STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

A 5010.64 (FRONT)

CLIENT & PROJECT	PAGE 1 OF
NIAGARA MOHAWK - NINE MILE POINT 2	63 including appendixes A & B

CALCULATION TITLE (Indicative of the Objective):	QA CATEGORY (✓)
INTEGRITY OF FEEDWATER CHECK VALVES FOLLOWING PIPE RUPTURE	☒ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ____ OTHER

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	Calculation Status
12177	NM(C)	1948	SQE	FINAL

APPROVALS - SIGNATURE & DATE [signature] 8-12-85

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES CALC. NO. OR REV. NO.	CONFIRMATION *REQUIRED (✓) YES	NO
J. Gwinn [signature] 6/27/85	Cam Ly [signature] 6/27/85	S. FELDMAN S. Feldman 6-29-85	New	—		X

*As listed in this block.

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SUMMARY

The reactor vessel is protected from blowdown following a postulated rupture of the feedwater piping outside the containment by Anchor/Darling check valve 2FWS*V012 inside the containment and by testable check valve 2FWS*AOV023 outside the containment. Breaks are not postulated in the piping between the valves because that region is classified as break exclusion.

The reverse flow caused by the sudden pressure reduction at the break rapidly closes both valves. This calculation examines the ability of these valves to withstand the impact of the disk on the seat without excessive leakage thereafter.

All stresses and loads from disk impact on the seat are computed using the non-linear transient option of the ANSYS computer program. Seismic, hydrodynamic and dead loads were not considered because of their insignificant magnitude compared to impact loads.

Since stresses in the rockshaft, tail link, seat and disk were below Class 1 ASME III allowables for faulted conditions, it is concluded that both valves will remain intact and that the leakage will be minimal.

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1. OBJECTIVE/INTRODUCTION

The purpose of this calculation is to evaluate the ability of Nine Mile Point 2 ASME III class 1 feedwater check valves 2FWS*AOV023(specification P303W) and 2FWS*V012(specification P303W) to withstand rapid closure following the postulated pipe break outside the containment(see Figure 1.1). Since long term leakage protection is provided by MOV21, the acceptance criterion for the faulted event is that gross leak rates do not occur because of disk rupture, serious fracture of the seat/disk interface or misalignment of the disk with respect to the seat.

Feedwater pump trip from high water level in the vessel, a normal operating condition, was found by the analysis in Reference 6 not to cause high energy impact of the disk on the seat. The inertia of the motor was sufficiently high that the pump took approximately 1000 seconds to completely stop. From the stand point of the valve, two(2) seconds were required to generate a reverse flow rate equal to the normal flow rate, resulting in a very gentle closing of these check valves. Pump trip is not a critical loading condition and is, therefore, not treated in this analysis.

Added to pipe rupture loads on a square-root-sum- of-squares basis are the seismic and hydrodynamic loads. However, they are considered negligible in this analysis because of insignificant magnitudes as compared to the impact forces generated by reverse flow following rupture of the feedwater line. For the same reason, dead load and opening loads are not considered in this analysis.

Figure 1.2 shows a cross-section of these valves from the vendor drawing. The details of the tail link are presented in Figure 1.3. Figure 1.4 is a sketch labelling typical dimensions and elements of importance to the integrity of these swing check valves.

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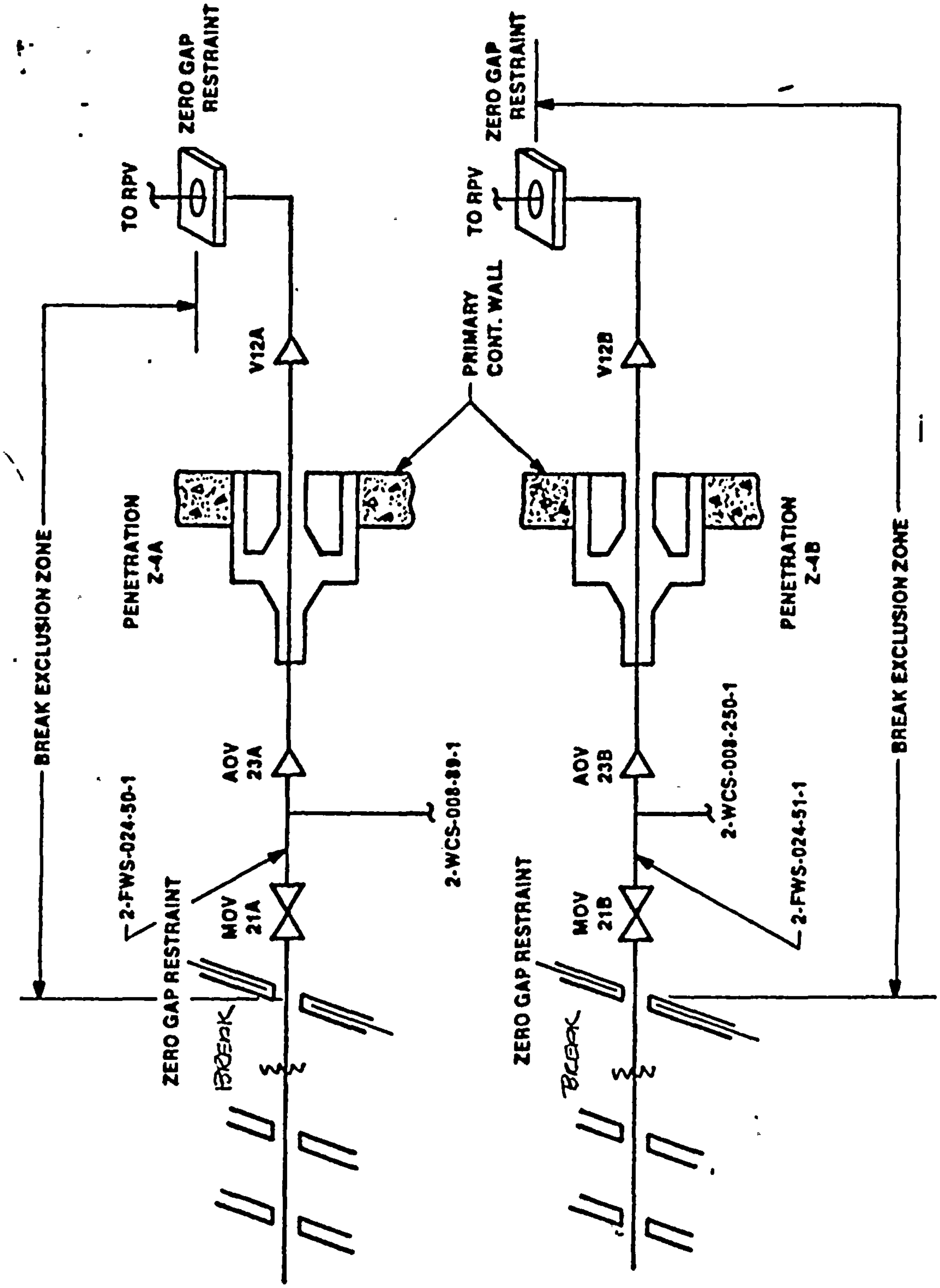

Figure 1.1 Sketch of Piping Model(Ref.13)

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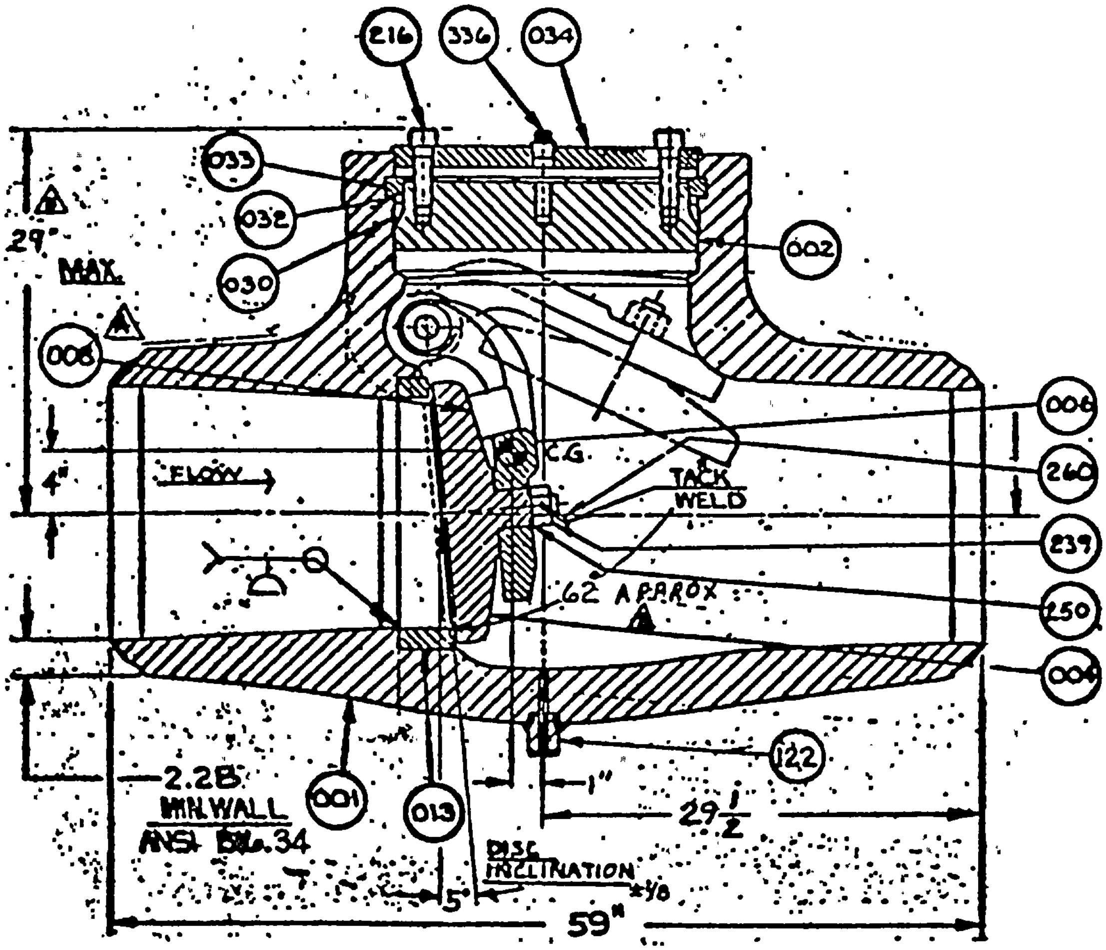

Figure 1.2 Cross-section of the AOV023/V012 Check Valve(Ref.2)

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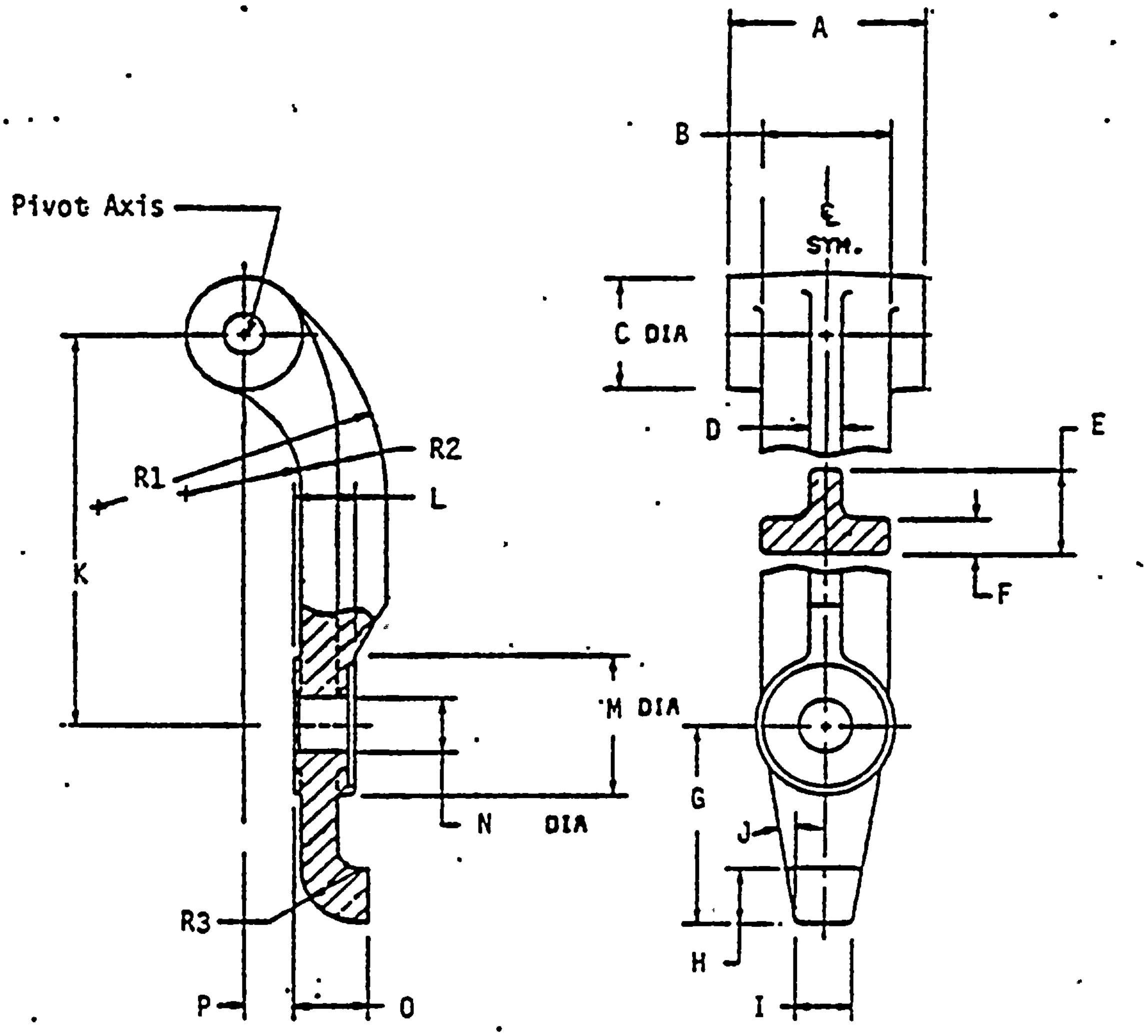

Figure 1.3 View of the AOV023/V012 Check Valve Tail Link(Ref,10)

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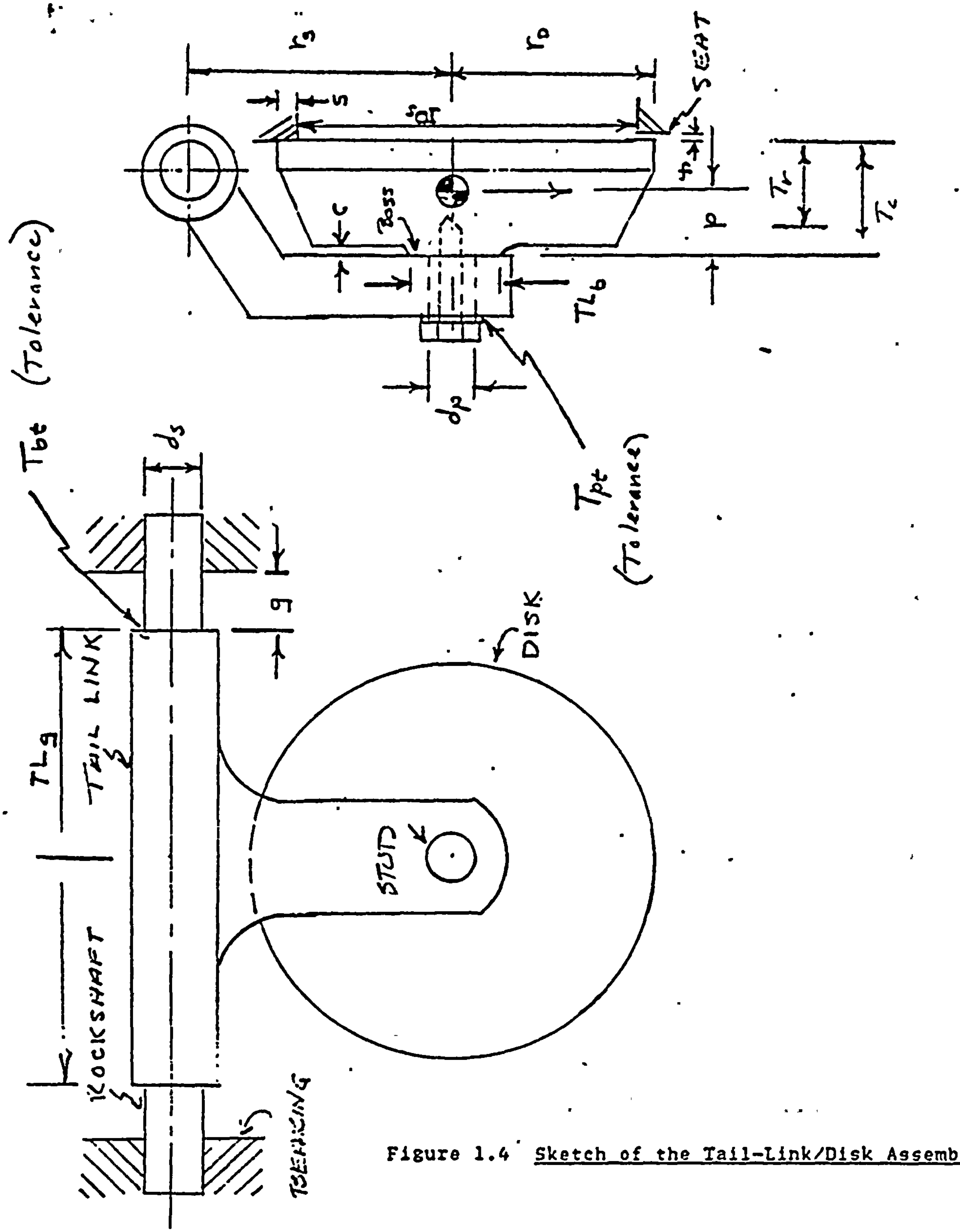

Figure 1.4 Sketch of the Tail-Link/Disk Assembly

2. METHOD

Elements critical to the integrity of a check valve identified in Figure 1.4, are the disk, the tail link, the stud which connects the tail link to the disk, the rockshaft and the seat/disk interface.

The dynamic loading just before impact is purely centrifugal, reacted by the rockshaft, stud and tail link. The resulting forces on the rockshaft and stud, the stress in the tail link and the deflection of the disk from its centered position on the seat were calculated by inelastic methods using the ANSYS(Ref.14) program. The stress/strain relationship was approximated by a bilinear curve (Fig.2.1) adjusted for strain rate and temperature effects. Shear stresses in the rockshaft and stud were obtained manually.

A second run was coded to calculate the force on the rockshaft and the stress in the disk from impact of the tail link on the disk. Shear stress in the rockshaft was, again, determined manually.

A third run was coded for computation of the force/deflection curve for the seat and the stress arising from impact.

A fourth run was coded to compute disk stress and seat force generated by impact and pressure surge, using the seat force/deflection curve obtained from the third program.

The acceptance criteria given in Section 1 was considered satisfied if all calculated stresses are below ASME III(Ref.7) Class 1 allowables for faulted service(App.F) and the deflection of the disk from its centered position on the seat is small compared to the seat annulus dimension.

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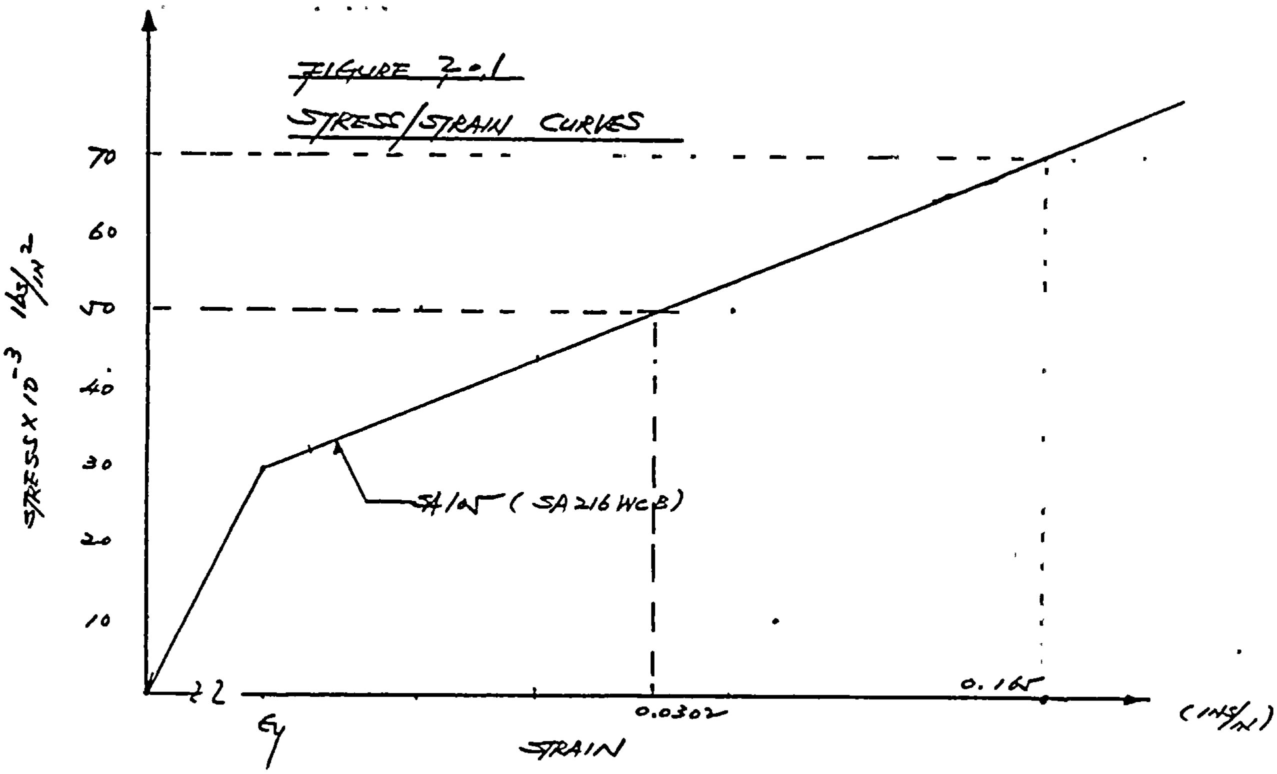

3. <u>ASSUMPTIONS</u>

1) The clearance between the tail link bushing and the stud on the disk is sufficient to preclude transfer of significant moment at the instant of impact. This allows analysis of the disk and tail link to be carried out independently.

4. DESIGN INPUT

Mass Properties

TABLE 4.1	Anchor/Darling Check Valve 2FWS*AOV023A,B 2FWS*V012A,B	REF.
Disk - wt.	310#	10
Tail Link - wt.	70	10
Mass Moment of Inertia/Rockshaft	17.7 slug-ft**2	10

Materials

TABLE 4.2	Anchor/Darling Check Valve 2FWS*AOV23A,B	REF.	Anchor/Darling Check Valve 2FWS*v12A,B	REF.
Disk	cs SA105	9	cs SA105	9
Hinge pin (R.Shaft)	cs A479,Type 410 (Nitronic-60)	9	cs A479,type 410 C12	9
Seat	cs SA516 Gr70 Stellite facing	9	cs SA516 Gr70 Stellite facing	9
Hinge (tail link)	cs SA216 WCB	9	cs SA216 WCB	9
Pin & Stud	cs SA105	9	cs SA105	9
Nut	cs SA194,8M	9	cs SA194,8M	9

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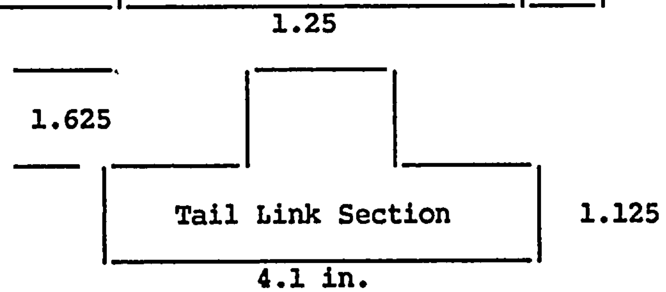
Dimensions

TABLE 4.3	Anchor/Darling 2FWS*AOV023A,B 2FWS*V012A,B	REF.
Diam of Disk	20. in.	10
Dist - Rkshft/Dsk Ctr	15.	10
Diam of Pin	1.25 (threaded)	10
Diam - Stud for Tlk	2.63	10
Diam of Rockshaft	2.0	12
Gap - Tlk/Bearing	.063	12
Dist- Dsk CG/Stud Seat	2.1	10
Clearance - Disk/Tlk	1.06	10
Thickness of Disk	3.75ctr,2.69rim	10
Seat Contact	.625 (stellite)	9
Seat Radius-Inside	9.375	9
Seat Radius-Outside	10.87	9
Tail Link Section	See sketch below	10
Tail Link Grip	11.94	10
Seat Inside Diam	18.75	10
Diam of Tlk Boss	5.25	10
Tolerance - Stud/Tlk	.012 (=articulation)	12



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Material Properties at 500F (Ref. 7, Appendix I)

TABLE 4.4	Sy (ksi)	Su (ksi)	Elong.* (%)	E (psi.e-6)	.7Su (ksi)
cs SA 216 WCB	29.1	70	22	27	49
cs SA 105	29.1	70	22	27	49
cs SA 516 Gr70	30.7	70	21	27	49
ss A479 Type410	34.7	66.3	20	26	46.4

* Ref.8(ambient temperatures)

Section Properties(calculated from Table 4.3)

TABLE 4.5		AOV023/V012
Tail Link	- Area	6.7 in**2
	- Mom of Inert/z	2.51 in**4
	- Torsion Const/y	2.2 in**4
Rockshaft	- Area	3.14
	- Mom of Inert/z	.785
Stud	- Area	5.4
	- Mom of Inert/z	2.35

Impact Speed and Hammer Pressure

TABLE 4.6	AOV023	V012	REF
Impact Speed(rad/sec)	32	41	1-pg 31
Max Pressure(psi) - a few milliseconds after impact	765	2080	1-pg A8, A11

Allowables for Faulted Service

Allowable primary stresses are in accordance with Appendix F of Reference 7, .7 times Su, as provided in Table 4.4 above.

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5. SUMMARY OF RESULTS

TABLE 5.1	AOV023 V012			
	Calc'd	Allow.	FS	PG#
Disk -stress ksi	37.5	49.	1.3	9-6
Disk Deflection - in. from Centered Pos'n	.003	.31	100	8-3
Rockshaft -stress ksi	12.0	28.3	2.4	8-4
Tail Link -stress ksi	34.2	49.	1.4	8-5
Stud -stress ksi	4.2	28.3	6.7	8-3
Seat -stress ksi	39.0	49.	1.26	10-1

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6. CONCLUSIONS

It is concluded that both 2FWS*AOV023 and 2FWS*V012 (specification P303W) valves will withstand rapid closure and that the pressure boundary will be maintained.

7. REFERENCES

1) SWEC Calculation 12177-NP(B)-1732-PX, Feedwater Check Valve Closure Following a Pipe Rupture Event, July 1984

2) Anchor/Darling Drawings 4020-3E & 4021-3E, Swing Check Valves (SWEC File No. 5.360-017-089E)

3) Anchor/Darling Drawings 4022-3E, Testable Swing Check Valves (SWEC File No. 5.360-017-090E)

4) SWEC Specification NMP2-P303W, Check Valves, July 1983

5) Juvinal,R.C., Stress, Strain and Strength, McGraw-Hill, 1967

6) SWEC Calculation 12177-NP(C)1733-PX, Water Hammer Analysis of Feedwater Piping for Partial and Total Pump Trip, Jan 1985.

7) ASME B & PV code, 1977, no addenda, Section III

8) Manual of ASTM Standards, 1977

9) Anchor/Darling Design Report for Class 1 24" Forged Carbon Steel Check Valve, ASME class 900#, Lab. No. 79.123, May 1980 (excerpts in App.A herein)

10) Anchor/Darling Report No. E3276 dated 3-15-84, Engineering Data on A/DV Swing Check Valves(App.A herein).

11) Rourke,R.J., Formulas for Stress and Strain, McGraw-Hill, 4th Edition

12) SWEC Telecon dated 4-23-85, J. Gwinn and R. Green(A/D), FW Check Valve AOV023 & V012 Dimensions (App.A herein).

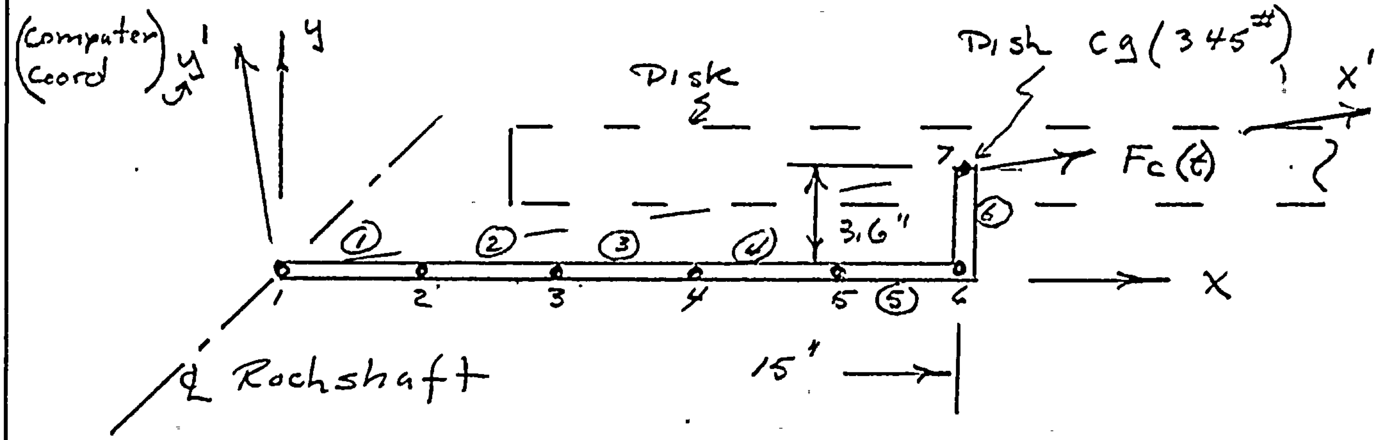
13) Nine Mile Point 2 Final Safety Analysis Report(FSAR)

14) ANSYS Engineering Analysis System User's Manual, Revision 4, 3/1/1983; SWEC Program ST-348, 04/1C

8.0 TAIL LINK

Two loading conditions are considered below: pre-impact and impact. Critical elements are the stress in the rockshaft, the stress in the tail link section itself, the stress in the stud which secures the disk to the tail link and the deflection of the disk from its centered position on the seat.

8.1 Pre-Impact (Run # 3)



The disk is accelerated about the rockshaft by the reversed flow until impact with the seat. Figure 8-1 shows the variation of centrifugal force, Fc, with time, obtained from the time history angular velocity derived in Ref. 1.

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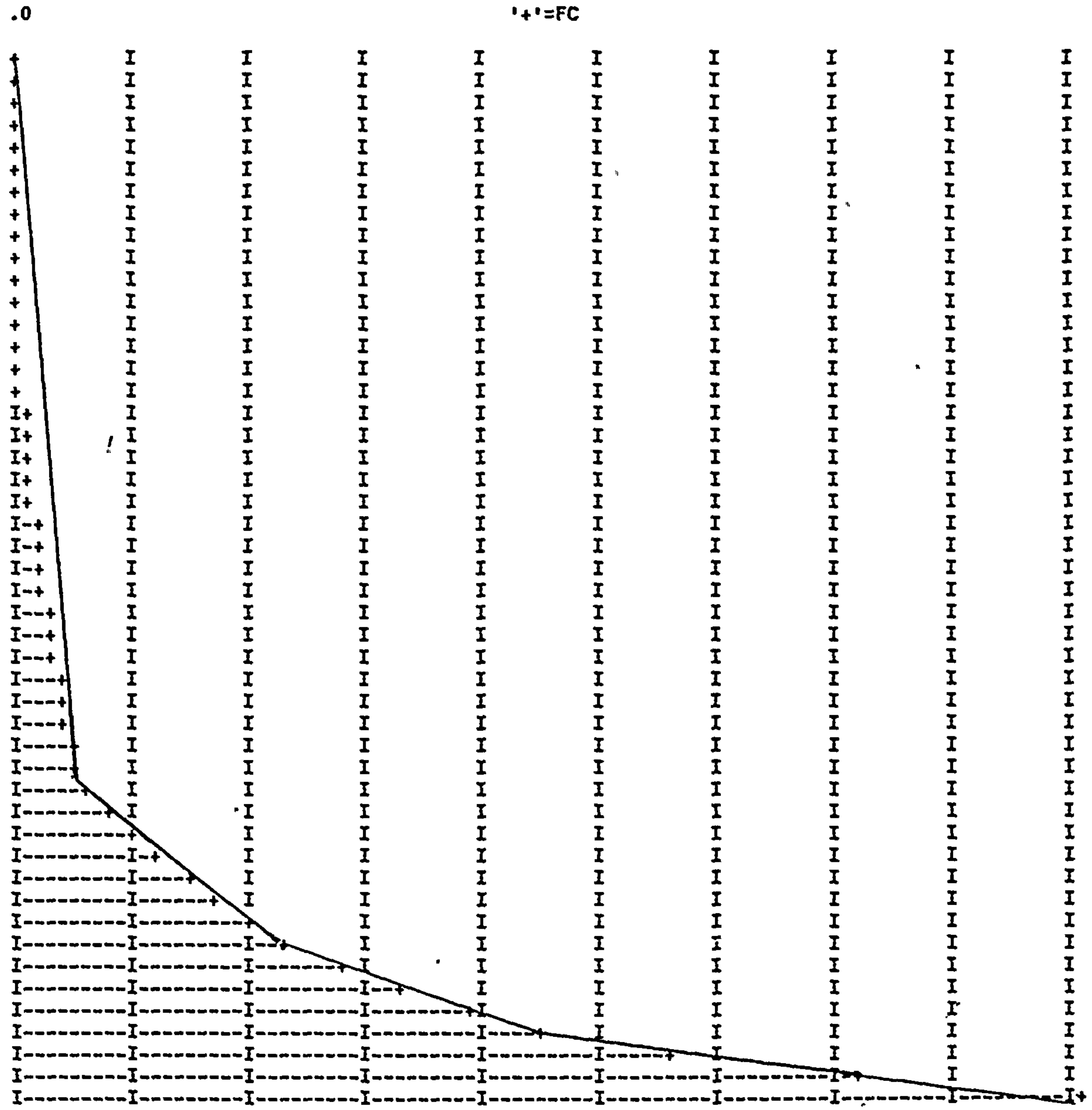
FC VS TIME FOR ANSYS INPUT — FIG. 8.1.

TIME	FC
.0	4.7630E-14
1.0000E-02	.20948
2.0000E-02	.83792
3.0000E-02	1.8853
4.0000E-02	3.3517
5.0000E-02	5.2370
6.0000E-02	7.5413
7.0000E-02	10.265
8.0000E-02	13.407
9.0000E-02	22.657
.10000	34.321
.11000	48.398
.12000	64.889
.13000	112.75
.14000	173.75
.15000	247.89
.16000	335.17
.16000	335.17
.16200	381.35
.16400	430.50
.16600	482.64
.16800	537.76
.17000	595.85
.17200	656.93
.17400	720.98
.17600	788.02
.17800	858.03
.18000	931.02
.18200	1007.0
.18400	1085.9
.18600	1167.9
.18800	1252.8
.19000	1340.7
.19200	1722.0
.19400	2151.0
.19600	2627.7
.19800	3152.1
.20000	3724.1
.20200	4343.8
.20400	5011.1
.20600	5912.4
.20800	7092.1
.21000	8379.2
.21200	9773.5
.21400	11275.
.21600	13901.
.21800	17959.
.22000	22536.



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The tail link was modelled for ANSYS (Ref. 14) computation as shown in the sketch. All of the dish weight (310#) plus 1/2 the tail link weight was lumped at node 7.

Results were as follows, from run #4

Maximum stress intensity in the tail link

= 29,300 psi < 49,000 — FS = 1.7 (OK)

Maximum deflection of the disk from its centered position (node 7)

= .003" < $\frac{.625}{2}$ = .31 — FS = 100 (OK)

Rockshaft

Stress in double shear (node 1)

= 22700/3.14(2) = 3.610 psi < $\frac{49000}{\sqrt{3}}$ = 28300 — FS = 7.8 (OK)

Stud

Stress in single shear

= 22700/5.4 = 4200 psi < 28300 — FS = 6.7 (OK)

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8.2 Impact (Run# 4)

At impact, the critical elements are stress in the tail link and the rock shaft. The same model as described above was used for ANSYS computation except that dish mass is not included and the stud was replaced by a zero gap element of stiffness equal to 4E7, the elastic stiffness of the disk. This is conservative because, since the disk is actually deflecting, its stiffness as seen by the tail link is reduced.

Rockshaft

The maximum reaction at the rockshaft, from the computer run (node 1) results in a shear stress

$$= \frac{75700}{2(3.14)} = 12{,}000 \text{ psi} < \frac{49000}{\sqrt{3}} < 28300$$

FS = 2.4

OK

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Tail Link

From the computer run, the maximum stress for all beam elements

$= 34{,}200$ psi < 49000 $\quad$ $FS = 1.4$

(OK)

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9.0 DISK ANALYSIS

Pre-impact loads on the disk are not significant, and therefore not addressed. At impact, the critical stresses are bending and membrane as a plate and the local stresses from contact with the seat. However, the disk material being the same as the seat, it is expected that the local stresses will be similar to those computed for the seat in section 10.

Figures 9.1 and 9.2 show the nodes and elements of the disk as modelled for ANSYS computation. Attached to the rim nodes are elements which represent the non-linear force/deflection character of the seat, obtained from the seat analysis in Section 10, reduced by a factor of 2 to account for the contribution from local yielding of the disk.

The nodal velocities corresponding to an impact speed of 41 rad/sec are presented in Table 9-1.

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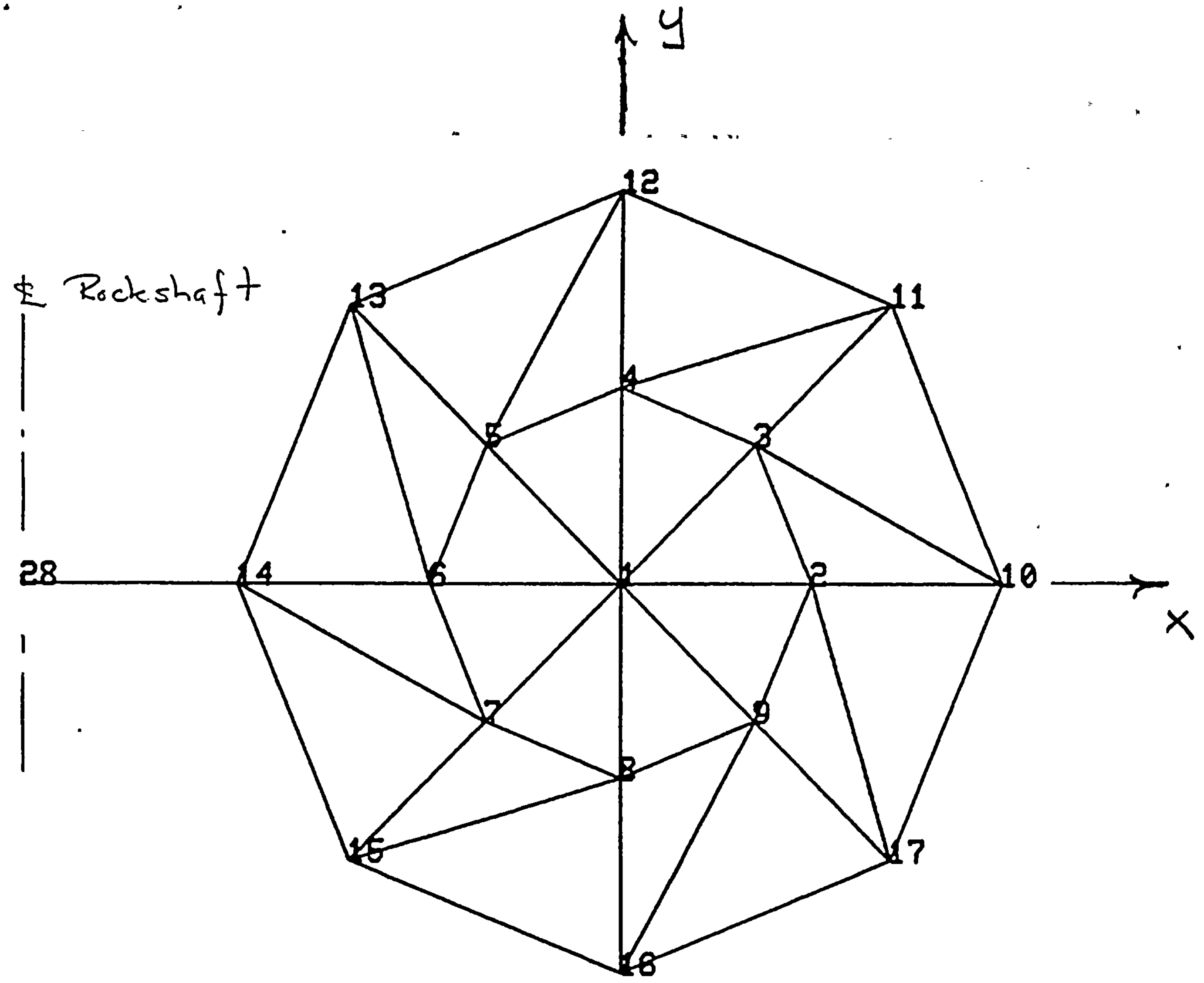

Figure 9.1 ANSYS Computer Model for Tail-Link/Disk Impact Loads(Nodes)

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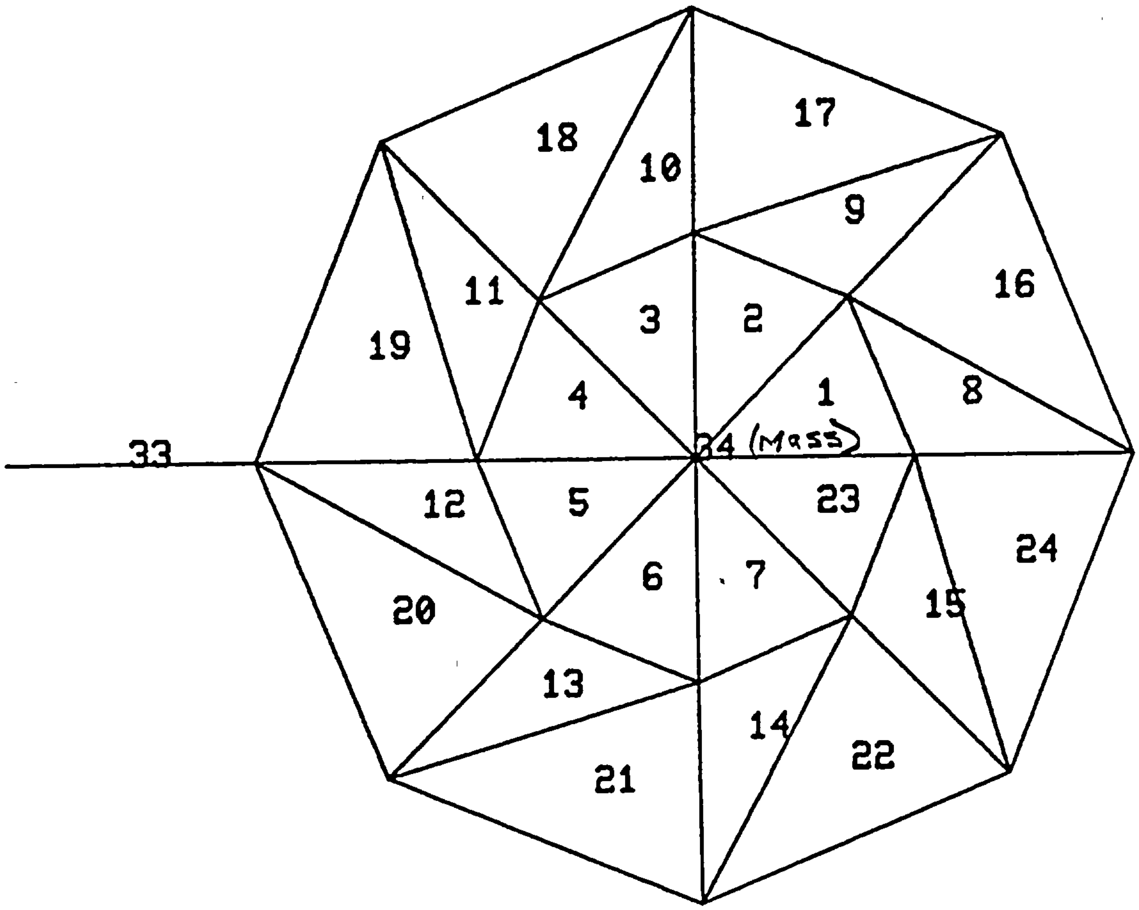

Figure 9.2 ANSYS Computer Model for Tail-Link/Disk Impact Loads(Elements)

	NODES								
	14	13 & 15	6	5 & 7	1, 4, 8, 12, 16	3 & 9	2	11 & 17	10
Radius (in)	5.4	8.4	10.2	11.7	15	18.3	19.8	21.6	24.6
Initial velocity (ips)	221	344	418	480	615	750	812	886	1009
Dspl. for Δt = 1-6 sec.	221-6	344-6	418-6	480-6	615-6	750-6	812-6	886-6	1009-6

TABLE 9.1 - NODAL VELOCITY INPUT FOR ANSYS
(41 RAD/SEC AT TIME = 0)
FROM REF. 1

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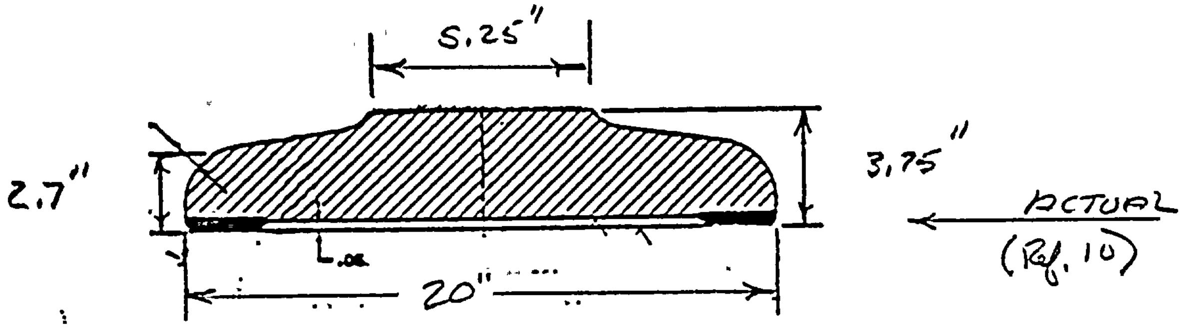
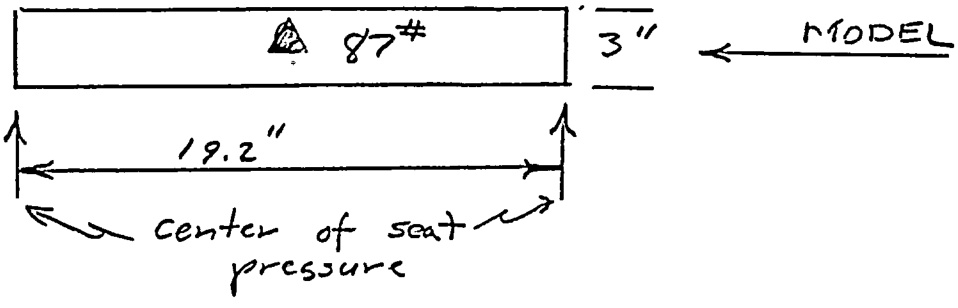
A comparison between the actual disk vs the model disk for ANSYS is shown below;





Effective mass including effect of tail link

$= 310^{\#} + 71/3 = 333^{\#}$ (Ref: Table 4.1)

The concentrated mass at the disk center

$= 333 - 3\left(19.2^2 \frac{\pi}{4}\right)(.283)$

$= 87^{\#}$

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From run # 1:

Maximum stress intensity in the disk, as computed by the ANSYS program, for element 24

= 37,500 psi < 49000 FS = 1.3 (OK)

from disk response as a plate, local stress from impact is expected to be similar to the local stress in the seat, as described in section 10 below.

Maximum seat force, variable 21

= 2.1E6 #

10. SEAT ANALYSIS (Run # 2)

A 12° sector of the seat ring was modelled for ANSYS computation of stress intensity and deflection as a function of the pressure applied by disk impact. Figure 10.1 shows the elements while Figures 10.2 and 10.3 identify the nodes on the left and right hand faces respectively.

Loading from the dish on elements 12, 18 and 24 in the z - direction was varied from .5E6 to 4E6 #'s. Results are summarized in Table 10.1 below.

The total area of the seat in contact with the dish is 30 sq in. The area of the segment is 1 sq. in.

From the dish impact analysis of section 9, the maximum reaction force on the seat was 2.1E6 #, which results in a stress

= 39 ksi < 49 ksi FS = 1.26

OK

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TOTAL FORCE (# • 10^{-6})	.5	.9	1.1	1.4	2	2.7	3.3	4.0
ELEMENT PRESSURE (ksi)	16.7	30	36.7	46.7	66.7	83.3	110	133
AVERAGE DISPL. (inches)	.00077	.0014	.0020	.0037	.0088	.016	.029	.046
STIFFNESS (#/in • 10^{-8})	6.5	6.5	5.6	3.8	2.3	1.7	1.1	.90
STRESS (ksi)	16.7	30	33	34.7	37.7	41.8	48	55.4

TABLE 10.1 - RESULTS OF ANSYS SEAT ANALYSIS

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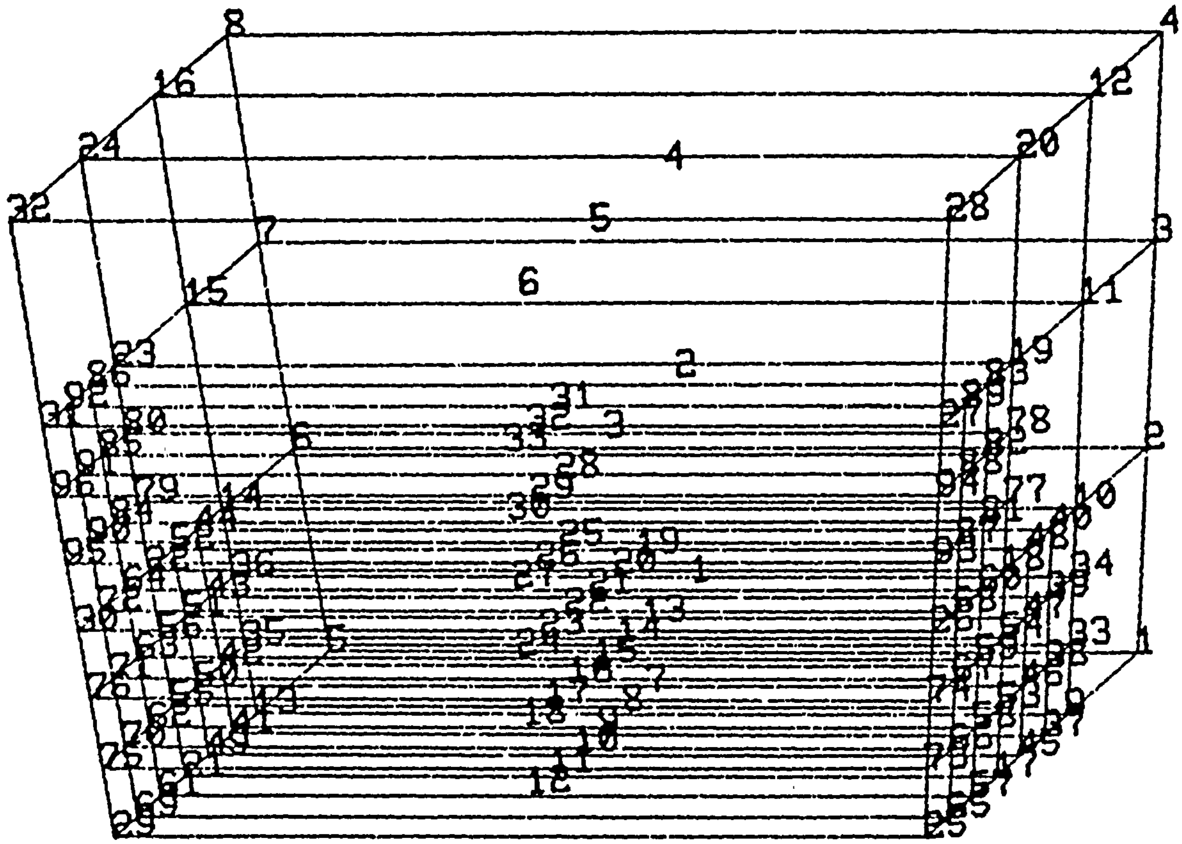

Figure 10.1 - Computer Model for Seat Analysis

32			24			16	8
31	92	86	23			15	7
96	91	85	80				
95	90	84	79				
30	72	64	22	52	44	14	6
76	71	63	56	51	43	36	
75	70	62	55	50	42	35	
29	69	61	21	49	41	13	5

Figure 10.2 - Nodes for Left Face of Model

28			20			12	4
27	89	83	19			11	3
94	88	82	78				
93	87	81	77				
26	68	60	18	48	40	10	2
74	67	59	54	47	39	34	
73	66	58	53	46	38	33	
25	65	57	17	45	37	9	1

Figure 10.3 - Nodes for Right Face of Model

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APPENDIX A

Miscellaneous Reference Material

Stone and Webster Engineering Corporation
CALCULATION SHEET

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