THE EFFECT OF FLOOR SLABS ON THE MOMENTS IN COLUMNS

by

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I. INTRODUCTION

Design practice at the present day trends toward more and more complex forms of the reinforced concrete frame. The essentially monolithic character of a reinforced concrete structure produces a continuous frame of column, beam, and slab. The result of continuity, a reduction of critical moments and shears, and the inherent wind bracing, are important contributions to increased building economy. In the continuous reinforced concrete structure, economy may be enhanced by recognizing the continuity between slabs and columns and utilizing the consequent reduction of critical beam and slab moments.

At the present, the design standards which apply to the slab and column type of structure are inexact because of limited knowledge of the behaviour of the slab-and-column continuous frame. This limited knowledge has heretofore been obtained by tedious measurements of the actual deformations of such frames, and the stresses and strains deduced by unwieldly computations. The arrival of the electric resistance strain gauge helps to make known the stresses and strains of statically indeterminate frames rapidly, reliably, and with a more complete understanding.

It is the purpose of this study to show the stress distribution in a slab supported by four columns fixed rigidly

to the slab and to show the relation of stresses in the slab to those in the column. It is hoped that the work and results of this investigation will furnish enough evidence to help provide proposals of analysis beyond those already available.

The study presented here comprises the loading and testing of a scale model building frame of slab and columns. For simplicity, a basic four-column square bay with a slab overhanging one-half bay on all sides, was chosen for the investigation. Structural steel was selected for the material because of availability and simplicity of construction. The behaviour of a similar reinforced concrete model may be approximated by making suitable allowance for the differences in properties of the two materials. Stresses in the slabs and columns were obtained through strain gauges for various load positions on the slab. Results were obtained from compilation of this data and some conclusions are drawn.

The author is indebted to the following: John F. Poulton, Associate Professor of Structural Design for the recommendation of this study and for his keen interest and guidance; John W. Flemer for his generous help in conducting this investigation; Professor D. H. Pletta, Professor F. J. Maher, Mr. W. P. Murden, Jr., and Mr. G. K. McCauley of the Applied Mechanics Department for their advice and assistance; the Virginia Bridge Company of Roanoke, Virginia from whom the materials

for the model were obtained; and Mrs. E. L. Miller, Jr. for her valuable aid in preparing this thesis.

II. PRELIMINARY DESIGN

A preliminary design was necessary to obtain a model capable of sustaining appreciable loadings, and at the same time able to withstand strains of an amount great enough to register accurately on the recording equipment. Previous work on this subject has produced the following approximation for design: a flat slab may be considered as a wide, shallow beam; in this beam, stresses resulting from a given loading diminish rapidly from the immediate region of the load; consequently it has been suggested that the workable equivalent beam width be considered as 1/4 of the span. Using this approximation the dimensions of the model were determined by analysis of a bent composed of two columns and a strip of slab.

Before undertaking the investigation of the model it was necessary to decide upon the locations of the electric resistance strain gauges and the loading positions. The gauges used in this study were rectangular rosette type, i.e. they recorded strains in three directions, 45° apart, thus enabling the magnitude and direction of the principal surface strains to be determined. It was decided that a maximum of 16 of these rosettes could be fastened on a 7" by 7" quadrant. This determined a grid of 1/6, i.e. the rosettes were located on the sixth parts of the plate (or third parts of the plate quadrant). Because the grid for the gauges

determined one extent of accuracy, it would have meant little to have a loading grid of greater accuracy. It was decided that a 1/4 grid would suffice for the loadings. This was somewhat substantiated by noting that the effect of a uniform load on a simple beam could be predicted with about 3% error from the effects of concentrated loads placed at the quarter points.

It was apparent that it would be necessary to load by symmetrical pairs in order that all four columns would have a downward thrust, since no simple method could be found to anchor the columns against tension. The pairs of loading would also greatly reduce the number of different loading positions.

The resulting model consisted of a square plate 28" by 28" by 1/2" supported by four one inch diameter round columns 10" high and 14" on center. The plate provided a 7" overhang (half bay) for the purpose of simulating a degree of continuity in the slab. It was decided to support the columns on a base plate 17" by 17" by 1/2" in order to prevent horizontal movements of the columns.

Figures 1, 2, and 3 present the results of the preliminary design.

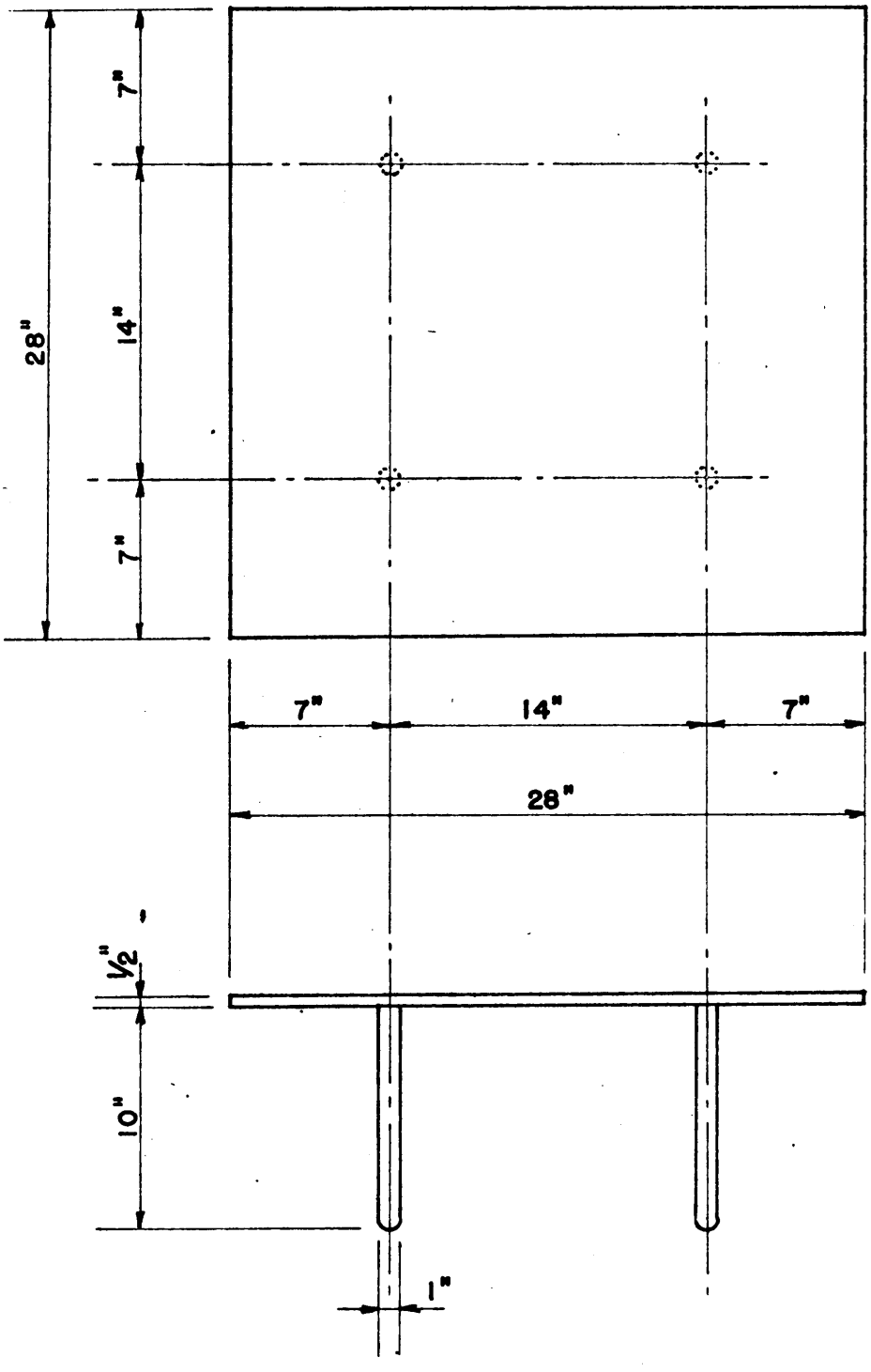
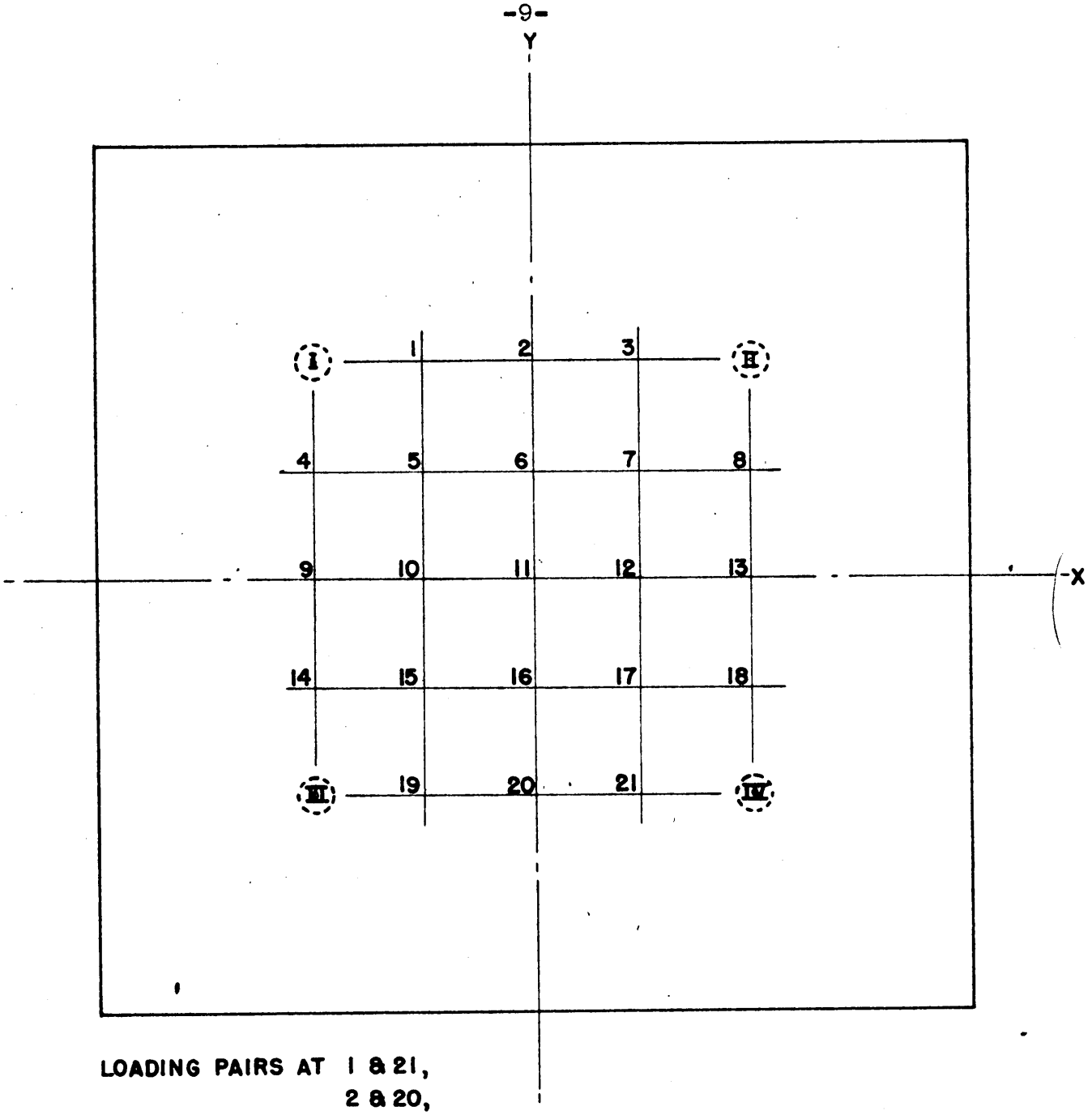
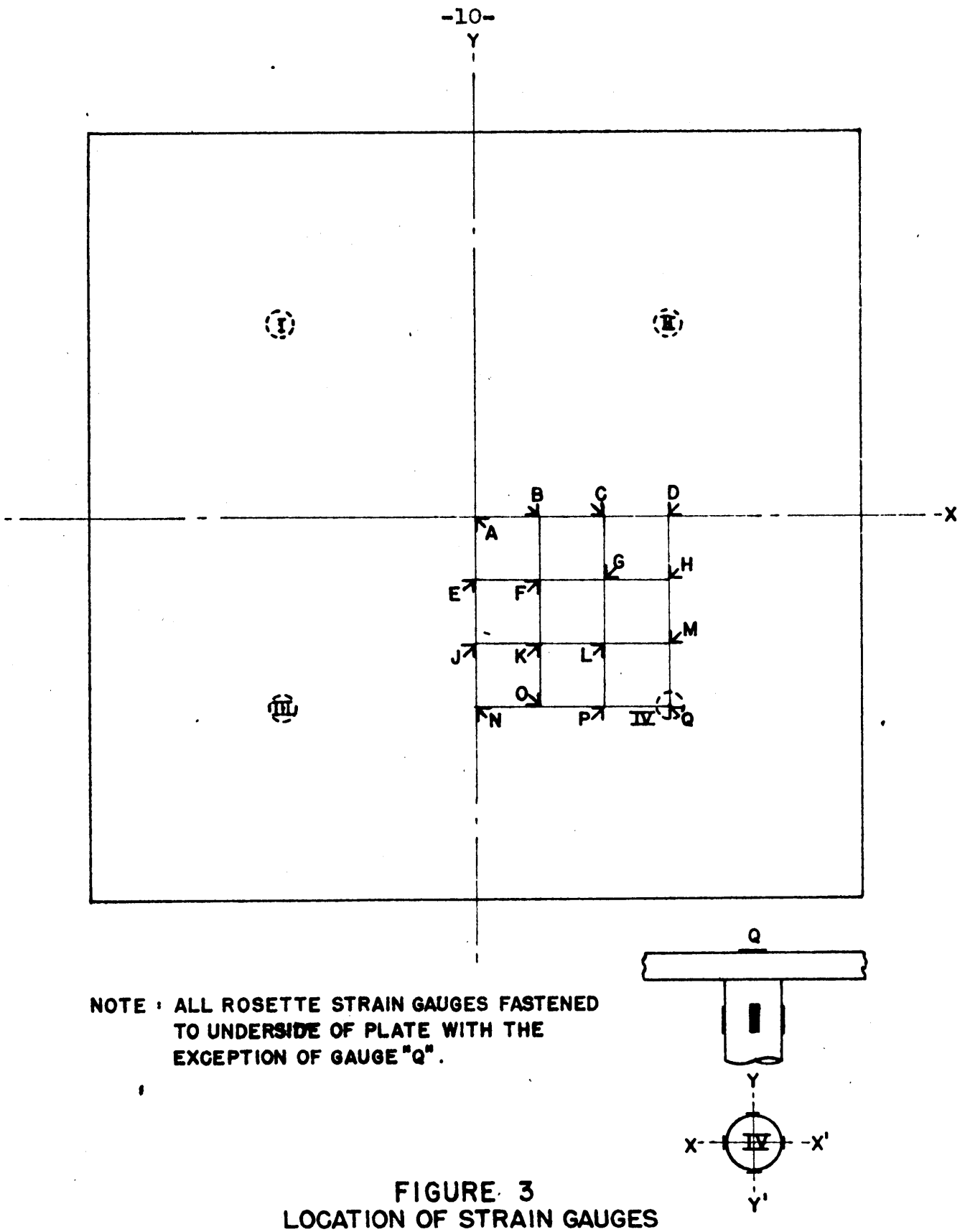


FIGURE 1: THE MODEL



LOADING PAIRS AT 1 & 21,
2 & 20,
3 & 19,
5 & 17,
6 & 16,
7 & 15
AND ONE AT 11

FIGURE 2
THE LOADING POINTS



NOTE : ALL ROSETTE STRAIN GAUGES FASTENED TO UNDERSIDE OF PLATE WITH THE EXCEPTION OF GAUGE "Q".

FIGURE 3
LOCATION OF STRAIN GAUGES

III. ASSEMBLY OF THE MODEL

The steel obtained from the Virginia Bridge Company of Roanoke, Virginia was of intermediate grade, structural quality. The slab plate and the base plate were sheared off at the sizes stated in the previous chapter. The columns were cut to approximate length and were finished to the specified dimensions at the VPI machine shop. The columns were designed as 10" lengths having slightly tapered and rounded ends so as to simulate "pinned" ends when seated in countersinks drilled in the base plate. The columns were electrically butt-welded to the underside of the slab plate. This was accomplished by laying the slab plate on a horizontal surface, setting the columns in their specified positions, bottom ends up, and clamping the inverted base plate over the rounded ends of the columns. Difficulty was encountered with the entire operation because of slight warping induced in the two plates when they were cut by shearing.

After the model had cooled and had been set up for checking purposes it was noted that the columns did not seat evenly in the countersinks. It was inferred that additional warping resulting from the heating and cooling of the metal was the cause. It was decided that an initial load, when testing the model, would deflect the structure sufficiently to seat the columns. In order to make the warped base plate seat evenly

upon a flat surface, flat round buttons of weld were fused to the under side and levelled to a single horizontal plane.

IV. PREPARATION OF THE MODEL FOR THE INVESTIGATION[1]

The surfaces of the model were cleaned where the gauges were to be attached. The loading grid and the gauge location grid which were determined in the preliminary design were scribed upon the slab plate. The rosette gauges were pasted upon the under side of the slab plate at points determined by the grid. Four linear type gauges, which would measure the column strains, were pasted symmetrically around the top of the column located in the quadrant where the rosettes were located. See Fig. 3.

Wire leads approximately 36" long were soldered to the gauges and carefully tagged. A twenty-four hour drying period was required before the model could be stressed. After this drying period the gauges were checked with an electric strain recorder and it was found that three gauges were defective. These were replaced, allowed to dry and rechecked. The model was now ready for the investigation.

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[1] W. B. Dobie and P. C. G. Isaac, Electric Resistance Strain Gauges, London, The English Universities Press Limited, 1948.

V. THE INVESTIGATION

A. EXPLANATION

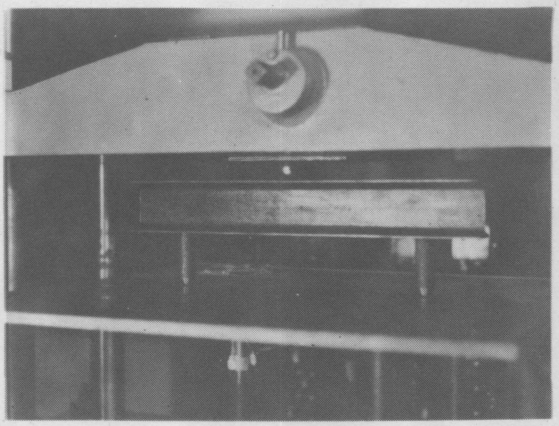
As was previously mentioned it was decided to load the model with symmetrical pairs. In order to do this it was necessary to devise a loading technique using an I-beam having as its reactions two movable pins, symmetrical about a fixed fulcrum in the center. This form made it possible to load at all points on the loading grid without necessitating moving the model or the position of the fulcrum (the I-beam was free to rotate in all directions). See Plate 1.

Because of the probability that the columns would not seat perfectly in the countersinks of the base plates, it was deemed necessary to apply a load of between 1000 and 1500 pounds before "zeroing in" the strain gauges. It was noted, after this initial load was applied, that by pushing the columns audible clicks indicated the final seatings of the columns. It was reasoned that the column ends were not coincident with the countersinks and the initial load with lateral aid was sufficient to force the columns to firm seatings in the countersinks. For an additional check, an Ames Dial was placed, in turn, against each column after they had been seated. By again pushing the columns, it was noted that but a slight deflection was indicated by the Ames Dial. It then seemed apparent that the columns were

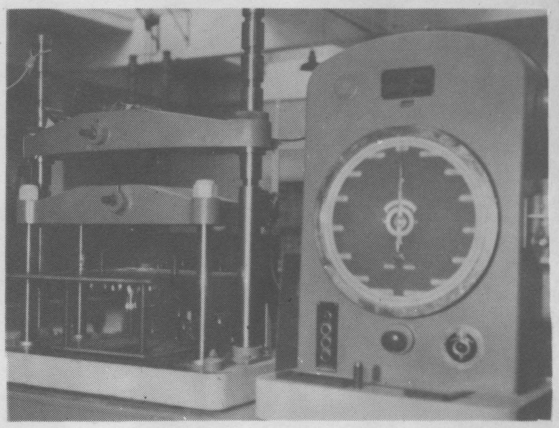
adequately seated. This was borne out later during the subsequent investigation when, at no time, under much greater loads, was there any indication of further movements at the seatings.

After the columns were seated under the initial load, all the rosette gauges on the plate, the linear gauges on the column, and the compensating gauge, were "zeroed in" at a reading of 1000 micro inches per inch on the electric strain recorder. By "zeroing" at 1000 micro inches per inch it was possible to read positive and negative strains. Readings below 1000 micro inches per inch would indicate compressive strains and the readings above 1000 micro inches per inch would denote tensile strains. After all the gauges were "zeroed" upon this mark an additional load of two or three thousand pounds was applied. Maintaining this load, each gauge was read and that gauge which indicated a maximum strain was located. This critical gauge having been determined, the loading was continued until a reading of approximately 900 or 1000 micro inches per inch, on either side of the 1000 mark, was reached. This indicated that the model was strained, at that particular gauge point, until a stress of approximately 30,000 pounds per square inch was produced. The load was then completely removed, the initial load of 1000 pounds again applied, and the gauges "zeroed" once more. This repeat operation was necessary because of some creep inherent in the

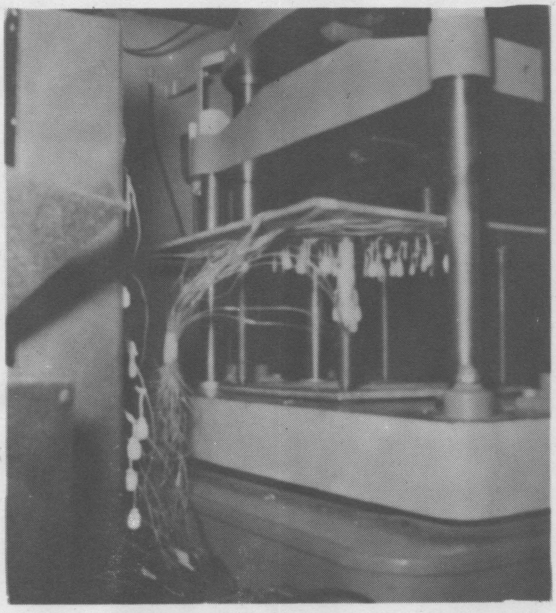
natures of the gauges, of the glue which fastened the gauges, and possibly of the wire connections. With reference to the critical gauge, the model was again loaded to that point where the gauge recorded 900 or 1000 micro inches per inch, plus or minus. The readings of all the gauges were recorded, and this having been done, all the load but that amount with which the gauges were "zeroed" was removed. All the gauges were checked for an additional serious creep and if there was such a creep, they were again "zeroed", the load reapplied, and strains rerecorded. This process was repeated for all the necessary loadings. See Plate 1.



THE LOADING TECHNIQUE



THE LOADING MACHINE



WIRE LEADS CONNECTING
STRAIN GAUGES AND
RECORDING INSTRUMENTS

THE RECORDING INSTRUMENTS

PLATE 1

B. RESULTS

Tables I and II and Figures 4 through 15 comprise the results of this thesis.

Table I presents the measured surface strains in micro inches per inch recorded by each gauge, corrected as follows. In order to approximate the effect of a uniform, distributed load, it was necessary to add the resulting strains for loads of equal magnitude at all loading points. However, not all the individual loads were equal so, to procure the uniform load, all the individual loads were proportioned to an equal amount of 5000 pounds. Hence, the strains presented in Table I are not those actually measured.

The principal stresses in thousands of pounds per square inch and stress directions in degrees analogous with the measured strains are presented in Table II. To obtain the maximum and minimum principal stresses the following equations were used:[1]

$$p,q = E\left[\left(\frac{\epsilon_x+\epsilon_y}{2}\right)\left(\frac{1}{1-\nu}\right) \pm \left(\frac{\frac{\sqrt{2}}{2}\sqrt{(\epsilon_x-\epsilon_{xy})^2+(\epsilon_{xy}-\epsilon_y)^2}}{1+\nu}\right)\right];$$

in which p,q are the maximum and minimum principal stresses respectively, E is the modulus of elasticity of steel (30,000,000 psi), ν is Poisson's ratio (.30 for steel), and $\epsilon_x, \epsilon_{xy}, \epsilon_y$ are the strains measured by components of the rectangular rosette gauge.

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[1] M. M. Frocht, Photoelasticity, Vol. I, Chap. I, New York, John Wiley and Sons, Inc. 1941.

The strain or stress directions were obtained by using the following equation: $\tan 2\theta_{pq} = \frac{2\epsilon_{xy} - (\epsilon_x + \epsilon_y)}{\epsilon_x - \epsilon_y}$;

in which θ is the angle measured from either the x or y axis indicating the direction of the principal stress. In Table II, the subletter x or y by the angle θ indicates the axis from which θ was measured.

Having obtained the principal stresses, curves connecting points of equal stress were plotted upon the quadrant having the gauge locations for each of the separate loadings. These were then combined in logical relationship to present stress curves for the whole plate within the confines of the columns. A linear interpolation was used to obtain the curves. These stress curves, presented in Figures 4 through 15, represent pictorially the results of this experiment.

TABLE I
MEASURED STRAINS

GAUGE	LOAD APPLICATIONS																							
	1 & 21			2 & 20			3 & 19			5 & 17			6 & 16			7 & 15			11			UNIFORM		
	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y	ϵ_x	ϵ_{xy}	ϵ_y
A	380	80	-87	610	243	-167	356	229	-90	479	263	455	1050	732	333	419	635	400	1110	1140	1080	4390	4610	4320
B	330	87	-70	475	193	-110	306	167	-77	506	326	443	682	582	465	440	550	390	263	419	577	3290	3825	4350
C	200	107	-30	194	117	-10	197	160	-37	326	420	427	193	350	483	296	270	343	27	207	343	1725	3290	4490
D	57	-13	13	50	50	33	50	87	7	-7	100	413	-93	167	400	7	290	370	-80	93	270	905	2755	4490
E	400	270	-70	670	267	-147	376	50	-77	450	627	512	1270	900	577	356	277	450	577	426	270	4350	3845	3320
F	430	194	-87	500	100	-83	256	20	-35	670	870	680	615	533	583	300	230	307	300	433	314	3450	3230	3480
G	267	0	-37	184	17	17	120	27	-17	443	420	705	133	310	467	157	210	250	37	253	277	1640	2115	3550
H	30	-63	13	17	17	33	30	67	0	-87	187	543	-127	200	367	-20	210	240	-77	137	220	235	1780	3305
J	413	313	0	900	416	-60	367	77	0	426	307	320	1220	850	367	376	376	280	380	207	27	4495	3275	1715
K	614	353	-30	532	67	17	210	0	-30	685	406	473	565	595	360	250	220	150	263	242	50	3550	2240	1685
L	330	-93	-37	100	-117	-10	30	-50	-40	413	530	413	243	210	200	67	70	47	57	130	57	1185	630	1165
M	-120	-114	7	-100	0	-27	-17	57	-37	-223	230	287	-200	160	133	-117	87	37	-100	100	57	-1145	805	965
N	370	230	100	1520	1185	815	330	247	87	487	330	-7	755	333	-83	370	90	10	253	93	-77	4430	2780	910
O	670	550	413	493	333	160	190	90	-40	550	273	-87	533	50	-67	240	10	-27	207	113	-63	3295	1640	240
P	357	257	187	50	-77	-160	7	-80	-147	273	220	-220	93	183	-150	40	90	-107	50	87	-87	985	785	1120
Q	-353	-270	-243	-243	-227	-233	-100	-120	-140	-243	-400	-187	-233	-333	-150	-120	-210	-90	-77	-150	-63	-2140	-3075	-2040
X	-1345			-1310			-900			-1145			-1255			-680			-487			-8390		
Y	-213			-83			17			-1190			-985			-775			-507			-8545		
X'	965			1080			747			850			1070			558			413			6045		
Y'	-37			-167			-127			845			705			620			400			6095		

TABLE 2
PRINCIPAL STRESSES AND DIRECTIONS

GAUGE	LOAD APPLICATIONS																							
	1 & 21			2 & 20			3 & 19			5 & 17			6 & 16			7 & 15			11			UNIFORM		
	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.	PRINCIPAL STRESSES		DIR.
	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ	MAX.	MIN.	θ
A	11.9	0.7	-8°$_X$	18.6	0.5	2°$_X$	11.3	0.1	12°$_X$	24.9	15.4	-43°$_X$	39.0	21.5	3°$_X$	22.9	12.3	44°$_X$	48.0	45.8	36°$_X$	193.0	179.0	41°$_X$
B	10.2	0.9	-7°$_X$	14.6	1.1	1°$_X$	9.6	0.4	8°$_X$	24.9	17.3	-39°$_X$	27.2	22.3	2°$_X$	21.0	14.7	40°$_X$	20.5	14.4	0°$_Y$	176.0	152.0	0°$_Y$
C	6.4	1.0	-5°$_X$	6.4	1.6	7°$_X$	6.7	0.4	17°$_X$	17.7	14.6	-20°$_Y$	17.9	11.2	-2°$_Y$	15.9	12.6	25°$_Y$	12.7	4.7	-1°$_Y$	165.0	101.0	-4°$_Y$
D	2.7	0.3	-33°$_X$	2.1	1.6	23°$_X$	2.7	-0.2	35°$_X$	14.1	3.4	13°$_Y$	12.3	0.9	-2°$_Y$	12.9	3.4	-15°$_Y$	8.0	0.0	0°$_Y$	156.0	74.0	-1°$_Y$
E	13.1	1.2	12°$_X$	20.8	2.1	0°$_X$	11.6	1.2	-12°$_X$	24.1	17.4	-39°$_Y$	46.9	32.5	-2°$_X$	21.4	14.6	39°$_Y$	21.6	14.7	1°$_X$	176.0	152.0	1°$_X$
F	13.4	1.4	2°$_X$	16.2	1.9	-10°$_X$	8.7	0.8	-15°$_X$	33.6	24.6	-45°$_Y$	27.3	24.1	-38°$_X$	14.7	11.3	44°$_Y$	15.0	10.2	-44°$_Y$	154.0	143.0	43°$_Y$
G	8.9	0.4	-18°$_X$	7.0	1.6	-23°$_X$	4.0	0.6	-10°$_X$	29.5	19.9	18°$_Y$	16.7	9.0	-2°$_Y$	9.8	7.4	-6°$_Y$	10.2	4.1	-17°$_Y$	138.0	87.0	14°$_Y$
H	3.0	-1.3	-42°$_X$	1.0	0.5	0°$_Y$	2.0	-0.6	37°$_X$	17.2	2.5	4°$_Y$	11.1	-0.9	-9°$_Y$	8.5	1.0	-19°$_Y$	6.8	-0.6	-12°$_Y$	106.0	40.0	0°$_Y$
J	14.2	6.8	14°$_X$	29.2	6.9	0°$_X$	12.7	3.0	-15°$_X$	17.7	14.0	-26°$_X$	44.0	24.1	4°$_X$	15.7	12.6	23°$_X$	12.7	4.6	1°$_X$	165.0	101.0	4°$_X$
K	20.1	5.1	5°$_X$	19.3	4.3	-19°$_X$	7.4	0.4	-18°$_X$	28.5	20.1	-29°$_X$	23.7	16.0	27°$_X$	9.8	7.4	11°$_X$	9.9	3.5	20°$_X$	136.0	89.0	-11°$_X$
L	13.2	-0.7	-27°$_X$	6.1	-1.9	-26°$_X$	1.0	-1.4	-26°$_X$	20.0	15.1	45°$_X$	9.7	9.5	-14°$_X$	2.9	2.1	27°$_X$	4.0	0.8	45°$_X$	63.0	38.0	44°$_X$
M	-0.6	-4.4	21°$_Y$	-1.0	-4.4	30°$_Y$	0.8	-3.1	42°$_X$	8.9	-6.0	-19°$_Y$	4.5	-7.4	-25°$_Y$	1.7	-5.0	-29°$_Y$	2.3	-4.3	-29°$_Y$	52.0	39.0	-35°$_X$
N	13.2	7.0	-1°$_X$	58.0	41.9	1°$_X$	11.9	6.2	7°$_X$	14.5	3.2	15°$_X$	24.0	4.7	0°$_X$	12.9	3.4	-15°$_X$	7.9	0.1	0°$_X$	156.0	74.0	2°$_X$
O	26.3	20.3	2°$_X$	16.9	9.9	4°$_X$	5.9	0.6	4°$_X$	17.4	2.6	3°$_X$	18.0	2.0	-16°$_X$	8.5	0.8	-18°$_X$	6.3	0.0	9°$_X$	106.0	40.0	-2°$_X$
P	13.7	9.7	-5°$_X$	0	-4.9	-6°$_X$	-1.2	-4.7	-4°$_X$	8.9	-6.0	19°$_X$	4.3	-6.9	30°$_X$	1.9	-4.7	30°$_X$	2.1	-3.9	28°$_X$	52.0	39.0	38°$_Y$
Q	-11.4	-14.3	-14°$_Y$	-9.9	-10.6	-33°$_Y$	-4.7	-5.6	0°$_X$	-5.0	-13.7	41°$_Y$	-4.9	-11.7	-31°$_Y$	-2.1	-7.0	41°$_Y$	-1.2	-4.8	43°$_Y$	-67.0	-112.0	44°$_Y$
X	-40.3			-39.2			-27.0			-34.3			-37.7			-20.4			-14.6			-251.4		
Y	-6.4			-2.5			0.5			-35.6			-29.5			-23.4			-15.2			-256.3		
X'	28.9			32.3			22.4			25.5			32.0			16.7			12.2			181.3		
Y'	-1.1			-5.0			-3.8			25.3			21.2			18.6			12.0			182.8		

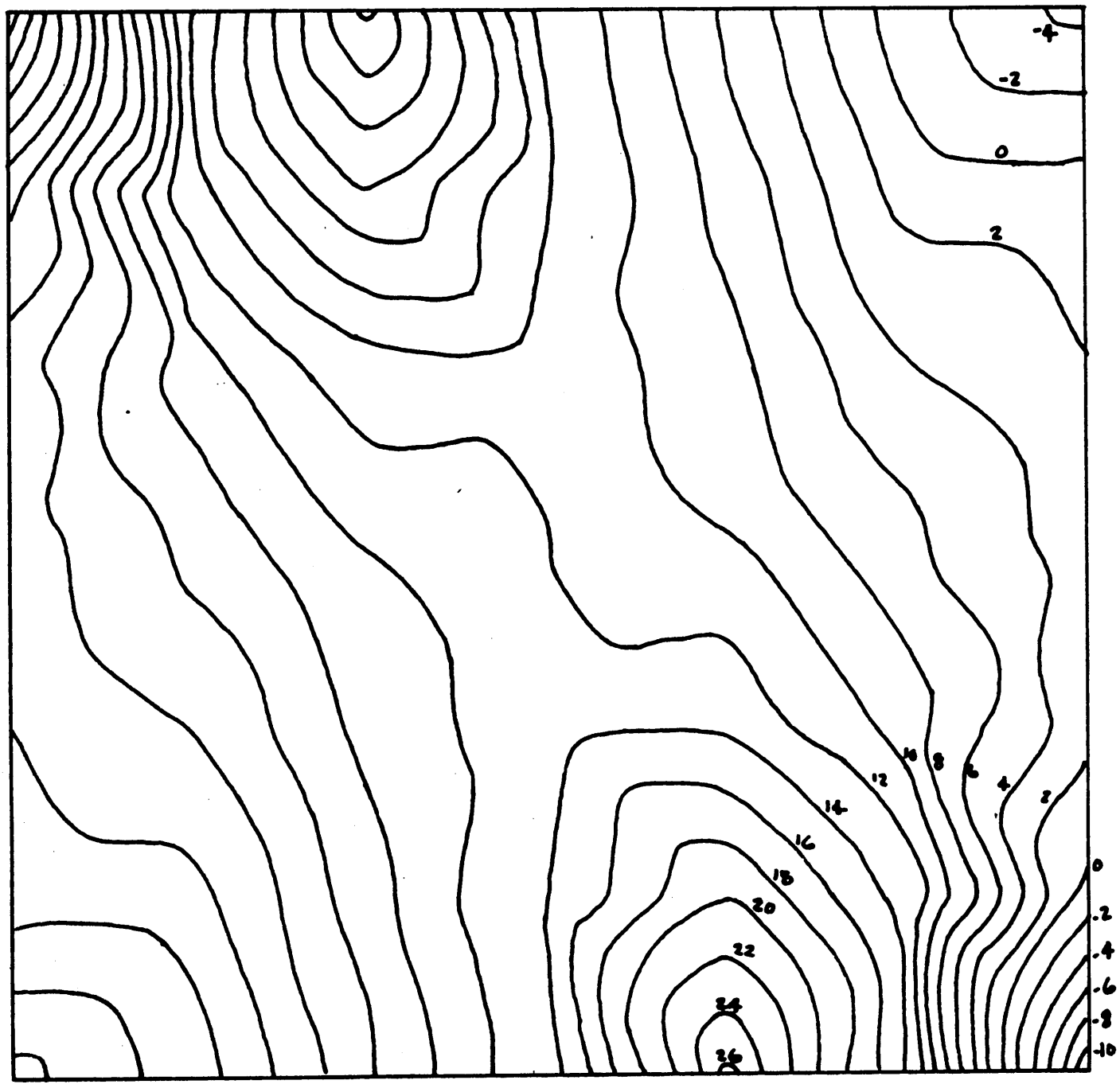

FIGURE 4
LOADING PAIR AT 1&21
MAX. PRINCIPAL STRESSES

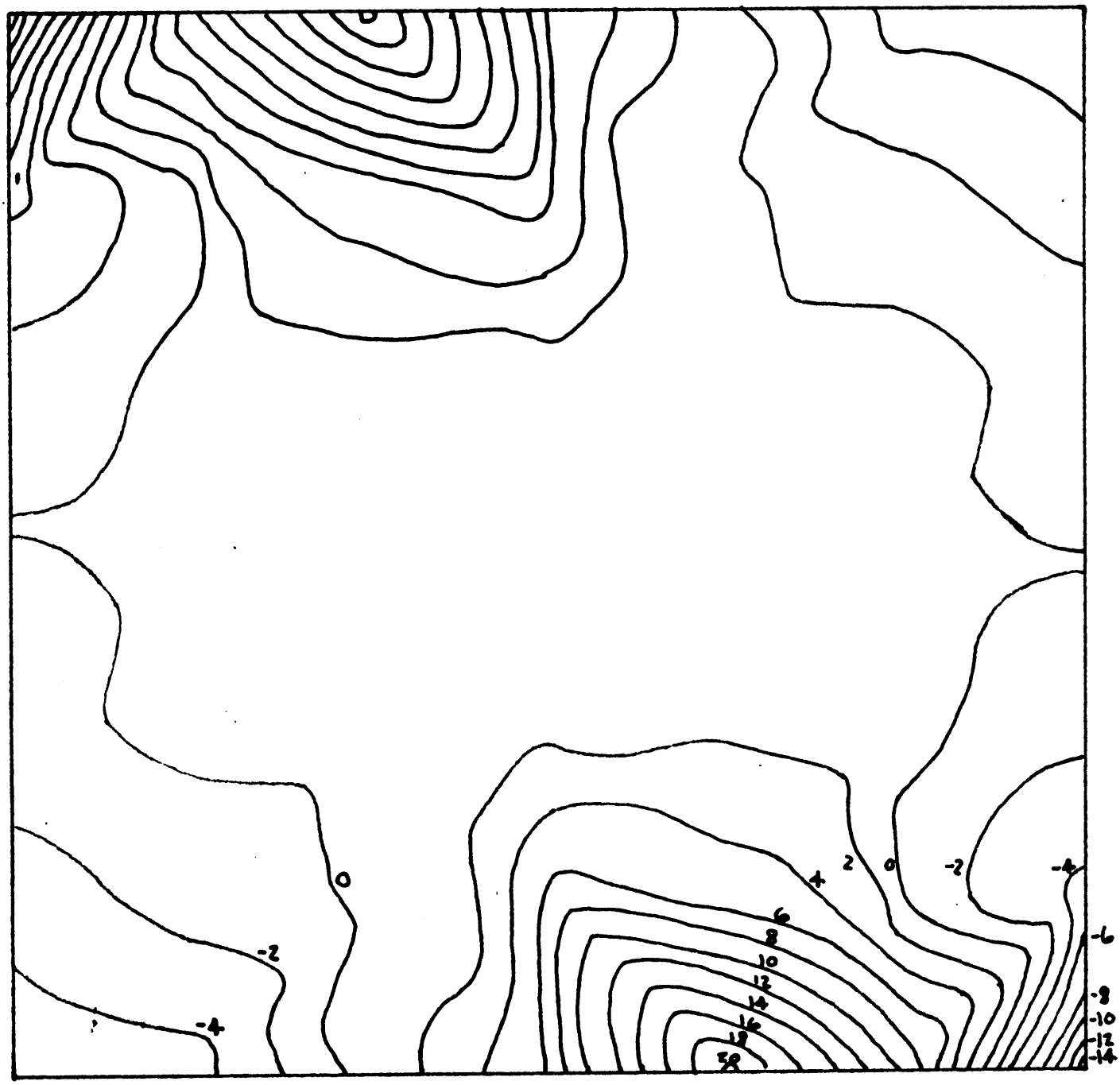

FIGURE 5
LOADING PAIR AT 1&21
MIN. PRINCIPAL STRESSES

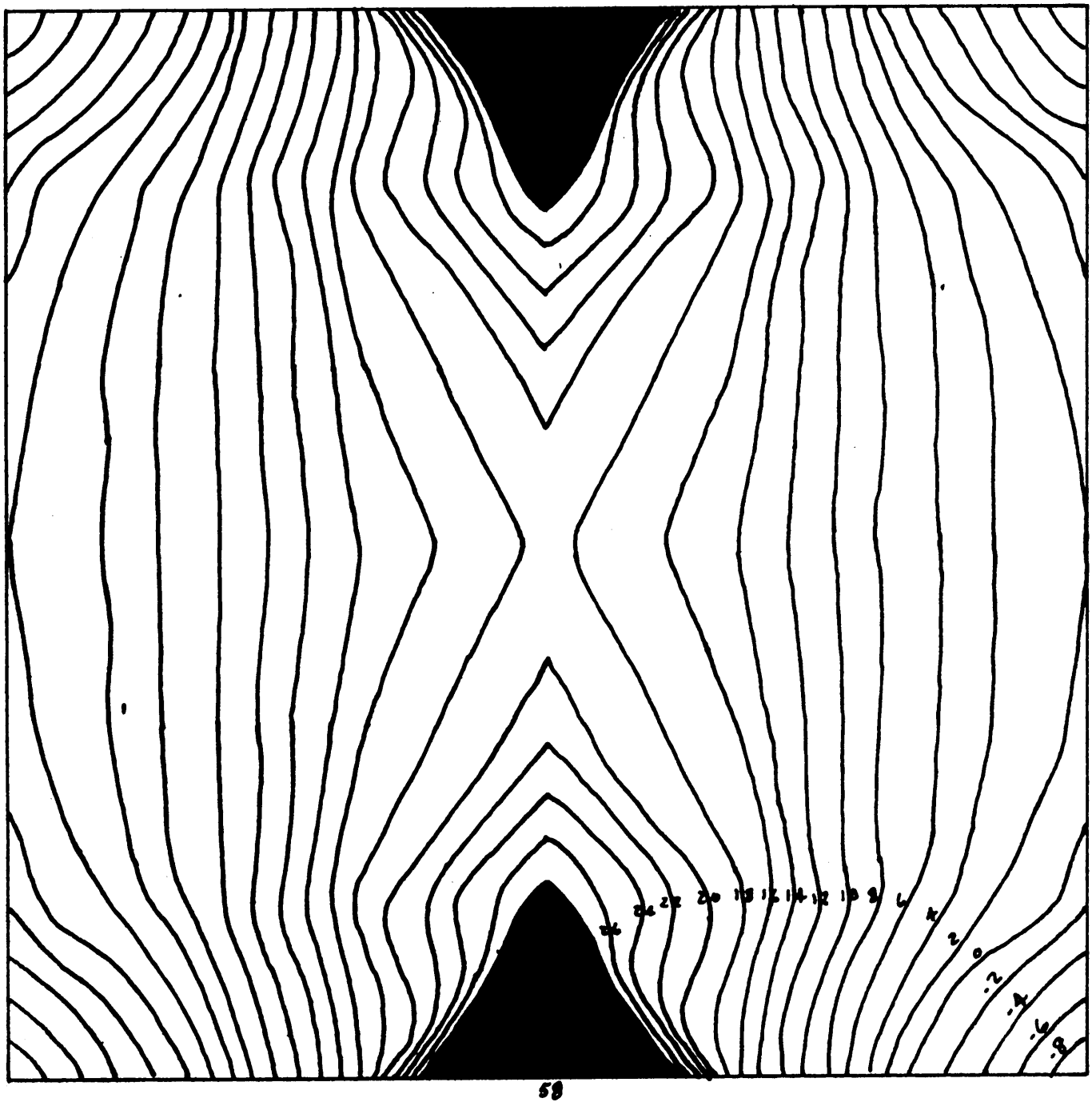

FIGURE 6
LOADING PAIR AT 2&20
MAX. PRINCIPAL STRESSES

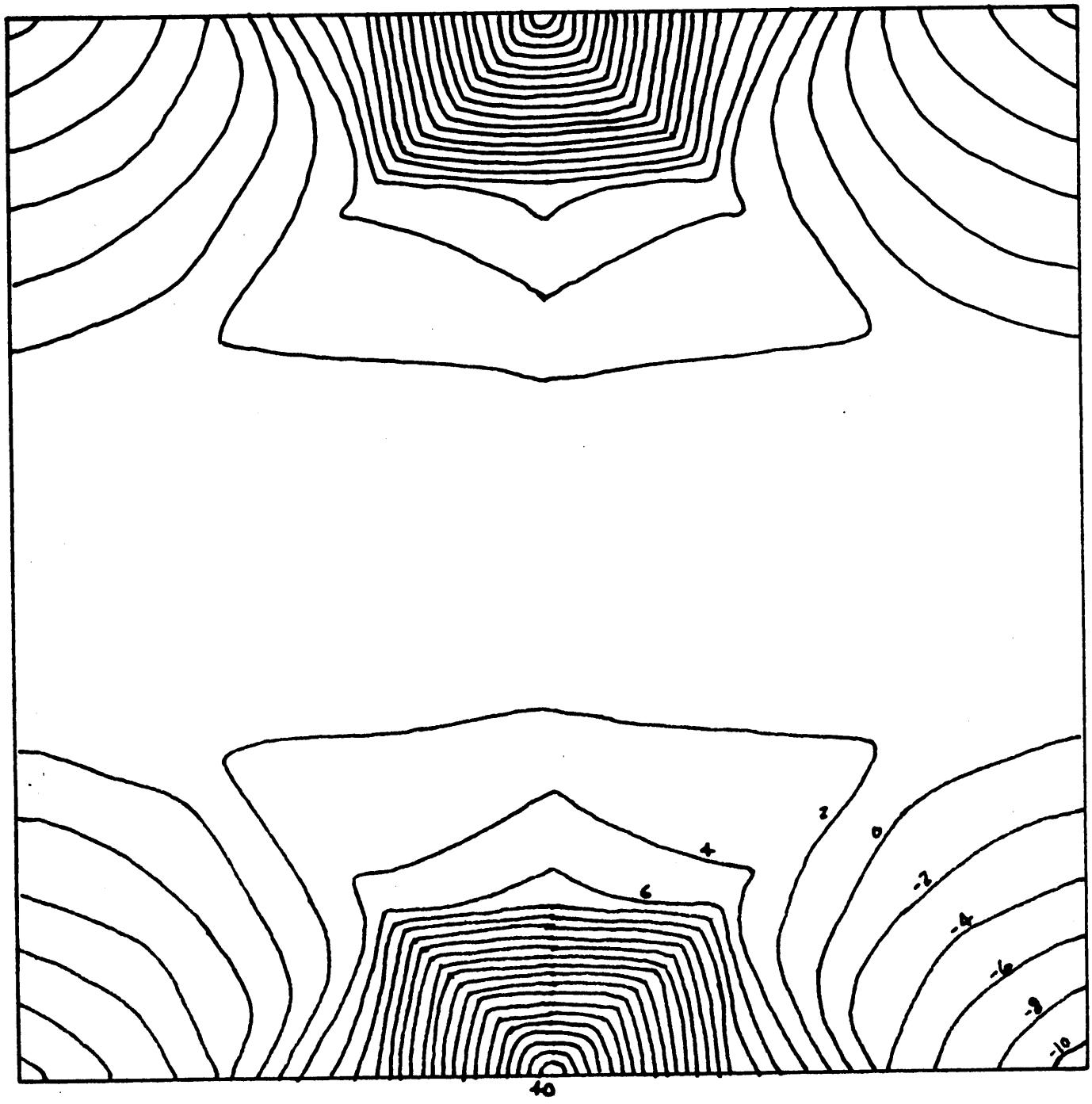

FIGURE 7
LOADING PAIR AT 2&20
MIN. PRINCIPAL STRESSES

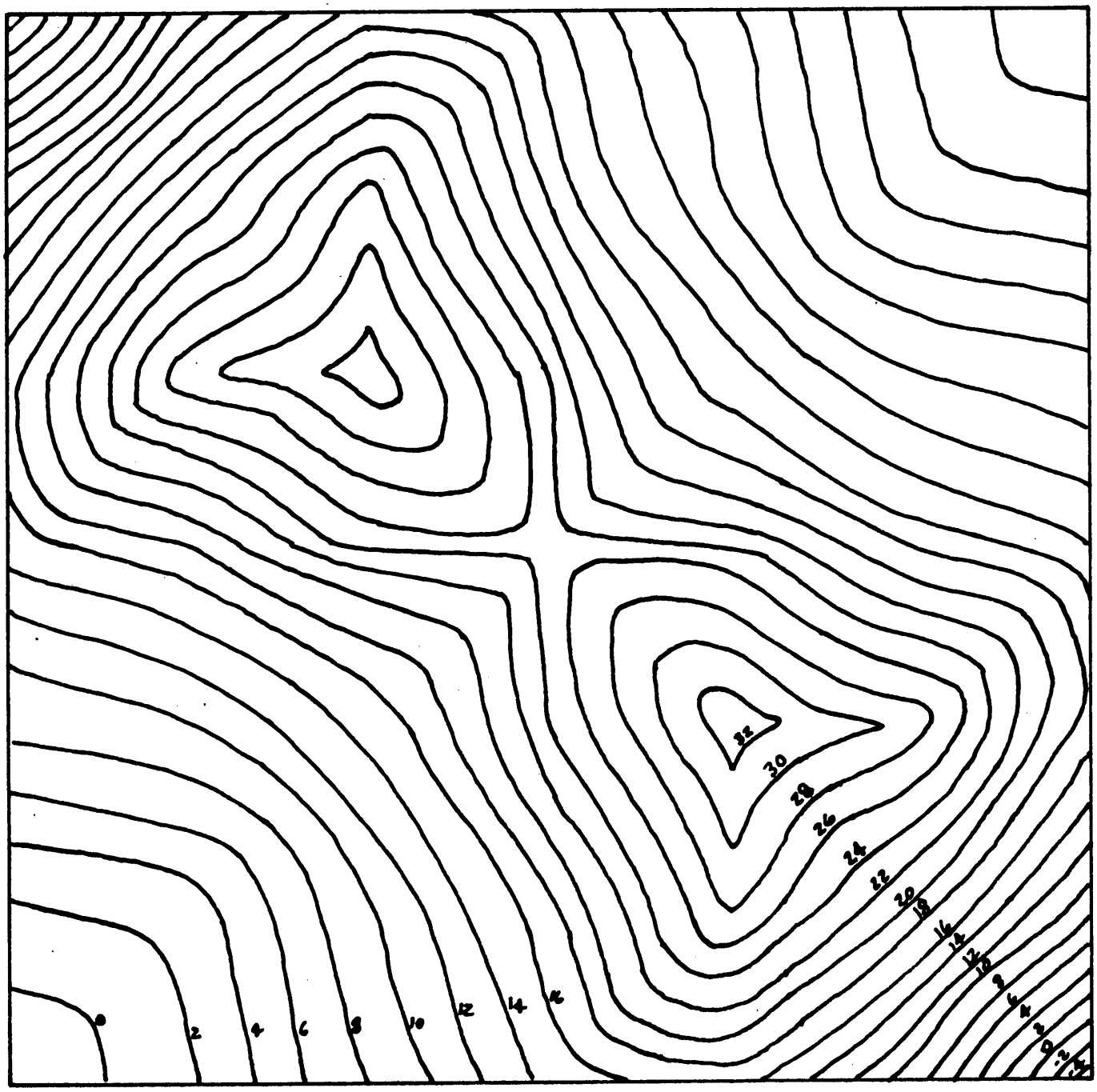

FIGURE 8
LOADING PAIR AT 5&17
MAX. PRINCIPAL STRESSES

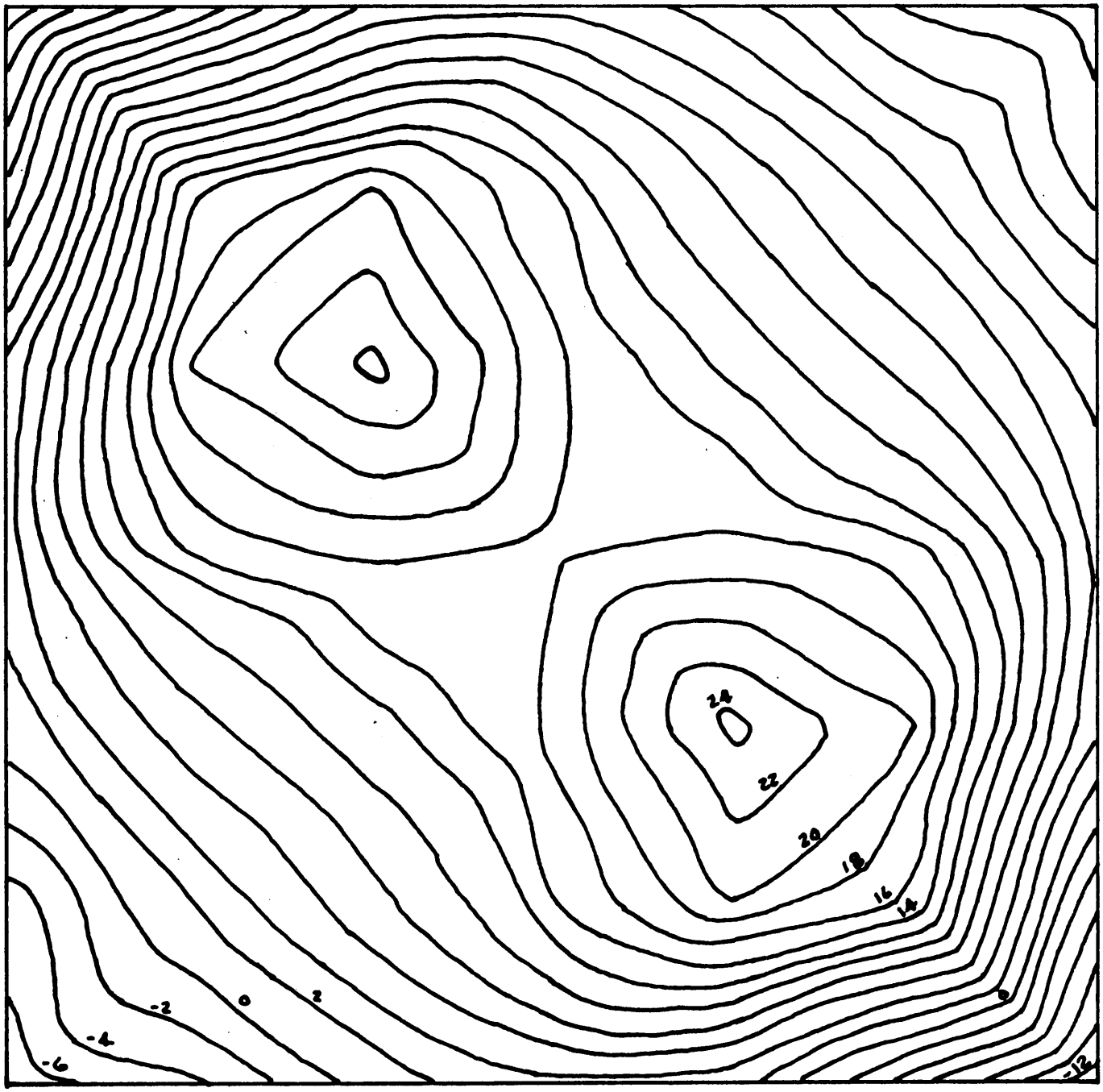

FIGURE 9
LOADING PAIR AT 5&17
MIN. PRINCIPAL STRESSES

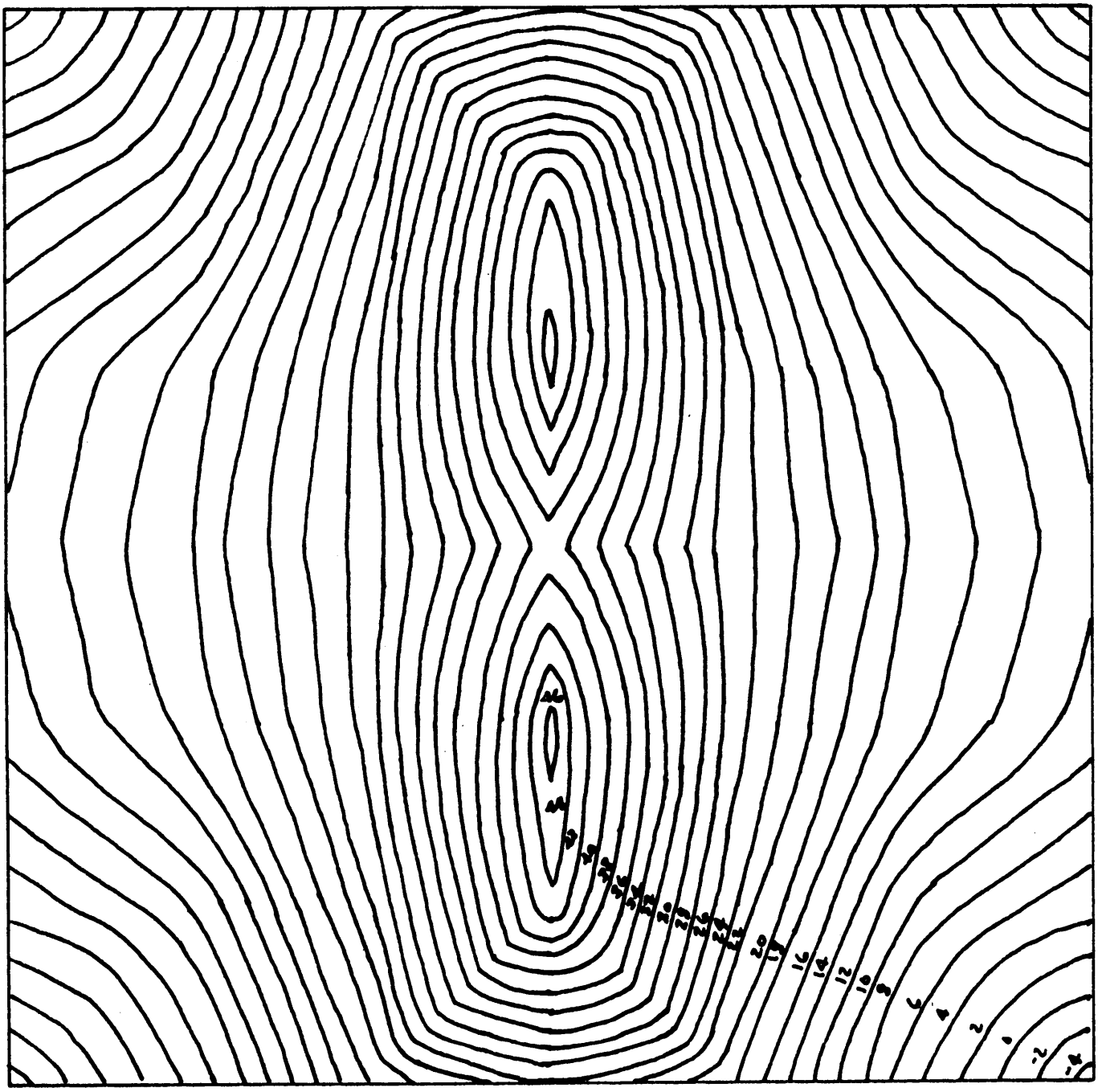

FIGURE 10
LOADING PAIR AT 6&16
MAX. PRINCIPAL STRESSES

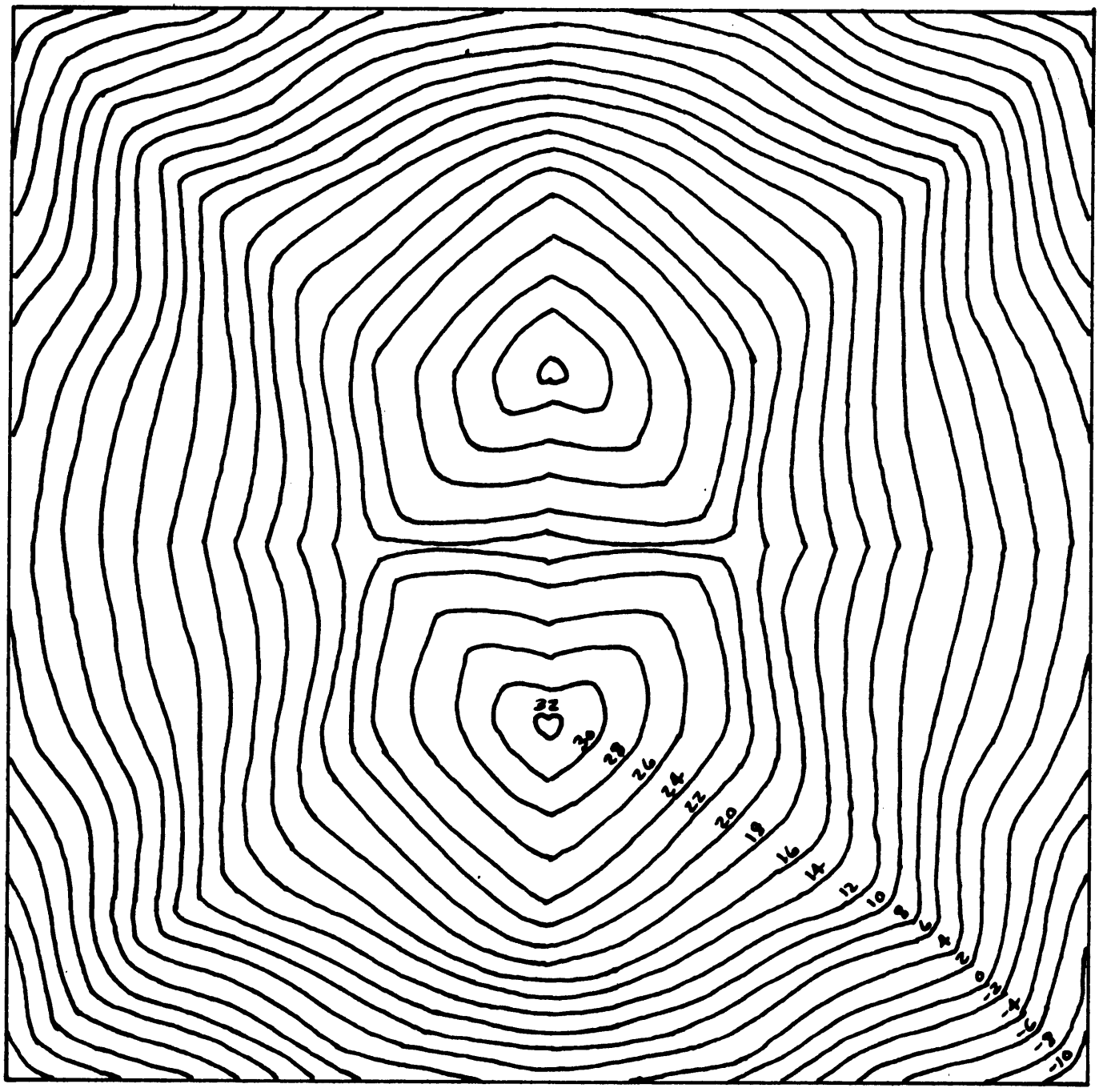

FIGURE 11
LOADING PAIR AT 6&16
MIN. PRINCIPAL STRESSES

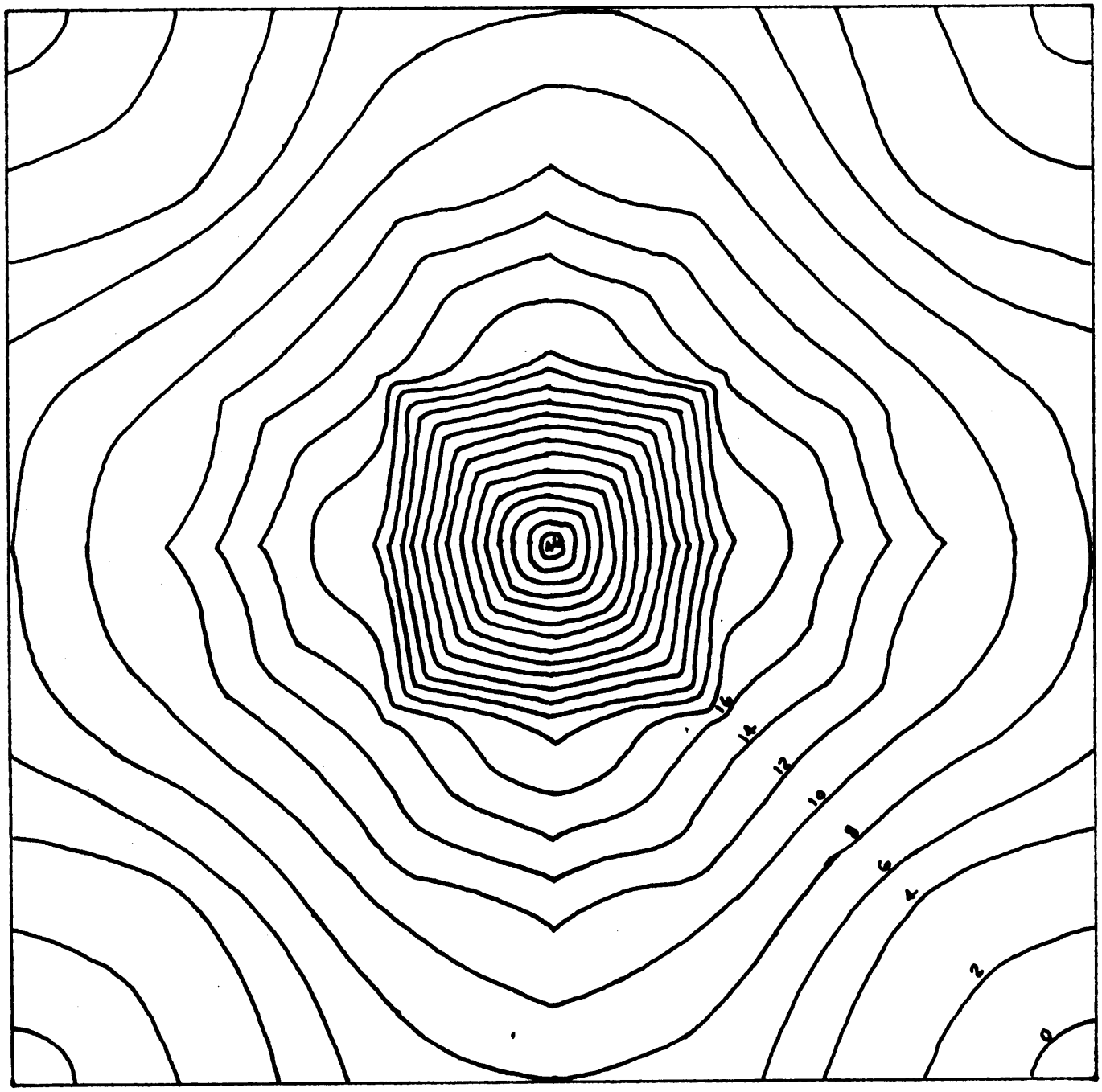

FIGURE 12
SINGLE LOAD AT 11
MAX. PRINCIPAL STRESSES

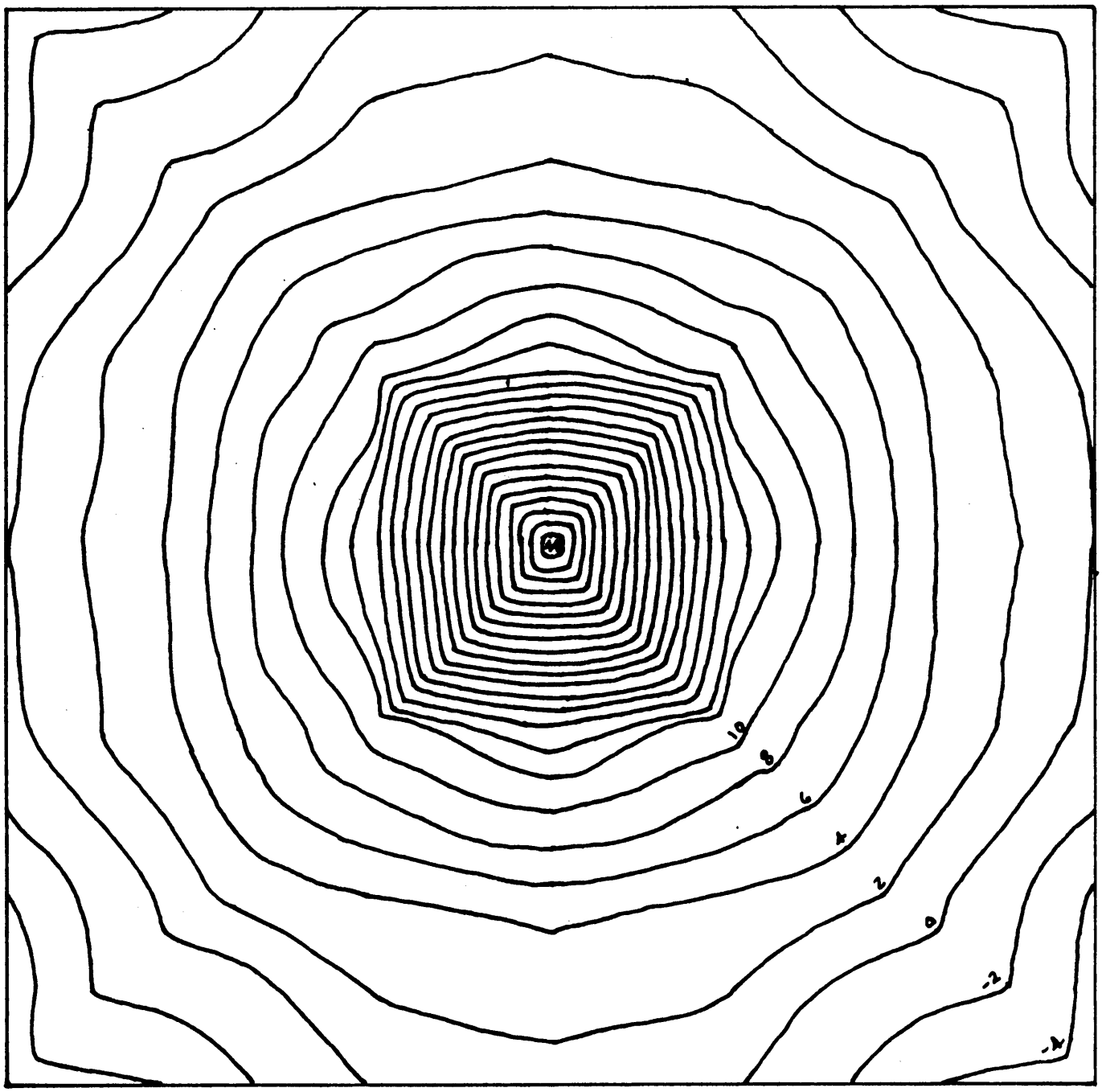

FIGURE 13
SINGLE LOAD AT 11
MIN. PRINCIPAL STRESSES

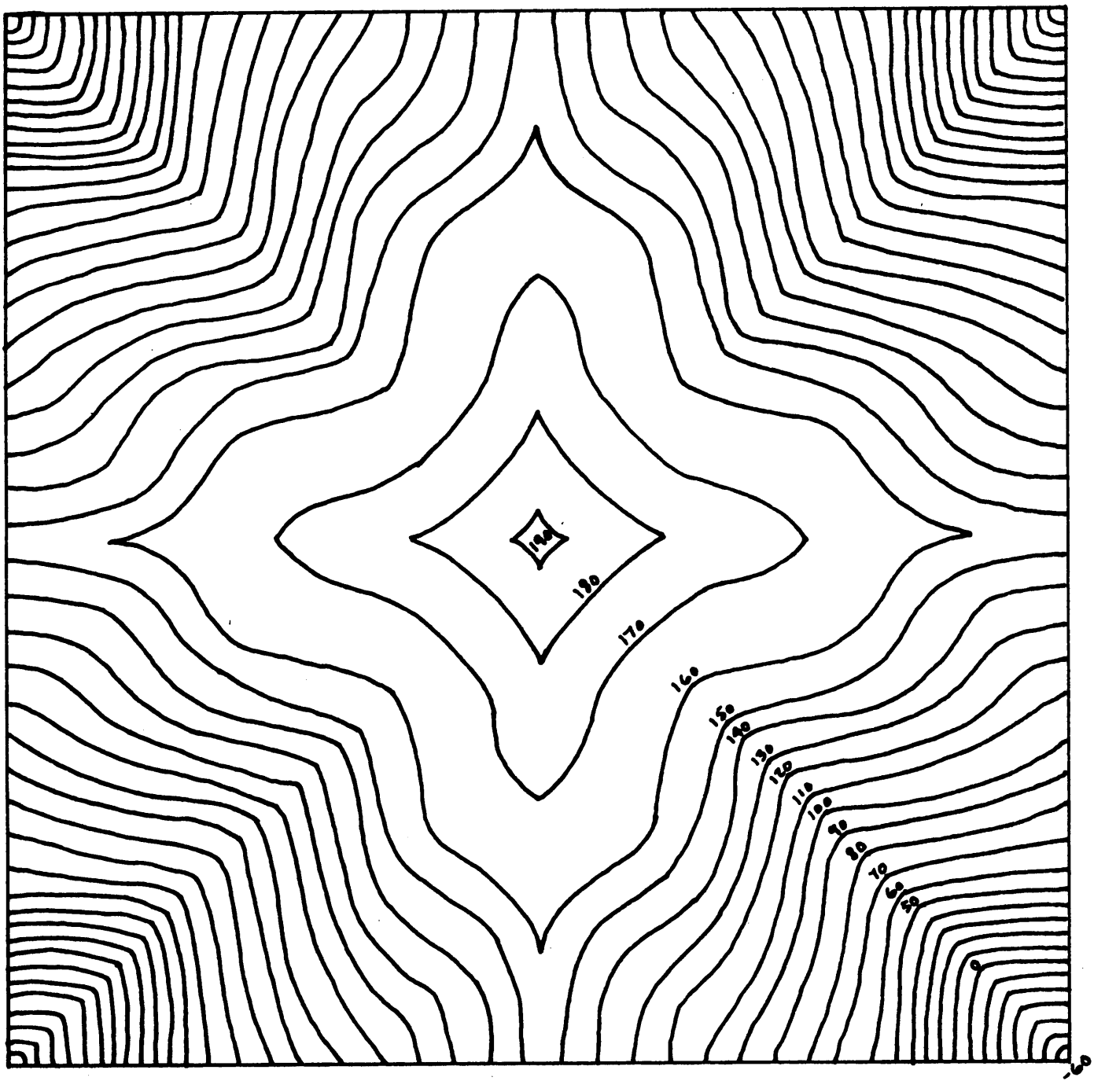

FIGURE 14
UNIFORM LOAD
MAX. PRINCIPAL STRESSES

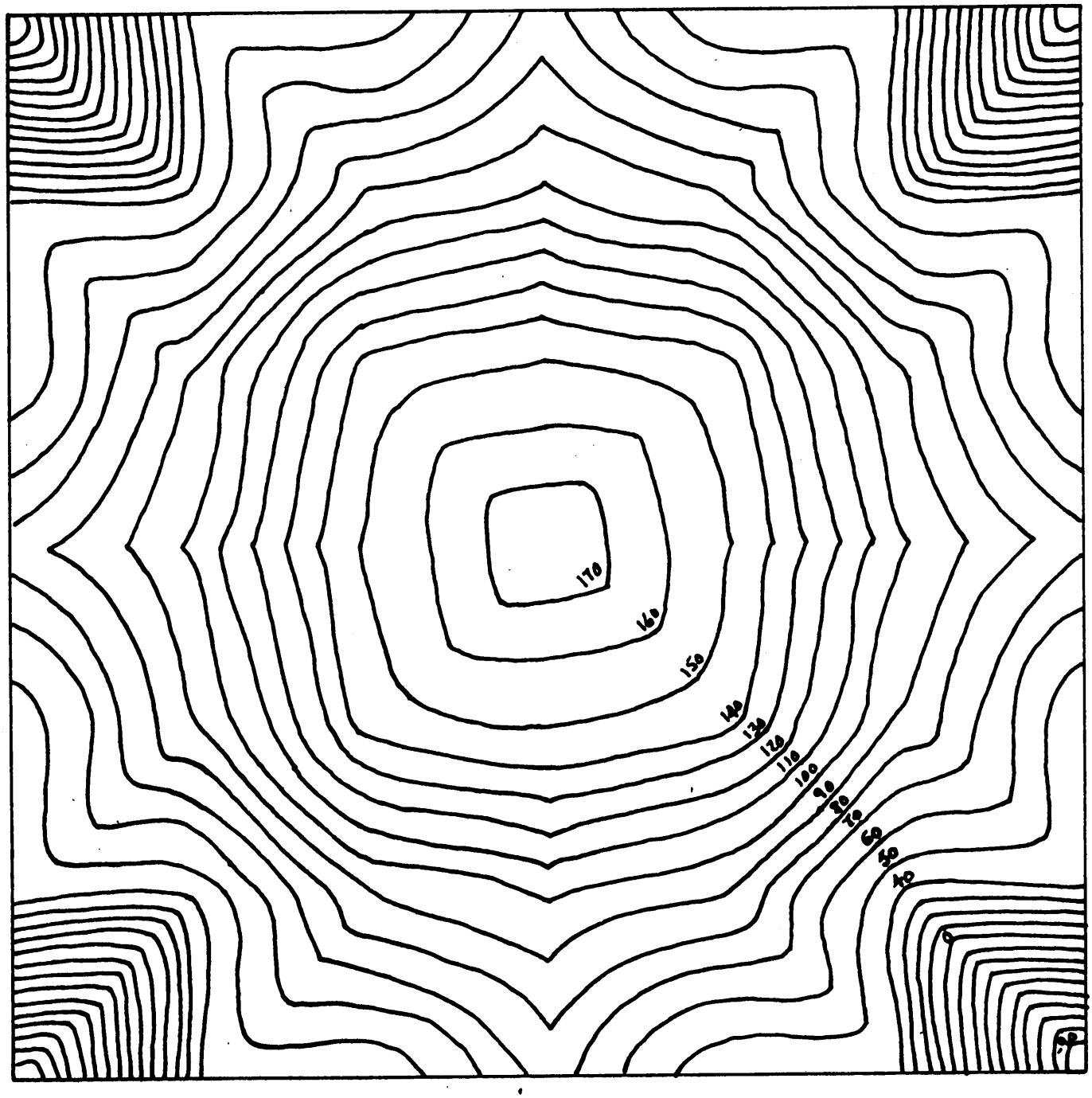

FIGURE 15
UNIFORM LOAD
MIN. PRINCIPAL STRESSES

VI. CONCLUSIONS

This thesis is one of several concerned with the problem of stress distribution in slabs which participate in frame action. R. J. Kolker[1] presented a thesis which listed and discussed previous literature on work with slabs and plates. J. W. Flemer,[2] in his thesis, is obtaining experimental results for a loaded model similar to this one, but with spandrel beams between the columns. J. V. Sutton,[3] in a proposed thesis, will compare analytical results with the experimental results obtained by Mr. Flemer. K. W. Cogan,[4] in a proposed thesis, will compare analytical results with the experimental results of this thesis.

The results of this thesis are estimated to be adequately reliable inasmuch as symmetrical conditions of load produced results which matched with small error at the lines between quadrants. A surprising result was the relative proportions

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[1] R. J. Kolker, A Bibliography Concerned with the Effect of Floor Slabs, with and without Spandrels on the Moments in Columns Due to Vertical or Lateral Loads, Thesis, Virginia Polytechnic Institute, Blacksburg, Virginia. June 1951.

[2] J. W. Flemer, The Effect of Floor Slabs, with Spandrels on the Moments in Columns Due to Vertical or Lateral Loads, Proposed Thesis, Virginia Polytechnic Institute, Blacksburg, Virginia. 1951.

[3] J. V. Sutton, The Elastic Effect of Columns on the Moments in Slabs, with Spandrels, Due to Vertical Loads, Proposed Thesis, Virginia Polytechnic Institute, Blacksburg, Virginia. 1951.

[4] K. W. Cogan, The Elastic Effect of Columns on the Moments in Slabs Due to Vertical Loads, Proposed Thesis, Virginia Polytechnic Institute, Blacksburg, Virginia. 1951.

of positive and negative bending stresses in the slab for the uniform load condition. The negative stresses over the columns are approximately 50% of those in the center of the plate. This might be due to a high stiffness factor of the plate in relation to that of the column. By the preliminary design method (see page 6), the amount of negative bending stresses over the columns are more nearly 100% of those in the center of the span. In general, the preliminary design was rather generous. At the time of the design it was estimated that, under a particular loading condition, a 3000 pound load would produce a stress of 35,000 pounds per square inch. Actually, under this condition of load, a 5000 pound load was required to produce this stress.

It is hoped that this thesis, along with the others previously mentioned at the beginning of this chapter and with those yet to be conducted pertaining to this subject, will help make possible more practical and more economical design approaches for the "Flat Slab" type of structure.

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