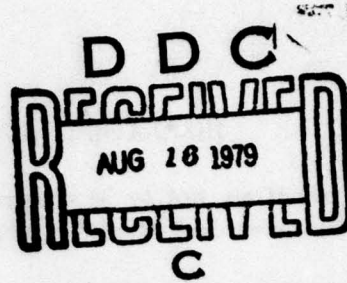


LEVEL II

USAAEFA PROJECT NO. 76-07

AD A 072830



**ARMY PRELIMINARY EVALUATION
IMPROVED MAIN ROTOR BLADE
INSTALLED ON A YAH-1R HELICOPTER**

FINAL REPORT

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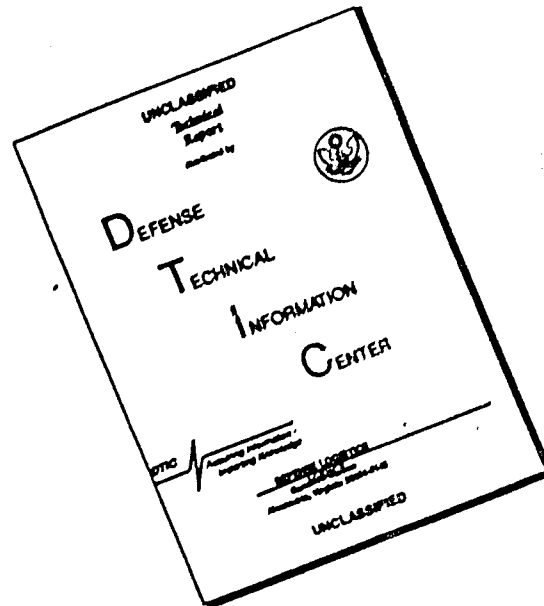
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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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mt

20. Abstract

ballistically tolerant spar. The helicopter was tested from 26 November through 6 December 1976 at the Kaman Aerospace Corporation facility in Bloomfield, Connecticut. During the test, eleven flights were flown for a total of 13.0 flight hours, 9.9 of which were productive. Test results indicate that the YAH-1R with the K-747 rotor has an increase in hover performance over the YAH-1S. A level flight performance improvement above 60 knots true airspeed became more pronounced as weight and altitude were increased. Climb and autorotational descent performance, static and dynamic stability, and mission maneuvering characteristics remain essentially unchanged from previous AH-1 helicopters. Qualitatively, there was a decrease in noise levels with the K-747 rotor. Simultaneous stability and control augmentation system (SCAS) hardovers occurred in all axes on five occasions during this evaluation. The lack of SCAS troubleshooting procedures in AH-1 organizational maintenance publications impeded timely correction of the problem and precluded completing all planned tests within the calendar time constraints. No deficiencies were found, and a total of eight shortcomings were noted, none of which were associated with the K-747 rotor, and most have been previously reported on AH-1 helicopters.

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DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
P O BOX 209, ST. LOUIS, MO 63166

25 MAY 1977

DRDAV-EQ

**SUBJECT: USAAEFA Project No. 76-07 Army Preliminary Evaluation,
Improved Main Rotor Blade Installed on a YAH-1R Helicopter
June 1977**

SEE DISTRIBUTION

1. The purpose of this letter is to present the Directorate for Development and Engineering position on the subject report.
2. Specific comments by paragraph are:
 - a. Abstract, 11th sentence - While the test results did indicate that the YAH-1R with K-747 rotor blades has an increase in hover performance over the AH-1S, the magnitude of the tests conducted were not sufficient to define the extent of the improvement.
 - b. Paragraph 42 - Agree with the general conclusions of this report.
 - c. Paragraph 43 - The five shortcomings identified in this paragraph have been described in previous AEFA reports. These shortcomings have been addressed and no corrective action is deemed necessary except for correction of inadequate low airspeed cues. This shortcoming will be corrected on the Modernized AH-1S.
 - d. Paragraph 44 - Correction of cited shortcomings is addressed in paragraph 2c above.
 - e. Paragraph 45 - The Marconi Avionics Air Data System will be installed in all Modernized AH-1S helicopters.
 - f. Paragraph 46 - Sufficient SCAS troubleshooting procedures have been developed and are contained in TM 55-1520-236-23.
 - g. Paragraph 47 - Increasing the published sideward velocity limit above 35 knots has been considered but the requirement has not been substantiated.
 - h. Paragraph 48 a, b, - The areas listed are being considered for further test projects.

25 MAY 1979

DRDAV-EQ

SUBJECT: USAAEFA Project No. 76-07 Army Preliminary Evaluation, Improved Main Rotor Blade Installed on a YAH-1R Helicopter, June 1977

i. Paragraph 58c - Contractor development test data has been thoroughly reviewed and no adverse characteristics or trends have been noted.

k. Appendix A Reference 15 - Kaman Report No. should be T-705 not T-70R as listed.

FOR THE COMMANDER:



WALTER A. RATCLIFF
Colonel, GS
Director of Development
and Engineering

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	
Background	1
Test Objectives	1
Description	1
Test Scope	2
Test Methodology	3
RESULTS AND DISCUSSION	
General	5
Handling Qualities	5
Control Positions in Trimmed Forward Flight	5
Control Positions in Sideward Flight	6
Static Longitudinal Stability	7
Static Lateral-Directional Stability	7
Maneuvering Stability	8
Controllability	10
Mission Maneuvering Characteristics	11
Lateral Acceleration/Deceleration/ Low-Speed Flight	11
Longitudinal Deceleration	12
Bob-Ups and Terrain Avoidance Maneuvers	12
Miscellaneous	13
Stability and Control Augmentation System Failures	13
Vibration	13
Engine Characteristics	14
Noise	14
Weight and Balance	14
CONCLUSIONS	
General	15
Shortcomings	15
RECOMMENDATIONS	17

TABLE OF CONTENTS

Page

APPENDIXES

A. References	18
B. Aircraft Description	20
C. Instrumentation	32
D. Test Techniques and Data Analysis Methods	38
E. Test Data	44

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RESULTS AND DISCUSSION

1	General
2	Handling Qualities
3	Control Characteristics
4	Stability
5	Maneuvering Capability
6	Control Sensitivity
7	Control Sensitivity
8	Control Sensitivity
9	Control Sensitivity
10	Control Sensitivity
11	Control Sensitivity
12	Control Sensitivity
13	Control Sensitivity
14	Control Sensitivity
15	Control Sensitivity
16	Control Sensitivity
17	Control Sensitivity
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INTRODUCTION

BACKGROUND

1. The United States Army Aviation Systems Command (AVSCOM) since redesignated the Army Aviation Research and Development Command (AVRADCOM) awarded a development contract to Kaman Aerospace Corporation (KAC) in May 1975 to design, fabricate, and test an improved main rotor blade, designated K-747, for the AH-1 series helicopter. The design objectives of the program were to provide improved hover performance, reduced ballistic vulnerability, and improved reliability and maintainability characteristics. In August 1976, AVSCOM directed the United States Army Aviation Engineering Flight Activity (USAAEFA) to conduct an Army Preliminary Evaluation (APE) of the YAH-1R helicopter with the K-747 rotor installed (refs 1 and 2, app A). A formal test plan for the APE was published in November 1976 (ref 3).

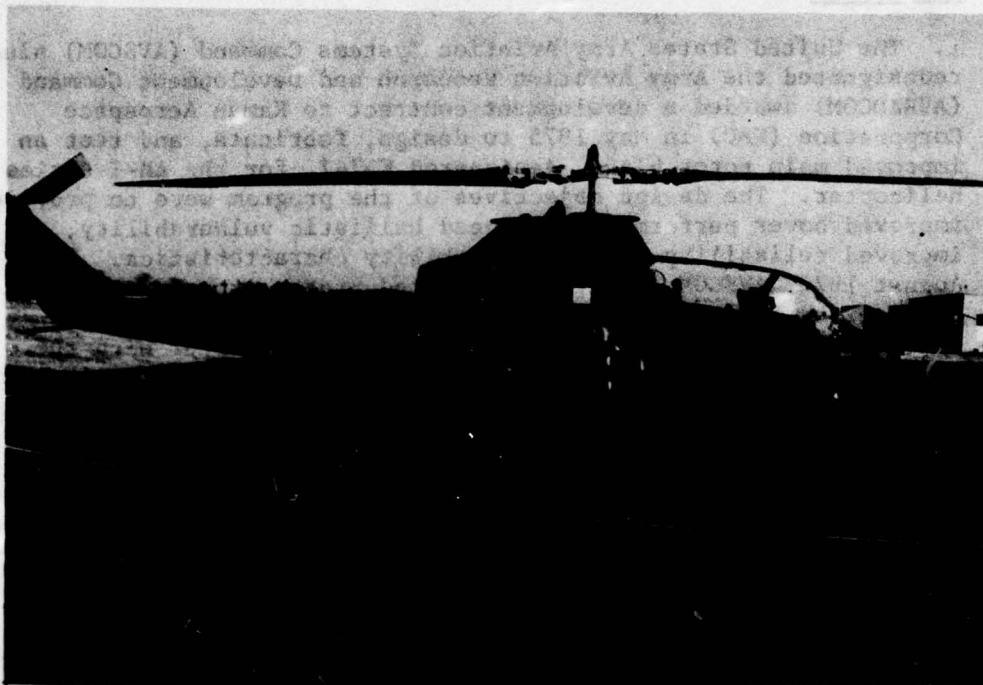
TEST OBJECTIVES

2. The objectives of the APE were as follows:
- a. Determine suitability of the aircraft incorporating the K-747 rotor for future Army testing.
 - b. Determine the effects of the K-747 rotor on YAH-1R performance.
 - c. Detect and allow for early correction of any deficiencies or shortcomings.

DESCRIPTION

3. The YAH-1R, shown in photo A, is a 10,000-pound maximum gross weight attack helicopter derived from the AH-1G HueyCobra. A detailed description of the AH-1G helicopter and its armament systems is included in the operator's manual (ref 4, app A). The increased gross weight capability, maneuverability, and agility are provided by incorporating uprated drive system components from the AH-1J SeaCobra, a Bell Helicopter Textron Model 212 tail rotor, and the Lycoming T53-L-703 engine, with an uninstalled thermal rating of 1800 shaft horsepower (shp), transmission limited to 1290 shp. Four wing-mounted external stores locations are

provided two on each side of the fuselage. The test aircraft had wings from an AH-1Q installed to allow mounting of TOW missile launchers. The aircraft is configured with an integral chin turret that is aimed by the gunner.



4. The K-747 rotor incorporates an advanced design airfoil with a tapered tip planform constructed of composite material with a multicell, ballistically tolerant spar. The blades are designed to be individually interchangeable. The K-747 rotor is designed to replace the standard AH-1 main rotor, designated the B-540, without modification other than pitch-link assembly adjustment. A detailed description of the Model 212 tail rotor is contained in USAASTA Final Report No. 72-30 (ref 5, app A). Appendix B provides a detailed description and photos of the test helicopter (SN 70-15936) and the K-747 rotor.

TEST SCOPE

5. The evaluation was conducted on the prototype YAH-1R at the KAC facility in Bloomfield, Connecticut (164-foot field elevation). Eleven flights totaling 9.9 productive flight hours were conducted

between 26 November and 6 December 1976. The contractor installed, calibrated, and maintained all instrumentation, and was responsible for test aircraft maintenance and logistical support during the tests. Flight restrictions and operating limitations were established by the AH-1S operator's manual (ref 6, app A) as modified by the safety-of-flight release (ref 7) issued by AVSCOM. Stringent calendar limitations, coupled with adverse weather conditions and stability and control augmentation system (SCAS) malfunctions, prevented completion of all phases of testing as specified in the test plan. The evaluation was conducted with SCAS ON. Aircraft configurations tested included 8-TOW (two dual-TOW launchers on each outboard wing store location); Hog-TOW (8-TOW configuration with an XM200 (one XM200 rocket launcher mounted on each inboard and outboard wing station). Flight test conditions are shown in table 1.

TEST METHODOLOGY

6. The engineering flight test techniques described in references 8 through 10, appendix A, were used in conducting performance and handling qualities tests. The data acquisition system utilized pulse code modulation (PCM) telemetered to and recorded at the contractor facility. Hand-recorded cockpit data were taken from calibrated cockpit indicators to facilitate correlation of the telemetered data. A detailed listing of the test instrumentation is contained in appendix C. Data reduction techniques are further described in appendix D. Data reduction was accomplished using the KAC computer facilities. A Handling Qualities Rating Scale (HQRS), shown in appendix D, was used to augment pilot comments relative to handling qualities.

Table 1. Flight Test Conditions.

Type of Test	Gross Weight (lb)	Longitudinal Center of Gravity Fuselage Station	Density Altitude (ft)	Airspeed (kt)	External Stores Configuration ¹	Remarks ²
Sideward flight	9540	195.2 mid	-3320	17 left to 22 right	8-TOW	---
Static longitudinal stability	9830	201.0 aft	5090	37 and 117 ³	Hog	---
Static lateral-directional stability	9690	201.0 aft	4910	36 and 118 ³	Hog	Varying sideslip
Maneuvering stability	9880	201.1 aft	5380	57 ³	Hog	Climb trim
	9660	201.0 aft	5550	117 ³	Hog	Level trim
Controllability	9950	194.4 mid	-3230	Less than 10 ³	Hog-TOW	50 ft
Mission maneuvers	9500	201.0 aft	-3300	Zero to 100 ³	Hog	Bell centered

¹ Configuration definitions given in paragraph 5 and shown in appendix B.

² Unless otherwise noted, tests were flown using K-747 rotor; rotor speed (N_R) at 325 rpm; zero sideslip; true airspeed.

³ Calibrated airspeed.

RESULTS AND DISCUSSION

GENERAL

7. An APE of the YAH-1R helicopter with the K-747 rotor installed was performed to determine the effect of the K-747 rotor on YAH-1R performance and handling qualities. A significant weight and balance computation error was discovered subsequent to these tests. The flight loadings of all contractor development and demonstration flights were also based on this erroneous weight and balance information. The data obtained during the development test should be critically reviewed for any adverse characteristics or trends with forward cg movement. Two flights were flown 1 inch aft of the aft cg limit because of the error. No adverse handling qualities associated with the aft cg were observed. Limited hover, level flight, and climb performance tests were conducted. The data are not presented for the following reason: the best available information at the time of the evaluation indicated that engine power could best be obtained using the relationship between torque pressure and engine torque used in reference 8; information received subsequent to the completion of the report indicated that the test engine differed significantly in the relationship between torque pressure and engine torque from that used in the analysis. Rather than recalculate the performance data, it was considered cost and time effective to eliminate the data from the report. Similar and more complete performance data on the IMRB are presented in the *Airworthiness and Flight Characteristics* report (project no. 76-08). Maneuvering, static, dynamic stability, and mission maneuvering characteristics remained essentially unchanged from standard AH-1 helicopters. Qualitatively, there was a decrease in noise levels with the K-747 rotor. Simultaneous SCAS hardovers occurred in all axes on five occasions during this evaluation. The lack of SCAS troubleshooting procedures in AH-1 organizational maintenance publications hindered timely correction of the problem. No deficiencies were found and a total of five shortcomings were noted, none of which were associated with the K-747 rotor, and most were previously noted on AH-1 helicopters.

HANDLING QUALITIES

Control Positions in Trimmed Forward Flight

8. Control positions in trimmed forward flight were determined

during level flight performance tests at the conditions listed in table 1. The helicopter was trimmed in steady-heading zero sideslip flight at the desired airspeed with control forces trimmed to zero. Data were recorded at each stabilized airspeed. Test results are presented in figures 9 and 10, appendix E.

9. The variation of longitudinal control position with airspeed was essentially linear, with increased forward cyclic required with increased airspeed. The variation of lateral control position with airspeed was nonlinear; cyclic position moved right with increasing airspeed to approximately 75 KCAS and then moved to the left as airspeed increased to 132 KCAS. The reversal (0.5 inch) was not discernible to the pilot. The variation of directional control position with airspeed was similar to that of the lateral cyclic control position. Within the scope of this test, control position characteristics in trimmed forward flight of the YAH-1R with K-747 rotor installed are not significantly changed from the basic aircraft and met the applicable requirements of military specification MIL-H-8501A (ref 14, app A).

Control Positions in Sideward Flight

10. The handling qualities during sideward flight of the YAH-1R helicopter with K-747 rotor installed were evaluated at the conditions shown in table 1. The test aircraft was flown IGE at an approximate skid height of 10 feet. A pace vehicle with calibrated speedometer was used as a speed reference. Winds during this test series were less than 5 knots. The aircraft was stabilized at an airspeed, and data were recorded. Test results are presented in figure 11, appendix E.

11. The variation of control positions with true airspeed in sideward flight showed varying gradients in all axes which presented no control problems. There were no objectionable control position changes in sideward flight. Within the limited scope of the test, the handling qualities of the YAH-1R with K-747 rotor installed in sideward flight simulating crosswind hovering are satisfactory and are not significantly changed from the standard aircraft.

12. During this evaluation, sideward flight only to 17 KTAS left and 22 KTAS right was flown because of failure in all axes of the SCAS after recovering from the 17-KTAS left sideward data point (para 49). Calendar time constraints did not allow completion of the low-speed flight characteristics tests after the SCAS failure was corrected.

Static Longitudinal Stability

13. Collective-fixed static longitudinal stability was evaluated at the conditions shown in table 1. The helicopter was trimmed in steady-heading zero sideslip flight at the desired trim airspeed. Then, with the collective stick held fixed, the helicopter was stabilized at incremental airspeeds greater than and less than the trim airspeed. Data were recorded at each stabilized airspeed. Test results are presented in figures 12 and 13, appendix E.

14. At a trim airspeed of 36 KCAS, the variation in longitudinal control position with airspeed was stable and the stick position gradient was shallow (0.6 inch of forward control travel from 21 to 51 KCAS). The variation of pitch attitude with airspeed was essentially zero. The neutral character of the pitch attitude gradient and shallow longitudinal control position gradient made pitch attitude and control position impossible to use as airspeed cues in low-speed flight (21 to 51 KCAS). However, this lack of pitch attitude change and small control change was helpful in hovering and low-speed flight in winds. Wind gusts will not upset the hover pitch attitude; thus, minimal pilot compensation will be required to maintain hover position (HQRS 3).

15. In high-speed cruise flight (94 to 139 KCAS), static longitudinal stability, as indicated by the variation of longitudinal cyclic position with airspeed, was essentially neutral. The variation of pitch attitude with airspeed was minimal (4.0-degree nose-down pitch attitude change from 94 to 139 KCAS), but due to the excellent cockpit references, small pitch attitude changes were easily detected and provided suitable cues to airspeed changes. Minimal pilot effort was required to maintain airspeed during high-speed cruise (HQRS 3). Within the scope of this evaluation, the static longitudinal stability of the YAH-1R helicopter with K-747 rotor installed is not significantly changed from the standard aircraft, met the requirements of MIL-H-8501A, and is satisfactory.

Static Lateral-Directional Stability

16. Static lateral-directional stability characteristics were determined at the conditions shown in table 1. The aircraft was initially trimmed at zero sideslip in level flight at the desired airspeed. With collective control fixed and airspeed held constant, the aircraft was stabilized at incremental sideslip angles from zero to the limit of the sideslip envelope, both left and right. Test results are presented in figures 14 and 15, appendix E.

17. Static directional stability, as indicated by the variation of directional control position with sideslip, was positive up to the limit of the sideslip envelope. Effective dihedral, as indicated by the variation of lateral cyclic control position with sideslip, was positive. The weak side-force characteristics during low-speed flight, as indicated by the variation of bank angle with sideslip, were determined to be essentially the same as the basic YAH-1R (ref 9, app A). The weak side-force characteristics resulted in extensive pilot effort to maintain low-speed flight (HQRS 6). Weak side-force characteristics during low-speed forward flight are a shortcoming.

18. Firing stowed or fixed weapons required known sideslip to obtain first-round hits. Weak side-force characteristics made this an extremely difficult task. An airspeed system capable of giving accurate velocity information, both magnitude and direction (sideslip), throughout the rearward, sideward, and forward airspeed envelopes should be installed in all AH-1 helicopters. Within the scope of this test, the static lateral-directional stability characteristics of the YAH-1R with K-747 rotor installed are not significantly changed from the standard aircraft.

Maneuvering Stability

19. Maneuvering stability characteristics were evaluated at the conditions shown in table 1 with SCAS ON. Trim conditions were 117 KCAS at maximum continuous power (MCP) and zero sideslip in level flight, and 57 KCAS in a zero sideslip maximum power climb. The variation of longitudinal and lateral cyclic and pedal control positions with cg normal acceleration was determined by stabilizing the aircraft in constant airspeed zero sideslip turns at incremental roll attitudes left and right. The collective control remained fixed during the maneuver, and power and rotor speed varied because of the pitch cone coupling and altitude variation during the turn. The quantitative results of the maneuvering stability evaluation are presented in figures 16 and 17, appendix E.

20. At 57 KCAS and near maximum power, the aircraft was in a climbing spiral with normal acceleration to approximately 1.2g, and in a descending spiral at normal accelerations in excess of 1.2g, as shown in figure 17, appendix E. The longitudinal control position variation with normal load factor showed a sharp change in slope at 1.30g. The gradient decreased but remained positive and essentially linear above 1.30g. The aircraft was easy to control during these maneuvering turns and minimal pilot compensation was required to achieve satisfactory performance in

simulated rapid returns to a target at 57 KCAS with maximum power (HQRS 3). As aircraft normal acceleration approached 1.5g, there was a noticeable increase in the 2-per-rotor-revolution (2/rev) vibration, which was not objectionable.

21. Figure 17, appendix E, shows maneuvering stability test results for the YAH-1R helicopter with K-747 rotor installed at 117 KCAS with MCP. Maneuvering stability under these conditions was positive below 1.5g; however, the stick position gradient became essentially neutral above 1.5g. The aircraft was very difficult to control precisely above 1.4g due to pitch oscillation. Although the aircraft did present control difficulty when the task was defined as precise airspeed control, the aircraft was responsive. The pilot could not prevent airspeed oscillations about the desired trim airspeed, but there was no tendency toward a divergence in pitch or roll. No divergent tendency was noted in symmetrical pull-ups to approximately 1.7g, the limit for this test. The neutral maneuvering stability above 1.5g at 117 KCAS is a shortcoming. This shortcoming was noted on an earlier APE (ref 9, app A). Tests should be conducted to investigate the maneuvering stability of the YAH-1R helicopter to the aircraft's full load factor capability at the more severe flight conditions of higher density altitude, heavier gross weight, and faster airspeed. Tests should include constant-power turns and symmetrical pull-ups.

22. During the maneuvering flight evaluation at 117 KCAS a 2/rev vertical vibration, which increased in intensity as normal load factor increased, was noted. A slight amount of cyclic control feedback was encountered at normal acceleration in excess of 1.5g. The cyclic control feedback did not materially affect the pilot's ability to obtain small increments of load factor.

23. Maneuvering stability tests revealed a longitudinal control position gradient change at approximately 1.30g at 57 KCAS and 1.5g at 117 KCAS. These levels of normal acceleration occurred at the pitch rate which resulted in full extension of the longitudinal SCAS actuator. The shift in maneuvering stability gradient probably reflects the difference in the artificially stabilized airframe and the basic airframe characteristics. Subsequent analysis of the data revealed that the longitudinal SCAS actuators fully extended at approximately 8 degrees per second pitch rate. The effective loss of longitudinal SCAS due to full actuator extension did not materially affect the maneuvering handling qualities at 57 KCAS; however, at 117 KCAS this effective loss of SCAS input degraded the maneuvering handling qualities, in that precise airspeed control required extensive pilot compensation during steeply banked diving turns (HQRS 6).

Within the scope of this test, the maneuvering stability characteristics of the YAH-1R helicopter with K-747 rotor installed are not significantly changed from the standard aircraft.

Controllability

24. Controllability characteristics were evaluated in IGE hover with SCAS ON at the conditions shown in table 1. The aircraft was trimmed in a stable hover attitude and control step inputs of varying sizes were applied to each axis, using a mechanical fixture to obtain the desired input size. The inputs were held until a maximum rate was established or until recovery was necessary. Test results are presented in figures 18 through 23, appendix E.

25. There were no objectionable delays in the development of angular rates in response to control displacements. Angular rates and accelerations developed in the proper direction within 0.2 second after the control displacement. Aircraft responses were essentially uncoupled except for right lateral cyclic control inputs. Responses from right lateral cyclic inputs resulted in right yaw coupling. This yaw coupling should cause no controllability problems in operational use.

26. Pitch attitude change in 1 second, maximum pitch acceleration, and maximum pitch rate were essentially linear functions of the longitudinal input size. The time to maximum pitch acceleration was 0.25 second. The time to maximum pitch rate was approximately 0.9 second and was independent of the input size within the accuracy of time determination.

27. Lateral step inputs produced responses which were linear with input size. Time to maximum roll acceleration was 0.2 second and time to maximum roll rate was approximately 0.9 second.

28. Yaw responses to step pedal control inputs were essentially linear for inputs up to 1.0 inch left and right. In comparing the test results of this evaluation with those of an earlier test, the only significant difference was in the time required to achieve a given yaw displacement for comparable yaw control inputs. This difference can be directly attributed to an instrumentation lag in heading output. A comparison of the transient tail rotor torque recorded during controllability tests and that resulting from the slower inputs during hover turn arrestments indicates that the maximum transient torques are primarily a function of the magnitude of the input and are relatively independent of the rate of input for input times of 0.1 to 1.0 second. An oscillation was

noted in both tail rotor torque and main rotor torque as a result of pedal inputs. This lightly damped torsional oscillation appears to contribute to the high peak tail rotor transient torque. A similar torsional oscillation has been noted in other AH-1 aircraft. Within the scope of this test, the controllability characteristics of the YAH-1R with K-747 rotor installed are not significantly changed from the standard aircraft.

Mission Maneuvering Characteristics

Lateral Acceleration/Deceleration/Low-Speed Flight:

29. Lateral acceleration handling qualities were evaluated at the conditions shown in table 1. The aircraft was stabilized at the desired hover height and then lateral acceleration was initiated by simultaneously applying lateral cyclic and increasing collective pitch to achieve torque equivalent to MCP. Lateral control was used to maintain a constant height as the aircraft accelerated. Lateral control reversals were initiated at maximum sideward velocity by reducing collective pitch and executing a side flare maneuver while attempting to maintain altitude.

30. Lateral accelerations/decelerations were conducted IGE at a gross weight of 9500 pounds. Aircraft handling qualities during lateral acceleration/deceleration maneuvers were good. Qualitatively, acceleration to the left was greater than to the right, as shown with the YAH-1R helicopter (ref 9, app A). Heading was easy to maintain in either direction throughout the maneuver (HQRS 2).

31. The YAH-1R/S sideward velocity envelope was expanded to 50 knots (refs 8 and 10, app A), which enhanced the lateral agility of the aircraft. The safety-of-flight release for this test limited the aircraft to 35 knots in sideward flight. Consideration should be given to expanding the sideward velocity envelope of all AH-1 helicopters to further enhance their lateral agility.

32. Sideward velocities were very difficult to judge during lateral accelerations. Attack helicopter tactics required rapid lateral translations over the ground to minimize vulnerability to enemy weapons. The aircraft has a limit airspeed (35 knots in sideward flight) which cannot be observed or sensed accurately by the pilot. The lack of adequate airspeed cues in low-speed flight (para 28) does not allow the pilot to fully utilize nap-of-the-earth (NOE) navigational techniques which require a constant low airspeed for a specific time period to navigate between two points at a low altitude. The low altitude requires the pilot to direct his attention outside the cockpit to avoid striking obstacles.

In low-speed flight (21 to 51 KCAS), airspeed could increase 100 percent or decrease 50 percent and no discernible cues would indicate the airspeed change to the pilot. Maintaining an airspeed in the low-airspeed range (21 to 51 KCAS) requires extensive pilot compensation (HQRS 6). The lack of airspeed cues during low-speed flight is a shortcoming. An omnidirectional airspeed system should be installed to give the pilot an indication of the magnitude and direction of the airspeed vector. Such a system would allow the pilot to more fully utilize the sideward flight and NOE capability of the AH-1 helicopter.

33. A side flare maneuver was performed to decelerate the helicopter from the peak sideward velocities obtained during the lateral accelerations. With the lateral control reversal initiating a side flare, the aircraft began to climb. Collective control was lowered to maintain altitude, resulting in an engine/rotor overspeed tendency noted previously on the YAH-1R helicopter. The deceleration could be accomplished faster by allowing engine speed to increase to 6700 rpm and maintaining this engine speed by controlling rapidity of maneuver rather than "beeping" engine speed down. This reduced rotor speed control problems as velocity approached zero. Heading control was easily maintained throughout the maneuver (HQRS 2) and no control limits were reached.

Longitudinal Deceleration:

34. Handling qualities during longitudinal decelerations were evaluated at the conditions shown in table 1. The aircraft was stabilized at 100 knots indicated airspeed (KIAS) at a skid height of 40 to 50 feet, power reduced, and aft longitudinal cyclic applied to reduce airspeed while maintaining altitude. Rotor speed control required extensive pilot compensation (HQRS 6). The tendency for engine overspeed resulting from poor engine/rotor dynamic characteristics is a shortcoming and should be corrected in future designs. Forward field of view is obstructed with the aircraft in a decelerating altitude, a shortcoming common to all AH-1 helicopters. The tendency to enter power settling at the termination of a rapid deceleration was previously reported on the YAH-1R helicopter and continues to exist. Power settling was avoided by decreasing the deceleration rate as the aircraft approached a hover.

Bob-Ups and Terrain Avoidance Maneuver:

35. The bob-up maneuver was accomplished by establishing an IGE hover and then conducting a maximum power vertical climb to an OGE hover, to simulate a climb above a masked position to engage

a target. A terrain avoidance maneuver was accomplished by establishing 100 KIAS in level flight, skid height of 40 to 50 feet, and then rapidly increasing altitude by 200 feet, using a cyclic climb and pushover to simulate obstacle clearance during contour flight. No handling qualities difficulties were encountered during these maneuvers (HQRS 2).

MISCELLANEOUS

Stability and Control Augmentation System Failures

36. During the conduct of this evaluation yaw oscillations occurred in all regimes of flight, but were more noticeable during stabilized performance data points. An example of these oscillations is presented in figure 24, appendix E. SCAS position instrumentation also indicated these oscillations. Following the installation of new SCAS channel control assemblies, SCAS failures occurred in all three axes simultaneously on five separate occasions. An example of the SCAS failures is presented in figure 25. Hardovers in all three SCAS channels occurred within 1 second. Productive testing ceased until the cause of the SCAS failures could be corrected. The organizational maintenance manuals for the AH-1 series helicopters do not contain troubleshooting guides for SCAS failures. A heat-sensitive roll SCAS channel control assembly was determined to have caused the hardovers. Published troubleshooting procedures for the SCAS would have saved many maintenance manhours and allowed an early solution to the SCAS failure problem. SCAS troubleshooting procedures should be established and published in organizational maintenance manuals.

Vibration

37. Vibration data were recorded on all flights at nine sensor locations on the aircraft. Examples of vibratory amplitudes at various main rotor blade harmonic frequencies are presented in figures 26 through 66, appendix E. No maneuvers were performed specifically to induce high vibrations.

38. The vibration characteristics of the YAH-1R with K-747 rotor installed demonstrated no significant change in the 2/rev main rotor harmonic frequency measured at the cg and pilot station. An approximate 50-percent reduction in the 2/rev frequency vibration was measured at the copilot station, as shown in figure 29, appendix E. A reduction of the 8/rev main rotor harmonic frequency from that with the B-540 rotor system was measured throughout the airspeed range tested, as shown in figures 26

through 32. An increase in the 6/rev frequency with the K-747 rotor over the B-540 rotor occurred in the 70 to 100-KIAS airspeed range. These vibration characteristic differences were noticeable to the pilot and copilot, but were not objectionable and did not impair performance or comfort. The vibration levels did not exceed the requirements of MIL-H-8501A.

Engine Characteristics

39. Throughout this evaluation, fluctuations in power turbine speed (N_2) and engine torque occurred with magnitudes of ± 100 rpm and ± 2 psi, respectively. These fluctuations were most noticeable during tests requiring constant power and airspeed. These fluctuations compromised the quality of the performance data and required extensive pilot compensation to stabilize the aircraft on a test point during the performance testing. Previous T53 series engines have displayed power train oscillations not unlike those experienced during this evaluation. Investigations of the power train oscillations with the T53-L-703 engine should be conducted to determine the cause, conditions that might increase severity, and any structural implications.

Noise

40. A qualitative noise evaluation of both the K-747 and B-540 rotors was made throughout the conduct of these tests. Both cockpit and ground noise levels were observed. The K-747 rotor demonstrated a reduction of the 2/rev "blade slap" from that of the B-540 rotor in all flight regimes. A quantitative noise evaluation of the K-747 rotor installed on an AH-1 is planned for future testing.

Weight and Balance

41. A significant weight and balance error (para 13, app B) was discovered after the aircraft was delivered to Edwards Air Force Base, California. The flight loadings of all contractor development and demonstration flights were also based on this erroneous weight and balance information. All testing was conducted at a cg of 1.0 to 2.5 inches aft of the desired location. The data obtained during the development test should be critically reviewed for any adverse characteristics or trends with forward cg movement, since tests have not been conducted at the forward cg limits. Two flights were flown 1 inch aft of the aft cg limit because of the error. No adverse handling qualities associated with the aft cg were observed.

CONCLUSIONS

GENERAL

42. Within the limited scope of this evaluation, the YAH-1R helicopter with K-747 rotor installed is suitable for future Army testing to the limits described in reference 7, appendix A, except that forward cg should be limited to that demonstrated. The following conclusions relative to the Kaman K-747 rotor installed on the YAH-1R helicopter have been made:

a. YAH-1R stability and control characteristics investigated were not significantly changed by installation of the K-747 rotor (paras 9, 11, 15, 18, 23, and 28).

b. Qualitatively, the K-747 rotor was quieter than the B-540 rotor (para 40).

c. The vibration characteristics of the YAH-1R with K-747 rotor installed were different from the B-540 rotor, but not objectionable to the pilot and copilot and did not impair performance or comfort (para 38).

d. No deficiencies and five shortcomings were found, none of which were associated with the K-747 rotor (para 7).

SHORTCOMINGS

43. The shortcomings listed below were identified during these tests. Most have been previously identified on the AH-1 series helicopter, are listed in the order of decreasing importance.

a. Adequate airspeeds cues did not exist during low-speed flight (para 32).

b. Weak side-force characteristics required extensive pilot effort during low-speed forward flight (para 17).

c. Maneuvering stability became neutral above 1.5g at 117 KCA\$ (para 21).

d. There existed a tendency for rotor/engine overspeed during constant altitude decelerations (para 34).

e. Forward field of view is obstructed with the aircraft in a decelerating attitude (para 34).

RECOMMENDATIONS

44. Shortcomings should be corrected on the production AH-1S.
45. An omnidirectional airspeed system capable of giving accurate magnitude and direction of relative airspeed over the rearward, sideward, and forward flight envelopes should be installed on the production AH-1S (paras 18 and 32).
46. AH-1 SCAS troubleshooting procedures should be developed and published in the appropriate maintenance manuals (para 36).
47. The sideward velocity limits of all AH-1 helicopters should be expanded to enhance their lateral agility (para 31).
48. The following areas should be further investigated during future tests and studies.
 - a. Investigate the power train oscillations with the T53-L-703 engine to determine the cause, conditions that might increase severity, and any structural implications (para 39).
 - b. Investigate maneuvering stability to the full load factor capability of the AH-1 with K-747 rotor installed over a complete airspeed, altitude, and gross weight range (para 21).
 - c. The data obtained during the contractor development test should be critically reviewed for any adverse characteristics or trends with forward cg movement (para 41).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, DRSAV-EQI, 17 August 1976, subject: Transmittal of Test Requests for the Army Preliminary Evaluation (APE) and Airworthiness and Flight Characteristics of the AH-1 Improved Main Rotor Blade (IMRB).
2. Letter, AVSCOM, DRSAV-EQI, 1 November 1976, subject: Army Preliminary Evaluation of AH-1R Equipped with Improved Main Rotor Blade.
3. Test Plan, USAAEFA, Project No. 76-07, *Army Preliminary Evaluation, Improved Main Rotor Blade Installed on a YAH-1R Helicopter*, November 1976.
4. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 12 December 1975.
5. Final Report, US Army Aviation Systems Test Activity (USAASTA), Project No. 72-30, *Engineering Flight Test, AH-1G Helicopter with Model 212 Tail Rotor, Part I, Load Survey*, June 1973.
6. Technical Manual, TM 55-1520-234-10, *Operator's Manual, Army Model AH-1S Helicopter*, 1 May 1976.
7. Letter, AVSCOM, DRSAV-EQI, 18 November 1976, subject: Safety-of-Flight Release for an APE of AH-1R with IMRB Installed, Project No. 76-07.
8. Final Report, USAAEFA, Project No. 74-34, *Airworthiness and Flight Characteristics Evaluation, YAH-1S Improved Cobra Agility and Maneuverability Helicopter*, August 1975.
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10. Addendum Final Report, USAAEFA, Project No. 74-33-1, *Army Preliminary Evaluation, YAH-1R Improved Cobra Agility and Maneuverability Helicopter*, August 1975.
11. Final Report, USAAEFA, Project No. 73-01, *Helicopter Lift Margin and Low-Speed Performance Evaluation, NUH-1M Helicopter*, to be published.

12. Final Report, USAASTA, Project No. 66-06, *Engineering Flight Test, AH-1G Helicopter (HueyCobra), Phase D, Part II, Performance*, April 1970.

13. Final Report, USAASTA, Project No. 72-43, *Airworthiness and Flight Characteristics Evaluation, AH-1Q Helicopter*, July 1973.

14. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

15. Final Report, Kaman Aerospace Corporation, T-70R, AH-1Q *Improved Main Rotor Blade, Airworthiness and Flight Characteristics Evaluation, Hover Performance*, Alamosa, Colorado, 15 March 1977.

16. Final Report, USAASTA, Project No. 72-30, *Engineering Flight Test, AH-1G Helicopter with Model 212 Tail Rotor, Part II, Performance and Handling Qualities*, September 1973.

APPENDIX B. AIRCRAFT DESCRIPTION

FUSELAGE

1. The YAH-1R fuselage is identical in outward appearance to the AH-1G helicopter with the exception of AH-1Q wings installed to accommodate the TOW weapon system. The aircraft differs in outward appearance from the YAH-1S, used in data comparison, in that the YAH-1S has a nose-mounted TOW sighting unit and a pylon-mounted pitot-static system, while the YAH-1R has an AH-1G nose and pitot-static system. The test aircraft was painted with low reflective paint except for the wings. Neither set of rotor blades tested had low reflective paint. Internal modifications to strengthen the fuselage structure to accept higher stresses due to increased gross weight, engine power, and tail rotor power included strengthened transmission mounts and associated structure and strengthened tail boom.

MAIN ROTOR BLADES

2. The Kaman improved main rotor blade configuration for the AH-1 helicopter is designated K-747. The K-747 rotor has a multicell filament-wound fiberglass spar, a Nomex core afterbody, and a Kevlar trailing edge spline, all inclosed by fiberglass skin. At the inboard end, cheek-plates carry blade loads to an aluminum adapter, which attaches the blade to the current AH-1 rotor hub by the hub pin.

3. The current AH-1 main rotor is designated the B-540. The K-747 rotor has the same diameter and essentially the same solidity as the current rotor, although the blade planform is changed. The blade twist is increased and advanced airfoil shapes are employed. The K-747 rotor dynamic characteristics were designed to match those of the B-540 rotor. A 55-pound brass tip weight, integral with the spar, provides rotor inertial characteristics similar to the B-540 rotor.

4. Over the constant chord section of the blade, the chord is 2.5 feet. This compares to 2.25 feet on the B-540 blade for the whole blade length. The outer 15 percent of the K-747 rotor blade is tapered in both thickness and planform. The tip planform taper is trapezoidal and results in a tip chord of 0.83 feet. The solidity of the rotor is 0.0625, compared to 0.065 for the current rotor.

5. The K-747 rotor blade airfoil shape is based on a family of advanced airfoils developed by Boeing Vertol. For the outer 15 percent of the blade (ie, from $r/R = .85$ (85 percent blade radius station)) out, the 8 percent-thick Boeing Vertol VR-8 airfoil is used; from $r/R = .25$ to $r/R = .67$, the 12 percent-thick Boeing Vertol VR-7 airfoil is used, with a linear transition between the 67 and 85 percent radius stations. From $r/R = .25$ station inboard, the blade is built-up gradually by cheek-plates. The leading edge becomes blunt and reaches a maximum thickness of 25 percent at the root end of the blade at $r/R = .18$. The current AH-1Q hub, which has its hub pin at $r/R = .15$, is retained. There is an attachment adapter fitting and drag brace between the pin and the root-end of the blade. Figure 1 presents a planform view and figure 2 a cross-section view of the K-747 rotor blade configuration.

ENGINE

6. The T53-L-703 engine installed in the YAH-1R helicopter reflects a growth step from the T53-L-13B engine. The T53-L-703 engine is a turboshaft engine with a two-stage axial flow-free power turbine; a two-stage axial flow turbine driving a combination five-stage axial, two-stage centrifugal compressor having a nominal 8:1 compression ratio at the thermodynamic rating of 1800 shp and incorporating compressor interstage air bleed; variable inlet guide vanes; and external annular atomizing combustor. A 3.2105:1 reduction gear housed in the air inlet housing reduces power turbine speed to output shaft speed (nominally 6604 rpm output shaft/324 rpm rotor speed). The engine reduction gearbox is limited to 1175 foot-pounds (ft-lb) torque (1477 shp) for 30 minutes and 1110 ft-lb torque (1396 shp) for continuous usage. The engine achieves this power growth over the T53-L-13B engine through increased gas producer speed and increased operating temperatures made possible by improved air cooling of the first-stage turbine. New materials are employed in the second-stage gas producer and power turbines. A T_7 interstage turbine temperature sensor harness has been incorporated for measurement of interstage turbine temperature, giving a more accurate indication of engine internal temperature than the T_9 temperature (exhaust gas) sensed in the T53-L-13B engine.

TRANSMISSION AND TAIL ROTOR DRIVE

7. An uprated transmission and tail rotor drive system is installed in the YAH-1R helicopter. These systems have the following limits:

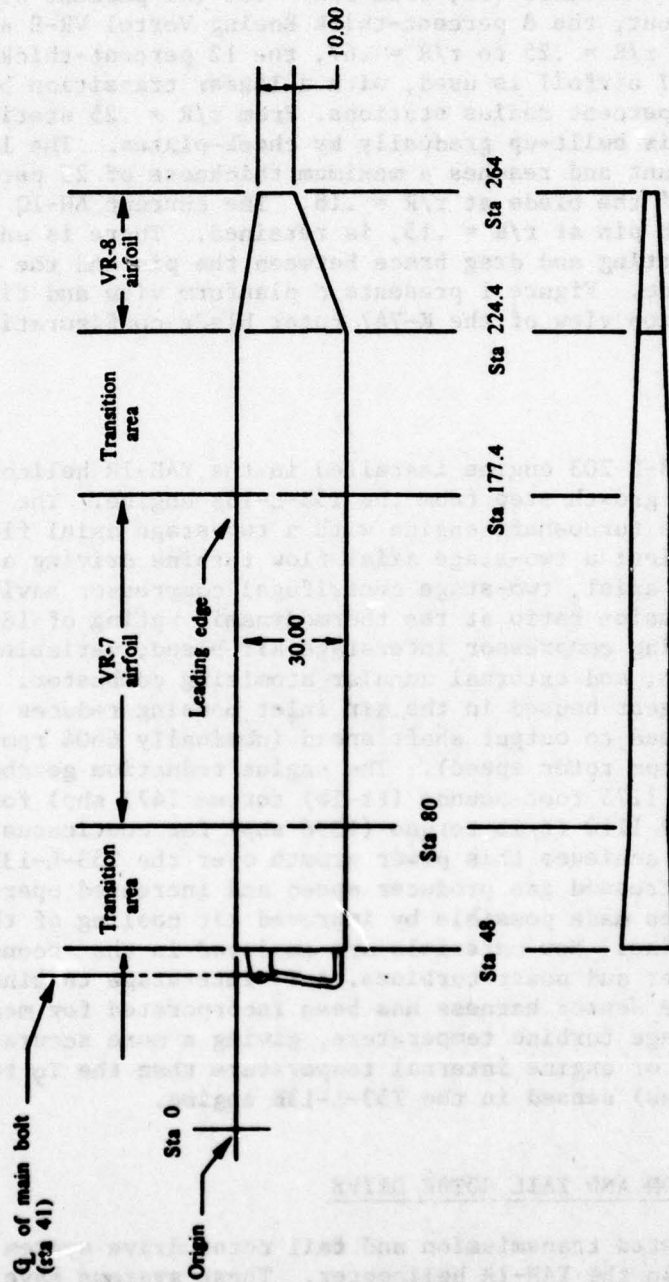
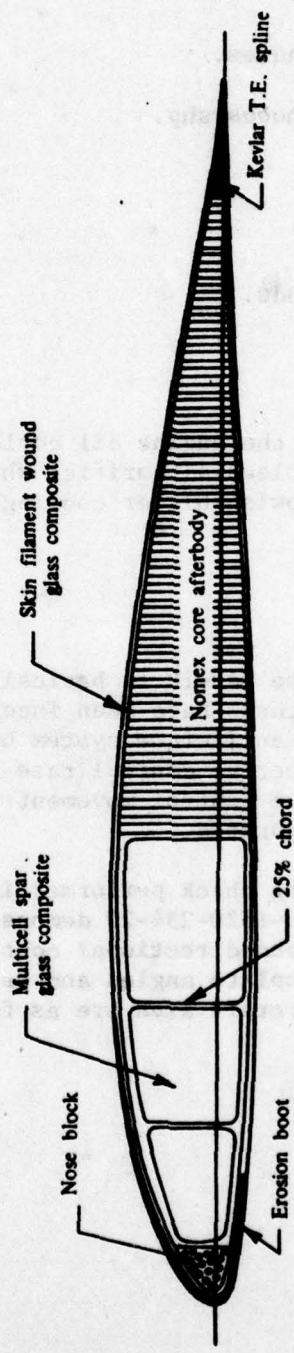


Figure 1. K-747 Rotor Blade Configuration.



Stations 66 through 177.4

Figure 2. K-747 Rotor Blade Cross-Section Structural Arrangement

a. **Transmission:**

- (1) 1290 shp for 30 minutes.
- (2) 1134 maximum continuous shp.

b. **Tail rotor drive:**

- (1) 187 shp MCP.
- (2) 260 shp for 4 seconds.

ENGINE OIL COOLER

8. The cooling capacity of the engine oil cooler has been increased by enlarging the bleed air orifice which drives the turbine oil cooler fan, allowing higher cooling fan speed and cooling air mass flow.

CONTROL SYSTEM

9. The control system of the YAH-1R is basically the same as the AH-1G; however, two new features have been incorporated. The cable controls in the AH-1G antitorque system have been replaced by push-pull tubes. A collective control rate limiter, which limits the rate of collective control movement to full throw is 0.87 second, has been incorporated.

10. A flight control rigging check performed in accordance with procedures outlines in TM 55-1520-234-20 demonstrated that the cyclic, collective, pitch, and directional controls were within prescribed limits. The swashplate angles and tail rotor blade pitch angles relative to aircraft axes are as follows:

SWASHPLATE ANGLES

<u>Cyclic Control Position</u>	<u>Lateral Angle</u>	<u>Longitudinal Angle</u>
Neutral	1.5 deg left down	1 deg nose-up
Full forward	5.0 deg right down	10 deg nose-down
Full aft	5.0 deg left down	12.5 deg nose-up
Full right	7.0 deg right down	4.5 deg nose-up
Full left	7.5 deg left down	3.5 deg nose-down

TAIL ROTOR BLADE PITCH ANGLES

<u>Pedal Position</u>	<u>Blade Angle</u>
Full left	19.9 deg
Full right	-11.0 deg

PRINCIPAL DIMENSIONS

11. Principal dimensional and general data concerning the YAH-1R helicopter are as follows:

Overall Dimensions

Length, rotor turning	52 ft, 11 in.
Width, rotor turning	44 ft
Height, tail rotor vertical	13 ft, 9.5 in.
Length, rotor removed	45 ft, 2.2 in.

Main Rotor

	<u>K-747</u>	<u>B-540</u>
Diameter	44 ft	44 ft
Disc area	1520.5 ft ²	1520.5 ft ²
Solidity	0.0625	0.0651
Number of blades	2	2
Blade chord	See fig. 1	2.25 ft, constant
Blade twist (linear)	-0.556 deg/ft	-0.455 deg/ft
Airfoil	See para 5	9.33 percent thickness, special symmetrical section

Tail Rotor

Diameter	8 ft, 6 in.
Disc area	56.75 ft ²
Solidity	0.1436
Number of blades	2
Blade chord	11.5 in., constant
Blade twist	0.0 deg/ft
Airfoil	NACA 0018 at blade root, changing linearly to special cambered section of 8.27 percent of the tip

Fuselage

Length, rotor removed	45 ft, 2.2 in.
Height:	
To tip of tail fin	10 ft, 4 in.
Ground to top of mast	11 ft, 7 in.
Ground to top of transmission fairing	10 ft, 2 in.
Ground to bottom of chin turret	1 ft, 2 in.
Width:	
Fuselage only	3 ft
Wing span	10 ft, 8.24 in.
Engine cowling	3 ft, 6 in.
Skid gear tread	7 ft, 4 in.
Elevator:	
Span	6 ft, 2 in.
Area	25.2 ft ²
Airfoil	Inverted Clark Y
Vertical fin:	
Area	18.5 ft ²
Airfoil	Special cambered
Height	5 ft, 6 in.
Wing:	
Span	10 ft, 8.24 in.
Area	27.8 ft ²
Incidence	14.0 deg
Airfoil (root)	NACA 0030
Airfoil (tip)	NACA 0024

WEIGHT AND BALANCE

12. The aircraft weight, longitudinal cg, and lateral cg were calculated from a weighing performed at the contractor's facility. The weighing was accomplished with all fuel drained and included instrumentation, empty chin turret, and empty wing stations. The weight was 6357 pounds with the longitudinal cg located at fuselage station (FS) 201.22 and the lateral cg located 0.18 inch right of the aircraft center line.

13. A significant weight and balance error was discovered after the aircraft was delivered to Edwards Air Force Base, California, for further testing. The flight loadings of all contractor development and demonstration flights were also based on this erroneous weight and balance information. The jack point locations used to calculate the cg from the weighing were erroneously taken from the AH-1G manual (TM 55-1520-221-10) (there are no AH-1R manuals; AH-1Q and AH-1S manuals were not available). The YAH-1R test aircraft was a modified AH-1G. One modification was the installation of prototype AH-1Q wings to allow loading of TOW missile launchers. This changed the wing jack point locations listed as FS 197.85 for the AH-1G/R wing to FS 200.35 for the AH-1Q/S. Actual measurement at Edwards using the forward jack point as a reference (there are no jig point locations in any AH-1 manuals) determined that the wing jack points were located at FS 200.45. A corrected weight and balance based on this value, resulted in a test aircraft empty weight of 6357 pounds, a longitudinal cg of 203.72, and a lateral cg of 0.18 right. All cg information in this report is based on this corrected weight and balance.

14. The external stores configurations, shown in photos 1, 2, and 3, were 8-TOW (two dual-TOW launchers with missile containers on each outboard wing station), heavy Hog (one XM200 rocket pod mounted on each inboard and outboard wing station), and Hog-TOW (8-TOW with one XM200 rocket pod on each inboard wing station). The TOW launchers and rocket pods were ballasted to achieve the desired takeoff weights.

15. Ballast weights were used at several longitudinal fuselage stations to achieve desired cg locations. Two cg locations were utilized during the test flights for evaluation. They were intended to be at the forward and aft limits of the cg envelope, respectively. Tables 1 and 2 show examples of intended and actual takeoff loadings to achieve the two cg locations.

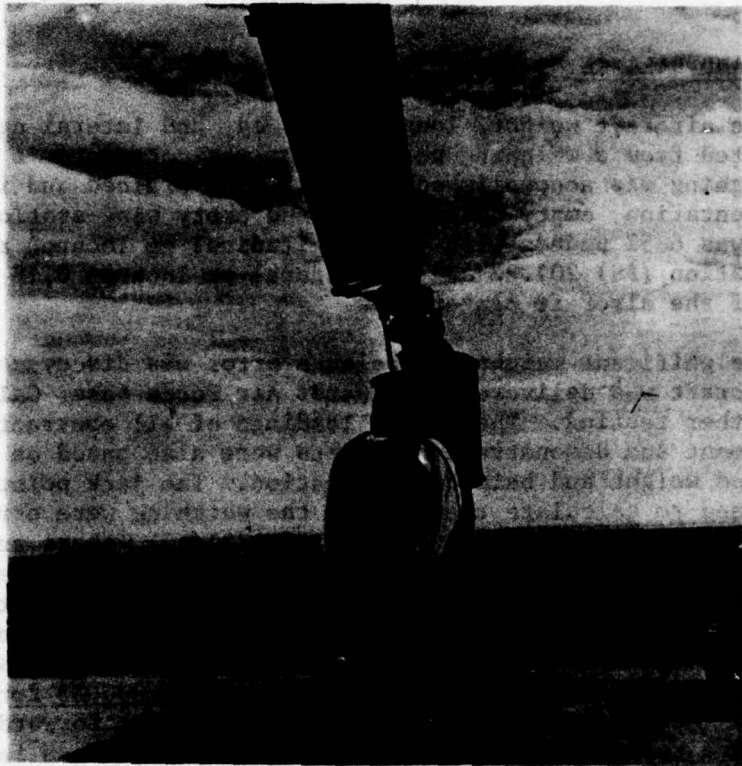


Photo 1. Test Aircraft 8-TOW External Stores Configuration.

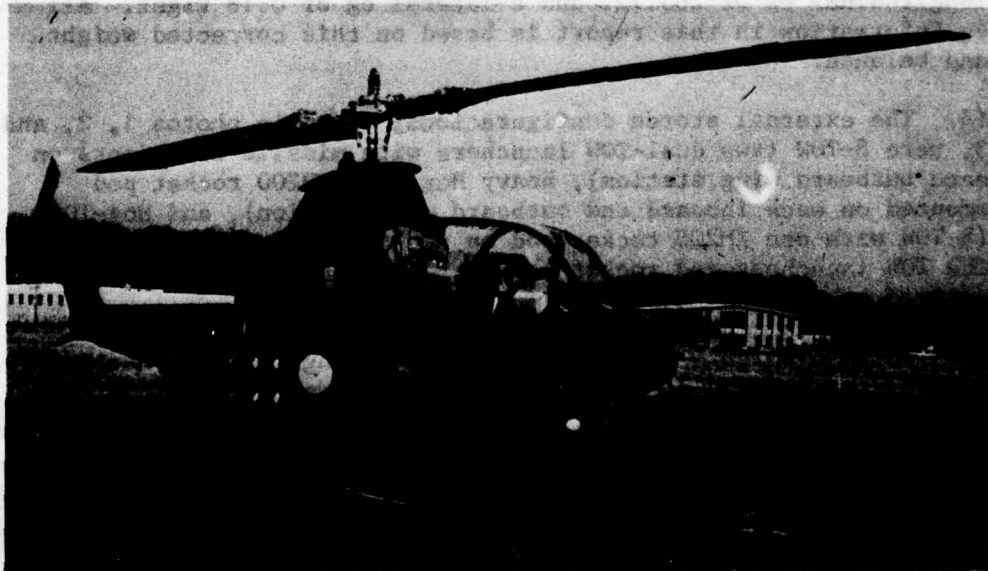


Photo 2. Test Aircraft HOG-TOW External Stores Configuration

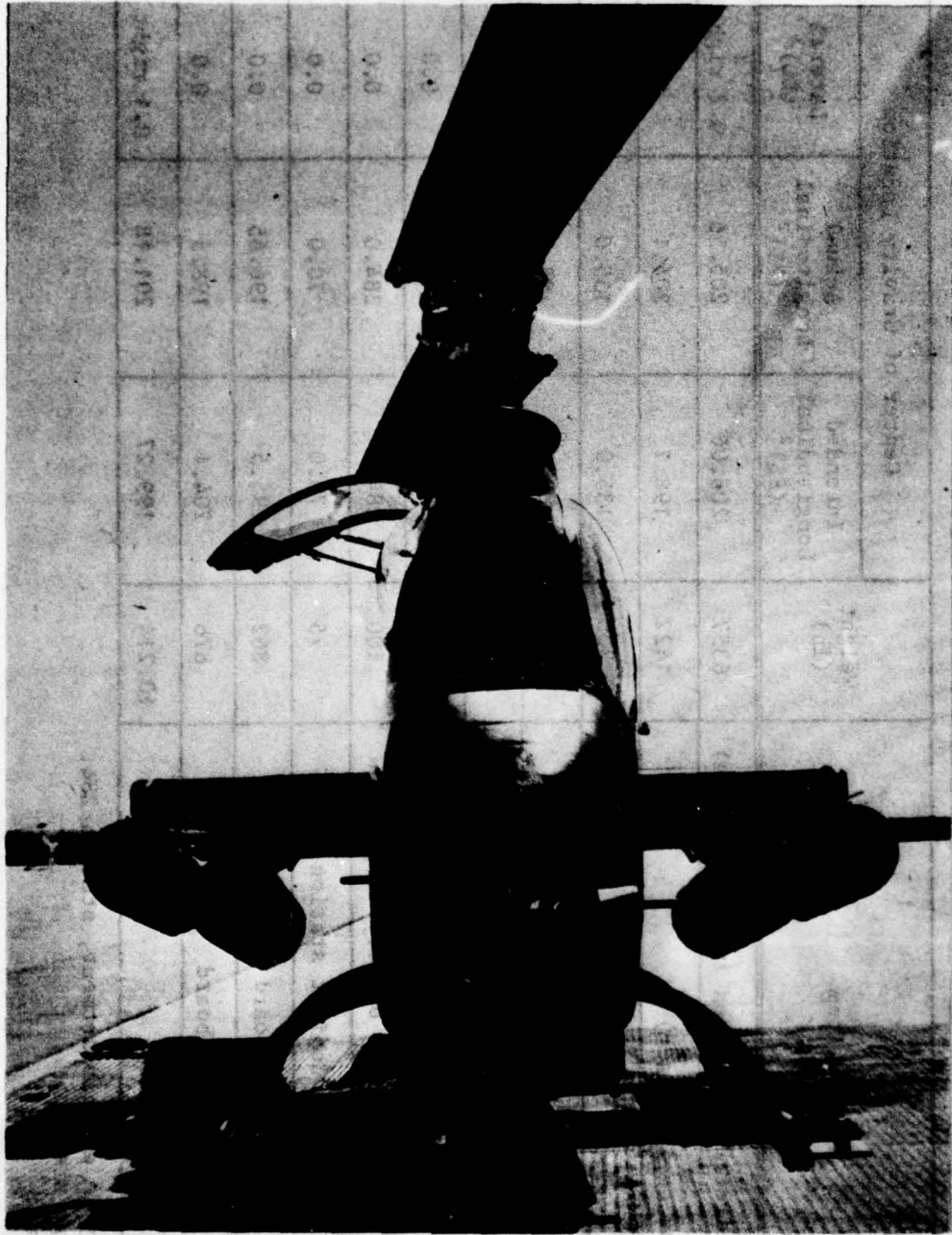


Photo 3. Test Aircraft HOG External Stores Configuration

Table 1. Aft Center of Gravity Loading Example.

Item	Weight (lb)	Center of Gravity Location		
		Intended Longitudinal (FS) ²	Actual Longitudinal (FS) ²	Lateral (BL) ³
Basic aircraft (includes instrumentation) ¹	6357	203.06	205.56	0.2 right
Fuel (at engine start)	1422	198.7	204.1	0.0
Pilot	220	135.0	135.0	0.0
Copilot	227	83.0	83.0	0.0
Ballast	At tail light	472.0	472.0	0.0
	At horizontal stabilizer	414.0	414.0	0.0
	Aft battery compartment	284.0	284.0	0.0
External stores	Copilot station	70.0	70.0	0.0
	Inboard	195.5	196.65	0.0
External stores	Outboard	204.1	198.3	0.0
	Total	199.27	201.18	0.1 right

¹Battery in aft compartment, station 284.

²Fuselage station.

³Buttline.

Table 2. Forward Center of Gravity Loading Example.

Item	Weight (lb)	Center of Gravity Location		
		Intended Longitudinal (FS)	Actual Longitudinal (FS)	Lateral (BL)
Basic aircraft (includes instrumentation) ¹	6357	201.22	203.73	0.2 right
Fuel (at engine start)	930	198.7	204.9	0.0
Pilot	220	135.0	135.0	0.0
Copilot	227	83.0	83.0	0.0
Ballast	Forward battery compartment	100	35.0	0.0
	Ammunition bay	75	70.0	0.0
	Ammunition bay	100	73.0	0.0
External stores	Inboard	1134	195.5	0.0
	Outboard	1069	204.8	0.0
Total	10,232	192.44	194.33	0.1 right

¹Battery in forward compartment, station 40.

APPENDIX C. INSTRUMENTATION

1. Instrumentation was installed in the test aircraft by KAC prior to the start of the test program and is shown in photos 1 through 4. The telemetry package was located in the ammunition bay for all testing. All instrumentation was calibrated and maintained by KAC. The following parameters were recorded:

Pilot Station

Event switch
Instrumentation control

Pilot Panel

Airspeed (boom)
Altitude (boom)
Altitude (radar)
Rate of climb (ship's system)
Rotor speed
Engine torque
Measured gas temperature
Gas generator speed
Control position:
 Longitudinal
 Lateral
 Directional
 Collective
Center-of-gravity normal acceleration
Angle of sideslip
Attitude gyro (ship's system)
Outside air temperature (sensitive)
Outside air temperature (ship's system)

Copilot/Engineer Station

Event switch
Control fixtures
Airspeed (ship's system)
Rotor speed
Engine torque
Measured gas temperature
Gas generator speed
Attitude gyro

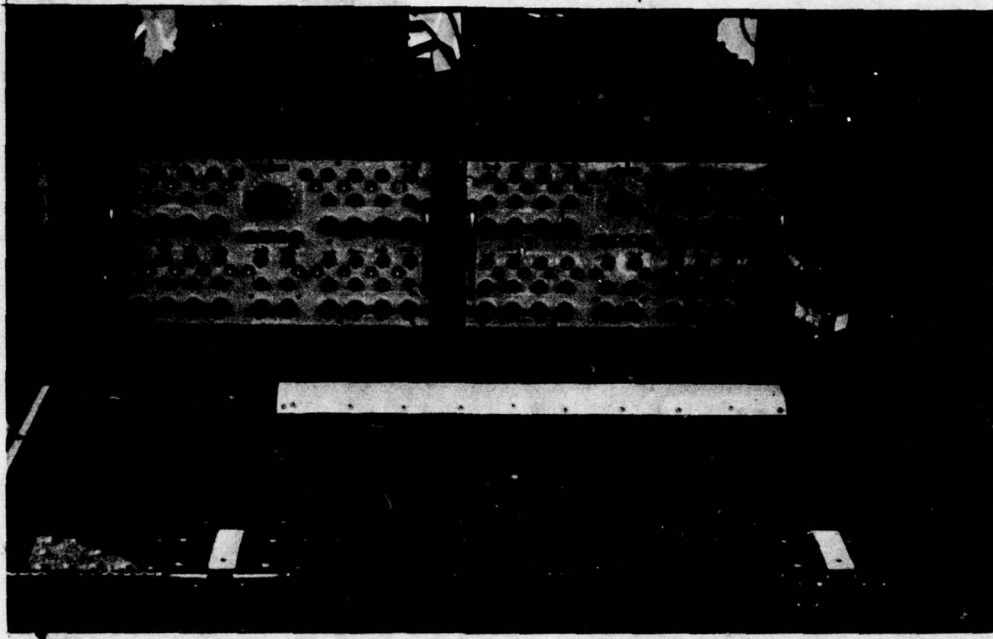


Photo 1. Instrumentation Package in Ammo Bay - Left-Side View.

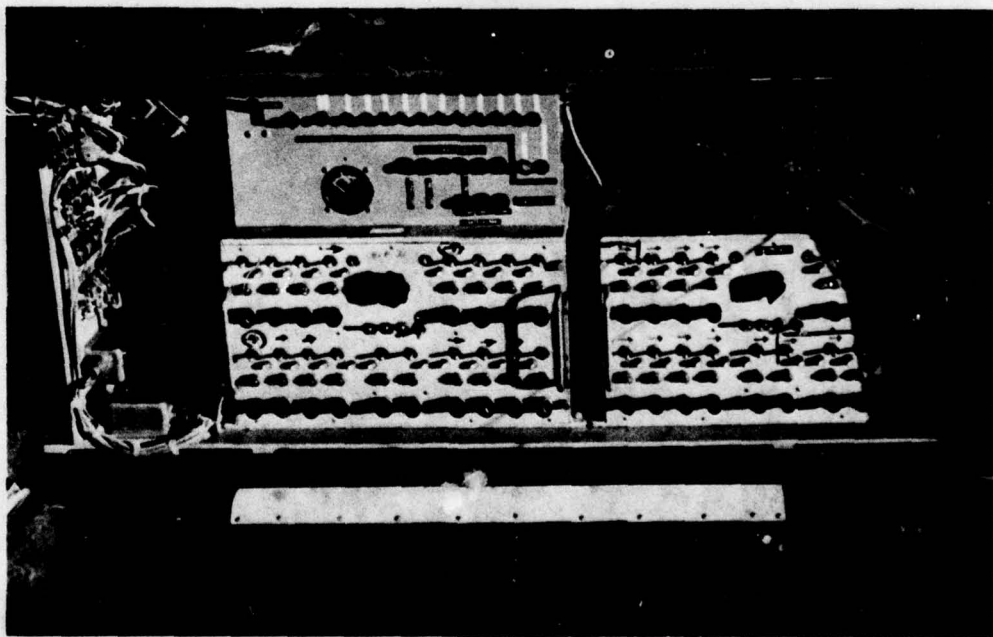


Photo 2. Instrumentation Package in Ammo Bay - Right-Side View.



Photo 3. Boom-Mounted Swiveling Pitot-Static Probe and YAPS Head.

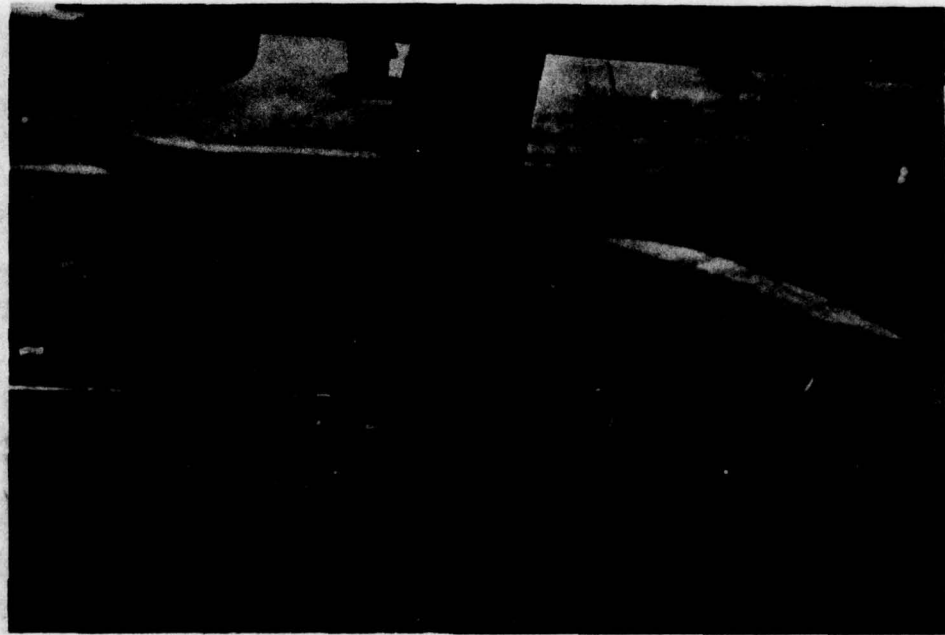


Photo 4. Skid-Mounted Telemetry Antenna

Fuel used (totalizer)
Time of day
Record counter

Digital (PCM) Parameters

Airspeed (boom)
Airspeed (ship's system)
Altitude (boom)
Outside air temperature
Main rotor speed (rotor blip)
Vibration acceleration:
 Pilot seat vertical
 Pilot seat lateral
 Pilot seat longitudinal
 Copilot seat vertical
 Copilot seat lateral
 Copilot seat longitudinal
 Center-of-gravity vertical
 Center-of-gravity lateral
 Center-of-gravity longitudinal
Main rotor loads:
 Pitch links(2)
 Drag brace axial (1)
 Hub station 5-flap bending
Main rotor cyclic blade angle
Fuel used at flow meter
Center-of-gravity normal acceleration
Angle of sideslip
Angle of attack
Engine output torque pressure
Fuel temperature (at flow meter)
Main rotor shaft torque
Tail rotor shaft torque
Pilot event
Engineer event
Correlation counter
Control positions:
 Longitudinal cyclic
 Lateral cyclic
 Collective
 Pedal
 Throttle
Flight control augmentation positions:
 Longitudinal
 Lateral
 Directional

Control force:
 Longitudinal
 Lateral
 Pedal
 Collective
Attitude:
 Pitch
 Roll
 Yaw
Angular velocity:
 Pitch
 Roll
 Yaw

2. External (drag producing) instrumentation included (1) nose boom with swiveling pitot-static probe mounted 7 feet forward of the nose; (2) belly-mounted sensitive OAT probe; (3) main rotor standpipe; (4) main and tail rotor slip ring assemblies; (5) main rotor hub loads instrumentation; (6) telemetry antenna with ground-plane plate mounted on skid; and (7) flush-mounted radar altimeter antennas. Neither set of main rotor blades was instrumented.

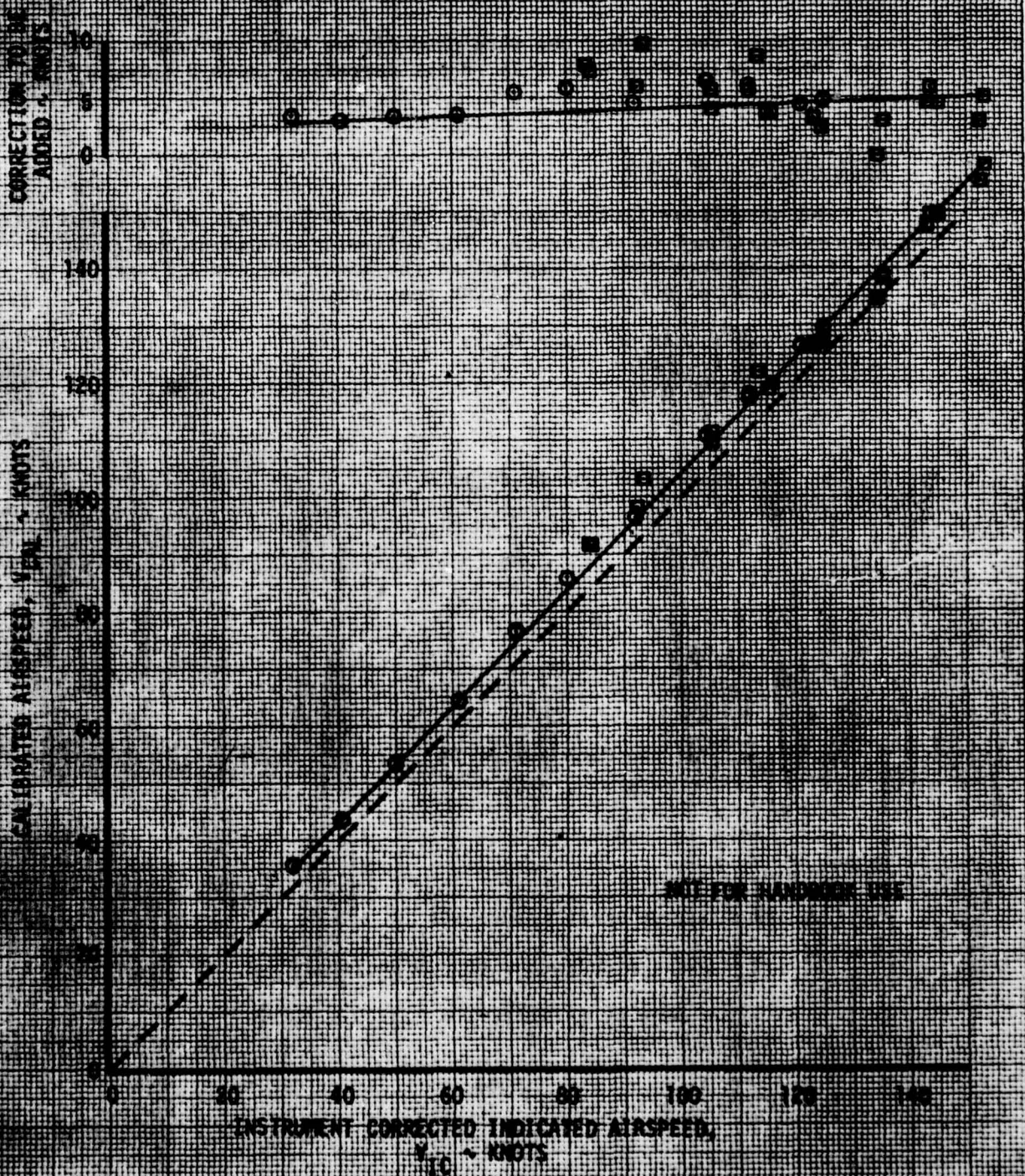
3. The instrumentation package was designed and primarily used for structural envelope expansion and flight load surveys by the contractor. As such, it was not well tailored for performance testing. Long-term or continuous recording was not practical. Several difficulties were encountered in determining OAT. The sensitive calibrated OAT had only ground (telemetered) read-out capability. Subsequent to the performance tests, a wiring error was discovered, which made this source of OAT erroneous. The standard ship's temperature probe data, which were hand-recorded intermittently during the tests, were used to process the performance data. This gage was difficult to read, being mounted through the fuselage skin behind the pilot's left knee. Reading error of $\pm 2^{\circ}\text{C}$ (attempts to postcalibrate it were inconclusive). Ram recovery effects are unknown. OAT's used and presented in the performance data may be in error by as much as 5°C . Subsequent to the performance tests, a calibrated sensitive OAT system with cockpit display was installed. The OAT data during handling qualities tests should be accurate within $\pm 2^{\circ}\text{C}$. Recorded pressure altitude had a resolution larger than 200 feet. Recorded PCM airspeed agreed with sensitive indicated airspeeds within 2 knots. Recorded PCM rotor speed disagreed with calibrated sensitive indicators by as much as 2 rpm.

4. The airspeed calibration presented in figure 1 was obtained from the contractor. The fairing was used for all airspeed data.

FIGURE 1
 AIRSPEED CALIBRATION
 YAC-119 ON THE T-28
 BOM SYSTEM

- FREE AIRSPEED
- INSTRUMENT

NOTE: DATA OBTAINED FROM CONTRACTOR



NOT FOR HANDBOOK USE

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

TEST TECHNIQUES

1. Standard test techniques were used during this evaluation of the YAH-1R helicopter with K-747 rotor installed (refs 8 through 10, app A).

DATA ANALYSIS METHODS

2. The helicopter performance test data were generalized by use of nondimensional coefficients. The following nondimensional coefficients were used to generalize the hover and level flight results obtained during this flight test program:

a. Coefficient of power (C_P):

$$C_P = \frac{\text{SHP}(550)}{\rho A (\Omega R)^3} \quad (1)$$

b. Coefficient of thrust (C_T):

$$C_T = \frac{W}{\rho A (\Omega R)^3} \quad (2)$$

c. Advance ratio (μ):

$$\mu = \frac{1.6878 V_T}{\Omega R} \quad (3)$$

d. Advancing tip Mach number (M_{tip}):

$$M_{\text{tip}} = \frac{1.6878 V_T + (\Omega R)}{a} \quad (4)$$

Where:

SHP = output shaft horsepower

550 = Conversion factor (ft-lb/sec/shp)

ρ = Air density (slug/ft³) = $2.3769 \times 10^{-3} \sigma$

R = Main rotor radius (ft) = 22 ft

A = Main rotor disc area (ft²) = πR^2 = 1520.5 ft²

Ω = Main rotor angular velocity (rad/sec) = $\frac{\pi}{30}$ x rpm

W = Aircraft gross weight (lb)

1.6878 = Conversion factor (ft/sec/kt)

V_T = True airspeed (kt)

a = Speed of sound (ft/sec) = 1116.45 $\sqrt{\theta}$

σ = Air density ratio = δ/θ

δ = Pressure ratio = $(1 - \frac{H_p}{145,442})^{5.25585}$

H_p = Pressure altitude (ft)

θ = Temperature ratio = $\frac{OAT + 273.15}{288.15}$

OAT = Ambient air temperature (°C) = $\frac{(OAT_{ic} + 273.15) - 273.15}{(1 + .2KM^2)}$

OAT_{ic} = Observed free air temperature corrected for instrument error (°C)

M = Mach number = $\frac{V_{cal}}{661.48\sqrt{\delta}}$

K = Probe recovery factor

V_{cal} = Calibrated airspeed (kt)

For a rotor speed of 324 rpm, the following constants were used:

R = 746.44

(ΩR)² = 557,176

(ΩR)³ = 4.159 x 10⁸

3. Each level flight data point C_p was corrected to the average C_T for the flight. The slopes of C_p versus C_T from reference 8, appendix A, were read at the μ of the point and average C_T. This value was then multiplied by the amount the test C_T was different from the average C_T and the result added to the test C_p.

Hence:

$$C_{P_{\text{corr}}} = C_{P_{\text{test}}} + [(dC_P/dC_T) \mu, C_T \times \Delta C_T]$$

Level flight C_P was then converted back to dimensional shaft horsepower as follows:

$$\text{SHP} = \frac{C_{P_{\text{corr}}} A (\Omega R)^3 \rho_{\text{avg}}}{550}$$

4. All computed atmospheric parameters were determined using 1962 U.S. standard atmosphere constants and functions.

5. Engine start gross weight was determined by adding crew weight, ballast weight, and engine start fuel weight, as determined during preflight by an external sight gage quantity reading and fuel specific weight, to aircraft empty weight (app B). Test point gross weight was then computed by subtracting fuel used, obtained from a fuel volume totalizer, multiplied by the preflight specific weight corrected for temperature difference between preflight fuel temperature and test point fuel temperature. Postflight fuel quantity was also determined using the sight gage and specific weight readings. This value was compared to fuel used as computed from the fuel totalizer.

6. Test shaft horsepower was determined by multiplying rotor speed by engine torque and appropriate gear ratios and conversion constants.

$$\text{SHP} = \frac{(N_R \times 20.383) \times \text{torque, ft-lb}}{5252.1}$$

$$\text{SHP} = \frac{N_R \times \text{torque}}{257.67}$$

Engine torque was determined by measuring differential torquemeter output pressure and applying the individual engine torquemeter conversion. The nominal conversion is 18.4 ft-lb/psi. The conversion for the test engine, SN LE 15124Z, was 1125 ft-lb/63.4 psi or 17.7 ft-lb/psi. These values were obtained from engine acceptance records and the engine data plate. During earlier contractor flights, use of this conversion resulted in substantial disagreement between engine torque and the sum of rotor shaft torques plus accessory losses. Also, performance data obtained by the contractor using the B-540 rotor disagreed with previous

B-540 data obtained with the YAH-1S (ref 8, app A). Use of the torque conversion function from reference 8 caused the contractor B-540 performance data and reference 8 data to agree and caused closer agreement between engine torque and the sum of shaft torques and accessory losses. This function was then used as being typical of the T53-L-703 series engine for both the contractor data and this project. The conversion is:

$$\text{Torque, ft-lb} = 0.13466 + 17.885 \text{ QE} + 3.8434 \times 10^{-3} \text{ QE}^2$$

Where:

QE = Differential torquemeter pressure

Subsequent to this test and data analysis for this project, data from a 19-point engine calibration were obtained for the test engine. Use of the torque conversion derived from these data resulted in even better agreement between engine torque and the sum of rotor shaft torques plus accessory losses. However, it degraded the comparison between reference 8 data and contractor B-540 rotor data. This conversion is:

$$\text{Torque, ft-lb} = 18.331 + 22.362 \text{ QE} - 0.12787 \text{ QE}^2 + 1.145 \times 10^{-3} \text{ QE}^3$$

Using this conversion would increase the power required shown in this report by approximately 2 percent. A further engine calibration was conducted and verified the original 19 point calibration.

7. Vertical speed for both climbs and autorotational descents was determined by measuring the time required to change altitude 1000 feet. This was converted to the rate of climb (descent) as follows:

$$R/C_{\text{time}} = \frac{\Delta H_P}{\Delta \text{time}} \left(\frac{\text{OAT}_{\text{test}} + 273.15}{\text{OAT}_{\text{std}} + 273.15} \right)$$

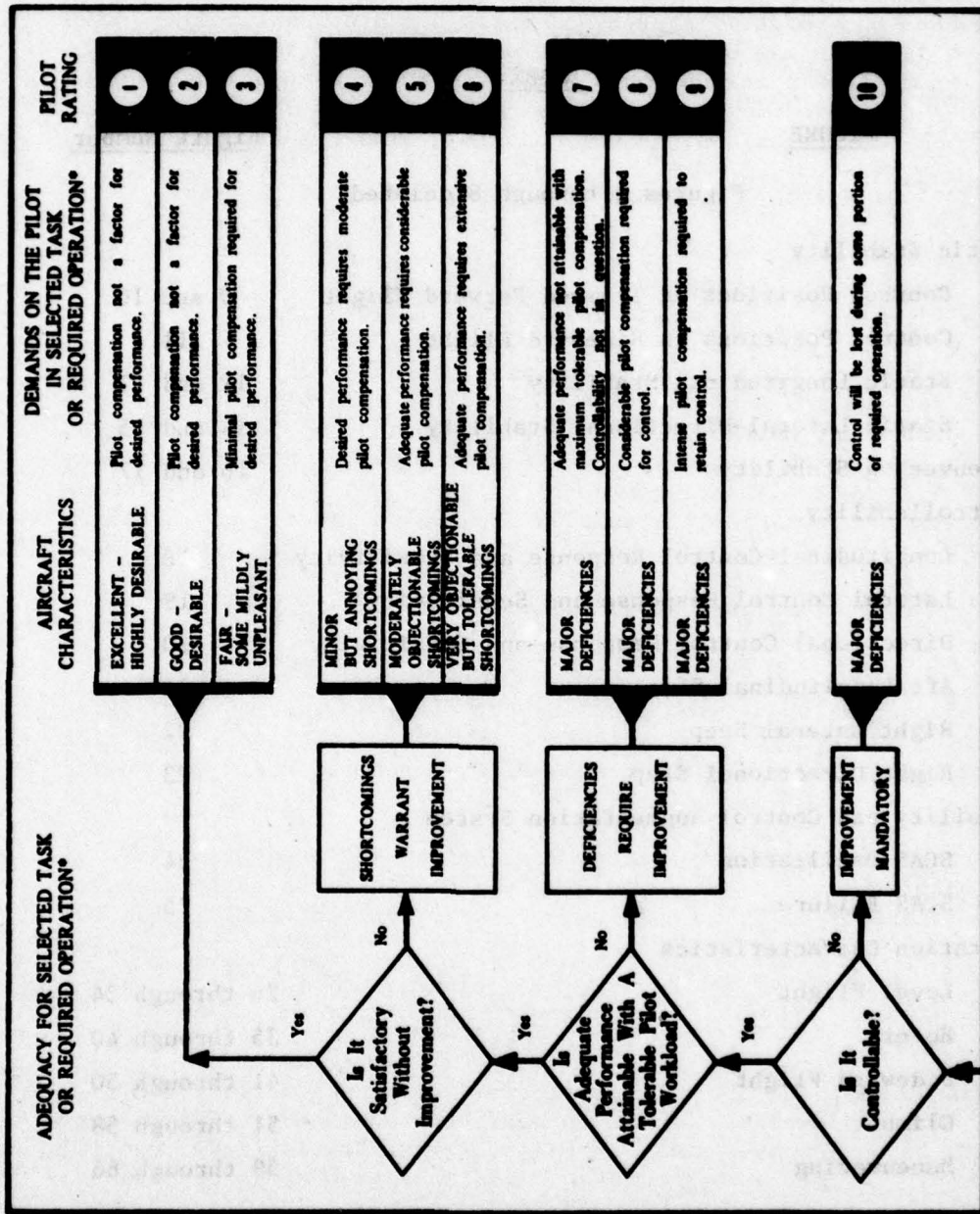
8. To determine the climb correction factors, the rates of climb were further corrected to average powers or gross weights as follows. For determining K_p , rates of climb were corrected to the average gross weight using:

$$R/C_{\text{wt-corr}} = R/C_{\text{test}} + KW \left[\frac{\Delta GW \times 33,000 \text{ SHP}_{\text{test}}}{\text{GW}^2} \right]$$

For determining K_W , rates of climb were corrected to the average shaft horsepower of a set using:

$$R/C_{\text{pwr-corr}} = R/C_{\text{test}} + \left[K_P \frac{\Delta\text{SHP} \times 33,000}{\text{GW}} \right]$$

9. Handling qualities ratings were quantified using figure 1.



*Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TRD-5153) And Definitions In Accordance With AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale.

APPENDIX E. TEST DATA

INDEX

<u>FIGURE</u>	<u>Figure Number</u>
Figures 1 through 8 deleted	
Static Stability	
Control Positions in Trimmed Forward Flight	9 and 10
Control Positions in Sideward Flight	11
Static Longitudinal Stability	12 and 13
Static Lateral-Directional Stability	14 and 15
Maneuvering Stability	16 and 17
Controllability	
Longitudinal Control Response and Sensitivity	18
Lateral Control Response and Sensitivity	19
Directional Control Response and Sensitivity	20
Aft Longitudinal Step	21
Right Lateral Step	22
Right Directional Step	23
Stability and Control Augmentation System	
SCAS Oscillation	24
SCAS Failure	25
Vibration Characteristics	
Level Flight	26 through 34
Hover	35 through 40
Sideward Flight	41 through 50
Climb	51 through 58
Maneuvering	59 through 66

APPENDIX E. TEST DATA

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Stability and Control Augmentation System	
SCAS Oscillation	24
SCAS Failure	25
Vibration Characteristics	
Level Flight	26 through 34
Hover	35 through 40
Sideward Flight	41 through 50
Climb	51 through 58
Maneuvering	59 through 66

TABLE 1
 CONTROL CHARACTERISTICS OF THE F-105
 (BASED ON 1955 DATA)

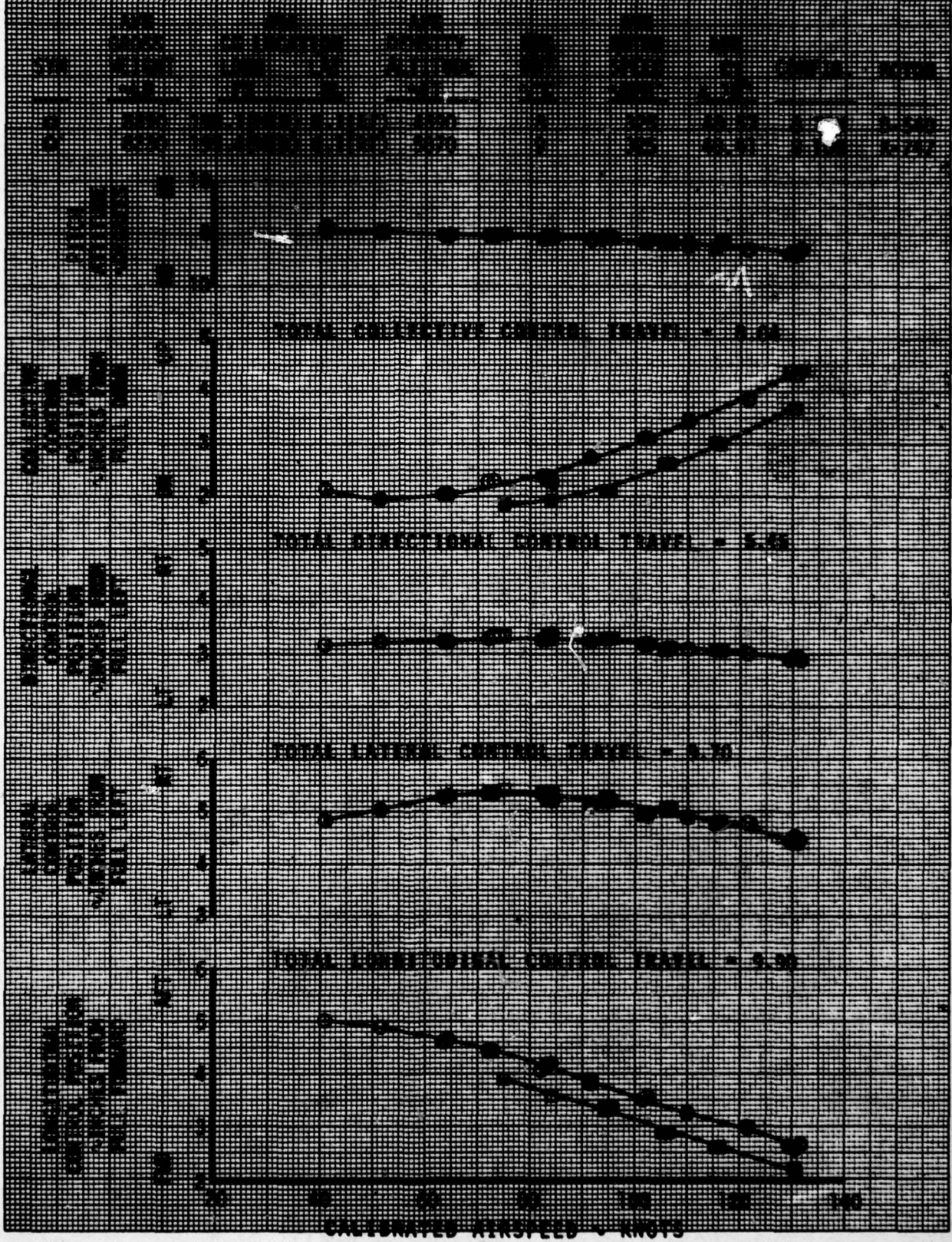


Figure 3
CONTROL SYSTEMS IN THE CONTROL ROOM
TABLE OF RESULTS

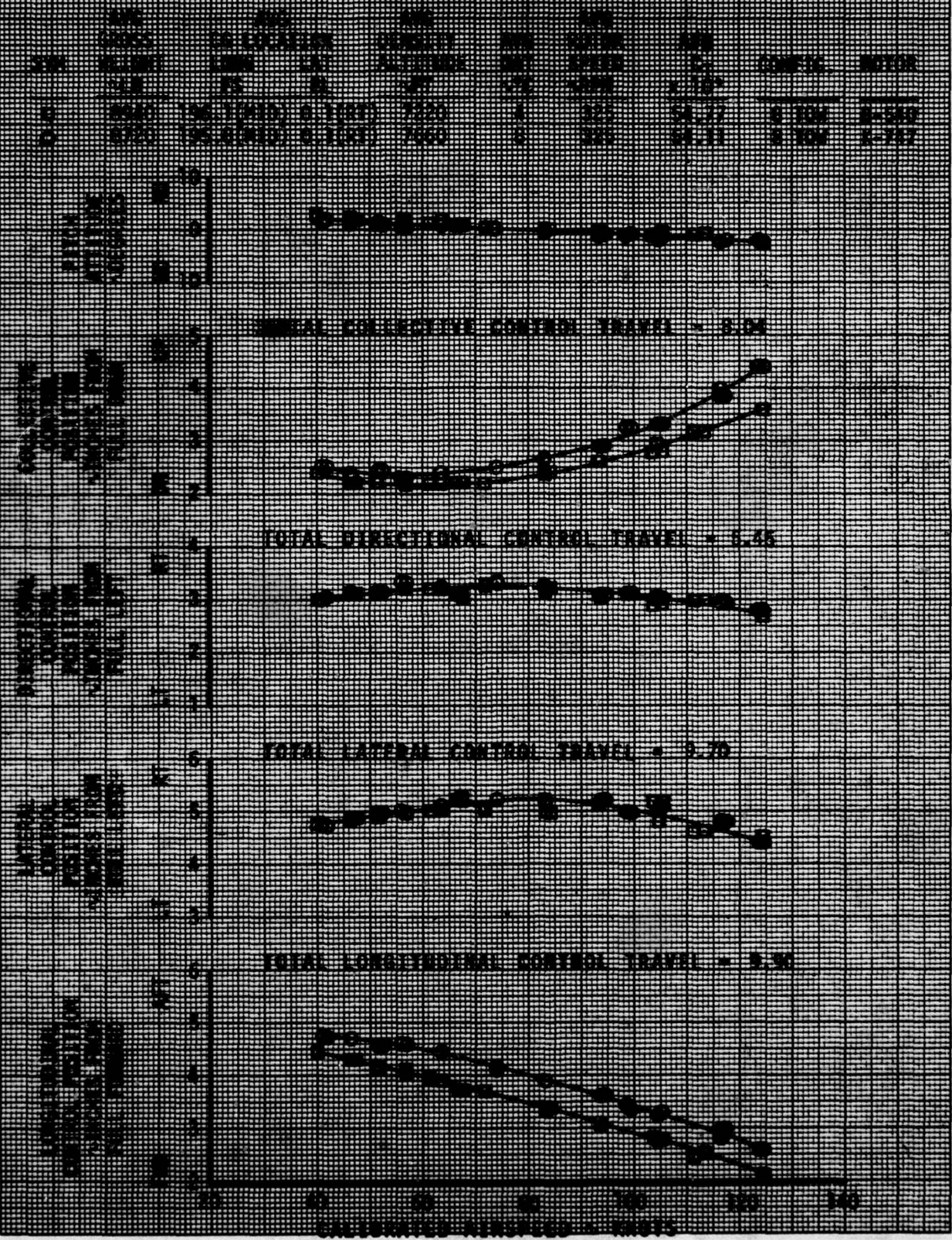


FIGURE 12
CONTROL POSITIONS IN STANDARD FLIGHT
 YAN-11 USA 5/18/78 1336

SYM	Avg Gross Weight	Avg Location		Avg Density Altitude	Avg Motor GAT	Avg Motor Speed	Avg Comp Ct	Avg Control Motor	
	LB	LONG FS	LAT DL	FT	°C	RPM	°	NO	NO
---	2240	196.2(190)	4.1(1.7)	-300	7	324	65.05	NO	1-540
---	2240	196.2(190)	0.7(1.0)	-3220	7	324	62.77	0.100	1-747

NOTES: 1. SMO WEIGHT = 20 LBS
 2. DASHED CURVES OBTAINED FROM REF 9

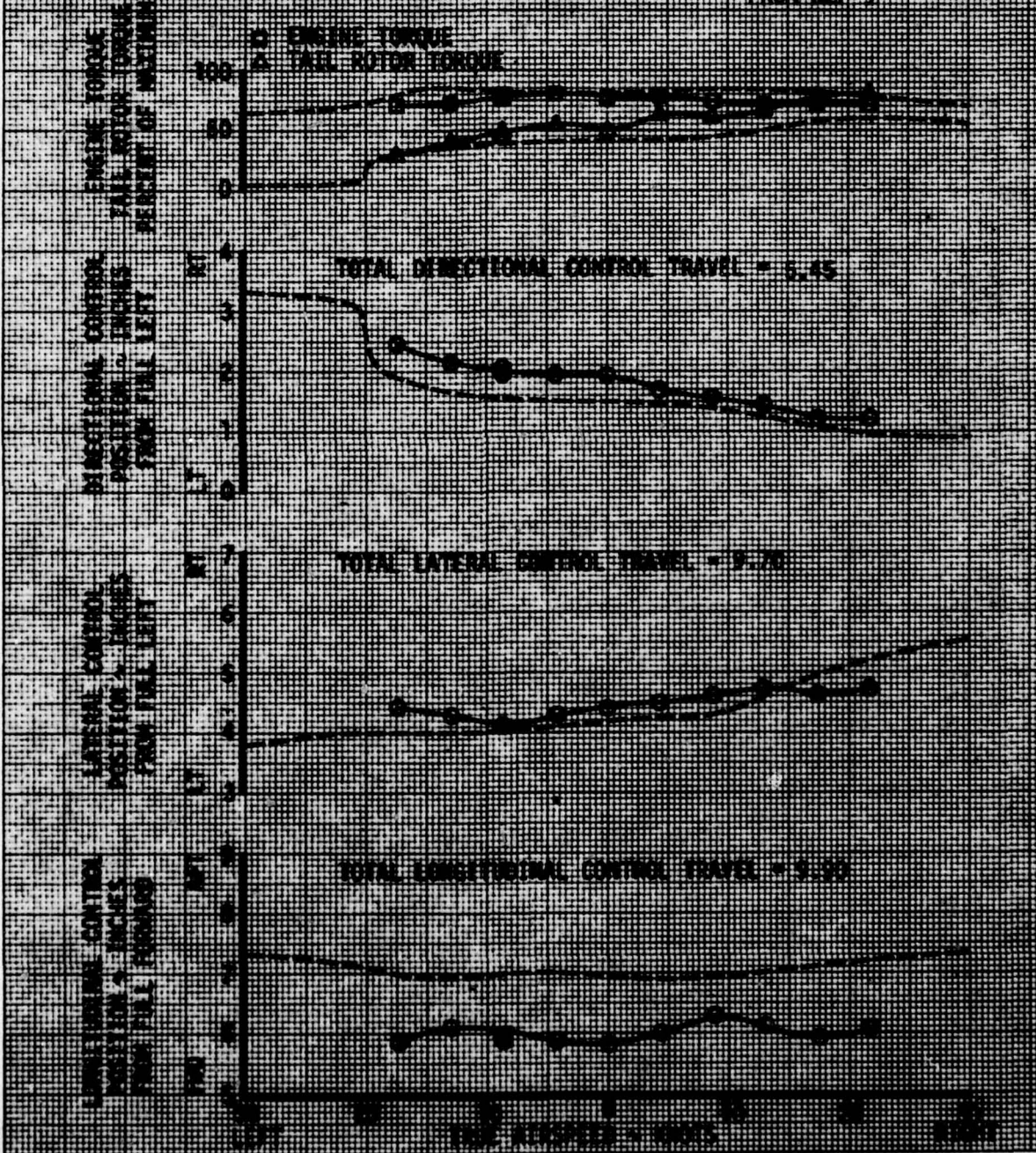
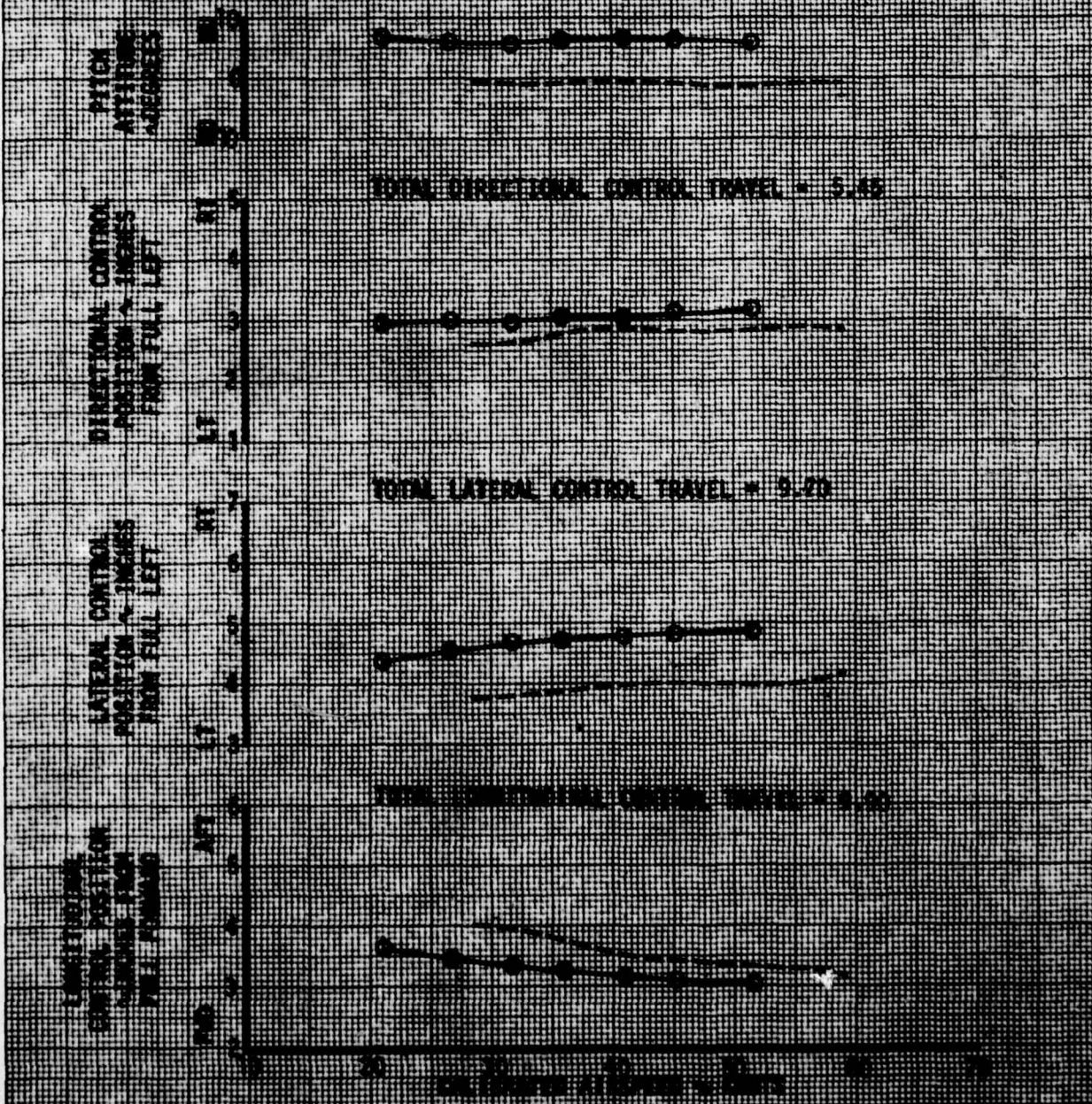


FIGURE 18
 DIRECTIONAL FLIGHT STATIC LONGITUDINAL STABILITY
 YAN-10 INR 574 70-15026

SYM	AVG GROSS WEIGHT LBS	AVG OR LOCATIONS		AVG WING SPAN FT	AVG WING AREA SQ FT	AVG WING LOAD PSF	AVG CONFIG CODE	AVG CONFIG CODE	AVG CONFIG CODE	
		LONG	LAT							
---	7000	1000000	0.1(LT)	8100	2.1	324	406	406	LEVEL FLIGHT	2-346
●	5000	2000000	0.1(RT)	4100	4	326	406	406	LEVEL FLIGHT	2-347

NOTES: 1. ANGLE OF SLEIGHT = ZERO DEGREES
 2. DASHED CURVES OBTAINED FROM REF 9
 AT A TRIM AIRSPEED OF 46.5 KIAS



**FIGURE 14
COLLECTIVE-TRIP STATE LONGITUDINAL STABILITY
W-1 RISE SITUATION**

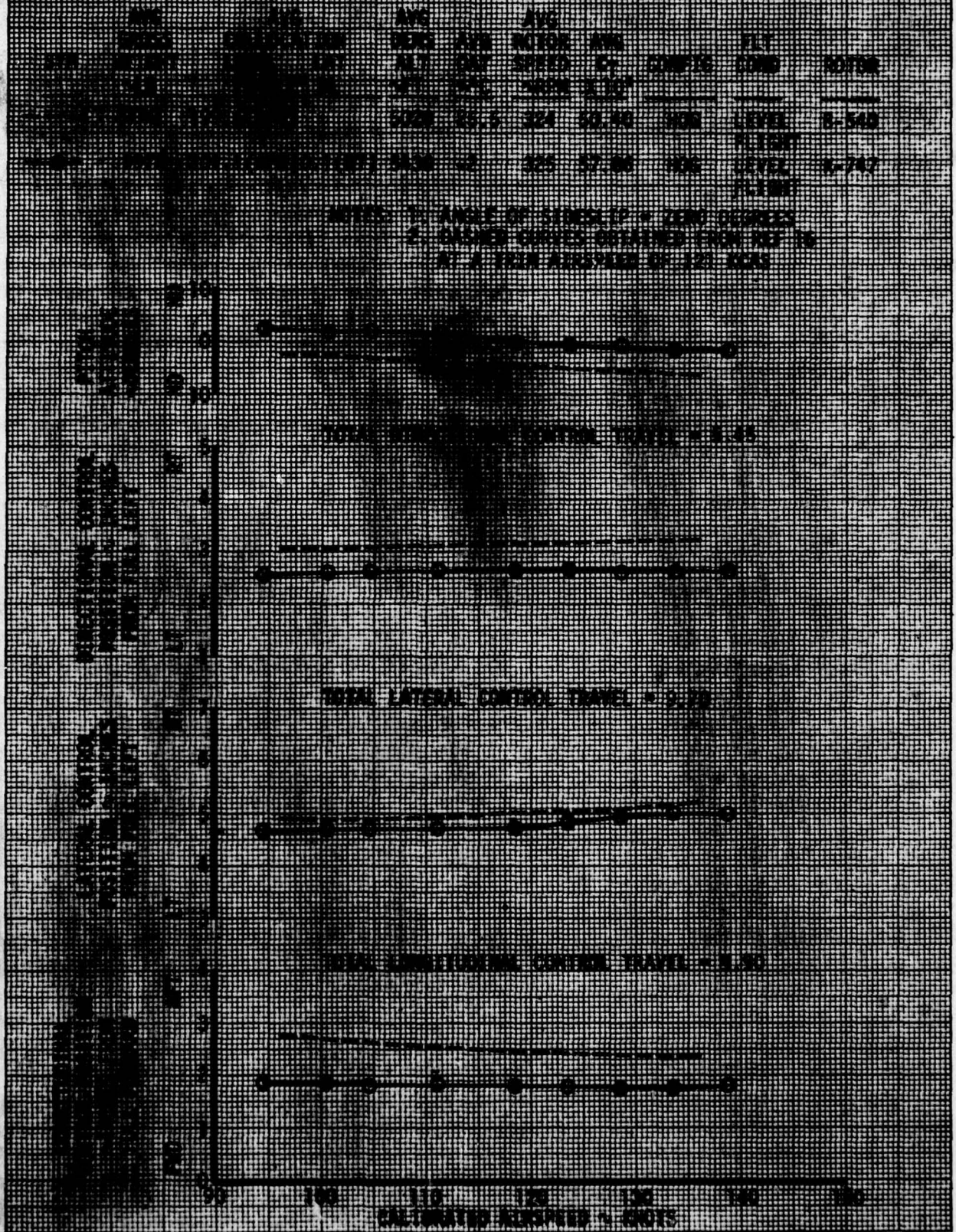


TABLE I
 TOTAL LATERAL CONTROL QUALITY
 1953 TO 1970-1975

Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	
1953-1954	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1955-1956	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1957-1958	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1959-1960	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1961-1962	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1963-1964	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1965-1966	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1967-1968	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1969-1970	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1971-1972	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1973-1974	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1975	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

NOTE: 1. ALL DATA ARE BASED ON THE YEAR 1953.

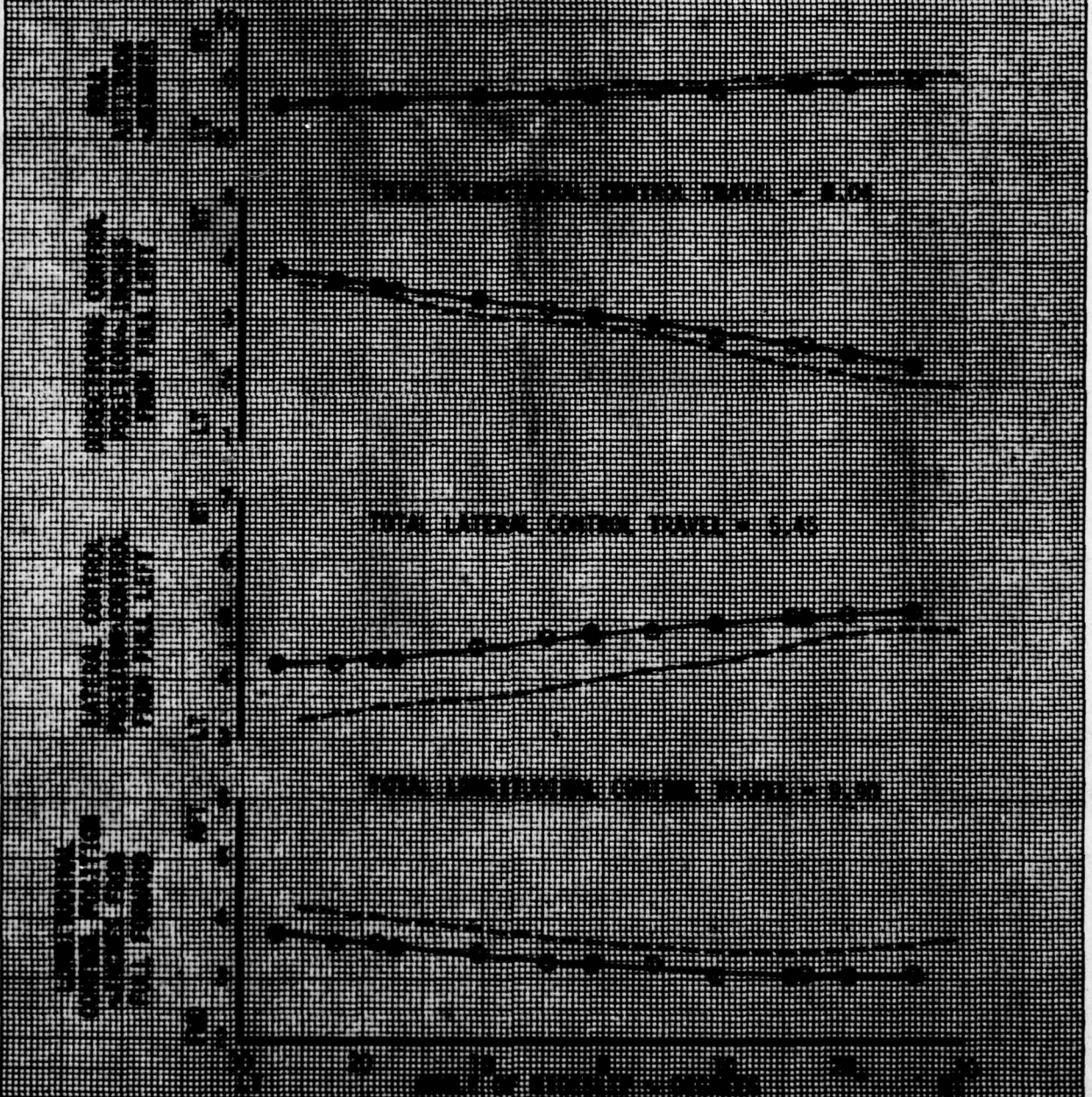


FIGURE 10
DATA LATERAL DIRECTIONAL STABILITY
MAY 19 53 10 70-1000

VIB	AS		AS		AS		VIB	VIB	VIB	VIB
	1000	100	100	100	1000	100				
100	10.0	10.0	10.0	10.0	10.0	10.0	100	100	100	100
200	20.0	20.0	20.0	20.0	20.0	20.0	200	200	200	200

NOTE: DASHED CURVES OBTAINED FROM TEST 10

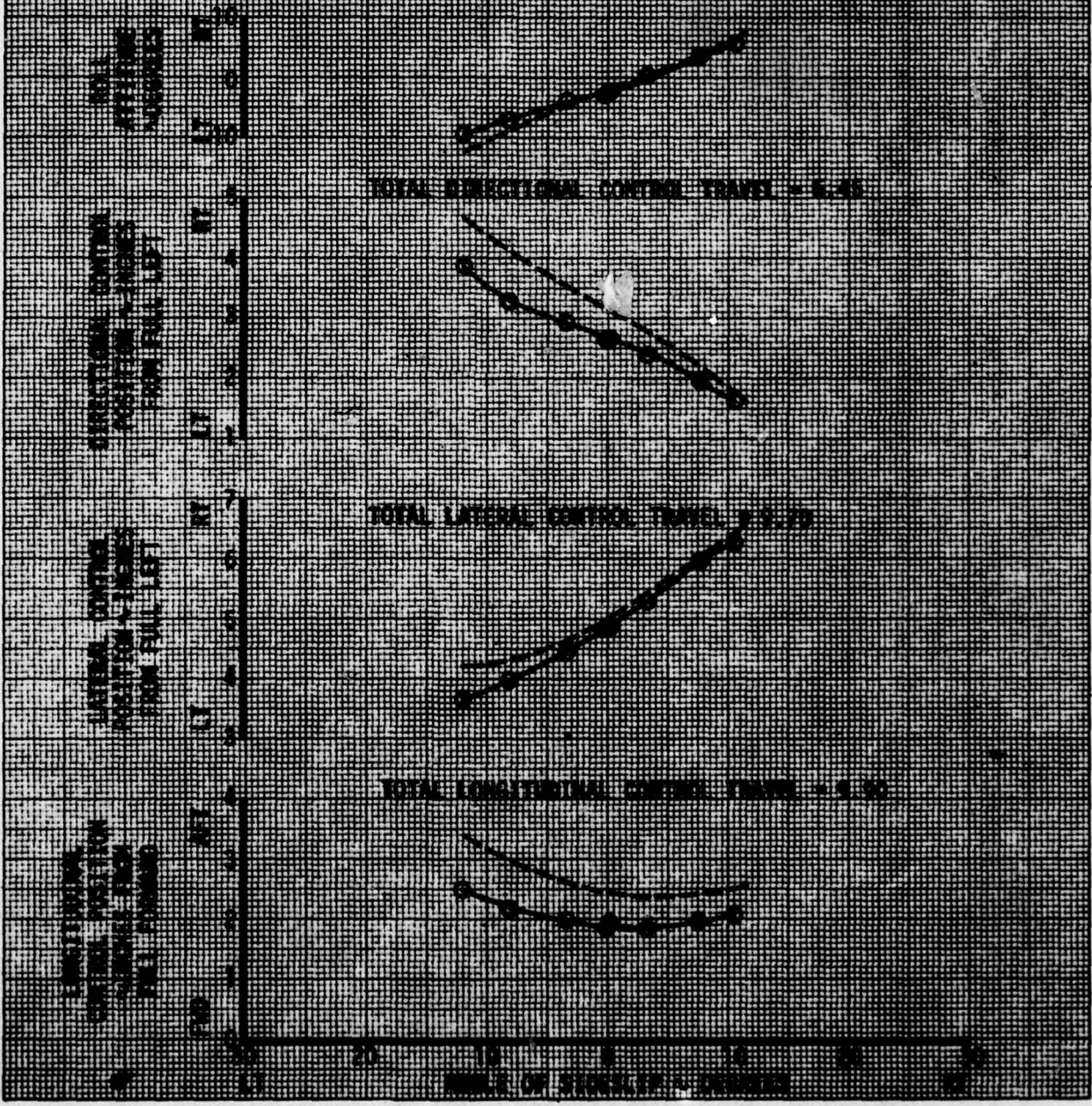


FIGURE 10
 ENGINEERING SUMMARY
 DALLAS USA C/N 70-10036

SYN	AIR		AIR		MOTOR	AVE	TRM	AVE	TRM	AVE	TRM
	WEIGHT	OR LOCATION	REQ	AVG							
9810	199.36(LB)	0.17(1)	15000	77	200	11.20	10	100	STEADY	2000	2000
9820	201.11(LB)	0.17(1)	15000	77	200	11.20	10	100	STEADY	2000	2000

NOTES: 1. TRM FORCE - 1120 LB (0.16G)
 2. DASHED CURVES OBTAINED FROM REF 9
 3. FLASHER SYMBOLS DENOTE LEFT TURN
 TOTAL DIRECTIONAL CONTROL TRAVEL - 3.45

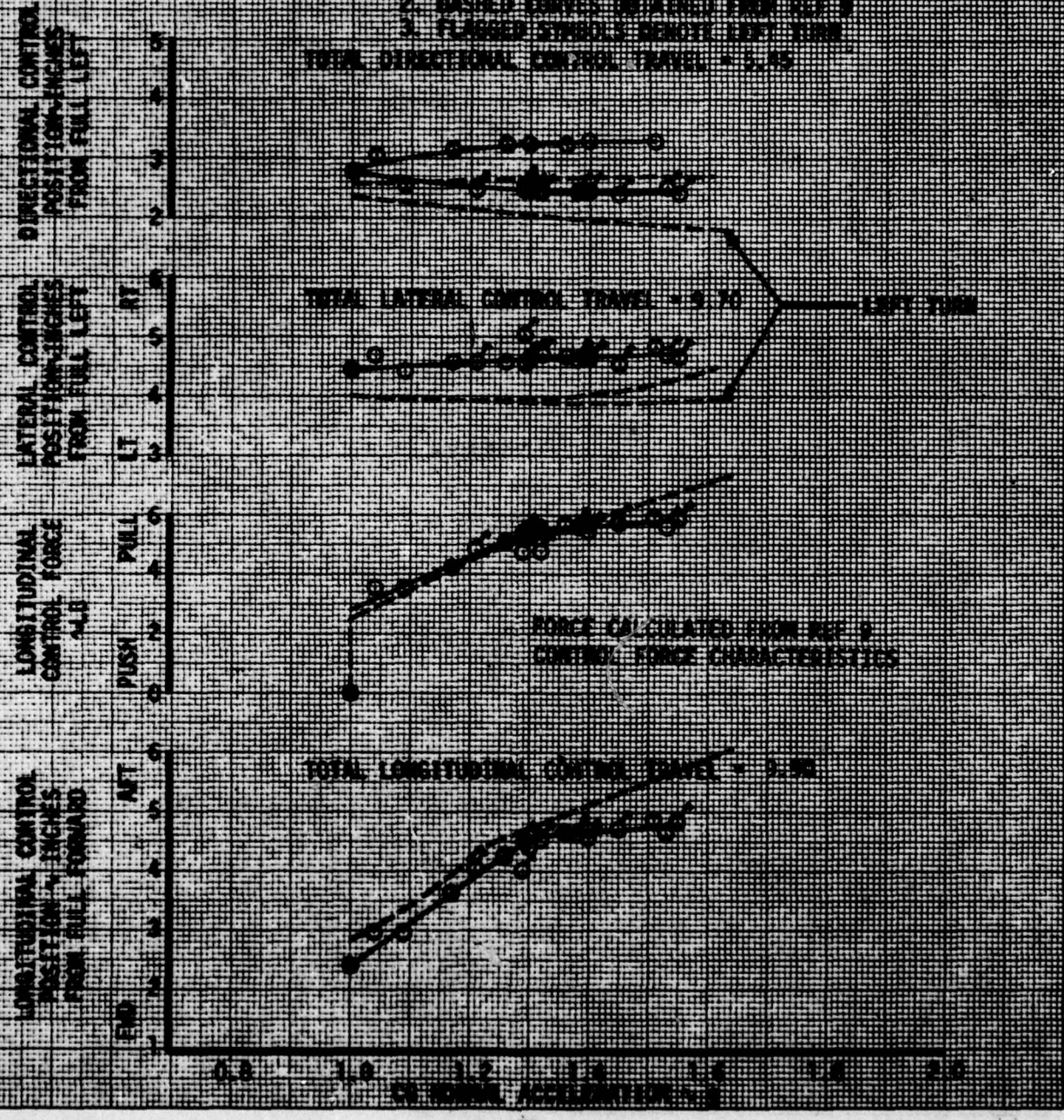


TABLE 10
 MECHANICAL PROPERTIES
 TESTS ON 10-10-10

NO.	NO. OF SPECIMENS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS	NO. OF TESTS
100	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10

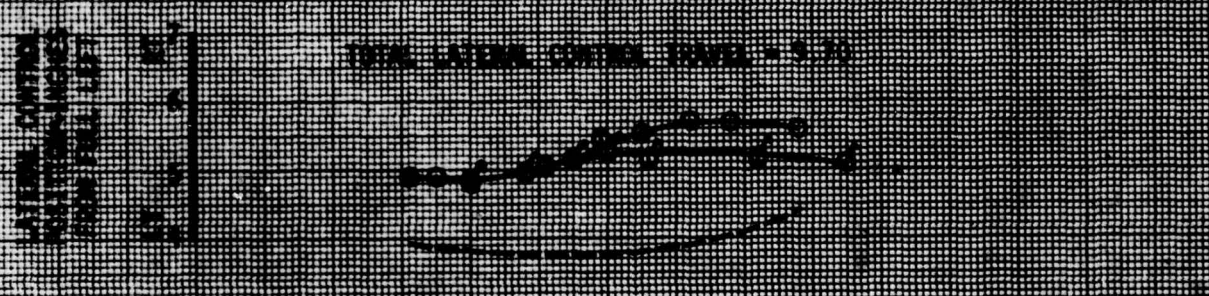


FIGURE 30
ENVIRONMENTAL CONTROL RESPONSE AND SENSITIVITY
VAN-12 USA C/N 70-1532

S/N	AVG. WEIGHT		AVG. CG LOCATION		AVG. DES. ALT		AVG. ROTOR RPM		AVG. %	TRIM	SKID WEIGHT	SWAY
	WGT	IN	LONG	LAT	FEET	FT	MIN	MAX				
1	2400	151	3.100	0.1 (LT)	700	13	324	40-60	1.10	WYER	200	0%
2	10130	134	3.000	0.1 (RT)	3500	4	324	45-75	1.10	WYER	20	10% TR

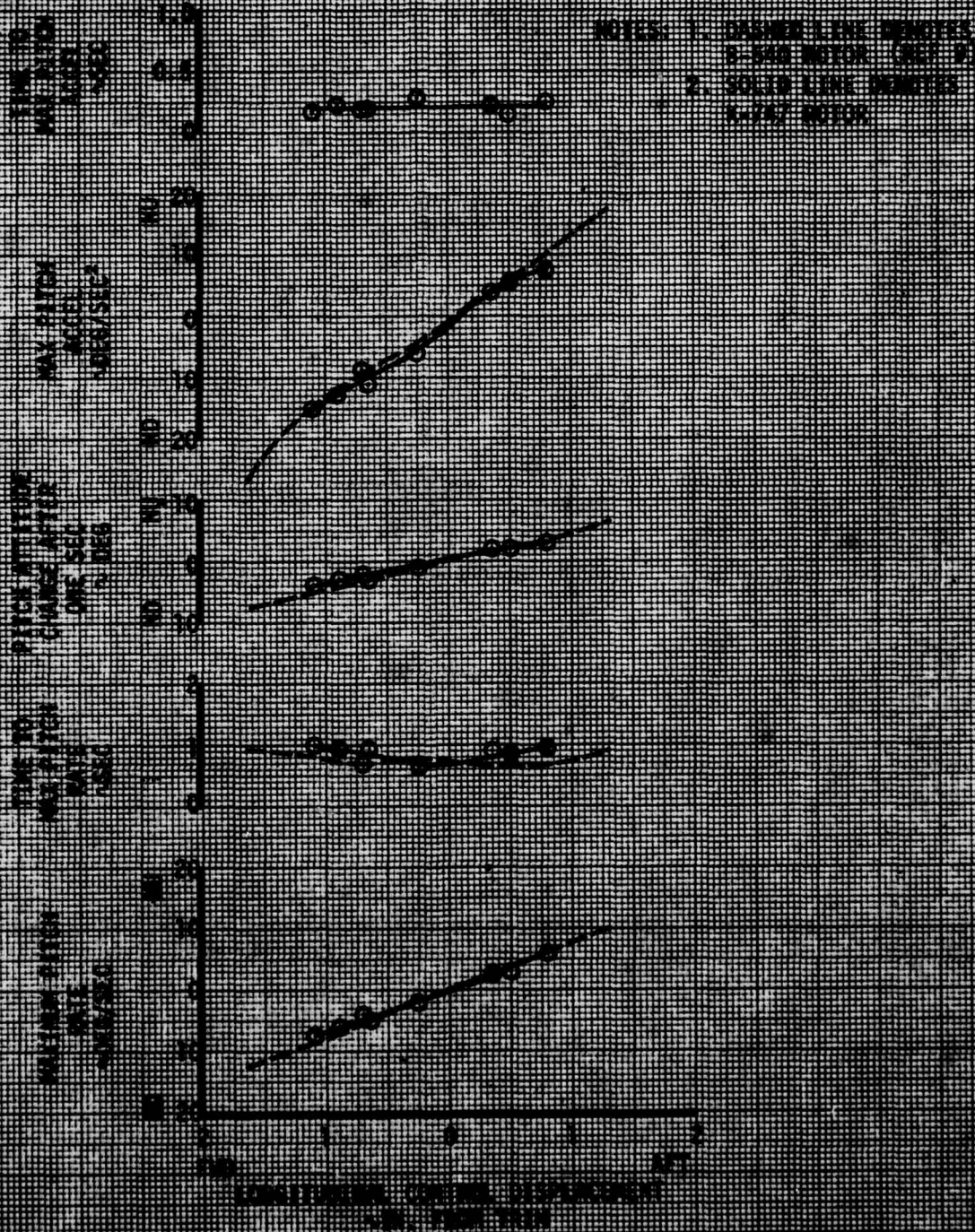


FIGURE 10
 EXTERNAL CONTROL RESPONSE AND SENSITIVITY
 (MARCH 1964 - MAY 1966)

MOTOR	SIGNAL	LOCATION		MAY 1964		MAY 1966		TRIM	SATO	HEIGHT	CONFIG
		CON	INT	CON	INT	CON	INT				
5500	100.0 (P)	0.0	0.0	0.0	0.0	0.0	0.0	POWER	200	100	100
5500	100.0 (I)	0.0	0.0	0.0	0.0	0.0	0.0	POWER	50	100	100

NOTES: 1. DASHED LINE DENOTES B-540 MOTOR (REF 9)
 2. SOLID LINE DENOTES K-747 MOTOR

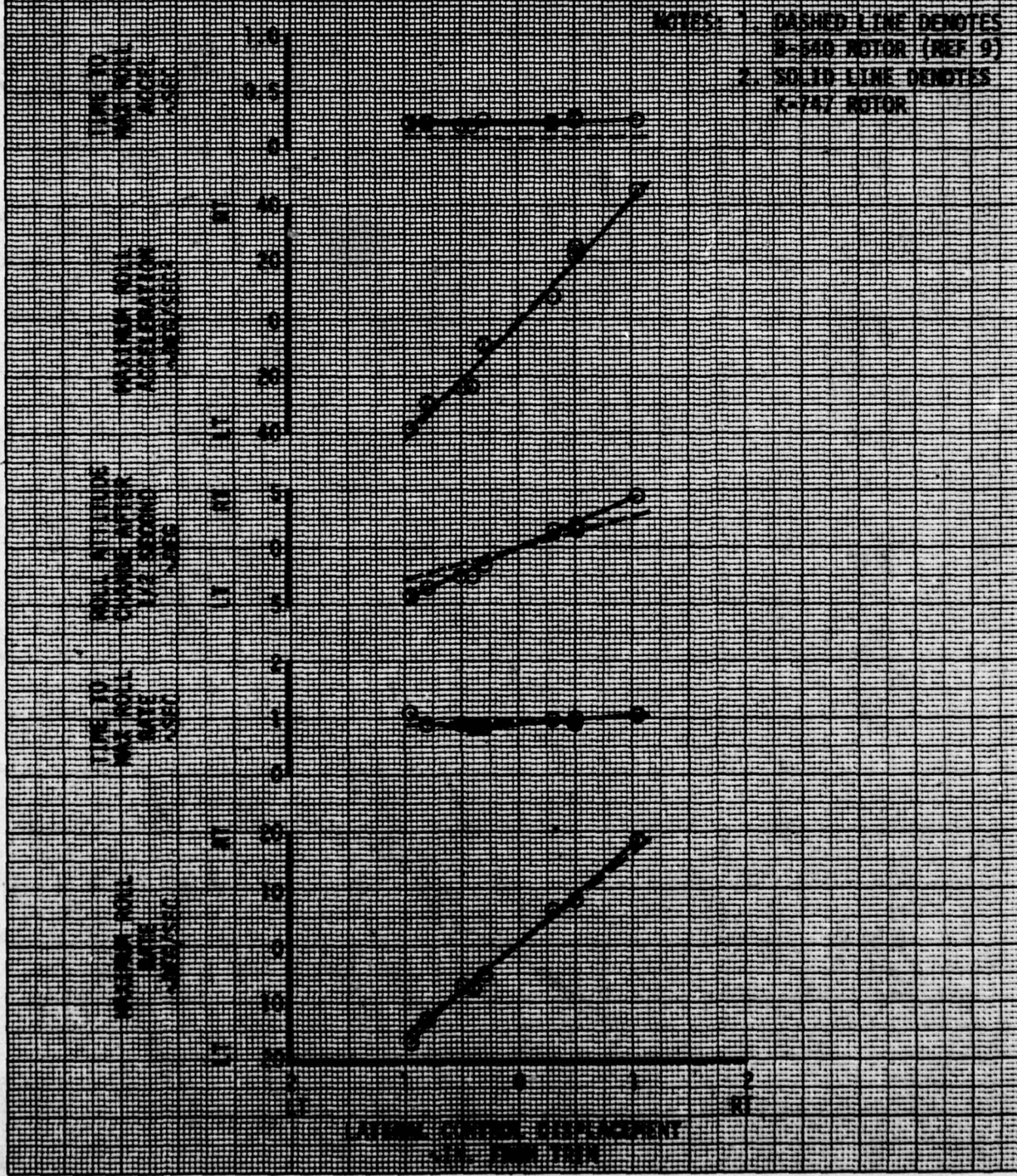


FIGURE 10
 EFFECT OF ROTOR SPEED ON STABILITY
 OF THE SYSTEM

SPR	NO. OF ROTORS	STATIONARY LINE	LINE	NO. OF ROTORS	NO. OF ROTORS	NO. OF ROTORS	AVG. LINE SPEED	TRIM AREA	SKID WEIGHT	CONFIG
100	100	100	100	100	100	100	100	100	100	HOG
100	100	100	100	100	100	100	100	100	100	HOG TON

NOTES: 1. DASHED LINE DENOTES
 K-747 ROTOR (REF. 9)
 2. SOLID LINE DENOTES
 K-747 ROTOR

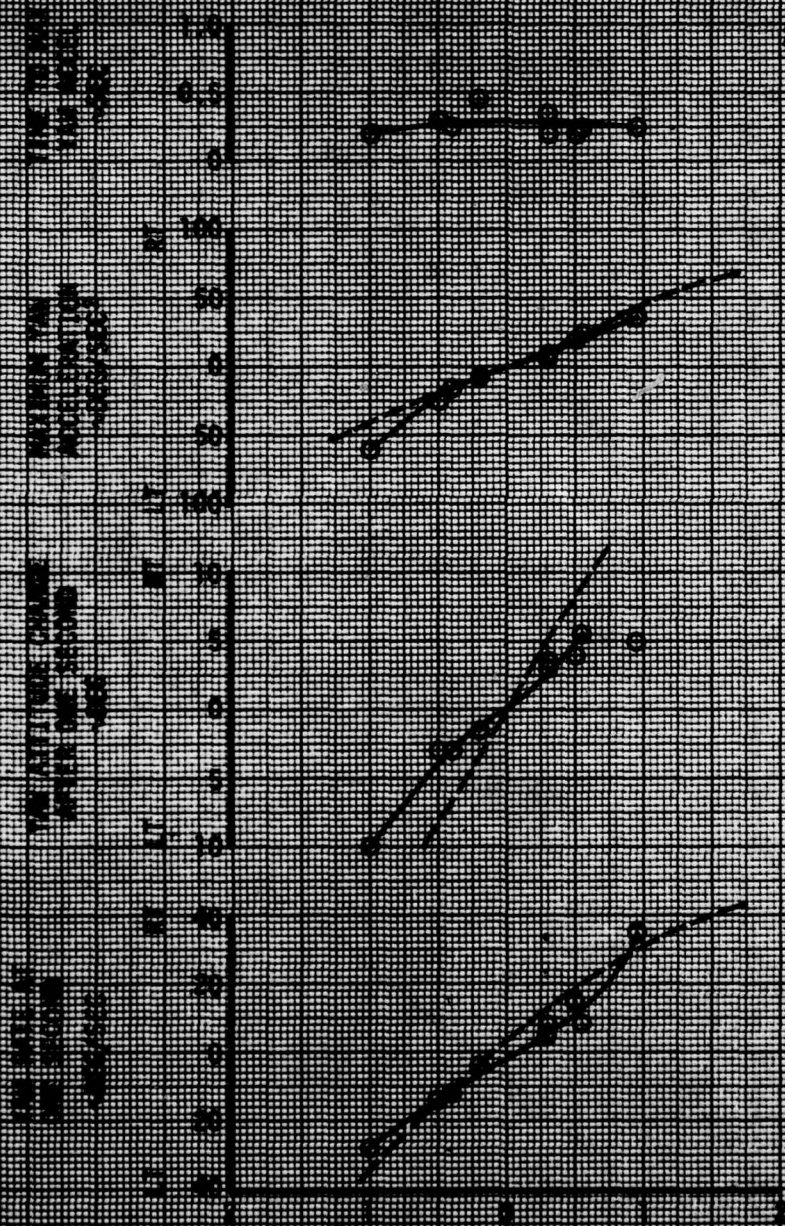


FIGURE 11
 EFFECT OF ROTOR SPEED ON STABILITY OF THE SYSTEM

FIGURE 27
AFT LONGITUDINAL STEP
YAH-1R USA S/N 70-15936

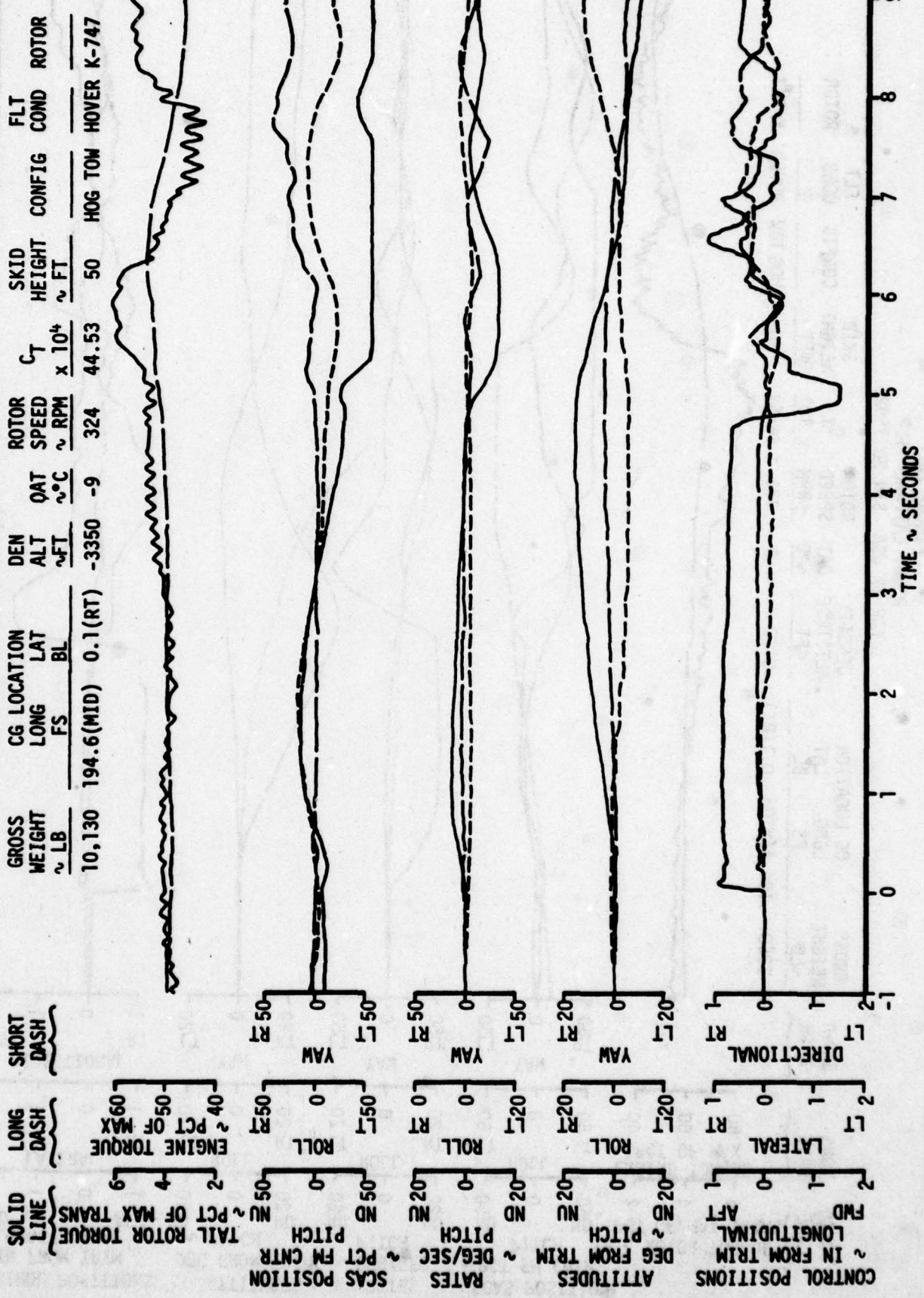


FIGURE 22
RIGHT LATERAL STEP
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION LONG FS	DENSITY ALTITUDE ~FT	OAT ~°C	ROTOR SPEED ~RPM	$C_T \times 10^4$	SKID HEIGHT ~FT	CONFIG	FLT COND	ROTOR
9950	194.4(MID)	-3170	-8	324	44.53	50	HOG TOM	HOVER	K-747

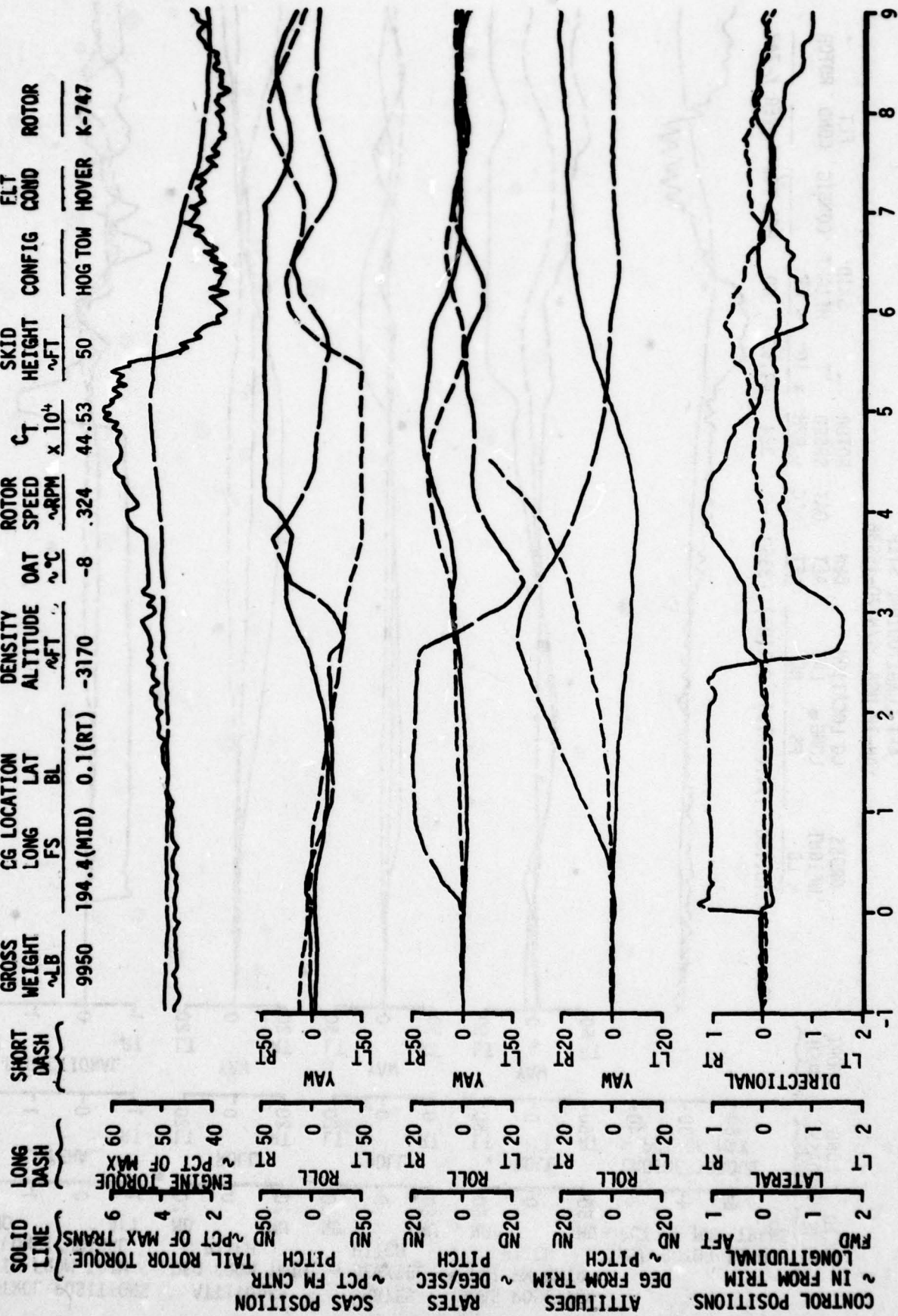


FIGURE 23
RIGHT DIRECTIONAL STEP
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~ LB	CG LOCATION LONG FS	DEN ALT ~ FT	OAT ~ °C	ROTOR SPEED ~ RPM	$C_T \times 10^4$	SKID HEIGHT ~ FT	CONFIG	FLT COND	ROTOR
9800	194.3(MID)	0.1(RT)	-3200	-8	43.82	50	HOG TOM	HOVER	K-747

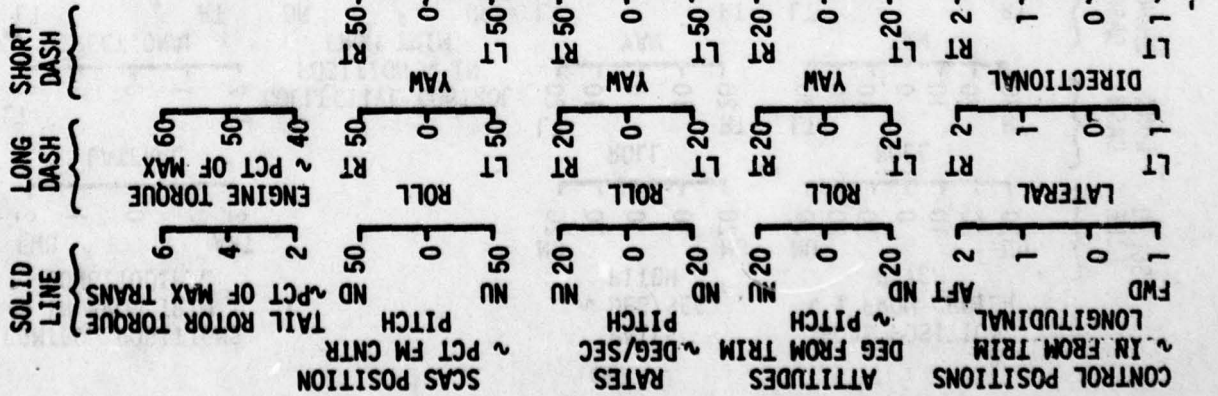
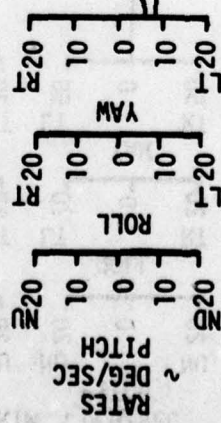
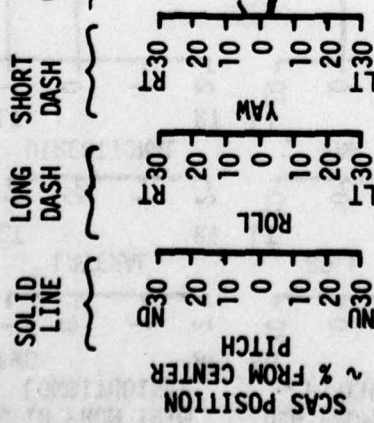
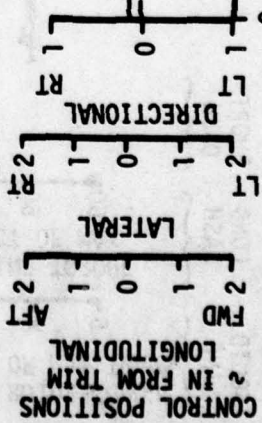
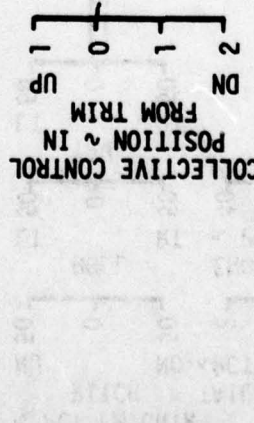


FIGURE 24
SCAS OSCILLATION
YAH-TR USA S/N 70-15936

APPROXIMATE CG LOCATION LONG	MID	APPROXIMATE DENSITY ALT ~ FT	N/A	APPROXIMATE OAT ~ °C	N/A	ROTOR SPEED ~ RPM	325	WIND ~ KTS	N/A	SKID HEIGHT	N/A	FLIGHT COND	Hover	ROTOR	K-747
------------------------------------	-----	------------------------------------	-----	----------------------------	-----	-------------------------	-----	---------------	-----	----------------	-----	----------------	-------	-------	-------



PITCH RATE NOT AVAILABLE



LATERAL CONTROL POSITION NOT AVAILABLE

TIME ~ SECONDS

FIGURE 25
SCAS FAILURE
YAH-1R USA S/N 70-15936

GROSS WEIGHT ~LB	CG LOCATION		DENSITY ALTITUDE ~FT	OAT ~°C	ROTOR SPEED ~RPM	C_T $\times 10^6$	CONFIG.	FLIGHT COND.
	LONG FS	LAT BL						
9540	195.2(MID)	0.1(RT)	-3320	-7	325	42.77	8-TOW	Hover

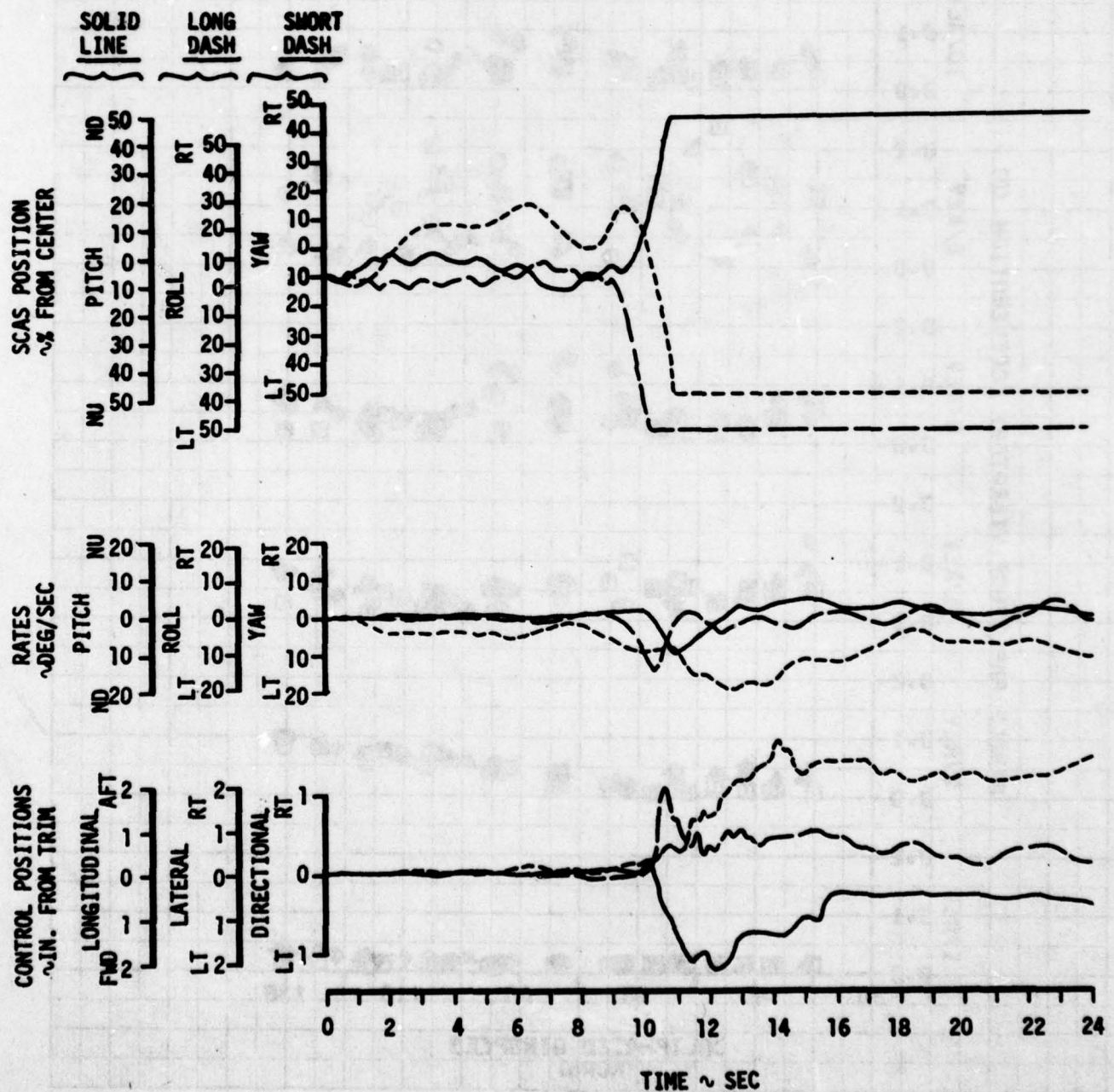
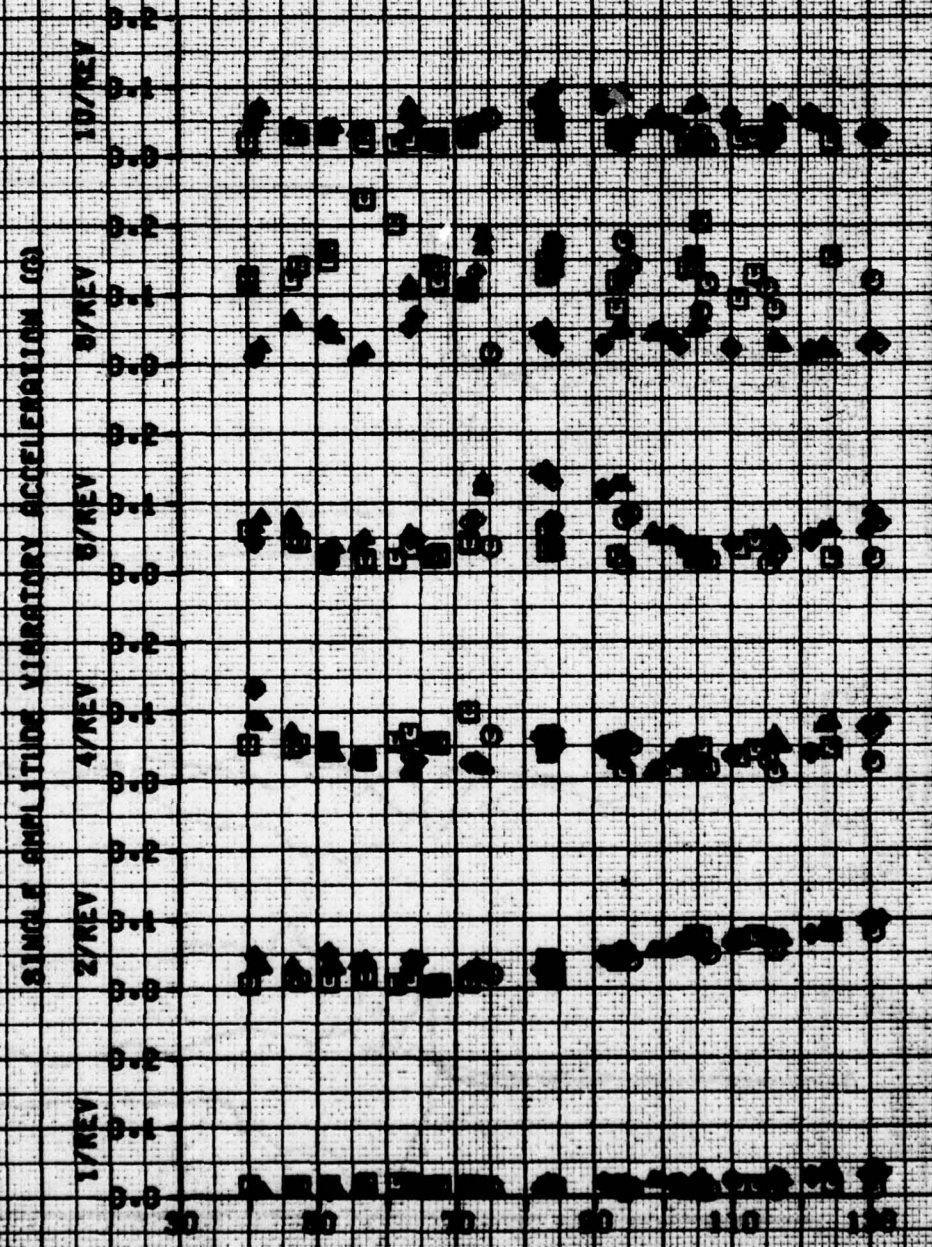


FIGURE 2
 LEVEL PLAIN VIBRATION COMPONENTS
 THE 1/2 IN. DIA. 1000
 POUND WEIGHT

SYM	GROSS WEIGHT LBS	CS LOCATION		DENSITY ALTIMETER LBS	RPM SPEED MIN	C _r K/10 ⁴	CONES	RPM	
		LONG S	LAT BL						
0	8590	95.7(NID)	0.1(RT)	4590	8	375	14.57	5 TOR	8-540
0	8940	96.1(NID)	0.1(RT)	7220	4	375	14.77	5 TOR	8-540
0	8230	98.4(NID)	0.1(RT)	5870	9	375	16.41	5 TOR	8-740
A	8720	95.8(NID)	0.1(RT)	7600	8	375	14.11	5 TOR	8-740



CALIBRATED AMPLITUDE

TABLE 2
LEVEL TEST VIBRATION CHARACTERISTICS
78-10-104-57-78-1980
PREF-LAYAL

SYM	GROSS WEIGHT - LB	CR. LOCATION		DENSITY ALTTITUDE - FT	DAY - °C	WIND SPEED - MPH	C _d X 10 ⁴	CONFIG	RATOR
		LONG FS	LAT BL						
0	8590	95.7(N/D)	0.1(RT)	6580	8	325	48.57	B TON	B-540
1	8940	96.1(N/D)	0.1(RT)	7220	4	325	54.77	B TON	B-540
2	8230	95.4(N/D)	0.1(RT)	5870	9	325	48.41	B TON	K-747
4	8720	95.8(N/D)	0.1(RT)	7680	8	325	54.11	B TON	K-747

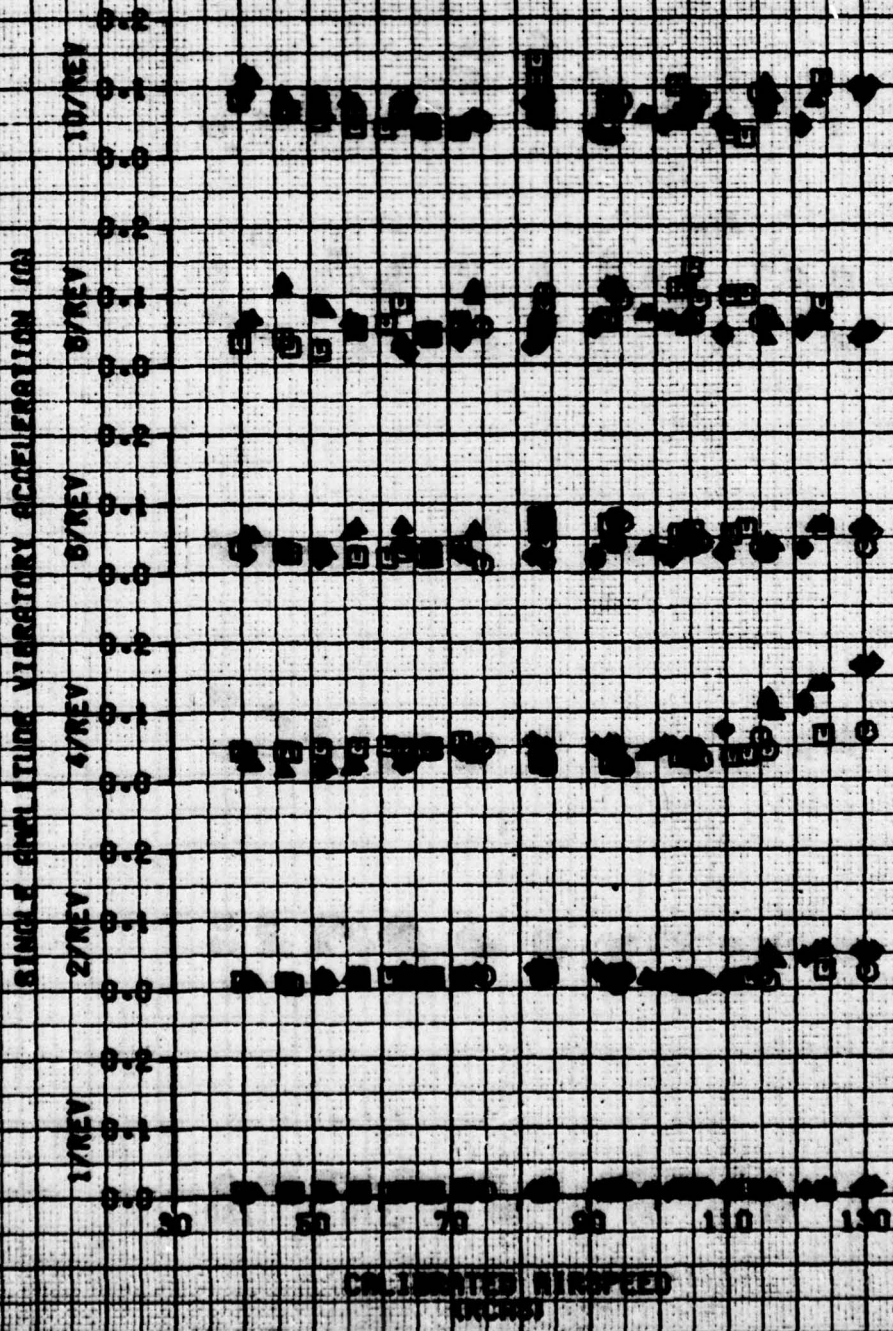


FIGURE 28

LEVEL FLIGHT VIBRATION CHARACTERISTICS
 F-4U USA S/N 70-15936
 PILOT LONGITUDINAL

SYM	GROSS WEIGHT LBS	CS LOCATION		DENSITY ALTITUDE FT	OAT °C	ROTOR SPEED RPM	C _T X 10 ⁴	CONFIG	ROTOR
		LONG FS	LAT BL						
0	8590	95.7(N/D)	0.1(RT)	4590	8	325	48.57	B TON	B-540
0	8940	96.1(N/D)	0.1(RT)	7220	4	325	54.77	B TON	B-540
0	8230	95.4(N/D)	0.1(RT)	5870	9	325	48.41	B TON	K-747
4	8720	95.8(N/D)	0.1(RT)	7880	8	325	54.11	B TON	K-747

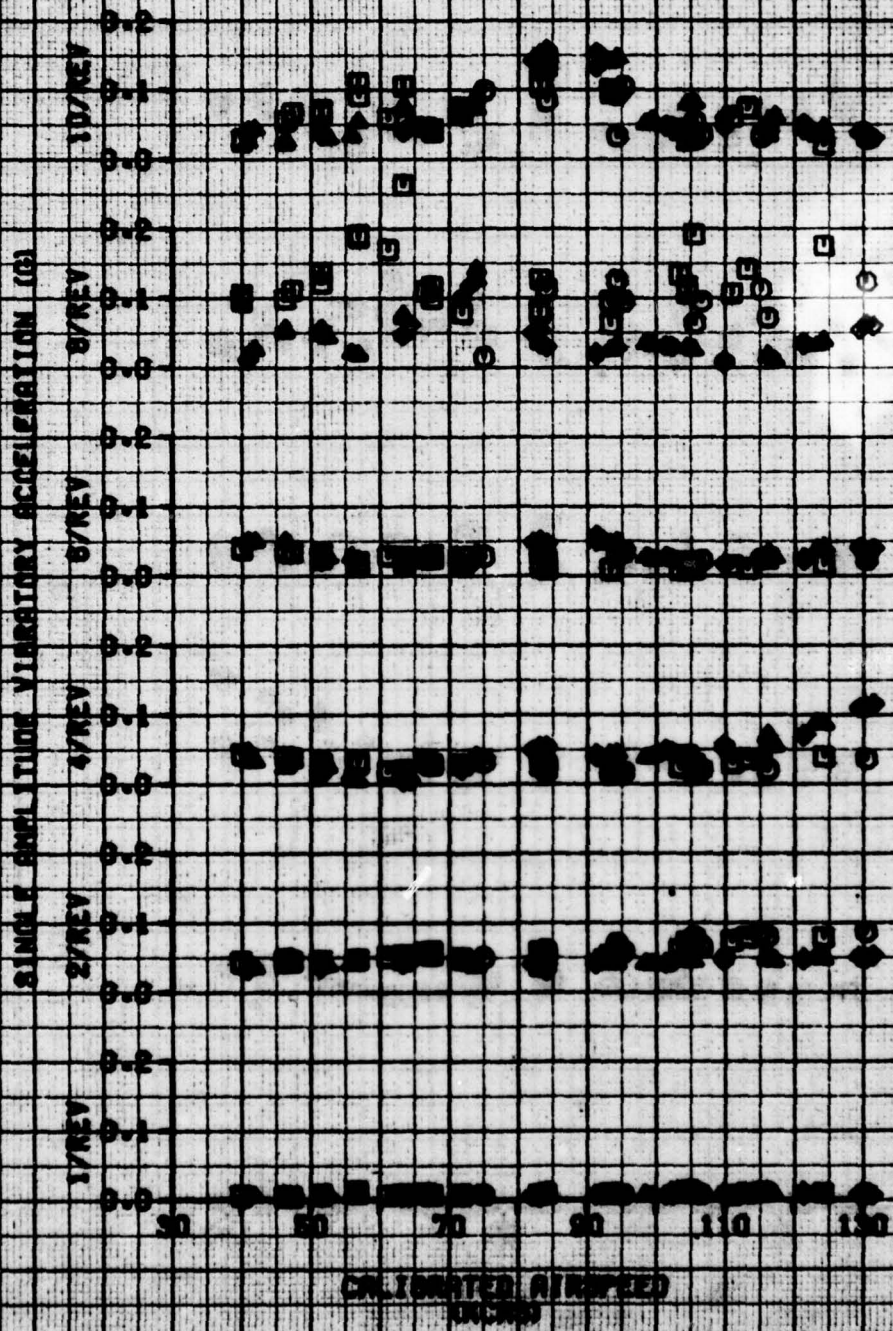


FIGURE 29

LEVEL FLIGHT VIBRATION CHARACTERISTICS
 W-12, USAF S/N 70-1789
 CO-PILOT VERTICAL

SYM	GROSS WEIGHT - LB	CG LOCATION		DENSITY ALTITUDE - FT	QAT - °C	ROTATION SPEED - RPM	C _g X 10 ⁴	CONFIG	NOTES
		LONG - FS	LAT - IN						
0	8590	195.7 (MID)	0.1 (RT)	4590	8	325	48.52	8 70M	B-540
B	8940	196.1 (MID)	0.1 (RT)	7220	4	325	54.77	8 70M	B-540
C	8230	195.4 (MID)	0.1 (RT)	5870	9	325	48.41	8 70M	K-749
A	8720	195.8 (MID)	0.1 (RT)	7660	8	325	54.11	8 70M	K-749

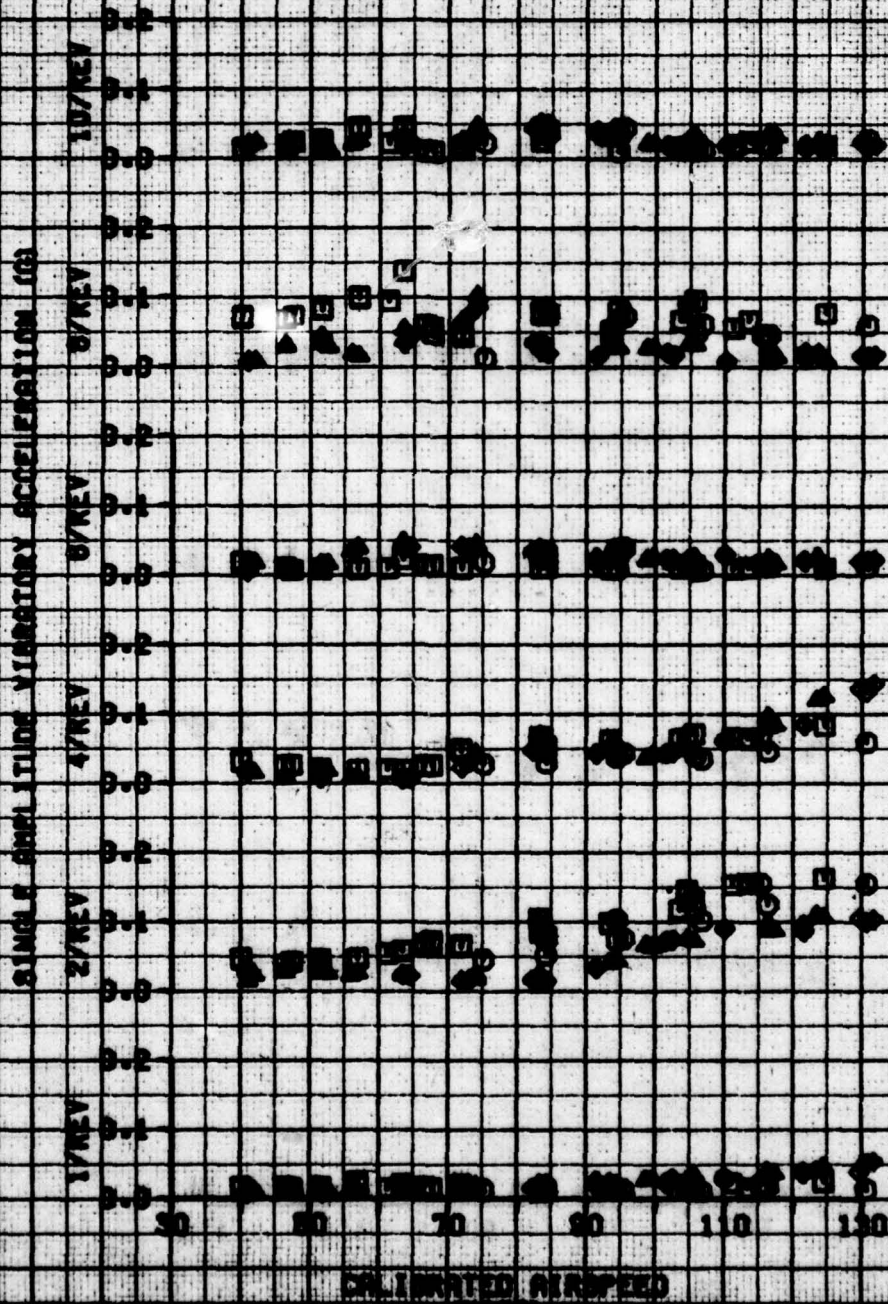


FIGURE 30
 LEVEL FLIGHT VIBRATION CHARACTERISTICS
 YAG-10 USA 57170-15916
 CO-PILOT LATERAL

SYM	GROSS WEIGHT LBS	CG LOCATION LONG ES	LAT BL	WEIGHT ALTIMETER LBS FT	DAT L/C	ROTOR SPEED RPM	G _r X 10 ²	CONFIG	NOTOR
○	8590	195.7 (MED)	0.1 (RT)	4590	8	325	48.57	8 TOV	8-540
□	8940	196.1 (MED)	0.1 (RT)	7220	4	325	54.77	8 TOV	8-540
◇	8230	195.4 (MED)	0.1 (RT)	5870	9	325	48.4	8 TOV	8-747
△	8720	195.8 (MED)	0.1 (RT)	7660	8	325	54.1	8 TOV	8-747

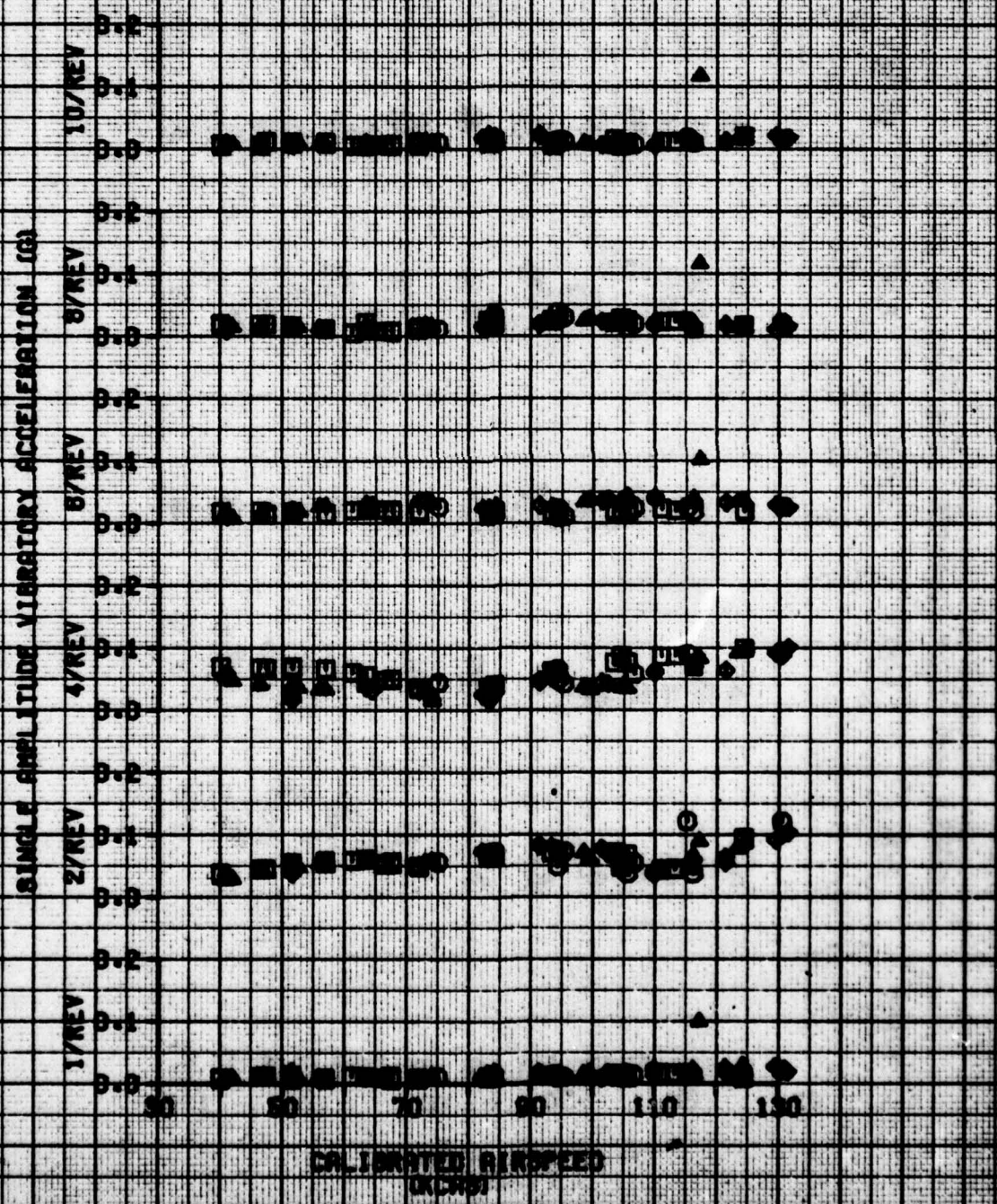
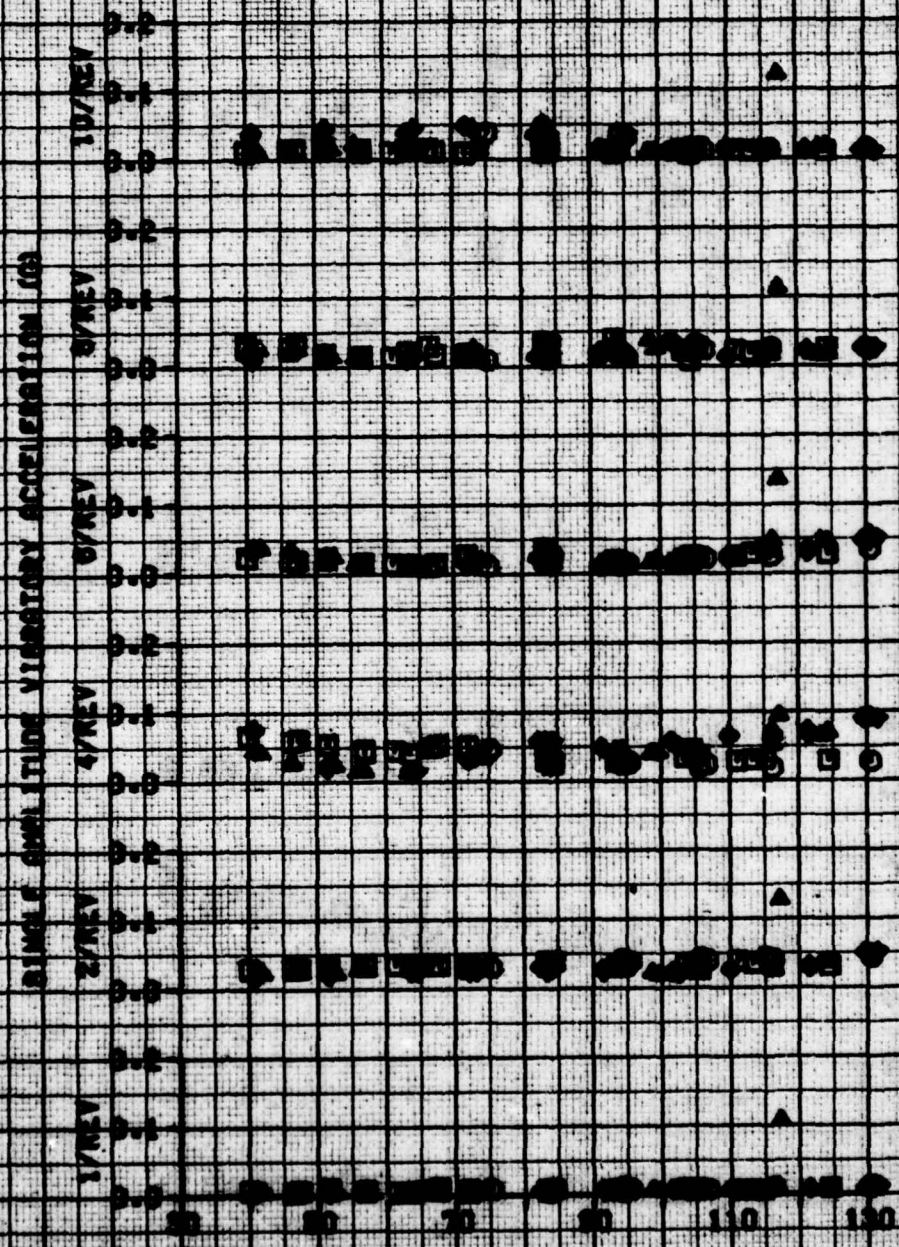


FIGURE 11

HYPERELLIPTIC VIBRATION CHARACTERISTICS
 PART I: 1957-1960
 CO-71107 (CONTINUED)

SYM	GROSS WEIGHT LBS	CR. LOCATION		DENSITY ALTITUDE FT	QAT °	ROTOR SPEED RPM	C _r K/100	CONFIG	ROTOR
		LONG °S	LAT °N						
0	8590	195.7 (MID)	0.1 (RT)	4190	8	325	48.57	8 TOM	B-540
0	8940	196.1 (MID)	0.1 (RT)	7220	4	325	54.77	8 TOM	B-540
0	8230	195.4 (MID)	0.1 (RT)	5870	9	325	48.41	8 TOM	K-747
2	8720	195.8 (MID)	0.1 (RT)	7660	8	325	54.11	8 TOM	K-747



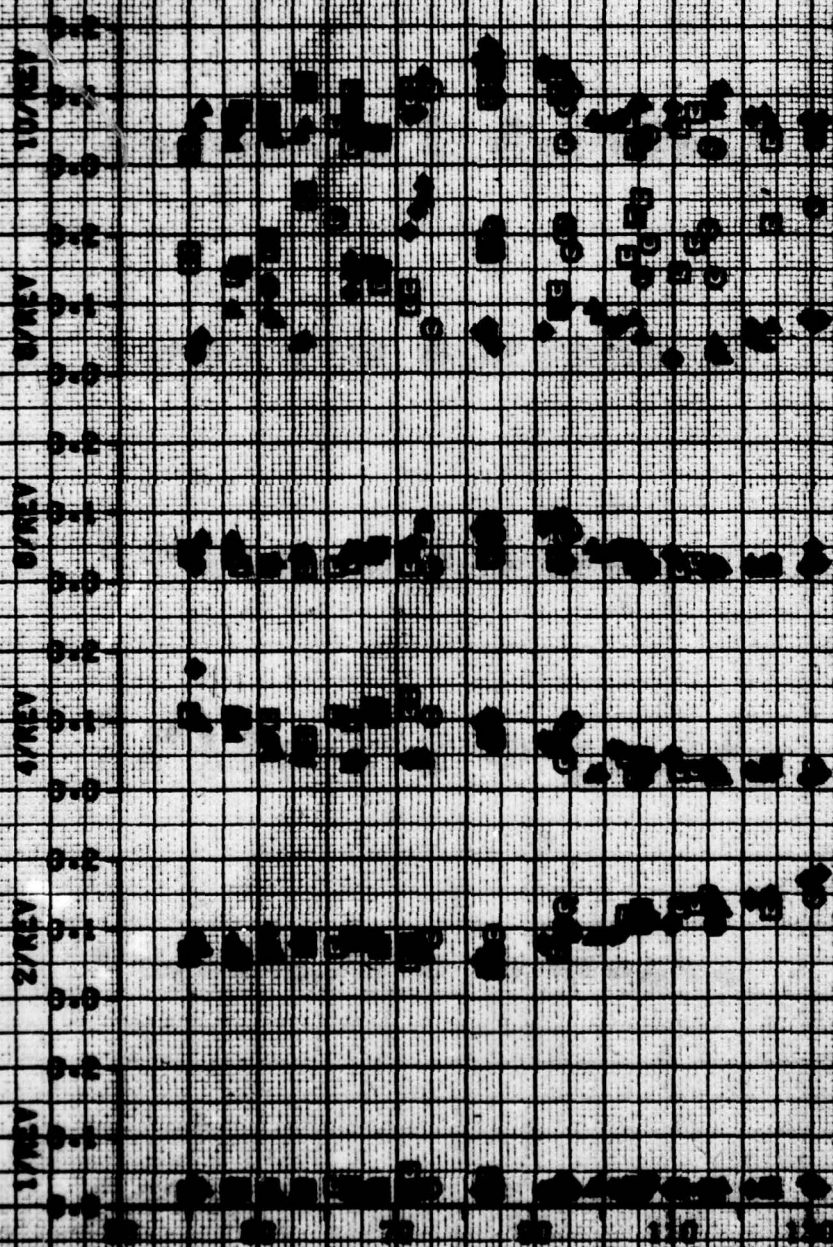
CALIBRATED AIRSPEED
 KNOTS

FIGURE 32

ENVIRONMENTAL DATA ON VIBROSTATISTICS
 20-19 20-19 20-19
 20-19 20-19 20-19

SYM	GROSS WEIGHT LBS	OR LOCATION		DENSITY ALTIMETER FT	OAT SEC	MOTOR SPEED RPM	C %	CORRECTION	NOTES
		LONG FS	LAT DL						
0	8500	96.7 (ND)	0.1 (RT)	4500	8	325	48.57	3 TON	10-20
0	8500	96.1 (ND)	0.1 (RT)	7220	4	325	54.77	3 TON	10-20
0	8200	96.4 (ND)	0.1 (RT)	5870	9	325	48.41	3 TON	10-20
0	8700	96.8 (ND)	0.1 (RT)	7000	8	325	54.11	3 TON	10-20

SINGLE AMPLITUDE VIBROSTATISTICS



CALCULATED FREQUENCY

FIGURE B3
LEVEL FLIGHT VIBRATION CHARACTERISTICS
 FM-1A (MAY 78-15938)
 2- LATERAL

SYM	GROSS WEIGHT - LB	CG LOCATION		DENSITY ALTITUDE - FT	DAY	SPEED - RPM	C _f - 10 ⁴	CONFIG	ROTOR
		LONG - FS	LAT - IN						
○	8590	195.7 (MID)	0.1 (RT)	4590	8	325	18.57	8 TOM	B-54D
□	8940	196.1 (MID)	0.1 (RT)	7220	4	325	54.77	8 TOM	B-54D
○	8230	195.4 (MID)	0.1 (RT)	5870	9	325	18.41	8 TOM	K-74D
△	8720	195.8 (MID)	0.1 (RT)	7660	8	325	54.11	8 TOM	K-74D

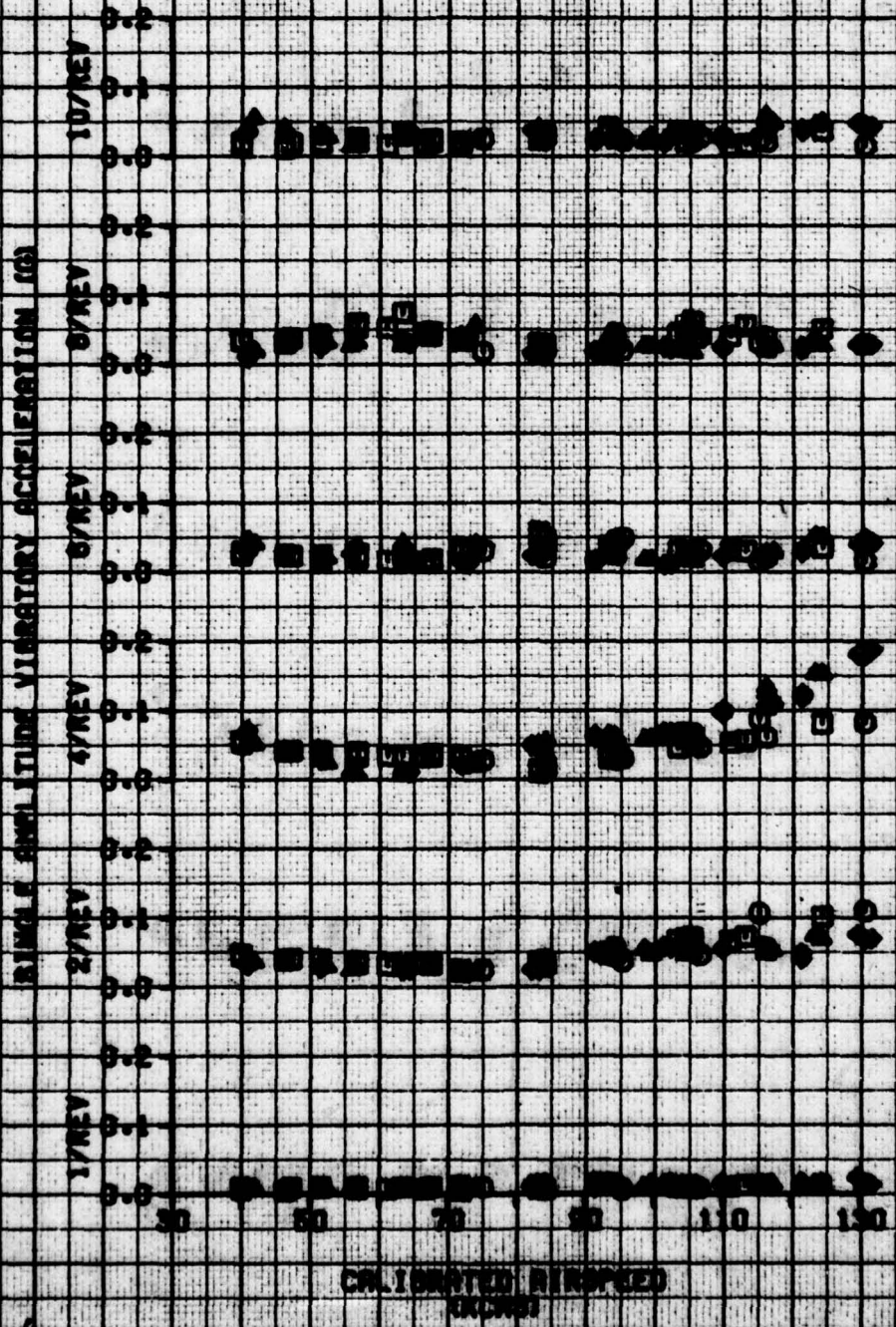


FIGURE 34
 LEVEL FLIGHT VIBRATION CHARACTERISTICS
 TAP-TR 100-214 70-12500
 CG LONGITUDINAL

SYM	GROSS WEIGHT LB	CG LOCATION		DENSITY ALTITUDE FT	OAT °C	ROTOR SPEED RPM	C _T 10 ⁴	CONFIG	ROTOR
		LONG FS	LAT BL						
O	8580	95.7 (MID)	0.1 (RT)	4590	8	325	18.57	8 TOR	8-540
□	8940	96.1 (MID)	0.1 (RT)	7220	4	325	54.77	8 TOR	8-540
○	8230	95.4 (MID)	0.1 (RT)	5870	9	325	18.41	8 TOR	K-747
△	8720	95.8 (MID)	0.1 (RT)	7660	8	325	54.11	8 TOR	K-747

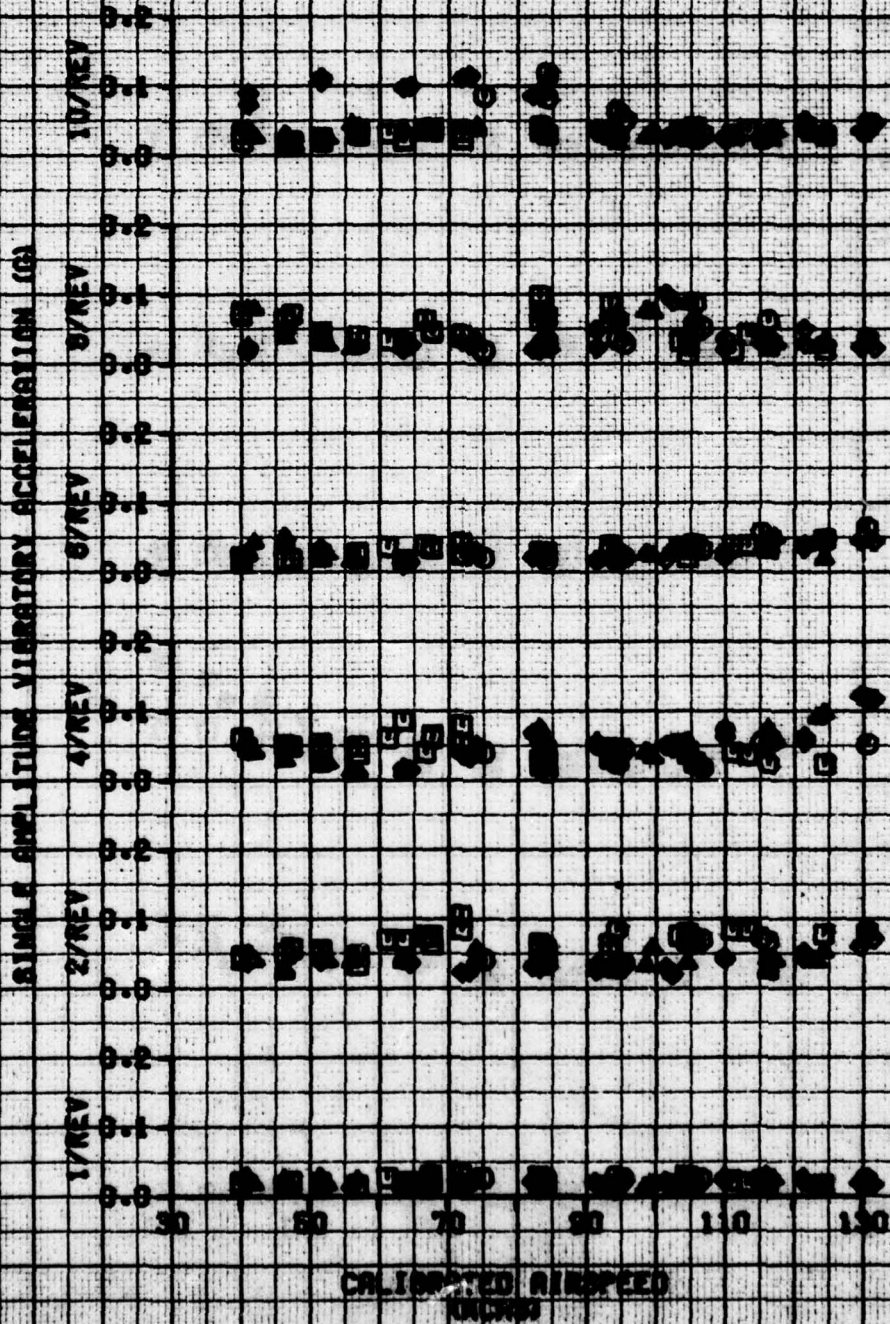


FIGURE 35
 HOVER VIBRATION CHARACTERISTICS
 PART I USA 50170-11930
 PART VERSION

GE LOCATION		DENSITY	GAT	MAX WINDS	SKID HEIGHT	ROTOR
LONG	LAT	ALTITUDE				
°S	°N	FT	°C	KTAS	FT	
196 51M.D	0 (RT)	3040	8	2	100	1-217

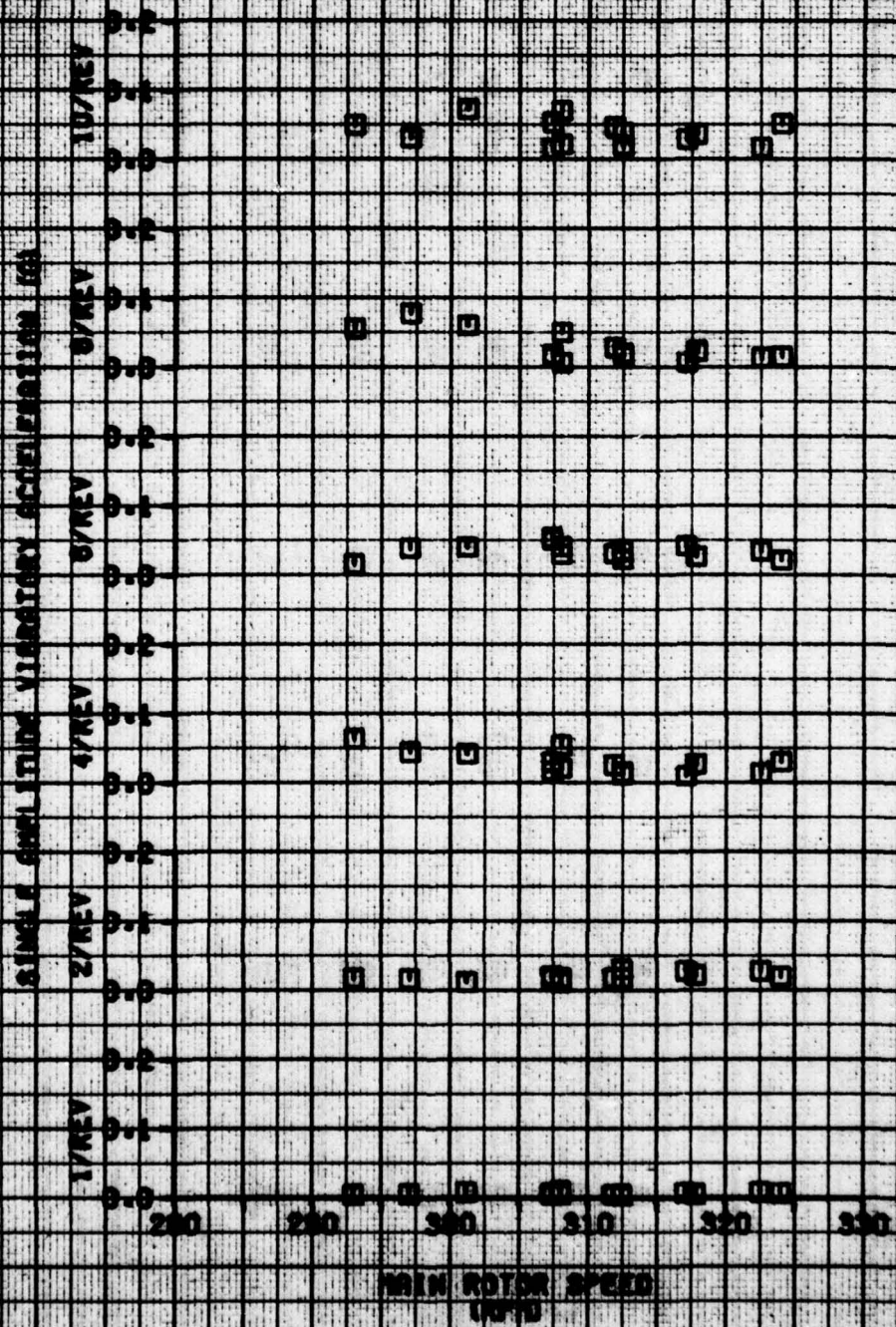


FIGURE 36
 HOVER VIBRATION CHARACTERISTICS
 FM-1A USA SYN 70-15936
 PLOT LATERAL

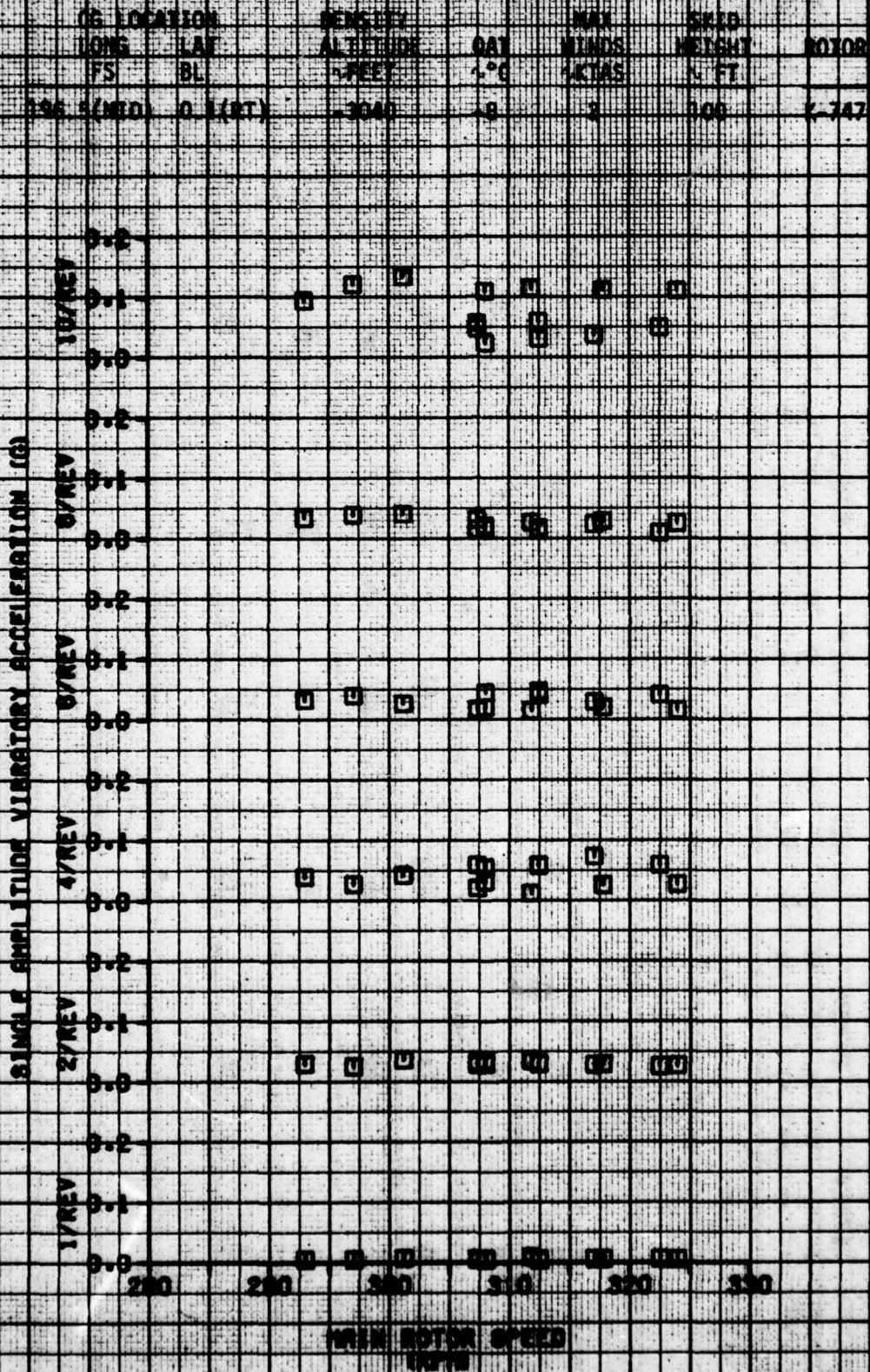


FIGURE 37
 HOVER VIBRATION CHARACTERISTICS
 YAW-TR. USAF 57N 70-14936
 PILOT LONGITUDINAL

CG LOCATION		DENSITY		MAX WINDS (KIAS)	SKID HEIGHT (FT)	ROTOR
LONG FS	LAT BL	ALTITUDE % FEET	GAY °C			
196.5 (MID)	0.1 (RT)	-3040	+8	2	100	K-747

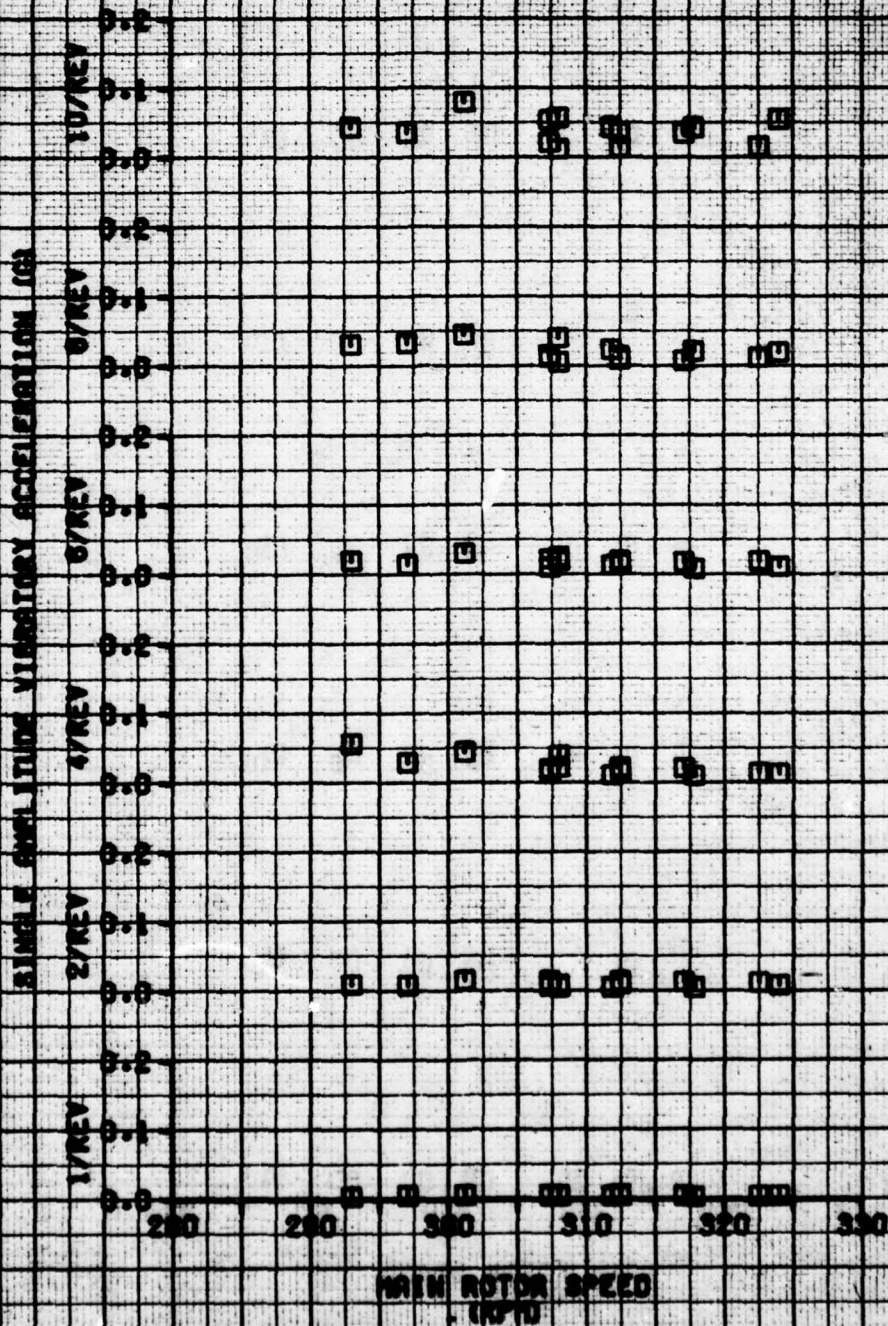


FIGURE 30
HOVER VIBRATION CHARACTERISTICS
YAN-11R USA S/N 70-15936
CO-PILOT VERTICAL

OG. LOCATION		DENSITY	OAT	MAX	SKID	ROTOR
LONG	LAT	ALTITUDE		WINDS	HEIGHT	
FS	BL	~ FEET	°C	KTAS	~ FT	
196.5 (MID)	0.1 (RT)	-3040	-8	2	100	K-747

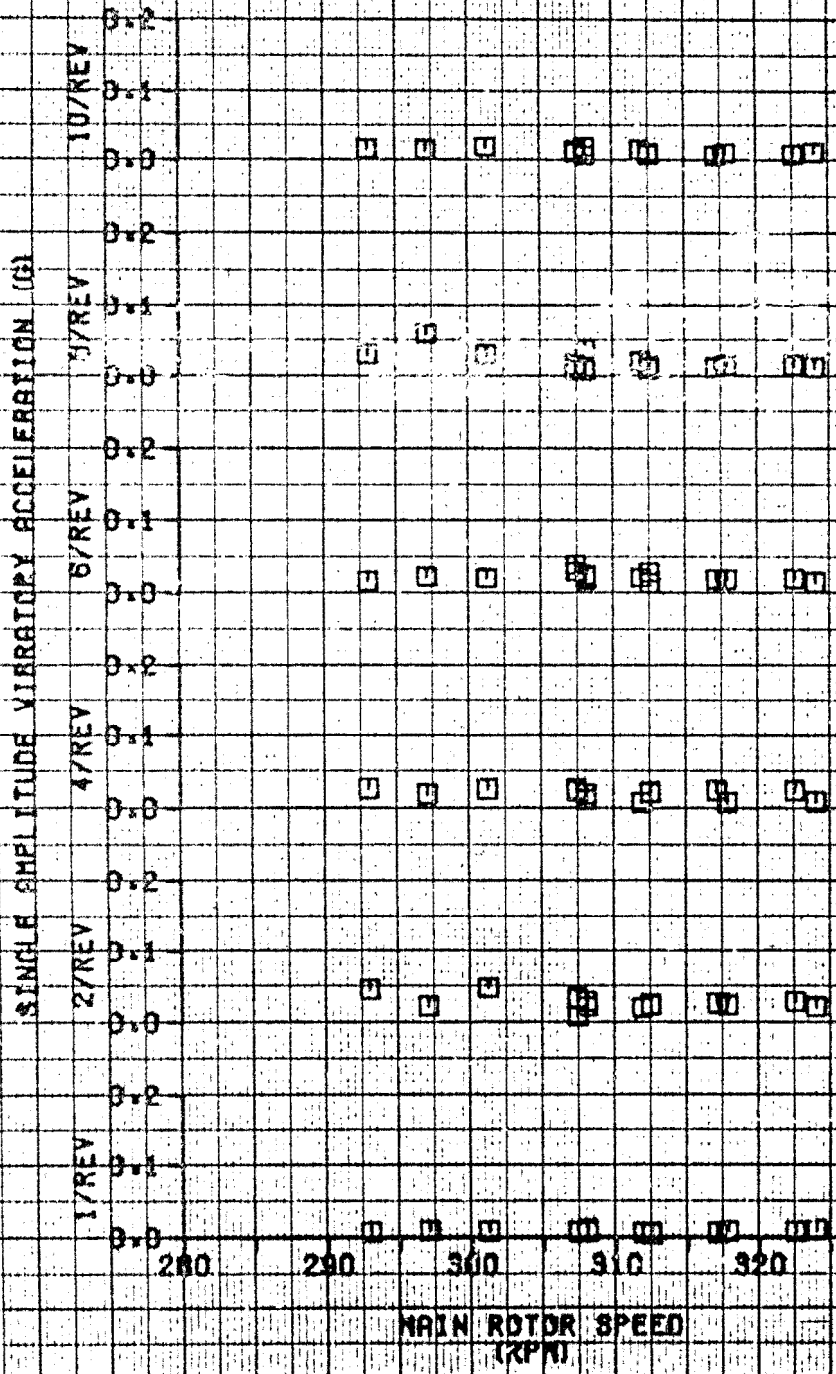


FIGURE 39
HOVER VIBRATION CHARACTERISTICS
 YAH-TK USA S/N 70-15936
 CO-PILOT LATERAL

CG LOCATION	DENSITY	MAX	SKED
LONG	ALTITUDE	WINDS	HEIGHT
FS	~ FEET	KTAS	FT
196 5 (MID)	3040	2	100
0 1 (RT)			
			6-347

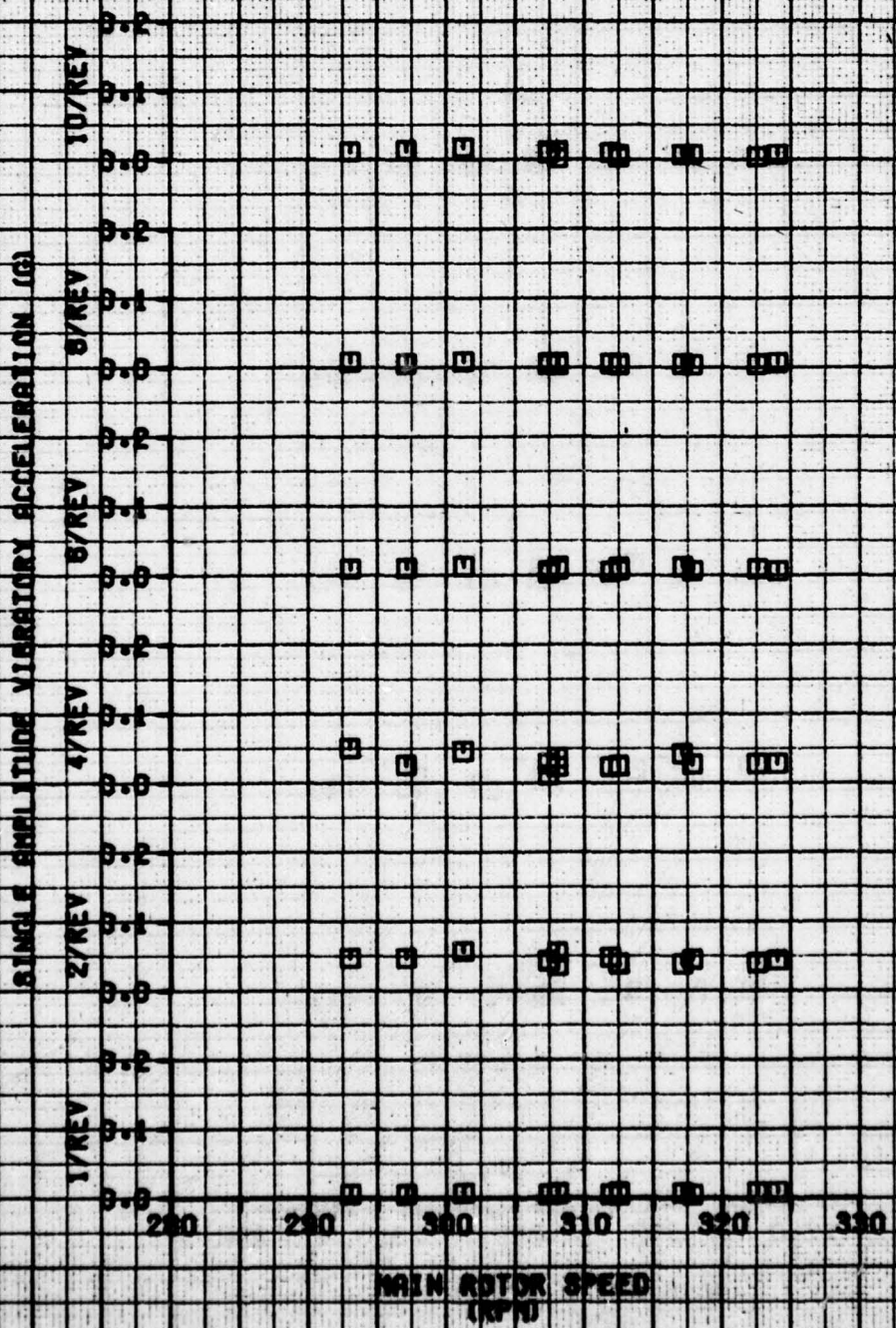


FIGURE 40
ROTOR VIBRATION CHARACTERISTICS
 196-1X 054-57X 70-1390G
 60-PILOT LONGITUDINAL

CG LOCATION		DENSITY		MAX WINDS KTS	SIBB HEIGHT FT	ROTOR
LONG FS	LAT BL	ALTITUDE FEET	DAT °C			
196.5 (MID)	0.1 (RT)	-3040	-8	2	100	1-7A7

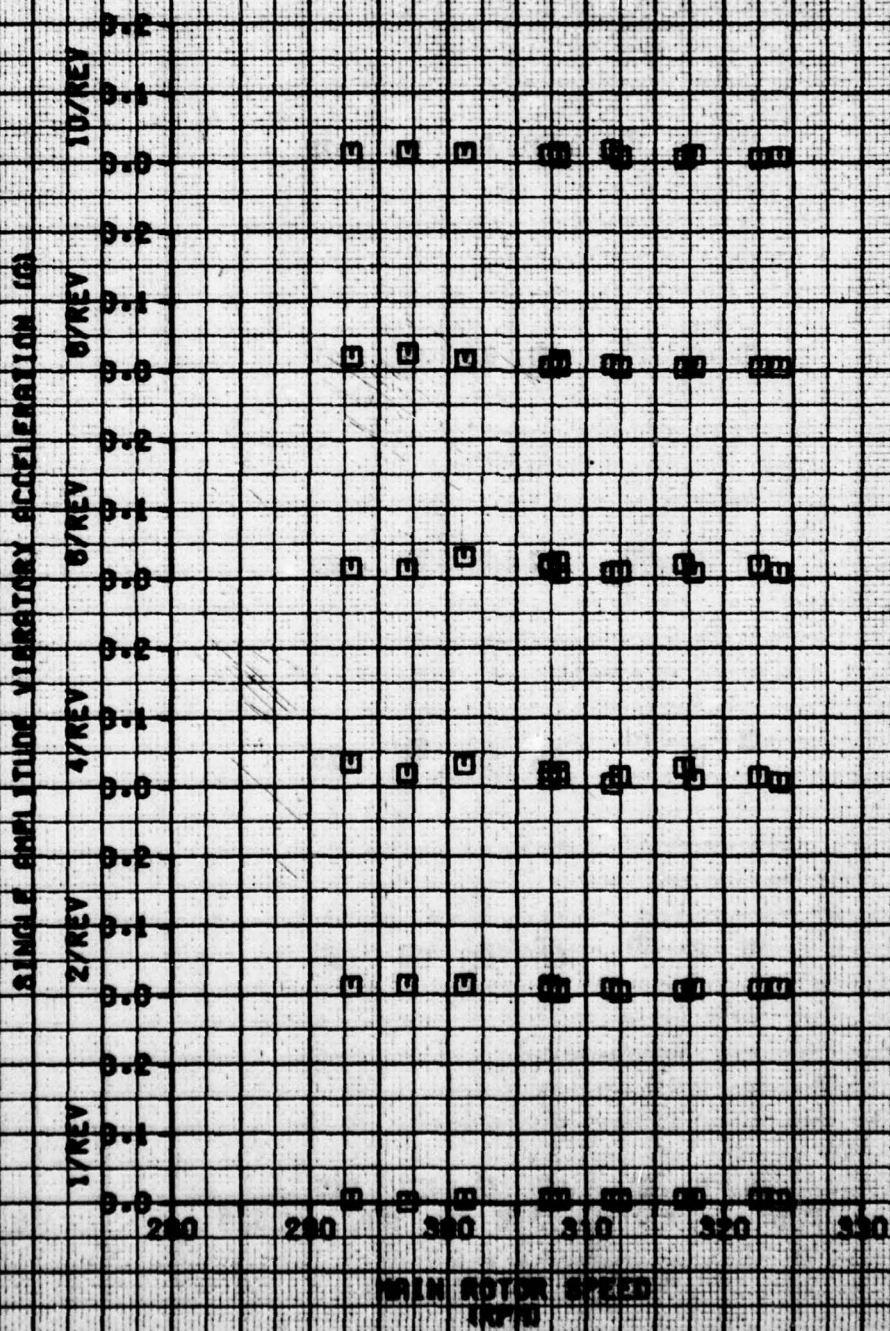


FIGURE 41
HOVER VIBRATION CHARACTERISTICS
78-18 USA 5710-1536
60 VERTICAL

ORIGIN LOCATION		DENSITY	WINDS	SKID	ROTOR
LONG	LAT	ALTITUDE	QAT	HEIGHT	
FS	BL	FEET	°C	FT	
196.5 (NHD)	0.1 (RT)	3000	8	2	1-747

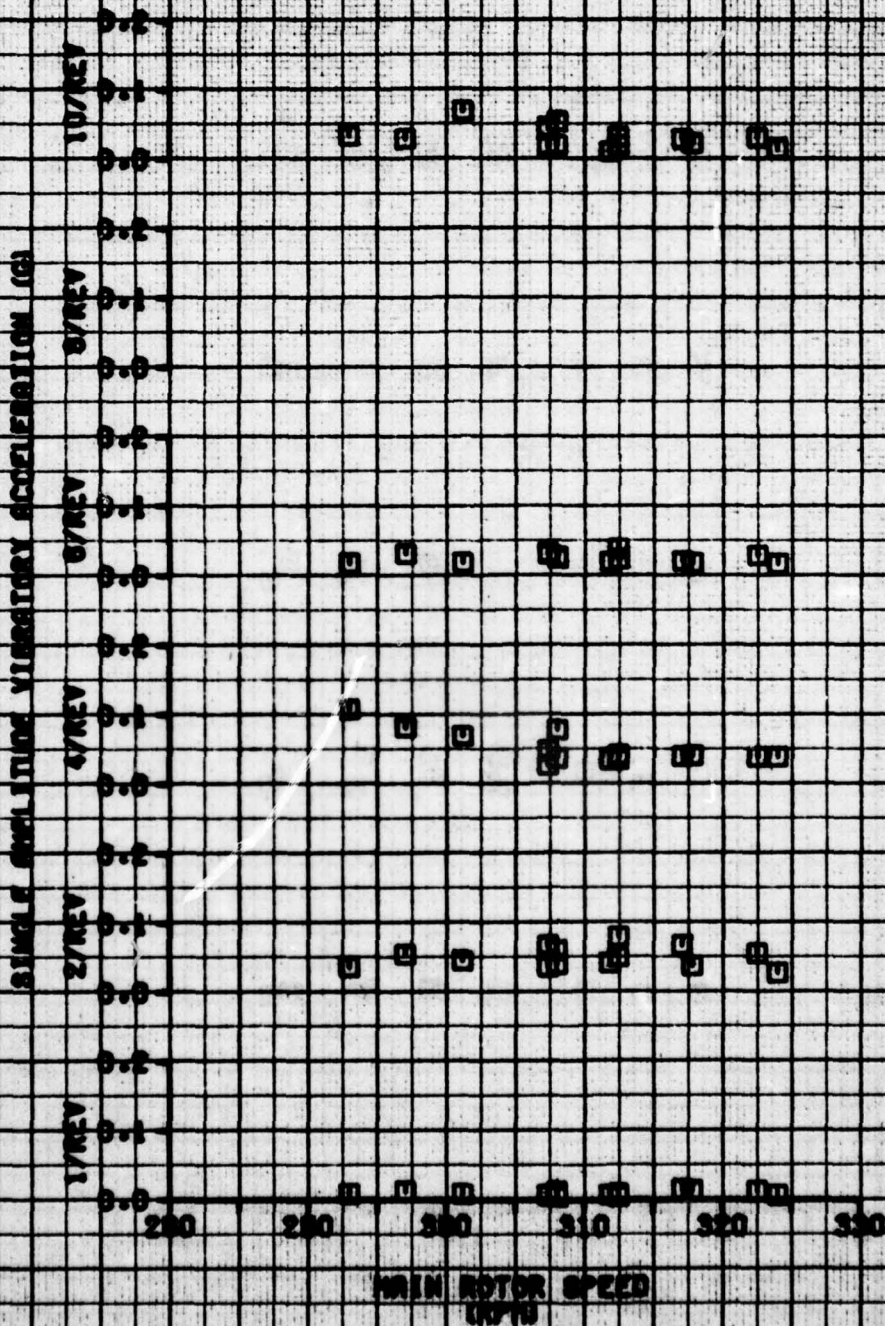


FIGURE 42
 POWER VIBRATION CHARACTERISTICS
 YAN-1A USA S/N 70-11936
 CG LATERAL

CG LOCATION		DENSITY	ALTITUDE	QAT	MAX	SKID	MOTOR
LONG	LAT		~ FEET	°C	KINDS	HEIGHT	
FS	BL				KTAS	~ FT	
196.5 (MLD)	0.1 (RT)		-3040	-8	2	100	6-247

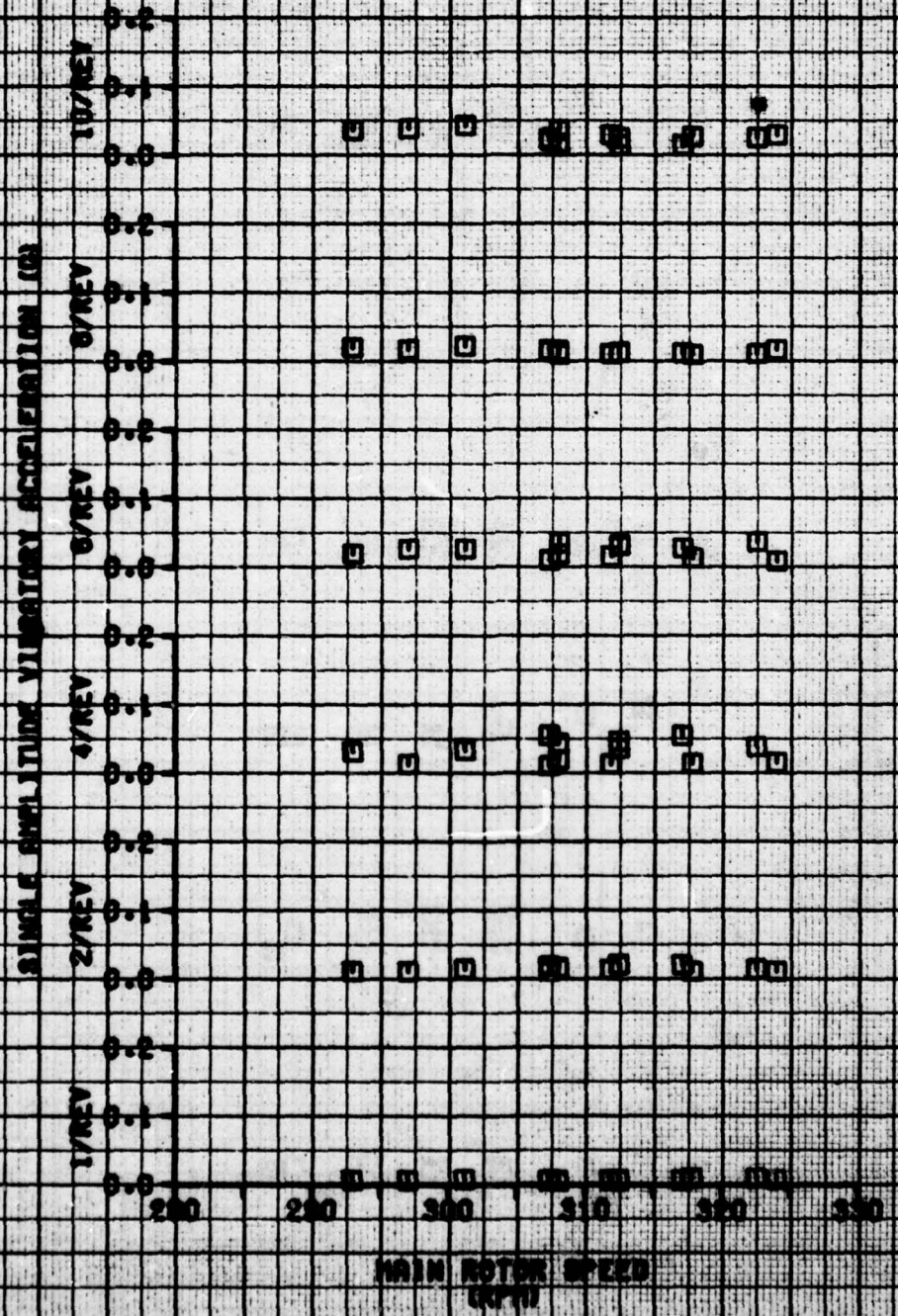


FIGURE 43
 HOVER VIBRATION CHARACTERISTICS
 196-10 USA S/N 701246
 CG LONGITUDINAL

CG LOCATION		DENSITY	MASS	SCALE	MOTOR
LONG	LAT	ALTITUDE	BAI	UNDS	
FS	BL	FEET	%	KIAS	
156.5	0.1	-3040	-8	2	1-747

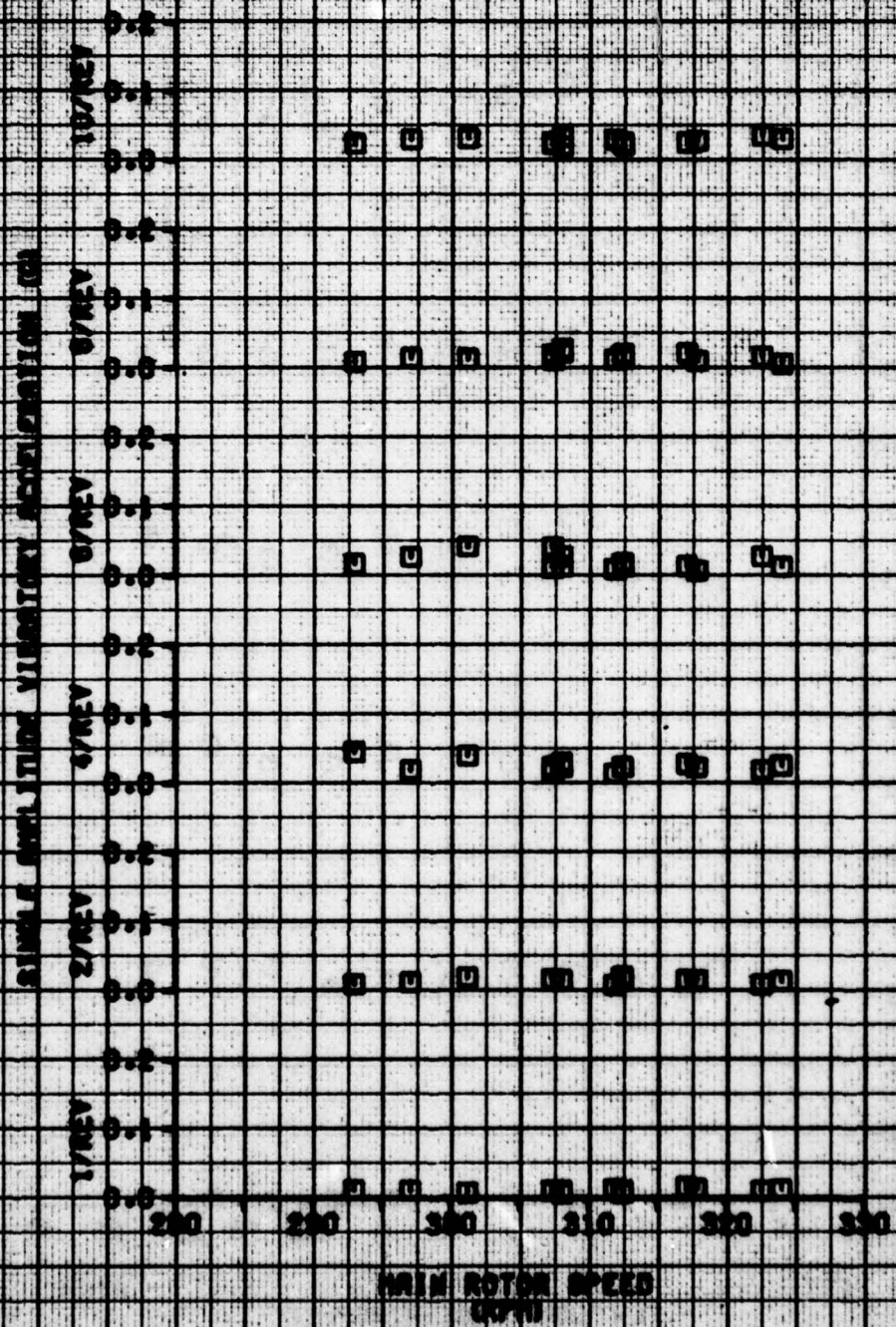


FIGURE 45

SIDEWARD FLIGHT VIBRATION CHARACTERISTICS

TIME PERIOD: 12/78-1990

PILOT: LONGTENNAL

AVG GROSS WEIGHT 3LB	AVG CG LOCATION		AVG DENSITY ALTITUDE FT	AVG ROTOR RPM	AVG Rotor CF X 10 ³	CONFIG	ROTOR
	LONG PS	LAT BL					
9540	195.2 (MID)	0.1 (RT)	-8320	-	325	8 TOW	X-747

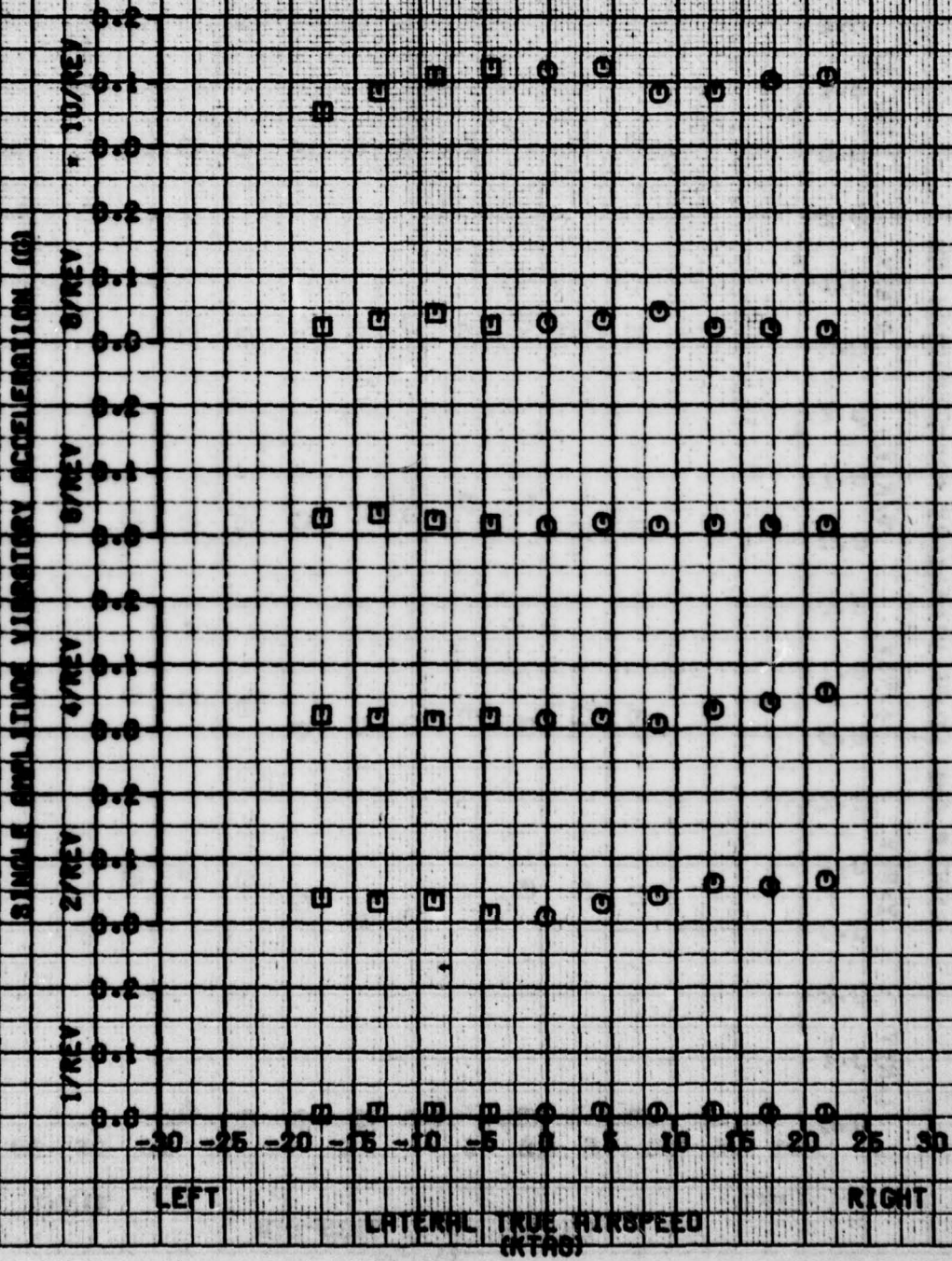


FIGURE 45
SIDEWIND FLIGHT VIBRATION CHARACTERISTICS
 YAN-17, USA, S/N 70-1597A
 30-PILOT VERTICAL

Avg GROSS WEIGHT (LB)	Avg CG LOCATION		Avg DENSITY ALTITUDE (FT)	Avg ROTOR SPEED (RPM)	Avg CONEYG (X 10 ³)	Avg ROTOR X-747
	LONG (FS)	LAT (IN)				
9540	195.2 (MED)	0.1 (RT)	-3320	525	42.77	3.70M

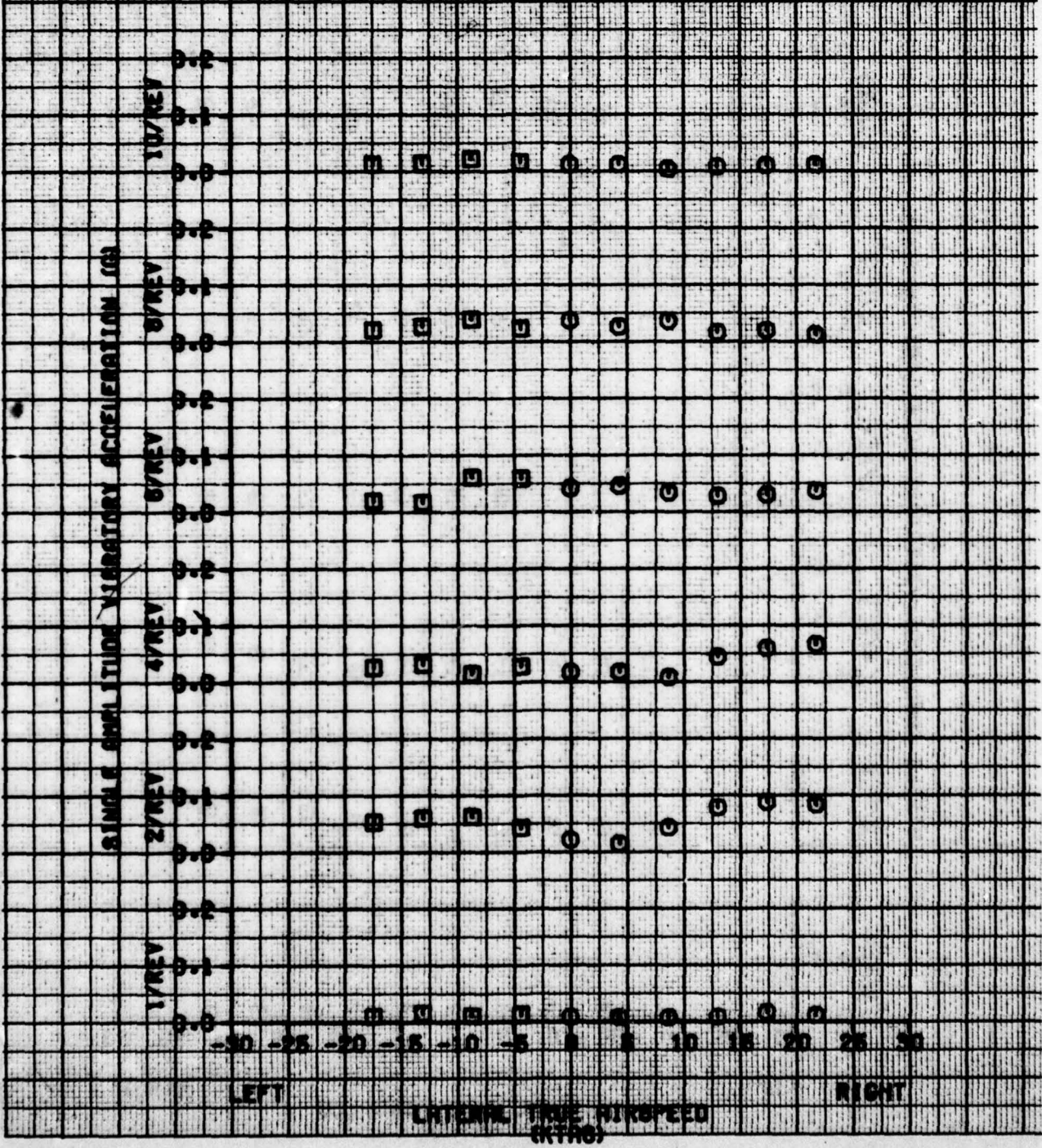


FIGURE 10
 HORIZONTAL VIBRATION CHARACTERISTICS
 30-FOOT INTERNAL

AVG GROSS WEIGHT LBS	CG LONG IS	AVG LOCATION LAY BL	AVG DENSITY ALTITUDE MFT	AVG DUT %C	AVG RATED SPEED RPM	AVG C X 10 ³	CONFIC	ROTOR
3540	195.20(MD)	0.18RT	-3320	-7	325	42.77	B 10A	K-747

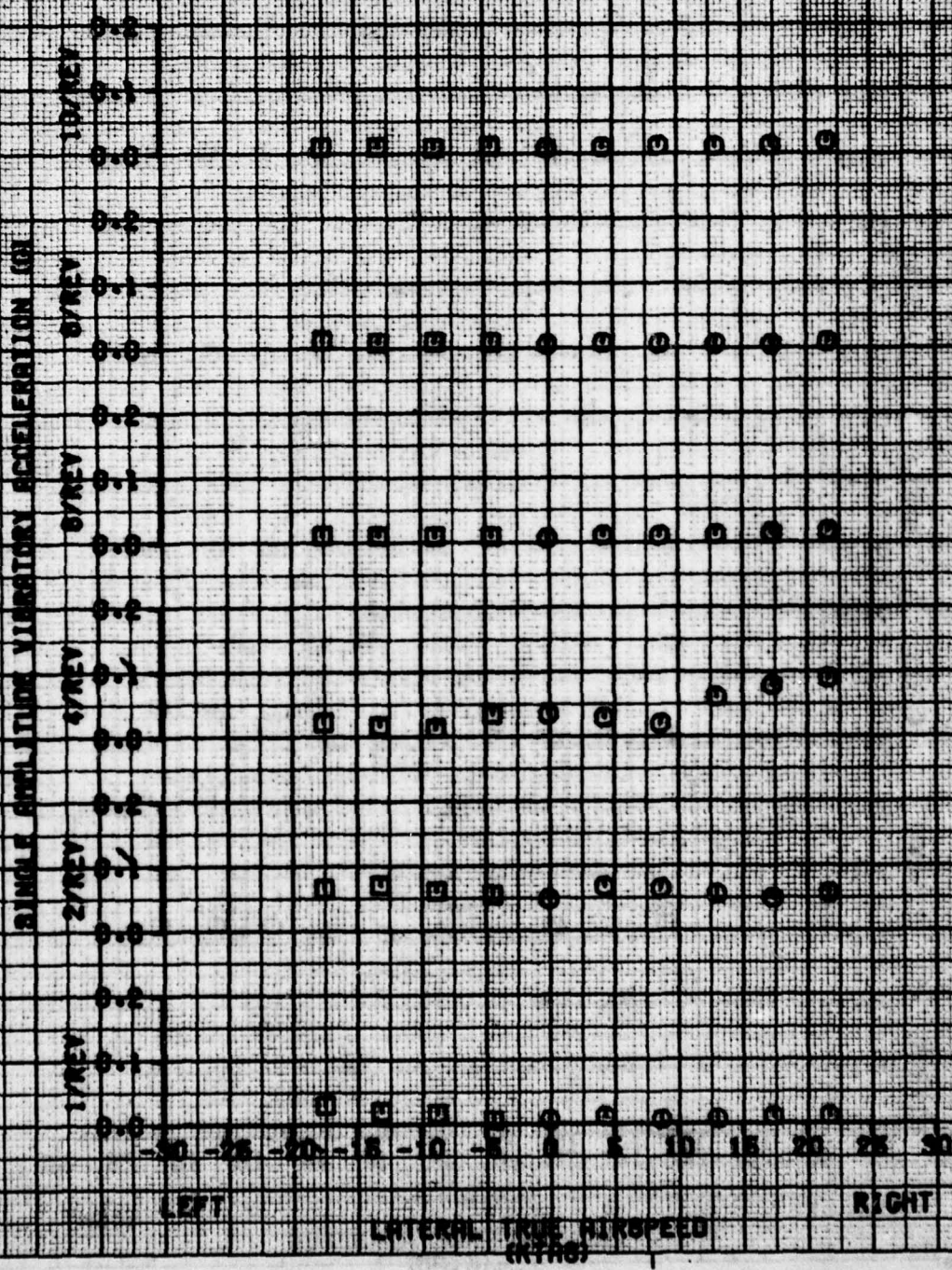


FIGURE 4B

SIDELAND FLIGHT VIBRATION CHARACTERISTICS

YAN-12 USA SYN 70-10936

CO-PILOT SEAT-ORIGINAL

AVG GROSS WEIGHT ~LB	AVG CG LOCATION		AVG DENSITY ALTITUDE ~FT	AVG OAT ~°C	AVG ROTOR SPEED ~RPM	AVG C _T X 10 ⁷	CONFIG	ROTOR
	LONG FS	LAT BL						
9540	195.2 (MID)	0.1 (RT)	-3320	-7	325	42.77	B TOM	K-747

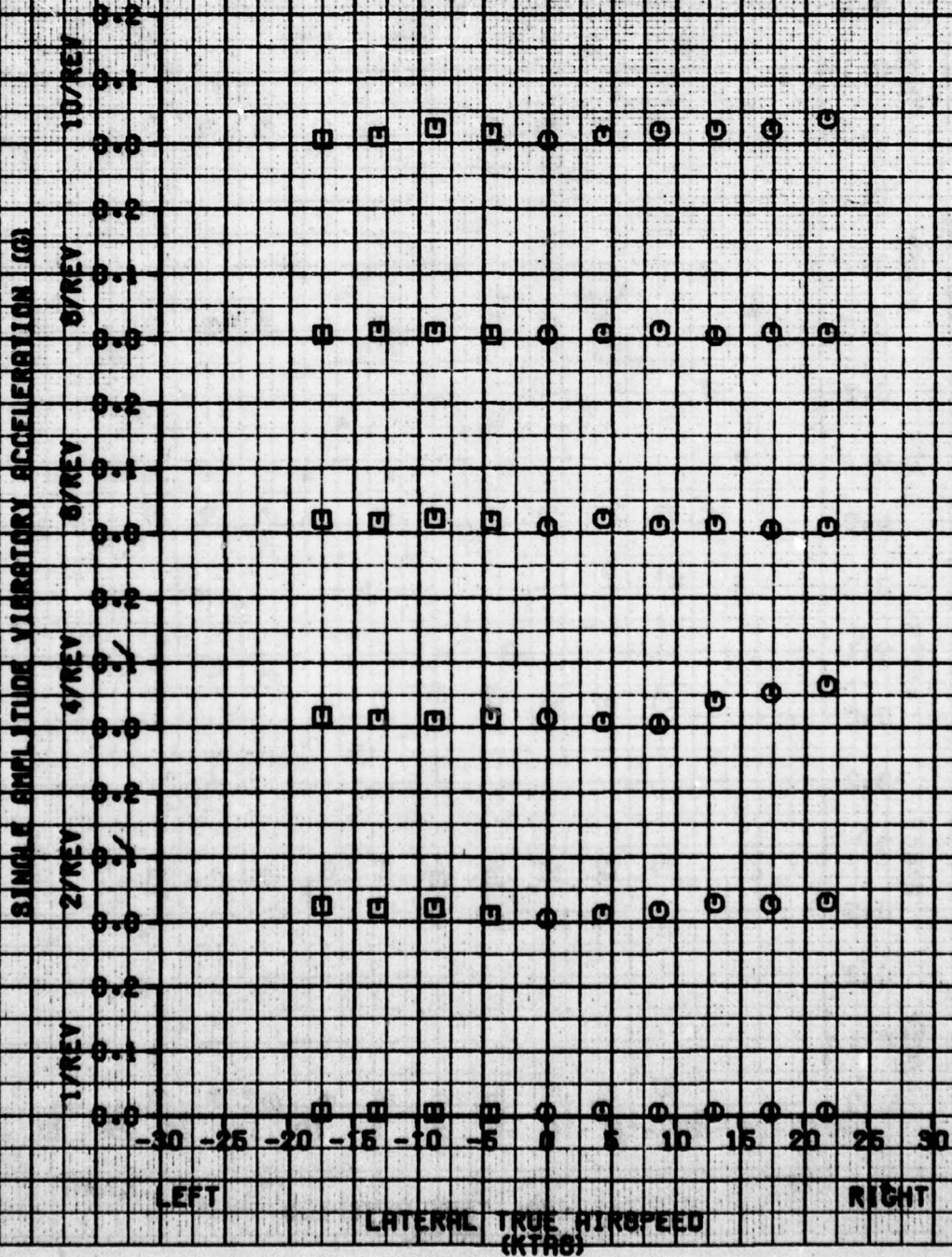


FIGURE 4
 SERVICE FLIGHT VIBRATION CHARACTERISTICS
 TYPE 1000-100-100000
 1000000

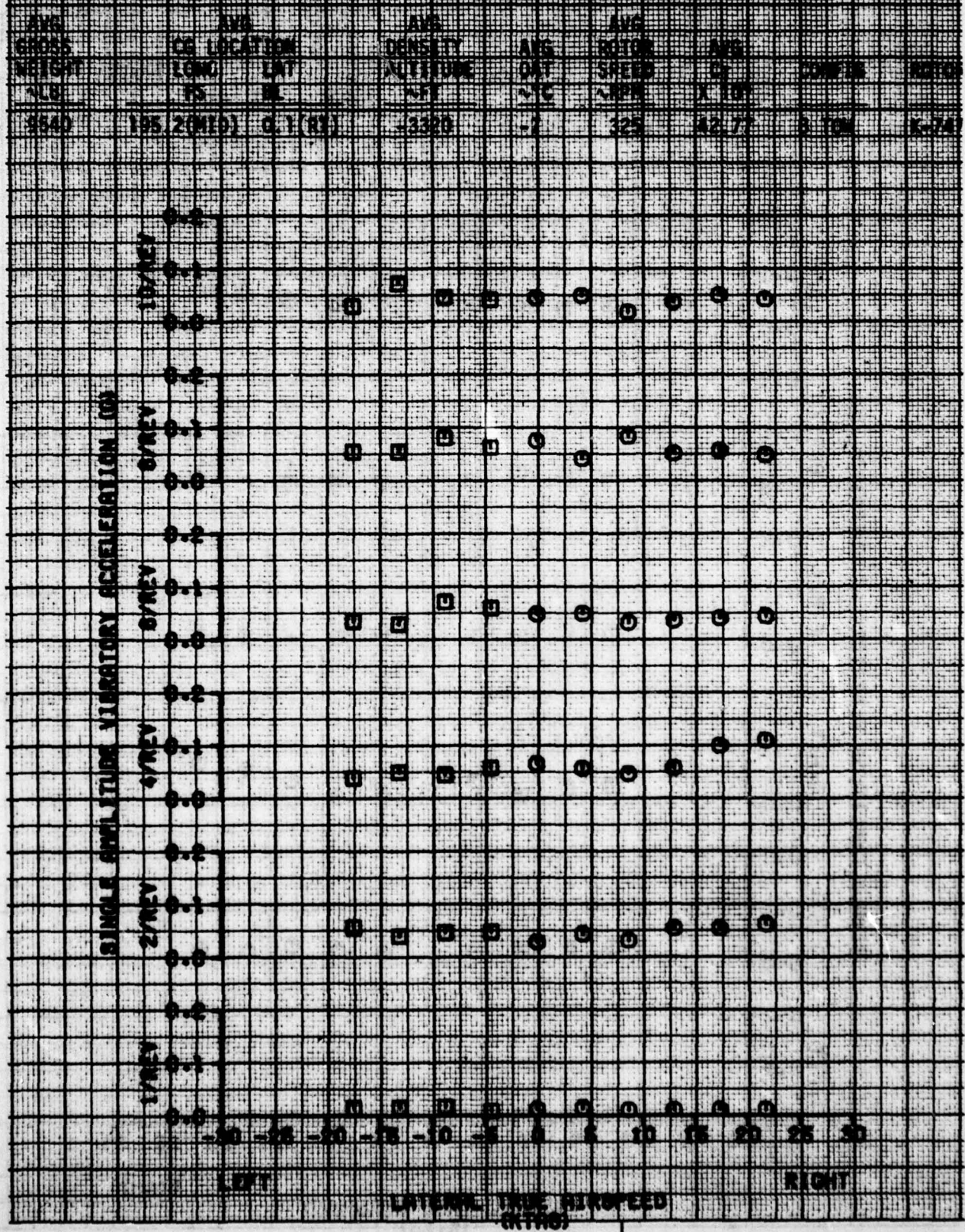


FIGURE 50
SIDEWARD FLIGHT VIBRATION CHARACTERISTICS
 YAG-18 (SR) S/N 70-15930
 100 LATERAL

AVG GROSS WEIGHT -LB	AVG LOCATION		AVG DENSITY ALTITUDE -FT	AVG OAT -C	AVG ROTOR SPEED -RPM	AVG C _f X 10 ³	CONFIG	ROTOR	
	LONG -FS	LAT -DEG							
9540	195	2(MID)	0.1(R)	-3320	-2	329	42.77	B TOL	K-747

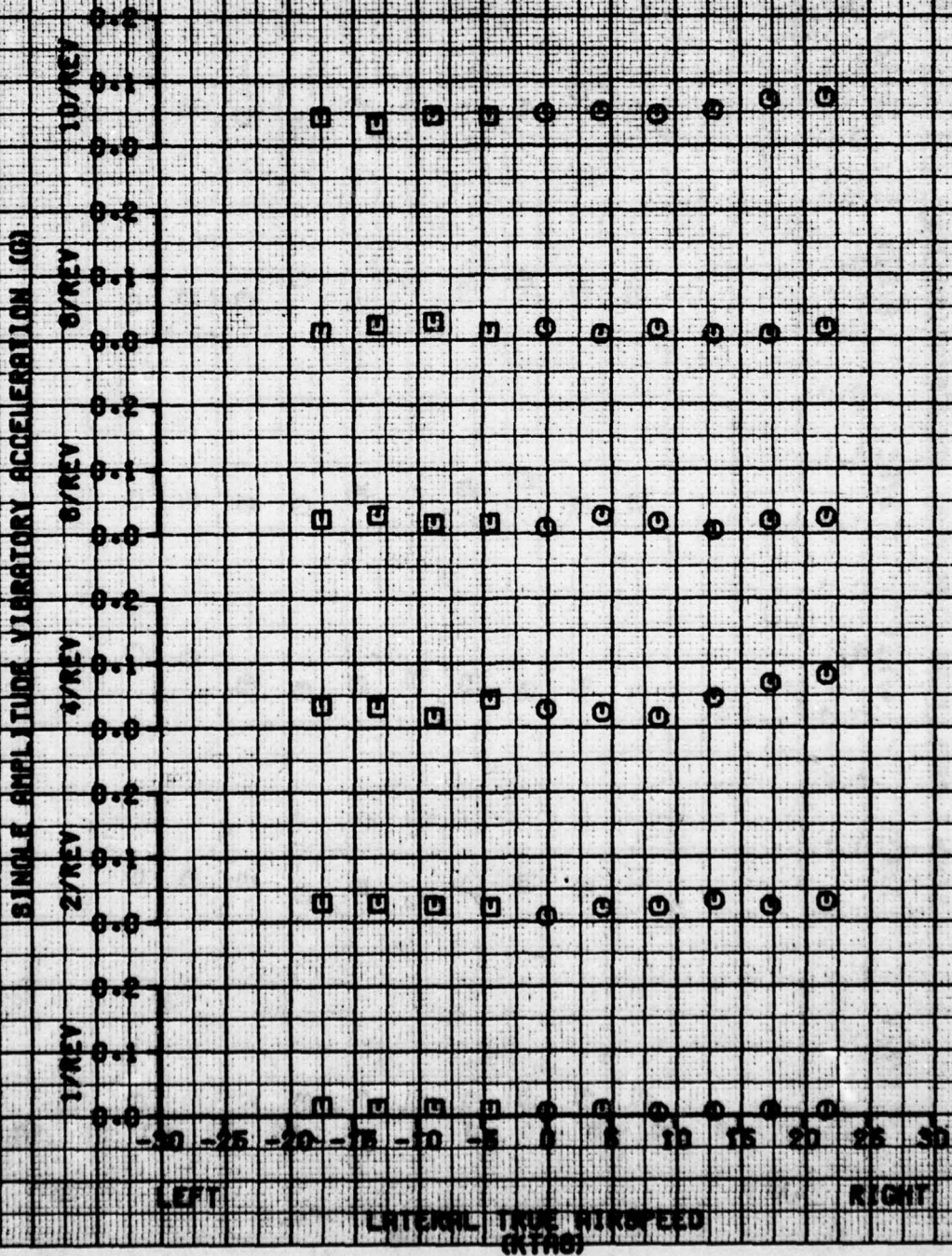


FIGURE 5
 CLIMB PROFILE CHARACTERISTICS
 TABLE 100, S/N 70-1596
 P250 VERTICAL

GROSS WEIGHT X LB	CG LOCATION		DENSITY ALTITUDE X FEET	MOTOR OAT TEMP °C	MOTOR SPEED X RPM	C _L X 10 ⁴	AIRSPEED X KCAS	CONFIG	MOTOR
	LONG IN	LAT IN							
9380	195.1 (MID)	0.1 (RT)	4780	4	325	53.36	57	B. 10V	K-747

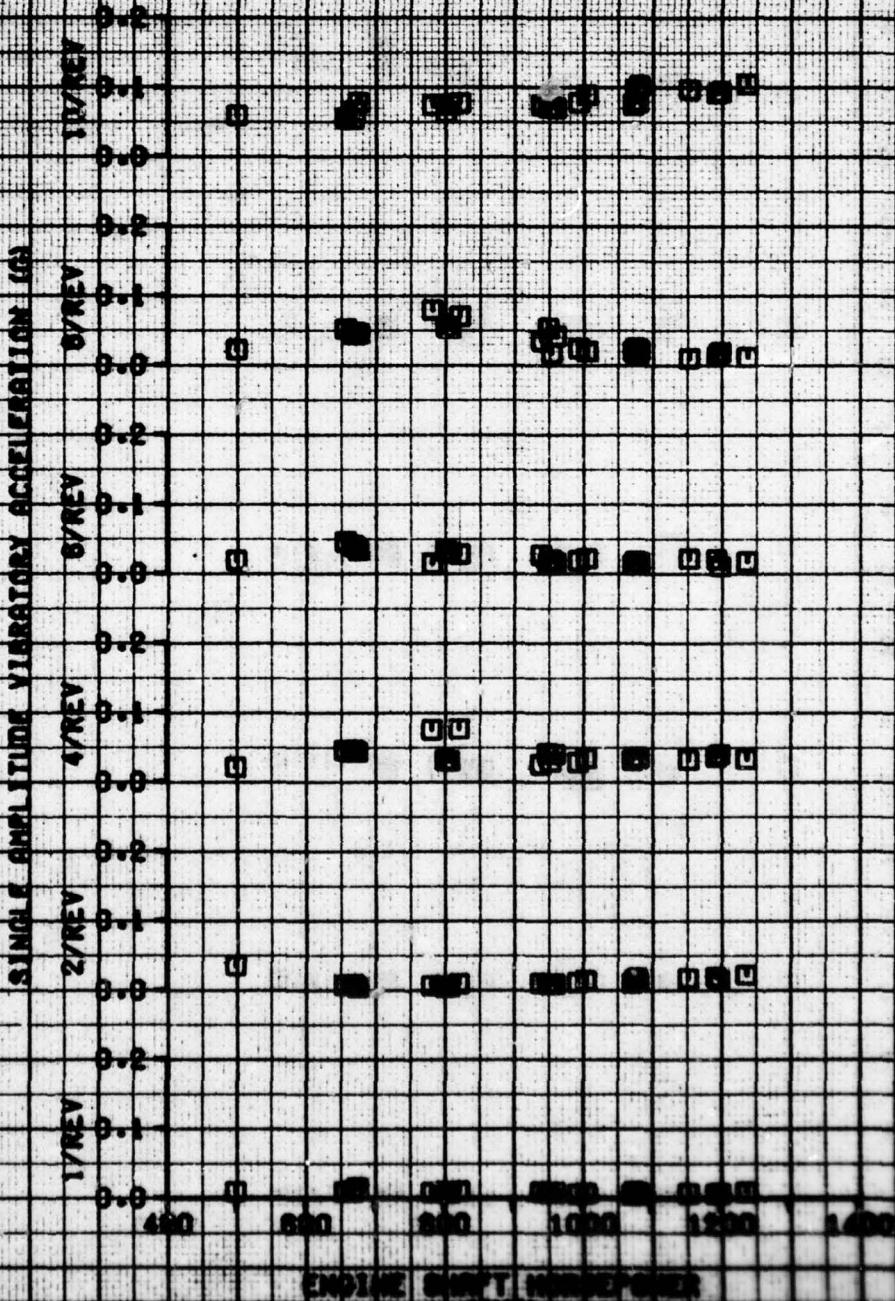
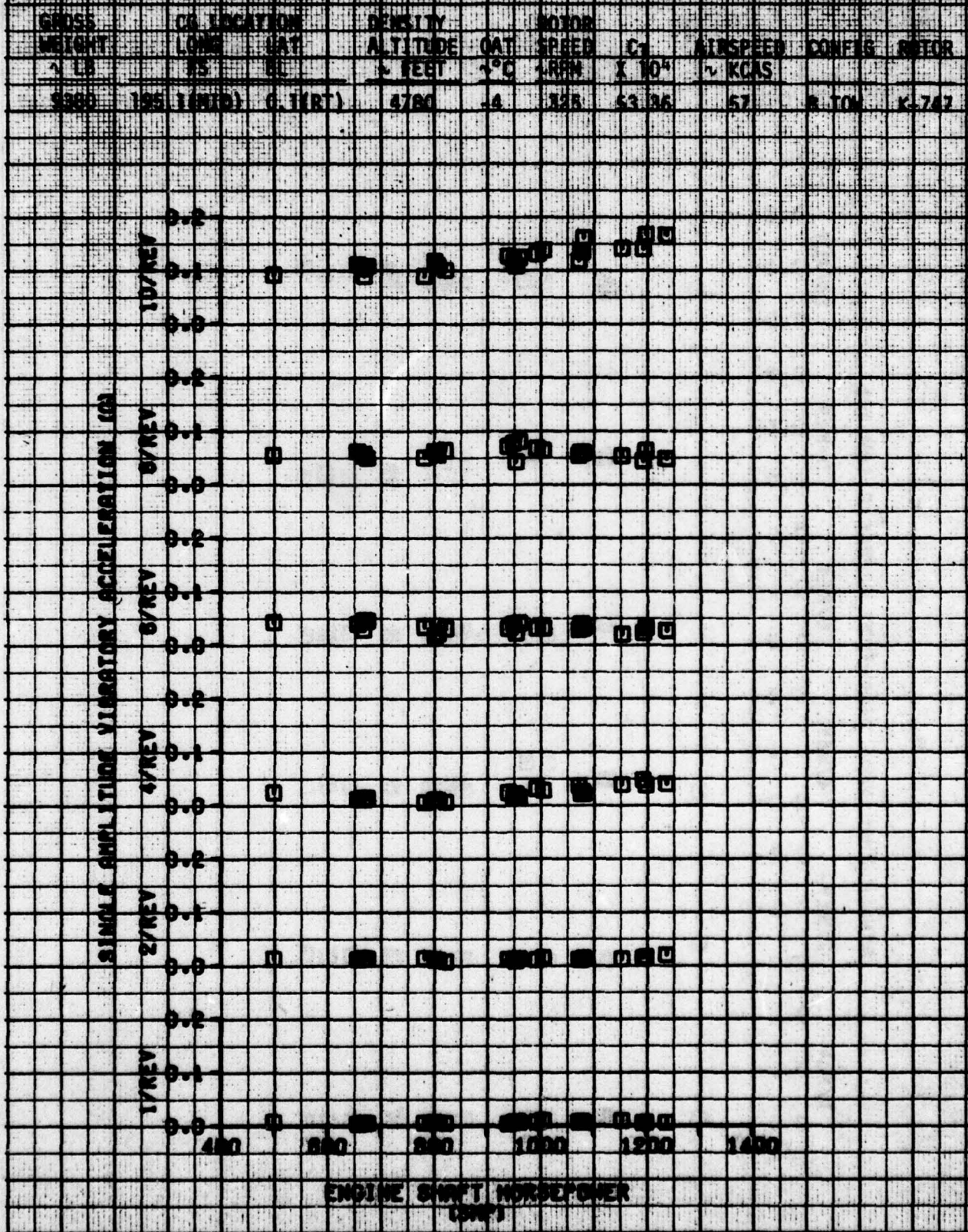


FIGURE 52
CLIMB VIBRATION CHARACTERISTICS
TYPE-X USA 300 TD-1530
PILOT LATERAL



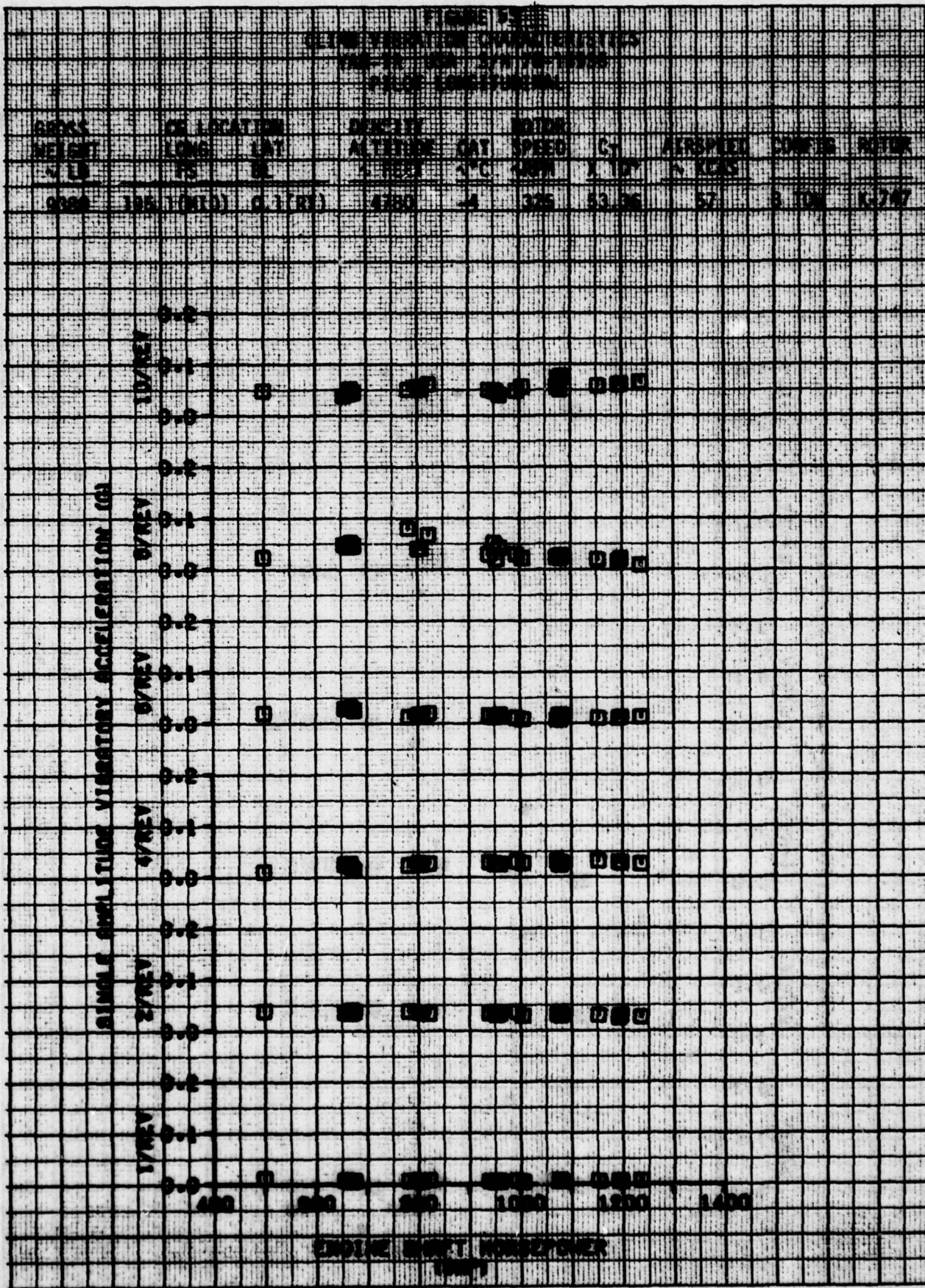


FIGURE 54

HELICOPTER VIBRATION CHARACTERISTICS
 MODEL: HO4S
 DATE: 12/15/56
 CO-PILOT VERSION

GROSS WEIGHT - LB	CG LOCATION		DENSITY ALTITUDE - FEET	ROTOR		C _T X 10 ⁴	AIRSPEED - KCAS	CONES	INCHES
	LONG - FS	LAT - BL		GAT - PC	SPEED - RPM				
9880	105.1 (MB)	0.1 (RT)	4700	4	325	53.85	57	8.10M	X.74T

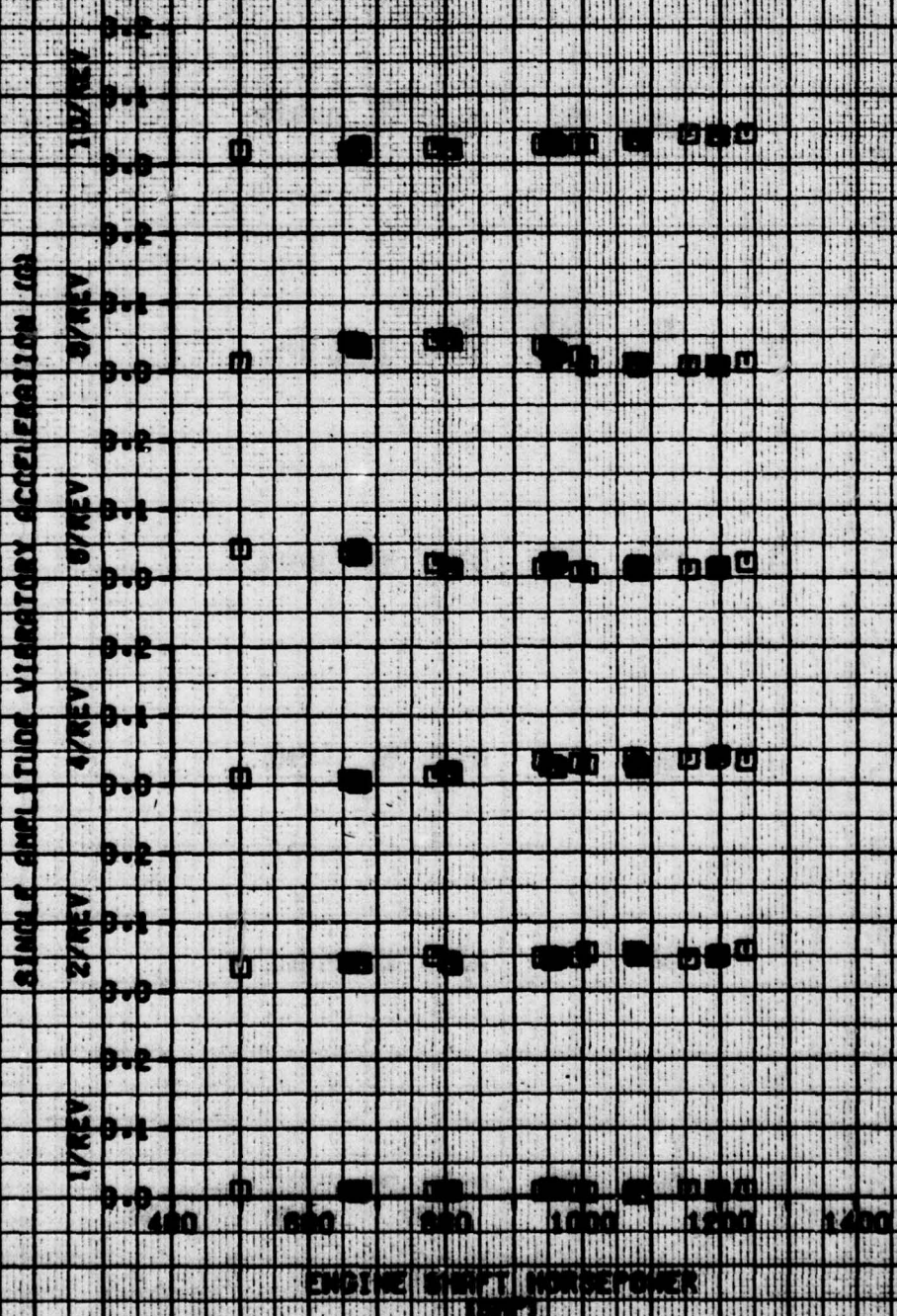


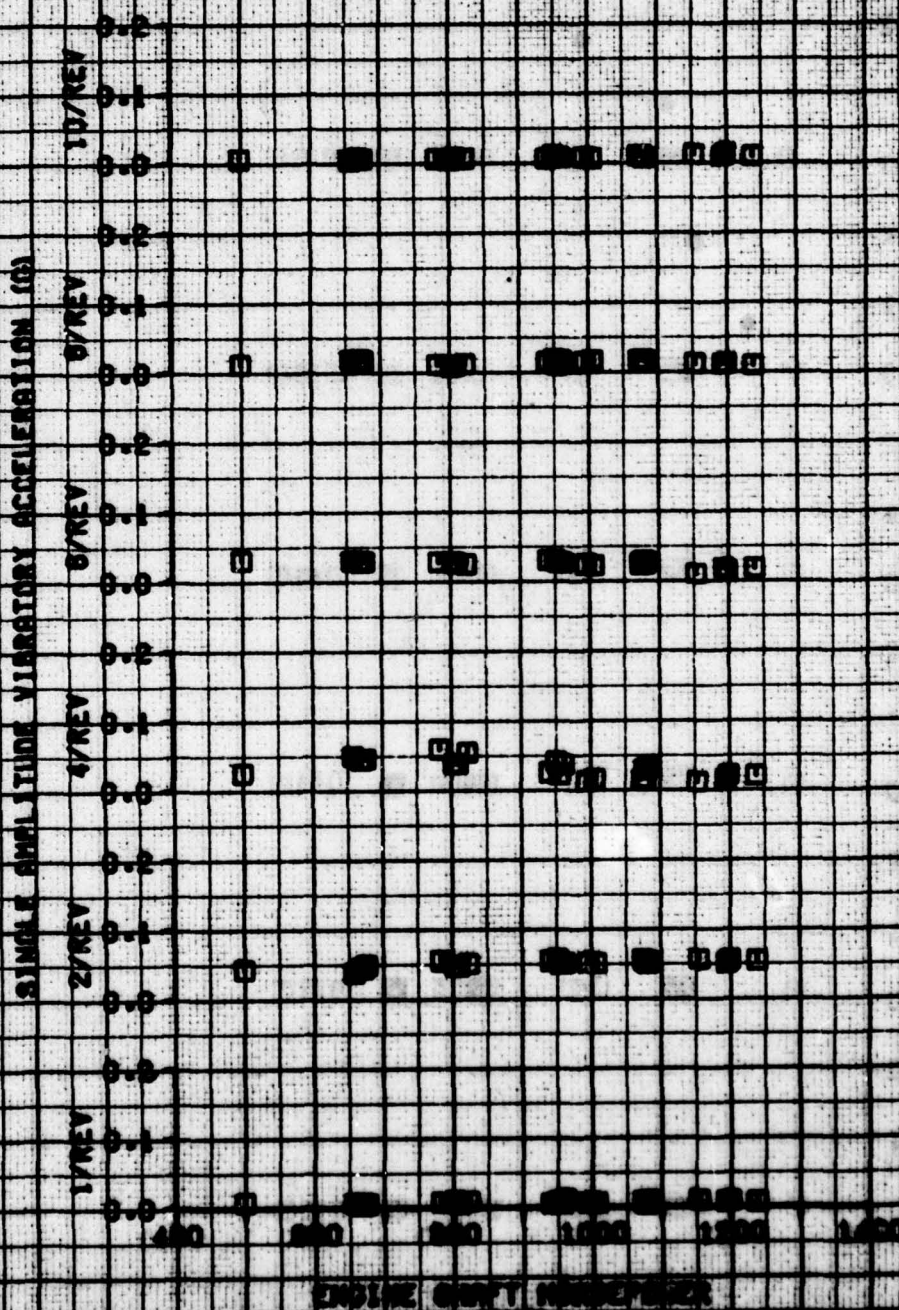
FIGURE 59

GLIDE VIBRATION CHARACTERISTICS

YAN-1R USA 5/17/70-10930

CO-PILOT LATERAL

GROSS WEIGHT ~ LB	ICE LOCATION		DENSITY		MOTOR		AIRSPEED ~ KCAS	CONFIG	ROTOR
	LONG FS	LAT BL	ALTITUDE FEET	QAT °C	SPEED RPM	C _T X 10 ⁴			
9000	195.1 (MTD)	0.1 (RT)	4280	-4	325	53.96	87	3 TOM	X.747



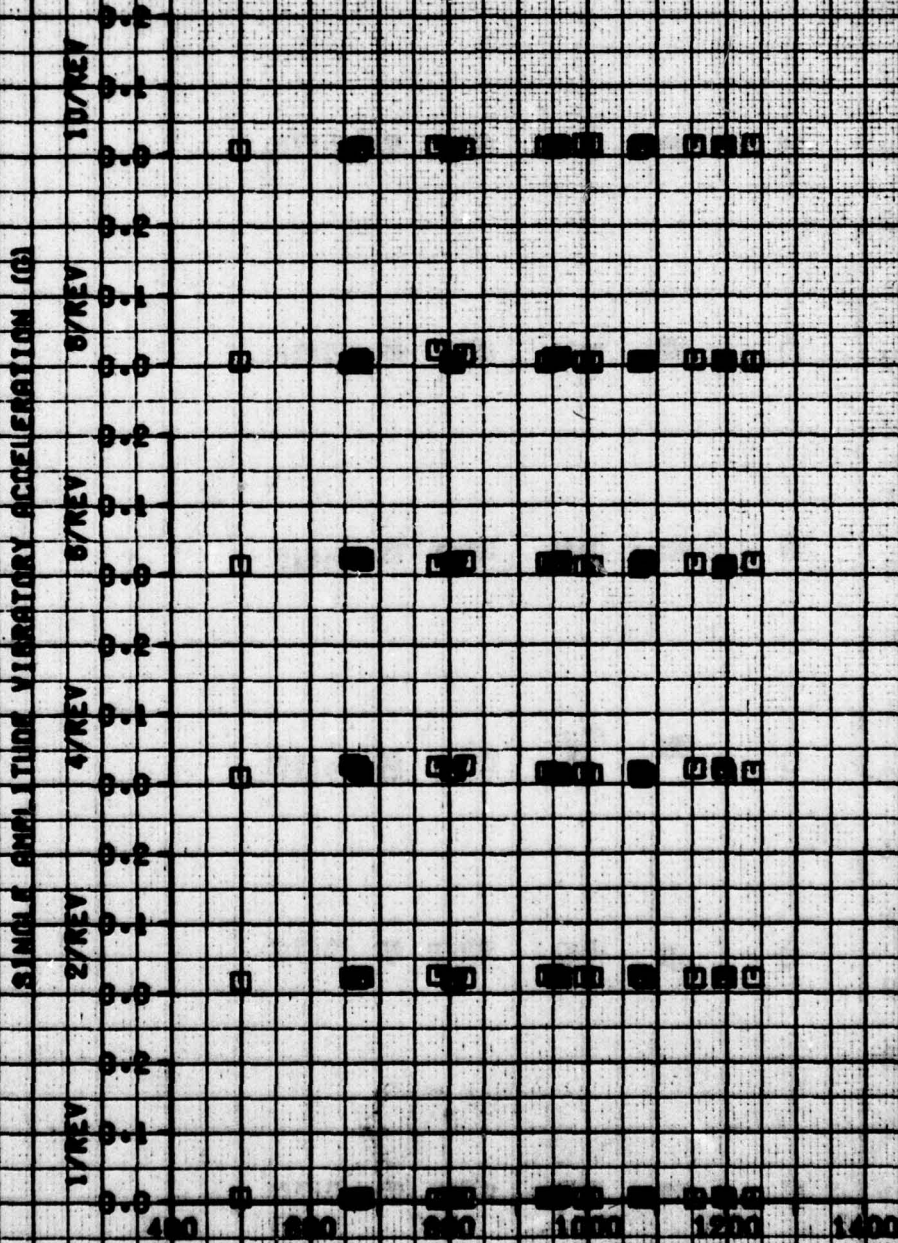
ENGINE SHAFT NUMBER

(RPM)

FIGURE 56

CLIMB VIBRATION CHARACTERISTICS
 T-28C USA 51070-10900
 30-4000 CONTINENTAL

GROSS WEIGHT ~ LB	CR. LOCATION		DENSITY ALTITUDE ~ FEET	MOTOR OAT ~ °C	MOTOR SPEED ~ RPM	C _T ~ 10 ³	AIRSPEED ~ KIAS	CONFIG.	ROTOR
	LONG °S	LAT °E							
9800	105	1(MID)	6.1(80)	4	325	53.06	57	3.704	K-747



ENGINE SHAFT HORSEPOWER

FIGURE 57
 G-MS VIBRATION CHARACTERISTICS
 1787-K USA S/N 70-15936
 CG VERTICAL

GROSS WEIGHT ~ LB	CG LOCATION		DENSITY ALTITUDE ~ FEET	MOTOR RAT SPEED ~ °C	MOTOR SPEED ~ RPM	C ₁ x 10 ⁴	AVERSHEEN ~ KCAS	CONING ~ 10 ⁴	MOTOR ~ 10 ⁴
	LONG FS	LAT BL							
9380	195 I (MD)	0.1 (RT)	1780	A	325	53.36	57	8.701	6.747

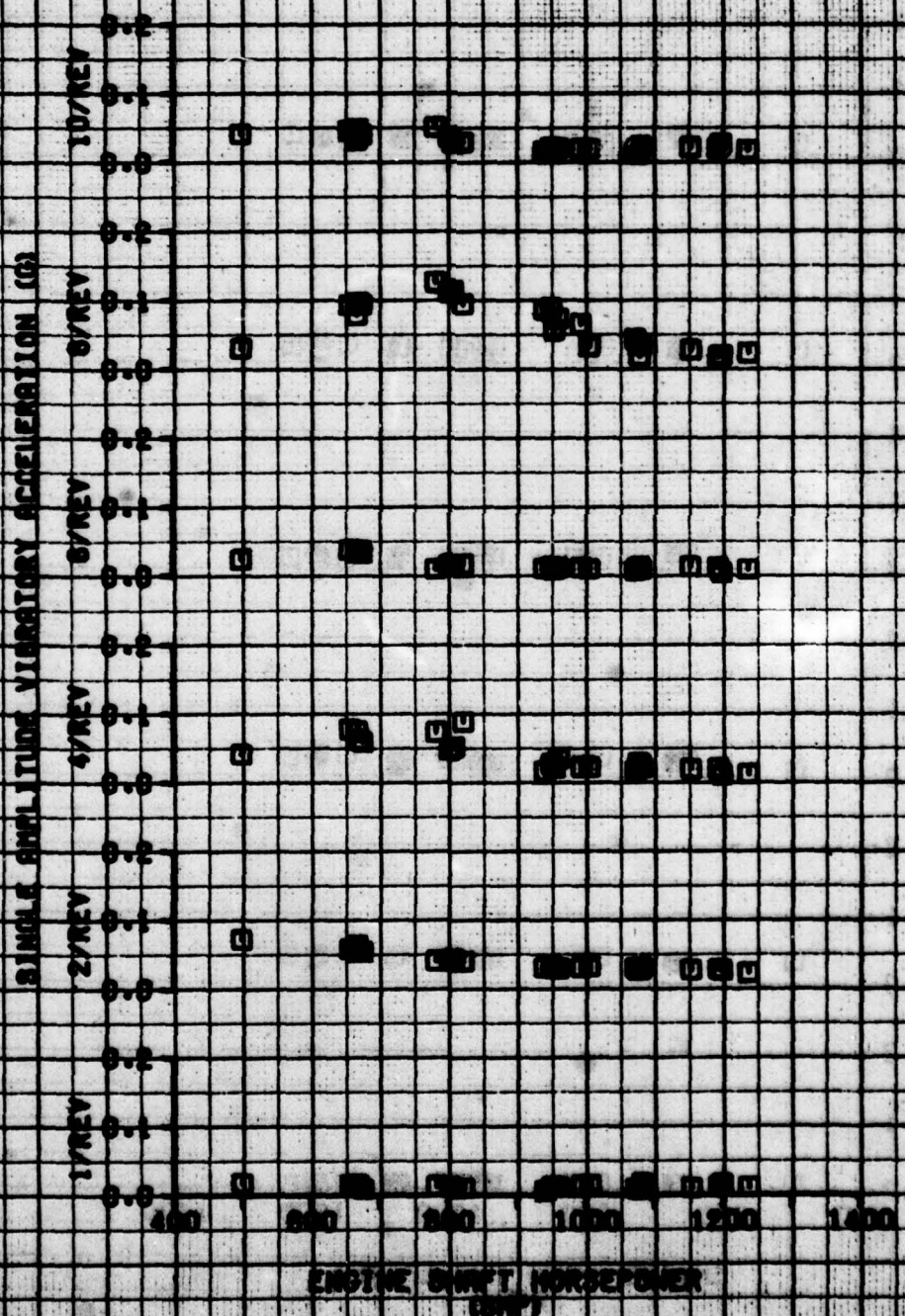


FIGURE 5B

CLIMB VIBRATION CHARACTERISTICS
 YAW-ROLL VIBRATION CHARACTERISTICS
 CG LATERAL

GROSS WEIGHT LBS	CG LOCATION		DENSITY ALTITUDE FT	OAT °C	ROTOR SPEED RPM	C _T x 10 ⁴	AIRSPEED KIAS	CONFIG	ROTOR
	LONG FS	LAT							
9380	195.1 (MID)	0.1 (RE)	4780	-4	325	53.86	57	2-TON	K-747

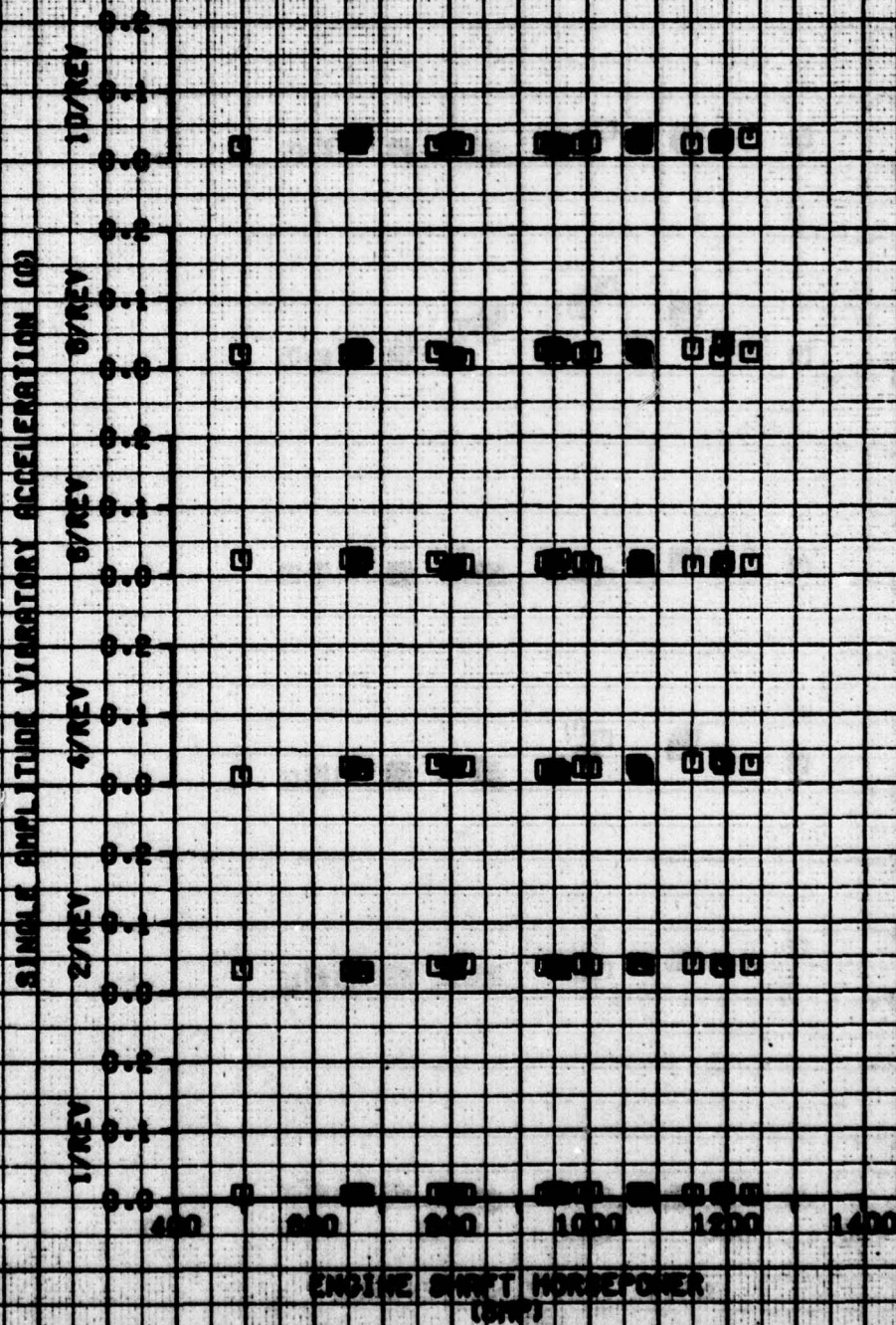


FIGURE 59

OPERATIONAL VIBRATION CHARACTERISTICS
 TEST NO. 17251765
 DATE OF LOGGING: 11/11/66

TEST VELOCITY	NO. OF LOCATIONS	NO. OF SENSORS	AVG. MOTOR OIL SPEED SIC RPM	AVG. ST RPM	TRIP V/S GACS	COMMENTS	REMARKS		
300	20 (APT)	0.1 (RT)	830	1	325	57.15	57	100	START 13.70 STOP

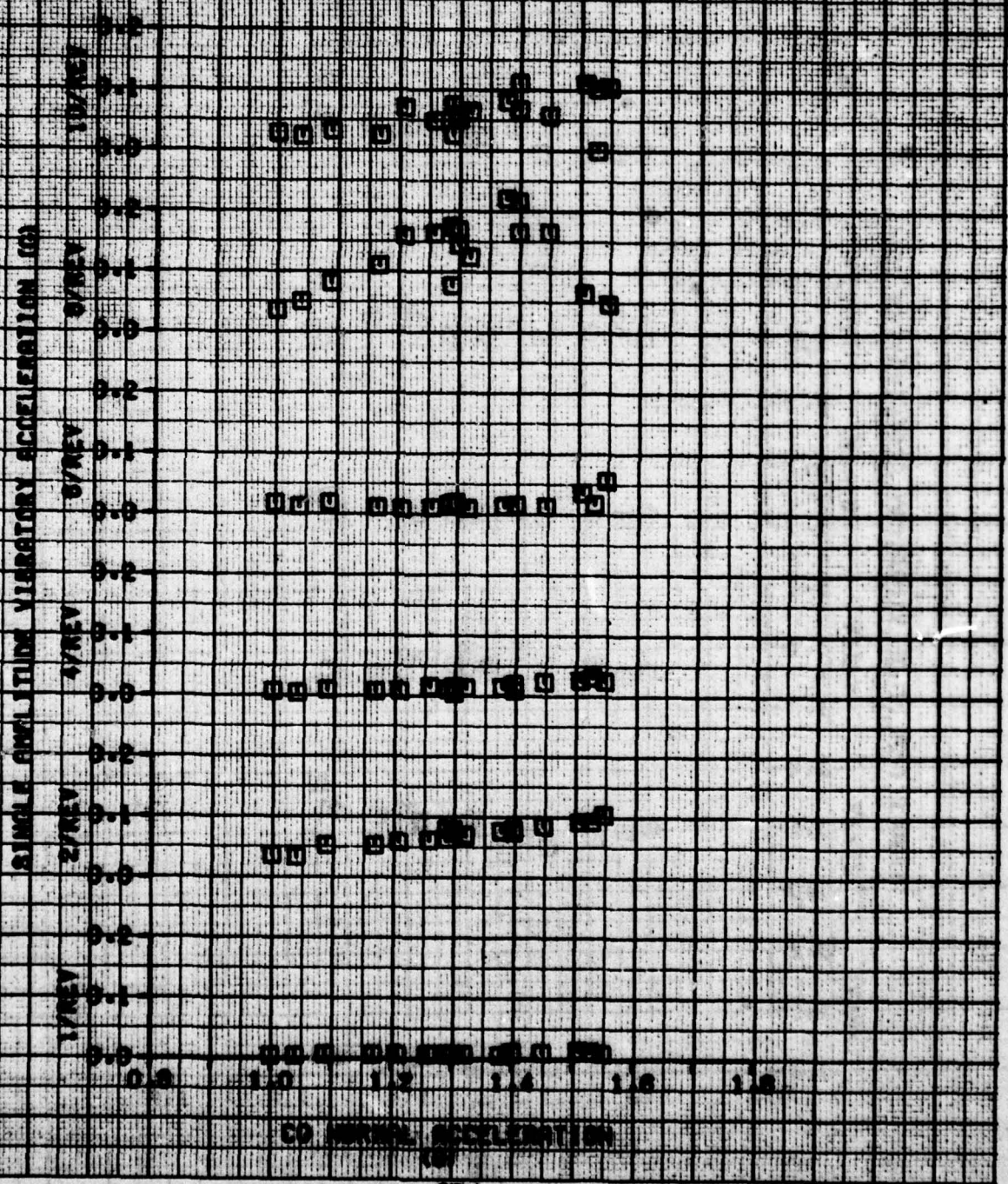


FIGURE 60
 VIBRATORY CHARACTERISTICS
 74-12 USA S/N 70-1596
 CO-PILOT POSITION

NET GROSS WEIGHT	AVE LOCATION		AVE DEFS	AVE ROTOR SPEED	AVE TRIM	CONTR	FLT COND	ROTOR			
LB	LONG	LAT	N	FT /C	N/S /CAS						
9800	201	(AFF) 0.1	(RT)	5000	-4	325	57.25	57	106	STEADY TURNS	K-747

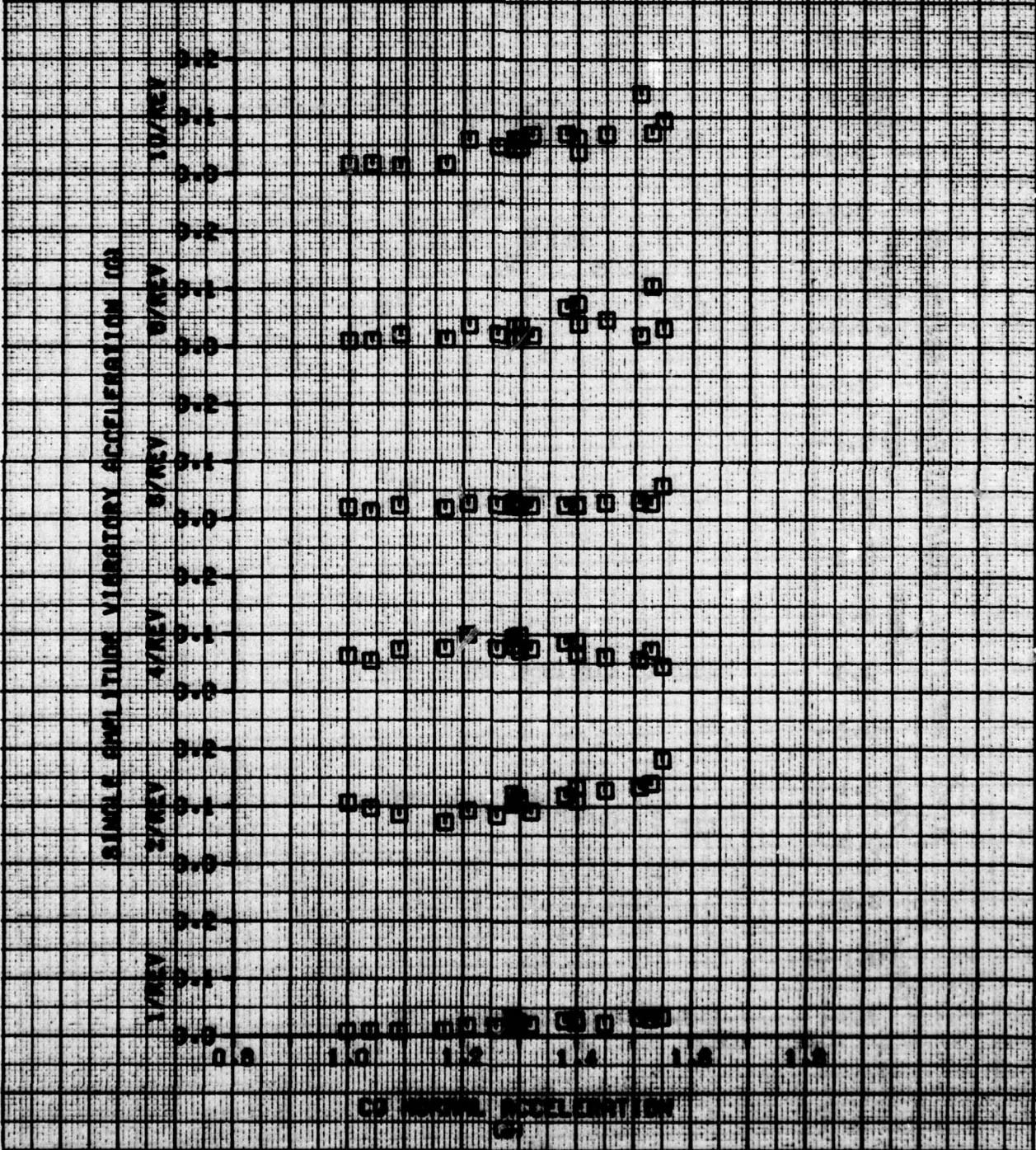
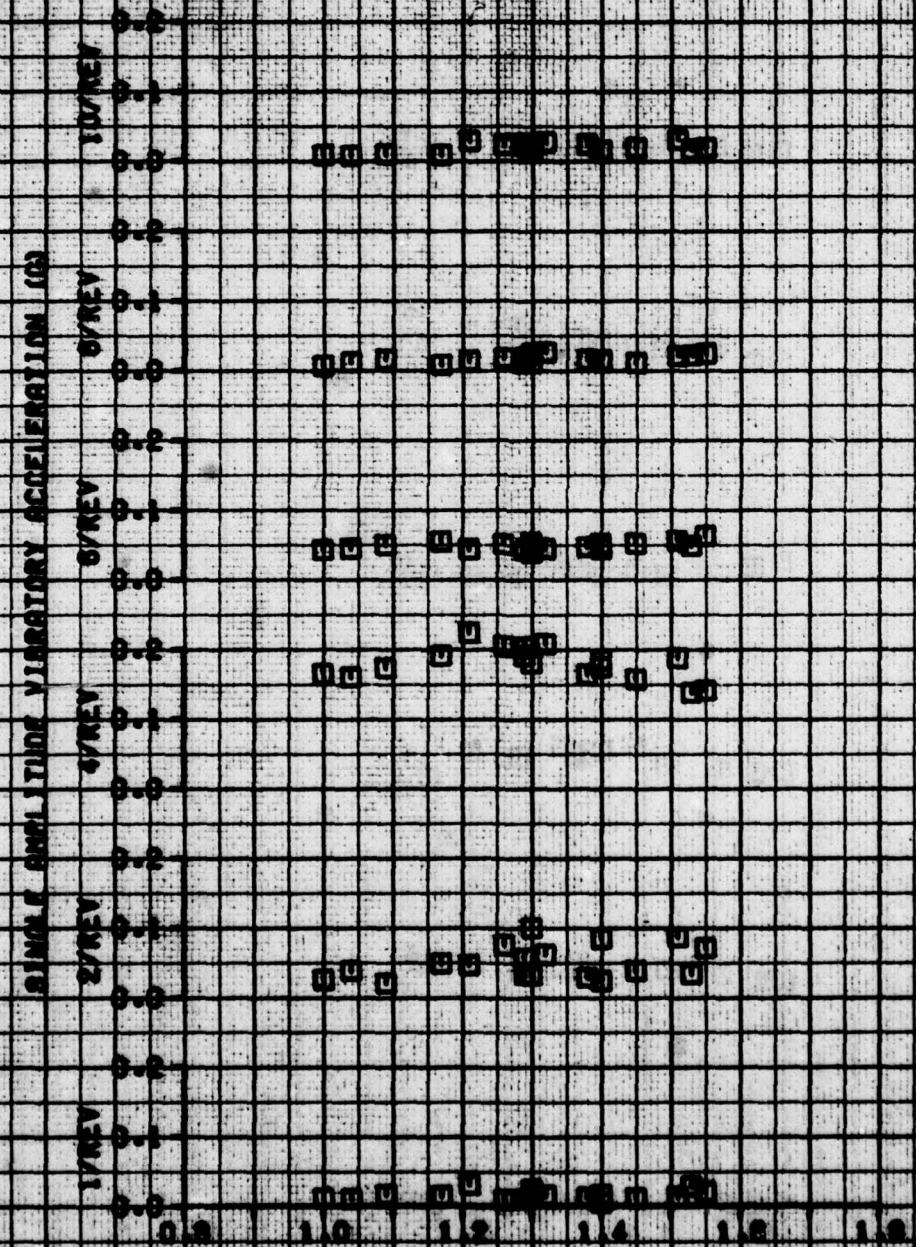


FIGURE 9
 ENGINE VIBRATION CHARACTERISTICS
 1954 K-747 S/N 10-10926
 2000 RPM

AVG GROSS WEIGHT -LB	AVG CG LOCATION		AVG DENS ALT -FT	AVG OUT TEMP -°C	AVG RPM SPEED	AVG CT -10°	TRIM A/S -KCAS	CONFIG	FLT COND	MOTOR	
	LONG -IN	LAT -IN									
9200	201	1(AFF)	0.1(RT)	5380	-4	325	57.25	57	H06	STEADY TURNS	K-747



CO RPMAL ACCELERATION

FIGURE 62

MANEUVERING VIBRATION CHARACTERISTICS
 TANKER USA 54874-15936
 CO PILOT 108570000

Avg GROSS WEIGHT	Avg CG LOCATION		Avg DEVS	Avg ROTOR	Avg TRIM	KEY					
LB	LONG FS	LAT BC	ALT CFT	ROT RPM	IN/100	COND ROTOR					
9880	201	1(AFT)	0.1(RT)	5340	-4	325	57.75	57	NO	STEADY	K-747

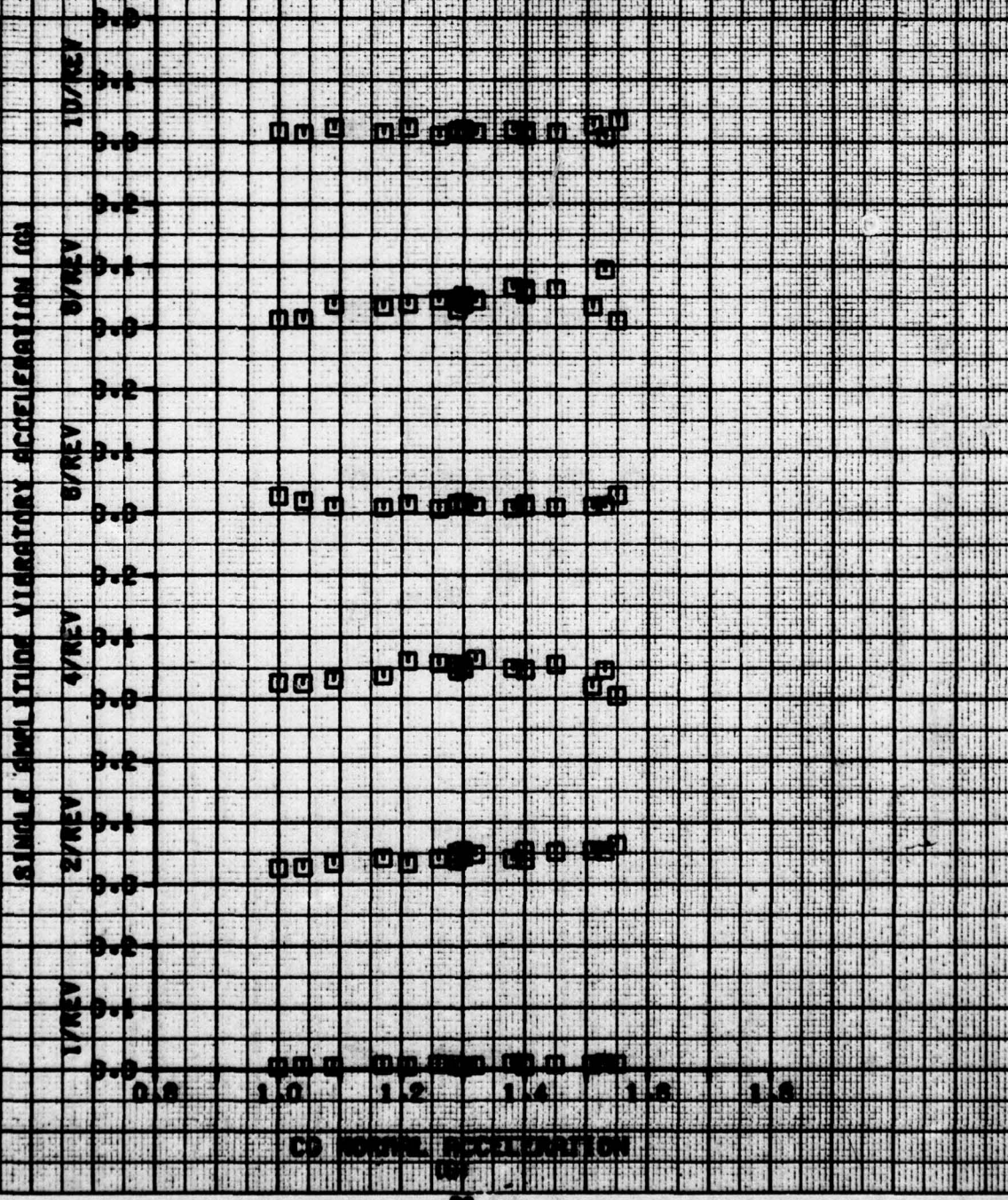


FIGURE 63
 MANEUVERING VIBRATION CHARACTERISTICS
 YAF-1R USA SYN 76-15936
 CG LATERAL

AVG GROSS WEIGHT \sqrt{B}	AVG CG LOCATION		AVG DENS ALT \sqrt{F}	AVG ROT SPEED \sqrt{C}	ROTOR SPEED \sqrt{RPH}	AVG CT $\times 10^4$	TRIM A/S \sqrt{KCAS}	CONFIG	FIT COND	ROTOR
	LONG FS	LAT BL								
9880	201	1(AFF) 0.1(RT)	5380	-4	325	57.25	57	H06	STEADY	K-747 TURNS

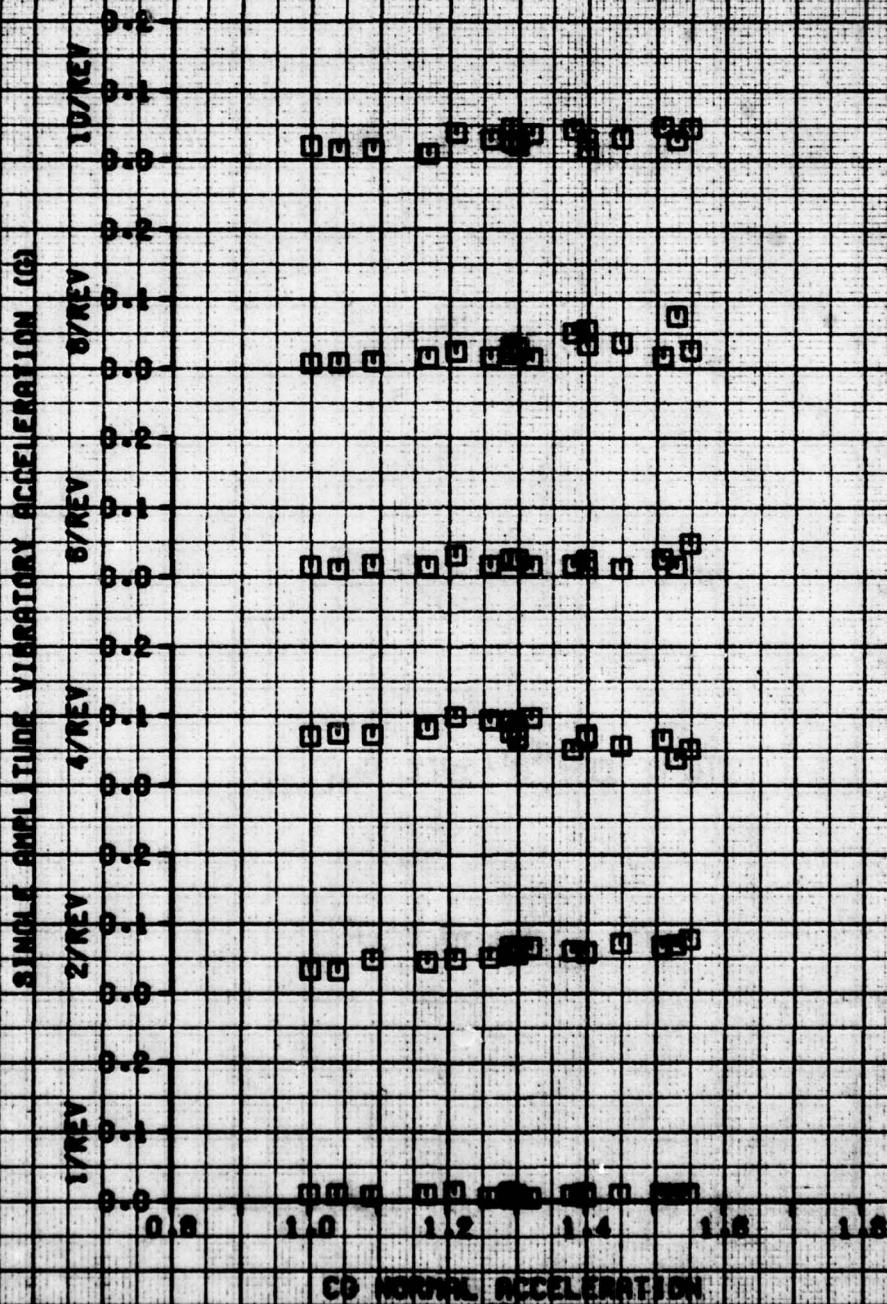


FIGURE 6
 VIBRATION CHARACTERISTICS
 AT 5000 RPM

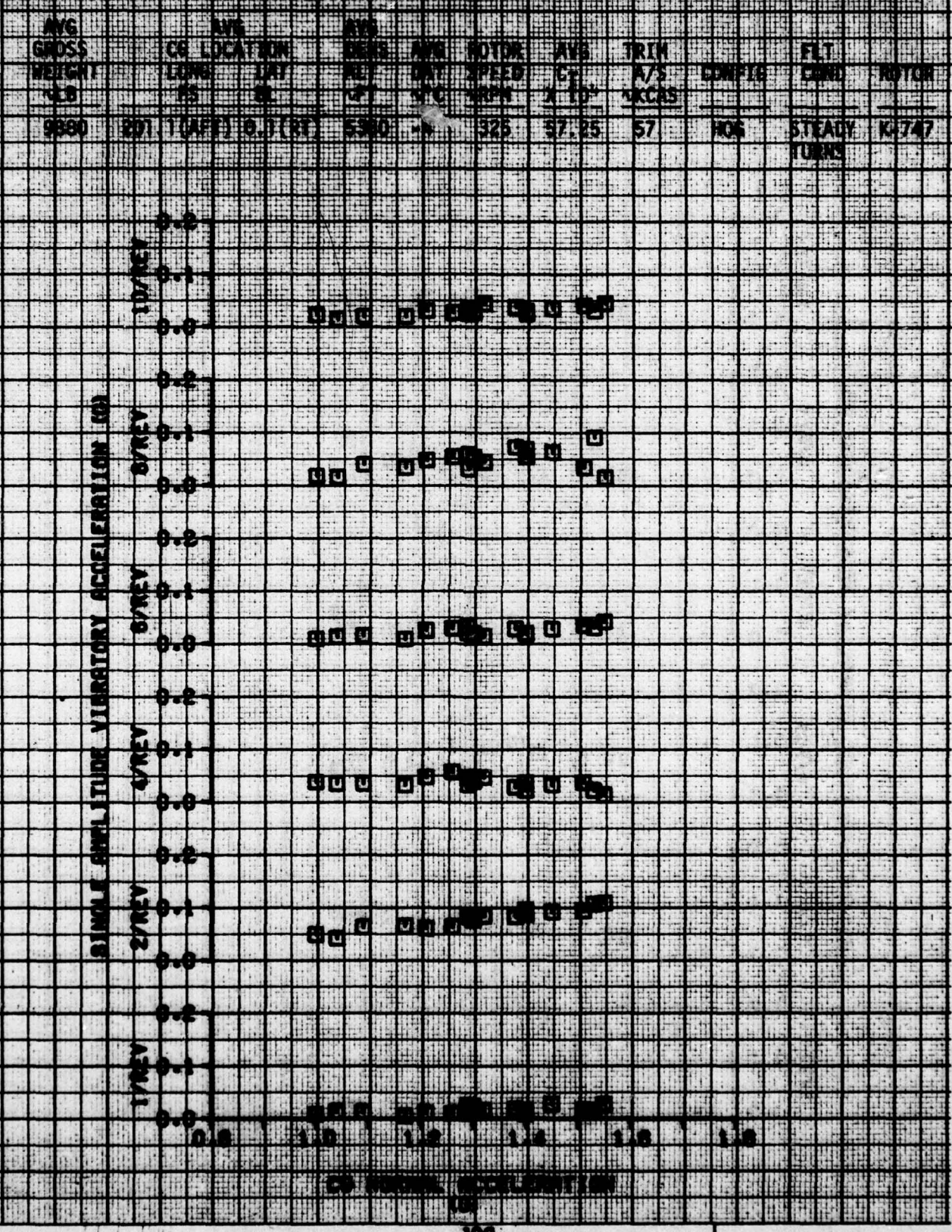


FIGURE 65
MANEUVERING VIBRATION CHARACTERISTICS
AD-70-10946
SYN 70-10946
PILOT CONSTITUTE

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENS ALT (FT)	AVG QAT (°C)	AVG ROTOR SPEED (RPM)	AVG CT X 10 ⁴	TRIM A/S (ARCAS)	CONFIG	FLT COND	ROTOR	
	LONG (RS)	LAT (BT)									
9600	201	0.0(AFD)	0.1(BT)	5550	-2	326	55.92	117	406	STEADY TURN	X-747

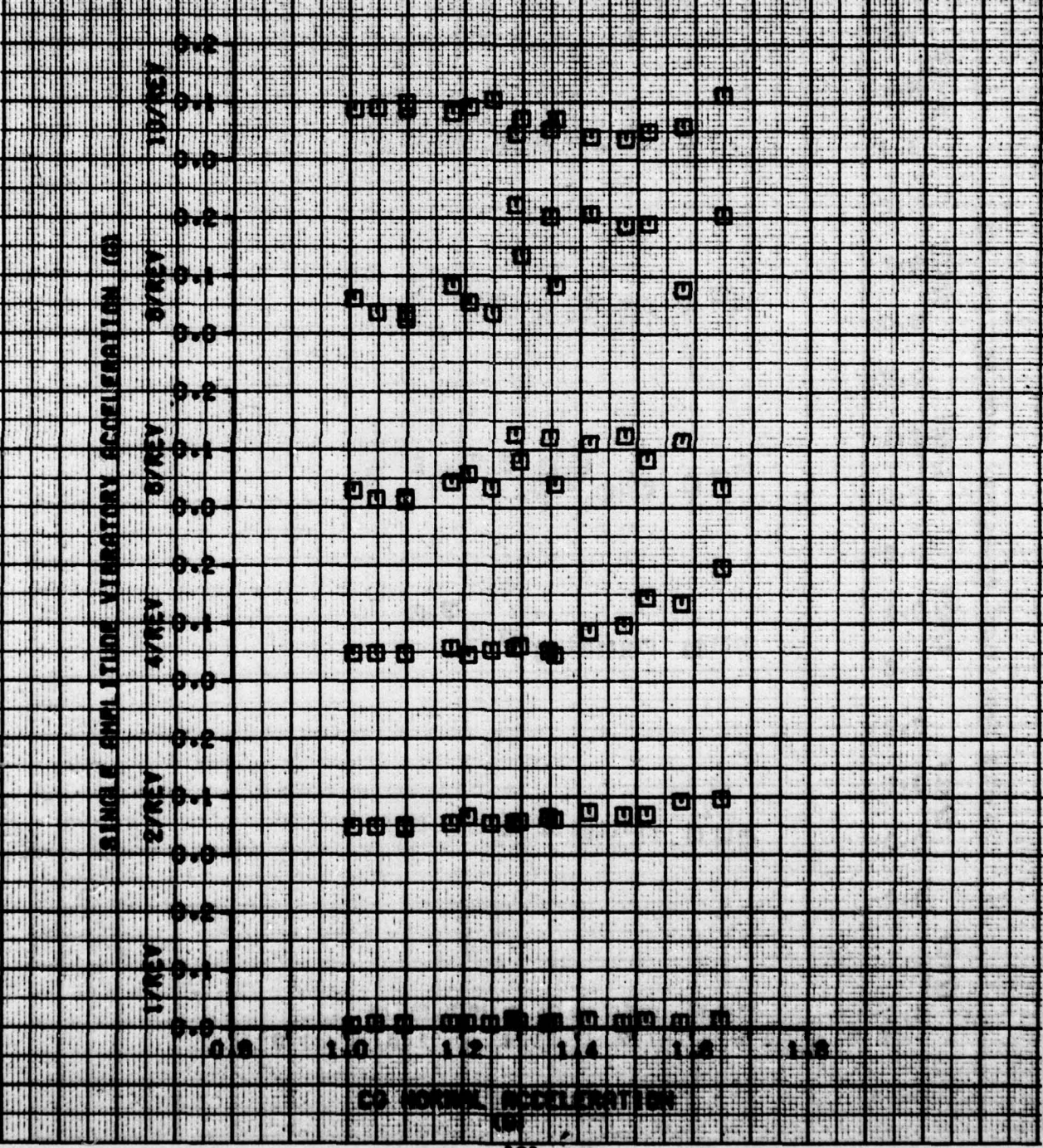
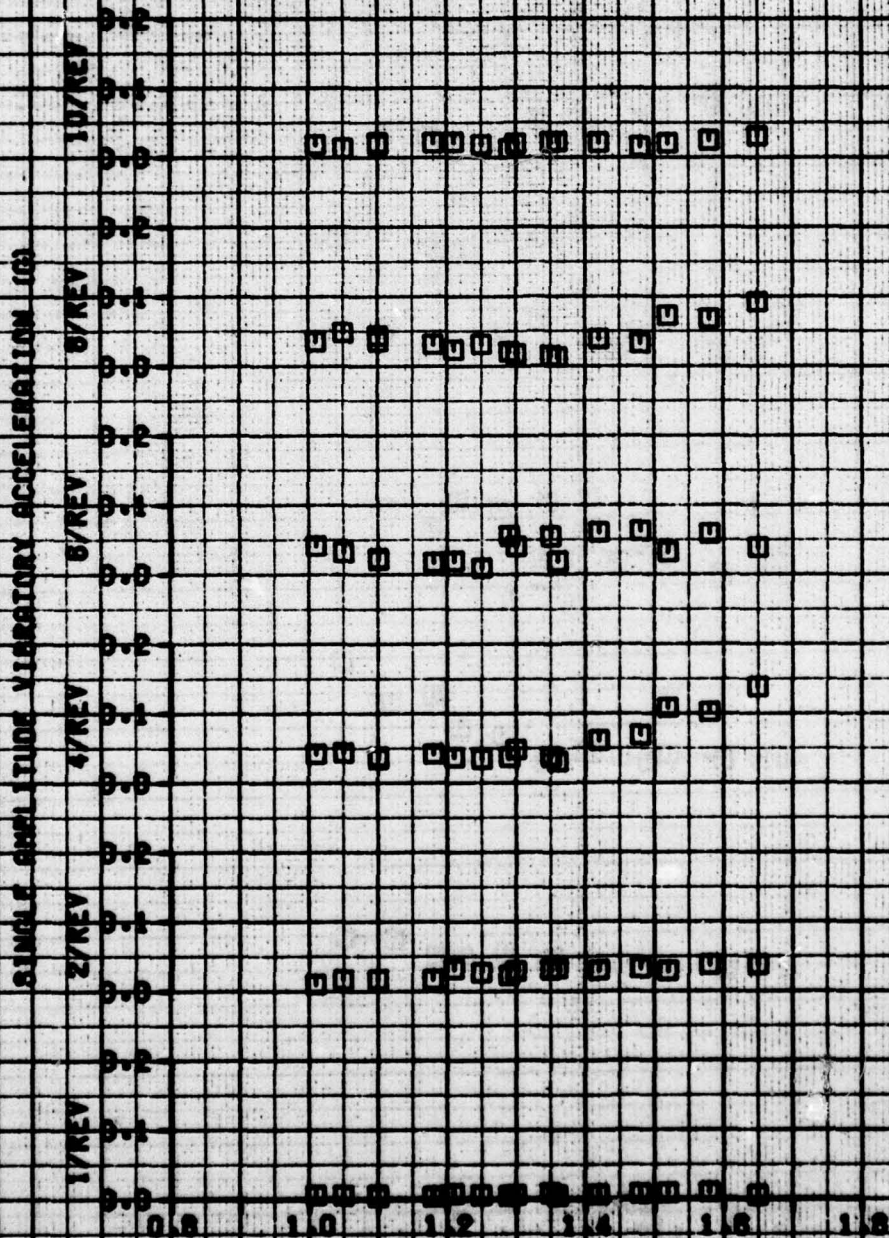


FIGURE 66
MANEUVERING VIBRATION CHARACTERISTICS
 YAF-10 USA 578 70-15986
 CD PILOT LONGERUDINAL

AVG GROSS WEIGHT ~LB	AVG CG LOCATION		AVG DENS	AVG	AVG	AVG	TRIM	CONFIG	FLT	ROTOR
	LONG	LAT	ALT	QAT	ROTOR	CT	A/S		COND	
	FS	BL	~FT	~°C	~RPM	~ 10°	~KCAS			
9600	201.0(AFT)	0.1(RT)	5550	-2	325	55.92	117	HOG	STEADY TURN	K-747



CG NORMAL ACCELERATION

(G)

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