valve opening has been derived from the result of the analysis performed by H. Pratt Company (Ref. 1). H. Pratt has also stated that the maximum value of C_t is apporximately 0.3. This is consistent with the values calculated in Section 4.5.

5. The opening angle vs. time curve has the same shape as that used in the H. Pratt report (Ref. 1). It is scaled to adjust for the 5 second and 8 second closing times.

6. The specific gravity and isentropic expansion coefficient for the containment mixture are taken from Ref. 1 as 0.738255 and 1.19775 respectively.

7. The flow rate as a function of the opening angle (for P_1 = Constant) follows the Equal Percentage Theorem. This is based on the comparison on Pg. 166 of Ref. 3.

8. Sonic flow will be determined by the critical pressure method. When the pressure drop in the valve exceeds ΔP (critical) as defined in Ref. 3, the flow will be choked. (See Section 4.4)

9. The maximum torque will occur at the onset of sonic flow. For all times after the onset of sonic flow, an increase in upstream pressure will cause a decrease in the dynamic torque. (Ref. 1)

10. For the times after the start of sonic flow assume that the pressure downstream of the valve is constant. This value is conservatively taken as equal to the downstream pressure when sonic flow first occurs. The results in the post-sonic region are approximate. (See Section 4.4)

11. The load distribution due to the applied pressure transient which produces the torque is approximated as an eccentric triangular distribution. (See Pg. 59)

12. The amount of eccentricity of the load is calculated from the geometry of the disc at the maximum torque angle. It is assumed that the maximum load vector intersects the dome along the center line of the pipe. (See Pg. 60 to 62)

13. The shop dwg. for the main stem (Ref. 11, Dwg. No. B-7757) specifies the material as a 304 stainless steel with 18% Cr-8% Ni nominal composition. Since this general designation covers a wide range of materials, the stress allowables are taken as the minimum possible value for all materials fitting this designation. The allowables are taken from the ASME Boiler and Pressure Vessel Code. (Ref. 8)

14. The material used for the tapered shear pins which connect the dome assembly to the stem is not specified. It is assumed to be at least as strong as the stem itself (S_y = 25.0 KSI, See Section 6.1).

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4.0 DEVELOPMENT OF TORQUE TIME HISTORY

The torque vs. time data will be developed for both a 5 second and 8 second closing time. The general procedure used is outlined below. The FORTRAN IV program used to generate the results is included in Appendix D.

1. For any given time (in seconds), determine the containment pressure (P1) and the opening angle (Θ). P1 is obtained from pressure vs. time curves shown in Figures 4-2 and 4-3, assuming a 1-second instrument delay time. Θ is assumed to be proportional to the Θ vs. time function used in Ref. 1.

2. Determine the resistance coefficient for the valve/piping system (K_T).

3. Calculate the weight flow rate (W) based on P1, P_{DISCH} and K_T. P_{DISCH} is the pressure on the discharge side of the line and is assumed to be atmospheric pressure (14.7 PSIA).

4. Calculate the pressure just downstream from the valve based on P1 and W and the flow coefficients and equations provided by the manufacturer (Fig 4-4). This also defines the pressure drop across the valve (P_V).

5. Calculate the critical pressure to produce sonic flow ($P_{V_{CRIT}}$) at each time step. If the valve pressure drop (P_V) is greater than $P_{V_{CRIT}}$ the flow is sonic. The maximum torque will occur when the flow first reaches sonic.

6. Calculate the torque based on ΔP_V and the dynamic torque coefficient (Ct). Ct is based on Ref. 1 (See Figure 4-7).

The details of each step are covered in the following sections.

4.1 RESISTANCE COEFFICIENTS

THE RESISTANCE COEFFICIENT FOR THE VALVES AND THE PIPING SYSTEM ARE ESTIMATED BASED ON THE VALUES IN REF 2. THE FRICTION FACTOR (f_T) FOR THE 42" DIAMETER SYSTEM IS EXTRAPOLATED FROM THE DATA ON PAGE A-26 OF REF 2.

$$f_T \approx 0.01$$

RESISTANCE COEFFICIENTS (K) FOR ALL OF THE COMPONENTS EXCEPT THE VALVE IN QUESTION ARE FOUND BY:

$$K_S = \sum K$$

90° SHORT RAD. ELBOW (2 REQ'D) : $K_{90} = 20 f_T$

45° MITRE (2 REQ'D): $K_{45} = 15 f_T$

BUTTERFLY VALVE - OPEN: $K_b = 20 f_T$

PIPE - 42"Ø : $K_p = (L_{TOTAL}/ID) f_T = (424/41) f_T$

EXIT : $K_e = 1.0$

REF 2 Pg A-26 to A-29

THEREFORE:

$$K_S = (0.01)\left[(2)(20) + (2)(15) + 20 + (424/41)\right] + 1.0$$

$$K_S = 2.0$$

RESISTANCE COEFFICIENTS (CONT.)

THE K FACTOR FOR THE VALVE BEING ANALYZED MUST ALSO BE INCLUDED AS A FUNCTION OF THE OPENING ANGLE, θ. THIS FUNCTION WILL BE DERIVED BASED ON THE FOLLOWING ASSUMPTION:

ASSUME: THE FLOW VS. ANGLE FUNCTION FOLLOWS THE EQUAL PERCENTAGE THEOREM.
I.E. $W_\theta = (\theta/90)\, W_{OPEN}$. (REF 3, PG 166)

THIS CAN BE RESOLVED INTO A FACTOR FOR K FOR THE VALVE AS FOLLOWS: (NOTE $\bar{V} = 1/\rho$)

$$W_\theta = \left[4538\,(Y D^2)\sqrt{\Delta P \rho / K_b}\right](\theta/90)$$

REF 2, PG 4-13

$$W_\theta = 4538\,(Y D^2)\sqrt{\frac{\Delta P \rho}{(90/\theta)^2 K_b}}$$

THEREFORE:

$$K_\theta = (90/\theta)^2 K_b$$

SINCE $K_b = 20 f_T = 0.2$ (FROM PREVIOUS PG)

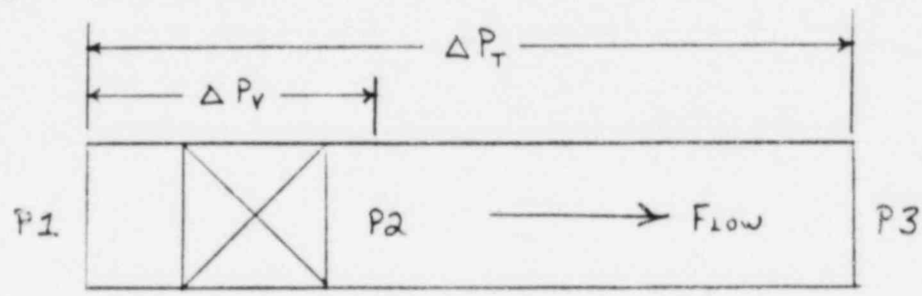
$$K_\theta = (90/\theta)^2 (0.2)$$

AND

$$\longrightarrow K_{TOTAL} = K_S + K_\theta = 2.0 + (90/\theta)^2 (0.2)$$

4.2 FLOW RATE IN SYSTEM

THE FLOW RATE (W) IN lbf/MIN IS CALCULATED BASED ON K_{TOTAL} USING THE MODIFIED DARCY EQUATION FROM PG 4-13 OF REF 2.



FROM REF 2 (CONVERTING TO lb/MIN WITH D IN FT)

$$W = (4538)(Y)(D^2)\sqrt{\frac{(\Delta P_T)(\rho_1)}{K_T}} \qquad (1)$$

WHERE

$\Delta P_T = P_1 - P_3$

P_1 IS THE CONTAINMENT PRESSURE AS A FUNCTION OF TIME (PSIA)

P_3 = ATMOSPHERIC = 14.7 PSIA

$\rho_1 = \frac{(2.7)(\text{Specific Gravity})\, P_1}{(T_1\ °R)}$ (SEE FIG 4-4)

T_1 IS ASSUMED CONSTANT AT 283°F = 743 °R (REF 1)

SG = 0.7382 (REF 1)

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FLOW RATE (CONT.)

K_T IS DEFINED IN PREVIOUS SECTION

D = INSIDE DIAMETER IN FT = 3.42 FT

Y = EXPANSION COEFFICIENT FROM PG A-22 OF REF 2. (SEE FIG 4-1)

NOTE THAT THE VALUE OF P1 IS TIME DEPENDENT. ALSO, SINCE θ, THE OPENING ANGLE, CHANGES WITH TIME, THE VALUE OF K_T IS TIME DEPENDENT. THE FLOW RATE CAN THEREFORE BE DETERMINED AT ANY GIVEN TIME. OR, AS IS DONE IN THIS REPORT, A TABLE OF FLOW VS TIME FOR T = 0 sec → T_{FINAL} CAN BE CREATED BY USING A FORTRAN PROGRAM AND SMALL INCREMENTAL TIME STEPS.

4.3 PRESSURE DROP ACROSS THE VALVE

AN EQUIVALENT FORM OF EQUATION (1), PG 11 HAS BEEN SUPPLIED (SEE FIG 4-4)

$$W = (4530)(C_f Y)(D^2)\sqrt{\Delta P_v \, \rho_1} \quad (\text{IN } {}^{lb}/_{min}) \qquad (2)$$

WHERE:

$C_f Y$ IS AN EXPANSION/FLOW COEFFICIENT DEFINED IN FIG. 4-4 AS A FUNCTION OF P1/P2 AND θ.

ΔP_v IS THE PRESSURE DROP ACROSS THE VALVE $= P_1 - P_2$

SOLVING THIS EQUATION FOR ΔP_v:

$$\Delta P_v = P_1 - P_2 = \frac{1}{\rho_1}\left[\frac{W}{(4530)(C_f Y)\,D^2}\right]^2 \qquad (3)$$

SINCE W WAS FOUND IN THE PREVIOUS STEP, THE PRESSURE DROP CAN BE CALCULATED IF $C_f Y$ IS KNOWN. HOWEVER, $C_f Y$ IS A FUNCTION OF P_2 ON THE CHART. THERE IS A UNIQUE SOLUTION TO THE $C_f Y$ vs P2 FUNCTION WHICH CAN BE FOUND BY ITERATION AS DESCRIBED ON THE NEXT PAGE.

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PRESSURE DROP ACROSS VALVE (CONT.)

ITERATION PROCEDURE FOR C_fY AND ΔP_V

1. ASSUME A VALUE FOR P_2. CALL IT P_2'
2. USING P_2', P_1 AND θ DETERMINE A C_fY VALUE FROM THE CHART.
3. USING THE KNOW VALUES FOR W AND P_1 AND THE VALUE OF C_fY DETERMINED IN STEP TWO ABOVE SOLVE EQUATION (3) FOR ΔP_V.
4. DEFINE THE NEW CALCULATED P_2 AS $P_2^* = P_1 - \Delta P_V$.
5. IF $|P_2^* - P_2'|$ IS NOT WITHIN AN ACCEPTABLE TOLERANCE (0.1 PSIA), SET $P_2' = P_2^*$ AND REPEAT STEPS 2 → 4.
6. ONCE P_2' AND P_2^* CONVERGE THE VALUES OF C_fY AND ΔP_V CAN BE EXTRACTED FROM THE LAST ITERATION STEP.

THE VALUES FOR W, P_1, P_2 AND ΔP_V CAN BE DETERMINED FOR EACH TIME STEP USING THE PRECEEDING METHODS.

4.4 CRITICAL PRESSURE

AS THE FLOW AND PRESSURE VS. TIME FUNCTIONS ARE GENERATED, IT IS IMPORTANT TO DETERMINE AT WHAT POINT SONIC FLOW THROUGH THE VALVE OCCURS. ONCE SONIC FLOW IS REACHED, ANY INCREASE IN THE UPSTREAM PRESSURE WILL RESULT IN A DECREASE IN THE DYNAMIC TORQUE ON THE VALVE. THE SONIC VELOCITY POINT IS THEREFORE CRITICAL.

THE ANALYTIC TECHNIQUE FOR CALCULATING THE DOWNSTREAM PRESSURE IS APPROXIMATE AFTER SONIC FLOW IS REACHED. HOWEVER, SINCE THE TORQUE WILL BE DECREASING THIS ANALYSIS IS NOT CONCERNED WITH THE POST-SONIC REGION. FOR THE CONVENIENCE OF COMPLETING THE TIME HISTORY TABLE, THE FOLLOWING ASSUMPTION IS MADE:

ASSUME - AT ALL TIMES AFTER SONIC VELOCITY IS REACHED, P2 IS CONSTANT, AND EQUAL TO P2 AT THE BEGINNING OF SONIC FLOW.

THE RESULTS, THEREFORE, IN THE POST-SONIC REGION ARE ONLY APPROXIMATE. THE CRITICAL RESULTS OCCUR AT THE ONSET OF SONIC FLOW. THESE VALUES ARE MARKED ON THE TIME HISTORY LISTING IN SECTION 4.7.

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CRITICAL PRESSURE (CONT.)

THE NATURE OF THE FLOW (SONIC VS. SUBSONIC) CAN BE DETERMINED BY COMPARING THE ACTUAL PRESSURE DROP IN THE VALVE TO A CRITICAL VALUE DEFINED IN REF 3.

(RATIO OF DIFFERENTIAL PRESSURE TO ABSOLUTE INLET STATIC PRESSURE) $X = \frac{P_1 - P_2}{P_1}$ REF 3, PG 204

(EXPANSION FACTOR) $Y = 1 - \frac{X}{3 F_k X_T}$ (EQ. 4) REF 3, PG 200

(RATIO OF SPECIFIC HEAT FACTOR) $F_k = k/1.4$ REF 3, PG 200

(TERMINAL VALUE OF X) $X_T = (0.84)\, C_f^2$ REF 3, PG 200

FOR THE PURPOSE OF THIS ANALYSIS

$k = 1.32$ REF 3, PG 202, P1<80

$C_f = F_L$ REF 3, PG 187

$F_L = f(\theta)$ CHART ON PG 124, REF 3

$\Delta P_v = P_1 - P_2$ DEFINITION

AT SONIC FLOW

$Y = Y_{MIN} = 0.667$ REF 3, PG 184

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CRITICAL PRESSURE (CONT)

THEREFORE, AT THE CRITICAL POINT BASED ON EQ.# 4

$$Y = 0.667 = 1 - \frac{\Delta P_{V_{CRIT}}}{(3)(K/1.4)(0.84)(C_f)^2(P1)}$$

$$\therefore \Delta P_{V_{CRIT}} = (K/1.4)(0.84)(C_f^2)(P1)$$

$$\Longrightarrow \Delta P_{V_{CRIT}} = 0.792\ (C_f)^2\ (P1)$$

IF THE ACTUAL ΔP_V IS LESS THAN $\Delta P_{V_{CRIT}}$ THE FLOW IS SUB-SONIC. IF $\Delta P_V \geq \Delta P_{V_{CRIT}}$ THE FLOW IS SONIC.

REMEMBER, $C_f = f(\theta)$.

4.5 TORQUE VS. TIME

REFERENCE 3 PG 130 GIVES A SIMPLE FORMULA RELATING THE DYNAMIC TORQUE TO THE PRESSURE DROP ACROSS THE VALVE.

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

WHERE:

C_t IS THE DYNAMIC TORQUE COEFFICIENT

D IS VALVE DIAMETER IN FT

ΔP_V IS IN PSF $= \Delta P_V (PSIA) \times 144.$

THE COEFFICIENT C_t IS A FUNCTION OF THE OPENING ANGLE, θ. FROM INFORMATION SUPPLIED BY H. PRATT, C_t MAXIMUM IS APPROXIMATELY 0.3. ADDITIONAL VALUES OF C_t AS A FUNCTION OF θ ARE DERIVED FROM THE H. PRATT ANALYSIS (REF. 1) BY THE FORMULA:

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

TORQUE VS. TIME (CONT)

THESE VALUES CAN THEN BE PLOTTED TO COMPLETE THE C_t VS θ CURVE. THE RESULTS SHOULD MEET THE FOLLOWING ACCEPTANCE CRITERIA:

1. C_t (MAX) $\approx$ 0.3
2. PER REF 3, PG 124, C_t (MAX) SHOULD OCCUR AT APPROXIMATELY θ = 70° TO 75°
3. THE SHAPE OF THE $C_t - \theta$ CURVE SHOULD RESEMBLE THE TYPICAL CURVE ON PG 123 OF REF 3.

THE TABULATED VALUES AND PLOT ON THE FOLLOWING TWO PAGES DO MEET THE ABOVE CRITERIA. C_t WILL BE TAKEN FROM THE PLOT IN FIG 4-7.

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TORQUE VS TIME (CONT.)

CALCULATED VALUES FOR C_t

(BASED ON REF. 1)

θ	$T_{d\,(IN\text{-}LB)}$	$\Delta P_{V\,(PSI)}$	C_t *	% MAX
90°	35823	4.77	.1090	39.4
85°	71056	7.69	.1307	47.2
80°	98441	10.33	.1383	50.0
75°	184575	12.45	.2151	77.7
72°	278291	14.59	.2768	100.0
70°	248382	14.28	.2524	91.2
65°	242673	15.82	.2228	80.5
60°	163512	17.04	.1392	50.3
55°	128916	17.92	.1044	37.7
50°	90139	18.46	.0708	25.6
45°	74682	18.64	.0581	21.0
40°	56453	18.92	.0433	15.6
35°	37226	19.75	.0278	9.9
30°	23423	21.08	.0161	5.8
25°	17084	22.65	.0108	3.9
20°	13496	24.95	.0078	2.8
15°	6633	27.27	.0035	1.3
10°	4479	29.65	.0022	.79
5°	3461	31.91	.0016	.58
0°	42532	38.00	.0162	5.9

* $C_t = T_d\,[D^3 \Delta P]^{-1}$

$[D = 41^{in}]$

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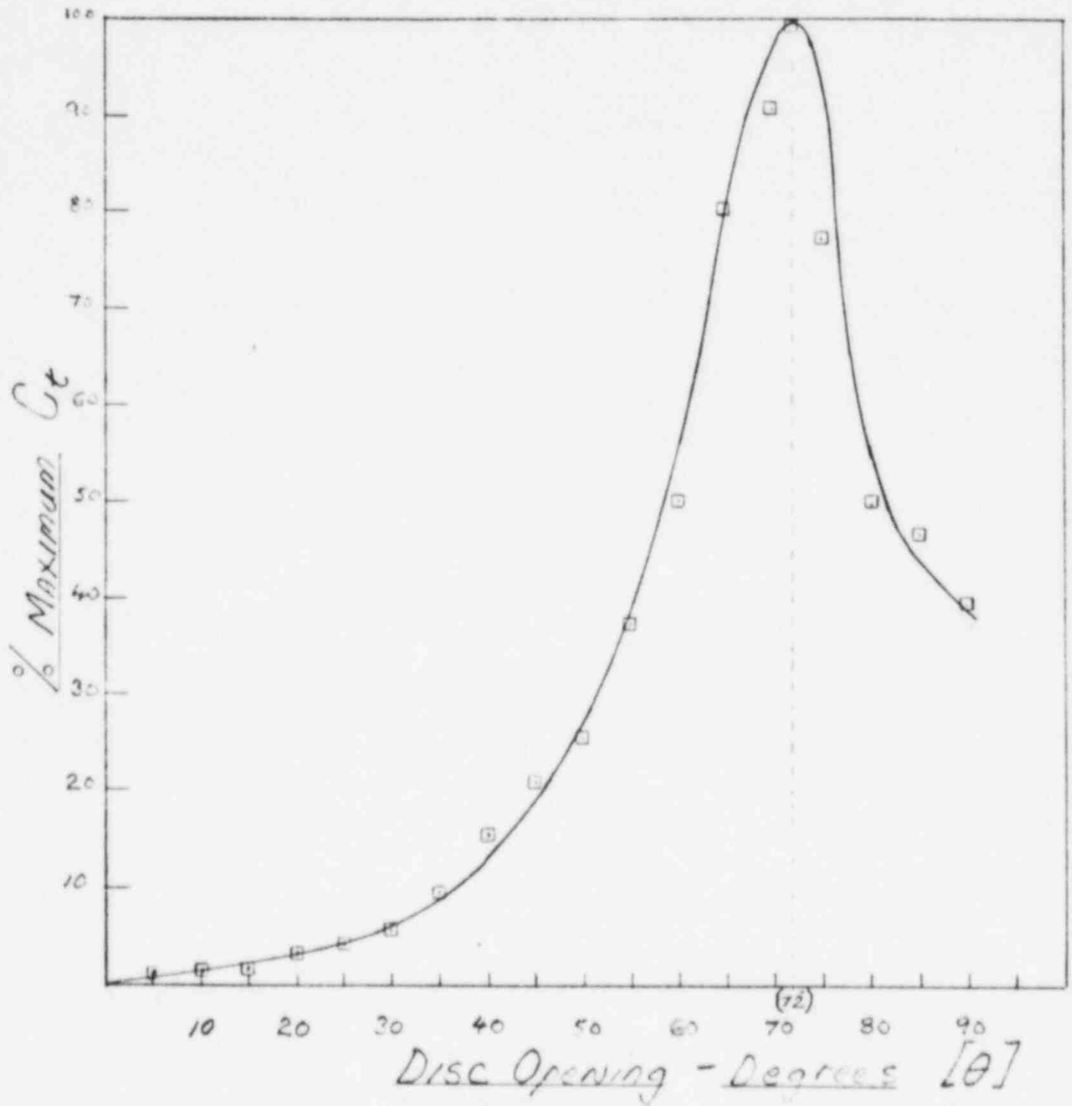
TORQUE VS. TIME (CONT.)

C_t VS θ

(BASED ON REF 1)



CYGNA	Calculation Sheet	Prepared By: JM Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: RP Casacco	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
	System: for Zion Units 1 & 2	Sheet No:	
	Analysis No: 1008 Rev. No: 0	1008-22	

4.6 CHARTS AND TABLES

SEVERAL OF THE COEFFICIENTS AND TIME DEPENDANT FUNCTIONS ARE SUPPLIED IN GRAPH FORM. THESE ARE INCLUDED HERE TOGETHER WITH A PLOT OF THE ENVLOPES USED TO MODEL EACH CURVE IN THE FORTRAN ANALYSIS. THE LIST OF FIGURES IN THIS SECTION IS GIVEN BELOW.

1006.00

CYGNA

Calculation Sheet

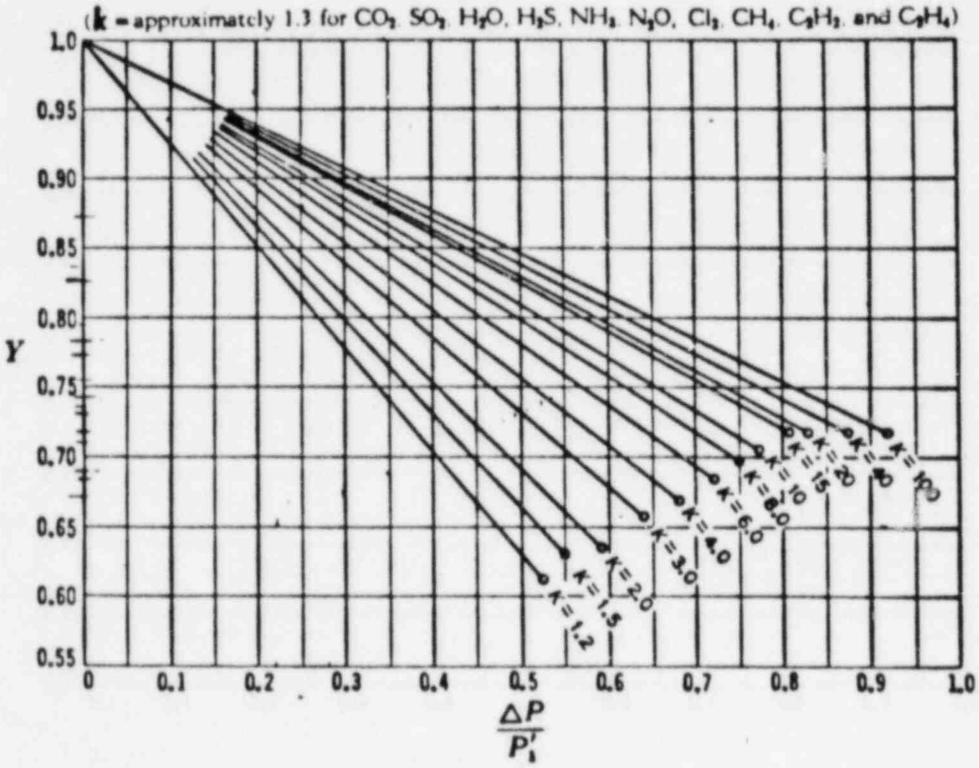
Project: Commonwealth Edison		Prepared By: J M Foley	Date: 12/15/82
Subject: 42" R1A8 Butterfly Valve		Checked By: [signature]	Date: 12/16/82
System: for Zion Units 1 & 2		Job No: 83003	File No: 1-F
Analysis No: 1008	Rev. No: 0	Sheet No: 1008-23	

FIGURE 4-1

Net Expansion Factor Y for Compressible Flow Through Pipe to a Larger Flow Area

k = 1.3

(k = approximately 1.3 for CO_2, SO_2, H_2O, H_2S, NH_3, N_2O, Cl_2, CH_4, C_2H_2, and C_2H_4)



Limiting Factors For Sonic Velocity

k = 1.3

K	$\frac{\Delta P}{P'_1}$	Y
1.2	.525	.612
1.5	.550	.631
2.0	.593	.635
3	.642	.658
4	.678	.670
6	.722	.685
8	.750	.698
10	.773	.705
15	.807	.718
20	.831	.718
40	.877	.718
100	.920	.718

CYGNA

Calculation Sheet

Project: Commonwealth Edison	Prepared By: JM Foley	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve	Checked By: R P Cavasco	Date: 12/16/82	
System: for Zion Units 1 & 2	Job No. 83003	File No. 1-F	
Analysis No. 1008 Rev. No. 0	Sheet No. 1008-24		

FIGURE 4-2

P1 Vs. TIME

CONTAINMENT CAPABILITY STUDY

ALL AVAILABLE ENERGIES

(REF. 13)

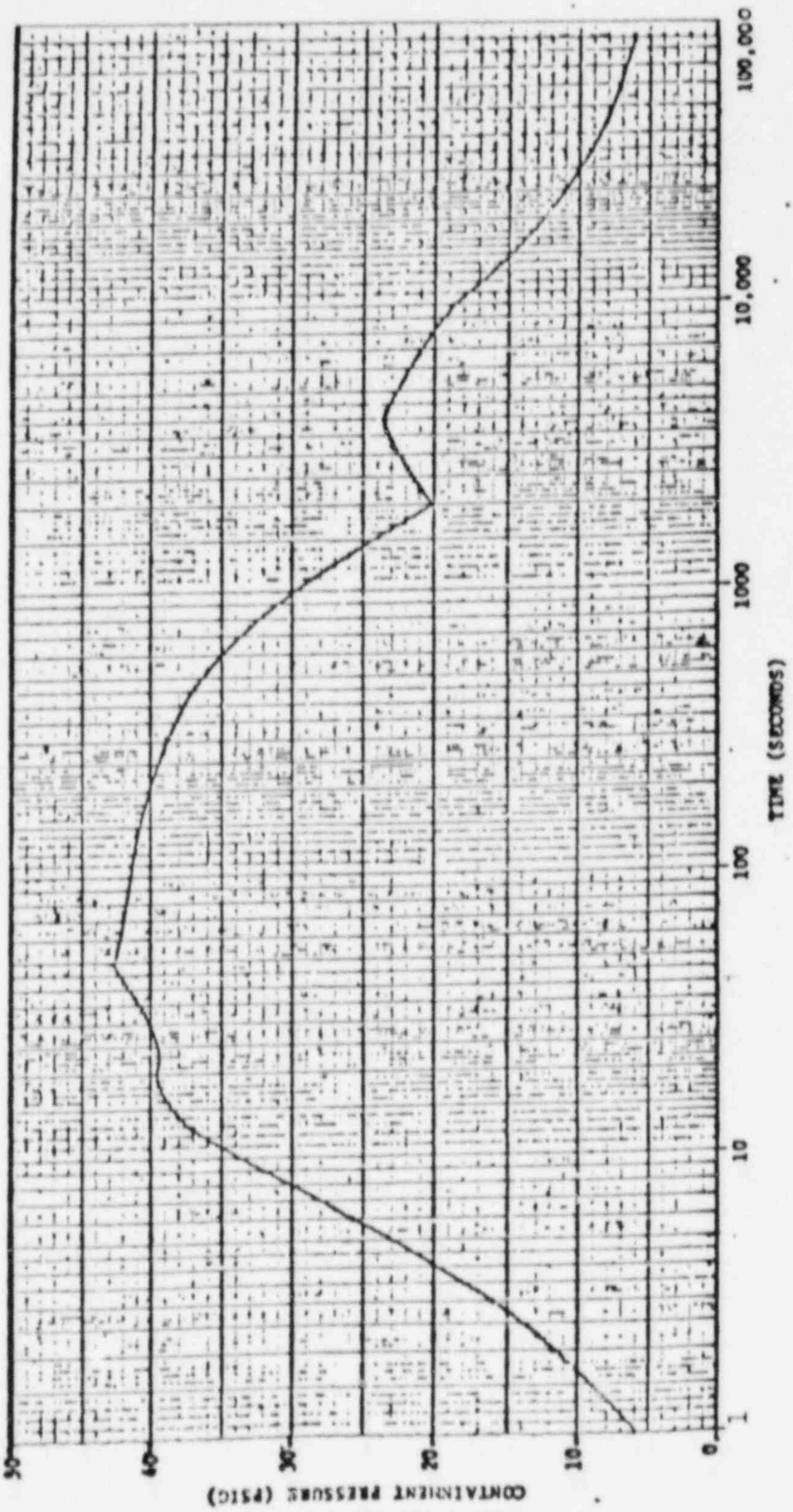
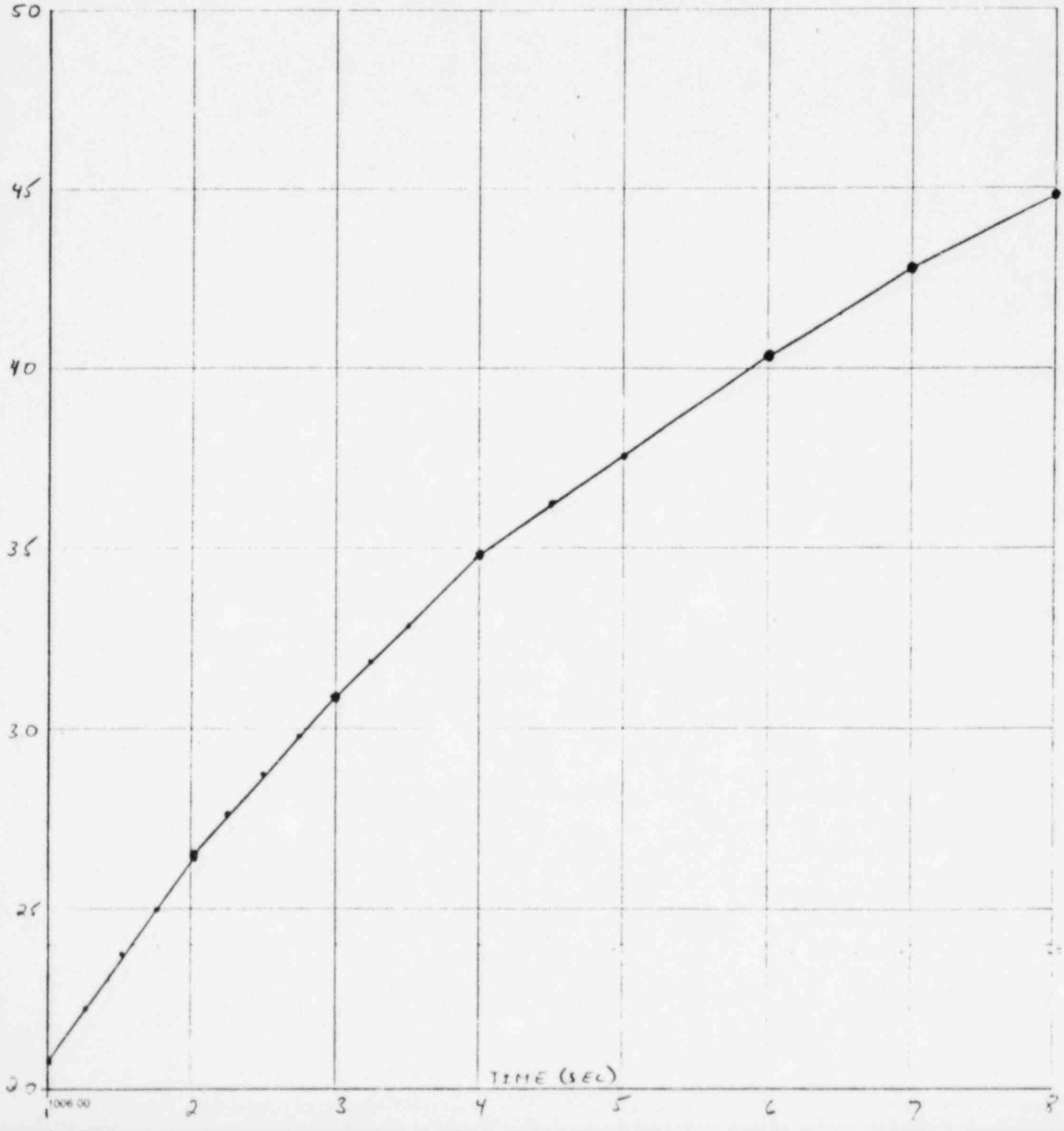


FIGURE 4-3

P1 Vs. TIME (Scalar)

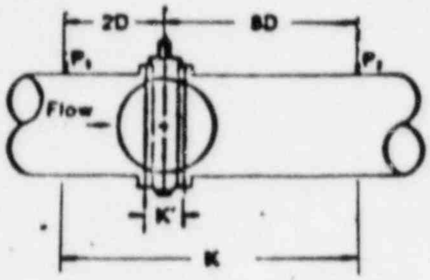
(Expanded from Fig. 4-2 curve)



Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Checked By: R P Casaccia	Date: 12/16/82
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-26	
Analysis No: 1008 Rev. No: 0		

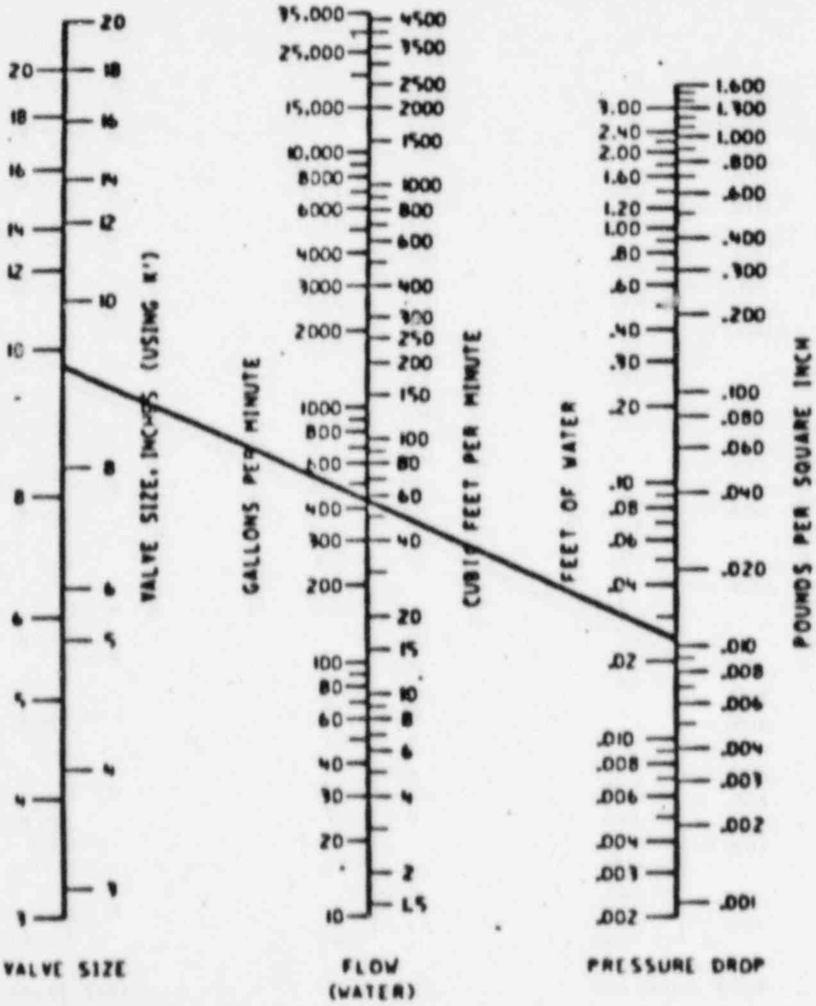
FIGURE 4-4

C_fY Vs. THETA (Actual)

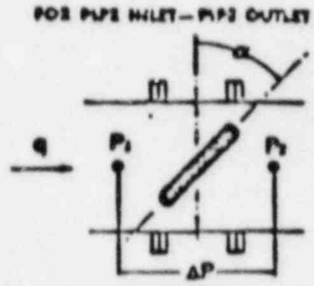


Nomograph
Flow Through Fully Open Butterfly Valve

(Nomograph is based on flows through Schedule 40 pipe per respective valve size)



*Pressure measurements made at two pipe diameters upstream of valve and eight diameters downstream of valve in accordance with recommended procedures of ASME Report on Fluid Meters. Fifth Edition.



Weight flow rate
$W = 75.5\,(C_fY)\,D^2\,\sqrt{\rho\Delta p}$

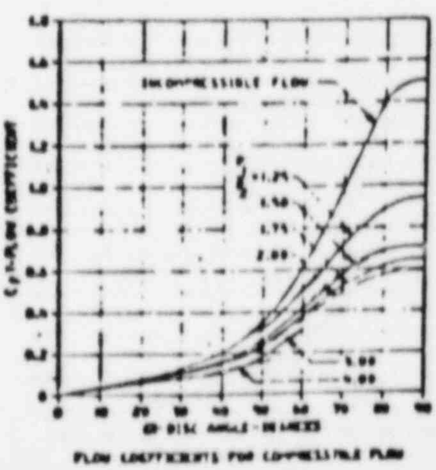
Flow rate
$q = 97350\,(C_fY)\,D^2\,\sqrt{\frac{P_1\Delta P}{T}}$ (for air)

Pressure drop
$\Delta p = \frac{1}{\rho}\left[\frac{W}{75.5\,(C_fY)\,D^2}\right]^2$

Explanations of Symbols

- W – Weight flow, pounds per second
- q – Standard cubic feet per minute (air at 60° F and 14.7 psia)
- Δp – Pressure drop across valve, pounds per square inch = $P_1 - P_2$
- D – Valve diameter, feet
- P_1 – Absolute pressure upstream of valve, pounds per square inch, absolute (psia)
- P_2 – Absolute pressure downstream of valve, pounds per square inch, absolute (psia)
- ρ – specific weight of gas, pounds per cubic feet (for air, $\rho = \frac{2.7\,P_1}{T}$ upstream conditions)
- T – Temperature ahead of valve, °R. (460° + °F)
- C_fY – Combined flow coefficient and expansion factor factor (from graph below)

Flow coefficient and expansion factors

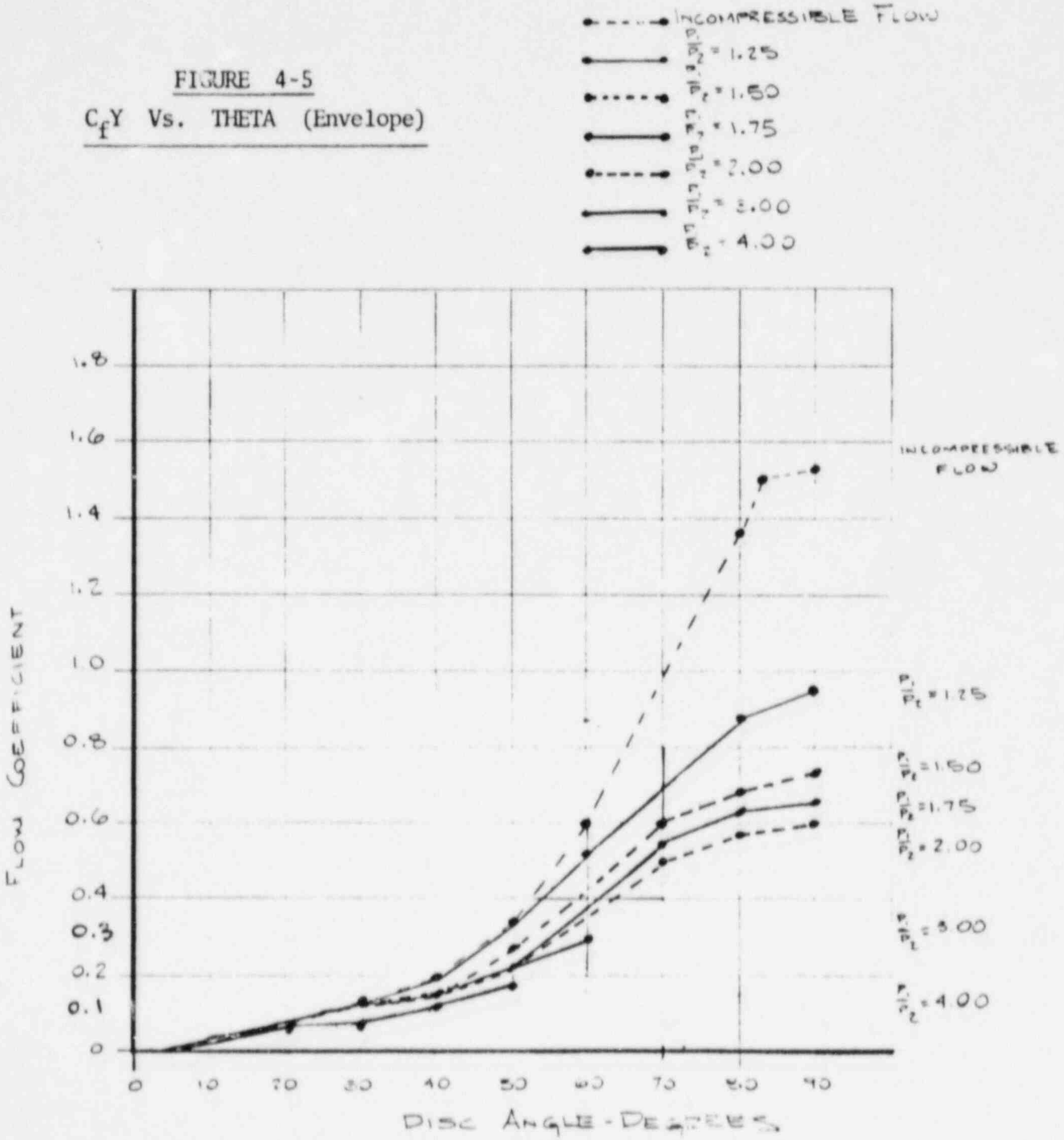


FLOW COEFFICIENTS FOR COMPRESSIBLE FLOW

Calculation Sheet	Prepared By: [signature]	Date: 12/15/82
	Checked By: [signature]	Date: [illegible]
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-27	
Analysis No: 1008 Rev. No: 0		

FIGURE 4-5

$C_f Y$ Vs. THETA (Envelope)



FLOW COEFFICIENTS FOR COMPRESSIBLE FLOW

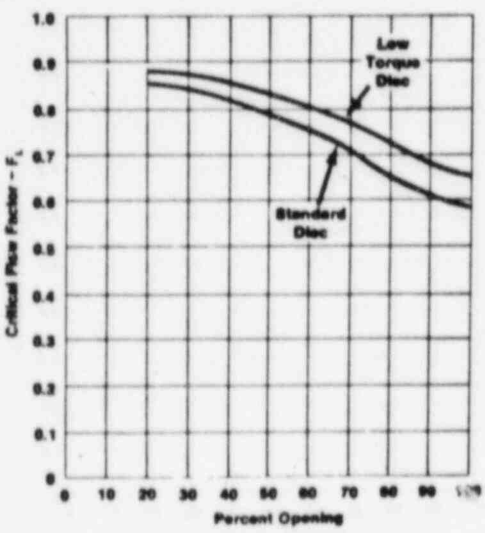
CYGNA

Calculation Sheet

Project: Commonwealth Edison	Prepared By: JM Fhg	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve	Checked By: R C Cassano	Date: 12/16/82	
System: for Zion Units 1 & 2	Job No: 83003	File No: 1-F	
Analysis No: 1008 Rev. No: 0	Sheet No: 1008-28		

FIGURE 4-6

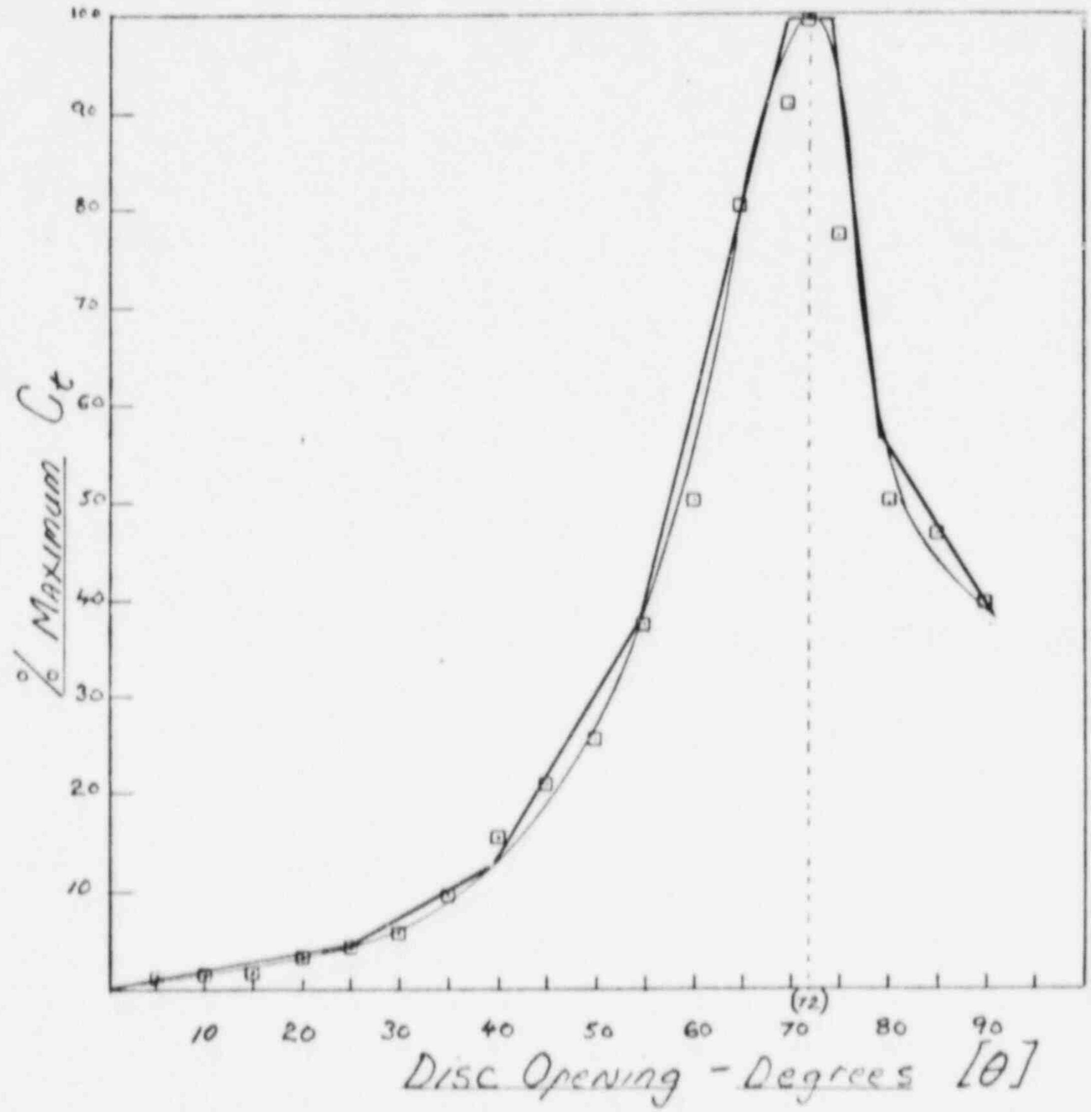
F_L Vs. THETA



Calculation Sheet		Prepared By: J M Foley	Date: 12/15/82
Project: Commonwealth Edison		Checked By: R P Carrasco	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve		Job No: 83003	File No: 1-F
System: for Zion Units 1 & 2		Sheet No: 1008-29	
Analysis No: 1008	Rev. No: 0		

FIGURE 4-7

C_t Vs. THETA (ENVELOPE)



Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Checked By: R P Casaro	Date: 12/16/82
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-30	
Analysis No: 1008 Rev. No: 0		

CYGNA

4.7 TORQUE RESULTS

THE COMPUTER GENERATED FLOW, PRESSURE AND TORQUE RESULTS ARE SUMMARIZED ON THE FOLLOWING PAGES FOR THE 5 SEC AND 8 SEC CLOSING TIMES. THE CRITICAL (SONIC VELOCITY) TIME HAS BEEN MARKED.

THE FOLLOWING MAXIMUM TORQUE VALUES ARE FOUND:

5 SEC	$T_{D_{max}} = 167{,}431$ IN-LB
8 SEC	$T_{D_{max}} = 189{,}576$ IN-LB

NOTE: IN REF 1 IT WAS SHOWN THAT THE BEARING AND HUB SEAL TORQUES ARE VERY SMALL COMPARED TO THE DYNAMIC TORQUE. SINCE THEY DO NOT SIGNIFICANTLY REDUCE T_D THEY ARE NEGLECTED HERE. THE VALUE AT 0° FROM REF 1 FOR SEATING + BEARING + HUB SEAL TORQUE IS STILL VALID.

$T_S + T_B + T_H$ @ $0° = 42532$ IN-LB (REF. 1)

CYGNA	Calculation Sheet	Prepared By J M Foley	Date 12/15/82
	Project: Commonwealth Edison	Checked By R Placasco	Date 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No 83003	File No 1-F
	for Zion Units 1 & 2		
	Analysis No 1008 Rev No 0	Sheet No 1008-31	

CLOSING TIME IS 8.00 IN STEPS OF 0.05

TIME SEC	THETA APPROX	P1 PSIA	P2 PSIA	DELP PSI	PCRIT PSI	FLOW LB/MIN	TD IN-LB
1.00	90.00	23.70	19.75	0.95	5.52	17122.	7096.
1.30	87.43	22.44	21.28	1.16	6.19	19376.	9399.
1.55	85.29	23.89	22.56	1.33	6.79	21074.	11460.
1.80	83.14	25.34	23.85	1.49	7.40	22653.	13613.
2.05	81.00	26.71	24.89	1.82	8.03	24058.	17628.
2.30	78.86	27.76	25.53	2.23	8.58	25075.	25160.
2.55	76.71	28.81	26.00	2.81	9.15	26057.	38861.
2.80	74.57	29.86	26.30	3.56	9.74	27005.	58363.
3.05	72.43	31.89	26.17	4.72	10.35	27907.	89263.
3.30	70.29	31.84	24.60	7.24	10.95	28709.	131313.
3.45	67.50	32.41	21.01	11.40	11.52	29116.	184155.
3.50	66.43	32.60	20.29	12.31	11.92	29240.	189576. ← MAX
3.55	65.36	32.79	20.29	12.50	11.92	29363.	183022.
3.60	64.29	32.98	20.29	12.69	11.92	29482.	176179.
3.65	63.21	33.17	20.29	12.88	11.92	29599.	169049.
3.70	62.14	33.36	20.29	13.07	11.92	29713.	161630.
3.80	60.00	33.74	20.29	13.45	11.92	29931.	145927.
4.05	54.64	34.64	20.29	14.35	11.92	30378.	101518.
4.30	49.29	35.37	20.29	15.08	11.92	30569.	83461.
4.55	43.93	36.09	20.29	15.80	11.92	30639.	63176.
4.80	38.57	36.82	20.29	16.53	11.92	30558.	44275.
5.05	33.21	37.54	20.29	17.25	11.92	30296.	33837.
5.30	27.86	38.27	20.29	17.98	11.92	29845.	22359.
5.55	22.50	38.99	20.29	18.70	11.92	29277.	12883.
5.80	18.85	39.72	20.29	19.43	11.92	29192.	11216.
6.05	16.71	40.42	20.29	20.13	11.92	29569.	10299.
6.30	14.57	41.02	20.29	20.73	11.92	[illegible]	9247.
6.55	12.43	41.62	20.29	21.33	11.92	31274.	8115.
6.80	10.29	42.22	20.29	21.93	11.92	19117.	6905.
7.05	8.14	42.80	20.29	22.51	11.92	15741.	5611.
7.30	6.00	43.30	20.29	23.01	11.92	11978.	4226.
7.55	3.86	43.80	20.29	23.51	11.92	7911.	2776.
7.80	1.71	44.30	20.29	24.01	11.92	3593.	1260.
8.00	0.00	44.70	20.29	24.41	11.92	0.	-0.

P_1 = Pressure Upstream of Valve

P_2 = Pressure Downstream of Valve

DELP = Pressure Differential Accross Valve

PCRIT = Critical Pressure Differential to Produce Sonic Flow

FLOW = Weight Flow Rate

TD = Dynamic Torque

CYGNA

Calculation Sheet

Prepared By: J M Foley	Date: 12/15/82	Checked By: R P Cannon	Date: 12/16/82
Job No: 83003	File No: 1-F	Sheet No: 1008-32	

Project: Commonwealth Edison

Subject: 42" R1A8 Butterfly Valve for Zion Units 1 & 2

System:

Analysis No: 1008 Rev No: 0

CLOSING TIME IS 5.00 IN STEPS OF 0.05

TIME SEC	THETA APPROX	P1 PSIA	P2 PSIA	DELP PSI	PCRIT PSI	FLOW LB/MIN	TD IN-LB
1.00	90.00	20.70	19.75	0.95	5.52	17122.	7096.
1.30	85.50	22.44	21.27	1.17	6.36	19340.	10066.
1.55	81.75	23.89	22.44	1.45	7.11	20997.	13803.
1.80	78.00	25.34	23.26	2.08	7.91	22525.	25576.
2.05	74.25	26.71	23.59	3.12	8.75	23866.	52273.
2.30	70.50	27.76	21.73	6.03	9.52	24807.	110247.
2.40	67.50	28.18	19.14	9.04	10.02	25108.	146124.
2.45	65.63	28.39	17.10	11.29	10.60	25234.	167431. ← MAX
2.50	63.75	28.60	17.10	11.50	10.60	25353.	155284.
2.55	61.88	28.81	17.10	11.71	10.60	25463.	142579.
2.80	52.50	29.86	17.10	12.76	10.60	25872.	82384.
3.05	43.13	30.89	17.10	13.79	10.60	25931.	51937.
3.30	33.75	31.84	17.10	14.74	10.60	25422.	29961.
3.55	24.38	32.79	17.10	15.69	10.60	24254.	11706.
3.80	18.00	33.74	17.10	16.64	10.60	23541.	9168.
4.05	14.25	34.64	17.10	17.54	10.60	23823.	7653.
4.30	10.50	35.37	17.10	18.27	10.60	15443.	5872.
4.55	6.75	36.09	17.10	18.99	10.60	10582.	3925.
4.80	3.00	36.82	17.10	19.72	10.60	4936.	1811.
5.00	0.00	37.40	17.10	20.30	10.60	0.	-0.

P_1 = Pressure Upstream of Valve

P_2 = Pressure Downstream of Valve

DELP = Pressure Differential Accross Valve

PCRIT = Critical Pressure Differential to Produce Sonic Flow

FLOW = Weight Flow Rate

TD = Dynamic Torque

5.0 FINITE ELEMENT MODEL

A finite element model representing the disc and stem was generated using the computer program ANSYS. The following areas are included in the model:

1.	Deep Disc. Plate	Dwg. B-7673
2.	Disc Plate	Dwg. B-7669
3.	Disc Edge Ring	Dwg. B-7659
4.	Shaft	Dwg. B-7757
5.	Top Hub Block	Dwg. B-7656
6.	Bottom Hub Block	Dwg. A-4360

These components are modeled using a variety of beam, pipe and shell elements. The loads will be applied as two cases. First, a set of loads and moments representing the maximum torque condition will be applied directly to the stem. The output from this case will be the maximum stress conditions for the stem/shaft. Then, a second case will be run using the maximum (closed position) pressure on the face of the dome. This will generate the maximum stresses in the dome. In addition, the critical applied pressure for which buckling of the dome will occur will be calculated. This will be compared to the actual maximum pressure to insure that no buckling, and possible leakage due to the associated warping of the dome, will take place.

5.1 GEOMETRY

THE FINITE ELEMENT MODEL CONSISTS OF 352 NODES AND 398 ELEMENTS, GROUPED INTO SIX REGIONS. THESE REGIONS ARE DESCRIBED BELOW. COMPUTER GENERATED PLOTS ARE INCLUDED AFTER THE DESCRIPTIONS.

REGION I - FRONT DOME — DWG B-7673

THIS IS A "DISHED" SHELL WITH A RADIUS OF CURVATURE OF 26", A THICKNESS OF 1/4", AND A MAXIMUM I.D. OF 36 1/2". NODES 1 TO 169 AND SHELL ELEMENT (STIF 63) NUMBERS 1 TO 168 ARE USED TO REPRESENT THIS AREA.

REGION II - BACK PLATE — DWG B-7669

THIS IS A 36 1/2" Ø, 1 1/4" THICK PLATE. IN THE MODEL IT IS REPRESENTED BY NODES 170 TO 338 AND SHELL ELEMENT (STIF 63) NUMBERS 193 TO 360.

REGION III - EDGE RING — DWG B-7659

THIS COMPONENT IS NOT MODELED DIRECTLY. INSTEAD, THE EDGE NODES OF THE FRONT AND BACK PLATES ARE TIED TOGETHER BY RIGID LINKS. THE LENGTH OF EACH LINK IS BASED ON THE EDGE RING THICKNESS AND 1/2 THE BACKPLATE THICKNESS. ELEMENTS 169 TO 192 ARE USED FOR THIS AREA.

GEOMETRY (CONT.)

REGION IV - HUBS/SHAFT DWGS: B-7658, A-4360, B-7656

THE HUBS AND GUIDE TUBE AROUND THE MAIN STEM ARE REPRESENTED BY THIS REGION. PIPE ELEMENT (STIF9) NUMBERS 387 TO 391 ARE USED TO MODEL THE SHAFT/HUBS. THESE ELEMENTS ARE COLINEAR WITH REGION V AND ARE COUPLED TO THE DOME AT THE PENETRATION POINTS.

REGION V - STEM DWG B-7757

THE STEM IS MODELLED AS A SET OF PIPE ELEMENTS (STIF9) WITH A WALL THICKNESS EQUAL TO THE OUTSIDE RADIUS, THUS FORMING A SOLID CYLINDER. ELEMENT NUMBERS 392 TO 398 ARE USED.

REGION VI - DOME-STEM CONNECTION

THE RIGID LINKS USED IN REGION III ARE ALSO USED TO CONNECT THE SHAFT/STEM ASSEMBLY TO THE DOME. ELEMENT NUMBERS 361 TO 386 ARE USED.

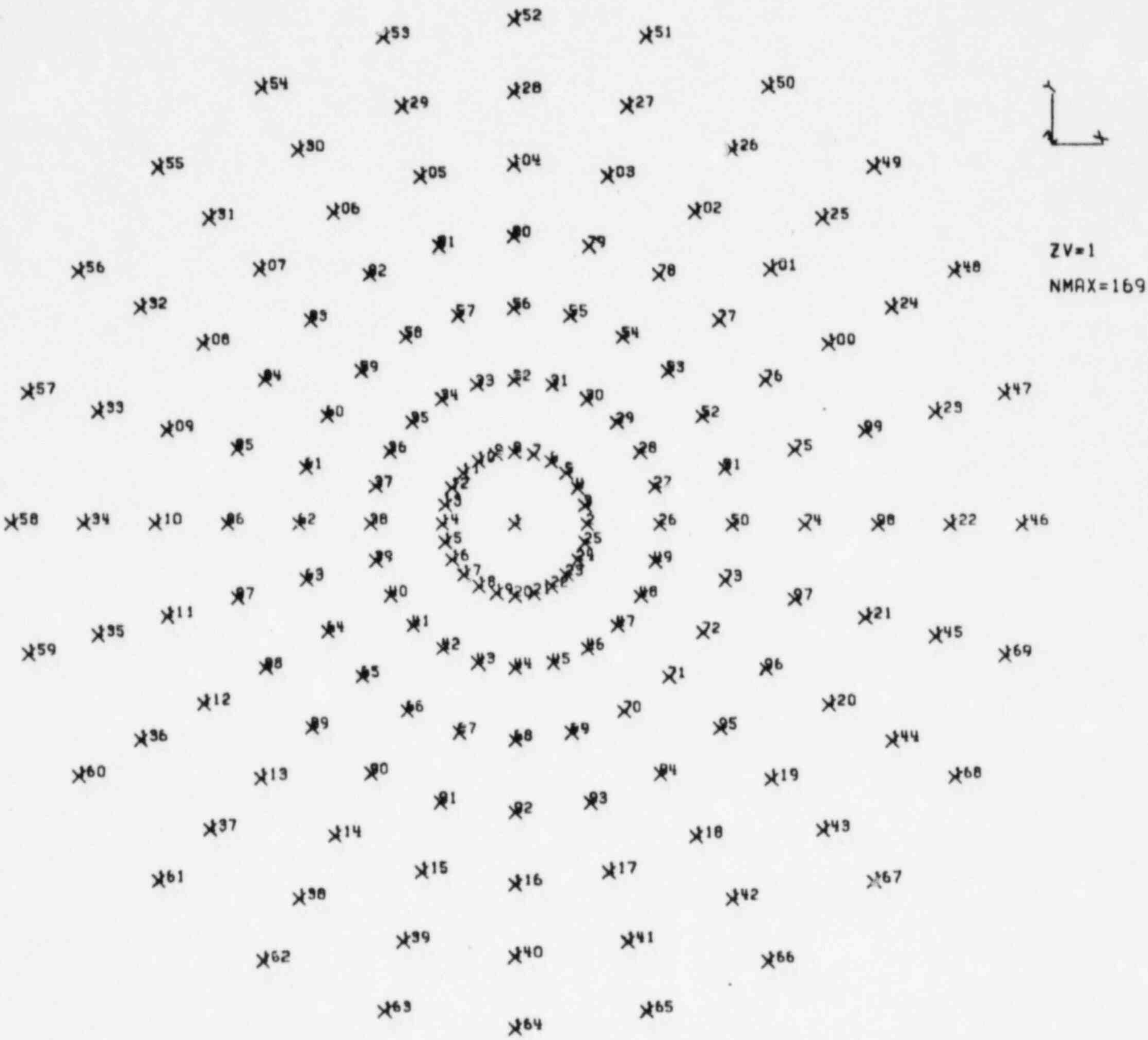
THE DRAWINGS REFERENCE ABOVE ARE INCLUDED IN SECTION 5.2 .

CYGNA

Calculation Sheet

Project: Commonwealth Edison	Prepared By: J M Foley	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve	Checked By: [illegible]	Date: 12/16/82	
System: for Zion Units 1 & 2	Job No. 83003	File No. 1-F	
Analysis No. 1008 Rev. No. 0	Sheet No. 1008-36		

12/13/82 13.149 D

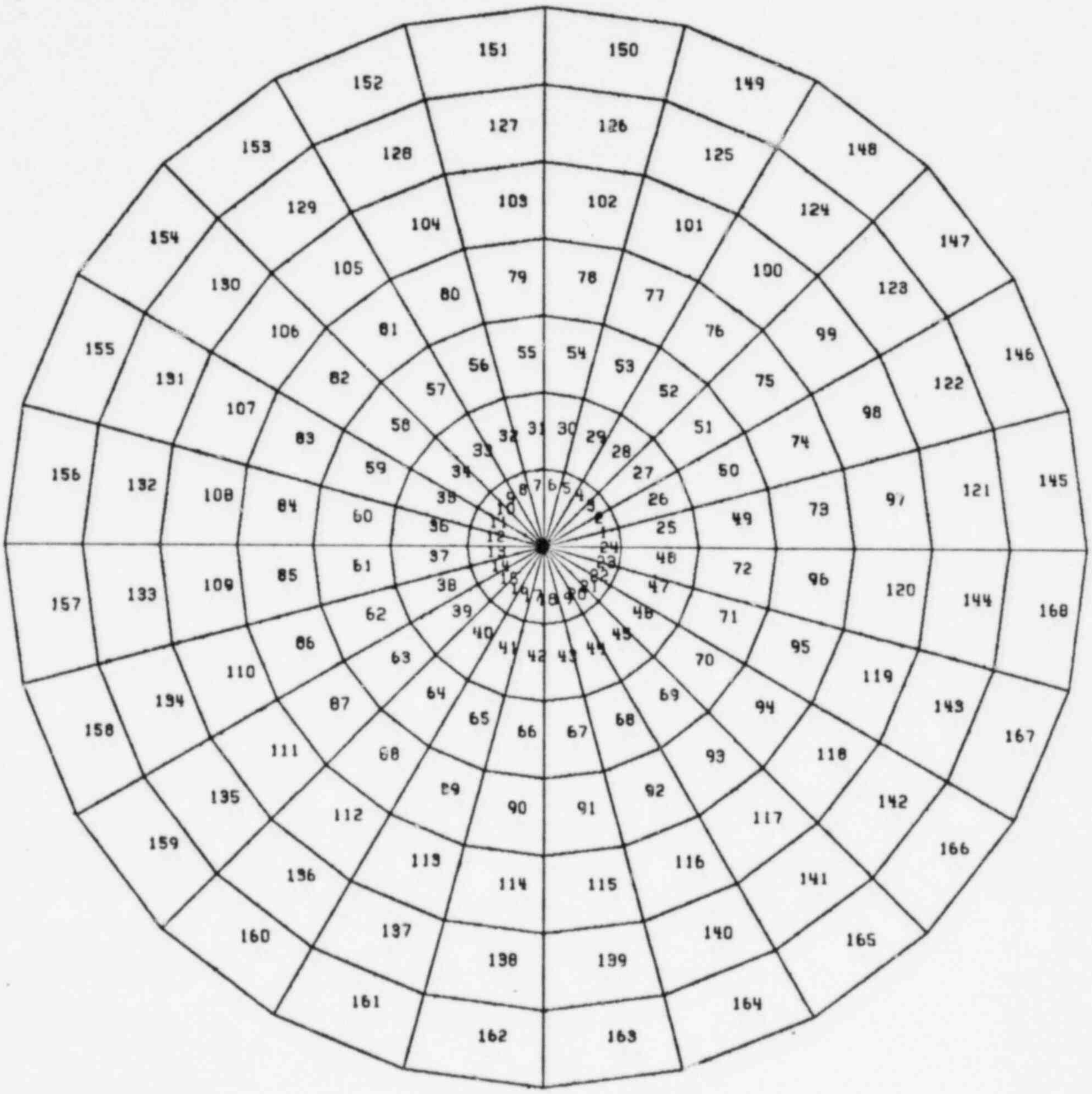


FRONT DOME

NPLT ANSYS 1

CYGNA	**Calculation Sheet**	Prepared By: J M Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: R P Lawrence	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
	System: for Zion Units 1 & 2	Sheet No. 1008-37	
	Analysis No. 1008 Rev. No. 0		

12/13/82 13.150 D



ZV=1
EMAX=168
ENUM=1

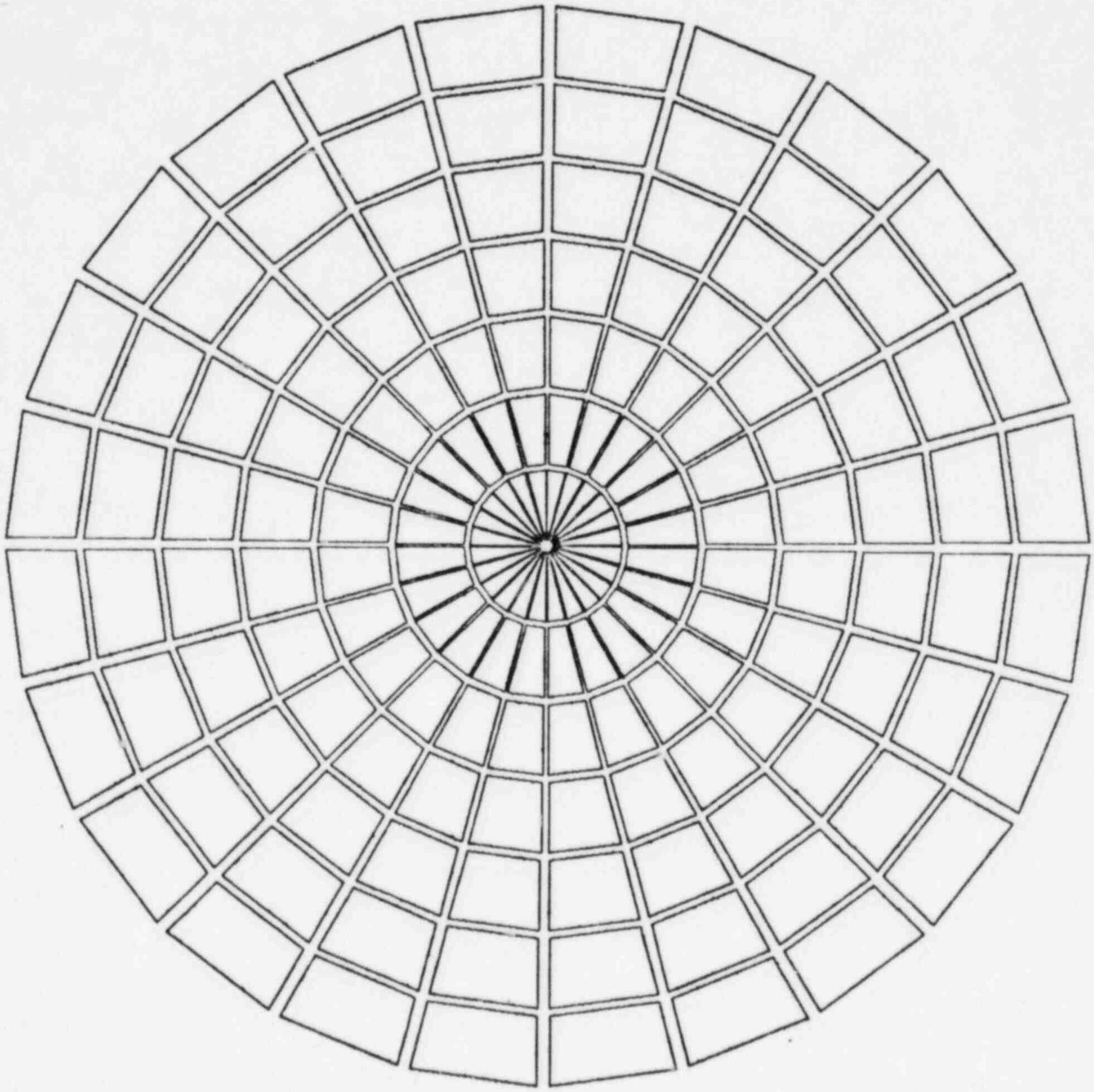
FRONT DOME

EPLT ANSYS 2

1006 00

Calculation Sheet	Prepared By: [signature]	Date: 12/15/82
Project: Commonwealth Edison	Checked By: [signature]	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
System: for Zion Units 1 & 2	Sheet No. 1008-38	
Analysis No. 1008 Rev. No. 0		

12/13/82 13.151 D



FRONT DOME

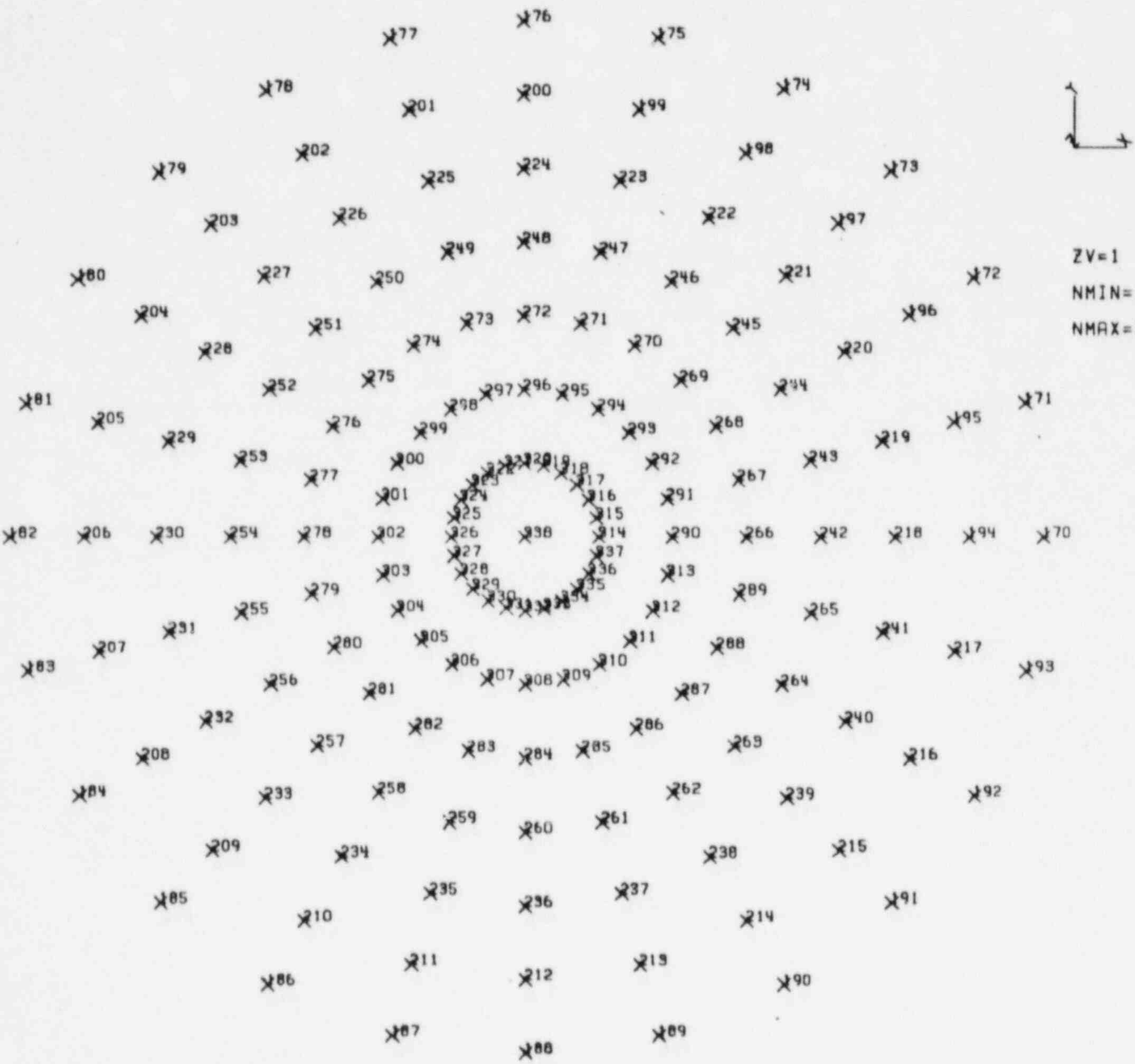
EPLT ANSYS 3

CYGNA

Calculation Sheet

Project: Commonwealth Edison	Prepared By: J M Foley	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve	Checked By: R F Lacasse	Date: 12/16/82	
System: for Zion Units 1 & 2	Job No. 83003	File No. 1-F	
Analysis No. 1008 Rev. No. 0	Sheet No. 1008-39		

12/13/82 13.152 0



ZV=1

NMIN=170

NMAX=338

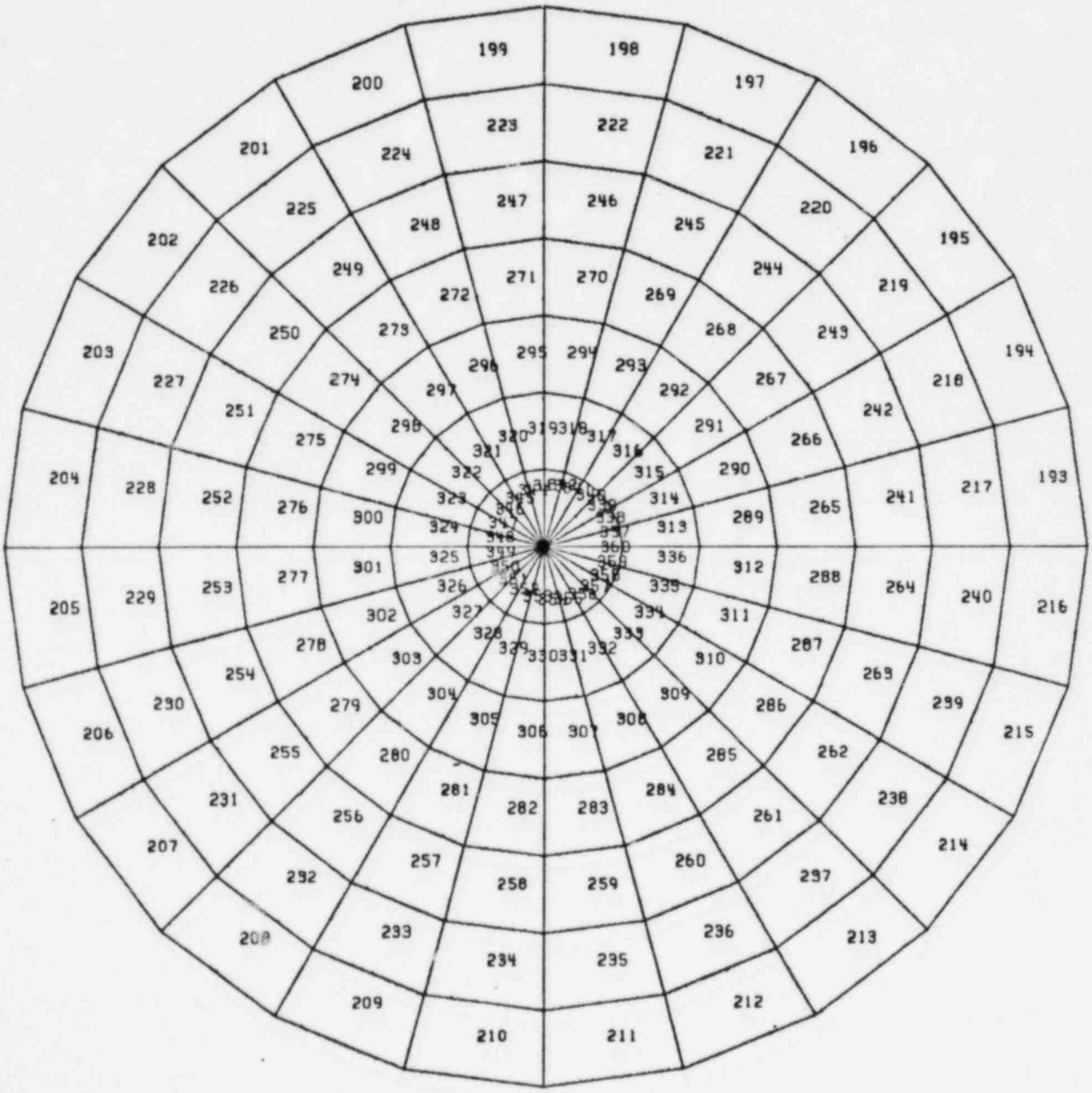
ACK PLATE

NPLT ANSYS 4

1006 00

CYGNA	Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: R P [illegible]	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve for Zion Units 1 & 2	Job No. 83003	File No. 1-F
	System:	Sheet No. 1008-40	
	Analysis No. 1008 Rev. No. 0		

12/13/82 13.153 D



ZV=1
EMIN=193
EMAX=360
ENUM=1

BACK PLATE

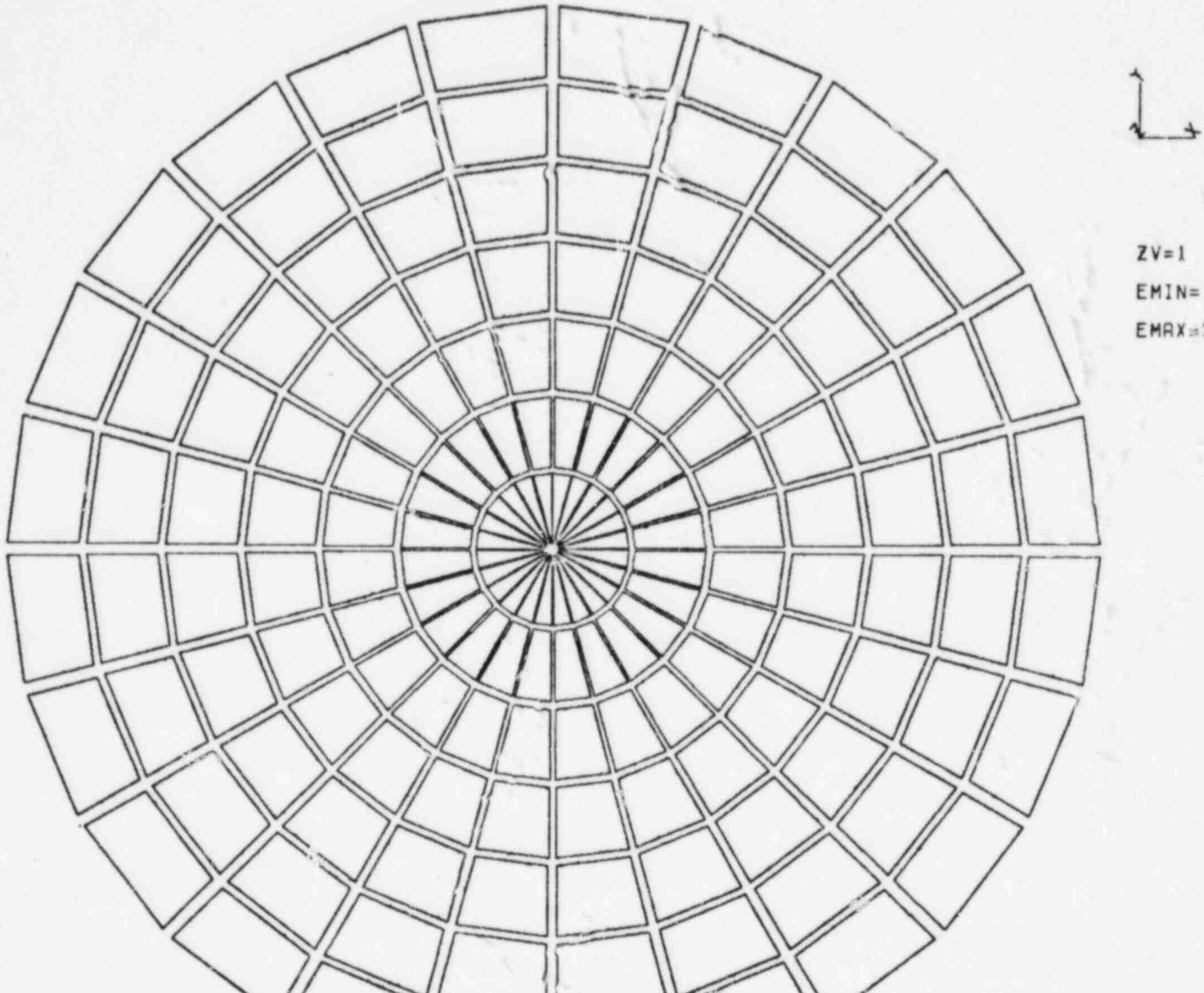
EPLT ANSYS 5

Calculation Sheet

CYGNA

Project: Commonwealth Edison	Prepared By: J M Foley	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve for Zion Units 1 & 2	Checked By: R P Caccese	Date: 12/16/82	
System:	Job No. 83003	File No. 1-F	
Analysis No. 1008 Rev. No. 0	Sheet No. 1008-41		

12/13/82 13.154 D



BACK PLATE

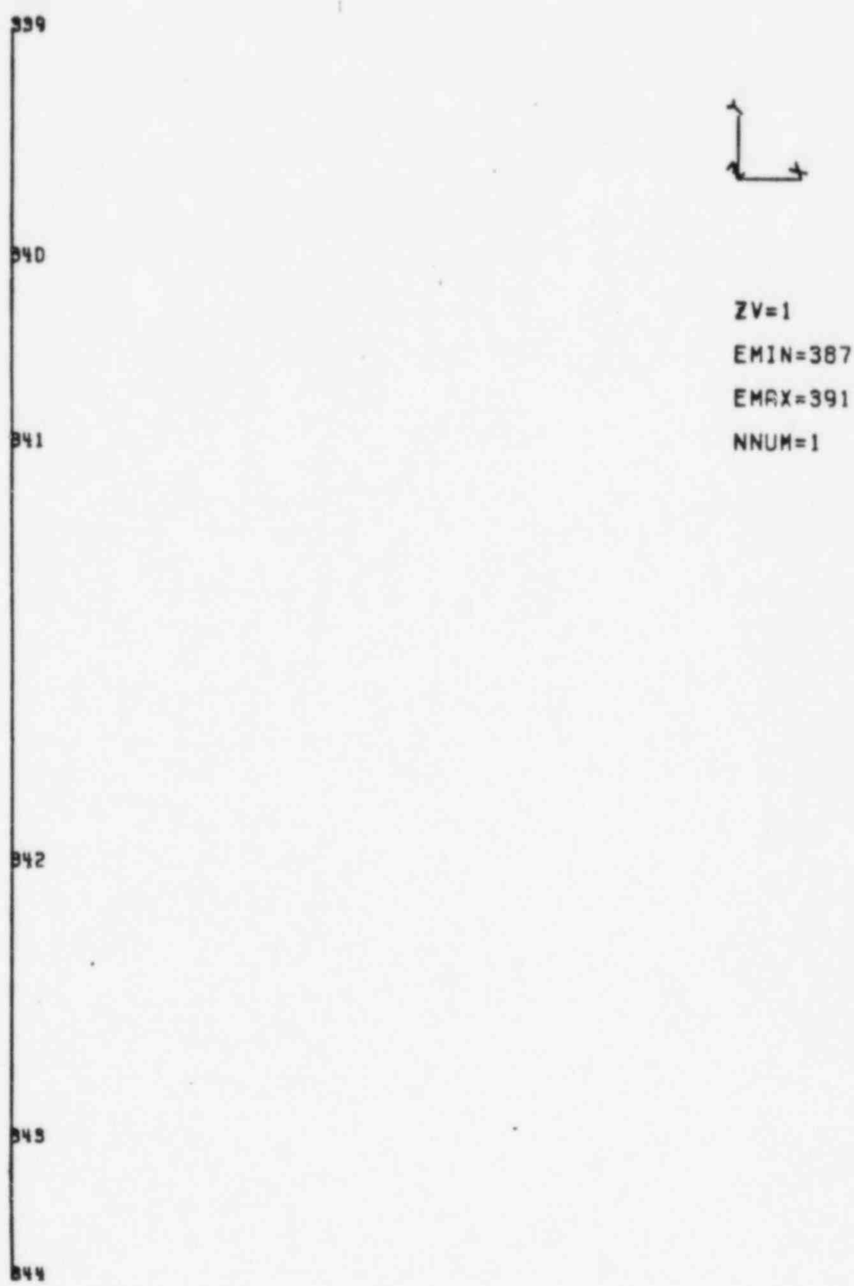
EPLT ANSYS 6

CYGNA

Calculation Sheet

Project	Commonwealth Edison	Prepared By: J M Foley	Date: 12/13/82
Subject	42" R1A8 Butterfly Valve	Checked By: R P Lawson	Date: 12/14/82
System	for Zion Units 1 & 2	Job No. 83003	File No. 1-F
Analysis No. 1008	Rev. No. 0	Sheet No. 1008-42	

12/13/82 13.155 D

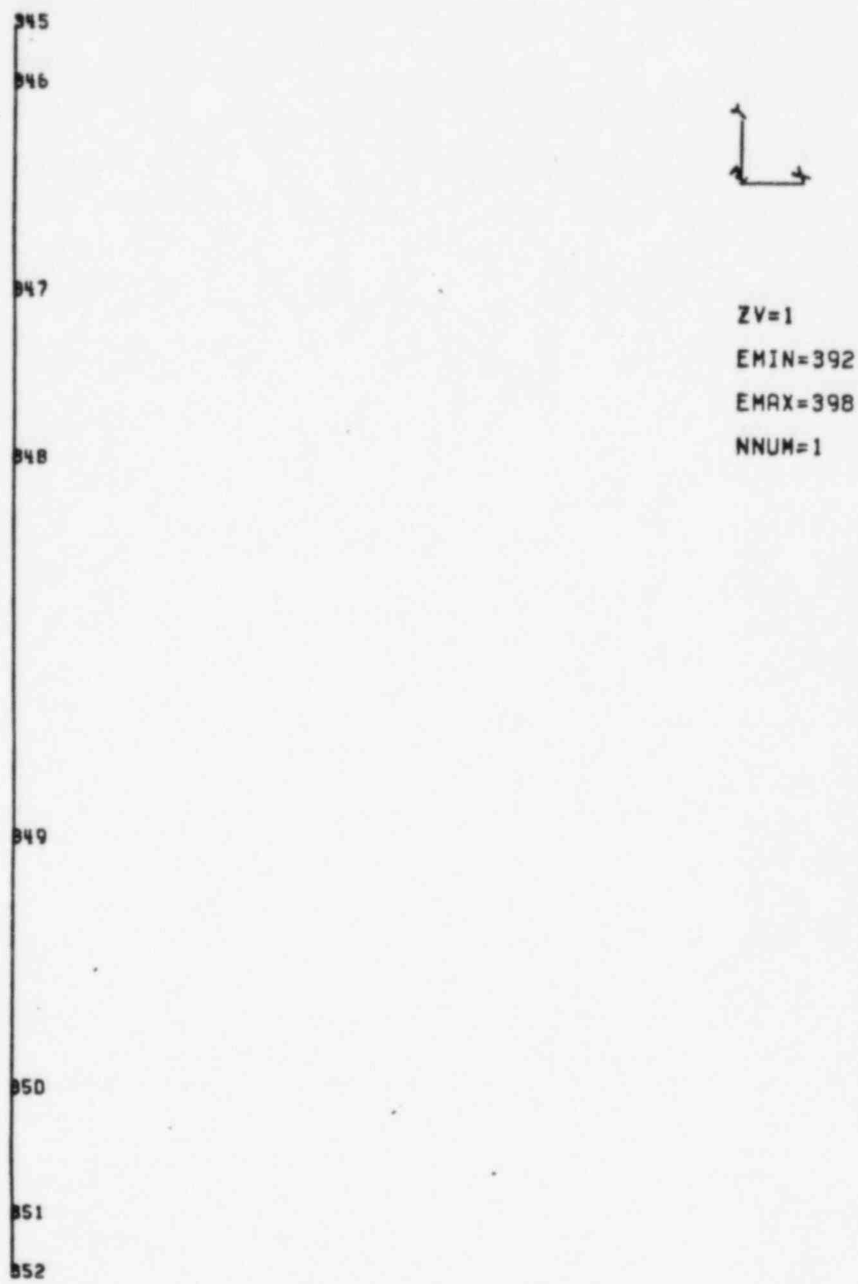


SHAFT

EPLT ANSYS 7

CYGNA	Calculation Sheet	Prepared By: JM Foley (signature)	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: RP Carson (signature)	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
	System: for Zion Units 1 & 2	Sheet No. 1008-43	
	Analysis No. 1008 Rev. No. 0		

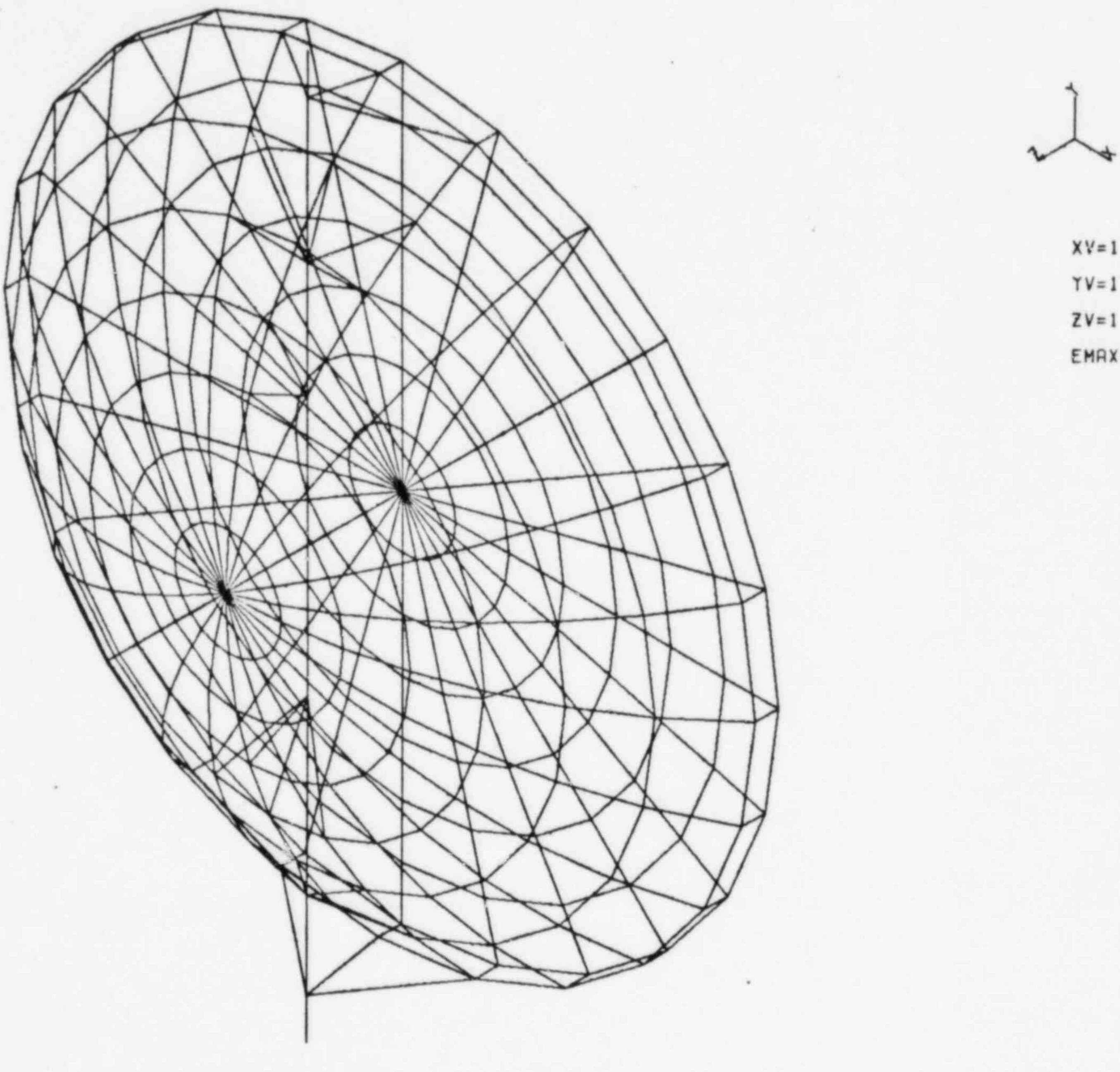
12/13/82 13.155 D



STEM EPLT ANSYS 8

CYGNA	Calculation Sheet	Prepared By: J M Foley (signature)	Date: 12/13/82
	Project: Commonwealth Edison	Checked By: (signature)	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve for Zion Units 1 & 2	Job No. 83003	File No. 1-F
	System:	Sheet No. 1008-44	
	Analysis No. 1008 Rev. No. 0		

12/13/82 13.157 D



FULL MODEL

EPLT ANSYS 9

CYGNA	Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: R P Caccamo	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
	System: for Zion Units 1 & 2	Sheet No: 1008-45	
	Analysis No: 1008 Rev. No: 0		

5.2 SECTION PROPERTIES

PLATE ELEMENTS - STIF63

REGION I THICKNESS = 0.25 IN
REGION II THICKNESS = 1.25 IN

RIGID LINKS - 3-D BEAMS / STIF4

REGION III & VI VERY STIFF PROPERTIES TO MODEL RIGID CONNECTION

AREA = 1,000 IN^2
$I_y = I_z = 100,000\ IN^4$
J = 100,000 IN^4

PIPE ELEMENTS - STIF9

REGION IV HUBS : OD = 6.5" t = 1.125"
SHAFT : OD = 4.6875" t = 0.219"

REGION V STEM : OD = 4.247" t = 2.123"

THE COMPONENT DRAWINGS FOR EACH OF THESE REGIONS ARE INCLUDED ON THE FOLLOWING PAGES.

Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Checked By: R.P. Lavaux	Date: 12/16/82

Project: Commonwealth Edison

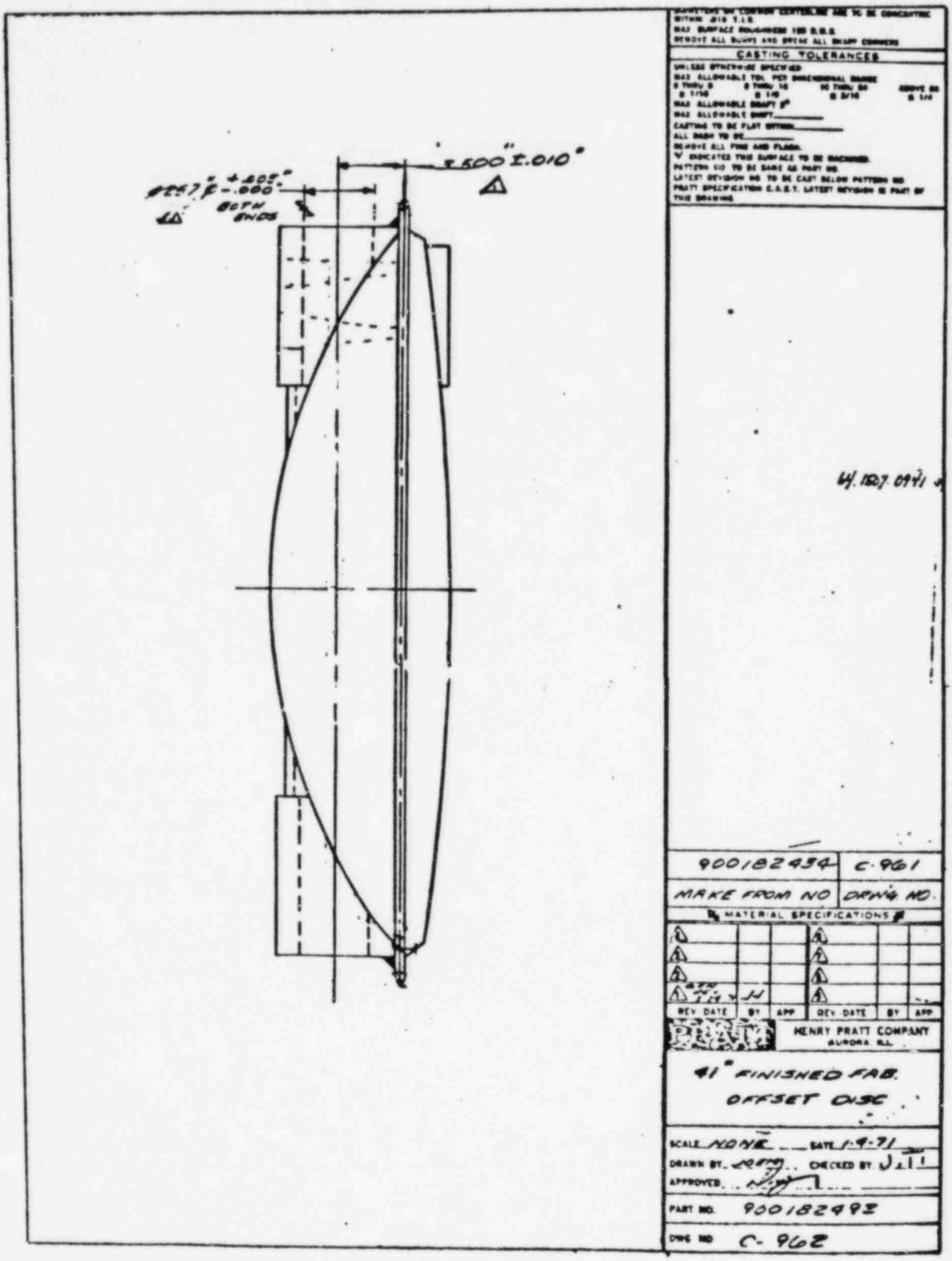
Subject: 42" R1A8 Butterfly Valve

System: for Zion Units 1 & 2

Analysis No. 1008 Rev. No. 0

Job No. 83003 File No. 1-F

Sheet No. 1008-46



1006.00

Calculation Sheet

CYGNA

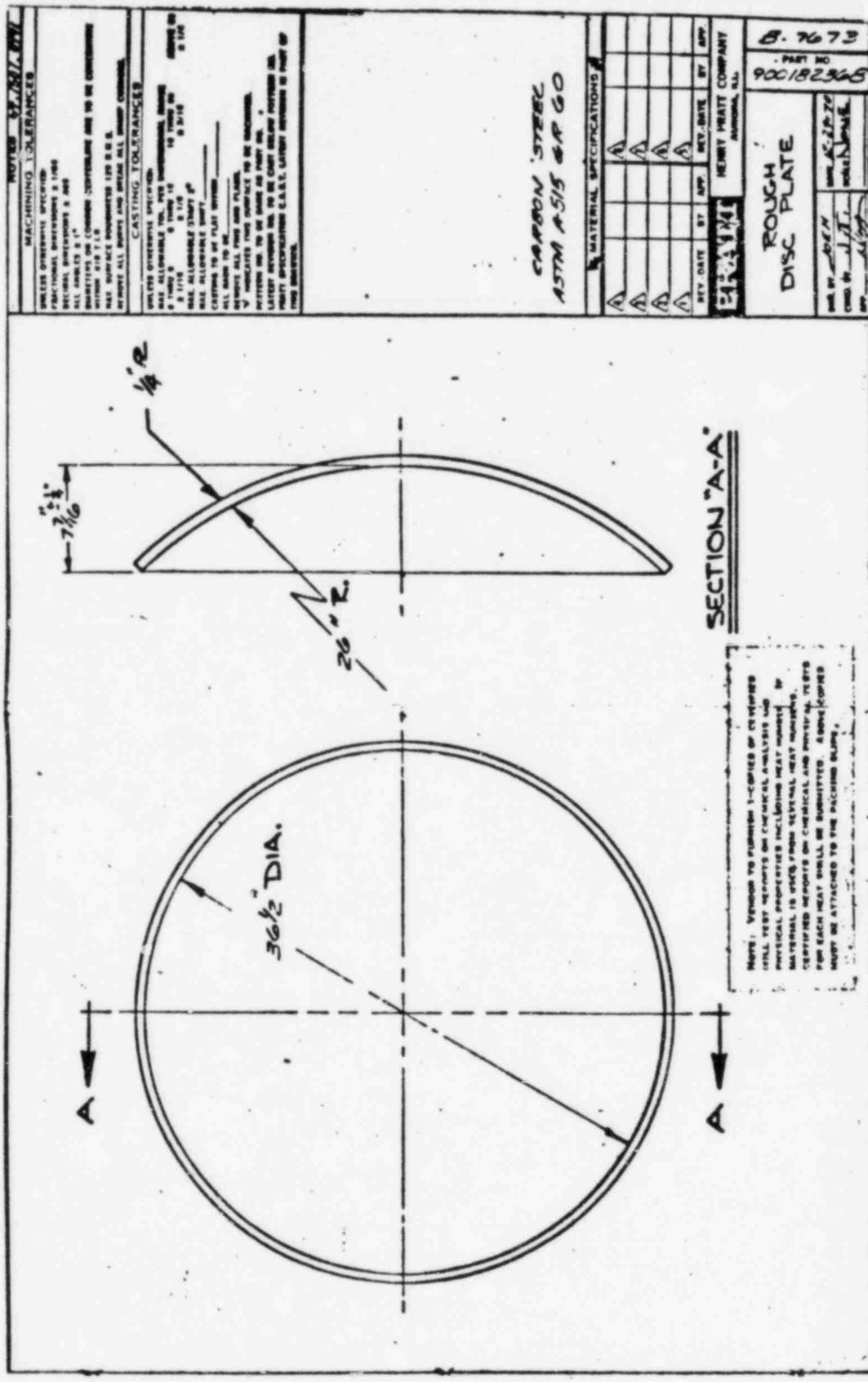
Prepared By: J M Foley	Date: 12/15/82
Checked By: R P Casrow	Date: 12/16/82
Job No.: 83003	File No.: 1-F
Sheet No.: 1008 - 47	

Project: Commonwealth Edison

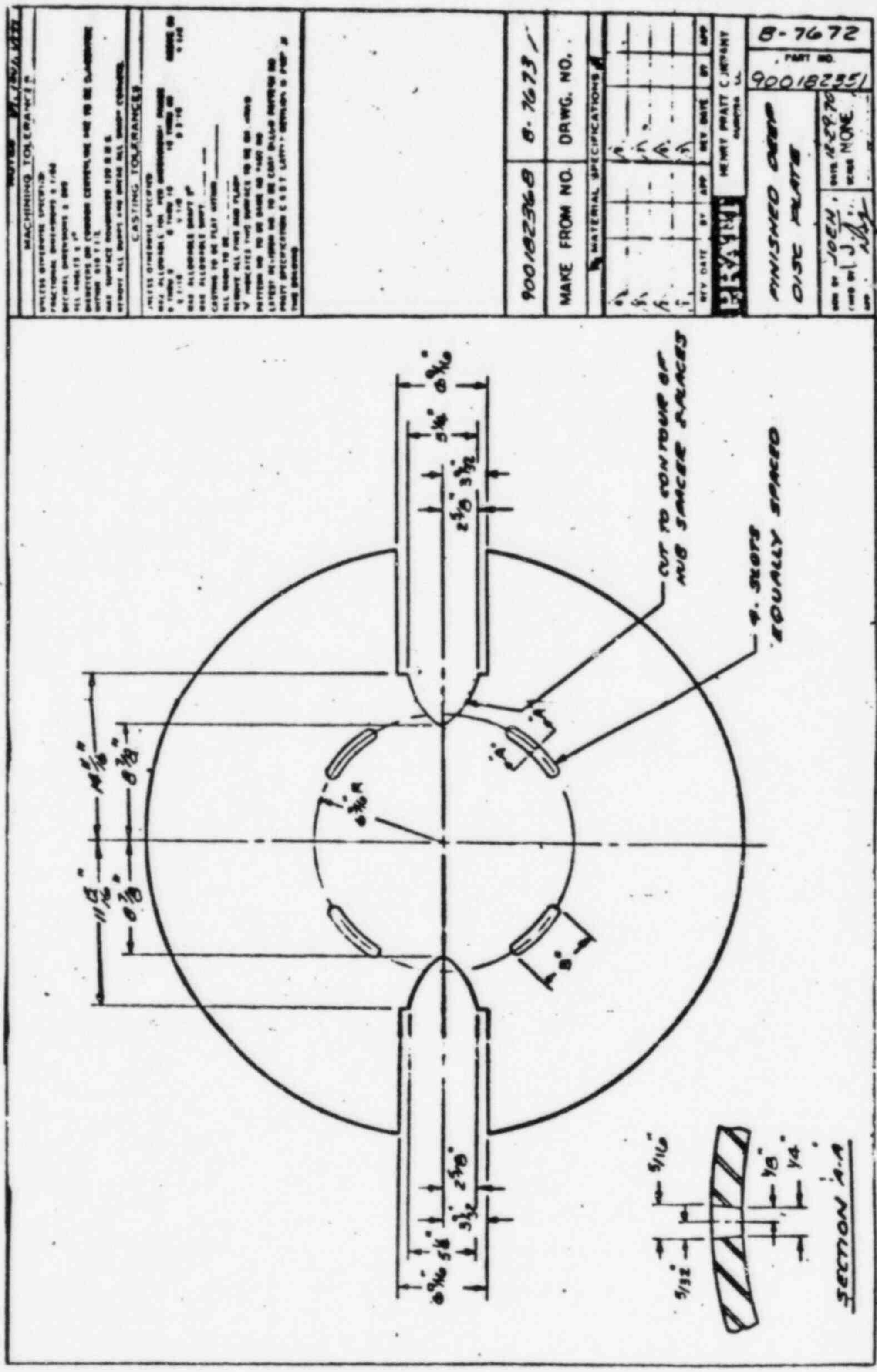
Subject: 42" R1A8 Butterfly Valve

System: for Zion Units 1 & 2

Analysis No.: 1008 Rev. No.: 0

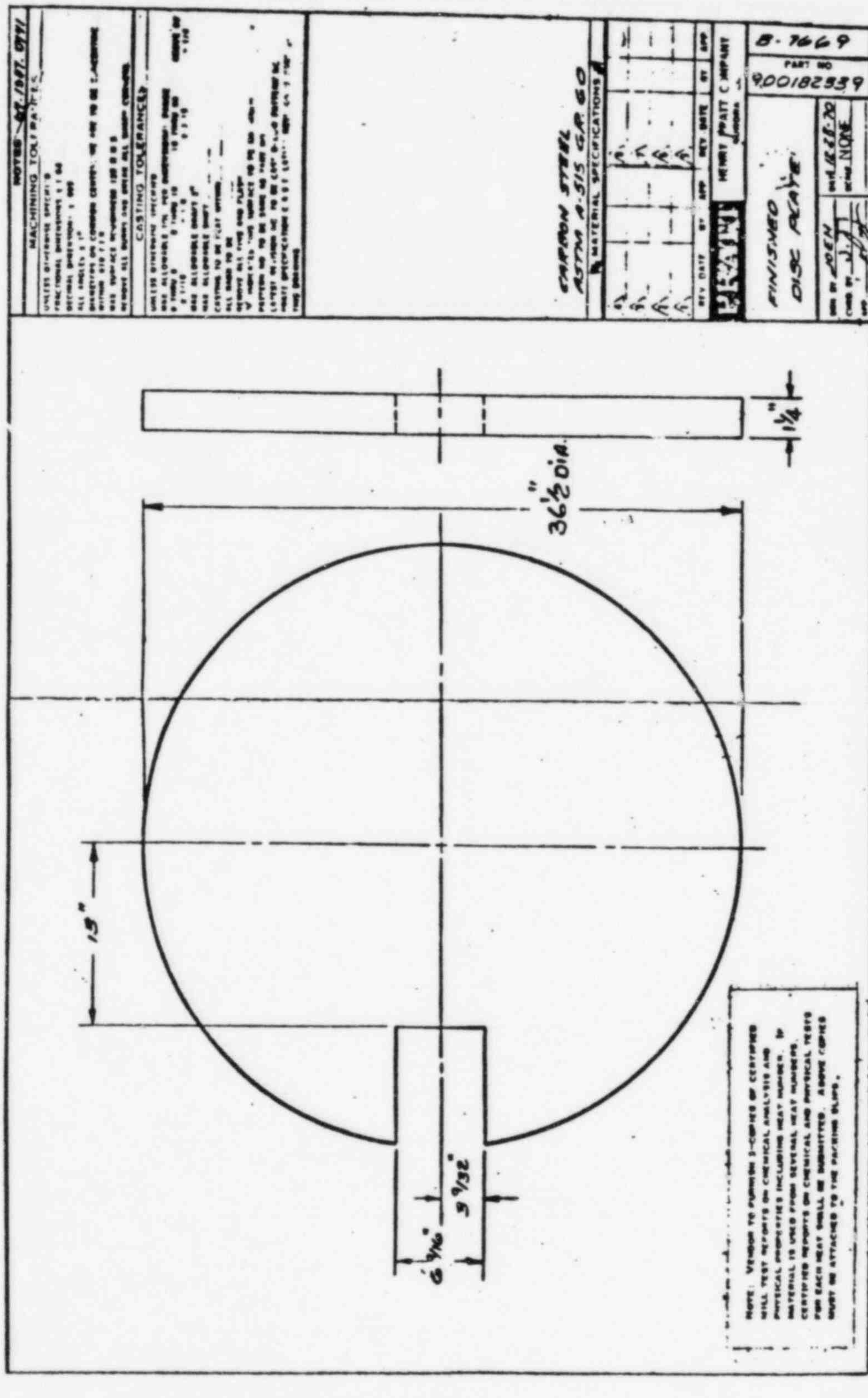


CYGNA	**Calculation Sheet**	Prepared By: J M Foley	Date: 12/15/82
		Checked By: R P Lo...	Date: 12/16/82
	Project: Commonwealth Edison	Job No.: 83003	File No.: 1-F
	Subject: 42" R1AR Butterfly Valve		
	System: for Zion Units 1 & 2	Sheet No.: 1008-48	
	Analysis No.: 1008 Rev. No.: 0		



Calculation Sheet

Prepared By	J M Foley
Date	12/15/82
Checked By	R P Lassaco
Date	12/16/82
Project	Commonwealth Edison
Subject	42" R1A8 Butterfly Valve
System	for Zion Units 1 & 2
Analysis No	1008
Rev. No	0
Job No.	83003
File No.	1-F
Sheet No.	1008-49



Calculation Sheet

CYGNA

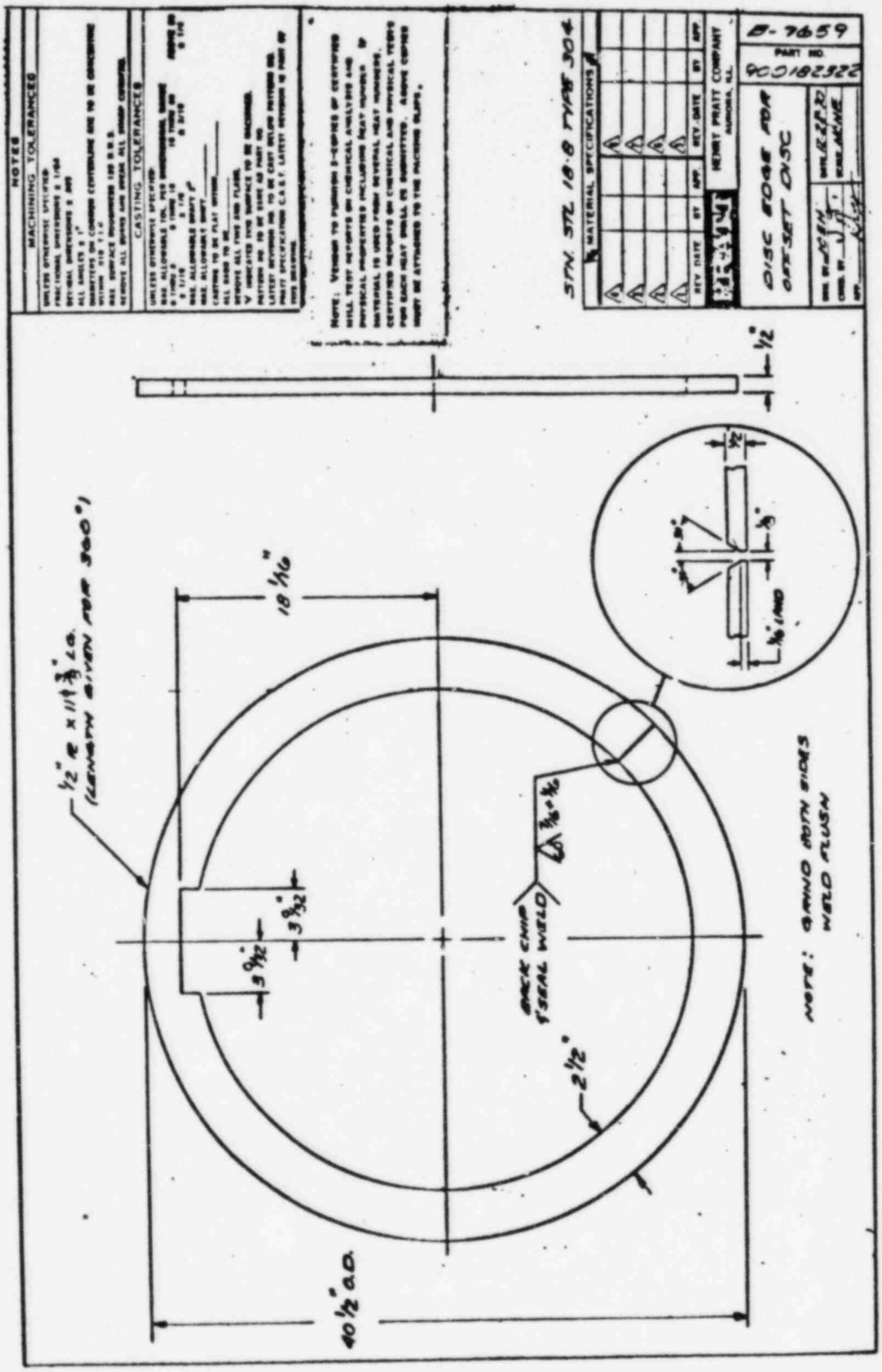
Prepared By: J M Foley	Date: 12/15/82		
Checked By: R E Lorenz	Date: 12/16/82		
Job No.: 83003	File No.: 1-F		
Sheet No.: 1008-50			

Project: Commonwealth Edison

Subject: 42" R1A8 Butterfly Valve

System: for Zion Units 1 & 2

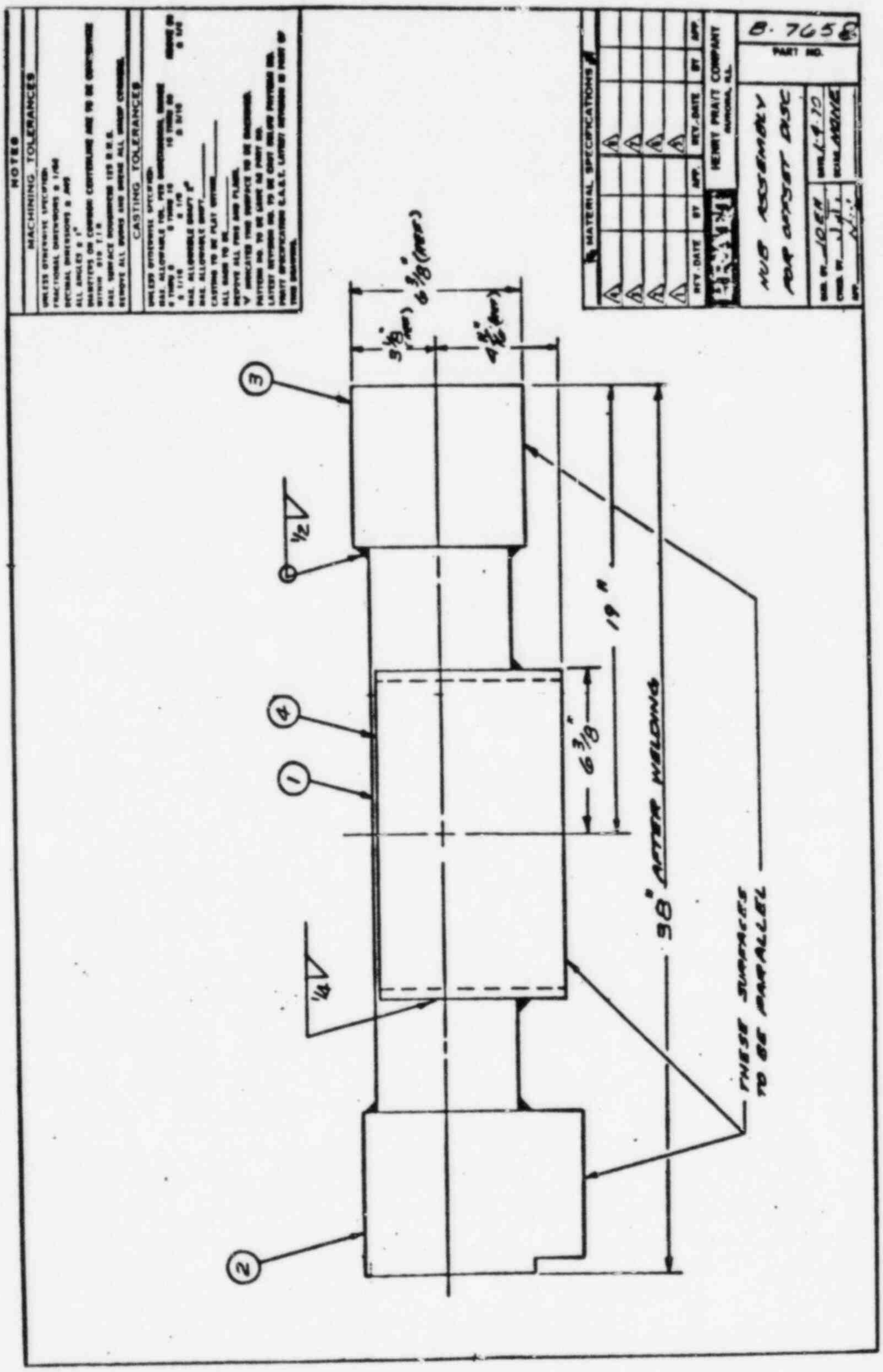
Analysis No.: 1008 Rev. No.: 0



Calculation Sheet

CYGNA

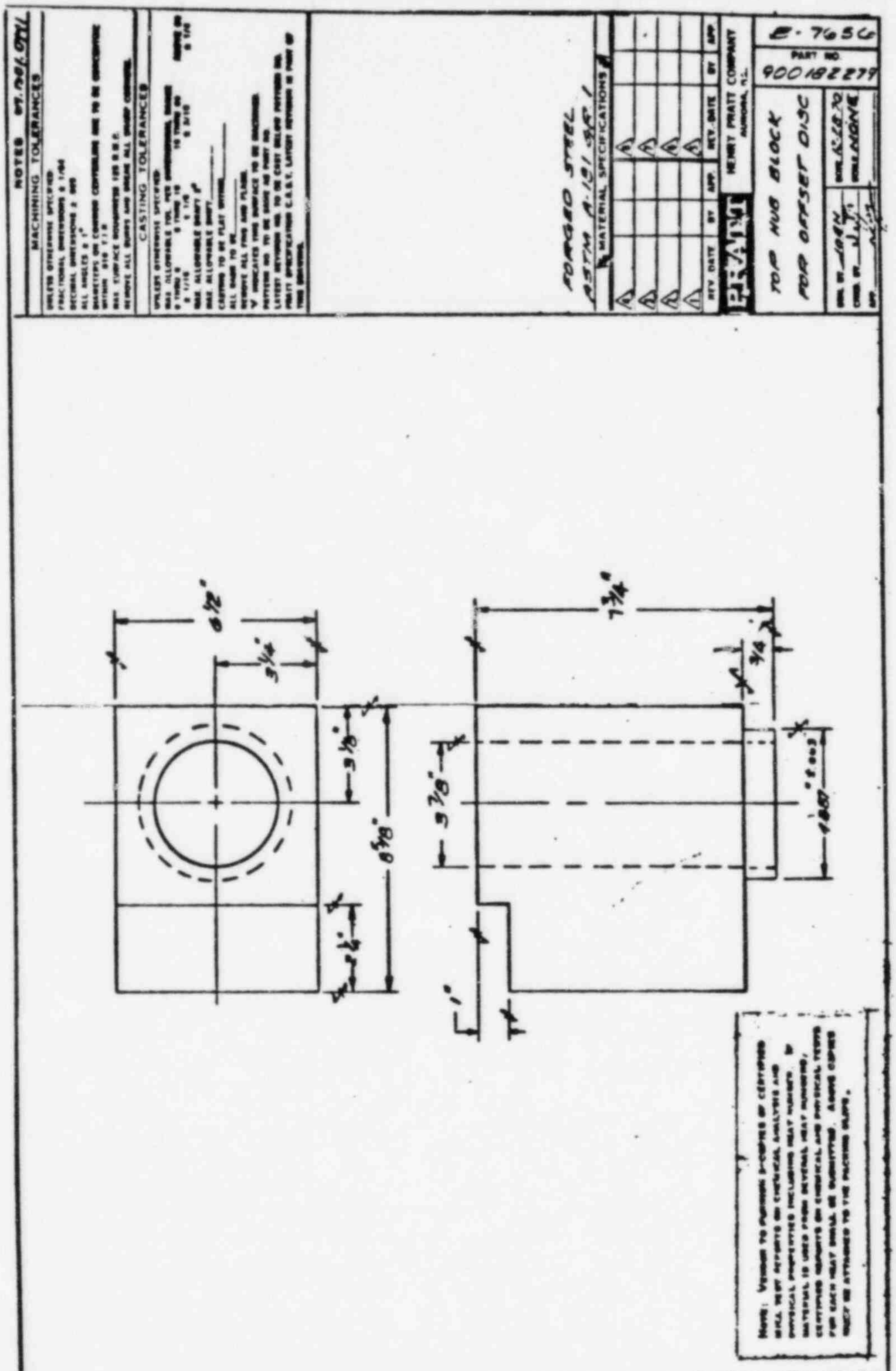
Prepared By	JM Foley
Date	12/15/82
Checked By	R Plason
Date	12/16/82
Project	Commonwealth Edison
Subject	42" R1A8 Butterfly Valve
System	for Zion Units 1 & 2
Analysis No	1008
Rev. No	0
Job No	83003
File No	1-F
Sheet No	1008-51



CYGNA

Calculation Sheet

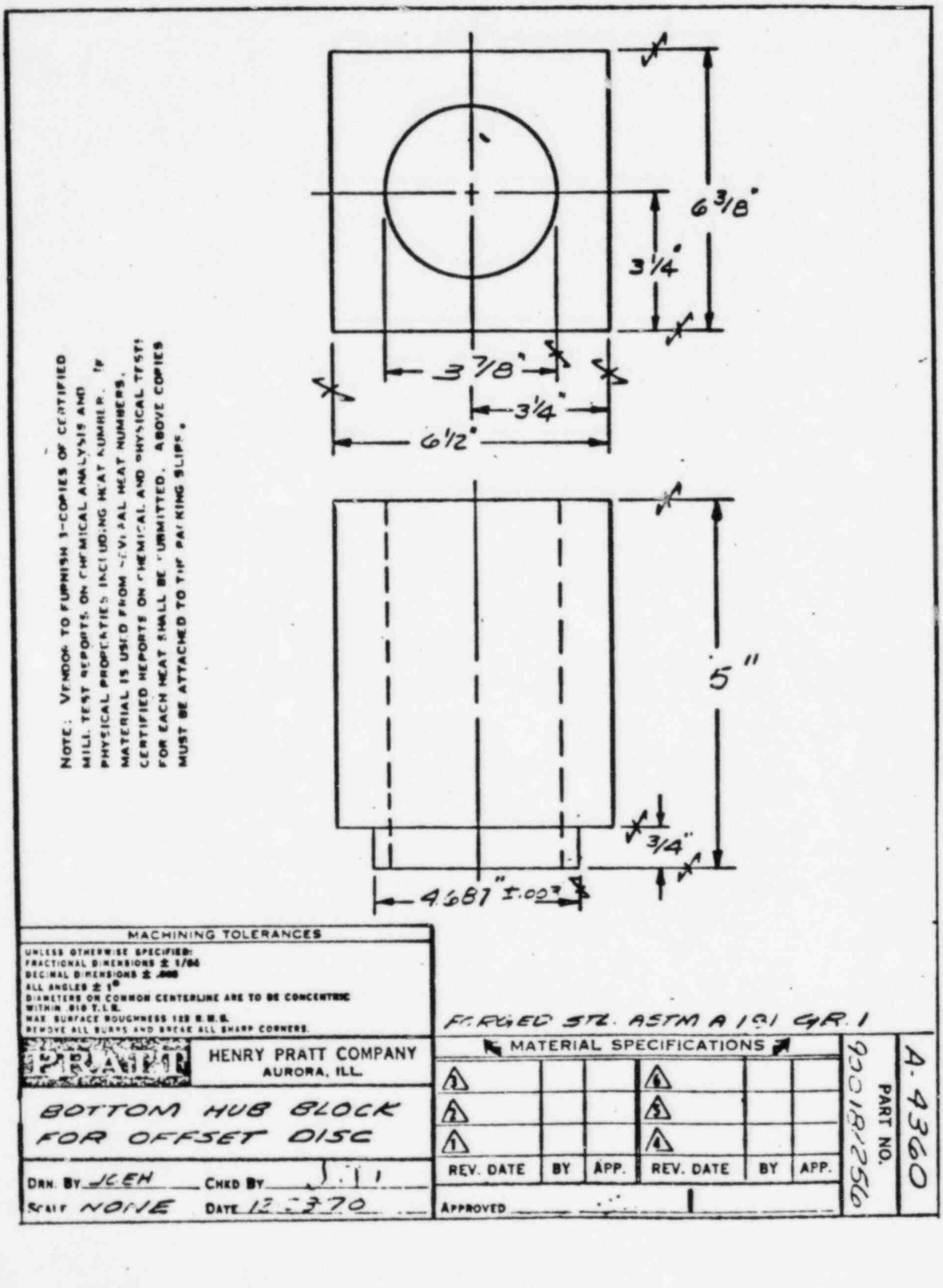
Project	Commonwealth Edison
Subject	42" R1A8 Butterfly Valve
System	for Zion Units 1 & 2
Analysis No.	1008
Rev. No.	0
Prepared By	JM Foley
Date	12/15/82
Checked By	RP Lasaxx
Date	12/16/82
Job No.	83003
File No.	1-F
Sheet No.	1008-52



Calculation Sheet

CYGNA

Project: Commonwealth Edison	Prepared By: J M Foley	Date: 12/15/82	
Subject: 42" R1A8 Butterfly Valve	Checked By: R L Crognan	Date: 12/16/82	
System: for Zion Units 1 & 2	Job No: 83003	File No: 1-F	
Analysis No: 1008 Rev. No: 0	Sheet No: 1008-53		

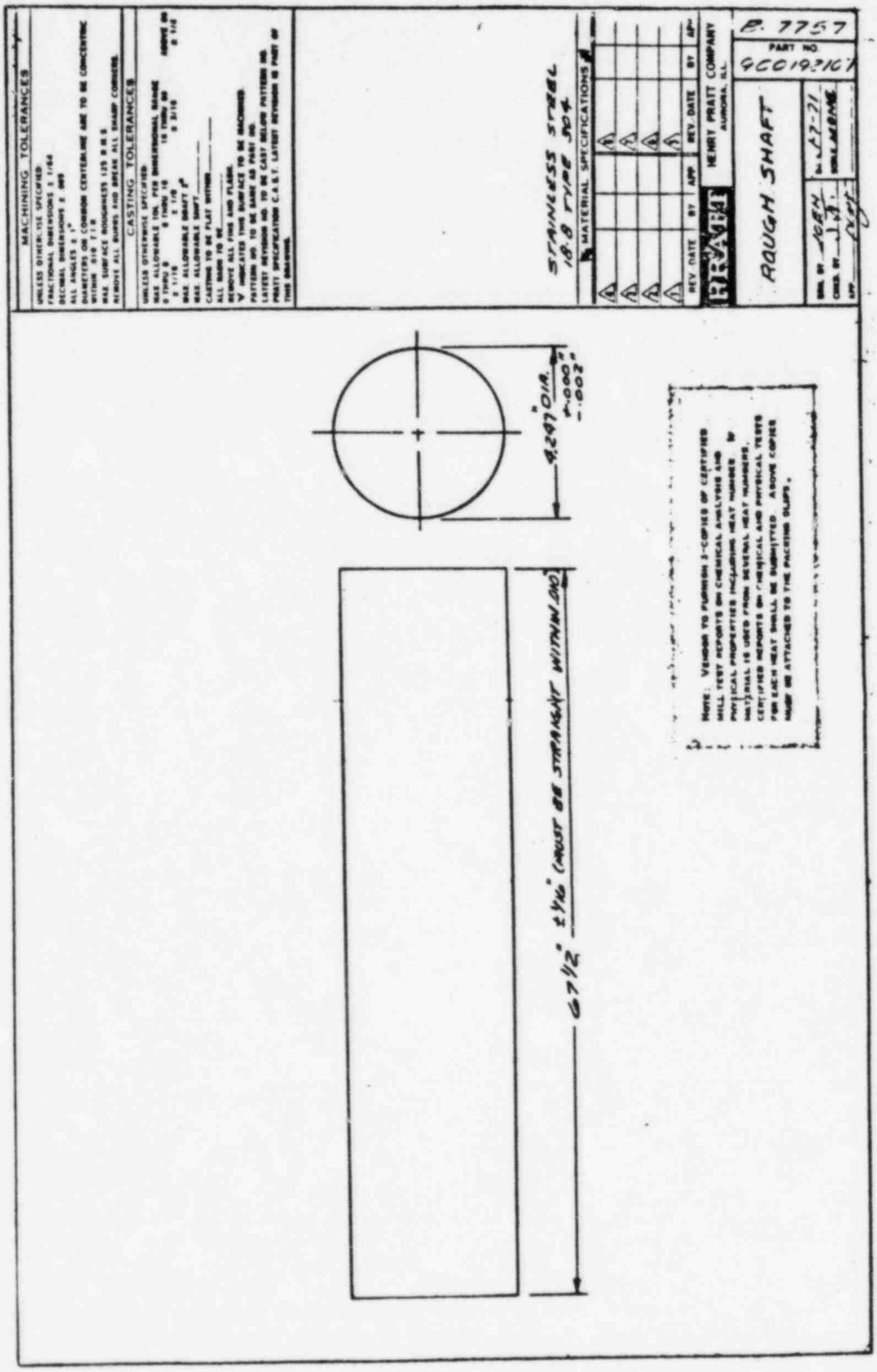


1006.00

CYGNA

Calculation Sheet

Project: Commonwealth Edison		Prepared By: J M Foley	Date: 12/15/82
Subject: 42" R1A8 Butterfly Valve		Checked By: R C [illegible]	Date: 12/16/82
System: for Zion Units 1 & 2		Job No: 83003	File No: 1-F
Analysis No: 1008	Rev. No: 0	Sheet No: 1008-54	



5.3 MATERIAL PROPERTIES

ALL OF THE COMPONENTS ARE MADE OF STEEL. THE FOLLOWING GENERAL PROPERTIES ARE USED:

E = YOUNG'S MODULUS = 29.0×10^6 PSI

ν = POISSON'S RATIO = 0.3

ρ = MASS DENSITY = $0.283/386.4 = 0.00073 \ \frac{\#\text{-sec}^2}{\text{IN}^4}$

α = THERMAL EXPANSION COEFFICIENT = 6.5×10^{-6} IN/IN/DEGREE

G = SHEAR MODULUS = 11.5×10^6 PSI

SINCE THE VARIOUS ELEMENT TYPES USED REQUIRE DIFFERENT SETS OF PROPERTIES, SEVERAL MATERIAL NUMBERS ARE DEFINED. EACH MATERIAL GROUPS ONLY THE PROPERTIES FROM THE ABOVE LIST WHICH APPLY TO A PARTICULAR ELEMENT TYPE.

5.4 NODAL COUPLING

TWO METHODS ARE USED TO RIGIDLY CONNECT VARIOUS SECTIONS OF THE MODEL, AND TO REPRESENT STIFF SEGMENTS OF THE ASSEMBLY.

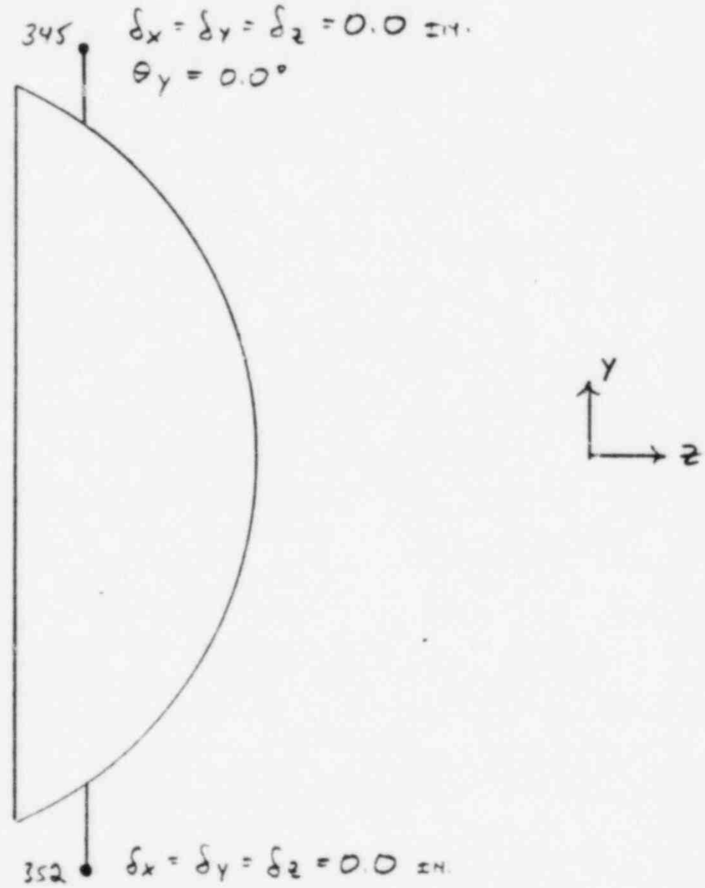
FIRST, RIGID MEMBERS (STIFF 3-D BEAMS) ARE USED TO TIE THE DISC TO THE DOME, AND TO CONNECT THE SHAFT TO THE DOME AT THE INTERSECTION POINTS BETWEEN THE HUBS AND THE CURVED SHELL.

SECOND, ANSYS NODAL COUPLING IS USED TO CONNECT THE STEM TO THE TOP OF THE UPPER HUB AND THE BOTTOM OF THE LOWER HUB. ALL SIX DEGREES OF FREEDOM AT EACH POINT ARE COUPLED.

Calculation Sheet	Prepared By: JM Foley	Date: 12/15/82
	Checked By: RP Casacco	Date: 12/16/82
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-57	
Analysis No: 1008 Rev. No: 0		

5.5 BOUNDARY CONDITIONS

THE ENDS OF THE STEM ARE ASSUMED TO BE SIMPLY SUPPORTED TO REPRESENT A SUPPORT AT A BEARING. IN ADDITION, THE AXIAL TRANSLATION OF THE STEM IS RESTRAINED AT BOTH ENDS. FINALLY, THE TORSIONAL ROTATION AT THE TOP OF THE STEM IS RESTRAINED TO REPRESENT THE REACTION LOAD APPLIED BY THE VALVE OPERATOR. THESE CONDITIONS ARE SHOWN BELOW.



5.6 DEVELOPMENT OF LOAD CASES

AN EXAMINATION OF THE NATURE OF THE LOADS ON THE DISC / STEM ASSEMBLY SHOWS THAT TWO LOAD CASES MUST BE CONSIDERED. AT ANY OF THE OPEN POSITIONS THE DISC EXPERIENCES AN ASYMMETRIC LOADING DISTRIBUTION DUE TO THE PRESSURE APPLIED BY THE FLUID. (SEE PG 124 OF REF 3). THIS LOAD WILL PRODUCE A TORSION ON THE STEM AS WELL AS A SHEAR LOAD. TO MODEL THIS CONDITION THE POINT OF MAX. DYNAMIC TORQUE WILL BE USED AS DETERMINED IN SECTION 4.7. A CORRESPONDING SHEAR LOAD WILL BE FOUND AND APPLIED WITH THE TORQUE TO THE SHAFT. THIS IS LOAD CASE #1 AND WILL BE USED TO CALCULATE THE MAXIMUM STRESSES IN THE SHAFT AND STEM. (BOTH 5 SEC & 8 SEC CASE ARE CONSIDERED.)

A SECOND LOAD CASE WILL BE APPLIED TO DETERMINE THE MAXIMUM DOME STRESSES. FOR THIS CASE THE MAXIMUM UPSTREAM PRESSURE EXPERIENCED BY THE VALVE WILL BE APPLIED DIRECTLY TO THE FACE OF THE DOME. THE PRESSURE USED WILL BE THE PEAK OF THE PRESSURE-TIME CURVE IN FIGURE 4-2. CRITICAL STRESSES AS WELL AS THE POSSIBILITY OF LOCAL BUCKLING OF THE DOME WILL BE CONSIDERED.

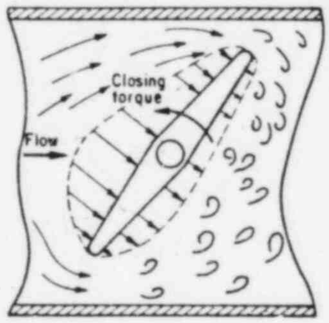
Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
Project: Commonwealth Edison	Checked By: R P Cesaro	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
System: for Zion Units 1 & 2	Sheet No. 1008-59	
Analysis No. 1008 Rev. No. 0		

CYGNA

DEVELOPMENT OF LOAD CASES (CONT.)

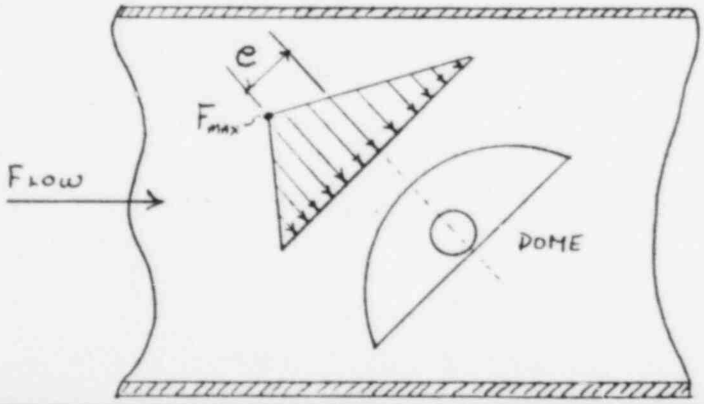
CASE #1 - MAX TORQUE

PAGE 124 OF REF 3 SHOWS THAT THE DYNAMIC FLOW TORQUE IS CAUSED BY THE UNEVEN LOAD DISTRIBUTION ALONG THE FACE OF THE DOME. THIS IS SHOWN IN THE FOLLOWING SKETCH.



AERODYNAMIC FORCES ACTING ON PARTIALLY OPEN FLAT VANE.

THIS LOAD DISTRIBUTION WILL BE APPROXIMATED BY AN ECCENTRIC TRIANGULAR DISTRIBUTED LOAD.



DEVELOPMENT OF LOAD CASES

CASE #1 - MAX. TORQUE (CONT.)

IN ORDER TO SOLVE THE LOAD DISTRIBUTION IT WILL BE NECESSARY TO DETERMINE THE MAXIMUM DISTRIBUTED LOAD (F_{MAX}) AND THE CORRESPONDING ECCENTRICITY (e) WHICH WILL PRODUCE THE MAX. TORQUE ON THE STEM. FIRST THE ECCENTRICITY IS APPROXIMATED BASED ON THE FOLLOWING ASSUMPTIONS:

1. THE OPENING ANGLE (θ) CORRESPONDING TO THE MAX TORQUE IS $\approx 66.0°$ [AVERAGE FOR BOTH CLOSING TIMES. (SEE SECTION 4.7)]

2. THE POINT OF MAX LOAD ON THE DOME WILL BE AT THE INTERSECTION OF THE DOME SURFACE AND THE CENTERLINE OF THE PIPE. THIS ASSUMPTION IS BASED ON THE FOLLOWING OBSERVATIONS:

   a. DUE TO VISCOUS DRAG, THE LOAD AT THE CENTER OF THE PIPE IS SLIGHTLY LARGER THAN AT THE WALLS OF THE PIPE.

   b. THE PRESSURE AT EACH POINT ON THE DOME SURFACE IS DECREASING FROM THE LEADING EDGE TO THE TRAILING EDGE OF THE DISC.

DEVELOPMENT OF LOAD CASES

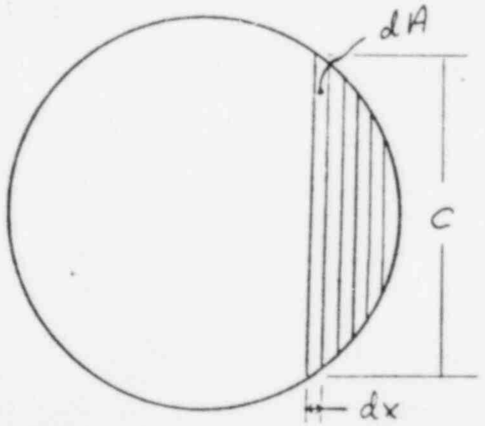
CASE #1 - MAX TORQUE (CONT.)

c. DUE TO THE CURVATURE OF THE DOME, FOR ANGLES NEAR FULL OPEN A LARGE SECTION OF THE LEADING EDGE IS ESSENTIALLY PERPENDICULAR TO THE FLOW. THEREFORE, THE PRESSURE IN THIS REGION WILL BE ESSENTIALLY UNIFORM.

d. THE REGION DESCRIBED IN "C" ABOVE EXTENDS TO APPROXIMATELY THE PIPE CENTER LINE. (SEE EXAMPLE ON PAGE 63)

e. THE FORCE IS PROPORTIONAL TO THE PRESSURE AND THE APPLIED AREA. THE DISTRIBUTED LOAD CAN BE FOUND FOR EACH POINT BY APPLYING A LIMIT ANALYSIS TO THE DIFFERENTIAL AREA AT EACH POINT AS DESCRIBED IN ITEM "f" BELOW

f. THE LOAD ON EACH DIFFERENTIAL SECTION SHOWN BELOW IS $L = P\,dA$ (L = LOAD)



FRONT VIEW OF DOME

DEVELOPMENT OF LOAD CASES

CASE #1 - MAX. TORQUE

f. (CONT)

IF $dx \rightarrow 0$ THEN $dA \rightarrow C$ (THE CORD LENGTH). AS THIS OCCURS THEN $L \rightarrow F$ (THE DISTRIBUTED LOAD IN LB/IN). FROM THIS IT IS CLEAR THAT FOR THE REGION WHERE P IS CONSTANT THE MAX F OCCURS AT THE POINT WITH THE LONGEST CORD LENGTH.

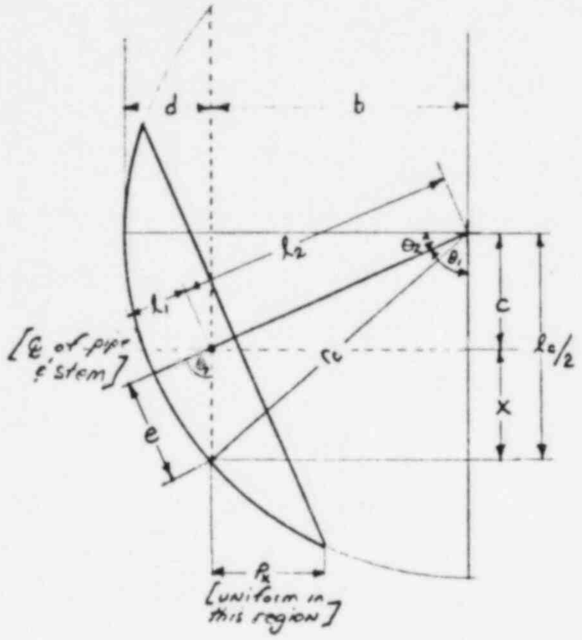
g. AS SHOWN ON THE SKETCH ON THE NEXT PAGE, FOR $\theta > 45°$ AND THE UNIFORM PRESSURE REGION ENDING AT APPROXIMATELY THE CENTERLINE OF THE PIPE, THEN THE LONGEST CORD WHICH WILL EXPERIENCE THE MAX PRESSURE WILL BE AT THE INTERSECTION OF THE DOME AND CENTERLINE.

3. THE ECCENTRICITY IS DEFINED AS THE DISTANCE (PARALLEL TO THE BACKPLATE) FROM THE MIDDLE OF THE DOME TO THE POINT OF MAX DISTRIBUTED LOAD.

THE GEOMETRIC SOLUTION FOR "e" IS SHOWN ON THE NEXT PAGE. THE SOLUTION IS FOR $\theta = 66.0°$ OPEN.

Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
Project: Commonwealth Edison	Checked By: R P [illegible]	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No.: 83003	File No.: 1-F
System: for Zion Units 1 & 2	Sheet No.: 1008-63	
Analysis No. 1008 Rev. No. 0		

Geometric Solution for 'e'.



r_c = radius of curvature = $\underline{26.25^{in}}$

$l_1 = 7\tfrac{7}{16}" + \tfrac{1}{2}(1\tfrac{1}{4}") - 3\tfrac{1}{2}"$

$l_1 = \underline{4.5625^{in}}$

$\theta_1 = \underline{66°}$

$b = l_2 \sin\theta_1 = \underline{19.813^{in}}$

$x = (l_c/2) - c = \underline{8.378^{in}}$

$d = r_c - b = \underline{6.437^{in}}$

$l_2 = r_c - l_1 = \underline{21.6875^{in}}$

$\theta_2 = 90° - \theta_1 = \underline{24°}$

$c = l_2 \sin\theta_2 = \underline{8.821^{in}}$

$l_c = 2\left[2dr_c - d^2\right]^{1/2} = \underline{34.439^{in}}$

$e = x \sin\theta_1 = \underline{7.67^{in}}$

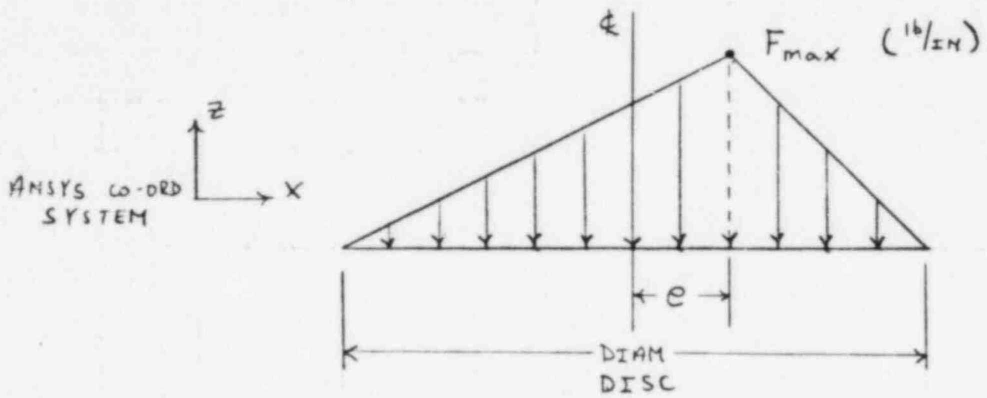
ref. dwg's: C-962, B-7673, B-7669

CYGNA	Calculation Sheet	Prepared By: J.M. Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: R.P. [illegible]	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
	System: for Zion Units 1 & 2	Sheet No: 1008-64	
	Analysis No: 1008 Rev. No: 0		

DEVELOPMENT OF LOAD CASES

CASE # 1 - MAX TORQUE (CONT.)

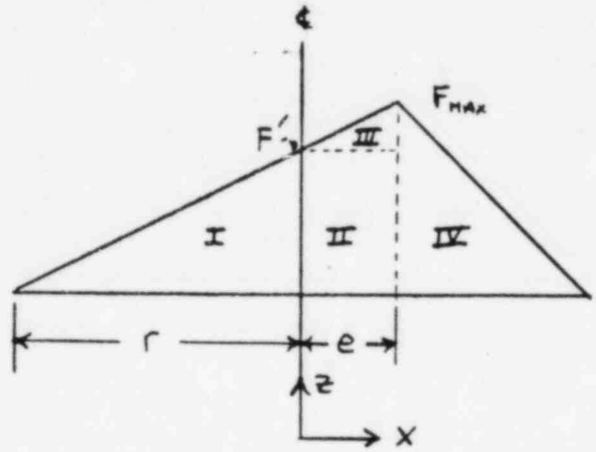
THE SHAPE OF THE LOAD DISTRIBUTION CAN NOW BE DEFINED BASED ON THE SOLUTION FOR "e".



THE TORQUE CAN NOW BE DEFINED AS THE DIFFERENCE IN THE MOMENTS PRODUCED BY THE AREA UNDER THE LEFT AND RIGHT SIDES OF THE CURVE. BY SETTING UP THE EQUATION FOR THE MOMENTS AS A FUNCTION OF F_{MAX} AND EQUATING IT TO THE MAX TORQUE, THE CORRESPONDING VALUE OF F_{MAX} CAN BE CALCULATED. THIS IS DONE ON THE FOLLOWING PAGES.

Calculation Sheet	Prepared By: JM Foley	Date: 12/15/82
	Checked By: RP Cavasso	Date: 12/16/82
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-65	
Analysis No: 1008 Rev. No: 0		

DEVELOPMENT OF LOAD CASES (CONT.)



r = 20.5"
e = 7.67"

$$T_D = (\Sigma F_I)\bar{x}_I + (\Sigma F_{II})\bar{x}_{II} + (\Sigma F_{III})\bar{x}_{III} + (\Sigma F_{IV})(\bar{x}_{IV})$$

WHERE ΣF_i = AREA OF SECTION i

$\bar{x}_i$ = DISTANCE FROM ℄ TO CENTROID OF SECTION i

F' = FORCE MAGNITUDE AT ℄

$$F' = \frac{(F_{MAX})(r)}{(r+e)} = (0.728)F_{MAX}$$

$$\Sigma F_I = F'\left(\frac{r}{2}\right) = (7.46)F_{MAX}$$

$$\bar{x}_I = -\,r/3 = -6.83$$

$$\longrightarrow \Sigma F_I \bar{x}_I = (-50.95)F_{MAX}$$

$$\Sigma F_{II} = F'e = (5.58)F_{MAX}$$

$$\bar{x}_{II} = e/2 = 3.84$$

$$\longrightarrow \Sigma F_{II}\bar{x}_{II} = (21.43)F_{MAX}$$

DEVELOPMENT OF LOAD CASES

CASE #1 MAX TORQUE (CONT.)

$$\Sigma F_{III} = \frac{(F_{max} - F')e}{2} = \frac{(F_{max})(1-0.728)e}{2} = (1.04)F_{max}$$

$$\bar{x}_{III} = 2e/3 = 5.11$$

$$\longrightarrow \Sigma F_{III}\bar{x}_{III} = 5.31\ F_{MAX}$$

$$\Sigma F_{IV} = F_{MAX}\left(\frac{r-e}{2}\right) = (6.4)F_{MAX}$$

$$\bar{x}_{IV} = e + \left(\frac{r-e}{3}\right) = 11.95$$

$$\longrightarrow \Sigma F_{IV}\bar{x}_{IV} = (76.5)F_{MAX}$$

$$T = F_{MAX}(-50.95 + 21.43 + 5.31 + 76.5)$$

$$\longrightarrow T = (52.3)F_{MAX}$$

$$F_{MAX} = T/52.3$$

FOR $T_{MAX} = 189576$ IN-LB {FROM SECTION 4.7, 8 SEC CLOSING TIME}

$$\Longrightarrow F_{MAX} = 189576/52.3 = 3625\ \#/\text{IN}$$

$$F_{TOTAL} = F_{MAX}\left(\frac{2r}{2}\right) = 74313\ \#$$

IN ADDITION TO THE TORQUE THIS LOAD WILL ALSO PRODUCE A SHEAR IN THE SHAFT. AGAIN, THIS LOAD WILL BE A FUNCTION OF THE PRESSURE AND AREA AND WILL BE DISTRIBUTED FROM THE TOP TO THE BOTTOM OF THE SHAFT ACCORDING TO THE AREA.

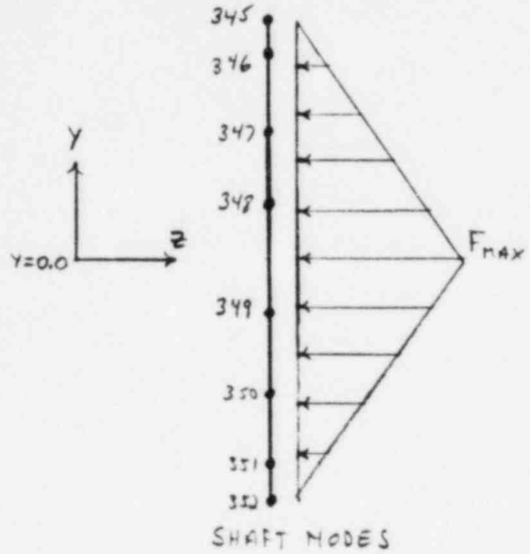
Calculation Sheet	Prepared By: JM [signature]	Date: 12/15/82
Project: Commonwealth Edison	Checked By: RR [signature]	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
System: for Zion Units 1 & 2	Sheet No: 1008-67	
Analysis No: 1008 Rev. No: 0		

CYGNA

DEVELOPMENT OF LOAD CASES

CASE #1 - MAX TORQUE (CONT)

ASSUME A SYMMETRIC, TRIANGULAR DISTRIBUTION FROM THE TOP TO THE BOTTOM OF THE DISC AS SHOWN BELOW. (NOTE: THE SEPARATION BETWEEN THE BEARINGS (NODES 345, 352) IS TAKEN AS THE PIPE O.D=42")



Y- COORDINATES OF NODES

	NODE	Y	TRIBUTARY-L*	MID POINT*
TOP BEARING	345	21.0	1.0	20.50
	346	19.0	4.5	17.75
	347	12.0	6.3125	12.34
	348	6.375	9.1875	4.59
	349	-6.375	10.5625	-5.28
	350	-14.75	6.3125	-13.72
	351	-19.0	3.125	-18.44
LOWER BEARING	352	-21.0	1.0	-20.50

*(1) THE TRIBUTARY LENGTH AT NODE i IS DEFINED AS

$$TRIB\text{-}L = \frac{(Y_i - Y_{i+1}) + (Y_{i-1} - Y_i)}{2} = \frac{Y_{i-1} - Y_{i+1}}{2}$$

FOR NODES 345 AND 352

$$TRIB\text{-}L = \frac{Y_i - Y_{i+1}}{2}$$

(2) THE MID POINT IS THE Y CO-ORDINATE OF THE CENTER OF EACH TRIBUTARY LENGTH.

$$MID = \frac{2Y_i + Y_{i+1} + Y_{i-1}}{4}$$

$$MID_{345,352} = Y_i - \frac{TRIB\text{-}L}{2}$$

Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
	Checked By: R P Cassano	Date: 12/16/82
Project: Commonwealth Edison	Job No: 83003	File No: 1-F
Subject: 42" R1A8 Butterfly Valve		
System: for Zion Units 1 & 2	Sheet No: 1008-68	
Analysis No: 1008 Rev. No: 0		

DEVELOPMENT OF LOAD CASES

CASE #1 - MAX TORQUE (CONT.)

THE LOAD AT EACH POINT IS THEN FOUND BY TAKING THE AVERAGE DISTRIBUTED LOAD (F AT MID-POINT LOCATION) TIMES THE TRIBUTARY LENGTH. THE DISTRIBUTED LOAD AT ANY POINT IS FOUND BY TAKING SIMILAR TRIANGLES WITH F_{MAX} AT THE MIDDLE:

$$F_i = \left(\frac{F_{MAX}}{r}\right)(r - |Y_m|) = \left(\frac{21 - |Y_m|}{21}\right) F_{MAX}$$

Y_m = Y AT MIDPOINT

THE TOTAL LOAD WAS BASED ON A 41" DISC/PLATE DIAMETER AND WAS FOUND TO BE

$$F_{TOTAL} = 74313\,\#$$ (8 SEC CLOSING)

THEREFORE, SINCE F_{TOTAL} = AREA UNDER THE TRIANGLE FOR A BEARING SEPARATION OF 42" ($r = 21"$):

$$F_{max} = F_{TOTAL}/r = F_{TOTAL}/21.$$

THEREFORE, COMBINING ALL THREE EQUATIONS ABOVE:

$$F_i = \left[\frac{(21 - |Y_m|)}{(21)^2}\right](74{,}313) = (21 - |Y_m|)(167.5)$$

AND THE TOTAL LOAD AT EACH NODE IS

$$F_{T_i} = (F_i)(\text{TRIB-L}_i)$$

CYGNA	**Calculation Sheet**	Prepared By: J M Foley	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: R P Larson	Date: 12/16/82
	Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
	System: for Zion Units 1 & 2	Sheet No: 1008-69	
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DEVELOPMENT OF LOAD CASES

CASE #1 - MAX TORQUE (CONT)

BASED ON THE PREVIOUS EQUATIONS, THE LOAD WILL BE APPLIED AS FOLLOWS (8 SEC CLOSING)

NODE	FORCE (F_{Ti})
345	84.26 lb
346	2464.65 lb
347	9212.51 lb
348	25407.65 lb
349	27981.99 lb
350	7744.46 lb
351	1348.18 lb
352	84.26 lb
TOTAL	74327.91 lb ≈ 74313 OK

IN ADDITION, THE TORQUE WILL BE APPLIED IN EQUAL PORTIONS AT NODES 348 AND 349.

$$MY_{348,349} = T_{MAX}/2 = 189576/2 = 94788.0 \text{ IN-LB}$$

THE LOADS FOR THE 5-SECOND CLOSING TIME (CASE-1A) ARE CALCULATED ON THE NEXT PAGE.

1006 00

DEVELOPMENT OF LOAD CASES

TORQUE FOR 5 SEC CLOSING TIME - CASE 1A

FOLLOWING THE DERIVATION OF THE EQUATION RELATING F MAX TO TORQUE ON PAGES 1008-59 THROUGH 1008-69 USE THE EQUATION $T = 52.3 F_{MAX}$ (P. 1008-66) TO COMPUTE F_{MAX}.

THE TORQUE ASSOCIATED WITH A 5 SECOND CLOSING TIME IS 167431 IN-LB (P. 1008-32)

$$F_{MAX} = \frac{167431^{\text{IN-LB}}}{52.3} = 3201 \frac{\text{lb}}{\text{in}}$$

$$F_{TOTAL} = F_{MAX}\left(\frac{2r}{2}\right) = 3201 \frac{\text{lb}}{\text{in}}(20.5\text{in}) = 65620\text{lb}$$

IN ADDITION TO THE TORQUE THE LOAD, F_{TOTAL} WILL PRODUCE A SHEAR IN THE SHAFT. THE LOAD WILL BE APPLIED TO THE SHAFT IN PROPORTION TO AREA OF THE DISC. USING THE SAME TRIANGULAR DISTRIBUTION AS WAS USED ON PAGE 1008-67 COMPUTE THE LOADS AT THE VARIOUS SHAFT NODES. THE NODAL LOADS FOR THE 5 SECOND CLOSING TIME ARE COMPUTED BY SIMPLY TAKING THE RATIO OF THE TOTAL LOADS FOR THE TWO CASES AND APPLYING IT TO THE NODAL LOADS FOR CASE 1 (P. 1008-69)

DEVELOPMENT OF LOAD CASES

TORQUE FOR 5 SEC CLOSING TIME - CASE 1A

RATIO: $\frac{65620}{74313 \text{ lb}} = 0.883$

NODE	$F_{CASE\ 1}$ (lb)		F_{5SEC} (lb)
345	84.26	× 0.883	74.4
346	2464.65		2176.3
347	9212.51		8134.6
348	25407.65		22435.0
349	27981.94		24708.1
350	7744.46		6838.4
351	1348.18		1190.4
352	84.26		74.4
		TOTAL	65631.6

65631.6 lb ≈ 65620 lb OK

THE TORQUE WILL BE APPLIED IN EQUAL PROPORTIONS TO NODES 348 & 349

$M_{Y\ 348,\ 349} = \frac{167431 \text{ IN-LB}}{2} = 83,715.5 \text{ IN-LB}$

DEVELOPMENT OF LOAD CASES

CASE # 2 - MAX PRESSURE

TO CHECK THE STRESSES IN THE DOME, THE MAXIMUM PRESSURE FROM THE P1 VS TIME CURVE (FIG 4-2) IS APPLIED TO THE DOME SHELL ELEMENTS. IN REALITY, THE PRESSURE WILL OCCUR AFTER THE DISC IS SEATED, AND THUS ADDITIONAL EDGE RESTRAINT COULD BE APPLIED. HOWEVER, FOR CONSERVATISM, THE SAME BOUNDARY CONDITIONS WILL BE APPLIED AS WERE USED IN CASE # 1. THE MEMBRANE PLUS BENDING STRESSES, AS WELL AS THE POSSIBILITY OF LOCAL BUCKLING IN THE DOME, WILL BE CONSIDERED. THE ELEMENT FACE PRESSURE OPTION OF ANSYS WILL BE USED TO APPLY THE LOAD.

6.0 STRESS ANALYSIS

The load cases described in Section 5.6 are applied to the ANSYS finite element model. The complete ANSYS output files are included with this report as Appendix B & C. Appropriate file names were assigned to each output for reference. These are:

NAME	DESCRIPTION
O_FORCE-8	Stress output for loads representing the maximum torque for the 8 second closing time.
O_FORCE-5	Stress output for loads representing the maximum torque for the 5 second closing time.
O_PRESS	Stress output for maximum pressure loads.

6.1 ALLOWABLE STRESSES

FIND THE ALLOWABLE STRESSES FOR THE VARIOUS MATERIALS ASSOCIATED WITH THIS VALVE. THE VALVE IS CLASSIFIED AS SEISMIC CLASS ONE (REFERENCE 4 p. 5) THE ALLOWABLE STRESS WILL BE TAKEN AS THE MINIMUM SPECIFIED YIELD STRESS OF THE MATERIAL TIMES A FACTOR BASED UPON AISC ALLOWABLES.

COMPONENT	MATERIAL	S_Y (min)
DOME BACKPLATE	A 515 GR 60	32.0
EDGE RING STEM	TYPE 304 STAINLESS STEEL 18 CR - 8 Ni	25.0
HUB	A - 181	30.0

(REF. ASME B&PV CODE TABLES I-1.1 & I-1.2

AISC ALLOWABLES ARE APPLIED TO THE NON - PRESSURE RETAINING PARTS OF THE VALVE. THE PRESSURE CASE THAT IS THE

6.1 ALLOWABLE STRESSES (CONTINUED)

SUBJECT OF THIS ANALYSIS IS THE RESULT OF A LOSS OF COOLANT ACCIDENT (LOCA) AND AS SUCH IS A FAULTED CONDITION.

MEMBRANE + BENDING - $0.96 S_Y$
SHEAR - $0.64 S_Y$

WHEN THE STRESS LEVELS IN THE VALVE PARTS SATISFY THESE STRESS ALLOWABLES OPERABILITY IS ALSO ADDRESSED.
THE STRESS LEVELS ARE LESS THAN THE YIELD STRESS SO NO PERMANENT DEFORMATION HAS OCCURED AND PARTS RETURN TO THEIR ORIGINAL DIMENSIONS.

6.2 STRESS RESULTS - ANSYS

THE MAXIMUM STRESSES FROM THE ANSYS ANALYSIS ARE SUMMARIZED IN THE FOLLOWING TABLES FOR EACH LOAD CASE. THESE TABLES COVER ALL OF THE COMPONENTS EXCEPT THE TAPER PINS WHICH ARE TREATED SEPARATELY IN SECTION 6.3. NOTE THAT SINCE ANSYS STIF9 ELEMENTS WERE USED FOR THE STEM, SHAFT AND HUBS, A SHEAR AREA OF ½ THE ACTUAL AREA IS USED TO CALCULATE THE SHEAR (SSF). THIS IS ACCEPTABLE FOR THE HOLLOW SHAFT AND HUBS, BUT SHOULD NOT BE INCLUDED FOR THE STEM. THEREFORE, THE ACTUAL STRESS FOR THE STEM EQUALS (½)(SSF) WHERE "SSF" IS THE SHEAR STRESS PRINTED BY ANSYS. THE COMPLETE STRESS RESULTS ARE INCLUDED IN APPENDIX B & C.

THE ALLOWABLES ARE FROM SECTION 6.1 OF THIS REPORT.

ANSYS TERMINOLOGY:

SDIR = DIRECT STRESS (σ)
SBEND = BENDING STRESS (σ_b)
ST = TORSIONAL STRESS (τ_T)
SSF = SHEAR STRESS (τ)

CYGNA	**Calculation Sheet**	Prepared By: J M Foley	Date: 12/15/82
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	Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
	System: for Zion Units 1 & 2	Sheet No.	
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STRESS RESULTS - ANSYS (CONT.)

LOAD CASE #1 - 8 SEC CLOSE

COMPONENT	WORST ELEMENT	SBEND (KSI)	0.96·Sy (KSI)	ST+SSF (KSI)	0.64·Sy (KSI)
STEM	392	9.8	24.0	15.2 (1)	16.0
SHAFT (3)	389	9.3	28.8	0.8	19.2
TOP HUB	387	8.6	28.8	2.7	19.2
BOTTOM HUB	391	9.0	28.8	4.2	19.2
DOME	55	10.6 (2)	30.7	N/A	N/A

NOTES: (1) SHEAR FOR STEM IS $ST + \frac{SSF}{2}$.

(2) THIS IS S.I. MAX FOR PLATE ELEMENTS.

(3) ASSUMED TO HAVE SAME MATERIAL AS HUBS.

Calculation Sheet	Prepared By: J M [signature]	Date: 12/15/82
Project: Commonwealth Edison	Checked By: R F Cas[signature]	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No: 83003	File No: 1-F
System: for Zion Units 1 & 2	Sheet No: 1008-78	
Analysis No: 1008 Rev. No: 0		

CYGNA

STRESS RESULTS - ANSYS (CONT.)

LOAD CASE #1A - 5SEC CLOSE

COMPONENT	WORST ELEMENT	SBEND (KSI)	0.96·Sy (KSI)	ST+SSF (KSI)	0.64·Sy (KSI)
STEM	392	8.6	24.0	13.4 (1)	16.0
SHAFT (3)	389	9.7	28.8	0.7	19.2
TOP HUB	387	7.6	28.8	2.4	19.2
BOTTOM HUB	391	1.4	28.8	3.7	19.2
DOME	55	9.4 (2)	30.7	N/A	N/A

NOTES: (1) SHEAR FOR STEM IS $ST + \frac{SSF}{2}$.

(2) THIS IS SI. MAX FOR PLATE ELEMENTS.

(3) ASSUMED TO HAVE SAME MATERIAL AS HUBS.

STRESS RESULTS - ANSYS (CONT.)

LOAD CASE #2 - MAX. PRESSURE

COMPONENT	WORST ELEMENT	SBEND (KSI)	$0.96 \cdot S_y$ (KSI)	ST+SSF (KSI)	$0.64 \cdot S_y$ (KSI)
STEM	398	7.6	24.0	4.1 (1)	16.0
SHAFT (3)	388	3.4	28.8	1.1	19.2
TOP HUB	387	3.0	28.8	1.3	19.2
BOTTOM HUB	391	3.1	28.8	1.4	19.2
DOME	149	12.5 (2)	30.7	N/A	N/A

NOTES: (1) SHEAR FOR STEM IS $ST + \frac{SSF}{2}$.

(2) THIS IS SI. MAX FOR PLATE ELEMENTS.

(3) ASSUMED TO HAVE SAME MATERIAL AS HUBS.

DISC - CRITICAL BUCKLING PRESSURE

COMPUTE THE CRITICAL BUCKLING PRESSURE OF THE DISC. TREAT THE DISC AS A SPHERICAL CAP UNDER UNIFORM EXTERNAL PRESSURE (ROARK, 5th Edition, p. 557, TABLE 35, CASE 22.)

$$q' = \left[1 - 0.00875(\phi^\circ - 20^\circ)\right]\left[1 - 0.000175\frac{R}{t}\right]\left[.3E\right]\left[\frac{t}{R}\right]^2$$

$\phi = \frac{1}{2}$ CENTRAL ANGLE , t = thickness

R = RADIUS OF SEGMENT

$\phi = \sin^{-1}\frac{18.25''}{26.0''} = 44.6^\circ$ (P. 1008-47)

$R = 18.25''$ $t = 0.25''$

So, $q' = (1 - 0.00875(44.6^\circ - 20^\circ))(1 - 0.000175\frac{(18.25)}{.25})$

$(.3)(27.9 \times 10^6 \text{psi})\left(\frac{.25''}{18.25''}\right)^2$

$q' = 1232 \text{ psi} \gg q_{ACTUAL} = 57.7 \text{ psi}$

DISC WILL NOT BUCKLE DUE TO PRESSURE LOAD.

CYGNA	**Calculation Sheet**	Prepared By: [signature]	Date: 12/15/82
	Project: Commonwealth Edison	Checked By: [signature]	Date: 12/16/82
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6.3 SHEAR STRESS IN DISC TO STEM TAPER PINS

FIND THE SHEAR STRESS IN THE TAPER PINS THAT JOIN THE DISC HUB BLOCK TO THE STEM. THE SHEAR LOAD WILL RESULT FROM THE CLOSING TORQUE. CHECK THE TORQUE FOR TWO CLOSING TIMES. REFER TO DWGS. C-963 AND B-7656 FOR BASIC DIMENSIONS.

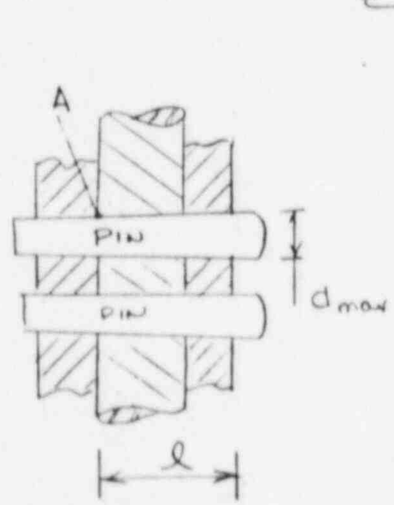
COMPUTE THE MINIMUM SHEAR AREA OF A PIN.

$d_{max} = 1.513"$ (C-963)

$\ell = 3\frac{1}{8}" + \frac{1}{2}\left(3\frac{7}{8}"\right) = 5.0625"$

B-7656

REF. 5 P. 8-34



$d_A = d_{max} - 2\left(\frac{1}{8}"\right)\left(\frac{\ell}{12"}\right) = 1.41$ IN

$A_{PIN} = \frac{\pi}{4}(1.41^{IN})^2 = 1.56$ IN²

$A_{TOTAL} = 2A_{PIN} = 3.12$ IN²

8 SEC TORQUE = 189576 IN-LB

SHEAR FORCE = $\frac{T_8}{d_{STEM}} = \frac{189576^{IN-LB}}{4.25"}$

$F_S = 44606$ lb

SHEAR STRESS 8 SEC. CLOSING $\tau_8 = \frac{44606 \text{ lb}}{3.12 \text{ IN}^2} = 14297$ PSI

Calculation Sheet	Prepared By [signature]	Date 12/15/82
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CYGNA

SHEAR STRESS IN TAPER PINS

5 SECOND TORQUE = 167,431 IN-LB

$$\tau_{5\ \text{SEC. CLOSING}} = \frac{167431\ \text{IN-LB}}{3.12\ \text{IN}^2\ (4.25\ \text{IN})} = 12627\ \text{psi}$$

THE PIN MATERIAL HAS NOT BEEN SPECIFIED ON THE AVAILABLE DRAWINGS. A SHEAR PIN OF THIS TYPE IS GENERALLY MADE OF A HIGH STRENGTH STEEL. FOR OUR CASE WE WILL USE THE MINIMUM ALLOWABLE OF THE THREE MATERIALS.

$$\sigma_v = 0.64\ (25.0\ \text{ksi}) = 16.0\ \text{ksi}$$

TAPER PIN SHEAR IS ADEQUATE.

CYGNA

Calculation Sheet

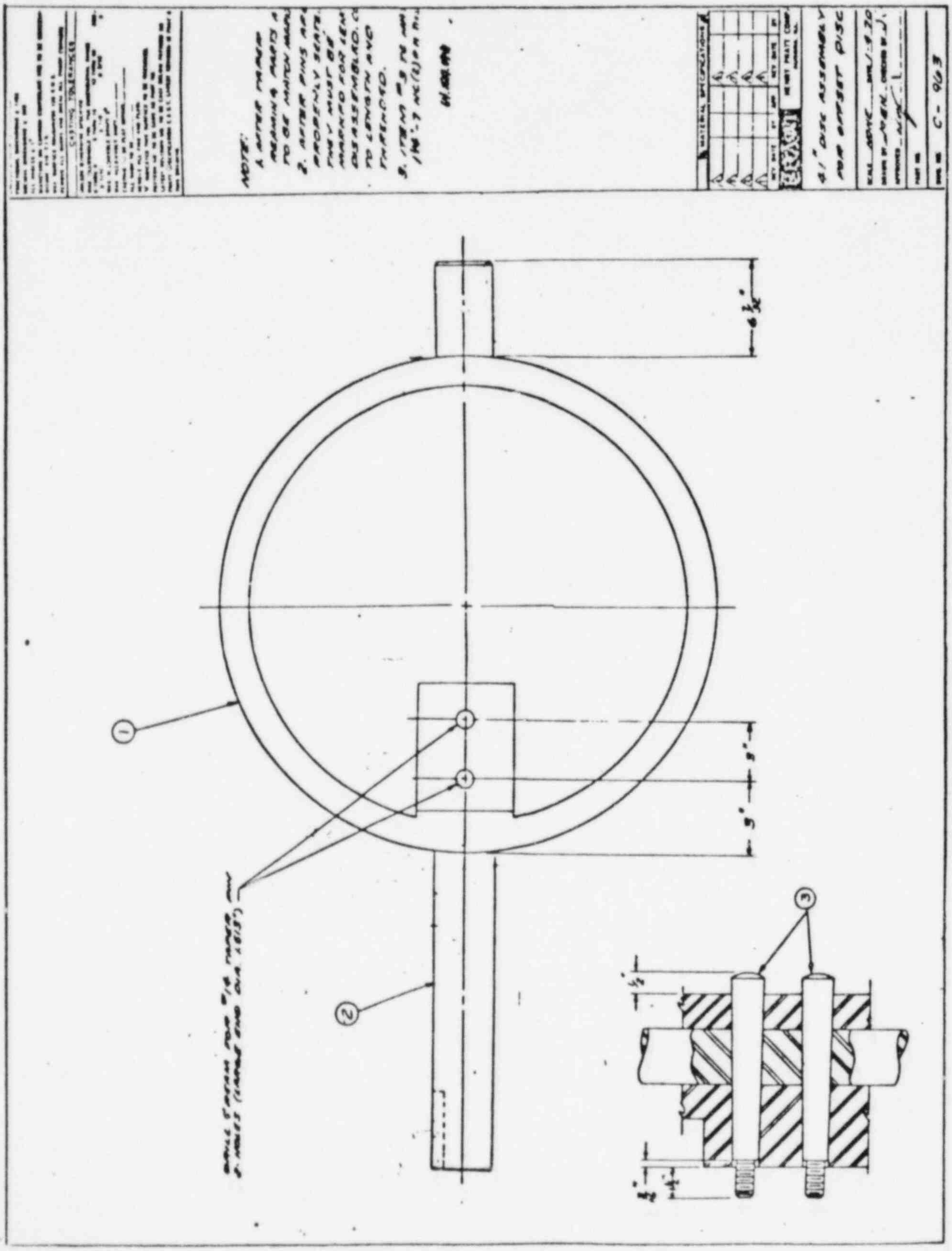
Prepared By: JM Foley	Date: 12/15/82	Checked By: E F Clarkson	Date: 12/16/82
Job No.: 83003	File No.: 1-F	Sheet No.: 1008-83	

Project: Commonwealth Edison

Subject: 42" R1A8 Butterfly Valve

System: for Zion Units 1 & 2

Analysis No.: 1008 Rev. No.: 0



Calculation Sheet	Prepared By: J M Foley	Date: 12/15/82
Project: Commonwealth Edison	Checked By: R P Cerone	Date: 12/16/82
Subject: 42" R1A8 Butterfly Valve	Job No. 83003	File No. 1-F
System: for Zion Units 1 & 2	Sheet No. 1008-84	
Analysis No. 1008 Rev. No. 0		

7.0 REFERENCES

1. "Isolation/Purge Valve Torque Calculation for 42"-R1A8 Butterfly Valve", by H. Pratt Co., Pratt Job No. 7-3794-1, dated 4/20/82.

2. Crane Catalogue, "Flow of Fluids through Valves, Fittings and Pipe", Technical Paper No. 410, Crane Co., NY, NY, 19th Printing, 1980.

3. "ISA Handbook of Control Valves", J. W. Hutchison, 2nd Edition.

4. Supplement 1 (Dated March 19, 1970) to specification X-2302 for miscellaneous butterfly valves for Zion Units 1 & 2, by Sargent & Lundy Engineers.

5. "Standard Handbook for Mechanical Engineers", L.S. Marks, 8th Edition.

6. "Formulas for Stress and Strain", Raymond J. Roark, Fifth Edition, McGraw Hill Book Company.

7. "Manual for Steel Construction", American Institute of Steel Construction, Seventh Edition.

8. "ASME Boiler and Pressure Vessel Code", 1980 Edition with addenda through Summer 1981.

9. "1981 User's Manual", Swanson Analysis Systems, Inc., Houston, PA, Rev. 4.0, November 1, 1981.

10 "ANSYS Theoretical Manual", Swanson Analysis Systems, Inc., Houston, PA, First Edition, November 1, 1977.

11 Shop drawings by H. Pratt Co., supplied by Commonwealth Edison. (Input document #83003-DID-001)

12. Telecon between S. Oppegaard (Commonwealth Edison) and J. M. Foley (Cygna) dated November 26, 1982.

13. Zion Nuclear Station FSAR.