NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3999

EXPERIMENTAL INFLUENCE COEFFICIENTS AND VIBRATION MODES OF A BUILT-UP 45° DELTA-WING SPECIMEN

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SUMMARY

Experimental influence coefficients and vibration modes and frequencies of a built-up 45° delta-wing specimen are presented. The symmetrical and antisymmetrical static influence coefficients were obtained on a three-point support. The first 10 vibration modes and frequencies were obtained for an essentially free-free condition. A detailed description of the structural properties of the specimen is also given.

INTRODUCTION

The provision of adequate stiffness in high-speed aircraft is a problem of primary importance to the designer. The problem is of particular concern for low-aspect-ratio wings because of the analytical difficulties involved in predicting their stiffness characteristics. In recent years various methods of load-deflection analysis for low-aspect-ratio wings (particularly delta wings) have been proposed. (See, for example, refs. 1 to 5.) However, very little experimental information about the load-deflection characteristics of such structures exists; only data on plastic models and on actual airplanes with uncertain support conditions are available for use in assessing the theories.

In order to provide some experimental information, static and vibration tests were performed in the laboratory on a large-scale built-up 45° delta-wing specimen. From the static tests the symmetrical and antisymmetrical influence coefficients of the specimen were obtained on a three-point support. (The three-point support was used so that the results of these tests could be converted readily to many of the more usual boundary conditions.) From the vibration tests the modes and frequencies were obtained for the delta-wing specimen in an essentially free-free condition.

The purpose of the present paper is to present the results of these experimental investigations. In order that the results can be of use in the evaluation of analyses, a detailed description of the stiffness properties and weight distribution of the wing specimen used in the investigation is also given.

Since this paper presents experimental results for only one specimen, no conclusions can be drawn.

DESCRIPTION OF DELTA-WING SPECIMEN

General Description

The specimen used in the experimental investigation is shown in figure 1. It is a 45° delta wing with a span of 18 feet $11\frac{7}{8}$ inches, a midchord of 8 feet $1\frac{5}{8}$ inches, and a uniform carry-through section of 2 feet 8 inches. It is uniform in depth in the chordwise direction but varies linearly in the spanwise direction from $5\frac{1}{2}$ inches at the carry-through section to $1\frac{3}{4}$ inches at the tip.

The covers are made up from a sheet-stringer combination with four stringers spaced between each of the spars. In order to facilitate construction, the stringers were placed on the outside of the covers. The internal construction of the wing, as shown in figure 2(a), consists of four spanwise spars, a bent leading-edge spar, and streamwise ribs spaced at 8-inch intervals. All parts of the wing were made from 2024 aluminum alloy.

Physical Properties

Detail dimensions.- Detail drawings of the delta wing are shown in figures 2. All dimensions and sizes shown are, of course, nominal. Since the dimensions of the actual parts can vary appreciably from the nominal values, accurate weights and dimensions were taken of the component parts before assembly, and overall dimensions and the total weight of the wing were taken after assembly. Sheet thicknesses were obtained by averaging a large number of micrometer readings taken along the edges. If the cross section of a component part was uniform along its length, its weight and length were measured and the cross-sectional area was calculated by using 0.100 pound per cubic inch as the density of aluminum. If a part was nonuniform in cross section along the length (for instance, the spar channels), its thickness and all other dimensions that could be accurately obtained (such as length and depth of spar channels) were measured. The remaining dimensions of the part (such as flange width) were adjusted so that the calculated and measured weight of the part agreed.

In this manner the pertinent dimensions of all component parts of the test specimen were obtained and are given in tables 1 and 2. The average cover thickness was found to be 0.0696 inch and the average thicknesses of the spar webs ranged from 0.0695 to 0.0720 inch. The average thickness of the 0.051-inch ribs was found to be 0.0508 inch. The average area of the stringers was 0.1689 square inch. The equation for the half-depth of the wing, as shown in table 1, was obtained by calculating an average taper from the depth measurements of the assembled wing.

Section properties.- In order to facilitate any analysis that might be performed on the test wing, the area moments of inertia of both the spars and the ribs were calculated. The moments of inertia of the ribs are given in table 2. In figure 3 the spanwise variation of the moments of inertia of all the spars is presented, and the numerical values of the moments of inertia of the spars at the intersection of every bulkhead are given in table 3.

Weight calculation.- A detailed weight analysis was performed on the test specimen. The weights of the spars, ribs, and stringers were measured before assembly. The weights of the cover sheets were calculated from the thickness and from overall measurements of the delta wing. The weights of these various wing components are given in table 4. All the remaining items such as filler blocks between the spars and ribs (see fig. 2(c)), leading-edge spar splice, corner reinforcements, and so forth, were considered as concentrated weights, and the locations of these weights are given in table 5. The difference between total weights of all the component parts and the total weight of the assembled wing was distributed along the spars and ribs in proportion to the number and size of the rivets used. (See table 4.) It might be of interest to mention that a calculation based on the approximate number and size of the rivets used and the nominal weight of the rivet head did approximate this difference in weight.

When the weights of all component parts are known, the correct distribution of the weight remains to be determined. The weights of the covers in pounds per square inch and the stringers and rivets in pounds per inch are given in table 4. The weights of the individual ribs are given in table 2 and the spanwise weight distribution of the individual spars is shown in figure 4. A detailed breakdown of the concentrated weights is shown in table 5.

STATIC TESTS

Tests were conducted on the delta wing described in the preceding section in order to obtain the deflectional behavior of the specimen under static loading. From these tests the influence coefficients under both symmetrical and antisymmetrical loading were determined; these influence coefficients can be used to obtain the deformation of the structure under any applied transverse loading.

In order to obtain the influence coefficients, the wing was mounted on three supports which restrained displacement but allowed free rotation. The advantage of the three-point support is twofold: First, the same support fixtures can be used for both symmetrical and antisymmetrical loading. Second, the influence coefficients appropriate to many other support conditions (such as cantilever and free-free) can be calculated from the coefficients obtained for the three-point support.

Test Setup

A general view of the static-test setup is shown in figure 5. The three supports can be seen in the photograph, two symmetrically placed along the trailing edge and one placed on the center line of the leading-edge spar.

A sketch of a support is shown in figure 6. Freedom of rotation at the supports was obtained by mounting the clamp-like fixtures on roller bearings and by placing a rocker between the clamp and the wing. Rollers between the rockers and the wing allowed chordwise motion. The horizontal bar immediately in front of the support was part of the counterbalancing system used to hold the wing firmly against each support.

Dial gages were used to measure the deflections of the wing at the network of points shown in figure 7. Gages mounted at the supports (stations 0, 2, and 41) afforded a measure of the support flexibility. At the interior stations, where deflections are small, dial gages with a minimum reading of 0.0001 inch and with 1/2-inch maximum travel were used whereas on the outboard stations dial gages with a minimum reading of 0.001 inch and with 1-inch maximum travel were used. Accuracy of the 0.0001-inch gages was better than ±0.0005 inch; the accuracy of the 0.001-inch gages was ±0.002 inch.

Loads were applied to the specimen by means of hydraulic jacks. These jacks were fitted with screw locks so that, once a given applied load was reached hydraulically, the load could be maintained mechanically.

Standard strain-gage load cells placed between the wing and the jacks were used to measure the applied load. Accuracy of these load cells was 0.5 percent.

Test Procedure and Results

Influence coefficients for the delta wing were measured for the stations shown in figure 7 under both symmetrical and antisymmetrical loading conditions. For each condition loads were applied successively to each of the stations and, for each loading, gage readings were taken at an initial preload and at each of the three equal load increments. The maximum load and, consequently, the load increments for each point of loading were chosen so that no buckling of the structure occurred. Also, the maximum deflection was never allowed to exceed the maximum travel of the dial gages.

The deflection data obtained from these tests showed that appreciable deflection occurred at the supports (stations 0, 2, and 41 of fig. 7). Therefore, before the data could be reduced to influence coefficients, corrections for the support deflection had to be applied. These corrections consisted of a superposition of three types of motion - roll, pitch, and translation. Of the corrections for these three motions, an accurate correction for roll was the most difficult to make. The rolling motion of the wing was caused by the unequal deflection of the supports (stations 0 and 2). However, if the rolling correction is calculated from deflection measurements at these supports, any error encountered in their measurements is magnified outboard of the supports. In the case of symmetrical loading, the amount of roll can be obtained from a comparison of deflections at symmetrically located stations near the wing tip (stations 8 and 50, 7 and 51, 18 and 52); thus, no magnification of errors due to inaccurate measurements occurs. In the case of antisymmetrical loading, however, only the deflections at the supports can be used to calculate the correction for roll.

Examination of the data showed that the deflections of the supports were nonlinear functions of the load. Consequently, corrections for each loading increment were necessary. The corrected deflections for each increment, however, were virtually linear and a straight line was drawn through these values to obtain the influence coefficients.

The influence coefficients for the symmetrical loading condition based on a 1,000-pound load are shown in table 6. In order that the matrix would be symmetrical, each value given in this table is the average of the two cross-coupling coefficients. Deviations from the mean are given in parentheses, the largest deviation being 0.004 inch or 0.46 percent of the maximum deflection.

The influence coefficients for the antisymmetrical loading condition are shown in table 7. Examination of this table shows that the deviations from the average for the antisymmetrical case are considerably larger (0.024 inch maximum) than those for the symmetrical case.

As was previously stated, corrections for roll in the antisymmetrical case were calculated from deflections of supports; thus any error in measurement was magnified. In order to minimize the error in roll due to inaccurate support-deflection measurements, a least-square computation was performed on the antisymmetrical influence-coefficient matrix. The method used for this computation is described in the appendix. The influence coefficients resulting from this least-square adjustment of roll are shown in table 8. As in table 6 each value given in table 8 is the average of the two cross-coupling terms, the deviation from the mean being shown in parentheses. The largest deviation in the adjusted influence coefficient is now 0.004 inch or 0.30 percent of maximum deflection and is comparable to that obtained for the symmetrical loading case. It is of interest to note that the resulting rolling corrections obtained by the least-square method were equivalent to noncompensating errors in support deflections of less than 0.0008 inch, except in one case in which the error was 0.0020 inch.

VIBRATION TESTS

Equipment

The equipment used in these tests consisted of a shaker system and response measuring and recording instruments. Detailed descriptions of this equipment are given in reference 6; however, a brief description follows:

The shaker system consists of four electromagnetic shakers, a control console, and a rotating-machine power supply with a frequency range of 5 to 500 cycles per second. Each shaker has a controlled force amplitude from 0 to 50 pounds and a phase control (0° or 180°) over the available frequency range. The total weight of the moving element of each shaker, including a velocity-sensitive signal generator, is 2.0 pounds.

The amplitude response of the test specimen was obtained from 16 velocity pickups connected through a switch panel to a 36-channel recording oscillograph. The weight of each pickup was 0.7 pound. A cathode-ray oscilloscope was also connected to the switch panel and was used for visual observation of the output from any pickup or signal generator. The frequency of vibration was obtained from a Stroboconn frequency indicator.

In addition to the measuring equipment described in reference 6, a portable probe pickup was used in these tests to survey the motion of the specimen at resonance. This pickup is similar in construction and weight to the velocity pickups except that a probe, which projects through the case, is attached to the moving coil. The weight of the probe element is approximately 1 gram and its spring constant is 9 pounds per inch. This pickup has a sensitivity of 94.5 millivolts per inch per second, an impedance of 850 ohms, and a frequency response that is essentially flat up to 500 cycles per second.

Test Setup and Instrumentation

An overall view of the vibration test setup is shown in figure 8. The delta wing was suspended from wooden support frames by flexible-steel aircraft cables attached to the leading-edge spar slightly forward of the chordwise center of gravity of the wing. This method of support allows essentially free-free vibrations in the horizontal direction. The four shakers were mounted in pairs: two shakers were placed on the floor and attached to the trailing-edge spar 2 feet from the tip, and two shakers were placed on steel pedestals and were attached to the middle spar 2 feet from the outboard end. One of the support cables and two of the shakers with necked-down force connectors are shown in figure 9.

The 16 pickups were mounted along the spars on one surface of the wing. Tapped holes in the spar caps at the intersection of the ribs and spars were provided for attaching the pickups. The locations of the pickups for these tests are shown in figure 10. Thirteen pickups were placed on one-half of the wing and the remaining three were placed on the other half to check the symmetry of vibration. In order to have symmetrical mass distribution about the spanwise center line, each pickup was counterbalanced, where necessary, with a symmetrically located steel weight. (See fig. 10.)

Test Procedure and Results

For these tests one pair of shakers was chosen as the master pair and the phase controls were set to produce the desired motion of the wing (symmetrical or antisymmetrical about spanwise center line); the other pair of shakers was set in the off position. In order to observe the motion of the wing, the output of one pickup was switched onto the Y-axis of the oscilloscope and the shaker force signal (current through the shaker drive coil) was switched to the X-axis. The power supply was turned on and the force output of the master shakers was equalized. The force output being held constant, the frequency was slowly increased until the amplitude of vibration reached a maximum as determined from the pickup output viewed on the oscilloscope. The form of the Lissajous ellipse shown on the oscilloscope was also used as an aid in determining the resonant frequency. The signal generator attached to the second pair of shakers was used to determine the relative amplitude and phase of motion at the attachment points and these shakers were then turned on and adjusted. The selector switches were set to the record position and a simultaneous record was made of the output from the pickups and the signal generators. The frequency of vibration was then read on the frequency indicator and recorded. With the frequency still held at resonance, the probe pickup was connected to the oscilloscope and an amplitude survey of the wing was made in order to locate the associated node lines. After the mode and frequency were established and the data were recorded, the frequency was increased again until the next resonance was detected. In this manner the first 10 natural modes of the delta wing were identified and recorded. After the survey was completed with one pair of shakers as the master pair, the tests were repeated with the other two shakers as the master pair. In order to insure that no modes were omitted because of node lines passing through the shaker-attachment points, the two shakers located along the trailing edge were moved to stations 13 and 19 (see fig. 10) and the tests were repeated. Relocation of the shakers had a slight effect on the natural frequencies and node-line pattern owing to the change in mass distribution. The vibration tests were conducted with all the shaker forces adjusted to the same value. In order to check the effect of unequal shaker forces on the modes of vibration, tests were made with several different force ratios between the two pairs of shakers. The results of these tests indicated that, for the small magnitudes of force required to maintain vibrations at resonance, the force ratio had very little effect on the mode shapes and frequencies as long as both shakers of a given pair were adjusted to the same force output.

The values of the resonant frequencies depended primarily on the accuracy of determining the maximum amplitude as viewed on the oscilloscope, since the frequency indicator could be read within 0.1 percent. As a check on the accuracy of determining the maximum amplitude for each mode, the tests were repeated several times, different observers reading the oscilloscope. From these checks it was found that the maximum amplitude (and hence, the resonant frequency) could be obtained within 0.5 percent. The node-line survey was also repeated and the accuracy of the node-line position for each mode was within 1/2 inch.

As a check on the duplicability of the results, a complete vibration survey was made both before and after the static test. The vibration survey made after the static test gave frequencies within 1 percent and node-line positions within one-half inch of the values obtained from the initial tests.

The first 10 natural frequencies (5 symmetrical and 5 antisymmetrical) were obtained and are presented in table 9. The deformations of the wing for each of the first 8 modes are given in table 10 where the normalized deflections (unit tip deflection) are listed for 15 stations on half the wing corresponding to the pickup locations of figure 10. The node-line patterns obtained for each mode by the survey with the probe pickup are shown in figure 11(a) for the symmetrical modes and in figure 11(b) for the antisymmetrical modes. For the first 8 modes there was very little evidence of panel vibration of the cover sheet; however, for the highest 2 modes shown in figure 11, panel vibration of the cover sheet was sufficient to obscure the node lines in some regions. These regions are shown in figure 11 by the dashed lines which represent the lines of minimum amplitude through these regions as measured by the probe pickup.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 8, 1957.

APPENDIX

LEAST-SQUARE CORRECTION FOR ROLL

If the matrix shown in table 7 is assumed to have errors in roll, the adjusted matrix $[\Delta]$ must be of the form

$$[\Delta] = [A] + |a|\lfloor\theta\rfloor \tag{A1}$$

where

$[A]$ experimental influence matrix shown in table 7

θ_i rolling correction associated with loading at ith section

a_i distance from center line to ith station

$[\,]$ rectangular matrix

$|\,|$ column matrix

$\lfloor\,\rfloor$ row matrix

The matrix $[A]$ can be separated into a symmetrical matrix $[G]$ and an antisymmetrical matrix $[E]$ such that

$$[A] = [G] + [E] \tag{A2}$$

Equation (A1) can now be rewritten as

$$[\Delta] = [B] + [\epsilon] \tag{A3}$$

where

$$[B] = [G] + \frac{1}{2}|a|\lfloor\theta\rfloor + \frac{1}{2}|\theta|\lfloor a\rfloor \tag{A4}$$

and

$$[\epsilon] = [E] + \frac{1}{2}|a|\lfloor\theta\rfloor - \frac{1}{2}|\theta|\lfloor a\rfloor \tag{A5}$$

Since $[B]$ is a symmetrical matrix, each element ϵ_{ij} of the matrix $[\epsilon]$ represents the error due to incorrect rolling corrections. Therefore, the most probable influence-coefficient matrix is the one in which the sum of the squares of ϵ_{ij} is a minimum; that is,

$$\frac{\partial}{\partial\theta_i}\sum_{m=1}^{N}\sum_{n=1}^{N}\epsilon_{mn}^2 = 0 \tag{A6}$$

From equation (A5)

$$\epsilon_{ij} = E_{ij} + \frac{1}{2}a_i\theta_j - \frac{1}{2}a_j\theta_i \tag{A7}$$

Therefore, since $E_{ij} = -E_{ji}$,

$$\sum_{m=1}^{N}\sum_{n=1}^{N}\epsilon_{mn}^2 = \sum_{m=1}^{N}\sum_{n=1}^{N}E_{mn}^2 + \frac{1}{2}\sum_{m=1}^{N}a_m^2\sum_{n=1}^{N}\theta_n^2 - \frac{1}{2}\left(\sum_{n=1}^{N}a_n\theta_n\right)^2 + 2\sum_{m=1}^{N}\sum_{n=1}^{N}a_m\theta_n E_{mn} \tag{A8}$$

Substitution of equation (A8) into equation (A6) gives

$$\theta_i\sum_{n=1}^{N}a_n^2 - a_i\sum_{n=1}^{N}a_n\theta_n + 2\sum_{n=1}^{N}a_nE_{ni} = 0 \qquad (i = 1, 2, 3, \ldots N) \tag{A9}$$

In order to make the problem determinate, one of the θ_i values must be assigned; therefore, let

$$\theta_M = 0 \tag{A10}$$

With the use of equation (A10), equation (A9) (for $i = M$) gives

$$\sum_{n=1}^{N} a_n \theta_n = -\frac{2}{a_M} \sum_{n=1}^{N} a_n E_{Mn} \tag{A11}$$

Substitution of equation (A11) into equation (A9) gives

$$\theta_i = \frac{2}{a_M \sum_{n=1}^{N} a_n^2} \sum_{n=1}^{N} a_n \left(a_M E_{in} - a_i E_{Mn} \right) \tag{A12}$$

which in matrix form is

$$|\theta| = \frac{2}{a_M \sum_{n=1}^{N} a_n^2} \left(a_M [E] |a| - |a| \lfloor E_M \rfloor |a| \right) \tag{A13}$$

The rolling correction θ_i calculated from equation (A13) is used in equation (A1) to obtain the adjusted influence coefficient matrix $[\Delta]$.

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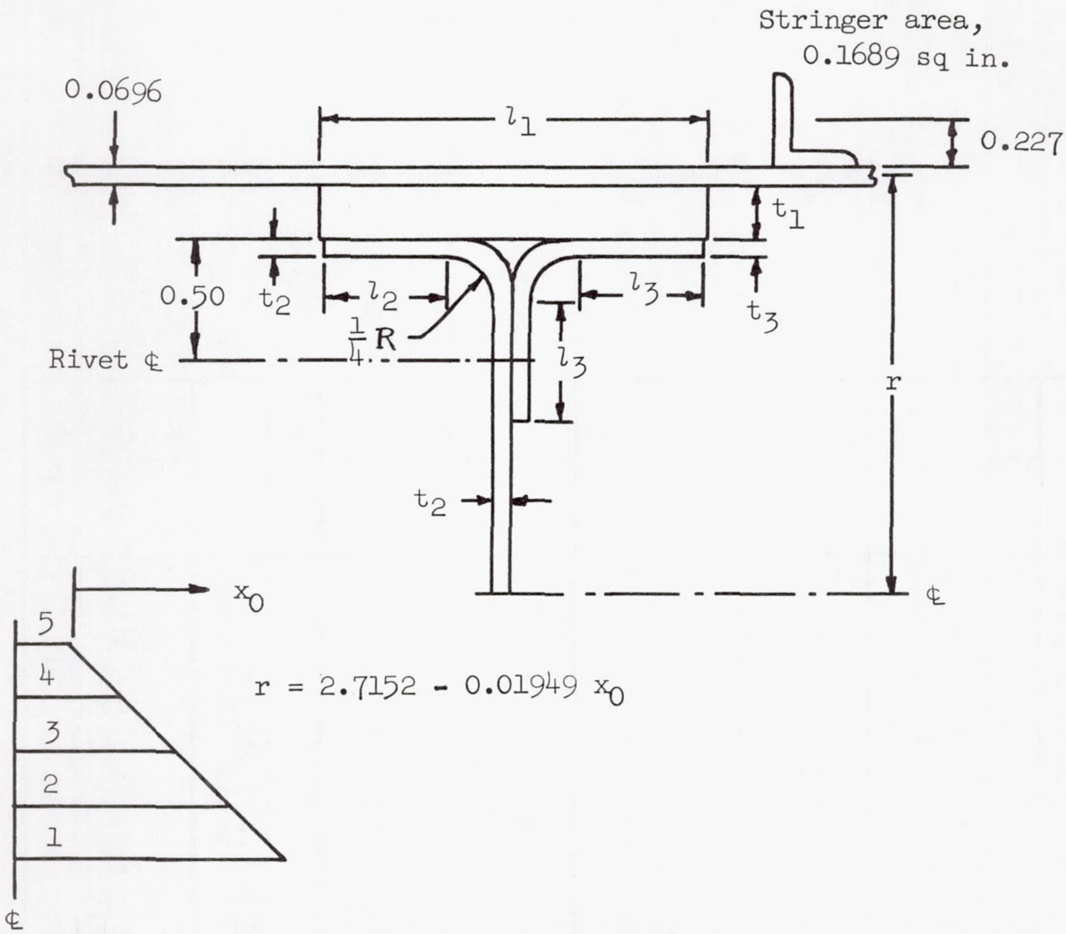
TABLE 1.- SPAR DIMENSIONS



Dimension, in.	Spar				
	1	2	3	4	5
t_1	0.1910	0.1896	0.7904	0.1910	0
t_2	.0695	.0701	.0718	.0720	.0706
t_3	.0700	.0700	.0700	0	0
l_1	{.8880* / 1.7533}	1.7591	1.7695	.8931	0
l_2	.5549	.5533	.5572	.5792	.4681
l_3	.5472	.5743	.5632	0	0

*Spar width outboard of x_0 = 72.

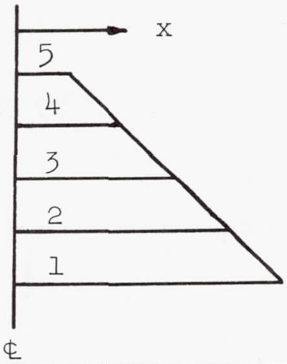
TABLE 2.- RIB PROPERTIES

Rib (a)	Sheet thickness, in.	Weight, lb	Moment of inertia, in.^{4} (b)	Rib (a)	Sheet thickness, in.	Weight, lb	Moment of inertia, in.^{4} (b)
1	0.0510	0.857	1.060	13	0.0502	0.432	0.533
2	.0511	.837	1.060	14	.0503	.194	.436
3	.0720	1.259	1.535	15	.0508	.626	.436
4	.0701	1.207	1.535	16	.0511	.591	.350
5	.0697	1.214	1.535	17	.0509	.591	.350
6	.0502	.517	.906	18	.0508	.362	.277
7	.0509	.799	.906	19	.0511	.541	.277
8	.0504	.742	.768	20	.0511	.516	.214
9	.0500	.238	.768	21	.0508	.154	.214
10	.0509	.696	.644	22	.0513	.471	.160
11	.0508	.708	.644	23	.0509	.282	.116
12	.0512	.675	.533	24	.0502	.114	.081

[a]See figure 2.

[b]For calculating the moment of inertia of the cross section, average thicknesses were used - 0.0508 inch for the 0.051-gage ribs and 0.0706 inch for the 0.072-gage ribs.

TABLE 3.- SPANWISE VARIATION OF SPAR MOMENT OF INERTIA



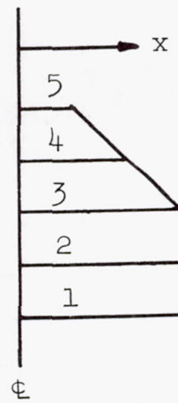
x, in.	Moment of inertia, in.^{4}, for -				
	Spar 1	Spar 2	Spar 3	Spar 4	Spar 5
0	6.843	6.876	6.949	3.630	1.491
8	6.843	6.876	6.949	3.630	1.491
16	6.843	6.876	6.949	3.630	1.491
24	5.986	6.005	6.086	3.157	1.278
32	5.192	5.197	5.285	2.722	1.086
40	4.458	4.452	4.546	2.324	.913
48	3.784	3.769	3.866		.760
56	3.169	3.146	3.245		.625
64	2.613	2.583	2.683		.506
72	2.113	2.079			.403
80	1.669	1.632			.314
88	{1.279 .623}	1.241			.240
96	.457				.177
104	.319				.126
112	.270				.085

TABLE 4.- WEIGHTS OF WING COMPONENTS

Component	Total weight, lb	Weight distribution
Cover sheet	180.287	0.00696 lb/sq in.
Spars	80.019	See figure 4
Stringers	70.668	.01689 lb/in.
Ribs	54.618	See table 2
Concentrated weights	2.648	See table 5
Spar rivet heads	7.162	See figure 4
Stringer rivet heads	9.645	.00230 lb/in.
Rib rivet heads	3.536	*.00169 lb/in.
Total	408.583	-----------------

*For ribs 3, 4, and 5, use 0.00329 lb/in.

TABLE 5.- LOCATIONS OF CONCENTRATED WEIGHTS



x, in.	Weight, lb				
	Spar 1	Spar 2	Spar 3	Spar 4	Spar 5
0	0.026	0.026	0.026	0.010	0.489
8	.026	.026	.026	.010	.010
16	.058	.058	.058	.020	.288
24	.025	.025	.025	.010	.010
32	.022	.022	.022	.008	.008
40	.020	.020	.020	.008	-----
48	.017	.017	.017		.007
56	.014	.014	.014		.006
64	.012	.012	.006		-----
72	.009	.009			.004
80	.008	.008			.004
88	.003	.003			-----
96	.003				.003
104	.003				.003
112	0				-----

TABLE 6.- SYMMETRICAL INFLUENCE

Load stations	Deflection[a]													
	1	2	3	4	5	6	7	8	11	12	13	14	15	16	17
1	0.013	0	(0.001) -.003	(0.001) -.005	(0.001) -.007	(0.001) -.009	(0.001) -.010	(0.001) -.012	(0.001) .002	(0.002) -.001	(0.002) -.003	(0.001) -.004	(0.002) -.006	(0.002) -.007	(0.002) -.007
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	(.000) -.003	0	.019	(.001) .026	(.001) .032	(.000) .036	(.000) .042	(.001) .045	(.001) .002	(.001) .004	(.001) .011	(.002) .016	(.001) .022	(.001) .026	(.001) .028
4	(-.001) -.005	0	(.000) .026	.059	(.000) .077	(.002) .090	(.001) .105	(.001) .119	(.001) .005	(.002) .008	(.001) .021	(.001) .037	(.001) .052	(.001) .065	(.001) .072
5	(-.001) -.007	0	(-.001) .032	(-.001) .077	.130	(.000) .164	(.000) .196	(.001) .226	(.002) .006	(.001) .012	(.000) .030	(.002) .055	(.001) .085	(.000) .116	(.000) .131
6	(-.001) -.009	0	(.000) .036	(-.002) .090	(.000) .164	.254	(.001) .317	(.000) .379	(.001) .009	(.001) .016	(.000) .038	(.000) .073	(.002) .119	(-.002) .169	(.000) .203
7	(-.002) -.010	0	(.000) .042	(-.001) .105	(-.001) .196	(.000) .317	.468	(-.003) .587	(.001) .010	(.000) .019	(.001) .046	(.001) .088	(.002) .150	(.001) .229	(.000) .279
8	(-.002) -.012	0	(-.002) .045	(-.002) .119	(-.002) .226	(-.001) .379	(.002) .587	.875	(.001) .012	(.000) .022	(.000) .052	(-.001) .103	(.000) .178	(.003) .284	(-.002) .348
11	(-.001) .002	0	(-.001) .002	(-.002) .005	(-.001) .006	(-.002) .009	(-.001) .010	(-.001) .012	.028	(-.002) .023	(-.002) .019	(-.001) .018	(-.001) .018	(-.002) .020	(-.001) .020
12	(-.001) -.001	0	(-.001) .004	(-.001) .008	(-.001) .012	(-.001) .016	(-.001) .019	(.000) .022	(.001) .023	.026	(.001) .023	(.000) .023	(-.001) .025	(.000) .027	(.000) .029
13	(-.001) -.003	0	(-.002) .011	(-.001) .021	(-.001) .030	(-.001) .038	(-.002) .046	(.000) .052	(.001) .019	(.000) .023	.034	(-.001) .037	(-.001) .041	(-.001) .047	(.000) .050
14	(-.001) -.004	0	(-.001) .016	(-.001) .037	(-.001) .055	(-.001) .073	(.000) .088	(.000) .103	(.001) .018	(.000) .023	(.000) .037	.056	(.000) .068	(-.001) .081	(.000) .087
15	(-.001) -.006	0	(-.001) .022	(-.001) .052	(.000) .085	(-.001) .119	(-.002) .150	(.000) .178	(.001) .018	(.000) .025	(.001) .041	(.001) .068	.107	(.001) .131	(-.001) .144
16	(-.002) -.007	0	(-.001) .026	(-.001) .065	(-.001) .116	(.002) .169	(-.002) .229	(-.002) .284	(.001) .020	(.000) .027	(.001) .047	(.000) .081	(-.001) .131	.193	(.000) .221
17	(-.002) -.007	0	(-.001) .028	(-.001) .072	(-.001) .131	(.000) .203	(.001) .279	(.001) .348	(.001) .020	(.000) .029	(.001) .050	(.000) .087	(.000) .144	(-.001) .221	.265
18	(-.001) -.009	0	(.000) .035	(.000) .088	(.000) .162	(-.001) .260	(.002) .371	(-.001) .478	(.001) .017	(.000) .026	(.001) .051	(.000) .093	(.001) .155	(.000) .240	(-.001) .298
21	(-.001) -.001	0	(-.001) .002	(-.002) .007	(-.002) .010	(-.002) .014	(-.002) .016	(-.002) .020	(.000) .027	(-.002) .028	(-.002) .027	(-.001) .027	(-.003) .029	(-.003) .031	(-.003) .032
22	(-.002) -.001	0	(-.002) .004	(-.001) .009	(-.002) .014	(-.001) .018	(-.001) .022	(-.001) .026	(.002) .028	(.000) .030	(.000) .031	(.000) .032	(-.001) .035	(.000) .038	(.000) .040
23	(-.002) -.002	0	(-.001) .006	(-.001) .014	(-.001) .023	(-.001) .030	(-.002) .038	(-.001) .044	(.002) .026	(.000) .030	(.000) .035	(-.001) .041	(-.001) .047	(-.001) .053	(.000) .057
24	(-.001) -.004	0	(-.001) .009	(-.001) .022	(-.001) .036	(-.001) .049	(-.001) .063	(.000) .074	(.001) .025	(-.001) .030	(-.001) .040	(.000) .052	(.000) .066	(-.001) .079	(-.001) .085
25	(-.001) -.005	0	(-.002) .012	(-.001) .031	(-.002) .053	(-.001) .074	(-.002) .097	(.000) .117	(.002) .027	(.000) .033	(.000) .046	(.000) .067	(-.001) .092	(-.001) .117	(.000) .128
26	(-.002) -.007	0	(-.001) .022	(-.001) .057	(-.001) .100	(.000) .151	(-.001) .201	(.001) .247	(.002) .022	(.000) .030	(-.001) .049	(.000) .081	(.000) .129	(-.001) .189	(.000) .217
31	(.001) .001	0	(-.001) .002	(-.001) .005	(-.001) .008	(-.001) .010	(-.001) .012	(.000) .014	(.000) .019	(-.001) .021	(.000) .021	(.000) .022	(-.001) .023	(-.001) .025	(-.001) .027
32	(-.002) -.001	0	(-.001) .002	(-.001) .005	(-.002) .008	(-.001) .011	(.000) .013	(.000) .017	(.001) .020	(-.001) .022	(.000) .023	(-.001) .025	(-.001) .027	(-.001) .030	(.000) .031
33	(-.001) -.002	0	(-.001) .003	(-.001) .008	(-.001) .012	(-.001) .017	(-.001) .022	(-.001) .026	(.001) .022	(.000) .024	(.000) .027	(.000) .031	(-.001) .037	(-.001) .040	(.000) .043
34	(-.001) -.002	0	(-.002) .004	(-.002) .009	(-.001) .015	(-.002) .021	(-.002) .028	(-.001) .032	(.001) .022	(-.001) .026	(.000) .030	(.000) .036	(-.001) .043	(-.001) .049	(.000) .052
35	(-.001) -.003	0	(-.002) .005	(-.002) .014	(.000) .024	(-.002) .034	(-.003) .044	(-.001) .052	(.001) .027	(-.001) .031	(-.001) .037	(.000) .047	(-.001) .058	(-.001) .068	(-.003) .070
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	(-.001) 0	0	(-.001) 0	(-.001) 0	(-.001) 0	(.000) .001	(.002) .002	(.000) .001	(.001) .006	(.000) .007	(.000) .007	(-.001) .007	(.001) .009	(.000) .009	(.000) .010
43	(-.001) -.001	0	(-.001) .002	(-.001) .005	(-.001) .008	(-.002) .013	(-.002) .016	(-.001) .019	(.001) .018	(-.001) .021	(.000) .023	(.000) .026	(-.001) .031	(-.001) .034	(.000) .036

[a]Values in parentheses are deviations from the mean value.

COEFFICIENTS BASED ON 1,000-POUND LOAD

stations														
18	21	22	23	24	25	26	31	32	33	34	35	41	42	43
(0.001) -.009	(0.002) -.001	(0.001) -.001	(0.001) -.002	(0.001) -.004	(0.002) -.005	(0.002) -.007	(-0.001) .001	(0.001) -.001	(0.002) -.002	(0.001) -.002	(0.002) -.003	0	(0.000) 0	(0.000) -.001
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(.001) .035	(.001) .002	(.001) .004	(.002) .006	(.002) .009	(.002) .012	(.002) .022	(.001) .002	(.001) .002	(.001) .003	(.001) .004	(.002) .005	0	(.001) 0	(.001) .002
(.000) .088	(.002) .007	(.002) .009	(.002) .014	(.002) .022	(.001) .031	(.001) .057	(.001) .005	(.001) .005	(.001) .008	(.002) .009	(.002) .014	0 0	(.000) 0	(.001) .005
(.000) .162	(.002) .010	(.001) .014	(.001) .023	(.001) .036	(.001) .053	(.001) .100	(.001) .008	(.001) .008	(.001) .012	(.001) .015	(.001) .024	0 0	(.001) 0	(.002) .008
(.000) .260	(.002) .014	(.002) .018	(.002) .030	(.001) .049	(.002) .074	(.001) .151	(.001) .010	(.001) .011	(.001) .017	(.001) .021	(.001) .034	0 0	(.000) .001	(.002) .013
(-.001) .371	(.002) .016	(.001) .022	(.002) .038	(.001) .063	(.002) .097	(.000) .201	(.001) .012	(.002) .013	(.001) .022	(.002) .028	(.003) .044	0 0	(-.002) .002	(.002) .016
(.001) .478	(.001) .020	(.001) .026	(.000) .044	(.000) .074	(.000) .117	(-.001) .247	(.000) .014	(.001) .017	(.001) .026	(.002) .032	(.001) .052	0 0	(.000) .001	(.001) .019
(-.002) .017	(.001) .027	(-.002) .028	(-.002) .026	(-.001) .025	(-.002) .027	(-.001) .022	(.000) .019	(-.001) .020	(-.001) .022	(-.001) .022	(-.002) .027	0 0	(-.001) .006	(-.001) .018
(.000) .026	(.003) .028	(.001) .030	(.001) .030	(.001) .030	(.000) .033	(.001) .030	(.001) .021	(.001) .022	(.001) .024	(.001) .026	(.000) .031	0 0	(.000) .007	(.000) .021
(.000) .051	(.002) .027	(.000) .031	(.001) .035	(.001) .040	(.000) .046	(.000) .049	(.000) .021	(.000) .023	(.001) .027	(.000) .030	(.000) .037	0 0	(.000) .007	(.000) .023
(-.001) .093	(.002) .027	(.001) .032	(.000) .041	(.001) .052	(-.001) .067	(.001) .081	(.001) .022	(.000) .025	(-.001) .031	(.000) .036	(.000) .047	0 0	(.000) .007	(.000) .026
(-.002) .155	(.003) .029	(.000) .035	(.001) .047	(.001) .066	(.002) .092	(.001) .129	(.000) .023	(.001) .027	(.000) .037	(.000) .043	(.001) .058	0 0	(.000) .009	(.001) .031
(.000) .240	(.003) .031	(.001) .038	(.001) .053	(.001) .079	(.000) .117	(.000) .189	(.001) .025	(.000) .030	(.001) .040	(.001) .049	(.001) .068	0 0	(.000) .009	(.000) .034
(.001) .298	(.002) .032	(.000) .040	(.001) .057	(.000) .085	(.000) .128	(.000) .217	(.000) .027	(.000) .031	(.001) .043	(.001) .052	(.003) .070	0 0	(.000) .010	(.001) .036
.378	(.002) .028	(.001) .035	(.002) .052	(.001) .082	(.001) .125	(.001) .227	(.000) .023	(.001) .026	(-.001) .037	(.001) .046	(.002) .067	0 0	(.001) .006	(.001) .031
(-.002) .028	.050	(-.003) .046	(-.003) .043	(-.002) .041	(-.003) .043	(-.002) .036	(-.002) .036	(-.002) .036	(-.003) .038	(-.003) .040	(-.003) .044	0 0	(-.001) .012	(-.002) .033
(.000) .035	(.004) .046	.051	(.000) .048	(.001) .047	(.000) .051	(.000) .044	(.000) .037	(.000) .039	(.000) .042	(.000) .045	(.000) .050	0 0	(-.001) .013	(.000) .037
(-.001) .052	(.002) .043	(.000) .048	.058	(.001) .059	(.000) .065	(-.001) .060	(-.001) .036	(.000) .039	(-.001) .048	(.000) .052	(-.001 .061	0 0	(-.001) .014	(.000) .041
(-.001) .082	(.001) .041	(-.001) .047	(.000) .059	.082	(-.002) .092	(-.001) .088	(-.001) .033	(-.002) .039	(-.002) .051	(-.003) .060	(-.002) .076	0 0	(-.003) .013	(.001) .049
(-.001) .125	(.003) .043	(.001) .051	(.000) .065	(.002) .092	.129	(.001) .131	(.001) .037	(.000) .043	(.000) .057	(.000) .070	(-.001) .093	0 0	(.001) .014	(.000) .051
(.000) .227	(.003) .036	(.000) .044	(.001) .060	(.001) .088	(-.001) .131	.202	(.000) .031	(.000) .036	(.000) .048	(.000) .058	(.000) .079	0 0	(.001) .011	(.000) .041
(.000) .023	(.002) .036	(-.001) .037	(.000) .036	(.001) .033	(-.002) .037	(.001) .031	.042	(.000) .037	(.000) .036	(-.001) .037	(-.001) .040	0 0	(.000) .016	(-.001) .034
(.000) .026	(.003) .036	(.000) .039	(.000) .039	(.002) .039	(.000) .043	(.000) .036	(-.001) .037	.042	(.000) .043	(.000) .045	(-.002) .044	0 0	(-.001) .021	(.001) .041
(.000) .037	(.000) .038	(.000) .042	(.000) .048	(.002) .051	(.001) .057	(.000) .048	(.001) .036	(-.001) .043	.056	(.000) .062	(-.001) .064	0	(.000) .021	(.000) .054
(-.002) .046	(.002) .040	(.000) .045	(.001) .052	(.002) .060	(.000) .070	(.000) .058	(.001) .037	(-.001) .045	(.000) .062	.073	(-.001) .077	0	(-.001) .023	(.000) .060
(-.002) .067	(.003) .044	(-.001) .050	(.000) .061	(.002) .076	(.000) .093	(.000) .079	(.001) .040	(.002) .044	(.001) .064	(.001) .077	.095	0	(.000) .020	(.000) .059
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(.000) .006	(.001) .012	(.001) .013	(.001) .014	(.003) .013	(-.001) .014	(.000) .011	(.001) .016	(.001) .021	(.000) .021	(.000) .023	(.000) .020	0	.027	(.001) .025
(-.001) .031	(.002) .033	(.000) .037	(.001) .041	(-.002) .049	(.000) .051	(-.001) .041	(.000) .034	(-.001) .041	(.000) .054	(.000) .060	(-.001) .059	0	(.000) .025	.058

TABLE 7.- INFLUENCE COEFFICIENTS FOR ANTISYMMETRICAL LOADING BASED ON 1,000 POUNDS AND WITHOUT LEAST-SQUARE ADJUSTMENT

Load stations	Deflection stations																						
	3	4	5	6	7	8	12	13	14	15	16	17	18	22	23	24	25	26	32	33	34	35	42	43
3	0.028	0.046	0.060	0.077	0.094	0.110	0.010	0.027	0.044	0.059	0.076	0.083	0.092	0.012	0.029	0.044	0.059	0.075	0.014	0.030	0.036	0.042	0.015	0.030
4	.046	.106	.148	.191	.232	.269	.020	.059	.101	.144	.183	.203	.224	.028	.065	.103	.139	.181	.031	.068	.085	.101	.033	.070
5	.068	.154	.241	.320	.392	.460	.033	.092	.160	.230	.302	.337	.375	.045	.097	.171	.222	.292	.051	.109	.137	.164	.052	.108
6	.084	.194	.321	.465	.586	.695	.045	.121	.212	.315	.425	.482	.551	.061	.137	.226	.304	.414	.071	.147	.186	.224	.072	.150
7	.100	.232	.396	.595	.821	.996	.058	.150	.266	.400	.555	.640	.744	.080	.181	.285	.395	.542	.089	.188	.234	.292	.090	.192
8	.120	.279	.469	.714	1.017	1.375	.068	.179	.322	.485	.683	.785	.935	.097	.220	.347	.491	.660	.109	.232	.293	.345	.110	.231
12	.008	.019	.030	.040	.052	.063	.009	.020	.031	.040	.052	.056	.058	.012	.026	.038	.050	.054	.013	.028	.042	.041	.012	.028
13	.035	.075	.113	.152	.191	.227	.024	.065	.104	.140	.176	.194	.205	.034	.077	.118	.156	.183	.038	.082	.102	.124	.040	.085
14	.042	.096	.147	.202	.256	.301	.030	.083	.136	.187	.235	.260	.274	.045	.101	.158	.208	.243	.050	.107	.136	.164	.055	.112
15	.066	.147	.230	.321	.402	.480	.044	.114	.195	.288	.365	.408	.430	.064	.145	.230	.308	.375	.076	.158	.198	.237	.077	.161
16	.080	.181	.298	.423	.545	.658	.053	.140	.239	.360	.487	.549	.585	.080	.178	.288	.391	.502	.094	.195	.246	.295	.096	.199
17	.090	.205	.335	.482	.636	.768	.061	.157	.269	.401	.552	.637	.685	.090	.199	.318	.433	.568	.104	.216	.273	.325	.107	.221
18	.096	.224	.375	.548	.744	.914	.060	.160	.282	.425	.583	.679	.781	.089	.201	.324	.441	.589	.104	.216	.277	.328	.108	.218
22	.010	.025	.041	.058	.073	.092	.010	.026	.042	.059	.075	.082	.084	.023	.035	.059	.076	.081	.023	.047	.055	.066	.024	.049
23	.030	.066	.102	.141	.180	.215	.025	.065	.102	.141	.179	.198	.204	.041	.094	.136	.175	.193	.045	.100	.125	.147	.045	.103
24	.042	.097	.151	.212	.272	.324	.039	.095	.155	.219	.284	.305	.311	.063	.135	.213	.275	.296	.073	.154	.193	.229	.077	.159
25	.062	.140	.220	.306	.392	.464	.051	.125	.214	.306	.392	.435	.445	.081	.178	.283	.384	.422	.096	.202	.257	.303	.102	.207
26	.080	.182	.290	.414	.537	.647	.057	.147	.252	.371	.502	.568	.593	.088	.191	.306	.417	.528	.102	.212	.268	.317	.106	.219
32	.016	.033	.048	.071	.089	.104	.015	.032	.054	.067	.094	.098	.104	.025	.051	.072	.094	.100	.035	.062	.078	.086	.036	.068
33	.031	.070	.109	.153	.197	.229	.028	.071	.114	.161	.204	.225	.229	.048	.106	.159	.207	.222	.062	.136	.168	.187	.070	.144
34	.038	.086	.135	.189	.242	.292	.037	.089	.144	.201	.253	.280	.283	.063	.135	.210	.261	.276	.079	.170	.214	.240	.090	.182
35	.046	.103	.163	.226	.289	.345	.044	.105	.170	.237	.303	.333	.338	.074	.156	.239	.310	.326	.092	.190	.233	.281	.104	.199
42	.014	.032	.050	.068	.088	.107	.014	.033	.054	.074	.094	.099	.104	.024	.050	.076	.099	.102	.034	.069	.086	.094	.053	.079
43	.031	.070	.109	.150	.194	.231	.031	.071	.113	.158	.201	.223	.225	.053	.108	.159	.205	.220	.070	.143	.175	.192	.083	.160

TABLE 8.- INFLUENCE COEFFICIENTS FOR ANTISYMMETRICAL LOADING BASED

Load stations	Deflection (a)											
	3	4	5	6	7	8	12	13	14	15	16	17
3	0.030	(-0.001) .048	(0.001) .066	(0.002) .083	(0.000) .100	(-0.001) .116	(0.000) .010	(-0.004) .025	(0.000) .046	(0.001) .064	(0.000) .082	(0.001) .090
4	(.001) .048	.107	(.001) .152	(.001) .194	(-.002) .233	(.000) .272	(.000) .021	(-.002) .058	(-.001) .102	(.000) .145	(.000) .185	(.000) .206
5	(-.002) .066	(-.002) .152	.240	(.002) .321	(.003) .393	(.001) .458	(.000) .033	(-.002) .089	(-.002) .157	(.000) .228	(.001) .301	(.000) .336
6	(-.001) .083	(-.001) .194	(-.003) .321	.468	(.003) .592	(.001) .700	(-.001) .044	(-.002) .120	(-.001) .212	(.000) .318	(.001) .428	(.000) .485
7	(.000) .100	(.001) .233	(-.003) .393	(-.002) .592	.821	(.002) .999	(-.001) .056	(.001) .151	(.000) .267	(.000) .400	(-.001) .554	(-.001) .639
8	(.001) .116	(.001) .272	(-.001) .458	(-.002) .700	(-.003) .999	1.356	(.001) .066	(.003) .177	(.000) .314	(.001) .475	(-.001) .668	(.001) .771
12	(.001) .010	(.000) .021	(.001) .033	(.000) .044	(.001) .056	(-.001) .066	.010	(-.002) .020	(.000) .032	(.000) .043	(.000) .055	(.002) .060
13	(.004) .025	(.003) .058	(.002) .089	(.001) .120	(-.001) .151	(-.003) .177	(.002) .020	.052	(.001) .086	(-.001) .113	(.000) .143	(.000) .158
14	(.000) .046	(.000) .102	(.002) .157	(.001) .212	(-.001) .267	(.000) .314	(.000) .032	(-.002) .086	.142	(-.001) .194	(-.001) .243	(-.001) .270
15	(-.001) .064	(.000) .145	(.000) .228	(-.001) .318	(.001) .400	(-.002) .475	(.000) .043	(.000) .113	(.001) .194	.286	(.001) .364	(-.001) .404
16	(-.001) .082	(.000) .185	(.000) .301	(.000) .428	(.002) .554	(.002) .668	(.000) .055	(.000) .143	(.001) .243	(-.001) .364	.493	(-.001) .555
17	(-.001) .090	(-.001) .206	(.000) .336	(.000) .485	(.000) .639	(-.001) .771	(-.001) .060	(.000) .158	(.000) .270	(.002) .404	(.000) .555	.639
18	(-.001) .098	(.000) .227	(.001) .376	(.000) .553	(-.003) .748	(-.002) .920	(.001) .062	(.002) .164	(.000) .285	(-.001) .428	(.001) .590	(.001) .686
22	(.000) .013	(.000) .029	(-.001) .045	(-.001) .063	(.000) .080	(-.002) .097	(.001) .012	(-.001) .028	(.000) .046	(.000) .064	(.000) .082	(.000) .089
23	(.000) .030	(.000) .066	(-.002) .100	(-.002) .140	(.000) .181	(-.001) .215	(.001) .026	(-.001) .064	(.001) .104	(.001) .143	(.000) .180	(.000) .200
24	(.000) .048	(-.001) .105	(.002) .166	(.002) .226	(.000) .286	(-.001) .340	(-.001) .041	(.000) .099	(.000) .163	(.000) .228	(-.003) .294	(.000) .319
25	(.000) .063	(.000) .141	(-.002) .222	(-.001) .308	(-.001) .395	(.004) .474	(.000) .052	(.002) .128	(.000) .216	(-.002) .308	(.000) .395	(-.002) .436
26	(-.001) .081	(.000) .183	(.000) .291	(-.001) .417	(.000) .541	(-.002) .649	(.000) .057	(.001) .149	(.000) .253	(.000) .373	(.001) .506	(-.001) .571
32	(-.001) .016	(-.002) .033	(-.001) .050	(-.001) .072	(.001) .090	(.000) .106	(-.001) .014	(.000) .032	(-.001) .053	(.004) .072	(-.001) .096	(.002) .102
33	(.001) .030	(.001) .068	(-.002) .107	(.000) .148	(-.001) .189	(.002) .224	(.001) .028	(.000) .069	(.000) .111	(.000) .157	(-.001) .198	(-.001) .218
34	(.001) .037	(.001) .084	(.002) .134	(.002) .186	(-.001) .235	(-.001) .286	(.004) .040	(-.001) .086	(.001) .141	(-.001) .197	(.000) .248	(.000) .274
35	(.000) .045	(.000) .102	(.001) .162	(.002) .225	(.003) .289	(-.002) .339	(.000) .043	(.000) .104	(.000) .170	(.000) .235	(.000) .299	(-.001) .328
42	(.000) .016	(.000) .033	(.000) .052	(.000) .072	(-.001) .091	(-.002) .110	(-.001) .014	(-.001) .034	(.000) .057	(.000) .077	(.000) .097	(.002) .105
43	(.000) .031	(-.001) .070	(.001) .108	(.000) .150	(.000) .193	(-.002) .228	(.000) .030	(.000) .071	(.001) .114	(.001) .159	(.000) .201	(.000) .222

[a]Values in parentheses are deviations from the mean value.

ON 1,000 POUNDS AND WITH LEAST-SQUARE ADJUSTMENT FOR ROLL

stations											
18	22	23	24	25	26	32	33	34	35	42	43
(0.002) .098	(0.000) .013	(-0.001) .030	(0.000) .048	(0.000) .063	(0.000) .081	(0.000) .016	(-0.001) .030	(-0.002) .037	(0.000) .045	(0.000) .016	(-0.001) .031
(.000) .227	(.000) .029	(.001) .066	(.000) .105	(.000) .141	(.000) .183	(.001) .033	(-.001) .068	(-.002) .084	(.000) .102	(.001) .033	(.000) .070
(.000) .376	(.002) .045	(.002) .100	(-.001) .166	(.001) .222	(.001) .291	(.000) .050	(.001) .107	(-.001) .134	(-.001) .162	(.000) .052	(-.001) .108
(-.001) .553	(.001) .063	(.002) .140	(-.001) .226	(.001) .308	(.000) .417	(.001) .072	(.000) .148	(-.001) .186	(-.001) .225	(.000) .072	(-.001) .150
(.003) .748	(.000) .080	(.000) .181	(.001) .286	(.000) .395	(.000) .541	(-.001) .090	(.001) .189	(.002) .235	(-.003) .289	(.001) .091	(.000) .193
(.001) .920	(.003) .097	(.001) .215	(.001) .340	(.004) .474	(.002) .649	(.000) .106	(-.003) .224	(.000) .286	(.003) .339	(.002) .110	(.003) .228
(.000) .062	(-.001) .012	(-.001) .026	(.000) .041	(.000) .052	(.001) .057	(.002) .014	(-.001) .028	(-.003) .040	(.001) .043	(.001) .014	(.001) .030
(-.001) .164	(.001) .028	(.001) .064	(.001) .099	(-.002) .128	(-.001) .149	(.001) .032	(.000) .069	(.001) .086	(.000) .104	(.000) .034	(.000) .071
(-.001) .285	(-.001) .046	(-.001) .104	(-.001) .163	(.000) .216	(.001) .253	(.002) .053	(.001) .111	(.000) .141	(-.001) .170	(.000) .057	(-.002) .114
(.002) .428	(.000) .064	(-.001) .143	(.001) .228	(.001) .308	(.000) .373	(-.004) .072	(.000) .157	(.000) .197	(.000) .235	(.000) .077	(-.001) .159
(-.002) .590	(.000) .082	(.000) .180	(.003) .294	(-.001) .395	(-.002) .506	(.000) .096	(.001) .198	(-.001) .248	(.001) .299	(.000) .097	(-.001) .201
(-.002) .686	(-.001) .089	(.000) .200	(-.001) .319	(.002) .436	(.001) .571	(-.003) .102	(.002) .218	(.000) .274	(.002) .328	(-.003) .105	(.001) .222
.788	(.000) .090	(.002) .204	(.000) .326	(.001) .447	(.002) .595	(.001) .106	(.002) .221	(.001) .279	(.002) .333	(.000) .109	(.002) .223
(.000) .090	.024	(.002) .039	(.001) .064	(.000) .081	(.000) .088	(.000) .024	(-.002) .048	(.002) .060	(.002) .072	(.000) .025	(.001) .052
(-.001) .204	(-.002) .039	.094	(.002) .138	(.002) .177	(-.001) .193	(.003) .048	(.001) .102	(.004) .129	(.003) .152	(.003) .049	(.002) .106
(.001) .326	(-.001) .064	(-.002) .138	.220	(.000) .285	(.000) .308	(-.001) .074	(-.002) .158	(.004) .203	(.000) .237	(-.001) .079	(-.002) .162
(-.001) .447	(.000) .081	(-.001) .177	(.000) .285	.386	(-.002) .422	(.000) .096	(.000) .203	(-.001) .258	(.002) .306	(.000) .102	(-.001) .206
(-.001) .595	(-.001) .088	(.001) .193	(.000) .308	(.003) .422	.531	(.000) .102	(.002) .215	(.000) .270	(.002) .322	(-.001) .106	(.000) .220
(-.001) .106	(-.001) .024	(-.003) .048	(.001) .074	(.000) .096	(.000) .102	.035	(-.001) .062	(-.001) .079	(.002) .089	(.000) .036	(.001) .069
(-.002) .221	(.002) .048	(-.001) .102	(.001) .158	(.000) .203	(-.002) .215	(.001) .062	.134	(.001) .167	(.002) .187	(.001) .070	(.000) .142
(-.001) .279	(-.002) .060	(-.003) .129	(-.004) .203	(.001) .258	(-.001) .270	(.000) .079	(-.001) .167	.211	(-.003) .234	(.000) .088	(-.003) .178
(-.001) .333	(-.002) .072	(-.004) .152	(.000) .237	(-.002) .306	(-.003) .322	(-.002) .089	(-.003) .187	(.003) .234	.279	(-.004) .100	(-.003) .195
(.000) .109	(.000) .025	(-.003) .049	(.001) .079	(.000) .102	(.000) .106	(.001) .036	(-.001) .070	(.001) .088	(.003) .100	.054	(.001) .082
(-.002) .223	(.000) .052	(-.002) .106	(.003) .162	(.002) .206	(.000) .220	(-.001) .069	(-.001) .142	(.002) .178	(.003) .195	(-.002) .082	.160

TABLE 9.- NATURAL FREQUENCIES FOR

FREE-FREE VIBRATIONS

Mode	Frequency, cps
1st symmetrical	43.3
1st antisymmetrical	52.2
2d symmetrical	88.8
2d antisymmetrical	91.7
3d symmetrical	122.8
3d antisymmetrical	131.1
4th symmetrical	164.2
4th antisymmetrical	169.2
5th symmetrical	179.7
5th antisymmetrical	215.7

TABLE 10.- DEFLECTIONS OF DELTA WING VIBRATING WITH UNIT TIP DEFLECTION

Mode	Frequency, cps	Deflection at station*														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1st symmetrical	43.3	0.126	0.034	0.062	-0.117	-0.013	0.130	-0.261	-0.125	0.133	0.464	-0.404	-0.252	0.092	0.551	1.000
1st antisymmetrical	52.2	-.245	-.207	-.518	-.156	-.356	-.496	-.078	-.150	-.130	.051	.040	.110	.275	.656	1.000
2d symmetrical	88.8	.613	.243	-.033	.037	-.312	-.655	.072	-.170	-.426	-.474	.278	.170	.154	.513	1.000
2d antisymmetrical	91.7	.101	.093	.280	.023	.070	.275	-.115	-.222	-.103	.292	-.274	-.538	-.500	.010	1.000
3d symmetrical	122.8	-.344	-.026	.028	.184	.135	.036	.183	.007	-.189	-.097	.031	-.201	-.366	.035	1.000
3d antisymmetrical	131.1	.454	.383	.534	.216	-.205	-.460	.182	.080	-.507	-1.015	.272	.460	.330	.443	1.000
4th symmetrical	164.2	.982	-.226	-.265	-.664	-.501	.658	.202	-.260	.255	1.595	1.435	.130	-1.368	-1.442	1.000
4th antisymmetrical	169.2	-.271	-.149	-.213	.013	.130	.151	.098	.216	0	-.143	.087	.078	-.266	-.131	1.000

*See figure 10 for station locations.

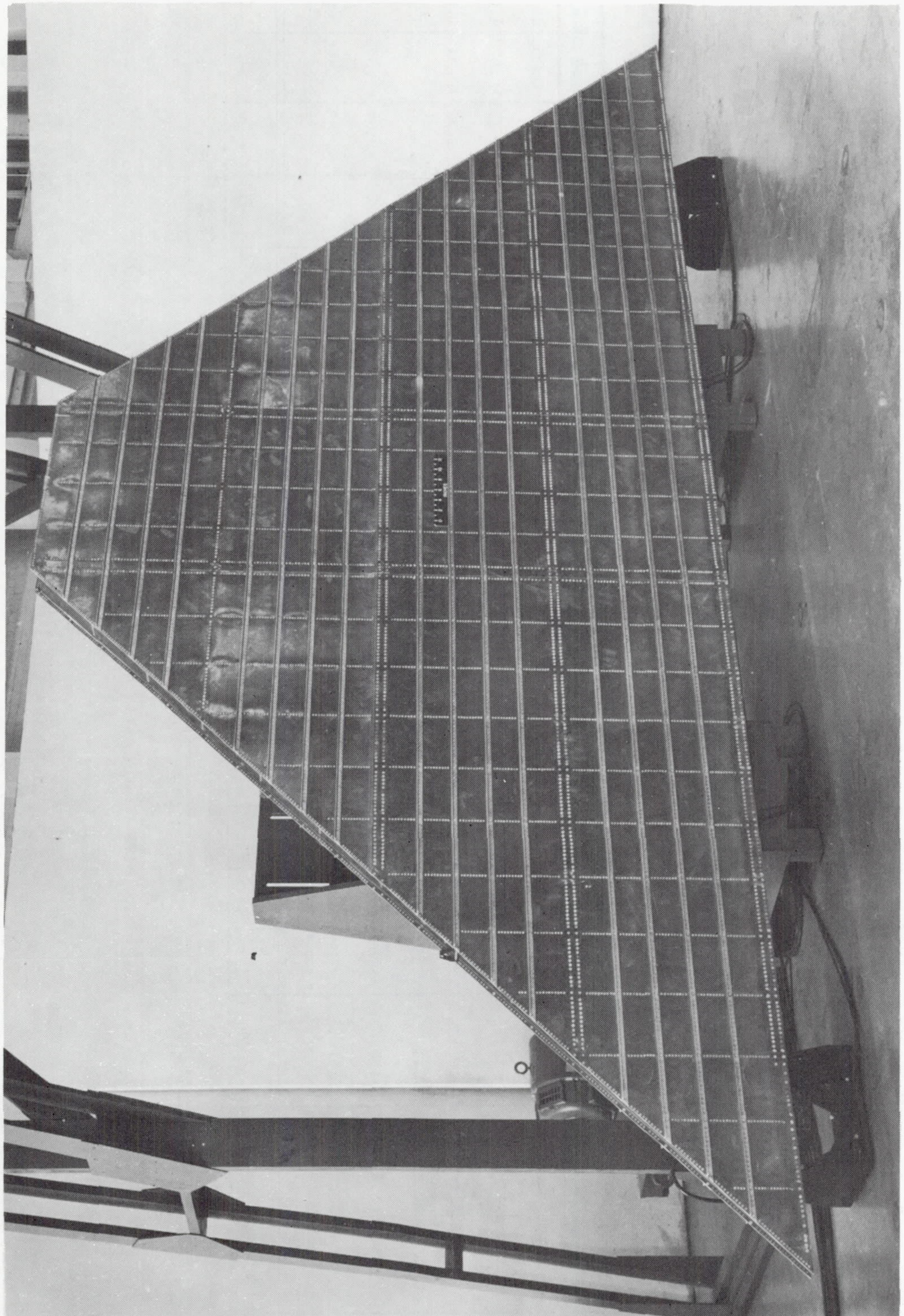
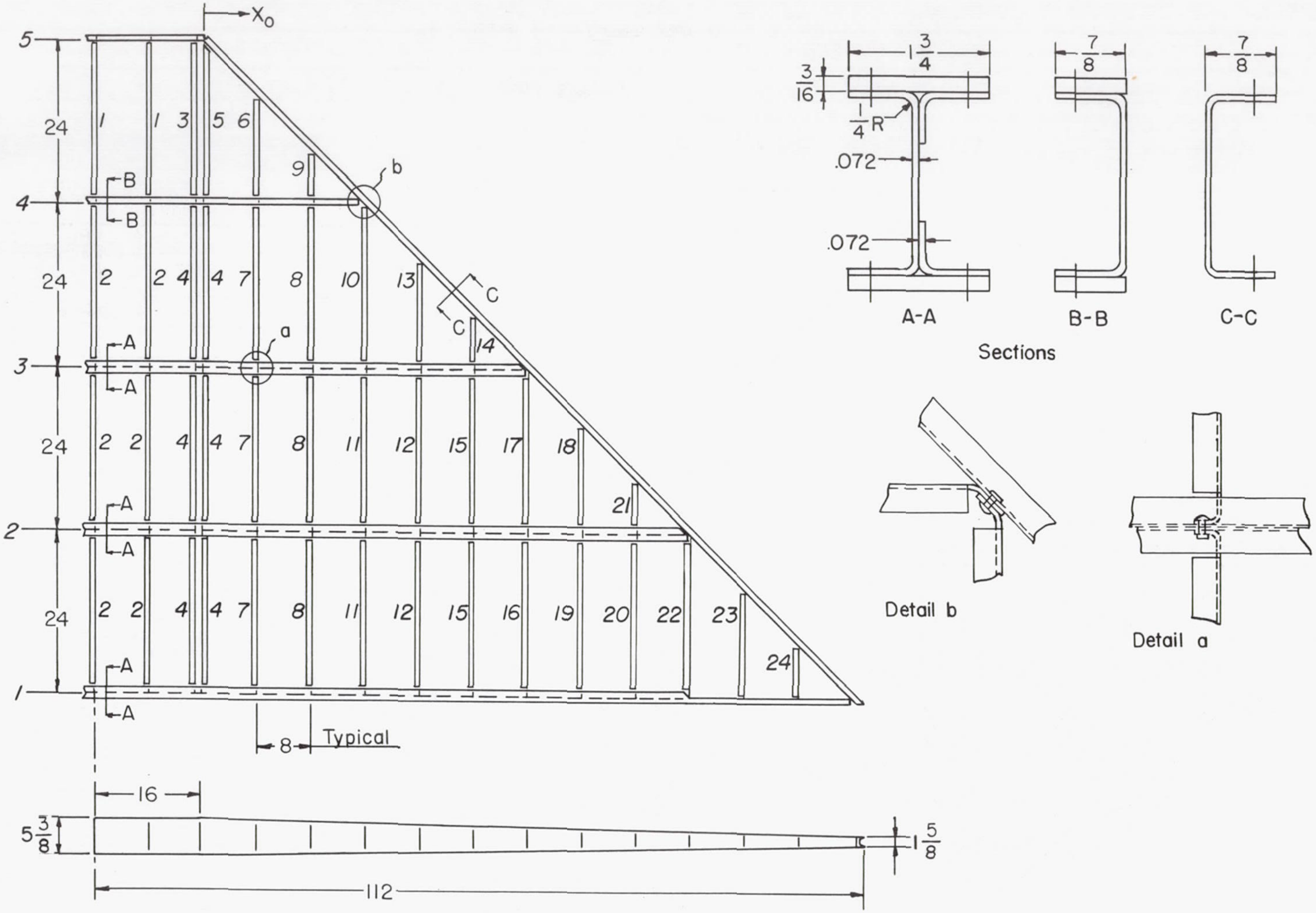
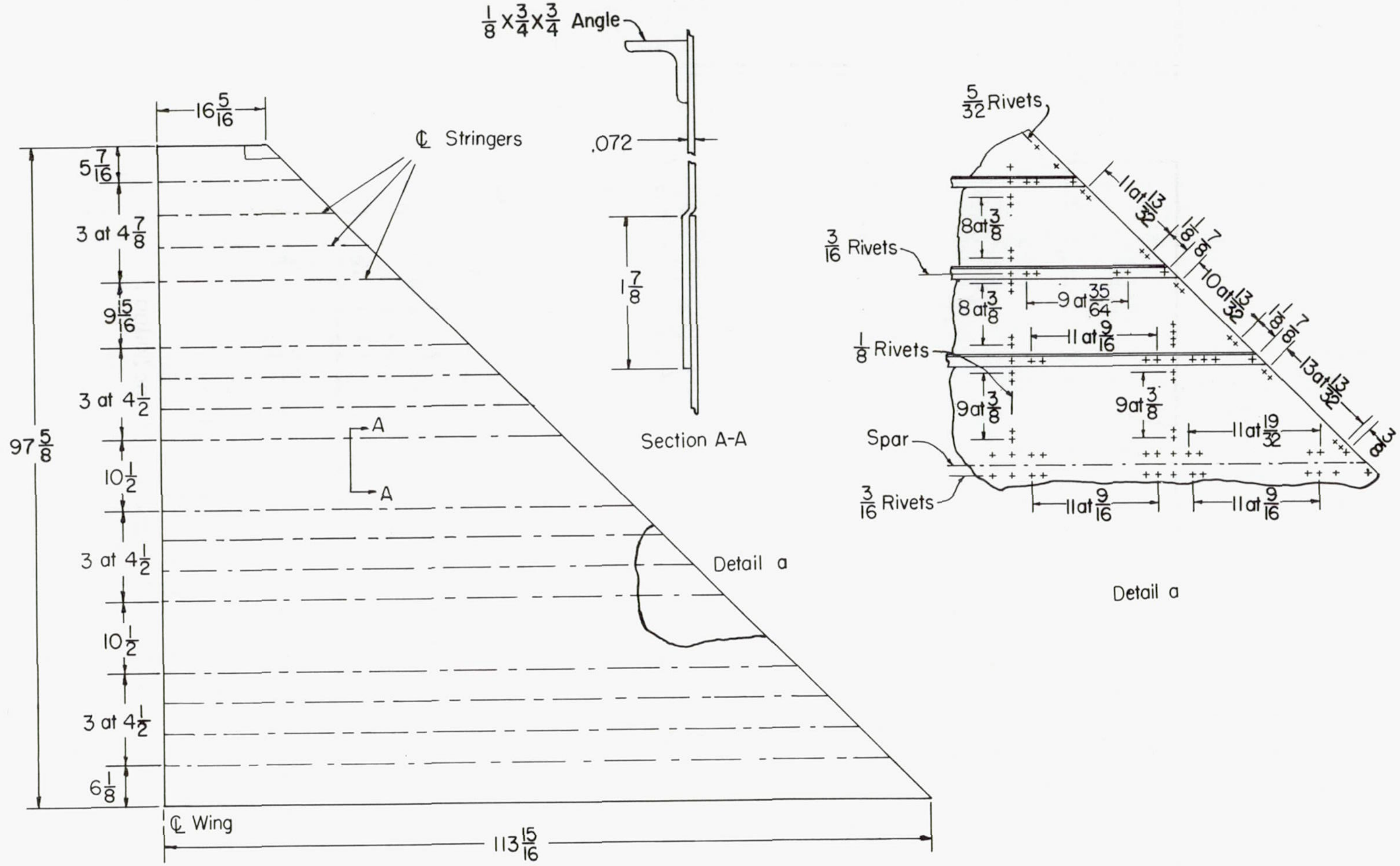


Figure 1.- Delta-wing specimen. L-88269



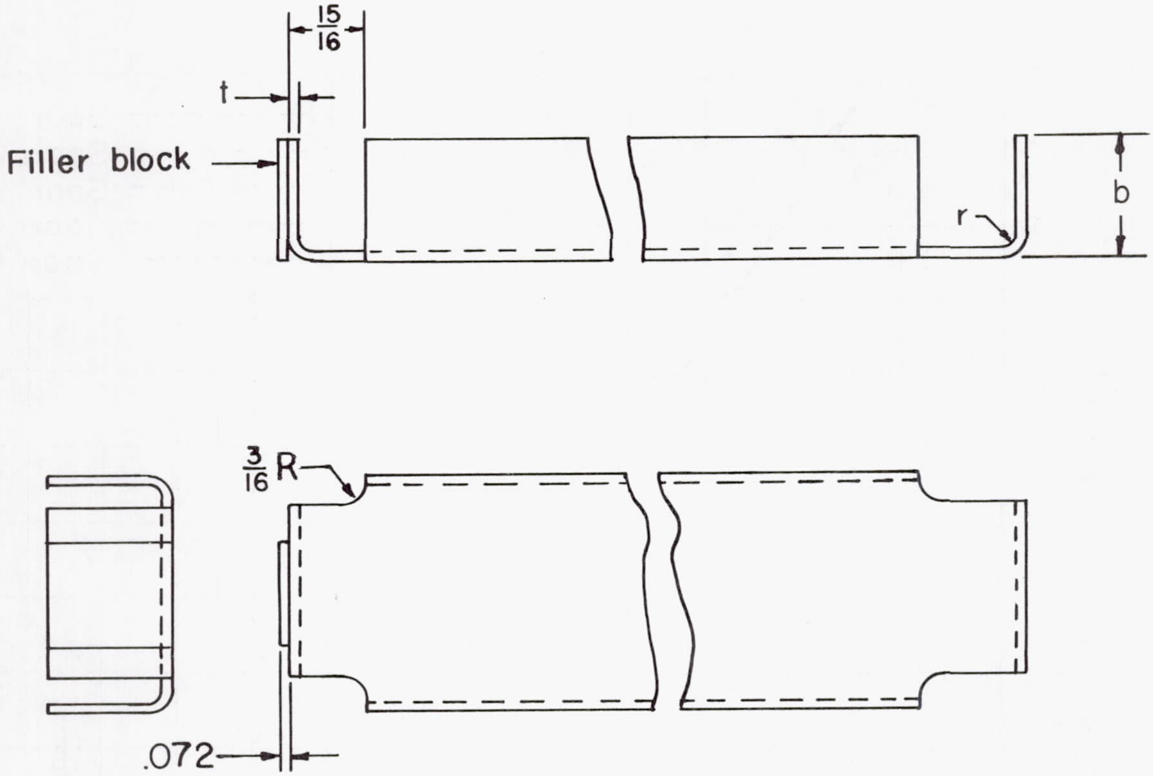
(a) Internal construction.

Figure 2.- Nominal dimensions of delta-wing specimen. All dimensions are in inches.



(b) Cover.

Figure 2.- Continued.



Rib	b	t	r
3-4-5	7/8	.072	5/16
All others	3/4	.051	1/4

(c) Ribs.

Figure 2.- Concluded.

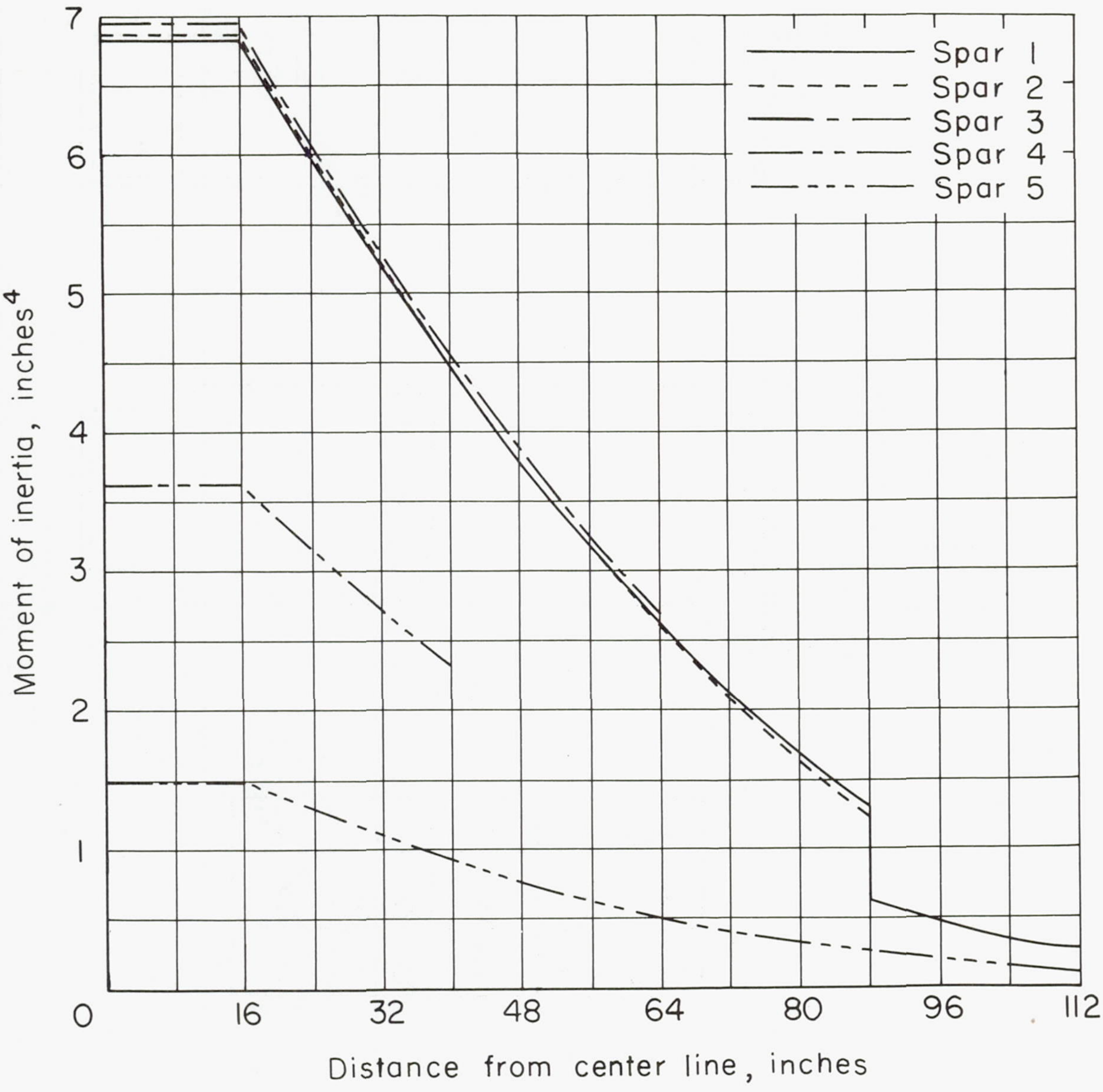


Figure 3.- Spanwise variation of spar moment of inertia.

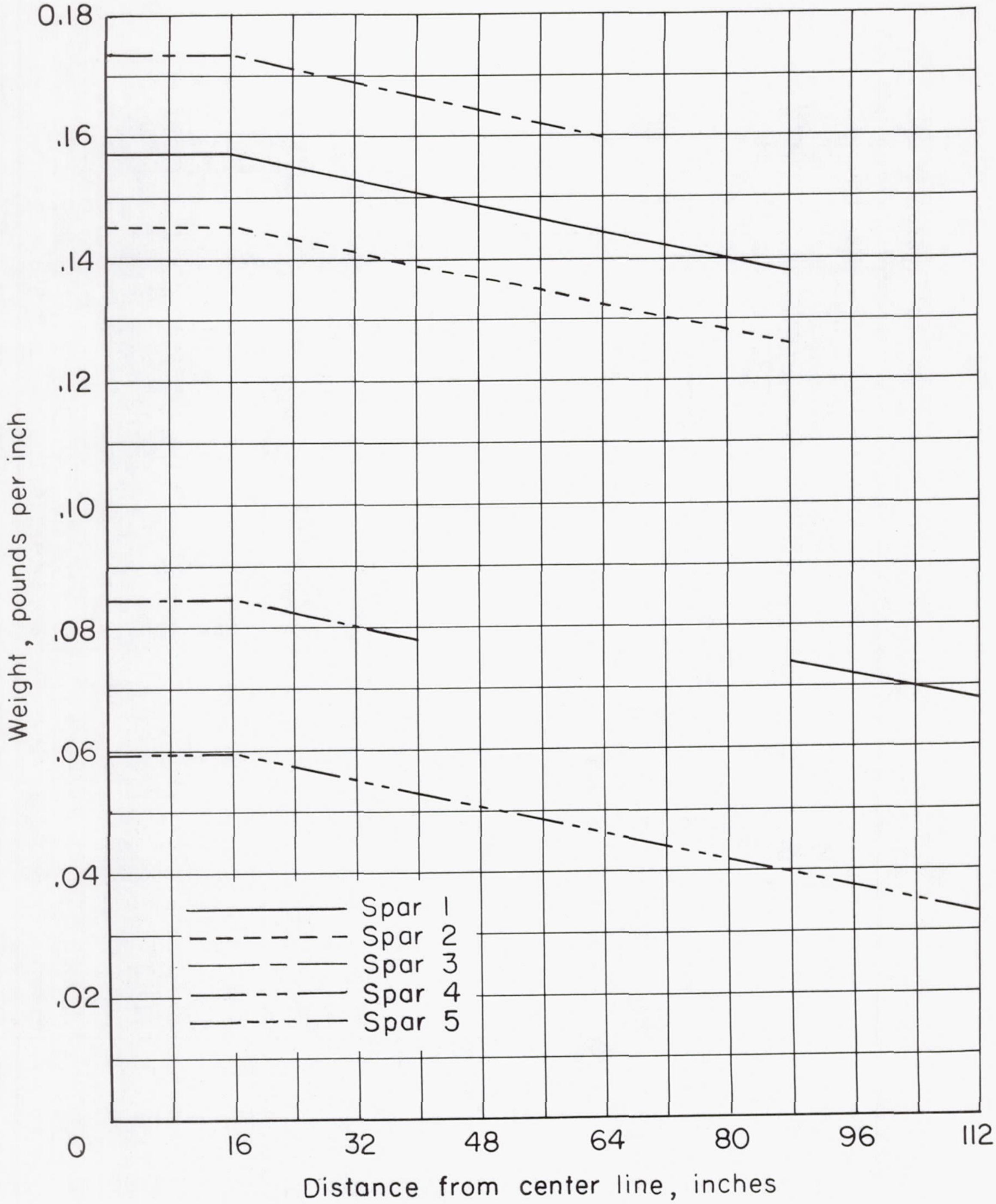


Figure 4.- Spanwise variation of spar weights (including rivets).

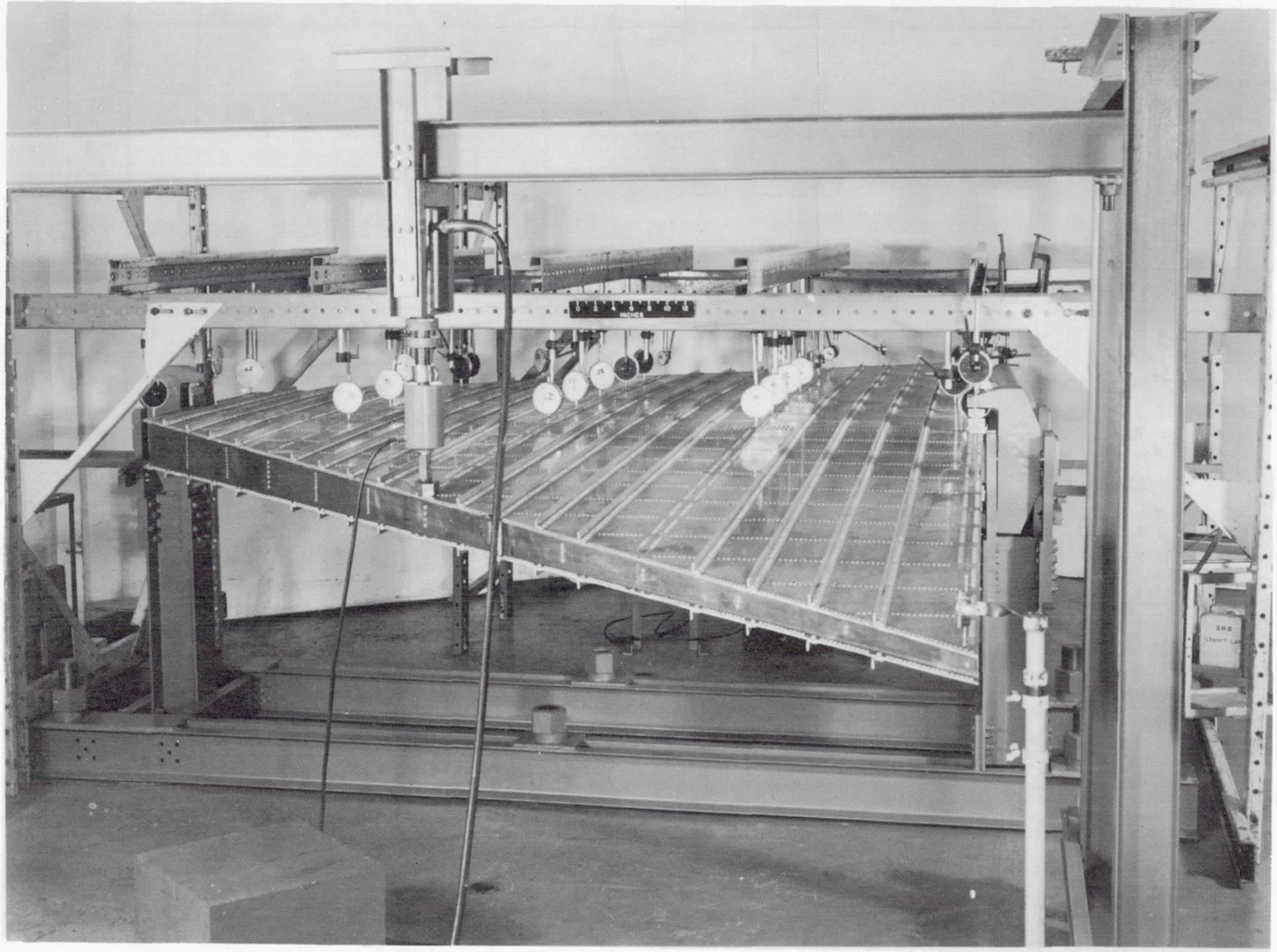


Figure 5.- General view of static-test setup. L-91358

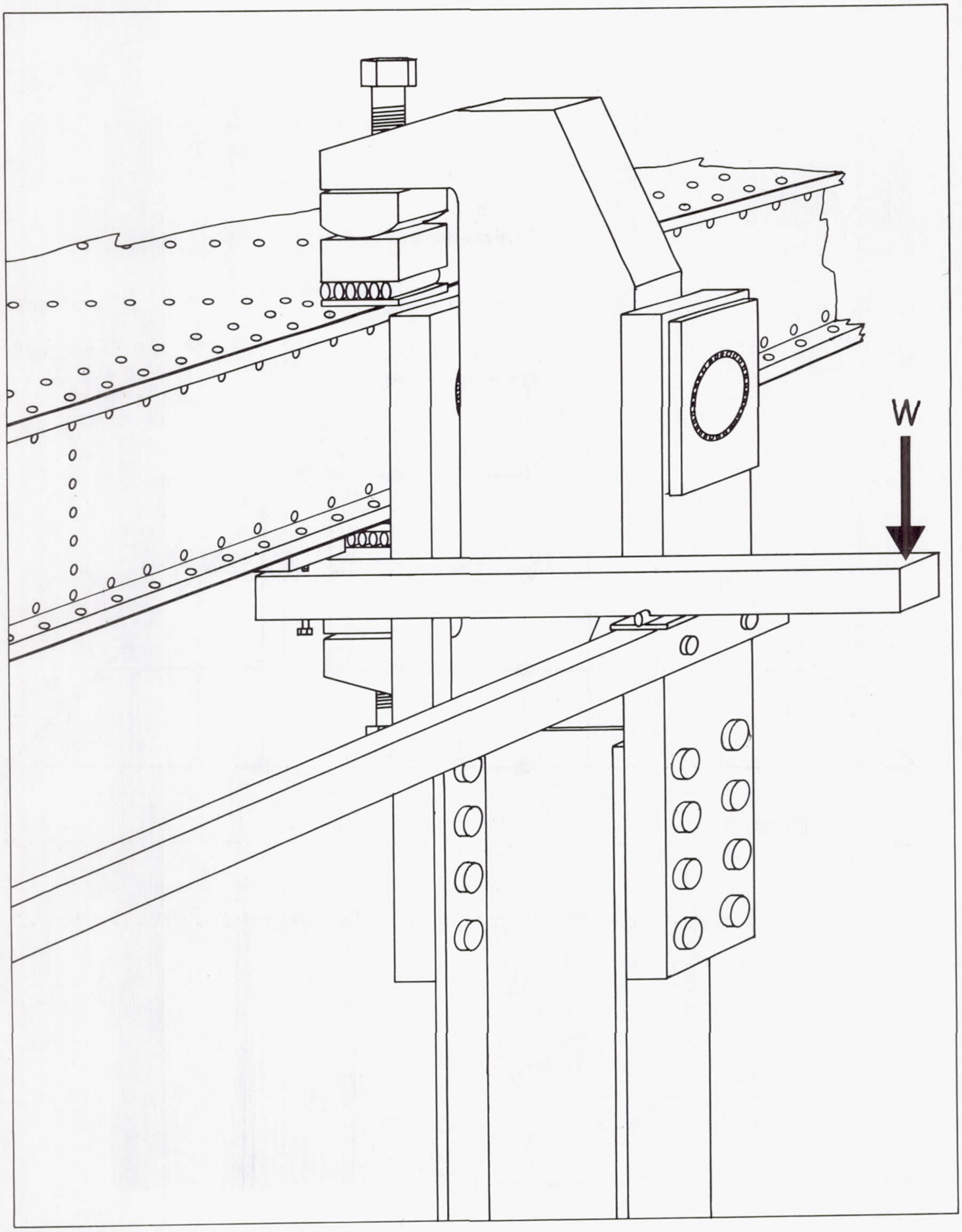


Figure 6.- Support fixture.

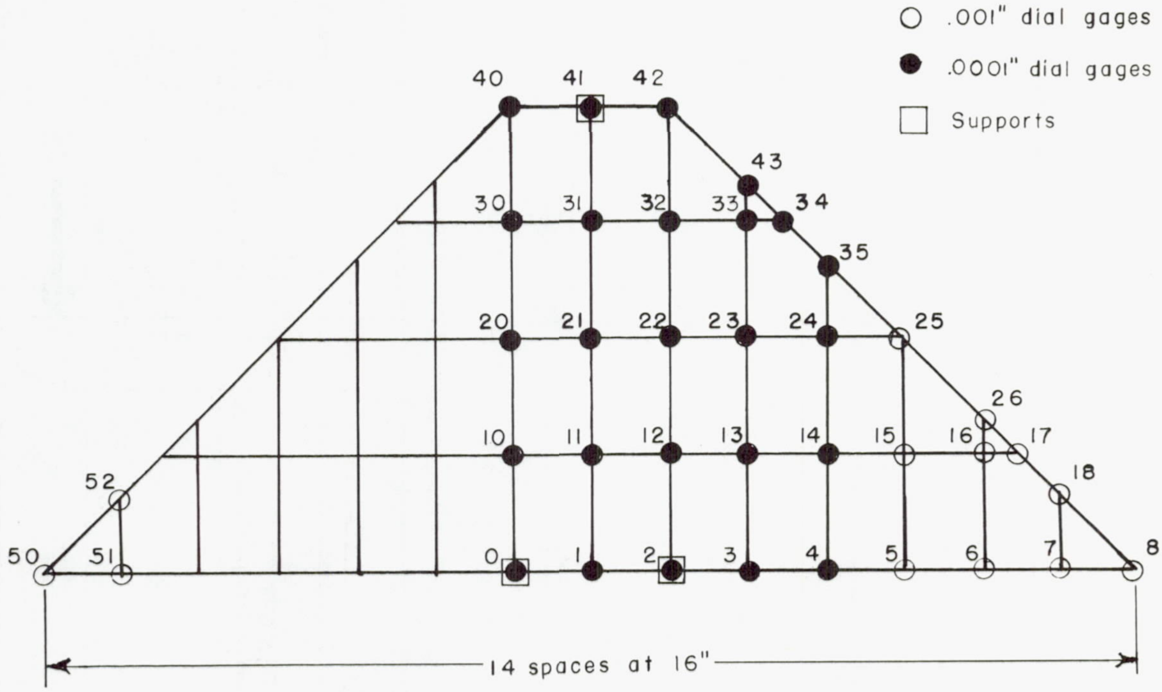


Figure 7.- Locations of supports and dial gages for static tests.

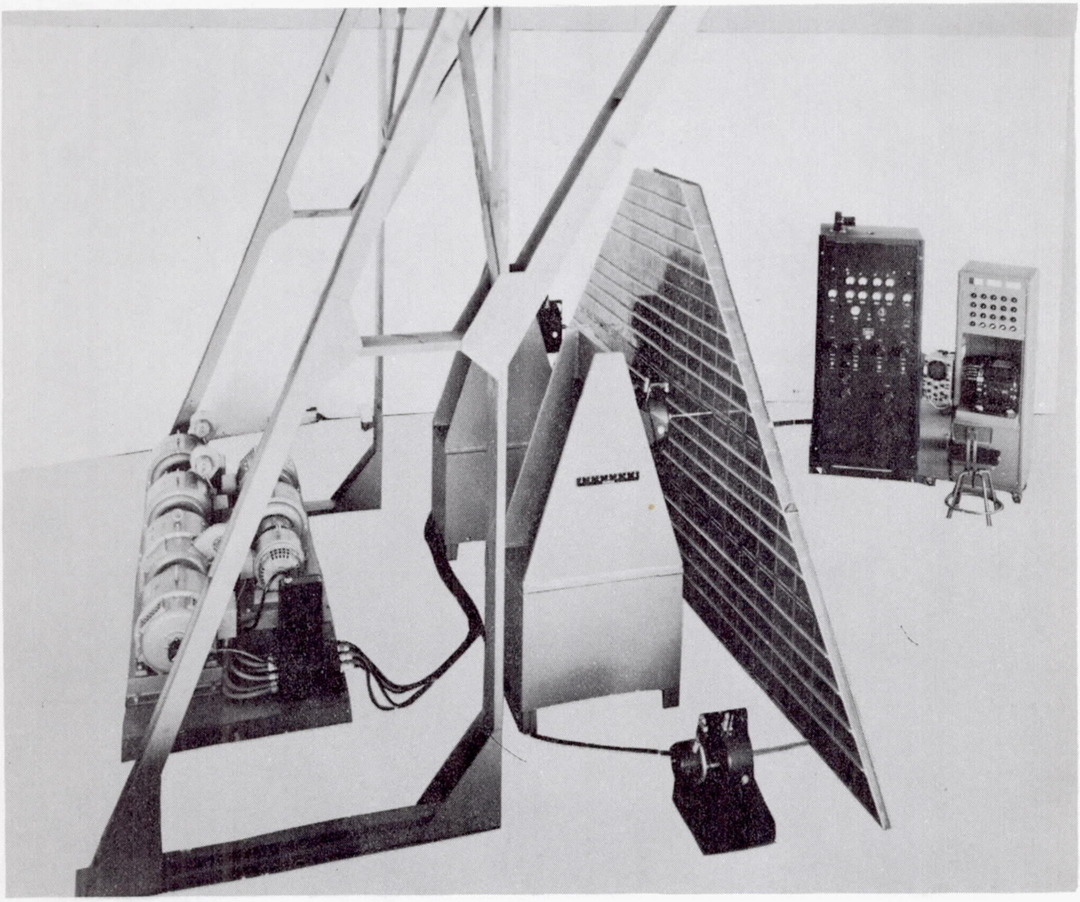


Figure 8.- General view of vibration-test setup. L-88071.1

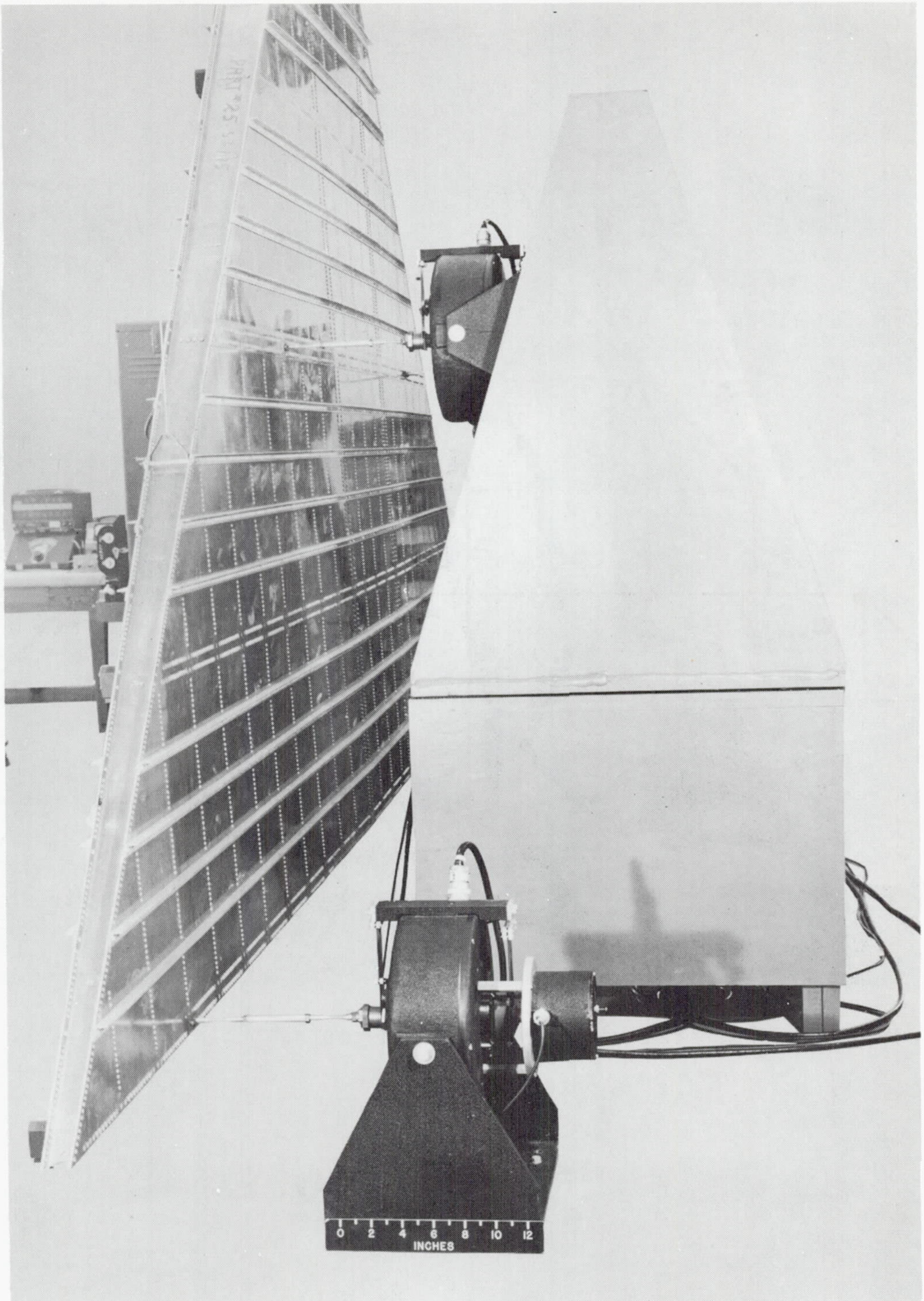


Figure 9.- View of shaker attachment. L-88068.1

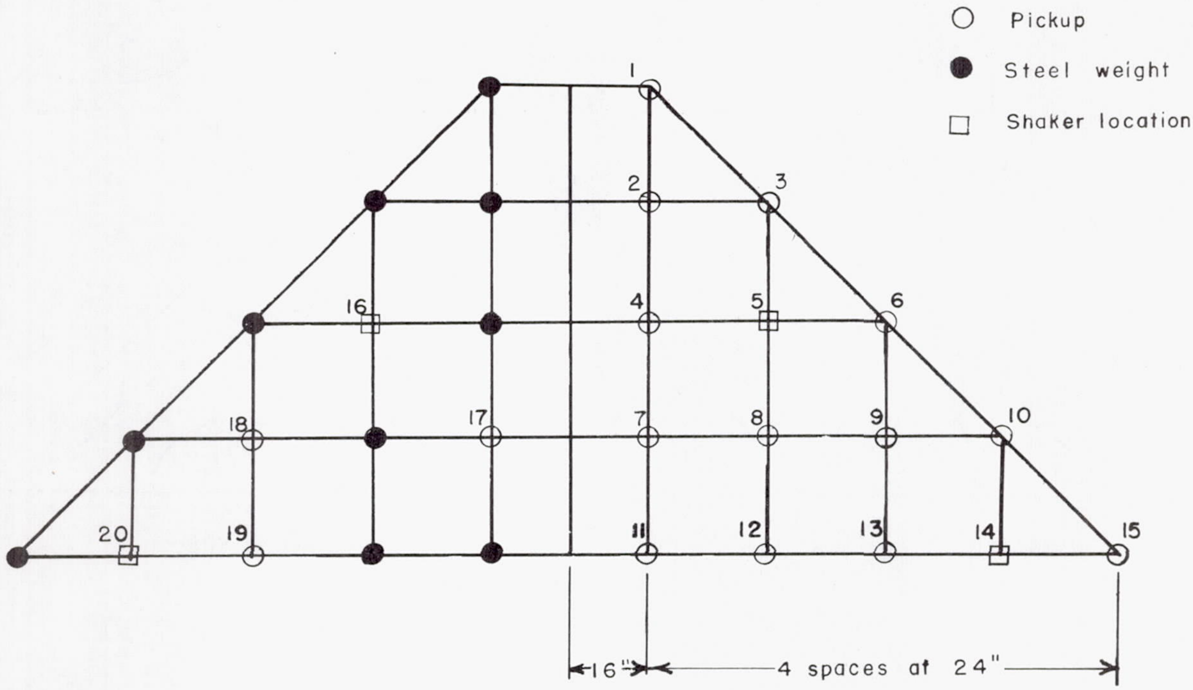
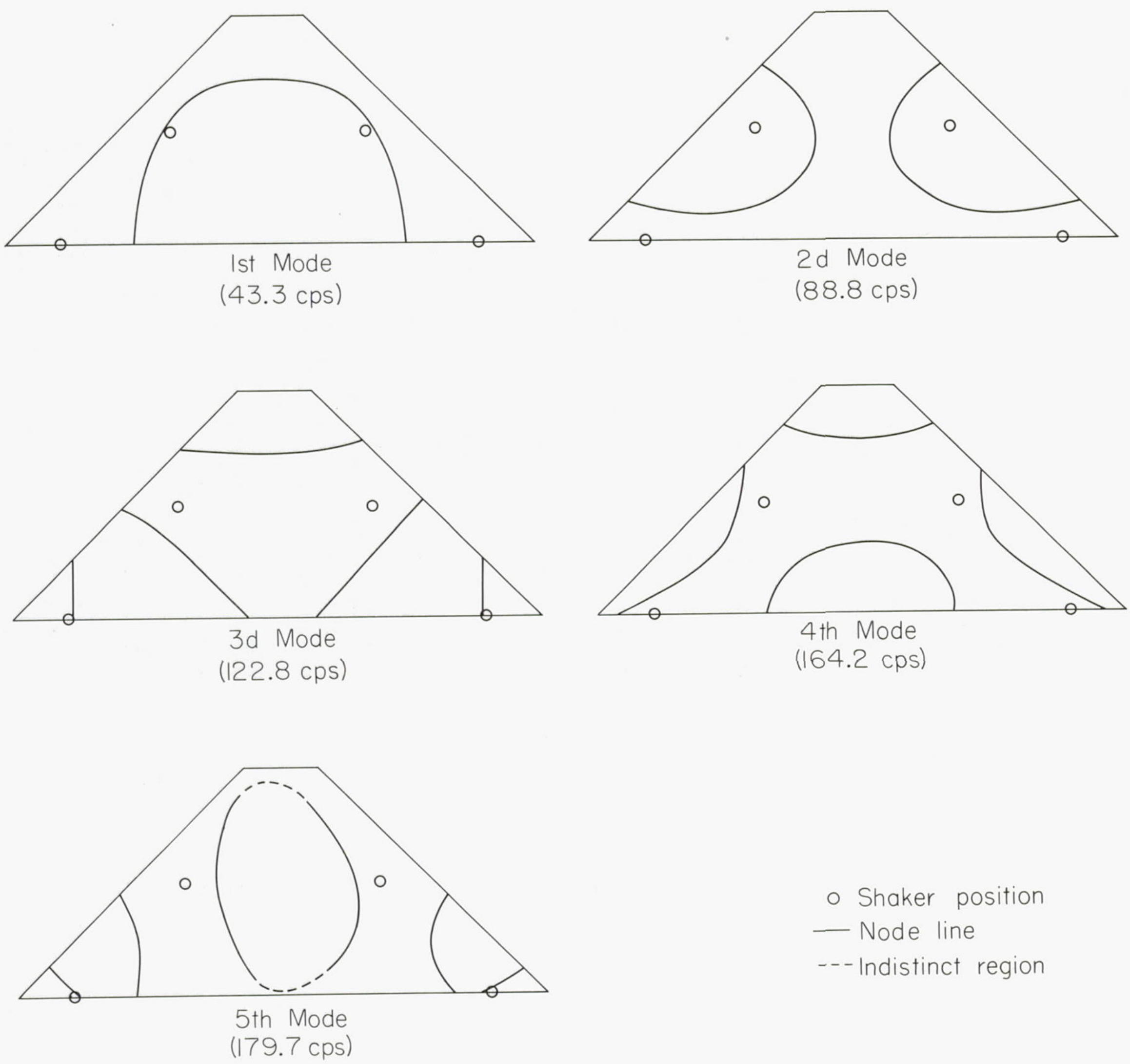
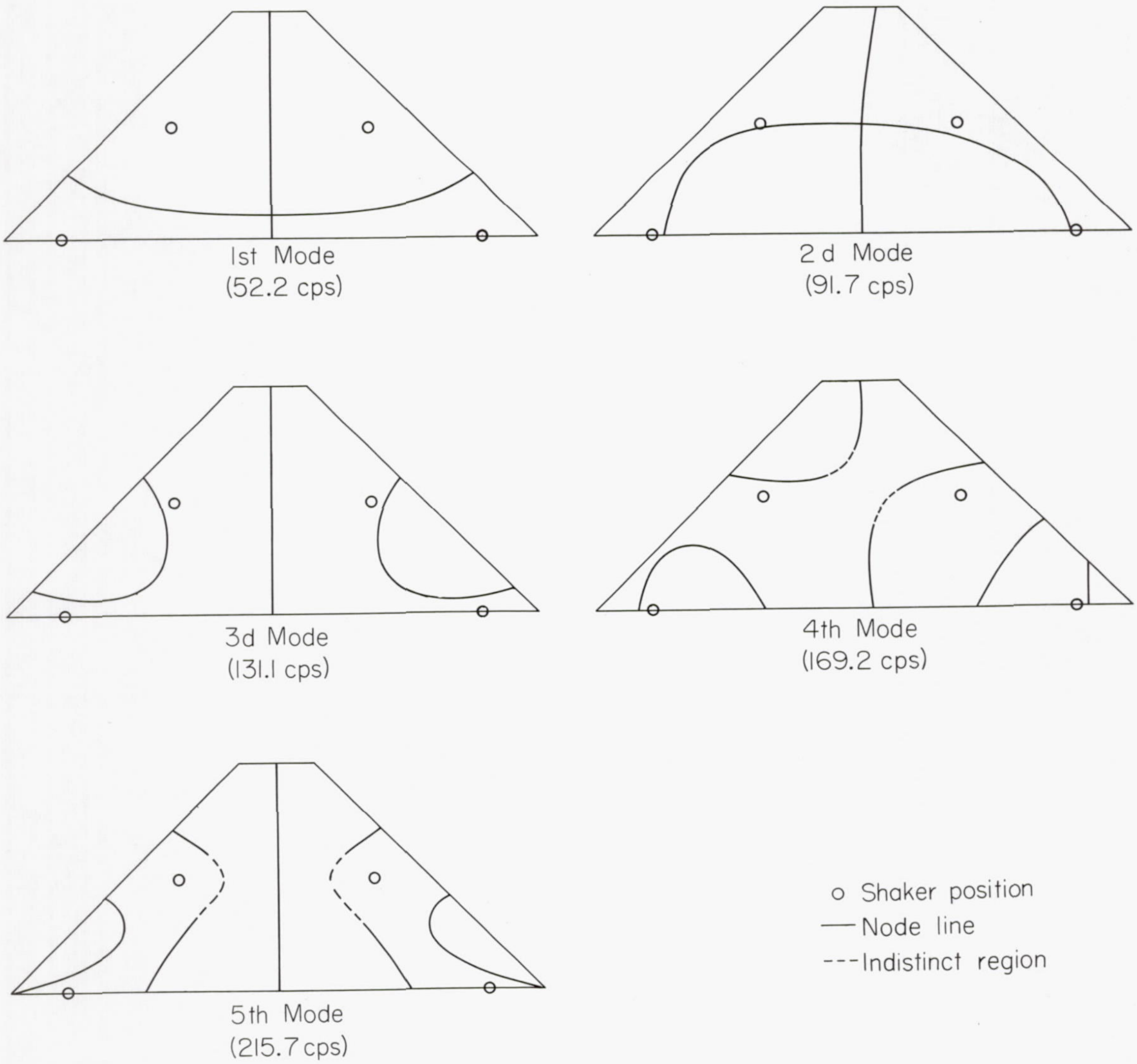


Figure 10.- Locations of pickups, shakers, and counterweights for vibration tests.



(a) Symmetrical modes.

Figure 11.- Modes and frequencies of a delta-wing specimen.



(b) Antisymmetrical modes.

Figure 11.- Concluded.