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USATECOM PROJECT NO. 4-40108-01

MILITARY POTENTIAL TEST OF THE MODEL 540 "DOOR HINGE" ROTOR SYSTEM

Supersedes AD-443687

February 1964

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Summary

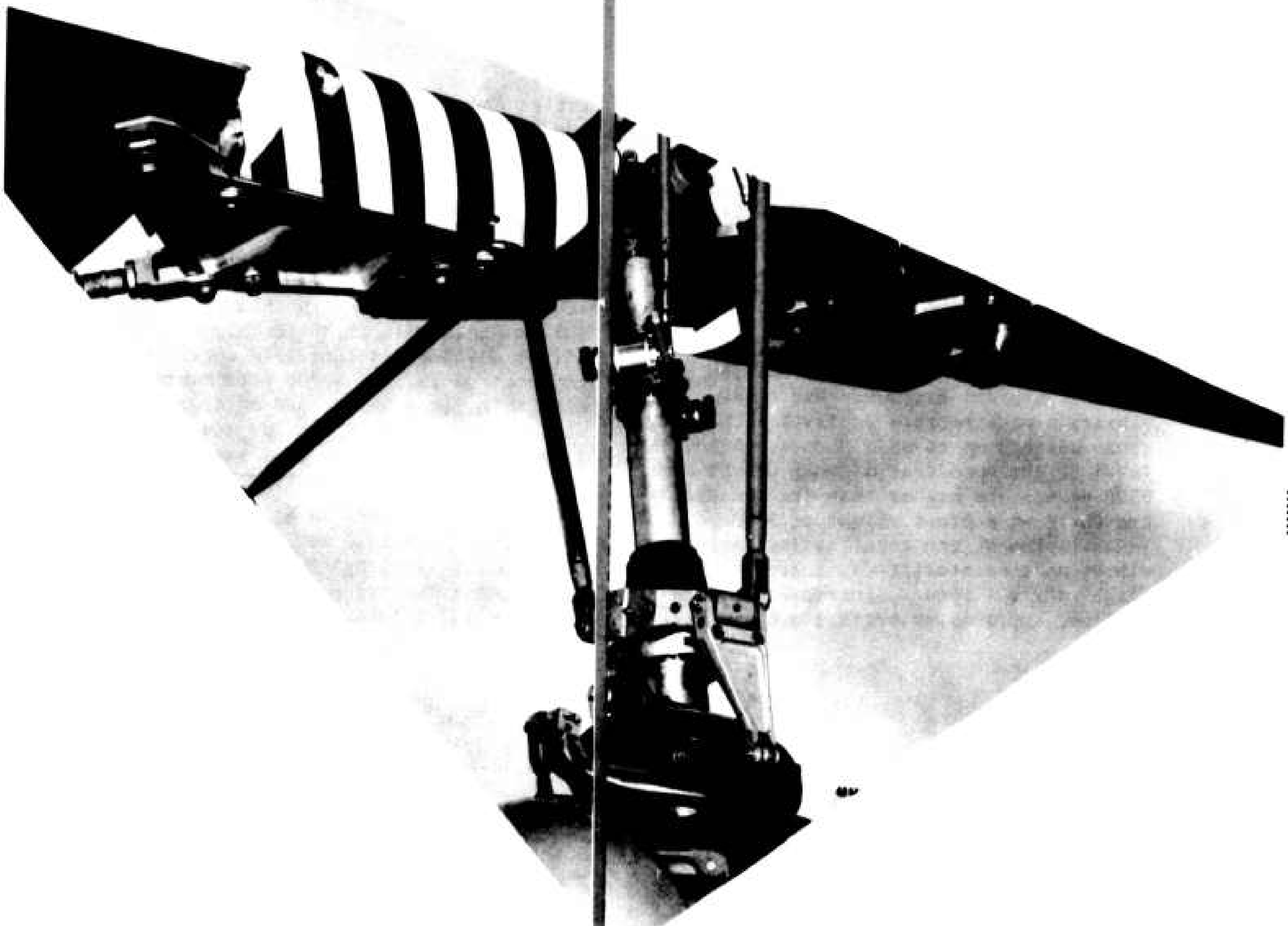
This report presents the results of a Military Potential Flight evaluation conducted on the Bell Helicopter Company's Model 540 "Door Hinge" Rotor System mounted on a company furnished commercial 204B helicopter.

The results of these tests show that the "Door Hinge" Rotor is a significant advance in the state-of-the art of two-bladed teetering rotor design. When equipped with this rotor, the UH-1B series helicopters are not maximum speed limited by vibration or structure in level flight at gross weights up to 9500 pounds. Allowable level flight speeds at a gross weight of 9500 pounds are higher than for the standard UH-1B at a gross weight of 7500 pounds. Installation of the rotor system improves vibration characteristics, increases level flight maximum speeds, increases service ceiling, improves autorotation characteristics and increases the maximum allowable load factors during turning flight. Installation of the "Door Hinge" Rotor, however, will decrease hovering performance, low altitude-low gross weight level-flight performance and low altitude climb performance.

The handling qualities of the UH-1 helicopter remain largely unchanged within the present UH-1B flight envelope. The flight envelope is increased considerably in terms of maximum speed attainable and allowable gross weight and development work will be necessary to provide adequate handling qualities for the UH-1 when operating in the new areas of the flight envelope.

Development work is still required in the areas of fatigue test, control loads, boost-off flight, pylon compatibility, and in-flight rotor track before the rotor system will be suitable for service use.

PART I general



A. REFERENCES

A list of references will be found in Part III, Annex A.

B. AUTHORITY

1. Test Directive

The test directive was received by 1st Indorsement from Headquarters, U. S. Army Test and Evaluation Command dated 31 December 1963, Subject: "Bell Helicopter Proposal for High Speed Door Hinge Rotor System." The U. S. Army Aviation Test Activity, Edwards Air Force Base, California was designated coordinating agency for the program and to be responsible for the accomplishment of the engineering portion of the tests and submission of the report of test. The U. S. Army Aviation Test Board, Ft. Rucker, Alabama, was designated to contribute qualitative "service pilot" opinion.

The basic letter to the test directive, AMCRD-DM-A, dated 3 December 1963, Subject: "Bell Helicopter Proposal for High Speed Door Hinge Rotor System", further defined the scope of the project. Flight time was nominally set at 20 hours maximum; no formal plan of test was required; and direct coordination was authorized with the Bell Helicopter Company which was to provide the test item at no cost to the government.

2. Purpose of Test

The purpose of this program was to conduct a Military Potential Test of the Bell Model 540 "Door Hinge" Rotor System. Areas of interest included determination of:

a. Advantages in speed and decreased vibration levels compared to the standard 44-foot and 48-foot rotor systems installed on the standard UH-1B and UH-1D.

b. Other significant advantages or disadvantages.

C. DESCRIPTION OF MATERIEL

1. Airframe-engine

The test item provided by the contractor for this program included a commercial 204B airframe with a T53-11 engine installed.

The commercial 204B airframe closely resembles the airframe of the military UH-1B. The principal difference is the length of the tail boom that is extended on the 204B to allow operation with a 48-foot rotor. Minor differences encountered with the test article (204B Serial No. N73977) included a nonstandard cockpit layout, installation of dual pilot-static airspeed systems, installation of an electrically driven boost pump to provide emergency hydraulic boost pressure for the collective control system and absence of military radio equipment.

The test engine, a T53-11, Serial No. L.E. 08102, was a commercial model that closely resembles the military T53-L-9 engine and conforms to the same specifications for power and fuel consumption. The differences are in the metered starting fuel plumbing on the fuel control and a different configuration of the burner liners. From the viewpoint of pilot operation, the commercial engine is identical to the military T-53 engine of the same power rating.

2. Model 540 "Door Hinge" Rotor System

The test article was equipped with an experimental rotor system which was the primary area of interest during the program.

The rotor is of a two-bladed teetering design with a 44-foot diameter, the same as the standard UH-1B rotor system. In all other respects, the test rotor differs considerably from a standard UH-1B rotor. This is illustrated by Table I, below which is based on information contained in Bell Report 540-099-002, dated 28 January 1964.

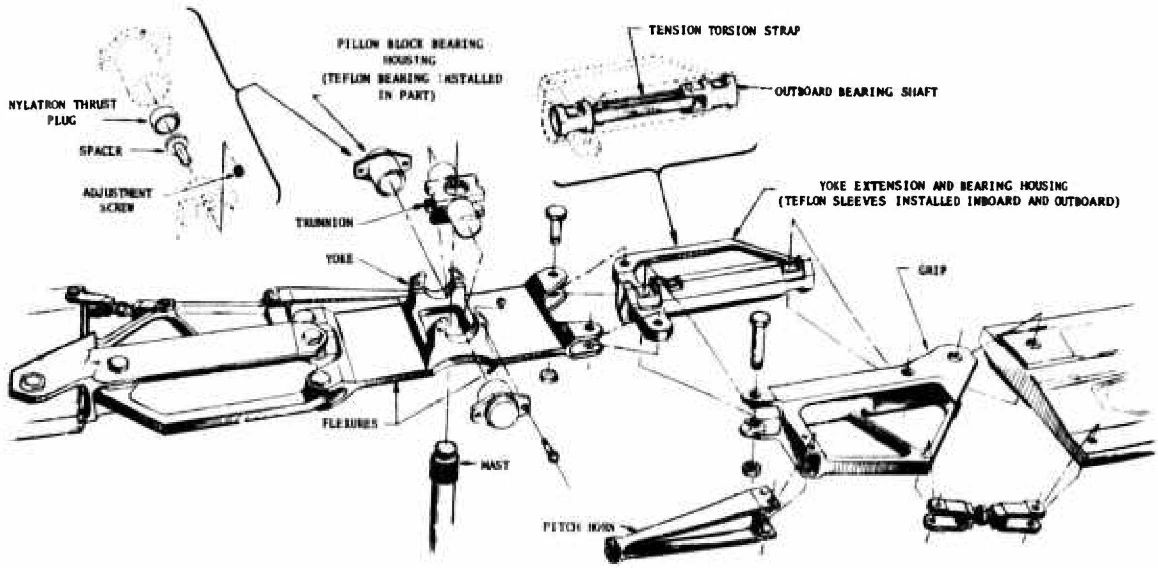
TABLE I

	UH-1B STANDARD ROTOR	MODEL 540 "DOOR HINGE" ROTOR
Rotor Diameter - feet	44	44
Chord - inches	21	27
Twist - degrees	-10°	-10°
Airfoil	NASA 0012	Special 0009 1/3
Disc Area - square feet	1520	1520
Blade Area - square feet per blade	38.5	49.5
Solidity Ratio	.0506	.0651
Rotational Inertia - slugs/feet squared	1660	2800

The higher rotational inertia of the "Door Hinge" Rotor is partially caused by the increased amount of tip weight (45 pounds) installed in each blade.

The Model 540 Rotor is characterized by its unique flapping and feathering axis hinge designs. A large amount of inplane stiffness is provided by means of flexures for flapping hinges and the feathering hinge that resembles a door hinge in design concept. No roller or ball bearings are used in the design. All bearings, including those in the teetering joint pillow block, are teflon sleeves and dry lubricated. As a result, no liquid lubrication is required in the rotor head and there is a complete absence of sight gages and other normal liquid lubrication accessories. Axial load reactions are taken up in tension torsion straps, one for each blade.

Control inputs about the feathering axis are imparted to the blades by means of pitch horns at the hub trailing edge. A standard UH-1B rotor incorporates pitch horns at the blade leading edge. As a result, control motions are modified by the installation of appropriately designed control systems hardware. The major change is a reversal in collective sleeve motion accomplished by the installation of a special "A Frame" mount at the top of the transmission housing. The stabilizer bar is a standard UH-1B component except for the weights and dampers, and operates in the normal manner.



GENERAL ARRANGEMENT
MODEL 540 ROTOR

D. BACKGROUND

In October 1963, the Bell Helicopter Company proposed a 20 hour flight evaluation of the Model 540 "Door Hinge" Rotor System at no direct cost to the government. In November 1963, the Office of the Chief of Research and Development, U. S. Army, Washington, D.C., requested the U. S. Army Materiel Command to accept the proposal.

The contractor's proposal claimed the following principal advantages for the Model 540 "Door Hinge" Rotor System:

1. Decreased vibration (approximately 70 percent)

2. Design simplicity

3. Maximum attainable level flight airspeed limited only by power available.

4. Increased rotor inertia for better autorotational characteristics.

In addition, the proposal claimed hovering performance to be comparable to that of the standard UH-1B and the power required in level flight to be less than for a standard UH-1B.

Primary interest in the program centered on the possible increase in UH-1 mission capability because of the rotor installation. Additional interest stemmed from the possibility of increasing the current helicopter speed capability by the installation of this system.

The tests were conducted at the Bell Helicopter Flight Test facility at Greater Southwest Airport, Ft. Worth, Texas, between the dates of 8 January 1964 and 22 January 1964.

E. TEST OBJECTIVES

The test objectives were as outlined in Section B.2.

F. FINDINGS

1. General

The findings of this report can be directly related to the characteristics of a standard UH-1B equipped with a 44-foot rotor. The findings may not be quantitatively compared to the UH-1D equipped with a 48-foot rotor because of the differences in drag and vibration characteristics of the airframes and a lack of substantiated performance and vibration data for the UH-1D. Most of the comparisons in this report, therefore, are made with reference to the standard UH-1B.

The rotor system bears a company Model Number 540. The term "Door Hinge" Rotor is a popular usage name. These designations are used interchangeably in this report.

The tests performed during this evaluation were necessarily limited in scope. If the Model 540 Rotor System is procured for service use, additional engineering testing will be required to provide operating data for the "Handbook of Operator's Instructions."

2. Starting and Rotor Engagement

No special starting and rotor engagement procedures were required with the Model 540 Rotor installation.

3. Hovering

a. The hovering handling qualities of the UH-1 helicopter equipped with the Model 540 "Door Hinge" Rotor were evaluated in and out-of-ground-effect (IGE and OGE) and performance was measured OGE effect. Atmospheric conditions during the project precluded the determination of IGE hovering performance.

b. The hovering handling qualities IGE were essentially unchanged from those of a standard UH-1B. Qualitative tests were conducted at the lightest practical loadings at both the forward and aft center-of-gravity limits. Additionally, qualitative tests were conducted at 9700 pounds gross weight and a mid center-of-gravity loading.

Hovering autorotation tests IGE showed that at light gross weights (6700-7000 pounds) the rotor rpm decay rate was approximagely 25 rpm per second and that the helicopter could be held off the ground as long as 5 seconds following a throttle chop at a skid height of three feet. At a high gross weight (9550 pounds) the rotor rpm decay rate was approximately 40 rpm per second and the helicopter could remain airborne for approximately 3 seconds from the same skid height.

During the OGE hovering performance tests, a large nose-down trim change occurred when the helicopter climbed vertically to obtain OGE conditions. The trim change remained as long as the helicopter was OGE. This trim change caused the pilot to move the cyclic control aft to an uncomfortable position. At this cyclic control position, the longitudinal forces could not be trimmed to zero because the range of authority of the force-feel trim system was exceeded. This trim change could result in an additional restriction on forward center-of-gravity position if the rearward flight requirments of MIL-H-8501A (30 knots) must be met under OGE flight conditions to insure mission compatibility.

c. Out-of-ground-effect hovering tests revealed that performance is decreased from that of a standard UH-1B for conditions of similar gross weights and installed engine power. The 95° Fahrenheit day OGE hovering ceiling was determined to be 3300 feet at a gross weight of 6600 pounds compared to 3950 feet for a standard UH-1B at the same gross weight (Reference FTC-TDR-62-21, titled "YHU-1B Category II Performance Tests"). The maximum gross weight that can be utilized under sea-level standard-day conditions for OGE hovering is 8720 pounds with the "Door Hinge" Rotor installed.

The Model 540 "Door Hinge" Rotor System would demonstrate more efficient OGE hovering performance, than the standard UH-1B rotor if the sea-level, standard-day installed engine power rating of both helicopters were higher than 1180 Shaft Horsepower (SHP). With this installed SHP, the rotor system would be capable of hovering OGE at a helicopter gross weight of 9660 pounds. Also, as density altitude increases the hovering performance improvement would occur at lower gross weights because the performance cross-over would occur whenever the rotor is operating at a thrust coefficient of .00484 or greater. The "Door Hinge" Rotor System is, therefore, better suited than the standard UH-1B rotor to gross weight and engine horsepower growth.

4. Takeoff

a. The takeoff performance of the UH-1 helicopter equipped with the Model 540 "Door Hinge" Rotor was not evaluated during these tests. The handling qualities were qualitatively evaluated and the vibration characteristics were measured. Vibration information is presented later in this report in a separate section titled "Vibration Characteristics."

b. The transition to forward flight from a hover produced normal UH-1 cyclic and rudder pedal trim changes. The usual nose-up and nose-left trim changes during translation were easily corrected.

5. Climbing Flight

a. The climb performance of the UH-1 helicopter equipped with the Model 540 "Door Hinge" Rotor was determined for the condition of a climb-start gross weight of 7660 pounds at sea level by conducting two check climbs. The analyzed data (See Figure 4, Part II) is compared to similar data contained in FTC-TDR-62-21 (Figure 50). In addition, the climb data was corrected to the power condition of Bell Report 204-099-712 to determine specification performance available and is presented in Figure 5.

b. A qualitative evaluation of flying qualities during climbing flight revealed no change from a standard UH-1B. Static longitudinal stability was positive and static lateral-directional stability was positive. Once power was established at maximum available, the climb airspeed schedule of 60 knots Indicated Airspeed (IAS) could be held without difficulty.

c. Analysis of the climb performance data revealed that at a climb-start gross weight of 7660 pounds, the standard UH-1B helicopter has a slightly higher rate of climb at density altitudes below 6500 feet. Above that altitude, however, the Model 540 "Door Hinge" Rotor System demonstrated improved climb performance and an increase in service ceiling of 3000 feet resulted. The analyzed data is presented in Figure 4, Part II.

As was the case in a hover, the performance crossover occurred at a rotor thrust coefficient of .00484. This indicates that the "Door Hinge" Rotor will have better performance characteristics than the standard UH-1B rotor when operated at the higher gross weights, power loadings and altitudes.

6. Level-Flight Performance

a. Level flight tests were conducted at density altitudes ranging from -650 feet to 9650 feet and gross weights ranging from 6380 pounds to 9375 pounds. Rotor speeds of 323 rpm were utilized for the majority of the tests, with one level flight test conducted at 314 rotor rpm. The vibration data obtained during these tests are presented in a later section titled "Vibration Characteristics."

b. At gross weights, below 8500 pounds, the UH-1 helicopter equipped with the Model 540 "Door Hinge" Rotor exhibited one significant handling quality difference, negative dihedral effect, when compared to a standard UH-1B. The effect was slight but was present. At gross weights less than 8500 pounds and altitudes of less than 5000 feet, the requirements of paragraph 3.3.9 of MIL-H-8501A were not met. Paragraph 3.3.9 requires positive dihedral effect under all flight conditions. Under increased gross weight loadings (8500 pounds and up) and at altitudes above 5000 feet, the helicopter demonstrated positive dihedral effect at the trim conditions of Table I of MIL-H-8501A.

The static longitudinal control position and force gradients were similar to those of a standard UH-1B at speeds up to 110 knots IAS. At speeds higher than 110 knots IAS, the gradients decreased rapidly and became too small for satisfactory service use at speeds greater than 125 knots IAS. This characteristic must be improved in order to comply with parpgraph 3.2.10 of MIL-H-8501A.

In addition to the trim authority limit previously discussed under "Hovering", the longitudinal trim authority was insufficient to trim out cyclic forces at airspeeds in excess of 120 knots IAS.

Ths usable level flight envelope extends to speeds above 120 knots IAS, and this characteristic must be corrected in order to be suitable for service use and to comply with paragraph 3.2.2. of MIL-H-8501A.

c. A brief investigation of high altitude handling qualities revealed no significant change from the standard UH-1B rotor when operated under similar high altitude conditions. At a density altitude of 15000 feet and a gross weight of 7500 pounds, the helicopter demonstrated positive static longitudinal stability, positive static lateral-directional stability and positive dihedral effect.

d. Although the UH-1 equipped with the Model 540 "Door Hinge" Rotor had a higher maximum speed than a standard UH-1B because of the absence of structure and vibration limits, range performance under similar conditions was not markedly different from that of the standard UH-1B. Analysis of the data collected during this program revealed that at rotor thrust coefficients below .00492 (See Figure 7), the range performance was less than that of a standard UH-1B. The cruise speeds with the "Door Hinge" Rotor increased, however, approximately 6 knots under high gross weight (8500 pounds) conditions. The increase was due to the capability of the "Door Hinge" Rotor to achieve optimum cruise speeds prior to encountering structure or vibration limits as is the case for the standard UH-1B rotor. There was no marked decrease in level-flight power required as claimed by the manufacturer in bell Report 540-099-001, titled "Preliminarmy Flight Test Results for the Model 540 Rotor System." Sea level cruise at all gross weights below 9850 pounds required more power for the "Door Hinge" Rotor than for the standard UH-1B.

e. The level-flight maximum speed is considerably increased, particularly at high gross weights, because of the capability of the "Door Hinge" Rotor to operate at power limited speeds without encountering vibration or structure limits. This will be discussed in detail in the section titled "Vibration Characteristics".

7. Maneuvering Flight

The maneuvering flight characteristics of the UH-1 were considerably improved by the installation of the "Door Hinge"Rotor. The improvement was due to the absence of blade stall and the ability of the rotor to operate smoothly at a high load factor. The allowable maneuvering envelope as defined by Bell is presented in Figure 67.

Qualitative tests within this envelope did not reveal any handling qualities problems and vibration levels remained low during maneuvering flight.

TABLE II

VIBRATION CHARACTERISTICS DURING MANEUVERING FLIGHT

			2 Per Rev Vibration				
Maneuver	**Density Altitude**	**V_{True}**	**Pilot Vertical**	**Copilot Vertical**	**Copilot Lateral**	**Sta. 123 Vertical**	**Sta. 123 Lateral**
1.6 g turn (7100 lb)	**920 ft**	**115 kt**	**.11g**	**.19g**	**.07g**	**.03g**	**.20g**
1.40g turn (9300 lb)	**2300 ft**	**109 kt**	**.09g**	**.19g**	**.20g**	**.06g**	**.15g**

(MIL-H-8501A Limits for transient condition are .3g)

Blade stall was not a maneuvering limit within the envelope investigated.

High speed turning flight was possible up to the limits of the installed power plant. During later testing of possible production configurations, the stick force per g characteristics should be established with an instrumented helicopter to insure satisfactory gradients.

8. Autorotational Characteristics

The autorotational characteristics of the UH-1 equipped with the "Door Hinge" Rotor were evaluated over a range of gross weight, center-of-gravity, and altitude conditions.

The hovering autorotational characteristics have been discussed previously in Section F.3 and will not be discussed again in this section.

Autorotation entries were performed at 6850 pounds and at 9150 pounds over a range of speeds up to the power limited maximum speeds. In all cases, the autorotation entry trim change was mild and easily controllable about all axes. The highest autorotation entry speed investigated was 137 knots calibrated airspeed at 6850 pounds.

The rotor rpm decay rate is considerably lower than that of a standard UH-1B under similar loading conditions (See Figure 19). The rotor had sufficient inertia to safely allow a two second collective hold under all test conditions. Rotor rpm buildup and collective control of the rotor rpm were satisfactory under all conditions tested.

Table III illustrates the relative inertia characteristics of the UH-1 series rotors:

[redacted]

The autorotational rate of descent is higher than that of a standard UH-1B under similar loading conditions. The "Door Hinge" Rotor demonstrates the characteristic of decreasing rate of descent in autorotation with increasing gross weight. This unusual situation is probably a result of the effect of the twist in the rotor blades and of the lift-drag ratios of airfoil sections as functions of angle of attack.

Autorotational touchdowns under the low density altitude conditions present during tests were easily accomplished at all gross weights up to 9500 pounds. The high rotor inertia allowed the flare and touchdown maneuvers to be performed without undue haste on the part of the pilot. An IAS of 70 knots and a rotor rpm of 320-324 were used on final approach, and a slight amount of up collective was required during the flare to prevent excessive rotor rpm buildup. No attempt was made during this program to refine pilot techniques sufficiently to allow minimum speed touchdowns. All touchdowns were made with a forward speed of 15-20 knots IAS.

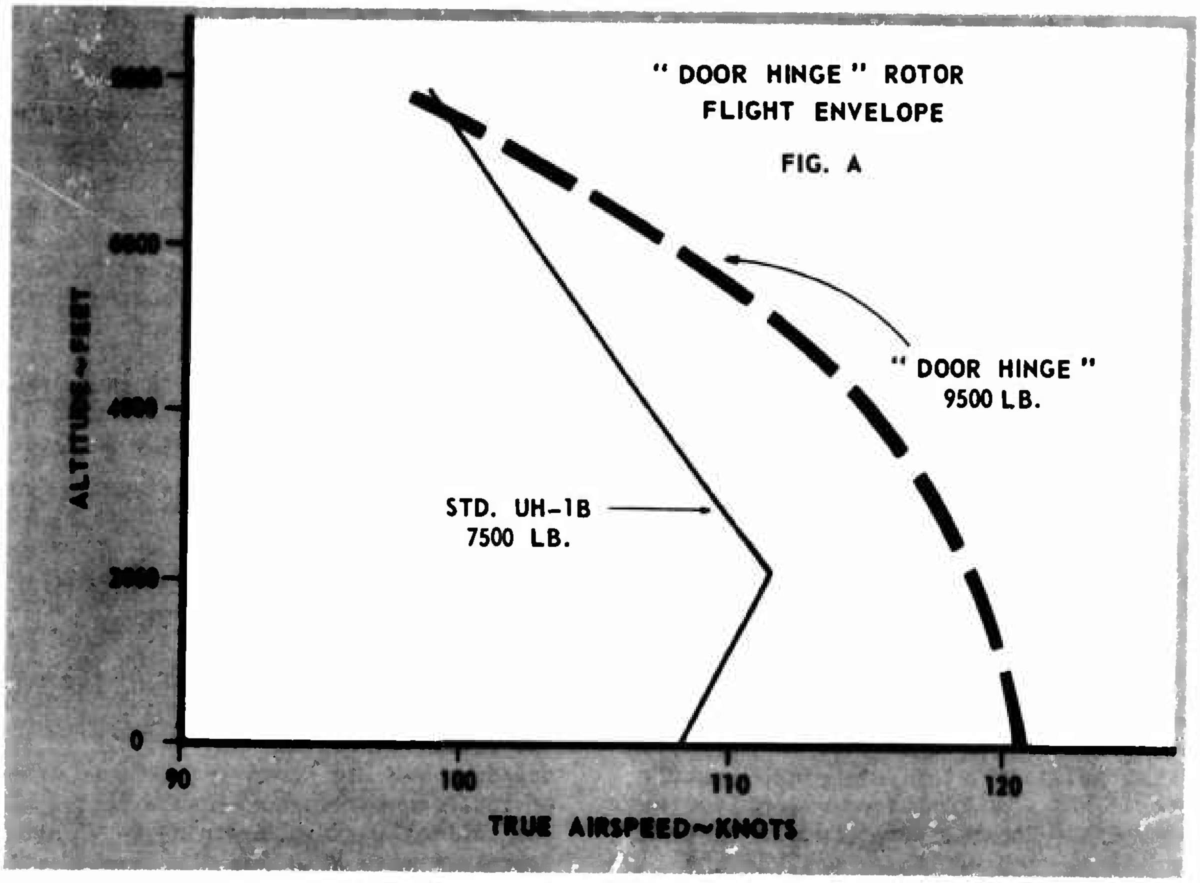
Based on a qualitative comparison, the test helicopter demonstrated a significant improvement over the autorotation characteristics of both the UH-1B and UH-1D helicopters and its characteristics were considered to be excellent.

The height-velocity curve characteristics have not been demonstrated by the contractor and this must be accomplished if the rotor system is procured for service use.

9. Vibration Characteristics

The vibration characteristics of the UH-1 equipped with the Model 540 Rotor System were improved considerably compared to standard UH-1 helicopters. Vibration levels were generally within the limits of MIL-H-8501A at all conditions that could be achieved during power-limited level flight, acceleration and deceleration. During a high speed descending maneuver at 156.5 knots true airspeed the four per rev components of the pilot vertical, copilot lateral and the Station 123 lateral vibrations exceeded the limits of MIL-H-8501A (See Figure 40). The one and two per rev components, however, remained within MIL-H-8501A limits during the same maneuver.

The large decrease in vibration levels of the "Door Hinge" Rotor equipped helicopter allowed a considerably enlarged flight envelope to be investigated (See Figure A). Because of the decreased vibration and stress levels, operation at 9500 pounds could be performed at speeds in excess of those previously established as limits for a UH-1 weighing 7500 pounds.



The increase in allowable airspeeds and gross weights represents a considerable increase in mission productivity.

Additionally, it was determined during the test program that the vibration characteristics were not adversely affected by changes in rotor rpm, gross weight, or center-of-gravity location. During hovering flight, over the entire range of allowable power-on rotor rpm (285-330) and at gross weights of 6770 pounds, 7170 pounds and 9630 pounds the vibration levels remained essentially constant (See Figures 23 through 34) and below the maximum allowable values of MIL-H-8501A. In forward flight, the helicopter vibration characteristics demonstrated the same insensitivity to changes in rotor rpm (See Figures 35 through 37). Changes in airspeed had more apparent effect on vibration levels.

The vibration tests revealed that the one-per-rev vibrations increased slightly, the two-per-rev vibrations were significantly reduced, and the four-per-rev vibrations were similar to those of a standard UH-1B at similar loading conditions. In all cases, the level-flight vibration levels were generally within the limits of MIL-H-8501A and the level-flight envelope of speed versus altitude was not vibration limited at any gross weight or altitude tested.

10. Airspeed Calibration

A joint contractor-Army effort established the airspeed calibration presented in Figure 62. A trailing bomb was used as a standard. Insufficient data was collected to allow presentation of a correction curve for the climb situation. A correction of negative one knot was assumed for climb situations based on previous contractor data.

11. Miscellaneous

During the early flights of this program, the test helicopter demonstrated an unsatisfactory amount of transmission pylon motion identified by the contractor as "pylon rock." The motion was characterized by a movement of the pylon assembly at a frequency of one-half cycle per revolution of the rotor. The result was an uncomfortable random angular acceleration of the helicopter that was predominantly lateral but also contained a longitudinal component. In an attempt to eliminate the condition, the contractor applied the following corrective action:

a. The pylon dampers were replaced by new parts, No. 204-031-960-1.

b. The pylon dampers were replaced by a new model, part No. 204-031-960-3, which provided a 50 percent increase in damping.

c. The stabilizer bar dampers were replaced.

d. .015 inch shims were installed in the pylon dampers to reduce the lost motion normally present and further increase damping.

e. .070 inch shims were installed in the pylon dampers to eliminate all lost motion.

f. The pylon mounts were changed to units with a 10000 pound/inch spring rate. The original units had a spring rate of 4500 pound/inch.

After all these changes were incorporated, undamped pylon rock was not present. Pylon rock could be induced, but damped rapidly (3 or 4 cycles). Production hardware will have to demonstrate freedom from this objectionable oscillation in order to be suitable for service use.

Some degree of difficulty was experienced during the program with maintaining proper rotor track at the extremes of gross weight and center-of-gravity locations. This may have been caused by the quality control of the contour of the prototype rotor blades. Production hardware will have to demonstrate the capability of maintaining proper track under all allowable flight and loading conditions.

Both cyclic and collective boost off control forces were excessive at helicopter gross weights above 8000 pounds. Rudder pedal forces were satisfactory. In addition to the high forces, a cyclic control force gradient reversal was present at airspeeds slightly above 100 knots IAS. At approximately 110 knots IAS, the high cyclic control forces reduced to zero. The investigation was not carried to airspeeds above 110 knots IAS because of lack of instrumentation to measure control loads. The collective forces during boost off operation were high and the pilot was limited to a range of mid-collective settings by the forces. The power range available was too small for landing attempts at high gross weights. Compliance with paragraph 3.5.8 of MIL-H-8501A must be demonstrated before the rotor system is acceptable for service use on the UH-1 helicopter.

During "quick stop" maneuvers, careful monitoring of rotor rpm was necessary to avoid exceeding the upper rpm limit of 330. This limit rpm is too low, considering that the power-on speed for normal flight is 323 rotor rpm (6600 engine rpm). The limit rotor rpm must be raised to at least the value of the present UH-1B rotor (339 rpm) before the rotor system can be considered satisfactory for service use.

The fatigue life of the "Door Hinge" Rotor System has not been established. The appropriate testing must be accomplished before the rotor can be considered suitable for service use.

Throughout the limited military evaluation, the contractor was concerned about the rotating control system and the tail rotor and consequently performed frequent inspections. The bolts in the rotating control systems were changed once. These components experienced high loads at the flight conditions that were achieved with the "Door Hinge" Rotor, and some redesign may be necessary to provide structural harmony in all dynamic components. The strength and fatigue life of the dynamic components must be established for the case of power limited level flight envelope before the rotor system is suitable for service use.

During one flight, two of the four mounting bolts for the modified collective "A Frame" broke in flight, allowing movement of the mount and "A Frame." The result was a large-amplitude self exciting one-per-rev vertical vibration. The vibration damped before the helicopter damaged itself and a successful landing was accomplished without further incident. Increased-strength components were installed, and there was no repetition of the problem during the remainder of the program. Although the affected components were not exactly the same as production hardware, the incident serves to emphasize that the control loads are higher than those of a standard rotor and strengthened hardware must be developed.

G. Conclusions

The Model 540 "Door Hinge" Rotor System is a significant breakthrough in the state-of-the-art of two-bladed teetering rotor design. The design concept of the Model 540 Rotor System is unique because it attacks the helicopter vibration problem at its source instead of attempting to provide "vibration cancellation." In addition, this system is not a "tuned system" and is not sensitive to rotor rpm, gross weight or other parameters that commonly affect helicopter vibration levels. For this reason, service use "Door Hinge" Rotors could be expected to provide low vibration levels without special maintenance or attention common to "tuned damper" systems.

The installation of the Model 540 Rotor System on a standard UH-1 helicopter would improve the vibration characteristics, increase the allowable level-flight airspeeds, increase the climb service ceiling, improve the autorotation characteristics, increase the maximum turning load factor that may be utilized, and allow operation at gross weights up to 9500 pounds.

Blade stall is notably absent over the complete flight envelope.

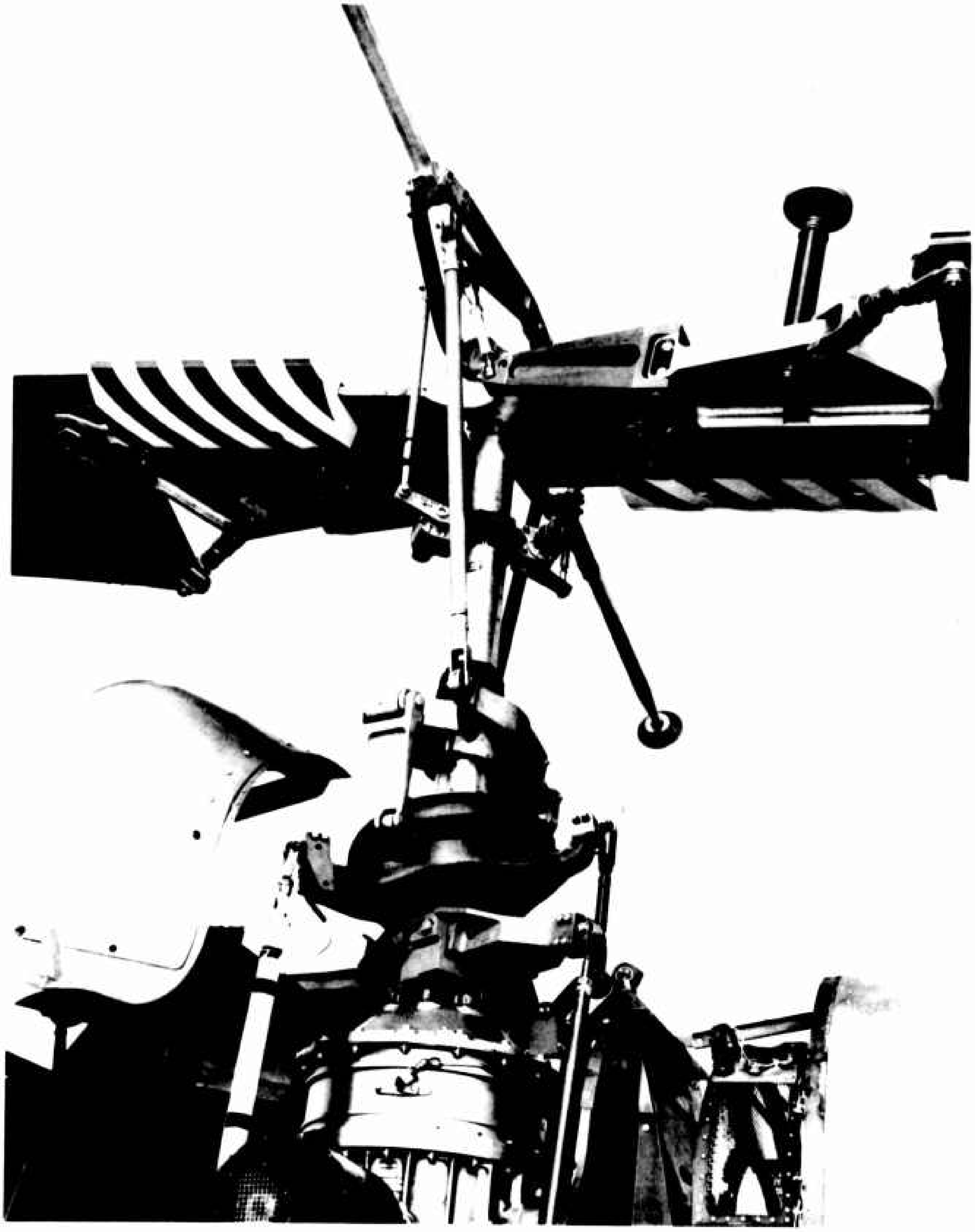
The capability to operate at the power-limited maximum speed at all gross weights relieves the pilot of the task of observing variable airspeed placards. This causes a reduced requirement for pilot attention.

The autorotation entry characteristics are excellent at all gross weights and center-of-gravity loadings up to the power-limited speeds for each configuration. This characteristic is highly desirable for helicopter missions in which the possibility of engine damage from ground fire or other causes is present during high speed flight. The problem of coping with large or violent trim changes in the event of engine failure would be minimized. This desirable characteristic should improve mission effectiveness and provide increased safety for flight crews.

At high gross weights, the UH-1B would be more efficient in level flight with the Model 540 Rotor System installed because the optimum cruise speeds may be attained everywhere in the flight envelope without regard to structural and vibration limits.

Considerable development remains to be performed, however, prior to procurement of the rotor system for general service use.

Other changes that would be caused by the rotor installation on the UH-1B are a decrease in out-of-ground-effect hovering performance, a small decrease in low-altitude low-gross-weight range performance, and a decrease in low-altitude climb performance. The performance decreases have not been pointed out in any of the contractor's proposal statements, but are not considered to be serious deficiencies.



THE MODEL 540
" DOOR HINGE " ROTOR SYSTEM

H. Recommendations

1. General

a. The Model 540 "Door Hinge" Rotor should be strongly considered for retrofit or application to the present UH-1 series helicopters.

b. Pending development of another rotor system with more promise, the Model 540 "Door Hinge" Rotor should be strongly considered for any growth version of the UH-1 helicopters or for any Bell Helicopter Company proposals for high speed designs.

2. The following recommendations are concerned with the development that must be accomplished before the Model 540 rotor is suitable for service use:

a. Provide a cyclic trim system that allows cyclic control forces to be trimmed out in accordance with the requirements of paragraph 3.2.10 of MIL-H-8501A.

b. Improve the static longitudinal cyclic control position and force gradients at speeds above 110 knots IAS to comply with paragraph 3.2.10 of MIL-H-8501A.

c. Demonstrate production configuration hardware that is free of undamped "pylon rock" at all allowable gross weight and center-of-gravity loadings within the proposed flight envelope.

d. Demonstrate production hardware that will maintain proper rotor track under all allowable gross weight and center-of-gravity loadings within the proposed flight envelope.

e. Demonstrate compliance with paragraph 3.5.8 of MIL-H-8501A in order to provide satisfactory boost-off control forces.

f. Raise upper rotor rpm limit to at least that of the present UH-1B rotor, i.e., 339 rpm.

g. The control system and other affected dynamic components such as tail rotor, must demonstrate satisfactory strength and fatigue life to allow operation at the increased speeds and gross weights available with the Model 540 Rotor System.

h. If the rotor system is developed for service use, a program of complete engineering flight tests should be scheduled by the U. S. Army Test and Evaluation Command to assure that the quality of the production hardware meets the expected improvement standards, to develop the data necessary for changes to the "Handbook of Operator's Instructions", and to determine that the adopted recommendations of this report are properly integrated in the production design.

3. The following recommendations are related with development work required to correct deficiencies that are not considered sufficiently serious to be unsuitable for service use but that should be investigated as soon as possible for improved service use.

a. Provide positive dihedral effect at light gross weights to comply with the requirements of paragraph 3.3.9 of MIL-H-8501A.

b. Establish the height-velocity characteristics of the UH-1 helicopter equipped with the Model 540 Rotor System. In view of the increased altitude capability, the contractor should demonstrate these characteristics at density altitudes up to 10000 feet and at the highest usable gross weights at the test altitudes.

Reviewed and approved by:

RICHARD J. KENNEDY, JR
Lieutenant Colonel, TC
Commanding

PART II GRAPHICAL ANALYZED TEST DATA

FIGURE NO. 1
HOVERING CEILING OUT OF GROUND EFFECT
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204B N73977

323 ROTOR RPM

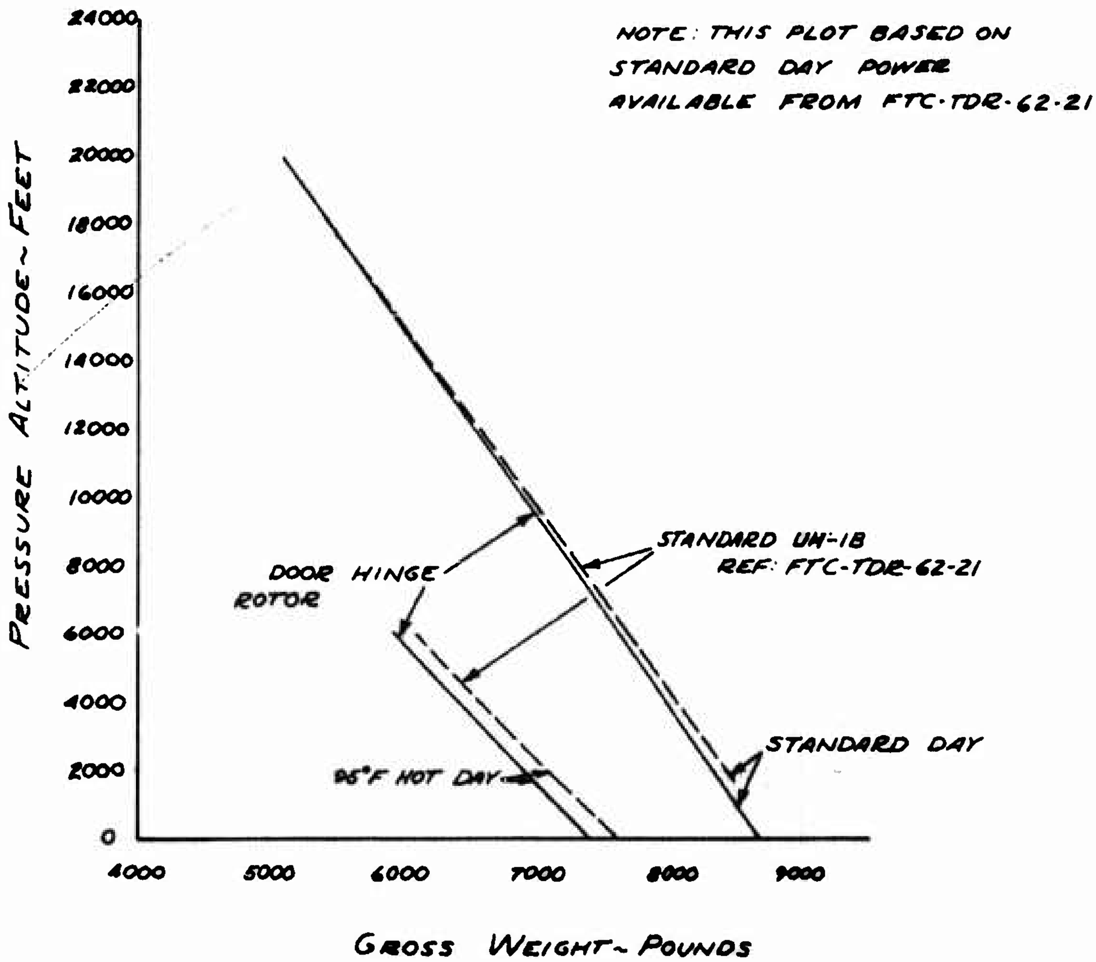


FIGURE NO. 2

NON-DIMENSIONAL HOVERING PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204B N73977

OUT OF GROUND EFFECT

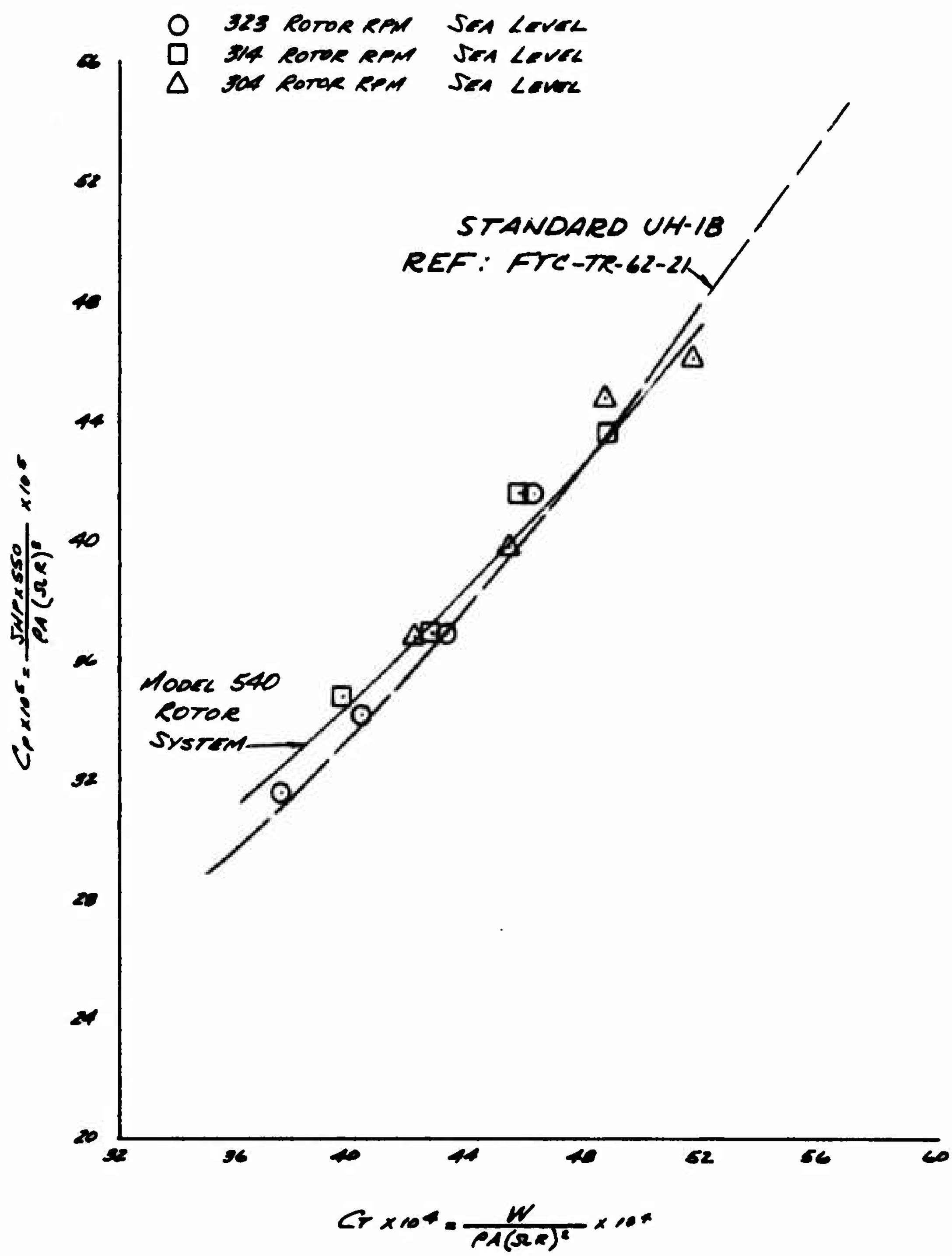


FIGURE No. 3

ESTIMATED SERVICE CEILING VS GROSS WEIGHT

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204 B N73977

323 ROTOR RPM

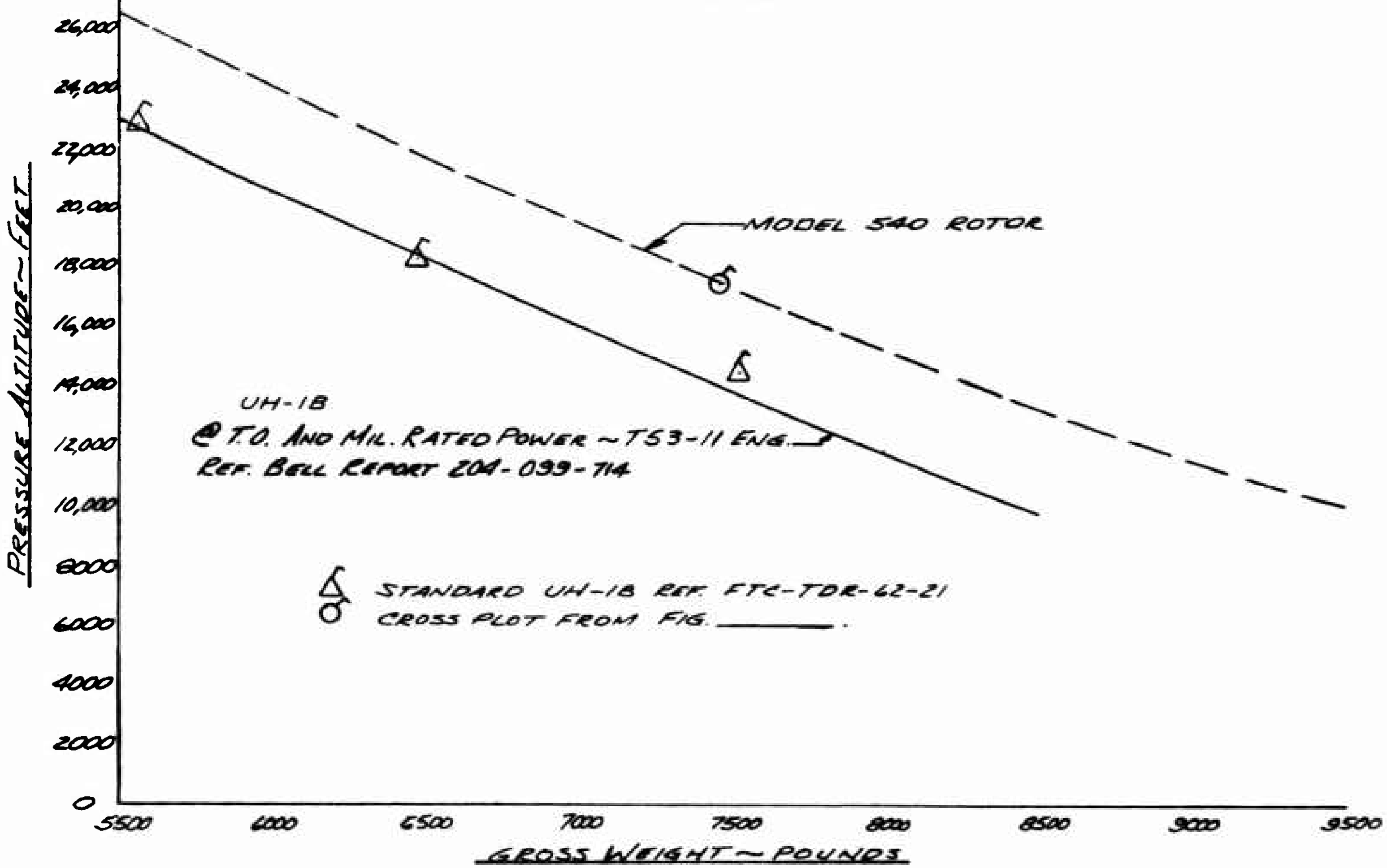


FIGURE No.4

CLIMB PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

7660 LBS AT SEA LEVEL

322.5 ROTOR RPM

C.G. STA. MID

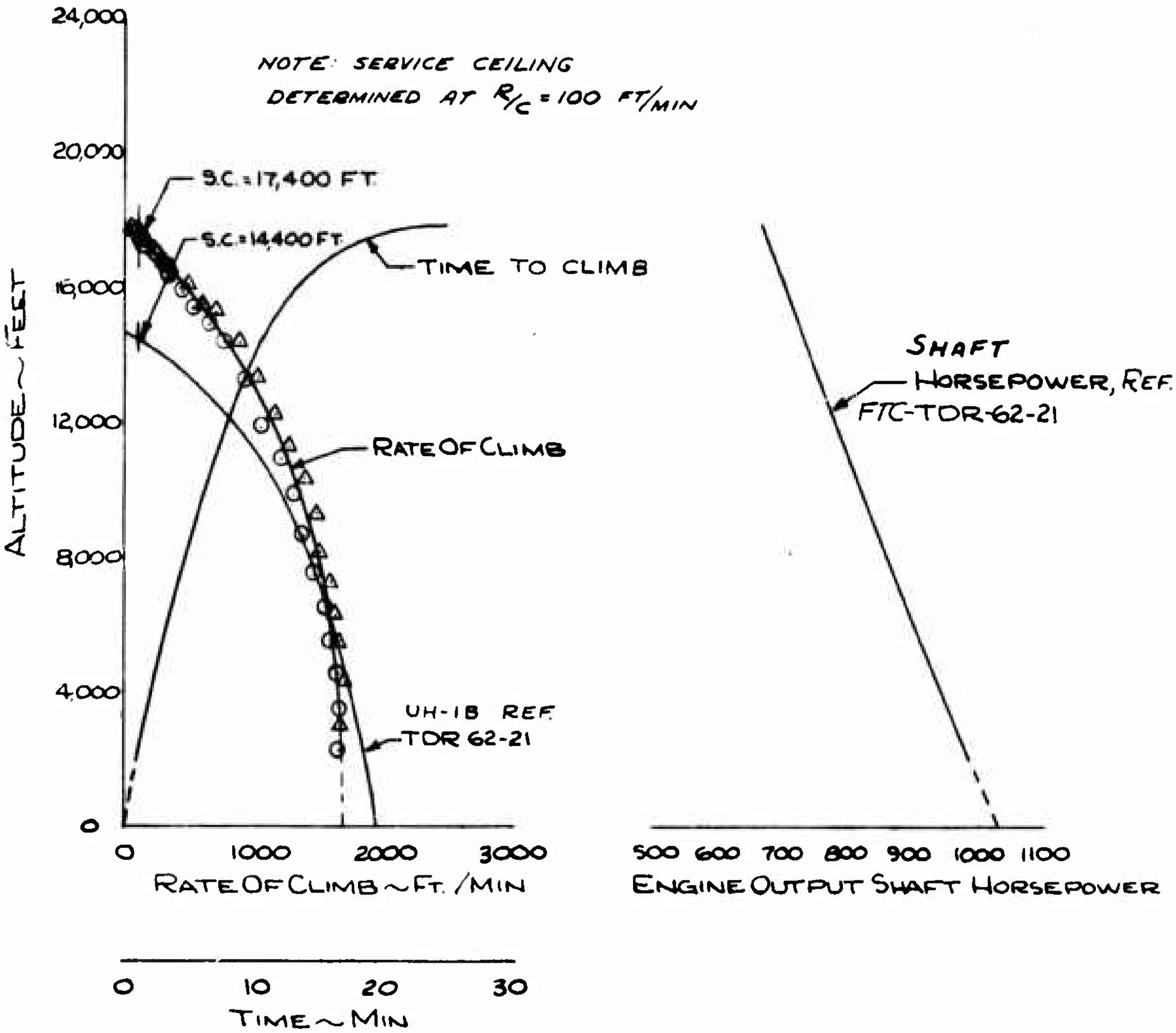


FIGURE 4 (CONT'D)

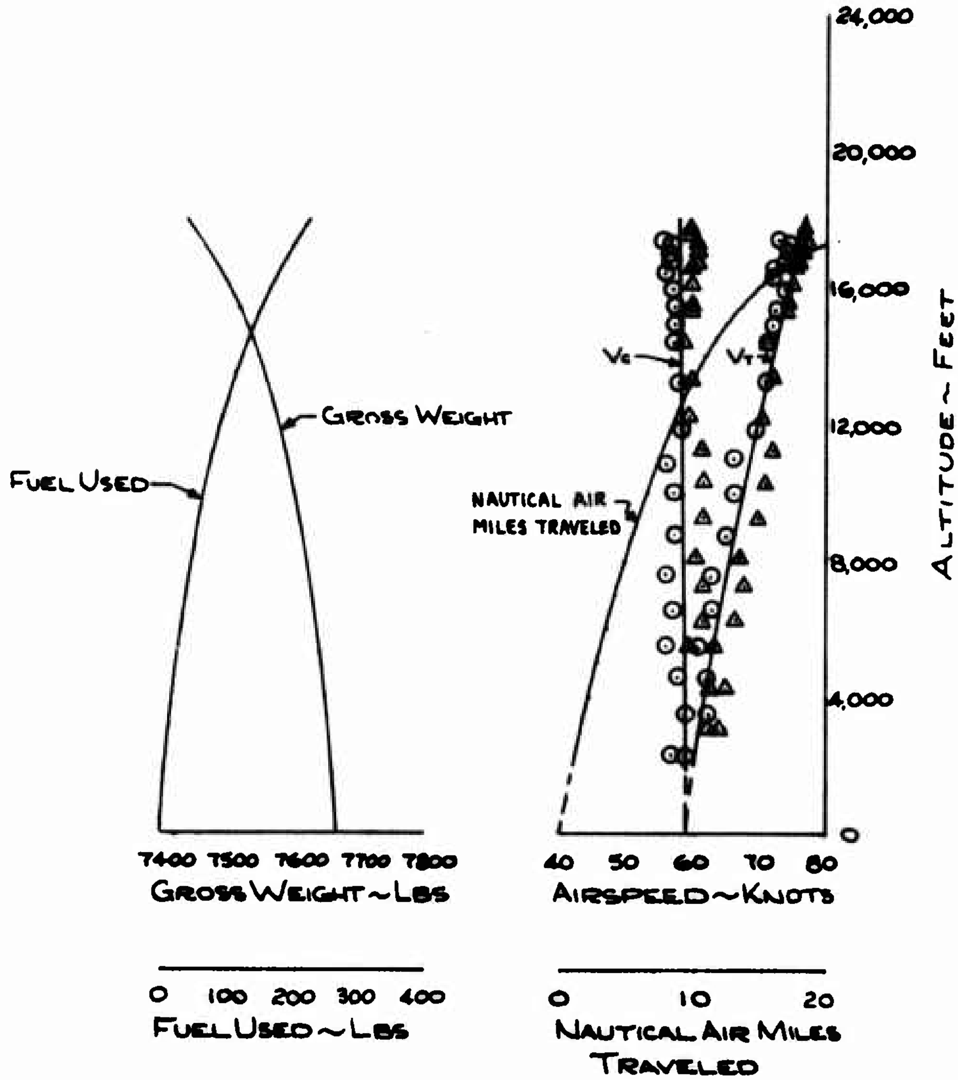


Figure No. 5
Climb Performance
Door Hinge Rotor System
Bell Model 204-B N73977
7660 Lbs At Sea Level
322.5 Rotor RPM
C.G. Sta. Mid

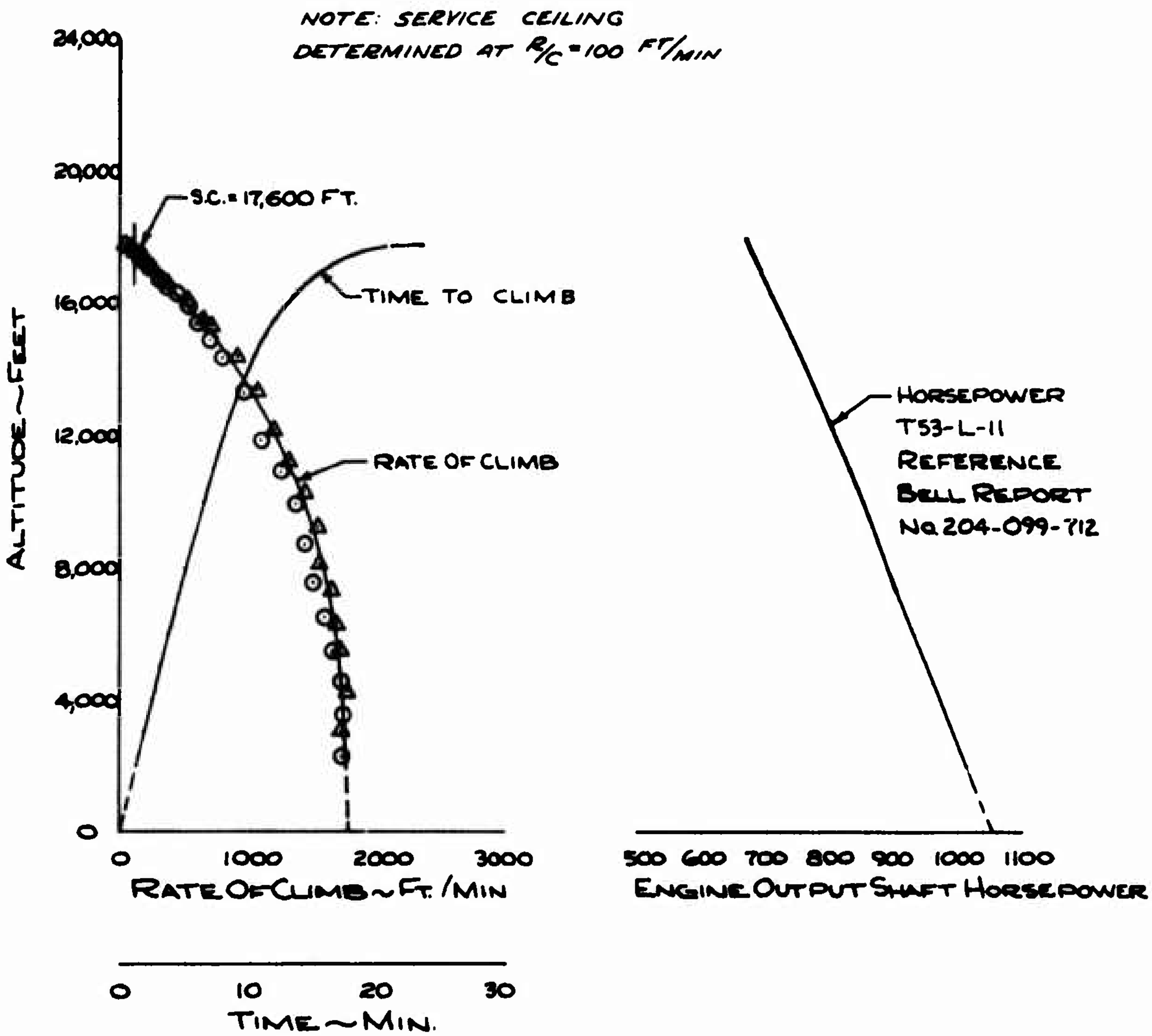


FIGURE NO. 5 (CONT'D)

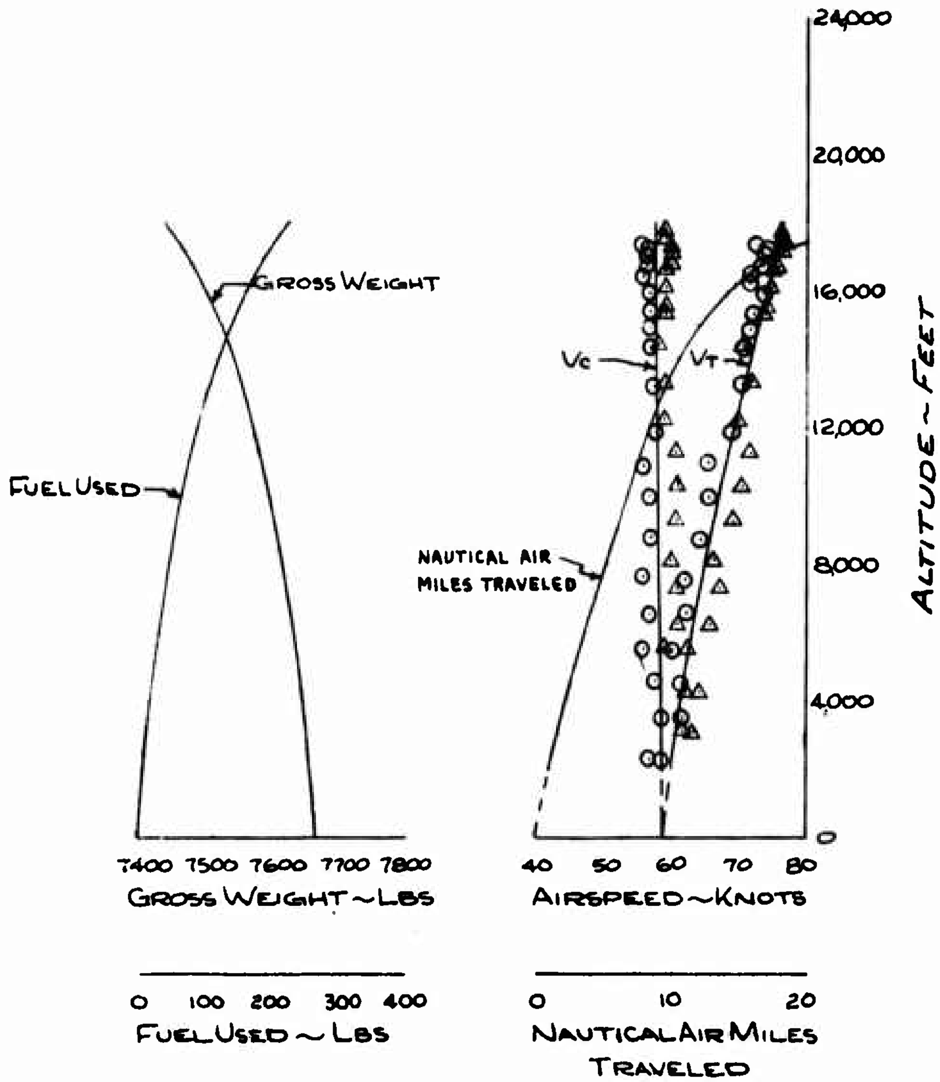


Figure No. 6
Maximum Permissible Speed
Door Hinge Rotor System
Bell Model 204-B N73977

323 Rotor RPM
Take-Off Power

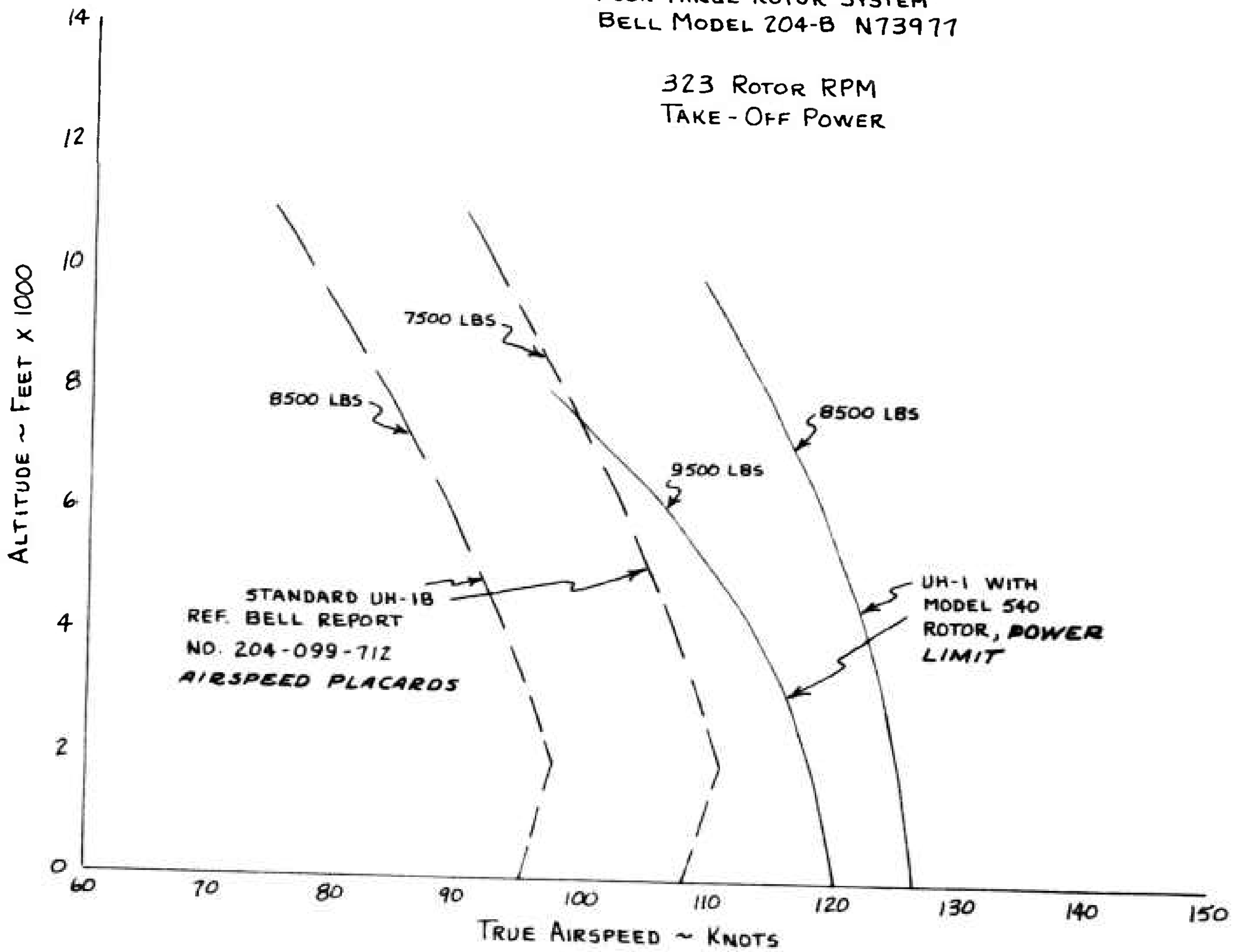
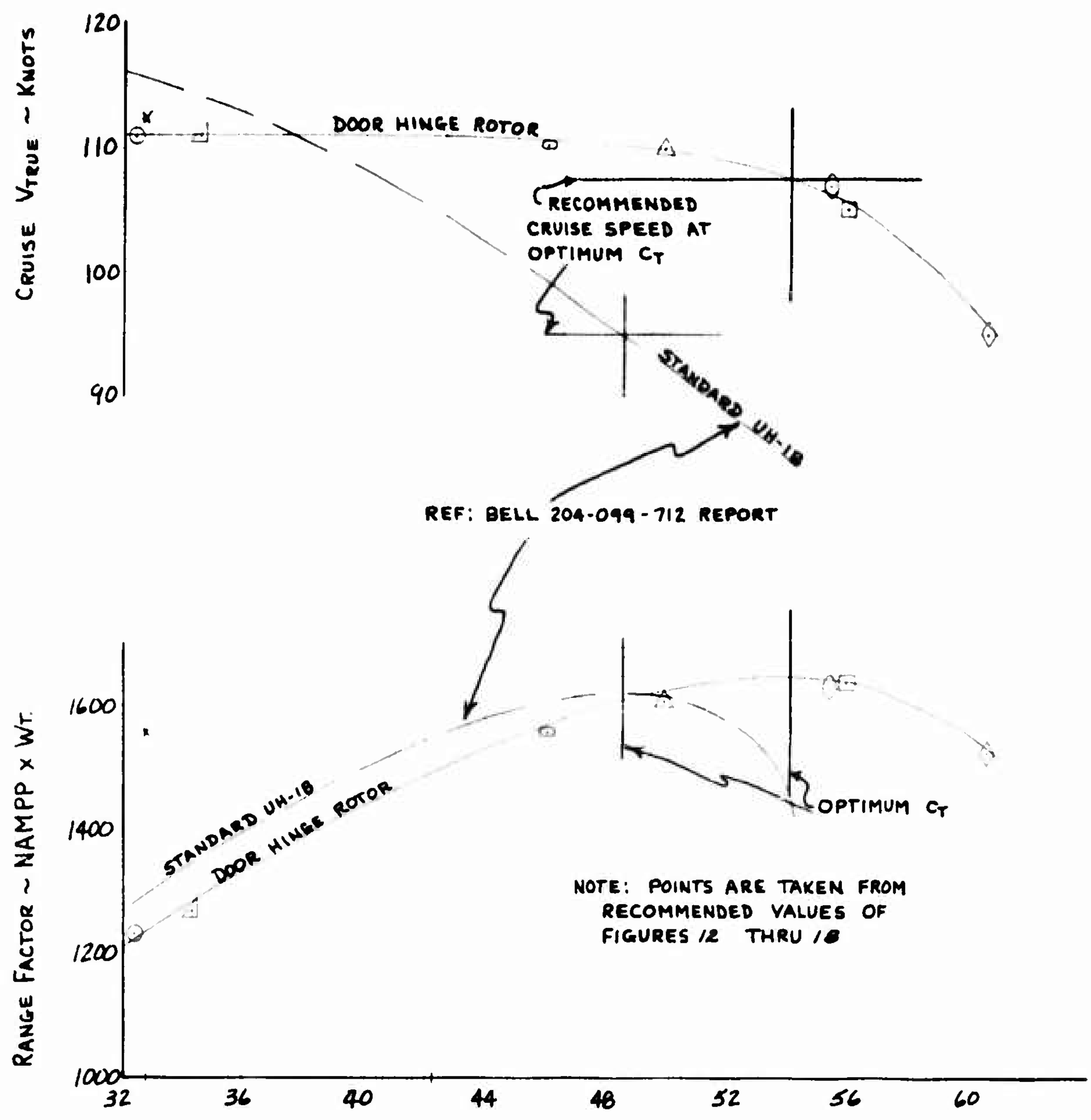


FIGURE No. 7

LEVEL FLIGHT SUMMARY

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977



$$C_T \times 10^4 = \frac{W}{\rho A (\Omega R)^2} \times 10^4$$

Figure No. 8

Non-Dimensional Level Flight Performance

Door Hinge Rotor System

Bell Model 204-B N73977

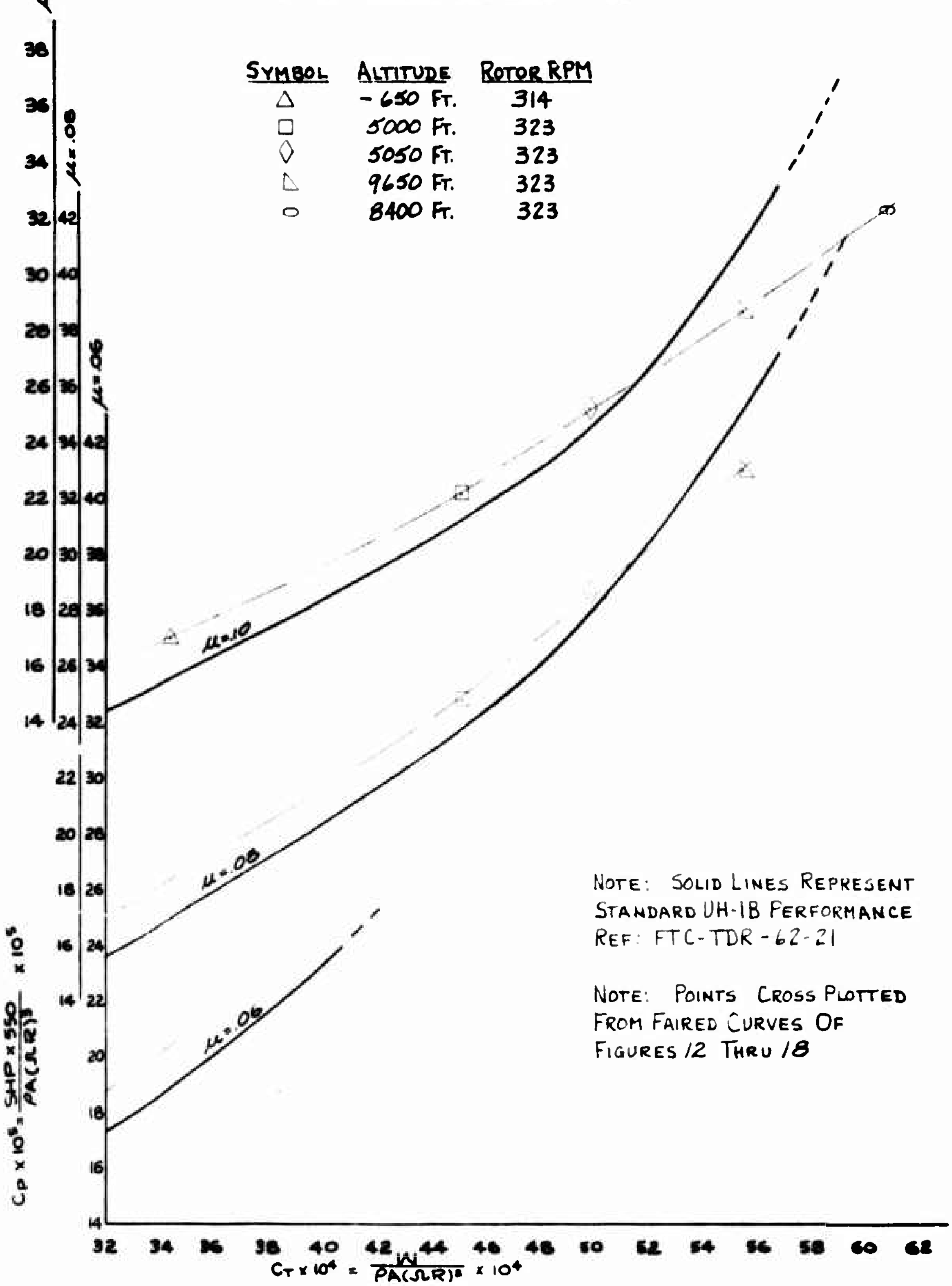


FIGURE NO. 9
NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

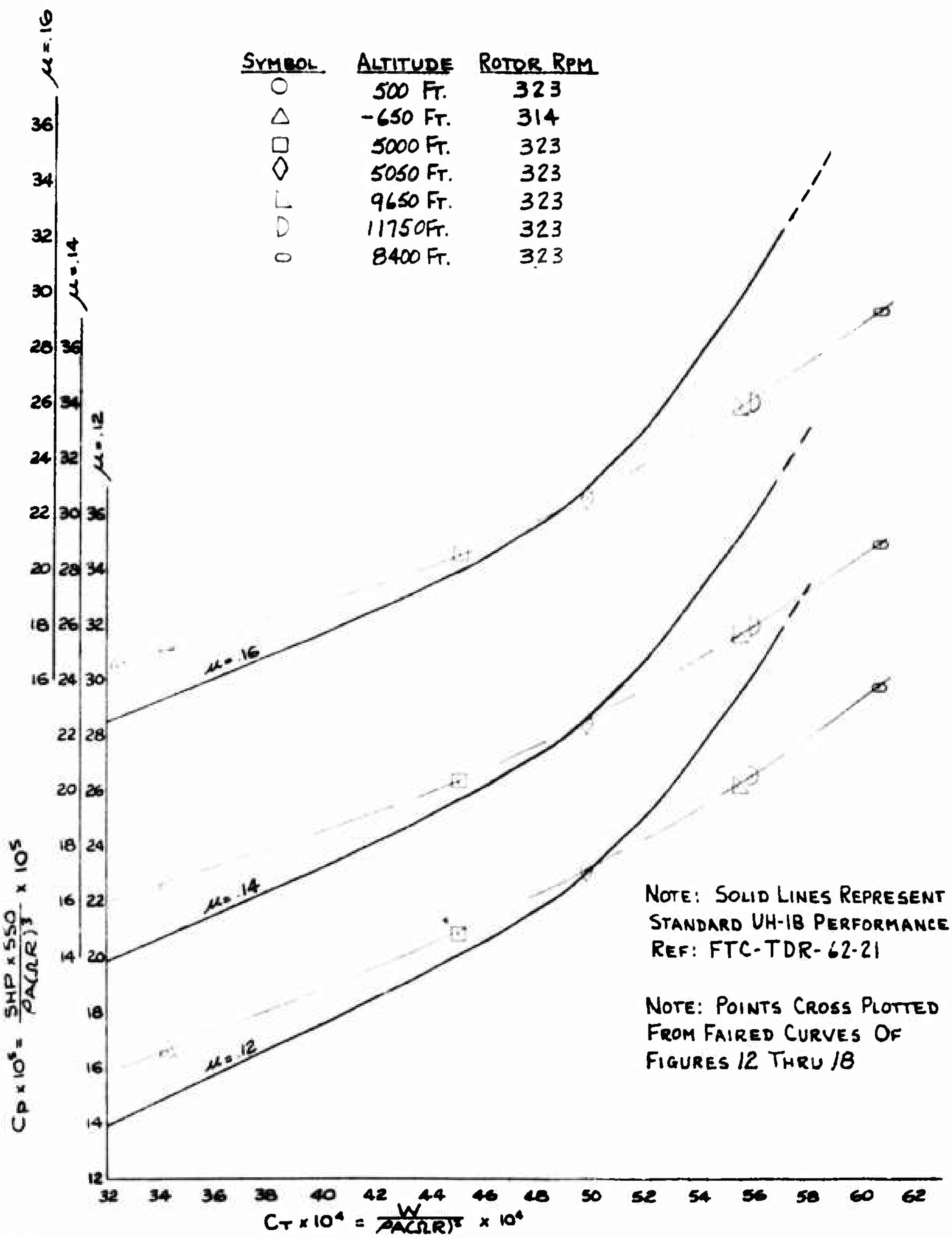


FIGURE NO. 10

NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

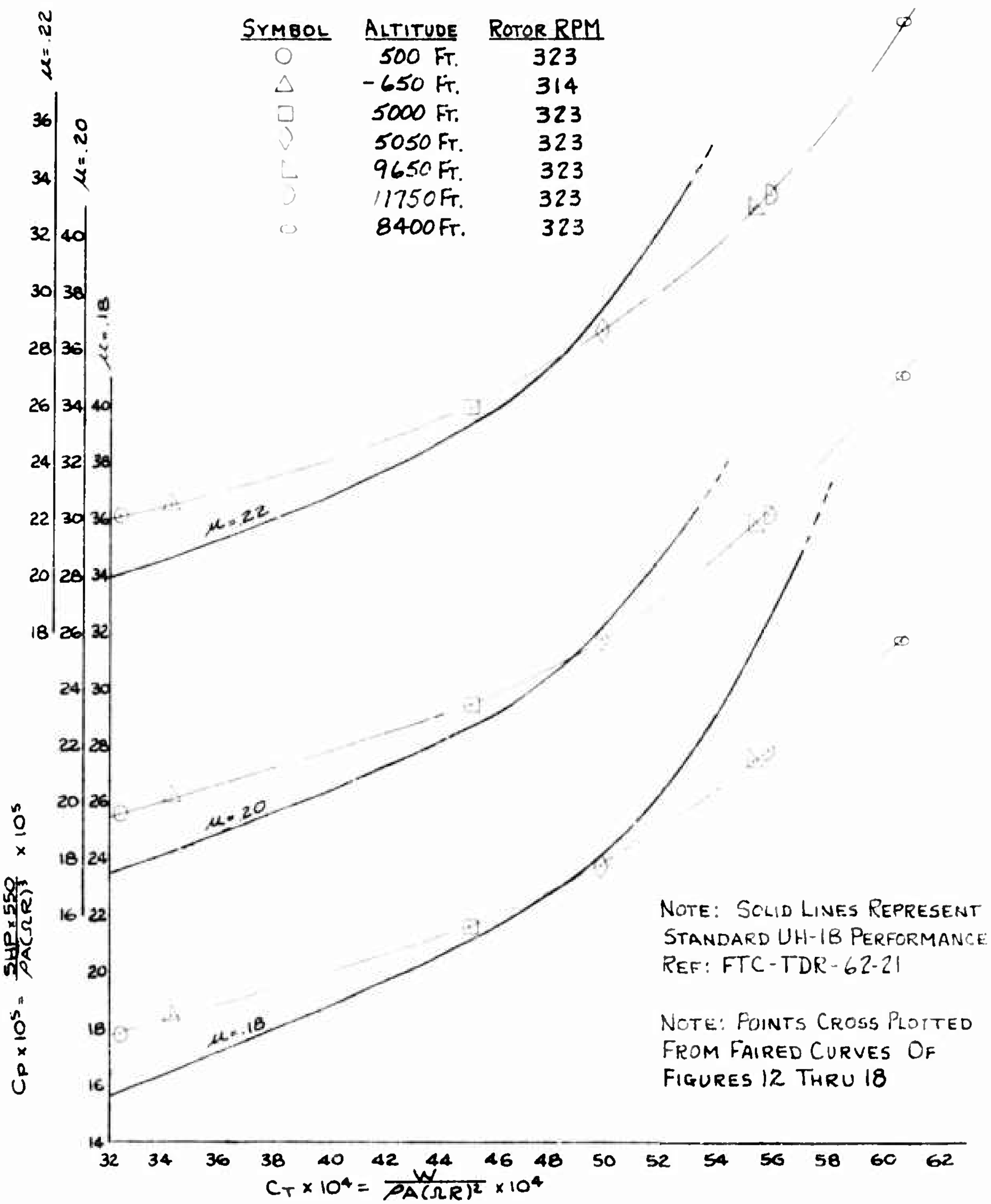
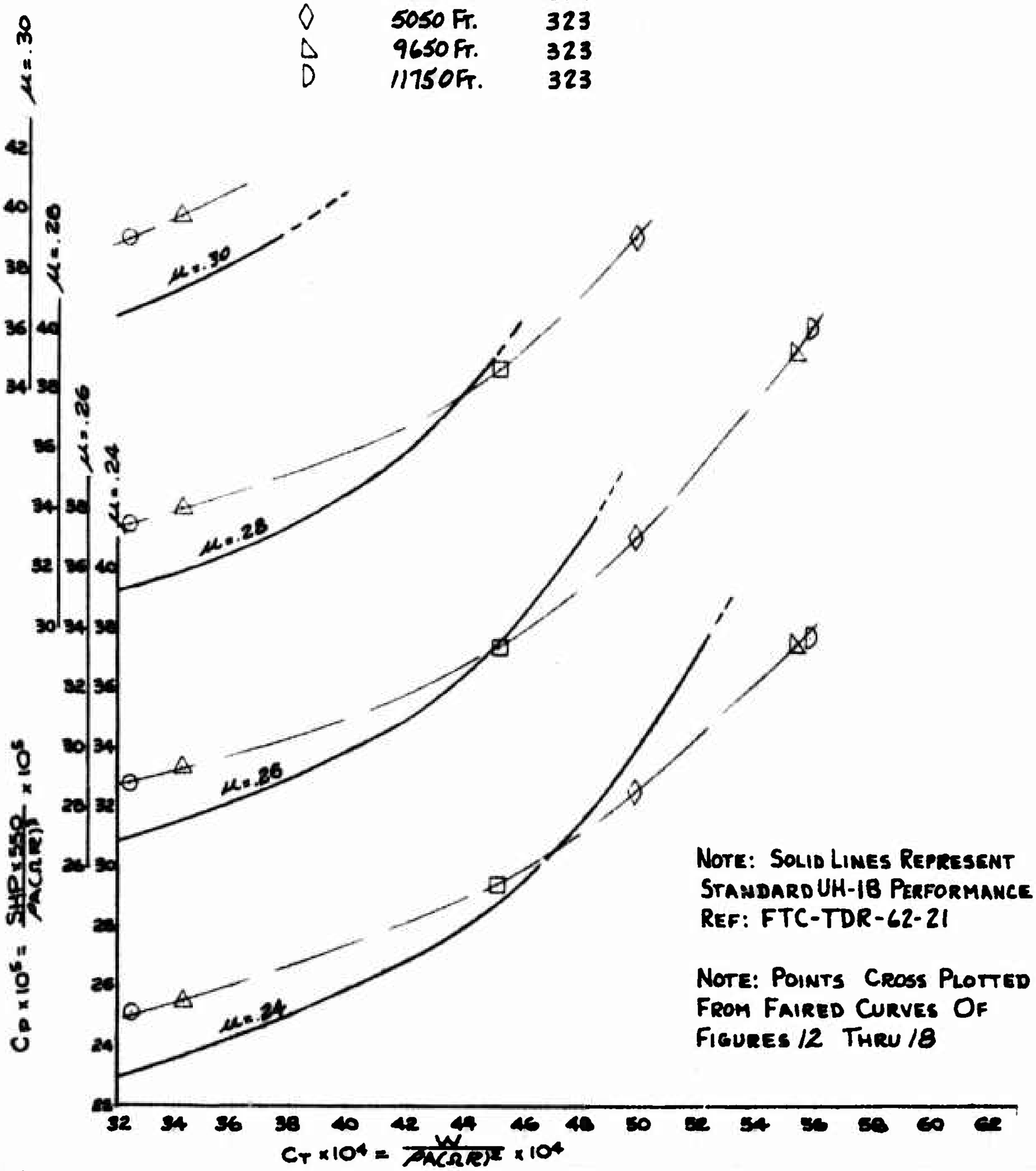


FIGURE NO. 11
NON-DIMENSIONAL LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

SYMBOL	ALTITUDE	ROTOR RPM
○	500 FT.	323
△	-650 FT.	314
□	5000 FT.	323
◇	5050 FT.	323
◺	9650 FT.	323
D	11750 FT.	323



NOTE: SOLID LINES REPRESENT STANDARD UH-1B PERFORMANCE REF: FTC-TDR-62-21

NOTE: POINTS CROSS PLOTTED FROM FAIRED CURVES OF FIGURES 12 THRU 18

FIGURE NO. 12

LEVEL FLIGHT PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N78977

RPM ~ 323 (ROTOR)
ALTITUDE ~ 500 FT.
CT ~ .00384
GROSS WEIGHT ~ 6380 LBS.
CENTER OF GRAVITY ~ MID

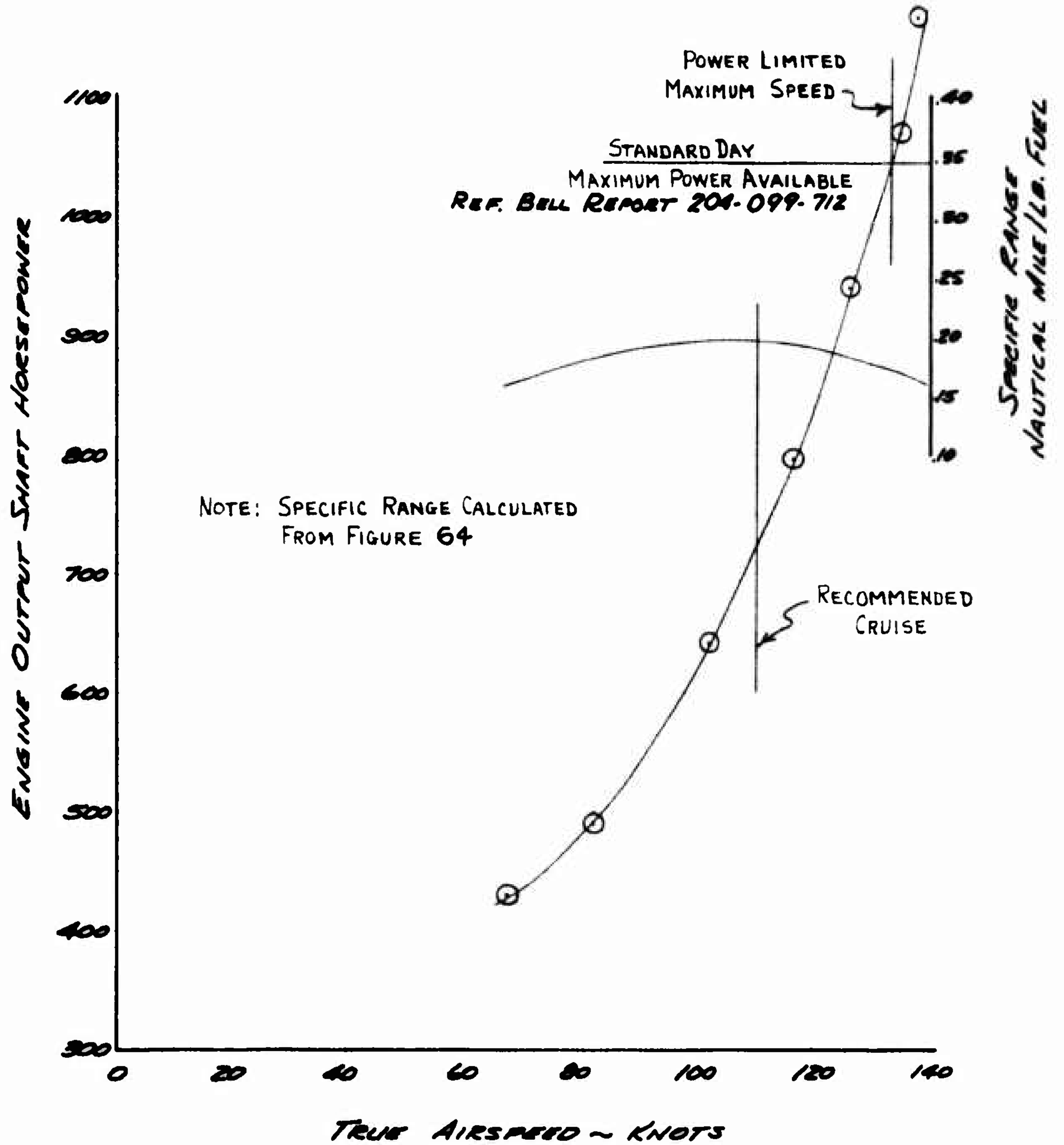


FIGURE NO. 13

LEVEL FLIGHT PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

RPM ~ 314 (ROTOR)
ALTITUDE ~ -650 FT.
CT ~ .00343
GROSS WEIGHT ~ 6615 LBS.
CENTER OF GRAVITY ~ MID

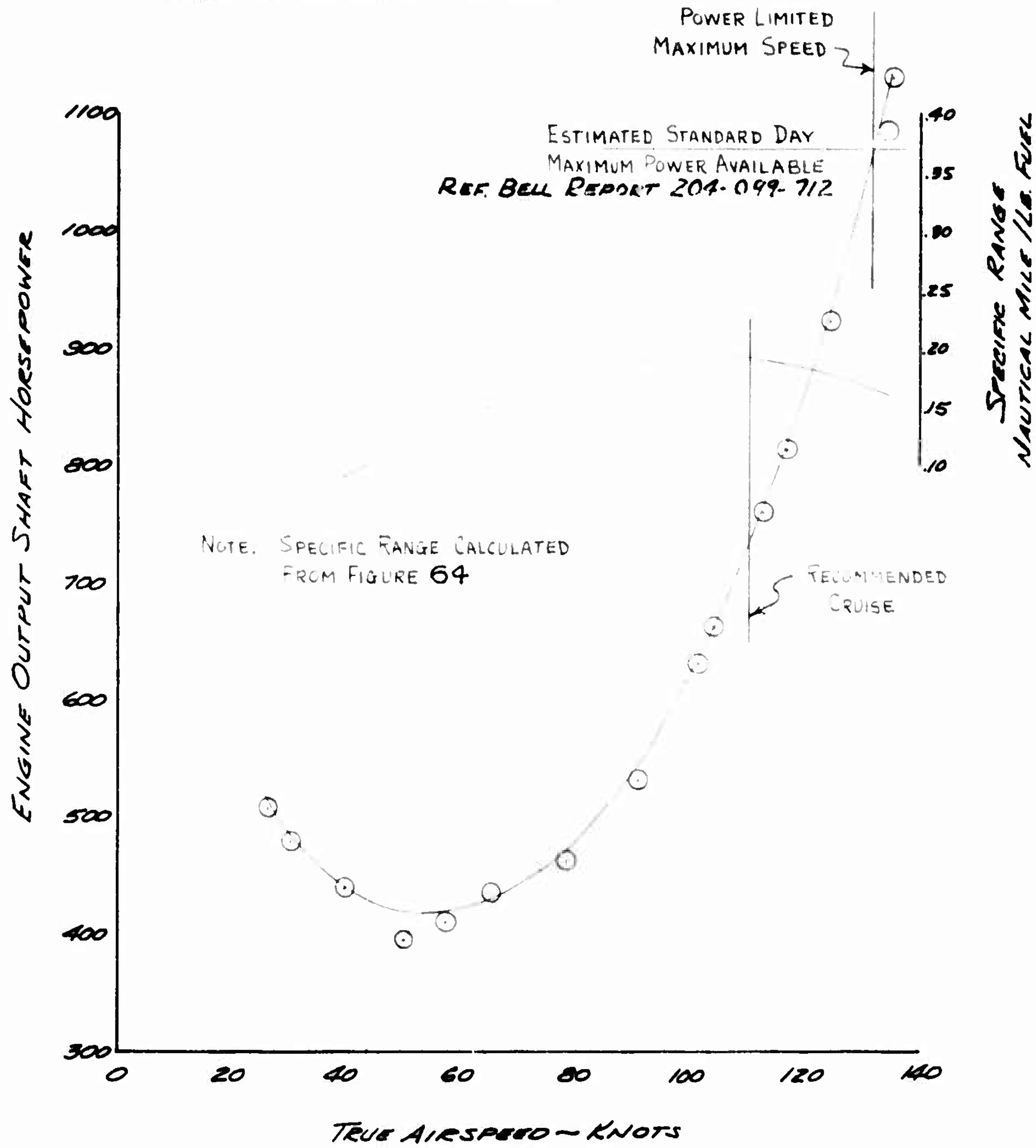


FIGURE NO. 14
LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

RPM ~ 323 (ROTOR)
ALTITUDE ~ 5000 FT.
CT ~ .00450
GROSS WEIGHT ~ 7730 LBS.
CENTER OF GRAVITY ~ MID

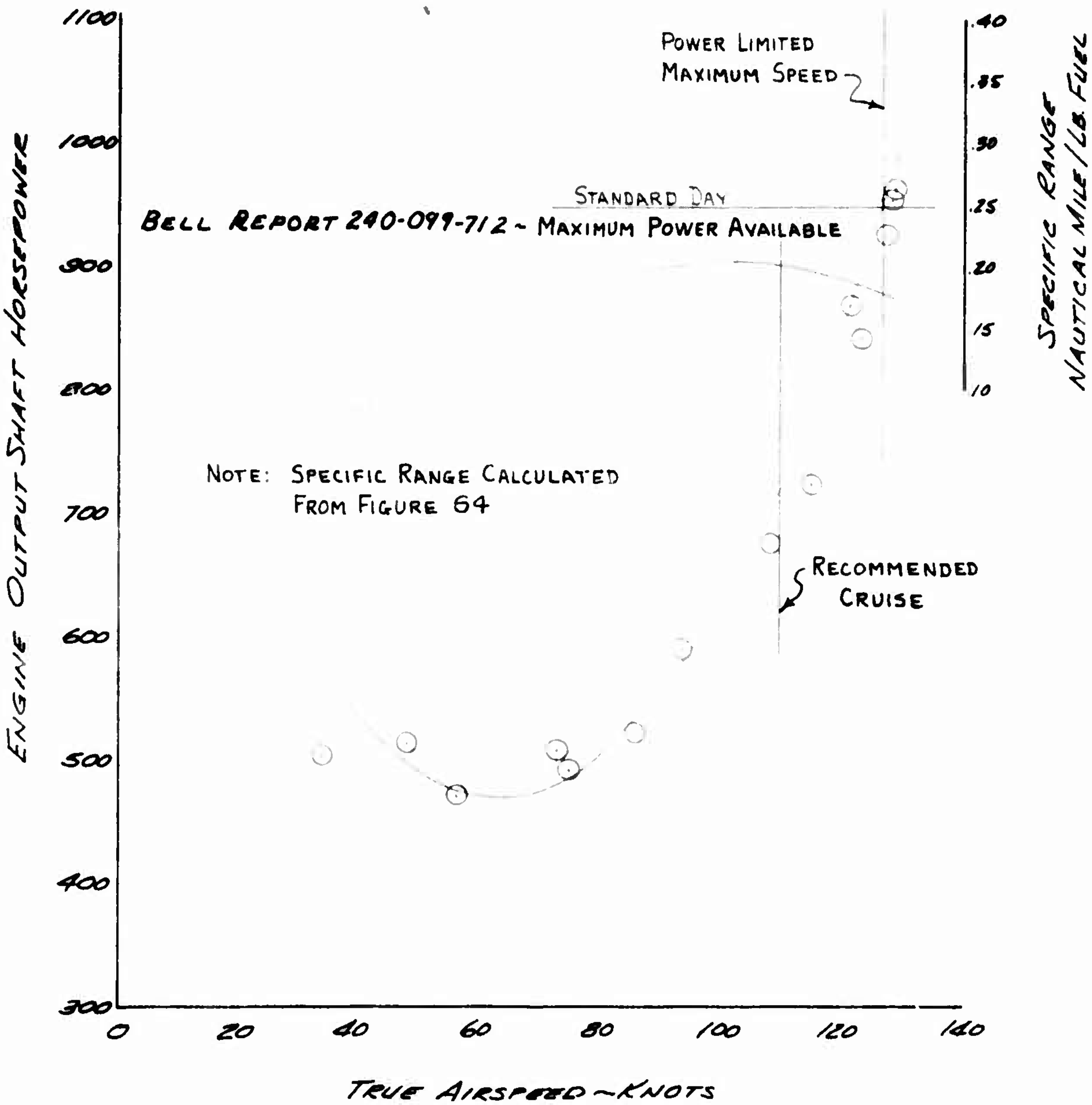


FIGURE NO. 15
LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

RPM ~ 323 (ROTOR)
ALTITUDE ~ 5050 FT.
CT ~ .00498
GROSS WEIGHT ~ 8565 LBS.
CENTER OF GRAVITY ~ MID

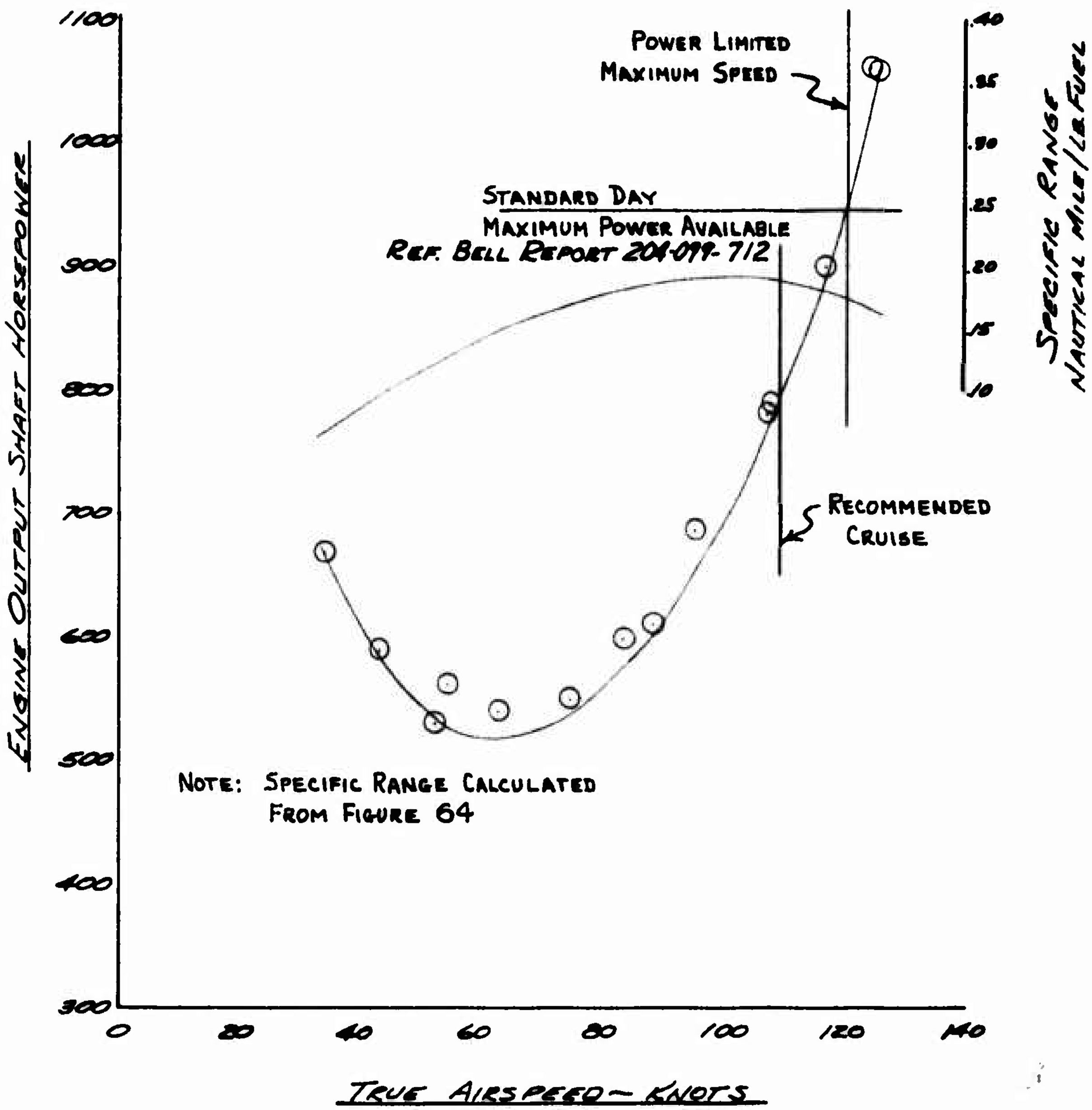


FIGURE No. 16
LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

RPM ~ 323 (ROTOR)
ALTITUDE ~ 3650 FT.
CT ~ .00553
GROSS WEIGHT ~ 8235 LBS.
CENTER OF GRAVITY ~ MID

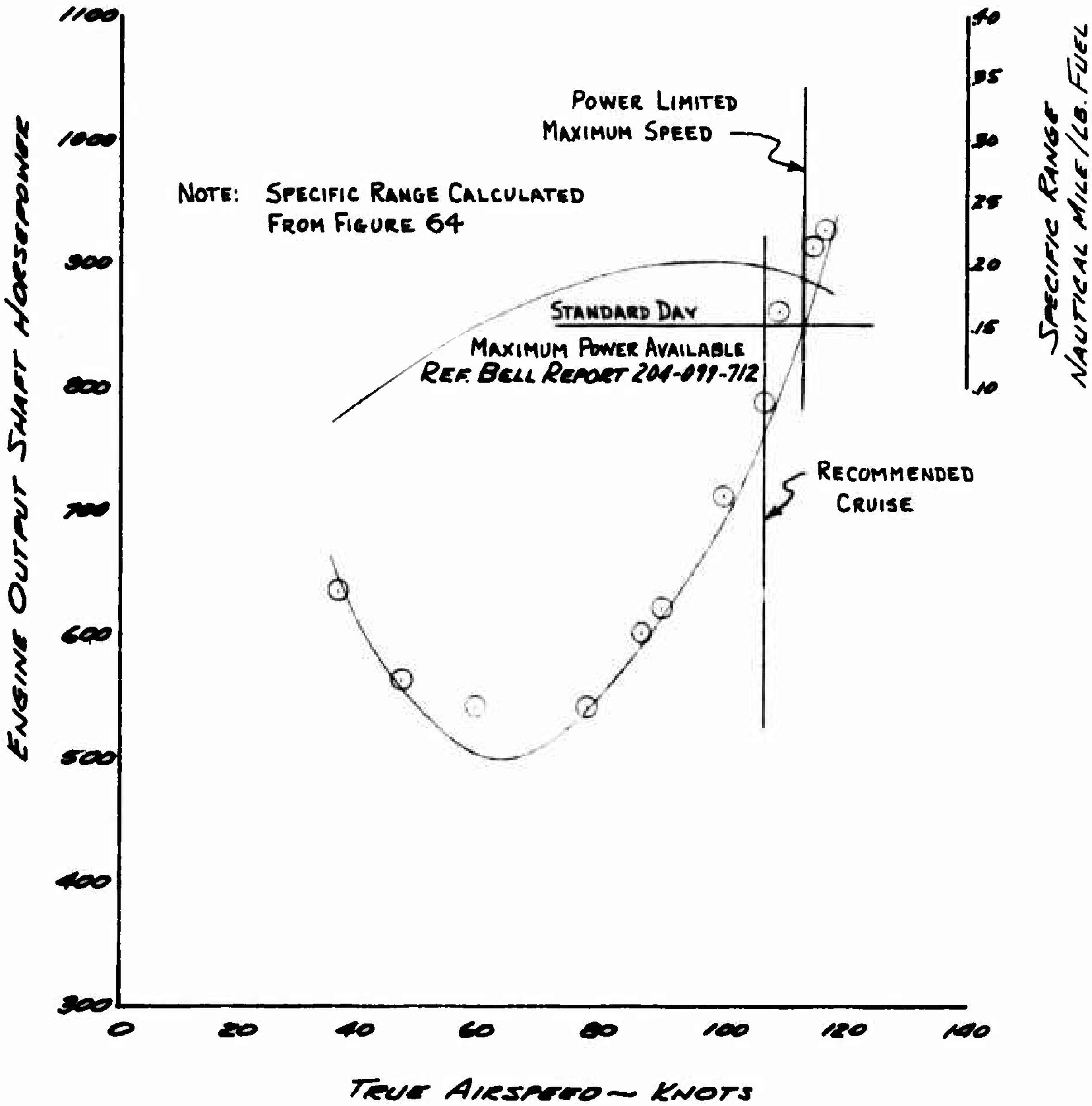


Figure No. 17
Level Flight Performance
Door Hinge Rotor System
Bell Model 204-B N73977

RPM ~ 323 (Rotor)
Altitude ~ 11,750 Ft.
CT ~ .00558
Gross Weight ~ 7785 Lbs.
Center Of Gravity ~ Mid

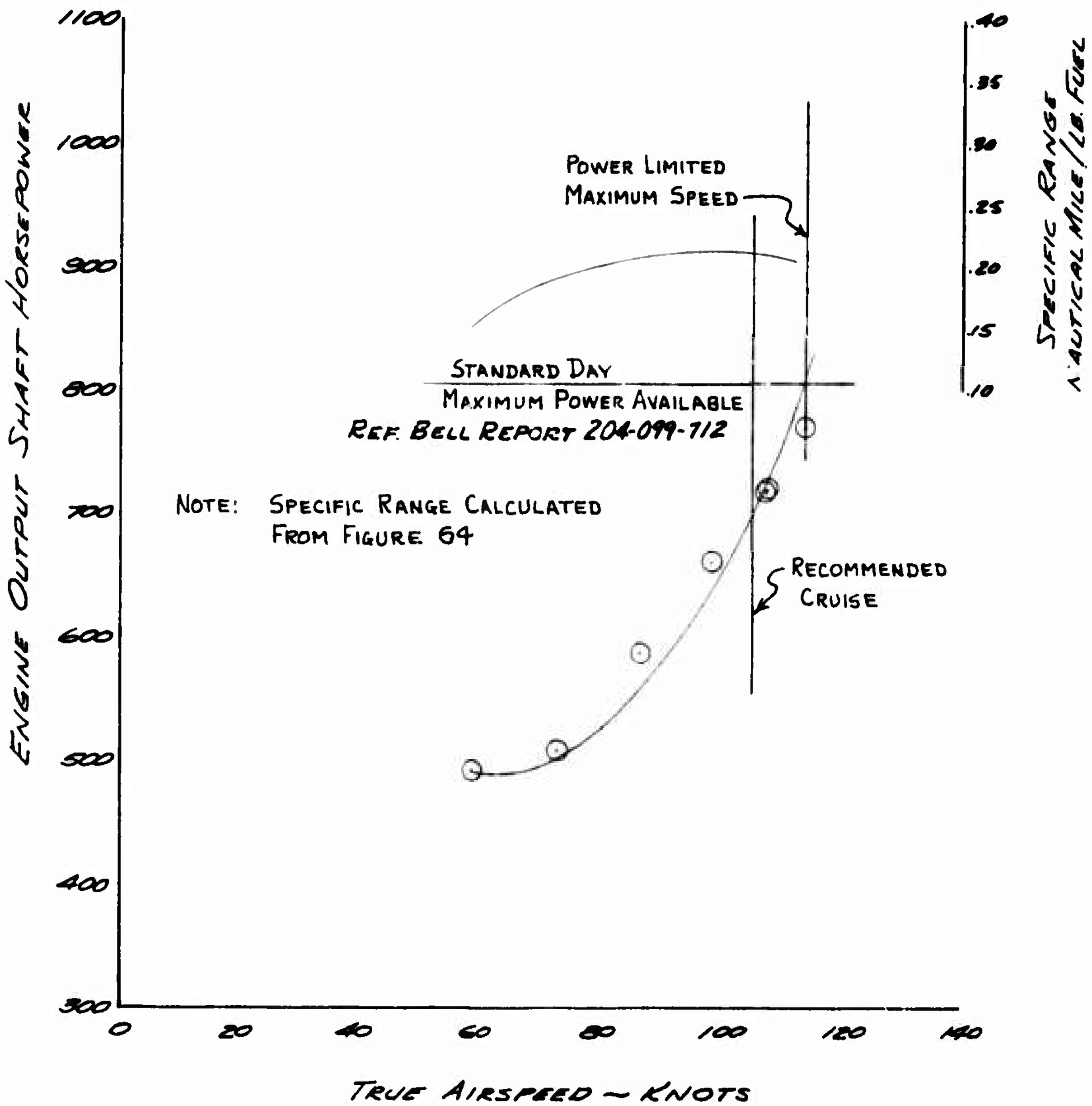


FIGURE No. 18
LEVEL FLIGHT PERFORMANCE
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

RPM ~ 323 (ROTOR)
ALTITUDE ~ 8400 FT.
CT ~ .00606
GROSS WEIGHT ~ 9375 LBS.
CENTER OF GRAVITY ~ M10

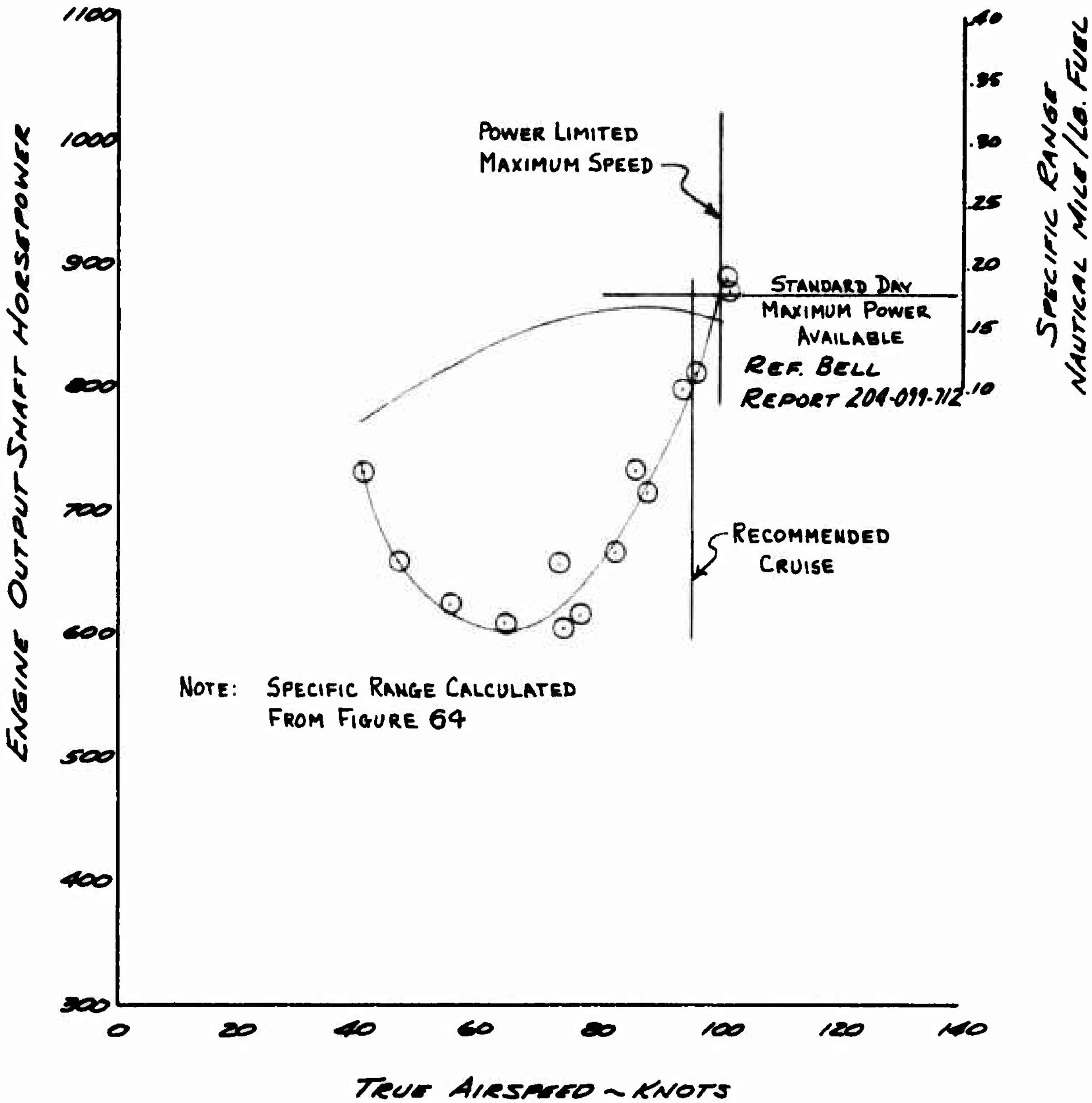


FIGURE No. 19
AUTOROTATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

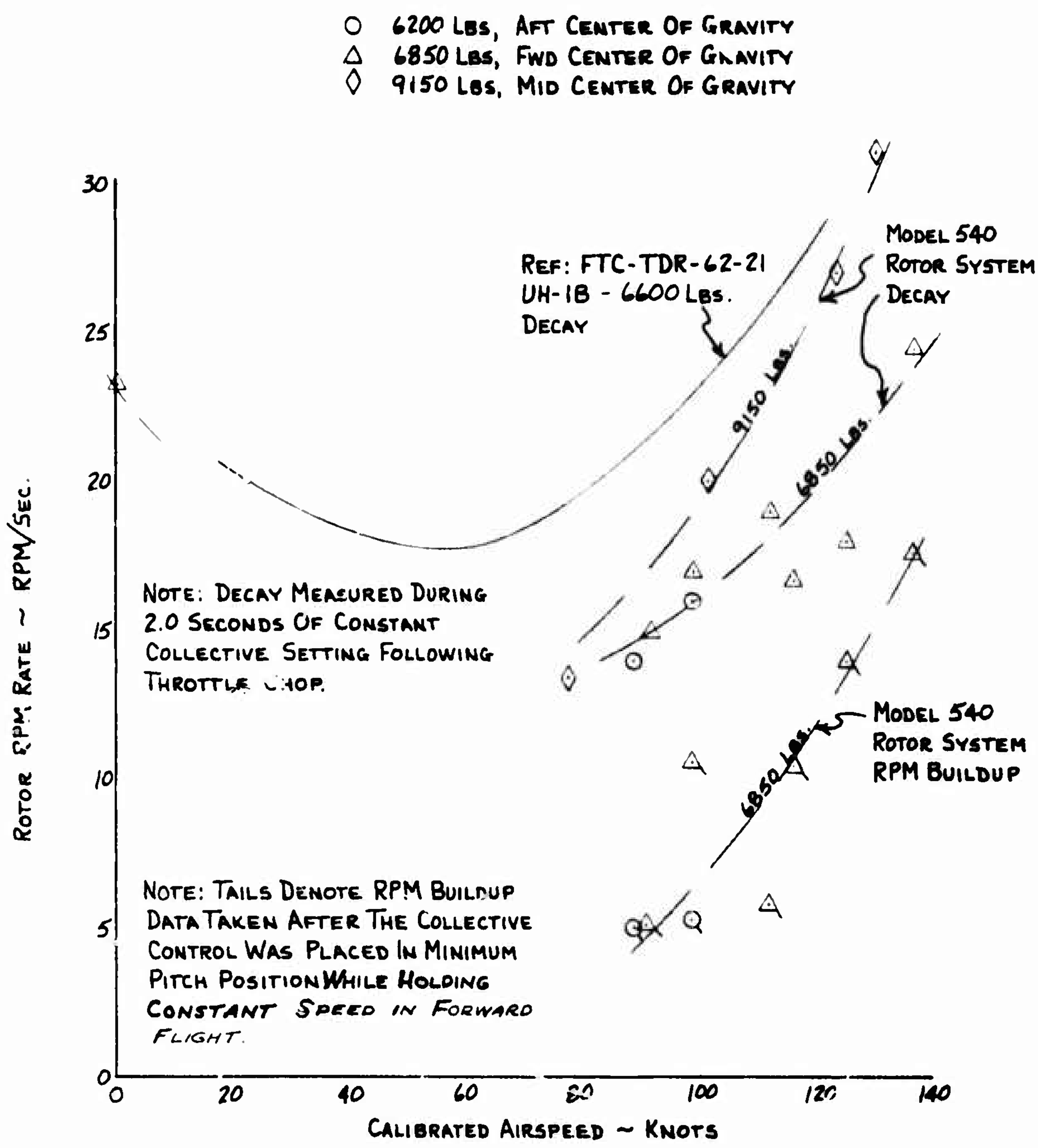


FIGURE NO. 20

AUTOROTATIONAL CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

	ALTITUDE	RPM	WEIGHT ~ LBS
⊙	5000 FT.	323	7500
△	6000 FT.	323	8000
◊	4000 FT.	323	9100

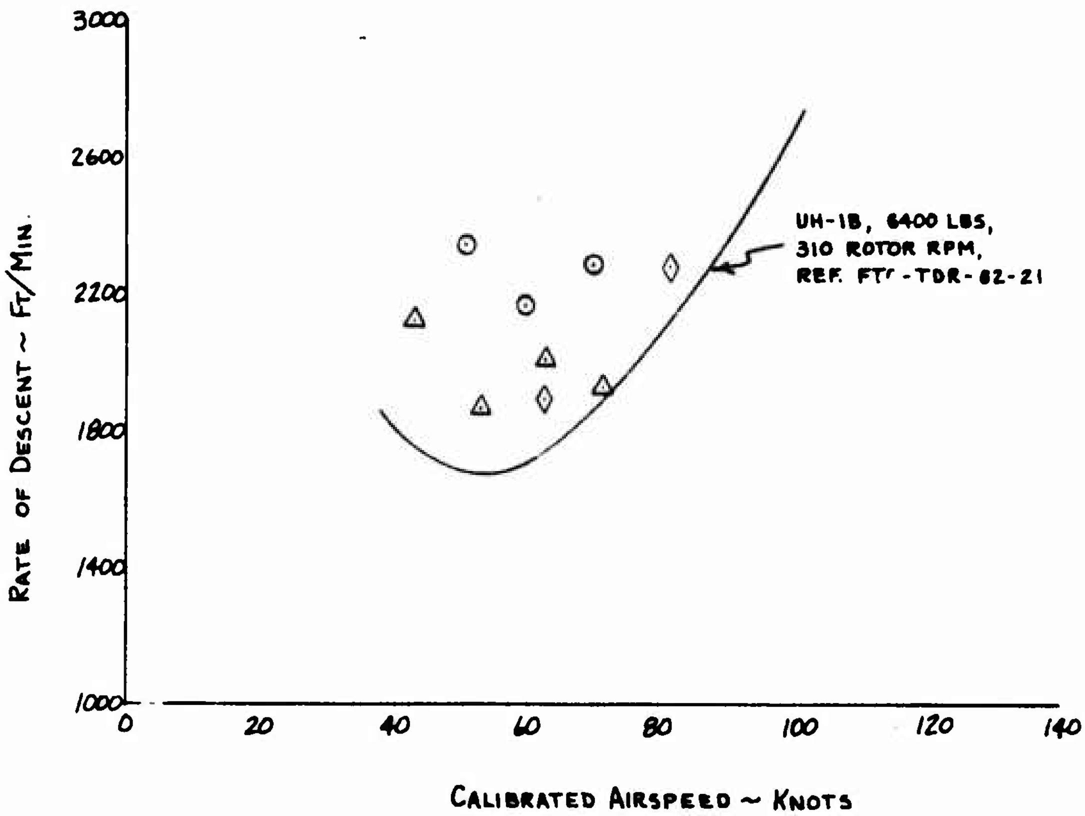


FIGURE No. 21

AUTOROTATION PERFORMANCE

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

304 ROTOR RPM GW=7500 LBS.

CENTER OF GRAVITY = STA. 128

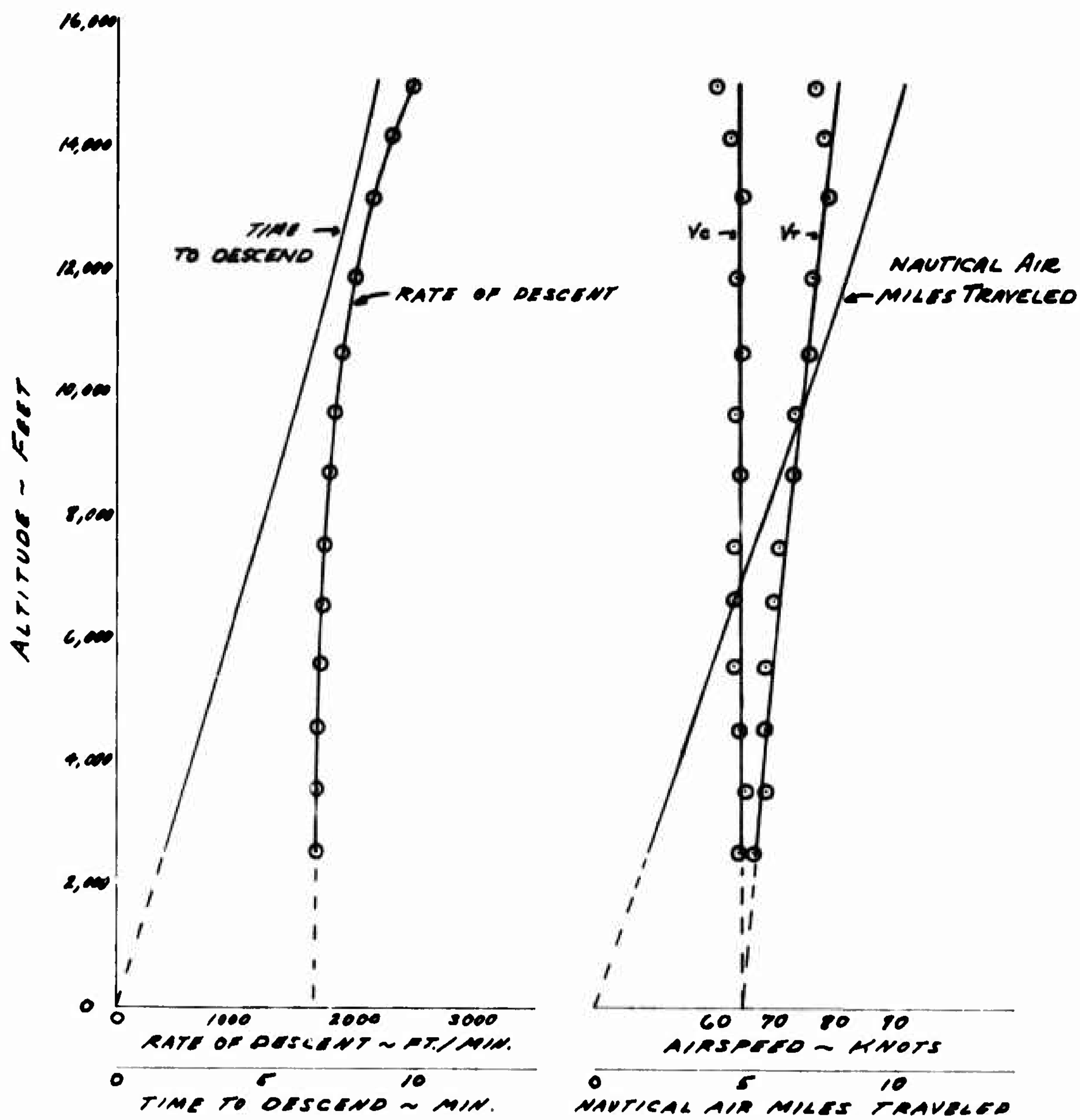


Figure No. 22
Autorotation Performance
Door Hinge Rotor System
Bell Model 204-B N73977
323 Rotor RPM G.W. = 7500 Lbs.

Center of Gravity = STA. 128.

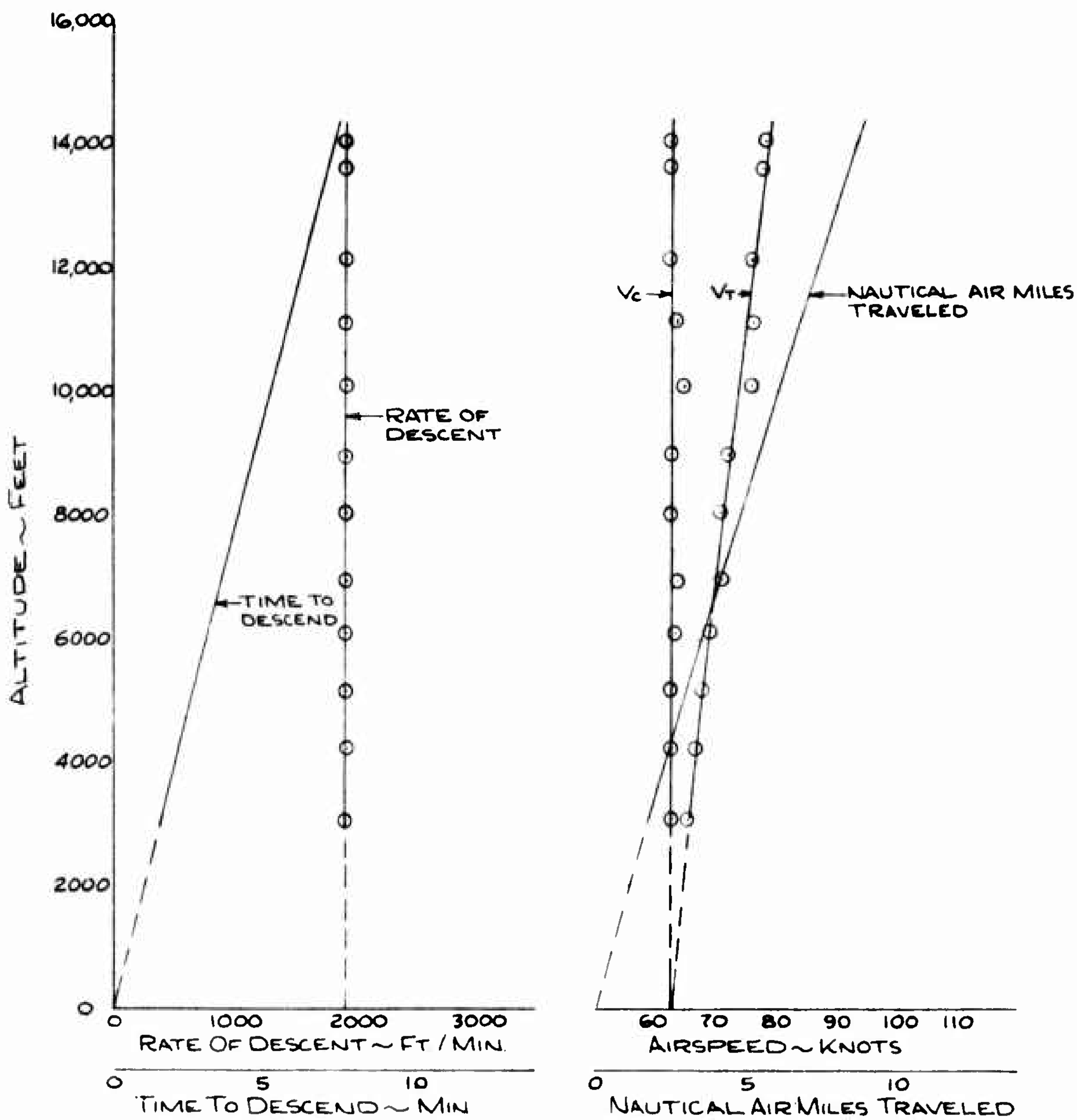


FIGURE NO. 23

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT 6770 LBS
ALTITUDE, -1500 FT. HD
CENTER OF GRAVITY 135.5 INS. (AFT)

PYLON CONFIG.
INSTALLED NEW
204-031-960-1
PYLON DAMPERS

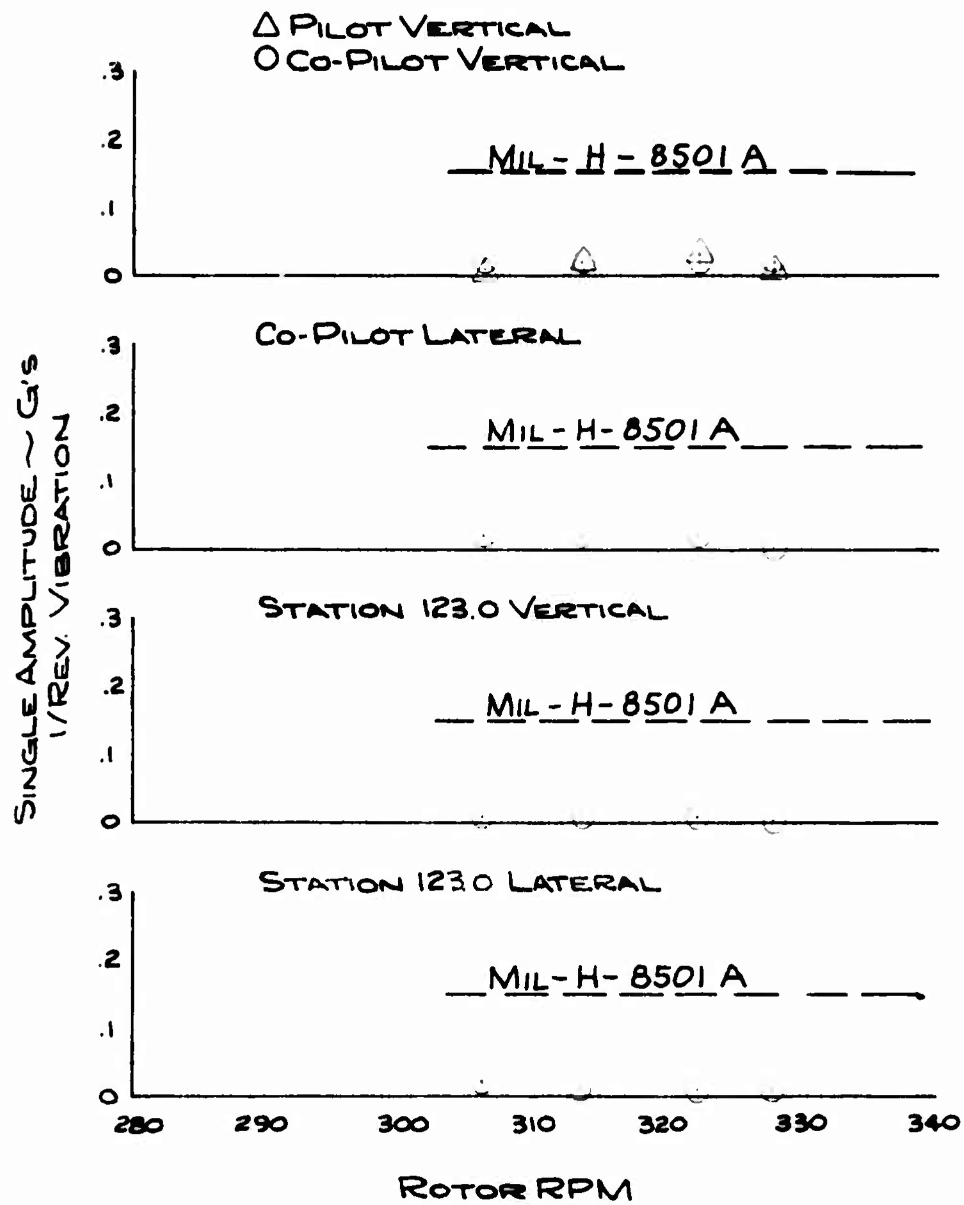


FIGURE NO. 24

VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT ~ 6770 LBS.
ALTITUDE, -1500 FT. HD
CENTER OF GRAVITY ~ 135.5 IN. (AFT)

PYLON CONFIG.
INSTALLED NEW
204-031-960-1
PYLON DAMPERS

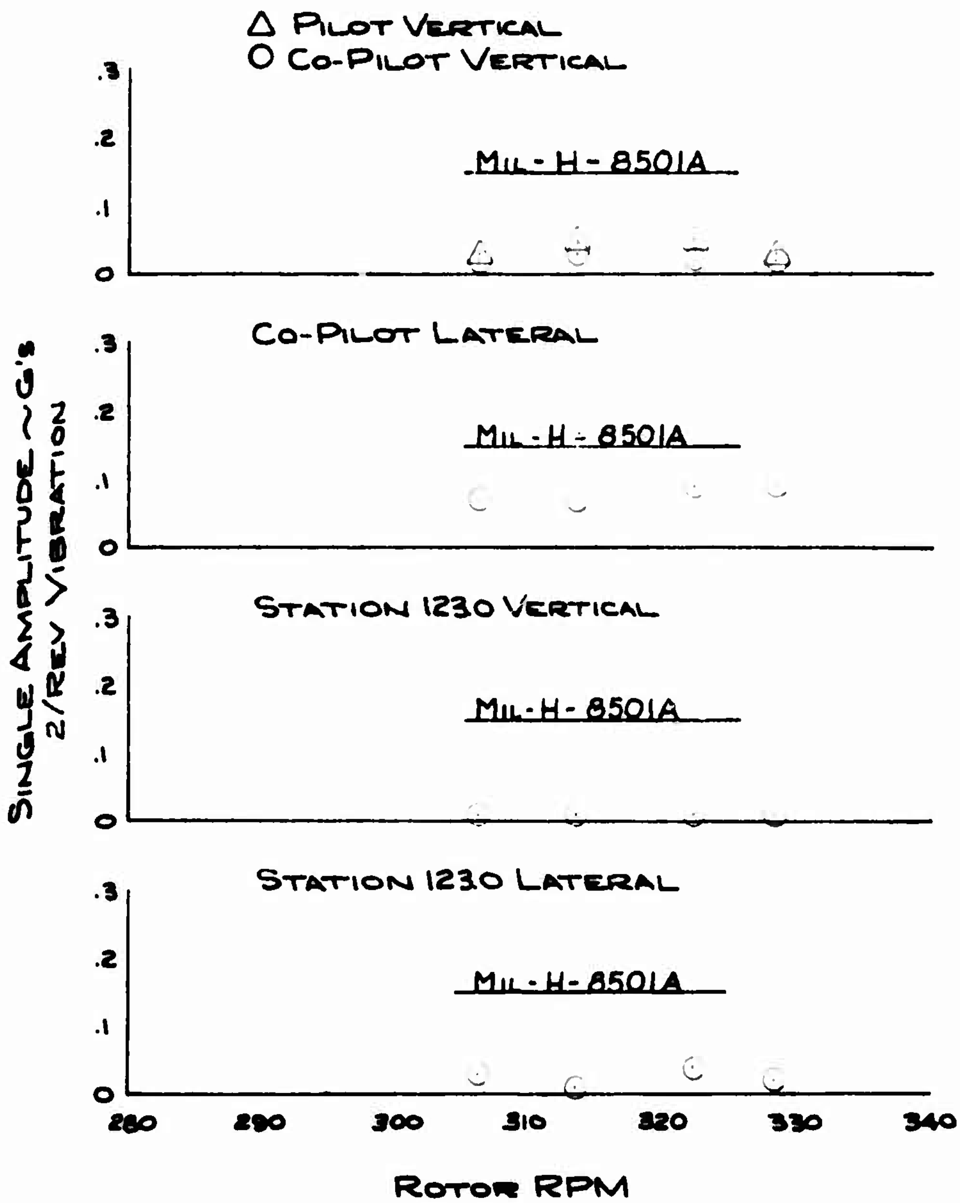


FIGURE NO. 25

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT 6770 LBS.
ALTITUDE, -1500 FT. HD
CENTER OF GRAVITY 135.5 IN. (AFT.)

PYLON CONFIG.
INSTALLED NEW
204-031-960-1
PYLON DAMPERS

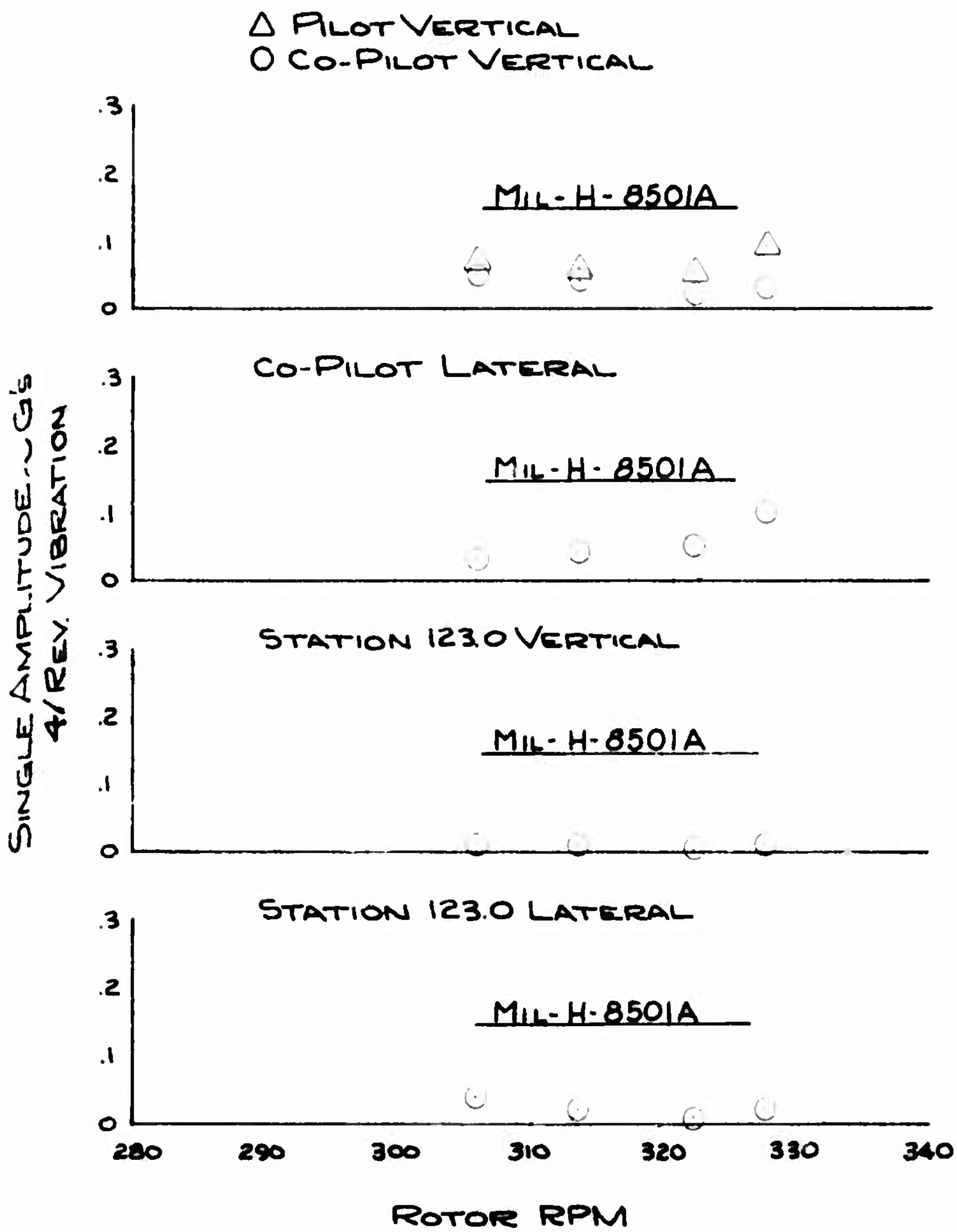


FIGURE NO. 26
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT ~ 7170 LBS.
ALTITUDE 60 FT. HD
CENTER OF GRAVITY ~ 125.3 (FWD)

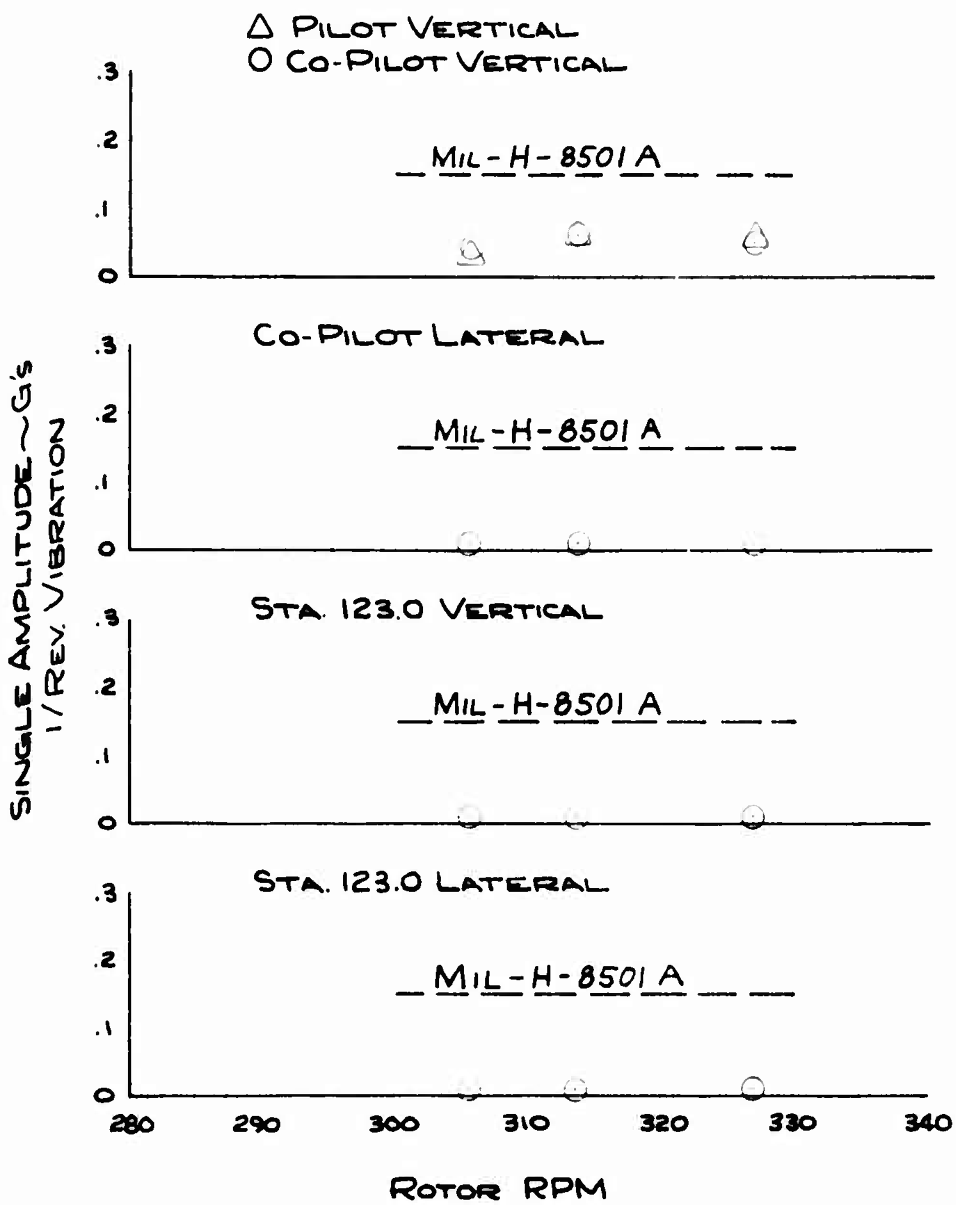


FIGURE No. 27
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT ~ 7170 LBS
ALTITUDE 60 FT. HD
CENTER OF GRAVITY ~ 125.3 IN. (FWD)

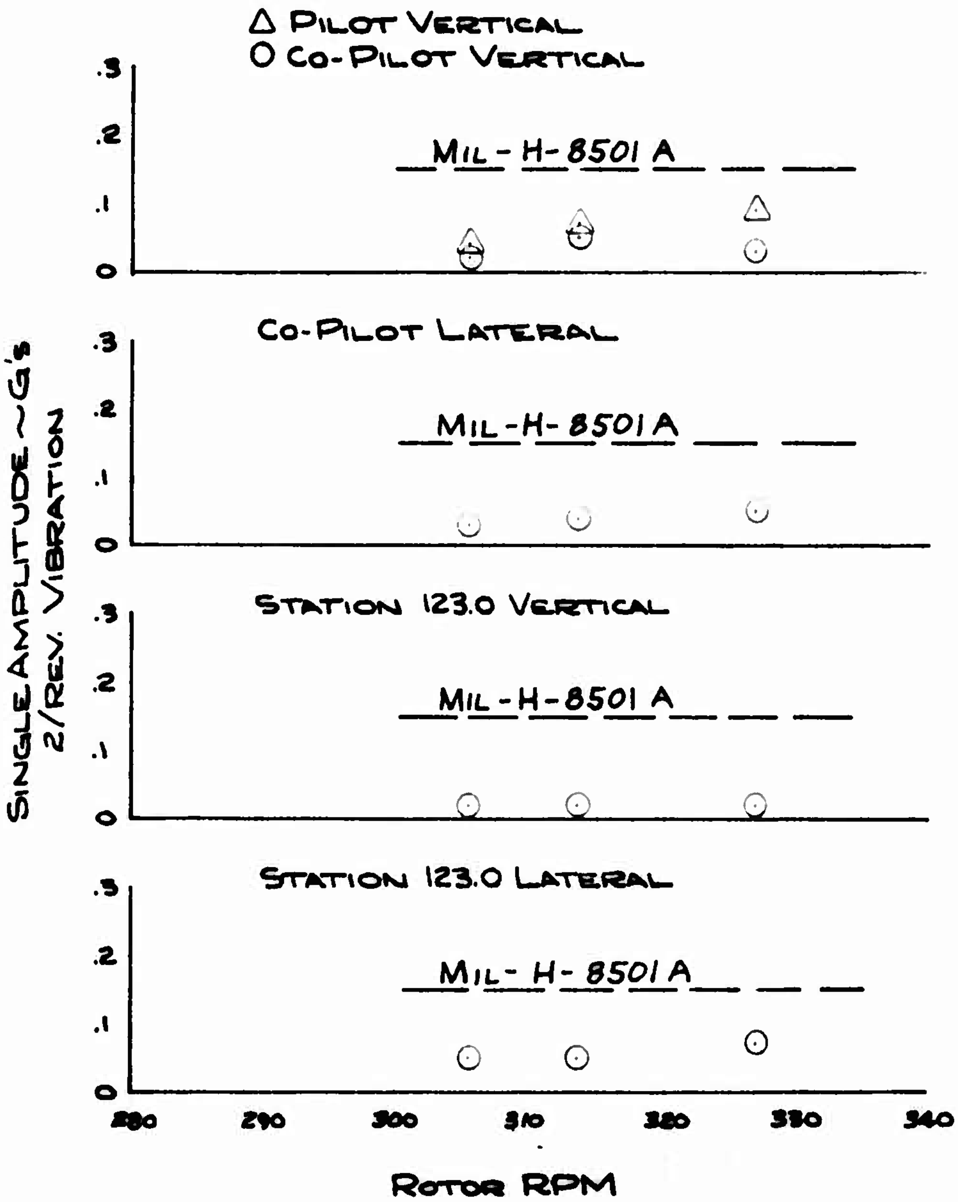


FIGURE No. 28
VIBRATION CHACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT ~ 7170 LBS.
ALTITUDE 60 FT. HD
CENTER OF GRAVITY ~ 125.3 IN. (FWD)

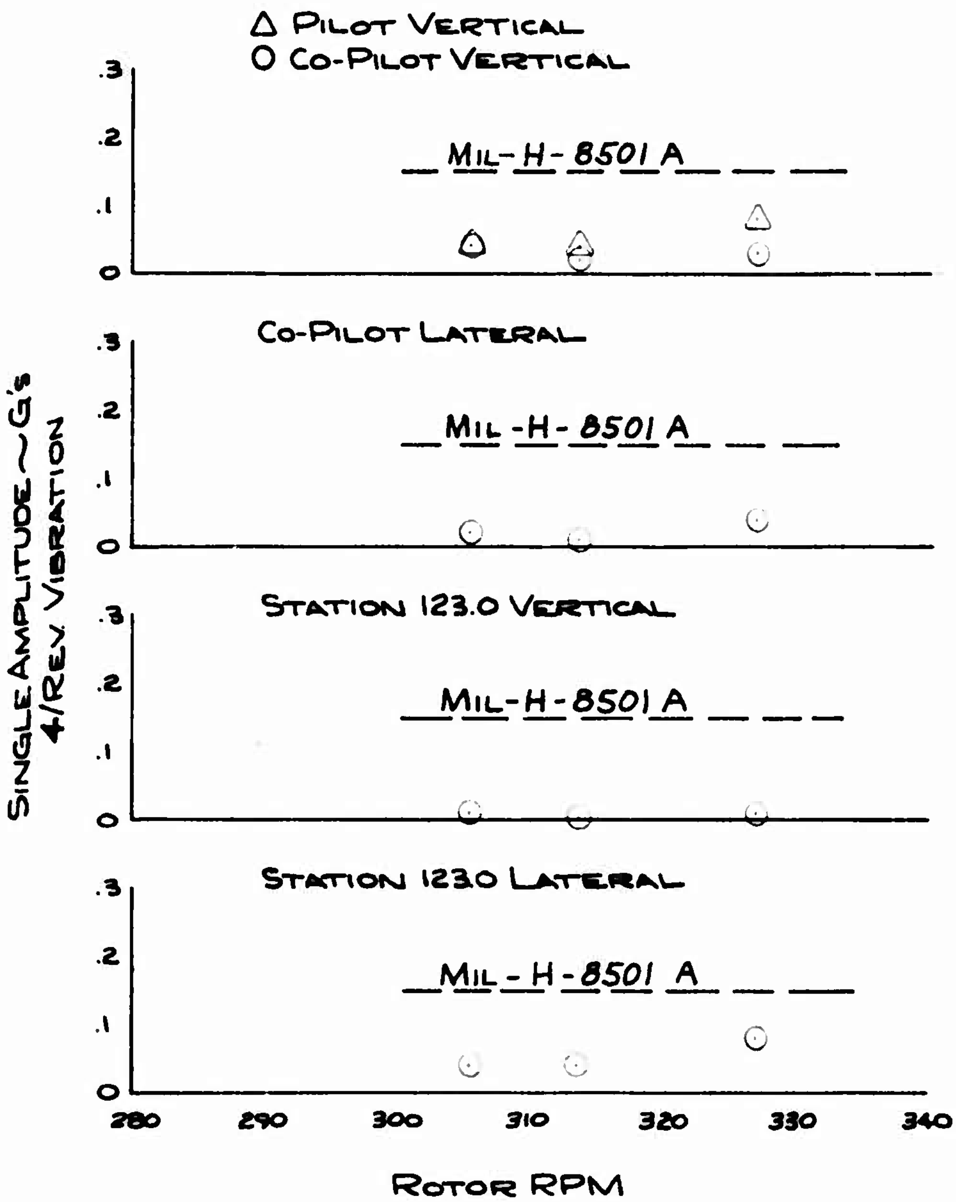


FIGURE No. 29
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT ~ 9630 LBS.
ALTITUDE 400 FT. HD
CENTER OF GRAVITY ~ 127.9 IN. (MID)

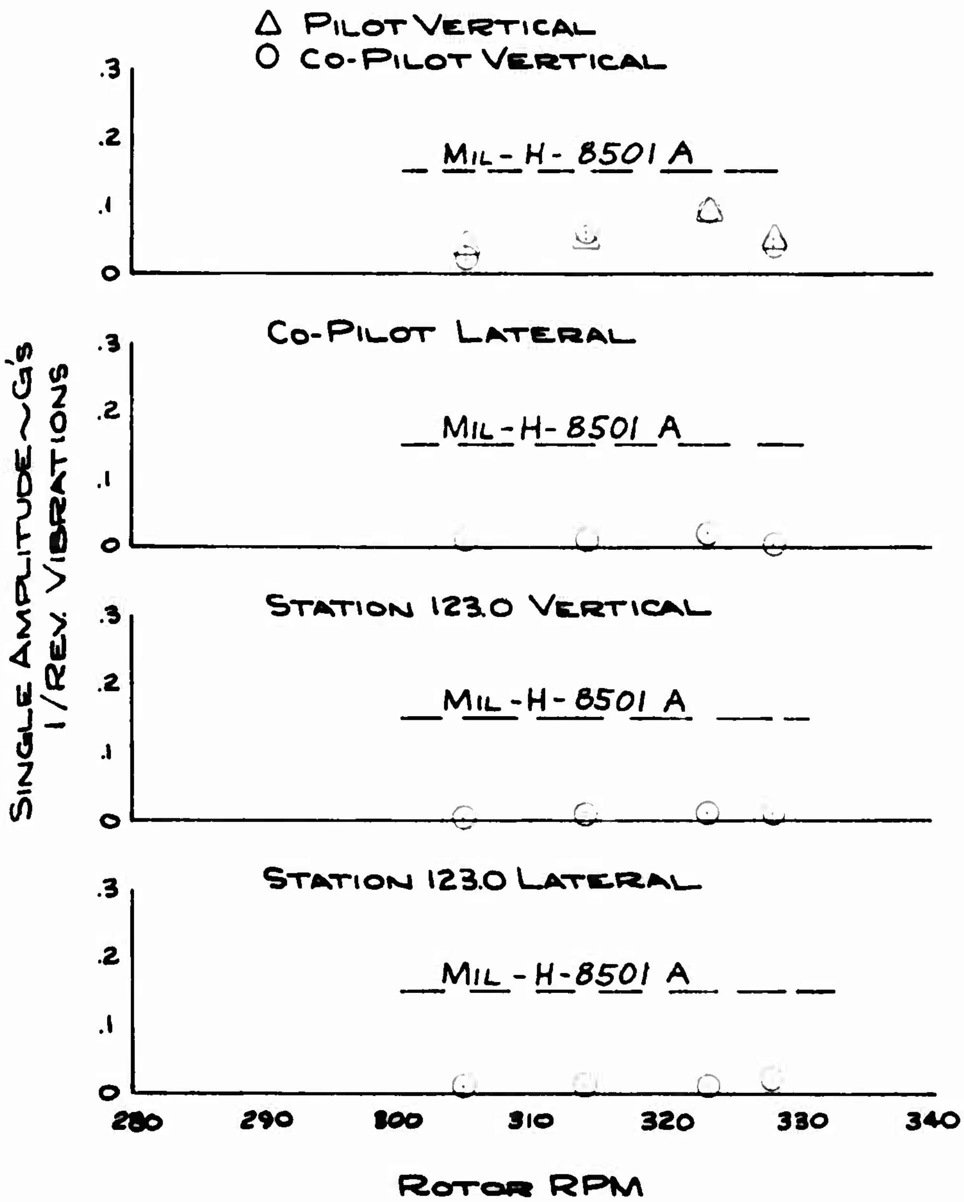


FIGURE No. 30

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

HOVER

GROSS WEIGHT ~ 9630 LBS

ALTITUDE 400 FT HD

CENTER OF GRAVITY ~ 127.9 IN. (MID.)

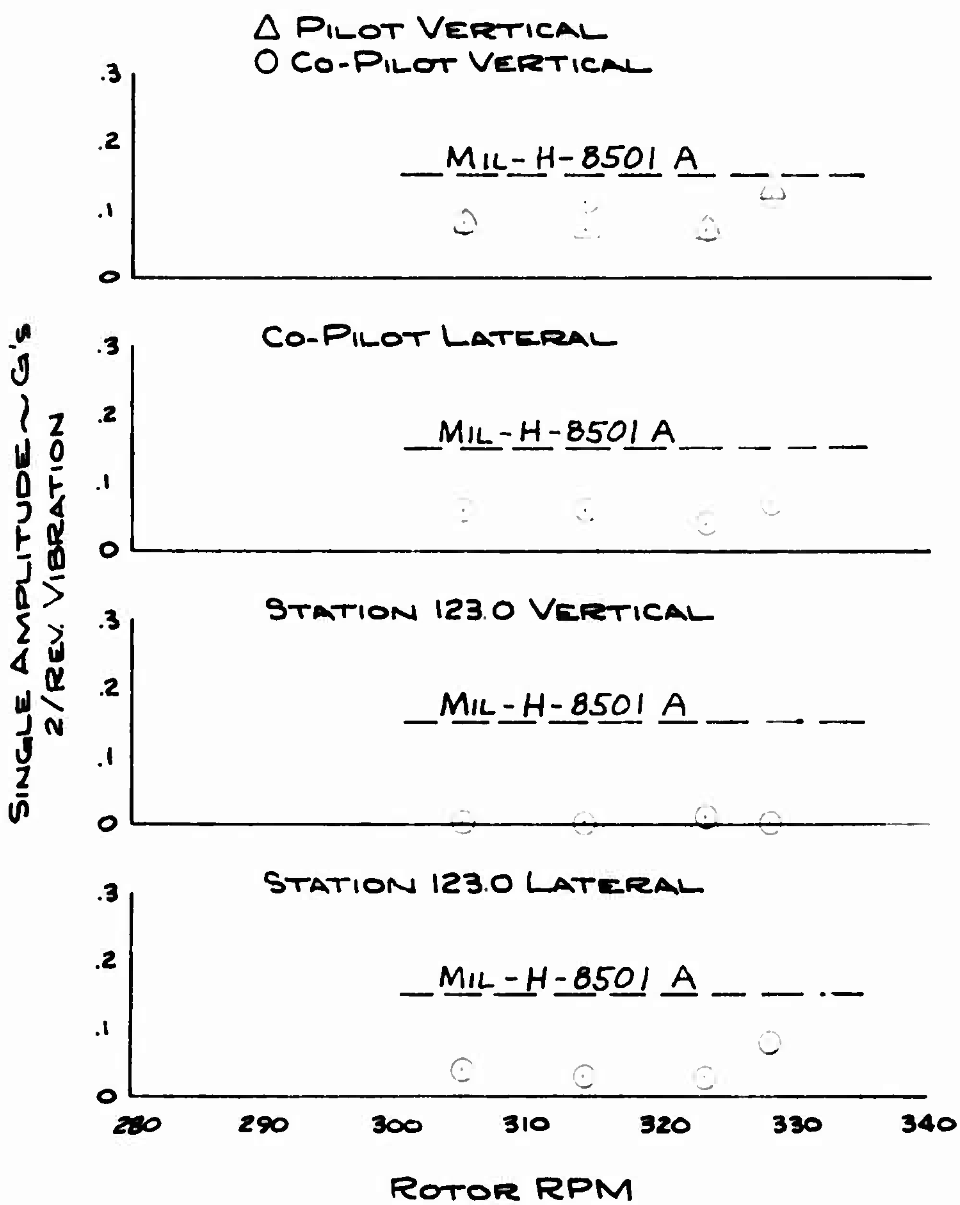


FIGURE NO. 34
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N 73977

HOVER
GROSS WEIGHT ~ 9630 LBS.
ALTITUDE 400 FT. HD
CENTER OF GRAVITY ~ 127.9 IN. (MID)

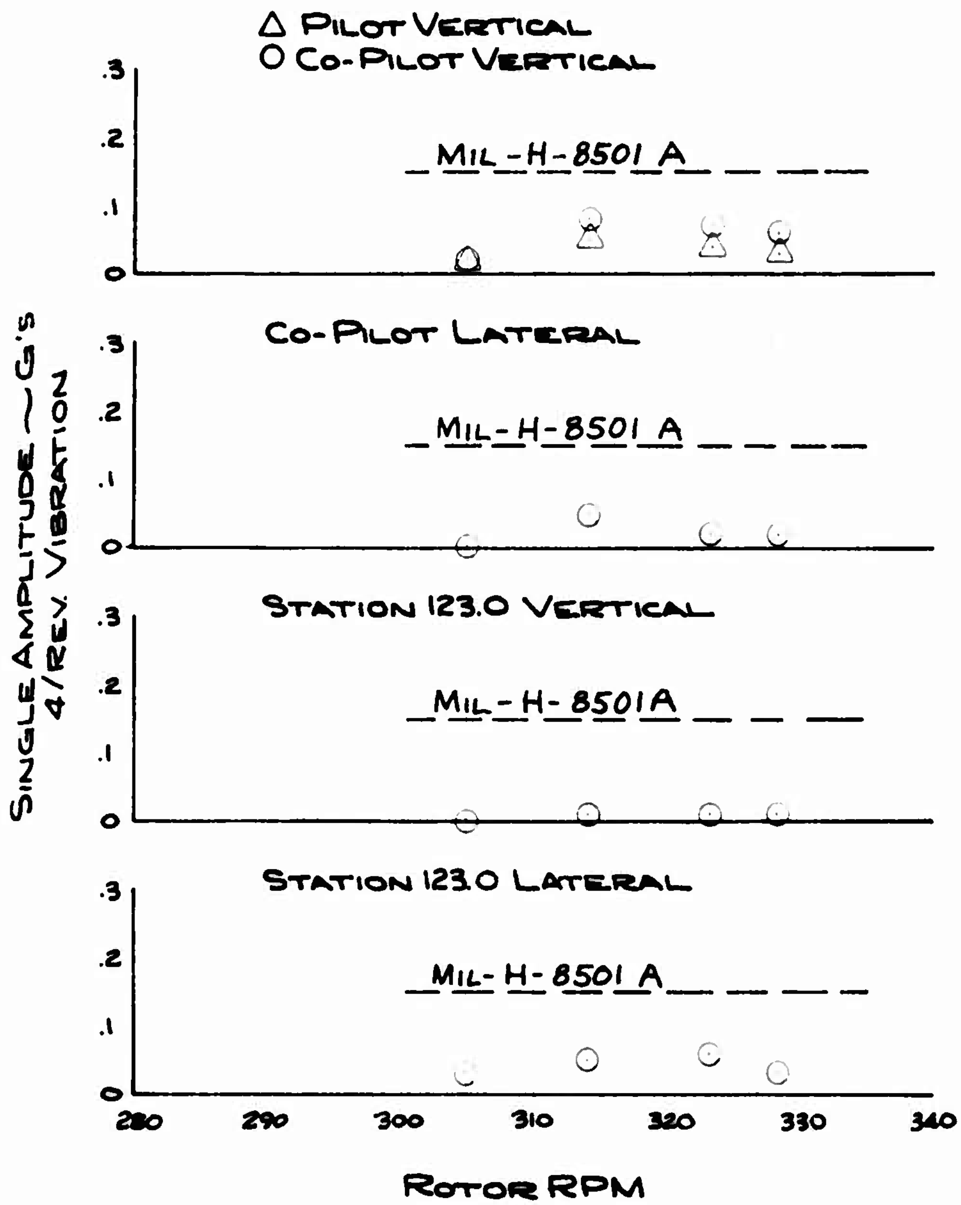


FIGURE No. 32
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT 6800 LBS
ALTITUDE, -100 FT HD
CENTER OF GRAVITY ~ 135.5 IN. (AFT)
PYLON CONFIG. ~ REMOVED FOUR 4500 LB/IN MOUNTS, REPLACED WITH 10,000 LB/IN MOUNTS.

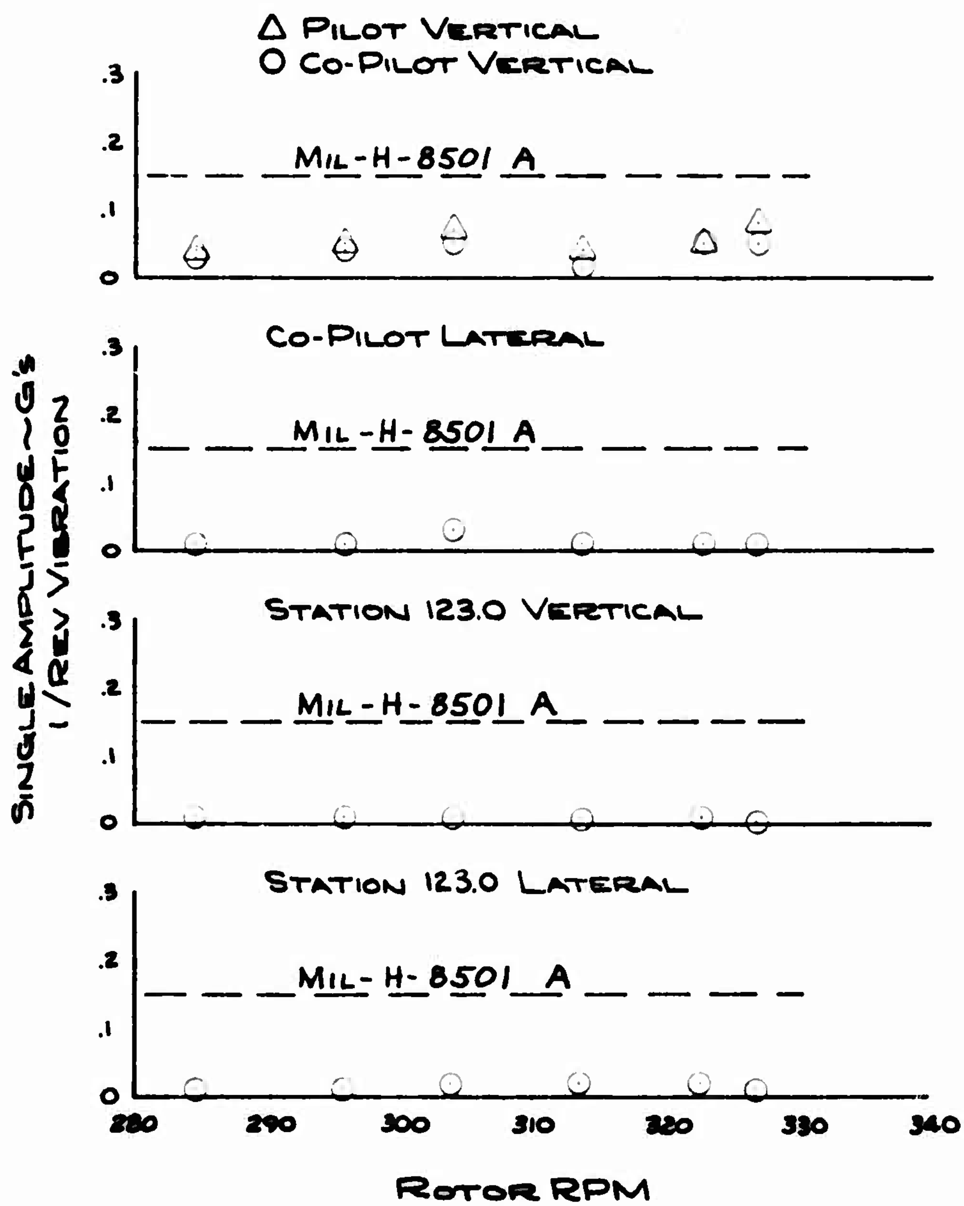


FIGURE NO. 33

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

HOVER
GROSS WEIGHT 6800 LBS
ALTITUDE, -100 FT. HD
CENTER OF GRAVITY 135.5 INS (AFT)
PYLON CONFIG. ~ REMOVED FOUR 4500 LB/IN MOUNTS, REPLACED WITH 10,000 LB/IN MOUNTS.

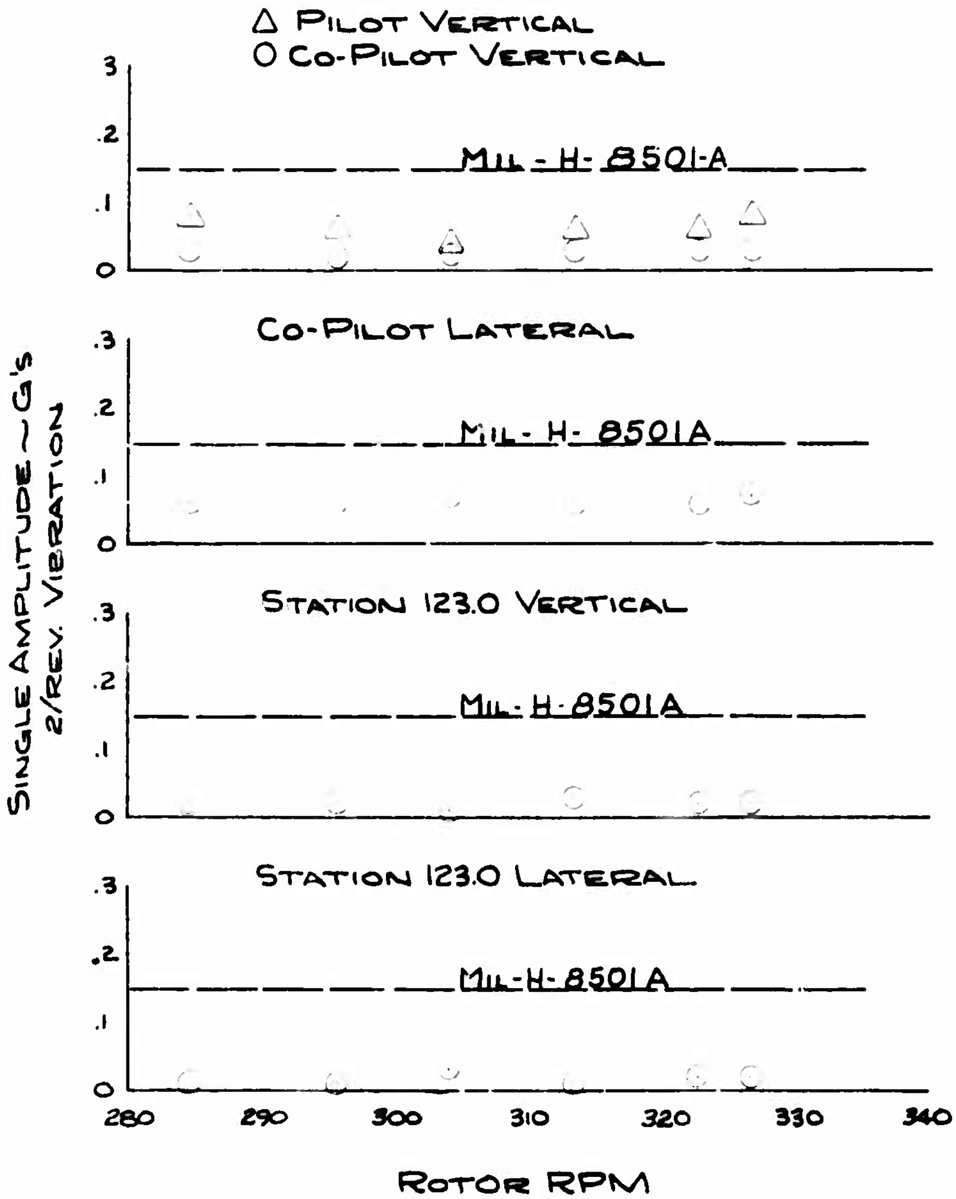


Figure No. 34

Vibration Characteristics

Door Hinge Rotor System

Bell Model 204-B N73977

Hover

Gross Weight 6800 Lbs

Altitude, -100 Ft. Hd

Center Of Gravity 135.5 Ins (Aft)

Pylon Config. ~ removed four 4500 LB/IN mounts, replaced with 10,000 LB/IN mounts.

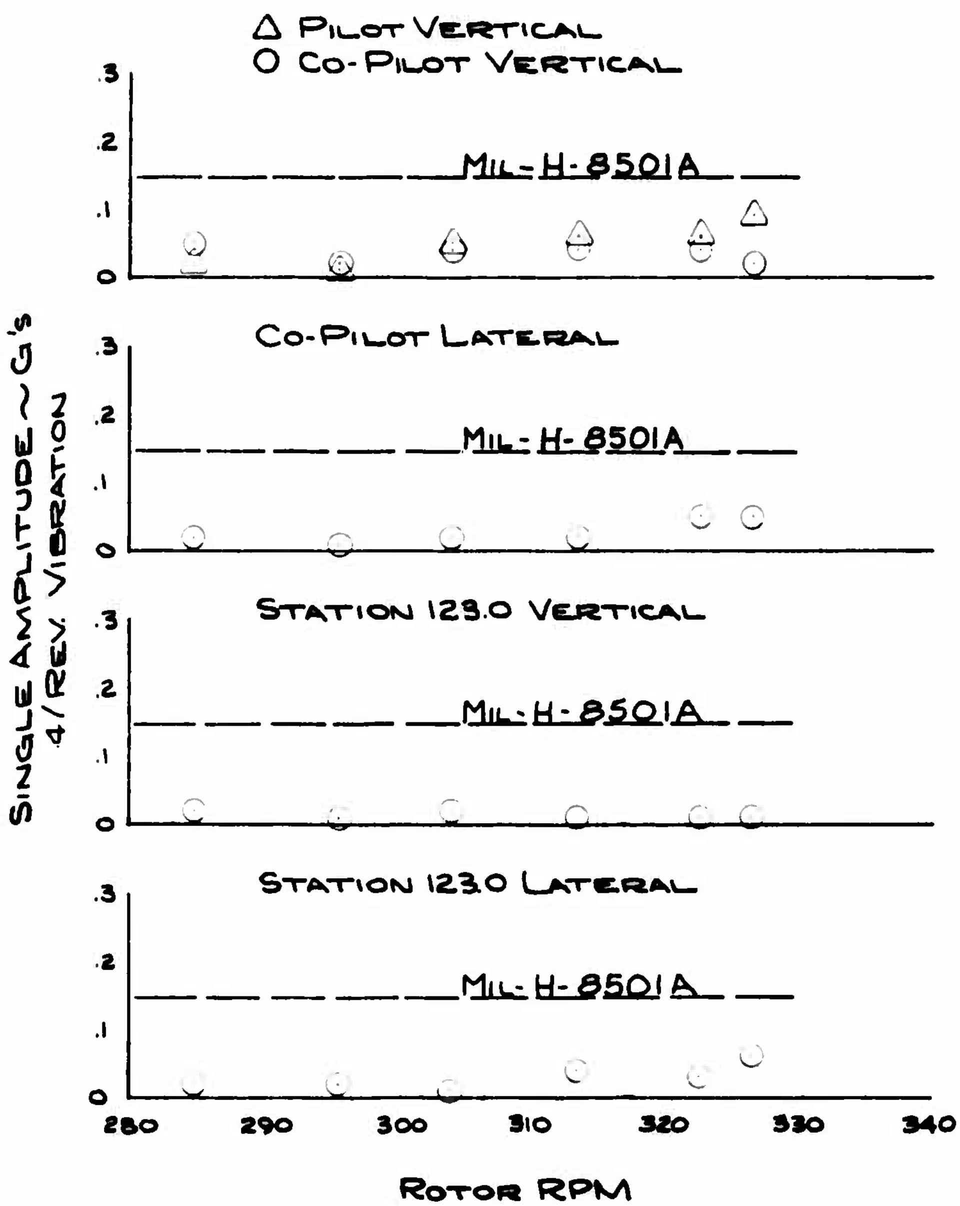


FIGURE NO. 35
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT ~ 9500 LBS.
ALTITUDE ~ 2885 FT. Hp (AVG.) 80 KTS.
~ 1920 FT. Hp (AVG.) 100 KTS.

CENTER OF GRAVITY ~ STA. 128

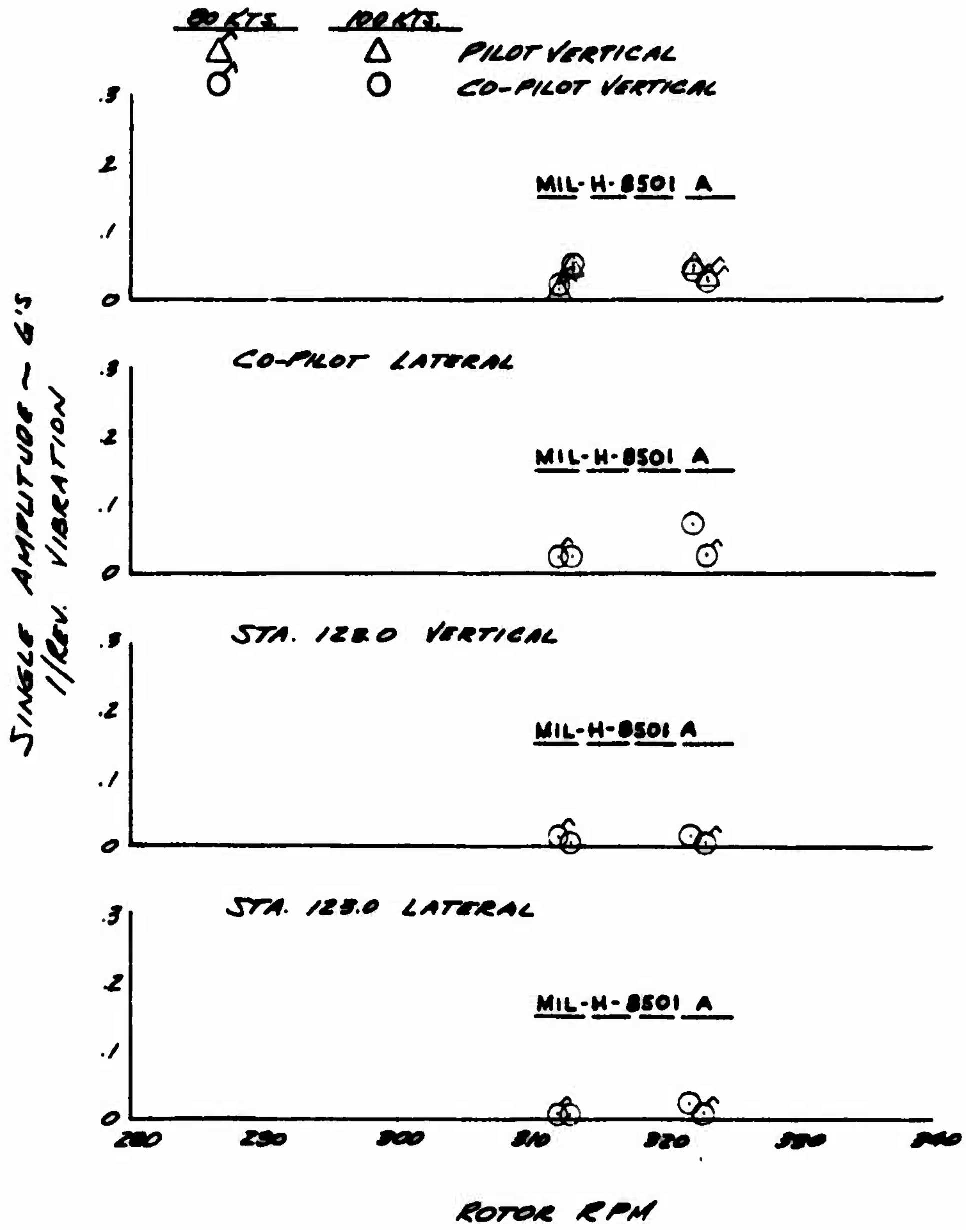


FIGURE NO. 36

VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT ~ 9500 LBS.
ALTITUDE ~ 2385 FT. Ho (AVG.) 80 KTS.
~ 1820 FT. Ho (AVG.) 100 KTS.

CENTER OF GRAVITY ~ STA. 128

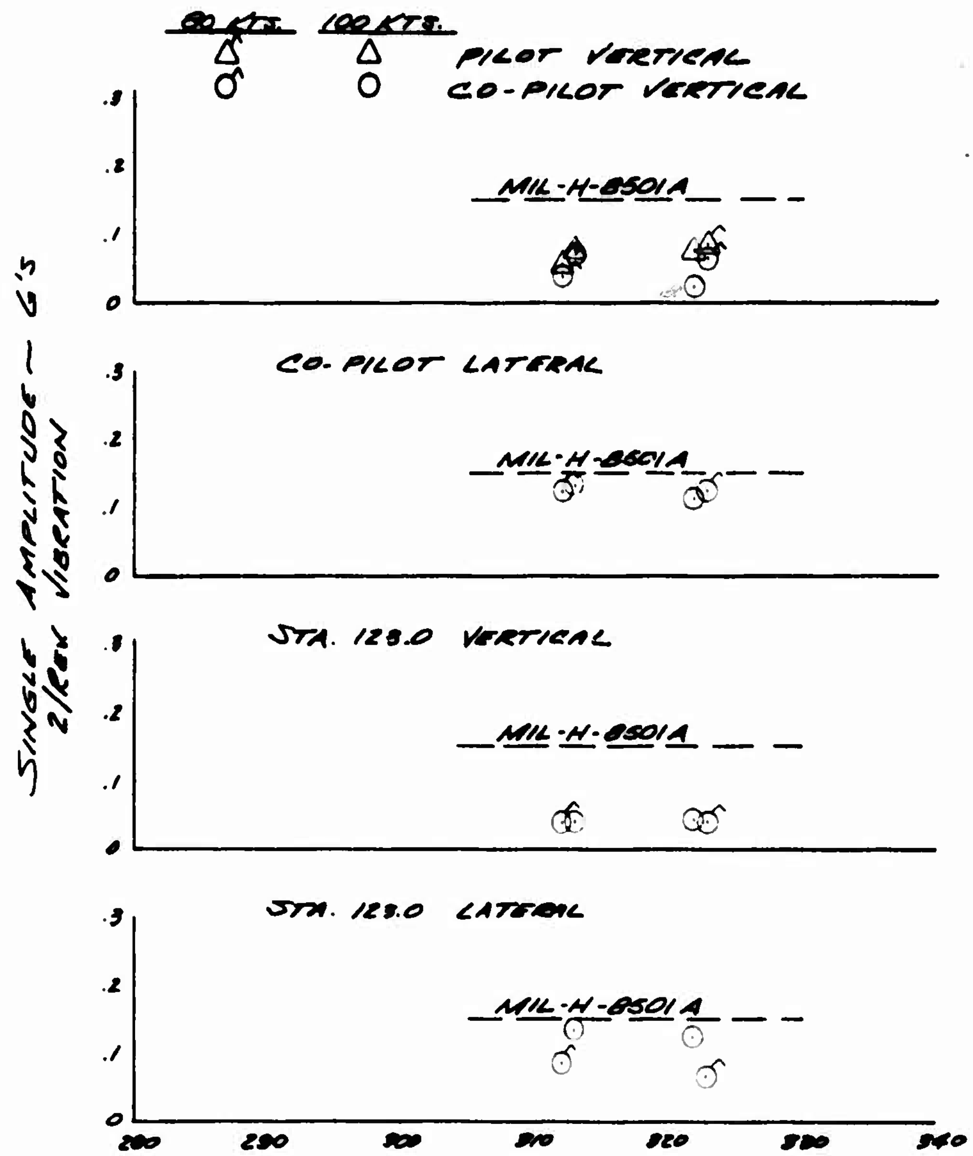


FIGURE No. 37
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT ~ 9500 LBS.
ALTITUDE ~ 2385 FT. H_D (AVG.) 80 KTS.
~ 1320 FT. H_D (AVG.) 100 KTS.

CENTER OF GRAVITY ~ STA. 128

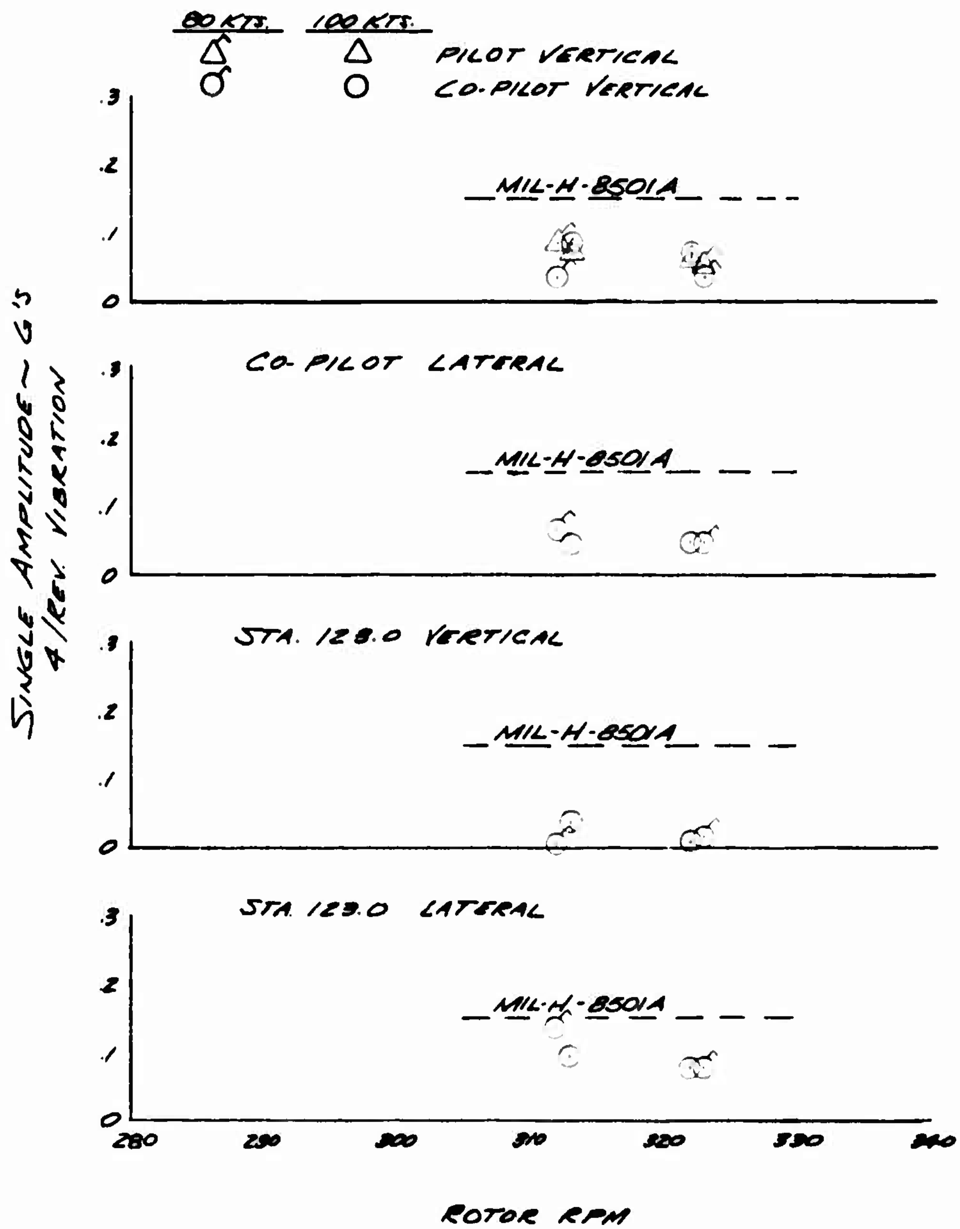


FIGURE NO. 38

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEMS

BELL MODEL 204-B N73977

GROSS WEIGHT 6380 LBS.
RPM 323 (ROTOR)
ALTITUDE 500 FT. H_D
CENTER OF GRAVITY ~ MID ~ STA. 130
PYLON CONFIG. ~ 0.015 IN. SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

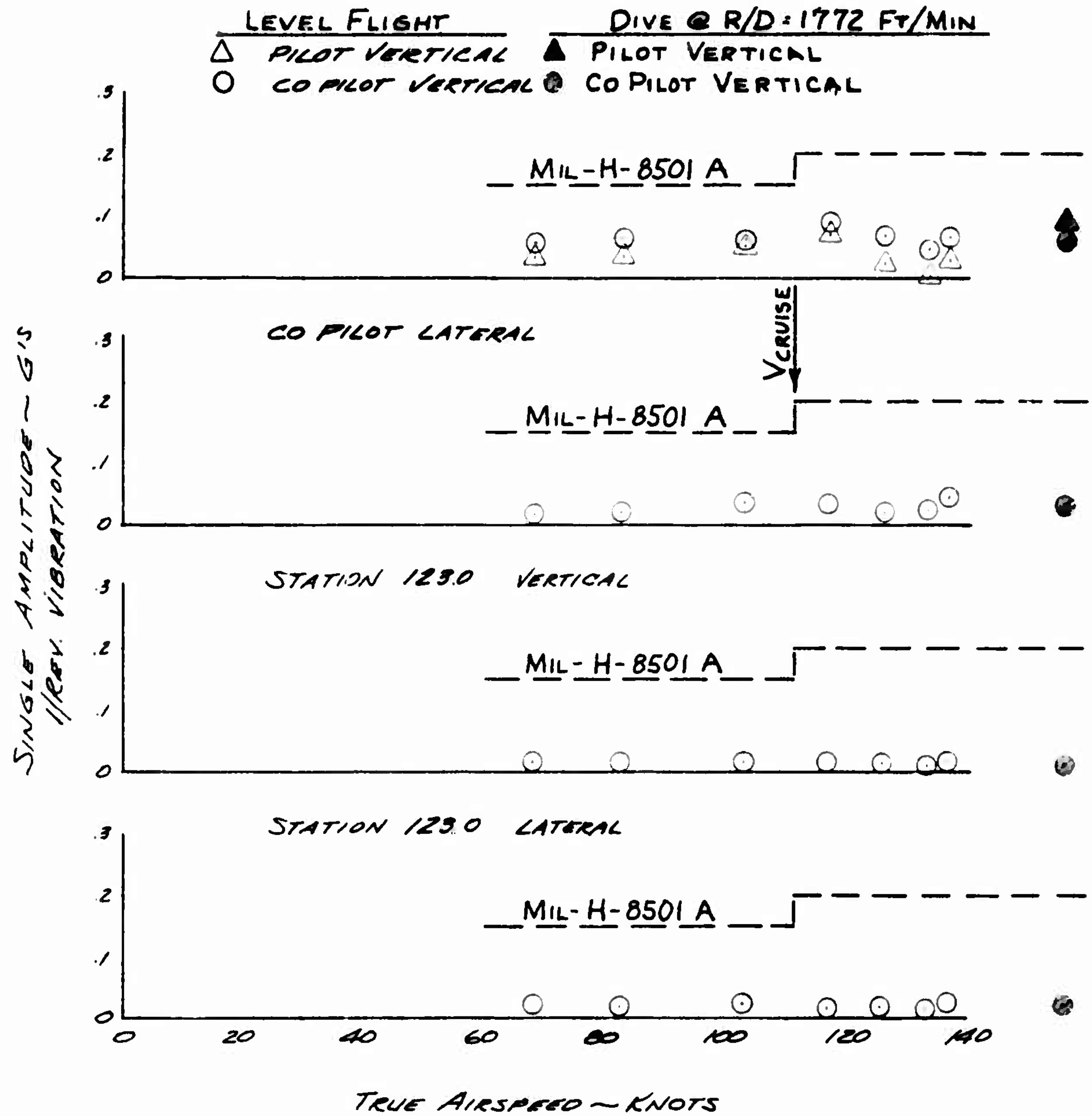


FIGURE NO. 39

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT 6380 LBS.
RPM 323 (ROTOR)
ALTITUDE 500 FT.
CENTER OF GRAVITY ~ MID - STA 130
PYLON CONFIG. ~ 0.015 IN. SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

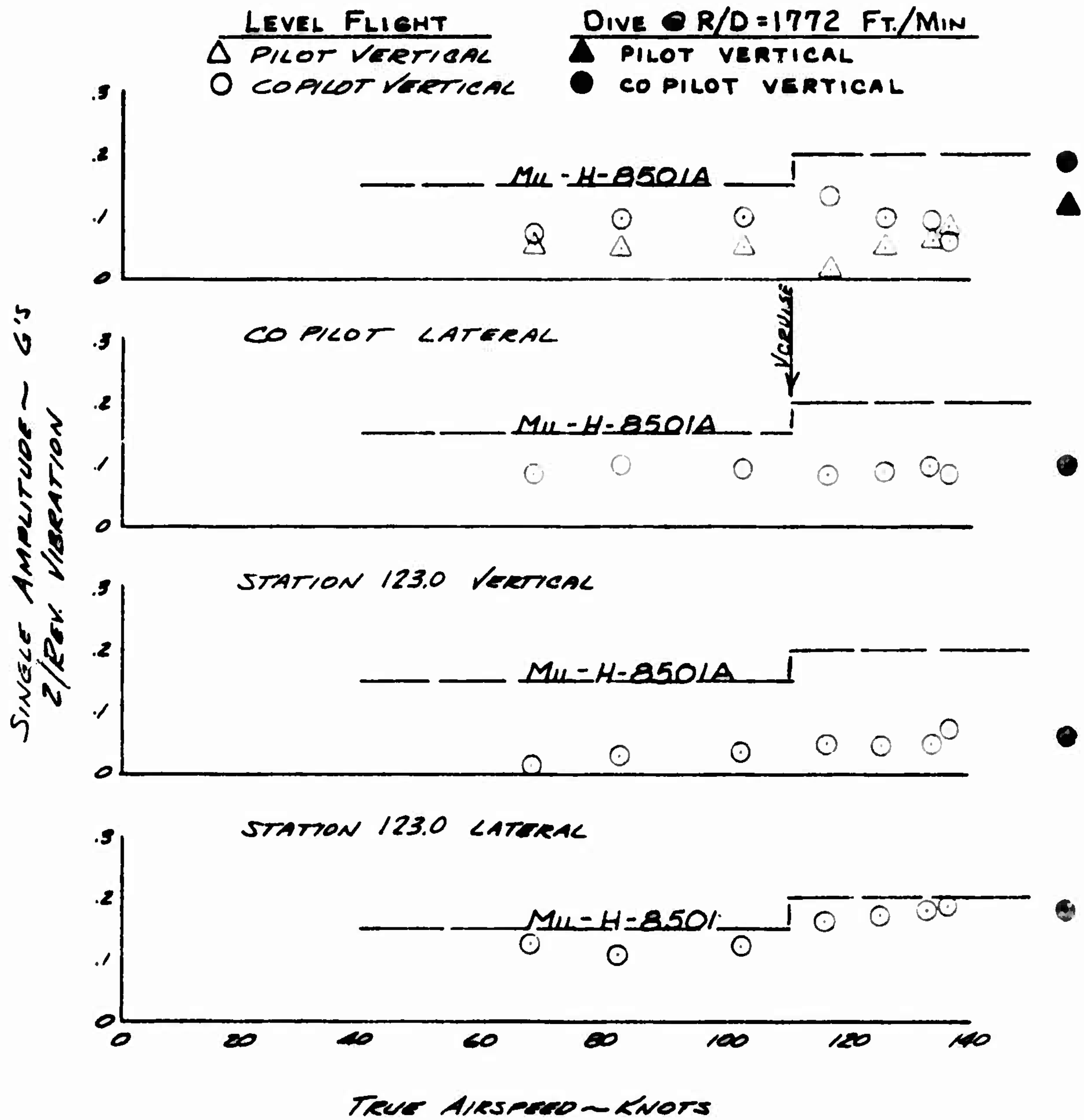


FIGURE NO. 40

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEMS

BELL MODEL 204-B N78977

GROSS WEIGHT 6380 LBS.
RPM 323 (ROTOR)
ALTITUDE 500 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130
PYLON CONFIG. ~ 0.015 IN. SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

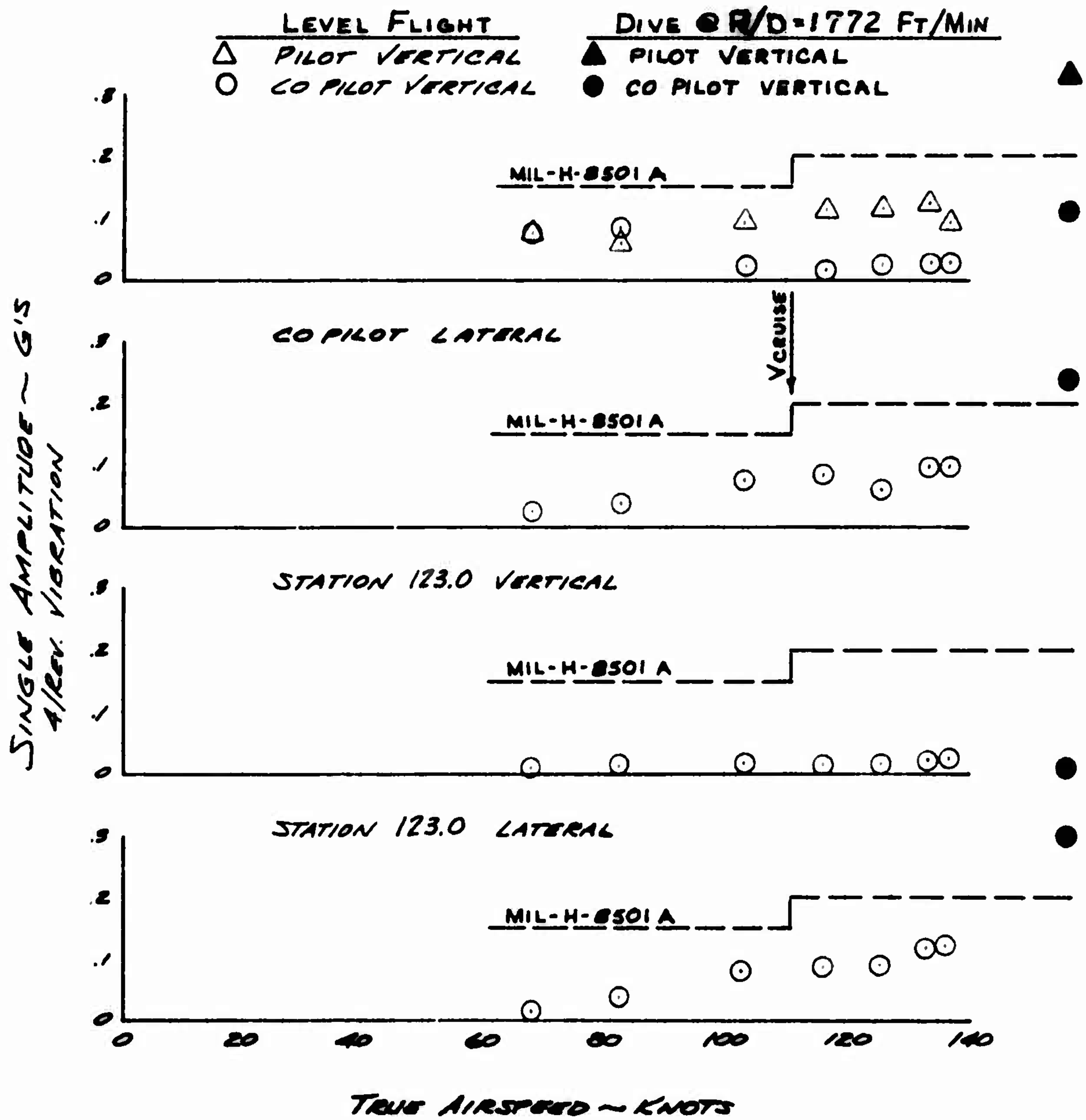


FIGURE NO. 41

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT 6615 LBS.
RPM 313.5 (ROTOR)
ALTITUDE -650 FT. H_D
CENTER OF GRAVITY ~ MID ~ STA 130.5
PYLON CONFIG. ~ 0.015 IN. SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

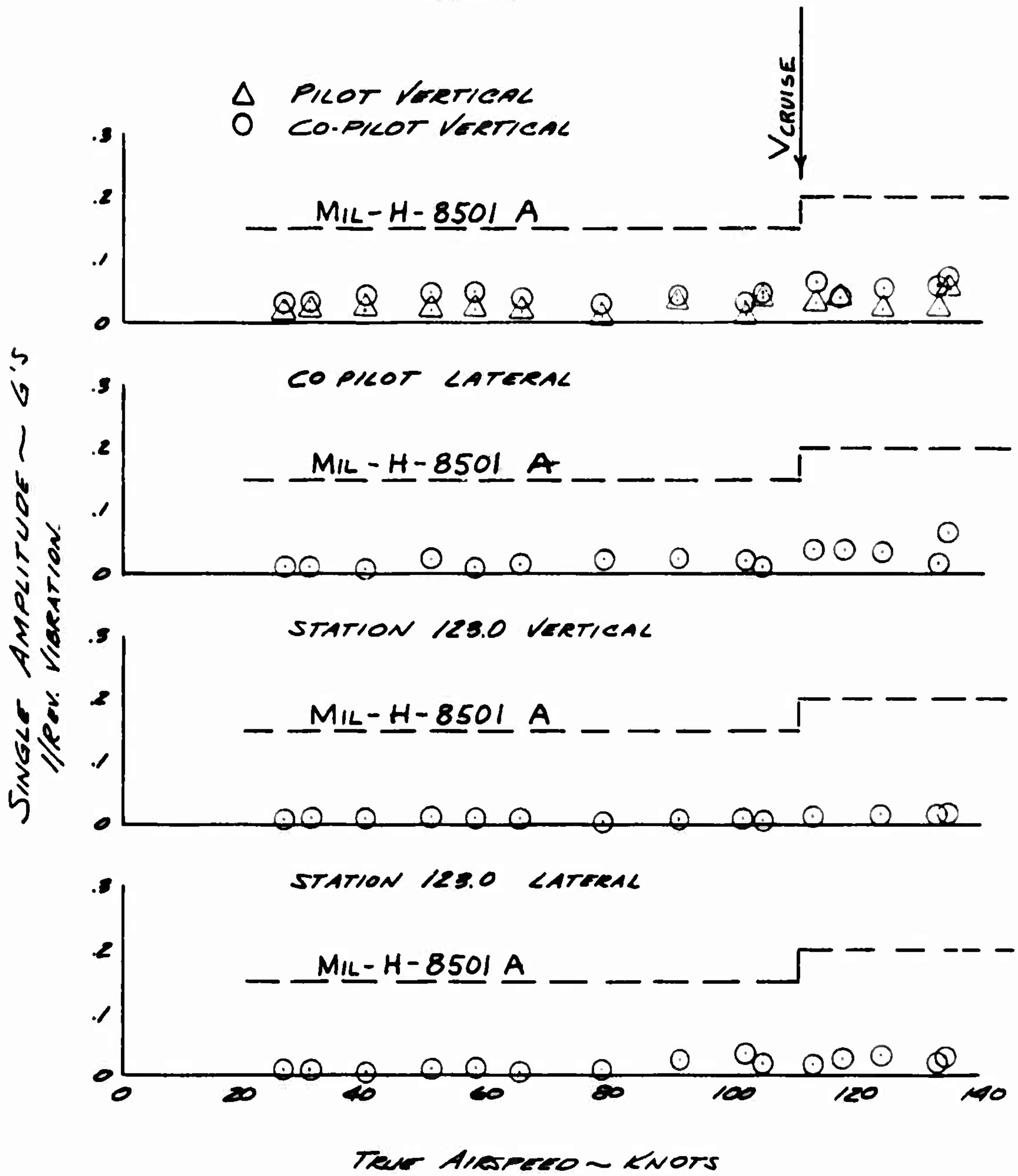


FIGURE No. 42
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 6615 LB.
RPM 313.5 (ROTOR)
ALTITUDE -650 FT. H_D
CENTER OF GRAVITY ~ MID ~ STA. 130.5
PYLON CONFIG. ~ 0.015 SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

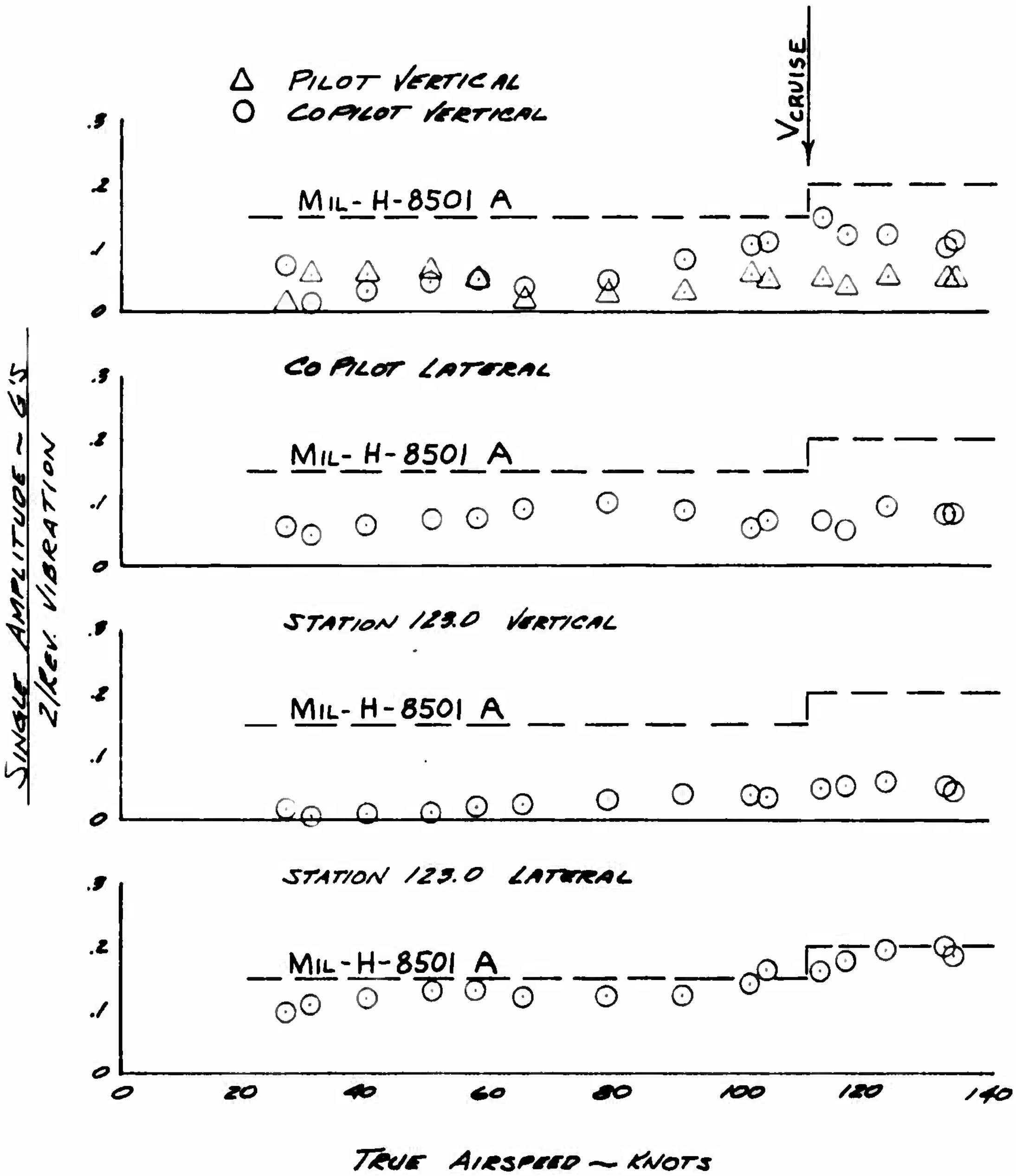


FIGURE NO. 49

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT 6615 LBS.
RPM 313.5 (ROTOR)
ALTITUDE -650 FT. HD
CENTER OF GRAVITY ~ MID ~ STA. 130.5
PYLON CONFIG. ~ 0.015 IN. SHIMS INSTALLED IN PYLON DAMPERS ~ NO LOST MOTION.

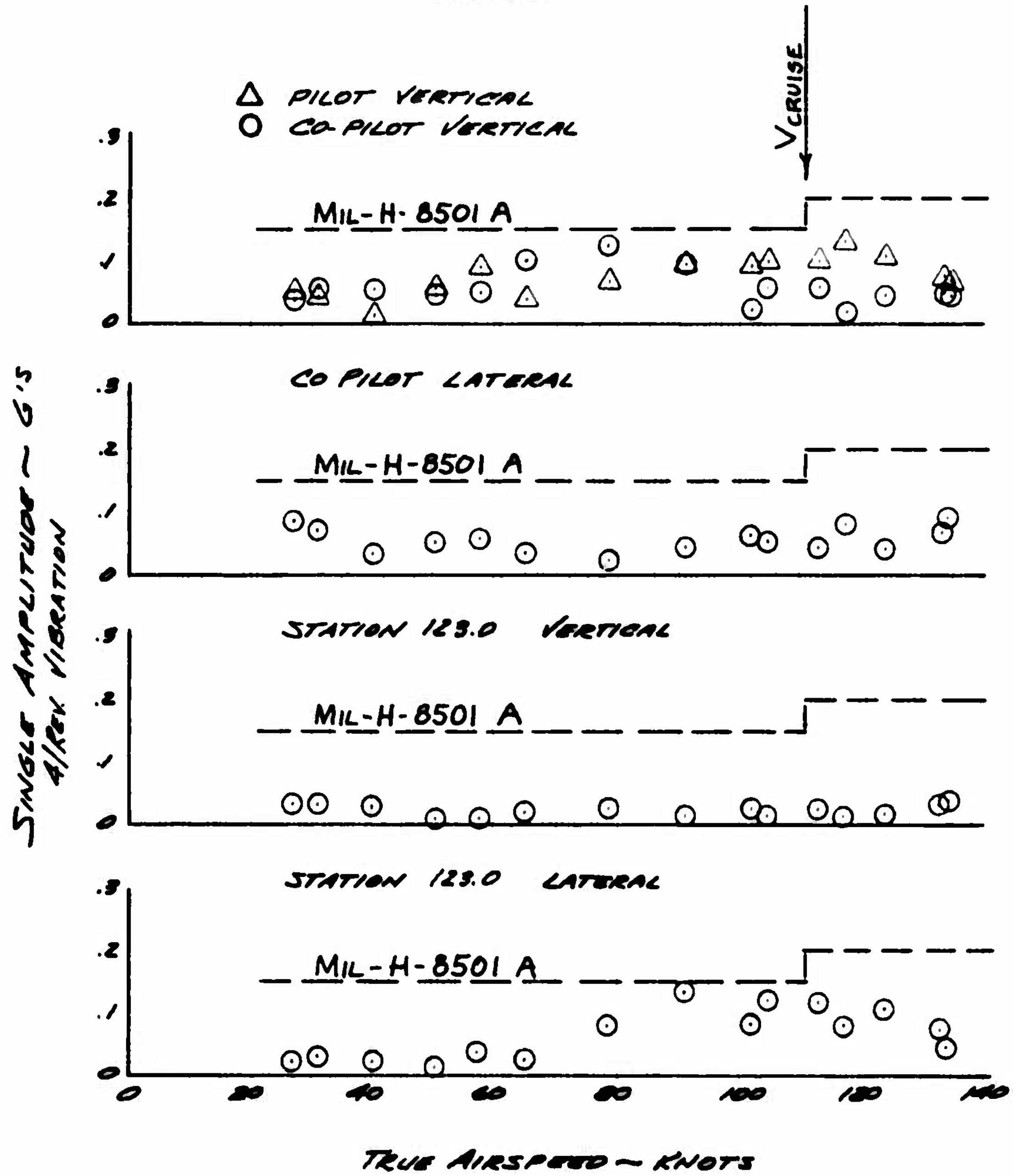


FIGURE No. 44
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 7730 LBS.
RPM 323 (ROTOR)
ALTITUDE 5000 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130.5
NOTE: AUTOROTATION ALTITUDE = 3000 FT.
PYLON CONFIG. ~ 20,000 LB/IN 5TH, FOUR 4500 LB/IN. MOUNTS
204-031-960-1 PYLON DAMPERS

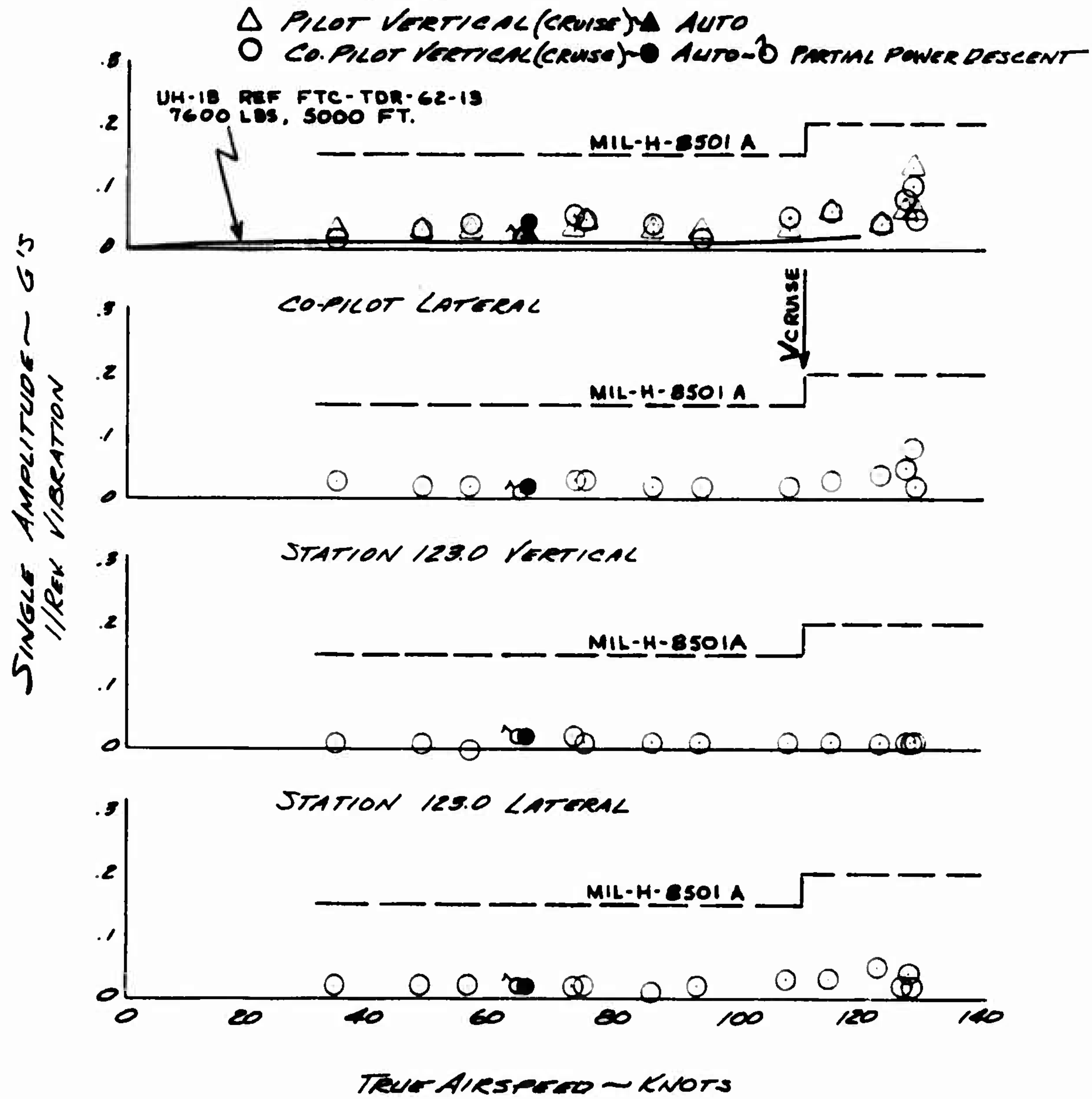


FIGURE NO. 45

VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 7730 LBS.
RPM 323 (ROTOR)
ALTITUDE 5000 FT
CENTER OF GRAVITY ~ MID ~ STA. 130.5
NOTE: AUTOROTATION ALTITUDE = 3000 FT.
PYLON CONFIG. ~ 20,000 LB/IN 5TH, FOUR 4500 LB/IN MOUNTS
204-031-960-1 PYLON DAMPERS

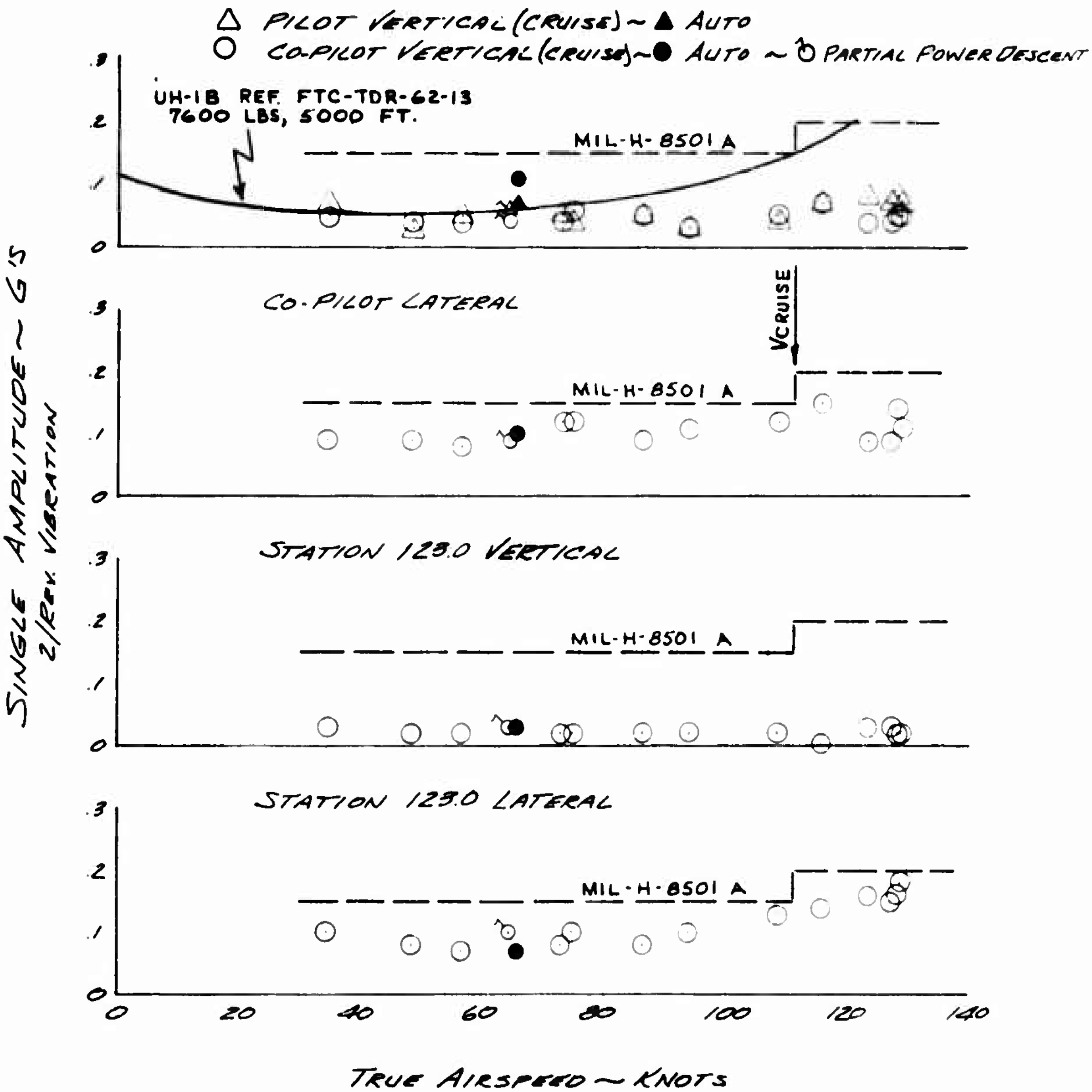


FIGURE NO. 46
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 7730 LBS.
RPM 323 (ROTOR)
ALTITUDE 5000 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130.5
NOTE: AUTOROTATION ALTITUDE = 3000 FT.
PYLON CONFIG. ~ 20,000 LB/IN 5TH, FOUR 4500 LB/IN. MOUNTS
204-031-960-1 PYLON DAMPERS

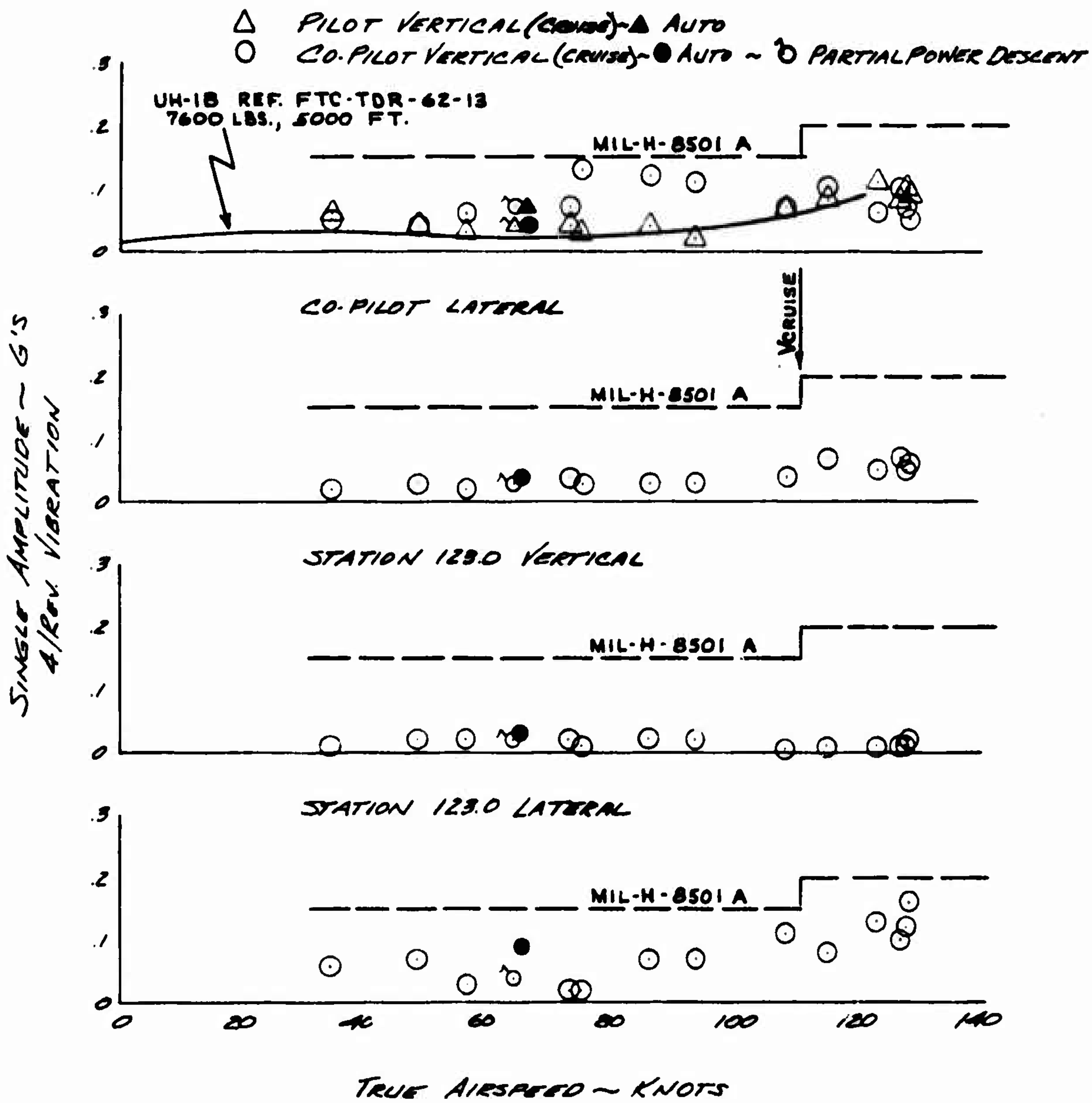


FIGURE NO. 47
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204B N73977

GROSS WEIGHT 7785 LBS.
RPM 323 (ROTOR)
ALTITUDE 11,750 FT.
CENTER OF GRAVITY ~ MID ~ STA. 131

PYLON CONFIG. ~ 20,000 LB/IN 5TH, FOUR 4500 LB/IN MOUNTS 204-031-360-1 PYLON DAMPERS

NOTE: AUTOROTATION ALTITUDES = 9840 FT. 83.4 KTS. VTRUE
7950 FT. 70.8 KTS. VTRUE
4940 FT. 56.6 KTS. VTRUE

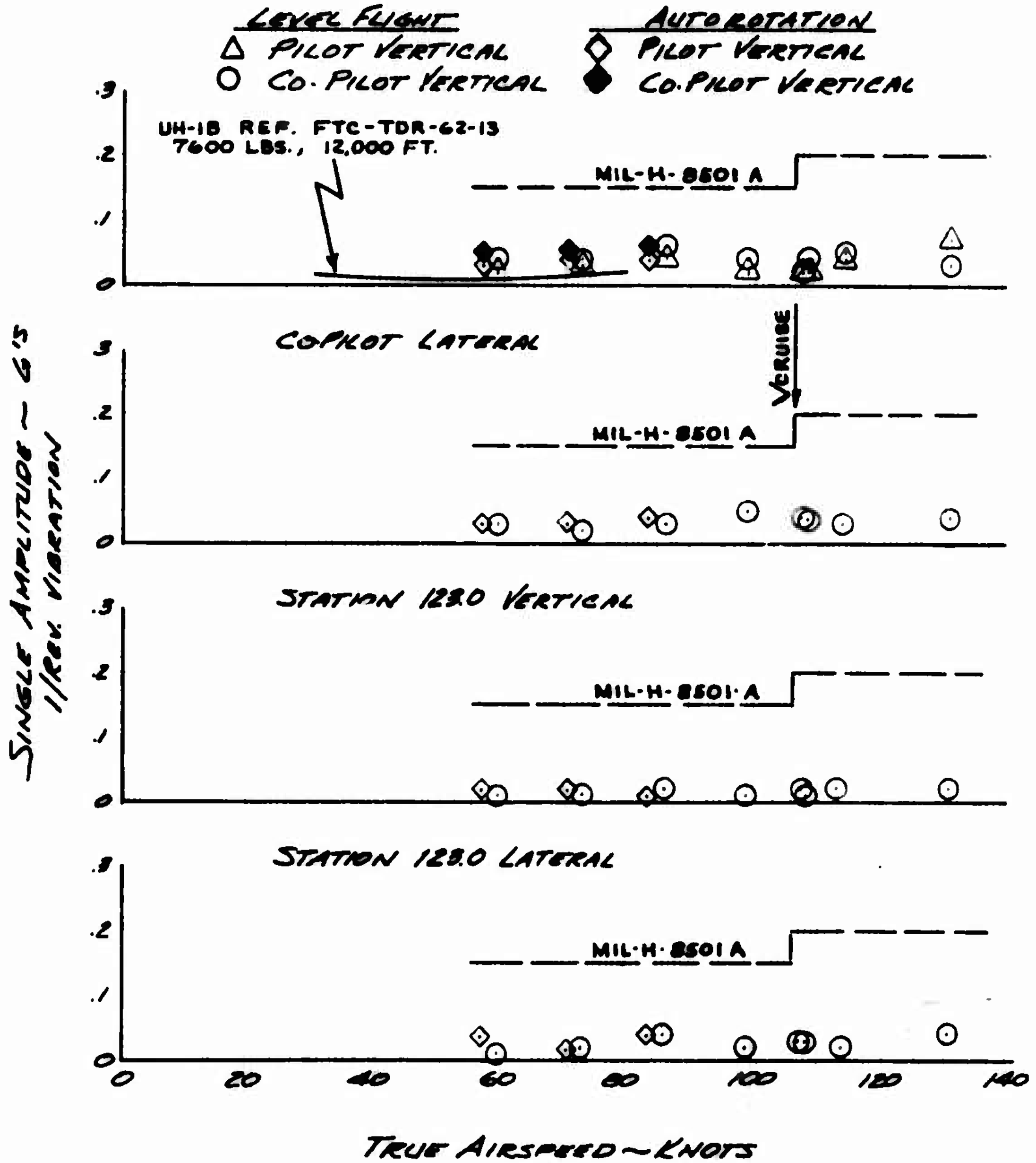


FIGURE NO. 48
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N78977

GROSS WEIGHT 7785 LBS.
RPM 323 (ROTOR)
ALTITUDE 11,750 FT.
CENTER OF GRAVITY ~ MID ~ STA. 131

PYLON CONFIG. ~ 20,000 LB/IN 5TH, FOUR 4500 LB/IN MOUNTS 204-031-360-1 PYLON DAMPERS.

NOTE: AUTOROTATION ALTITUDES = 9940 FT. 89.4 KTS. VTRUE
7950 FT. 70.8 KTS. VTRUE
4940 FT. 56.6 KTS. VTRUE

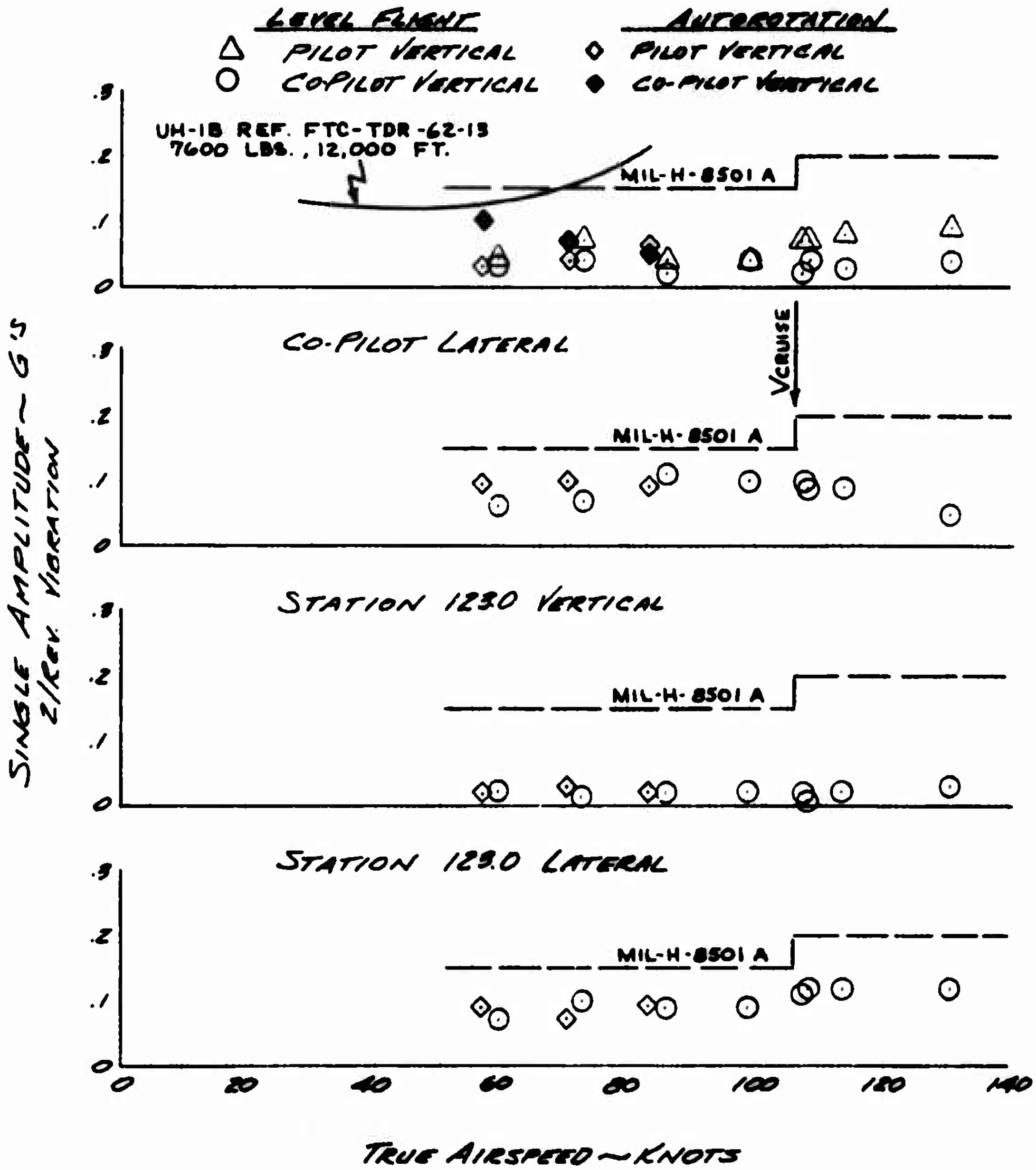


FIGURE NO. 50

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT 7785 LBS. PYLON CONFIG. ~ 20,000 LB/IN 5 IN, FOUR 4500 LB/IN MOUNTS 204-031-960-1 PYLON DAMPERS.

RPM 323 (ROTOR)

ALTITUDE 11,750 FT.

CENTER OF GRAVITY ~ MID ~ STA. 131

NOTE: AUTOROTATION ALTITUDES = 9340 FT. 89.4 KTS. VTRUE

7950 FT. 70.3 KTS. VTRUE

4950 FT. 56.6 KTS. VTRUE

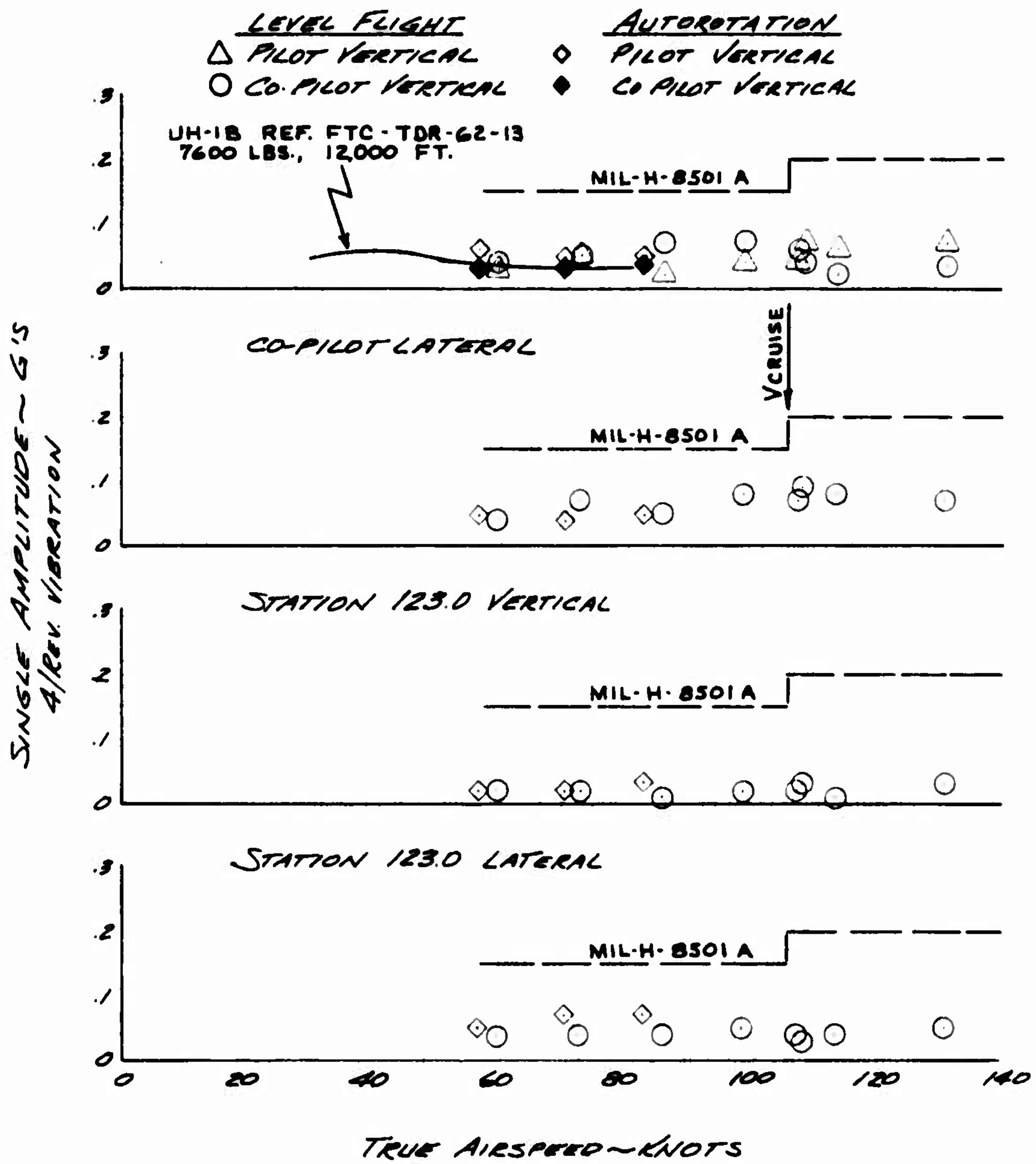


FIGURE No. 50

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73971

GROSS WEIGHT 8235 LBS. PYLON CONFIG. ~ 204-031-960-3
RPM 323 (ROTOR) PYLON DAMPERS
ALTITUDE 9650 FT. 0.070 IN. SHIMS
CENTER OF GRAVITY ~ MID ~ STA. 130 REMOVED
NOTE: AUTOROTATION ALTITUDES = 7480 FT. 50 KTS. VTRUE
6100 FT. 60.3 KTS. VTRUE
3620 FT. 68.9 KTS. VTRUE
930 FT. 77.2 KTS. VTRUE

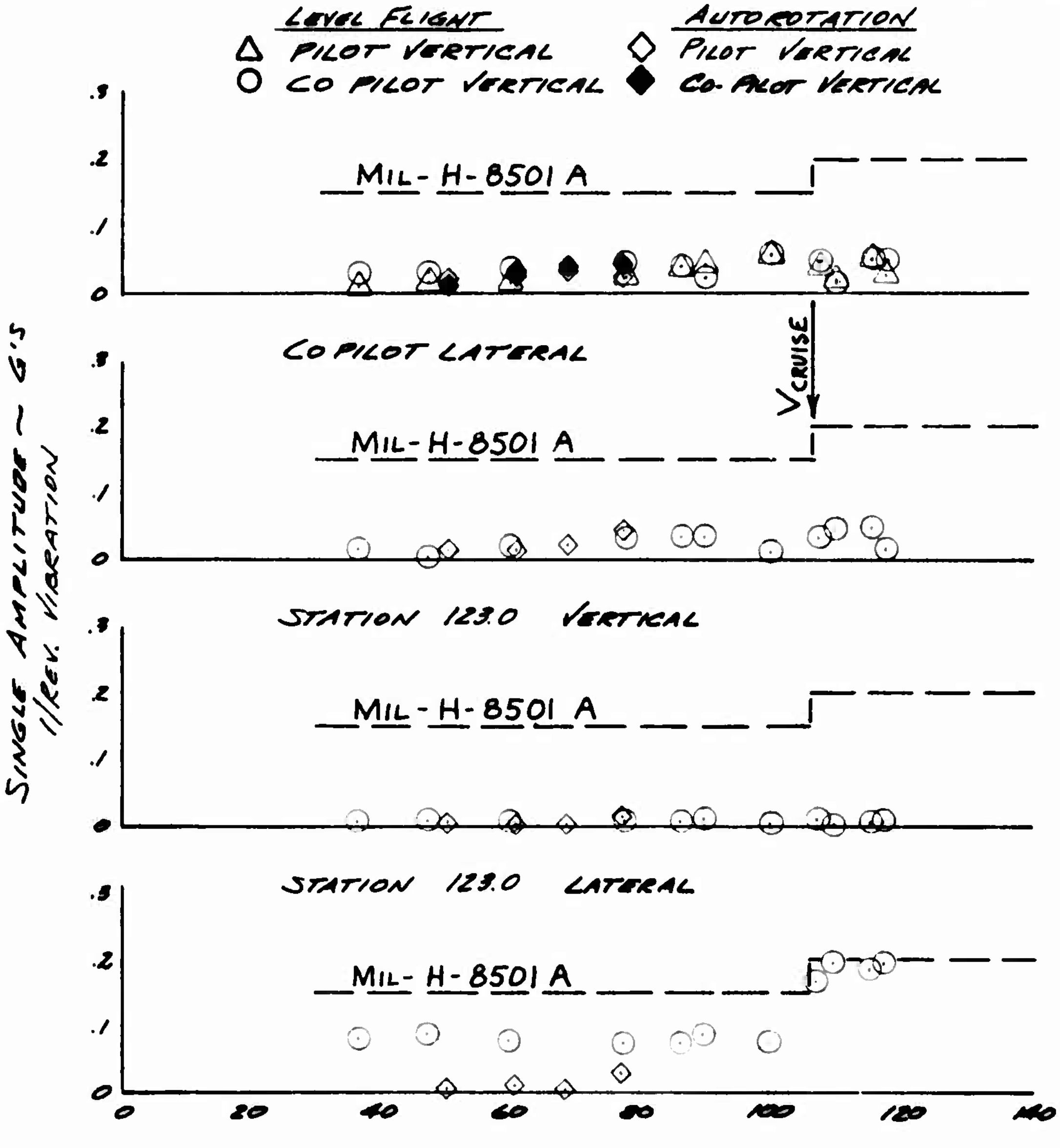


FIGURE NO. 51

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT 8235 LBS.
RPM 323 (ROTOR)
ALTITUDE 9650 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130

PYLON CONFIG. ~ 204-031-360-3
PYLON DAMPERS
0.070 IN. SHIMS
REMOVED.

NOTE: AUTOROTATION ALTITUDES:

7480 FT.	50 KTS. VTRUE
6100 FT.	60.3 KTS. VTRUE
3620 FT.	68.9 KTS. VTRUE
930 FT.	77.2 KTS. VTRUE

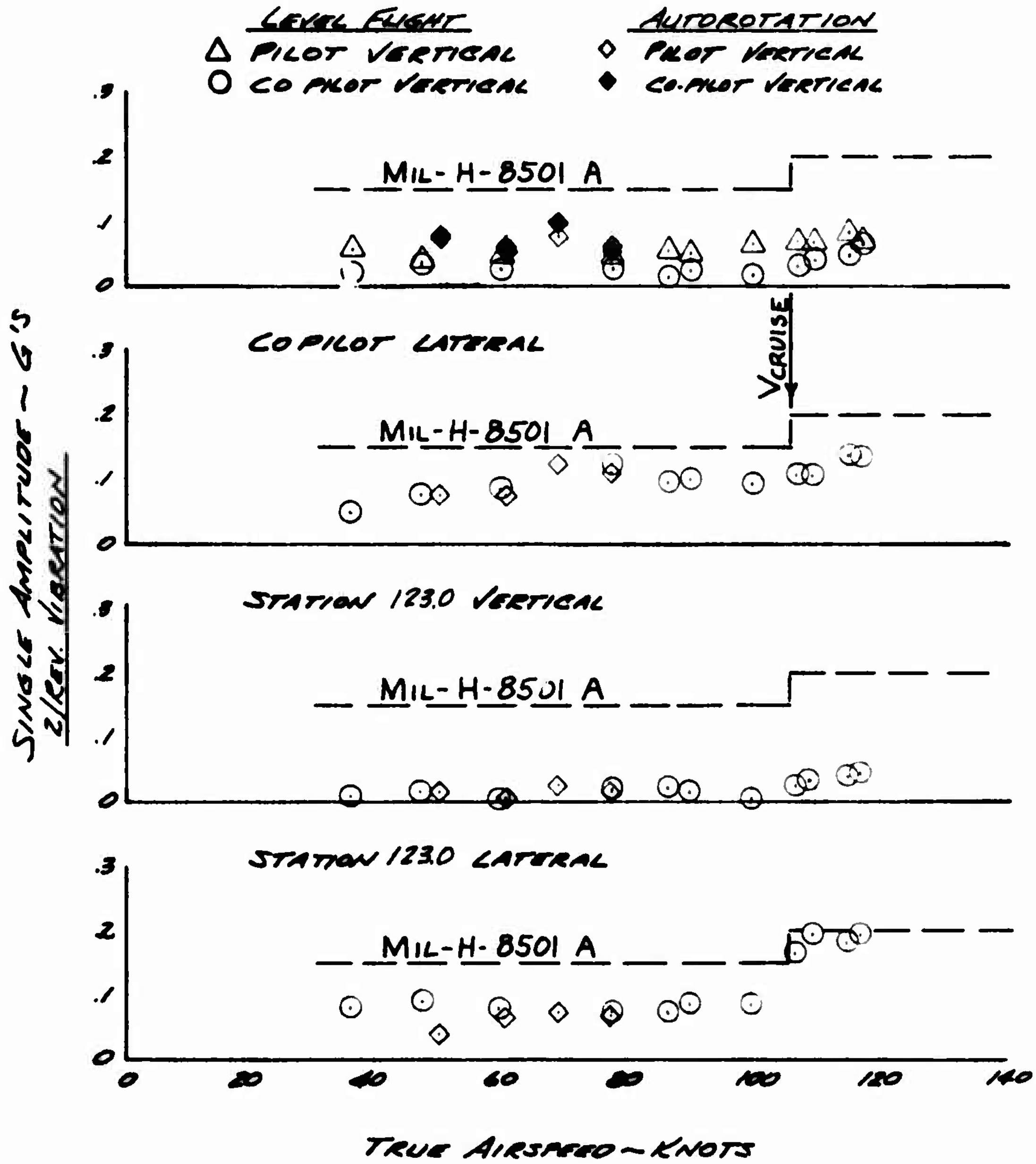


Figure No. 52
Vibration Characteristics
Door Hinge Rotor System
Bell Model 204-B N73977

Gross Weight 8235 Lbs.
RPM 323 (Rotor)
Altitude 9650 Ft.
Center Of Gravity ~ Mid ~ Sta. 130

Pylon Config. ~ 204-031-960-3
Pylon Dampers
0.070 in. Shims
Removed.

Note: Autorotation Altitudes = 7480 Ft. 50 Kts. Vtrue
6100 Ft. 62.9 Kts. Vtrue
3620 Ft. 68.9 Kts. Vtrue
930 Ft. 77.2 Kts. Vtrue

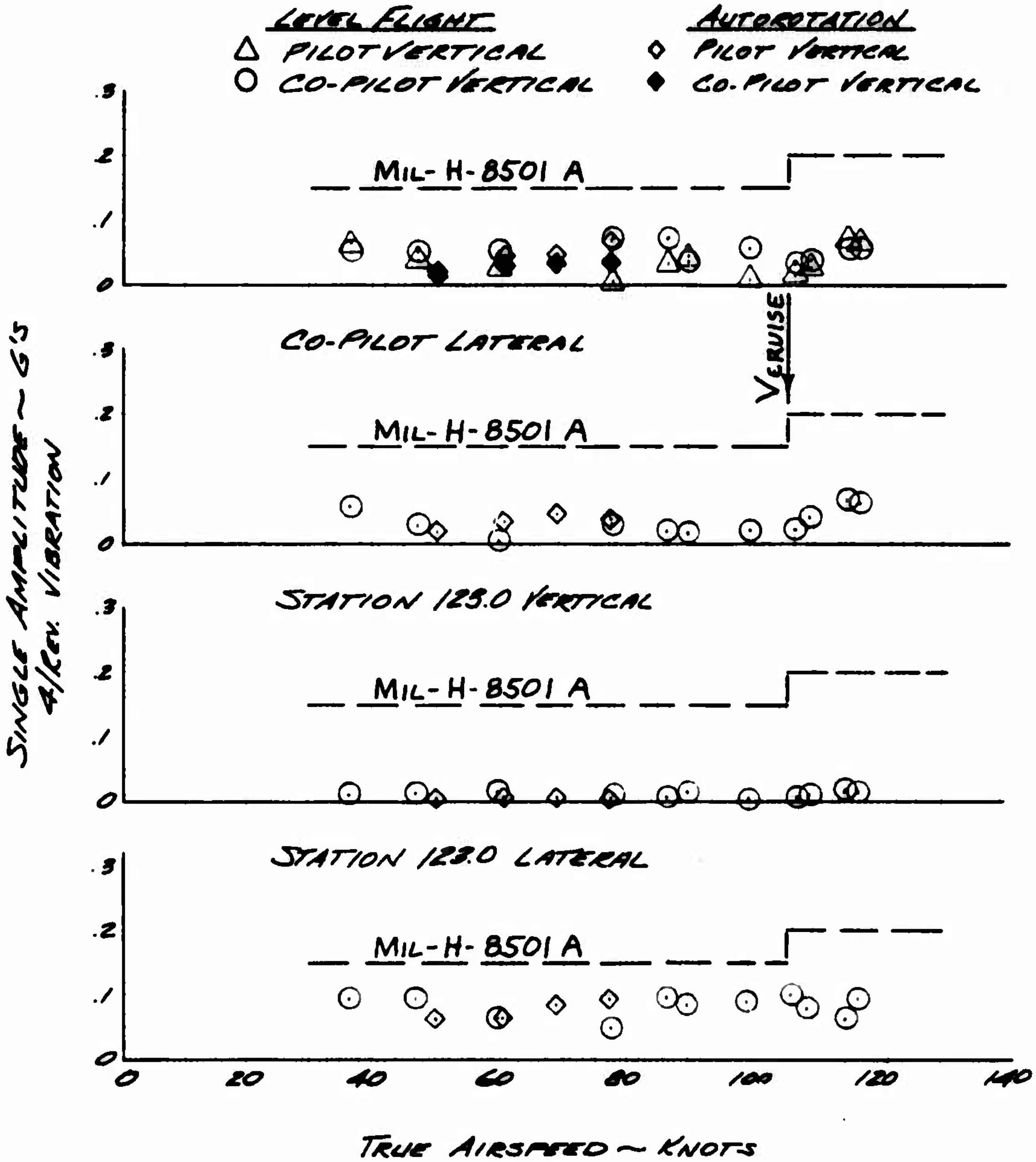


FIGURE NO. 53
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 8565 LBS.
RPM 323 (ROTOR)
ALTITUDE 5050 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130.5
PYLON CONFIG. ~ 204-031-960-3 PYLON DAMPERS
0.070 IN. SHIMS REMOVED

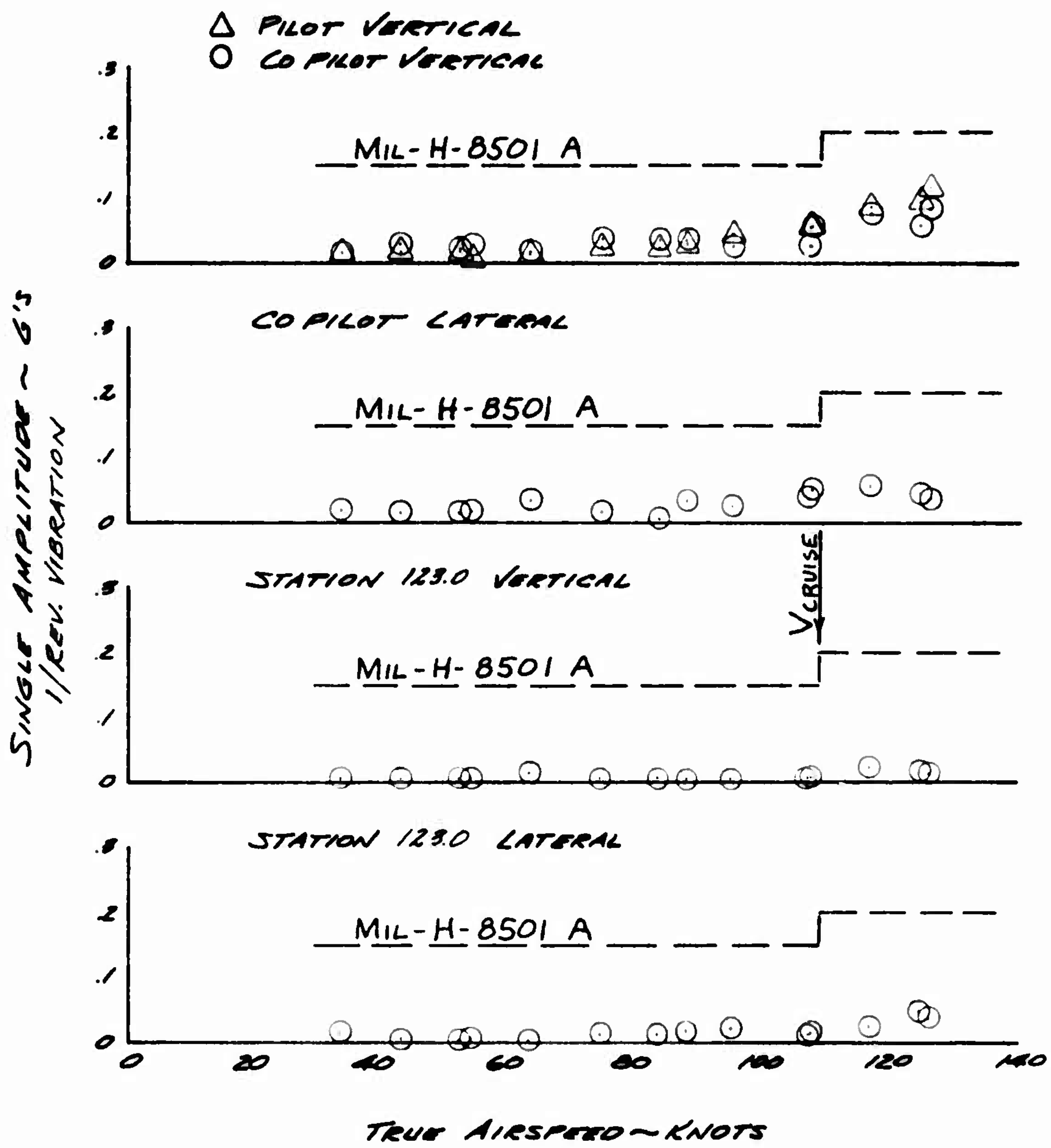


FIGURE NO. 54
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 8565 LBS.
RPM 323 (ROTOR)
ALTITUDE 5050 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130.5
PYLON CONFIG. ~ 204-031-960-3 PYLON DAMPERS
0.070 IN. SHIMS REMOVED

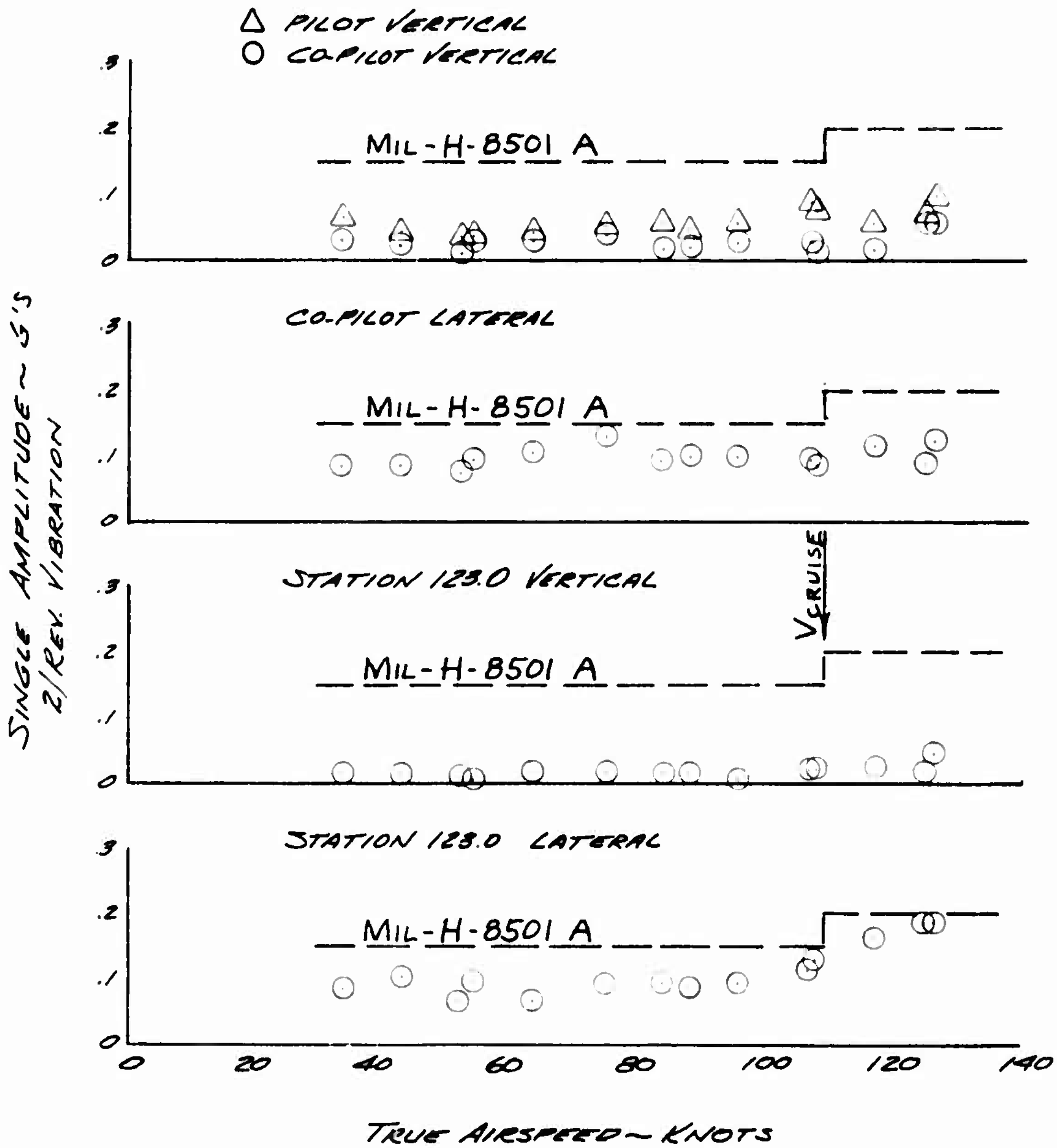


FIGURE NO. 55
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 8565 LBS.
RPM 323 (ROTOR)
ALTITUDE 5050 FT.
CENTER OF GRAVITY ~ MID ~ STA. 130.5
PYLON CONFIG. ~ 204-031-360-3 PYLON DAMPERS
0.070 IN. SHIMS REMOVED

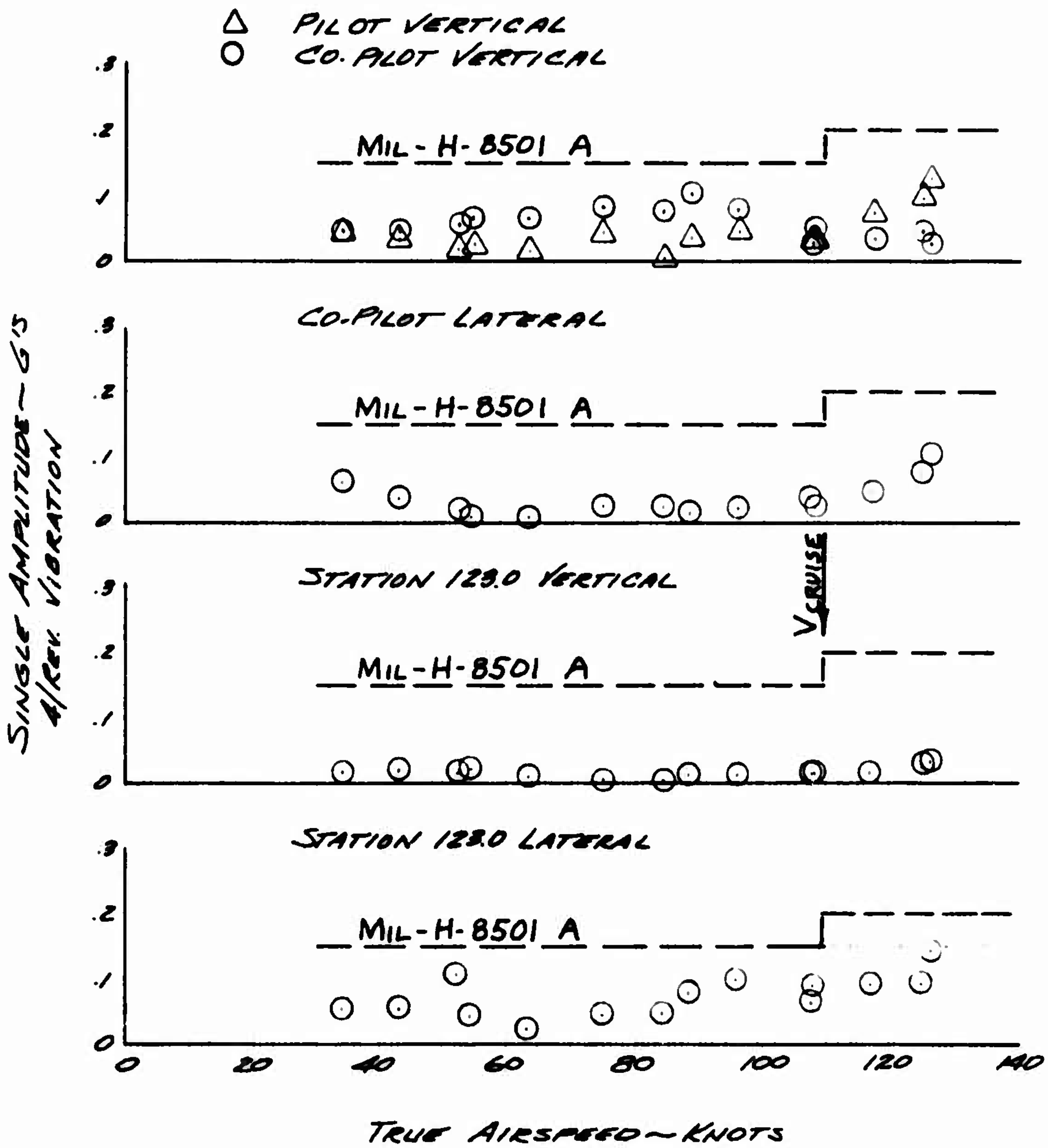


FIGURE No. 56

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N78977

GROSS WEIGHT ~ 9875 LBS.
RPM ~ 322 (ROTOR)
ALTITUDE ~ 8400 FT. H_D
CENTER OF GRAVITY ~ MID ~ STA. 127.5

PYLON CONFIG. ~ REMOVED FOUR 4800 LB/IN. MOUNTS, REPLACED WITH 10,000 LB/IN. MOUNTS.

NOTE: AUTOROTATION ALTITUDES = 6580 FT. 70.2 KTS VTRUE
1580 FT. 88.3 KTS. VTRUE

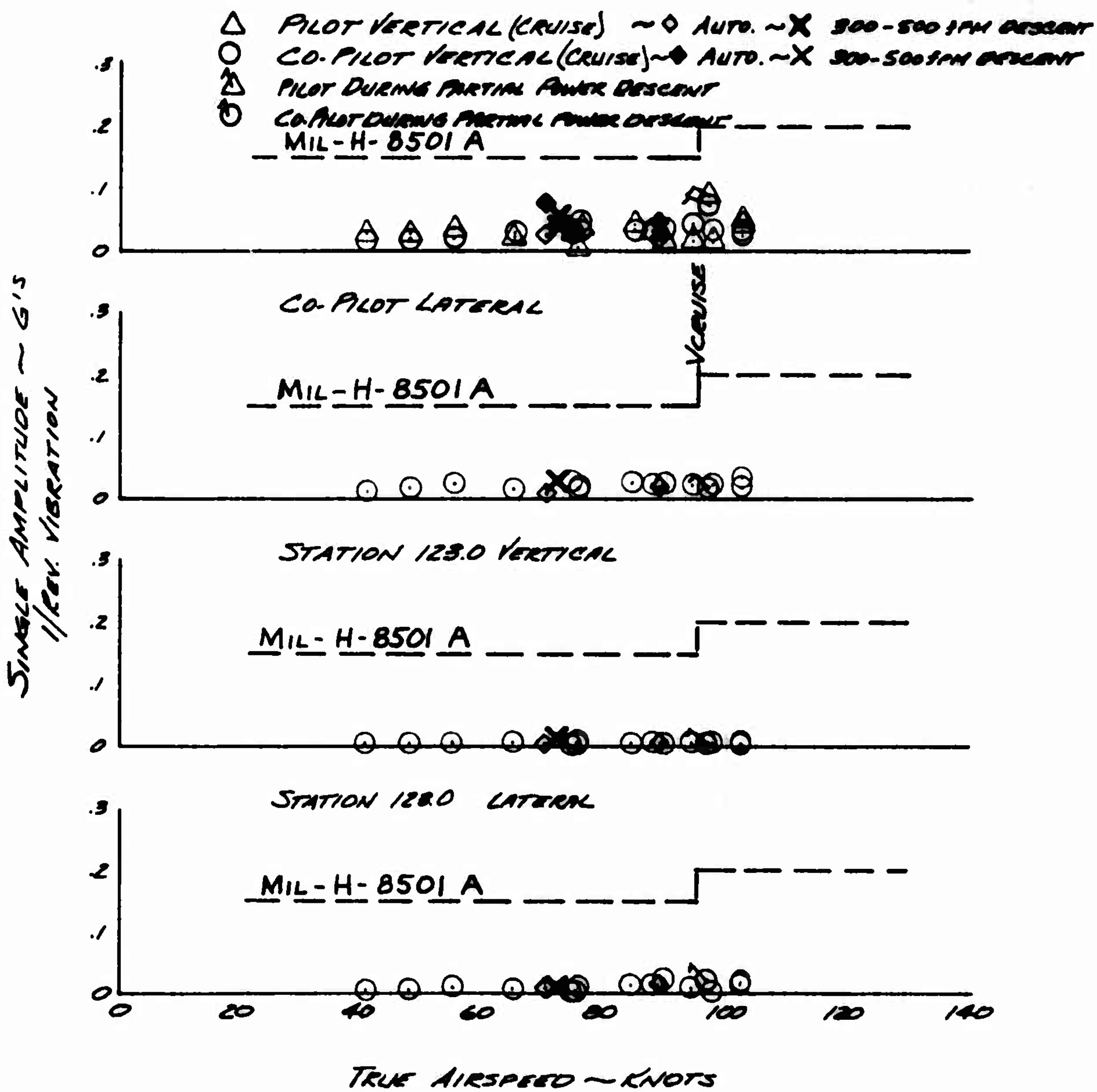


FIGURE NO. 57

VIBRATION CHARACTERISTICS

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N73977

GROSS WEIGHT ~ 9375 LBS.
RPM ~ 322 (ROTOR)
ALTITUDE ~ 8400 FT.
CENTER OF GRAVITY ~ MID ~ STA. 127.5

PYLON CONFIG. ~ REMOVED FOUR 4500 LB/IN MOUNTS, REPLACED WITH 10,000 LB/IN. MOUNTS

NOTE: AUTOROTATION ALTITUDES = 6530 FT. 70.2 KTS. VTRUE
1580 FT. 88.8 KTS. VTRUE

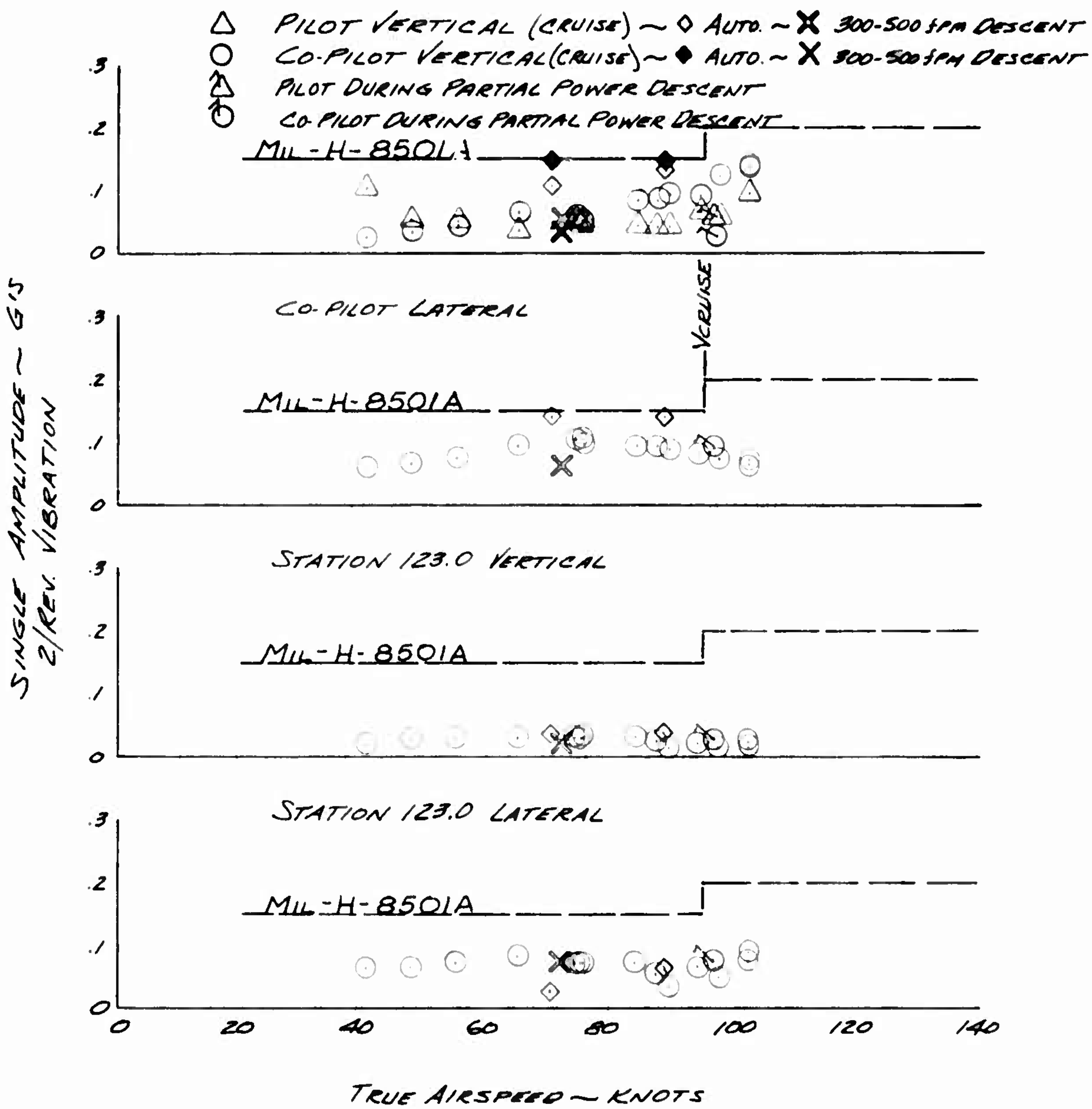


FIGURE No. 58
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT ~ 9375 LBS.
RPM ~ 322 (ROTOR)
ALTITUDE ~ 8400 FT.
CENTER OF GRAVITY ~ MID ~ STA. 127.5
NOTE: AUTOROTATION ALTITUDES = 6530 FT. 70.2 KTS. VTRUE
1580 FT. 88.8 KTS. VTRUE

PYLON CONFIG. ~ REMOVED FOUR 4500 LB/IN. MOUNTS, REPLACED WITH 10,000 LB/IN. MOUNTS

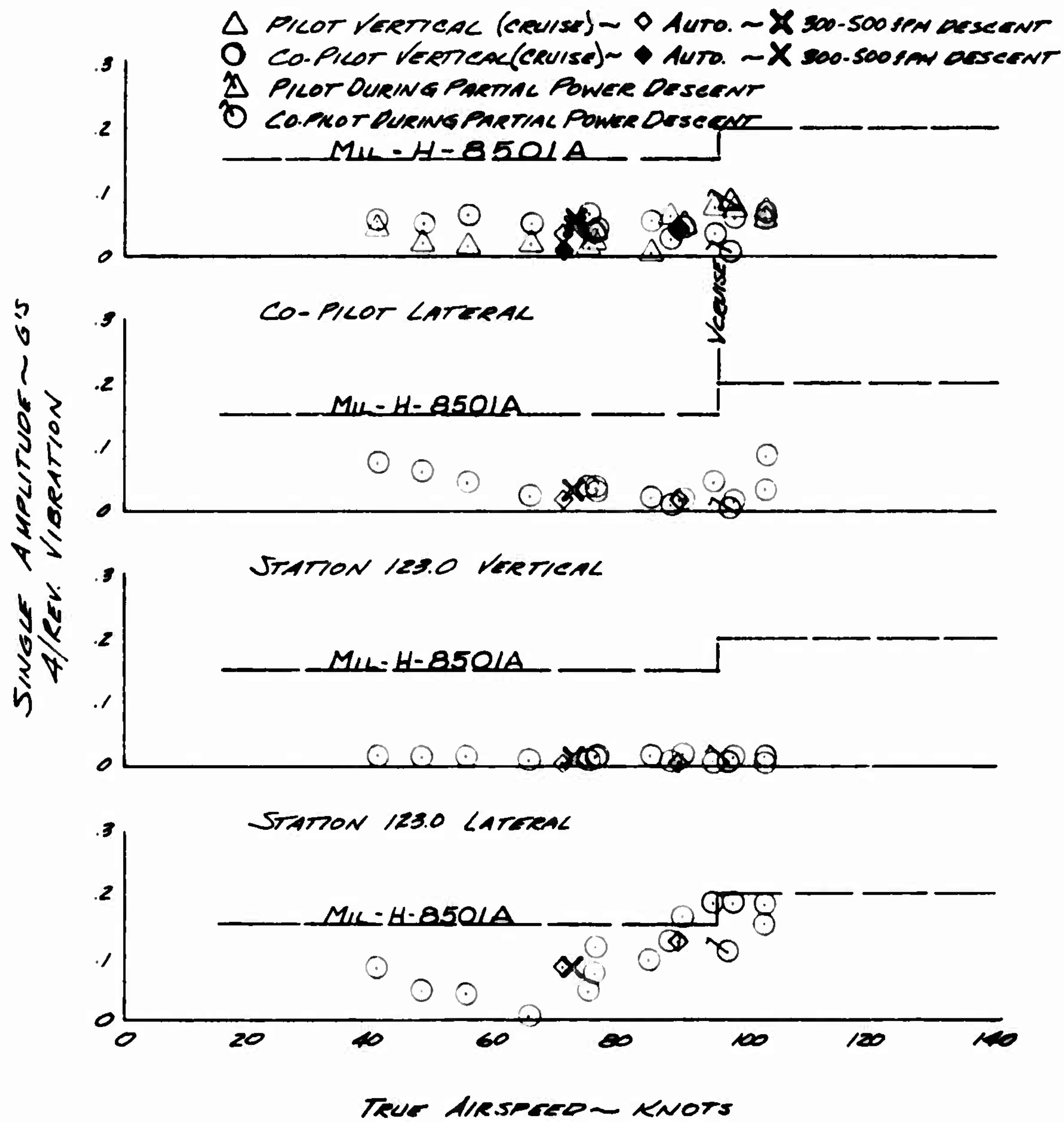


Figure No. 59
Vibration Characteristics
Door Hinge Rotor System
Bell Model 204B N73977

Gross Weight ~ 7030 Lbs.
RPM ~ 323 (Rotor)
Altitude ~ 170 Feet Hd
Center Of Gravity ~ 125.3 (Fwd)

Level Acceleration at Partial Power

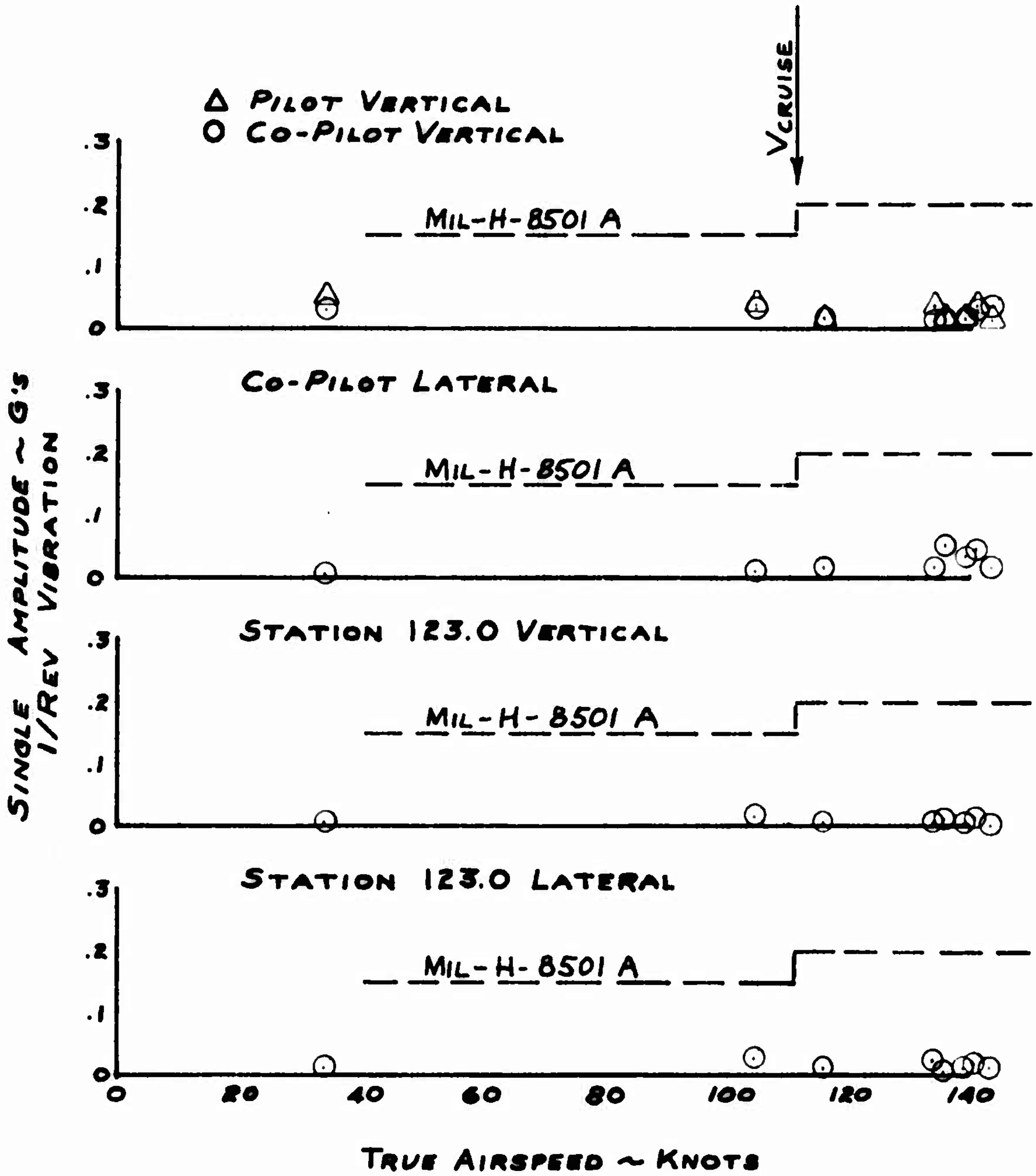


FIGURE No. 60
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204B N73977

GROSS WEIGHT 7030 LBS
RPM ~ 323 (ROTOR)
ALTITUDE ~ 170 FT HD
CENTER OF GRAVITY ~ 125.3 (FWD)

LEVEL ACCELERATION AT PARTIAL POWER

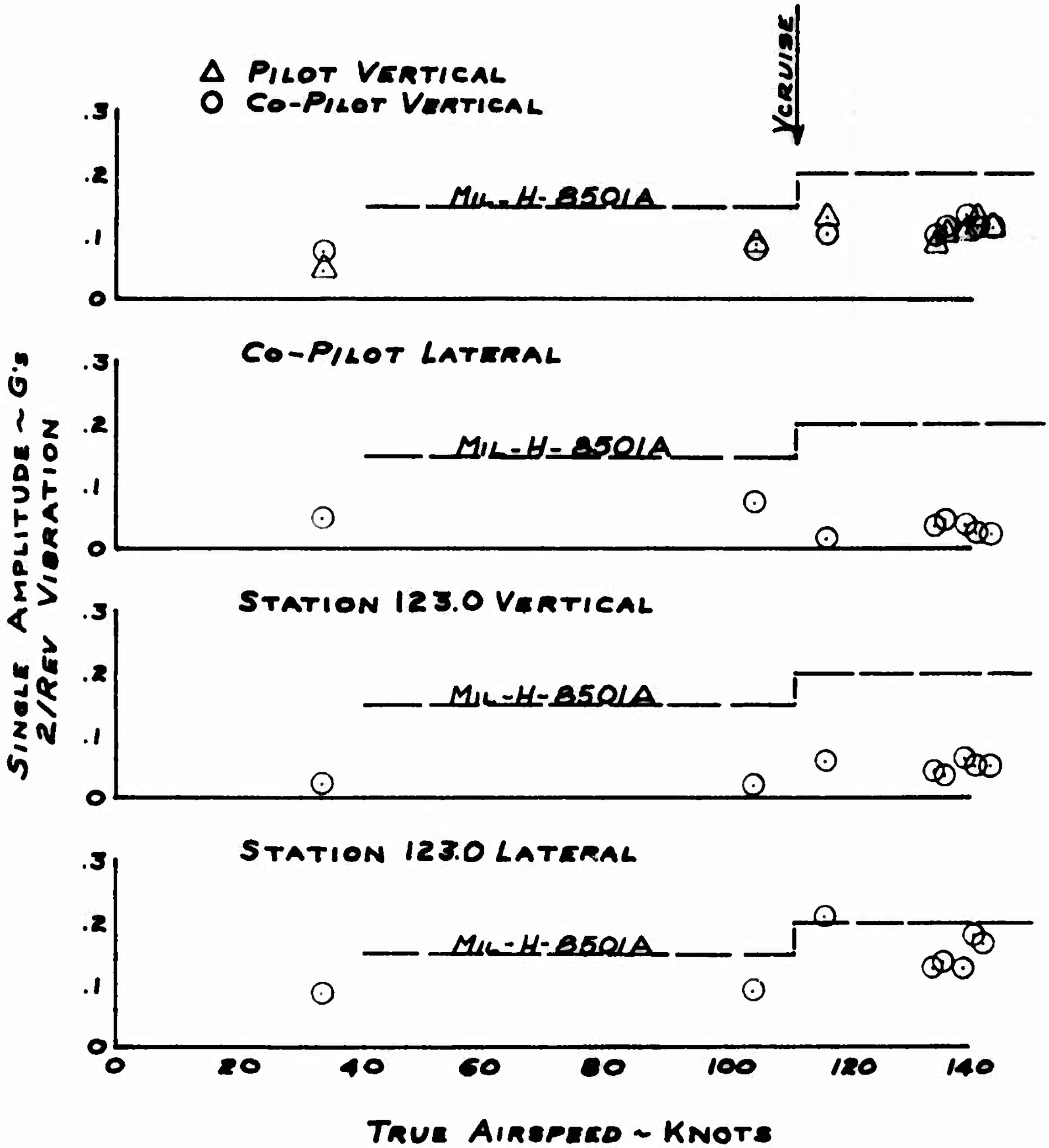


FIGURE NO. 61
VIBRATION CHARACTERISTICS
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

GROSS WEIGHT 7030 LBS
RPM ~ 323 (ROTOR)
ALTITUDE ~ 170 FT HD
CENTER OF GRAVITY ~ 125.3 (FWD)

LEVEL ACCELERATION AT PARTIAL POWER

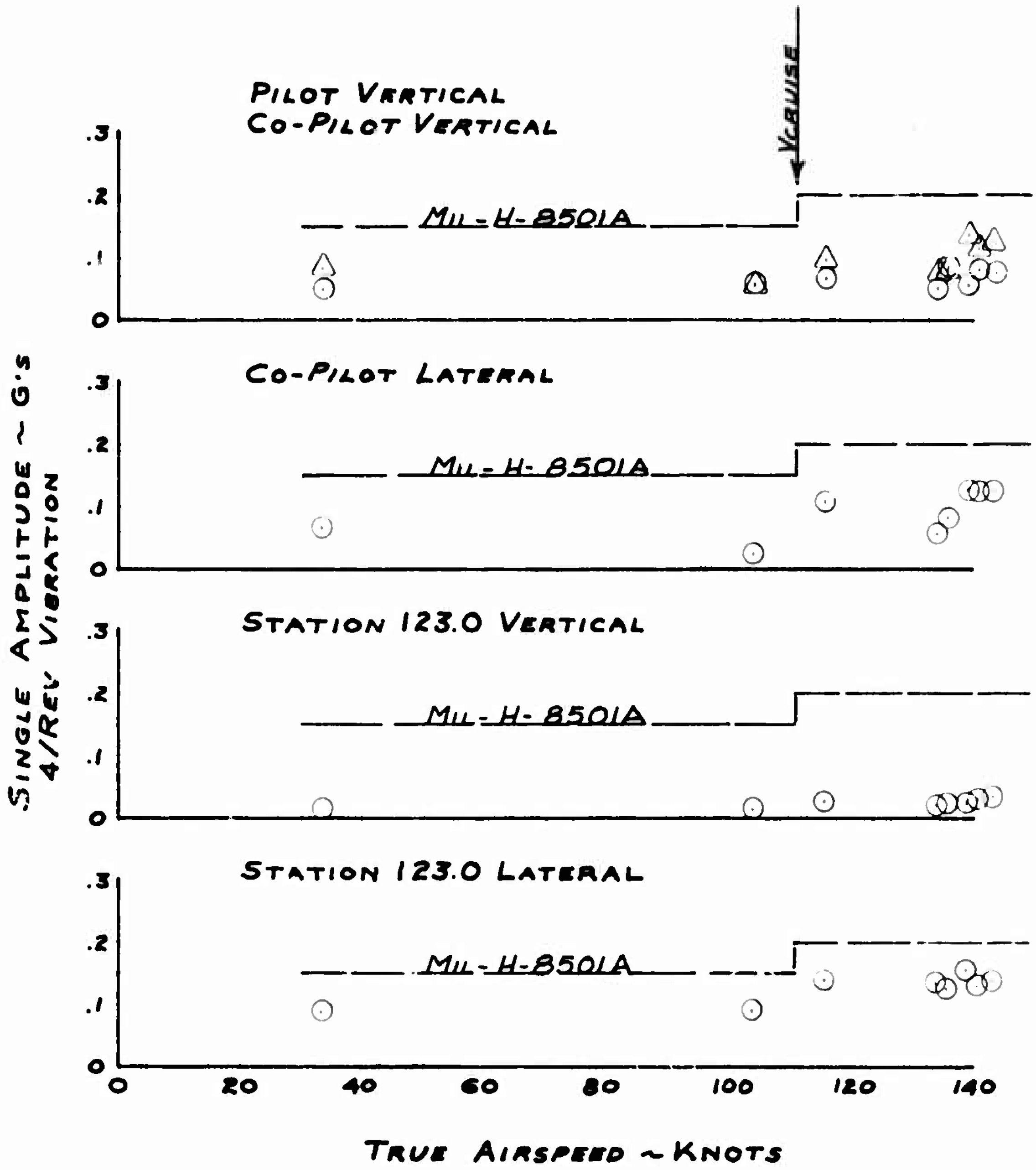


FIGURE No. 62
AIRSPEED CALIBRATION:
DOOR HINGE ROTOR SYSTEM
BELL MODEL 204-B N73977

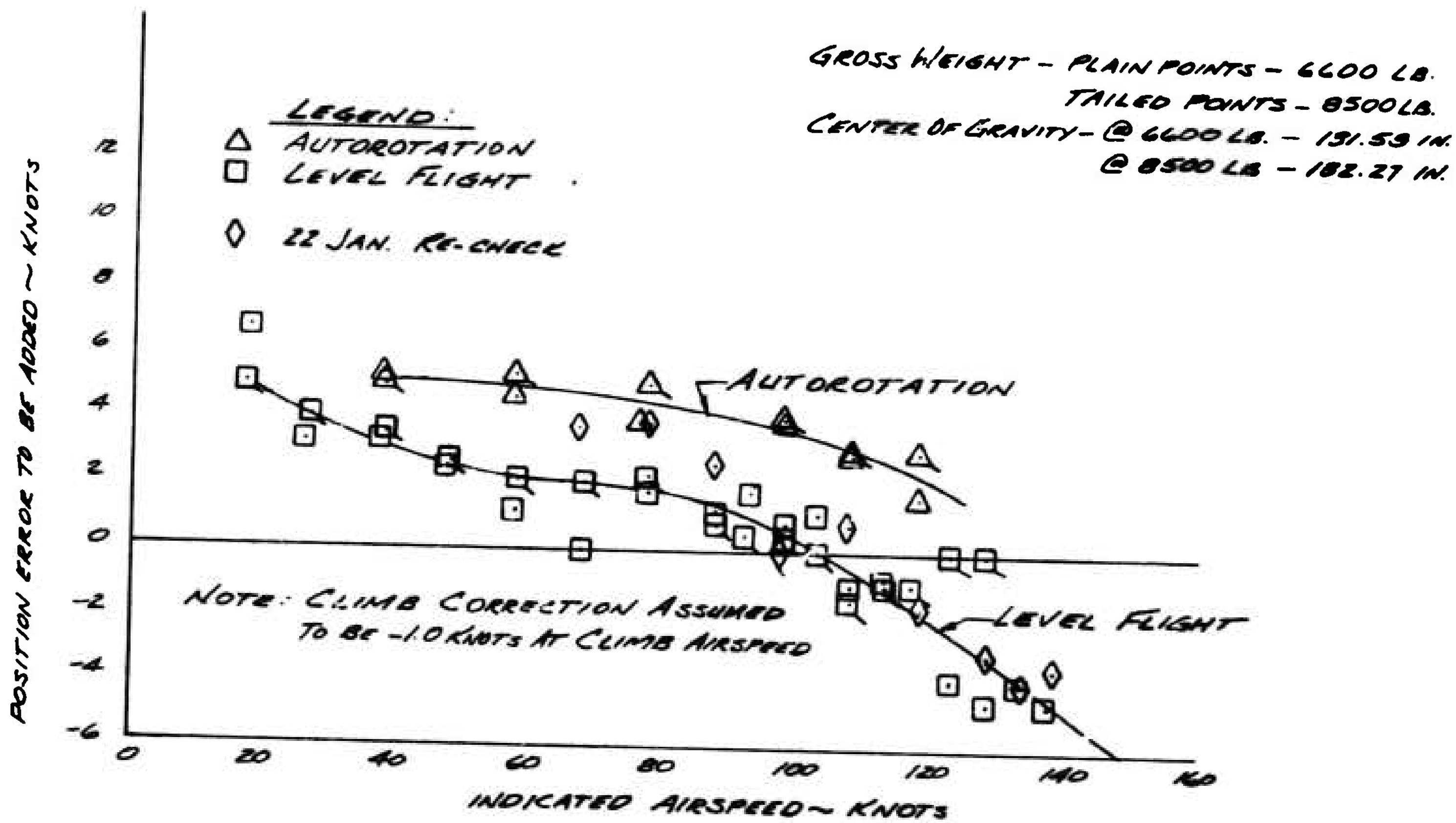


FIGURE No. 63

POWER AVAILABLE

STANDARD DAY

T53-L-9 & 11 ENGINES

6600 RPM

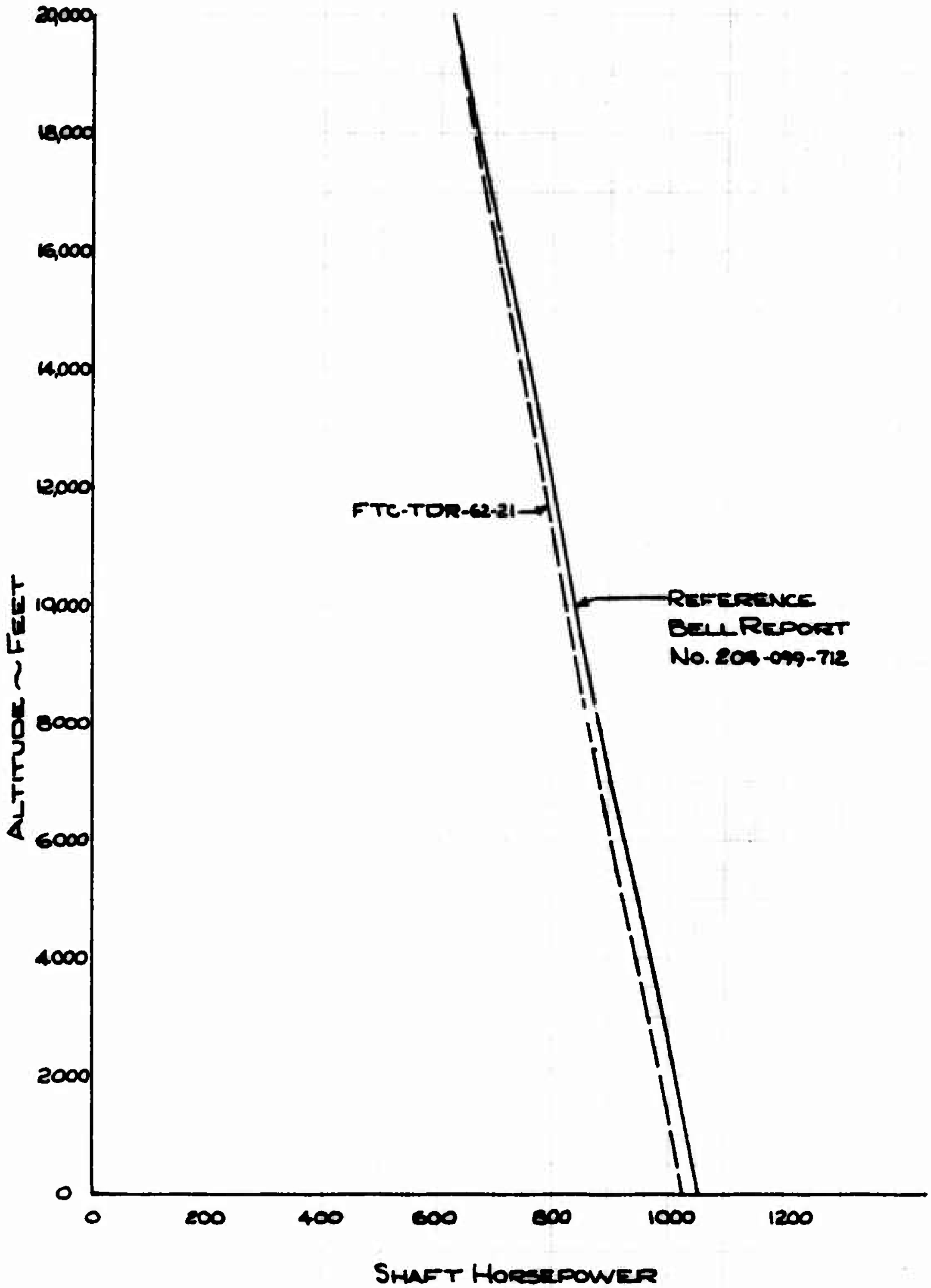
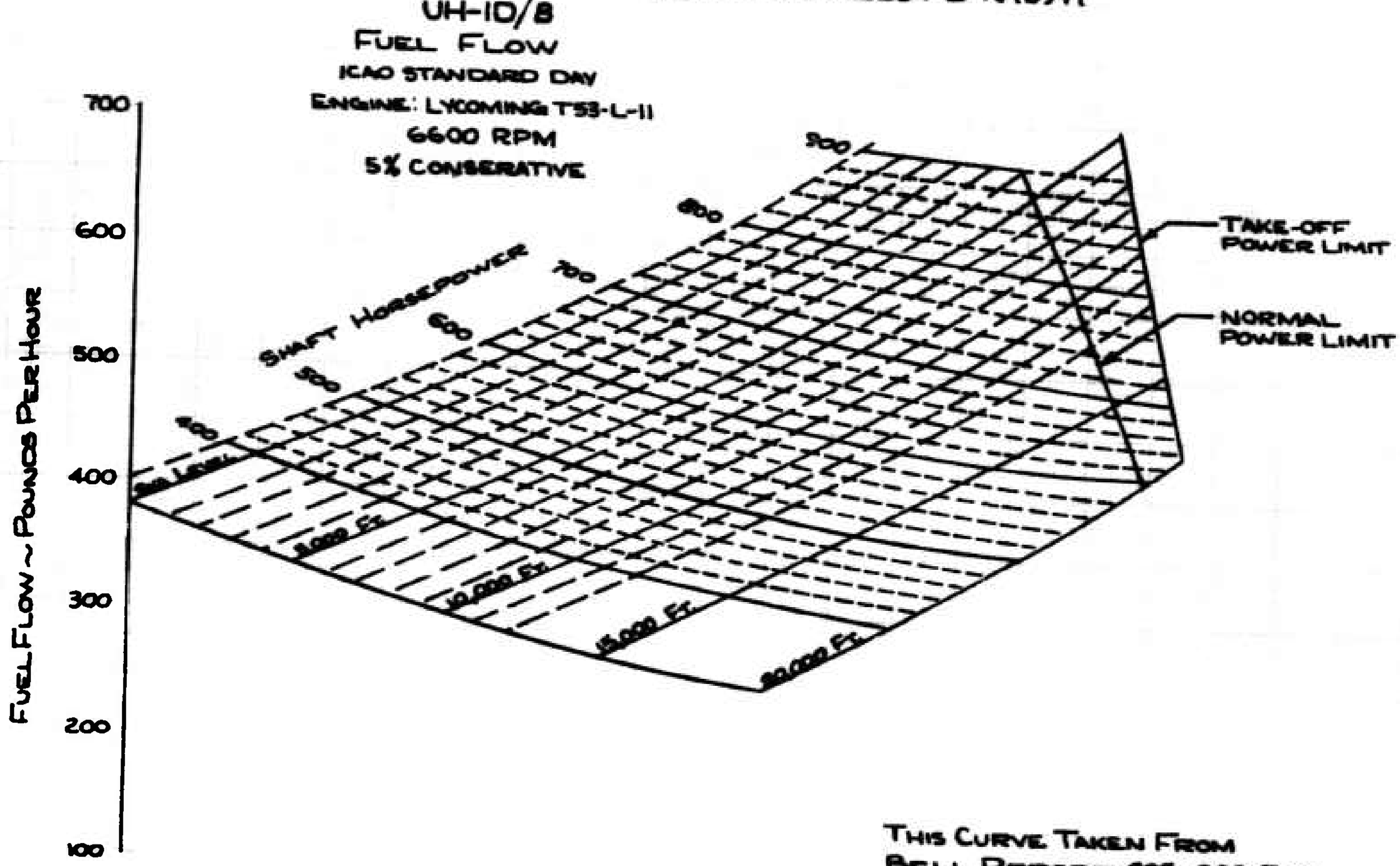


FIGURE 64

SPECIFICATION FUEL FLOW

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204-B N739TT



THIS CURVE TAKEN FROM BELL REPORT 205-099-705

Figure No. 65
Engine Characteristics
Door Hinge Rotor System
Bell Model 204-B N73977

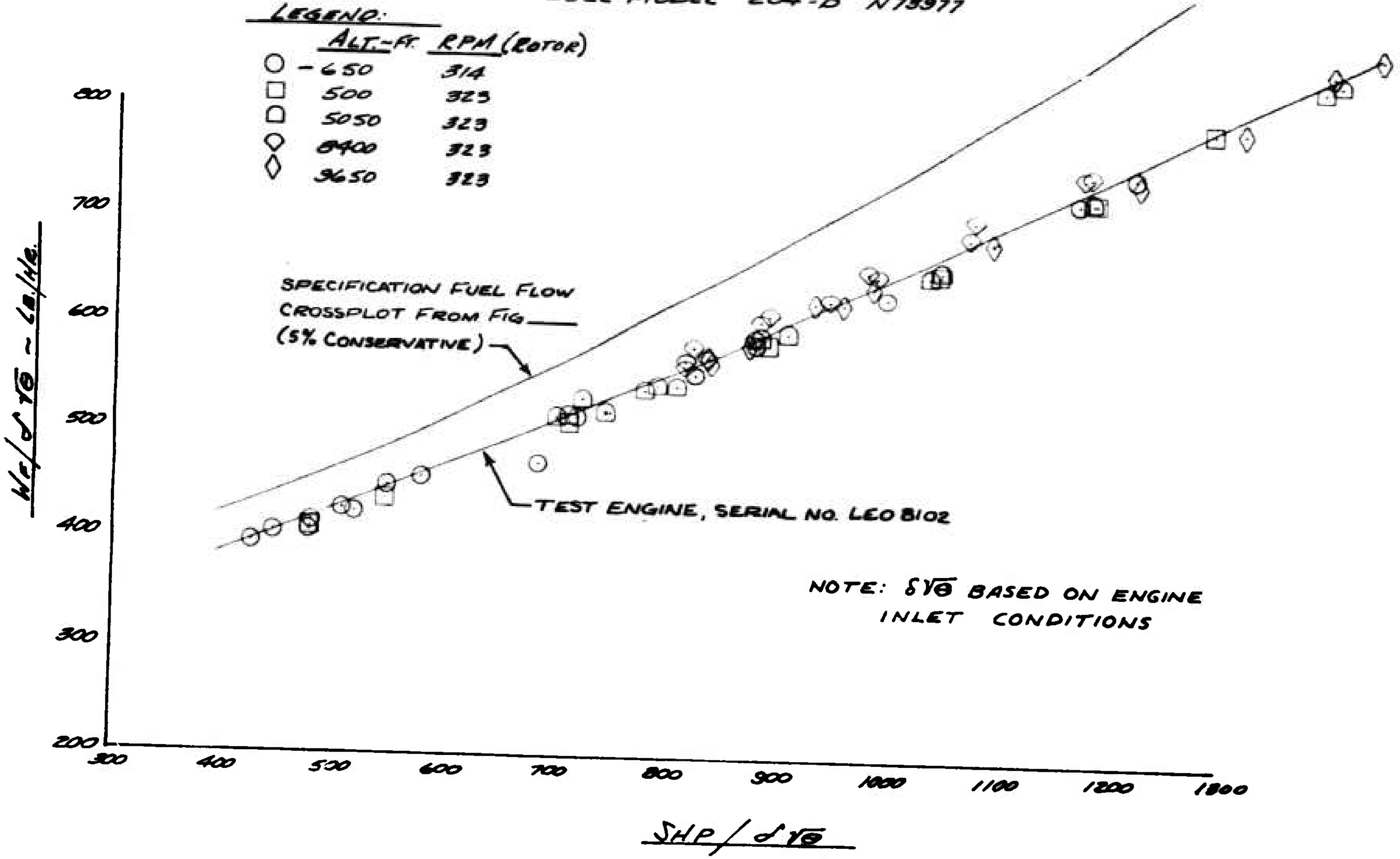
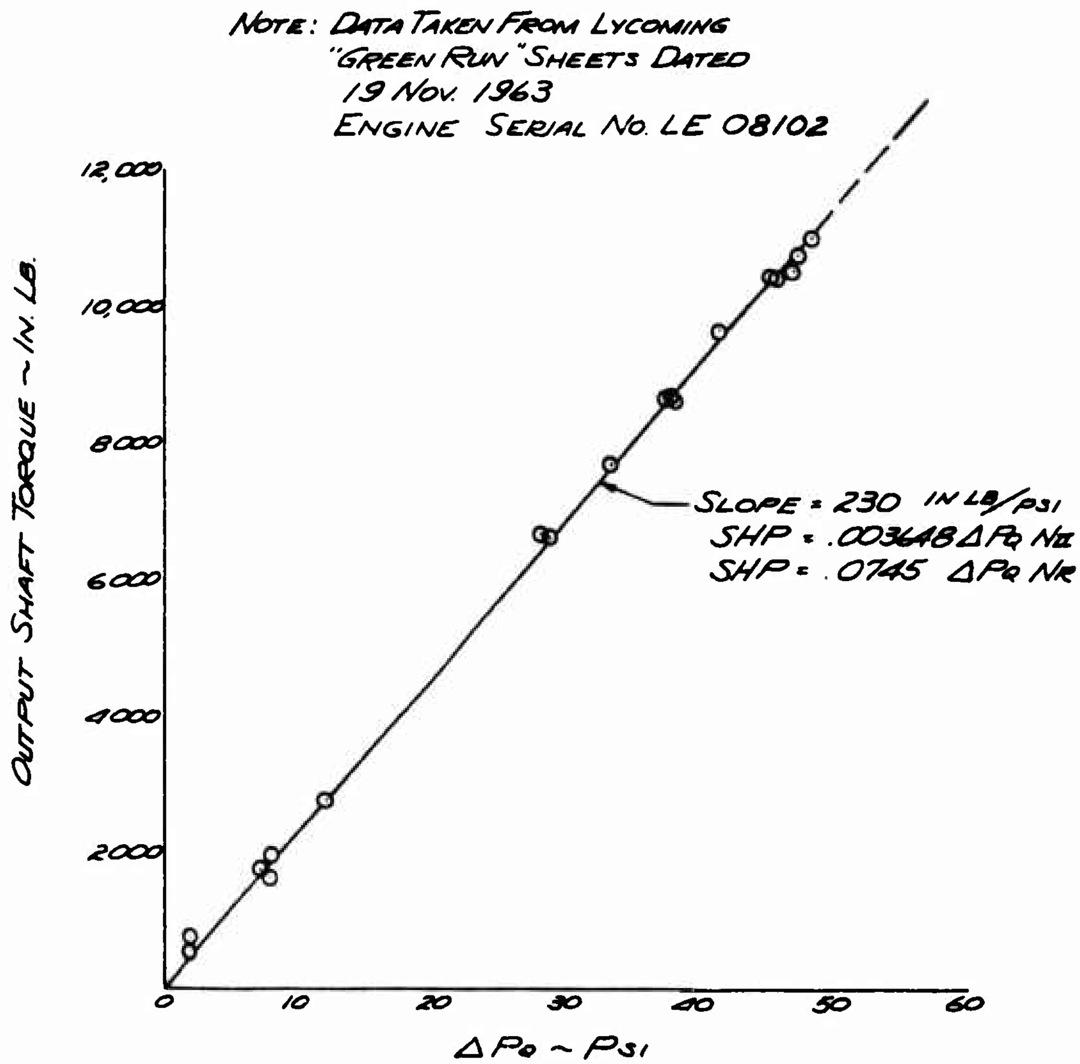


FIGURE No. 66

ENGINE TORQUE METER CALIBRATION

DOOR HINGE ROTOR SYSTEM

BELL MODEL 204B S/N N73977



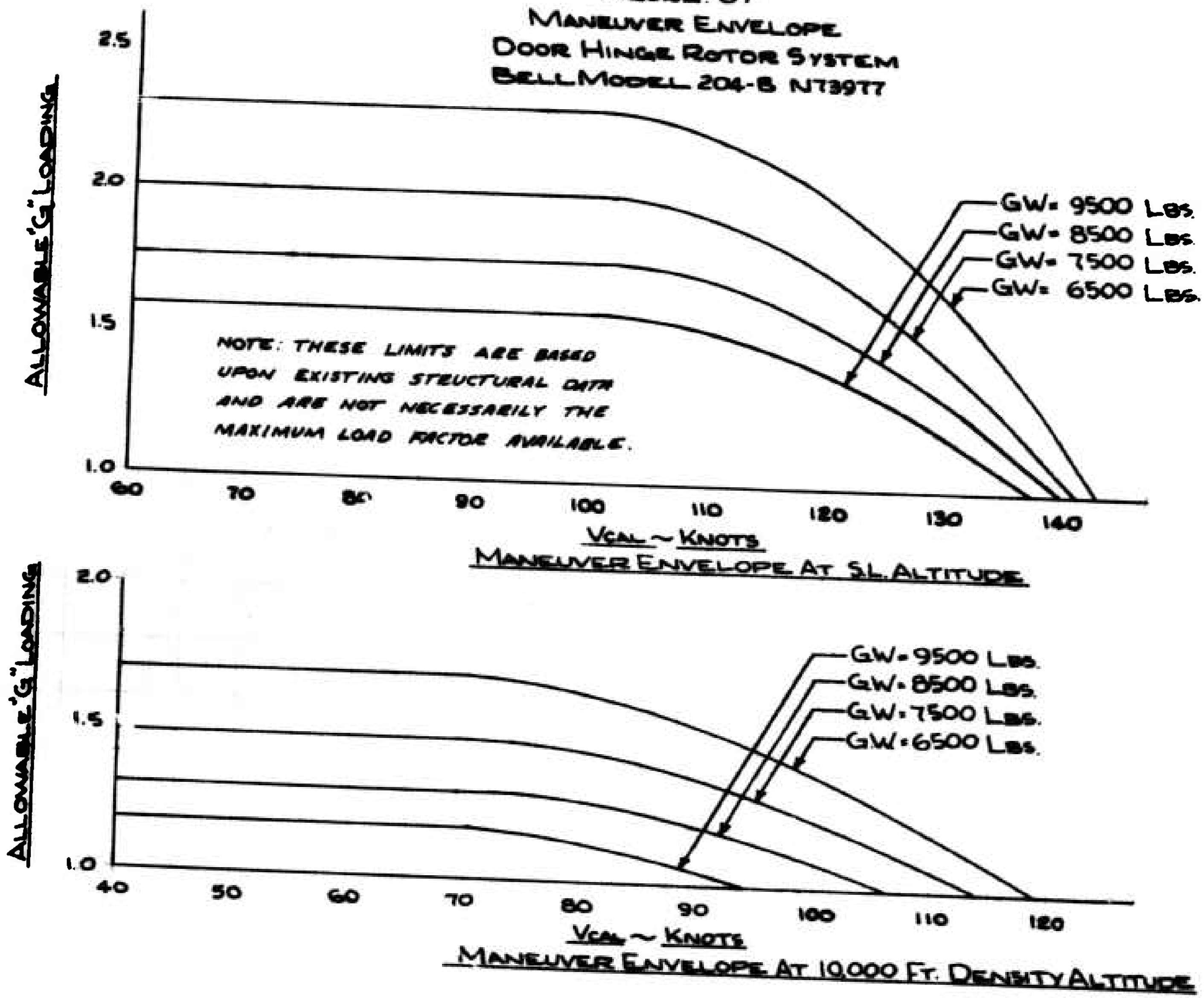
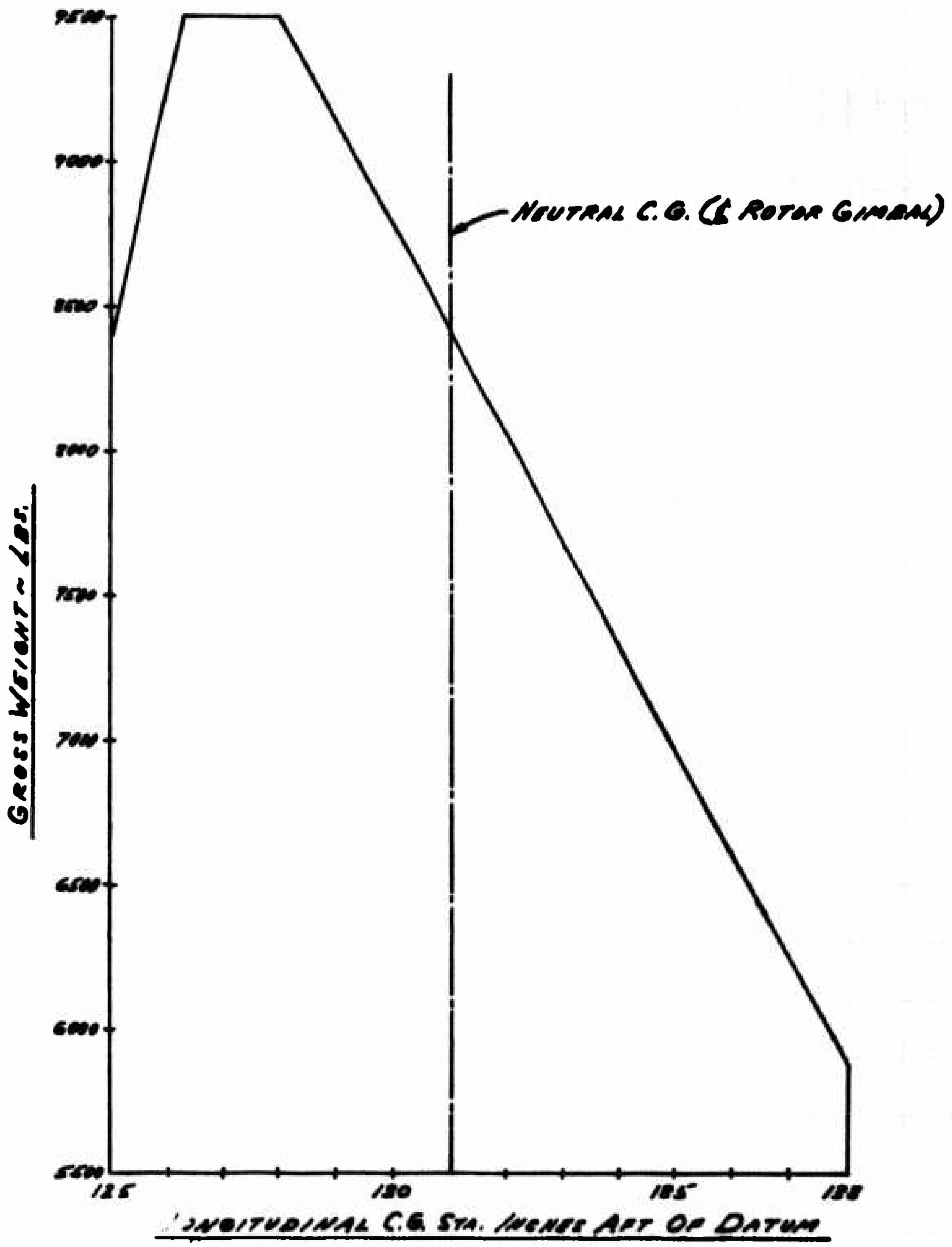


Figure 67
Maneuver Envelope
Door Hinge Rotor System
Bell Model 204-B N7397T

Fig. No. 68
Center of Gravity Vs. Gross Weight Limits
Door Hinge Rotor System
Bell Model 204-B N73977



PART III

ANNEXES *

ANNEX A

REFERENCES

1. Air Force Flight Test Center Report FTC-TDR-62-21, titled "YHU-1B Category II Performance Tests," dated December 1962.

2. Air Force Flight Test Center Report FTC-TDR-62-12, titled "YHU-1B Stability and Control Tests," dated August 1962.

3. MIL-H-8501A as Revised 11 January 1961, "Helicopter Flying and Ground Handling Qualities, General Specifications For."

4. Bell Helicopter Company Report No. 540-099-002, "Engineering Summary Report, Model 540 Rotor System on the UH-1 Helicopter."

5. Bell Helicopter Company Report No. 540-099-001, "Preliminary Flight Test Results for the Model 540 Rotor System on Model 204B, Ship No. 1501."

6. Bell Helicopter Company Report No. 204-099-712, "Substantiating Data for the Standard Aircraft Characteristics Charts for the UH-1B Helicopter, Addendum I - Flight Handbook Data."

ANNEX B

CALCULATION AND ANALYSIS METHODS

1. General

The test techniques employed and the data analysis methods required to correct the performance data from test conditions are described in this section.

Data analysis is generally based on use of the helicopter dimensionless performance parameters C_p, C_T, and μ. These parameters are defined by the following equations:

$$C_p = \frac{550\ SHP}{\rho A(\Omega R)^3} \sim \text{Coefficient of Power}$$

$$C_T = \frac{W}{\rho A(\Omega R)^2} \sim \text{Coefficient of Weight}$$

$$\mu = \frac{V_T}{\Omega R} \sim \text{Tip Speed Ratio}$$

The symbols used in this report are tabled below:

SYMBOL	DEFINITION	UNITS
SHP	Shaft Horsepower	550 ft lb/sec
ρ	Atmospheric Density	Slugs/ft^3
ρo	Standard-Day Sea-Level Atmospheric Density	Slugs/ft^3
σ	Atmospheric Density Ratio	
A	Rotor Disc Area	ft^2
Ω	Rotor Angular Velocity	radians/sec
R	Rotor Radius	ft
W	Gross Weight	lb
V	Airspeed	kt
V_H	Maximum Level Flight Airspeed	KT
V_L	Limit Dive Flight Airspeed	KT
R/C	Rate of Climb (Tapeline)	ft/min
dHp/dt	Slope of Pressure Altitude vs. Time Plot	ft/min
R/D	Rate of Descent (Tapeline)	ft/min
T	Temperature	°K
N_I	Gas Producer Speed	rpm
N_{II}	Power Turbine Speed	rpm
θ	Temperature Ratio	
δ	Pressure Ratio	
Wf	Fuel Flow	lb/hr
G, η	Load Factor, Acceleration	
t	Time	hr, min, sec

SUBSCRIPT	DEFINITION
Δ	Increment to be added
t	Test condition
s	Standard condition
a	Ambient condition

2. Power Determination

a. Power Required

Power required data was obtained by means of calibrated rpm and torque meter instrumentation. Three separate indicating systems were installed: One each for the oscillograph, the photo panel and the pilot's panel.

b. Power Available

Standard-day power available information was taken from Bell Report 204-099-712. The installed power available from this report is presently the basis for the performance data in the UH-1B "Handbook of Operator's Instructions." The fuel flow information presented in Figure 64 is similarly the present basis for range performance for the "Handbook of Operator's Instructions."

The standard-day power available presented in FTC-TDR-62-21 was also utilized in order to determine performance increments due to installation of the "Door Hinge" Rotor when compared to a standard UH-1B. For all comparisons, the fuel flow data of Figure 64 was utilized.

3. Hovering Performance

Hovering performance was measured for the out-of-ground-effect case by hovering at various rotor rpm's and helicopter gross weights. The data was converted to C_p and C_T form and is presented on Figure 2 of Part II. The power available as defined by FTC-TDR-62-21 was used along with Figure 2 to form the hovering summary plot, Figure 1 of Part II.

4. Climb Performance

The observed rate-of-climb was corrected to tapeline by the expression:

$$R/C_t = \frac{dHp}{dt} \times \frac{Tt}{T_s}$$

Power corrections were made by the use of:

$$\Delta R/Cp = Kp \frac{SHP\ 33000}{W_t}$$

Where Kp = .67 (Reference FTC-TDR-62-21)

Weight corrections were made by the use of:

$$\Delta R/Cw = K_w\ SHP_s\ 33000 \left(\frac{1}{Ws} - \frac{1}{Wt}\right)$$

Where Kw = .745 (Reference FTC-TDR-62-21)

5. Level Flight

During the level flight tests, density altitude was increased as fuel was consumed so as to maintain a near constant value of C_T.

The analyzed data was plotted as SHP required as a function of true airspeed and is presented in Figures 12 through 18 of Part II. Specific range was determined for each level flight curve by determining fuel flow from Figure 64 and making the appropriate calculations.

The data was cross-plotted in dimensionless Cp, C_T and μ form and is presented in Figures 8 through 11 of Part II.

Figure 7, the Level Flight Summary, was obtained by selecting the recommended cruise condition values of Figures 12 through 18 and calculating Range Factor (NAMPP x Weight) and determining cruise airspeeds. The data was then plotted as functions of thrust coefficient C_T.

6. Autorotation Performance

Autorotation performance was determined in terms of rotor decay rates and rates of descent at various airspeeds and rotor rpm. The resulting data is presented in Figures 19 and 20 of Part II.

The observed rate of descent was corrected to tapeline by the expression:

$$R/D = \frac{dHp}{dt} \times \frac{T_t}{T_s}$$

Rotor decay rates were determined from time history plots of rotor rpm at the various test conditions.

7. Vibration Characteristics

The vibration data was analyzed into the 1, 2 and 4-per-rev components of the recorded waveforms. These frequencies are of primary interest for the analysis of two-bladed rotor vibration.

The data was analyzed by two methods, graphical and computer analysis. Sufficient data was analyzed by both methods to assure agreement between methods.

8. Airspeed Calibration

An airspeed calibration was performed by the contractor and witnessed by U. S. Army Aviation Test Activity personnel. The calibration was rechecked during the final flight of the program. The trailing bomb method was used for all of the data collected; atmospheric conditions precluded use of the ground speed course method.

ANNEX C

INSTRUMENTATION

The following calibrated instrumentation was installed and maintained by contractor personnel. Calibrations were witnessed or verifeid by U. S. Army Aviation Test Activity personnel.

Cockpit Panel

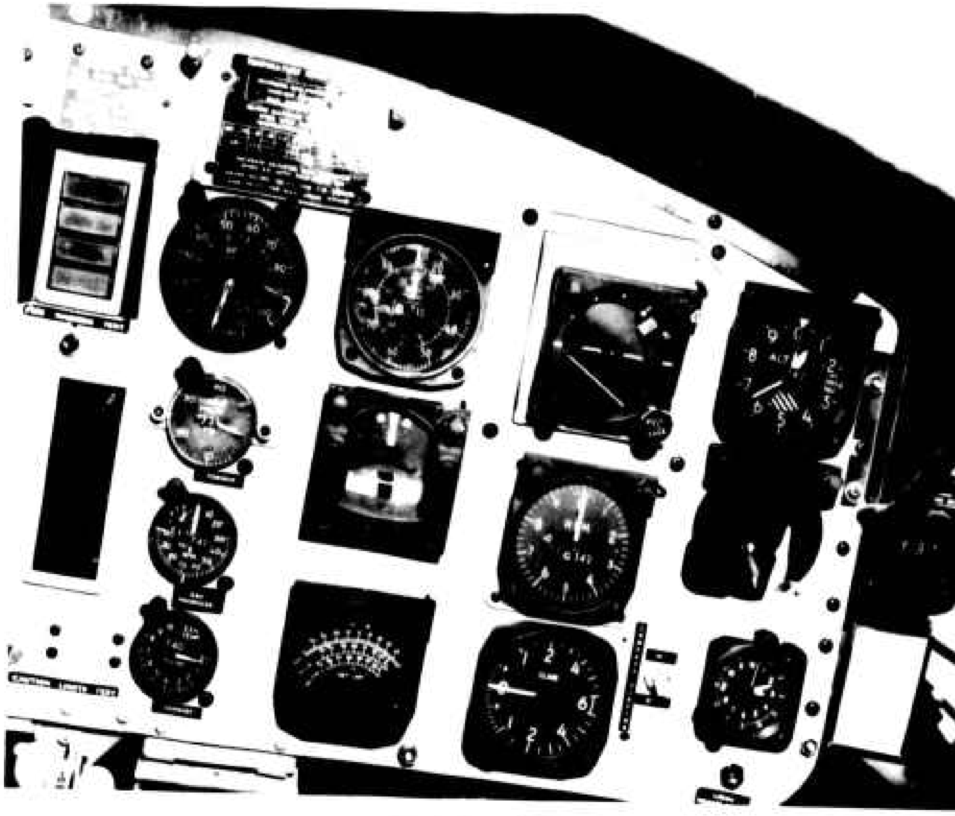
- Altitude
- Airspeed
- Free Air Temperature
- Compressor Inlet Temperature
- High Torque Pressure
- Low Torque Pressure
- Fuel Used Counter
- Gas Generator RPM
- Exhaust Gas Temperature
- Rotor RPM

Photo Panel

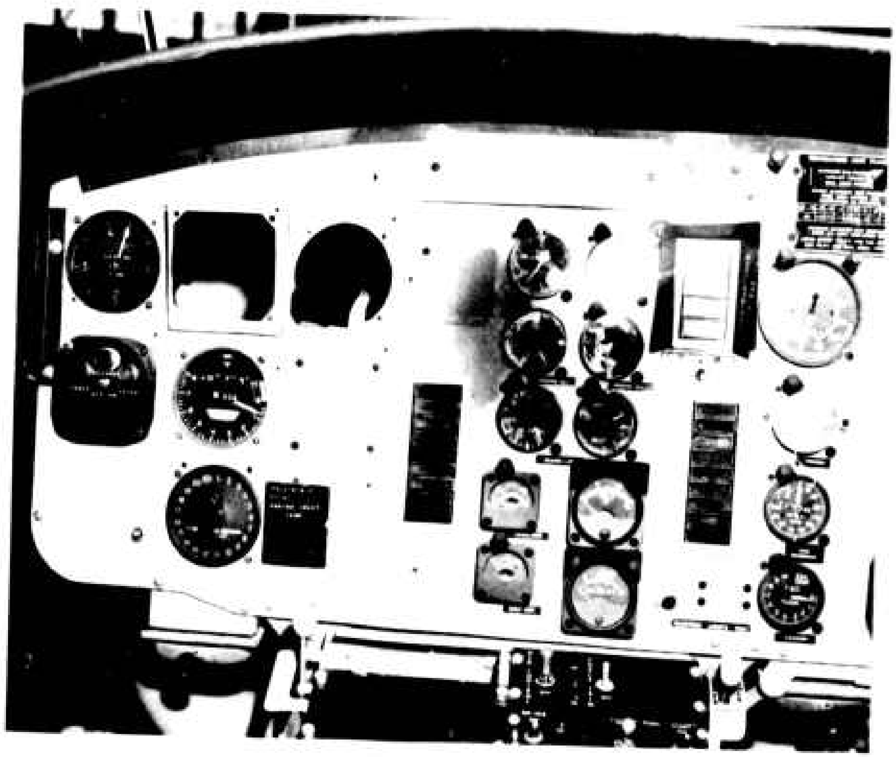
- Low Torque Pressure
- High Torque Pressure
- Gas Producer RPM
- Exhaust Gas Temperature
- Free Air Temperature
- Engine Inlet Temperature
- Altitude
- Airspeed
- Time

Oscillograph

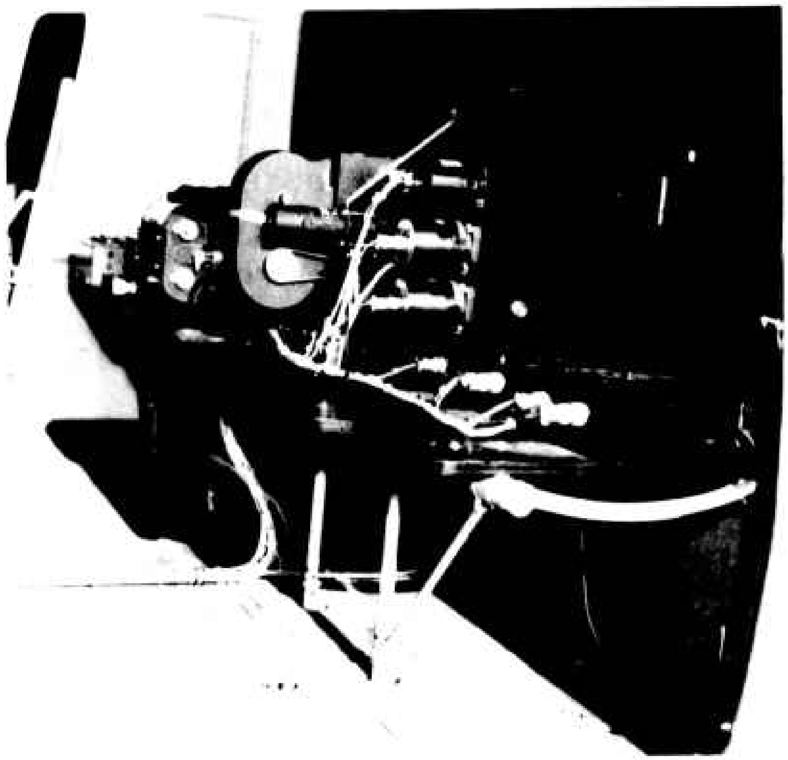
- Fuel Flow
- Torque Differential Pressure
- Rotor RPM
- Pilot's Vertical Accelerometer
- Copilot's Vertical Accelerometer
- Copilot's Lateral Accelerometer
- Sta. 123 Vertical Accelerometer
- Sta. 123 Lateral Accelerometer



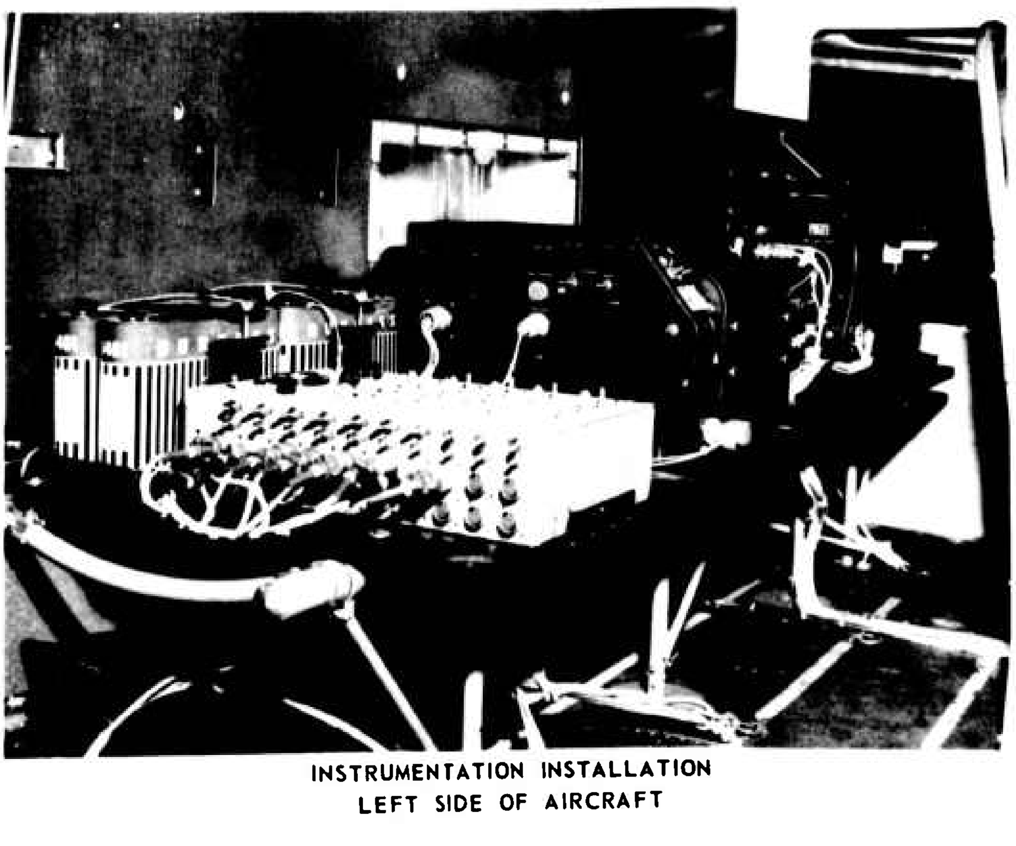
PILOTS PANEL



CO-PILOTS PANEL



INSTRUMENTATION INSTALLATION
RIGHT SIDE OF AIRCRAFT



INSTRUMENTATION INSTALLATION
LEFT SIDE OF AIRCRAFT

ANNEX D

FLIGHT LIMITS

The following flight limits were established by the contractor for use during the evaluation:

1. Engine: Takeoff Power 1100 SHP

   Military Power 1000 SHP

   Normal Rated Power 900 SHP

2. Rotor RPM Limits:

   a. Power On

      (1) Hover

      Minimum 285 RPM (5800 engine RPM)

      Maximum 324 RPM (6600 engine RPM)

      (2) Forward Flight

      Minimum 304 RPM (6200 engine RPM)

      Maximum 324 RPM (6600 engine RPM)

   b. Power Off (Steady State)

      Minimum 304 RPM

      Maximum 330 RPM

3. Altitude:

   SL to 20,000 ft.

4. Gross Weight:

   9500 lb Maximum

5. Center-of-Gravity:

   As presented in Figure 68, Part II.

6. Airspeed:

   As limited by power available in level flight to an absolute limit of 156 knots V_{cal} based on fuselage design strength.

7. Maneuvering Load Factor:

   As presented in Figure 67, Part II.

ANNEX E

WEIGHT & BALANCE

The test helicopter was weight and balance checked at the beginning of the program. The results are presented below:

Basic Weight	5133 lb
(Includes oil and trapped fuel, instrumentation installed, no crew and no payload)	
Fuel Weight	1073 lb
(165.5 gal @ 6.5 lb/gal)	
Total	6206 lb
(Without crew or payload)	

Ballast was added as required to obtain the desired test gross weights and center-of-gravity locations.

ANNEX F

TEST RESULTS
U. S. ARMY AVIATION TEST BOARD

UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36362

STEBG-TD

SUBJECT: Report of Test, USATECOM Project No. 4-4-0108-02, "Military Potential Test of the 'Door Hinge' High-Speed Rotor System"

TO: Commanding Officer
US Army Aviation Test Activity
Edwards Air Force Base, California 93523

1. References.

a. Letter, Bell Helicopter Company, 22 October 1963, subject: "Flight Evaluation of Bell's High Speed Door Hinge Rotor System."

b. Letter, STEBG-TPD, US Army Aviation Test Board, 9 January 1964, subject: "Plan of Test for the Bell Door Hinge Rotor Helicopter."

2. Authority.

a. Directive. Letter, AMCRD-DM-A, Headquarters, US Army Materiel Command, 3 December 1963, subject: "Bell Helicopter Proposal for High Speed Door Hinge Rotor System," with 1st Indorsement, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 31 December 1963.

b. Purpose. To contribute a qualitative "service pilot" opinion to USATECOM Task No. 4-4-0108-01 (US Army Aviation Test Activity is the coordinating agency).

3. Background. Bell Helicopter Company developed the "Door Hinge" High Speed Rotor System from company funds to meet an Army requirement for helicopter operation at high airspeeds with a low vibration level. In October 1963, Bell offered to provide a commercial

Bell 204B (UH-1B type helicopter), equipped with the "Door Hinge" rotor for Army evaluation of the rotor at no cost to the government. Headquarters, US Army Materiel Command (USAMC), requested that US Army Test and Evaluation Command (USATECOM) accomplish a military potential evaluation of the "Door Hinge" rotor system in December 1963. USATECOM designated the US Army Aviation Test Activity (USAATA), Edwards Air Force Base, California, as the coordinating agency and the US Army Aviation Test Board (USAAVNTBD) as contributing agency to conduct a 20-flight-hour evaluation at the manufacturer's test flight facilities, Fort Worth, Texas.

4. Description of Materiel.

a. "Door Hinge" Rotor. The "Door Hinge" rotor, designated Model 540 by the manufacturer, is a two-bladed, semi-rigid type with a flapping hinge and underslung feathering axis, which incorporates a unique pitch-change bearing arrangement (door hinge). All the bearings in the hub assembly are Teflon-lined sleeves; therefore, the hub requires no lubrication.

b. Rotor Installation. The "Door Hinge" rotor was mounted on a commercial Model 204B Helicopter. The 204B is similar to the UH-1B except that it has a longer tail boom to accept a 48-foot rotor blade.

5. Test Objectives.

a. To determine whether the "Door Hinge" High-Speed Rotor System has advantages in speed and vibration level compared to the 44-foot and 48-foot rotor systems presently utilized in the UH-1 series helicopters.

b. To determine other significant advantages and disadvantages.

6. Scope. The USAAVNTBD portion of the test was conducted during the period 13-21 January 1964 at the manufacturer's test flight facilities, Fort Worth, Texas. The Model 204B Helicopter with the "Door Hinge" rotor system installed was flown a total of 5 hours and 35 minutes at gross weights of 7500, 8500, and 9500 pounds. A

standard production UH-1B was flown once at a gross weight of 8500 pounds for a comparison of vibration levels and autorotational characteristics.

7. Findings. (Details of test are contained in inclosure 1.)

a. The "Door Hinge" rotor system offered significant advantages in the reduction of vibration at high speeds compared with rotor systems presently used in the UH-1 series helicopters.

b. The approximate 70-percent increase in rotor inertia made autorotation touchdowns less critical to perform, particularly above gross weights of 8000 pounds.

c. Blade slap noise was significantly reduced at high airspeeds and gross weights.

d. Operational suitability was improved by higher speeds, greater maneuverability, and better autorotative characteristics.

e. The simplicity of the rotor hub design and the use of Teflon bearings which require no lubrication improved the maintenance suitability.

f. The rotor system design would permit an increase in the maximum gross weight of UH-1B Helicopters.

8. Conclusions.

a. The Model 540 "Door Hinge" High-Speed Rotor System improves the operational suitability of UH-1 type helicopters, particularly at high speeds.

b. The Model 540 "Door Hinge" High Speed Rotor System improves the maintenance suitability of UH-1 type helicopters.

STEBG-TD
SUBJECT: Report of Test, USATECOM Project No. 4-4-0108-02, "Military Potential Test of the 'Door Hinge' High Speed Rotor System"

9. Recommendations. It is recommended that:

a. The "Door Hinge" High Speed Rotor System be further developed and further testing be conducted to determine its full potential.

b. The "Door Hinge" High Speed Rotor System(s) be developed as a product improvement program for the UH-1B and UH-1D Helicopters, and be incorporated in production models as soon as practicable.

1 Incl
as

A. J. RANKIN
Colonel, Armor
President

Copies furnished:
CG, USATECOM

DETAILS OF TEST

1. Vibration. The most significant feature of the "Door Hinge" rotor system was the reduction in two-per-revolution vibration. At all tested gross weights (7500-9500 pounds), the helicopter was limited by available power rather than by vibration. Vibration levels did not significantly change with variations in gross weight and airspeed under all tested flight conditions. For a comparison of vibration levels a portable accelerometer was carried in the test helicopter and in the standard UH-1B at a gross weight of 8500 pounds. The accelerometer was placed just to the rear of the copilot's seat, the point of greatest vibration amplitude in the cockpit. A comparison of the two resulting tapes indicated that the vibration level of the test aircraft at 130 knots indicated airspeed was equivalent to that of a standard UH-1B at 80-85 knots.

2. Maneuvering Flight.

a. Angles of bank to approximately 75 degrees were made at gross weights to 8500 pounds at airspeeds from 60-120 knots. Bank angles of 45 degrees were made at 120 knots at a gross weight of 9500 pounds. Control feel was positive and no vertical two-per-revolution vibration was encountered.

b. Abrupt pull-ups were made at all gross weights from straight and level flight and dives of 2000 feet per minute. Control feel was very good and there was no tendency to "mush out."

c. Blade stall was not approached during any maneuver.

3. Throttle "Chops." Throttle "chops" were made at all tested gross weights and at airspeeds from zero to Vmax. The highest airspeed was 140 knots at 7500 pounds. There were no adverse tendencies, and only the normal yaw reaction was encountered.

a. During the throttle "chops," reduction of collective pitch was delayed from 1-3 seconds with no adverse control requirement change in pitch or yaw. Rotor r.p.m. decay was slightly slower than that of the standard UH-1B rotor system. The time required for the rotor r.p.m. to recover to normal after entering the autorotation varied, depending on whether airspeed was maintained or a flare entered. The high rotor inertia did not have a perceptible adverse effect on recovering rotor r.p.m. The altitude required to regain r.p.m. depended on airspeed. At low airspeeds, more altitude was required.

b. The rate of sink was comparable to that of the standard UH-1B. However, the approximate 70-percent increase in rotor inertia made the touch-down considerably less critical, particularly at gross weights above 8000 pounds where the performance of the 44-foot diameter blade becomes marginal.

4. Criticality of R. P. M. The high r. p. m. limits of the prototype installation tested were critical because the blade retention straps were the laminated UH-1B type and not the improved wire wound straps. Limits were:

Power on: 285-324 r. p. m.
Power off: 300-330 r. p. m.

5. Noise Level. The characteristic Bell blade slap was significantly reduced at high airspeeds and gross weights. It could not be induced to any appreciable extent by abrupt pull-ups or tight turns. At low airspeeds (60-70 knots), the slapping noise was normal.

6. Boost Controls. A dual boost pump was installed for collective control. This was required because the prototype blade mass balance was not as it would be in production, i. e., the blade balance material, 45 pounds/tip, was located in the blade leading edge. The resulting force prevented the pitch control from being manually operated with boost off above 85 knots at a gross weight of 9500 pounds. In production models, this condition could be corrected easily by repositioning the blade tip weights.

7. Attitude. The flight attitude did not vary to a measurable extent during hover, cruise, or Vmax from that of a standard UH-1B.

8. Time Required for Rotor R. P. M. to Decay to Zero at Shutdown. The time required for the rotor r. p. m. to decay to zero at shutdown did not vary significantly from that of a standard UH-1B.

9. Stability. Stability in hovering and cruise was comparable with that of the UH-1B.

10. Trim. The trim device would not hold trim at airspeeds above approximately 130 knots.

11. Flare Characteristics. The flare characteristics could not be investigated as desired because the high rotor speeds encountered in

abrupt flares would exceed the structural limitations of the laminated-type blade retention straps installed on the test helicopter. The use of wire-wound retention straps scheduled for use on the 48-foot rotor blade will eliminate this problem.

12. Compatibility with 48-Foot Rotor. The "Door Hinge" hub assembly as developed for the 27-inch chord, 44-foot diameter rotor blade is not compatible with the 48-foot rotor. However, the basic design could be adapted as a new hub assembly for the UH-1B and UH-1D with 48-foot rotor blades.

13. Maintenance Requirements. The reduced number of parts and the use of Teflon bearings should significantly reduce maintenance requirements.

PART IV

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