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TECHNICAL NOTE 3192

EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS

SHEAR LOAD

By Floyd R. Schlechte and Richard Rosecrans

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

A cylindrical semimonocoque shell of circular cross section was mounted as a cantilever and loaded by a direct shear at the tip. The cylinder was tested with no cutout, with a rectangular cutout on the tension side, and with the cutout centered on the neutral axis on one side of the cylinder. The cutout was successively enlarged through six sizes varying from 30° to 130° in circumference and from 1 to 2 bays in length. Strain measurements were made with resistance-type wire strain gages near the cutout on the stringers, the skin, and the rings for each case, and the stresses obtained are presented in tables.

INTRODUCTION

Stresses obtained in torsion tests of a stiffened circular cylinder with a cutout are given in reference 1 and stresses found in pure bending tests of the same cylinder are given in reference 2. The present report, which is the last on this series of tests, gives results for two loading cases: shear load with the cutout on the tension side of the cylinder and shear load with the cutout centered on the neutral axis. In this report the cutout centered on the neutral axis is called a side cutout.

Results of related experimental work by other investigators are given in references 3 to 5. Reference 3 gives some data for stresses around cutouts for a series of tests of a cylinder loaded by torque or direct shear. Only shear stresses are given for the tests of the cylinder under torque loading, and only axial stresses are given for the tests with direct shear loading. Reference 4 gives stringer stresses and shear stresses in a circular cylindrical shell with two opposing side cutouts and loaded by direct shear and torque. Reference 5 presents experimental and theoretical studies of stresses in a fuselage model loaded by direct shear and having two opposing side cutouts.

TEST SPECIMEN AND PROCEDURE

Although the test specimen was the same one as that used in reference 1, a description of the cylinder is repeated here for completeness of the present paper. The test cylinder, which is shown in figure 1, consisted of a 24S-T aluminum-alloy skin 0.051 inch thick, 36 external $3/4 \times 3/4 \times 3/32$ angle stringers with cross-sectional area of 0.1373 square inch, and 8 equally spaced 24S-T aluminum-alloy Z-section rings with cross-sectional area of 0.4413 square inch. The rings were made of 1/8-inch sheet and were 2 inches deep with 1-inch flanges. The moment of inertia of the cylinder about a diameter was calculated to be 1119.3 in.^{4}. After an initial test of the cylinder without a cutout, the series of cutout tests began with a cutout 1 bay in length by 30° in circumference. In four succeeding tests, the cutouts were 1 bay long and varied up to 130° in circumference. A final test was made with a cutout 2 bays long by 130° in circumference. The size of the cutout for each test is given in table 1.

The test procedure was analogous to that used in the tests of references 1 and 2. The cylinder was mounted on a heavy ring which was bolted to a rigid support. (See fig. 2.) Load was applied to a steel bulkhead at the tip by means of a hydraulic jack. The tip bulkhead was attached to the cylinder by a steel sleeve so that the distance from the end of the specimen to the point of load application was $12\frac{1}{8}$ inches.

Baldwin SR-4 wire strain gages mounted near the cutout on the stringers, skin, and rings were used for obtaining all the strain measurements. Type A-12 gages were used on the stringers and rings and type AR-1 rosette gages were used on the skin. Typical gage mountings are shown in figure 3. Stringer gages were mounted along the inside corner of the stringer angle, either at the rings or halfway between rings. Rosette gages were mounted either halfway between rings or $1\frac{1}{4}$ inches from a ring. In each rosette, two gages mounted at angles of 45° and 135° to the axis of the cylinder were used to measure the shear strain. Ring gages were mounted near the neutral axis of the ring cross section and on both flanges. The gage pattern in figure 4(a) shows the location of all the strain gages used in tests 2 to 6. The angular coordinate θ is measured from the center line of the cutout. All the gages shown were used in the test with a 30° cutout 1 bay long. For successive tests with a cutout 1 bay long, the cutout was enlarged by removing panels symmetrically located on either side of the longitudinal center line. All gages not cut away by enlarging the cutout were used in the next test. The gage pattern for test 7, with a 130° cutout 2 bays long, is shown in figure 4(b).

In each test, the maximum load was chosen to make the most highly strained gage indicate tension or compression of about 10,000 psi. This value was well below the buckling load in each test but was considered high enough to avoid the large relative errors associated with measurements of very small strains.

About 300 or 400 gages were read in each test, but the equipment available permitted only 80 gages to be read at one time. The procedure was as follows: A group of approximately 80 gages was read at each of four successively higher loads; then the first load was repeated as a check. If for some gages the original reading and the check reading differed by more than about 100 psi, the data for those gages were rejected and a test was performed for those gages only. Testing continued until satisfactory checks were obtained. If the temperature varied more than 1° F during a test run, the entire run was repeated. The reruns required only a small portion of the total testing time. After satisfactory data were obtained for a group of gages, another set of about 80 gages was read and the testing continued until all the gages had been read.

DATA REDUCTION AND ACCURACY

For each test, load was plotted against strain for the data from each gage, and the slope of a straight line through the test points determined the value taken as the strain at the maximum test load. Strains were converted to stresses with Young's modulus taken as 10,600,000 psi and the shear modulus as 4,000,000 psi. Tension is considered positive for normal stresses, and positive shear stresses are those that would be produced by a clockwise tip torque.

Because of symmetry, the stress at each longitudinal station at an angle θ° from the center line of the cutout should be the same as the one at $-\theta^{\circ}$; consequently, except for the cases noted in the next section, the stresses from symmetrically located gages were averaged. The final stresses were all reduced to correspond to stresses for a load of 2,000 pounds.

Errors in measuring the applied load include an uncertainty of 1 percent in the jack load and a small amount of friction in the loading frame. In addition, the strain gages may have inaccuracies of 200 psi at the loads of the actual tests or 3 percent, whichever is larger.

RESULTS

Stresses are presented in tables for all of the cutout tests and the actual maximum load used in each test is also given. Results of tests of the cylinder with the cutout on the tension side are given in tables 2 to 7 and results of tests of the cylinder with the cutout centered on the neutral axis (the side cutout) are given in tables 8 to 13. A test of the cylinder without a cutout gave stresses that were very close to those determined by elementary theory. Consequently, for the cutout tests, "stringer stresses due to cutout only" and "shear stresses due to cutout only" were calculated by subtracting from the measured stresses the stresses determined by ordinary beam theory for the uncut cylinder.

Each table gives a set of stresses for one test corresponding to a certain cutout size and loading condition. In each table, stringer stresses are given in part (a) and "stringer stresses due to cutout only" are given in part (b). Shear stresses are presented in part (c) and "shear stresses due to cutout only" are presented in part (d). Finally, the ring stresses are given in part (e). When stringer stresses that might be averaged differed by more than 1,000 psi at the actual test load, both values instead of the average value are given in the tables. For these cases, the numbers giving the stresses from the region where θ is negative are in parentheses, but the signs are chosen as if these stresses were in the region where θ is positive. Ring stresses for the case of shear load on the cylinder with a side cutout were not averaged because they were very inconsistent. In several instances, values of stress that were from obviously inaccurate gage readings were omitted from the tables.

The stress distributions around the cutout are presented in figures 5 to 8. Stresses for shear load with the cutout on the tension side of the cylinder are given for the 30° cutout in figure 5 and for the 90° cutout in figure 6. Stresses for shear load with the side cutout are presented for the 30° cutout in figure 7 and for the 90° cutout in figure 8. Figures 5 to 8 have four parts each, corresponding to parts (a), (b), (c), and (d) of the tables. The test points, which are represented by the height of the heavy vertical lines, are joined by straight lines to give a pictorial view of the stress field. In the figures showing shear stresses, the lines joining points on opposite sides of the coaming stringer near the cutout have been broken because a straight line is not very accurate in this region.

CONCLUDING REMARKS

Stresses obtained in a series of tests of a stiffened cylindrical shell with a cutout subjected to a tip shear are presented in tables. The data presented are intended primarily to serve as a check on methods of analysis or as a guide to the development of such methods. Consequently, no attempt has been made in this paper to interpret the data or draw conclusions therefrom.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 12, 1954.

REFERENCES

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5. Butler, S., and Butterworth, F. E.: Type 167 Shear Tests on Half Scale Fuselage With Entrance Door Cut-Outs. S & M Memo. No. 6/50 (Rep. No. C. R. 539), The Bristol Aeroplane Co., Ltd., Jan. 1949.

TABLE 1.- CUTOUT SIZE

Test number	Length of cutout, bays	Width of cutout, deg
1	None	None
2	1	30
3	1	50
4	1	70
5	1	90
6	1	130
7	2	130

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		928		580	0		0	1,075		2,203	
15		972		1,445	2,329	2,974	2,937	2,126		2,150	
		988		1,581	1,966	2,212	2,334	2,203		2,203	
		979		1,431	1,630	1,826	1,926	1,993		2,047	
45		898		1,185	1,374	1,458	1,595	1,737		1,890	
		773		1,023	1,107	1,190	1,303	1,355		1,617	
		583		746	822	892	947	1,063	1,115	1,263	
75		392		486	530	542	595	707		828	
		-38		-103	-71	-118	-103	-162	-103	-77	
105											

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-209		-881	-1,623		-1,947	-1,034		-230	
15		-135		22	749	1,236	1,041	73		-219	
		-55		241	477	574	548	268		-29	
		32		214	279	340	305	237		21	
45		75		128	200	167	186	211		130	
		100		158	147	134	151	107		177	
		80		100	104	103	86	131	111	187	
75		74		78	77	43	51	118		148	
		38		-5	38	1	27	-21	49	86	
105											

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	36	30	24	18	12	6	0	6	12	18	24
						51		32	56		
15	142		82		-389	-800		1,319	778		
						43	103 229 437	441	650		
45	404		340		311	335	485 397 316	419	469		
					559	530	570 561 486	477	452		
	610		641		700	671	645 635 640	576	558	649	623
					823	776	758 744 698	652			
75	795		835		870	813	815 801 770	756	661	757	
						862	835 824 830	846	755		
105	872		888		856	824	807 849 801	883	809	840	
						718	755 716		780		
135											
			557			525	571 525				
165						339					
							182 160				

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

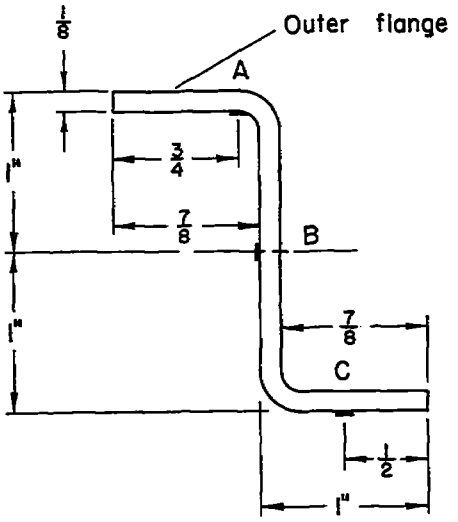
(d) Shear stresses due to cutout only

Distance from center line of cutout, in.

θ, deg	36	30	24	18	12	6	0	6	12	18	24
						51		32	56		
15	-1		-61		-532	-943		1,176	635		
						-239	-177 -53 155	159	368		
45	-8		-72		-101	-77	73 -15 -96	7	57		
					29	0	40 -31 -44	-53	-78		
	-22		9		68	39	13 3 8	-56	74	17	-9
					109	62	44 30 -16	-62			
75	21		61		96	39	41 27 -4	-18	-113	-17	
						50	23 12 18	34	-57		
105	60		76		44	12	-5 37 -11	71	-3	28	
						4	41 2		66		
135											
			27			-5	41 -5				
165						57					
							39 17				

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5	-71	-219	-266	-77	-321	-321
15	-197	-281	-107	-271	-315	-72
25	-157	-162	-1	-147	-136	51
35	-118	-51	0	-150	-52	106
45	-118	-31	59	-200	-16	146
55	-125	0	86	-166	-7	131
65	-91	0	52	-150	-3	90
75	-66	0	44	-111	9	37
85	0	0	0	-37	0	0
95	0	0	0	0	0	0

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,000 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		566		202	0		0	594		1,755	
15		691		492	0		0	878		1,895	
		776		1,344	2,724	3,511	3,759	2,332		1,963	
		910		1,658	2,094	2,421	2,546	2,430		2,001	
45		854		1,412	1,690	1,819	1,944	1,997		1,942	
		816		1,168	1,289	1,340	1,505	1,518		1,696	
		610		831	926	937	1,039	1,111	1,206	1,323	
75		471		458	572	568	610	700		912	
		0		-123	-85	-165	-132	-199	-98	-26	
105											

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,000 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-571		-1,259	-1,623		-1,947	-1,515		-678	
15		-416		-931	-1,580		-1,896	-1,175		-474	
		-267		4	1,235	1,873	1,973	397		-269	
		-37		441	743	935	925	674		-25	
45		31		355	516	528	535	471		182	
		143		303	329	284	353	170		256	
		107		185	208	148	178	179	202	247	
75		153		50	119	69	66	111		232	
		76		-25	24	-46	-2	-58	54	137	
105											

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,000 POUNDS) - Continued

(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	36	30	24	18	12	6	0	6	12	18	24
						0		49	15		
15	132		-61		-324	-190		550	690		
						-975		1,889	1,215		
	316		203		-3	132	244 305 503	523	826		
					499	508	667 577 405	525	461		
45	559		595		784	717	773 649 615	459	427	675	688
					893	855	816 755 700	535			
	814		872		951	925	859 799 776	633	570	737	
75						929	875 832 821	722	666		
	906		919		882	822	806 847 806	829	808	822	
105											
						717	747 719	780	798		
135			544			519	562 531				
						247					
165							191 371				

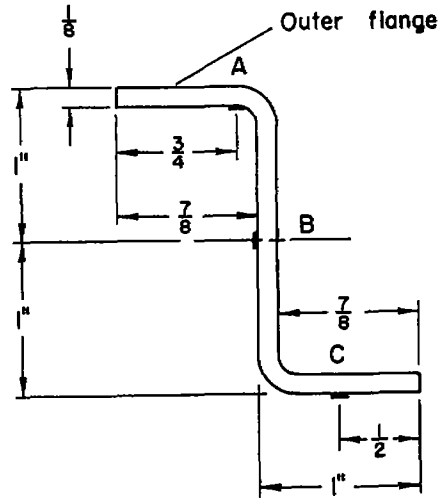
TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,000 POUNDS) - Continued

(d) Shear stresses due to cutout only

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						0		49	15		
15	-11		-204		-567	-333		407	547		
						-1,257		1,607	933		
	-96		-209		-415	-280	-168 -107 91	111	414		
45					-31	-22	-137 47 -125	-5	-69		
	-73		-37		152	85	-141 17 -17	-173	-185	43	56
					179	141	102 41 -14	-179			
75	40		98		177	151	85 25 2	-141	-204	-37	
						117	63 20 9	-90	-146		
105	94		107		70	10	-6 35 -6	17	-4	20	
						-3	33 5	66	84		
135											
			14				32 1				
165											
							48 128				

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,000 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5	63	-407	-456	-4	-636	-689
15	63	---	-358	159	-352	-475
25	-121	-229	-68	-44	-212	0
35	-163	62	150	-174	67	263
45	-155	---	222	-221	168	343
55	-191	123	258	-274	184	401
65	-221	102	254	-282	131	343
75	-191	---	199	-248	106	246
85	-138	38	153	-172	40	117
95	-134	-15	87	-76	-4	40

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,400 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		280		67	0		0	424		1,431	
15		460		111	0		0	453		1,623	
		595		491	0		0	1,012		1,831	
		812		1,869	3,257	4,466	4,807	2,905		1,918	
45		975		1,843	2,534	2,842	3,004	2,751		1,831	
		973		1,607	1,862	1,927	2,103	2,023		1,831	
		848		1,178	1,269	1,224	1,404	1,503	1,515	1,542	
75		665		843	780	761	843	934		1,132	
		173		-15	53	-91	-81	-154	72	120	
105											

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,400 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 30	24	18	12	6	0	6	12	18	24	30
		-857		-1,394	-1,623		-1,947	-1,685		-1,002	
15		-647		-1,312	-1,580		-1,896	-1,600		-746	
		-448		-849	-1,489		-1,786	-923		-401	
		-135		652	1,906	2,980	3,186	1,149		-108	
45		152		786	1,360	1,551	1,595	1,225		71	
		300		742	902	871	951	775		391	
		345		532	551	435	543	571	511	466	
75		347		435	327	262	299	345		452	
		249		83	162	28	49	-13	224	283	
105											

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,400 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-37		45	6		
15	51		-64		-142	-100		426	492		
						-242		938	1,092		
	228		70		-559	-1,040		2,447	1,683		
45					118	257	391 590 764	496	863		
	483		477		695	726	946 726 560	361	391	783	784
					1,020	968	990 854 708	363			
75	740		889		1,093	992	964 925 803	545	406	694	
						1,044	955 955 848	580	543		
105	966		946		946	889	805 843 833	807	726	751	
						704	734 712	814	796		
135											
			556			504	573 494				
165						258					
							185 187				

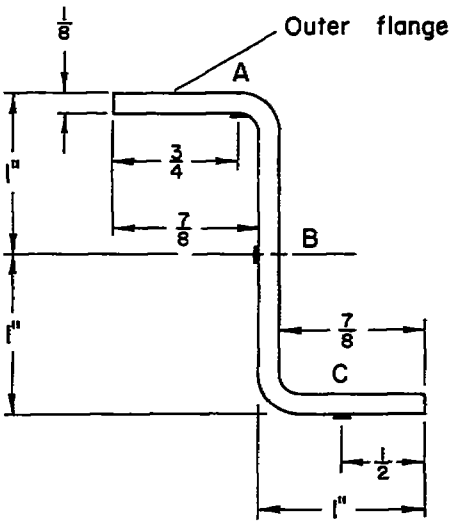
TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,400 POUNDS) - Continued

(d) Shear stresses due to cutout only

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-37		45	6		
15	-92		-207		-285	-243		283	349		
						-524		656	810		
	-184		-342		-971	-1,452		2,035	1,271		
45					-412	-273	-139 60 234	-34	333		
	-149		-155		63	94	114 94 -72	-271	-241	151	152
					306	254	176 142 -6	-351			
75	-34		115		319	218	190 151 29	-219	-368	-80	
						232	143 143 36	-232	-269		
105	154		134		134	77	-7 31 21	-5	-86	-61	
						-10	20 -2	100	82		
135											
			26			-26	43 -36				
165						-24					
							42 44				

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,400 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5	313	-523	-696	255	-1,036	-1,229
15	226	---	-583	265	-747	-1,048
25	156	-207	-328	315	-278	-499
35	-193	-147	67	-265	-10	308
45	-260	---	328	-374	308	590
55	-265	219	434	-458	374	701
65	-364	275	537	-534	349	720
75	-357	---	405	-520	197	506
85	-280	183	352	-434	96	294
95	-253	114	248	-258	34	125

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 3,600 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		44		-18	0		0	294		1,060	
15		159		9	0		0	318		1,231	
		374		82	0		0	418		1,508	
		686		568	0		0	1,125		1,826	
45		910		2,091	3,901	5,607	6,004	3,439		1,943	
		1,060		2,241	2,704	3,316	3,386	2,956		2,055	
		1,057		1,685	1,973	1,932	2,167	2,061	1,958	1,885	
75		877		1,178	1,207	1,066	1,178	1,266		1,407	
		342		59	194	-41	6	-165	224	294	
105											

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 3,600 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-1,093		-1,479	-1,623		-1,947	-1,815		-1,373	
15		-948		-1,414	-1,580		-1,896	-1,735		-1,138	
		-669		-1,258	-1,489		-1,786	-1,517		-724	
		-261		-649	-1,351		-1,621	-631		-200	
45		87		1,034	2,727	4,316	4,595	1,913		183	
		387		1,376	1,744	2,260	2,234	1,708		615	
		554		1,039	1,255	1,143	1,306	1,129	954	809	
75		559		770	754	567	634	677		727	
		418		157	303	78	136	-24	376	457	
105											

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED, 3,600 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-46		85	-5		
15	23		-76		-27	-48		381	334		
						-86		725	762		
	117		-42		-380	-245		1,250	1,361		
					-617	-1,216		2,987	1,921		
45	366		287		240	422	563 664 1,103	351	848	1,046	1,003
					941	968	1,174 1,042 710	177			
	737		826		1,177	1,169	1,151 1,058 861	288	183	648	
75						1,214	1,060 989 925	375	291		
	1,005		1,074		1,069	1,014	824 845 817	650	616	625	
105											
						744	687 714	746	760		
135			586			501	522 492				
						206					
165							179 147				

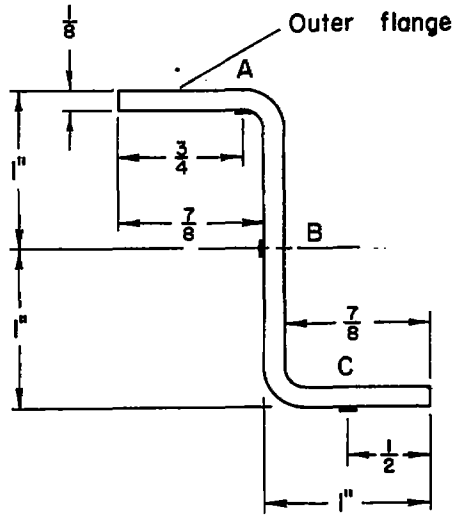
TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 3,600 POUNDS) - Continued

(d) Shear stresses due to cutout only

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-46		85	-5		
15	-120		-219		-170	-191		238	191		
						-368		443	480		
	-295		-454		-792	-657		838	949		
45					-1,147	-1,746		2,457	1,291		
	-266		-345		-392	-210	-69 32 471	-281	116	414	371
					227	254	460 328 -4	-537			
75	-37		52		403	395	377 284 87	-486	-591	-126	
						402	248 177 113	-437	-521		
105	193		262		257	202	12 33 5	-162	-196	-187	
						30	-27 0	32	46		
135											
			56			-29	-8 -38				
165						-76					
							36 4				

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 3,600 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5	598	-648	-866	666	-1,346	-1,767
15	418	---	-727	539	-1,031	-1,440
25	262	-336	-530	289	-580	-801
35	41	-118	-236	224	144	-29
45	-392	---	298	-607	453	887
55	-444	241	562	-616	733	1,260
65	-518	406	733	-751	780	1,417
75	-507	---	698	-833	589	1,116
85	-416	383	712	-727	416	780
95	-350	268	527	-512	186	442

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-202		-140	0		0	48		529	
15		-158		-115	0		0	193		626	
		63		-38	0		0	203		915	
		299		64	0		0	346		1,253	
45		722		236	0		0	578		1,773	
		1,190		993	0		0	1,725		2,313	
		1,478		3,168	5,968	8,190	9,568	5,155	3,041	2,518	
75		1,732		3,245	4,091	4,254	4,700	4,064		2,455	
		1,155		1,204	1,309	925	1,175		1,406	1,356	
105											

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-1,339		-1,601	-1,623		-1,947	-2,061		-1,904	
15		-1,265		-1,538	-1,580		-1,896	-1,860		-1,743	
		-980		-1,378	-1,489		-1,786	-1,732		-1,317	
		-648		-1,153	-1,351		-1,621	-1,410		-773	
45		-101		-821	-1,174		-1,409	-948		13	
		517		128	-960		-1,152	477		873	
		975		2,522	5,250	7,401	8,707	4,223	2,037	1,442	
75		1,414		2,837	3,638	3,755	4,156	3,475		1,775	
		1,231		1,302	1,418	1,044	1,305		1,558	1,519	
105											

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-7		75	0		
15	-97		-58		134	68		257	122		
						130		470	300		
	-101		-84		174	15		751	582		
45					-21	23		1,084	1,082		
	56		-32		-393	-204		1,732	1,896	1,566	1,435
					-787	-1,738		4,302			
75	506		420		315	661	1,019 1,126	-86	932	1,103	
						1,465	1,812 1,592 1,105	-371	-15		
105	1,053		1,236		1,611	1,500	1,185 1,135 944	86	64	262	
						1,086	655 715	506	596		
135											
			805			566	461 401				
165						184					
							131 101				

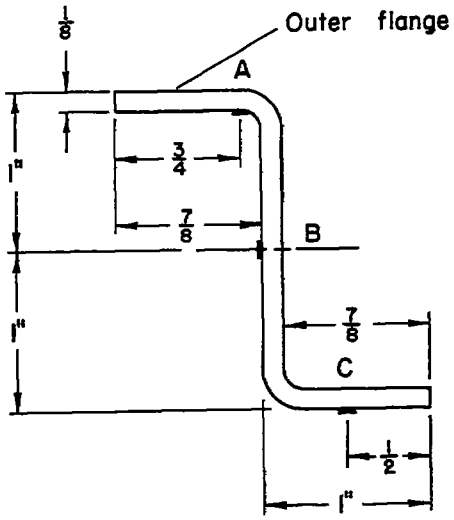
TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-7		75	0		
15	-240		-201		-9	-75		114	-21		
						-152		188	18		
	-313		-496		-238	-397		339	170		
45					-551	-507		554	552		
	-576		-664		-1,025	-836		1,100	1,264	934	803
					-1,501	-2,452		3,588			
75	-268		-354		-459	-113	245 352	-860	158	329	
						653	1,000 780 293	-1,183	-827		
105	241		424		799	688	373 323 132	-726	-748	-550	
						374	-59 1	-208	-118		
135											
			275			36	-69 -129				
165						-98					
							-12 -42				

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5	1,026	-665	-1,253	1,749	-1,836	-3,025
15	885	---	-1,098	1,460	-1,696	-2,554
25	691	-545	-920	993	-1,243	-1,816
35	260	-434	-593	184	-505	-698
45	-102	---	-58	-434	318	482
55	-693	164	289	-616	1,345	1,615
65	-1,133	265	1,075	-1,898	1,489	3,035
75	-1,113	---	1,484	-1,768	1,720	3,016
85	-1,012	901	1,609	-1,513	1,513	2,625
95	-962	843	1,764	-1,494	993	1,869

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	24	18	12	6	0	6	12	18	24	30	36
		-38	0				0	115		578	
15		-53	0				0	193		665	
		0	0				0	289		838	
		43	0				0	472		1,291	
45		178	0				0	616		1,802	
		655	0				0	1,667		2,303	
		2,120	3,517	5,006	6,456	7,931	(8,480) 9,530	5,011	3,035	2,515	
75		2,303		3,469	4,009	4,385	4,799	4,053		2,582	
		1,368		1,108	1,416	867	1,108		1,349	1,368	
105											

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	24	18	12	6	0	6	12	18	24	30
		-1,175	-1,299				-1,947	-1,994		-1,855
15		-1,160	-1,265				-1,896	-1,860		-1,704
		-1,043	-1,192				-1,786	-1,646		-1,394
		-904	-1,082				-1,621	-1,284		-735
45		-645	-940				-1,409	-910		42
		-18	-769				-1,152	419		863
		1,617	2,943	4,360	5,738	7,142	(7,619) 8,669	4,079	2,031	1,439
75		1,985		3,061	3,556	3,886	4,255	3,464		1,902
		1,444		1,206	1,525	986	1,238		1,501	1,531
105										

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 30	24	18	12	6	0	6	12	18	24	30
								90	4		
15	-75		142					243	112		
								476	296		
	-21		223					712	530		
45								1,038	1,011		
	-19		-191					1,657	1,807	1,543	1,424
								4,078			
75	390		234		794	946	948 1,124 1,813	105	940	1,144	
						1,206	1,659 1,547 1,079	-243	22		
105	1,161		1,435		1,225	1,154	1,274 1,266 1,067	75	52	251	
						790	655 715	464	603		
135											
			809			569	382 371				
165						292					
							90 97				

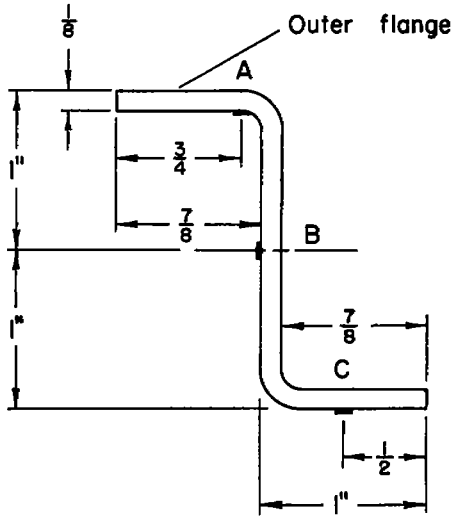
TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Continued

(d) Shear stresses due to cutout only

θ, deg	Distance from center line of cutout, in. 30	24	18	12	6	0	6	12	18	24	30
								90	4		
15	-218		-1					100	-31		
								194	14		
	-433		-189					300	118		
								508	481		
45	-651		-823					1,025	1,175	911	792
								3,364			
75	-384		-540		20	172	174 350 1,039	-669	166	370	
						394	847 735 267	-1,055	-790		
105	349		623		413	342	462 454 255	-737	-750	-561	
						76	-59 1	-250	-111		
135			-179			39	-148 -159				
						10					
165							-53 -46				

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS ON TENSION SIDE OF CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
5				2,072	-1,973	-3,218
15				1,696	-1,647	-2,804
25				1,176	-1,387	-1,936
35				269	-597	-771
45				-458	280	419
55				-781	1,296	1,691
65				-1,879	1,335	3,180
75	-530	---	304	-1,894	1,744	3,276
85	-313	92	371	-1,855	1,537	2,780
95	-197	187	419	-1,638	1,133	2,125

TABLE 8.- STRESSES AROUND SIDE CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		118		203	0		0	-103		88	
15		337		908	1,786	474	-941	-177		389	
		554		856	935	736	502	509		810	
		730		845	872	972	1,076	1,148		1,207	
45		817		932	1,028	1,148	1,393	1,440		1,513	
		919		1,067	1,182	1,399	1,690	1,737		1,943	
		983		1,175	1,366	1,611	1,849	1,947	2,092	2,120	
75		1,001		1,251	1,487	1,693	1,855	2,064		2,341	
		1,057		1,590		1,752	2,061		2,385	2,426	
105											

TABLE 8.- STRESSES AROUND SIDE CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 30	24	18	12	6	0	6	12	18	24	30
		42		105	-108		-130	-244		-75	
15		105		558	1,397	46	-1,408	-682		-194	
		93		264	278	13	-287	-345		-176	
		95		30	-34	-24	-10	-29		-151	
45		27		-82	-99	-91	41	-24		-176	
		-1		-115	-131	-45	115	31		-25	
		-40		-139	-94	5	98	50	49	-68	
75		-93		-155	-75	-25	-19	34		0	
		-80		129		-33	114		114	-7	
105											

TABLE 8.- STRESSES AROUND SIDE CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-973		-1,197	-1,184		
	-849		-890		-1,071	-1,328		-1,329	-1,081		
15						-450	-1,057 -1,079 -1,070	-454	-671		
	-719		-698		-510	-532	-1,056 -1,282 -1,124	-528	-518		
					-510	-566	-961 -1,095 -1,025	-551	-520		
45	-540		-488		-494	-509	-798 -867 -785	-492	-519	-432	-466
					-423	-429	-544 -582 -566	-413			
	-279		-283		-388	-344	-300 -341 -333	-330	-433	-224	
75						-175	-93 -118 -98	-191	-264		
	150		157		164	109	293 220 257	167	66	-108	
105											
						384	500 474	483	422		
135			637			633	651 666				
						788					
165							816 784				

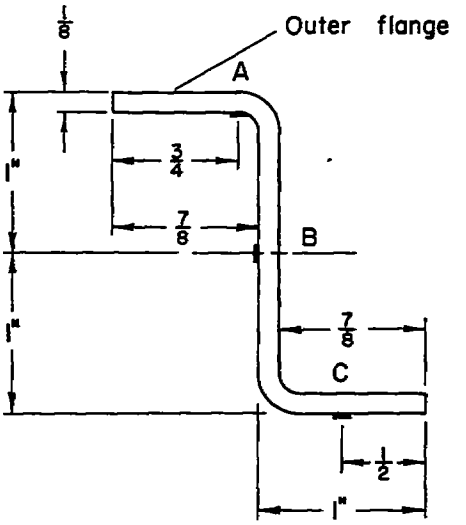
TABLE 8.- STRESSES AROUND SIDE CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-148		-372	-359		
15	-37		-78		-259	-516		-517	-269		
						324	-283 -305 -296	320	103		
	-5		16		204	182	-342 -568 -410	186	196		
45					122	66	-329 -463 -393	81	112		
	-10		42		36	21	-268 -337 -255	38	11	98	64
					-11	-17	-132 -170 -154	-1			
75	3		-1		-106	-62	-18 -59 -51	-48	-151	58	
						-32	50 25 45	-48	-121		
105	7		14		21	-34	150 77 114	24	-77	251	
						-28	88 62	71	10		
135											
			5			1	19 34				
165						14					
							4 -28				

TABLE 8.- STRESSES AROUND SIDE CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	-53	848	965	573	339	-360
85	0	1,007	1,028	605	244	-392
75	212	---	954	466	244	-339
65	625	901	625	127	222	-74
55	816	424	85	-212	530	360
45	944	---	-551	-297	854	806
35	742	-932	-1,034	-117	1,369	1,282
25	371	-1,389	-1,632	424	1,696	1,441
15	---	---	-1,642	509	1,272	1,272
5	---	-815	-742	816	456	42
5	636	519	350	0	-1,060	-1,113
15	350	---	1,230	53	-1,908	-2,109
25	-148	1,272	1,358	0	-2,067	-1,961
35	-742	848	1,071	148	-1,696	-1,590
45	-944	---	626	10	-1,007	-764
55	-848	-329	106	0	-392	0
65	-647	-657	-276	-636	0	530
75	-540	-752	-520	-952	201	848
85	-435	-785	-520	-1,166	297	1,007
95	-318	-710	-530	-1,230	0	901

TABLE 9.- STRESSES AROUND SIDE CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		124		91	0		0	0		44	
15		433		484	0		0	-12		294	
		603		1,343	2,792	878	-1,178	-77		661	
		780		1,101	1,199	1,022	788	794		1,072	
45		831		922	989	1,151	1,400	1,475		1,428	
		874		958	1,006	1,414	1,731	1,825		1,875	
		911		1,034	1,134	1,502	1,870	2,017	2,035	2,179	
75		965		1,172	1,314	1,600	1,958	2,086		2,356	
		967		1,508		1,686	2,036		2,378	2,453	
105											

TABLE 9.- STRESSES AROUND SIDE CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		48		-7	-108		-130	-141		-119	
15		161		134	-389		-467	-517		-289	
		142		751	2,135	155	-1,967	-931		-325	
		145		286	293	26	-298	-383		-286	
45		41		-92	-138	88	48	11		-261	
		46		-224	-307	-30	156	119		-93	
		-112		-280	-326	-104	119	120	-8	-9	
75		-129		-234	-248	-118	84	56		15	
		-70		47		-99	89		-107	20	
105											

TABLE 9.- STRESSES AROUND SIDE CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	36	30	24	18	12	6	0	6	12	18	24
						-787		-1,138	-1,162		
15	-851		-925		-958	-889		-1,154	-1,118		
						-1,527		-1,267	-950		
	-738		-682		-524	-218	-1,372 -1,532 -1,410	-120	-403		
45					-372	-389	-1,321 -1,556 -1,358	-325	-317		
	-512		-437		-402	-407	-1,111 -1,220 -1,080	-398	-391	-386	-402
					-437	-389	-756 -787 -766	-373			
75	-249		-260		-417	-331	-393 -434 -442	-304	-461	-212	
						-195	-100 -132 -58	-232	-334		
105	141		114		130	101	351 288 287	119	23	73	
						348	550 514		391		
135			640			732	682 651	455			
						795					
165							808 810				

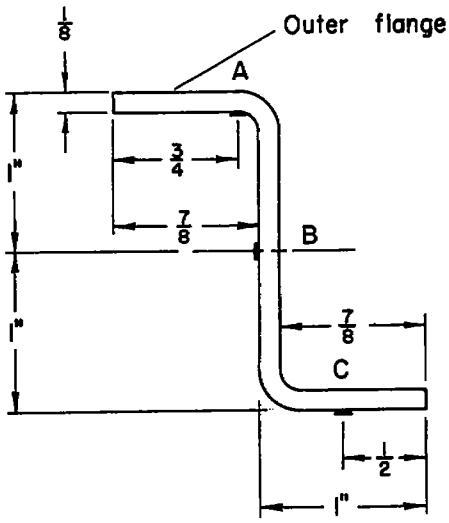
TABLE 9.- STRESSES AROUND SIDE CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						38		-313	-337		
15	-39		-113		-146	-77		-342	-306		
						-753		-493	-176		
	-24		32		190	496	-658 -818 -696	594	311		
45					260	243	-689 -924 -726	307	315		
	18		93		128	123	-581 -690 -520	132	139	144	128
					-25	23	-344 -375 -354	39			
75	33		22		-135	-49	-111 -152 -160	-22	-179	70	
						-52	43 11 85	-89	-191		
105	-2		-29		-13	-42	208 145 144	-24	-120	-70	
						-64	138 102	-177	-21		
135											
			8			100	50 19				
165						21					
							-4 -2				

TABLE 9.- STRESSES AROUND SIDE CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 7,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	-498	1,325	1,760	1,177	-286	-1,208
85	-212	1,654	1,802	912	-541	-1,272
75	286	1,208	1,484	413	-488	-1,071
65	985	1,198	763	-191	-53	-424
55	1,400	180	-339	-721	742	636
45	1,484	-572	-1,516	-742	1,802	1,728
35	1,113	-2,385	-2,438	-371	2,809	2,851
25	159	-2,470	-3,286	106	2,968	3,339
15	0	-1,548	-2,120	625	2,385	2,088
5	456	-1,028	-986	488	753	403
5	254	604	551	572	-1,283	-1,643
15	435	1,749	1,813	32	-2,957	-3,074
25	-53	2,300	3,021	371	-3,244	-3,869
35	-965	2,109	2,533	392	-3,106	-3,201
45	-1,357	-74	1,579	530	-1,875	-1,749
55	-1,399	-106	583	265	-625	-339
65	-1,060	-922	-445	-403	244	742
75	-615	-1,166	-996	-975	636	1,484
85	-233	-1,442	-1,261	-1,304	742	1,770
95	74	-1,219	-996	-1,622	562	1,654

TABLE 10.- STRESSES AROUND SIDE CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,600 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		99		41	0		0	15		34	
15		413		204	0		0	19		223	
		641		668	0		0	-45		477	
		842		1,794	3,713	1,211	-1,305	-15		871	
45		965		1,300	1,452	1,355	1,128	1,090		1,336	
		978		1,003	987	1,507	1,808	1,866		1,760	
		927		933	1,022	1,722	2,110	2,240	2,035	2,158	
75		946		1,098	1,222	1,703	2,195	2,385		2,441	
		985		1,456		1,741	2,082		2,460	2,500	
105											

TABLE 10.- STRESSES AROUND SIDE CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,600 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		23		-57	-108		-130	-126		-129	
15		141		-156	-389		-467	-486		-360	
		180		76	-657		-789	-899		-509	
		207		979	2,807	215	-2,391	-1,192		-487	
45		175		286	325	116	-224	-374		-353	
		58		-179	-326	63	233	160		-208	
		-96		-381	-438	116	359	343	-8	-30	
75		-148		-308	-351	-15	221	355		100	
		-152		-5		-44	135		189	67	
105											

TABLE 10.- STRESSES AROUND SIDE CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,600 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-656		-1,168	-1,094		
15	-872		-893		-712	-699		-1,086	-1,075		
						-869		-1,056	-1,027		
	-697		-696		-1,055	-1,726		-1,100	-686		
45					-390	54	-1,768 -1,970 -1,793	269	-115		
	-532		-422		-188	-162	-1,584 -1,980 -1,565	-100	-115	-259	-309
					-281	-274	-1,146 -1,414 -1,255	-238			
75	-241		-218		-374	-305	-674 -725 -741	-281	-456	-160	
						-212	-222 -212 -246	-253	-396		
105	129		93		72	44	438 374 371	78	-69	47	
						354	621 603	402	-347		
135											
			633			609	684 714				
165						792					
							762 731				

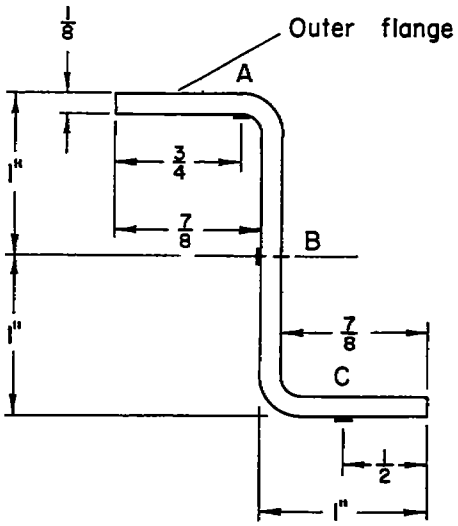
TABLE 10.- STRESSES AROUND SIDE CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,600 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						169		-343	-269		
15	-60		-81		100	113		-274	-263		
						-95		-282	-253		
	17		18		-341	-1,012		-386	28		
					242	686	-1,136 -1,338 -1,161	901	517		
45	-2		108		342	368	-1,054 -1,450 -1,035	430	415	271	221
					131	138	-734 -1,002 -843	174			
	41		64		-92	-23	-392 -443 -459	1	-174	122	
75						-69	-79 -69 -103	-110	-253		
	-14		-50		-71	-99	295 231 228	-65	-212	-96	
105											
						-58	209 191	-10	-759		
135			1			-23	52 82				
						18					
165							-50 -81				

TABLE 10.- STRESSES AROUND SIDE CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 5,600 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	-551	1,473	2,173	1,272	-763	-1,887
85	-95	1,823	2,067	890	-1,028	-1,887
75	721	1,177	1,304	106	-594	-1,336
65	1,134	816	403	-636	74	-106
55	1,473	-413	-901	-1,039	1,399	1,484
45	1,251	-1,230	-2,311	-848	2,756	2,968
35	456	-2,555	-3,286	-912	3,392	4,240
25	647	-2,841	-3,180	-318	3,445	3,943
15	795	---	-2,120	-488	2,120	2,438
5	689	-700	-816	106	752	424
5	-371	477	742	827	-1,188	-1,654
15	-806	1,272	2,120	1,007	-2,756	-3,021
25	-392	2,841	2,809	678	-3,604	-4,240
35	-901	2,544	3,445	859	-3,551	-4,505
45	-1,166	---	2,438	647	-2,650	-2,756
55	-1,367	657	1,092	445	-1,113	-848
65	-1,145	-498	-265	0	276	773
75	-689	-1,166	-1,145	-636	1,007	1,665
85	-159	-1,516	-1,654	-1,177	1,219	2,226
95	371	-1,643	-1,579	-1,526	1,124	2,226

TABLE 11.- STRESSES AROUND SIDE CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,200 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		83		55	0		0	35		40	
15		346		150	0		0	10		136	
		598		328	0		0	-50		313	
		921		906	0		0	-131		590	
45		1,065		2,183	4,970	1,726	-1,651	-86		1,000	
		1,141		1,560	1,641	1,716	1,507	1,479		1,464	
		1,035		994	1,010	1,772	2,304	2,392	2,011	2,009	
75		1,000		969	1,045	1,777	2,473	2,706		2,448	
		889		1,318		1,797	2,408		2,766	2,690	
105											

TABLE 11.- STRESSES AROUND SIDE CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,200 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		7		43	-108		-130	-106		-123	
15		74		200	-389		-467	-495		-447	
		137		264	-657		-789	-904		-673	
		286		91	-906		-1,086	-1,308		-768	
45		275		1,169	3,843	487	-3,003	-1,550		-689	
		221		378	328	272	-68	-227		-504	
		12		-320	450	166	553	495	-32	-179	
75		-94		-437	517	59	599	676		107	
		-248		-143		12	461		495	257	
105											

TABLE 11.- STRESSES AROUND SIDE CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,200 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0	6	12	18	24
						-530		-1,124	-1,012		
15	-916		-881		-579	-589		-1,097	-991		
						-671		-1,048	-981		
	-748		-783		-1,012	-952		-960	-852		
45					-1,232	-2,080		-963	-510		
	-510		-464		-240	389	-2,349 -2,609 -2,178	670	137	-203	-276
					-12	24	-1,874 -2,344 -1,972	97			
75	-206		-194		-202	-173	-1,220 -1,466 -1,369	-165	-302	-58	
						-124	-563 -593 -614	-257	-420		
105	-135		-61		-20	0	487 471 449	-41	-218	-18	
						288	765 783	332	-251		
135											
			647			604	767 828				
165						804					
							698 704				

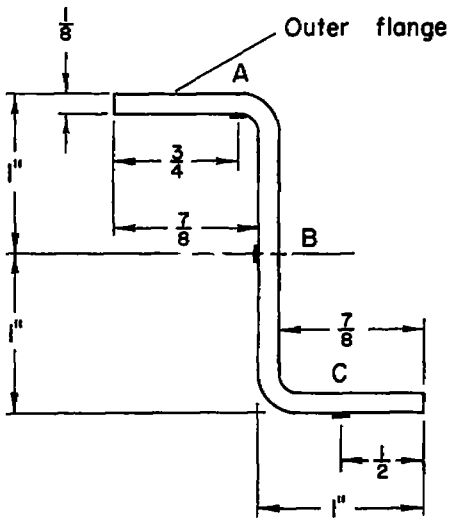
TABLE 11.- STRESSES AROUND SIDE CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,200 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0		6	12	18	24
						295			-299	-187		
15	-104		-69		-233	233			-285	-179		
						103			-274	-207		
	-34		-69		-298	-238			-246	-138		
45						-1,448			-331	122		
	20		-66		-290	919	-1,819	-2,079 -1,648	1,200	667	327	254
						436	-1,462	-1,932 -1,560	509			
75	76		80		80	109	-938	-1,184 -1,087	117	-20	224	
						19	-420	-450 -457	-114	-277		
105	8		-163		-163	-143	344	328 306	-184	-361	-161	
						-124		353 371	-80	-663		
135												
			15			-28		137 196				
165						30						
								-114 108				

TABLE 11.- STRESSES AROUND SIDE CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 4,200 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	-445	1,643	2,438	1,230	-1,675	-2,438
85	132	1,802	2,003	604	-1,378	-2,120
75	848	859	1,124	-138	-678	-1,060
65	1,219	-32	-276	-583	636	477
55	1,293	-1,420	-1,728	-827	2,184	2,162
45	859	---	-3,286	-1,272	3,127	4,113
35	954	-2,512	-2,968	-1,166	3,604	4,452
25	1,495	-2,120	-2,809	-1,548	3,169	4,092
15	1,081	---	-1,802	-1,049	2,067	2,544
5	509	-413	-647	-233	625	668
5	-329	488	594	912	-848	-1,526
15	-1,177	731	2,014	1,516	-2,268	-3,201
25	-1,420	2,321	3,032	1,855	-3,286	-4,282
35	-710	2,915	3,032	1,272	-3,880	-4,653
45	-890	---	3,286	1,124	-3,244	-3,710
55	-986	1,463	1,802	498	-1,834	-1,696
65	-1,166	212	307	212	-138	53
75	-742	-943	-954	-424	742	1,410
85	-265	-1,590	-1,738	-880	1,431	2,396
95	371	-1,834	-1,940	-1,442	1,579	2,639

TABLE 12.- STRESSES AROUND SIDE CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,800 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		64		34	0		0	0		0	
15		276		124	0		0	-84		-68	
		484		212	0		0	-114		-53	
		734		321	0		0	-129		53	
45		984		553	0		0	-151		212	
		1,234		1,287	0		0	-273		583	
		1,306		2,989	(6,299) 8,236	2,264	(-2,658) -901	151	(772) 1,393	1,060	
75		1,090		1,628	1,885	2,059	1,991	2,042		1,787	
		765		636		1,893	3,096	3,324	3,021	2,831	
105											

TABLE 12.- STRESSES AROUND SIDE CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,800 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
		-12		-64	-108		-130	-141		-163	
15		4		-226	-389		-467	-589		-651	
		23		-480	-657		-789	-968		-1,039	
		99		-494	-906		-1,086	-1,306		-1,305	
45		194		-461	-1,127		-1,352	-1,615		-1,477	
		314		105	-1,313		-1,575	-1,979		-1,385	
		283		1,675	(4,839) 6,776	658	(-4,409) -2,652	-1,746	(-1,271) -650	-1,128	
75		-4		222	323	341	117	12		-554	
		-372		-825		108	1,149	1,215	750	398	
105											

TABLE 12.- STRESSES AROUND SIDE CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,800 POUNDS) - Continued

(c) Shear stresses, psi

θ, deg	Distance from center line of cutout, in. 36	30	24	18	12	6	0		6	12	18	24
						-309			-956	-739		
15	-795		-597		-184	-362			-931	-716		
						-415			-902	-762		
	-721		-675		-527	-500			-837	-790		
45					-875	-724			-780	-828		
	-530		-653		-1,329	-1,205			-783	-692	-325	-331
					-1,368	-2,968			-743			
75	-240		-275		-50	1,083	-3,520 -3,626	-3,275	1,354	180	207	
						468	-2,490 -3,193	-2,445	359	65		
105	171		88		-74	0	-12 -132	-177	-321	-559	-44	
						197	1,177	1,009	-44	-156		
135												
			536			597	1,171	1,186				
165						887						
							736	739				

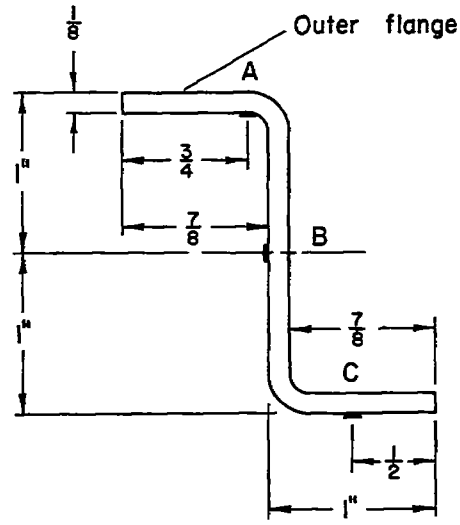
TABLE 12.- STRESSES AROUND SIDE CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,800 POUNDS) - Continued

(d) Shear stresses due to cutout only, psi

θ, deg	36	30	24	18	12	6	0	6	12	18	24
						Distance from center line of cutout, in.					
						516		-131	86		
15	17		215		628	450		-119	96		
						359		-128	12		
45	-7		39		187	214		-123	-76		
					-243	-92		-148	-196		
	0		-123		-799	-675		-253	-162	205	199
					-956	-2,556		-331			
75	42		7		232	1,365	-3,238 -3,344 -2,993	1,636	462	489	
						611	-2,347 -3,050 -2,302	502	208		
105	28		-55		-217	-143	-155 -175 -320	-464	-702	-187	
135						-215	765 597	-456	-568		
			-96			-35	539 554				
165						113					
							-76 -73				

TABLE 12.- STRESSES AROUND SIDE CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,800 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	-106	1,548	2,364	657	-1,664	-2,490
85	191	742	1,283	212	-498	-1,113
75	509	---	-265	-212	1,198	710
65	265	-1,590	-1,950	-1,092	2,406	3,140
55	625	-2,417	-2,480	-1,378	3,820	4,150
45	1,696	---	-2,798	-2,406	3,450	4,480
35	2,120	-1,410	-2,576	-2,714	2,870	4,450
25	1,781	-1,208	-2,184	-2,247	2,280	3,390
15	1,134	---	-1,399	-1,134	1,124	1,887
5	445	-392	-625	-21	186	191
5	-318	212	350	1,092	-901	-1,590
15	-1,124	---	1,208	1,908	-1,855	-3,190
25	-1,887	1,208	2,131	2,671	-2,544	-4,140
35	-2,131	1,696	2,650	2,756	-3,270	-4,800
45	-1,834	---	2,968	2,014	-3,340	-4,380
55	-647	2,406	2,682	869	-2,650	-3,160
65	-710	1,643	2,184	466	-1,484	-1,590
75	-541	---	731	-678	-371	106
85	-466	-445	-742	-721	1,007	2,099
95	0	-1,548	-1,696	-1,399	1,982	3,250

TABLE 13.- STRESSES AROUND SIDE CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,000 POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	24	18	12	6	0	6	12	18	24	30	36
		21	0				0	-53		-83	
15		129	0				0	-170		-318	
		244	0				0	-307		-339	
		371	0				0	-244		-392	
45		546	0				0	-551		-382	
		1,368	0				0	-689		0	
		3,610	9,026	(4,558) 6,519	(1,357) 3,440	-1,590	(-5,194) -2,258	-1,378	(117) 1,187	477	
75		1,601		1,484	1,473	1,357	562	816		1,155	
				1,642		2,750	3,180		2,750	2,650	
105											

TABLE 13.- STRESSES AROUND SIDE CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,000 POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	24	18	12	6	0	6	12	18	24	30	36
		-55	-87				-130	-194		-246	
15		-143	-311				-467	-675		-901	
		-217	-526				-789	-1,161		-1,325	
		-264	-725				-1,086	-1,421		-1,750	
45		-244	-902				-1,352	-2,015		-2,071	
		448	-1,051				-1,575	-2,395		-1,968	
		2,587	7,857	(3,244) 5,205	(-103) 1,980	-3,196	(-6,945) -4,009	-3,275	(-1,926) -856	-1,711	
75		507		78	-89	-361	-1,312	-1,214		-1,186	
				181		965	1,233		479	217	
105											

TABLE 13.- STRESSES AROUND SIDE CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,000 POUNDS) - Continued

(c) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
								-762	-482		
	-667		82					-761	-523		
15								-770	-589		
	-787		-550					-765	-659		
								-812	-742		
45	-775		-1,537					-890	-832	-354	-336
								-1,481			
	-107		146		-2,727	-2,265	-2,348 -2,278 -2,379	1,689	206	233	
75						-2,553	-2,534 -2,493 -1,825	-906	466		
	284		-111		-643	-713	-577 -803 -660	-214	-325	190	
105											
						618	577 474	-148	-297		
135			536			1,191	1,071 1,108				
						1,096					
165							1,112 1,166				

TABLE 13.- STRESSES AROUND SIDE CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,000 POUNDS) - Continued

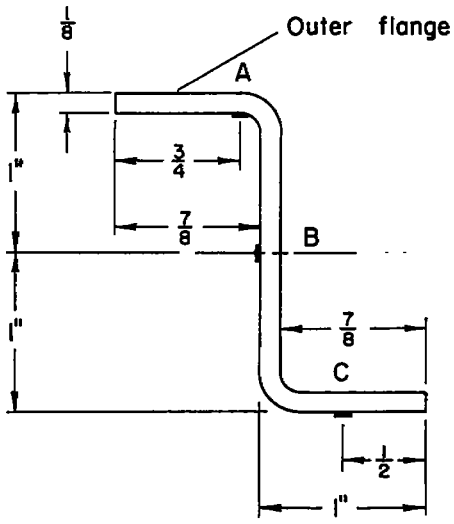
(d) Shear stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	30	24	18	12	6	0	6	12	18	24	30
								63	343		
15	145		894					51	289		
								4	185		
	-73		164					-51	55		
45								-180	-110		
	-245		-1,007					-360	-302	176	194
								-1,069			
75	175		428		-2,445	-1,983	-2,066 -1,996 -2,097	1,971	488	515	
						-2,410	-2,391 -2,350 -1,682	-763	609		
105	141		254		-786	-856	-720 -946 -803	-257	-468	47	
						206	165 62	-560	-709		
135											
			-96			559	439 476				
165						322					
							300 354				

TABLE 13.- STRESSES AROUND SIDE CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY SHEAR FORCE OF 2,000 POUNDS AT TIP (ACTUAL APPLIED LOAD, 2,000 POUNDS) - Concluded

(e) Ring stresses, psi



θ, deg	Ring 1			Ring 2		
	A	B	C	A	B	C
95	344	224	95	519	-848	-1,367
85	281	212	-26	-85	710	0
75	-148	---	21	-689	1,558	1,707
65				-1,632	2,533	3,498
55				-1,749	3,074	3,816
45				-2,279	2,533	3,371
35				-2,226	2,035	3,392
25				-1,929	1,463	2,417
15				-827	716	1,378
5				85	0	138
5				1,007	-1,505	-1,272
15				1,749	-742	-2,099
25				2,438	-1,908	-2,968
35				2,385	-2,353	-3,710
45				2,173	-2,544	-3,466
55				1,378	-2,067	-2,830
65				1,113	-1,208	-1,908
75	-175	---	138	106	-541	-424
85	-313	0	191	-498	477	1,345
95	-286	0	180	-1,166	1,420	2,170

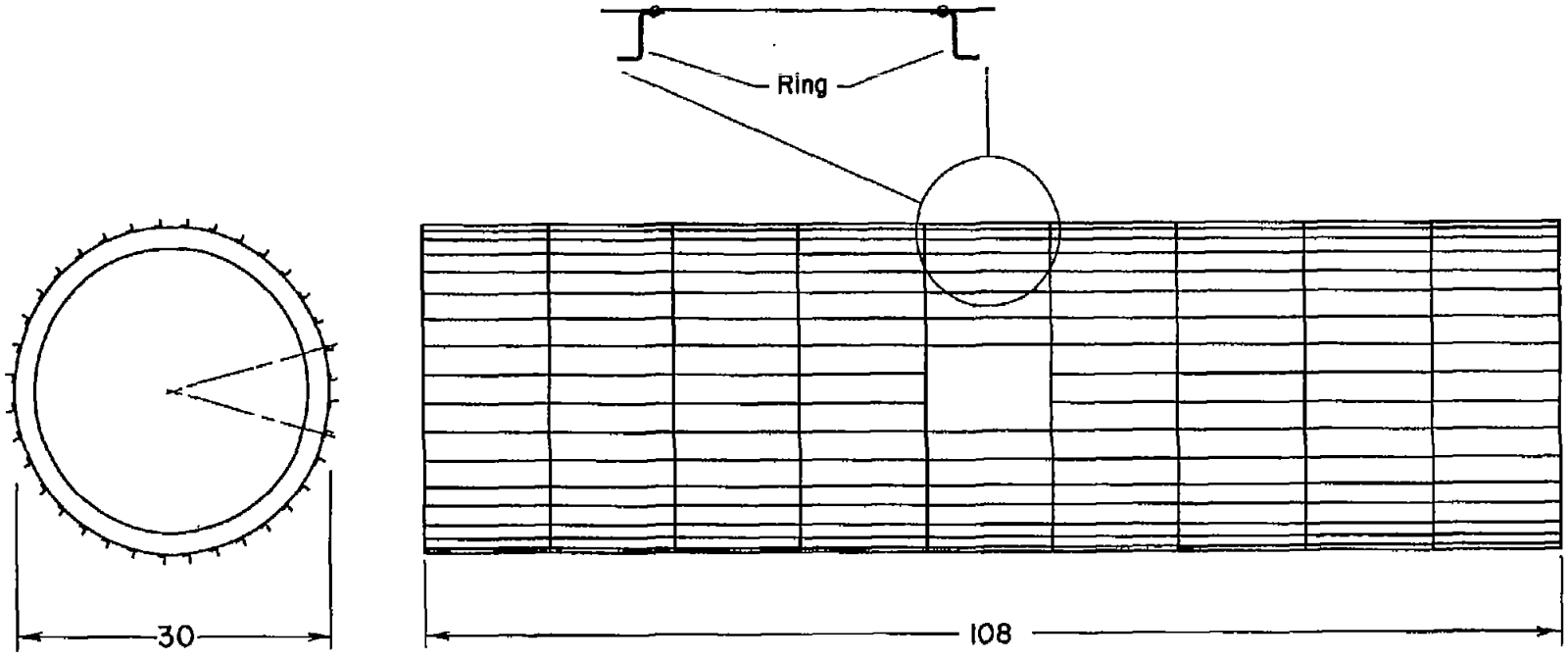


Figure 1. - Test specimen.

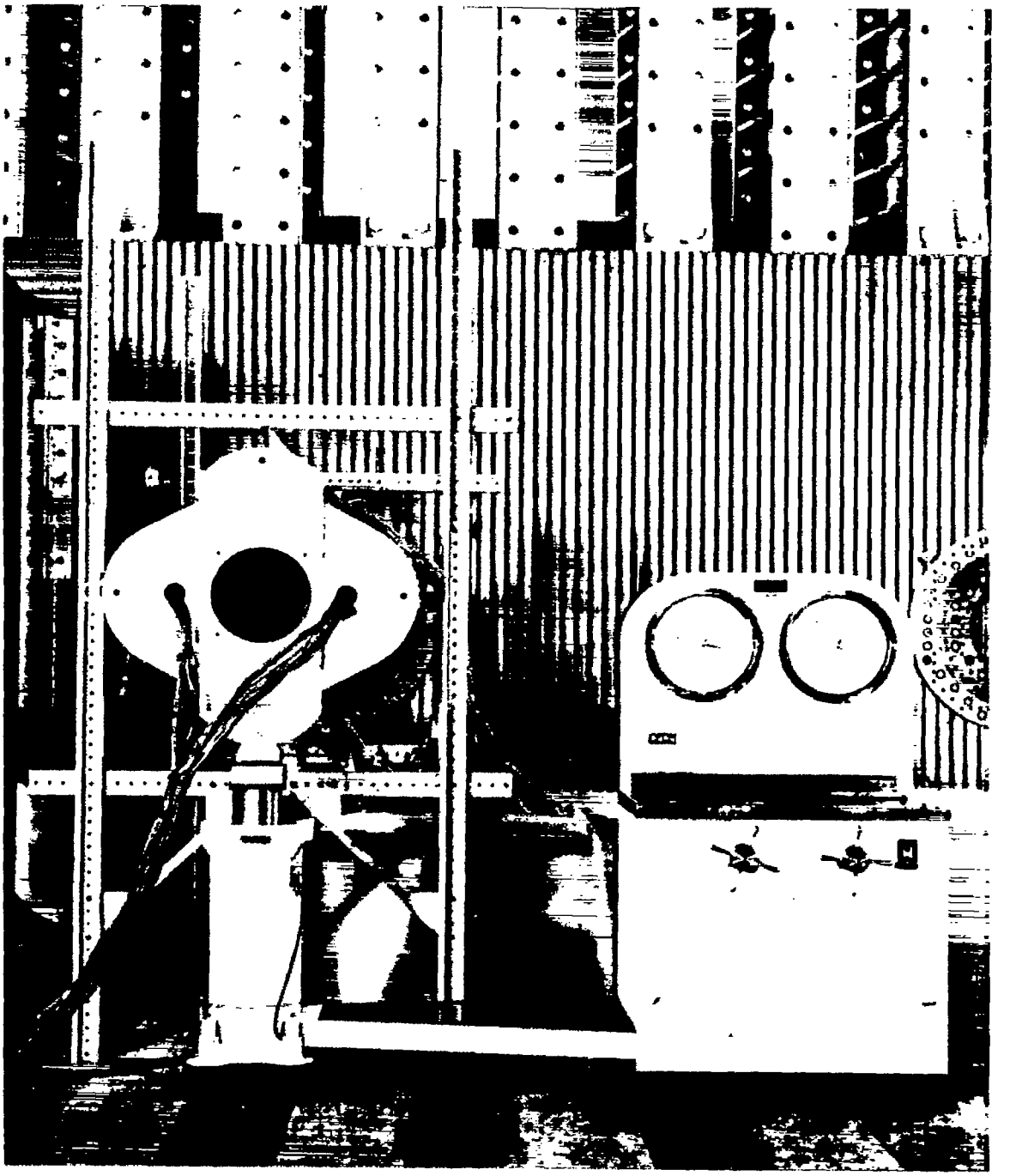


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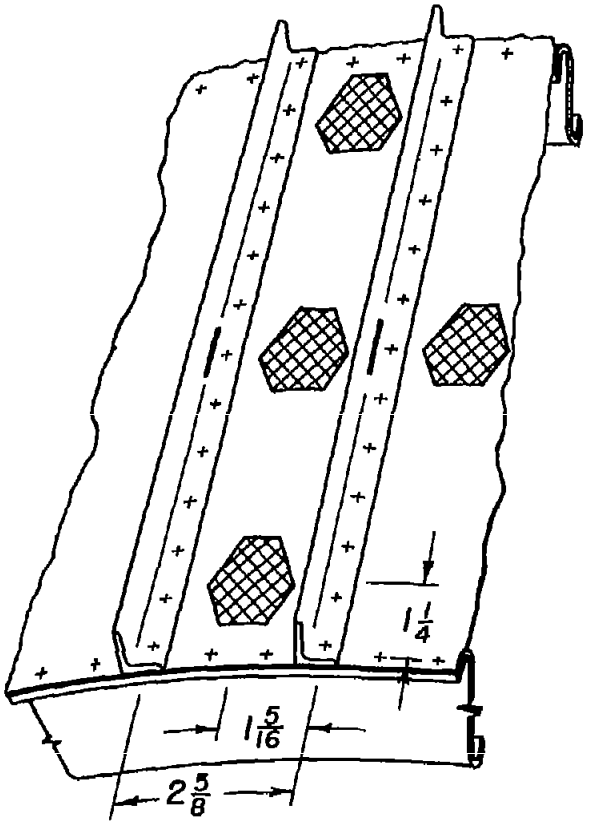
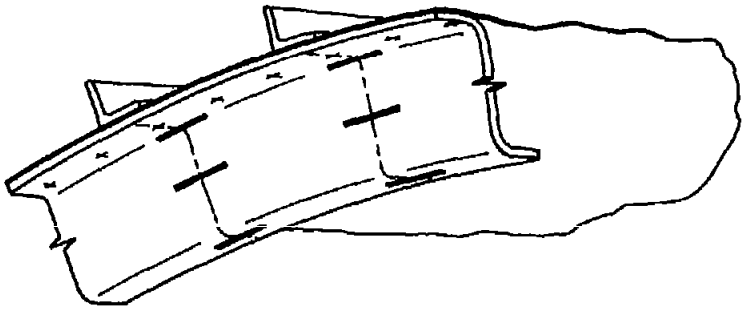
Figure 2. - Loading system.

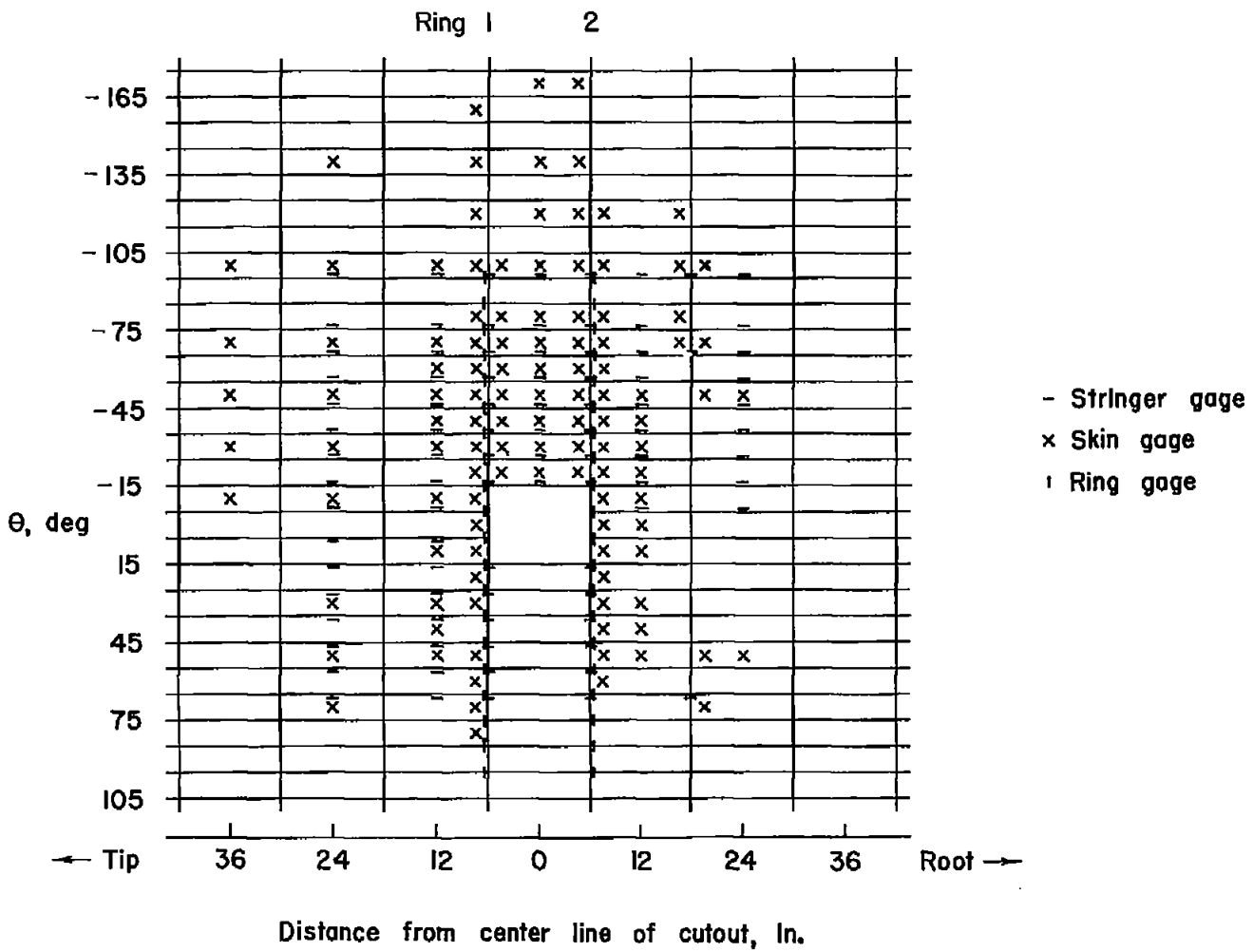


(a) Stringer and skin gages.



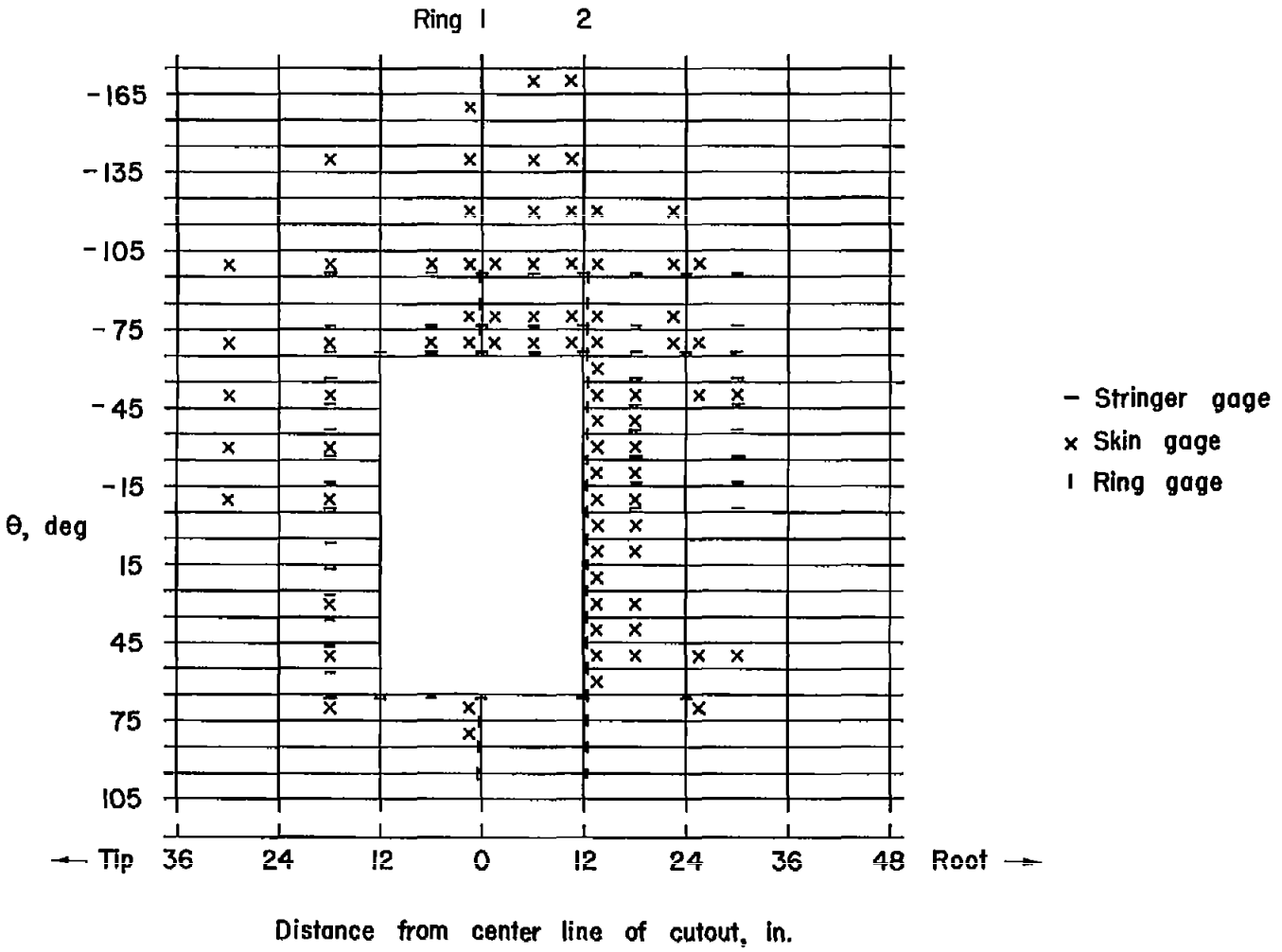
(b) Ring gages.

Figure 3. - Typical gage mountings.



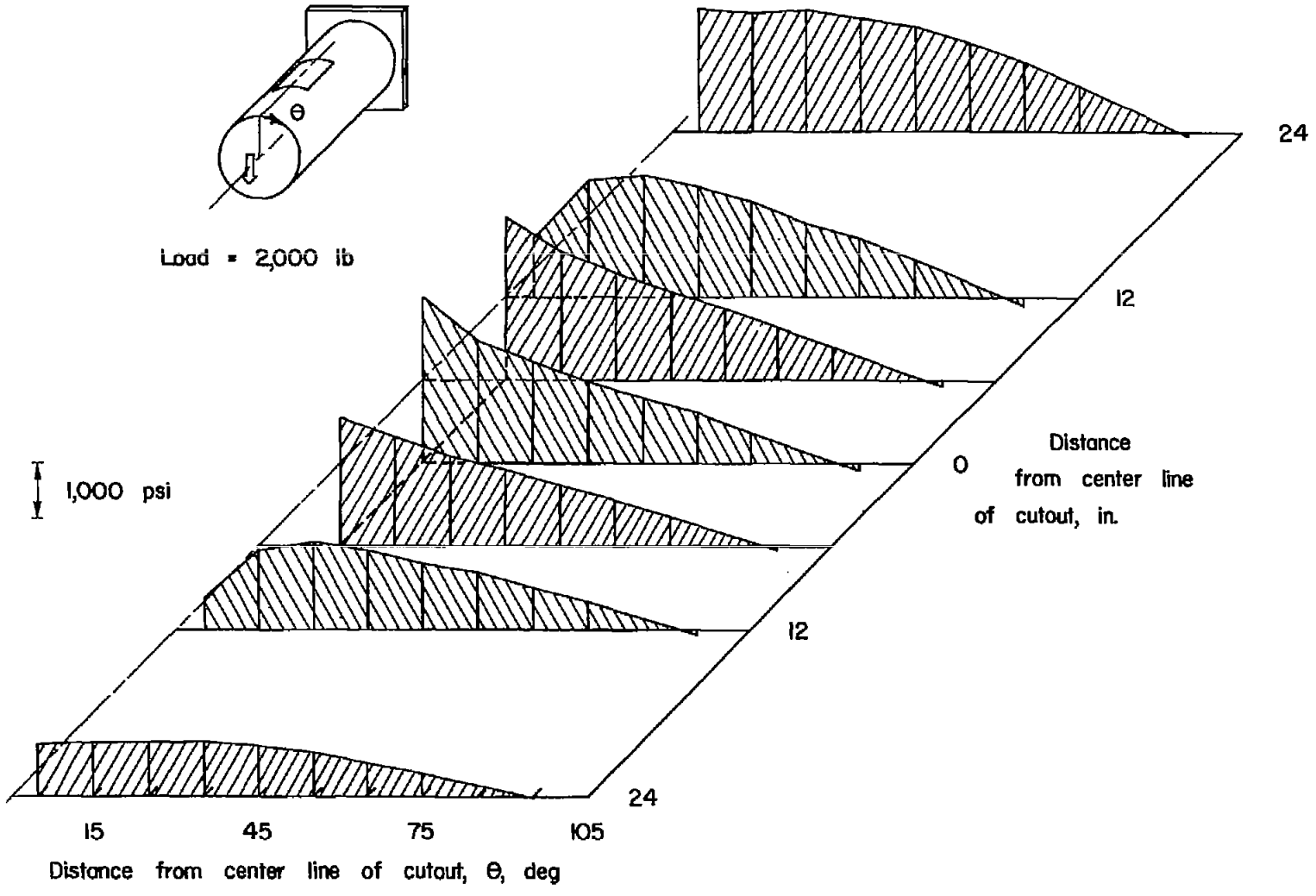
(a) Cutout 1 bay long.

Figure 4.- Gage pattern.



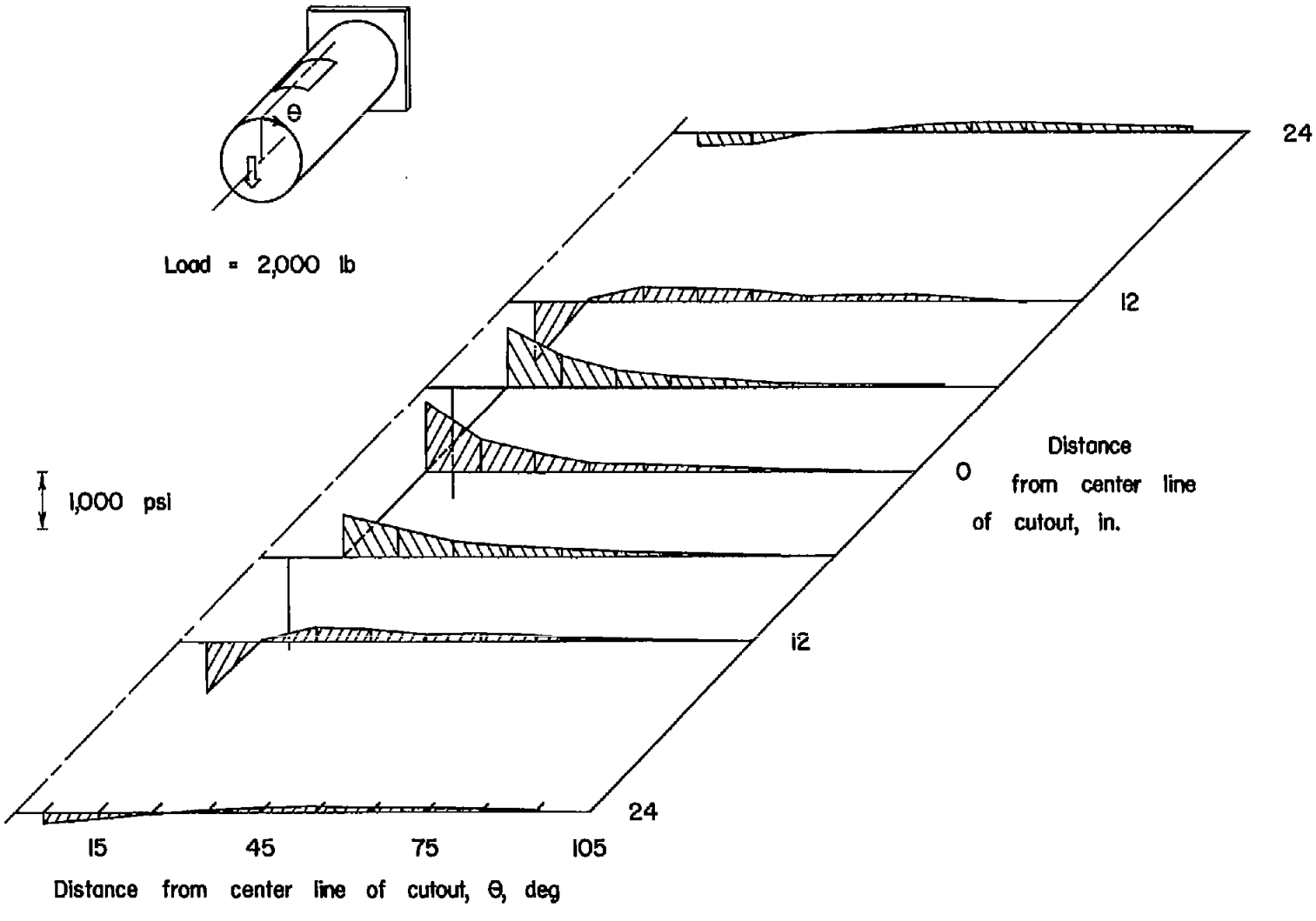
(b) Cutout 2 bays long.

Figure 4.- Concluded.



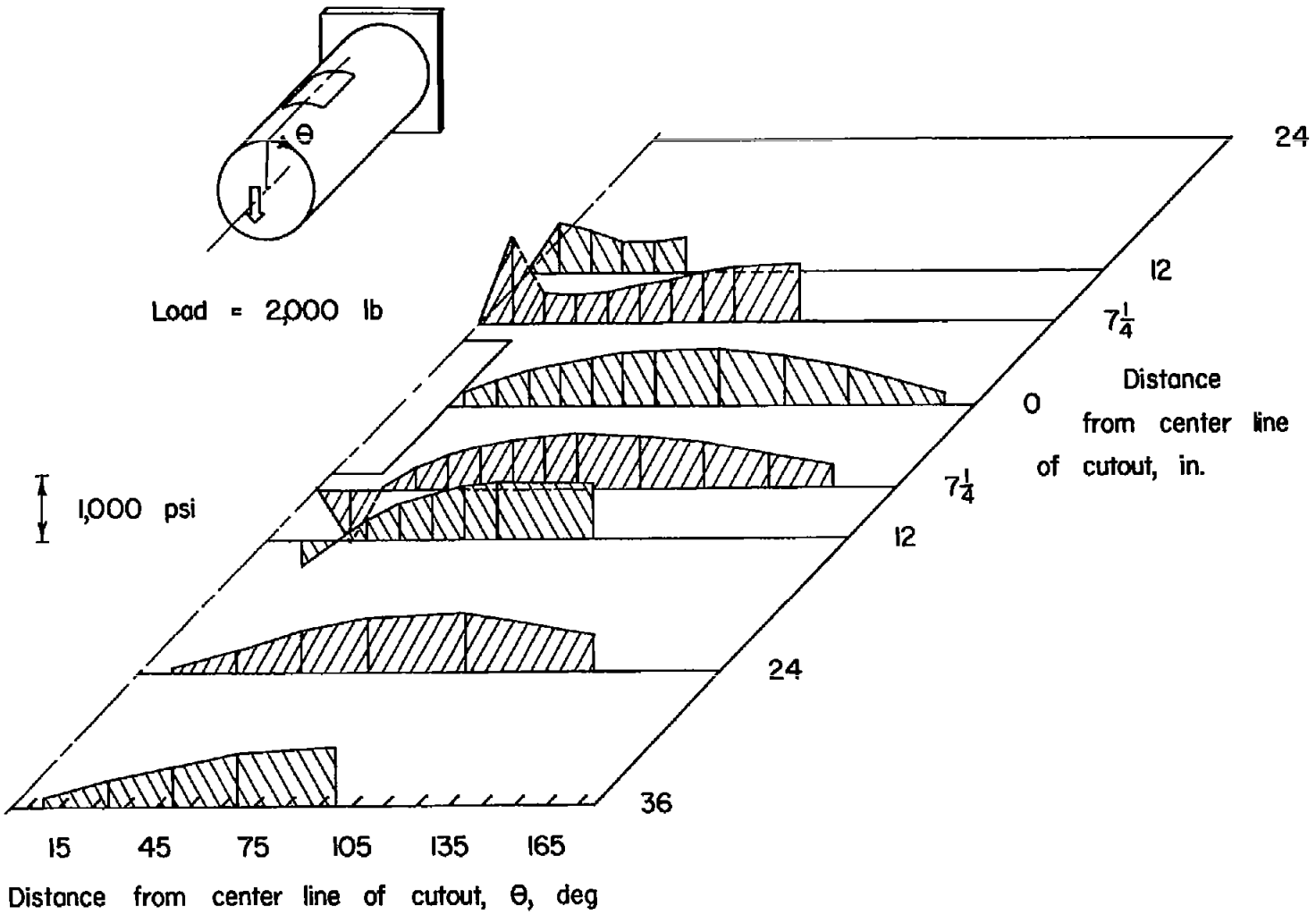
(a) Stringer stresses.

Figure 5. - Stress distribution, 30° cutout on tension side.



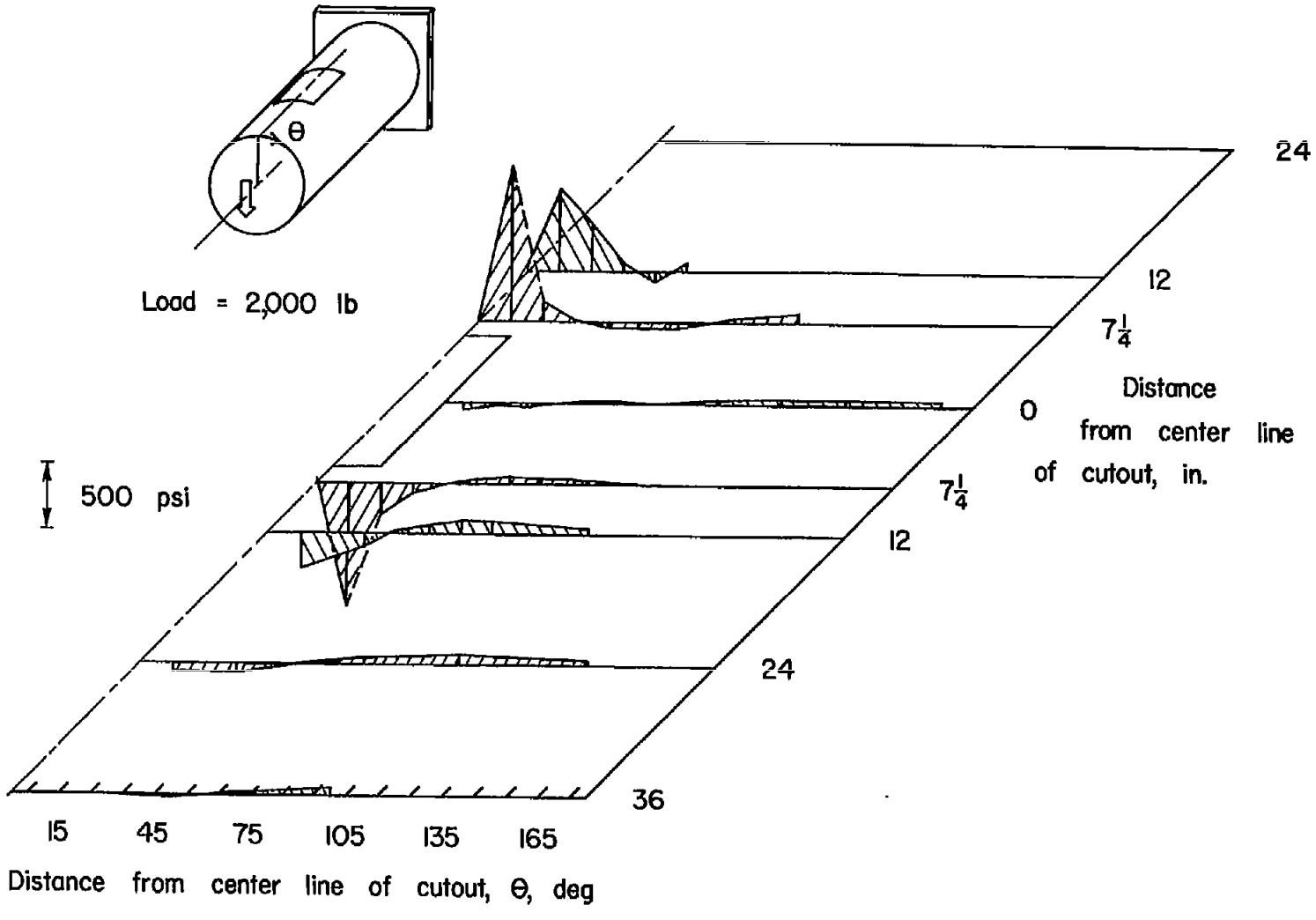
(b) Stringer stresses due to cutout only.

Figure 5. - Continued.



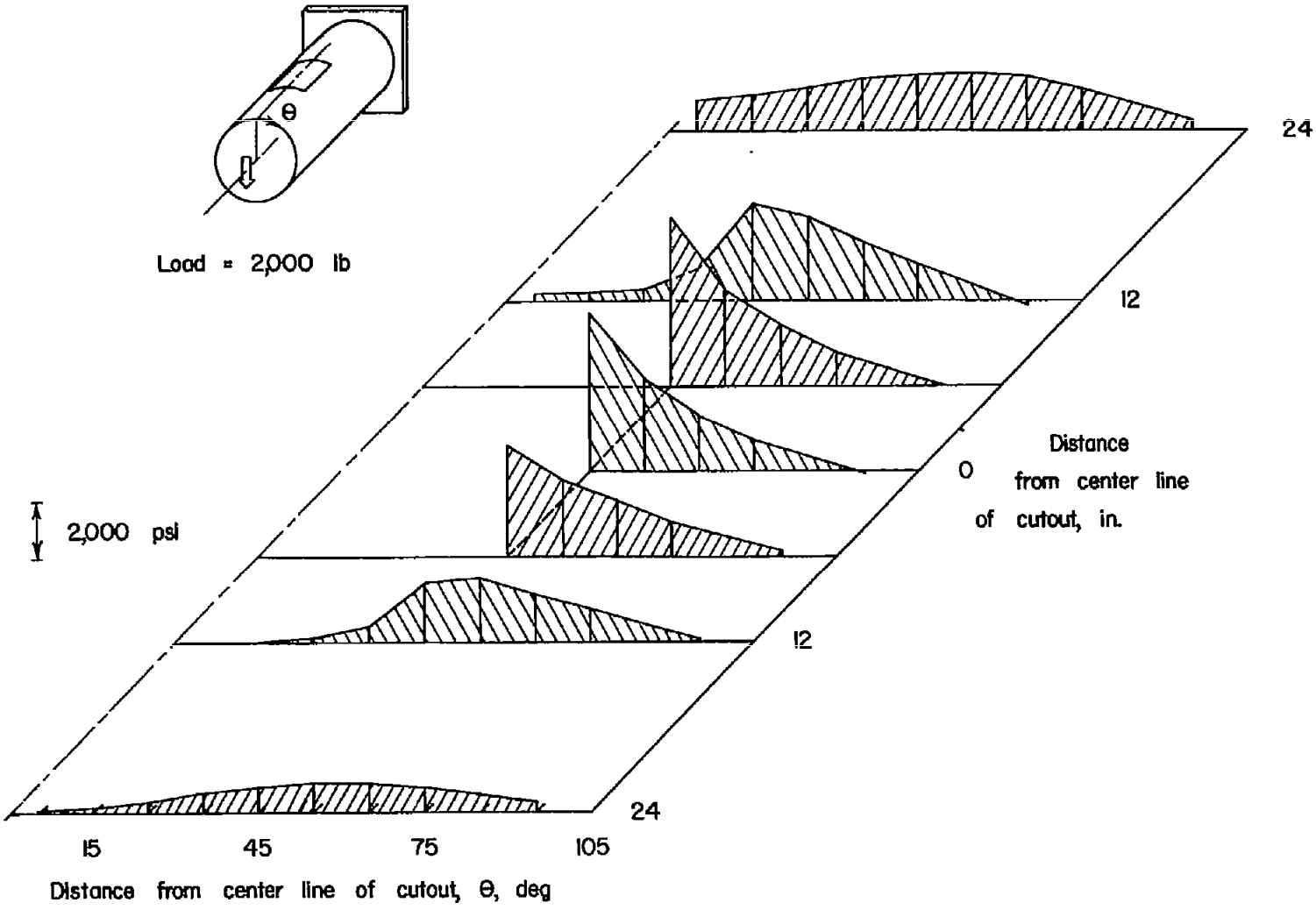
(c) Shear stresses.

Figure 5. - Continued.



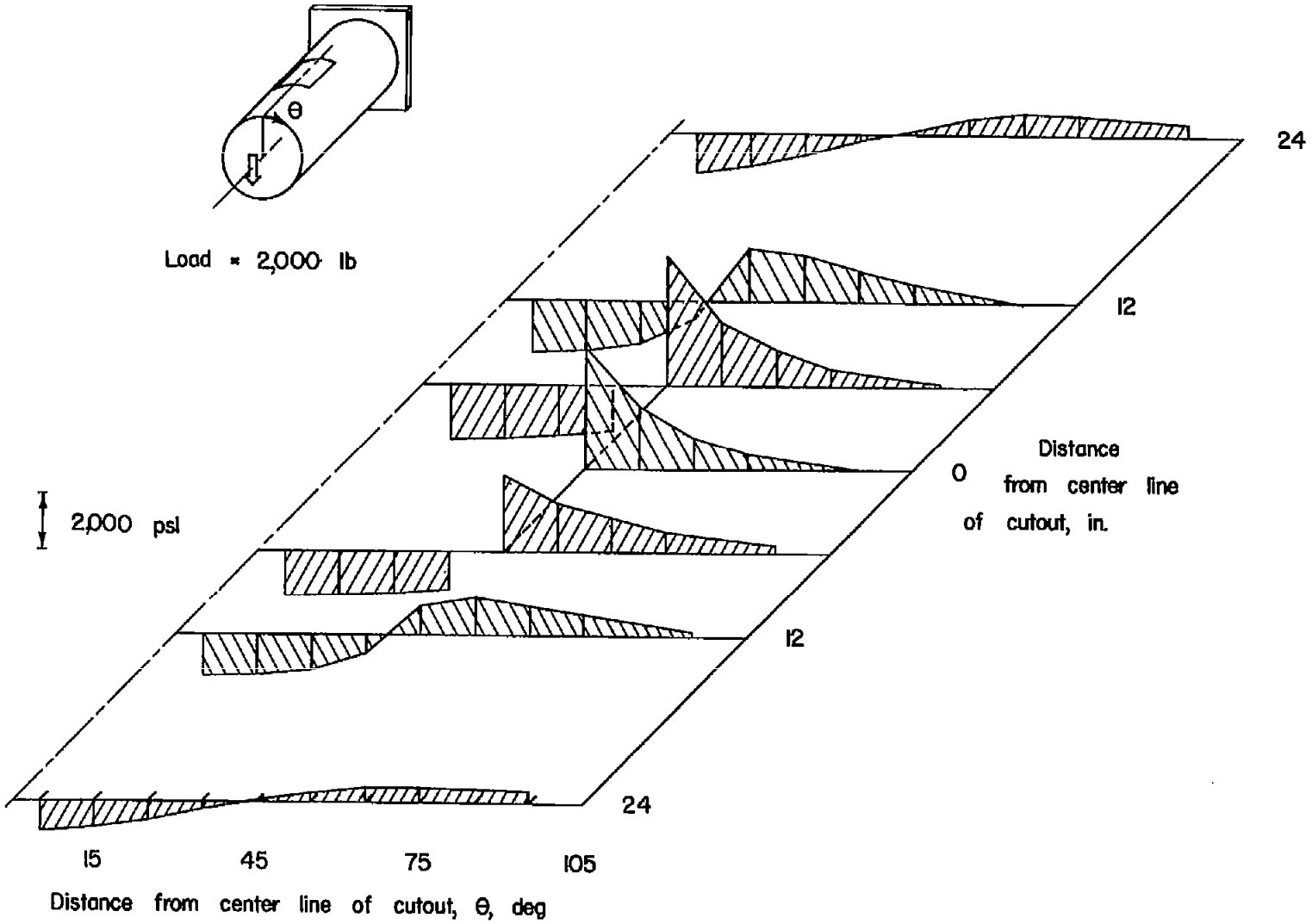
(d) Shear stresses due to cutout only.

Figure 5. - Concluded.



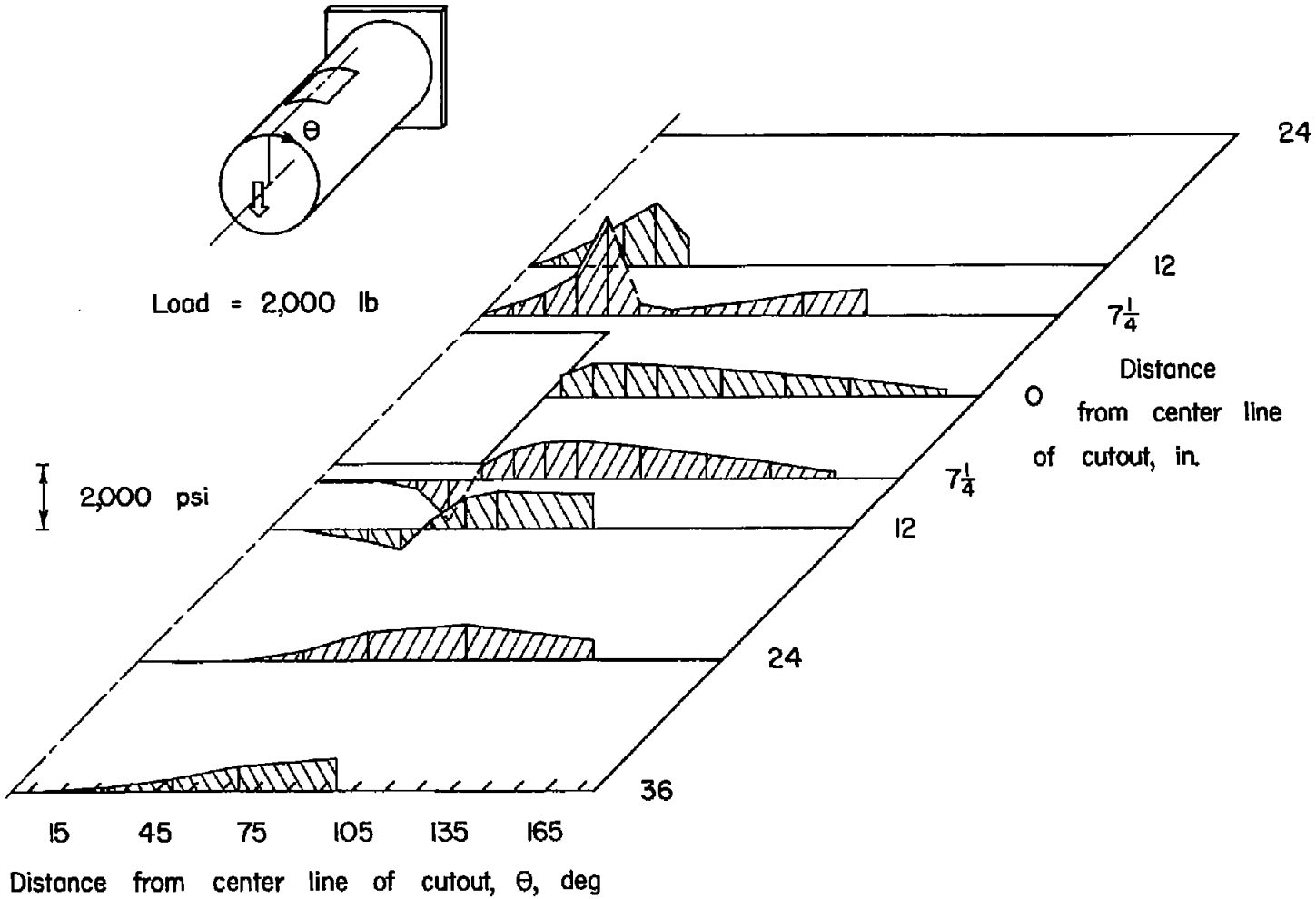
(a) Stringer stresses.

Figure 6. - Stress distribution, 90° cutout on tension side.



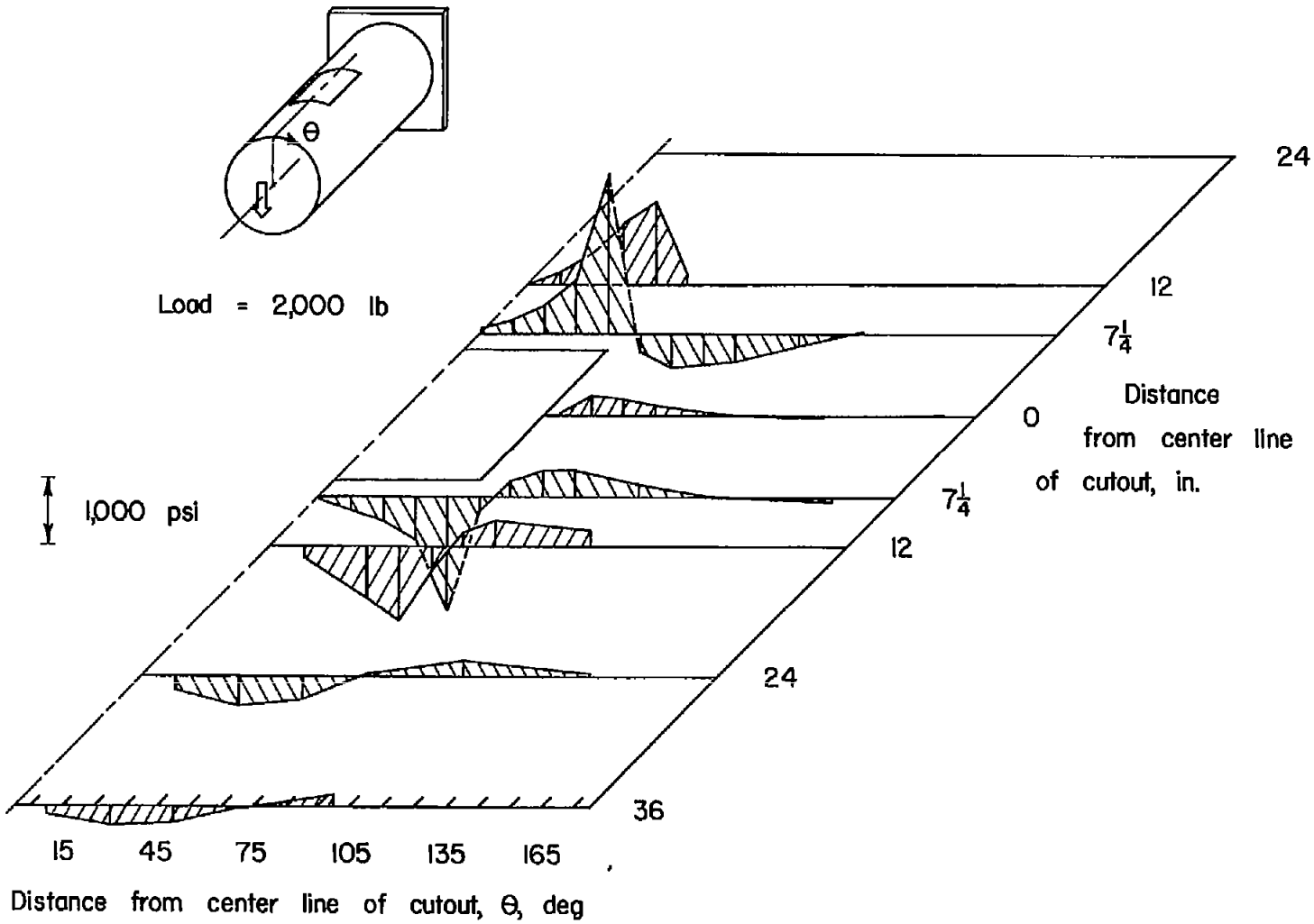
(b) Stringer stresses due to cutout only.

Figure 6. - Continued.



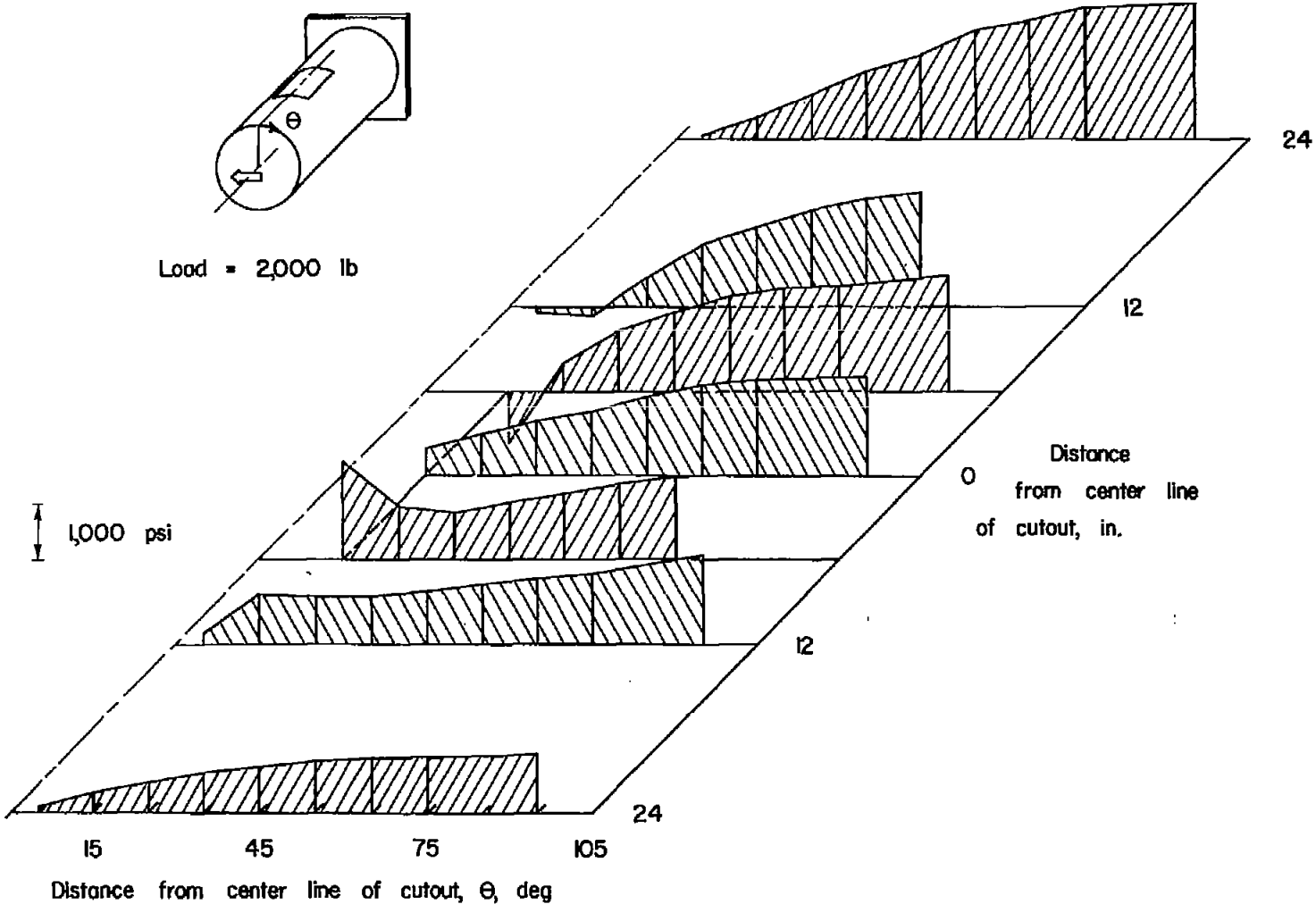
(c) Shear stresses.

Figure 6. - Continued.



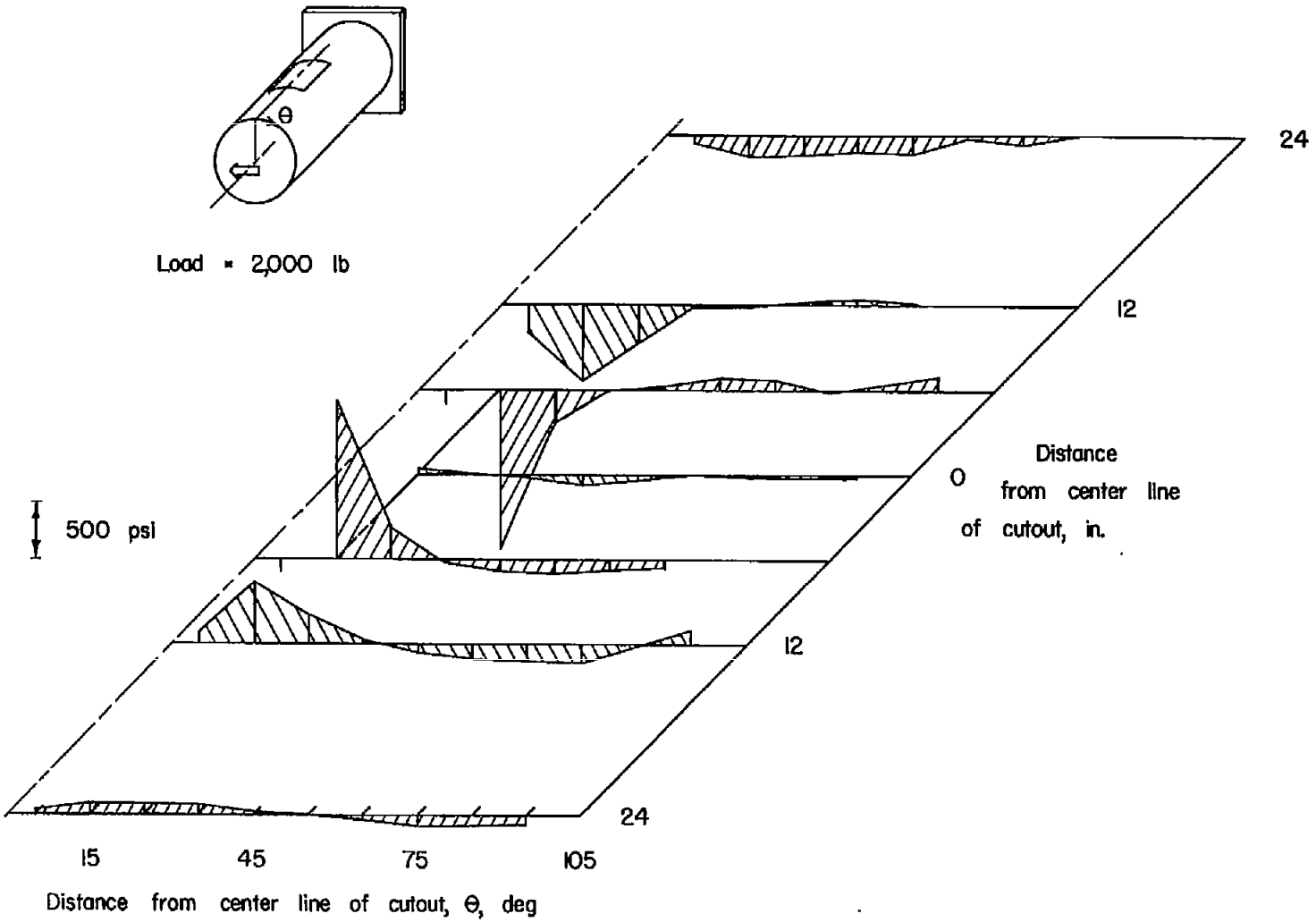
(d) Shear stresses due to cutout only.

Figure 6. - Concluded.



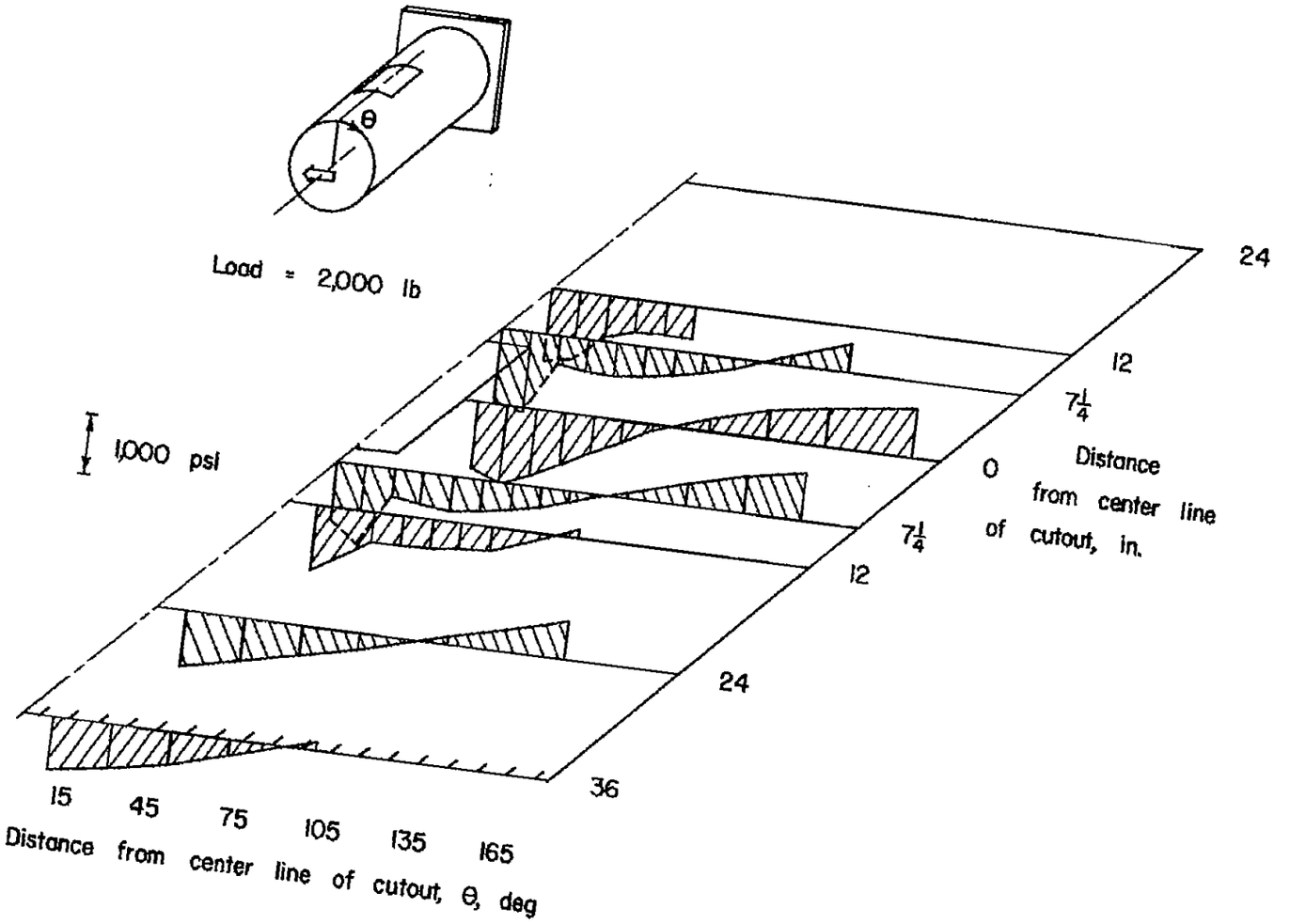
(a) Stringer stresses.

Figure 7 - Stress distribution, 30° side cutout.



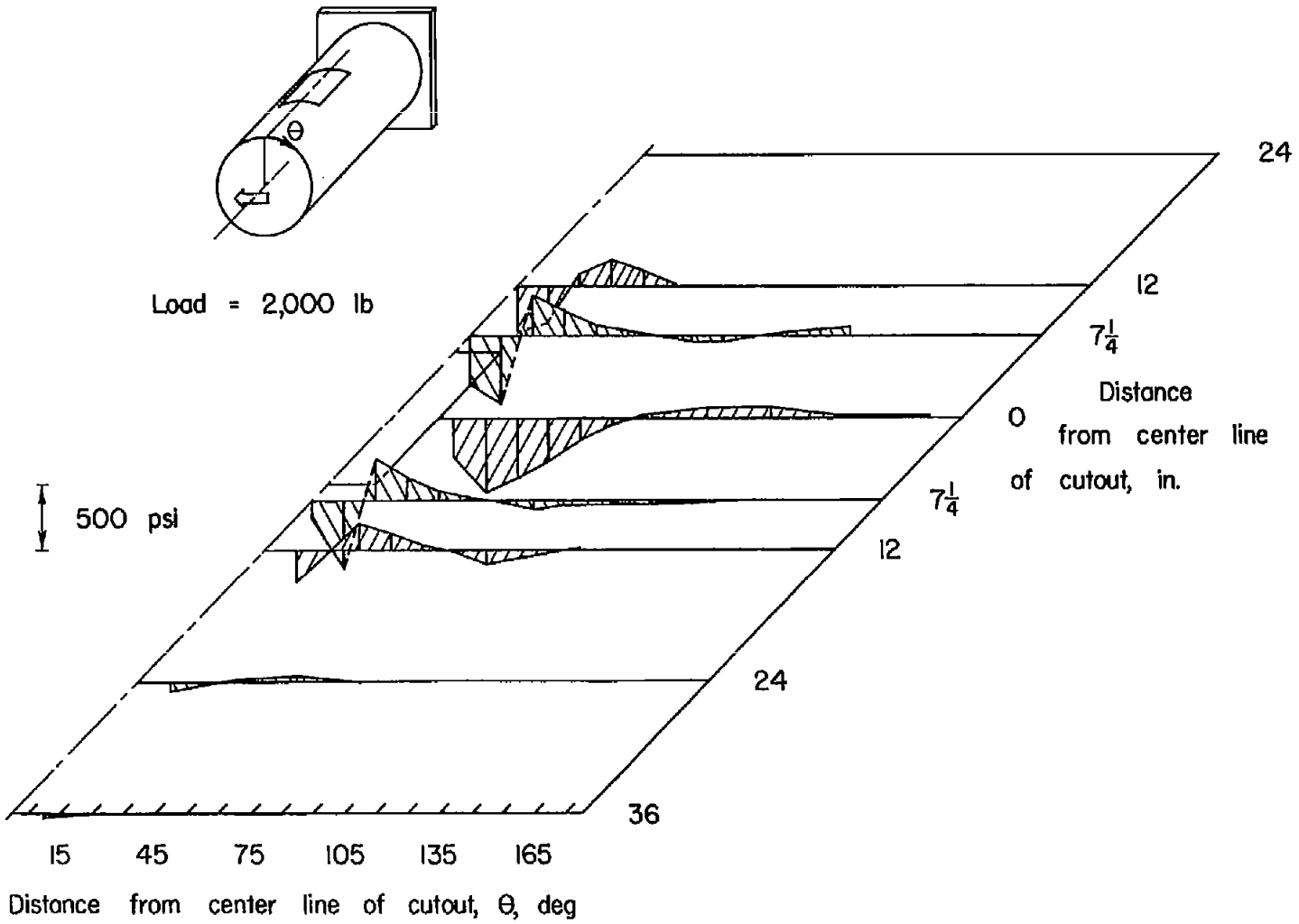
(b) Stringer stresses due to cutout only.

Figure 7. - Continued.



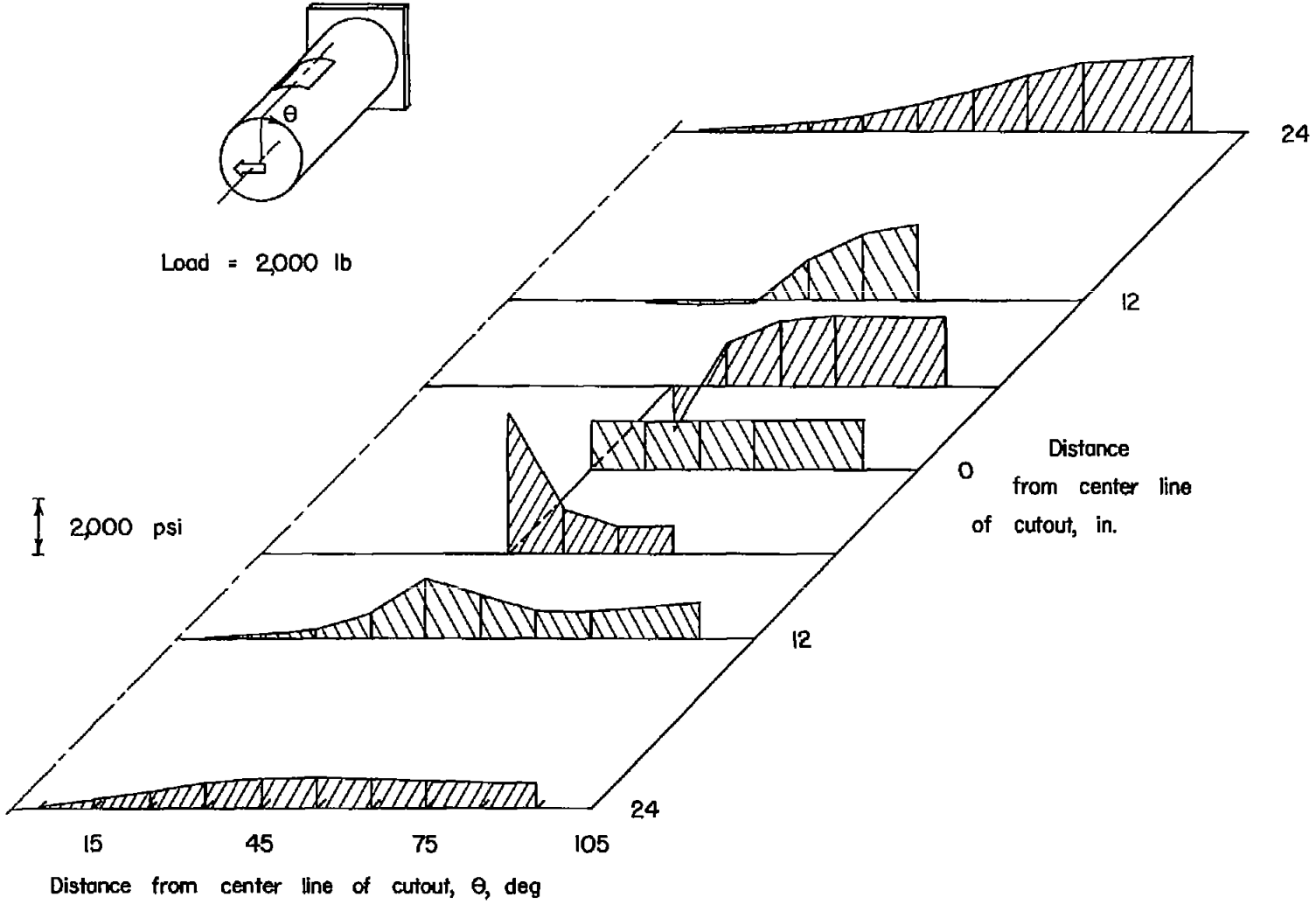
(c) Shear stresses.

Figure 7. - Continued.



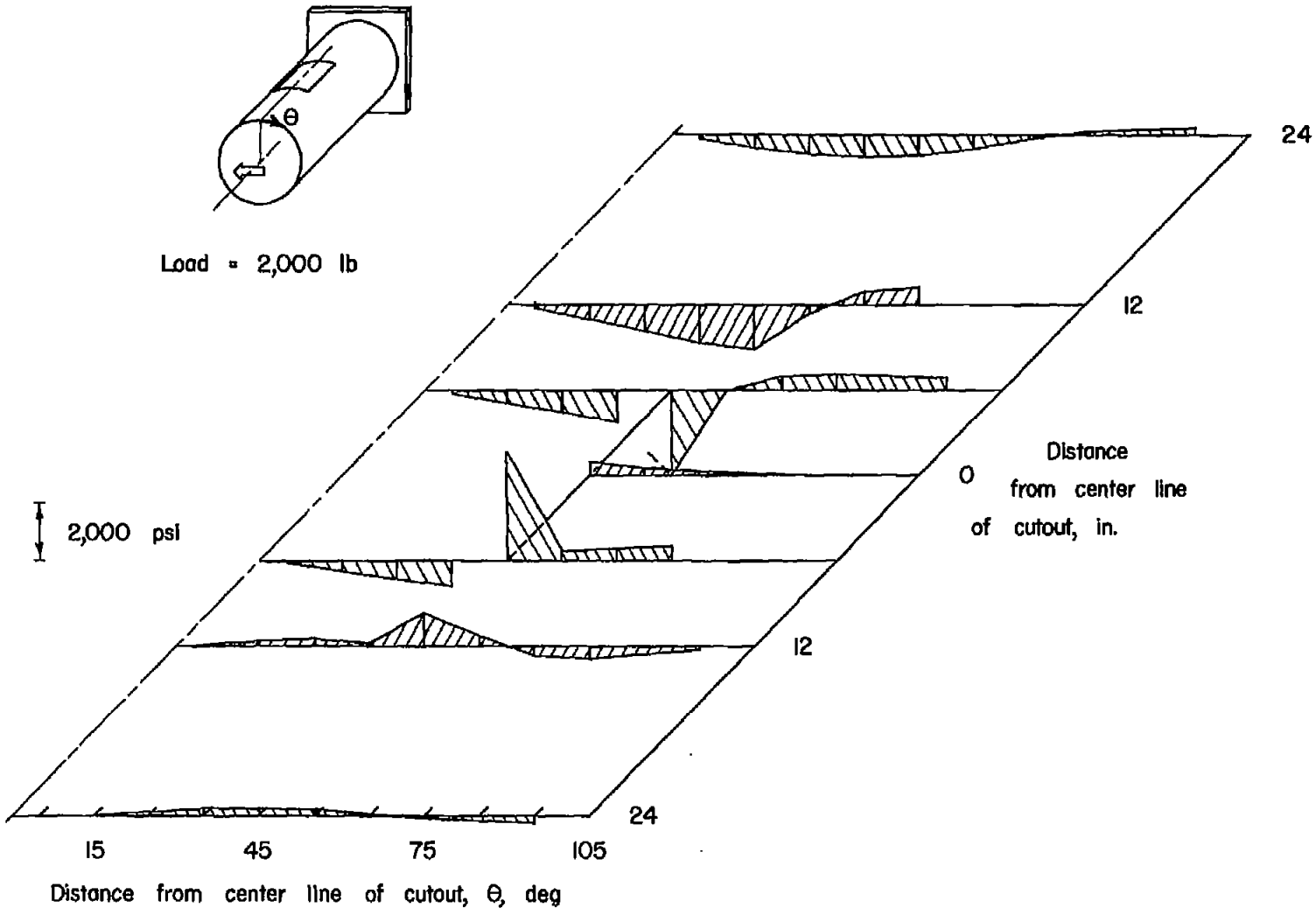
(d) Shear stresses due to cutout only.

Figure 7 - Concluded.



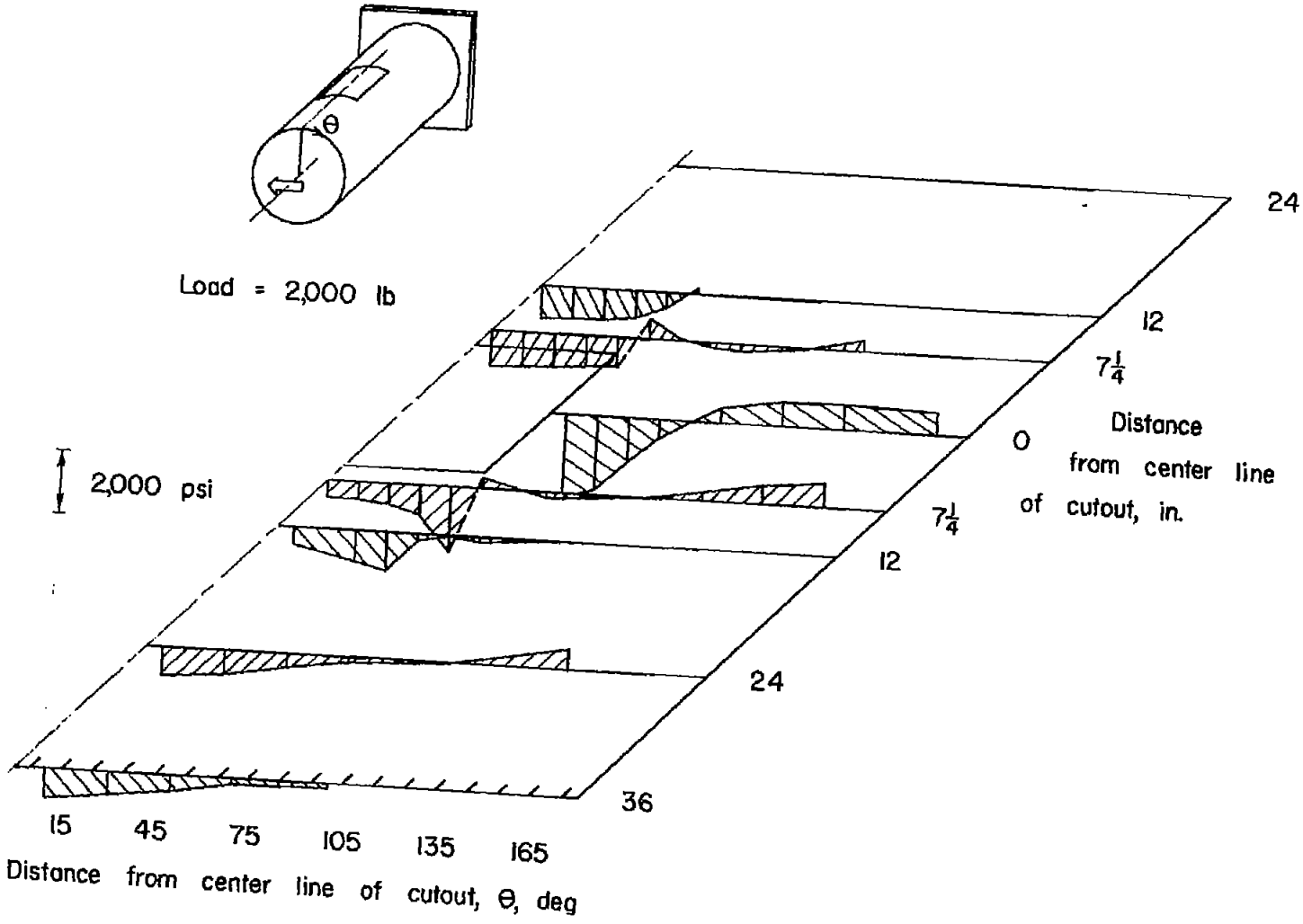
(a) Stringer stresses.

Figure 8. - Stress distribution, 90° side cutout.



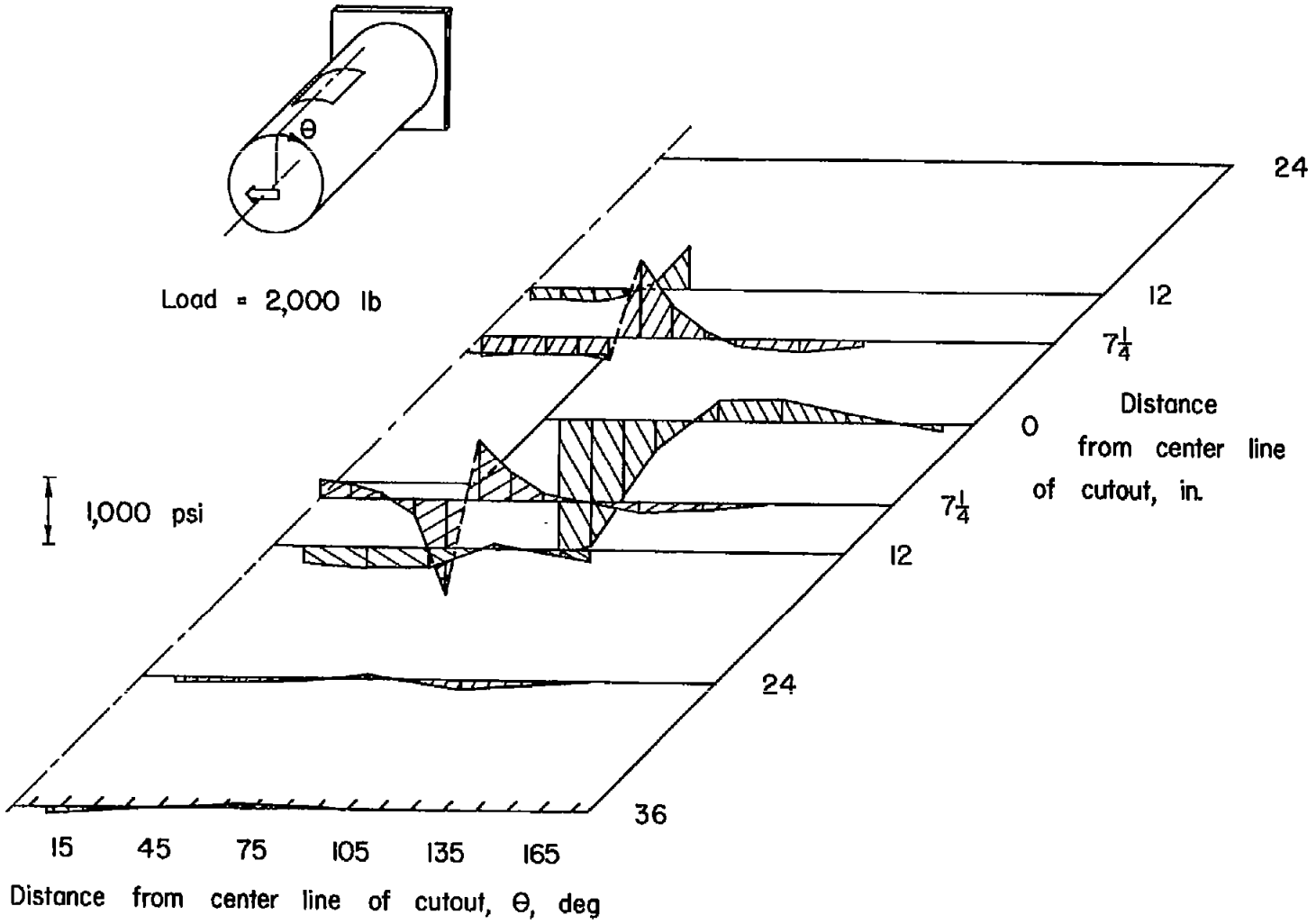
(b) Stringer stresses due to cutout only.

Figure 8. - Continued.



(c) Shear stresses.

Figure 8. - Continued.



(d) Shear stresses due to cutout only.

Figure 8. - Concluded.

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