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FLUTTER TESTS (OS1) OF THE 0.02-SCALE SHUTTLE ORBITER WING/ELEVON SEMI-SPAN MODEL 23-0

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by

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National Aeronautics and Space Administration
Houston, Texas

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WIND TUNNEL TEST SPECIFICS:

TEST NUMBER: LARC 26TBT - 545

NASA SERIES NO.: ØS1

TEST DATES: 6/6/73 - 6/10/73

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FLUTTER TESTS (OS1) OF THE

0.02-SCALE SHUTTLE ORBITER WING/ELEVON

SEMI-SPAN MODEL 23-0

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ABSTRACT

A series of simple wing/elevon flutter models of the Shuttle Orbiter were tested in the NASA Langley Research Center's 26-inch Transonic Blowdown Tunnel. Flutter points were obtained for two levels of scaled elevon actuator stiffness. This report makes no attempt to analyze the data obtained or draw a correlation to the actual vehicle; it provides a description of the wind tunnel models and the test procedures utilized in this experiment.

Descriptors

Aeroelasticity

Flutter

Space Shuttle

Wind Tunnel Models

Wind Tunnel Testing

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SECTION 1.

INTRODUCTION

This report describes the results of Test ØS1 (TBT Test #545) conducted in the NASA Langley Research Center (LRC) 26-inch Transonic Blowdown Tunnel (TBT) during the period of 6 through 10 August 1973. The configuration tested was the Space Shuttle Orbiter wing/elevon flutter Model 23-0. Purpose of the test was to acquire, early in the design process, experimental flutter boundary data in the transonic flight regime to support analytical flutter predictions. Grumman Aerospace Corporation (GAC) was responsible for model construction and for analyzing the test results, which includes a correlation with analytical data obtained subsonically with the Wright-Patterson doublet-lattice computer program (AFFDL-TR-71-5), converted to a flutter program in Task NAS9-10635-10, and supersonically with the Mach Box method.

Preliminary model flutter boundaries (M vs q) are presented for two levels of simulated model elevon actuator stiffness. These boundaries include flutter points in the subsonic and transonic flight regime. Also included in this report are descriptions of the models and their properties and a presentation of tunnel test conditions and results.

All material presented herein is unclassified.

SECTION 2.

REMARKS

A total of thirty runs was completed in seventy-two occupancy hours for this test including nine hours for model installation.

The most frequent model flutter damage was loss of the outboard elevon. In these cases, the damaged models were quickly repaired with spare hinges and elevons. During runs #22 and #27, flutter was violent enough to fracture the wing frame of two models (#1 and #2). Post-run frequency checks were used to detect any non-visible model damage.

During run #2 the oscillograph paper jammed due to a defective supply roll. Data for this test were lost. Several of the model instrumentation signals were lost during runs #9, #14, and #28, due to high-speed flow in the test section plenum which pulled the model wiring out of its protective sheath. These occurrences required a change of the model wiring protection system during high Mach number test conditions.

Erratic traces of the model torsion signal, experienced on numerous occasions, were found to be due to faulty tunnel cabling. The problem was never severe enough to require repair. A similar situation with the tunnel total temperature thermocouple was corrected by switching to a backup thermocouple.

Camera coverage of the model was obtained for runs 3, 10, 12, 13, 23, 27 and 29. Film from these runs was edited and copies sent to SD, GAC, and NASA-LRC.

SECTION 2. - Continued

During the test, it was felt that the flow over the model was not sufficiently turbulent to excite flutter when the model initially entered the flutter boundary. For example, Runs 4 and 20 in Figure 11 show low response even when well into the flutter region noted. To insure turbulent flow, grit was applied to the leading edge of wing #2 for run 22. During this run divergent flutter was experienced, indicating the grit may have had an effect. Because of the lengthy time required to apply the grit and the test objectives had been reasonable attained, the test was completed without transitions strips on the model.

High frequency, low amplitude oscillations were noted at several points in the test (see Run 12 in the run schedule). It was felt at the time that these oscillations may have been due to some unique arrangement of shock waves in the tunnel. However, it was found using Reference 1 that no shock wave effects because of tunnel/model geometry were indicated but that a high subsonic buzz condition might have existed for the elevons. Reference 2 provides a descriptive outline of the possible buzz mechanism.

SECTION 3.

APPARATUS

3.1 Test Facility

NASA-LRC 26-inch TBT description provided by Chrysler (found in 3.1 of DMS-DR-2067).

3.2 Model Description

Model 23-0 was a 0.02-scale semi-span model of the Shuttle wing/elevon. The predicted full-scale frequency ratios (fi/f1) and node lines of the flutter critical modes were simulated to assure that the experimental flutter mechanism was closely similar to that predicted by analysis.

Models simulating two full-scale wing/elevon configurations were fabricated. The simulated configurations were the basic wing and;

1) 11 Hz inboard and 13.5 Hz outboard elevon rotation frequencies.
2) 11 Hz inboard and 11 Hz outboard elevon rotation frequencies.

The elevon frequencies were selected on the basis that an upper limit of approximately 14 Hz on the full scale configuration could be achieved because of elevon/wing back-up structure flexibility.

The full-scale stiffness distribution was used as the primary design guide for the models, with mass distribution playing a secondary role in achieving the desired frequency ratios and mode shapes. Stiffness distribution on the model was obtained by properly locating cutouts in a tapering thickness aluminum alloy plate.

Aerodynamic contour was achieved by shaping end-grain balsa wood bonded to the plate to minimize the stiffness contribution of the balsa wood. The balsa was sealed with a sanding sealer for surface smoothness and protection. Mylar strips were attached to the wing leading edge to insure against flow penetration between the balsa and the base plate, and to provide distinctive contrast of the wing for the movie film. The elevon trailing edge was also painted orange for contrast.

The elevon frequencies mentioned above were simulated by beryllium-copper flexures attached at the wing/elevon interface. For the 11 Hz/13.5 Hz configuration, flexure thicknesses were 0.050-inch for both the inboard and outboard elevons, designated (50/50) configuration. For the 11 Hz/11Hz configuration, flexure thicknesses were 0.050-inch and 0.040 inch, respectively, designated (50/40) configuration.

The elevons were attached to the wing by hinges at the inboard and outboard ends of each elevon, which defined the elevon hinge line. Each hinge consisted of two small flexures which restrained any elevon movement except rotation. Since the hinges acted as a torsional spring, contributing to the rotational frequency, they were installed during the pretest tuning of the elevon frequencies. As there was no shear tie between elevons, each elevon/hinge/flexure assembly simulated its own rotational frequency.

To simulate a slab wing, steel flexures were installed on the elevons, and the flexible hinges were replaced by tight fitting pins. This raised the elevon frequencies sufficiently that the elevon rotation would not be a part of the flutter mechanism.

The following model items were available for this test:

- 8 wing/elevon assemblies (Nos. 1-8)
- 6 spare elevon sets (Nos. 9-14)
- 3 spare elevon hinge assemblies
- 5 spare elevon flexure sets (11 Hz/13.5 Hz)
- 5 spare elevon flexure sets (11 Hz/11 Hz)
- 2 steel (rigid) elevon flexure sets

3.3 Model Nomenclature and Dimensional Data

Nomenclature for Model 23-0 is as follows:

W_{113}	Wing
E_{24}	Elevon
X_{17}	Transition Strip

The following two pages tabulate dimensional data for the wing and the elevon, based on the VL70-000139 lines study-orbiter, modified to exclude camber, twist, and dihedral. Also, the thickness distribution from Y_0 = 108 to Y_0 = 199.045 has been reduced to agree with the Model 30-OTS design (see Reference 3) - to assure continuity at the wing/body interface.

Page 10 describes the location of the transition strip on the wing leading edge.

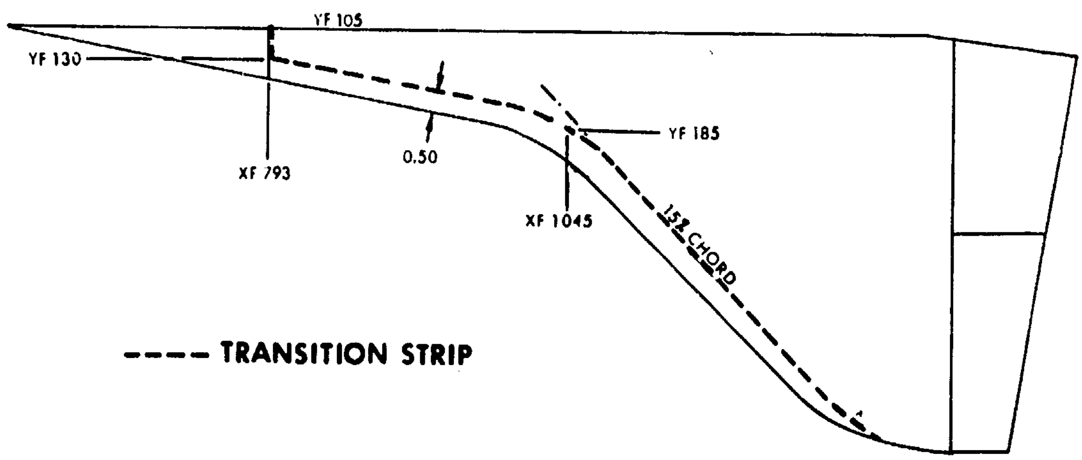
X17 Transition Strip

Description: Wing transition strip is composed of #220 carborundum grit on a base of polaroid Print Coater. Nominal density of grit coverage is 10% of strip area.

Location: (Full-Scale Stations)

Strip midline starts at X_f 793, Y_f 105 and extends to X_f 793, Y_f 130. From there the midline follows the leading edge cuff planform, 0.5 in. measured perpendicularly from the cuff leading edge. The line intersects the point X_f 1045, Y_f 185; from this point the midline follows the 15% chord line to the wing tip (see sketch below).

Strip width is 0.10 in.



MODEL COMPONENT: ELEVON - E24

GENERAL DESCRIPTION: Orbiter Configuration 3 modified.

NOTE: Elevon has some planform as E22 with different airfoil thickness for W113

Model Scale = 0.02

DRAWING NUMBER: ____________

DIMENSIONS:	FULL-SCALE	MODEL SCALE
Area - FT^2	205.52	0.0822
Span (equivalent) - IN.	353.34	7.0668
Inb'd equivalent chord	114.78	2.2956
Outb'd equivalent chord	55.00	1.1000
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.208	.208
At Outb'd equiv. chord	.400	.400
Sweep Back Angles, degrees		
Leading Edge	0.00	0.00
Tailing Edge	-10.24	-10.24
Hingeline	0.00	0.00
Area Moment (Normal to hinge line)- FT3	1548.07	0.01238

MODEL COMPONENT: WING-W 113

GENERAL DESCRIPTION: Orbiter Configuration 3 Modified

NOTE: Same planform as W103 (VL70-000139), except no dihedral, incidence, twist, or camber. *Aft of .40C: Straight line extrapolation from Y_o = 199.0. Forward of .40C: 0006.5-64 Mod to match thickness of section aft of .40C.

Model Scale =

TEST NO. DWG. NO.

DIMENSIONS:

	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.) Ft^2		
Planform	2690.00	1.0760
Span (Theo In.	936.68	18.7336
Aspect Ratio	2.265	2.265
Rate of Taper	1.177	1.177
Taper Ratio	0.200	0.200
Dihedral Angle, degrees	0	0
Incidence Angle, degrees	0	0
Aerodynamic Twist, degrees	0	0
Sweep Back Angles, degrees		
Leading Edge	45.00	45.00
Trailing Edge	-10.24	-10.24
0.25 Element Line	35.209	35.209
Chords:		
Root (Theo) B.P.O.O.	689.24	13.7848
Tip, (Theo) B.P.	137.85	2.7570
MAC	474.81	9.4962
Fus. Sta. of .25 MAC	1136.89	22.7378
W.P. of .25 MAC	299.20	5.9840
B.L. of .25 MAC	182.13	3.6426
EXPOSED DATA		
Area (Theo) Ft^2	1752.29	0.7009
Span, (Theo) In. BP108	720.68	14.4136
Aspect Ratio	2.058	2.058
Taper Ratio	0.2451	0.2451
Chords		
Root BP108	562.40	11.2480
Tip 1.00 $\frac{b}{2}$	137.85	2.7570
MAC	393.03	7.8606
Fus. Sta. of .25 MAC	1185.31	23.7062
W.P. of .25 MAC	300.20	6.0040
B.L. of .25 MAC	251.76	5.0352
Airfoil Section (Rockwell Mod NASA) XXXX-64		
Root $\frac{b}{2}$ = @ Y_o = 108	*	*
Tip $\frac{b}{2}$ =	0.120	0.120
Data for (1) of (2) Sides		
Leading Edge Cuff Planform Area Ft^2	120.33	2.4066
Leading Edge Intersects Fus M. L. @ Sta	560.0	11.2000
Leading Edge Intersects Wing @ Sta	1035.0	20.7000

3.4 Model Drawings

Model drawings describing this model are as follows:

Number	Title
SS-S-00275	General Arrangement; Wall and Splitter Plate Supports
SS-S-00326	Basic Wall Mount and Side Plate
SS-S-00328	Wing - Assembly
SS-S-00329	Wing - Elevon
SS-S-00330	Wing/Elevon Fittings
SS-S-00332	No. 1 - Wing/Elevon Fittings
SS-S-00333	No. 2 - Wing/Elevon Fittings
SS-S-00334	No. 3 - Wing/Elevon Fittings
SS-S-00335	No. 4 - Wing/Elevon Fittings
SS-S-00336	Flexures

Model drawings are available from GAC. Reduced drawings of the general arrangement and the wing/elevon are included in this report (Figures 1 and 2). Checkout of test items is summarized in Reference 5.

3.5 Instrumentation

Instrumentation on the model consisted of two strain gage circuits of four gages each and two magnet-induction coil pickups. The strain gages were located near the wing root and were used to measure wing bending and torsion. The magnet-induction coils are located between the wing and the elevon to detect elevon rotation. Figure 3 illustrates the model instrumentation locations.

Tunnel parameter instrumentation consisted of two static pressure transducers, one total pressure transducer, and two total temperature thermocouples (one spare).

One high-speed (1000 frames/sec) movie camera was set up to view the model from the side and record any model dynamic instability.

Model and tunnel parameter instrumentation was input through amplifiers and signal conditioners. Resultant output was recorded on a high-speed oscillograph. Also recorded on the oscillograph was a static pressure reference, a 60 Hz frequency reference, and a "camera-on" reference.

Additional instrumentation required for pre- and post-run frequency and damping checks was provided by LRC. This included a dual-beam oscilloscope, a variable-frequency oscillator, an electromechanical shaker, and a suitable amplifier to drive the shaker.

Figure 4 illustrates, in block diagram form, the arrangement of the test instrumentation.

3.6 Model Installation

The model was installed on a splitter plate to isolate the model from boundary layer at the tunnel wall. The plate was mounted on the starboard wall of the test section, looking upstream (see General Arrangement drawing; see also Figures 5 and 6).

SECTION 4.
PROCEDURE

4.1 Test Conditions

Model 23-0 was tested at nominal Mach numbers of 0.55 to 1.3, and nominal dynamic pressures of 2 to 30 psi. The actual test conditions for each run is shown on the run schedule (Table 1).

4.2 Test Procedure

The general procedure adhered to for each run was as follows:

1. Install and visually inspect the model in the tunnel.
2. Perform sign checks of model instrumentation.
3. Perform the pre-run frequency and damping checks.
4. Make preparations to achieve the desired tunnel operating conditions (Mach number and total pressure).
5. Perform instrumentation and system checks, including pre-run pressure transducer and thermocouple calibrations.
6. Begin run, starting camera at pre-selected total pressure.
7. Shut down the tunnel when the operating limit was reached or when flutter occured. Take post-run calibrations.
8. Perform the post-run model inspection and frequency and damping checks to determine if the model was damaged.

During a series of runs, where the model was not damaged in the prior run, only Steps 4 through 8 were followed.

The sign checks performed in Step 2 above were to assure uniform trace direction on the oscillograph record for all models. The sign convention utilized was:

1. Positive bending - Tip up
2. Positive torsion - Leading edge up
3. Positive elevon rotation - Trailing edge down

The positive direction on the oscillograph traces was always to the right of the zero line, facing the recorder.

The technique utilized to obtain a particular flutter point depended on the region of interest and the known characteristics of the model response in the neighborhood of this region, but always followed one of two approaches:

> One approach was to set a constant nominal Mach number and increase tunnel total pressure (and corresponding dynamic pressure) until the tunnel operating limit or flutter was attained.
>
> The second approach occasionally used, which was felt to minimize the potential for damaging the model, was to slowly increase total pressure to a selected value and then increase or decrease Mach number until flutter was achieved.

This latter approach provided more data points close to the flutter boundary, but used up a greater volume of stored air and did not always achieve the desired Mach number and dynamic pressure due to the operating limitations of the tunnel.

4.3 Data Recording

All tunnel and model instrumentation data was recorded with oscillograph traces, both during the run and during pre-and post-run frequency and damping checks. Pressure and thermocouple calibrations to references, and a thermocouple zero reading, were taken immediately prior to and after a run to provide requisite deflection references for these channels. Since only the dynamic response was of interest for the model instrumentation, no deflection reference for these oscillograph recordings was required (Run #1 cleared the model of any potentially excessive static loads; for this run a nominal load was applied to the model and recorded as a reference for that run). A 60 Hz reference trace was provided, however, to check the model frequencies. Figures 7 and 8 show typical oscillograph traces to flutter, in these cases during Runs 12 and 27.

Model fluctuations during a run were also recorded on high speed movie film, as previously mentioned.

4.4 Data Reduction

Mach number and dynamic pressure data were calculated using the measured freestream static and stagnation pressures from selected points of each run. These data were plotted on a typical operating characteristics chart for the Tunnel (see Figures 9, 10 and 11) and used for determining the conditions for the next run.

Points were selected from each run to be read from the oscillograph traces by LRC personnel, reduced, and printed in tabulated form. Table 2 presents the tabulated data format. The data reduction procedure utilized is summed in the next section.

4.5 Equations and Methods

Constants:

$$C_V = 4290 \text{ ft}^2/\text{sec}^2 - {}^\circ R$$

$$\gamma = 1.4$$

$$R = 1716 \text{ ft}^2/\text{sec}^2 - {}^\circ R$$

$$RHOSL = 0.0023769 \text{ slugs/ft}^3$$

Calculate M:

$$M = \left[\frac{2\left[\left(\frac{Po}{Ps}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}{\gamma - 1}\right]^{1/2}$$

Convert T_o from °F to °R

$$T_o\ (^\circ F) + 459.69 = T_o\ (^\circ R)$$

Calculate T_S:

$$T_S = T_o \left(1 + \frac{\gamma-1}{2} M^2\right)^{-1}$$

Calculate Q:

$$Q = \frac{\gamma}{2} M^2 P_S$$

Calculate A:

$$A = (\gamma R T_S)^{\frac{1}{2}}$$

Calculate V:

$$V = AM$$

Calculate RHO

$$RHO = \frac{2Q}{V^2}$$

Calculate RHO/RHOSL:

$$RHO/RHOSL = \frac{RHO}{RHOSL}$$

Calculate VKEAS:

$$VKEAS = \left[\frac{2 \times Q \times 144\ (in^2/ft^2)}{RHOSL} \right]^{1/2} \quad [0.5921\ (kts/ft/sec)]$$

Calculate μ_o:

$$\mu_o = 2.270 \left[\frac{T_o^{\ 3/2}}{T_o + 198.6} \right] \times 10^{-8} \ \frac{lb\text{-}sec}{ft^2}$$

Calculate RN:

$$RN = \frac{P_o M}{\mu_o} \sqrt{\frac{\gamma}{(\gamma-1)\ C_v\ T_o}} \quad \left(\frac{T_o}{T_s}\right)^{\frac{\gamma-2}{\gamma-1}} \left[\frac{\frac{T_s}{T_o} + \frac{198.6}{T_o}}{1 + \frac{198.6}{T_o}} \right]$$

Above procedures are from Reference 6, with the exception of the VKEAS term, which is found in Reference 7.

SECTION 5.
RESULTS

5.1 Calibration Data

Table A-1, Appendix A, presents the pre- and post-run frequency calibration data acquired during the test. The frequencies shown are close to the model frequencies obtained during the Ground Vibration Survey (GVS) completed prior to the test, with the exception of the circled frequencies, which indicated model damage. GVS frequencies are summed in Table A-2 of the appendix, and node line locations for the models are illustrated in Figures A-1 through A-8. Measured mode shapes for wing #1 with 50-50 flexures are presented in Figures A-9 through A-13 and with 50-40 flexures in Figures A-14 through A-18.

Frequency checks in the tunnel were simplified by being able to manually vibrate the wing to obtain the first three modes, one wing first-bending and the two elevon rotation frequencies. The fourth and fifth modes were excited with the electro-mechanical shaker hand-held at a convenient high-response location. Removal of the shaker enabled the model to shift to its proper frequency (without the shaker mass).

Pre-run frequency examination for Run #30, where steel flexures were utilized and the elevon spring hinges were replaced with solid pins, was complicated by the fact that no prior GVS had been made of this configuration. However, examination of the effects of the flexures on the frequency ratios of the model ($frequency_i$/frequency 1st bending), together with judicious selection of shaker location, allowed acquisition of the first four frequencies, adequate for this particular run.

As previously mentioned, calibrations were made for the tunnel pressure sensors and thermocouple immediately prior to and after each run. These calibrations were utilized in tabulating data for selected points in each run and are not presented explicitly in this report.

5.2 Tabulated Data

Table 3 presents the tabulated data for this test. Mach numbers and dynamic pressures from this data were used for plotting the flutter boundaries illustrated in Figures 10 and 11. Selected tabulated data points of high confidence will be used in the post-test analysis being performed by GAC.

5.3 Preliminary Model Flutter Boundaries

Figures 10 and 11 present preliminary model flutter boundaries for the two simulated elevon actuator stiffness levels. As these boundaries must be corrected to reflect actual flight densities instead of wind tunnel flow densities - part of the GAC final analysis of the data - no conclusions are presented in this report regarding the flutter boundaries except that flutter points were obtained in the subsonic and transonic flow regimes for both simulated elevon actuator stiffness levels. Due to the operating limits of the tunnel and the rapid recovery of the flutter boundary in the supersonic flow region, no flutter points were obtained in this area.

SECTION 6.

REFERENCES

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2. Nakamura, Y. "Some Contributions on a Control-Surface Buzz at High Subsonic Speeds." Journal of Aircraft, V.5, No. 2, 1968, pp 118-125.

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4. Foust, J. W., "Flutter Tests (OS2) of the Shuttle Orbiter Fin/Rudder Model 24-0".

5. Anon., "Model Readiness Review - Shuttle Wind Tunnel Model 23-0" (Letter Contract M3W3XMZ-483002).

6. Ames Research Staff, "Equations, Tables, and Charts for Compressible Flow", NACA Report 1135, 1953.

7. Silbert, H. W., "High Speed Aerodynamics," Prentice-Hall, Inc., New York, 1948, p. 71.

Table 1 Test Run Schedule

RUN NO.	Model Configuration			Flexure[1]		Nominal Mach No.	Dynamic Pressure q	MOVIE	Initial Valve Setting	Comments
	Wing No.	OB Elevon No.	IB Elevon No.	OB	IB					
1	2	2	2	50	50	Var.	Trim & Flutter	B&W	6485	Model trimmed OK/No flutter
2	2	2	2	50	50	0.7	Flutter	↓	4580	No flutter. Oscillograph jammed.
3	2	2	2	50	50	0.8	↓	↓	4725	Intermittent flutter. Model not damaged.
4	2	2	2	50	50	0.9	↓	↓	4875	Low damping. Model not damaged.
5	2	2	2	50	50	1.0	↓	↓	5010	Low damping. IB elevon bottomed out. No camera.
6	5	5	5	40	50	0.8	↓	↓	4875	Divergent flutter. OB elevon damaged.
7	6	6	6	40	50	0.75	↓	↓	4700	Divergent flutter. Camera too late. OB elevon lost.
8	7	7	7	40	50	0.65	↓	↓	4550	Steady-state flutter. Broke OB elevon hinge.
9	7	7	7	40	50	1.25	↓	↓	6435	No flutter. Lost bending & torsion signals. Model OK.
10	7	7	7	40	50	Var.	↓	↓	5070	Steady-state flutter. Model not damaged.
11	7	7	7	40	50	Var.	↓	↓	5000	Low damping. Some hi-freq. osc. Model OK.
12	7	7	7	40	50	Var.	↓	↓	5300	Low damping. Low amplitude, high frequency oscillations. Model not damaged.

1. Numbers in flexure column (40 & 50) refer to thickness of soft and stiff flexures (0.0[illegible] & 0.0[illegible]) respectively.

Table 1 (Continued)

RUN NO.	Model Configuration			Flexure [1]		Nominal Mach No.	Dynamic Pressure q	MOVIE	Initial Valve Setting	Comments
	Wing No.	OB Elevon No.	IB Elevon No.	OB	IB					
13	7	7	7	40	50	Var.	Flutter	B&W	5300	Steady-state & divergent flutter. OB elevon lost and wing damaged.
14	3	3	3	50	50	Var.			5300	Lost bending & torsion signals. Steady-state and intermittent flutter. Model OK.
15	3	3	3	50	50	0.6			4250	No flutter.
16	2	2	2	50	50	Var.			5300	Steady-state flutter. Model not damaged.
17	2	2	2	50	50	0.9			4990	Low damping. Elevons bottomed out (bad hinge).
18	4	4	4	50	50	Var.			5175	Low damping. No camera. Model OK.
19	4	4	4	50	50	0.65			4475	No flutter. Model not damaged.
20	4	4	4	50	50	0.65			4475	No flutter. Model OK.
21	4	4	4	50	50	Var.			4550	Divergent flutter. OB elevon damaged.
22	2	2	2	50	50	Var.			4775	Divergent flutter. OB elevon lost. Grit on wing this run (X17)
23	3	3	3	50	50	Var.			5175	Steady-state & divergent flutter. Lost OB elevon.
24	5	9	5	40	50	0.75			4650	Divergent flutter. OB elevon hinges broken. Camera did not run.

1. Numbers in flexure column (40 & 50) refer to thickness of soft and stiff flexures (0.040 & 0.050) respectively.

Table 1 (Continued)

RUN NO.	Model Configuration			Flexure [1]		Nominal Mach No.	Dynamic Pressure q	MOVIE	Initial Valve Setting	Comments
	Wing No.	OB Elevon No.	IB Elevon No.	OB	IB					
25	8	8	8	40	50	1.4	Flutter	B&W	6448	No flutter. Model not damaged.
26	8	8	8	40	50	Var.			5175	Divergent flutter at shutdown. Model damaged.
27	1	1	1	40	50	0.75			4750	Divergent flutter. Lost OB elevon.
28	4	10	10	50	50	1.4			6485	No flutter. Lost torsion signal. Model OK.
29	4	10	10	50	50	0.65			4400	Divergent flutter. OB elevon damaged.
30	5	9	5	Steel[2]	Steel[2]	0.75			4625	Slab wing simulation. Intermittent flutter. Model not damaged.
NOTE:	OB is	Outboard								
	IB is	Inboard								

1. Numbers in flexure column (40 & 50) refer to thickness of soft and stiff flexures (0.040 & 0.050) respectively.
2. 'Steel' in flexure column refers to steel flexures and pinned hinges used to simulate a slab wing condition.

Table 2 Tabulated Data Format

Col. No.	5	10	16	23	30	36	43	51	58	66	75	83	91	95	101	111
								TBT	TEST	NO. 545	08/13/73	09.03.27				
	RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
	XX	XX	XX.XX	XX.XX	XX.XX	.XXXX	XXX.XX	X.XXX	XX.XX	.XXXXX	XXX.X	XXXX.X	XX.XX	XXX	X.XXX	XX.XXX

Item	Description	Units
RUN	Run number of data point	-
PT	Tabulated data point	-
PA	Atmospheric pressure	psia
H	Tunnel freestream total pressure	psia
P	Tunnel freestream static pressure	psia
P/H	Static/total pressure ratio	-
TS	Tunnel freestream total temperature	^{o}F
M	Tunnel freestream Mach number	-
Q	Tunnel freestream dynamic pressure	psi
RHO	Tunnel freestream density	slugs/ft^3
T	Tunnel freestream static temperature	^{o}R
A	Tunnel freestream speed of sound	ft/sec
V	Tunnel freestream velocity	ft/sec
VKEAS	Tunnel freestream equivalent velocity	knots
RHO/RHOSL	Tunnel/sea level density ratio	-
RN* 1.E6	Tunnel freestream Reynolds number per foot (x 10^6)	(1/ft) x 10^6

James Foost

AUG 13 1973

Preliminary Data
N.A.S.A. LANGLEY

Table 3 Tabulated Data

TBT TEST NO. 545 08/13/73 09.03.27.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
1	1	14.79	24.89	10.87	.4366	73.28	1.156	10.16	.00217	420.6	1005.2	1162	657	.912	7.965
1	2	14.79	31.40	12.21	.3890	62.43	1.244	13.24	.00257	398.7	978.6	1218	750	1.081	10.347
1	3	14.79	35.51	13.33	.3755	54.00	1.271	15.07	.00288	388.3	965.9	1227	801	1.212	11.948
1	4	14.79	35.68	13.56	.3800	49.07	1.262	15.11	.00295	385.9	962.8	1215	802	1.240	12.166
1	5	14.79	44.58	16.92	.3796	34.50	1.263	18.88	.00379	374.7	948.8	1198	896	1.594	15.806
1	6	14.79	50.05	19.16	.3828	24.11	1.256	21.17	.00437	367.7	939.9	1181	949	1.840	18.268
1	7	14.79	48.17	18.83	.3908	14.75	1.241	20.29	.00436	362.7	933.5	1158	929	1.832	18.056
2	1	14.78	25.05	18.93	.7555	47.64	.646	5.52	.00339	468.3	1060.7	685	485	1.427	6.734
2	2	14.78	30.02	22.07	.7351	38.79	.678	7.10	.00406	456.5	1047.3	710	549	1.706	8.519
2	3	14.78	39.43	28.46	.7216	38.43	.699	9.73	.00526	453.8	1044.1	730	643	2.214	11.416
3	1	14.78	31.56	21.28	.6744	46.93	.772	8.87	.00395	452.7	1042.9	805	614	1.660	9.458
3	2	14.78	36.69	24.42	.6655	41.61	.785	10.54	.00459	446.3	1035.4	813	670	1.932	11.253
3	3	14.78	39.09	25.65	.6563	49.07	.800	11.48	.00477	451.1	1041.0	832	699	2.008	11.867
3	4	14.78	41.32	27.34	.6616	46.93	.791	11.98	.00509	450.2	1040.0	823	714	2.143	12.545
4	1	14.78	27.96	17.47	.6248	72.57	.848	8.79	.00315	465.3	1057.3	897	612	1.325	8.231
4	2	14.78	32.07	19.71	.6146	56.82	.864	10.29	.00368	449.5	1039.1	897	662	1.548	9.895
4	3	14.78	38.75	23.08	.5955	54.00	.893	12.89	.00437	443.0	1031.6	922	740	1.839	12.211
4	4	14.78	47.65	28.34	.5948	48.71	.894	15.87	.00543	438.3	1026.1	918	822	2.283	15.229
4	5	14.78	57.07	34.51	.6047	29.50	.879	18.67	.00683	423.7	1008.9	887	891	2.875	19.052
5	1	14.78	25.57	15.45	.6044	51.89	.879	8.37	.00293	443.1	1031.7	907	597	1.231	8.049
5	2	14.78	30.02	17.02	.5671	49.41	.938	10.48	.00330	432.9	1019.8	957	668	1.388	9.747
5	3	14.78	33.61	18.48	.5498	48.36	.965	12.06	.00362	428.2	1014.3	979	716	1.523	11.049
5	4	14.78	35.67	19.71	.5527	43.39	.961	12.74	.00390	424.7	1010.1	970	736	1.639	11.859
5	5	14.78	46.62	25.65	.5502	27.00	.965	16.71	.00525	410.3	992.9	958	843	2.207	16.217
6	1	14.81	33.13	20.19	.6095	59.28	.872	10.74	.00376	450.5	1040.3	907	676	1.582	10.199
6	2	14.81	56.07	33.08	.5900	46.93	.902	18.84	.00637	435.7	1023.1	923	895	2.680	18.062
6	3	14.81	62.23	37.01	.5946	38.43	.895	20.74	.00723	429.4	1015.6	909	939	3.043	20.434
7	1	14.32	24.92	17.29	.6936	108.17	.742	6.67	.00284	511.5	1108.5	823	532	1.193	6.309
7	2	14.82	29.37	19.30	.6572	109.55	.798	8.61	.00321	504.9	1101.4	879	605	1.350	7.704
8	1	14.31	20.97	16.49	.7863	61.72	.596	4.10	.00284	486.8	1081.4	645	418	1.196	5.153
8	2	14.81	32.10	23.11	.7198	48.36	.702	7.97	.00419	462.5	1054.1	740	582	1.764	9.080
8	3	14.81	38.09	27.03	.7095	47.64	.718	9.74	.00493	460.0	1051.2	754	644	2.075	10.940
8	4	14.81	49.55	35.66	.7195	33.07	.702	12.31	.00667	448.5	1038.1	729	724	2.807	14.595
8	5	14.81	52.30	38.13	.7290	29.50	.687	12.61	.00716	447.0	1036.2	712	732	3.012	15.347
8	6	14.81	54.53	39.70	.7280	28.07	.689	13.19	.00748	445.5	1034.5	713	749	3.146	16.084

No cal on T

TBT TEST NO. 545 08/13/73 09.03.27.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
8	7	14.81	52.47	38.35	.7309	24.46	.685	12.58	.00727	442.7	1031.3	706	731	3.059	15.566
9	1	14.79	26.26	10.42	.3967	83.34	1.229	11.02	.00210	417.0	1000.9	1231	685	.882	8.216
9	2	14.79	29.86	11.31	.3790	73.62	1.264	12.65	.00235	404.2	985.4	1245	734	.988	9.560
9	3	14.79	36.19	13.67	.3777	64.89	1.266	15.34	.00289	397.2	976.8	1237	808	1.215	11.844
9	4	14.79	40.98	15.46	.3773	56.46	1.267	17.38	.00332	390.7	968.6	1228	860	1.397	13.706
9	5	14.79	47.32	18.15	.3836	44.82	1.255	20.00	.00397	383.7	960.1	1205	922	1.670	16.322
9	6	14.79	50.23	19.16	.3815	37.36	1.259	21.26	.00426	377.4	952.2	1199	951	1.792	17.674
9	7	14.79	55.54	21.40	.3854	16.19	1.251	23.46	.00496	362.4	933.1	1167	999	2.085	20.727
10	1	14.79	22.32	14.34	.6425	82.66	.821	6.76	.00252	478.0	1071.5	880	536	1.059	6.317
10	2	14.79	26.43	15.35	.5808	79.18	.915	9.02	.00279	461.4	1052.8	965	620	1.175	7.902
10	3	14.79	29.86	16.25	.5442	75.00	.974	10.80	.00303	449.4	1039.0	1012	678	1.276	9.204
10	4	14.79	33.62	17.70	.5266	68.72	1.003	12.46	.00338	440.0	1028.1	1031	728	1.421	10.612
10	5	14.79	34.65	18.49	.5336	65.93	.991	12.72	.00353	439.3	1027.3	1018	736	1.486	10.978
11	1	14.30	20.62	14.80	.7177	85.45	.705	5.15	.00250	495.9	1091.4	769	468	1.054	5.339
11	2	14.80	25.76	15.47	.6007	78.48	.885	8.49	.00279	465.3	1057.2	936	601	1.174	7.611
11	3	14.80	29.69	17.83	.6003	64.54	.885	9.79	.00330	453.1	1043.3	924	645	1.389	9.082
11	4	14.80	29.87	18.39	.6157	61.03	.862	9.57	.00340	453.3	1043.6	900	638	1.432	9.111
11	5	14.80	30.04	19.28	.6420	54.00	.821	9.11	.00358	452.6	1042.8	857	622	1.504	9.125
11	6	14.80	30.38	21.08	.6938	40.55	.742	8.12	.00392	450.6	1040.5	772	588	1.651	9.058
11	7	14.80	30.38	23.99	.7898	15.11	.591	5.86	.00454	443.8	1032.6	610	499	1.908	8.373
12	1	14.82	39.47	17.51	.4436	70.48	1.143	16.02	.00350	420.3	1004.9	1149	825	1.471	12.708
12	2	14.82	39.99	20.76	.5192	58.57	1.015	14.96	.00405	429.8	1016.1	1031	798	1.706	12.967
12	3	14.82	39.99	21.10	.5276	57.86	1.001	14.80	.00411	431.2	1017.7	1019	793	1.728	12.964
12	4	14.82	39.99	25.69	.6426	47.29	.821	12.11	.00483	446.8	1036.0	850	718	2.030	12.352
12	5	14.82	39.99	29.28	.7323	37.36	.682	9.54	.00540	454.7	1045.2	713	637	2.273	11.438
13	1	14.82	24.24	12.91	.5329	86.83	.993	8.91	.00237	456.6	1047.3	1040	615	.999	7.300
13	2	14.82	49.92	21.66	.4339	57.52	1.161	20.42	.00446	407.4	989.4	1148	932	1.877	16.627
13	3	14.82	50.60	23.00	.4545	49.76	1.124	20.34	.00475	406.7	988.5	1111	930	1.997	17.141
13	4	14.82	49.40	26.03	.5269	37.00	1.002	18.30	.00528	413.6	996.8	999	882	2.222	16.916
13	5	14.82	49.57	26.25	.5296	35.93	.998	18.30	.00533	413.3	996.5	994	882	2.243	17.003
13	6	14.82	49.74	29.95	.6021	26.29	.883	16.35	.00598	420.4	1005.0	887	834	2.515	16.784
13	7	14.82	50.09	31.19	.6226	24.11	.851	15.82	.00619	422.6	1007.5	858	820	2.606	16.735
14	1	14.80	43.73	18.84	.4307	74.31	1.165	17.94	.00377	419.8	1004.2	1171	873	1.584	13.969
14	2	14.80	54.18	26.46	.4884	27.71	1.066	21.04	.00559	397.2	976.8	1041	946	2.352	19.299
14	3	14.80	54.86	28.59	.5211	20.52	1.012	20.48	.00602	398.6	978.6	990	933	2.532	19.695

TBT TEST NO. 545 08/13/73 09.03.27.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
14	4	14.80	54.69	29.04	.5309	19.79	.996	20.15	.00609	400.1	980.5	976	926	2.562	19.589
14	5	14.80	52.81	30.49	.5775	11.11	.922	18.13	.00636	402.5	983.3	906	878	2.675	18.896
14	6	14.80	50.58	30.49	.6029	7.50	.882	16.60	.00633	404.3	985.5	869	840	2.663	17.972
15	1	14.78	36.18	29.35	.8113	85.10	.555	6.32	.00480	513.2	1110.4	616	519	2.019	7.975
15	2	14.78	44.91	35.97	.8008	76.07	.572	8.25	.00600	502.8	1099.1	629	592	2.525	10.347
15	3	14.78	61.52	49.08	.7979	56.46	.577	11.45	.00851	483.9	1078.2	622	698	3.581	14.963
15	4	14.78	67.00	54.35	.8113	39.86	.555	11.71	.00969	470.6	1063.3	590	706	4.078	16.513
16	1	14.78	25.57	12.76	.4992	88.21	1.048	9.81	.00238	449.3	1038.9	1089	646	1.003	7.777
16	2	14.78	36.69	16.13	.4395	72.57	1.151	14.94	.00322	420.8	1005.5	1157	797	1.353	11.759
16	3	14.78	43.03	18.82	.4373	56.82	1.155	17.56	.00387	407.8	989.8	1143	864	1.629	14.352
16	4	14.78	44.23	20.61	.4660	36.29	1.104	17.58	.00434	398.8	978.8	1081	865	1.825	15.488
16	5	14.78	43.88	22.85	.5207	29.14	1.012	16.39	.00473	405.7	987.2	999	835	1.989	15.389
16	6	14.78	44.23	23.08	.5218	28.43	1.011	16.50	.00478	405.3	986.8	997	838	2.010	15.532
16	7	14.78	43.88	23.41	.5335	27.00	.992	16.11	.00483	406.7	988.5	980	828	2.032	15.391
17	1	14.77	24.19	15.44	.6385	83.00	.827	7.39	.00271	477.4	1070.9	886	561	1.142	6.863
17	2	14.77	25.07	15.89	.6096	79.54	.872	8.45	.00285	468.1	1060.5	924	599	1.198	7.635
17	3	14.77	38.40	21.50	.5599	63.14	.949	13.56	.00407	443.0	1031.6	979	759	1.713	12.089
17	4	14.77	45.78	25.42	.5433	44.46	.976	16.94	.00504	423.5	1008.7	984	849	2.119	15.586
18	1	14.78	26.94	14.22	.5279	78.14	1.001	9.96	.00266	448.1	1037.6	1038	651	1.120	8.303
18	2	14.78	34.47	16.69	.4841	71.17	1.073	13.45	.00325	431.5	1018.1	1093	756	1.365	10.980
18	3	14.78	34.64	21.39	.6176	54.71	.859	11.05	.00401	448.3	1037.7	891	686	1.685	10.721
19	1	14.78	42.69	32.04	.7507	66.64	.653	9.58	.00554	484.9	1079.4	705	638	2.333	11.026
19	2	14.78	54.86	41.12	.7499	30.57	.655	12.34	.00764	451.6	1041.6	682	724	3.215	15.554
19	3	14.78	57.41	43.37	.7554	12.57	.645	12.67	.00835	435.9	1023.3	661	734	3.512	16.949
20	1	14.78	50.22	36.98	.7363	85.79	.676	11.83	.00621	499.8	1095.8	741	709	2.612	12.662
20	2	14.78	55.53	41.24	.7426	72.21	.666	12.81	.00708	488.6	1083.4	722	738	2.980	14.326
20	3	14.78	64.77	48.52	.7491	32.00	.656	14.61	.00899	452.8	1042.9	684	788	3.784	18.321
20	4	14.78	59.46	44.60	.7500	16.19	.654	13.37	.00854	438.3	1026.2	672	754	3.592	17.531
21	1	14.78	39.09	27.56	.7050	97.17	.725	10.13	.00459	503.9	1100.3	797	656	1.931	10.010
21	2	14.78	48.68	34.62	.7112	90.28	.715	12.39	.00582	499.0	1094.8	783	726	2.450	12.567
21	3	14.78	51.59	36.75	.7124	87.86	.713	13.09	.00621	497.0	1092.7	779	746	2.611	13.374
21	4	14.78	53.81	37.98	.7059	85.45	.723	13.91	.00646	493.5	1088.8	788	769	2.717	14.147
22	1	14.74	39.74	24.60	.6192	102.69	.857	12.64	.00421	490.4	1085.4	930	733	1.771	10.941
22	2	14.74	43.67	26.85	.6147	100.62	.864	14.01	.00462	487.6	1082.3	935	772	1.944	12.124
23	1	14.72	39.37	17.63	.4479	97.86	1.136	15.92	.00334	443.2	1031.9	1172	823	1.405	11.855

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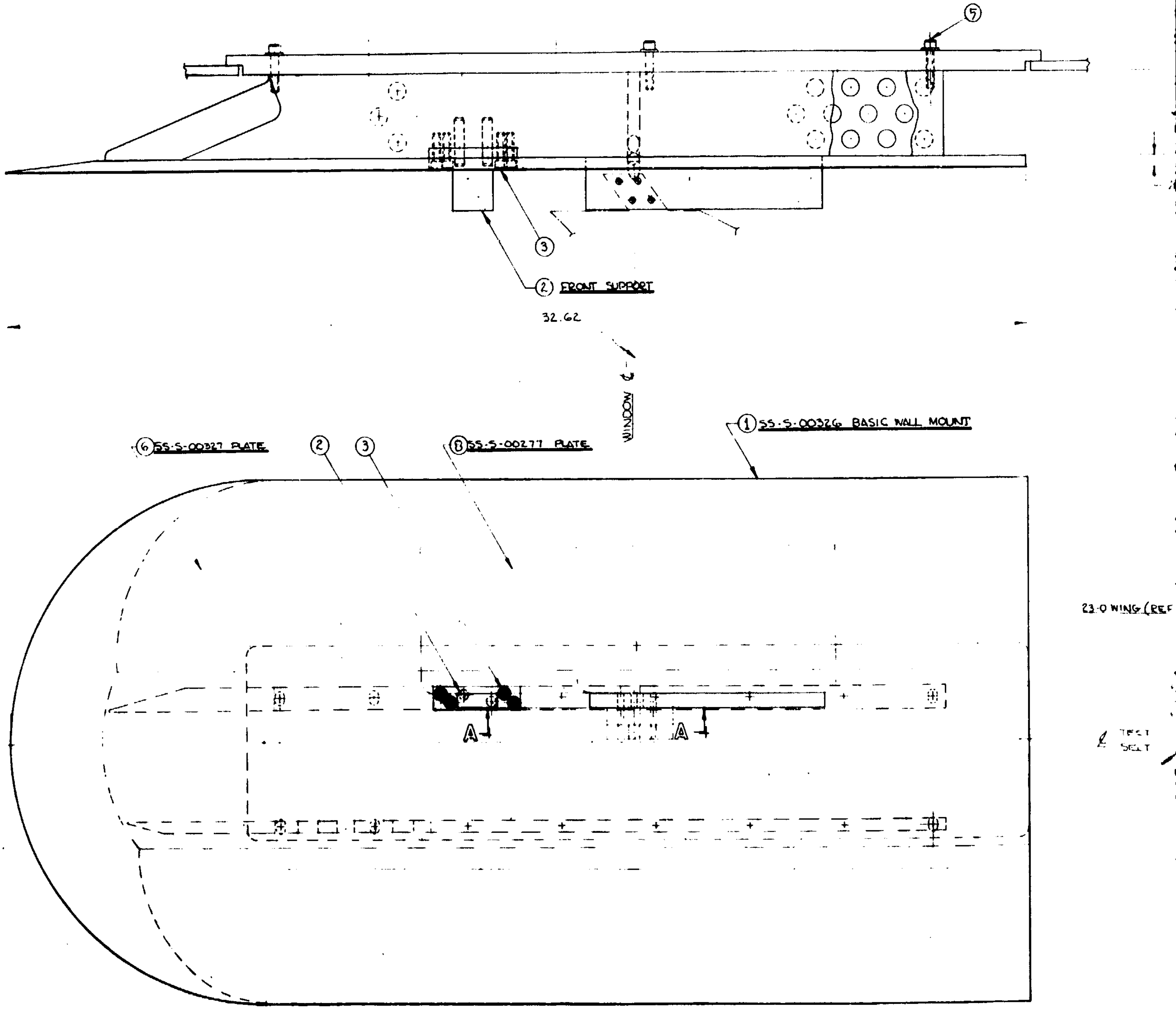
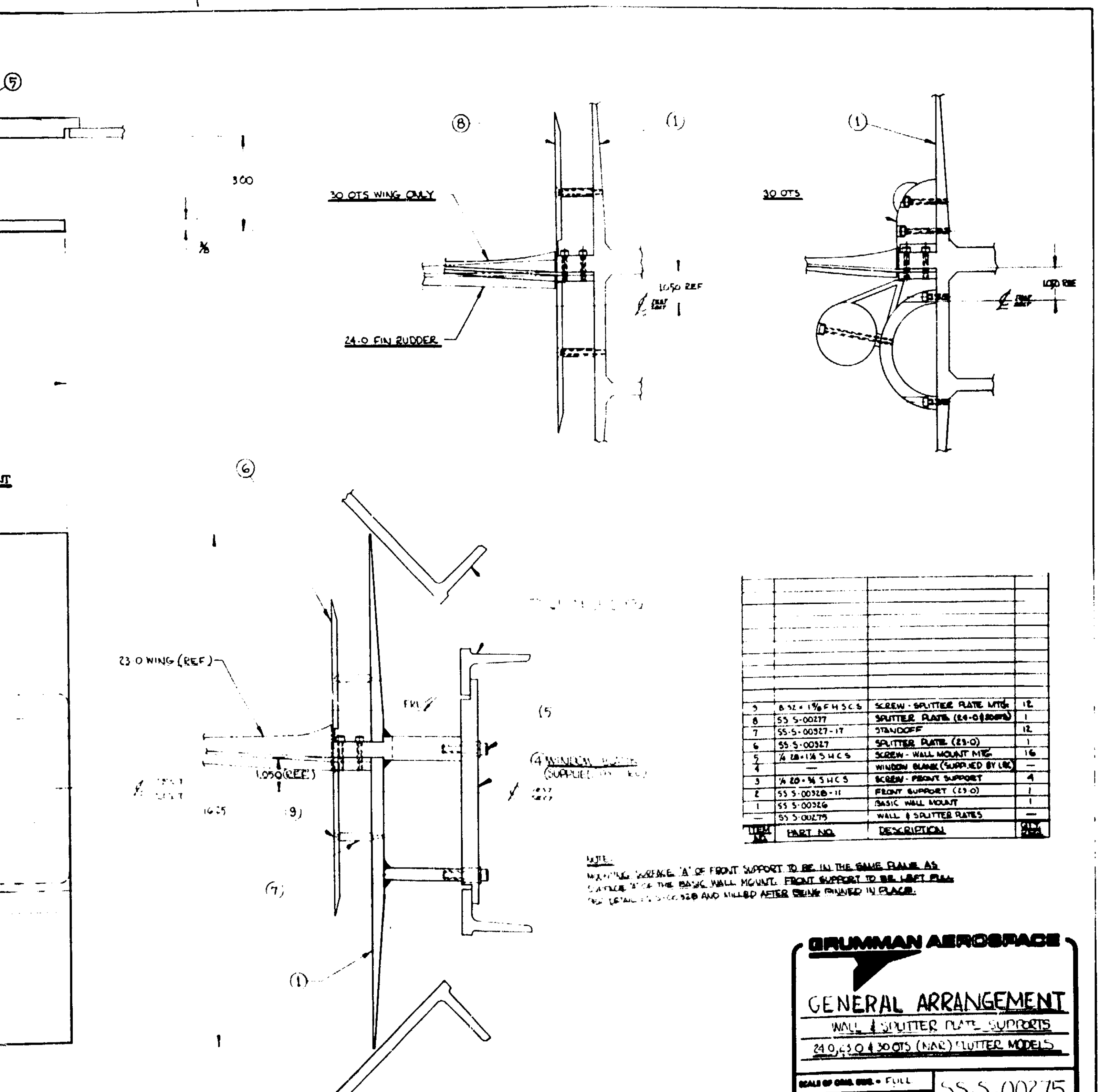
RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
23	2	14.72	53.63	33.78	.5304	57.17	.997	23.48	.00657	431.2	1017.8	1014	999	2.765	20.658
23	3	14.72	63.51	34.45	.5424	55.41	.977	23.03	.00668	432.5	1019.3	996	990	2.812	20.578
23	4	14.72	63.17	37.36	.5915	41.96	.900	21.17	.00726	431.8	1018.5	916	949	3.055	20.594
24	1	14.71	38.68	26.59	.6875	88.55	.752	10.51	.00453	492.6	1087.8	818	669	1.906	10.315
24	2	14.71	44.84	30.63	.6830	87.52	.758	12.33	.00524	490.8	1085.8	824	724	2.203	12.049
25	1	14.72	38.35	14.38	.3751	86.83	1.271	16.28	.00292	413.0	996.1	1266	832	1.230	11.882
25	2	14.72	58.31	22.90	.3353	49.07	1.354	29.37	.00516	372.3	945.8	1280	1118	2.172	23.133
26	1	14.72	26.36	13.82	.5244	100.28	1.006	9.80	.00249	465.7	1057.7	1064	646	1.048	7.721
26	2	14.72	72.07	33.22	.4609	43.75	1.113	28.80	.00691	403.5	984.5	1096	1107	2.906	24.771
26	3	14.72	59.75	31.42	.5259	35.93	1.004	22.16	.00639	412.5	995.5	999	971	2.689	20.525
26	4	14.72	56.49	30.64	.5423	30.93	.977	20.48	.00624	411.9	994.8	972	933	2.626	19.520
26	5	14.72	42.63	25.15	.6135	6.78	.865	13.71	.00541	405.7	987.3	854	764	2.276	15.055
27	1	14.74	23.81	16.98	.7131	85.79	.712	6.03	.00288	495.3	1090.8	777	506	1.211	6.198
27	2	14.74	28.61	19.22	.6720	80.59	.775	8.09	.00334	482.3	1076.4	835	587	1.407	7.907
27	3	14.74	29.12	19.56	.6717	79.89	.775	8.24	.00341	481.6	1075.6	835	592	1.434	8.065
28	1	14.74	44.02	15.41	.3502	91.31	1.322	18.86	.00317	408.3	990.4	1309	896	1.333	13.442
28	2	14.74	71.06	23.71	.3336	58.57	1.357	30.57	.00525	378.7	953.9	1295	1140	2.210	23.465
29	1	14.74	50.69	37.94	.7485	89.93	.657	11.46	.00629	506.0	1102.5	724	698	2.648	12.427
29	2	14.74	67.30	50.95	.7571	80.24	.643	14.76	.00857	498.7	1094.5	704	792	3.607	16.651
29	3	14.74	68.53	52.63	.7684	78.83	.625	14.40	.00884	499.5	1095.4	685	783	3.720	15.684
30	1	14.7?	62.49	44.10	.7057	31.29	.724	16.17	.00833	444.4	1033.3	748	829	3.503	18.824

FOLDOUT FRAME



FOLDOUT FRAME 2



ITEM NO.	PART NO.	DESCRIPTION	QTY. REQ.
9	8-32 × 1⅝ F H S C S	SCREW - SPLITTER PLATE MTG.	12
8	SS S-00277	SPLITTER PLATE (24.0 & 30 OTS)	1
7	SS-S-00327-17	STANDOFF	12
6	SS-S-00327	SPLITTER PLATE (23.0)	1
5	¼ 28 × 1¼ S H C S	SCREW - WALL MOUNT MTG.	16
4	—	WINDOW BLANK (SUPPLIED BY LRC)	—
3	¼ 20 × ¾ S H C S	SCREW - FRONT SUPPORT	4
2	SS S-00328-11	FRONT SUPPORT (23.0)	1
1	SS S-00326	BASIC WALL MOUNT	1
—	SS S-00275	WALL & SPLITTER PLATES	—

Figure 1. - General Arrangement.

FOLDOUT FRAME

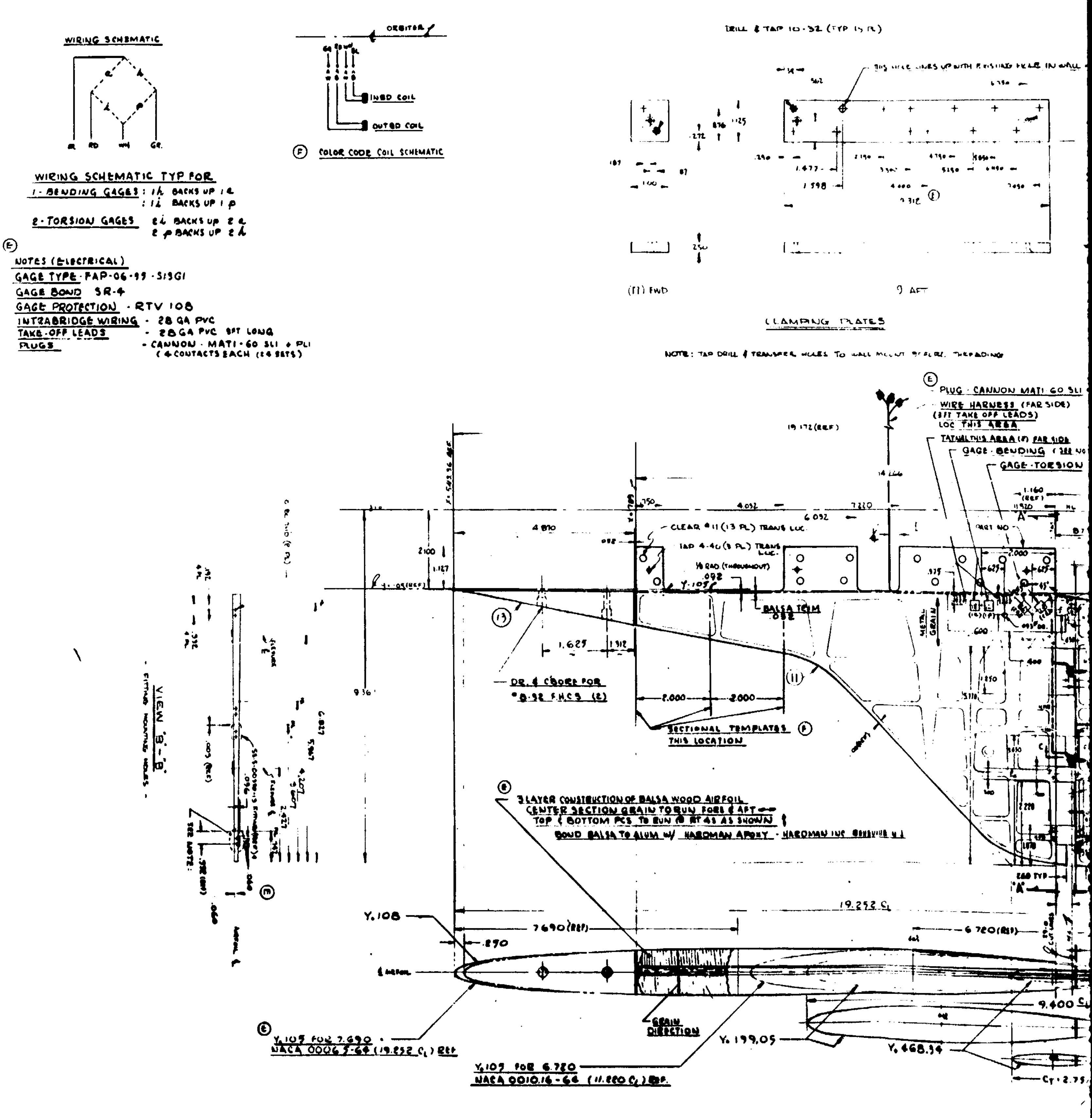
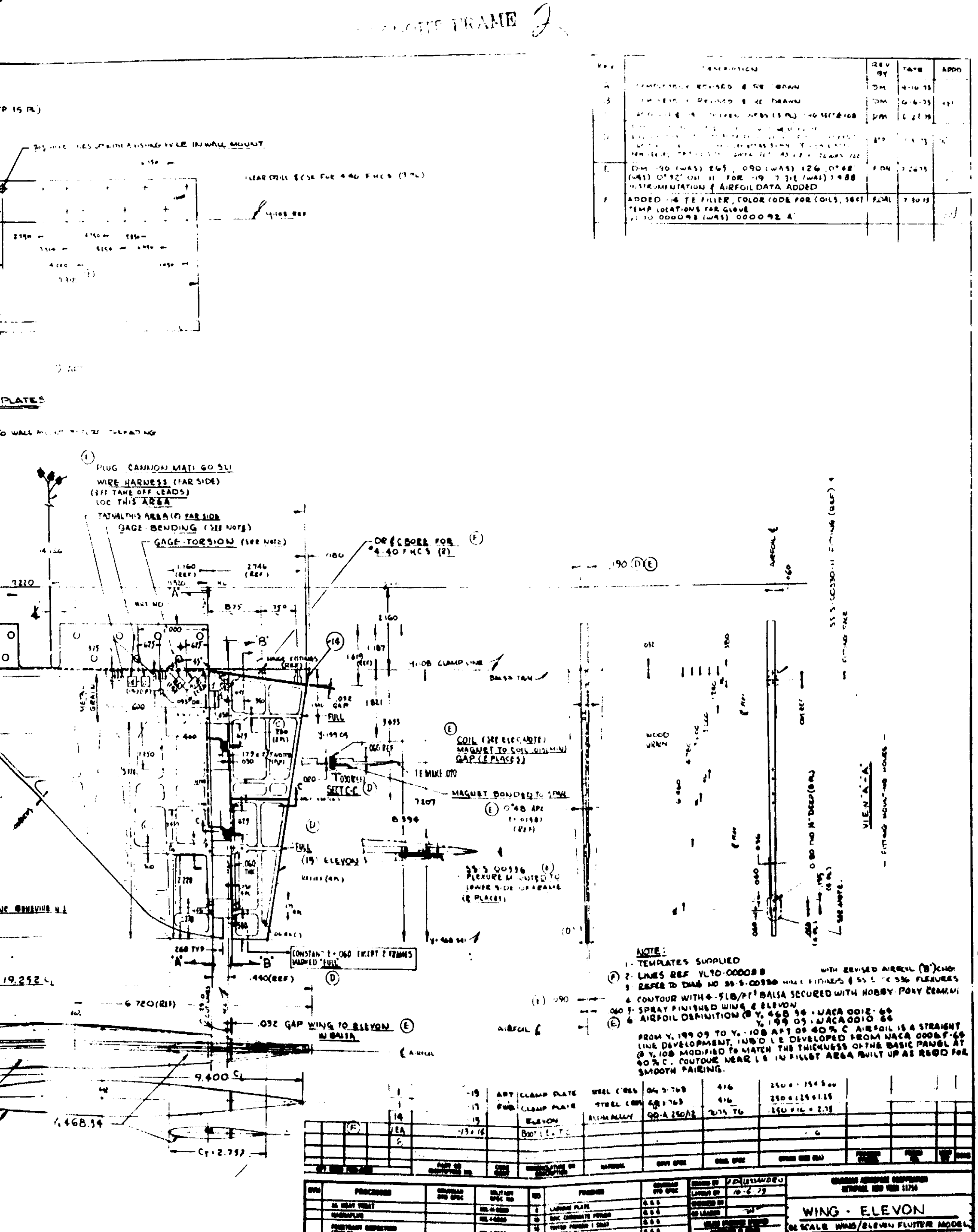


Figure 2. - Wing - Elevon.


WING - ELEVON
SS-S-00329
E
NOTE:
1. TEMPLATES SUPPLIED
VIEW 'A-A'
COIL (SEE ELEC NOTE)
MAGNET BONDED TO STRUT
(19) ELEVON
CONSTANT t = .060 EXCEPT 2 FRAMES MARKED "FULL"
.032 GAP WING TO ELEVON IN BALSA
9.400 C_L
19.252 C_L
PLUG CANNON MATI GO SLI
WIRE HARNESS (FAR SIDE)
GAGE BENDING (SEE NOTE)
GAGE TORSION (SEE NOTE)

Elevon.

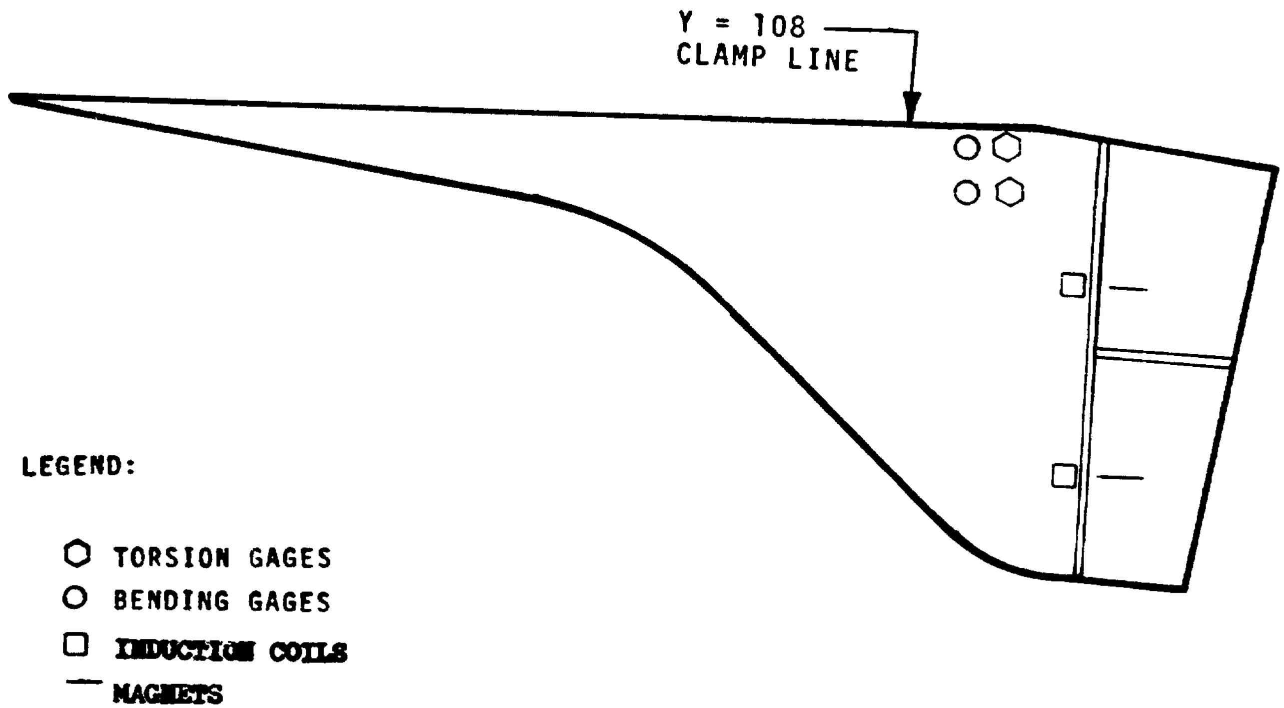


Figure 3 Model 30-OTS Instrumentation

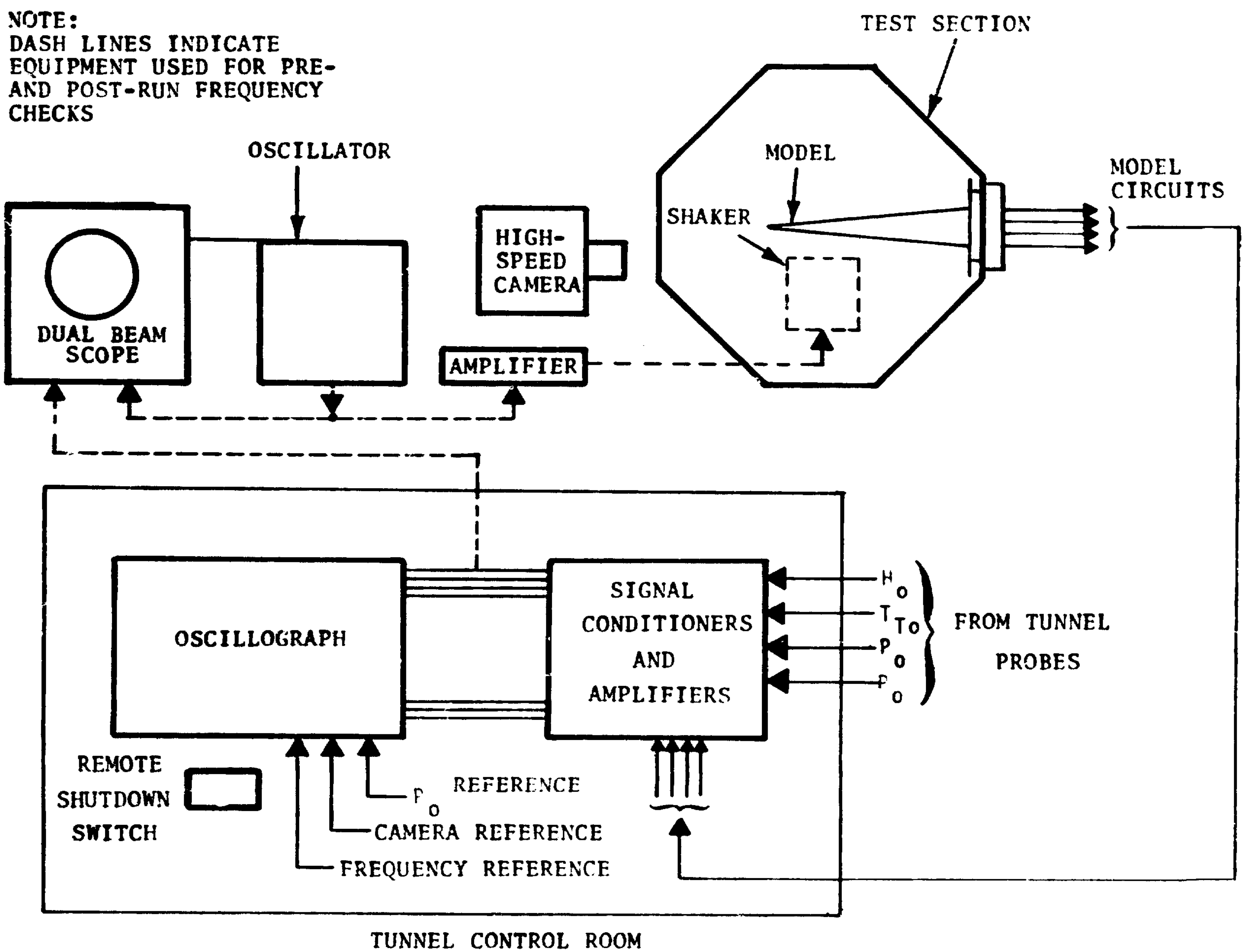


Figure 4. Instrumentation Equipment

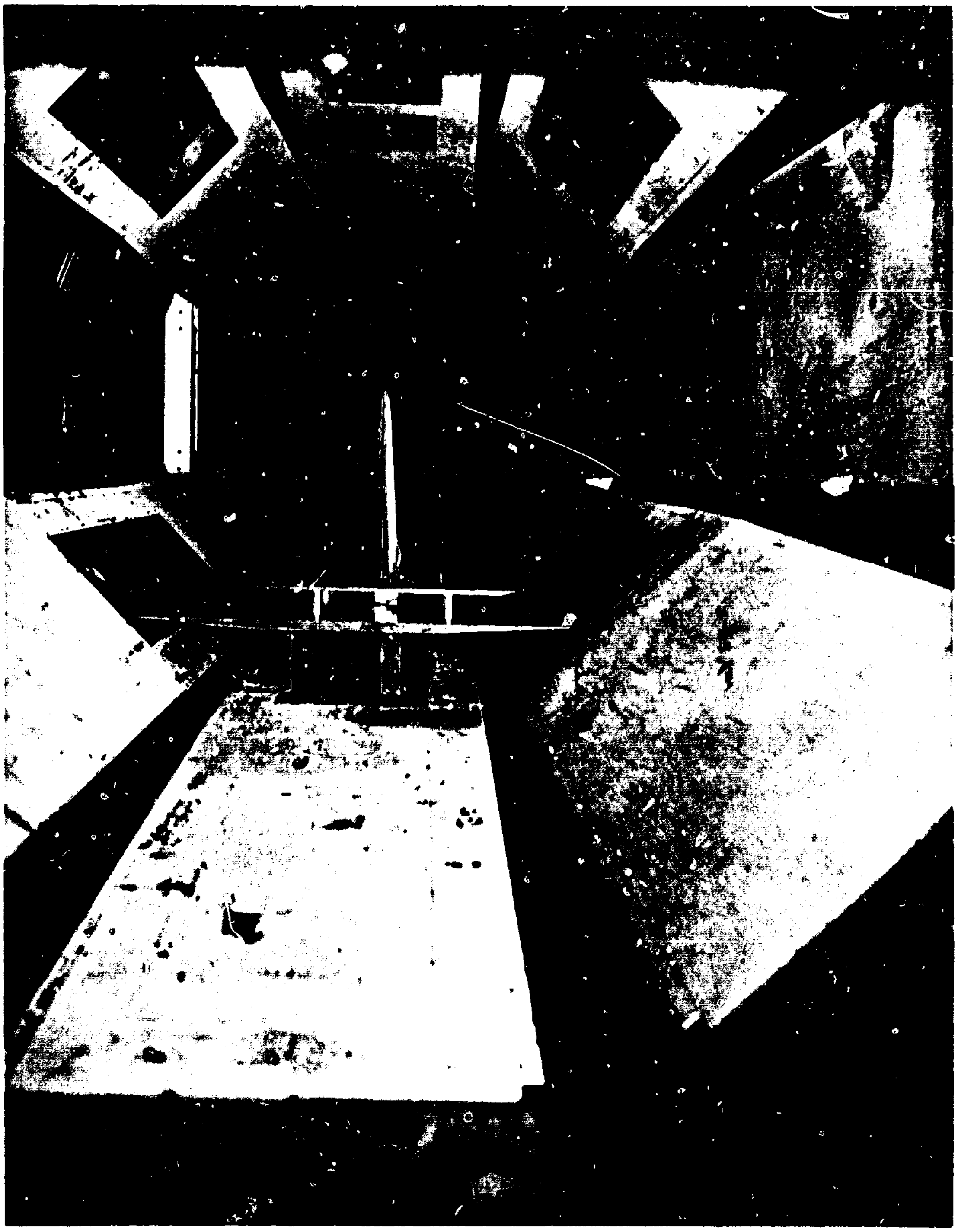


Figure 5. - Model Installation.

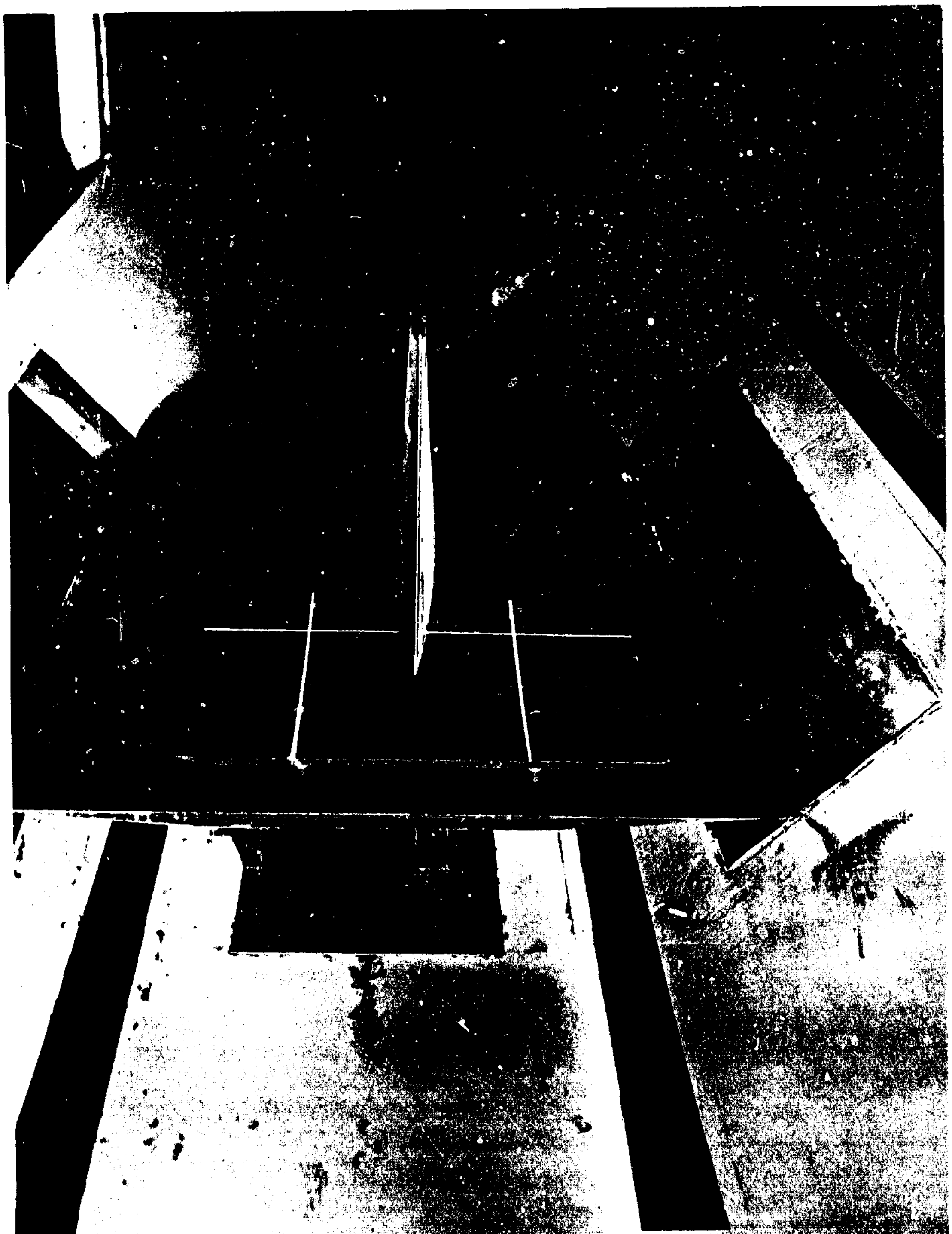
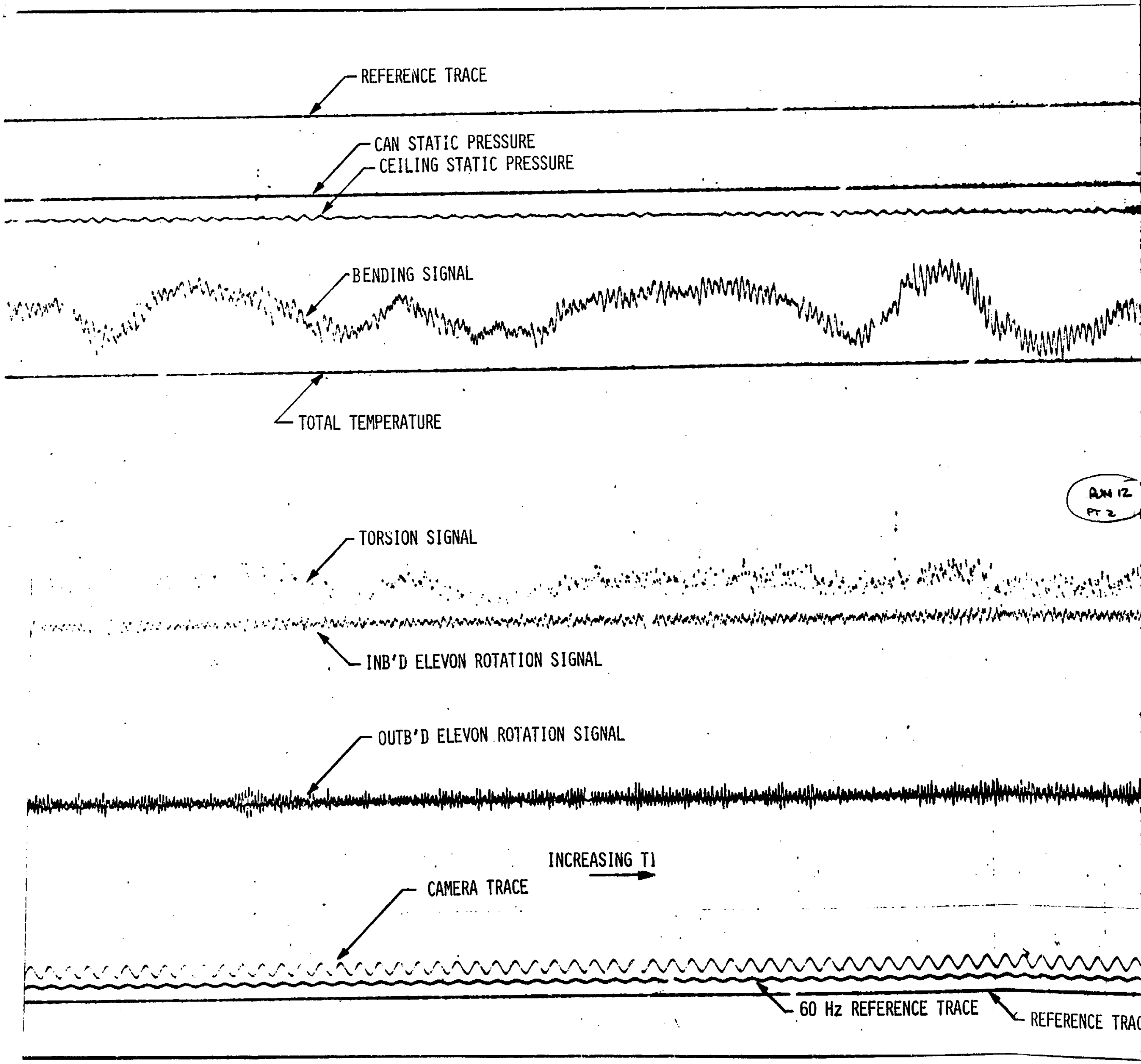


Figure 6. - Model Installation.

FOLDOUT FRAME



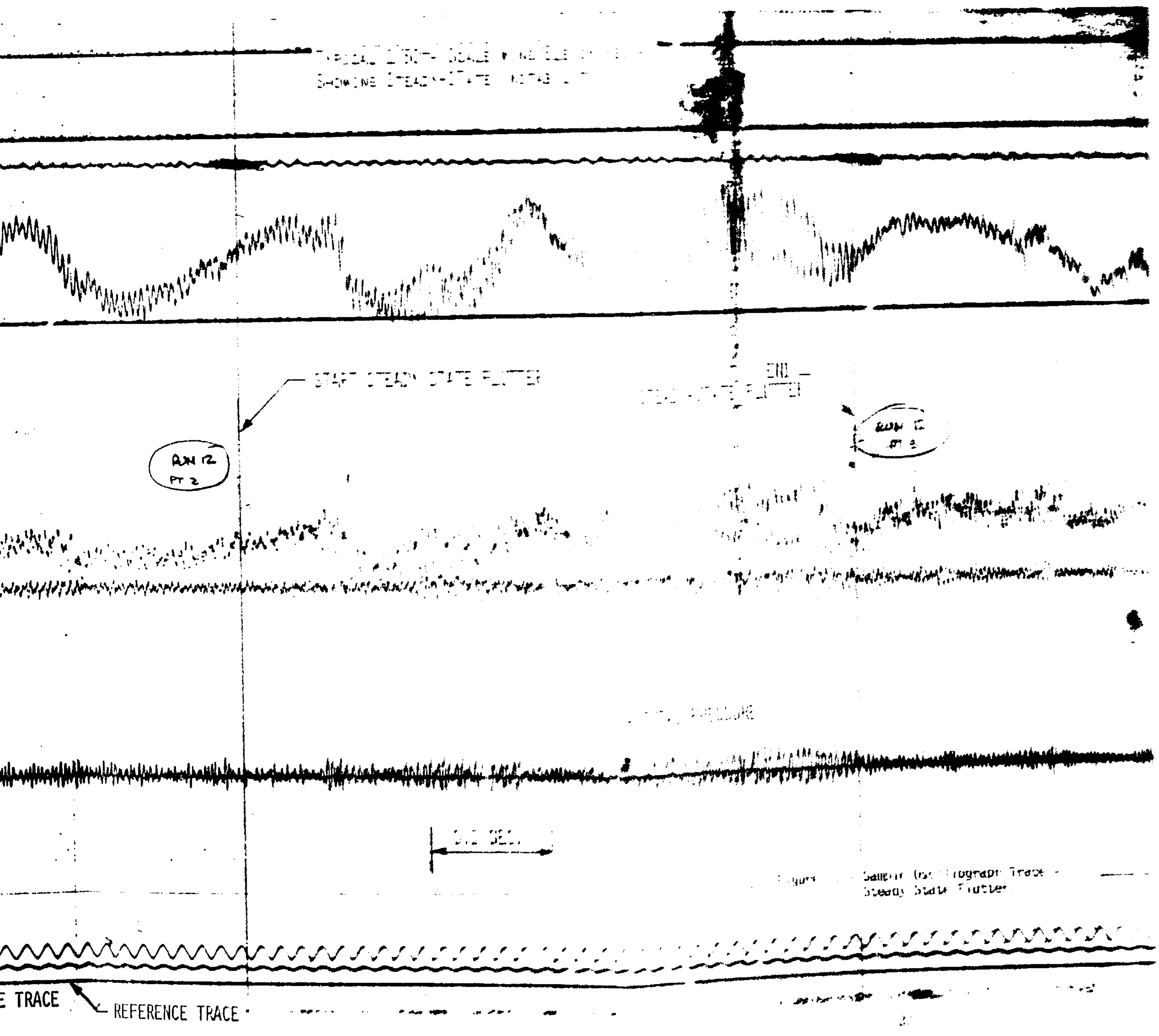


Figure — Sample Oscillograph Trace - Steady State Flutter

FOLDOUT FRAME

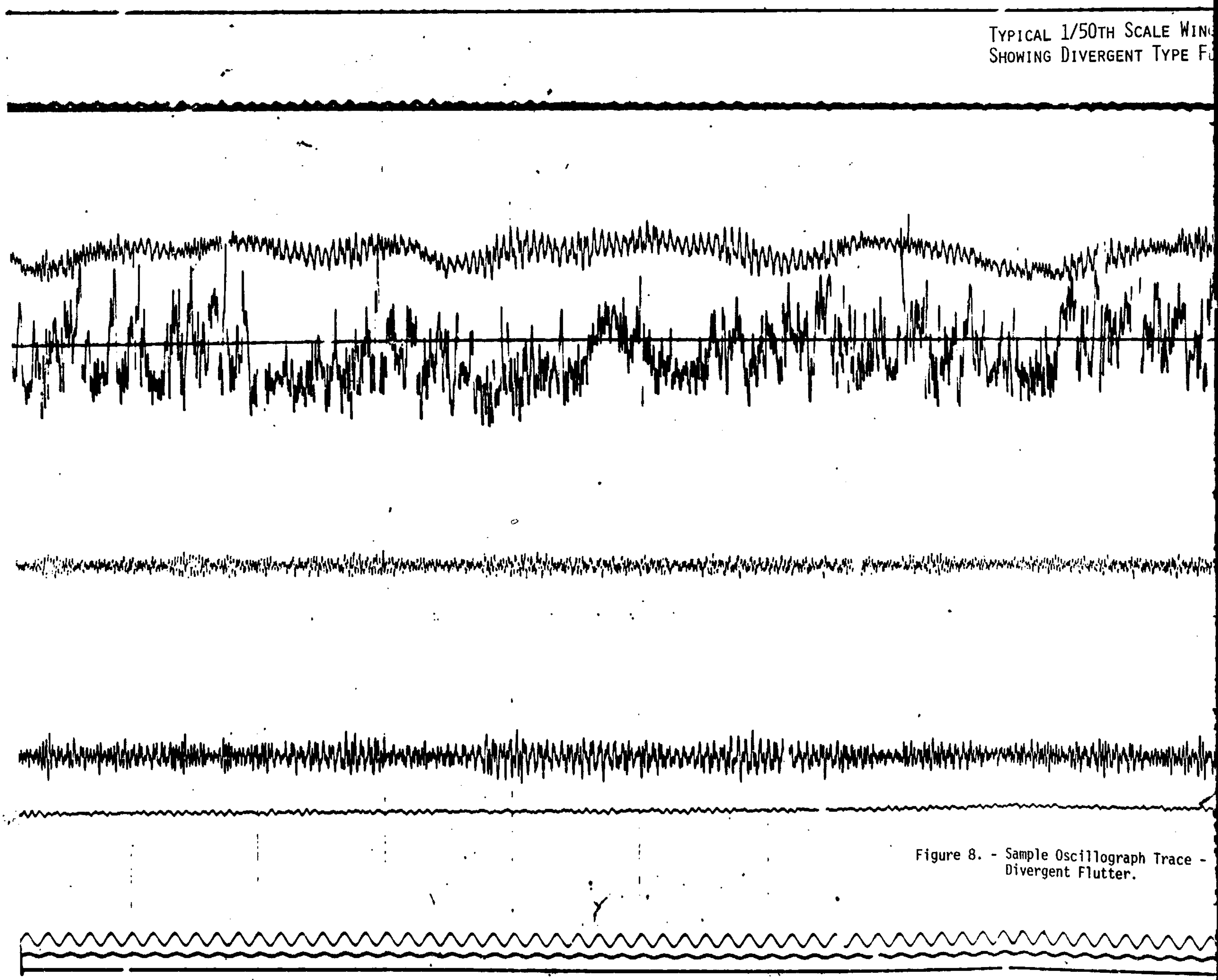
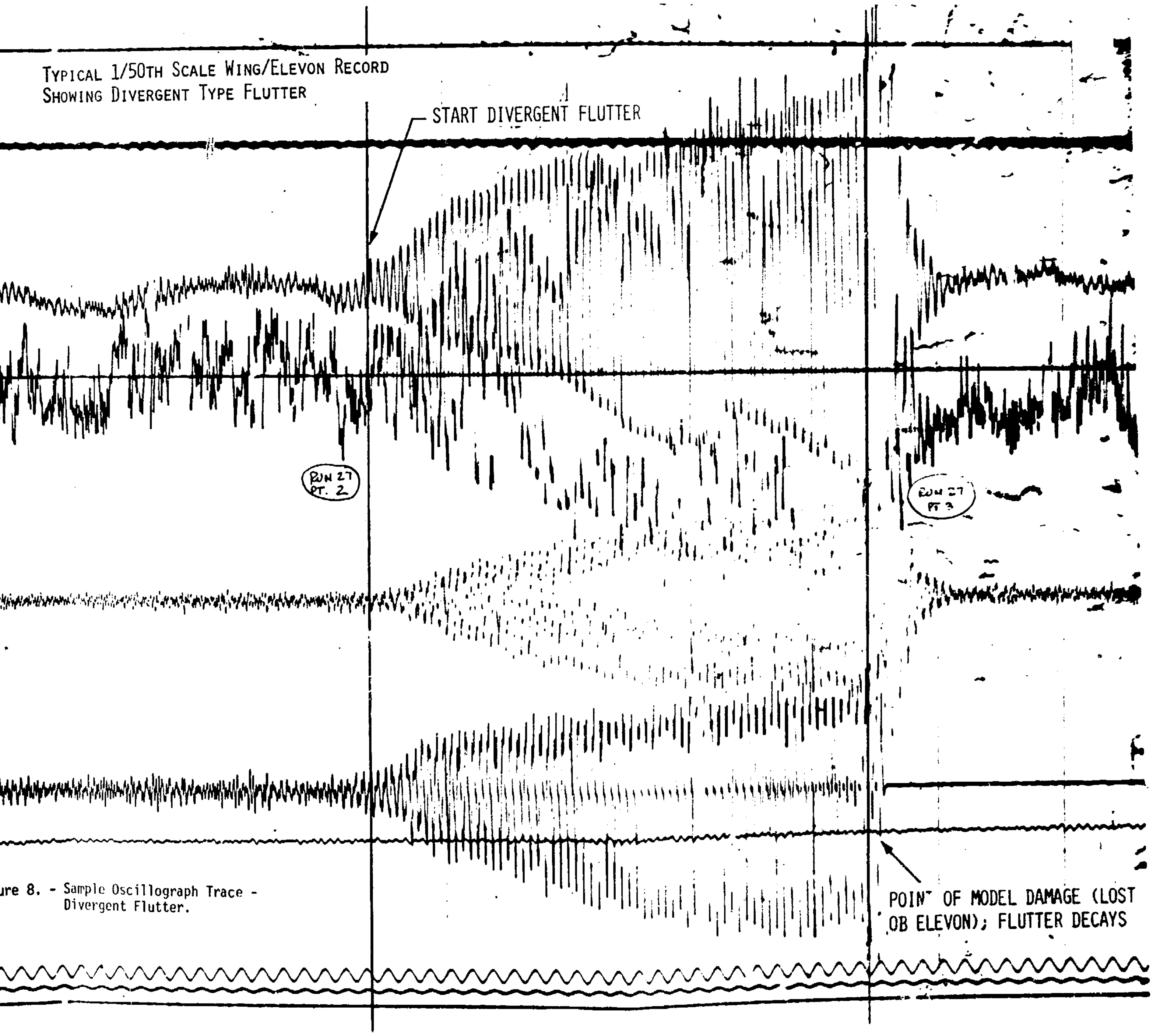


Figure 8. - Sample Oscillograph Trace -
Divergent Flutter.

FOLDOUT FRAME 2



ure 8. - Sample Oscillograph Trace - Divergent Flutter.

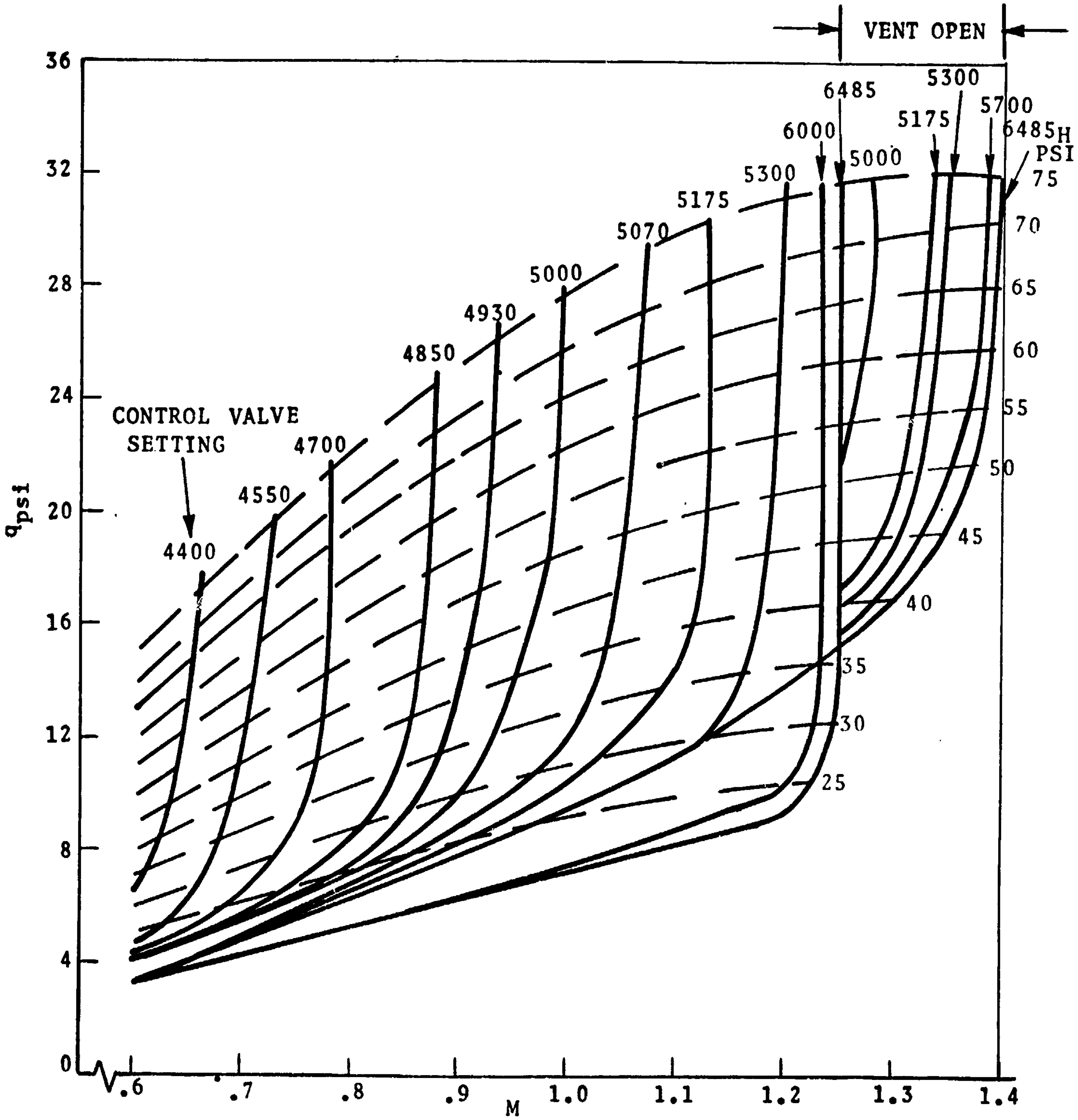
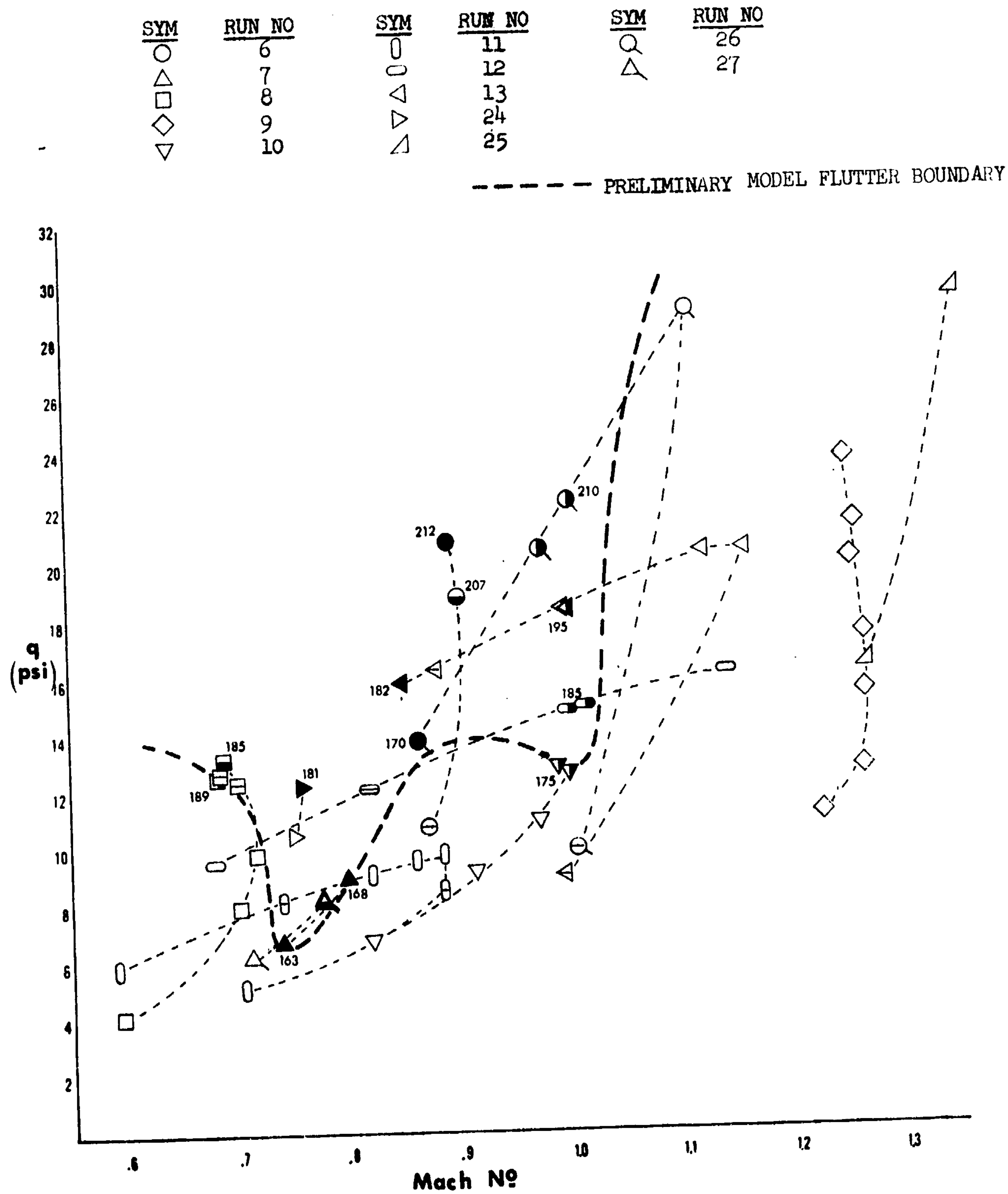


Figure 9. Typical Operating Characteristics of 26-inch Langley Transonic Blowdown Tunnel. Wall attached 3-inch diameter sting is located approximately 7 inches from wall and has model installed.

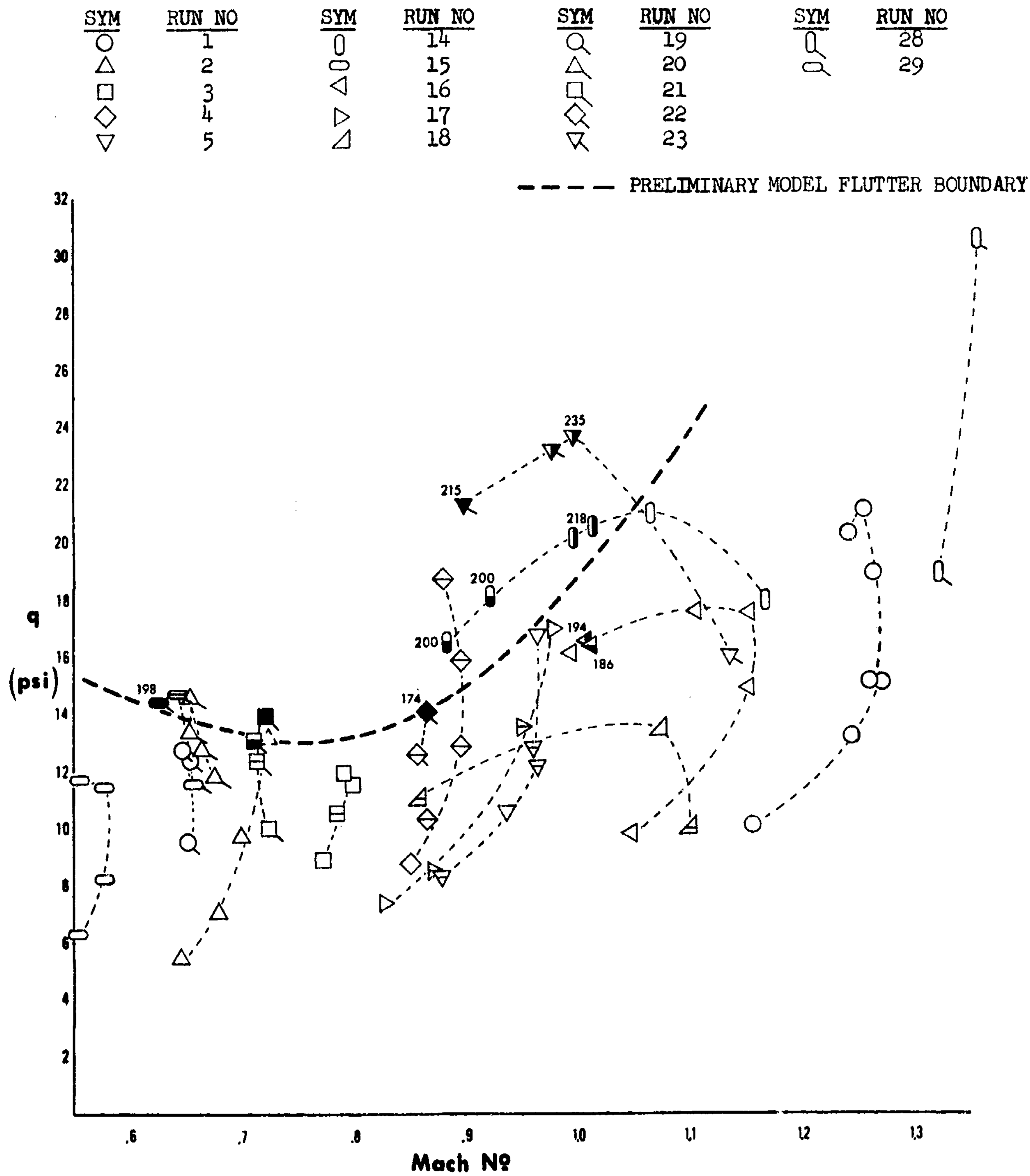


50-40 (STIFF/SOFT) CONFIG

Number adjacent to flutter symbol denotes frequency

No flutter
Low damping
Intermittent flutter
Steady-state flutter
Divergent flutter

Figure 10. - Preliminary Model Flutter Boundary-
50/40 Configuration.



50-50 (STIFF/STIFF) CONFIG.

Number adjacent to flutter symbol denotes frequency

- No flutter
- Low damping
- Intermittent flutter
- Steady-state flutter
- Divergent flutter

Figure 11. - Preliminary Model Flutter Boundary-
50/50 Configuration.

APPENDIX A

CALIBRATION DATA

Table A-1 illustrates the pre-and post-run frequency data obtained during this test. Comparing the results of the table with Table A-2, the frequencies obtained during the GVS prior to the test, there is generally good agreement. Note that for the post-run 15 and post-run 26 frequency checks (Table A-1), model damage is evidenced by discrepant frequencies.

Since no GVS was performed for the Run 30 configuration (steel flexures and pin hinges simulating a slab wing), comparison was impossible. However, the frequencies obtained were in good agreement with what was anticipated for this arrangement and approximate a slab wing condition.

Figures A-1 through A-8 in this appendix illustrate the node lines generated during the GVS of the eight models. The modal shapes for the entire wing/elevon (wing #1 in these figures) are illustrated in Figures A-9 through A-13 for the stiff/stiff elevon flexures configuration and in Figures A-14 through A-18 for the stiff/soft elevon flexures configuration.

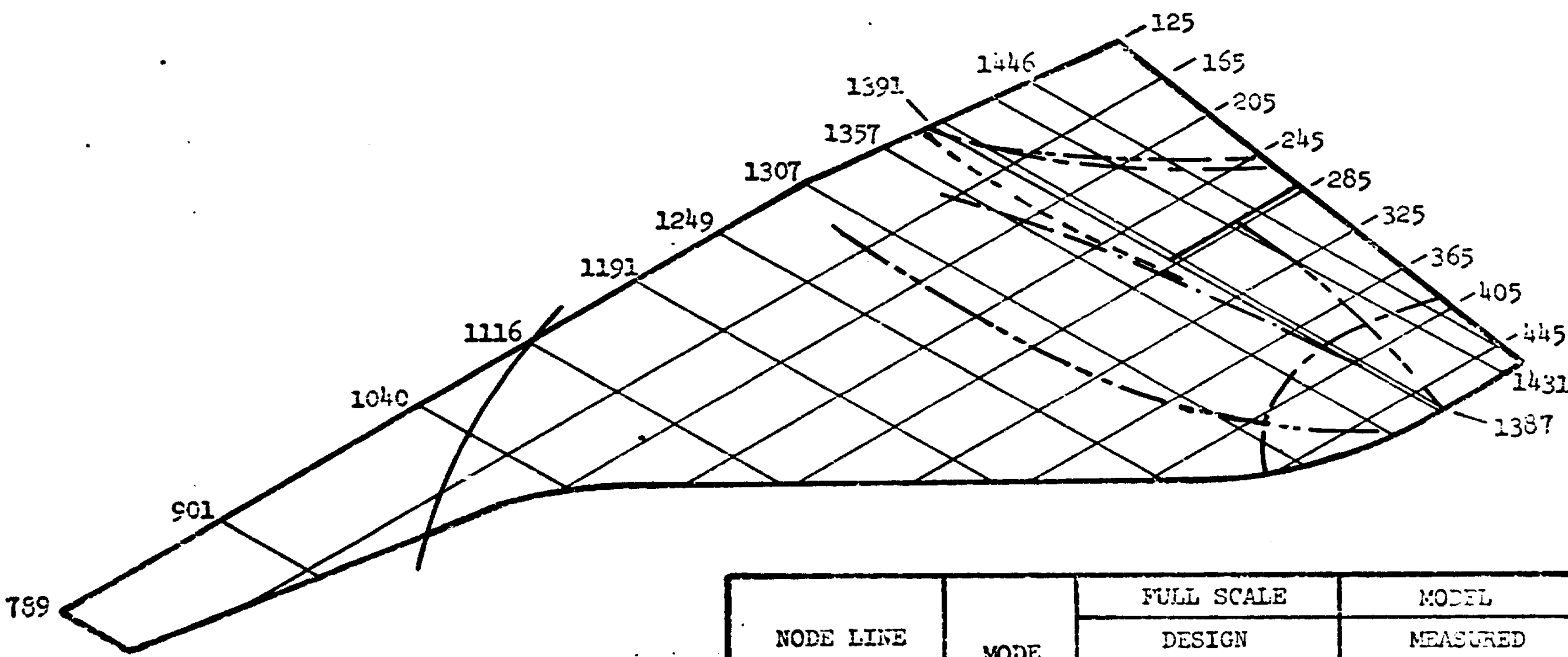
Table A-1 Pre- and Post-Run Frequency Data

RUN	MODEL			FREQUENCIES (Hz)					REMARKS
	WING	OB ELEVON	IB ELEVON	1	2	3	4	5	
PRE-1	2	2/.050	2/.050	125	218	262	408	478	FIRST 3 FREQ. OBTAINED BY PLUCKING; LAST 2 BY SHAKER
PRE-2	2	2/.050	2/.050	128	220	260	405	480	
PRE-3	2	2/.050	2/.050	127	224	260	415	480	
PRE-4	2	2/.050	2/.050	127	224	260	410	476	
PRE-5	2	2/.050	2/.050	125	222	255	404	463	
PRE-5	2	2/.050	2/.050	125	222	256	402	462	REMOVING MODEL FOR INSTALLATION OF #5
PRE-6	2	2/.040	5/.050	125	215	230	400	475	REMOVING MODEL FOR INSTALLATION OF #5
PRE-7	6	6/.040	6/.050	125	213	235	415	500	
PRE-8	7	7/.040	7/.050	127	220	248	420	480	OB HINGES DAMAGED
PRE-9	7	7/.040	7/.050	127	223	256	410	480	
PRE-10	7	7/.040	7/.050	126	225	250	408	416	
PRE-11	7	7/.040	7/.050	125	223	245	400	476	
PRE-12	7	7/.040	7/.050	125	218	240	400	470	
PRE-13	7	7/.040	7/.050	125	220	240	400	470	
PRE-14	3	3/.050	3/.050	130	215	265	405	500	
PRE-15	3	3/.050	3/.050	128	210	260	405	500	
POST-15	3	3/.050	3/.050	127	215	239	393	485	REMOVING MODEL
PRE-16	2	2/.050	2/.050	124	223	265	404	480	
PRE-17	2	2/.050	2/.050	127	225	268	405	485	
POST-17	2	2/.050	2/.050	125	217	265	--	485	IB ELEVON DEFLECTED UPWARD--REMOVING MODEL
PRE-18	4	4/.050	4/.050	129	214	265	405	480	
POST-18	4	4/.050	4/.050	130	214	265	410	460	
POST-19	4	4/.050	4/.050	130	215	265	408	465	
POST-20	4	4/.050	4/.050	130	217	265	405	470	
PRE-22	2	2/.050	2/.050	127	215	270	410	480	
PRE-23	3	3/.050	3/.050	127	218	266	400	485	
PRE-24	5	9/.040	5/.050	120	218	235	400	470	
PRE-25	8	8/.040	8/.050	123	218	243	390	472	
PRE-26	8	8/.040	8/.050	122	219	241	395	475	
POST-26	8	8/.040	8/.050	108	215	--	--	--	MODEL DAMAGED - REMOVED
PRE-27	1	1/.040	1/.050	122	205	233	400	480	OB ELEVON DAMAGED
PRE-28	4	10/.050	10/.050	120	204	265	390	480	
PRE-29	4	10/.050	10/.050	120	203	263	390	470	
PRE-30	5	SOLID	SOLID	120	335	470	660	--	

Table A-2 GVS Frequencies

MODEL NO.	ELEV. (INB'D) .050 x .320 (11.0 Hz EQUIV.) ELEV. (OUTB'D) .050 x .320 (13.5 Hz EQUIV.)					ELEV. (INB'D) .050 x .320 (11.0 Hz EQUIV.) ELEV. (OUTB'D) .040 x .320 (11.0 Hz EQUIV.)				
	1	2	3	4	5	1	2	3	4	5
1*	123.1	203.8	262.7	403.3	481.5	121.2	20[illegible].6	235.0	398.4	464.6
2	124.8	210.2	263.9	406.6	479.5	--	--	--	--	--
3	126.7	217.7	266.4	400.0	486.4	--	--	--	--	--
4	129.7	217.9	267.1	405.1	436.7	--	--	--	--	--
5	--	--	--	--	--	123.8	219.8	235.5	396.8	472.9
6	--	--	--	--	--	125.4	211.0	240.6	405.0	482.4
7	--	--	--	--	--	123.1	223.3	247.8	394.7	467.5
8	--	--	--	--	--	121.7	220.8	240.7	392.8	475.7

*NOTE: MODEL #1 FREQUENCIES MEASURED WITH PICKUP TARGETS FOR MODE SHAPES (MODE LINE SHEET WITHOUT TARGETS).



1/50 SCALE WING MODEL 23-0

CONFIGURATION:

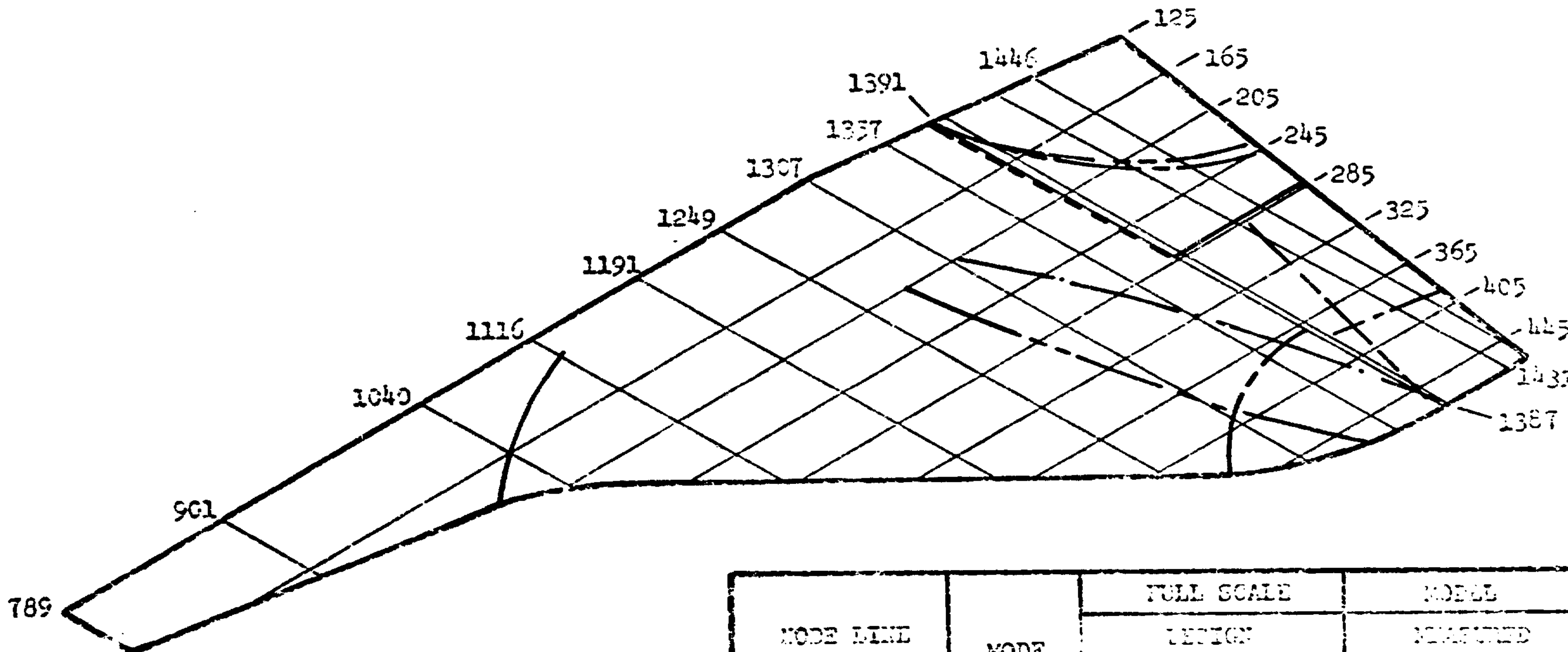
	FLEXURE	FREQUENCY
INBOARD	.050 x .320 BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.050 x .320 BERYLLIUM-COPPER	13.5 Hz

MODEL NO. 1

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN		MODEL MEASURED	
		FREQ.	F/R	FREQ.	F/R
————————	1	5.7	1.0	123.3	1.0
— — — — —	2	9.8	1.72	211.2	1.710
—·—·—	3	11.6	2.035	266.1	2.115
—— —— ——	4	16.0	2.810	403.2	3.270
——-·-——	5	21.6	3.790	483.4	3.920

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-1 Model Node Line Locations - Model No. 1



1/50 SCALE WING MODEL 23-0

CONFIGURATION:

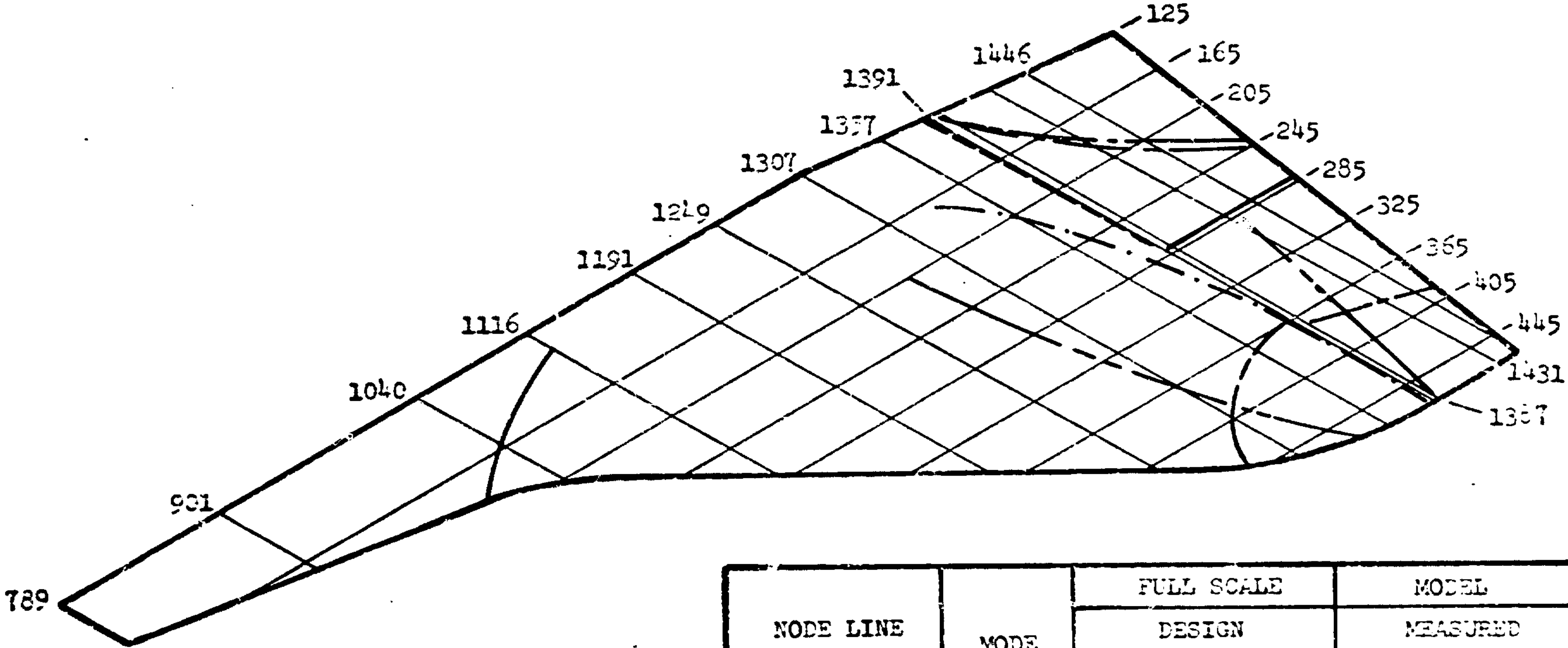
	FLEXURE	FREQUENCY
INBOARD	.050 x .320 BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.050 x .320 BERYLLIUM-COPPER	13.5 Hz

MODEL NO. 2

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN FREQ.	FULL SCALE DESIGN F/R	MODEL MEASURED FREQ.	MODEL MEASURED F/R
————————	1	5.7	1.0	124.8	1.0
– – – – – –	2	9.8	1.72	210.2	1.685
—— · —— · ——	3	11.6	2.035	263.9	2.110
—— – —— – ——	4	16.0	2.810	406.6	3.260
—— - - —— - -	5	21.6	3.790	479.5	3.840

NOTE: SECONDARY NODE LINES NOT SHOWN
FOR SAKE OF CLARITY

Figure [illegible]-2 Model Node Line Locations - Model No. 2



1/50 SCALE WING MODEL 93-C

CONFIGURATION:

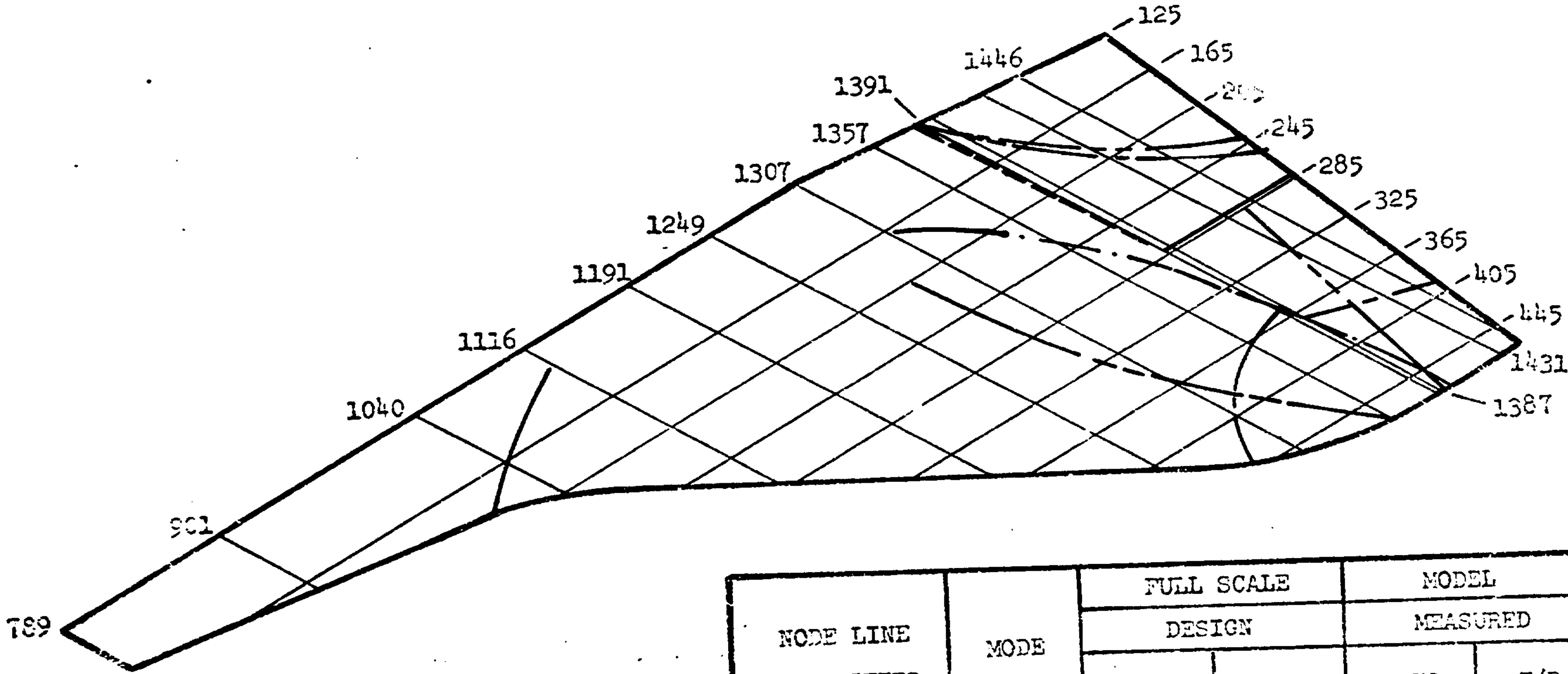
	FLEXURE	FREQUENCY
INBOARD	.050 x .320 BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.050 x .320 BERYLLIUM-COPPER	13.5 Hz

MODEL NO. 3

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN FREQ.	FULL SCALE DESIGN F/R	MODEL MEASURED FREQ.	MODEL MEASURED F/R
————————	1	5.7	1.0	126.7	1.0
— — — — — —	2	9.8	1.72	217.7	1.717
— · — · — ·	3	11.6	2.035	266.4	2.105
—— —— ——	4	16.0	2.810	400.0	3.155
——— - - -	5	21.6	3.790	486.4	3.840

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-3 Model Node Line Locations - Model No. 3



1/50 SCALE WING MODEL 23-0

CONFIGURATION:

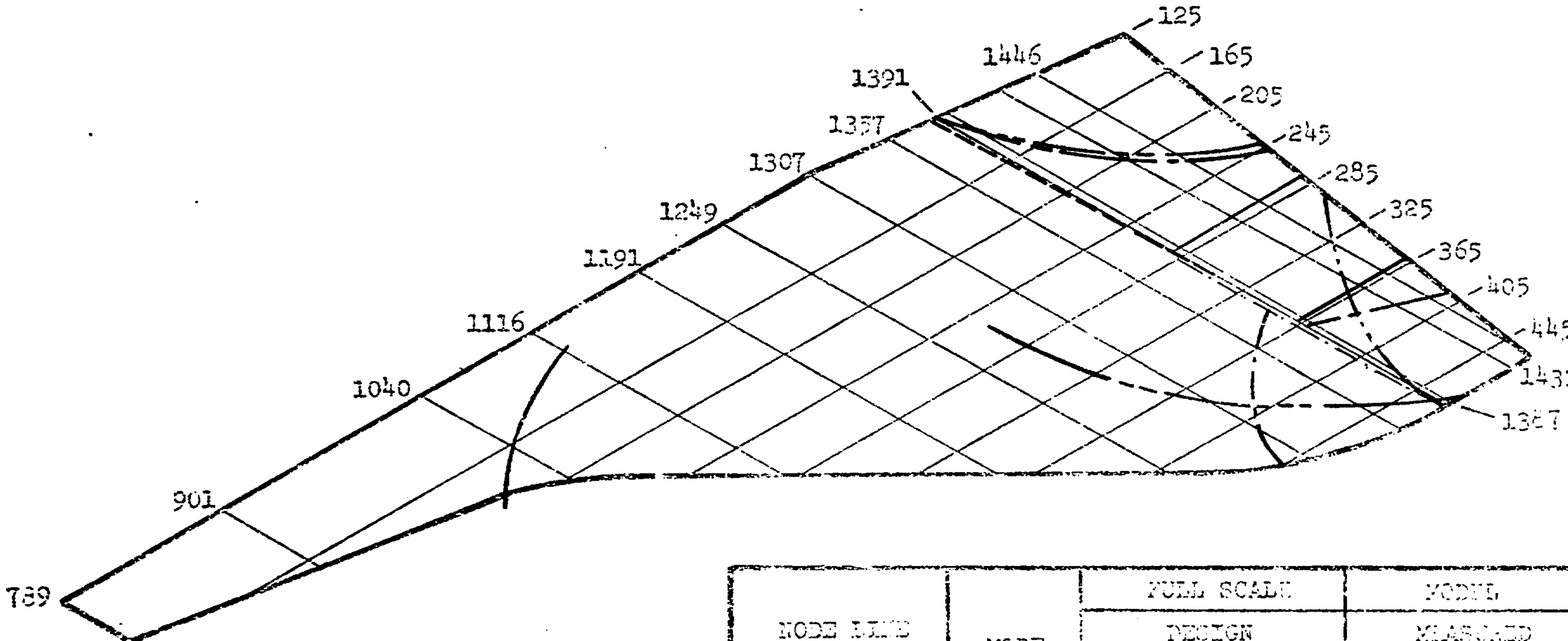
	FLEXURE	FREQUENCY
INBOARD	.050 x .320 BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.050 x .320 BERYLLIUM-COPPER	13.5 Hz

MODEL NO. 4

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN FREQ.	FULL SCALE DESIGN F/R	MODEL MEASURED FREQ.	MODEL MEASURED F/R
———————	1	5.7	1.0	129.7	1.0
— — — — — —	2	9.8	1.72	217.9	1.68
—·—·—·	3	11.6	2.035	267.1	2.06
—— —— ——	4	16.0	2.810	405.1	3.12
—— - - ——	5	21.6	3.790	486.7	3.75

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-4 Model Node Line Locations - Model No. 4



1/50 SCALE WING MODEL 23-0

CONFIGURATION:

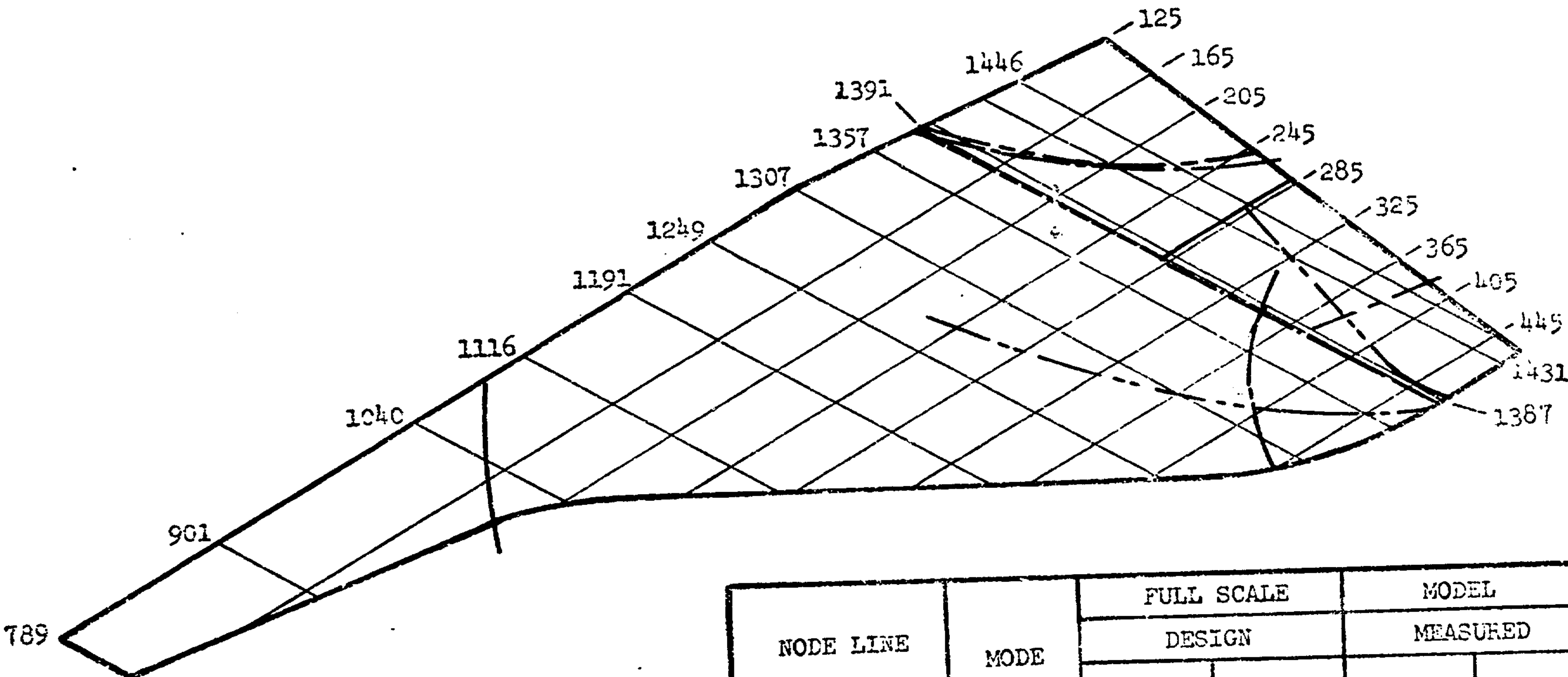
	FLEXURE		FREQUENCY
INBOARD	.050 x .320	BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.040 x .320	BERYLLIUM-COPPER	11.0 Hz

MODEL NO. 5

NODE LINE IDENTIFIER	MODE	FULL SCALE		MODEL	
		DESIGN		MEASURED	
		FREQ.	F/R	FREQ.	F/R
	1	5.7	1.0	123.8	1.0
	2	9.8	1.72	219.8	1.78
	3	11.6	2.035	235.5	1.90
	4	16.0	2.810	396.8	3.20
	5	21.[illegible]	3.790	472.9	3.82

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-5 Model Node Line Locations - Model No. 5



1/50 SCALE WING MODEL 23-0

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN FREQ.	FULL SCALE DESIGN F/R	MODEL MEASURED FREQ.	MODEL MEASURED F/R
————————	1	5.7	1.0	125.4	1.0
— — — — — —	2	9.8	1.72	211.0	1.680
—·—·—·	3	11.6	2.035	240.6	1.920
—— —— ——	4	16.0	2.810	405.0	3.230
—— - - —— -	5	21.6	3.790	482.4	3.845

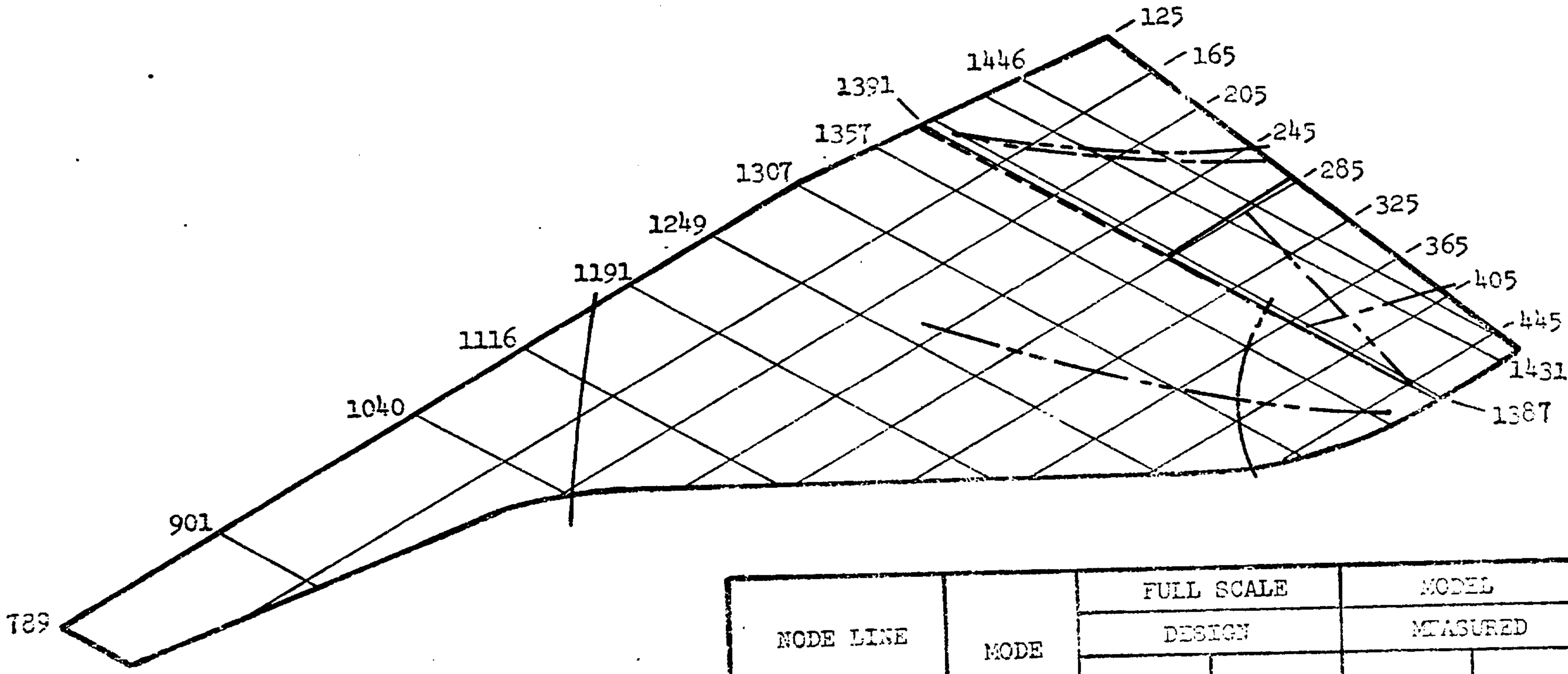
CONFIGURATION:

		FLEXURE	FREQUENCY
INBOARD	.050 x .320	BERYLLIUM-COPPER	11.0 Hz
OUTOBARD	.040 x .320	BERYLLIUM-COPPER	11.0 Hz

MODEL NO. 6

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-6 Model Node Line Locations - Model No. 6



1/50 SCALE WING MODEL 23-0

CONFIGURATION:

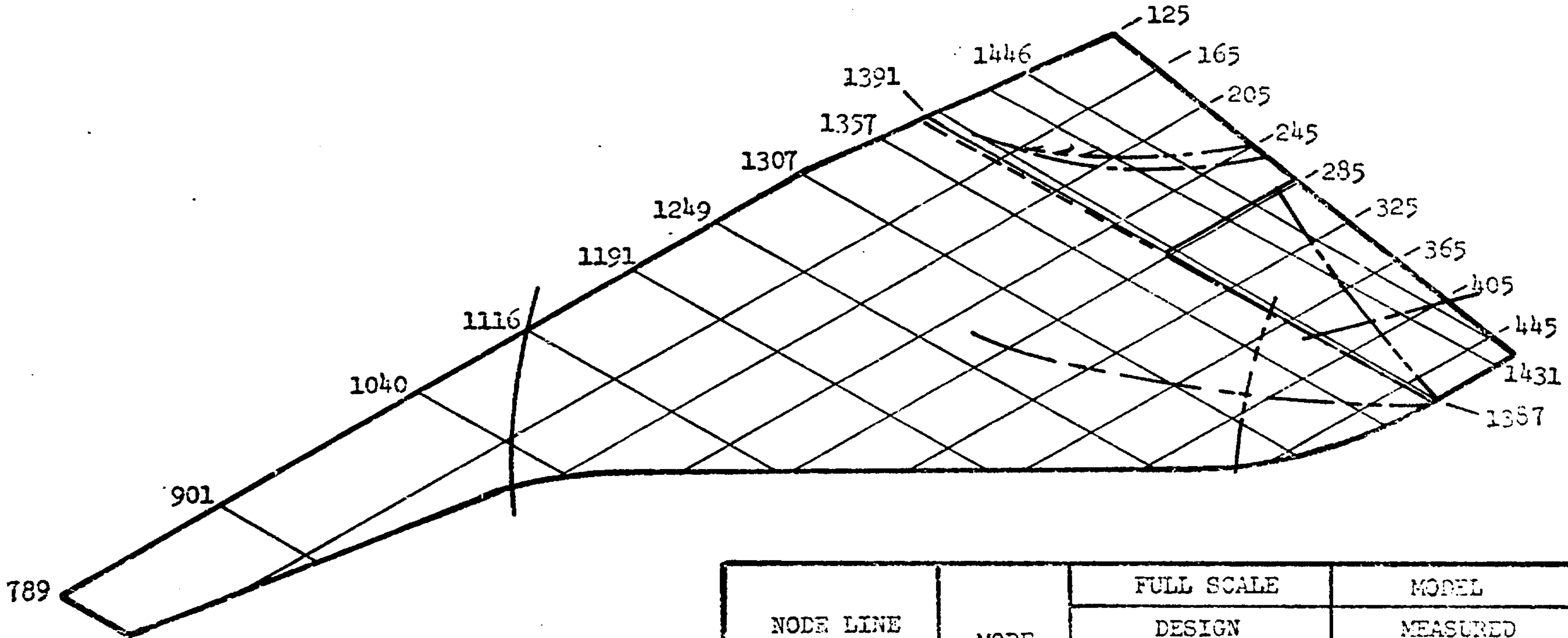
		FLEXURE	FREQUENCY
INBOARD	.050 x .320	BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.040 x .320	BERYLLIUM-COPPER	11.0 Hz

MODEL NO. 7

NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN		MODEL MEASURED	
		FREQ.	F/R	FREQ.	F/R
————————	1	5.7	1.0	123.1	1.0
— — — — — —	2	9.8	1.72	223.3	1.810
—·—·—·	3	11.6	2.035	247.8	2.010
—— — —— —	4	16.0	2.810	394.7	3.210
—— - - —— - -	5	21.6	3.790	467.5	3.800

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-7 Model Node Line Locations - Model No. 7



NODE LINE IDENTIFIER	MODE	FULL SCALE DESIGN FREQ.	FULL SCALE DESIGN F/R	MODEL MEASURED FREQ.	MODEL MEASURED F/R
————	1	5.7	1.0	121.7	1.0
— — — —	2	9.8	1.72	220.8	1.815
—·—·—	3	11.6	2.035	240.7	1.980
—— —— ——	4	16.0	2.810	392.8	3.230
——-—-——	5	21.6	3.790	475.7	3.910

1/50 SCALE WING MODEL 23-0

CONFIGURATION:

	FLEXURE	FREQUENCY
INBOARD	.050 x .320 BERYLLIUM-COPPER	11.0 Hz
OUTBOARD	.040 x .320 BERYLLIUM-COPPER	11.0 Hz

MODEL NO. 8

NOTE: SECONDARY NODE LINES NOT SHOWN FOR SAKE OF CLARITY

Figure A-8 Model Node Line Locations - Model No. 8

MODEL 23-0
WING #1 - 50/40 CONFIGURATION
f = 121.2 Hz

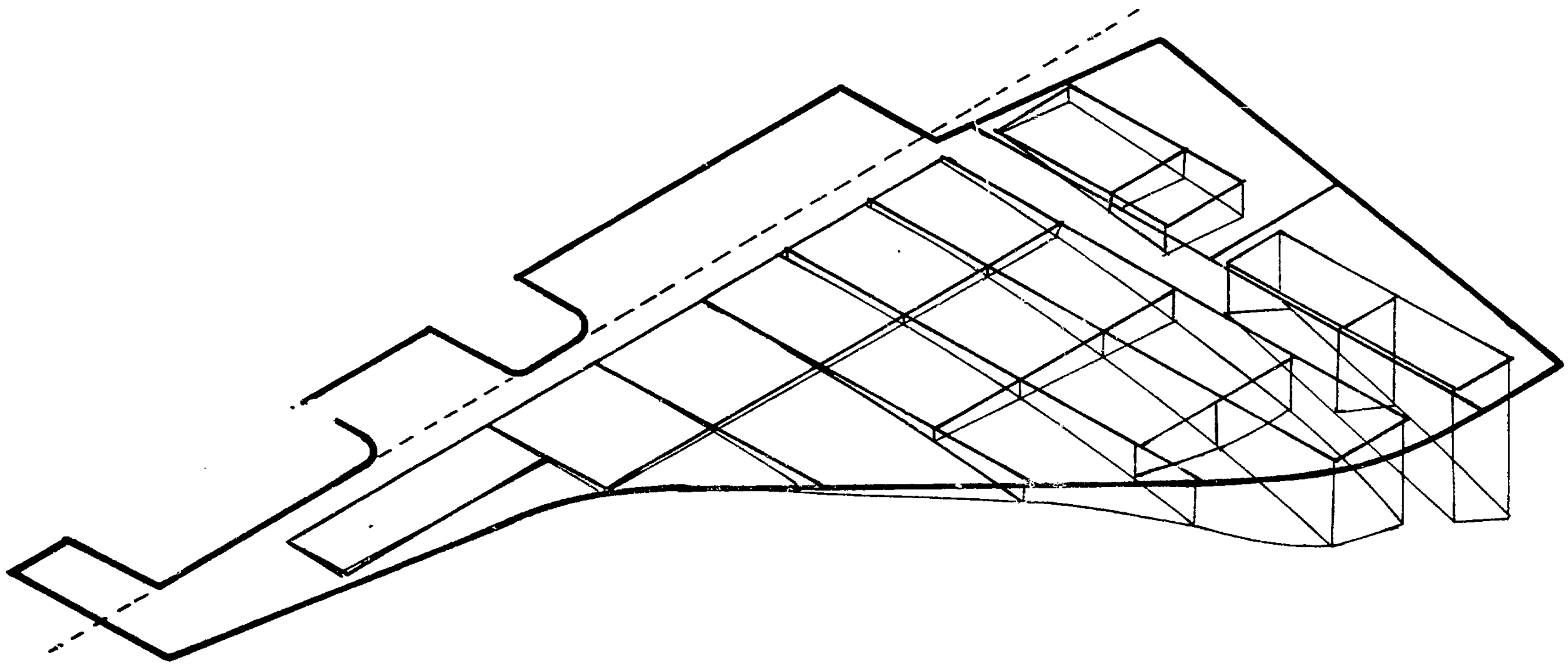


Figure A-9 GVS Modal Shape - 1st Frequency (50/40 Config)

MODEL 23-0
WING #1 - 50/40 CONFIGURATION
f = 201.6 Hz

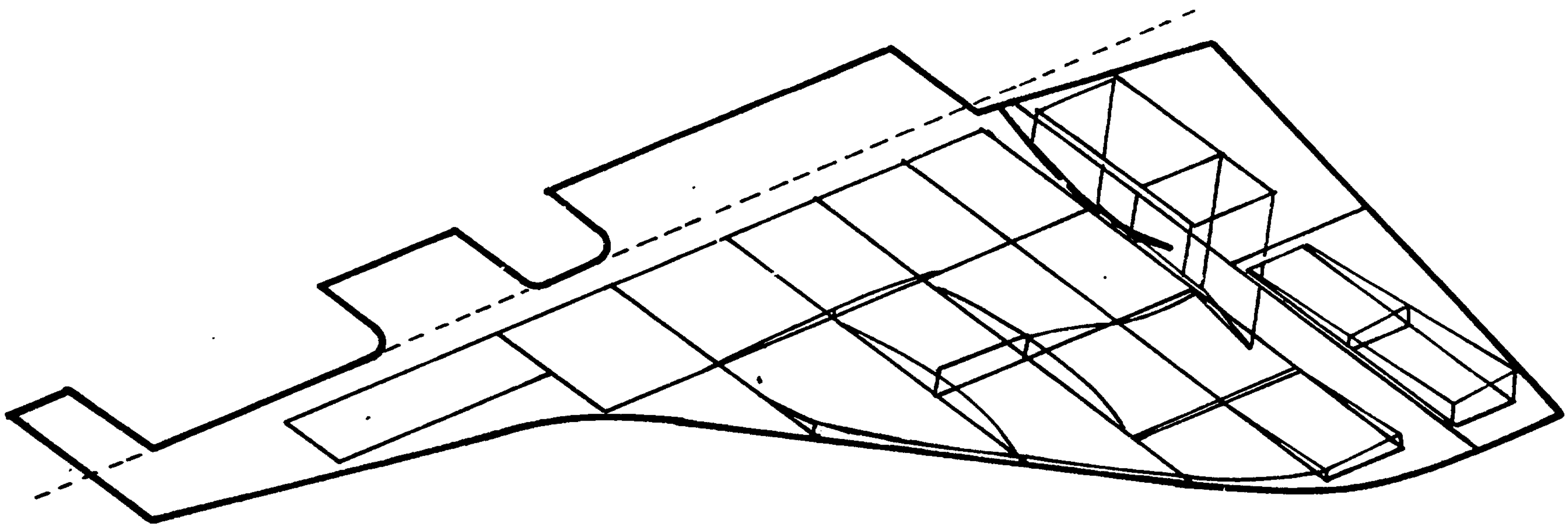


Figure A-10 GVS Modal Shape - 2nd Frequency (50/40 Config)

MODEL 23-0
WINO #1 - 50/40 CONFIGURATION
f = 235.0 Hz

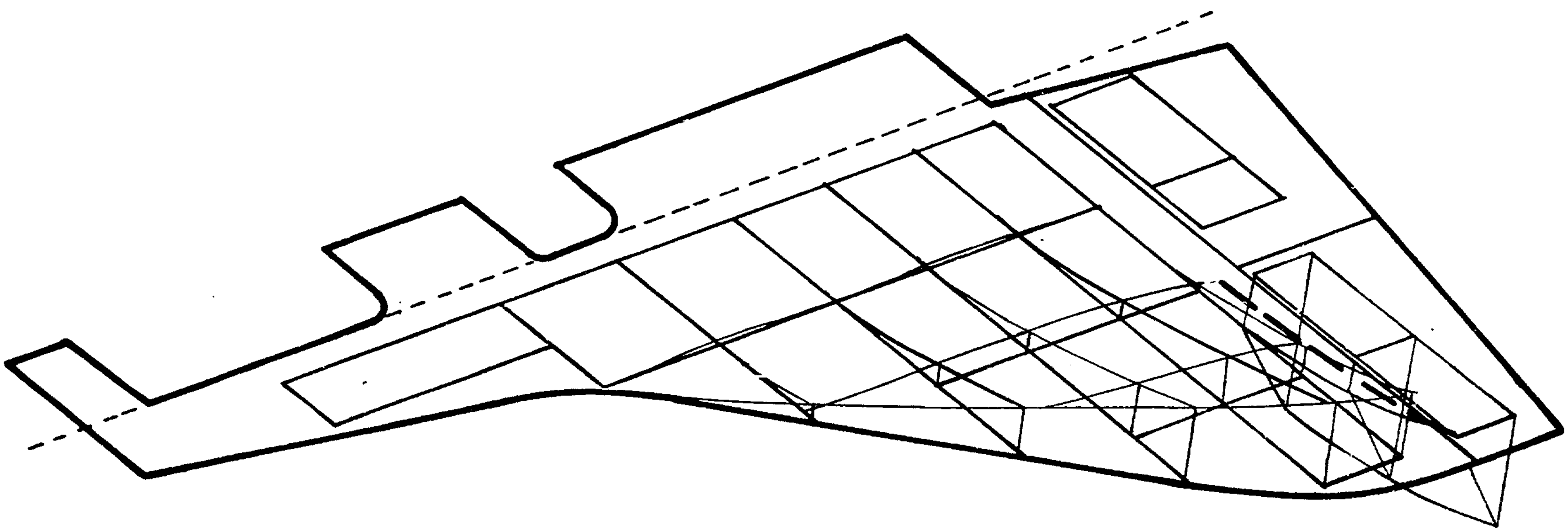


Figure A-11 GVS Modal Shape - 3rd Frequency (50/40 Config)

MODEL 23-0
WING #1 - 50/40 CONFIGURATION
f = 398.4 Hz

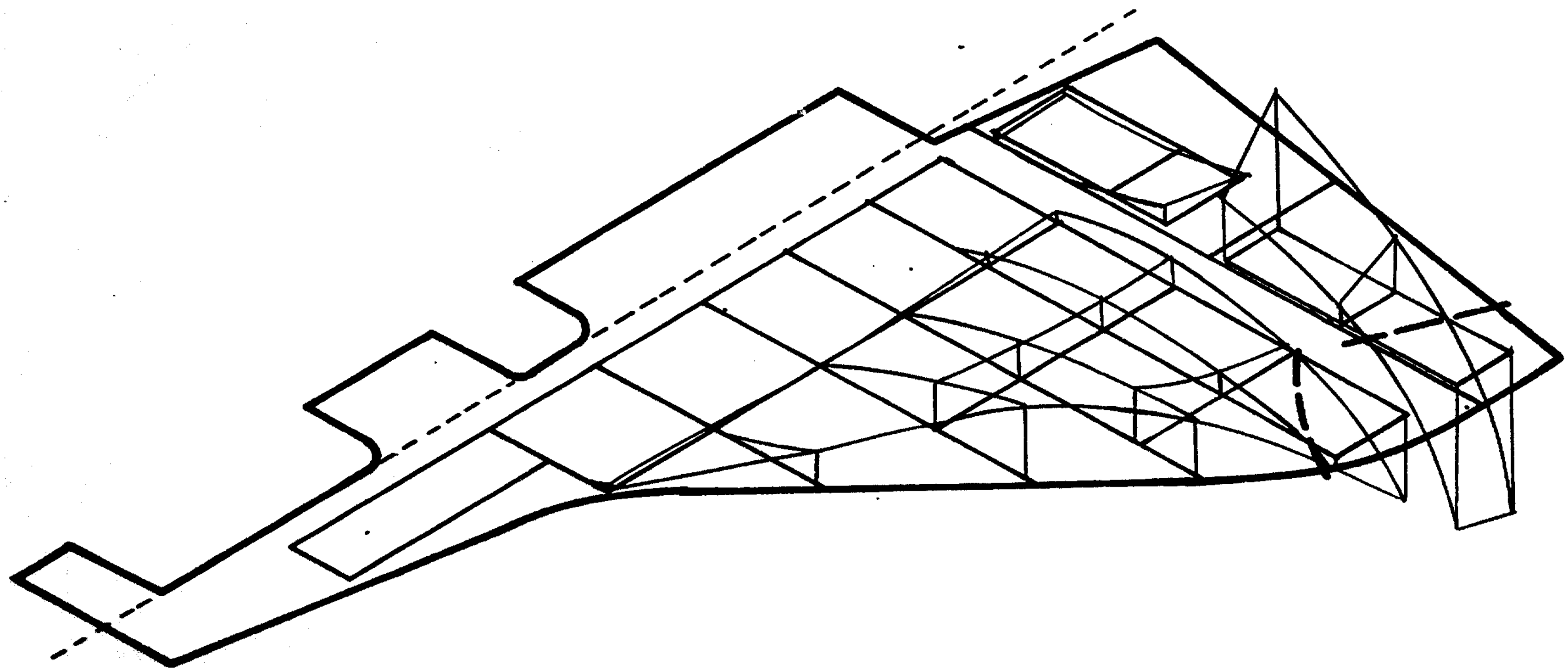


Figure A-12 GVS Modal Shape - 4th Frequency(50/40 Config)

MODEL 23-0
WING #1 - 50/40 CONFIGURATION
f = 464.6 Hz

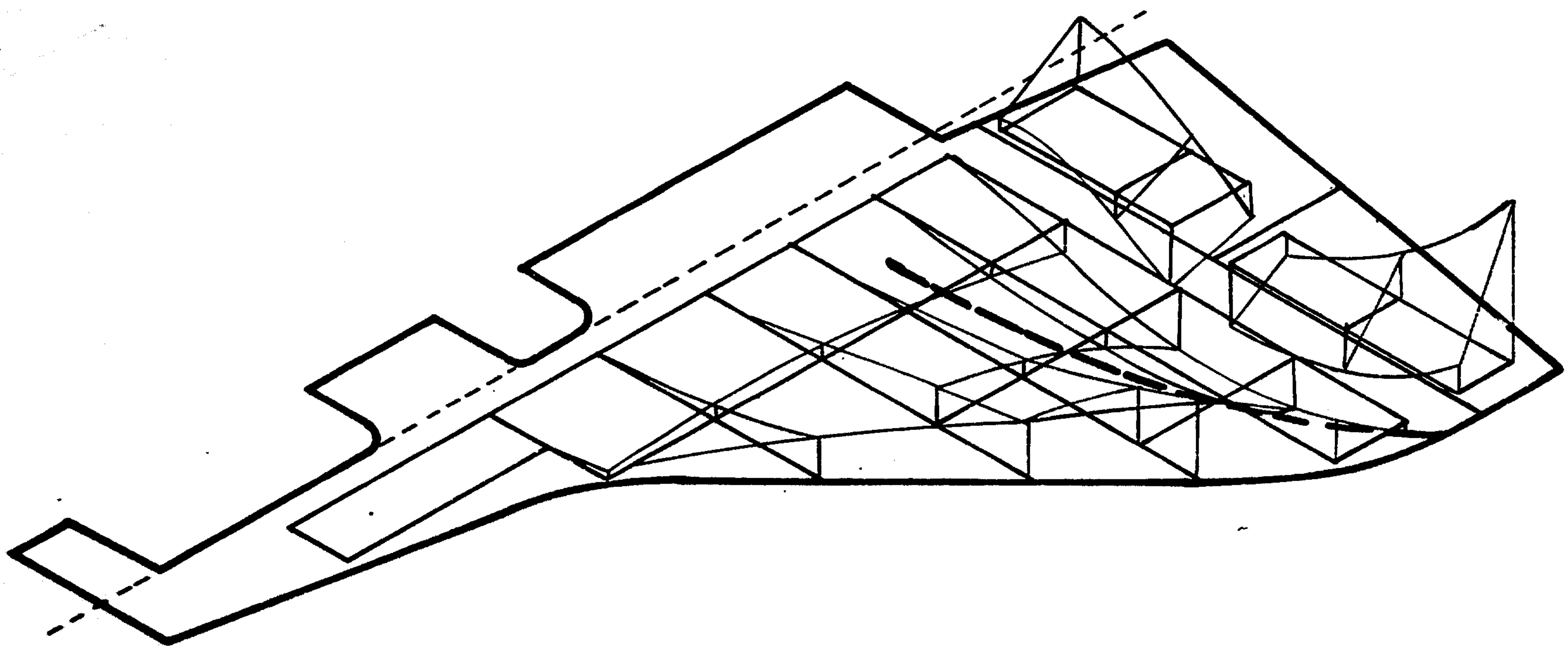


Figure A-13 Modal Shape - 5th Frequency (50/40 Config)

MODEL 23-0
WING #1 - 50/50 CONFIGURATION
f = 123.3 Hz

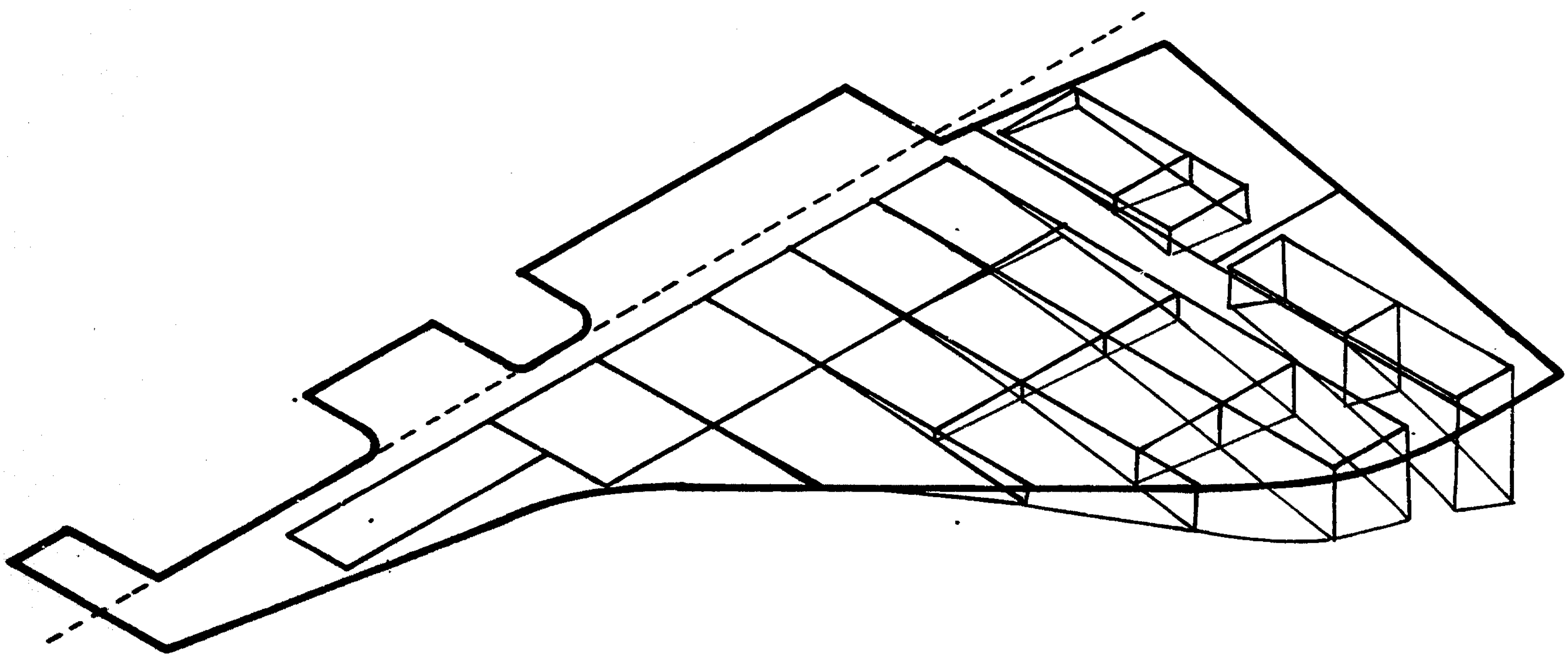


Figure A-14 GVS Modal Shape - 1st Frequency (50/50 Config).

MODEL 23-0
WING #1 - 50/50 CONFIGURATION
f = 203.4 Hz

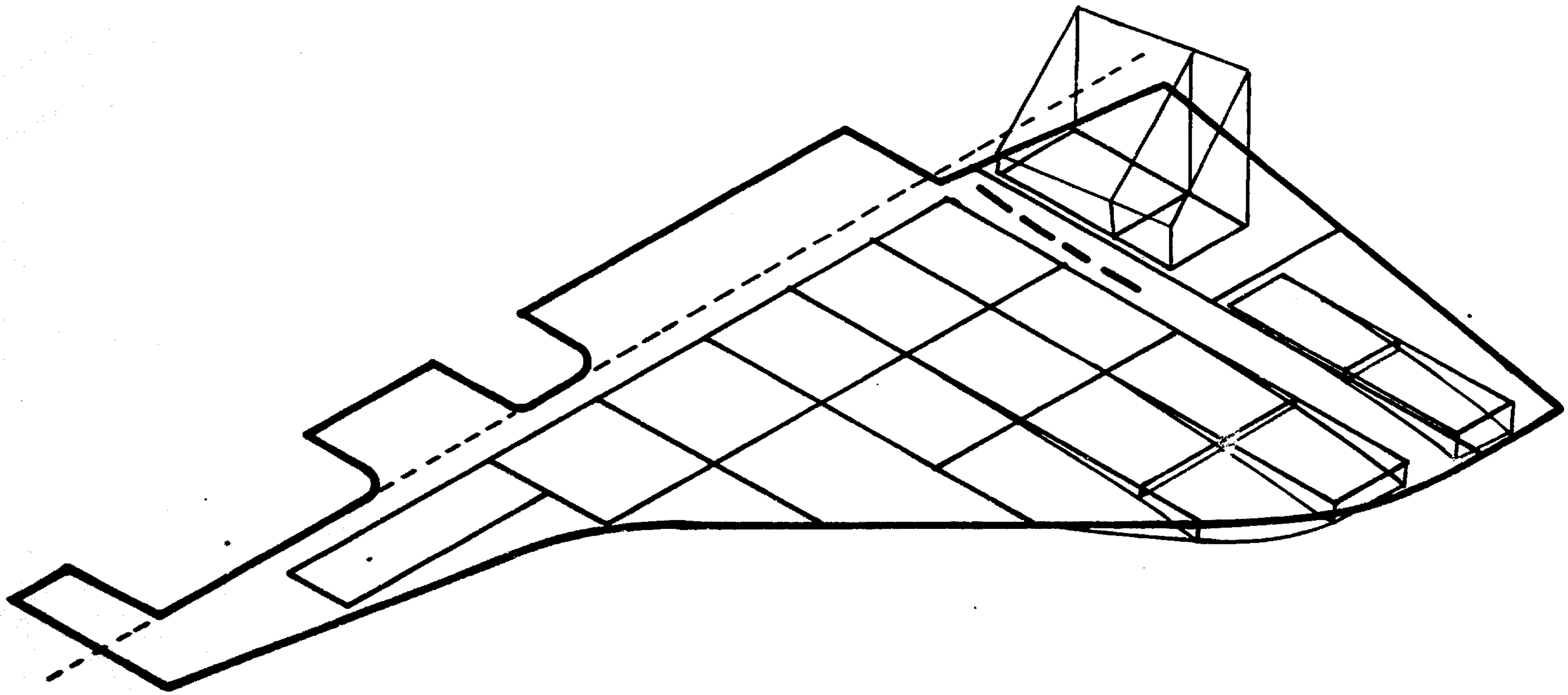


Figure A-15 GVS Modal Shape - 2nd Frequency (50/50 Config)

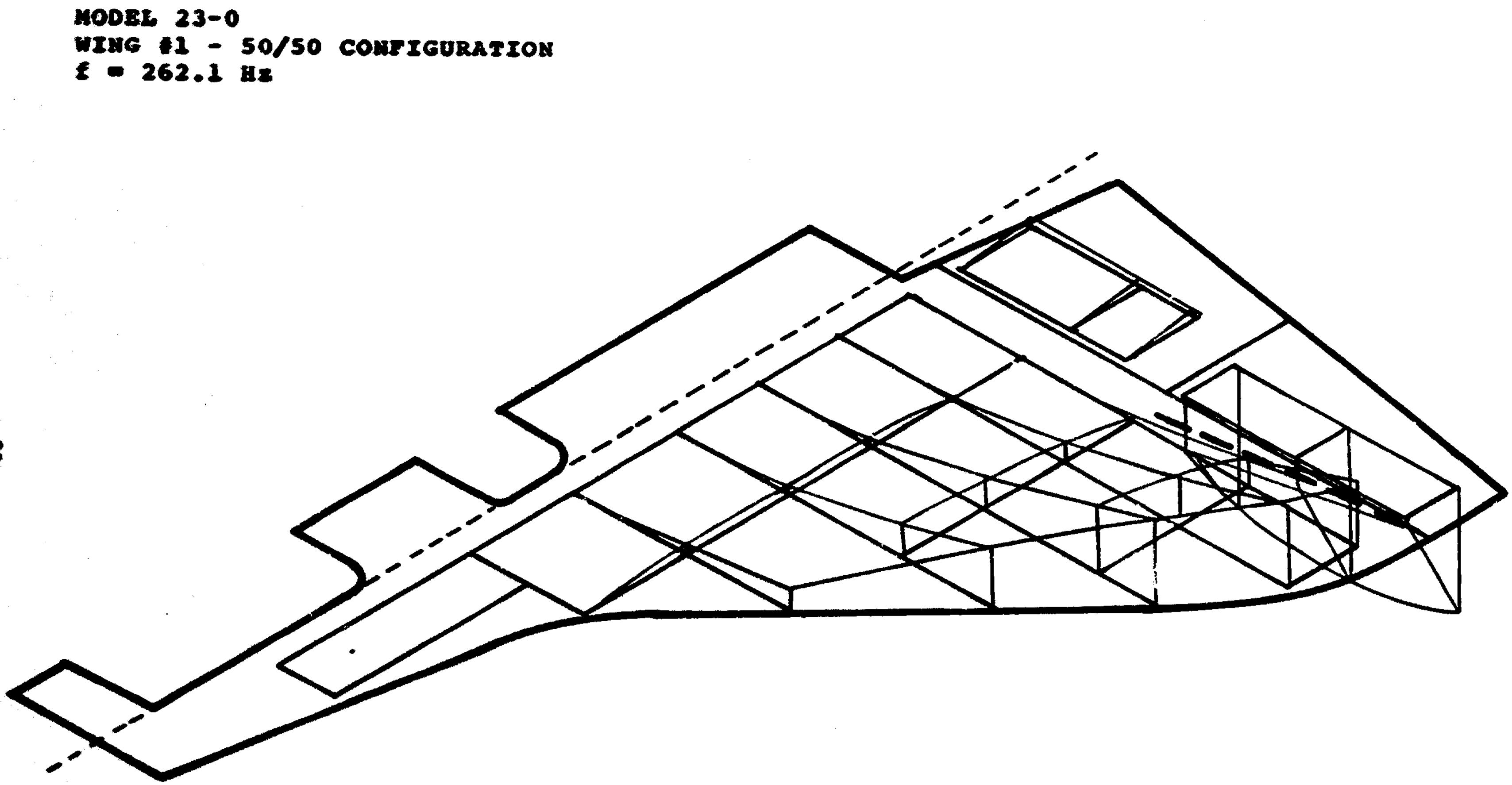


Figure A-16 GV3 Modal Shape - 3rd Frequency (50/50 Config)

MODEL 23-0
WING #1 - 50/50 CONFIGURATION
f = 403.2 Hz

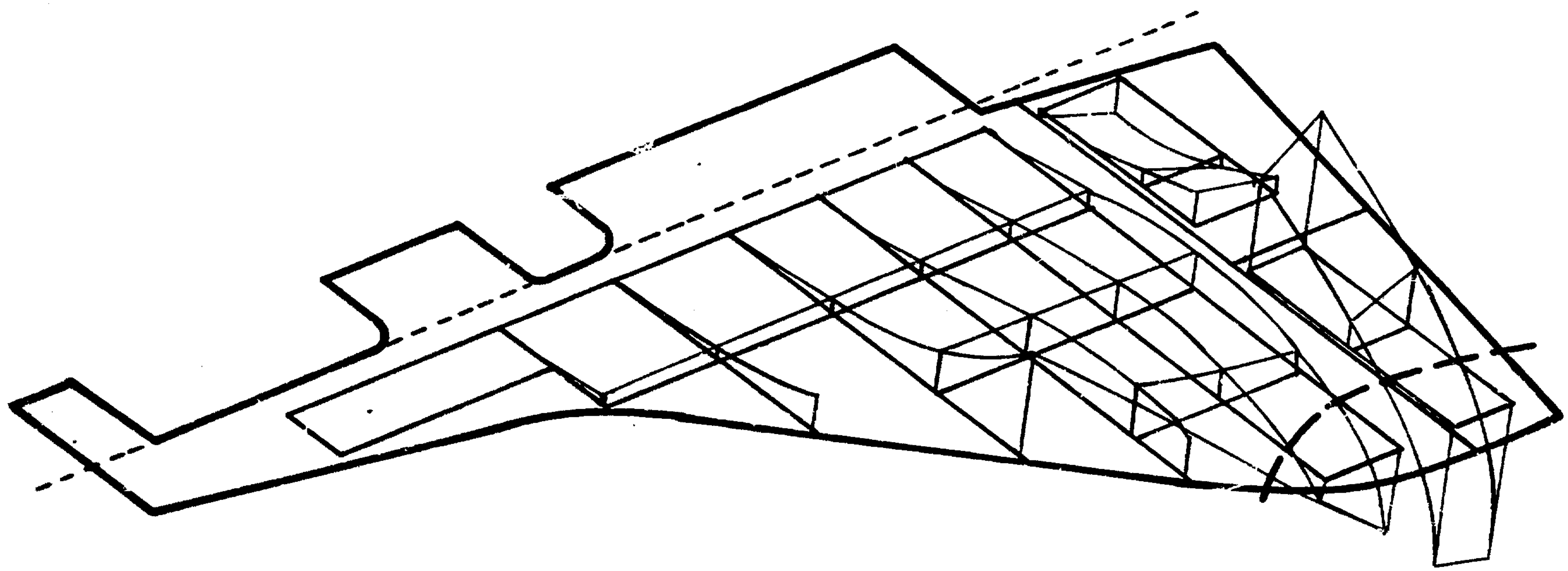


Figure A-17 GVS Modal Shape - 4th Frequency (50/50 Config)

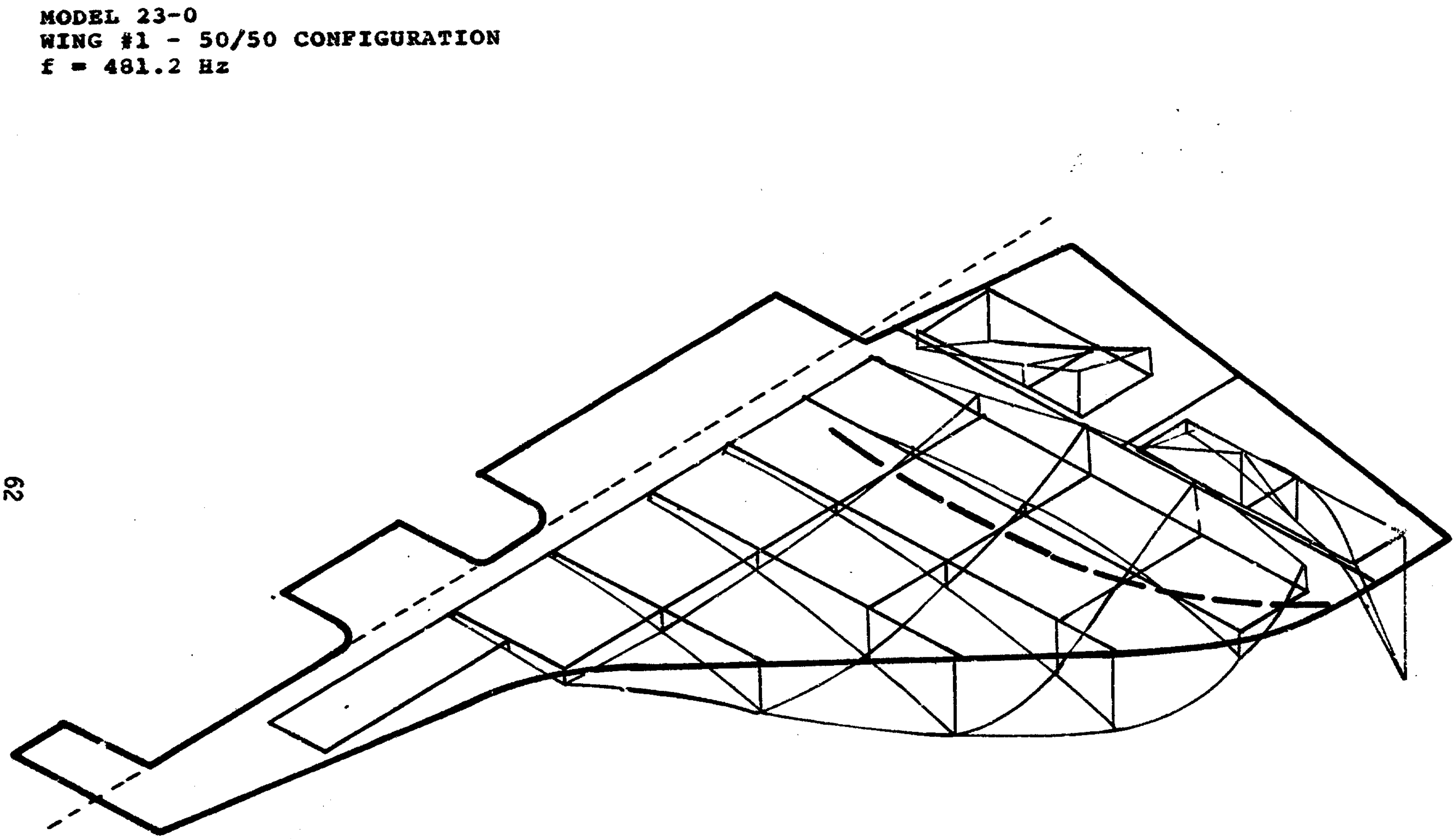


Figure A-18 GVS Modal Shape - 5th Frequency (50/50 Config)