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Design and Fabrication of the NASA Decoupler Pylon for the F-16 Aircraft, Addendum II

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GENERAL DYNAMICS
Fort Worth Division
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Contract NAS1 — 16879
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SUMMARY

The initial ground and flight tests of the assembled ship set of decoupler pylons were completed. From these tests it was determined that a high level of friction existed in the pylon pivot joints. The evaluation of the test data indicated that the friction was large enough that the onboard airplane excitation system could not excite the GBU-8 pitch mode. This excessive friction could possibly have prevented the decoupler pylon from operating successfully in suppressing wing/store flutter.

A design modification which replaced the bushings in the pylon pivot joints with roller bearings was proposed. This modification was incorporated in the pylons. This hardware modification was supported with dynamic, stress and load analyses and ground tests of the hardware in a fixture. The details of this design change, the supporting analyses, and the fixture tests are presented in this document.

INTRODUCTION

The NASA Langley Research Center has investigated the use of a decoupler pylon as a means of suppressing wing/store flutter (references 1 through 6). The concept consists of reducing the pylon pitch stiffness until the store/pylon pitch frequency is less than the fundamental wing bending frequency. These studies and wind tunnel tests have been expanded to include the fabrication of a ship set of pylons for the F-16. These pylons have been ground and flight tested. These tests revealed the need for reduced friction in the pylon pivot joints. A retrofit design was developed which incorporated roller bearings in the pivot joints to replace the original bushings.

This addendum to the basic report summarizes the design changes, load, stress and dynamic analyses related to this design change and the test of the pylons in a fixture. The analyses and fixture tests described herein were required parts of the development program which is in preparation for the second phase of the complete airplane ground and flight test program. The primary ground test will be a complete airplane ground vibration test. The flight test program will include flutter tests, maneuvering flight and a single store ejection. The airplane ground vibration test and the flight test are not described in this document.

DESIGN MODIFICATION

The pivot joint links and pins were redesigned to incorporate needle bearings in place of the bronze bushings which were in the original design. In addition, thrust bearings were placed between the links and support lugs. The purpose of these changes was to reduce the pivot joint friction and to reduce joint bind-up under side loading and yawing moment load conditions. The original design had constant diameter pins. The new pins have smaller diameters on the ends to accommodate the bearings. To provide space for the thrust bearings, both links were reduced in width from 7.24 cm (2.85 in.) to 6.91 cm (2.72 in.). Bushings were designed which could be used as bearing races and spacers between the bearing and holes in the upper strongback and in the holes in the lower side plates. All other components of the pylon system remained unchanged.

Needle bearings were selected from the Torrington catalog. Aircraft quality bearings were selected. The bearings which were selected are:

Catalog No.	Installation Location
12 NBC 1882 YZP	Upper Aft Pin
10 NBC 1620 YZP	Lower Aft Pin
10 NBC 1620 YZP	Upper Fwd Pin
9 NBC 1419 YZP	Lower Fwd Pin

This selection was based upon space available and load capacity.

Thrust bearings were also selected from the Torrington catalog. The thrust bearings which were selected are:

Total No. Req'd	Catalog No.	Installation Location
1	NTA 2435	Upper Aft Pin
1	TRA 2435	Upper Aft Pin
3	NTA 2031	Lower Aft Pin, Upper Fwd, Lower Fwd
3	TRA 2031	Lower Aft Pin, Upper Fwd, Lower Fwd

An O-ring seal was placed around the outer diameter of each thrust bearing. The catalog numbers of the O-rings are:

Total No. Req'd	Catalog No.	Installation Location
1	MS28775-228	Upper Aft
3	MS28775-226	Lower Aft, Upper End and Lower Fwd

The details of each joint assembly are shown on a section drawing. These sections are shown on Figures 1 and 2. These figures show the modified link and pin geometry, and the complete assembly.

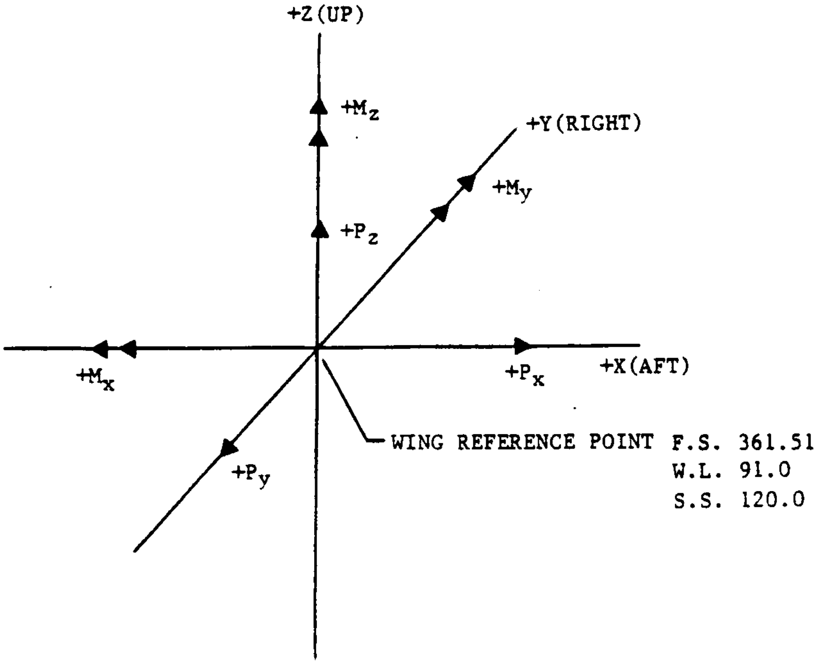
LOADS ANALYSIS

A series of load conditions which could be used to determine the stress margins of safety of the design modification was generated. These conditions are a subset which gave the greatest loads from the load conditions used in analyzing the pylon originally. The general guideline for these load conditions was to evaluate the airplane with the modified decoupler pylons for 4 g wind-up-turns up to a Mach number of 0.9 at an altitude of sea level. The airplane store configuration was AIM-9 and launcher on the wing tip, GBU-8 on stations 3 and 7 (span station 120) and 370 gallon tank with the center bay empty at stations 4 and 8 (span station 71). Limit loads compatible with these flight test conditions and airplane configuration were calculated.

The loads analysis used a pylon weight of 118.1 kg (260.4 lb) with a center of gravity at fuselage station 349.3, buttock line 120.0, and water line 83.1. The GBU-8 weight used was 1027 kg (2265 lb) with the center of gravity at FS 338.5, BL 120.0, and WL 64.9.

The design envelope for carriage of the decoupler pylon with the roller bearing kit on the F-16 includes altitudes from sea level to 20,000 ft, and all speeds from 0 to 550 KCAS up to Mach 0.95. Aircraft maneuvers included balanced symmetric pull-ups at load factors ranging from $n_z = 0$ g to +4.0 g for carriage and ejection, and roll maneuvers for carriage only at load factors ranging from $n_z = 0$ g to +3.0 g. Roll maneuvers are limited to no abrupt roll command, 90° bank angle and store configuration switch set to CAT III. The range of flight conditions and maneuver conditions (GBU-8 carriage only) for which the loads were computed are shown on Table 1. All combinations shown on Table 1 were not analyzed. Only the most critical combinations which were selected based upon the stress analysis results were analyzed. Therefore, a coordinated effort between the Loads Group and the Stress Group to determine the critical load conditions was required. In the previous loads analyses (Reference 7) GBU-8 carriage and other store carriage on the decoupler pylon were considered.

A composite list of decoupler pylon loads are presented in Appendix A. The positive sign convention for the reference point load is shown below. The reference point is in the wing plane at the decoupler pylon span station.



Pylon loads were generated from the reference point loads (Appendix A) which are in the wing plane. These reference point loads were transferred to the pylon by using the geometry of the pylon with it aligned and for misalignment angles of ± 1/2 degree.

Incremental loads due to store ejection combined with steady state loads were considered for 1.0 g and 4.0 g ejections at several Mach numbers and altitudes. The net limit loads during ejection are tabulated in Appendix A.

These load conditions were also used to determine stress margins of safety. These stress margins of safety are included in Appendix B.

STRESS ANALYSIS

The stress analysis of the design modification was devoted entirely to pylon links, pins, and bearings. These components were the only ones modified in the retrofit to roller bearings. A finite element model was not available to use in the stress analysis, therefore, a computer program which transferred the loads from the wing reference point to the linkage apex was developed and used. The reference point loads are discussed in the loads analysis section and are presented in Appendix A. The loads at the apex were then transferred to the links. A distribution of 40% of the load to the forward link and 70% of the load to the aft link was assumed. This assumption adds a 10% conservatism factor to the predicted margins of safety. The margins of safety were calculated for store misalignments of zero and ± 1/2 degree. These misalignment angles of ± 1/2 degree result in a different relationship between the axial load and the bending moment at the forward and aft links. This difference is due to the movement of the apex and change in the linkage angles.

The small reduction in the link width from 7.24 cm (2.85 in.) to 6.91 cm (2.72 in.) results in a very small increase in stress level. These links have large margins of safety with the original links and this margin is not significantly reduced by the reduction in width. The original pins, however, were constant diameter. The new pins have a small diameter at the ends (Figures 1 and 2) which results in higher stress levels and lower margins of safety. All other components of the pylon have high margins of safety, therefore, only the margins of safety for the pins were computed for a large number of load conditions. The pin margins of safety for the zero misalignment load condition are shown in Appendix B. High roll rate in combination with large n_z results in the minimum margins. Store misalignment angle has a very small effect upon the pin margins of safety. The lowest margin occurs on the aft lower pin at 0.60 Mach at sea level with n_z = 3.0 g and a roll rate of 75 degrees per second for the three alignment angles (zero, ± 1/2 degree).

The low margins of safety case identified above results in a maneuvering flight restriction on the airplane when carrying the GBU-8 on the decoupler pylon. This restriction was set at roll rates of less than 70 deg/sec when pulling a positive 4g for all flight conditions. All parts of the flight test demonstration of the pylon could be accomplished with this maneuver restriction, since the primary purpose of the demonstration was the flutter suppression potential of the pylon.

DYNAMIC ANALYSIS

The test data obtained from a complete airplane ground vibration test of the F-16 with the decoupler pylon was used as one set of data to improve the airplane simulation. The complete airplane ground vibration test results are presented in reference 8. A fixture test of the pylons after retrofit with the roller bearings was conducted. This test data is presented here and was used to improve the pylon simulation. These simulations, airplane and pylon, were combined into a finite element model which was used to compute complete airplane modes of vibration. The modes of vibration were then used to conduct flutter analyses and aeroservoelastic analyses. The mode shape tuning, the flutter analyses and the aeroservoelastic analyses are discussed here.

Mode Shape Tuning

The ground vibration test data reported in reference 8 (1983 GVT) and 1984 GVT data were obtained with the airplane supported on the landing gear with partly inflated tires and collapsed main and nose gear struts. Therefore, a finite element simulation of the airplane on the landing gear was used to tune the simulation to the test data. An existing simulation with gear springs was used as the baseline for the tuning process. The first step in the process was to tune the gear springs. The second step was to tune the decoupler pylon and the remaining parts of the airplane structure.

The complete airplane symmetric modes of vibration were computed with the baseline gear springs. The lowest two mode frequencies with this simulation are shown on Table 2. The 1/2 airplane gear spring rates are also shown on Table 2. These springs produced a lower pitch frequency than was obtained from the measurements. In this case the nose gear spring included both the tire and the strut. The tire has an estimated spring rate of 416 kN/m (2375 lb/in) and the strut has an estimated spring rate of 44 kN/m (253 lb/in). These two spring rates in series result in the baseline value used initially for the nose gear. The nose gear spring rate was increased by the ratio of the square of the measured frequency to the 1983 calculated value. The frequencies computed from this increased nose gear spring rate are identified on Table 2 as Iteration 1. This nose gear spring rate of 453 kN/m (2591 lb/in) is close to the estimated nose gear tire spring rate of 416 kN/m (2375 lb/in). The nose gear spring rate was increased to 544 kN/m (3109 lb/in) to increase the pitch frequency to a value of 2.03 Hz. The resulting frequencies are identified as Iteration 2 on Table 2. The nose gear stiffness increase did not raise the pitch frequency by the ratio of the nose stiffness increase, and therefore, an increase in the main gear stiffness was incorporated to increase the pitch frequency. This increased main gear stiffness is Iteration 3 on Table 2. This iteration was considered a good enough match to the test data.

The complete airplane antisymmetric modes of vibration were computed with the baseline gear springs. The lowest three mode frequencies with this simulation are shown on Table 3. The gear spring rates for 1/2 airplane are also shown on Table 3. The lowest frequency mode was roll. The second mode was a combination of yaw and roll, and the third mode was primarily a side translation mode. These rigid body airplane modes are coupled which makes the individual gear springs effect all the rigid body mode frequencies. The individual gear spring rates were changed and the modes were computed. These iterations are shown on Table 3. With these changes in the gear springs it was impossible to match closely the 1983 ground vibration test data. The frequencies for the fifth iteration and with the wings empty show the effect of wing fuel upon the rigid body mode frequencies.

The five iterations in the gear spring were made prior to obtaining the 1984 ground vibration test results. These iterations were made to attempt to match the 1983 GVT data. After obtaining the 1984 GVT results it became obvious that Iteration number 1 was the best match of the 1984 GVT results. The Iteration number 1 frequencies were computed with the wing full and the 1984 GVT data were measured with empty wings. The analysis data in Table 3 indicates that the wing fuel effect on the rigid body frequencies is not very large.

In addition to the gear spring tuning, the decoupler pylon finite element simulation was modified and tuned to the latest fixture test data on the pylons, which is reported in detail in the fixture test section. The finite element model of the pylon was supported at the forward and aft attachment which is the same as the fixture test. The lowest two pylon pitch modes were computed and compared to the fixture ground vibration test data. This comparison is shown on Table 4. The baseline stiffness value on Table 4 is the pitch stiffness which was used to tune the simulation to the first fixture test conducted in 1983 on the pylons with bushings in the pivot joints. The variations in the stiffness elements shown on Table 4 were examined. A combination of the original spring stiffness and a reduction of the strongback beam stiffness resulted in the best match of the two pylon pitch frequencies to the 1984 test data.

The tuned gear springs and the tuned decoupler pylon simulation were incorporated into the complete airplane simulation. Symmetric and antisymmetric modes were computed with these simulation revisions. The modes were computed with the wing fuel tanks full and with the wing fuel tanks empty. The computed symmetric mode frequencies are shown on Table 5. These frequencies are compared with the GVT data from 1983 and 1984. The computed antisymmetric mode frequencies are shown on Table 6. These frequencies are compared with the GVT data from 1983 and 1984. The 1983 modes were measured with the wing fuel tanks full and the 1984 tests were conducted with the wing fuel tanks empty.

The most direct comparison between the test data and the computed natural frequencies is obtained by comparing the 1984 GVT data and the tuned on gear wing empty computed data. The ratios of the GVT frequencies to the computed frequencies for the flexible modes are:

SYMMETRIC	RATIO	
1st Wing Bending	.9613	
GBU-8 Pitch	.9698	
Tip Missile Pitch	1.0167	
370 Gallon Tank Pitch	1.0285	R/H
	.9495	L/H

ANTISYMMETRIC	RATIO	
GBU-8 Pitch	1.0126	
GBU-8 Pitch	.9319	
Tip Missile Pitch	.9377	
370 Gallon Tank Pitch	1.0638	R/H
	.9696	L/H

The largest difference in the natural frequency is less than 7%. The mode shapes also compare well between test and analysis.

The tuned simulations were then used to compute free-free symmetric and antisymmetric modes. The natural frequencies of these modes are shown on Table 5 and Table 6. The first three mode shapes for these modes are shown in Appendix C. The gear support has a small effect upon the natural frequencies and mode shapes.

Flutter Analysis

Symmetric and antisymmetric flutter analyses were conducted using the computed free-free mode shapes which have the mass and stiffness distribution which correlated best with the 1984 ground vibration test results. These analyses were conducted for subsonic Mach numbers of 0.6 and 0.9. The subsonic unsteady aerodynamic terms were computed with the doublet lattice aerodynamic program. A standard k solution flutter analysis was made. The flutter speeds were computed for altitudes of sea level and ±10,000 ft. The symmetric flutter analysis included the rigid body modes, vertical translation and pitch, plus the lowest 15 flexible modes. The antisymmetric flutter analysis included the three rigid body modes, lateral translation, yaw and roll, plus the lowest 15 flexible modes.

The symmetric and antisymmetric flutter speeds for both Mach numbers and all three altitudes are high. The roots cross zero damping at a velocity of approximately 1029 m/s (2000 KTS EAS). This high speed root has a flutter frequency of approximately 13 Hz. The low frequency flutter root which is unstable on the standard pylon at 5.0 Hz, has low damping with the decoupler pylon but never crosses the zero damping line.

Aeroservoelastic Analysis

Symmetric and antisymmetric aeroservoelastic analyses were conducted using the free-free mode shapes discussed above. These analyses were conducted for subsonic Mach numbers of 0.6 and 0.9. The subsonic unsteady aerodynamic terms were computed with the doublet lattice aerodynamic program. The analyses were conducted at an altitude of sea level and for velocities which were compatible with the Mach number. Flight control system gains which were compatible with the flight conditions were used for each analysis case. The Nyquist criteria was used to evaluate the flight control system gain and phase margins.

The longitudinal aeroservoelastic analysis was conducted with the two rigid body modes, vertical translation and pitch, and 15 flexible modes. The first step in the analysis was to compute the sensor frequency response functions per unit horizontal tail deflection. These transfer functions were then combined with the pitch channel flight control system. The gain and phase margins of the pitch channel were determined from the Nyquist plot of the open loop response. This data is shown on Figure 3 for a Mach number of 0.6 and an altitude of sea level. This analysis was repeated for a Mach number of 0.9 and an altitude of sea level. This data is shown on Figure 4. The analysis covered a frequency range of 0.2 Hz to 10.0 Hz which will include all the significant response peaks. Over this frequency range, infinite gain margin and an infinite phase margin are predicted.

The lateral aeroservoelastic analysis was conducted with the three rigid body modes, lateral translation, yaw and roll, and 15 flexible modes. The lateral system stability was evaluated by closing the yaw loop, determining its stability, and obtaining the gain and phase margins from the roll loop. The first step in the analysis was to compute the sensor frequency response functions with the yaw loop closed. These transfer functions were per unit aileron deflection. The transfer functions were then combined with the roll channel flight control system. The gain and phase margins of the roll channel were determined from the Nyquist plot of the open loop response. This data is shown on Figure 5 for a Mach number of 0.6 and an altitude of sea level. The analysis was repeated for a Mach number of 0.9 and an altitude of sea level. This data is shown on Figure 6. For Mach number 0.9 the maximum gain crossing of the negative real axis is

0.315 at a frequency of 3.35 Hz. The phase margin is 78.88 degrees.

The longitudinal and lateral gain margins and phase margins exceed the accepted standard requirement. These accepted requirements are ± 6dB (2.0 and 0.5 gain crossover) gain margin and a phase margin of ± 45 degrees. No aeroservoelastic instabilities involving the flight test configuration with the decoupler pylon are anticipated.

FIXTURE TESTS

Two types of fixture tests were conducted on the pylons after they were retrofitted with roller bearings in the pivot joints. These were: (1) pivot joint breakout friction tests and (2) vibration tests to determine the pitch frequencies of the pylon with the GBU-8 weapon installed. A complete friction and vibration test was conducted on both pylons. The tests were conducted in the General Dynamics/Fort Worth Test Facility in a fixture which was designed for this type of testing. The fixture is the same one which was used to conduct the initial fixture tests on the pylons (reference 7). This fixture with the pylon with the dummy store is shown on Figure 7.

The objectives of the tests were to determine the pylon breakout friction and compare this data with similar data obtained on the pylons with the bushings in the pivot joints. A second objective was to determine the effect of the roller bearing joints upon the pylon pitch frequencies.

A dummy store was installed on the pylon for both tests. This dummy store has the correct dynamic characteristics (mass, mass moment of inertia and center of gravity) to simulate a flyable GBU-8.

Breakout Friction Tests

The breakout friction tests were conducted for a variety of test conditions. These variations included misalignment angle, damper in and out and external applied loads. The breakout friction was determined for both nose up and nose down moment. All tests were conducted with the dummy GBU-8 weapon installed. This weapon weighs 1027 kg (2265 lb). The store misalignment angle was varied from zero degrees to ±2.0

degrees, and tests were conducted for the misalignment angles shown on Table 7. At each misalignment angle breakout friction was determined for both nose up and nose down applied moments.

In addition to the tests for variations in misalignment angle, limited tests were conducted with applied yawing moment and side load. These tests were conducted with zero misalignment angle. These test conditions are also shown on Table 7.

The entire breakout friction test program was conducted with the pitch spring disconnected from the alignment motor drive system. The tests without external applied loads were conducted with the damper installed and with the damper disconnected. The damper had its orifice removed and was loaded with hydraulic fluid. This damper configuration provides a minimum damping coefficient with the damper installed and is the configuration used for the flight tests. The lower pylon nose up and nose down stops are in the damper and therefore, the damper must be connected for flight test.

The external applied yawing moment and side load values used represent approximately 1/3 of limit load. The yawing moment and the side load were applied at the centerline of the store in a horizontal direction. The yawing moment was applied as a couple about the center of gravity of the store in a lateral direction. The side load was applied at the center of gravity of the store in a lateral direction.

The relative deflection between the support fixture (upper pylon component) and the store (the lower pylon component) was measured with a dial gage located 109.2 cm (43 in.) forward of the store center of gravity. The loads which were used to create the pitching moment were applied 101.6 cm (40 in.) from the store center of gravity. For the nose down friction test, loads were applied forward of the c.g. only. For the nose up friction test, loads were applied aft of the c.g. only.

The load was added in 22.24N or 44.48N (5 or 10 lb) increments and a dial gage reading was made at each load increment. The 44.48N (10 lb) increments were used at the beginning of the load buildup and the 22.24N (5 lb) increment was used near the expected breakout point. Above breakout, 22.24N load increments were used. At each loading increment the dial gage reading was plotted versus the load. In each case the plotted data indicated a highly linear system and a distinct break in the line at the breakout point. The linearity effect held true below the breakout load and above the breakout load.

The results of the friction test for each test condition described in Table 7 are tabulated on Tables 8 through 15. This data indicates a difference in breakout moment due to misalignment angle. At zero misalignment angle, the nose up and nose down moments are approximately the same. At nose up misalignment angles, the nose up moments are larger than the nose down moments. At nose down misalignment angles, the nose down moments are larger. These effects are primarily caused by the geometry of the linkage. The breakout moment required is also significantly less for the damper out cases. This increment shows the friction effect contributed by the damper. This damper increment is on the order of 1/3 of the total friction. For zero and nose up misalignment, the damper contribution to the friction is larger for nose up moments. For nose down misalignment angles, the damper contribution to the friction is smaller for nose up moments.

The friction levels shown are less than 50% of the levels which were obtained on the pylons with bushings in the pivot joints (reference 7).

Ground Vibration Tests

The ground vibration tests in the fixture were conducted for a variety of test conditions. These variations included misalignment angle and external applied loads. The lowest two store pitch mode frequencies were determined for each test condition. All tests were conducted with the dummy GBU-8 weapon installed. The pitch spring was attached to the alignment system and the store misalignment angle was varied with the alignment drive system. Vibration tests were conducted for the misalignment angles shown on Table 7. Frequency sweeps were made at different excitation force levels to determine the friction breakout force level and to determine the change in natural frequency as a function of force level. Shakers were attached to the bottom side of the store to force the store in a vertical direction. Two shakers were used. One shaker was 132.1 cm (52 in.) forward of the store c.g. and the second was 294.6 cm (116 in.) aft of the forward shaker. The shakers were attached to the bottom of the dummy GBU-8 weapon. Store motion was measured with a roving accelerometer at the forward and aft locations on the store.

The acceleration response for each input force level was plotted versus frequency. These plotted frequency sweeps are shown in Appendix D. At force levels where the first two modes were excited the mode was tuned by adjusting the frequency to obtain the maximum response. These tuned pitch frequencies were recorded and are shown on Tables 16 through 23 for each test configuration. The lower frequency mode is the primary spring bending mode which involves the pivot joint rotation. The higher frequency mode is also a store pitch mode which is the bending of the upper strongback between the forward and aft attachment points. In some cases, there was a secondary peak near the spring mode frequency. When this occurred the frequency of this mode was also tuned and its frequency was tabulated also. The frequency of this mode is labeled with an asterisk on Tables 16 through 21.

The measured frequencies vary only slightly as a function of force level and indicate that no significant level of nonlinearity exists. Also the natural frequencies are not effected by misalignment angle, side load or yawing moment. The measured natural frequencies are less than the values obtained on the previous fixture tests conducted on the pylons with bushings in the pivot joints. The frequency measured during the previous tests (reference 7) was 3.6 Hz. This frequency was measured with an excitation force which was approximately twice as big as the force used in the test reported herein. During the current test the natural frequencies could be obtained with a minimum excitation of approximately 395 N m(3500 in-lb).

CONCLUSIONS

The existing ship set of decoupler pylons was modified and the roller bearings were incorporated. This design modification was supported with loads and stress analyses of the new parts. The stress analysis indicated that maneuver restrictions on the airplane were required when carrying the GBU-8 weapons on the decoupler pylons. The airplane was restricted to roll rates of less than 70 deg/sec when pulling a positive 4 g.

The modified pylons were ground tested in the General Dynamics/Fort Worth pylon test fixture. Breakout friction tests and vibration tests were conducted on both pylons. These tests indicate a significant decrease in the pivot joint friction with the roller bearings. This friction level was less than one half with the roller bearing than was achieved with bushings.

The finite element model used to compute the modes of vibration was modified to incorporate available test data. There were two sources of available test data. These were (1) complete airplane ground vibration tests and (2) pylon fixture tests with the roller bearings. The modes were used to conduct flutter analyses and aeroservoelastic analyses. The flutter analysis indicated that the airplane flutter speed with decoupler pylon is high. The aeroservoelastic analysis results indicated that the airplane flight control system has more than adequate gain and phase margins with the decoupler pylons installed.

RECOMMENDATIONS

It is recommended that a flight test demonstration of the decoupler pylons with roller bearings be conducted on the F-16. The flight test demonstration should include 1-g flight flutter testing and maneuver flight within the stated limits. The maneuvering flight tests should be conducted with and without the pylon alignment system engaged. The flight test program would demonstrate the flutter suppression capabilities of the pylons both in 1-g flight and during maneuvers. The maneuvering part of the flight test program will serve two purposes: (1) The flutter suppression capability of the decoupler pylon under maneuver loads can be demonstrated. (2) The performance of the pylon alignment system can be evaluated.

TABLE 1.- RANGE OF FLIGHT CONDITIONS AND MANEUVER CONDITIONS FOR LOADS ANALYSIS

MACH	ALT FT	NON-SYMMETRICAL ROLL RATE VARIATION DEG/SEC	NON-SYMMETRICAL n_z g's	SYMMETRICAL n_z g's
0.6	0	75-100	1-3	1-4
0.7	0	80-100	1-3	1-4
0.8	0	80-100	1-3	1-4
0.8	5000	80-100	1-3	1-4
	10000	80-100	1-3	1-4
0.9	0	80-100	1-3	1-4
	10000	80-100	1-3	1-4
	20000	80-100	1-3	1-4
0.95	10000	80-100	1-3	1-4
	20000	80	1-3	1-4

TABLE 2.- SPRING CONSTANTS AND RIGID BODY FREQUENCIES FOR SYMMETRIC AIRPLANE-ON-GEAR SIMULATION

	Spring K (½ A/P) KN/m (LB/IN)		Frequency (Hz)	
	Main Gear	Nose Gear	Translation	Pitch
Baseline	1947(11125)	40(228.6)(Tire + Strut)	2.446	.603
Iteration 1	1947(11125)	453(2591)	2.617	1.816
Iteration 2	1947(11125)	544(3109)	2.675	1.921
Iteration 3	2336(13350)	544(3109)	2.761	1.976
1983 GVT on Gear Wing Full (Reference 8)			-	2.03
1984 GVT on Gear Wing Empty			2.73	1.83

TABLE 3.- SPRING CONSTANTS AND RIGID BODY FREQUENCIES FOR ANTISYMMETRIC AIRPLANE-ON-GEAR SIMULATION

	Spring K (½ A/P) KN/m (LB/IN)			Frequency (Hz)		
	Main Gear	Nose Gear	Gear Roll	Translation	Yaw	Roll
Baseline	487(2781)	77(442)	4.2×10^6 (24×10^6)	.995	.635	1.942
Iteration 1	1947(11125)	309(1768)	4.2×10^6 (24×10^6)	1.203	1.100	2.462
Iteration 2	1947(11125)	309(1768)	2.1×10^6 (12×10^6)	.865	1.142	2.425
Iteration 3	1947(11125)	309(1768)	6.3×10^6 (36×10^6)	1.370	1.123	2.502
Iteration 4	7788(44500)	1238(7072)	4.2×10^6 (24×10^6)	1.196	1.682	2.882
Iteration 5	487(2781)	77(442)	$57.2\times10^6(327\times10^6)$	1.262	.636	3.062
Wing Empty	487(2781)	77(442)	$57.2\times10^6(327\times10^6)$	1.285	.644	2.996
1983 GVT on Gear Wing Full (Reference 8)				3.59	2.36 (/Roll)	1.34
1984 GVT on Gear Wing Empty				1.20	.91	2.17

TABLE 4.- CANTILEVERED DECOUPLER PYLON FREQUENCIES TUNED TO 7-84 GVT ON FIXTURE

CASE	MODEL STIFFNESS	FREQUENCY (Hz)	
		MODE 1	MODE 2
Baseline	Tuned to first (1983) fixture test, 100%	3.667	5.494
First Iteration	Reduced beam spring stiffness to 90.95%	3.518	5.465
Second Iteration	Reduced beam spring stiffness to 90.95% Reduced strongback stiffness to 70.98%	3.426	4.726
Third Iteration	Baseline beam spring stiffness, 100% Reduced strongback stiffness to 67.25%	3.520	4.691
Fourth Iteration	Baseline beam spring stiffness, 100% Reduced strongback stiffness to 61.91%	3.470	4.566
1984 Fixture GVT		3.40	4.60

TABLE 5.- SYMMETRIC MODE FREQUENCIES (Hz)

MODE	1983 GVT on Gear Wing (F)	1984 GVT on Gear Wing (E)	Tuned on Gear Wing (F)	Tuned on Gear Wing (E)	Tuned Free-Free Wing (E)
Rigid Body Pitch	2.03	1.83	1.973	1.983	
Rigid Body Translation		2.73	2.712	2.753	
GBU-8 Pitch	4.08	3.305	3.158	3.176	3.115
1st Wing Bending	3.02	3.95	4.078	4.109	3.702
GBU-8 Pitch		4.24	4.370	4.372	4.619
GBU-8 Lateral			5.252	5.261	5.226
Tip Missile Pitch	6.27	6.09	5.981	5.990	5.988
Missile Pitch/Wing Bending			6.601	6.671	6.615
370 Gallon Tank Pitch	7.49	7.55 R/H 6.97 L/H	7.328	7.341	7.327
370 Gallon Tank Yaw			7.920	7.924	7.921
2nd Wing Bending	9.77	9.64	9.716	9.818	9.871
Fuselage Vert Bending					11.626
GBU-8 Pitch (Nose Up)	4.14	4.65			
GBU-8 Pitch (Pylon Binding)	4.68				

Wing (F) - Wing Full of Fuel
Wing (E) - Wing Empty

TABLE 6.- ANTISYMMETRIC MODE FREQUENCIES (Hz)

MODE	1983 GVT on Gear Wing (F)	1984 GVT on Gear Wing (E)	Tuned on Gear Wing (F)	Tuned on Gear Wing (E)	Tuned Free-Free Wing (E)
Rigid Body Yaw	2.36	.91	.635	.644	
Rigid Body Translation	3.59	1.2	1.262	1.285	
Rigid Body Roll	1.34	2.17	2.972	2.996	
GBU-8 Pitch	3.92	3.285	3.185	3.244	3.089
GBU-8 Pitch		4.30	4.605	4.614	4.609
GBU-8 Lateral	4.82 R/H 4.75 L/H				4.963
GBU-8 Lateral/Yaw	5.29		5.232	5.244	
Tip Missile Pitch	5.32	5.53	5.860	5.897	5.537
GBU-8 Yaw/Tip Missile Pitch			6.414	6.447	6.212
370 Gallon Tank Pitch	7.35	7.57 R/H 6.90 L/H	7.092	7.116	7.047
370 Gallon Tank Yaw			8.057	8.061	8.018
1st Wing Bending	8.71	8.66	9.328	9.455	8.684
Vertical Tail Bending	11.91	11.81	12.112	12.122	11.563
GBU-8 Pitch (Nose Up Limit)	4.0	4.55			
GBU-8 Pitch (Pylon Binding)	4.51				

Wing (F) - Wing Full of Fuel
Wing (E) - Wing Empty

TABLE 7.- FIXTURE TEST CONDITIONS

Misalignment Pitch Angle Deg	Applied Yaw Moment N m(IN-LB)	Applied Side Load kN(LBS)
0	0	0
+0.5	0	0
-0.5	0	0
+2.0	0	0
-2.0	0	0
0	2260(20,000)	0
0	0	3.425(770)
0	2260(20,000)	3.425(770)

1. Pitching Moment Applied Nose Up and Nose Down in Each Case (Nose Up is a Positive Angle).
2. Test Conducted on Both Pylons.
3. Test Conducted with the Dummy GBU-8 Weapon Installed.

TABLE 8.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS;
RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

0 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER OUT

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	146.9(1300)	262.2(2320)	204.5(1810)
PYLON #2	169.5(1500)	325.4(2880)	247.5(2190)
AVERAGE	158.2(1400)	293.8(2600)	226.0(2000)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	298.3(2640)	271.2(2400)	284.8(2520)
PYLON #2	239.6(2120)	375.2(3320)	307.4(2720)
AVERAGE	268.9(2380)	323.2(2860)	296.1(2620)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
INCREMENT DUE TO DAMPER

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	151.4(1340)	9.0(80)	80.3(710)
PYLON #2	70.1(620)	49.8(440)	59.9(530)
AVERAGE	110.7(980)	29.4(260)	70.1(620)

TABLE 9 .- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS; RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

+0.5 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER OUT

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	479.1(4240)	33.9(300)	256.5(2270)
PYLON #2	456.5(4040)	54.2(480)	255.4(2260)
AVERAGE	467.8(4140)	44.1(390)	256.0(2265)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	569.5(5040)	42.9(380)	306.2(2710)
PYLON #2	533.4(4720)	85.9(760)	309.7(2740)
AVERAGE	551.5(4880)	64.4(570)	308.0(2725)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
INCREMENT DUE TO DAMPER

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	90.4(800)	9.0(80)	49.7(440)
PYLON #2	76.9(680)	31.7(280)	54.3(480)
AVERAGE	83.7(740)	20.3(180)	52.0(460)

TABLE 10.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS; RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

-0.5 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER OUT

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	18.1(160)	406.8(3600)	212.5(1880)
PYLON #2	72.3(640)	411.3(3640)	241.8(2140)
AVERAGE	45.2(400)	409.1(3620)	227.2(2010)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	56.5(500)	533.4(4720)	295.0(2610)
PYLON #2	58.8(520)	479.1(4240)	269.0(2380)
AVERAGE	57.7(510)	506.3(4480)	282.0(2495)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
INCREMENT DUE TO DAMPER

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	38.4(340)	126.6(1120)	82.5(730)
PYLON #2	-13.5(-120)	67.8(600)	27.2(240)
AVERAGE	12.5(110)	97.2(860)	54.8(485)

TABLE 11.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS;
RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

+2.0 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER OUT

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	610.2(5400)	27.1(240)	318.7(2820)
PYLON #2	583.1(5160)	40.7(360)	311.9(2760)
AVERAGE	596.7(5280)	33.9(300)	315.3(2790)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	890.4(7880)	54.2(480)	472.3(4180)
PYLON #2	727.8(6440)	74.6(660)	401.2(3550)
AVERAGE	809.1(7160)	64.4(570)	436.8(3865)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
INCREMENT DUE TO DAMPER

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	280.2(2480)	27.1(240)	153.6(1360)
PYLON #2	144.6(1280)	33.9(300)	89.3(790)
AVERAGE	212.4(1880)	30.5(270)	121.5(1075)

TABLE 12.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS;
RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

-2.0 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
DAMPER OUT

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	4.5(40)	397.8(3520)	201.2(1780)
PYLON #2	70.1(620)	379.7(3360)	224.9(1990)
AVERAGE	37.3(330)	388.8(3440)	213.1(1885)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	31.6(280)	465.6(4120)	248.6(2200)
PYLON #2	76.8(680)	406.8(3600)	241.8(2140)
AVERAGE	54.2(480)	436.2(3860)	245.2(2170)

BREAKOUT PITCHING MOMENT - N m (IN-LB)
INCREMENT DUE TO DAMPER

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	27.1(240)	67.8(600)	47.4(420)
PYLON #2	6.7(60)	27.1(240)	16.9(150)
AVERAGE	16.9(150)	47.4(420)	32.1(285)

TABLE 13.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS;
RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

0 PITCH MISALIGNMENT ANGLE - DEG
2260(20000) YAW MOMENT PRELOAD - N m (IN-LB)
0 SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	278.0(2460)	307.4(2720)	292.7(2590)
PYLON #2	280.2(2480)	397.8(3520)	339.0(3000)
AVERAGE	279.1(2470)	352.6(3120)	315.9(2795)

TABLE 14.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS;
RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

0 PITCH MISALIGNMENT ANGLE - DEG
0 YAW MOMENT PRELOAD - N m (IN-LB)
3.425(770) SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	309.6(2740)	375.2(3320)	342.4(3030)
PYLON #2	241.8(2140)	433.9(3840)	337.9(2990)
AVERAGE	275.7(2440)	404.6(3580)	340.2(3010)

TABLE 15.- MODIFIED NASA DECOUPLER PYLON FIXTURE TESTS; RESULTS OF PYLON PIVOT BREAKOUT FRICTION TESTS

0 PITCH MISALIGNMENT ANGLE - DEG
2260(20000) YAW MOMENT PRELOAD - N m (IN-LB)
3.425(770) SIDE LOAD PRELOAD - KN (LB)

BREAKOUT PITCHING MOMENT -N m (IN-LB)
DAMPER IN

	NOSE UP	NOSE DOWN	AVERAGE
PYLON #1	404.5(3580)	366.1(3240)	385.3(3410)
PYLON #2	345.8(3060)	463.3(4100)	404.6(3580)
AVÉRAGE	375.2(3320)	414.7(3670)	395.0(3495)

TABLE 16.- GROUND VIBRATION TEST RESULTS

0 MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
0 APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.051(11.4)		
.104(23.4)		
.149(33.6)		4.6
.200(45.0)	3.36(3.65*)	4.54
.250(56.2)	3.34(3.60*)	4.55
.283(63.7)	3.43	4.55

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.048(10.8)		
.098(22.1)		
.135(30.3)	3.42(3.68*)	4.6
.190(42.7)	3.43	4.63
.228(51.3)	3.55	4.6
.286(64.3)	3.62	4.6

* SECONDARY RESPONSE PEAK

TABLE 17.- GROUND VIBRATION TEST RESULTS

+0.5 MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
0 APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.049(11.0)		
.102(23.0)		
.149(33.4)		4.60
.187(42.1)	3.40(3.65*)	4.58
.244(54.8)	3.35(3.60*)	4.54
.294(66.0)	3.34(3.61*)	4.50

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.045(10.2)		
.094(21.2)		
.138(31.1)		4.57
.173(39.0)	3.40(3.61*)	4.59
.233(52.3)	3.46	4.57
.277(62.3)	3.56	4.60

* SECONDARY RESPONSE PEAK

TABLE 18.- GROUND VIBRATION TEST RESULTS

-0.5 MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
0 APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.048(10.8)		
.099(22.2)		4.55
.148(33.2)	3.33(3.64*)	4.55
.186(41.8)	3.48	4.55
.232(52.1)	3.59	4.55
.278(62.4)	3.56	4.55

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.049(11.1)		
.101(22.6)		
.147(33.0)	3.45(3.70*)	4.63
.197(44.3)	3.38(3.60*)	4.61
.243(54.6)	3.57	4.57
.292(65.6)	3.59	4.60

* SECONDARY RESPONSE PEAK

TABLE 19.- GROUND VIBRATION TEST RESULTS

+2.0° MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
0 APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.044(10.0)		
.095(21.4)		
.140(31.5)		4.65
.186(41.8)	3.46(3.66*)	4.66
.231(52.0)	3.37(3.64*)	4.71
.278(62.6)	3.35(3.61*)	4.71

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.049(11.0)		
.098(22.0)		
.141(31.8)	3.45(3.68*)	4.70
.190(42.8)	3.37(3.57*)	4.71
.234(52.6)	3.37	4.76
.272(61.2)	3.39	4.70

* SECONDARY RESPONSE PEAK

TABLE 20.- GROUND VIBRATION TEST RESULTS

-2.0° MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
0 APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.045(10.2)		
.094(21.2)		4.51
.141(31.6)	3.43(3.66*)	4.55
.186(41.9)	3.50	4.55
.232(52.1)	3.58	4.55
.278(62.6)	3.62	4.55

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.046(10.4)		
.099(22.2)		4.75
.142(32.0)	3.75	4.56
.177(39.8)	3.51(3.66*)	4.53
.233(52.4)	3.57	4.54

* SECONDARY RESPONSE PEAK

TABLE 21.- GROUND VIBRATION TEST RESULTS

0	MISALIGNMENT PITCH ANGLE-DEG
2260(20000)	APPLIED YAW LOAD - N m (IN-LB)
0	APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.046(10.3)		
.093(21.0)		
.132(29.8)	3.29(3.58*)	4.57
.180(40.5)	3.44	4.57
.226(50.9)	3.52	4.57
.269(60.4)	3.55	4.57

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.046(10.4)		
.097(21.8)		
.138(31.0)	3.51(3.74*)	4.59
.179(40.3)	3.45(3.63*)	4.62
.222(50.0)	3.34(3.60*)	4.62
.276(62.0)	3.56	4.58

* SECONDARY RESPONSE PEAK

TABLE 22.- GROUND VIBRATION TEST RESULTS

0 MISALIGNMENT PITCH ANGLE-DEG
0 APPLIED YAW LOAD - N m (IN-LB)
3.425(770) APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.046(10.4)		
.097(21.7)		
.145(32.5)		
.187(42.0)		4.51
.233(52.4)	3.36	4.51
.278(62.4)	3.38	4.51

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.047(10.6)		
.097(21.8)		
.140(31.4)	3.58	4.56
.183(41.1)	3.50	4.61
.229(51.4)	3.52	4.61
.274(61.6)	3.56	4.61

TABLE 23.- GROUND VIBRATION TEST RESULTS

0 MISALIGNMENT PITCH ANGLE-DEG
2260(20000) APPLIED YAW LOAD - N m (IN-LB)
3.425(770) APPLIED SIDE LOAD - KN (LB)

PYLON NO. 1

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.048(10.8)		
.097(21.9)		
.144(32.3)		
.187(42.1)		4.52
.233(52.4)	3.46	4.52
.278(62.6)	3.36	4.51

PYLON NO. 2

EXCITATION FORCE KN (LB)	PITCH MODE FREQUENCIES (Hz)	
	SPRING BENDING	STRONGBACK BENDING
.047(10.6)		
.097(21.8)		
.141(31.6)		
.185(41.6)	3.66	4.54
.229(51.4)	3.54	4.57
.274(61.7)	3.53	4.59

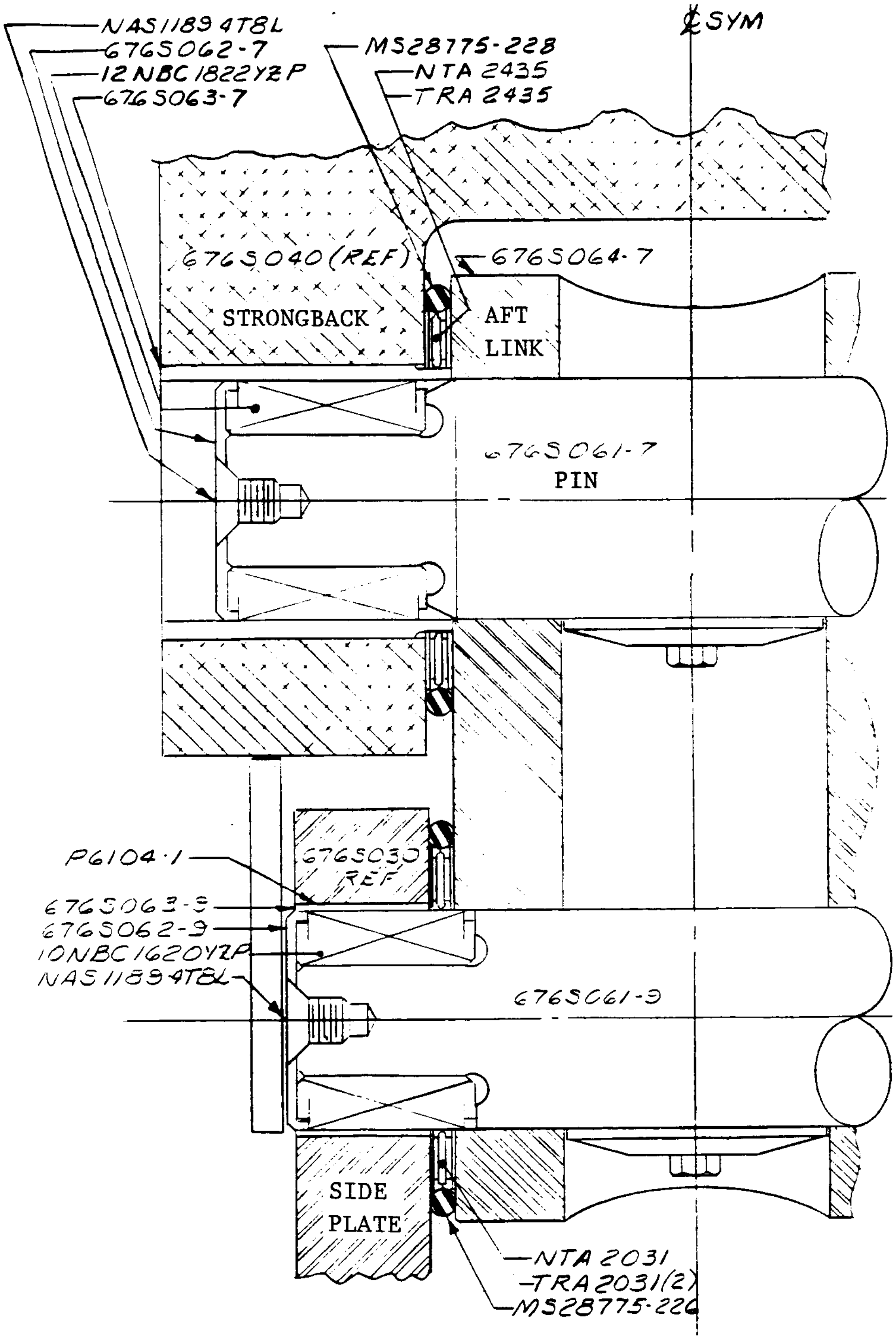


Figure 1.- Decoupler Pylon Aft Attachment Fitting

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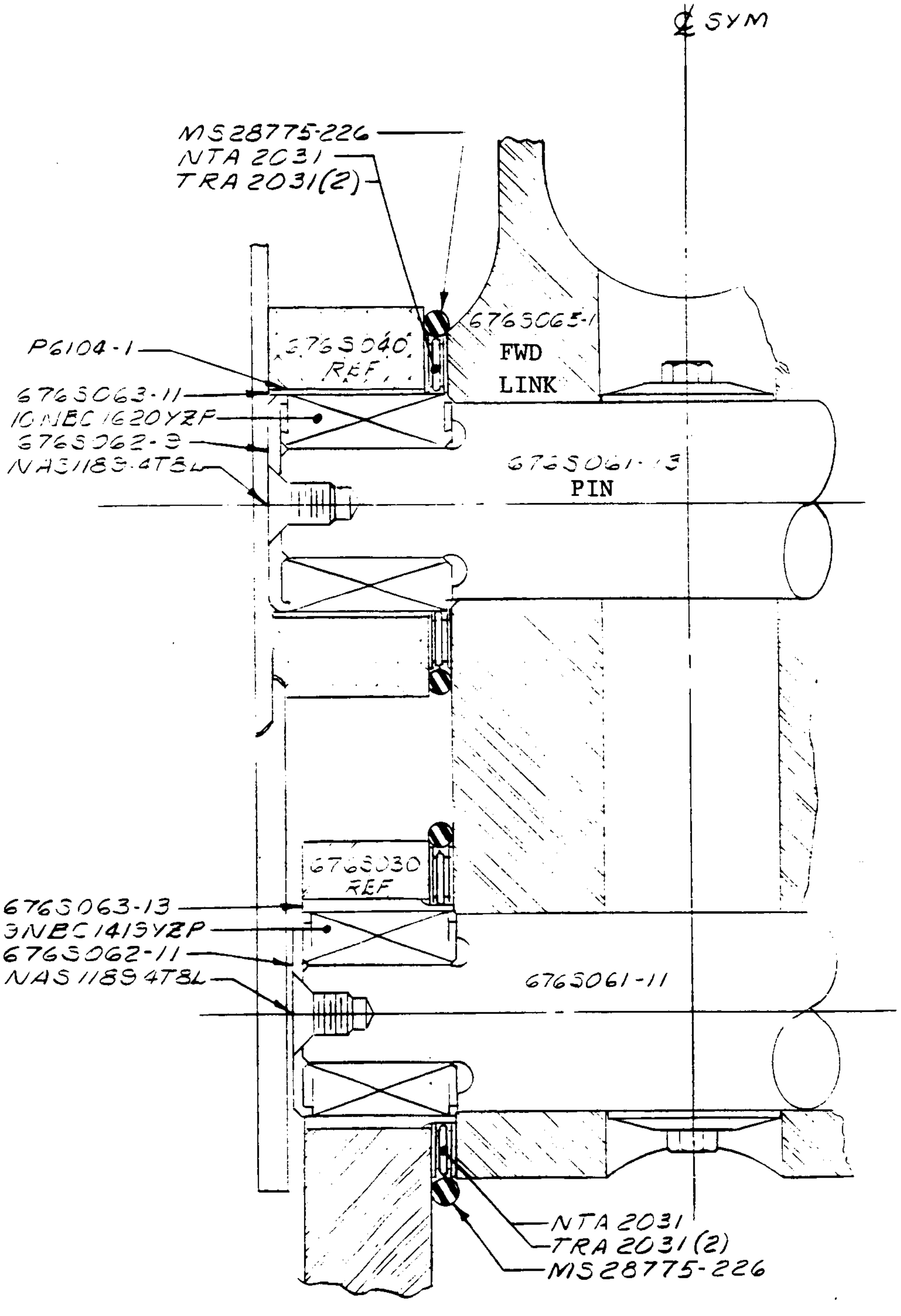

Figure 2.- Decoupler Pylon Forward Attachment Fitting

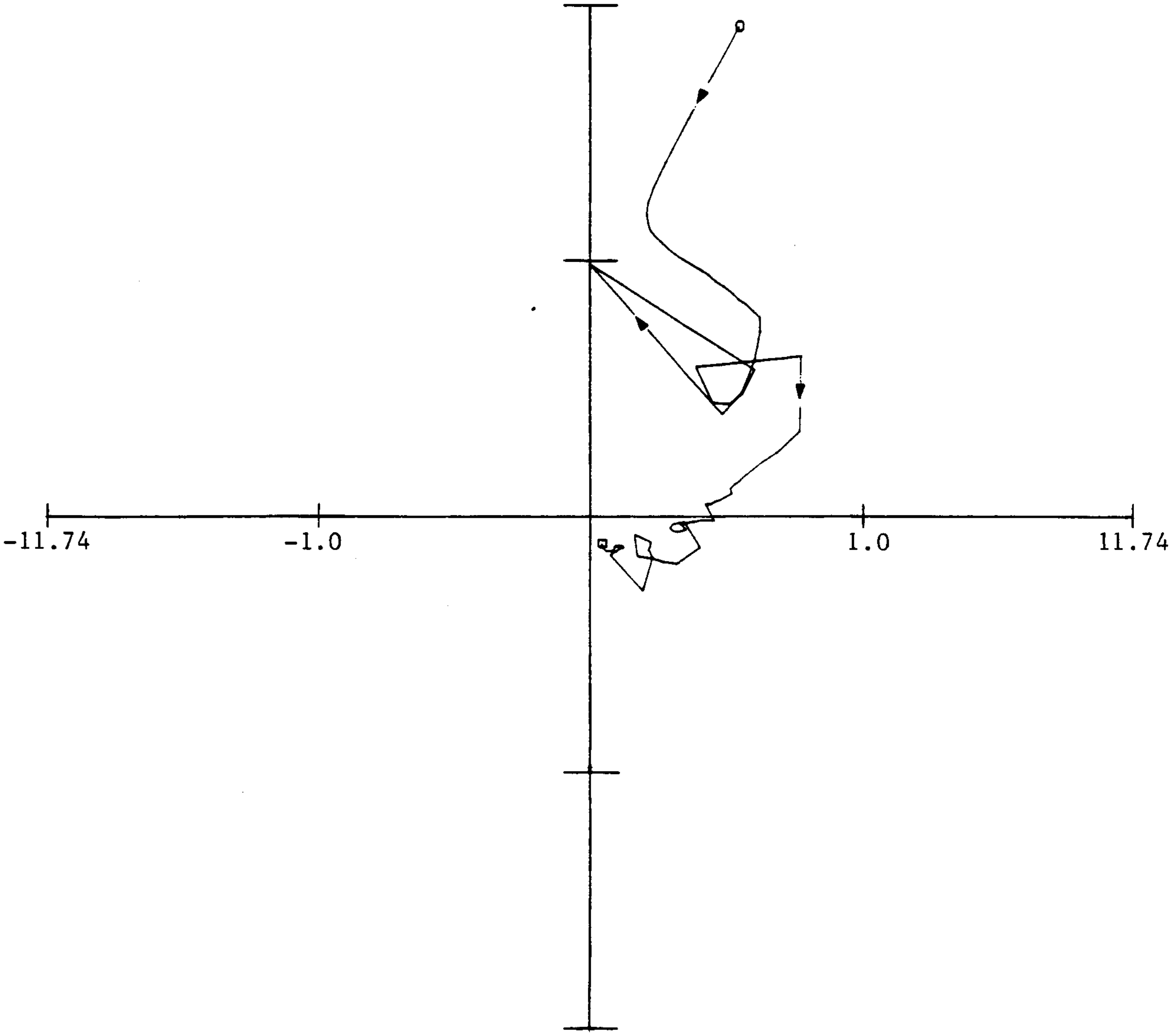

Figure 3.- Nyquist Plot of Open Loop Response
Symmetric M=0.6 Sea Level

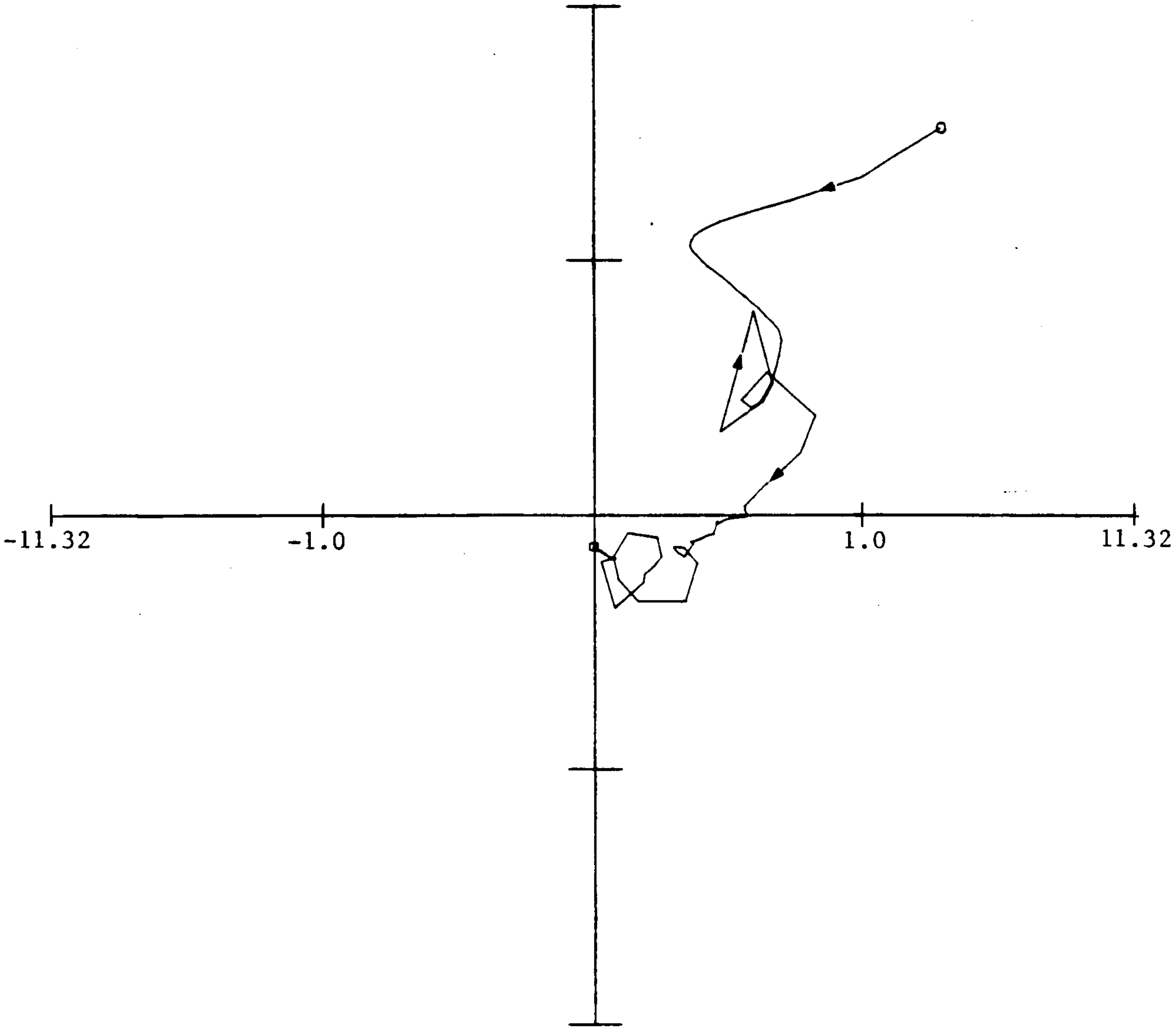

Figure 4.- Nyquist Plot of Open Loop Response
Symmetric M=0.9 Sea Level

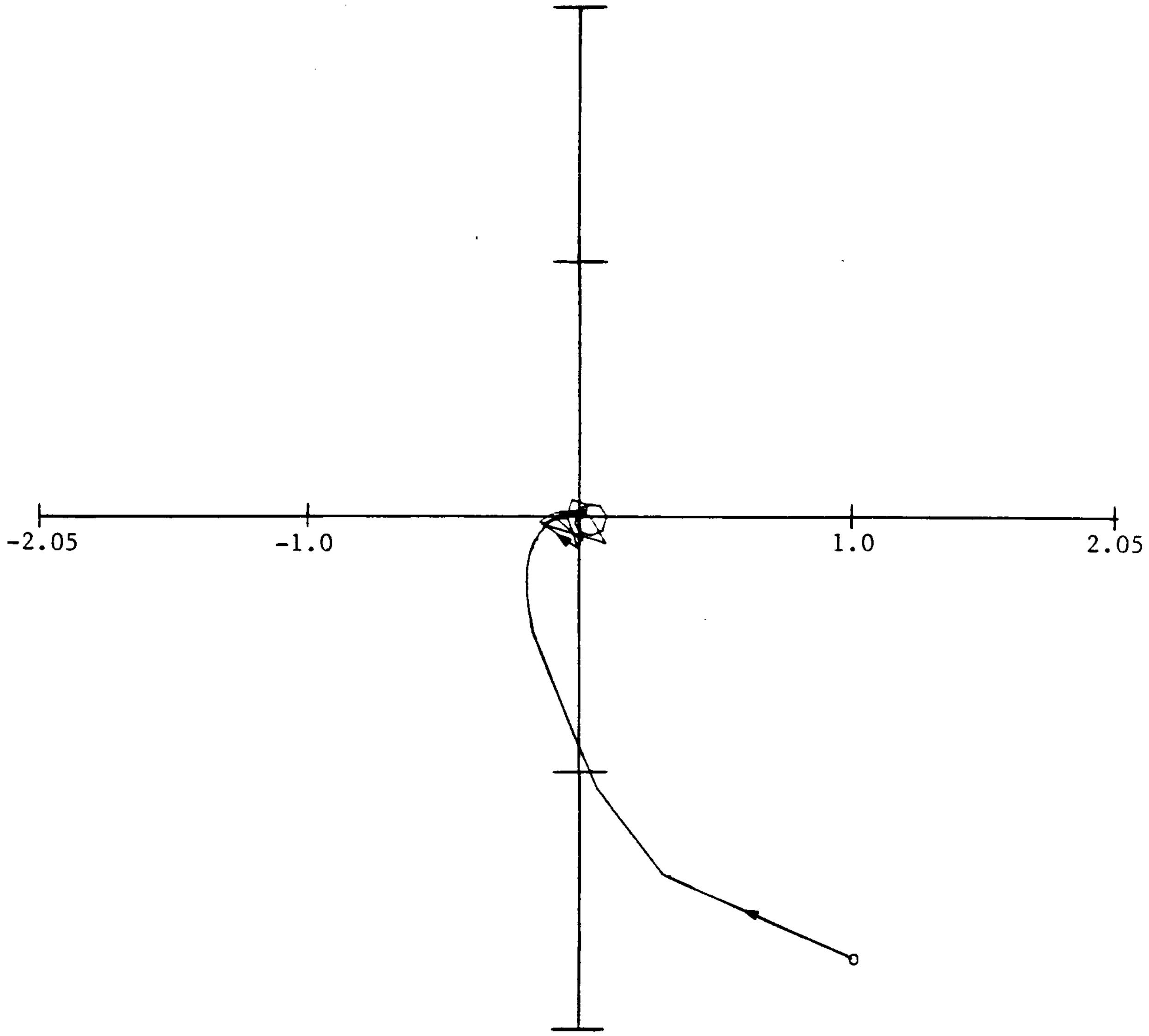

Figure 5.- Nyquist Plot of Open Loop Response
Antisymmetric M=0.6 Sea Level

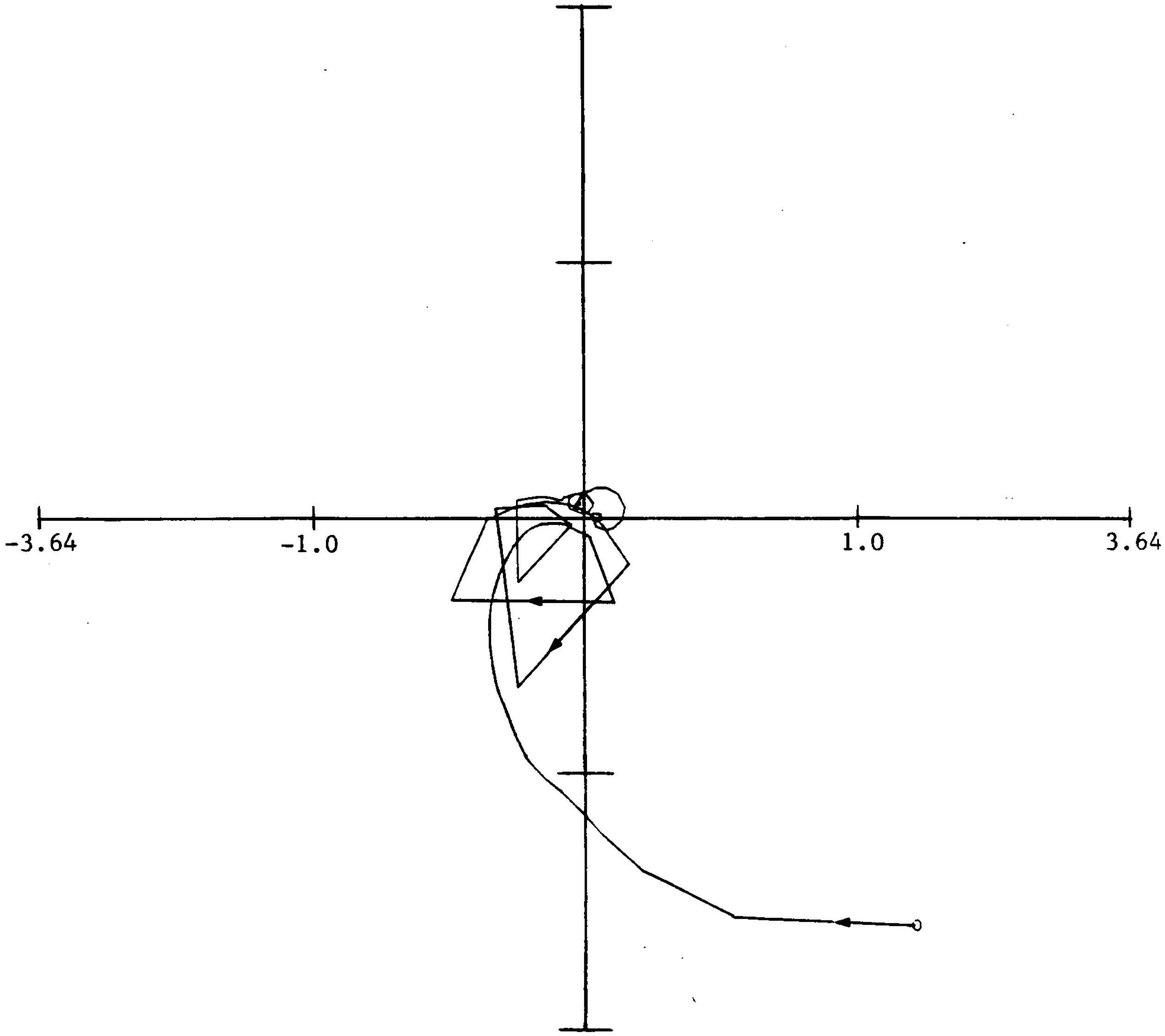

Figure 6.- Nyquist Plot of Open Loop Response
Antisymmetric M=0.9 Sea Level

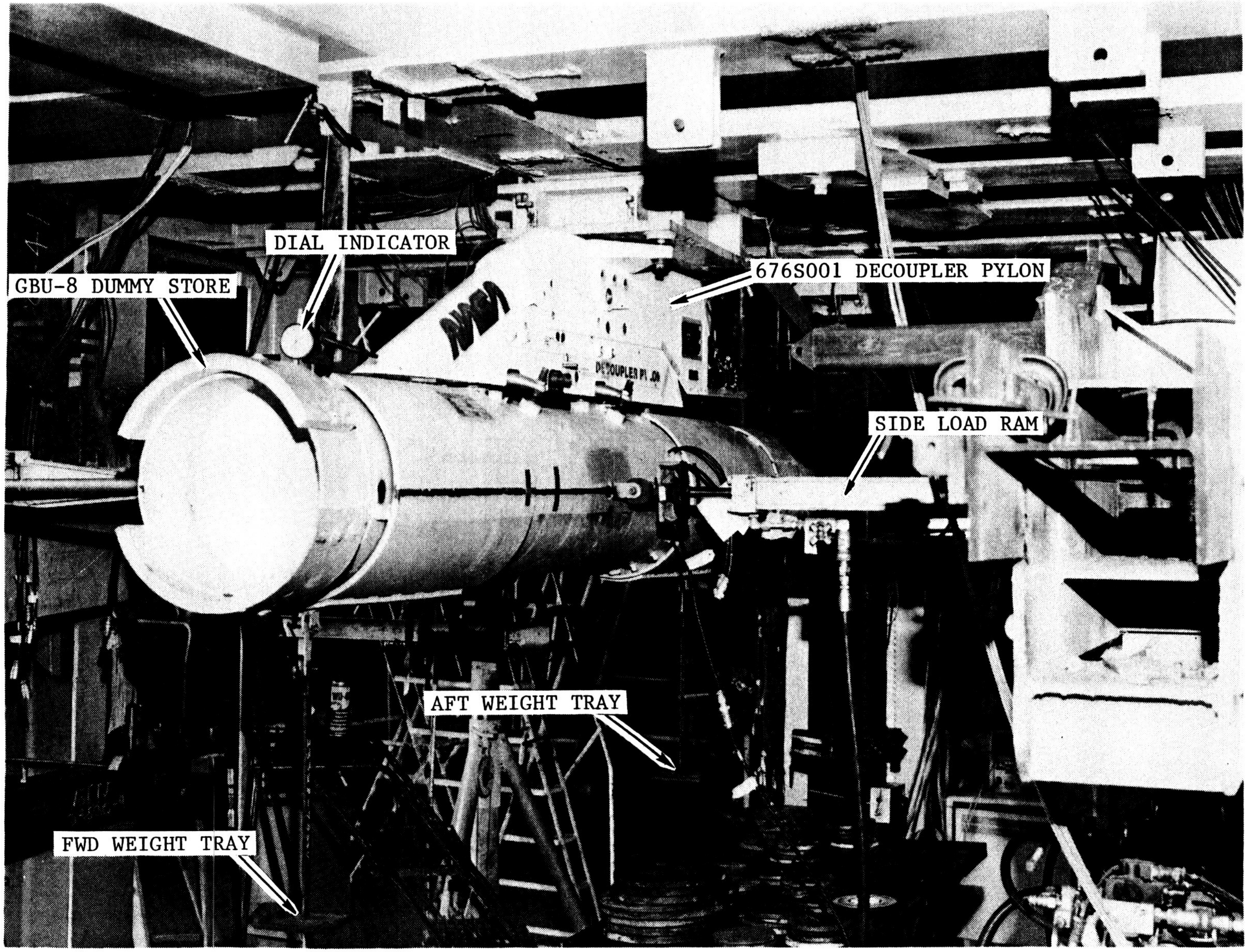

Figure 7.- Pylon Test Setup

APPENDIX A

DECOUPLER PYLON LOADS

This appendix contains a tabulation of decoupler pylon store loads at the wing reference point (FS 361.51) for the pylon aligned case. Also included is a tabulation of loads during ejection for pylon aligned.

TABLE A1.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
NON-SYMMETRICAL 0.60 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
41-4.1L	.60	0.	100.	1.	-3051.	2116.	384.	-75034.	51850.	52764.
41-4.1R	.60	0.	100.	1.	-3077.	2559.	384.	-74486.	59418.	65865.
41-4.1L	.60	0.	90.	1.	-2961.	1684.	384.	-73026.	41206.	43702.
41-4.1R	.60	0.	90.	1.	-2984.	2083.	384.	-72523.	48032.	55407.
41-4.1L	.60	0.	80.	1.	-2881.	1299.	384.	-71229.	31718.	35688.
41-4.1R	.60	0.	80.	1.	-2901.	1654.	384.	-70771.	37801.	45998.
51-4.1L	.60	0.	90.	2.	-5517.	2268.	384.	-127334.	51533.	57173.
51-4.1R	.60	0.	90.	2.	-5488.	2734.	384.	-127777.	60494.	57379.
51-4.1L	.60	0.	80.	2.	-5436.	1886.	384.	-125447.	42175.	48380.
51-4.1R	.60	0.	80.	2.	-5409.	2301.	384.	-125867.	50147.	48540.
61-4.1L	.60	0.	75.	3.	-7874.	2260.	384.	-181230.	48425.	44000.
61-4.1R	.60	0.	75.	3.	-7744.	2746.	384.	-186532.	57728.	41760.

TABLE A2.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
SYMMETRICAL 0.60 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
1-4.1	.60	0.	0.	1.	-2583.	-57.	384.	-64367.	-2426.	8458.
11-4.1	.60	0.	0.	2.	-5132.	454.	384.	-118327.	7048.	15303.
21-4.1	.60	0.	0.	3.	-7538.	1156.	384.	-177820.	20471.	12889.
31-4.1	.60	0.	0.	4.	-9891.	1835.	384.	-241504.	33812.	14173.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A3.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
NON-SYMMETRICAL 0.70 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
42-4.1L	.70	0.	100.	1.	-3056.	1842.	523.	-78262.	46897.	45339.
42-4.1R	.70	0.	100.	1.	-3087.	2341.	523.	-78112.	55028.	64569.
42-4.1L	.70	0.	90.	1.	-2965.	1410.	523.	-76300.	36259.	36443.
42-4.1R	.70	0.	90.	1.	-2995.	1861.	523.	-76157.	43574.	54028.
42-4.1L	.70	0.	80.	1.	-2885.	1029.	523.	-74503.	26827.	28578.
42-4.1R	.70	0.	80.	1.	-2911.	1428.	523.	-74413.	33276.	44536.
52-4.1L	.70	0.	90.	2.	-5526.	1977.	523.	-131334.	45643.	56589.
52-4.1R	.70	0.	90.	2.	-5548.	2471.	523.	-129901.	54839.	62888.
52-4.1L	.70	0.	80.	2.	-5446.	1608.	523.	-129464.	36471.	48491.
52-4.1R	.70	0.	80.	2.	-5465.	2048.	523.	-128168.	44679.	53896.
62-4.1L	.70	0.	80.	3.	-7989.	1996.	523.	-183768.	43668.	53646.
62-4.1R	.70	0.	80.	3.	-7967.	2473.	523.	-183823.	52859.	54230.

TABLE A4.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
SYMMETRICAL 0.70 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
2-4.1	.70	0.	0.	1.	-2590.	-302.	523.	-67736.	-7005.	3391.
12-4.1	.70	0.	0.	2.	-5139.	105.	523.	-122650.	-68.	15515.
22-4.1	.70	0.	0.	3.	-7689.	693.	523.	-176168.	11051.	21190.
32-4.1	.70	0.	0.	4.	-10121.	1311.	523.	-234646.	22863.	19320.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A5.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
NON-SYMMETRICAL 0.80 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
43-4.1L	.80	0.	100.	1.	-3086.	1658.	683.	-92182.	41837.	46929.
43-4.1R	.80	0.	100.	1.	-3082.	2224.	683.	-87443.	51800.	69065.
43-4.1L	.80	0.	90.	1.	-2992.	1223.	683.	-89554.	31197.	38015.
43-4.1R	.80	0.	90.	1.	-2990.	1740.	683.	-85622.	40299.	57993.
43-4.1L	.80	0.	80.	1.	-2908.	836.	683.	-87137.	21713.	30149.
43-4.1R	.80	0.	80.	1.	-2908.	1305.	683.	-84012.	29954.	47969.
53-4.1L	.80	0.	90.	2.	-5515.	1797.	683.	-140755.	41300.	59730.
53-4.1R	.80	0.	90.	2.	-5495.	2392.	683.	-139323.	52133.	71011.
53-4.1L	.80	0.	80.	2.	-5432.	1438.	683.	-138837.	32338.	51778.
53-4.1R	.80	0.	80.	2.	-5415.	1966.	683.	-137516.	41931.	62171.
63-4.1L	.80	0.	80.	3.	-7952.	1596.	683.	-193840.	35213.	54958.
63-4.1R	.80	0.	80.	3.	-7930.	2141.	683.	-193014.	45189.	61575.
71-4.1L	.80	5000.	100.	1.	-3073.	1778.	568.	-87873.	44468.	47696.
71-4.1R	.80	5000.	100.	1.	-3069.	2256.	568.	-83812.	52885.	66427.
71-4.1L	.80	5000.	90.	1.	-2979.	1340.	568.	-85340.	33775.	38622.
71-4.1R	.80	5000.	90.	1.	-2978.	1777.	568.	-81961.	41463.	55530.
71-4.1L	.80	5000.	80.	1.	-2895.	950.	568.	-83018.	24239.	30596.
71-4.1R	.80	5000.	80.	1.	-2896.	1346.	568.	-80323.	31197.	45677.
72-4.1L	.80	5000.	90.	2.	-5503.	1815.	568.	-137176.	42148.	56741.
72-4.1R	.80	5000.	90.	2.	-5486.	2320.	568.	-135976.	51331.	66199.
72-4.1L	.80	5000.	80.	2.	-5418.	1511.	568.	-135121.	34162.	49867.
72-4.1R	.80	5000.	80.	2.	-5401.	1965.	568.	-134206.	42442.	57118.
73-4.1L	.80	5000.	80.	3.	-7941.	1581.	568.	-190348.	35442.	51284.
73-4.1R	.80	5000.	80.	3.	-7922.	2042.	568.	-189653.	43893.	56853.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

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TABLE A5.- (CONCLUDED)

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
45-4.1L	.80	10000.	100.	1.	-3058.	1986.	470.	-82575.	48596.	52939.
45-4.1R	.80	10000.	100.	1.	-3054.	2422.	470.	-80355.	56333.	66865.
45-4.1L	.80	10000.	90.	1.	-2966.	1583.	470.	-80434.	37982.	43777.
45-4.1R	.80	10000.	90.	1.	-2963.	1944.	470.	-78407.	44923.	66437.
45-4.1L	.80	10000.	80.	1.	-2884.	1168.	470.	-78503.	28525.	35663.
45-4.1R	.80	10000.	80.	1.	-2882.	1515.	470.	-76670.	34670.	47056.
55-4.1L	.80	10000.	90.	2.	-5484.	2098.	470.	-133420.	47723.	59533.
55-4.1R	.80	10000.	90.	2.	-5461.	2552.	470.	-133253.	56106.	61065.
55-4.1L	.80	10000.	80.	2.	-5396.	1850.	470.	-131303.	40770.	53164.
55-4.1R	.80	10000.	80.	2.	-5372.	2265.	470.	-131518.	48504.	51748.
65-4.1L	.80	10000.	80.	3.	-7909.	2068.	470.	-186823.	44840.	52419.
65-4.1R	.80	10000.	80.	3.	-7845.	2482.	470.	-189246.	52486.	52234.
48-4.1L	.80	20000.	100.	1.	-3041.	2253.	314.	-76228.	53993.	57809.
48-4.1R	.80	20000.	100.	1.	-3033.	2572.	314.	-75178.	59750.	65315.
48-4.1L	.80	20000.	90.	1.	-2950.	1814.	314.	-74127.	43267.	48404.
48-4.1R	.80	20000.	90.	1.	-2942.	2102.	314.	-73212.	48471.	55030.
48-4.1L	.80	20000.	80.	1.	-2868.	1422.	314.	-72238.	33697.	40047.
48-4.1R	.80	20000.	80.	1.	-2861.	1680.	314.	-71457.	38348.	45793.
58-4.1L	.80	20000.	90.	2.	-5455.	2334.	314.	-128647.	52776.	54943.
58-4.1R	.80	20000.	90.	2.	-5394.	2656.	314.	-131171.	58726.	55150.
58-4.1L	.80	20000.	80.	2.	-5363.	2043.	314.	-127097.	45088.	45745.
58-4.1R	.80	20000.	80.	2.	-5292.	2329.	314.	-130313.	50338.	46486.
68-4.1L	.80	20000.	80.	3.	-7816.	2332.	314.	-185797.	50403.	46522.
68-4.1R	.80	20000.	80.	3.	-7693.	2617.	314.	-191923.	55537.	49449.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A6.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
SYMMETRICAL 0.80 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
3-4.1	.80	0.	0.	1.	-2599.	-460.	683.	-78745.	-11188.	5508.
13-4.1	.80	0.	0.	2.	-5124.	-107.	683.	-132114.	-4947.	17917.
23-4.1	.80	0.	0.	3.	-7635.	331.	683.	-186403.	3004.	26711.
33-4.1	.80	0.	0.	4.	-10127.	951.	683.	-241833.	14508.	26879.
5-4.1	.80	10000.	0.	1.	-2576.	-192.	470.	-70672.	-5514.	8481.
15-4.1	.80	10000.	0.	2.	-5093.	193.	470.	-124785.	1431.	17670.
25-4.1	.80	10000.	0.	3.	-7587.	747.	470.	-180223.	11710.	18202.
35-4.1	.80	10000.	0.	4.	-9909.	1411.	470.	-245296.	23828.	21568.
8-4.1	.80	20000.	0.	1.	-2557.	20.	314.	-65026.	-1017.	9632.
18-4.1	.80	20000.	0.	2.	-5063.	427.	314.	-120101.	6469.	12399.
28-4.1	.80	20000.	0.	3.	-7446.	946.	314.	-182097.	15975.	14445.
38-4.1	.80	20000.	0.	4.	-9828.	1641.	314.	-246815.	29129.	21102.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A7.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
NON-SYMMETRICAL 0.90 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
44-4.1L	.90	0.	100.	1.	-3205.	1506.	1044.	-117432.	37299.	54674.
44-4.1R	.90	0.	100.	1.	-3138.	2127.	1044.	-108635.	47967.	72224.
44-4.1L	.90	0.	90.	1.	-3108.	1073.	1044.	-114628.	26653.	45669.
44-4.1R	.90	0.	90.	1.	-3048.	1637.	1044.	-106919.	36369.	61421.
44-4.1L	.90	0.	80.	1.	-3019.	687.	1044.	-112035.	17162.	37712.
44-4.1R	.90	0.	80.	1.	-2969.	1196.	1044.	-105414.	25927.	51665.
54-4.1L	.90	0.	90.	2.	-5570.	1704.	1044.	-161779.	37523.	63008.
54-4.1R	.90	0.	90.	2.	-5529.	2383.	1044.	-157522.	49707.	76476.
54-4.1L	.90	0.	80.	2.	-5481.	1405.	1044.	-159104.	29548.	56646.
54-4.1R	.90	0.	80.	2.	-5445.	2016.	1044.	-155509.	40588.	68284.
64-4.1L	.90	0.	80.	3.	-8007.	1394.	1044.	-214599.	29362.	56391.
64-4.1R	.90	0.	80.	3.	-7971.	2305.	1044.	-210981.	40377.	68070.
46-4.1L	.90	10000.	100.	1.	-3114.	1939.	718.	-97530.	46376.	59623.
46-4.1R	.90	10000.	100.	1.	-3082.	2454.	718.	-93568.	55367.	71337.
46-4.1L	.90	10000.	90.	1.	-3023.	1511.	718.	-95314.	35831.	50269.
46-4.1R	.90	10000.	90.	1.	-2992.	1972.	718.	-91713.	43885.	60874.
46-4.1L	.90	10000.	80.	1.	-2937.	1130.	718.	-93310.	26443.	41963.
46-4.1R	.90	10000.	80.	1.	-2912.	1539.	718.	-90069.	33558.	51459.
56-4.1L	.90	10000.	90.	2.	-5508.	2137.	718.	-146204.	46878.	63903.
56-4.1R	.90	10000.	90.	2.	-5478.	2648.	718.	-143848.	56316.	70578.
56-4.1L	.90	10000.	80.	2.	-5414.	1932.	718.	-143290.	40701.	58687.
56-4.1R	.90	10000.	80.	2.	-5387.	2399.	718.	-141532.	49464.	62565.
66-4.1L	.90	10000.	80.	3.	-7936.	1991.	718.	-198368.	41777.	59776.
66-4.1R	.90	10000.	80.	3.	-7908.	2463.	718.	-196729.	50672.	62928.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A7.- (CONCLUDED)

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
49-4.1L	.90	20000.	100.	1.	-3064.	2311.	480.	-85240.	54029.	62551.
49-4.1R	.90	20000.	100.	1.	-3042.	2689.	480.	-82997.	60842.	69787.
49-4.1L	.90	20000.	90.	1.	-2972.	1875.	480.	-83087.	43351.	53013.
49-4.1R	.90	20000.	90.	1.	-2952.	2216.	480.	-81095.	49512.	59478.
49-4.1L	.90	20000.	80.	1.	-2889.	1487.	480.	-81146.	33828.	44523.
49-4.1R	.90	20000.	80.	1.	-2871.	1791.	480.	-79404.	39338.	50218.
59-4.1L	.90	20000.	90.	2.	-5464.	2440.	480.	-135644.	53710.	61420.
59-4.1R	.90	20000.	90.	2.	-5409.	2796.	480.	-136812.	60371.	62892.
59-4.1L	.90	20000.	80.	2.	-5374.	2179.	480.	-133367.	46637.	53340.
59-4.1R	.90	20000.	80.	2.	-5299.	2485.	480.	-136253.	52284.	54154.
69-4.1L	.90	20000.	80.	3.	-7844.	2419.	480.	-190802.	51077.	54035.
69-4.1R	.90	20000.	80.	3.	-7726.	2706.	480.	-196754.	56268.	55237.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A8.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51) SYMMETRICAL 0.90 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
4-4.1	.90	0.	0.	1.	-2573.	-617.	1044.	-100986.	-15990.	11353.
14-4.1	.90	0.	0.	2.	-5180.	-232.	1044.	-153231.	-9326.	20522.
24-4.1	.90	0.	0.	3.	-7681.	167.	1044.	-205934.	-2228.	28854.
34-4.1	.90	0.	0.	4.	-10179.	616.	1044.	-258842.	5938.	37116.
6-4.1	.90	10000.	0.	1.	-2616.	-196.	718.	-84881.	-7044.	13250.
16-4.1	.90	10000.	0.	2.	-5117.	210.	718.	-137602.	193.	21592.
26-4.1	.90	10000.	0.	3.	-7614.	697.	718.	-190748.	9188.	28037.
36-4.1	.90	10000.	0.	4.	-10011.	1434.	718.	-249605.	22932.	30836.
9-4.1	.90	20000.	0.	1.	-2572.	109.	480.	-73491.	-435.	13867.
19-4.1	.90	20000.	0.	2.	-5073.	518.	480.	-127043.	7122.	19041.
29-4.1	.90	20000.	0.	3.	-7491.	1040.	480.	-185992.	16829.	20765.
39-4.1	.90	20000.	0.	4.	-9757.	1667.	480.	-255853.	28212.	25979.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A9.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51)
NON-SYMMETRICAL 0.95 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
47-4.1L	.95	10000.	100.	1.	-3111.	1753.	1269.	-117656.	43278.	56370.
47-4.1R	.95	10000.	100.	1.	-3017.	2332.	1269.	-113996.	52947.	72771.
47-4.1L	.95	10000.	90.	1.	-3015.	1328.	1269.	-115464.	32779.	47234.
47-4.1R	.95	10000.	90.	1.	-2930.	1849.	1269.	-112161.	41476.	62024.
47-4.1L	.95	10000.	80.	1.	-2928.	951.	1269.	-113484.	23435.	39147.
47-4.1R	.95	10000.	80.	1.	-2852.	1414.	1269.	-110548.	31166.	52293.
57-4.1L	.95	10000.	90.	2.	-5430.	2072.	1269.	-166957.	45429.	65957.
57-4.1R	.95	10000.	90.	2.	-5382.	2616.	1269.	-166212.	55275.	73418.
57-4.1L	.95	10000.	80.	2.	-5325.	1896.	1269.	-164641.	39698.	60761.
57-4.1R	.95	10000.	80.	2.	-5292.	2385.	1269.	-164687.	48768.	65494.
67-4.1L	.95	10000.	80.	3.	-7851.	1388.	1269.	-220065.	39572.	60647.
67-4.1R	.95	10000.	80.	3.	-7817.	2378.	1269.	-220083.	48630.	65453.
50-4.1L	.95	20000.	100.	1.	-3050.	2128.	849.	-99493.	50826.	59706.
50-4.1R	.95	20000.	100.	1.	-2994.	2536.	849.	-97665.	57864.	69023.
50-4.1L	.95	20000.	90.	1.	-2955.	1694.	849.	-97357.	40179.	50320.
50-4.1R	.95	20000.	90.	1.	-2905.	2061.	849.	-95704.	46509.	58728.
50-4.1L	.95	20000.	80.	1.	-2870.	1308.	849.	-95433.	30688.	41981.
50-4.1R	.95	20000.	80.	1.	-2825.	1635.	849.	-93955.	36311.	49482.
60-4.1L	.95	20000.	90.	2.	-5414.	2224.	849.	-150745.	49406.	61354.
60-4.1R	.95	20000.	90.	2.	-5391.	2608.	849.	-151030.	56606.	64382.
60-4.1L	.95	20000.	80.	2.	-5330.	1838.	849.	-148901.	39951.	52782.
60-4.1R	.95	20000.	80.	2.	-5310.	2181.	849.	-149200.	46372.	55352.
70-4.1L	.95	20000.	80.	3.	-7838.	2132.	849.	-204532.	45446.	55078.
70-4.1R	.95	20000.	80.	3.	-7793.	2452.	849.	-206450.	51451.	57695.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

TABLE A10.- PYLON + STORE LOADS AT WING REFERENCE POINT (F.S. 361.51) SYMMETRICAL 0.95 MACH

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	M_y	M_x	M_z
7-4.1	.95	10000.	0.	1.	-2582.	-346.	1269.	-105252.	-9695.	12180.
17-4.1	.95	10000.	0.	2.	-5041.	131.	1269.	-158410.	-1506.	23405.
27-4.1	.95	10000.	0.	3.	-7521.	601.	1269.	-212934.	6937.	30518.
37-4.1	.95	10000.	0.	4.	-10020.	1175.	1269.	-269231.	17809.	33746.
10-4.1	.95	20000.	0.	1.	-2535.	-60.	849.	-87649.	-3622.	13008.
20-4.1	.95	20000.	0.	2.	-5017.	353.	849.	-142039.	3732.	19947.
30-4.1	.95	20000.	0.	3.	-7522.	775.	849.	-198035.	11715.	22506.
40-4.1	.95	20000.	0.	4.	-9911.	1206.	849.	-259558.	19649.	28061.

TABLE A11.- PYLON + STORE LOADS + STORE EJECTION LOADS AT WING REFERENCE POINT (F.S. 361.51) SYMMETRICAL

COND.	MACH	ALT	ROLL RATE	N_z	F_z	F_y	F_x	$M_y^{(1)}$	M_x	M_z	$F_v^{(2)}$
3-4.1	.80	0.	0.	1.	-2599.	-460.	683.	50035.	-11188.	5508.	10842.
5-4.1	.80	10000.	0.	1.	-2576.	-192.	470.	58108.	-5514.	8481.	10842.
4-4.1	.90	0.	0.	1.	-2678.	-617.	1044.	27794.	-15990.	11353.	10842.
6-4.1	.90	10000.	0.	1.	-2616.	-196.	718.	43899.	-7044.	13250.	10842.
7-4.1	.95	10000.	0.	1.	-2582.	-346.	1269.	23528.	-9695.	12180.	10842.
33-4.1	.80	0.	0.	4.	-10127.	951.	683.	2157.	14508.	26879.	23224.
35-4.1	.80	10000.	0.	4.	-9909.	1411.	470.	-1306.	23828.	21568.	23224.
34-4.1	.90	0.	0.	4.	-10179.	616.	1044.	-14852.	5938.	37116.	23224.
36-4.1	.90	10000.	0.	4.	-10011.	1434.	718.	-5615.	22932.	30836.	23224.
37-4.1	.95	10000.	0.	4.	-10020.	1175.	1269.	-25241.	17809.	33746.	23224.

Altitude in Feet
Roll Rate in Deg/Sec
N_z in g's
Force (F) in Lb
Moment (M) in In-Lb

(1) Resultant Moment
(2) Incremental Force

APPENDIX B

DECOUPLER PYLON PIN MARGINS OF SAFETY

This appendix contains a tabulation of decoupler pylon pin margins of safety for the zero alignment angle case. Also included is a tabulation of pin margins of safety for store ejection loads with the pylon aligned.

TABLE B1.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS NON-SYMMETRICAL 0.60 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
41-4.1L	0.60	0.	100.	1.	0.62	0.54	0.90	0.23
41-4.1R	0.60	0.	100.	1.	0.43	0.43	0.75	0.12
41-4.1L	0.60	0.	90.	1.	0.89	0.82	1.44	0.55
41-4.1R	0.60	0.	90.	1.	0.66	0.69	1.23	0.39
41-4.1L	0.60	0.	80.	1.	1.22	1.19	2.29	1.03
41-4.1R	0.60	0.	80.	1.	0.95	1.02	1.94	0.79
51-4.1L	0.60	0.	90.	2.	0.41	0.35	0.90	0.23
51-4.1R	0.60	0.	90.	2.	0.40	0.22	0.49	0.05
51-4.1L	0.60	0.	80.	2.	0.60	0.53	1.33	0.50
51-4.1R	0.60	0.	80.	2.	0.59	0.38	0.79	0.26
61-4.1L	0.60	0.	75.	3.	0.46	0.21	0.69	0.23
61-4.1R	0.60	0.	75.	3.	0.48	0.09	0.32	0.04

TABLE B2.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS SYMMETRICAL 0.60 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
1-4.1	0.60	0.	0.	1.	4.86	3.97	9.32	12.33
11-4.1	0.60	0.	0.	2.	2.21	2.14	15.81	7.54
21-4.1	0.60	0.	0.	3.	1.51	0.77	2.06	1.66
31-4.1	0.60	0.	0.	4.	0.94	0.23	0.76	0.59

TABLE B3.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS NON-SYMMETRICAL 0.70 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
42-4.1L	0.70	0.	100.	1.	0.72	0.59	1.08	0.35
42-4.1R	0.70	0.	100.	1.	0.43	0.48	1.01	0.23
42-4.1L	0.70	0.	90.	1.	1.03	0.89	1.76	0.75
42-4.1R	0.70	0.	90.	1.	0.67	0.76	1.67	0.57
42-4.1L	0.70	0.	80.	1.	1.41	1.29	2.88	1.37
42-4.1R	0.70	0.	80.	1.	0.95	1.12	2.77	1.09
52-4.1L	0.70	0.	90.	2.	0.40	0.42	1.35	0.41
52-4.1R	0.70	0.	90.	2.	0.33	0.29	0.86	0.20
52-4.1L	0.70	0.	80.	2.	0.58	0.63	2.07	0.78
52-4.1R	0.70	0.	80.	2.	0.50	0.47	1.34	0.48
62-4.1L	0.70	0.	80.	3.	0.31	0.26	1.25	0.41
62-4.1R	0.70	0.	80.	3.	0.30	0.14	0.69	0.18

TABLE B4.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS SYMMETRICAL 0.70 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
2-4.1	0.70	0.	0.	1.	5.75	2.99	6.19	6.56
12-4.1	0.70	0.	0.	2.	2.14	2.05	7.06	9.86
22-4.1	0.70	0.	0.	3.	1.21	1.08	7.97	4.15
32-4.1	0.70	0.	0.	4.	0.85	0.41	1.87	1.34

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TABLE B5.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS
NON-SYMMETRICAL 0.80 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
43-4.1L	0.80	0.	100.	1.	0.67	0.65	1.53	0.53
43-4.1R	0.80	0.	100.	1.	0.36	0.52	1.37	0.32
43-4.1L	0.80	0.	90.	1.	0.96	0.99	2.59	1.05
43-4.1R	0.80	0.	90.	1.	0.57	0.81	2.27	0.72
43-4.1L	0.80	0.	80.	1.	1.31	1.44	4.73	1.95
43-4.1R	0.80	0.	80.	1.	0.84	1.20	3.99	1.35
53-4.1L	0.80	0.	90.	2.	0.35	0.47	2.08	0.63
53-4.1R	0.80	0.	90.	2.	0.23	0.32	1.31	0.33
53-4.1L	0.80	0.	80.	2.	0.51	0.69	3.39	1.13
53-4.1R	0.80	0.	80.	2.	0.37	0.51	2.12	0.69
63-4.1L	0.80	0.	80.	3.	0.28	0.36	2.48	0.81
63-4.1R	0.80	0.	80.	3.	0.22	0.23	1.44	0.45
71-4.1L	0.80	5000.	100.	1.	0.68	0.63	1.34	0.46
71-4.1R	0.80	5000.	100.	1.	0.40	0.52	1.23	0.30
71-4.1L	0.80	5000.	90.	1.	0.97	0.95	2.23	0.93
71-4.1R	0.80	5000.	90.	1.	0.63	0.81	2.01	0.67
71-4.1L	0.80	5000.	80.	1.	1.33	1.38	3.87	1.71
71-4.1R	0.80	5000.	80.	1.	0.91	1.18	3.41	1.26
72-4.1L	0.80	5000.	90.	2.	0.40	0.47	1.74	0.54
72-4.1R	0.80	5000.	90.	2.	0.29	0.34	1.19	0.31
72-4.1L	0.80	5000.	80.	2.	0.55	0.67	2.61	0.94
72-4.1R	0.80	5000.	80.	2.	0.45	0.51	1.72	0.60
73-4.1L	0.80	5000.	80.	3.	0.34	0.37	2.11	0.73
73-4.1R	0.80	5000.	80.	3.	0.27	0.26	1.35	0.44

TABLE B5.- (CONCLUDED)

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
45-4.1L	0.80	10000.	100.	1.	0.60	0.58	1.14	0.33
45-4.1R	0.80	10000.	100.	1.	0.41	0.47	0.97	0.20
45-4.1L	0.80	10000.	90.	1.	0.87	0.88	1.85	0.72
45-4.1R	0.80	10000.	90.	1.	0.63	0.75	1.59	0.52
45-4.1L	0.80	10000.	80.	1.	1.20	1.27	3.05	1.32
45-4.1R	0.80	10000.	80.	1.	0.90	1.10	2.61	1.01
55-4.1L	0.80	10000.	90.	2.	0.37	0.40	1.25	0.35
55-4.1R	0.80	10000.	90.	2.	0.35	0.27	0.74	0.16
55-4.1L	0.80	10000.	80.	2.	0.51	0.56	1.69	0.61
55-4.1R	0.80	10000.	80.	2.	0.53	0.40	0.97	0.35
65-4.1L	0.80	10000.	80.	3.	0.33	0.25	1.11	0.37
65-4.1R	0.80	10000.	80.	3.	0.33	0.15	0.66	0.18
48-4.1L	0.80	20000.	100.	1.	0.55	0.52	0.86	0.19
48-4.1R	0.80	20000.	100.	1.	0.45	0.43	0.71	0.10
48-4.1L	0.80	20000.	90.	1.	0.81	0.80	1.38	0.49
48-4.1R	0.80	20000.	90.	1.	0.68	0.69	1.16	0.36
48-4.1L	0.80	20000.	80.	1.	1.12	1.16	2.18	0.93
48-4.1R	0.80	20000.	80.	1.	0.97	1.02	1.82	0.73
58-4.1L	0.80	20000.	90.	2.	0.45	0.33	0.76	0.18
58-4.1R	0.80	20000.	90.	2.	0.44	0.24	0.51	0.07
58-4.1L	0.80	20000.	80.	2.	0.65	0.48	1.01	0.38
58-4.1R	0.80	20000.	80.	2.	0.64	0.38	0.72	0.25
68-4.1L	0.80	20000.	80.	3.	0.41	0.18	0.63	0.18
68-4.1R	0.80	20000.	80.	3.	0.37	0.12	0.47	0.09

TABLE B6.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS SYMMETRICAL 0.80 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
3-4.1	0.80	0.	0.	1.	4.87	2.10	3.36	3.43
13-4.1	0.80	0.	0.	2.	1.91	1.49	3.80	5.05
23-4.1	0.80	0.	0.	3.	1.02	1.16	5.10	8.11
33-4.1	0.80	0.	0.	4.	0.69	0.56	5.43	2.94
5-4.1	0.80	10000.	0.	1.	4.68	3.07	6.04	7.34
15-4.1	0.80	10000.	0.	2.	2.03	2.17	7.57	11.38
25-4.1	0.80	10000.	0.	3.	1.33	1.06	5.89	3.70
35-4.1	0.80	10000.	0.	4.	0.81	0.39	1.81	1.30
8-4.1	0.80	20000.	0.	1.	4.73	4.40	10.60	14.72
18-4.1	0.80	20000.	0.	2.	2.48	2.21	12.68	7.28
28-4.1	0.80	20000.	0.	3.	1.50	0.93	3.02	2.26
38-4.1	0.80	20000.	0.	4.	0.82	0.32	1.19	0.84

TABLE B7.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS NON-SYMMETRICAL 0.90 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
44-4.1L	0.90	0.	100.	1.	0.47	0.65	2.39	0.72
44-4.1R	0.90	0.	100.	1.	0.28	0.51	1.75	0.42
44-4.1L	0.90	0.	90.	1.	0.69	0.99	4.59	1.40
44-4.1R	0.90	0.	90.	1.	0.47	0.80	3.11	0.90
44-4.1L	0.90	0.	80.	1.	0.95	1.44	12.27	2.73
44-4.1R	0.90	0.	80.	1.	0.69	1.18	6.41	1.71
54-4.1L	0.90	0.	90.	2.	0.27	0.46	3.51	1.01
54-4.1R	0.90	0.	90.	2.	0.15	0.30	1.95	0.54
54-4.1L	0.90	0.	80.	2.	0.40	0.66	6.57	1.73
54-4.1R	0.90	0.	80.	2.	0.27	0.47	3.13	0.97
64-4.1L	0.90	0.	80.	3.	0.23	0.39	5.19	1.45
64-4.1R	0.90	0.	80.	3.	0.13	0.25	2.71	0.83
46-4.1L	0.90	10000.	100.	1.	0.46	0.57	1.55	0.45
46-4.1R	0.90	10000.	100.	1.	0.33	0.44	1.13	0.25
46-4.1L	0.90	10000.	90.	1.	0.68	0.87	2.56	0.90
46-4.1R	0.90	10000.	90.	1.	0.52	0.71	1.87	0.60
46-4.1L	0.90	10000.	80.	1.	0.95	1.25	4.53	1.62
46-4.1R	0.90	10000.	80.	1.	0.76	1.04	3.17	1.14
56-4.1L	0.90	10000.	90.	2.	0.30	0.37	1.57	0.47
56-4.1R	0.90	10000.	90.	2.	0.23	0.25	0.99	0.24
56-4.1L	0.90	10000.	80.	2.	0.41	0.51	2.12	0.75
56-4.1R	0.90	10000.	80.	2.	0.36	0.37	1.27	0.43
66-4.1L	0.90	10000.	80.	3.	0.23	0.27	1.75	0.58
66-4.1R	0.90	10000.	80.	3.	0.20	0.16	1.04	0.31

TABLE B7.- (CONCLUDED)

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
49-4.1L	0.90	20000.	100.	1.	0.46	0.49	1.01	0.24
49-4.1R	0.90	20000.	100.	1.	0.37	0.39	0.77	0.12
49-4.1L	0.90	20000.	90.	1.	0.69	0.76	1.61	0.57
49-4.1R	0.90	20000.	90.	1.	0.58	0.64	1.26	0.40
49-4.1L	0.90	20000.	80.	1.	0.96	1.10	2.58	1.05
49-4.1R	0.90	20000.	80.	1.	0.83	0.94	1.99	0.79
59-4.1L	0.90	20000.	90.	2.	0.35	0.31	0.88	0.22
59-4.1R	0.90	20000.	90.	2.	0.33	0.21	0.58	0.09
59-4.1L	0.90	20000.	80.	2.	0.51	0.44	1.15	0.41
59-4.1R	0.90	20000.	80.	2.	0.49	0.34	0.81	0.26
69-4.1L	0.90	20000.	80.	3.	0.31	0.17	0.76	0.22
69-4.1R	0.90	20000.	80.	3.	0.29	0.10	0.55	0.12

TABLE B8.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS SYMMETRICAL 0.90 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
4-4.1	0.90	0.	0.	1.	3.25	1.28	1.74	1.78
14-4.1	0.90	0.	0.	2.	1.61	0.96	2.56	3.23
24-4.1	0.90	0.	0.	3.	0.89	0.74	3.19	4.51
34-4.1	0.90	0.	0.	4.	0.48	0.58	4.34	7.27
6-4.1	0.90	10000.	0.	1.	3.48	2.23	3.76	4.34
16-4.1	0.90	10000.	0.	2.	1.71	1.67	5.92	9.07
26-4.1	0.90	10000.	0.	3.	0.98	1.10	13.65	7.60
36-4.1	0.90	10000.	0.	4.	0.61	0.39	2.74	1.73
9-4.1	0.90	20000.	0.	1.	3.74	3.67	9.92	16.19
19-4.1	0.90	20000.	0.	2.	1.95	2.07	29.82	9.89
29-4.1	0.90	20000.	0.	3.	1.23	0.88	3.69	2.55
39-4.1	0.90	20000.	0.	4.	0.70	0.32	1.50	1.04

TABLE B9.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS NON-SYMMETRICAL 0.95 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
47-4.1L	0.95	10000.	100.	1.	0.39	0.47	1.51	0.41
47-4.1R	0.95	10000.	100.	1.	0.23	0.36	1.18	0.23
47-4.1L	0.95	10000.	90.	1.	0.59	0.73	2.49	0.84
47-4.1R	0.95	10000.	90.	1.	0.40	0.59	1.98	0.56
47-4.1L	0.95	10000.	80.	1.	0.82	1.05	4.38	1.51
47-4.1R	0.95	10000.	80.	1.	0.60	0.88	3.29	1.07
57-4.1L	0.95	10000.	90.	2.	0.20	0.29	1.87	0.55
57-4.1R	0.95	10000.	90.	2.	0.14	0.17	1.15	0.29
57-4.1L	0.95	10000.	80.	2.	0.30	0.40	2.45	0.83
57-4.1R	0.95	10000.	80.	2.	0.25	0.27	1.44	0.48
67-4.1L	0.95	10000.	80.	3.	0.16	0.20	2.51	0.85
67-4.1R	0.95	10000.	80.	3.	0.11	0.10	1.48	0.50
50-4.1L	0.95	20000.	100.	1.	0.42	0.45	1.11	0.28
50-4.1R	0.95	20000.	100.	1.	0.32	0.36	0.87	0.15
50-4.1L	0.95	20000.	90.	1.	0.63	0.70	1.77	0.62
50-4.1R	0.95	20000.	90.	1.	0.51	0.59	1.42	0.44
50-4.1L	0.95	20000.	80.	1.	0.88	1.01	2.85	1.13
50-4.1R	0.95	20000.	80.	1.	0.74	0.87	2.26	0.86
60-4.1L	0.95	20000.	90.	2.	0.29	0.30	1.29	0.39
60-4.1R	0.95	20000.	90.	2.	0.26	0.20	0.87	0.22
60-4.1L	0.95	20000.	80.	2.	0.45	0.47	1.98	0.76
60-4.1R	0.95	20000.	80.	2.	0.41	0.36	1.36	0.51
70-4.1L	0.95	20000.	80.	3.	0.25	0.18	1.26	0.44
70-4.1R	0.95	20000.	80.	3.	0.22	0.11	0.90	0.28

TABLE B10.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS SYMMETRICAL 0.95 MACH

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
7-4.1	0.95	10000.	0.	1.	2.72	1.52	2.51	2.60
17-4.1	0.95	10000.	0.	2.	1.33	1.18	4.31	6.25
27-4.1	0.95	10000.	0.	3.	0.76	0.94	11.10	52.57
37-4.1	0.95	10000.	0.	4.	0.45	0.37	6.78	3.43
10-4.1	0.95	20000.	0.	1.	3.18	2.50	5.13	6.11
20-4.1	0.95	20000.	0.	2.	1.65	1.86	13.90	49.07
30-4.1	0.95	20000.	0.	3.	1.03	0.90	9.69	5.13
40-4.1	0.95	20000.	0.	4.	0.59	0.40	3.51	2.14

TABLE B11.- MARGINS OF SAFETY FOR FORWARD AND AFT PINS STORE EJECTION LOADS INCLUDED

					MARGINS OF SAFETY			
			ROLL RATE		FWD		AFT	
COND.	MACH	ALT(FT)	DEG/SEC	NZ	UPPER	LOWER	UPPER	LOWER
3-4.1	0.80	0.	0.	1.	2.07	0.92	2.01	1.69
5-4.1	0.80	10000.	0.	1.	1.68	1.02	3.11	2.77
4-4.1	0.90	0.	0.	1.	2.31	0.91	1.14	0.98
6-4.1	0.90	10000.	0.	1.	1.76	1.06	2.20	1.99
7-4.1	0.95	10000.	0.	1.	2.29	1.26	1.59	1.35
33-4.1	0.80	0.	0.	4.	0.44	0.30	3.90	2.09
35-4.1	0.80	10000.	0.	4.	0.47	0.14	1.67	1.16
34-4.1	0.90	0.	0.	4.	0.43	0.51	2.54	2.88
36-4.1	0.90	10000.	0.	4.	0.41	0.21	2.12	1.27
37-4.1	0.95	10000.	0.	4.	0.49	0.41	2.91	1.45

APPENDIX C

TUNED FREE-FREE SYMMETRIC AND ANTISYMMETRIC MODES

This appendix contains the first three computed free-free symmetric and antisymmetric mode shapes. The modes were computed using the tuned simulation.

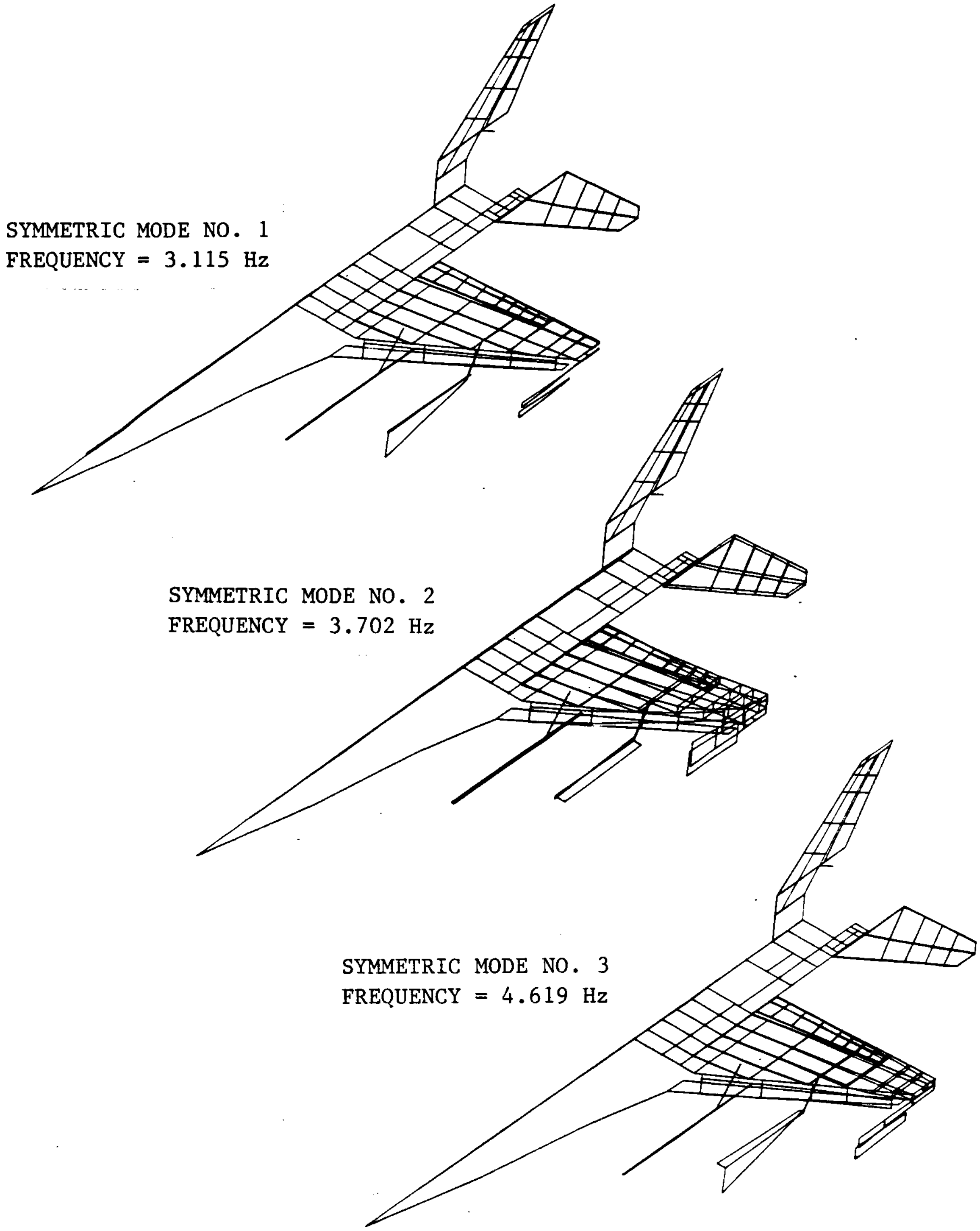

Figure C1.- First three symmetric modes with the decoupler pylon stiffness based on 1984 fixture test.

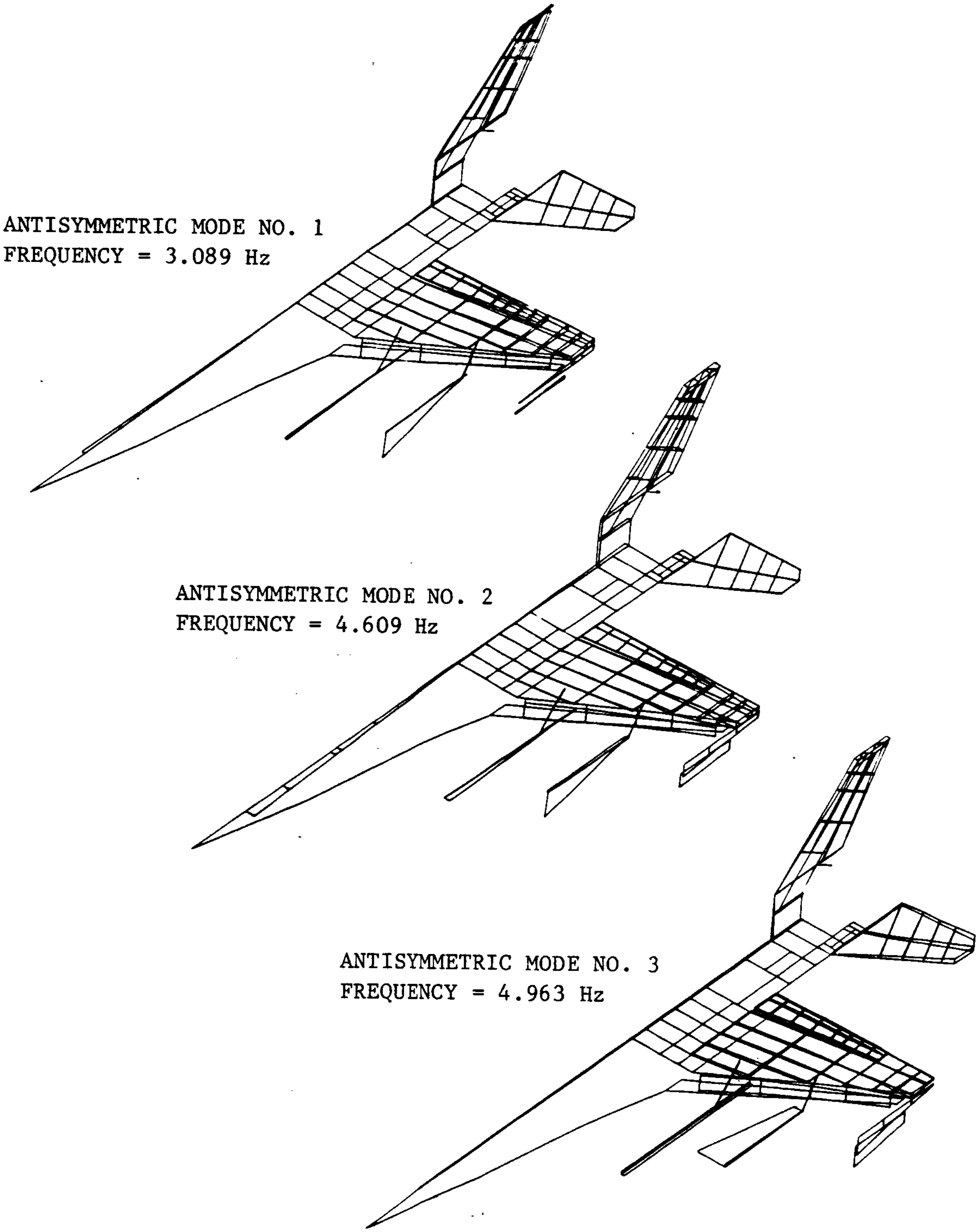

Figure C2.- First three antisymmetric modes with the decoupler pylon stiffness based on 1984 fixture test.

APPENDIX D

FIXTURE GROUND VIBRATION TEST FREQUENCY SWEEPS

This appendix contains plots of frequency sweeps which were obtained during ground vibration tests of the decoupler pylon in the fixture.

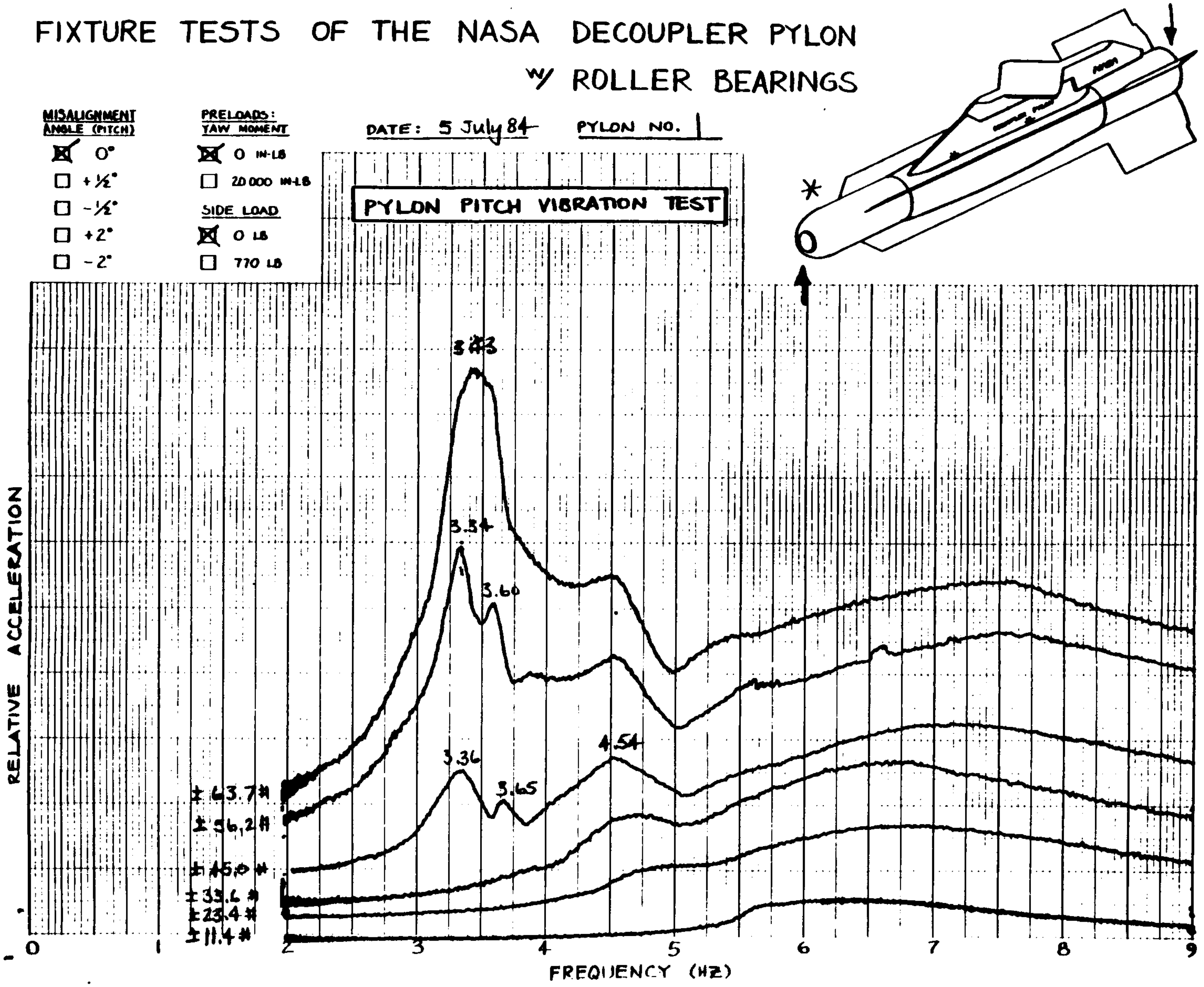

Figure D1.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

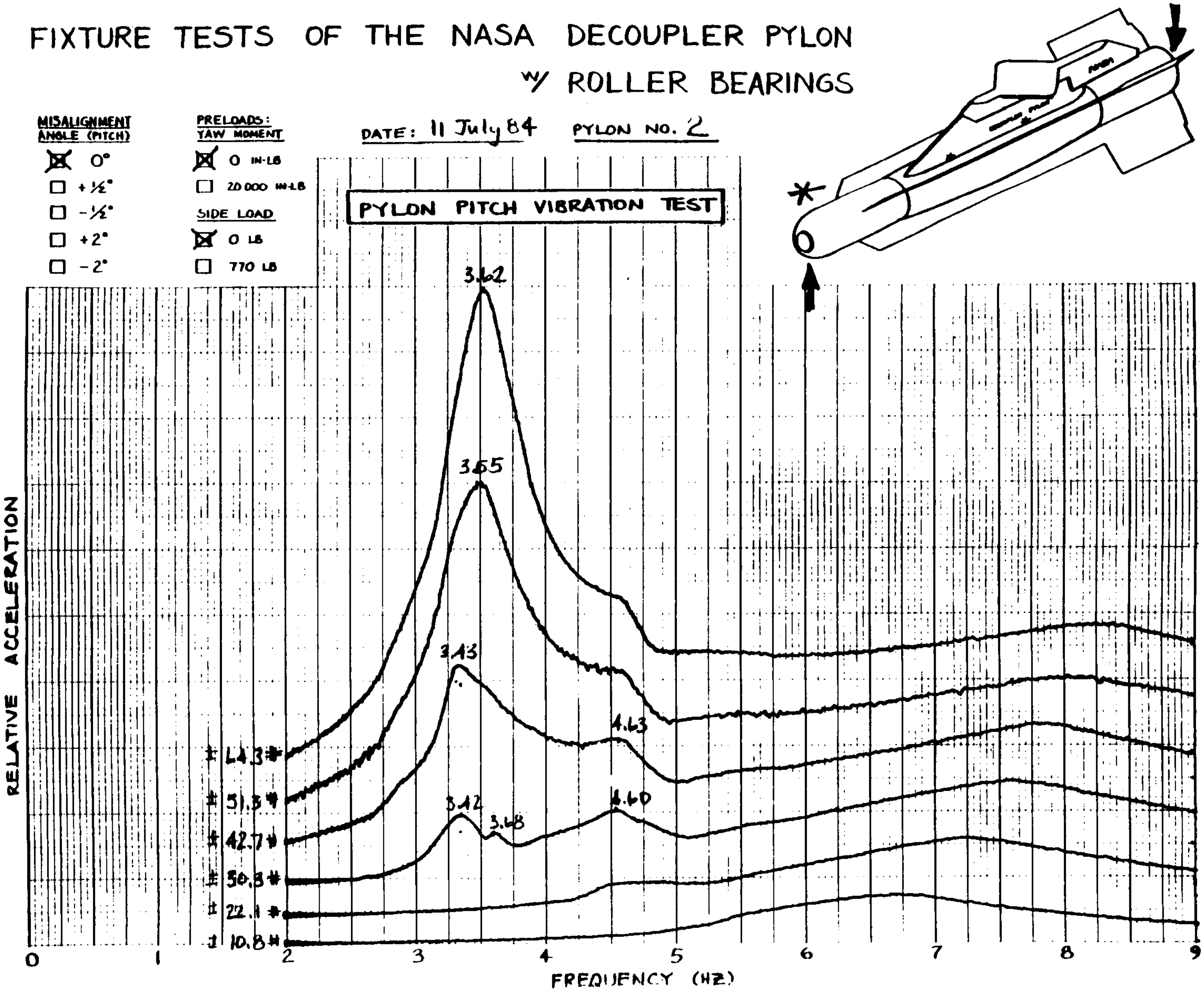

Figure D2.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

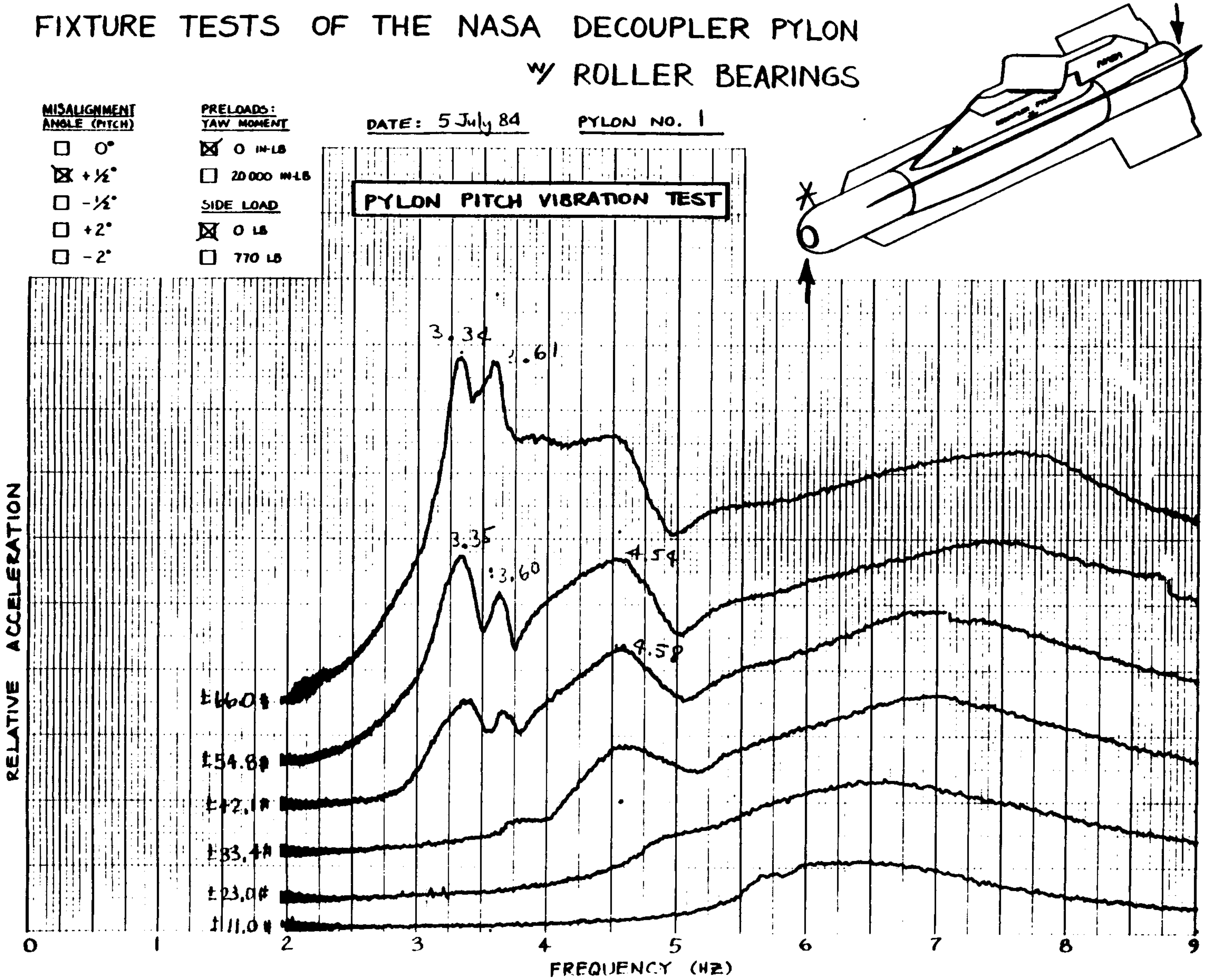

Figure D3.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

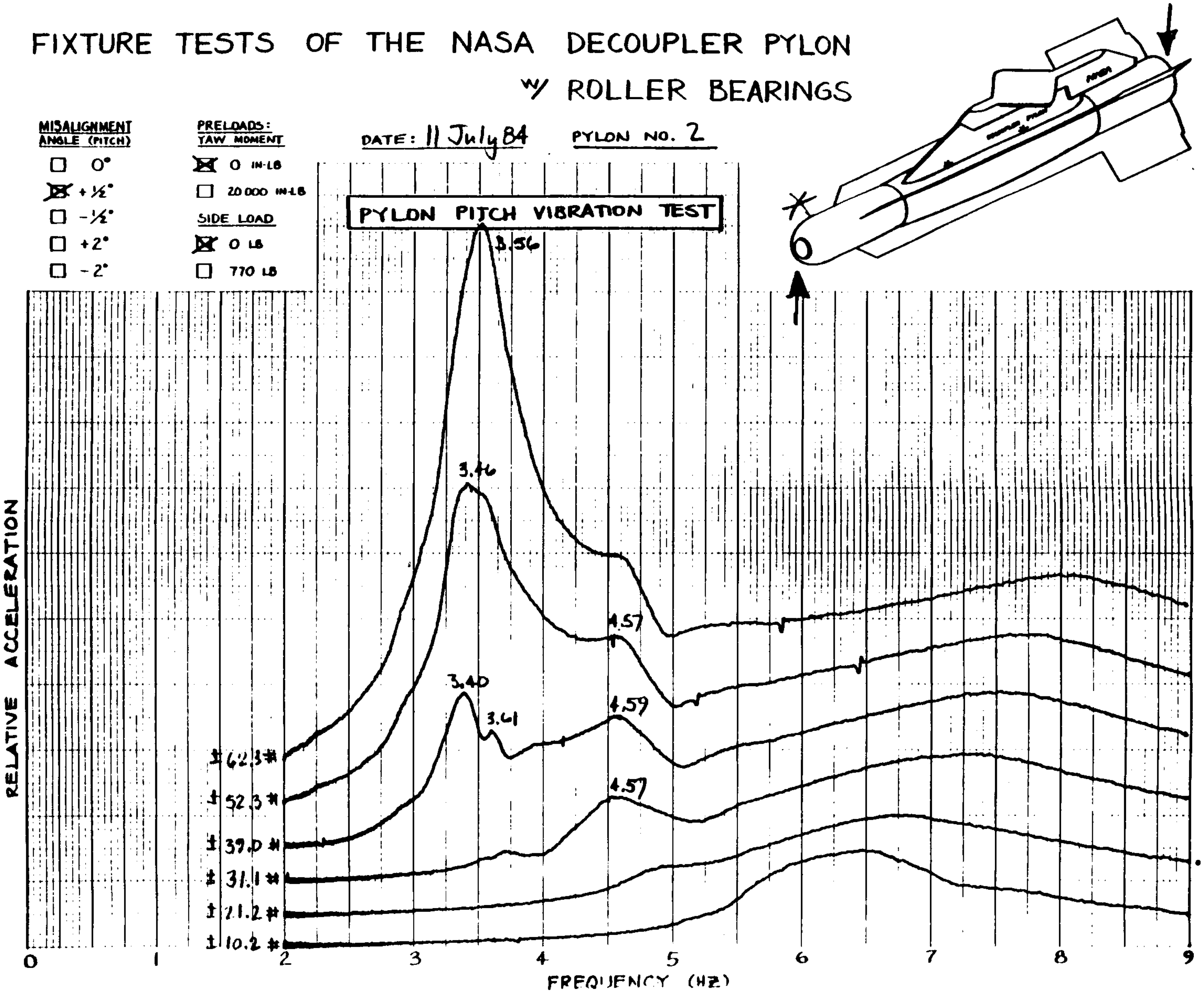

Figure D4.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

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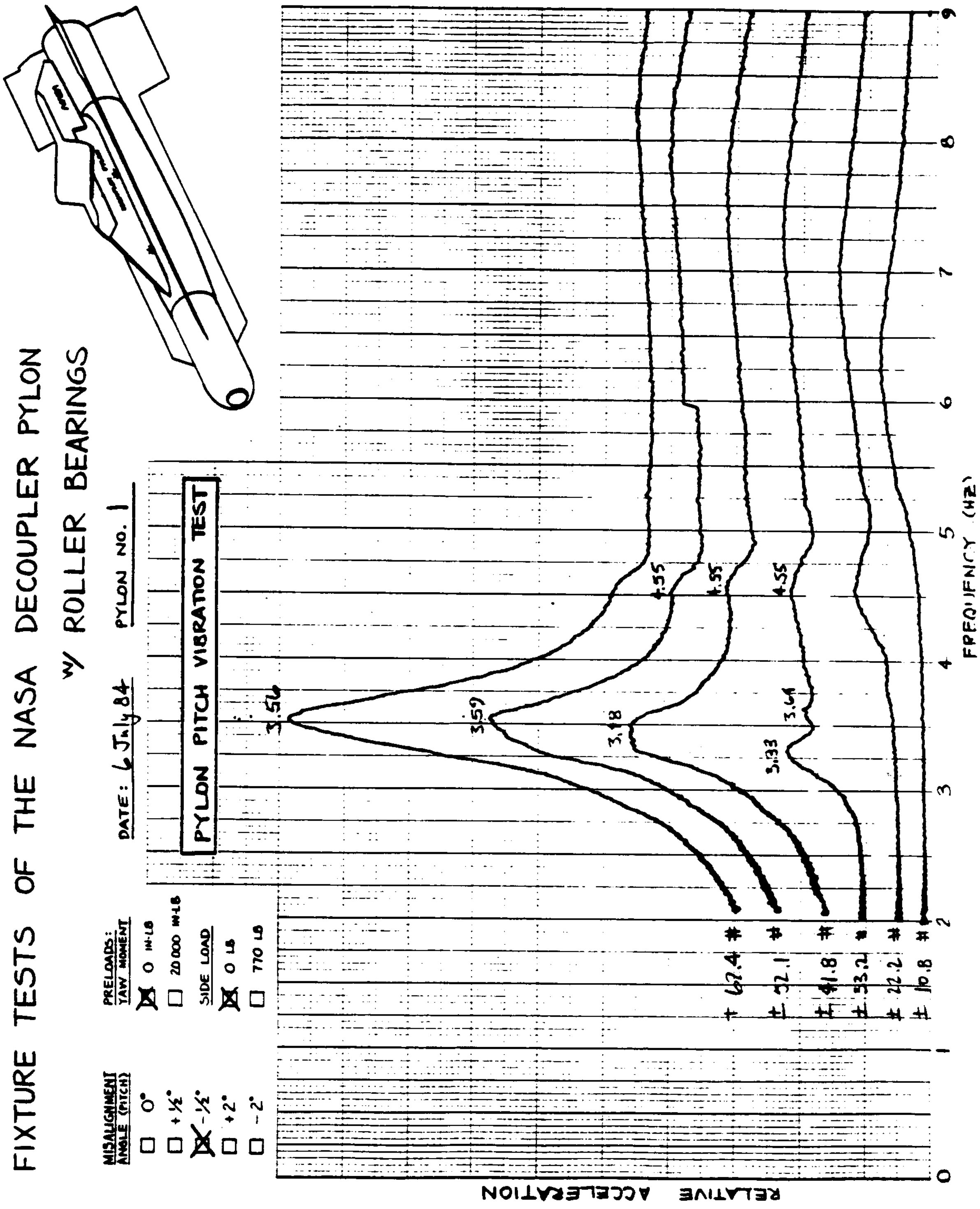

Figure D5.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

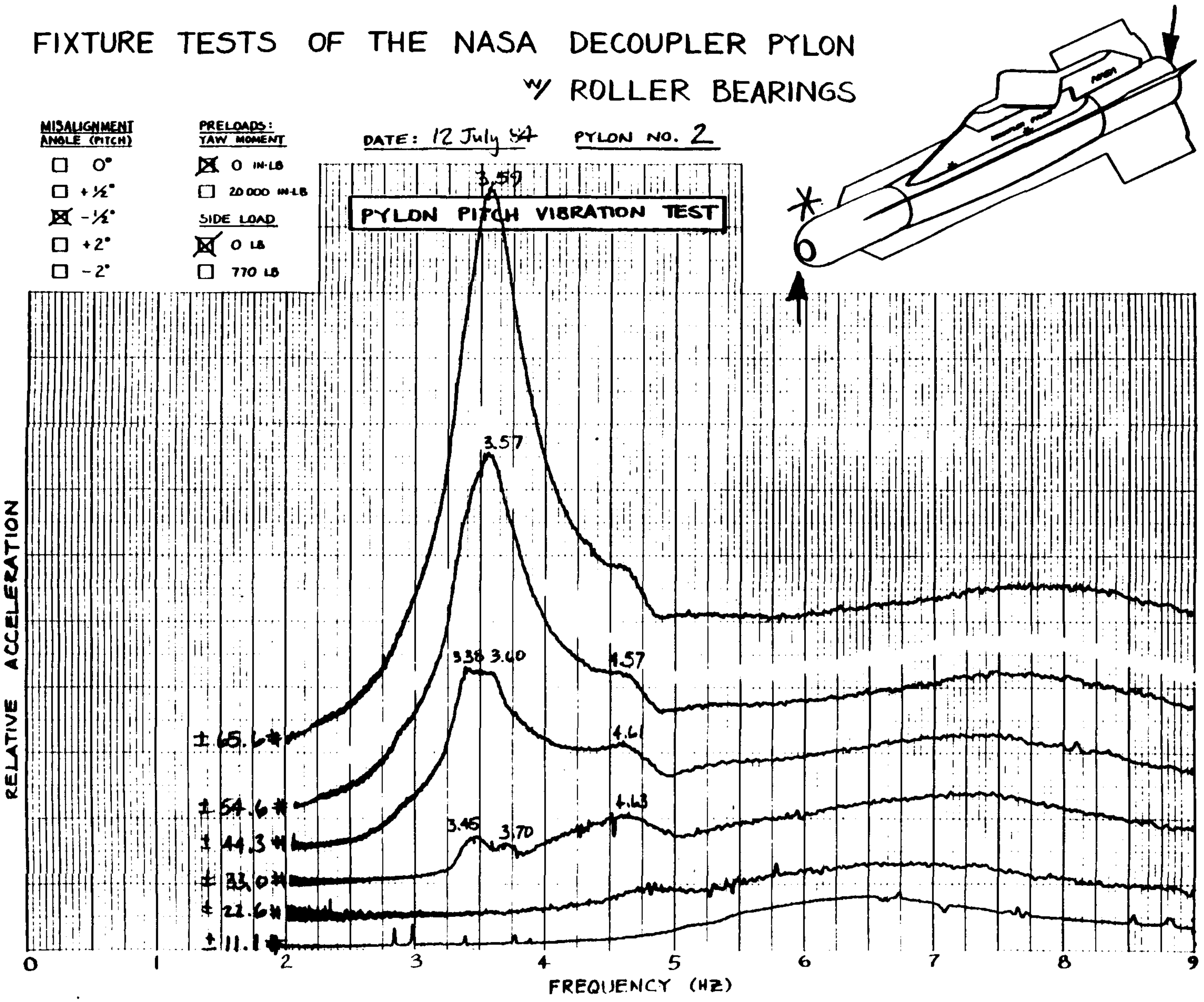

Figure D6.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

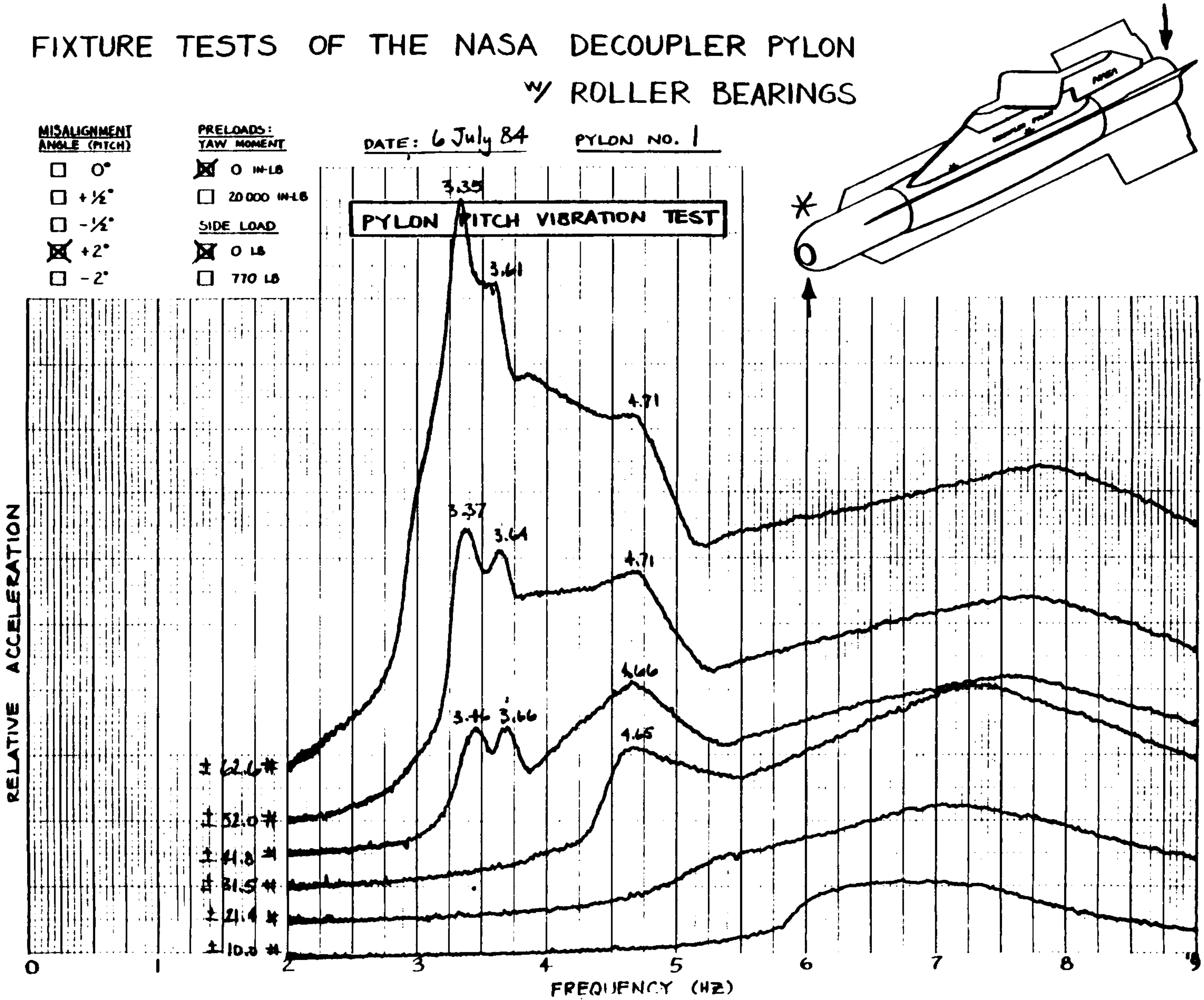

Figure D7.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

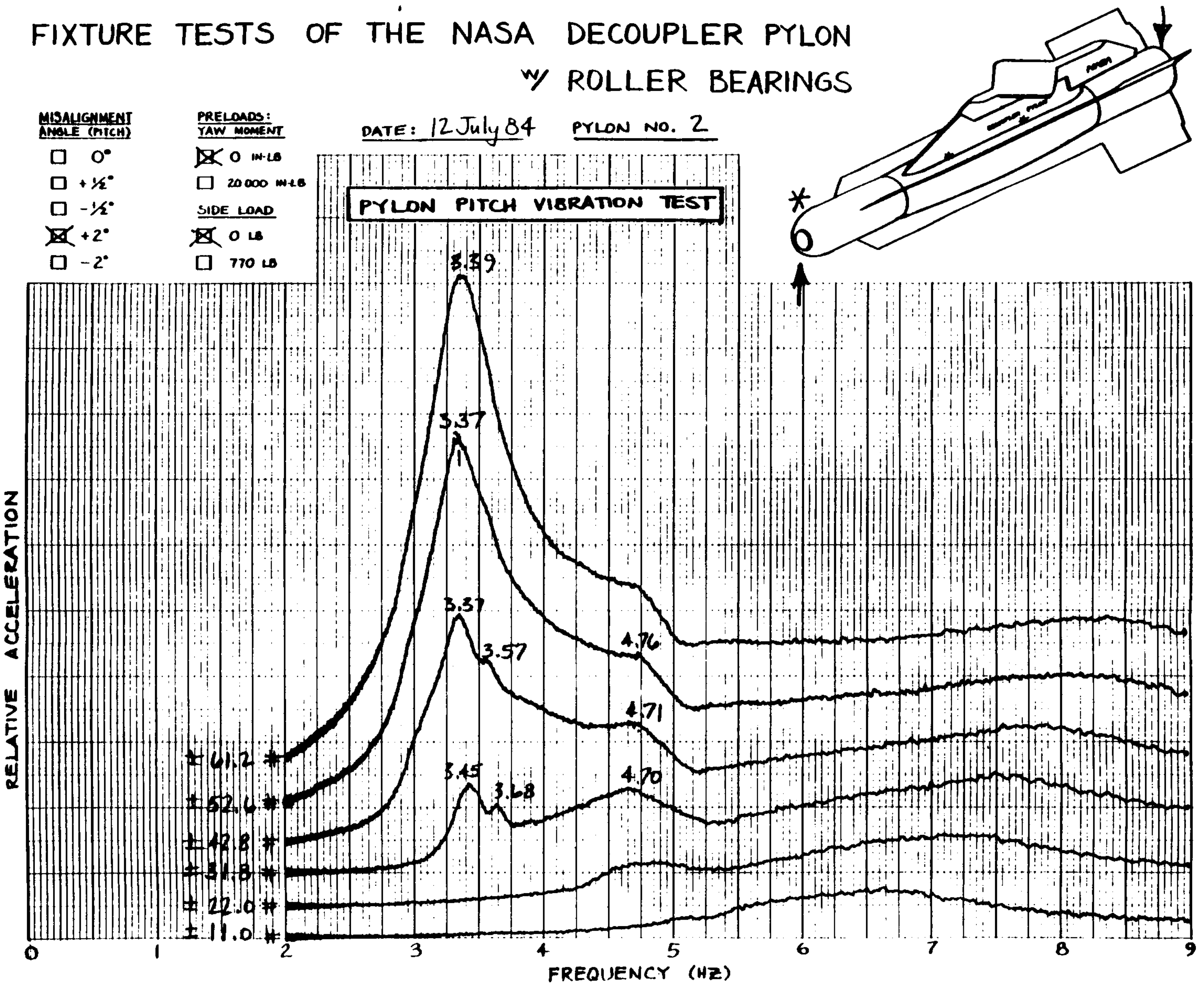

Figure D8.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

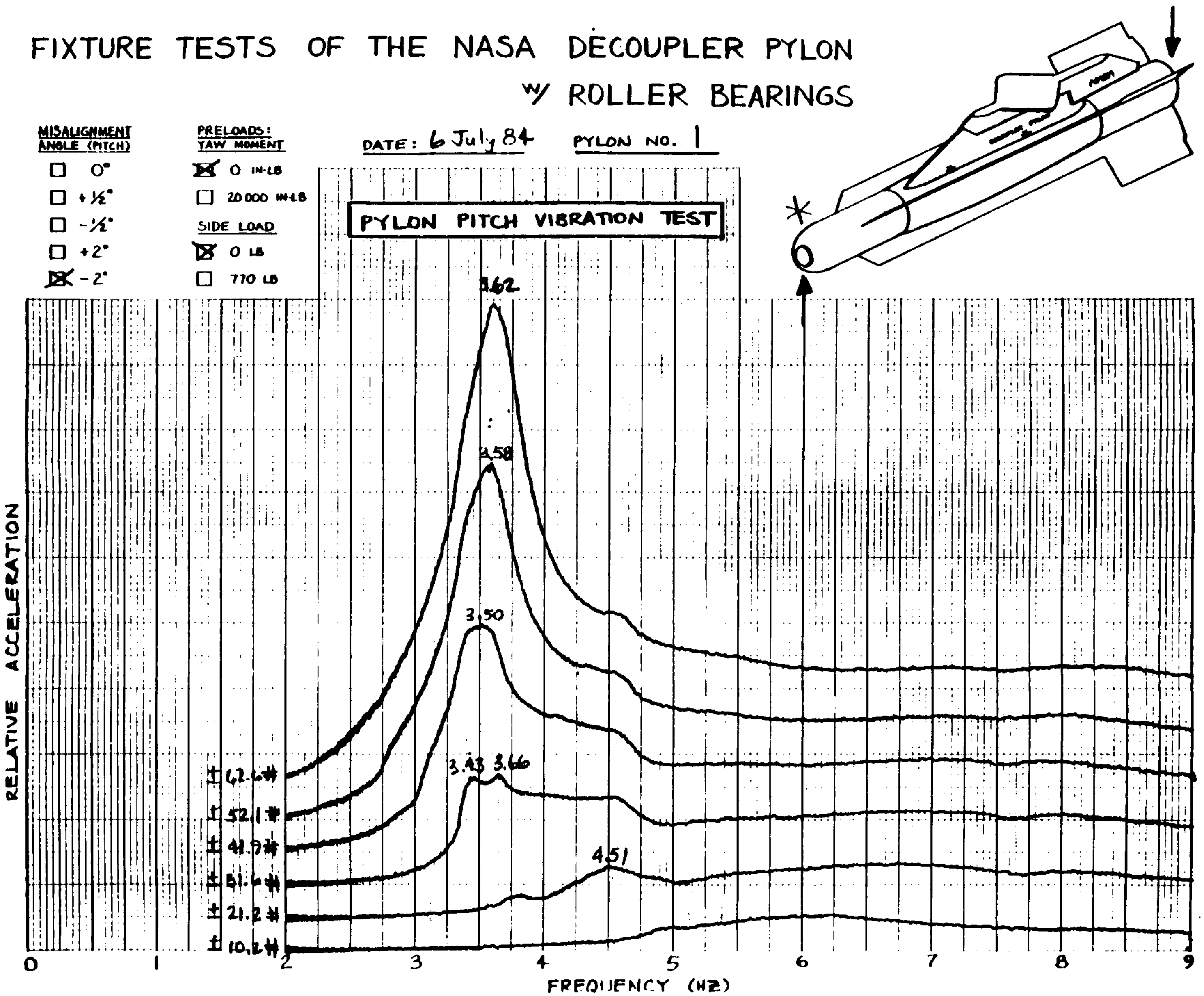

Figure D9.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

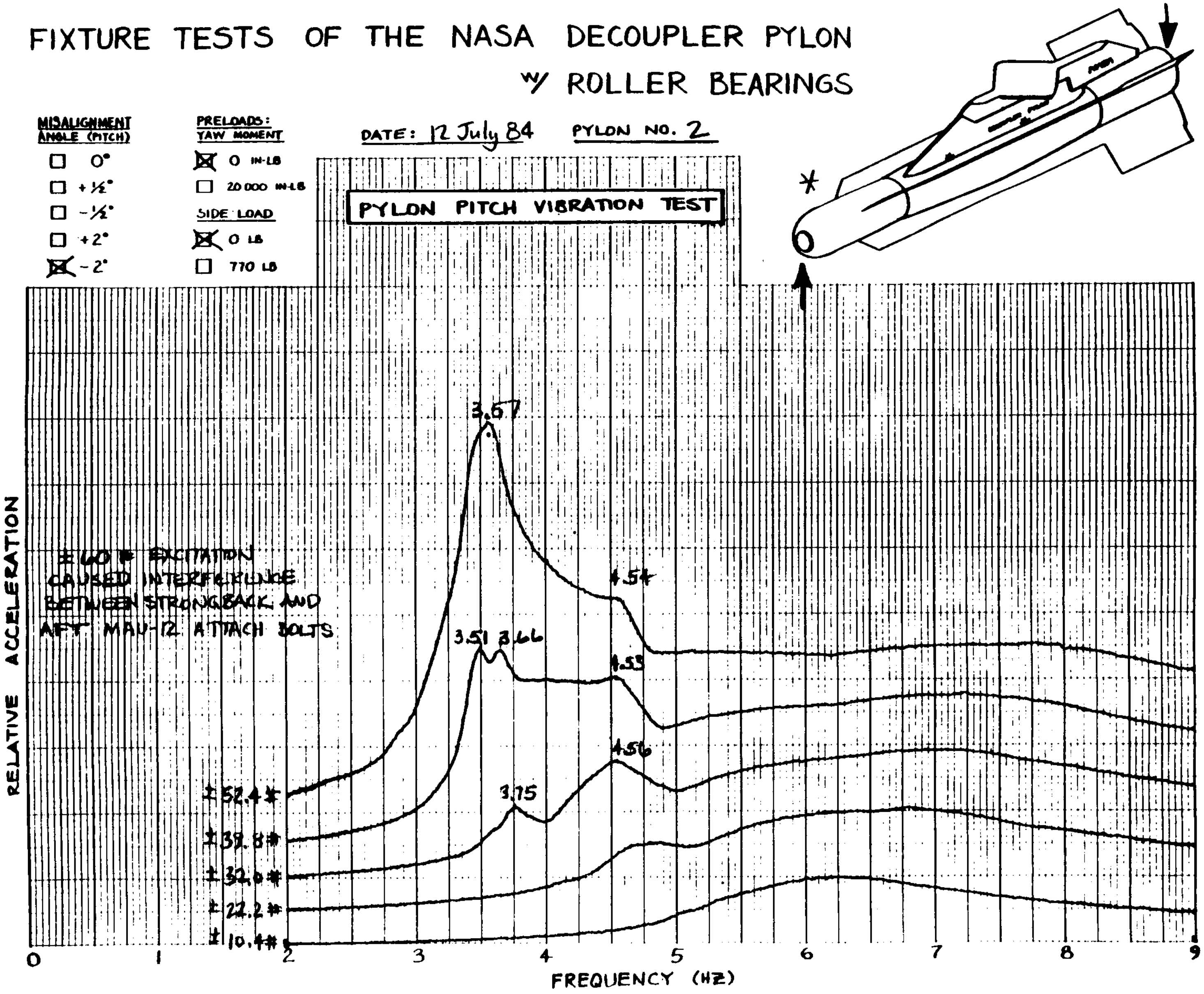

Figure D10.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

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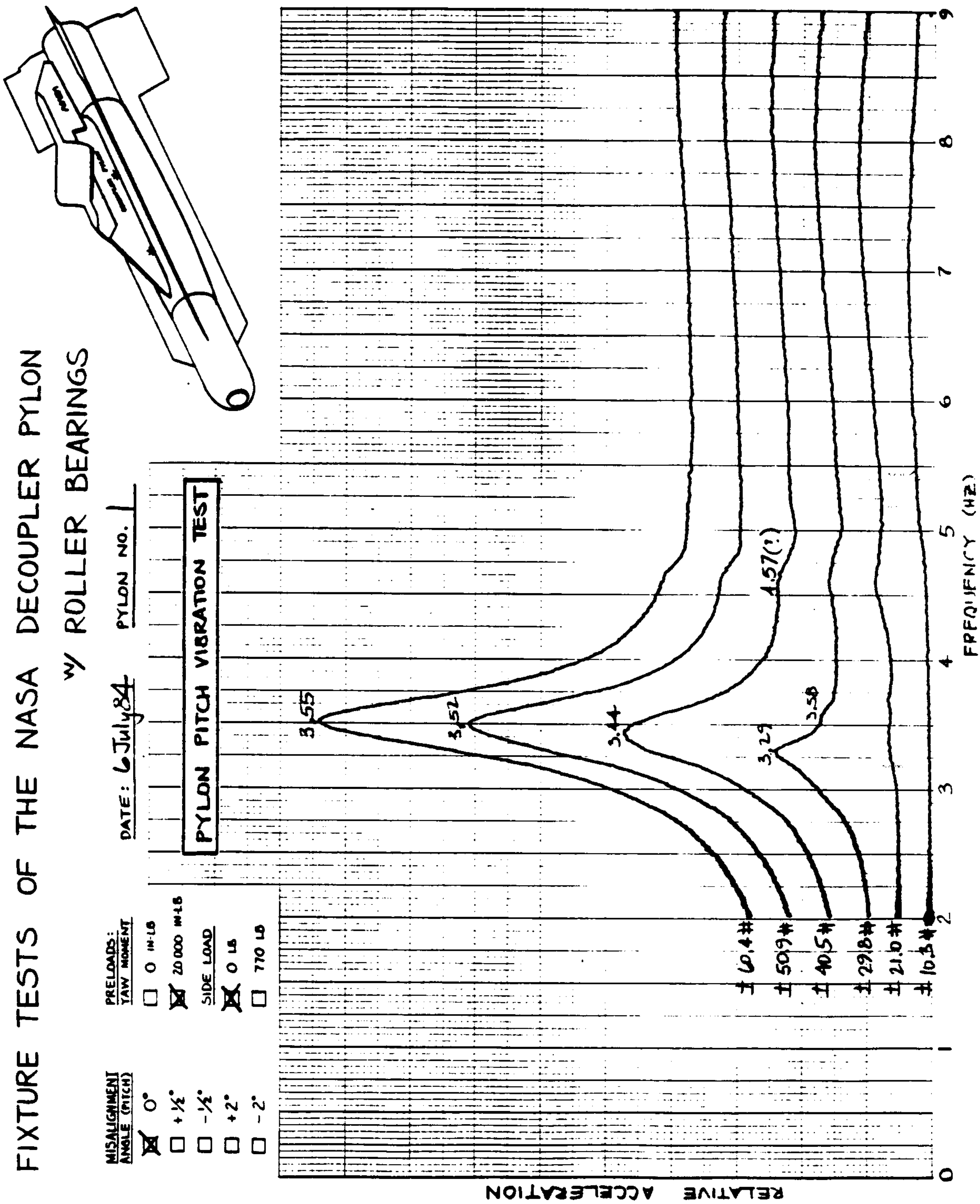

Figure D11.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

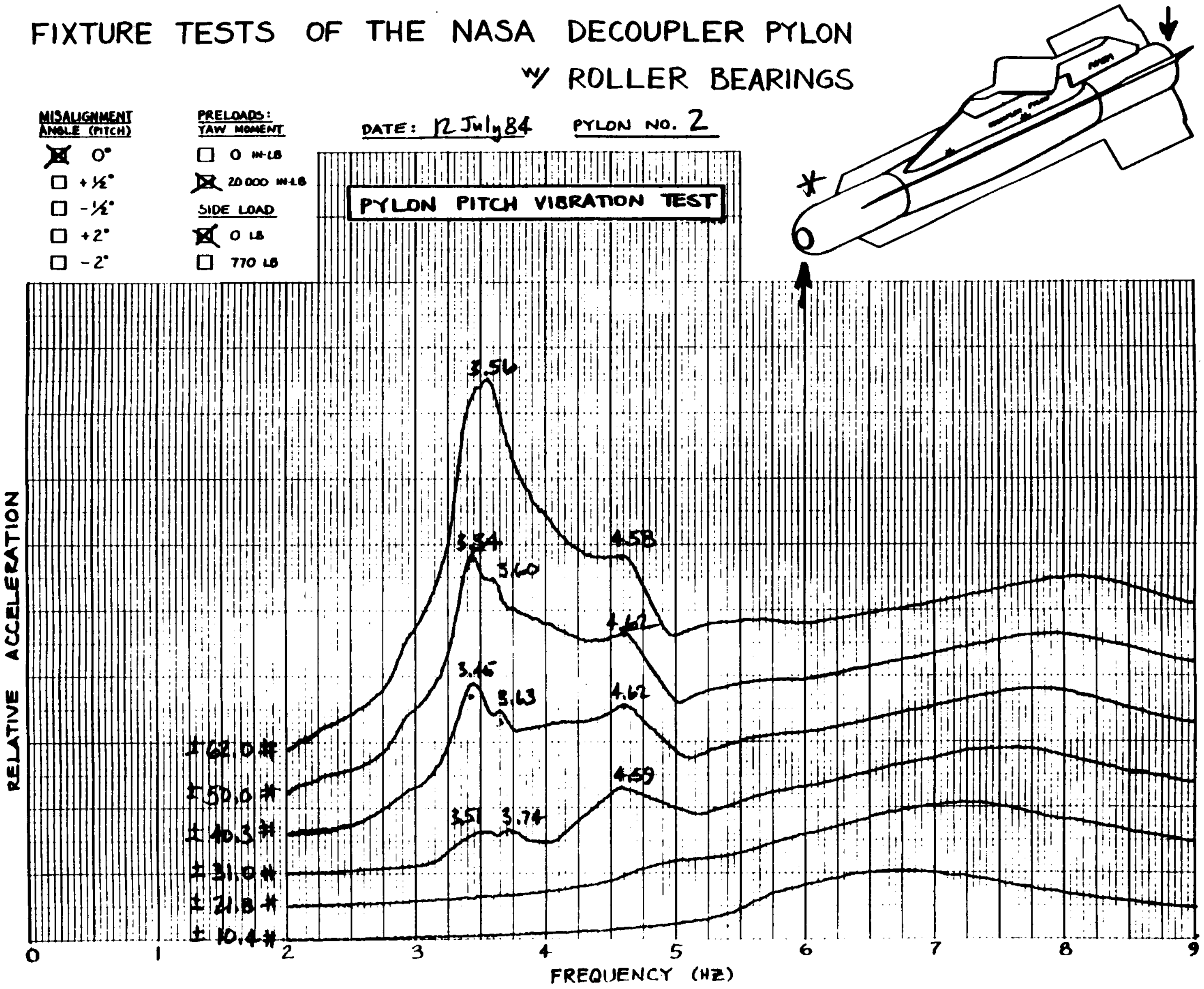

Figure D12.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

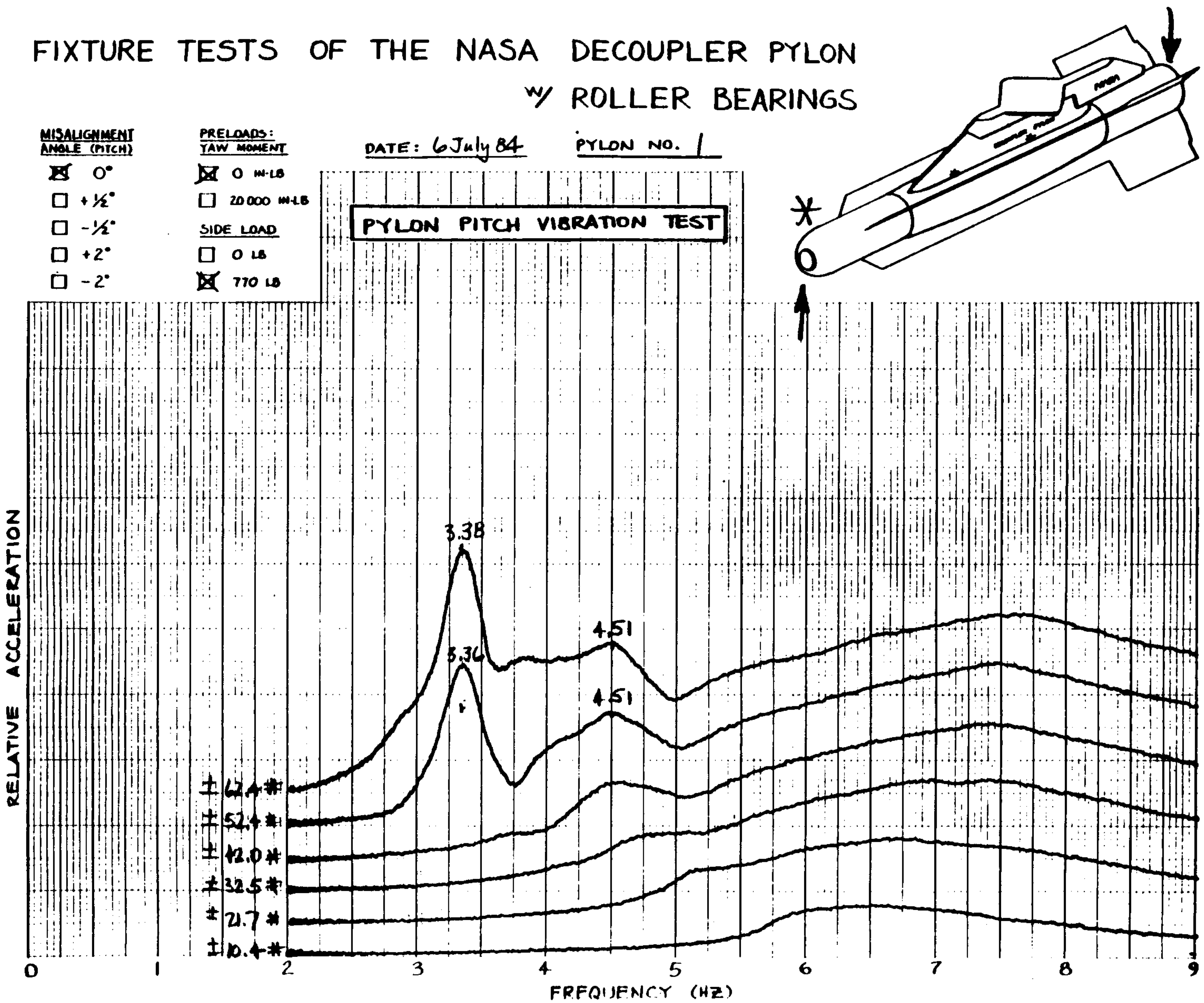

Figure D13.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

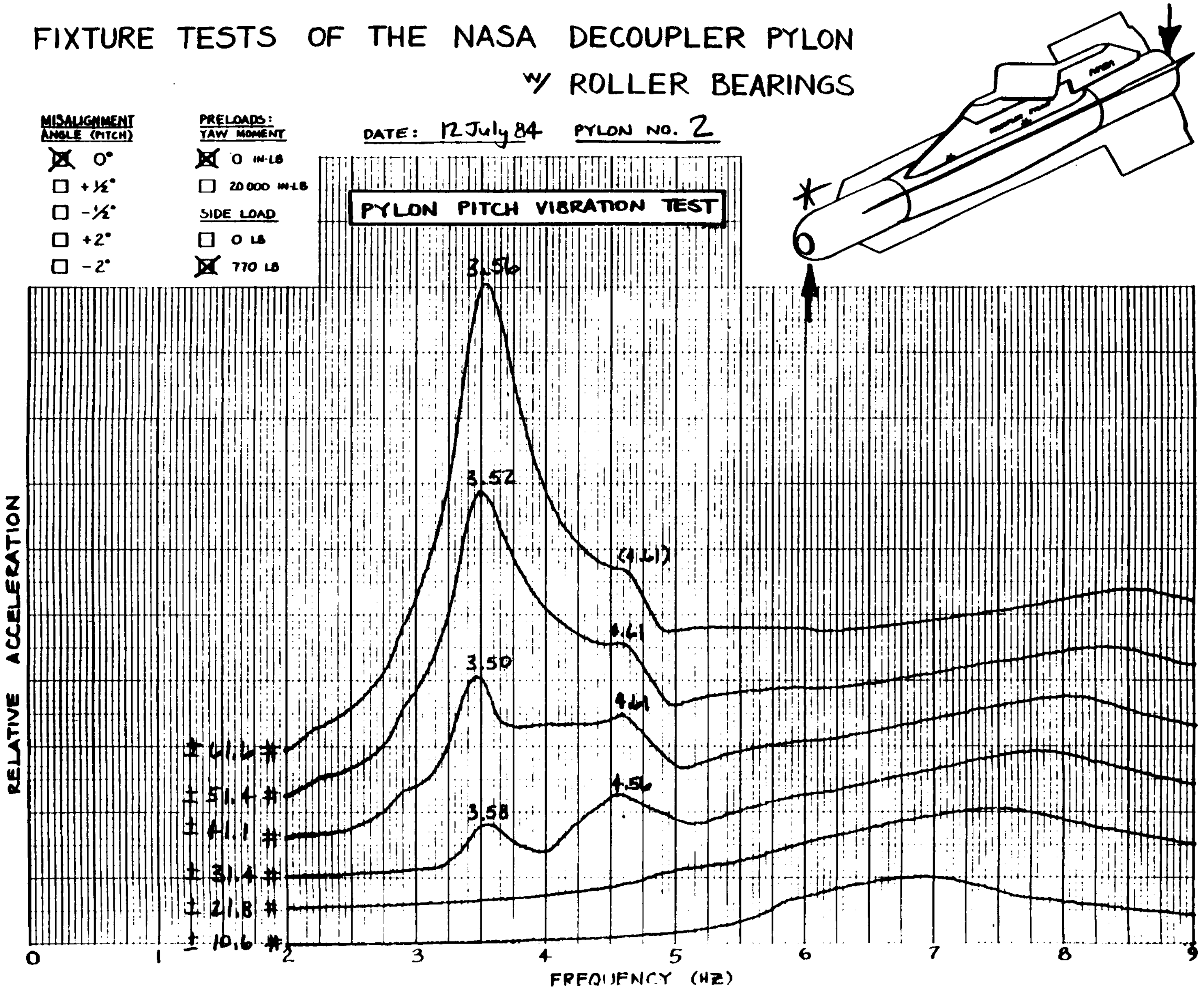

Figure D14.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

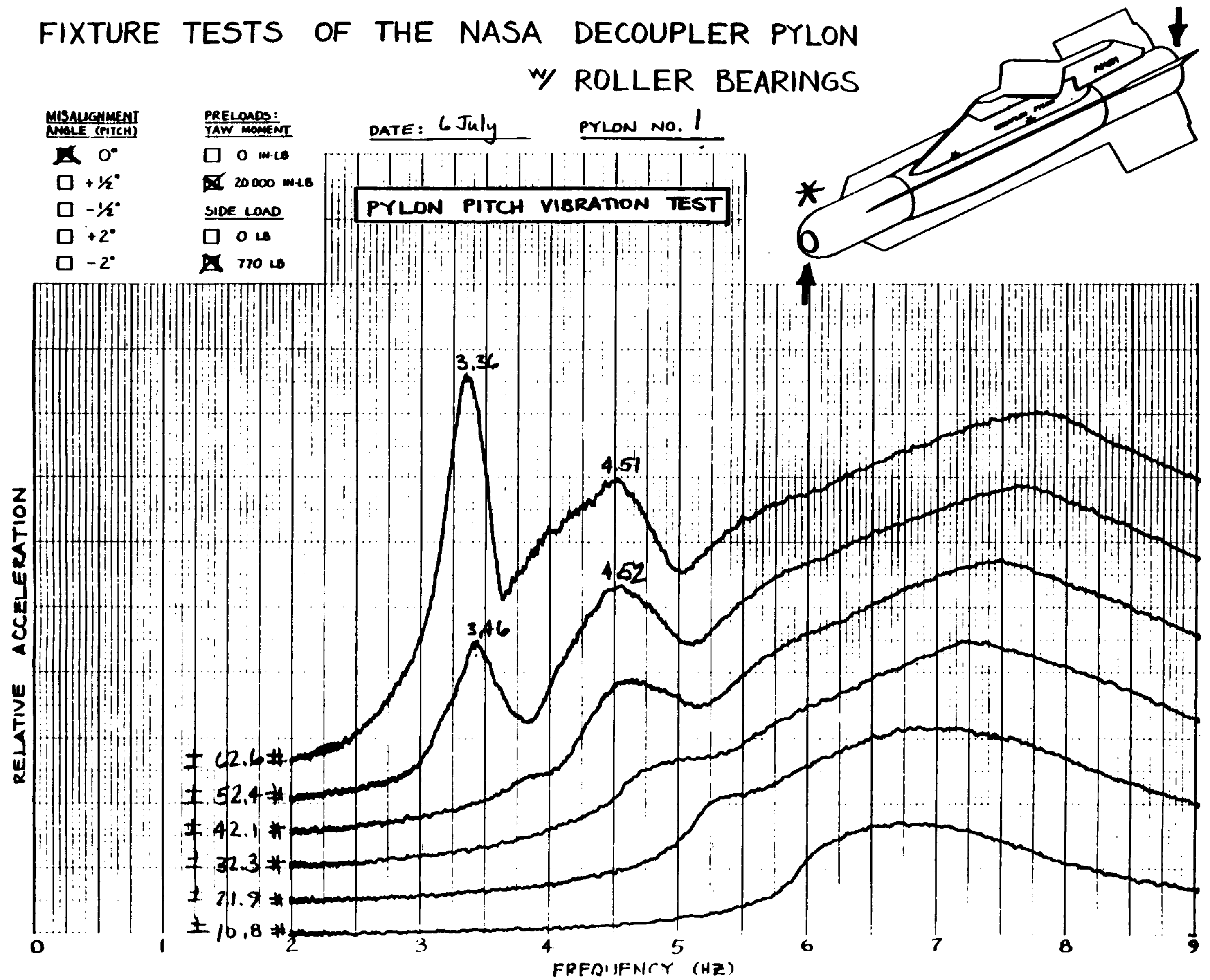

Figure D15.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 1

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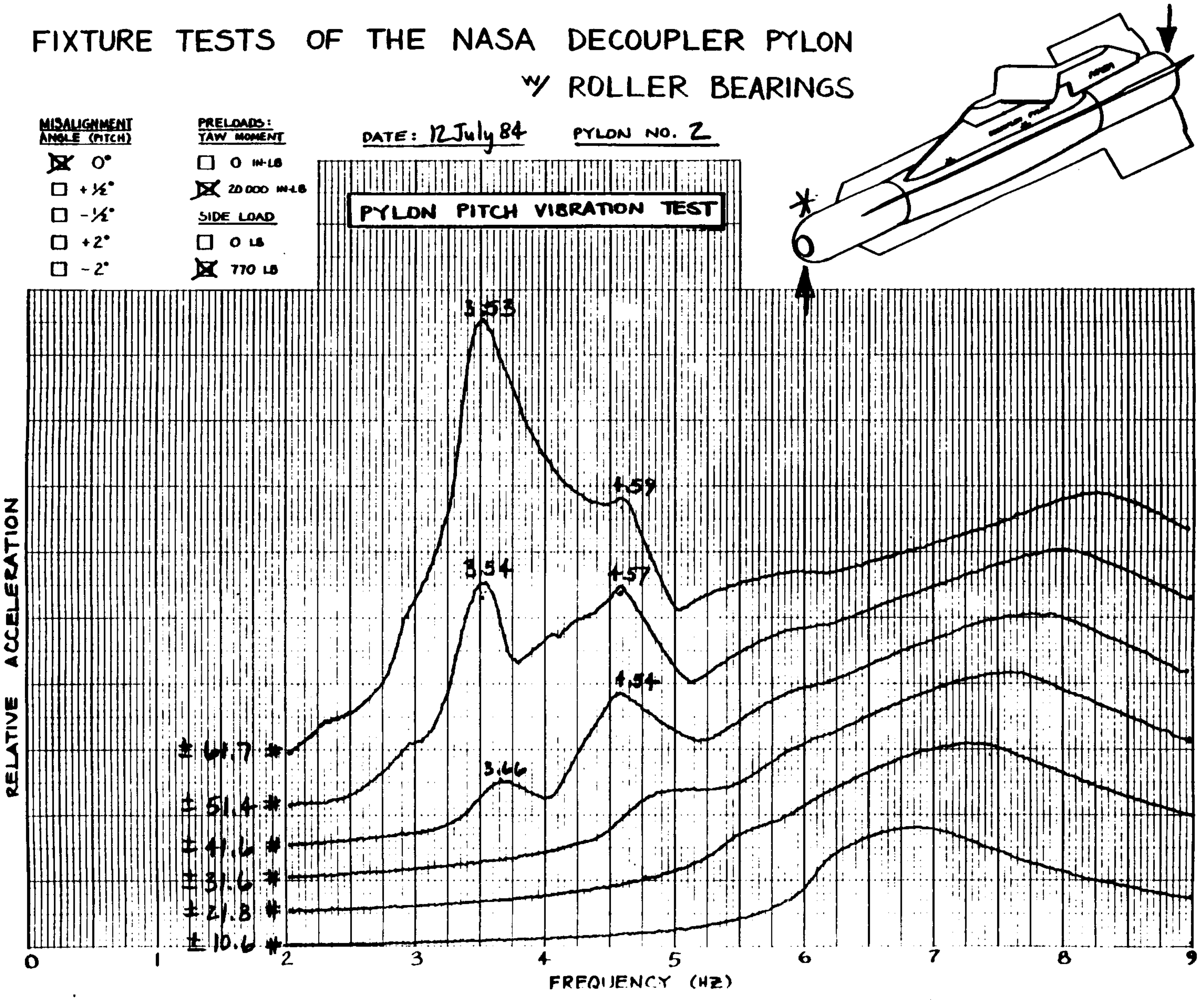

Figure D16.- Decoupler Pylon Fixture Test Frequency Sweep Pylon No. 2

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16. Abstract

The decoupler pylons which were originally designed and assembled with bushings in the pivot joints were retrofitted with roller bearings. This retrofit, the supporting analyses and the fixture tests of the modified pylons are reported in this document. The loads and stress analysis was directed toward the redesigned parts which were the pylon links and pins. The loads and stress analysis indicates that the pylons with the bearing installation have reduced capacity with respect to the bushing design. Fixture tests of the redesigned pylons were conducted in the GD/FW facility. Breakout friction tests and vibration tests were conducted. The tests show that the joint friction is approximately one-half the level with bearings as compared with the bushing installation. The vibration test data was used to tune the pylon mathematical simulation and this revised pylon simulation was used to recompute complete airplane modes of vibration. These computed modes of vibration were used in complete airplane symmetric and antisymmetric flutter and aeroservoelastic analyses.

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