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Experimental test results of a shell arch. Roof model under different types of loading, December 1950

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PROGRESS REPORT 213G

APPENDIX TO PROGRESS REPORTS 213C to 213F

EXPERIMENTAL TEST RESULTS OF A SHELL ARCH ROOF MODEL UNDER DIFFERENT TYPES OF LOADING

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Figures 1 to 9

Test Results of the Tests T-1 to T-9, each Test having:

1. Sketch of the Applied Loads (Figs. 10 to 13)
2. Table of all Strain Gage Readings
3. Table of the Deflection and Rotation Readings

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SYNOPSIS

This report presents a complete record of all measured values obtained from 9 different tests on a shell arch roof model (Fig. 1). Strains were indicated by SR-4 electrical strain gages and the deflections were measured by means of Ames dials with an accuracy of 0.001 in. No interpretation of the results is made herein, this having been done in 4 previously published Progress Reports 213C to 213F.

1. Reported Test Cases:

Nine different experimental load cases are reported, arranged in the following order:

(1) Appendix to Progress Report 213C*

Test Results for 3 cases of Lateral Loads on a Model of an Arch Roof.

T-1: "Uniformly" Distributed Load

T-2: Two Concentrated Loads at the Center

T-3: One Concentrated Load Near the Quarter Point of the Span

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* In Progress Report 213C, p. 20 reference to these 3 cases is made.

(2) Appendix to Progress Report 213D*

Test Results for Simulated Dead Load and Uniformly Distributed Live Load over the Half-span on a Model of an Arch Roof.

T-4: "Dead Load"

T-5: "Uniformly" Distributed Live Load.

(3) Appendix to Progress Report 213E**

Test Results for a Model of an Arch Roof Under Horizontal Foundation Movement and End Rotation of the Abutments.

T-6: Horizontal Foundation Displacement

T-7: End Rotation of the Abutments

(4) Appendix to Progress Report 213F***

Tests Results for a Model of an Arch Roof under two cases of a Concentrated Load.

T-8: Concentrated Load on the Middle Rib at the Center of the Span

T-9: Concentrated Load on an Exterior Rib at the Center of the Span

In the following the tests will be referred to by their respective number, e.g. T-1.

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* See Progress Report 213D, p. 33, where reference to these tests is made.

** See Progress Report 213E, p. 20

*** See Progress Report 213F, p.

2. Description of the Model

Geometrically the test structure is a model in the approximate scale 1:30 of an actual shell-roof (e.g. hangar at Rapid City, South Dakota).

The material of an actual shell structure is reinforced concrete. However the model is built of structural steel. Different considerations, especially the scale of the model, prohibited the use of concrete or plaster. The dimensions of the model are shown in Fig. 1.

A rigid supporting frame consisting primarily of 3 interconnected 10WF29 beams forms the "foundation" for the model (see Fig. 2). This entire unit is simply supported on a sub-structure.

3. Description of the Loading Devices

For the different cases a number of loading devices were designed.

(1) Lateral Loads:

Fig. 3 shows the set-up for lateral loads. Wire cables pulled horizontally on the shell. Their direction was changed to a vertical one by pulleys having roller bearings to keep friction at a minimum. The cables were attached to lever arms at the end of which the loads (water buckets) were applied, (advantage of the lever system 1 to 7.5). By using water to produce the loads all problems such as handling weights, speed of loading, etc. were solved in a satisfactory way.

The loads corresponding to the tests T-1, T-2, and T-3, are given in Fig. 10. They are computed from the weight of the loads, applied to the end of the levers times the advantage of the system.

(2) Distributed Vertical Loads:

An arrangement developed by the Martin Aircraft Corp., Baltimore, Md. for applying distributed loads to airplane wings was used. Rubber tension pads,* 5x5 in., were vulcanized to the bottom of the shell (Fig. 4). The function of the pad is to distribute a concentrated tension force applied through a bolt and a spherical washer to the center of the steel plate of the pad over its entire area. Pilot tests with pads gave excellent results, being adequately strong and at the same time freely permitting the plate to bend.

A total of 80 pads were fixed to the shell. By a system of levers 8 pads were combined in one loading unit to which a lever arm of advantage 1 to 10 transmitted the weight of a water bucket hanging at its end (see Figs. 4 and 2).

"Dead Load" was artifically produced by loading all tension pads, "Live Load" over half the span, by loading one half. The load can be considered uniformly distributed over the area covered by the 80 pads which is a part of the total area only. Fig. 11 gives the actual loadings for the

---

* Manufactured by F. C. Schenuit Rubber Company, Baltimore, Md.

two tests, the load on one pad being determined by the weight of the applied water bucket and the advantage of the lever system.

(3) Foundation Movements:

The mechanism to produce a horizontal foundation displacement is shown in Fig. 5. The 3 10WF29 of the supporting frame were cut in the middle and the right side was fixed to the sub-structure. The left side of the frame was guided by T-pieces horizontally and free to undergo corresponding movements induced by two turnbuckles (the screws on the left side of the T-pieces are loose). Two Ames dials on each side recorded the horizontal displacement to 0.001 in. accuracy. This mechanism eliminated almost completely any rotation of the abutments, as was checked by level bars.

Fig. 6 illustrates the test set-up used to produce end rotations. The supporting frame rotated around an axis in the middle at the height of the spring line of the shell. By moving the frame in the center vertically by means of a turnbuckle, end rotations were induced, the span of the shell being kept practically constant. Level bars measured the end rotations and Ames Dials checked the change in the span.

(4) Concentrated Vertical Loads:

A special loading frame (Fig. 7) with a jack at the bottom transmitted a load into the top by way of a loading ring which measured the magnitude. The sensitivity of the system

is ± 50 lbs. which is reasonably small compared with the magnitude of the applied loads.

Fig. 13 shows the manner by which the concentrated load was introduced to the rib and gives its magnitude.

4. Arrangement of the Recording Devices:

(1) Strain Gages:

To the arch roof model (Fig. 1) a total of 44 rosette (AR-1), 137 cross (AX-5) and 81 single gages (A-5) were applied. The lay-out of the gages is shown in Fig. 8. Any gage is located by a coordinate system which is again used in the tables for the presentation of the strain gage readings.

(2) Dial Gages:

Vertical and horizontal deflections were measured by Ames Dials (accuracy 0.001 in.). Fig. 9 shows their disposition. The dials (1) to (13) indicated vertical deflections, positive if downward; dial ◇14◇ recorded the change in the span, positive for an increase in span.* The dials [15] to [19] measured the lateral deflections, taken positive as shown in Fig. 9 (positive in direction of the applied lateral forces shown in Fig. 11).

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* Note that for the analysis in the Progress Reports 213C to 213E the opposite sign convention for a change in the span was adopted.

(3) Level Bars:

The rotation of the abutments was measured by two level bars L-1 and L-2 (Fig. 9) with an accuracy of 0.0002 radians. Inward rotation is said to be positive, producing compression in the top and tension in the bottom fiber of the rib (positive moment).

5. Reported Results:

All results are average values of two sets of readings. The tests were performed by taking readings at the arbitrary "initial load,"* then the model was loaded up to the specified load and a complete set of readings was made. By repeating the complete procedure accidental errors were discovered. A close correspondence between the two sets was obtained.

For any load local non-linearity of stress-strain relations induced by rolling and welding stresses was eliminated prior to any particular test by subjecting the model several times to loads about 10% higher than the succeeding test load. As a result, for each test load, elastic behavior was obtained in all parts of the model.

6. Presentation of the Results:

The presentation of the results for each test, T-1 to T-9, is arranged in the following order:

---

* Initial load included the dead weight of the loading system and an additional initial load to "set" the whole system.

1. Sketch of the applied loads. (Figs. 10 to 13)

2. Table of all strain gage readings.

3. Table of the deflection and rotation readings.

Referring to the table of the strains, to illustrate, consider the strains at the point 03 for the test T-1:

Fig. 8: (Lay-out of the strain gages)

Location of the point 03:

6.00 in. from the outer rib S

31.30 in. from the $\mathbb{C}$ of the span to the right.

Table T-1: Point 03

In axial direction (x - direction)

Upper side of the shell: $\varepsilon_{xu} = 37.2 \cdot 10^{-6}$

Lower side of the shell: $\varepsilon_{xL} = 42.5 \cdot 10^{-6}$

In circumferential direction (ω- direction)

Upper side of the shell: $\varepsilon_{\omega u} = -38.2 \cdot 10^{-6}$

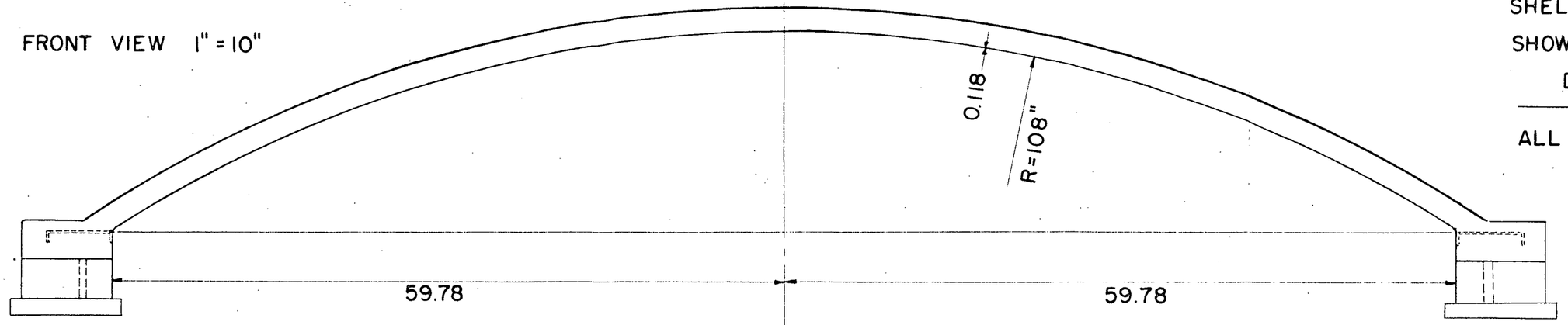
Lower side of the shell: $\varepsilon_{\omega L} = -76.3 \cdot 10^{-6}$

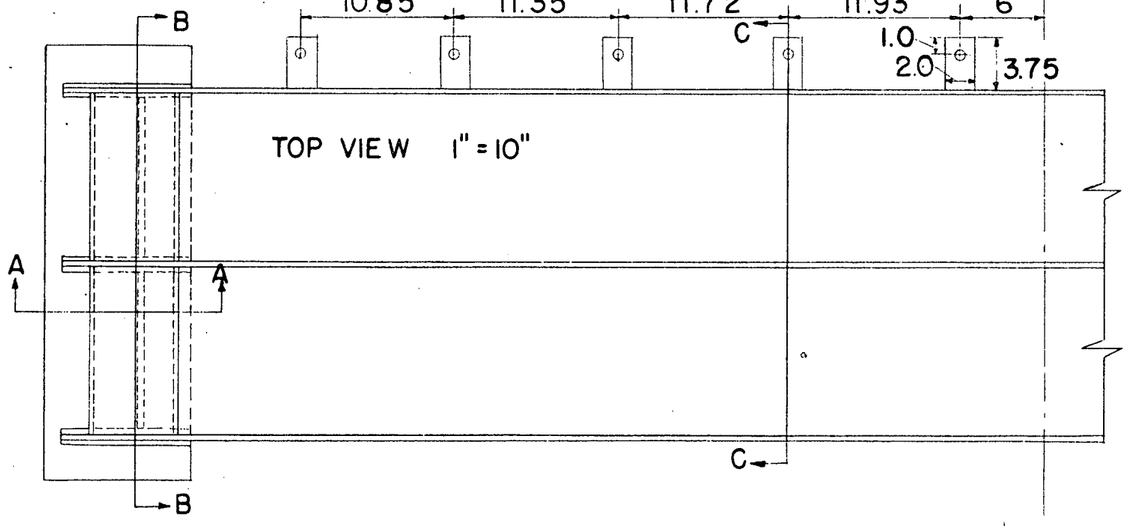
The interpretation of the table of the deflection and rotation readings by means of Fig. 9 (lay-out of the dial gages) is self-explanatory.

SHELL ROOF MODEL SHOWING MEASURED DIMENSIONS.

ALL DIMENSIONS IN INCHES

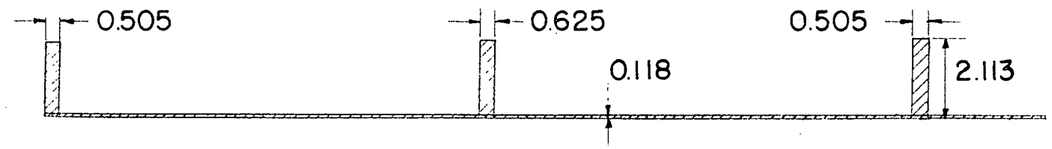
FRONT VIEW 1" = 10"

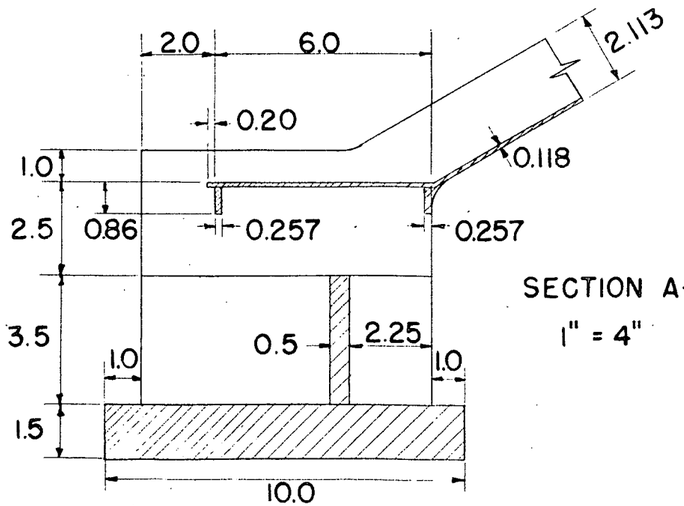




TOP VIEW 1" = 10"

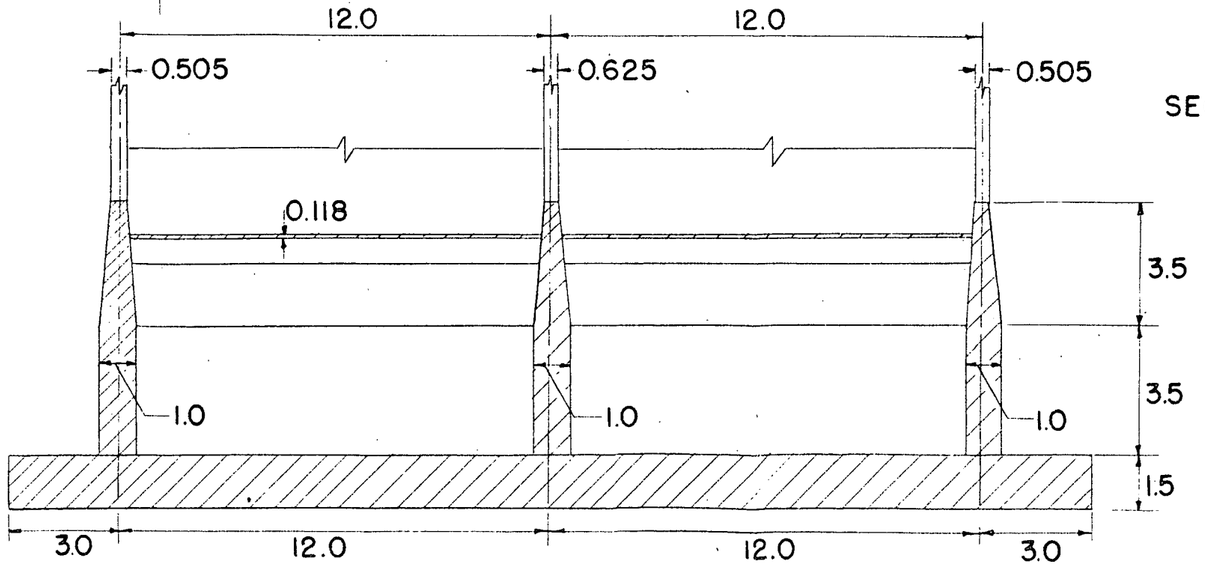
SECTION C-C 1" = 4"





SECTION A-A

1" = 4"



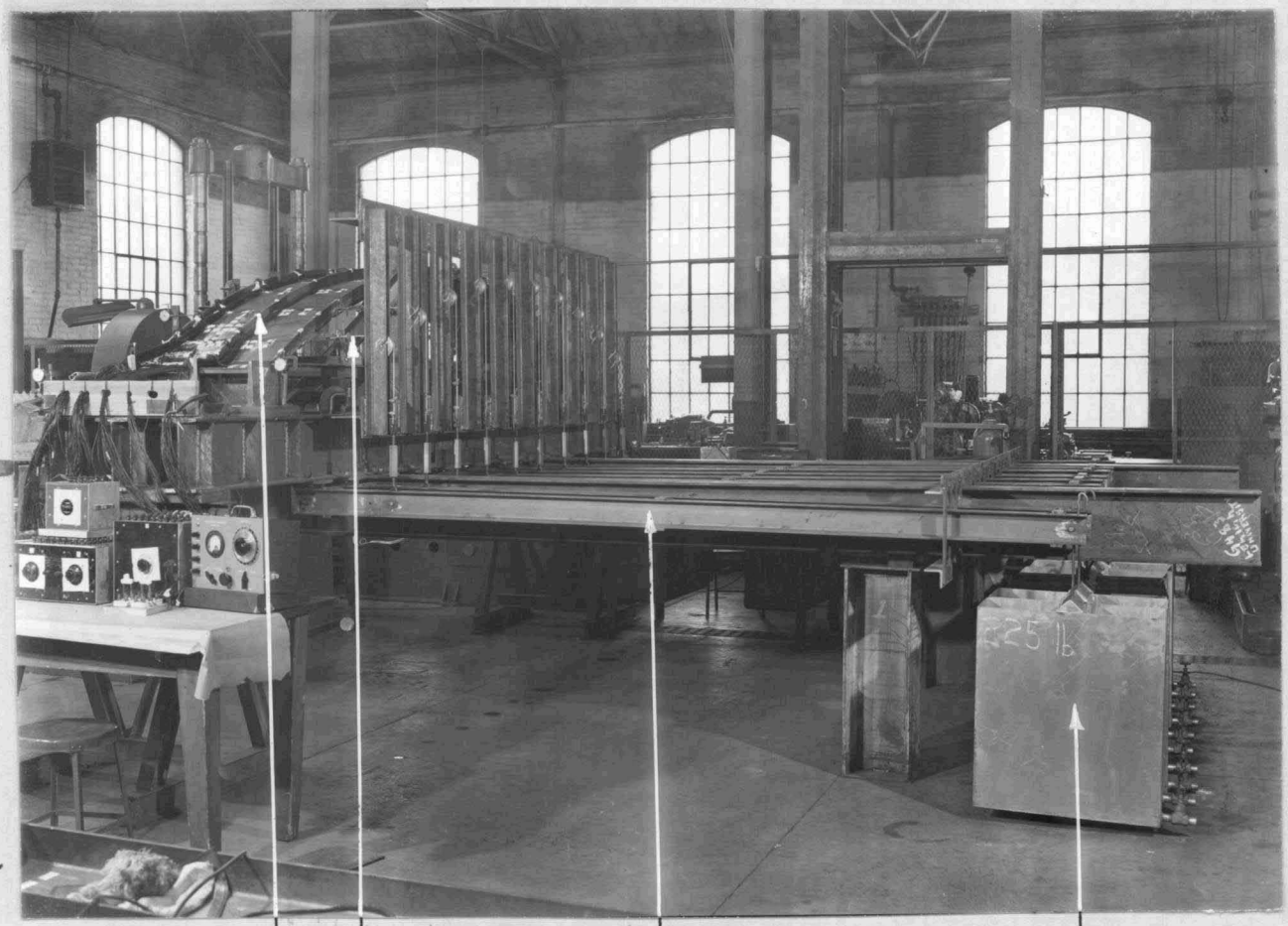
SECTION B-B

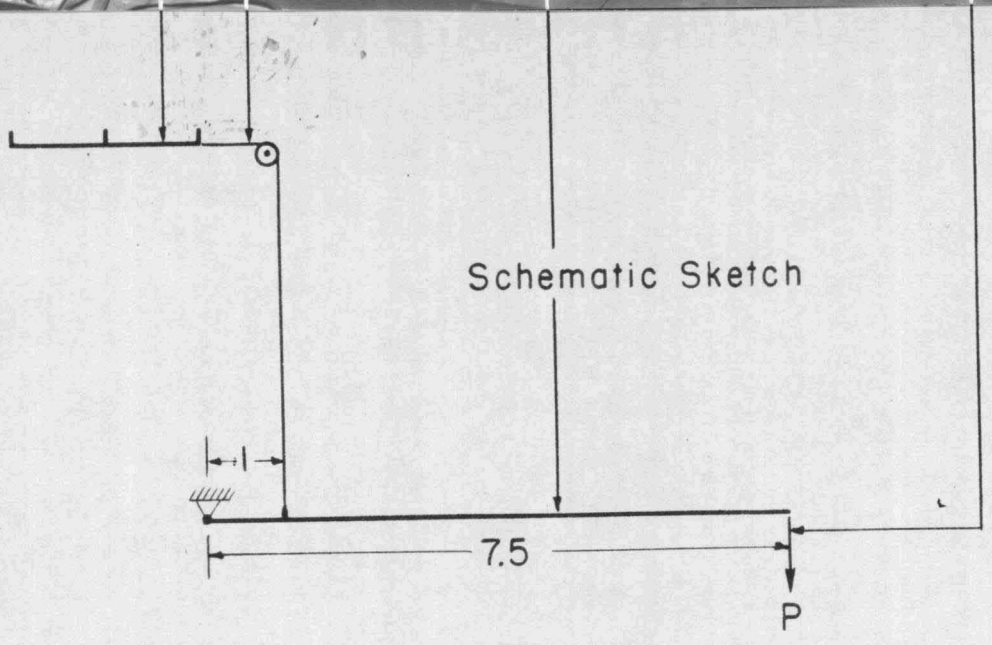
1" = 4"

FIG. 1

(Test Set-up for Vertical Loads)

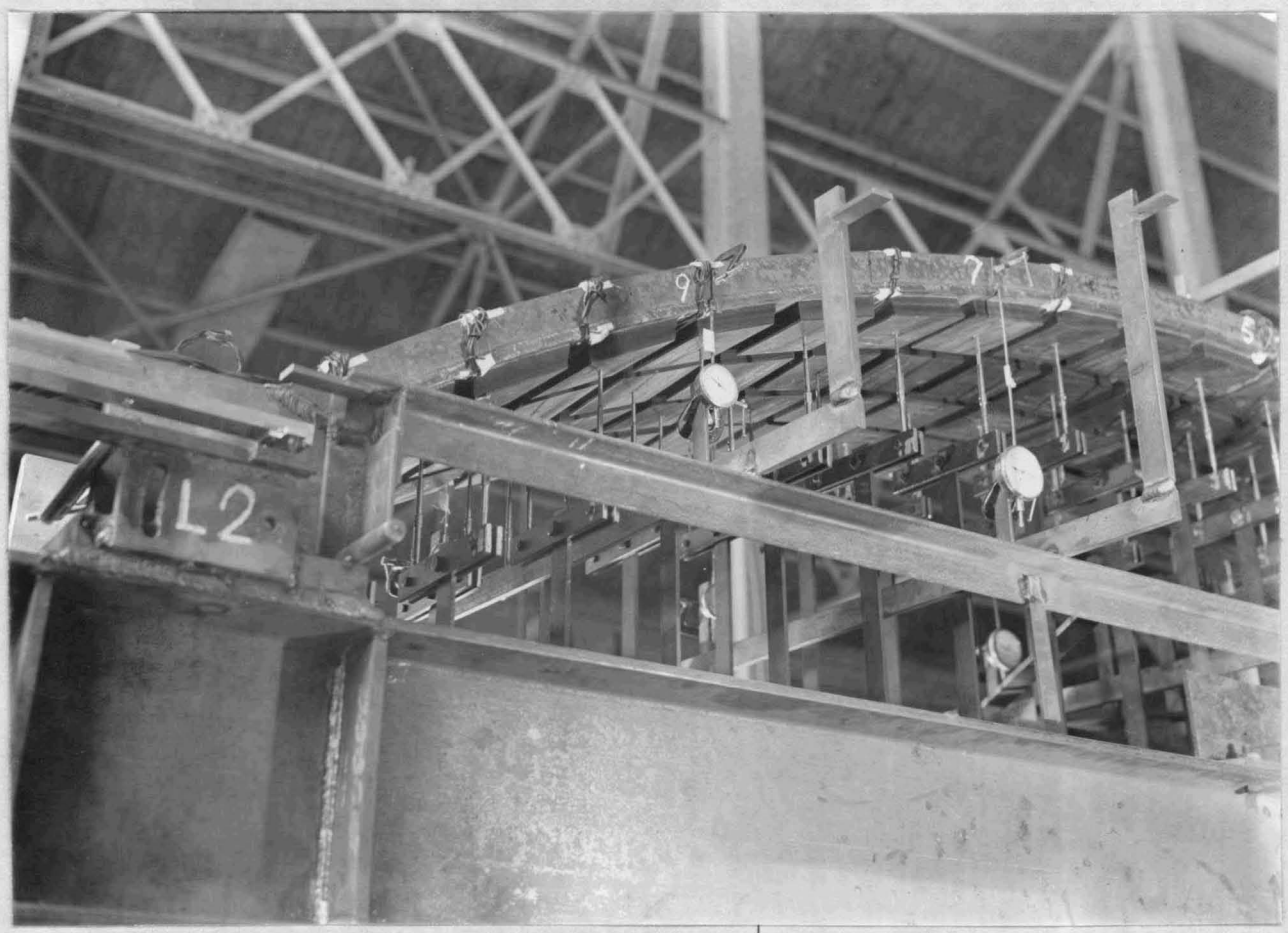
Fig 2

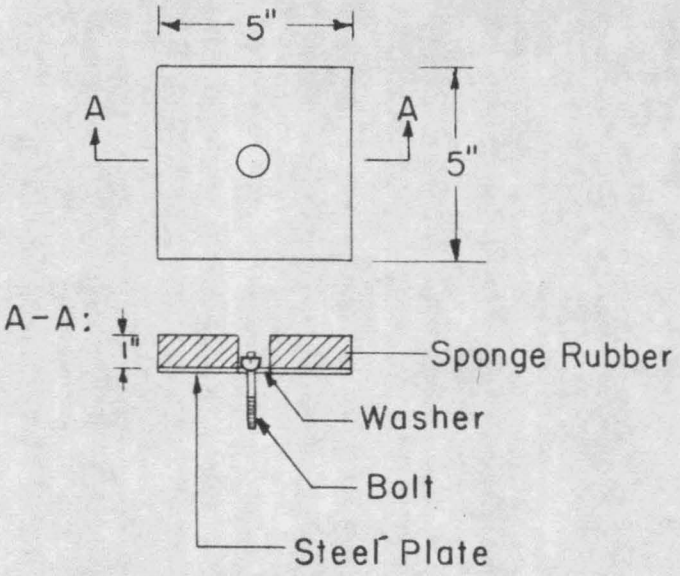




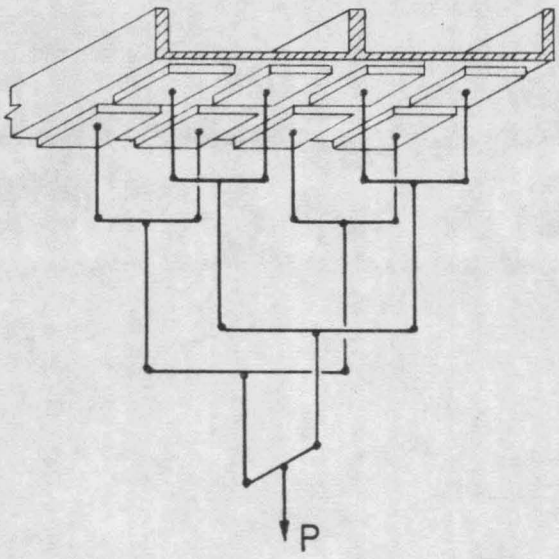
Lateral Loads

FIG 3





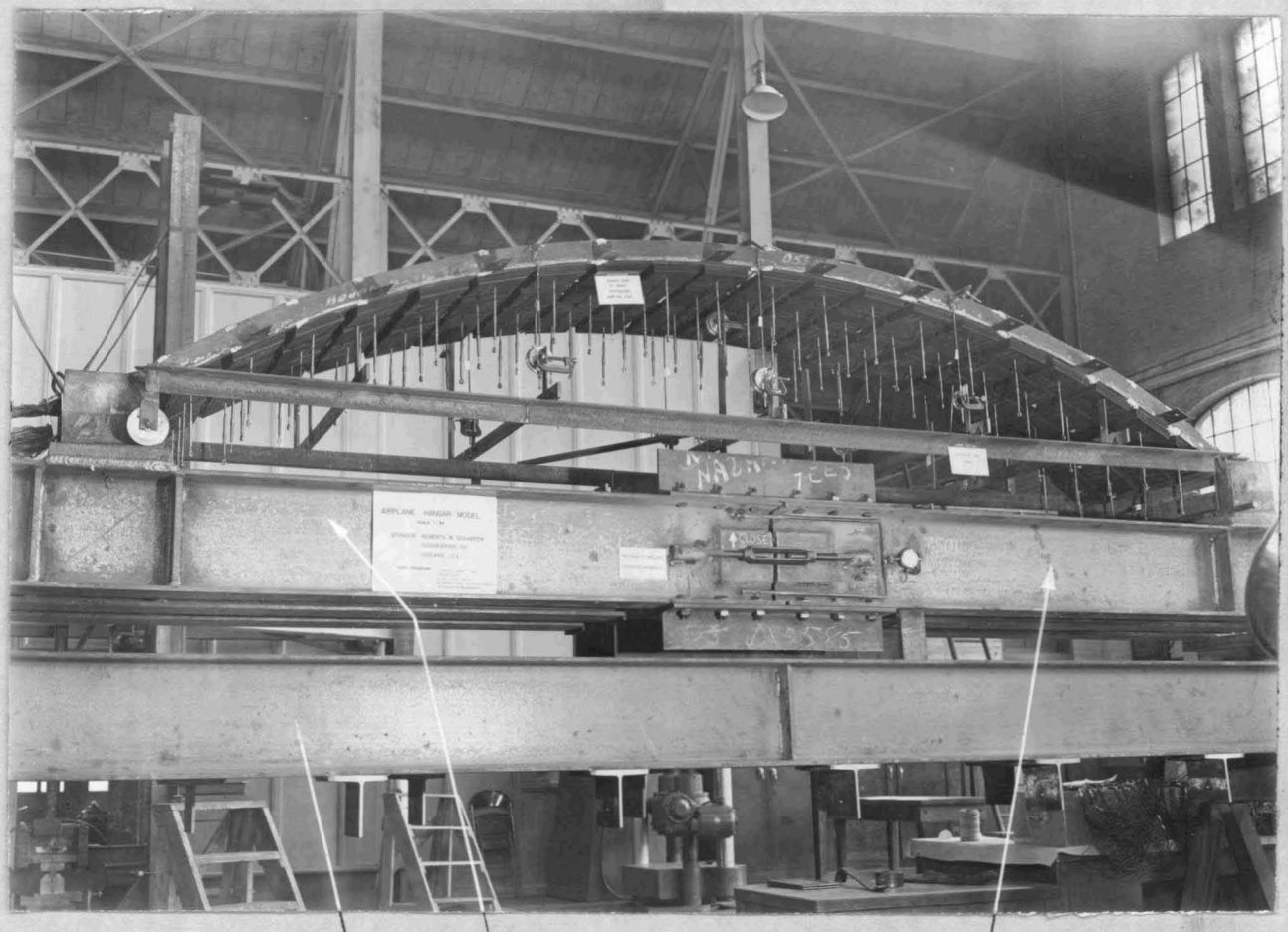
Tension Pad



Loading Unit (8 Pads)

—VERTICAL LOADS—

FIG 4



Schematic Sketch

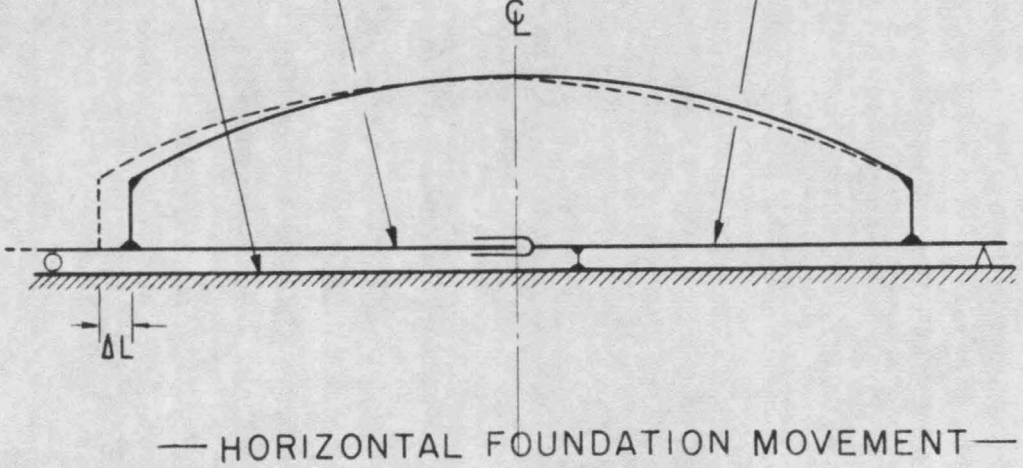
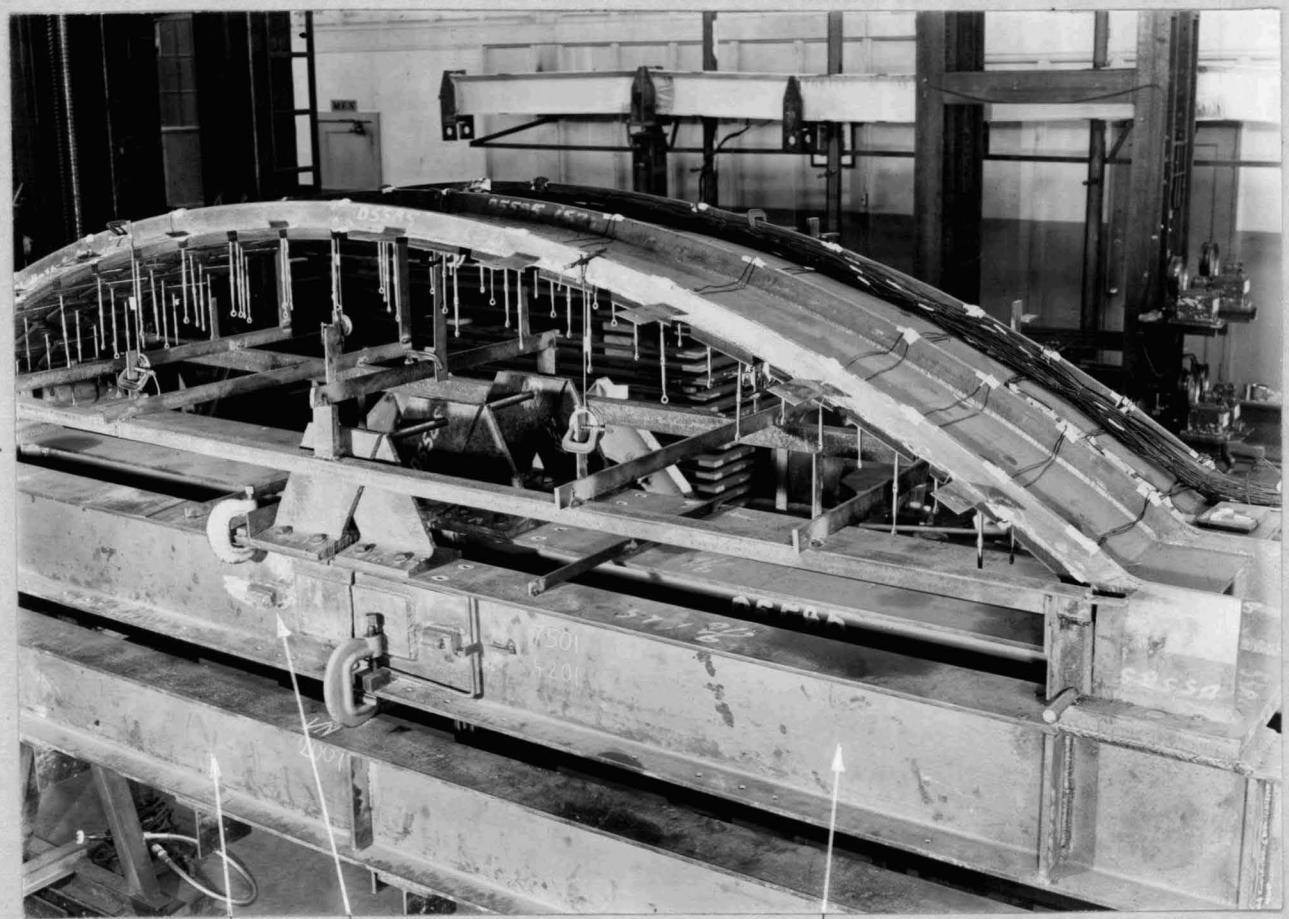
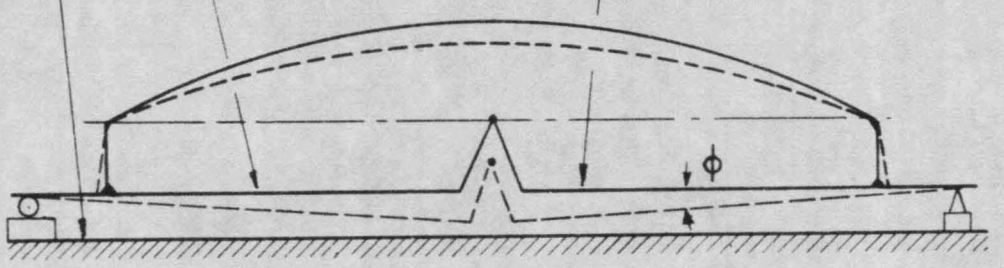


FIG 5

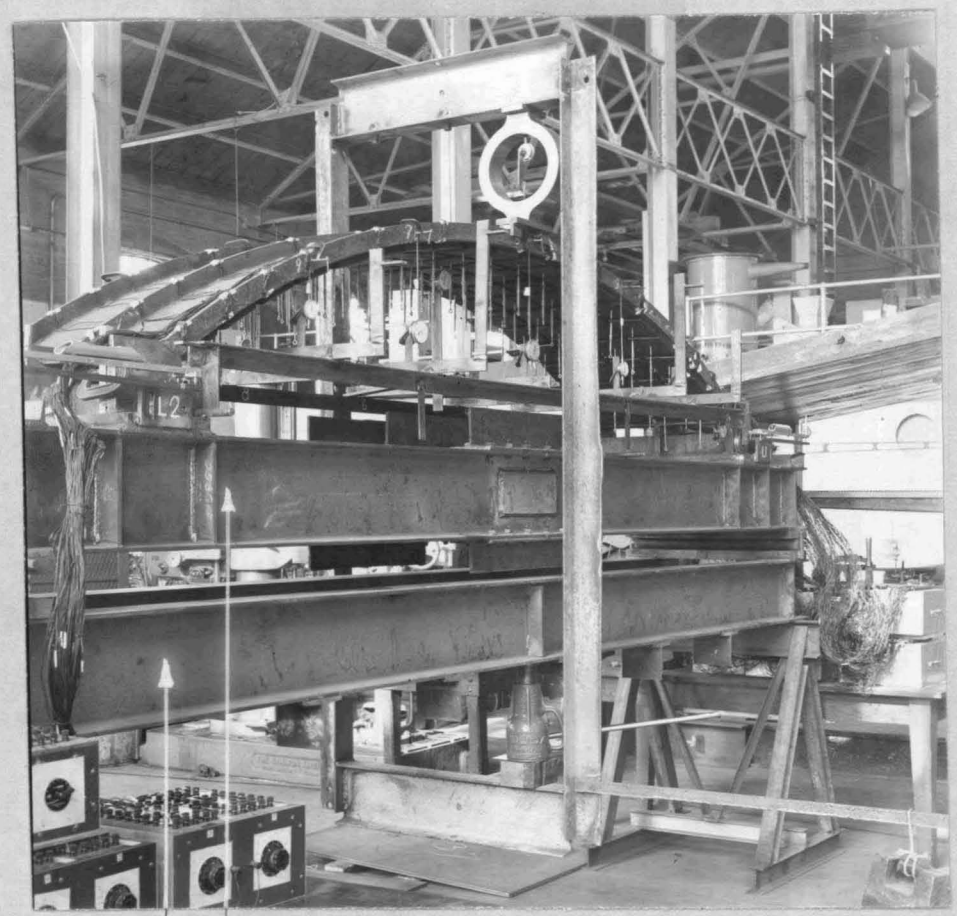


Schematic Sketch



—END ROTATIONS—

FIG 6



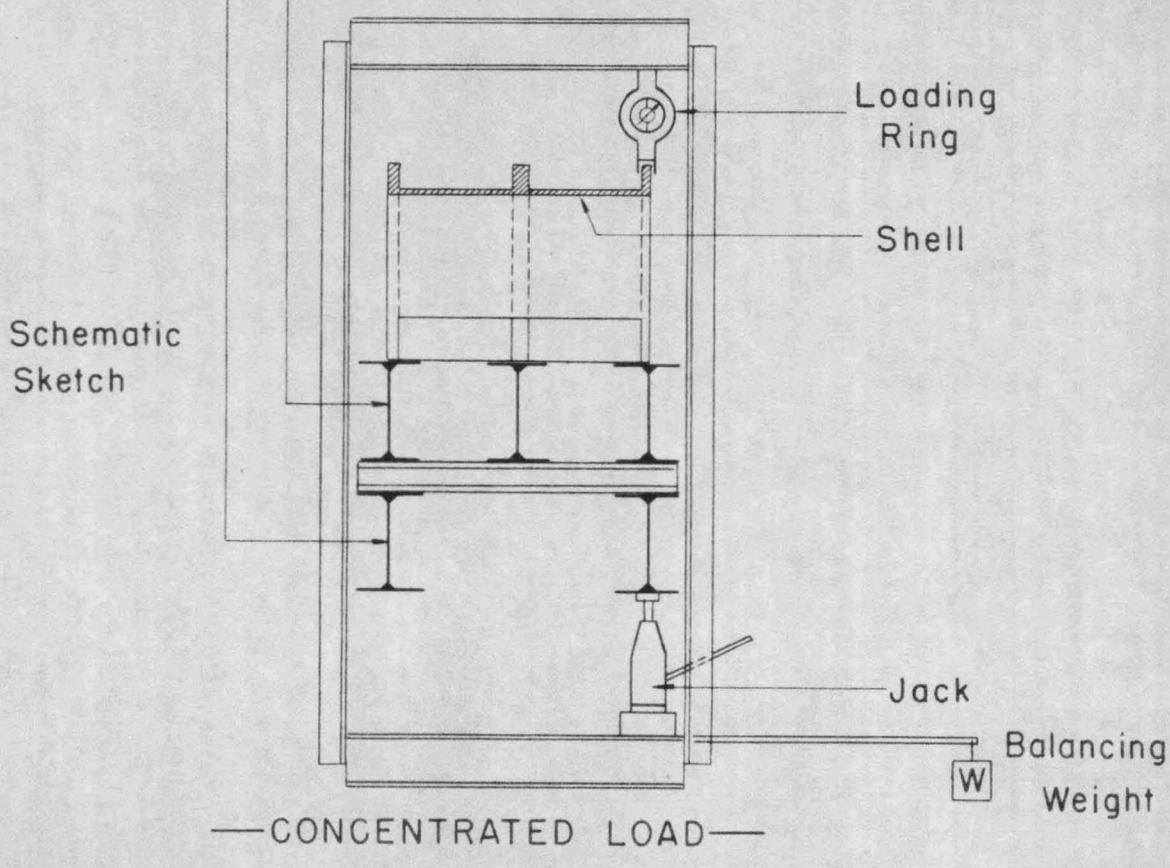
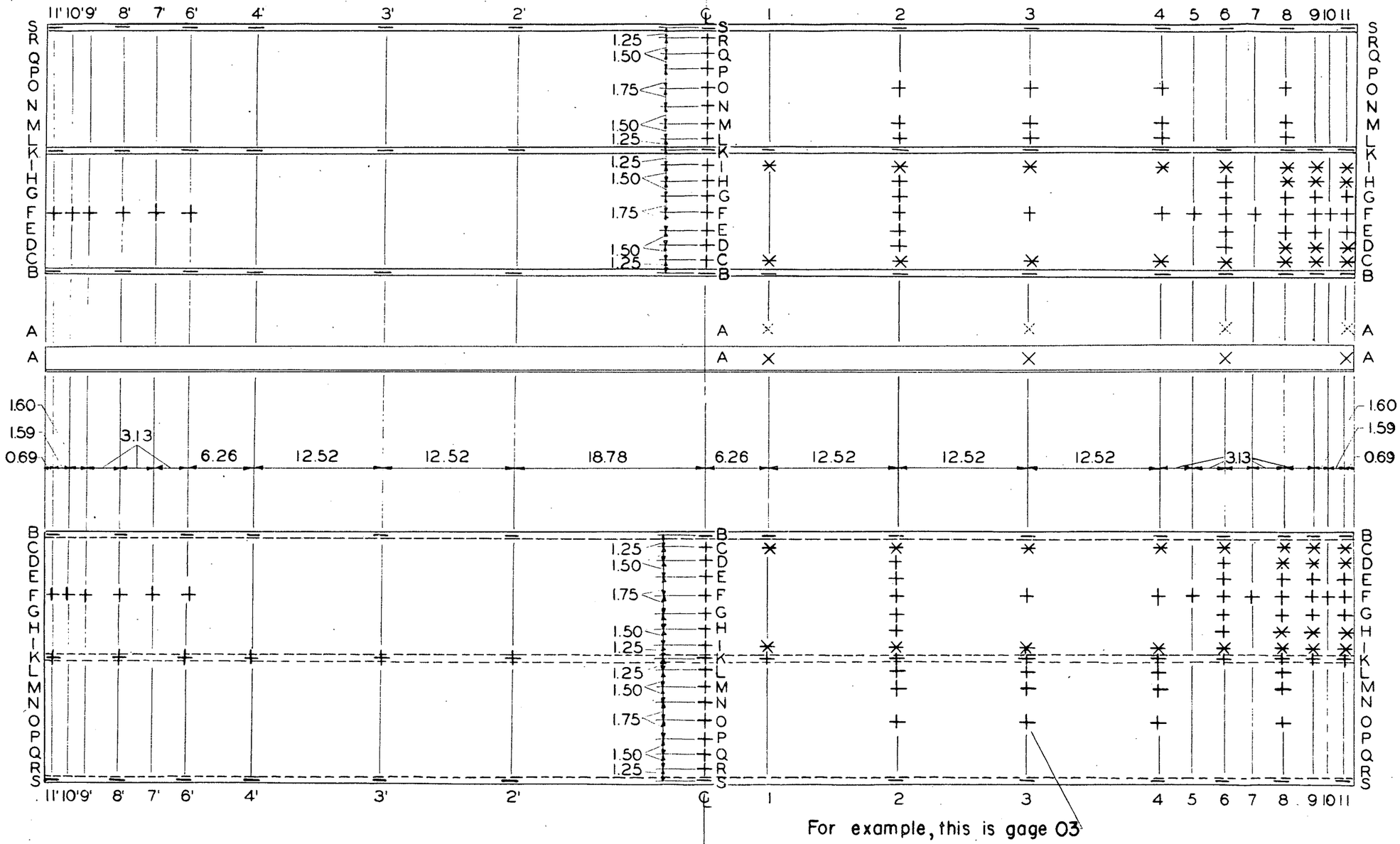
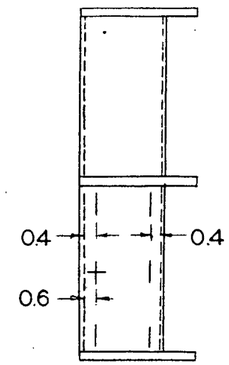
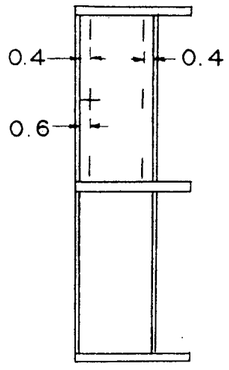

Loading
Ring
Shell
Schematic
Sketch
Jack
Balancing
Weight
W
—CONCENTRATED LOAD—

FIG 7







— Single gage
+ Cross gage
✕ Rosette gage

LAY-OUT OF STRAIN GAGE COORDINATE SYSTEM. FIG. 8

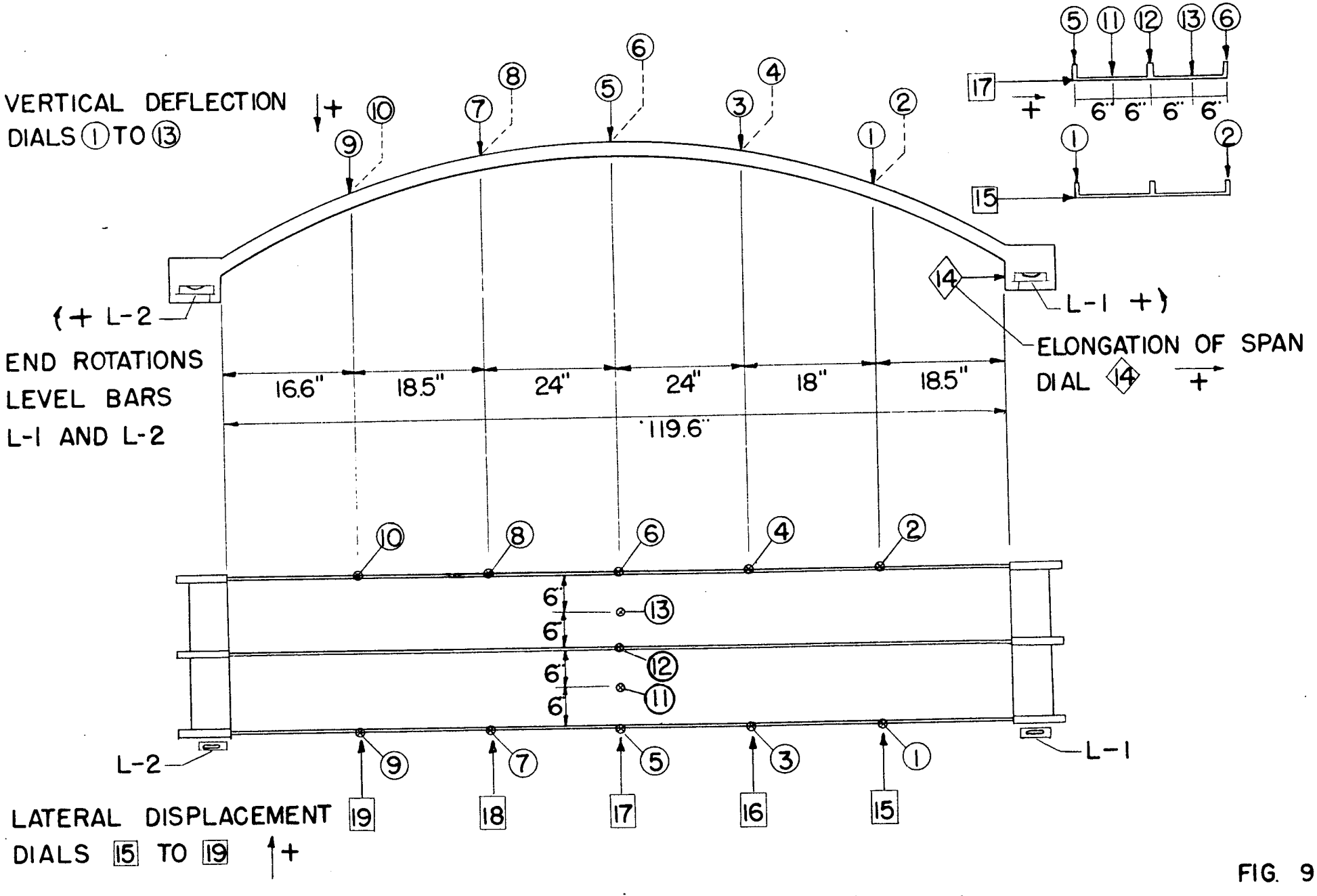
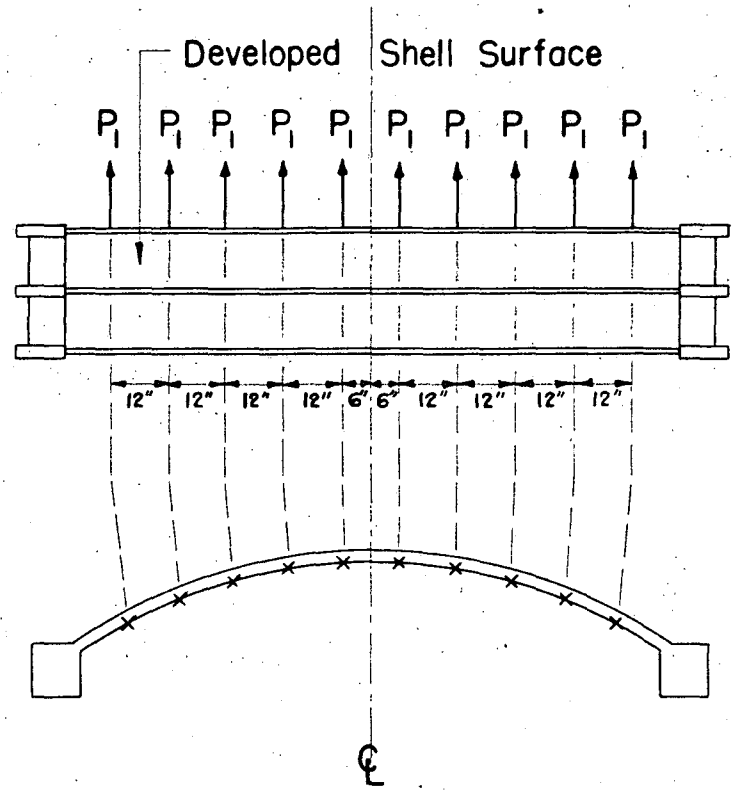


FIG. 9

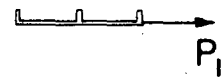
LAY-OUT OF DIAL GAGES AND LEVEL BARS

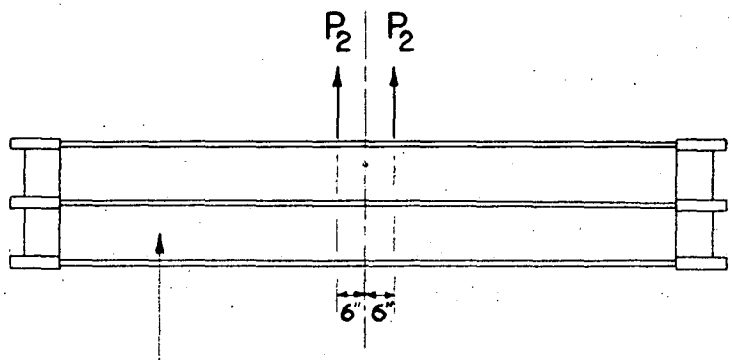


T-1:

"Uniformly" Distributed Lateral Wind Load

P_1 = 1687.5 lbs.

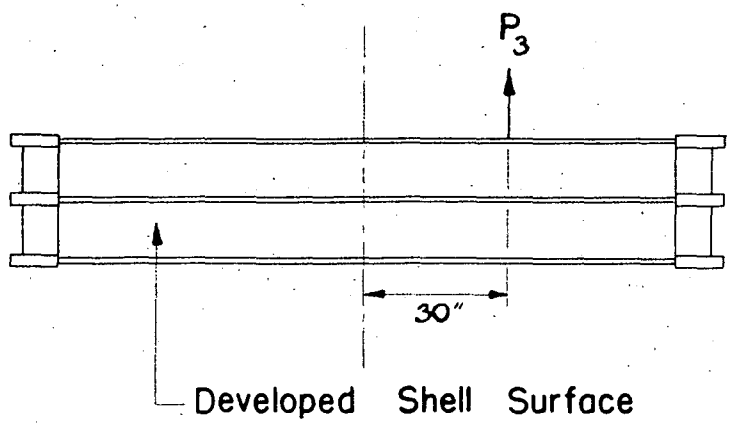




T-2:

Two Concentrated Lateral Loads at the Center

P_2 = 3187.5 lbs.

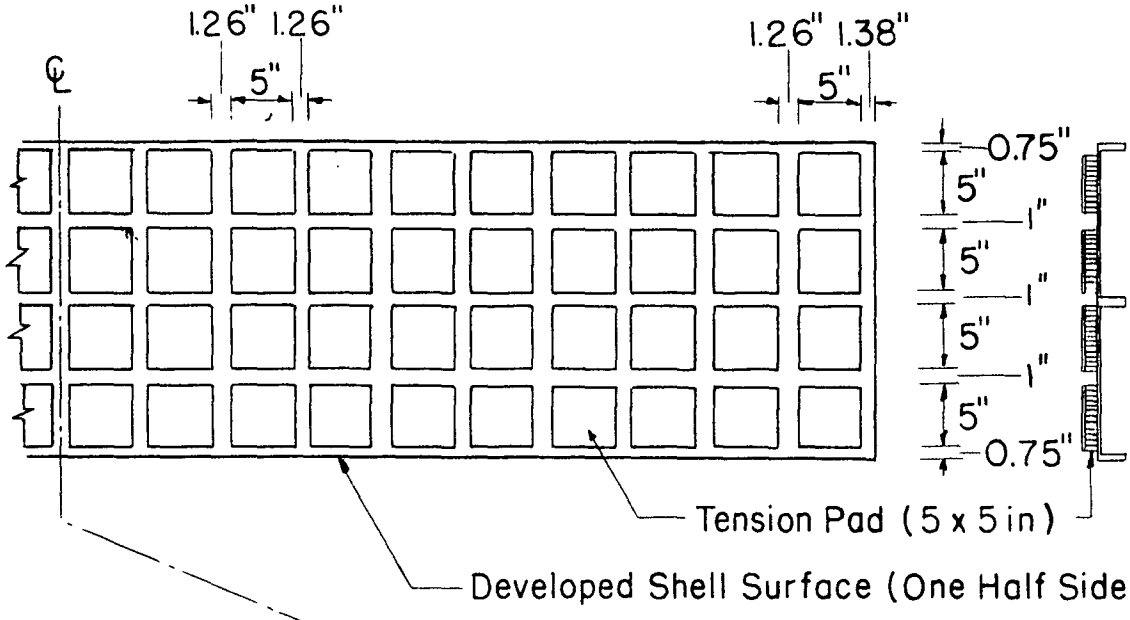


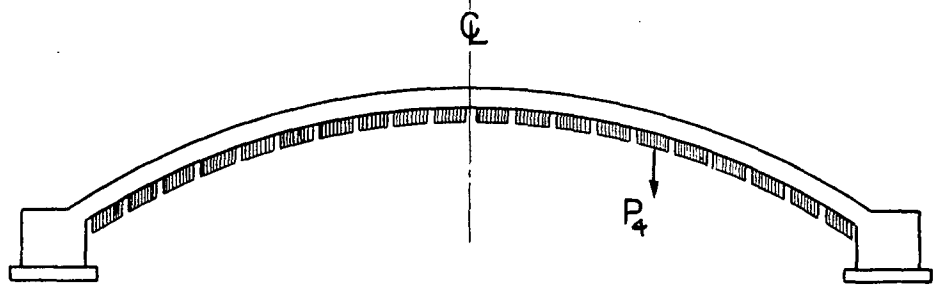
T-3:

Concentrated Lateral Load Near the Quarter point

P_3 = 5647.5 lbs.

Fig. 10

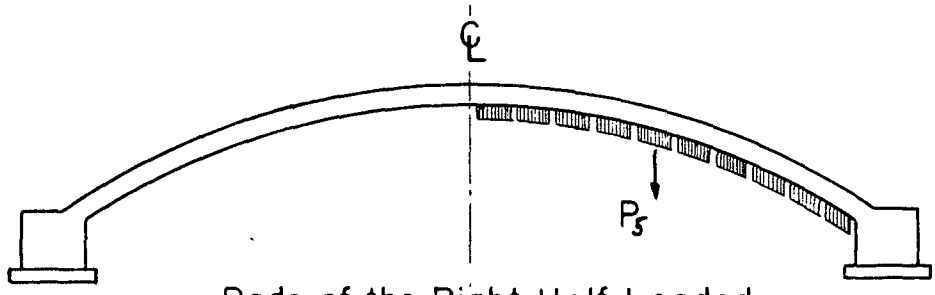




T-4:

"Dead Load"

All Pads Loaded
Load per Pad: P_4= 312.5 lbs



T-5:

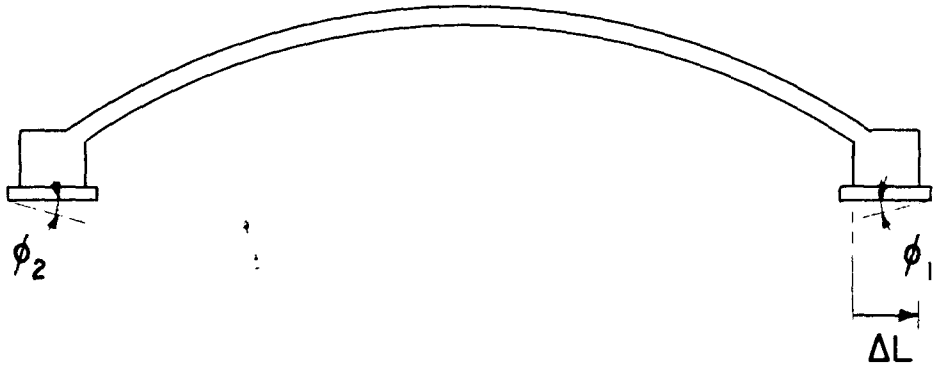
"Live Load"

Pads of the Right Half Loaded
Load per Pad: P_5 = 187.5 lbs

FIG 11

T-6:

Horizontal Foundation Movements



Induced Deformations: $\Delta L = 0.3300$ in.

$\phi_1 = 8.94 \cdot 10^{-4}$ radians

$\phi_2 = 6.52 \cdot 10^{-4}$ radians

T-7:

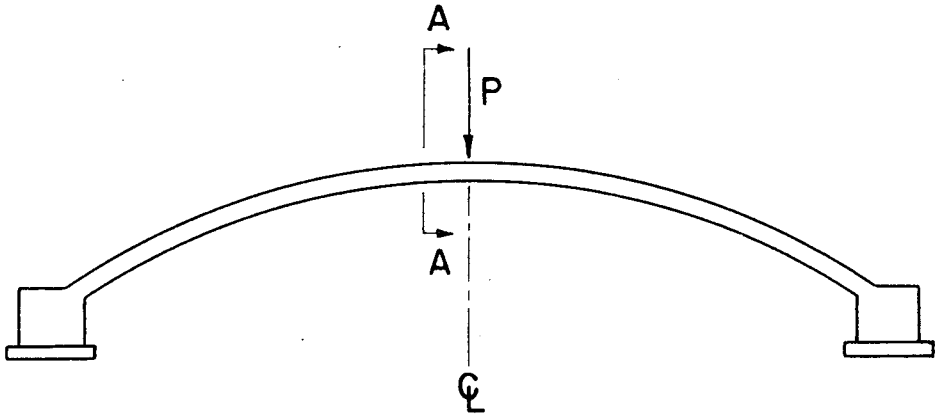
End Rotation of the Abutments

Induced Deformations: $\Delta L = 0.0150$ in.

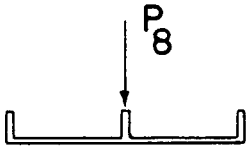
$\phi_1 = 73.83 \cdot 10^{-4}$ radians

$\phi_2 = 73.88 \cdot 10^{-4}$ radians

Fig. 12



A-A:

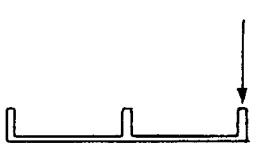


T-8:

Concentrated Load on the Middle Rib:

P_8 = 5040 lbs.

A-A:



T-9:

Concentrated Load on an Exterior Rib:

P_9 = 2540 lbs.

Detail of the Application of the Load to the Rib

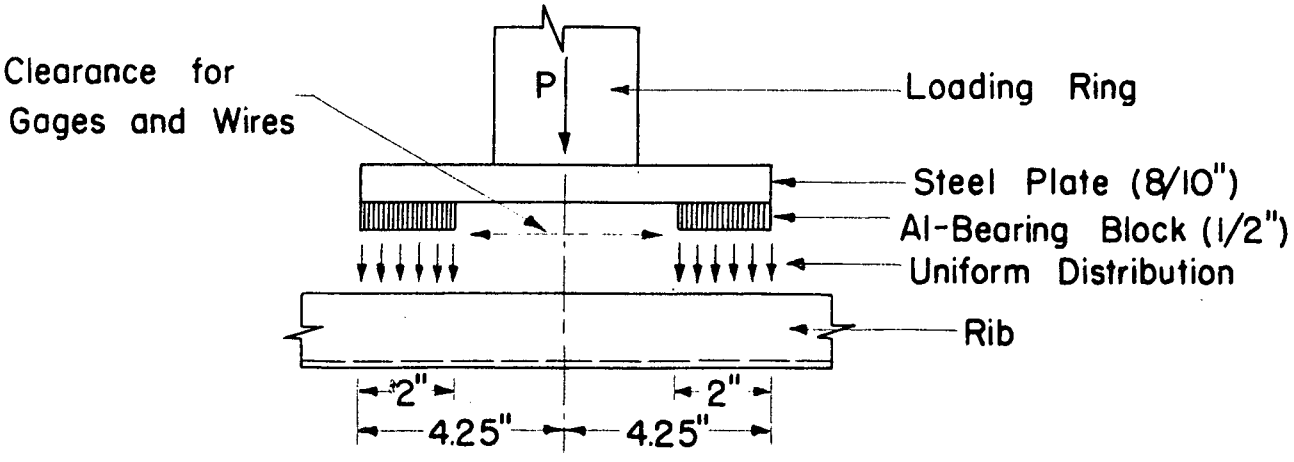


Fig. 13

Test: T-1, Lateral Load, Uniformly Distributed (Fig. 10)

Gage No.	Measured	Gage No.	Measured
①	.0384 in.	⑪	---------
②	-.0275 in.	⑫	---------
③	-.0175 in.	⑬	---------
④	.0256 in.	◇14◇	.0103 in.
⑤	-.0910 in.	[15]	.0088 in.
⑥	.0988 in.	[16]	.0350 in.
⑦	-.0354 in.	[17]	.0576 in.
⑧	.0490 in.	[18]	.0463 in.
⑨	.0224 in.	[19]	.0196 in.
⑩	-.0156 in.	L-1	$9.64 \cdot 10^{-4}$ radians
		L-2	$11.89 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-2, Lateral Load, Concentrated Load at Center (Fig. 10)

Gage No.	Measured	Gage No.	Measured
①	.0290 in.	⑪	---------
②	-.0298 in.	⑫	---------
③	-.0084 in.	⑬	---------
④	.0076 in.	◇14◇	---------
⑤	-.0712 in.	[15]	-.0023 in.
⑥	.0716 in.	[16]	.0139 in.
⑦	-.0177 in.	[17]	.0309 in.
⑧	.0211 in.	[18]	.0213 in.
⑨	.0238 in.	[19]	.0060 in.
⑩	-.0241 in.	L-1	$4.05 \cdot 10^{-4}$ radians
		L-2	$5.58 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-3, Lateral Load, Concentrated Load Near Quarter-Point (Fig. 10)

Gage No.	Measured	Gage No.	Measured
①	-.0120 in.	⑪	---------
②	.0168 in.	⑫	---------
③	-.0460 in.	⑬	---------
④	.0544 in.	◇14	---------
⑤	-.0260 in.	[15]	.0159 in.
⑥	.0362 in.	[16]	.0285 in.
⑦	.0265 in.	[17]	.0248 in.
⑧	-.0170 in.	[18]	.0074 in.
⑨	.0296 in.	[19]	-.0009 in.
⑩	-.0242 in.	L-1	$5.93 \cdot 10^{-4}$ radians
		L-2	$0.84 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-4, "Dead Load" (Fig. 11)

Gage No.	Measured	Gage No.	Measured
①	.0038 in.	⑪	.0811 in.
②	-.0040 in.	⑫	.0554 in.
③	.0276 in.	⑬	.0910 in.
④	.0140 in.	◇14	.0056 in.
⑤	.0372 in.	15	---------
⑥	.0344 in.	16	---------
⑦	.0065 in.	17	---------
⑧	.0154 in.	18	---------
⑨	-.0100 in.	19	---------
⑩	-.0023 in.	L-1	---------
		L-2	---------

Vertical and Horizontal Displacements, Rotations (Fig. 9)

$\left.\begin{matrix} \delta_k \\ \phi_k \end{matrix}\right\}$ are taken = 0 in 213-D

Test: T-5, "Uniformly" Distributed Live Load (Fig. 11)

Gage No.	Measured	Gage No.	Measured
①	.0754 in.	⑪	.0525 in.
②	.0584 in.	⑫	.0308 in.
③	.1199 in.	⑬	.0533 in.
④	.0987 in.	◇14	.0020 in.
⑤	.0191 in.	[15]	---------
⑥	.0164 in.	[16]	---------
⑦	-.0996 in.	[17]	---------
⑧	-.0855 in.	[18]	---------
⑨	-.0746 in.	[19]	---------
⑩	-.0588 in.	L-1	$-0.44 \cdot 10^{-4}$ radians
		L-2	$-0.40 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-6, Horizontal Foundation Displacement (Fig. 12)

Gage No.	Measured	Gage No.	Measured
①	---------	⑪	---------
②	---------	⑫	.4503 in.
③	.3215 in.	⑬	---------
④	.3227 in.	◇14	.3300 in.
⑤	.4378 in.	15	---------
⑥	.4409 in.	16	---------
⑦	.3342 in.	17	---------
⑧	.3288 in.	18	---------
⑨	---------	19	---------
⑩	---------	L-1	$8.94 \cdot 10^{-4}$ radians
		L-2	$6.52 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-7, End Rotation of the Abutments (Fig. 12)

Gage No.	Measured	Gage No.	Measured
①	---------	⑪	---------
②	---------	⑫	-.0290 in.
③	.0015 in.	⑬	---------
④	.0035 in.	◇14◇	.0150 in.
⑤	-.0296 in.	15	---------
⑥	-.0287 in.	16	---------
⑦	-.0049 in.	17	---------
⑧	-.0024 in.	18	---------
⑨	---------	19	---------
⑩	---------	L-1	$73.83 \cdot 10^{-4}$ radians
		L-2	$73.88 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-8, Concentrated Load on Middle Rib at Center of Span (Fig. 13)

Gage No.	Measured	Gage No.	Measured
①	-.0166 in.	⑪	---------
②	-.0276 in.	⑫	.1303 in.
③	.0222 in.	⑬	---------
④	.0041 in.	◇14	.0053 in.
⑤	.0794 in.	15	---------
⑥	.0783 in.	16	---------
⑦	.0101 in.	17	---------
⑧	.0240 in.	18	---------
⑨	-.0270 in.	19	---------
⑩	-.0164 in.	L-1	$-3.46 \cdot 10^{-4}$ radians
		L-2	$-2.77 \cdot 10^{-4}$ radians

Vertical and Horizontal Displacements, Rotations (Fig. 9)

Test: T-9, Concentrated Load on Exterior Rib at Center of Span (Fig. 13)

Gage No.	Measured	Gage No.	Measured
(1)	-.0499 in.	(11)	---------
(2)	.0043 in.	(12)	.0455 in.
(3)	.0270 in.	(13)	---------
(4)	-.0088 in.	◇14◇	.0042 in.
(5)	.1562 in.	[15]	---------
(6)	-.0291 in.	[16]	---------
(7)	.0201 in.	[17]	---------
(8)	.0089 in.	[18]	---------
(9)	-.0425 in.	[19]	---------
(10)	.0190 in.	L-1	$-4.00 \cdot 10^{-4}$ radians
		L-2	$-0.89 \cdot 10^{-4}$ radians

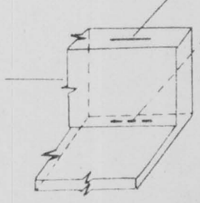
Vertical and Horizontal Displacements, Rotations (Fig. 9)

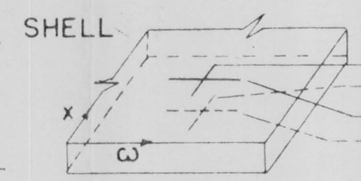
TEST: T-1: LATERAL LOAD, UNIFORMLY DISTRIBUTED

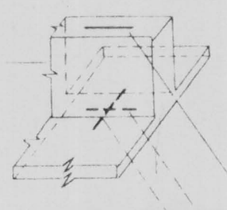
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

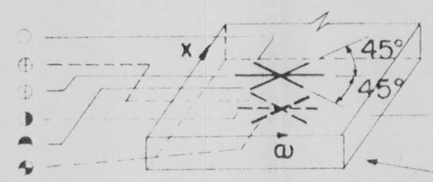
FOR LOCATION OF STRING GAGES SEE FIGURE 8

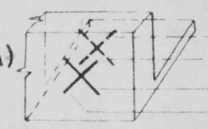
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-102.0			21.0		203.0	238.0	96.0	-105.0	-239.0		-59.0	149.0	262.0		183.0		-35.0			524.0
Rib x=h	-61.0			-347.0		-389.0	-334.0	-72.0	153.0	301.0		113.0	-121.0	-381.0		-419.0		-329.0			-38.0
R										-205.1 126.4 161.7 192.6											
Q										-181.5 197.9 22.0 56.3											
P										-103.3 — -46.5 -1.0											
O										-36.0 96.0 — —		17.3 94.6 -70.5 -50.1	37.2 42.5 -38.2 -76.3	82.7 -2.2 -24.7 -52.9				80.7 — 7.3 -77.0			
N										5.4 22.0 -12.2 0.3											
M										52.0 -69.7 28.2 22.3		61.0 5.8 -31.0 4.8	-3.9 45.7 -31.8 -21.5	-54.6 103.9 -70.1 -29.4				29.3 21.1 -8.9 -32.7			
L										115.2 -160.5 20.2 19.3		114.0 -69.3 4.2 12.9	9.3 82.3 -8.3 -9.1	-92.1 116.3 -52.9 -13.9				-83.2 156.0 -21.2 -35.2			
K	13.0			23.0		6.0	-8.0	-12.0	-2.0	8.0	5.0	-7.0	-8.0	-2.0		6.0		16.0	20.0		23.0
Middle Rib	-18.6			-18.6		-5.4	3.2	13.0	10.3	0.1	-4.6	-1.8	11.2	9.8		9.2		-0.8	-15.2		11.7
	49.6			18.6		13.2	24.9	0.6	20.7	-2.0	47.1	24.1	-5.4	-25.3		-7.3		24.0	10.5		8.6
I											-10.3	69.1	170.8	209.6		207.5		172.0	108.0		79.6
										-99.0	67.4	63.6	6.8	61.5		51.0		95.2	89.9		85.3
										115.9	-32.7	-24.9	12.3	39.8		26.5		21.7	-4.5		-80.7
										-26.7	-35.7	-2.8	37.4	58.3		65.1		16.4	—		-104.6
										-29.8	-74.7	-96.5	-40.8	13.3		-27.6		-50.8	-46.4		-119.7
											27.5	-30.4	-37.1	-159.3		-138.1		-146.1	-124.9		-194.8
H										-22.3 41.0 -21.3 -31.3		3.0 92.1 -30.1 -4.1				3.8 23.1 -23.1 56.2		147.0 153.6 36.5 -193.7 -47.2 -165.3	87.7 152.5 -28.3 -5.9 -101.9 -114.3		78.2 114.6 -26.1 -34.1 -146.9 -209.0
G										13.0 1.7 -0.4 -20.0		-3.3 21.2 -21.8 -7.7				-9.6 41.4 -40.6 17.6		43.2 23.0 22.5 -30.7	9.0 40.6 -31.3 -20.3		-38.2 -38.7 8.3 -36.7
F	0.5 8.6 43.9 -78.2	-8.4 41.2 -18.7 -38.3	-8.1 — -39.7 -14.0	-34.4 45.2 -47.8 -8.5	-54.3 57.7 -48.1 37.0	-15.9 86.5 1.5 -16.9				46.6 -32.5 10.4 -14.9		6.3 1.3 -8.2 -9.0	-25.5 52.2 -14.1 -37.7	-72.1 83.9 -55.6 -0.7	-54.2 83.0 -23.2 -31.7	-23.3 76.0 -51.2 -0.5	-24.5 93.8 45.1 1.9	9.8 50.9 4.7 -28.7	22.1 18.6 -3.7 -17.6	9.2 19.8 -5.3 -25.6	-20.9 -20.8 26.7 -36.3
E										98.2 -87.8 -8.3 -34.0		24.0 -19.6 -1.8 -11.3				-104.1 129.7 -42.5 34.6		-46.1 76.1 5.5 24.4	10.0 16.0 0.7 -0.5		-0.2 -3.9 36.0 -31.8
D										144.3 -116.0 -72.7 -86.0		41.6 -33.0 -18.4 -27.8				-170.0 133.9 65.6 152.4		132.8 209.1 64.2 95.4 -82.9 -11.6	168.1 195.4 63.8 57.3 -141.7 -110.3		213.1 161.1 71.8 -38.4 -98.7 -187.5
C										159.6 -40.5 -173.1 -222.4	3.3 -88.0 -150.8 -125.0 -13.1 -131.0	27.6 0.7 -49.9 -56.5 -28.6 -76.0	97.1 123.6 345.0 149.8 -51.1 13.2	149.2 208.3 217.9 308.7 -58.3 26.4		175.0 222.5 226.1 280.5 -48.9 16.0		242.2 229.7 174.2 169.1 -151.3 -36.1	231.6 209.6 117.4 141.8 -21.4 -31.6		257.9 252.9 104.3 18.8 -136.7 -224.5
B	478.0			39.0		-159.0	-239.0	-122.0	118.0	306.0	276.0	91.0	-147.0	-250.0		-156.0		84.0	294.0		542.0
Rib x=0	70.0			331.0		373.0	377.0	155.0	-130.0	-319.0	-292.0	-93.0	198.0	415.0		402.0		287.0	193.0		48.0
A											-15.8 -6.6 25.5 -11.8		-18.1 19.6 33.6 11.3			104.9 32.2 -30.4 51.9					207.0 88.4 -7.9 103.9









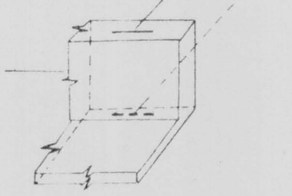


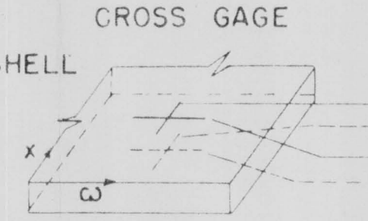
TEST: T-2: LATERAL LOAD, CONCENTRATED LOAD AT CENTER

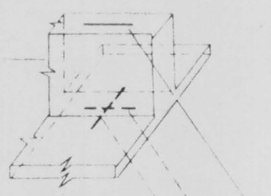
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

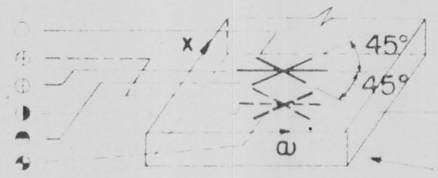
FOR LOCATION OF STRING GAGES SEE FIGURE 8

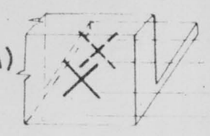
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-316.0			-19.0		142.0	200.0	123.0	-62.0	-231.0		-36.0	134.0	217.0		134.0		-47.0			385.0
Rib x=h	57.0			-183.0		262.0	-296.0	-146.0	91.0	307.0		63.0	-181.0	-314.0		-279.0		-179.0			61.0
R										-150.7 58.2 174.8 201.7											
Q										-172.1 196.9 39.7 -33.5											
P										-101.1 — -53.6 -7.0											
O										-36.0 136.0 — -35.5		-10.5 16.3 -13.6 -10.5	13.1 -20.2 -3.4 5.7	27.5 -65.0 15.1 1.2				27.6 -19.3 -10.1 -20.3			
N										17.1 60.6 33.5 15.0											
M										69.5 -52.4 11.7 12.7		3.4 -4.1 -11.1 2.1	-23.9 16.2 -1.2 -5.5	-65.7 40.6 -35.8 -18.3				-1.3 5.8 -20.9 -23.2			
L										154.3 -175.3 14.8 15.9		42.1 -46.1 -3.4 4.5	-67.4 43.3 -16.7 -9.4	-113.9 87.8 -31.2 -26.9				-66.2 84.6 -21.7 -20.8			
K	34.0			23.0		16.0	2.0	-13.0	-6.0	7.0	7.0	-10.0	-23.0	3.0		11.0		18.0	26.0		33.0
Middle Rib	-31.9			-16.2		-9.2	-2.4	12.4	17.9	-1.4	-6.7	2.3	6.5	0.0		0.2		-6.3	-18.1		-6.9
	28.0			7.5		5.3	11.1	-11.4	3.4	12.0	51.2	-10.1	-16.2	-31.0		-5.0		10.2	4.6		-3.8
I										-60.1 105.9 -25.0 29.5	15.6 81.9 -32.3 -35.5 -72.3 3.2	65.2 65.1 -15.5 6.8 -101.4 -51.4	108.7 -9.4 12.6 28.4 -34.4 -27.8	91.5 16.8 10.9 32.1 20.0 -79.3		90.8 0.5 13.1 31.1 9.0 -69.0		65.2 35.7 13.1 6.2 -8.4 -75.8	36.2 33.3 -1.6 -60.6 -11.8 -50.7		26.2 26.1 -49.3 -62.6 -54.5 -95.5
H										-3.3 45.0 -23.1 30.5		-19.2 11.9 24.3 3.6				3.2 -7.9 -5.1 28.2		51.1 64.8 14.3 -8.8 -5.1 -83.4	27.7 55.2 -11.1 -4.1 -32.6 -57.2		25.4 55.0 -11.3 -18.6 -63.5 -90.2
G										22.3 17.9 -9.7 -28.6		-15.8 6.1 -6.5 -2.2				-4.5 18.5 -15.9 13.4		15.4 2.5 16.4 -16.1	-1.7 9.2 -9.9 -5.3		-25.2 -23.4 6.8 -18.2
F	-6.9 -0.9 28.2 31.9	-7.2 10.6 6.2 -17.3	-90.3 — 1.3 -3.0	-19.6 22.1 -10.3 -4.7	-28.4 24.2 -17.0 23.2	-17.9 45.1 -1.4 -4.5				42.8 -16.2 3.6 -24.4		-4.9 -10.0 -3.8 1.3	-47.6 -27.5 -11.4 -16.9	-54.1 40.7 -26.2 8.6	-49.4 43.5 -17.3 -15.4	-25.1 43.8 -26.1 4.5	2.0 46.9 -29.0 1.4	-1.3 18.6 4.0 -18.6	0.7 -0.5 8.0 -15.0	-8.2 1.6 5.3 -17.0	-17.5 -16.4 16.6 -16.4
E										96.5 -67.5 -19.2 -42.7		6.1 -24.9 -3.2 -1.8				75.4 99.3 -16.5 25.4		-30.1 36.7 4.0 7.8	-6.8 -3.7 25.2 -9.9		-5.6 -8.5 17.2 -13.7
D										134.6 -92.3 -81.4 -96.2		20.4 -32.5 -12.7 12.9				-123.1 94.0 36.1 57.8		47.6 94.9 32.2 37.9 -74.0 0.9	62.1 71.3 32.3 5.8 -51.4 -61.6		81.0 64.1 27.8 -23.8 -45.8 -95.4
C										137.6 -35.7 -173.3 -217.6	4.7 -70.0 -146.2 -171.9 -33.1 -131.4	36.6 17.4 -26.7 -30.6 -29.8 -64.4	76.6 104.3 120.2 152.3 -26.7 30.7	83.0 143.0 163.4 231.3 43.1 43.8		90.6 130.2 147.5 165.9 -30.0 32.1		114.0 116.0 83.2 81.1 -90.5 -0.6	90.5 89.6 36.1 34.3 -115.0 -28.0		85.5 95.6 19.0 -32.1 -68.9 -119.1
B	427.0			87.0		-102.0	-193.0	-143.0	63.0	276.0	246.0	61.0	-164.0	-198.0		-105.0		88.0	236.0		421.0
Rib x=0	-94.0			166.0		258.0	311.0	193.0	-64.0	-294.0	-262.0	-51.0	204.0	314.0		266.0		150.0	51.0		-54.0
A											-13.9 -2.6 27.4 -11.9		-10.6 5.7 17.3 8.8			81.9 26.6 -28.7 40.1					147.5 51.3 -19.9 51.3









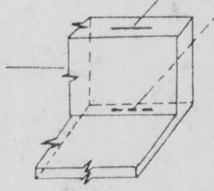


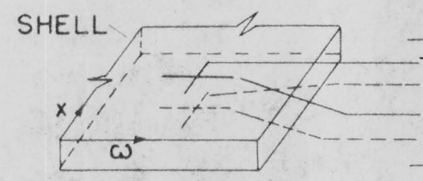
TEST: T-3: LATERAL LOAD, CONCENTRATED LOAD NEAR QUARTER POINT

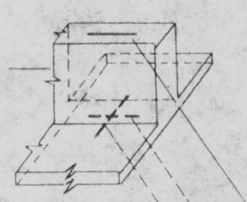
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

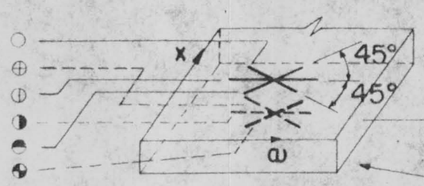
FOR LOCATION OF STRING GAGES SEE FIGURE 8

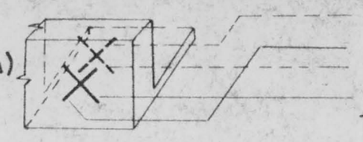
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-250.0			-85.0		21.0	87.0	125.0	76.0	-60.0		-128.0	-109.0	83.0		138.0		118.0			-18.0
Rib x=h	113.0			-10.0		-85.0	-139.0	-153.0	-68.0	72.0		145.0	262.0	-112.0		-200.0		-263.0			-77.0
R										-60.1 45.6 36.0 41.4											
Q										-48.2 48.6 6.6 11.4											
P										-21.8 31.9 -5.3 0.9											
O										-10.0 8.0 0.3 -0.3		-18.1 67.7 -25.8 -24.2	167.1 176.9 -95.1 -152.7	16.9 -16.3 2.4 -21.4				35.7 -25.9 36.8 -32.1			
N										5.6 -12.2 11.8 7.4											
M										11.4 -28.3 16.6 9.9		46.6 -11.8 10.4 24.4	89.9 60.2 -29.0 -38.0	-35.7 41.9 -36.8 1.6				-3.0 3.7 -0.9 -21.1			
L										7.9 -33.2 3.7 6.1		114.2 -91.0 21.2 34.0	166.8 -59.9 0.0 -1.1	-34.3 27.8 -18.8 5.1				-92.3 97.6 -17.9 -22.2			
K	14.0			9.0		6.0	4.0	-5.0	-4.0	2.0	4.0	9.0	11.0	7.0		6.0		11.0	29.0		18.0
Middle Rib	-15.3			-7.1		-1.1	0.8	8.0	8.0	-0.9	-2.2	-1.0	-10.5	11.4		13.6		-4.9	-7.8		2.8
	9.5			4.3		3.0	6.0	0.7	-1.3	-3.0	7.1	30.0	45.3	-11.4		-18.4		-3.8	-6.7		4.9
I										-34.8 29.2 -3.8 -8.0	-63.0 11.5 -11.8 -24.3 -0.6 22.7	-61.5 13.4 -15.4 -27.6 -20.6 28.7	88.8 38.7 -14.4 -22.6 -37.0 -30.9	126.1 64.1 12.6 23.1 -50.8 -94.4		125.3 38.8 5.6 30.6 -60.7 -80.8		104.0 43.9 11.9 8.1 -45.9 -88.9	58.7 35.5 0.4 — -30.3 -69.8		31.4 33.0 -42.6 -5.0 -63.7 -92.7
H										-9.0 3.2 1.3 -6.1		1.3 37.7 -8.0 -22.0				-14.5 11.2 -15.5 24.6		91.1 72.0 19.4 -5.6 -50.0 -91.6	45.3 74.6 -21.1 58.0 -50.0 -71.6		29.6 62.3 -18.5 -21.5 -72.6 103.3
G										0.7 -8.1 9.0 3.3		13.0 18.5 -0.4 -16.6				-4.5 18.8 -15.8 4.4		11.0 1.4 -0.4 -11.0	1.8 12.3 -25.0 -8.4		-24.0 -23.1 1.8 -26.2
F	-6.2 -4.9 5.2 -1.8	-10.4 -1.0 11.3 -1.0	-14.5 — 14.5 -5.0	-2.3 3.1 0.1 -4.1	-2.8 3.9 -4.9 3.9	-4.9 10.0 -2.8 -0.3				9.6 -10.2 11.7 7.3		29.6 -3.5 11.0 -14.9	4.5 35.6 -16.1 -50.1	-28.9 33.0 -33.0 -2.1	-31.7 31.5 -7.9 -16.0	-7.1 35.0 -25.7 -1.2	-37.0 44.8 -27.7 4.5	-12.6 29.2 -11.6 -8.0	10.9 13.2 -27.3 -2.4	5.7 10.7 -20.2 -20.3	-10.5 -13.7 16.3 -37.5
E										18.7 -23.2 7.4 6.8		55.9 -47.7 1.1 -8.4				-52.0 58.2 1.7 21.0		-43.6 53.0 -10.6 27.2	-12.4 28.2 -16.6 23.0		5.9 1.7 31.8 -51.0
D										33.2 -23.6 -7.1 -12.2		95.7 -72.0 -24.2 -57.6				-63.4 42.3 45.1 80.5		84.4 142.9 55.6 81.3 -107.8 -0.2	90.1 141.0 12.4 87.7 -97.0 -5.1		136.7 59.9 72.0 -41.6 -33.2 -88.3
C										44.0 -20.6 -30.4 -42.3	○ -66.2 ⊕ 45.0 ⊖ -56.7 ◑ -78.5 ◓ 11.5 ◔ -44.0	-13.0 -78.3 -99.7 -125.5 1.3 -74.2	42.7 -28.3 -62.4 -75.1 -31.9 -76.7	91.4 65.9 64.7 92.4 -18.0 -40.5		111.1 97.5 116.6 145.3 -7.5 -22.2		159.8 136.7 147.3 188.6 -37.5 -33.0	121.9 127.4 133.3 129.6 -87.6 22.2		202.4 155.3 124.9 67.7 -65.5 197.4
B	294.0			106.0		-5.0	-93.0	-133.0	-288.0	67.0	118.0	177.0	84.0	-58.0		-94.0		-67.0	-23.0		27.0
Rib x=0	-159.0			-4.0		84.0	144.0	162.0	98.0	-67.0	-120.0	-193.0	-98.0	115.0		193.0		235.0	—		202.0
A											7.0 2.3 0.8 -8.1		-21.5 2.6 15.7 -18.1			31.0 6.2 -2.0 22.8					61.1 51.6 -5.0 71.2









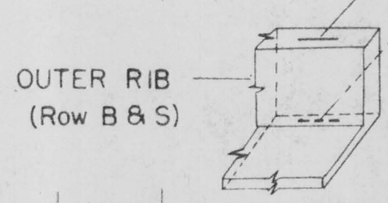


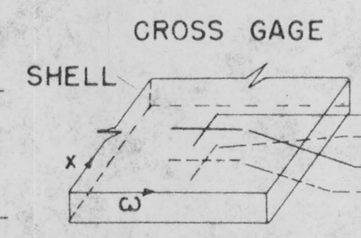
TEST: T-4: "DEAD LOAD"

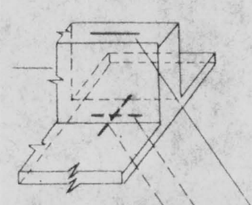
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

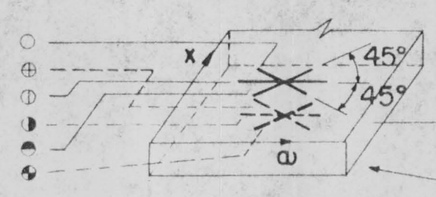
FOR LOCATION OF STRING GAGES SEE FIGURE 8

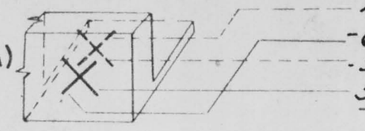
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-160.0			-60.0		-24.0	9.0	28.0	-71.0	-117.0		-52.0	19.0	50.0		-13.0		-74.0			-176.0
Rib x=h	-172.0			-158.0		-115.0	-120.0	-108.0	-2.0	50.0		-10.0	-97.0	-165.0		-122.0		-141.0			-151.0
R										-134.0 -196.3 -85.4 -103.4											
Q										-155.6 293.6 -217.6 -238.5											
P										-98.4 245.5 -286.4 -262.9											
O										-43.7 148.3 -306.2 -192.7		-19.7 108.8 353.3 -686.8	150.9 135.2 -116.8 -580.9	129.0 92.8 -95.2 -386.7				47.3 68.2 -10.5 -337.9			
N										-110.1 180.8 -235.1 -148.9											
M										-57.7 54.1 -122.9 -95.7		-10.8 6.6 143.8 -438.7	96.2 67.3 80.7 -401.8	112.4 62.3 -46.7 -311.7				34.3 53.4 -40.1 -254.5			
L										225.9 -323.7 -65.5 -59.1		57.9 -81.2 -57.9 -202.1	104.7 -2.6 -55.4 -220.7	81.5 59.4 -106.6 -221.7				80.8 -24.1 -117.6 -177.0			
K	-141.0			-90.0		-67.0	6.0	-18.0	-170.0	-277.0	-271.0	-164.0	-45.0	81.0		-41.0		-75.0	-87.0		-101.0
Middle Rib	-206.9 59.9			-146.3 43.9		-118.1 -22.0	-191.8 61.3	-182.2 42.0	-87.2 -52.0	-4.9 -91.7	-7.3 -80.7	-64.2 -52.8	-166.4 46.5	-192.9 63.4		-136.2 -18.4		-158.0 36.2	-191.3 74.3		-111.8 27.7
I										263.4 -318.0 62.1 -79.3	76.1 -162.7 2.4 -23.6 175.3 -146.3	54.2 -38.4 -33.6 -64.8 125.7 -206.0	3.5 -91.5 -42.5 -300.4 155.8 -288.8	-61.8 26.9 -105.5 -270.0 173.3 -398.4		9.7 -128.5 -115.8 -164.8 -32.2 -113.1		14.0 -50.5 -114.5 -167.7 -44.3 -156.8	114.9 -61.1 -137.3 — -132.5 -135.6		91.6 125.8 -160.6 -231.4 -162.0 -309.6
H										-44.9 22.3 207.3 -369.3		0.5 78.6 -134.9 -171.4				1.1 54.5 -123.9 -196.6		-21.9 -19.4 -74.9 -218.3 -47.5 -161.5	42.5 -18.3 -93.2 -175.3 -157.9 -78.6		41.5 156.7 -63.7 -108.9 -111.9 -213.4
G										-193.1 120.1 328.1 -575.4		-38.3 149.7 -198.5 -234.7				-21.0 77.3 -149.1 -192.4		-12.6 51.8 -58.6 -235.5	-37.1 68.8 -56.7 -146.1		-2.7 -49.4 -9.9 -76.3
F	26.4 32.2 18.1 -67.0	10.3 -22.7 -214.1 -128.1	13.5 — -136.3 1.0	61.9 52.0 29.9 -332.4	-51.3 44.6 -319.9 -108.4	-109.2 109.0 -379.9 -64.7				-233.2 133.8 403.3 -716.7		16.7 122.8 -260.3 -267.8	107.2 167.6 201.2 -683.8	10.0 152.9 -60.3 -450.6	173.4 54.6 -106.7 -288.5	43.0 36.6 -181.2 -198.0	-8.0 -4.9 -268.4 -92.7	34.3 6.4 -70.7 -222.0	25.1 -31.6 -32.8 -100.8	360 -57.5 -18.1 107.8	27.2 31.4 -6.9 -43.0
E										-234.2 211.7 313.5 -778.2		-6.7 232.3 -245.5 -315.4				-4.2 113.6 -174.7 -260.5		-76.4 87.9 -77.0 -240.7	-25.4 9.8 -17.1 -155.5		14.8 48.2 4.5 -68.5
D										-176.6 214.6 112.8 -652.4		-115.4 259.6 -192.9 -280.3				-34.9 139.2 169.7 -211.0		-132.4 -211.4 -113.7 -241.6 -26.1 69.7	-172.6 -157.4 -48.8 -186.6 74.8 21.5		-100.6 -169.1 -8.6 -88.0 95.2 144.7
C										-142.4 194.2 -43.2 -252.2	○ -50.5 ⊕ 1.5 ◑ -91.1 ◑ -82.2 ◓ -155.8 ◕ 66.9	-113.8 -7.9 -109.5 -140.5 -141.4 86.1	-139.0 -103.1 -108.1 -278.7 86.9 50.2	-1.6 -272.3 -130.1 -276.8 -151.9 155.0		-134.0 -66.7 -166.3 -218.3 -44.0 -57.5		-138.9 -237.3 -145.7 -174.4 -2.9 108.2	-239.8 -162.9 -106.6 -197.2 129.3 -0.4		-116.4 -294.7 -83.5 -132.9 66.6 218.4
B	-251.0			-107.0		-34.0	61.0	63.0	-57.0	-159.0	-152.0	-80.0	-10.0	18.0		-1.0		-60.0	-95.0		-130.0
Rib x=0	-151.0			-138.0		-113.0	-176.0	87.0	-26.0	58.0	74.0	5.0	-67.0	-131.0		-148.0		-152.0	-174.0		-180.0
A										48.2 -65.8 -97.5 57.1			42.1 -54.7 -95.3 53.8			26.7 -96.9 -78.8 60.2					21.4 -151.4 -130.4 18.0









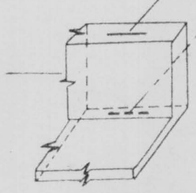


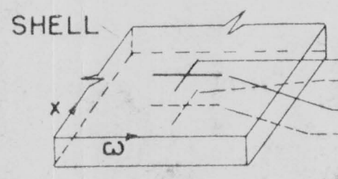
TEST: T-5: "UNIFORMLY" DISTRIBUTED LIVE LOAD

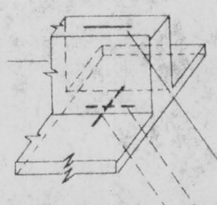
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

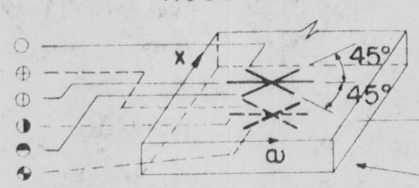
FOR LOCATION OF STRING GAGES SEE FIGURE 8 -

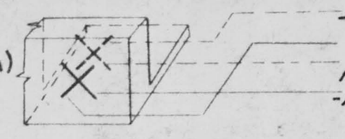
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-559.0			-287.0		-73.0	90.0	299.0	305.0	-29.0		-327.0	-296.0	-78.0		64.0		262.0			512.0
Rib x=h	374.0			156.0		-17.0	-157.0	-317.0	259.0	6.0		251.0	272.0	71.0		-52.0		-250.0			456.0
R										-44.1 58.3 -26.5 -41.9											
Q										-20.7 65.8 -37.0 -86.1											
P										-25.6 68.6 -48.2 -109.2											
O										-20.1 51.8 -56.3 -86.6		-121.1 187.8 37.0 -328.6	-36.9 126.3 27.2 -311.9	20.5 97.6 -84.6 -231.0				40.7 16.6 6.6 -197.3			
N										-42.5 64.3 -42.5 -70.1											
M										-25.4 16.6 -16.1 -47.5		-135.2 64.8 131.4 -26.1	-66.1 51.4 65.1 -42.7	10.4 44.2 -12.3 -97.4				70.8 22.5 -87.3 -194.5			
L										43.7 -95.9 -22.4 -28.8		-219.2 -398.4 -196.5 206.1	182.8 -268.7 120.8 148.8	109.1 -94.7 24.3 23.1				34.5 95.5 -165.0 -228.9			
K	-660.0			-311.0		-65.0	137.0	378.0	382.0	-72.0	-298.0	-486.0	-415.0	-155.0		32.0		282.0	440.0		618.0
	417.5			135.5		-32.4	-153.9	-312.4	-289.6	-0.9	162.3	271.4	201.7	49.3		-57.3		-246.5	-388.6		-293.1
Middle Rib	-149.8			-48.5		14.1	63.1	142.3	117.9	-34.0	-134.3	-170.9	-116.6	-39.6		-20.0		84.1	151.8		102.7
I										29.7 63.3 7.0 -19.9	205.7 77.7 223.2 132.5 161.5 100.2	-262.5 -31.4 212.1 215.3 254.1 -27.3	155.2 -12.5 129.7 155.8 209.4 -22.7	45.4 6.2 52.5 3.1 206.0 -144.1		-11.5 -82.7 -35.1 -64.4 71.8 -59.1		-84.3 -43.2 -158.4 -221.1 -30.1 -81.0	10.1 -146.8 -219.3 — 141.2 -96.7		111.6 14.4 -319.1 -446.4 -345.3 -382.1
H										13.2 16.9 22.5 -116.4		-35.1 -95.7 33.1 -5.8				-15.7 45.6 -67.4 -109.4		-4.0 -27.7 -78.5 -196.0 0.1 -147.3	89.3 -102.0 -61.7 -251.7 -109.9 -133.6		32.1 95.8 -114.7 -77.9 -188.6 -172.0
G										31.6 39.3 39.9 -190.1		-108.1 220.4 -114.6 -108.2				-18.6 63.9 -101.3 -120.0		44.7 0.1 -23.5 -183.8	-12.9 -13.1 26.4 -176.4		-38.3 -4.0 -49.7 0.1
F	30.4	52.2	27.1	-19.0	-18.6	4.8				42.1		-83.1	-72.5	-28.4	5.74	19.1	16.8	41.9	-19.4	-39.6	-18.0
	30.3	55.3	—	17.6	12.7	-10.1				39.8		222.2	165.7	130.5	50.6	30.5	-11.4	-18.6	-51.1	-79.9	-8.4
	18.0	-67.7	-94.8	-58.3	-12.4	6.8				-26.6		-203.0	46.4	-77.0	-103.8	-122.5	-144.4	1.6	73.6	-39.6	-28.4
	-69.9	-9.8	-	40.4	7.6	4.3				-206.1		-162.2	-356.1	-258.1	-169.5	-134.9	-76.5	-162.2	-116.2	60.6	43.2
E										0.5 84.1 15.0 -186.6		-154.3 284.7 -164.7 -148.3				-17.7 77.5 -127.3 -168.4		20.9 5.8 -28.7 -174.0	-12.9 -51.6 88.3 -160.1		-26.9 -7.4 -33.1 42.2
D										-34.9 101.2 -0.8 -124.2		-187.3 227.0 -44.7 -38.5				-51.2 124.0 -112.2 -124.0		-50.4 -159.2 101.2 -200.7 -25.8 14.5	-59.6 -167.2 21.1 -241.3 120.3 -123.2		-113.6 -39.7 -80.7 -8.0 -12.5 34.8
C										-54.5 63.0 -14.2 -33.1	○ 79.1 ⊕ -16.5 ○ 78.9 ◑ 104.8 ◓ 84.4 ◔ -22.6	53.7 65.1 154.5 182.7 53.7 80.5	32.0 87.1 159.3 142.1 -1.7 84.1	57.5 -44.5 22.6 -3.6 -112.1 116.9		-36.7 5.8 -78.5 -106.3 -99.1 5.8		-104.9 -135.8 -188.5 -216.9 -138.6 86.9	-213.5 -104.4 -195.7 -345.0 -17.2 -112.6		-218.9 -212.9 -219.0 -235.0 -1.1 48.7
B	-724.0			-350.0		-92.0	130.0	358.0	371.0	-35.0	-224.0	-397.0	-349.0	-118.0		66.0		284.0	424.0		620.0
Rib x=0	535.0			182.0		-31.0	-203.0	-354.0	-346.0	31.0	205.0	345.0	322.0	120.0		-47.0		-253.0	-380.0		-511.0
A										-137.9 97.6 121.5 -110.1			32.1 -35.8 -64.0 27.2			120.1 -64.9 -127.9 89.1					157.9 -78.4 -111.1 4.6









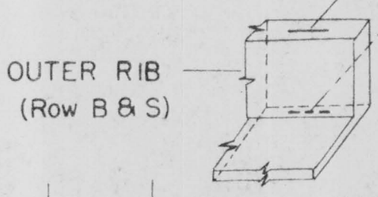


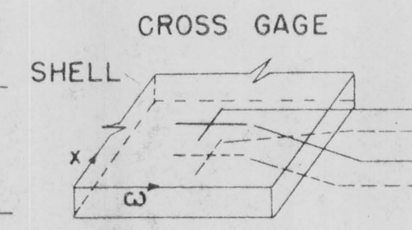
TEST: T-6: HORIZONTAL FOUNDATION DISPLACEMENT

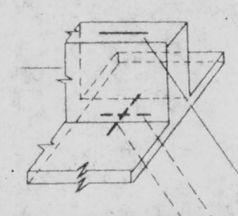
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

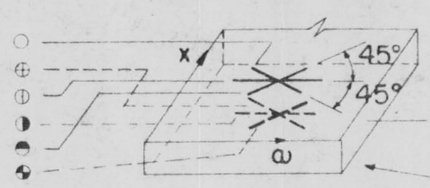
FOR LOCATION OF STRING GAGES SEE FIGURE 8

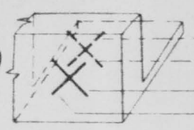
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	955.0			662.0		405.0	210.0	-130.0	-333.0	472.0		-331.0	-153.0	207.0		130.0		701.0			1048.0
Rib x=h	-669.0			-462.0		-234.0	-82.0	184.0	288.0	435.0		291.0	200.0	-77.0		-239.0		-471.0			-656.0
R										-130.5 -2.1 -206.1 301.7											
Q										-200.5 184.4 81.6 131.7											
P										-164.2 208.2 -18.5 47.0											
O										-134.8 165.0 19.5 25.5		-124.0 112.3 -26.8 18.2	-42.9 30.9 -1.6 1.0	26.7 -23.5 9.1 -13.2				90.4 -61.9 74.9 -60.9			
N										-120.7 98.5 84.9 71.7											
M										-46.3 -90.1 222.3 154.8		-120.3 37.6 102.9 189.5	-38.5 3.9 17.6 91.8	23.3 -7.7 -10.8 -38.7				144.6 -12.2 -142.7 -174.4			
L										154.5 -367.7 279.6 274.9		167.9 -335.7 236.2 301.9	62.1 -128.3 83.8 133.1	-38.8 52.4 -35.7 -72.7				-65.6 302.7 -279.5 -331.7			
K	997.0			669.0		400.0	201.0	-161.0	-407.0	-557.0	-555.0	-429.0	-179.0	203.0		417.0		697.0	870.0		1044.0
Middle Rib	-709.2			-394.6		-194.0	-84.2	139.8	275.3	371.2	363.8	292.9	138.1	-82.0		-215.5		-402.8	-536.9		-366.0
	240.4			150.0		84.6	39.8	-60.6	-107.1	-183.2	-156.9	-128.6	-53.3	33.7		112.1		187.2	224.6		133.1
I										136.8 -351.0 302.1 371.3	176.9 0.9 223.4 305.9 182.0 50.0	146.7 -3.6 207.6 233.0 192.7 73.0	34.0 16.9 70.6 144.3 89.2 51.6	-95.8 -24.9 -46.0 -81.0 11.1 -6.5		-166.3 -11.9 -156.7 -180.1 -31.3 -3.7		-188.6 6.6 -287.1 -340.1 -148.9 -28.1	-87.2 -198.8 -291.0 — -215.0 -50.6		97.4 -86.4 -407.6 -523.7 -468.1 -343.9
H										-150.6 39.3 113.9 259.4		-31.8 27.3 115.9 109.0				53.8 6.1 -86.7 -94.1		32.0 -83.1 -131.5 -200.2 -8.1 -133.1	141.8 -228.2 -36.5 291.1 -61.1 -164.9		-0.6 2.1 -183.2 -13.3 -243.1 47.0
G										-170.4 114.9 -13.3 150.0		-74.4 105.4 15.5 45.4				67.7 -41.5 -24.2 -42.6		104.2 -82.5 18.3 -104.1	48.3 -101.7 110.3 -155.4		-60.1 -57.6 -113.9 140.8
F	-47.6 -40.8 -70.3 175.2	-79.5 -92.3 102.5 42.0	-36.1 — 185.0 -72.0	73.2 -53.8 111.4 -65.2	92.0 -101.6 25.9 -7.6	96.4 -95.9 16.4 -29.8				-157.6 113.6 -35.7 69.2		-77.4 124.7 -15.4 4.8	-43.5 39.3 -12.5 -10.3	34.7 -16.4 6.8 -18.4	43.7 -34.6 8.5 -11.9	63.4 -68.4 16.9 -14.7	81.0 -83.0 27.3 -33.8	78.9 -63.9 91.3 -58.9	-30.8 -48.1 175.9 -84.3	-94.5 -74.0 107.0 32.4	-49.3 -35.0 -80.3 181.0
E										-182.0 147.7 5.1 65.0		-103.9 146.2 -30.5 20.1				88.4 -79.5 14.1 -41.3		106.4 -105.9 46.4 -61.4	32.9 -101.9 180.7 -118.5		48.5 -52.5 -102.3 195.5
D										-200.6 127.3 86.6 138.6		-144.3 134.8 42.7 93.4				95.5 -20.1 -47.1 -116.2		28.7 -115.5 -92.7 -138.1 11.4 -111.4	58.2 -134.1 69.3 -247.0 169.7 -266.9		-127.6 114.1 -194.7 115.9 -105.2 -52.5
C										-137.8 -12.9 237.3 296.1	○ 64.4 ⊕ 118.2 ○ 209.1 ◑ 260.8 ◓ 25.6 ◔ 124.4	62.0 106.5 176.1 216.4 -0.3 113.6	38.8 65.4 90.7 114.3 -39.8 73.6	-1.6 12.6 -58.7 -91.3 -109.9 13.7		-48.4 0.0 -153.4 -210.1 -162.9 -42.0		-127.3 -76.9 -278.0 -306.2 -211.1 -3.3	-180.6 -33.0 -267.9 -435.8 -105.0 -226.2		-279.8 -56.5 -318.6 -237.9 -47.4 -110.7
B	1035.0			660.0		408.0	190.0	-148.0	-360.0	-460.0	-447.0	-361.0	-141.0	188.0		388.0		636.0	777.0		1009.0
Rib x=0	-828.0			-449.0		-223.0	-61.0	196.0	338.0	395.0	400.0	345.0	178.0	-80.0		-242.0		-429.0	-538.0		-605.0
A											21.8 -25.7 -55.1 20.8		104.4 -57.6 -106.4 81.8			93.6 25.5 -51.9 -44.1					128.3 44.4 46.7 -74.4









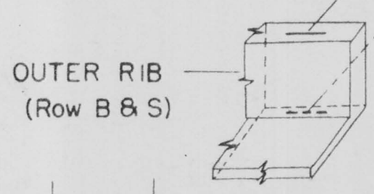


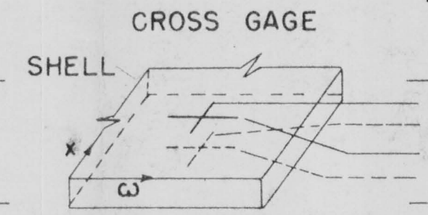
TEST: T-7: END ROTATION OF THE ABUTMENTS

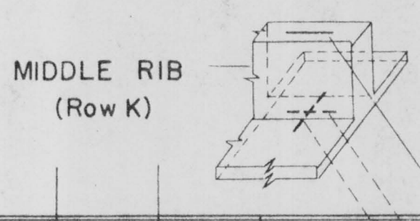
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

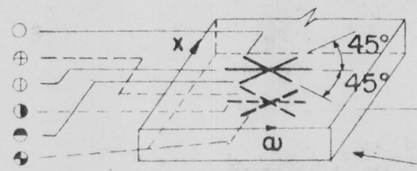
FOR LOCATION OF STRING GAGES SEE FIGURE 8

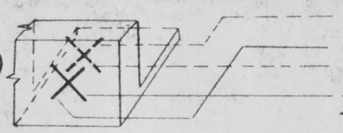
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-682.0			-508.0		-361.0	-253.0	-60.0	57.0	130.0		57.0	-62.0	-264.0		-382.0		-524.0			-723.0
Rib x=h	481.0			369.0		234.0	162.0	18.0	-61.0	-117.0		-62.0	16.0	165.0		241.0		368.0			460.0
R										19.5 33.0 -76.6 -90.0											
Q										54.8 -37.6 -24.8 -38.7											
P										51.7 -53.5 7.3 -12.2											
O										46.7 -47.7 7.4 -6.3		-34.1 -22.8 5.1 -4.2	-6.9 4.9 -0.8 3.8	-44.5 -44.2 -14.5 7.5				-75.9 53.4 -60.4 47.2			
N										42.7 -30.3 -22.4 -19.0											
M										14.2 26.5 -65.4 -44.8		32.7 -4.7 -22.1 -39.8	-5.1 3.7 2.2 9.9	-32.8 9.6 26.1 82.6				101.8 4.1 117.3 146.7			
L										-46.2 114.4 -81.4 -76.7		-34.6 79.1 -50.8 -65.6	-45.2 -13.6 8.5 17.4	69.4 -105.2 76.8 128.4				55.3 -246.3 227.9 255.9			
K	696.0			-512.0		-367.0	-270.0	-73.0	69.0	150.0	141.0	73.0	-77.0	-289.0		-388.0		-531.0	-620.0		-714.0
	503.8			309.2		198.7	149.7	23.3	-59.8	-105.9	-102.6	-68.0	16.3	146.9		202.3		314.7	396.0		256.5
Middle Rib	-159.6			-106.2		-88.5	-55.9	-8.8	26.0	60.5	51.4	32.2	-8.5	-60.8		-104.6		-105.3	-162.0		-84.5
I										-37.9 109.5 -90.6 -108.5	-52.7 -0.7 -66.9 -88.3 -55.8 -13.9	-28.8 1.4 -53.2 -53.7 -54.3 -20.0	27.4 8.0 9.0 19.2 -18.6 -1.2	113.1 19.3 91.6 137.7 36.5 32.6		143.6 -1.2 154.5 173.4 60.8 8.0		131.9 -13.4 228.4 263.9 144.0 16.3	62.0 136.0 218.5 — 177.5 41.0		-78.6 52.5 287.0 369.2 342.6 248.7
H										47.9 -12.5 -27.6 -75.5		4.9 -11.2 -28.1 -23.6				-52.8 -19.0 85.7 90.5		-33.3 62.8 103.4 153.4 12.7 95.6	-107.3 161.4 38.9 217.8 59.4 114.4		3.0 -4.8 135.8 -11.1 181.8 34.9
G										52.7 -31.4 6.2 -45.9		14.9 -24.8 0.5 -6.2				-69.7 41.6 22.3 39.6		-114.6 63.5 -9.2 83.8	-30.4 80.2 -75.9 110.2		41.6 39.6 90.5 -108.2
F	36.6 34.5 69.7 -140.0	65.2 72.0 -67.1 -31.4	18.4 — -133.5 -51.0	-66.3 58.9 -79.7 59.9	-75.4 93.5 -14.5 10.9	-63.5 99.1 -13.8 22.7				49.5 -35.1 12.3 -24.8		21.7 -28.8 7.3 -6.0	-4.8 -2.0 -4.8 1.1	-41.4 40.9 -15.6 0.6	-56.4 37.7 -15.1 6.7	-67.2 68.0 -22.7 27.7	-60.1 98.6 -26.0 9.7	-66.6 56.4 -70.7 46.1	19.3 46.7 -128.5 66.4	67.4 57.8 -73.2 -26.9	37.5 28.7 72.7 -140.8
E										53.9 -36.3 -1.2 -20.8		24.8 -28.7 6.2 -8.0				-88.1 76.6 -25.0 38.4		-89.4 91.2 -45.0 51.9	-27.6 85.2 -129.9 82.1		36.0 37.1 88.7 -154.1
D										53.0 -27.4 -31.7 -47.0		26.5 -16.1 -13.1 -26.4				-88.4 42.6 43.9 101.5		-23.5 82.8 67.4 123.4 -20.5 96.1	-33.1 95.5 -48.3 182.3 -128.2 202.8		100.3 -83.7 144.1 89.7 73.8 33.8
C										19.3 35.5 -70.6 -85.1	○ -35.5 ⊕ -26.6 ◑ -66.0 ◑ -80.6 ◓ -22.2 ◔ -18.4	-36.0 -10.6 -44.9 -55.5 -7.2 -15.8	-23.4 6.1 8.3 10.1 20.5 3.8	8.6 18.3 79.0 125.5 62.8 32.6		37.6 14.6 141.7 193.2 106.1 61.6		98.8 59.6 210.5 243.3 141.7 16.7	142.6 22.2 198.4 321.6 59.8 171.4		218.4 39.2 232.5 168.8 20.1 78.1
B	-705.0			-493.0		-364.0	-249.0	-56.0	56.0	121.0	118.0	67.0	-55.0	-245.0		-363.0		-497.0	-571.0		-717.0
Rib x=0	576.0			353.0		227.0	148.0	18.0	-69.0	-110.0	-109.0	-77.0	17.0	156.0		239.0		347.0	401.0		433.0
A											-9.6 13.2 18.3 -5.4		-54.5 14.0 45.8 -30.4			-30.5 -57.7 -14.0 -7.1					-66.3 -42.8 -77.7 86.3









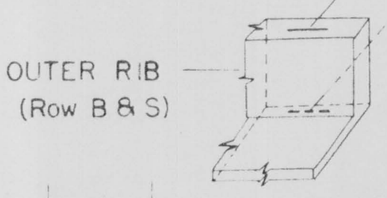


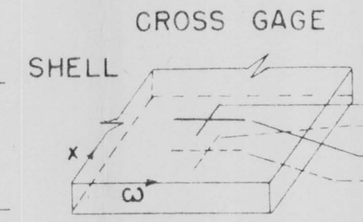
TEST: T-8: CONCENTRATED LOAD ON MIDDLE RIB AT CENTER OF SPAN

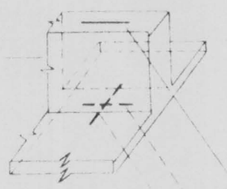
EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

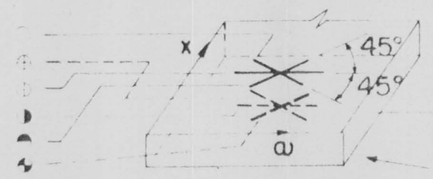
FOR LOCATION OF STRING GAGES SEE FIGURE 8

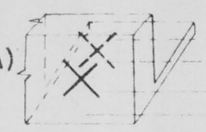
	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	-269.0			-46.0		97.0	187.0	175.0	-46.0	-328.0		4.0	228.0	211.0		88.0		-104.0			-398.0
Rib x=h	136.0			-52.0		-151.0	-243.0	-208.0	41.0	352.0		-2.0	-266.0	-282.0		-186.0		-29.0			189.0
R										65.5 -229.4 252.5 288.3											
Q										-100.2 13.3 130.2 169.4											
P										-118.4 76.8 30.9 94.3											
O										-99.5 53.8 -11.7 63.1		62.9 -38.6 29.9 -9.7	92.9 -43.1 -2.1 -25.5	78.2 -59.8 20.4 -3.0				21.3 -21.2 -9.7 7.7			
N										-108.8 27.6 26.6 72.0											
M										-107.9 48.3 119.6 130.5		84.5 0.8 -76.7 -143.9	109.8 10.1 -57.6 182.1	73.6 -3.2 -50.4 -143.7				1.4 11.8 -42.0 -23.4			
L										-117.6 -143.3 201.7 354.5		-61.0 212.2 -177.8 -222.8	-69.5 242.6 -162.5 -264.8	-92.0 179.6 -145.8 -233.7				-19.4 36.1 -48.3 -39.2			
K	-347.0			-66.0		113.0	245.0	295.0	12.0	-1115.0	-855.0	13.0	293.0	262.0		119.0		-73.0	-199.0		-363.0
Middle Rib	160.2 -71.3			-43.4 12.4		-149.2 69.9	-235.2 102.7	-300.9 156.9	-216.3 107.1	320.4 -202.5	137.3 -109.5	-228.0 127.5	-289.5 145.5	-251.5 114.3		-154.2 101.0		-37.6 18.2	44.7 -21.5		87.5 -50.9
I										-147.3 -172.2 194.7 281.4	-161.3 -91.4 63.4 94.4 105.5 155.0	-181.9 -127.8 -159.9 -194.0 0.0 36.8	-132.2 -98.0 -155.2 -303.8 -35.0 -85.8	-122.4 -11.2 -163.6 -223.9 -115.2 -82.7		-59.4 24.5 -127.5 -131.5 -115.6 -24.5		23.0 35.4 -42.3 -29.0 -91.5 -16.8	31.1 42.3 10.7 — -51.6 -14.9		-6.0 42.8 55.1 105.8 47.1 52.0
H										-254.8 32.6 44.5 190.7		76.7 -27.9 -82.5 -93.0				42.3 -2.8 -69.3 -66.8		25.9 4.8 -27.2 -18.1 -43.5 -8.9	3.6 11.7 -12.6 19.8 -30.0 12.7		2.9 8.6 -6.2 17.8 6.0 19.8
G										199.5 34.6 -39.3 131.7		85.0 -52.3 -33.8 -48.2				56.5 -41.0 -17.9 -28.6		20.4 -12.4 -13.6 -17.6	5.7 3.4 -20.2 18.9		12.7 8.6 -22.4 10.7
F	10.7 9.4 -26.3 17.7	18.0 10.4 -30.6 16.6	21.0 — -29.7 14.0	21.2 -15.0 -6.7 0.5	35.0 -46.8 -1.2 -3.4	49.6 -66.6 11.3 -8.8				-154.4 22.2 41.8 106.1		40.0 -20.4 -2.3 -18.3	100.4 -39.0 13.6 -29.7	73.1 -65.7 24.5 -6.8	69.3 -42.9 -18.7 -1.6	51.4 -47.7 16.3 -6.4	30.8 -33.9 6.0 -0.9	21.1 -20.1 -3.7 4.7	15.7 0.5 -22.5 14.9	18.0 6.4 -30.6 18.8	10.0 6.4 -29.3 17.8
E										-142.2 35.6 10.7 128.7		9.6 13.4 12.7 -12.4				65.5 -62.2 12.8 -20.9		27.1 -25.9 -9.9 -0.1	22.7 0.5 -21.7 15.9		11.0 5.4 -31.3 17.8
D										-105.4 17.6 106.4 191.4		-17.6 18.9 18.6 1.4				77.0 -42.9 -32.5 -62.5		-8.6 -4.2 -16.7 -17.5 26.2 -34.9	-6.2 14.2 -15.4 10.1 7.1 -8.3		-11.0 9.7 -23.2 17.9 2.2 14.8
C										71.8 -259.9 243.3 306.3	115.5 -8.7 202.9 234.4 109.4 79.1	-20.9 -34.2 25.1 20.9 -3.5 98.7	-97.9 -70.2 -135.7 -175.2 -46.8 11.5	-92.1 -54.4 -142.0 -204.2 -38.9 -24.8		-76.6 -37.1 -111.1 -141.1 -18.3 -41.2		-55.7 -17.6 -39.3 -35.9 34.2 -19.6	-21.8 2.0 0.7 17.3 37.5 0.0		10.6 22.5 17.8 50.0 16.8 23.5
B	-405.0			-106.0		85.0	220.0	221.0	-5.0	-324.0	-293.0	-57.0	159.0	199.0		107.0		-35.0	-146.0		-284.0
Rib x=0	236.0			-29.0		-176.0	-284.0	-260.0	10.0	338.0	307.0	52.0	-200.0	-242.0		-182.0		-59.0	26.0		110.0
A											61.9 -44.5 -58.0 45.4		50.1 -43.5 -63.6 45.4			-64.6 12.1 51.1 -33.4					-104.7 1.3 59.4 -41.0











TEST: T-9: CONCENTRATED LOAD ON EXTERIOR RIB AT CENTER OF SPAN

EXPERIMENTAL STRAINS IN SHELL AND RIBS + TENSION, − COMPRESSION } IN MICRO-INCHES

FOR LOCATION OF STRING GAGES SEE FIGURE 8

	11'	10'	9'	8'	7'	6'	4'	3'	2'	℄	1	2	3	4	5	6	7	8	9	10	11
S	238.0			88.0		-14.0	-78.0	-108.0	-28.0	126.0		19.0	-47.0	-47.0		-12.0		40.0			115.0
Rib x=h	-137.0			-12.0		73.0	129.0	148.0	26.0	-167.0		-14.0	104.0	99.0		65.0		20.0			-49.0
R										123.0 -75.6 -94.0 -99.4											
Q										98.0 -76.4 -33.2 -45.6											
P										46.6 -18.1 -18.9 -26.4											
O										-0.2 51.6 -24.0 -19.7		-13.1 -8.9 2.4 -3.7	19.7 -11.2 8.3 6.4	17.9 -5.2 2.4 6.2				15.5 -1.9 14.5 -2.9			
N										-27.6 108.0 -12.1 -2.6											
M										-17.1 96.2 33.5 21.8		-34.2 -8.0 7.1 -0.7	50.1 -19.5 -4.7 -44.3	55.6 -33.5 -19.8 -44.8				17.2 -6.8 -6.6 -4.8			
L										83.8 -24.6 92.1 78.7		-51.2 5.9 7.7 3.8	6.3 34.7 -40.2 -81.1	24.9 31.1 -56.8 -94.9				-4.2 23.7 -24.2 -21.8			
K	-177.0			-32.0		58.0	116.0	112.0	-24.0	-195.0	-179.0	-19.0	120.0	140.0		69.0		-26.0	-97.0		-187.0
Middle Rib	84.3			-26.1		-87.0	-127.1	-115.3	3.9	165.0	148.3	0.6	-107.8	-134.6		-85.8		-29.5	20.2		47.4
	-41.8			3.9		32.9	36.2	42.8	-26.1	-40.0	-72.9	-19.0	57.5	82.4		55.8		15.0	-6.7		-14.5
I										338.0 -321.0 183.0 205.0	144.4 -21.8 119.6 185.5 206.7 -57.5	-52.9 54.0 11.4 18.2 41.1 -47.1	-116.9 26.0 -68.7 -139.2 -90.4 -47.5	-102.9 20.4 -111.9 -143.8 -135.7 -19.4		-64.4 41.0 -93.9 -92.7 -15.5 0.1		5.7 16.0 -44.3 -30.9 -79.1 1.7	18.0 14.9 -3.4 -44.4 2.7		1.6 24.1 30.2 65.9 21.0 39.5
H										42.0 27.0 47.0 154.0		-21.5 -21.1 15.7 4.7				16.7 14.6 -50.5 -49.4		19.1 -19.2 -32.9 -13.0 -50.4 11.4	10.5 -9.3 -11.8 2.9 -22.2 14.2		0.0 -5.6 -11.2 12.7 -1.0 28.1
G										-54.0 126.0 -63.0 87.0		-9.8 -35.3 25.3 10.2				37.9 -32.3 2.7 -19.9		13.4 -10.2 -12.4 7.3	12.5 -1.4 -15.4 12.0		13.7 11.4 -20.4 17.6
F	8.2 6.7 -36.2 9.8	22.3 10.7 -38.7 7.6	18.1 — -32.6 8.0	12.5 -21.3 -16.4 8.7	25.0 -42.9 0.2 -2.6	42.1 -67.6 26.6 -9.7				-102.0 150.0 -82.0 56.0		13.1 -59.0 26.5 2.0	80.5 -74.7 13.3 24.5	60.9 -72.4 30.9 15.4	33.0 -57.5 27.1 16.9	37.7 -51.9 36.7 -2.3	22.5 -38.6 13.2 18.3	8.1 -14.6 -2.3 17.5	17.7 6.3 -20.5 19.8	20.9 7.4 -28.7 17.7	9.7 9.4 -20.3 18.7
E										-173.0 189.0 -30.0 95.0		37.9 -73.5 2.7 -12.5				79.8 -83.4 35.3 -14.2		18.0 -19.5 0.4 16.6	14.0 19.9 -30.4 31.3		16.6 13.9 -19.5 3.5
D										-207.3 135.7 107.8 215.3		36.4 -43.1 -44.2 -56.5				118.2 -105.4 -9.9 -74.4		4.5 -7.3 -4.6 -1.1 23.9 -33.8	-2.8 33.3 -18.0 49.6 -9.9 29.3		-2.2 -9.8 -7.3 13.7 10.0 36.2
C										-110.5 -113.4 318.3 434.3	○ 180.7 ⊕ 158.1 ◐ 202.7 ◑ 273.0 ◓ -36.0 ◒ 37.5	5.2 28.6 -113.1 -126.5 -143.0 -72.6	-43.8 -121.9 -250.7 -313.4 -101.0 -135.3	-60.0 -118.3 -190.4 -277.1 1.3 -120.3		-48.2 -83.0 -127.6 -165.5 12.1 -89.2		-33.5 -36.1 -20.1 -17.6 67.7 -30.2	7.5 -1.5 35.0 64.7 66.8 22.0		45.5 28.9 51.5 97.1 22.0 40.3
B	-629.0			-184.0		100.0	315.0	364.0	-4.0	-1036.0	-845.0	-46.0	315.0	281.0		132.0		-102.0	-268.0		-471.0
Rib x=0	373.0			-22.0		-256.0	-434.0	-480.0	-196.0	552.0	387.0	-165.0	-407.0	-376.0		-242.0		-47.0	81.0		212.0
A										44.2 -66.5 -218.2 -104.3			1.0 -15.2 -30.0 -24.5			-100.5 12.8 77.2 -54.4					-144.1 0.4 67.7 -43.0