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RESONANCE TEST ON NOMAD N22 FITTED WITH EXTERNAL STORES.(U)

JAN 78 G LONG, C M BAILEY

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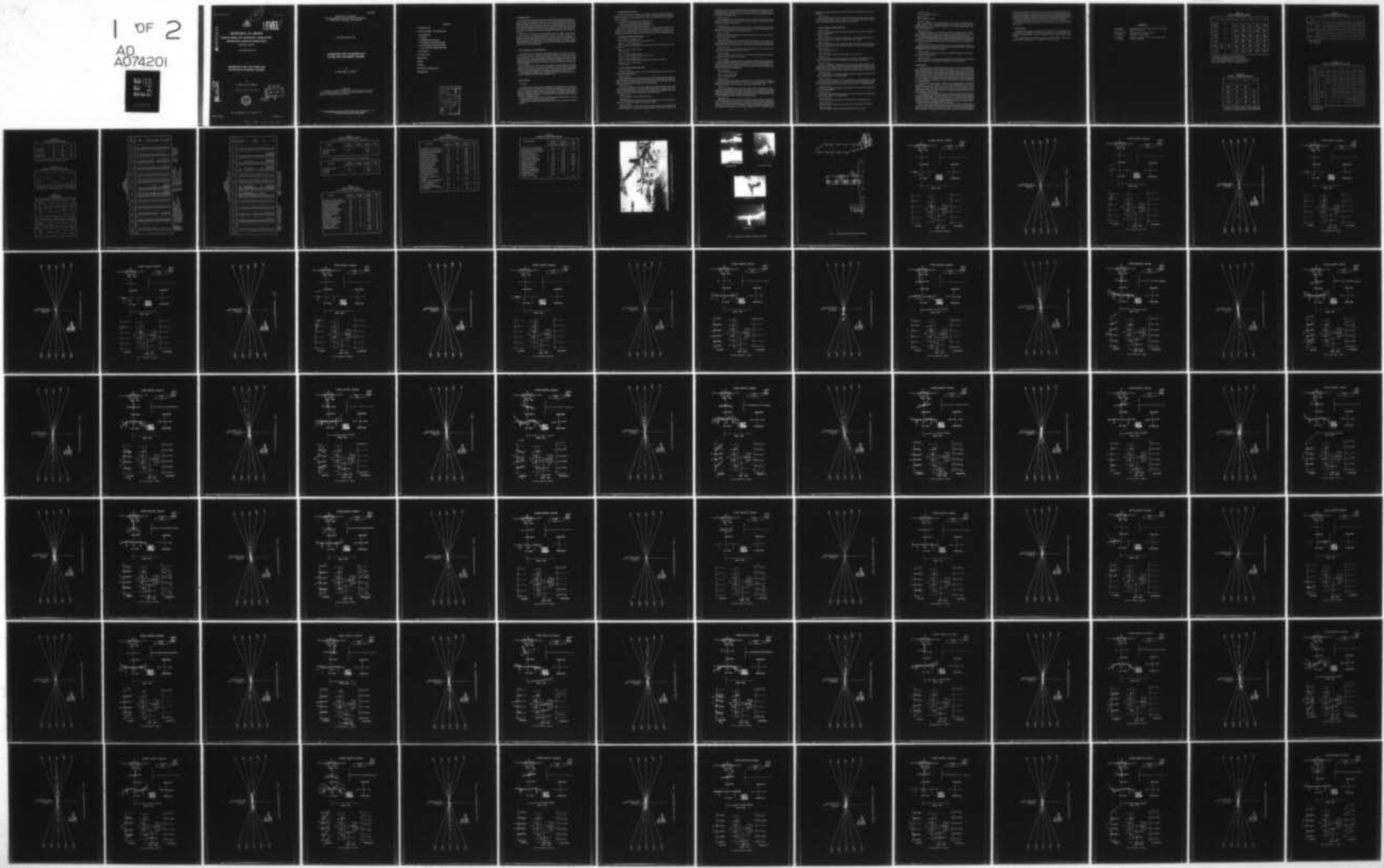

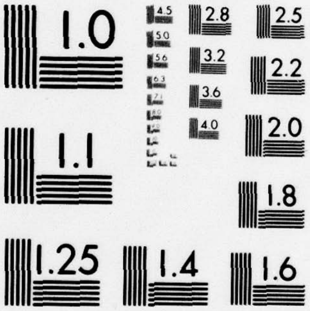

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STRUCTURES NOTE 449

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RESONANCE TEST ON NOMAD N22 FITTED WITH EXTERNAL STORES

by

⑩ G. LONG ~~and~~ C. M. BAILEY

SUMMARY

A resonance test on the N22 Nomad, fitted with external stores, has been conducted. The natural modes and frequencies of vibration have been measured for two store configurations, in the frequency range up to 30 hertz.

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CONTENTS

1. INTRODUCTION

The resonance test data for the basic N22 Nomad aircraft are presented in Reference 1. Since that test, the only significant modification to the aircraft has been the fitting of stiffer engine mountings. The present test was carried out to determine the modes and frequencies of the Nomad when fitted with external stores. There are two attachment points on each wing and two series of tests were conducted. In the first test a single 227 kg (500 lb) store was mounted on the inboard attachment on each wing. For the second test these stores were moved to the outer stations. Two types of store crutch were investigated but only one type was used throughout the tests.

The aircraft was suspended on springs such that its rigid body degrees of freedom were all of the order of 1 Hz. For these tests the fuel tanks were each 50% full, no interior trim was fitted, the pilots seats were simulated by 34 kg (75 lb) masses, the aircraft was unpainted, no spinners were fitted to the engines and the top and bottom engine covers were left open. A photograph of the aircraft, suspended for the test, is reproduced in Figure 1. The aircraft weighed 2428 kg (5348 lb) and its centre of gravity was at BS 195·8. The stores weighed 454 kg (1000 lb) and had a centre of gravity at BS 185·4.

2. TEST EQUIPMENT AND PROCEDURE

The equipment used was basically as described in Reference 2; however in this test a maximum of 13 shakers was used and the vibration amplitudes were continuously monitored by 16 accelerometers. A 16 channel resolved component ratiometer was also used and this improved the rate of modal tuning. Modal amplitudes were measured by traversing a single accelerometer which could be attached rigidly to the structure by means of a suction cup. Both in-phase and quadrature responses were measured at each station although only the quadrature response is plotted.

Since the primary aim of the test was the determination of the complete aircraft modes and not the control surface modes, clamps were applied to all control surfaces. Photographs of the method of clamping are reproduced in Figure 2. [In previous tests it had been found that the friction and backlash present in controls aggravated the problems of mode isolation.]

Modal damping was determined by measuring the rate of decay of amplitude in the mode after the excitation force had been suddenly reduced to zero.

3. TEST RESULTS

3.1 General

In Figures 4A–48A selected quadrature components of the modal responses are plotted to indicate the mode shape of vibration. Also plotted in Figures 4B–48B are the vector responses at every measured station. These figures are an indication of the degree of modal isolation achieved. A complete summary of all the modal responses, both in-phase and quadrature is intended to be presented in Reference 3. The locations of the measuring stations are indicated in Figure 3 and defined in table 1.

Since a considerable amount of shaker re-positioning occurred during the tests, a summary of the shaker positions on the aircraft is contained in Table 2.

Summaries of the natural frequencies measured for the various test conditions are contained in Tables 3–5.

3.2 Measurement of Store Modes

In order to provide some information on the stiffness of the pylon, crutch and wing attachments, the wings were propped, to restrict their freedom in bending, and the uncoupled frequencies of a single store were measured. Props, in the form of contour boards on adjustable stands, were located:

1. 737 mm (29 inches) inboard of station W12 (starboard).
2. Directly on the outboard hard point (starboard).
3. 356 mm (14 inches) inboard of station W9 (starboard).
4. 737 mm (29 inches) inboard of station W1 (port).

Three modes of the standard crutch mounting were measured and three modes of the extended crutches. Following these tests all subsequent measurements were made on the stores supported by the extended crutches. Two series of tests were carried out, one with the stores mounted on the inboard hard-points and one with the stores on the outboard hard-points.

3.3 Uncoupled Store Modes-Wing Propped

Mode at 4·06 Hz—Standard crutches

This is store lateral bending but includes some store yaw.

Mode at 11·7 Hz—Standard crutches

This is store pitch, and although the wing is propped, there is significant motion of the wing rear spar.

Mode at 12·72 Hz—Standard crutches

This is store yaw.

Mode at 5·44 Hz—Extended crutches

This is store lateral bending and includes some store yaw.

Mode at 11·92 Hz—Extended crutches

This is store pitch and again includes significant vertical motion of the wing.

Mode at 16·6 Hz—Extended crutches

This is store yaw.

3.4 Stores Mounted on Inboard Hard Points

Mode at 4·72 Hz

This mode is designated symmetric store lateral bending although there is some store yaw and some wing bending present.

Mode at 5·08 Hz

This is anti-symmetric store lateral bending and includes fuselage lateral and wing anti-symmetric bending. Considerable lateral motion of the aircraft support frame and significant engine lateral motion occurred in this mode. The lateral motion of the propeller hubs was approximately 50% greater in magnitude than the vertical motion.

Mode at 6·52 Hz

This mode is designated anti-symmetric engine heave. Significant engine motion occurs and the engine pitches about a node well aft of the support yoke. The modes at 14·71 and 15·3 Hz in which the nodal line is close to the engine support yoke are designated engine pitch modes. This mode involves some anti-symmetric wing bending motion.

Mode at 6·63 Hz

This is the symmetric form of the mode at 6·52 Hz.

Mode at 9·06 Hz

This mode is designated symmetric wing bending although it involves a large amount of engine motion. There is also significant fuselage vertical motion.

Mode at 9·99 Hz

This mode is difficult to classify and contains a significant amount of anti-symmetric wing torsion and bending. It is considered that the large moment of inertia of the stores about the wing elastic axis has lowered the wing torsion frequency significantly and brought it down into this frequency range. In the previous resonance test on the N22 (see Ref. 1) significant torsion occurred in the mode at 15·4 Hz and it is possible that this mode has dropped in frequency as a result of the increased inertia.

Mode at 10·52 Hz

This is considered to be the anti-symmetric form of the mode at 9·06 Hz. Both the frequencies of 9·06 and 10·52 Hz for this pair of modes are comparable to the values of 8·85 Hz and 10·64 Hz measured on N22 (Ref. 1).

Mode at 11·5 Hz

It is considered that this is the symmetric wing torsion mode but significant store pitching motion also occurs. Little engine motion is present in this mode and the modal isolation parameter of 0·258 indicates that it has not been well isolated.

Mode at 12·78 Hz

This mode is designated fuselage lateral bending. Significant fin lateral and wing anti-symmetric bending motion occurs.

Mode at 14·09 Hz

This mode has been designated fin bending. What little motion that occurs on the wing is in the opposite sense to that in the mode at 12·78 Hz. These two modes are most likely a symmetric and anti-symmetric pair made up from the fuselage lateral bending and fin lateral bending.

Mode at 14·71 Hz

This mode is anti-symmetric engine pitch, the engines pitching about a node close to the support yoke. [Compare also the mode at 6·52 Hz.]

Mode at 15·3 Hz

This is the symmetric form of the mode at 14·71 Hz although significant tailplane motion is present. [Compare also the mode at 6·63 Hz.]

Mode at 16·0 Hz

This is designated the tailplane symmetric bending mode, although some rotation occurs. It should be remembered that the tailplane was restrained from rotation, as described in Section 2, so that these results are not necessarily representative of the normal aircraft response. It is considered that the presence of the stores would not significantly change the tailplane mode shapes from those presented in Reference 1.

Mode at 16·3 Hz

This is anti-symmetric store yaw.

Mode at 16·74 (Not illustrated)

This is symmetric store yaw.

Mode at 17·4 Hz

This mode again involves tailplane rotation and since this was affected by the method of clamping (see Section 2) the results must be used with care. The mode has been designated tailplane rotation which on N22 occurred at a frequency of approximately 11 Hz.

Mode at 21·7 Hz

This was a very difficult mode to tune and to classify. There is a large amount of aileron bending and some fuselage bending present. Great difficulty was encountered when trying to bring both wings into phase at this frequency, possibly due to the proximity of another aileron bending, anti-symmetric mode. The mode has been called fuselage vertical bending. This mode has proved difficult to tune in every version of the Nomad tested.

Mode at 29·5 Hz

The phase of this mode was so bad that no attempt was made to measure it in detail. The response was measured on one wing only as the response on the other wing was of extremely poor phase and it was clear that the mode was not well isolated. The mode appears to have significant wing torsion and aileron bending. The difficulty in tuning this mode was undoubtedly caused by the presence of the adjacent mode at 30·6 Hz. Neither mode could be effectively isolated.

Both modes are similar in shape and it is probable that they are a symmetric and an anti-symmetric pair.

Mode at 30·6 Hz

Again, as for the mode at 29·5 Hz, no attempt was made to measure the response on other than one wing since the phase response was poor on the other wing. Most of the comments for the previous mode apply to this mode. Isolation was not possible.

3.5 Stores Mounted on Outboard Hard Points

Mode at 4·59 Hz

This is symmetric lateral bending of the stores, little engine motion occurs although there is significant wing bending.

Mode at 5·05 Hz

This is anti-symmetric store lateral bending. Some anti-symmetric wing bending and considerable fuselage yaw occurs. Significant engine lateral motion is present.

Mode at 5·51 Hz

This is a difficult mode to classify, significant tailplane and fin roll occurs and the wings and fuselage are performing a scissors type motion. Some anti-symmetric wing bending is present.

Mode at 6·33 Hz

This is symmetric engine heave.

Mode at 6·55 Hz

This is anti-symmetric engine heave, little motion of the stores occurs.

Mode at 8·47 Hz

This mode is designated wing bending although a large amount of engine motion occurs. Unlike the modes at 6·33 Hz and 6·55 Hz there is very little wing torsion apparent.

Mode at 10·10 Hz

This is an anti-symmetric wing torsion mode with some wing bending present. It is comparable in shape to the mode at 9·99 Hz (stores mounted inboard) except that the engine motion is reduced and the wing torsion increased. More store and fin motion also occur in this mode. The store has a large anti-symmetric pitch motion with a smaller amount of symmetric yaw.

Mode at 10·41 Hz

This is anti-symmetric wing bending, negligible wing torsion is present, but there is a large amount of engine motion. No store motion occurs.

Mode at 11·32 Hz

This is symmetric wing torsion with store symmetric pitch and some symmetric yaw. This is the symmetric form of the mode at 10·10 Hz and in neither mode is there significant engine motion. Both modes were well isolated, as indicated by the low values of isolation parameters.

Mode at 12·91 Hz

This mode is designated fuselage lateral bending but does involve some fin bending and wing anti-symmetric bending.

Mode at 13·49 Hz

This mode is designated fin lateral bending. It is similar in shape to that measured at 14·09 Hz when the stores were mounted inboard.

Mode at 14·53 Hz

This is symmetric engine pitch about a nodal line close to the engine support yoke.

Mode at 15·45 Hz

This is anti-symmetric engine pitch but involves some anti-symmetric wing bending.

Mode at 15·65 Hz

This is the tailplane symmetric bending mode [See also mode at 16·0 Hz.]

Mode at 17·1 Hz

This is anti-symmetric store yaw.

Mode at 17·3 Hz

This is symmetric store yaw.

Mode at 17·96 Hz

This is anti-symmetric wing overtone bending. The mode is rather asymmetric and was extremely difficult to isolate. Considerable repositioning of shakers was required before a reasonable approximation to the mode was obtained. A lot of aileron bending occurs in this mode but little store motion.

Mode at 18·67 Hz

The frequency range between 17 and 20 Hz was an extremely difficult range to work in. There appeared to be many resonances and at each resonance, modal isolation was extremely difficult. Considerable shaker repositioning was required for all the modes in this range.

This mode is designated symmetric wing overtone bending and is thought to be the symmetric form of the mode at 17·96 Hz. Considering the proximity of other modes and the large structural non-linearities apparent whilst tuning, the modal isolation parameter of 0·211 is reasonably low.

Mode at 18·92 Hz

This mode was not measured in detail since it was not well enough isolated, however the displacements measured along the front and rear spar indicate that the mode is a combination of symmetric wing torsion and overtone bending.

Mode at 19·37 Hz

This was another difficult mode to isolate. It is designated anti-symmetric wing torsion. Some symmetric store yaw occurs.

Mode at 23·46 Hz

This is another poorly isolated mode. It is designated wing anti-symmetric overtone bending and torsion. Because of the poor isolation the mode was not measured in detail.

4. DISCUSSION

In general the degree of modal isolation in both series of tests is good. Approximately 63% of the data have modal isolation parameters less than 0·15. As in previous tests, large isolation parameters occur only for the modes with frequencies greater than 18 Hz approximately. Particular difficulty in obtaining good modal isolation was experienced in the second series of tests when the stores were mounted in the outboard positions. Around 18 Hz there were many indications of resonance, when using a single shaker input. Many of these turned out to be spurious when investigated in detail by using more shakers, however great difficulty was always experienced in this frequency range and considerable time was spent in optimising the structural response.

In general it was found necessary to measure the mode approximately to determine its shape and then to re-locate the shakers at points of larger amplitude. Because of the large number of nodal lines on the wing, it was very easy to locate the shaker too close to a node and effectively nullify its effect. This shaker repositioning was a time consuming process and, while it helped to improve the modal response, the resulting isolation parameters for modes in this frequency range were still high.

It is considered that by clamping the ailerons, rudder and tabs the task of mode tuning was made considerably easier. Also a sixteen channel resolved component ratiometer improved the rate at which the degree of isolation could be assessed. For some modes the ratiometer significantly reduced the time taken to achieve isolation, but in other modes it was of lesser use. In all instances it gave a very rapid and reliable assessment of modal purity, without the necessity of making a preliminary measurement of the modal response.

In table 6 the measured frequencies for the basic N22 and the N22 carrying stores are compared. It may be seen that the agreement in frequency between N22 and N22 with inboard stores, is reasonably good for most of the modes; however the wing torsion modes at approximately 10 Hz and 11·5 Hz, measured on the aircraft with stores, have dropped considerably in frequency when compared with the basic N22. This indicates that the major effect of the stores is to increase the moment of inertia of the wing about its elastic axis thus lowering the wing torsion modes dramatically. The frequencies of the fundamental wing bending modes have not changed greatly although the wing second bending mode, previously greater than 30 Hz, drops in frequency to approximately 18 Hz when the stores are on the outboard hard points.

The apparent increases in frequency of the engine heave modes over the basic N22 are caused by the stiffer engine mounts, fitted to the aircraft since the last resonance test was carried out.

5. CONCLUSIONS

The major structural modes and frequencies of the N22 for two store configurations are presented. With the exception of the overtone wing bending mode at approximately 18 Hz the modes have been adequately isolated. No attempt was made to measure control surface modes.

The extended crutches are recommended as the more practical of the two crutches tested and the detailed results presented are only applicable to this crutch system.

REFERENCES

1. G. Long and Petra M. Cox	Resonance test on Nomad production version. Tech. Memo. ARL/Struc. 230, 1975.
2. Betty Emslie and P. A. Farrell	Resonance test on N24 Nomad aircraft. ARL/Struc. Note 426, 1976.
3. G. Long and C. M. Bailey	Resonance test results for N22—External Stores version. Memo to be published.

TABLE 1A
Locations of Wing Measuring Stations

ξ η	−0·632	0·049	0·146	0·563	0·688	0·785	0·986
+0·980			W1A	W1B	W1C	W1D	W1E
−0·980			W12A	W12B	W12C	W12D	W12E
+0·757			W2A	W2B	W2C	W2D	W2E
−0·757			W11A	W11B	W11C	W11D	W11E
+0·565			W3A	W3B	W3C	W3D	W3E
−0·565			W10A	W10B	W10C	W10D	W10E
+0·473			W4A	W4B	W4C	W4D	W4E
−0·473			W9A	W9B	W9C	W9D	W9E
+0·278	E1A	E1B	W5A	W5B	W5C	W5D	W5E
−0·278	E2A	E2B	W8A	W8B	W8C	W8D	W8E
+0·129			W6A	W6B	W6C	W6D	W6E
−0·129			W7A	W7B	W7C	W7D	W7E

ξ is proportion of wing chord aft of wing leading edge
η is proportion of wing semi-span from aircraft centreline
E1A is on port propeller hub, E2A is on starboard propeller hub
E1B is on port engine rear, E2B is on starboard engine rear.

TABLE 1B
Locations of Tailplane Measuring Stations

ξ η	0·192	0·846	0·981
+0·939	T1A	T1B	
−0·939	T8A	T8B	
+0·630	T2A	T2B	T2C
−0·630	T7A	T7B	T7C
+0·351	T3A	T3B	T3C
−0·351	T6A	T6B	T6C
+0·075	T4A	T4B	T4C
−0·075	T5A	T5B	T5C

ξ is proportion of tailplane chord aft of tailplane leading edge
η is proportion of tailplane semi-span from aircraft centreline

TABLE 1C
Location of Fuselage Measuring Stations

Station		1	2	3	4	5	6	7	8	9
Horizontal A	BS		139·75	182·75	212·75	290·75	336·25	399·75	435·25	462·75
	WL		106·75	104·75	104·75	107·75	107·75	107·75	107·75	107·75
Horizontal B	BS	65·75	139·75	182·75	212·75	290·75	336·25	399·75	435·25	462·75
	WL	53·75	53·75	53·75	53·75	53·75	65·75	82·25	91·25	98·0
Vertical	BS	62·0	125·5	182·0	212·0	290·0	335·5	399·0	434·5	462·0

BS — Body station.
WL — Water line.

TABLE 1D
Location of Fin and Rudder Measuring Stations

Station		F1	F2	F3	F4	F5	F6	F7
A	BS	448·25	446·75	445·75	440·0	437·0	421·75	406·75
	WL	222·5	218·0	198·0	175·5	153·5	130·5	116·0
B	BS		463·0	463·0	463·0	463·0	463·0	463·0
	WL		216·0	198·0	175·5	153·5	130·5	116·0
C	BS			471·5	472·0	473·0	473·0	472·5
	WL			198·0	175·5	153·5	130·5	116·0
D	BS	488·0		494·0	499·0	499·0	503·0	505·5
	WL	222·5		198·0	175·5	153·5	130·5	116·0
E	BS					505·0	509·0	511·5
	WL					153·5	130·5	116·0

BS Body station
WL Water line

TABLE 1E
Location of Store Measuring Stations

ξ	0·028	0·208	0·431
Vertical port	D1A	D1B	D1C
Vertical stbd.	D2A	D2B	D2C
Horizontal port	D3A	D4A	D5A
Horizontal stbd.	D3B	D4B	D5B

ξ is proportion of wing chord aft of leading edge.

TABLE 1F
Location of Stub Wing Measuring Stations

ξ η	0·103	0·178	0·766	0·720
0·957	S1A		S1B	
0·698		S2A		S2B

ξ is proportion of stub wing chord aft of stub wing leading edge
η is proportion of stub wing semi-span from aircraft centreline

TABLE 2A
Locations of Shakers

Stores mounted inboard on standard crutches and wing propped

Serial No.	12 974	12 976	14 757	14 754
stiffness frequency Hz	25 lb/in	28 lb/in	66 lb/in	49 lb/in
4·06			SD2	SD4
11·70	SDV5	SDV1		
12·72			SD2	SD4

Stores mounted inboard on extended crutches and wing propped

Serial No.	12 974	12 976	14 757	14 754
stiffness frequency Hz	25 lb/in	28 lb/in	66 lb/in	49 lb/in
5·44			SD2	SD4
11·92	SDV5	SDV1		
16·6			SD2	SD4

TABLE 2B
Locations of Shakers
Stores mounted inboard on extended crutches

Serial No.	12980	12981	12979	12977	12974	12975	12976	12978	14757	14754	14756	14755	14086
stiffness / freq. Hz	26 lb/in	25 lb/in	30 lb/in	26 lb/in	25 lb/in	27 lb/in	28 lb/in	20 lb/in	66 lb/in	49 lb/in	57 lb/in	51 lb/in	80 lb/in
4·72	T8B	T1B	T8A	T1A	W12B	E1A	W12A	E2A	SD4	PD4	W1A	W1B	—
5·08	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2A	E1A	F2A
6·52	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2A	E1A	F2A
6·63	T8B	T1B	T8A	T1A	W12B	E1A	W12A	E2A	SD4	PD4	W1A	W1B	—
9·06	T8B	T1B	T8A	T1A	W12B	E1A	W12A	E2A	SD4	PD4	W1A	W1B	—
9·99	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SDV1	PDV1	E2B	E1B	B1
10·52	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2A	E1A	F2A
11·5	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2B	E1B	F2A
12·78	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SDV1	PDV1	E2B	E1B	F2A
14·09	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2B	E1B	B1
14·71	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2		E2A	E1A	F2A
15·3	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2B	E1B	F2A
16·0	T8B		T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2B	E1B	F2A
16·3	T8B	T1B	T8A	T1A	W12B	E1A	W12A	E2A	SD2	PD2	W1A	W1B	—
16·74	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD2	PD2	E2A	E1A	F2A
17·4	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	HFDS	HFDP	E2B	E1B	B1
21·7	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	FAF	E1B	B1
29·5	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	B1	E1B	FAF
30·6	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	B1	E1B	FAF

AOBHS — Aileron Outboard Hinge Starboard.
AOBHP — Aileron Outboard Hinge Port.
HFDS — Horizontal Fore and Aft Store, Starboard
HFDP — Horizontal Fore and Aft Store, Port
FAF — Fore and Aft on Fin

SD2 — 102 mm (4 in) aft of D3B
SD4 — 654 mm (25·75 in) aft of D3B
PD1 — Station D3A
PD2 — 102 mm (4 in) aft of D3A
PD4 — 654 mm (25·75 in) aft of D3A

SDV1 — Station D2A
SDV5 — Station D2C
PDV1 — Station D1A

TABLE 2C
Locations of Shakers
Stores Mounted Outboard on Extended Crutches

Serial No.	12980	12981	12979	12977	12974	12975	12976	12978	14757	14754	14756	14755	14086
stiffness / freq. Hz	26 lb/in	25 lb/in	30 lb/in	26 lb/in	25 lb/in	27 lb/in	28 lb/in	20 lb/in	66 lb/in	49 lb/in	57 lb/in	51 lb/in	80 lb/in
4·59	T8B	T1B	T8A	T1A	*AIBHS	*AIBHP	W12A	W1A	SD1	PD1	E2A	E1A	F2A
5·05	T8B	T1B	T8A	T1A	AIBHS	AIBHP	W12A	W1A	SD1	PD1	E2A	E1A	F2A
5·51	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A		PD1	E2B	E1B	FAF
6·33	T8B	T1B	T8A	T1A	*AOBHS	*AOBHP	W12A	W1A	SDV1	PDV1	E2A	E1A	—
6·55	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2A	E1A	F2A
8·47	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2A	E1A	—
10·10	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2B	E1B	—
10·41	T8B		T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2B	E1B	—
11·32	T8B	T1B	T8A	T1A	AIBHS	AIBHP	W12A	W1A	SDV1	PDV1	E2A	E1A	F2A
12·91	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD1	PD1	E2B	E1B	F2A
13·49	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A		PD1	E2B	E1B	F2A
14·53	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD1	PD1	E2B	E1B	—
15·45	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD1	PD1	E2B	E1B	—
15·65	T8B	T1B	T8A	T1A	AOBHS	AOBHP	W12A	W1A	SDV1	PDV1	E2B	E1B	—
17·10	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD1	PD1	E2B	E1B	F2A
17·30	T8B	T1B	T8A	T1A	W12B	W1B	W12A	W1A	SD1	PD1	E2B	E1B	—
17·96	W11D	W2D	T8A	T1A	E2B	AOBHP	W12A	W1A	*FOBHS	*FOBHP	AOBHS	E1B	—
18·67	W11D	W2D	T8A	T1A	E2B	AOBHP	W12A	W1A	FOBHS	FOBHP	AOBHS	E1B	—
18·92	W11D	W2D	T8A	T1A	E2B	AOBHP	W12A	W1A	FOBHS	FOBHP	AOBHS	E1B	—
19·37	W11D	W2D	T8A	T1A	E2B	AOBHP	W12A	W1A	FOBHS	FOBHP	AOBHS	E1B	—
23·46	T8B	T1B	T8A	T1A	E2B	AOBHP	W12A	W1A	*HFDS	*HFDP	AOBHS	E1B	F2A

* AIBHS — Aileron Inboard Hinge Stbd.
AIBHP — Aileron Inboard Hinge Port.
FOBHS — Flap Outboard Hinge Stbd.
FOBHP — Flap Outboard Hinge Port.

TABLE 3

Summary of Uncoupled Store Modes

A Stores mounted inboard, standard crutches, wing propped

Description	Natural frequency Hz	Damping % critical	Isolation parameter	Figure No.
Store lateral bending	4·06		0·108	4
Store pitch	11·7		0·064	5
Store yaw	12·72		0·178	6

B Stores mounted inboard, extended crutches, wing propped

Description	Natural frequency Hz	Damping % critical	Isolation parameter	Figure No.
Store lateral bending	5·44		0·04	7
Store pitch	11·92		0·202	8
Store yaw	16·6		0·084	9

TABLE 4

Summary of Measured Modes

Stores mounted inboard, extended crutches

Description	Natural frequency Hz	Damping % critical	Isolation parameter	Figure No.
Symmetric store lateral bending	4·72	1·0	0·096	10
Anti-symmetric store lateral bending	5·08	0·7	0·094	11
Anti-symmetric engine heave	6·52	1·1	0·102	12
Symmetric engine heave	6·63	1·2	0·078	13
Symmetric wing bending	9·06	1·2	0·108	14
Anti-symmetric wing torsion	9·99	1·5	0·070	15
Anti-symmetric wing bending	10·52	1·2	0·083	16
Symmetric wing torsion	11·5	1·0	0·258	17
Fuselage lateral bending	12·78	1·1	0·146	18
Fin bending	14·09	1·9	0·160	19
Anti-symmetric engine pitch	14·71	2·9	0·185	20
Symmetric engine pitch	15·3	2·5	0·138	21
Symmetric tailplane bending	16·0	1·6	0·152	22
Store yaw anti-symmetric	16·3	0·8	0·074	23
Store yaw symmetric	16·74	1·0		N.I.
Tailplane rotation	17·4	3·6	0·097	24
Fuselage vertical bending	21·7	0·9	0·284	25
	29·5		0·404	26
	30·6		0·74	27

TABLE 5
Summary of Measured Modes
Stores mounted outboard—extended crutches

Description	Natural frequency Hz	Damping % critical	Isolation Parameter	Figure No.
Symmetric store lateral bending	4·59	0·7	0·091	28
Anti-symmetric store lateral bending	5·05	0·6	0·054	29
Wing-fuselage scissors type mode	5·51	1·1	0·074	30
Symmetric engine heave	6·33	0·9	0·071	31
Anti-symmetric engine heave	6·55		0·076	32
Symmetric wing bending	8·47	2·6	0·122	33
Anti-symmetric wing torsion	10·10	0·9	0·036	34
Anti-symmetric wing bending	10·41	1·5	0·115	35
Symmetric wing torsion	11·32		0·060	36
Fuselage lateral bending	12·91	1·1	0·197	37
Fin lateral bending	13·49	3·6	0·137	38
Symmetric engine pitch	14·53	3·0	0·117	39
Anti-symmetric engine pitch	15·45	3·4	0·139	40
Tailplane symmetric bending	15·65	2·0	0·230	41
Anti-symmetric store yaw	17·10	1·0	0·102	42
Symmetric store yaw	17·3	1·0	0·101	43
Anti-symmetric wing overtone bending	17·96	1·3	0·278	44
Symmetric wing overtone bending	18·67	3·5	0·211	45
Symmetric wing torsion and overtone bending	18·92		0·359	46
Anti-symmetric wing torsion	19·37	1·2	0·475	47
Anti-symmetric overtone bending and torsion	23·46	1·0	0·820	48

TABLE 6
Comparison of Measured Modal Frequencies

Mode description	N22-stores inboard frequency Hz	N22-stores outboard frequency Hz	N22 frequency Hz
Symmetric store lateral bending	4·72	4·59	N.A.
Anti-symmetric store lateral bending	5·08	5·05	N.A.
Wing fuselage scissors type mode		5·51	
Symmetric engine heave	6·63	6·33	6·51
Anti-symmetric engine heave	6·52	6·55	6·01
Symmetric wing bending	9·06	8·47	8·85
Anti-symmetric wing torsion	9·99	10·10	20·09
Anti-symmetric wing bending	10·52	10·41	10·64
Symmetric wing torsion	11·5	11·32	20·79
Fuselage lateral bending	12·78	12·91	13·02
Fin lateral bending	14·09	13·49	14·13
Symmetric engine pitch	15·3	14·53	
Anti-symmetric engine pitch	14·71	15·45	15·4
Tailplane symmetric bending	16·0	15·65	16·0
Anti-symmetric store yaw	16·3	17·1	
Symmetric store yaw	16·74	17·3	
Fuselage vertical bending	21·7		20·79

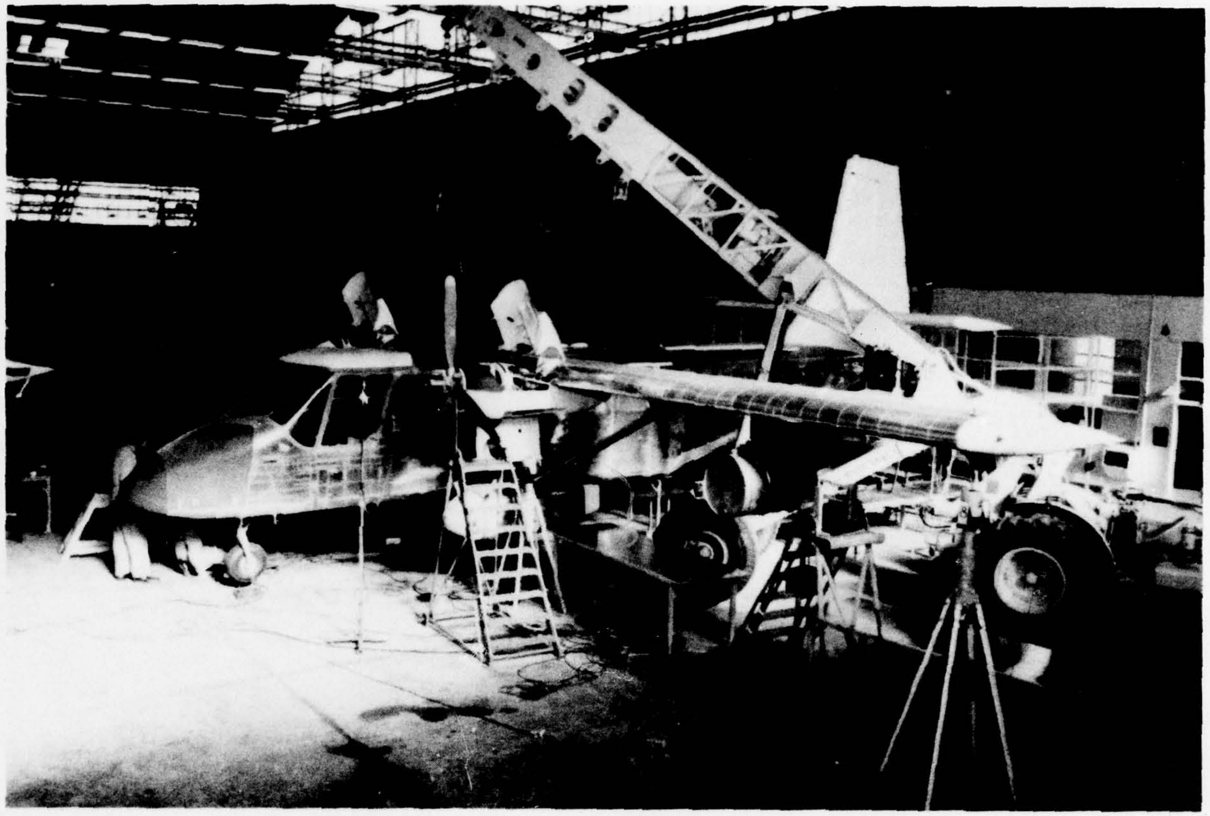
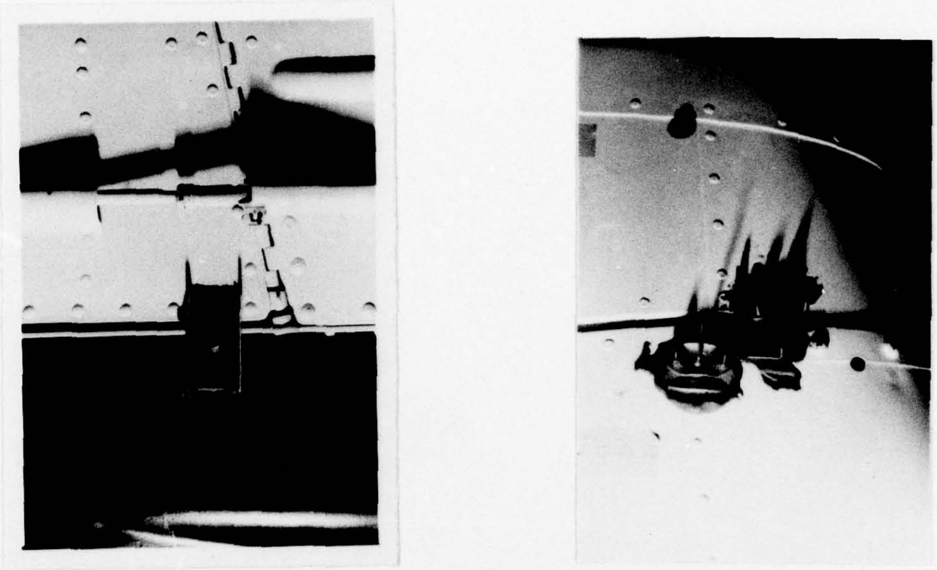


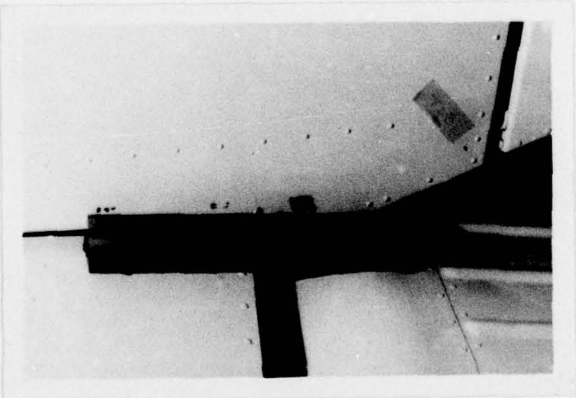
FIG. 1. GENERAL VIEW OF AIRCRAFT SUPPORTED FOR TEST



Rudder clamp

Horn balance clamp

Aileron clamp



Tailplane clamp

FIG. 2. DETAILS OF CONTROL SURFACE CLAMPS

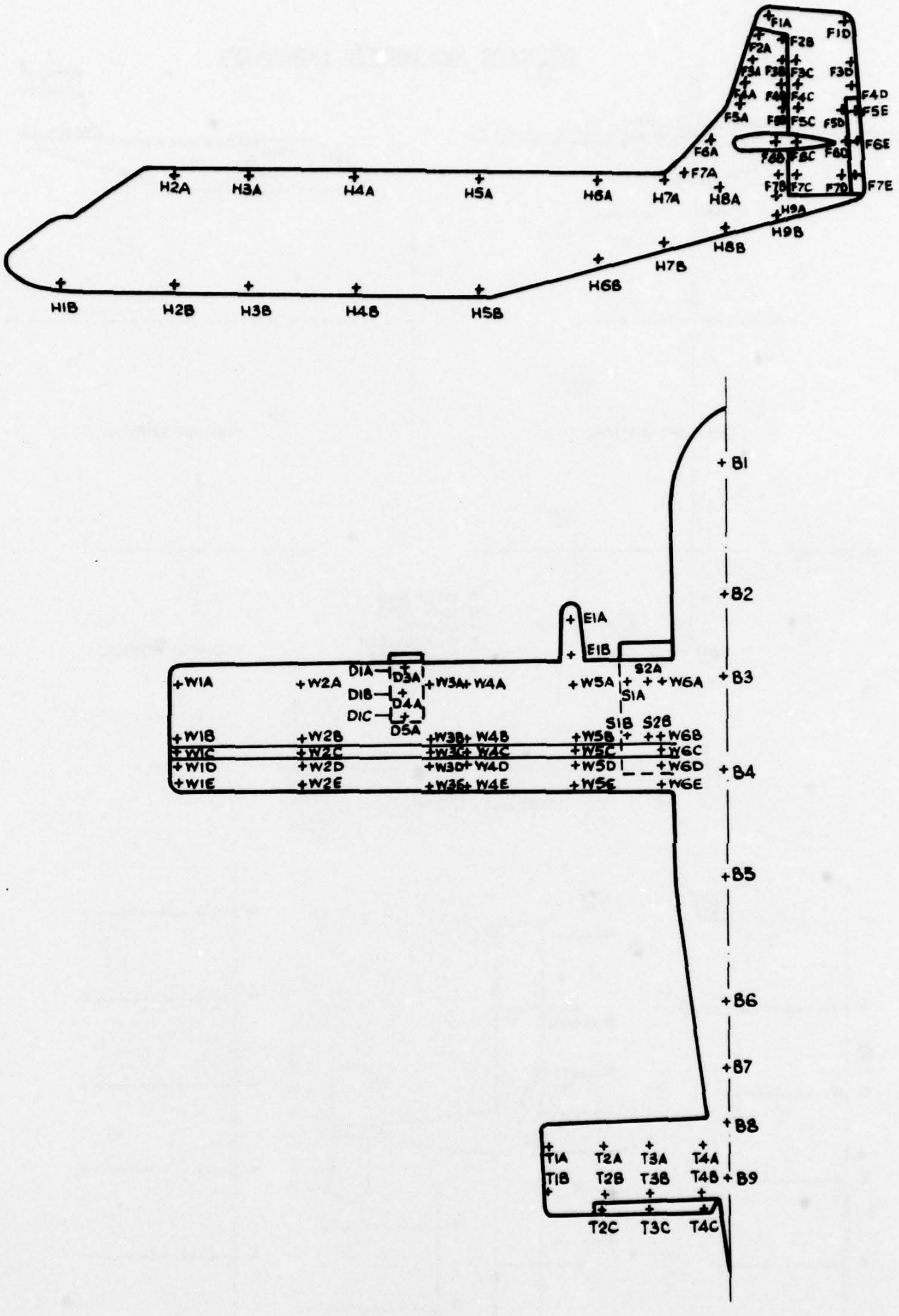


FIG. 3. LOCATIONS OF MEASURING STATIONS

STORES MOUNTED INBOARD

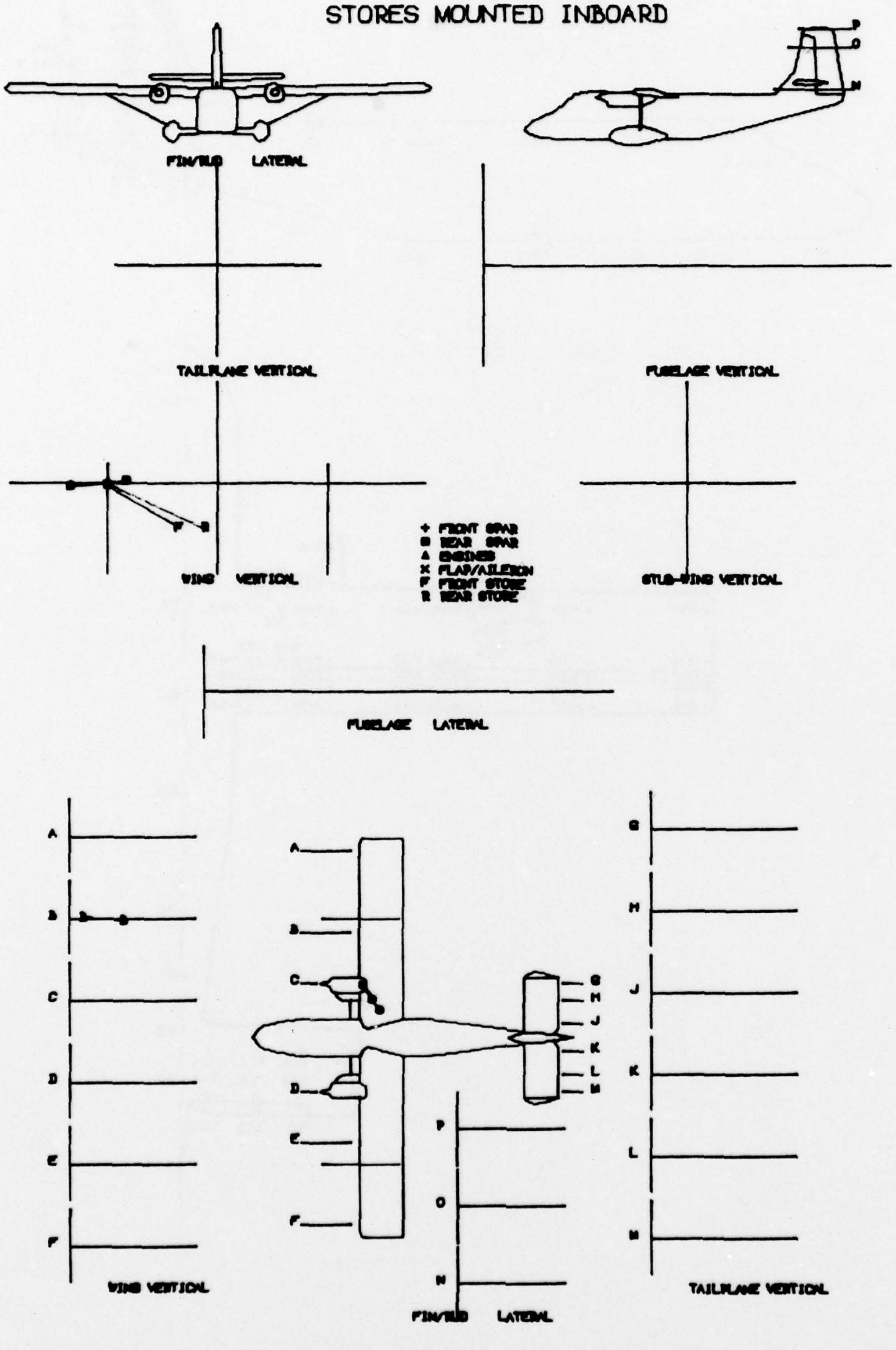


FIG. 4a MODE AT 4.06 Hz

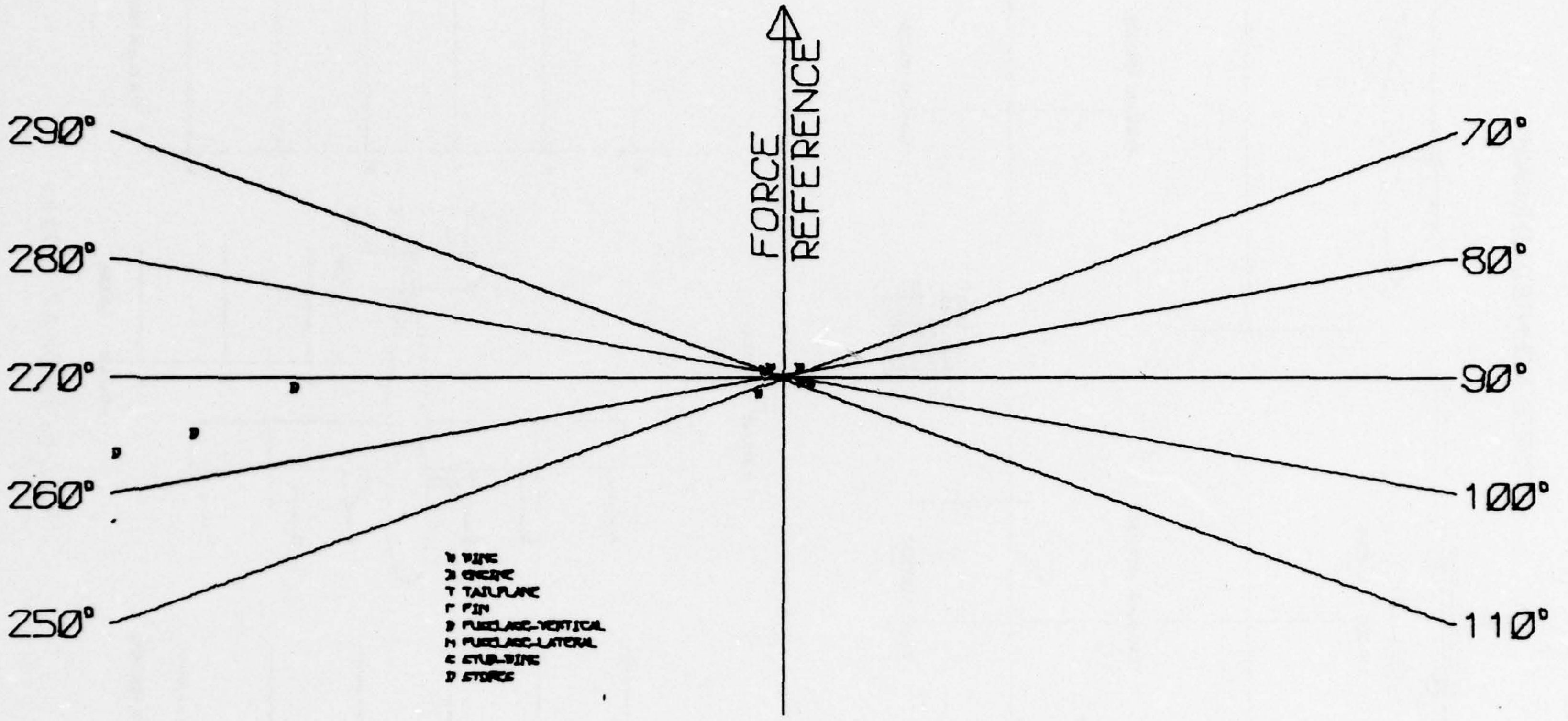


FIG. 4b VECTOR RESPONSE MODE AT 4.06 Hz

STORES MOUNTED INBOARD

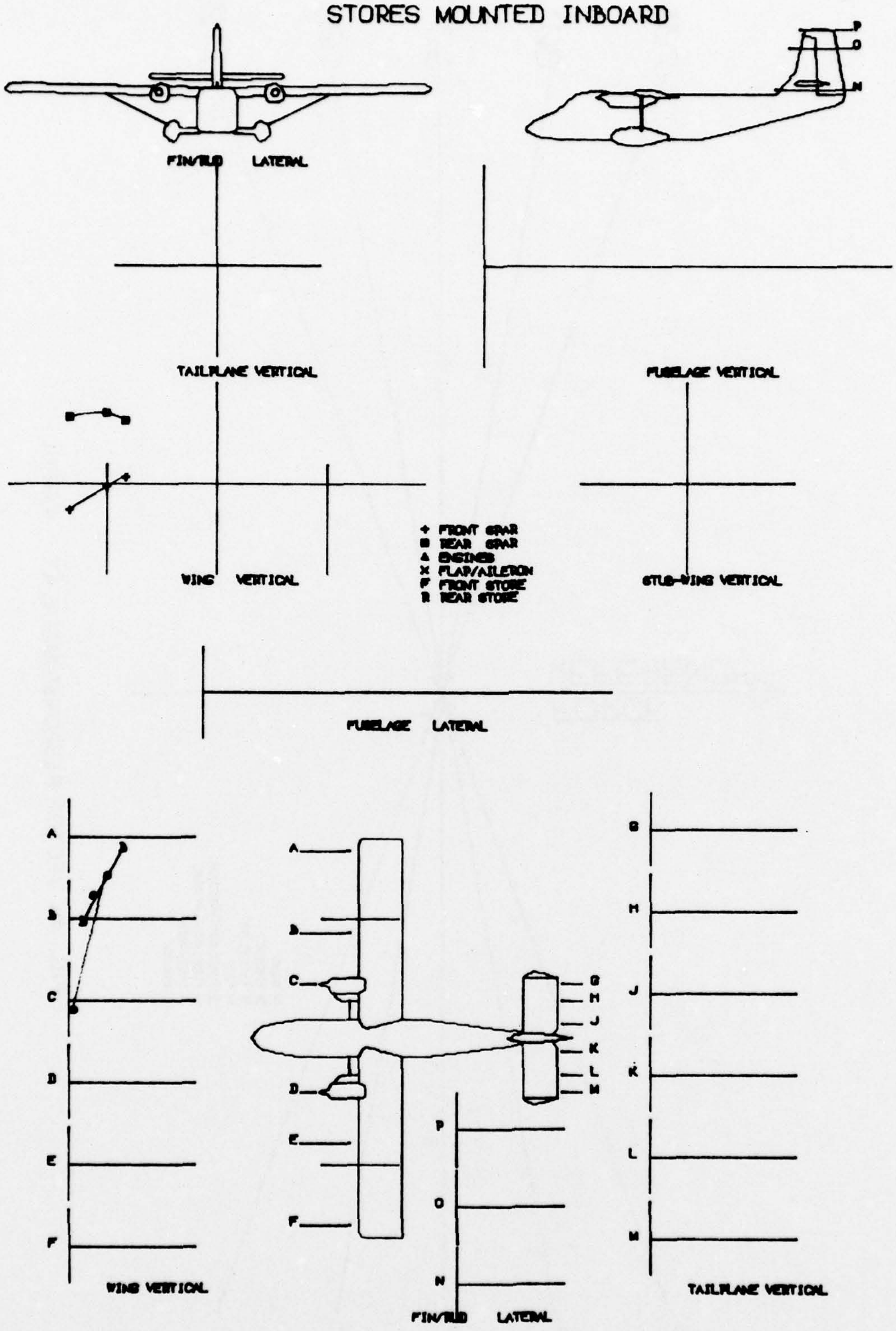


FIG. 5a MODE AT 11.70 Hz

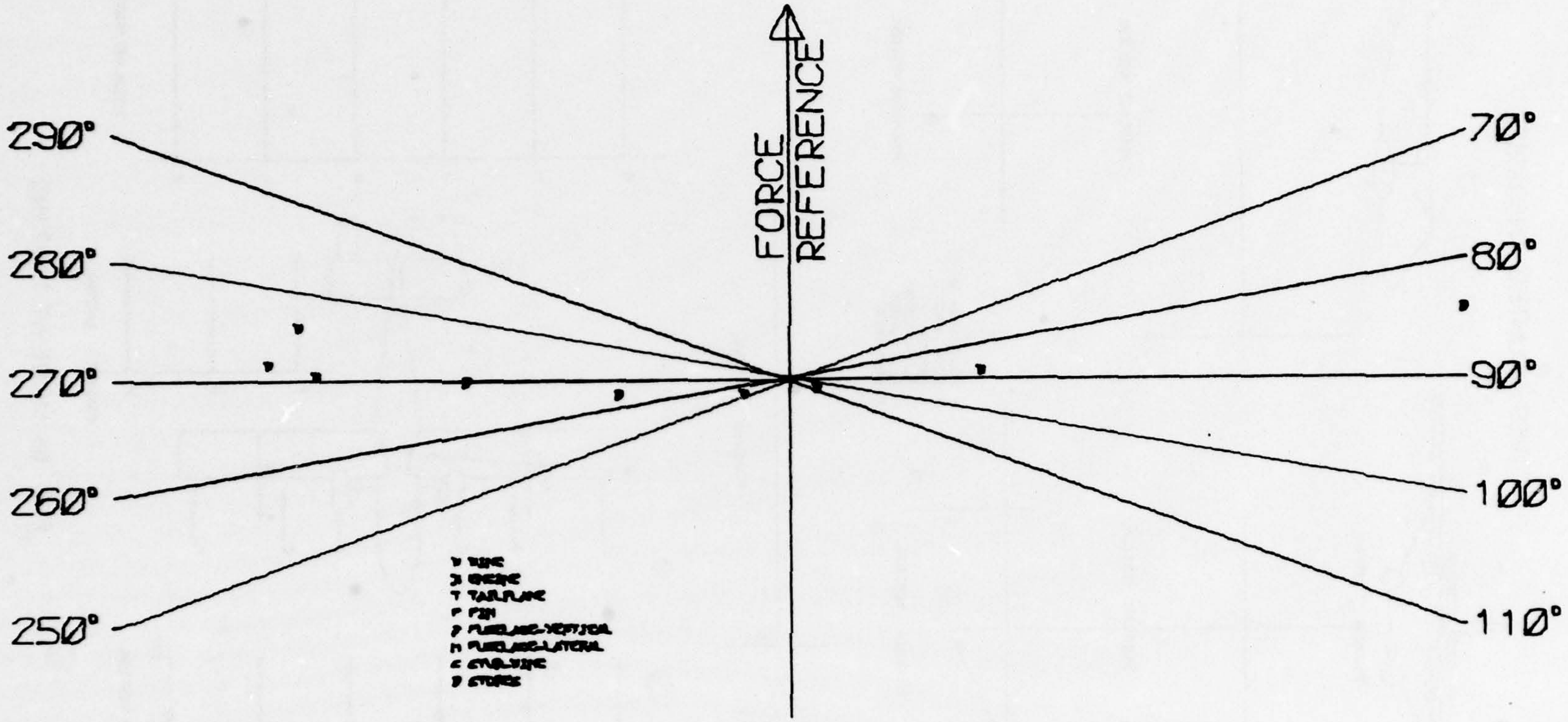


FIG. 5b VECTOR RESPONSE MODE AT 11.70 Hz

STORES MOUNTED INBOARD

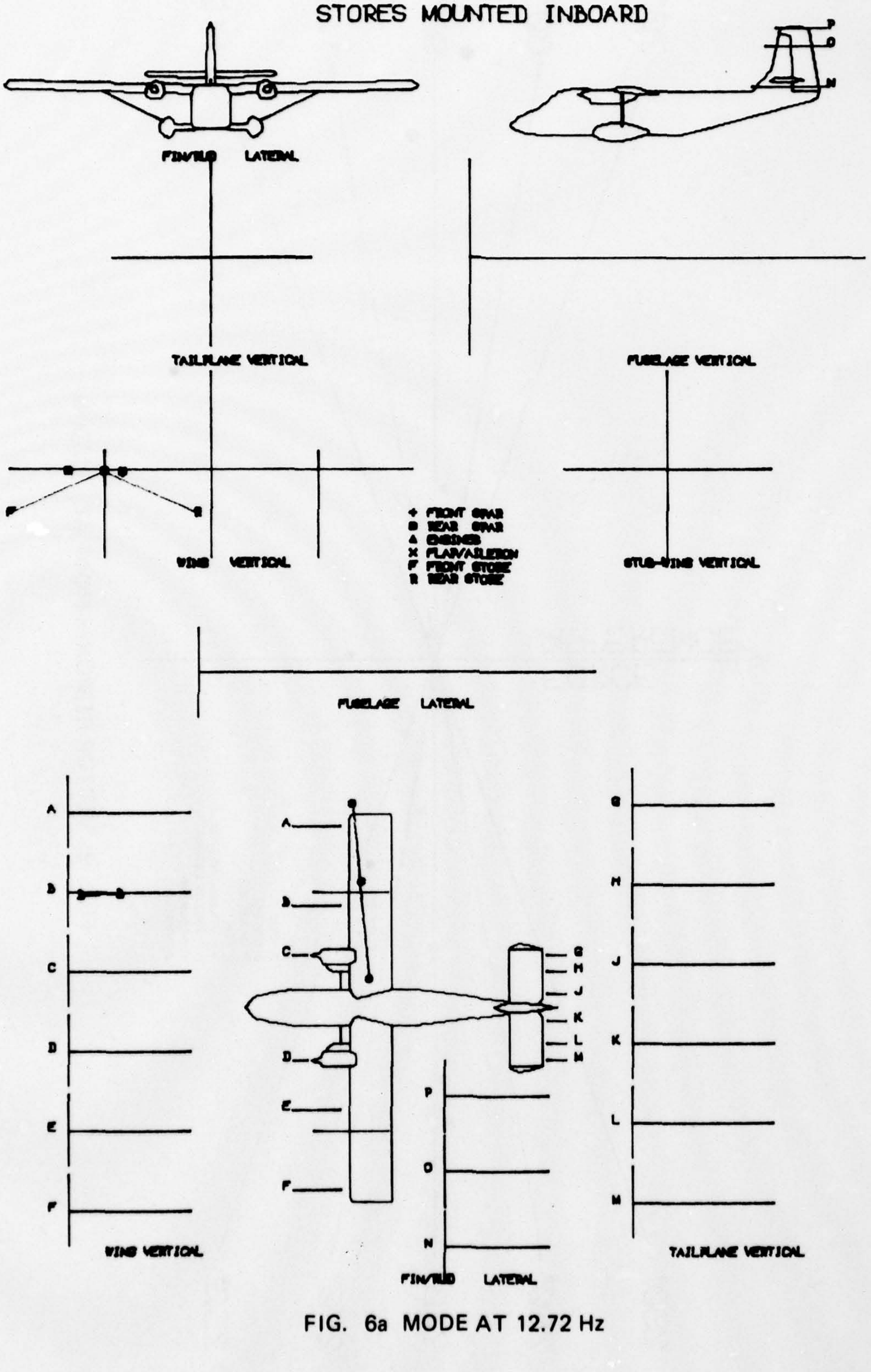


FIG. 6a MODE AT 12.72 Hz

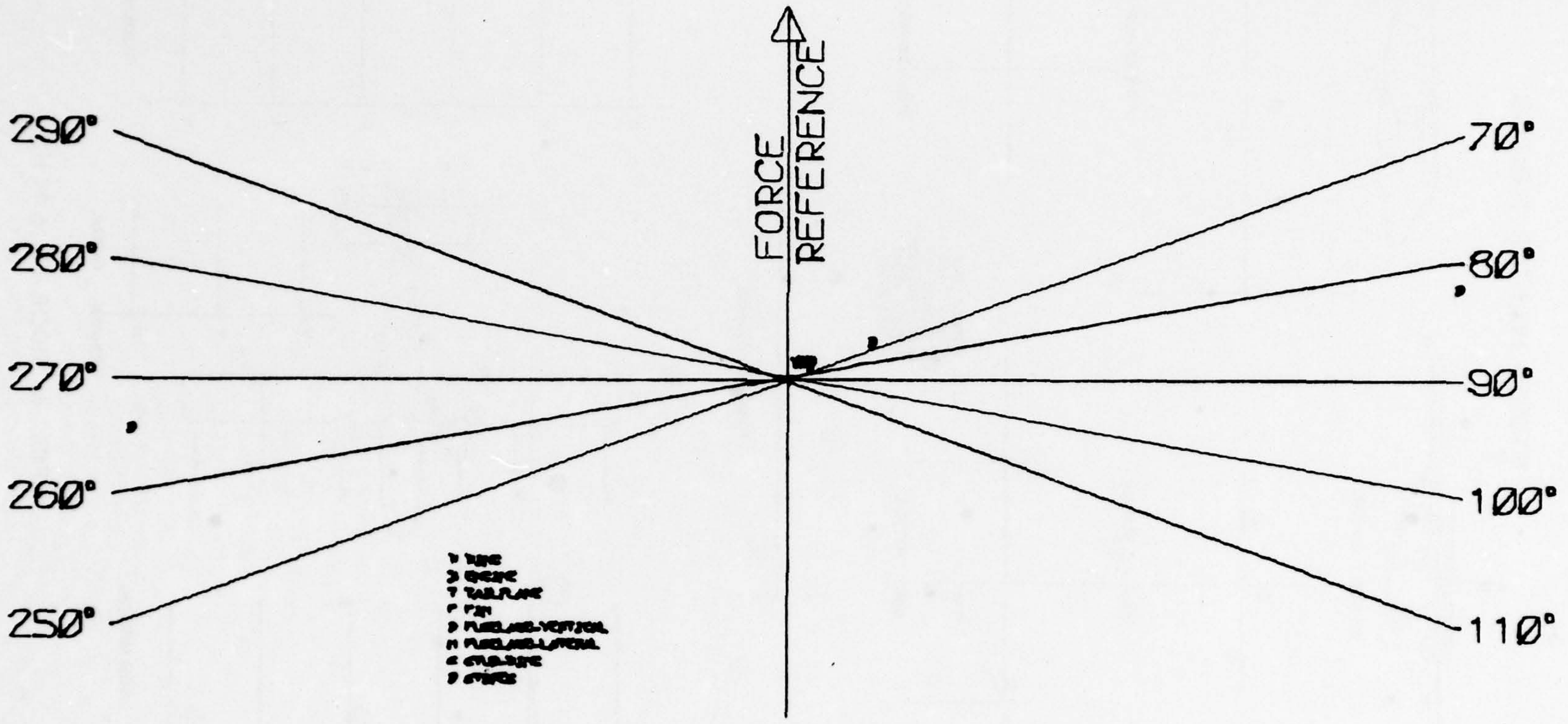


FIG. 6b VECTOR RESPONSE MODE AT 12.72 Hz

STORES MOUNTED INBOARD

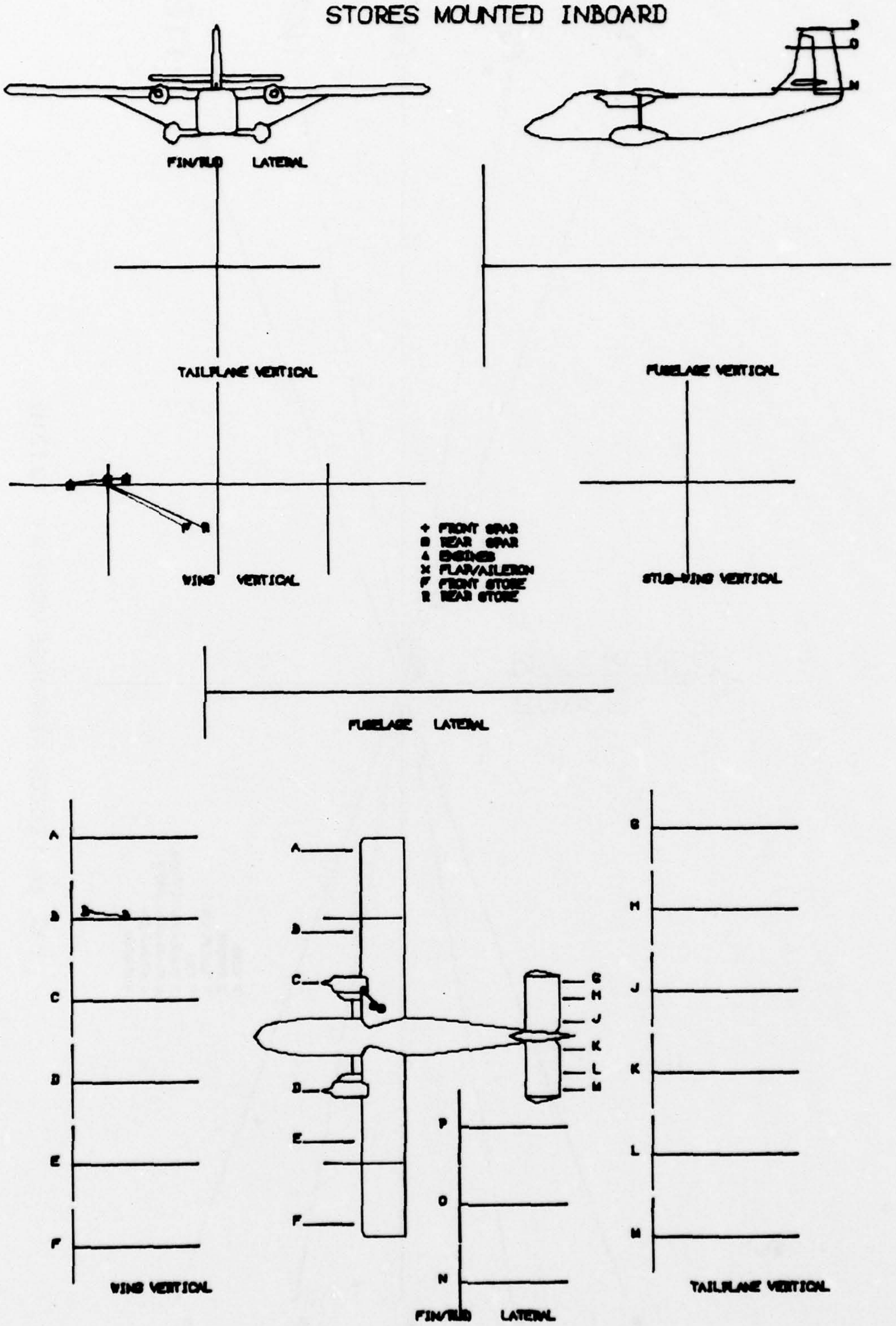


FIG. 7a MODE AT 5.44 Hz

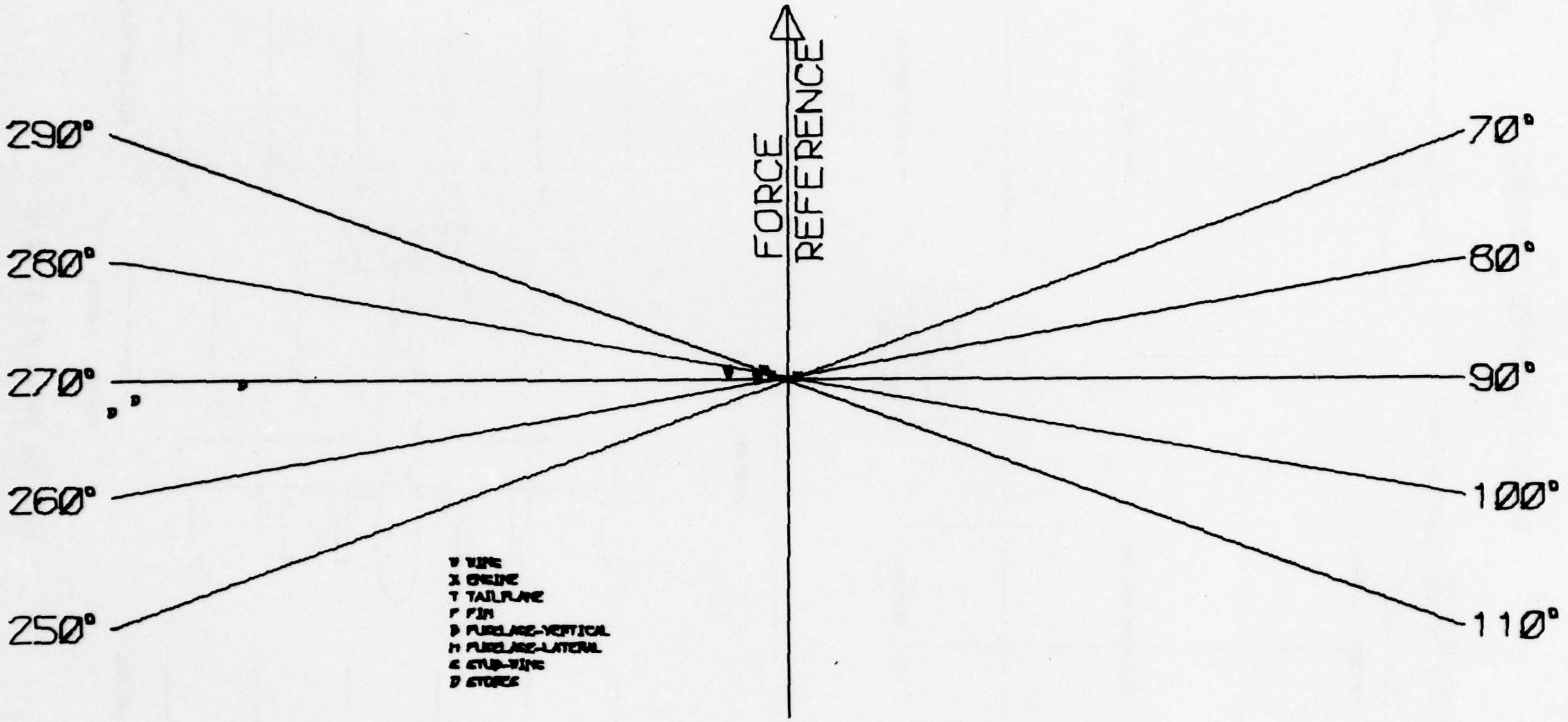


FIG. 7b VECTOR RESPONSE MODE AT 5.44 Hz

STORES MOUNTED INBOARD

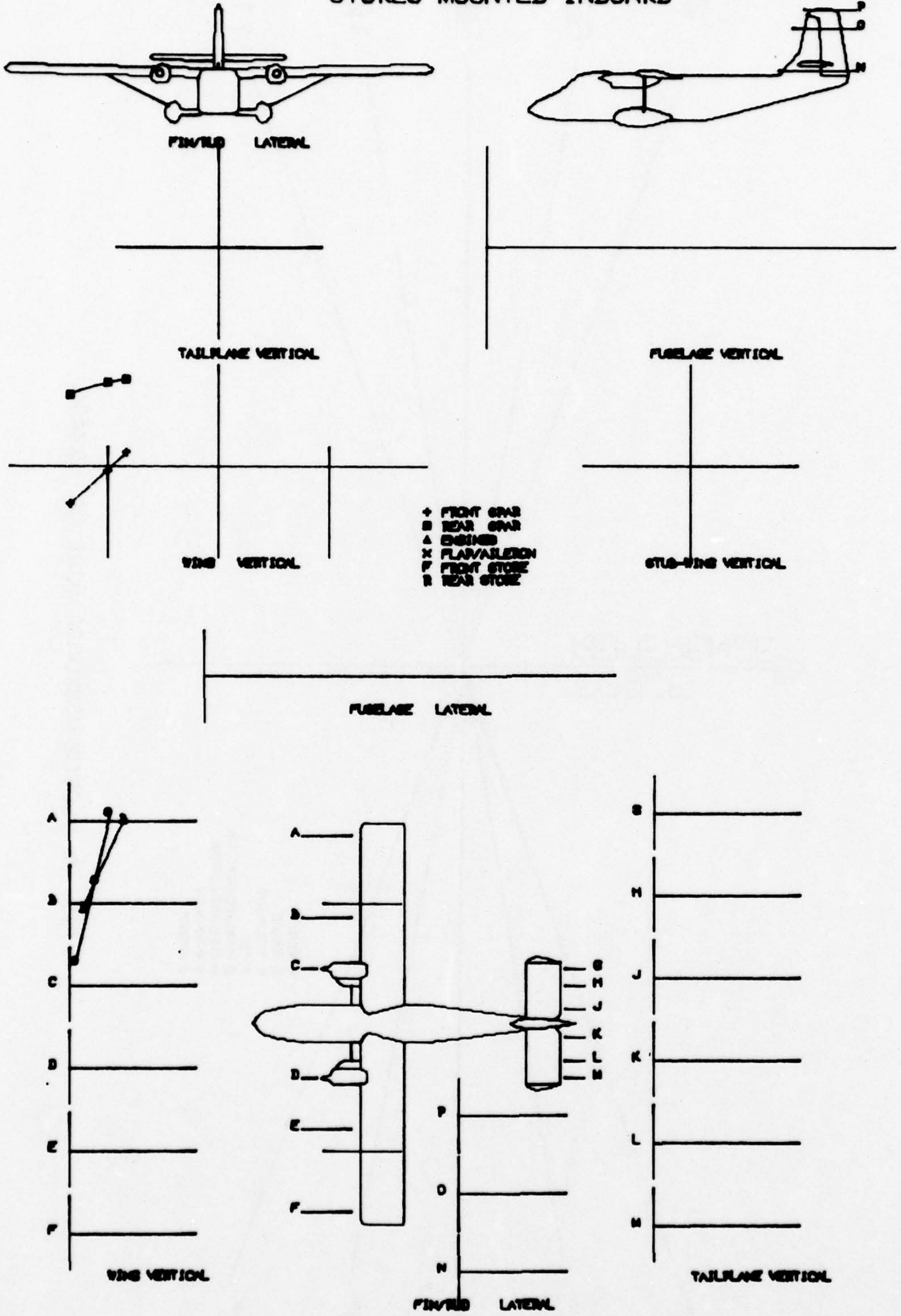


FIG. 8a MODE AT 11.92 Hz

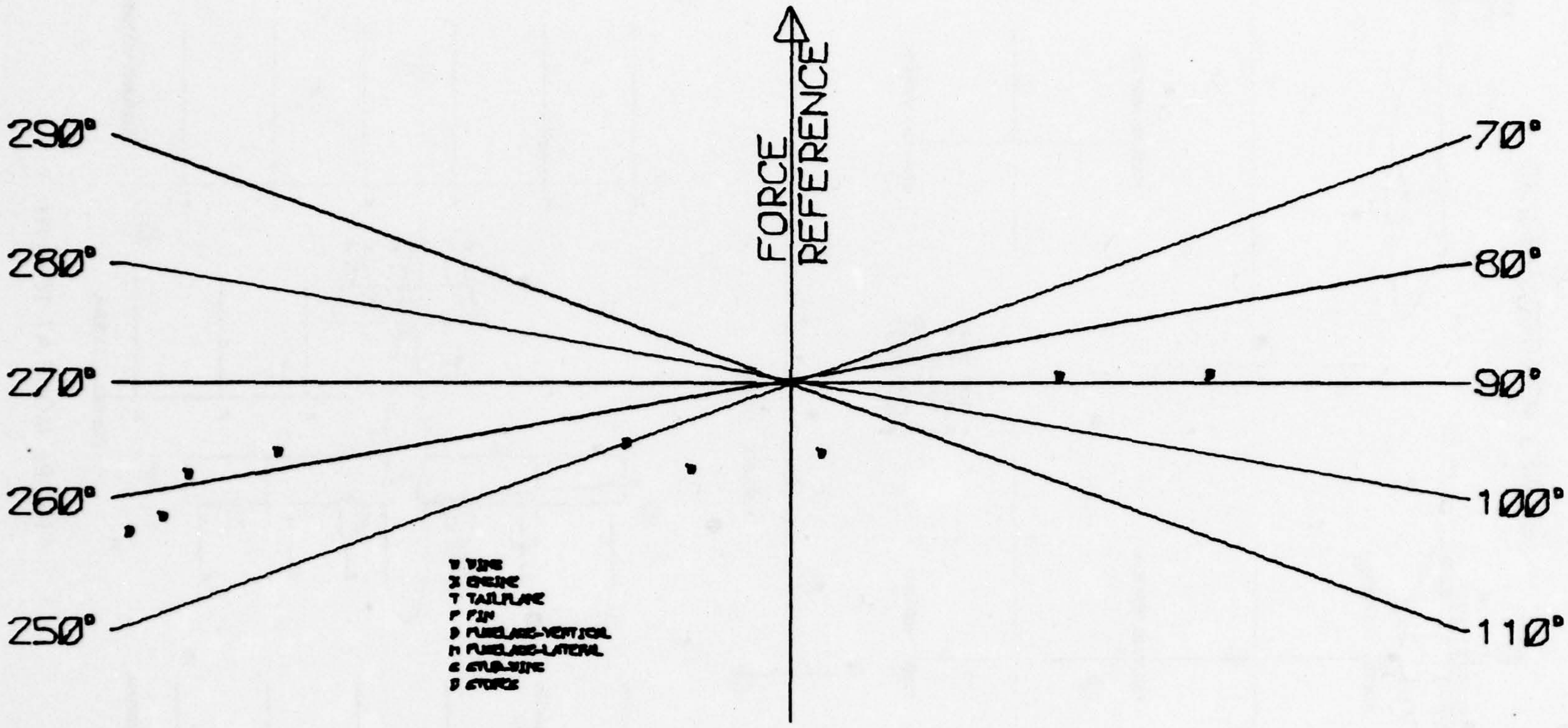


FIG. 8b VECTOR RESPONSE MODE AT 11.92 Hz

STORES MOUNTED INBOARD

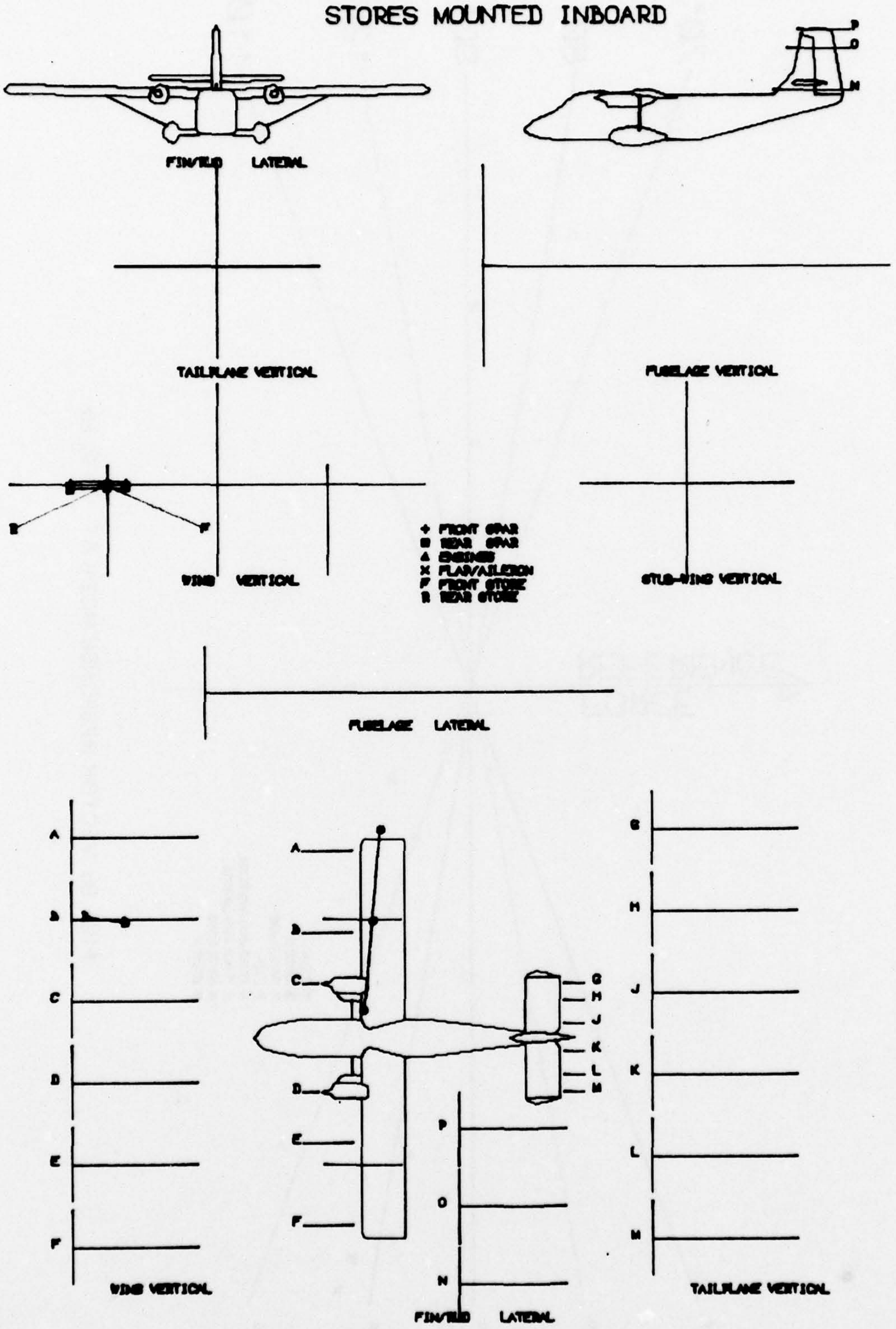


FIG. 9a MODE AT 16.60 Hz

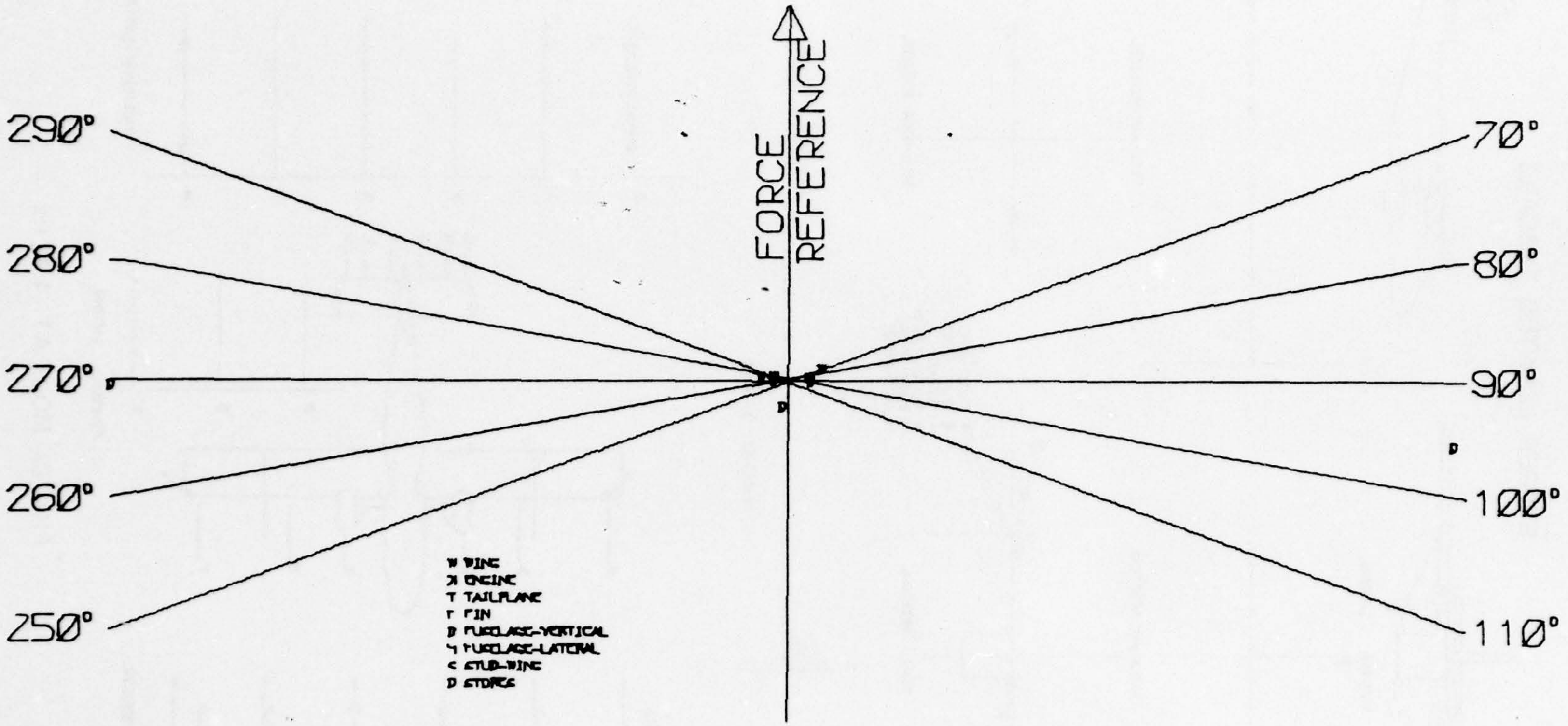


FIG. 9b VECTOR RESPONSE MODE AT 16.60 Hz

STORES MOUNTED INBOARD

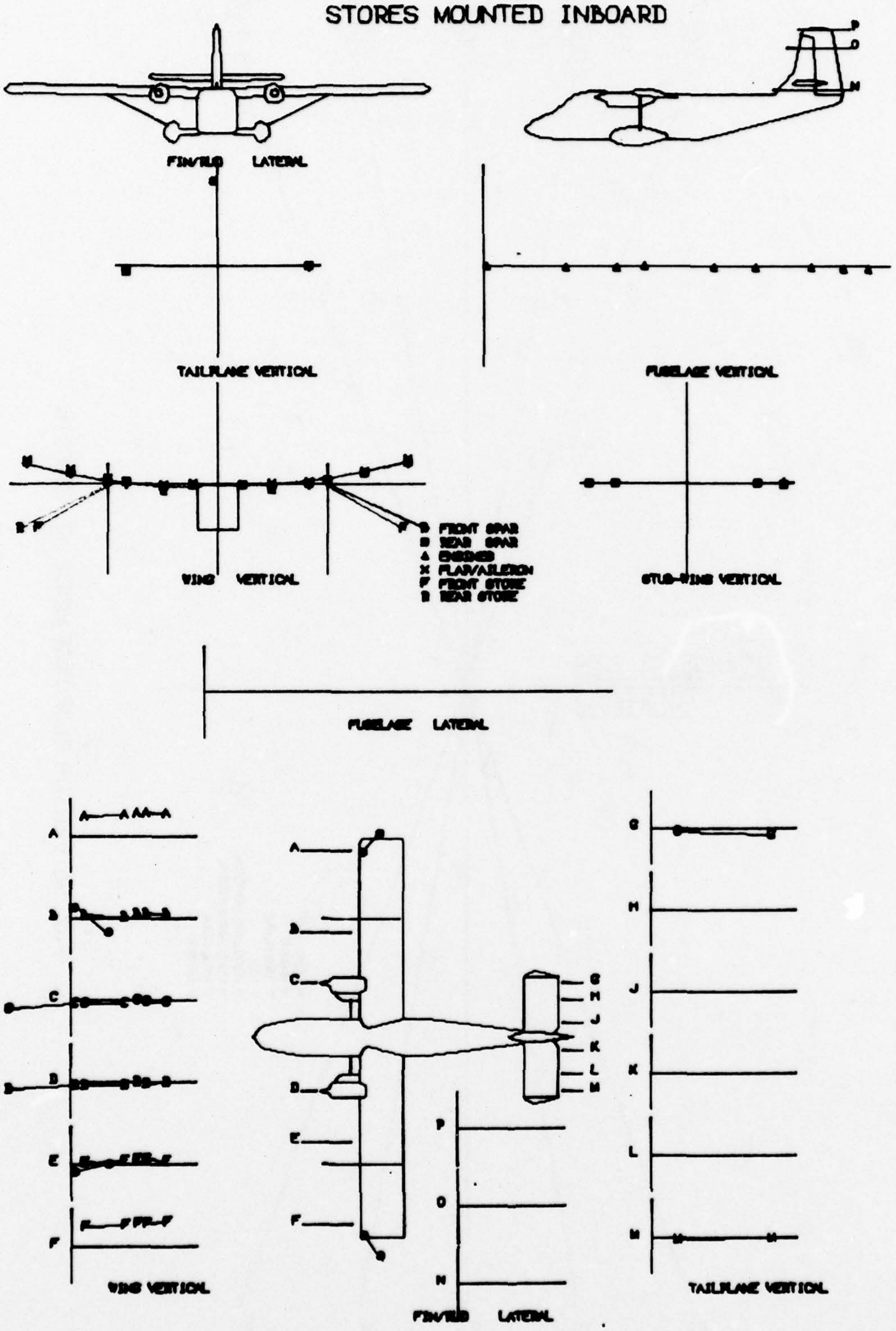


FIG. 10a MODE AT 4.72 Hz

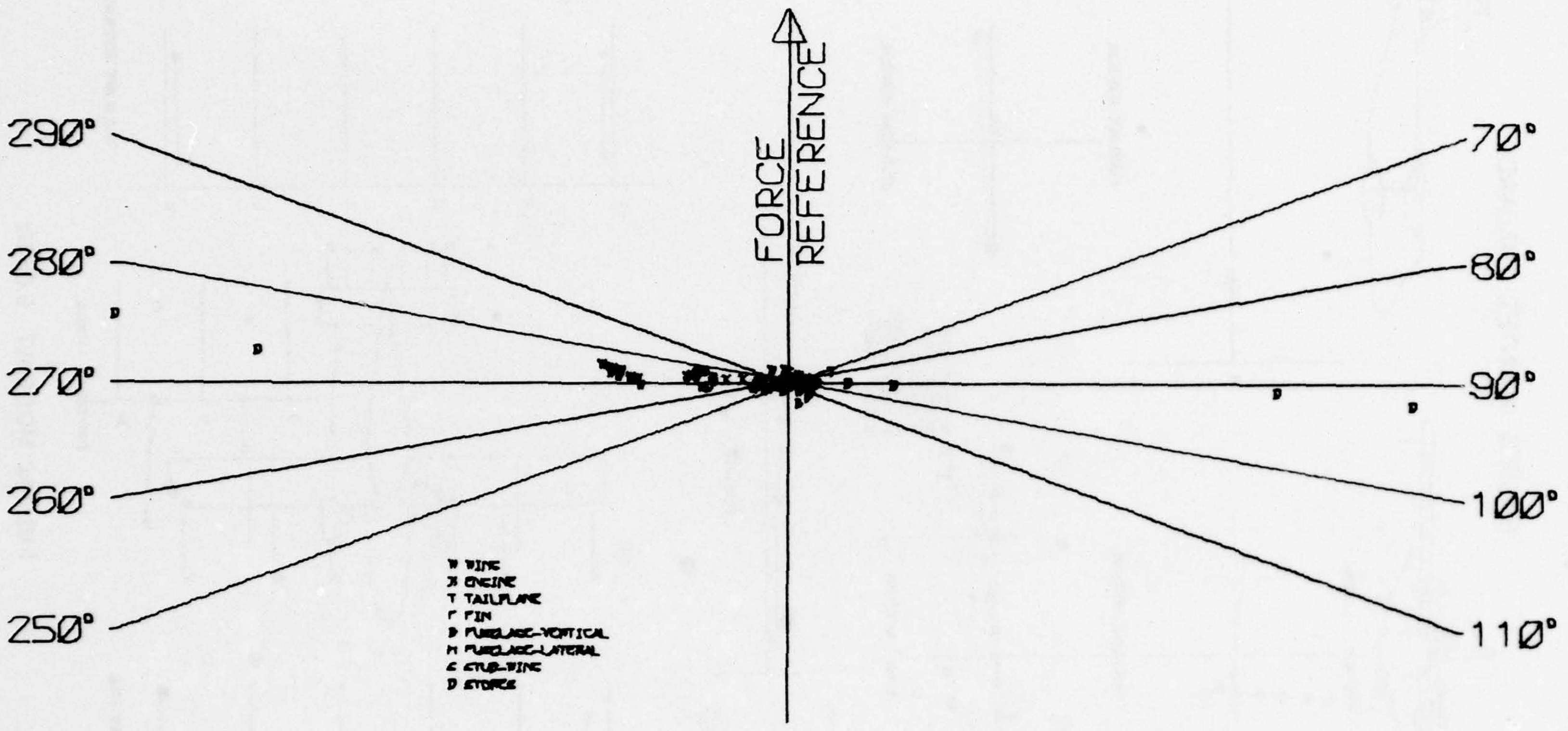


FIG. 10b VECTOR RESPONSE MODE AT 4.72 Hz

STORES MOUNTED INBOARD

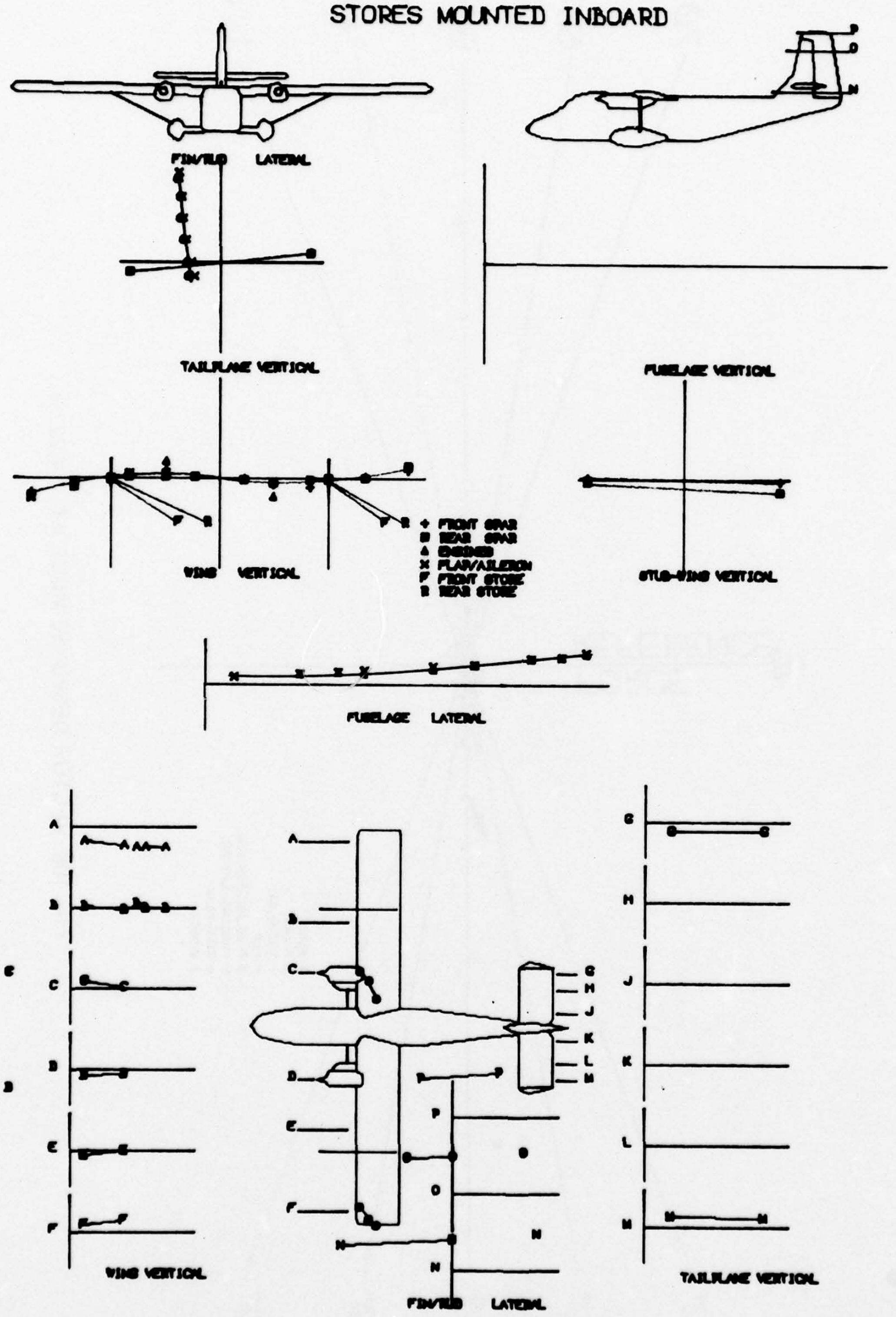


FIG. 11a MODE AT 5.08 Hz

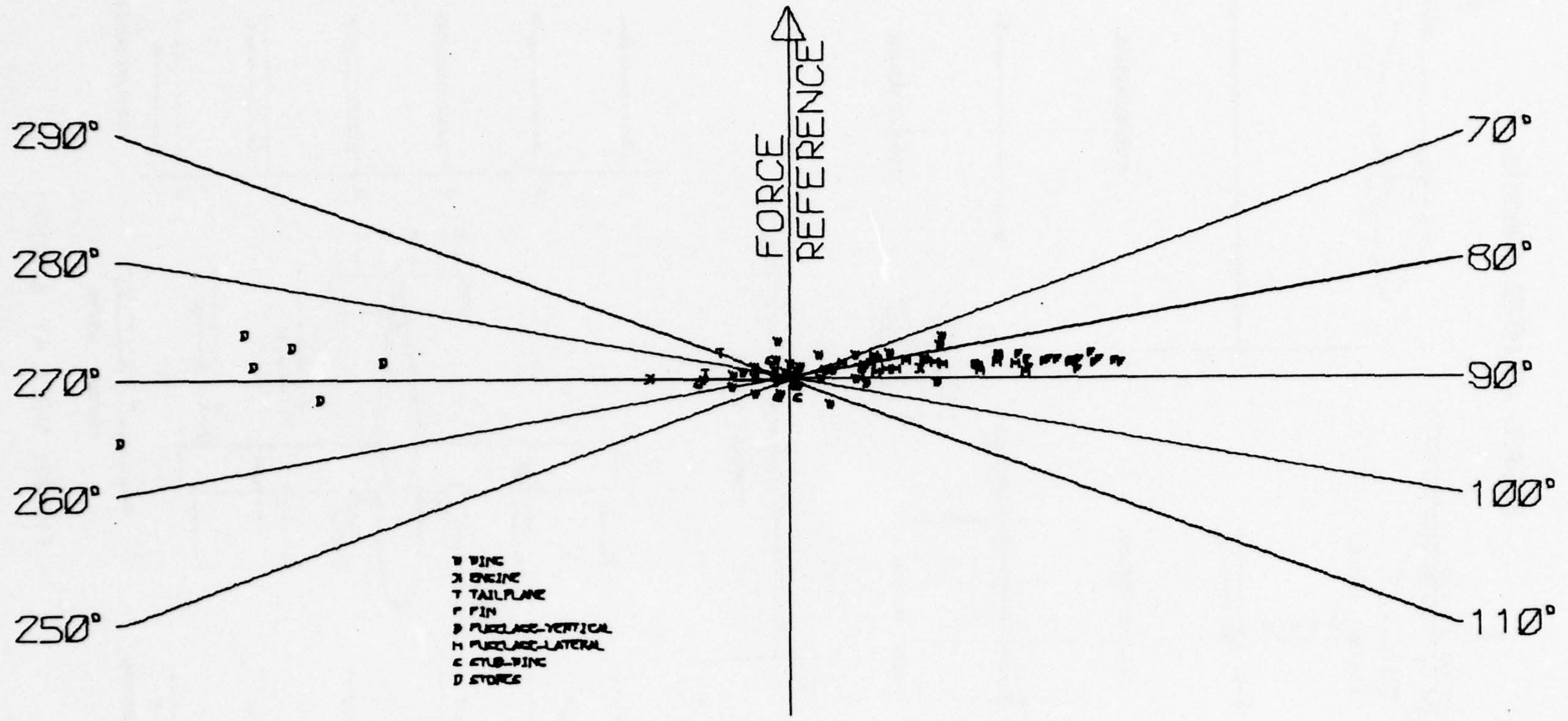


FIG. 11b VECTOR RESPONSE MODE AT 5.08 Hz

STORES MOUNTED INBOARD

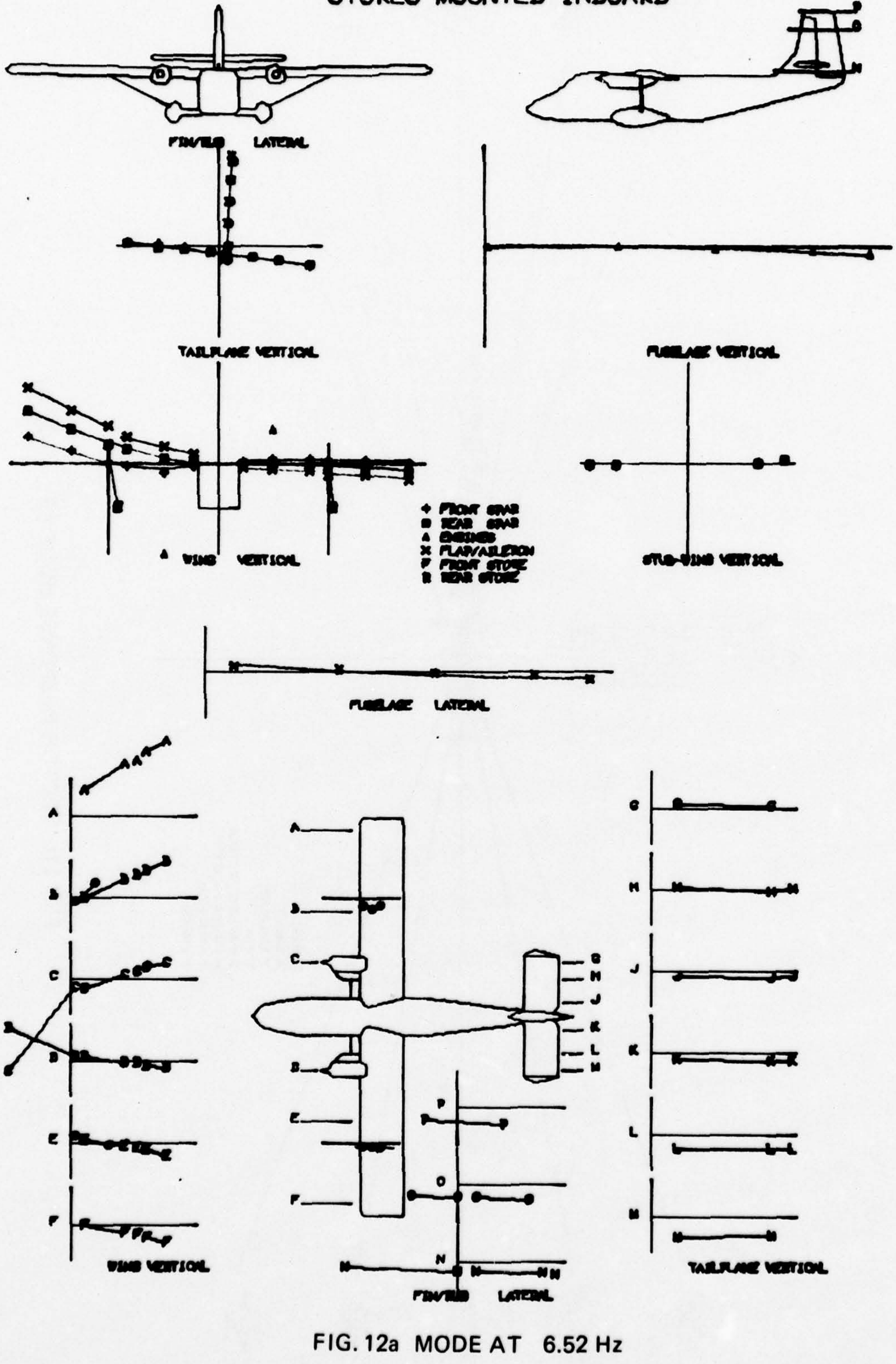


FIG. 12a MODE AT 6.52 Hz

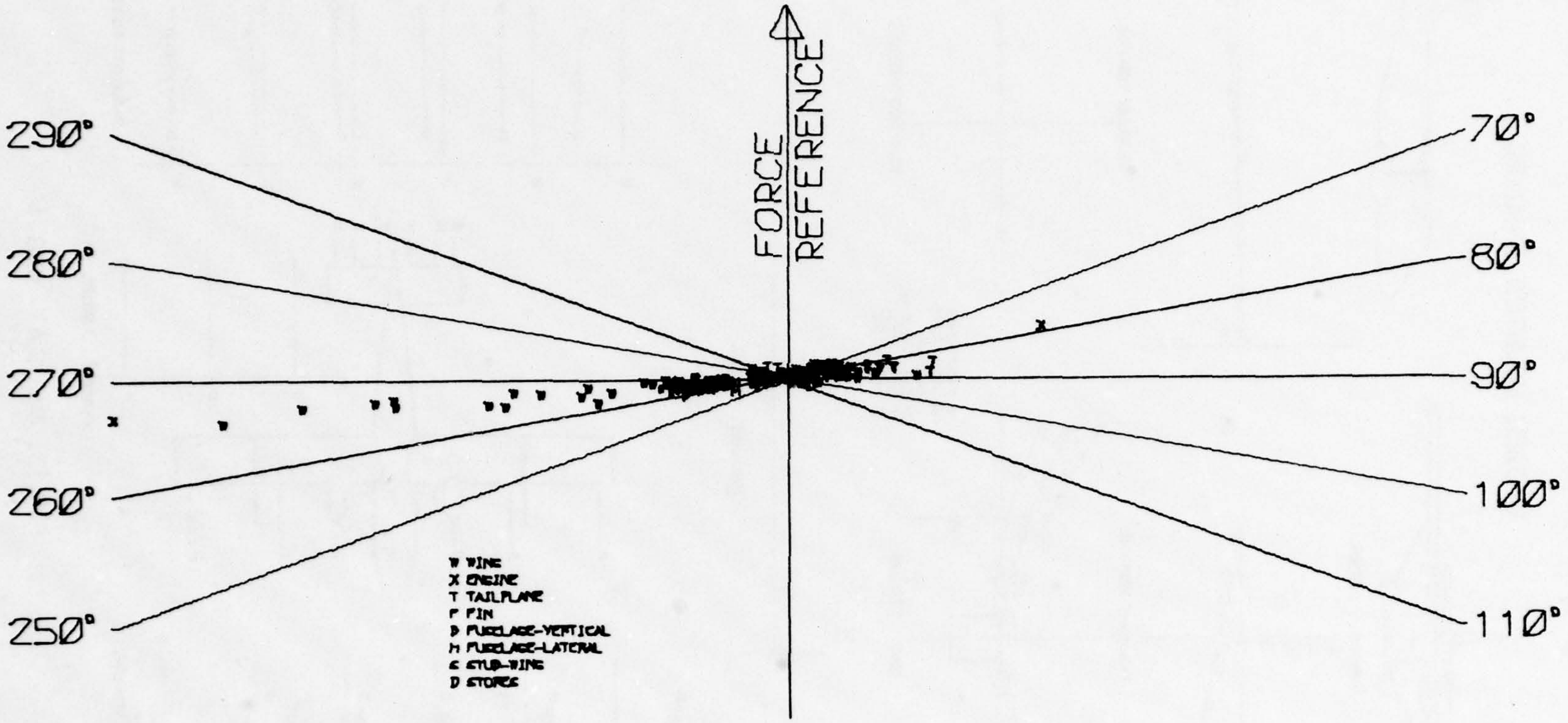


FIG. 12b VECTOR RESPONSE MODE AT 6.52 Hz

STORES MOUNTED INBOARD

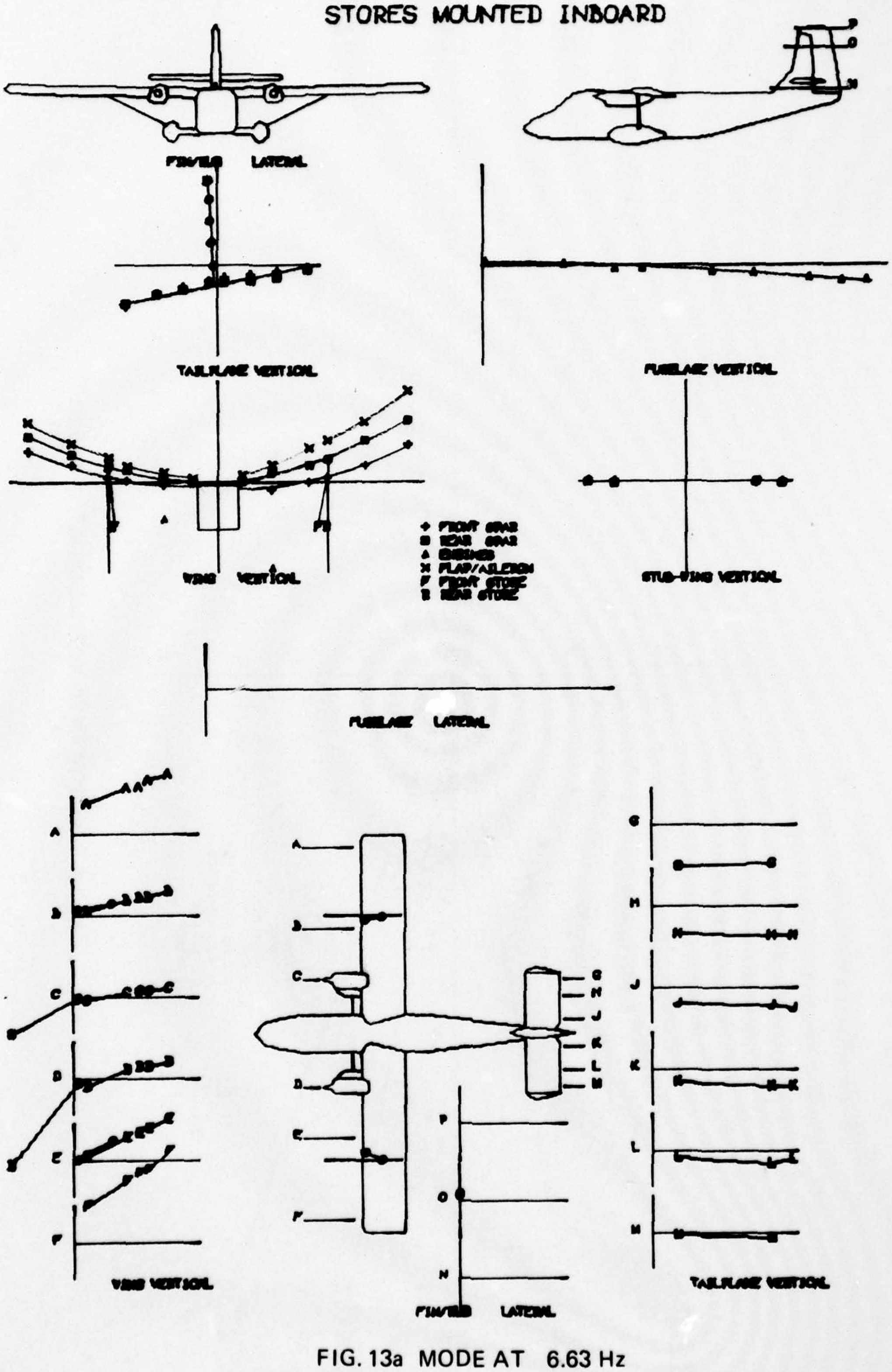


FIG. 13a MODE AT 6.63 Hz

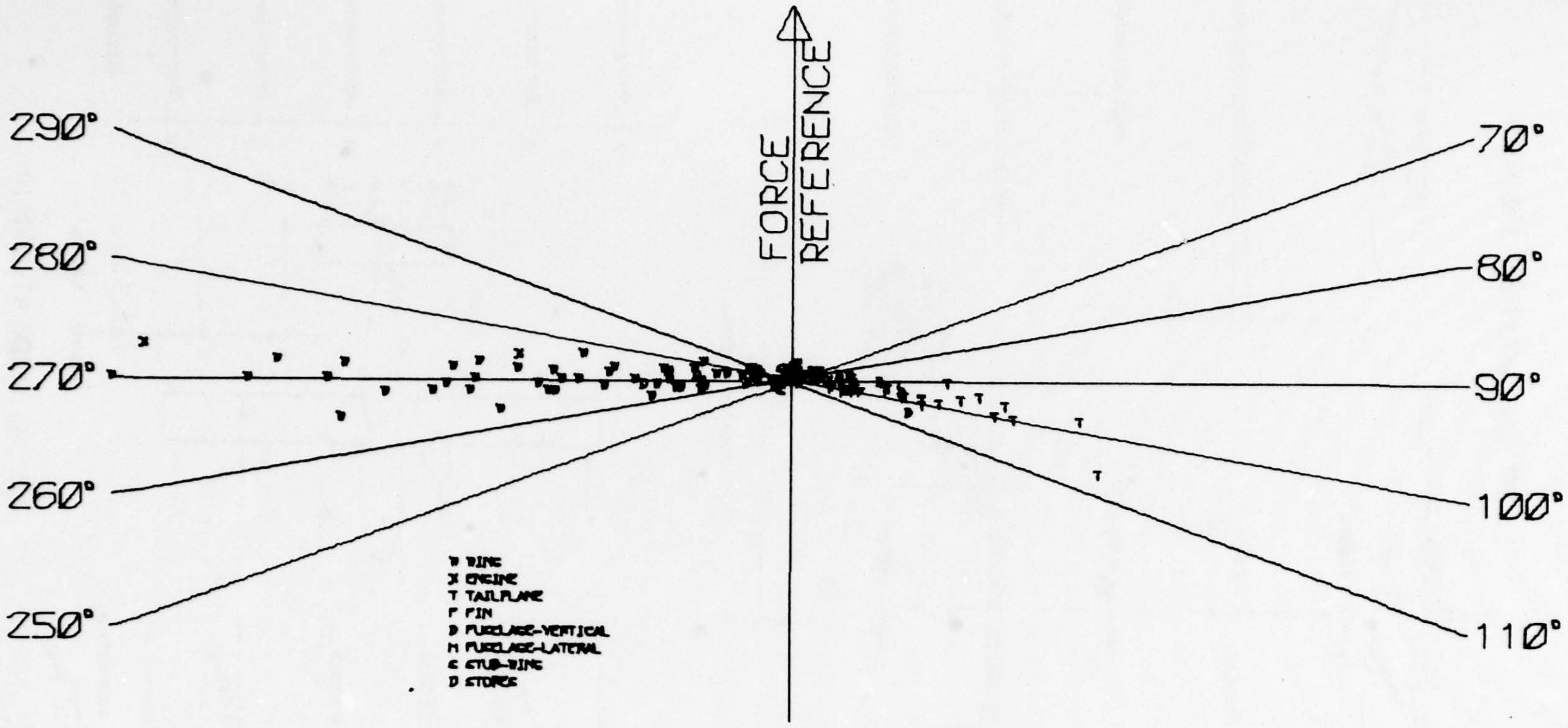


FIG. 13b VECTOR RESPONSE MODE AT 6.63 Hz

STORES MOUNTED INBOARD

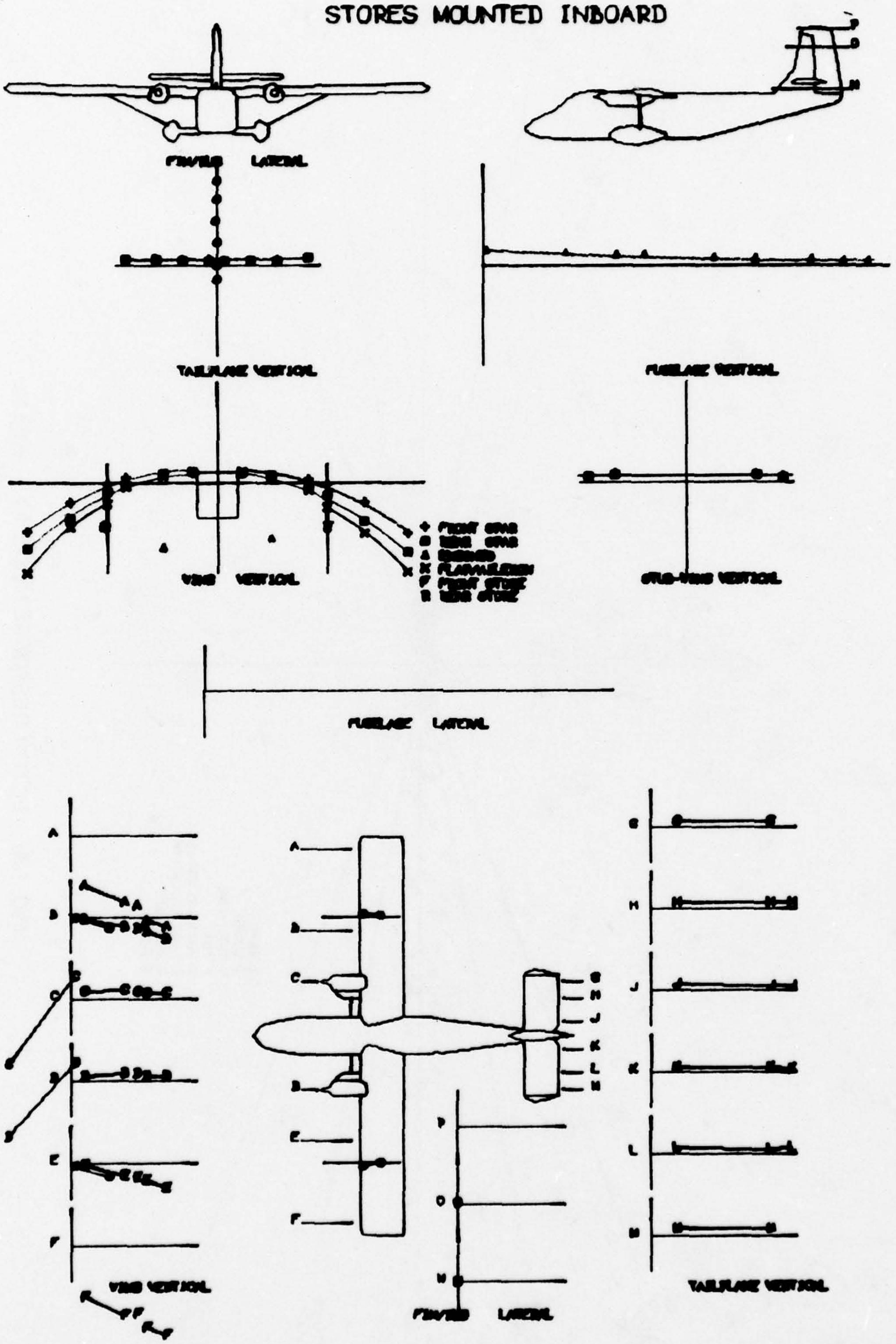


FIG. 14a MODE AT 9.06 Hz

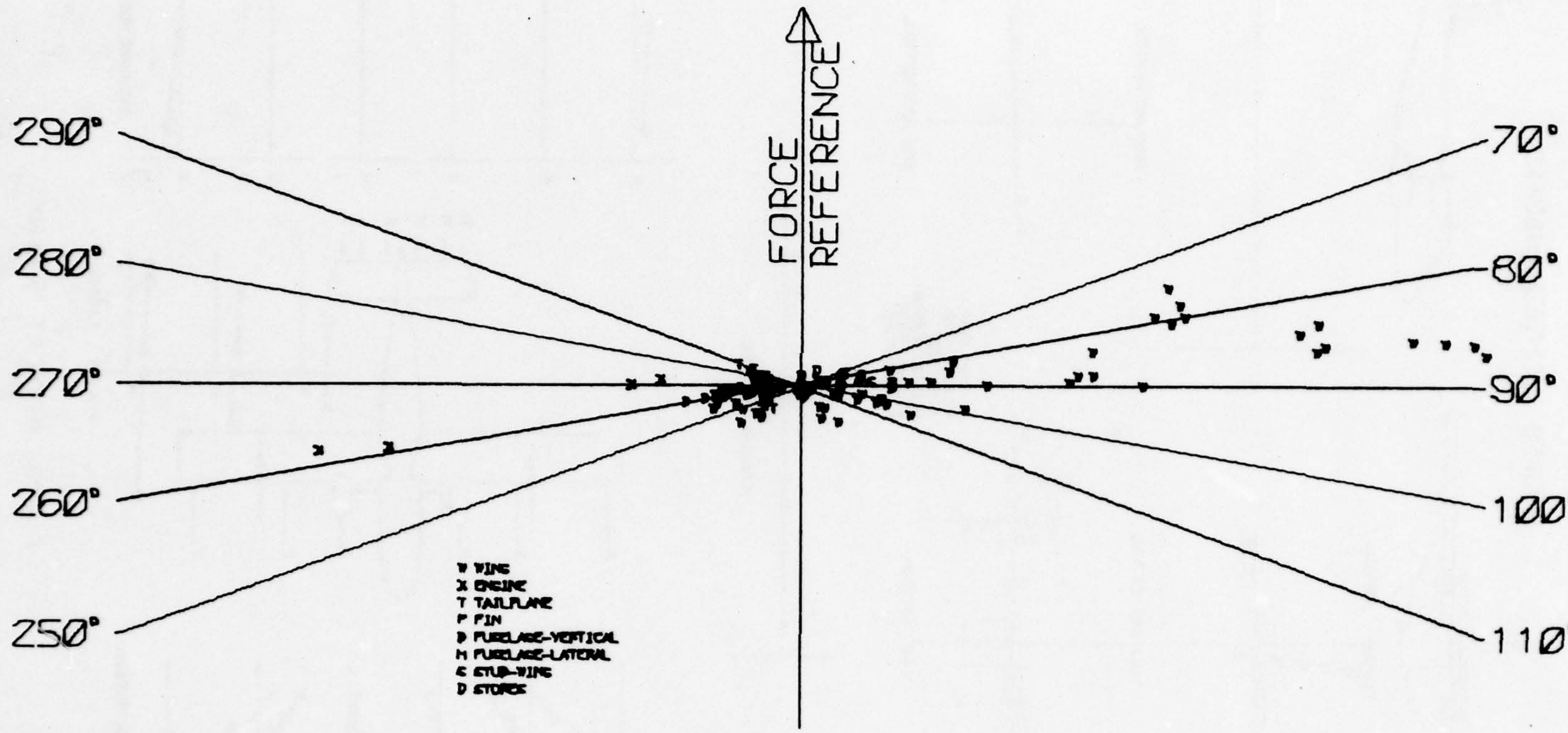


FIG. 14b VECTOR RESPONSE MODE AT 9.06 Hz

STORES MOUNTED INBOARD

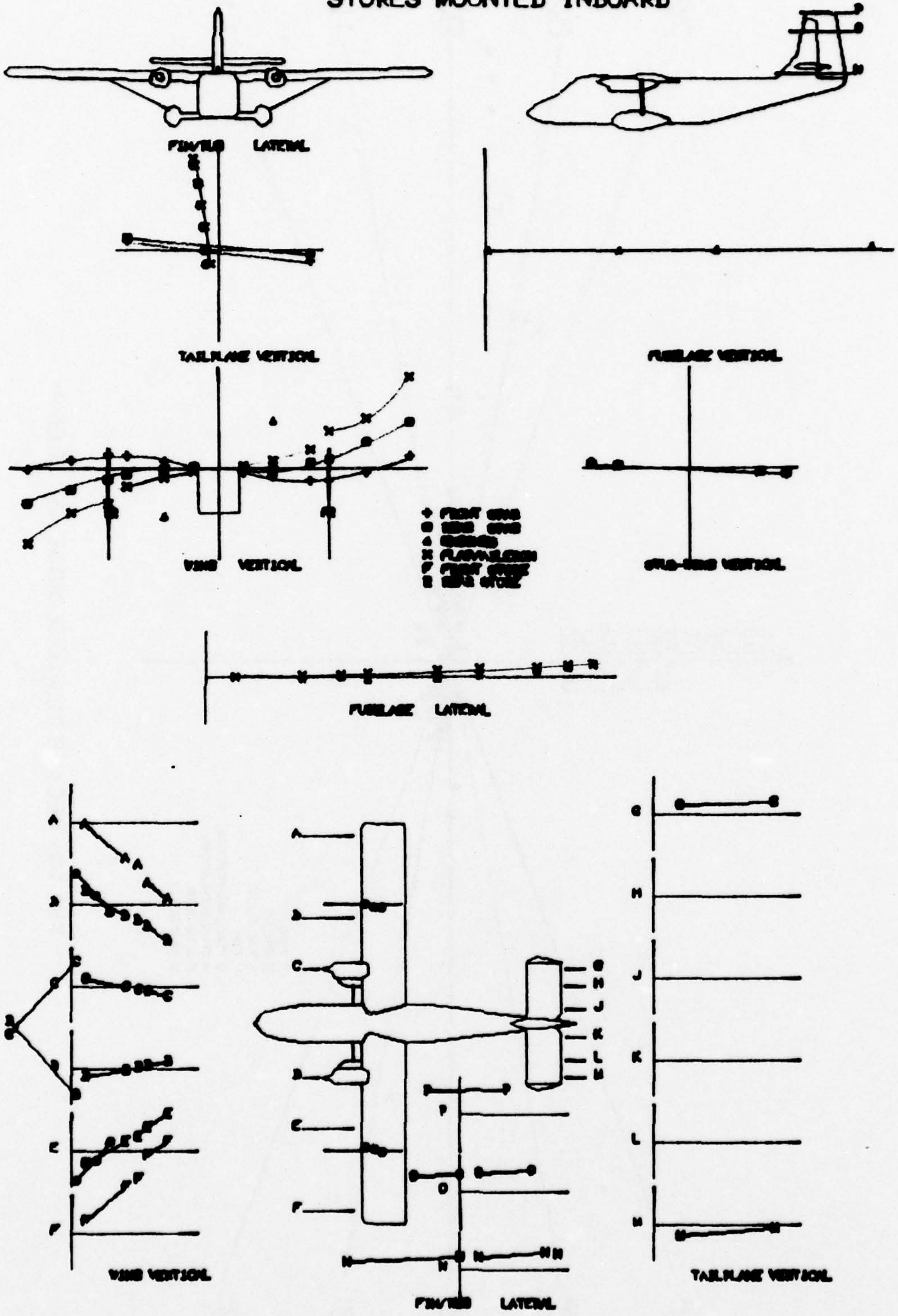


FIG. 15a MODE AT 9.99 Hz

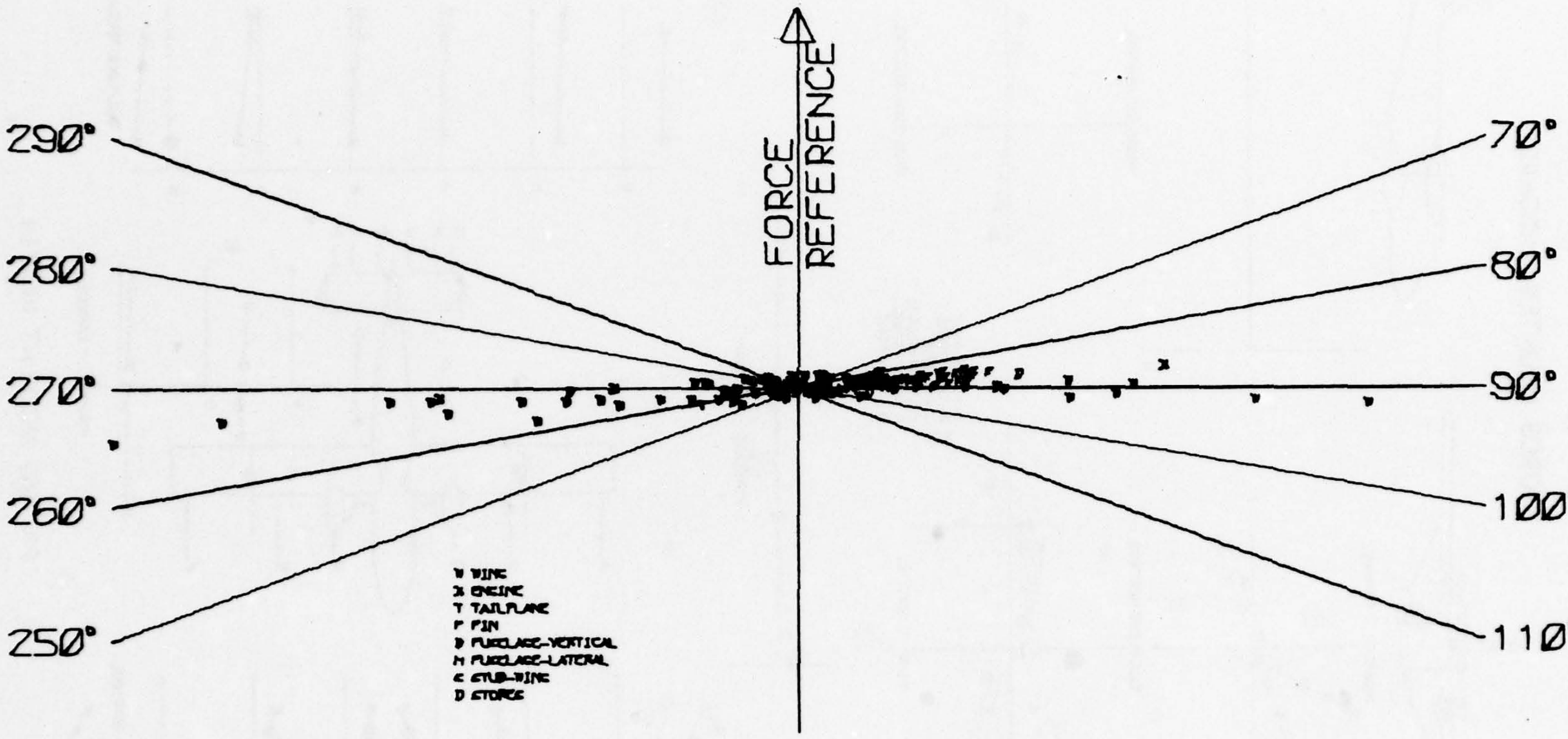


FIG. 15b VECTOR RESPONSE MODE AT 9.99 Hz

STORES MOUNTED INBOARD

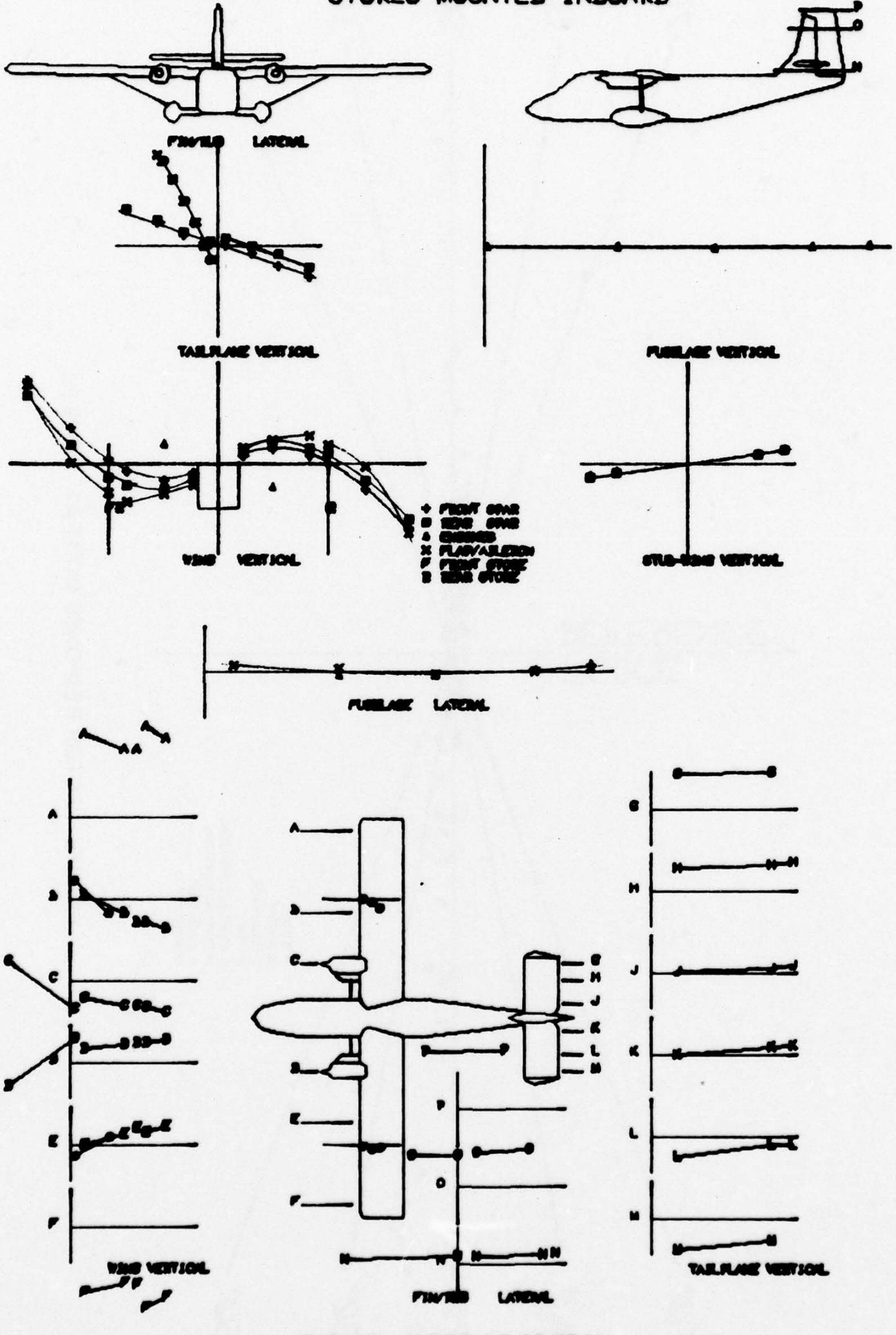


FIG. 16a MODE AT 10.52 Hz

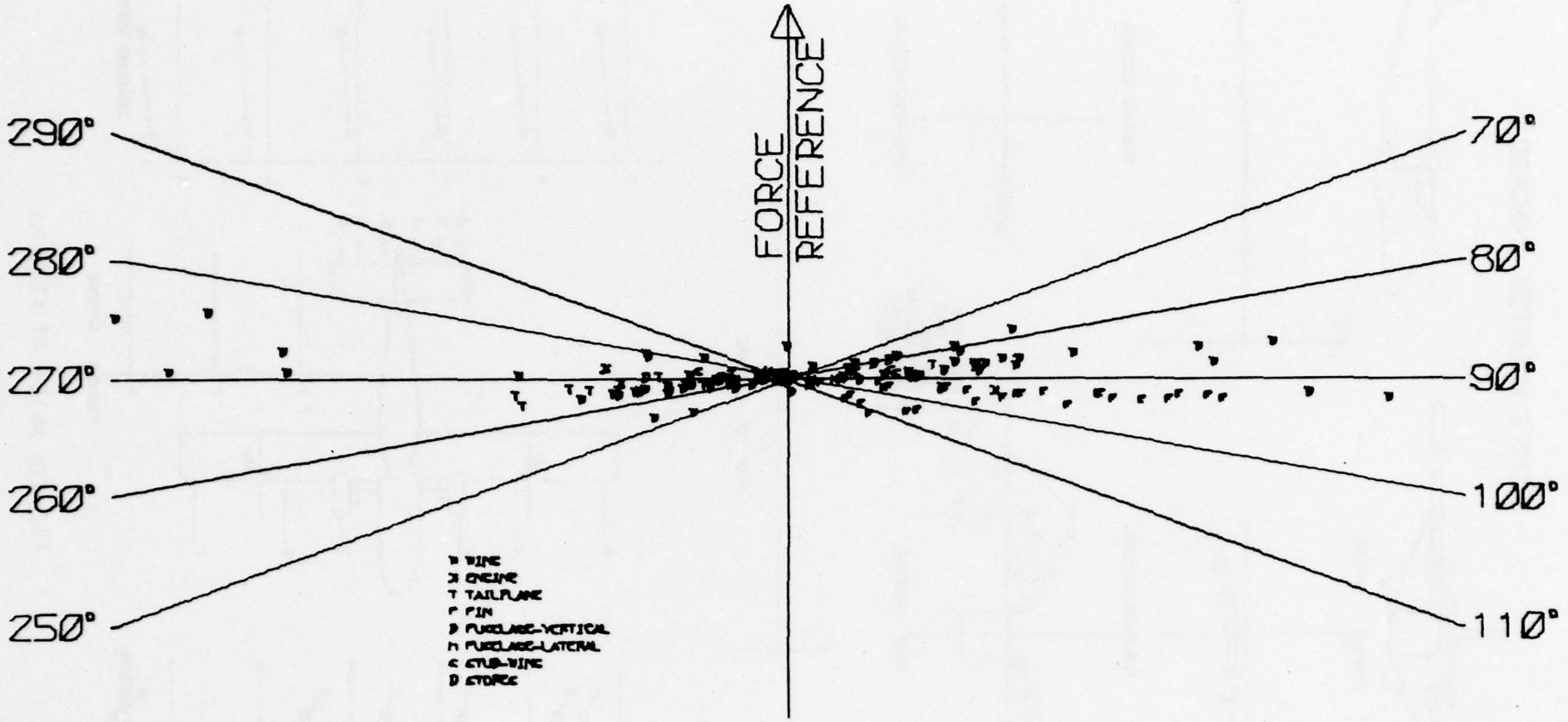


FIG. 16b VECTOR RESPONSE MODE AT 10.52 Hz

STORES MOUNTED INBOARD

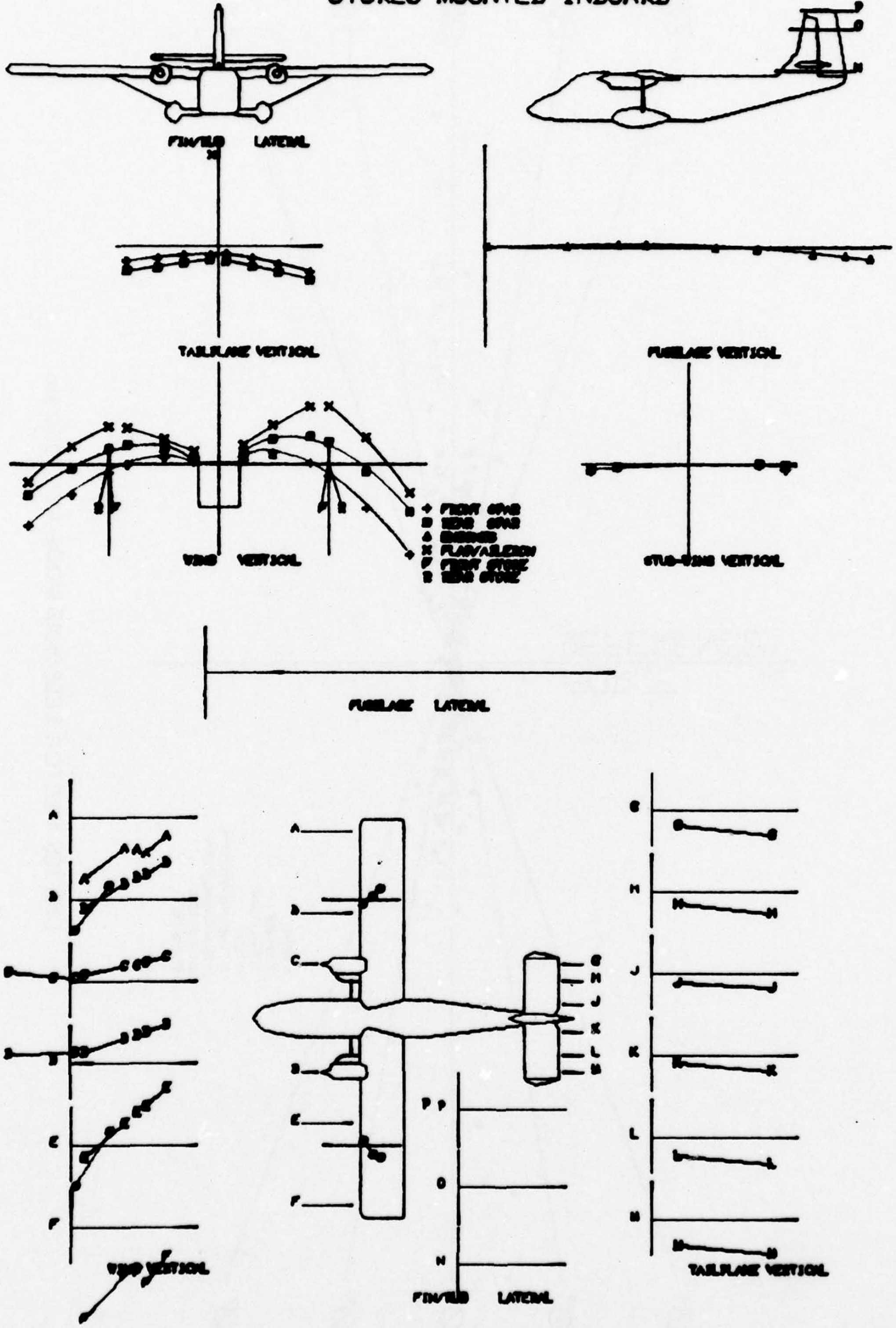


FIG. 17a MODE AT 11.50 Hz

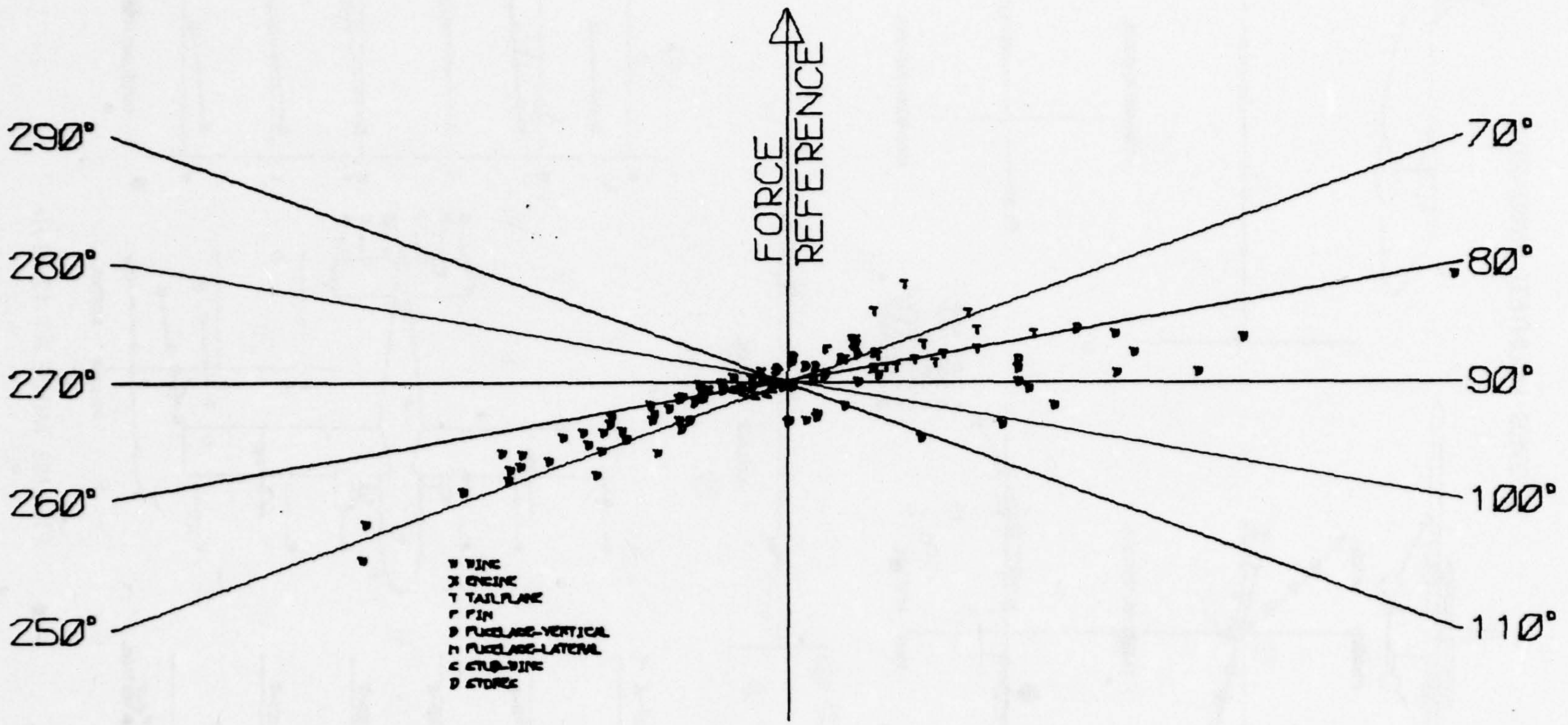


FIG. 17b VECTOR RESPONSE MODE AT 11.50 Hz

STORES MOUNTED INBOARD

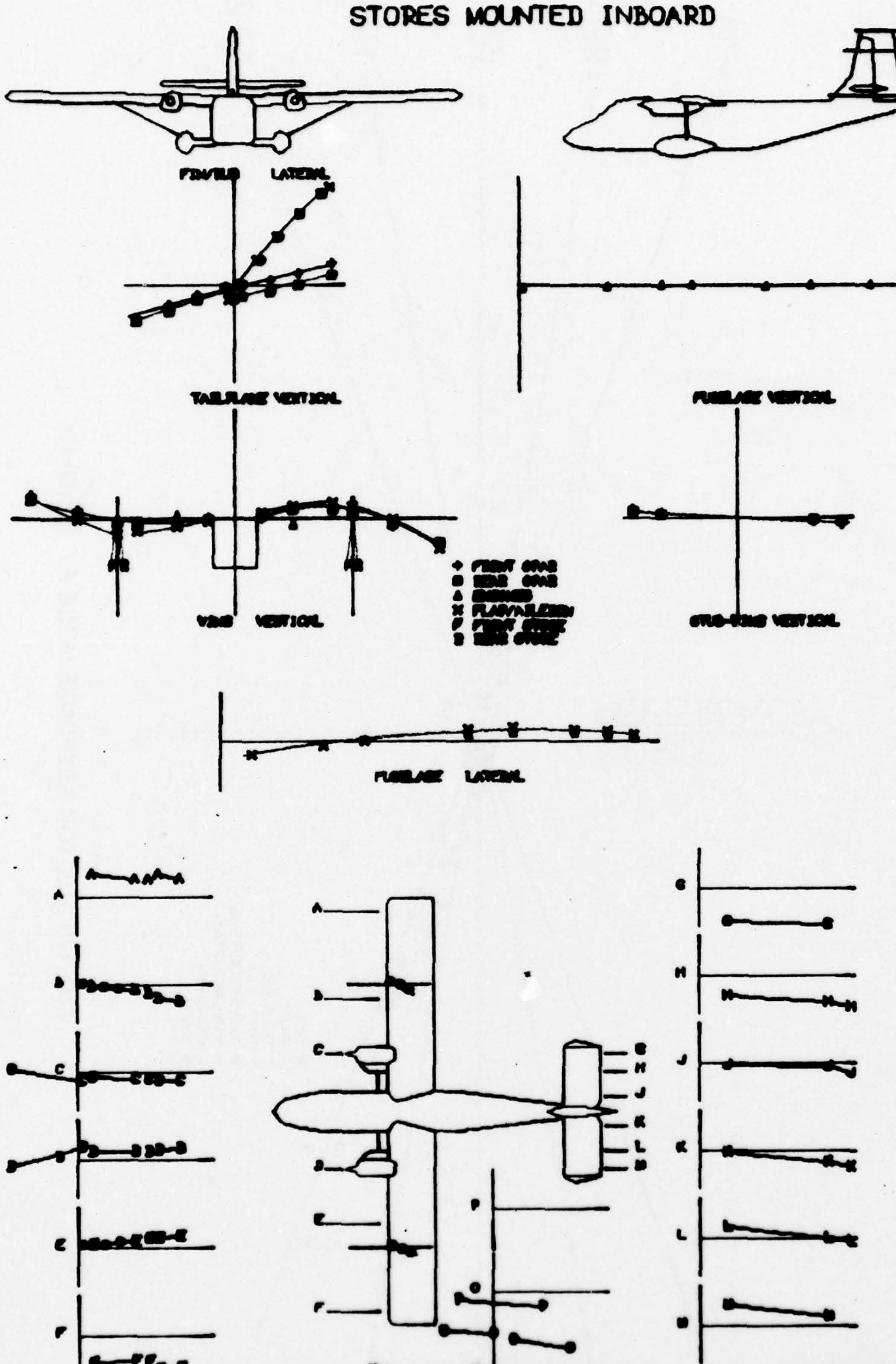


FIG. 18a MODE AT 12.78 Hz

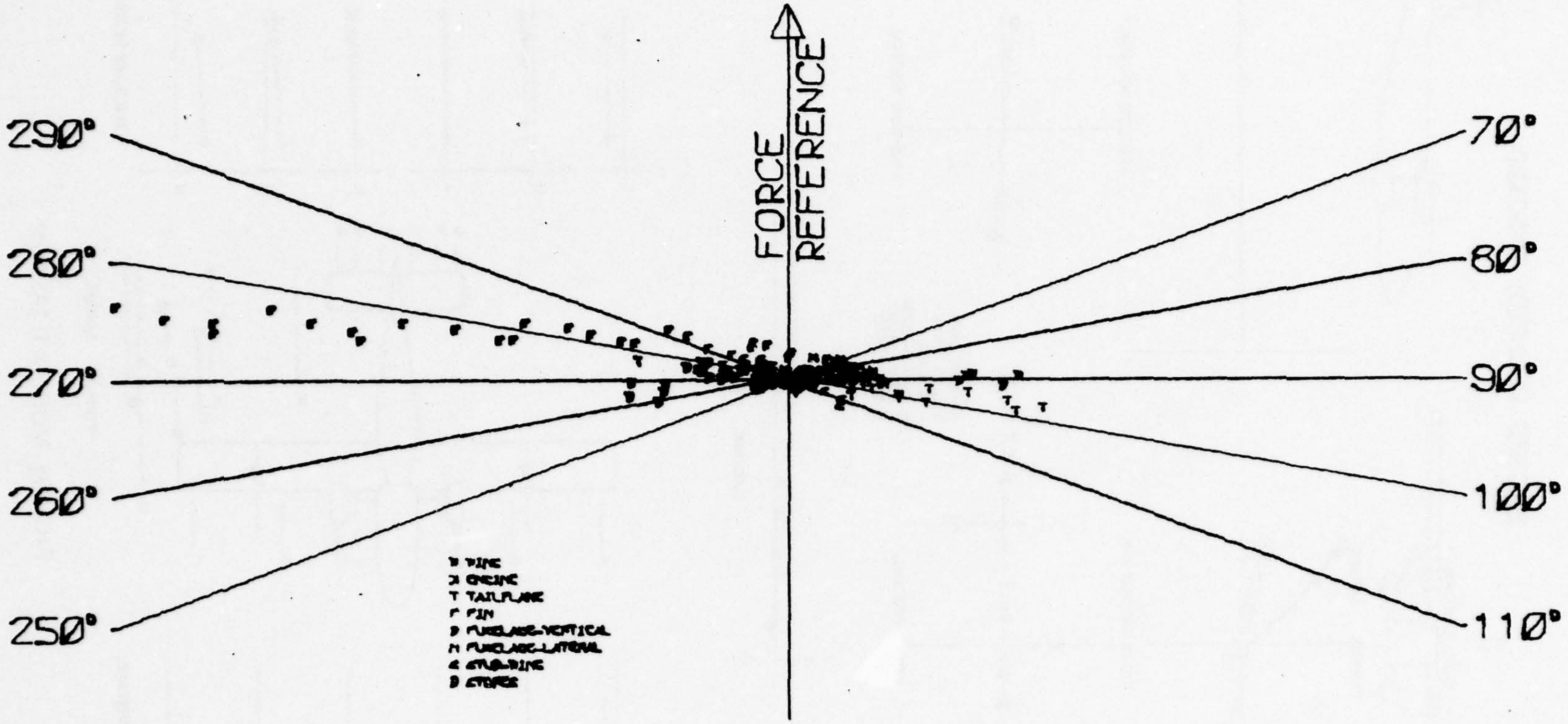


FIG. 18b VECTOR RESPONSE MODE AT 12.78 Hz

STORES MOUNTED INBOARD

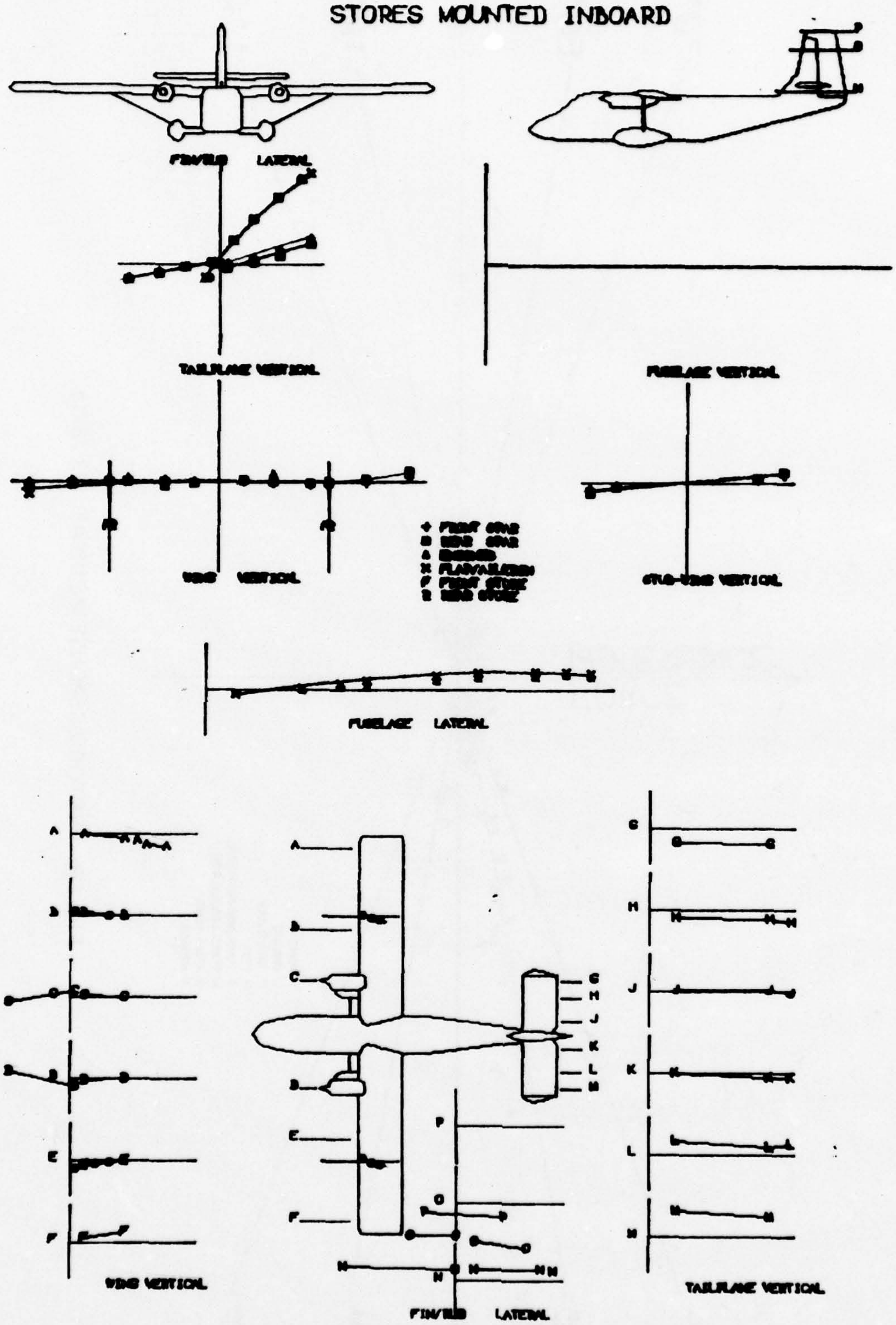


FIG. 19a MODE AT 14.09 Hz

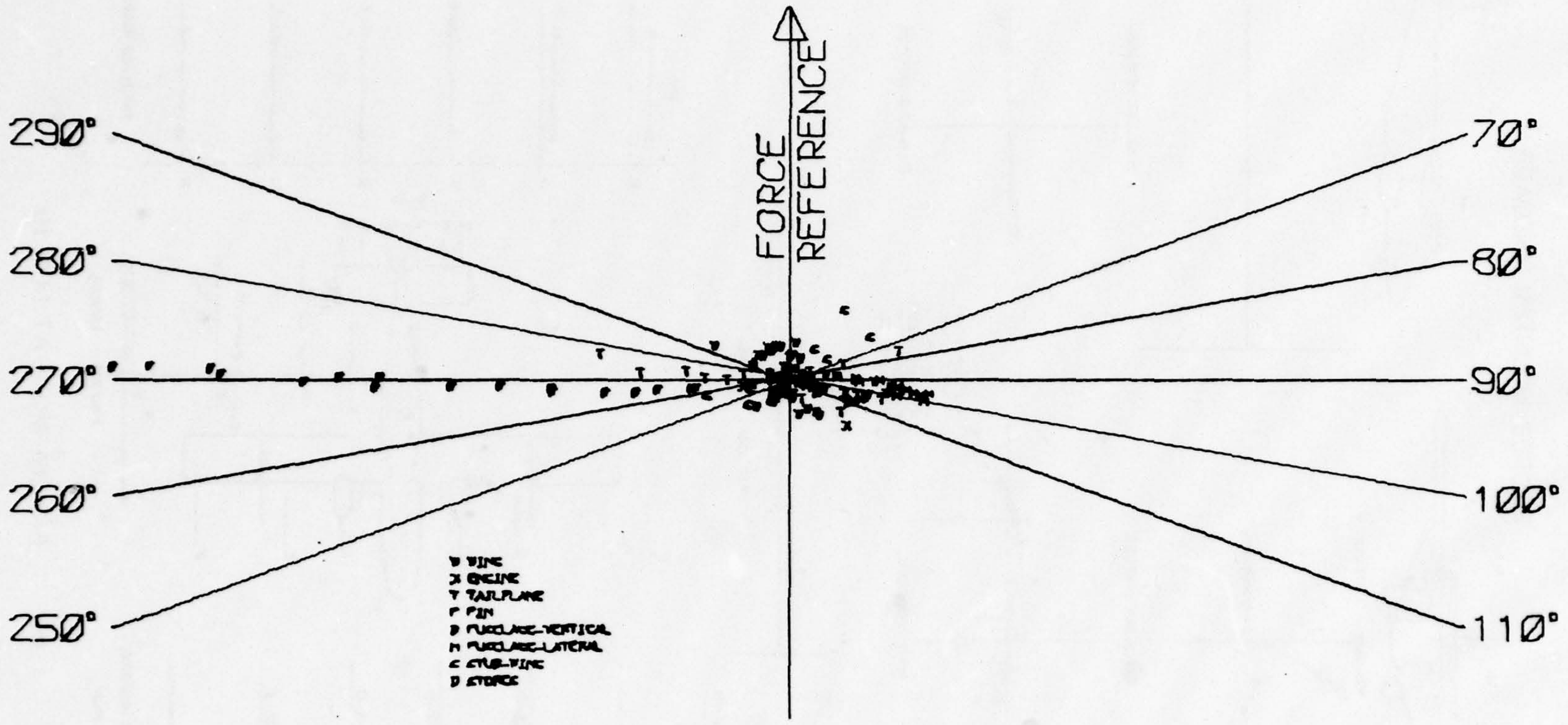


FIG. 19b VECTOR RESPONSE MODE AT 14.09 Hz

STORES MOUNTED INBOARD

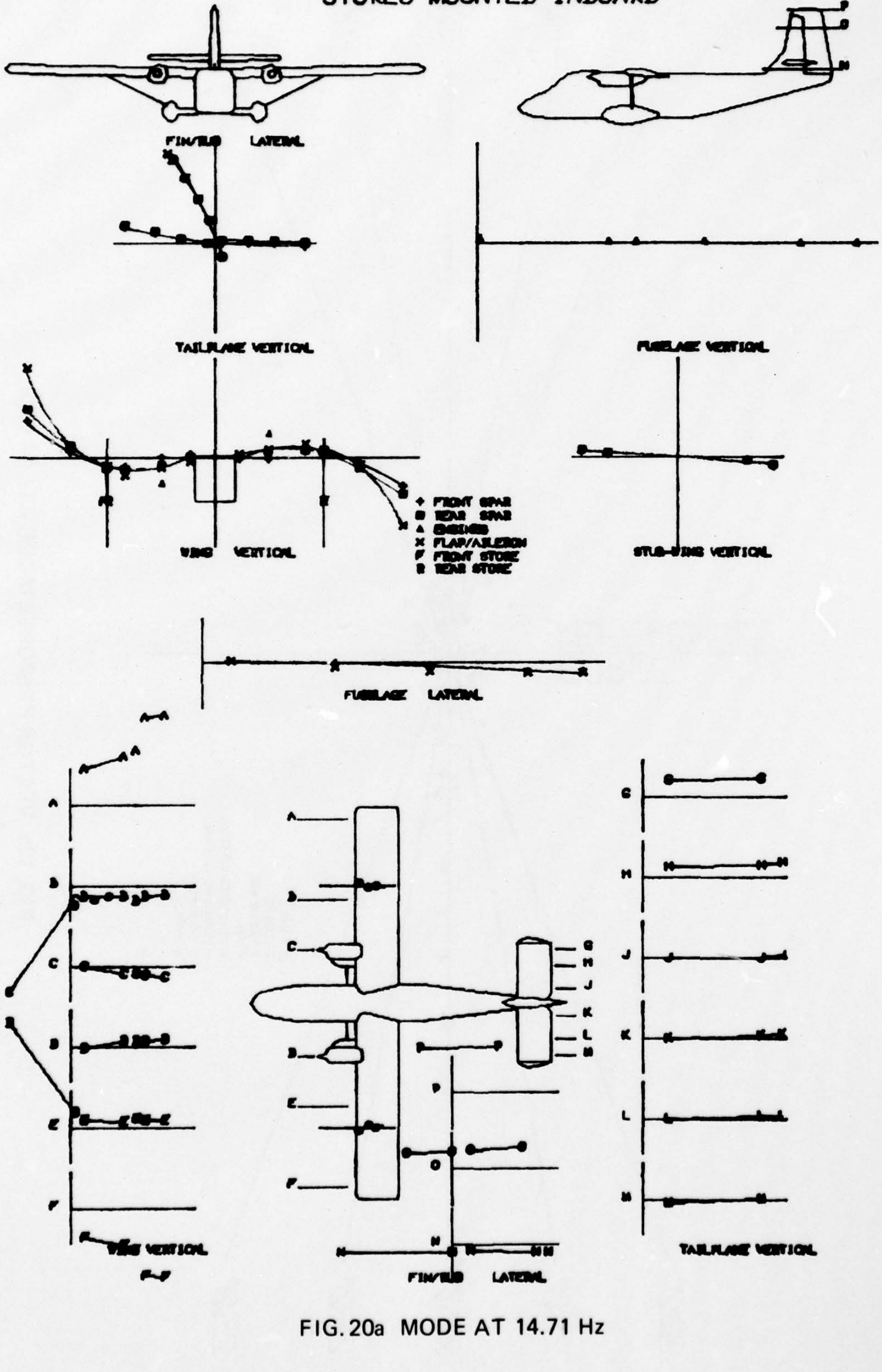


FIG. 20a MODE AT 14.71 Hz

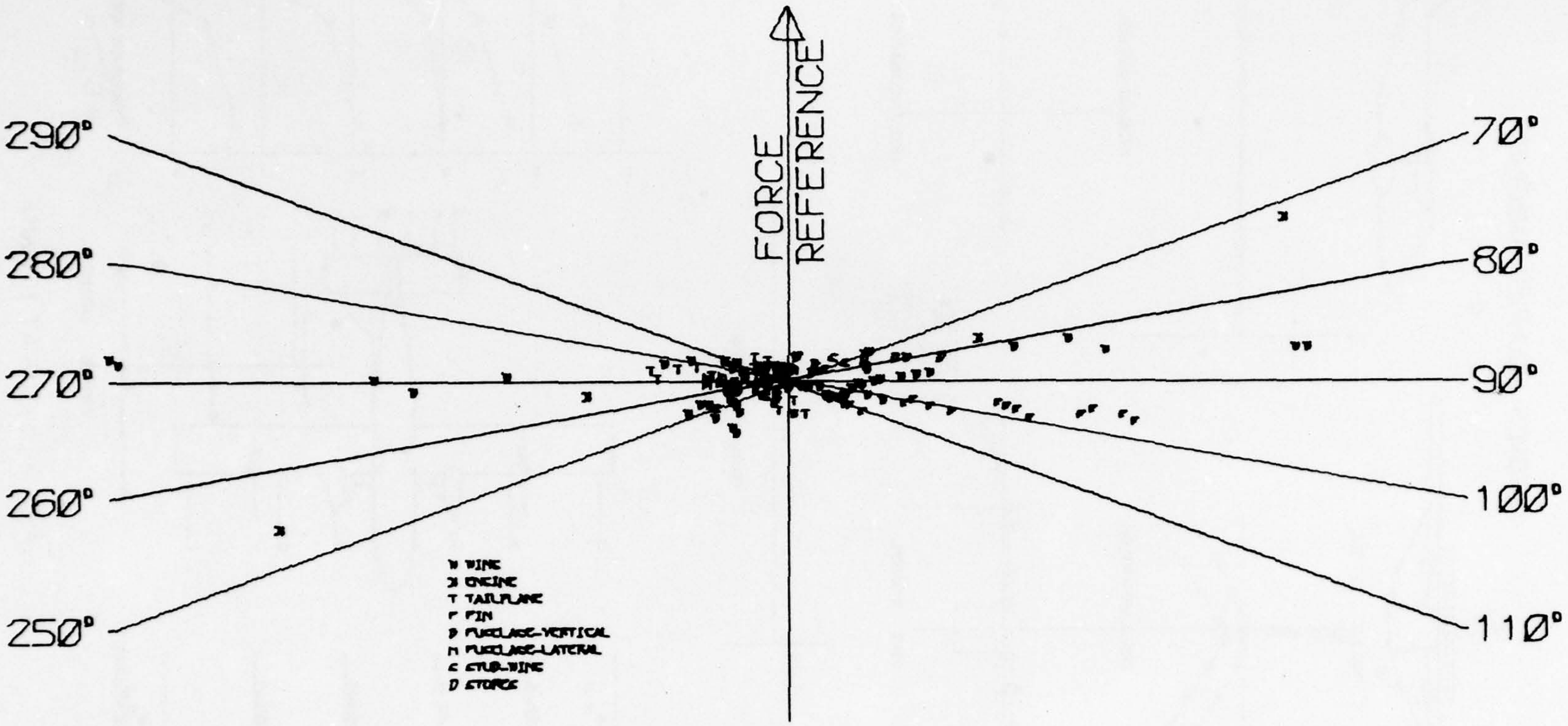


FIG. 20b VECTOR RESPONSE MODE AT 14.71 Hz

STORES MOUNTED INBOARD

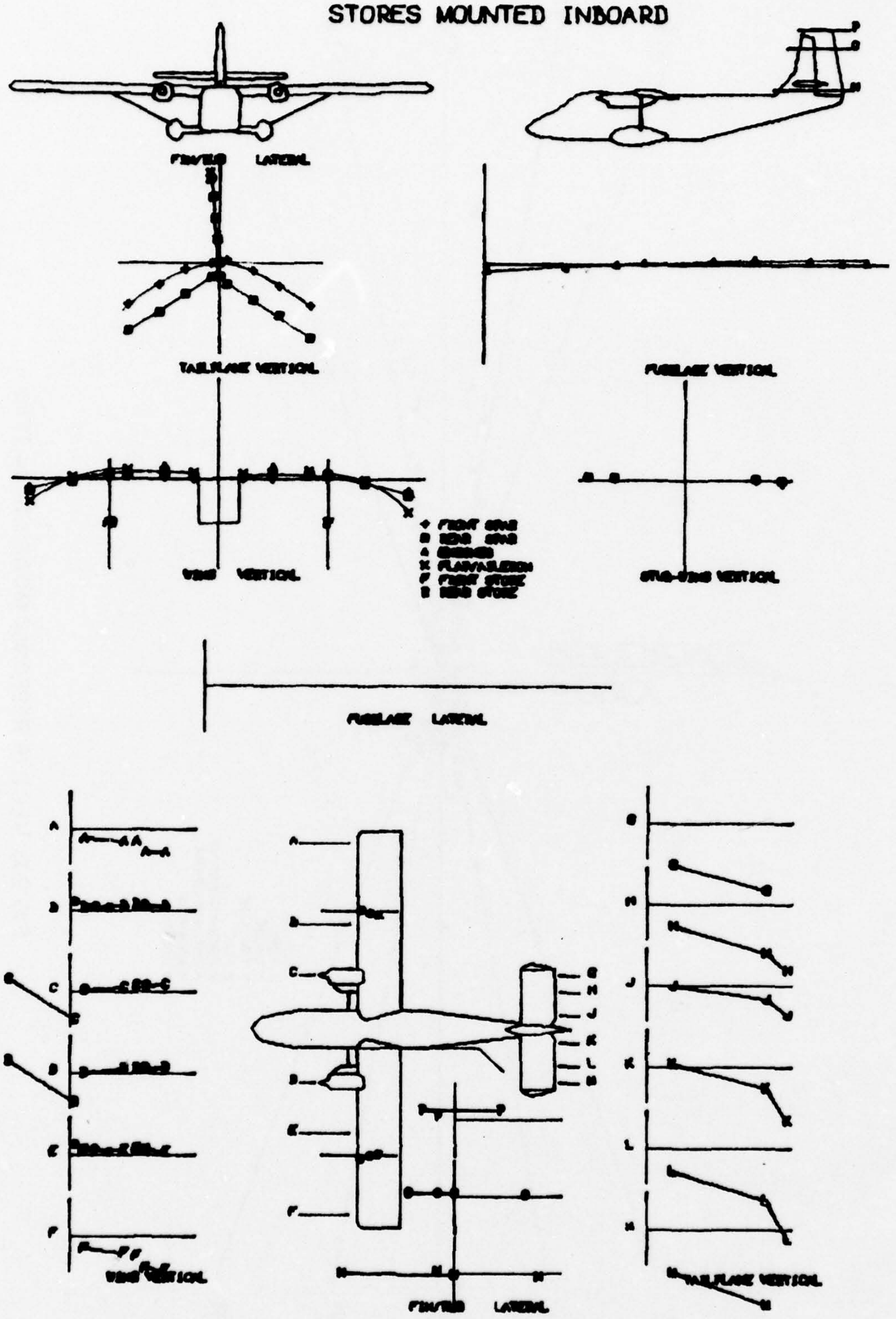


FIG. 21a MODE AT 15.30 Hz

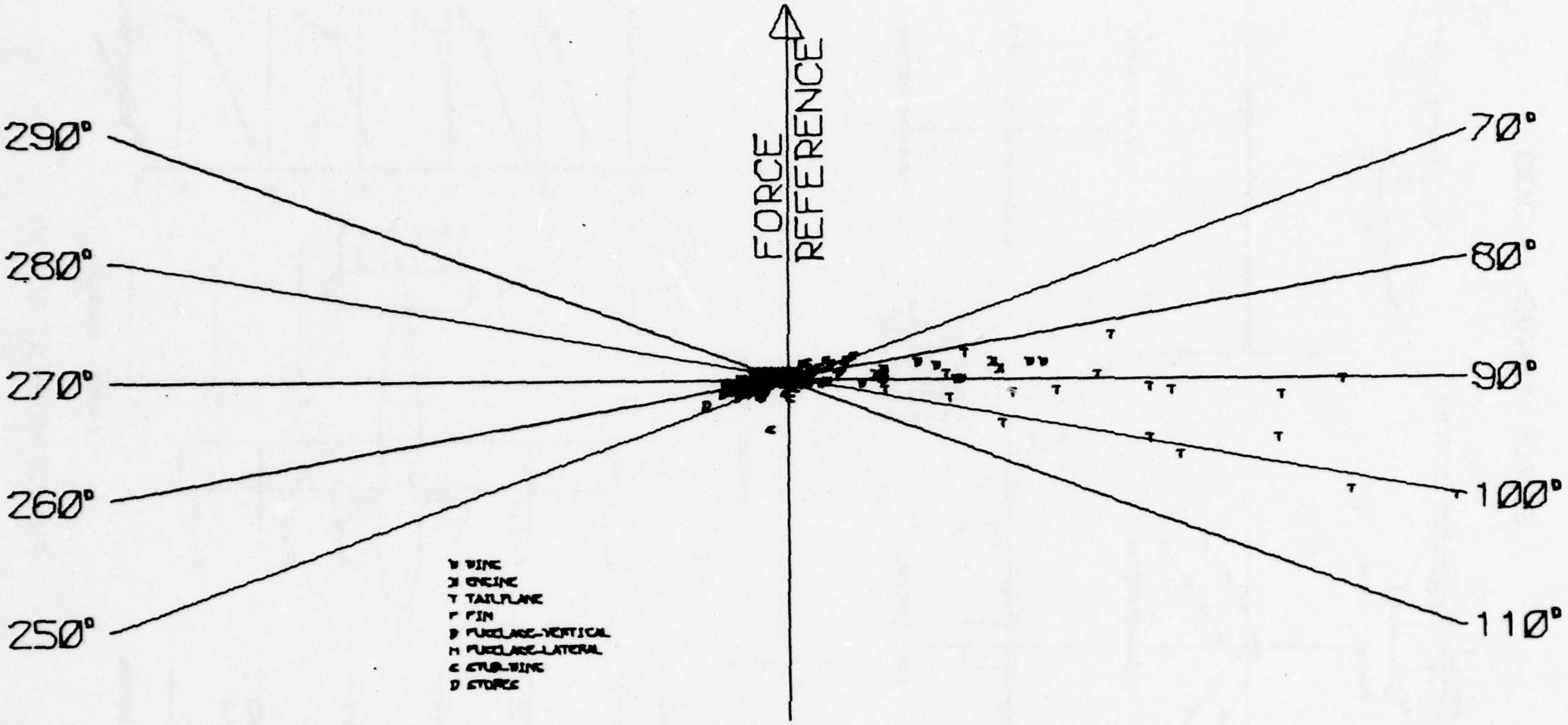


FIG. 21b VECTOR RESPONSE MODE AT 15.30 Hz

STORES MOUNTED INBOARD

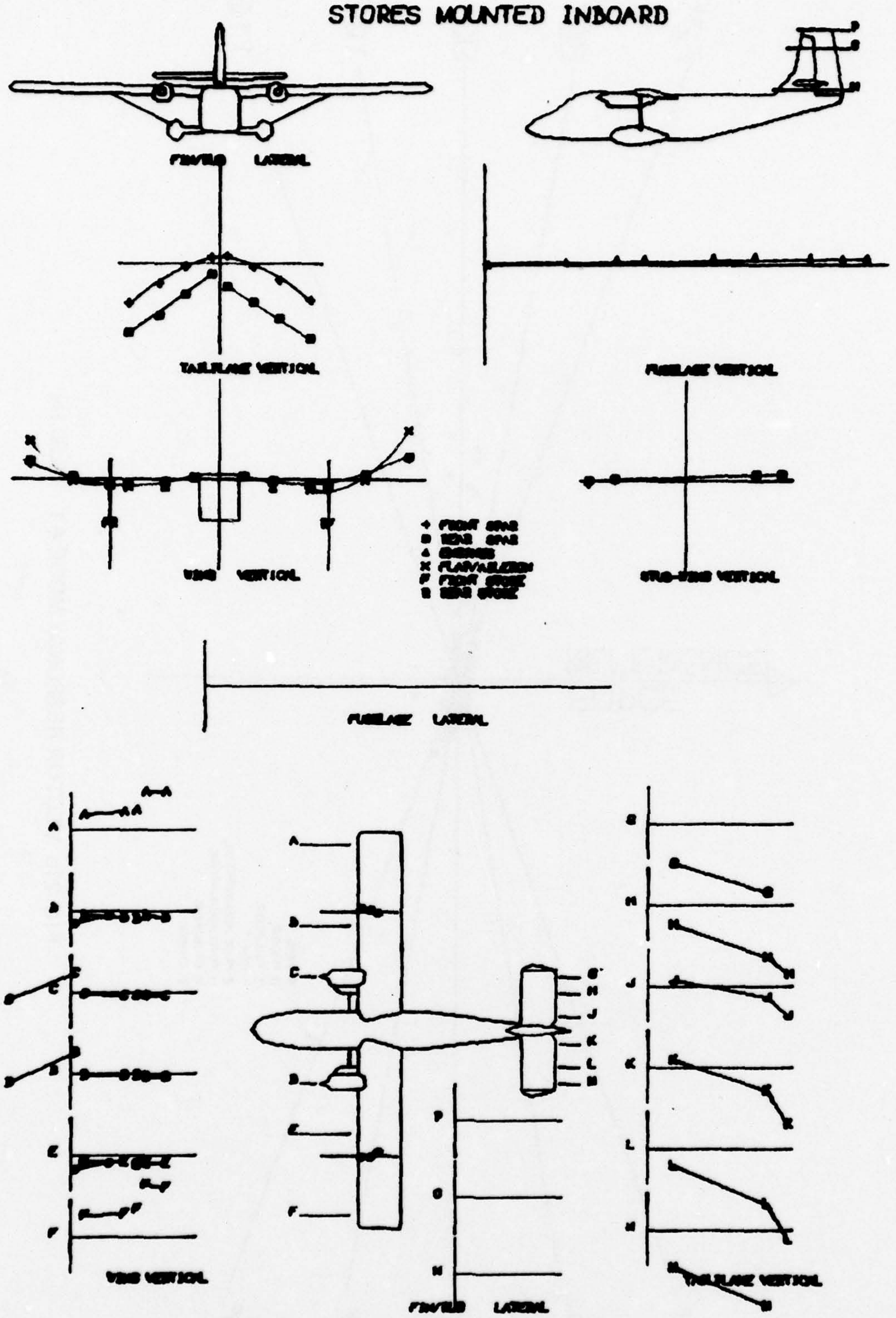


FIG. 22a MODE AT 16.00 Hz

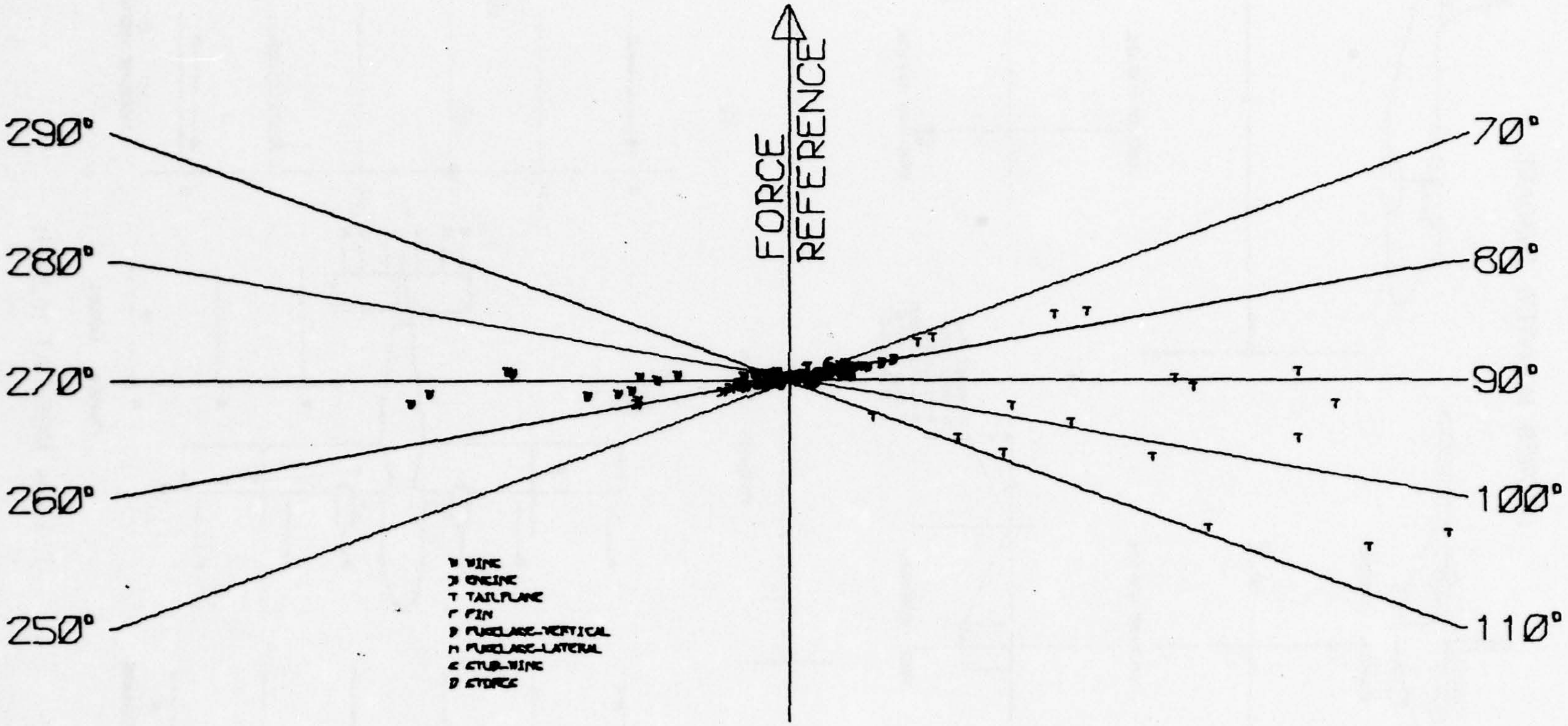


FIG. 22b VECTOR RESPONSE MODE AT 16.00 Hz

STORES MOUNTED INBOARD

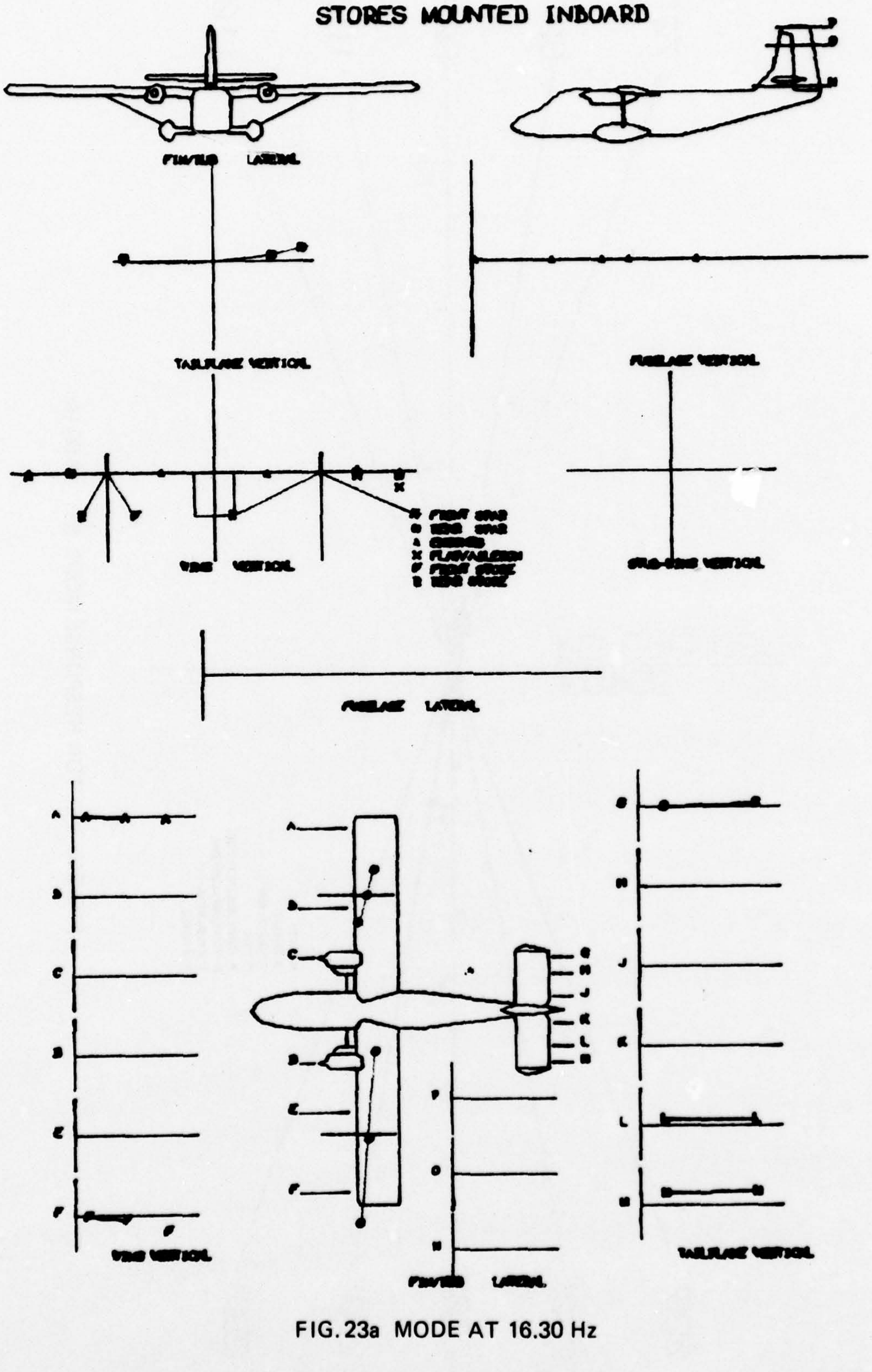


FIG. 23a MODE AT 16.30 Hz

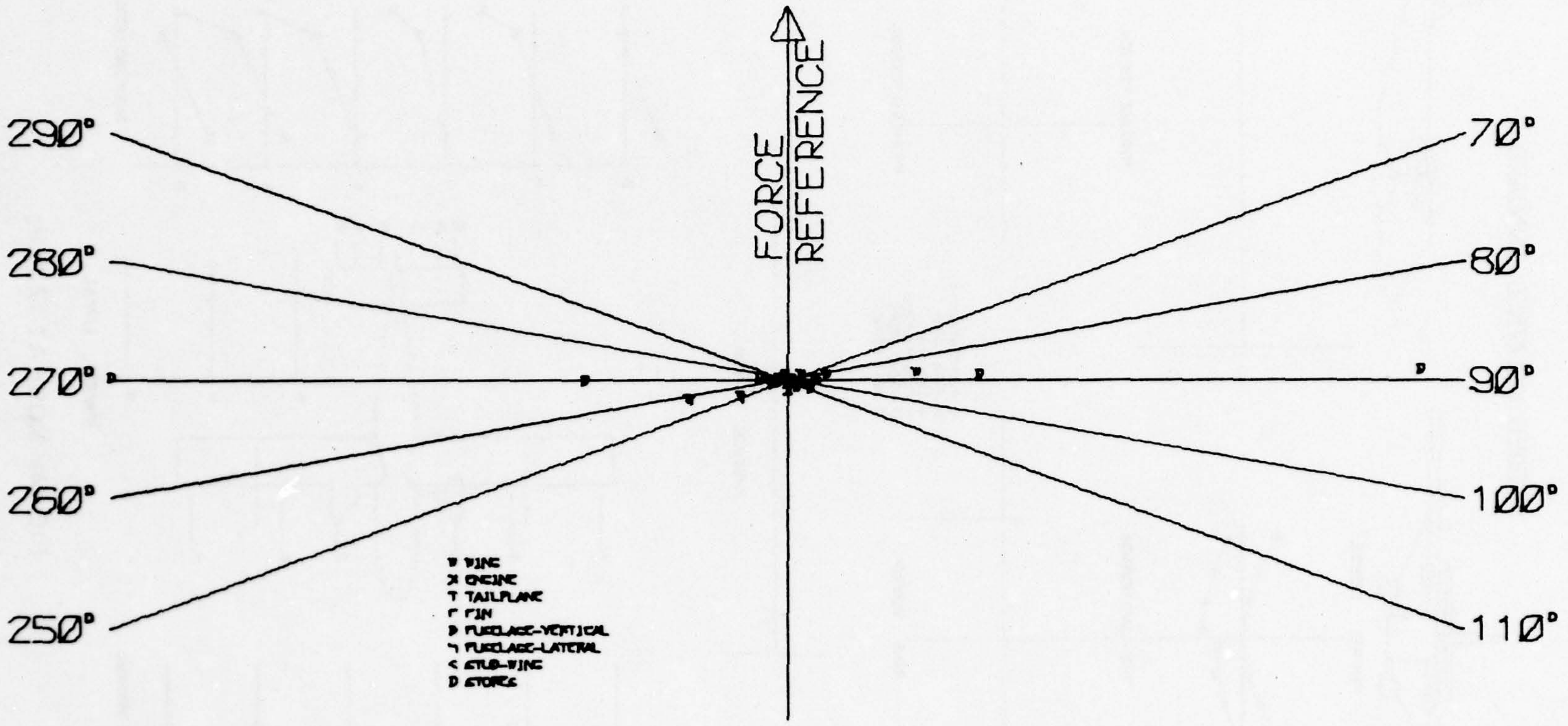


FIG. 23b VECTOR RESPONSE MODE AT 16.30 Hz

STORES MOUNTED INBOARD

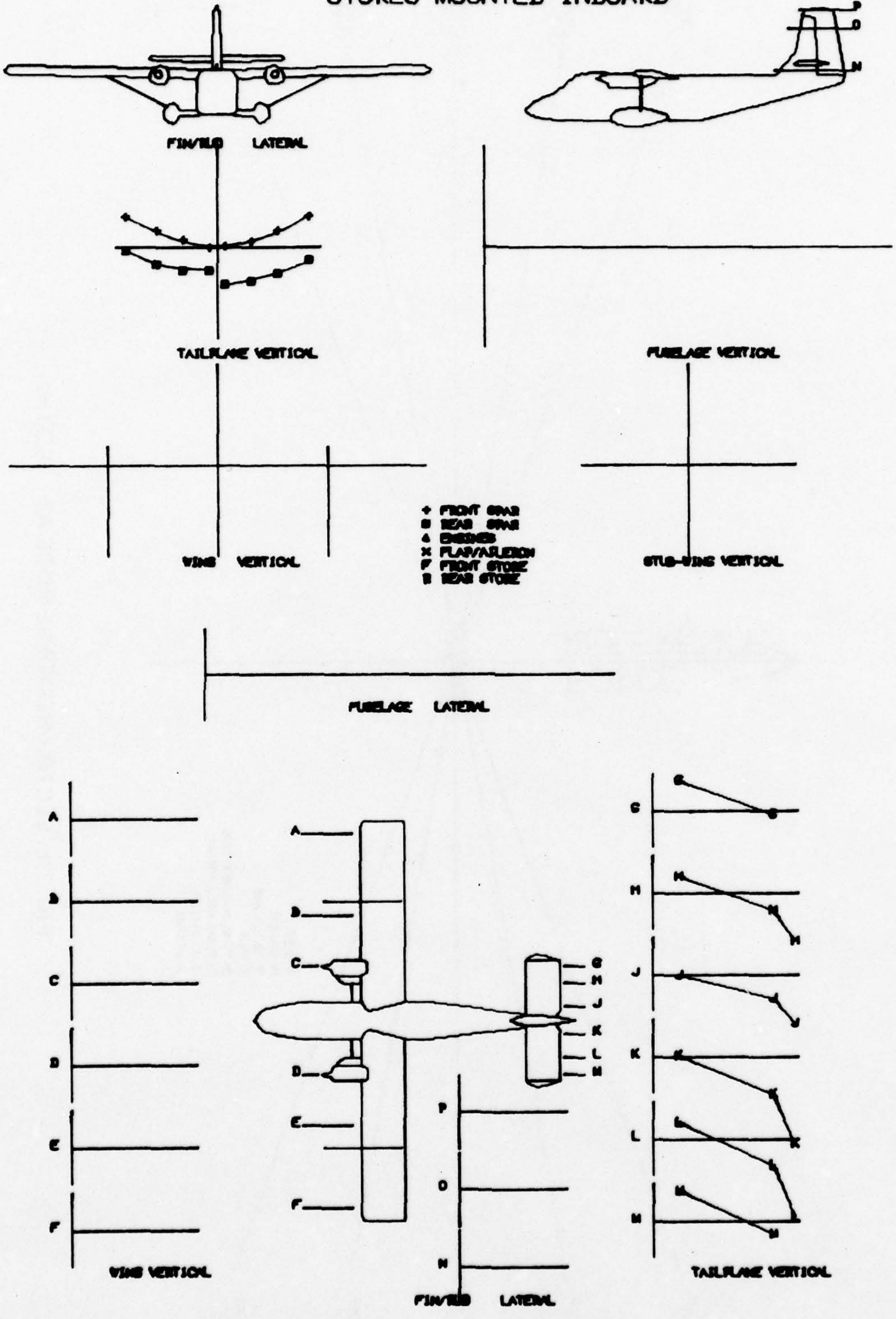


FIG. 24a MODE AT 17.40 Hz

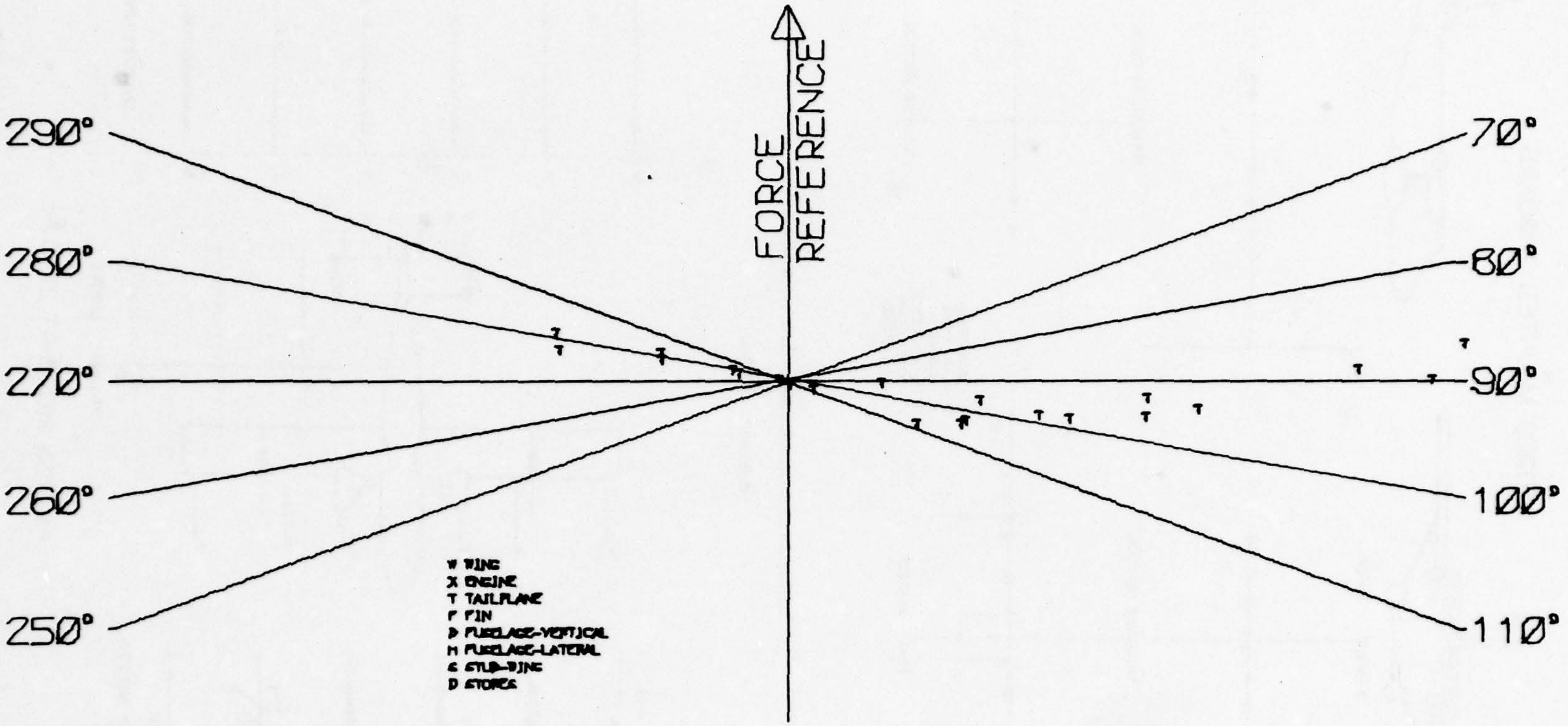
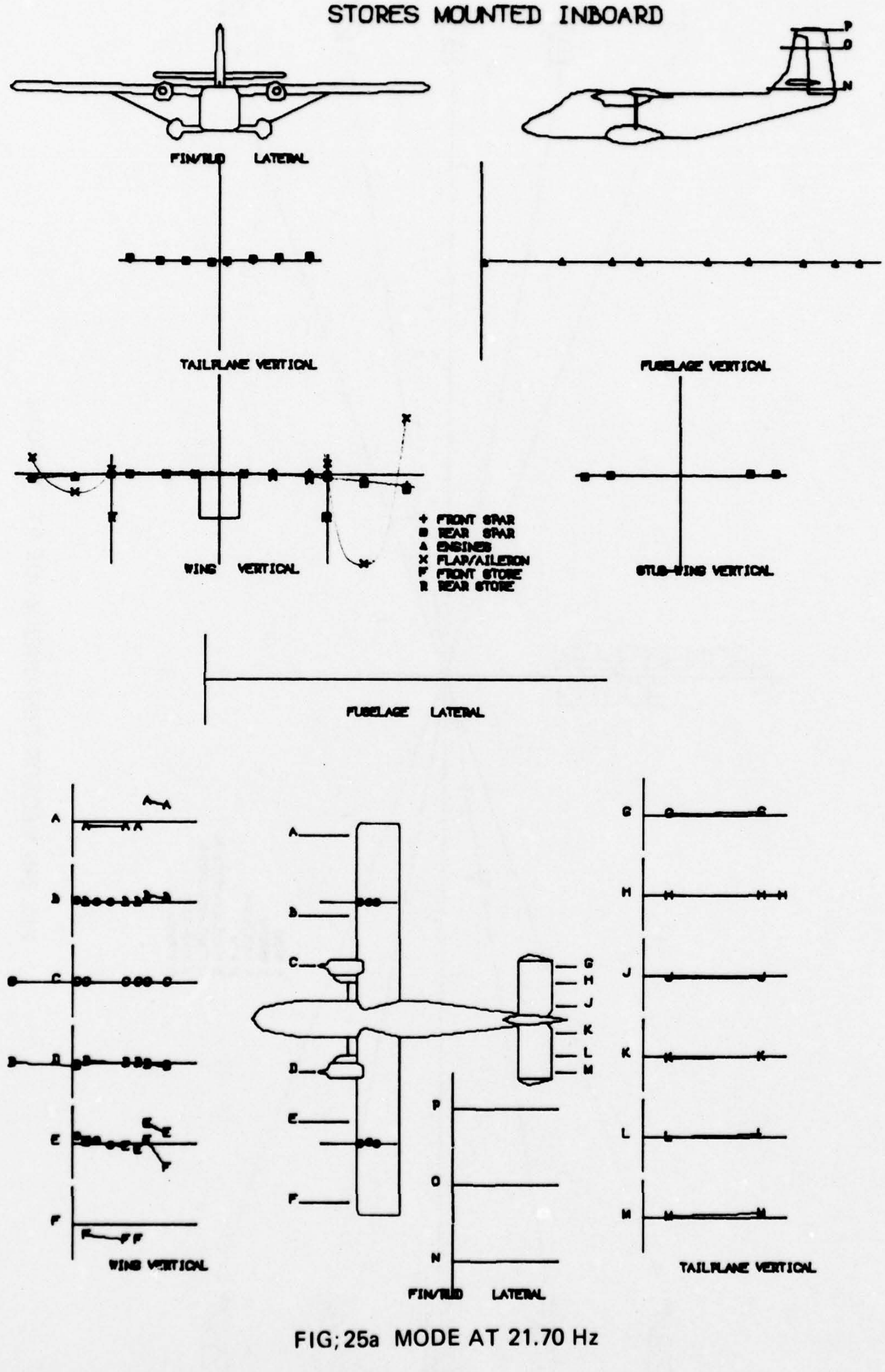


FIG. 24b VECTOR RESPONSE MODE AT 17.40 Hz

STORES MOUNTED INBOARD



FIG; 25a MODE AT 21.70 Hz

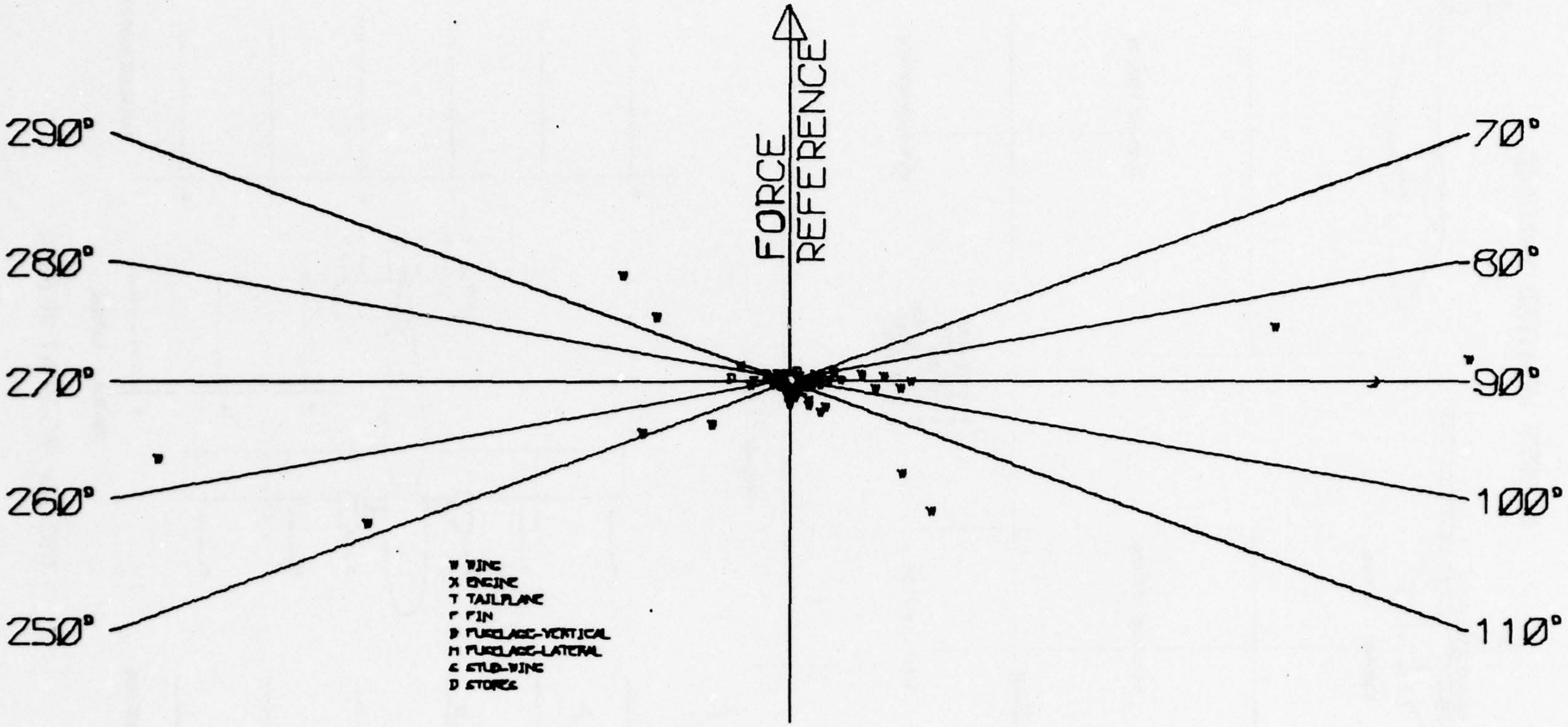


FIG. 25b VECTOR RESPONSE MODE AT 21.70 Hz

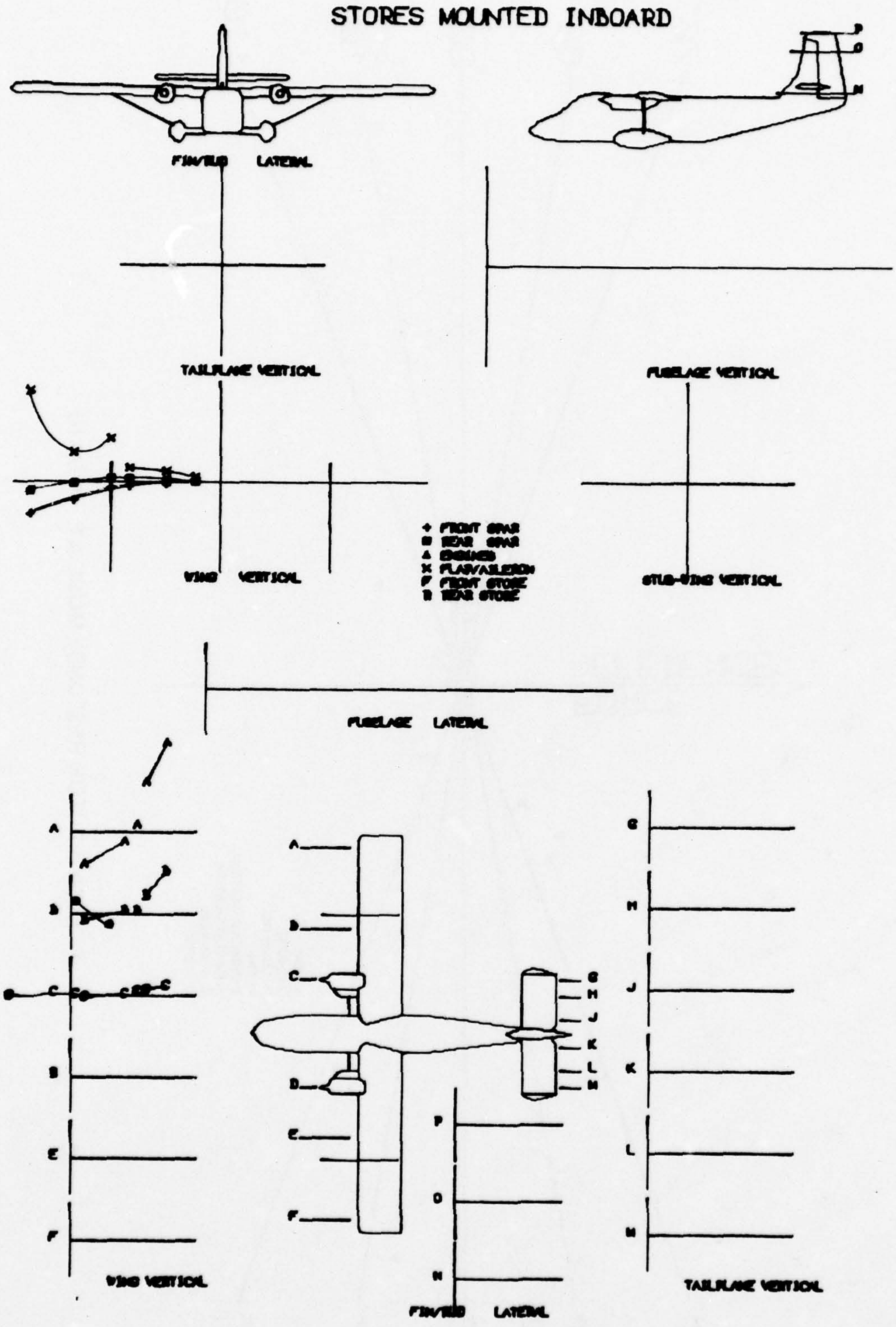


FIG. 26a MODE AT 29.50 Hz

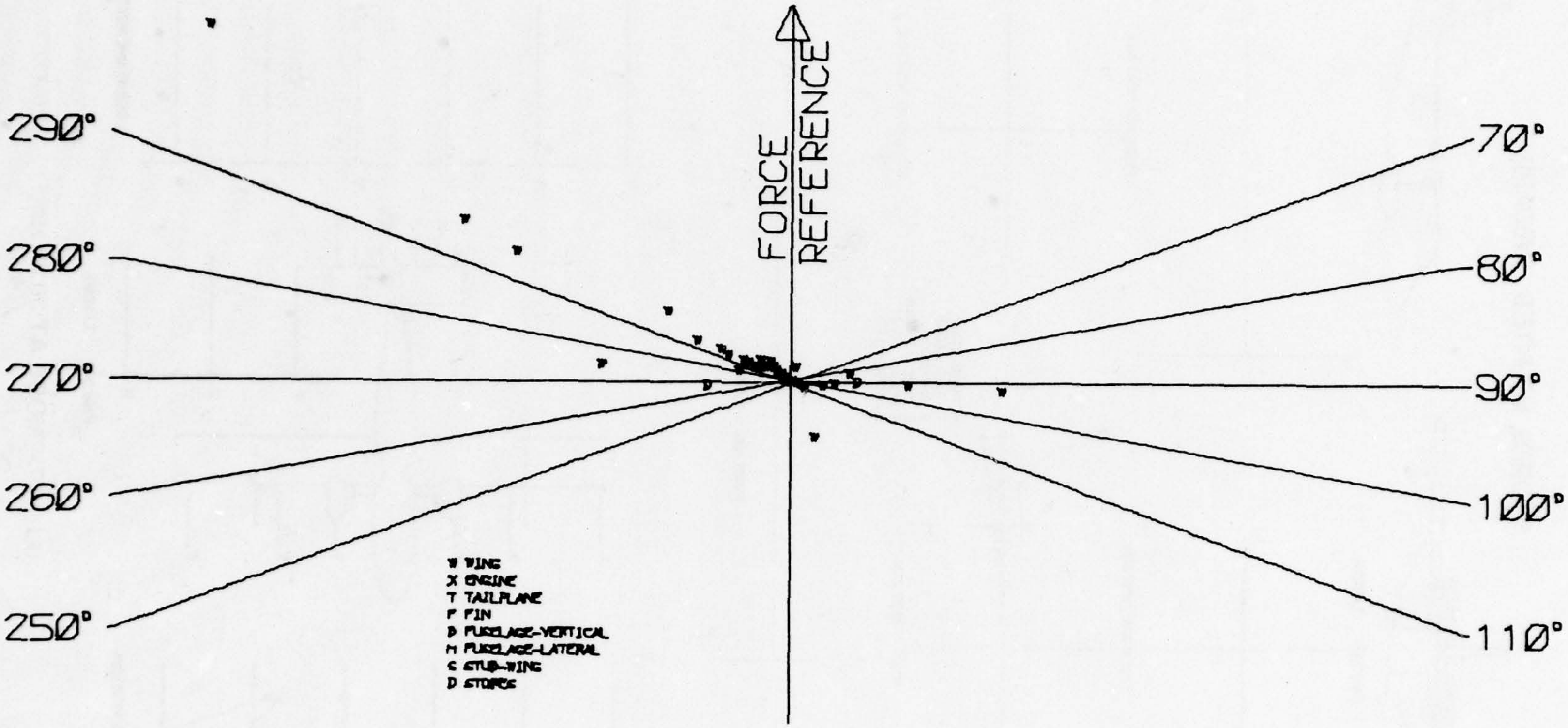


FIG. 26b VECTOR RESPONSE MODE AT 29.50 Hz

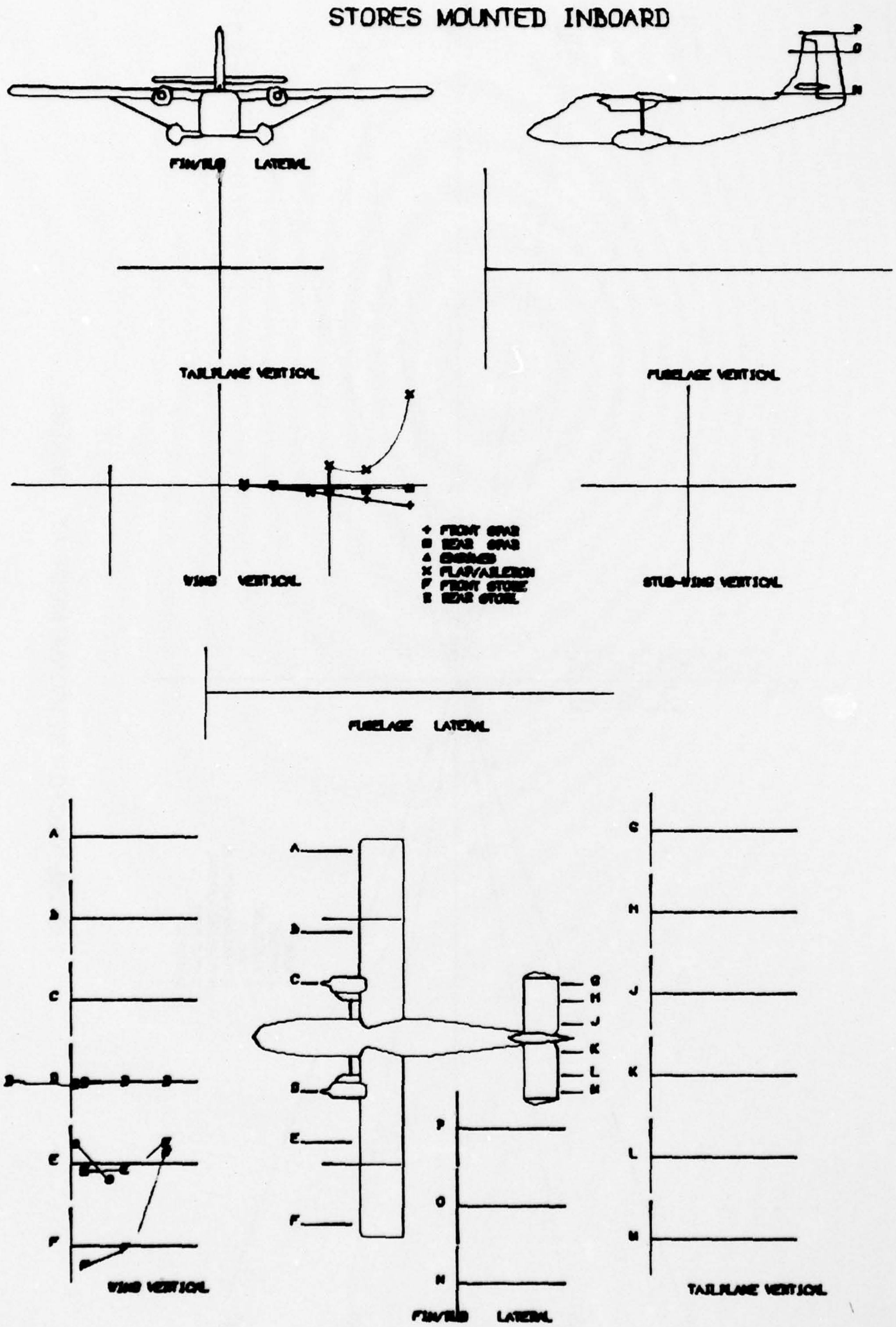


FIG. 27a MODE AT 30.60 Hz

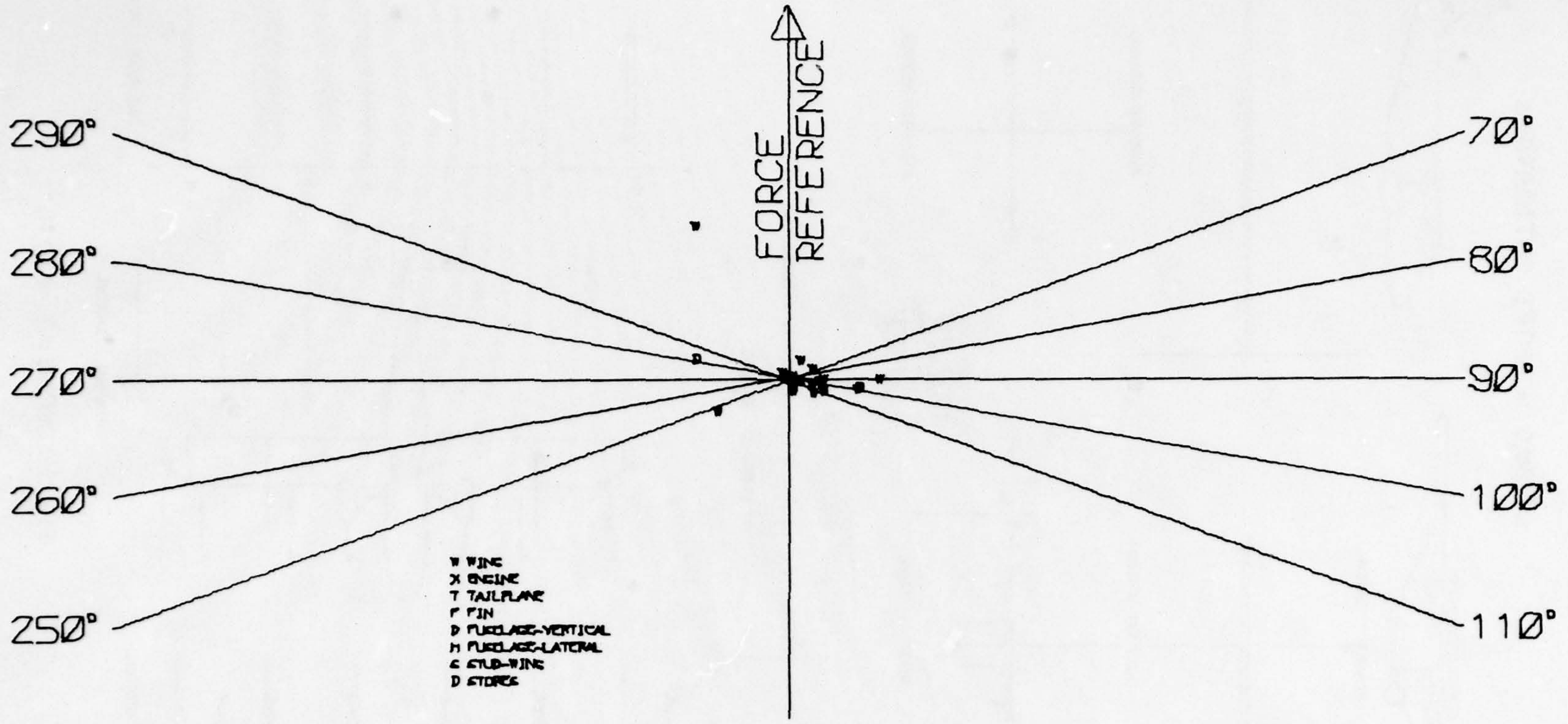


FIG. 27b VECTOR RESPONSE MODE AT 30.60 Hz

STORES MOUNTED OUTBOARD

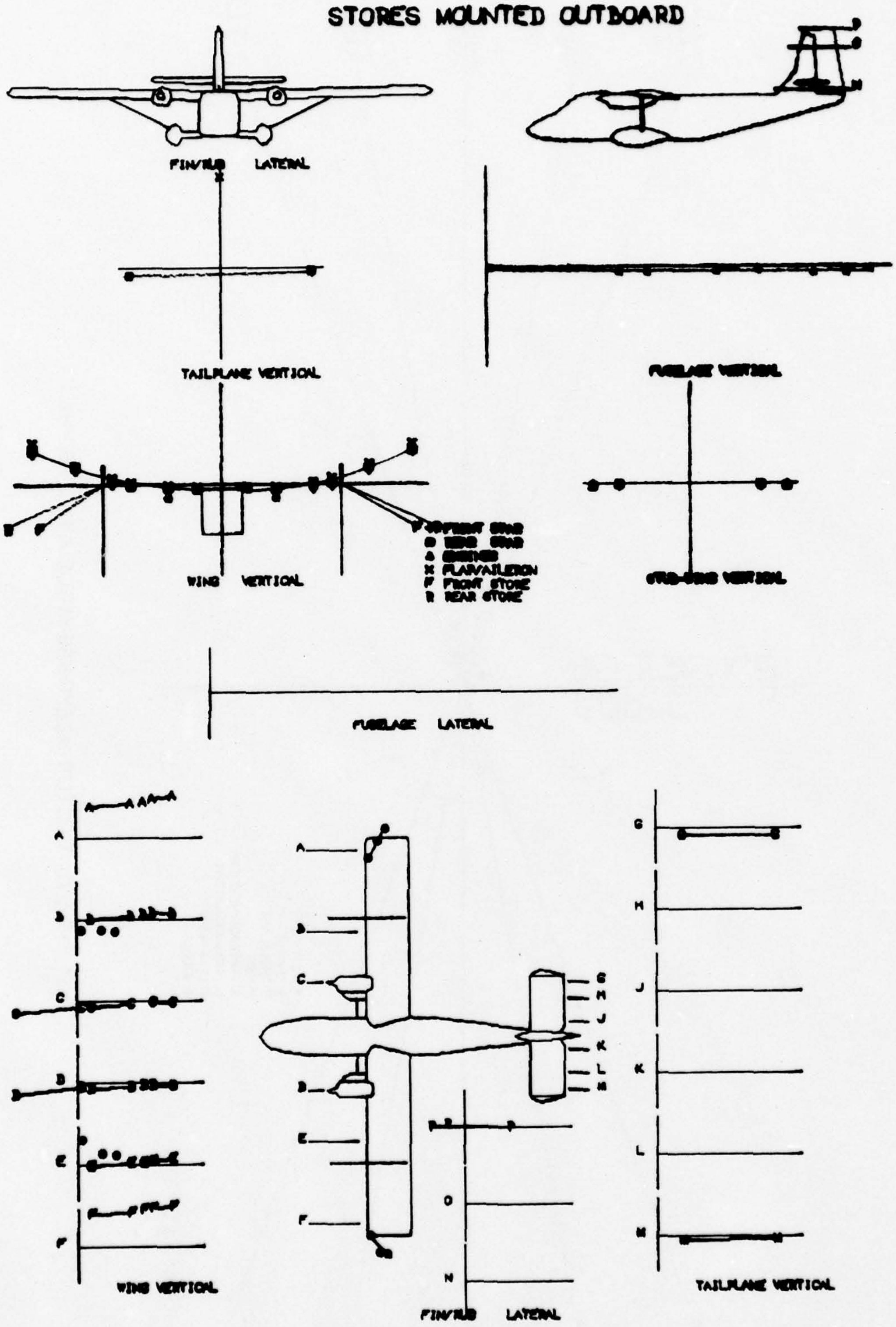


FIG. 28a MODE AT 4.59 Hz

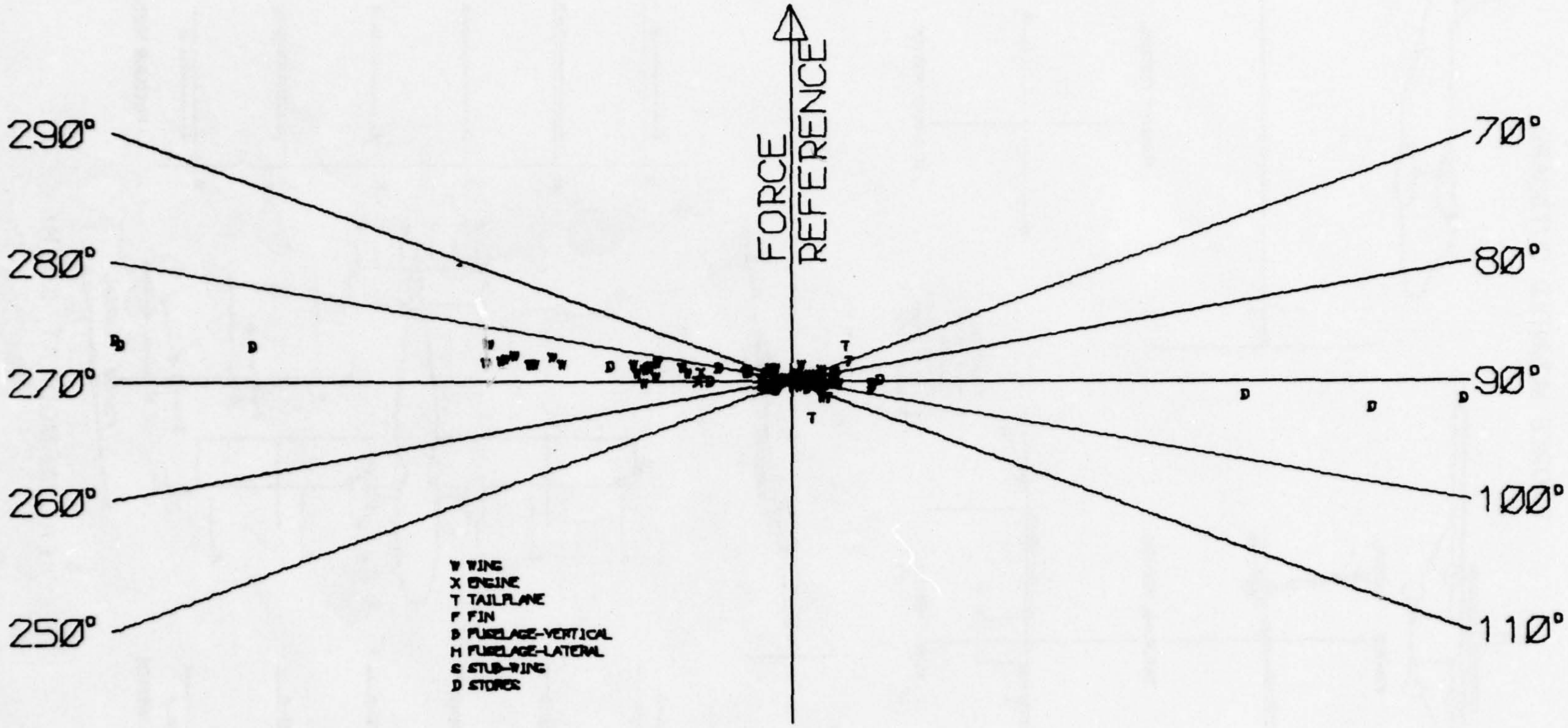


FIG. 28b VECTOR RESPONSE MODE AT 4.59 Hz

STORES MOUNTED OUTBOARD

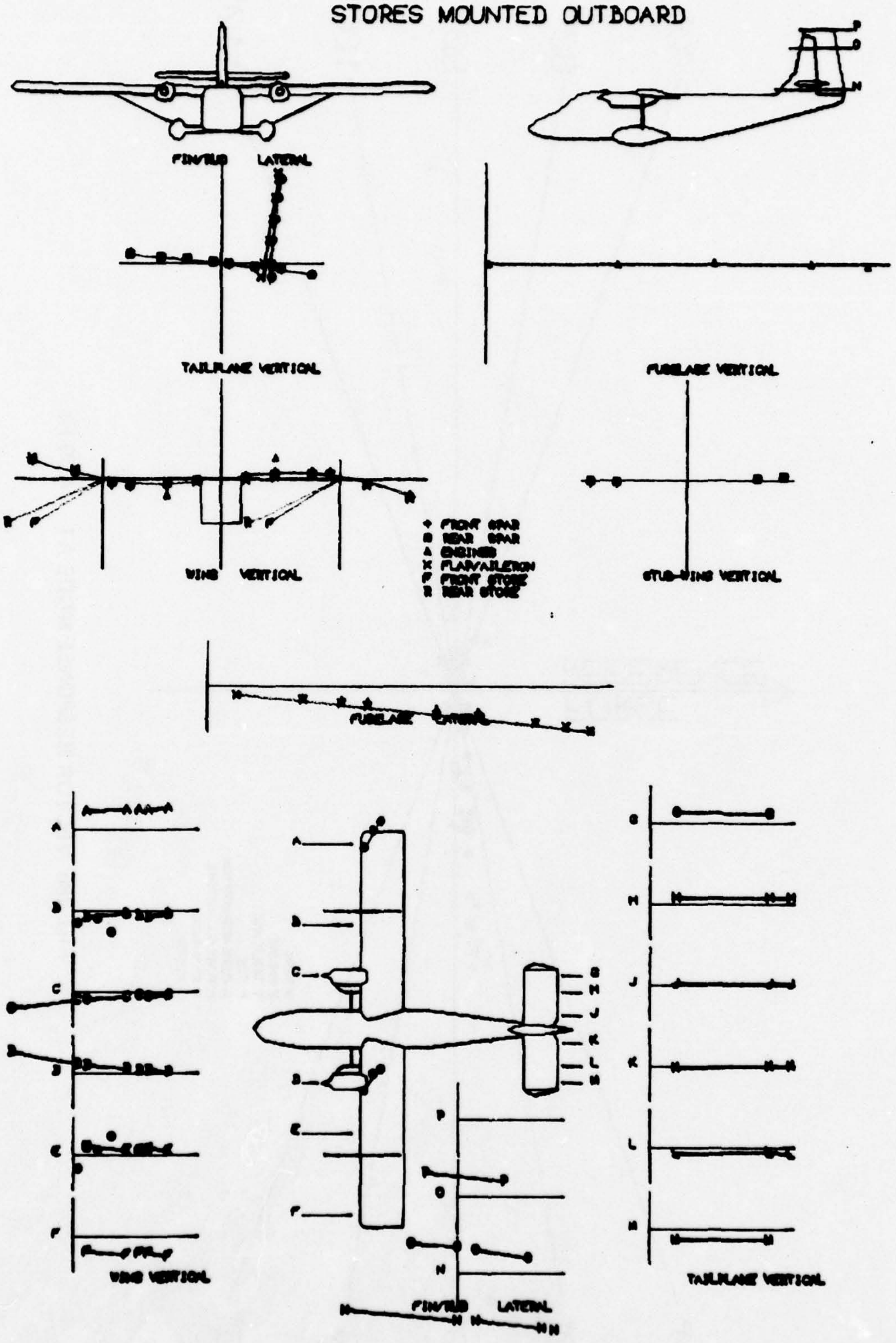


FIG. 29a MODE AT 5.05 Hz

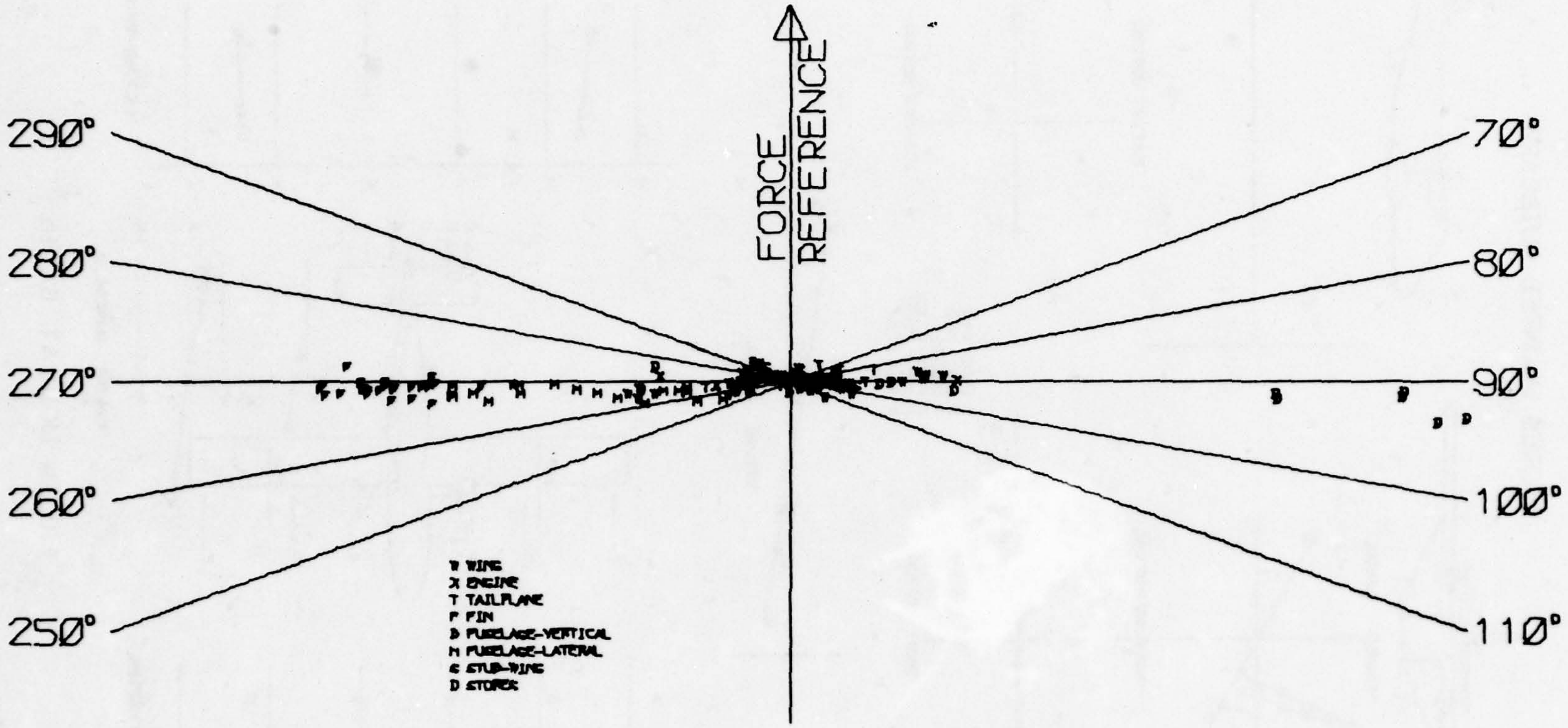


FIG. 29b VECTOR RESPONSE MODE AT 5.05 Hz

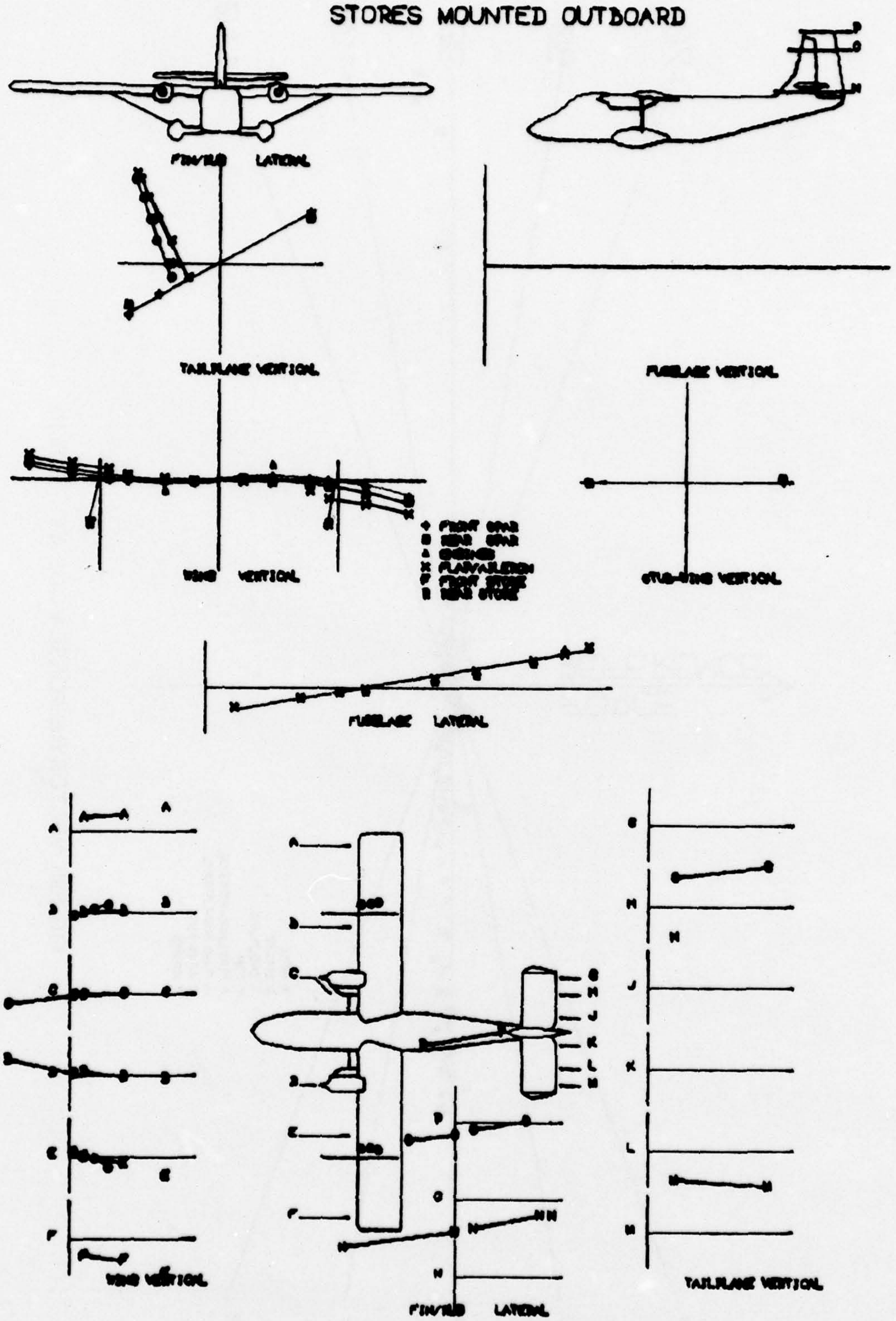


FIG. 30a MODE AT 5.51 Hz

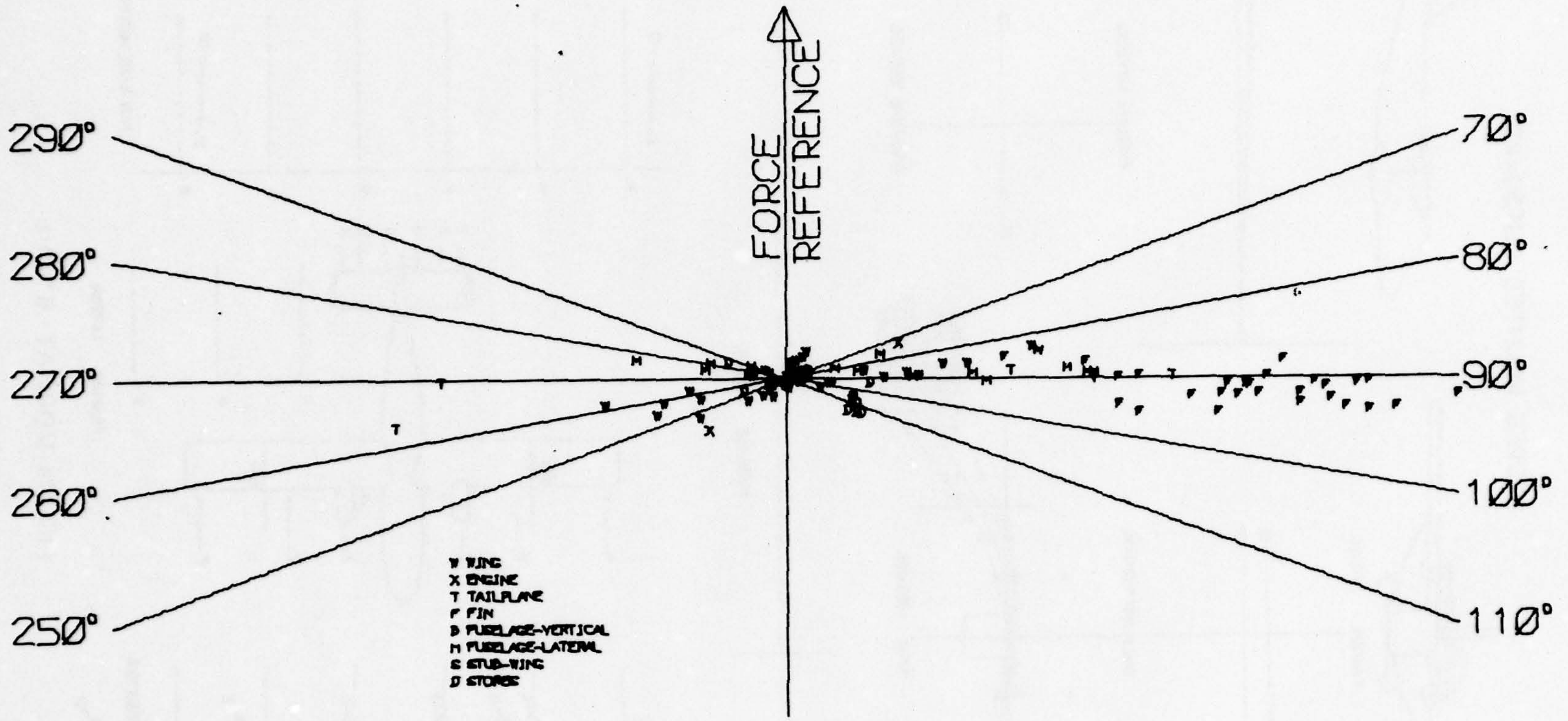


FIG. 30b VECTOR RESPONSE MODE AT 5.51 Hz

STORES MOUNTED OUTBOARD

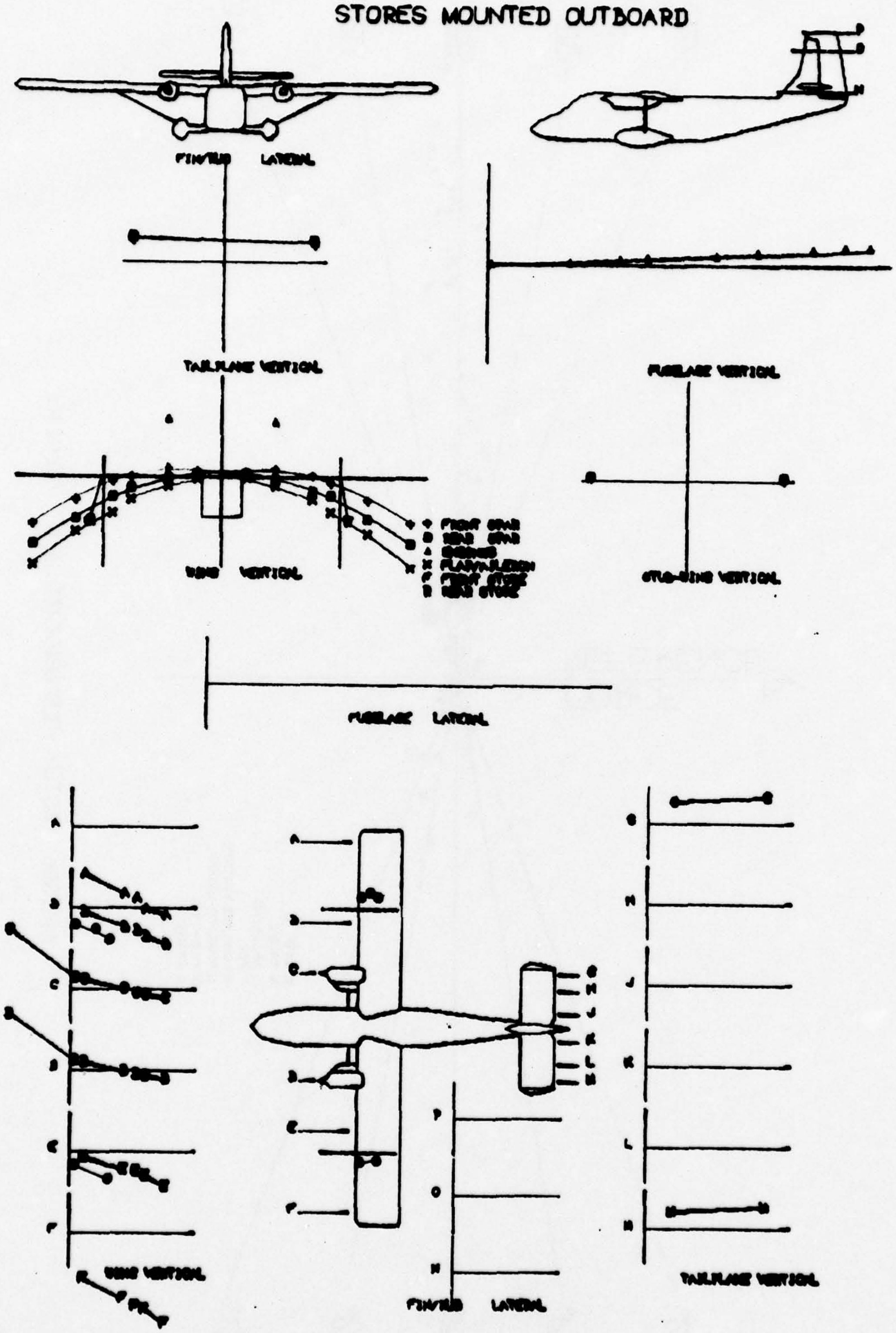


FIG. 31a MODE AT 6.33 Hz

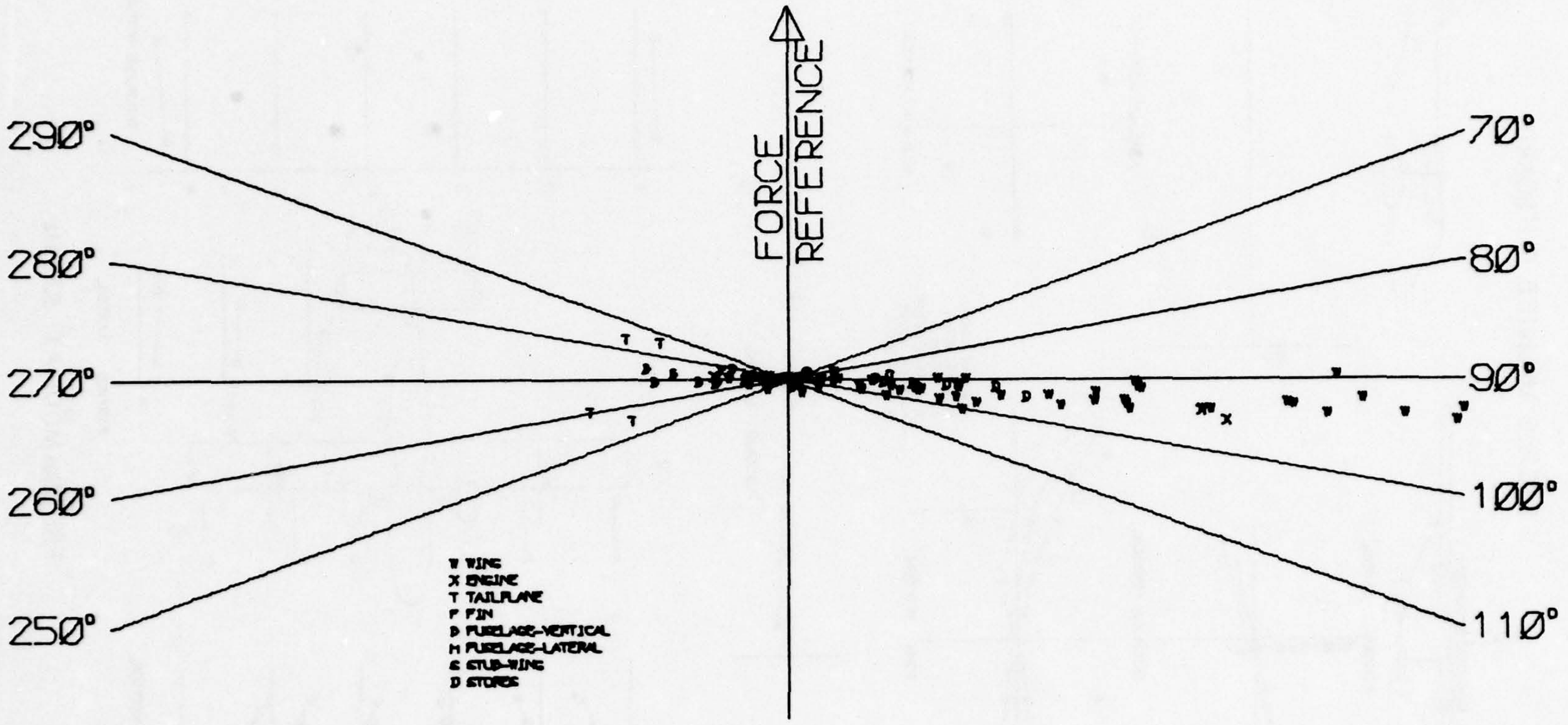


FIG. 31b VECTOR RESPONSE MODE AT 6.33 Hz

STORES MOUNTED OUTBOARD

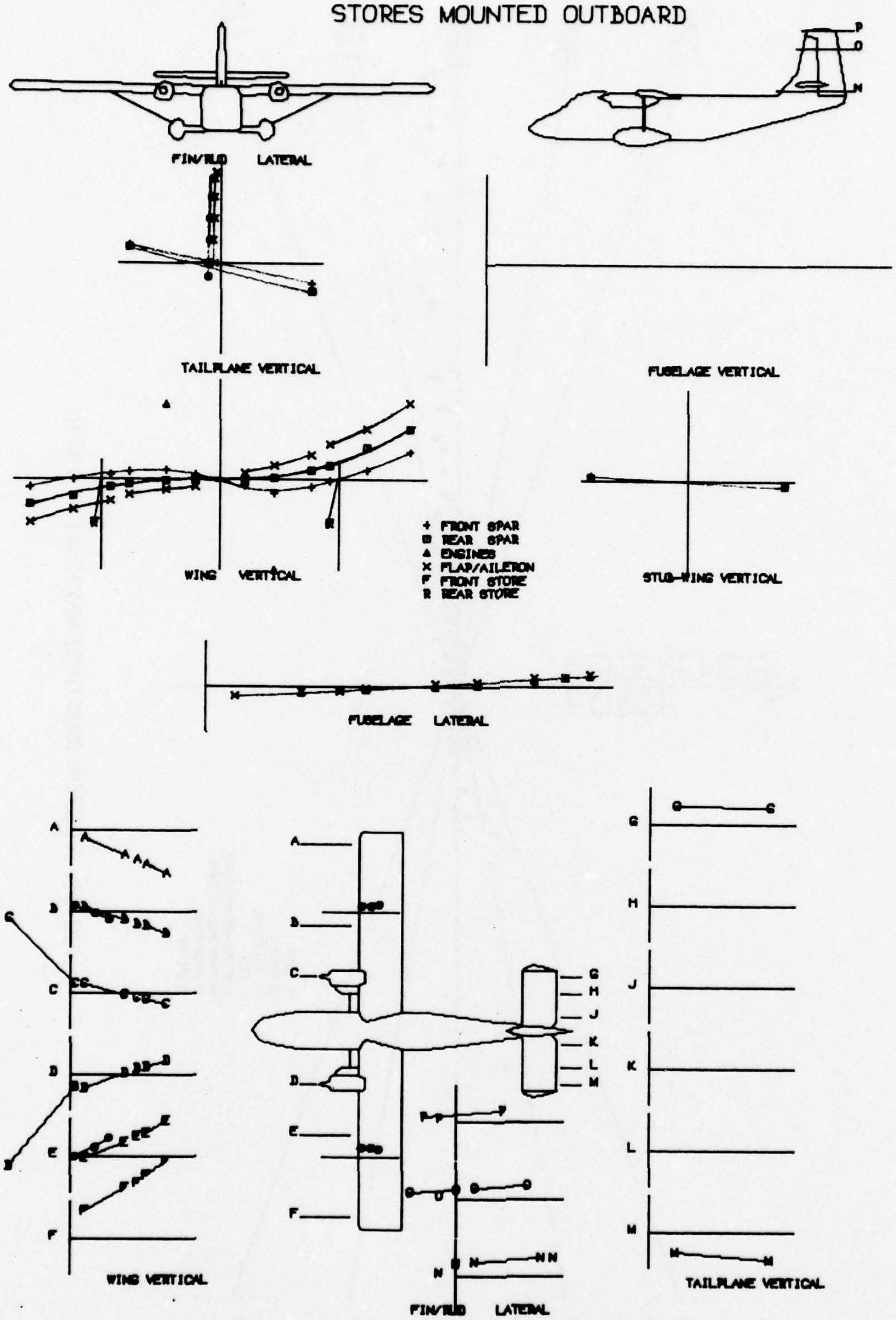


FIG. 32a MODE AT 6.55 Hz

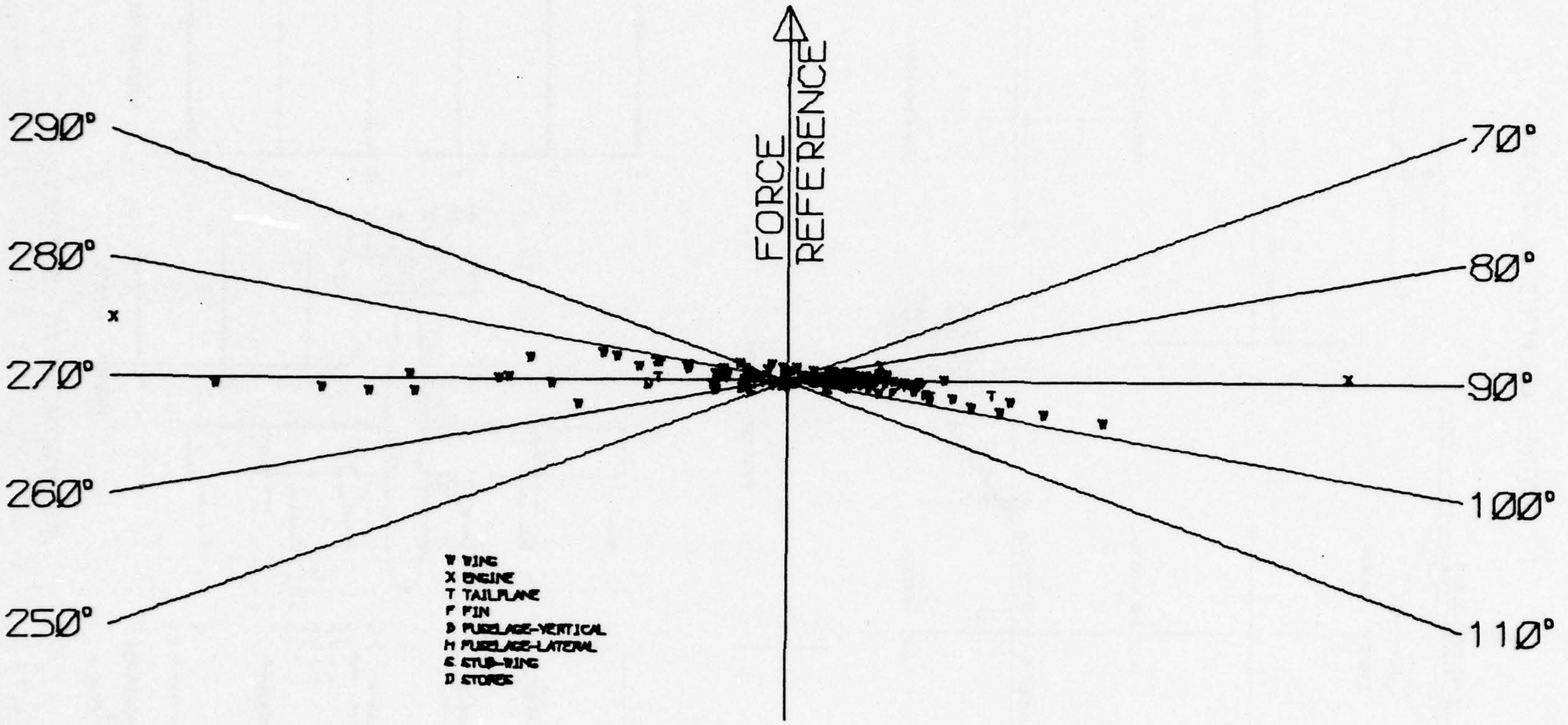


FIG. 32b VECTOR RESPONSE MODE AT 6.55 Hz

STORES MOUNTED OUTBOARD

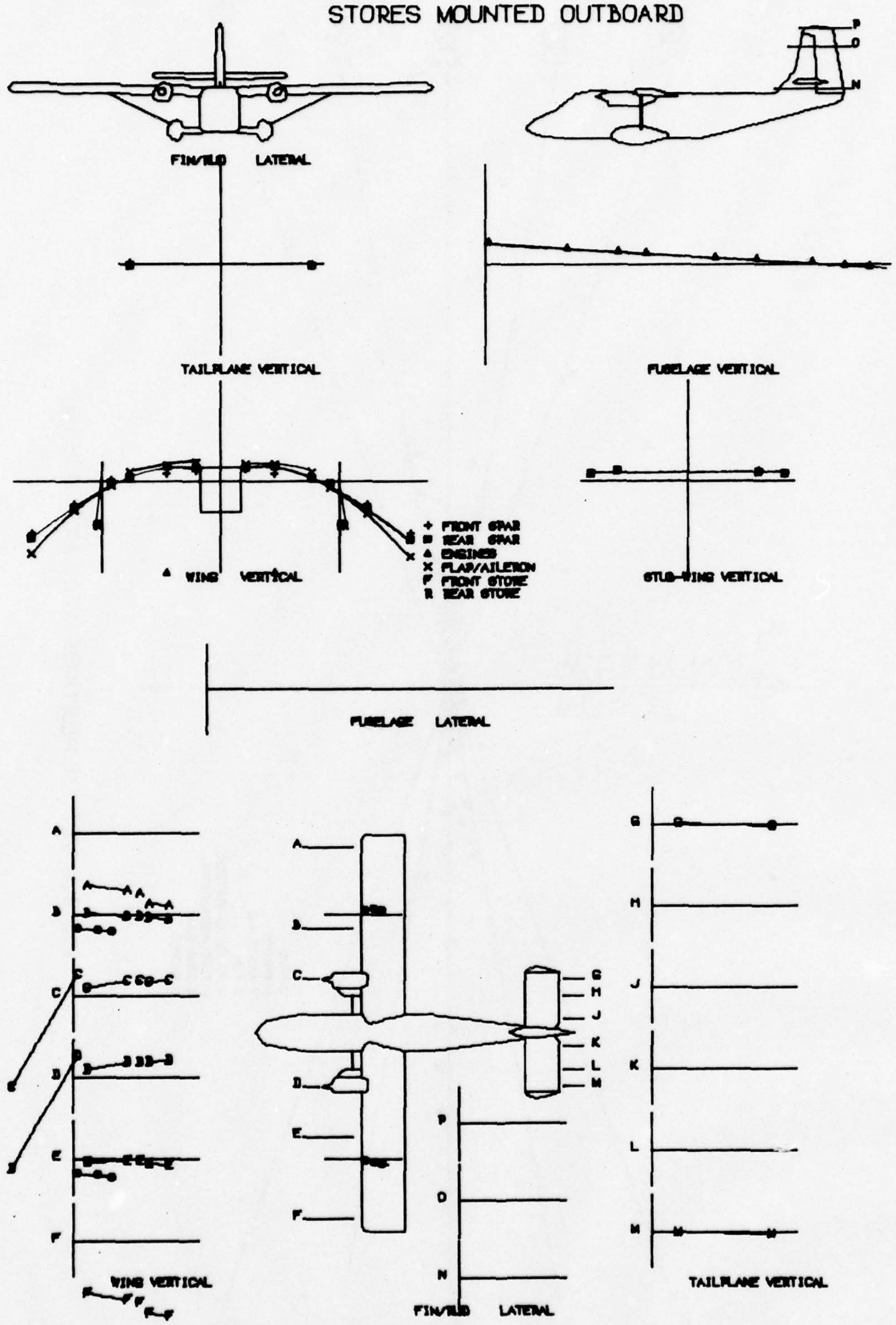


FIG.33a MODE AT 8.47 Hz

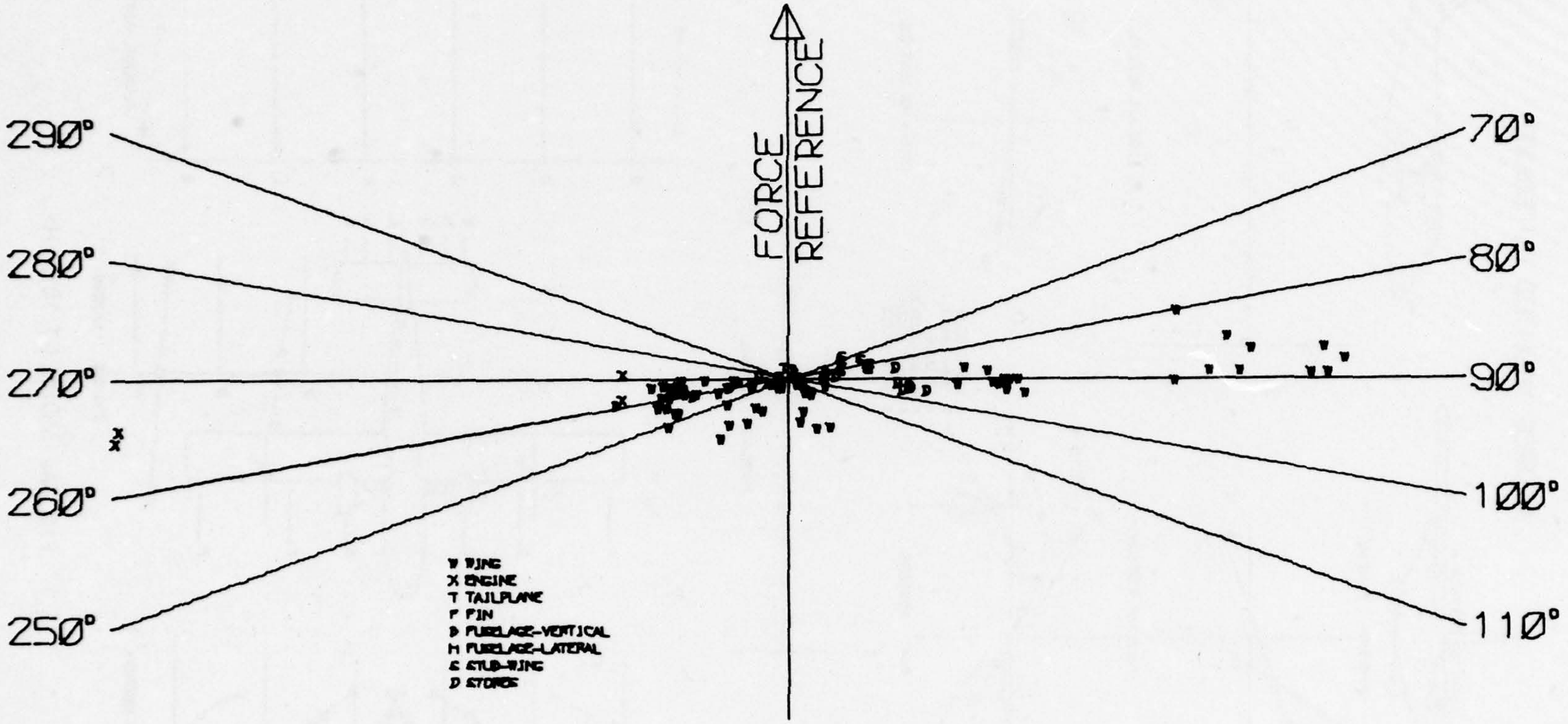


FIG. 33b VECTOR RESPONSE MODE AT 8.47 Hz

STORES MOUNTED OUTBOARD

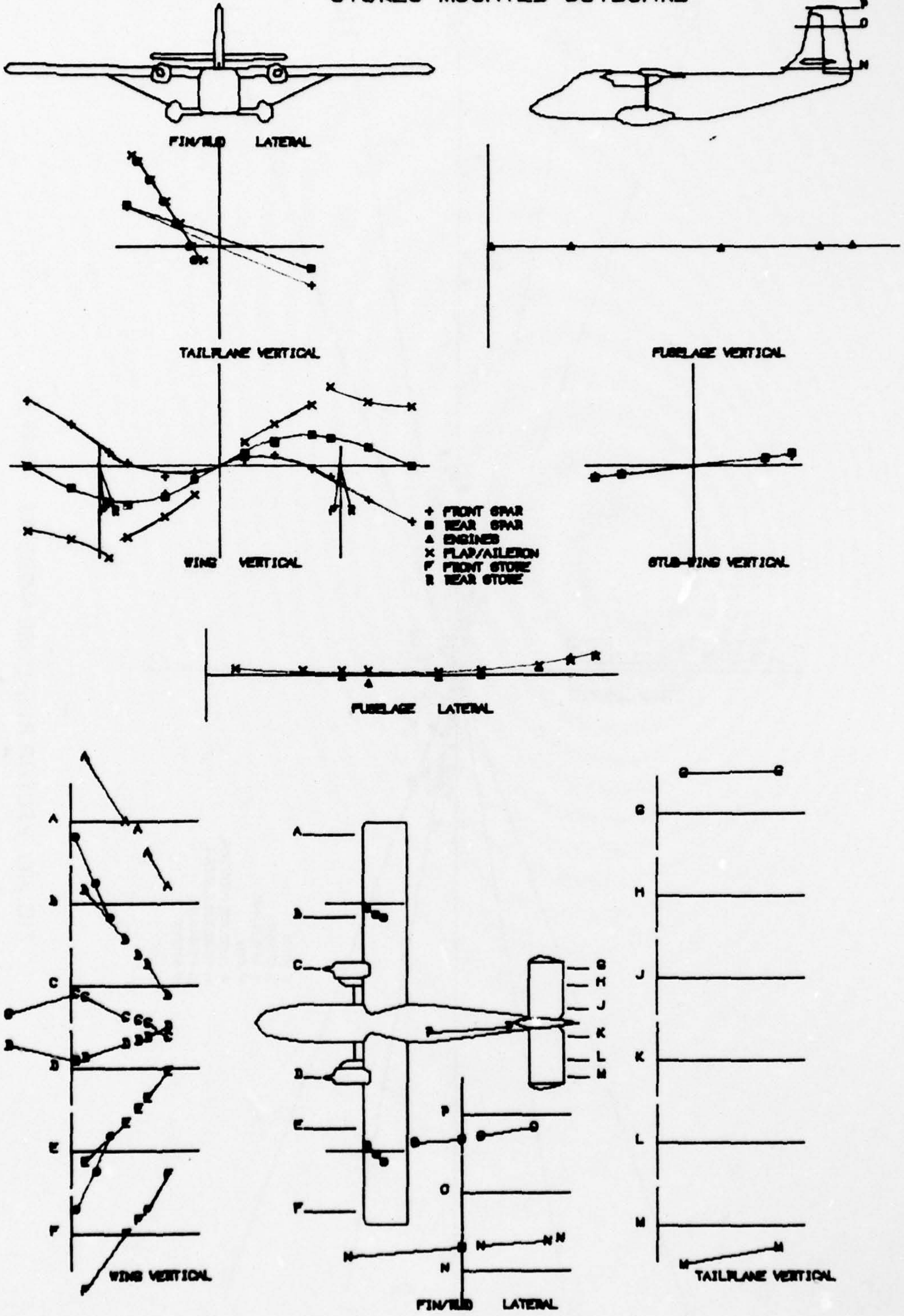


FIG. 34a MODE AT 10.10 Hz

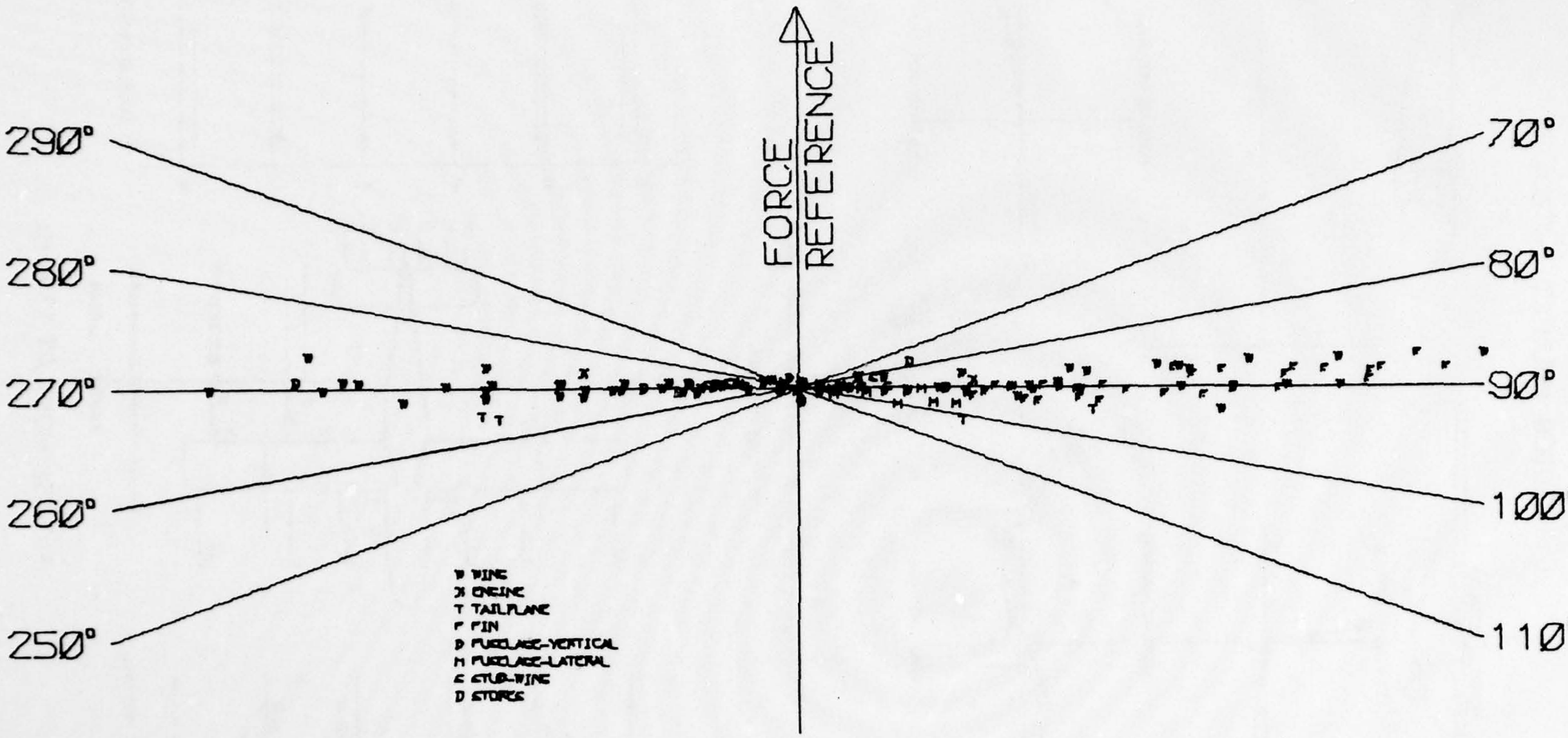


FIG. 34b VECTOR RESPONSE MODE AT 10.10 Hz

STORES MOUNTED OUTBOARD

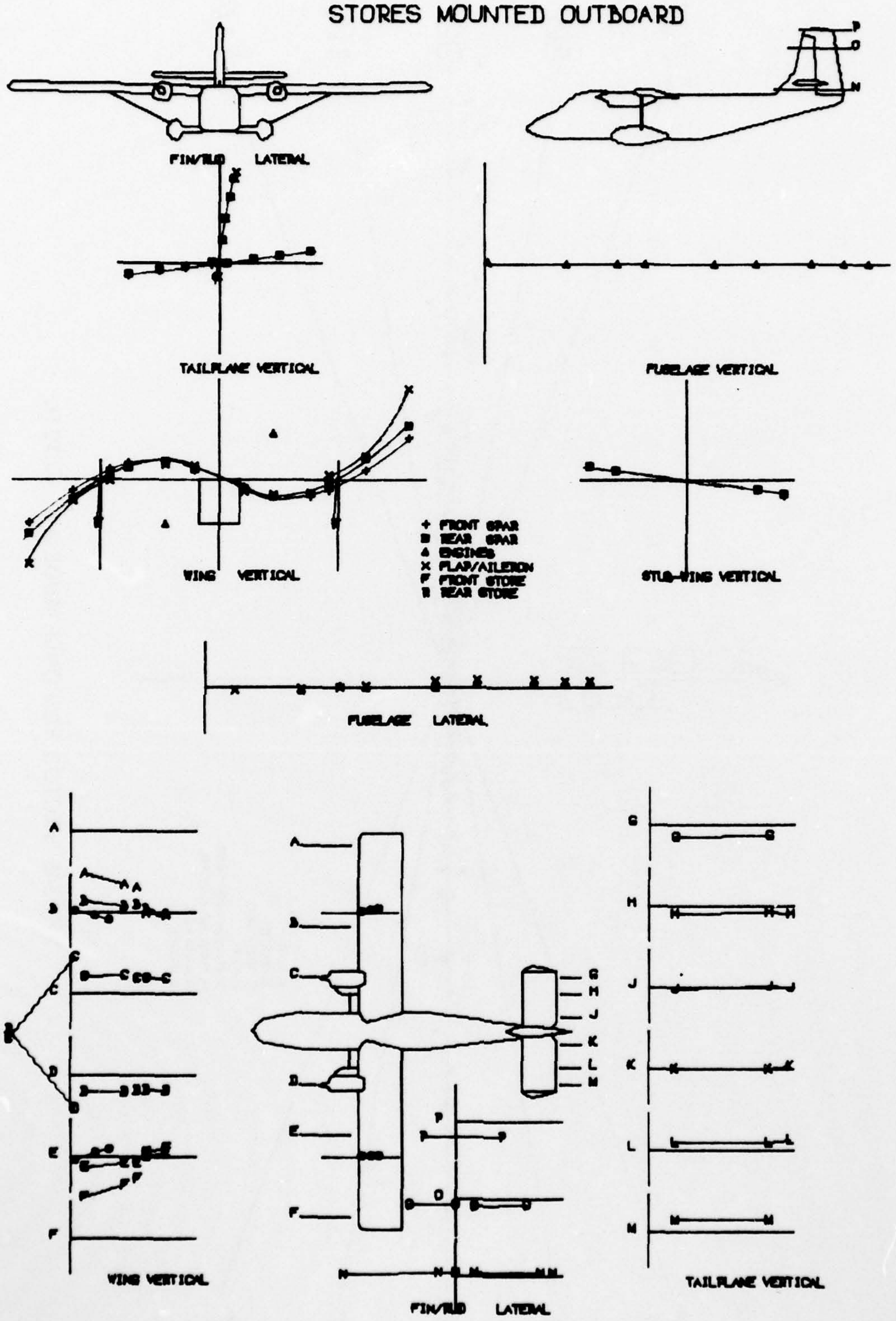


FIG. 35a MODE AT 10.41 Hz

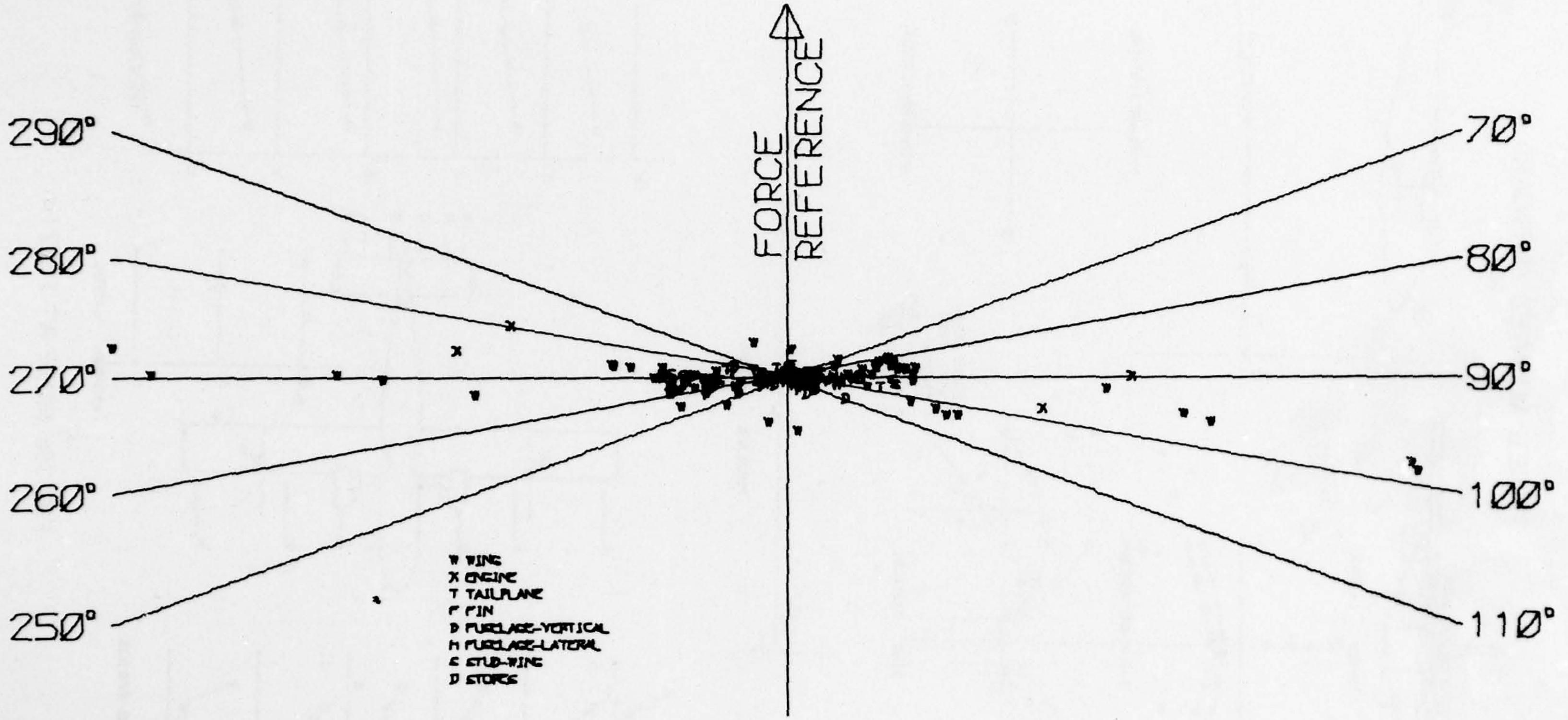


FIG.35b VECTOR RESPONSE MODE AT 10.41 Hz

STORES MOUNTED OUTBOARD

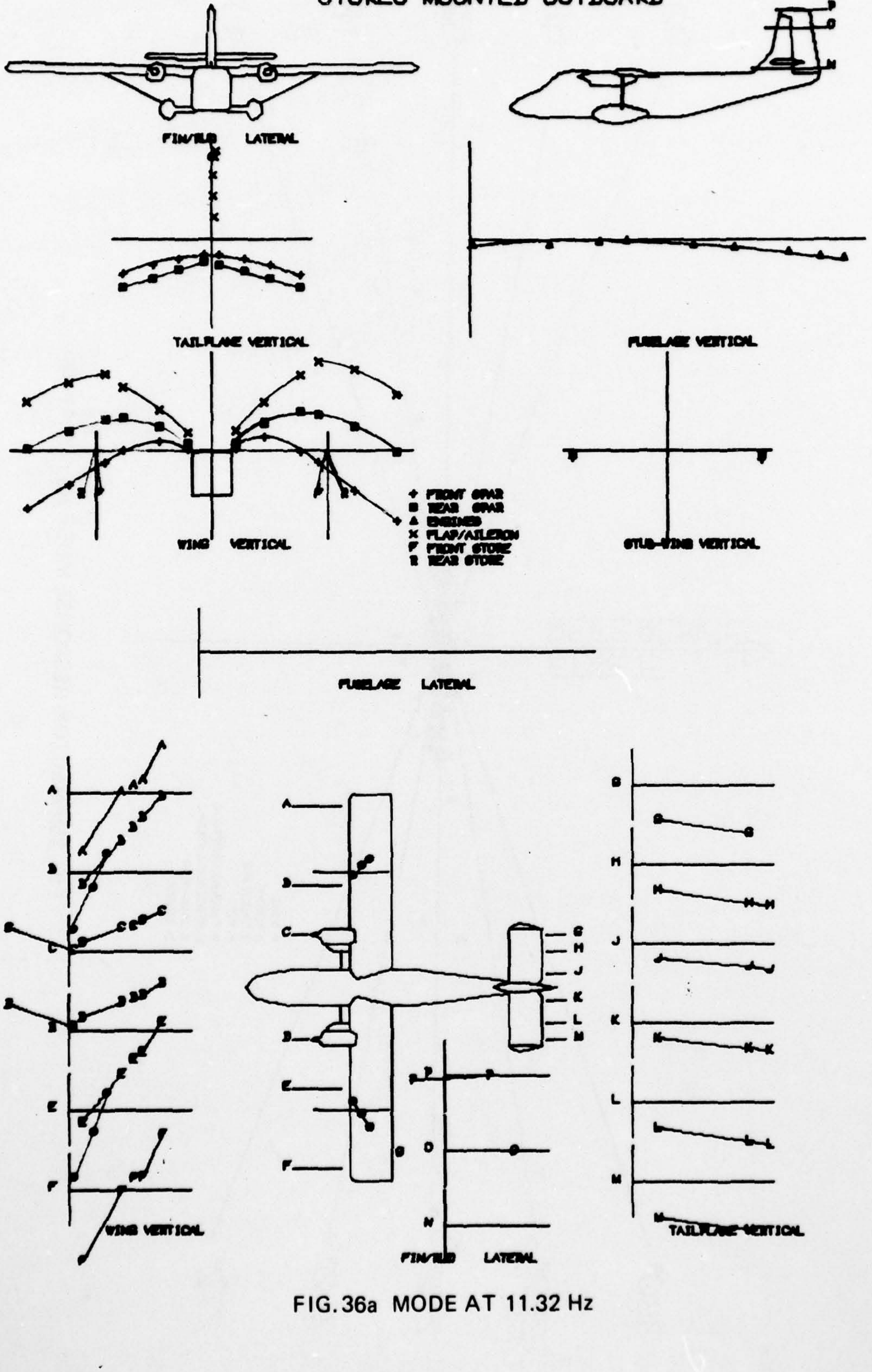


FIG. 36a MODE AT 11.32 Hz

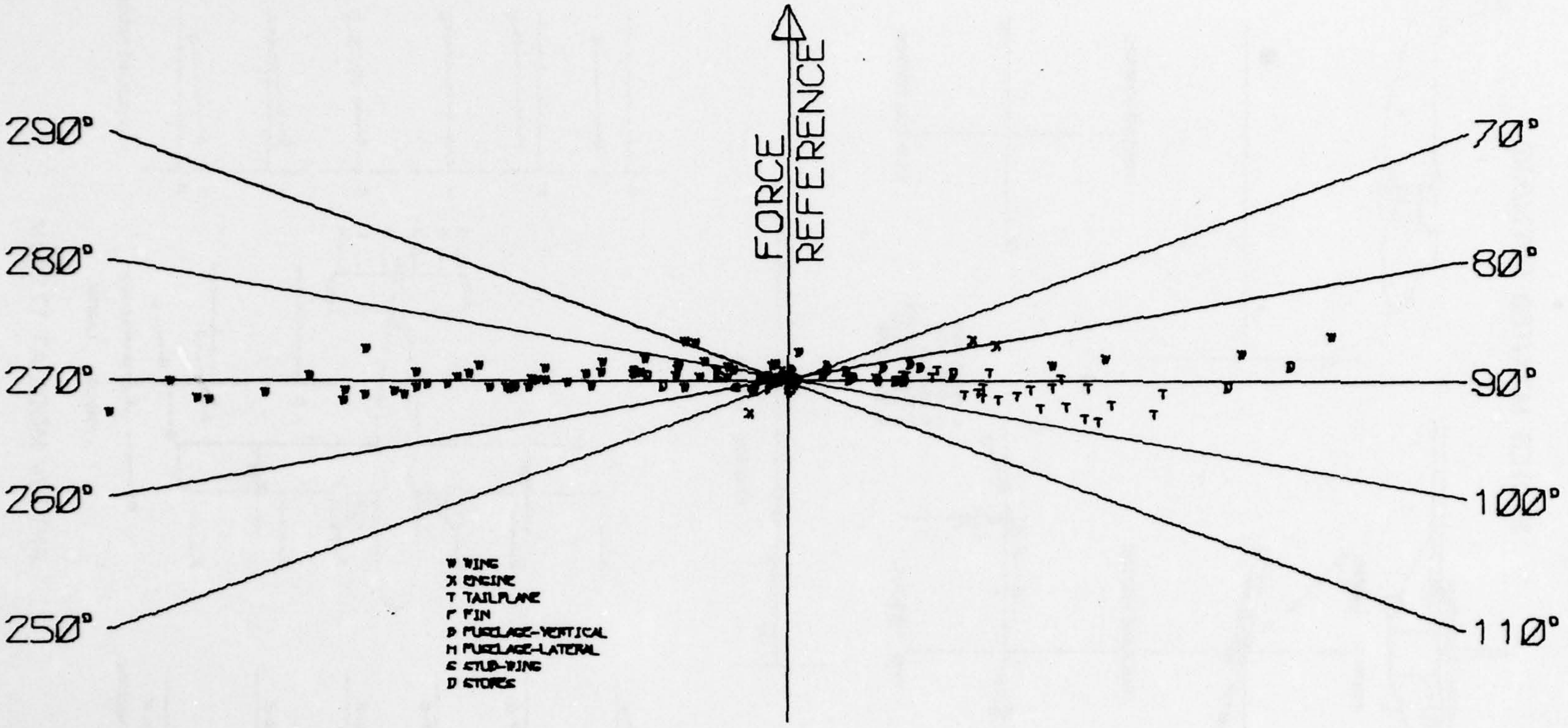


FIG.36b VECTOR RESPONSE MODE AT 11.32 Hz

STORES MOUNTED OUTBOARD

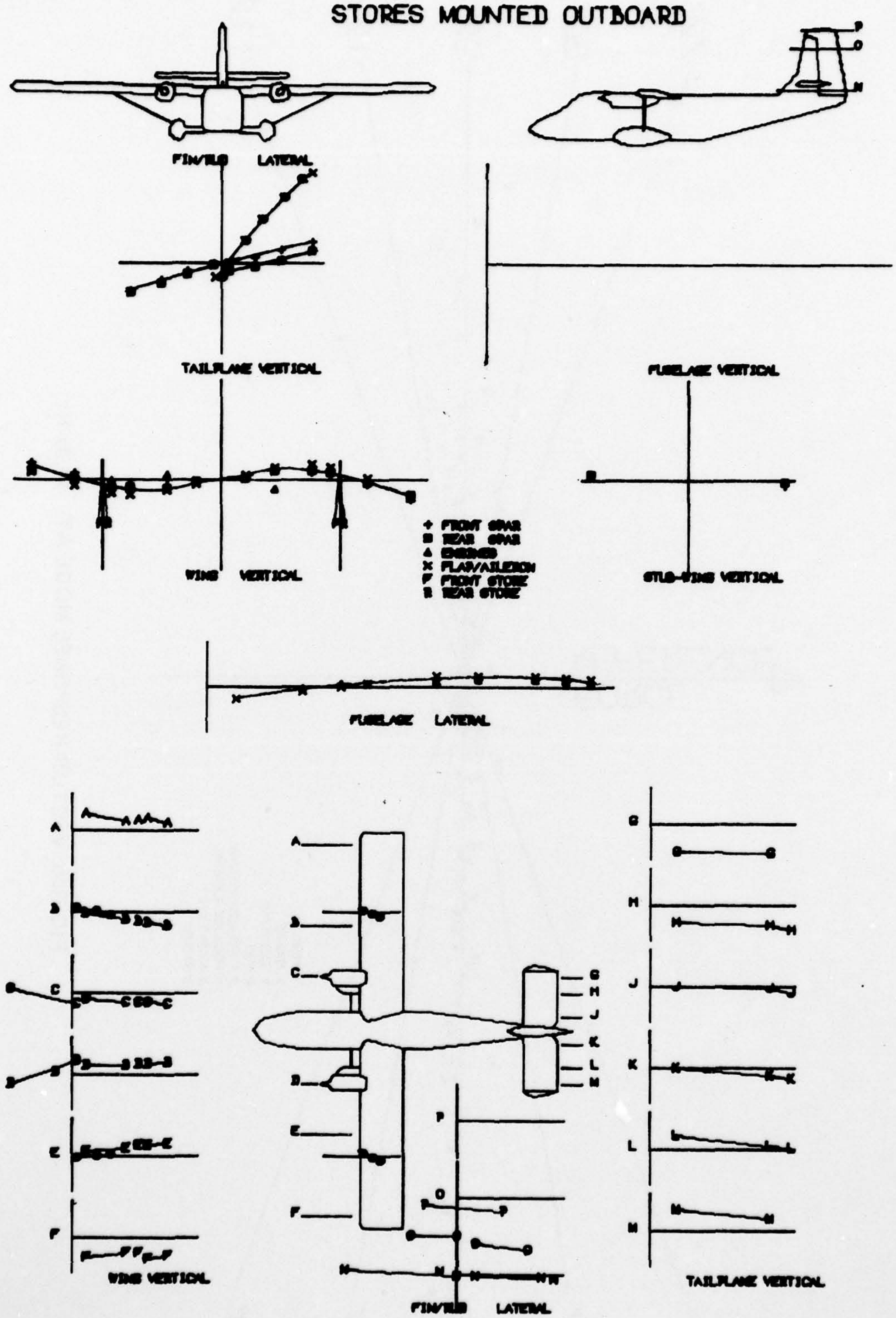


FIG. 37a MODE AT 12.91 Hz

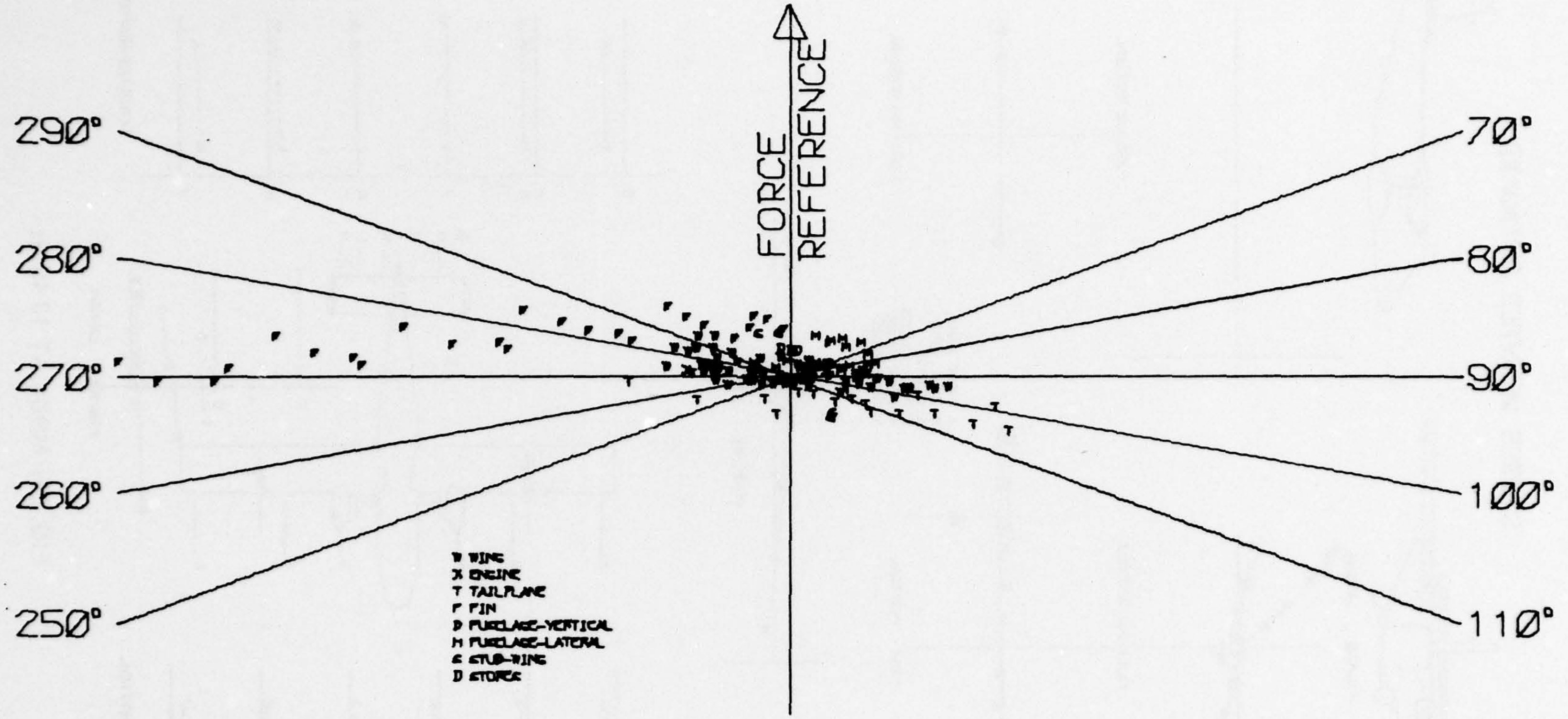


FIG. 37b VECTOR RESPONSE MODE AT 12.91 Hz

STORES MOUNTED OUTBOARD

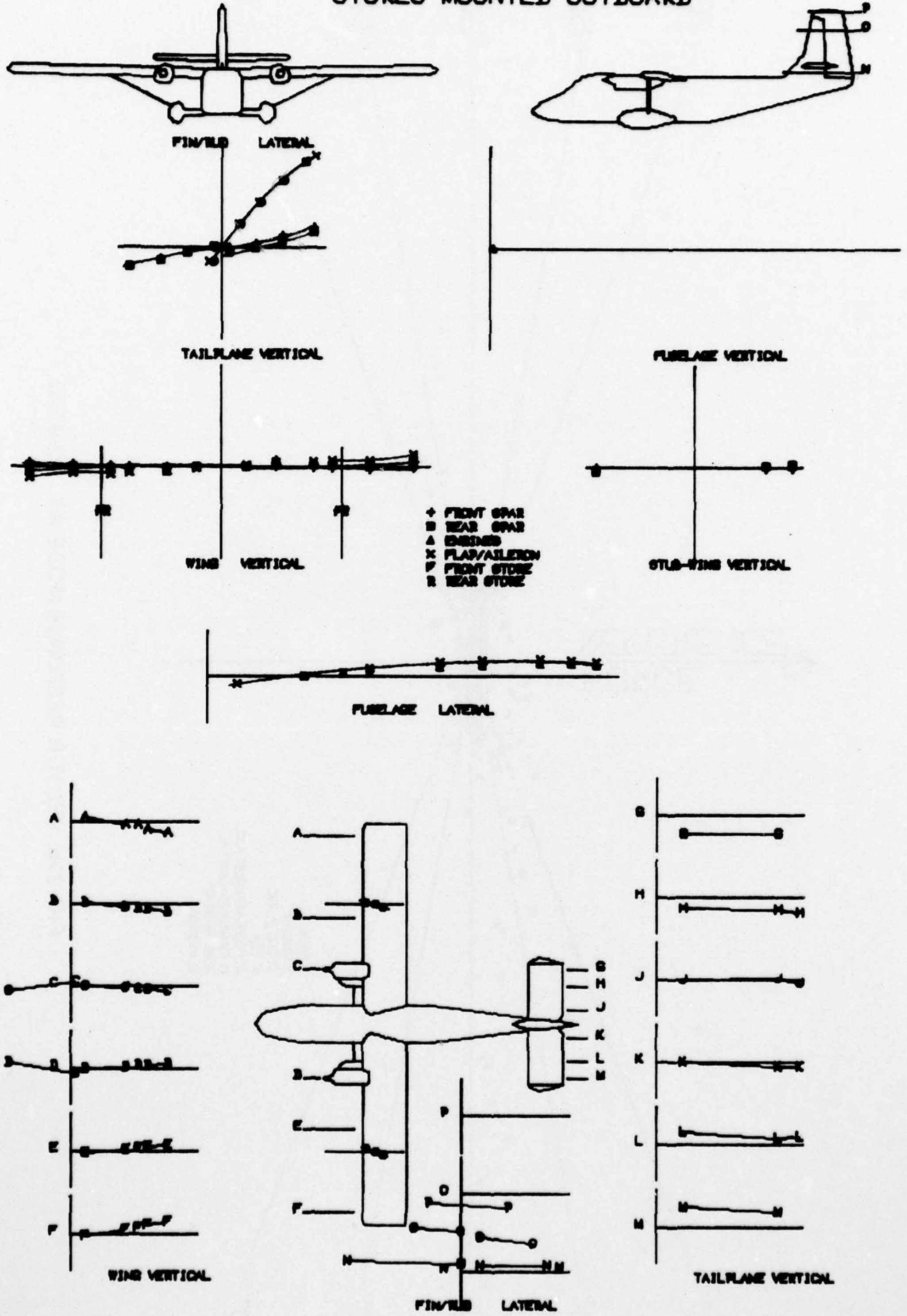


FIG. 38a MODE AT 13.49 Hz

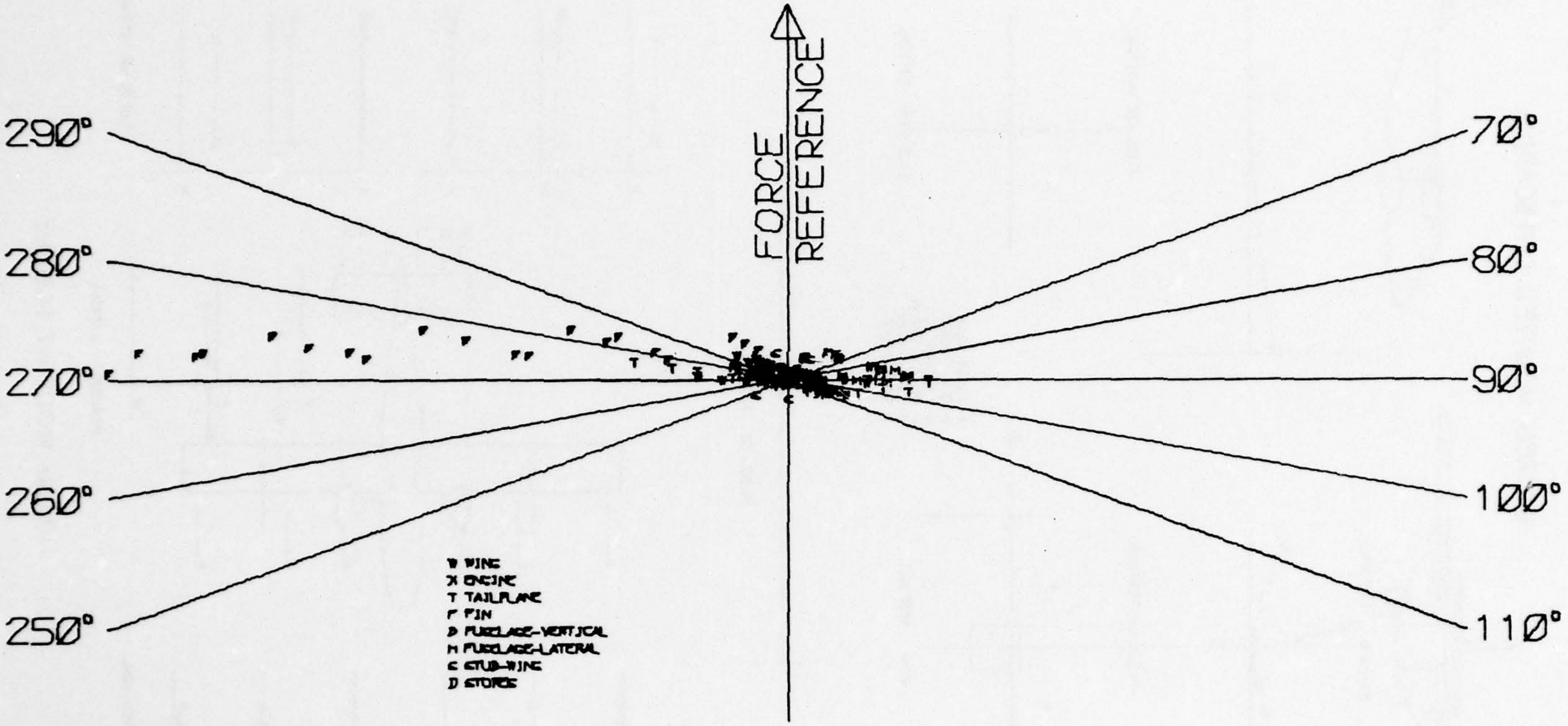


FIG. 38b VECTOR RESPONSE MODE AT 13.49 Hz

STORES MOUNTED OUTBOARD

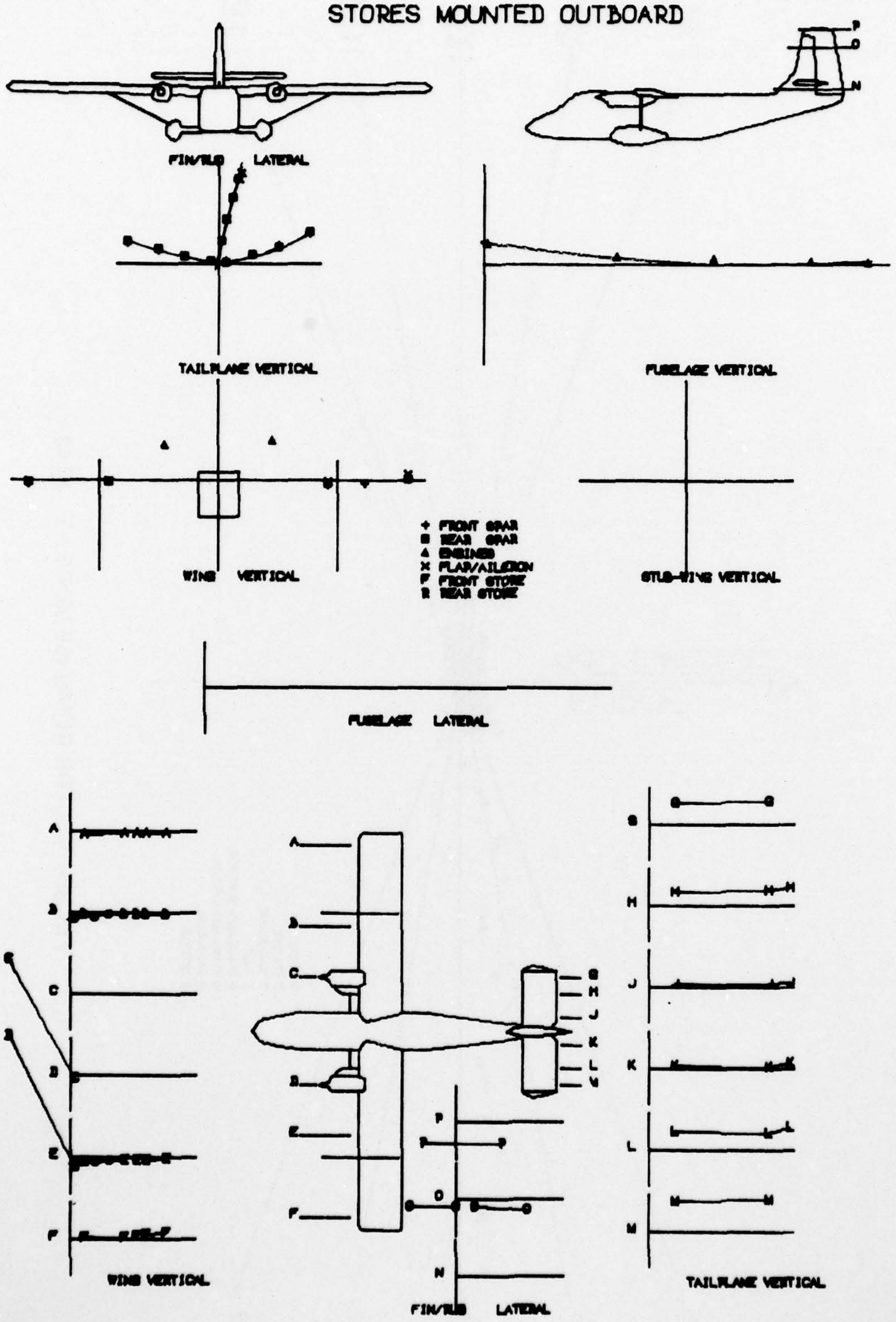


FIG. 39a MODE AT 14.53 Hz

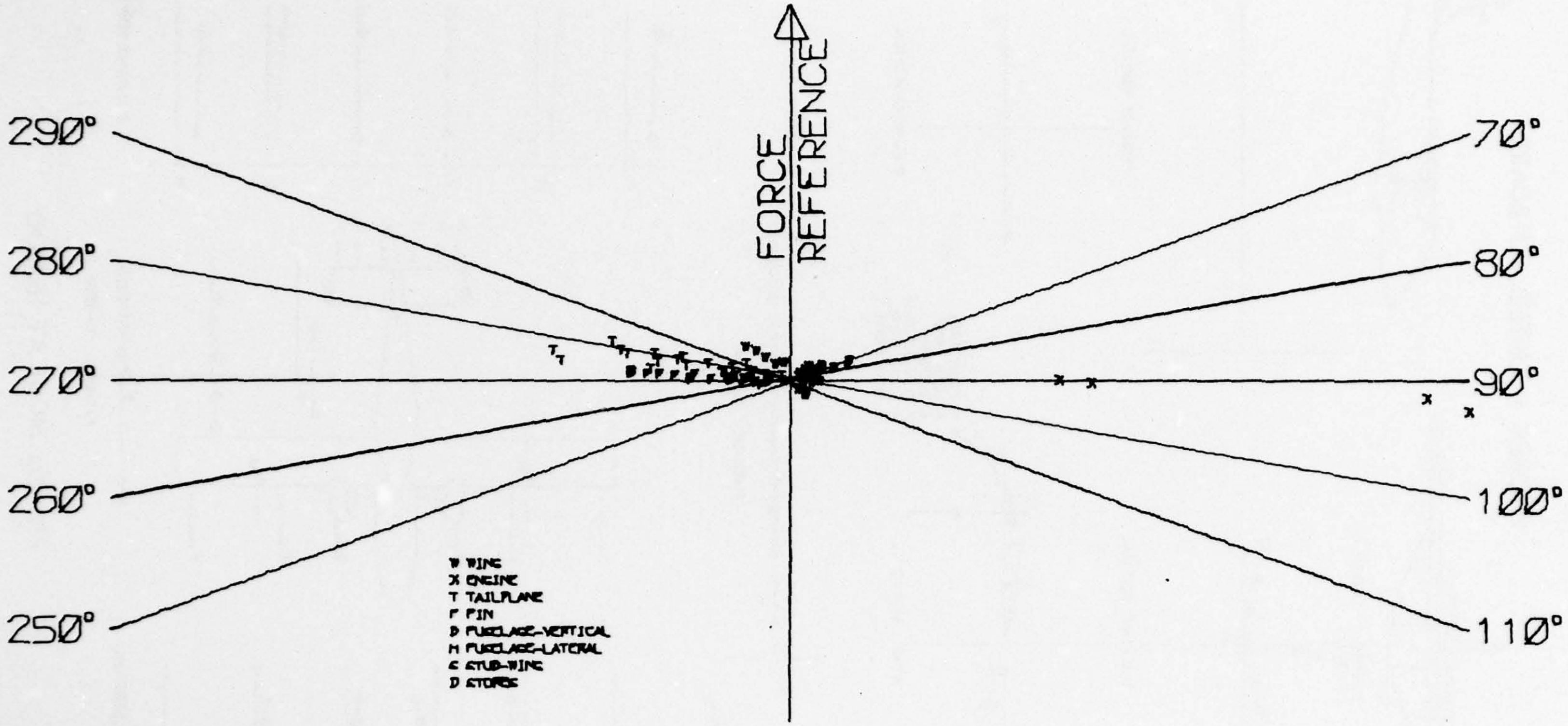


FIG. 39b VECTOR RESPONSE MODE AT 14.53 Hz

STORES MOUNTED OUTBOARD

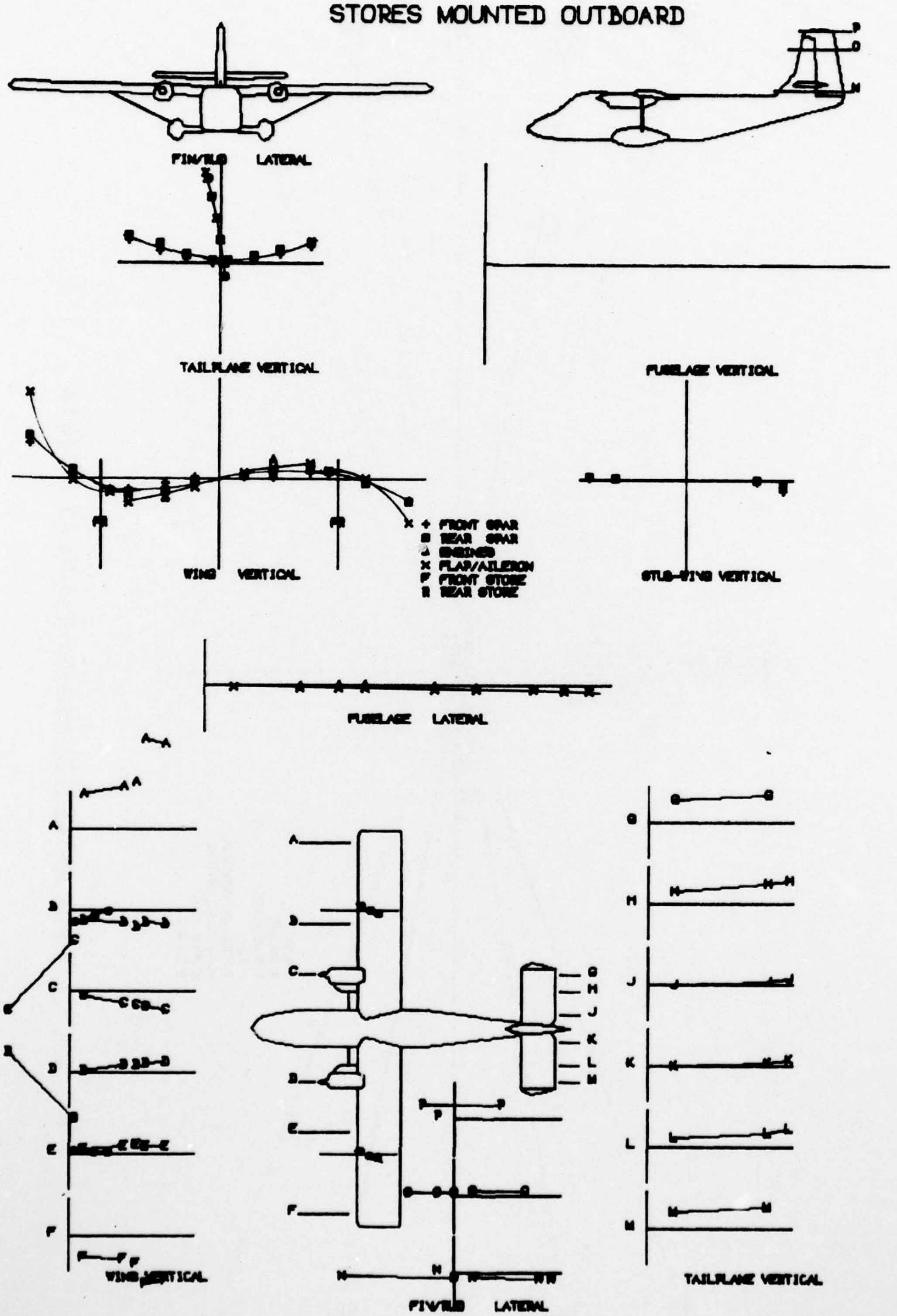


FIG. 40a MODE AT 15.45 Hz

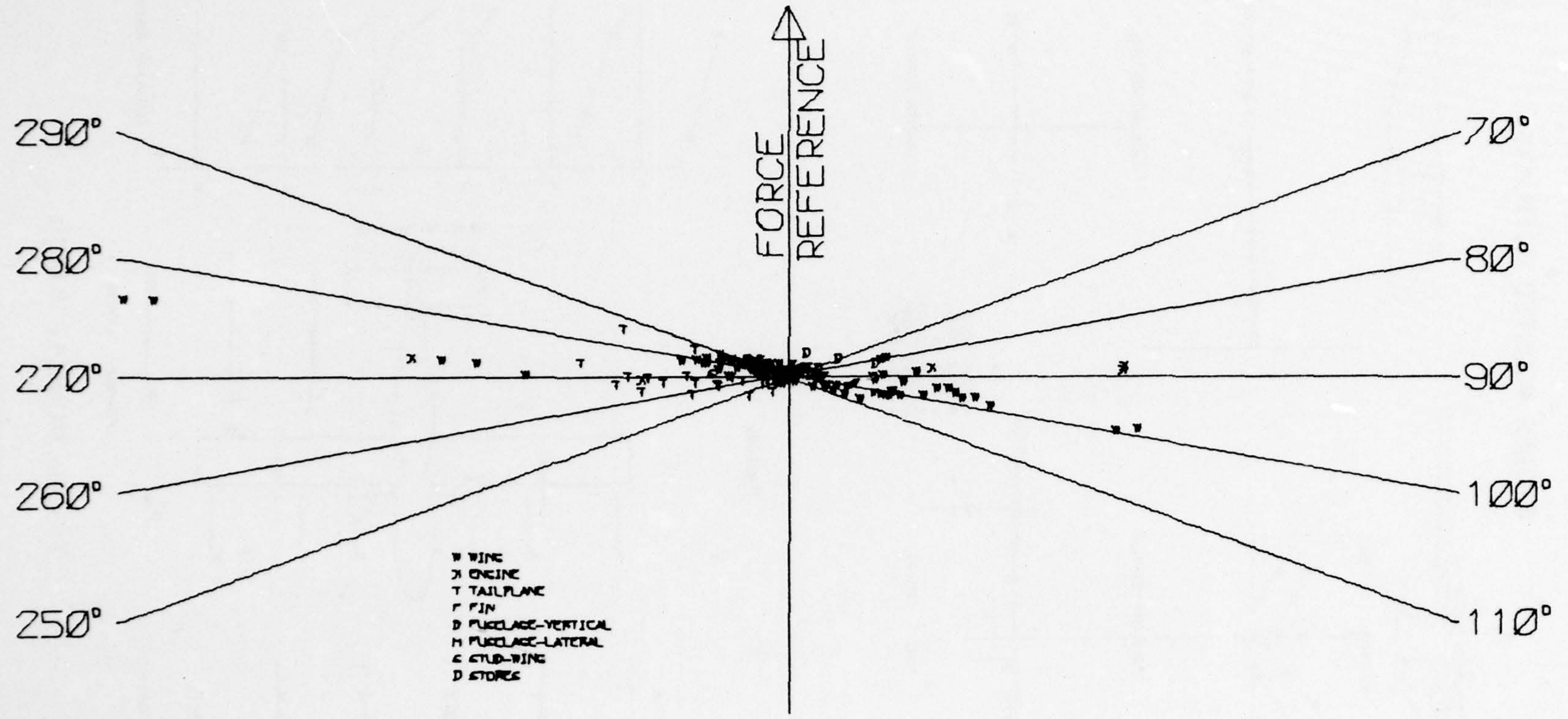


FIG. 40b VECTOR RESPONSE MODE AT 15.45 Hz

STORES MOUNTED OUTBOARD

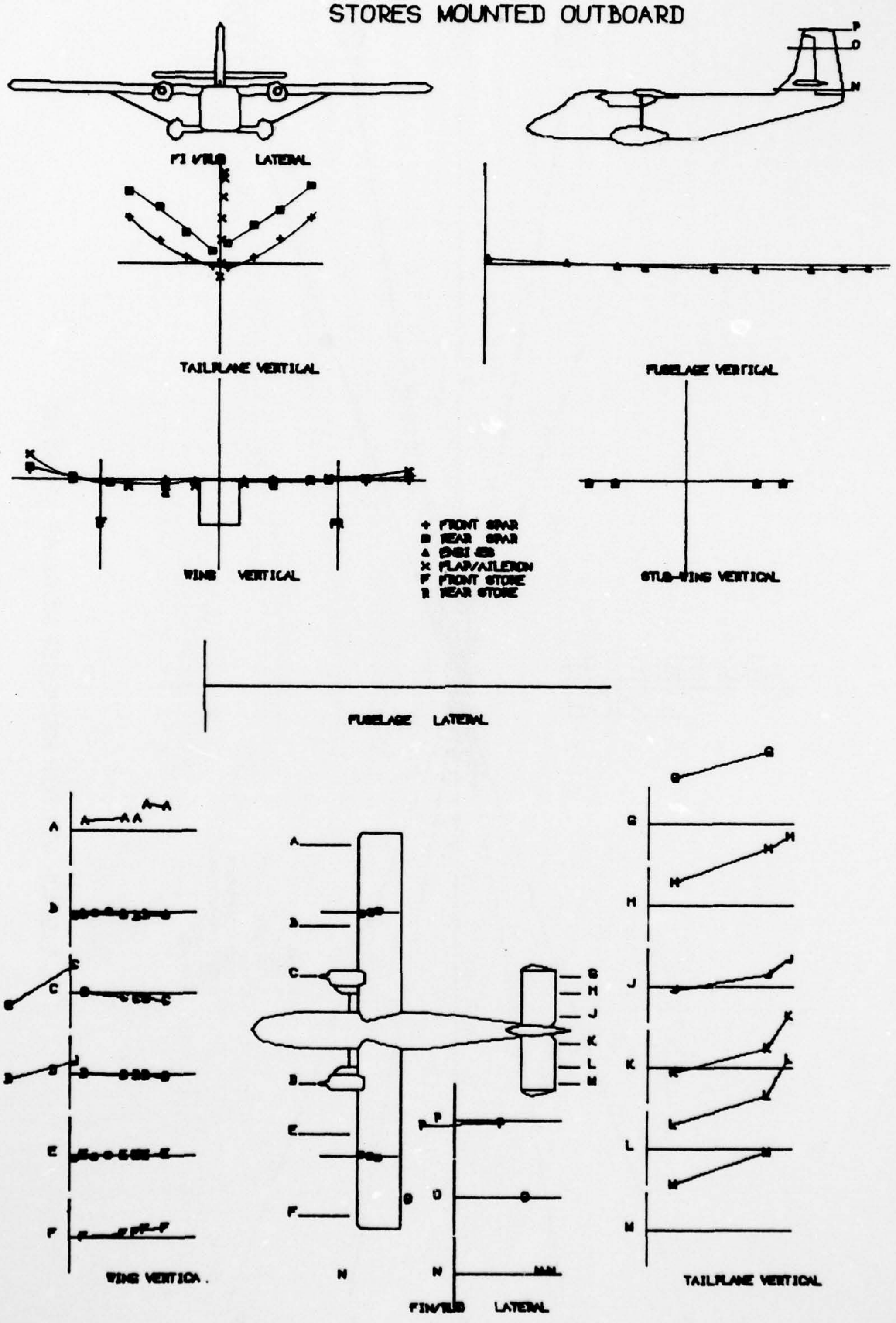


FIG.41a MODE AT 15.65 Hz

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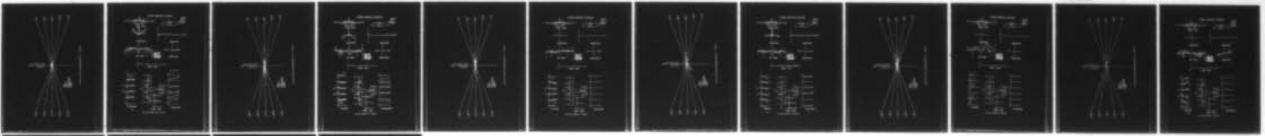

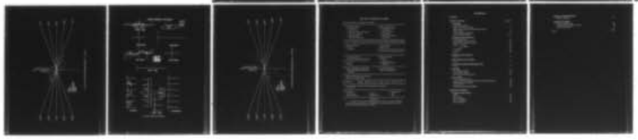

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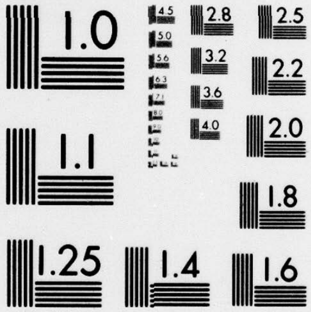

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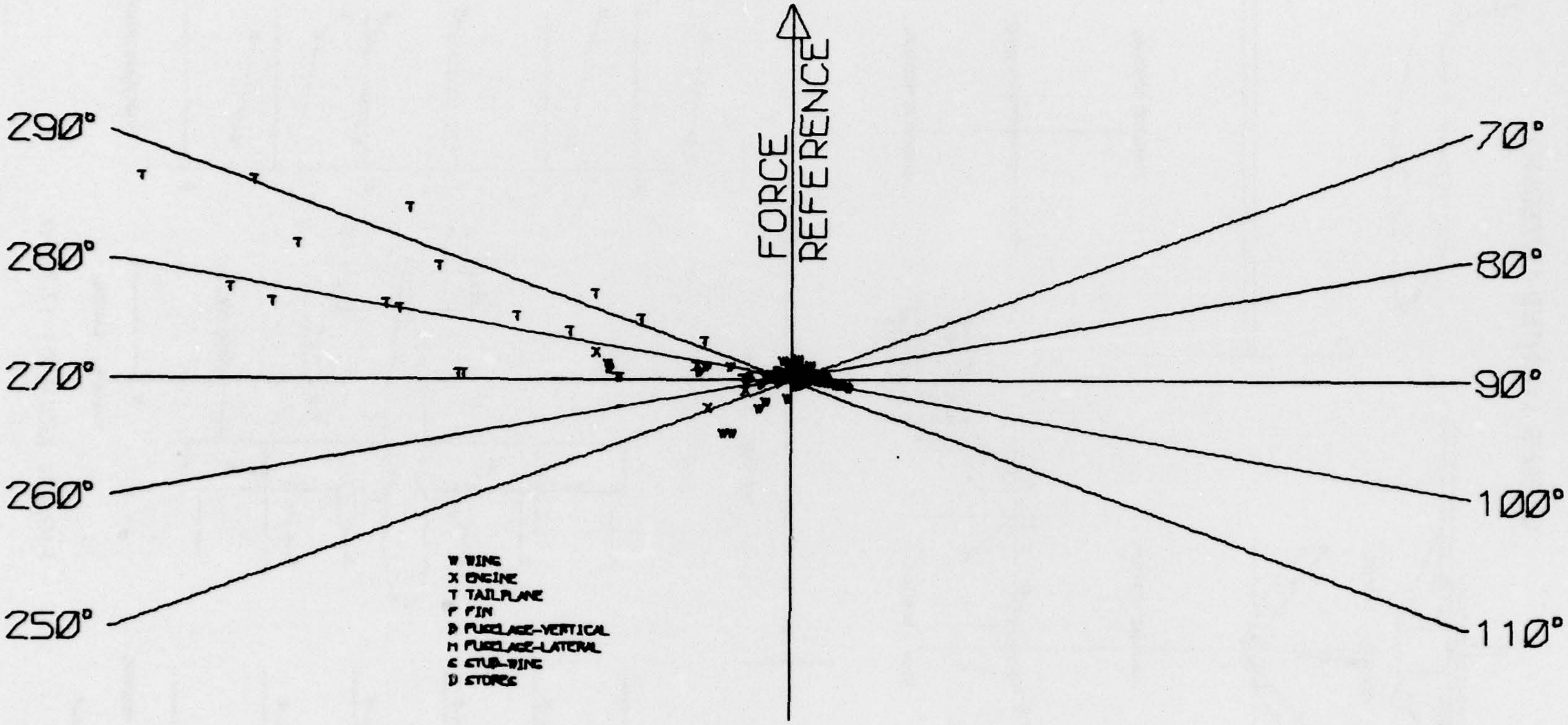

FIG. 41b VECTOR RESPONSE MODE AT 15.65 Hz

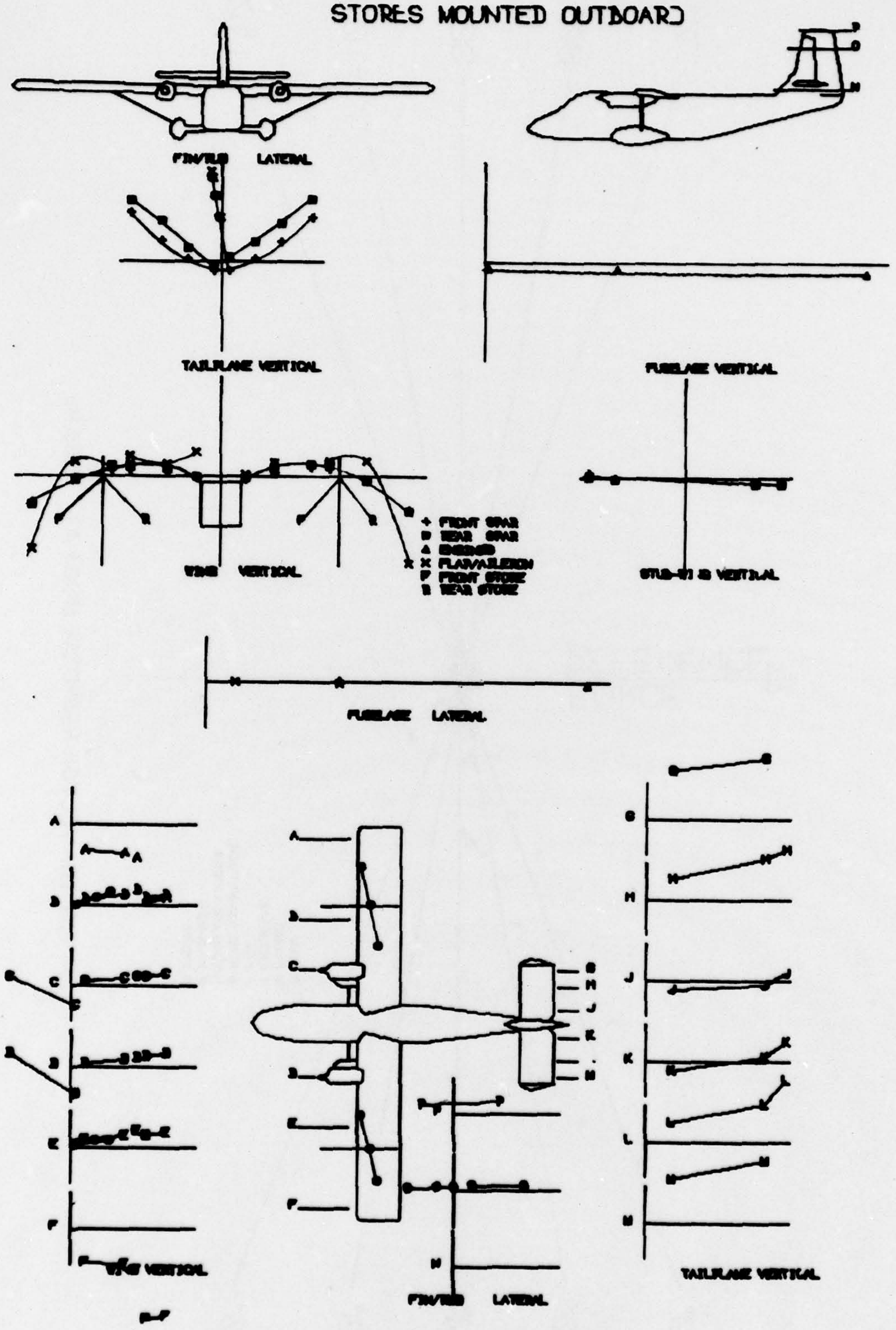

FIG.42a MODE AT 17.10 Hz

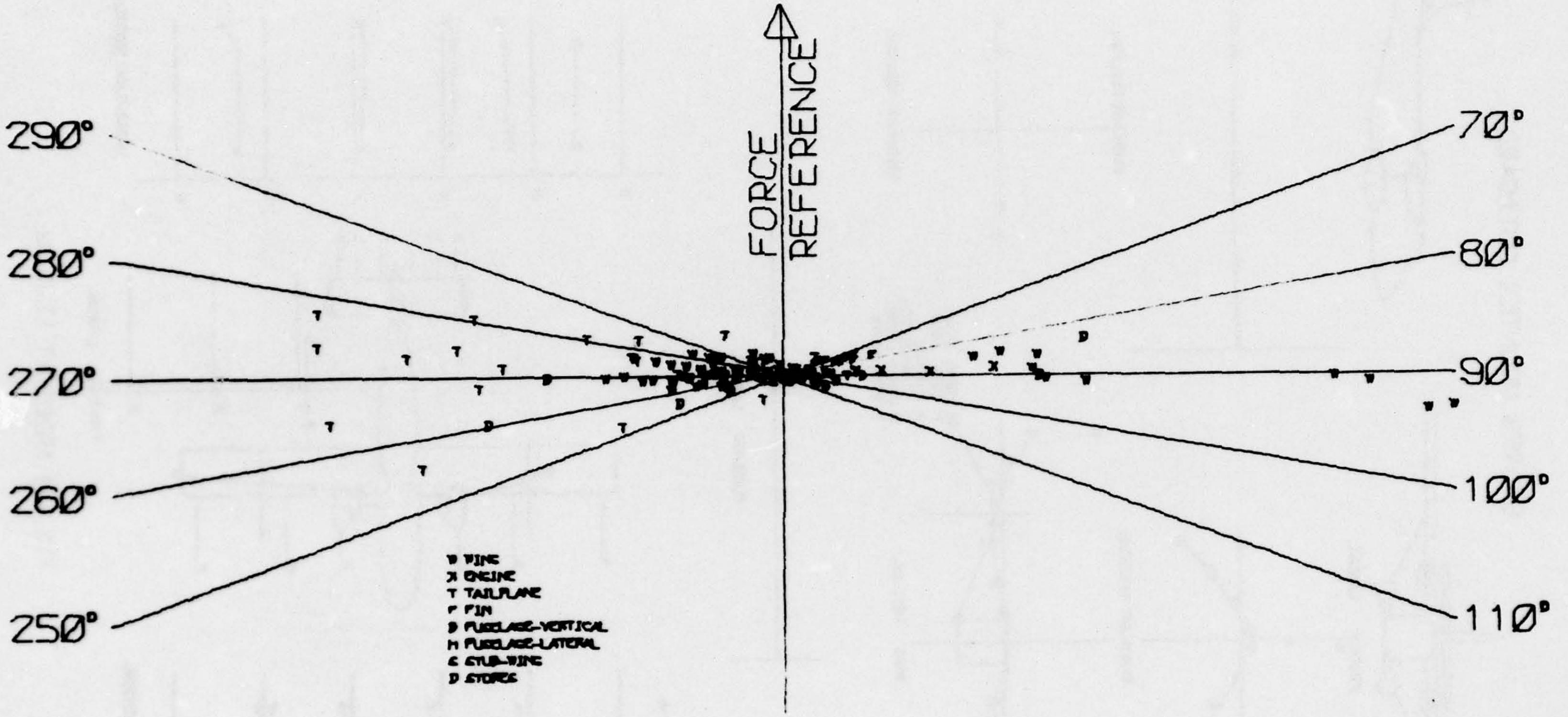

FIG. 42b VECTOR RESPONSE MODE AT 17.10 Hz

STORES MOUNTED OUTBOARD

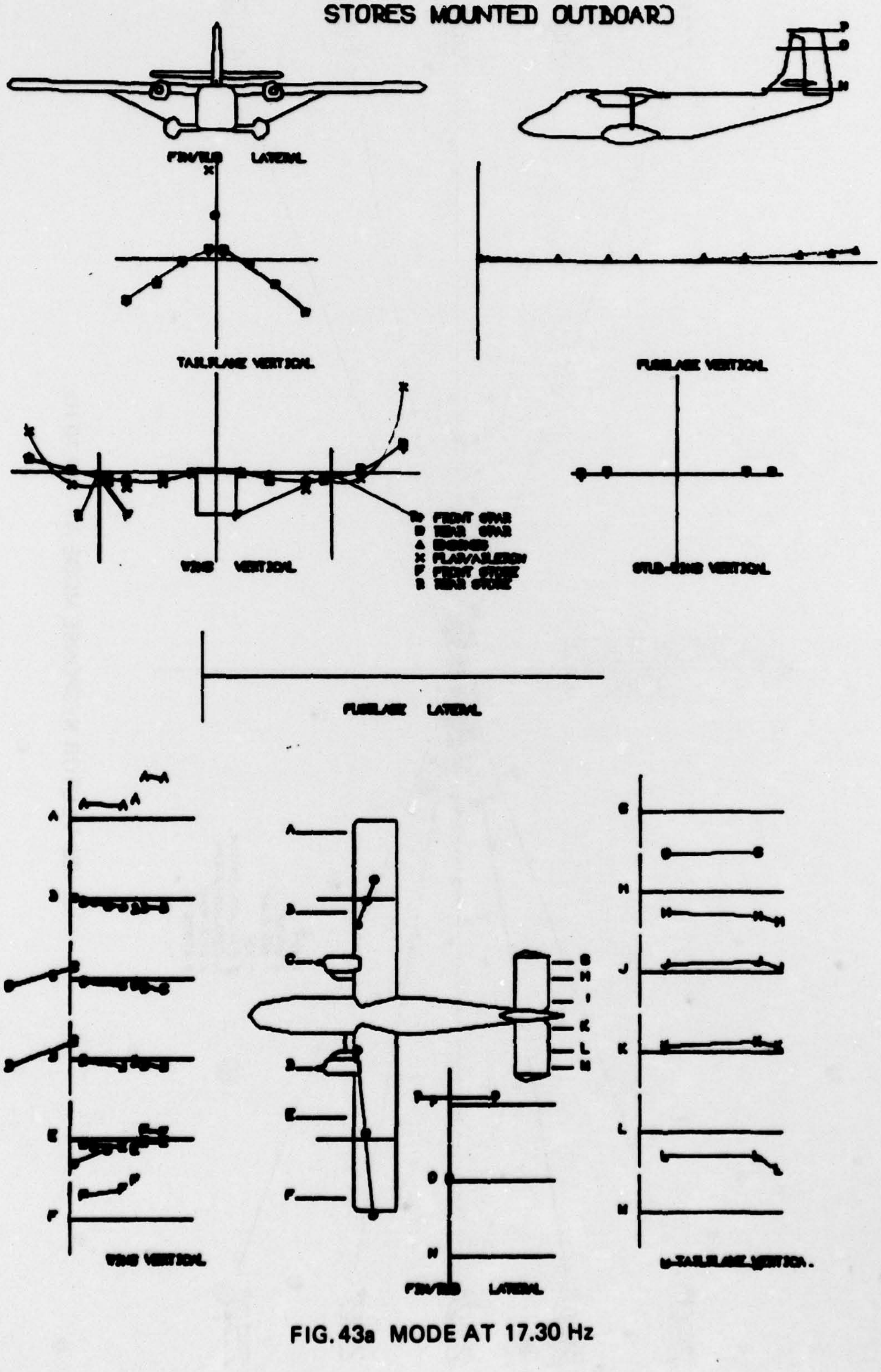

FIG. 43a MODE AT 17.30 Hz

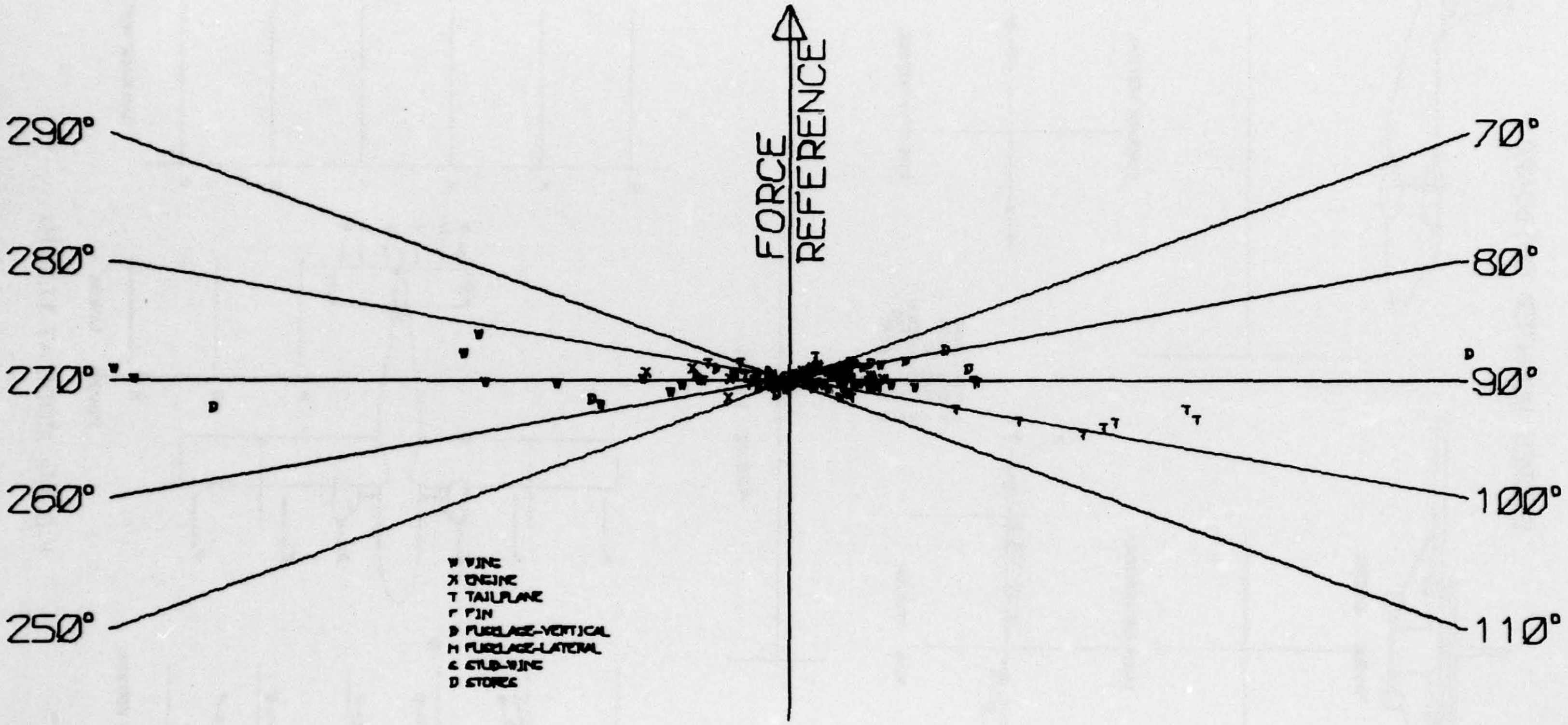

FIG. 43b VECTOR RESPONSE MODE AT 17.30 Hz

STORES MOUNTED OUTBOARD

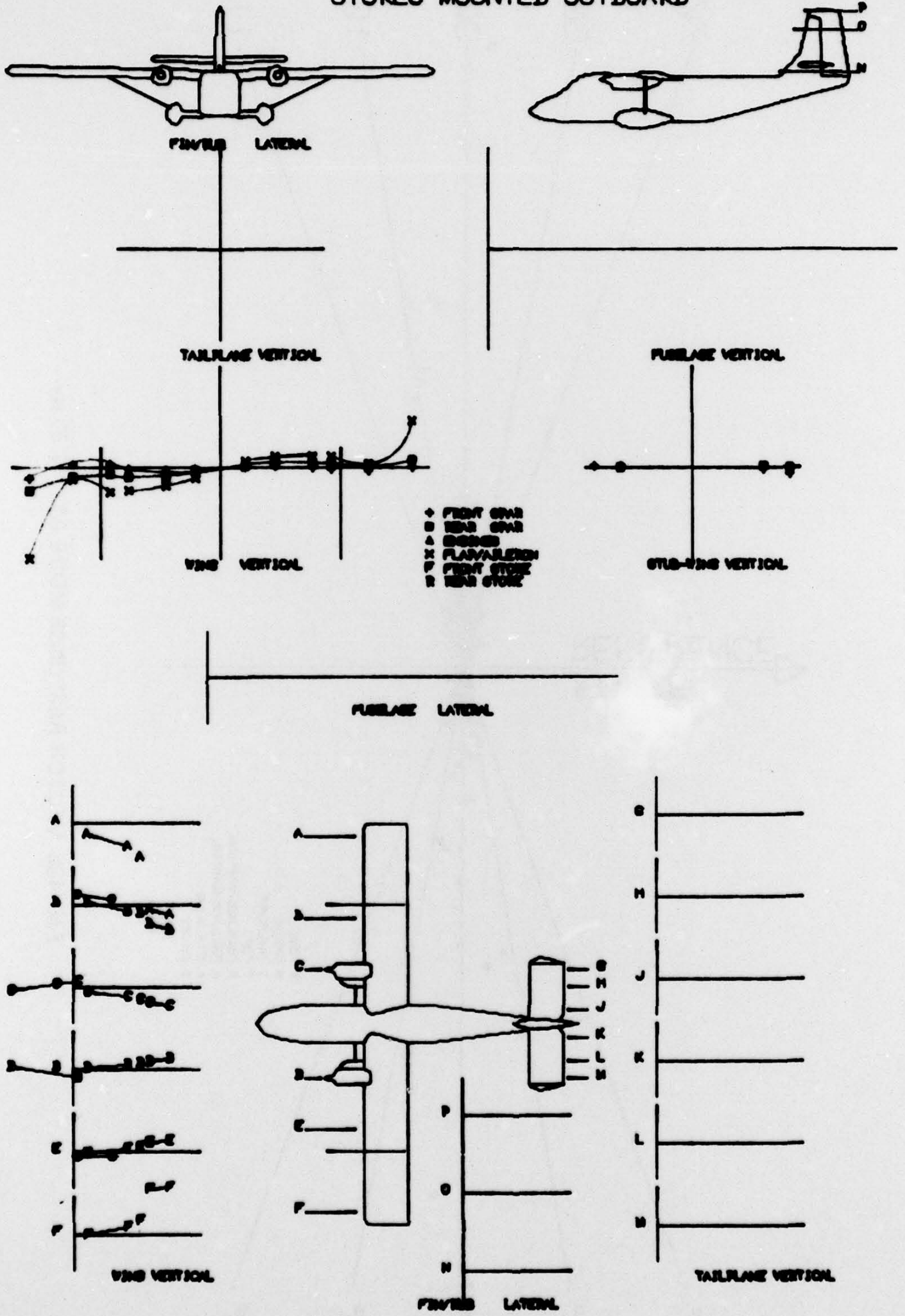

FIG. 44a MODE AT 17.96 Hz

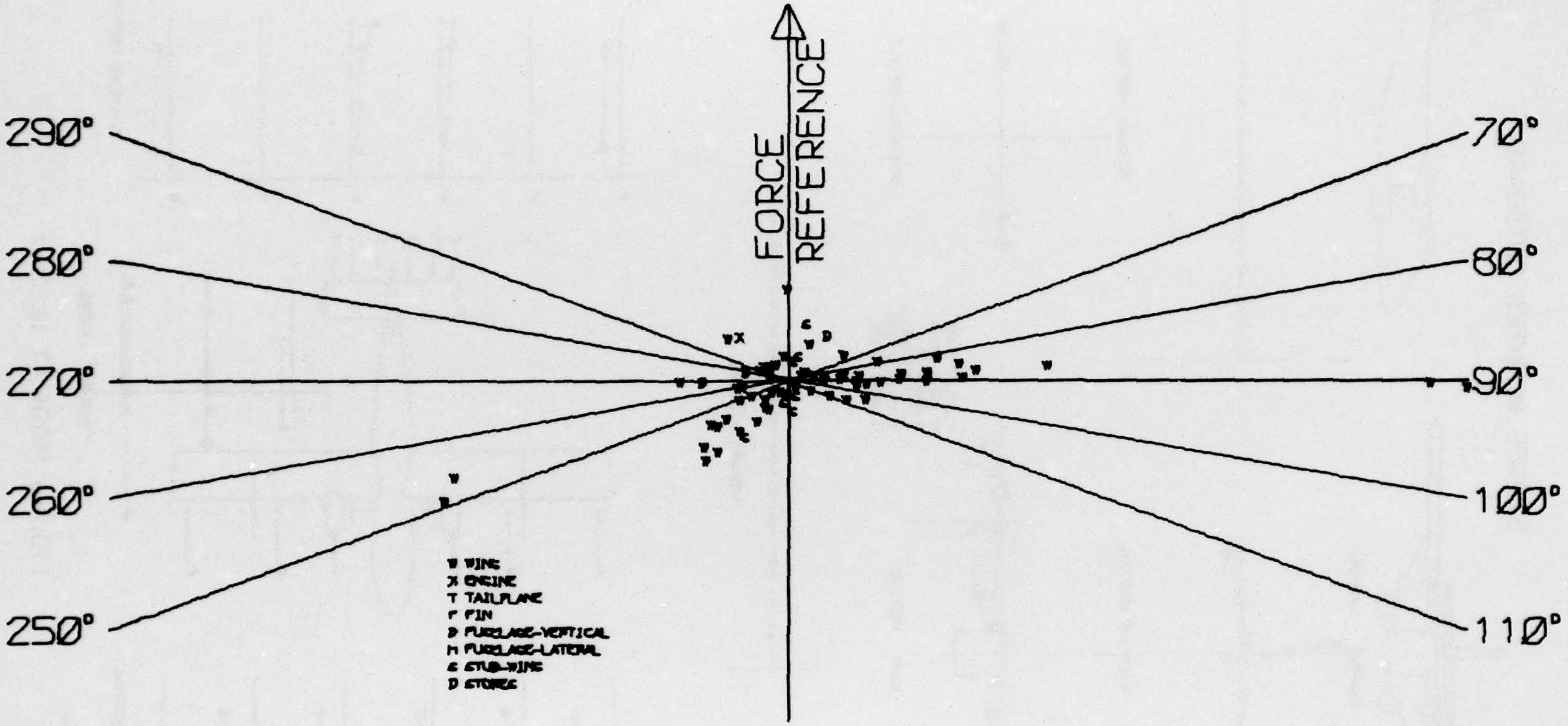

FIG. 44b VECTOR RESPONSE MODE AT 17.96 Hz

STORES MOUNTED OUTBOARD

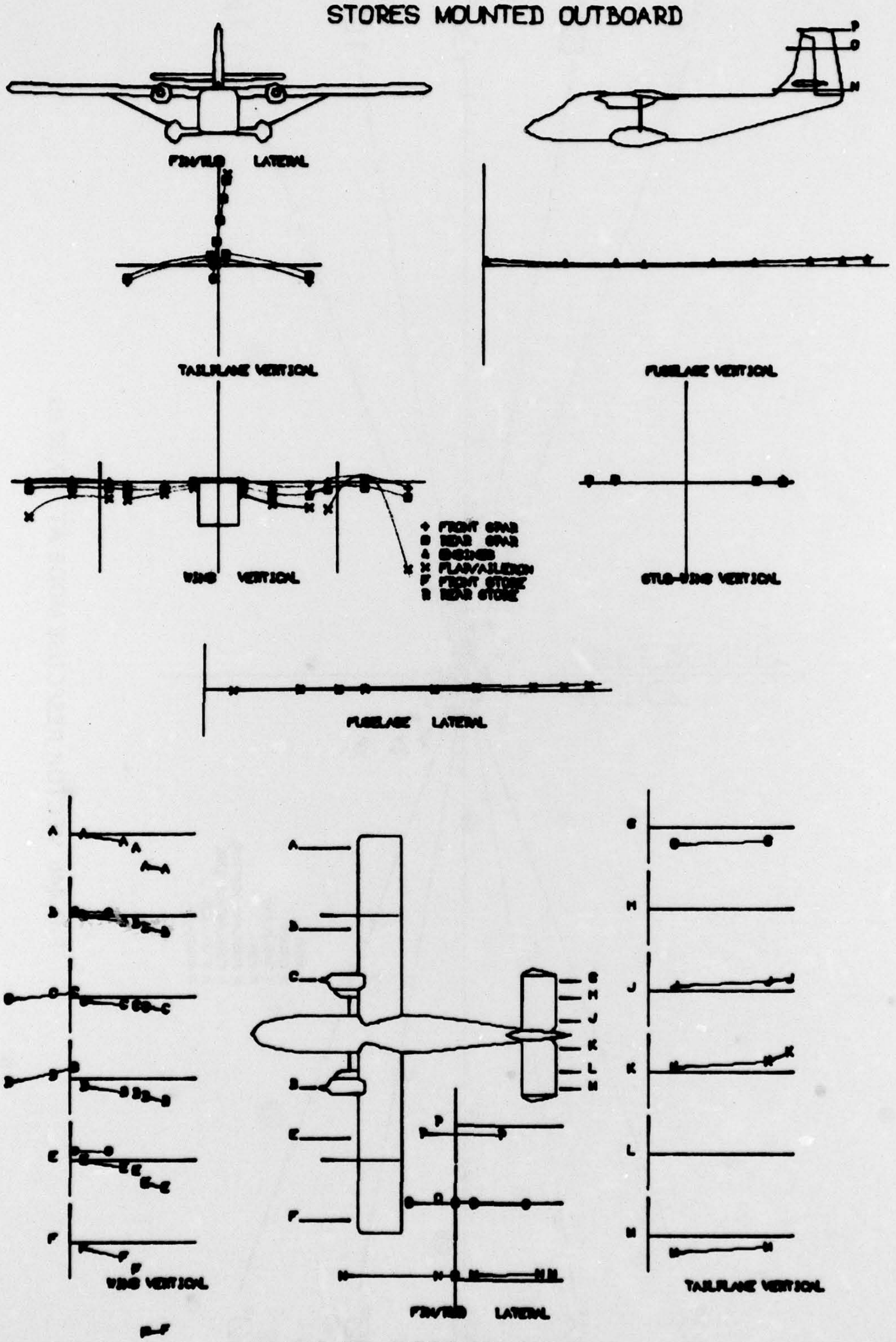

FIG. 45a MODE AT 18.67 Hz

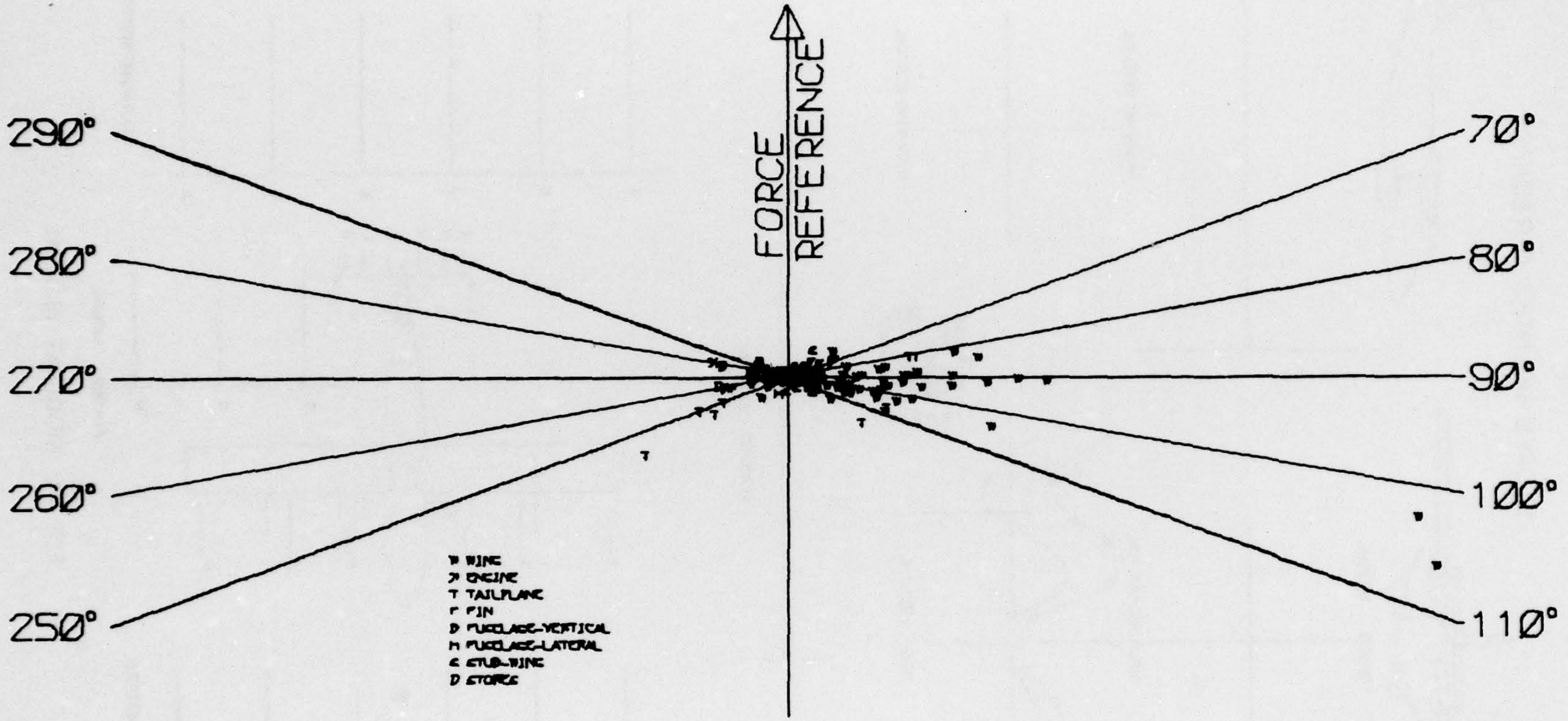

FIG. 45b VECTOR RESPONSE MODE AT 18.67 Hz

STORES MOUNTED OUTBOARD

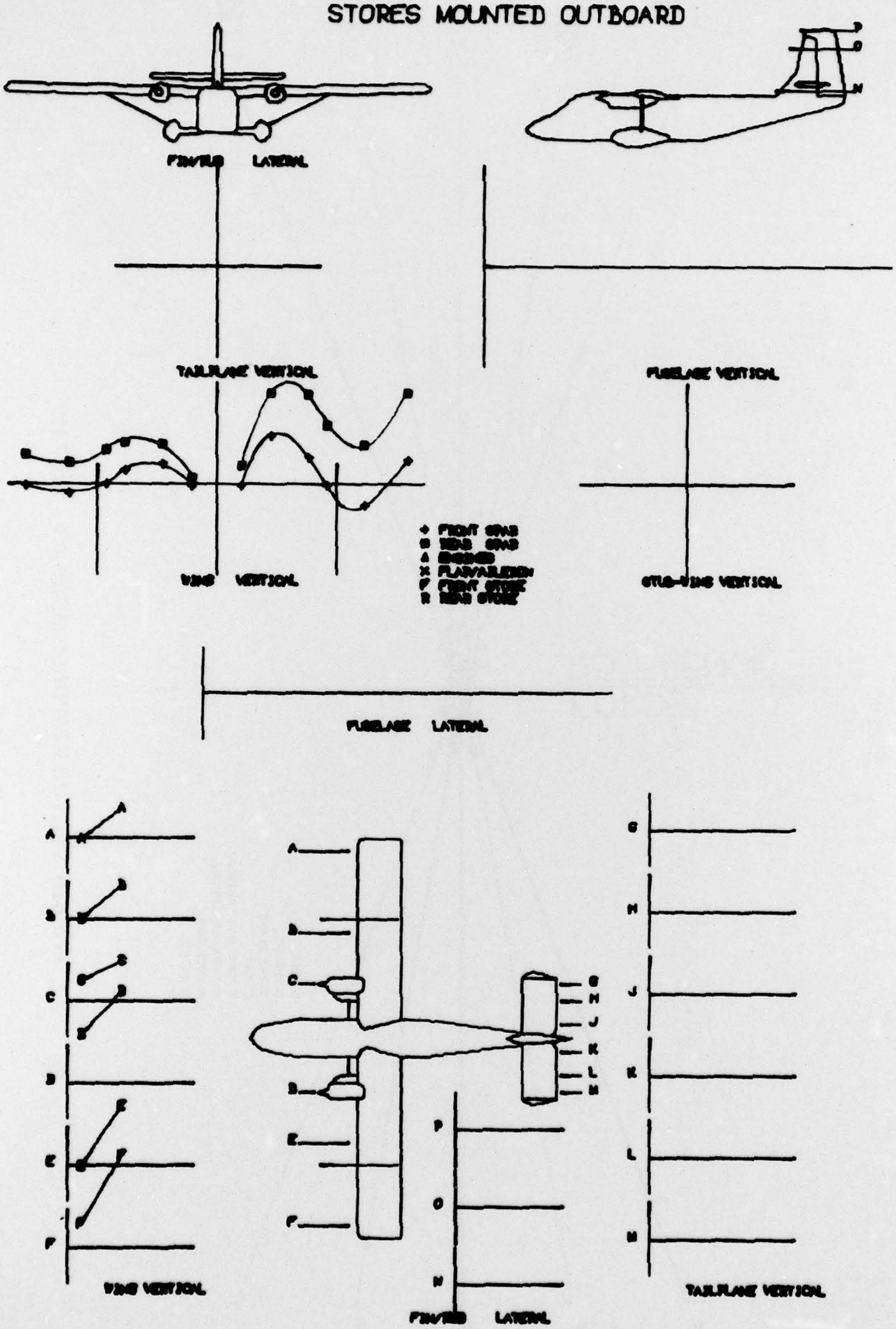

FIG. 46a MODE AT 18.92 Hz

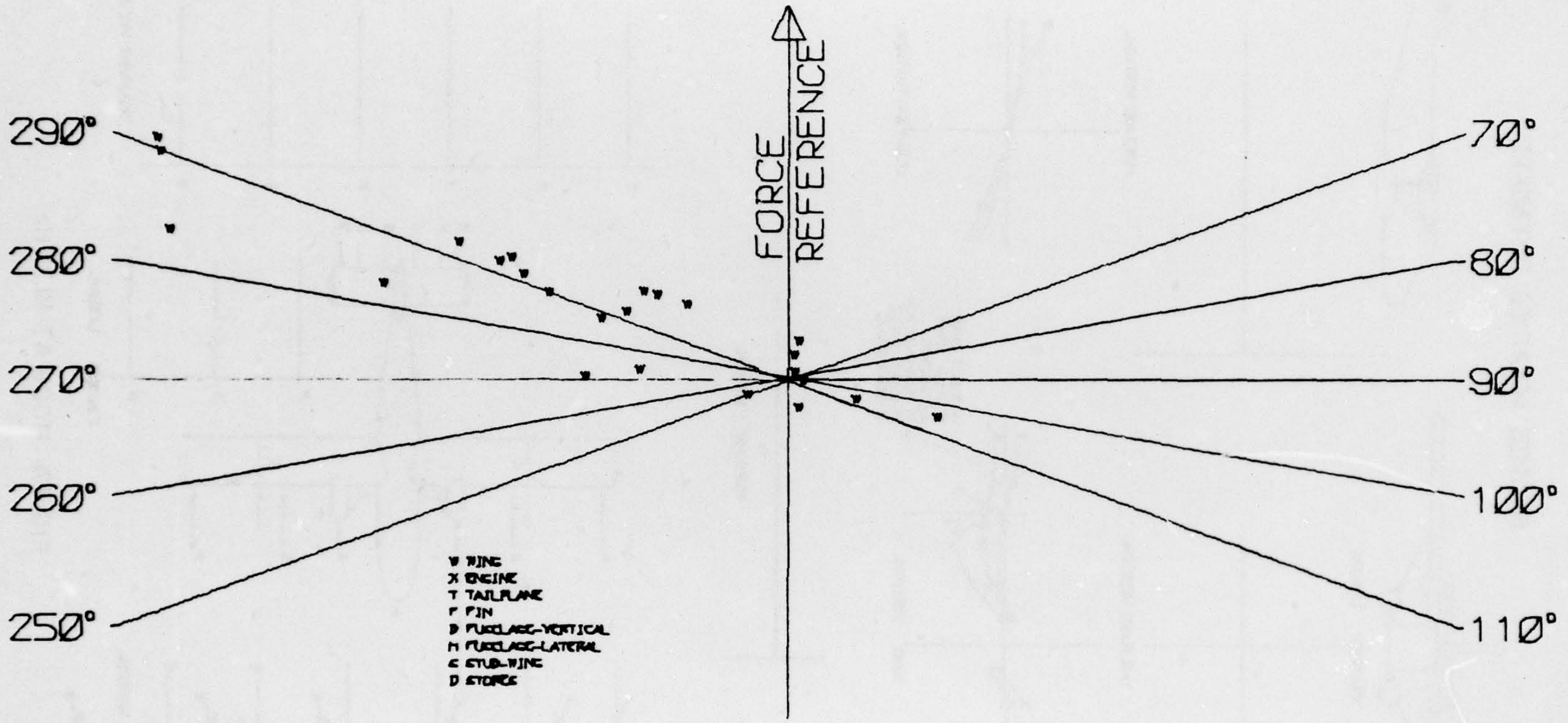

FIG. 46b VECTOR RESPONSE MODE AT 18.92 Hz

STORES MOUNTED OUTBOARD

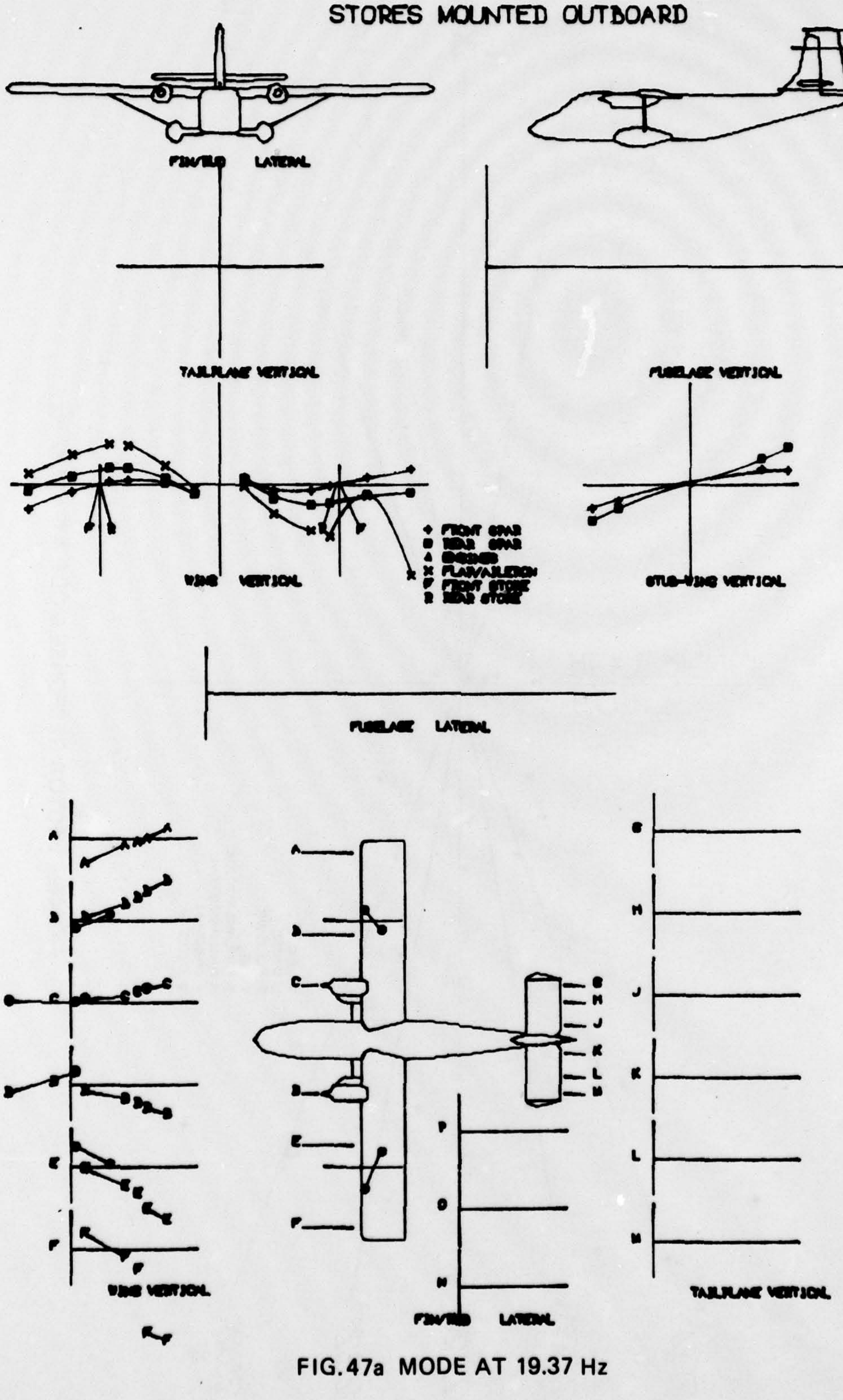

FIG.47a MODE AT 19.37 Hz

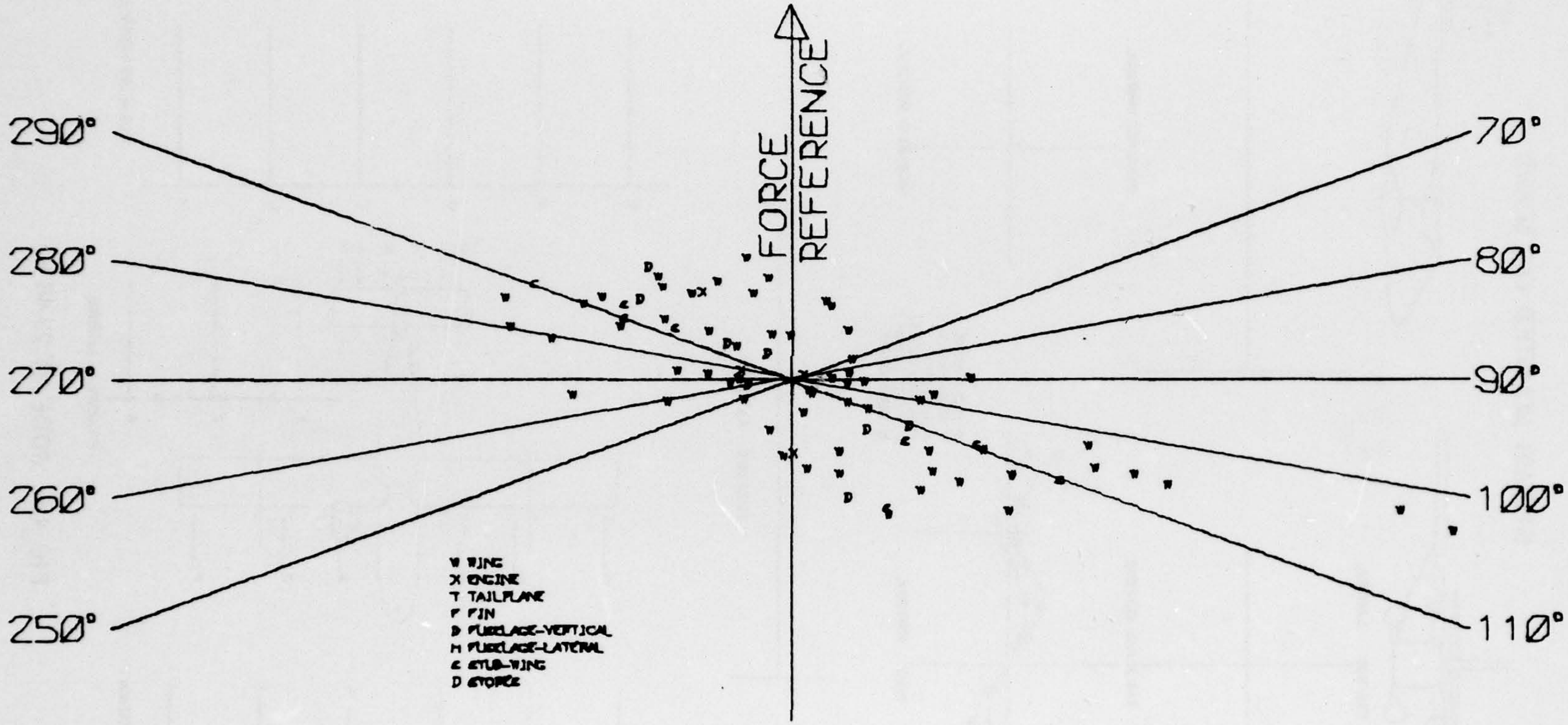

FIG. 47b VECTOR RESPONSE MODE AT 19.37 Hz

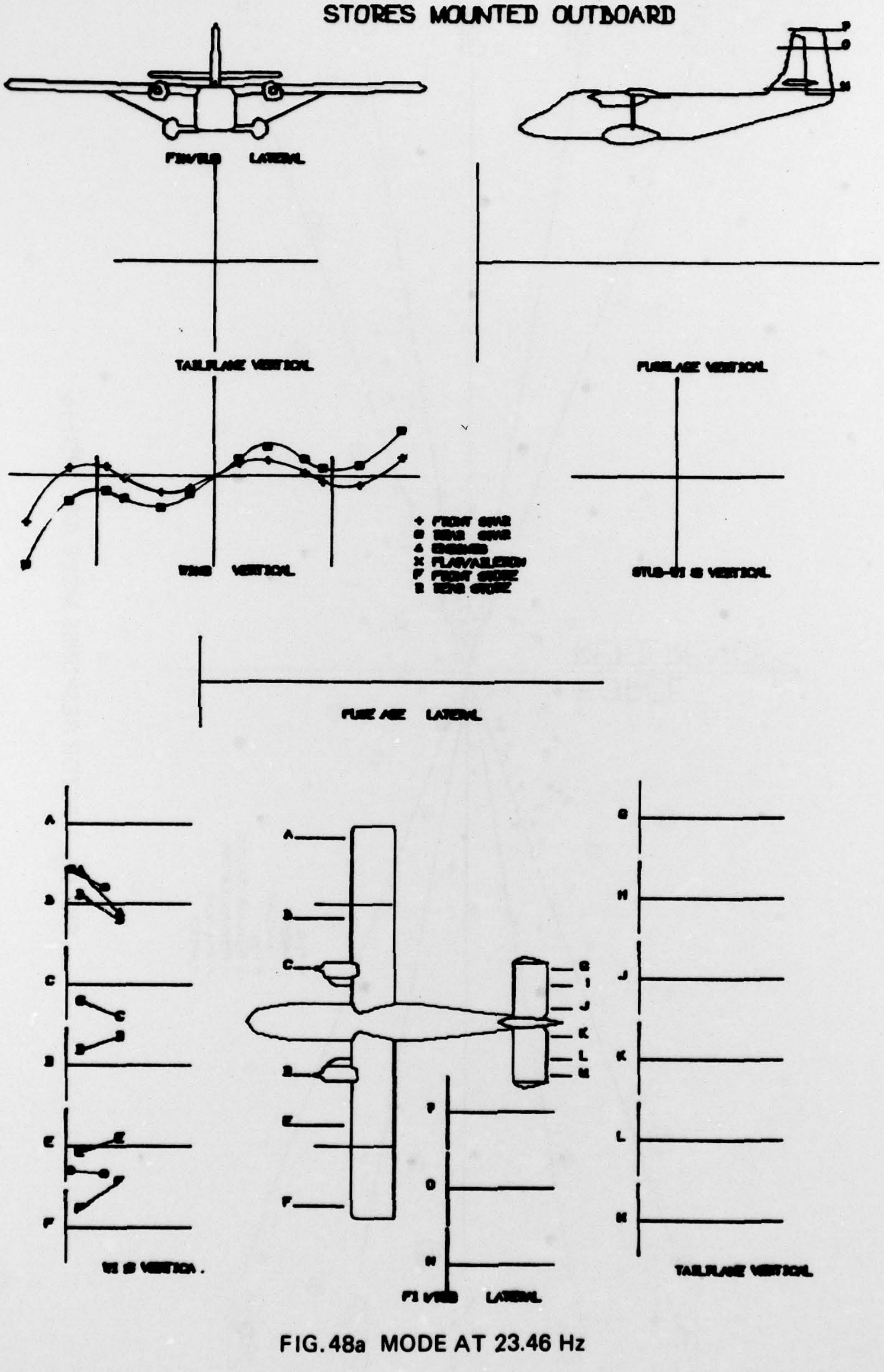

FIG. 48a MODE AT 23.46 Hz

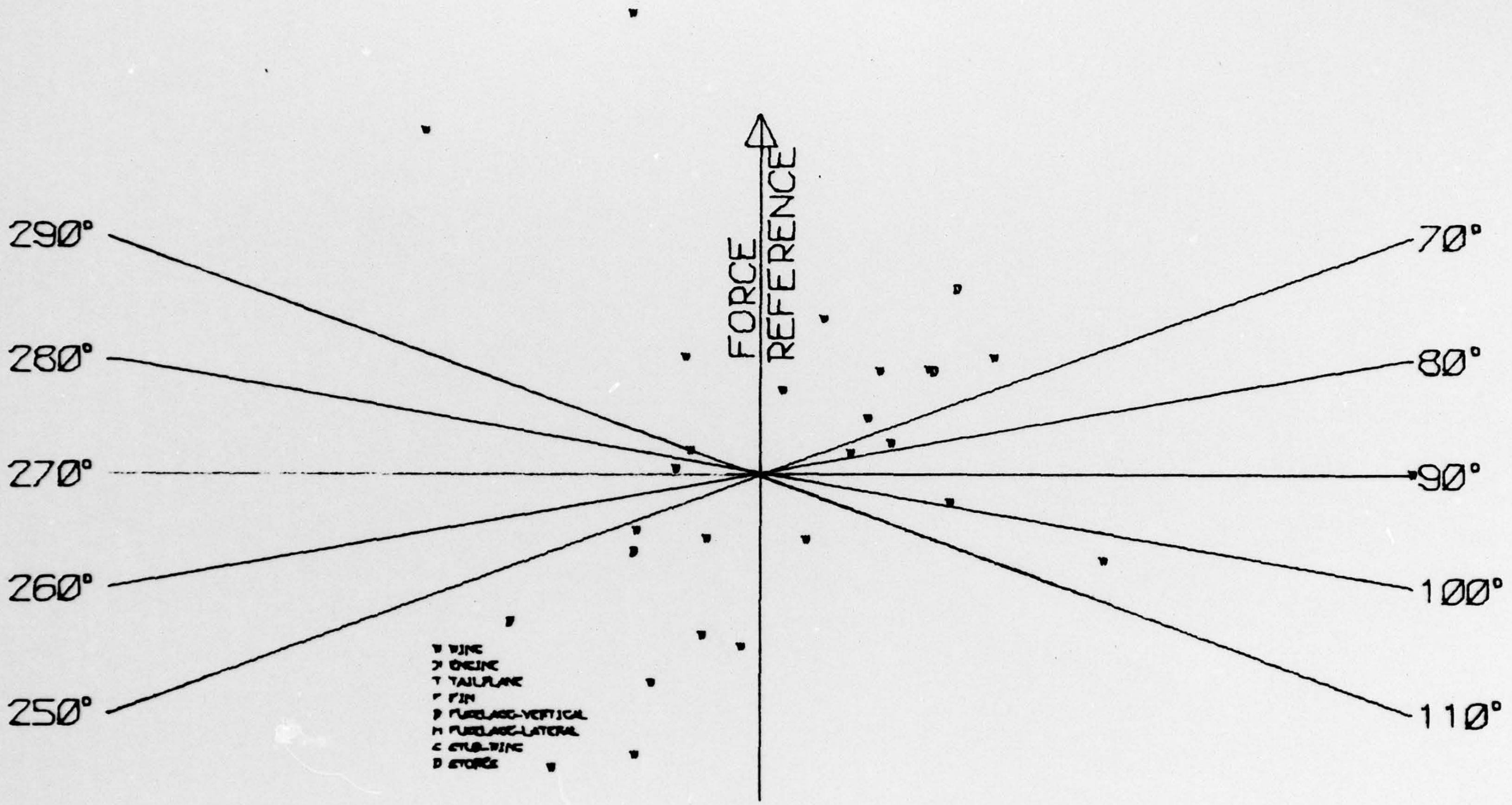

FIG. 48b VECTOR RESPONSE MODE AT 23.46 Hz

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16. *ABSTRACT*

A resonance test on the N22 Nomad, fitted with external stores, has been conducted. The natural modes and frequencies of vibration have been measured for two store configurations, in the frequency range up to 30 hertz.

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