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GROUND VIBRATION TEST RESULTS

XV-5A

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL  ELECTRIC

OR for CPST, per telecon with Mr. Horn, Aviation National Agency (formerly TRECOM),
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GROUND VIBRATION TEST RESULTS

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XV-5A Lift Fan Flight Research Aircraft
Contract No. DA44-177-TC-715

April, 1966

ADVANCED TECHNOLOGY AND DEMONSTRATOR PROGRAMS DEPARTMENT
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

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1.0 SUMMARY

The U.S. Army XV-5A Lift Fan Research Aircraft was subjected to ground tests in the summer and fall of 1963 for evaluation of aircraft characteristics complementary to the flutter and vibration analyses conducted on the XV-5A aircraft. In general, the outline as presented in Reference 1 "Ground Resonance Test Plan, U.S. Army XV-5A Lift Fan Research Aircraft" was followed with several items omitted due to time restrictions.

The basic item, that of the airplane ground vibration test, was completed in late 1963 and these results are summarized below. The configuration of the XV-5A aircraft tested represented the aircraft in its conventional flight mode with a gross weight of approximately 9,700 pounds (c. g. at F.S. 243.5). Both symmetric and antisymmetric modes of the aircraft were determined. Although the modes have been classified as airplane normal modes, each mode exhibits a predominant motion of one or more aircraft components i. e. wing, fuselage, horizontal and vertical stabilizers and control surfaces.

SYMMETRIC AIRPLANE MODES

<u>MODE NO.</u>	<u>FREQUENCY (cps)</u>	<u>DAMPING (g)</u>	<u>PREDOMINANT MODAL CHARACTERISTIC</u>
1	11.2	0.040	Wing Bending
2	14.1	0.044	1st Fuselage Bending
3	21.4	0.106	2nd Fuselage Bending
4	29.4	0.124	Wing and Fan Mode
5	31.3	0.031	Horizontal Stabilizer Bending
6	36.3	0.037	Aileron Rotation
7	44.7	0.068	Wing Torsion
8	55.9	0.033	Horizontal Stab. Pitch and Torsion
9	67.8	0.031	Higher Wing Mode
10	90.3	0.031	Elevator Bending

ANTISYMMETRIC AIRPLANE MODES

<u>MODE NO.</u>	<u>FREQUENCY (cps)</u>	<u>DAMPING (g)</u>	<u>PREDOMINANT MODAL CHARACTERISTIC</u>
1	8.8	0.030	Vertical Stabilizer Bending
2	11.9	0.045	Horizontal Stabilizer Yaw- Vertical Stabilizer Torsion

ANTISYMMETRIC AIRPLANE MODES (Continued)

<u>MODE NO.</u>	<u>FREQUENCY (cps)</u>	<u>DAMPING (g)</u>	<u>PREDOMINANT MODAL CHARACTERISTIC</u>
3	14.5	0.023	Horizontal Stabilizer Roll - 1st Fuselage Bending
4	18.5	0.046	Wing Bending
5	23.0	0.019	2nd Fuselage Bending
6	25.3	0.046	Fuselage Torsion
7	34.8	0.040	Fuselage Torsion (Forebody)
8	36.8	0.058	Aileron Rotation
9	44.6	0.063	Wing Torsion
10	50.6	0.033	Rudder Bending - Fuselage Torsion
11	72.9	0.025	Horizontal Stabilizer Torsion

2.0 INTRODUCTION

This report contains the results of a experimental investigation of the static and dynamic characteristics of the U.S. Army XV-5A Lift Fan Research Aircraft as pertaining to the flutter and vibration effort on the XV-5A aircraft. The general arrangement of the aircraft tested is shown in Figure 1. The XV-5A is a V/STOL aircraft designed for research flight testing of the General Electric X353-5 Lift Fan Propulsion System.

The report is divided into three basic parts plus an addendum; the basic parts following in general the test plan as outlined in Reference 1, (i.e., Airplane Resonances, Component Resonances and Component Static tests) while the addendum presents the results, in terms of airplane resonances (normal modes) of structural modifications to the empennage required for flutter prevention. The modes presented in the addendum are representative of the current aircraft and thereby void their equivalents presented in the main body of the report. All the other modes presented were not affected by the structural change and therefore are representative of the current aircraft.

The aircraft considered for the airplane resonant test phase was Aircraft No. 2, S/N 506 in its design gross weight condition of approximately 9,700 pounds (partial fuel). The dynamic system was in essence a free-free aircraft with control surfaces free, but with cockpit controls locked in neutral (aileron flight tabs and rudder trim tab were locked to their respective parent surface).

Components considered for the second phase of the testing were all of the control surfaces (conventional flight mode), wing fan doors, pitch fan doors, wing flaps and thrust spoilers. These latter items were tested as installed on the aircraft (No. 1 aircraft, S/N 505) whereas the testing of the horizontal stabilizer was limited to a jig-mounted stabilizer with a simulated pivotal joint.

Static testing, i.e., free play and rotational stiffness tests, were confined to the horizontal stabilizer mounted in the above mentioned jig.

Evaluation of structural modifications to the empennage (presented in the addendum) was conducted on Aircraft No. 1, S/N 505 for the same aircraft configuration as for the basic airplane resonant test, with the exception of the suspension system for which in the latter tests were the actual landing gear with partially deflected tires and locked nose wheel struts.

3.0 AIRPLANE RESONANCE TEST

The initial ground vibration test of the XV-5A aircraft was conducted at the Ryan Aeronautical Company's plant, San Diego, California during the period of 30 September, 1963 to 27 October, 1963.

3.1 TEST CONFIGURATION

The aircraft configuration consisted of a complete aircraft (No. 2, S/N 62-4506), fueled for a gross weight condition of 9,700 pounds with a c.g. location of F.S. 243.5. All flight instrumentation was either installed or simulated by dummy weights as was pilot simulation. Electrical power and hydraulic system power were supplied by external means. The aircraft was aligned in a level flight attitude simulating the CTOL mode, with all controls locked in neutral by means of the appropriate cockpit control. The aircraft was in a clean state, i. e. all other auxiliary devices such as flaps, thrust spoilers, wing fan louvers, etc. were fully retracted. Wing and pitch lift fans were blocked to their stator/|blades by means of shock cord for the initial test.

The airplane was suspended to simulate a free-flight condition by means of spring-mounted platforms at the main and nose gear CTOL positions. Figure 2 shows the airplane on its suspension system undergoing final preparation before commencement of testing, whereas Figure 3 presents details of the airplane suspension system.

3.2 TEST EQUIPMENT AND INSTRUMENTATION

Excitation of the aircraft was provided by eight electromagnetic shakers mounted at various locations on the aircraft as shown in Figure 4. Various combinations of shakers, up to the maximum of eight, were used for modal surveys as will be discussed later. Resonant frequencies and modal surveys were established from the recorded output of accelerometers located throughout the aircraft, the pickup locations being shown in Figures 5 & 6 for the symmetric and antisymmetric test phase of the airplane resonance test. Control surface motion was detected by means of strain-gaged beams in addition to accelerometer outputs. Figures 7 through 9 present the location of the control surface points at which measurements were taken, while Figures 5 and 6 show the location of the strain-gaged beams. Table 1 lists the test equipment and instrumentation utilized in the test.

3.3 GENERAL TEST PROCEDURE

Both symmetric and antisymmetric resonances were investigated in a similar manner and differed only by the sense of application of shaker forces. The resonant frequencies of the aircraft were established from the recorded output of certain fixed accelerometers as indicated in Figures 5 and 6. These resonant frequencies were selected on the basis of response studies of various shaker combinations under different force inputs. Frequency sweeps for each main component of the aircraft (i. e. wing, fuselage, horizontal and vertical stabilizers) were made under different loading conditions. The response of the aircraft from one of the fixed accelerometers at one of the drive points plus selected accelerometer outputs from the fuselage and horizontal stabilizer in the case of a symmetric sweep and wing excitation and from the horizontal and vertical stabilizers in the case of antisymmetric sweeps and wing excitation, were utilized in establishing the resonant conditions. Table 2 lists the shaker combinations and selected accelerometer outputs displayed on the response plot (X-Y recorders). Establishment of the airplane resonant frequencies was through a study of the abovementioned response plots, deliberate tuning to the particular mode with the best shaker combination for that component, as shown by the response, study of the decay characteristics of the structure upon excitation cutoff and visual monitoring of the mode. Having established the resonances, tuning to a particular resonance for modal surveys attempted to follow the procedure as discussed in Reference 2. Although not followed completely, the technique of observing force-velocity phasing (through calibrated strain-gaged links between aircraft and shaker coil) as discussed in Reference 2, allowed utilization of available exciters. The mode shapes for the particular resonant condition were established by utilizing a battery of roving pickups (accelerometers) with measurements made at the pickup locations as shown in Figures 5 through 9. In addition to measurements taken at these points, measurements of suspension system platforms in the coordinate directions were also made. Measurements were recorded in terms of voltages with phasing, with reference to a master pickup determined from oscilloscopes. In addition to these readings, oscillograph recordings were made for each measurement for damping and frequency determination, in addition to the post-vibration-test scanning of doubtful areas.

3.4 RESULTS AND CONCLUSIONS

Initial testing of the airplane on its suspension system yielded the following airplane rigid body modes:

Vertical Translation	2.2 cps
Side Translation	1.9 cps

Fore and Aft Translation	0.7 cps
Pitch	1.7 cps
Roll	2.2 cps
Yaw	0.7 cps

Excitation for the above modes was by shaker or hand - forcing with response monitored by accelerometers (Statham) located at several points on the aircraft.

Following establishment of the resonant frequencies for both the symmetric and antisymmetric case, complete modal surveys of the aircraft were made utilizing a battery of roving accelerometers (Endevco) as mentioned previously. Examination of the resulting mode shapes, when plotted against major structural elements, (for example, deflection along the wing rear spar versus butt-line) indicated inconsistencies among data points in a number of cases. Assuming errors in voltmeter readings, the oscillograph recordings were reduced to reflect the deflection relative to the voltage reading at a reference point and plotted. To determine the final mode shape, the individual plots, if necessary, were smoothed by the method of least squares utilizing best fit data (voltmeter or oscillograph readings). The smoothed plot was then further scrutinized for continuity at major structural intersections and refitted or faired, if necessary, to obtain continuity. A major reason for inconsistencies among mode shapes was the inability of maintaining calibration among the battery of five accelerometers used for modal surveys. Preliminary node line sketches, taken during mode set-up, aided in establishing the deflection shapes of each mode.

A summary of the resonant frequencies and the predominant nature of the mode is given in Table 3. The normalized displacements of the symmetric modes are presented in Tables 4 through 13 and are shown in pictorial form in figures 10 through 19. The fuselage readings for the antisymmetric case were reduced to reflect the linear and angular displacements about W. L. 100. Similar results for the antisymmetric modes are shown in Tables 14 through 24 and in Figures 20 through 30. Structural damping coefficients (g) for each mode are also presented in Table 3, with these values determined from the modal decay oscillograph recording of the dominant pickup location for the predominant component of the airplane.

The predominant modes of interest in an analysis of the empennage, the critical aspect of the XV-5A aircraft with respect to a flutter analysis, would be Modes 1, 2, 3, 4, 5, 8 and 10, symmetric. Although several of these modes have been classified as predominant wing or fuselage modes, the response of the empennage (horizontal tail) in these modes is significant enough to be included in an analysis. Modes 5 and 8 are the

basic elastic modes of the horizontal stabilizer, with Mode 8 being coupled pitch-torsion. There was no evidence of a pure pitch mode existing, a fact established previously, (see Section 4.0).

For the antisymmetric case, the modes of interest to an empennage analysis would be Modes 1, 2, 3, 5, 6, 10 and 11. The horizontal tail rigid body modes of yaw and roll are pronounced, as evidenced in the pictorial views of Figures 21 and 22. Horizontal tail pitch no longer appears, due to the symmetric nature of this mode. Vertical stabilizer torsion is evident in Mode 2, but is highly coupled with the fuselage and the effects of the horizontal tail yaw. The node line is evidenced by Figure 21, (although not drawn), runs up the vertical stabilizer and is swept back through the trailing edge of the stabilizer, due to the elastic effects of the fuselage.

4.0 COMPONENT RESONANCE TEST

With the establishment of the basic airplane vibration modes, emphasis was then placed upon determining the vibration characteristics of miscellaneous components of the aircraft i.e. lateral, longitudinal and directional control systems (CTOL mode), flaps, wing fan doors, pitch fan doors and thrust spoiler. Separate resonance testing of the jig-mounted horizontal stabilizer was performed to determine rigid body modes about the pivotal joint. The former test period extended from 18 November, 1963 to 25 November, 1963, whereas the latter preceded the ground vibration testing of the complete aircraft and covered the period of from 7 September, 1963 to 9 September, 1963.

4.1 TEST CONFIGURATIONS

The test configurations, so employed in the component resonance test, may be conveniently grouped into three categories, mainly primary control systems, horizontal stabilizer and finally miscellaneous components.

4.1.1 Primary Control Systems

In order to provide meaningful data for eventual incorporation into future analytical flutter analyses, the test configuration of the aileron, elevator and rudder systems were so arranged to provide both a stick-free and stick-fixed system with the locking out by external means of any control surface or tab degree of freedom as the case warranted. Since the primary objects of these tests were systems, and not airframe, the airplane was placed upon its jacks to provide additional restraints. The aircraft tested for this phase was the No. 1 aircraft, S/N 505, which was in a partial state of completion at the time of testing. Electrical power and hydraulic system power were supplied by external means.

4.1.2 Horizontal Stabilizer

Since the sole objective of the horizontal stabilizer test was to determine its rigid body vibratory characteristics, the test configuration used was the complete stabilizer (with a simulated pivotal joint) from the No. 2 (S/N 62-506) aircraft mounted on a rigid test stand. A flight pitch actuator was used and the pivot and actuator attach fittings on the test stand were manufactured with identical tolerances with the flight hardware. The pitch

actuator, being a mechanical jackscrew, driven by hydraulic motors, was preset in the desired position mechanically and thereby no external means of power was required for these tests.

4.1.3 Miscellaneous Components

Test configurations of the flaps, wing fan doors, pitch fan doors and thrust spoiler were the actual items as installed on the aircraft, with the same aircraft used as during the primary control systems test.

4.2 TEST EQUIPMENT AND INSTRUMENTATION

Excitation of the aircraft components was provided by one or two, (as the case warranted) electromagnetic shakers mounted either in the cockpit or at an optimum position on the appropriate control or auxiliary device. Excitation of the horizontal stabilizer was by means of two shakers located at various points on the surface to provide the required moment about the pivotal joint, as shown in Figure 4. These locations were designated by the term, "secondary". Resonant frequencies and modal surveys, if any, were established from the recorded output (voltages) of accelerometers (Endevco) which were located at strategic points on the components. Figures 7 through 9 present the locations of the control surface points which were used for the tests, while Figures 31 through 34 present the locations of pick-up points on the flap, wing fan door, pitch fan door and thrust spoiler. Horizontal stabilizer locations are shown in Figures 5 and 6 with the appropriate points used as per sense of excitation.

4.3 TEST PROCEDURE

In general, the test procedure used in determining the component resonances was similar to that performed on the basic airplane vibration test. Initial frequency sweeps were made of the particular system or component under investigation. The resonances were noted from the resulting response plot and visual observation, manually tuning to these resonances for sharper definition and finally, modal surveys made, if needed by the roving pickup technique with a pair of accelerometers (Endevco), one being used as a reference and one as the roving transducer. Upon completion of the survey, oscillograph records were taken for frequency and damping determination.

4.4 RESULTS AND CONCLUSIONS

Since the rigid body modes were the primary objectives of this phase of testing, no pictorial views are presented.

The primary control systems' resonance test yielded partial results, due to difficulties encountered in modal coupling with the airframe proper. Additional restraints, other than aircraft jacks, proved to be impractical. Therefore, only those vibration modes which were felt to be indicative of the control systems are recorded herein. Table 25 presents the results of this phase of the component resonance testing. As can be seen from the results, the aileron system and elevator system tests proved to be more fruitful than the rudder system tests. This ties in with the manner in which the aircraft is supported by jacks; the two on the wings plus the fuselage jack at location F-8 provided the additional vertical restraint needed for excitation in the vertical sense, whereas excitation in the horizontal plane as in the case of rudder system, brought into play the lateral flexibility of the fuselage and vertical stabilizer. Isolation of the aileron flight tab uncoupled rotational mode proved to be an impossibility, since the only restraint provided for the aileron itself was the hydraulic actuator which provided only a point fixity.

Determination of the miscellaneous components was relatively simple and the results of these tests are presented in Table 26.

Establishment of the rigid body modes of the horizontal stabilizer yielded only one, or at the best, two valid frequencies, that of yaw and roll. The yaw mode was 12.9 cycles per second and could be considered representative of the actual case, whereas the roll mode was determined to be 16.85 cycles per second. Investigation of jig motion revealed that a small percentage of coupling was apparent between jig and stabilizer. Comparison of these modes with those presented in Section 3.0 shows 11.9 cycles per second, yaw versus 12.9 cycles per second and 14.5 cycles per second, roll versus 16.85 cycles per second. Comparison is good when considering the nature of the test, i. e. jig-mounted horizontal versus actual aircraft shake, wherein modal coupling is more pronounced, due to vertical stabilizer and fuselage effects. In any event, these modes were considered for inertia correlation, as will be discussed in Section 5.0. Isolation of the pitch mode, particular to the effects of simulation, was impossible, due to coupling with the elastic modes of the horizontal stabilizer. The following modes were noted for interpretive purposes:

Bending - Pitch	24.7 cps
Pitch - Bending - Torsion	42.1 cps
Pitch - Torsion - Bending	50.8 cps

Examination of these modes with those determined from the airplane resonance test, and the frequency determined from the static tests (Section 5.0) verified the inability of determining the true uncoupled pitch mode.

5.0 COMPONENT STATIC TEST

Static testing of components of the XV-5A aircraft for flutter and vibration correlation was restricted entirely to determination of the effective spring rates (about coordinate axes) of the three degrees of freedom associated with the rigid body motion of the horizontal stabilizer. This test was conducted jointly with the resonance testing of the horizontal stabilizer, as discussed in Section 4.0, and covered the period of from 7 September, 1963 to 9 September, 1963 and also 17 March 1964.

5.1 TEST CONFIGURATION

The test configuration, employed for this phase was the complete horizontal tail from the No. 2 (S/N 506) aircraft for the yaw and roll investigations, whereas the No. 1 (S/N 505) horizontal stabilizer (less elevators) was used for the pitch tests. Mounting was separate from the aircraft and employed the same fixture as described in Section 4.0 with the actual actuator installed.

5.2 TEST EQUIPMENT AND INSTRUMENTATION

In each phase of the testing of the horizontal stabilizer, loads were applied to the horizontal stabilizer through a loading jig that enclosed the rib at BL 70.16 on both ends of the stabilizer. An additional pair of loading jigs at BL 16.56 was used in the pitch test. A pulley system was used to obtain the proper load direction, and 20 or 25-pound shot bags placed upon load pans provided the applied torque in the appropriate direction.

Dial gages located at selected points on the surface were used to measure deflection. In addition, small mirrors, reflecting a cross-hair image from a light source onto a calibrated screen, were used to measure change of slope. Schematics of the pitch, roll and yaw loading and instrumentation set-ups are shown in Figures 35 through 37, whereas Figure 38 depicts a photo of the test set-up for the pitch phase.

5.3 TEST PROCEDURE

The test procedure to determine effective restraints was simply orientation of the loading jig and dial gages and/or mirrors for proper axis definition, with the load being applied in incremental parts with deflection and/or

slope information being simultaneously measured. A complete load cycle gave data on both sides of the free-play regime, enabling the spring rates and free-play to be determined.

5.4 RESULTS AND CONCLUSIONS

Interpretation of effective spring rates as obtained from these series of tests was somewhat difficult, since it was not known to what extent local back-up structure in the vertical stabilizer had in the apparent idealization of these effective springs. It was assumed that for the roll and yaw springs, the pivotal joint (which was of the same material and incorporated actual pivot bolts) would yield approximate results valid for analysis purposes.

The pitch spring was apparently misleading, since the effective pitch spring is, in essence, composed of the actuator, pivot fittings, bearings, horizontal stabilizer local back-up structure and also local back-up structure of the vertical stabilizer which was not simulated. Therefore, determination of this spring rate had to be approached with caution.

5.4.1 Pitch Spring

The deflection and load data taken at the locations shown in Figure 35 were reduced and plotted as angular rotation versus applied pitching moment as shown in Figure 39. These data were reduced by treating the root ribs as an overhanging box beam simply supported at the actuator - front spar intersection and horizontal stabilizer pivot. Deflection data for each increment of load taken at dial gages 1 and 2 were averaged, and combined with the average data from gages 3 and 4 to describe the rotation of a plane representative of the elastically - undeformed horizontal stabilizer. Then, computing the angular rotation of the support jig for each increment of load from the deflection data of gages 7 through 11, and subtracting, the net angular rotation in pitch versus applied load was obtained.

Figure 39 shows that the spring rate is non-linear and increases with applied load. This result is reasonable, since the system has a number of bearing contacts where total bearing area increases with load.

The minimum pitch spring rate and the minimum average pitch spring rate determined from the slope of the curves between the first two data points on both sides of the free-play region are:

Minimum Pitch Spring Rate = 9.5×10^6 in-lb./rad.

Minimum Average Pitch Spring Rate = 11.4×10^6 in-lb./rad.

The experimental pitch spring rate used in conjunction with calculated effects of vertical stabilizer was 10.33×10^6 in-lb./rad., with a resulting effective pitch spring rate of 6.09×10^6 in-lb./rad.

Approximately 2,000 inch - pounds of moment (leading edge down) was required to balance the stabilizer in the loading jig. The free play was determined from Figure 39 at this load level to be as follows:

Pitch Free Play = 0.0011 radians

Inability to shake out a rigid body pitch mode resulted in using experimental inertia properties in an attempt to arrive at a value for use in flutter analysis correlation. Swinging of the horizontal tail gave the following results as compared to the calculated value:

$I_{\text{Pivot}} = 43,085 \text{ lb.} \cdot \text{in}^2$ Experimental

$I_{\text{Pivot}} = 34,440 \text{ lb.} \cdot \text{in}^2$ Calculated

Thus, it can be seen that the calculated value had been underestimated by a factor of 1.25.

Using the minimum projected spring rate of 6.09×10^6 in-lb./rad. in conjunction with the experimental inertia value, the estimated value of the uncoupled pitch frequency was determined to be:

$f = 37.2$ cycles/second

5.4.2 Roll Spring

The mirror and load data taken at the locations shown in Figure 36 were reduced and plotted as angular rotation versus applied rolling moment as shown in Figure 40. The angular values in the plot were determined by averaging the net roll angle experienced at mirror locations 1 and 2 obtained by subtracting from each the angular rotation at mirror location 3. An average of the slope of the two straight line least square fits of the data for each load direction was considered to be the roll spring rate, and the horizontal distance between their zero load intercepts was considered the roll free-play. These values are as follows:

Average Roll Rotational Spring Ratio = 11.3×10^6 in. - lb./rad.

Roll Rotational Free-Play = 0.00032 radians

The difficulty inherent in the geometry of the horizontal stabilizer pivot fitting support, wherein the applied rolling moment must be reacted by a couple with only a 6.06 inch moment - arm, created an impractical test situation. The roll spring is composed of the elasticity present in the pivot fitting, bearings and local back-up structure. Any method of loading this system must produce elastic deformation of the stabilizer surface proper. Therefore, the measurements of slope during the test included any beam deformation of the horizontal stabilizer. In deriving the roll spring rate from the test data, it was assumed that the change in slope of the elastic curve due to deformation of the stabilizer as a beam in the support area was small, compared to the change of slope due to rigid body roll.

Comparison of roll inertias (about BL O and WL 201.75) both calculated from weights information and also from static and frequency measurements yielded the following:

$$I_{\text{Roll}} = 389,544 \text{ lb.} \cdot \text{in.}^2 \quad \text{Experimental}$$

$$I_{\text{Roll}} = 166,541 \text{ lb.} \cdot \text{in.}^2 \quad \text{Calculated}$$

From the above, it can be seen that the calculated value had been underestimated by a factor of 2.34. However, closer examination of the spring rate determination indicated movement of the support jig which also may have been involved in the vibration mode. Consequently, the factor of 2.34 may be somewhat larger than it should be, if jig motion was non-existent during resonance. The test essentially indicates an uncoupled roll frequency of the order of 16 cps and also that calculated inertia values are low. Examination of deflection data taken during the vibration test indicated some small deflection, both in the lateral and vertical sense of the pivot assembly and mounting jig, thereby warranting the above conclusion.

5.4.3 Yaw Spring

The mirror and load data taken at the locations shown in Figure 37 were reduced and plotted as angular rotation versus yawing moment as shown in Figure 41. The angular values in the plot were obtained by subtracting the rotation at mirror 2 from the rotation at mirror 1 for each loading increment. An average slope of the straight line least square fits of the data for each loading direction established the spring rate, and the horizontal distance between their zero load intercepts represented the free-play. These values are as follows:

$$\text{Average Yaw Rotational Spring Rate} = 3.11 \times 10^6 \text{ in.} \cdot \text{lb.} / \text{rad.}$$

$$\text{Yaw Rotational Free-Play} = 0.00033 \text{ radians}$$

Comparison of yaw inertias (about vertical axis through pivot), calculated from weights information and also from the static and frequency measurements yielded the following:

$$I_{\text{Yaw}} = 182,919 \text{ lb.} - \text{in.}^2 \quad \text{Experimental}$$

$$I_{\text{Yaw}} = 194,434 \text{ lb.} - \text{in.}^2 \quad \text{Calculated}$$

From the above, it can be seen that the calculated value had been over-estimated by a factor of 0.94. Examination of the deflection measurements taken during the shake test indicates negligible movement of the base (jig) and therefore correlation between the inertias as shown above is considered excellent.

6.0 APPENDIX

REFERENCES

1. Ground Resonance Test Plan, Report Number 128, September, 1963.
2. Lewis, R.C. and Wisley, D.L.; A System for the Excitation of Pure Natural Modes of Complex Structures, Journal of the Aeronautical Sciences, Volume 19, 1950.
3. Preliminary Flutter Analysis, Volume II - Empennage, Report Number 163, November, 1965.

TABLE 1
TEST EQUIPMENT AND INSTRUMENTATION

Exciter System

1. Calidyne Model 3810 exciter system utilizing eight (8) Calidyne Model D-88 excitors rated at 100 pound vector force.
2. MB Model PT 112537 exciter system utilizing two (2) MB Model C-1-H excitors rated at 50 pound vector force.
3. Hewlett-Packard sweep oscillator Model 202A.
4. Hewlett-Packard frequency counter Model 522.
5. Ryan manufactured strain gaged force rings in conjunction with a CEC Model 1-113 carrier amplifier.
6. Brüel and Kjaer vacuum tube Model 2409 voltmeters.
7. Dumont dual beam Model 304 oscilloscopes.

Instrumentation

1. Endevco Model 2213 crystal-type accelerometers used in conjunction with Endevco Model 2607 amplifiers.
2. Statham Model F-10-350 strain-gage accelerometers used in conjunction with Consolidated Electrodynamics System "D" amplifier/power supply.
3. Minneapolis-Honeywell 12-channel Model 906 oscillograph.
4. Minneapolis-Honeywell 24-channel Model 1508 oscillograph.
5. X-Y plotters.
6. Dumont dual beam Model 304 oscilloscopes.
7. Brüel and Kjaer vacuum tube Model 2409 voltmeter.
8. Khron-Hite variable band-pass Model 330M filters.

TABLE 2

SHAKER AND SELECTED ACCELEROMETER COMBINATIONS
Airplane Resonance Sweeps

Aircraft Component	Sweep Configuration	Shaker Configuration				Symmetry	Plotter Component	Plotter Configuration			
		Shaker Locations Phase						1 Wing	2 Fuselage	2 V. T.	3 H. T.
Wing	A	P-1 +			P-2 +	S	Pickup Location	LW-1	F-2	—	LH-1
	B		P-3 +	P-4 +		S		LW-15	F-2	—	LH-1
	C	P-1 +	P-3 +	P-4 +	P-2 +	S		LW-1	F-2	—	LH-1
	D	P-1 +	P-3 —	P-4 —	P-2 +	S		LW-1	F-2	—	LH-1
	J		P-3A +	P-4A +		S		LW-13	F-2	—	LH-1
	K	P-1 +	P-3A +	P-4A +	P-2 +	S		LW-13	F-2	—	LH-1
	L	P-1 +	P-3A —	P-4A —	P-2 +	S		LW-13	F-2	—	LH-1
	X	P-3 +	P-3A —	P-4 +	P-4A —	S		LW-15	F-2	—	LH-1
	M	P-1 +			P-2 —	A/S		LW-1	F-12	—	LH-1
	Q	P-1 +	P-3A —	P-4A +	P-2 —	A/S		LW-1	—	V-10	LH-1
	R	P-1 +	P-3A +	P-4A —	P-2 —	A/S		LW-1	—	V-10	LH-1
	S		P-3A +	P-4A —		A/S		LW-13	—	V-10	LH-1
	T		P-3 +	P-4 —		A/S		LW-15	—	V-10	LH-1
	U	P-1 +	P-3 —	P-4 +	P-2 —	A/S		LW-1	—	V-10	LH-1
	V	P-1 +	P-3 +	P-4 —	P-2 —	A/S		LW-1	—	V-10	LH-1
	C-C	P-3 +	P-3A —	P-4 —	P-4A +	A/S		LW-15	—	V-10	LH-1
Fuselage	E	P-5 +				S	LW-1	F-2	—	LH-1	
	F				P-5A +	S	LW-1	F-8	—	LH-1	
	H	P-5 +			P-5A +	S	LW-1	F-2	—	LH-1	
	I	P-5 +			P-5A —	S	LW-1	F-2	—	LH-1	
Horizontal Tail	G	P-6 +			P-7 +	S	LW-1	F-2	—	LH-1	
	W	P-6A +			P-7A +	S	LW-1	F-2	—	LH-2	

TABLE 2 (Continued)

SHAKER AND SELECTED ACCELEROMETER COMBINATIONS
Airplane Resonance Sweeps

Aircraft Component	Sweep Configuration	Shaker Configuration				Symmetry	Plotter Component	Plotter Configuration			
		Shaker Locations Phase						1 Wing	2 Fuselage	2 V. T.	3 H. T.
Horizontal Vertical Tail	P	P-6 +			P-7 —	A/S	Pickup Location	LW-1	—	V-10	LH-1
	Y		P-8 +			A/S		LW-1	—	V-10	LH-1
	Z			P-9 +		A/S		LW-1	—	V-11	LH-1
	A-A		P-8 +	P-9 +		A/S		LW-1	—	V-11	LH-1
	B-B		P-8 +	P-9 —		A/S		LW-1		V-11	LH-1

TABLE 3
RESULTS OF AIRPLANE RESONANCE TEST
Symmetric

Mode	Frequency cps	g	Table No.	Figure No.	Predominant Modal Characteristic
1	11.2	0.040	4.0	10.0	Wing Bending
2	14.1	0.044	5.0	11.0	1st Fuselage Bending
3	21.4	0.106	6.0	12.0	2nd Fuselage Bending
4	29.4	0.124	7.0	13.0	Wing and Fan Mode
5	31.3	0.031	8.0	14.0	Horizontal Stabilizer Bending
6	36.3	0.037	9.0	15.0	Aileron Rotation
7	44.7	0.068	10.0	16.0	Wing Torsion
8	55.9	0.033	11.0	17.0	Horizontal Stabilizer Pitch & Torsion
9	67.8	0.031	12.0	18.0	Higher Wing Mode
10	90.3	0.031	13.0	19.0	Higher Horizontal Stabilizer Mode

Anti-Symmetric

Mode	Frequency cps	g	Table No.	Figure No.	Predominant Modal Characteristic
1	8.8	0.030	14.0	20.0	Vertical Stabilizer Bending
2	11.9	0.045	15.0	21.0	Horizontal Stabilizer Yaw - Vertical Stabilizer Torsion
3	14.5	0.023	16.0	22.0	Horizontal Stabilizer Roll - 1st Fuselage Bending
4	18.5	0.046	17.0	23.0	Wing Bending
5	23.0	0.019	18.0	24.0	2nd Fuselage Bending
6	25.3	0.046	19.0	25.0	Fuselage Torsion
7	34.8	0.040	20.0	26.0	Fuselage Torsion (Forebody)
8	36.8	0.058	21.0	27.0	Aileron Rotation
9	44.6	0.063	22.0	28.0	Wing Torsion
10	50.6	0.033	23.0	29.0	Rudder Bending - Fuselage Torsion
11	72.9	0.025	24.0	30.0	Horizontal Stabilizer Torsion

TABLE 4

SYMMETRIC MODE SHAPE

MODE 1

 $f = 11.2 \text{ cps } g = 0.040$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.6932	LH-1	0.3973	F-1	0.3086	LA-1	0.8559	LE-1	0.5386
LW-2	0.7749	LH-2	0.4715	F-2	0.2029	LA-2	1.0000	LE-2	0.6654
LW-3	0.8935	LH-3	0.3973	F-3	0.1403	LA-3	0.7390	LE-3	0.5386
LW-4	0.5787	LH-4	0.4715	F-4	0.0909	LA-4	0.8897	LE-4	0.6654
LW-5	0.6656	LH-5	0.3973	F-5	0.0489	LA-5	0.6329	LE-5	0.5386
LW-6	0.7447	LH-6	0.4715	F-6	0.0384	LA-6	0.7871	LE-6	0.6654
LW-7	0.4730	LH-7	0.2890	F-7	0.0677	LA-7	0.5072	LE-7	0.5386
LW-8	0.5591	LH-8	0.3973	F-8	0.1236	LA-8	0.5760	LE-8	0.6654
LW-9	0.6076	LH-9	0.4715	F-9	0.1966	LA-9	0.4384	LE-9	0.5386
LW-10	0.3762	LH-10	0.2890	F-10	0.3663	LA-10	0.5143	LE-10	0.6654
LW-11	0.4555	LH-11	0.4715	Wing Fan		LA-11	0.4008	LE-11	0.5386
LW-12	0.4821	LH-12	0.2890	Vert. Defl. + Up		LA-12	0.4753	LE-12	0.6654
LW-13	0.2901	LH-13	0.4715	Position					
LW-14	0.3568	LH-19	0.3973	LWF-1	0.1996				
LW-15	0.3707	LH-20	0.3973	LWF-2	0.2205				
LW-16	0.1985	F & A Defl. + Aft		LWF-3	0.4125				
LW-17	0.2521			LWF-4	0.1160				
LW-18	0.1198	LH-14	0.3042	Pitch Fan					
LW-19	0.1483	LH-15	0.3042	Vert. Defl. + Up					
LW-20	0.0572	LH-16	0.3042	Position					
LW-21	0.0702	LH-17	0.3042	NF-1	0.2148				
LW-22	—	LH-18	0.3042						
LW-23	—								

TABLE 5

SYMMETRIC MODE SHAPE
MODE 2

$f = 14.1 \text{ cps}$ $g = 0.044$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.6081	LH-1	0.3405	F-1	0.4412	LA-1	0.7349	LE-1	0.6023
LW-2	0.6772	LH-2	0.5395	F-2	0.1942	LA-2	1.0000	LE-2	0.5581
LW-3	0.6721	LH-3	0.3240	F-3	0.0581	LA-3	0.6442	LE-3	0.5814
LW-4	0.5002	LH-4	0.5019	F-4	0.0502	LA-4	0.9093	LE-4	0.5465
LW-5	0.5616	LH-5	0.3074	F-5	0.1093	LA-5	0.5530	LE-5	0.5395
LW-6	0.5588	LH-6	0.4698	F-6	0.1442	LA-6	0.8209	LE-6	0.5232
LW-7	0.3998	LH-7	0.2209	F-7	0.1302	LA-7	0.4277	LE-7	0.4953
LW-8	0.4500	LH-8	0.2909	F-8	0.0486	LA-8	0.6512	LE-8	0.5140
LW-9	0.4516	LH-9	0.4437	F-9	0.0565	LA-9	0.3442	LE-9	0.4465
LW-10	0.3070	LH-10	0.2209	F-10	0.2940	LA-10	0.5651	LE-10	0.4884
LW-11	0.3416	LH-11	0.4237	Wing Fan		LA-11	0.2893	LE-11	0.4326
LW-12	0.3502	LH-12	0.2209	Vert. Defl. + Up		LA-12	0.5186	LE-12	0.4884
LW-13	0.2235	LH-13	0.4072	Position					
LW-14	0.2393	LH-19	0.2837	LWF-1	0.2442				
LW-15	0.2567	LH-20	0.2837	LWF-2	0.3047				
LW-16	0.1333			LWF-3	0.0930				
LW-17	0.1521		F & A Defl. + Aft	LWF-4	0.1581				
LW-18	0.0547	LH-14	0.3209	Pitch Fan					
LW-19	0.0581	LH-15	0.3209	Vert. Defl. + Up					
LW-20	0.0102	LH-16	0.3209	Position					
LW-21	0.0249	LH-17	0.3209	NF-1	0.2791				
LW-22	—	LH-18	0.3209						
LW-23	—								

TABLE 6

SYMMETRIC MODE SHAPE

MODE 3

f = 21.4 cps g = 0.106

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.2829	LH-1	0.4153	F-1	1.0000	LA-1	0.5128	LE-1	0.7140
LW-2	0.3855	LH-2	0.6638	F-2	0.3294	LA-2	0.8201	LE-2	0.6388
LW-3	0.4825	LH-3	0.2880	F-3	0.0464	LA-3	0.4487	LE-3	0.6145
LW-4	0.1392	LH-4	0.4989	F-4	0.1034	LA-4	0.7515	LE-4	0.5504
LW-5	0.3128	LH-5	0.1939	F-5	0.1463	LA-5	0.3957	LE-5	0.4752
LW-6	0.3985	LH-6	0.3716	F-6	0.0840	LA-6	0.6874	LE-6	0.4244
LW-7	0.0177	LH-7	0.0427	F-7	0.1702	LA-7	0.3205	LE-7	0.3890
LW-8	0.2502	LH-8	0.1328	F-8	0.2144	LA-8	0.6123	LE-8	0.3382
LW-9	0.3247	LH-9	0.2818	F-9	0.2100	LA-9	0.2741	LE-9	0.3095
LW-10	0.0729	LH-10	0.0502	F-10	0.1105	LA-10	0.5614	LE-10	0.2431
LW-11	0.1976	LH-11	0.2299	Wing Fan		LA-11	0.2431	LE-11	0.2763
LW-12	0.2611	LH-12	0.0601	Vert. Defl. + Up		LA-12	0.5261	LE-12	0.1989
LW-13	0.1282	LH-13	0.2175	Position					
LW-14	0.1558	LH-19	0.0928	LWF-1	0.2011				
LW-15	0.2087	LH-20	0.0752	LWF-2	0.2454				
LW-16	0.1463	F & A Defl. + Aft		LWF-3	0.1039				
LW-17	0.1589			LWF-4	0.1083				
LW-18	0.1463	LH-14	0.3117	Pitch Fan					
LW-19	0.1238	LH-15	0.3117	Vert. Defl. + Up					
LW-20	0.1463	LH-16	0.3117	Position					
LW-21	.1039	LH-17	0.3117	NF-1	0.2277				
LW-22	—	LH-18	0.3117						
LW-23	—								

TABLE 7

SYMMETRIC MODE SHAPE

MODE 4

f = 29.4 cps g = 0.124

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.3556	LH-1	0.3659	F-1	0.0331	LA-1	0.5165	LE-1	0.6476
LW-2	0.3632	LH-2	0.4989	F-2	0.0256	LA-2	1.0000	LE-2	0.6096
LW-3	0.4368	LH-3	0.2440	F-3	0.0137	LA-3	0.4505	LE-3	0.5740
LW-4	0.1691	LH-4	0.3919	F-4	0.0141	LA-4	0.9473	LE-4	0.5247
LW-5	0.2796	LH-5	0.1231	F-5	0.0436	LA-5	0.3879	LE-5	0.4379
LW-6	0.5519	LH-6	0.3022	F-6	0.0012	LA-6	0.8945	LE-6	0.3834
LW-7	0.0357	LH-7	0.1571	F-7	0.0352	LA-7	0.3066	LE-7	0.3124
LW-8	0.2049	LH-8	0.0330	F-8	0.0725	LA-8	0.9352	LE-8	0.2745
LW-9	0.2762	LH-9	0.2300	F-9	0.0978	LA-9	0.2582	LE-9	0.1890
LW-10	0.0522	LH-10	0.1989	F-10	0.0912	LA-10	0.9044	LE-10	0.1729
LW-11	0.1391	LH-11	0.1754	Wing Fan		LA-11	0.2297	LE-11	0.1428
LW-12	0.2095	LH-12	0.2143	Position	Vert. Defl. + Up	LA-12	0.8846	LE-12	0.1448
LW-13	0.1015	LH-13	0.1319	LWF-1	0.1945				
LW-14	0.0834	LH-19	0.0264	LWF-2	0.2604				
LW-15	0.1532	LH-20	0.0571	LWF-3	0.1231				
LW-16	0.1226	F & A Defl. + Aft		LWF-4	0.1132				
LW-17	0.0973			Pitch Fan					
LW-18	0.1144								
LW-19	0.0527	LH-14	0.0833	Position	Vert. Defl. + Up				
LW-20	0.0909	LH-15	0.0833	NF-1	0.0198				
LW-21	0.0255	LH-16	0.0833						
LW-22	—	LH-17	0.0833						
LW-23	—	LH-18	0.0833						

TABLE 8

SYMMETRIC MODE SHAPE

MODE 5

 $f = 31.3 \text{ cps } g = 0.031$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	-	LH-1	0.7397	F-1	0.0174	LA-1	-	LE-1	0.8498
LW-2	-	LH-2	1.0000	F-2	0.0224	LA-2	-	LE-2	0.8653
LW-3	-	LH-3	0.4487	F-3	0.0137	LA-3	-	LE-3	0.7284
LW-4	-	LH-4	0.6784	F-4	0.0037	LA-4	-	LE-4	0.7375
LW-5	-	LH-5	0.2168	F-5	0.0186	LA-5	-	LE-5	0.5136
LW-6	-	LH-6	0.4151	F-6	0.0211	LA-6	-	LE-6	0.5144
LW-7	-	LH-7	0.0960	F-7	0.0336	LA-7	-	LE-7	0.3291
LW-8	-	LH-8	0.0438	F-8	0.0361	LA-8	-	LE-8	0.3267
LW-9	-	LH-9	0.2099	F-9	0.0236	LA-9	-	LE-9	0.1112
LW-10	-	LH-10	0.1550	F-10	0.0759	LA-10	-	LE-10	0.1143
LW-11	-	LH-11	0.0629	Wing Fan		LA-11	-	LE-11	0.0037
LW-12	-	LH-12	0.1696	Vert. Defl. + Up		LA-12	-	LE-12	0.0174
LW-13	-	LH-13	0.0383	Position					
LW-14	-	LH-19	0.0647	LWF-1	-				
LW-15	-	LH-20	0.1057	LWF-2	-				
LW-16	-	F & A Defl. + Aft		LWF-3	-				
LW-17	-			LWF-4	-				
LW-18	-			Pitch Fan					
LW-19	-			Vert. Defl. + Up					
LW-20	-	LH-14	0.2581	Position					
LW-21	-	LH-15	0.2581	NF-1	-				
LW-22	-	LH-16	0.2581						
LW-23	-	LH-17	0.2581						
		LH-18	0.2581						

TABLE 9

SYMMETRIC MODE SHAPE

MODE 6

 $f = 36.3 \text{ cps } g = 0.037$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.7443	LH-1	0.1437	F-1	0.0562	LA-1	0.7971	LE-1	0.1514
LW-2	0.7354	LH-2	0.1423	F-2	0.0134	LA-2	0.7292	LE-2	0.1896
LW-3	0.7422	LH-3	0.0967	F-3	0.0417	LA-3	0.6286	LE-3	0.1292
LW-4	0.5863	LH-4	0.0906	F-4	0.0056	LA-4	0.8333	LE-4	0.1597
LW-5	0.5986	LH-5	0.0630	F-5	0.0952	LA-5	0.4870	LE-5	0.0833
LW-6	0.5581	LH-6	0.0480	F-6	0.0979	LA-6	0.9201	LE-6	0.1028
LW-7	0.4446	LH-7	0.0514	F-7	0.0299	LA-7	0.3434	LE-7	0.0424
LW-8	0.4722	LH-8	0.0424	F-8	0.0375	LA-8	0.9201	LE-8	0.0507
LW-9	0.3969	LH-9	0.0146	F-9	0.0715	LA-9	0.2850	LE-9	0.0118
LW-10	0.3196	LH-10	0.0333	F-10	0.0368	LA-10	0.9722	LE-10	0.0153
LW-11	0.3576	LH-11	0.0096	Wing Fan		LA-11	0.2652	LE-11	0.0361
LW-12	0.2583	LH-12	0.0340	Vert. Defl. + Up		LA-12	1.0000	LE-12	0.0458
LW-13	0.2129	LH-13	0.0269	Position					
LW-14	0.2569	LH-19	0.0278	LWF-1	0.1514				
LW-15	0.1447	LH-20	0.0201	LWF-2	0.2000				
LW-16	0.1059	F & A Defl. + Aft		LWF-3	0.1146				
LW-17	0.0374			LWF-4	0.2361				
LW-18	0.0222			Pitch Fan					
LW-19	0.0375	LH-14	0.1345	Vert. Defl. + Up					
LW-20	0.0360	LH-15	0.1345	Position					
LW-21	0.0808	LH-16	0.1345	NF-1	0.0458				
LW-22	—	LH-17	0.1345						
LW-23	—	LH-18	0.1345						

TABLE 10
SYMMETRIC MODE SHAPE
MODE 7
 $f = 44.7 \text{ cps}$ $g = 0.068$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.1857	LH-1	0.1141	F-1	0.0994	LA-1	0.2286	LE-1	0.1393
LW-2	0.1335	LH-2	0.1386	F-2	0.0444	LA-2	1.0000	LE-2	0.1657
LW-3	0.1001	LH-3	0.0828	F-3	0.0818	LA-3	0.2950	LE-3	0.1250
LW-4	0.3233	LH-4	0.1082	F-4	0.0534	LA-4	0.9429	LE-4	0.1514
LW-5	0.2046	LH-5	0.0558	F-5	0.0168	LA-5	0.3486	LE-5	0.0978
LW-6	0.1944	LH-6	0.0820	F-6	0.0114	LA-6	0.8893	LE-6	0.1243
LW-7	0.3949	LH-7	0.0309	F-7	0.0071	LA-7	0.4129	LE-7	0.0736
LW-8	0.2381	LH-8	0.0331	F-8	0.0314	LA-8	0.8679	LE-8	0.1000
LW-9	0.2519	LH-9	0.0599	F-9	0.0686	LA-9	0.4450	LE-9	0.0440
LW-10	0.4121	LH-10	0.0102	F-10	0.0414	LA-10	0.8214	LE-10	0.0714
LW-11	0.2344	LH-11	0.0386	Wing Fan		LA-11	0.4500	LE-11	0.0315
LW-12	0.2809	LH-12	0.0354	Vert. Defl. + Up		LA-12	0.8021	LE-12	0.0604
LW-13	0.3874	LH-13	0.0286	Position					
LW-14	0.1944	LH-19	0.0143	LWF-1	0.0821				
LW-15	0.2846	LH-20	0.0043	LWF-2	0.0964				
LW-16	0.3192	F & A Defl. + Aft		LWF-3	0.1464				
LW-17	0.2611			LWF-4	0.0643				
LW-18	0.2293			Pitch Fan					
LW-19	0.2143	LH-14	0.0637	Vert. Defl. + Up					
LW-20	0.1366	LH-15	0.0637	Position					
LW-21	0.1496	LH-16	0.0637	NF-1	0.0586				
LW-22	—	LH-17	0.0637						
LW-23	—	LH-18	0.0637						

TABLE 11

SYMMETRIC MODE SHAPE

MODE 8

 $f = 55.9 \text{ cps}$ $g = 0.033$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.2775	LH-1	0.5141	F-1	0.0168	LA-1	0.3033	LE-1	0.2684
LW-2	0.2562	LH-2	0.2916	F-2	0.0110	LA-2	0.5990	LE-2	0.3123
LW-3	0.2360	LH-3	0.3335	F-3	0.0200	LA-3	0.2904	LE-3	0.1036
LW-4	0.2479	LH-4	0.0458	F-4	0.0226	LA-4	0.7528	LE-4	0.1058
LW-5	0.2284	LH-5	0.1878	F-5	0.0045	LA-5	0.2646	LE-5	0.1536
LW-6	0.2069	LH-6	0.1393	F-6	0.0019	LA-6	0.4754	LE-6	0.2112
LW-7	0.2181	LH-7	0.2542	F-7	0.0161	LA-7	0.2420	LE-7	0.3243
LW-8	0.2000	LH-8	0.0770	F-8	0.0277	LA-8	0.2934	LE-8	0.4136
LW-9	0.1786	LH-9	0.2635	F-9	0.0290	LA-9	0.2194	LE-9	0.4388
LW-10	0.1882	LH-10	0.1652	F-10	0.0064	LA-10	0.7983	LE-10	0.4982
LW-11	0.1710	LH-11	0.3149	Wing Fan		LA-11	0.2065	LE-11	0.3775
LW-12	0.1511	LH-12	0.1361	Vert. Defl. + Up		LA-12	1.0000	LE-12	0.4252
LW-13	0.1589	LH-13	0.3259	Position					
LW-14	0.1420	LH-19	0.0277	LWF-1	0.0458				
LW-15	0.1249	LH-20	0.0006	LWF-2	0.0536				
LW-16	0.1238	F & A Defl. + Aft		LWF-3	0.0419				
LW-17	0.0947			LWF-4	0.0426				
LW-18	0.0892			Pitch Fan					
LW-19	0.0658	LH-14	0.0439	Vert. Defl. + Up					
LW-20	0.0566	LH-15	0.0439	Position					
LW-21	0.0399	LH-16	0.0439	NF-1	0.0103				
LW-22	—	LH-17	0.0439						
LW-23	—	LH-18	0.0439						

TABLE 12

SYMMETRIC MODE SHAPE

MODE 9

 $f = 67.8 \text{ cps } g = 0.031$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	0.5975	LH-1	0.0207	F-1	0.1230	LA-1	0.8363	LE-1	0.0186
LW-2	0.6500	LH-2	0.0142	F-2	0.1013	LA-2	1.0000	LE-2	0.0308
LW-3	0.6925	LH-3	0.0176	F-3	0.0934	LA-3	0.5034	LE-3	0.0175
LW-4	0.1122	LH-4	0.0138	F-4	0.0184	LA-4	0.6842	LE-4	0.0300
LW-5	0.1697	LH-5	0.0153	F-5	0.0371	LA-5	0.2078	LE-5	0.0153
LW-6	0.2172	LH-6	0.0134	F-6	0.0196	LA-6	0.4079	LE-6	0.0286
LW-7	0.1921	LH-7	0.0234	F-7	0.0103	LA-7	0.1268	LE-7	0.0132
LW-8	0.1474	LH-8	0.0133	F-8	0.0011	LA-8	0.2303	LE-8	0.0271
LW-9	0.0895	LH-9	0.0132	F-9	0.0071	LA-9	0.2976	LE-9	0.0100
LW-10	0.3479	LH-10	0.0172	F-10	0.0203	LA-10	0.3947	LE-10	0.0249
LW-11	0.3079	LH-11	0.0128	Wing Fan		LA-11	0.3837	LE-11	0.0080
LW-12	0.2568	LH-12	0.0150	Vert. Defl. + Up		LA-12	0.4947	LE-12	0.0234
LW-13	0.3875	LH-13	0.0124	Position					
LW-14	0.3553	LH-19	0.0125	LWF-1	0.1579				
LW-15	0.3137	LH-20	0.0125	LWF-2	0.2237				
LW-16	0.3308		F & A Defl. + Aft	LWF-3	0.1237				
LW-17	0.2814			LWF-4	0.1303				
LW-18	0.2079	LH-14	—	Pitch Fan					
LW-19	0.1842	LH-15	—	Vert. Defl. + Up					
LW-20	0.0867	LH-16	—	Position					
LW-21	0.0782	LH-17	—	NF-1	0.0882				
LW-22	—	LH-18	—						
LW-23	—		—						

TABLE 13

SYMMETRIC MODE SHAPE

MODE 10

 $f = 90.3 \text{ cps } g = 0.031$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	-	LH-1	0.5083	F-1	-	LA-1	-	LE-1	0.7170
LW-2	-	LH-2	0.6187	F-2	-	LA-2	-	LE-2	1.0000
LW-3	-	LH-3	0.3619	F-3	-	LA-3	-	LE-3	0.8679
LW-4	-	LH-4	0.2383	F-4	-	LA-4	-	LE-4	0.9811
LW-5	-	LH-5	0.2419	F-5	0.0009	LA-5	-	LE-5	0.6226
LW-6	-	LH-6	0.0475	F-6	0.0206	LA-6	-	LE-6	0.7170
LW-7	-	LH-7	0.1630	F-7	0.0725	LA-7	-	LE-7	0.0943
LW-8	-	LH-8	0.1483	F-8	0.0389	LA-8	-	LE-8	0.2736
LW-9	-	LH-9	0.2394	F-9	0.1985	LA-9	-	LE-9	0.5660
LW-10	-	LH-10	0.0951	F-10	0.1225	LA-10	-	LE-10	0.5660
LW-11	-	LH-11	0.3370	Wing Fan		LA-11	-	LE-11	0.4717
LW-12	-	LH-12	0.2366	Vert. Defl. + Up		LA-12	-	LE-12	0.4717
LW-13	-	LH-13	0.3396	Position	-				
LW-14	-	LH-19	0.0660	LWF-1	-				
LW-15	-	LH-20	0.0189	LWF-2	-				
LW-16	-	F & A Defl. + Aft		LWF-3	-				
LW-17	-			LWF-4	-				
LW-18	-	LH-14	0.1142	Pitch Fan					
LW-19	-	LH-15	0.1142	Vert. Defl. + Up					
LW-20	-	LH-16	0.1142	Position	-				
LW-21	-	LH-17	0.1142	NF-1	-				
LW-22	-	LH-18	0.1142						
LW-23	-								

TABLE 14

ANTISYMMETRIC MODE SHAPE
MODE 1

$f = 8.8 \text{ cps } g = 0.030$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X103*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.2549	LH-1	0.9689	V-1	0.0525	F-11-12	0.2062	0.3891	LA-1	0.3268	LE-1	0.9844	R-1	0.6089
LW-2	0.2665	LH-2	1.0000	V-2	0.0895	F-13-14	0.1370	0.3891	LA-2	0.3502	LE-2	0.9844	R-2	0.6089
LW-3	0.2588	LH-3	0.7782	V-3	0.0946	F-15-16	0.0428	0.3891	LA-3	0.3016	LE-3	0.8949	R-3	0.4786
LW-4	0.2140	LH-4	0.8171	V-4	0.1304	F-17-18	0.0000	0.3891	LA-4	0.3230	LE-4	0.8949	R-4	0.4786
LW-5	0.2245	LH-5	0.5992	V-5	0.1907	F-19-20	0.0673	0.1249	LA-5	0.2743	LE-5	0.7198	R-5	0.3696
LW-6	0.2241	LH-6	0.6304	V-6	0.2218	F-21-22	0.0860	0.6257	LA-6	0.2957	LE-6	0.7198	R-6	0.3696
LW-7	0.1790	LH-7	0.4280	V-7	0.2996	F-23-24	0.0860	1.0245	LA-7	0.2374	LE-7	0.5331	R-7	0.3619
LW-8	0.1907	LH-8	0.4163	V-8	0.3307	F-25-30	0.0778	1.8482	LA-8	0.2588	LE-8	0.5331	R-8	0.3152
LW-9	0.1899	LH-9	0.4356	V-9	0.4144	F-26-31	0.0603	2.6264	LA-9	0.2101	LE-9	0.2529	R-9	0.2646
LW-10	0.1498	LH-10	0.2335	V-10	0.4552	F-27-32	0.0268	3.4630	LA-10	0.2335	LE-10	0.2529	R-10	0.2257
LW-11	0.1623	LH-11	0.2412	V-11	0.5447	Wing Fan			LA-11	0.1907	LE-11	0.0778	R-11	0.1732
LW-12	0.1556	LH-12	0.2335	V-12	0.6420				LA-12	0.2179	LE-12	0.0778	R-12	0.1401
LW-13	0.1214	LH-13	0.1704	V-13	0.7043	Position								
LW-14	0.1374	LH-14	0.1704	V-14	0.1704									
LW-15	0.1237	LH-15	0.8482	V-15	0.2685									
LW-16	0.0918	LH-16	0.9728	V-16	0.3813									
LW-17	0.0895	LH-17	0.8755	V-17	0.5097	LWF-1								
LW-18	0.0626	LH-18	0.8755	V-18	0.0778									
LW-19	0.0595	LH-19	0.8755	F-25	0.0778	LWF-2								
LW-20	0.0401	LH-20	0.8755	F-26	0.0595									
LW-21	0.0381	LH-21	0.3716	F-27	0.0245	LWF-3								
LW-22	-	LH-22	0.5377											
LW-23	-	LH-23	0.7039			LWF-4								
		LH-24	0.8700											
F & A Defl. + Aft														
LW-24	0.2288													
LW-25	0.1821													
LW-26	0.1362													
LW-27	0.0825													

TABLE 15

**ANTISYMMETRIC MODE SHAPE
MODE 2**

$f = 11.9 \text{ cps } g = 0.045$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)				Aileron		Elevator		Rudder										
Position	Vert. Defl. + Up	Vert. Defl. + Up		Lat. Defl. + Left		Position	Lat. Defl. + Left	Ang. Defl. X10 ³ *	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left										
		Position	Lat. Defl. + Left	Position	Lat. Defl. + Left										Position	Lat. Defl. + Left	Position	Lat. Defl. + Left						
LW-1	0.0465	LH-1	0.5833	V-1	0.0239	F-11-12	0.0321	0.0482	LA-1	0.0478	LE-1	0.5355	R-1	0.0363										
LW-2	0.0451	LH-2	0.5833	V-2	0.0038	F-13-14	0.0208	0.0350	LA-2	0.0602	LE-2	0.4877	R-2	0.0478										
LW-3	0.0478	LH-3	0.4720	V-3	0.0249	F-15-16	0.0054	0.0073	LA-3	0.0411	LE-3	0.4838	R-3	0.0048										
LW-4	0.0392	LH-4	0.4720	V-4	0.0430	F-17-18	0.0023	0.0371	LA-4	0.0545	LE-4	0.4399	R-4	0.0191										
LW-5	0.0373	LH-5	0.3605	V-5	0.0105	F-19-20	0.0084	0.0302	LA-5	0.0354	LE-5	0.3787	R-5	0.0191										
LW-6	0.0382	LH-6	0.3605	V-6	0.0669	F-21-22	0.0046	0.0316	LA-6	0.0478	LE-6	0.3481	R-6	0.0000										
LW-7	0.0300	LH-7	0.2492	V-7	0.0086	F-23-24	0.0080	0.0074	LA-7	0.0289	LE-7	0.2754	R-7	0.0287										
LW-8	0.0300	LH-8	0.2492	V-8	0.0918	F-25-30	0.0235	0.1100	LA-8	0.0325	LE-8	0.2544	R-8	0.0105										
LW-9	0.0306	LH-9	0.2492	V-9	0.0277	F-26-31	0.0352	0.1893	LA-9	0.0229	LE-9	0.1300	R-9	0.0478										
LW-10	0.0229	LH-10	0.1377	V-10	0.1243	F-27-32	0.0495	0.3060	LA-10	0.0287	LE-10	0.1147	R-10	0.0268										
LW-11	0.0239	LH-11	0.1377	V-11	0.0516	Wing Fan Vert. Defl. + Up			LA-11	0.0218	LE-11	0.0344	R-11	0.0612										
LW-12	0.0239	LH-12	0.1377	V-12	0.0708				LA-12	0.0249	LE-12	0.0268	R-12	0.0402										
LW-13	0.0184	Lat. Defl. + Left		V-13	0.1071	Position LWF-1 LWF-2 LWF-3 LWF-4 0.0880 0.1186 0.0382 0.0421																		
LW-14	0.0199	+ Left		V-14	0.0115																			
LW-15	0.0191	0.5068		V-15	0.0287																			
LW-16	0.0109	0.0765		V-16	0.0459																			
LW-17	0.0134	0.3155		V-17	0.0688																			
LW-18	0.0057	F & A Defl. + Aft		F-25	0.0235																			
LW-19	0.0086	0.2360		F-26	0.0352																			
LW-20	0.0029	0.4270		F-27	0.0493																			
LW-21	0.0048	0.6181		1.0000																				
LW-22	-	0.8091																						
LW-23	-	1.0000																						
F & A Defl. + Aft																								
LW-24	0.0404																							
LW-25	0.0321																							
LW-26	0.0241																							
LW-27	0.0145																							

* Left Wing Down

TABLE 17

**ANTISYMMETRIC MODE SHAPE
MODE 4**

$f = 18.5 \text{ cps } g = 0.046$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10 ³	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.6114	LH-1	0.4456	V-1	0.0145	F-11-12	0.1548	4.6197	LA-1	0.7130	LE-1	0.4508	R-1	0.0249
LW-2	0.6114	LH-2	0.4829	V-2	0.0124	F-13-14	0.1024	3.6062	LA-2	1.0000	LE-2	0.4684	R-2	0.0383
LW-3	0.6777	LH-3	0.3378	V-3	0.0477	F-15-16	0.0398	3.6197	LA-3	0.6176	LE-3	0.4000	R-3	0.0062
LW-4	0.4269	LH-4	0.3689	V-4	0.0352	F-17-18	0.0247	3.9026	LA-4	0.9119	LE-4	0.4166	R-4	0.0135
LW-5	0.4684	LH-5	0.2404	V-5	0.0187	F-19-20	0.0332	3.2974	LA-5	0.5285	LE-5	0.3067	R-5	0.0332
LW-6	0.5513	LH-6	0.2632	V-6	0.0497	F-21-22	0.0452	3.0508	LA-6	0.8290	LE-6	0.3171	R-6	0.0104
LW-7	0.2653	LH-7	0.1492	V-7	0.0083	F-23-24	0.0622	2.8062	LA-7	0.4104	LE-7	0.2176	R-7	0.0394
LW-8	0.3420	LH-8	0.1513	V-8	0.0580	F-25-30	0.0794	2.6943	LA-8	0.6591	LE-8	0.2228	R-8	0.0218
LW-9	0.4332	LH-9	0.1679	V-9	0.0280	F-26-31	0.0920	2.7606	LA-9	0.3347	LE-9	0.0933	R-9	0.0591
LW-10	0.1306	LH-10	0.0808	V-10	0.0642	F-27-32	0.1096	3.0466	LA-10	0.5907	LE-10	0.0995	R-10	0.0435
LW-11	0.2342	LH-11	0.0767	V-11	0.0104	Wing Fan			LA-11	0.2839	LE-11	0.0228	R-11	0.0788
LW-12	0.3275	LH-19	0.0767	V-12	0.0415	Vert. Defl. + Up			LA-12	0.5492	LE-12	0.0311	R-12	0.0642
LW-13	0.0311	Lat. Defl. + Up	+ Up	V-13	0.0508	Position + Up			LWF-1	0.2073	LWF-2	0.2902	LWF-3	0.1762
LW-14	0.1575			V-14	0.0124									
LW-15	0.2332			V-15	0.0301									
LW-16	0.0539			V-16	0.0425									
LW-17	0.1347	LH-12	0.0199	V-17	0.0518	F & A Defl. + Aft			LWF-4	0.1492	LH-14	0.0166	LH-15	0.0290
LW-18	0.0953	LH-20	0.0174	F-25	0.0794									
LW-19	0.0518	F & A Defl. + Aft	+ Aft	F-26	0.0914	+ Aft								
LW-20	0.0933			F-27	0.1076									
LW-21	0.0207													
LW-22	—													
LW-23	—	F & A Defl. + Aft												
LW-24	0.0151													
LW-25	0.0095													
LW-26	0.0064													
LW-27	0.0048													

• Left Wing Down

TABLE 18

ANTISYMMETRIC MODE SHAPE
MODE 5

$f = 23.0 \text{ cps } g = 0.019$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Vert. Defl. + Up		Lat. Defl. + Left		Position	Lat. Defl. Ang. Defl. + Left N103°		Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
		Position												
LW-1	0.4138	LH-1	0.6034	V-1	0.0665	F-11-12	0.2241	3.0764	LA-1	0.6256	LE-1	0.7241	R-1	0.2414
LW-2	0.4828	LH-2	0.7167	V-2	0.0788	F-13-14	0.0665	6.2483	LA-2	1.0000	LE-2	0.6700	R-2	0.2414
LW-3	0.5222	LH-3	0.4557	V-3	0.1576	F-15-16	0.0596	3.9847	LA-3	0.5788	LE-3	0.6305	R-3	0.1182
LW-4	0.2833	LH-4	0.5320	V-4	0.0123	F-17-18	0.0577	3.3768	LA-4	0.9542	LE-4	0.5764	R-4	0.1182
LW-5	0.3768	LH-5	0.3261	V-5	0.0788	F-19-20	0.0483	2.6424	LA-5	0.5320	LE-5	0.4631	R-5	0.0197
LW-6	0.4557	LH-6	0.3695	V-6	0.0493	F-21-22	0.0296	1.7734	LA-6	0.9089	LE-6	0.4039	R-6	0.0197
LW-7	0.1601	LH-7	0.1823	V-7	0.0049	F-23-24	0.1300	0.2138	LA-7	0.4695	LE-7	0.3153	R-7	0.0246
LW-8	0.2808	LH-8	0.2084	V-8	0.1232	F-25-30	0.2222	1.7631	LA-8	0.7709	LE-8	0.2364	R-8	0.0246
LW-9	0.3926	LH-9	0.2315	V-9	0.0985	F-26-31	0.2611	3.1527	LA-9	0.4286	LE-9	0.1330	R-9	0.0985
LW-10	0.0394	LH-10	0.0813	V-10	0.1970	F-27-32	0.2675	4.5872	LA-10	0.7325	LE-10	0.0172	R-10	0.0985
LW-11	0.1897	LH-11	0.1123	V-11	0.2069	Wing Fan			LA-11	0.4015	LE-11	0.0345	R-11	0.1675
LW-12	0.3300	LH-12	0.1034	V-12	0.3005	Vert. Defl. + Up			LA-12	0.7079	LE-12	0.1084	R-12	0.1675
LW-13	0.0640	Lat. Defl. + Left		V-13	0.3547	Position								
LW-14	0.1084			V-14	0.0123	LWF-1			0.1527					
LW-15	0.2685			V-15	0.0542	LWF-2			0.2512					
LW-16	0.1256			V-16	0.1305	LWF-3			0.0576					
LW-17	0.2044			V-17	0.2118	LWF-4			0.0552					
LW-18	0.1232			F-25	0.2222									
LW-19	0.1429	F & A Defl. + Aft		F-26	0.2601									
LW-20	0.0936	+ Aft		F-27	0.2640									
LW-21	0.0887	LH-14	0.0690											
LW-22	-	LH-15	0.1246											
LW-23	-	LH-16	0.1803											
		LH-17	0.2360											
		LH-18	0.2916											
	F & A Defl. + Aft													
LW-24	0.2739													
LW-25	0.2182													
LW-26	0.1635													
LW-27	0.0990													

* Left Wing Down

TABLE 19
ANTISYMMETRIC MODE SHAPE
MODE 6
 $f = 25.3 \text{ cps}$ $g = 0.046$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (W/L 100)				Aileron		Elevator		Rudder		
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10 ³ *	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left
LW-1	0.3823	LH-1	0.4248	V-1	0.0619	F-11-12	0.0655	6.9942	LA-1	0.5591	LE-1	0.5310	R-1	0.1540		
LW-2	0.4313	LH-2	0.4903	V-2	0.0602	F-12-14	0.0159	3.4280	LA-2	1.0000	LE-2	0.5133	R-2	0.1027		
LW-3	0.4704	LH-3	0.3133	V-3	0.0841	F-13-16	0.0301	2.2271	LA-3	0.4956	LE-3	0.4513	R-3	0.0735		
LW-4	0.2628	LH-4	0.3575	V-4	0.0363	F-17-18	0.0441	2.0018	LA-4	0.9375	LE-4	0.4336	R-4	0.0310		
LW-5	0.3274	LH-5	0.2088	V-5	0.0478	F-19-20	0.0354	1.7342	LA-5	0.4398	LE-5	0.3186	R-5	0.0071		
LW-6	0.3850	LH-6	0.2425	V-6	0.0071	F-21-22	0.0000	1.2389	LA-6	0.9230	LE-6	0.3080	R-6	0.0230		
LW-7	0.1717	LH-7	0.1026	V-7	0.0088	F-23-24	0.0379	0.4779	LA-7	0.3761	LE-7	0.2195	R-7	0.0230		
LW-8	0.2411	LH-8	0.1124	V-8	0.0319	F-25-30	0.1177	0.3540	LA-8	0.7292	LE-8	0.2088	R-8	0.0487		
LW-9	0.3150	LH-9	0.1389	V-9	0.0377	F-26-31	0.1416	1.0619	LA-9	0.3363	LE-9	0.0973	R-9	0.0761		
LW-10	0.1027	LH-10	0.0336	V-10	0.0796	F-27-32	0.1480	1.9802	LA-10	0.7027	LE-10	0.0938	R-10	0.0920		
LW-11	0.1681	LH-11	0.0584	V-11	0.0814	Wing Fan			LA-11	0.3097	LE-11	0.0310	R-11	0.1257		
LW-12	0.2566	LH-19	0.0354	V-12	0.1212	Vert. Defl. + Up			LA-12	0.6576	LE-12	0.0265	R-12	0.1310		
LW-13	0.0487	Lat. Defl. + Left		V-13	0.1558	Position										
LW-14	0.0970			V-14	0.0319	LW F-1	0.2124									
LW-15	0.2018			V-15	0.0000	LW F-2	0.3115									
LW-16	0.0106			V-16	0.0354	LW F-3	0.0814									
LW-17	0.1416			V-17	0.0814	LW F-4	0.1257									
LW-18	0.0593	F & A Defl. + Aft		F-25	0.1177											
LW-19	0.0850			F-26	0.1414											
LW-20	0.0726			F-27	0.1465											
LW-21	0.0487	LH-14	0.0381													
LW-22	-	LH-15	0.0690													
LW-23	-	LH-16	0.0998													
		LH-17	0.1306													
		LH-18	0.1614													
F & A Defl. + Aft																
LW-24	0.0857															
LW-25	0.0683															
LW-26	0.0512															
LW-27	0.0310															

* Left Wing Down

TABLE 20

ANTISYMMETRIC MODE SHAPE
MODE 7

$f = 34.8 \text{ cps}$ $g = 0.040$

Wing	Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)		Aileron		Elevator		Rudder	
	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Ang. Defl. N103*	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position
LW-1	0.6408	LH-1	0.0363	V-1	0.0352	0.0317	0.4648	LA-1	0.0423	LE-1	0.0845	R-1
LW-2	0.5915	LH-2	0.0423	V-2	0.0282	0.0000	0.5930	LA-2	0.0592	LE-2	0.0704	R-2
LW-3	0.5676	LH-3	0.0338	V-3	0.0282	0.0352	0.2676	LA-3	0.0296	LE-3	0.0423	R-3
LW-4	0.5535	LH-4	0.0225	V-4	0.0352	0.1026	0.7310	LA-4	0.0465	LE-4	0.0169	R-4
LW-5	0.4563	LH-5	0.0163	V-5	0.0282	0.0056	0.0831	LA-5	0.0127	LE-5	0.0190	R-5
LW-6	0.3268	LH-6	0.0127	V-6	0.0310	0.0190	0.5648	LA-6	0.0296	LE-6	0.0085	R-6
LW-7	0.4746	LH-7	0.0423	V-7	0.0239	0.0120	0.1408	LA-7	0.0042	LE-7	0.0169	R-7
LW-8	0.3380	LH-8	0.0113	V-8	0.0254	0.0084	0.7746	LA-8	0.0183	LE-8	0.0141	R-8
LW-9	0.1296	LH-9	0.0056	V-9	0.0085	0.0169	0.3662	LA-9	0.0028	LE-9	0.0141	R-9
LW-10	0.4028	LH-10	0.0225	V-10	0.0211	0.0197	0.2535	LA-10	0.0056	LE-10	0.0239	R-10
LW-11	0.2324	LH-11	0.0028	V-11	0.0197	Wing Fan Vert. Defl. + Up	0.2676	LA-11	0.0014	LE-11	0.0113	R-11
LW-12	0.0239	LH-12	0.0056	V-12	0.0335		1.0000	LA-12	0.0014	LE-12	0.0282	R-12
LW-13	0.3296	LH-13	0.0479	V-13	0.0352							
LW-14	0.1577	LH-14	0.0063	V-14	0.0254							
LW-15	0.1268	LH-15	0.0114	V-15	0.0225	Position						
LW-16	0.2479	LH-16	0.0165	V-16	0.0127	LWF-1						
LW-17	0.1958	LH-17	0.0217	V-17	0.0042	LWF-2						
LW-18	0.1746	LH-18	0.0084	F-25	0.0084	LWF-3						
LW-19	0.2056	LH-19	0.0268	F-26	0.0170	LWF-4						
LW-20	0.1127	LH-20		F-27	0.0196							
LW-21	0.1620	LH-21										
LW-22	—	LH-22										
LW-23	—	LH-23										
F & A Defl. + Aft		LH-14	0.0063									
LW-24	0.0944	LH-15	0.0114									
LW-25	0.0752	LH-16	0.0165									
LW-26	0.0562	LH-17	0.0217									
LW-27	0.0341	LH-18	0.0268									

* Left Wing Down

TABLE 21

**ANTISYMMETRIC MODE SHAPE
MODE 8**

$f = 36.8 \text{ cps } g = 0.058$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X10 ³	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.4602	LH-1	0.0722	V-1	0.0266	F-11-12	0.0030	3.9549	LA-1	0.2481	LE-1	0.1624	R-1	0.0301
LW-2	0.4211	LH-2	0.1496	V-2	0.0239	F-13-14	0.0075	2.5865	LA-2	0.7669	LE-2	0.1609	R-2	0.0221
LW-3	0.3489	LH-3	0.0481	V-3	0.0244	F-15-16	0.0038	1.4436	LA-3	0.1504	LE-3	0.1429	R-3	0.0030
LW-4	0.4421	LH-4	0.1119	V-4	0.0203	F-17-18	0.0153	1.0226	LA-4	0.8481	LE-4	0.1368	R-4	0.0015
LW-5	0.3263	LH-5	0.0286	V-5	0.0211	F-19-20	0.0234	0.6015	LA-5	0.0586	LE-5	0.1068	R-5	0.0150
LW-6	0.2241	LH-6	0.0785	V-6	0.0081	F-21-22	0.0195	0.4511	LA-6	0.9233	LE-6	0.0977	R-6	0.0134
LW-7	0.4015	LH-7	0.0180	V-7	0.0147	F-23-24	0.0111	0.4211	LA-7	0.0526	LE-7	0.0782	R-7	0.0211
LW-8	0.2481	LH-8	0.0120	V-8	0.0095	F-25-30	0.0000	0.4060	LA-8	0.8662	LE-8	0.0677	R-8	0.0195
LW-9	0.1158	LH-9	0.0492	V-9	0.0038	F-26-31	0.0099	0.3759	LA-9	0.1278	LE-9	0.0376	R-9	0.0316
LW-10	0.3459	LH-10	0.0271	V-10	0.0331	F-27-32	0.0218	0.3759	LA-10	0.9459	LE-10	0.0286	R-10	0.0286
LW-11	0.1955	LH-11	0.0241	V-11	0.0105	Wing Fan			LA-11	0.1729	LE-11	0.0150	R-11	0.0361
LW-12	0.0278	LH-12	0.0015	V-12	0.0233	Vert. Defl. + Up			LA-12	1.0000	LE-12	0.0060	R-12	0.0331
LW-13	0.2767	Lat. Defl. + Left		V-13	0.0611	Position		LWF-1	0.0331					
LW-14	0.1534			V-14	0.0195			LWF-2	0.1008					
LW-15	0.0406			V-15	0.0090			LWF-3	0.1128					
LW-16	0.1910			V-16	0.0060			LWF-4	0.0526					
LW-17	0.0992			V-17	0.0263									
LW-18	0.1128	F & A Defl. + Aft		F-25	0									
LW-19	0.1248			F-26	0.0099									
LW-20	0.0496			F-27	0.0221									
LW-21	0.1158													
LW-22	-													
LW-23	-													
F & A Defl. + Aft														
LW-24	0.0502													
LW-25	0.0400													
LW-26	0.0299													
LW-27	0.0182													

* Left Wing Down

TABLE 22

ANTISYMMETRIC MODE SHAPE

MODE 9

 $f = 44.6 \text{ cps } g = 0.063$

Wing		Horiz. Stab. **		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator **		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Ang. Defl. X103*	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.0796	LH-1	0.0135	V-1	0.0152	F-11-12	0.0256	4.0136	LA-1	0.0401	LE-1	0.0094	R-1	0.0110
LW-2	0.0980	LH-2	0.0122	V-2	0.0151	F-13-14	0.0041	2.3129	LA-2	1.0000	LE-2	0.0141	R-2	0.0116
LW-3	0.1099	LH-3	0.0109	V-3	0.0161	F-15-16	0.0109	1.0204	LA-3	0.1020	LE-3	0.0073	R-3	0.0224
LW-4	0.1619	LH-4	0.0097	V-4	0.0173	F-17-18	0.0269	0.6803	LA-4	0.8844	LE-4	0.0080	R-4	0.0238
LW-5	0.0680	LH-5	0.0088	V-5	0.0152	F-19-20	0.0086	0.4762	LA-5	0.1401	LE-5	0.0118	R-5	0.0279
LW-6	0.1544	LH-6	0.0080	V-6	0.0174	F-21-22	0.0041	0.4762	LA-6	0.8503	LE-6	0.0067	R-6	0.0291
LW-7	0.2102	LH-7	0.0126	V-7	0.0136	F-23-24	0.0105	0.4762	LA-7	0.1633	LE-7	0.0170	R-7	0.0288
LW-8	0.0299	LH-8	0.0076	V-8	0.0152	F-25-30	0.0069	0.4422	LA-8	0.5510	LE-8	0.0107	R-8	0.0296
LW-9	0.1823	LH-9	0.0068	V-9	0.0111	F-26-31	0.0017	0.3401	LA-9	0.1721	LE-9	0.0168	R-9	0.0272
LW-10	0.2299	LH-10	0.0126	V-10	0.0110	F-27-32	0.0177	0.0680	LA-10	0.5660	LE-10	0.0129	R-10	0.0269
LW-11	0.0156	LH-11	0.0061	V-11	0.0075	Wing Fan			LA-11	0.1735	LE-11	0.0096	R-11	0.0218
LW-12	0.1952	LH-19	0.0068	V-12	0.0049	Vert. Defl.			LA-12	0.5850	LE-12	0.0061	R-12	0.0199
LW-13	0.2269	Lat. Defl. + Left		V-13	0.0084	Position		+ Up						
LW-14	0.0673			V-14	0.0154	LWF-1		0.0354						
LW-15	0.1952			V-15	0.0135	LWF-2		0.0292						
LW-16	0.1996			V-16	0.0094	LWF-3		0.1007						
LW-17	0.1796			V-17	0.0033	LWF-4		0.0184						
LW-18	0.1565	F & A Defl.		F-25	0.0069									
LW-19	0.1503	+ Aft		F-26	0.0018									
LW-20	0.1068	LH-14	0.0143	F-27	0.0178									
LW-21	0.1122	LH-15	0.0136											
LW-22	-	LH-16	0.0129											
LW-23	-	LH-17	0.0122											
F & A Defl.		LH-18	0.0116											
+ Aft		RH-18	0.0190											
LW-24	0.0258													
LW-25	0.0206													
LW-26	0.0154													
LW-27	0.0093													

* Left Wing Down

** Symmetric Response (essentially Elevator Bending with Response at higher frequency)

TABLE 23
ANTISYMMETRIC MODE SHAPE

Mode 10

$f = 50.6 \text{ cps}$ $g = 0.033$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (N.L. 100)			Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Up	Position	Lat. Defl. + Left	Ang. Defl. X10 ³ .	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	0.0406	LH-1	0.1190	V-1	0.1611	F-11-12	0.0241	1.4977	LA-1	0.0215	LE-1	0.0817	R-1	0.4717
LW-2	0.0464	LH-2	0.0697	V-2	0.0610	F-13-14	0.0080	0.2730	LA-2	0.0464	LE-2	0.1023	R-2	0.4572
LW-3	0.0381	LH-3	0.1154	V-3	0.1451	F-15-16	0.0061	0.5155	LA-3	0.0174	LE-3	0.0871	R-3	0.8926
LW-4	0.0132	LH-4	0.0813	V-4	0.1582	F-17-18	0.0232	0.4139	LA-4	0.0552	LE-4	0.1103	R-4	0.8708
LW-5	0.0370	LH-5	0.1016	V-5	0.1451	F-19-20	0.0813	2.6392	LA-5	0.0123	LE-5	0.0929	R-5	1.0000
LW-6	0.0522	LH-6	0.0827	V-6	0.1654	F-21-22	0.1248	3.4833	LA-6	0.0631	LE-6	0.1161	R-6	0.9826
LW-7	0.0051	LH-7	0.0936	V-7	0.1596	F-23-24	0.1379	3.5254	LA-7	0.0058	LE-7	0.0856	R-7	0.9564
LW-8	0.0283	LH-8	0.0813	V-8	0.1742	F-25-30	0.1045	3.1640	LA-8	0.0726	LE-8	0.1045	R-8	0.9434
LW-9	0.0450	LH-9	0.0726	V-9	0.2496	F-26-31	0.0363	2.6415	LA-9	0.0029	LE-9	0.0544	R-9	0.7141
LW-10	0.0203	LH-10	0.0552	V-10	0.1858	F-27-32	0.1559	1.8142	LA-10	0.0784	LE-10	0.0639	R-10	0.7083
LW-11	0.0210	LH-11	0.0552	V-11	0.3019	Wing Fan			LA-11	0.0014	LE-11	0.0247	R-11	0.2758
LW-12	0.0377	LH-12	0.0493	V-12	0.2685	Vert. Defl. + Up			LA-12	0.0827	LE-12	0.0283	R-12	0.2758
LW-13	0.0276	Lat. Defl. : Left		V-13	0.0435									
LW-14	0.0145	: Left		V-14	0.0552									
LW-15	0.0319	: Left		V-15	0.0435									
LW-16	0.0290	: Left		V-16	0.0268									
LW-17	0.0247	: Left		V-17	0.0203									
LW-18	0.0247	: Left		F-25	0.1045									
LW-19	0.0174	F & A Defl. + Aft		F-26	0.0369									
LW-20	0.0189	: Aft		F-27	0.1546									
LW-21	0.0116	: Aft												
LW-22	-	: Aft												
LW-23	-	: Aft												
F & A Defl. + Aft														
LW-24	-													
LW-25	-													
LW-26	-													
LW-27	-													

TABLE 24

ANTISYMMETRIC MODE SHAPE

MODE 11

 $f = 72.9 \text{ cps}$ $g = 0.025$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)			Aileron		Elevator		Rudder		
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Lat. Defl. + Left	Ang. Defl. N103°	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left		
LW-1	-	LH-1	1.0000	V-1	-	-	-	F-11-12	-	LA-1	-	LE-1	0.6163	R-1	0.0163
LW-2	-	LH-2	0.3243	V-2	-	-	-	F-13-14	-	LA-2	-	LE-2	0.4084	R-2	0.0074
LW-3	-	LH-3	0.6082	V-3	-	-	-	F-15-16	-	LA-3	-	LE-3	0.8292	R-3	0.0129
LW-4	-	LH-4	0.4611	V-4	-	-	-	F-17-18	-	LA-4	-	LE-4	0.6287	R-4	0.0124
LW-5	-	LH-5	0.3126	V-5	-	-	-	F-19-20	-	LA-5	-	LE-5	0.9530	R-5	0.0262
LW-6	-	LH-6	0.5027	V-6	-	-	-	F-21-22	-	LA-6	-	LE-6	0.6510	R-6	0.0228
LW-7	-	LH-7	0.3490	V-7	-	-	-	F-23-24	-	LA-7	-	LE-7	0.7871	R-7	0.0282
LW-8	-	LH-8	0.1134	V-8	-	-	-	F-25-30	-	LA-8	-	LE-8	0.5248	R-8	0.0248
LW-9	-	LH-9	0.4488	V-9	-	-	-	F-26-31	-	LA-9	-	LE-9	0.4156	R-9	0.0228
LW-10	-	LH-10	0.1656	V-10	-	-	-	F-27-32	-	LA-10	-	LE-10	0.2030	R-10	0.0208
LW-11	-	LH-11	0.2995	V-11	-	-	-		-	LA-11	-	LE-11	0.1485	R-11	0.0079
LW-12	-	LH-12	0.0104	V-12	-	-	-	Wing Fan	-	LA-12	-	LE-12	0.0545	R-12	0.0032
LW-13	-			V-13	-	-	-	Position	Vert. Defl.						
LW-14	-		Lat. Defl. + Left	V-14	-	-	-	LWF-1	+ Up						
LW-15	-	LH-12	0.0396	V-15	-	-	-	LWF-2	-						
LW-16	-	LH-13	0.0223	V-16	-	-	-	LWF-3	-						
LW-17	-	LH-20	0.0148	V-17	-	-	-	LWF-4	-						
LW-18	-		F & A Defl. + Aft	F-25	-	-	-								
LW-19	-			F-26	-	-	-								
LW-20	-	LH-14	-	F-27	-	-	-								
LW-21	-	LH-15	-												
LW-22	-	LH-16	-												
LW-23	-	LH-17	-												
		LH-18	-												
		F & A Defl. + Aft													
LW-24	-														
LW-25	-														
LW-26	-														
LW-27	-														

• Left Wing Down

TABLE 25

**PRIMARY CONTROL SYSTEMS RESONANCES
CTOL MODE**

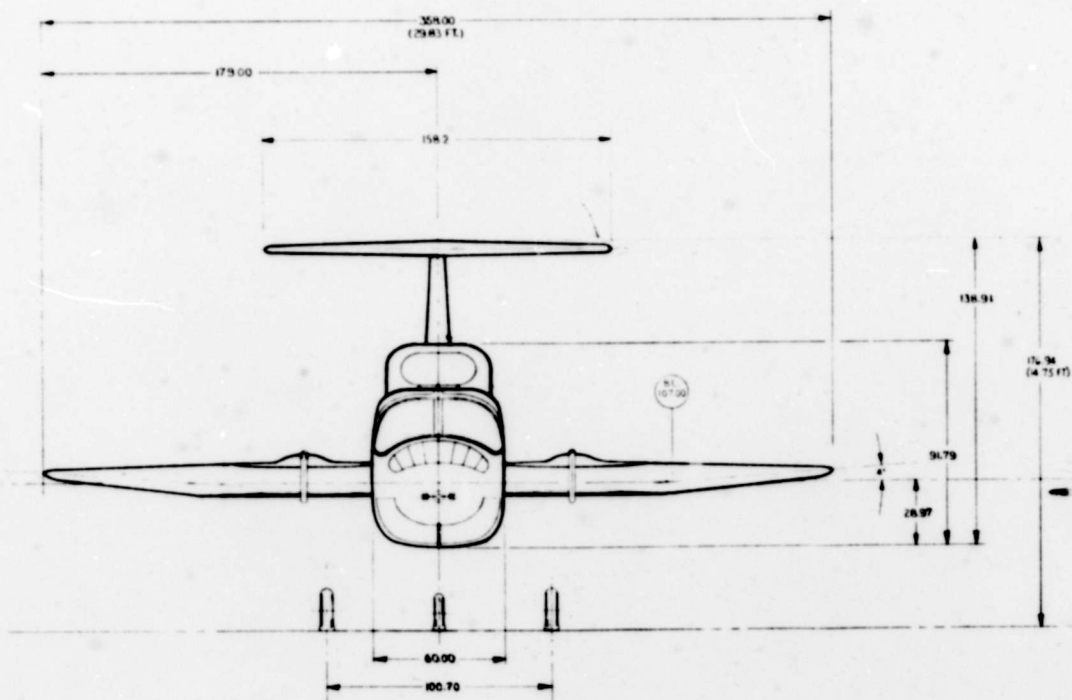
Component	Degrees of Freedom	Sense of Excitation	Location of Excitation	Frequency cps	Damping (g)	Remarks
Aileron System	Aileron Rotation Flight Tab Rotation Stick Rotation	Antisymmetric	Stick (A-CP)	48.6 92.3	— —	Inconclusive
	Aileron Rotation Flight Tab Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	42.1 —	— —	
	Aileron Rotation Flight Tab Rotation	Symmetric	Aileron (LA-12) (RA-12)	43.6 79.1	— —	
	Aileron Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	42.9*	—	
	Aileron Rotation	Antisymmetric	Aileron (LA-12) (RA-12)	40.5*	—	Single Hydraulic System
	Aileron Rotation	Symmetric	Aileron (LA-12) (RA-12)	42.9*	—	
	Aileron Rotation	Symmetric	Aileron (LA-12) (RA-12)	40.2*	—	Single Hydraulic System
	Flight Tab Rotation	Antisymmetric	Tab (LAT-4) (RAT-4)	—	—	Inconclusive
	Flight Tab Rotation	Symmetric	Tab (LAT-4) (RAT-4)	—	—	Inconclusive
Elevator System	Horizontal Tail Rotation Elevator Rotation Stick Rotation	Symmetric	Stick (E-CP)	— 18.3	— —	Inconclusive
	Horizontal Tail Rotation	Symmetric	Elevator (LE-10) (RE-10)	— 24.4	— —	Inconclusive
	Elevator Rotation	Antisymmetric	Elevator (LE-10) (RE-10)	—	—	Inconclusive
Rudder System	Rudder Rotation Trim Tab Rotation Pedal Rotation	—	Pedal (R-CP)	17.0 —	— —	Inconclusive
	Rudder Rotation Trim Tab Rotation	—	Rudder (R-9)	— —	— —	Inconclusive Inconclusive
	Rudder Rotation	—	Rudder (R-11)	7.3	—	Inconclusive
	Trim Tab Rotation	—	Tab (RT-3)	—	—	

*Average of Left and Right Ailerons

TABLE 26

MISCELLANEOUS COMPONENT RESONANCES

COMPONENT	POSITION	POINT OF EXCITATION	EXCITATION FORCE POUNDS	ROTATIONAL FREQUENCY cps	DAMPING (g)
Pitch Fan Doors	Forward Stick (43°)	NFD-2	10	17.9	.203
Pitch Fan Doors	Neutral Stick (77°)	NFD-2	10	12.8	.101
Pitch Fan Doors	Aft Stick (92°)	NFD-2	10	13.9	.270
Flaps	Streamwise (0°)	FL-2	5	56.3	High
Flaps	Fully Extended (45°)	FL-2	5	42.7	.082
Wing Fan Door	Fully Open (90°)	WFD-5	5	19.4	High
Thrust Spoilers		Between TS-1 and TS-2	3	70.9	.077



A

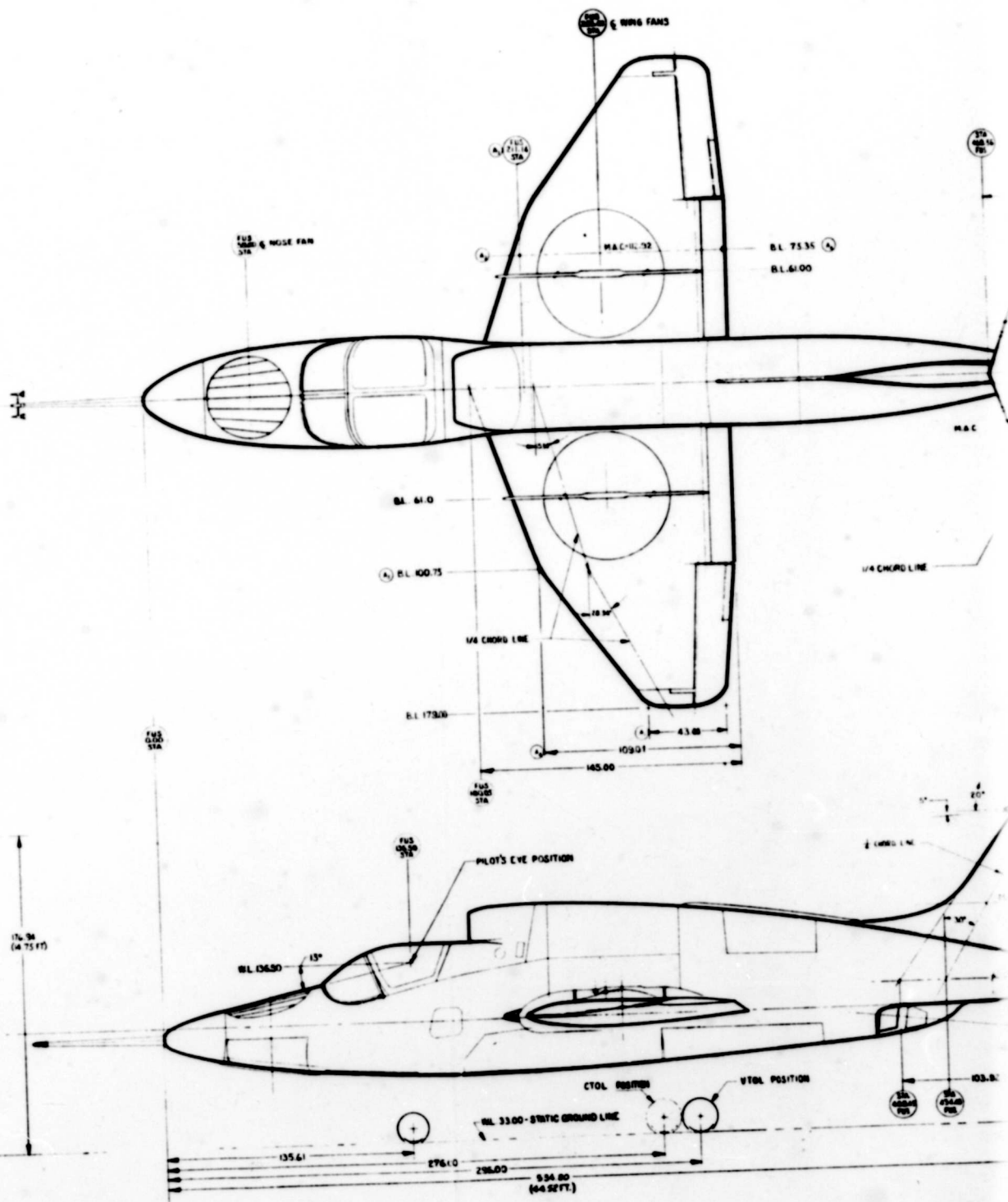


Figure 1 General Arrangement

B



49

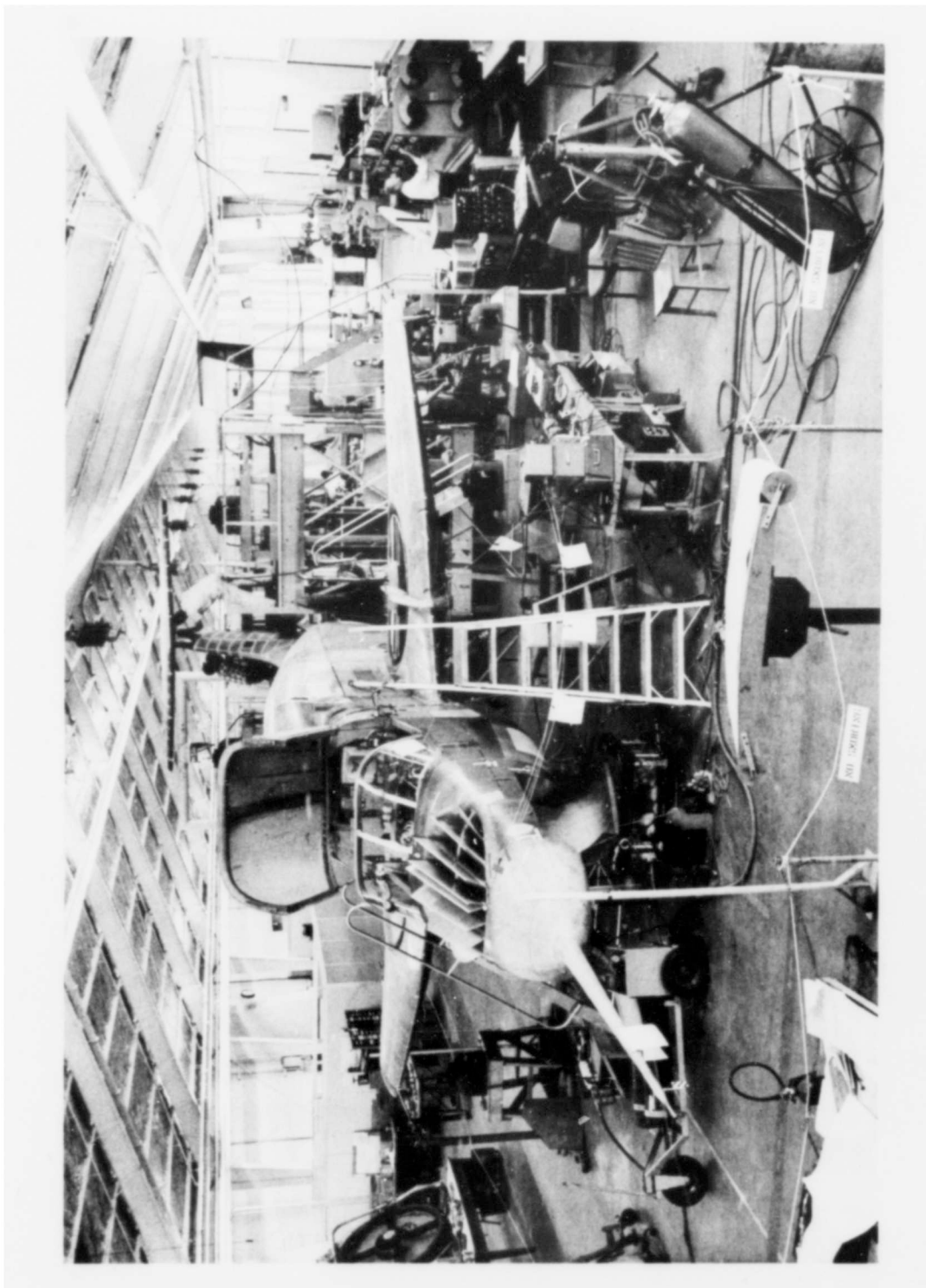


Figure 2 Airplane in Test Position Undergoing Final Test Preparation

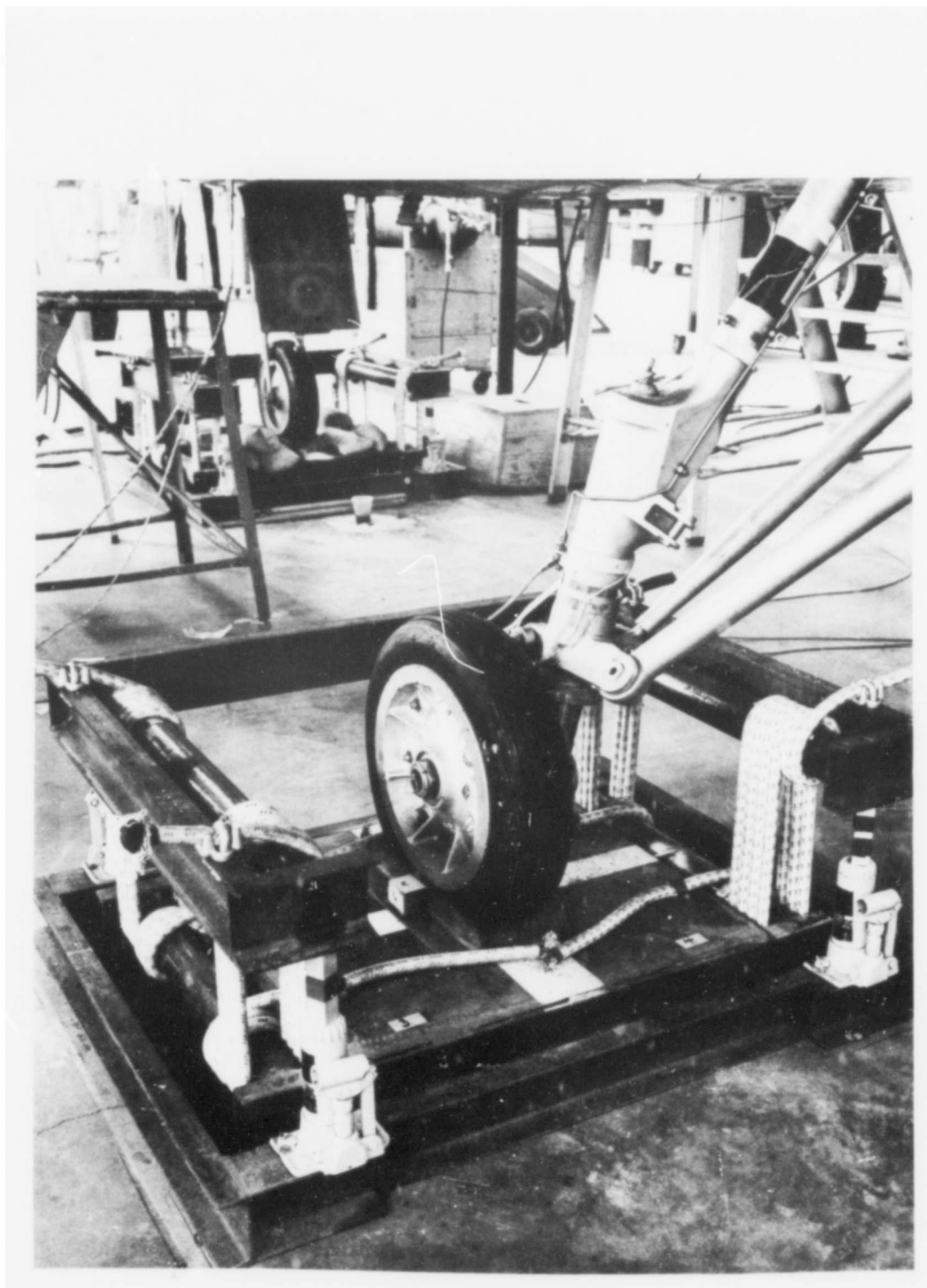


Figure 3 Details of Airplane Suspension System

□ PRIMARY

□ PRIMARY
▲ SECONDARY

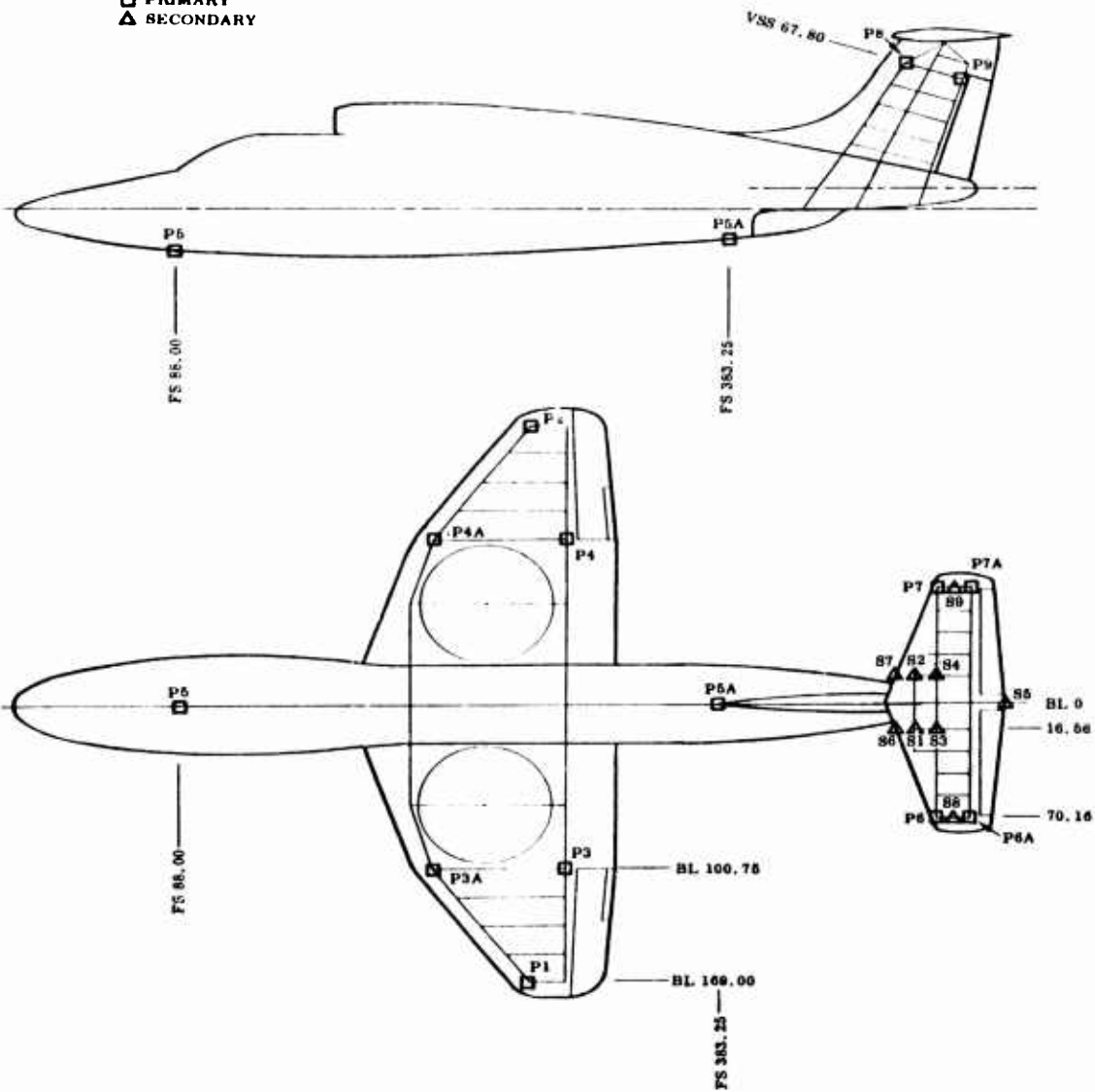


Figure 4. Shaker Locations

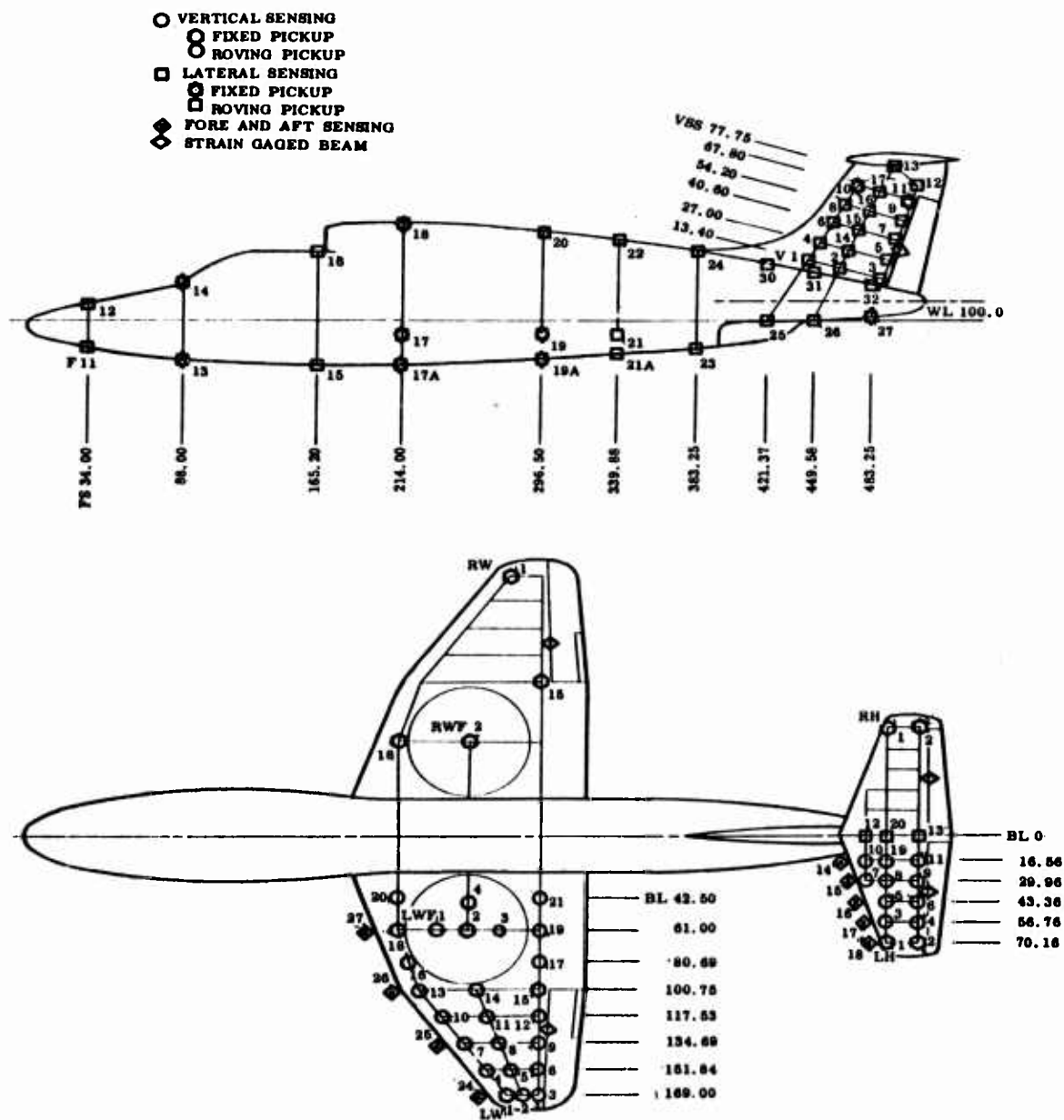


Figure 6 Antisymmetric Pickup Locations

⊙ VERTICAL SENSING
 ⊙ ROVING PICKUP

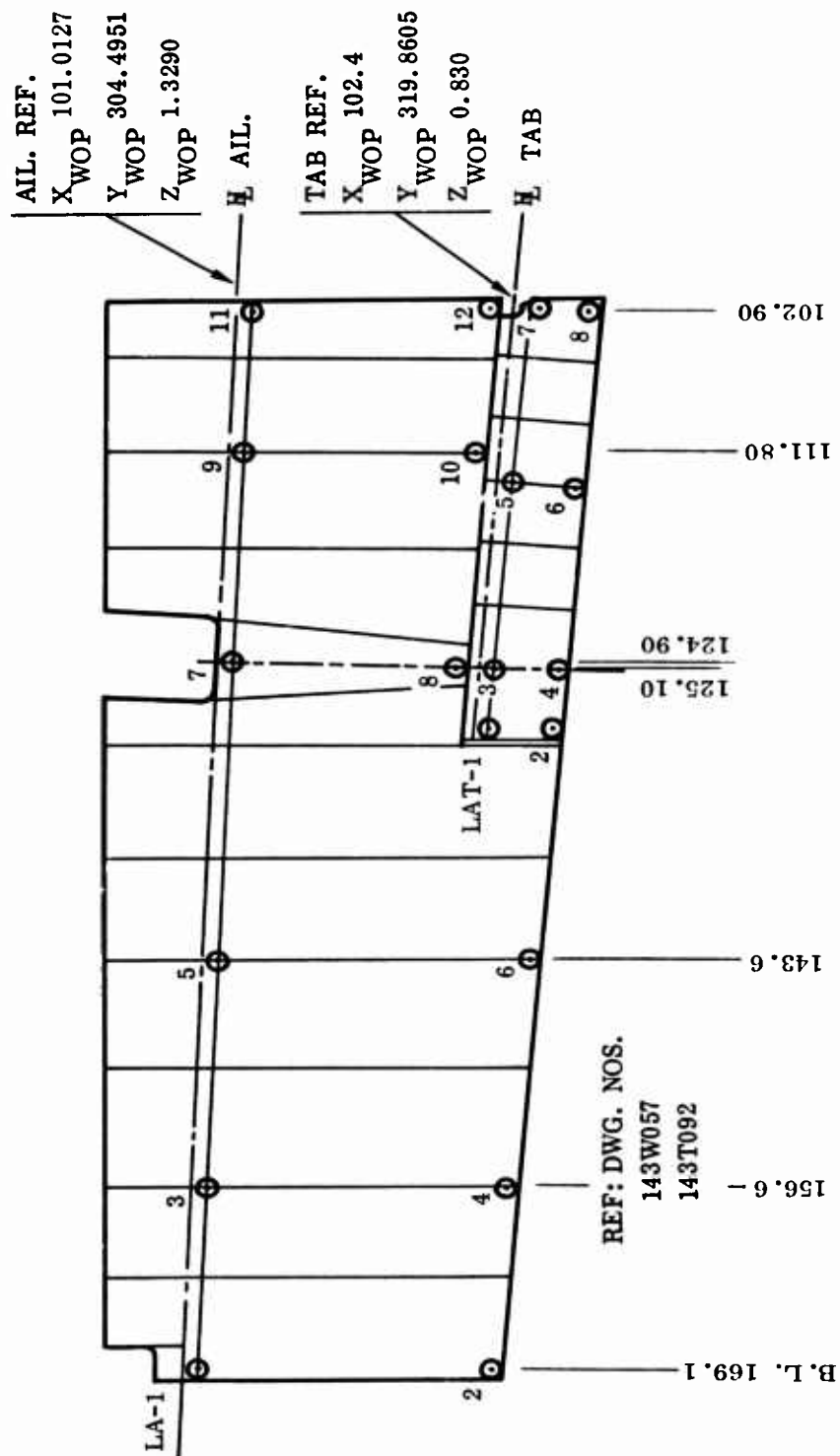


Figure 7. Control Surface Pickup Locations - Aileron and Aileron Tab

⊙ VERTICAL SENSING
 ⊙ ROVING PICKUP

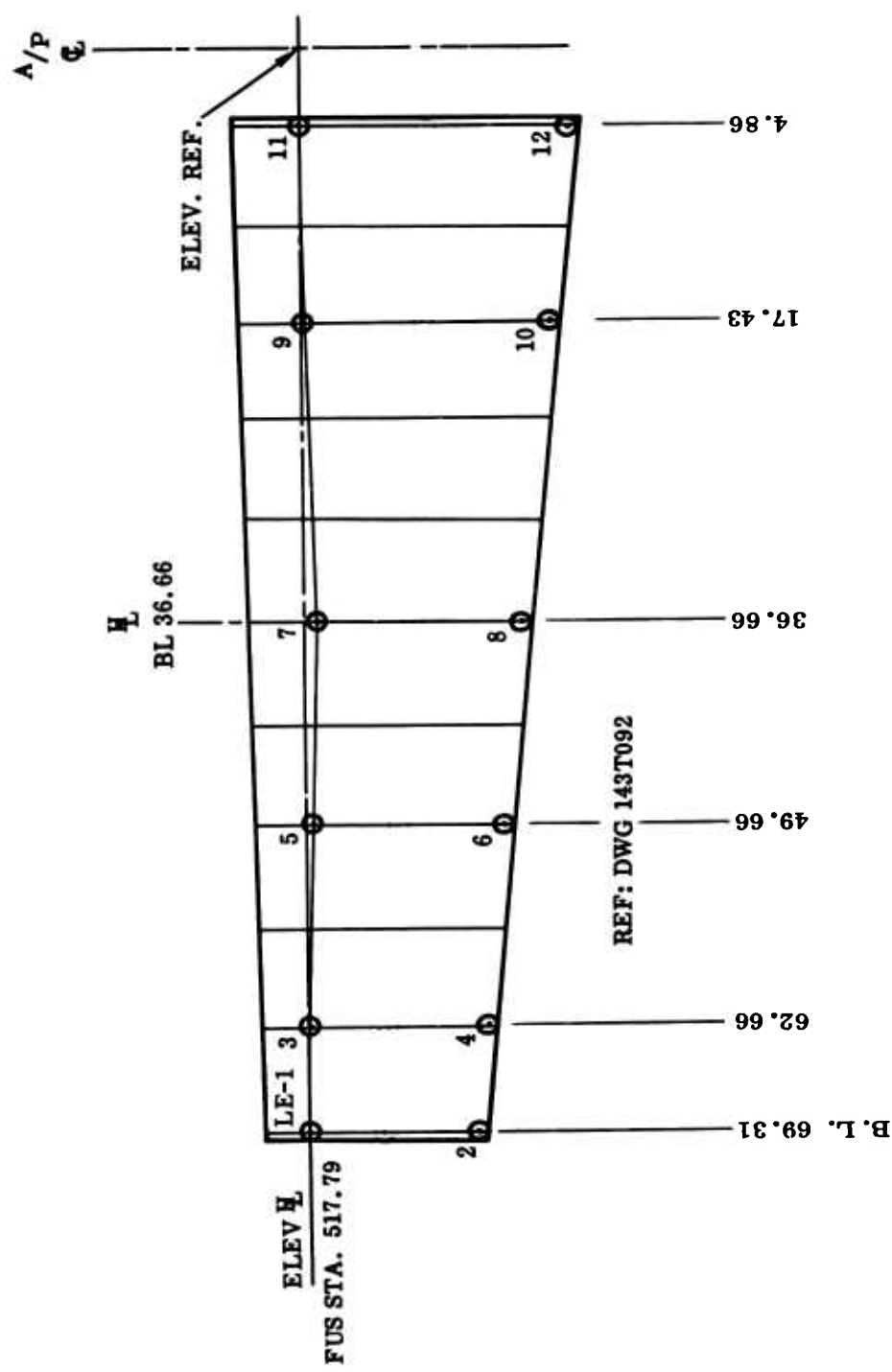
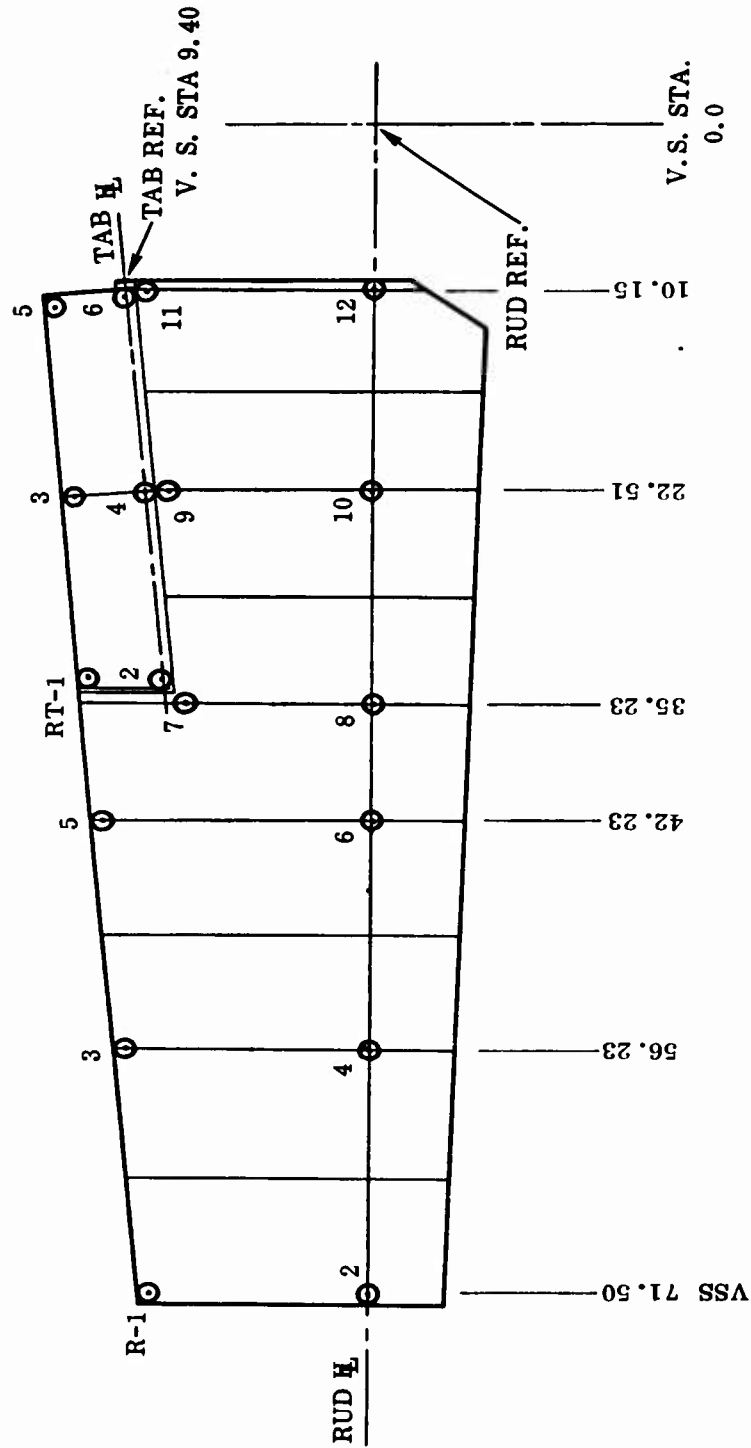


Figure 8. Control Surface Pickup Locations - Elevator

⊙ LATERAL SENSING

⊙ ROVING PICKUP



REF: DWG 143T050 AND 143T053

Figure 9 Control Surface Pickup Locations - Rudder and Rudder Tab

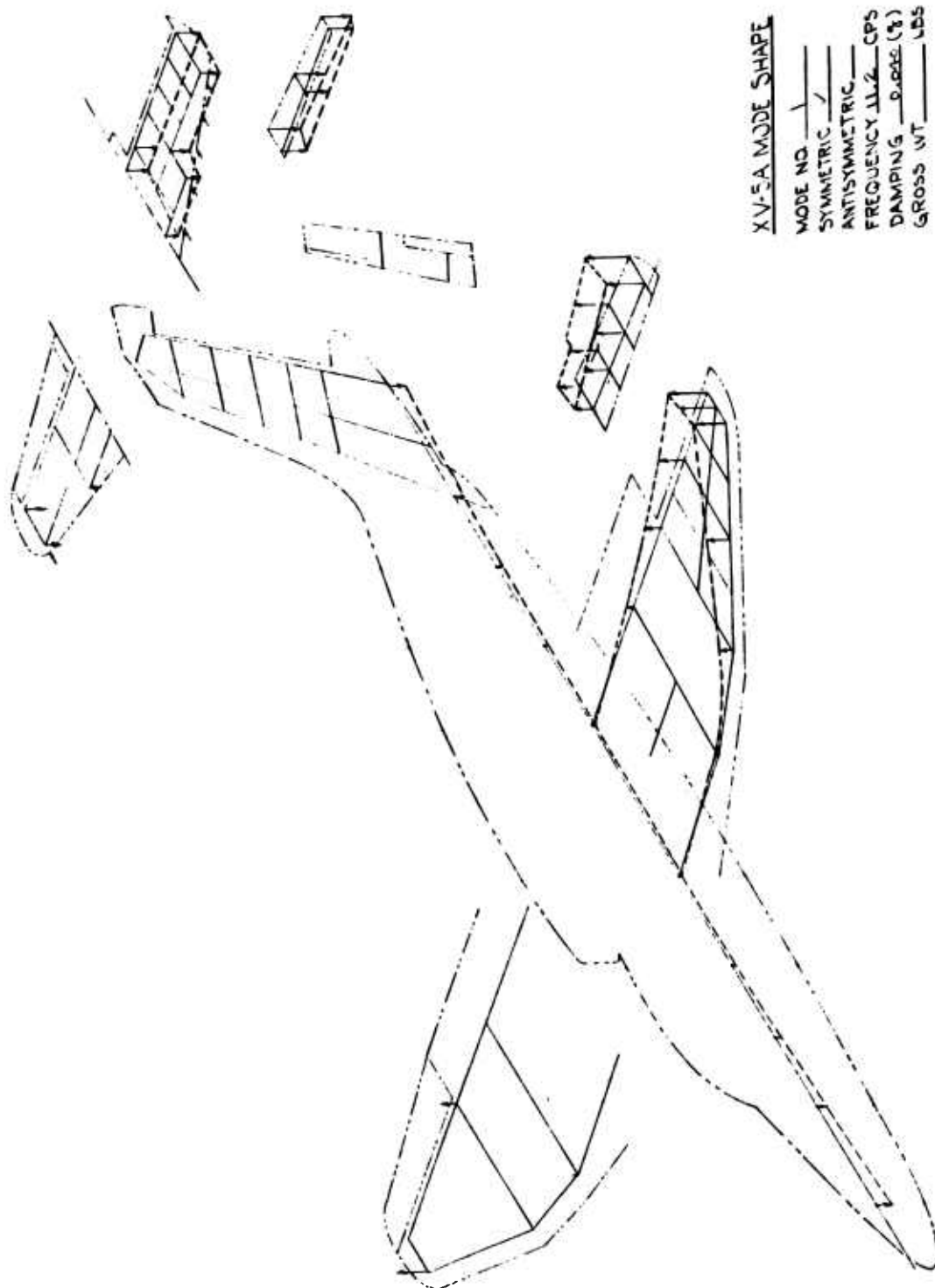
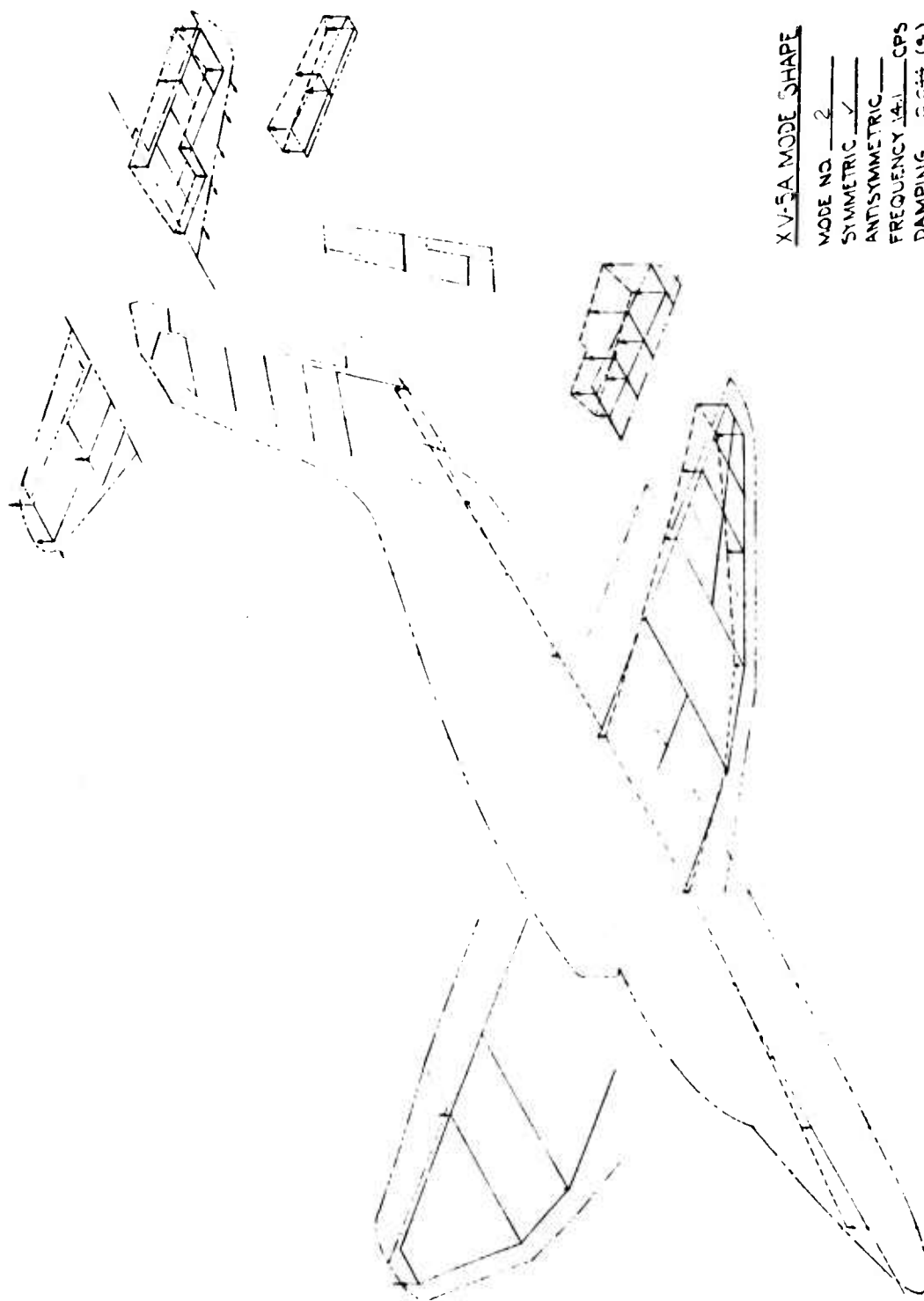


Figure 10 XV-5A Mode Shape - Mode No. 1



XV-5A MODE SHAPE

MODE NO. 2
 SYMMETRIC ✓
 ANTISYMMETRIC —
 FREQUENCY 14.1 CPS
 DAMPING 0.044 (8)
 GROSS WT — LBS

Figure 11 XV-5A Mode Shape - Mode No. 2

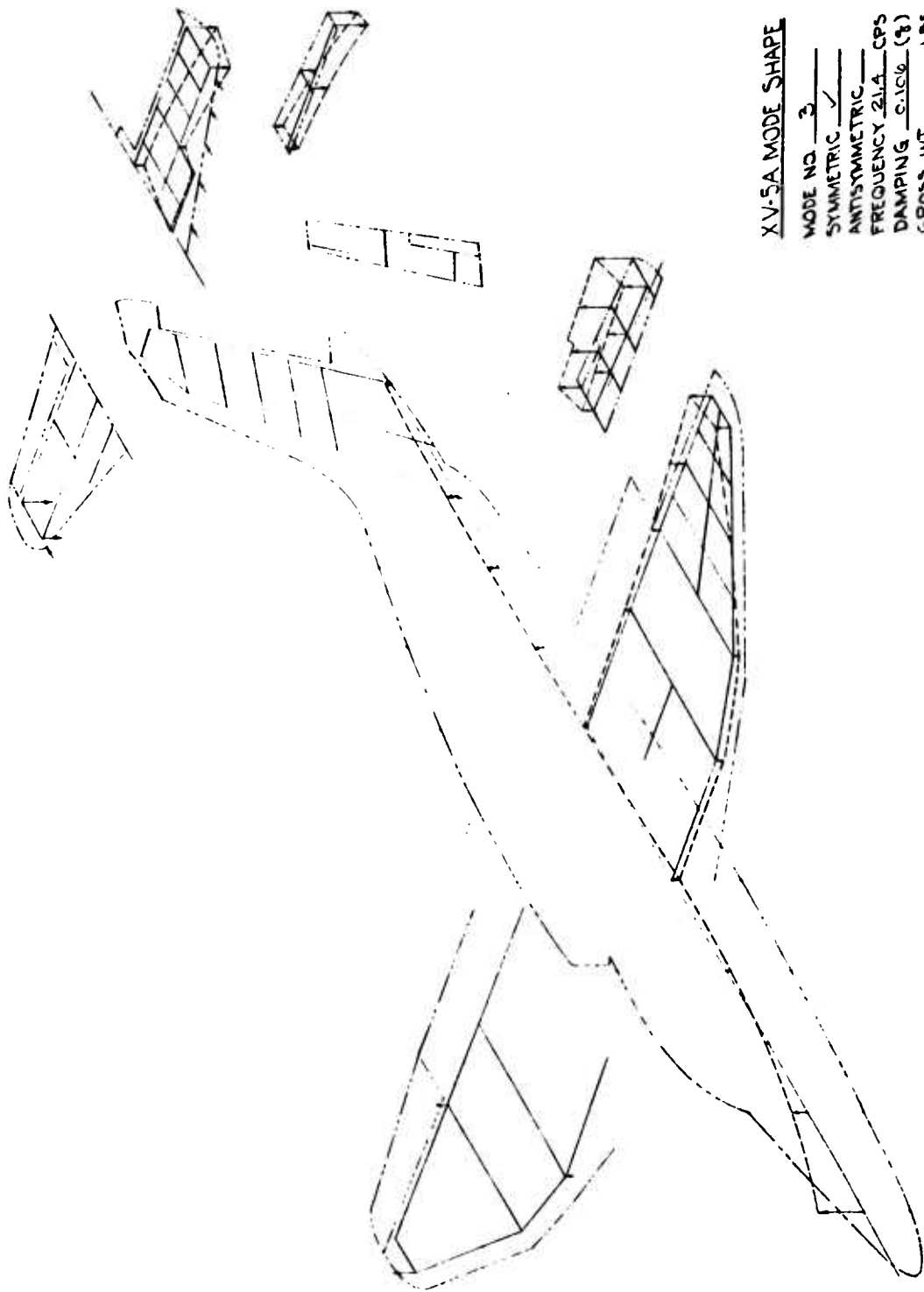


Figure 12 XV-5A Mode Shape - Mode No. 3

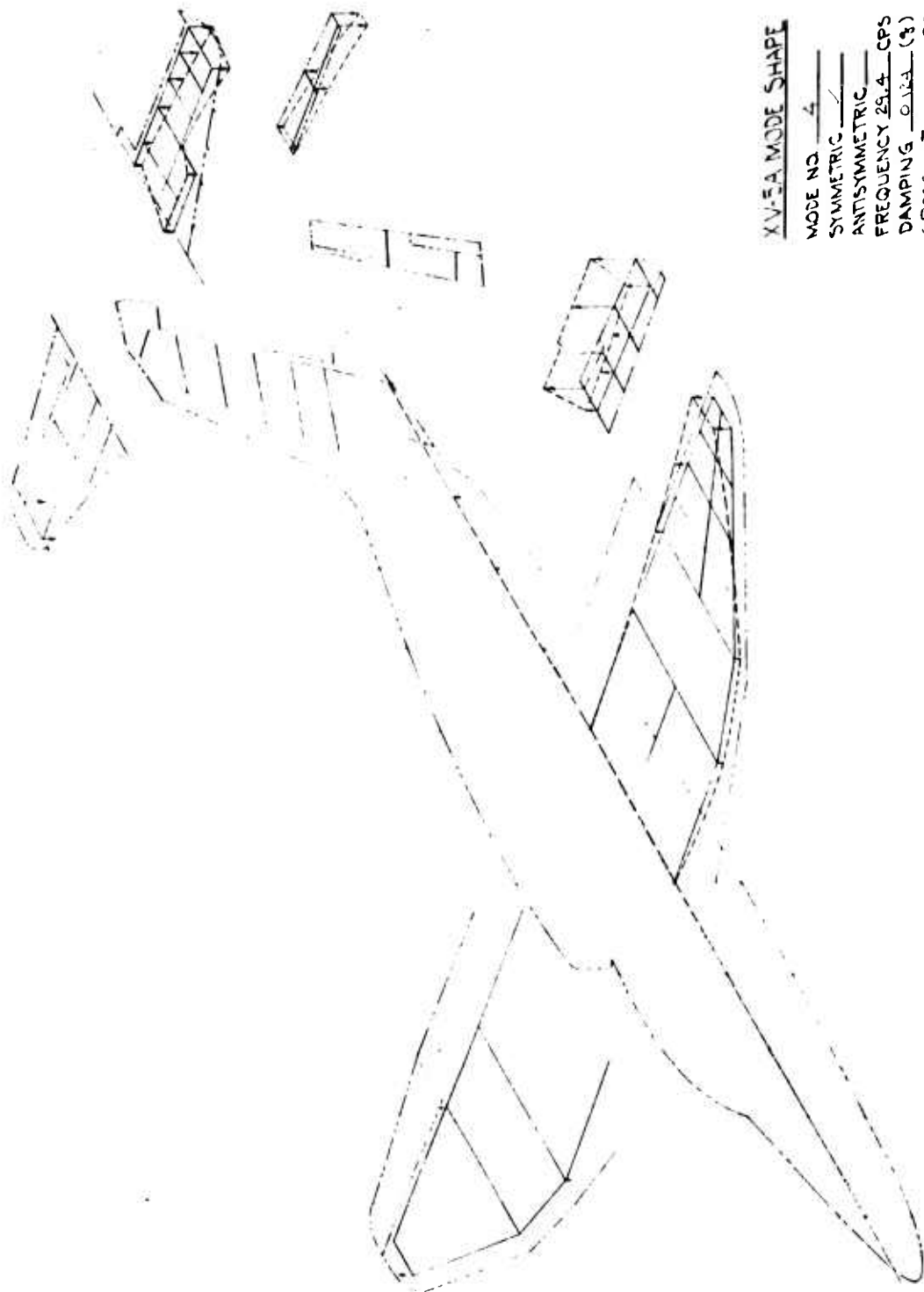


Figure 13 XV-5A Mode Shape - Mode No. 4

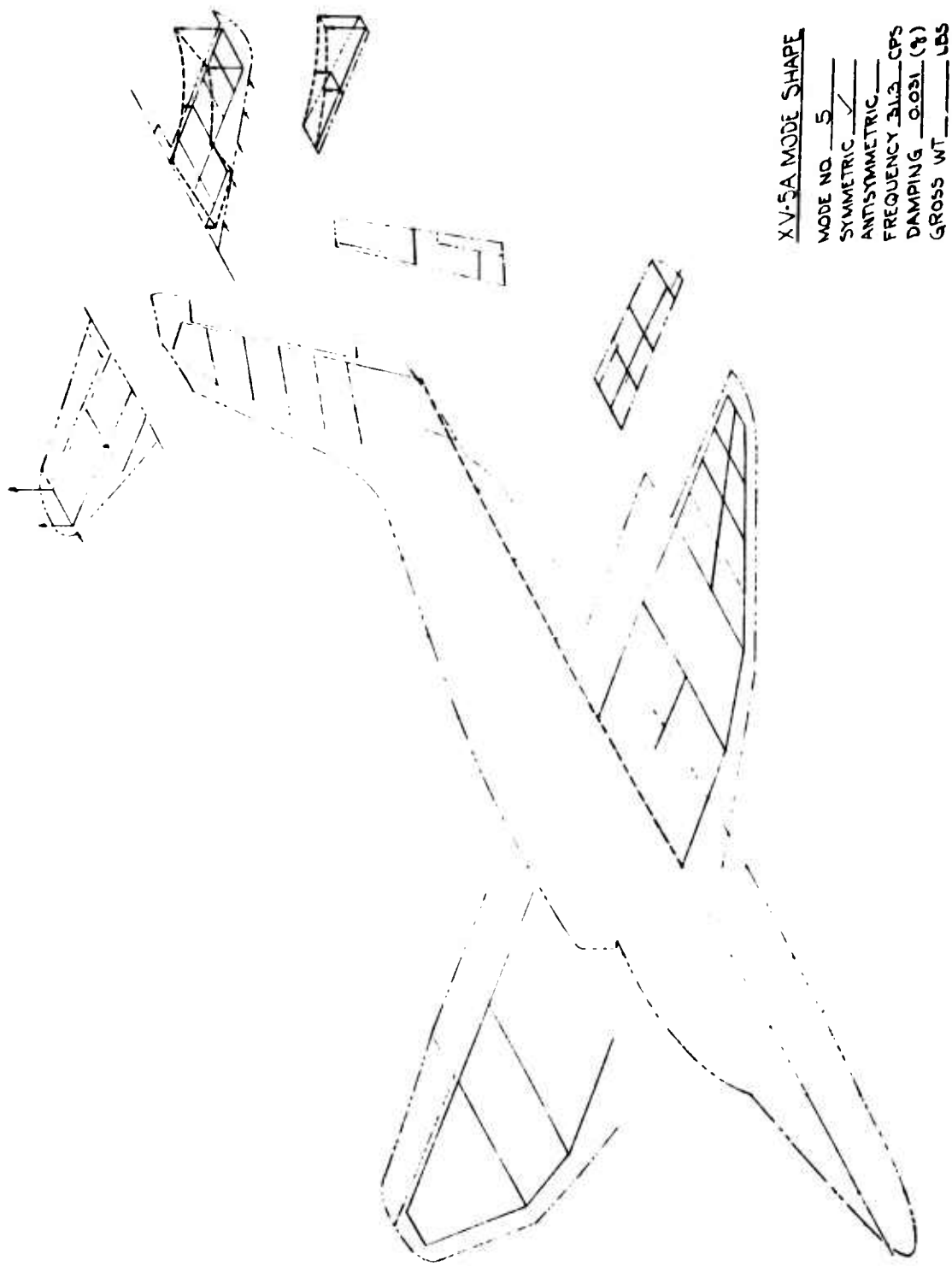
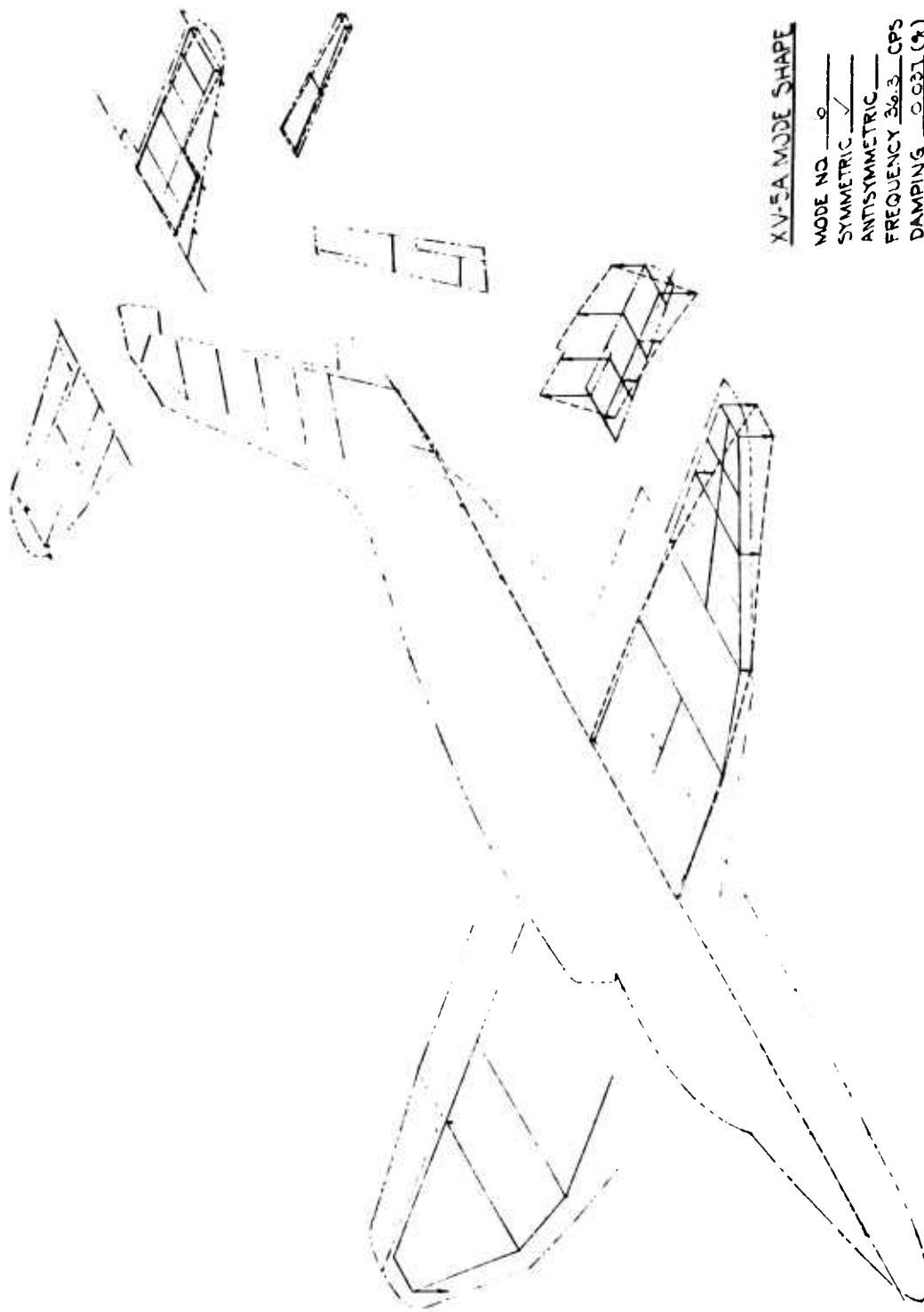


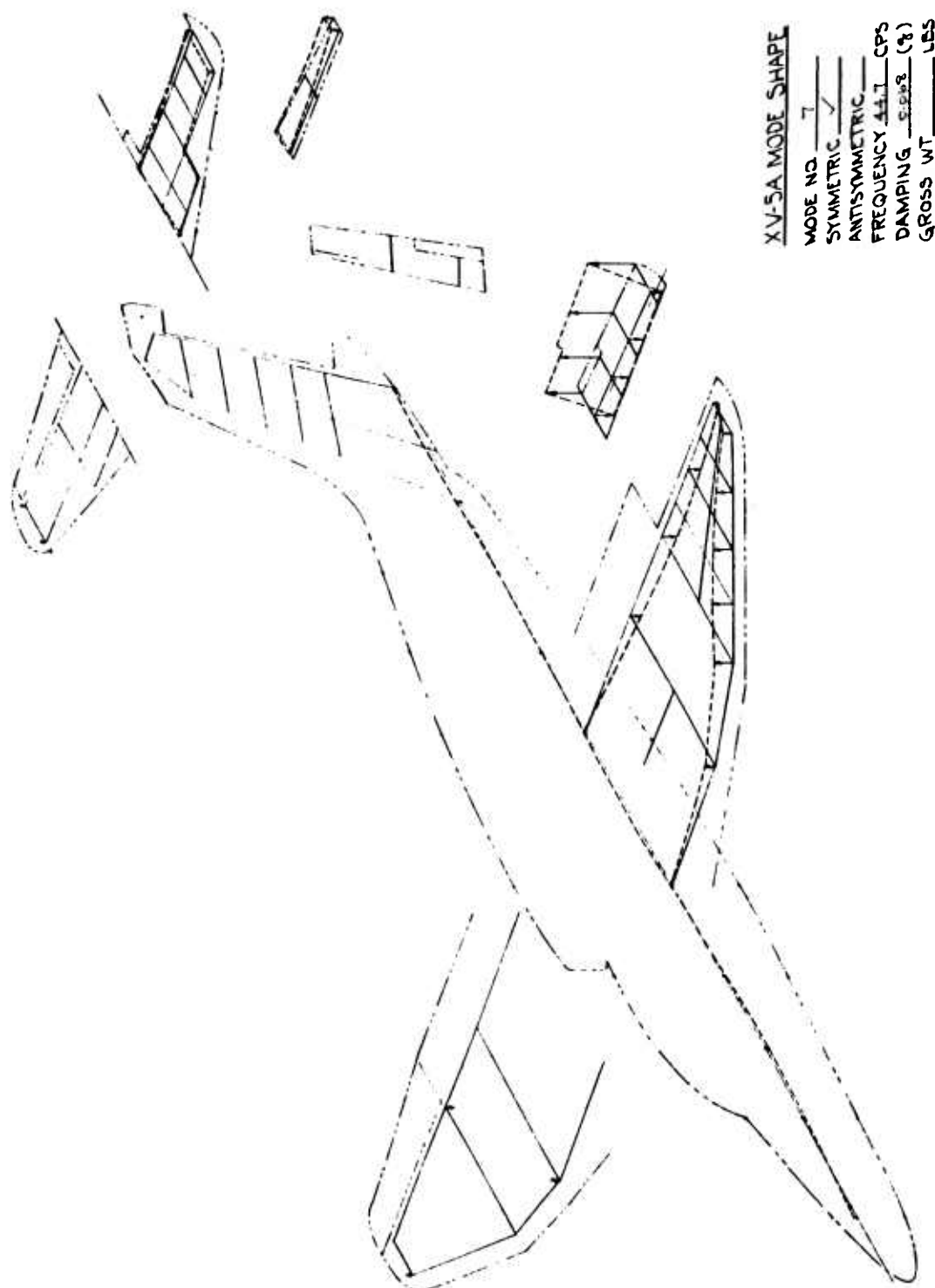
Figure 14 XV-5A Mode Shape - Mode No. 5



XV-5A MODE SHAPE

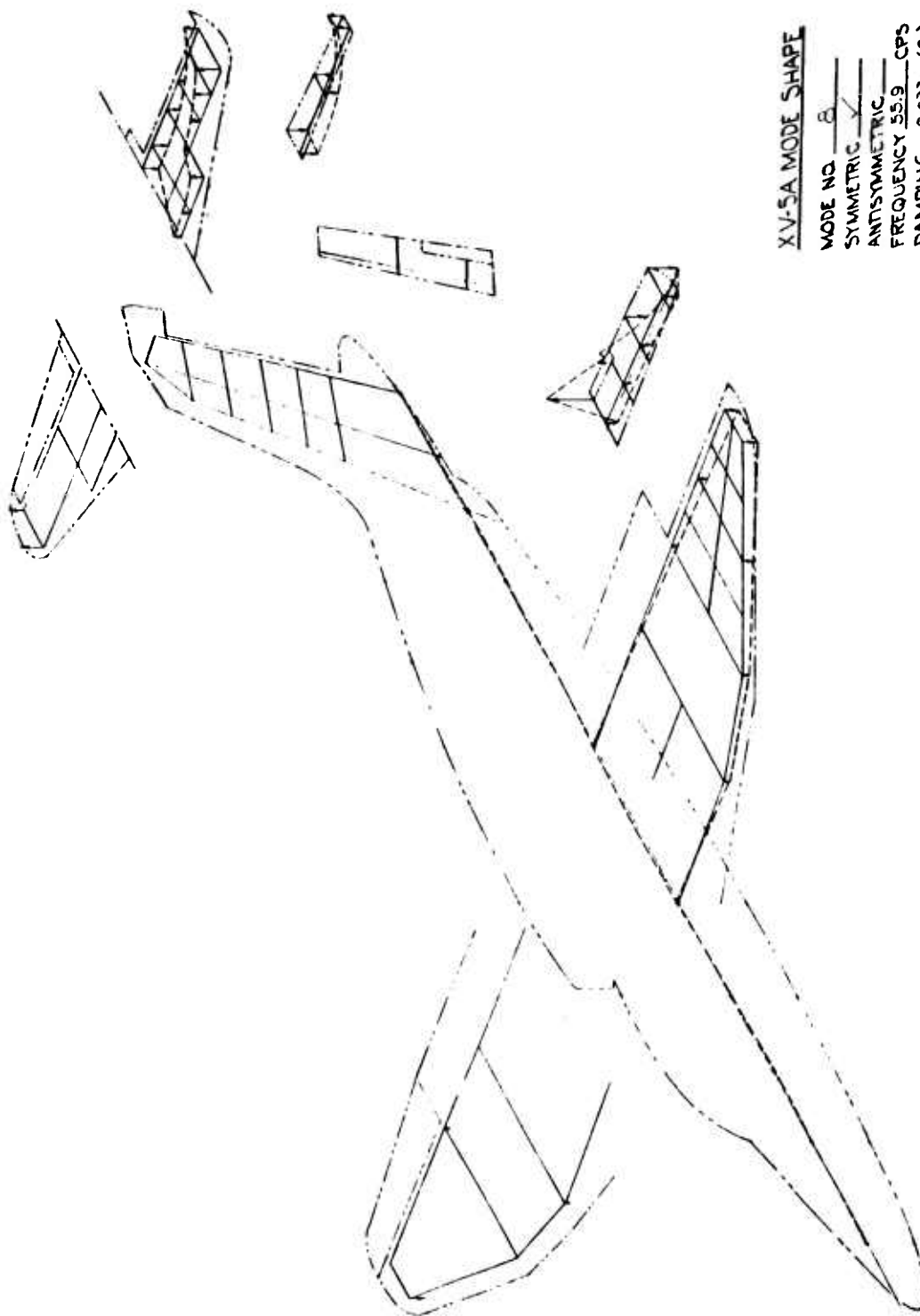
MODE NO. 6
 SYMMETRIC ✓
 ANTISYMMETRIC —
 FREQUENCY 36.3 CPS
 DAMPING 0.031 (%)
 GROSS WT. — LBS

Figure 15 XV-5A Mode Shape - Mode No. 6



XV-5A MODE SHAPE
 MODE NO. 7
 SYMMETRIC ✓
 ANTISYMMETRIC
 FREQUENCY 44.1 CPS
 DAMPING 0.008 (8)
 GROSS WT 125 LBS

Figure 16 XV-5A Mode Shape - Mode No. 7



XV-5A MODE SHAPE

MODE NO. 8
 SYMMETRIC X
 ANTISYMMETRIC
 FREQUENCY 55.9 CPS
 DAMPING 0.033 (8)
 GROSS WT. LBS

Figure 17 XV-5A Mode Shape - Mode No. 8

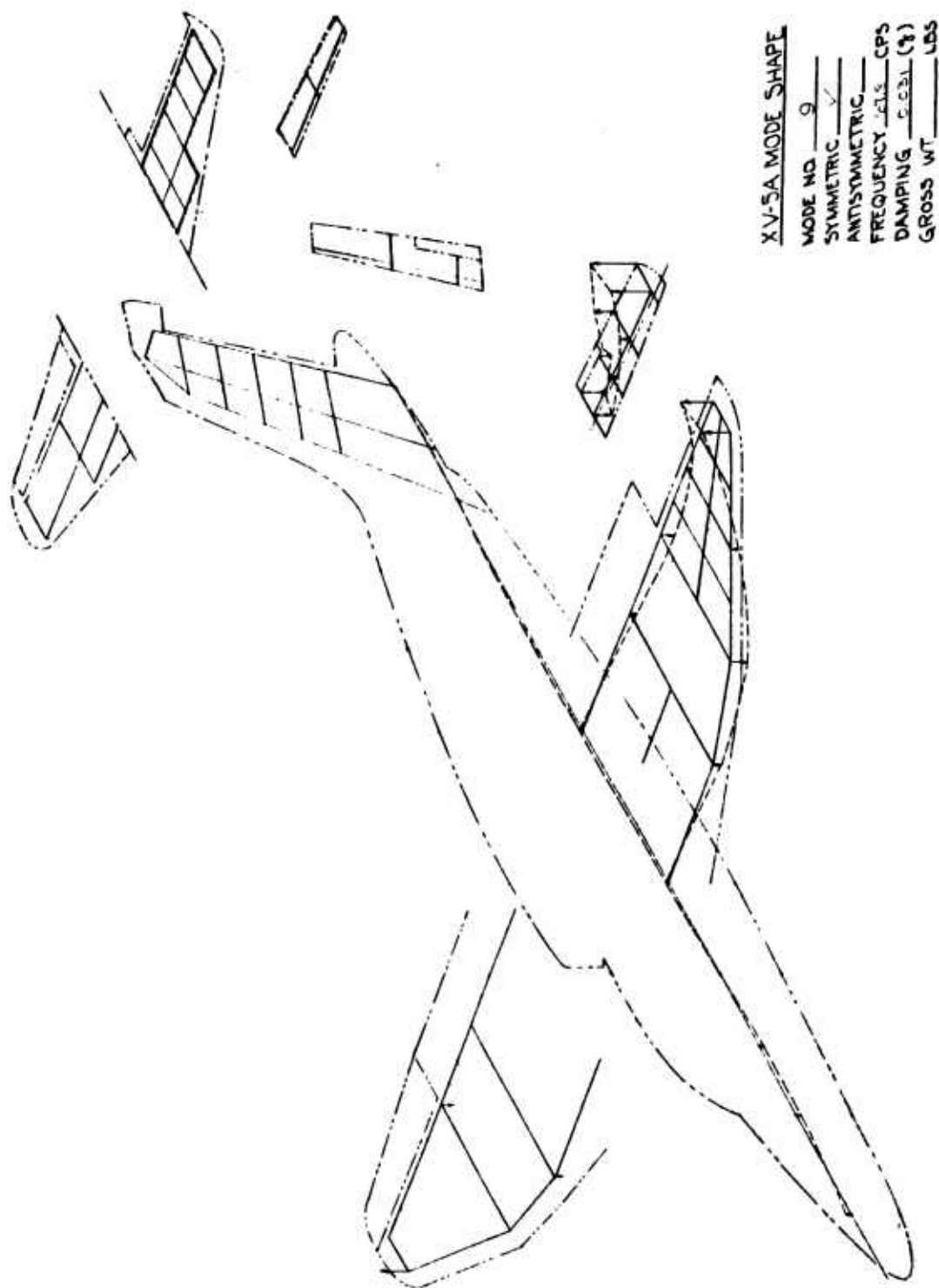


Figure 18 XV-5A Mode Shape - Mode No. 9

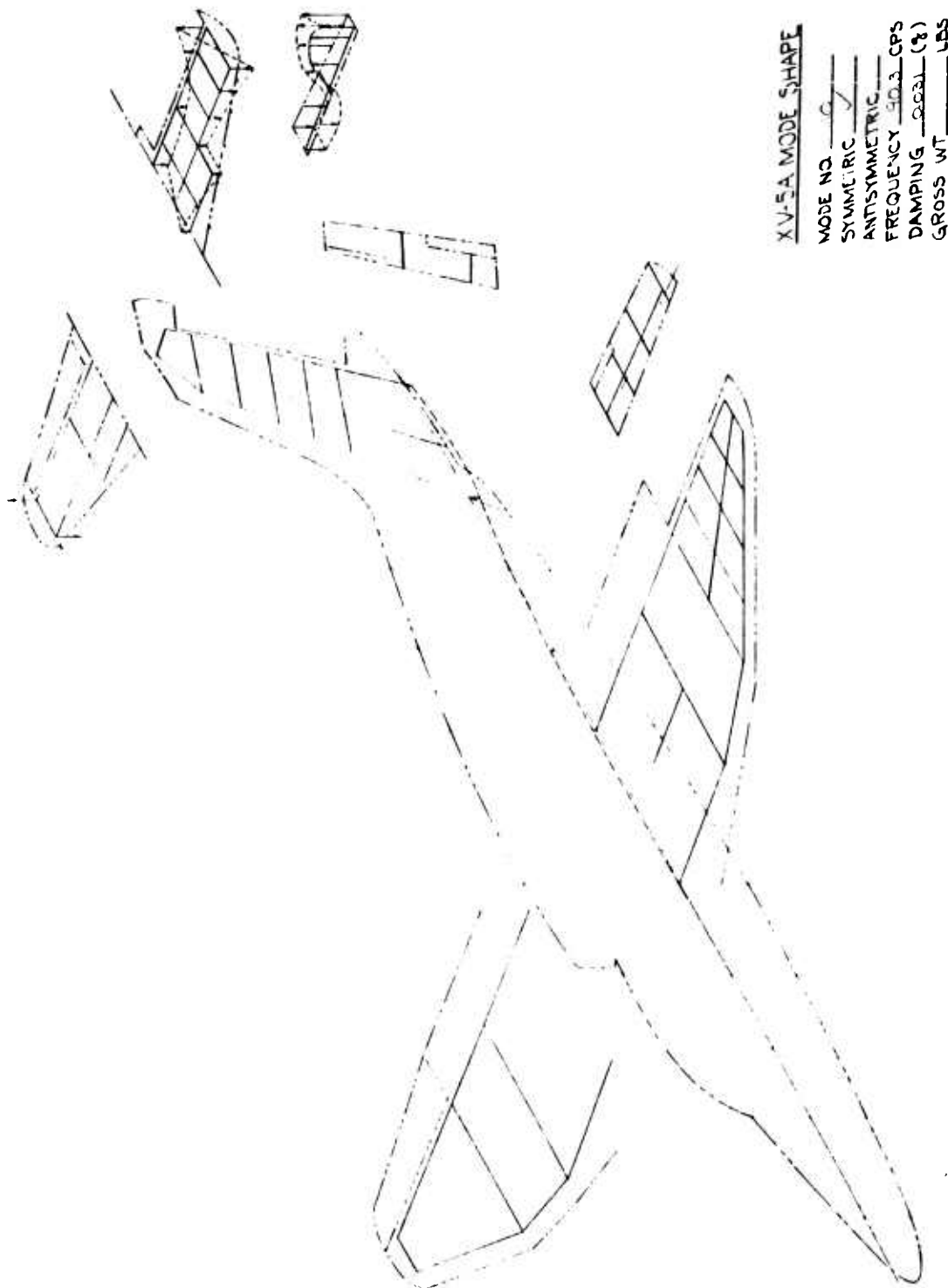
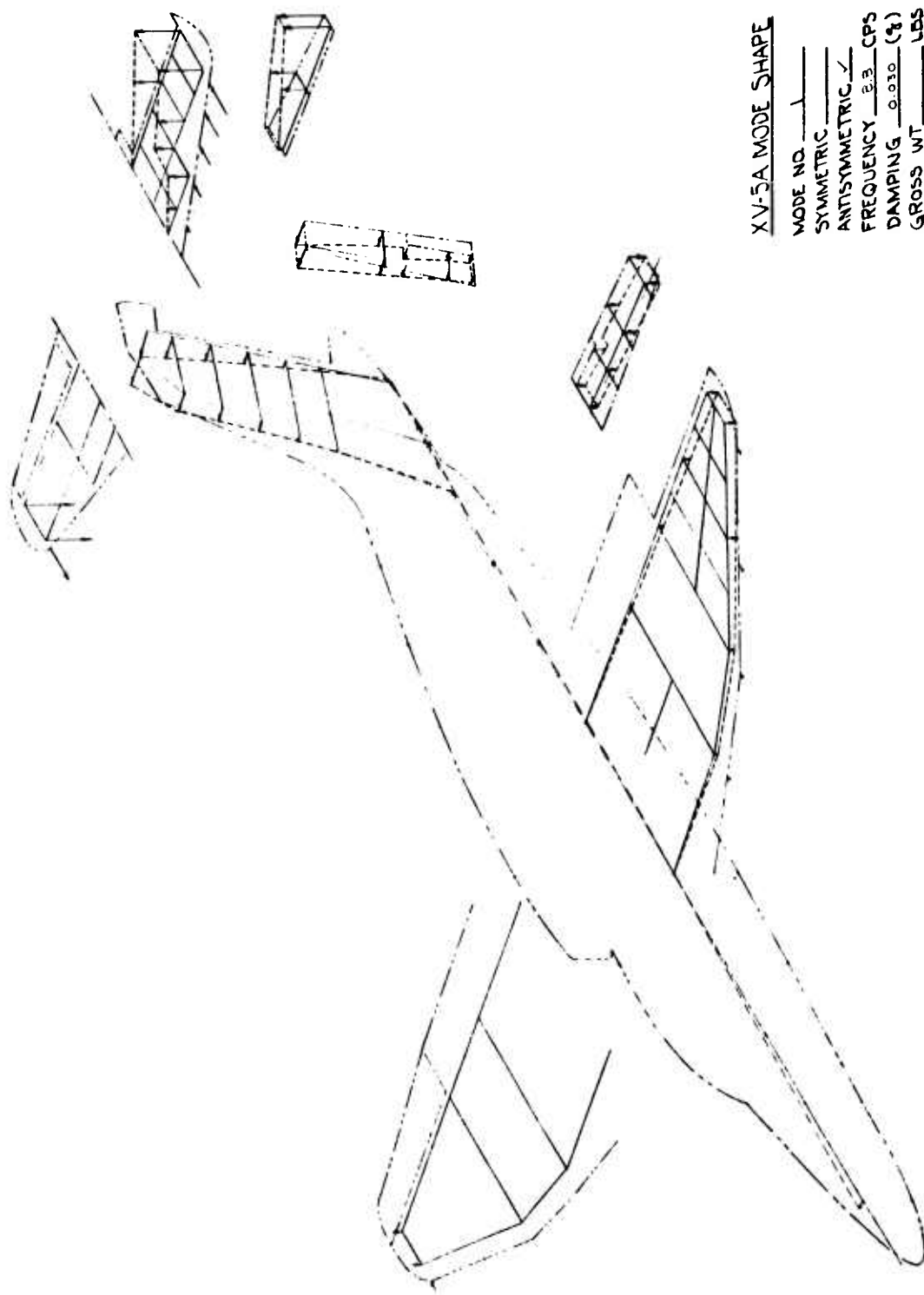


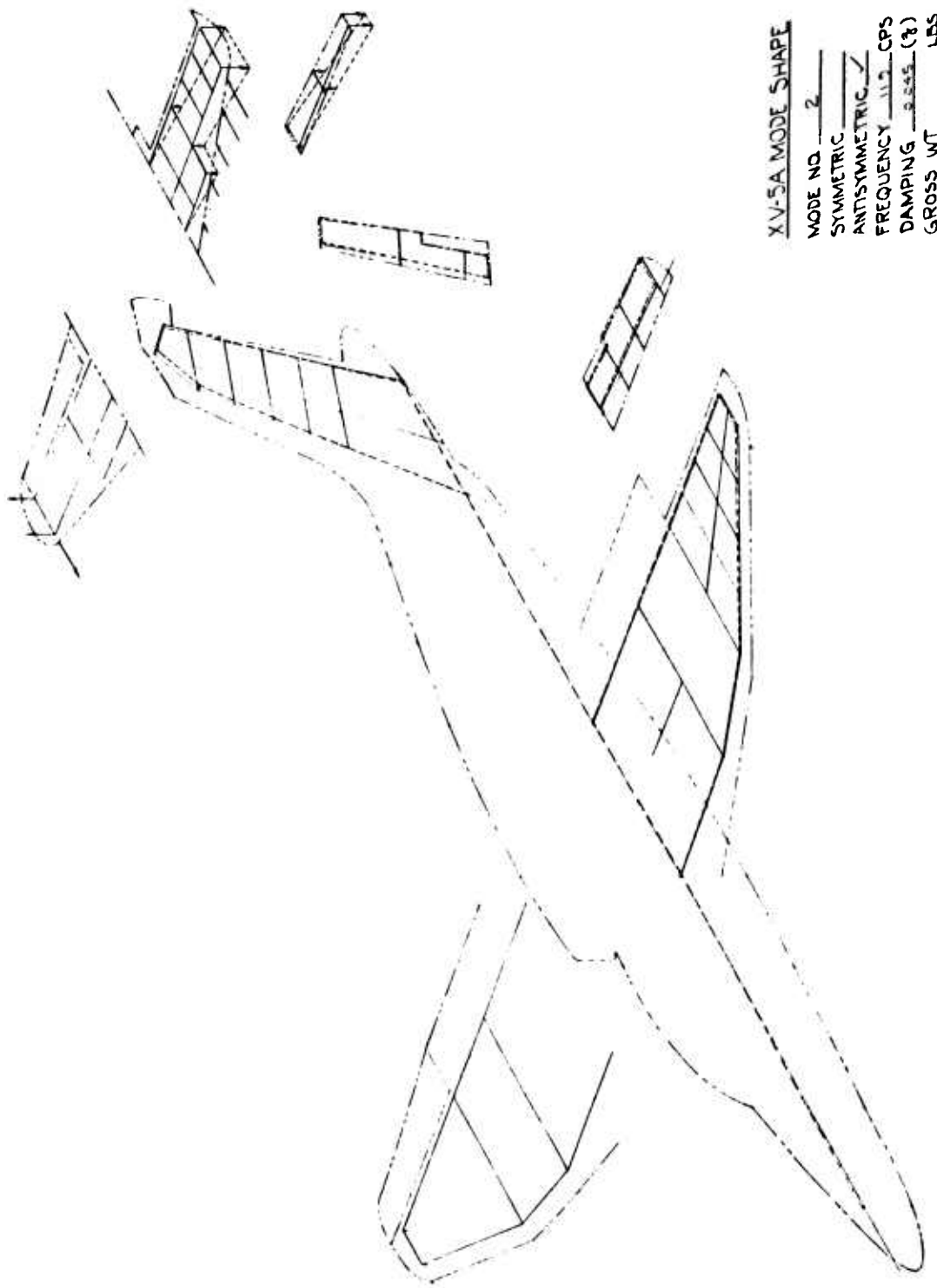
Figure 19 XV-5A Mode Shape - Mode No. 10



XV-5A MODE SHAPE

MODE NO. 1
 SYMMETRIC
 ANTISYMMETRIC ✓
 FREQUENCY 2.3 CPS
 DAMPING 0.030 (g)
 GROSS WT LBS

Figure 20 XV-5A Mode Shape - Mode No. 1



XV-5A MODE SHAPE

MODE NO.	2
SYMMETRIC	
ANTISYMMETRIC	✓
FREQUENCY	11.2 CPS
DAMPING	0.045 (3)
GROSS WT.	_____ LBS

Figure 21 XV-5A Mode Shape - Mode No. 2

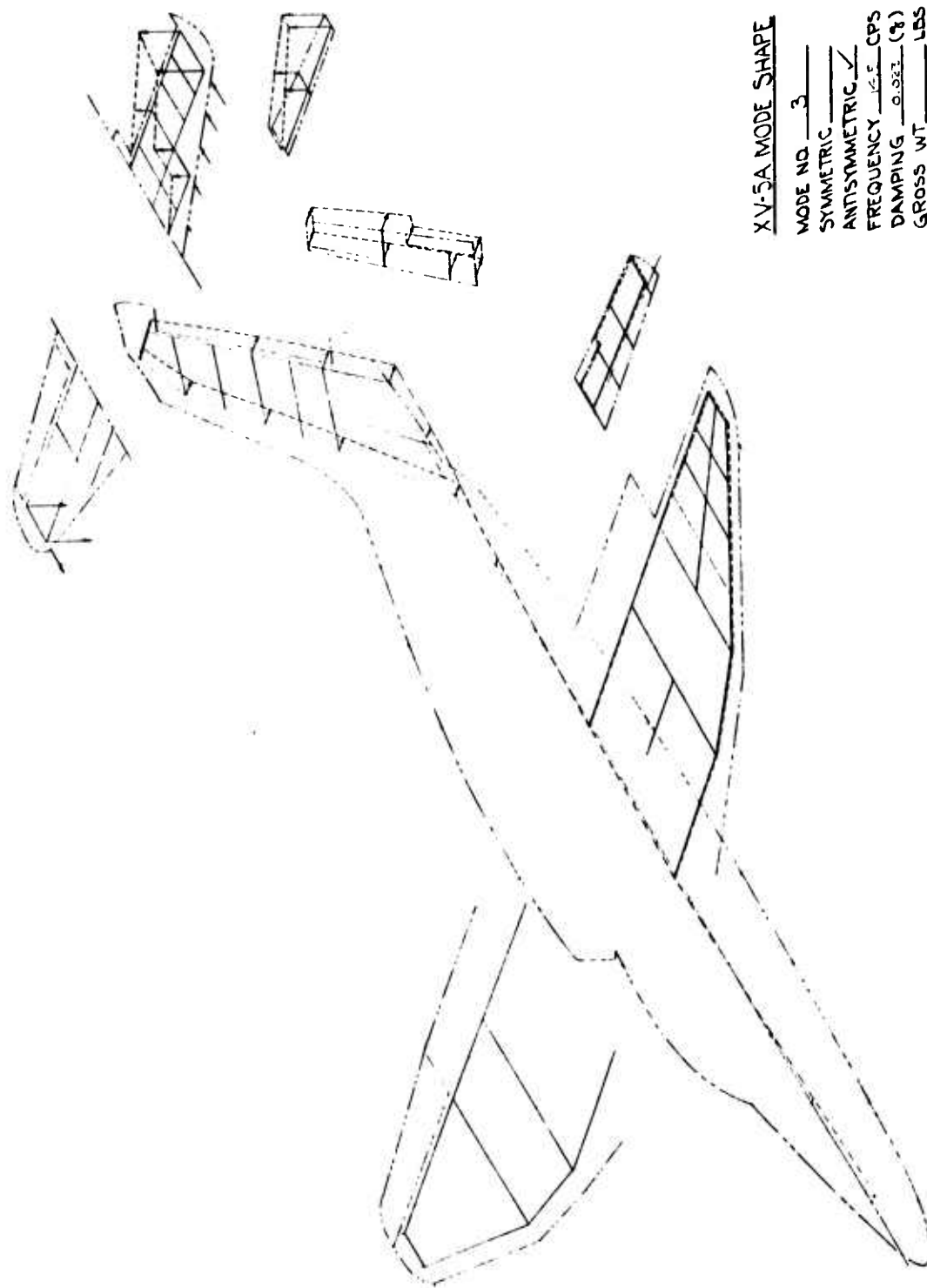
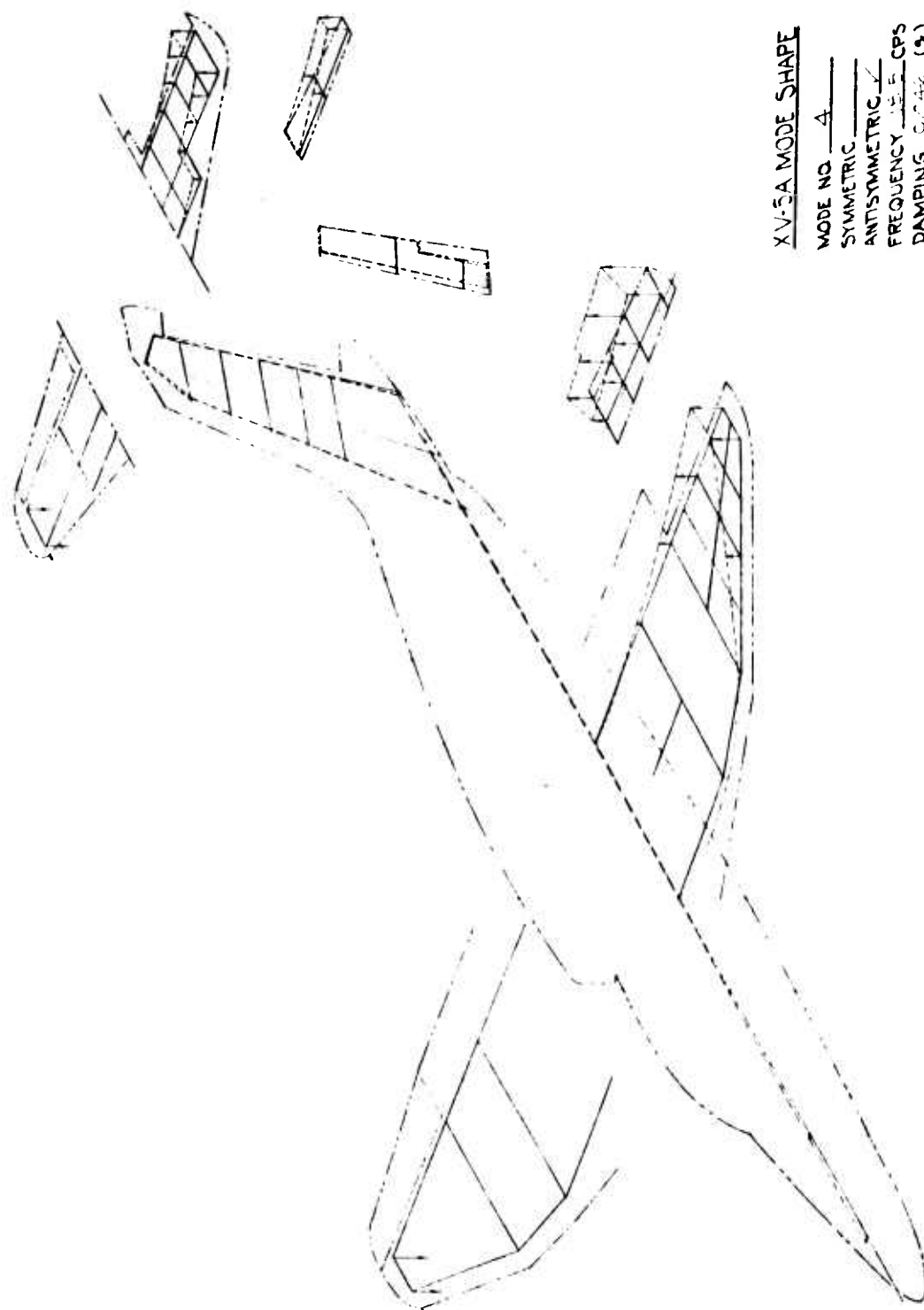


Figure 22 XV-5A Mode Shape - Mode No. 3



XV-5A MODE SHAPE

MODE NO. 4
 SYMMETRIC
 ANTISYMMETRIC ✓
 FREQUENCY 15.5 CPS
 DAMPING 0.0044 (%)
 GROSS WT LBS

Figure 23 XV-5A Mode Shape - Mode No. 4

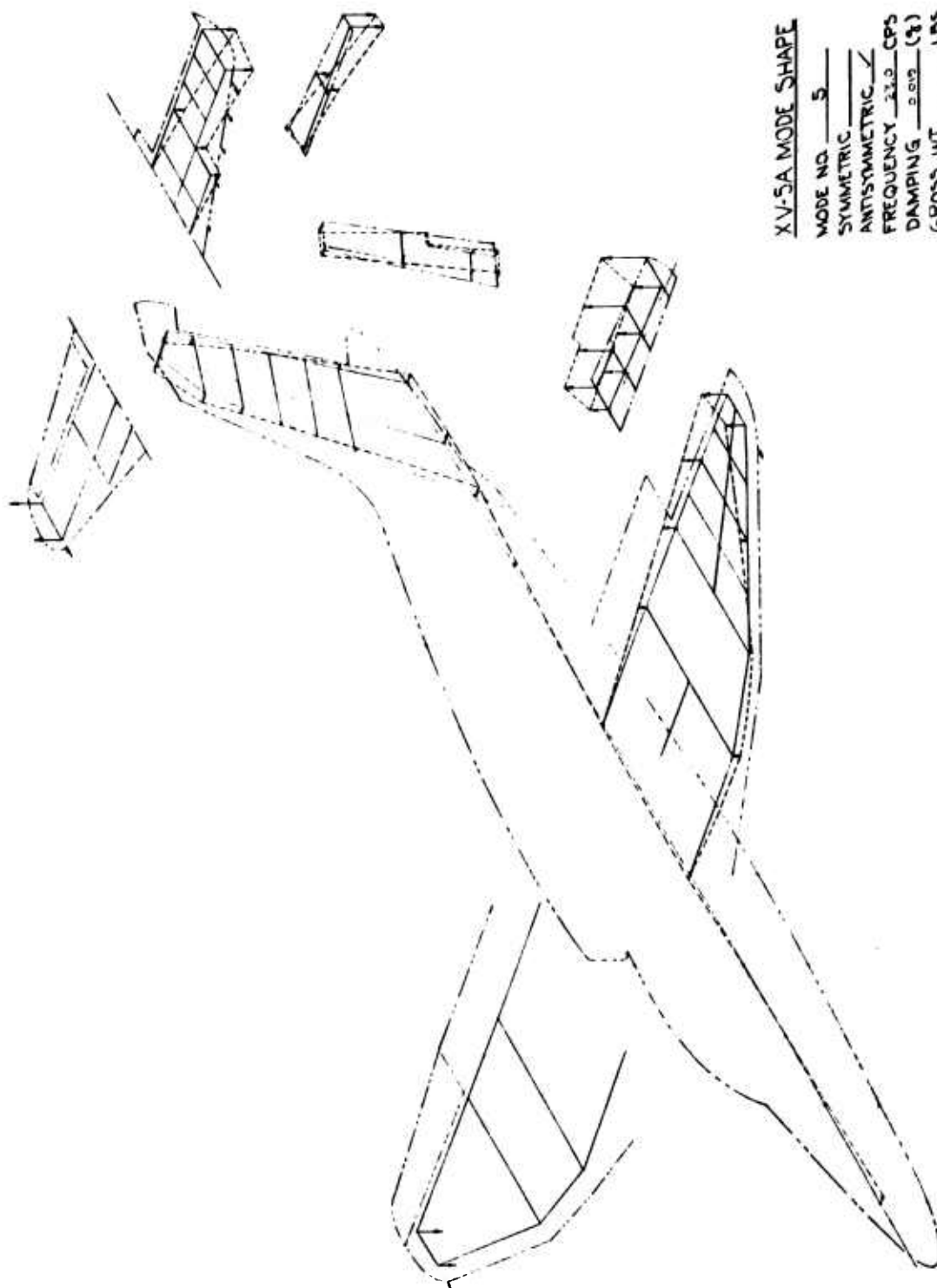
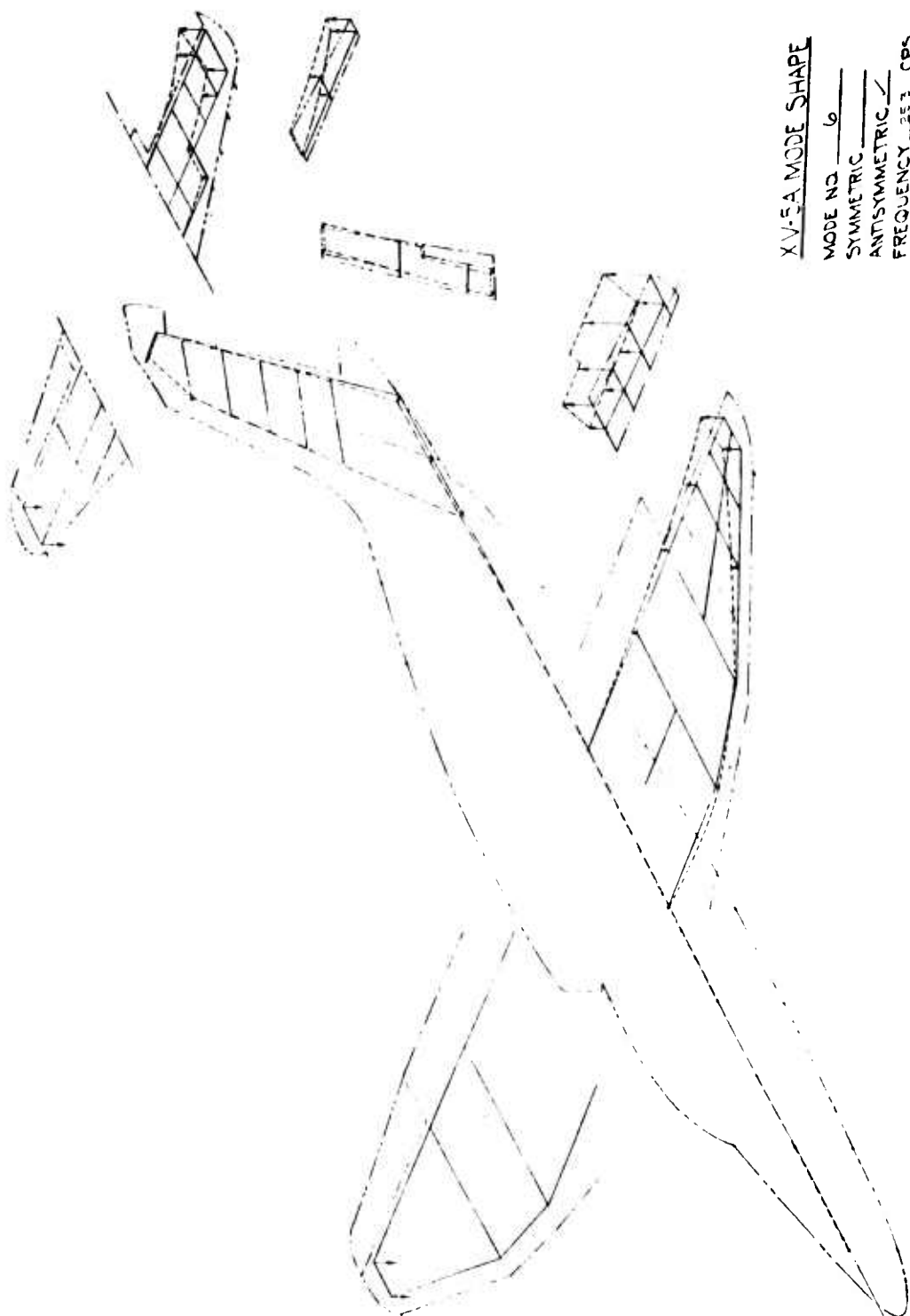


Figure 24 XV-5A Mode Shape - Mode No. 5



XV-5A MODE SHAPE

MODE NO. 6
 SYMMETRIC
 ANTISYMMETRIC ✓
 FREQUENCY 25.3 CPS
 DAMPING 0.002 (%)
 GROSS WT LBS

Figure 25 XV-5A Mode Shape - Mode No. 6

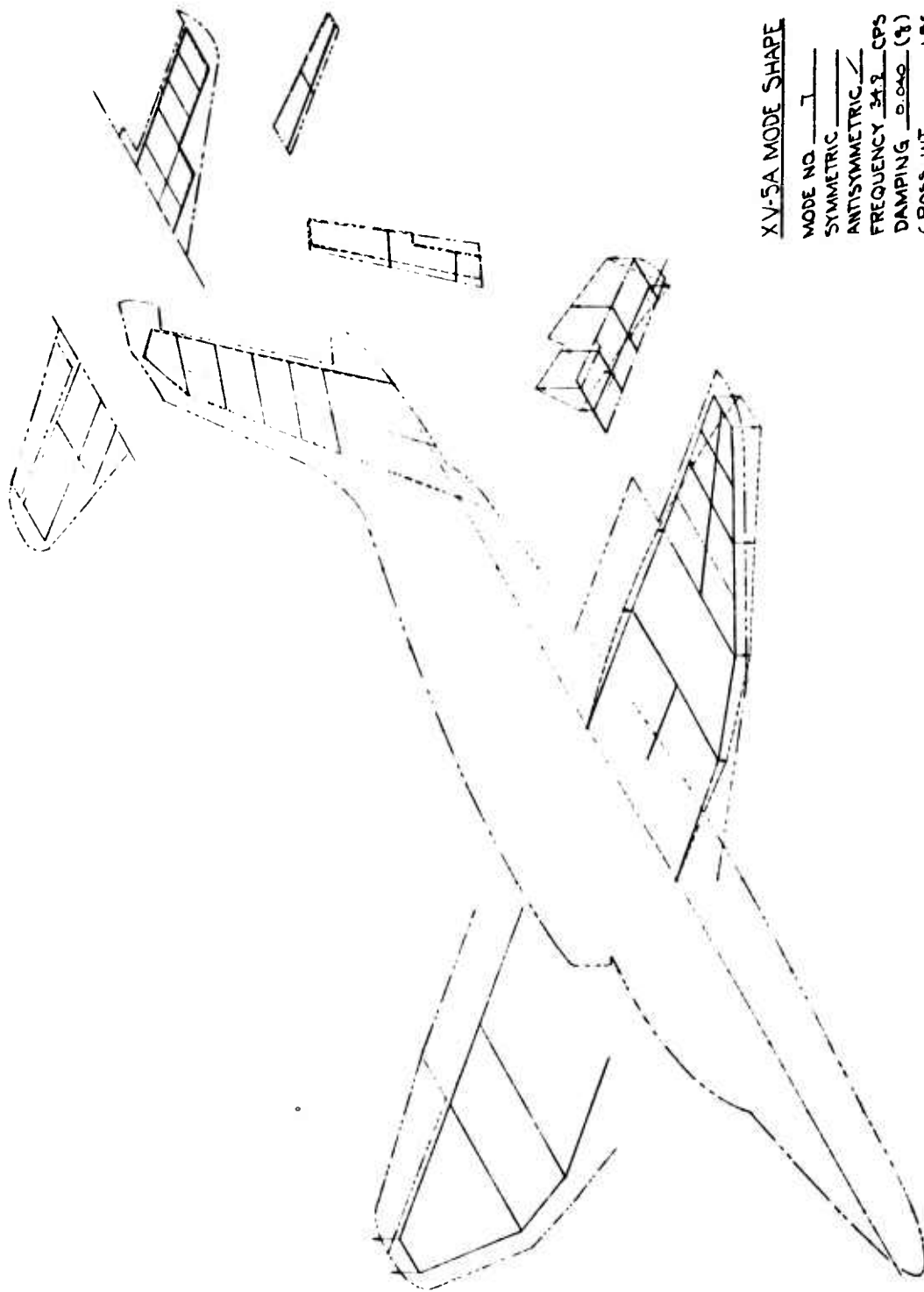


Figure 26 XV-5A Mode Shape - Mode No. 7

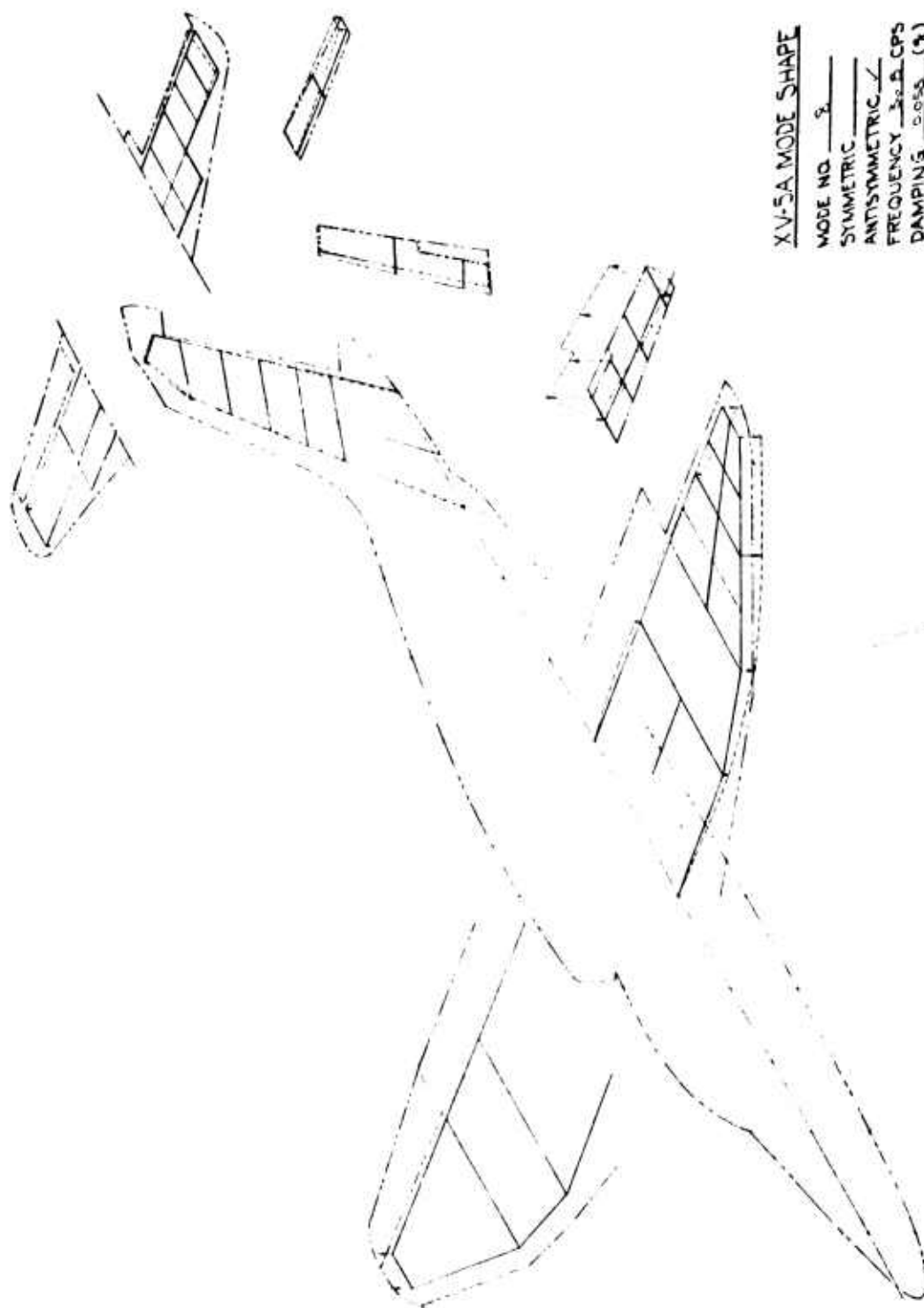
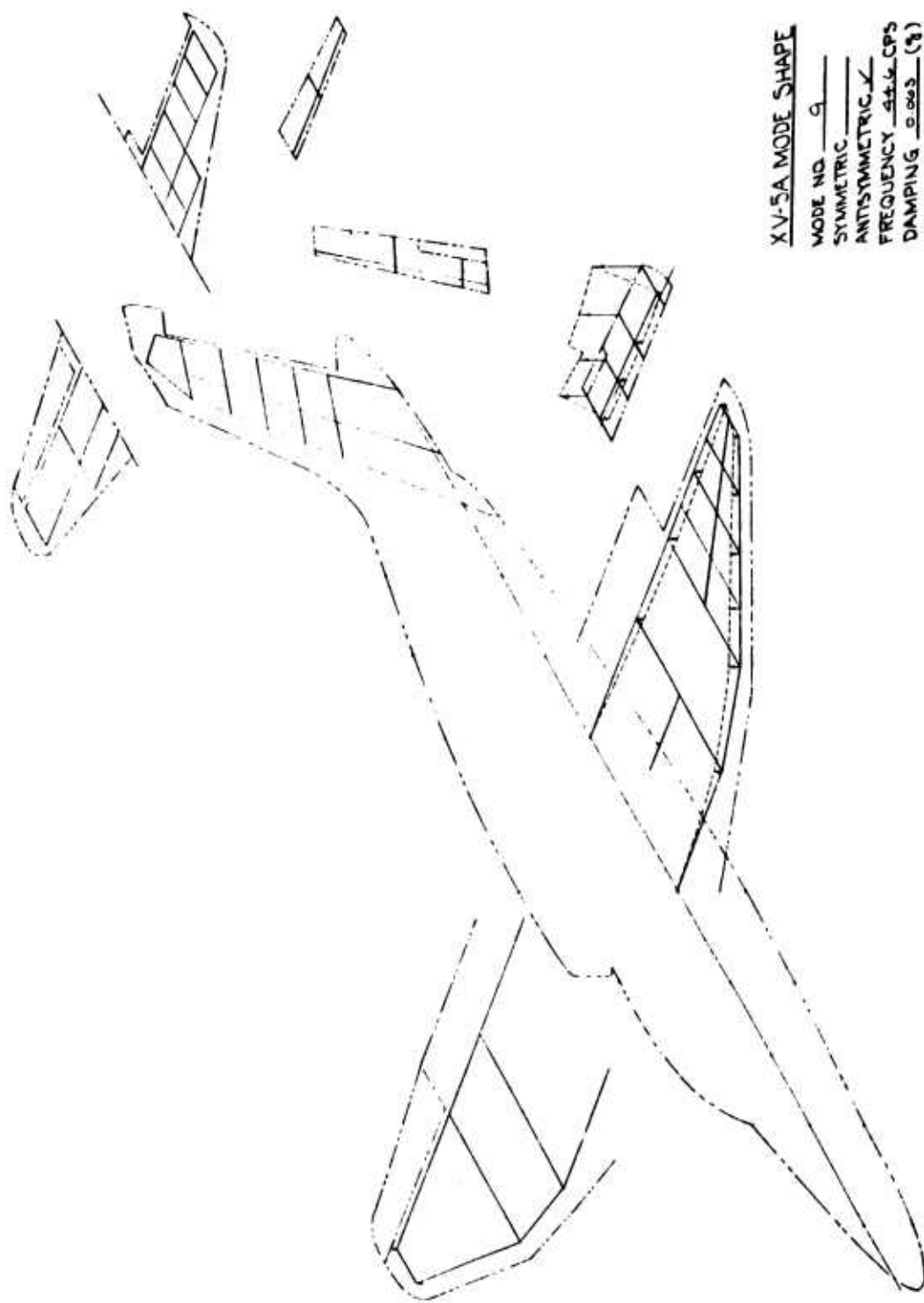


Figure 27 XV-5A Mode Shape - Mode No. 8



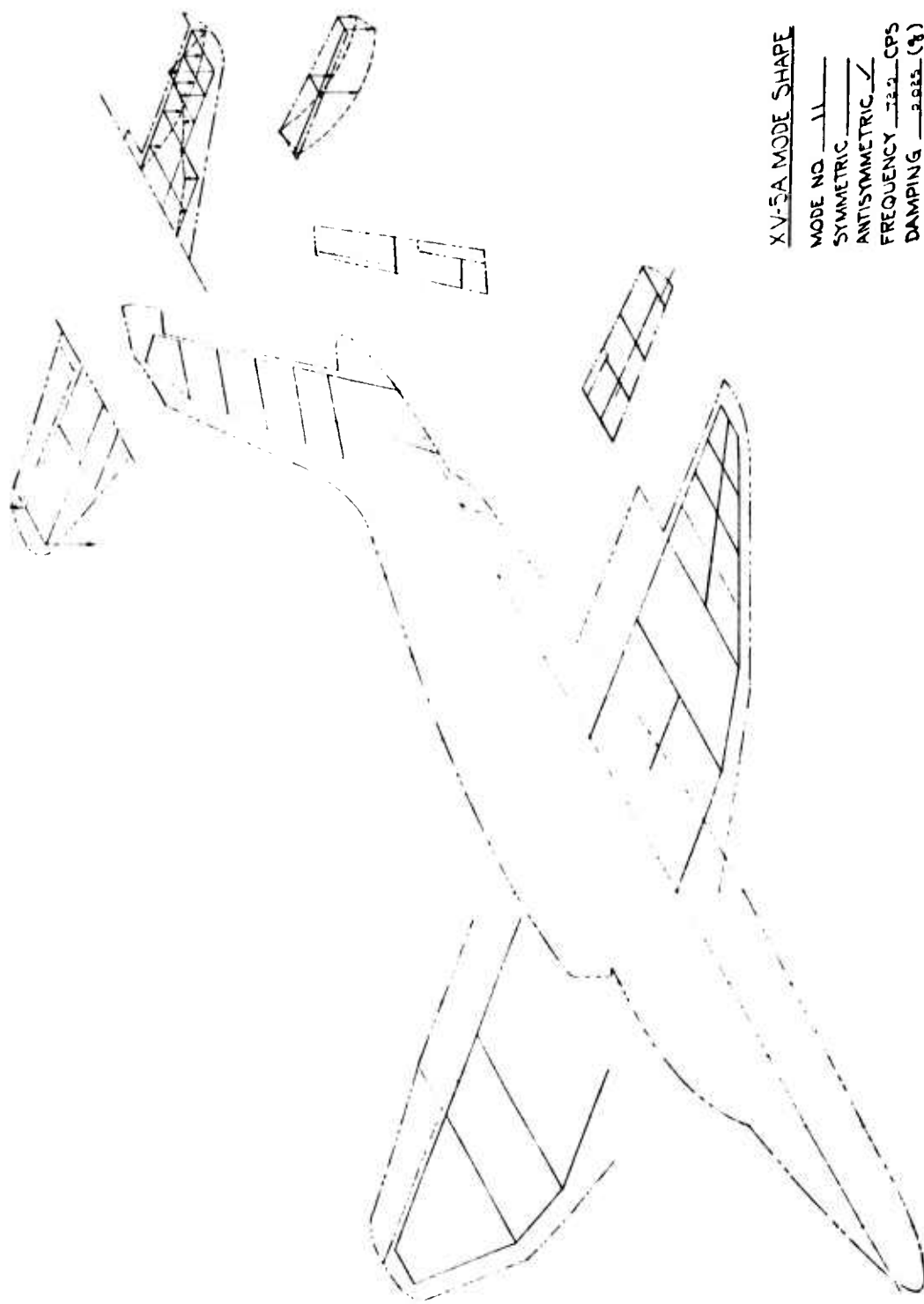
XV-5A MODE SHAPE

MODE NO. 9
 SYMMETRIC
 ANTISYMMETRIC X
 FREQUENCY 44.6 CPS
 DAMPING 0.003 (%)
 GROSS WT. 105 LBS

Figure 28 XV-5A Mode Shape - Mode No. 9



Figure 29 XV-5A Mode Shape - Mode No. 10



XV-5A MODE SHAPE

MODE NO. 11
 SYMMETRIC
 ANTISYMMETRIC ✓
 FREQUENCY 12.2 CPS
 DAMPING 2.825 (%)
 GROSS WT LBS

Figure 30 XV-5A Mode Shape - Mode No. 11

⊙ ROVING PICKUP

REF: DWG 143W010

POINT	STA.	WL	BL
INBD HINGE	308.15	92.58	24.62
OUTBD "	308.15	92.58	100.75
ACTUATOR	307.50	100.58	21.94

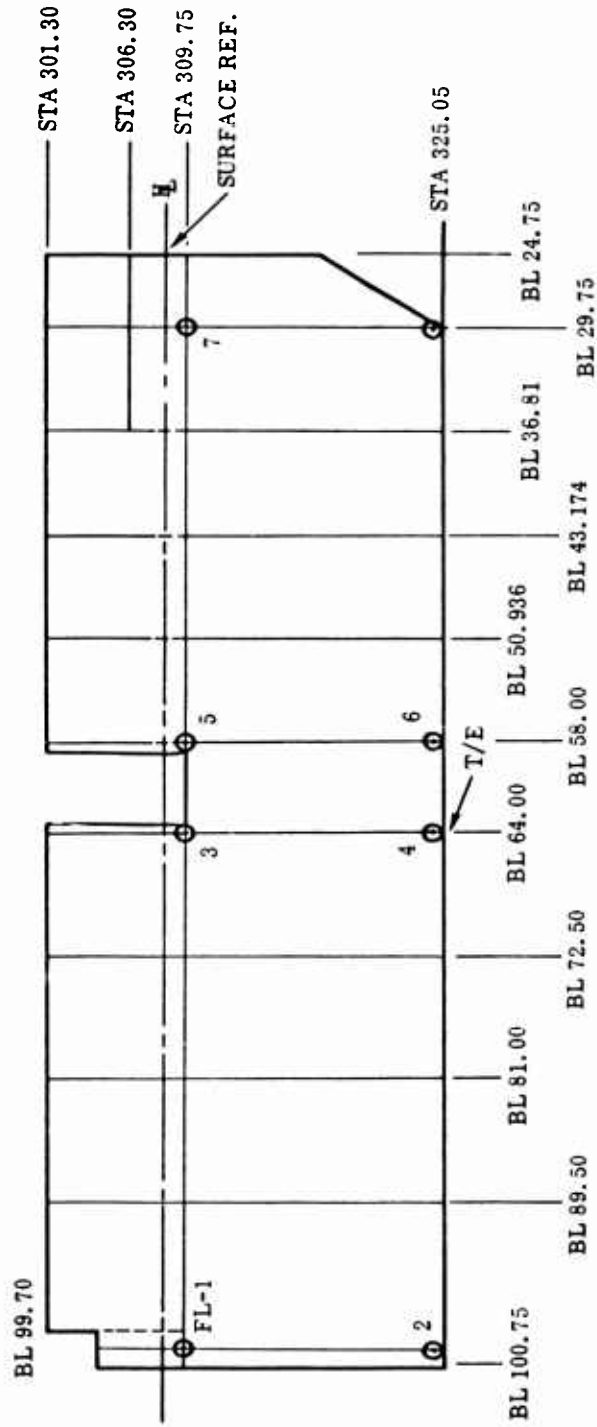


Figure 31 Miscellaneous Component Pickup Locations - Flap

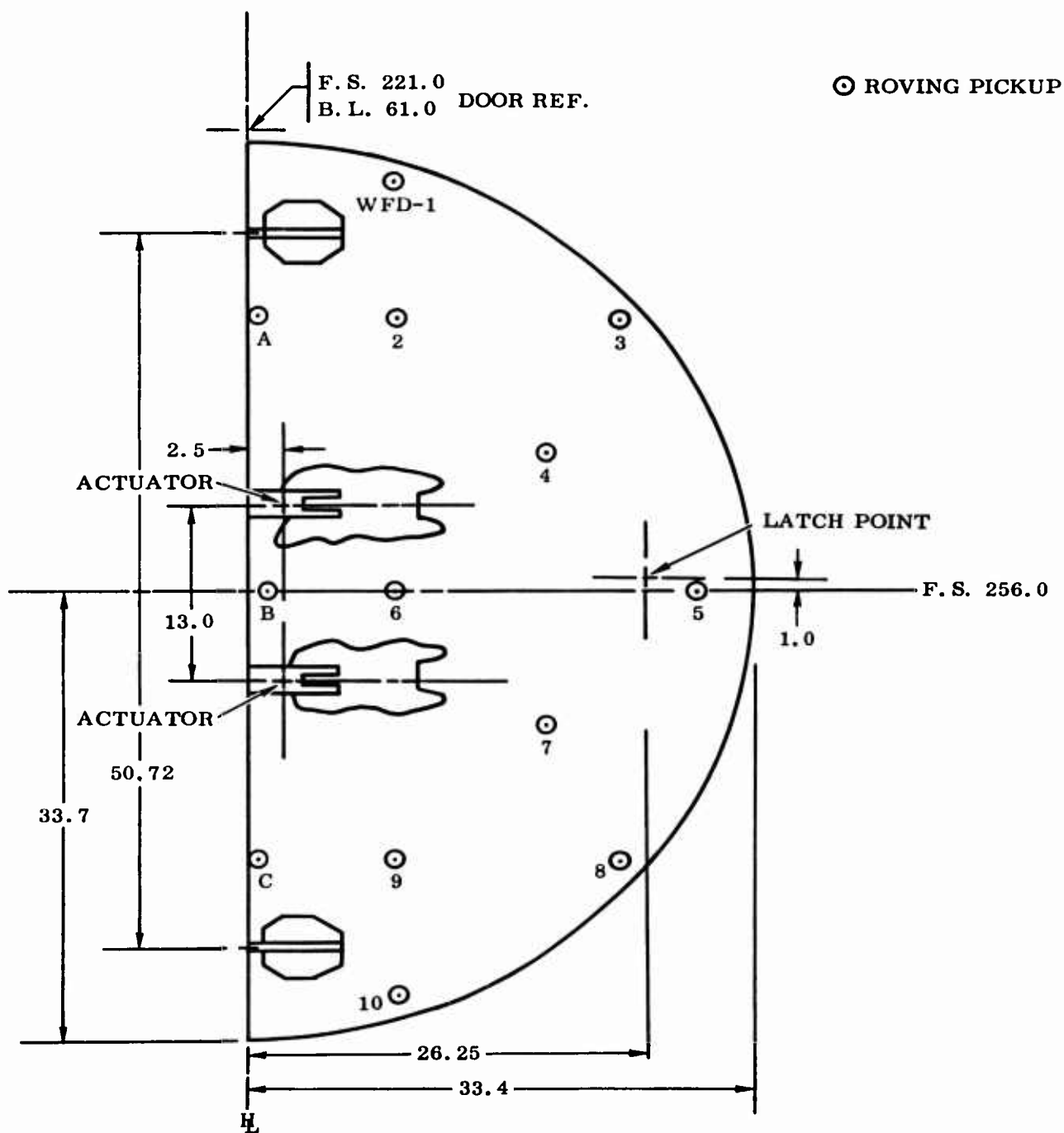


Figure 32 Miscellaneous Component Pickup Locations - Wing Fan Door

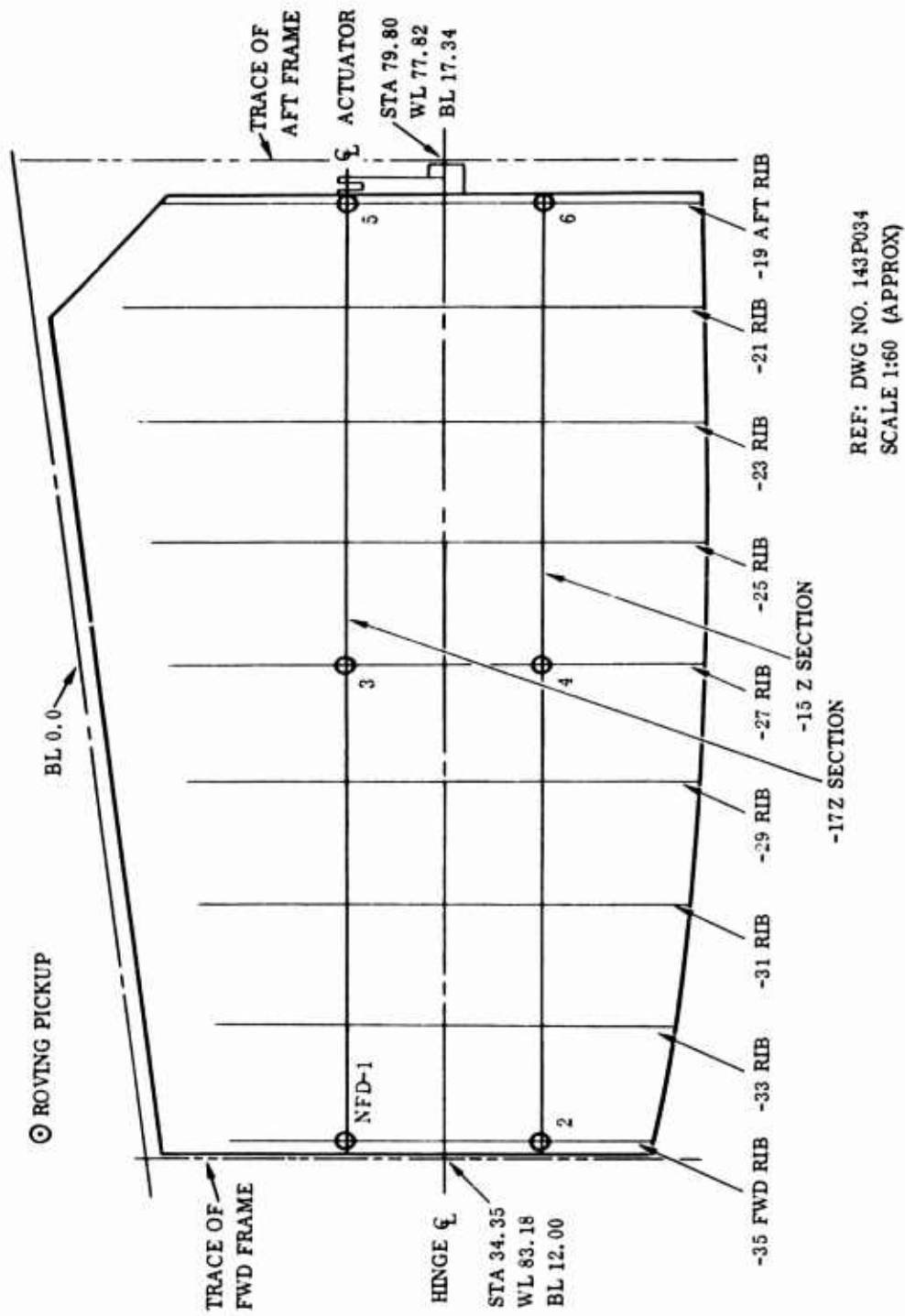


Figure 33 Miscellaneous Component Pickup Locations - Nose Fan Door

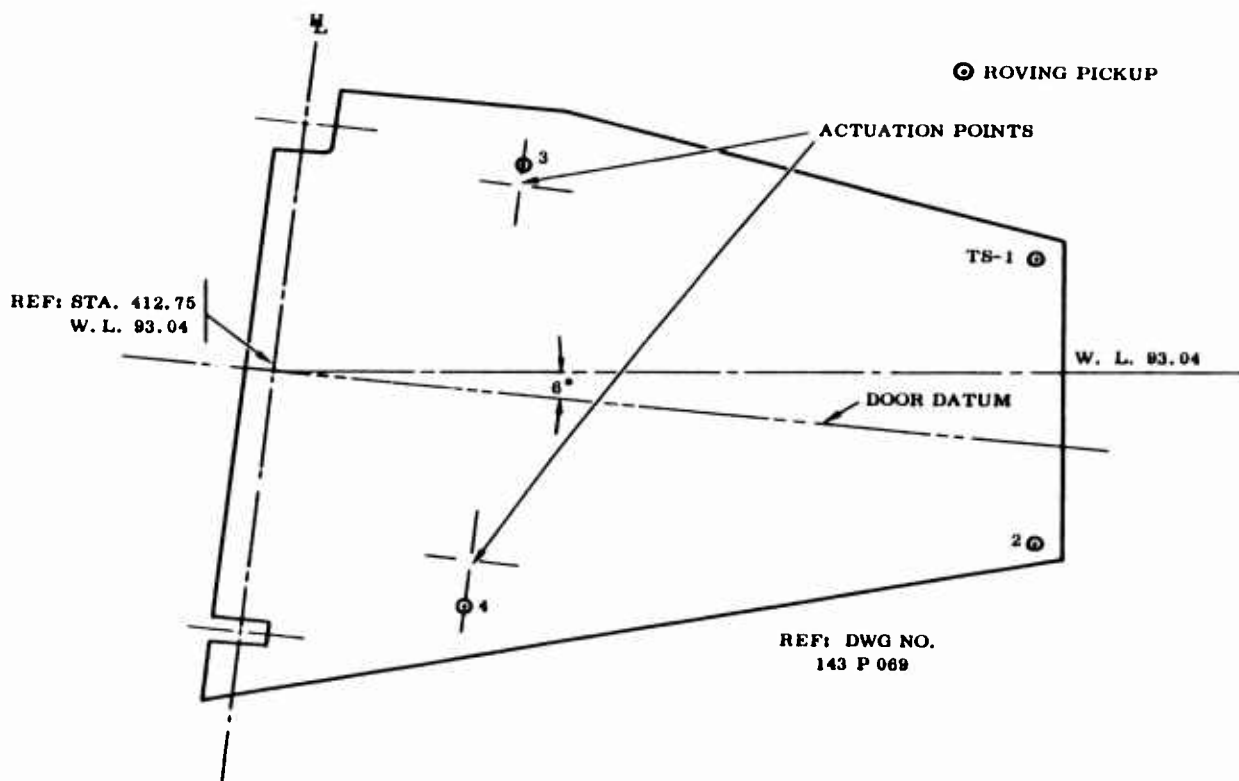


Figure 34 Miscellaneous Component Pickup Locations - Thrust Spoiler

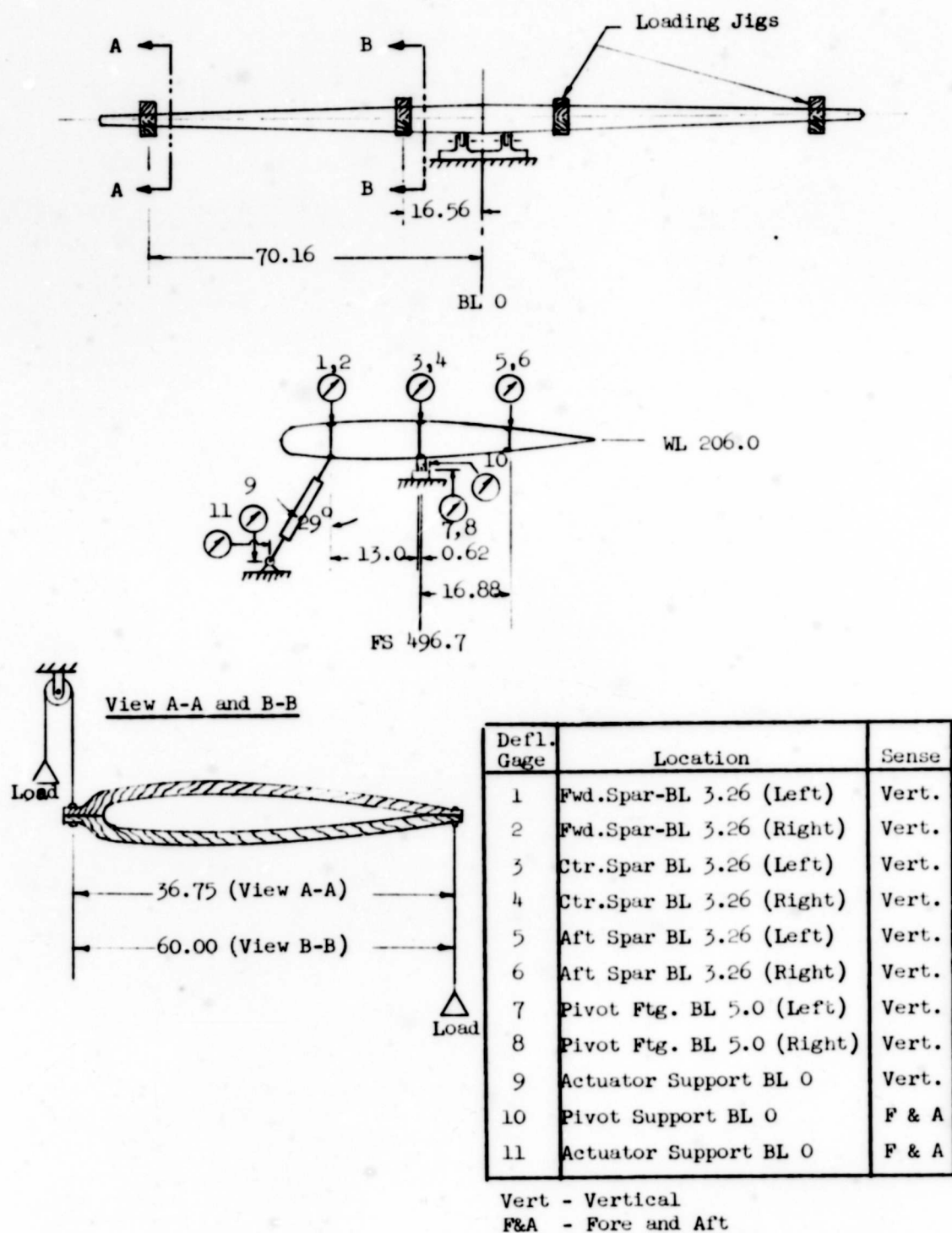


Figure 35. Horizontal Stabilizer Pitch Spring - Load and Instrumentation Schematic

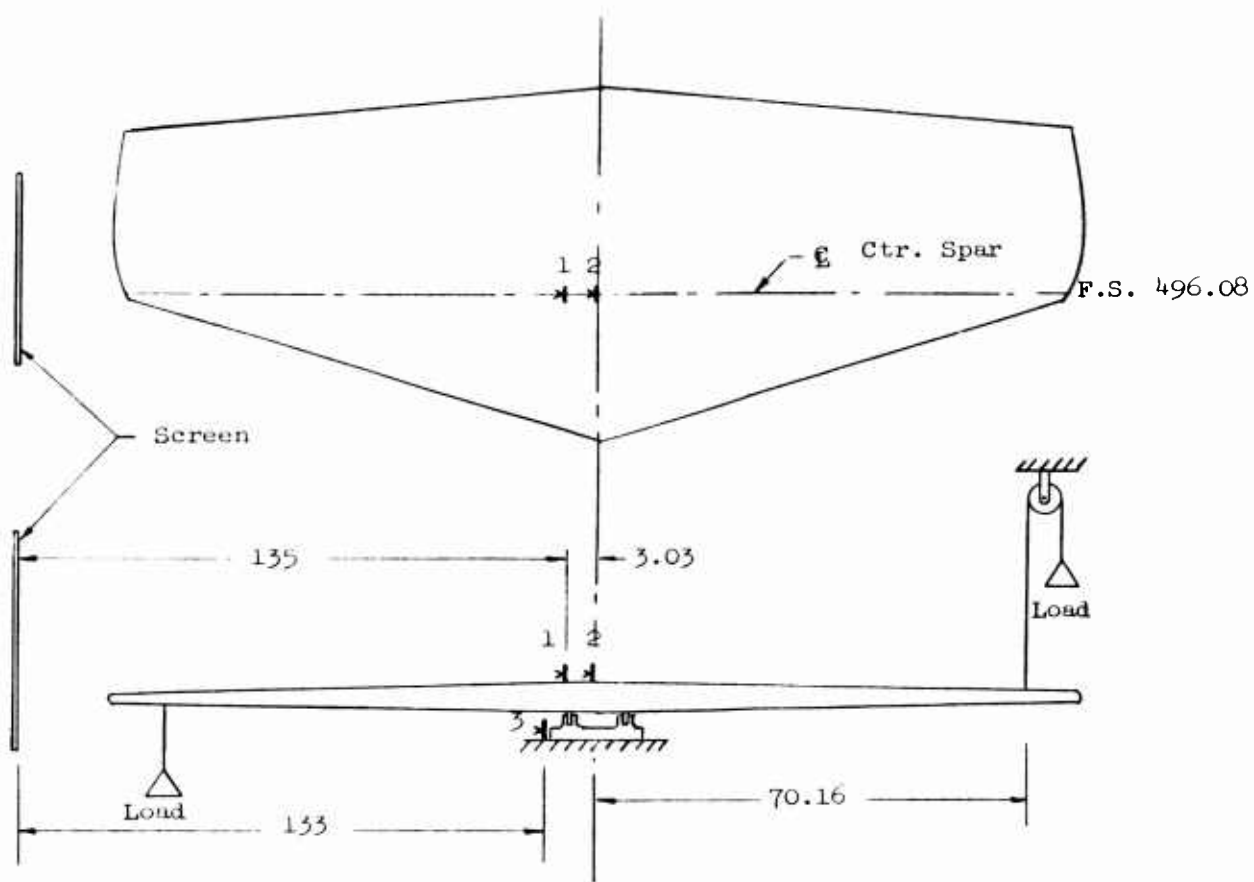
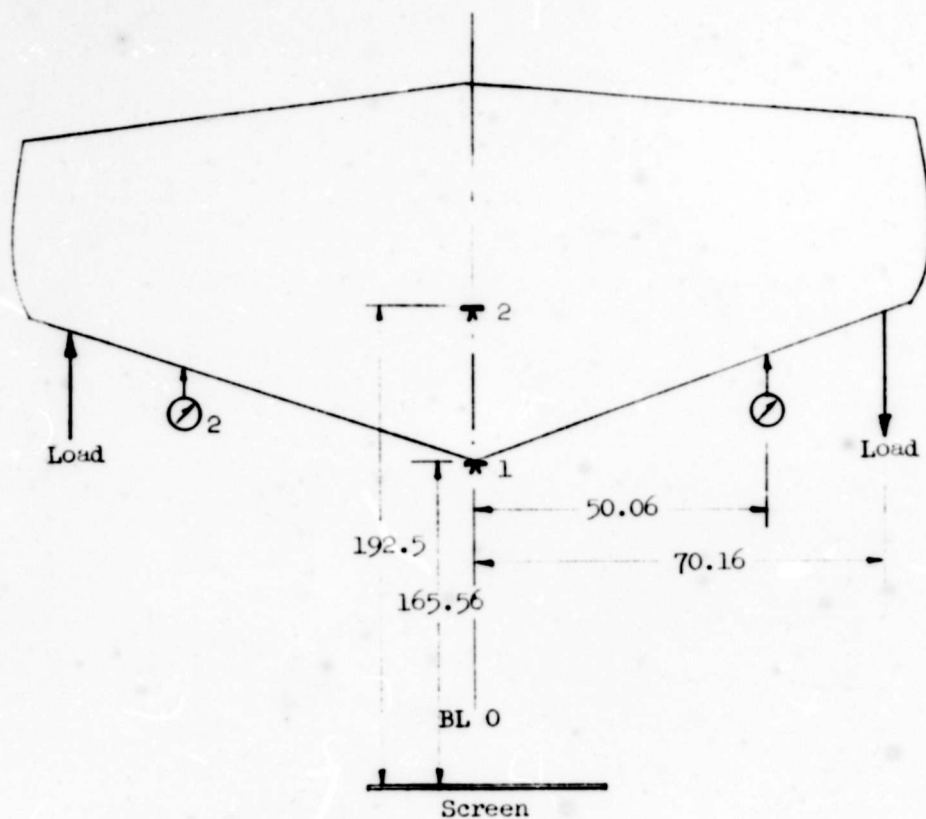


Figure 36. Horizontal Stabilizer Roll Spring - Load and Instrumentation Schematic



Note:  Indicates Defl. Gage
 Indicates Mirror Location
 Mirror 2 Located on Support Jig
 At Horiz. Stab. Pivot Fitting.

Figure 37. Horizontal Stabilizer Yaw Spring - Load and Instrumentation Schematic

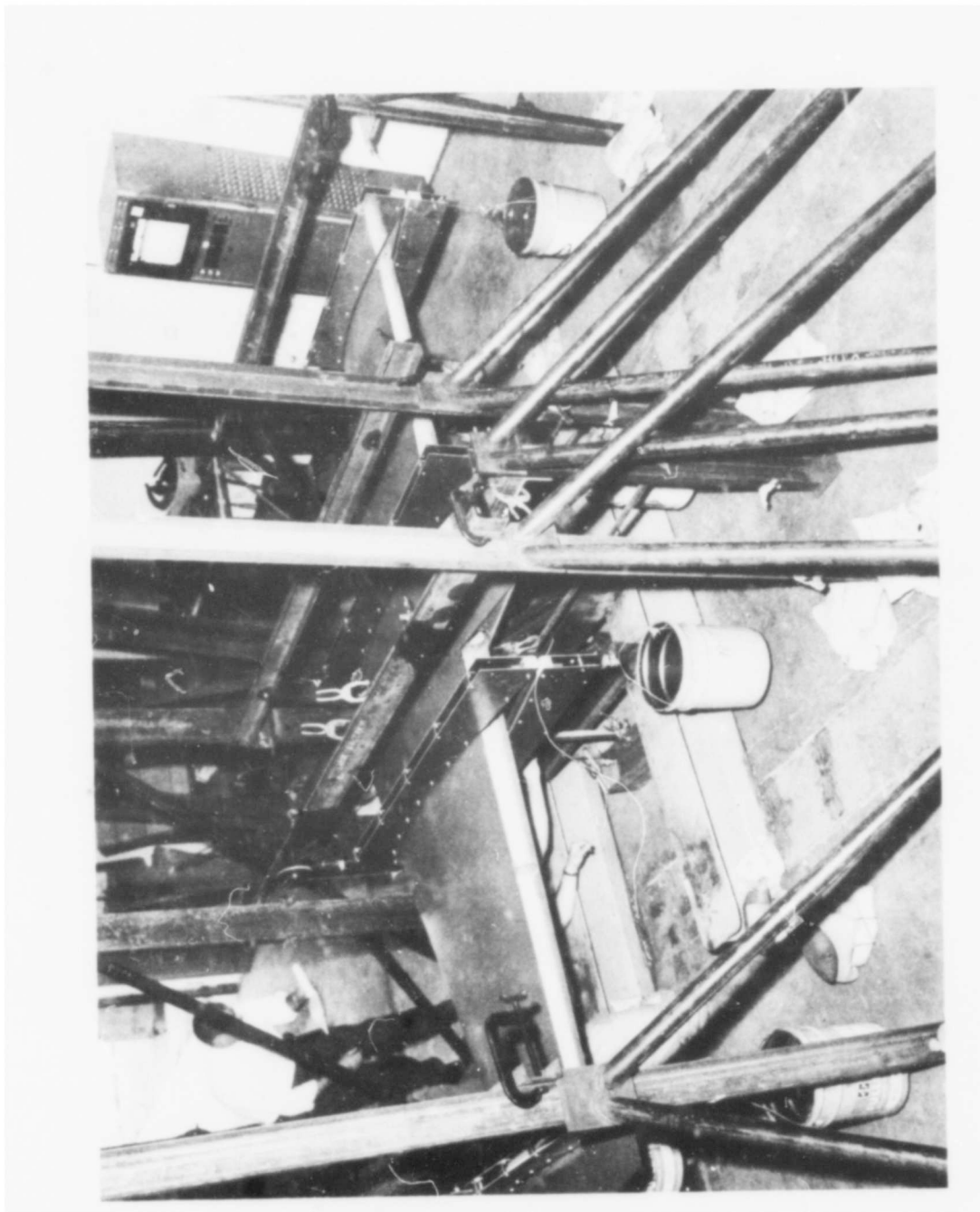


Figure 38. Test Setup - Horizontal Stabilizer Pitch Restraint

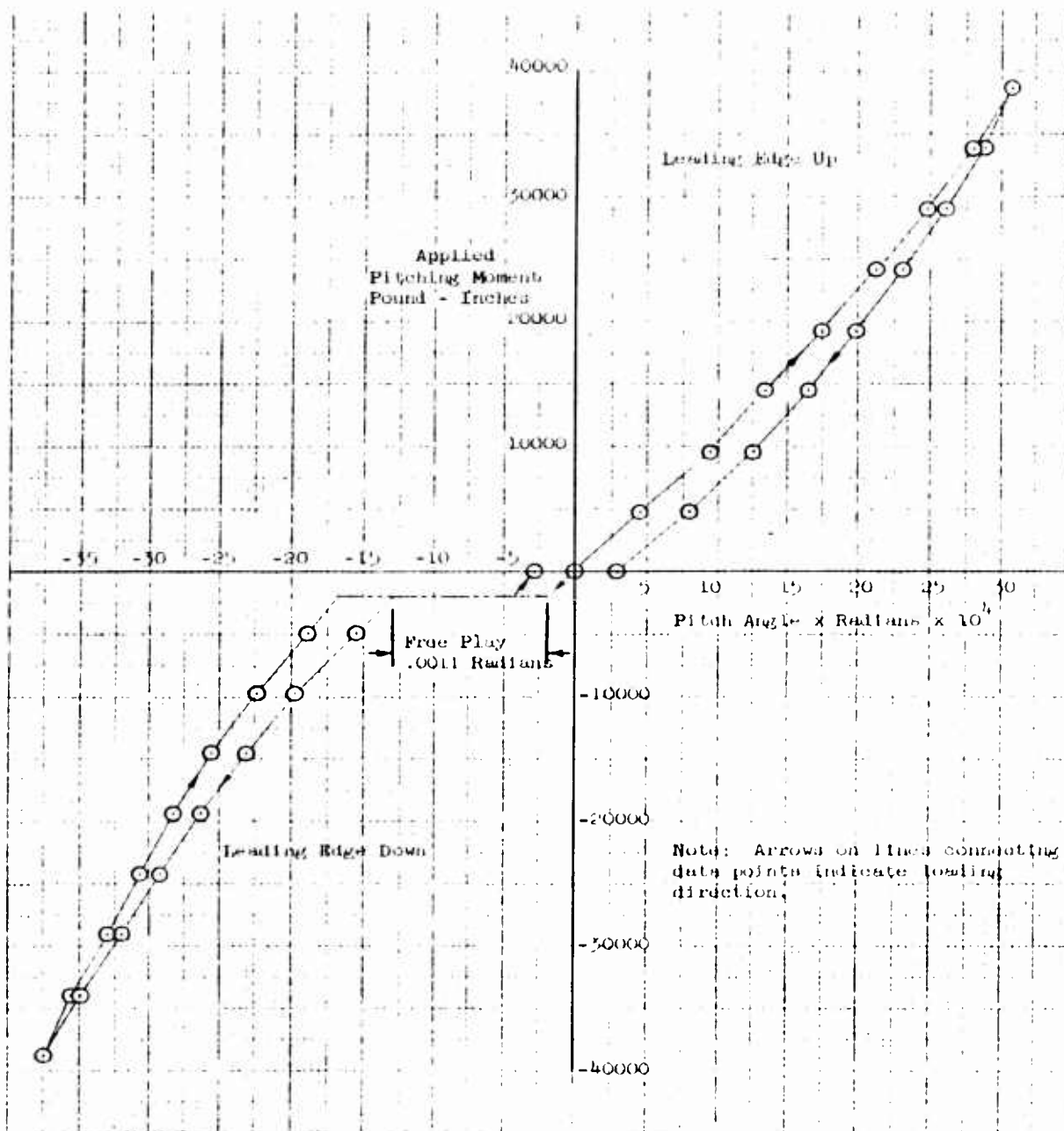


Figure 39. Horizontal Stabilizer - Pitch Free Play and Rotational Restraint

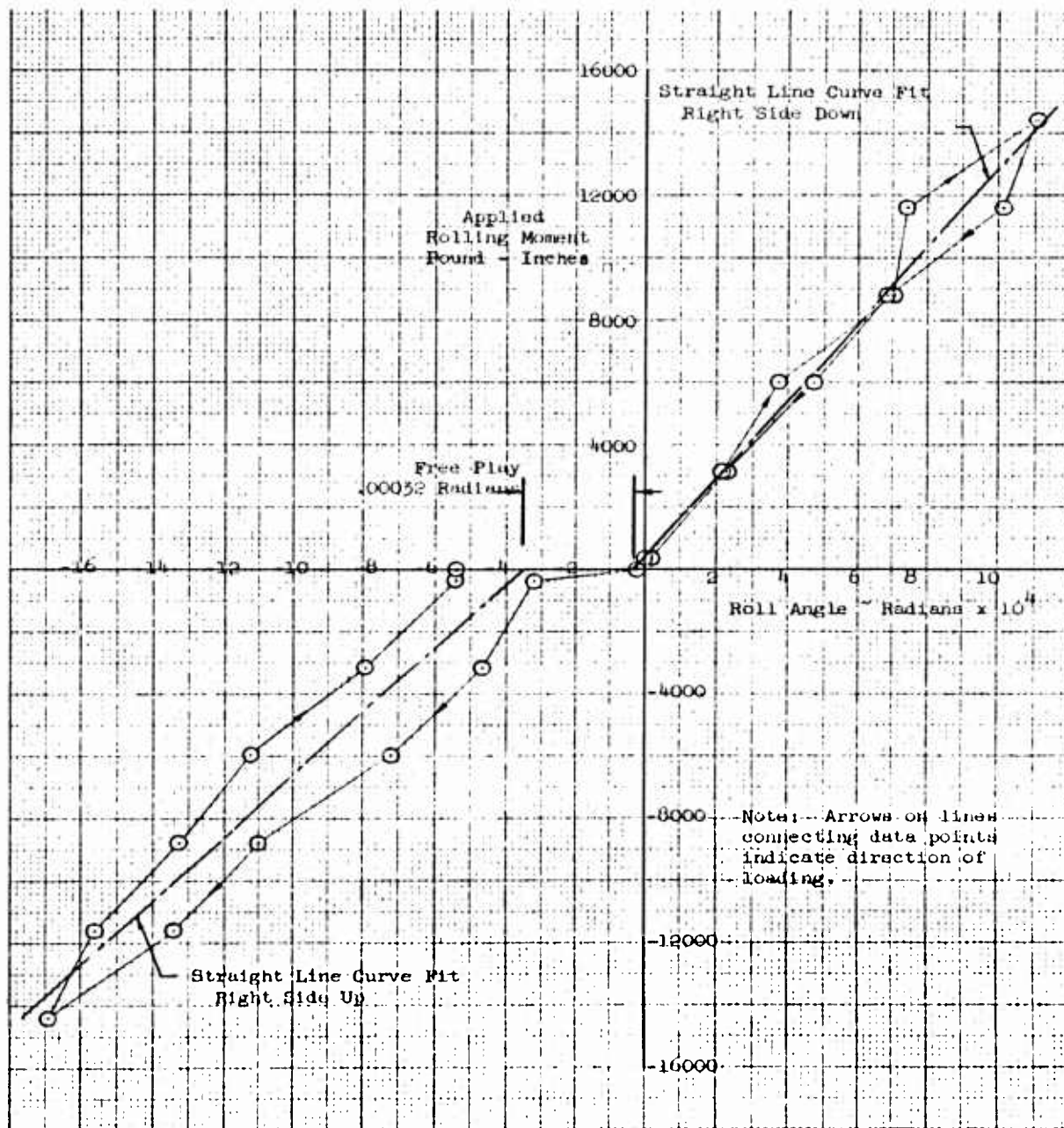


Figure 40. Horizontal Stabilizer - Roll Free Play and Rotational Restraint

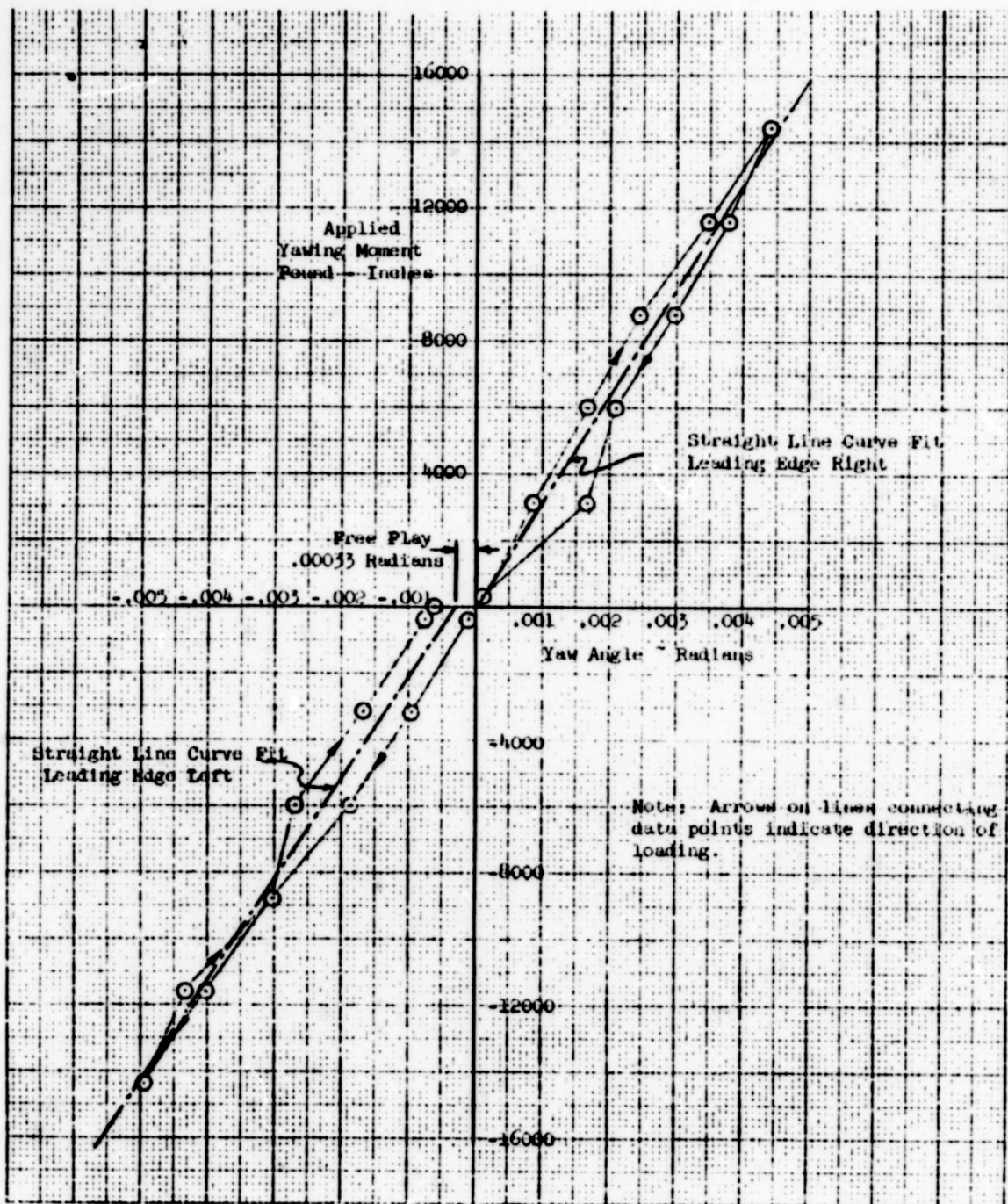
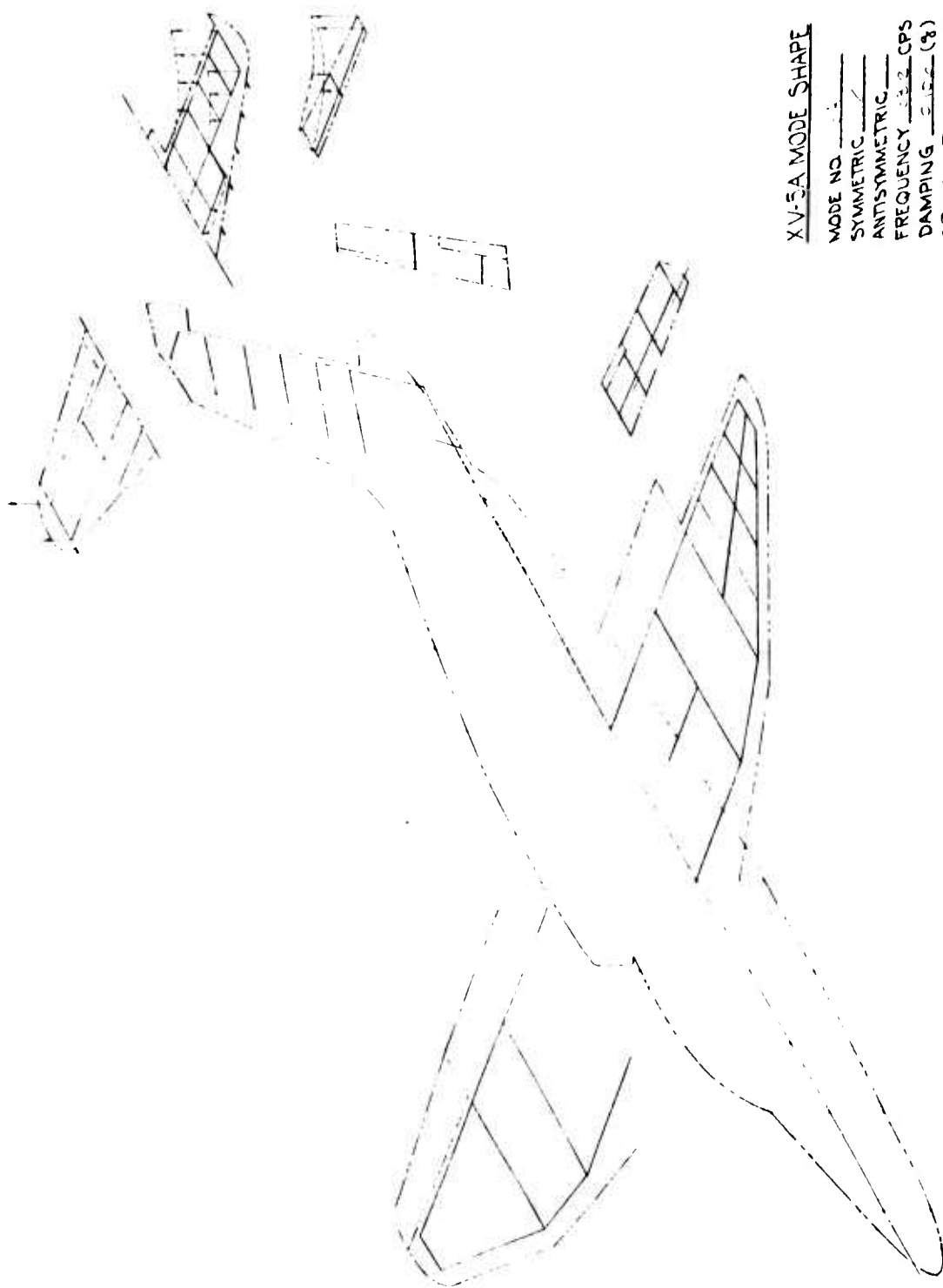


Figure 41. Horizontal Stabilizer - Yaw Free Play and Rotational Restraint



XV-5A MODE SHAPE

MODE NO. 5A
 SYMMETRIC /
 ANTISYMMETRIC /
 FREQUENCY 13.2 CPS
 DAMPING 5.124 (%)
 GROSS WT. LBS

Figure 42 XV-5A Mode Shape - Mode No. 5A

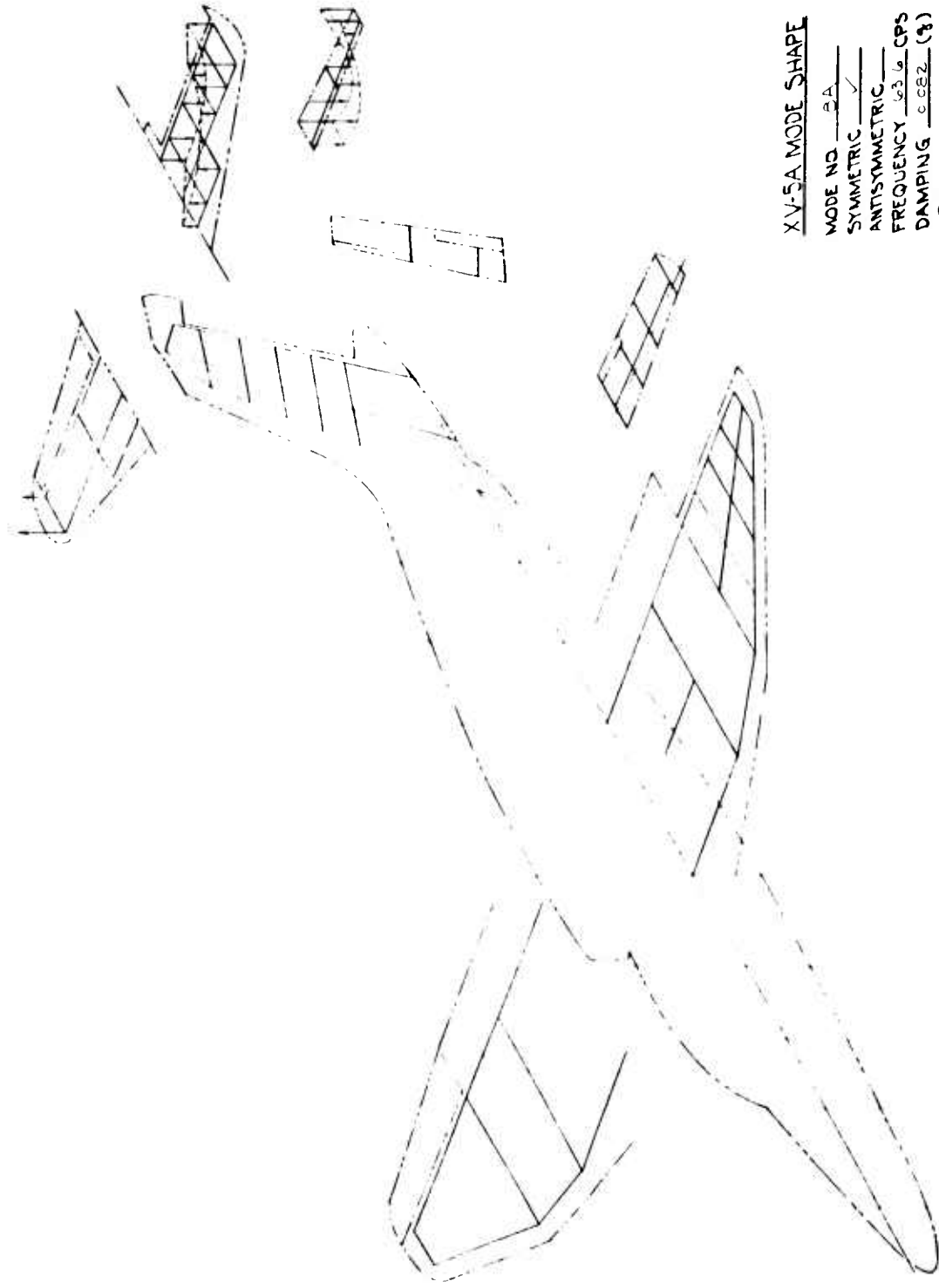
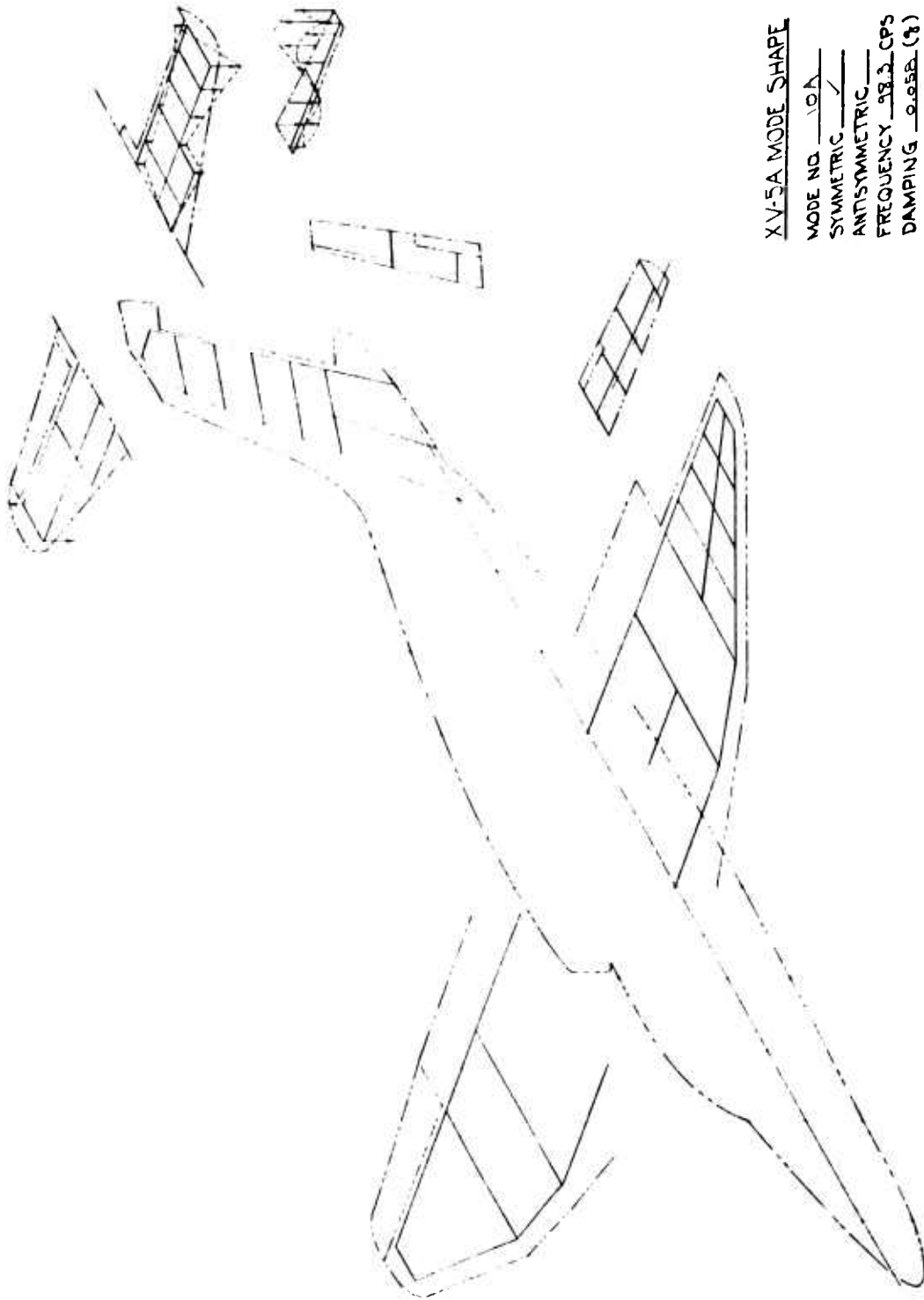


Figure 43 XV-5A Mode Shape - Mode No. 8A



XV-5A MODE SHAPE
 MODE NO. 10A
 SYMMETRIC /
 ANTISYMMETRIC —
 FREQUENCY 98.2 CPS
 DAMPING 0.058 (%)
 GROSS WT — LBS

Figure 44 XV-5A Mode Shape - Mode No. 10A

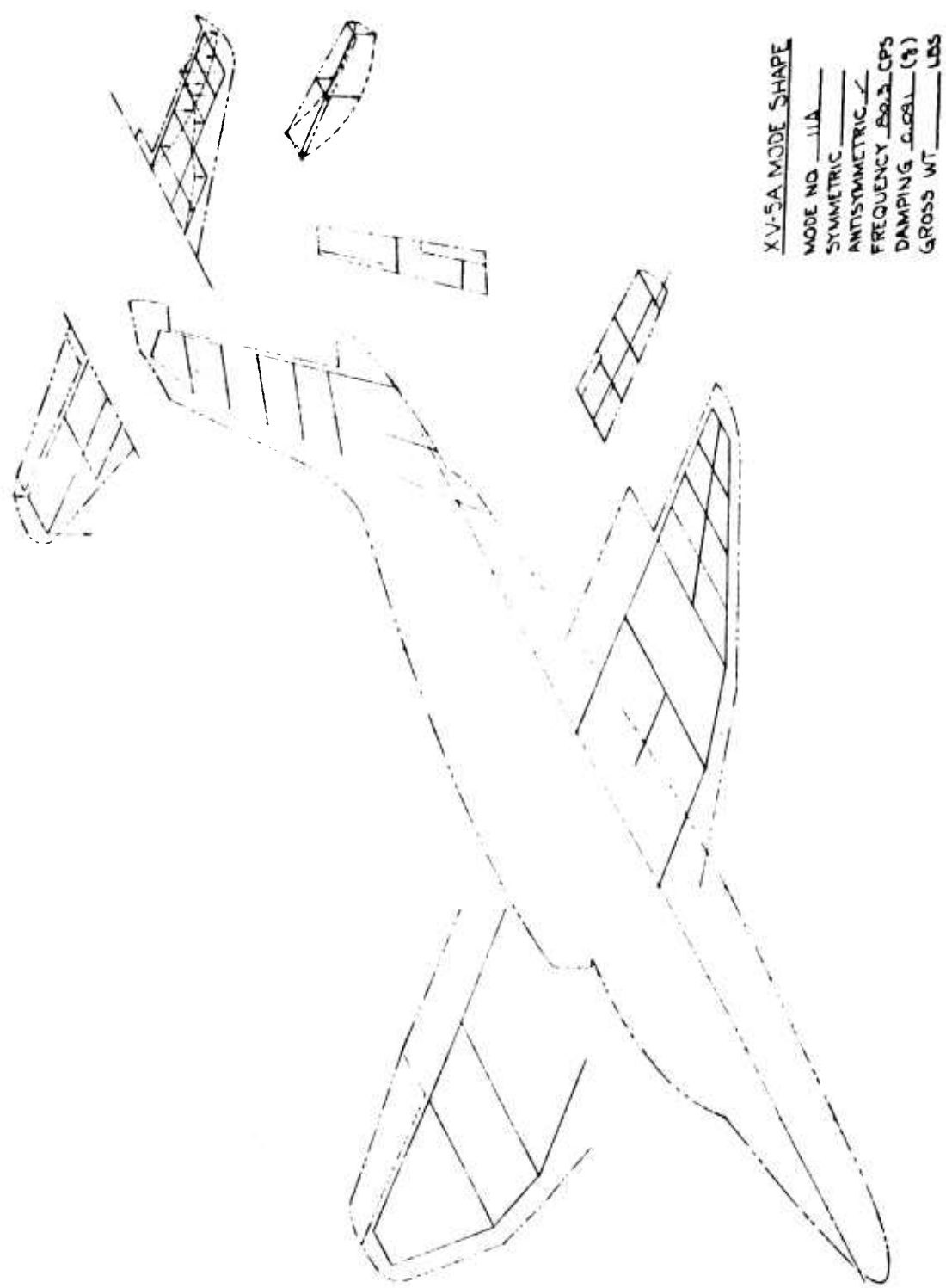


Figure 45 XV-5A Mode Shape - Mode No. 11A

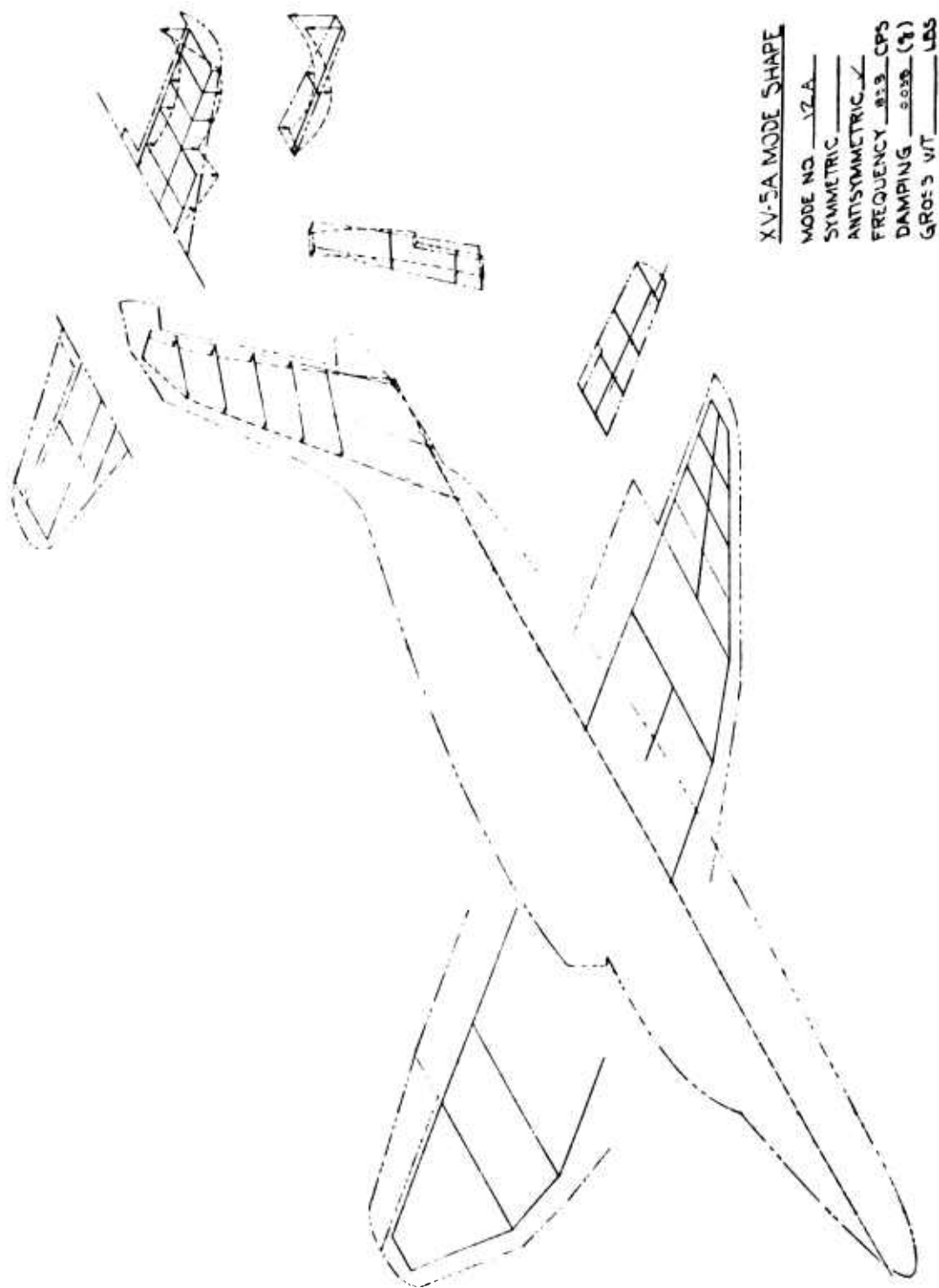


Figure 46 XV-5A Mode Shape - Mode No. 12A

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ADDENDUM A

INTRODUCTION

Flutter considerations of the horizontal tail necessitated a reworking of the horizontal and vertical stabilizers to achieve a higher pitch frequency. Reference 3 presents the results of the preliminary flutter analysis of the empennage. These studies have shown that to meet the 15% flutter margin on the aircraft envelope, a uncoupled pitch frequency of approximately 55 cycles per second was required. The basic ground test of the airplane had shown this mode to be approximately 37 cycles per second, which was deduced from a combination of experimental and analytical results as discussed in Section 5.0. Accordingly, to check the results of the increased stiffness, a vibration test was conducted on the No. 1 aircraft (S/N 62-505) at EAFB during the period of 1 October, 1964 to 8 October, 1964. Emphasis was placed upon empennage characteristics with general checking of other modes in which doubtful areas existed.

TEST CONFIGURATION AND INSTRUMENTATION

The aircraft configuration utilized for this test consisted of the complete aircraft (No. 1, S/N 62-4505), fueled for a gross weight condition of approximately 9700 pounds with a c.g. location at F.S. 243.85. The aircraft was aligned in a level flight attitude simulating the CTOL mode, with all controls locked in neutral by means of the appropriate cockpit control. Wing and pitch fans were blocked to their stator blades by means of shock chord. To provide a soft mount the aircraft tires were reflat to 125 psig for the main gear and to 90 psig for the nose gear. The nose gear shock strut was filled with hydraulic fluid with locking bars intalled to eliminate the damping action of the strut.

Shaker equipment consisted of two (2) MB Model PT 112537 exciters with associated equipment. Recording instrumentation was similar to that used during the initial ground vibration test, except that one accelerometer (Endevco Model 2213) was used for modal surveys with one accelerometer used as a fixed reference.

TEST PROCEDURE

In general, the test procedure followed that of the first ground vibration test. Initial frequency sweeps of the empennage were made utilizing the

two shakers at positions noted in Figure 4. Resonances were noted from the resulting response plots and modal surveys of the aircraft were made utilizing pickup locations as noted in Figures 5 through 9 upon establishment of the mode. Final oscillograph records were taken of the fixed instrumentation at the conclusion of the survey for frequency and damping values.

RESULTS AND CONCLUSIONS

Excitation of the aircraft by hand produced the following rigid body aircraft modes:

Pitch	2.67 cps
Vertical Translation	3.70 cps
Yaw	1.67 cps
Roll	1.54 cps
Side Translation	1.40 cps

From these results, it was concluded that aircraft suspension frequencies were adequate in view of the elastic modes determined from the first aircraft shake test.

Since stiffening of the horizontal tail pitch restraint is directly tied to symmetric vibration modes of the horizontal tail, initial emphasis was to find the equivalent modes as measured during the initial ground vibration test. The tail modes were numbered Modes 5, 8 and 10. (See Table 3) and were found to be primarily horizontal tail bending, horizontal tail pitch-torsion and a higher tail mode of primarily bending. The results of the second test showed the following in comparison to the original modes:

	1st TEST		2nd TEST	
	f	g	f	g
	cps		cps	
Mode 5	31.3	0.031	33.2	0.106
Mode 8	55.9	0.033	63.6	0.082
Mode 10	90.3	0.031	98.3	0.058

These modes are shown in Figures 14, 17 and 19 and are tabulated in Tables 8, 11 and 13 for the first test, whereas the results of the second test are shown in Tables 27, 28 and 29, with pictorial views shown in Figures 42, 43 and 44. Comparison of the modes show that although mode shapes are similar, frequencies have increased due to the stiffening. Neglecting differences between the two airplanes which might explain the

fifth mode frequencies, it was concluded that the second set of modes do actually represent the stiffening effect. As previously, a true uncoupled pitch mode was not readily determined. In order to determine the uncoupled pitch mode frequency, calculations were performed, on a modal coupling basis and correlated to the experimental results. These results indicate that an uncoupled pitch frequency of 47 cycles per second in turn coupled with a first bending mode (calculated) of 40.5 cycles per second and a first torsional mode (calculated) of 81.6 cycles per second, yielded as the first and second coupled frequencies 33+ and 63+ cycles per second respectively, which is in good agreement with the experimental results. The third coupled mode (calculated) yielded approximately 127+ cycles per second, whereas the third experimental proved to be 98.3 cycles per second. This was felt to be insignificant in that the flutter mode of concern was the pitch-torsion mode. The technique of modal coupling yields progressively poorer results for the higher modes.

The antisymmetric vibration test showed that the stiffening also played a part in changing the torsional characteristics of the horizontal stabilizer. The initial mode indicated a frequency of 72.9 cycles per second (shown in Figure 30 and Table 24) whereas the stiffening raised this to 80.3 cycles per second. The latter mode is tabulated in Table 30 and a pictorial view is shown in Figure 45.

Figure 46 depicts a higher antisymmetric bending mode of 89.8 cps per second with the mode shape tabulated in Table 31. This mode had been noted at approximately 77 cycles per second in the initial test, but had not been surveyed due to the relative unimportance of the mode.

Comparison of several modes taken during this second ground test with those obtained during the first ground test indicated no appreciable change due to suspension system restraints i. e. effects of spring-mounted platforms versus deflated gear. Difference in airplanes, that is in stiffness and/or weight were neglected in evaluating this effect.

TABLE 27

SYMMETRIC MODE SHAPE

MODE 5A

 $f = 33.2 \text{ cps}$ $g = 0.106$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	-	LH-1	0.6458	F-1	-	LA-1	-	LE-1	1.0000
LW-2	-	LH-2	0.9667	F-2	-	LA-2	-	LE-2	1.0000
LW-3	-	LH-3	0.4167	F-3	-	LA-3	-	LE-3	0.8625
LW-4	-	LH-4	0.6667	F-4	-	LA-4	-	LE-4	0.8542
LW-5	-	LH-5	0.2083	F-5	-	LA-5	-	LE-5	0.5917
LW-6	-	LH-6	0.4042	F-6	0.0092	LA-6	-	LE-6	0.5625
LW-7	-	LH-7	0.0521	F-7	0.0154	LA-7	-	LE-7	0.3458
LW-8	-	LH-8	0.0250	F-8	0.0238	LA-8	-	LE-8	0.3167
LW-9	-	LH-9	0.1792	F-9	0.0325	LA-9	-	LE-9	0.1250
LW-10	-	LH-10	0.1250	F-10	0.0658	LA-10	-	LE-10	0.1000
LW-11	-	LH-11	0.0417	Wing Fan		LA-11	-	LE-11	0.0625
LW-12	-	LH-12	0.1375	Vert. Defl. + Up		LA-12	-	LE-12	0.0708
LW-13	-	LH-13	0.0417	Position	-				
LW-14	-	LH-19	0.0583	LWF-1	-				
LW-15	-	LH-20	0.1083	LWF-2	-				
LW-16	-	F & A Defl. + Aft.		LWF-3	-				
LW-17	-			LWF-4	-				
LW-18	-			Pitch Fan					
LW-19	-	LH-14	0.1925	Vert. Defl. + Up					
LW-20	-	LH-15	0.1925	Position	-				
LW-21	-	LH-16	0.1925	NF-1	-				
LW-22	-	LH-17	0.1925						
LW-23	-	LH-18	0.1925						

TABLE 28

SYMMETRIC MODE SHAPE
MODE 8A

$f = 63.6 \text{ cps}$ $g = 0.082$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	-	LH-1	1.0000	F-1	0.0130	LA-1	-	LE-1	0.4300
LW-2	-	LH-2	0.5200	F-2	0.0070	LA-2	-	LE-2	0.7300
LW-3	-	LH-3	0.6400	F-3	0.0090	LA-3	-	LE-3	0.2000
LW-4	-	LH-4	0.0700	F-4	0.0050	LA-4	-	LE-4	0.4200
LW-5	-	LH-5	0.3200	F-5	0.0080	LA-5	-	LE-5	0.2000
LW-6	-	LH-6	0.2800	F-6	0.0070	LA-6	-	LE-6	0.1400
LW-7	-	LH-7	0.4700	F-7	0.0050	LA-7	-	LE-7	0.5200
LW-8	-	LH-8	0.1150	F-8	0.0240	LA-8	-	LE-8	0.5700
LW-9	-	LH-9	0.4700	F-9	0.0350	LA-9	-	LE-9	0.8000
LW-10	-	LH-10	0.3500	F-10	0.0300	LA-10	-	LE-10	0.8700
LW-11	-	LH-11	0.5500	Wing Fan		LA-11	-	LE-11	0.7100
LW-12	-	LH-12	0.2900	Vert. Defl. + Up		LA-12	-	LE-12	0.7300
LW-13	-	LH-13	0.5700	Position					
LW-14	-	LH-19	0.0600	LWF-1	-				
LW-15	-	LH-20	0.0530	LWF-2	-				
LW-16	-	F & A Defl. + Aft		LWF-3	-				
LW-17	-			LWF-4	-				
LW-18	-	LH-14	-	Pitch Fan					
LW-19	-	LH-15	-	Vert. Defl. + Up					
LW-20	-	LH-16	-	Position					
LW-21	-	LH-17	-	NF-1	-				
LW-22	-	LH-18	-						
LW-23	-								

TABLE 29

SYMMETRIC MODE SHAPE
MODE 10A

$f = 98.3 \text{ cps } g = 0.058$

Wing		Horiz. Stab.		Fuselage		Aileron		Elevator	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up
LW-1	-	LH-1	0.6613	F-1	-	LA-1	-	LE-1	0.3871
LW-2	-	LH-2	0.2645	F-2	-	LA-2	-	LE-2	0.7903
LW-3	-	LH-3	0.4452	F-3	-	LA-3	-	LE-3	0.6194
LW-4	-	LH-4	0.0742	F-4	-	LA-4	-	LE-4	1.0000
LW-5	-	LH-5	0.2742	F-5	-	LA-5	-	LE-5	0.5387
LW-6	-	LH-6	0.0548	F-6	-	LA-6	-	LE-6	0.7484
LW-7	-	LH-7	0.1935	F-7	-	LA-7	-	LE-7	0.0000
LW-8	-	LH-8	0.1387	F-8	-	LA-8	-	LE-8	0.1000
LW-9	-	LH-9	0.1161	F-9	-	LA-9	-	LE-9	0.4194
LW-10	-	LH-10	0.0645	F-10	-	LA-10	-	LE-10	0.6774
LW-11	-	LH-11	0.1548	Wing Fan		LA-11	-	LE-11	0.2613
LW-12	-	LH-12	0.0516	Vert. Defl. + Up		LA-12	-	LE-12	0.5677
LW-13	-	LH-13	0.1677	Position					
LW-14	-	LH-19	0.0597	LWF-1	-				
LW-15	-	LH-20	0.0226	LWF-2	-				
LW-16	-	F & A Defl. + Aft		LWF-3	-				
LW-17	-			LWF-4	-				
LW-18	-	LH-14	-	Pitch Fan					
LW-19	-	LH-15	-	Vert. Defl. + Up					
LW-20	-	LH-16	-	Position					
LW-21	-	LH-17	-	NF-1	-				
LW-22	-	LH-18	-						
LW-23	-								

TABLE 30

ANTISYMMETRIC MODE SHAPE
MODE 11A

$f = 80.3 \text{ cps}$ $g = 0.091$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)		Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	-	LH-1	1.0000	V-1	-	F-11-12	-	LA-1	-	LE-1	0.4561	R-1	0.0161
LW-2	-	LH-2	0.2805	V-2	-	F-13-14	-	LA-2	-	LE-2	0.2341	R-2	0.0132
LW-3	-	LH-3	0.5366	V-3	-	F-15-16	-	LA-3	-	LE-3	0.7634	R-3	0.0080
LW-4	-	LH-4	0.4122	V-4	-	F-17-18	-	LA-4	-	LE-4	0.4634	R-4	0.0073
LW-5	-	LH-5	0.2317	V-5	-	F-19-20	-	LA-5	-	LE-5	0.8605	R-5	0.0176
LW-6	-	LH-6	0.4634	V-6	-	F-21-22	-	LA-6	-	LE-6	0.5220	R-6	0.0161
LW-7	-	LH-7	0.2707	V-7	-	F-23-24	-	LA-7	-	LE-7	0.7122	R-7	0.0190
LW-8	-	LH-8	0.0732	V-8	-	F-25-30	-	LA-8	-	LE-8	0.3878	R-8	0.0168
LW-9	-	LH-9	0.4183	V-9	-	F-26-31	-	LA-9	-	LE-9	0.3707	R-9	0.0176
LW-10	-	LH-10	0.1341	V-10	-	F-27-32	-	LA-10	-	LE-10	0.1024	R-10	0.0168
LW-11	-	LH-11	0.2610	V-11	-	Wing Fan	Vert. Defl. + Up	LA-11	-	LE-11	0.1317	R-11	0.0088
LW-12	-	LH-12	0.0220	V-12	-			LA-12	-	LE-12	0.0780	R-12	0.0058
LW-13	-	Lat. Defl. + Left	0.0329	V-13	-								
LW-14	-			V-14	-								
LW-15	-			V-15	-	Position							
LW-16	-	LH-12	0.0329	V-16	-	LWF-1	-						
LW-17	-	LH-13	0.0307	V-17	-	LWF-2	-						
LW-18	-	LH-20	0.0095	V-17	-	LWF-3	-						
LW-19	-	F & A Defl. + Aft	0.0095	F-25	-	LWF-4	-						
LW-20	-			F-26	-								
LW-21	-			F-27	-								
LW-22	-				-								
LW-23	-	LH-14	-		-								
		LH-15	-		-								
		LH-16	-		-								
		LH-17	-		-								
		LH-18	-		-								
		F & A Defl. + Aft											
LW-24	-												
LW-25	-												
LW-26	-												
LW-27	-												

* Left Wing Down

TABLE 31

ANTISYMMETRIC MODE SHAPE
MODE 12A

$f = 89.8 \text{ cps } g = 0.038$

Wing		Horiz. Stab.		Vert. Stab.		Fuselage (WL 100)		Aileron		Elevator		Rudder	
Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left	Position	Lat. Defl. + Left	Position	Vert. Defl. + Up	Position	Vert. Defl. + Up	Position	Lat. Defl. + Left
LW-1	-	LH-1	0.1897	V-1	0.1126	F-11-12	-	LA-1	-	LE-1	0.7299	R-1	0.2828
LW-2	-	LH-2	0.6092	V-2	0.1011	F-13-14	-	LA-2	-	LE-2	1.0000	R-2	0.2356
LW-3	-	LH-3	0.3908	V-3	0.0575	F-15-16	-	LA-3	-	LE-3	0.5977	R-3	0.0816
LW-4	-	LH-4	0.0087	V-4	0.1483	F-17-18	-	LA-4	-	LE-4	0.8448	R-4	0.0414
LW-5	-	LH-5	0.4425	V-5	0.1322	F-19-20	0.0261	LA-5	-	LE-5	0.2184	R-5	0.0804
LW-6	-	LH-6	0.2126	V-6	0.1644	F-21-22	0.0321	LA-6	-	LE-6	0.3563	R-6	0.0989
LW-7	-	LH-7	0.4770	V-7	0.2046	F-23-24	0.0285	LA-7	-	LE-7	0.2609	R-7	0.1356
LW-8	-	LH-8	0.3678	V-8	0.1632	F-25-30	0.0092	LA-8	-	LE-8	0.1839	R-8	0.1322
LW-9	-	LH-9	0.2931	V-9	0.2529	F-26-31	0.0491	LA-9	-	LE-9	0.4138	R-9	0.1264
LW-10	-	LH-10	0.2713	V-10	0.1425	F-27-32	0.1117	LA-10	-	LE-10	0.5517	R-10	0.1333
LW-11	-	LH-11	0.2069	V-11	0.2471	Wing Fan		LA-11	-	LE-11	0.1149	R-11	0.0874
LW-12	-	LH-12	0.2299	V-12	0.1897			LA-12	-	LE-12	0.2253	R-12	0.0770
LW-13	-			V-13	0.0115								
LW-14	-			V-14	0.1425								
LW-15	-	LH-12	0.1804	V-15	0.1678	Position + Up							
LW-16	-	LH-13	0.1322	V-16	0.1759								
LW-17	-	LH-20	0.1552	V-17	0.1494								
LW-18	-			F-25	0.0092								
LW-19	-			F-26	0.0483								
LW-20	-			F-27	0.1037								
LW-21	-	LH-14	0.0057										
LW-22	-	LH-15	0.0115										
LW-23	-	LH-16	0.0161										
		LH-17	0.0218										
		LH-18	0.0264										
		F & A Defl. + Aft											
LW-24	-												
LW-25	-												
LW-26	-												
LW-27	-												

* Left Wing Down