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NASA-CR-134092) FLUTTER TESTS (IS4) OF THE 0.0125-SCALE SHUTTLE REFLECTION PLANE MODEL 30-OTS IN THE LANGLEY RESEARCH CENTER 26-INCH TRANSONIC BLOWDOWN TUNNEL (Chrysler Corp.) 72 p HC $6.75 CSCL 22B G3/31

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FLUTTER TESTS (IS4) OF THE 0.0125-SCALE SHUTTLE REFLECTION PLANE MODEL 30-OTS IN THE LANGLEY RESEARCH CENTER 26-INCH TRANSONIC BLOWDOWN TUNNEL TEST NO. 547

By

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Prepared under NASA Contract Number NAS9-13247

By

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for

Engineering Analysis Division

Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number: LaRC - 26-inch TBT Test No. 547
NASA Series Number: IS4
Model Number: 30 OTS
Test Dates: 24 through 28 September 1973
Occupancy: 57.5 hours

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FLUTTER TESTS (IS4) OF THE 0.0125-SCALE SHUTTLE REFLECTION PLANE MODEL 30-OTS IN THE LANGLEY RESEARCH CENTER 26-INCH TRANSONIC BLOWDOWN TUNNEL TEST NO. 547

By Michael A. Kotch, Rockwell International Space Division

ABSTRACT

A series of slab wing flutter models with rigid Orbiter fuselage, external tank, and SRB models of the Space Shuttle were tested, in a reflection plane arrangement, in the NASA Langley Research Center's 26-inch Transonic Blowdown Tunnel. Model flutter boundaries were obtained for both a wing-alone configuration and a wing-with-Orbiter, tank and SRB configuration. Additional test points were taken of the wing-with-Orbiter configuration, as a correlation with the wing-alone condition. This report provides a description of the wind tunnel models and test procedures utilized in the experiment.

Descriptors

Aeroelasticity

Flutter

Space shuttle

Wind Tunnel Models

Wind Tunnel Testing

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INTRODUCTION

This report describes the procedures and results of Test IS4, conducted in the NASA Langley Research Center (LaRC) 26-inch Transonic Blowdown Tunnel (TBT). The 30-OTS model consisted of a slab wing as a flutter specimen and rigid fuselage, tank and SRB structures, to simulate vehicle aerodynamics.

Purpose of this test was to isolate the effects of interfering aerodynamics, generated by the Orbiter, tank, and SRB, on the wing flutter boundary. To fulfill this objective, one boundary was determined for the wing alone (mounted on a splitter plate) while another boundary was obtained for the wing with models of the half-Orbiter, half-tank, and SRB, all mounted on a reflection plane (wing-OTS configuration). Additionally, two runs (37 and 38) were made with the wing and half-Orbiter on a reflection plane (wing-O configuration). These runs indicated the validity of the wing-alone configuration in simulating basic wing aerodynamics.

Preliminary flutter boundaries (M vs. q) are presented for the wing-alone and wing-OTS configurations. These boundaries include flutter points in the subsonic and transonic flight regions. Also included in this report are descriptions of the models and their properties. Presentations of the tunnel test conditions and run schedules are given in Tables I & II, respectively.

All material is unclassified.

NOMENCLATURE

Symbols and abbreviations used in this report:

Item	Description
A	Speed of sound (ft/sec)
C_v	Specific heat-constant volume (4290 ft^2/sec^2-°R)
ET	External Tank
F	Frequency, Hz
g	damping
GAC	Grumman Aerospace Corporation
GVS	Ground Vibration Survey
H	Total pressure, psia
LaRC	Langley Research Center
M	Mach number
O	Orbiter
P	Pressure (freestream), psia
Q,q	Dynamic pressure (freestream) psi
R	Gas constant (1716 ft^2/sec-°R)
RHO	Density (slugs/ft^3)
RN	Reynolds number per foot (1/ft)
RHOSL	Sea level density (0.0023769 slugs/ft^3)
S	Solid Rocket Booster
SD	Space Division, Rockwell International
SRB	Solid Rocket Booster

SRM	Solid Rocket Motor
T	Temperature (freestream), °F unless otherwise noted; also External Tank
TBT	Transonic Blowdown Tunnel
TS	Stagnation (Total)Temperature, °F-tabulated data only
V	Velocity (ft/sec)
VKEAS	Veolocity, equivalent airspeed in knots
W	Wing
γ	Ratio of specific heats (1.4)
μ	Viscosity (lb-sec/ft^2)

Subscripts

i	Item
o	Stagnation, or total, conditions
s	Static conditions

REMARKS

All the test objectives of Test IS4 were accomplished during the period from 24 to 28 September 1973 in 57.5 chargeable hours including 7.5 hours for model installation.

The initial runs indicated that flutter points could not be obtained within tunnel operating limits with the original wings (#1-7) as fabricated for the test. Consequently, a more flexible wing (#1M), which was constructed for NASA and designed to flutter at lower dynamic pressures, was used for Runs 3-12. Steady state flutter points were obtained with this wing configuration over a narrow range of Mach numbers in the low transonic region. This wing was then modified to obtain an even lower stiffness level (1M*, 2M*) by milling slots in the wing root tab (Figure 2). More definite flutter boundaries were established with this wing for all scheduled model configurations extending from the high subsonic to high transonic regions during Runs 13-38. Plots of these data are shown in Figures 9 and 10.

No frequency data were obtained during Run 1 due to wind damage of instrumentation wires and Run 26 due to off-scale model signals. Wing 1M* was damaged during Run 28 after being subjected to several seconds of steady state flutter and was replaced with wing 2M* for subsequent runs in the IS4 test.

Divergent flutter conditions were not encountered during the IS4 phase of testing. Normally, as dynamic pressure was increased, the dynamic response would gradually progress from random excitation to intermittent flutter to steady state flutter. As a result, it was impossible to indicate exactly (in terms of M and q) where flutter was initiated. So, instead of a sharp flutter boundary, only a flutter zone could be defined.

The more flexible 1M-8M wings, as modified on-site, which were used for the majority of the IS4 test and all of the subsequent NASA/LaRC phases of the program, were designed and fabricated by GAC as part of a current NASA shuttle development flutter program with GAC. The NASA testing phase was a logical extension of the Rockwell test since it incorporated common model components and mounting fixtures. Therefore, it was run immediately following completion of Test IS4 using consecutive run numbers and the same facility test number. The plotted data (Figures 11-14) and tabulated data have been included with the IS4 data, but the test objectives and descriptions have been presented in Appendix B.

CONFIGURATIONS INVESTIGATED

The 30-OTS model was a 0.0125-scale reflection plane model of the Shuttle system, including the Orbiter, ET and SRB. To isolate the interfering aerodynamic effects of the Orbiter fuselage, ET and SRB on the flutter behavior of the Orbiter wing, the model was tested in three configurations: wing alone, wing-with-Orbiter, and wing-with-Orbiter, ET, and SRB.

For the wing-alone configuration, the wing was supported at the root by a splitter plate which isolated the wing from the boundary layer effects of the reflection plane and the test section wall. The splitter plate also maintained the wing in the same test section position it had occupied in the other two configurations. In this way, any effects of tunnel flow field variation with test section position were eliminated.

For the wing-with-Orbiter configuration, the splitter plate was removed and the wing attached to a half-Orbiter mounted on the reflection plane.

The wing-with-Orbiter, ET, and SRB (-OTS) configuration was similar to the wing-with-Orbiter (-O) configuration, except a half-tank was mounted on the reflection plane and a SRB was rigidly clamped to the half-tank. The attachment truss between the Orbiter, tank, and SRB was provided for this configuration; however, the truss only provided aerodynamic simulation, and did not physically connect the tank to the Orbiter or SRB.

The wing stiffness distribution was approximated by properly located cutouts in a tapering thickness wing base plate. Aerodynamic contour of the wing was achieved by bonding balsa wood to the base plate and sealing the wood with a suitable sealer to provide surface smoothness. To minimize the stiffness contribution of the balsa, the wood grain was oriented normal to the wing reference plane. Figure 1 illustrates three steps in wing construction.

A set of seven wings was prepared at one stiffness level for the SD tests; another set of eight wings was prepared for NASA-LaRC at a lower stiffness level and made available for Test IS4. This latter set was further reduced in stiffness by milling slots in the wing base plate as detailed by Figure 2.

Only the wing stiffness was simulated for this test; all other structures (Orbiter, ET, and SRB) were rigid bodies mounted, without flexibility, to the reflection plane. Figure 3 illustrates the wing and bodies mounted in this manner.

The wing leading and trailing edges were painted to provide distinctive color contrast for the test movie film. The Orbiter, ET, and SRB were also outlined with a contrasting color. A vertical reference line was provided on the splitter plate and reflection plane at the intersection of the wing trailing edge. Horizontal reference lines were provided on the plate and reflection plane at, and ±1 inch from, the wing reference plane.

Nomenclature for Model 30-OTS is as follows:

B17	Body
C7	Canopy
M4	OMS pod
W115	Wing

S8 Solid Rocket Booster

T10 External Tank

Table III tabulates dimensional data for this model, based on the VL-70-000139 configuration 3 Orbiter. The model wing lines exclude camber, twist, and dihedral. Hence, thickness distribution from Y_o = 108 to Y_o = 199.045 has been reduced to ensure continuity at the wing-body interface.

The half-Orbiter and the half-external tank are left-hand models.

Model drawings used for this test are as follows:

Number	Title
SS-S-00275	General Arrangement
SS-S-00276	Wing
SS-S-00277	Splitter Plate
SS-S-00278	Fuselage
SS-S-00279	Tank & SRB
SS-S-00280	Struts, Fwd-Aft
SS-S-00281	General Assy, Wing/Body
SS-S-00282	General Assy-Wing Alone
SS-S-00326	Basic Wall Mount
SS-S-00328	Mounting Plate Layout

Model drawings are included in Reference 1, and are available from GAC. Reduced drawings of the general assemblies (-281 and -282) are included in this report as Figures 4 and 5.

INSTRUMENTATION

Instrumentation on the model consisted of two strain gage circuits of four gages each. The strain gages were located near the wing root, and were used to measure wing bending and torsion. Figure 6 illustrates the model instrumentation locations.

Tunnel parameters were measured with two static pressure transducers (one spare), one total pressure transducer, and two total temperature thermocouples (one spare).

Model dynamic response was recorded by a 1000 frames/sec movie camera viewing the model from the side.

Model and tunnel parameter instrumentation were input through amplifiers and signal conditioners and recorded on a high-speed oscillograph. A static pressure and a total pressure reference trace were also recorded on the oscillograph to permit absolute determination of tunnel pressures. A 60 Hz signal was recorded as a frequency reference, and a "camera on" reference was provided, yielding nine channels of recorded data and references.

LaRC provided additional instrumentation for pre and post-run frequency checks. This instrumentation consisted of a dual-beam oscilloscope, a variable-frequency oscillator, an electromechanical and a suitable amplifier to drive the shaker.

Figure 7 illustrates, in block diagram form, the arrangement of the test instrumentation.

FACILITY DESCRIPTION

Air was the test medium. The tunnel exhausts into the atmosphere. It is operated manually with independent control of Mach and Reynolds numbers. The test section is octagonally slotted and measures 26 inches between flats.

Operating conditions of the tunnel are as follows:

Mach number	0.6 to 1.45
Stagnation pressure	20 to 75 psia
Stagnation temperature	510 to 550^{o}R
Reynolds number per foot	2.0×10^6 to 27.0×10^6
Run time (depending on Mach number and stagnation pressure)	20 to 50 sec.

Figure 8 shows typical operating characteristics of the LRC 26-inch TBT.

TEST PROCEDURES

The model reflection plane was mounted on the starboard wall of the test section, looking upstream. The reflection plane served as the base for the three model configurations:

1. Wing-Alone. The model splitter plate was attached with spacers and bolts to the reflection plane, and the wing root was bolted to the splitter plate.
2. Wing-with-Orbiter. The wing and half-Orbiter were attached to the reflection plane.
3. Wing-with-Orbiter, ET and SRB. The wing, half-Orbiter, and half-tank were attached to the reflection plane. The one SRB was bolted to the half-tank.

Model instrumentation wiring was routed from the wing through the model splitter plate and/or reflection plane to terminal strips in the plenum chamber surrounding the test section.

The model was installed at a nominal 0° angle of attack to minimize static loads on the wing. This was verified by monitoring the mean deflection of the wing bending and torsion oscillograph traces during the initial runs.

The general test procedure 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 preselected total pressure.
7. Shutdown the tunnel when the operating limit was reached or when flutter occurred. 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, and was to be run again, only steps 4 thru 8 were followed.

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

1. Positive bending - Tip up
2. Positive torsion - Leading edge up

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 in the neighborhood of this region, but always followed one of two approaches. In the first approach, the downstream tunnel diffuser throat was set at a constant predetermined area to yield a constant nominal Mach number. Tunnel total pressure was then increased, and correspondingly the dynamic pressure, until the tunnel operating limit or flutter was attained. On occasion a second approach was utilized to minimize the potential for damaging the model.

This approach called for the increase of tunnel total pressure to a preselected constant, while at a predetermined initial diffuser throat valve setting. The valve setting was then either increased or decreased, altering Mach number and, to a lesser extent, dynamic pressure, until flutter was achieved, or the tunnel could no longer provide the desired total pressure. This latter approach provided more data points in the neighborhood of the flutter boundary, but used up a greater volume of stored air, and was not always capable of achieving the desired Mach number and dynamic pressure, due to the operating limitations of the tunnel.

All tunnel and model instrumentation data were recorded on an oscillograph, both during the runs and during pre and post-run frequency checks. In the latter case, model frequencies were read from the bending and torsion records.

The tunnel pressure and temperature required calibration signals since they were absolute measurements. Calibration readings were made immediately prior to and after each run. All pressure data were zeroed to atmospheric pressure; P_{atm} was obtained before each run from NASA-LaRC. Tunnel temperature zero was recorded on the oscillograph by switching the thermocouple switch to the "zero" position.

Normally only dynamic response was of interest for the model instrumentation. Hence no calibration or zero signals were required; however, during the initial runs a check was made to ensure that the wing static loads were not excessive. For this purpose a nominal bending moment and torque were applied to the wing. The deflection of the respective instrumentation signals on the oscillograph indicated load limits for the wing.

DATA REDUCTION

Given P_o and P_s from the test data we have

$$M = \left[\frac{2 \left[(P_o / P_s)^{\frac{\gamma-1}{\gamma}} - 1 \right]}{\gamma - 1} \right]^{\frac{1}{2}} \quad \text{and } Q = \gamma/2 \, M^2 \, P_s$$

M & Q were calculated for selected points on the oscillograph record of each run and were plotted on a tunnel typical operating characteristics chart (Figure 8) to determine the tunnel conditions for the next run.

M & Q for these points were also plotted as in Figures 9 and 10 to define the flutter boundary.

Additional parameters of interest were also calculated during post-test data reduction. Tunnel temperature, T_o, from the test data was in °F and was first converted to °R; then the following calculations were made:

$$V = AM$$

or

$$V = \sqrt{\gamma R T_s} \, M$$

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

Also, $RHO = 2Q/V^2$

and $VKEAS = \left[\dfrac{288Q}{RHOSL} \right]^{1/2} (0.5921)$

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

where $\mu_o = 2.270 \left[\dfrac{T_o^{\,1.5}}{T_o + 198.6} \right] \times 10^{-8}$

For the above the following constants were used:

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

$$\gamma = 1.4$$

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

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

The above procedures are taken from References 2 and 3.

DISCUSSION OF RESULTS

Each model assembly underwent vibration tests at GAC before wind tunnel testing. These tests are used by GAC for the model flutter analysis that supports this test program (see Reference 4).

One model assembly of each stiffness level was subjected to a complete ground vibration survey (GVS). Subsequent models were checked for frequencies, f_i, and damping coefficients, g_i, and node line locations. GVS frequencies are summed in Table IV.

Pre and post-run frequency checks were made in the test section during the test. Since the wing root tab modification was made during the test, no GVS data was available for comparison after run 12. In this case, the initial frequencies obtained during the pre-run 13 frequency check were taken as target frequencies for subsequent runs. Pre and post-run frequencies are tabulated in Table V.

Tabulated data of tunnel conditions of points of interest in the test are presented in Appendix A. These points were utilized in defining preliminary flutter boundaries. Explanation of the tabulated data format is found in Table VI.

Preliminary model flutter points for the wing-alone and wing/OTS configurations are presented in Figures 9 and 10, respectively. Because these points must be corrected to reflect actual flight densities, of the actual shuttle trajectory, no conclusions can be presented other than, flutter points were obtained for subsonic and transonic flow conditions. (GAC will present a final model analysis with corrected test data comparisons). Due to the rapid recovery of the flutter boundary in the supersonic region, it was not possible to obtain flutter information in this area within the tunnel operating limits.

As noted in the Remarks section, the model flutter behavior changed gradually, and not abruptly, over a range of dynamic pressure. The boundary is not a clearly defined line, but more like a zone. The boundary indicated in the figures is a qualitative description of the bounds where intermittent flutter became pronounced.

REFERENCES

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2. Ames Research Staff: Equations, Tables, and Charts for Compressible Flow. NASA Report 1135, 1953.

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

4. Thomas, W.; Zentgraf, J.; and Foley, T.: Results Obtained from Tests and Analyses on the 1/80th Scale Wing/Body Models (30-OTS) of the Rockwell Shuttle. GAC Report No. LD-RS-7, December 1973.

TABLE I. - TUNNEL TEST CONDITIONS

Nominal M	Dynamic Pressure, psi
1.25	Trim run; q = 4 psi
0.585	Flutter or maximum
0.65	↓
0.68	
0.69	
0.70	
0.74	
0.75	
0.785	
0.80	
0.83	
0.835	
0.85	
0.88	
0.895	
0.915	
0.95	
0.953	
0.98	
1.0	
1.03	
1.05	
1.09	
1.1	
1.12	
1.24	
1.3	
1.35	↓

TABLE II. - TEST RUN SCHEDULE

1/80th Scale Wing/Body Model (30-ØTS)   Tunnel Log

Run No.	Point No.	Wing No.	Model Configuration: Bodies (F-Fuselage, T-Tank, S-SRM)	Model Configuration: SRM Flex	Tunnel Conditions: Mach* No.	Tunnel Conditions: q* (psi)	Model Freq. (HZ)	Records: O'graph	Records: Movie	Remarks	Date
1	1	1	----	----	1.261	23.39		X		Trim Run - Tunnel fog at H = 55	9/24/73
2	1	2			.781	19.62			X	L.D.	
3	1	1M			.805	16.45				L.D.	
	2				.785	17.48				F.I.	
	3				.789	18.67	320			FSS	
4	1	1M			.871	22.42				FI-LD	
5	1				1.092	25.56				Max H	
	2				.964	22.46				FI	
	3				.937	22.0	320			FSS	
6	1	1M			1.102	21.79				MAX H	
	2				.819	16.38				Start FI	
	3				.803	16.05				End FI	
	4				.72	14.01					
7	1	1M			1.021	23.65					
	2				1.002	25.14					
	3				.98	25.9	358			Start FSS	
8	1	1M			.722	18.29				Stable	9/25/73
9	1	1M			.884	19.90					
9	2	1M			.887	23.0				FSS	
	3				.893	18.46				FI	

* Mach No. and q* [illegible] computed during the test

X = Record taken

S = stable
LD = Low Damping
FI = Intermittent Flutter
FSS = Steady State Flutter
FD = Divergent Flutter
H = Total Pressure

Table II - cont.

1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configuration: Wing No.	Model Configuration: Bodies F-Fuselage T-Tank S-SRM	Model Configuration: SRM Flex.	Tunnel Conditions: Mach* No.	Tunnel Conditions: q* (psi)			Model Freq. (HZ)	Records: O'graph	Records: Movie	Remarks	Date
10	1	1M	F,T,S	——	.857	22.31				X	X	Stable————LD	9/25/73
11	1	1M	F,T,S		1.061	25.36						S	
	2	1M			.898	21.69						FI	
	3	1M			.731	16.77						FI	
	4	1M			.627	13.31						LL	
12	1	1M	F,T,S		.657	13.39						S	
13	1	1M*			.813	12.61			272		No Movie		
	2				.795	13.88			283			FSS	
14	1	1M*			.830	7.93							
	2				.933	16.11			270		X	FI	
	3				.946	17.91			271		X	FSS	
15	1	1M*			.667	12.7					No Movie	FI - LD	
	2				.664	14.07			311			FSS	
16	1	1M*			1.034	21.28					X	FI	
	2				1.027	24.73						FI	
	3				1.018	27.06						FSS	
	4				.988	25.49						FD	
17	1	1M*			.871	10.17						LD	9/26/73
	2				.869	12.78						FI	
	3				.874	14.59						FSS	
	4				.865	15.19						FSS max H	

* TANG MODIFICATION

Table II - cont. 1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configuration: Wing No.	Model Configuration: Bodies F-Fuselage T-Tank S-SRM	Model Configuration: SRM Flex.	Tunnel Conditions: Mach* No.	Tunnel Conditions: q* (psi)	Model Freq. (HZ)	Records: O'graph	Records: Movie	Remarks	Date
18	1	1M*	-----	----	.700	15.81		X	X	FSS	9/26/73
	2				.683	15.5					
19	1	1M*	T,F,S		.68	15.7				LD	
	2				.68	16.05				FI	
20	1	1M*	T,F,S		.85	16.2				FI	
	2				.85	20.0				FSS (MAX Q)	
21	1	1M*	T,F,S		.77	14.4				FI	
	2				.755	15.9				FSS	
22	1	1M*	T,F,S							LD	
	2				.902	19.24				FI	
	3				.908	20.5				FSS	
23	1	1M*	T,F,S		.585	13.9				S	
24	1	1M*	T,F,S,								
	2				1.30	30.4				SLarge Static Loads on Model	
25	1	1M*	T,F,S							S Static Load Building	
	2									S	
	3				1.09	28.3				S Max H pt.	
26		1M*	T,F,S					NG	X	Strain gage sens. too high (will repeat)	

* Tang Modifications

Table II - cont. 1/80th Scale Wing/ Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configurations: Wing No.	Bodies: F-Fuselage, T-Tank, S- SRM	SRM Flex.	Tunnel Conditions: Mach* No.	q* (psi)			Model Freq. (HZ)	Records: O'graph	Movie	Remarks	Date
27	1	1M*	F,T,S	-----									9/26/73
	2												
	3				.915	24.0			335	X	X	FSS	
28	1	1M*	F,T,S									Max Control H (Tunnel Malfunct. Could not Shut down)	
	2											Dec. to Min H	
	3											FI; H Increased	
	4											rapidly	
	5								315			FSS	
	6											FSS max H pt	
												FSS End (shutdown)	
29	1	2M*	-----									S	
	2				1.35	29.4						Max H S	
30	1	2M*			1.25	30.3						Max H S	
31	1	2M*			1.12	25.3							9/27/73

* Tang Modifications

Table II -cont

1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configurations: Wing No.	Bodies F-Fuselage T-Tank S-SRM	SRM Flex.	Tunnel Conditions: Mach* No.	q* (psi)	Model Freq. (HZ)	Records: O'graph	Movie	Remarks	Date
32	1	2M*	----	----	.68	17.1		X	X	S	9/28/73
33	1	2M*			.945	17.1	260	X	X	FSS	
	2				.953	20.3	273		X	FSS	
34	1	2M*			.835	15.75	275	X	X	FSS	
35	1	2M*			.74	16.15	305	X	X	FSS	
36	1	2M*			.69	16.78	315	X	X	FSS	
	2		√				314		X	FSS	
37	1	2M*	F		.845	17.0	268		X	FI	
	2						272		X	FI	
38	1	2M*	F				279		color	FI	
	2						299			FI	
	3				1.03	24.0	316			FSS	
39	1	2M*	F		.605	14.3		X	color	Stable to LD (Note tunnel will show Run 38 on Film)	10/1/73
40	1	2M*	F		.77	14.3		X	color	FI	
	2	2M*	F		.75	18.6	303	X	B&W	FSS	
41	1	2M*	F		.93	18.0		X	B&W	FI	
	2	2M*	F		.91	18.7	270			FSS	
42	1	2M*	F		1.046	24.5		X	B&W	FI	
	2		F							FI	
	3	2M*	F	√	1.02	26.4				Stable to LD	

Table II - cont. 1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run NO.	Point No.	Model Configuration: Wing No.	Model Configuration: Bodies F-Fuselage T-Tank S-SRM	Model Configuration: SRM Flex.	Tunnel Conditions: Mach* No.	Tunnel Conditions: q* (psi)	Model Freq. (HZ)	Records: O'graph	Records: Movie	Remarks	Date
43	1	2M*	F	----	1.113	26.8		X	b&w	FI	10/1/73
	2	2M8	F		1.11	27.8		X	X	LD (Almost Stable)	
44	1	2M*	F		.64	14.6		X	X	LD	
45	1	2M*	F		.76	13.55		X	No	LD	
	2	2M*	F		.75	15.30		X	No.	FI	
	3	2M*	F		.71	16.90		X	X	FSS	
46	1	2M*	F		.82	13.0		X	X	Cam Start FI	
	2	2M*	F		.83	15.7		X	X	FSS	
47	1	2M*	F		.93	13.8		X	No	FI	
	2	2M*	F		.91	16.9		X	X	FSS	
48	1	2M*	F		.99	18.4		X	X	FI	
	2	2M*	F		.98	23.4		X	X	FSS	
49	1	2M*	F		1.18	25.3		X	X	LD Cam on	
	2	2M*	F		1.17	29.9		X	X	LD	
50	1	2M*	F		1.254	27.2		X	X	LD	
	2	2M*	f		1.258	32.0		X	X	Stable	
51	1	2M*	F	√	1.377	25.5		X	X	LD	10/2/73
	2	2M*	F		1.333	30.2		X	X	Stable	

END - ORBITER RUNS

Table II - cont. 1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configuration: Wing No.	Bodies F-Fuselage T-Tank S-SRM	SRM Flex.	Tunnel Conditions: Mach* No.	q* (psi)			Model Freq. (HZ)	Records: O'graph	Movie	Remarks	Date
52	1	2M*	F & T	------	.600	14.16				X	X	Stable (No Flutter)	10/2/73
53	1	2M*	F & T		.85	16.62				X	X	FI	
	2	2M*	F & T		.837	17.20				X	X	FSS	
54	1	2M*	"		.726	14.9				X	X	FI	
	2	2M*	"		.716	17.05				X	X	FSS	
55	1	2M*	"		.78	15.95				X	X	FI	
	2	2M*	"		.779	17.20				X	X	FSS	
56	1	2M*	"		.90	16.50				X	X	FI	
	2	2M*	"		.91	19.05				X	X	FSS	
57	1	2M*	"		.95	22.3				X	X	FSS	
58	1	2M*	"		.97	26.2				X	X	FSS (after shutdown)	
	2	2M*	"		.91	22.5				X	X	FSS	
59	1	2M*	"		1.10	27.3				X	X	FSS	
60	1	2M*	"		1.13	29.8				X	X	FI	
61	1	2M*	"		1.24	31.5				X	X	LD	
62	1	2M*	"		1.34	31.1				X	X	FSS	
63	1	2M*	"		.89	17.5				X	X	FSS	
64	1	2M*	"		.73	16.1				X	X	FSS	
	2	2M*	"		.71	17.6						FSS	
65	1	2M*	"		1.002	23.7				X	X	FI	
	2	2m*	"		.972	24.2				X	X	LD	

* Tang Modifications

Table II - cont.   1/80th Scale Wing/Body Model (30-OTS)   Tunnel Log

Run No.	Point No.	Model Configuration: Wing No.	Bodies F-Fuselage T-Tank S-SRM	SRM Flex.	Tunnel Conditions: Mach* No.	q* (psi)			Model Freq. (HZ)	Records: O'graph	Movie	Remarks	DATE
66	1	2M*	F,T,S	Case 1	.62	14.3				X	X	Flutter FI	10/3
67	1	"	"	"	,88	18.4				X	X	" "	
68	No Data									X	X	Gd. Flutter @ 65	
69	1	2M*	"	"	.789	16.0				X	X	Repeat 68 --FF Lost Wing	
	2	2M*	"	"	.727	16.15				X	X	" FSS Torsion Circuit	10/4
70	1	5M*	"	"	.779	15.32				X	X	Lost Wing - FI	
	2	5M*	"	"	.779	18.04				X	X	Ctr. Panel FD	
71	1	6M*	"	"	.88	23.4				X	X	FD	
72	1	6M*	"	"	.95	24.2				X	X	FD	
73	1	6M*	"	"	.98	26.6				X	X	FI	
	2	6M*	"	"	.92	22.9				X	X	FD (After shutdown)	
74	1	6M*	"	"	1.075	29.25				X	X	No Flutter	
	2	"	"	"	.91	19.4				X	X	FSS (After shutdown)	
75	1	"	"	"	1.12	30.1				X	X	No Flutter	
76	1	"	"	"	1.21	31.0				X	X	No Flutter	
77	1	"	"	"	1.32	30.9				X	X	" "	
78	1	"	"	"	.91	18.1				X	X	FSS	
79	1	6M*	"	"	.852	16.0				X	X	FSS	
	2	"	"	"	.824	17.45				X	X	FD	
80	1	"	"	"	.664	13.80						FSS	
	2	"	"	"	.662	14.60							

Table II - concluded. 1/80th Scale Wing/Body Model (30-OTS) Tunnel Log

Run No.	Point No.	Model Configuration: Wing No.	Model Configuration: Bodies F-Fuselage t-Tank S-SRM	Model Configuration: SRM Flex.	Tunnel Conditions: Mach* No.	Tunnel Conditions: q* (psi)	Tunnel Conditions	Tunnel Conditions	Model Freq. (HZ)	Records: O'graph	Records: Movie	Remarks	Date
81	1	6M*	F,T,S	II	.642	12.25				X	X	FI	10/5
	2	"	"	"	.655	13.83				X	X	FSS	
82	1	"	"	"	.786	13.97				X	X	FSS	
	2	"	"	"	.786	14.70				X	X	FD	
83	1	"	"	"	.740	14.7				X	X	FD	
84	1	"	"	"	.950	21.5				X	X	FSS	
85	1	"	"	"	.910	15.5				X	X	FSS	
86	1	"	"	"	.860	16.1				X	X	FSS	
87	1	"	"	"	.850	15.7				X	X	FSS	
88	1	"	"	"	.82	14.6				X	X	FSS	
89	1	"	"	"	.71	14.1				X	X	FSS	
90	1	"	"	"	.98	26.2				X	X	FI	
	2	"	"	"	.94	22.2				X	X	FSS (After shutdown)	
91	1	"	"	"	.96	20.2				X	X	FSS	
92	1	"	"	"	1.07	29.1				X	X	Flutter after shutdown	
93	1	"	"	"	1.22	31.2				X	X	No flutter	
94	1	"	"	"	.93	17.35				X	X	FSS	

TABLE III. - MODEL DIMENSIONAL DATA

MODEL COMPONENT: BODY - B17

GENERAL DESCRIPTION: Fuselage, 3 Configuration, Lightweight Orbiter per Rockwell Lines VL70-000139 modified to allow smooth intersection with the symmetrical wing.

Model Scale = 0.0125

DRAWING NUMBER VL70-000139

DIMENSION:	FULL SCALE	MODEL SCALE
Length - IN.	1290.3	16.12875
Max Width - IN.	267.6	3.34500
Max Depth - IN.	244.5	3.05625
Fineness Ratio	4.82175	4.82175
Area - FT^2		
Max Cross-Sectional	386.67	0.06042
Planform		
Wetted		
Base		

TABLE III. - Continued.

MODEL COMPONENT: Canopy - C7

GENERAL DESCRIPTION: Configuration 3 per Rockwell Lines VL70-000139

Model Scale = 0.0125

DRAWING NUMBER VL70-000139

DIMENSION:	FULL SCALE	MODEL SCALE
Length (X_o = 433 to X_o = 670) - in. FS	237	2.96250
Max Width		
Max Depth		
Fineness Ratio		
Area		
Max Cross-Sectional		
Planform		
Wetted		
Base		

TABLE III. - Continued.

MODEL COMPONENT: OMS Pod - M4

GENERAL DESCRIPTION: Configuration 3 per Rockwell Lines VL70-000139

NOTE: M_4 identical to M_3, except intersection to fuselage.

Model Scale = 0.0125

DRAWING NUMBER VL70-000139

DIMENSION:	FULL SCALE	MODEL SCALE
Length - IN	346.0	4.32500
Max Width - IN	108.0	1.35000
Max Depth - IN	113.0	1.41250
Fineness Ratio		
Area - FT^2		
Max Cross-Sectional		
Planform		
Wetted		
Base		

MODEL COMPONENT: WING-W115

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.
Forward of 40c: 0006.5-64 modified to match thickness of section aft of .40c.

Model Scale = 0.0125

TEST NO.

DIMENSIONS:	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.) Ft^2		
Planform	2690.00	0.42031
Wetted		
Span (Theo In.)	936.68	11.70850
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
Toe-In Angle		
Cant Angle		
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.0.0	689.24	8.61550
Tip, (Theo) B.P.	137.85	1.72312
MAC	474.81	5.93512
Fus. Sta. of .25 MAC	1136.89	14.21112
W.P. of .25 MAC	299.20	3.74000
B.L. of .25 MAC	182.13	2.27662
Airfoil Section		
Root		
Tip		
EXPOSED DATA		
Area (Theo) Ft^2	1752.29	0.27380
Span, (Theo) In. BP108	720.68	9.00850
Aspect Ratio	2.058	2.058
Taper Ratio	0.2451	0.2451
Chords		
Root BP108	562.40	7.03000
Tip 1.00 b/2	137.85	1.72312
MAC	393.03	4.91288
Fus. Sta. of .25 MAC	1185.31	14.81638
W.P. of .25 MAC	300.20	3.75250
B.L. of .25 MAC	251.76	3.14700

TABLE III. - Continued.

Airfoil Section (Rockwell Mod NASA) XXXX-64	251.76	3.14700
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	0.01880
Leading Edge Intersects Fus M. L. @ Sta	560.0	7.000
Leading Edge Intersects Wing @ Sta	1035.0	12.93750

TABLE III. - Continued.

MODEL COMPONENT: BOOSTER SOLID ROCKET MOTOR - S8

GENERAL DESCRIPTION: Booster Solid Rocket, 3 Configuration, Body of Revolution, Data for (1) of (2) sides, per Rockwell Lines VL77-000036 and VL72-000088

Model Scale = 0.0125

DRAWING NUMBER VL72-000088
VL77-000036

DIMENSION:	FULL SCALE	MODEL SCALE
Length (Includes Nozzle) - IN	1741.0	21.76250
Max Width (Tank Dia.) - IN	142.0	1.77500
Max Depth (Aft Shroud) - IN	205.0	2.56250
Fineness Ratio	8.49268	8.49268
Area - FT^2		
Max Cross-Sectional	229.21	0.03581
Planform		
Wetted		
Base		
WP of BSRB Centerline (Z_T) - IN	400.0	5.000
FS of BSRM Nose (X_T) - IN	200.0	2.500

TABLE III. - Concluded.

MODEL COMPONENT: EXTERNAL TANK - T10

GENERAL DESCRIPTION: External Oxygen Hydrogen Tank, 3 Configuration per Rockwell Lines VL78-000041 and VL72-000088

Model Scale = 0.0125

DRAWING NUMBER VL72-000088
VL78-000041

DIMENSION:	FULL SCALE	MODEL SCALE
Length - IN (Nose @ X_T = 309)	1865	23.31250
Max Width (Dia) - IN.	324	4.0500
Max Depth	-	-
Fineness Ratio	5.75617	5.75617
Area - FT^2		
Max Cross-Sectional	572.555	0.08946
Planform		
Wetted		
WP of Tank Centerline (X_T) IN.	400.0	5.000

TABLE IV. - GVS FREQUENCIES

1/80th Scale SD Wing Model (30-ØTS)

SUMMARY OF MODEL FREQUENCIES

Model No.	f1 Hz	f2 Hz	f3 Hz	f4 Hz	f5 Hz
1	258.6	616.4	825.2	1272.8	1472.2
2	259.2	608.3	845.1	1268.0	1459.3
3	258.9	635.2	840.2	1316.5	1460.1
4	256.3	612.0	807.8	1270.5	1381.9
5	247.0	606.8	809.0	1241.1	1446.7
6	257.5	609.7	827.6	1254.7	1432.7
7	243.1	607.9	801.2	1247.4	1459.5

TABLE IV. – continued.

1/80th Scale NASA Wing Model

SUMMARY OF MODEL FREQUENCIES

Model No.	f1 Hz	f2 Hz	f3 Hz	f4 Hz	f5 Hz
1M	205.7	511.3	662.7	1026.2	1209.0
2M	207.5	540.3	696.6	1117.0	1307.4
3M	208.8	540.1	695.1	1103.5	1297.1
4M	231.2	554.5	717.7	1125.1	1245.8
5M	221.2	526.4	697.0	1054.8	1179.8
6M	229.1	552.0	704.8	1108.3	1224.9
7M	223.1	549.1	711.3	1124.8	1266.3
8M	230.8	567.5	722.7	1150.6	1290.0

TABLE V. - PRE - AND - POST - RUN FREQUENCIES

1/80TH SCALE WING/BODY MODEL (30 - ØTS)

PRE-RUN FREQUENCY CHECKS

RUN	MODEL CONFIGURATION: WING NO.	BODIES F-FUSELAGE T-TANK S-SRM	SRM FLEXURE	FREQUENCIES (Hz): 1	2	3	4	REMARKS
PRE 1	1	----------	-------	253	616	825	1270	
PRE 2	2	----------	-------	253	612	785	----	
POST 2	2	----------	-------	248	590	840	----	
PRE 3	1M	----------	-------	210	540	680	----	
PRE 4	1M	----------	-------	205	520	650	----	
PRE 5	1M	----------	-------	209	535	670	----	
PRE 6	1M	----------	-------	209	532	660	----	
PRE 7	1M	----------	-------	209	530	660		
PRE 8	1M	----------	-------	204	516	654		
PRE 9	1M	----------	-------	205	510	660		
PRE 10	1M	T, S, F	-------	204	515	668	----	
PRE 11	1M	T, S, F	-------	204	516	675	----	
PRE 12	1M	T, S, F	-------	204	516	670	----	
PRE 13	1M*	----------	-------	186	477	576	----	
PRE 14	1M*	----------	-------	185	468	570	----	
PRE 15	1M*	----------	-------	185	468	570	----	
PRE 16	1M*	----------	-------	182	465	566	----	
PRE 17	1M*	----------	-------	186	470	570	----	
PRE 18	1M*	----------	-------	186	475	565	----	
PRE 19	1M*	T, S, F	-------	185	470	570	----	
PRE 20	1M*	T, S, F	-------	186	470	572	----	
PRE 21	1M*	T, S, F	-------	186	468	570	----	
PRE 22	1M*	T, S, F	-------	186	468	568		
PRE 23	1M*	T, S, F	-------	184	466	570		
PRE 24	1M*	T, S, F	-------	185	460	576		
PRE 25	1M*	T, S, F	-------	185	470	570		
PRE 26	1M*	T, S, F	-------	185	470	570		
PRE 27	1M*	T, S, F	-------	184	466	560		
PRE 28	1M*	T, S, F	-------	185	470	560		
POST 28	1M*	T, S, F	-------	175	520	550	CHANGING MODEL. APPARENT DAMAGE.	
PRE 29	2M*	----------	-------	188	510	600		
PRE 30	2M*	----------	-------	185	500	590		
PRE 31	2M*	----------	-------	184	492	590		
PRE 32	2M*	----------	-------	182	497	585		

*TANG MODIFICATION

TABLE V - continued.

1/80TH SCALE WING/BODY MODEL (30 - ØTS)

PRE-RUN FREQUENCY CHECKS

RUN	MODEL CONFIGURATION			FREQUENCIES (Hz)			REMARKS
	WING NO.	BODIES F-FUSELAGE T-TANK S-SRM	SRM FLEXURE	1	2	3	
PRE 32	2M*	————	————	182	497	585	
PRE 33	2M*	————	————	180	490	580	
PRE 34	2M*	————	————	179	490	572	
PRE 35	2M*	————	————	178	488	580	
PRE 36	2M*	————	————	178	478	576	
POST 36	2M*	————	————	175	465	570	
PRE 37	2M*	F	————	176	468	570	
PRE 38	2M*	F	————	175	470	580	
PRE 39	2M*	F	————	176	470	575	
PRE 40	2M*	F	————	176	468	575	
PRE 41	2M*	F	————	176	470	580	
PRE 42	2M*	F	————	176	470	575	
PRE 43	2M*	F	————	176	470	575	
PRE 44	2M*	F	————	175	470	575	
PRE 45	2M*	F	————	178	470	550	
PRE 46	2M*	F	————	177	460	560	
PRE 47	2M*	F	————	176	480	550	
PRE 48	2M*	F	————	175	460	560	
PRE 49	2M*	F	————	177	460	560	
PRE 50	2M*	F	————	173	465	560	
PRE 51	2M*	F	————	175	465	560	
PRE 52	2M*	F&T	————	175	470	565	
PRE 53				174	468	565	
PRE 54				174	468	570	
PRE 55				174	470	570	
PRE 56				174	470	570	
PRE 57				175	480	560	
PRE 58				175	470	560	
PRE 59				176	470	560	
PRE 60				178	480	580	
PRE 61				178	470	560	
PRE 62				175	470	570	
PRE 63				175	480	570	
PRE 64				175	460	560	
PRE 65				169	477	570	

TABLE V - concluded.

1/80TH SCALE WING/BODY MODEL (30 - ØTS)

PRE-RUN FREQUENCY CHECKS

RUN	MODEL CONFIGURATION			FREQUENCIES (Hz)			REMARKS
	WING NO.	BODIES F-FUSELAGE T-TANK S-SRM	SRM FLEXURE	1	2	3	
PRE 66	2M*	F, T & S	I	170	460	550	124HZ (PITCH)
PRE 67	2M*	F, T & S	I	170	450	NA	
PRE 68	2M*	F, T & S	I	170	470	560	
PRE 69	2M*	F, T & S	I	170	470	560	WG. TORSION CKT. - OUT
PRE 70	5M*	F, T & S	I	194	480	590	LOST CTR. PANEL
PRE 71	6M*	F, T & S	I	202	480	640	
PRE 72	6M*	F, T & S	I	175	450	560	DECAYS OK.
PRE 73	6M*	F, T & S	I	175	450	560	DECAYS OK.
PRE 74	6M*	F, T & S	I	179	460	560	DECAYS OK.
PRE 75	6M*	F, T & S	I	178	450	540	
PRE 76	6M*	F, T & S	I	175	450	520	
PRE 77	6M*	F, T & S	I	170	440	---	
PRE 78	6M*	F, T & S	I	174	440	540	
PRE 79	6M*	F, T & S	I	176	445	545	
PRE 80	6M*	F, T & S	I	170	450	540	
PRE 81	6M*	F, T & S	II	174	445	545	
PRE 82	6M*	F, T & S	II	170	450	545	
PRE 83	6M*	F, T & S	II	168	450	545	
PRE 84	6M*	F, T & S	II	168	450	540	
PRE 85	6M*	F, T & S	II	167	430	520	
PRE 86	6M*	F, T & S	II	170	440	520	
PRE 87	6M*	F, T & S	II	168	420	520	222 on SRM (PITCH)
PRE 88	6M*	F, T & S	II	166	430	520	
PRE 89	6M*	F, T & S	II	167	420	520	
PRE 90	6M*	F, T & S	II	165	420	520	
PRE 91	6M*	F, T & S	II	170	420	520	
PRE 92	6M*	F, T & S	II	165	430	520	
PRE 93	6M*	F, T & S	II	165	420	520	
PRE 94	6M*	F, T & S	II	165	420	520	

TABLE VI. - TABULATED DATA FORMAT

TBT TEST NO. 545 08.13/73 09.03.27

Col. No.:	5	10	16	23	30	36	43	51	58	66	75	83	91	95	101	111
	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

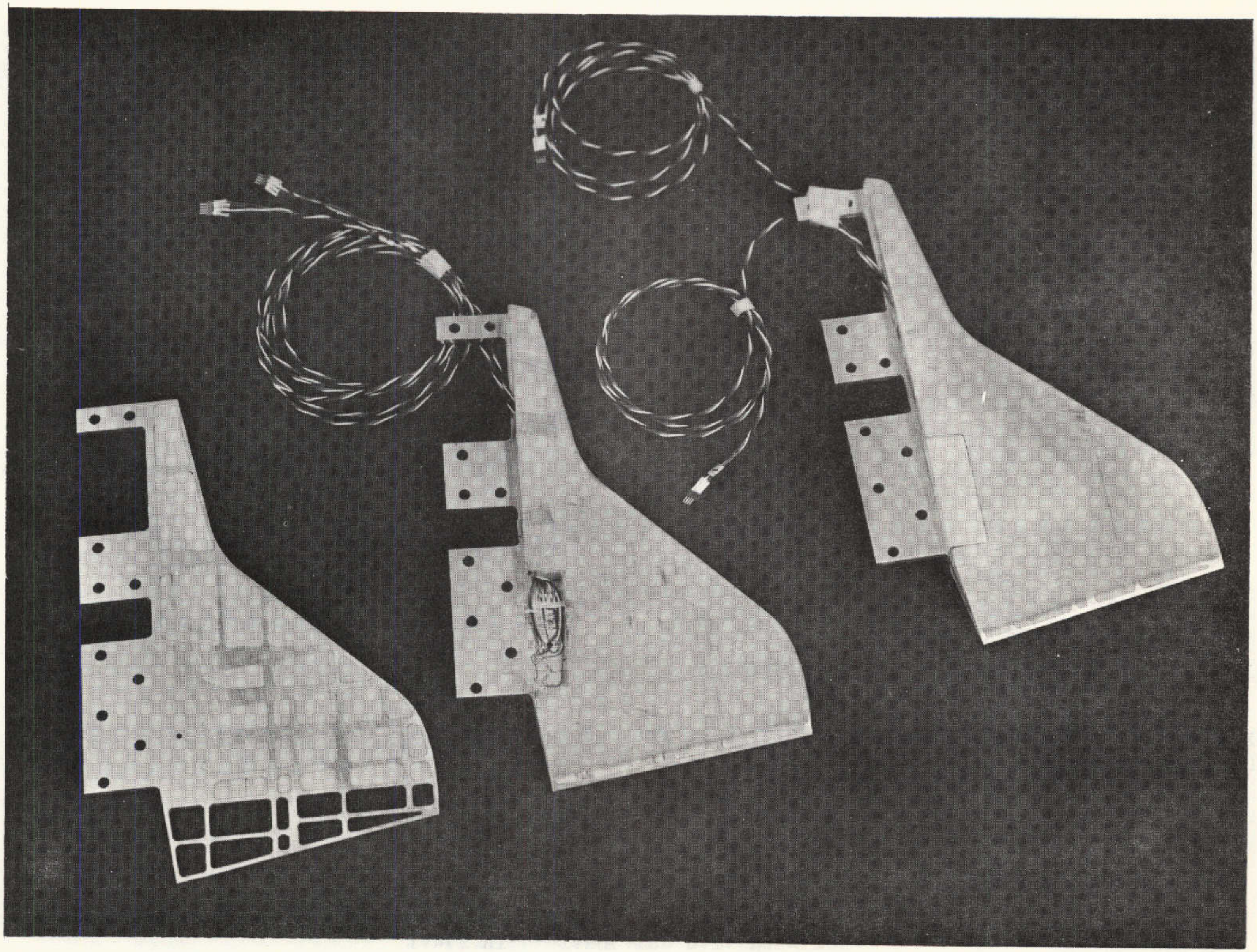


Figure 1. - Photograph - Wing Construction Detail.

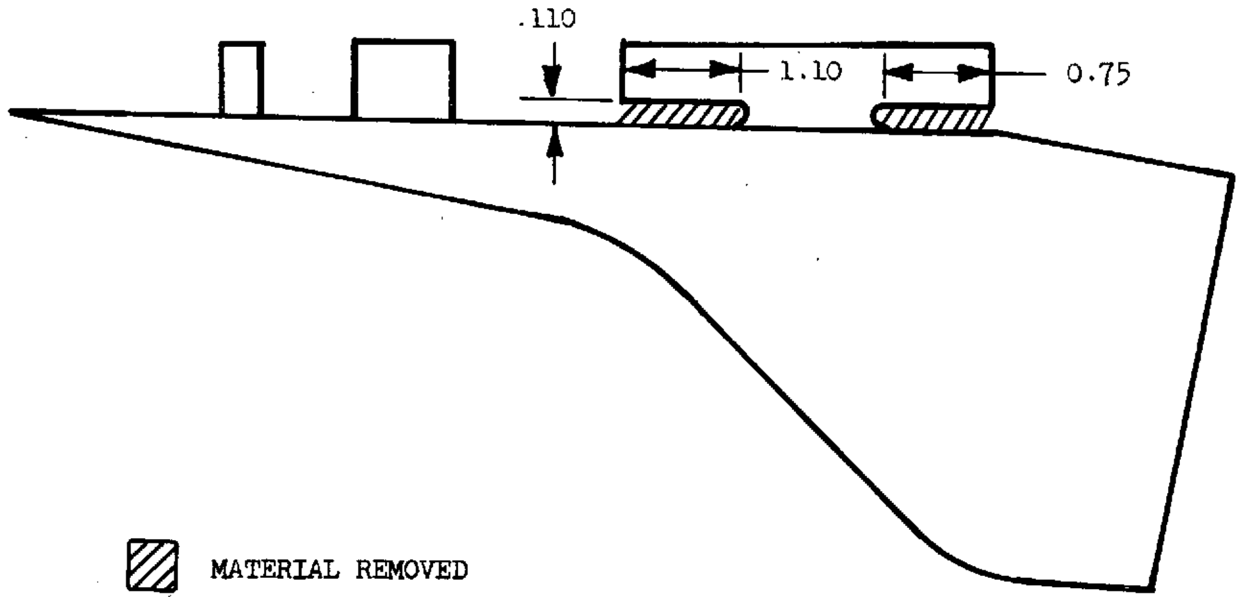


Figure 2.- Root Tab Modification.

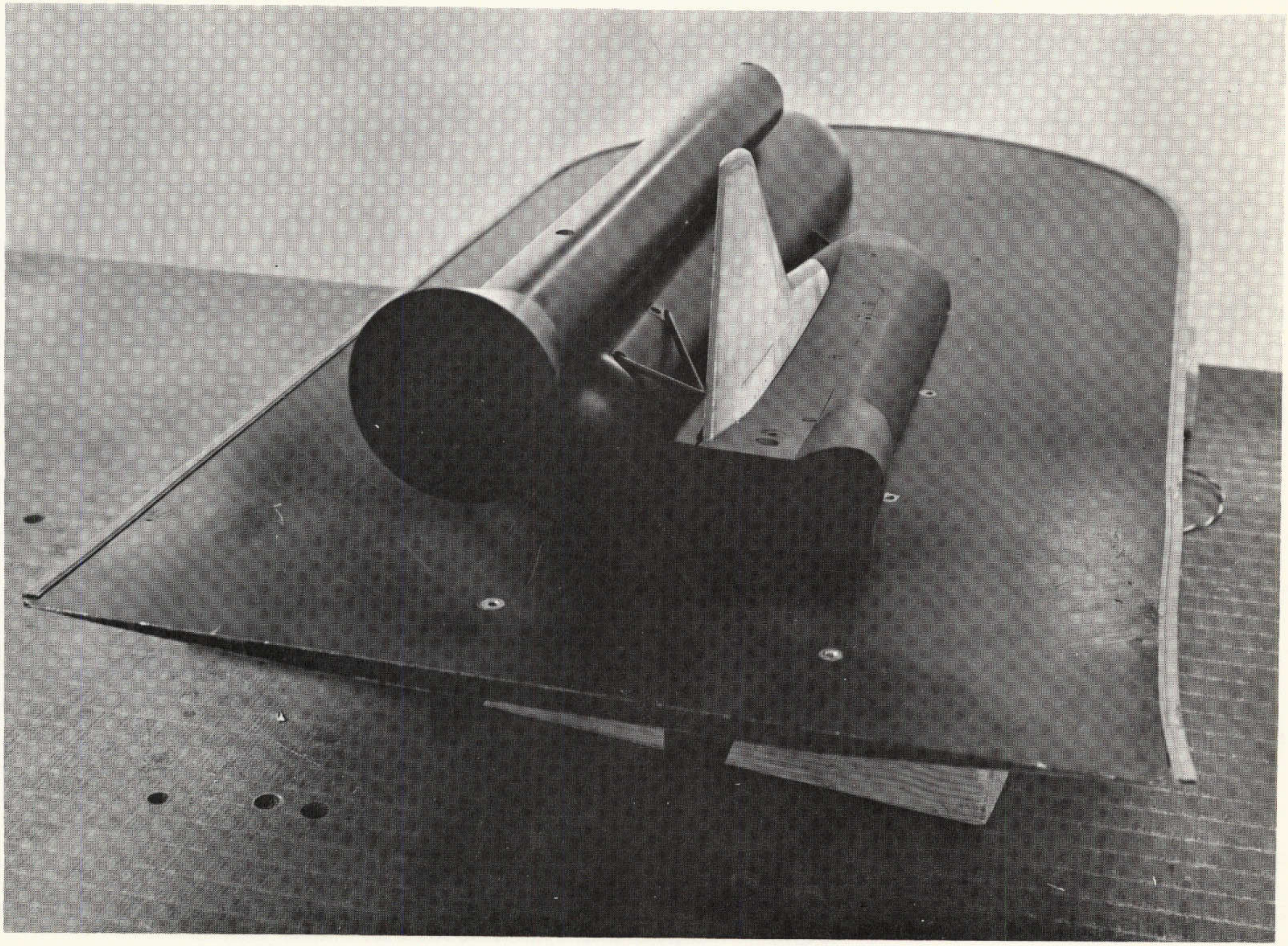


Figure 3. - Photograph - Wing/Body Assembly.

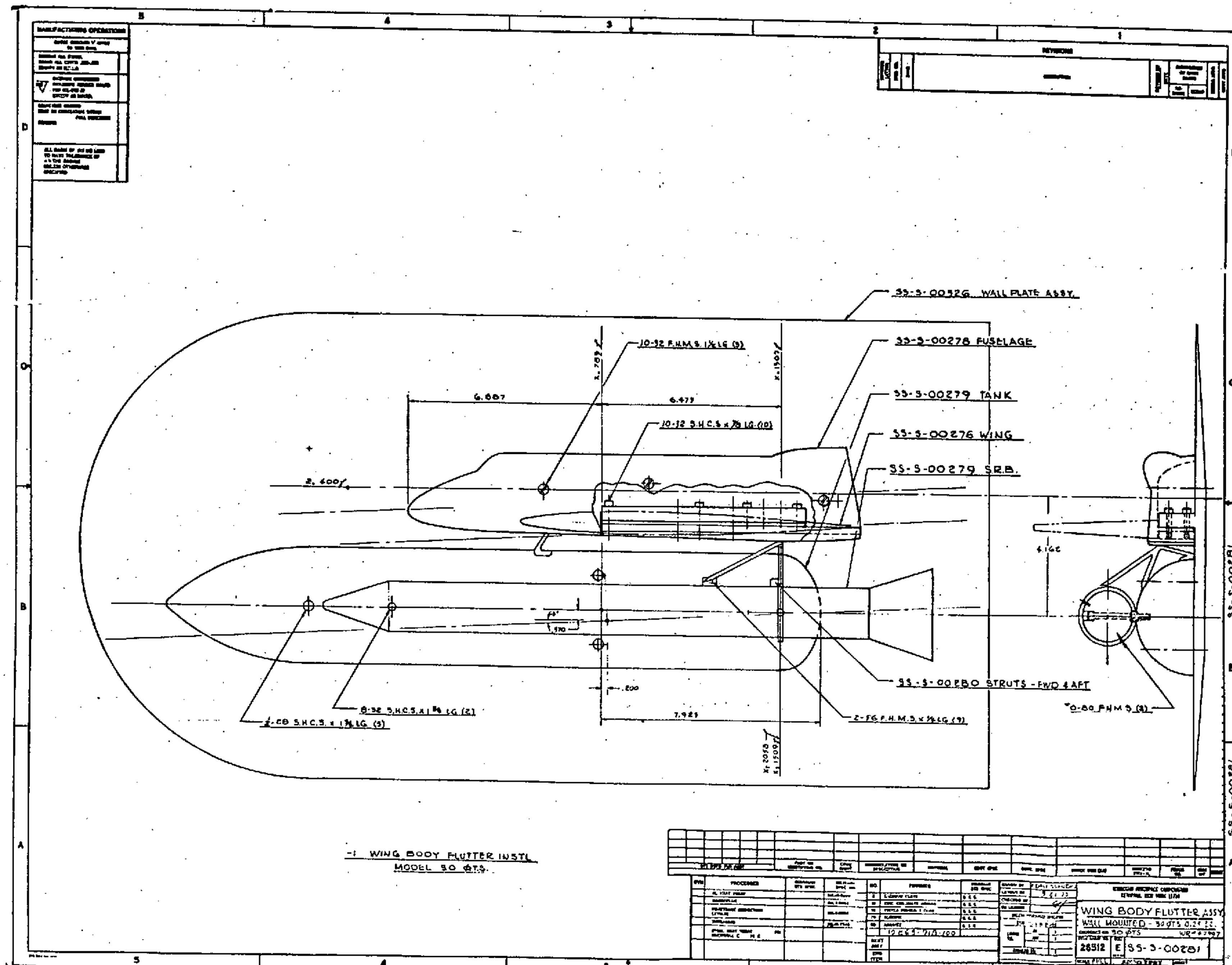


Figure 4. - General Assemby - Wing/Body.

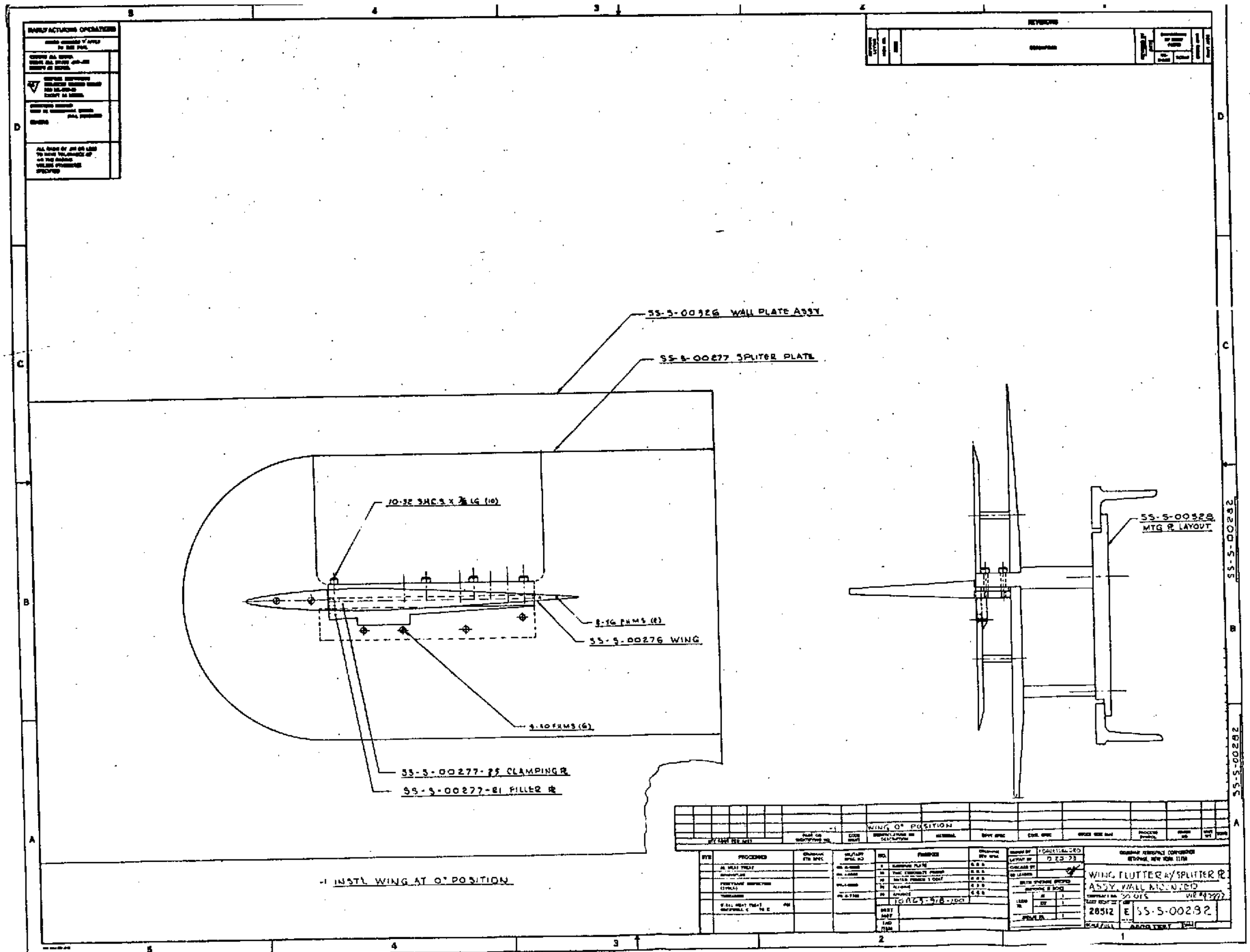
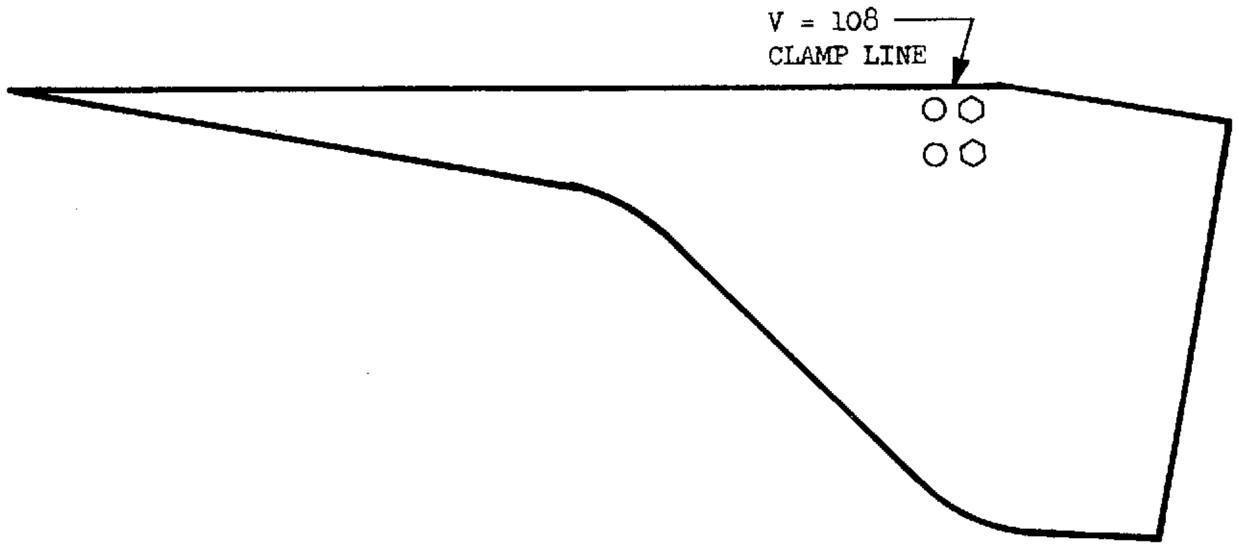


Figure 5. - General Assembly - Wing Alone.



LEGEND:

⬡ TORSION GAGES

○ BENDING GAGES

Figure 6.- Model 30-OTS Instrumentation.

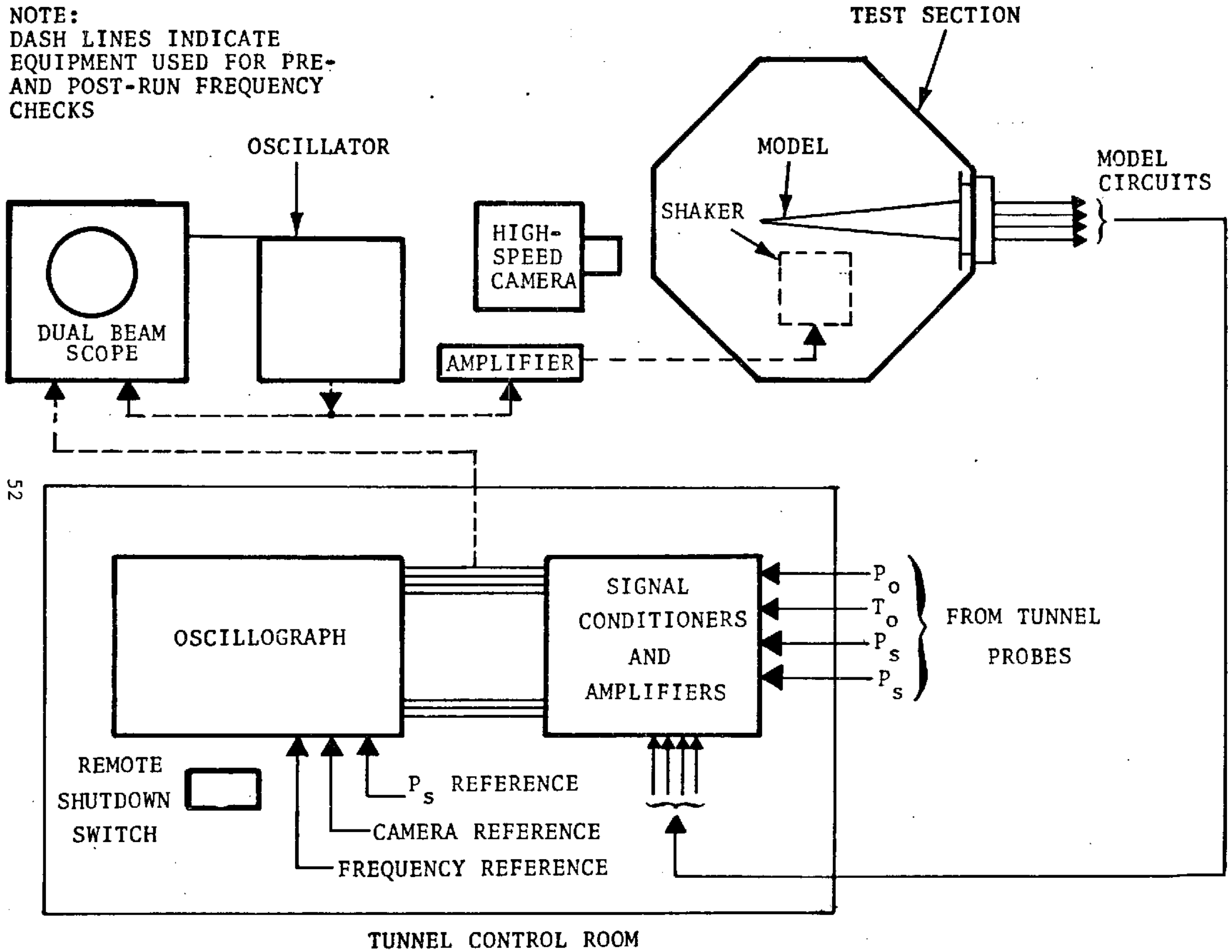


Figure 7.- Instrumentation Equipment.

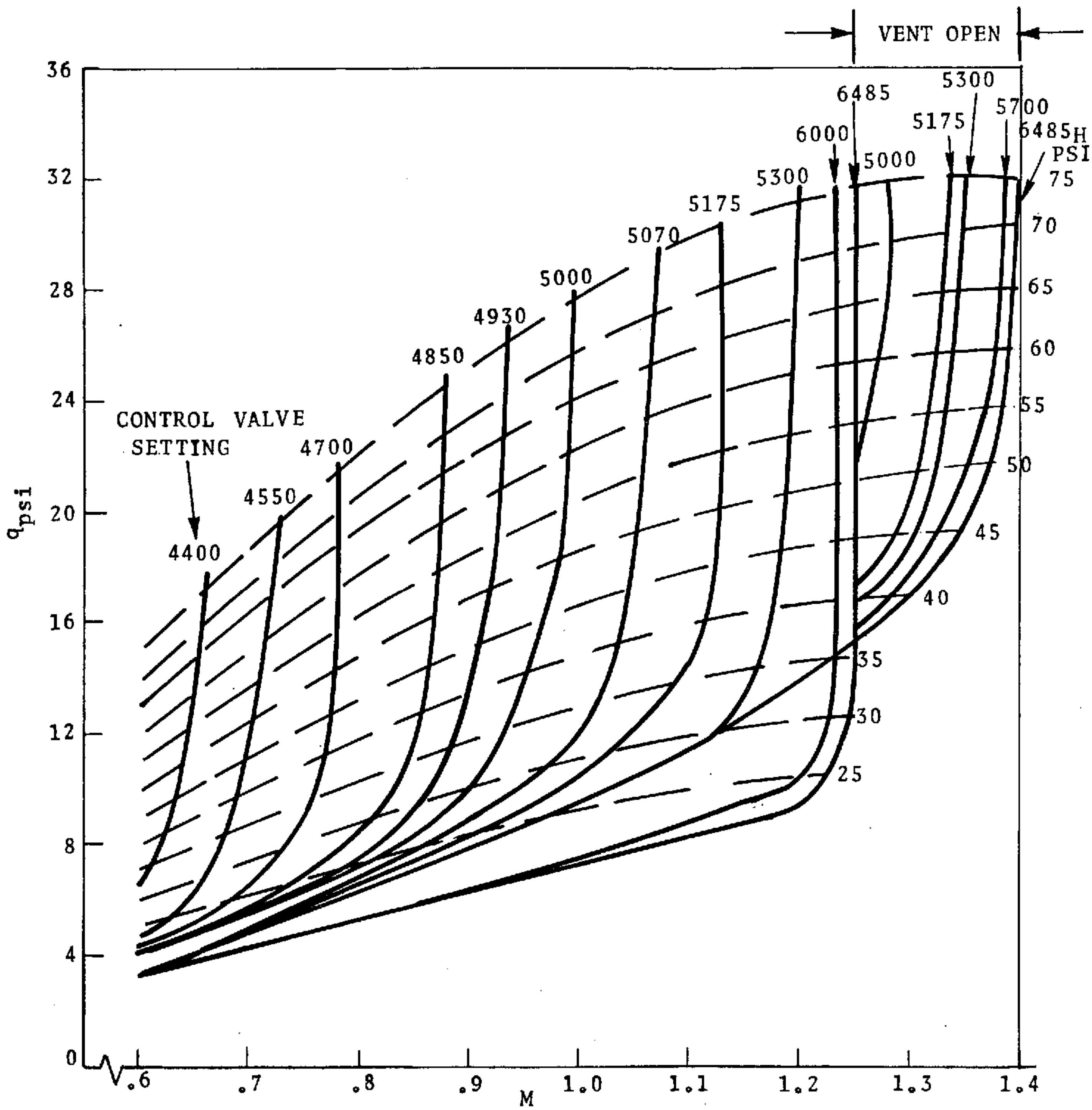


Figure 8.-Typical Operating Characteristics of 26-inch Langley Transonic Blowdown Tunnel. Wall attached 3-inch diameter sting is located approximately 7 inches from wall and has model installed.

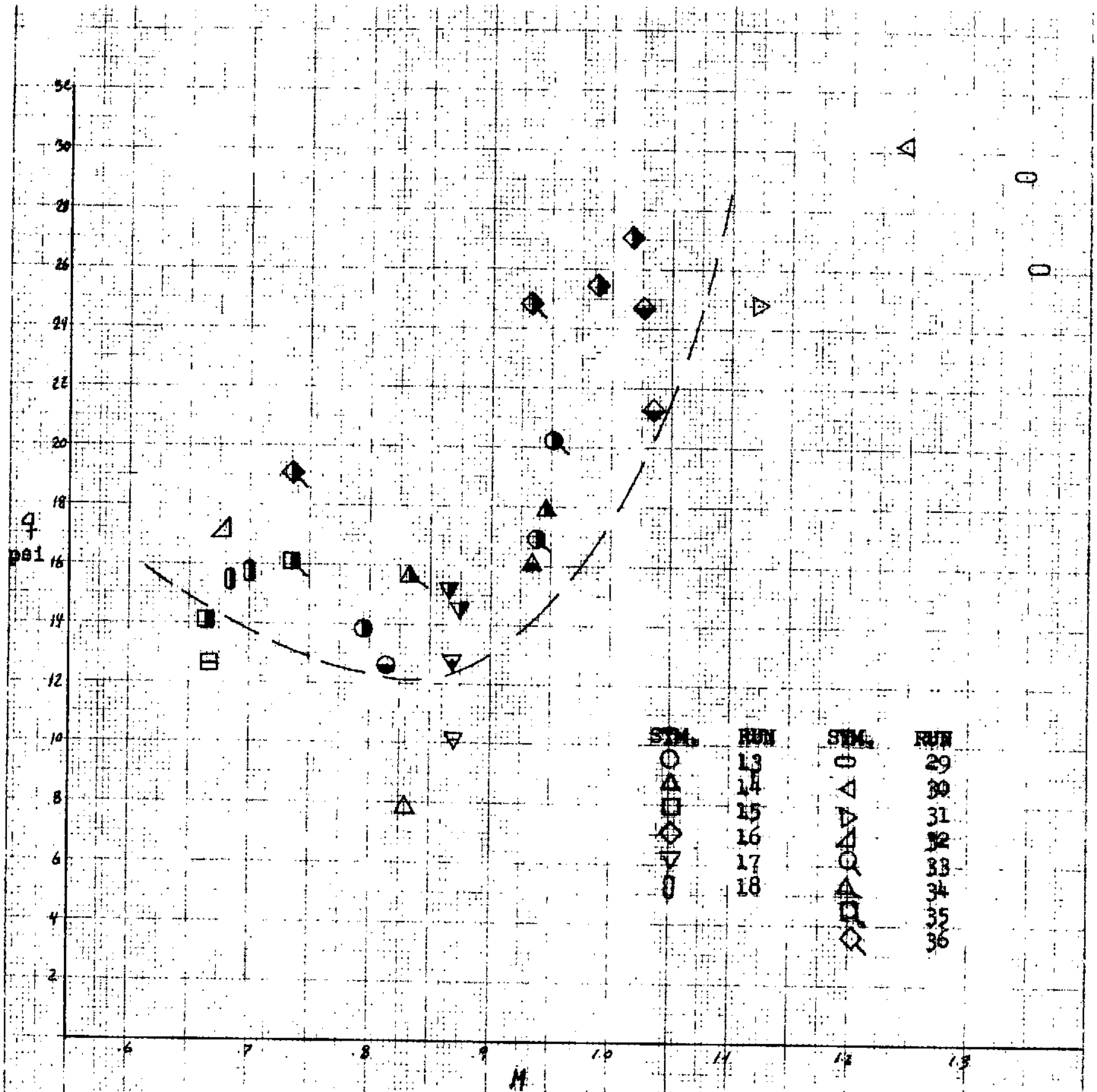


Figure 9. Preliminary Flutter Boundary
TBT 547 Wing alone.

○ NO FLUTTER (NF)
⊖ LOW DAMPING (LD)
◒ FLUTTER, INTERMITTENT (FI)
◑ FLUTTER, STEADY-STATE (FSS)
● FLUTTER, DIVERGENT (FD)

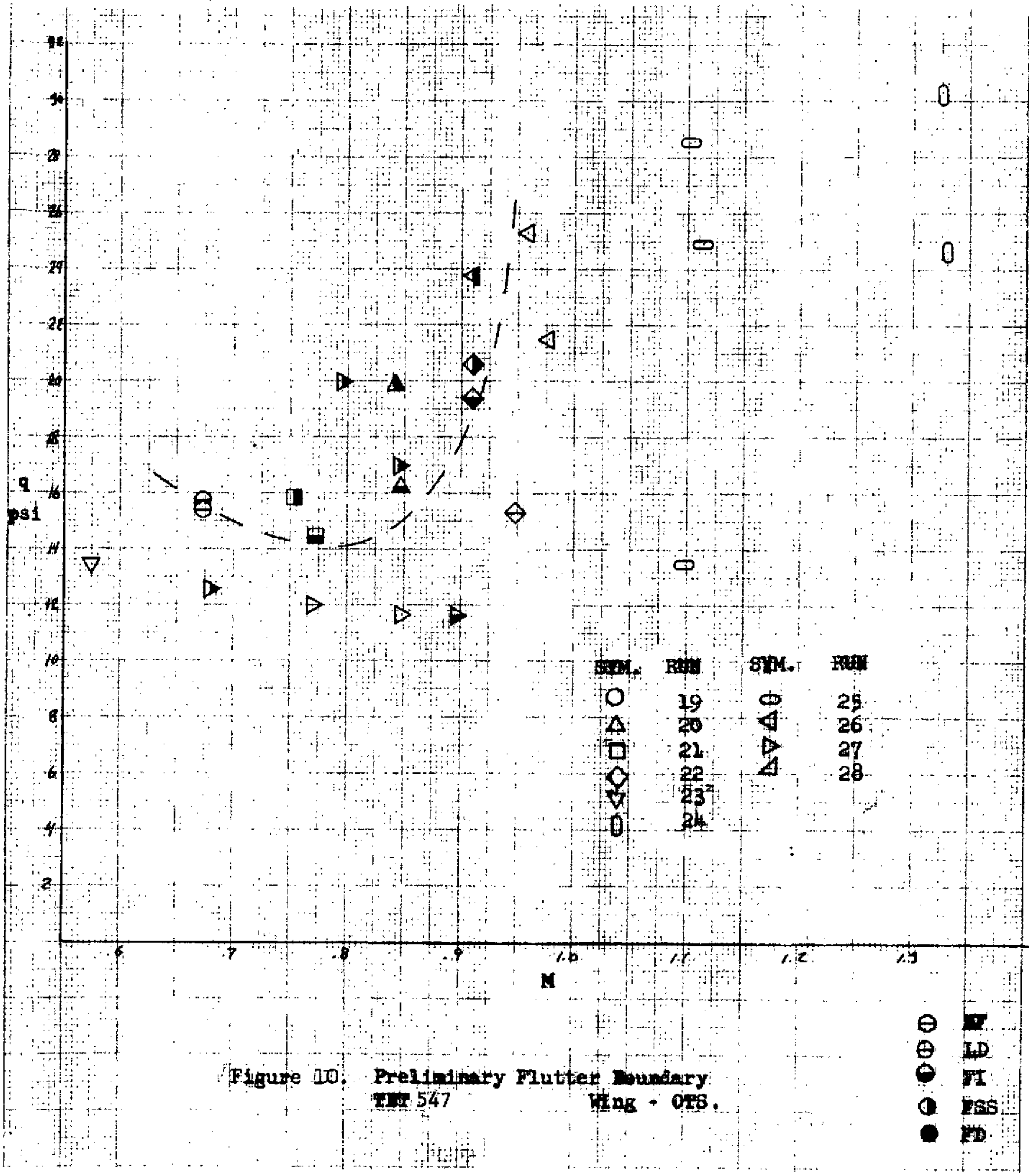


Figure 10. Preliminary Flutter Boundary
TDT 547 Wing - OTS.

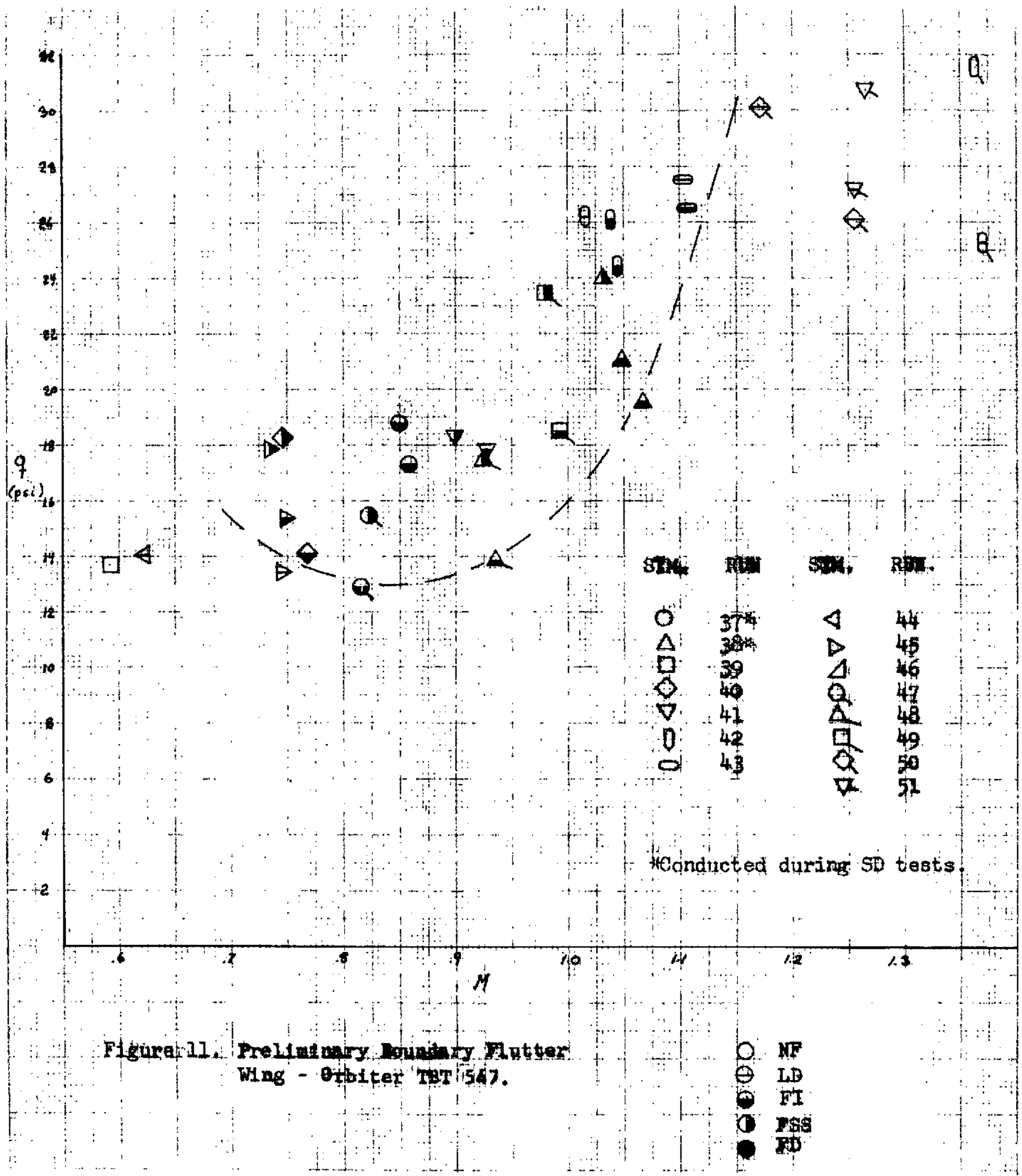


Figure 11. Preliminary Boundary Flutter Wing - Orbiter TBT 547.

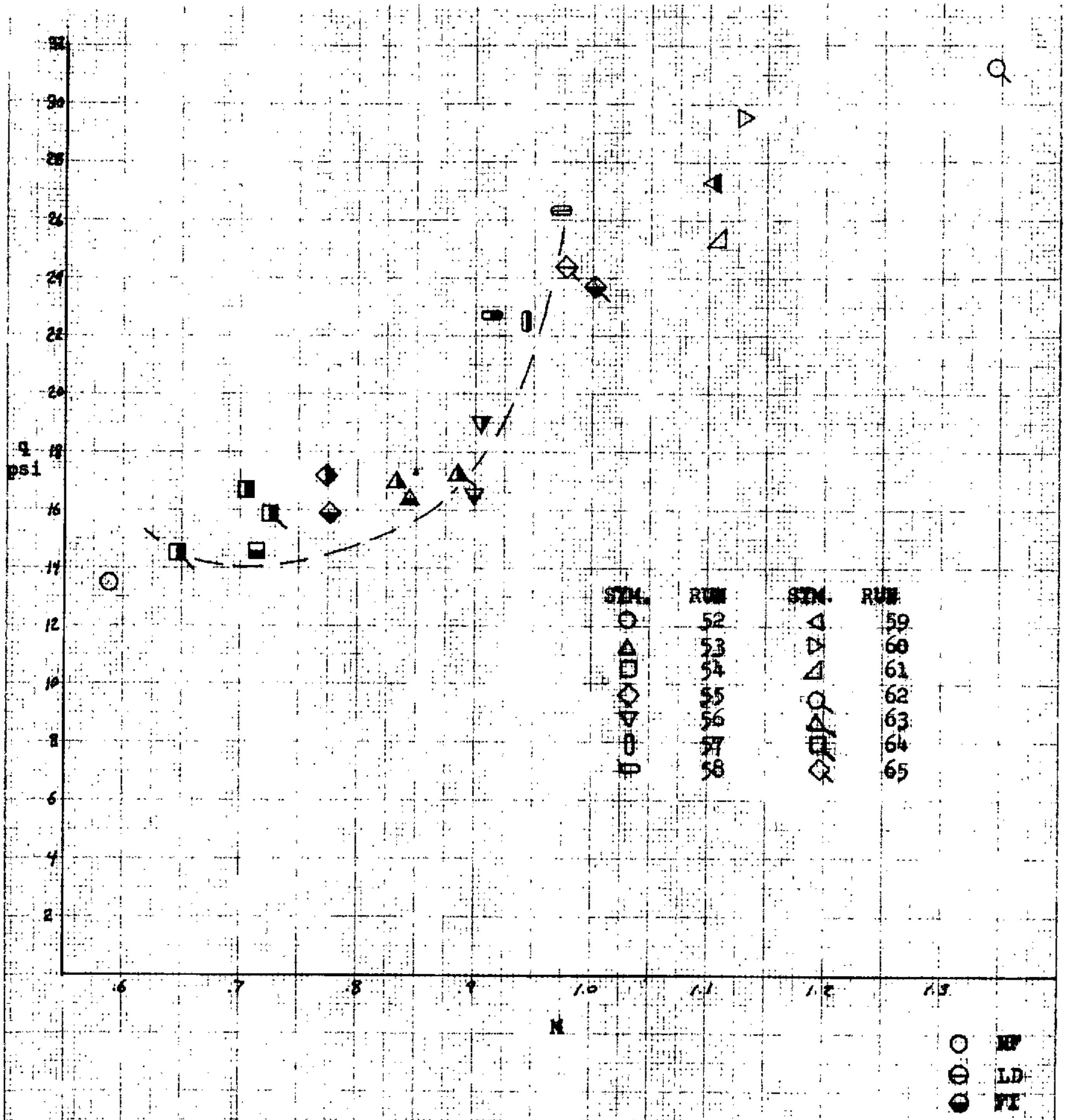


Figure 12. Preliminary Flutter Boundary
TDT 547 Wing - OT.

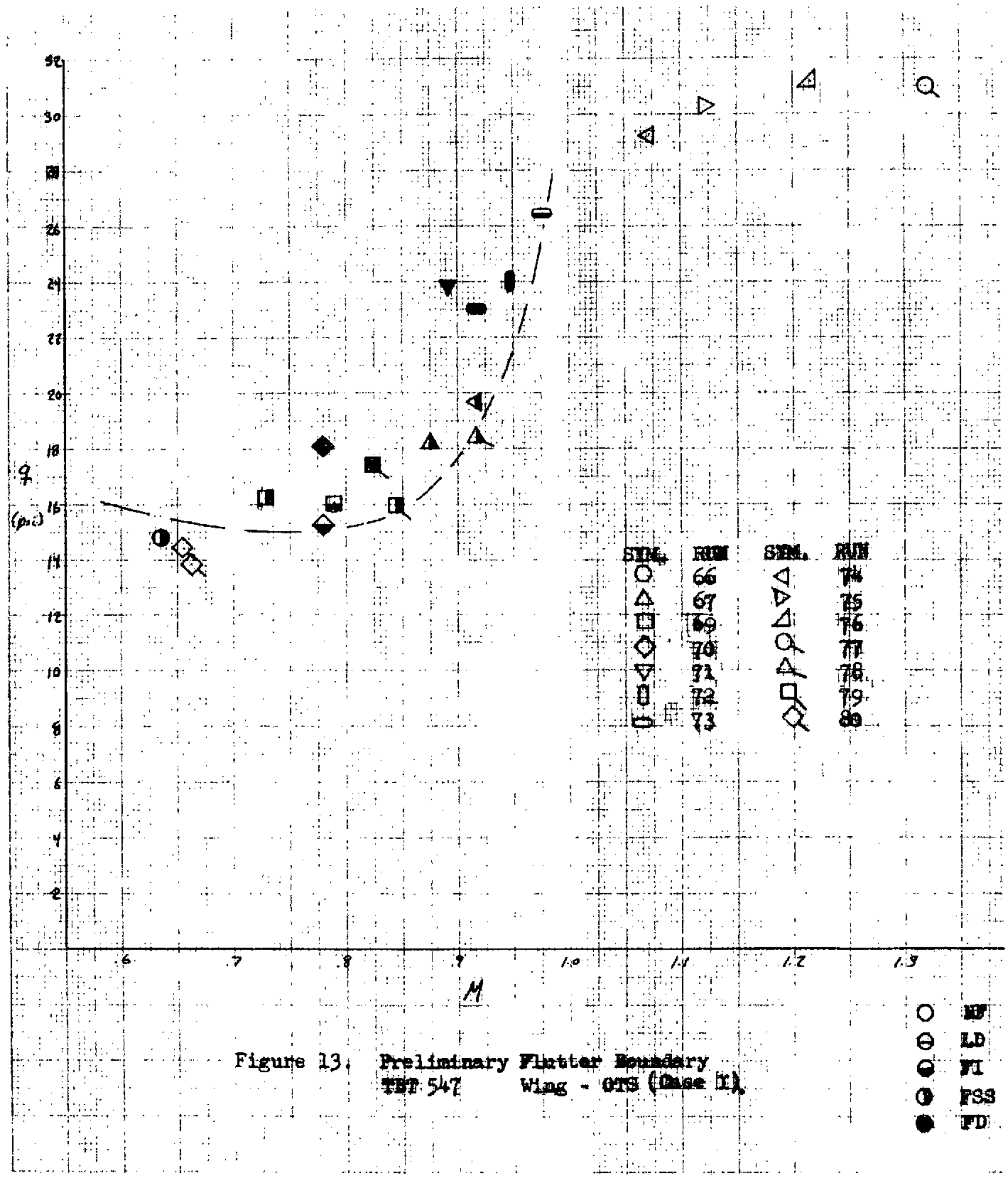


Figure 13. Preliminary Flutter Boundary
TBT 547 Wing - OTS (Case I)

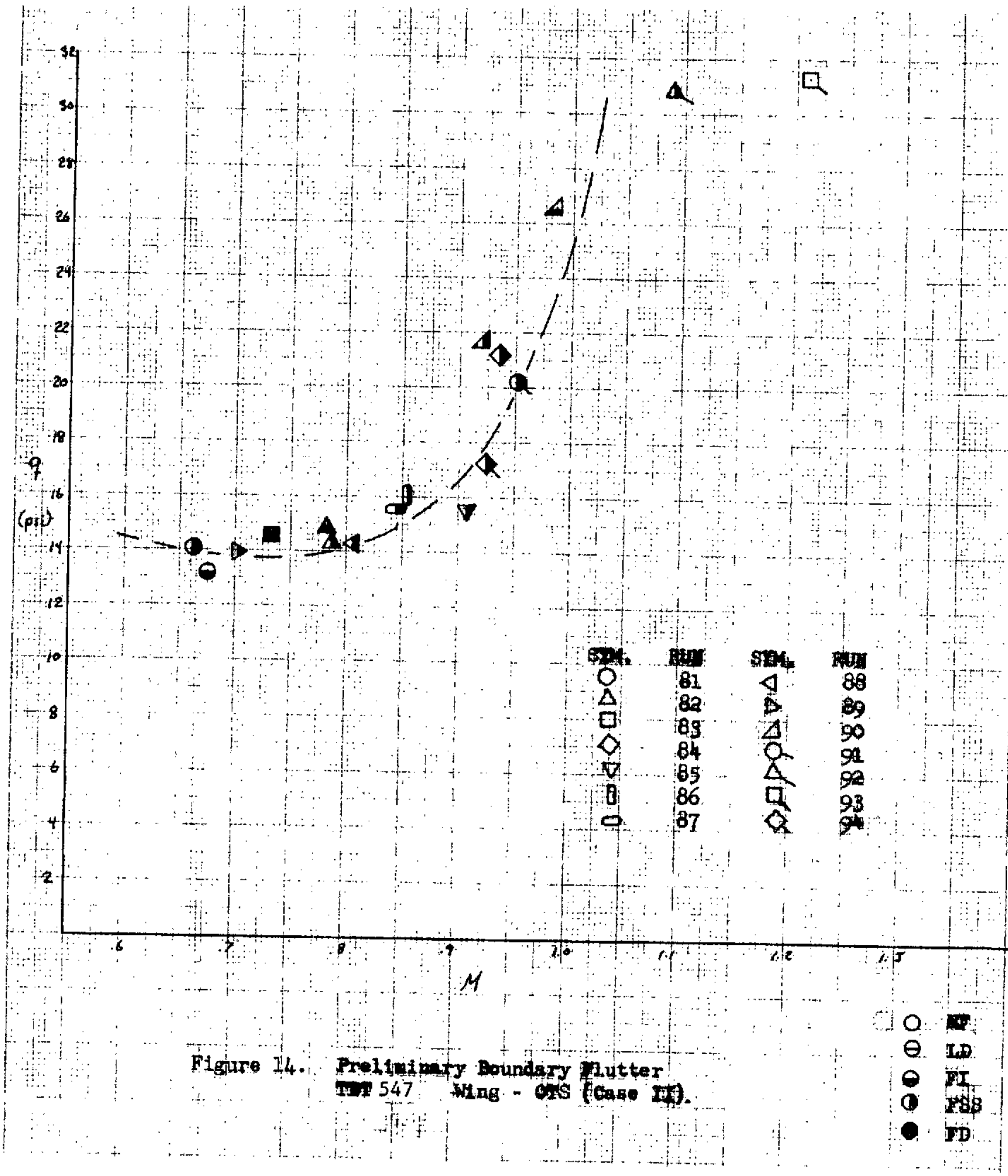


Figure 14. Preliminary Boundary Flutter
TBT 547 Wing - OTS (Case II).

APPENDIX A

TABULATED DATA

TBT TEST NO. 547 10/12/73 11.47.40.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
1	1	14.81	55.22	20.99	.3802	61.03	1.261	23.39	.00446	395.0	974.2	1229	997	1.876	18.256
2	1	14.80	68.74	45.95	.6684	53.29	.781	19.62	.00843	457.2	1048.0	818	913	3.548	20.397
3	1	14.80	55.55	36.26	.6527	70.14	.805	16.45	.00649	469.0	1061.5	855	836	2.729	16.050
3	2	14.80	60.89	40.55	.6659	62.43	.785	17.48	.00732	464.9	1056.8	829	862	3.080	17.703
3	3	14.80	64.57	42.81	.6630	64.54	.789	18.67	.00771	466.2	1058.2	835	891	3.242	18.728
4	1	14.80	69.24	42.24	.6101	43.04	.871	22.42	.00812	436.5	1024.1	892	977	3.416	22.213
5	1	14.79	64.72	30.60	.4728	58.93	1.092	25.56	.00613	418.7	1002.9	1096	1043	2.580	21.326
5	2	14.79	62.72	34.55	.5509	48.71	.964	22.46	.00676	428.8	1014.9	978	977	2.845	20.585
5	3	14.79	63.05	35.80	.5677	47.29	.937	22.00	.00697	431.3	1017.9	954	967	2.930	20.579
6	1	14.80	54.88	25.64	.4672	55.07	1.102	21.79	.00520	414.2	997.5	1099	963	2.186	18.287
6	2	14.80	54.21	34.90	.6438	40.90	.819	16.38	.00664	441.4	1029.8	843	835	2.791	17.007
6	3	14.80	54.38	35.58	.6543	38.79	.803	16.05	.00676	441.6	1030.0	827	826	2.845	16.988
6	4	14.80	54.55	38.63	.7082	32.36	.720	14.01	.00727	445.9	1035.0	745	772	3.059	16.331
7	1	14.79	62.89	32.41	.5153	62.07	1.021	23.65	.00630	431.7	1018.4	1040	1003	2.650	20.276
7	2	14.79	67.90	35.80	.5272	58.93	1.002	25.14	.00695	431.9	1018.7	1020	1034	2.926	21.957
7	3	14.79	71.24	38.51	.5405	57.17	.980	25.90	.00745	433.6	1020.6	1000	1049	3.136	22.999
8	1	14.84	70.92	50.12	.7066	26.29	.722	18.29	.00956	440.1	1028.2	743	882	4.021	21.625
9	1	14.86	60.49	36.40	.6017	46.57	.884	19.90	.00698	437.9	1025.6	906	920	2.935	19.347
9	2	14.86	69.62	41.73	.5994	19.79	.887	23.00	.00845	414.3	997.6	885	989	3.556	23.959
9	3	14.86	55.51	33.07	.5957	57.52	.893	18.46	.00622	446.1	1035.2	925	886	2.617	17.338
10	1	14.88	70.13	43.42	.6191	17.64	.857	22.31	.00875	416.2	1000.0	857	974	3.683	23.921
11	1	14.88	65.49	32.16	.4911	53.29	1.061	25.36	.00645	418.7	1002.9	1064	1039	2.712	21.780
11	2	14.88	64.82	38.40	.5924	42.68	.898	21.69	.00745	432.6	1019.4	916	960	3.134	21.080
11	3	14.88	64.00	44.87	.7012	27.00	.731	16.77	.00856	439.8	1027.8	751	844	3.602	19.607
11	4	14.88	63.00	48.33	.7671	13.30	.627	13.31	.00925	438.5	1026.4	644	752	3.891	18.200
12	1	14.88	59.21	44.31	.7484	34.86	.657	13.39	.00817	455.3	1045.8	687	755	3.436	16.640
13	1	14.87	42.08	27.25	.6476	56.14	.813	12.61	.00502	455.6	1046.2	851	732	2.112	12.651
13	2	14.87	47.56	31.34	.6590	55.54	.795	13.88	.00575	457.4	1048.2	834	768	2.419	14.164
14	1	14.87	25.82	16.43	.6363	67.07	.830	7.93	.00298	463.0	1054.6	876	581	1.253	7.630
14	2	14.87	46.40	26.46	.5704	53.51	.933	16.11	.00508	437.2	1024.8	956	828	2.137	14.878
14	3	14.87	50.88	28.58	.5618	51.58	.946	17.91	.00553	433.6	1020.7	966	873	2.327	16.478
15	1	14.87	55.02	40.85	.7423	62.88	.667	12.70	.00714	479.9	1073.8	716	735	3.005	14.532
15	2	14.87	61.33	45.64	.7442	60.11	.664	14.07	.00802	477.7	1071.3	711	774	3.373	16.263
16	1	14.87	56.02	28.41	.5072	53.57	1.034	21.28	.00564	422.8	1007.8	1043	951	2.373	18.515
16	2	14.87	65.48	33.52	.5119	49.42	1.027	24.73	.00669	420.5	1005.1	1032	1026	2.815	21.835

TBT TEST NO. 547 10/12/73 11.47.40.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
16	3	14.87	72.12	37.30	.5172	38.30	1.018	27.06	.00759	412.5	995.5	1013	1073	3.192	24.710
16	4	14.87	69.63	37.30	.5356	37.60	.988	25.49	.00752	416.1	999.8	988	1041	3.165	23.708
17	1	14.93	31.41	19.17	.6102	76.56	.871	10.17	.00345	465.7	1057.7	921	658	1.453	9.261
17	2	14.93	39.57	24.18	.6112	65.36	.869	12.78	.00445	456.2	1046.8	910	737	1.872	11.982
17	3	14.93	44.89	27.31	.6082	53.76	.874	14.59	.00514	445.5	1034.5	904	788	2.164	14.028
17	4	14.93	47.22	28.98	.6136	54.43	.865	15.19	.00544	447.2	1036.5	897	804	2.288	14.671
18	1	14.94	63.89	46.05	.7207	28.79	.700	15.81	.00869	444.9	1033.8	724	820	3.654	18.998
18	2	14.94	64.88	47.49	.7320	24.82	.683	15.50	.00899	443.2	1031.9	705	812	3.783	19.198
19	1	14.95	66.22	48.95	.7392	32.73	.671	15.45	.00909	451.7	1041.7	699	811	3.826	18.981
19	2	14.95	67.38	49.73	.7381	34.92	.673	15.78	.00920	453.5	1043.8	703	819	3.872	19.235
20	1	14.95	51.57	32.23	.6250	34.55	.848	16.21	.00626	432.1	1018.9	864	830	2.633	16.721
20	2	14.95	63.56	39.92	.6282	32.28	.843	19.85	.00778	430.8	1017.3	857	919	3.272	20.678
21	1	14.95	51.29	34.57	.6741	53.43	.772	14.43	.00633	458.4	1049.5	810	783	2.662	15.124
21	2	14.95	58.09	39.81	.6853	40.81	.755	15.88	.00744	449.3	1038.9	784	822	3.128	17.479
22	1	14.94	43.33	24.31	.5609	60.53	.948	15.28	.00462	441.0	1029.3	975	806	1.946	13.724
22	2	14.94	57.36	33.56	.5851	49.59	.910	19.44	.00644	437.0	1024.6	932	909	2.711	18.411
22	3	14.94	60.86	35.57	.5843	48.92	.911	20.65	.00684	436.2	1023.7	932	937	2.878	19.580
23	1	14.93	72.67	58.08	.7991	35.12	.575	13.45	.01050	464.1	1055.9	607	756	4.418	18.620
24	1	14.92	57.56	19.94	.3463	53.01	1.330	24.69	.00442	378.7	953.8	1269	1025	1.859	19.341
24	2	14.92	70.67	24.62	.3484	43.41	1.326	30.30	.00555	372.2	945.6	1254	1135	2.335	24.367
25	1	14.93	34.18	16.04	.4695	65.96	1.098	13.54	.00318	423.5	1008.7	1108	759	1.338	11.072
25	2	14.93	62.39	28.75	.4609	50.80	1.113	24.93	.00590	409.2	991.4	1103	1030	2.481	21.049
25	3	14.93	72.01	33.66	.4674	41.42	1.102	28.59	.00700	403.3	984.3	1084	1103	2.947	24.865
27	1	14.93	59.23	32.10	.5419	53.70	.978	21.49	.00625	431.0	1017.5	995	956	2.630	19.281
27	2	14.93	71.01	39.35	.5541	47.19	.959	25.31	.00771	428.2	1014.2	972	1037	3.244	23.362
27	3	14.93	70.18	41.02	.5844	39.98	.911	23.81	.00803	428.6	1014.7	924	1006	3.379	23.109
28	1	14.93	42.72	28.87	.6758	57.03	.770	11.97	.00524	462.0	1053.5	811	714	2.206	12.460
28	2	14.93	18.90	16.27	.8608	21.46	.468	2.49	.00296	461.0	1052.4	492	326	1.246	4.280
28	3	14.93	34.94	20.73	.5932	63.90	.897	11.67	.00386	451.0	1040.9	934	705	1.623	10.758
28	4	14.93	54.30	33.99	.6261	83.71	.846	17.03	.00600	475.4	1068.7	904	851	2.525	15.541
28	5	14.93	68.68	45.26	.6589	42.47	.796	20.05	.00852	445.7	1034.8	823	923	3.584	21.157
28	6	14.93	53.30	39.12	.7340	26.40	.680	12.65	.00738	445.0	1033.9	703	733	3.104	15.659
29	1	14.84	60.64	20.21	.3334	57.03	1.358	26.08	.00449	377.5	952.4	1293	1053	1.890	20.101
29	2	14.84	68.27	23.13	.3387	48.74	1.346	29.34	.00520	373.2	946.8	1275	1117	2.188	23.160
30	1	14.84	71.59	27.83	.3887	48.36	1.245	30.18	.00602	387.9	965.3	1202	1133	2.533	24.469

TBT TEST NO. 547 10/12/73 11.47.40.

RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
31	1	14.84	62.12	28.61	.4606	35.54	1.113	24.83	.00605	396.9	976.4	1087	1028	2.545	21.823
32	1	14.75	72.36	53.15	.7344	61.83	.679	17.15	.00934	477.5	1071.1	727	854	3.929	19.387
33	1	14.74	48.47	27.45	.5662	75.98	.939	16.95	.00506	455.3	1045.9	982	849	2.128	14.733
33	2	14.74	57.16	31.94	.5589	71.13	.951	20.22	.00596	449.5	1039.2	988	927	2.509	17.652
34	1	14.74	50.81	32.24	.6346	74.58	.833	15.66	.00577	469.2	1061.7	884	816	2.426	14.762
35	1	14.74	60.83	42.41	.6971	68.03	.737	16.12	.00748	476.0	1069.4	788	828	3.145	16.855
36	1	14.74	72.69	50.76	.6984	84.75	.735	19.19	.00867	491.4	1086.5	798	903	3.647	19.316
36	2	14.74	71.52	40.83	.5708	85.10	.932	24.82	.00738	464.2	1056.0	984	1027	3.105	21.208
37	1	14.74	54.32	33.60	.6186	54.27	.858	17.30	.00629	448.1	1037.5	890	858	2.648	16.818
37	2	14.74	59.50	37.10	.6236	51.50	.850	18.76	.00697	446.7	1035.9	880	893	2.932	18.477
38	1	14.74	50.26	24.45	.4865	60.81	1.069	19.56	.00484	423.7	1008.9	1078	912	2.038	16.419
38	2	14.74	54.95	27.39	.4984	57.71	1.049	21.10	.00542	424.1	1009.3	1059	947	2.280	18.026
38	3	14.74	63.49	32.36	.5096	54.62	1.031	24.05	.00640	424.2	1009.5	1040	1011	2.693	20.910
39	1	14.86	70.56	55.60	.7880	34.92	.593	13.71	.01010	462.1	1053.6	625	764	4.248	18.501
40	1	14.87	50.32	34.08	.6772	57.17	.767	14.05	.00618	462.4	1054.0	809	773	2.602	14.648
40	2	14.87	67.96	46.95	.6909	14.75	.746	18.31	.00923	426.9	1012.7	756	882	3.883	21.795
41	1	14.88	51.88	29.77	.5738	65.28	.927	17.92	.00558	447.9	1037.4	962	873	2.346	16.118
41	2	14.88	54.54	32.23	.5911	52.87	.900	18.29	.00613	441.1	1029.4	927	882	2.580	17.290
42	1	14.88	63.83	31.94	.5004	47.68	1.046	24.45	.00644	416.3	1000.1	1046	1020	2.708	21.472
42	2	14.88	68.64	34.61	.5043	36.90	1.039	26.17	.00711	408.4	990.5	1029	1055	2.992	23.725
42	3	14.88	69.97	36.29	.5186	16.50	1.016	26.21	.00771	394.8	973.8	989	1056	3.245	25.429
43	1	14.88	66.65	30.93	.4641	41.87	1.107	26.55	.00644	402.8	983.7	1089	1063	2.711	23.005
43	2	14.88	69.30	32.27	.4657	32.35	1.105	27.56	.00685	395.5	974.8	1077	1083	2.881	24.527
44	1	14.87	66.80	51.37	.7690	5.11	.624	14.01	.01000	431.2	1017.8	635	772	4.206	19.682
45	1	14.84	49.19	33.73	.6858	62.07	.754	13.43	.00604	468.5	1060.9	800	756	2.542	14.012
45	2	14.84	56.89	39.24	.6897	57.52	.748	15.38	.00708	465.1	1057.1	791	809	2.978	16.320
45	3	14.84	67.45	47.00	.6968	51.89	.737	17.88	.00855	461.4	1052.9	776	872	3.596	19.463
46	1	14.83	42.99	27.82	.6470	61.78	.814	12.89	.00507	460.5	1051.8	856	741	2.133	12.749
46	2	14.83	51.09	32.79	.6418	58.31	.822	15.50	.00603	456.4	1047.1	861	812	2.536	15.354
47	1	14.83	39.96	22.77	.5699	69.79	.934	13.89	.00424	450.9	1040.8	972	769	1.783	12.304
47	2	14.83	50.58	29.12	.5757	58.93	.924	17.41	.00552	442.9	1031.6	953	861	2.321	15.947
48	1	14.83	50.30	26.80	.5329	62.12	.993	18.48	.00516	435.9	1023.4	1016	887	2.171	16.094
48	2	14.83	64.58	34.93	.5409	53.07	.980	23.47	.00681	430.2	1016.6	996	999	2.867	21.067
49	1	14.83	61.88	23.68	.3826	52.87	1.257	26.17	.00510	389.5	967.4	1216	1055	2.146	20.895
49	2	14.83	73.35	31.39	.4280	45.94	1.171	30.15	.00664	396.8	976.3	1144	1132	2.793	25.195

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RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
50	1	14.85	64.29	24.59	.3825	55.64	1.257	27.19	.00527	391.6	969.9	1219	1075	2.217	21.553
50	2	14.85	72.45	27.50	.3796	28.17	1.263	30.69	.00624	369.9	942.7	1190	1142	2.625	26.137
51	1	14.84	58.84	19.28	.3277	58.15	1.370	25.33	.00430	376.5	951.1	1303	1038	1.808	19.418
51	2	14.84	73.39	24.28	.3308	27.10	1.363	31.58	.00562	362.2	932.8	1272	1159	2.367	25.628
52	1	14.84	70.72	55.96	.7914	17.30	.588	13.54	.01053	446.2	1035.3	609	759	4.429	19.312
53	1	14.82	52.37	22.80	.6265	63.58	.845	16.41	.00601	457.8	1048.8	887	836	2.530	15.738
53	2	14.82	55.18	35.03	.6348	57.32	.833	17.00	.00647	454.1	1044.4	870	850	2.723	16.728
54	1	14.81	57.23	40.67	.7107	53.12	.716	14.59	.00734	465.1	1057.1	757	788	3.087	16.183
54	2	14.81	66.91	47.98	.7171	32.43	.706	16.74	.00900	447.5	1036.9	732	844	3.785	19.802
55	1	14.79	56.14	37.71	.6718	51.88	.776	15.89	.00693	456.6	1047.4	812	822	2.916	16.659
55	2	14.79	61.01	41.10	.6737	46.38	.773	17.19	.00763	452.1	1042.1	805	855	3.210	18.326
56	1	14.80	49.26	29.14	.5916	59.28	.899	16.50	.00547	446.7	1035.9	932	838	2.303	15.358
56	2	14.80	56.15	32.98	.5874	59.62	.906	18.95	.00620	446.1	1035.2	938	898	2.610	17.541
57	1	14.79	64.24	36.18	.5632	48.74	.944	22.57	.00704	431.5	1018.2	961	980	2.960	20.942
58	1	14.76	72.71	39.62	.5449	36.55	.973	26.27	.00797	417.2	1001.2	974	1057	3.352	24.716
58	2	14.76	66.86	38.94	.5824	32.70	.914	22.76	.00775	421.9	1006.8	920	984	3.259	22.474
59	1	14.76	68.69	31.96	.4654	53.70	1.105	27.33	.00650	412.6	995.6	1100	1078	2.735	22.979
60	1	14.74	73.31	33.02	.4505	34.06	1.131	29.58	.00705	393.2	971.9	1099	1122	2.966	25.912
61	1	14.74	63.51	29.41	.4630	48.94	1.109	25.33	.00605	408.2	990.3	1098	1038	2.543	21.524
62	1	14.76	72.86	24.68	.3388	36.29	1.346	31.31	.00569	364.1	925.2	1259	1154	2.394	25.557
63	1	14.76	52.55	31.55	.6005	55.87	.886	17.32	.00594	445.7	1034.7	916	858	2.500	16.424
64	1	14.76	61.20	43.19	.7057	60.32	.724	15.83	.00770	470.7	1063.4	769	821	3.239	17.105
64	2	14.76	66.03	49.88	.7554	54.71	.646	14.57	.00882	474.8	1068.0	690	787	3.709	17.438
65	1	14.79	64.07	33.74	.5267	38.43	1.003	23.74	.00683	414.7	998.2	1001	1005	2.872	21.858
65	2	14.79	67.22	36.42	.5418	-1.26	.978	24.40	.00794	384.8	961.5	941	1019	3.341	25.434
66	1	14.76	68.86	52.44	.7616	62.88	.636	14.85	.00910	483.5	1077.7	685	795	3.830	17.638
67	1	14.75	56.03	34.04	.6075	63.18	.875	18.23	.00630	453.5	1043.7	913	881	2.650	17.108
69	1	14.80	55.55	36.76	.6618	67.68	.791	16.10	.00658	468.7	1061.2	839	828	2.769	16.006
69	2	14.80	62.23	43.68	.7019	55.31	.729	16.27	.00787	465.5	1057.5	771	832	3.313	17.695
70	1	14.74	63.34	42.40	.6694	53.92	.779	18.03	.00777	458.0	1048.9	818	876	3.268	18.745
71	1	14.74	72.02	42.96	.5964	56.11	.892	23.92	.00810	445.0	1034.0	922	1009	3.408	22.562
72	1	14.75	68.36	38.37	.5614	51.31	.947	24.09	.00743	433.3	1020.3	966	1012	3.127	22.160
73	1	14.75	73.20	39.72	.5426	46.14	.977	26.53	.00785	424.8	1010.2	987	1062	3.301	24.289
73	2	14.75	67.35	39.05	.5797	43.75	.918	23.04	.00761	430.8	1017.4	934	990	3.200	22.025
74	1	14.75	75.04	36.32	.4840	50.60	1.073	29.28	.00735	414.8	998.2	1071	1116	3.092	25.183

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RUN	PT	PA	H	P	P/H	TS	M	Q	RHO	T	A	V	VKEAS	RHO/RHOSL	RN*1.E6
74	2	14.75	57.67	33.38	.5789	40.16	.919	19.75	.00655	427.6	1013.5	932	917	2.756	19.046
75	1	14.75	75.54	34.43	.4558	53.57	1.122	30.33	.00705	410.1	992.5	1113	1136	2.964	25.331
76	1	14.75	74.54	30.04	.4031	45.26	1.217	31.17	.00647	389.5	967.3	1178	1151	2.723	25.689
77	1	14.75	72.36	25.37	.3505	50.80	1.321	31.00	.00563	378.4	953.4	1260	1148	2.367	24.475
78	1	14.76	53.84	31.22	.5799	56.68	.918	18.41	.00593	441.9	1030.4	946	885	2.494	17.027
79	1	14.76	50.83	31.78	.6252	66.66	.847	15.97	.00579	460.3	1051.5	891	824	2.438	15.176
79	2	14.76	57.34	36.71	.6401	59.84	.824	17.47	.00673	457.4	1048.2	864	862	2.833	17.195
80	1	14.76	60.39	44.99	.7450	52.67	.662	13.82	.00802	471.0	1063.8	705	767	3.372	16.296
80	2	14.76	63.71	47.68	.7484	47.88	.657	14.41	.00856	467.2	1059.5	696	783	3.603	17.312
81	1	14.76	56.34	41.52	.7369	58.57	.675	13.24	.00734	475.0	1068.2	721	751	3.086	15.162
81	2	14.76	61.85	46.11	.7455	53.15	.662	14.13	.00821	471.6	1064.4	704	775	3.452	16.658
82	1	14.76	49.66	33.01	.6647	53.70	.787	14.30	.00606	456.9	1047.6	824	780	2.551	14.777
82	2	14.76	52.00	34.69	.6671	48.57	.783	14.89	.00643	452.8	1042.9	817	796	2.705	15.638
83	1	14.76	55.54	38.91	.7005	45.34	.732	14.58	.00716	456.2	1046.9	766	787	3.011	16.227
84	1	14.76	60.87	34.58	.5681	60.60	.936	21.22	.00656	442.7	1031.3	966	950	2.758	19.198
85	1	14.76	45.72	26.78	.5858	68.02	.909	15.48	.00496	452.9	1043.1	948	811	2.088	14.002
86	1	14.74	50.70	31.49	.6211	52.93	.854	16.06	.00591	447.4	1036.7	885	827	2.485	15.719
87	1	14.75	49.60	31.04	.6259	57.03	.846	15.56	.00576	452.0	1042.0	882	814	2.425	15.159
88	1	14.75	48.15	31.38	.6517	57.52	.807	14.29	.00575	457.7	1048.6	846	780	2.421	14.369
89	1	14.76	56.18	40.39	.7190	49.76	.703	13.97	.00731	463.6	1055.4	742	771	3.076	15.850
90	1	14.76	72.71	39.02	.5367	46.07	.986	26.58	.00773	423.4	1008.5	995	1063	3.254	24.199
90	2	14.76	63.19	36.52	.5779	31.29	.921	21.68	.00730	419.8	1004.2	925	960	3.071	21.382
91	1	14.79	57.07	31.88	.5585	48.19	.951	20.20	.00622	430.0	1016.4	967	927	2.617	18.680
92	1	14.79	78.25	37.12	.4743	55.41	1.090	30.85	.00748	416.3	1000.0	1090	1146	3.148	26.006
93	1	14.79	74.91	30.40	.4058	50.11	1.212	31.27	.00647	394.0	972.9	1179	1153	2.724	25.489
94	1	14.80	50.20	28.93	.5762	54.36	.924	17.27	.00553	439.1	1027.1	949	857	2.326	16.009

APPENDIX B

NASA TEST OF THE 30-OTS MODEL

B-1 Remarks

Following the Rockwell SD tests of the 30-OTS model, NASA-LaRC conducted a Space Shuttle Technology research test on the model from 1 to 5 October, 1973; 56 Runs were completed. This test was covered by the same facility test number - TBT547 - as SD test IS4. So, the run sequence for this test went from run 39 to run 94.

Purpose of the test was to examine the aerodynamic effects of a flexibly mounted SRB on the wing flutter boundary. Two SRB mount stiffness levels, which bracket SD design levels, were tested.

B-2 Configurations Investigated

The model utilized for this test was the same as used for SD test IS4 except for the SRB mounting arrangement. The SD SRB was a simple body, geometrically scaled, and rigidly mounted to the external tank. The SRB used for the NASA test was additionally scaled to mass and inertia. The NASA SRB mount consisted of two flexures which duplicated scaled SRB pitch, vertical translation, and first-bending frequencies. In this way, unsteady aerodynamics of a flexible SRB could be simulated. It should be noted that there was no structural path between the wing and the SRB to simulate inertial coupling.

Two sets of flexures, simulating two different stiffness levels, were provided. These were identified as Case I and Case II, flexible and stiff respectively.

Model drawings for this test are identical to test IS4 drawings, with the following additions:

Drawing Number	Title
518 MOD 1513	Tank flexures, Assy and Details
518 MOD 1514	0° + -3° Body, Wing, E Tank, & SRB

The above drawings are available from GAC.

B-3 Instrumentation

Wing instrumentation and tunnel parameter instrumentation for this test were identical to test IS4. Additional instrumentation consisted of bending strain gage circuits on the SRB-ET flexures. As with the wing gages, the signals were conditioned and recorded on a high-speed oscillograph. SRB pitch and vertical translation could be ascertained by studying the relative amplitudes and phase difference between the oscillograph records of the fore and the aft ET-SRB flexures.

B-4 Test Procedures

Test procedure for this test was identical to the procedure of test IS4.

B-5 Results

Pre-and post-run frequency data for this test is included in Table V of this report. Tabulated data of selected points from Runs 39 through 94 (i.e. this test) are included with the test IS4 data in Appendix A.

Figures 11 through 14 illustrate the flutter points obtained during this test. Note that in Figure 11 data is included from test IS4 Runs

37 & 38.

A comparison of Figure 11, the test baseline, with Figures 13 and 14, which show the OTS Case I and Case II, configurations, respectively, indicates some alteration of the flutter boundary with SRB flexibility. However, the difference is not very great at any Mach number, and at no time is a severe wing/SRB aerodynamic coupling indicated.