Department of Energy
Washington, D.C. 20545

Docket No. 50-537
HQ:S:82:169

DEC 29 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

CONTAINMENT VESSEL/CODE CASE(S) ANALYSIS WORKING MEETING - SUMMARY

This letter transmits a summary of the Containment Vessel/Code Case(s) Analysis Working Meeting held on December 8, 1982. The summary indicates the general trend of the meeting and identifies other relevant information.

Sincerely,

J. E. Statler for

John R. Longenecker
Acting Director, Office of
Breeder Demonstration Projects
Office of Nuclear Energy

Enclosure

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Containment Vessel/Code Case(s)
Analysis Working Meeting - Summary

A working meeting was held on December 8, 1982 to resolve NRC concerns to the Containment Vessel/ASME Code Case(s) Analysis. The presentations and subsequent discussions responded to NRC concerns in the following areas:

1) The 1974 versus 1980 ASME Code Comparison (NRC Question 220.25)
2) The Ultimate Capacity of Containment (NRC Question 220.30)
3) The NRC Audit Findings
4) The Identification of Closed Issues

The presentations highlighted the essential elements of the Applicants responses to the NRC concerns. From subsequent discussions of the presentations and the Applicants' developed responses to the NRC concerns it appeared that the Applicants had closed all of the subject issues. However, the NRC reviewers indicated that some minor clarifications would be needed in the information formally transmitted. See Attachment (1) for a list of closed issues, Attachment (2) for clarifications of formal responses to NRC concerns, Attachment (3) for formal responses to NRC concerns, Attachment (4) for meeting viewgraphs, Attachment (5) for the meeting agenda and Attachment (6) for meeting attendees.

Attachment (1)
CR-783:VF:82-598

Responses to NRC Comments on Previous Question Responses

1. NRC Question 220.25

   a) What is the justification for assuming that the external containment pressure (P_E) is 0 for the assessment of containment buckling according to Code Case N-284?

   Status: Closed Issue

   b) Provide further information on the effect of the equipment access hatch on the margin against buckling. The N-284 buckling evaluation provided by the Applicant as part of the response to NRC Question 220.25 does not adequately address the effect of the equipment access hatch. Describe the methodology used in design including consideration of buckling.

   Status: Will provide additional information at FSAR stage, closed issue for SER.

   c) Nozzle piping transition. The comparison included in the response to NRC Question 220.25 relies on engineering judgement. Provide numerical comparisons for typical piping penetration.

   Status: Closed Issue

2. NRC Question 220.30

   a) The ultimate capacity prediction for the containment should be expanded to include the effect of all discontinuities and the capabilities of all penetration components including seals, doors, etc. Appropriate thermal effects should be included.

   Status: Closed Issue

3. NRC Audit Findings (May 1982)

a) Finding (1.C.1.A) - In evaluating the equipment and personnel airlock for seismic loads, an assumption was made that it penetrates containment in a radial direction. To develop the dynamic model for the airlock, only two degrees of freedom were allowed; radial and rotation about a horizonal axis. In addition, with the maximum live load in the extreme end of the airlock, it is fundamental frequency is below the peak of the design response spectrum for that location. To adequately evaluate the airlock the following needs to be done.

A three-degree-of-freedom model needs to be developed that includes the skewed penetration angle effects. The additional degree of freedom should be rotation about the vertical axis.

Status: Closed Issue

b) Finding (1.C.1.B) - Amounts of live load that allow the fundamental frequency to fall on the peak of the design response spectrum should be considered.

Status: Closed Issue

c) Finding (1.C.2) - The seismic lumped mass model includes stiffness coupling terms to simulate the fundamental dome breathing mode. The frequency and mode shape of this mode needs to be confirmed with a more refined model.

Status: Closed Issue

d) Finding (1.D.3) - All significant computer codes used for structural design need to addressed in the PSAR along with verification documentation.

Status: Closed Issue, a brief description will be incorporated in Appendix A of the PSAR. The detailed verifications are included in Attachment (3).

Attachment (2)

CR-783:VF:82-598

1. Supplement to: Why was Pe = 0 used in the N-284 analysis.

New question: What would be the effect if Pe = .5 psig instead of Pe - 0.

Response: The buckling safety factor would be reduced less than 10% (see below). This information has been supplied as requested; however, there is no requirement for these loading conditions to be analyzed.

N-284 SAFETY FACTORS

	Pe = 0	Pe = .5 psig
OBE	2.5*	2.4**
SSE	1.9*	***

*See response to 220.25 for calculations

**Same calculations were used for Pe = .5 psig

***Calculation not performed, however, the percentage change is expected to be similar to the OBE calculation.

2. Supplement to: 220.25 Equipment Hatch Buckling

New question: Evaluate the stress in the shell above the equipment hatch and the horizontal stiffener.

Response: The stress in the shell above the equipment hatch and the horizontal stiffener will be analyzed and a qualified summary will be provided in the FSAR.

3. The calculations in Table 3-10 (CRBRP-3, Vol. 2, Rev. 0, Page 3-85) were based on the applicable 1975 ASME Code requirements. As requested by the NRC, the ultimate capacity calculations (Question 220.30) were done in accordance with a later Code Case N-284, although the design criteria remains as those of the 1975 ASME Code.

   Using the 1975 code and the CRBRP developed interaction equations, it was determined that the critical failure mode was shell buckling and not the hatch cover. Shell buckling calculations were therefore used to develop Table 3-10.

   The recent (220.30) ultimate capacity calculations were performed to the more recent Code Case N-284 and therefore differ slightly. The significant difference is that the hatch buckling becomes more critical than the shell due to the application of the more conservative N-284 criteria.

   Results from the new (N-284) analysis are quite close to the previous predictions in Table 3-10; i.e., at 450°F, the N-284 analysis predicts failure of the hatch at 40 psig and the earlier analysis predicts "yielding" of the shell at 39 psig.

   Therefore, the most recent calculations performed in response to Question 220.30 are reasonably consistent with the earlier predictions in Table 3-10, and no change to the PSAR is considered necessary.

Attachment 3

CR-783:VF:82-598

NRC MEETNG
DEC. 8, 1982

$Pe = 0$

Question

What is the justification for assuming that the external containment pressure (P_E) is 0 for the assessment of containment buckling according to Code Case N284?

Response

"External pressure" is an expression for a positive pressure measured from outside the containment vessel to inside the containment vessel. There is no known mechanism for actually generating a positive pressure outside the containment; rather, the concern is the potential for generating a negative pressure inside the containment vessel which has the effect of creating a positive differential from outside to inside.

P_E was set equal to zero for the analysis of the critical buckling region (just above the operating floor) using N -284 criteria and PSAR loading combinations for SSE and OBE. This was done because an external pressure condition is not postulated to occur in combination with a seismic event for reasons given below.

The design specification for the CRBRP containment vessel identifies a negative "design pressure" of 0.5 psig. This pressure was conservatively chosen early in the design of the plant to assure that there would be no event which could independently challenge the capability of the vessel to contain a negative pressure. This pressure was not mechanistically derived but is included in the equipment specification and analyzed as a conservative assessment of vessel capability.

The only identified scenario which could cause a measurable negative pressure in the steel containment would be a large sodium fire followed by cool down of the containment atmosphere, without in-leakage of the outside atmosphere. The bounding case of such a scenario is presented as part of the containment building design evaluation in Section 6.2.1.3 of the PSAR.

The pressure in containment, following the large sodium fire discussed in Section 6.2.1.3, would not become negative until the containment atmosphere has cooled down for more than fifty hours. The negative internal pressure attained in the steel containment is limited by operation of the vacuum breakers. The set point of the vacuum breakers is 3.5 inches water gauge (0.13 psig). Therefore, once the pressure inside containment has become negative, it will remain negative only until the vacuum breaker set point is reached. When the vacuum breakers open, the pressure differential across the containment will drop until the low set point on the vacuum breaker valves (1.75 inches water gauge) is reached and the vacuum breakers close. Thus, the set point of the vacuum breakers (3.5 inches water gauge) is a reasonable upper-bound value of the external containment pressure following a large sodium fire.

The pressure relief function of the vacuum breakers is assured by (1) providing redundant separated penetrations with vacuum breakers, (2) sizing each vacuum breaker for adequate inlet flow to ensure that the negative pressure differential in containment would not exceed 3.5 inches water gauge, (3) sizing each vacuum breaker penetration to provide adequate inward flow assuming failure of the vacuum breaker(s) on the other penetration and (4) designing and qualifying the vacuum breaker "valves" to assure that they will open at their design set point during or after any design basis sodium fire inside containment.

Analysis has shown that there is a negligible difference in loads that set $P_E = 0$ and loads that set $P_E = 3.5$ inches water gauge (0.13 psig) as input to the loading combination. Even though the external pressure was selected to be zero for the analysis of the critical buckling region, a reasonable upper-bound value of 3.5 inches water gauge for the external pressure would not significantly affect the outcome of the analysis.

Summary

An external containment pressure condition is not postulated to occur in combination with a seismic event. Nonetheless, selection of a reasonable upper-bound value of 3.5 inches water gauge for the external pressure would not significantly affect the outcome of the critical buckling region analysis using N -284 criteria and PSAR loading combinations for SSE and OBE.

EG. HATCH
BUCKLE

A DISCUSSION OF HATCH OPENING EFFECTS ON VESSEL BUCKLING

The hatch opening has a diameter of 44'-6", which is approximately 25% of the vessel diameter. The opening has been reinforced by area replacement rules of the ASME Code, Section III, Subsection NE. In addition, a stiffening system around the opening has been provided to maintain continuity of the ring stiffeners. (See attached sketch.)

The local area around this large opening is stiffened by the insert plate, barrel neck and the stiffening system. Unsupported plate areas within the stiffening system are small enough that local plate buckling is not a consideration.

For overall shell buckling analysis, it has been assumed that the buckling strength of the containment vessel is not reduced by the presence of this large opening. This assumption has been justified by assuring that the local vessel stiffness, in both directions, is equal to or more than the stiffness required for the unpenetrated shell. The basic principle of the buckling design of a stiffened shell, such as we have here, is that the stiffeners be capable of carrying all loads in case local panels have buckled and are not capable of carrying any loads. By maintaining the required stiffness continuity of the ring stiffeners, it is assured that overall compressive loads, in both directions, can be carried around the opening, without causing buckling. The stiffening system around the opening, in fact, has a much greater stiffness than that required to maintain continuity. (See Sheets H7.7 and H7.8 of the Design Report)

To assure that stiffening system members do not disproportionately share in carrying loads causing local failure, a frame analysis has been performed around the opening. The results of this frame analysis indicate that individual members of the stiffening system can properly carry their portion of the load. The proximity of the barrel neck, insert plate and the stiffening system result in their acting together. This results in quite large beam and column sections (see Sheets H8.6 and 8.8 of the Design Report), which are more than adequate to safely carry the loads.

To eliminate the possibility of the vertical stiffeners attracting a disproportionate share of the meridional compressive loads, causing panel buckling in the plate immediately above these stiffeners, the portion of the ring stiffener at elevation 856' between the vertical stiffeners is designed as a beam. This stiff beam and the diagonal stiffeners carry the meridional loads into the vertical stiffeners, without any significant "bunching" of the stress lines above the vertical stiffeners.

As a further justification for assumption that an opening the size of the equipment hatch, if properly reinforced, will not deteriorate the buckling capability of the vessel, we refer to a paper entitled "Experimental Study of the Buckling of Cylindrical Shells With Reinforced Openings". This paper authored by C. D. Miller was presented at the Second Joint ASME/ANS Nuclear Engineering Conference, Portland, Oregon, July 25-28, 1982. Figure 2 of this paper presents the results for Model #1 which had an opening with $r/\sqrt{RT}$ of 6.36 which is identical to that of the hatch opening. This figure indicates that the buckling capability of the cylindrical shell under axial compression was not reduced by the presence of the opening, when the opening was reinforced by area replacement rules. ~~A number of other investigators have demonstrated by tests that for cylinders under axial compression, a reinforced opening could be of fairly large size without deteriorating the buckling capability of the unpenetrated shell. This is particularly true of fabricated shells. Due to fabricated cylinders sensitivity to imperfections, under axial compression, the knockdown factors from classical buckling values are significant. These knockdown factors would allow for considerable local disturbances and stress concentrations without causing buckling.~~

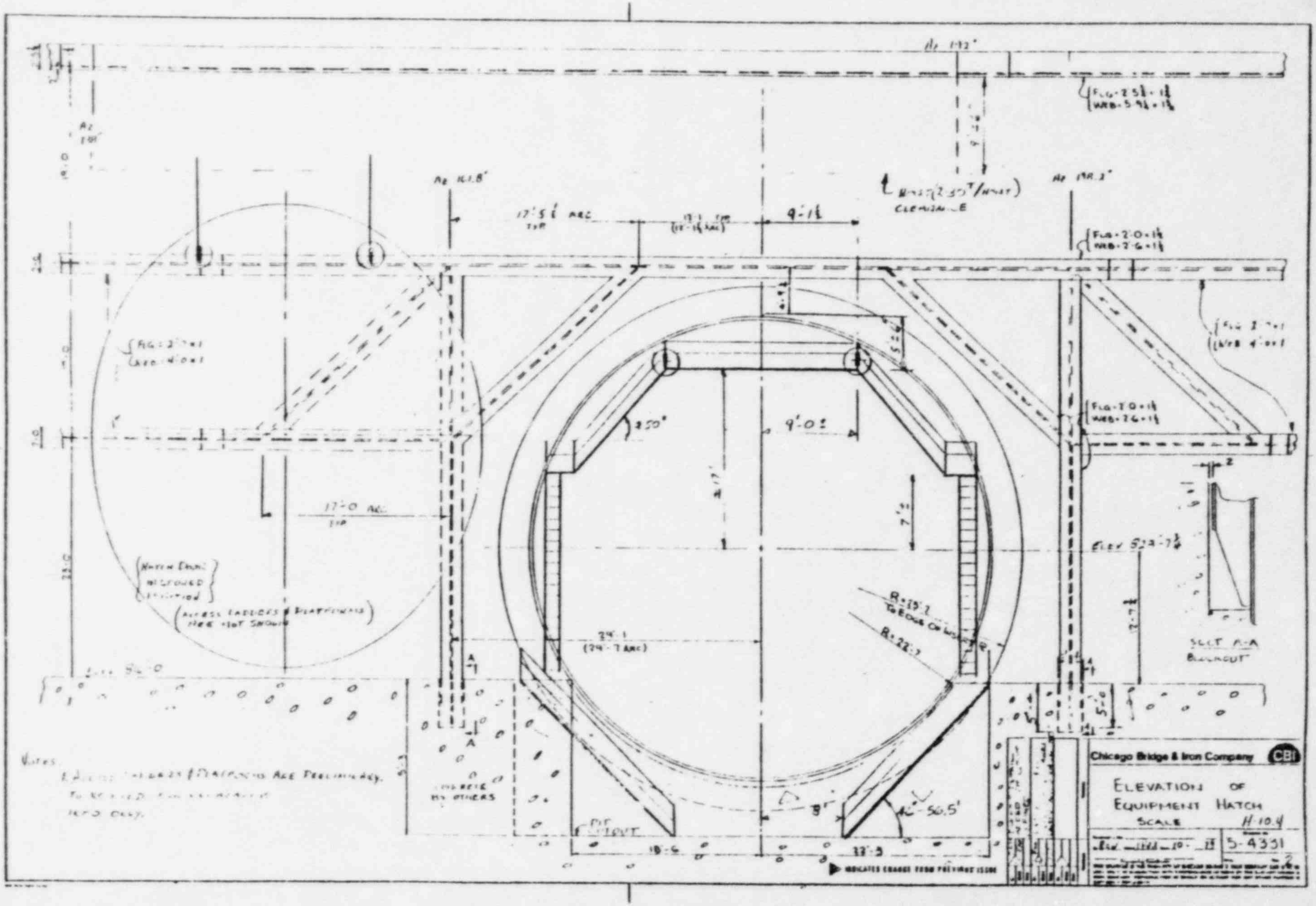
SEE INSERT A

INSERT A

A number of other investigators have demonstrated by tests that for cylinders under axial compression, a reinforced opening could be of fairly large size without deteriorating the critical buckling capability of the shell. This is particularly true for fabricated shells under axial compression where the imperfection knockdown factors from classical buckling values are significant. Effects of the penetration are found to be more significant than imperfections and test results including penetrations are within the scatter of test results of unpenetrated shells. The CRBRP containment shell has been evaluated against ASME Code Case N-284 which uses knockdown factors established from lower bound test data of fabricated vessels without penetrations. Test results also indicate these knockdown factors will provide lower bound values to test data obtained from vessels with penetrations.

In summary, we believe that by providing the extensive amount of stiffening around the hatch opening, local shell buckling is precluded. Also, by providing stiffness continuity of ring stiffeners and conservatively checking members locally as beams and columns to carry the loads around the opening, the buckling capacity of the vessel is not adversely affected.

SUBJECT	MADE BY KM	CHKD BY RAW	REV	BY		CHARGE NO. 5-4331
				CHKD		
CRBRP CONTAINMENT VESSEL	DATE 11/82	DATE 11/82		DATE		SHT 3 OF 4


Az 172°
Fl.G - 2·5½ × 1¼
WEB - 5·9½ × 1¼
Az 191°
Az 161.8°
Az 198.3°
℄ Hatch (2·55' / hatch)
CLEARANCE
17'·5¼ ARC TYP
17'·1 TYP (17'·1¼ ARC)
9'·1¼
FLG - 2·0 × 1¼
WEB - 2·6 × 1¼
FLG - 2·0 × 1
WEB - 4·0 × 1
FLG - 2·0 × 1
WEB - 2·6 × 1¼
FLG - 2·7 × 1
WEB - 4·0 × 1
25°
9'·0¼
17'·0 ARC TYP
Hatch Door Shown (Position)
(Access Ladders & Platforms Are Not Shown)
ELEV 523'·7¼
R = 23'·2 TO EDGE OF LINER
R = 22'·7
29'·1 (29'·7 ARC)
SECT A-A BLOCKOUT
ELEV 541'·0
A
A
CONCRETE BY OTHERS
5'·0
8"
56.5°
18'·6
22'·3
▶ INDICATES CHANGE FROM PREVIOUS ISSUE
Chicago Bridge & Iron Company
CBI
ELEVATION OF
EQUIPMENT HATCH
SCALE
H-10.4
5-4331
2
NOTES:
1. ACCESS LADDERS & PLATFORMS ARE PRELIMINARY.
TO BE USED FOR CLEARANCE
REQ'D ONLY.

PENETRATIONS

CONTAINMENT

ULTIMATE CAPABILITY

SKEWED
AIR LOCK

EQUIPMENT PERSONNEL AIRLOCK - NONRADIAL STUDY

This study concerns the analysis of the equipment personnel airlock as a nonradial attachment in order to demonstrate that the containment vessel shell is adequate for these effects. The analysis of the airlock in CBI's Design Report demonstrates that the shell is adequate for the loads of the airlock as analyzed as a radial attachment.

This study demonstrates that the effect of the nonradial analysis of the airlock has an insignificant effect on the containment vessel. The analysis of the stresses in the containment vessel has been performed in the same manner as shown in CBI's Design Report, Section F. The dynamic model, however, was analyzed using CBI program E1724A (SAP IV) and includes the skewed effect.

The results of the analysis shows that the accelerations either were reduced or remained approximately the same as the radial analysis. The loads applied to the containment vessel shell in general showed a reduction for the radial and longitudinal direction and the loads applied in the circumferential direction increased significantly, however the loads applied in the circumferental direction do not control.

The results of the membrane stress analysis of the nonradial loads show that the maximum increase in the vessel stress intensity will be approximately 11%. The maximum stress intensity in the shell will be reduced, however, since the longitudinal (vertical) moment and the radial load have been reduced.

In conclusion, the results of the nonradial analysis shows that the additional skewed effect of the airlock will produce an insignificant effect on the containment vessel and it will actually reduce the maximum stress intensities.

GO 787

SUBJECT	MADE BY	CHKD BY	REV			
INTRODUCTION	RAH	RAN		BY		5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		CHKD		SHT A-1 OF
				DATE		

EQUIPMENT PERSONNEL AIRLOCK - NONRADIAL STUDY

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PAGE DESCRIPTION

INTRODUCTION

NONRADIAL MODEL

SPECTRAL RESPONSE DATA

E1724A PROGRAM RESULTS

STRESS INTENSITY RESULTS

SUBJECT TABLE OF CONTENTS	MADE BY RAH	CHKD BY RAW	REV	BY		CONTRACT 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		CHKD		SHT OF
				DATE		

Comparisons Accelerations

DIRECTION	OBE		SSE	
	RADIAL	NON-RADIAL	RADIAL	NON-RADIAL
RADIAL (x)	1.585g	1.59g	2.083g	2.15g
LONG. (Y)	2.166g	1.98g	3.385g	2.82g
CIRC (z)	1.07g	.80g	1.74g	1.25g

Comparisons LOADS.

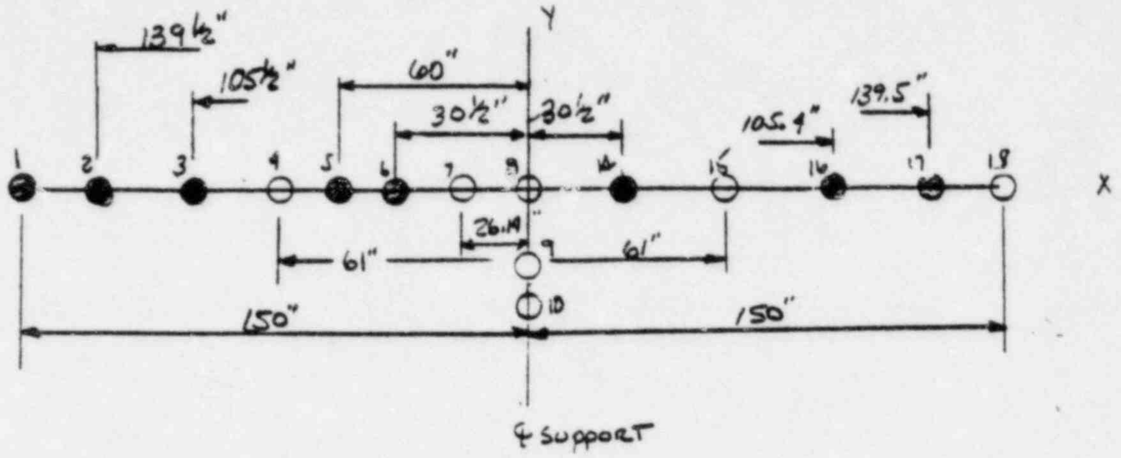
DIRECTION	OBE		SSE	
	RADIAL	NON RADIAL	RADIAL	NON-RADIAL
RADIAL	298K	268K	364K	356K
VERTICAL SHEAR	40.9K	83.8K	73.5K	127.5K
M_L (TOTAL)	1931 FT-K	1538 FT-K	2822 FT-K	2596 FT-K
CIRC SHEAR	52K	50.7K	87.7K	77.6K
M_C (TOTAL)	418 FT-K	776.8 FT-K	730 FT-K	1279 FT-K
TORSION	—	1001.7 FT-K	—	1427.4 FT-K

SUBJECT Summary of ACCEL/LOADS.	MADE BY RAH	CHKD BY RAW	REV	By	CHARGE NO 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd	SHT A-2 OF
				Date	

CBI

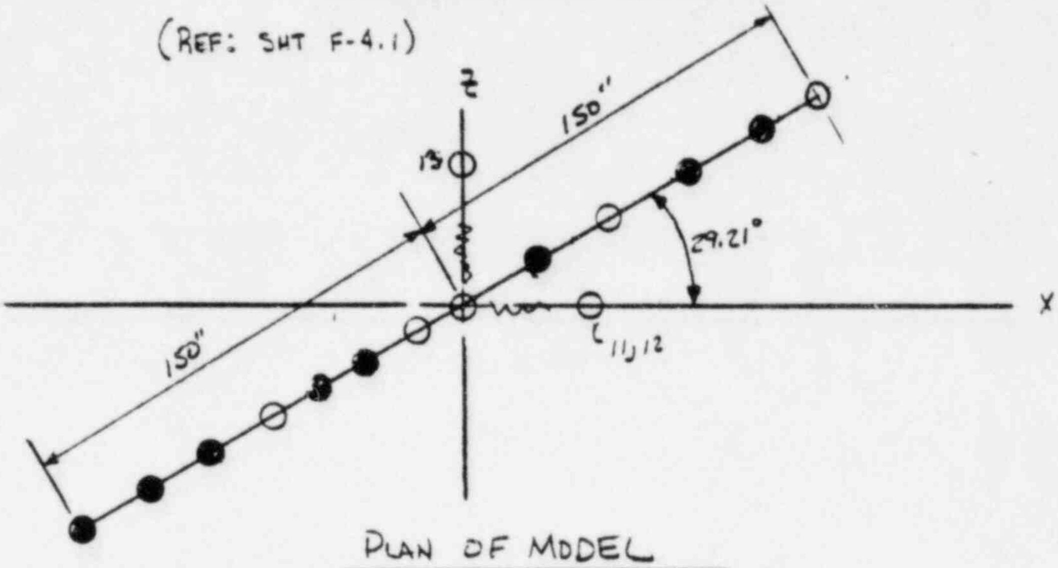
OAK BROOK
Location SPECIAL STRUCTURES DESIGN

SAP IV ANALYSIS OF AIRLOCK



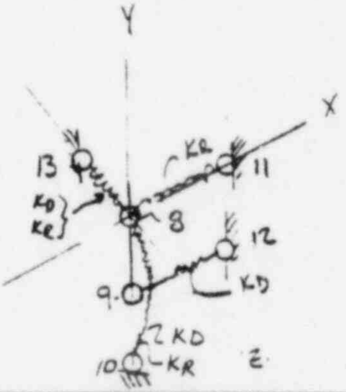
ELEVATION OF MODEL

(REF: SHT F-4.1)



PLAN OF MODEL

COUPLING.



SUBJECT MODEL DIAGRAM - NON-RADIAL	MADE BY RAH	CHKD BY RAW	REV	By		CHARGE NO. 5-4331
				Chkd		
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Date		SHT B-1 OF

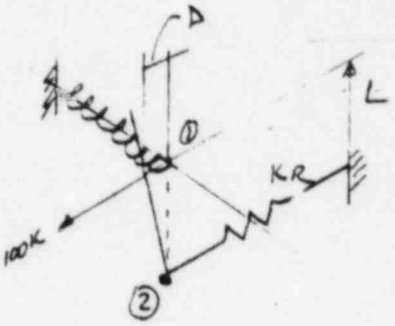
GO 64 REV 4-73

Coupling Effect From Radial & Long. Degrees of Freedom.

From sheet F-3.2.4 @ 100K Radial load produces .001336 radians of rotation

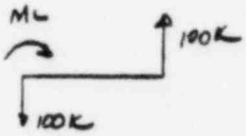
$K_L = .31172\times10^{10}$ IN-LB/RAD. (F-4.4.1)

$\Delta_{TOTAL} =$ .1938 INCHES



$M_L = .31172\times10^{10}(.001336) = 4.165\,10^6$ IN-LBS.

FREE Body, of 1-2



$\Sigma F_X = 0 \quad \therefore \quad P = 100K$

$\Sigma M = 0 \quad \therefore \quad M_L - L(100\times10^3) = 0$

$$L = \frac{M_L}{100\times10^3} = \frac{4.165\,10^6}{1\times10^5} = 41.65''$$

$\Delta_{TOTAL} = \Delta_\phi + \Delta_R$

$\Delta_\phi = L(.001336\,RAD) = .0556$ in

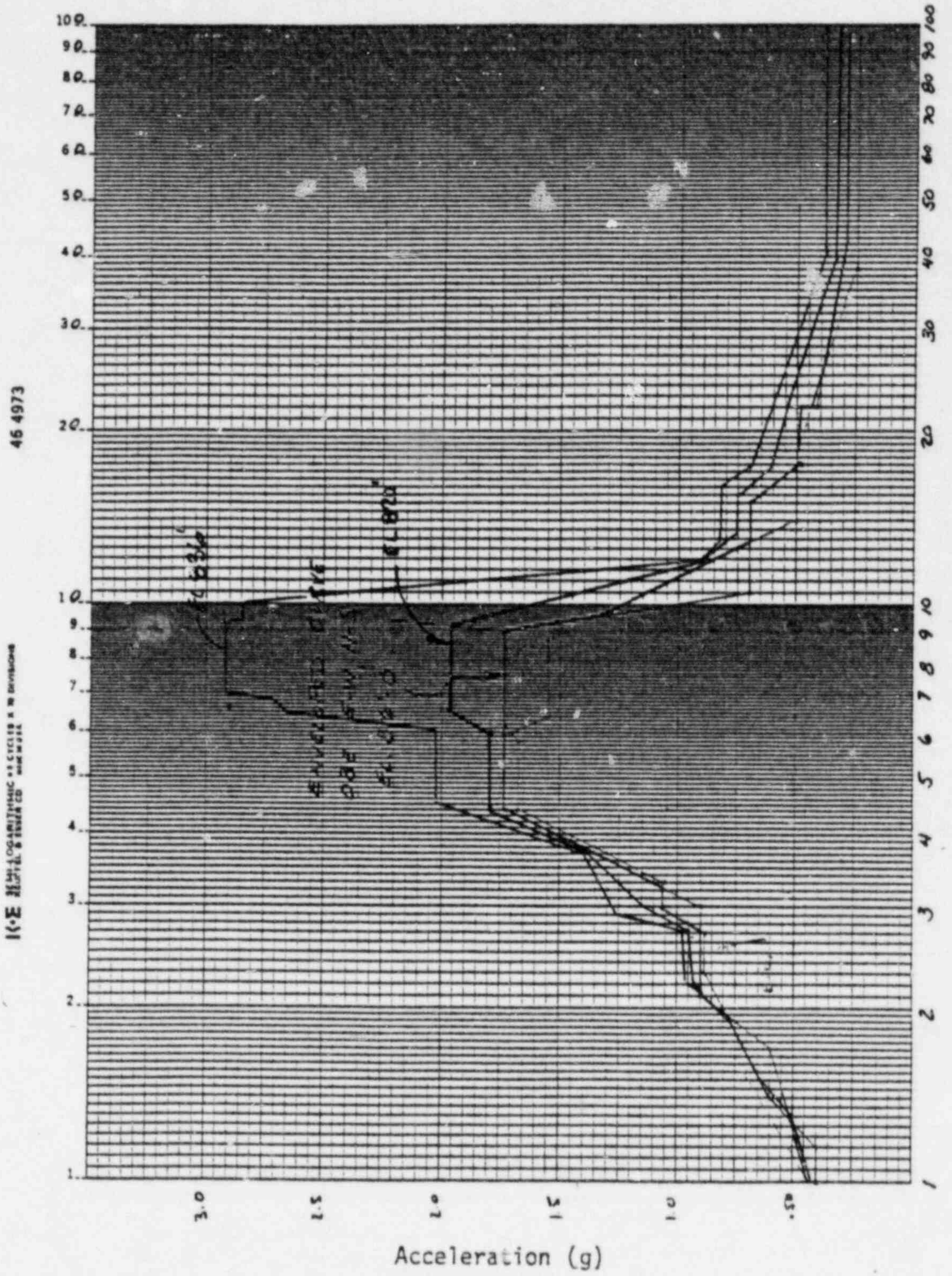
$\Delta_R = .1938 - .0556$ in $= .1382$ in

$$K_R = \frac{100\,000}{.1382} = 723589 \ \#/in.$$

SUBJECT Coupling Effect	MADE BY RAH	CHKD BY RAN	REV	By	CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd Date	SHT B-2 OF

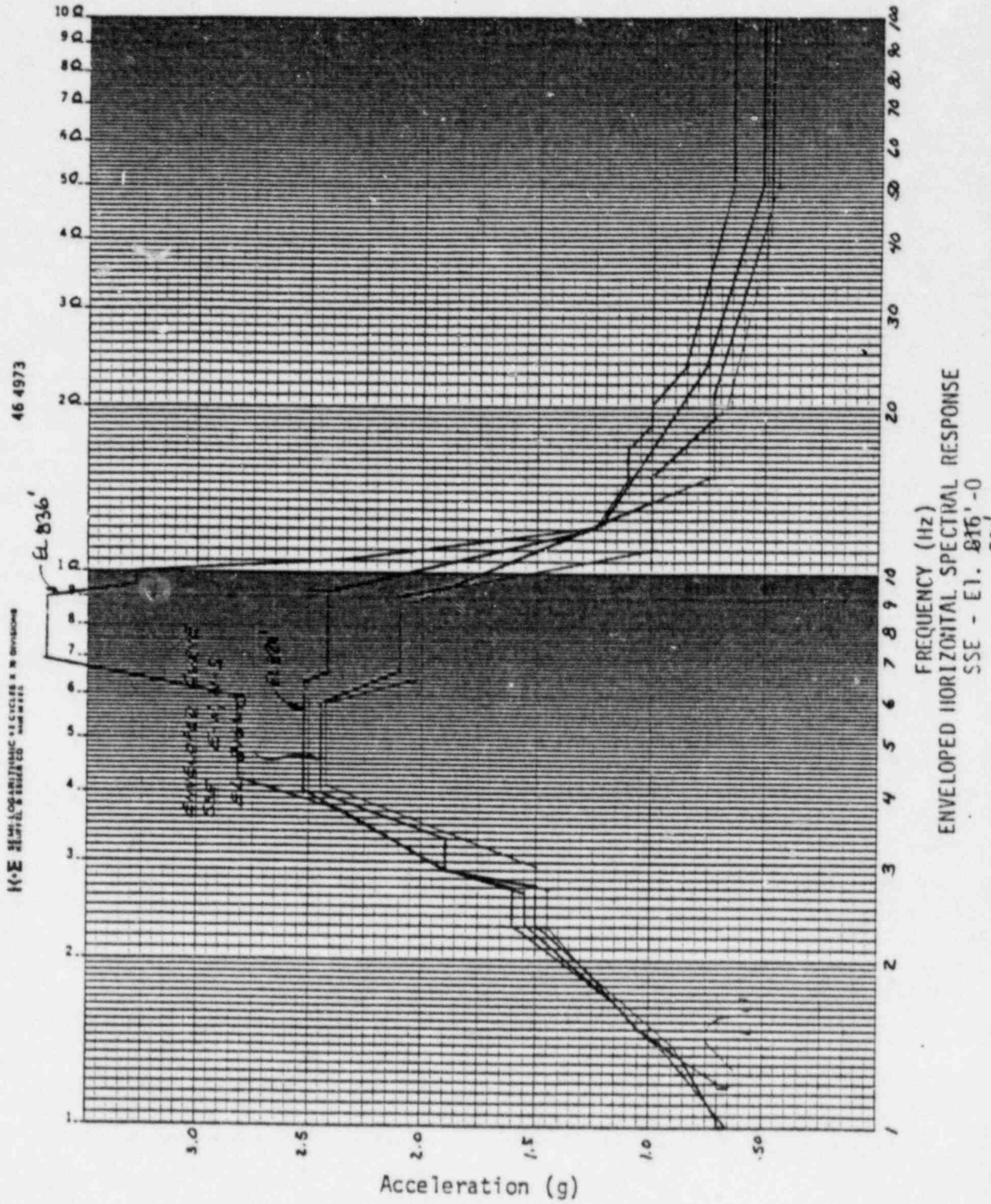
GO 64 REV 4-73

OAK BROOK
SPECIAL STRUCTURES DESIGN



ENVELOPED HORIZONTAL SPECTRAL RESPONSE
OBE - El. ~~816'0~~ 820'

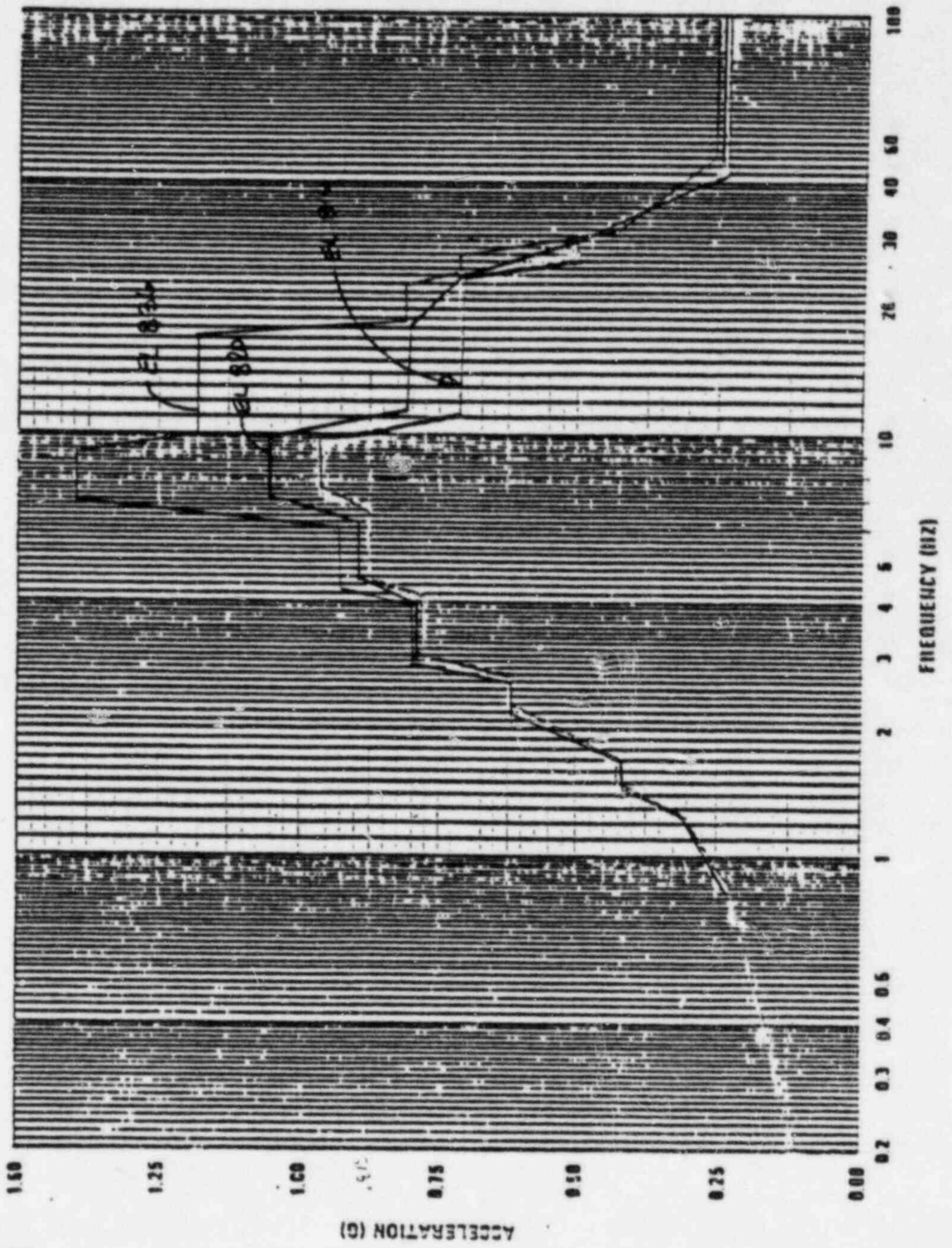
SUBJECT	MADE BY	CHKD BY	REV	BY		5-4331
SPECTRAL RESPONSE CURVE	SAH	RAVI				
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		CHKD		SHT C-1
				DATE		



SUBJECT	MADE BY	CHKD BY	REV	BY		CH
SPECTRAL RESPONSE CURVE CRBRP Containment Vessel	RAH	RAW				5-4331
	DATE 11/82	DATE 11/82		CHKD		SHT. C-2 OF
				DATE		

COMPONENT: CONTAINMENT VESSEL

PAGE NO. H-49
E953014



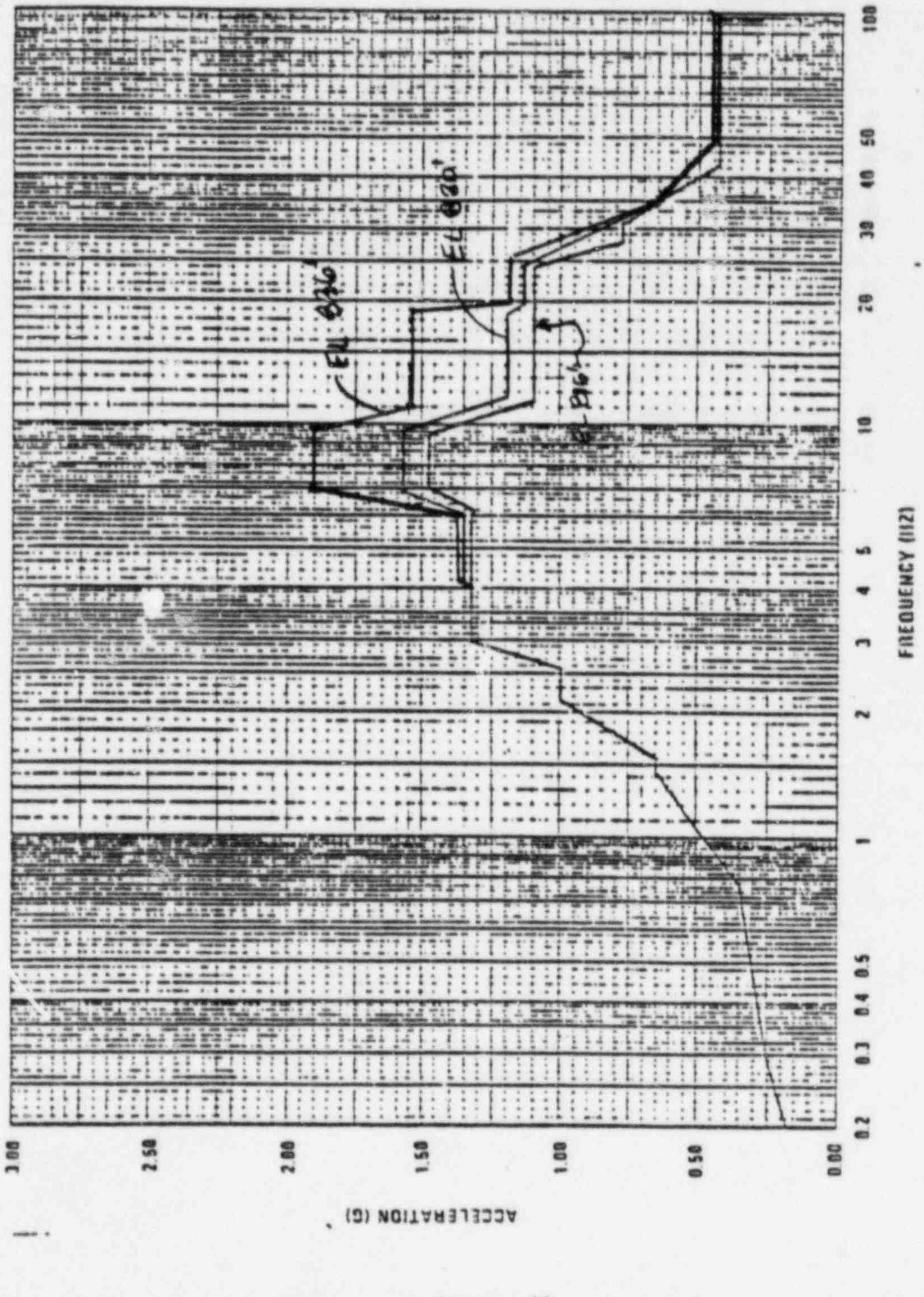
CRBRP OBE COMBINED VERTICAL DESIGN RESPONSE SPECTRUM FOR REACTOR CONTAINMENT BUILDING AT EL. ~~816'~~ 820'; COORDINATES 43.7'W, 82.1'S; 2% DAMPING.

796L:

FIGURE 35

SUBJECT	MADE BY	CHKD BY	REV	BY		5-4331
Spectral Response Curve	RAH	RAW				
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		CHKD		SHT C-3 OF
				DATE		

REVISION NO. 38 DATE 7/80



CRBRP SSE COMBINED VERTICAL DESIGN RESPONSE SPECTRUM FOR REACTOR CONTAINMENT BUILDING AT EL. ~~876'~~ 820'; COORDINATES 43.7'W, 82.1'S; 3% DAMPING.

Figure 14

SUBJECT	MADE BY	CHKD BY	REV	BY		CH 5-4331
Spectral Response Curve		RAW		CHKD		
CRBRP Containment Vessel	DATE	DATE 11/82		DATE		SHT C-4 OF

CBI

CAF. ET

Location

RESPONSE SPECTRA EL 820'

OBE HORIZONTAL.

FREQ.	ACCEL G's	ACCEL IN/SEC²
1.0	.45	174
2.2	.94	363
2.7	.94	363
3.0	1.15	444
3.8	1.4	541
4.4	1.8	696
6.0	1.8	696
6.5	1.95	753
9.2	1.95	753
14.0	.90	348
40.0	.35	135
10000	.35	135

SSE HORIZONTAL.

FREQ.	ACCEL G's	ACCEL IN/SEC²
1.0	.7	271
2.3	1.55	599
2.6	1.55	599
2.9	1.8	696
4.0	2.53	978
6.3	2.53	978
6.6	2.4	927
9.2	2.4	927
14.	1.25	483
24.	.75	290
50.	.53	205
10000	.53	205

OBE VERTICAL

FREQ.	ACCEL G's	ACCEL IN/SEC²
1.0	.25	97
2.2	.38	147
2.6	.38	147
3.0	.79	305
4.0	.79	305
4.6	.90	348
6.2	.90	348
7.0	1.05	406
10.0	1.05	406
11.5	.81	313
18.0	.81	313
24.0	.70	270
30.0	.50	193
46.0	.25	97
10000	.25	97

SSE VERTICAL.

FREQ.	ACCEL G's	ACCEL IN/SEC²
1.0	.50	193
2.1	1.0	386
2.6	1.0	386
3.0	1.33	514
4.0	1.33	514
4.2	1.35	522
6.0	1.35	522
7.0	1.58	611
10.0	1.58	611
12.0	1.20	464
18.5	1.20	469
20.0	1.15	388
25.0	1.15	388
35.0	.65	251
50.0	.45	174
10000	.45	174

SUBJECT SPECTRAL RESPONSE DATA INPUT VALUES FOR E1722A	MADE BY RAH	CHKD BY RAW	REV	By		5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd		SHT C-5 OF
				Date		

GO 64 REV 4-73

CBI

OAF [illegible]
[illegible]
Location

COMBINED LOADS FROM SAP IV CONC. LL. @ END.

MODE FREQUENCIES. $f_1 = 2.95$ Hz $f_2 = 4.04$ Hz $f_3 = 7.52$ Hz

OBE

DIRECTION	P KIPS	VL KIPS	VC KIPS	ML FT-KIPS	MC FT-KIPS	MT FT-KIPS
RADIAL	226.1	53.6	13.3	1278.3	356.4	829.9
CIRC.	13.3	2.9	35.8	10.3	389.3	45.9
LONG.	28.3	27.3	1.6	249.1	31.1	125.9
TOTAL	267.7	83.8	50.7	1537.7	776.8	1001.7

SSE

DIRECTION	P KIPS	VL KIPS	VC KIPS	ML FT-KIPS	MC FT-KIPS	MT FT-KIPS
RADIAL	291.4	74.4	20.2	2013.5	584.2	1153.3
CIRC.	20.2	4.5	54.8	166.8	641.8	69.8
LONG.	44.3	48.6	2.6	415.5	52.7	204.3
TOTAL	355.9	127.5	77.6	2595.8	1278.7	1427.4

SUBJECT COMBINED LOADS	MADE BY RAH	CHKD BY RAW	REV	By		CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd		
				Date		SHT D-1 OF

GO 64 REV 4-73

CBI

Location OAK [illegible] ECIAL STRUC[illegible]

ACCELERATIONS @ END OF LOCK (NODE 1)

(RESULTS OBTAINED FROM PGM E1724A)

$$\text{ACCEL (G's)} = (\text{SPECTRAL DISPLACEMENT}) \frac{(2\pi f_i)^2}{386.4}$$

EVENT	DIRECTION	MODE	FREQUENCY	SPECTRAL DISPLACEMENTS X	SPECTRAL DISPLACEMENTS Y	SPECTRAL DISPLACEMENTS Z	SPECTRAL ACCELERATIONS G X	SPECTRAL ACCELERATIONS G Y	SPECTRAL ACCELERATIONS G Z
OBE	RADIAL	1	2.95	.1926	.0228	-.3123	.1713	.0203	-.2777
		2	4.04	.2446	.6071	.1109	.4079	1.012	.1849
		3	7.52	.1987	-.2242	.0433	1.1480	-1.2954	.2502
	LONG.	1	2.95	.0109	.0129	-.0177	.0097	.0115	-.0157
		2	4.04	.0498	.1237	.0226	.0830	.2063	.0377
		3	7.52	.0214	-.0243	.0047	.1236	-.1404	.0272
	CIRC.	1	2.95	.2252	.0267	-.3651	.2002	.0237	-.3246
		2	4.04	.0178	.0441	.0081	.0297	.0735	.0135
		3	7.52	.0073	-.008	.0016	.0422	.0462	.0092
SSE	RADIAL	1	2.95	.3176	.0376	-.5149	.2824	.0334	-.4578
		2	4.04	.3950	.9805	.1792	.6587	1.6351	.2988
		3	7.52	.2438	-.2760	.0533	1.4086	-1.5947	.3080
	LONG.	1	2.95	.0191	.0023	-.0309	.0170	.0020	-.0275
		2	4.04	.0834	.2071	.0379	.1391	.3454	.0632
		3	7.52	.03226	-.0365	.0071	.1864	.2109	.0410
	CIRC.	1	2.95	.3713	.0440	-.6021	.3301	.0391	-.5353
		2	4.04	.0287	.0712	.0130	.0479	.1187	.0217
		3	7.52	.0089	-.0102	.0019	.0514	-.0589	.0109

SUBJECT Combined Accel.	MADE BY RAH	CHKD BY RAW	REV	By	CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd	
				Date	SHT D-2 OF

ACCELERATIONS @ END OF LOCK

SRSS OF MODAL ACCELERATIONS. RESULTS.

OBE	X	Y	Z
RADIAL	1.23	1.64	.42
LONG	.15	.25	.05
CIRC.	.21	.09	.33
TOTAL	1.59	1.98	.80

SSE	X	Y	Z
RADIAL	1.58	2.28	.63
LONG.	.23	.40	.08
CIRC.	.34	.14	.54
TOTAL	2.15	2.82	1.25

SUBJECT ACCELERATION SUMMARY	MADE BY	CHKD BY RAW	REV	By		CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE	DATE 11/82		Chkd		SHT D-3 OF
				Date		

Location OAK [illegible]
SPECIAL STRUC[illegible]

LOAD FACTOR DETERMINATION:

PROGRAM E1374 WAS generated using a 100K Radial load and 100 FT-K moments. The actual forces and moments will be to factor the results from E1374.

For CONCENTRATED Live load.

SSE: RADIAL LOAD: P= 355.9 Kips ∴ FACTOR = 3.56

Long Moment, ML

Due to Seismic = 2595.8 FT-K
Due to LL+DL = 331.7 $(174.1 \times \frac{22.9^2}{12})$
2927.5 FT-K
∴ FACTOR = [illegible]

Circ Moment, Mc = 1278.7 FT-K
∴ FACTOR = 12.79

OBE: RADIAL LOAD: P= 267.7 Kips ∴ FACTOR = 2.68

Long. Moment, ML

Due to Seismic = 1537.7 FT-K
Due to DL+LL = 331.7
1869.4 FT-K
∴ FACTOR = 18.69

Circ. Moment, Mc = 776.8 FTK ∴ FACTOR = 7.77

SUBJECT LOAD FACTORS DETERMINATIONS	MADE BY RAH	CHKD BY RAW	REV	By		5-4331
				Chkd		
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Date		SHT 5-1 OF

GO 64 REV 4-73

CBI

OAK BROOK
Location SPECIAL STRUCTURES DESIGN

FORCES FOR UNIT
LOADS AND MOMENTS

UNRESTRAINED CASE

LOADING CONDITION	N_θ (#/IN)	N_ϕ (#/IN)	M_ϕ (IN·#/IN)	M_θ (IN·#/IN)
AT EDGE OF AIRLOCK ATT.				
RADIAL	3680	3787	2196	3310
LONG	378	925	428	319
CIRC	636	374	496	1159
AT $0.5\sqrt{RT}$ FROM AIR LOCK ATT.				
RADIAL	2914	2711	1951	2192
LONG	247	567	194	158
CIRC	484	381	322	800
AT EDGE OF INSERT PL				
RADIAL	2497	2342	1767	1722
LONG	207	462	135	120
CIRC	404	368	298	632

SUBJECT - UNRESTRAINED SHELL [illegible] FOR UNIT LOADS AND MOMENTS	MADE BY MPT	CHKD BY DAB	REV	By		CHARGE NO 5-4331
CRBRP Containment Vessel	DATE 4/82	DATE 4/82		Chkd		SHT F-5.5 OF
				Date		

SUBJECT UNIT LOADING FROM E1374 PGM	MADE BY RAH	CHKD BY RAW	REV	By		5-4331
CRBRP Containment Vessel	DATE	DATE 11/82		Chkd		SHT E-2 OF

MEMBRANE FORCES - UNRESTRAINED CASE

W/CONCENTRATED LL - OBE

LOADING CONDITION	LOAD FACTOR	N_ϕ #/in	N_θ #/in	$N_{\phi\theta}$ #/in
@ Edge of Airlock attach $r_0 = 86.5"$				
RADIAL	2.68	9862	10149	0
LONG.	18.69	7065	17288	187
Circ.	7.77	4442	2906	950
TORSION.	—	—	—	256
@ 5 FT from Airlock att. $r_0 = 108.6$				
RADIAL	2.68	7810	7265	0
LONG	18.69	4616	10597	149
Circ.	7.77	3761	2960	757
TORSION	—	—	—	162
@ EDGE OF INSERT PL $r_0 = 123.5"$				
RADIAL	2.68	6692	6277	0
LONG.	18.69	3869	8635	131
Circ	7.77	3139	2859	665
TORSION	—	—	—	125

NOTE: $N_{\phi\theta} = V_L / \pi r_0$ for Circ. Locations V_L = DL+LL+Seismic
$N_{\phi\theta} = V_C / \pi r_0$ for Long. locations V_C : Seismic

$N_{\phi\theta} = M_T / 2\pi r_0^2$ for Torsion

SUBJECT OBE - MEMBRANE FORCES	MADE BY RAH	CHKD BY RAW	REV	By	CHARGE NO 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd	
				Date	SHT E-3 OF

GO 64 REV 4-73

MEMBRANE STRESS INTENSITIES
IN SHELL DUE TO AIRLOCK LOADS.
– UNRESTRAINED CASE · OBE LOADS. –

I @ Airlock to BARREL JUNCTION $t = 3''$

1. @ Meridian of Airlock.

	$N\phi$	$N\theta$	$N\phi\theta$
RAD	9862	10149	0
LONG	7065	17288	187
TORS.	–	–	256
	16927.0	27437	443

$\sigma_\phi = 5642$ psi $\sigma_\theta = 9146$ psi $\sigma_{\phi\theta} = 148$ psi

$S_1 = 9152$ psi $S_2 = 5636$ psi $S_3 = 0$

$S.I. = |S1 - S3| =$ 9152 psi

2. @ ℄ Elevation of Airlock

	$N\phi$	$N\theta$	$N\phi\theta$
RAD	9862	10149	0
CIRC	4942	2906	950
TORS	–	–	256
	14804	13055	1206

$\sigma_\phi = 4935$ psi $\sigma_\theta = 4352$ psi $\sigma_{\phi\theta} = 402$ psi

$S_1 = 5140$ psi $S_2 = 4147$ psi $S_3 = 0$

$S.I. = |S1 - S3| =$ 5140 psi

II @ $.5\sqrt{RT}$ from Airlock $t = 3''$

1. @ Meridian of Airlock

	$N\phi$	$N\theta$	$N\phi\theta$
RAD	7810	7265	0
LONG	4616	10577	149
TORS	–	–	162
	12426	17862	311

σ_ϕ = 4142 psi σ_θ = 5954 psi $\tau_{\phi\theta}$ = 104 psi

S_1 = 5960 psi S_2 = 4136 psi S_3 = 0 psi

S.I. = $|S_1 - S_3|$ = 5960 psi

2. @ ℄ Elevation of Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	7810	7265	0
CIRC	3761	2960	757
TORS	—	—	162
	11571	10225	919

σ_ϕ = 3857 psi σ_θ = 3402 psi $\sigma_{\phi\theta}$ = 306 psi

S_1 = 4012 psi S_2 = 3253 psi S_3 = 0

S.I = $|S_1 - S_3|$ = 4012 psi

III @ EDGE OF INSERT t = 1.75"

1. @ Meridian of Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	6692	6277	0
LONG	3869	8635	131
TORS	—	—	125
	10561	14912	438

σ_ϕ = 6035 psi σ_θ = 8521 psi $\sigma_{\phi\theta}$ = 250 psi
S_1 = 8546 psi S_2 = 6010 psi S_3 = 0 psi SI = $|S_1 - S_3|$ = 8546 psi

2. @ ℄ Elevation of Airlock.

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	6692	6277	0
CIRC	3139	2859	665
TORS	—	—	125
	9831	9136	790

σ_ϕ = 5618 psi σ_θ = 5221 psi $\sigma_{\phi\theta}$ = 451 psi

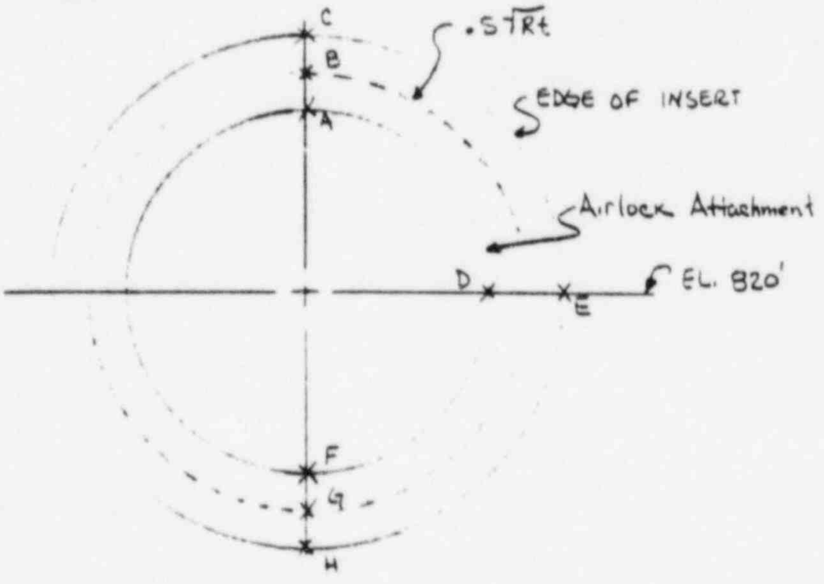
S_1 = 5912 psi S_2 = 4927 psi S_3 = 0 SI = $|S_1 - S_3|$ = 5912 psi

SUBJECT OBE - MEMBRANE STRESSES	MADE BY RAH	CHKD BY RAW	REV	By		CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd		SHT E-5 OF
				Date		

COMBINED MEMBRANE S. I.
- UNRESTRAINED CASE -
OBE LOADS

	①				
LOCATION	STRESS INTENSITY FROM All LOADS	SHELL MEMBRANE STRESS INTENSITY	TOTAL STRESS INTENSITY	PREVIOUS TOTAL S.I. (SHT F-S.22)	Δ%
A t=3"	9152 psi	4234 psi	13386 psi	14854 psi	-11
B t=3"	5960 psi	4234 psi	10194 psi	11104 psi	-9
C t=1.75"	8546 psi	7258 psi	15804 psi	17065 psi	-8
D t=3"	5140 psi	3240 psi	8380 psi	7698 psi	+9
E t=1.75"	5912 psi	5555 psi	11467 psi	10666 psi	+8
F t=3"	9152 psi	5581 psi	14733 psi	16201 psi	-10
G t=3"	5960 psi	5581 psi	11541 psi	12451 psi	-8
H t=1.75"	8546 psi	9567 psi	18113 psi	19374 psi	-7

NOTES: ① SEE SHT F-S.22



LOCATION SKETCH

SUBJECT OBE MEMBRANE S.I.	MADE BY KAH	CHKD BY RAW	REV	By		5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd		SHT E-6 OF
				Date		

CBI

MEMBRANE FORCES - UNRESTRAINED CASE

W/CONCENTRATED LL - SSE

LOADING CONDITION	LOAD FACTOR	N_ϕ #/in	N_θ #/in	$N_{\phi\theta}$ #/in
@ Edge of Airlock attach r_0: 86.5"				
RADIAL	3.56	13101	13482	0
LONG.	29.28	11068	27084	286
CIRC.	12.79	8134	4783	1111
TORSION.	—	—	—	364
@ 5½T From Airlock att. r_0=108.6				
RADIAL	3.56	10374	9651	0
LONG	29.28	7232	16602	227
CIRC.	12.79	6190	4873	885
TORSION	—	—	—	231
@ EDGE OF INSERT PL r_0=123.5"				
RADIAL	3.56	8889	8338	0
LONG.	29.28	6061	13527	200
CIRC	12.79	5167	4707	778
TORSION.	—	—	—	179

NOTE: $N_{\phi\theta} = V_L/\pi r_0$ for Circ. Locations V_L = DL+LL+Seismic
$N_{\phi\theta} = V_C/\pi r_0$ for Long. locations V_C = Seismic

$N_{\phi\theta} = M_T/2\pi r_0^2$ for Torsion

SUBJECT SSE MEMBRANE FORCES	MADE BY RAH	CHKD BY RAW	REV By	CHARGE NO 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82	Chkd	E-7

CBI

Location SPECIAL STRUCT [illegible]

MEMBRANE STRESS INTENSITIES
IN SHELL DUE TO AIRLOCK LOADS
- UNRESTRAINED CASE · SSE LOADS -

I @ Airlock TO BARREL JUNCTION t = 3"

1. @ MERIDIAN OF AIRLOCK

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	13101	13482	0
LONG	11068	27084	286
TORS	-		364
	24169	40566	650

$\sigma_\phi = 8057$ psi $\sigma_\theta = 13522$ psi $\sigma_{\phi\theta} = 217$ psi

$S_1 = 13531$ psi $S_2 = 13531$ psi $S_3 = 0$

S.I. = $|S_1 - S_3|$ = 13531 psi

2. @ ℄ ELEVATION OF AIRLOCK.

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	13101	13482	0
CIRC	8134	4783	1111
TORS	-	-	364
	21235	18265	1475

$\sigma_\phi = 7078$ psi $\sigma_\theta = 6088$ psi $\sigma_{\phi\theta} = 492$ psi

$S_1 = 7281$ psi $S_2 = 5885$ psi $S_3 = 0$

S.I. = $|S_1 - S_3|$ = 7281 psi

II @ $.5\sqrt{RT}$ FROM Airlock t = 3"

1. @ Meridian of Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	10374	9651	0
LONG.	7231	16602	227
TORS	-	-	231
	17606	26253	458

$\sigma_\phi = 5869$ psi $\sigma_\theta = 8751$ psi $\sigma_{\phi\theta} = 153$ psi

$S_1 = 8759$ psi $S_2 = 5861$ $S_3 = 0$

S.I. = $|S_1 - S_3|$ = 8759 psi

SUBJECT SSE MEMBRANE STRESSES	MADE BY RAH	CHKD BY RAW	REV	By		CHARGE NO 5-4331
CRBRP Containment Vessel	DATE 11/82	DATE 11/82		Chkd		SHT E-8 OF
				Date		

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2. @ ℄ Elevation of Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	10374	9651	0
CIRC	6190	4873	865
TORS.	—	—	231
	16564	14524	1116

σ_ϕ = 5521 psi σ_θ = 4841 psi $\sigma_{\phi\theta}$ = 372 psi
S_1 = 5685 psi S_2 = 4677 psi S_3 = 0 psi
S.I. = $|S_1 - S_3|$ = 5685 psi

III A. EDGE of INSERT t = 1.75"

1. @ MERIDIAN OF Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	8889	8338	0
LONG	6061	13527	200
TORS.	—	—	179
	15244	22521	379

σ_ϕ = 8543 psi σ_θ = 12494 psi $\sigma_{\phi\theta}$ = 217 psi
S_1 = 12506 psi S_2 = 8531 psi S_3 = 0 psi

S.I. = $|S_1 - S_3|$ = 12506 psi

2. @ ℄ Elevation of Airlock

	N_ϕ	N_θ	$N_{\phi\theta}$
RAD	8889	8338	0
CIRC.	5167	4707	778
TORS.	—	—	179
	14056	13045	957

σ_ϕ = 8032 psi σ_θ = 7454 psi $\tau_{\phi\theta}$ = 547 psi

S_1 = 8367 psi S_2 = 7124 psi S_3 = 0

S.I. = $|S_1 - S_3|$ = 8362 psi

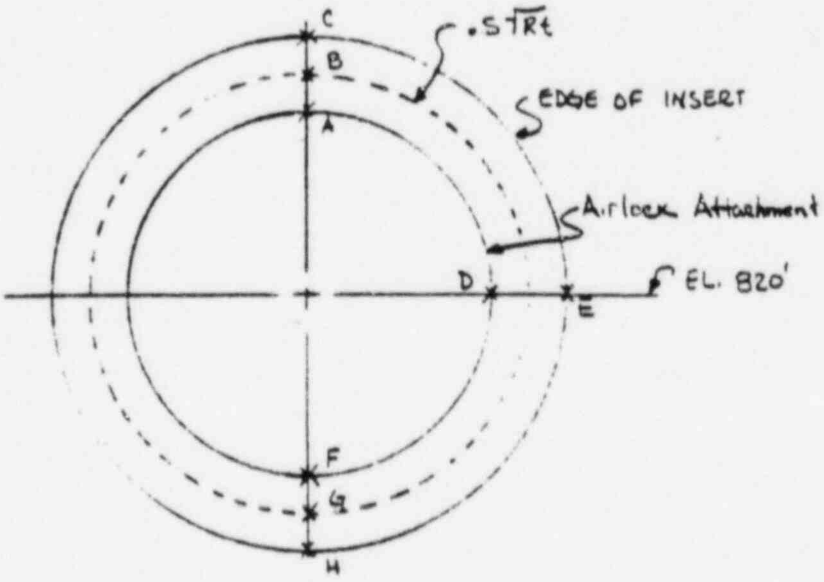
CBI

OAK BROOK
Location SPECIAL STRUCTURES [illegible]

COMBINED MEMBRANE S. I.
- UNRESTRAINED CASE -
SSE LOADS.

LOCATION	STRESS INTENSITY FROM All LOADS ①	SHELL MEMBRANE STRESS INTENSITY	TOTAL STRESS INTENSITY	PREVIOUS TOTAL S.I. (SHT F-5.21)	Δ%
A t=3"	13531	4739 psi	18270	19206 psi	-5
B t=3"	8759	4739 psi	13498	14080 psi	-4
C t=1.75"	12506	8124 psi	20630	21450 psi	-4
D t=3"	7281 psi	3809 psi	11090 psi	9964 psi	+11
E t=1.75"	8362 psi	6530 psi	14892 psi	13607 psi	+9
F t=3"	13531	5581 psi	19112	20048 psi	-5
G t=3"	8759	5581 psi	14340	14922 psi	-4
H t=1.75"	12506	9567 psi	22073	22893 psi	-4

NOTES: ① REF SHT F-5.21



LOCATION SKETCH

SUBJECT SSE MEMBRANE S.I.	MADE BY KAH	CHKD BY RAW	REV	By		CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE [illegible]	DATE 11/82		Chkd		E-10

AIR LOCK
LIVE LOAD

EQUIPMENT/PERSONNEL AIRLOCK LIVE LOAD

Section F, "Equipment/Personnel Airlock Effects on the Shell" of the containment vessel design report develops the frequency and accelerations of the airlock and the airlock's effects on the shell, moments and forces. The dynamic analysis in Section F considers the full live load (40k) at the end of the airlock as encompassing the worst condition. During a recent NRC Design Review, the location and magnitude of the live load became a concern of the reviewers. The reviewers felt that if the live load was reduced or relocated away from the end of the airlock, the frequency of the airlock may increase enough to result in an increased acceleration and an increased load on the shell. The final result being that the "worst condition" may not have been used for design.

In response to the stated concerns of the reviewers, the dynamic analysis in Section F was reexamined and we offer the following explanation to the reviewers in response to their concern.

If the live load magnitude is reduced from 40^k and/or the live load is moved toward the center of the airlock, the following anticipated effects would occur.

1. The center of gravity of the airlock would move toward the center of the airlock. This would reduce the moment arm distance. With a reduced moment arm, the circumferential moment and the longitudinal moment would be reduced significantly whether or not the live load itself was reduced.

2. The frequency of the airlock would increase but would remain approximately within a 10% range. A higher frequency would result in a slightly higher first mode spectral acceleration. However, the final airlock accelerations would only change an insignificant amount. This insignifigant change in acceleration would not be greater than the significant reduction which would occur from Item #1.

3. The force or moment on the shell will decrease.

A detailed listing of the anticipated effects are listed on pages
Our examination of the effects of a reduced or relocated live load reveal that the accelerations will either remain the same or will decrease and the radial force and moments on the shell will decrease.

LIVE LOAD IN AIRLOCK

Max. LL 40^k
Assumed at End of Lock
Result

RADIAL - $f_1 = 3.42$ cps left of peak spectral acceleration
$f_2 = 6.96$ on the peak spectral acceleration

	OBE	SSE
Acceleration	1.585	2.083 g
Rotation	0.00897 (Radians)	0.0127 (Radians)
F	277^k	364^k
M_L	1633^{1-k}	2317^{1-k}

VERT. EQ - $f_1 = 3.74$ cps left of peak
$f_2 = 126.14$

	OBE	SSE
Acceleration	2.166 g	3.385 g
M_L	298^{1-k}	505^{1-k}

CIRC EQ - $f_1 = 2.74$ cps left of peak
$f_2 = 126.14$

	OBE	SSE
Acceleration	1.07 g	1.74 g
M_L	418^{1-k}	730^{1-k}

I. Liveload $<40^k$ at End of Lock

- A. Anticipated Results (Radial)
  - 1. Frequency will increase slightly, still approximately within 10%.
    - Note: a. Response spectra curve is adjusted 10%.
    - b. CBI uses a 10% adjusted factor frequency ±10% to arrive at maximum spectral acceleration.
    - c. First mode frequency gives higher spectral acceleration. However, the second mode frequency will remain on peak. The second mode frequency has a high participation factor
  - 2. Location of C.G. will change.
  - 3. Acceleration of lock will change insignificantly.
  - 4. Radial force on shell will go down (less mass).
  - 5. Summary
    - a. Acceleration unchanged.
    - b. Load on shell less.

- B. Anticipated Results (Long. Eq.)
  - 1. C.G. of lock will be closer to shell.
  - 2. Frequency will go up slightly, approximately within 10% range.
    - Note: a. Response Spectra curve is adjusted 10%.
    - b. CBI uses a 10% adjusted factor f ±10% to arrive at maximum spectral acceleration.
  - 3. First mode spectral acceleration will go up slightly.
  - 4. Acceleration of system changes insignificantly. C.G. closer to shel
  - 5. M_L decreases. C.G. closer to shell + less mass.
  - 6. Summary
    - a. Acceleration changes insignificantly.
    - b. Moment on shell will decrease.

- C. Anticipated Results (Circ Eq.)
  - 1. C.G. of lock will be closer to shell.
  - 2. Frequency will go up slightly, approximately within a 10% range.
    - Note: a. Response spectra curve is adjusted 10%.
    - b. CBI uses a 10% adjusted factor f ±10% to arrive at a maximum spectral acceleration.

3. First mode spectral acceleration will increase slightly.
4. Acceleration of system changes insignificantly.
5. M_C decreases, C.G. closer to shell + less mass.
6. Summary
   a. Accelerations remain the same.
   b. Moment on shell decreases.

II. Liveload = 40^k Located Away From End

A. Anticipated Results (Radial)

1. Frequency will increase slightly, still approximately within 10%.
   Note: a. Response spectra curve is adjusted 10%.
   b. CBI uses a 10% adjusted factor frequency ±10% to arrive at maximum spectral acceleration.
   c. First mode frequency gives a higher spectral acceleration However, the second mode frequency will remain on the peak. The second mode frequency has a high participation factor.
2. Acceleration of lock will change only insignificantly.
3. Radial force on shell will decrease slightly.
4. Summary
   a. Accelerations change insignificantly.
   b. Load on shell less.

B. Anticipated Results (Long. Eq.)

1. C.G. of lock will be closer to shell.
2. Frequency will go up slightly, approximately within 10% range.
   Note: a. Response spectra curve is adjusted 10%.
   b. CBI uses a 10% adjusted factor f ±10% to arrive at maximum spectral acceleration.
3. First mode spectral acceleration will go up slightly.
4. Acceleration of system changes insignificantly.
5. M_L decreases. C.G. closer to shell.
6. Summary
   a. Accelerations change insignificantly.
   b. Moment on shell will decrease.

C. Anticipated Results (Circ. Eq.)

1. C.G. of lock will be closer to shell.
2. Frequency will go up slightly, approximately within a 10% range.
   Note: a. Response spectra curve is adjusted 10%.
   b. CBI uses a 10% adjusted factor f ±10% to arrive at a maximum spectral acceleration.
3. First mode spectral acceleration will increase slightly.
4. Acceleration of system changes insignificantly.
5. M_C decreases, C.G. closer to shell.
6. Summary
   a. Accelerations remain approximately the same.
   b. Moment on shell decreases.

SUBJECT	MADE BY	CHKD BY	REV			CHARGE NO.
	RAW	RAW		BY		5-4331
CRBRP CONTAINMENT VESSEL	DATE 11/82	DATE 11/82		CHKD		SHT OF
				DATE		

TO: R.E. Gale (W-OR) 11/30/82

FROM: D.L. Coroneos (W-WM)

RE: Equip. Airlock Freq. Variation with Load Mag. & Loc.

Please find attached a table of freq. variations.
A complete SARD will follow by mail.
Note that if the ±10% criteria is required also for the <u>New</u> frequencies, the (Δg's)% max is 15.6%; otherwise, the (Δg's)% max is 5%

WESTINGHOUSE ADVANCED REACTORS DIVISION CALCULATION SHEET

SYSTEM ______ COMPONENT CRBRP Containment Vessel SARB NO. ______ REV. ______
SUBJECT/PURPOSE Equip Airlock Freq. Variation with Load Mag. & Loc.
PREPARED BY: D. T. Caranca DATE 11/23/82

Table ____
Freq. Variation with LL Mag. & Loc.

	$LL_{(TOTAL)} = 43,400 lbs$			$LL = 21,700$	$LL = 4,340$
X	$\bar{N}$	ω_1 *		ω_1 *	ω_1 *
		$k = .31172\times10^{10}$	$k = .1678\times10^{10}$	$k = .31172\times10^{10}$	$k = .31172\times10^{10}$
0	26.12959	3.738	2.743	3.962	4.172
10	23.64106	3.815	2.799	4.007	4.183
20	21.15253	3.888	2.853	4.048	4.192
30	18.66399	3.957	2.903	4.087	4.200
40	16.17546	4.020	2.949	4.121	4.208
50	13.68693	4.076	2.991	4.152	4.214
60	11.19840	4.125	3.027	4.177	4.220
70	8.70987	4.166	3.057	4.198	4.224
80	6.22133	4.197	3.079	4.214	4.227
90	3.73280	4.218	3.095	4.224	4.229
100	1.24427	4.229	3.103	4.2296	4.230+
105	0.0	4.230+ ▷	3.104- ▷	4.230+ ▷	4.230+ ▷
Δ%	N.A.	13.162	13.161	13.162	13.161

▷ The limit value is $\sqrt{k/m}$. for $m = 4,412,091.8$:
for $k = .31172\times10^{10}$ ____ $\omega_1 = 4.2303879$ Hz
for $k = .1678\times10^{10}$ ____ $\omega_1 = 3.1038008$ Hz

* ω_2 for all cases is above ZPA.

WESTINGHOUSE ADVANCE REACTORS DIVISION CALCULATION SHEET

SYSTEM ____________ COMPONENT CRBRP Containment Vessel CARB NO. ____________

REV. NO. ____________ SUBJECT/PURPOSE Equip Airlock Freq Variation with Load Mag & Loc.

PREPARED BY: D. L. Caravacos DATE 11/23/82

E'quake	OBE		SSE	
Elev.	816'	836'	816'	836'
New*	1.06 [1]	1.29 [3]	1.9 [2]	2.04 [4]
Old**	1.06	1.27	1.9	1.98
Δ%	0%	1.57%	0%	3.03%

Table ____

E'quake	OBE		SSE	
Elev.	816'	836'	816'	836'
New+10%*	1.16 [1]	1.35 [3]	1.98 [2]	2.21 [4]
Old**	1.06	1.27	1.9	1.98
Δ%	9.4%	6.3%	4.2%	11.6%

Table ____

(Δg_i)% Due to Freq Chg. Circumferential Moment

$k = 0.1678 \times 10^{10}$

** Ref. 1, Pg. F-4.5

* Response Curves Herein

[1] Pg. F-4.3.1
[2] Pg. F-4.3.2
[3] Pg. F-4.3.3
[4] Pg. F-4.3.4

WESTINGHOUSE ADVANCE REACTORS DIVISION CALCULATION SHEET

SYSTEM ________ COMPONENT CRBRP Containment Vessel ARS NO. ________

REV. NO. ________ SUBJECT/PURPOSE Equip Airlock Freq. Variation with Lead Mass & Loc.

PREPARED BY: D. L. Caraccos DATE 11/23/82

E'quake / Elev	OBE		SSE	
	816'	836'	816'	836'
New*	.785[1]	.840[2]	1.32[1]	1.37[2]
Old**	.77	.80	1.32	1.37
Δ%	1.9%	5%	0%	0%

Table ____

E'quake / Elev	OBE		SSE	
	816'	836'	816'	836'
New* 40%	0.875[1]	0.925[2]	1.36[1]	1.38[2]
Old**	0.77	0.8	1.32	1.37
Δ%	13.6%	15.6%	3%	0.7%

Table ____

$(\Delta g's)\%$ Due to Freq. Chg. Longitudinal Moment

$k = .31172 \times 10^{10}$

** Ref. 1, Pg. F-4.4.3

* Response Curves Used in Ref. 2

[1] Pg. H-69, Fig. 35
[2] Pg. H-61, Fig. 47

“VESSEL HEAD

“DOME BREATHING

CHICAGO BRIDGE & IRON COMPANY

Location Oak Brook Engineering

TOP HEAD STIFFNESS VERIFICATION

To account for the vertical "dome breathing" mode of the steel containment vessel top head, a stiffness matrix coupling the mass points in the dome was developed. This stiffness matrix is described in subsection 5 of the Section E, Seismic, of the Containment Vessel Design Report. The purpose of this study is to compare the frequency and mode shape of this method with a more refined model.

A dynamic shells of revolution model was chosen to provide this confirmation. The shell model used for this comparison is shown on sheet 2.

Subsection 5 of Section E provides a complete stiffness matrix for a vertical model as shown on sheet EA-5.19 of Section E. The frequency and mode shape was not provided in subsection 5. Therefore, a lumped mass model analysis with the stiffness matrix shown on Sheet EA-5.19 was developed. An additional mass point was added 60 inches above the base to facilitate the analysis. This additional mass point does not effect the top head stiffness matrix.

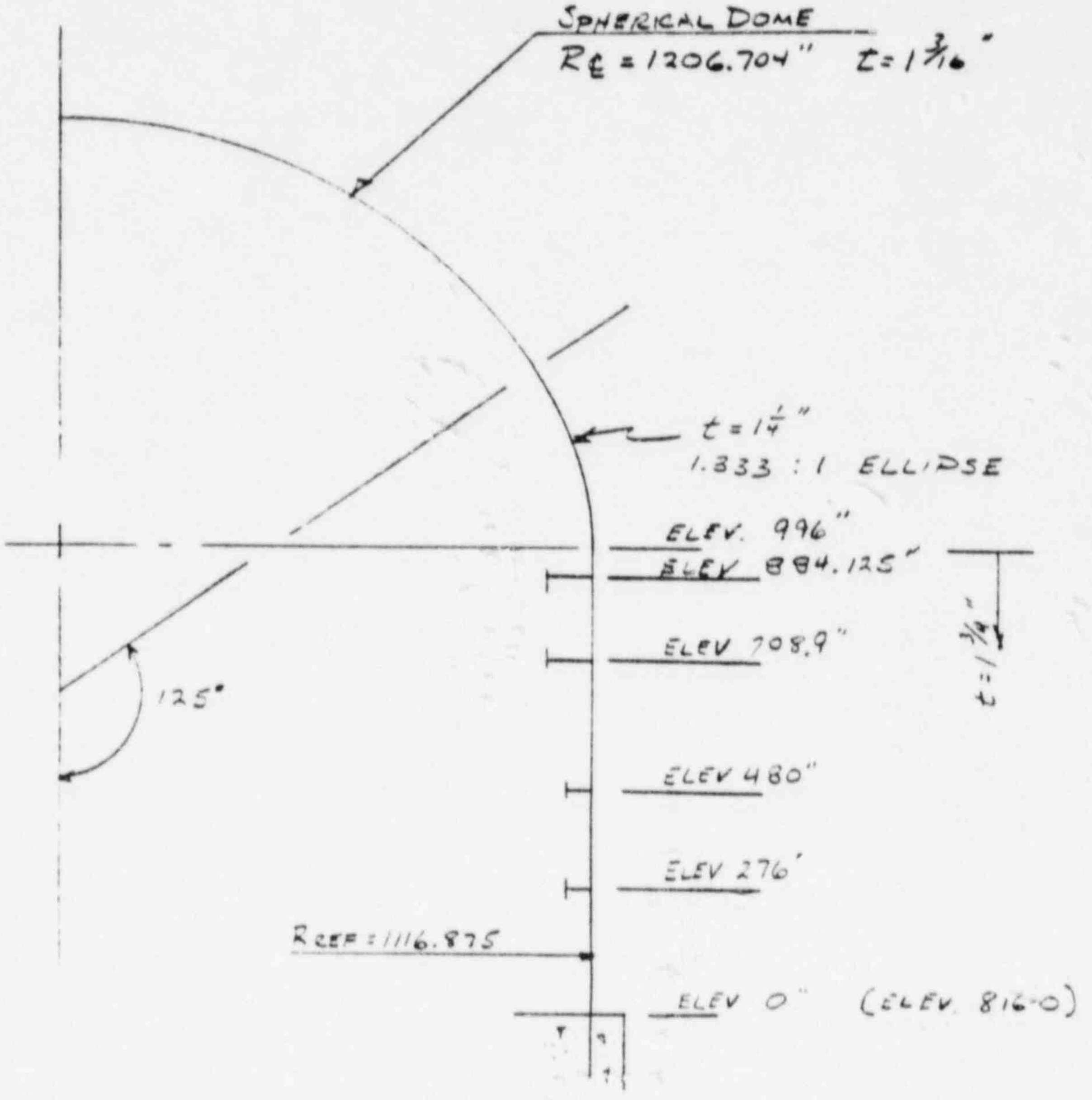
A comparison of the results of the two methods is shown on sheet 7. The plotted mode shapes are in very close agreement and the frequencies are within 10%. In conclusion, the dynamic shell of revolution analysis compares favorably with the vertical "dome breathing" mode provided in the containment design report.

SUBJECT	MADE BY RAW	CHKD BY RAW	REV	BY		CHARGE NO. 5-4331
	DATE 11/82	DATE [illegible]		CHKD		
				DATE		SHT 1 OF

CBI

Location OAKBROOK

SHELLS OF REVOLUTION
DYNAMIC ANALYSIS MODEL

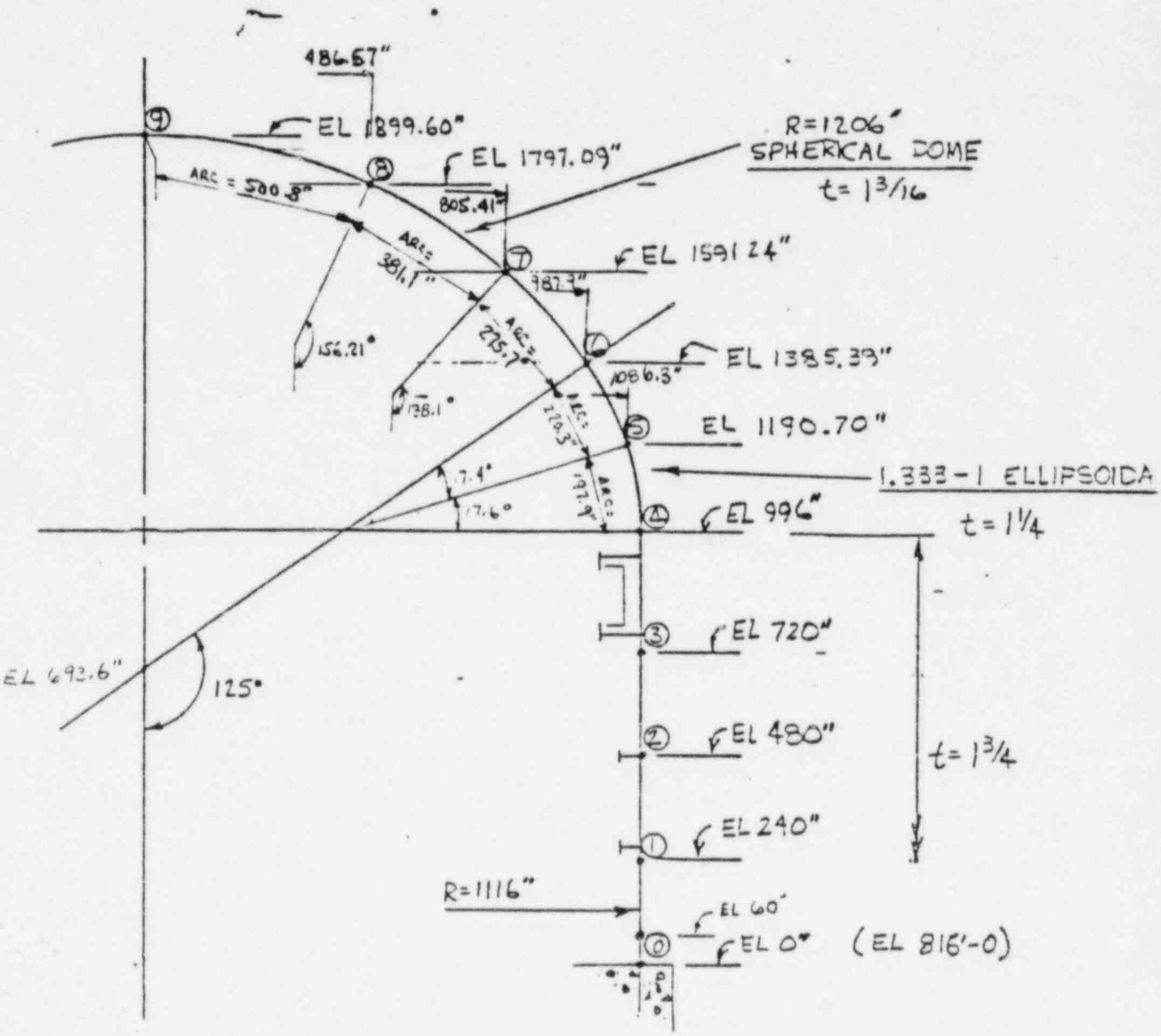


SUBJECT	MADE BY [illegible]	CHKD BY RAH	REV	By		CHARGE NO 5-4331
	DATE 11/82	DATE [illegible]		Chkd		
				Date		SHT 2 OF

GO 64 REV 4-73

Location ~~SPECIAL STRUCTURES DESIGN~~

GEOMETRY OF VESSEL FOR WHICH STIFFNESS MATRIX IS DETERMINED



SUBJECT	MADE BY	CHKD BY	BY		5-4331
CRBRP Containment Vessel	DATE	DATE	CHKD		SHT 3 OF
			DATE		

CBI

Location OAK BROOK
SPECIAL STRUCTURES DESIGN

COMPLETE STIFFNESS MATRIX FOR *
VERTICAL MODEL

$$\begin{bmatrix} F_9 \\ F_8 \\ F_7 \\ F_6 \\ F_5 \\ F_4 \\ F_3 \\ F_2 \\ F_1 \\ F_0 \end{bmatrix} = \begin{bmatrix} 7.0752\times10^6 & -1.7743\times10^6 & -1.3660\times10^6 & -1.0778\times10^6 & -9.691\times10^5 & -1.8881\times10^6 & 0 & 0 & 0 & 0 \\ -1.7743\times10^6 & 2.8563\times10^7 & -7.7271\times10^6 & -5.1848\times10^6 & -4.7148\times10^6 & -9.1625\times10^6 & 0 & 0 & 0 & 0 \\ -1.3660\times10^6 & -7.7271\times10^6 & 5.4773\times10^7 & -1.4695\times10^7 & -1.0327\times10^7 & -2.0615\times10^7 & 0 & 0 & 0 & 0 \\ -1.0778\times10^6 & -5.1848\times10^6 & -1.4695\times10^7 & 9.8263\times10^7 & -3.4136\times10^7 & -4.3168\times10^7 & 0 & 0 & 0 & 0 \\ -9.691\times10^5 & -4.7148\times10^6 & -1.0329\times10^7 & -3.4138\times10^7 & 3.2975\times10^8 & -2.7159\times10^8 & 0 & 0 & 0 & 0 \\ -1.8881\times10^6 & -9.1625\times10^6 & -2.0615\times10^7 & -4.3168\times10^7 & -2.7197\times10^8 & 1.7423\times10^9 & -1.3069\times10^9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1.3069\times10^9 & 2.9360\times10^9 & -1.5491\times10^9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1.5491\times10^9 & 3.0182\times10^9 & -1.5491\times10^9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1.5491\times10^9 & 3.[illegible]\times10^9 & -2.0655\times10^9 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2.0655\times10^9 & 6.1904\times10^9 \end{bmatrix} \begin{bmatrix} u_9 \\ u_8 \\ u_7 \\ u_6 \\ u_5 \\ u_4 \\ u_3 \\ u_2 \\ u_1 \\ u_0 \end{bmatrix}$$

* COPIED FROM SHT EA-5.19 OF CBI DESIGN REPORT

SUBJECT	MADE BY	CHKD BY	REV 1		CHARGE NO
CRBRP Containment Vessel	RAH	[illegible]	By	RAH	[illegible]
	DATE	DATE	Chkd	[illegible]	
	7/82	[illegible]	Date	[illegible]	SHT 4 OF

CBI

Location OAK BROOK
SPECIAL STRUCTURES DESIGN

MASS POINTS

$W_0 = 2\pi(1116.875)(120)(1.75)(.2836) = 417936$ Lbs — $W_0 = 417936$ Lbs $M_0 = 1081.6$ $\frac{k^s}{in}$

$W_1 = 2\pi(1116.875)(240)(1.75)(.2836) = 335872$ Lbs — $W_1 = 974925$ Lbs $M_1 = 2523.1$
$2\pi(1116-32.167)(72)(.2836) = 139053$ Lbs

$W_2 = 2\pi(1116.875)(240)(1.75)(.2836) = 835872$ Lbs — $W_2 = 974925$ Lbs $M_2 = 2523.1$
$2\pi(1116-32.167)(72)(.2836) = 139053$ Lbs

$W_3 = 2\pi(1116.875)(258)(1.75)(.2836) = 898563$ Lbs — $W_3 = 1229108$ Lbs $M_3 = 3180.9$
$2\pi(1116-45.29)(173.25)(.2836) = 330545$ Lbs

$W_4 = 2\pi(1116.875)(138)(1.75)(.2836) = 480627$ Lbs — $W_4 = 1076090$ Lbs $M_4 = 2784.9$
$2\pi(1116-46.65)(183.315)(.2836) = 349304$ Lbs
$2\pi(1116.875)(98.95)(1.25)(.2836) = 246159$ Lbs

$W_5 = 2\pi(1086.3)(209.1)(1.25)(.2836) = 505941$ Lbs — $W_5 = 505941$ Lbs $M_5 = 1309.4$

$W_6 = 2\pi(987.9)(110.15)(1.25)(.2836) = 242378$ Lbs — $W_6 = 505047$ Lbs $M_6 = 1307.1$
$2\pi(1206)(102.93)(1.1875)(.2836) = 262669$ lbs

$W_7 = 2\pi(1206)(205.85)(1.1875)(.2836) = 525313$ Lbs — $W_7 = 525313$ Lbs $M_7 = 1359.5$

$W_8 = 2\pi(1206)(154.18)(1.1875)(.2836) = 393455$ Lbs — $W_8 = 393455$ Lbs $M_8 = 1018.3$

$W_9 = 2\pi(1206)(51.26)(1.1875)(.2836) = 130811$ Lbs — $W_9 = 130811$ Lbs $M_9 = 338.5$

TOP HD ONLY $W = 2306726$ Lbs $M = 5969.8$
TOTAL $W = 6733551$ LBS $M = 17426.4$

SUBJECT MASS POINTS	MADE BY SAH	CHKD BY	REV	By		CHARGE NO 5-4371
CRBRP Containment Vessel	DATE 9/72	DATE 9/72		Chkd		SHT 5 OF
				Date		

GO 64 REV 4-73

OAK BROOK
SPECIAL STRUCTURES DESIGN

CBI

Location________________

Complete Mass Matrix for Vertical Vessel

$$\left[\begin{array}{cccccccccc|c}
338.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & M_9 \\
 & 1018.3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & M_8 \\
 & & 1359.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & M_7 \\
 & & & 1302.1 & 0 & 0 & 0 & 0 & 0 & 0 & M_6 \\
 & & & & 1309.4 & 0 & 0 & 0 & 0 & 0 & M_5 \\
 & & & & & 2784.9 & 0 & 0 & 0 & 0 & M_4 \\
 & \text{SYMMETRICAL} & & & & & 3180.9 & 0 & 0 & 0 & M_3 \\
 & & & & & & & 2523.1 & 0 & 0 & M_2 \\
 & & & & & & & & 2523.1 & 0 & M_1 \\
 & & & & & & & & & 1081.6 & M_0
\end{array}\right]$$

SUBJECT MASS MATRIX	MADE BY FAH	CHKD BY LFL	REV	By		CHARGE NO. 5-[illegible]
CRBRP Containment Vessel	DATE [illegible]/82	DATE 7/82		Chkd		
				Date		SHT 6 OF ____

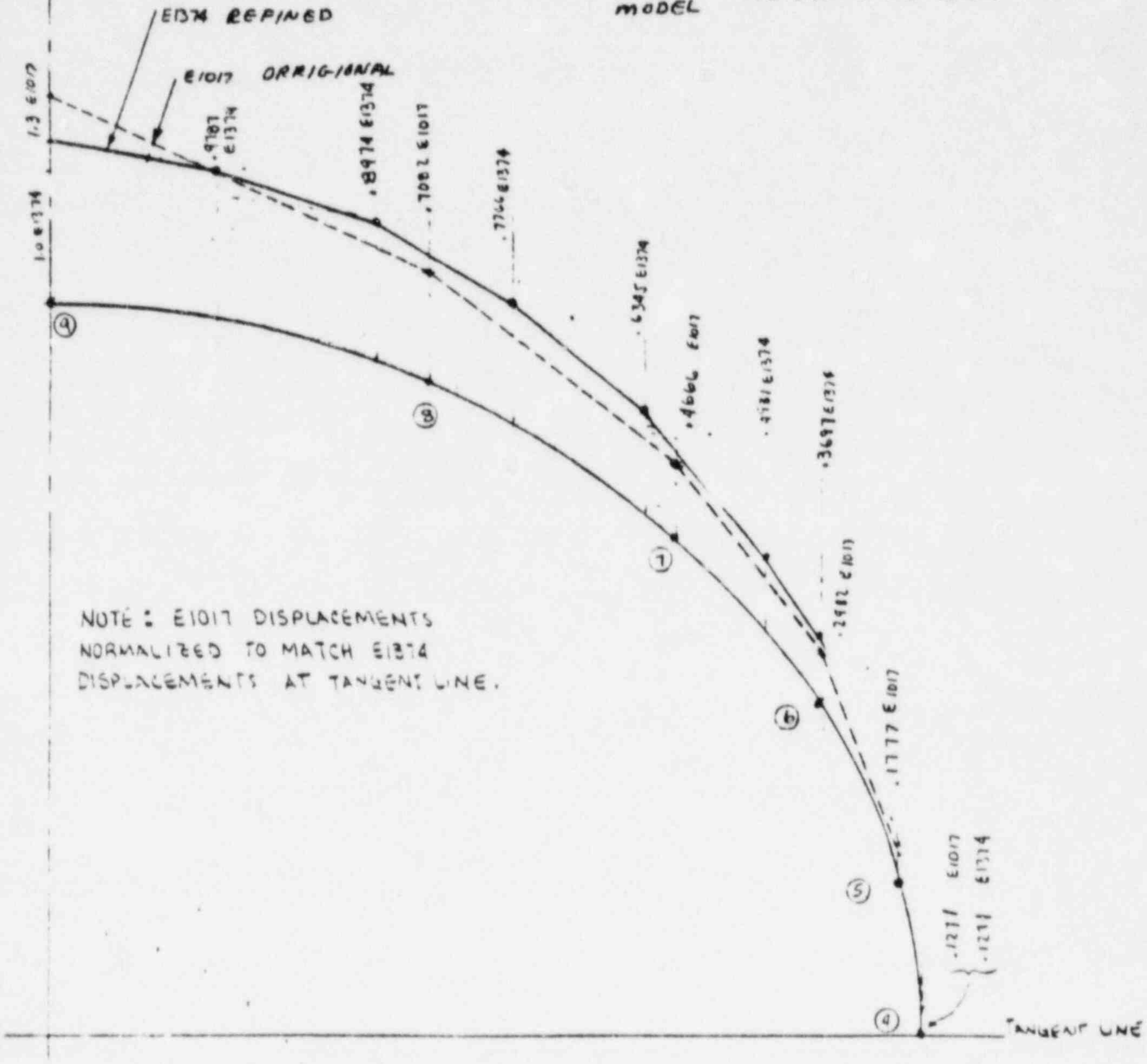
GO 64 REV 4-73

CBI

OAK BROOK
Location SPECIAL STRUCTURES DESIGN

REFINED MODEL $f_1 = 17.62$ HZ E1374 PGM.

ORRIG. MODEL $f_1 = 19.45$ HZ E1017 PGM.



NOTE: E1017 DISPLACEMENTS NORMALIZED TO MATCH E1374 DISPLACEMENTS AT TANGENT LINE.

MODAL DISPLACEMENTS FOR TOP HEAD

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO
	RAH	LRL		Chkd		[illegible]
CRBRP Containment Vessel	DATE 7/72	DATE 7/72		Date		SHT 7 OF

GO 64 REV 4-73

COMPUTER
PROGRAM
VERIFICATION

15 NRC Regulations

The intent and requirements of Appendix J to 10 CFR Part 50, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors", will be complied with, as applicable. A listing of exceptions to 10CFR50 Appendix J is provided in Section 6.2.1.4.

3.8.2.2.4 Applicable CRBRP General Design Criteria (GDC)

The applicable CRBRP GDC are listed below.

Criterion 1:	Quality Standards and Records.
Criterion 2:	Design Bases for Protection.
Criterion 3:	Fire Protection.
Criterion 3.a	Protection Against Sodium Reactions.
Criterion ~~4~~:5	Environmental and Missile Design Bases.
CRITERION 14:	CONTAINMENT DESIGN
Criterion ~~50~~:41	Containment Building Structure Design Bases.
Criterion ~~51~~:42	Fracture Prevention of Reactor Containment Boundary
Criterion ~~52~~:43	Capability for Containment Leakage Rate Testing.
Criterion ~~53~~:44	Provisions for Containment Testing and Inspection.
Criterion ~~54~~:45	Piping Systems Penetrating Containment.
Criterion ~~55~~:46	Reactor Coolant Boundary Penetrating Containment.
Criterion ~~56~~:47	Reactor Containment Isolation.
Criterion ~~57~~:48	Closed Systems Penetrating Containment.
Criterion ~~58.a:~~ 49	Containment Atmosphere ~~Control~~ CLEANUP.
Criterion ~~58.b~~ 50:	Inspection of Containment Atmosphere ~~Control~~ CLEANUP Systems.
Criterion ~~58.c:~~ 51	Testing of Containment Atmosphere ~~Control~~ CLEANUP Systems.
Criterion ~~64~~:56	Monitoring Radioactivity Releases.

P

GDC 2.8.2.2.4

Location____________________

CHICAGO BRIDGE + IRON COMPANY

COMPUTER PROGRAM VERIFICATION
FOR
CRBRP CONTAINMENT VESSEL
CBI CONTRACT 5-4331

SUBJECT	MADE BY RAW	CHKD BY	REV	By		CHARGE NO. 5-4331
	DATE 11/82	DATE		Chkd		
				Date		SHT ____ OF ____

GO 64 REV 4-73

This section provides the verification of all CBI computer programs used in the design of the containment vessel. This verification is accomplished by sample calculations and explanation of the methods used.

The following is a list of the program numbers and titles used in the design of the containment vessel:

1.)	655	Analysis of Ring-Stiffened Cylindrical Shells
2.)	772	Nozzle Reinforcing Area Check
3.)	781	General Shell of Revolution
4.)	907	T/R Ratio and Geometry for Elliptical Head
5.)	1017	Modal Analysis of Structures Using the Eigenvalue Technique
6.)	1027	Stress Intensities at Loaded Attachments; Cylinders and Spheres
7.)	1036	Maximum Stress Intensities in Jumbo Insert Plates
8.)	1374	Shell of Revolution - Dynamics Program
9.)	1392	Pipe Stresses Due to External Loads and Shell Stresses for Nuclear Containment Vessels
10.)	—VOID—	
11.)	1671	Preprocessor for Programs 772, 1036, and 1392
12.)	1691	Three Dimensional Space Frame and Truss Analysis
13.)	1823	Structural Analysis for Personnel Lock Bulkhead, Door, Hinge, and Latching Device

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAW	REV	By		CHARGE NO. 54331
Verification	DATE 10/27/82	DATE 11/8-2		Chkd		
				Date		SHT i OF

CBI

Location

CBI Program 655

This program calculates values of shear, moment, thrust, radial deflection, tangential deflection, angular deflection and shear at desired points of a cylinder or ring. Values derived are based on bending moment loads, tangential loads, and radial loads which are in the plane of the stiffener ring.

Author : JS Endicott
Dated Versions : 6/77 and 7/81
Limitations : on pages 1-2 and 1-3

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAW	REV	By		CHARGE NO. 54331
Verification	DATE 11/15/82	DATE 11/82		Chkd		
				Date		SHT 1-1 OF

INTRODUCTION

This program is a complete revision of Program 655. Program 655 had some deficiencies in the manner of programming. These are as follows:

1. Only finds displacements and forces on the loaded ring and the two adjacent rings (3 rings total). If more than one ring is loaded erroneous results will be obtained.
2. Has option of using partial structure.

These were changed in the revision to:

1. Displacements and forces are found on all rings, loaded or unloaded.
2. No partial structure is used in the solution.
3. Option: Displacements, forces, and stresses may be calculated for one portion of consecutive bays.

Additions and limitations are as follows:

1. Ring geometry is read in to obtain the stresses in the ring and shell. Program has option whether or not to calculate stresses.
2. Loads are printed out in single table, not at the ring before the loaded ring.
3. Displacements, forces, and stresses may be printed out at the points of loading. This is optional.
4. Total number of load points (if printed out) plus number of increments must be ≤145. Maximum of 99 for each type of load.

Additions and limitations (continued)

5. This is a finite element program with very simple elements. These elements are:
   a. Ring element which only bends in its own plane.
   b. Cylindrical membrane element with constant shear (one element between rings).

   Therefore, since there is only one very simple element between rings, the rings must be close together, etc.

DISCUSSION OF THEORY

This program is a result of the Technical Note NACA 1219, "Stress Analysis by Recurrence Formula of Reinforced Circular Cylinders Under Lateral Loads" by John E. Duberg and Joseph Kempner.

This paper contains the development of a general recurrence formula suitable for the stress analysis of cylinders that may be nonuniform in construction, arbitrarily supported at the boundaries, and arbitrarily loaded in the planes of the reinforcing rings. The development is based upon the maintenance of continuity of deformation between the rings and shell. In any particular problem the recurrence formula together with appropriate boundary equations are used to obtain sets of simultaneous linear equations for the corrections to the stresses given by the elementary theory.

In the development of the recurrence formula that can be used to obtain the desired stress corrections, several simplifying assumptions are made: that part of the sheet area which is considered to resist normal stresses is added to the stringer area and the combination is uniformly distributed about the periphery of the cylinder. This resulting combination is an effective sheet thickness that resists normal stresses. The actual sheet area is considered capable of supporting only shear stresses. It then follows that within a bay the shear stresses vary in the circumferential direction but are constant in the longitudinal direction. Inextensional deformation,of rings and sheet is also assumed, and Poisson's ratio is considered to be zero.

The elementary theory of ring analysis used herein is from "Formulas For Stress and Strain," by Raymond J. Roark, McGraw-Hill Book Co., Inc., New York, N.Y., 1954.

FORM OF EQUATIONS

From "Theory of Elastic Stability" by Timoshenko and Gere, page 279, comes the expression for the differential equation for the deflection of a ring.

$$M = \frac{EI}{R^2}\left[\frac{d^2w}{d\phi^2} + w\right]$$

where

M = bending moment
E = modulus of elasticity
I = moment of inertia
R = radius
w = radial deflection (positive inward)
ϕ = angular location of point on center line from reference

Furthermore, from the equilibrium equations, compatibility equations, and constitutive equations the following expressions are found:

$$\frac{dv}{d\phi} - w = 0$$

$$Q = \frac{dM}{Rd\phi} \qquad F = -\frac{dQ}{d\phi}$$

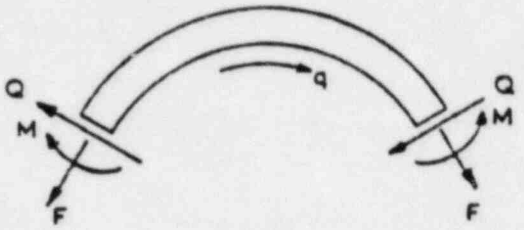
$$\theta = \frac{1}{R}\left(\frac{dw}{d\phi} + v\right)$$

$$M = -\frac{EI}{R}\frac{d\theta}{d\phi}$$

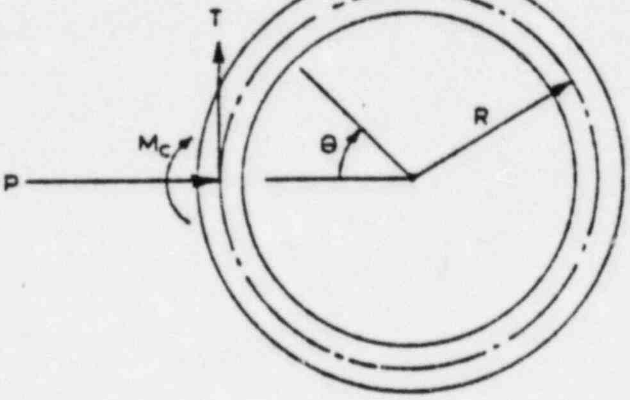
where

v = tangential displacement (positive clockwise)
Q = shear force
θ = rotation
F = axial force

Sign convention



q = shear flow



P = radial load

T = tangential load

M_c = concentrated moment

Therefore, the forces and displacements are as follows:

$b_{i,n} = b_{t,in} + b_{m,in}$ i.e. the sum of the tangential load and concentrated moment effects.

For the shell:

$$q_i(\phi) = q_e + \sum_{n=2}^{n_{max}} \left[a_{in} \sin n\phi + b_{in} \cos n\phi \right]$$

For the ring:

$$w_i(\phi) = w_e + \frac{R^4}{EI_i} \sum_{n=2}^{n_{max}} \frac{1}{n(n^2-1)^2} \left[\left(a_{i,n} - a_{i-1,n}\right) \cos n\phi - \left(b_{i,n} - b_{i-1,n}\right) \sin n\phi \right]$$

$$v_i(\phi) = v_e + \frac{R^4}{EI_i} \sum_{n=2}^{n_{max}} \frac{1}{n^2(n^2-1)^2} \left[\left(a_{i,n} - a_{i-1,n}\right) \sin n\phi + \left(b_{i,n} - b_{i-1,n}\right) \cos n\phi \right]$$

$$M_i(\phi) = M_e + R^2 \sum_{n=2}^{n_{max}} \frac{1}{n(n^2-1)} \left[\left(a_{i,n} - a_{i-1,n}\right) \cos n\phi - \left(b_{i,n} - b_{i-1,n}\right) \sin n\phi \right]$$

$$S_i(\phi) = Q_e + R \sum_{n=2}^{n_{max}} \frac{1}{n^2-1} \left[-\left(a_{i,n} - a_{i-1,n}\right) \sin n\phi - \left(b_{i,n} - b_{i-1,n}\right) \cos n\phi \right]$$

$$F_i(\phi) = F_e + R \sum_{n=2}^{n_{max}} \frac{n}{n^2-1} \left[\left(a_{i,n} - a_{i-1,n}\right) \cos n\phi - \left(b_{i,n} - b_{i-1,n}\right) \sin n\phi \right]$$

$$\theta(\phi) = \theta_e + \frac{R^3}{EI_i} \sum_{n=2}^{n_{max}} \frac{1}{n^2(n^2-1)} \left[-\left(a_{i,n} - a_{i-1,n}\right) \sin n\phi - \left(b_{i,n} - b_{i-1,n}\right) \cos n\phi \right]$$

The subscript e refers to the elementary solutions.

ELEMENTARY SOLUTIONS FOR RADIAL LOAD

$$M = \frac{PR}{2\pi}\left[\frac{\cos\phi}{2} - (\pi-\phi)\sin\phi + 1\right]$$

$$F = -\frac{P}{2\pi}\left[\frac{3\cos\phi}{2} + (\pi-\phi)\sin\phi\right]$$

$$Q = \frac{P}{2\pi}\left[\frac{\sin\phi}{2} - (\pi-\phi)\cos\phi\right]$$

$$\Theta = \frac{-PR^2}{2\pi EI}\left[\frac{3\sin\phi}{2} - (\pi-\phi)(1-\cos\phi)\right]$$

$$W = \frac{-PR^3}{2\pi EI}\left[1 - \frac{(\pi-\phi)}{2}\sin\phi + \cos\phi\left\{\frac{\phi}{2}\left(\pi-\frac{\phi}{2}\right) - \left(\frac{\pi^2}{6} - \frac{11}{8}\right) - 1\right\}\right]$$

$$V = \frac{PR^3}{2\pi EI}\left[(\pi-\phi)(1-\cos\phi) - \sin\phi\left\{\frac{\phi}{2}\left(\pi-\frac{\phi}{2}\right) - \left(\frac{\pi^2}{6} - \frac{11}{8}\right)\right\}\right]$$

$$q = -\frac{P}{\pi R}\sin\phi$$

SUBJECT	MADE BY	CHKD BY	BY	CHANGE NO. 54331
	DATE	DATE 6-73	CHKD DATE	

ELEMENTARY SOLUTIONS FOR TANGENTIAL LOAD

$$M = -\frac{TR}{2\pi}\left[\frac{3\sin\phi}{2} - (\pi-\phi)(1-\cos\phi)\right]$$

$$F = -\frac{T}{2\pi}\left[-\frac{\sin\phi}{2} + (\pi-\phi)\cos\phi\right]$$

$$Q = -\frac{T}{2\pi}\left[\frac{\cos\phi}{2} - (\pi-\phi)\sin\phi + 1\right]$$

$$\Theta = \frac{-TR^2}{2\pi EI}\left[\frac{5}{2}(1-\cos\phi) + (\pi-\phi)\sin\phi - \phi\left(\pi-\frac{\phi}{2}\right) + \frac{\pi^2}{3} - \frac{7}{2}\right]$$

$$W = \frac{-TR^3}{2\pi EI}\left[\frac{\phi}{2}\left(\pi-\frac{\phi}{2}\right)\sin\phi - (\pi-\phi)(1-\cos\phi) + \sin\phi\left(\frac{11}{8}-\frac{\pi^2}{6}\right)\right]$$

$$V = \frac{TR^3}{2\pi EI}\left[\phi\left(\pi-\frac{\phi}{2}\right)\left(1+\frac{\cos\phi}{2}\right) - \frac{3}{2}(\pi-\phi)\sin\phi - \frac{3}{2}(1-\cos\phi) + \cos\phi\left(\frac{11}{8}-\frac{\pi^2}{6}\right) - \frac{\pi^2}{3} + \frac{7}{2}\right]$$

$$q = \frac{-T}{\pi R}\left[\frac{1}{2} + \cos\phi\right]$$

SUBJECT	MADE BY	CHKD BY		CHANGE NO.
	DATE	DATE 6-73		54331

ELEMENTARY SOLUTIONS FOR CONCENTRATED MOMENT

$$M = \frac{M_c}{2\pi}\left[\pi - \phi - 2\sin\phi\right]$$

$$F = -\frac{M_c}{\pi R}\sin\phi$$

$$Q = -\frac{M_c}{2\pi R}\left[1 + 2\cos\phi\right]$$

$$\Theta = -\frac{M_c R}{2\pi E I}\left[-2(1-\cos\phi) + \phi\left(\pi - \frac{\phi}{2}\right) + 2 - \frac{\pi^2}{3}\right]$$

$$W = -\frac{M_c R^2}{2\pi E I}\left[(\pi-\phi)(1-\cos\phi) - \frac{3}{2}\sin\phi\right]$$

$$V = \frac{M_c R^2}{2\pi E I}\left[1 - \cos\phi + (\pi-\phi)\sin\phi - \phi\left(\pi - \frac{\phi}{2}\right) - \frac{3}{2}\cos\phi - \left(2 - \frac{\pi^2}{3}\right)\right]$$

$$q = -\frac{M_c}{2\pi R^2}$$

SUBJECT	MADE BY	CHKD BY	BY		CHARGE NO. 54331
	DATE	DATE 6-73	CHKD DATE		SHT OF

COMPUTER INPUT DATA SHEET

TO: Oak Brook
COMPUTER OPERATIONS

RETURN TO: ______ (NAME) ______ (LOCATION)

ontract or Est. No. ______

From: ______ (MADE BY) ______ (DATE)

Printout needed by: ______ (DATE)

______ (CHECKED BY) ______ (DEPT OR LOCATION)

PROGRAM E0655A (NO.) Input Data for (DESCRIPTION) ANALYSIS OF A STIFFENED CYLINDER WITH CONCENTRATED LOADS IN PLANE OF RING (REF NACA 1219)

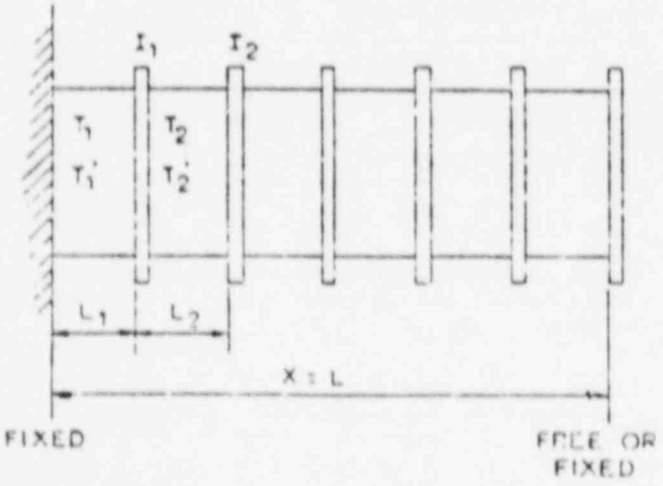
Programmer

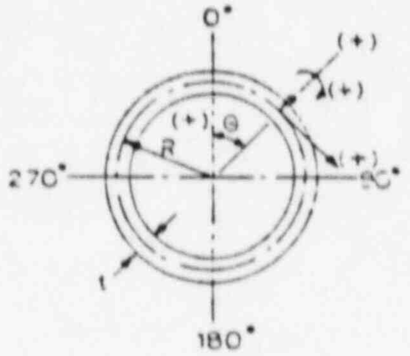
Card 1

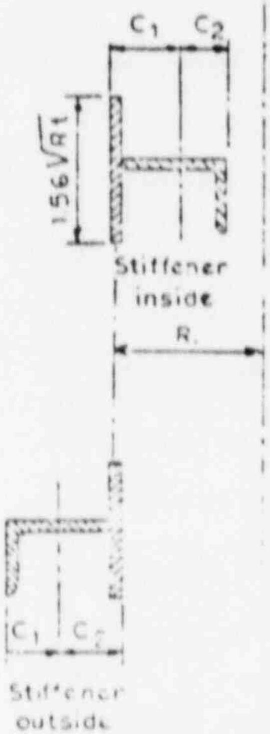
CONTRACT OR CHARGE NO	JOB DESCRIPTION	NAME	DATE
(LIMIT TOTAL NUMBER OF CHARACTERS TO 80)			

	Description	E YOUNGS MODULUS	G SHEAR MODULUS	R RADIUS	NO. OF BAYS (4 MIN)	FOURIER TERMS(1)	EDGE CODE 0=FREE @ X=L -1=FIXED @ X=L	STRESS CODE 0 = NONE 1 = STRESSES
2	Units	K.S.I.	K.S.I.	IN.	(30 MAX)	(10 MAX)		
	Data							

	Description	NUMBER OF ANGLE INCREMENTS (2)	START ANGLE	FINISH ANGLE	START BAY (3)	FINISH BAY (3)	DATA SHEET REVISION	
3	Units	(145 MAX)	DEG.	DEG.				
	Data						1	







Note (1) As required for convergence. 6 to 10 normally sufficient.

(2) 0 = Values at loads only
+N = Values at loads and increments
-N = Values at increments only
For max. values see (3) next page

(3) START BAY = Printout begins with this bay
FINISH BAY = Printout ends with this bay

4(1)

Description	I RING-SHELL	BAY LENGTH L_i	T	T' (2)	AREA RING-SHELL(4)	C_1 (4)	C_2 (4)	WEB AREA (4)	LOAD (3) CODE
Units	IN^4	IN	IN	IN	IN^2	IN	IN	IN^2	
Data									

Note (1) One card for each bay.

(2) Longitudinal stiffeners may be used, but must be smeared out around circumference.

(3) Example of load code: 012009

01 Moment load 20 Tangential load 09 Radial load	Total no. of load points (if printed out) + no. of increments ≤ 145	Max. of 99 for each type of load

(4) May be filled with zeros if stress code is 0.

Description	LOAD	ANGLE	LOAD	ANGLE	LOAD	ANGLE	LOAD	ANGLE	LOAD	ANGLE
Units	KIPS OR KIP. — IN.	DEG.								
Data										

Notes (1) Enter all moment loads and angles for first loaded ring, then start new card for all tangential loads and angles, start another new card for all radial loads and angles. —Repeat for each loaded ring—Omit cards for rings without loads.

VERIFICATION OF PROGRAM 655

Two studies have been performed to verify the results obtained from Program 655. First, the results of Program 655 were compared to the results of Program 781, "Shells in Revolution". Second, to verify that ten harmonics were sufficient, comparisions of stress results were made using a varying number of harmonics.

The models used for Program 655 are shown on Sheets 1-15 and 1-16. Both models consist of a stiffened shell with the top head modeled as an extension of the shell rising to 1/3 the elevation of the head. In Model 1 an ASME Code stiffener is modeled at elevation 924.1', while Model 2 is fixed at that elevation. Results from Model 1 were used in Section J of the Design Report. The model used for Program 781 is shown on Sheet 1-17.

To reduce the number of harmonics required for Program 781, loads were applied over 30° of the circumference. In Program 781, a uniform distributed load was applied over 30° using harmonics. In Program 655, 21 equal concentrated loads were spread over the 30°. Sheets 1-19 thru 1-23 show comparisions of inside and outside hoop stresses due to applied radial and tangential loads. In the case of the inside stresses due to an applied radial load (Sheet 1-19) there is a significant difference in Programs 655 and 781 results. A correction factor of 30% will be used to correlate the inside stresses of Program 655 with those of Program 781. *CONT. P14a*

Sheets 1-24 thru 1-26 show comparisons of Program 655 stress results using a varying number of harmonics. The results show that convergence of the recurrence formula has occured using ten harmonics.

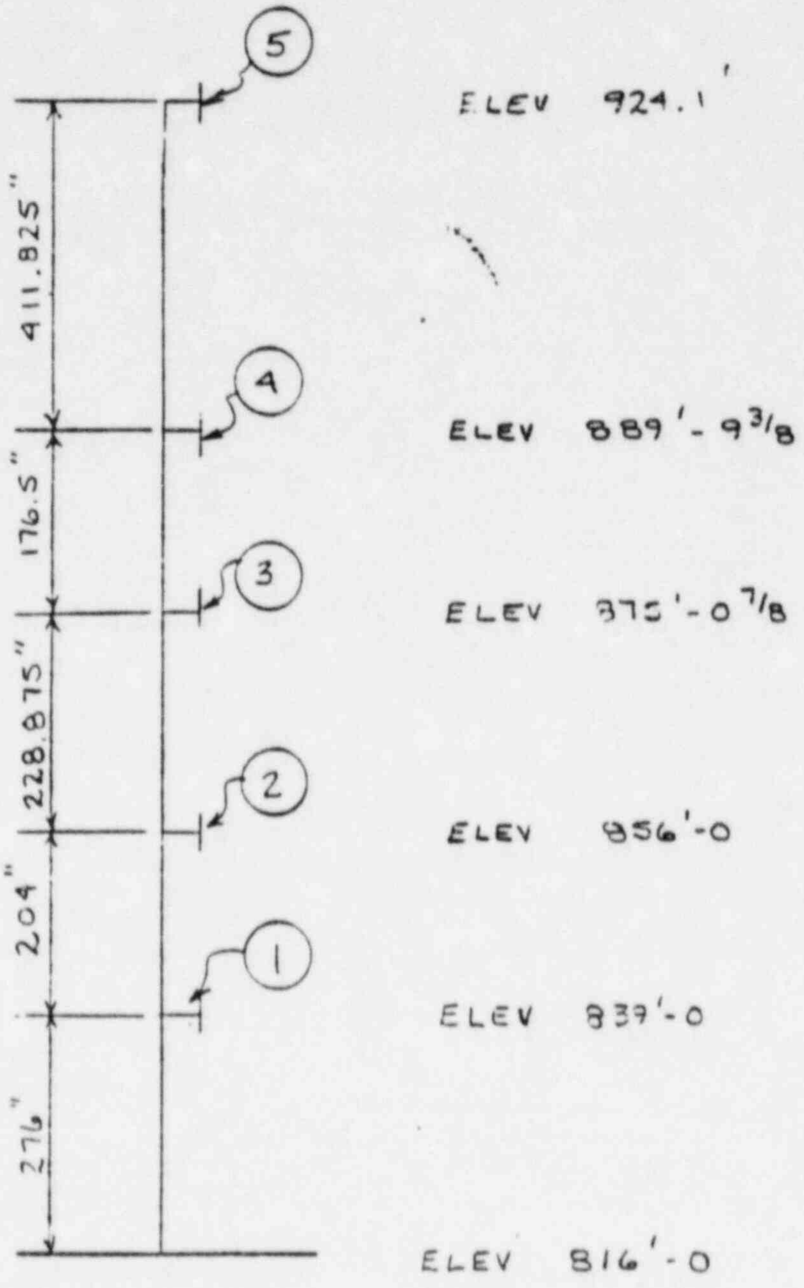
SUBJECT	MADE BY	CHKD BY	REV	BY		CHARGE NO.
	SCB	RAW				5-4231
	DATE 10/78	DATE 10/78		CHKD		
				DATE		SHT

CB&I's analysis uses the peak values only. Therefore, variation at other locations need not be addressed. The plots of the inside and outside stresses caused by a tangential load (see Pages 1-21 and 1-22) also indicate a significant difference. However, the program 655 analysis predicted higher stress values, so no adjustment was required.

CBI

Location____________________

PROGRAM USS MODEL 1



1-15

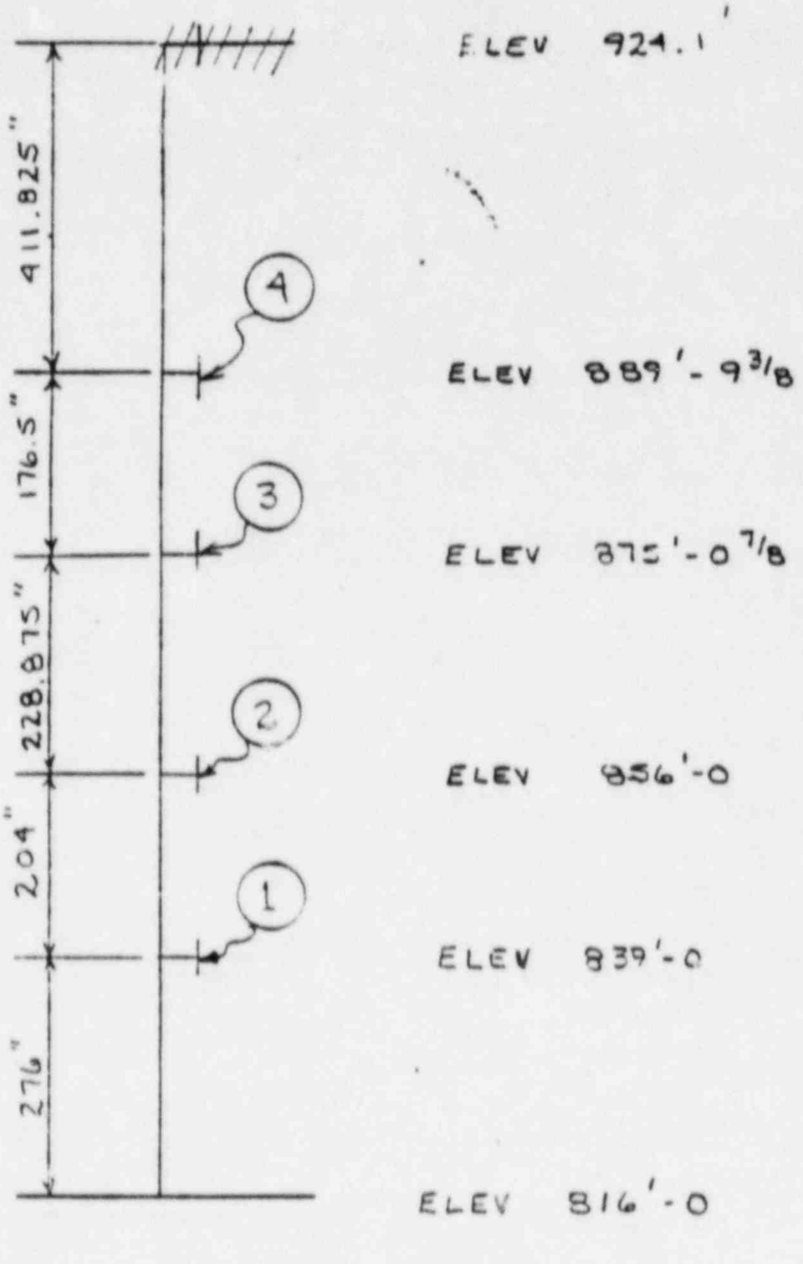
SUBJECT	MADE BY SCB	CHKD BY RAW	REV	By		CHARGE NO. 5-4221
	DATE 6/12/78	DATE 6/78		Chkd		
				Date		SHT____ OF ____

GO 64 REV 4-73

CBI

Location ____________________

PROGRAM 655 MODEL 2



1-16

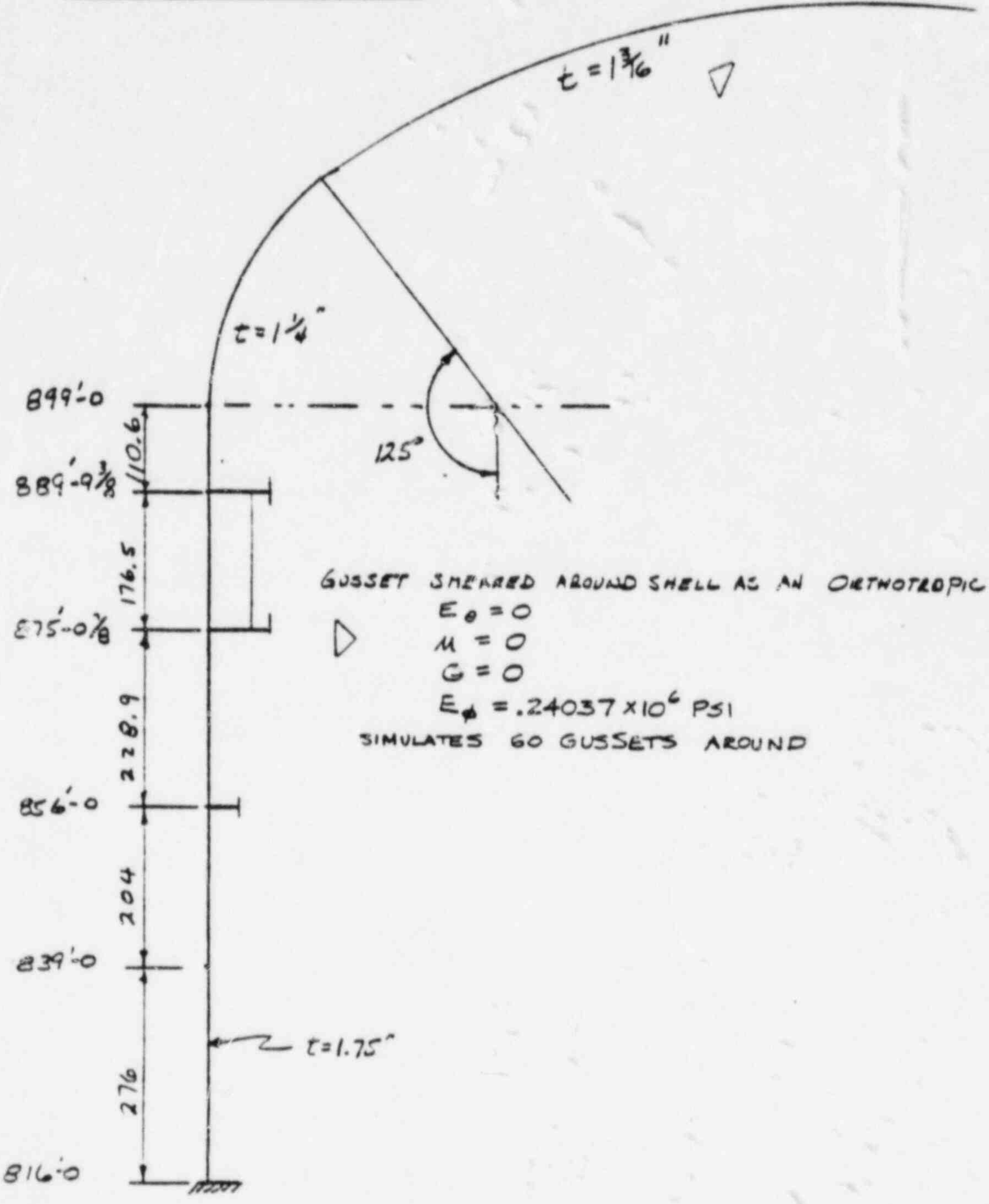
SUBJECT	MADE BY SCB	CHKD BY RAW	REV	By		CHARGE NO. 5-4371
				Chkd		
	DATE 6-15-76	DATE 6-78		Date		SHT ____ OF ____

GO 64 REV 4-73

CBI

Location________________________

PROGRAM 781 MODEL



GUSSET SMEARED AROUND SHELL AS AN ORTHOTROPIC LAYER

▷ $E_\theta = 0$

$\mu = 0$

$G = 0$

$E_\phi = .24037 \times 10^6$ PSI

SIMULATES 60 GUSSETS AROUND

1-17

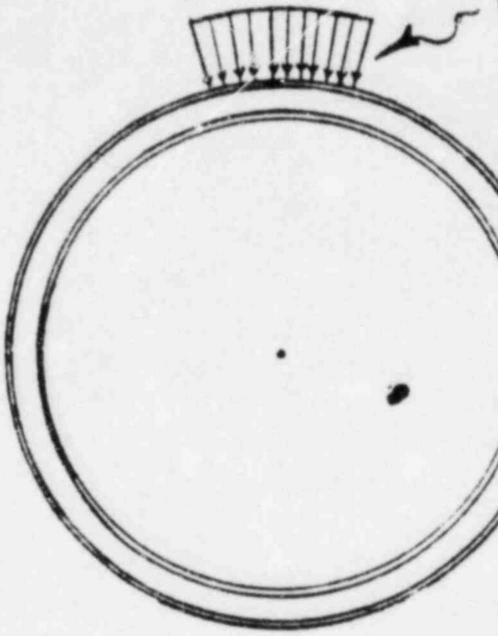
SUBJECT	MADE BY RAW	CHKD BY SCB	REV 1	By	DAM	CHARGE NO. S-4331
	DATE 10/78	DATE 3/79		Chkd	RAW	
				Date	9/79	SHT____ OF____

GO 64 REV 4-73

CBI

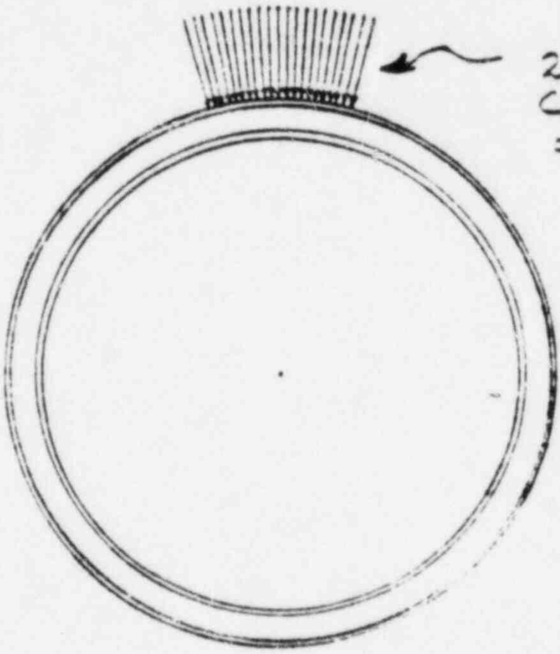
Location__________________________

781 MODEL LOADING



UNIFORM
LOAD DISTRIBUTED
OVER 30°

655 MODEL LOADING



21 EQUAL
CONCENTRATED LOADS
OVER 30°

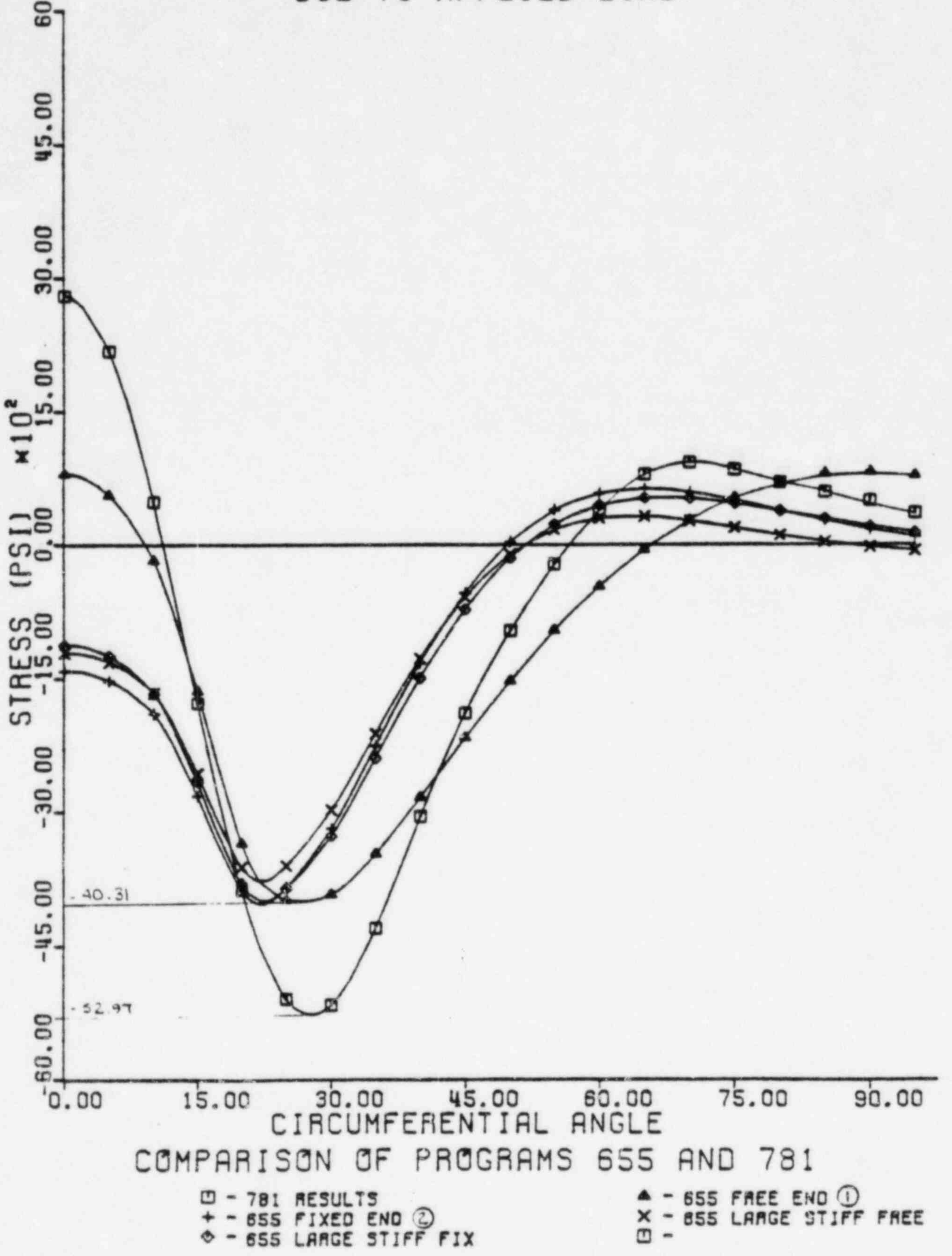
1-18

SUBJECT	MADE BY SCB	CHKD BY RAW	REV	By		CHARGE NO. 5-433
	DATE 6-9-78	DATE 6/78		Chkd		
				Date		SHT_____ OF_____

GO 64 REV 4-73

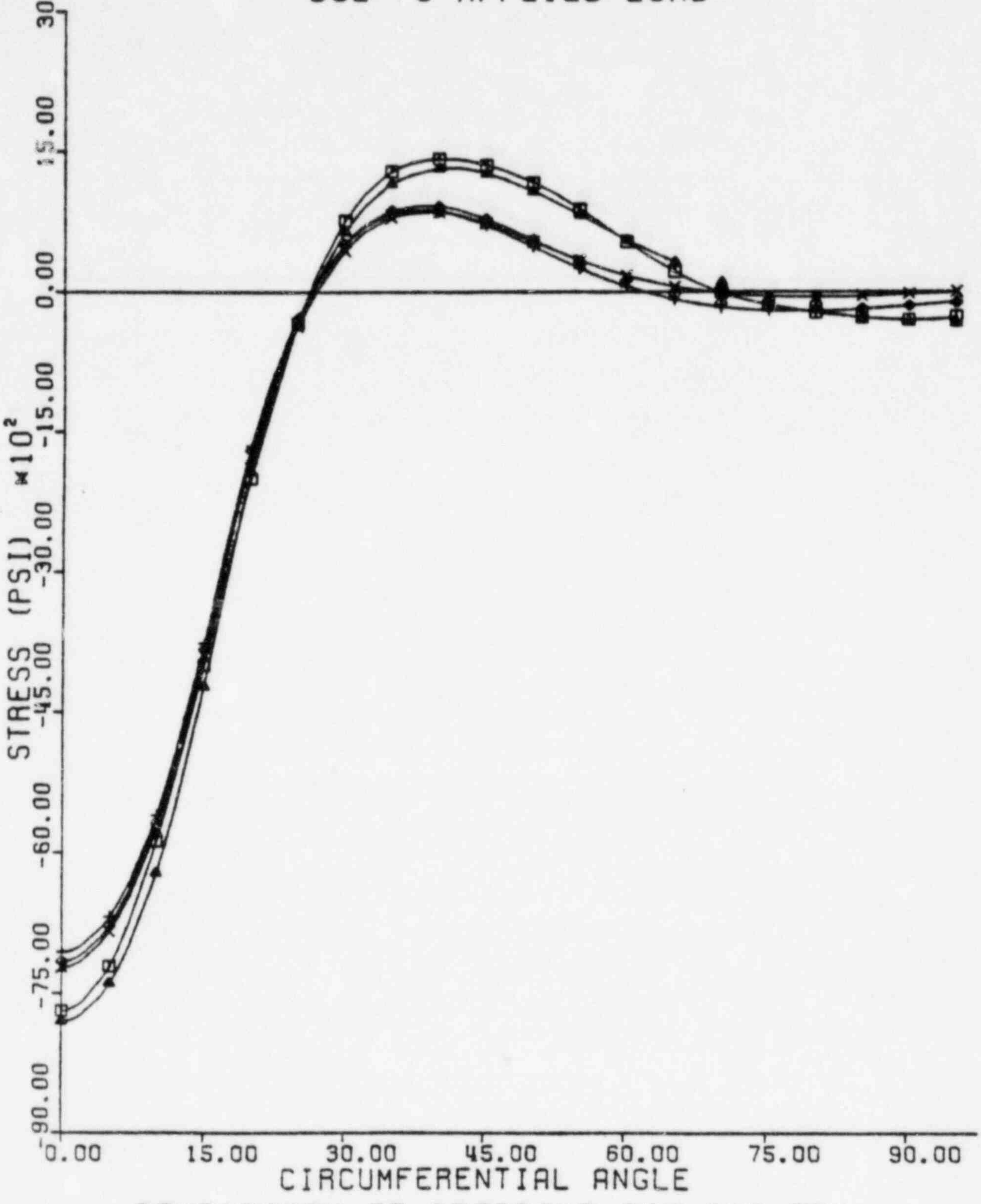
CRBRP Containment Vessel	DATE 9 - 9	DATE 10/78	CHKD DATE	2.79	SHT

5-4331 INSIDE RADIAL STRESSES DUE TO APPLIED LOAD



COMPARISON OF PROGRAMS 655 AND 781

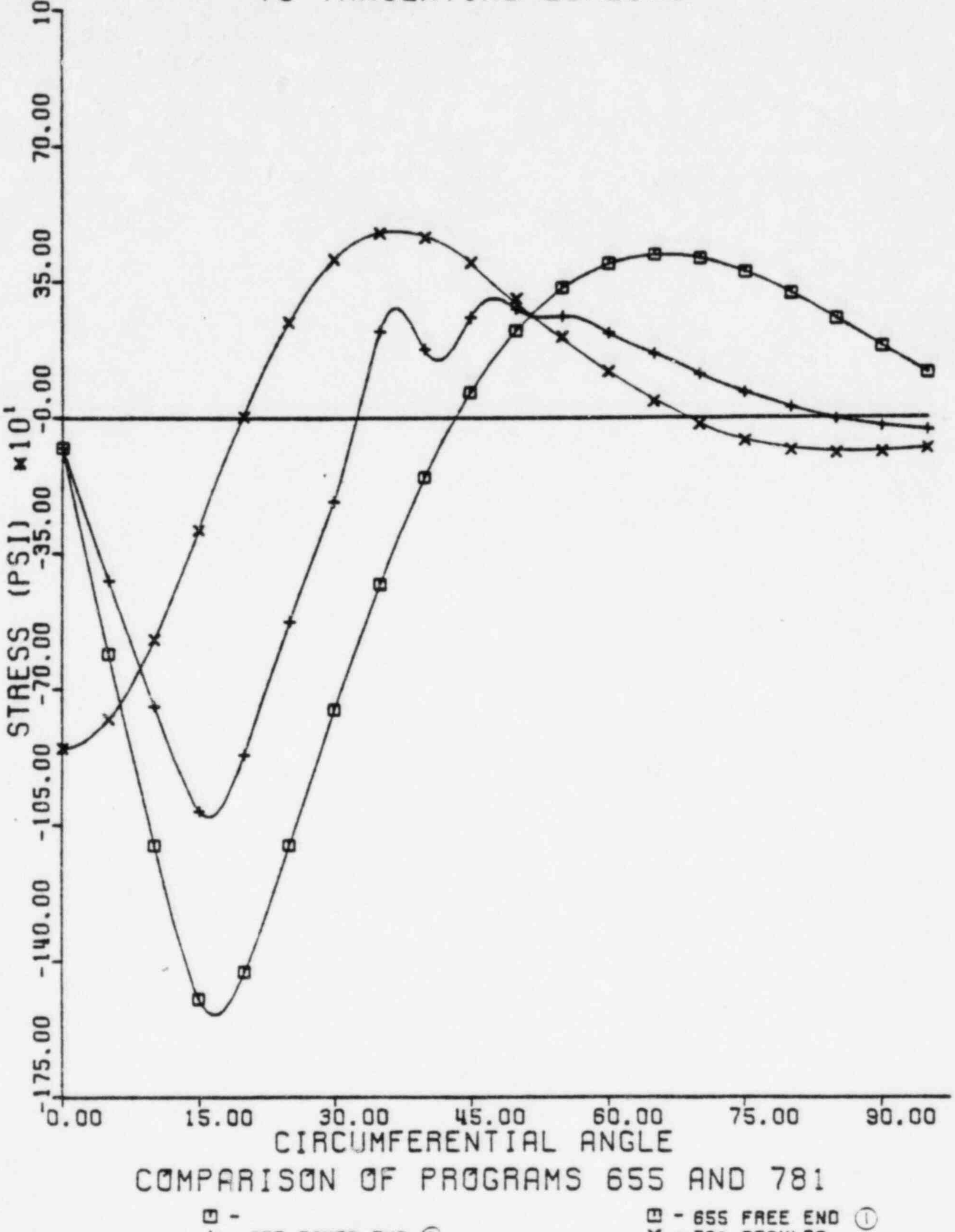
5-4331 OUTSIDE RADIAL STRESSES
DUE TO APPLIED LOAD



COMPARISON OF PROGRAMS 655 AND 781

⊡ - 781 RESULTS
+ - 655 FIXED END ②
◇ - 655 LARGE STIFF FIX
▲ - 655 FREE END ①
✕ - 655 LARGE STIFF FREE
⊡ -

5-4331 INSIDE STRESSES DUE TO TANGENTIAL LOADING

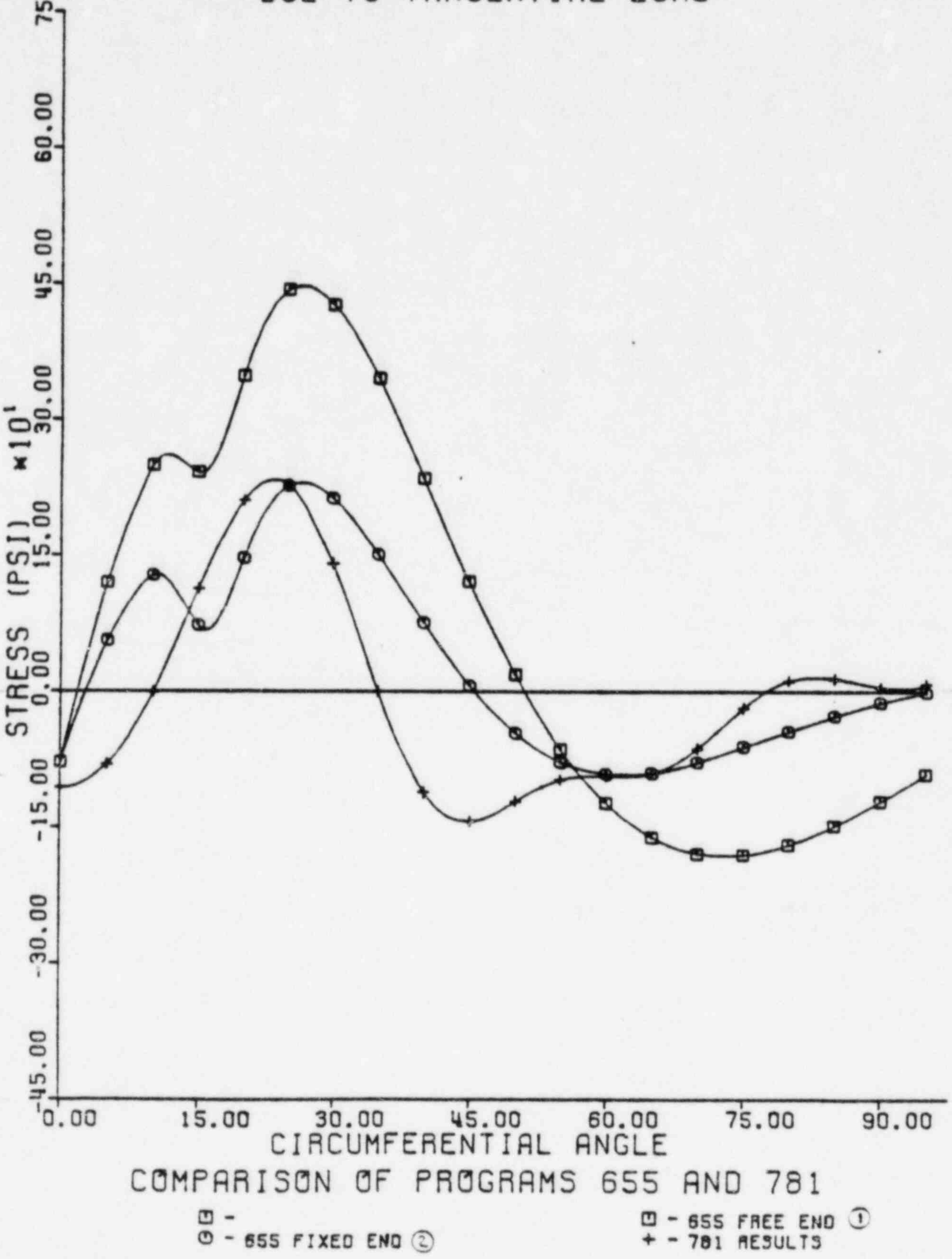


COMPARISON OF PROGRAMS 655 AND 781

⊡ -
\+ - 655 FIXED END ②
⊡ - 655 FREE END ①
× - 781 RESULTS

CRBRP Containment Vessel	DATE	10/78	CHKD		5-4331
			DATE		SHT OF

5-4331 OUTSIDE STRESSES DUE TO TANGENTIAL LOAD



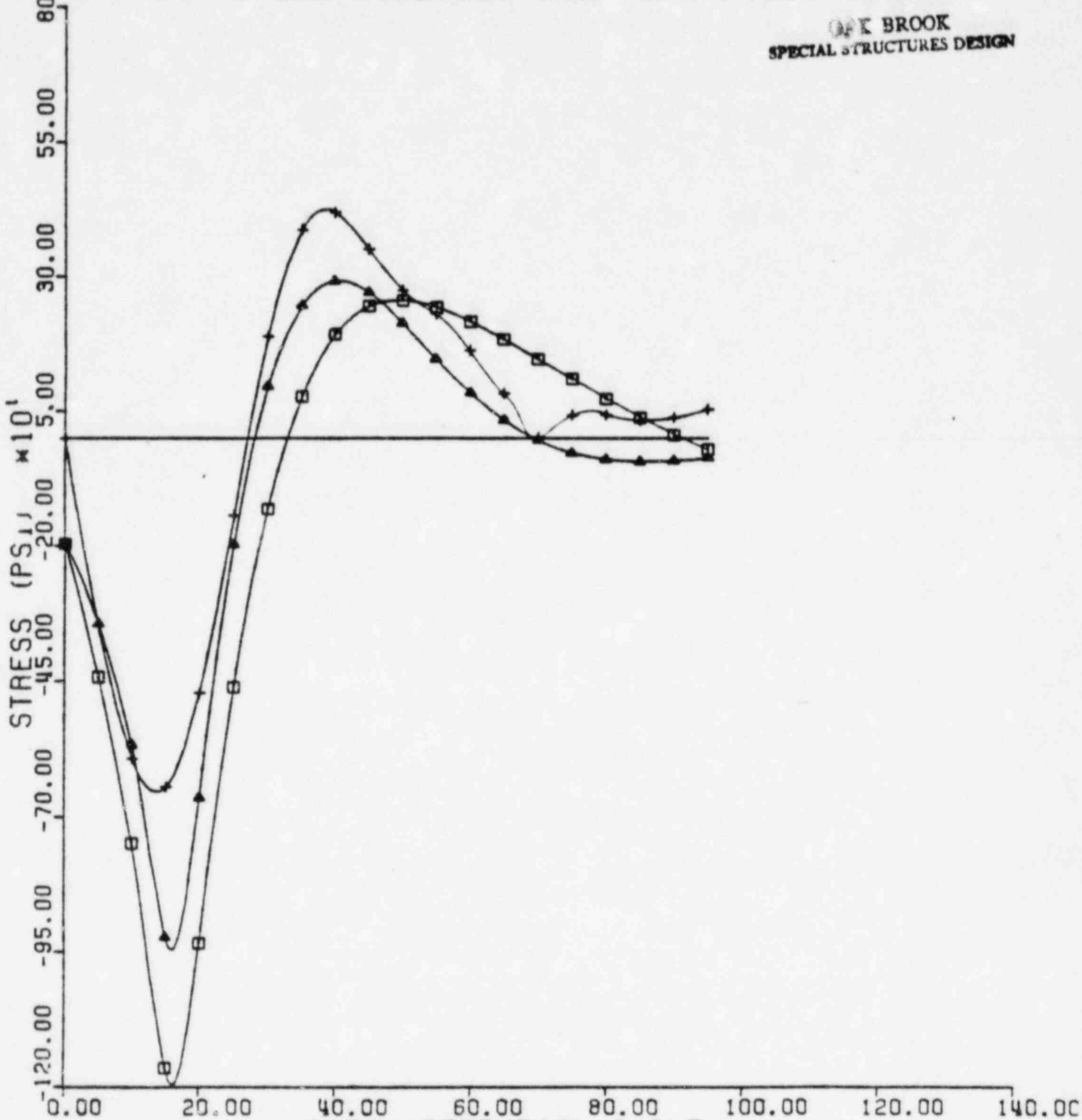
SUBJECT	MADE BY	CHKD BY	REV			5-4331
CRBRP Containment Vessel	DATE 5/79	KAW DATE 10/78	1	BY	CAW	
				CHKD	KAW	
				DATE	5/79	SHT OF

~~AR-4.05~~

▽ 5-4331

RADIAL SHEAR STRESSES DUE TO APPLIED LOAD

OAK BROOK
SPECIAL STRUCTURES DESIGN



COMPARISON OF PROGRAMS 655 AND 781

⊡ -
▲ - 655 FIXED END ℄
⊡ - 655 FREE END ○
+ - 781

EW SSE SEISMIC LOAD W/TROLLEY @ MIDSPAN

MAXIMUM 4TH RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	-434	-809	940	366
PROGRAM 655 USING 9 HARMONICS	-467	-821	879	354
PROGRAM 655 USING 10 HARMONICS	-476	-826	865	352

MAXIMUM 3RD RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	-136	-549	-914	426
PROGRAM 655 USING 9 HARMONICS	-172	-561	-742	414
PROGRAM 655 USING 10 HARMONICS	-185	-567	-724	411

1-24

SUBJECT	MADE BY SCB	CHKD BY RAW	REV	By		CHARGE NO 5-4331
				Chkd		
	DATE 6-7-78	DATE 10/78		Date		~~[illegible]~~ SHT _____ OF _____

CBI

Location

175 TON STATIC LOAD W/TROLLEY @ QUARTER SPAN

MAXIMUM 4TH RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	-1474	-1340	-1797	-247
PROGRAM 655 USING 8 HARMONICS	-1497	-1347	-1841	-251
PROGRAM 655 USING 10 HARMONICS	-1496	-1346	-1840	-251

MAXIMUM 3RD RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	1384	1485	1354	286
PROGRAM 655 USING 8 HARMONICS	1405	1492	1397	285
PROGRAM 655 USING 10 HARMONICS	1404	1492	1395	285

SUBJECT	MADE BY SCB	CHKD BY RAW	REV	By		CHARGE NO. S-4331
	DATE 6-7-78	DATE 10/78		Chkd		
				Date		SHT ____ OF ____

GO 64 REV 4-73

Location ____________________

300 TON STATIC LOAD W/TROLLEY @ MIDSPAN

MAXIMUM 4TH RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	-1075	-1289	-858	-181
PROGRAM 655 USING 10 HARMONICS	-1085	-1293	-878	-182

MAXIMUM 3RD RING STRESSES (PSI)

	DIRECT STRESS	OUTSIDE STRESS	INSIDE STRESS	SHEAR STRESS
PROGRAM 655 USING 6 HARMONICS	1167	1263	1126	254
PROGRAM 655 USING 10 HARMONICS	1180	1267	1151	251

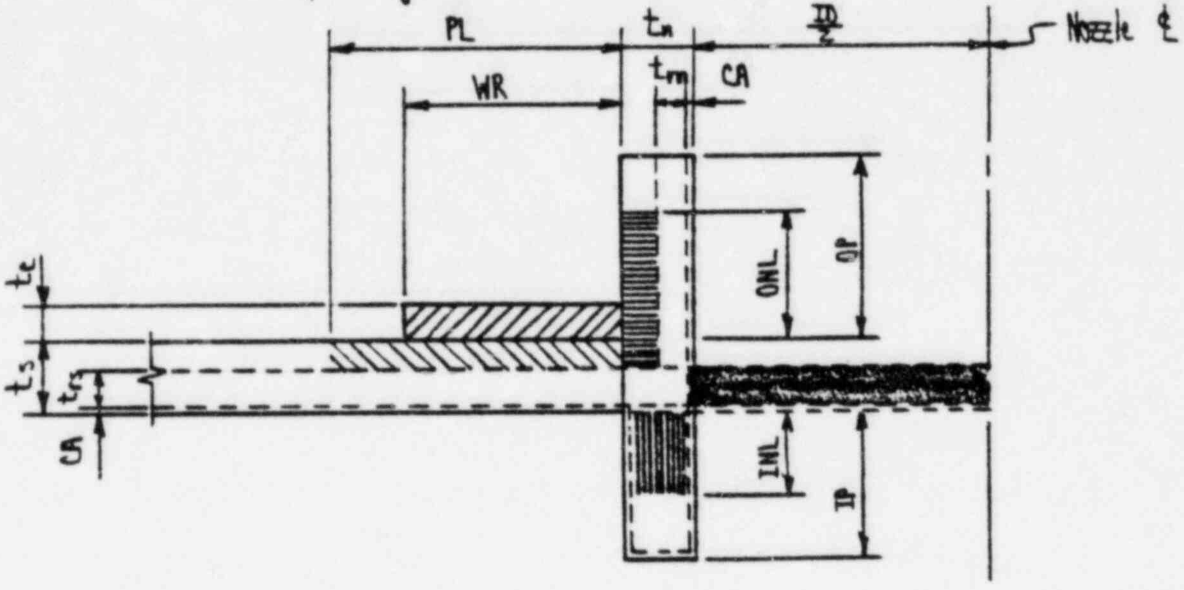
SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
	SCB	RAW		Chkd		5-4331
	DATE	DATE		Date		~~[illegible]~~
	6-5-78	10/78				SHT ____ OF ____

Location

CBI Program T72

This program calculates the nozzle reinforcing area available in shell, reinforcement, and nozzle wall and compares it to the area required by ASME Section VIII and/or Section III. Nozzle may have pressure or vacuum application.

Formulas and geometry used are as follow:



ID = inside nozzle diameter
CA = corrosion allowance
t_{rs} = reqd shell thk
t_s = shell thk
t_e = pad pl thk
t_n = nozzle thk
SL = shell limit, if full value of PL can be used, then SL = 0.
t_{rn} = reqd nozzle thk

R_{ms} = ℄ shell radius
R_{mn} = ℄ nozzle radius = $\frac{ID}{2} + CA + \frac{t_n - CA}{2}$
OP = outside projection
IP = inside projection
WR = width of reinforcing
n/s = ratio of allowable nozz. stress to allow. shell stress
r/s = ratio of allowable reinf. stress to allow. shell stress

Author: J S Vasilion
Dated Version: 7/78
Limitations: none

SUBJECT Computer Program Verification	MADE BY GLN	CHKD BY RAH	REV	By	CHARGE NO. 54331
	DATE 11/15/82	DATE 11/82		Chkd	
				Date	SHT 2-1 OF

CBI

Location

100% Area Reqd = $\left(\frac{ID}{2} + CA\right) t_{rs}$

PL = parallel limit = maximum of :

$\left(\frac{ID}{2} + CA\right) - t_n + CA$

or $\left(t_s + t_n - 2CA\right) - t_n + CA$

Area available in shell = $PL\left(t_s - t_{rs} - CA\right)$

Area available in reinforcing = $WR\left(t_e\right)\left({}^{r}/_{s}\right)$, if $WR < PL$ otherwise use PL

INL = inside normal limit = $2.5\left(t_n - CA\right)$

Area available in inside projection = $INL\left(t_n - 2CA\right)\left({}^{n}/_{s}\right)$

ONL = outside normal limit = minimum of :

$2.5\left(t_s - CA\right)$

or $2.5\left(t_n - CA\right) + t_e$

Area available in nozzle neck = $\left(ONL + t_s - t_{rs} - CA\right)\left(t_n - t_{rn} - CA\right)\left({}^{n}/_{s}\right)$

Area available in weld metal = 0 , for full fusion nozzle neck - to - shell weld

Total area available = sum of individual area availables

SUBJECT	Computer Program Verification	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
		DATE 11/15/82	DATE 11/82		Chkd		SHT 2-2 OF
					Date		

$2/3$ Area Reqd = $2/3$ (100% Area Reqd)

PL = parallel limit = minimum of :

$$0.5\sqrt{R_{ms}(t_s - CA)} - t_n + CA$$

or $\left(\frac{ID}{2} + CA\right) - t_n + CA$

Area available in shell = $PL\,(t_s - t_{rs} - CA)$

Area available in reinforcing = $WR(t_e)(r/s)$, if $WR < PL$ otherwise use PL

Area available in inside projection = same as 100% Area Reqd

t_{es} = minimum of :

$$t_e$$

or $1.5(t_s - CA)$

ONL = outside normal limit = maximum of :

$$0.5\sqrt{R_{mn}(t_n - CA)} + t_{es}$$

or $2.5(t_n - CA) + t_{es}$

Area available in nozzle neck = $(ONL + t_s - t_{rs} - CA)(t_n - t_{rn} - CA)(n/s)$

Area available in weld metal = same as 100% Area Reqd

Total area available = sum of individual area availables

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/15/82	DATE 11/82		Chkd Date		SHT 2-3 OF

Sample Problem:

$ID = 10.02''$
$CA = 0.125''$
$t_{rs} = 0.438''$
$t_s = 1.0''$
$t_e = 0.5''$
$t_n = 0.365''$
$SL = 0$
$t_m = 0.240''$

$R_{ms} = 100''$
$OP = 10''$
$IP = 5''$
$WR = 8''$
$n/s = 0.86$
$r/s = 1.0$

Calculate Rmn, 100% Area Reqd, 2/3 Area Reqd, and areas available and compare with computer values.

$R_{mn} = \frac{10.02}{2} + 0.125 + \frac{0.365-0.125}{2} = 5.255''$ vs computer's $5.255''$ ✓

100% Area Reqd $= \left(\frac{10.02}{2} + 0.125\right)(0.438) = 2.249\ in^2$ vs computer's $2.25\ in^2$ ✓

PL = maximum of:
$\left(\frac{10.02}{2} + 0.125\right) - 0.365 + 0.125 = 4.895''$ ←
or
$[1.0 + 0.365 - 2(0.125)] - 0.365 + 0.125 = 0.875''$

Area available on shell $= 4.895(1.0 - 0.438 - 0.125) = 2.139\ in^2$ vs computer's $2.14\ in^2$ ✓

Area available in reinforcing $= 4.895(0.5)(1.0) = 2.448\ in^2$ vs computer's $2.45\ in^2$ ✓

INL $= 2.5(0.365 - 0.125) = 0.6''$

Area available in inside projection $= 0.6[0.365 - 2(0.125)](0.86) = 0.059\ in^2$ vs computer's $0.06\ in^2$ ✓

ONL = minimum of:
$2.5(1.0 - 0.125) = 2.188''$
or
$2.5(0.365 - 0.125) + 0.5 = 1.100''$ ←

Area available in nozzle neck $= (1.100 + 1.0 - 0.438 - 0.125)(0.365 - 0.240 - 0.125)(0.86) = 0$ vs computer's 0 ✓

Area available in weld metal $= 0$ vs computer's 0 ✓

Total Area Available $= 2.139 + 2.448 + 0.059 + 0 + 0 = 4.646\ in^2$ vs computer's $4.65\ in^2$ ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54351
Verification	DATE 11/15/82	DATE 11/82		Chkd		SHT 2-4 OF
				Date		

$2/3$ Area Reqd = $2/3(2.249) = 1.499\ in^2$ vs computer's $1.50\ in^2$ ✓

P_L = minimum of:

$0.5\sqrt{100(1.0-0.125)} - 0.365 + 0.125 = 4.437"$ ←

or

$(\frac{10.02}{2} + 0.125) - 0.365 + 0.125 = 4.895"$

Area available in shell = $4.437(1.0 - 0.438 - 0.125) = 1.939\ in^2$ vs computer's $1.94\ in^2$ ✓

Area available in reinforcing = $4.437(0.5)(1.0) = 2.219\ in^2$ vs computer's $2.22\ in^2$ ✓

Area available in inside projection = $0.059\ in^2$ vs computer's $0.06\ in^2$ ✓

t_{es} = minimum of;

$0.5"$ ←

or

$1.5(1.0 - 0.125) = 1.313"$

ONL = maximum of:

$0.5\sqrt{5.255(0.365 - 0.125)} + 0.5 = 1.062"$

or

$2.5(0.365 - 0.125) + 0.5 = 1.100"$ ←

Area available in nozzle neck = $(1.100 + 1.0 - 0.438 - 0.125)(0.365 - .240 - .125)(0.86)$
= 0 vs computer's 0 ✓

Area available in weld metal = 0 vs computer's 0 ✓

Total Area Available = $1.939 + 2.219 + 0.059 + 0 + 0 = 4.217\ in^2$ vs computer's $4.22\ in^2$ ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/15/82	DATE 11/82		Chkd		
				Date		SHT 2-5 OF

```
PROG E0772A: NOZZLE REINFG & WELD CHECK, REV 5/78

NOZZLE REINFORCEMENT PER ASME SECT. III-NE
PAD TYPE

          REINFORCED FOR PRESSURE

INSIDE     CORR       SHELL THK    NOMINAL      PAD       NOMINAL    SHELL
NOZ DIA    ALLOW       REQ'D      SHELL THK    PL THK     NOZ THK    LIMIT
 10.02     0.1250      0.4380      1.0000      0.5200     0.3650     2.0

RECD NOZ     RAD MIDDLE      RAD MIDDLE     OUTSIDE     INSIDE     WIDTH
  THK        LINE SHELL       LINE NOZ       PROJ        PROJ      REINF
 0.2400       100.0000         5.2550       10.0000     5.0000     8.0000

2/3 AREA REQ'D =  1.50                       AREA REQ'D =  2.25

AREA AVAILABLE IN                            AREA AVAILABLE IN

SHELL       =  1.94                          SHELL       =  2.14

REINF.      =  2.22                          REINF.      =  2.45

INS.PROJ    =  0.06                          INS.PROJ    =  0.06

NOZZ.NECK   =  0.0                           NOZZ.NECK   =  0.0

WELD METAL  =  0.0                           WELD METAL  =  0.0

      TOTAL =  4.22                              TOTAL   =  4.65


NOTE: AREA REQ'D & AREA FURNISHED ARE BASED ON HALF SECTION OF NOZZLE
      SHELL JUNCTION

      RATIOS: (NOZZLE STRESS/SHELL STRESS) = 0.86
       (REINFORCEMENT STRESS/SHELL STRESS) = 1.00

      NOZZLE-NECK-TO-SHELL-WELD IS FULL FUSION




CHICAGO BRIDGE & IRON CO.

NOZZLE REINFORCING AREA CHECK, CONTRACT 00054331
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2-6

CBI Program 781

This program calculates the stresses and displacements in thin-walled elastic shells of revolution, when subjected to static edge, surface, and/or temperature loads with arbitrary distribution over the surface of the shell. The geometry of the shell must be symmetric but the shape of the meridian is arbitrary. Since this program is based on classical shell theory, it has the same limitations. The shell thickness, physical properties of the materials, and loading may all vary arbitrarily along the meridian. The loading, including temperatures, may vary arbitrarily around the circumference by using Fourier Series. There may be junctions or branches. The shape of the shell may be a cylinder, cone, sphere, torroid, ellipse, or parabola.

Author: J S Endicott
Dated Versions: 8/79, 11/80, 3/82, 6/82
Limitations: same as classical shell theory

8/79 version was approved per CBI QA manual
11/80 version had a title change
3/82 version corrected the program to call a subroutine when
a sine series harmonics was specified
6/82 version enlarge the program

SUBJECT Computer Program	MADE BY GLN	CHKD BY Rnw	REV	By	CHARGE NO. 54331
Verification	DATE 11/16/82	DATE 1/82		Chkd Date	SHT 3-1 OF

3. PROGRAMS E0781A AND E0781S - KALNIN'S SHELL OF REVOLUTION ANALYSIS

3.1 Comparison of 2/1 Ellipsoidal and Torispherical Heads

The structure consists of a torispherical and 2/1 Ellipsoidal head connected with a cylinder. The loading consists of a uniformly distributed pressure acting on the inner surface of the structure. This problem checks the program's ability to generate cylindrical, torisphercal, and ellipsoidal shapes. The results are compared to show the differences, between the hoop force and longitudinal bending in the two heads. These results are then compared with published results.

3.2 Cylindrical Water Tank with Tapered Walls

The problem considered here is a cylindrical water tank with a tapered inner wall. The loading consists of a linear pressure applied to the inside wall. The results are compared with the theoretical solution.

3.3 Circular Hole in Plate

The problem consists of a plate with a circular hole subject to uniform axial tension. This problem illustrates Program E0781S's capability to evaluate a stress distribution generated by a harmonic series. The KALNIN's results are compared to the theoretical solution.

3.4 Inclined Cylinder under Hydrostatic Loading

The problem considered is a inclined cylinder which is fixed at one end and free at the other end. The structure is analyzed for an internal hydrostatic loading. The KALNIN's results are compared with a published shell solution.

SUBJECT	MADE BY TES	CHKD BY	REV 2	BY	TES	CHARGE NO. [redacted]
	DATE 7/76	DATE		CHKD		SHT [redacted] OF
				DATE	12/76	

PROGRAMS E0781A AND E0781S - KALNIN'S SHELL OF REVOLUTION ANALYSIS

~~Anticipated uses of Computer Program~~	~~Reference to section of Structural Evaluation Plan~~
~~1. Check Stresses in the Support Skirt~~	

Feature or Cability (Type Of Analysis) \ Problem	3.1	3.2	3.3	3.4
Pressure Load	X	X		X
Membrane Solution Boundary Cond.	X			X
Fixed Boundary Condition		X		
Free Boundary Condition		X		X
Concentrated Load			X	

SUBJECT	MADE BY TES	CHKD BY	REV 2	BY	TES	CHARGE NO. ~~[illegible]~~
	DATE 7/76	DATE		CHKD		
				DATE	12/76	SHT ~~[illegible]~~ OF

3.1 COMPARISON OF 2/1 ELLIPSOIDAL AND TORISPHERICAL HEADS

Introduction

This problem illustrates Program E0781A's ability to generate cylindical, torispherical, and ellipsoidal shapes.

A comparison is made to an experimental investigation of 2:1 ellipsoidal heads subjected to internal pressure (see reference 3.4).

Problem Definition

The problem consists of comparing a 2/1 ellipsoidal head to an equivalent torispherical head subjected to the same uniformly distributed internal pressure. An equivalent torisphere will be defined as one having the same height above the tangent line as the ellipsoid and a minimal L/b ratio (thus having the least possible discontinuity between the torus and the sphere). For the geometry shown in Fig. 3.1.1:

$$(L-b)\sin \varnothing_o = A-b \quad (1)$$
$$(L-b)\cos \varnothing_o = L-B \quad (2)$$

Minimizing L/b using (1) and (2):

$$\tan \varnothing_o = B/A = 0.5019$$
$$\varnothing_o = 26.653^\circ$$
$$L/A = \frac{c \pm \sqrt{c^2-2c}}{2}$$
$$c = B/A + A/B = 2.494$$
$$L = \frac{18.19}{2}\left[2.5 + \sqrt{6.22-4.99}\right] = 32.778 \text{ inches}$$
$$b = B\left[B/A-L/A\right] + A = 9.13\left[.5019-1.80198\right] + 18.19 = 6.32 \text{ inches}$$

Note: For purpose of calculation

$A = 18.19$ inches
$B = 9.13$ inches
from Fig. 3.1.2

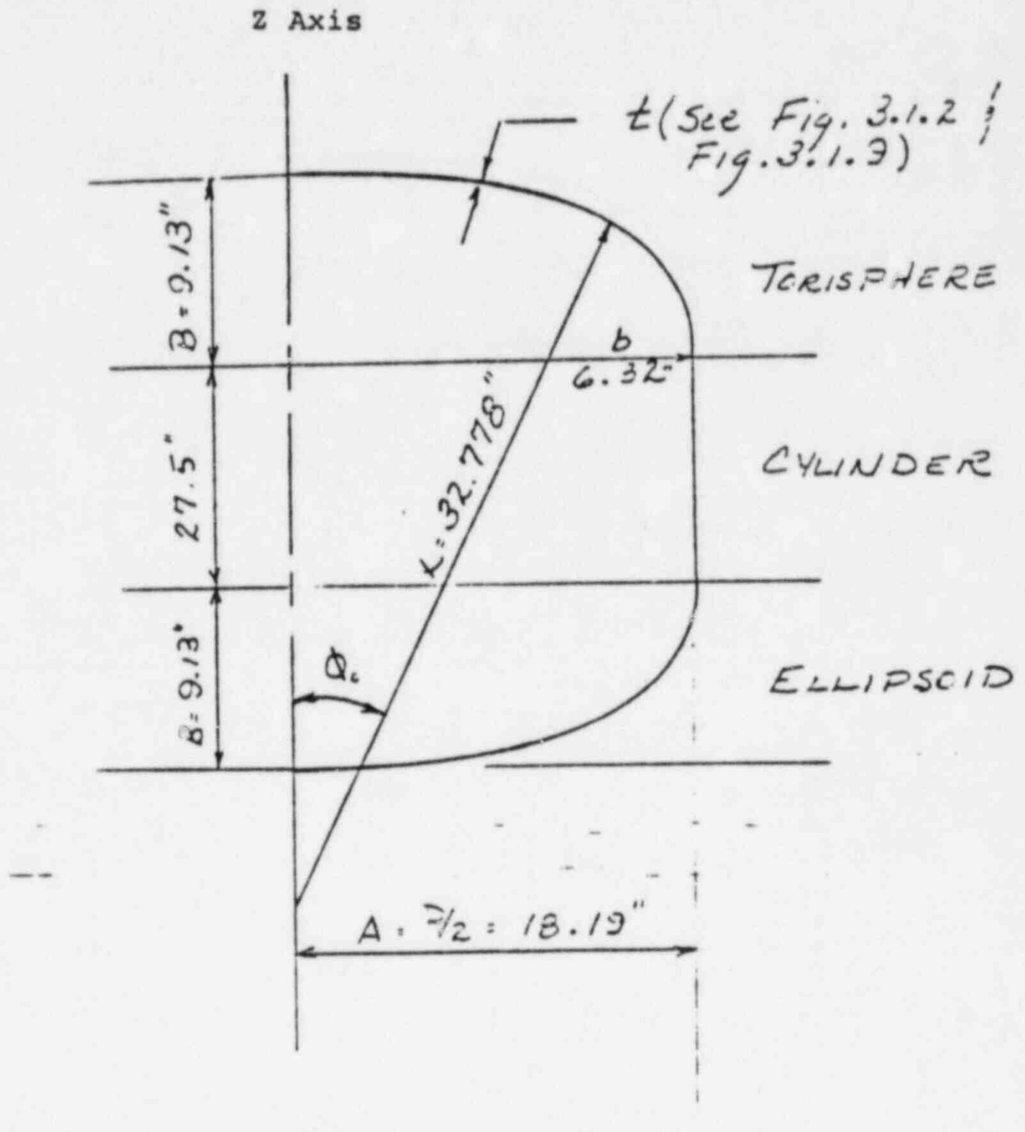


Fig. 3.1.1

GEOMETRY OF TORISPHERICAL AND ELLIPSOIDAL HEADS

(Fit to correspond to geometry of ellipsoidal head in reference 3.1)

SUBJECT E0781A	MADE BY PM	CHKD BY	REV 1	BY	PM	CHARGE NO.
	DATE 6/77	DATE		CHKD		SHT
				DATE		

CHICAGO BRIDGE & IRON COMPANY

Location OB ENG. SERVICES

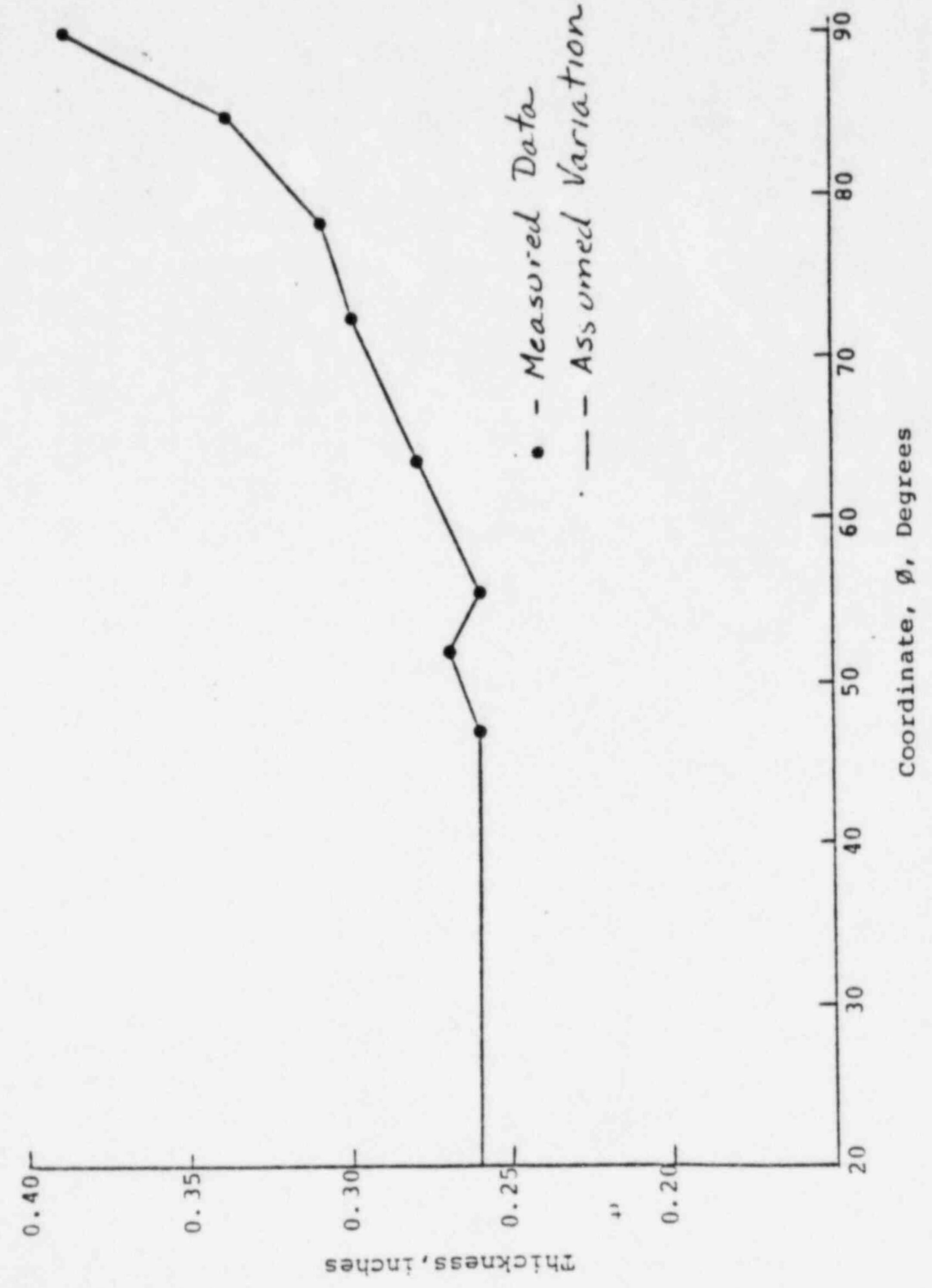


Fig. 3.1.2

Measured Thickness Variation In Experimental Head No.1
(From Ref. 5, Page 18)

3-6

SUBJECT	MADE BY	CHKD BY	REV	BY		CHARGE NO.
	DATE	DATE		CHKD		SHT
				DATE		

GO 787

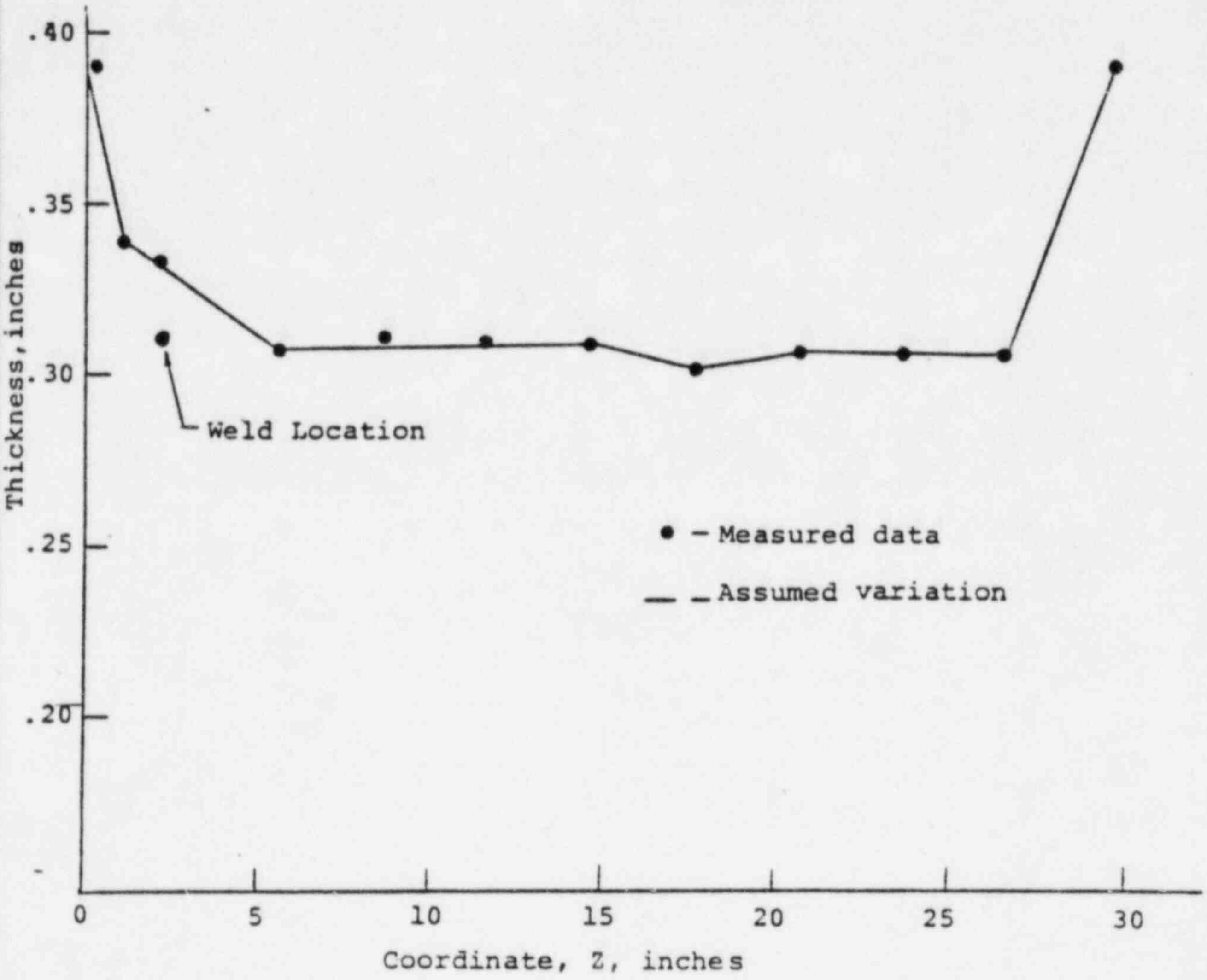


Fig. 3.1.9
Thickness Variation In Cylinder No. 1
(From Ref. 3 - Fig. 4)

Segment lengths used are:

cylinder - $\sqrt{rt} = \sqrt{18.16\ (0.31)} = 2.37$

torisphere

from 5° to 10° - 4 segments @ 1.25°

from 10° to 26.567° - 4 segments @ 4.13°

from 26.567° to 90° - 6 segments @ 10.57°

ellipsoid

from 5° to 10° - 4 segments @ 1.25°

from 10° to 30° - 4 segments @ 5°

from 30° to 90° - 6 segments @ 10°

BOUNDARY CONDITIONS

It will be assumed that at 5° from the pole a membrane state of stress exists in both the ellipsoid and the torisphere:

$$Q = M\phi = 0$$

$$N\phi = \frac{pr}{2\sin\phi}$$

where

r = distance to pole

Q = effective transverse shear in ϕ direction.

$M\phi$ = moment resultant in ϕ direction.

$N\phi$ = membrane force in ϕ direction.

Letting $p = 680$ psi

Then for the torisphere:

$N\phi = (680/2)(32.778) = 11{,}144.5$ lb/in.

If $N\phi = 11{,}144.5$ lb/in., a preliminary run yields $Q = 95.202$ lb/in, so a new value for $N\phi$ for the torisphere was calculated:

$$\Delta N = \frac{\Delta Q}{\tan c}$$

$N\phi = 11{,}144.5 + \Delta N = 10056.3$ lb/in and an appropriate membrane state was generated.

For the ellipsoid

$$r = \frac{A \sin \emptyset}{R}$$

where $R = \sqrt{C_1 + (1 - C_1)\sin^2\phi}$

$$C_1 = (B/A)^2 = 0.2519$$

$$R = \sqrt{.2519 + .7481(0.0871557)^2} = 0.5075 \text{ in.}$$

$$N\phi = \frac{A \sin\phi}{R} \quad \frac{P}{2\sin\phi} = \frac{18.19(680)}{1(0.5075)2} = 12{,}185.78 \text{ lb/in.}$$

To better compare the heads it seemed desirable to have the displacement at the center of the cylinder 0($\mu_\phi = 0$). So the problem was run twice, the first run yielding the W required for 0 displacement at the center (w = 0.0966 inches).

1. Start W = 0.0966" Nϕ = 10,056 lb/in Mϕ = N = 0
2. End Q = N = Mϕ = 0 Nϕ = 12,186 lb/in

Results

To check the results, first the answers at the boundaries should be examined. It was assumed that there was a membrane state of stress at the boundaries and therefore at the edges Q and Mϕ must be approximately 0.

	Q (lb/in)	Mϕ (lb-in/in)
Start	-0.08636	0.0
End	-0.0009252	-0.0001487

Also to satisfy equilibrium in the cylinder, $N\phi \simeq 0.5pr$ = 6169 lb/in.

Plots of the hoop force and longitudinal bending from E0781A results compare the ellipsoidal and torispherical heads. Even though the change in radii has been minimized, the discontinuity at the junction of the sphere and torus is considerable, and has been taken into account.

Comparison to the experimental ellipsoidal head including the discontinuity region shows good correlation of stress values for program 781. See Fig. 3.14 through 3.18 for plots of $\nabla\phi$ and $\nabla\theta$ on the inside,outside, and meridian of the head. Deviations are caused by the changes in thickness and the experimental head's variation from a true 2:1 ellipsoidal head.

CHICAGO BRIDGE & IRON COMPANY

Location OB ENG. SERVICES

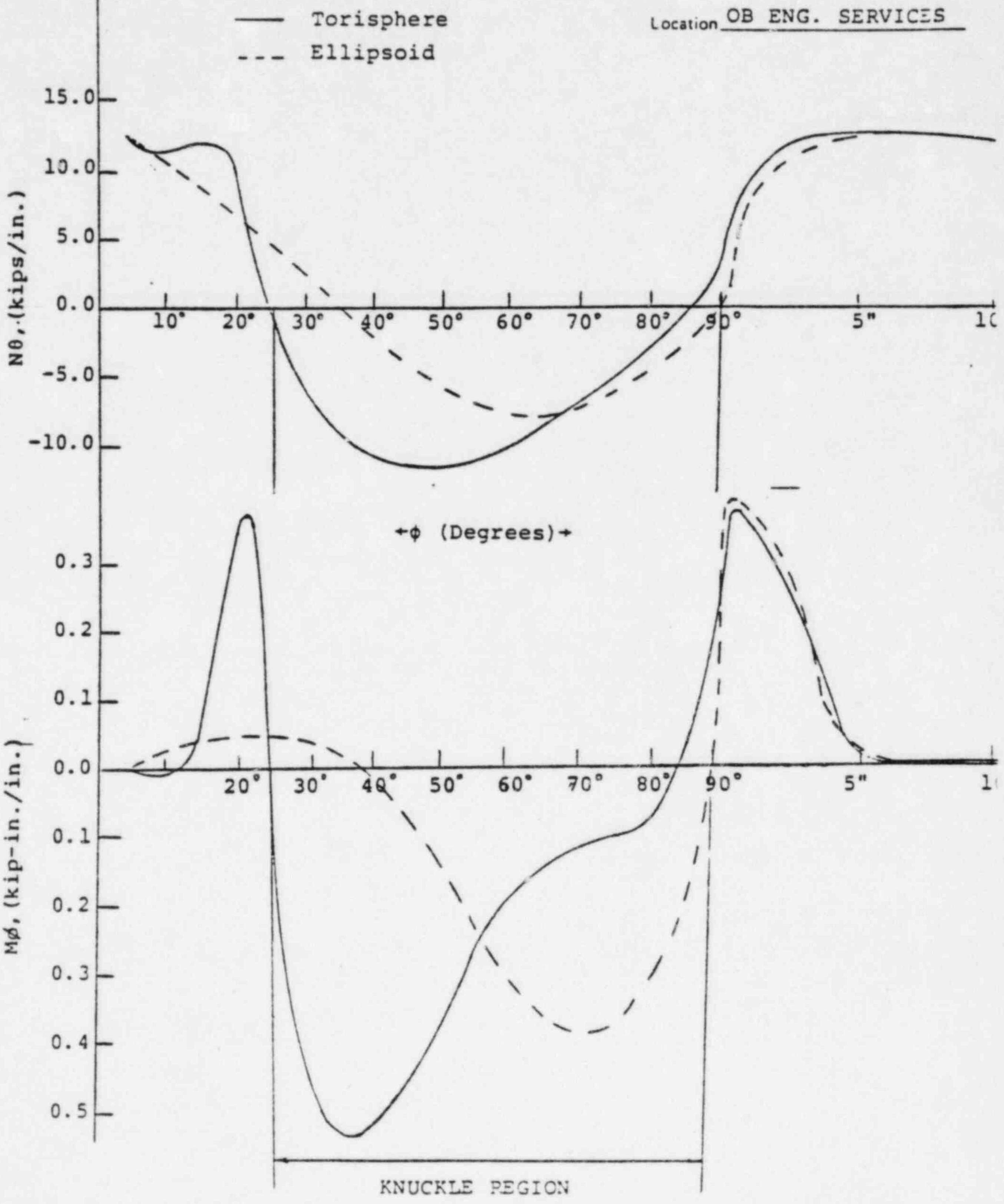


Fig. 3.1.3 Plot Of Nθ And Mφ From E0781A Output

3-11

SUBJECT	MADE BY	CHKD BY	REV	BY		CHARGE NO.
E0781A	PM		1		PM	
	DATE 6/77	DATE		CHKD		
				DATE		SHT ~~[illegible]~~

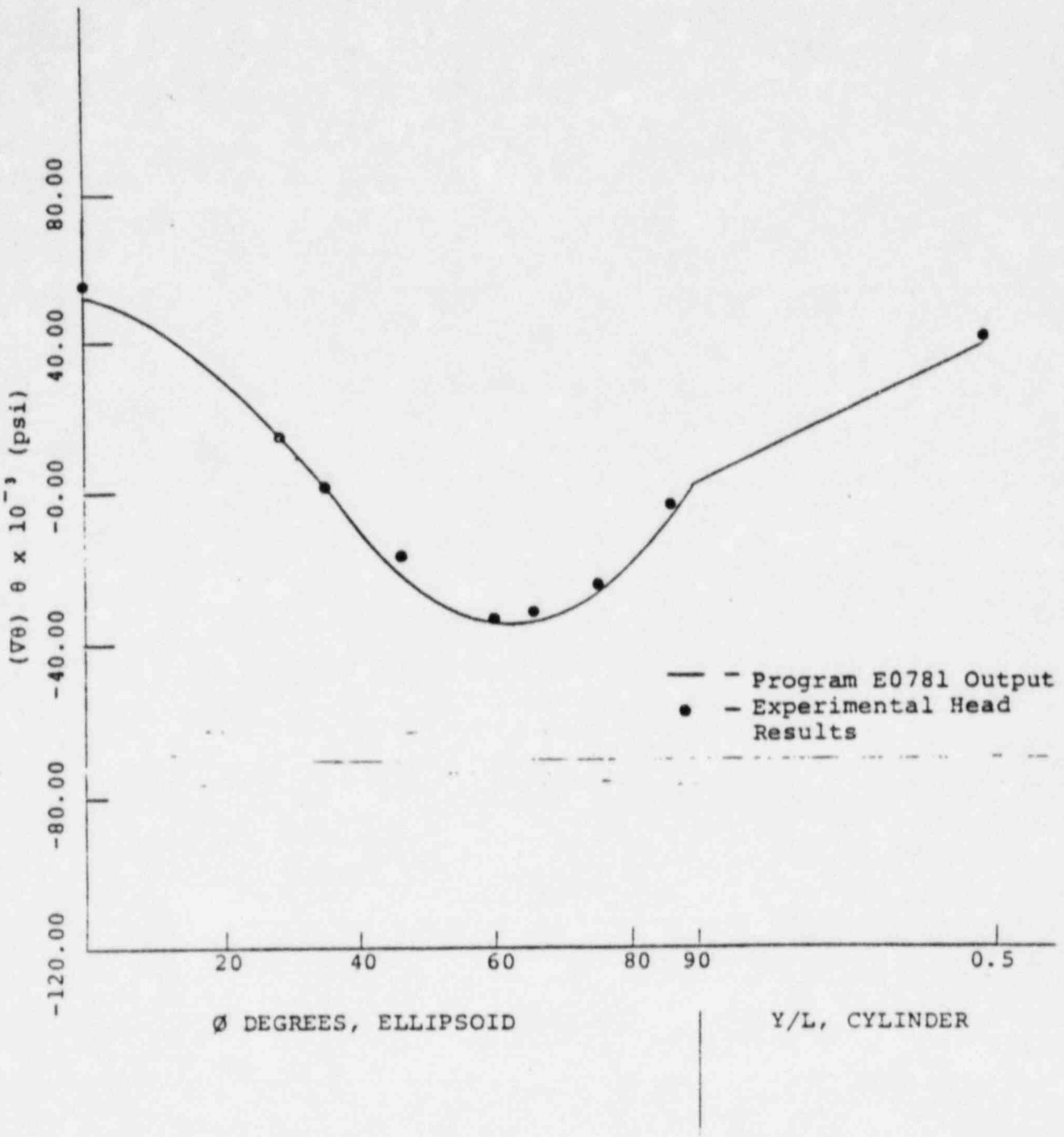


Fig. 3.1.5

Plot of Stress In The θ Direction
On The Outside Surface (θ = 0)
(Ref. 3.6 - page G-11)

SUBJECT	MADE BY	CHKD BY	BY		CHARGE NO.
	DATE	DATE	CHKD		SHT ~~[illegible]~~
			DATE		

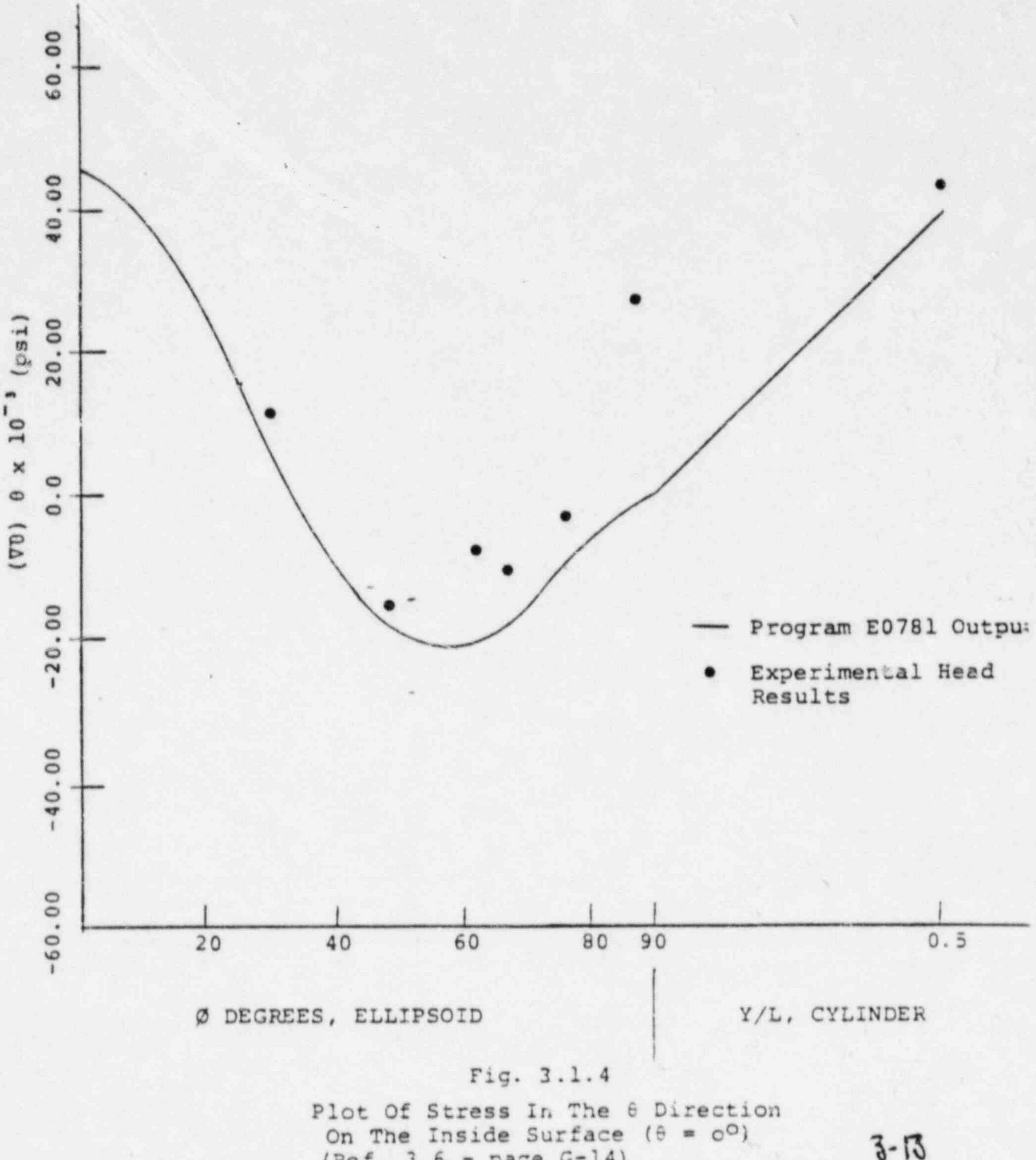


Fig. 3.1.4

Plot Of Stress In The θ Direction
On The Inside Surface (θ = o°)
(Ref. 3.6 - page G-14)

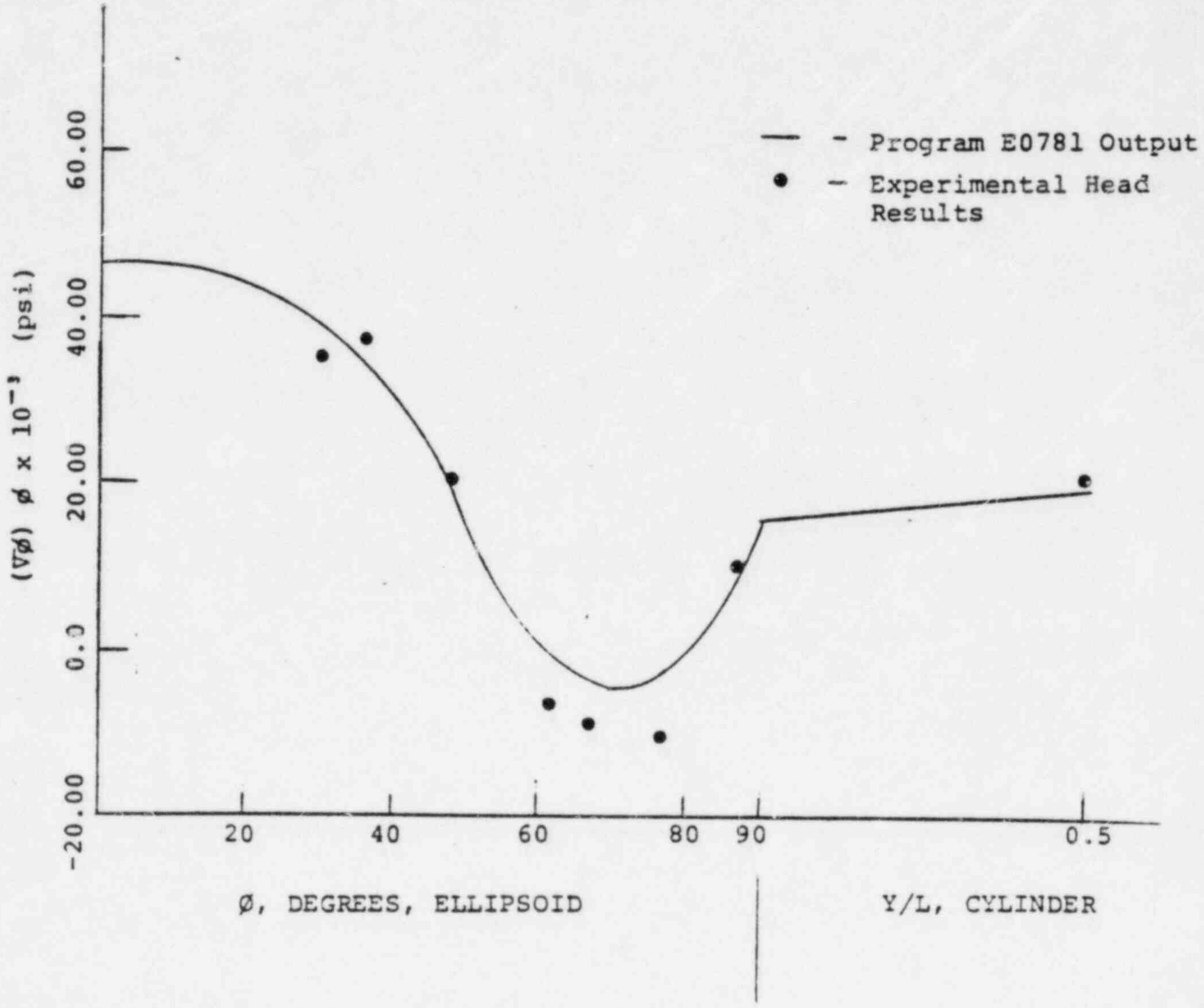


Fig. 3.1.7

Plot of Stress In The Ø Direction
On The Outside Surface (θ = 0°)

(Ref. 3.6 - page G-17)

CHICAGO BRIDGE & IRON COMPANY

Location OB ENG. SERVICES

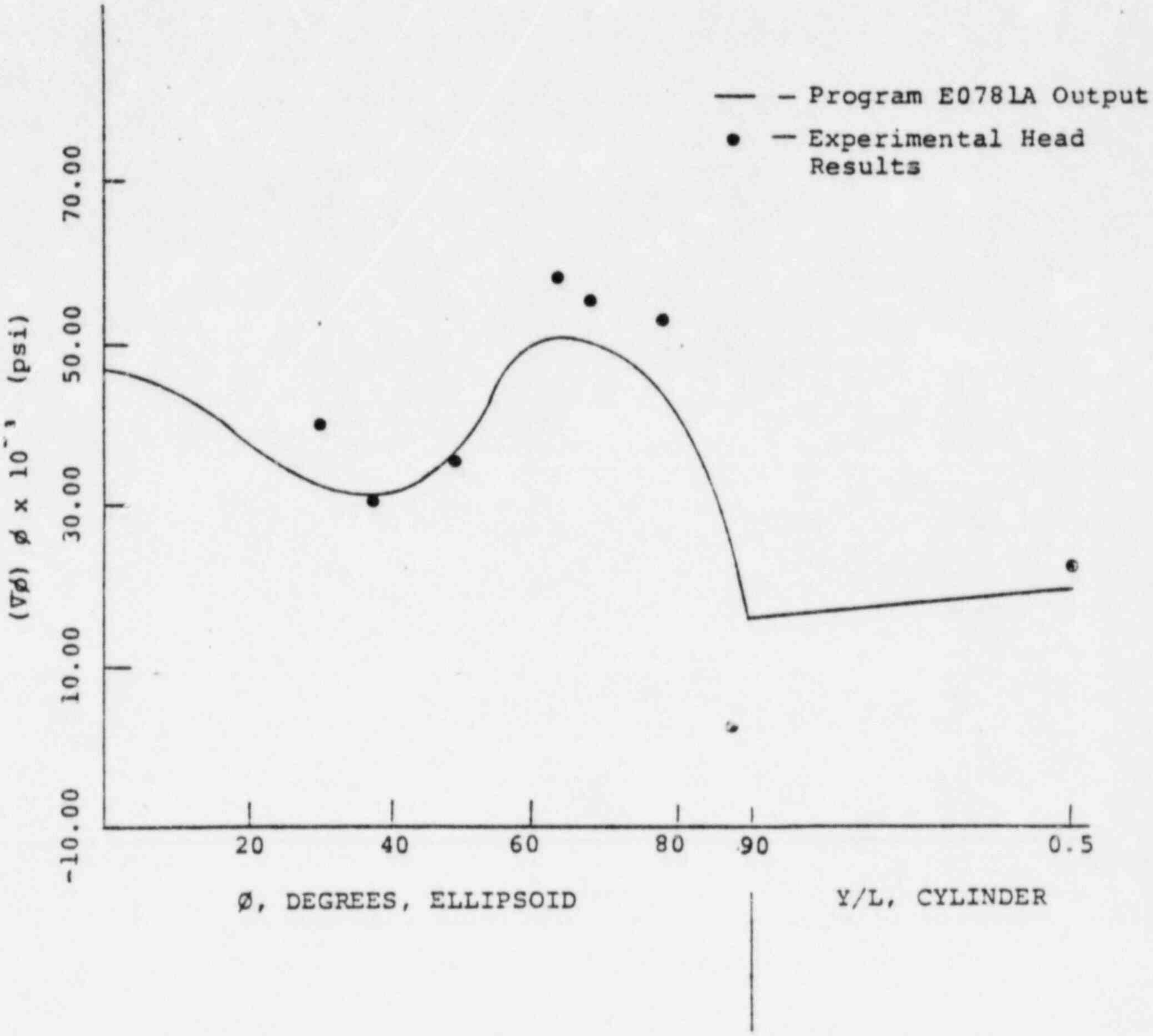


Fig. 3.1.6

Plot of Stress In The Ø Direction
On the Inside Surface (θ = 0°)

(Ref. 3.6 - page G-20)

3-15

SUBJECT	MADE BY	CHKD BY	REV	BY	CHARGE NO.
	DATE	DATE		CHKD	
				DATE	SHT

GO 787

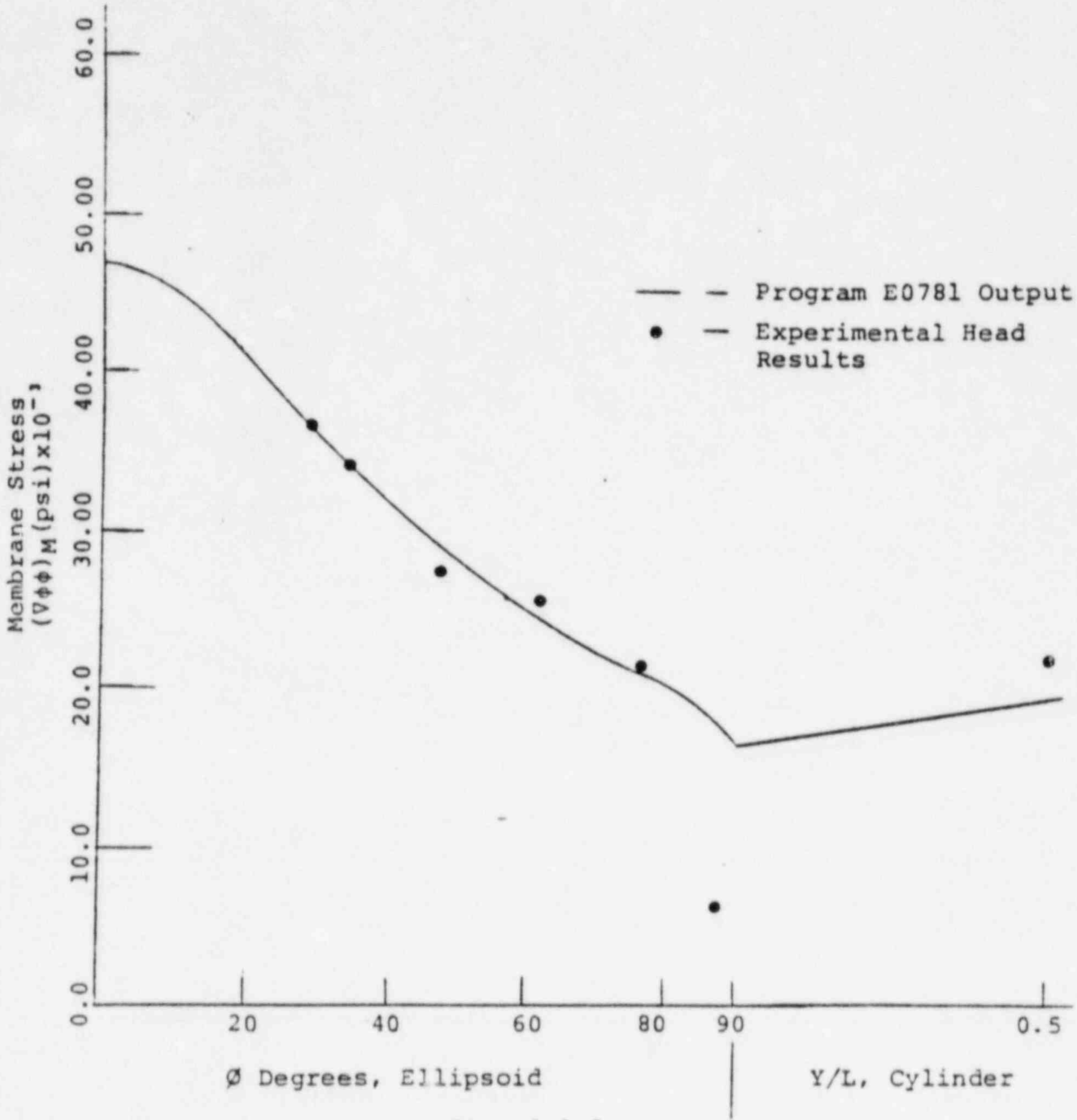


Fig. 3.1.8

Plot Of Membrane Stress ($\theta = 0^{\circ}$)

(Ref. 3.6 - page G-23)

SUBJECT	MADE BY	CHKD BY	REV	BY		CHARGE NO.
	DATE	DATE		CHKD		
				DATE		SHT

3.2 CYLINDRICAL WATER TANK WITH TAPERED WALLS

Introduction

This problem illustrates Program E0781A's capability to analyze a pressure load with one fixed boundary condition and one free boundary condition.

The problem used for this verification is "Shell of Variable Thickness" taken from "Stresses in Shells", by W. Flugge, pp. 289-295 (Reference Number 3.1)

Problem Definition

The problem consists of a tapered shell filled with water. The shell has a radius of 9'-0 and is 12'-0 high. The shell thickness varies from 11" at the bottom to 3" at the top. See Fig. 3.2.1 for location of the Z axis. The length of a segment is 18"($\sqrt{rt}$).

Boundary Conditions

W - displacement normal to surface
$U\phi$ - displacement component in ϕ direction
$\beta\phi$ - rotation of reference surface in ϕ direction
Q - effective transverse shear in ϕ direction
$N\phi$ - membrane force in ϕ direction
$M\phi$ - moment resultant in ϕ direction

1. fixed at start $W = U\phi = \beta\phi = 0$
2. free at end $Q = N\phi = M\phi = 0$

Loading

Taking the weight of water as 62.5 lb/ft³, the pressure at the bottom of the tank is

$$p = \frac{(12\ \text{ft})(62.5\ \text{lb/ft}^3)}{144\ \text{in.}^2/\text{ft}^2} = 5.2083\ \text{psi}$$

The pressure at the top is zero. The pressure varies lineraly so that only two points are needed in the function generator in order to fully describe the function.

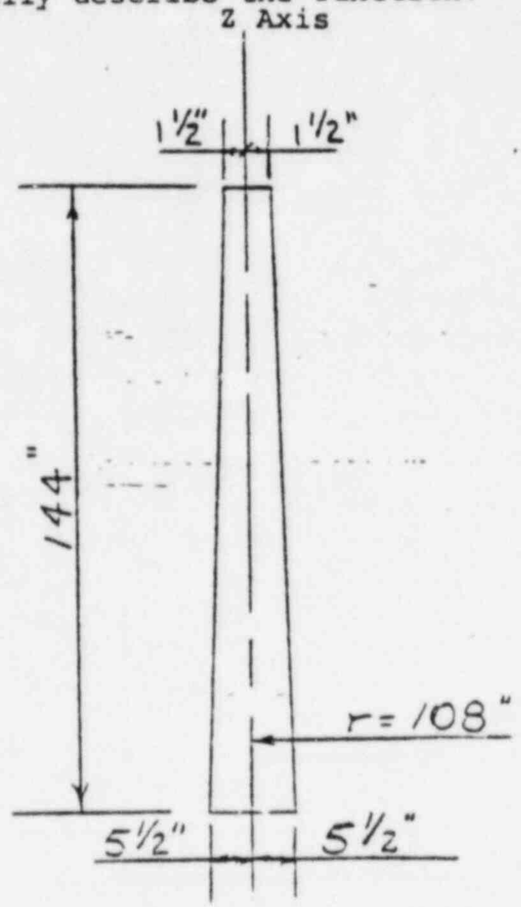


FIG. 3.2.1

SUBJECT E0781A	MADE BY PM	CHKD BY	1	BY	PM	CHARGE NO.
	DATE 6/77	DATE		CHKD		
				DATE		

Results

Program E0781A gives maximum hoop force - $N\theta$ = 346.8 lb/in. located at 54" from the base.

Kalnin's Program	Theoretical Solution "Stresses in Shells"
346.8 lb/in.≈4160 lb/ft	4180 lb/ft

The program gives a 0.48% diviation from the theoretical solution.

Program E0781A gives a maximum moment at the base of

$M\phi$ = -1539 in.-lb/in.

Kalnin's Program	Theoretical Solution "Stresses in Shells"
-1539 in.-lb/in.=-1539 ft-lb/ft	-1470 ft-lb/ft

The program gives a 4.69% deviation from the theoretical solution.

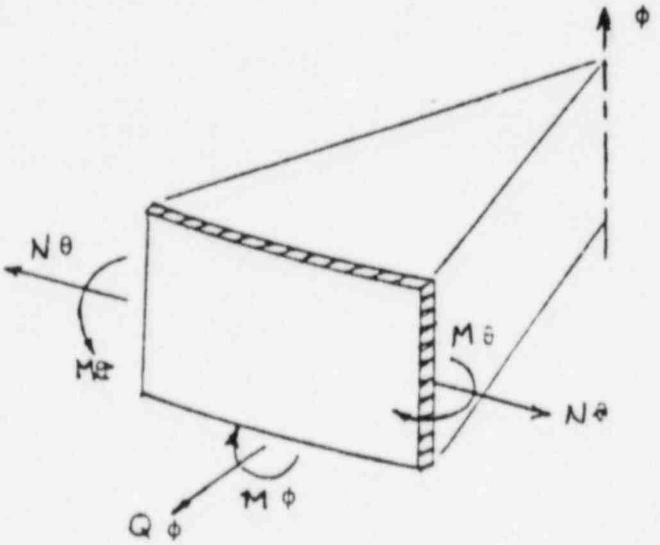


FIG. 3.2.2
Location of ϕ and θ axis

3-19

Program E0781A Results			"Stresses In Shells" Solution At Maximums
Distance From Base (inches)	$N\theta$ lb/in.	$M\phi$ $\frac{\text{in.-lb}}{\text{in.}}$	
0.0	5.919×10^{-6}	→ -1539.0	$M\phi = -1470$ ft-lb/ft
6.0	21.15	-903.9	
12.0	71.29	-440.5	
18.0	134.0	-124.8	
24.0	194.3	71.47	
30.0	253.3	177.1	
36.0	297.2	218.3	
42.0	327.3	217.6	
48.0	343.3	192.8	
54.0	→346.8	157.1	$N\theta = 4160$ lb/ft
60.0	339.6	119.5	
66.0	324.2	85.46	
72.0	303.0	57.80	
78.0	277.9	36.29	
84.0	250.8	23.41	
90.0	222.9	15.00	
96.0	195.1	10.58	
102.0	167.8	8.685	
108.0	141.4	8.075	
114.0	115.9	7.754	
120.0	91.45	7.032	
126.0	68.13	5.584	
132.0	46.29	3.453	
138.0	26.50	1.177	
144.0	9.453	-1.481×10^{-3}	

TABLE 3.2.1

Comparison of Final Results for $N\theta$ and $M\phi$

3.3 CIRCULAR HOLE IN PLATE

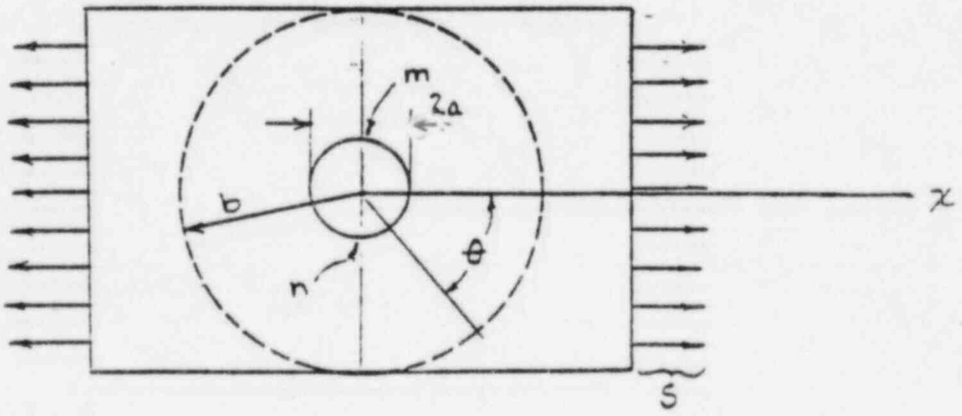
Introduction

This problem illustrates Program E0781S's capability to evaluate a stress distribution generated by a harmonic series.

The problem used for this verification is presented in "The Effect of Circular Holes on Stress Distribution in Plates" taken from "Theory of Elasticity" by Timoshenko and Goodier, pp. 90-97 (Reference Number 3.2).

Problem Definition

The problem consists of a plate with a circular hole, submitted to a uniform tension of magnitude S in the x direction as shown in Fig. 3.3.1.



$a = 1"$
$b = 10"$
$S = 1$

Fig. 3.3.1

Boundary Conditions

w - displacement normal to surface

$N\phi$ - membrane force in ϕ direction

$M\phi$ - moment resultant in ϕ direction

N - effective in plane shear

start: $w = N\phi = M\phi = N = 0$
$(r = 1)$
end: $N\phi = 0.5S \quad N = -0.5S$
$(r = 10) \quad M\phi = w = 0$

Results

At r = b the stresses are effectively the same as in a plate without the hole and are given by:

$$\nabla r = \tfrac{1}{2}S(1 + \cos 2\theta)$$
$$\tau r\theta = -\tfrac{1}{2}S \sin 2\theta$$

at 45° $\quad \nabla r = \tfrac{1}{2}S$
$\quad \tau r\theta = -\tfrac{1}{2}S$

at r = 10" and $\theta = 45°$

Program E0781S gives $\nabla r(N\phi) = 0.5S$ and $\tau r\theta(N \text{ shear}) = -0.5S$.

At r = a, the edge of the hole:

From "Theory of Elasticity", by Timoshenko and Goodier

$$\nabla r = (-2A - 6C/r^4 - 4D/r^2) \cos 2\theta + \left(\frac{b^2}{b^2-a^2}\right)\left(1 - \frac{a^2}{r^2}\right) \frac{S}{2} \quad (1)$$

$$\nabla\theta = (2A + 6C/r^4 + 12Br^2) \cos 2\theta + \left(\frac{b^2}{b^2-a^2}\right)\left(1 + \frac{a^2}{r^2}\right) \frac{S}{2} \quad (2)$$

[Equations (1) and (2) are a result of requirements on p. 90 (parag.2). The stress distribution within the ring ($r_i = 1"$, $r_o = 10"$) is a combination of equations (45), p. 71 and equations (d), p. 91.]

3-22

using the boundary conditions:

$\nabla r \ (10'',\theta) = S/2(1 + \cos 2\theta); \ \nabla r(0,\theta) = 0$

$\tau r\theta \ (10'',\theta) = -S/2 \sin 2\theta \ ; \ \tau r\theta(0,\theta) = 0$

The constants are evaluated:

$A = 0.520664(S/2)$

$B = 0.00010306(S/2)$

$C = 0.520458(S/2)$

$D = 1.041019(S/2)$

From equations (1) and (2):

$(\nabla\theta)$ max occurs at $\theta = \pi/2$(pt.m)

$\nabla r = 0$

$\nabla\theta = 3.09152S$

Program E0781A

$N\phi(\nabla r) = 0$

$N\theta(\nabla\theta) = 3.092S$

Kalnin's Program E0781A	Theoretical Solution "Theory of Elasticity"
$N\theta = 3.092$ S	$N\theta = 3.0915$ S

The program gives a 0.02% deviation from the theoretical solution.

SUBJECT	MADE BY	CHKD BY	REV	BY	CHARGE NO.
E0781A	PM		1	PM	
	DATE	DATE		CHKD	
	4/77			DATE	SHT [redacted]

3.4 INCLINED CYLINDER UNDER HYDROSTATIC LOADING

Introduction

This problem illustrates Program E0781A's capability to analyze a pressure load with a free boundary condition and a membrane solution boundary condition.

The problem used for this verification is "Inclined Cylinder" (3.1.2.3) taken from "Stress in Shells" by W. Flügge, pp. 114-118 (Reference Number 3.1).

Problem Definition

The problem consists of an inclined cylinder partially filled with water. The uniform cylinder has a radius of 100", length of 300", and a thickness of 5/16" (see Fig. 3.4.1). The length of a segment is approximately $1\frac{1}{2}\sqrt{Rt}$, using 36 segments.

Boundary Conditions

Q - effective transverse shear in ϕ direction

$N\phi$ - membrane force in ϕ direction

$M\phi$ - moments resultant in ϕ direction

N - effective in plane shear

$u\phi$ - displacement component in ϕ direction

$u\theta$ - displacement component in θ direction

1. membrane conditions at start $Q=u\phi=M\phi=u\theta=0$
2. free at end $Q=N\phi=M\phi=N=0$

Loading

The loading in the loaded region is given as:

$$p = -\gamma\,(x \cos\alpha + r \sin\alpha \cos\theta)$$

Using Kalnin's notation with maximum pressure at 180°

γ = density = 64lb/ft^3 = 0.037037 lb/in.^{3}

α = angle of inclination = 45°

r = radius = 100"

x = distance along the meridian from a point 150" from the base to the point at which the pressure is being calculated

Therefore:

$$p(x,\theta) = -3.70370 \frac{\sqrt{2}}{2} (x/r + \cos\theta)$$

This function was expanded into a Fourier series at

x/r=0, ±0.2, ±0.4, ±0.6, ±0.8, -1.0, -1.5

for a total of 11 series. The amplitudes at +1.0 and +1.5 are zero. Letting:

$\xi_i = x_i/r$

x_i = x at the ith elevation

θ_i = one half the angle over which the pressure is applied at the ith elevation

Then the amplitudes of the nth harmonic at the ith elevation are:

$$a_{i0} = C\left[-\xi_i\theta + \sin\theta_i\right]$$

$$a_{i1} = C\left[2\xi_i \sin\theta_i - \sin\theta_i\cos\theta_i - \theta_i\right]$$

$$= C\left[\xi_i \sin\theta_i - \theta_i\right]$$

$$a_{in} = C\left[\xi_i \frac{\sin n\theta_i}{n} + \frac{\sin(n-1)\theta_i}{n-1} + \frac{\sin(n+1)\theta_i}{n+1}\right], n>1$$

where:

$$C = \frac{3.7037}{\pi} \frac{\sqrt{2}}{2} = 0.83362$$

$$\theta_i = \text{arc}\cos\xi_i$$

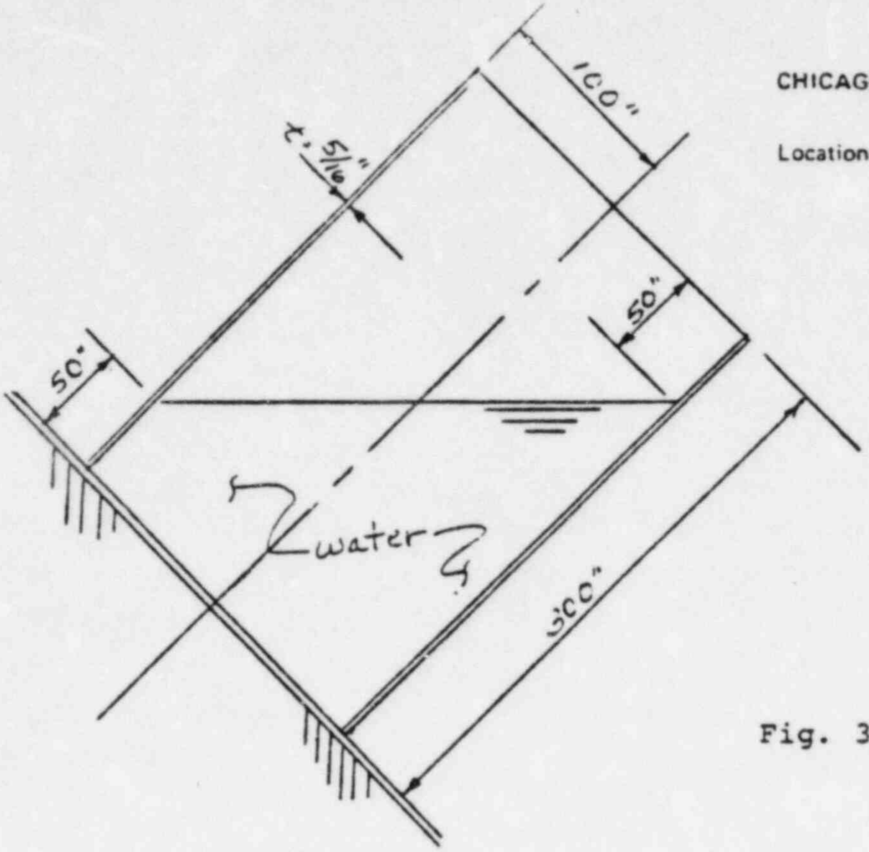


Fig. 3.4.1

Results

From Flugge's "Stresses in Shells", p.115, come the following equations:

(1) $N\theta = \gamma a(x\cos\alpha - a\sin\alpha\ \cos\theta)$

(2) $N = \gamma/2\left[x^2\cos\theta - 2a\ x\ \tan\alpha(\cos^2\theta - \sin^2\theta) + a^2\tan^2\alpha(\cos^2\theta - 2\ \sin^2\theta)\cos\theta\right]\sin\alpha$

(3) $N\phi\theta = \gamma a(a\ \tan\alpha\ \cos\theta - x)\sin\alpha\ \sin\theta$

These equations yield the results shown for the theoretical solution in Table 3.4.1.

Maximum pressure occurs at $\theta=0^\circ$ in Flugge's work and $\theta= 180^\circ$ in Kalnin's (Program E0781A).

	$\theta = 180^\circ$, $\xi = -1$(S = 50")			$\theta = 180^\circ$, $\xi = 0$(S = 150")		
	Theoretical Solution	Program E0781A	% Deviation	Theoretical Solution	Program E0781A	% Deviation
$N_\phi\left(\frac{lb}{in}\right)$	-523.8	-513.7	1.92	-130.9	-125.9	3.8
$N_\theta\left(\frac{lb}{in}\right)$	523.8	523.7	0.01	261.89	261.4	0.19
	$\theta = 240^\circ$, $\xi = -1$(S = 50")					
$N_{\phi\theta}\left(\frac{lb}{in}\right)$	340.2	340.3	0.03			
	$\theta = 225^\circ$, $\xi = 0$(S = 50")					
$N_{\phi\theta}\left(\frac{lb}{in}\right)$	130.9	129.7	0.92			

Table 3.4.1
Final Compared Results

REFERENCES

3.1 Flügge, W., *Stresses In Shells*, Springer-Verlag, New York, 1973.

3.2 Goodier, J.N. and Timoshenko, S.P., *Theory of Elasticity*, McGraw-Hill, New York, 1970.

3.3 Gerdeen, J.C., *Progress Report on The Effect of Geometrical Variations On The Limit Pressures For Ellipsoidal Head Vessels, September 27, 1972*, Michigan Technology Univ., for Welding Research Council.

3.4 Horowitz, J.M. and R. Henschel, *Experimental Investigation of 2:1 Ellipsoidal Heads Subjected to Internal Pressure (Volume One)*, Progress Report January 17, 1974 to April 16, 1976, Foster Wheeler Energy Corp., for WRC.

3.5 Gerdeen, J.C., *The Effect of Geometrical Variations On The Limit Pressures For 2:1 Ellipsoidal Head Vessels Under Internal Pressure, April 1975*. Michigan Technology Univ., for WRC.

3.6 Horowitz, J.M. and R. Henschel, *Experimental Investigation of 2:1 Ellipsoidal Heads Subjected to Internal Pressure (Volume Two)*, Progress Report January 17, 1974 to April 16, 1976, Foster Wheeler Energy Corp., for WRC.

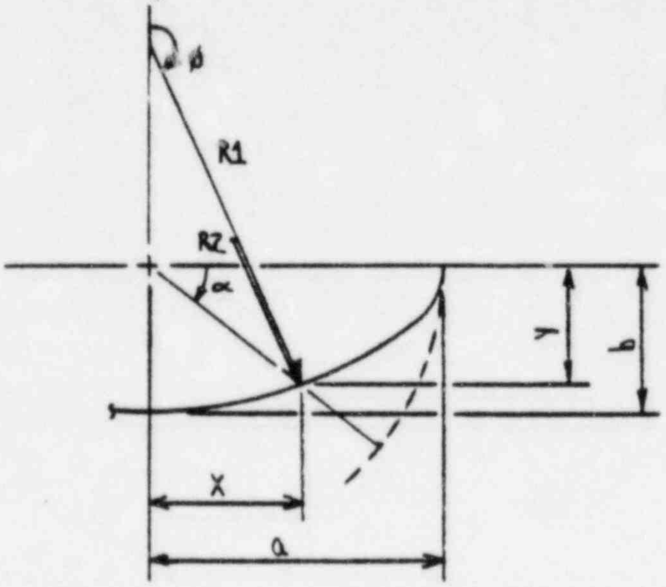
CBI

Location____________________

CBI Program 907

This program solves for the geometry of an elliptical head for any major-to-minor axis ratio. The output includes the cone radius and radius of curvature at requested intervals along the head.

Formulas and geometry used are as follow:



Ellipse Eqn = $\frac{X^2}{a^2} + \frac{Y^2}{b^2} = 1$

φ = angle from vertical to point under consideration

$$X = \sqrt{\frac{\frac{a^4}{b^2}}{\frac{1}{\sin^2\phi} + \frac{a^2}{b^2} - 1}} \qquad Y = \sqrt{b^2 - \frac{b^2 X^2}{a^2}}$$

Cone Radius = $R1 = \frac{a^2}{b}\sqrt{1 - \frac{X^2}{a^2}\left(1 - \frac{b^2}{a^2}\right)}$

Radius of Curvature = $R2 = \frac{b^2}{a^4}(R1)^3$

T/R2 Ratio = thickness / Radius of Curvature

Author: K Gustafson
Dated Version: 11/72
Limitations: φ increment must be less than 10° or arc length accuracy is lost.

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Location ______________________

$$\text{Arc Length} = a\int_{\alpha_0}^{\alpha_1} \sqrt{1 - \frac{a^2-b^2}{a^2}\cos^2\alpha}\; d\alpha$$

the integral is solved using Simpson's rule

$$\text{Arc Length} = \frac{\alpha_1-\alpha_0}{3m}(a)\left[H_0 + 4H_1 + 2H_2 + \dots + 2H_{m-2} + 4H_{m-1} + H_m\right]$$

where m = an <u>even number of equal spaces</u> of $\alpha_1 - \alpha_0 = 8$
and $H = \sqrt{1 - \frac{a^2-b^2}{a^2}\cos^2\alpha}$

<u>Sample Problem</u>:

a = 100" , $\frac{a}{b}$ ratio = 2.5 , increment Ø = 5° , and thk = 1"

calculate Ø, x, y, cone radius, radius of curvature, arc length, and T/R ratio at Ø = 130° and compare with computer values.

Ø = 130° ✓

$$X = \sqrt{\frac{\frac{(100)^4}{(40)^2}}{\frac{1}{\sin^2 130} + \frac{(100)^2}{(40)^2} - 1}} = 94.8025'' \approx \text{computer's } 94.80'' \checkmark$$

$$Y = \sqrt{(40)^2 - \frac{(40)^2(94.8025)^2}{(100)^2}} = 12.7278'' \approx \text{computer's } 12.73'' \checkmark$$

$$\text{Cone Radius} = \frac{(100)^2}{40}\sqrt{1 - \frac{(94.8025)^2}{(100)^2}\left(1 - \frac{(40)^2}{(100)^2}\right)} = 123.7560'' \approx \text{computer's } 123.76'' \checkmark$$

$$\text{Radius of Curvature} = \frac{(40)^2}{(100)^4}(123.7560)^3 = 30.3263'' \approx \text{computer's } 30.33'' \checkmark$$

$$T/R2 \text{ ratio} = \frac{1}{30.3263} = 0.032975 \approx \text{computer's } 0.03298 \checkmark$$

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Arc Length is as follows:

$m = 3 \quad , \quad a = 100 \quad , \quad b = 40$

ϕ	m	α	$H = \sqrt{1 - \frac{a^2-b^2}{a^2}\cos^2\alpha}$
90.00	0	0	.4000
95.78	1	2.319	.4017
101.47	2	4.639	.4068
106.97	3	6.958	.4151
112.21	4	9.277	.4264
117.16	5	11.596	.4404
121.78	6	13.916	.4567
126.05	7	16.235	.4750
130.00	8	18.554	.4950

$$\alpha_0 = \arccos\frac{x_0}{a} = \arccos\frac{100}{100} = 0^\circ = 0 \text{ rad.}$$

$$\alpha_1 = \arccos\frac{x_1}{a} = \arccos\frac{94.8025}{100} = 18.554^\circ = 0.3238 \text{ rad.}$$

$$\text{Arc Length} = \frac{0.3238 - 0}{3(8)}(100)\left[.4000 + 4(.4017) + 2(.4068) + 4(.4151) + 2(.4264) + 4(.4404) + 2(.4567) + 4(.4750) + .4950\right]$$

$$= 1.3492\,[\,10.4036\,] = 14.037'' \text{ vs computer's } 14.04 \checkmark$$

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
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				Date		

```
  PROGRAM NO. 937  NOV. 1972

            T/R RATIO AND GEOMETRY FOR AN ELLIPTICAL HEAD

 INPUT DATA

    MAJOR AXIS OF ELLIPSE =  100.00 IN

    2.50:1 ELLIPTICAL HEAD

    PHI INCREMENT         =    5.00 DEGREES

    HEAD THICKNESS         =  1.0000 IN
```

```
CHICAGO BRIDGE AND IRON COMPANY                    OAK BROOK ENGINEERING
       CONTRACT  00054331  DATE 10-23-82  BY GLN SHT       REV   0
```

✓RAH 11/82

T/R RATIO AND GEOMETRY FOR AN ELLIPTICAL HEAD

PHI NORMAL DEGREES	X COORDINATE (IN)	Y COORDINATE (IN)	CONE RADIUS (IN)	RADIUS OF CURVATURE (IN)	ARC FROM TANGENT (IN)	T/R RATIO (IN/IN)
90.00	100.00	0.0	100.00	16.00	0.0	0.06250
95.00	99.94	1.40	100.32	16.15	1.40	0.06190
100.00	99.75	2.81	101.29	16.63	2.83	0.06014
105.00	99.43	4.26	102.94	17.45	4.31	0.05730
110.00	98.96	5.76	105.31	18.69	5.88	0.05352
115.00	98.30	7.33	108.47	20.41	7.59	0.04899
120.00	97.44	9.00	112.51	22.79	9.47	0.04389
125.00	96.29	10.73	117.55	25.08	11.59	0.03987
130.00	94.80	12.73	123.76	30.32	14.24	0.03298
135.00	92.85	14.86	131.31	36.22	16.93	0.02761
140.00	90.27	17.21	140.43	44.31	20.42	0.02257
145.00	86.83	19.84	151.38	55.51	24.75	0.01802
150.00	82.20	22.79	164.40	71.09	30.24	0.01407
155.00	75.90	26.04	179.60	92.66	37.33	0.01079
160.00	67.30	29.59	196.77	121.91	46.64	0.00820
165.00	55.66	33.23	215.03	159.08	59.55	0.00629
170.00	40.34	36.60	232.29	200.54	74.57	0.00499
175.00	21.37	39.08	245.16	235.74	93.67	0.00424
180.00	0.0	40.00	250.00	250.00	115.07	0.00400

CHICAGO BRIDGE AND IRON COMPANY OAK BROOK ENGINEERING
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CBI Location

CBI Program 1017

This program calculates the natural periods for a system consisting of lumped masses. The system can take into account anchor bolt stretch with appropriate modeling, foundation interaction, and wave sloshing. The output includes stiffness and mass matrices as well as periods, deflections, shear, and moments for each mode. If spectral values are inputted, then maximum responses are obtained.

Author : C J Pieper
Dated Version : 9/78
Limitations : none

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
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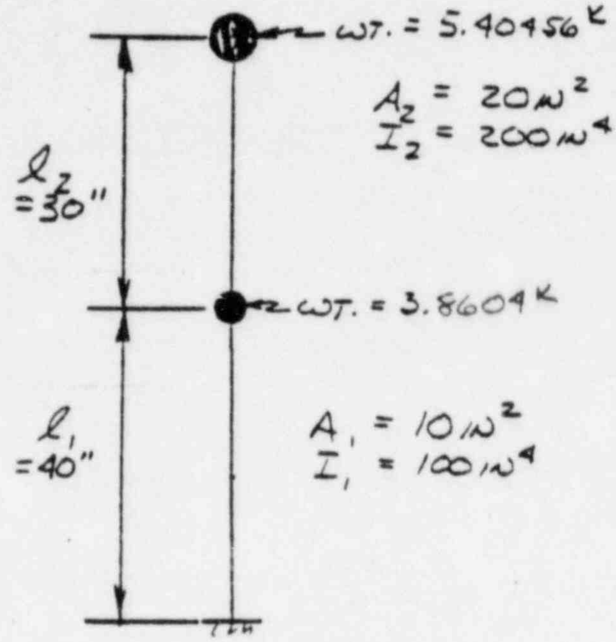
PROGRAM E1017A TEST CASE

FOLLOWING IS A MODEL WITH HAND CALCULATIONS MADE TO CHECK PROGRAM E1017A

THE TEST MODEL IS:



$E = 2.8 \times 10^7$ PSI

$\nu = 0.3$

$$G = \frac{E}{2(1+\nu)} = \frac{2.8(10^7)}{2(1.3)} = 1.0769 \times 10^7$$

CALCULATE STIFFNESS MATRIX TERMS*

$$[K] = \begin{array}{cccc} \theta_i & \theta_j & M_i & u_j \\ \left[\begin{array}{cccc} \frac{(4+\phi)EI}{\ell(1+\phi)} & \frac{(2-\phi)EI}{\ell(1+\phi)} & \frac{6EI}{\ell^2(1+\phi)} & \frac{-6EI}{\ell^2(1+\phi)} \\ \frac{(2-\phi)EI}{\ell(1+\phi)} & \frac{(4+\phi)EI}{\ell(1+\phi_y)} & \frac{6EI}{\ell^2(1+\phi)} & \frac{-6EI}{\ell^2(1+\phi)} \\ \frac{6EI}{\ell^2(1+\phi)} & \frac{6EI}{\ell^2(1+\phi)} & \frac{12EI}{\ell^3(1+\phi)} & \frac{-12EI}{\ell^3(1+\phi)} \\ \frac{-6EI}{\ell^2(1+\phi)} & \frac{-6EI}{\ell^2(1+\phi)} & \frac{-12EI}{\ell^3(1+\phi)} & \frac{12EI}{\ell^3(1+\phi)} \end{array}\right] \end{array}$$

* REF: PRZEMIENIECKI, THEORY OF MATRIX STRUCTURAL ANALYSIS, P. 70-79

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LET :

$$C = \frac{(4+\phi)EI}{\ell(1+\phi)} \qquad A = \frac{12EI}{\ell^3(1+\phi)}$$

$$D = \frac{(2-\phi)EI}{\ell(1+\phi)} \qquad B = \frac{6EI}{\ell^2(1+\phi)}$$

THE MATRIX FOR ANY ENTIRE STRUCTURE IS :

$$\begin{array}{c|cccccc|cccccc}
 & \theta_1 & \theta_2 & \theta_3 & \theta_4 & \cdot\cdot & \theta_n & u_1 & u_2 & u_3 & u_4 & \cdot\cdot & u_n \\
\hline
\cancel{M_1} & \cancel{C_1} & \cancel{D_1} & \cancel{0} & \cancel{0} & & \cancel{0} & \cancel{B_1} & \cancel{B_1} & \cancel{0} & \cancel{0} & \cdot\cdot & \cancel{0} \; =0 \\
M_2 & D_1 & C_1+C_2 & D_2 & 0 & \cdots & 0 & B_1 & B_2-B_1 & -B_2 & 0 & \cdot\cdot & 0 \\
M_3 & 0 & D_2 & C_2+C_3 & D_3 & \cdot\cdot & 0 & 0 & B_2 & B_3-B_2 & -B_3 & \cdots & 0 \\
\hline
\cancel{P_1} & \cancel{B_1} & \cancel{B_1} & \cancel{0} & \cancel{0} & \cdot\cdot & \cancel{0} & \cancel{A_1} & \cancel{-A_1} & \cancel{0} & \cancel{0} & \cdot\cdot & \cancel{0} \\
P_2 & -B_1 & B_2-B_1 & B_2 & 0 & \cdots & 0 & -A_1 & A_1+A_2 & -A_2 & 0 & \cdots & 0 \\
 & & -B_2 & B_3-B_2 & B_3 & \cdots & 0 & & -A_2 & A_2+A_3 & -A_3 & \cdot\cdot & 0
\end{array}$$

$u_1 = \theta_1 = 0$ BECAUSE OF FIXED B.C. THEIR RESPECTIVE STIFFNESS MATRIX TERMS CAN BE IGNORED.
THIS MATRIX CAN BE PARTITIONED AS FOLLOWS :

$$\left\{ \begin{array}{c} M \\ \hdashline F \end{array} \right\} = \left[\begin{array}{c:c} A_1' & A_2' \\ \hdashline A_3' & A_4' \end{array} \right] \left\{ \begin{array}{c} \theta \\ \hdashline u \end{array} \right\}$$

5-3

SUBJECT	MADE BY	CHKD BY	REV	By		CONTRACT NO.
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SINCE THERE ARE NO EXTERNAL MOMENTS EXCEPT ROTATORY INERTIA, WHICH IS NEGLECTED

$$\{M\} = 0$$

$$A_1'\theta + A_2'\mu = 0$$

$$\theta = -[A_1']^{-1}[A_2']\{\mu\}$$

AND

$$\{F\} = \left\{-[A_3'][A_1']^{-1}[A_2'] + [A_4']\right\}\{\mu\}$$

$$= A_3'\theta + A_4'\mu$$

$$C = \frac{(4+\phi)EI}{\ell(1+\phi)} \qquad A = \frac{12EI}{\ell^3(1+\phi)}$$

$$D = \frac{(2-\phi)(EI)}{\ell(1+\phi)} \qquad B = \frac{6EI}{\ell^2(1+\phi)}$$

WHERE $\phi = \frac{12EI}{GA_s\,\ell^2}$

THE STIFFNESS TERMS FOR
THE MODEL SHOWN ARE:

$$\phi_1 = \frac{(12)(2.8\times10^7)(10^2)}{(1.0769\times10^7)(10)(40)^2} = 0.19500$$

$$A_1 = \frac{12(2.8\times10^7)(10^2)}{40^3(1.1950)} = 4393\times10^2$$

$$B_1 = \frac{40A_1}{2} = 8786\times10^3$$

$$C_1 = \frac{4.195\times2.8\times10^7\times10^2}{40(1.195)} = 24.573\times10^7$$

$$D_1 = \frac{1.805}{4.195}\times C_1 = 10.573\times10^7$$

STIFFNESS TERMS, (CONT'D)

$$\Phi_2 = \frac{12\times(2.8\times10^7)\times(2\times10^2)}{1.0769(10^7)(20)(30)^2} = 0.34667$$

$$A_2 = \frac{12(2.8\times10^7)\,2(10^2)}{(30)^3(1.34667)} = 18482\times10^2$$

$$B_2 = \frac{30A_2}{2} = 27722\times10^3$$

$$C_2 = \frac{4.34667\times(2.8\times10^7)(200)}{30(1.34667)} = 60.2507\times10^7$$

$$D_2 = \frac{1.65333}{4.34667}\times C_2 = 22.9174\times10^7$$

$$\left[\begin{array}{cc|cc}
84.824\times10^7 & 22.9174\times10^7 & 18936\times10^3 & -27722\times10^3 \\
22.9174\times10^7 & 60.2507\times10^7 & 27722\times10^3 & -27722\times10^3 \\
\multicolumn{2}{c|}{A_1'} & \multicolumn{2}{c}{A_2'} \\
\hline
18936\times10^3 & 27722\times10^3 & 22875\times10^2 & -18482\times10^2 \\
-27722\times10^3 & -27722\times10^3 & -18482\times10^2 & 18482\times10^2 \\
\multicolumn{2}{c|}{A_3'} & \multicolumn{2}{c}{A_4'}
\end{array}\right]$$

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DEVELOP STIFFNESS MATRIX

INVERT A_1' −

$$\begin{bmatrix} 84.824\times10^{7} & 22.9174\times10^{7} \\ 22.9174\times10^{7} & 60.2507\times10^{7} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ \hline a & b \\ b & c \end{bmatrix}$$

$$84.824a + 22.9174b = 10^{-7}$$

$$22.9174a + 60.2507b = 0$$

$$b = \frac{-22.9174}{60.2507}a = -0.38037a$$

$$\left[84.824 - (0.38037)(22.9174)\right]a = 10^{-7} \Rightarrow a = 1.3139\times10^{-9}$$

$$b = -0.49978(10^{-9})$$

$$84.824(-0.49978) + 22.9174c = 0 \rightarrow c = 1.8498(10^{-9})$$

$$\left[A_1'\right]^{-1} = \left(10^{-9}\right)\begin{bmatrix} 1.3139 & -0.49978 \\ -0.49978 & 1.8498 \end{bmatrix}$$

5-7

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
	CAB	BW		Chkd		5-4331
CRBRP Containment Vessel	DATE 5/82	DATE 6/82		Date		SHT ~~6~~ OF ~~24~~

$$[A_1']^{-1}[A_2'] = 10^{-6}\begin{bmatrix}11025 & -22569\\ 41816 & -37425\end{bmatrix}$$

$$[A_3'][A_1']^{-1}[A_2'] = \begin{bmatrix}13680 & -14649\\ -14649 & 16632\end{bmatrix}(10^{2})$$

$$\therefore [K] = \left\{-[A_3'][A_1']^{-1}[A_2'] - [A_4']\right\}$$

$$[K] = \begin{bmatrix}0.9195\times10^{6} & -0.3833\times10^{6}\\ -0.3833\times10^{6} & 0.1850\times10^{6}\end{bmatrix}$$

THE MASS MATRIX IS:

$$\begin{bmatrix}10 & 0\\ 0 & 14\end{bmatrix}$$

SUBSTITUTE PERIODS INTO CHARACTERISTIC EQUATIONS TO CHECK AND SEE IF DET. = 0

$$* \left| -\omega^2 [M] + [K] \right| = 0$$

FROM PRINTOUT, PAGE
SECOND MODE PERIOD = $.195256 \times 10^{-1}$

$$\omega = \frac{2\pi(10)}{.195256} = 321.79 \Rightarrow \omega^2 = 10.355 \times 10^4$$

$$-\omega^2 [M] + [K] =$$

$$\begin{matrix} [-10.355 \times 10^5 + 9.19409 \times 10^5] & [-0 + (-.383201 \times 10^6)] \\ [-0 + (-.383201 \times 10^6)] & [-14.497 \times 10^5 + .18458 \times 10^6] \end{matrix}$$

$$= \begin{vmatrix} -1.1609 & -3.83201 \\ -3.83201 & -12.648 \end{vmatrix} \times 10^5$$

$$(-1.1609)(-12.648) - [(-3.83201)^2] = -.001 \quad \underline{\underline{OK}}$$

*REF: BIGGS, INTRODUCTION TO STRUCTURAL DYNAMICS

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				Date		SHT ~~5~~ OF ~~24~~

PROGRAM HAS BEEN CHECKED ON PREVIOUS PAGE TO SHOW THAT THE SOLUTION FOR THE EIGENVALUES OF THE SYSTEM (n VALUES OF ω^2) ARE CORRECT. THIS HAS BEEN SHOWN TO BE OK.

$\therefore$ 1ST MODE $T = .157276$

$$\omega = \frac{2\pi}{.157276} \Rightarrow \omega^2 = 1.596 \times 10^3$$

$$\text{2ND MODE} \Rightarrow \omega^2 = 10.355 \times 10^4$$

CALCULATE EIGENVECTORS, SCALED EIGENVECTORS

$$\left\{ -\omega^2 [M] + [K] \right\} \{ u \} = 0$$

$$\left[-1.596(10^4) + 91.9409(10^4) \right] u_1 - 38.32 \times 10^4 (u_2) = 0$$

IF $u_2 = 1$, THEN $u_1 = .4242$

SCALE FACTOR —

$$\gamma_1 = \frac{\{\phi_{im}\}^T \{m_i\}}{\{\phi_{im}\}^T [m_i] \{\phi_{im}\}}$$

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
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$$\left\{\Phi_{im}\right\}^T \left\{m_i\right\}$$

$$= \left\{.4242 \quad 1\right\} \begin{Bmatrix} 10 \\ 14 \end{Bmatrix} \quad 18.242$$

$$\left\{\Phi_{im}\right\}^T \left[m_i\right]$$

$$\left\{.4242 \quad 1\right\} \begin{bmatrix} 10 & 0 \\ 0 & 14 \end{bmatrix} \quad 4.242 \quad 14$$

$$\left\{\Phi_{im}\right\}^T \left[m_i\right] \left\{\Phi_{im}\right\}$$

$$\left\{4.242 \quad 14\right\} \begin{Bmatrix} .4242 \\ 1 \end{Bmatrix} \quad 15.80$$

$$\therefore \gamma_1 = \frac{18.242}{15.80} = 1.155$$

5-11

AND SCALED EIGENVECTORS FOR 1ST MODE ARE –

$u_1 = .4899$ $u_2 = 1.155$ OK//

SUBJECT	MADE BY	CHKD BY	REV			CHARGE NO.
	DAB	Bw		By		5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6/82		Chkd		
				Date		SHT 10 OF 24

SCALED EIGENVECTORS, 2^{ND} MODE

$(-1.1609\times10^{5})u_1 - 3.832\times10^{5})u_2 = 0$

IF $u_2 = 1$ $u_1 = -3.301$

FROM PRINTOUT, $\gamma_2 = -.155$

∴ SCALED EIGENVECTORS, 2^{ND} MODE ARE:

$u_1 = .5117$
$u_2 = -.155$ OK

∴ SCALED EIGENVECTORS OK!!

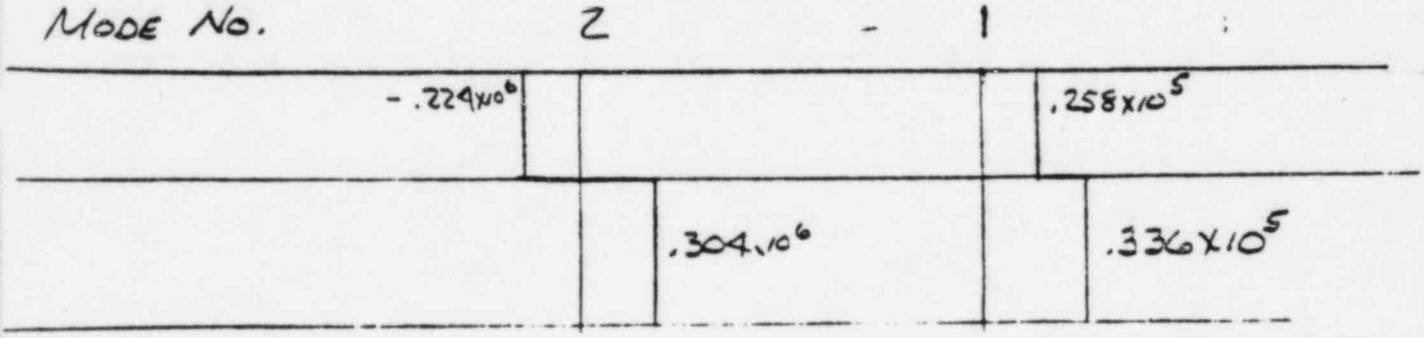
5-12

CALCULATE FORCES

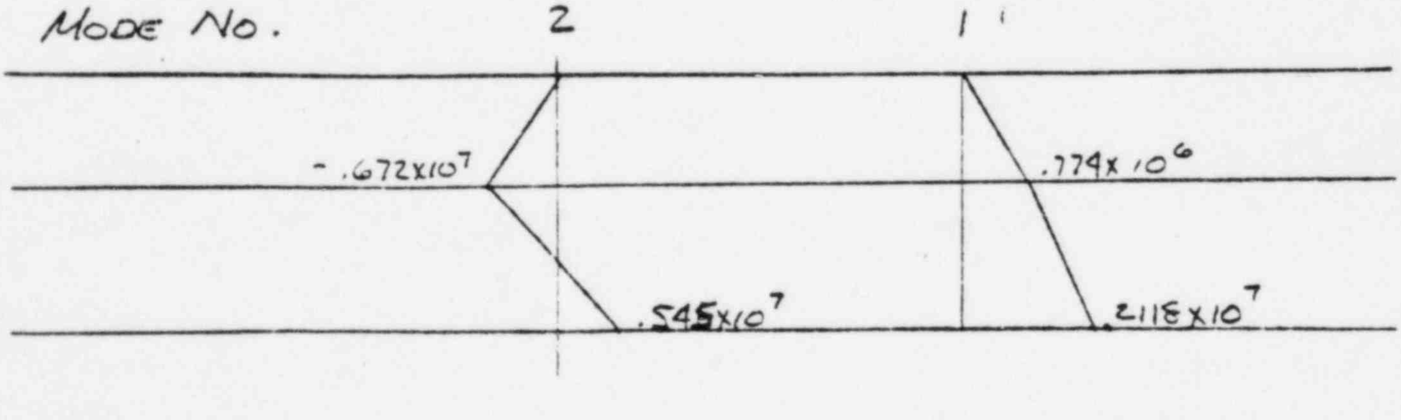
$$\begin{bmatrix} .919409\times10^6 & -.383201\times10^6 \\ -.383201\times10^6 & .18488\times10^6 \end{bmatrix} \quad \begin{array}{cc} \text{2ND MODE} & \text{1ST MODE} \\ .528\times10^6 & .00779\times10^6 \\ -.224\times10^6 & .0258\times10^6 \end{array}$$

$$\begin{bmatrix} .5103 & .4897 \\ -0.1546 & 1.1546 \end{bmatrix}$$

SHEARS



MOMENTS



5-13

SUBJECT	MADE BY CAB	CHKD BY Bu	REV	By	CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6/82		Chkd Date	SHT

USING INPUT SPECTRAL DISPLACEMENTS :

MODE #1 S.D. = .5
MODE #2 S.D. = .3

DISPLACEMENTS, FORCES, AND ACCELERATIONS BY RMS

SCALED EIGENVECTORS ARE :

MODE No. 2

.510274 -.154596

MODE No. 1

.489726 1.1546

DISPLACEMENTS:

FREEDOM #1

$[(.5(.489726))^2 + (.3(.510274))^2]^{1/2} = .2888''$ OK

FREEDOM #2

$[(.5(1.1546))^2 + (.3(-.154596))^2]^{1/2} = .5792''$ OK

SHEARS

MODE #2
$.304 \times 10^6$ $-.224 \times 10^6$

MODE #1
$.336 \times 10^5$ $.258 \times 10^5$

FREEDOM #1

$[(.5(.336 \times 10^5))^2 + (.3(.304 \times 10^6))^2]^{1/2} = 92734$ OK

FREEDOM #2

$[(.5(.258 \times 10^5))^2 + (.3(-.224 \times 10^6))^2]^{1/2} = 68426$ OK

5-14

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
CRBRP Containment Vessel	DAB	BW		Chkd		5-4331
	DATE 6/82	DATE 6/82		Date		~~SHT 12 OF 74~~

MOMENTS

MODE #2

$.545 \times 10^7$ $-.672 \times 10^7$

MODE #1

$.212 \times 10^7$ $.774 \times 10^6$

BASE $[(.5(.212\times10^7))^2 + (.3(.545\times10^7))^2]^{1/2} = .1948\times10^7$ OK

FREEDOM #1 $[(.5(.774\times10^6))^2 + (.3(-.672\times10^7))^2]^{1/2} = .2053\times10^7$ OK

ACCELERATIONS

SPECTRAL ACCELERATIONS INPUT

MODE #1 = .5 = SPECTRAL DISPLACEMENT FOR MODE #1

MODE #2 = .3 = " " " " #2

∴ ACCELERATIONS OF EACH FREEDOM NO. = DISPLACEMENTS OF EACH FREEDOM NO.

$$\left.\begin{array}{l} \text{FREEDOM \# 1} = .2888\,g \\ \text{FREEDOM \# 2} = .5792\,g \end{array}\right\} \text{OK}$$

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
CRBRP Containment Vessel	DAB DATE 6/82	DATE 5/82		Chkd Date		5-4331 SH

GO 64 REV 4-73

```
                    PROGRAM E1017A REV SEP 1978
       MODAL ANALYSIS OF STRUCTURES USING EIGENVALUE TECHNIQUE.
                    DATA SHEET REVISION--  A  --


   E1017A TWO NODE MODEL TEST CASE

         SOLUTION CONSIDERS TRANSLATIONAL DEGREES OF FREEDOM ONLY


   INPUT DATA

         MODULUS OF ELASTICITY= 0.280E+08 PSI

         POISSON'S RATIO= 0.3000

MASS NO.  MOMENT OF INERTIA    AREA     ELEVATION     WEIGHT   PRODUCT WT.
               (IN**4)        (IN**2)     (IN.)       (K PS)     (KIPS)

   1         .10000+03       .1000E+02  .4000E+02   .3860E+01   .0
   2         .20000+03       .2000E+02  .7000E+02   .5405E+01   .0


   SPECTRAL DISPLACEMENT VALUES

         MODE NO.       SPECTRAL DISPLACEMENT

            1                 .500E+00
            2                 .300E+00


   SPECTRAL ACCELERATION VALUES

         MODE NO.              SPECTRAL ACCELERATIONS

            1                 .500E+00
            2                 .300E+00
            3                 .0
```

```
DEGREE OF FREEDOM        ELEVATION
                           (IN.)

        1                .4000E+02              HORIZONTAL TRANSLATION
        2                .7000E+02              HORIZONTAL TRANSLATION
```

5-17

SUBJECT CRBRP Containment Vessel	MADE BY DAB	CHKD BY R	REV	BY		CHARGE NO. 5-4331
	DATE 6/82	DATE 6/82		CHKD		~~[illegible]~~
				DATE		

```
                    STIFFNESS MATRIX (LB/IN)

  0.9194090D+06  -0.3832010D+06

 -0.3832010D+06   0.1848800D+06
```

```
                    MASS MATRIX (LB-SEC**2/IN)

     0.1000000D+02  0.0

     0.0            0.140000D+02
```

SUBJECT	MADE BY	CHKD BY	REV			CHARGE NO.
	DAB	Tw		BY		5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6/82		CHKD		~~SH. 18 OF 24~~
				DATE		

```
DEGREE OF ORTHOGONALITY OF EIGENVECTORS

     0.0
```

5-20

SUBJECT	MADE BY	CHKD BY	REV			
	DAB	Bw		BY		5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6/82		CHKD		
				DATE		

```
                    SCALED EIGENVECTOR ARRAY (IN)

MODE NO.= 2    PERIOD(SEC)=0.195256E-01

     0.510274D+00  -0.154596D+00

MODE NO.= 1    PERIOD(SEC)=0.157276E+00

     0.489726D+00   0.115460D+01
```

5-21

SUBJECT	MADE BY DAB	CHKD BY Bw	REV	BY		5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6/82		CHKD		~~[illegible] 20 [illegible] 21~~
				DATE		

```
SHEAR DUE TO SCALED EIGENVECTORS (LB)

MODE NO.= 2
        0.304D+06    -0.224D+06

MODE NO.= 1
        0.336D+05     0.258D+05
```

SUBJECT	MADE BY	CHKD BY	REV			CHARGE NO.
CRBRP Containment Vessel	DAB	Sw		BY		5-4331
	DATE	DATE		CHKD		~~[illegible]~~
	6/82	6/82		DATE		

```
          MOMENTS DUE TO SCALED EIGENVECTORS (IN-LB)

MODE NO.= 2
      0.545D+07      -0.672D+07

MODE NO.= 1
      0.212D+07       0.774D+06
```

SUBJECT	MADE BY	CHKD BY	REV			CHARGE NO.
CRBRP Containment Vessel	DAB	[illegible]		BY		5-4331
	DATE	DATE		CHKD		
	[illegible]	[illegible]		DATE		

```
              PRODUCTS OF RESPONSES AND SPECTRAL DISPLACEMENTS
          VALUES FOR THE FIRST 2MODES SUMMED B  ROOT MEAN SQUARES

                 FREEDOM DISPLACEMENT      SHEAR          MOMENT
                   NO.   (IN. OR RAD.)    (LBS.)        (IN.-LBS.)


                   2        .579D+00     .685D+05       .000E 00

                   1        .289D+00     .928D+05       .205D+07

                 BASE       .000E 00     .928D+05       .195D+07
```

```
          ACCELERATIONS OF THE FIRST  2 MODES SUMMED BY
            ROOT MEAN SQUARE (INCLUDING RIGID BODY
                MOTION OF 0.0          GRAVITI S)

            FREEDOM             ACCELERATION
              NO.                (GRAVITIES)

               2                  0.579E+00

               1                  0.289E+00

             BASE                 0.0
```

SUBJECT	MADE BY DAB	CHKD BY [illegible]	REV	BY		CHARGE NO. 5-4331
CRBRP Containment Vessel	DATE 6/82	DATE 6 [illegible]		CHKD		~~[illegible]~~
				DATE		

Location

CBI Program 1027

This program computes the local shell stresses and stress intensities in the vicinity of an attachment to a spherical or cylindrical shell. Stresses are calculated for loads on the attachment given at the shell ℄ centerline. The attachment is assumed to be rigid with solid cross-section. Formulas used in the program are based on work done by Professor P.P. Bijlaard as presented in Welding Research Council Bulletin 107 (WRC-107), August, 1965 and revised March, 1979.

Formulas and geometry used are per Table 5 of WRC-107. (See following page.)

In addition, initial stresses in the shell are combined with stresses due to attachment loads.

$$SX_{\text{Total}} = SX_{\text{Initial Stress}} + SX_{\text{WRC-107}}$$

$$SO_{\text{Total}} = SO_{\text{Initial Stress}} + SO_{\text{WRC-107}}$$

In addition, membrane stresses in the shell are also calculated from the WRC-107 surface stresses.

at Point A : $SX_m = \dfrac{SX_U + SX_L}{2}$

$$SO_m = \frac{SO_U + SO_L}{2}$$

and etc. for Points B, C, and D.

Author: K Gustafson
Dated Version : 1/82
Limitations : $5 \leq \gamma \leq 650$
$.005 \leq \beta \leq .500$

10/78 version was updated for the WRC-107 Rev 3/79 edition.

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By	CHARGE NO. 54331
				Chkd	
Verification	DATE 11/1/82	DATE 11/82		Date	SHT 6-1 OF

GO 64 REV 4-73

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

1. Applied Loads*

Radial load, $P =$ ——— lb.
Circ. Moment, $M_c =$ ——— in. lb.
Long. Moments, $M_L =$ ——— in. lb.
Torsion Moment, $M_T =$ ——— in. lb.
Shear Load, $V_c =$ ——— lb.
Shear Load, $V_L =$ ——— lb.

2. Geometry

Vessel thickness, $T =$ ——— in.
Attachment radius, $r_o =$ ——— in.
Vessel radius, $R_m =$ ——— in.

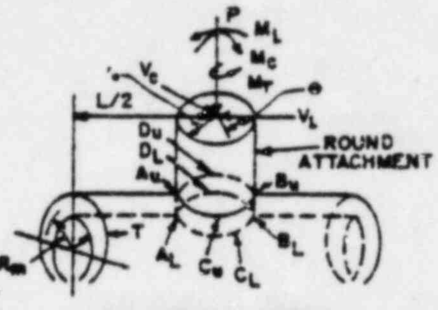
3. Geometric Parameters

$\gamma \quad \frac{R_m}{T} =$ ———

$\beta \quad (0.875)\frac{r_o}{R_m} =$ ———

Stress Concentration due to:
a) membrane load, K_n ———
b) bending load, K_b ———

*NOTE: Enter all force values in accordance with sign convention



CYLINDRICAL SHELL

From Fig.	Read curves for	Compute absolute values of stress and enter result	STRESSES – if load is opposite that shown, reverse signs shown							
			A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
3C or 4C	$\frac{N_\phi}{P/R_m} =$	$K_n\left(\frac{N_\phi}{P/R_m}\right)\cdot\frac{P}{R_mT} =$	−	−	−	−	−	−	−	−
1C or 2C-1	$\frac{M_\phi}{P} =$	$K_b\left(\frac{M_\phi}{P}\right)\cdot\frac{6P}{T^2} =$	−	+	−	+	−	+	−	+
3A	$\frac{N_\phi}{M_c/R_m^2\beta} =$	$K_n\left(\frac{N_\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T} =$	▨	▨	▨	▨	−	−	+	+
1A	$\frac{M_\phi}{M_c/R_m\beta} =$	$K_b\left(\frac{M_\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2} =$	▨	▨	▨	▨	−	+	+	−
3B	$\frac{N_\phi}{M_L/R_m^2\beta} =$	$K_n\left(\frac{N_\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T} =$	−	−	+	+	▨	▨	▨	▨
[redacted] 1B-1	$\frac{M_\phi}{M_L/R_m\beta} =$	$K_b\left(\frac{M_\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2} =$	−	+	+	−	▨	▨	▨	▨
Add algebraically for summation of Φ stresses, σ_ϕ.										
3C or 4C	$\frac{N_x}{P/R_m} =$	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT} =$	−	−	−	−	−	−	−	−
1C-1 or 2C	$\frac{M_x}{P} =$	$K_b\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2} =$	−	+	−	+	−	+	−	+
4A	$\frac{N_x}{M_c/R_m^2\beta} =$	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T} =$	▨	▨	▨	▨	−	−	+	+
2A	$\frac{M_x}{M_c/R_m\beta} =$	$K_b\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2} =$	▨	▨	▨	▨	−	+	+	−
4B	$\frac{N_x}{M_L/R_m^2\beta} =$	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T} =$	−	−	+	+	▨	▨	▨	▨
[redacted] 2B-1	$\frac{M_x}{M_L/R_m\beta} =$	$K_b\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2} =$	−	+	+	−	▨	▨	▨	▨
Add algebraically for summation of X stress s, $\sigma_x =$										
Shear stress due to Torsion, M_T		$\tau_{\phi x} = \tau_{x\phi} = \frac{M_T}{2\pi r_o^2 T}$	+	+	+	+	+	+	+	+
Shear stress due to load, V_c		$\tau_{x\phi} = \frac{V_c}{\pi r_o T}$	+	+	−	−	▨	▨	▨	▨
Shear stress due to load, V_L		$\tau_{x\phi} = \frac{V_L}{\pi r_o T}$	▨	▨	▨	▨	−	−	+	+
Add Algebraically for summation of shear stresses, $\tau =$										

COMBINED STRESS INTENSITY - S

1) When $\tau \neq 0$, S = largest absolute magnitude of either
$S = 1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right]$ or $\sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}$.

2) When $\tau = 0$, S = largest absolute magnitude of either
$S = \sigma_x$, σ_ϕ or $(\sigma_x - \sigma_\phi)$.

$N_x/(M_L/R_m^2\beta)$ as determined by (C_L) from Table 8 (see para. 4.3).

4.2.2.5.2: When considering bending moment (M_L): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ where K_L is given in Table 8.

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 Circumferential Stresses (σ_ϕ):

Step 1. Using the applicable values of β and γ

CBI

Location________________

Sample Problem:

K_m = membrane stress concentration factor = 1.0
K_b = bending stress concentration factor = 1.0
R_m = 100"
T = 1"
r_0 = 5.375"
TP = pad ℓ thk = $\frac{1}{2}$"
W = pad ℓ width of reinforcing 8"
P = 5000 lbs
VL = -6500 lbs
VC = 5800 lbs
MC = -15000 in-lbs
ML = 14000 in-lbs
MT = 10000 in-lbs

Initial shell stresses at all locations = 9000 psi

Calculate the outer and inner surface stress intensities at Points A, B, C, D next to the attachment, at $0.5\sqrt{R_mT}$ from the attachment, and at the edge of reinforcement. Calculate the outer and inner surface stress intensities including initial shell stresses, the membrane stress intensities, and the membrane stress intensities including initial shell stresses at Point A at all locations. Compare all calculations with computer values.

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/5/82	DATE 11/82		Chkd		SHT 6-3 OF ____
				Date		

GO 64 REV 4-73

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

next to attachment

Note: Stresses due to bending moments are increased by 30% per WRC-49 and WRC-50 for reinforced attachments.

1. Applied Loads*

Radial load, P = 5000 lb.
Circ. Moment, Mc = [illegible] in. lb.
Long. Moments, ML = [illegible] in. lb.
Torsion Moment, MT = [illegible] in. lb.
Shear Load, Vc = [illegible] lb.
Shear Load, VL = [illegible] lb.

2. Geometry

T+TP ~~Vessel~~ thickness, T = 1.5 in.
Attachment radius, r_o = [illegible] in.
Vessel radius, R_m = [illegible] in.

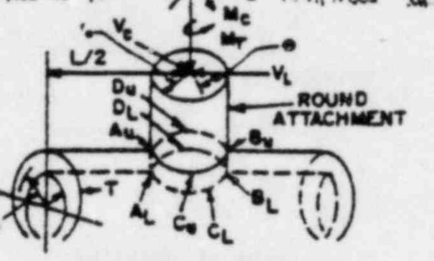
3. Geometric Parameters

$\gamma = \frac{R_m}{T}$ = 17

$\beta = (0.875)\frac{r_o}{R_m}$ = .04703

Stress Concentration due to:
a) membrane load, Kn = 1
b) bending load, Kb = 1

*NOTE: Enter all force values in accordance with sign convention



CYLINDRICAL SHELL

A&B	C&D	From Fig.	Read curves for	Compute absolute values of stress and enter result		Au	AL	Bu	BL	Cu	CL	Du	DL
7.866	18.416	3C or 4C	$\frac{N\phi}{P/R_m}$ =	$K_n\left(\frac{N\phi}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 596	614	−596	−596	−596	−596	−614	−614	−614	−614
.137	.182	1C or 2C-1	$\frac{M\phi}{P}$ =	$1.3(K_b)\left(\frac{M\phi}{P}\right)\cdot\frac{6P}{T^2}$ = 2192	2912	−2192	+2192	−2192	+2192	−2912	+2912	−2912	+2912
2.317		3A	$\frac{N\phi}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = −49		▨	▨	▨	▨	+49	+49	−49	−49
.105		1A	$\frac{M\phi}{M_c/R_m\beta}$ =	$1.3(K_b)\left(\frac{M\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = −1072		▨	▨	▨	▨	+1072	−1072	−1072	+1072
1 7.825		3B	$\frac{N\phi}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 155		−155	−155	+155	+155	▨	▨	▨	▨
.058		~~1B~~ 1B-1	$\frac{M\phi}{M_L/R_m\beta}$ =	$1.3(K_b)\left(\frac{M\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 552		−552	+552	+552	−552	▨	▨	▨	▨
✓		Add algebraically for summation of Φ stresses, σ_ϕ.				−3495	1993	−2081	1199	−2405	1275	−4647	3321
18.416	17.866	3C or 4C	$\frac{N_x}{P/R_m}$ =	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 614	596	−614	−614	−614	−614	−596	−596	−596	−596
.182	.137	1C-1 or 2C	$\frac{M_x}{P}$ =	$1.3(K_b)\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2}$ = 2912	2192	−2912	+2912	−2912	+2912	−2192	+2192	−2192	+2192
3		4A	$\frac{N_x}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = −65		▨	▨	▨	▨	+65	+65	−65	−65
.061		2A	$\frac{M_x}{M_c/R_m\beta}$ =	$1.3(K_b)\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = −623		▨	▨	▨	▨	+623	−623	−623	+623
2.246		4B	$\frac{N_x}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 45		−45	−45	+45	+45	▨	▨	▨	▨
.093		~~2B~~ 2B-1	$\frac{M_x}{M_L/R_m\beta}$ =	$1.3(K_b)\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 886		−886	+886	+886	−886	▨	▨	▨	▨
		Add algebraically for summation of X stresses, σ_x =				−4457	3139	−2595	1457	−2100	1038	−3476	2154
		Shear stress due to Torsion, MT		$\tau_{\phi x} = \tau_{x\phi} = \frac{M_T}{2\pi r_o^2 T}$ = 37		+37	+37	+37	+37	+37	+37	+37	+37
		Shear stress due to load, Vc		$\tau_{x\phi} = \frac{V_c}{\pi r_o T}$ = 229		+229	+229	−229	−229	▨	▨	▨	▨
		Shear stress due to load, VL		$\tau_{x\phi} = \frac{V_L}{\pi r_o T}$ = −257		▨	▨	▨	▨	+257	+257	−257	−257
		Add Algebraically for summation of shear stresses, τ =				266	266	−192	−192	294	294	−220	−220
		COMBINED STRESS INTENSITY - S =				4526	3198	2659	1559	2584	1473	4687	3361

1) When τ ≠ 0, S = largest absolute magnitude of either

$$S = 1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right] \text{ or } \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}.$$

2) When τ = 0, S = largest absolute magnitude of either

$$S = \sigma_x,\ \sigma_\phi \text{ or } (\sigma_x - \sigma_\phi).$$

$N_i/(M_L/R_m^2\beta)$ so determined by (C_L) from Table 8 (see para. 4.3).

4.2.2.5.2: When considering bending moment (M_i): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ where K_L is given in Table 8.

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 Circumferential Stresses (σ_ϕ):

Step 1. Using the applicable values of β and γ

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

at $0.5\sqrt{R_m T}$

Note: Stresses due to bending moments are increased by 30% per WRC-49 and WRC-50 for rectangular attachments.

1. Applied Loads*

Radial load, P = 5000 lb.
Circ. Moment, Mc = [illegible] in. lb.
Long. Moment, ML = [illegible] in. lb.
Torsion Moment, MT = [illegible] in. lb.
Shear Load, Vc = [illegible] lb.
Shear Load, VL = [illegible] lb.

2. Geometry

T+ TP ~~Vessel thickness,~~ T = 1.5 in.
$r_o + .5\sqrt{R_m T}$ ~~Attachment radius,~~ r_o = 10.375 in.
Vessel radius, Rm = 100 in.

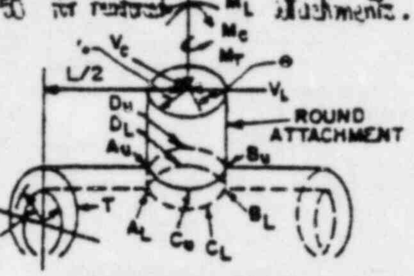
3. Geometric Parameters

$\gamma = \frac{R_m}{T} = 67$

$\beta = (0.875)\frac{r_o}{R_m} = .09078$

Stress Concentration due to:
a) membrane load, Kn
b) bending load, Kb

*NOTE: Enter all force values in accordance with sign convention



CYLINDRICAL SHELL

A&B ✓	C&D	From Fig.	Read curves for	Compute absolute values of stress and enter result	Au	AL	Bu	BL	Cu	CL	Du	DL
15.743	12.922	3C or 4C	$\frac{N\phi}{P/R_m}$ =	$K_n\left(\frac{N\phi}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 525 / 431	-525	-525	-525	-525	-431	-431	-431	-431
.078	.116	1C or 2C-1	$\frac{M\phi}{P}$ =	$12(K_b)\left(\frac{M\phi}{P}\right)\cdot\frac{6P}{T^2}$ = 1248 / 1856	-1248	+1248	-1248	+1248	-1856	+1856	-1856	+1856
3.716		3A	$\frac{N\phi}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = -41	▨	▨	▨	▨	+41	+41	-41	-41
.093		1A	$\frac{M\phi}{M_c/R_m\beta}$ =	$12(K_b)\left(\frac{M\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = -492	▨	▨	▨	▨	+492	-492	-492	+492
10.979		3B	$\frac{N\phi}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 113	-113	-113	+113	+113	▨	▨	▨	▨
.042		1B-1	$\frac{M\phi}{M_L/R_m\beta}$ =	$12(K_b)\left(\frac{M\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 207	-207	+207	+207	-207	▨	▨	▨	▨
✓		Add algebraically for summation of Φ stresses, σ_ϕ			-2093	817	-1453	629	-1754	974	-2820	1876
12.922	15.743	3C or 4C	$\frac{N_x}{P/R_m}$ =	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 431 / 525	-431	-431	-431	-431	-525	-525	-525	-525
.116	.078	1C-1 or 2C	$\frac{M_x}{P}$ =	$12(K_b)\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2}$ = 1856 / 1248	-1856	+1856	-1856	+1856	-1248	+1248	-1248	+1248
47		4A	$\frac{N_x}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = -66	▨	▨	▨	▨	+66	+66	-66	-66
.051		2A	$\frac{M_x}{M_c/R_m\beta}$ =	$12(K_b)\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = -270	▨	▨	▨	▨	+270	-270	-270	+270
3.679		4B	$\frac{N_x}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 38	-38	-38	+38	+38	▨	▨	▨	▨
.064		2B-1	$\frac{M_x}{M_L/R_m\beta}$ =	$12(K_b)\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 316	-316	+316	+316	-316	▨	▨	▨	▨
		Add algebraically for summation of X stresses, σ_x			-2641	1703	-1933	1147	-1437	519	-2109	927
		Shear stress due to Torsion, MT		$\tau_{x\phi} = \frac{M_T}{2\pi r_o^2 T}$ = 10	+10	+10	+10	+10	+10	+10	+10	+10
		Shear stress due to load, Vc		$\tau_{x\phi} = \frac{V_c}{\pi r_o T}$ = 119	+119	+119	-119	-119	▨	▨	▨	▨
		Shear stress due to load, VL		$\tau_{x\phi} = \frac{V_L}{\pi r_o T}$ = -133	▨	▨	▨	▨	+133	+133	-133	-133
		Add algebraically for summation of shear stresses, τ =			129	129	-109	-109	143	143	-123	-123
		COMBINED STRESS INTENSITY - S =			2670	1721	1957	1169	1809	1015	2841	1892

1) When $\tau \neq 0$, S = largest absolute magnitude of either
$S = 1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right]$ or $\sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}$.

2) When $\tau = 0$, S = largest absolute magnitude of either
$S = \sigma_x$, σ_ϕ or $(\sigma_x - \sigma_\phi)$.

$N_x/(M_L/R_m^2\beta)$ **so determined by** (C_L) **from Table 8 (see para. 4.3).**

4.2.2.5.2: When considering bending moment (M_L): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ **where** K_L **is given in Table 8.**

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 Circumferential Stresses (σ_ϕ):

Step 1. Using the applicable values of β and γ

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

at edge of reinforcement

1. Applied Loads*

Radial load, P = 5000 lb.
Circ. Moment, Mc = -15000 in. lb.
Long. Moment, ML = [illegible] in. lb.
Torsion Moment, MT = [illegible] in. lb.
Shear Load, Vc = [illegible] lb.
Shear Load, VL = [illegible] lb.

2. Geometry

Vessel thickness, T = 4 in.
r_0+W radius, r_0 = 13.375 in.
Vessel radius, R_m = 100 in.

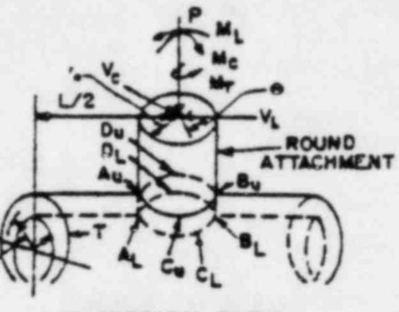
3. Geometric Parameters

γ $\frac{R_m}{T}$ = 100

β (0.875) $\frac{r_0}{R_m}$ = .1170

Stress Concentration due to:
a) membrane load, Kn = 1
b) bending load, Kb = 1

*NOTE: Enter all force values in accordance with sign convention



CYLINDRICAL SHELL

A&B	C&D	From Fig.	Read curves for	Compute absolute values of stress and enter result •	Au	AL	Bu	BL	Cu	CL	Du	DL
					STRESSES – if load is opposite that shown, reverse signs shown							
14.482	10.297	3C or 4C	$\frac{N\phi}{P/R_m}$ =	$K_n\left(\frac{N\phi}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 724/515	-724	-724	-724	-724	-515	-515	-515	-515
.044	.076	1C or 2C-1	$\frac{M\phi}{P}$ =	$K_b\left(\frac{M\phi}{P}\right)\cdot\frac{6P}{T^2}$ = 1520/2280	-1520	+1520	-1520	+1520	-2280	+2280	-2280	+2280
4.036		3A	$\frac{N\phi}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = -52					+52	+52	-52	-52
.078		1A	$\frac{M\phi}{M_c/R_m\beta}$ =	$K_b\left(\frac{M\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = -600					+600	-600	-600	+600
10.791		3B	$\frac{N\phi}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 129	-129	-129	+129	+129				
.028		1B-1	$\frac{M\phi}{M_L/R_m\beta}$ =	$K_b\left(\frac{M\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 201	-201	+201	+201	-201				
		Add algebraically for summation of Φ stresses, σ_ϕ			-2574	668	-1714	524	-2143	1217	-3447	2313
10.297	14.482	3C or 4C	$\frac{N_x}{P/R_m}$ =	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 515/724	-515	-515	-515	-515	-724	-724	-724	-724
.076	.044	1C-1 or 2C	$\frac{M_x}{P}$ =	$K_b\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2}$ = 2280/1520	-2280	+2280	-2280	+2280	-1320	+1320	-1320	+1320
19		4A	$\frac{N_x}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = -93					+93	+93	-93	-93
.039		2A	$\frac{M_x}{M_c/R_m\beta}$ =	$K_b\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = -300					+300	-300	-300	+300
4.036		4B	$\frac{N_x}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 48	-48	-48	+48	+48				
.038		2B-1	$\frac{M_x}{M_L/R_m\beta}$ =	$K_b\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 273	-273	+273	+273	-273				
		Add algebraically for summation of X stress s, σ_x			-3116	1990	-2474	1540	-1651	389	-2437	803
		Shear stress due to Torsion, MT		$\tau_{\phi x} = \tau_{x\phi} = \frac{M_T}{2\pi r_0^2 T}$ = 9	+9	+9	+9	+9	+9	+9	+9	+9
		Shear stress due to load, Vc		$\tau_{x\phi} = \frac{V_c}{\pi r_0 T}$ = 138	+138	+138	-138	-138				
		Shear stress due to load, VL		$\tau_{x\phi} = \frac{V_L}{\pi r_0 T}$ = -155					+155	+155	-155	-155
		Add Algebraically for summation of shear stresses, τ =			147	147	-129	-129	164	164	-146	-146
		COMBINED STRESS INTENSITY - S =			3144	2006	2495	1556	2193	1248	3468	2327

1) When $\tau \neq 0$, S = largest absolute magnitude of either
$S = 1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right]$ or $\sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}$.

2) When $\tau = 0$, S = largest absolute magnitude of either
$S = \sigma_x$, σ_ϕ or $(\sigma_x - \sigma_\phi)$.

$N_x/(M_L/R_m^2\beta)$ so determined by (C_L) from Table 8 (see para. 4.3).

4.2.2.5.2: When considering bending moment (M_L): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ where K_L is given in Table 8.

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 Circumferential Stresses (σ_ϕ):

Step 1. Using the applicable values of β and γ

5-6

Location

surface stresses + shell initial stresses :

for Point Au , next to attachment

$SX_{total} = 9000 + (-4457) = 4543$ vs computer's 4547 ✓

$S\theta_{total} = 9000 + (-3495) = 5505$ vs computer's 5510 ✓

$S_I = \frac{1}{2}\left[4543 + 5505 + \sqrt{(4543 - 5505)^2 + 4(226)^2} \right]$

$= 5574$ vs computer's 5579 ✓

for Point Au , at $0.5\sqrt{R_m T}$

$SX_{total} = 9000 + (-2641) = 6359$ vs computer's 6351 ✓

$S\theta_{total} = 9000 + (-2093) = 6907$ vs computer's 6907 ✓

$S_I = \frac{1}{2}\left[6359 + 6907 + \sqrt{(6359 - 6907)^2 + 4(129)^2} \right]$

$= 6935$ vs computer's 6935 ✓

for Point Au , at edge of reinforcement

$SX_{total} = 9000 + (-3116) = 5884$ vs computer's 5873 ✓

$S\theta_{total} = 9000 + (-2374) = 6626$ vs computer's 6636 ✓

$S_I = \frac{1}{2}\left[5884 + 6626 + \sqrt{(5884 - 6626)^2 + 4(147)^2} \right]$

$= 6654$ vs computer's 6663 ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY BAH	REV	By		CHARGE NO. 54331
				Chkd		
Verification	DATE 11/5/82	DATE 11/82		Date		SHT 6-7 OF

GO 64 REV 4-73

membrane stresses :

for Point A_m, next to attachment

$SX = \frac{-4457 + 3139}{2} = -659$ vs computer's -658 ✓

$S\theta = \frac{-3495 + 1993}{2} = -751$ vs computer's -751 ✓

$$SI = \left| \frac{1}{2}\left[-659 - 751 - \sqrt{(-659 + 751)^2 + 4(266)^2} \right] \right|$$

$= 975$ vs computer's 974 ✓

for Point A_m, at $0.5\sqrt{R_m T}$

$SX = \frac{-2641 + 1703}{2} = -469$ vs computer's -469 ✓

$S\theta = \frac{-2093 + 817}{2} = -638$ vs computer's -638 ✓

$$SI = \left| \frac{1}{2}\left[-469 - 638 - \sqrt{(-469 + 638)^2 + 4(129)^2} \right] \right|$$

$= 708$ vs computer's 707 ✓

for Point A_m, at edge of reinforcement

$SX = \frac{-3116 + 1990}{2} = -563$ vs computer's -563 ✓

$S\theta = \frac{-2374 + 668}{2} = -853$ vs computer's -853 ✓

$$SI = \left| \frac{1}{2}\left[-563 - 853 - \sqrt{(-563 + 853)^2 + 4(147)^2} \right] \right|$$

$= 914$ vs computer's 915 ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY BAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/5/82	DATE 11/82		Chkd		SHT 6-8 OF
				Date		

membrane stresses + shell initial stresses :

for Point Am , next to attachment

$SX_{total} = 9000 + (-659) = 8341$ vs computer's 8342 ✓

$S\theta_{total} = 9000 + (-751) = 8249$ vs computer's 8249 ✓

$SI = \frac{1}{2}\left[8341 + 8249 + \sqrt{(8341-8249)^2 + 4(226)^2} \right]$

$= 8565$ vs computer's 8565 ✓

for Point Am , at $0.5\sqrt{R_m T}$

$SX_{total} = 9000 + (-469) = 8531$ vs computer's 8531 ✓

$S\theta_{total} = 9000 + (-638) = 8362$ vs computer's 8362 ✓

$SI = \frac{1}{2}\left[8531 + 8362 + \sqrt{(8531-8362)^2 + 4(129)^2} \right]$

$= 8601$ vs computer's 8601 ✓

for Point Am , at edge of reinforcement

$SX_{total} = 9000 + (-563) = 8437$ vs computer's 8437 ✓

$S\theta_{total} = 9000 + (-853) = 8147$ vs computer's 8147 ✓

$SI = \frac{1}{2}\left[8437 + 8147 + \sqrt{(8437-8147)^2 + 4(147)^2} \right]$

$= 8498$ vs computer's 8498 ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/5/82	DATE 11/82		Chkd		SHT 6-9 OF
				Date		

```
PROG E1027A, REV JAN 82    (WRC-107 REV MAR 79)
STRESS INTENSITIES AT LOADED ATTACHMENTS IN CYLINDERS AND SPHERES

INPUT
          ATTCHMTS     VESSEL      LOADING       ANALYSIS
              1         1=CYL      -1=FIXED         2D

                KN           KB          RM             T          LOC          C
              1.00         1.00     100.000         1.000       0.5000        1.65

                RO           TI          TP             W
             5.375          0.0       0.500         8.000

                 P           VL          VC            MC           ML           MT
           5000.00     -6500.00     5800.00     -15000.00     14000.00     10000.00

INITIAL STRESSES NEXT TO ATTCHMNT
   SX(AU)   SO(AU)   SX(CU)   SO(CU)   SX(AM)   SO(AM)   SX(CM)   SO(CM)
    9000.    9000.    9000.    9000.    9000.    9000.    9000.    9000.

INITIAL STRESSES AT LOC*SQRT(R*T)
   SX(AU)   SO(AU)   SX(CU)   SO(CU)   SX(AM)   SO(AM)   SX(CM)   SO(CM)
    9000.    9000.    9000.    9000.    9000.    9000.    9000.    9000.

INITIAL STRESSES AT EDGE OF REINF
   SX(AU)   SO(AU)   SX(CU)   SO(CU)   SX(AM)   SO(AM)   SX(CM)   SO(CM)
    9000.    9000.    9000.    9000.    9000.    9000.    9000.    9000.


OUTPUT
                  ✓
BIJLAARD COEFICIENTS                      ✓                       ✓
          NEXT TO ATTCHMNT         AT LOC*SQRT(R*T)        AT EDGE OF REINF
            A & B     C & D         A & B     C & D         A & B     C & D
NX/P       18.416    17.866        12.922    15.743        10.297    14.482
MX/P        0.182     0.137         0.116     0.078         0.076     0.044
NX/MC           3.039                   5.947                   7.249
MX/MC           0.061                   0.051                   0.039
NX/ML           2.246                   3.679                   4.036
MX/ML           0.093                   0.064                   0.038
NO/P       17.866    18.416        15.743    12.922        14.482    10.297
MO/P        0.137     0.182         0.078     0.116         0.044     0.076
NO/MC           2.317                   3.716                   4.036
MO/MC           0.105                   0.093                   0.078
NO/ML           7.825                  10.979                  10.791
MO/ML           0.058                   0.042                   0.028


54331 GLN 11-2-82
     ✓ RAH 11/82
ROUND ATTCHMT                                    ON A CYLINDRICAL VESSEL
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       OUTPUT EXCLUDING INITIAL STRESSES
       SURFACE STRESS INTENSITIES NEXT TO ATTCHMNT (U=OUTS);(L=INS)
       RC=  5.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL)
  ✓    SX    -4453.     3136.   -2588.     1449.    -2101.     1039.    -3470.     2150.
  ✓    SO    -3490.     1988.   -2081.     1200.    -2394.     1265.    -4646.     3320.
  ✓    TAU     266.      266.    -192.     -192.      293.      293.     -220.     -220.
  ✓    SI     4521.     3194.    2652.     1554.     2576.     1466.     4686.     3360.

       SURFACE STRESS INTENSITIES AT LOC*SQRT(R*T) (U=OUTS);(L=INS)
       RC= 10.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL )
  ✓    SX    -2649.     1712.   -1940.     1154.    -1438.      520.    -2106.      926.
  ✓    SC    -2093.      818.   -1452.      628.    -1763.      984.    -2826.     1883.
  ✓    TAU     128.      128.    -109.     -109.      143.      143.     -123.     -123.
  ✓    SI     2678.     1730.    1963.     1176.     1817.     1024.     2847.     1899.

       SURFACE STRESS INTENSITIES AT EDGE OF REINF (U=OUTS);(L=INS)
       RC= 13.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL )
  ✓    SX    -3127.     2001.   -2488.     1555.    -1643.      381.    -2432.      798.
  ✓    SC    -2364.      658.   -1711.      521.    -2159.     1233.    -3456.     2322.
  ✓    TAU     147.      147.    -129.     -129.      164.      164.     -146.     -146.
  ✓    SI     3155.     2017.    2509.     1570.     2207.     1263.     3476.     2336.

       OUTPUT INCLUDING INITIAL STRESSES
       SURFACE STRESS INTENSITIES NEXT TO ATTCHMNT (U=OUTS);(L=INS)
       RC=  5.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL)
       SX   ✓4547.    12136.    6412.    10449.     6899.    10039.     5530.    11150.
       SO   ✓5510.    10988.    6919.    10200.     6606.    10265.     4354.    12320.
       TAU     266.      266.    -192.     -192.      293.      293.     -220.     -220.
       SI   ✓5579.    12194.    6984.    10554.     7081.    10466.     5570.    12360.

       SURFACE STRESS INTENSITIES AT LOC*SQRT(R*T) (U=OUTS);(L=INS)
       RC= 10.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL )
       SX   ✓6351.    10712.    7060.    10154.     7562.     9520.     6894.     9926.
       SO   ✓6907.     9818.    7548.     9628.     7237.     9984.     6174.    10883.
       TAU     128.      128.    -109.     -109.      143.      143.     -123.     -123.
       SI   ✓6935.    10730.    7571.    10176.     7616.    10024.     6914.    10899.

       SURFACE STRESS INTENSITIES AT EDGE OF REINF (U=OUTS);(L=INS)
       RC= 13.375;
               (AU)      (AL)      (BU)      (BL)      (CU)      (CL )     (DU)      (DL )
       SX   ✓5873.    11001.    6512.    10555.     7357.     9381.     6568.     9798.
       SC   ✓6636.     9658.    7289.     9521.     6841.    10233.     5544.    11322.
       TAU     147.      147.    -129.     -129.      164.      164.     -146.     -146.
       SI   ✓6663.    11017.    7310.    10570.     7405.    10263.     6588.    11336.




       54331 GLN 11-2-82
          ✓ RAH 11/82
       ROUND  ATTCHMT                                     ON A CYLINDRICAL  VESSEL
```

```
OUTPUT EXCLUDING INITIAL STRESSES
CTRLINE STRESS INTENSITIES NEXT TO ATTCHMNT (M=CTRL)
RC=  5.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓-658.              -569.               -531.               -660.
SO            ✓-751.              -440.               -565.               -663.
TAU              266.             -192.                293.               -220.
SI            ✓ 974.               708.                842.                882.

CTRLINE STRESS INTENSITIES AT LOC*SQRT(R*T) (M=CTRL)
RC= 10.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓-469.              -393.               -459.               -590.
SC            ✓-638.              -412.               -390.               -472.
TAU              128.             -109.                143.               -123.
SI            ✓ 707.               512.                571.                668.

CTRLINE STRESS INTENSITIES AT EDGE OF REINF (M=CTRL)
RC= 13.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓-563.              -467.               -631.               -817.
SC            ✓-853.              -595.               -463.               -567.
TAU              147.             -129.                164.               -146.
SI            ✓ 915.               675.                731.                884.

OUTPUT INCLUDING INITIAL STRESSES
CTRLINE STRESS INTENSITIES NEXT TO ATTCHMNT (M=CTRL)
RC=  5.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓8342.              8431.               8469.               8340.
SO            ✓8249.              8560.               8435.               8337.
TAU              266.             -192.                293.               -220.
SI            ✓8565.              8698.               8746.               8558.

CTRLINE STRESS INTENSITIES AT LOC*SQRT(R*T) (M=CTRL)
RC= 10.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓ 8531.             8607.               8541.               8410.
SC            ✓ 8362.             8588.               8610.               8528.
TAU              128.             -109.                143.               -123.
SI            ✓ 8601.             8707.               8722.               8606.

CTRLINE STRESS INTENSITIES AT EDGE OF REINF (M=CTRL)
RC= 13.375;
                 (AM)                (BM)                (CM)                (DM)
SX            ✓8437.              8533.               8369.               8183.
SC            ✓8147.              8405.               8537.               8433.
TAU              147.             -129.                164.               -146.
SI            ✓8498.              8613.               8637.               8500.
```

54331 GLN 11-2-82
✓ RAW 11/82

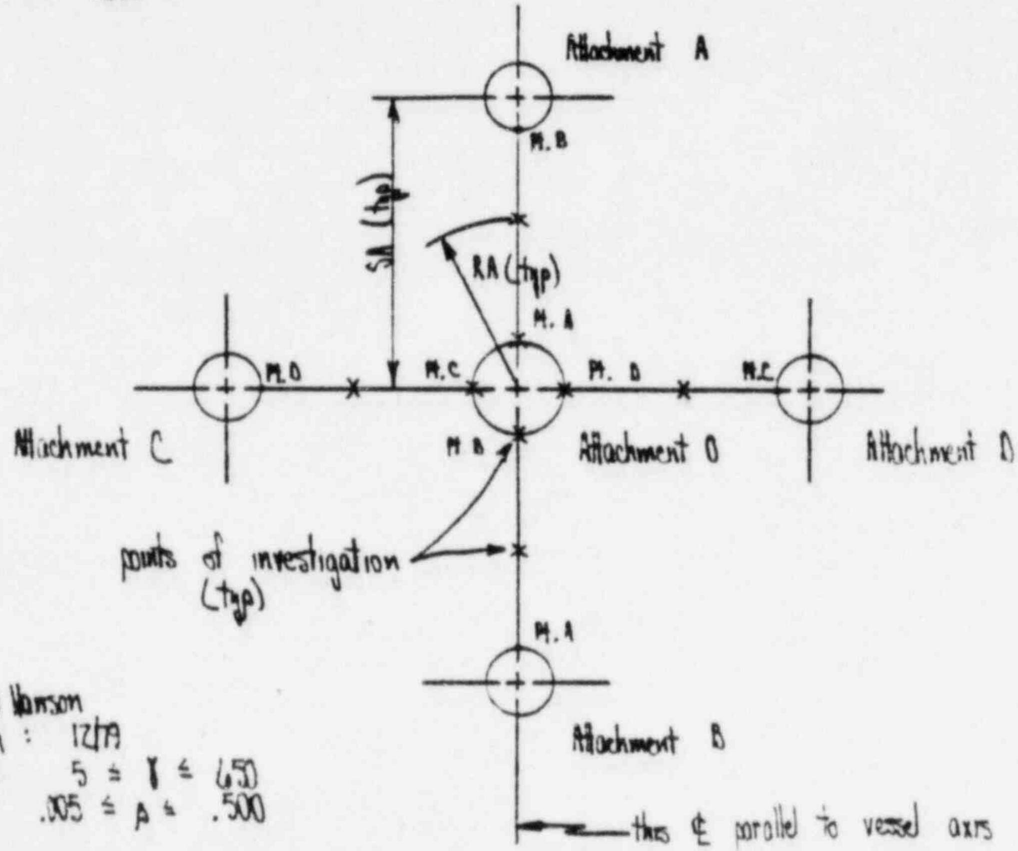
ROUND ATTCHMT ON A CYLINDRICAL VESSEL

CBI Program 1036

This program calculates the maximum stress intensity that is developed among several points of investigation around an externally loaded attachment on a jumbo insert plate in a cylindrical vessel. Stress analysis is in accordance with Welding Research Council Bulletin No. 107 (WRC-107).

Formulas and geometry used are the same as those used in CBI Program 1027.

In addition, for a group of penetrations the following geometry is used:



Author: RD Hanson
Dated Version: 12/79
Limitations: $5 \leq \gamma \leq 650$
$.005 \leq \beta \leq .500$

SUBJECT	Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
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					Date		SHT 7-1 OF

By superposition, the stresses at a point due to loads on an attachment are added to the stresses at the same point due to loads on an adjacent attachment.

for example:

stresses at Pt. A of Attachment 0 =

stresses at Pt. A due to loads on Attachment 0 +

stresses at Pt. A due to loads on Attachment A

Sample Problem:

Use the sample problem in CBI Program 1027 as Attachment 0.
In addition, RA = RB = RC = RD = 13.375", SA = SB = SC = SD = 26.75",
Loads on Attachment A: P = 5000 lbs, YL = -6500 lbs; Loads on Attachment B:
VL = -6500 lbs, VC = 5800 lbs; Loads on Attachment C: VC = 5800 lbs, ML = 14000 in-lbs;
Loads on Attachment D: ML = 14000 in-lbs, MC = -15000 in-lbs, MT = 10000 in-lbs.

Calculate the outer and inner surface stress intensities at Point A next to Attachment 0 and between Attachment 0 and Attachment A. Also calculate the outer and inner surface stress intensities including initial shell stresses, the membrane stress intensities, and the membrane stress intensities including initial shell stresses at Point A for both locations. Compare all calculations with computer values.

Table 5—Computation Sheet for Local Stresses in Cylindrical Shells

next to attachment 0 for adjacent attachments

acts on attachments A, B, C, D

1. Applied Loads*

Radial load, P = 5000 lb.
Circ. Moment, M_c = [illegible] in. lb.
Long. Moment, M_L = [illegible] in. lb.
Torsion Moment, M_T = [illegible] in. lb.
Shear Load, V_c = [illegible] lb.
Shear Load, V_L = [illegible] lb.

2. Geometry

T+TP Vessel thickness, T = 1.5 in.
SA- r_0 Attachment radius, r_0 = 21.375 in.
Vessel radius, R_m = 100 in.

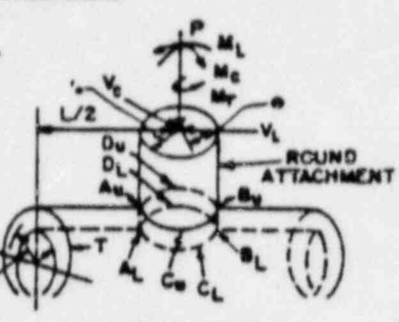
3. Geometric Parameters

$\gamma = \frac{R_m}{T}$ = 67

$\beta = (0.875)\frac{r_0}{R_m}$ = .1870

Stress Concentration due to:
a) membrane load, K_n = 1
b) bending load, K_b = 1

*NOTE: Enter all force values in accordance with sign convention



CYLINDRICAL SHELL

A&B	C&D	From Fig.	Read curves for	Compute absolute values of stress and enter result →		A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
						STRESSES – if load is opposite that shown, reverse signs shown							
11.519	5.771	3C or 4C	$\frac{N_\phi}{P/R_m}$ =	$K_n\left(\frac{N_\phi}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 384	192	−384	−384	−384	−384	−192	−192	−192	−192
.020	.045*	1C or 2C-1	$\frac{M_\phi}{P}$ =	$K_b\left(\frac{M_\phi}{P}\right)\cdot\frac{6P}{T^2}$ = 267	600	−267	+267	−267	+267	−600	+600	−600	+600
3.608		3A	$\frac{N_\phi}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N_\phi}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = −19						+19	+19	−19	−19
.060		1A	$\frac{M_\phi}{M_c/R_m\beta}$ =	$K_b\left(\frac{M_\phi}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = −128						+128	−128	−128	+128
7.967		3B	$\frac{N_\phi}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N_\phi}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 40		−40	−40	+40	+40				
.015		1B-1	$\frac{M_\phi}{M_L/R_m\beta}$ =	$K_b\left(\frac{M_\phi}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 30		−30	+30	+30	−30				
A&B	C&D	Add algebraically for summation of ϕ stresses, σ_ϕ				N/A →							
5.771	11.519	3C or 4C	$\frac{N_x}{P/R_m}$ =	$K_n\left(\frac{N_x}{P/R_m}\right)\cdot\frac{P}{R_mT}$ = 192	384	−192	−192	−192	−192	−384	−384	−384	−384
.045	.020*	1C-1 or 2C	$\frac{M_x}{P}$ =	$K_b\left(\frac{M_x}{P}\right)\cdot\frac{6P}{T^2}$ = 600	267	−600	+600	−600	+600	−267	+267	−267	+267
6		4A	$\frac{N_x}{M_c/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_c/R_m^2\beta}\right)\cdot\frac{M_c}{R_m^2\beta T}$ = −48						+48	+48	−48	−48
.067		2A	$\frac{M_x}{M_c/R_m\beta}$ =	$K_b\left(\frac{M_x}{M_c/R_m\beta}\right)\cdot\frac{6M_c}{R_m\beta T^2}$ = −58						+58	−58	−58	+58
3.656		4B	$\frac{N_x}{M_L/R_m^2\beta}$ =	$K_n\left(\frac{N_x}{M_L/R_m^2\beta}\right)\cdot\frac{M_L}{R_m^2\beta T}$ = 18		−18	−18	+18	+18				
.020		2B-1	$\frac{M_x}{M_L/R_m\beta}$ =	$K_b\left(\frac{M_x}{M_L/R_m\beta}\right)\cdot\frac{6M_L}{R_m\beta T^2}$ = 40		−40	+40	+40	−40				
		Add algebraically for summation of x stresses, σ_x				N/A →							
		Shear stress due to Torsion, M_T		$\tau_{x\phi} = \tau_{\phi x} = \frac{M_T}{2\pi r_0^2 T}$ = 2		+2	+2	+2	+2	+2	+2	+2	+2
		Shear stress due to load, V_c		$\tau_{x\phi} = \frac{V_c}{\pi r_0 T}$ = 58		+58	+58	−58	−58				
		Shear stress due to load, V_L		$\tau_{x\phi} = \frac{V_L}{\pi r_0 T}$ = −65						+65	+65	−65	−65
		Add algebraically for summation of shear stresses, τ				N/A →							
		COMBINED STRESS INTENSITY - S				N/A →							

1) When $\tau \neq 0$, S = largest absolute magnitude of either
$S = 1/2\left[\sigma_x + \sigma_\phi \pm \sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}\right]$ or $\sqrt{(\sigma_x - \sigma_\phi)^2 + 4\tau^2}$.

2) When $\tau = 0$, S = largest absolute magnitude of either
$S = \sigma_x$, σ_ϕ or $(\sigma_x - \sigma_\phi)$.

$N_x/(M_L/R_m^2\beta)$ so determined by (C_L) from Table 8 (see para. 4.3).

4.2.2.5.2: When considering bending moment (M_L): $\beta = K_L\sqrt[3]{\beta_1\beta_2^2}$ where K_L is given in Table 8.

* from Fig 1C-1 instead of 1C
* from Fig 2C-1 instead of 2C

4.3 Calculation of Stresses

4.3.1 STRESSES RESULTING FROM RADIAL LOAD, P.

4.3.1.1 *Circumferential Stresses* (σ_ϕ):

Step 1. Using the applicable values of β and γ

Surface Stresses at Attachment 0 (Stresses due to loads only)

for Point A(U)

SX = −4457 + (−192−600) = −5249 vs computer's −5240 ✓
SΘ = −3495 + (−384−267) = −4146 vs computer's −4142 ✓
τ = 266 + 0 = 266 vs computer's 266 ✓
$SI = \left| \frac{1}{2}\left[-5249-4146-\sqrt{(-5249+4146)^2+4(266)^2}\right] \right| =$ 5310 vs computer's 5301 ✓

for Point A(L)

SX = 3139 + (−192 + 600) = 3547 vs computer's 3539 ✓
SΘ = 1993 + (−384 + 267) = 1876 vs computer's 1872 ✓
τ = 266 + 0 = 266 vs computer's 266 ✓
SI = 3588 vs computer's 3580 ✓

Surface Stresses at Attachment 0 (Stresses due to loads and initial stresses)

for Point A(U)

SX = −5249 + 9000 = 3751 vs computer's 3760 ✓
SΘ = −4146 + 9000 = 4854 vs computer's 4858 ✓
τ = 266 = 266 vs computer's 266 ✓
SI = 4915 vs computer's 4919 ✓

for Point A(L)

SX = 3547 + 9000 = 12547 vs computer's 12539 ✓
SΘ = 1876 + 9000 = 10876 vs computer's 10872 ✓
τ = 266 = 266 vs computer's 266 ✓
SI = 12588 vs computer's 12580 ✓

Surface Stresses between Attachments (Stresses due to loads only)

for Point A(U)

SX = −3116 + (−515−2280) = −5911 vs computer's −5935 ✓
SΘ = −2574 + (−724−1320) = −4418 vs computer's −4402 ✓
τ = 147 + 0 = 147 vs computer's 147 ✓
SI = 5925 vs computer's 5949 ✓

for Point A(L)

SX = 1990 + (−515 + 2280) = 3755 vs computer's 3779 ✓
SΘ = 668 + (−724 + 1320) = 1264 vs computer's 1247 ✓
τ = 147 + 0 = 147 vs computer's 147 ✓
SI = 3764 vs computer's 3787 ✓

SUBJECT	MADE BY	CHKD BY	REV		CHARGE NO.
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Surface Stresses between Attachments (Stresses due to loads and initial stresses)

for Point A(U)

SX = -5911 + 9000 = 3089 vs computer's 3065 ✓
SΘ = -4418 + 9000 = 4582 vs computer's 4598 ✓
γ = 147 = 147 vs computer's 147 ✓
SI = 4596 vs computer's 4612 ✓

for Point A(L)

SX = 3755 + 9000 = 12755 vs computer's 12779 ✓
SΘ = 1264 + 9000 = 10264 vs computer's 10247 ✓
γ = 147 = 147 vs computer's 147 ✓
SI = 12764 vs computer's 12787 ✓

Membrane Stresses at Attachment 0 (Stresses due to loads only)

for Point A(M)

SX = ½(-5249 + 3547) = -851 vs computer's -851 ✓
SΘ = ½(-4146 + 1876) = -1135 vs computer's -1135 ✓
γ = 266 = 266 vs computer's 266 ✓
SI = 1295 vs computer's 1294 ✓

Membrane Stresses at Attachment 0 (Stresses due to loads and initial stresses)

for Point A(M)

SX = ½(3751 + 12547) = 8149 vs computer's 8149 ✓
SΘ = ½(4854 + 10876) = 7865 vs computer's 7865 ✓
γ = 266 = 266 vs computer's 266 ✓
SI = 8309 vs computer's 8308 ✓

Membrane Stresses between Attachments (Stresses due to loads only)

for Point A(M)

SX = ½(-5911 + 3755) = -1078 vs computer's -1078 ✓
SΘ = ½(-4418 + 1264) = -1577 vs computer's -1577 ✓
γ = 147 = 147 vs computer's 147 ✓
SI = 1617 vs computer's 1617 ✓

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				Date		SHT 7-5 OF ____

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Location__________

Membrane Stresses between Attachments (Stresses due to loads and initial stresses)

for Point A (M)

$S_X = \frac{1}{2}(3089 + 12755) = 7922$ vs computer's 7922 ✓

$S_\theta = \frac{1}{2}(4582 + 10264) = 7423$ vs computer's 7423 ✓

$\tau = 147 = 147$ vs computer's 147 ✓

$SI = 7962$ vs computer's 7962 ✓

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
Verification	DATE 11/9/82	DATE 11/82		Chkd		SHT 7-6 OF ____
				Date		

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```
PROG 1036: STRESS INTENSITIES IN JUMBO INSERT PLATES
                  CALCS & NOTATION PER WRC 107 REV 3/79;  PROG REV 12/79
 INPUT DATA
                                                      RVS LD    # OF LD     OUTPUT
     KN          KB          RM            C           CODE      CASES        CODE
    1.000       1.000     100.000       1.650           -1          1            3

     DISTANCES FROM CENTRAL ATTCHMT TO PTS OF INVESTIGATION
      RC               RA               RB               RC               RD
      5.375            13.375           13.375           13.375           13.375

     DISTANCE BETWEEN ATTCHMTS
        SA                    SB                    SC                    SD
      26.750                26.750                26.750                26.750

     INSERT OR SHELL PLATE THK AT PT OF INVESTIGATION
      TC               TA               TB               TC               TD
     1.5000           1.0000           1.0000           1.0000           1.0000

     LOADS AT ATTCHMTS FOR LOAD CASE =    1
     PT          P           VL          VC          ML          MC          MT
      C       5000.      -6500.       5800.      14000.     -15000.      10000.
      A       5000.      -6500.          0.          0.          0.          0.
      B          0.      -6500.       5800.          0.          0.          0.
      C          0.          0.       5800.      14000.          0.          0.
      D          0.          0.          0.      14000.     -15000.      10000.

     INITIAL STRESSES IN INSERT AT ATTCHMT
             ON OUTS OF SHELL OR INSERT           ON CTRLN OF SHELL OR INSERT
     PT       A       B       C       D        A       B       C       D
     SX   9000.   9000.   9000.   9000.    9000.   9000.   9000.   9000.
     SO   9000.   9000.   9000.   9000.    9000.   9000.   9000.   9000.

     INITIAL STRESSES IN INSERT AT PTS BTWN ATTCHMTS
             ON OUTS OF SHELL OR INSERT           ON CTRLN OF SHELL OR INSERT
     PT       A       B       C       C        A       B       C       D
     SX   9000.   9000.   9000.   9000.    9000.   9000.   9000.   9000.
     SC   9000.   9000.   9000.   9000.    9000.   9000.   9000.   9000.
```

54331 CLN 11-5-82
✓ RAH 11/82

```
PROG 1036 OUTPUT

BIJLAARD COEFFICIENTS

  AT ATTCHMT C             ✓                                       ✓
                  FOR CTR ATTACHMENT                       FOR ADJ ATTACHMENT
             A        B        C        D        A        B        C        D
  NX/P    18.416   18.416   17.866   17.866    5.771    5.771   11.519   11.519
  MX/P     0.182    0.182    0.137    0.137    0.045    0.045    0.020*   0.020*
  NX/MC    3.039    3.039    3.039    3.039    8.996    8.996    8.996    8.996
  MX/MC    0.061    0.061    0.061    0.061    0.027    0.027    0.027    0.027
  NX/ML    2.246    2.246    2.246    2.246    3.656    3.656    3.656    3.656
  MX/ML    0.093    0.093    0.093    0.093    0.020    0.020    0.020    0.020

  NO/P    17.866   17.866   18.416   18.416   11.519   11.519    5.771    5.771
  MO/P     0.137    0.137    0.182    0.182    0.020    0.020    0.045#   0.045#
  NO/MC    2.317    2.317    2.317    2.317    3.608    3.608    3.608    3.608
  MO/MC    0.105    0.105    0.105    0.105    0.060    0.060    0.060    0.060
  NO/ML    7.825    7.825    7.825    7.825    7.967    7.967    7.967    7.967
  MO/ML    0.058    0.059    0.058    0.059    0.015    0.015    0.015    0.015


  BTWN ATTCHMT             ✓                                       ✓
                  FOR CTR ATTACHMENT                       FOR ADJ ATTACHMENT
             A        B        C        D        A        B        C        D
  NX/P    10.297   10.297   14.482   14.482   10.297   10.297   14.482   14.482
  MX/P     0.076    0.076    0.044    0.044    0.076    0.076    0.044    0.044
  NX/MC    7.249    7.249    7.249    7.249    7.249    7.249    7.249    7.249
  MX/MC    0.039    0.039    0.039    0.039    0.039    0.039    0.039    0.039
  NX/ML    4.036    4.036    4.036    4.036    4.036    4.036    4.036    4.036
  MX/ML    0.038    0.038    0.038    0.038    0.038    0.038    0.038    0.038

  NO/P    14.482   14.482   10.297   10.297   14.482   14.482   10.297   10.297
  MO/P     0.044    0.044    0.076    0.076    0.044    0.044    0.076    0.076
  NO/MC    4.036    4.036    4.036    4.036    4.036    4.036    4.036    4.036
  MO/MC    0.078    0.078    0.078    0.078    0.078    0.078    0.078    0.078
  NO/ML   10.791   10.791   10.791   10.791   10.791   10.791   10.791   10.791
  MO/ML    0.028    0.028    0.028    0.028    0.028    0.029    0.028    0.028

*    COEF FROM FIG 2C-1 INSTEAD OF 2C
#    COEF FROM FIG 1C-1 INSTEAD OF 1C


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✓ RAH 11/82

```
 SURFACE   STRESSES FOR PTS.   AT ATTCHMT C( (U)=OUTS; (L)=INS )

        STRESSES DUE TO ATTCHMT LCADS ONLY
          A(U)        A(L)        B(U)        B(L)        C(U)        C(L)        D(U)        D(L)
  SX    -5240.✓     3539.✓    -2588.       1449.      -2101.       1039.      -3365.       2141.
  SC    -4142.✓     1872.✓    -2081.       1200.      -2394.       1265.      -4498.       3211.
  TAU     266.✓      266.✓     -135.       -135.        293.        293.       -218.       -218.
  SI     5301.✓     3580.✓     2621.       1508.       2576.       1466.       4539.       3253.

        STRESSES DUE TO ATTCHMT LOADS + INITIAL STRESSES
          A(U)        A(L)        B(U)        B(L)        C(U)        C(L)        D(U)        D(L)
  SX     3760.✓    12539.✓     6412.      10449.       6959.      10039.       5635.      11141.
  SC     4858.✓    10872.✓     6919.      10230.       6606.      10265.       4502.      12211.
  TAU     266.✓      266.✓     -135.       -135.        293.        293.       -218.       -218.
  SI     4919.✓    12580.✓     6953.      10508.       7081.      10466.       5675.      12253.


  SURFACE   STRESSES FOR PTS.   BTWN ATTCHMT( (U)=OUTS; (L)=INS )

        STRESSES DUE TO ATTCHMT LOADS ONLY
          A(U)        A(L)        B(U)        B(L)        C(U)        C(L)        D(U)        D(L)
  SX    -5935.✓     3779.✓    -2488.       1555.      -1643.        381.      -2038.        589.
  SC    -4402.✓     1247.✓    -1711.        521.      -2159.       1233.      -2807.       1778.
  TAU     147.✓      147.✓        9.          9.        164.        164.       -137.       -137.
  SI     5949.✓     3787.✓     2488.       1555.       2207.       1263.       2831.       1793.

        STRESSES DUE TO ATTCHMT LOADS + INITIAL STRESSES
          A(U)        A(L)        B(U)        B(L)        C(U)        C(L)        D(U)        D(L)
  SX     3065.✓    12779.✓     6512.      10555.       7357.       9381.       6962.       9589.
  SC     4598.✓    10247.✓     7289.       9521.       6841.      10233.       6193.      10778.
  TAU     147.✓      147.✓        9.          9.        164.        164.       -137.       -137.
  SI     4612.✓    12787.✓     7289.      10555.       7405.      10263.       6986.      10793.
```

54331 GLN 11-5-82

✓ GAH 11/8~

CBI

Location

CBI Program 1374

This program determines the basic behavior of thin walled elastic shells of revolution, when subjected to either static or dynamic pressures with arbitrary distribution over the surface of the shell. The geometry of the shell must be made up of spheres, torispheres, ellipsoids, and cylinders with stiffeners. Since the program is based on classical shell theory, it has the same limitations, namely:

1.) The material is linearly elastic.
2.) All displacements are very small.
3.) Both the stress and strain normal to the surface of the shell are so small that they may be neglected entirely.
4.) The shearing strains through the thickness are negligible so that normals to the midsurface remain straight and normal after deformation.
5.) Both principal radii are much greater than the shell thickness, so that $\frac{1}{R_\phi+t} \approx \frac{1}{R_\phi}$ and $\frac{1}{R_\theta+t} \approx \frac{1}{R_\theta}$

Generally R/t must be greater than 10 for adequate accuracy.

Author : J S Endicott

Dated Version : 12/75

Limitations : above

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
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				Date		SHT 8-1 OF

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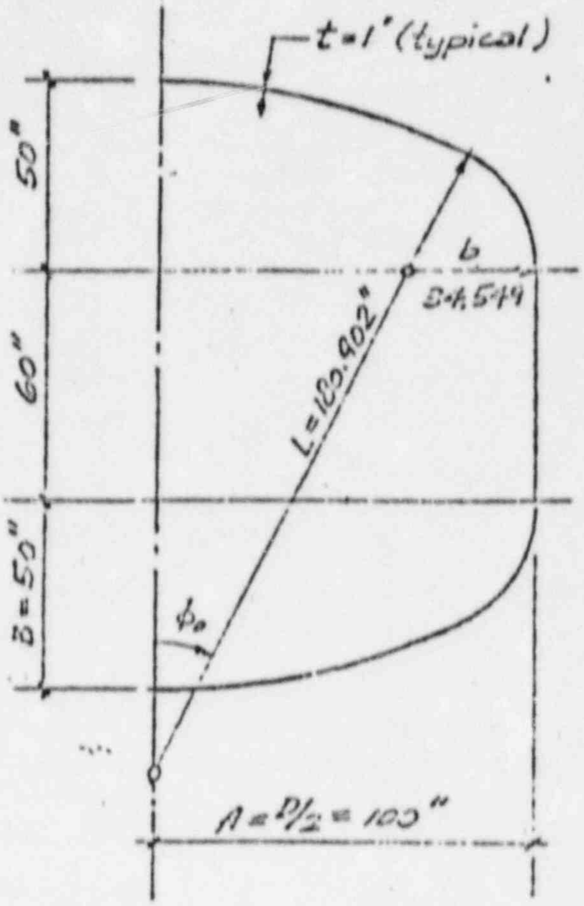
A.1 Example Problems: Static

A.1.1 Sample Problem 1, Comparison of 2/1 Ellipsoidal and Torispherical Heads

Geometry:

For this example, an equivalent torisphere will be defined as one that has the same height above the tangent line as the ellipsoid and has a minimal L/b ratio. (It thus has the least possible discontinuity between the torus and sphere.) It can be shown that for this geometry



$$\tan \phi_o = B/A = 1/2$$

$$\therefore \quad \phi_o = 26.567^\circ$$

$$L/A = \frac{c \pm \sqrt{c^2 - 2c}}{2}$$

$$c = B/A + A/B = 2\tfrac{1}{2}$$

$$\therefore \quad L = 50\left[\,2.5 + \sqrt{6.25 - 5.}\,\right] = 180.902"$$

$$b = B\left[\,B/A - L/A\,\right] + A = 50\left[0.5 - 1.80902\right] + 100. = 34.549"$$

Segment Lengths:

cylinder $\sqrt{rt} = \sqrt{100 \times 1} = 10.''$

torus $\sqrt{34.5 \times 1} = 5.9''$; $\frac{5.9 \times 57.3}{34.5} = 9.8^\circ$

sphere $\sqrt{180.9 \times 1} = 13.5''$; $\frac{13.5 \times 57.3}{180.9} = 4.3^\circ$

ellipsoid same as torisphere

However, the closer the pole or axis is approached the harder the equations become to integrate because of the factor 1/r which enters into them, r being the distance to the axis. One way to compensate for this is to use the distance to the pole as the radius in the above expressions.

sphere @ 5° from pole $r \simeq 180.9 \times \frac{5}{57.3} = 15.7''$

$\therefore \sqrt{rt} = \sqrt{15.7 \times 1} = 3.97''$; $\frac{3.97 \times 57.3}{180.9} = 1.26^\circ$

Actual segment lengths used in the torisphere:

5° to 10° 4 @ 1.25°

10° to 26.567° 4 @ 4.13°

26.567 to 90° 6 @ 10.57°

Boundary Conditions:

It will be assumed that, at 5° from the pole, a membrane state of stress exists in both the ellipsoid and the torisphere, or

$$Q = M_\phi = 0$$

$$N_\phi = \frac{pr}{2\sin\phi}$$

where r = distance to pole

Letting $p = 100$ psi

then for the torisphere

$$N_\phi = \frac{100}{2}(180.902) = 9045.1 \text{ lb./in.}$$

For the ellipsoid

$$r = \frac{A\sin\phi}{R}$$

where $R = \sqrt{C + (1-C)\sin^2\phi}$

$$C = (B/A)^2 = 1/4$$

$$\therefore \quad R = \sqrt{1/4 + 3/4\,(.0871557)^2} = 0.505664$$

$$N_\phi = \frac{A\sin\phi}{R}\,\frac{p}{2\sin\phi} = \frac{pA}{2R} = \frac{5000}{.5056} = 9887.97$$

However at the beginning edge a displacement component parallel to the axis of revolution must be specified. This is best done in this problem by defining the radial movement at the start. Assuming a sphere in a membrane state of stress

8-4

$$w = \frac{p\tilde{L}^2}{Et}\frac{(1-\mu)}{2}$$

where $\tilde{L}$ = radius of spherical cap which would be required to close the remaining distance to the pole

E = Young's modulus = 30 000 000.

μ = Poisson's ratio = 0.3

$$\tilde{L} = \frac{r}{\sin\phi} = \frac{A}{R} = \frac{100}{.5056} = 197.76$$

$$\therefore \quad w = \frac{(100)(197.76)^2(.7)}{30(10^6)(1)(2)} = 0.045627$$

This value of w would be equivalent to setting Q=0. The center of radius for the sphere would be the reference point, i.e. it would not move if the sphere expanded uniformly as assumed.

But, in order to better compare the heads, it seemed desireable to have the displacement at the center of the cylinder zero. Therefore the problem was solved twice, the results of the first run yielding the w required for zero displacement at the center:

8-5

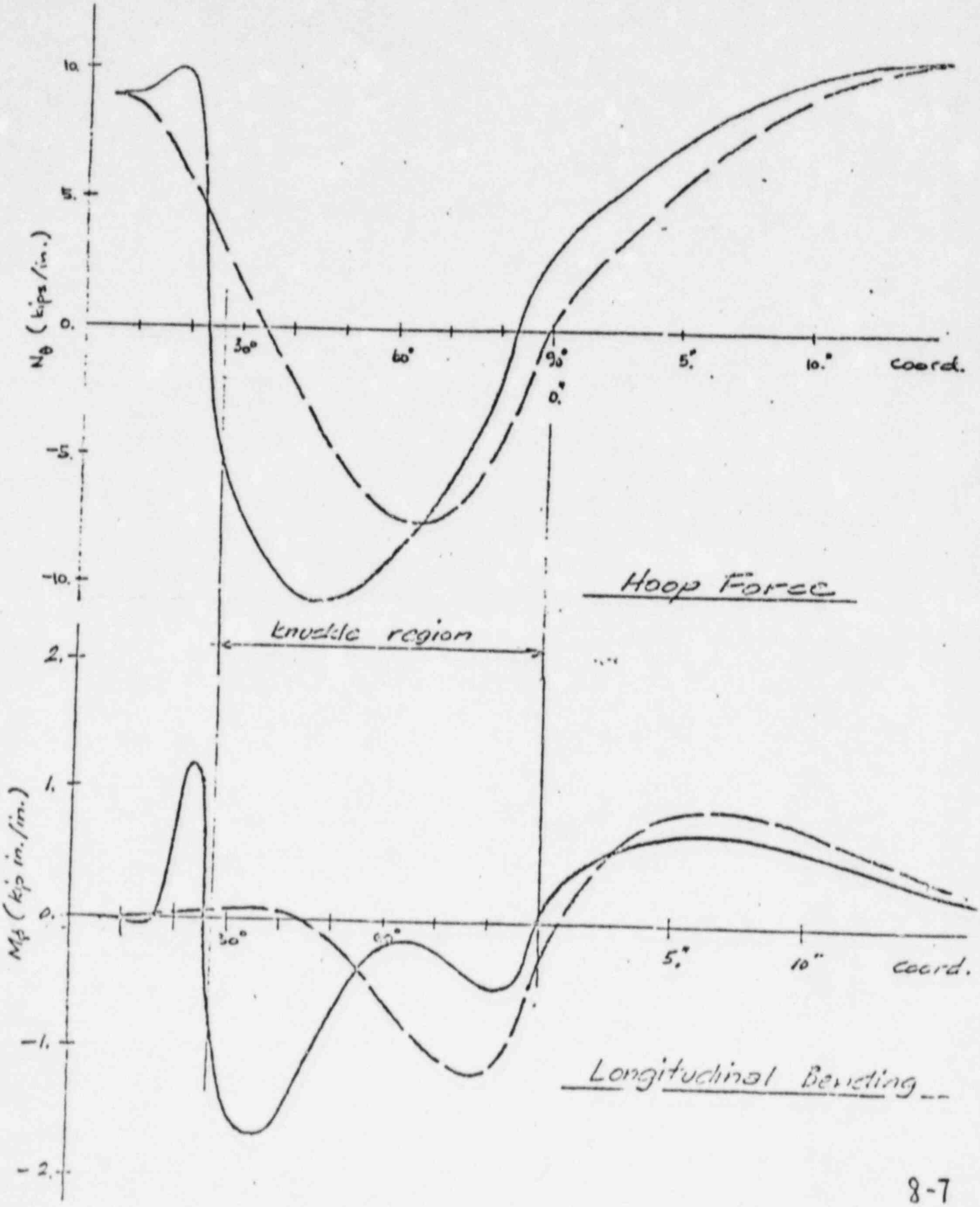
Results:

In order to check the results, first the answers at the boundaries should be examined. For example, in this problem it was assumed that there was a membrane state of stress at the boundaries. Therefore at the edges Q and M_ϕ must be approximately zero. If this is not the case either the assumption or the data is wrong. Also, in this problem, N_θ should be approximately equal to N_ϕ if a membrane state exists

Note, too, that in order to satisfy equilibrium in the cylinder, $N_\phi = 0.5\,pr = 5000$ lb./in.

The segment lengths are adequately short since there is good agreement between beginning and end of segments.

The difference in the two heads shows up quite well in the plots of hoop force and longitudinal bending on the next page. Even though the change in radii has been minimized the disturbance at the junction of the sphere and torus is considerable.


10.
5.
0.
-5.
-10.
N_θ (kips/in.)
30°
60°
90°
0.°
5."
10."
coord.
Hoop Force
knuckle region
2.
1.
0.
-1.
-2.
M_ϕ (kip in./in.)
30°
60°
5."
10"
coord.
Longitudinal Bending

A.1.2 Sample Problem 2: Spherical Roof under Asymmetric Snow Load

Geometry:

tank dia. = 500."

roof radius = 650."

height to dome = 576."

compression member =

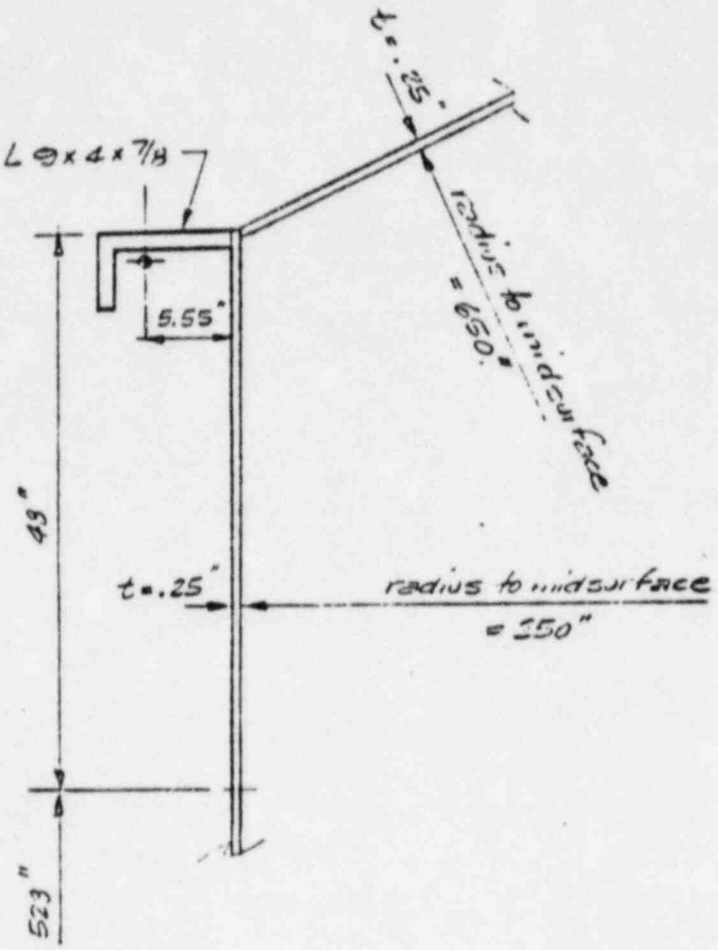
L 9x4x7/8

$I = 86.8$ in.^{4}

$A = 10.61$ in.^{2}

$\bar{y} = 3.45"$

shell thickness = 1/4"

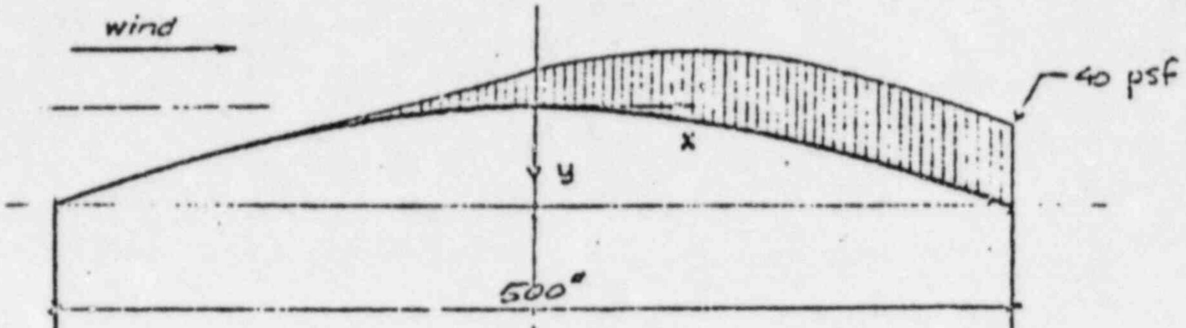


Assuming that accurate stresses are desired in the roof and about 2' of shell, use $24" + 3\sqrt{Rt} = 48"\pm$

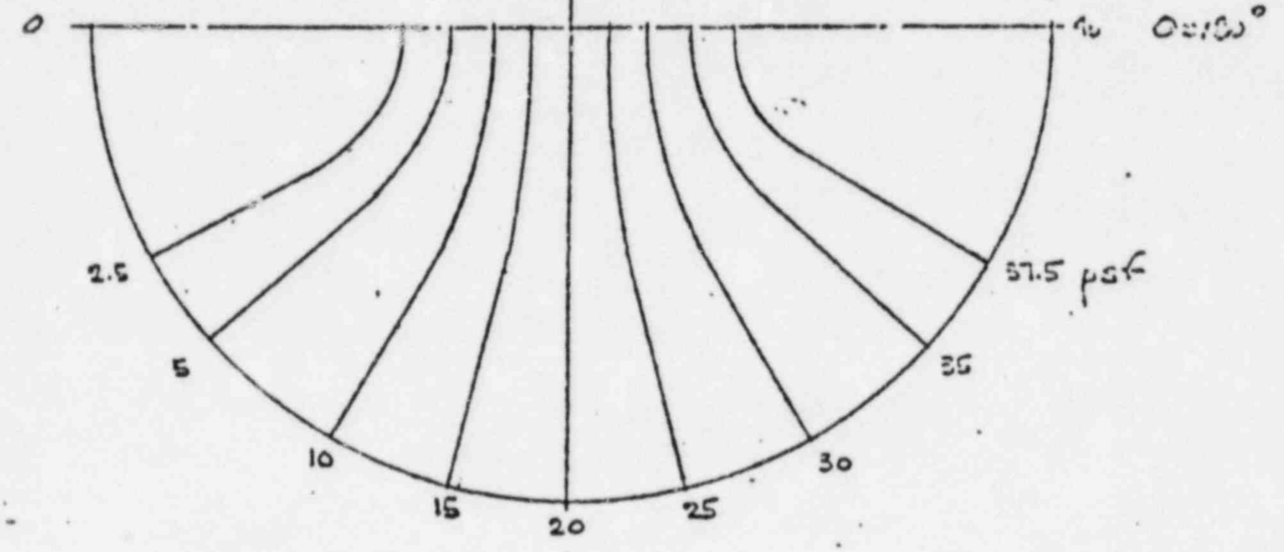
loading:

The distribution of wind blown snow will be approximated by the loading $p = p_0 + p_1(\theta)\cos\theta$ as shown below, where $p_0 = p_1(\max) = 30$ psf.

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
Sample Problem 2	[illegible]			Chkd		
	DATE 9/78	DATE		Date		SHT 1 OF 6



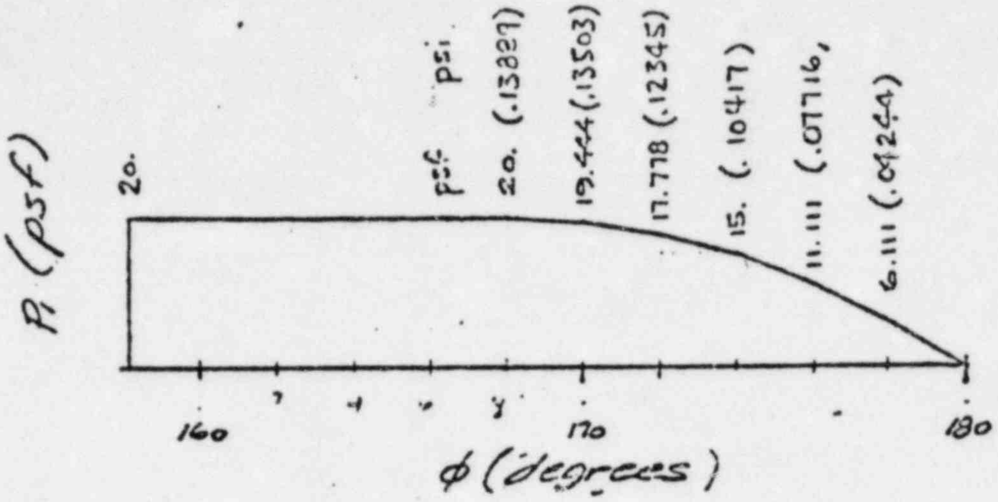
Section thru Axis of Symmetry



Contour Plan of Snow Pressure

To the p_0 above will be added the weight of the plate 10.2 psf. The total uniform load then is $p_0 = -.20972$ psi (neglecting the slope of the plate). The value of $p_1(\phi)$ is entered as a series of straight lines as follows:

SUBJECT [illegible]	MADE BY [illegible]	CHKD BY	REV	By		CHARGE NO.
				Chkd		
	DATE 5/79	DATE		Date		SHT. 5 OF 6



On the cylinder, a wind load of $p = -.2\cos\theta$ has been used.

Boundary Conditions:

Physically there is no cut at the pole, hence no boundary. But mathematically there must be two boundaries. This situation is handled in the program by making a small hole at the pole and filling it with a modified flat plate stiffness matrix. The radius of the hole is 1/50 of the radius to the next to last output point.

At the start of the problem the structure must be fixed against rotation about an axis thru $\theta = \pm 90°$ and horizontal and vertical movement. This is best done by specifying u_ϕ and u_θ at the start. If only stresses and relative displacement are desired, these initial

8-10

displacements can be set arbitrarily. If absolute deflections (i.e. relative to the base) are needed, one can consider the part of the cylindrical tank which is not included in the above model as a beam/column of circular section. Then for $n=0$

$$u_\phi = \frac{PL}{EH} = \frac{N_\phi(2\pi 250)\,528}{30(10^6)\,2\pi 250(1/4)} = N_\phi\,70.4(10^{-6})$$

For $n=1$, bending

$$u_\theta = \frac{qL^4}{8EI} + \frac{PL^3}{3EI} + \frac{ML^2}{2EI}$$

$$= \left[\frac{.2(528)^4}{8} + \frac{N(528)^3}{3} + \frac{N_\phi(250)(528)^2}{2}\right]\frac{\pi 250}{30(10^6)\,\pi(250)^3}$$

$$= \left[\frac{105.6(5.28)^3}{8} + \frac{N(5.28)^3}{3} + N_\phi\frac{(2.5)(5.28)^2}{2}\right]10^{-4}/30.(2.50)^2\,1/4$$

$$u_\theta = (41.451 + 1.0467N + .74342N_\phi)10^{-4}$$

$$\frac{u_\phi}{r} = \frac{qL^3}{6EI} + \frac{PL^2}{2EI} + \frac{ML}{EI}$$

$$u_\phi = \left[\frac{105.6(5.28)^2}{6} + N\frac{(5.28)^2}{2} + N_\phi(2.5)(5.28)\right]10^{-4}/30.(2.5)\,1/4$$

$$u_\phi = (26.167 + .74342N + .70400N_\phi)10^{-4}$$

To complete the membrane type boundary conditions $Q = u_\phi = 0$ in both harmonics.

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SUBJECT Sample Problem 2	MADE BY JTF	CHKD BY	REV	By		CHARGE NO.
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n = 1, shear displacement

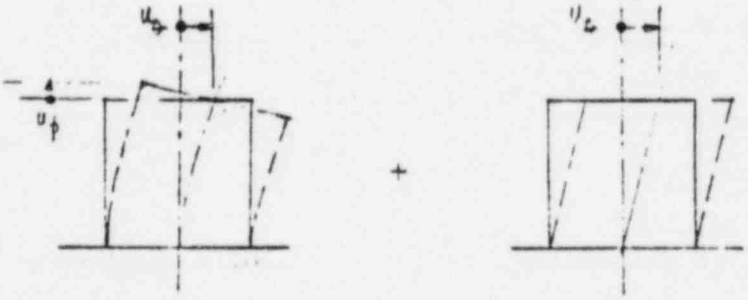
This is a very short beam, with a length only slightly greater than its depth. There fore the shear deformation is significant. The shear deformation can be obtained by integrating the shear strain along the center line of the beam, $\theta = \pm 90^\circ$.

$$u_z(L) = \int_0^L \frac{\tau(s)}{G}\,ds$$

$$= \int_0^L \left(\frac{N + qs}{Gt}\right) ds = \left(NL + q\frac{L^2}{2}\right)/Gt$$

$$u_z = N\,\frac{528\,(10^{-6})}{11.538\,(1/4)} + \frac{(.2)(528^2)\,10^{-6}}{(2)\,11.538\,(1/4)} = 183.04(10^{-6})N + .009664$$

This should be added to the bending value.



So that the final spring matrix is:

$$\begin{bmatrix} Q \\ u_\phi \\ M_\phi \\ u_z \end{bmatrix} = \begin{bmatrix} 0. & 0. & 0. & 0. \\ 0. & .70400 & 0. & .74342 \\ 0. & 0. & 0. & 0 \\ 0. & .74342 & 0. & 2.5711 \end{bmatrix} \begin{bmatrix} H \\ M_\phi \\ Q_1 \\ N \end{bmatrix} 10^{-4} + \begin{bmatrix} 0. \\ .002617 \\ 0. \\ .013810 \end{bmatrix}$$

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Location

Results:

Checking the boundary, there is very little disturbance in the displacements caused by setting Q=M=0. on the boundary so it can be concluded that things have essentially reached a membrane state at the boundary.

The printed results here demonstrate output at various angles. The plotted results illustrate output at various angles and combining more than one plot on a page. Also note here that OUTPUT=2 has been used. As a result the data are printed as stored in COMMON and the stiffness matrices which are generated by the program are also printed.

SUBJECT Sample Problem 2	MADE BY JSB	CHKD BY	REV	By		CHARGE NO.
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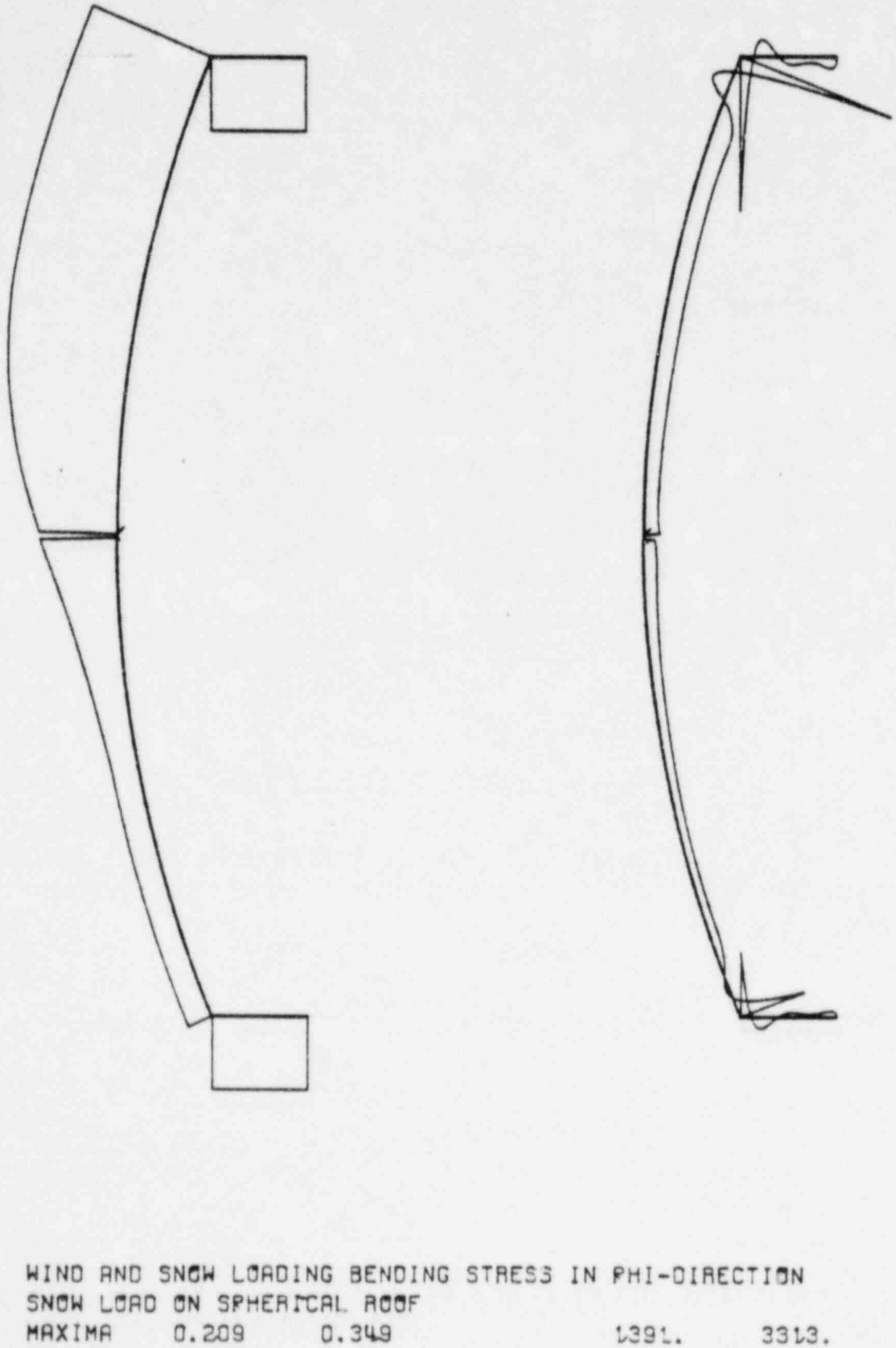


WIND AND SNOW LOADING BENDING STRESS IN PHI-DIRECTION
SNOW LOAD ON SPHERICAL ROOF
MAXIMA 0.209 0.349 1391. 3313.

ation

A.1.3

Sample Problem 3, Inclined Cylinder under Hydrostatic Loading

Geometry:

This is a uniform cylinder with

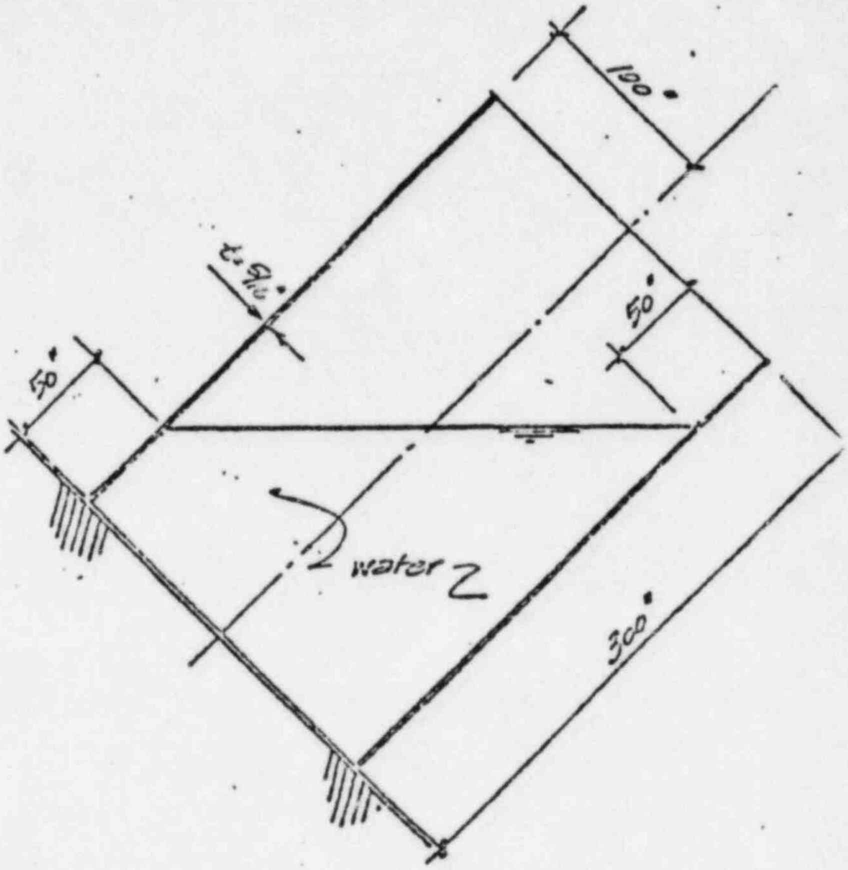
radius = 100."

length = 300."

thickness = 5/16"

Segment Lengths:

$\sqrt{100 \times 5/16} = 5.6$



Because output points were desired at the start and end of the partially loaded region, 50" to 250", the total number of segments was set at a multiple of 6.

Taking a segment length of $\sim 1\frac{1}{2}\sqrt{Rt}$, use 36 segments.

Boundary Conditions:

The shell is free at the end, $Q = N_\phi = M_\phi = N = 0$.

In order to better compare with Flügge's membrane solution membrane conditions were used at the start, $Q = u_\phi = M_\phi = u_\theta = 0$.

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Sample Problem 3	JSE					
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Loading:

The problem was taken from Flügge's "Stresses in Shells" pp. 118-119. The loading, in the loaded region is given as

$$p = -\gamma\,(x \cos\alpha + r \sin\alpha \cos\theta)$$

using Kalnins' notation with max. pressure at 180°, where

γ = density = 64 #/ft³ = .0370370 #/in³

α = angle of inclination = 45°

r = radius = 100.″

x = distance along the meridian from a point 150″ from the base to the point at which the pressure is being calculated.

There fore

$$p(x,\theta) = -3.70370\,\frac{\sqrt{2}}{2}\left(\frac{x}{r} + \cos\theta\right)$$, where p positive

This function was expanded into a Fourier series at

$x/r = 0, \pm 0.2, \pm 0.4, \pm 0.6, \pm 0.8, -1., -1.5$

for a total of 11 series. The amplitudes at +1. and +1.5 are all zero. Letting

$\xi_i = x_i/r$

x_i = x at the ith elevation

θ_i = one half of the angle over which the pressure is applied at the ith elevation

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				DATE		SHT 2 OF 6

Then the amplitudes of the nth harmonic at the ith elevation are:

$$a_{i0} = C\left[-\xi_i\theta_i + \sin\theta_i\right]$$

$$a_{i1} = C\left[2\xi_i \sin\theta_i - \sin\theta_i\cos\theta_i - \theta_i\right]$$
$$= C\left[\ \xi_i \sin\theta_i - \theta_i\right]$$

$$a_{in} = C\left[-2\xi_i \frac{\sin n\theta_i}{n} + \frac{\sin(n-1)\theta_i}{n-1} + \frac{\sin(n+1)\theta_i}{n+1}\right], n>1$$

where

$$C = \frac{3.7037}{\pi}\frac{\sqrt{2}}{2} = .83362$$
$$\theta_i = \text{arc}\cos\xi_i$$

Evaluating all the a_{in} yields a 13×10 matrix which is shown on the next page. The rows of this matrix are the amplitudes of the Fourier terms at the given elevation. The columns are the function generators for the indicated harmonic.

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Sample Problem 3	JBE		BY		
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Location Oak Brook

S	$\bar{F}_i$	θ_i	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
300.	1.5	0.	.0	.0	.0	.0	.0					
250.	1.0	0.	.0	.0	.0	.0	.0					
230.	.8	36.8696	.071	-.136	.120	-.076	.068	-.041	.017	.0	-.009	.01
210.	.6	53.1299	.203	-.373	.235	-.171	.066	.004	-.032	.027	-.007	-.0
190.	.4	66.4218	.378	-.661	.428	-.171	-.003	.059	-.032	-.010	.024	-.
170.	.2	78.4631	.539	-.978	.523	-.105	-.079	.056	.018	-.033	.0	.0
150.	.0	90.	.834	-1.310	.556	.0	-.111	.0	.048	.0	-.026	.0
130.	-.2	101.5369	1.112	-1.641	.523	.105	-.079	-.056	.018	.033	.0	-.0
110.	-.4	113.5782	1.425	-1.959	.428	.171	-.003	-.059	-.032	.010	.024	.0
90.	-.6	126.8701	1.774	-2.246	.235	.171	.066	-.004	-.032	-.027	-.007	.0
70.	-.8	143.1304	2.166	-2.483	.120	.076	.068	.041	.017	.0	-.009	-.01
50.	-1.0	180.	2.619	-2.619	.0	.0	.0					
0.	-1.5	180.	3.928	-2.619	.0	.0	.0					

SUBJECT Sample Problem 3	MADE BY JSE DATE 12-/73	CHKD BY DATE	REV	BY CHKD DATE	CHARGE NO. SHT 4 OF 6

Results:

The first 3 plots show the loading plotted in various fashions. The curves only approximate the loading, of course, since we are using 10 functions with continuous derivatives to represent a function which has a discontinuity in its slope. There fore at the air/water interface we get faired-in pressures in stead of an abrupt change. This error can be made smaller by adding more terms to the series. For example at $\xi = 0$ and $\theta = 90°$ the pressure reduces to

$$p = C\left[1 - (1 - 1/3) + (-1/3 + 1/5) - (1/5 - 1/7) + (-1/7 + 1/9)\right] = C/9 = .09$$

so that the error is inversely proportional to the number of terms included.

The curves for N_ϕ or N_x differ from those in Flügge's "Stresses in Shells", pp. 118-119, principally in the manner presented. Flügge's curve are plotted on the projection of the cylinder while the plots here are made on half of the circumference. Since this is a rather thin shell without disruptions one would expect that Flügge's membrane solution to be quite close to the solution including bending. This is indeed the case. At the

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angle where maximum pressure occurs ($\theta = 0°$ in Flügge's example and $\theta = 180°$ in this example) the results at $\xi = -1.$ ($s = 50°$) and $\xi = 0$ ($s = 150°$) are

	Flügge's membrane		program results	
	$s = 50$	$s = 150$	$s = 50$	$s = 150$
N_ϕ	−523.8	−130.9	−513.8	−126.9
N_θ	522.2	261.2	523.8	261.3

At 60° from the above angle with $\xi = -1.$ ($s = 50°$)

$N_{\phi\theta}$	340.2	340.3

At 45° from the angle of maximum pressure with $\xi = 0$ ($s = 150°$)

$N_{\phi\theta}$	130.9	129.7

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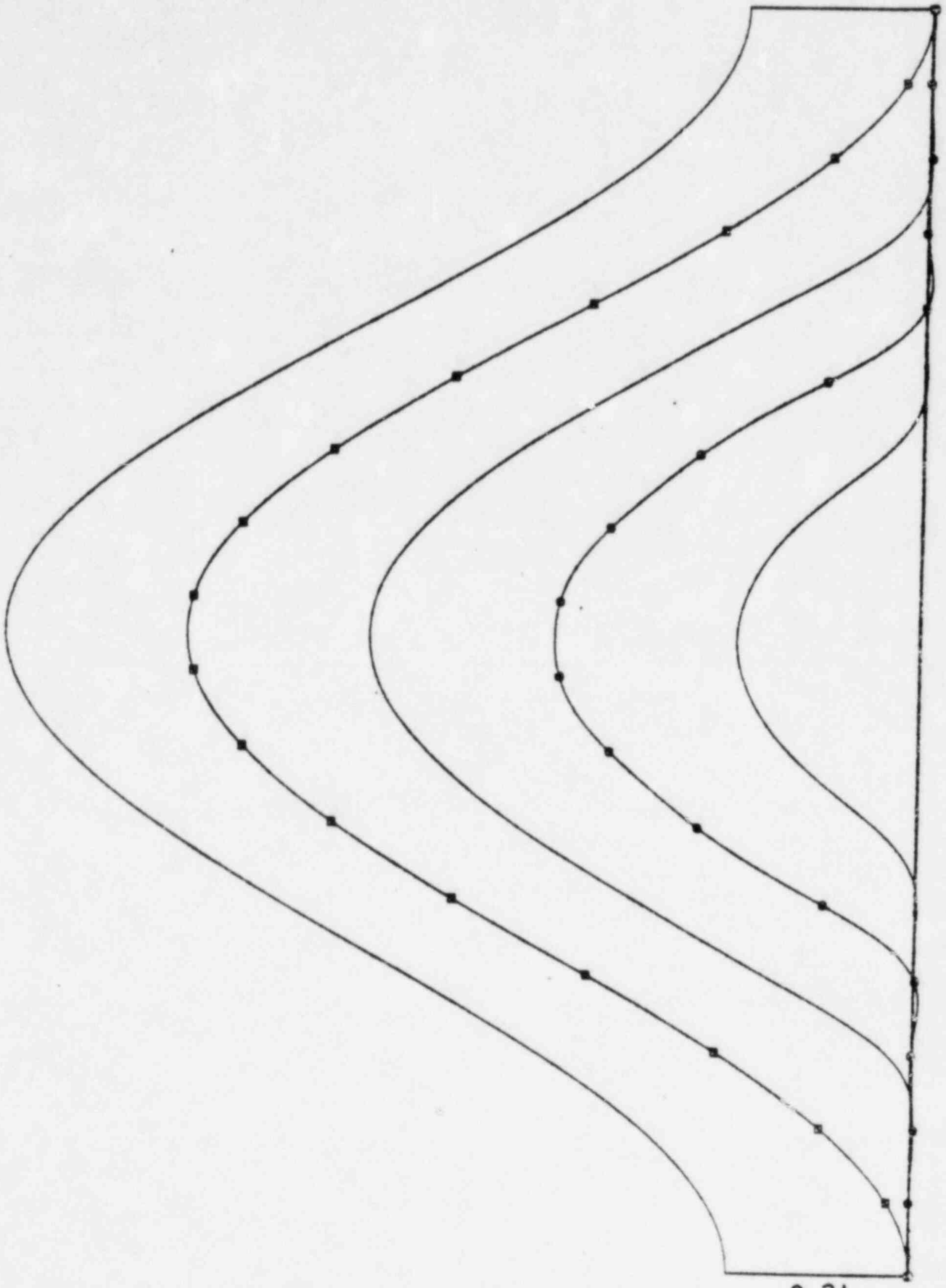
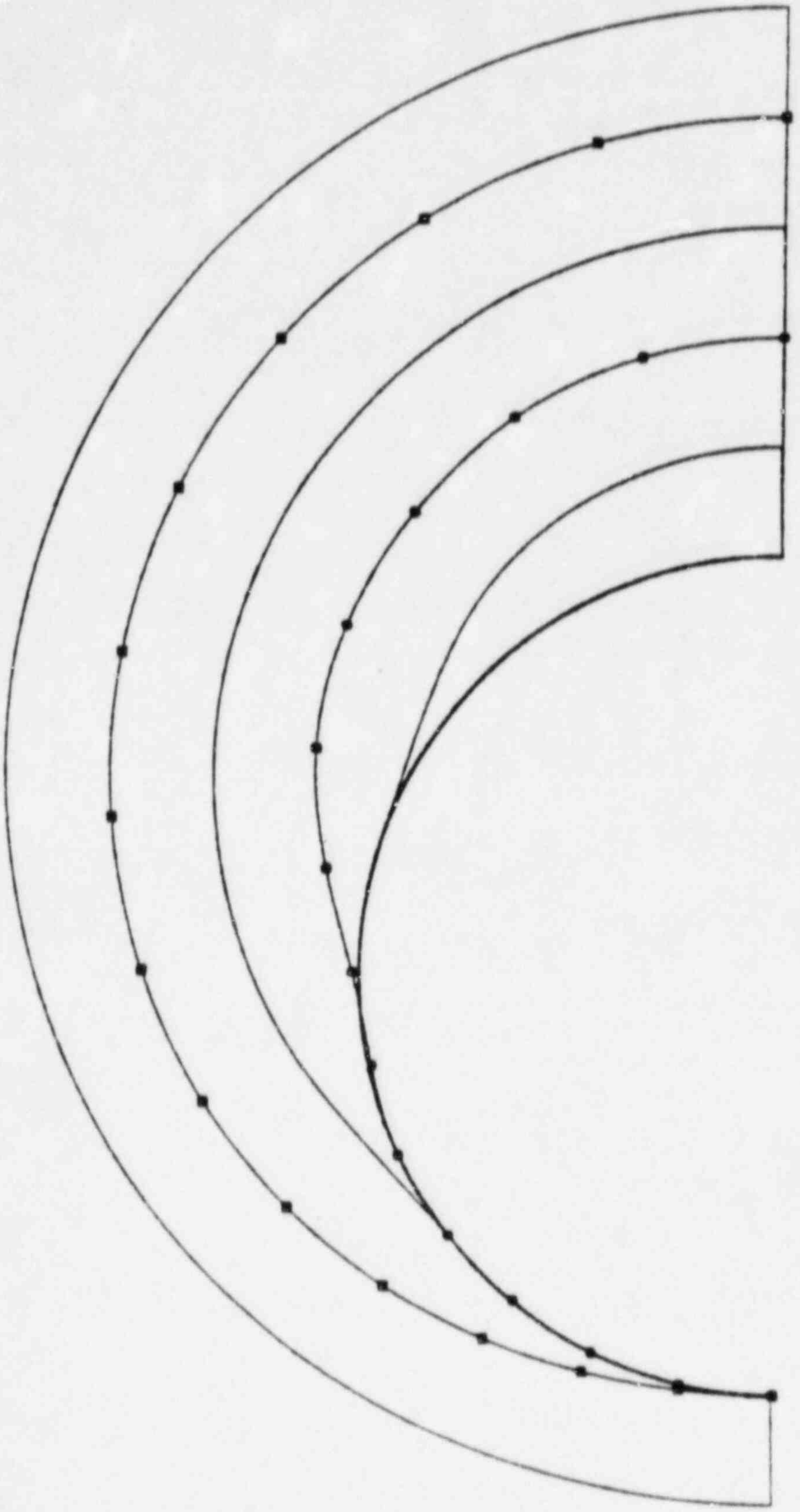
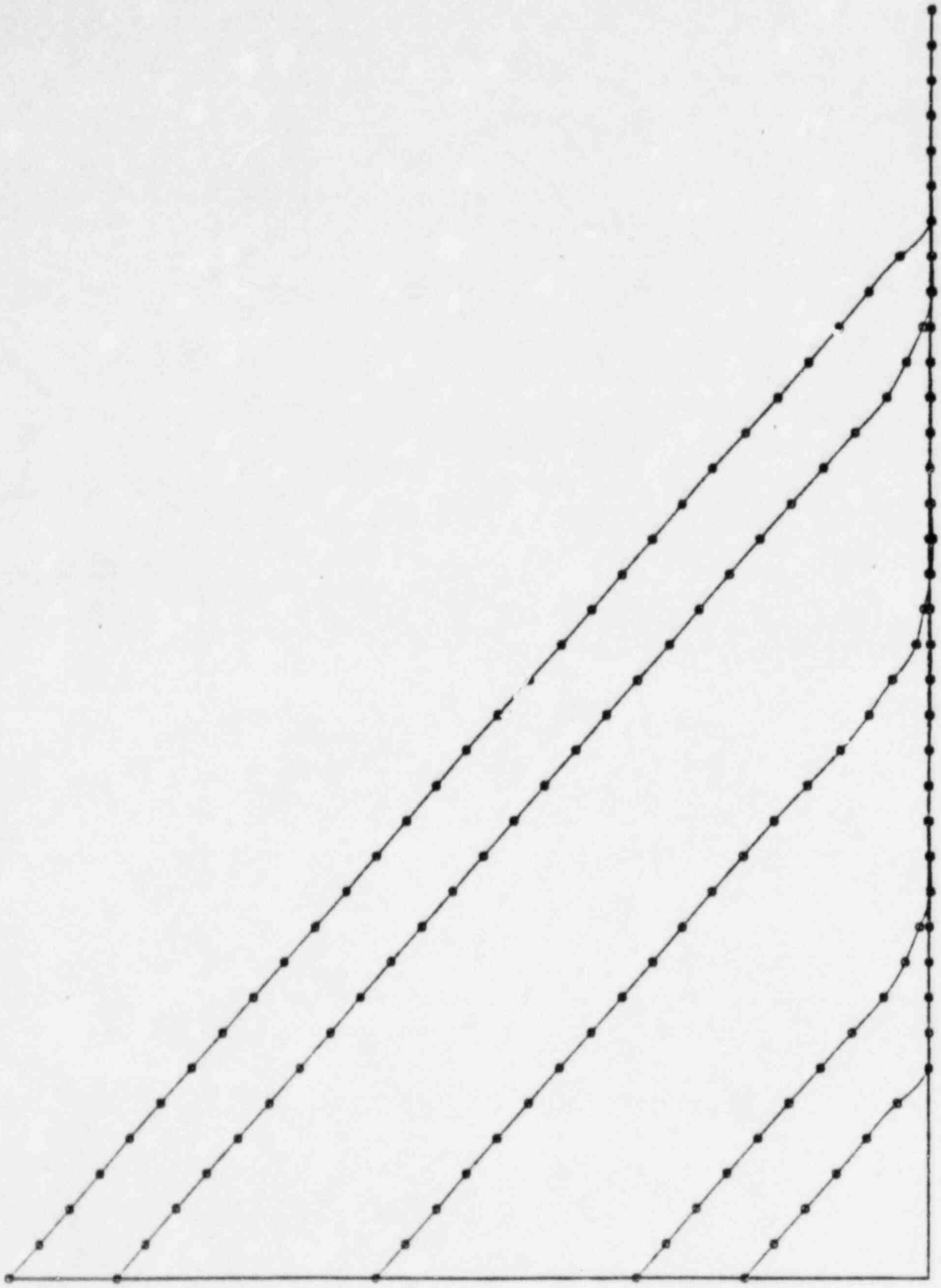
			DATE		SHT 6 OF 6



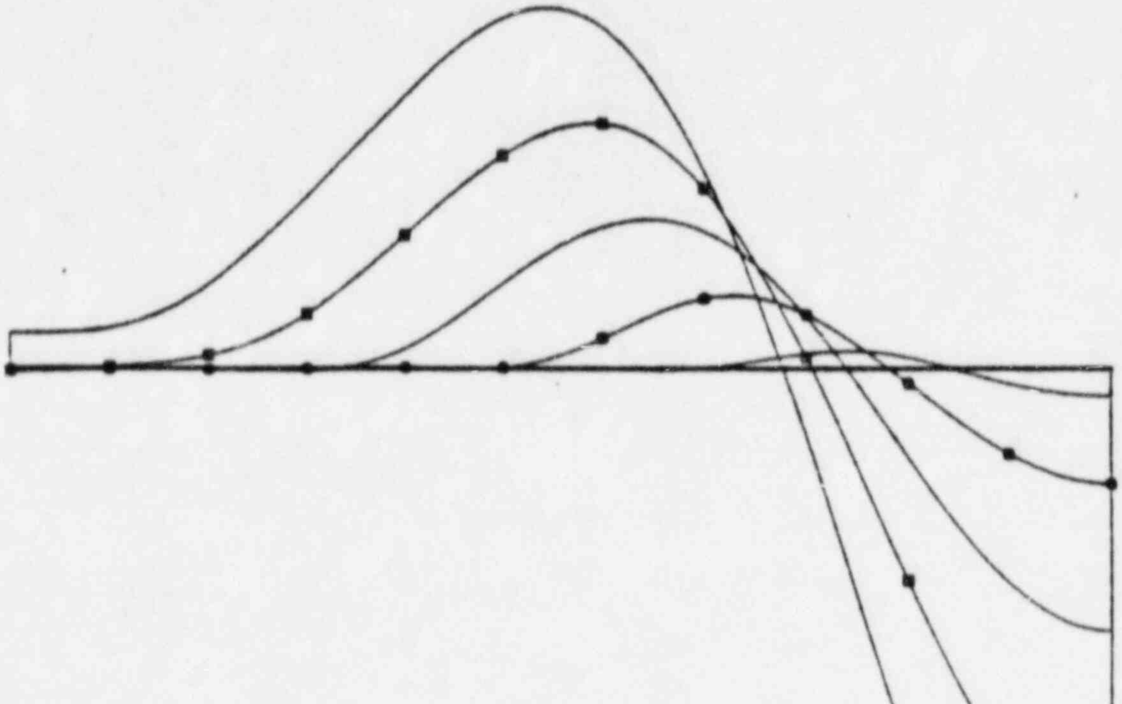
PRESSURE DISTRIBUTION AT 50 INCH INTERVALS (SCALE: INCH=PSI)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 6.547 5.238 3.926 2.611 1.312



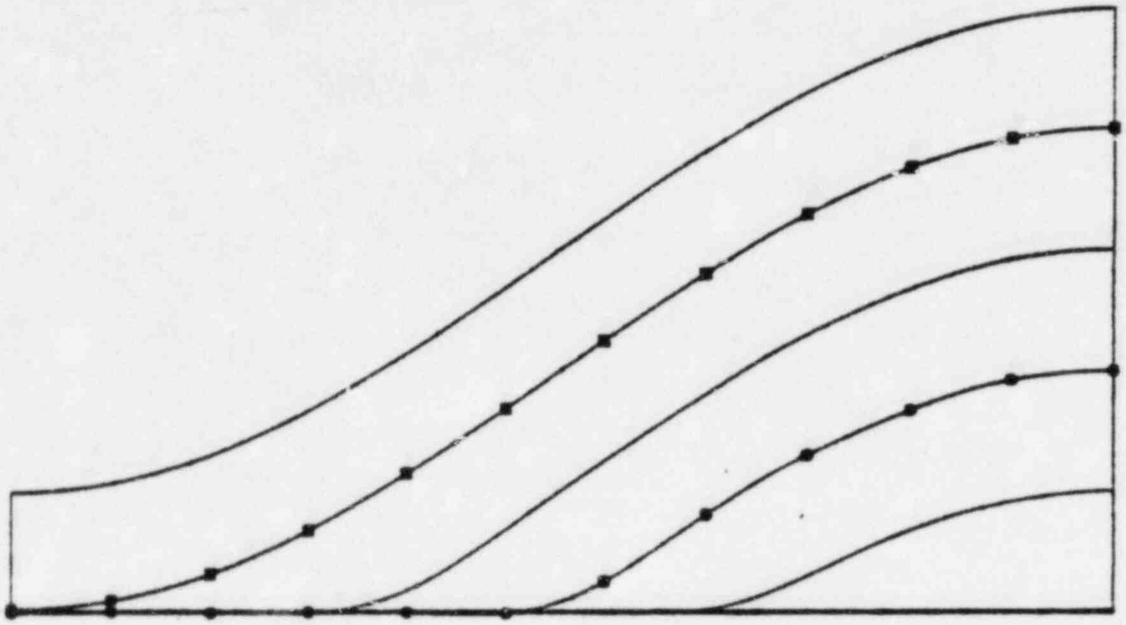
PRESSURE DISTRIBUTION AT 50 INCH INTERVALS (SCALE, INCH=2 PSI)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 6.547 5.238 3.926 2.611 1.312



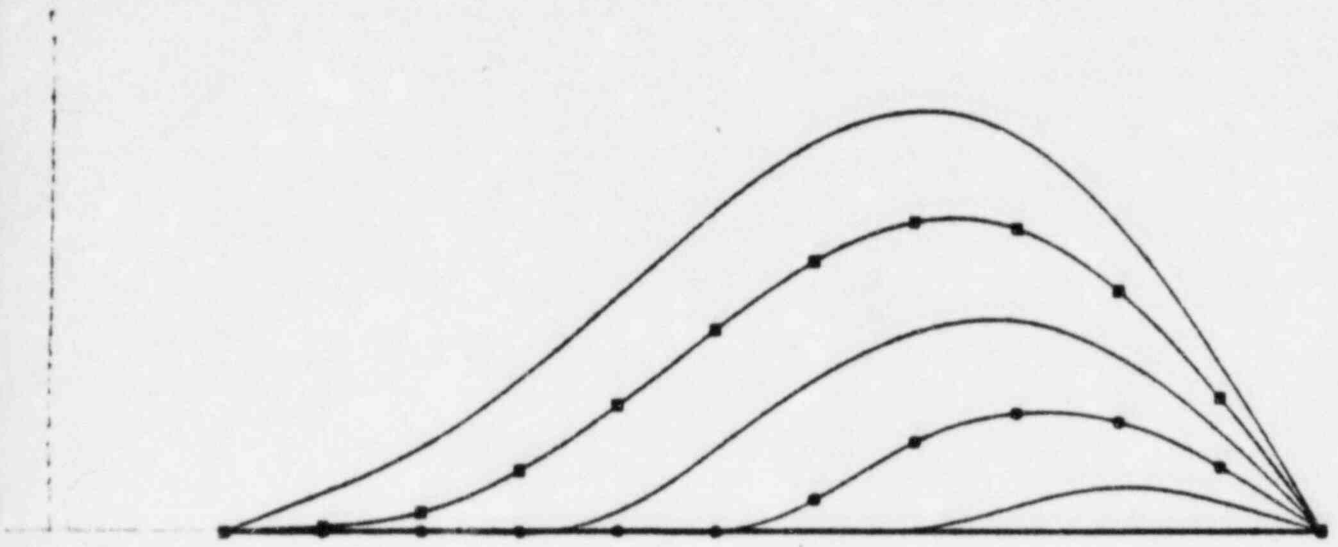
PRESSURE DISTRIBUTION AT 45 DEGREE INCREMENTS (SCALE: INCH=PSI)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 1.309 2.076 3.928 5.780 6.547



LONGITUDINAL FORCE AT 50 INCH INTERVALS (SCALE: INCH=200 LB/INCH)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 807.656 513.764 286.611 125.865 29.949



CIRCUMFERENTIAL FORCE AT 50 INCH INTERVALS (SCALE: INCH=200 LB/INCH)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 653.297 523.809 392.579 261.322 131.266



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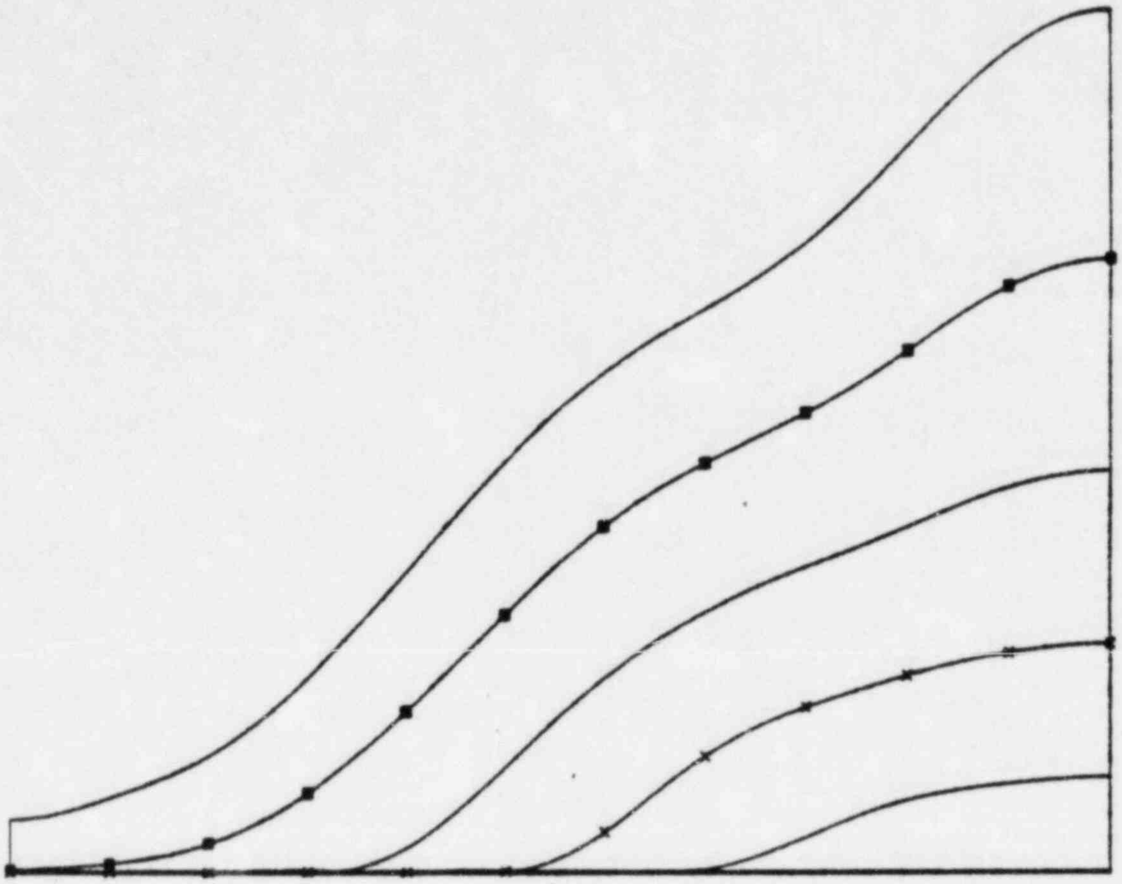
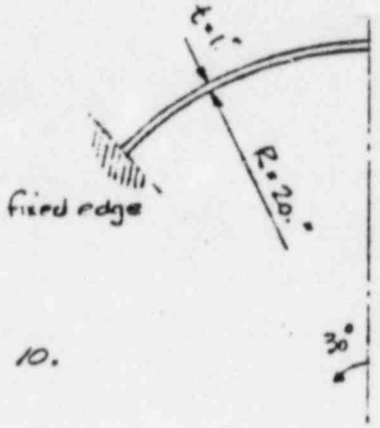
MEMBRANE SHEAR FORCE AT 50 INCH INTERVALS (SCALE: INCH=200 LB/INCH)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 456.695 340.340 230.490 129.709 48.217



MAXIMUM SHEARING STRESS AT 50 INCH INTERVALS (SCALE: INCH=1000PSI)
INCLINED CYLINDER UNDER VARIABLE HYDROSTATIC LOADING
MAXIMA 4675. 3320. 2173. 1239. 515.989

A.2.1 Sample Problem 1 : Freely Vibrating Spherical Cap N=1

Geometry and Properties:



This problem is taken from "Thin Elastic Shells", by Harry Kraus, Wiley, 1967. It is presented in dimensionless form $a/R = .5$ and $a/t = 10.$

where t = thickness

a = rotational radius at the edge

R = spherical radius

letting $E = 30000000.$ psi

$\mu = .3$

$\gamma = .283$ #/in³

$g = 386.4$ in/sec²

$R = 20.$

then $t = 1.$

ϕ (at start) $= 180 - 30 = 150°$

$$\Omega' = \omega a(\rho/E)^{1/2} = \omega(10)(.283/386.4 \times 30\times10^6)^{1/2}$$

$$= (2\pi f)(.04941)10^{-3} = .31045(10)^{-3} f$$

or $f = 3221.1\ \Omega'$

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				Date		SHT ___ OF 5

This is a fairly thick shell with an arc length of $2.3\sqrt{Rt}$. However in order to given more detail to the plots so that they may be compared with the published results, 16 segments were used.

Boundary Conditions:

Starting edge is specified as clamped; therefore

$$w = u_\phi = \beta_\phi = u_\theta = 0.$$

Results:

The published results are included on the next page so that they may be compared with the program's results. One can see that the primary displacement of each mode agrees very well, while some of the secondary displacements differ slightly. However there are errors in the published plots of the same magnitude (mode 5 does not go to 1., mode 3 does have u_ϕ and u_θ exactly equal and opposite) so one can say that the agreement is very good. Note that the sign convention for u_r is different in the two solutions.

Location________________________

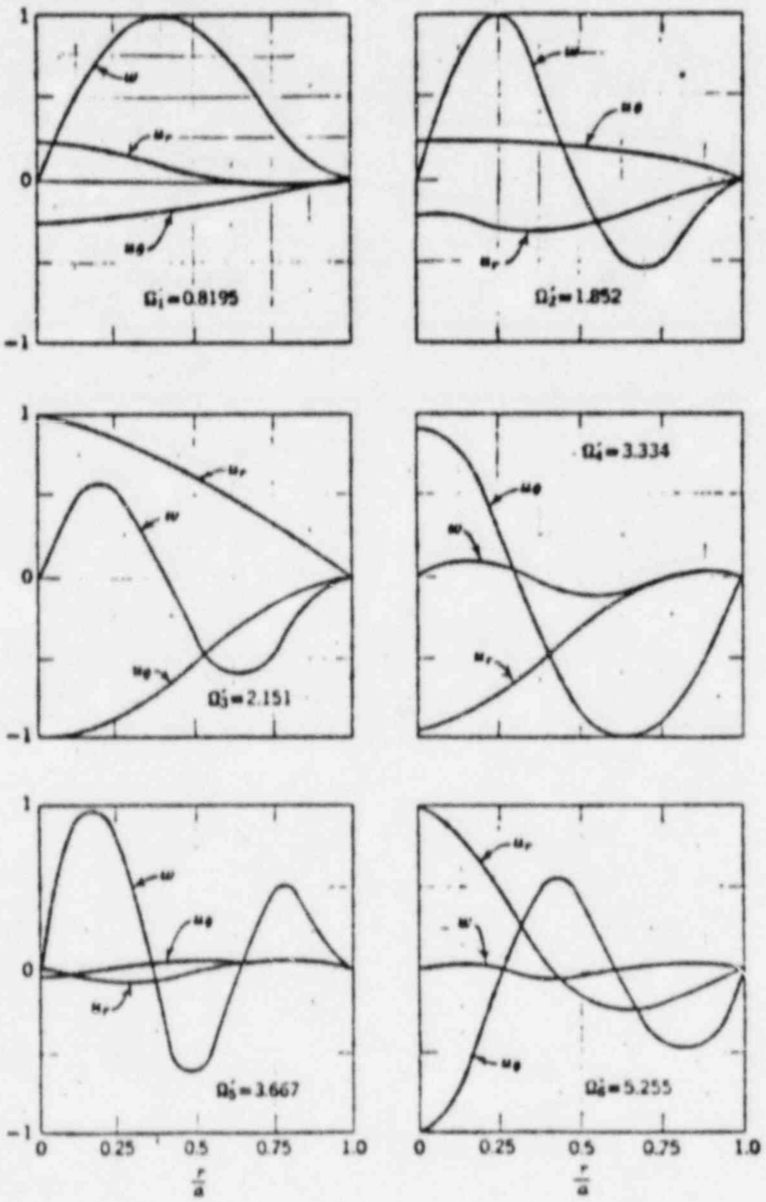

Figure 8.6 Displacement patterns for a clamped shallow spherical shell ($a/R = 0.5$, $n = 1$).

8-30

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Converting the dimensionless Ω' to frequencies in Hertz yields the following comparison:

mode	Kraus	program
1	2640.	2453.
2	5966.	5456.
3	6929.	6561.
4	10739.	10214.
5	11812	10761.
6	16927	16921. (estimated)

The disagreement here is surprising since the eigenvalues, and especially the lowest, are much less sensitive than the mode shapes. One would expect the agreement in the lowest eigenvalue to be an order of magnitude better than the mode shape; but this is not the case. However if one uses the mode shape of the first mode as a pressure distribution the maximum deflection is 5.7258 (10^{-4}). If this value is factored from all displacements, in order to normalize them, all displacements agree within .0005 of the original mode shape. And the frequency $= \left(\frac{1}{v'_{max}} \; \frac{g}{\gamma t}\right)^{1/2} \frac{1}{2\pi} = 2457.$ This indicates that the program is satisfying the original differential equations quite well. The static results follow.

```
[illegible]
 1   1   1   1   1   0 3. 00000.    0.30000    0.28300     386.40
 2       20.000      150.000      180.000      1.00000  16       0.0


 1  0.0            3  0.0              5  0.0              7  0.0               0.0
    0.0            0.0             0.0      17   17   17
 151.875      0.033    153.750       0.122    155.625       0.252    157.500       0.407
 159.375      0.569    161.250       0.724    163.125       0.855    165.000       0.950
 166.875      1.000    168.750       0.997    170.625       0.940    172.500       0.828
 174.375      0.669    176.250       0.469    178.125       0.242    180.000       0.0
 151.875      0.003    153.750       0.005    155.625       0.003    157.500      -0.004
 159.375     -0.016    161.250      -0.035    163.125      -0.059    165.000      -0.087
 166.875     -0.119    168.750      -0.152    170.625      -0.184    172.500      -0.214
 174.375     -0.239    176.250      -0.259    178.125      -0.271    180.000      -0.275
 151.875     -0.019    153.750      -0.040    155.625      -0.061    157.500      -0.083
 159.375     -0.105    161.250      -0.128    163.125      -0.151    165.000      -0.173
 166.875     -0.194    168.750      -0.214    170.625      -0.231    172.500      -0.246
 174.375     -0.259    176.250      -0.268    178.125      -0.273    180.000      -0.275




CMN USED
       111          2780
```

```
                       W              uφ              βφ              uθ
1
     150.000   1  0.0             0.0             0.0             0.0
     151.875   2  0.18893E-06  0.18496E-07 -0.55574E-06 -0.11137E-06
     153.750   3  0.70036E-06  0.27891E-07 -0.98219E-06 -0.22778E-06
     155.625   4  0.14460E-05  0.16868E-07 -0.12701E-05 -0.34926E-06
     157.500   5  0.23322E-05 -0.22549E-07 -0.14141E-05 -0.47518E-06
     159.375   6  0.32639E-05 -0.94819E-07 -0.14150E-05 -0.60437E-06
     161.250   7  0.41482E-05 -0.20086E-06 -0.12803E-05 -0.73512E-06
     163.125   8  0.48999E-05 -0.33819E-06 -0.10248E-05 -0.86526E-06
     165.000   9  0.54457E-05 -0.50129E-06 -0.67038E-06 -0.99226E-06
     166.875  10  0.57298E-05 -0.68208E-06 -0.24449E-06 -0.11134E-05
     168.750  11  0.57123E-05 -0.87062E-06  0.22104E-06 -0.12258E-05
     170.625  12  0.53812E-05 -0.10559E-05  0.69213E-06 -0.13266E-05
     172.500  13  0.47435E-05 -0.12267E-05  0.11347E-05 -0.14133E-05
     174.375  14  0.38291E-05 -0.13723E-05  0.15168E-05 -0.14934E-05
     176.250  15  0.26879E-05 -0.14836E-05  0.18111E-05 -0.15350E-05
     178.125  16  0.13855E-05 -0.15533E-05  0.19765E-05 -0.15666E-05
     180.000  17  0.43657E-07 -0.15770E-05  0.20587E-05 -0.15769E-05
```

Sample Problem 4   Sh. 5 of 5

A.2.2 Sample Problem 5: Fixed, Free Cylinder Natural Frequencies

Geometry, Properties, and Boundary Conditions:

See Sample Problem 6.

Results:

The main purpose for finding the natural frequencies here is to help in determining the time step which will be needed in the transient analysis of this fixed, free cylinder. This aspect is discussed in Sample Problem 6. Since it is known that a transient analysis is to be executed, time can be saved by saving the stiffness and mass matrices. This has been done by setting OUTPUT = 101 and assigning unit #50 to a permanent disc file. A summary of results:

harmonic	mode 1		mode 2	
	freq	period	freq	period
0	2271.	440. μ sec.	3617.	276. μ sec.
1	816.	1225.	2239.	447.
2	382.	2618.	1365.	733.

Note however that the first n=0 mode is a longitudinal "pogo stick" mode which will not participate much in the following blast problem.

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SUBJECT Sample Problem 5	MADE BY [illegible]	CHKD BY	REV	By		CHARGE NO.
				Chkd		
	DATE [illegible]	DATE		Date		SHT ____ OF ____

Location

A.3.1 Sample Problem 6: Clamped, Free Cylinder under Transient Blast Loading

Geometry, Properties, and Boundary Conditions:

This problem was taken from a paper, "Dynamic Response of a Cylindrical Shell: Two Numerical Methods", AIAA Journal, Vol. 4, No. 3, p. 486, by D. Johnson and R. Greif. Excerpts from this paper, included on the next page, describe the geometry, material properties, and boundary conditions.

Loading:

The loading distribution in space and time is supposed to represent the pressures that would be imposed on the shell due to a blast. These are described on the next page. One should be advised that the time distribution in vastly distorted. For the time period considered, the rise is instantaneous and the load constant thereafter. The time vs. pressure plot for $n=0$ shows there pressure distribution in scale.

Time Conditions & Parameters:

The shell is initially at rest. $u(0) = v(0) = w(0) = 0$.

SUBJECT Sample Problem 6	MADE BY JSB	CHKD BY	REV	By		CHARGE NO.
				Chkd		
	DATE 7/79	DATE		Date		SHT 1 OF 4

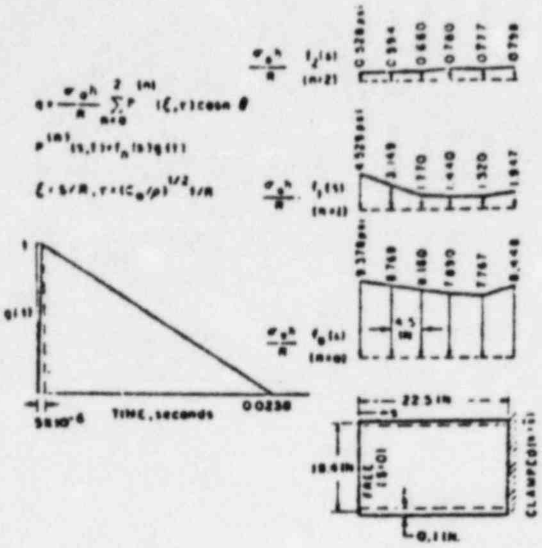

Fig. 3 Blast loading on a clamped-free circular cylindrical shell.

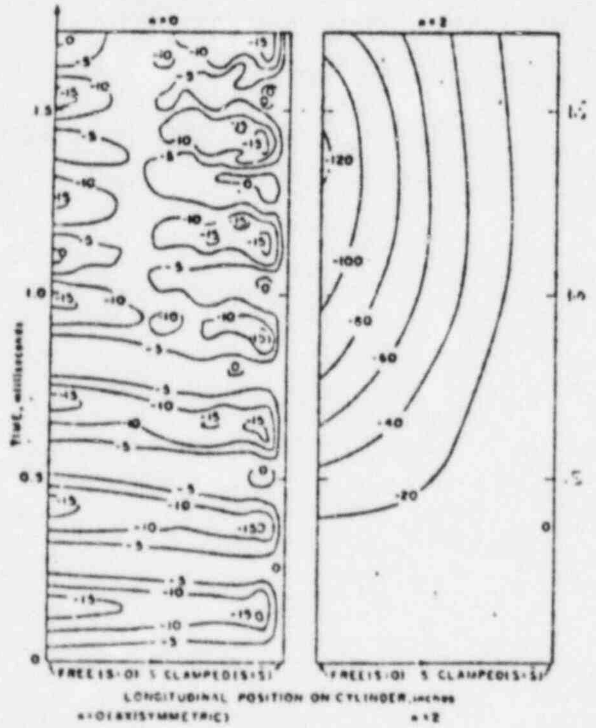

Fig. 5 Contour plot of $u^{(n)}$ for $n = 0$ and $n = 2$ (nondimensional Fourier coefficient of normal displacement).

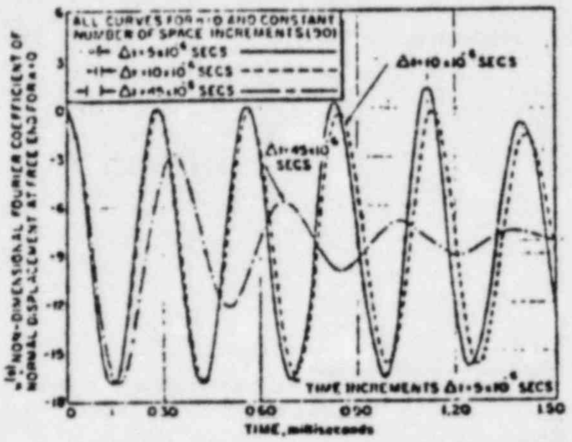

Fig. 7 Dependence of decay factor in Houbolt method on coarseness of time grid.

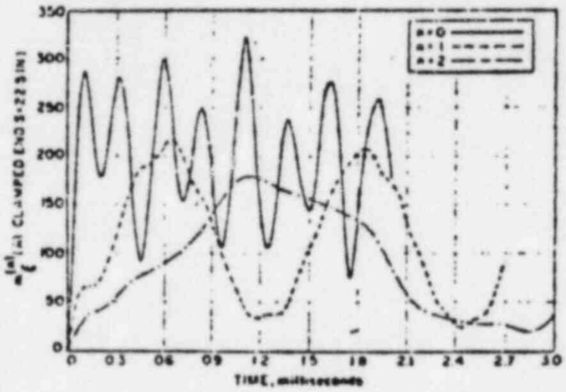

Fig. 6 Nondimensional Fourier coefficient of axial bending moment at clamped end vs time.

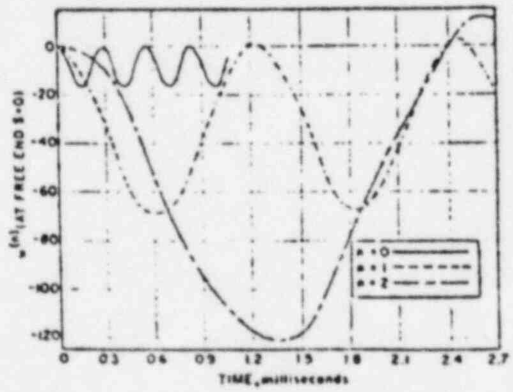

Fig. 4 Nondimensional Fourier coefficient of normal displacement at free end vs time.

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For the two harmonic Johnson & Greif use 5μ.sec. time steps. In order to compare results, this time step was used also in executing this sample problem. This is 1/55 of the longest participating period. If this fraction were used for the other harmonics (see Sample Problem 5):

n=1 $\Delta t = 1225/55 = 22\mu$ sec.

n=2 $\Delta t = 2613/55 = 48$

In order to output at the same times these were adjusted to even multiples 5, 20, & 40 μsec. In order to keep the output to a modest level, it was decided to solve only out to 1200 μsec. and to print at 200 μsec. intervals. However there are continuous plots of the values shown in the Johnson & Greif paper.

Results:

It can be seen that all the plots agree in general shape. To compare specific points one must convert the dimensionless values

$$\sigma_0 \frac{t}{R} = 1.$$

$$w = \frac{R\sigma_0}{E} w^{(n)} = \frac{R^2}{Et} w^{(n)} = 80.61(10^{-6}) w^{(n)}$$

$$M_\xi = \frac{\sigma_0 t^3}{R} m_\xi^{(n)} = t^2 m_\xi^{(n)} = .01\, m_\xi^{(n)}$$

SUBJECT Sample Problem 6	MADE BY JSE	CHKD BY	REV	By		CHARGE NO.
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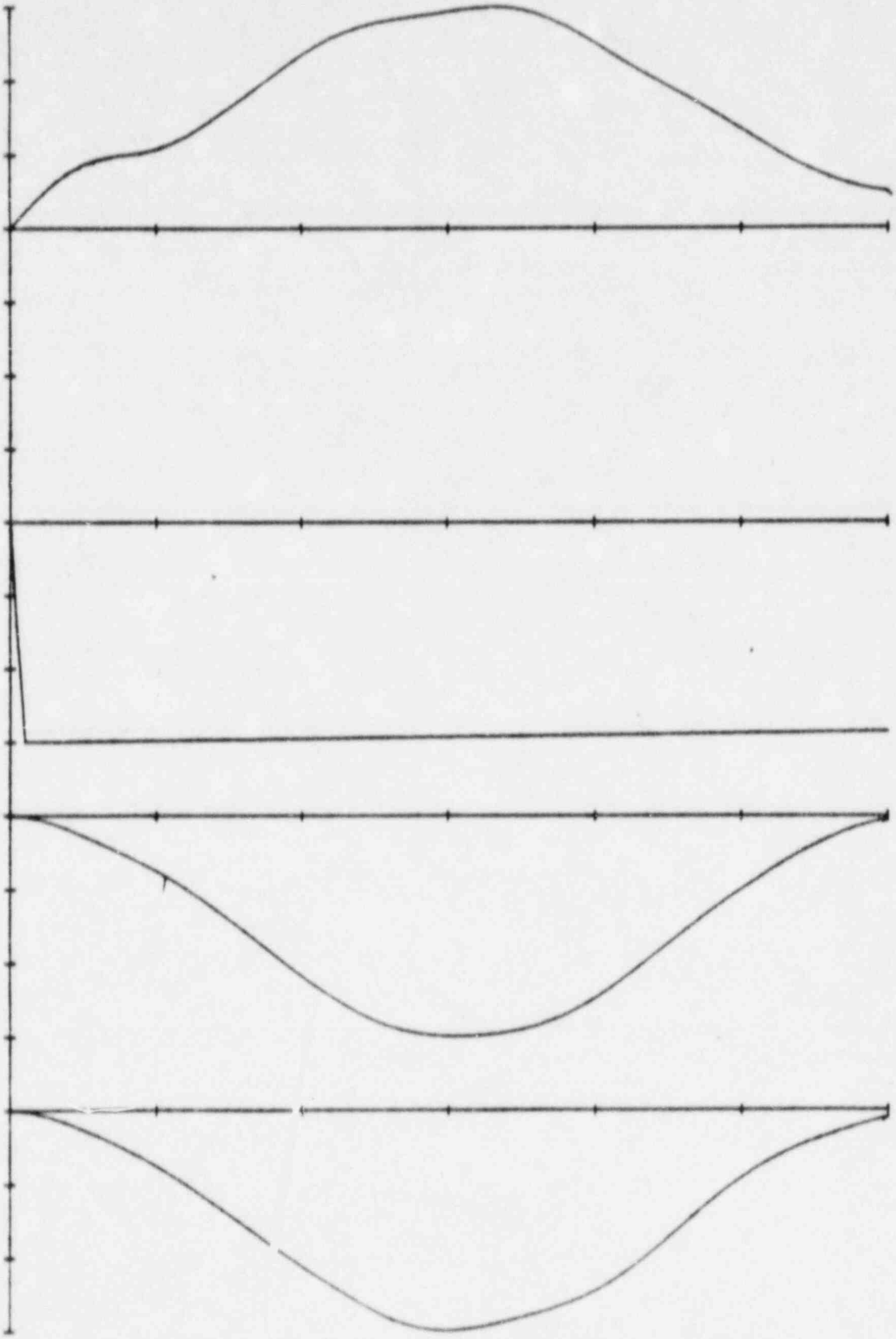
A sampling of some maxima, minima follows:

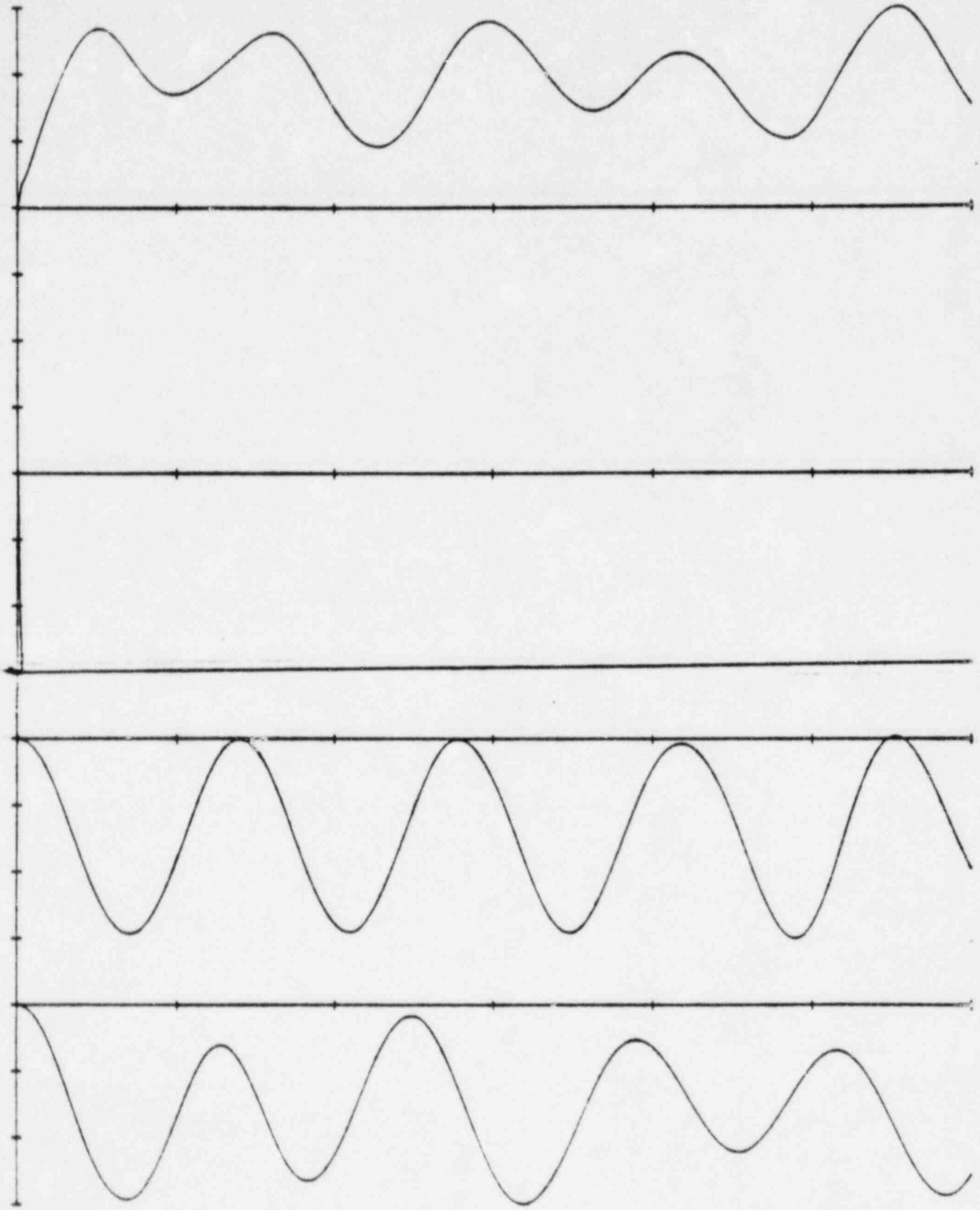
variable	harmonic	end	J&G value	J&G time	program value	program time
W	0	free	-.00134	.98	-.001532	.980
	0		.00011	1.10	.00002	1.105
	0		-.00136	.14	-.00148	.140
	1		-.00551	.6	-.006003	.601
	2		-.00943	1.2	-.01057	1.2
M_ϕ	0	fixed	.94	.44	1.08	.456
	0		3.00	.58	3.24	.596
	0		3.23	1.09	3.527	1.105
	1		2.19	.65	2.331	.67
	1		.35	1.18	.38	1.23
	2		1.81	1.12	2.035	1.2

Basically then the times seem to agree rather well while the maxima seem to be off by 8 to 12%. This would indicate that the models are about equal but the entire loading is about 5% off (amplification factor here is about 2.). Note that the period for n=0 is (.98-.14)/3 = .28 milli sec. which is in good agreement with the eigenvalue run.

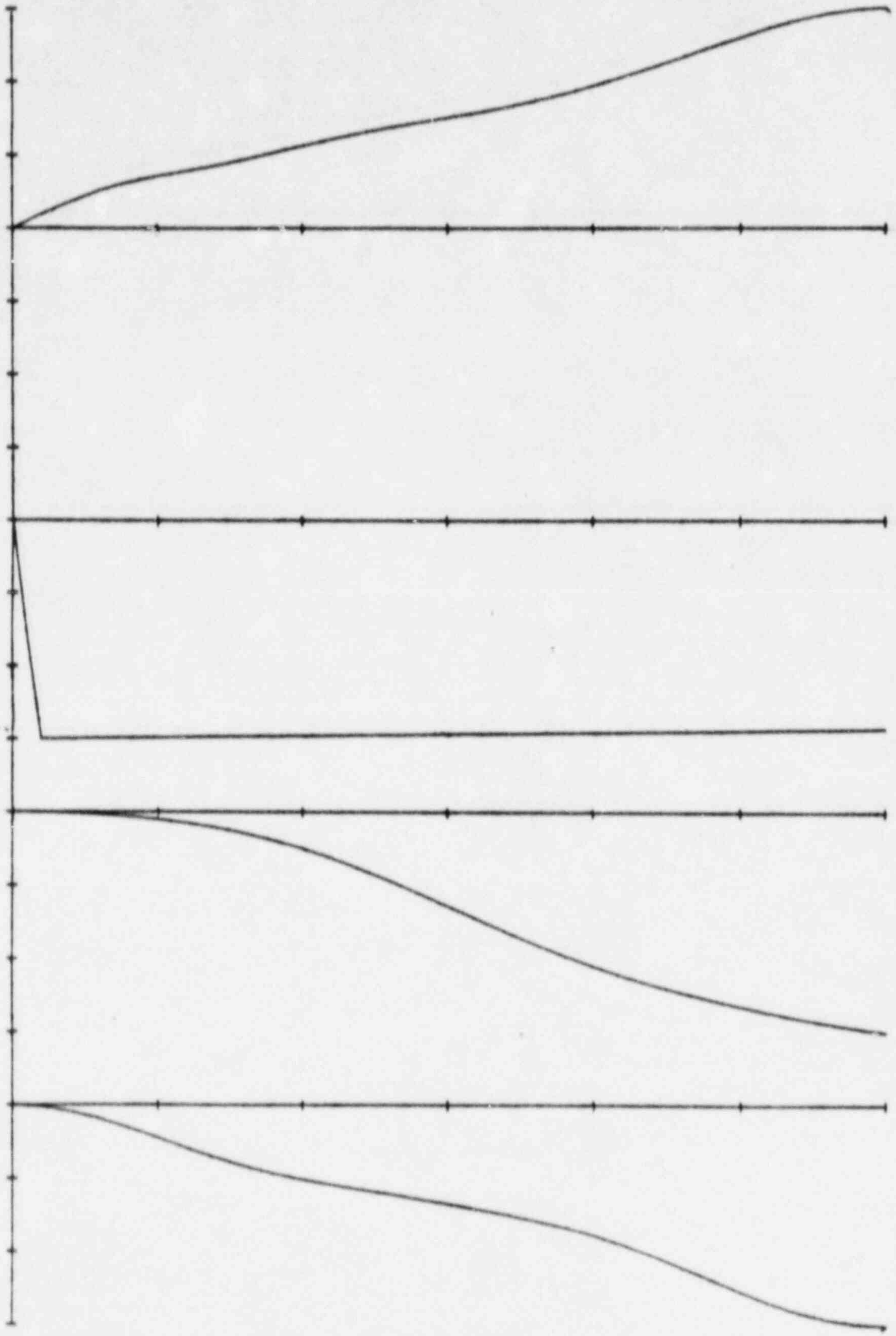
SUBJECT Sample Problem G	MADE BY JSC	CHKD BY	REV	By	CHARGE NO.
	DATE 9/74	DATE		Chkd Date	SHT 3 OF 4



```
CLAMPED FREE CYLINDER UNDER TRANSIENT BLAST LOADING
NVALUE= 1       TL TIME= 0.001200     STEPS= 60
VARIABLE  61         211          60         17
MAXIMUM   0.001821  0.006003   4.529      2.391
```



```
CLAMPED FREE CYLINDER UNDER TRANSIENT BLAST LOADING
NVALUE= 0        TL TIME= 0.001200     STEPS= 240
VARIABLE  61          211          20          17
MAXIMUM   0.001168  0.001532  7.767       3.534
```



```
CLAMPED FREE CYLINDER UNDER TRANSIENT BLAST LOADING
NVALUE= 2       TL TIME= 0.001200    STEPS= 30
VARIABLE  61          211         60          17
MAXIMUM   0.002355  0.010183  0.528000  2.035
```

CBI

Location

A.3.2 Sample Problem 7: Freely Vibrating Cylinder Starting with Zero Acceleration

Geometry and Properties:

Steel cylinder with

$R = 100.''$

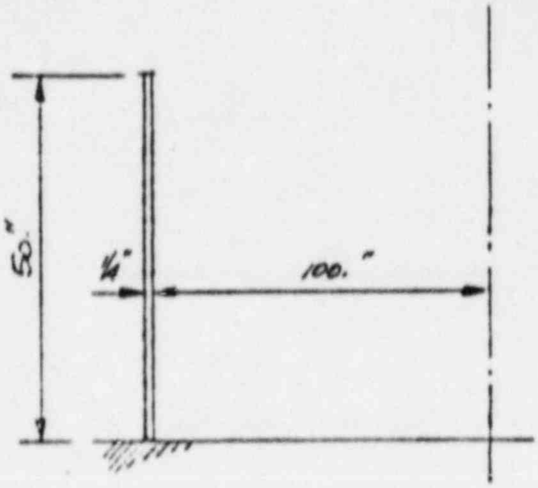
$L = 50.''$

$t = .25''$

$\rho = .283/386.4$

$E = 30\,000\,000.$

$\mu = .3$



Boundary Conditions:

At base $w = u_\phi = M_\phi = u_\theta = 0.$

At top, free $Q = N_\phi = M_\phi = N = 0.$

Loading:

Without worrying about how it got there, a uniform pressure is applied over the entire shell in order to demonstrate vibration about a static displacement field.

Initial Conditions:

The velocity has been set everywhere to the maximum velocity that would occur if this shell was vibrating freely with a maximum displacement of unity. The acceleration

SUBJECT Sample Problem 7	MADE BY [illegible]	CHKD BY	REV	By		CHARGE NO.
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				Date		SHT 1 OF 2

Location

has been set everywhere to zero. The initial displacements must then be the static displacements caused by the 200 psi uniform pressure.

Results:

It can be seen, most easily from the time vs. displacement plots, that the variables do indeed vibrate in a sinusoidal fashion (except for the mathematical damping due to the time integration scheme) about the static displacements.

SUBJECT Sample Problem 7	MADE BY JSP	CHKD BY	REV	By		CHARGE NO.
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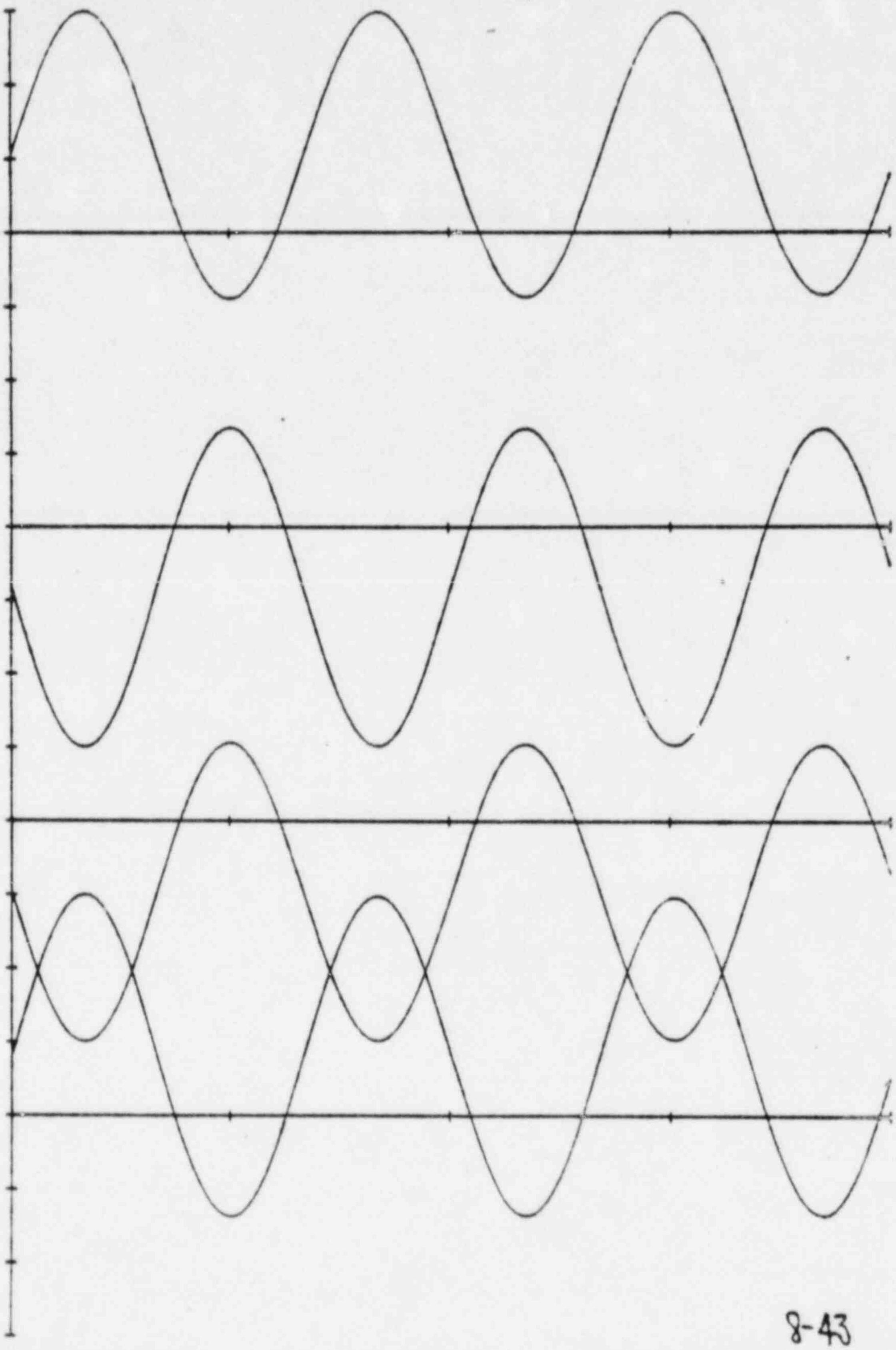
				Date		SHT 2 OF 2



```
FREE VIBRATION OF OPEN TOP TANK STARTING WITH ZERO ACCELERATION
NVALUE= 1       TL TIME= 0.010867    STEPS= 144
VARIABLE  61          62        64        31
MAXIMUM   1.359       0.136690  0.358719  0.933010
```

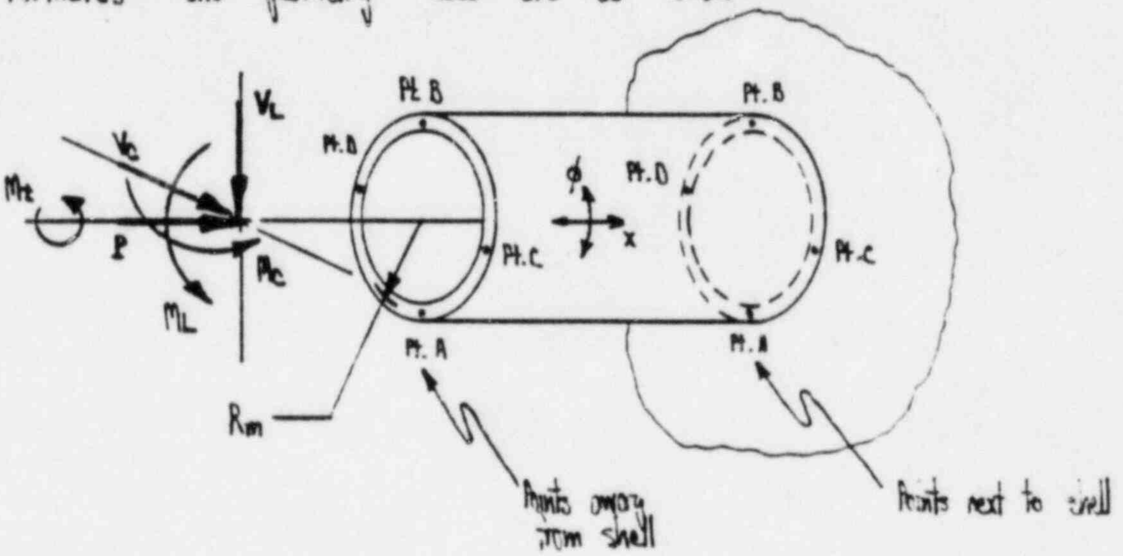
CBI

Location____________________

CBI Program 1392

This program determines the stress intensity in a nozzle by analyzing the nozzle as a beam and adding the stress caused by internal or external pressure by superposition. Nomenclature and direction of loading is similar to that shown in WRC-107. The stresses are computed for 4 points around the nozzle. These stresses are calculated near the shell (inside the area of shell reinforcement) and away from the shell (outside the area of shell reinforcement). The stresses found are then used to calculate combined stress intensities.

Formulas and geometry used are as follow:



OD = outside diameter of nozzle

nominal t_n = nominal thk of nozzle

under thk tolerance = $12\frac{1}{2}$% mill tolerance

I.S. = initial membrane stress in circumferential direction due to pressure in the vessel

P = pressure in pipe

Author: RD Hanson

Dated Version: 3/79

Limitations: maximum of 10 loading cases

4/79 version was revised to make changes in labelling of answers

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
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adjusted t_n = nominal t_n $(1 - 0.125)$

ratio IR / t_n = $\left(\frac{OD}{2} - t_n\right) / t_n$

metal area = $A = \pi(R_o^2 - R_I^2)$

moment of inertia = $I = \frac{\pi}{4}(R_o^4 - R_I^4)$

section modulus = $S = \frac{I}{R_m}$

polar moment of inertia = $J = 2(I)$

stresses:

SX @ Pt. A = $-\frac{P}{A} - \frac{M_L}{S} + \frac{PR_m}{2t_n}$

SX @ Pt. B = $-\frac{P}{A} + \frac{M_L}{S} + \frac{PR_m}{2t_n}$

SX @ Pt. C = $-\frac{P}{A} - \frac{M_c}{S} + \frac{PR_m}{2t_n}$

SX @ Pt. D = $-\frac{P}{A} + \frac{M_c}{S} + \frac{PR_m}{2t_n}$

$S\phi$ @ Pt. A, B, C, D = I.S. (next to shell)

$S\phi$ @ Pt. A, B, C, D = $\frac{PR_m}{t_n}$ (away from shell)

τ @ Pt. A = $\frac{V_c}{\pi R_m t_n} + \frac{M_t R_m}{J}$

τ @ Pt. B = $-\frac{V_c}{\pi R_m t_n} + \frac{M_t R_m}{J}$

τ @ Pt. C = $-\frac{V_L}{\pi R_m t_n} + \frac{M_t R_m}{J}$

τ @ Pt. D = $\frac{V_L}{\pi R_m t_n} + \frac{M_t R_m}{J}$

if SX and $S\phi$ have like signs, stress intensity = SI = max of $\frac{1}{2}\left[S\phi + SX + \sqrt{(S\phi - SX)^2 + 4\tau^2}\right]$

or $\sqrt{(S\phi - SX)^2 + 4\tau^2}$

if SX and $S\phi$ have unlike signs, $SI = \sqrt{(S\phi - SX)^2 + 4\tau^2}$

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54551
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CBI

Location

<u>Sample Problem</u>:

OD = 10.75" , nominal t_n = 0.365" , under thk tolerance = 12½ % ,

IS = 9000 psi , P = −5000 lbs , V_L = 2500 lbs , V_C = −2200 lbs .

M_L = −4000 in-lbs , M_C = 4500 in-lbs , M_t = 3200 in-lbs , P = 45 psi

calculate adj. thk. , ratio IR / t , metal area , section modulus , polar moment of inertia , SX at Pt. A , B , C , D next to shell and away from shell , SΦ at Pt. A , B , C , D next to shell and away from shell , τ at Pt. A , B , C , D next to shell and away from shell , and SI at Pt. A , B , C , D next to shell and away from shell and compare with computer values :

adjusted t_n = $0.365(1-0.125) = 0.319375"$ vs computer's 0.3194" ✓

ratio IR / t_n = $\left(\frac{10.75}{2} - 0.319375\right) / 0.319375 = 15.829746$ vs computer's 15.83 ✓

metal area = $\pi\left[(5.375)^2 - (5.055625)^2\right] = 10.465527$ in² vs computer's 10.466 in² ✓

moment of inertia = $\frac{\pi}{4}\left[(5.375)^4 - (5.055625)^4\right] = 142.461912$ in⁴

section modulus = $\frac{142.461912}{5.215313} = 27.316081$ in³ vs computer's 27.316 in³ ✓

polar moment of inertia = $2(142.461912) = 284.923824$ in⁴ vs computer's 284.925 in⁴ ✓

SX @ Pt. A = $-\left(\frac{-5000}{10.465527}\right) - \left(\frac{-4000}{27.316081}\right) + \frac{45(5.215313)}{2(0.319375)} = 992$ psi vs computer's 992 psi ✓

SX @ Pt. B = $-\left(\frac{-5000}{10.465527}\right) + \left(\frac{-4000}{27.316081}\right) + \frac{45(5.215313)}{2(0.319375)} = 699$ psi vs computer's 699 psi ✓

SX @ Pt. C = $-\left(\frac{-5000}{10.465527}\right) - \frac{4500}{27.316081} + \frac{45(5.215313)}{2(0.319375)} = 680$ psi vs computer's 680 psi ✓

SX @ Pt. D = $-\left(\frac{-5000}{10.465527}\right) + \frac{4500}{27.316081} + \frac{45(5.215313)}{2(0.319375)} = 1010$ psi vs computer's 1010 psi ✓

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Computer Program	GLN	BAH	By		54351
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next to shell

σ_ϕ @ Pt. A, B, C, D = 9000 psi vs computer's 9000 psi ✓

away from shell

σ_ϕ at Pt. A, B, C, D = $\frac{45(5.215313)}{0.319375}$ = 735 psi vs computer's 735 psi ✓

τ @ Pt. A = $\frac{-2800}{\pi(5.215313)(0.319375)} + \frac{3200(5.215313)}{294.928824}$ = -477 psi vs computer's -477 psi ✓

τ @ Pt. B = $-\left[\frac{-2900}{\pi(5.215313)(0.319375)}\right] + \frac{3200(5.215313)}{294.928824}$ = 594 psi vs computer's 594 psi ✓

τ @ Pt. C = $-\frac{2500}{\pi(5.215313)(0.319375)} + \frac{3200(5.215313)}{294.928824}$ = -419 psi vs computer's -419 psi ✓

τ @ Pt. D = $\frac{2500}{\pi(5.215313)(0.319375)} + \frac{3200(5.215313)}{294.928824}$ = 536 psi vs computer's 536 psi ✓

next to shell

SI @ Pt. A = $\frac{1}{2}\left[9000 + 992 + \sqrt{(9000-992)^2 + 4(-477)^2}\right]$ = 9028 psi vs computer's 9028 psi ✓

SI @ Pt. B = $\frac{1}{2}\left[9000 + 699 + \sqrt{(9000-699)^2 + 4(594)^2}\right]$ = 9042 psi vs computer's 9042 psi ✓

SI @ Pt. C = $\frac{1}{2}\left[9000 + 680 + \sqrt{(9000-680)^2 + 4(-419)^2}\right]$ = 9021 psi vs computer's 9021 psi ✓

SI @ Pt. D = $\frac{1}{2}\left[9000 + 1010 + \sqrt{(9000-1010)^2 + 4(536)^2}\right]$ = 9036 psi vs computer's 9036 psi ✓

away from shell

SI @ Pt. A = $\frac{1}{2}\left[735 + 992 + \sqrt{(735-992)^2 + 4(-477)^2}\right]$ = 1358 psi vs computer's 1357 psi ✓

SI @ Pt. B = $\frac{1}{2}\left[735 + 699 + \sqrt{(735-699)^2 + 4(594)^2}\right]$ = 1311 psi vs computer's 1311 psi ✓

SI @ Pt. C = $\frac{1}{2}\left[735 + 680 + \sqrt{(735-680)^2 + 4(419)^2}\right]$ = 1127 psi vs computer's 1128 psi ✓

SI @ Pt. D = $\frac{1}{2}\left[735 + 1010 + \sqrt{(735-1010)^2 + 4(536)^2}\right]$ = 1426 psi vs computer's 1426 psi ✓

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Verification	DATE 11/1/82	DATE 11/82		Chkd		SHT 9-4 OF ____
				Date		

```
E1392A STRESSES IN PIPE DUE TO EXTERNAL LOADS

  AND SHELL STRESSES FOR NUCLEAR CONTAINMENT---REV MAR 79

     INPUT DATA:

                      NOMINAL          UNDER
       OUTSIDE         NOZZLE          THICKNESS        INITIAL
       DIAMETER       THICKNESS        TOLERANCE         STRESSES
        (IN)            (IN)             (%)              (PSI)
        10.7500         0.3650          12.50           9000.00

     EXTERNAL LOADS,DESIGN PRESSURE(PRS), AND INITIAL STRESSES(IS) Y OR N

   CASE       P          VL         VC            ML            MC            MT        PRS   IS

     1     -5000.      2500.     -2800.        -4000.         4500.         3200.     45.00   Y




     OUTPUT:
                                                                                 POLAR
       ADJUSTED           RATIO              METAL              SECTION        MOMENT OF
       THICKNESS           R/T                AREA              MODULUS         INERTIA
        (IN)                               (SQ.IN.)             (IN**3)         (IN**4)
        0.3194            15.83              10.466              27.216         284.925

                       STRESSES NEXT TO SHELL                    STRESSES AWAY FROM SHELL
               A           B           C           D           A           B           C           D
   SX        992.        659.        680.       1010.        992.        659.        680.       1010.
   SO       9000.       9000.       9000.       9000.        735.        735.        735.        735.
   TAU      -477.        594.       -419.        536.       -477.        594.       -419.        536.
   SI       9029.       9042.       9021.       9036.       1357.       1311.       1128.       1426.




   54331 GLN 11-1-82
```

✓ BAH 11/82

CBI Program 1671

This program processes penetration loads and geometry, for a cylindrical containment vessel, to obtain specific loading combinations. Penetrations not on the cylinder must be analyzed separately. The output is in a format acceptable as input to programs 772, 1036, and 1392.

This program's input and output is shown as the input for programs 772, 1036, and 1592.

Author : R D Hanson

Dated Version : 9/78

Limitations : none

SUBJECT Computer Program	MADE BY GLN	CHKD BY RAH	REV	By		CHARGE NO. 54331
				Chkd		
Verification	DATE 10/27/82	DATE 11/82		Date		SHT 11-1 OF

CBI Program 1691

Author : RS Wozniak
Dated Version : 1/79
Limitations : see page 12-2

0.1 Scope: This standard describes the use of program E1691A and documents inherent limitations and restrictions.

0.2 Introduction: The program analyzes two or three dimensional frames or trusses for member end forces, end moments, joint deflections and rotations. An analysis can be made on structures with rigid, hinged or free support conditions, rigid ① or hinged member end conditions, and any number of loading conditions. Included in the program is a provision to use rectangular or cylindrical coordinates to describe the structure and a plotting option for a geometry check. The program can combine several loading conditions and can analyze the structure for member deadloads when the unit weight of the material has been input.

Section 1.0 describes the format of the program with particular emphasis on required input and interpretation of output. A brief summary of the mode of analysis and a collection of notes to aid the user follow in section 2.0.

0.3 Related Programs: Computer program E1689A is also available for large structures which cannot be handled by E1691A. Since E1689A is just an extended version of E1691A which requires more computer time and memory, the subsequent details will generally be applicable to it as well. See section 2.0 for noted differences in the two programs. Program E1688A is available to check and plot input data for E1689A. If it is necessary to use these two programs, contact Oak Brook Development Engineering and Technical Consulting (OZE).

Program E1690A checks and plots the input data for program E1691A. Input is the same as input data for program E1691A. Program E1690A uses less core and computer time than program E1691A. If the input data is out of order or is insufficient, error messages will be printed. The plot will reveal any incorrect coordinates. Program does not check if the problem was modeled correctly. Output is the same as program E1691A except no forces or deflections are printed. All input data for the first run of any significant size for program E1691A should be debugged on this program to eliminate errors and reduce the number of runs required of program E1691A. The input data sheet for E1691A may be used for E1690A.

0.4 Limitations: Program E1691A is similar to the STRESS program developed at Massachusetts Institute of Technology, but is not as versatile. Program E1691A does not have the facility to change structural properties during a given run.

Limitations on parameters for program E1691A are listed below:

420	structural members
320	joints
1250	degrees of freedom
140	half band width
50	member types

As described under section 1.0 the displacement stiffness method is the mode of analysis incorporated into the program. Due to the banded nature of the structural stiffness matrix, a Gaussian forward elimination and direct back substitution on the matrix performs the necessary mathematics. The capability of the program, however, is directly limited by the half-band width of the structural stiffness matrix. See Fig. 1.1a for details on estimating the half-band width of a particular structure.

1.0 DESCRIPTION OF PROGRAM

The program utilizes the displacement stiffness method to mathematically describe the structure and a Gauss forward elimination and back substitution for the solution. The method of solution entails:

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① Rigid is defined as a joint capable of carrying moment.

1 Assembling a stiffness matrix for the structure from individual member and joint information.

2 Assembling a loading vector for the structure from individual member and joint loading information.

3 Solving the resulting matrix equation for structure joint deflections and rotations.

4 Substituting back for individual member end forces and moments.

Figs. 1.1a and 1.1b illustrate input data sheets describing the typical arrangement of input information. The first portion of input data described in Fig. 1.1a is concerned primarily with parameters of structural geometry, member properties and other existing conditions. These items are input once and remain unchanged for each job; while loading condition parameters (Fig. 1.1b) may be input several times to correspond with the number of loading conditions. This feature is quite economical when analyzing a structure for different loading conditions.

Prior to setting up data for Fig. 1.1a, it is advantageous to rough out a sketch of the structure to be analyzed in order to establish a global coordinate system.

There are two axis systems used by the program. The two systems are (a) an overall global system that applies to the complete structure, and (b) a member local axis system. Each coordinate system is a right hand orthogonal X, Y, Z system. This is explained as follows:

Right-Handed Coordinate Systems The program assumes that all coordinate positions, angles and rotations are specified according to a right-handed system of cartesian coordinates with orthogonal axes, as illustrated in Fig. 1.0a.

HOLD the RIGHT HAND so that the thumb and first two fingers are orthogonal to one another see Fig. 1.0b. The sequence of thumb, forefinger and next finger point in the positive directions of the X, Y, and Z axes of a right-handed coordinate system.

Imagine grasping a coordinate axis by the right hand, with the thumb pointing along the axis in its positive direction. See Fig. 1.0a The positive sense of an angle, or an angular rotation, will be given the direction in which the fingers curl around this axis. A negative sign for an angle will specify a rotation in the opposite direction.

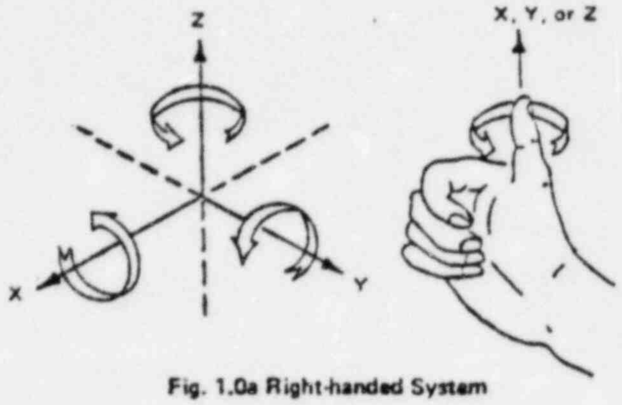


Fig. 1.0a Right-handed System

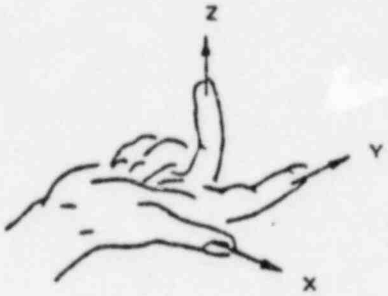


Fig. 1.0b Right Hand Rule

For further information on Axis System see Appendix A in program folder for E1691A.

E1691A is equipped to handle input for cartesian or cylindrical coordinate system. Each joint should then be assigned a set of coordinates. Each member should be assigned an identification number beginning with one (1) and increasing in consecutive order.

The joints should likewise be numbered, attempting to minimize the difference in joint numbers for every member. This will minimize the half-band width and computer time required to analyze the structure.

Note that many structures are symmetrical, and only a portion of the structure might need be analyzed. If so, both computer time and the user's time can be reduced.

Fig. 1.1a and 1.1b are to be used only as guides in coding the input data. Form GO 1077 (pages 1 to 8) are available for coding input data card by card following the format outlined by Figs. 1.1a and 1.1b. Program E1690A should be used to check input data to program E1691A. It will flag any input errors and plot the structure for a visual geometry check.

COMPUTER PROGRAM FOR
THREE DIMENSIONAL FRAME
AND TRUSS ANALYSIS

PROGRAM E1691A Input Data for Three Dimensional Frame and Truss Program

Card 1	Contract or Charge No.	Job Description	Name	Date
	(Limit total number of characters to 80)			

Card 2	NTRY Total number of loading conditions	IREV Data sheet revision number	NJ Total number of joints (320 max)	NMC Total number of members (420 max)	NMTYPE Total no. of member types (50 max)	NCOL ① Half band width estimate (140 max)	NCOR Coordinate system 0 = Rect. 1 = Cylin.	E Modulus of elasticity (ksi)	UNU Poisson's ratio	ALPB Average thermal expansion coefficient in/in - °F	NCOMB Number of loading combinations
		2									

Card 3	NPLOT Number of plots (4 max) 0 if NJ ≤ 12	NYMPX ② Plot size 0 = 12 in. 1 = 30 in.	Azimuth and elevation for orientation of plot(s) ② ③							
			AZ(1) (deg)	EL(1) (deg)	AZ(2) (deg)	EL(2) (deg)	AZ(3) (deg)	EL(3) (deg)	AZ(4) (deg)	EL(4) (deg)

Card(s) 4	NC Number of loading conditions in this combination (9 max)	Loading conditions to be combined in this combination and multipliers ④																	
		1		2		3		4		5		6		7		8		9	
		ICO	M	ICO	M	ICO	M	ICO	M	ICO	M	ICO	M	ICO	M	ICO	M	ICO	M

Cards 5	IJ Joint number	Joint degrees of freedom: 1 = restrained, ⑤ 0 = unrestrained, −1 = initial translation or rotation						Joint coordinates (rectangular or cylindrical) (use right hand system)		
		Translation			Rotation					
		IXT	IYT	IZT	IXR	IYR	IZR	X or R (ft)	Y or θ (ft or deg)	Z or H (ft)

Card(s) 6	NIJ Number of displaced joint	Initial joint translations and rotations (global coordinates) ⑤					
		Translation (inches)			Rotation (radians)		
		X - direction or radial direction	Y - direction or θ-direction (radian)	Z - direction or H - direction	About X - axis or about radial axis	About Y - axis or about tangential axis	About Z-axis or about H - axis

Card(s) 7	MTYPE Member type	AREA Cross-sectional area (in^2)	Moments of Inertia			ASY Shear area in y - direction (in^2)	ASZ Shear area in z - direction (in^2)	MWT Member weight kips/ft ⑥
			IX Polar inertial moment about x - axiz (in^4)	IY Inertial moment about y - axis (in^4)	IZ Inertial moment about z - axis (in^4)			

Cards 8	IMEM Member number	IL Left joint number	IR Right joint number	IT End conditions 0 = rigid-rigid -1 = hinged-rigid 1 = rigid hinged 2 = hinged-hinged	GAM Roll about local x - axis (deg)	MT Member type of this member	TT Increase in temperature of this member (deg)	KODMK Member flag code −1 = no compression 1 = no tension 0 = no flag

NOTE: Cards 4, 5, 6, 7 and 8 must include one card for each loading combination, joint, initially displaced joint, member type, and member respectively. Place all #4 cards together, then all #5 cards, then all #6 cards, then all #7 cards and finally all #8 cards.

① NCOL = 6 (|J - K| + 1) where J and K are member joint numbers and |J-K| is the largest absolute difference for any member in the structure.

② Enter zero if NPLOT = 0. All locations on card 3 must be 0 if not used.

③ See Figure (1) on next sheet.

④ Loading condition are identified as LTRY on card 10. (See sheet 2) If no combinations are necessary omit card 4.

⑤ Use card 6 for a joint only if the joint has an initial displacement as indicated on card 5 by a −1.

⑥ Input value for member types for which dead load is to be independant of member area and unit weight (SG on Card 10). Otherwise input as −1.

Fig. 1.1a Form 1076, Arrangement of Input (for coding use form GO 1077, pages 1 - 8)

PROGRAM E1691A Input Data for Three Dimensional Frame and Truss Program

<table>
<tr><td rowspan="3">Card 9</td><td colspan="7">Title card for each loading condition</td></tr>
<tr><td colspan="7">(Limit total number of characters to 80)</td></tr>
<tr><td colspan="7"></td></tr>
<tr><td rowspan="2">Card 10</td><td colspan="2">LTRY
Loading condition number</td><td colspan="2">NOLJS
Number of joints loaded</td><td colspan="2">NOLDS
Number of members loaded</td><td>SG ⑦
Unit weight of material for dead load kips/ft^3</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="3">Card(s) 11</td><td rowspan="2">IJX
Number of loaded joint</td><td colspan="6">Joint loads in global coordinates (or cylindrical coordinates)</td></tr>
<tr><td>FX (IJX)
[FR (IJX)]
kips</td><td>FY (IJX)
[Fθ (IJX)]
kips</td><td>FZ (IJX)
[FH (IJX)]
kips</td><td>MX (IJX)
[MR (IJX)]
ft-kips</td><td>MY (IJX)
[Mθ (IJX)]
ft-kips</td><td>MZ (IJX)
[MH (IJX)]
ft-kips</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Card(s) 12</td><td>IMEX
Number of loaded member</td><td>IXXI
0 = last or only load on IMEX
1 = another load for IMEX follows</td><td>IPL ⑨
Loading plane
0 = load in local x - z plane
1 = load in local x - y plane</td><td>AB2 ⑧
Distance from left end to load
ft</td><td>AB3 ⑧
Distance from left end to end of load
ft</td><td>AB4 ⑧
Angle from load direction to member normal
deg</td><td>AB1
Load (if AB2 = AB3)
kips
load intensity (if AB3 > AB2)
kips/ft</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

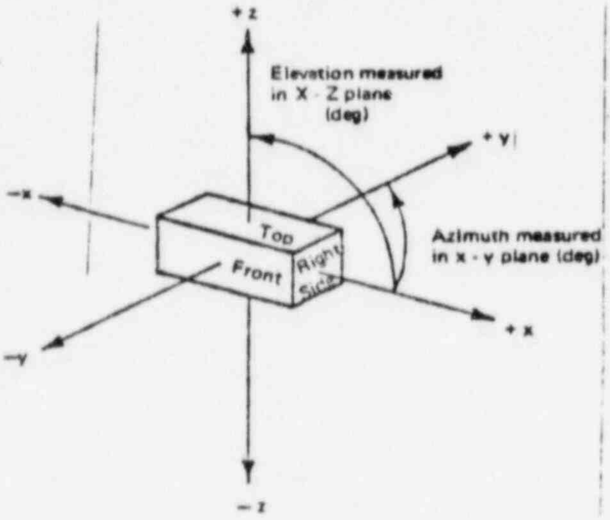


Fig. 1 Plot Orientation

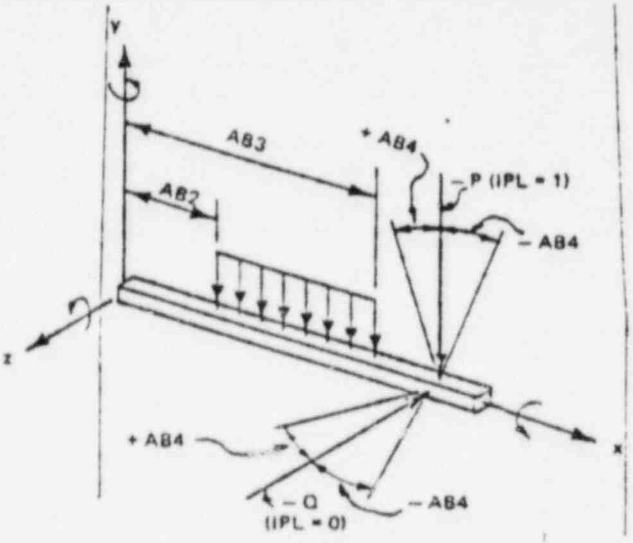


Fig. 2 Sign Convention for Member Loads

Notes: For each loading condition the following sequence should be repeated. Place card 9, then card 10, then all joint load cards (cards 11) and then all member load cards (cards 12).

⑦ If the structure's dead load is not to be included in a loading condition enter zero. To include dead load, global coordinate axis z must be vertical and positive upward

⑧ See Fig. 2.

⑨ If load is not in x - z or x - y plane, resolve the load into these two planes.

Fig. 1.1b Arrangement of Input (for coding use form GO 1077 pages 1 - 8)

12-5

~~A-2~~

1.1 Input Data: Following is an explanation of input items for Figs. 1.1a and 1.1b.

Card 1

Eighty spaces are available for a contract number, job description, name and date.

Card 2

Card 2 specifies the boundary parameters for the job and the material property constants.

Total Number of Loading Conditions (NTRY): The number of loading conditions should be equal to the number of times cards 9 through 12 appear.

Data Sheet Revision Number: The program will accept only the latest data sheet or format of input data.

Total Number of Joints (NJ): The maximum number of joints which the structure may have has been limited to 320.

Total Number of Members (NMC): The maximum number of members which the structure may have is 420.

Total Number of Member Types (NMTYPE): The number of members in the structure with different cross-sectional properties is limited to 50.

Half Band Width Estimate (NCOL): This is an estimate of the half band width of the structural stiffness matrix. This half band width is dependent upon the manner in which the structure's joints are numbered by the user. The estimate may be made by the following relationship:

$$\text{NCOL} = 6(|J-K| + 1)$$

Where 6 represents the number of degrees of freedom of a joint and J and K are joint numbers of a member. Since the largest half band width estimate is required, $|J\text{-}K|$ must be the largest absolute difference for any member in the structure. Program memory requirements limit E1691A to a maximum half band width of 140. It is essential that the user numbers the joints of the structure so as to minimize (J-K). Note, if a joint is completely restrained against rotation and deflection, it does not affect band width and can be ignored in calculating NCOL. For small structures (less than 12 members) make NCOL zero.

Two times NCOL must always be less than the number of degrees of freedom. Adding extra intermediate points will usually increase the degrees of freedom without increasing NCOL if the user pays attention to numbering.

Coordinate System (NCOR): This parameter defines the coordinate system in which the joint locations are defined by the user. The user may specify

0 for rectangular coordinates

1 for cylindrical coordinates

Modulus of Elasticity (E), Poisson's Ration (UNU), and Average Coefficient of Thermal Expansion (ALPB): The program cannot handle material property variations from member to member; therefore, the material constants are input only once. Units for the modulus of elasticity are kips/inch^2. Units for coefficient of thermal expansion are in inches/inch-degree fahrenheit.

Number of Loading Combinations (NCOMB): The program will combine up to nine loading conditions. This parameter indicates how many combinations of loading conditions are to be made, and the number of number 4 cards required.

Card 3

The program retains an option whereby a line diagram of the structure with numbered joints may be plotted. Card 3 specifies the user's need concerning the plot(s) of the structure.

Number of Plots (NPLOT): In order to have a structure plotted, it must have more than twelve (12) joints. If no plot is desired, zero (0) is specified for all the parameters on card 3. The user may specify up to four (4) plots of the structure all of which may vary in line of sight or orientation.

Plot Size (NYMPX): Twelve (12) inch and thirty (30) inch paper is available for plotting. The plotting routine automatically scales the structure to the specified size of paper. Use

NYMPX = 0 for 12" plot
NYMPX = 1 for 30" plot

Azimuth and Elevation for Orientation of Plot (AZ, EL): For each desired plot the user must indicate the azimuth and elevation which is desired. The plot is viewed from this direction Fig. 1 in Fig. 1.1b illustrates the orientation measurements required. If less than four plots are requested, remaining azimuth and elevation parameters must be set to zero. Some typical azimuth and elevations are:

View	Azimuth	Elevation
Toward −X	0.	0.
Toward +X	180.	0.
Toward −Y	90.	0.
Toward +Y	−90.	0.
Toward −Z	−90.	90.
Toward +Z	−90.	−90.
Isometric	−45.	35.

Card(s) 4

The program's option to combine loading conditions is regulated by card(s) 4. There should be one card 4 for each combination (specified on card 2).

Number of Loading Conditions In This Combination (NC): Enter the number of loadings to be combined. The maximum number of loadings in any combination is nine.

Loading conditions to be combined (ICO) and Multiplier (M): For ICO enter the number of each loading (LTRY on card 10) to be combined. The number of entries here should correspond to the first parameter (NC) on this card. M is a multiplier for the particular loading condition. For example, if only 50% of a particular loading condition is required, that condition can be input under ICO with a .5 Multiplier (M). A negative combination is valid and has the effect of applying a load in the opposite direction.

Cards 5

There should be one card 5 for each joint in the structure. This card describes the joint's location and characteristic degrees of freedom. Since there are several number 5 cards (the same is true for cards 6, 7, 8) the user may wish to lay out grid sheets for tabulation of multiple card input or use forms GO 1077 (pages 1 to 8).

Joint Number (IJ): This is the number of the joint whose coordinates are defined on this card. The user has an arbitrary choice when numbering the joints except that the joint number of differences for a given member should be minimal for efficiency. Joints must be input in ascending order.

Joint Degrees of Freedom (IXT, IYT, IZT, IXR, IYR, IZR): These parameters describe the conditions of each of the joint's six (6) degrees of freedom, i.e., translation in the X,Y, and Z directions and rotation about the X,Y, and Z axes of the joint as defined by the structure coordinate (global) system. The codes are defined below:

1 = translation or rotation of the joint is not permitted

0 = translation or rotation of the joint is permitted

-1 = an initial displacement or rotation has been imposed. (Any initial displacement or rotation will be described on card 6).

Joint Coordinates (X or R, Y or THETA, Z or H): The joint coordinates are input in the corresponding coordinate system specified on card 2. For the rectangular coordinates use X (ft), Y (ft), and Z (ft); for the cylindrical system use R (ft), θ (degrees), and H (ft).

Card(s) 6

Card(s) 6 is used to input initial displacements or rotations for only those joints having a -1 specified for degree of freedom code on card 5. If no joints have initial displacements, card 6 is ignored.

Number of the Displaced Joint: Only numbers of joints which are subjected to an initial displacement.

Initial Joint Translations and Rotations (DX, DY, DZ, θx, θy, θz): Initial displacements must be entered in the global coordinate system. For rectangular coordinates, input X, Y, and Z translations in inches and rotations θx, θy, and θz in radians. For cylindrical global coordinates input R and H displacements in inches, and other displacements in radians. Initial displacements may be input only once for each run and are incorporated into the first loading condition only.

Card(s) 7

Card(s) 7 describes the section properties of the various different types of members in the structure. There should be as many number 6 cards as number of member types specified on card 2.

Member Type (MTYPE): A number identifying the member type is assigned in ascending order beginning with one. A maximum of 50 different types of members may be used.

Area of Section (AREA): The cross sectional area of each member type should be input on each card(s) 7 in units of (in.^{2}). Input values must be greater than 0.

Moments of Inertia (IX, IY, IZ): Input the member cross sectional polar moment of inertia (IX) and the cross sectional moments of inertia (IY, IZ) of the area about the local Y and Z coordinate axes in units of inches ^{4}. See Fig. 1.1b for details for local member coordinates. For closed members $IX = IY + IZ$, for open members $IX = \Sigma bt^3/3$ or see property J in AISC manual of steel construction, 7th edition, properties for designing, J is given for individual shapes. Input values of IX, IY, IZ must be greater than zero.

Shear Areas (ASY, ASZ): Input the member type cross sectional area (in.^{2}) which is available for shear in local Y and Z directions. If shear deflection is to be neglected, enter zero.

Member Weight MWT: In dead load calculations the user may wish, for modeling purposes, to input a member weight (kips/ft) which is independent of member area. If, however, member dead loads are to be a function of member area and material density (as indicated with S.G. on card 10) input a value of -1 for MWT. When using MWT, SG (on card 10) must be greater than zero. When SG is set equal to zero, dead load will be neglected irregardless of the value input for MWT. For dummy members, set MWT = 0 when dead load option (SG card 10) is used. Otherwise, dummy member weights will be included.

Cards 8

Card 8 describes for each member in the structure its end joint numbers, the end conditions and other properties peculiar to each single member. There should be one card 8 for each member in the structure as specified on card 2.

Member Number (IMEM): Identification number of member described on this card is assigned by the user. The member should be numbered consecutively and a member number may neither exceed the total number of members (as specified on card 2) nor the maximum number of 420 members which E1691A can handle.

Joint Numbers (IL, IR): Input the individual member's left end joint number (IL) and right end joint number (IR). Left and right ends may be assigned arbitrarily but caution should be taken to adhere to the initially established convention.

End Condition Code (IT): This code indicates the support condition for each member. End fixity refers to the left joint and right joint respectively, (i.e. rigid-hinged means rigid left joint, hinged right joint). Four conditions are possible:

IT = 0 denotes a rigid - rigid condition

IT = −1 denotes a hinged - rigid condition

IT = 1 denotes a rigid - hinged condition

IT = 2 denotes a hinged - hinged condition

Roll About Local X Axis (GAM): Input the rotation of the cross section about the positive local x-axis in units of degrees. This eliminates transforming the member cross sectional properties by hand.

The position of a member in space is determined by the global coordinates of its points. However, unless the member is axially symmetric, there is one unspecified degree of freedom, that is, the rotation of the principal axes of the member from the global axes. This additional quantity is called the angle GAMMA (γ) see Fig. 1.1c

For differentiation, call X, Y, Z a global coordinate system and x, y, z a member system. Let A be a plane containing the member x axis and a line parallel to the global Y axis (therefore perpendicular to the X-Z plane). Let y' be a coordinate in this plane and perpendicular to the x axis. The direction of y' must be taken so that the projection of y' on the Y axis is in the positive Y direction. Then γ the angle from y' to y, positive by the right-hand rule around x. This definition is not sufficient if the x axis is parallel to the Y axis, in which case the plane A is indeterminate. Then γ is the angle from the −X axis to the y axis if the x axis is in the same direction as the Y axis and from the +X axis if not.

For plane structures, the definition is taken that when $\gamma = 0$, the member z axis is parallel to and in the same direction as the Z axis. For plane structures, γ must be either zero or a multiple of 90°; γ is given in decimal degrees.

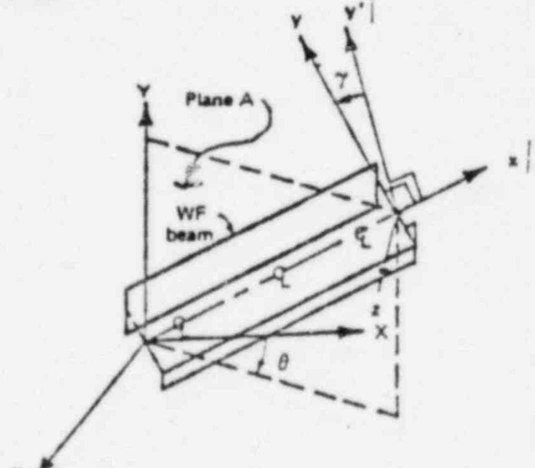


Fig. 1.1c Local Coordinates For a Member

Member Type (MTYPE): Enter the number of the member type which corresponds to this member.

Increase in Temperature (TT): If thermal stresses are to be considered, enter the desired increase (decrease is negative) in temperature which the member will undergo in degrees Fahrenheit. Joint displacements and member forces will be correspondingly adjusted. Enter zero if thermal stresses are not to be considered. Program can handle only one thermal case per run and will incorporate thermal effects into only the first load case in a particular run. The temperature effect can be included in other cases by using the load combination option.

Member Flag Code (IFLAG): The member flag code is used to indicate when member properties or characteristics dictate its use as a tension or compression member only. No internal changes are made to eliminate or change flagged members. The code is defined as follows:

IFLAG = −1 Tension member only

IFLAG = 1 Compression member only

IFLAG = 0 Member may take tension or compression

The following comments form an explanation of input items corresponding to Fig. 1.1b which deals entirely with loading condition information. The cards included on Fig. 1.1b are repeated in sequence for each loading condition.

Card 9

Card 9 is simply a title card with eighty (80) spaces available to describe or name each loading condition.

Card 10

Card 10 inputs the number of the loading condition (LTRY) and the number of loaded joints (NOLJS) and members (NOLDS) for purposes of reading in cards 11 and 12. An automatic dead load option is available so that the user need not load each member with its own weight. If the dead load of all the members is desired the unit weight of the material (SG) should be input. If dead load is not to be added set SG = 0. Sign convention is very important; when using this option, global coordinate axis Z must be vertical and positive upward.

Card(s) 11

For each loaded joint card 11 gives the number of that joint (IJX), the three components (global coordinates) of force on that joint (FX, FY, FZ) in units of kips, and the three components of moment on that joint (MX, MY, MZ) in units of foot-kips.

Card(s) 12

The purpose of card 12 is to describe a member load. Program E1691A is capable of processing concentrated loads or distributed loads anywhere along the length of the member applied in either the local x-y plane or x-z plane. A load may be inclined at an angle measured from the normal to the member. One card 12 is necessary for each load on each member.

Number of Loaded Member (IMEX): The number of the member upon which the load acts must correspond with the IMEM system previously established.

Multiple Load Code (IXXI): All loads pertaining to a particular member must be input sequentially. The multiple load code indicates whether or not another load follows for the particular member being loaded. The code is defined below:

IXXI = 0 Indicates that this load card is the last (or only) load to be read in for the specified member (IMEX).

IXXI = 1 Indicates that more member loads follow for this member.

Load Plane Code (ITL): The plane in which the load acts is specified as follows:

IPL = 0 When loads are in local x-z plane

IPL = 1 When loads are in local x-y plane

Distance from left end to load (AB2), distance from left end to end of load (AB3), angle from load direction to member normal (AB4) are self-explanatory and are best described in Fig. 2 on Fig. 1.1b.

For distributed loads where AB3 equals the member length, AB3 may be input as any value greater than or equal to the actual member length. The program will use the member length as calculated from the joint coordinates and run the load to the end of the member. Therefore, if exact member lengths are unknown and the distributed load runs to the end of the member, AB3 may be input longer than the member actually is.

Load or Load Intensity (AB1): If the load is concentrated (AB2 = AB3) the load is input in units of kips; if the load is distributed the input units are kips per foot.

1.2 Output Data: Figs. 1.2a thru 1.2g illustrate output from a sample run of E1691A. Although the output data is relatively clear and self explanatory, the following comments may serve as a guide to the familiar user.

Several pages of output should be generated with each job. The output includes an "echo" of the input data with minor additions such as member lengths and angles of orientation with respect to global coordinates. Orientation consists of a Z-Y-X rotation (See (6) in 2.0). For each loading condition the printed output includes (1) a listing of joint loads and member loads, (2) computed global joint displacements (in.) and rotations (radians) for each joint, (3) member end forces (kips) and moments (ft-kips) in local coordinates and finally (4) the reactions at the restained joints.

Loading combination output is self explanatory.

Various messages of warning and diagnostic notes will be printed when faulty input warrants the attention of the user.

2.0 THEORETICAL SUMMARY AND NOTES

The topic of displacement solution of frames and trusses known as the stiffness method is thoroughly covered in many texts concerned with matrix methods of structural analysis. Since this standard is limited in length, the reader who desires a greater depth or background in the topic is encouraged to consult other available literature for a full understanding. A very brief survey of the stiffness (or displacement) method follows.

The stiffness method expresses internal member forces and moments in terms of the joint components of displacement. These expressions are substituted into a structure equilibrium matrix equation of the form:

$$(P) + [K]\ (u) = 0$$

Where (P) represents the initial out of balance member forces translated to joint displacement components, [K] represents the structural stiffness matrix containing the assembled member stiffness coefficients and (u) represents the unknown joint displacements (one for each degree of freedom) of the structure due to the given loading condition. Stiffness coefficients for structural members may be defined more fully as the relation denoting joint force components resulting from corresponding individual unit displacements.

The matrix equation is simply a system of linear simultaneous equations with joint displacement components as the unknowns. Once the joint displacements are known the member end forces are easily obtained.

The following notes and comments have been compiled to aid the user in the usage of programs E1691A and E1689A.

1) Limitations on parameters for program E1689A are listed below:

1200	members
700	joints
3200	degrees of freedom
250	half band width
100	member types

2) Very large structures will require a considerable amount of time irregardless of the version (E1691A or E1689A) used.

3) When using cylindrical coordinates the programs will not accept radius entries of zero. Any zero entry for radius made by the user will be automatically changed to 0.01 feet. The user must correct headings on the printout when cylindrical coordinates are used (i.e. X to R, Y to θ, and Z to H). This applies to all global output.

4) Economy of computer resources and the user's time and effort is always important; only a portion of a symmetrical structure in many cases may be necessary for a complete analysis.

5) Choosing global coordinates for a structure can be very important. In particular, if member loads are present, care must be taken to avoid reversing the local coordinate system as illustrated in Figs 2.0a and 2.0b below. It is recommended planar problems be located in the X-Y global system. For normal usage, the X-Y gobal plane should be chosen for the horizontal plane in three dimensional problems.

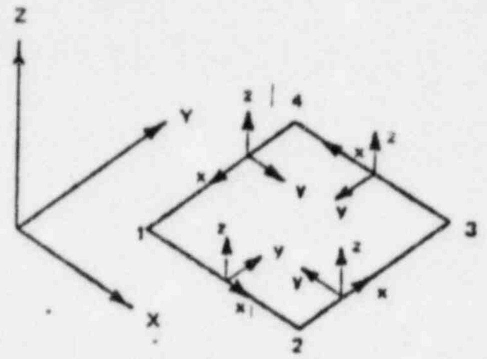


Fig. 2.0a Frame Located in Global X—Y Plane

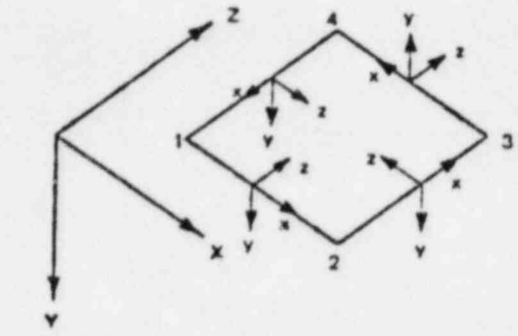
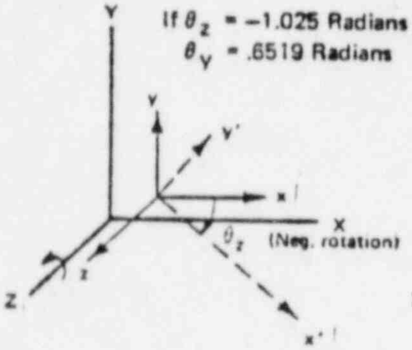
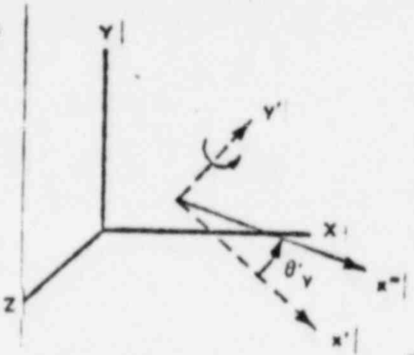
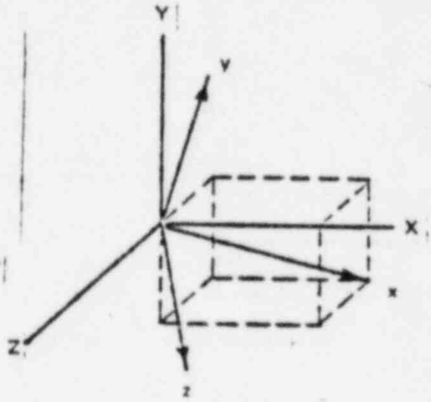


Fig. 2.0b Frame Located in Global X—Z Plane
Note Reversed Direction of Local y on Member 3—4

6) In order to determine local axis orientation of a member, begin with member in global system and rotate through angles listed with member properties.



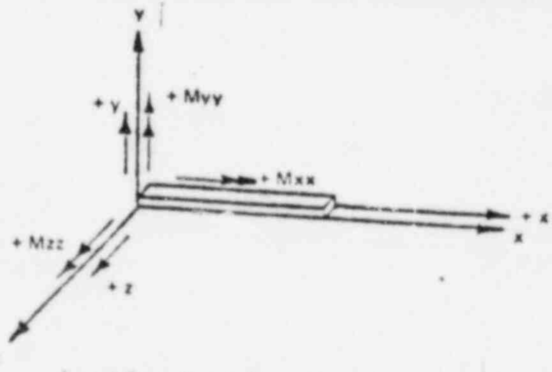




Final Member Coordinate System Orientation

OUTPUT GIVEN

Member	Jt	Fx	Fy	Fz	Mx	My	Mz
	1	−163.2	−.85	.439	1.73	−5.2	−13.2
	3	163.2	.85	−.439	−1.73	−3.85	−14.26



Local Coordinate Force Sign Convention

12-11

~~A~~

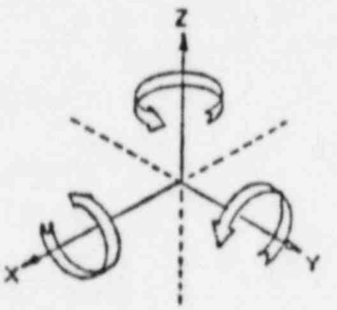
2. Axis Systems

There are two axis systems used by the program. The two systems are (a) an overall global system that applies to the complete structure, and (b) a member local axis system. Each coordinate system is a right hand orthogonal X, Y, Z system. This is explained as follows:

Right-Handed Coordinate Systems

The program assumes that all coordinate positions, angles and rotations are specified according to a right-handed system of cartesian coordinates with orthogonal axes, as illustrated in the figure on this page.

HOLD the RIGHT HAND so that the thumb and first two fingers are orthogonal to one another. The sequence of thumb, forefinger and next finger point in the positive directions of the X-, Y- and Z-axes of a right-handed coordinate system.



Imagine grasping a coordinate axis by the right hand, with the thumb pointing along the axis in its positive direction. The positive sense of an angle, or an angular rotation, will be given by the direction in which the fingers curl around this axis. A negative sign for an angle will specify a rotation in the opposite direction.

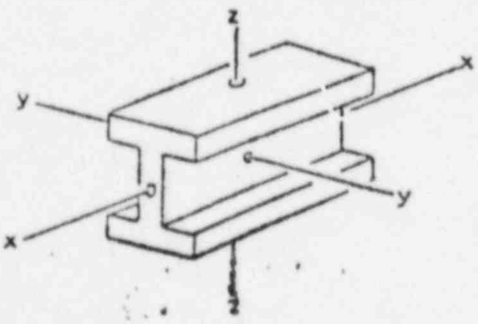
The two major axis systems used by the program are discussed in the following sections.

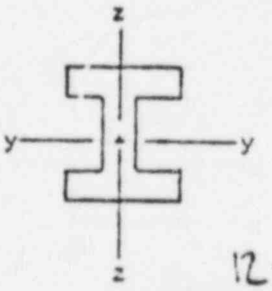
a. Overall Global Axis System

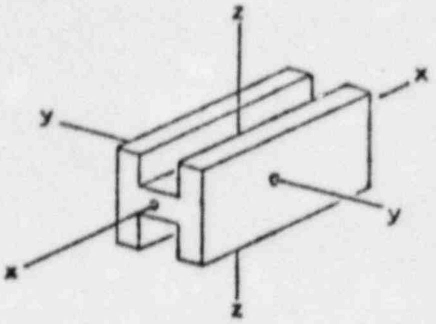
The overall global axis system applies to the complete structure and is used for locating joints of the structure. The coordinate values given on the joint data cards refer to this system. The overall axis system may also be used to specify load directions, such as dead loads or wind loads. The overall axis system has one origin and its location is input by the user. It is usually placed to take advantage of symmetry on the structure if it exists. This greatly reduces the problem of generating the coordinate location of joints. In the overall axis system the X-Y plane usually represents the horizontal plane of the structure, and the overall Z is orthogonal to the plane and in a direction opposite to gravity. This generally agrees with normal conventions used in structural analysis. See Figure 1 of the main report.

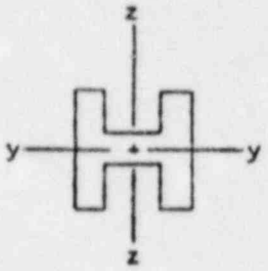
b. Member Local Axis System

The member local axis system is used for describing the physical properties of each member. Each member in the structure has an axis system. The axes are labeled x, y, z using lower case letters to differentiate them from the overall global system. The x direction is always along the axial direction of the member and y-z plane is orthogonal to the x. The y-z plane contains the member's cross-section. Two examples follow:









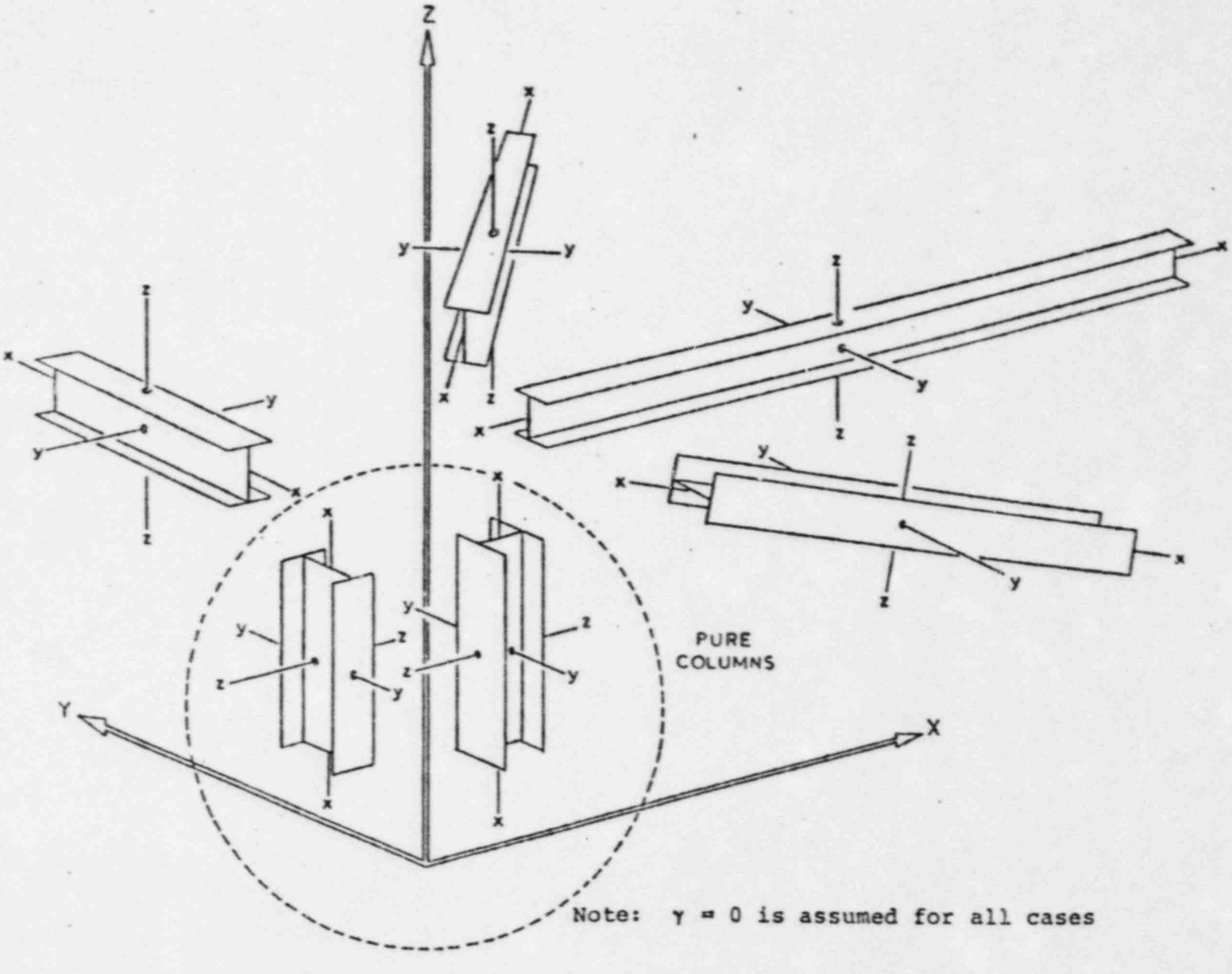
c. Relationship Between Overall Global Axis and Member Local Axis Systems

The particular arrangement of the y, z axis with respect to the cross-sectional geometry of the "I" beam depends on the particular structure, and how the member may be rotated. There is a set relationship between the overall axis system and the member axis system so that the program can associate each member's properties to the complete structure. This set relationship of x, y, z has nothing to do with the strongest direction of a cross-section of a member nor with the axis shown in the Steel Construction Manual. The set relationship between x, y, z and X, Y, Z is shown on the following page.

The figure on the following page refers to the relationship between the overall axis system and the member axis system. The general case is the beam, brace, or diagonal member while a pure column, with its axial direction exactly agreeing with overall Z, is treated as a special case. For the following, it is assumed that the members are not rotated about its local axial axis ($\gamma = 0$).

Rules for the general case member:

(1) The x axis is always along the axial direction of the member no matter how it is used in the structure. The positive direction of x is assumed to be from the left joint to the right joint.



Note: $\gamma = 0$ is assumed for all cases

(2) The z axis of the member is generally made to agree with the direction of overall Z.

(3) The member y axis is generally made parallel to the overall X-Y horizontal plane.

(4) The x, y, z axis system is a right-hand system and is orthogonal.

Note: For $\gamma = 0$, all vertical loads on the structure will cause bending moments about each general case member's y axis.

Consider the general member, and notice the direction of the z axis as the member is rotated about its y axis: the z axis is approaching the horizontal position. At the same time, the member x axis is agreeing more and more with the overall Z. When the member becomes <u>absolutely</u> vertical, we have the special case of a pure column.

Rules for pure columns: ($\gamma = 0$)

(1) As in the general case, the x axis is always along the axial direction of the member (positive left to right).

(2) The x axis always agrees exactly in direction with overall Z.

(3) The member y axis always agrees exactly in direction with overall Y.

(4) The member y axis is parallel to the overall X-Y plane.

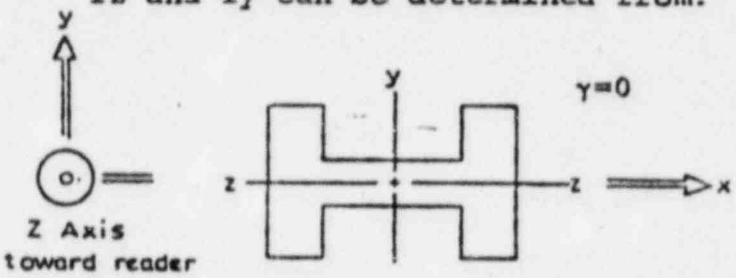
(5) The member z axis always agrees exactly in direction with overall X.

(6) The member z axis is parallel to the overall X-Y plane.

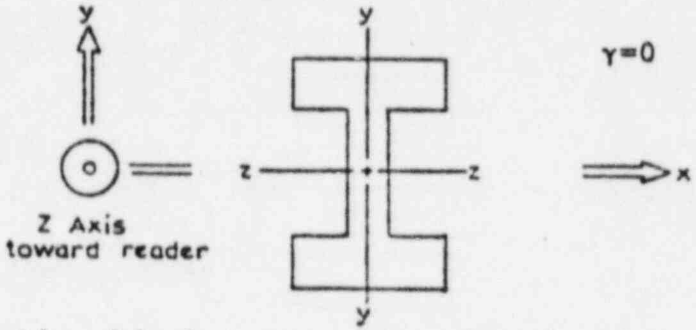
Note: All horizontal loads in the overall X direction will cause bending moments about the y axis in pure columns.
All horizontal loads in the overall X direction will cause bending moments about the z axis in pure columns.

In the axis system illustration the type of members shown is unimportant, and how they are placed within their own axis system in unimportant. However, the relationship between the member local axis system and the overall global axis system is important. As members are placed in the structure, knowledge of axis system relationships enables one to determine values for the moments of inertia about the y and z axes. These examples explain this:

Example #1: If an "I beam" is to be used as a column (pure column) and it is desired that the web be parallel with the Z-X plane of the structure Iz and Iy can be determined from:

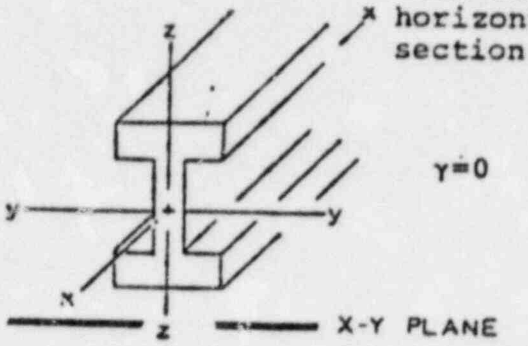


Example #2: For the previous column, if the webbing of the "I beam" were to be perpendicular to the Z-X plane of the structure, the cross-section would appear as follows:

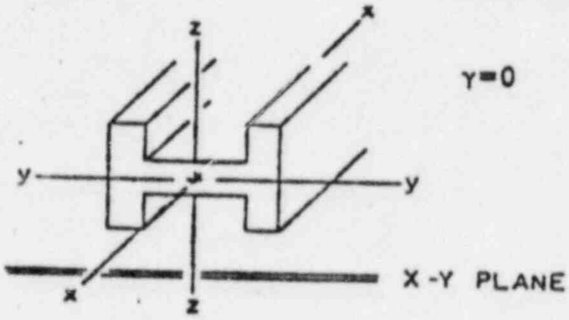


The relationship between the member local axis system and the overall global system has not changed -- just the placing of the member within the system.

Example #3: If a beam or angle brace of a structure is to be an "I beam" with its webbing vertical to the horizontal X-Y plane, its cross-section would appear this way:



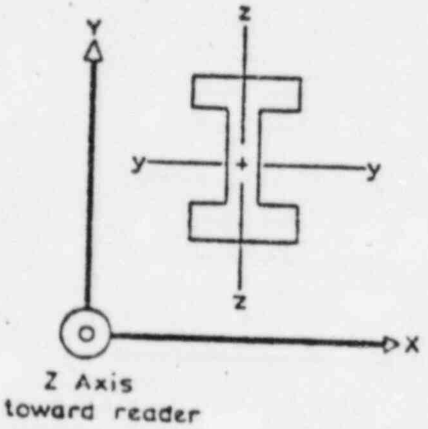
Example #4: If the beam of Example #3 were to have its web parallel to the X-Y plane, it would appear as follows. (If the "I beam" were a diagonal, the web in the cross-sectional view would be parallel to the X-Y plane).



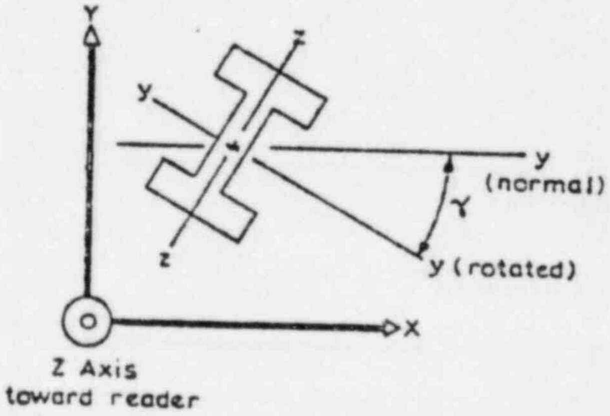
Note: When plane frames are analyzed, a vertical plane of the relationship just discussed is used -- either the Z-X plane or the Z-Y plane. In plane frame analysis some moments of inertia are not needed if all loads act in the plane.

3. Rotated Member Axis ($\gamma \neq 0$)

In some cases a structure is built where a rotated axis system is needed for some members. In the case of "pure columns" one might have a circular structure where the member's principal cross-sectional axis may lie on the radius of the circle and, therefore, the member's y and z axes will not be parallel to the overall X and Y respectively. For the "general case member" (e.g. beams, braces, diagonals) the member's y axis may be so placed that it is not parallel to the overall X-Y horizontal plane. In either case, the member's cross-section has been rotated through an angle γ. The member axis may be rotated for geometrical reasons or for analysis output reasons. If a pipe (circular cross-section) is used in a structure and the desired forces and moments are needed in a direction other than the normal output direction, the axis may be rotated in some desired direction to agree with an oblique joint or another member's axis system. In either the "pure column" or the "general member" case, the rotated angle γ is measured from the normal position of the y axis to the rotated position of the y axis. The positive sense is determined from the right hand rule and the direction of the member's x axis. This angle γ is given in degrees on the member property type card (Card 12, Table 1). γ has a range from -180.0° to +180.0° ($-180.0° \le \gamma \le 180.0°$). Two examples are given to clarify the discussion of γ.



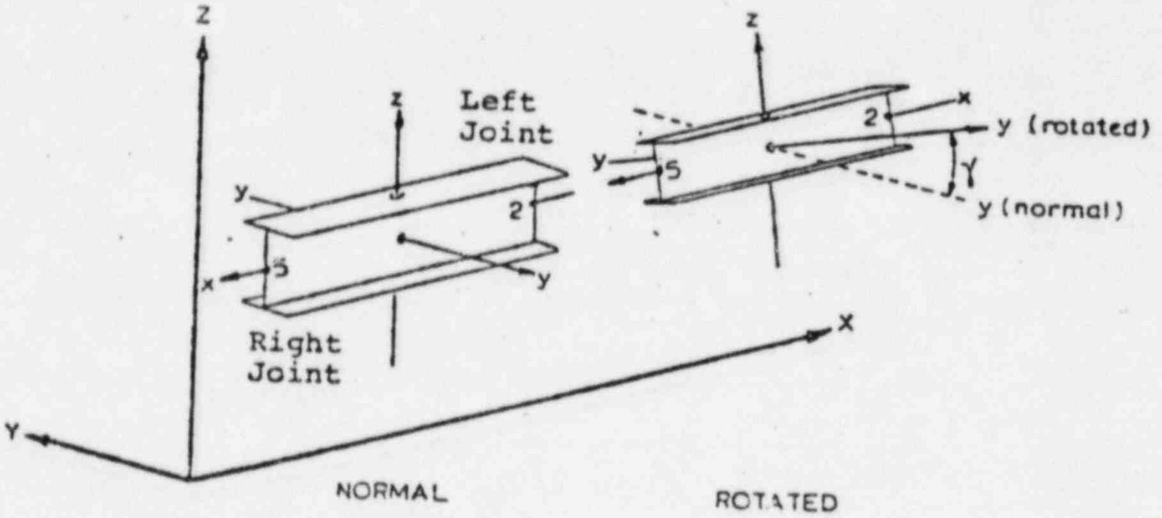
Example 1: Normal Relationship
$y \| X$, $z \| Y$



Example 2: Rotated Pure Column

In the second example the γ angle shown is from the normal γ relationship to the rotated y. To determine the sense of the angle, note the direction of the member x axis and use the right hand rule. In the previous example, <u>if</u> the x was out of the paper, the counter clockwise direction would be positive and the value of γ would be negative.

In the "general member" case the member's y axis may not be parallel to the overall X-Y plane after it has been rotated. The normal relationship for this member is to have its y axis parallel to X-Y plane. Therefore, measure γ from the normal y axis position to its new rotated y position. This angle is measured in the member's y-z plane, and its sense is determined from the right hand rule applied to the member x axis.



If this member had been labeled 2 5 on the MEMBER card, the x axis would be positive from left to right as shown and the γ angle shown would be positive.

Note:

1) For rotated members the plane of the cross-section does not change -- just the orientation of the principal axis in the plane. The angle γ is always measured in this plane from the normal y position to the new rotated y position.

2) A member does not have a positive x direction until it has been entered on the MEMBER card, positive x being from left joint to right joint.

```
*BCD
E1691A--S.P.#1     DEFLECTION CHECK -- W/MEMBER WT OPTION
  3,4,3,1,0,0,30000,.3,0,0,
   .0,0,0,0,0,0,0,0,
..0,1,1,0,0,0,0,0,0,
2,0,1,1,0,0,0,40,0,0,
3,0,1,-1,0,0,0,90,0,0,
4,1,1,1,1,1,1,130,0,0,
3,0,0,-1,0,0,0,
1,0,70.7,0,100,15724,950,0,0,.2405,4*0,
1,1,2,0,0,1,0,0,
2,2,3,0,0,1,0,0,
3,3,4,0,0,1,0,0,
LOAD COND 1 - DEFLECTION ONLY
1,0,0,0,
LOAD COND 2 - MEMBER WT ONLY
1,0,0,1,
*BCD
E1691A--S.P.#2     DEFLECTION CHECK -- W/SHEAR DEFLECTION
0,3,4,3,1,0,0,30000,.3,0,0,
10*0,
1,0,1,1,0,0,0,0,0,0,
2,0,1,1,3*0,40,0,0,
3,0,1,-1,3*0,90,0,0,
4,6*1,130,0,0,
3,0,0,-1,3*0,
1,0,70.7,0,100,15724,950,2*35.3,-1,4*0,
1,1,2,0,0,1,0,0,
  2,3,0,0,1,0,0,
   ,4,0,0,1,0,0,
   D
E1691A--S.P.#3     24 MEMBER FRAME  MULTIPLE LOADING
4,3,16,24,1,0,0,30000,.3,0,0,
1,0,30,30,6*0,
1,1,1,1,1,0,1,0,10,0,
2,1,1,1,1,0,1,0,0,0,
3,1,1,1,1,0,1,5,0,0,
4,1,1,1,1,0,1,5,10,0,
5,0,0,0,0,0,0,0,10,5,
6,0,0,0,0,0,0,0,0,5,
7,0,0,0,0,0,0,5,0,5,
8,0,0,0,0,0,0,5,10,5,
9,0,0,0,0,0,0,0,10,10,
10,0,0,0,0,0,0,0,0,10,
11,0,0,0,0,0,0,5,0,10,
12,0,0,0,0,0,0,5,10,10,
13,0,0,0,0,0,0,0,10,15,
14,0,0,0,0,0,0,0,0,15,
15,0,0,0,0,0,0,5,0,15,
16,0,0,0,0,0,0,5,10,15,
1,0,1.,0,.166667,.083333,.083333,0.,0,-1,4*0,
1,1,5,0,0,1,0,0,
2,5,9,0,0,1,0,0,
3,2,6,0,0,1,0,0,
4,3,7,0,0,1,0,0,
   ,3,0,0,1,0,0,
    ,5,0,0,1,0,0,
..5,8,0,0,1,0,0,
 ,6,7,0,0,1,0,0,
9,7,8,0,0,1,0,0,
```

card list of
Sample DATA

12-22

```
10,9,13,0,0,1,0,0,
 ,6,10,0,0,1,0,0,
 ,7,11,0,0,1,0,0,
3,8,12,0,0,1,0,0,
14,9,10,0,0,1,0,0,
15,9,12,0,0,1,0,0,
16,10,14,0,0,1,0,0,
17,11,15,0,0,1,0,0,
18,12,16,0,0,1,0,0,
19,10,11,0,0,1,0,0,
20,11,12,0,0,1,0,0,
21,13,14,0,0,1,0,0,
22,14,15,0,0,1,0,0,
23,15,16,0,0,1,0,0,
24,16,13,0,0,1,0,0,
LOADING NO 1
1,2,0,0,
9,1.,0,0,0,0,0,
10,1.,0,0,0,0,0,
LOADING NO 2
2,2,0,0,
9,2.,0,0,0,0,0,
10,2.,0,0,0,0,0,
LOADING NO 3
3,0,1,0,
14,1,1,0,0,0,1.,
14,0,1,10,10,0,1.,
LOADING NO 4
  0,0,.49,
  0D
E1691A--S.P.#4     3 BAR FRAME THERMAL DEFLECTION ONLY
0,3,4,3,1,0,0,29000,.3,.001,0,
0,0,0,0,0,0,0,0,0,0,
1,1,1,1,1,1,1,-5,0,0,
2,0,0,1,1,1,0,-5,10,0,
3,0,0,1,1,1,0,5,10,0,
4,1,1,1,1,1,1,5,0,0,
1,0,2,0,2,1,1,0,0,-1,4*0,
1,1,2,0,0,1,10,0,
2,2,3,0,0,1,10,0,
3,3,4,0,0,1,10,0,
*BCD
E1691A--S.P.#5     3D TRUSS      NO STRESS CALCULATIONS
1,3,13,20,4,0,0,29000,.3,0,0,
4,0,-135,30,180,0,-90,0,-90,90,
4*1,4*0,15,0,
2,3*1,6*0,
3,6*0,0,7.5,10,
4,6*0,0,15,10,
5,6*0,0,0,10,
6,6*0,20,0,5,
7,6*0,5,0,12.5,
8,6*0,10,0,15,
9,6*0,10,0,10,
10,6*0,15,0,12.5,
 ,5*0,20,0,10,
 ,6*0,15,0,10,
13,6*1,20,0,0,
1,0,5.20,0.0,.2100,107.0,10.8,0.0,0.0,-1,4.95,4.95,2.875,2.875
2,0,3.81,0.0,.1900,10.50,3.3 ,0.0,0.0,-1,2.00,2.00,1.970,1.970
```

```
3,0,2.23,3.5,6.040,3.020,3.02,0.0,0.0,-1,0.00,0.00,0.000,0.000
4,0,4.56,0.0,.1110,30.10,9.67,0.0,0.0,-1,3.00,3.00,3.000,3.000
   ,4,0,0,1,0,0,
   ,5,0,0,1,0,0,
3,13,6,0,0,1,0,0,
4,6,11,0,0,1,0,0,
5,3,5,0,0,3,0,0,
6,5,9,0,0,3,0,0,
7,9,12,0,0,3,0,0,
8,12,11,0,0,3,0,0,
9,4,3,0,0,3,0,0,
10,5,7,0,0,2,0,0,
11,7,8,0,0,2,0,0,
12,8,10,0,0,2,0,0,
13,10,11,0,0,2,0,0,
14,7,9,2,0,4,0,0,
15,8,9,2,0,4,0,0,
16,10,9,2,0,4,0,0,
17,2,3,0,0,3,0,0,
18,3,1,0,0,3,0,0,
19,5,6,0,0,3,0,0,
20,4,8,0,0,3,0,0,
DISTRIBUTED AND CONCENTRATED LOADS
1,3,1,0,
5,0,15,4*0,
6,6,5*0,
12,0,0,-5,3*0,
12,3*0,5.59,26.56,-2,
*300
   91A--S.P.4c     3D TRUSS      STRESS CALCULATIONS-TOTALS
   ,13,20,4,0,0,29000,.3,0,0,
4,0,-135,30,180,0,-90,0,-90,90,
4*1,4*0,15,0,
2,3*1,6*0,
3,6*0,0,7.5,10,
4,6*0,0,15,10,
5,6*0,0,0,10,
6,6*0,20,0,5,
7,6*0,5,0,12.5,
8,6*0,10,0,15,
9,6*0,10,0,10,
10,6*0,15,0,12.5,
11,6*0,20,0,10,
12,6*0,15,0,10,
13,6*1,20,0,0,
1,2,6.20,0.0,.2100,107.0,10.8,0.0,0.0,-1,4.95,4.95,2.875,2.875
2,2,3.81,0.0,.1900,10.50,3.36,0.0,0.0,-1,2.00,2.00,1.970,1.970
3,1,2.23,3.5,6.040,3.020,3.02,0.0,0.0,-1,0.00,0.00,0.000,0.000
4,2,4.56,0.0,.1110,30.10,9.67,0.0,0.0,-1,3.00,3.00,3.000,3.000
1,1,4,0,0,1,0,0,
2,2,5,0,0,1,0,0,
3,13,6,0,0,1,0,0,
4,6,11,0,0,1,0,0,
5,3,5,0,0,3,0,0,
6,5,9,0,0,3,0,0,
7,9,12,0,0,3,0,0,
   2,11,0,0,3,0,0,
  4,3,0,0,3,0,0,
10,5,7,0,0,2,0,0,
11,7,8,0,0,2,0,0,
```

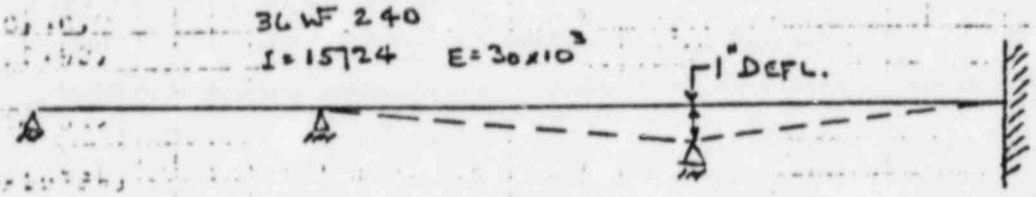
```
12,8,10,0,0,2,0,0,
13,10,11,0,0,2,0,0,
 4,7,9,2,0,4,0,0,
  ,8,9,2,0,4,0,0,
 6,10,9,2,0,4,0,0,
17,2,3,0,0,3,0,0,
18,3,1,0,0,3,0,0,
19,5,6,0,0,3,0,0,
20,4,8,0,0,3,0,0,
DISTRIBUTED AND CONCENTRATED LOADS
1,3,1,0,
5,0,15,4*0,
6,6,5*0,
12,0,0,-5,3*0,
12,3*0,5.59,26.56,-2,
*BCD
E1691A--S.P.#7    3D TRUSS LOAD COMBINATION  STRESS CALCS-BREAKDOWN
2,3,13,20,4,0,0,29000,.3,0,-1,
4,0,-135,30,180,0,-90,0,-90,90,
2,1,.5,2,.5,
4*1,4*0,15,0,
2,3*1,6*0,
3,6*0,0,7.5,10,
4,6*0,0,15,10,
5,6*0,0,0,10,
6,6*0,20,0,5,
7,6*0,5,0,12.5,
8,6*0,10,0,15,
9,6*0,10,0,10,
  ,6*0,15,0,12.5,
 ,6*0,20,0,10,
12,6*0,15,0,10,
13,6*1,20,0,0,
1,-2,6.20,0.0,.2100,107.0,10.8,0.0,0.0,-1,4.95,4.95,2.875,2.875
2,-2,3.81,0.0,.1900,10.50,3.36,0.0,0.0,-1,2.00,2.00,1.970,1.970
3,-1,2.23,3.5,6.040,3.020,3.02,0.0,0.0,-1,0.00,0.00,0.000,0.000
4,-2,4.56,0.0,.1110,30.10,9.67,0.0,0.0,-1,3.00,3.00,3.000,3.000
1,1,4,0,0,1,0,0,
2,2,5,0,0,1,0,0,
3,13,6,0,0,1,0,0,
4,6,11,0,0,1,0,0,
5,3,5,0,0,3,0,0,
6,5,9,0,0,3,0,0,
7,9,12,0,0,3,0,0,
8,12,11,0,0,3,0,0,
9,4,3,0,0,3,0,0,
10,3,7,0,0,2,0,0,
11,7,8,0,0,2,0,0,
12,8,10,0,0,2,0,0,
13,10,11,0,0,2,0,0,
14,7,9,2,0,4,0,0,
15,8,9,2,0,4,0,0,
16,10,9,2,0,4,0,0,
17,2,3,0,0,3,0,0,
18,3,1,0,0,3,0,0,
 9,5,6,0,0,3,0,0,
  ,4,8,0,0,3,0,0,
LOAD COND 1
1,3,1,0,
5,0,15,4*0,
```

```
6,6,5*0,
12,0,0,-5,3*0,
12,3*0,5.59,26.56,-2,
  LOAD COND 2
2,3,1,0,
5,0,15,4*0,
6,6,5*0,
12,0,0,-5,3*0,
12,3*0,5.59,26.56,-2,
*BOD
E1691A--S.P.#8    3D TRUSS LOAD COMBINATION  STRESS CALCS-TOTALS
2,3,13,20,4,0,0,29000,.3,0,1,
4,0,-135,30,180,0,-90,0,-90,90,
2,1,.5,2,.5,
4*1,4*0,15,0,
2,3*1,6*0,
3,6*0,0,7.5,10,
4,6*0,0,15,10,
5,6*0,0,0,10,
6,6*0,20,0,5,
7,6*0,5,0,12.5,
8,6*0,10,0,15,
9,6*0,10,0,10,
10,6*0,15,0,12.5,
11,6*0,20,0,10,
12,6*0,15,0,10,
13,6*1,20,0,0,
1,2,6.20,0.0,.2100,107.0,10.8,C.0,0.0,-1,4.95,4.95,2.875,2.875
2,2,3.91,0.0,.1900,10.50,3.36,C.0,0.0,-1,2.00,2.00,1.970,1.970
3,2.23,3.5,6.040,3.020,3.02,C.0,0.0,-1,0.00,0.00,0.000,0.000
4,4.56,0.0,.1110,30.10,9.67,C.0,0.0,-1,3.00,3.00,3.000,3.000
1,1,4,0,0,1,0,0,
2,2,5,0,0,1,0,0,
3,13,6,0,0,1,0,0,
4,6,11,0,0,1,0,0,
5,2,5,0,0,3,0,0,
6,5,9,0,0,3,0,0,
7,9,12,0,0,3,0,0,
8,12,11,0,0,3,0,0,
9,4,3,0,0,3,0,0,
10,5,7,0,0,2,0,0,
11,7,8,0,0,2,0,0,
12,8,10,0,0,2,0,0,
13,10,11,0,0,2,0,0,
14,7,9,2,0,4,0,0,
15,8,9,2,0,4,0,0,
16,10,9,2,0,4,0,0,
17,2,3,0,0,3,0,0,
18,3,1,0,0,3,0,0,
19,5,6,0,0,3,0,0,
20,4,8,0,0,3,0,0,
LOAD COND 1
1,3,1,0,
5,0,15,4*0,
6,6,5*0,
12,0,0,-5,3*0,
12,3*0,5.59,26.56,-2,
  LOAD COND 2
2,3,1,0,
5,0,15,4*0,
```

```
[illegible].6,5*0,
12.0,0.-5.3*0.
   3*0.5.55,25.56,-2.
```

CHICAGO BRIDGE & IRON COMPANY

Location (OZE) OAK BROOK



0 377^in-k 707^in-k -865^in-k ← CK ANSWER

REF: P412 THEORY OF SIMPLE STRUCTURES
BY
SHEDD AND VAWTER

12-28

SUBJECT	MADE BY	CHKD BY	REV	BY		CHARGE NO.
	DATE	DATE		CHKD		
				DATE		SHT OF

CO 64
Rev 5-70

CBI

Location [illegible]

Member 1 [illegible] Type 1 [illegible] Rectangular Cross Section

Area = 6.11 in² DIY = 4.95 DZY = 4.95 IY = 106.3 in⁴

DIZ = 2.875 DZZ = 2.875 IZ = 9.7 in⁴

AXSTL = $-\frac{.0[illegible]}{6.11}$ = -.002326 ksi

AYSTL = AXSTL

Joint 1

YLIPL = AP(5) * DIY / IY * 12.
= (-.0002[illegible]) * (4.95)/(106.3) * 12. = -.00016498

YLL = YLIPL

ZLL = AP(6) * DIZ / IZ * 12.
(-.00791[illegible]) * (2.875)/(9.7) * 12. = -.028322

ZRL = ZLL

TCULL = AXSTL - YLIL - ZLL
= (-.002326) - (-.00016948) - (-.028322) = .02[illegible]166

TCURL = AXSTL - YLIL + ZRL
(-.002326) - (-.00016948) + (-.028322) = -.03047[illegible]

TCLLL = AXSTL + YLL - ZLL
= (-.002326) + (-.00016948) - (-.028322) = .[illegible]26

TCLRL = AXSTL + YLL + ZRL
(-.002326) + (-.00016948) + (-.028322) = [illegible]8179

Joint 4

YLIPL = AP(11) * DIY / IY * 12.
= (.0006[illegible]) * (4.[illegible])/(106.[illegible]) * 12. = .000[illegible]664

YLL = AP(11) * DIY / IY * 12.
= (.000[illegible]) * (4.95)/([illegible]) * 12. = .000[illegible]664

12-29

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO
[illegible]	[illegible]			Chkd		[redacted]
[illegible]	DATE	DATE		Date		SHT 1 OF 2

CBI

Location ODE

ZLR = -AF(12)*7.14/LTZ*12.
= -(.071169)*(2.875)/(4.7)*12. = -.312168

ZRL = ZLL

TSULL = AXSTR + YULRR + ZLR
= (-.002326)+(.0003664)+(-.312168) = -.31412

TSULR = AXSTR + YULRL - ZRR
= (-.002326)+(.0003664)-(-.312168) = .31020

TSLLR = AXSTR - YLR + ZLR
= (-.002326)-(.0003664)+(-.312168) = -.31486

TSLRR = AXSTR - YLR - ZRR
= (-.002326)-(.0003664)-(-.312168) = .30947

Summary

JT	UP LEFT	UP RIGHT	LOW LEFT	LOW RIGHT
1	.026444	-.030477	.025826	-.0302179
4	-.31412	.31020	-.31486	.30947

12-30

SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
[illegible]	[illegible]			Chkd		[redacted]
	DATE	DATE		Date		SHT ____ OF ____

11. [illegible]

AREA = 6.19 in²   D1Y = 4.95 in   D2Y = 4.95   IY = 106.2 in⁴

D1Z = 2.775 in   D2Z = 2.775 in   IZ = 9.7 in⁴

AXSTL = [illegible] / 6.19 in² = −.[illegible]226 ksi

AXSTR = −.014 kips / 6.19 in² = −.00226 ksi

YURL = 0

YLL =

ZLL = −[illegible] (2.775 in) / 9.7 in⁴ (12 in/ft) = −.02845 ksi

ZRL = −.02845 ksi

TSULL = −.0[illegible] ~~0~~ + (+.02845) = .02619 ksi

TSURL = −.00226 ~~0~~ + (−.02845) = −.03071 ksi

TSLLL = −.00226 ~~0~~ − −.02845 = +.02619 ksi

TSLRL = [illegible] + −.02845 = −.03071 ksi

YURR = [illegible] (4.95 in) / 106.2 in⁴ (12 in/ft) = .00027 ksi

YLR = [illegible] ksi

ZLR = −.0[illegible] (2.[illegible] in) / 9.7 in⁴ (12 in/ft) = −.31299 ksi

ZRR = −.31299 ksi

TSULR = -.00226 + .000371 + -.31299 = -.31488

TSURR = -.00226 + .00037 + + .31299 = .31110

TSLLR = -.00226 - .00037 + -.31299 = -.31562

TSLRR = -.00226 - .00037 + + .31299 = .31036

mber 1

JTS

1	+.02619	-.03071	+.02619	-.03071
4	-.31488	.31110	-.31562	.31036

[illegible] = [illegible] type = circular cross-section

AREA = 2.228 in² DIAM = 3.5 in IY = 3.017 in⁴ IZ = 6.3 in⁴

$$AXSTL = \frac{-14.973\text{ k}}{2.228\text{ in}^2} = -6.7204\text{ ksi}$$

$$AXSTR = \frac{-14.973\text{ k}}{2.228\text{ in}^2} = -6.704\text{ ksi}$$

$$BENL = \frac{\sqrt{.054^2 + .012^2}\,(\text{ft-k})\ \frac{3.5\text{ in}}{2}}{6.3\text{ in}^4} \times \frac{12\text{ in}}{\text{ft}} = .18248\text{ ksi}$$

$$BENR = \frac{\sqrt{.126^2 + .088^2}\,(\text{ft-k})\ \frac{3.5\text{ in}}{2}}{6.3\text{ in}^4} \times \frac{12\text{ in}}{\text{ft}} = .51234\text{ ksi}$$

TSTL = 6.7204 + .18248 = -6.9029 ksi
TSTR = 6.7204 + .51234 = -7.2328 ksi

Member 5

— ST 3 = -6.9029 ksi
5 = -7.2328 ksi

CBI Program 1823

This program calculates stresses and some reactions for the personnel lock barrel, bulkhead, door, hinge, and latching device due to pressure and seismic loads. Loads and standard or modified coefficients for each stress summary sheet are inputted. Stresses or reactions are computed by multiplying the loads by the coefficients.

Author : R D Hanson

Dated Version : 10/79

Limitations : none

SUBJECT	MADE BY	CHKD BY	REV		CHARGE NO.
Computer Program	GLN	RAH	By		54331
	DATE	DATE	Chkd		
Verification	11/4/82	11/82	Date		SHT 13-1 OF

BARREL DESIGN

The lock barrel is 1/2" thick for fabrication reasons. The thickness is checked as a cylindrical shell in accordance with ASME rules usng the design pressure loads.

The design internal pressure will be external pressure on that portion of the lock barrel that extends inside the containment vessel. The maximum length that the barrel may project inside the containment vessel is determined based on this pressure. For 1/2" barrel and 60 psi, this length is 38".

The maximum length that the barrel may project from the containment wall and remain dynamically rigid is determined. For 1/2" barrel, this length is limited to 27'-5". The additional length is added between bulkheads. For the 27'-5" barrel length, the bulkhead to bulkhead length is limited to 23'-11". This length is checked for the design external pressure. The stress due to Dead Load and acceleration load will be determined based on the projections as determined above.

Design is based on barrel for 4'-0 x 6'-8 door size.

The barrel is analyzed using unit load. The resulting stresses are multiplied by the appropriate factor and tabulated on the stress summary for the barrel. Stresses are reported only at points of interest.

Loads: Design Temperature = 400 °F.

1) PI = Design Internal Pressure = 60 psig

2) PE = Design External Pressure = 5 psig

3) D = Dead Load = 50000 lb.

4) Ahz = Acceleration (horizontal along Z axis) = 1.5 g

5) Ahx = Acceleration (horizontal along X axis) = 1.5 g

6) Av = Acceleration (Vertical) = 1.0 g

Load Case 1B: PI + D + Ahz + Ahx + Av

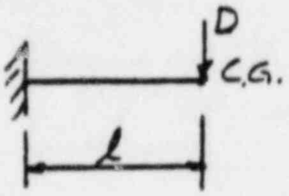
Load Case 2B: PE + D + Ahz + Ahx + Av

13-2

SUBJECT BARREL DESIGN	MADE BY LDF	CHKD BY CRS	REV	By	CHARGE NO. STD. PL
	DATE 8-22-79	DATE 9/6/79		Chkd Date	SHT 1 OF

GO 64 REV 6-73

BARREL LOADS



ℓ = 173.2 (Based on length required for 1/2" thick barrel to remain dynamically rigid)

(D)(1) = Moment due to Dead Load = 50000(173.2) = 8.660×10^6 in-lb.

A_{HZ} = Horiz. Force due to Accel on D
= 1.5 (50000) = 75000 lb.

A_{HX} = Horiz. Force Due to Accel on (D)(1)
= 1.5 (8.660×10^6) = 12.990×10^6 in-lb.

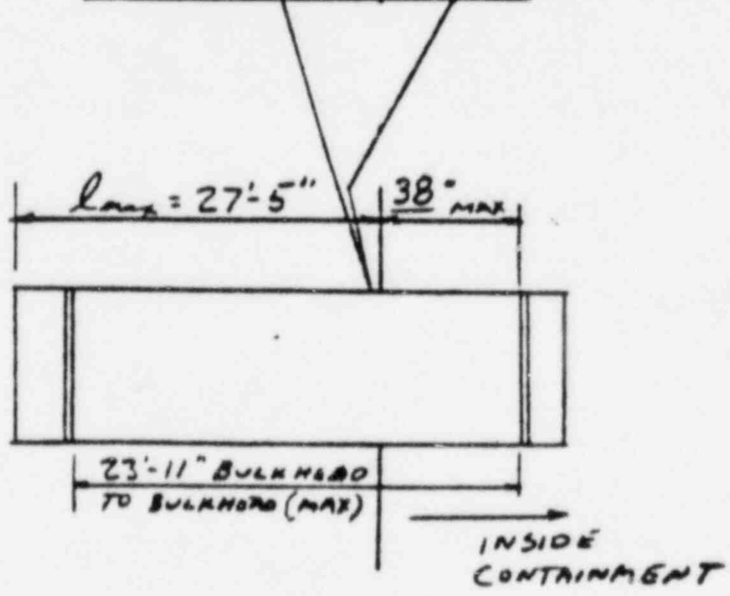
A_V = Vertical Force Due to Accel. on (D)(1)
1.0 8.660×10^5 = 8.660×10^6 in-lb.

SUBJECT BARREL LOADS	MADE BY LDF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 8-22-79	DATE 9/6/79		Chkd		
				Date		SHT ~~3~~ OF

CASE NO.	UNIT LOAD / ACTUAL LOAD	STRESSES (PSI) UNIT STRESS / ACTUAL STRESS σ_θ	σ_ϕ
1B	P_I / 60	126 / 7560	63 / 3780
2B	P_E / 5	-126 / -630	-63 / -315
1B & 2B	(D)(ℓ) / 8.66×10^6		$\pm1.578\times10^{-4}$ / ±1385
1B & 2B	AHZ / 75000		±.005 / ±375
1B & 2B	AHX / 12.99×10^6		$\pm1.578\times10^{-4}$ / ±2075
1B & 2B	A / 8.66×10^6		$\pm1.578\times10^{-4}$ / ±1385

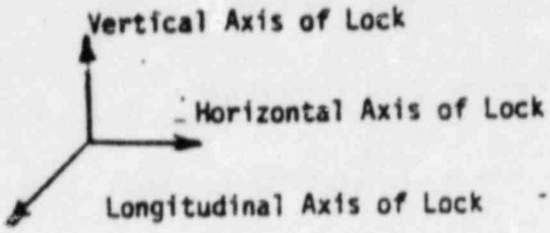
TOTALS

CASE 1B	7560	9000 -1440
CASE 2B	-630	4905 -5535

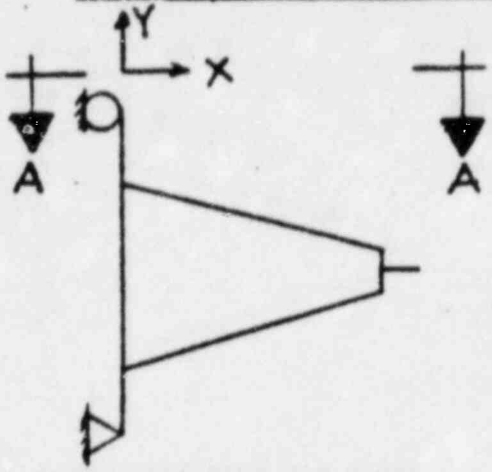


SUBJECT STRESS SUMMARY BARREL	MADE BY LDF DATE 8-22-79	CHKD BY CRS DATE 9/6/79	REV	By Chkd Date	CHARGE NO. STD. PL SHT ~~5~~ 3 OF

GO 84 REV 4-73

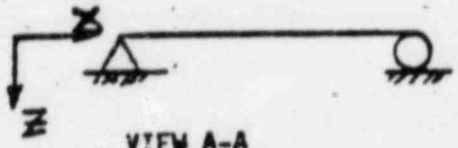


AIRLOCK COORDINATE SYSTEM



HINGE FREE BODY X-Y PLANE

In the X-Y plane the hinge is modeled as a cantilever frame supported at the upper hinge support bracket.and lower hinge support bracket.



VIEW A-A

In the X-Z plane the hinge is modeled as a simply supported frame supported by the upper and lower hinge bracket at one end and by the latch bar assembly at the other end.

The hinge will be designed for the following load case:

Case 1 - Seismic Acceleration acting vertical downward, Horizontally outward (along Z axis tending to unseat door) and horizontally across face of door (along X axis) in combination with the dead load, pressure load, and gasket seating load.

Loads: Design Temperature = 400°F.

1) D - Dead Load
2) Pe - Design External Pressure = 5 PSIG
3) Pg - Gasket Seating Load - 25 lb/in (req'd to maintain 1/8" compression)

4) Ahz - Seismic Acceleration (horizontal along Z axis) = 1.5 g
5) Ahx - Seismic Acceleration (horizontal along X axis) = 1.5 g
6) Av - Seismic Acceleration (vertical) = 1.0 g.

Load Case 1 = D + Pe + Pg + Ahz + Ahx + Av

SUBJECT Hinge Design	MADE BY LOF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL.
	DATE 9-18-79	DATE 10/1/79		Chkd		
				Date		SHT ~~[illegible]~~ OF

An analysis is performed utilizing a unit load. The resulting stresses are multiplied by the appropriate factor and combined in accordance with Case 1. These stresses are tabulated on the stress summary for the hinge. Stresses are reported only at points of interest.

Hinge design is based on dimensions and loads required for a 4'-0x6'-8 door.

SUBJECT HINGE DESIGN	MADE BY LDE	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 9-28-79	DATE 10-1-79		Chkd		
				Date		SHT ~~5of5~~ OF

HINGE DESIGN

HINGE LOADS

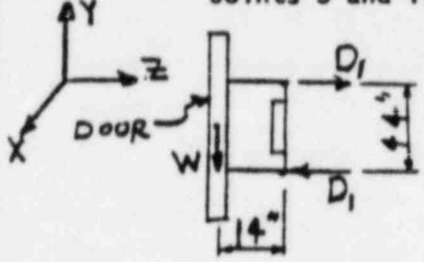
Pe = Pressure Load due to 5 PSI acting over area of door

= (4050) 5 = 20250

Pg = Load due to gasket seating (25#/in)

= Door perimeter x 25 = (250)(25) = 6250#

D1 = Couple produced by Dead Weight of door being cantilevered from Joints 3 and 11



$$D_1 = \frac{W(14)}{44} = \frac{2670(14)}{44} = \pm 850\#$$

D_2 = Wt of door = -2670#

D_3 = Wt of Main Hinge Pin = -350#

D_4 = Wt of Hinge Arm + CTr. Hinge Pin = -1400 + -480 = -1900

D_5 = Wt of Roller Assy. = -100#

A_{HZ1} = Horiz. Force due to accel. on D_1. Although resultant force is horizontal, the cause is vertical. Use vertical Accel. Factor.

= 1.0 (850) = ±850

A_{HZ2} = Horiz. Force Due to Accel. on D_2

= 1.5 (2670) = 4000

A_{HX2} = Horiz. Force Due to Accel on D_2

= 1.5 (2670) = 4000

A_{HZ3} = Horiz Force Due to Accel on D_3

= 1.5 (350) = 525

A_{HX_3} = Horiz. Force Due To Accel. on D_3

1.5 (350) = 525

SUBJECT HINGE LOADS	MADE BY LDF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 3-27-79	DATE 7/16/79		Chkd		
				Date		SHT ~~5-8~~ OF

GO 64 REV 4-73

A_{HZ4} = Horiz. Force due to Accel. on D_4

= 1.5(1900) = 2850

A_{HX4} = Horiz Force Due to Accel On D_4

= 1.5(1900) = 2850

A_{HZ5} = Horiz Force Due to Accel On D_5

= 1.5(100) = 150

A_{HX5} = Horiz. Force Due to Accel on D_5

= 1.5(100) = 150

A_{V2} = Vertical Force Due to Accel on D_2

= -1.0(2670) = -2670

A_{V3} = Vertical Force Due to Accel on D_3

= -1.0(350) = -350

A_{V4} = Vertical Force Due to Accel. on D4

-1.0(1900) = -1900

A_{V5} = Vertical Force Due to Accel on D_5

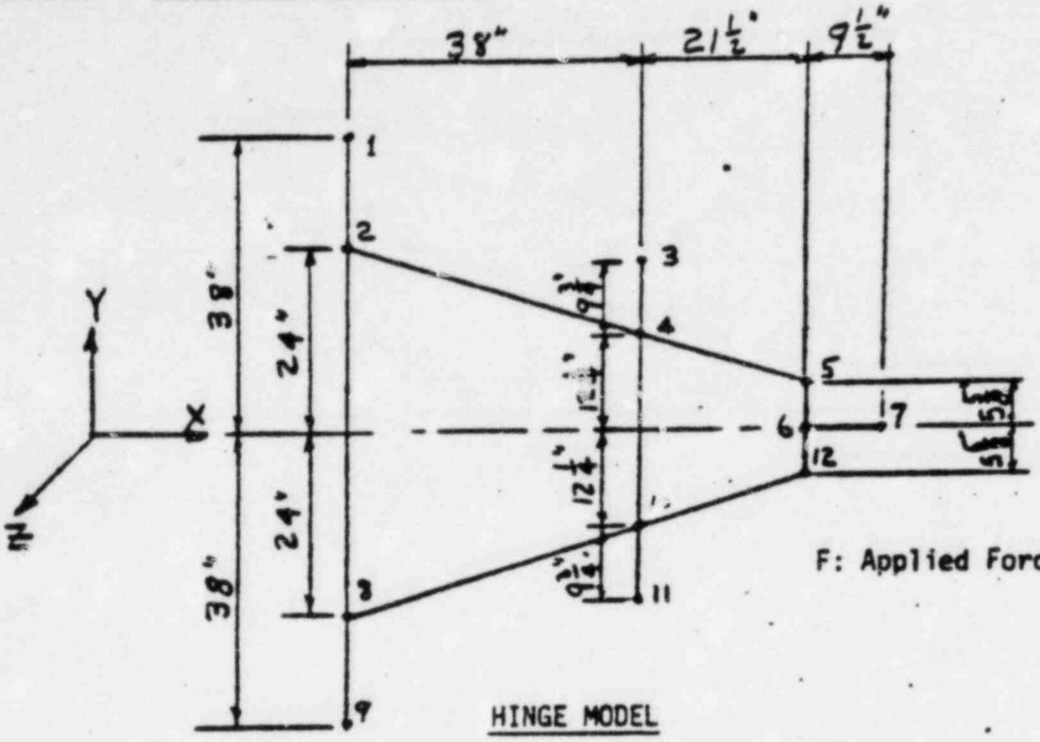
= -1.0(100) = -100

13-8

SUBJECT Hinge Loads	MADE BY LDF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 7-27-79	DATE 7/16/79		Chkd		
				Date		SHT ~~5-7~~ OF

CBI LOADS ON HINGE

Location BIRMINGHAM DESIGN



HINGE MODEL

F: Applied Forces from Load Case

	LOAD CASE 1		
JOINT	Fx	Fy	Fz
2	$\frac{1}{2}(A_{HX3})$	0	$1/2\ (A_{HZ3})$
8	$\frac{1}{2}\ (A_{HX3})$	0	$1/2\ (A_{HZ3})$
9	0	$D_3 + A_{v3}$	0
3	$\frac{1}{2}(A_{HX2})$	$D_2 + A_{v2}$	$\frac{1}{2}(PE+PG)-D_1-A_{HZ1}+\frac{1}{2}(A_{HZ2})$
4	$1/2(A_{HX4})$	$\frac{1}{2}(D_4+A_{v4})$	$1/2\ (A_{HZ4})$
10	$1/2(A_{HX4})$	$\frac{1}{2}(D_4+A_{v4})$	$1/2\ (A_{HZ4})$
11	$\frac{1}{2}(A_{HX2})$	0	$\frac{1}{2}(PE+PG)+D_1+A_{HZ1}+\frac{1}{2}(A_{HZ2})$
5	$1/2(A_{HX5})$	$D_5 + A_{v5}$	$1/2(A_{HZ5})$
12	$1/2(A_{HX5})$	0	$1/2(A_{HZ5})$

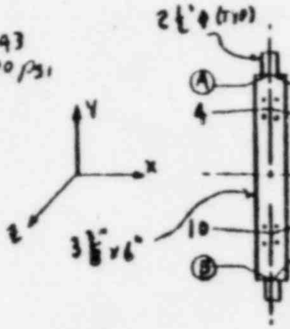
SUBJECT	MADE BY	CHKD BY	REV	By		CHARGE NO.
HINGE MODEL	LDF	CRS		Chkd		STD PL.
	DATE 9-18-79	DATE 10/1/79		Date		SHT ~~5~~ OF

Unit Load / Actual Load (lb)	UNIT STRESS / ACTUAL STRESS (PSI)											UNIT REACTION / ACTUAL REACTION (lb)					
	f_aⒶ	f_{bx}Ⓐ	f_{bz}Ⓐ	f_{a4}	f_{bx4}	f_{bz4}	f_{a10}	f_{bx10}	f_{bz10}	f_{bx}Ⓑ	f_{bz}Ⓑ	R_{Y4}	R_{X4}	R_{Z4}	R_{Y10}	R_{X10}	R_{Z10}
Pe / 10125		1.062 / 10755			1.367 / 13840			1.367 / 13840		1.062 / 10755				1.0 / 10125			1.0 / 10125
Pg / 3125		1.062 / 3320			1.367 / 4275			1.367 / 4275		1.062 / 3320				1.0 / 3125			1.0 / 3125
D1 / 850		-1.062 / -905			-1.367 / -1165			1.367 / 1165		1.062 / 905				-1.796 / -1530			1.796 / 1530
A+B1 / 850		-1.062 / -905			-1.367 / -1166			1.367 / 1165		1.062 / 905				-1.796 / -1530			1.796 / 1530
D2 / 2670	.204 / 545			.039 / 105			.039 / 105					.5 / 1335			.5 / 1335		
AWE2 / 2000		1.062 / 2125			1.367 / 2735			1.367 / 2735		1.062 / 2125				1.0 / 2000			1.0 / 2000
AWL / 2000			1.062 / 2125			.797 / 1600			.797 / 1600		1.062 / 2125		1.0 / 2000			1.0 / 2000	
A+2 / 2670	.204 / 545			.039 / 105			.039 / 105					.5 / 1335			.5 / 1335		
D4 / 1900				.039 / 75			.039 / 75					.5 / 950			.5 / 950		
AWE4 / 1425														1.0 / 1425			1.0 / 1425
AWL4 / 1425													1.0 / 1425			1.0 / 1425	
A+4 / 1900				.039 / 75			.039 / 75					.5 / 950			.5 / 960		

TOTALS

CASE 1	1090	14390	2125	360	18520	1600	360	23180	1600	18010	2125	4570	3425	13615	4570	3425	19735

MAT'L: SA320 L43
$S_m = 27500$ psi



COMBINED STRESS (PSI) CASE 1	STRESS CATEGORY
FcA = 15640	$P_L + P_b$
Fc4 = 20480	$P_L + P_b$
Fc10 = 25140	$P_L + P_b$
FcB = 18135	P_b

COMBINED STRESS:

AT Ⓐ & Ⓑ: $f_c = \sqrt{(f_{bx})^2 + (f_{bz})^2} + f_a$

AT 4 or 10: $f_c = f_{bx} + f_{bz} + f_a$

FOR SHEAR STRESS AS NORMAL STRESS

▶ INDICATES REVISION FROM PREVIOUS ISSUE

Chicago Bridge & Iron Company CBI

STRESS SUMMARY & REACTIONS
CENTER HINGE PIN

Purchaser's No.
By LBF Chkd CRS Date 9-20-79
W.W. LaRIVIERE
ENGINEERING COORDINATOR
Contract No. STD. PL
Sheet 339

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FORM DR 12A REV NOV 78

13-10

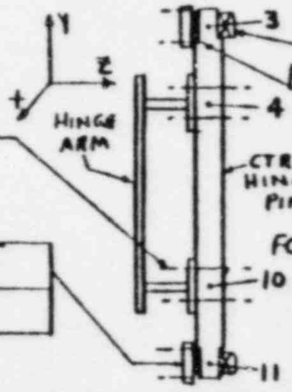
UNIT LOAD / ACTUAL LOAD (lb)	BOLTS-CTR HINGE PIN TO HINGE ARM — UNIT STRESS / ACTUAL STRESS (PSI)					LOADS AT CTR. HINGE PIN BEARINGS — UNIT LOAD / ACTUAL LOAD (lb)					JOINT 3 BOLTS-CTR. HINGE PIN BEARINGS — UNIT STRESS / ACTUAL STRESS (PSI)			
	f_{T1}	f_{T2}	f_{T3}	f_{V1}	f_{V2}	F_{X3}	F_{Y3}	F_{Z3}	F_{X11}	F_{Z11}	f_{E1}	f_{E2}	f_{V1}	f_{V2}
½ Pg / 10125		.454 / 4600						1.0 / 10125		1.0 / 10125				
⅓ Pg / 3125		.454 / 1420						1.0 / 3125		1.0 / 3125				
D1 / 850		.815 / 695						-1.0 / -850		1.0 / 850				
Aw21 / 850		.815 / 695						-1.0 / -850		1.0 / 850				
D2 / 2670			.263 / 705	.227 / 610			1.0 / 2670					2.860 / 7640		.828 / 2210
½ Aw13 / 2000		.454 / 910						1.0 / 2000		1.0 / 2000				
½ Aw26 / 2000	.438 / 880				.454 / 910	1.0 / 2000			1.0 / 2000		.807 / 1615		.828 / 1660	
Av3 / 2670			.263 / 705	.227 / 610			1.0 / 2670					2.860 / 7640		.828 / 2210
D4 / 1900			.263 / 500	.227 / 435										
½ Aw15 / 1425		.454 / 650												
½ Aw24 / 1425	.438 / 625				.454 / 650									
Av4 / 1900			.263 / 500	.227 / 435										

TOTALS

CASE 1	1505	8970	2410	2090	1560	2000	5340	13550	2000	16950	1615	15280	1660	4420

$$FCBA = \sqrt{(f_{T1}+f_{T2}+f_{T3})^2+4\left[(f_{V1})^2+(f_{V2})^2\right]}$$

$$FCBP = \sqrt{(f_{E1}+f_{E2})^2+4\left[(f_{V1})^2+(f_{V2})^2\right]}$$



FCBA:

BOLT STRESS INTENSITY	
CASE 1	13900

FE11

STATIC CAPACITY	BEARINGS $F_E = \sqrt{(F_{XII})^2+(F_{ZII})^2}$	
30840 lb	CASE 1	17070

FE3:

BEARINGS $F_E = .67\sqrt{(F_{X3})^2+(F_{Z3})^2}+2.6\,F_{Y3}$		STATIC CAPACITY
CASE 1	23060	30840 lb

FCBP:

BOLT STRESS INTENSITY	
CASE 1	19355

Chicago Bridge & Iron Company CBI

BOLT STRESS, BEARINGS, & LOADS
CENTER HINGE PIN

Purchaser's No. ______
By LDF Chkd CRS Date 9-4-79
W.W. LaRiviere
ENGINEERING COORDINATOR
Contract No. STD. PL

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FORM OR 12A REV NOV 78

UNIT LOAD / ACTUAL LOAD (lb)	JOINT 11 MOUNTING PLATE		JOINT 3 WELD-MOUNTING ℞ TO GUSSET					JOINT 3 GUSSETS			JOINT 3 WELD-GUSSET ℞ TO DOOR				
	UNIT STRESS / ACTUAL STRESS		UNIT STRESS / ACTUAL STRESS (PSI)					UNIT STRESS / ACTUAL STRESS (PSI)			UNIT STRESS / ACTUAL STRESS (PSI)				
	f_{by_1}	f_{by_2}	f_{w31}	f_{w32}	f_{w33}	f_{wx}	f_{wy}	f_{bx}	f_{by}	f_{AB}	f_{wG1}	f_{wG2}	f_{wG3}	f_{wx}	f_{wy}
½Pc / 10125	.665 / 6715	☒	☒	☒	.323 / 3270	☒	☒	☒	☒	.095 / 965	☒	☒	.162 / 1640	☒	☒
½Pc / 3125	.665 / 2080	☒	☒	☒	.323 / 1010	☒	☒	☒	☒	.095 / 300	☒	☒	.162 / 510	☒	☒
D1 / 850	.665 / 565	☒	☒	☒	-.323 / -275	☒	☒	☒	☒	-.095 / -80	☒	☒	-.162 / -140	☒	☒
Ax4 / 850	.665 / 565	☒	☒	☒	-.323 / -275	☒	☒	☒	☒	-.095 / -80	☒	☒	-.162 / -140	☒	☒
D2 / 2670	☒	☒	1.732 / 4625	☒	☒	☒	.323 / 865	.571 / 1525	☒	☒	1.94 / 5180	☒	☒	☒	.162 / 435
Ax2 / 2000	.665 / 1330	☒	☒	☒	.323 / 650	☒	☒	☒	☒	.095 / 190	☒	☒	.162 / 325	☒	☒
Ax2 / 2000	☒	.274 / 550	☒	.289 / 580	☒	.323 / 650	☒	☒	.105 / 210	☒	☒	.354 / 710	☒	.162 / 325	☒
Ax3 / 2670	☒	☒	1.735 / 4625	☒	☒	☒	.323 / 865	.571 / 1525	☒	☒	1.94 / 5180	☒	☒	☒	.162 / 435

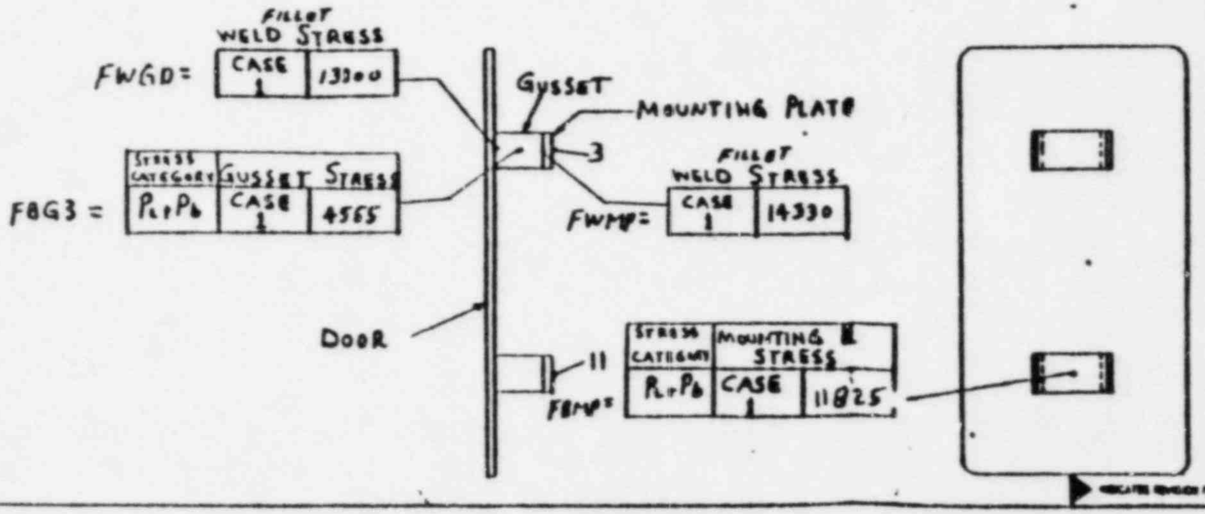
CASE 1	11275	550	9260	580	4380	650	1730	3050	210	1295	10360	710	2195	325	870

$$FBMP = f_{by_1} + f_{by_2}$$

$$FWMP = \sqrt{(f_{w31} + f_{w32} + f_{w33})^2 + (f_{wx})^2 + (f_{wy})^2}$$

$$FBG3 = f_{bx} + f_{by} + f_{AB}$$

$$FWGD = \sqrt{(f_{wG1} + f_{wG2} + f_{wG3})^2 + (f_{wx})^2 + (f_{wy})^2}$$



FWGD =

FILLET WELD STRESS	
CASE 1	13900

FBG3 =

STRESS CATEGORY	GUSSET STRESS	
$P_L + P_b$	CASE 1	4565

FWMP =

FILLET WELD STRESS	
CASE 1	14330

FBMP =

STRESS CATEGORY	MOUNTING ℞ STRESS	
$P_L + P_b$	CASE 1	11825

INDICATES REVISION FROM PREVIOUS ISSUE

Chicago Bridge & Iron Company CBI

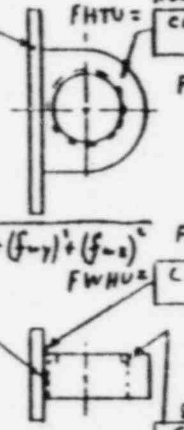
STRESS SUMMARY
MOUNTING BRACKET
CENTER HINGE PIN

Purchaser's No.
By LOP Chkd CRS Date 2-4-79
W.W. LaRiviere
ENGINEERING COORDINATOR
Contract No. STD. PL
Dwg. 8-77 Rev.

UNIT LOAD / ACTUAL LOAD (lb)	UPPER BEARING HOUSING - JOINT 3 UNIT STRESS / ACTUAL STRESS (PSI)												LOWER BEARING HOUSING - JOINT 11 UNIT STRESS / ACTUAL STRESS (PSI)						
	f_{c1}	f_{c2}	f_{bsh}	f_{bz1}	f_{bz2}	f_{bz3}	f_{wz1}	f_{wz2}	f_{wz3}	f_{wy}	f_{wx}	f_b	f_{c1}	f_{c2}	f_{bz1}	f_{bz2}	f_{wz1}	f_{wz2}	f_{wx}
3Pa / [illegible]		.335 / 2580				.038 / 385			.189 / 1915					.298 / 3020		.046 / 445		.189 / 1915	
n Pa / 3125		.255 / 800				.038 / 120			.189 / 590					.298 / 930		.046 / 140		.189 / 590	
D1 / 850		-.255 / -215				-.038 / -35			-.189 / -160					.298 / 255		.046 / 40		.189 / 160	
Axl1 / 850		-.255 / -215				-.038 / -35			-.189 / -160					.298 / 255		.046 / 40		.189 / 160	
D3 / 2670			1.435 / 3830	.229 / 610			.377 / 1005			.189 / 505		2.332 / 6225							
n Axial / 2000		.255 / 510				.038 / 75			.189 / 380					.298 / 600		.046 / 90		.189 / 380	
n Axl2 / 2000	.255 / 510				.107 / 215			.528 / 1055			.189 / 380	.81 / 1620	.298 / 600		.124 / 250		.528 / 1055		.189 / 380
Ax3 / 2670			1.435 / 3830	.229 / 610			.377 / 1005			.189 / 505		2.332 / 6225							

TOTALS

CASE 1	510	3460	7660	1220	215	510	2010	1055	2565	1010	380	13765	600	5060	250	755	1055	3206	380



BASE PLATE

$FB = f_B =$ CASE 1: 13765

HOUSING TENSION

FHTU = CASE 1: 3500

$FHTU = \sqrt{(f_{c1})^2 + (f_{c2})^2}$

$FWHU = \sqrt{(f_{wz1} + f_{wz2} + f_{wz3})^2 + (f_{wy})^2 + (f_{wx})^2}$

FILLET WELD

FWHU = CASE 1: 5735

HOUSING

FHU = CASE 1: 1945

$FHU = f_{bz1} + f_{bz2} + f_{bz3}$

SHOULDER

FBSH = (f_{bsh}) CASE 1: 7660

UPPER BEARING HOUSING

HOUSING TENSION

FHTL = CASE 1: 5100

$FHTL = \sqrt{(f_{c1})^2 + (f_{c2})^2}$

$FHL = f_{bz1} + f_{bz2}$

$FWHL = \sqrt{(f_{wz1} + f_{wz2})^2 + (f_{wx})^2}$

FILLET WELD

FWHL = CASE 1: 4275

HOUSING

FHL = CASE 1: 1005

LOWER BEARING HOUSING

STRESS CATEGORY FOR HOUSING TENSION = P_m

ALL OTHER STRESSES REPORTED, EXCEPT WELD STRESSES, ARE STRESS CATEGORY $P_L + P_b$

Chicago Bridge & Iron Company CBI

BEARING HOUSINGS

CENTER HINGE PIN

Purchaser's No.

By LDF Chk'd CRS Date 9-11-7[illegible]

W.B. [illegible]

ENGINEERING COORDINATOR

Contract No. STD. PL

FORM OR 72[illegible] REV NOV 78

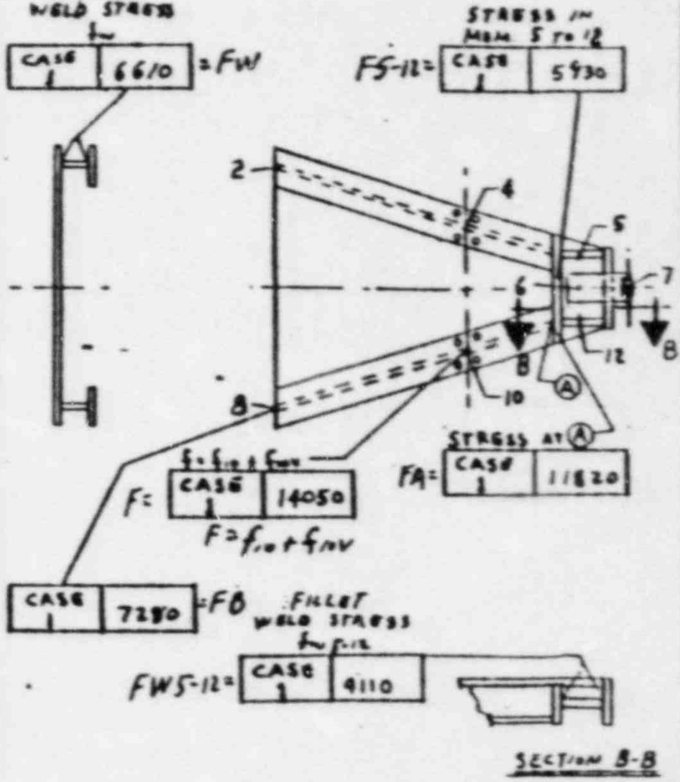
13-13

UNIT LOAD / ACTUAL LOAD (lb)	REACTIONS & SHIMS (lbs) UNIT REACTION / ACTUAL REACTION: K_{27}	$V_{12}+V_5$	R_{22}	R_{BB}	STRESSES-HINGE ARM (PSI) UNIT STRESS / ACTUAL STRESS: f_{10}	$f_{Ⓐ}$	f_B	f_{nv}	f_w	STRESSES-MEM 5 TO 12 (PSI) UNIT STRESS / ACTUAL STRESS: f_{5-12}	f_{w5-12}
F6 / 10125	1.102 / 11160	.551 / 5580	.450 / 4555	.450 / 4555	.592 / 5995	.362 / 3665			.153 / 1550	.353 / 3575	.247 / 2500
F6 / 3125	1.102 / 3445	.551 / 1725	.450 / 1405	.450 / 1405	.592 / 1850	.362 / 1130			.153 / 480	.353 / 1105	.247 / 770
D1 / 850			-1.796 / -1530	1.796 / 1530	2.360 / 2005	2.301 / 1955			.602 / 510		
A+12 / 850			-1.796 / -1530	1.796 / 1530	2.360 / 2005	2.301 / 1955			.602 / 510		
D2 / 2670					-.009 / -25	-.010 / -25	.616 / 1645		.265 / 710		
A-22 / 2000	1.102 / 2205	.551 / 1105	.450 / 900	.450 / 900	.592 / 1185	.362 / 725			.153 / 305	.353 / 705	.247 / 495
A+22 / 2000					.057 / 115	.061 / 125	.463 / 925		.172 / 345		
A+2 / 2670					-.009 / -25	-.010 / -25	.616 / 1645		.265 / 710		
D3 / 1900					-.009 / -20	-.010 / -20	.616 / 1170		.265 / 505		
A-23 / 1425	1.102 / 1570	.551 / 785	.450 / 640	.450 / 640	.592 / 845	.362 / 515			.153 / 220	.353 / 505	.247 / 350
A+23 / 1425					.057 / 75	.061 / 90	.463 / 660		.172 / 245		
A+3 / 1900					-.009 / -20	-.010 / -20	.616 / 1170		.265 / 505		
A-24 / 265			1.0 / 265	1.0 / 265							
A+24 / 265					.057 / 15	.061 / 15	.057 / 15				
D5 / 100											
A-25 / 75	1.724 / 130	-.138 / -10	.138 / 10	.138 / 10	.181 / 15	.370 / 30			.046 / 5	.552 / 40	-.067 / -5
A+25 / 75					.057 / 5	.061 / 5	.623 / 50	.238 / 20	.172 / 10		
A+5 / 100											

TOTALS

CASE 1	18510	9186	4715	10835	14030	11820	7280	20	6610	5930	4110

ALL STRESSES REPORTED, EXCEPT WELD STRESSES, ARE STRESS CATEGORY P_m



Chicago Bridge & Iron Company CBI

REACTIONS & STRESSES
HINGE ARM

By LDF Chkd CES Date 3-29
W.W. LARIVIERE
ENGINEERING COORDINATOR

Contract No. 5172 P2

Sheet 9

FORM DR 72A REV NOV 78

REACTIONS (lbs)

UNIT REACTION / ACTUAL REACTION

UNIT LOAD / ACTUAL LOAD lb	R_{x2}	R_{x8}	R_{y9}	R_{y1}	R_{x9}	R_{z1}	R_{z9}
1 Po / 10125						.450 / 4555	.450 / 4555
1 Po / 3125						.450 / 1405	.450 / 1405
D1 / 850						-1.135 / -965	1.135 / 965
A+21 / 850						-1.135 / -965	1.135 / 965
D2 / 3670	.792 / 2115	.792 / 2115	1.0 / 3670	.5 / 1335	.5 / 1335		
3 A+21 / 2000						.450 / 900	.450 / 900
3 A+25 / 2000	1.0 / 2000	-1.0 / -2000		1.0 / 2000	-1.0 / -2000		
A+2 / 3670	.792 / 2115	.792 / 2115	1.0 / 3670	.5 / 1335	.5 / 1335		
D3 / 350			1.0 / 350				
3 A+25 / 265						1.0 / 265	1.0 / 265
3 A+23 / 265	1.0 / 265	-1.0 / -265		1.0 / 265	-1.0 / -265		
A+3 / 350			1.0 / 350				
D4 / 1900	.792 / 1505	.792 / 1505	1.0 / 1900	.5 / 950	.5 / 950		
3 A+24 / 1425						.450 / 640	.450 / 640
3 B+24 / 1425	1.0 / 1425	-1.0 / -1425		1.0 / 1425	-1.0 / -1425		
A+4 / 1900	.792 / 1505	.792 / 1505	1.0 / 1900	.5 / 950	.5 / 950		
D5 / 100	1.438 / 145	1.438 / 145	1.0 / 100	.909 / 90	.909 / 90		
3 A+25 / 75						.138 / 10	.138 / 10
3 A+25 / 75	1.0 / 75	-1.0 / -75		1.0 / 75	-1.0 / -75		
A+5 / 100	1.438 / 145	1.438 / 145	1.0 / 100	.909 / 90	.909 / 90		

TOTALS

CASE 1	11295	3765	10040	8515	985	5845	9705

Chicago Bridge & Iron Company CBI

REACTIONS
MAIN HINGE PIN

Purchaser's No. _____	Contract No. STD PL
By LDF Chkd. CSS Date 8-11-79	
W. W. LARIMER	
ENGINEERING COORDINATOR	

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FORM DR 12A REV NOV 78

	STRESSES (PSI)									WELD-HINGE ARM & PIN (PSI)		
UNIT LOAD / ACTUAL LOAD	UNIT STRESS / ACTUAL STRESS									UNIT STRESS / ACTUAL STRESS		
lb	f_{aB}	f_{bzB}	f_{bxB}	f_a Ⓒ	f_{bz} Ⓒ	f_{bx} Ⓒ	f_a Ⓓ	f_{bz} Ⓓ	f_{bx} Ⓓ	f_{wy}	f_{wx}	f_{wa}
Dy PG / 10125	X	X	.454 / 4600	X	X	.158 / 1600	X	X	.514 / 5205	X	X	.081 / 820
Dx PG / 3125	X	X	.454 / 1420	X	X	.158 / 495	X	X	.514 / 1610	X	X	.081 / 255
D1 / 850	X	X	1.147 / 975	X	X	.400 / 340	X	X	1.297 / 1105	X	X	.322 / 275
Av1 / 850	X	X	1.147 / 975	X	X	.400 / 340	X	X	1.297 / 1105	X	X	.322 / 275
D2 / 2670	.041 / 110	.504 / 1345	X	.054 / 145	.176 / 470	X	.204 / 545	.571 / 1525	X	.090 / 240	1.257 / 3355	X
3AH22 / 2000	X	X	.454 / 910	X	X	.160 / 320	X	X	.514 / 1030	X	X	.081 / 165
3AH22 / 2000	X	-1.008 / -2015	X	X	-.352 / -705	X	X	-1.143 / -2290	X	X	.547 / 1095	X
Av2 / 2670	.041 / 110	.504 / 1345	X	.054 / 145	.176 / 470	X	.204 / 545	.571 / 1525	X	.090 / 240	1.257 / 3355	X
D3 / 350	.041 / 15	X	X	.054 / 20	X	X	.204 / 70	X	X	X	X	X
3AV23 / 265	X	X	1.008 / 265	X	X	.358 / 95	X	X	1.143 / 305	X	X	.179 / 50
3AH23 / 265	X	-1.008 / -265	X	X	-.352 / -95	X	X	-1.143 / -305	X	X	-.179 / -50	X
Av3 / 350	.041 / 15	X	X	.054 / 20	X	X	.204 / 70	X	X	X	X	X
D4 / 1900	.041 / 80	.504 / 960	X	.054 / 105	.176 / 335	X	.204 / 390	.571 / 1085	X	.090 / 170	1.257 / 2390	X
3AH24 / 1425	X	X	.454 / 645	X	X	.158 / 225	X	X	.514 / 735	X	X	.081 / 115
3AH24 / 1425	X	-1.008 / -1435	X	X	-.352 / -500	X	X	-1.143 / -1630	X	X	.547 / 780	X
Av4 / 1900	.041 / 80	.504 / 960	X	.054 / 105	.176 / 335	X	.204 / 390	.571 / 1085	X	.090 / 170	1.257 / 2390	X
D5 / 100	.041 / 5	.916 / 90	X	.054 / 5	.320 / 35	X	.204 / 20	1.039 / 105	X	X	.257 / 25	X
3AH25 / 75	X	X	.139 / 10	X	X	.049 / 5	X	X	.152 / 10	X	X	.025 / 0
3AH25 / 75	X	-1.008 / -75	X	X	-.352 / -25	X	X	-1.143 / -85	X	X	.961 / 75	X
Av5 / 100	.041 / 5	.916 / 90	X	.054 / 5	.320 / 35	X	.204 / 20	1.039 / 105	X	X	.257 / 25	X

TOTALS

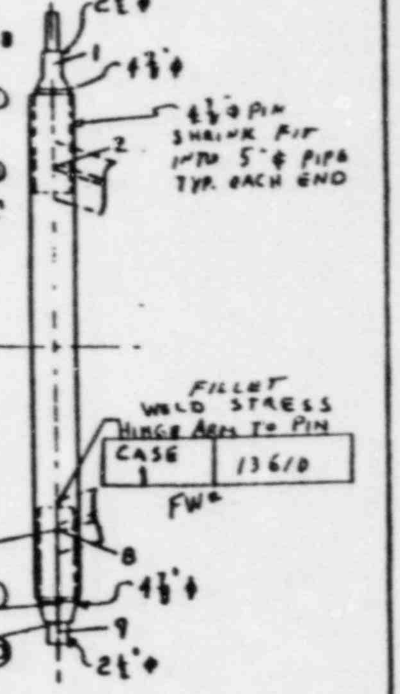
CASE 1	420	1000	9800	550	355	3420	2050	1120	11105	820	13440	1965

$$FCB = \sqrt{(f_{bxB})^2 + (f_{bzB})^2} + f_{aB}$$

$$FCC = \sqrt{(f_{bzC})^2 + (f_{bxC})^2} + f_{aC}$$

$$FCD = \sqrt{(f_{bzD})^2 + (f_{bxD})^2} + f_{aD}$$

$$FW = \sqrt{(f_{wy})^2 + (f_{wx})^2 + (f_{wa})^2}$$



COMBINED STRESS (PSI)
CASE 1
FCB = 10270
FCC = 3990
FCD = 13210

FILLET WELD STRESS HINGE ARM TO PIN

CASE 1	13610

FW*

ALL STRESSES REPORTED, EXCEPT WELD STRESSES, ARE STRESS CATEGORY $P_L + P_b$.

Chicago Bridge & Iron Company CBI

STRESS SUMMARY
MAIN HINGE PIN

Purchaser's No.
By LDP Chkd CRS Date 9-8-78
V.W. LaRiviere
ENGINEERING COORDINATOR

Contract No. STD PL

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UNIT LOAD / ACTUAL LOAD (lb)	BOLT STRESS (PSI)			MTG. PL STRESS (PSI)	WELD-MTG. PL TO GUSSET (PSI)			GUSSET STRESS (PSI)		WELD-GUSSET TO BULKHD (PSI)		
	UNIT STRESS / ACTUAL STRESS			UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS			UNIT STRESS / ACTUAL STRESS		UNIT STRESS / ACTUAL STRESS		
	f_{c1}	f_{c2}	f_v	f_b	f_{wz1}	f_{wz2}	f_{wx}	f_{by}	f_{ez}	f_{wz1}	f_{wz2}	f_{wx}
P2 / 10125		.373 / 1780		.310 / 3140		.121 / 1225			.032 / 325		.061 / 620	
P6 / 3125		.373 / 1165		.310 / 970		.121 / 380			.032 / 100		.061 / 190	
D1 / 850		-.940 / -800		-.781 / -665		-.305 / -260			-.082 / -70		-.153 / -130	
A+D1 / 850		-.940 / -800		-.781 / -665		-.305 / -260			-.082 / -70		-.153 / -130	
D2 / 2670	.404 / 1080		.414 / 1105	.336 / 900	.664 / 1775		.135 / 360	.283 / 755		.534 / 1425		.068 / 180
A+11 / 2000		.373 / 745		.310 / 620		.121 / 245			.032 / 65		.061 / 125	
A+12 / 2000	.807 / 1615		.828 / 1655	.670 / 1340	1.328 / 2655		.269 / 540	.566 / 1130		1.068 / 2140		.135 / 270
A+2 / 2670	.404 / 1080		.414 / 1105	.336 / 900	.664 / 1775		.135 / 360	.283 / 755		.534 / 1425		.068 / 180
D3 / 350												
A+13 / 265		.828 / 220		.680 / 185		.269 / 70			.081 / 20		.135 / 35	
A+23 / 265	.807 / 215		.828 / 220	.670 / 180	1.328 / 350		.269 / 70	.566 / 150		1.068 / 285		.136 / 35
A+3 / 350												
D4 / 1900	.404 / 770		.414 / 790	.336 / 640	.664 / 1260		.135 / 260	.283 / 540		.534 / 1015		.068 / 130
A+14 / 1425		.373 / 530		.310 / 440		.121 / 175			.032 / 45		.061 / 85	
A+24 / 1425	.807 / 1150		.828 / 1180	.670 / 955	1.328 / 1895		.269 / 385	.566 / 810		1.068 / 1520		.135 / 190
A+4 / 1900	.404 / 770		.414 / 790	.336 / 640	.664 / 1260		.135 / 260	.283 / 540		.534 / 1015		.068 / 130
D5 / 100	.734 / 75		.753 / 75	.609 / 60	1.207 / 120		.245 / 25	.515 / 50		.971 / 100		.123 / 15
A+15 / 75		.115 / 10		.095 / 10		.037 / 5			.019 / 0		[illegible] / 0	
A+25 / 75	.807 / 60		.828 / 60	.670 / 55	1.328 / 100		.269 / 20	.566 / 45		1.068 / 80		.135 / 10
A+5 / 100	.734 / 75		.753 / 75	.609 / 60	1.207 / 120		.245 / 25	.515 / 50		.971 / 100		.123 / 15

CASE 1	6890	4850	7065	9760	1130	1680	2305	4830	425	9105	795	1155

GUSSET STRESS = FG

CASE 1	5255

STRESS CATEGORY = P_L

FILLET WELD STRESS

CASE 1	9970

FWGB =

MOUNTING PLATE

CASE 1	9760

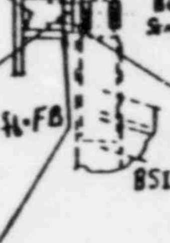
= f_b = FB

STRESS CATEGORY = P_B

FILLET WELD STRESS -

CASE 1	13095

= FWMG



BEARING

PEM = $P_E = \sqrt{(R_{x1})^2 + (R_{z1})^2}$

CASE 1	10330 lb

BEARING STATIC CAPACITY = 30340 lb

BOLT STRESS INTENSITY

BSI =

CASE 1	18355

$$BSI = \sqrt{(f_{c1} + f_{c2})^2 + 4 f_v}$$

$$FWMG = \sqrt{(f_{wz1} + f_{wz2})^2 + (f_{wx})^2}$$

$$FG = f_{by} + f_{ez}$$

$$FWGB = \sqrt{(f_{wz1} + f_{wz2})^2 + (f_{wx})^2}$$

INDICATES REVISIONS FROM PREVIOUS ISSUE

Chicago Bridge & Iron Company CBI

UPPER BEARING, BOLTING, & MOUNTING BRACKET MAIN HINGE PIN

Purchaser's No.
By LDF Chkd CRS Date 2-8-79
N.W. LaRIVIERE
ENGINEERING COORDINATOR

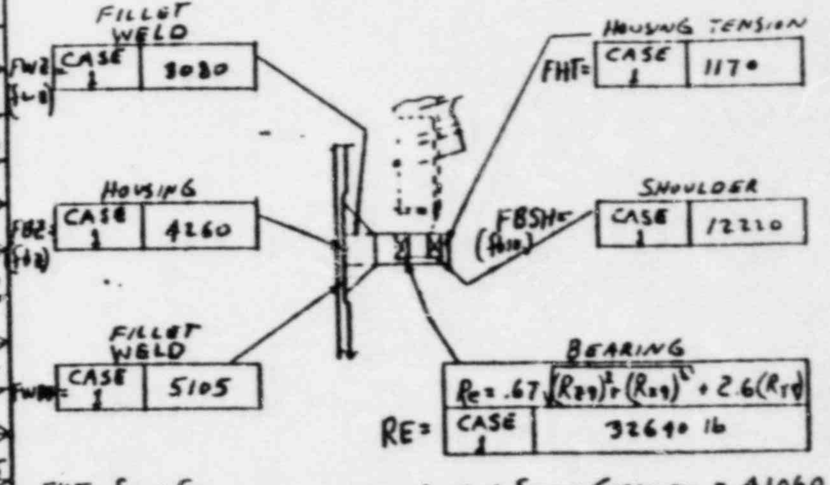
Contract No. STA PL

Unit stress / Actual load (lb)	HOUSING-TENSION PSI UNIT STRESS / ACTUAL STRESS f_{T1}	 f_{T2}	SHOULDER (PSI) f_{bsh}	f_{b2}	f_{wB}	WELD-BRACKET TO BULKHEAD PSI UNIT STRESS / ACTUAL STRESS f_{wB1}	 f_{wB2}	 f_{wB3}	 f_{wy}	 f_{wx}
Pa / 10125		.054 / 545		.013 / 130	.077 / 780			.030 / 300		
Pa / 3125		.054 / 170		.013 / 40	.077 / 240			.030 / 95		
D1 / 850		.137 / 115		.032 / 30	.194 / 165			.076 / 65		
A-9' / 850		.137 / 115		.032 / 30	.194 / 165			.076 / 65		
D2 / 2670	.061 / 165		1.217 / 3250	.467 / 1250	.183 / 490	.086 / 230	.421 / 1125		.067 / 180	.034 / 90
[illegible] / 2000		.054 / 110		.013 / 25	.077 / 155			.030 / 60		
[illegible] / 2000	-.121 / -240			-.178 / -355	-.104 / -210	-.172 / -345				-.067 / -135
A12 / 2670	.061 / 165		1.217 / 3250	.467 / 1250	.183 / 490	.086 / 230	.421 / 1125		.067 / 180	.034 / 90
D3 / 350			1.217 / 425	.378 / 130	.131 / 45		.421 / 150		.067 / 25	
[illegible] / 265		.121 / 30		.028 / 10	.171 / 45			.052 / 20		
[illegible] / 265	-.114 / -30			-.178 / -50	-.104 / -30	-.172 / -45				-.067 / -20
A13 / 350			1.217 / 425	.378 / 130	.131 / 45		.421 / 150		.067 / 25	
D4 / 1900	.061 / 115		1.217 / 2315	.467 / 890	.183 / 350	.086 / 165	.421 / 800		.067 / 130	.034 / 65
[illegible] / 1985		.054 / 80		.010 / 20	.055 / 110			.030 / 45		
[illegible] / 1925	-.131 / -175			-.178 / -255	-.104 / -150	-.172 / -245				-.067 / -95
A-4 / 1900	.061 / 115		1.217 / 2315	.467 / 890	.183 / 350	.086 / 165	.421 / 800		.067 / 130	.034 / 65
D5 / 100	.110 / 10		1.217 / 120	.54 / 55	.226 / 25	.156 / 15	.421 / 45		.067 / 5	.061 / 5
[illegible] / 75		.07 / 0		.004 / 0	.024 / 0			.009 / 0		
[illegible] / 75	-.121 / -10			-.178 / -15	-.104 / -10	-.172 / 15				-.067 / -5
A15 / 100	.110 / 10		1.217 / 120	.548 / 55	.226 / 25	.156 / 15	.421 / 45		.067 / 5	.061 / 5

CASE 1	125	1165	12220	4260	3080	170	4240	650	680	65

STRESS CATEGORY FOR HOUSING TENSION = P_m

ALL OTHER STRESSES REPEATED, EXCEPT WELD STRESSES, ARE STRESS CATEGORY $P_L + P_b$.



FILLET WELD

F_{WZ} (f_{wB}) = CASE 1: 3080

HOUSING

F_{BZ} (f_{b2}) = CASE 1: 4260

FILLET WELD

F_{WBB} = CASE 1: 5105

HOUSING TENSION

FHT = CASE 1: 1170

SHOULDER

FBSH = (f_{bsh}) CASE 1: 12220

BEARING

$R_E = .67\sqrt{(R_{Bx})^2 + (R_{By})^2} + 2.6(R_T)$

RE = CASE 1: 32640 lb

FHT = $f_{T1} + f_{T2}$

BEARING STATIC CAPACITY = 41060 lb

$$FWBB = \sqrt{(f_{wB1} + f_{wB2} + f_{wB3})^2 + (f_{wy})^2 + (f_{wx})^2}$$

Chicago Bridge & Iron Company CBI

LOWER MOUNTING BRACKET, BEARING & WELD. MAIN HINGE PIN

Purchaser's No. ____

By LRF Chkd. CRS Date 9-4-79

W. W. LARIVIERE
ENGINEERING COORDINATOR

Contract No. STD. PL

Sheet
Drg. Rev.

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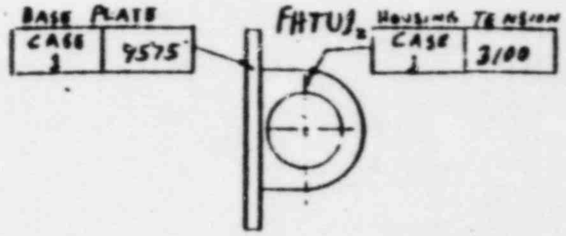
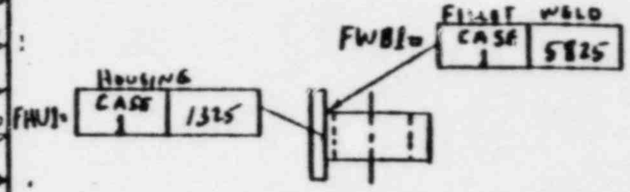
UPPER BEARING HOUSING - JOINT 1

UNIT LOAD / ACTUAL LOAD (lb)	f_{t1}	f_{t2}	f_{bB1}	f_{bB2}	f_{wB1}	f_{wB2}	f_{wx}	f_b
	UNIT STRESS / ACTUAL STRESS (psi)							
½ Pe 10125		.134 1360		.020 205		.085 860		.304 3080
½ Pe 3125		.134 420		.020 65		.085 265		.304 950
D1 850		-.338 -290		-.050 -45		-.218 -185		-.766 -650
AH31 850		-.338 -290		-.050 -45		-.215 -185		-.766 -650
D2 2670	.149 400		.062 165		.264 705		.095 255	.329 880
½AH32 2000		.134 270		.020 40		.085 170		.304 610
½AH32 2000	.298 600		.124 250		.528 1055		.189 380	.658 1315
AV2 2670	.149 400		.062 165		.264 705		.095 255	.329 880
D3 350								
½AH33 265		.298 80		.044 10		.189 50		.675 180
½AH33 265	.298 80		.124 35		.528 140		.189 50	.658 175
AV3 350								
D4 1900	.149 285		.062 120		.264 500		.095 180	.329 625
½AH34 1425		.134 190		.020 30		.085 120		.304 435
½AH34 1425	.298 425		.124 180		.528 755		.189 270	.658 940
AV4 1900	.149 285		.062 120		.264 500		.095 180	.329 625
D5 100	.270 30		.115 10		.480 50		.172 20	.558 60
½AH35 75		.041 5		.006 0		.026 0		.093 10
½AH35 75	.298 25		.135 10		.528 40		.189 15	.658 50
AV5 100	.270 30		.115 10		.480 50		.172 20	.558 60

CASE 1	2560	1745	1065	260	4500	1095	1625	9575





$$FHTU1 = \sqrt{(f_{t1})^2 + (f_{t2})^2}$$

$$FHU1 = f_{bB1} + f_{bB2}$$

$$FWB1 = \sqrt{(f_{wB1} + f_{wB2})^2 + (f_{wx})^2}$$

STRESS CATEGORY FOR HOUSING TENSION = P_m

ALL OTHER STRESSES REPORTED, EXCEPT WELD STRESSES, ARE STRESS CATEGORY $P_L + P_b$

Chicago Bridge & Iron Company CBI

UPPER BEARING HOUSING
MAIN HINGE PIN

Purchaser's No. ______
By LDP Chkd CRS Date 9-31-75
Contract No.
ENGINEERING COORDINATOR

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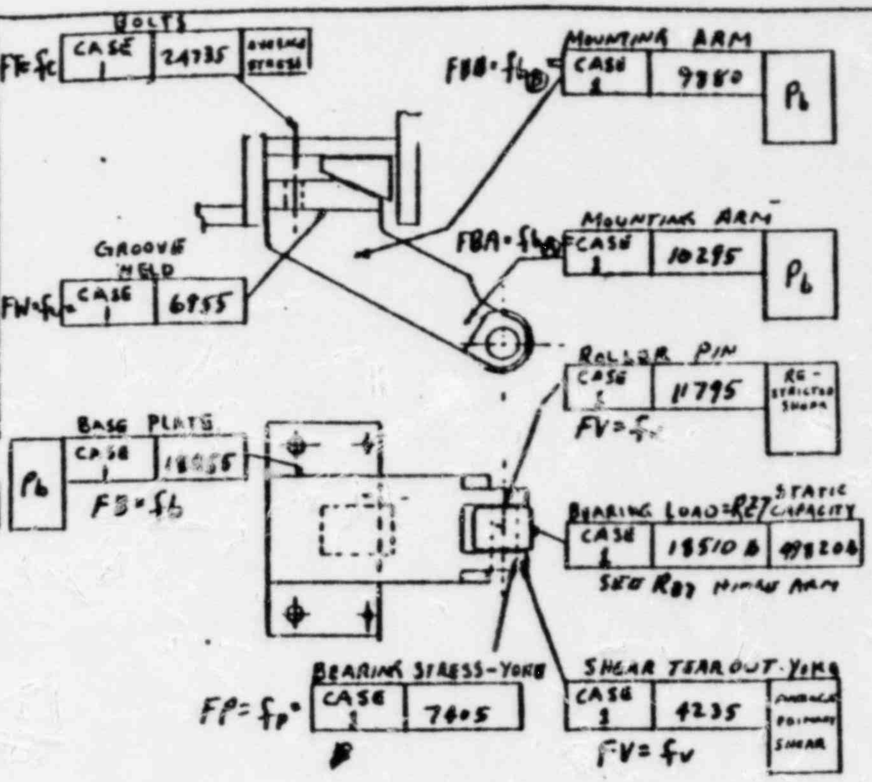
INDICATES REVISION FROM PREVIOUS ISSUE

FORM DR 72A REV NOV 78

UNIT LOAD / ACTUAL LOAD (lb)	BEARING MOUNTING ARM (PSI) UNIT STRESS / ACTUAL STRESS f_bⒶ	BEARING MOUNTING ARM (PSI) UNIT STRESS / ACTUAL STRESS f_mⒷ	WELD-BEARING MTG. ARM TO BASE UNIT STRESS / ACTUAL STRESS f_w	BOLTS UNIT STRESS / ACTUAL STRESS f_c	ROLLER PIN UNIT STRESS / ACTUAL STRESS f_v	SHEAR TEAROUT MTG. ARM YOKE UNIT STRESS / ACTUAL STRESS f_v	BEARING STRESS MTG. ARM YOKE UNIT STRESS / ACTUAL STRESS f_p	MOUNTING ARM BASE PLATE UNIT STRESS / ACTUAL STRESS f_b
P_R / 10125	.613 / 6210	.588 / 5955	.414 / 4190	1.473 / 14910	.702 / 7110	.252 / 2550	.441 / 4465	1.123 / 11370
P_T / 3125	.613 / 1915	.588 / 1840	.414 / 1295	1.475 / 4605	.702 / 2195	.252 / 790	.441 / 1380	1.123 / 3510
A_{H2} / 2000	.613 / 1225	.588 / 1175	.414 / 830	1.473 / 2945	.702 / 1405	.252 / 505	.441 / 880	1.123 / 2245
A_{H3} / 1425	.613 / 875	.588 / 840	.414 / 590	1.473 / 2100	.702 / 1000	.252 / 360	.441 / 630	1.123 / 1600
A_{H5} / 75	.959 / 70	.919 / 70	.698 / 50	2.305 / 175	1.100 / 85	.385 / 30	.690 / 50	1.737 / 130

TOTALS

CASE 1	10295	9880	6955	24735	11795	4235	7405	18855



Chicago Bridge & Iron Company

STRESS SUMMARY
ROLLER ASSEMBLY

Purchaser's No.
By LD? Chk CRS Date 8-4-79
W. L. LaRiviere
ENGINEERING COORDINATOR

Contract No.
STD. PL

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▶ INDICATES REVISIONS FROM PREVIOUS ISSUE

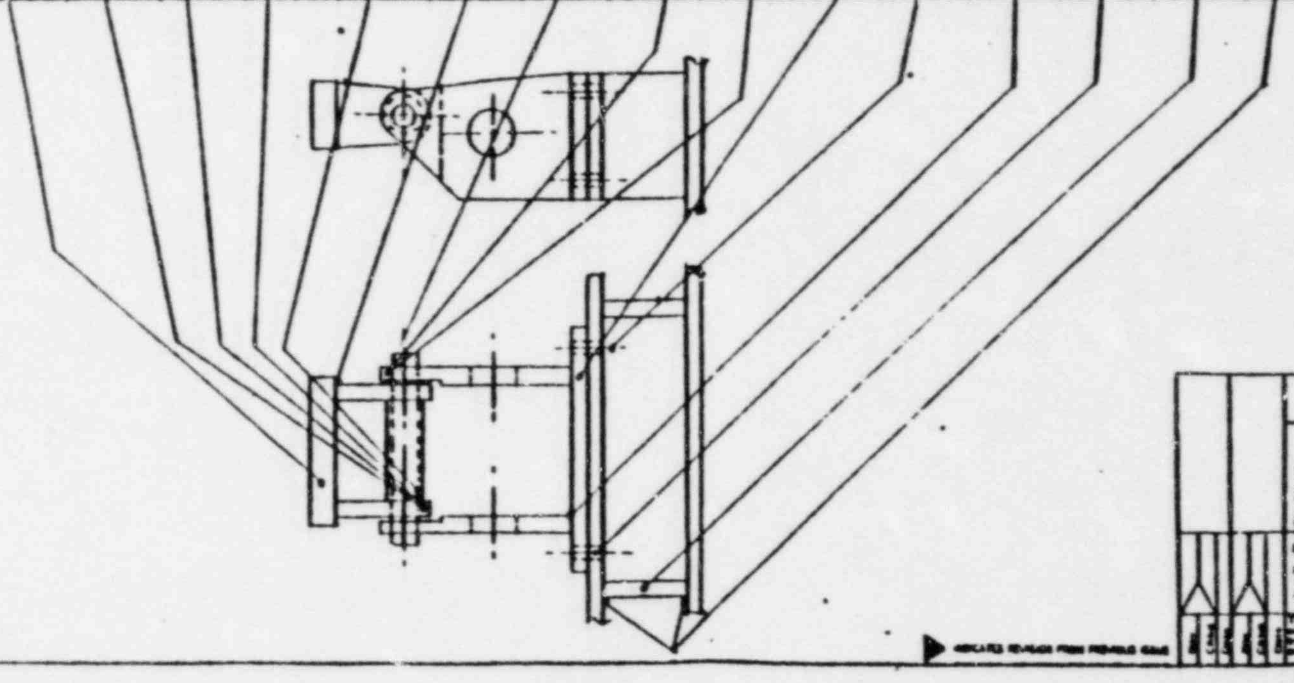
FORM DR 73A REV NOV 76

13-20

	LATCH BAR ASSEMBLY						LATCH BRACKET ASSEMBLY						LATCH BRACKET MTG. PAD		
	LATCH BAR	GUSSETS			PIN	WELD LATCH BAR TO GUSSET	GUSSETS			BASE PLATE	BOLTS	WELD GUSSET TO BASE	MOUNTING PLATE	GUSSET PLATE	WELD GUSSET & MTG. PL
	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS			UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS			UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS	UNIT STRESS / ACTUAL STRESS
UNIT LOAD / ACTUAL LOAD	f_b	f_t	f_s	f_p	f_b	f_w	f_c	f_s	f_p	f_b	f_t	f_w	f_b	f_c	f_w
lb															
3 DR / 10125	1.080 / 10940	.441 / 4465	.441 / 4465	.313 / 3190	1.113 / 11270	.278 / 2815	.560 / 5670	.560 / 5670	.360 / 3645	.984 / 9965	.913 / 9245	.151 / 1530	1.106 / 11200	.044 / 445	.151 / 1530
3 Pe / 3125	1.080 / 3375	.441 / 1380	.441 / 1380	.313 / 985	1.113 / 3480	.278 / 870	.560 / 1750	.560 / 1750	.360 / 1125	.984 / 3075	.913 / 2855	.151 / 470	1.106 / 3455	.044 / 140	.151 / 470
3 AH15 / 2000	1.080 / 2160	.441 / 880	.441 / 880	.313 / 630	1.113 / 2225	.278 / 565	.560 / 1120	.560 / 1120	.360 / 720	.984 / 1970	.913 / 1825	.151 / 300	1.106 / 2210	.044 / 90	.151 / 300
3 AH·25 / 1425	1.080 / 1540	.441 / 630	.441 / 630	.315 / 450	1.113 / 1590	.278 / 400	.560 / 800	.560 / 800	.360 / 515	.984 / 1400	.913 / 1300	.151 / 215	1.106 / 1580	.044 / 65	.151 / 215
3 AV25 / 75	1.670 / 125	.690 / 50	.690 / 50	.473 / 35	1.741 / 130	.434 / 35	.876 / 65	.876 / 65	.564 / 40	1.538 / 115	1.427 / 110	.236 / 20	1.731 / 130	.069 / 5	.236 / 20

TOTALS

STRESS CATEGORY →	P_b	P_m	AVERAGE PRIMARY SHEAR	BEARING STRESS	P_b	FILLET WELD	P_m	AVERAGE PRIMARY SHEAR	BEARING STRESS	P_b	AVERAGE STRESS	FILLET WELD	- P_b	P_m	FILLET WELD
CASE 1	18140	7405	7405	5290	18695	4675	9405	9405	6045	16525	15335	2535	18575	745	2535



Chicago Bridge & Iron Company CBI

STRESS SUMMARY
LATCH BAR ASSEMBLY
LATCH BRACKET ASSEMBLY
LATCH BRACKET MTG. PAD

Purchaser's No. ____
Dr. LDF Chkd. CRS Date 9-4-?
Contract No. STD. PL
W.W. LARIVIERE
ENGINEERING COORDINATOR

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FORM DH 724 REV NOV 78

BULKHEAD DESIGN

The bulkhead consists of a stiffened flat plate. The thickness is determined based on the largest panel using flat plate design. The primary and secondary stiffeners are designed as simple beams. The reactions from the hinge and latch are taken out at the primary stiffeners. A portion of the bulkhead plate is assumed to act with the stiffener.

The bulkhead is designed for two load cases:

Case 1A - Seismic acceleration acting horizontal (along longitudinal axis of lock) in combination with specified design internal pressure and reactions from hinge and latch.

Case 2A - Seismic acceleration acting horizontal (along longitudinal axis of lock) in combination with specified design external pressure and reactions from hinge and latch.

Loads: Design Temperature = 400°F

1) PI = Specified Design Internal Pressure - 60 PSIG
2) Pe = Specified Design External Pressure - 5 PSIG
*3) PEQ= Equivalent Pressure Due to Seismic Acceleration (Horiz. along longitudinal axis of lock) = .74 Ahz = .74(1.5) = 1.11 PSI
4) Rz7= Reaction from latch
5) Rx1= Reaction at Joint 1 main hinge pin
6) Rz1= Reaction at Joint 1 main hinge pin
7) Rx9= Reaction at Joint 9 main hinge pin
8) Ry9= Reaction at Joint 9 main hinge pin
9) Rz9= Reaction at Joint 9 main hinge pin

*Note: PEQ is derived by uniformly distributing the bulkhead stiffeners and door stiffeners to arrive at an equivalent thickness. Equivalent thickness of bulkhead and door are assumed equal.

The bulkhead and stiffeners are analyzed using unit loads. The resulting stresses are multiplied by the appropriate factor and combined in accordance with Case 1A and Case 2A. These stresses are tabulated on the stress summary for the bulkhead. Stresses are reported only at points of interest.

Load Case 1A: PI + PEQ + Rz7 + Rx9 + Ry9 + Rz9

Load Case 2A: Pe + PEQ + Rz7 + Rx9 + Ry9 + Rz9

SUBJECT BULKHEAD DESIGN	MADE BY LDF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 9-18-79	DATE 10/1/79		Chkd		SHT ~~[illegible]~~ OF
				Date		

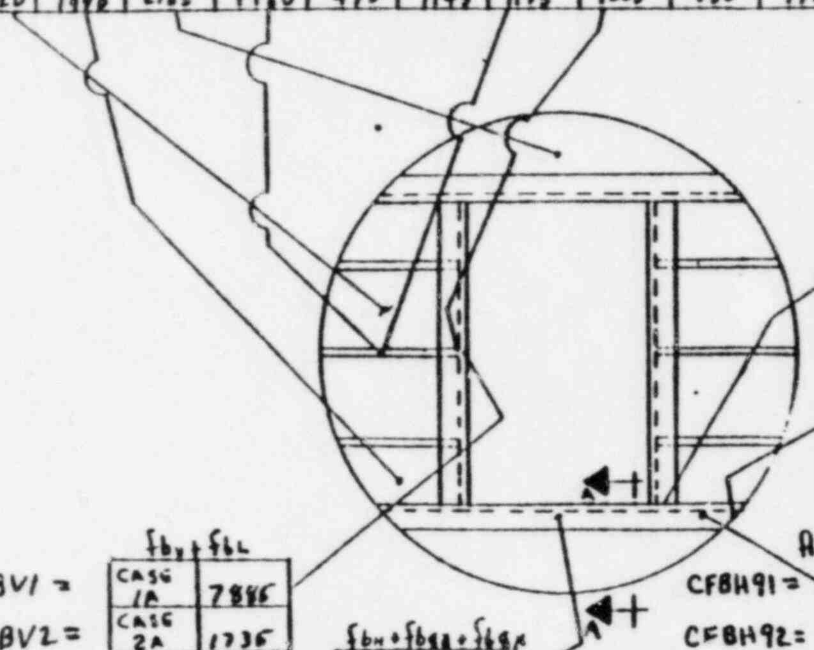
STRESSES (PSI)

UNIT STRESS / ACTUAL STRESS

LOAD CASE	UNIT LOAD / ACTUAL LOAD (PSI)	σ_{mx_1}	σ_{mx_2}	σ_{mv_8}	f_b (18)	f_{bv}	f_{bn}	f_w (18)	f_{w22}	f_{wF31}	f_{wp}	f_{w13}	f_{w16}	f_{bq}	
1A	P_1 / 60	314 / 18840	244 / 14640	357 / 21420	291 / 17460	124.67 / 7480	285.56 / 17130	195 / 11700	197 / 11820	174 / 10440	189 / 11340	145 / 8700	172 / 10320	153.44 / 9240	
2A	P_2 / 5	314 / 1570	244 / 1220	357 / 1785	291 / 1455	69.97 / 350	164.76 / 825	195 / 975	197 / 985	107 / 535	116 / 580	89 / 445	85 / 425	97.64 / 490	
1A & 2A	P_{sa} / 1.11	314 / 350	244 / 270	357 / 400	291 / 325	124.67 / 140	285.56 / 320	195 / 220	197 / 220	174 / 195	189 / 210	145 / 160	172 / 190	151.44 / 170	

TOTALS

STRESS CATEGORY	P_b	P_b	P_b	P_m	P_m	P_m	FILLET WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS	GROOVE WELD STRESS	FILLET WELD STRESS	P_m	
CASE 1A	19190	14910	21820	17785	7620	17440	11920	12040	10635	11550	8860	10510	9410	
CASE 2A	1920	1490	2185	1780	490	1145	1195	1205	730	790	605	615	660	

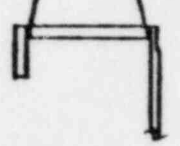


$f_{wp} + f_{wFwt} + f'_{wFw}$

CFW21 = CASE 1A	12570
CFW22 = CASE 2A	2315

$f_{wF31} + f_{wF1} + f'_{wFF}$

CFW11 = CASE 1A	12660
CFW12 = CASE 2A	3205



SECTION A-A

$f_{w14} + f_{wv}$

CASE 1A	10780 = CFW31
CASE 2A	1895 = CFW32

$f_{wn} + f_{wn1} + f_{wF31} + f_{wF1} + f_{w24}$

CASE 1A	10705 = CFW45
CASE 2A	2835 = CFW42

$f_{by} + f_{bL}$

CCFBV1 = CASE 1A	7885
CFBV2 = CASE 2A	1735

$f_{bH} + f_{bqR} + f_{bqx}$

CFBHS1 = CASE 1A	17630
CFBHS2 = CASE 2A	1865

$A_p + f_{bqR} + f_{bqx} + f_{bqy}$

CFBH91 = CASE 1A	12335
CFBH92 = CASE 2A	3970

▶ INDICATES REVISION FROM PREVIOUS ISSUE

Chicago Bridge & Iron Company

CBI

STRESS SUMMARY

BULKHEAD

Purchaser's No. ______

By LOF Chkd CRS Date 8-4-7

Contract No. STD. PL

W. W. LARIVIERE

ENGINEERING COORDINATOR

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FORM DR 73A REV NOV 78

13-23

CASE NO.	UNIT LOAD × ACTUAL LOAD (lb)	STRESSES (PSI)														
		UNIT STRESS / ACTUAL STRESS														
		fbL	fb1E	fbgE	fb1x	fbgx	fbgY	fwrq	f'wrq	fwFw	fwB1	fwB2	fwB3	fwB4	fwv	f'wFw
2A	½Pe / 10125	.074 / 750	.029 / 295	.040 / 405				.034 / 345		.038 / 385	.029 / 295				.076 / 770	
2A	½PG / 3125	.074 / 230	.029 / 90	.040 / 125				.034 / 105		.038 / 120	.029 / 90				.076 / 240	
1A & 2A	D1 / 850		.054 / 45	.031 / 30				.065 / 55		.070 / 60	.054 / 45					
1A & 2A	Av1 / 850		.054 / 45	.031 / 30				.065 / 55		.070 / 60	.054 / 45					
1A & 2A	D2 / 2670				.003 / 10	.010 / -30	.269 / 720	.003 / 10	.176 / 470	.004 / 10	.003 / 10	.048 / 130	.037 / 100	.075 / 200		.072 / 195
1A & 2A	½Av2 / 2000	.074 / 150	.029 / 60	.040 / 80				.034 / 70		.038 / 75	.029 / 60				.076 / 150	
1A & 2A	½Av2 / 2000				-.005 / -10	.020 / 40		-.006 / -15		-.007 / -15	-.005 / -10					
1A & 2A	Av2 / 2670				.003 / 10	-.010 / -30	.269 / 720	.003 / 10	.176 / 470	.004 / 10	.003 / 10	.048 / 130	.037 / 100	.075 / 200		.072 / 195
1A & 2A	D3 / 350						.269 / 95		.176 / 60			.048 / 20	.037 / 15	.075 / 30		.072 / 25
1A & 2A	½Av3 / 265		.048 / 15	.029 / 10				.057 / 15		.057 / 15	.048 / 15					
1A & 2A	½Av3 / 265				-.005 / 0	.020 / 5		-.006 / 0		-.007 / 0	-.005 / 0					
1A & 2A	Av3 / 350						.269 / 95		.176 / 60			.048 / 20	.037 / 15	.075 / 30		.072 / 25
1A & 2A	D4 / 1900				.003 / 5	-.010 / -20	.269 / 510	.003 / 5	.176 / 335	.004 / 10	.003 / 5	.048 / 90	.037 / 70	.075 / 140		.072 / 140
1A & 2A	½Av4 / 1425	.074 / 105	.029 / 40	.040 / 60				.034 / 50		.038 / 55	.029 / 40				.076 / 110	
1A & 2A	½Av4 / 1425				-.005 / -10	.020 / 30		-.006 / -10		-.007 / -10	-.005 / -10					
1A & 2A	Av4 / 1900				.003 / 5	-.010 / -20	.269 / 510	.003 / 10	.176 / 335	.004 / 10	.003 / 5	.048 / 90	.037 / 70	.075 / 140		.072 / 140
1A & 2A	D5 / 100				.005 / 0	-.018 / 0	.269 / 30	.005 / 0	.176 / 20	.004 / 0	.005 / 0	.048 / 5	.037 / 5	.075 / 10		.072 / 10
1A & 2A	½Av5 / 75	.116 / 10	.019 / 0	.047 / 5				.022 / 0		.024 / 0	.019 / 0				.119 / 10	
1A & 2A	½Av5 / 75				-.005 / 0	.020 / 0		-.006 / 0		-.007 / 0	-.005 / 0					
1A & 2A	Av5 / 100				.005 / 0	-.018 / 0	.269 / 30	.005 / 0	.176 / 20	.004 / 0	.005 / 0	.048 / 5	.037 / 5	.075 / 10		.072 / 10

TOTALS

STRESS CATEGORY	Pm	Pm	Pm	Pm	Pm	Pm	FILLET WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS
CASE 1A	265	205	215	10	-25	2710	255	1770	280	215	490	380	760	270	740
CASE 2A	1245	590	745	10	-25	2710	705	1770	785	600	490	380	760	1280	740

Chicago Bridge & Iron Company CBI

STRESSES IN BULKHEAD STIFFENERS DUE TO LATCH LOAD

Purchaser's No. ______

By LDF Chkd CRS Date [illegible]

W. W. LARIMORE

ENGINEERING COORDINATOR

Contract No. STD. PL

FORM DR 72A REV NOV 1

DOOR DESIGN

The door consists of a stiffened flat plate. The thickness is determined based on the largest panel using a flat plate design. The stiffeners are designed as a simple beam with a uniform load. A portion of the door is assumed to act with the stiffener.

The worst pressure load on the door is the design internal pressure. An equivalent pressure due to horizontal acceleration acting over the area of door is combined with the design internal pressure. Stresses due to vertical acceleration is zero.

Loads: Design Temperature = 400°F

1) PI = Design Internal Pressure = 60 psig

2) PEQ = Equivalent pressure due to acceleration (horizontal along longitudinal axis of lock) = .74 A_{hz} = .74 (1.5) psi (See bulkhead design for PEQ)

The door plate and stiffeners are analyzed using unit load. The resulting stresses are multiplied by the appropriate factor and tabulated on the stress summary for the door. Stresses are reported only at points of interest.

This design covers three different size doors 4'-0x6'-8, 3'-6x6'-8 and 2'-6x6'-8. All three doors utilize the same plate thickness, stiffener sections, and stiffened arrangement.

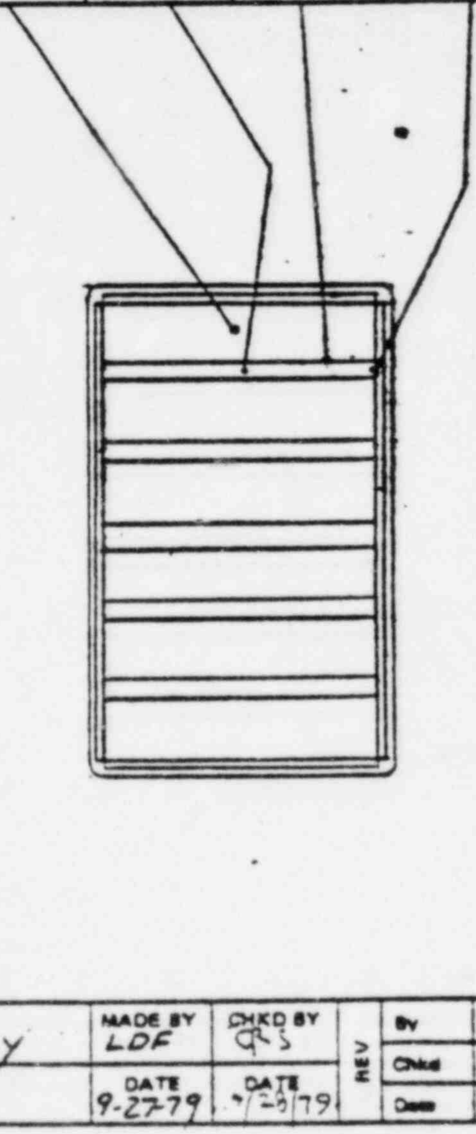
The only dimensional difference between the door sizes is the width. The largest width occurs on the 4'-0x6'-8 door. Therefore, the design is based on the 4'-0x6'-8 door.

SUBJECT Door Design	MADE BY LOF	CHKD BY CRS	REV	By		CHARGE NO. STD. PL
	DATE 9-18-79	DATE 10/1/79		Chkd		
				Date		SHT ___ OF ___

UNIT LOAD / ACTUAL LOAD (PSI)	STRESSES (PSI) UNIT STRESS / ACTUAL STRESS σ_{MAX}	f_b	f_w	σ_w
P_I 60	60.39 3625	292.43 17545	209.52 12570	146.82 8810
P_{EQ} 1.11	60.39 65	292.43 325	209.52 235	146.82 165

TOTALS

STRESS CATEGORY →	P_b	$\bar{P}_m$	FILLET WELD STRESS	GROOVE WELD STRESS
	3690	17870	12805	8975



13-26

SUBJECT	MADE BY	CHKD BY	REV		CHARGE NO.
STRESS SUMMARY	LDF	GRS	By		STD. PL
DOOR	DATE 9-27-79	DATE 9/28/79	Chkd		SHT ~~[illegible]~~ OF
			Date		

GO 64 REV 4-73

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PROG E1823N: STRUCTURAL ANALYSIS FOR PERSONNEL LOCK PULKHEAD,DOCR,HINGE
             AND LATCHING DEVICE BASED ON COEFFICIENTS FOR STANDARD
             DETAILS AS LISTED ON TABLE OF CONTENTS SHEETS SPL-0 R.0
             & SPL-0.1 R.0
             REV.0 OCTOBER 1979

SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING
06/18/92

     *** PRESSURE LOADS ***

     PI = DESIGN INTERNAL PRESSURE=                         60.00 PSI
     PE = DESIGN EXTERNAL PRESSURE=                          5.00 PSI
     PEQ = EQUIVALENT PRESSURE DUE TO SFISMIC=               1.11 PSI

     *** BARREL LOADS ***

     (D+LL)L = MOMENT DUE    TO DEAD LOAD + LIVE LOAD=       8.660E+06 IN-LB
     AHZ = RADIAL FORCE DUE TO HORIZ ACC ON D=           75000. LB
     AHX = TANG FORCE DUE TO HORIZ ACC ON BDM=               1.299E+07 IN-LB
     A = VERT FORCE DUE TO VERT ACC ON BDM=                  8.660E+06 IN-LB

     *** HINGE LOADS ***

     1/2PRLD = 1/2(PRESSURE LOAD DUE TO EXTERNAL PRESSURE
     ACTING OVER DOOR)=                                  10125. LB
     1/2PG = 1/2(LOAD DUE TO GASKET SEATING)=             3125. LB
     D1 = COUPLE PRODUCED BY ECCENTRICITY OF DOOR=         850. LB
     AHZ1 = TANG FORCE DUE TO VERT ACC ON D1=              850. LB
     D2 = WEIGHT OF DOOR=                                 2670. LB
     1/2AHZ2 = 1/2(RADIAL FORCE DUE TO HORIZ ACC ON D2)=  2000. LB
     1/2AHX2 = 1/2(TANG FORCE DUE TO HORIZ ACC ON D2)=    2000. LB
     AV2 = VERT FORCE DUE TO VERT ACC ON D2=              2670. LB
     D3 = WEIGHT OF MAIN HINGE PIN=                        350. LB
     1/2AHZ3 = 1/2(RADIAL FORCE DUE TO HORIZ ACC ON D3)=   265. LB
     1/2AHX3 = 1/2(TANG FORCE DUE TO HORIZ ACC ON D3)=     265. LB
     AV3 = VERT FORCE DUE TO VERT ACC ON D3=               350. LB
     D4 = WEIGHT OF HINGE ARM + CENTER HINGE PIN=         1900. LB
     1/2AHZ4 = 1/2(RADIAL FORCE DUE TO HORIZ ACC ON D4)=  1425. LB
     1/2AHX4 = 1/2(TANG FORCE DUE TO HORIZ ACC ON D4)=    1425. LB
     AV4 = VERT FORCE DUE TO VERT ACC ON D4=              1900. LB
     D5 = WEIGHT OF ROLLER ASSEMBLY=                       100. LB
     1/2AHZ5 = 1/2(RADIAL FORCE DUE TO HORIZ ACC ON D5)=    75. LB
     1/2AHX5 = 1/2(TANG FORCE DUE TO HORIZ ACC ON D5)=      75. LB
     AV5 = VERT FORCE DUE TO VERT ACC ON D5=               100. LB
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

           *** INPUT UNIT STRESS COEFFICIENTS ***
                          BARREL

                 UNIT LOAD     STHETA   SPHI

                    PI           0.     0.0

                    PE           0.     0.0

                 ID+LLIL         0.     0.0

                   AHZ           0.     0.0

                   AHX           0.     0.0

                    A            0.     0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                        *** INPUT UNIT STRESS COEFFICIENTS ***
                                                      SHEET 59

UNIT ID  FAA    FBXA   FBZA   FA4    FBX4   FBZ4   FA10   FBX10  FBZ10  FBXB   FBZB   RY4    RX4    RZ4    RY10   RX10   RZ10

1/2PRLD  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 1/2PG   0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  D1     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 AHZ1    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  D2     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHZ2  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHX2  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AV2    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  D4     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHZ4  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHX4  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AV4    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                         *** INPUT UNIT STRESS COEFFICIENTS ***
                                      SHEET S10

UNIT LOAD    FT1    FT2    FT3    FV1    FV2    FX3    FY3    FZ3    FX11   FZ11   FT1    FT2    FV1    FV2

1/2PRLD      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 1/2PG       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  D1         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 AHZ1        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  D2         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHZ2      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHX2      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AV2        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0

  D4         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHZ4      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHX4      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AV4        0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** INPUT UNIT STRESS COEFFICIENTS ***
                                                SHEET S11

UNIT LOAD   FBY1   FBY2   FWZ1   FWZ2   FWZ3   FWX    FWY    FBX    FBY    FAZ    FWZ1   FWZ2   FWZ3   FWX    FWY

1/2PRLD     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
 1/2PG      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
   D1       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AHZ1      0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
   D2       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHZ2     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
1/2AHX2     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
  AV2       0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** INPUT UNIT STRESS COEFFICIENTS ***
                                                SHEET S12

UNIT LOAD  FT1  FT2  FBSH FBZ1 FBZ2 FBZ3 FWZ1 FWZ2 FWZ3 FWY  FWX  FW   FT1  FT2  FBZ1 FBZ2 FWZ1 FWZ2 FWX

 1/2PRLD   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 1/2PG     0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
   D1      0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  AHZ1     0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
   D2      0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 1/2AHZ2   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 1/2AHX2   0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  AV2      0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                               *** INPUT UNIT STRESS COEFFICIENTS ***
                                            SHEET S13

UNIT LOAD        RZ7    V5=V12    RZ2     RZ8     F10      FA      F8     F10V     FW    F5-12   FW5-12

1/2PRLD          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2PG           0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  D1             0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 AHZ1            0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  D2             0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ2          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX2          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  AV2            0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ3          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX3          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  D4             0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ4          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX4          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  AV4            0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  D5             0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ5          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX5          0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  AV5            0.0     0.0      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

*** INPUT UNIT STRESS COEFFICIENTS ***
SHEET S14

UNIT LOAD	RX2	RX8	RY9	RX1	RX9	RZ1	RZ9
1/2PRLD	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2PG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AHZ1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHX2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHX3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHX4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHX5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                        *** INPUT UNIT STRESS COEFFICIENTS ***
                                                      SHEET S15

UNIT LOAD        FAB    FBZB    FBXB    FAC    FBZC    FBXC    FAD    FBZD    FBXD    FWY    FWX    FWZ

1/2PRLD          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2PG            0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
D1               0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
AHZ1             0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
D2               0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHZ2          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHX2          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
AV2              0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
D3               0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHZ3          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHX3          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
AV3              0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
D4               0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHZ4          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHX4          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
AV4              0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
D5               0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHZ5          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
1/2AHX5          0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
AV5              0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0     0.0     0.0    0.0    0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** INPUT UNIT STRESS COEFFICIENTS ***
                                                SHEET S16

UNIT LOAD     FT1     FT2     FV      FB      FWZ1    FWZ2    FWX     FBY     FAZ     FWZ1    FWZ2    FWX

1/2PRLD       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2PG         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
D1            0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
AHZ1          0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
D2            0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ2       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX2       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
AV2           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
D3            0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ3       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX3       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
AV3           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
D4            0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ4       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX4       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
AV4           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
D5            0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHZ5       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
1/2AHX5       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
AV5           0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                  *** INPUT UNIT STRESS COEFFICIENTS ***
                                                SHEET S17

UNIT LOAD      FT1      FT2      FBSH     FBZ      FWZ      FWZ1     FWZ2     FWZ3     FWY      FWX

 1/2PRLD       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2PG         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   D1          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   AHZ1        0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   D2          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHZ2       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHX2       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   AV2         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   D3          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHZ3       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHX3       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   AV3         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   D4          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHZ4       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHX4       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   AV4         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   D5          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHZ5       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHX5       0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   AV5         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                   *** INPUT UNIT STRESS COEFFICIENTS ***
                                SHEET S18

UNIT LOAD       FI1      FI2      FBZ1     FBZ2     FWZ1     FWZ2     FWX      FB

1/2PRLD         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
 1/2PG          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  D1            0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  AHZ1          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  D2            0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHZ2         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHX2         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  AV2           0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  D3            0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHZ3         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHX3         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  AV3           0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  D4            0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHZ4         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHX4         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  AV4           0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  D5            0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHZ5         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
1/2AHX5         0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
  AV5           0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                    *** INPUT UNIT STRESS COEFFICIENTS ***
                                 SHEET S19

UNIT LOAD       FBA     FBB      FW      FT      FV      FV      FP      FB

 1/2PRLD        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
  1/2PG         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2AHZ2        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2AHZ4        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2AHZ5        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                 *** INPUT UNIT STRESS COEFFICIENTS ***
                                               SHEET S20

UNIT LOAD     FB    FT    FS    FP    FB    FW    FT    FS    FP    FB    FT    FW    FB    FT    FW

1/2PRLD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2PG       0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
1/2AHZ2      0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
1/2AHZ4      0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
1/2AHZ5      0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** INPUT UNIT STRESS COEFFICIENTS ***
                                                 SHEET S22

UNIT LOAD      SMAX1    SMAX2    SMAX3    FB38    FBV    FBH    FW38    FW22   FWF33    FWF     FW13    FW14    FB9

   PI           0.0      0.0      0.0      0.0     0.0    0.0    0.0     0.0    0.0      0.0     0.0     0.0     0.0

   PE           0.0      0.0      0.0      0.0     0.0    0.0    0.0     0.0    0.0      0.0     0.0     0.0     0.0

   PEQ          0.0      0.0      0.0      0.0     0.0    0.0    0.0     0.0    0.0      0.0     0.0     0.0     0.0
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                              *** INPUT UNIT STRESS COEFFICIENTS ***
                                             SHEET S23

UNIT LOAD   FBL   FB9Z  FUCLZ  FB9X  FUCLX  FB9Y  FWF9  F*WF9  FWFW  FWB1  FWB2  FWB3  FWB4  FWV   F*WFW

 1/2PRLD    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
  1/2PG     0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   D1       0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   AHZ1     0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   D2       0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHZ2    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHX2    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   AV2      0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   D3       0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHZ3    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHX3    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   AV3      0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   D4       0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHZ4    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHX4    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   AV4      0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   D5       0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHZ5    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
 1/2AHX5    0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
   AV5      0.0   0.0   0.0    0.0   0.0    0.0   0.0   0.0    0.0   0.0   0.0   0.0   0.0   0.0   0.0
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  SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

         *** INPUT UNIT STRESS COEFFICIENTS ***
                        SHEET S25

UNIT LOAD    SMAX    FB    FW    SW

   PI         0.0    0.0   0.0   0.0

   PEC        0.0    0.0   0.0   0.0
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

          *** BARREL UNIT STRESS COEFFICIENTS ***

                 UNIT LOAD    STHETA   SPHI

                      PI       126.    63.000
                      PE      -126.   -63.000
                 1D*LLIL        0.    1.598E-04
                     AHZ        0.    5.000E-01
                     AHX        0.    1.598E-04
                       A        0.    1.598E-04
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

            *** STRESS SUMMARY BARREL ***
                        (PSI)

          LOAD       STHETA     SPHI      SPHI
                                +REV      -REV

            PI        7560.     3780.     3780.

            PE        -630.     -315.     -315.

       (D+LL)L           0.     1384.    -1384.

           AHZ           0.      375.     -375.

           AHX           0.     2076.    -2076.

             A           0.     1384.    -1384.
                     ------------------------

       CASE 1B        7560.     8999.    -1439.

       CASE 2B        -630.     4904.    -5534.
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

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                        *** CENTER HINGE PIN UNIT STRESS COEFFICIENTS ***
                                            SHEET 59

  LOAD     FAA    FBXA    FBZA   FA4     FBX4    FBZ4   FA10   FBX10  FBZ10   FBXB   FBZB   RY4    RX4    RZ4     RY10   RX10   RZ10

1/2PRLD  0.0     1.062  0.0    0.0     1.367  0.0    0.0     1.367  0.0     1.062  0.0    0.0    0.0     1.000  0.0    0.0    1.000
 1/2PG   0.0     1.062  0.0    0.0     1.367  0.0    0.0     1.367  0.0     1.062  0.0    0.0    0.0     1.000  0.0    0.0    1.000
  D1     0.0    -1.062  0.0    0.0    -1.367  0.0    0.0     1.367  0.0     1.062  0.0    0.0    0.0    -1.796  0.0    0.0    1.796
 AHZ1    0.0    -1.062  0.0    0.0    -1.367  0.0    0.0     1.367  0.0     1.062  0.0    0.0    0.0    -1.796  0.0    0.0    1.796
  D2     0.204   0.0    0.0    0.039   0.0    0.0    0.039   0.0    0.0     0.0    0.0    0.500  0.0     0.0    0.500  0.0    0.0
1/2AHZ2  0.0     1.062  0.0    0.0     1.367  0.0    0.0     1.367  0.0     1.062  0.0    0.0    0.0     1.000  0.0    0.0    1.000
1/2AHX2  0.0     0.0    1.062  0.0     0.0    0.797  0.0    0.0    0.797   0.0    1.062  0.0    1.000   0.0    0.0    1.000  0.0
  AV2    0.204   0.0    0.0    0.039   0.0    0.0    0.039   0.0    0.0     0.0    0.0    0.500  0.0     0.0    0.500  0.0    0.0
  D4     0.0     0.0    0.0    0.039   0.0    0.0    0.039   0.0    0.0     0.0    0.0    0.500  0.0     0.0    0.500  0.0    0.0
1/2AHZ4   0.0    0.0     0.0    0.0     0.0    0.0    0.0    0.0     0.0    0.0    0.0    0.0    0.0    1.000   0.0    0.0    1.000
1/2AHX4   0.0    0.0     0.0    0.0     0.0    0.0    0.0    0.0     0.0    0.0    0.0    0.0    1.000  0.0     0.0    1.000  0.0
  AV4     0.0    0.0     0.0    0.039   0.0    0.0    0.039  0.0     0.0    0.0    0.0    0.500  0.0    0.0     0.500  0.0    0.0
```

13-46

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** STRESS SUMMARY CENTER HINGE PIN ***
                                                SHEET 59
        ****************************************************************************************************
        *                                  STRESS                           *              REACTIONS            *
        *                                  (PSI)                            *                (LB)               *
        *************************************************************      **************************************

  LOAD    FAA    FBXA   FBZA    FA4    FBX4   FBZ4   FA10  FBX10  FBZ10   FBX8   FBZ8    RY4    RX4    RZ4   RY10   RX10   RZ10

 1/2PRLD   0.  10753.    0.     0.  13841.    0.     0.  13841.    0.  10753.    0.     0.     0.  10125.    0.     0.  10125.
 1/2PG     0.   3319.    0.     0.   4272.    0.     0.   4272.    0.   3319.    0.     0.     0.   3125.    0.     0.   3125.
  D1       0.   -903.    0.     0.  -1162.    0.     0.   1162.    0.    903.    0.     0.     0.  -1527.    0.     0.   1527.
  AH71     0.   -903.    0.     0.  -1162.    0.     0.   1162.    0.    903.    0.     0.     0.  -1527.    0.     0.   1527.
  D2     545.     0.     0.   104.     0.     0.   104.     0.     0.     0.     0.  1335.    0.     0.  1335.    0.     0.
 1/2AHZ2   0.   2124.    0.     0.   2734.    0.     0.   2734.    0.   2124.    0.     0.     0.   2000.    0.     0.   2000.
 1/2AHX2   0.     0.  2124.    0.     0.  1594.    0.     0.  1594.    0.  2124.    0.  2000.    0.     0.  2000.    0.
  AV2    545.     0.     0.   104.     0.     0.   104.     0.     0.     0.     0.  1335.    0.     0.  1335.    0.     0.
  D4       0.     0.     0.    74.     0.     0.    74.     0.     0.     0.     0.   950.    0.     0.   950.    0.     0.
 1/2AHZ4   0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.   1425.    0.     0.   1425.
 1/2AHX4   0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.     0.  1425.    0.     0.  1425.    0.
  AV4      0.     0.     0.    74.     0.     0.    74.     0.     0.     0.     0.   950.    0.     0.   950.    0.     0.
          -----------------------------------------------------------------------------------------------------------------
 CASE 1 1089.  14390.  2124.  356.  18523.  1594.  356.  23171.  1594.  18001.  2124.  4570.  3425.  13622.  4570.  3425.  19728.

      FCA=  15635.
      FC4=  20473.
      FC10=  25121.
      FCB=  16126.
```

SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

*** CENTER HINGE PIN UNIT STRESS COEFFICIENTS ***
SHEET 510

LOAD	FT1	FT2	FT3	FV1	FV2	FX3	FY3	FZ3	FX11	FZ11	FT1	FT2	FV1	FV2
1/2PHLD	0.0	0.454	0.0	0.0	0.0	0.0	0.0	1.000	0.0	1.000	0.0	0.0	0.0	0.0
1/2PG	0.0	0.454	0.0	0.0	0.0	0.0	0.0	1.000	0.0	1.000	0.0	0.0	0.0	0.0
D1	0.0	0.815	0.0	0.0	0.0	0.0	0.0	-1.000	0.0	1.000	0.0	0.0	0.0	0.0
AHZ1	0.0	0.815	0.0	0.0	0.0	0.0	0.0	-1.000	0.0	1.000	0.0	0.0	0.0	0.0
D2	0.0	0.0	0.263	0.227	0.0	0.0	1.000	0.0	0.0	0.0	0.0	2.860	0.0	0.828
1/2AHZ2	0.0	0.454	0.0	0.0	0.0	0.0	0.0	1.000	0.0	1.000	0.0	0.0	0.0	0.0
1/2AHX2	0.438	0.0	0.0	0.0	0.454	1.000	0.0	0.0	1.000	0.0	0.807	0.0	0.828	0.0
AV2	0.0	0.0	0.263	0.227	0.0	0.0	1.000	0.0	0.0	0.0	0.0	2.860	0.0	0.828
D4	0.0	0.0	0.263	0.227	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ4	0.0	0.454	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHX4	0.438	0.0	0.0	0.0	0.454	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AV4	0.0	0.0	0.263	0.227	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                              *** STRESS SUMMARY CENTER HINGE PIN ***
                                             SHEET S10
          ***************************************************************************************
          *                                   *                                    *         JOINT 3        *
          *   BOLTS-CTR. HINGE ARM            *  LOADS AT CTR. HINGE PIN BEARINGS  *  BOLTS-CTR. HINGE PIN BEARINGS *
          *            STRESS                 *               LOAD                 *            STRESS      *
          *            (PSI)                  *               (LB)                 *            (PSI)       *
          ***************************************************************************************

 LOAD          FT1     FT2     FT3     FV1     FV2     FX3     FY3     FZ3    FX11    FZ11     FT1     FT2     FV1     FV2

 1/2PRLD        0.   4597.      0.      0.      0.      0.      0.  10125.      0.  10125.      0.      0.      0.      0.
 1/2PG          0.   1419.      0.      0.      0.      0.      0.   3125.      0.   3125.      0.      0.      0.      0.
 D1             0.    693.      0.      0.      0.      0.      0.   -850.      0.    850.      0.      0.      0.      0.
 AHZ1           0.    693.      0.      0.      0.      0.      0.   -850.      0.    850.      0.      0.      0.      0.
 D2             0.      0.    702.    606.      0.      0.   2670.      0.      0.      0.      0.   7636.      0.   2211.
 1/2AHZ2        0.    908.      0.      0.      0.      0.      0.   2000.      0.   2000.      0.      0.      0.      0.
 1/2AHX2      876.      0.      0.      0.    908.   2000.      0.      0.   2000.      0.   1614.      0.   1656.      0.
 AV2            0.      0.    702.    606.      0.      0.   2670.      0.      0.      0.      0.   7636.      0.   2211.
 D4             0.      0.    500.    431.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 1/2AHZ4        0.    647.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 1/2AHX4      624.      0.      0.      0.    647.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 AV4            0.      0.    500.    431.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
               ---------------------------------------------------------------------------------------------------------
 CASE 1      1500.   8956.   2404.   2075.   1555.   2000.   5340.  13550.   2000.  16950.   1614.  15272.   1656.   4422.

          FCBA=  13866.                          FC3=  23061.                         FCAP=  19347.
                                                 FC11=  17068.
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                    *** CENTER HINGE PIN UNIT STRESS COEFFICIENTS ***
                                          SHEET S11

LOAD       FBY1   FBY2   FWZ1   FWZ2   FWZ3   FWX    FWY    FBX    FBY    FAZ    FWZ1   FWZ2   FWZ3   FWX    FWY

1/2PWLD    0.665  0.0    0.0    0.0    0.323  0.0    0.0    0.0    0.0    0.095  0.0    0.0    0.162  0.0    0.0
1/2PG      0.665  0.0    0.0    0.0    0.323  0.0    0.0    0.0    0.0    0.095  0.0    0.0    0.162  0.0    0.0
D1         0.665  0.0    0.0    0.0   -0.323  0.0    0.0    0.0    0.0   -0.095  0.0    0.0   -0.162  0.0    0.0
AHZ1       0.665  0.0    0.0    0.0   -0.323  0.0    0.0    0.0    0.0   -0.095  0.0    0.0   -0.162  0.0    0.0
D2         0.0    0.0    1.732  0.0    0.0    0.0    0.323  0.571  0.0    0.0    1.940  0.0    0.0    0.0    0.162
1/2AHZ2    0.665  0.0    0.0    0.0    0.323  0.0    0.0    0.0    0.0    0.095  0.0    0.0    0.162  0.0    0.0
1/2AHX2    0.0    0.274  0.0    0.289  0.0    0.323  0.0    0.0    0.105  0.0    0.0    0.354  0.0    0.162  0.0
AV2        0.0    0.0    1.732  0.0    0.0    0.0    0.323  0.571  0.0    0.0    1.940  0.0    0.0    0.0    0.162
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                              ooo STRESS SUMMARY CENTER HINGE PIN ooo
                                                            SHEET S11
                 oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
                 o  JOINT 11    o                 JOINT 3                o     JOINT 3          o            JOINT 3               o
                 oMOUNTING PLATEWELD-MOUNTING PL TO GUSSET                o     GUSSETS          o     WELD-GUSSET PL TO DOOR       o
                 o    STRESS    o                 STRESS                 o     STRESS           o             STRESS               o
                 o    (PSI)     o                 (PSI)                  o     (PSI)            o             (PSI)                o
                 oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo

  LOAD         FBY1   FBY2   FWZ1   FWZ2   FWZ3   FWX    FWY    FBX    FBY    FAZ    FWZ1   FWZ2   FWZ3   FWX    FWY

 1/2PRLD       6733.    0.     0.     0.  3270.    0.     0.     0.     0.   962.     0.     0.  1640.    0.     0.
 1/2PG         2078.    0.     0.     0.  1009.    0.     0.     0.     0.   297.     0.     0.   506.    0.     0.
  D1            565.    0.     0.     0.  -275.    0.     0.     0.     0.   -81.     0.     0.  -138.    0.     0.
  AHZ1          565.    0.     0.     0.  -275.    0.     0.     0.     0.   -81.     0.     0.  -138.    0.     0.
  D2              0.    0.  4624.     0.     0.    0.   862.  1525.    0.     0.  5180.     0.     0.    0.   433.
 1/2AHZ2       1330.    0.     0.     0.   646.    0.     0.     0.     0.   190.     0.     0.   324.    0.     0.
 1/2AHX2          0.  548.     0.   578.     0.  646.     0.     0.   210.     0.     0.   708.     0.  324.     0.
  AV2             0.    0.  4624.     0.     0.    0.   862.  1525.    0.     0.  5180.     0.     0.    0.   433.
               ---------------------------------------------------------------------------------------------------------
 CASE 1       11272.  548.  9249.   578.  4377.  646.  1725.  3049.   210.  1287. 10360.   708.  2195.  324.   865.

               FBMP=  11820.   FWMP=  14322.                    FBG3=   4546.        FWGD=  13295.
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                        *** CENTER HINGE PIN UNIT STRESS COEFFICIENTS ***
                                           SHEET S12

LOAD     FT1   FT2    FBSH  FBZ1  FBZ2  FBZ3   FWZ1  FWZ2  FWZ3   FWY   FWX   FB    FT1   FT2   FBZ1  FBZ2  FWZ1  FWZ2  FWX

1/2PRLO  0.0   0.255  0.0   0.0   0.0   0.038  0.0   0.0   0.189  0.0   0.0   0.0   0.0   0.298 0.0   0.044 0.0   0.189 0.0
1/2PG    0.0   0.255  0.0   0.0   0.0   0.038  0.0   0.0   0.189  0.0   0.0   0.0   0.0   0.298 0.0   0.044 0.0   0.189 0.0
D1       0.0  -0.255  0.0   0.0   0.0  -0.038  0.0   0.0  -0.189  0.0   0.0   0.0   0.0   0.298 0.0   0.044 0.0   0.189 0.0
AHZ1     0.0  -0.255  0.0   0.0   0.0  -0.038  0.0   0.0  -0.189  0.0   0.0   0.0   0.0   0.298 0.0   0.044 0.0   0.189 0.0
D2       0.0   0.0    1.435 0.229 0.0   0.0    0.377 0.0   0.0    0.189 0.0   2.332 0.0   0.0   0.0   0.0   0.0   0.0   0.0
1/2AHZ2  0.0   0.255  0.0   0.0   0.0   0.038  0.0   0.0   0.189  0.0   0.0   0.0   0.0   0.298 0.0   0.044 0.0   0.189 0.0
1/2AHX2  0.255 0.0    0.0   0.0   0.101 0.0    0.0   0.528 0.0    0.0   0.189 0.258 0.298 0.0   0.124 0.0   0.528 0.0   0.189
AV2      0.0   0.0    1.435 0.229 0.0   0.0    0.377 0.0   0.0    0.189 0.0   2.332 0.0   0.0   0.0   0.0   0.0   0.0   0.0
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                         *** STRESS SUMMARY CENTER HINGE PIN ***
                                                         SHEET S12
          ***********************************************************************************************************
          *                      UPPER BEARING HOUSING-JOINT 3                   *       LOWER BEARING HOUSING-JOINT 11          *
          *                                 STRESS                               *                 STRESS                        *
          *                                 (PSI)                                *                 (PSI)                         *
          ***********************************************************************************************************

LOAD        FT1   FT2  FBSH  FBZ1  FBZ2  FBZ3  FWZ1  FWZ2  FWZ3   FWY   FWX    FB   FT1   FT2  FBZ1  FBZ2  FWZ1  FWZ2   FWX

1/2PALD       0  2581     0     0     0   384     0     0  1913     0     0     0     0  3017     0   445     0  1913     0

1/2PG         0   796     0     0     0   118     0     0   590     0     0     0     0   931     0   137     0   590     0

D1            0  -219     0     0     0   -32     0     0  -160     0     0     0     0   253     0    37     0   160     0

AHZ1          0  -216     0     0     0   -32     0     0  -160     0     0     0     0   253     0    37     0   160     0

D2            0     0  3831   611     0     0  1006     0     0   504     0  6226     0     0     0     0     0     0     0

1/2AHZ2       0   509     0     0     0    75     0     0   378     0     0     0     0   595     0    87     0   378     0

1/2AHX2     509     0     0     0   213     0     0  1055     0     0   378  1315   595     0   248     0  1055     0   378

AV2           0     0  3831   611     0     0  1006     0     0   504     0  6226     0     0     0     0     0     0     0
          -------------------------------------------------------------------------------------------------------------

CASE 1      509  3455  7662  1222   213   514  2013  1055  2560  1009   378 13768   595  5051   248   745  1055  3203   378

            FB=  13769.
            FBSH=   7663.
            FHTU=   3493.                                                           FHTL=    5086.
            FHU=   1952.                                                            FHL=     994.
            FWHU=   5732.                                                           FWHL=    4276.
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                   *** HINGE UNIT STRESS COEFFICIENTS ***
                                                SHEET S13

  LOAD        BZZ    V5=V12   BZZ     BZB     F10      FA      FB      F10V     FW     F5-12   FW5-12

 1/2PRLD     1.102   0.551   0.450   0.450   0.592   0.362   0.0     0.0     0.153   0.353   0.247
  1/2PG      1.102   0.551   0.450   0.450   0.592   0.362   0.0     0.0     0.153   0.353   0.247
   D1        0.0     0.0    -1.796   1.796   2.360   3.301   0.0     0.0     0.602   0.0     0.0
  AHZ1       0.0     0.0    -1.796   1.796   2.360   3.301   0.0     0.0     0.602   0.0     0.0
   D2        0.0     0.0     0.0     0.0    -0.009  -0.010   0.616   0.0     0.265   0.0     0.0
 1/2AHZ2     1.102   0.551   0.450   0.450   0.592   0.362   0.0     0.0     0.153   0.353   0.247
 1/2AHX2     0.0     0.0     0.0     0.0     0.057   0.061   0.463   0.0     0.172   0.0     0.0
   AV2       0.0     0.0     0.0     0.0    -0.009  -0.010   0.616   0.0     0.265   0.0     0.0
 1/2AHZ3     0.0     0.0     1.000   1.000   0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2AHX3     0.0     0.0     0.0     0.0     0.057   0.061   0.057   0.0     0.0     0.0     0.0
   D4        0.0     0.0     0.0     0.0    -0.009  -0.010   0.616   0.0     0.265   0.0     0.0
 1/2AHZ4     1.102   0.551   0.450   0.450   0.592   0.362   0.0     0.0     0.153   0.353   0.247
 1/2AHX4     0.0     0.0     0.0     0.0     0.057   0.061   0.463   0.0     0.172   0.0     0.0
   AV4       0.0     0.0     0.0     0.0    -0.009  -0.010   0.616   0.0     0.265   0.0     0.0
   D5        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
 1/2AHZ5     1.724  -0.138   0.138   0.138   0.181   0.370   0.0     0.0     0.045   0.552  -0.062
 1/2AHX5     0.0     0.0     0.0     0.0     0.057   0.061   0.693   0.230   0.172   0.0     0.0
   AV5       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
```

```
SAMPLE PROBLEM = STANDARD LOCK DETAILS WITH STANDARD LOADING

                                        *** STRESS SUMMARY HINGE ***
                                                   SHEET 513
                 ************************************************************************************
                 *       REACTIONS & SHEARS          *              STRESSES-HINGE ARM          * STRESS-MEM.  *
                 *              (LB)                 *                   (PSI)                  * 5 TO 12 (PSI) *
                 ************************************************************************************

    LOAD         RZ7    V5=V12    RZ2      RZ8      F10      FA       FB      F10V     FW    F5-12   FW5-12

  1/2PRLD      11158.   5579.   4556.    4556.    5994.    3665.      0.       0.    1549.   3574.   2501.
  1/2PG         3444.   1722.   1406.    1406.    1050.    1131.      0.       0.     478.   1103.    772.
    D1             0.      0.  -1527.    1527.    2006.    2806.      0.       0.     512.      0.      0.
   AHZ1            0.      0.  -1527.    1527.    2006.    2806.      0.       0.     512.      0.      0.
    D2             0.      0.      0.       0.     -24.     -27.   1645.       0.     708.      0.      0.
  1/2AHZ2       2204.   1102.    900.     900.    1184.     724.      0.       0.     306.    706.    494.
  1/2AHX2          0.      0.      0.       0.     114.     122.    926.       0.     344.      0.      0.
   AV2             0.      0.      0.       0.     -24.     -27.   1645.       0.     708.      0.      0.
  1/2AHZ3          0.      0.    265.     265.       0.       0.      0.       0.       0.      0.      0.
  1/2AHX3          0.      0.      0.       0.      15.      16.     15.       0.       0.      0.      0.
    D4             0.      0.      0.       0.     -17.     -19.   1170.       0.     503.      0.      0.
  1/2AHZ4       1570.    785.    641.     641.     844.     516.      0.       0.     218.    503.    352.
  1/2AHX4          0.      0.      0.       0.      81.      87.    650.       0.     245.      0.      0.
   AV4             0.      0.      0.       0.     -17.     -19.   1170.       0.     503.      0.      0.
    D5             0.      0.      0.       0.       0.       0.      0.       0.       0.      0.      0.
  1/2AHZ5        129.    -10.     10.      10.      14.      28.      0.       0.       3.     41.     -5.
  1/2AHX5          0.      0.      0.       0.       4.       5.     52.      17.      33.      0.      0.
   AV5             0.      0.      0.       0.       0.       0.      0.       0.       0.      0.      0.
               ------------------------------------------------------------------------------------
  CASE 1       18505.   9178.   4726.   10832.   14029.   11814.   7283.      17.    6602.   5926.   4114.

                                        F=  14047.
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

            *** MAIN HINGE PIN UNIT STRESS COEFFICIENTS ***
                              SHEET S14

   LOAD        RX2      RX8      RY9      RX1      RX9      RZ1      RZ9

  1/2PRLD      0.0      0.0      0.0      0.0      0.0      0.450    0.450
  1/2PG        0.0      0.0      0.0      0.0      0.0      0.450    0.450
    D1         0.0      0.0      0.0      0.0      0.0     -1.135    1.135
   AHZ1        0.0      0.0      0.0      0.0      0.0     -1.135    1.135
    D2         0.792    0.792    1.000    0.500    0.500    0.0      0.0
  1/2AHZ2      0.0      0.0      0.0      0.0      0.0      0.450    0.450
  1/2AHX2      1.000   -1.000    0.0      1.000   -1.000    0.0      0.0
   AV2         0.792    0.792    1.000    0.500    0.500    0.0      0.0
    D3         0.0      0.0      1.000    0.0      0.0      0.0      0.0
  1/2AHZ3      0.0      0.0      0.0      0.0      0.0      1.000    1.000
  1/2AHX3      1.000   -1.000    0.0      1.000   -1.000    0.0      0.0
   AV3         0.0      0.0      1.000    0.0      0.0      0.0      0.0
    D4         0.792    0.792    1.000    0.500    0.500    0.0      0.0
  1/2AHZ4      0.0      0.0      0.0      0.0      0.0      0.450    0.450
  1/2AHX4      1.000   -1.000    0.0      1.000   -1.000    0.0      0.0
   AV4         0.792    0.792    1.000    0.500    0.500    0.0      0.0
    D5         1.438    1.438    1.000    0.909    0.909    0.0      0.0
  1/2AHZ5      0.0      0.0      0.0      0.0      0.0      0.138    0.138
  1/2AHX5      1.000   -1.000    0.0      1.000   -1.000    0.0      0.0
   AV5         1.438    1.438    1.000    0.909    0.909    0.0      0.0
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

               *** STRESS SUMMARY MAIN HINGE PIN ***
                             SHELT S14

                             REACTIONS
                               (LB)

 LOAD          RX2     RX8     RY9     RX1     RX9     RZ1     RZ9

1/2PRLD         0.      0.      0.      0.      0.   4556.   4556.
 1/2PG          0.      0.      0.      0.      0.   1496.   1496.
  D1            0.      0.      0.      0.      0.   -965.    965.
 AHZ1           0.      0.      0.      0.      0.   -965.    965.
  D2         2115.   2115.   2670.   1335.   1335.      0.      0.
1/2AHZ2         0.      0.      0.      0.      0.    900.    970.
1/2AHX2      2000.  -2000.      0.   2000.  -2000.      0.      0.
  AV2        2115.   2115.   2670.   1335.   1335.      0.      0.
  D3            0.      0.    350.      0.      0.      0.      0.
1/2AHZ3         0.      0.      0.      0.      0.    265.    265.
1/2AHX3       265.   -265.      0.    265.   -265.      0.      0.
  AV3           0.      0.    350.      0.      0.      0.      0.
  D4         1505.   1505.   1900.    950.    950.      0.      0.
1/2AHZ4         0.      0.      0.      0.      0.    641.    641.
1/2AHX4      1425.  -1425.      0.   1425.  -1425.      0.      0.
  AV4        1505.   1505.   1900.    950.    950.      0.      0.
  D5          144.    144.    100.     91.     91.      0.      0.
1/2AHZ5         0.      0.      0.      0.      0.     10.     10.
1/2AHX5        75.    -75.      0.     75.    -75.      0.      0.
  AV5         144.    144.    100.     91.     91.      0.      0.
            --------------------------------------------------------
 CASE 1     11291.   3761.  10040.   8517.    987.   5850.   9709.
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                         *** MAIN HINGE PIN UNIT STRESS COEFFICIENTS ***
                                          SHEET 515

   LOAD        FAB    FBZB    FBXB   FAC     FBZC    FBXC    FAD     FBZD    FBXD   FWY     FWX     FWZ

 1/2PRLD      0.0    0.0     0.454  0.0     0.0     0.158   0.0     0.0     0.514  0.0     0.0     0.081
 1/2PG        0.0    0.0     0.454  0.0     0.0     0.158   0.0     0.0     0.514  0.0     0.0     0.081
   D1         0.0    0.0     1.144  0.0     0.0     0.400   0.0     0.0     1.257  0.0     0.0     0.322
  AHZ1        0.0    0.0     1.144  0.0     0.0     0.400   0.0     0.0     1.297  0.0     0.0     0.322
   D2         0.041  0.504   0.0    0.054   0.176   0.0     0.204   0.571   0.0    0.090   1.257   0.0
 1/2AHZ2      0.0    0.0     0.454  0.0     0.0     0.158   0.0     0.0     0.514  0.0     0.0     0.081
 1/2AHX2      0.0   -1.008   0.0    0.0    -0.352   0.0     0.0    -1.143   0.0    0.0     0.547   0.0
  AV2         0.041  0.504   0.0    0.054   0.176   0.0     0.204   0.571   0.0    0.090   1.257   0.0
   D3         0.041  0.0     0.0    0.054   0.0     0.0     0.204   0.0     0.0    0.0     0.0     0.0
 1/2AHZ3      0.0    0.0     1.008  0.0     0.0     0.352   0.0     0.0     1.143  0.0     0.0     0.179
 1/2AHX3      0.0   -1.008   0.0    0.0    -0.352   0.0     0.0    -1.143   0.0    0.0    -0.179   0.0
  AV3         0.041  0.0     0.0    0.054   0.0     0.0     0.204   0.0     0.0    0.0     0.0     0.0
   D4         0.041  0.504   0.0    0.054   0.176   0.0     0.204   0.571   0.0    0.090   1.257   0.0
 1/2AHZ4      0.0    0.0     0.454  0.0     0.0     0.158   0.0     0.0     0.514  0.0     0.0     0.081
 1/2AHX4      0.0   -1.008   0.0    0.0    -0.352   0.0     0.0    -1.143   0.0    0.0     0.547   0.0
  AV4         0.041  0.504   0.0    0.054   0.176   0.0     0.204   0.571   0.0    0.090   1.257   0.0
   D5         0.041  0.916   0.0    0.054   0.320   0.0     0.204   1.039   0.0    0.0     0.257   0.0
 1/2AHZ5      0.0    0.0     0.139  0.0     0.0     0.049   0.0     0.0     0.158  0.0     0.0     0.025
 1/2AHX5      0.0   -1.008   0.0    0.0    -0.352   0.0     0.0    -1.143   0.0    0.0     0.961   0.0
  AV5         0.041  0.916   0.0    0.054   0.320   0.0     0.204   1.039   0.0    0.0     0.257   0.0
```

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SAMPLE   UBLEM - STANDARD LOCK DETAILS WITH STANDARD LOAD,

                              *** STRESS SUMMARY MAIN HINGE PIN ***
                                             SHEET 515
         ****************************************************************************************
         *                          STRESSES                                 *WELD-HINGE ARM TO PIN *
         *                           (PSI)                                   *    STRESS (PSI)      *
         ****************************************************************************************

 LOAD          FAB    FBZB    FBXB    FAC    FBZC    FBXC    FAD    FBZD    FBXD    FWY    FWX    FWZ

1/2PRLD         0.      0.   4597.     0.      0.   1600.     0.      0.   5204.     0.     0.   820.
1/2PG           0.      0.   1419.     0.      0.    494.     0.      0.   1606.     0.     0.   253.
 01             0.      0.    972.     0.      0.    340.     0.      0.   1102.     0.     0.   274.
 AHZ1           0.      0.    972.     0.      0.    340.     0.      0.   1102.     0.     0.   274.
 02           109.   1346.      0.   144.    470.      0.   545.   1525.      0.   240.  3356.     0.
1/2AHZ2         0.      0.    908.     0.      0.    316.     0.      0.   1028.     0.     0.   162.
1/2AHX2         0.  -2016.      0.     0.   -704.      0.     0.  -2286.      0.     0.  1094.     0.
 AV2          109.   1346.      0.   144.    470.      0.   545.   1525.      0.   240.  3356.     0.
 03            14.      0.      0.    19.      0.      0.    71.      0.      0.     0.     0.     0.
1/2AHZ3         0.      0.    267.     0.      0.     93.     0.      0.    303.     0.     0.    47.
1/2AHX3         0.   -267.      0.     0.    -93.      0.     0.   -303.      0.     0.   -47.     0.
 AV3           14.      0.      0.    19.      0.      0.    71.      0.      0.     0.     0.     0.
 04            78.    958.      0.   103.    334.      0.   388.   1085.      0.   171.  2388.     0.
1/2AHZ4         0.      0.    647.     0.      0.    225.     0.      0.    732.     0.     0.   115.
1/2AHX4         0.  -1436.      0.     0.   -502.      0.     0.  -1629.      0.     0.   779.     0.
 AV4           78.    958.      0.   103.    334.      0.   388.   1085.      0.   171.  2388.     0.
 05             4.     92.      0.     5.     32.      0.    70.    104.      0.     0.    26.     0.
1/2AHZ5         0.      0.     10.     0.      0.      4.     0.      0.     12.     0.     0.     2.
1/2AHX5         0.    -76.      0.     0.    -26.      0.     0.    -86.      0.     0.    72.     0.
 AV5            4.     92.      0.     5.     32.      0.    70.    104.      0.     0.    26.     0.
              ------------------------------------------------------------------------------------
 CASE 1       412.    995.   9793.   542.    347.   3412.  2048.   1123.  11091.   823. 13438.  1947.

          FCB= 10235.            FCC=  3971.            FCC= 13195.           FW= 13604.
```

SAMPLE PROBLEM = STANDARD LOCK DETAILS WITH STANDARD LOADING

*** MAIN HINGE PIN UNIT STRESS COEFFICIENTS ***
SHEET 516

LOAD	FT1	FT2	FV	FB	FWZ1	FWZ2	FWX	FBY	FAZ	FWZ1	FWZ2	FWX
1/2PRLD	0.0	0.373	0.0	0.310	0.0	0.121	0.0	0.0	0.032	0.0	0.061	0.0
1/2PG	0.0	0.373	0.0	0.310	0.0	0.121	0.0	0.0	0.032	0.0	0.061	0.0
D1	0.0	-0.940	0.0	-0.781	0.0	-0.305	0.0	0.0	-0.081	0.0	-0.153	0.0
AHZ1	0.0	-0.940	0.0	-0.781	0.0	-0.305	0.0	0.0	-0.081	0.0	-0.153	0.0
D2	0.404	0.0	0.414	0.336	0.664	0.0	0.135	0.283	0.0	0.534	0.0	0.068
1/2AHZ2	0.0	0.373	0.0	0.310	0.0	0.121	0.0	0.0	0.032	0.0	0.061	0.0
1/2AHX2	0.807	0.0	0.828	0.670	1.329	0.0	0.269	0.566	0.0	1.068	0.0	0.135
AV2	0.404	0.0	0.414	0.336	0.664	0.0	0.135	0.283	0.0	0.534	0.0	0.068
D3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2AHZ3	0.0	0.828	0.0	0.688	0.0	0.269	0.0	0.0	0.071	0.0	0.135	0.0
1/2AHX3	0.807	0.0	0.829	0.670	1.328	0.0	0.269	0.566	0.0	1.068	0.0	0.135
AV3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D4	0.404	0.0	0.414	0.336	0.664	0.0	0.135	0.283	0.0	0.534	0.0	0.068
1/2AHZ4	0.0	0.373	0.0	0.310	0.0	0.121	0.0	0.0	0.032	0.0	0.061	0.0
1/2AHX4	0.807	0.0	0.828	0.671	1.329	0.0	0.269	0.566	0.0	1.068	0.0	0.135
AV4	0.404	0.0	0.414	0.336	0.664	0.0	0.135	0.283	0.0	0.534	0.0	0.068
D5	0.734	0.0	0.753	0.609	1.207	0.0	0.245	0.515	0.0	0.971	0.0	0.123
1/2AHZ5	0.0	0.115	0.0	0.095	0.0	0.037	0.0	0.0	0.010	0.0	0.019	0.0
1/2AHX5	0.807	0.0	0.828	0.670	1.328	0.0	0.269	0.566	0.0	1.068	0.0	0.135
AV5	0.734	0.0	0.753	0.609	1.207	0.0	0.245	0.515	0.0	0.971	0.0	0.123

```
PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LC

                                   *** STRESS SUMMARY MAIN HINGE PIN ***
                                              SHEET 516
          ******************************************************************************************
          *     BOLT STRESS        * MTG.PL* WELD-MTG.PL TO GUSSET * GUSSET STRESS * WELD-GUSSET TO BULKHEAD*
          *        (PSI)           * STRESS*        (PSI)          *    (PSI)      *        (PSI)           *
          *                        * (PSI) *                       *               *                        *
          ******************************************************************************************

   LOAD        FT1     FT2      FV      FB     FWZ1    FWZ2     FWX      FBY     FAZ    FWZ1    FWZ2    FWX

 1/2PHLD        0.   3777.      0.   3139.      0.   1225.      0.       0.    324.      0.    618.      0.
 1/2PG          0.   1166.      0.    969.      0.    378.      0.       0.    100.      0.    191.      0.
   D1           0.   -799.      0.   -664.      0.   -259.      0.       0.     69.      0.   -130.      0.
  AHZ1          0.   -799.      0.   -664.      0.   -259.      0.       0.    -69.      0.   -130.      0.
   D2        1079.      0.   1105.    897.   1773.      0.    360.     756.      0.   1426.      0.    182.
 1/2AHZ2        0.    746.      0.    620.      0.    242.      0.       0.     64.      0.    122.      0.
 1/2AHX2     1614.      0.   1656.   1340.   2656.      0.    538.    1132.      0.   2136.      0.    270.
  AV2        1079.      0.   1105.    897.   1773.      0.    360.     756.      0.   1426.      0.    182.
   D3           0.      0.      0.      0.      0.      0.      0.       0.      0.      0.      0.      0.
 1/2AHZ3        0.    219.      0.    182.      0.     71.      0.       0.     19.      0.     36.      0.
 1/2AHX3      214.      0.    219.    178.    352.      0.     71.     150.      0.    283.      0.     36.
  AV3           0.      0.      0.      0.      0.      0.      0.       0.      0.      0.      0.      0.
   D4         768.      0.    787.    638.   1262.      0.    256.     538.      0.   1015.      0.    129.
 1/2AHZ4        0.    532.      0.    442.      0.    172.      0.       0.     46.      0.     87.      0.
 1/2AHX4     1150.      0.   1180.    955.   1892.      0.    383.     807.      0.   1522.      0.    192.
  AV4         768.      0.    787.    638.   1262.      0.    256.     538.      0.   1015.      0.    129.
   D5          73.      0.     75.     61.    121.      0.     25.      51.      0.     97.      0.     12.
 1/2AHZ5        0.      9.      0.      7.      0.      3.      0.       0.      1.      0.      1.      0.
 1/2AHX5       61.      0.     62.     50.    100.      0.     20.      42.      0.     80.      0.     10.
  AV5          73.      0.     75.     61.    121.      0.     25.      51.      0.     97.      0.     12.
          ------------------------------------------------------------------------------------------
 CASE 1      6878.   4850.   7052.   9746.  11310.   1573.   2296.    4821.    415.   9096.    794.   1154.

          DSI=  18343.
          PEM=  10332.                 FWMG=  13086.            FG =   5236.   FWGB=   9957.
```

SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

*** MAIN HINGE PIN UNIT STRESS COEFFICIENTS ***
SHEET 517

LOAD	FT1	FT2	FBSH	FBZ	FWZ	FWZ1	FWZ2	FWZ3	FWY	FWX
1/2PBLD	0.0	0.054	0.0	0.013	0.077	0.0	0.0	0.030	0.0	0.0
1/2PG	0.0	0.054	0.0	0.013	0.077	0.0	0.0	0.030	0.0	0.0
D1	0.0	0.137	0.0	0.032	0.194	0.0	0.0	0.076	0.0	0.0
AHZ1	0.0	0.137	0.0	0.032	0.194	0.0	0.0	0.076	0.0	0.0
D2	0.061	0.0	1.217	0.467	0.183	0.086	0.421	0.0	0.067	0.034
1/2AHZ2	0.0	0.054	0.0	0.013	0.077	0.0	0.0	0.030	0.0	0.0
1/2AHX2	-0.121	0.0	0.0	-0.178	-0.104	-0.172	0.0	0.0	0.0	-0.067
AV2	0.061	0.0	1.217	0.467	0.183	0.086	0.421	0.0	0.067	0.034
D3	0.0	0.0	1.217	0.378	0.131	0.0	0.421	0.0	0.067	0.0
1/2AHZ3	0.0	0.121	0.0	0.029	0.171	0.0	0.0	0.067	0.0	0.0
1/2AHX3	-0.121	0.0	0.0	-0.178	-0.104	-0.172	0.0	0.0	0.0	-0.067
AV3	0.0	0.0	1.217	0.378	0.131	0.0	0.421	0.0	0.067	0.0
D4	0.061	0.0	1.217	0.467	0.183	0.086	0.421	0.0	0.067	0.034
1/2AHZ4	0.0	0.054	0.0	0.013	0.077	0.0	0.0	0.030	0.0	0.0
1/2AHX4	-0.121	0.0	0.0	-0.178	-0.104	-0.172	0.0	0.0	0.0	-0.067
AV4	0.061	0.0	1.217	0.467	0.183	0.086	0.421	0.0	0.067	0.034
D5	0.110	0.0	1.217	0.540	0.226	0.156	0.421	0.0	0.067	0.061
1/2AHZ5	0.0	0.017	0.0	0.004	0.024	0.0	0.0	0.009	0.0	0.0
1/2AHX5	-0.121	0.0	0.0	-0.178	-0.104	-0.172	0.0	0.0	0.0	-0.067
AV5	0.110	0.0	1.217	0.540	0.226	0.156	0.421	0.0	0.067	0.061

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOAD.

                                  *** STRESS SUMMARY MAIN HINGE PIN ***
                                                 SHEET 517
          ***************************************************************************************
          *HOUSING-TENSION  *SHOULDR*HOUSNG-* WELD-  *        WELD-BRACKET TO BULKHEAD          *
          *    STRESS       * STRESS* BEND  * GUSSET*                 STRESS                   *
          *    (PSI)        * (PSI) * +TENS *TO HSNG*                 (PSI)                    *
          *                 *       * STRESS* STRESS*                                          *
          *                 *       * (PSI) * (PSI) *                                          *
          ***************************************************************************************

  LOAD         FT1      FT2      FBSH     FBZ      FWZ      FWZ1     FWZ2     FWZ3     FWY      FWX

1/2PRLD         0.     547.        0.     132.     780.       0.       0.     334.       0.       0.
1/2PG           0.     169.        0.      41.     241.       0.       0.      94.       0.       0.
D1              0.     116.        0.      27.     165.       0.       0.      65.       0.       0.
AHZ1            0.     116.        0.      27.     165.       0.       0.      65.       0.       0.
D2            163.       0.     3249.    1247.     489.     230.    1124.       0.     175.      91.
1/2AHZ2         0.     108.        0.      26.     154.       0.       0.      63.       0.       0.
1/2AHX2      -242.       0.        0.    -356.    -208.    -344.       0.       0.       0.    -134.
AV2           163.       0.     3249.    1247.     489.     230.    1124.       0.     175.      91.
D3              0.       0.      426.     132.      46.       0.     147.       0.      23.       0.
1/2AHZ3         0.      32.        0.       7.      45.       0.       0.      18.       0.       0.
1/2AHX3       -32.       0.        0.     -47.     -28.     -46.       0.       0.       0.     -18.
AV3             0.       0.      426.     132.      46.       0.     147.       0.      23.       0.
D4            116.       0.     2312.     887.     348.     163.     800.       0.     127.      65.
1/2AHZ4         0.      77.        0.      19.     110.       0.       0.      43.       0.       0.
1/2AHX4      -172.       0.        0.    -254.    -148.    -245.       0.       0.       0.     -95.
AV4           116.       0.     2312.     887.     348.     163.     800.       0.     127.      65.
D5             11.       0.      122.      54.      23.      16.      42.       0.       7.       6.
1/2AHZ5         0.       1.        0.       0.       2.       0.       0.       1.       0.       0.
1/2AHX5        -9.       0.        0.     -13.      -8.     -13.       0.       0.       0.      -5.
AV5            11.       0.      122.      54.      23.      16.      42.       0.       7.       6.
            ---------------------------------------------------------------------------------------

CASE 1        124.    1167.    12219.    4250.    3079.     170.    4277.     648.     673.      71.

          FHT=   1133.
          RE=   32642.                                   FWBD=    5090.
```

```
SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                 *** MAIN HINGE PIN UNIT STRESS COEFFICIENTS ***
                                  SHEET S18

   LOAD         FT1     FT2     FBZ1     FBZ2     FWZ1     FWZ2     FWX      FR

 1/2PRLD        0.0     0.134   0.0      0.020    0.0      0.085    0.0      0.304
  1/2PG         0.0     0.134   0.0      0.020    0.0      0.085    0.0      0.304
   D1           0.0    -0.338   0.0     -0.050    0.0     -0.215    0.0     -0.766
  AHZ1          0.0    -0.338   0.0     -0.050    0.0     -0.215    0.0     -0.766
   D2           0.149   0.0     0.062    0.0      0.264    0.0      0.095    0.329
 1/2AHZ2        0.0     0.134   0.0      0.020    0.0      0.085    0.0      0.304
 1/2AHX2        0.298   0.0     0.124    0.0      0.528    0.0      0.189    0.658
   AV2          0.149   0.0     0.062    0.0      0.264    0.0      0.095    0.329
   D3           0.0     0.0     0.0      0.0      0.0      0.0      0.0      0.0
 1/2AHZ3        0.0     0.298   0.0      0.044    0.0      0.189    0.0      0.675
 1/2AHX3        0.298   0.0     0.124    0.0      0.528    0.0      0.189    0.658
   AV3          0.0     0.0     0.0      0.0      0.0      0.0      0.0      0.0
   D4           0.149   0.0     0.062    0.0      0.264    0.0      0.095    0.329
 1/2AHZ4        0.0     0.134   0.0      0.020    0.0      0.085    0.0      0.304
 1/2AHX4        0.298   0.0     0.124    0.0      0.528    0.0      0.189    0.658
   AV4          0.149   0.0     0.062    0.0      0.264    0.0      0.095    0.329
   D5           0.270   0.0     0.113    0.0      0.480    0.0      0.172    0.598
 1/2AHZ5        0.0     0.041   0.0      0.006    0.0      0.026    0.0      0.093
 1/2AHX5        0.298   0.0     0.124    0.0      0.528    0.0      0.189    0.658
   AV5          0.270   0.0     0.113    0.0      0.480    0.0      0.172    0.598
```

13-6A

```
* PROBLEM - STANDARD LOCK DETAILS WITH STANDARD      PIN

                  *** STRESS SUMMARY MAIN HINGE PIN ***
                               SHEET 518

                    UPPER BEARING HOUSING JOINT 1
                                STRESS
                                 (PSI)

   LOAD        FT1     FT2    FBZ1    FBZ2    FWZ1    FWZ2     FWX      F9

  1/2PRLD       0.   1357.      0.    202.      0.    861.      0.   3078.
  1/2PG         0.    419.      0.     62.      0.    266.      0.    950.
    D1          0.   -287.      0.    -43.      0.   -183.      0.   -651.
   AHZ1         0.   -287.      0.    -43.      0.   -183.      0.   -651.
    D2        398.      0.    166.      0.    705.      0.    254.    876.
  1/2AHZ2       0.    268.      0.     40.      0.    170.      0.    608.
  1/2AHX2     596.      0.    248.      0.   1056.      0.    378.   1316.
   AV2        398.      0.    166.      0.    705.      0.    254.    876.
    D3          0.      0.      0.      0.      0.      0.      0.      0.
  1/2AHZ3       0.     79.      0.     12.      0.     50.      0.    179.
  1/2AHX3      79.      0.     33.      0.    140.      0.     50.    174.
   AV3          0.      0.      0.      0.      0.      0.      0.      0.
    D4        283.      0.    118.      0.    502.      0.    191.    625.
  1/2AHZ4       0.    191.      0.     28.      0.    121.      0.    433.
  1/2AHX4     425.      0.    177.      0.    752.      0.    269.    938.
   AV4        283.      0.    118.      0.    502.      0.    191.    625.
    D5         27.      0.     11.      0.     48.      0.     17.     63.
  1/2AHZ5       0.      3.      0.      0.      0.      2.      0.      7.
  1/2AHX5      22.      0.      9.      0.     40.      0.     14.     49.
   AV5         27.      0.     11.      0.     48.      0.     17.     63.
            ---------------------------------------------------------------

  CASE 1     2538.   1742.   1056.    261.   4497.   1104.   1614.   9557.

          FHTU1=   3078.  FHU1=   1317.   FWB1=   5829.
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

          *** ROLLER ASSEMBLY UNIT STRESS COEFFICIENTS ***
                              SHEET S19

  LOAD          FBA     FBR     FW      FT      FV      FV      FP      FR

1/2PRLD        0.613   0.588   0.414   1.473   0.702   0.252   0.441   1.123
 1/2PG         0.613   0.588   0.414   1.473   0.702   0.252   0.441   1.123
1/2AH22        0.613   0.588   0.414   1.473   0.702   0.252   0.441   1.123
1/2AH24        0.613   0.588   0.414   1.473   0.702   0.252   0.441   1.123
1/2AH25        0.959   0.919   0.648   2.305   1.100   0.395   0.690   1.757
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                    *** STRESS SUMMARY ROLLER ASSEMBLY ***
                                 SHEET *1?
               ****************************************************************
               *    BEARING      * WELD- * BOLTS *ROLLER * SHEAR *BEARING*MOUNTING*
               MOUNTING          *BEARING*       *  PIN  *TEAROUT*STRESS *  ARM   *
               *      ARM        *MTG ARM*       *       *MTG ARM*MTG ARM* BASE   *
               *     (PSI)       *TO BASE*       *       * YOKE  * YOKE  * PLATE  *
               ****************************************************************

  LOAD           FUA      FBB      FW       FT       FV       FV       FP       FR

 1/2PRLD         6207.    5953.    4192.   14914.    7108.    2551.    4465.   11370.

 1/2PG           1916.    1837.    1294.    4603.    2194.     787.    1378.    3509.

 1/2AHZ2         1226.    1176.     828.    2946.    1404.     504.     882.    2246.

 1/2AHZ4          874.     838.     590.    2099.    1000.     359.     628.    1600.

 1/2AHZ5           72.      69.      49.     173.      83.      30.      52.     132.
                 ---------------------------------------------------------------

 CASE 1         10294.    9874.    6952.   24735.   11788.    4232.    7405.   18858.
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                     *** LATCH UNIT STRESS COEFFICIENTS ***
                                                   SHEET S20

  LOAD          FB     FI     FS     FP     Fb     FW     FT     FS     FP     FR     FI     FW     FB     FT     Fw

1/2PRLD        1.080  0.441  0.441  0.315  1.113  0.278  0.560  0.560  0.360  0.984  0.913  0.151  1.106  0.044  0.151
 1/2PG         1.080  0.441  0.441  0.315  1.113  0.278  0.560  0.560  0.360  0.984  0.913  0.151  1.106  0.044  0.151
1/2AH72        1.090  0.441  0.441  0.315  1.113  0.278  0.560  0.560  0.360  0.984  0.913  0.151  1.106  0.044  0.151
1/2AH24        1.080  0.441  0.441  0.315  1.113  0.278  0.560  0.560  0.360  0.984  0.913  0.151  1.106  0.044  0.151
1/2AH25        1.690  0.690  0.690  0.493  1.741  0.434  0.876  0.976  0.564  1.540  1.427  0.236  1.731  0.069  0.236
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                        ooo STRESS SUMMARY LATCH ooo
                                               SHEET S20
                oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
                o          LATCH BAR ASSEMBLY                o          LATCH BRACKET ASSEMBLY          oLATCH BRACKET MOUNTING PADo
                oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
                o LATCH o          GUSSETS          o PIN  o WELD o          GUSSETS          o BASE oBOLTS o WELD oMOUNTGoGUSSETo WELD       o
                o  BAR  o                           o      oLCH BRo                           oPLATE o      oGUSSEToPLATE oPLATE oGUS PL TO   o
                o       o                           o      oTO GUSo                           o      o      oTO BSEo      o      oMTG PL      o
                oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo

  LOAD               FB      FT      FS      FP      FB      FW      FT      FS      FP      FB      FT      FW      FB      FT      FW

  1/2PRLD         10935.   4465.   4465.   3189.  11269.   2815.   5670.   5670.   3645.   9963.   9244.   1529.  11198.    445.   1529.
   1/2PG           3375.   1378.   1378.    984.   3478.    869.   1750.   1750.   1125.   3075.   2853.    472.   3456.    137.    472.
  1/24HZ2          2160.    882.    882.    630.   2226.    556.   1120.   1120.    720.   1968.   1826.    302.   2212.     88.    302.
  1/24HZ4          1539.    628.    628.    449.   1586.    396.    798.    798.    513.   1402.   1301.    215.   1576.     63.    215.
  1/24HZ5           127.     52.     52.     37.    131.     33.     66.     66.     42.    115.    107.     18.    130.      5.     18.
                 ----------------------------------------------------------------------------------------------------------------------
  STRESS             PB      PM     AVG    BRG       PB   FILLET     PM     AVG    BRG      PB     AVG   FILLET    PB      PM   FILLET
  CATEGORY                         PRIM   STRESS             WELD            PRIM   STRESS          STRESS  WELD                   WELD
                                   SHEAR                                     SHEAR

   CASE 1         18136.   7405.   7405.   5290.  18690.   4668.   9464.   9404.   6045.  16524.  15331.   2536.  18572.    739.   2536.
```

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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                              *** BULKHEAD UNIT STRESS COEFFICIENTS ***
                                             SHEET 52)
                                               (PSI)

LOAD        SHAX1   SHAX2   SHAX3    FB38     FBV      FBH      FW38     FW22    FWF33     FWF     FW13     FW24     FB9

 PI       314.000 244.000 357.000 291.000 124.670 285.340 195.000 197.000 174.000 189.000 145.000 172.000 153.940
 PE       314.000 244.000 357.000 291.000  67.789 164.176 195.000 197.000 107.000 116.000  89.000  85.000  97.640
 PEQ      314.000 244.000 357.000 291.000 124.670 285.340 195.000 197.000 174.000 189.000 145.000 172.000 153.940
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SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

                                        *** STRESS SUMMARY BULKHEAD ***
                                                     SHEET 522
                                                       (PSI)

LOAD         SMAX1   SMAX2   SMAX3    FB38     FBV     FBH    FW39    FW22   FWF33     FWF    FW13    FW14     FP9

PI          18840.  14640.  21420.  17460.   7480.  17120.  11700.  11820.  10440.  11340.   8700.  10320.   9236.

PE           1570.   1220.   1785.   1455.    339.    821.    975.    985.    535.    580.    445.    425.    488.

PEO           349.    271.    396.    323.    138.    317.    216.    219.    193.    210.    161.    191.    171.
            ---------------------------------------------------------------------------------------------------------

STRESS         PB      PB      PB      PM      PM      PM  FILLET  FILLET  FILLET  FILLET  GROOVE  FILLET      PM
CATEGORY                                                     WELD    WELD    WELD    WELD    WELD    WELD
                                                           STRESS  STRESS  STRESS  STRESS  STRESS  STRESS

CASE 1A     19189.  14911.  21816.  17783.   7619.  17437.  11716.  12039.  10633.  11550.   8861.  10511.   9407.

CASE 2A      1919.   1491.   2181.   1778.    477.   1138.   1191.   1204.    728.    790.    606.    616.    659.

            CCFBV1=   7881.          CFBV2=   1720.
            CFBHS1=  17618.          CFBHS2=   1849.
            CFBH91=  12323.          CFBH92=   3959.
            CFW11=  12650.           CFW12=  3195.
            CFW21=  12551.           CFW22=  2295.
            CFW31=  10780.           CFW32=  1692.
            CFW45=  10682.           CFW42=  2811.
```

SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

*** BULKHEAD UNIT STRESS COEFFICIENTS ***
SHEET 523

LOAD	FBL	FB9Z	FBCLZ	FB9X	FBCLX	FB9Y	FWF9	F'WF9	FWFW	FWB1	FWB2	FWB3	FWB4	FWV	F'WFW
1/2PRLD	0.074	0.029	0.040	0.0	0.0	0.0	0.034	0.0	0.038	0.029	0.0	0.0	0.0	0.076	0.0
1/2PG	0.074	0.029	0.040	0.0	0.0	0.0	0.034	0.0	0.038	0.029	0.0	0.0	0.0	0.076	0.0
D1	0.0	0.054	0.031	0.0	0.0	0.0	0.065	0.0	0.070	0.054	0.0	0.0	0.0	0.0	0.0
AHZ1	0.0	0.054	0.031	0.0	0.0	0.0	0.065	0.0	0.070	0.054	0.0	0.0	0.0	0.0	0.0
D2	0.0	0.0	0.0	0.003	-0.010	0.269	0.003	0.176	0.004	0.003	0.048	0.037	0.075	0.0	0.072
1/2AHZ2	0.074	0.029	0.040	0.0	0.0	0.0	0.034	0.0	0.038	0.029	0.0	0.0	0.0	0.076	0.0
1/2AHX2	0.0	0.0	0.0	-0.005	0.020	0.0	-0.006	0.0	-0.007	-0.005	0.0	0.0	0.0	0.0	0.0
AV2	0.0	0.0	0.0	0.003	-0.010	0.269	0.003	0.176	0.004	0.003	0.048	0.037	0.075	0.0	0.072
D3	0.0	0.0	0.0	0.0	0.0	0.269	0.0	0.176	0.0	0.0	0.048	0.037	0.075	0.0	0.072
1/2AHZ3	0.0	0.048	0.028	0.0	0.0	0.0	0.057	0.0	0.062	0.048	0.0	0.0	0.0	0.0	0.0
1/2AHX3	0.0	0.0	0.0	-0.005	0.020	0.0	-0.006	0.0	-0.007	0.005	0.0	0.0	0.0	0.0	0.0
AV3	0.0	0.0	0.0	0.0	0.0	0.269	0.0	0.176	0.0	0.0	0.048	0.037	0.075	0.0	0.072
D4	0.0	0.0	0.0	0.003	-0.010	0.269	0.003	0.176	0.004	0.003	0.048	0.037	0.075	0.0	0.072
1/2AHZ4	0.074	0.029	0.040	0.0	0.0	0.0	0.034	0.0	0.038	0.029	0.0	0.0	0.0	0.076	0.0
1/2AHX4	0.0	0.0	0.0	-0.005	0.020	0.0	-0.006	0.0	-0.007	-0.005	0.0	0.0	0.0	0.0	0.0
AV4	0.0	0.0	0.0	0.003	-0.010	0.269	0.003	0.176	0.004	0.003	0.048	0.037	0.075	0.0	0.072
D5	0.0	0.0	0.0	0.005	-0.018	0.269	0.005	0.176	0.006	0.005	0.048	0.037	0.075	0.0	0.072
1/2AHZ5	0.116	0.019	0.047	0.0	0.0	0.0	0.072	0.0	0.074	0.019	0.0	0.0	0.0	0.119	0.0
1/2AHX5	0.0	0.0	0.0	-0.005	0.020	0.0	-0.006	0.0	-0.007	-0.005	0.0	0.0	0.0	0.0	0.0
AV5	0.0	0.0	0.0	0.005	-0.018	0.269	0.005	0.176	0.006	0.005	0.048	0.037	0.075	0.0	0.072

SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

*** STRESS SUMMARY BULKHEAD ***
SHEET S23

LOAD	FBL	FB9Z	FBCLZ	FB9X	FBCLX	FB9Y	FWE9	F'WE9	FWFW	FWB1	FWB2	FWB3	FWB4	FWV	F'WFW
1/2PRLD	749.	294.	405.	0.	0.	0.	344.	0.	385.	294.	0.	0.	0.	769.	0.
1/2PG	231.	91.	125.	0.	0.	0.	106.	0.	119.	91.	0.	0.	0.	237.	0.
D1	0.	46.	26.	0.	0.	0.	55.	0.	59.	46.	0.	0.	0.	0.	0.
AHZ1	0.	46.	26.	0.	0.	0.	55.	0.	59.	46.	0.	0.	0.	0.	0.
D2	0.	0.	0.	8.	-27.	718.	8.	470.	11.	8.	128.	99.	200.	0.	192.
1/2AHZ2	148.	58.	80.	0.	0.	0.	68.	0.	76.	58.	0.	0.	0.	152.	0.
1/2AHX2	0.	0.	0.	-10.	40.	0.	-12.	0.	-14.	-10.	0.	0.	0.	0.	0.
AV2	0.	0.	0.	8.	-27.	718.	8.	470.	11.	8.	128.	99.	200.	0.	192.
D3	0.	0.	0.	0.	0.	94.	0.	62.	0.	0.	17.	13.	26.	0.	25.
1/2AHZ3	0.	13.	7.	0.	0.	0.	15.	0.	16.	13.	0.	0.	0.	0.	0.
1/2AHX3	0.	0.	0.	-1.	5.	0.	-2.	0.	-2.	-1.	0.	0.	0.	0.	0.
AV3	0.	0.	0.	0.	0.	94.	0.	62.	0.	0.	17.	13.	26.	0.	25.
D4	0.	0.	0.	6.	-19.	511.	6.	334.	8.	6.	91.	70.	142.	0.	137.
1/2AHZ4	105.	41.	57.	0.	0.	0.	48.	0.	54.	41.	0.	0.	0.	108.	0.
1/2AHX4	0.	0.	0.	-7.	28.	0.	-9.	0.	-10.	-7.	0.	0.	0.	0.	0.
AV4	0.	0.	0.	6.	-19.	511.	6.	334.	8.	6.	91.	70.	142.	0.	137.
D5	0.	0.	0.	3.	-2.	27.	0.	18.	1.	0.	5.	4.	7.	0.	7.
1/2AHZ5	9.	1.	4.	0.	0.	0.	2.	0.	2.	1.	0.	0.	0.	9.	0.
1/2AHX5	0.	0.	0.	-0.	1.	0.	-0.	0.	-1.	-0.	0.	0.	0.	0.	0.
AV5	0.	0.	0.	3.	-2.	27.	0.	18.	1.	0.	5.	4.	7.	0.	7.
STRESS CATEGORY	PM	PM	PM	PM	PM	PM	FILLET WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	GROOVE WELD STRESS	FILLET WELD STRESS	FILLET WELD STRESS
CASE 1A	262.	205.	201.	10.	-20.	2701.	290.	1767.	279.	215.	482.	371.	753.	269.	723.
CASE 2A	1243.	590.	731.	10.	-20.	2701.	700.	1767.	782.	599.	482.	371.	753.	1276.	723.

```
   SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

     *** DOOR UNIT STRESS COEFFICIENTS ***

UNIT LOAD     SMAX     FB      FW      SW

  PI          60.39  292.43  209.52  146.82

  PIC         60.39  292.43  209.52  146.82
```

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     SAMPLE PROBLEM - STANDARD LOCK DETAILS WITH STANDARD LOADING

               *** STRESS SUMMARY DOOR ***
                         (PSI)

 UNIT LOAD    SMAX     FB      FW      SW

   PI        3623.  17546.  12571.   8809.

   PEC         67.    325.    233.    163.

  STRESS      PB       PM    FILLET  GROOVE
 CATEGORY                     WELD    WELD
                             STRESS  STRESS

 CASE 1A     3690.  17870.  12804.   8972.
```

Attachment (4)
CR-783:VF:82-598

CONTAINMENT VESSEL
SUMMARY OF PRESENTATION

- RESOLVE ALL QUESTIONS - RE: 1974 VS. 1980 ASME CODE (220.25).
- RESOLVE ALL QUESTIONS - RE: ULTIMATE CAPACITY (220.30).
- RESOLVE ALL NRC AUDIT (MAY 1982) QUESTIONS.
- RESOLVE ALL OUTSTANDING PSAR QUESTIONS.
- CONCLUDE THAT ALL SAFETY EVALUATION REPORT ISSUES HAVE BEEN SATISFACTORILY RESOLVED.

CONTAINMENT VESSEL OUTSTANDING ISSUES

RESOLVE COMMENTS ON PREVIOUS RESPONSES:

- 220.25 - WHY WAS 1974 ASME CODE USED (ALSO AUDIT CONCERN II.2).
  - WHY WAS $P_E = 0$ USED IN N-284 ANALYSIS.
  - DEMONSTRATE THAT THE SHELL DOES NOT BUCKLE IN THE VICINITY OF THE EQUIPMENT HATCH.
  - PROVIDE NUMERICAL COMPARISONS FOR TYPICAL PIPING PENETRATIONS.
- 220.30 - EXPAND THE ULTIMATE CAPACITY PREDICTION (ALSO AUDIT FINDING I.B.I).

NRC AUDIT FINDINGS (MAY 1982)

- RE-EVALUATE THE SKEWED AIRLOCK EFFECTS.
- RE-EVALUATE THE LIVE-LOAD EFFECTS ON THE AIRLOCK FREQUENCY RESPONSE.
- CONFIRM THE FUNDAMENTAL DOME BREATHING MODE.
- VERIFY ALL SIGNIFICANT COMPUTER CODES.

MISCELLANEOUS

- CRITERIONS ARE NOT CURRENT IN PSAR 3.8.2.2.4

$P_E = 0$

QUESTION: (220.25) WHAT IS THE JUSTIFICATION FOR ASSUMING THAT THE EXTERNAL CONTAINMENT PRESSURE (P_E) IS 0 FOR THE ASSESSMENT OF CONTAINMENT BUCKLING ACCORDING TO CODE CASE N-284?

RESPONSE:

- CONTAINMENT BUCKLING WAS EVALUATED FOR BOTH EXTERNAL PRESSURE AND EARTHQUAKE.
- THESE LOADS RESULT FROM TOTALLY INDEPENDENT ACCIDENT SCENARIOS AND THEREFORE ARE NOT COMBINED.
- EXTERNAL PRESSURE IS AN AFTER EFFECT OF A NA FIRE (C.V. ATMOSPHERE COOLDOWN).
  - MAXIMUM P_E = .13 PSIG (BASED ON REFINED ANALYSIS).
  - PROBABILITY IS EXTREMELY REMOTE.
  - PERIOD IS VERY BRIEF.
  - OCCURS VERY LATE INTO THE SCENARIO.
  - C.V. WAS CONSERVATIVELY DESIGNED FOR .5 PSIG USING ASME RULES (N-284 DID NOT CHANGE).
- EARTHQUAKE LOADS GOVERN THE DESIGN BY A SIGNIFICANT MARGIN.
  - NO KNOWN SCENARIO CONNECTED TO EXTERNAL PRESSURE
  - EFFECT OF COMBINING EXTERNAL PRESSURE WOULD BE INSIGNIFICANT.
- THEREFORE, P_E = 0 WAS APPROPRIATE FOR THE N-284 ANALYSIS.

EQUIPMENT HATCH BUCKLING

QUESTION: (220.25) PROVIDE FURTHER INFORMATION ON THE EFFECT OF THE EQUIPMENT ACCESS HATCH ON THE MARGIN AGAINST BUCKLING. THE N-284 BUCKLING EVALUATION PROVIDED BY THE APPLICANT AS PART OF THE RESPONSE TO QUESTION 220.25 DOES NOT ADEQUATELY ADDRESS THE EFFECT OF THE EQUIPMENT ACCESS HATCH. DESCRIBE METHODOLOGY USED IN DESIGN INCLUDING CONSIDERATION OF BUCKLING.

RESPONSE:

- OPENING HAS BEEN REINFORCED BY ASME AREA REPLACEMENT VALUES.
- ADDITIONAL STIFFENING SYSTEM PROVIDED TO MAINTAIN CONTINUITY OF RING STIFFNESS.
  - ANALYZED AS A STRUCTURAL FRAME UTILIZING STANDARD DESIGN PRACTICES FOR BEAMS AND COLUMNS.
  - STIFFNESS EQUAL TO OR GREATER THAN UNPENETRATED SHELL.
  - ALL LOADS CARRIED BY STIFFENING SYSTEM.
- STIFFENING SYSTEM CARRIES ALL LOADS IN THE REGION AND, THEREFORE, THE SHELL CANNOT BUCKLE.
- ANALYSIS SUPPORTED BY EXPERIMENTAL STUDY - REFERENCE: "EXPERIMENTAL STUDY OF THE BUCKLING OF CYLINDRICAL SHELLS WITH REINFORCED OPENINGS", C. D. MILLER - JULY 25-28, 1982.
- LARGE EQUIPMENT HATCH OPENING DOES NOT AFFECT THE MARGIN AGAINST BUCKLING.

PENETRATIONS

QUESTION: (220.25) NOZZLE PIPING TRANSITION. THE COMPARISON INCLUDED IN THE RESPONSE TO QUESTION 220.25 RELIES ON ENGINEERING JUDGEMENT. PROVIDE NUMERICAL COMPARISONS FOR TYPICAL PIPING PENETRATIONS.

RESPONSE:

- ALL DESIGN LOADS ARE STATED CONSERVATIVELY.
- FOUR OF THE HIGHEST STRESSED PENETRATIONS WERE SELECTED FOR ANALYSIS.
- MEMBRANE AND SURFACE STRESS WERE EVALUATED AT CRITICAL LOCATIONS.
- ALL STRESSES SATISFY THE 1980 CODE REQUIREMENTS.
- IT IS CONCLUDED THAT THE CURRENT PENETRATION DESIGN PROVIDES A LEVEL OF SAFETY EQUIVALENT TO THAT WHICH WOULD RESULT FROM FULL IMPLEMENTATION OF THE 1980 ASME CODE.

ULTIMATE CAPACITY

QUESTION: (220.30) THE ULTIMATE CAPACITY PREDICTION FOR THE CONTAINMENT SHOULD BE EXPANDED TO INCLUDE THE EFFECT OF ALL DISCONTINUITIES AND THE CAPABILITIES OF ALL PENETRATION COMPONENTS INCLUDING SEALS, DOORS, ETC. APPROPRIATE THERMAL EFFECTS SHOULD BE INCLUDED.

RESPONSE: BUCKLING OF THE EQUIPMENT HATCH IS CALCULATED TO OCCUR AT 43 PSIG AND 70°F. PENETRATIONS, DOORS, DISCONTINUITIES, SEALS, ETC. ARE NOT CONTROLLING.

BUCKLING OF THE EQUIPMENT HATCH IS ALSO CALCULATED TO OCCUR AT 40 PSIG AND 450°F. PENETRATIONS, DOORS, DISCONTINUITIES, SEALS, ETC. ARE NOT CONTROLLING.

SKEWED AIRLOCK

QUESTION: (1.C.1.A) IN EVALUATING THE EQUIPMENT AND PERSONNEL AIRLOCK FOR SEISMIC LOADS, AN ASSUMPTION WAS MADE THAT IT PENETRATES CONTAINMENT IN A RADIAL DIRECTION. TO DEVELOP THE DYNAMIC MODEL FOR THE AIRLOCK, ONLY TWO DEGREES OF FREEDOM WHERE ALLOWED; RADIAL AND ROTATION ABOUT A HORIZONTAL AXIS. IN ADDITION, WITH THE MAXIMUM LIVE LOAD IN THE EXTREME END OF THE AIRLOCK, ITS FUNDAMENTAL FREQUENCY IS BELOW THE PEAK OF THE DESIGN RESPONSE SPECTRUM FOR THIS LOCATION. TO ADEQUATELY EVALUATE THE AIRLOCK, THE FOLLOWING NEED TO BE DONE.

A. A THREE-DEGREE-OF-FREEDOM MODEL NEEDS TO BE DEVELOPED THAT INCLUDES THE SKEWED PENETRATION ANGLE EFFECTS. THE ADDITIONAL DEGREE OF FREEDOM SHOULD BE ROTATION ABOUT THE VERTICAL AXIS.

RESPONSE:

- A DYNAMIC MODEL E-1724A WAS DEVELOPED TO PROVIDE FREQUENCIES, FORCES AND MOMENTS WITH A SKEWED PENETRATION.
- THE RESULTANT ACCELERATIONS INCREASED LESS THAN 3.2%.
- NON-CONTROLLING STRESSES INCREASED UP TO 11%.
- CONTROLLING STRESSES WERE REDUCED BY 4%.
- THE ASSUMPTIONS IN THE DESIGN REPORT REGARDING THE SKEWED AIRLOCK ARE CONSIDERED VALID.

LIVE LOAD IN AIRLOCK

QUESTION: (1.C.1.B) B. AMOUNTS OF LIVE LOAD THAT ALLOW THE FUNDAMENTAL FREQUENCY TO FALL ON THE PEAK OF THE DESIGN RESPONSE SPECTRUM SHOULD BE CONSIDERED.

RESPONSE:

- MULTIPLE SCOPING CALCULATIONS WERE PERFORMED.
  - LOAD VALUE AND LOCATION WAS VARIED.
  - MAXIMUM FREQUENCY RESULTED FROM CENTERED LOAD.
  - MAXIMUM FREQUENCY SHIFT WAS 13%.
- DESIGN CALCULATION CONSIDERED ± 10% FREQUENCY SHIFT.
- SINCE THE SPECTRAL ACCELERATIONS ARE MAXIMUM AT THE MINIMUM MOMENT ARM, THE EFFECT OF THE 3% FREQUENCY SHIFT IS NEGLIGIBLE.
- THE FREQUENCY IS ALWAYS ON THE LEFT SIDE OF THE PEAK FOR THE VERTICAL AND CIRCUMFERENTIAL RESPONSE.
- THEREFORE, THE DESIGN CALCULATIONS ARE ACCEPTABLE.

DOME BREATHING MODE

QUESTION: (1.C.2) THE SEISMIC LUMPED MASS MODEL INCLUDES STIFFNESS COUPLING TERMS TO SIMULATE THE FUNDAMENTAL DOME BREATHING MODE. THE FREQUENCY AND MODE SHAPE OF THIS MODE NEEDS TO BE CONFIRMED WITH A MORE REFINED MODEL.

RESPONSE:

- CRBRP USED COMPUTER PROGRAM NO. 1017 TO ANALYZE SHELL.
- DYNAMIC SHELL OF REVOLUTION COMPUTER PROGRAM NO. 1374 WAS USED TO CONFIRM RESULTS.
- MODE SHAPES ARE IN CLOSE AGREEMENT.
- FREQUENCIES ARE WITHIN 10%.
- THEREFORE, THE DESIGN CALCULATIONS ARE CONFIRMED.

VERIFY COMPUTER CODES

QUESTION: (1.D.3) ALL SIGNIFICANT COMPUTER CODES USED FOR STRUCTURAL DESIGN NEED TO BE ADDRESSED IN THE PSAR ALONG WITH VERIFICATION DOCUMENTATION.

RESPONSE:

- ALL COMPUTER CODES USED IN THE CONTAINMENT VESSEL DESIGN HAVE BEEN VERIFIED (NO'S 655, 772, 781, 907, 1017, 1027, 1036, 1374, 1392, 1671, 1691, 1823).
- THESE VERIFICATIONS WILL BE ADDED TO APPENDIX A OF THE PSAR.

PSAR 3.8.2.2.4

QUESTION: CRITERIONS ARE NOT NUMBERED CORRECTLY AND #14 IS MISSING.

RESPONSE: CRITERION 14 HAS BEEN ADDED.

CRITERION 4, 50-58 AND 64 HAVE BEEN RENUMBERED.

Enclosure (5)
CR-783:VF:82-598

MEETING NOTICE

SUBJECT: CONTAINMENT VESSEL/CODE CASE(S) ANALYSIS

LOCATION: WLLCO, Landow Building, Room 1111
7910 Woodmond Avenue
Bethesda, MD

TIME: 8:30 AM

DATE: December 8, 1982

PURPOSE: To resolve the outstanding containment vessel/code case(s) issues.

SCOPE: This meeting will address:

a) The 1974 versus 1980 ASME Code Comparison (NRC Question 220.25).
b) The Ultimate Capacity (NRC Question 220.30).
c) The NRC Audit Questions.
d) The Identification of Closed Issues.

Containment Vessel/Code Case(s) Analysis Working Meeting Agenda

I.	Introduction	DOE/PO
II.	Responses to NRC Questions on the 1974 versus 1980 ASME Code Comparison	W-LRM
III.	Responses to NRC Questions on the Ultimate Capacity Analysis	W-LRM
IV.	The NRC Audit Questions	W-LRM
V.	Discussion and Resolution	DOE/PO W-LRM
VI.	Identification of Closed Issues	DOE/PO W-LRM

Attachment (6)
CR-783:VF:82-598

ATTENDANCE

Name	Organization	Phone
Tom Butler	Los Alamos	(505) 667-5171
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