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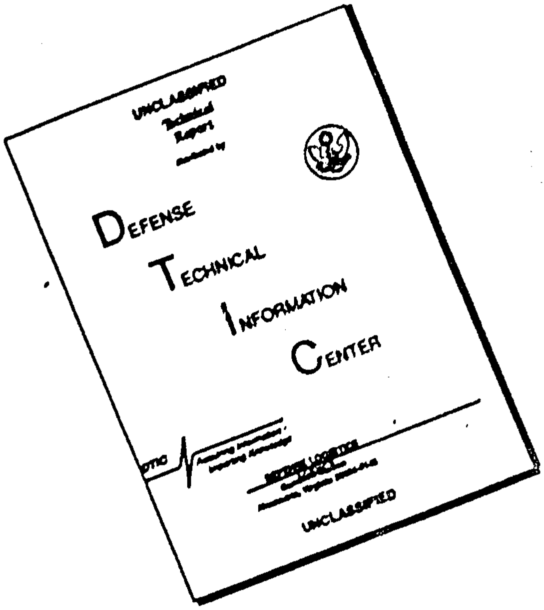
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CONTRACT Nonr-1357 (00)

BORNE PERSONNEL PLATFORM

SUMMARY REPORT

NOVEMBER 1956

FC

HILLER HELICOPTERS
PALO ALTO, CALIFORNIA

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HILLER HELICOPTERS
PALO ALTO, CALIFORNIA

ENGINEERING REPORT

REPORT NO. 56-110

MODEL NO. 1031-A

TITLE SUMMARY REPORT - PHASE III - AIRBORNE PERSONNEL PLATFORM - CONTRACT Nonr 1357(00)

NO. OF PAGES 45

Appendix I
Appendix II
Appendix III
Appendix IV
Appendix V
Appendix VI

DATE 30 November 1956

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REVISIONS

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This document has been reviewed in accordance with OPNAVINST 5510.17, paragraph 5. The security classification assigned hereto is correct.

Cdr. C. J. Latimer USN.

Date: 12/30/56 for

By direction of
Chief of Naval Research (Code 461)

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TABLE OF CONTENTS

PAGE NUMBER

LIST OF FIGURES

LIST OF FIGURES (continued)

SUMMARY

As the result of Phase III analytical and design studies and development testing, the Model 1031-A airborne personnel platform was found to be dynamically stable in hovering and in forward flight up to a speed of 16 miles per hour. This stability was achieved by raising the vertical center-of-gravity and installing a gyro-paddle stabilizer system. Hovering and forward flights at low altitude in winds of 15 miles per hour with 5 miles per hour gusts, demonstrated the reduced gust sensitivity and improved controlability attained under this program.

Methods of reducing and controlling pitching moment were studied. Boundary layer control of duct and propeller lift was considered and found to not favor a simple solution. A duct inlet radial vane control system was found to offer good promise of providing pitching moment control mechanically available to the pilot.

A general method was developed for calculating power required in forward flight.

INTRODUCTION

Since early 1954 through November 1956, this Contractor has been conducting a program of research and development of an airborne personnel platform under Contract Nonr 1357(00) awarded by the Office of Naval Research, Department of the Navy. Work to date has been performed under Phases I, II, and III of this contract.

Phase I provided for the design, fabrication, and testing of a research platform capable of being stabilized and controlled by the pilot's instinctive reflex responses. Both Hiller Helicopters and the Office of Naval Research designed the Phase I program for the purpose of extending the work initiated by Mr. Charles Zimmerman and studies conducted by the National Advisory Committee for Aeronautics. The objective of Phase I was to determine the feasibility and design and flight characteristics of this type of aircraft. The guiding philosophy of vehicle design was that control and stability in hovering and forward flight would be attained by kinesthetic control which utilizes the same human muscular reflexes in flight as are used by man to maintain the body upright when standing on a fixed surface. This principal is illustrated and described in detail in Appendix I and was successfully demonstrated by the NACA in 1952 and 1953 (References (a), (b), and (c)) with several test vehicles dependent on a ground power source. Phase I efforts resulted in the Hiller Model 1031 airborne platform employing ducted coaxial, fixed pitch, propellers driven independently by two Nelson Model H-59 engines of 40 horsepower each. This vehicle is shown in

Appendix I as it was successfully tested in hovering free-flight on 4 February 1955. This flight followed a tether flight test program in which the feasibility of this type of aircraft was proven and the flying qualities were generally determined. The platform was found to be controllable in hovering and forward flight in calm air but control in gusty winds was very difficult; the platform was considered unsafe for free-flight and additional study of this problem was recommended. Reference (d) presents further details of the Phase I program.

Phase II was initiated on 15 March 1955 to improve the flight characteristics and safety of the platform. A test program was conducted in which quantitative data was obtained relative to pitching moment, lift, drag, thrust, propeller speed, engine speed, and duct pressure distribution as a function of various angles of tilt and forward speed. The platform was redesigned to employ a coaxial gear box propeller drive to provide balanced torque for both engines or only one engine operating so that yaw control would be better in free-flight and so that a safe emergency landing could be made from low altitude in the event of a single engine failure. This redesigned machine was designated Model 1031-A and is shown in free-flight in Appendix II. Tether flight tests were conducted to obtain qualitative data relative to general mechanical performance, thrust versus forward speed and altitude, steady and transient pitching moments, pilot control capabilities in pitch and roll, maximum forward speed, and effect on pitching moment characteristics of increased inertia. Free-flight tests were conducted to permit pilot appraisal of performance and flight characteristics without the limitations imposed by the tether test equipment. Phase II work resulted in a quantitative understanding of the forces and moments acting on the platform in forward flight with a recommendation for stability analyses and tests. Free-flights demonstrated that the platform was very easily controlled in hovering, forward, sideward, and coordinated turn maneuvers in calm air. It was recommended that the platform stability characteristics be thoroughly studied supported by a flight test program and that studies be made of methods of providing the pilot with a boost control system since pitching moment control was shown to be marginal at higher forward speeds. It was further recommended that additional research be conducted to investigate the influence of various duct shapes on performance. Reference (e) presents further details of the Phase II program.

This report presents the scope, objective, results, conclusions and recommendations of the Phase III program in the following sections.

PHASE III PROGRAM

A. SCOPE AND OBJECTIVES

Phase III of Contract Nonr 1357(00) was initiated in work on 1 February 1956 in order to provide technical information considered necessary to the design of a prototype evaluation platform being negotiated by Hiller Helicopters with the Bureau of Aeronautics, Department of the Navy and funded by the Department of the Army.

As recommended by Reference (e) at the conclusion of the Phase II program and as authorized by Contract Nonr 1357(00), the following items of work were initially scheduled under Phase III:

Truck Tests

a. Measure power requirements in forward flight.

b. Measure vane control system effectiveness as a function of attitude and forward speed.

c. Aerodynamic flow investigations:

   1) Complete pressure distribution measurement.
   2) Check on propeller design.
   3) Determine lift distribution between propellers and duct.
   4) Study effect of boundary layer control and methods of duct pressure distribution control.

Flight Tests - Compare manual versus boosted controls.

Reports - Performance, control forces, and aerodynamic improvements possible for ducted fans.

Initial work was performed to prepare the truck test bed for the scheduled tests and concurrently tether flight tests were conducted with controlable duct outlet mounted vanes described in a following section of this report. Flight tests were initiated at the earliest possible date because of this Contractor's concern about the gust sensitivity characteristics of the Model 1031-A Airborne Platform.

Flight tests of the duct mounted outlet vane control system proved unsatisfactory and the Contractor proposed a revision of the Phase III program to provide for concentrated effort directed toward the improvement of stability and control characteristics. Although the proposed revised program did not provide the quantitative data relative to power requirements in forward flight, lift distribution between propeller and duct, and more complete pressure distribution data originally sought, it was proposed in the belief that successful solution of the stability and control problem was fundamental to the success of any future airborne platforms. Accordingly, the following work was programmed under Contract Nonr 1357(00), Phase III, as revised:

1. Compute power requirements in forward flight.
2. Install vane control system and evaluate control effectiveness as a function of attitude and forward speed.
3. Modify two existing engines and purchase an additional modified engine for use as a spare.

4. Aerodynamic flow investigations:
   a. Make pressure distribution measurements.
   b. Study outlet velocity distribution and check propeller design.
   c. Study effect of boundary layer control and methods of duct pressure distribution control.
   d. Compare manual versus boosted controls.
   e. Reports on performance, control forces, and aerodynamic improvements on ducted fans.
5. Conduct tethered flight tests of gyro-controlled stabilizer vanes to determine and to develop proper linkage ratios, gyro damping, number and size of vanes required, and optimum center-of-gravity elevation to be used in combination with the vanes in both calm air and gusty wind conditions.
6. Continued analyses of stability and control characteristics to investigate stability in forward flight at relatively high speeds.
7. Free-flight tests with the best stability and control factors developed under this program. Tests will include low altitude flights to maximum forward speed as limited either by psychological factors or by stability and control characteristics. These tests will also include rearward and sideward flights, quick stops, and banked turn maneuvers.

A detailed discussion of the program accomplishments and work performed under Phase III is presented in following sections of this report.

B. STABILITY AND CONTROL

Stability and control of the Model 1031-A airborne personnel platform was improved markedly for both hovering and forward flight conditions by raising the vertical center-of-gravity and adding a gyro-paddle stabilizer system. Dynamic stability in hovering and slow speed flight was improved to such a degree that such flights were performed in calm air and in gusts to 5 miles per hour velocity with equal ease. Forward free-flights at a speed of 16 miles per hour were conducted in calm air and in gusts to 5 miles per hour with some pitching up of the platform evident at this speed when the machine was hit by a gust; however, the pitching rate for this condition was reduced considerably compared to the basic platform at the end of Phase II. A maximum forward speed of 20 miles per hour was attained during free-flight in calm air with the Model 1031-A in its final test configuration including a gyro-paddle stabilizer system in combination with a raised vertical center-of-gravity. Figures 1 and 2 show the platform as finally tested in free-flight.

The final configuration of the Model 1031-A was arrived at as the result of analytical and design studies and development testing. Test investigations included duct outlet vanes, raised vertical center-of-gravity location, de-coupling of pitch and roll, and a gyro-paddle stabilizer system as means of stabilizing and controlling the platform. Details of the work performed and the results obtained under this section in satisfaction of items 2, 4d, 5, 6, and 7 of Annex A to the subject contract follows:

1. Analytical Studies

The dynamic equations of motion for the hovering condition of the airborne platform were derived for the pilot fixed condition and showed that motions described by the platform's forward displacement are coupled with the pitching angular displacement. An identical set of two equations described the sidewards velocity and the rolling angular displacement. Analysis showed that for the airborne platform, symmetrical in all aspects except for the product of inertia about the vertical axis, the above four degrees of motion were coupled. It was also shown that this inertia coupling is unstable since the separate motions in the pitch and roll planes are identical because of symmetry.

The coupling of pitch and roll through the product of inertia about the vertical axis is shown in Figure 10. Since the platform engines are actually located off the pitch and roll axes, any acceleration about the pitch axis y-y will induce inertia forces that will cause moments about the roll axis x-x . The platform as a free body in space will tend to pitch about its minimum moment of inertia axis which is located on a line through both engines.

A two degree of freedom hovering analysis (angular displacement (θ), forward velocity (μ)) was made to show the stability variation with vertical center-of-gravity location. This analysis neglected the change in fore and aft force set up by a unit change in angular ptiching velocity (X_q) and indicated that the platform was very sensitive to vertical center-of-gravity location. The platform was shown to be stable for a very small range of positive M_μ's near zero (M_μ = change in net moment about the center-of-gravity incurred by a unit change in forward velocity) and unstable for all negative M_μ's. By varying the vertical center-of-gravity elevation, M_μ can be made positive, zero, or negative.

A two degree of freedom analysis considering the previously neglected fore and aft force (X_q) showed that the platform could be made stable at all center-of-gravity locations if it could be designed such that

$$\left| X_\mu + \frac{M_q}{KB^2} \right| > \left| \frac{g}{X_q} \right|$$

Practically, this relationship could be attained by mounting a vane on a boom below the center-of-gravity and in the duct outlet airstream.

A preliminary investigation was made of the pilot's floor mounted on springs. It was supposed that such a system would produce uninitiated motion of the pilot relative to the platform and so achieve a certain amount of stability. This did not prove to be the case and it was concluded that this system held no promise for improving platform stability.

Two free pivoted, air damped, gyro-bars, similar to the Hiller servo rotor, were studied. These devices were used to sense the pitching and rolling angular velocities and to control vanes located at the platform duct outlet to correct the sensed motions. The system acts as a lag rate autopilot giving signals whose components are proportional to displacement and rate of change of displacement.

It was found that the gyro-bar stabilizer system would always stabilize a system whose unstable characteristics were of an oscillatory divergent type. However, if the vehicle were unstable in a non-oscillatory (aperiodic) manner, the gyro-paddle would not make the vehicle stable. This is described physically by recognizing that the gyro-paddle senses rate of change of motion and in the case of aperiodic motion, the rate is continuously increasing with time and the gyro-paddle does not catch up. For the oscillatory divergent case, the rate varies between plus and minus values, passing through zero, and the gyro-paddle can achieve the necessary stability.

The Model 1031-A airborne platform even with the gyro-paddle stabilizer device can be unstable for two different conditions. If the vertical center-of-gravity is elevated such that M_μ is negative ($H > 35.20$ inches, H = c.g. height above duct outlet) the platform will not be stabilized in hovering and its motion is aperiodically divergent. If the vertical center-of-gravity is located such that $H = 34.0$ inches (such that M_μ is positive for hovering and platform will be stable in hovering) the forward speed cannot exceed 18.3 miles per hour or the motion will become aperiodically divergent.

A coupled pitch and roll analysis of the platform with the gyro-bars installed and considered as a symmetrical system, showed the system unstable. The phenomena is best described as being similar to the product of inertia effect where the identical motions are coupled through the quantity (inertia). The gyro-paddles couple the symmetrical pitch and roll motions of the stabilizer vanes to make the symmetrical system unstable. This theoretical instability can be avoided by making the linkage ratio in roll different from that in pitch.

It must be remembered that all of the stability analyses conducted to date considered the pilot fixed and in no instance were the actions of the human autopilot evaluated.

Reference (g) and (h) present platform stability analyses in further detail.

2. Tests

a. Duct Outlet Vanes

During 22 March through 2 April 1956, tether flight tests were conducted with duct outlet control vanes actuated by two different methods; one a tilting pilot floor and ring, the other a fixed floor and tilting ring.

Since past flight experience with the airborne platform showed it to be sensitive to gusts and since otherwise the machine was found to be easily controllable, the gust sensitivity and control problem was given first attention in the Phase III program.

1) Design - A simple system of vane control was designed for the purpose of providing a control boost system as well as a system of gust control which still preserved the basic concept of kinesthetic control by instinctive actions and reactions by the operator. Only longitudinal control was provided by this system because of the power limitations of the platform, the weight of the control system, and thrust losses predicted by duct exit blockage. This system was designed so that as the pilot leaned forward, the trailing edge of the duct outlet mounted control vanes tilted forward producing a lift vector acting at the center of pressure of the vanes and directed aft to produce a forward pitching moment about the platform center-of-gravity. It was hypothesized that in the case of a sudden horizontal gust acting on the machine, the machine would pitch in response to the gust causing machine motion relative to the pilot and pilot's floor and thus produce vane control motion resulting in a restoring moment.

Figure 3 shows seven (7) control vanes symmetrically mounted at the bottom of the duct, and supported at each end by self-aligning bearings. All vanes were interconnected by links at the center of the duct such that control input motion at the control horn, shown in Figure 4, was transmitted equally to all vanes. Vane control actuation was provided by means of a bungee restrained, tilting pilot floor and ring assembly as shown in Figure 5. The pilot's safety ring was attached to the pilot's floor which was mounted on a uniball bearing pivot attached to the basic structure by means of a sheet metal support enclosing the upper part of the gear box. The tilting floor assembly was restrained by means of landing gear shock cords attached at four corners with provisions for varying the stiffness of this bungee system. A control arm was provided, attached to the tilting floor and projecting forward and attached to the input side of a flexible push-pull cable. A mechanical stop was employed to limit the floor tilt to 10 degrees maximum angle.

2) Tether Tests - Twenty-eight (28) tether flights were made with this system with various combinations of bungee stiffness, linkage ratio, and numbers of vanes. Tests were initiated using seven outlet vanes and were concluded with only the two most aft vanes in operation. Flights were conducted within-ground-effect in both calm air and gusty winds. Generally, the flight characteristics of the platform were unsatisfactory with this system, although, with only two aft vanes installed, for the first time hovering flights were made in 20 miles per hour winds with approximately 5 miles per hour gusts. Pilot control effort was noticeably less for the two vane system than for the machine without vanes. To varying degrees, depending on the number

of vanes and to a lesser degree for the two vane system, over controlling and lack of orienting feel was a common pilot complaint. These poor flight characteristics were caused by the platform moving aft initially in response to the vane motion followed by a pitching in the direction of applied control. This aft motion was caused by the unbalanced vane lift force.

In an attempt to improve pilot feel, the vane control system was modified such that the pilot's floor was fixed and the safety ring was moveable. This control is shown in Figure 6 and was used to actuate just two, aft located, duct outlet vanes as shown in Figure 7. Hovering and forward flights were conducted in calm air and in winds up to 20 miles per hour velocity. The platform was controlable at all times with most of the pitching moment control being provided by the vanes, the pilot remaining substantially fixed relative to the floor. The pilot's feet and ankles tired rapidly and control was criticized as being far from instinctive after performing 12 flights to gain complete familiarization.

For both vane control systems, the angle of tilt of the duct was greater for a given forward speed than for the machine without the duct outlet vanes. Table I of Appendix V, presents a summary log of these tests.

As the result of this investigation, it was concluded that the fixed-floor tilting ring vane control system produced the best control experienced with the platform under wind and gust conditions to date (2 April 1956) but that pilot comfort and instinct were severely compromised.

b. Vertical Center-Of-Gravity Location

Following the generally unsatisfactory tests of the duct outlet control system, an analytical investigation was made of the forces acting on the platform in flight and their effect on stability and control. As the result of these studies, tether tests were conducted to check the effect of various vertical center-of-gravity positions on stability and control characteristics.

The controlled duct outlet vanes were abandoned entirely based on examination of the force system produced by these vanes as applied to the Model 1031-A airborne platform (see Section C, Part 1) and in view of the improvements promised by raising the center-of-gravity.

Analytically, it was predicted that by proper vertical center-of -gravity location, neutral stability and reduced pilot control effort would be realized for hovering and slow speed forward flight. These predictions were substantiated by the tether tests discussed herein. Reference (g) presents an analysis of vertical center-of-gravity position effect on stability and control characteristics.

1) Design - Modifications were made to the platform to permit incremental raising of the pilot's floor and the gross weight center-of-gravity for the pilot fixed condition. Raising the pilot was the obvious expedient method of raising the center-of-gravity since the engines represent the only other items of large mass and could not be raised without the additional complication of a cooling system. Adjustable floor height provisions were simply made by fabricating several sets of telescoping tube supports with holes drilled through and fastened with bolts at the desired tube length.

The tether test rig was rebuilt to provide greater overhead clearance beneath the tether cable as required to accommodate the increased overall height of the piloted platform. Details of this modification are presented in Appendix III.

2) Tether Tests - Tests were conducted to determine the vertical center-of-gravity location that would produce neutral stability for the Model 1031-A platform.

In order to determine the effect on center-of-gravity position on dynamic stability, the platform was hovered on the tether rig and externally forced to pitch while the pilot remained fixed. The nose of the platform was forced down and the platform permitted to oscillate freely with the pilot fixed until the oscillation became uncomfortably severe. The amplitude and time history of the oscillations were observed and recorded on film. From projections of the film, at the same speed at which the film was exposed, the amplitude and period of the oscillations were measured to check progress. During these tests, the pilot floor height was raised from the original design level of 18.75 inches to a maximum elevation of 42.75 inches above the duct outlet (total floor raise = 24 inches). The corresponding vertical center-of-gravity movement was from 30.50 inches to 39.25 inches above the duct outlet (total c.g. raise = 8.75 inches) For every one (1) inch increase in floor height, the vertical center-of-gravity movement was .32 inches for a 175 pound pilot. Figure 8 shows the platform rigged for tests with the highest center-of-gravity location. Table II, of Appendix V, presents a summary log of these tests.

These tests clearly showed an increase in the period of oscillation and a reduction in the amplitude as the center-of-gravity was raised. Figure 9 presents a time history of the free oscillation for two different vertical center-of-gravity locations and clearly shows the effect of raising the center-of-gravity. These curves show, for a 4.2 inch difference in vertical center-of-gravity location, a 4 second difference in period.

Tethered forward flights were conducted for various vertical center-of-gravity locations to obtain pilot's comments relative to flight characteristics. Both pilots felt that the platform was easier to control at all higher center-of-gravity elevations except the maximum which was 8.75 inches above the design level. The pilots commented that the platform seemed difficult to recover from tilt at forward speed at the 8.75 center-of-gravity raised position, but seemed satisfied when flying at a center -of-gravity located at only .64 inches lower. These comments indicated that the analytically predicted center-of-gravity location had been closely approached at which the aperiodic motion becomes divergent and no further center-of-gravity elevations were tested.

Hovering and forward flights to speeds up to 18 miles per hour were conducted in calm air and winds up to 15 miles per hour with 5 miles per hour gusts successfully for the center-of-gravity vertical elevation at 5.76 inches to 8.75 inches above the original design level.

c. De-Coupling of Pitch and Roll

The engine installation design of the Model 1031-A platform produces an unsymmetrical mass distribution geometry resulting in an unbalanced product of inertia about the vertical centerline. Figure 10 shows diagrammatically, the unbalanced mass distribution and engine installation geometry.

Tether flight tests were conducted early in June, 1956 to confirm analytical predictions that pitch and roll motions could be decoupled by making the product of inertia about the vertical axis zero. As an expedient method of accomplishing this, one weight was attached to each of two diagonally opposed landing gear attachment fittings to offset the unbalance caused by the engine installation geometry. The location of these weights is shown in figure 10. Tests were run with three different sets of weights; one set weighing 3.3 pounds, another set at 3.7 pounds, and the third set at 4.1 pounds.

Tethered oscillation tests were conducted and in every case, the rolling motion was markedly reduced when the platform was excited to oscillate in pitch. For the 3.7 pound weight, the coupled rolling with pitching motion was virtually eliminated proving the validity of the analysis and showing the need to provide a zero product of inertia about the vertical axis in the design of this type machine.

d. Gyro-Paddle Stabilizer Device

Analysis of stability characteristics showed that the high vertical center-of-gravity location required for dynamic stability in hovering and slow speed flight could be reduced by employing a free pivoted, air damped, gyro-bar actuating duct outlet mounted vanes. By providing corrective moments in pitch and roll in proportion to the angular rate and platform attitude, this device was shown analytically to make the platform dynamically stable in hover and forward flight by providing system damping inherently lacking in the basic Model 1031-A configuration. This lack of damping was attributed to the small rotor diameter, high disc loading of 23.3 lb/ft^2, and the low pitching and rolling moment of inertia of 20 slug feet^2 for the platform.

A gyro-paddle stabilizer device was designed and tested in tethered and free-flights with resulting improved stability with no sacrifice of controlability. Test results agreed almost identically with theoretical predictions.

1) Design - Design parameters were determined as required to produce a corrective pitching moment of 6.4 ft-lb/degree of gyro-paddle tilt in pitch for a two vane control system and a platform vertical center-of-gravity location 34.5 inches above the duct outlet (pilot's floor 30 inches above the duct outlet: floor raised 11.5 inches above original design elevation).

   Design studies produced a system as shown in Figure 11(a) which provided for damping in pitch and roll. This system consisted of two pairs of aerodynamic vanes mounted at the duct outlet. One pair of vanes was mounted with one vane near the forward edge of the duct and the other near the aft edge to provide pitching moment. The other pair was similarly mounted near each side of the duct to provide rolling moment. Span of each vane was

40 inches, chord 6 inches, with an area of 228 square inches considering a 2 inch spanwise gap at the control horn. Actuation of the vanes was provided by two freely and independently pivoted gyro-bars. The gyro-bars were designed to have a polar moment of inertia of .010 slug ft.^{2} including a small airfoil shaped paddle mounted at the tip of each bar to provide aerodynamic damping of the bar flapping motion.

A simplified swash plate consisting of a standard universal joint fitted with a transfer assembly provided for the transfer of tilting motion of the rotating gyro-paddles to the stabilizer vanes fixed to the duct. Conventional turnbuckle adjustable links fitted with rod end bearings linked the gyro-paddles to the swash plate (universal joint) assembly. Similar, but longer links connected the vane control horn to a post projecting from the non-rotating portion of the swash plate assembly. This non-rotating assembly was mounted on a bearing to permit free rotation of the propeller driven gyro-paddles which were mounted on an extension of the lower propeller shaft. The linkage ratio of vane tilt angle to gyro-paddle tilt angle was set up at .65:1 with provisions in the vane control horn for decreasing or increasing this ratio.

Figure 11(b) shows the mechanical operation of the system for the case of the duct pitched down at the nose. The dash lines show the relative position of the bar and vanes to the duct and the lift force "L" so produced by the vanes. This lift force of the vanes produces a damping moment opposing the pitching or rolling moment of the platform.

2) <u>Tether Tests</u> - The gyro-paddle stabilizer system was fabricated and tests were initiated on 12 July 1956 with whirl tests of the gyro-paddles installed on the Model 1031-A platform. No difficulties were encountered and tether flights were initiated on 15 July 1956 with the complete system installed. A total of 72 tether flights were made in calm air and gusty winds with various linkage ratios and two sets of gyro-paddles having different values of inertia were tested in combination with various vertical center-of-gravity positions. Oscillograph records were made showing the effective damping in pitch produced by the gyro-paddle stabilizer system for forced and free oscillations of the platform with no pilot corrective control by testing for the following conditions:

1. Vanes disconnected - propellers not driven
2. Vanes disconnected - propellers driven to design maximum rpm
3. Gyro-paddle system operating - propellers driven to design maximum rpm

Tether tests were completed on 11 September 1956 resulting in greatly increased hovering stability and reduction of gust sensitivity of the platform in hover and forward flight.

First tether tests of the gyro-paddle system showed very little motion of the vanes for both slow and rapid rates of pitch and/or roll. Changing the linkage ratio from .65:1 to 1.0:1 ratio produced no apparent improvement which led to an investigation of the system friction losses and gyro-paddle inertia. A component by component check of the system disclosed very high friction in the assembly consisting of the universal joints, gyro-paddles, and links between these components. The needle bearing cups of the universal joint were adjusted axially for each joint axis and friction in the universal joint was greatly reduced. One link of each set of two links from each gyro-paddle to the swash plate was modified to allow one rod end bearing to float axially. Thus all control motions and loads were transmitted by one link per gyro-paddle and the other link of each set served only to maintain static balance. All rod end bearings and universal joint bearings were oil lubricated and overall system friction was greatly reduced. Following tests of the system showed increased vane motion but the motion was not in agreement with the 1:1 linkage ratio used. Additional observation disclosed deflection of the vanes at the center span point due to control load applied at the pitch horn. A local support was fabricated and installed and subsequent tests proved the stabilizer system to be operating satisfactorily.

In order to investigate various combinations of gyro-paddle inertia and vertical center-of-gravity position after vane motion was determined to be satisfactory, the following tests were programmed for tether flight:

	Gyro-Paddle Inertia (slug-ft^2)	Vertical c.g. (inches above duct outlet)	Pilot's Floor (inches above duct outlet)
1.	.010	38.50	40.75
2.	(no paddles) .016	38.50	40.75
3.	.016	38.50	40.75
4.	None (vanes locked)	38.50	40.75
5.	.010	37.00	36.75
6.	.016	37.00	36.75
7.	None (vanes locked)	37.00	36.75
8.	.010	34.70	30.75
9.	.016	34.70	30.75

Each combination of parameters was tested in tether flight to obtain a qualitative evaluation based on pilot comments and observed changes in free oscillation period and amplitude. Oscillograph records were made of forced and free oscillations of the platform without the stabilizer system both without engines running and with engines running to determine the influence of rotor damping on pitching oscillations. Records were also made with the engine running and with the gyro-paddle system operating to determine its effect on damping in pitch.

Figure 12 shows the test set up on the static test stand for the forced and free oscillation tests. Figure 13 shows the installation of a potentiometer for measuring angle of tilt of the duct. Figure 14 shows the installation of a potentiometer for measuring angle of tilt of the pitching vanes relative to the duct. Similarly, a potentiometer was mounted on one of the two roll vanes.

Tests on the static stand were conducted by forcing the platform through an angle of ±20 degrees at various angular velocities. Oscillograph traces were checked to observe the phasing of vane tilt angle and platform tilt angle in order to determine the function and response of the gyro-paddle stabilizer system. Figures 15(a), (b), and (c) show oscillograph traces for the free oscillation of the platform with no power and with no vanes. Amplitude of tilt angle of platform versus time is presented covering an elapsed period of time of 31.15 seconds. These curves are also indicative of the oscillation amplitude and time history for the platform with power on and with no vanes which clearly confirms the lack of damping. Figures 16(a), (b), and (c) present a time history of amplitude of oscillation of platform for power on and no vanes. Figure 17 shows the time history of amplitude of oscillation of the platform for power on and vanes operating. It is clearly shown that the platform oscillation is almost completely damped in 2 cycles. Because of system friction, the gyro-paddle stabilizer is relatively insensitive to low angular velocities as evidenced by the fact that the platform oscillations are highly divergent for large angular velocities, as shown in Figure 17 for the first two cycles, and neutrally stable for low angular velocities, as shown in the third cycle.

Tether stand tests were conducted with the pivot point for all oscillations being the tether cable. These tests were conducted in order to obtain oscillograph traces for a longer period of oscillation in order that the vane phase angle and response could be determined for a period of oscillation substantially the same as the natural period of the platform as flown without the gyro-paddle stabilizer system. Figure 18 shows this test set up. These test results showed substantially the same vane-duct tilt phase relationship as obtained for the faster period oscillations and confirmed the low damping characteristics of the platform without the vane system.

The final best configuration of the platform at the conclusion of these tests was as shown in Figure 19. Significant parameters are as follows:

Center-of-gravity elevation	34.75 inches above duct outlet
Pilot's floor elevation	30.75 inches above duct outlet
Increased c.g. elevation compared to original design	4.00 inches
Increased floor elevation compared to original design	12 inches
Gyro-paddle polar moment of inertia	.010 slug-ft^2
Linkage ratio (vane angle to gyro-paddle flapping angle)	1.25:1

Although pilots preferred the easier control of platform at higher floor elevations up to 24 inches above original design level, psychological factors in forward flight produced a strong preference for the lower floor elevation as finally determined above.

During the tether tests, hovering and forward flights were made in calm air and winds of 15 miles per hour maximum velocity with 5 miles per hour gusts. A maximum forward speed of 18 miles per hour was recorded. For all configurations tested using the 1.25:1 linkage ratio, the platform was easily controlled and displayed good dynamic stability. Flight characteristics seemed little changed by changes in vertical center-of-gravity location within the limits tested.

Table III, Appendix V, presents a summary log of these tests.

3) Free-Flight Tests - Free-flight tests were initiated on 12 September 1956 and were conducted to confirm the findings of the tether test program without the encumbrances of the tether rig. Hovering, forward, rearward, sideward, and quick stop maneuvers were performed at low altitude. Rotation about the yaw axis while flying forward, and coordinated "S" turn maneuvers were executed. All maneuvers were conducted in both calm air and in winds of 15 miles per hour maximum velocity with 5 miles per hour gusts. For all flight maneuvers and conditions, stability was very good and control was remarkably easy up to the maximum sustained forward speed of 16 miles per hour tested. Maximum altitude attained was 12 feet in hover and 5 feet in forward flight as limited by available power at a gross weight of 505 pounds which represented a 32 pound overweight condition of the platform. A total of 24 flights were made for a total of two (2) hours, seven (7) minutes free-flight time.

These free-flights were conducted at the end of the Phase III program and were concluded with flight demonstrations at the Contractor's facility for representatives of both the Office of Naval Research, Department of the Navy, and the Office, Chief of Research and Development, Department of the Army. Representatives of both these agencies flew the platform on the tether rig with notable ease in both calm air, in 5 miles per hour gusts and in winds up to 15 miles per hour velocity.

The free-flight program duplicated the tether test evaluation of flight characteristics for various combinations of gyro-paddle inertia and vertical center-of-gravity location. As the result of these tests, the preferred configuration was the same as selected by tether tests of Part 2 of this section except that the heavier gyro-paddle (.016 slug-ft.^{2}) was selected.

The platform was easily controlable at all times and exhibited no instability for all maneuvers and at all speeds tested. Two of the Contractor's test pilots flew all the maneuvers and it is indicative of the relative simplicity of the control of this machine to note that one of the pilots accumulated all of his total time of 48 minutes free-flight experience during this test program with a background of a total of 4 hours, 4 minutes tether flight time of which 1 hour, 37 minutes was training time. Appendix VI presents a summary log of the training program for the new pilot.

Sustained forward speed was limited to 16 miles per hour because of the occurrence of a random, intermittent, pitching-up of the nose in the speed range of from 12 - 16 miles per hour and because of power limitations of the platform in its overweight condition. The pitching-up at the nose was of noticeably lower amplitude and rate than was experienced for the basic Model 1031-A as tested under the Phase II program. (See Figure A, II-1, Appendix II). It was generally believed that this disturbance was caused by turbulent air generated beneath the platform in flight at the low altitudes (4 - 5 feet) necessitated by power limitations. The random nature of these oscillations strongly supports this opinion. Power limitations made it impossible to conduct forward flight tests out-of-ground effect (approximately 2 rotor diameters for platform - 10 feet). A hover altitude of 15 feet was attained in one flight for a few seconds but only because of the low early morning ambient air temperature and the initial higher power produced by the 2 cycle engines while still warming up. Normally, all flights were at maximum power settings while hovering at 8 feet altitude and as the platform was tilted forward to fly forward, it spilled some of the ground cushion and settled to within 5 feet of the ground.

Table IV presents a summary log of total log of airframe and engine hours to the end of Phase III.

Table V, Appendix V, presents a summary log of these tests. Figure 1 and 2 show the final configuration of the Model 1031-A as tested under this program.

C. METHODS OF CONTROL

The basic forces acting on the platform to produce pitching moment were analyzed and several methods of controlling pitching moment were studied. This work was performed in order to determine a suitable means of reducing pitching moments of the platform and to provide the pilot with a control power boost system.

Phase II truck test data (Reference (f)) and flight experience showed that the nose-up pitching moment of the platform increased with forward speed and was accompanied by a narrowing of the positive margin of control available to the pilot by pure kinesthetic means. Figure 20 presents this curve for the Model 1031 platform as tested under Phase II. In light of these data and in anticipation of a possible increase in pitching moment versus forward speed for the evaluation platforms (Model 1031-B) being negotiated under Reference (i), these studies were made in an effort to insure that subsequent personnel platforms of larger size could be controlable by kinesthetic control, aerodynamic controls, or a combination of both.

Two methods of reducing pitching moment were given a preliminary study. One system employed a ventilated forward and aft duct inlet lip with the forward and aft vents interconnected by a plenum chamber. This system was proposed to use the differential pressure between the forward and aft duct lips to provide boundary layer control reducing lift on the forward lip and increasing lift on the aft lip, thereby reducing the differential lift between these two lip areas and reducing the nose-up pitching moment without an appreciable effect on net thrust. Based on a qualitative preliminary analysis, it was concluded that the amount of pressure available by this means was insufficient to provide the necessary boundary layer control and that a power driven suction pump would be required.

The second system of pitching moment control proposed was based on reducing propeller tip losses by control of the boundary layer at the propeller tips. By this means, it was believed possible to produce a cyclic lift on the propeller which could be used to reduce or increase pitching moment. This system was given only a cursory examination because of the limitations of time and money and the priority assigned to work on stability.

It was generally concluded that boundary layer control system studies should be given greater emphasis only if other simpler means of pitching moment control are not realized.

Three methods of pitching moment control for the pilot by other than kinesthetic means were investigated.

A duct outlet mounted vane control system was analyzed following tests described under Section B, Part 2a. It was concluded that this system designed as the sole means of control was unsatisfactory because of the unbalanced drag force produced by vane lift and the associated increase in platform tilt angle for a given forward speed.

A duct inlet mounted vane system was studied which provided for the differential operation of vanes mounted above the fore and aft duct lip regions in such a way that the lift on these vanes could be used to produce pitching moment in the desired direction. Analyzed as the only means of control, this system was found to produce insufficient moment to provide the required nose -down moment control.

A system of duct inlet radial guide vanes was studied in which radial controlable vanes were located in the duct inlet just above the upper propeller. By changing the pitch angle of these vanes, the angle of attack of the propellers could be changed by the change in direction of the relative inlet airstream and thus cyclic lift could be produced and used for pitching moment control. This system was found to be the most promising of all systems considered as an independent moment control system. It was concluded that more extensive studies substantiated by wind tunnel tests should be undertaken to explore the full capabilities of this system.

Reference (j) presents the details of these studies conducted in satisfaction of Items 4a, 4c, and 4e, of Annex A, of the subject contract.

D. PERFORMANCE

1. Method of Calculating Power Required for Forward Flight

The power required was determined from considerations of the energy level of the airstream prior to and immediately after passing through the propeller. Equilibrium conditions were satisfied through the use of momentum equations and the resultant equations were solved for tilt angle and power.

For the Model 1031-A platform, the power required was found to be essentially constant throughout the flight range and was attributed to the unclean inlet conditions and large percentage of duct area blocked by the engines.

Reference (j) presents this method of analysis and compares calculated results with truck test data of Phase II.

This work was accomplished in satisfaction of Item 1 of Annex A of the subject contract.

2. Thrust Increase

a. Increased Propeller RPM

1) Special Fuels - The platform was found to be unable to hover with outlet vanes installed, more than 1 to 2 feet above the ground in 70 degrees to 75 degrees F ambient air temperature. Because of spilling of the ground cushion in forward flight, such flights were impossible with such a low hovering ceiling. Since the testing program faced "stretch-out" because of the necessity of flying only in the cooler morning hours in March, 1956, static stand tests were conducted in which static thrust was increased 15 pounds by the use of a special fuel mixture consisting of 40 percent aviation gasoline, 40 percent Benzol, and 20 percent lubricating oil by volume.

Various proportions of Benzol, aviation gasoline, and lubricating oil were tested in the Nelson H-59 engines (rated 40 hp at 4,000 rpm). For each fuel mixture tried, adjustments in spark and carburetor settings were made until best thrust at allowable cylinder operating temperature (350°F for 70°F ambient temperature) was recorded. Best fuel mixture was found to be one composed of 40 percent Benzol, 40 percent aviation gasoline, and 20 percent lubricating oil. Attempts to run on pure Benzol and oil resulted in severe carburetor icing.

Special fuel mixture ingredients tested were:

Aviation gasoline, 80-87 octane, regular, non-leaded
Aviation motor oil, SAE 30
Benzol, Technical 99-100 percent

Standard fuel mixture ingredients were:

Aviation gasoline, 80-87 octane, regular, non-leaded
Aviation motor oil, SAE 30
Proportions: 4 parts gasoline to 1 part oil by volume

All duct outlet control vane tests described in Section B, Part 2a, were conducted using the special fuel mixture selected by these tests.

Vanes were installed and thrust measurements were made to determine actual losses due to the drag of the vanes at various pitch angles. Figure 21 shows the variation of thrust with engine rpm for various spark settings for the 40 percent Benzol, 40 percent aviation gasoline and 20 percent lubricating oil mixture and the standard fuel mixture at two different altitudes. Figure 22 shows the variation of thrust with vane angle of pitch at the different altitudes for the special fuel and standard fuel.

2) <u>Mild Supercharging</u> - Since the thrust obtained by use of special fuel was still marginal for platform flight with vanes installed, an attempt was made to obtain increased power by mild supercharging.

Tuned stacks were installed on each carburetor inlet as shown in Figure 23. This technique has worked successfully with four-stroke cycle engines but could not be made to work on the Nelson H-59, two-stroke cycle engine. The arrangement tested consisted of two telescoping lengths of aluminum tubing with a range of adjustment on each side of the calculated required length for air wave resonance.

3) <u>Reworked Nelson Engines</u> - Since power was still marginal on all but the coolest days even with the use of the special fuel mixture and since the warmer summer months were approaching, the 40 horsepower Nelson H-59 engines were returned to the engine supplier for rework and modification as required to produce 42 horsepower at 4,000 rpm. This horsepower increase was considered fundamental to the successful exploration of vertical center-of-gravity location tests which were planned to be conducted out-of-ground effect. A spare engine was purchased to insure the test program schedule.

The engines were completely rebuilt including new crankcase, pistons, and cylinders and were reinstalled in the platform.

Static thrust tests were conducted to measure platform thrust, engine rpm, and cylinder temperatures at two different altitudes close to the ground.

Static thrust test data for the 42 horsepower Nelson engine corrected to standard conditions, showed a static thrust of 523 pounds for duct outlet at 18 inches above ground, engine rpm of 3800 and spark setting of 30 degrees. A thrust of 453 pounds was measured for the duct at 69 inches above ground, engine rpm of 3980 and spark setting of 30 degrees. At no time did cylinder head temperatures present a problem. The new heads constructed of an improved aluminum alloy permit an allowable temperature of 450 degrees F.; maximum stabilized temperature recorded was 400 degrees F. Figure 24 shows a comparison of thrust versus engine rpm for various altitudes tested for the Nelson 40 horsepower and 42 horsepower engines. It will be noted that the platform static thrust in-ground-effect is 23 pounds higher with the 42 horsepower engine. Out-of-ground effect (69 inch altitude), the static thrust is only 7 pounds higher for the 42 horsepower engine compared to the 40 horsepower engine. Pressure surveys of the duct outlet indicate that there is a flow reversal in the central region of the duct which is much more pronounced out-of-ground effect than in-ground-effect. It was hypothesized that the additional blockage of the duct created by the somewhat larger cooling vane area of the reworked Nelson engines was enough to cause increased turbulence behind the cylinder heads with associated loss of thrust at altitude. The addition of a streamlined cowling over the cylinder heads of each engine did nothing to reduce this turbulence.

With the results of these tests with the increased horsepower engines, all hopes of conducting flight tests out-of-ground effect were virtually abandoned since it was clearly shown that a thrust of 464 pounds (design gross weight of basic Model 1031-A helicopter) was available at a maximum of 4 feet altitude on a standard day. It was evident that early morning tests would be required to obtain larger ground clearance for forward flight.

This work was conducted in satisfaction of Item 3, Annex A of the subject contract.

b. Duct Outlet Diffuser

An analysis was made of the potential thrust increase promised by a duct outlet diffuser. It was predicted that for a conical diffuser of 12 degrees included angle of expansion and 12 inches in length, a 6 percent thrust increase would be realized. This percentage increase represented 32 pounds static thrust increase for the Model 1031-A helicopter.

Practical problems associated with fairing the joint of attachment of the conical diffuser to the basic duct, consideration of time and expense, and the unknown weight penalty of this device, resulted in the shelving of this idea until it was found necessary as a last resort.

Figure 25 presents a plot of percent thrust increase versus divergent nozzle length for a 12 degree equivalent angle of expansion conical exit nozzle.

c. Drag Reduction

In order to improve the static thrust of the platform out-of-ground effect, as indicated possible by pressure surveys, an attempt was made to clean-up the duct inlet.

Aluminum fairings were made and installed on the engines and the engine support tubes were built up with cardboard and doped tape to give a streamline shape to the round basic tube. For the junction of the duct inlet to engine support tube, a strealined transition shape fairing was built up from cardboard and doped tape. The aluminum fairings were shaped to enclose the sides of the engine (fitting over the cylinder heads) and the back end of the engine which is well out toward the duct wall. This fairing extended down from the top of the cylinder heads in a converging shape to very close proximity to the upper propeller.

Tether flight tests showed about one foot apparent increase in altitude resulting from this clean-up. The aluminum engine cowling was hoped to provide the most thrust gain by reducing the large amount of reverse flow measured below the engine cylinders; however, tests made with this cowling removed for repairs to fatigue cracks, showed no reduction in hover altitude. All subsequent flight tests were conducted with just the engine tube and tube-duct intersection fairing as shown in Figure 26.

d. Reduced Propeller Tip Clearance

Propeller clearance between the blade tip and the wall of the duct was reduced from a nominal .25 inch gap to a .125 inch gap by correcting the out-of-roundness of the duct and by installing two new propellers trimmed to clear the duct at local patches by only .062 inches. Improved thrust resulted in an increase in hovering altitude from 5 feet to 8 feet and an increase from 3 feet to 5 feet altitude in forward flight. These gains in altitude permitted all horizontal flight maneuvers to be performed with the gyro-paddle stabilizer system installed and with the platform 32 pounds over basic design gross weight.

The duct diameter was out-of-round due to ageing of the foamed in place filler material used in the propeller shroud portion of the duct assembly. Sheet metal brackets were fastened to this shroud and cables with turnbuckles were used to apply desired tension between the brackets and a truer roundness of the propeller shroud resulted. Local patches on the inner surface of the shroud prohibited reducing the gap to less than an average of .125 inches although local clearances over critical patched areas was as little as .062 inches without producing blade-duct contact in landing maneuvers.

The tension cable support brackets can be seen in Figure 1.

3. Propeller Design Check

The propeller for the platform Model 1031-A was designed, with one exception, according to the analysis contained in Reference (k). All calculations were carried out using the equations developed in that report. However, the resulting blade settings for any radius were found to be almost identical for the upper and lower blades. For simplicity of fabrication the values were averaged and used for both blades. No deviation greater than .2 degrees resulted.

In terms of gross characteristics, the correlation between design and test values is quite good. The induced velocity at design rpm is 2 percent greater than calculated, and, as should be expected, the thrust is greater by approximately the square of the induced velocity ratio, or 3.5 percent. Correspondingly, the power required is slightly higher than predicted, implying that the propeller efficiency is correctly estimated.

Propellers designed strictly according to the analysis of Reference (k) should introduce zero net swirl into the wake. Since the design employed

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does not maintain proper blade settings the proper inflow angle is not maintained. A slipstream swirl resulting from this is believed to be the source of a residual torque of 55 ft.lb.

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CONCLUSIONS AND RECOMMENDATIONS

The Model 1031-A airborne platform, as modified by raising the center-of-gravity and installing a gyro-paddle stabilizer system, is dynamically stable and easily controlable in hovering and forward flight at speeds up to 16 miles per hour, in winds up to 15 miles per hour, and in 5 miles per hour gusts. Free-flight test experience and correlation with Phase II truck test data shows that analytical methods of calculating performance, stability and control characteristics are reasonably accurate. Forward speed is limited by power limitations of present Model 1031-A and a random nose-up pitching at 16 miles per hour which is attributed to ground disturbances.

It is recommended that additional research be conducted to quantitatively evaluate the thrust augmentation and pitching moment characteristics of various duct shapes as applied to the Model 1031 airborne platform. Further studies of stability and control should be conducted based on these duct characteristics with the primary objective of increasing speed in forward flight. Such a program, properly designed, would provide data useful in the design of future airborne platforms such that higher forward speeds may be assured with good control and stability characteristics.

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REFERENCES

a. NACA RM L52D10, "Preliminary Experimental Investigation of the Flight of a Person Supported by a Jet Thrust Device Attached to his Feet", dated January, 1953.

b. NACA RM L54B12a, "Flight Tests of a Man Standing on a Platform Supported by a Teetering Rotor", dated March, 1954.

c. NACA RM L54B16, "Flight Tests of a 0.4 Scale Model of Stand-On Type of Vertically Rising Aircraft", dated 24 March 1954.

d. Hiller Report No. 680.1, "Final Report - Phase I - Airborne Personnel Platform Development".

e. Hiller Report No. 474.4, "Summary Report - Phase II - Airborne Platform", dated 24 April 1956.

f. Hiller Report No. 680.2, "Truck Tests of Hiller Airborne Personnel Platform", dated 15 September 1955

g. Hiller A.R.D. Report No. 111, "Some Remarks on the Control and Stability Characteristics of the Flying Platform", dated 26 April 1956.

h. Hiller A.R.D. Report No. 112, "Stability Analyses of Flying Platform in Hovering and Forward Flight", dated 12 October 1956.

i. Contract NOa(s) 56-935.

j. Hiller Report No. 56-108, "Aerodynamics of Ducted Propellers as Applied to the Platform Principal", dated 30 November 1956.

k. Hiller Report No. 102.3, "Ducted Coaxial Propeller Blade Angle Settings" dated 12 March 1954

FIGURE 1

FREE FLIGHT-FINAL CONFIGURATION
PILOT JOHNSTON

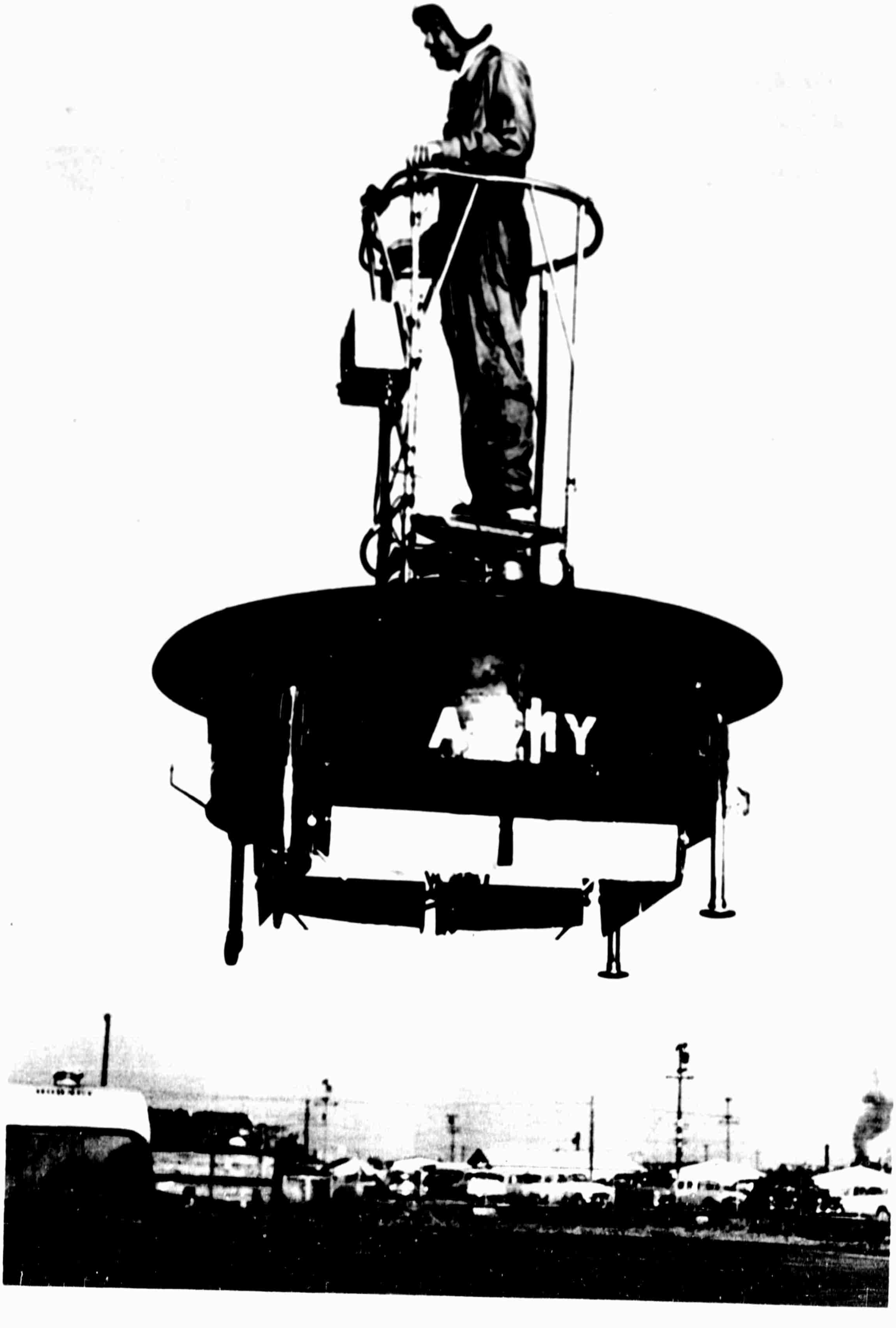

FIGURE 2

FREE FLIGHT-FINAL CONFIGURATION
PILOT LAPE

FIGURE 3

DUCT OUTLET MOUNTED CONTROL VANES

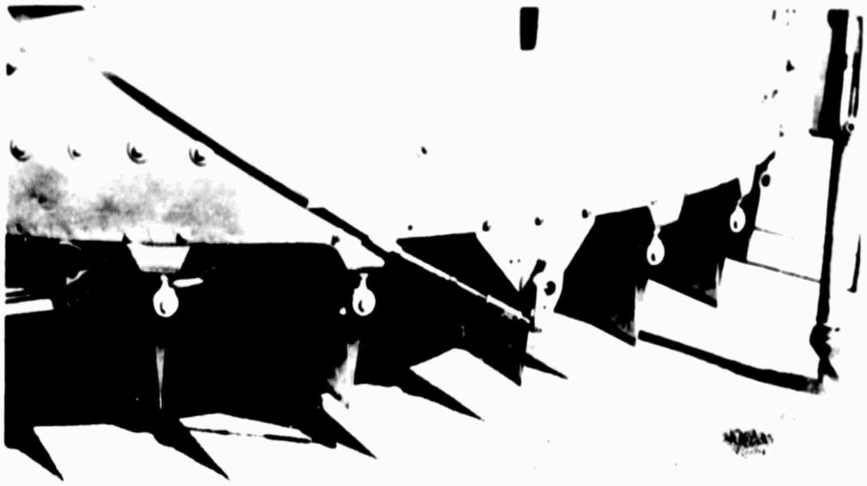

FIGURE 4

VANE CONTROL HORN AND FLEXIBLE CABLE

FIGURE 5

TILTING FLOOR VANE CONTROL

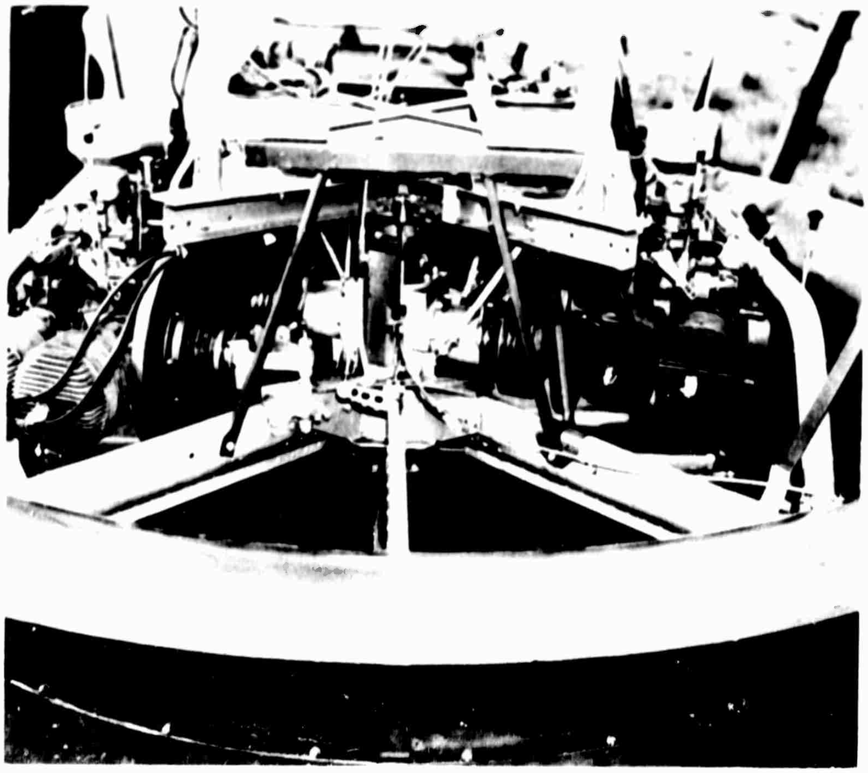

FIGURE 6

TILTING RING - FIXED FLOOR VANE CONTROL

FIGURE 7

TWO AFT DUCT MOUNTED VANES

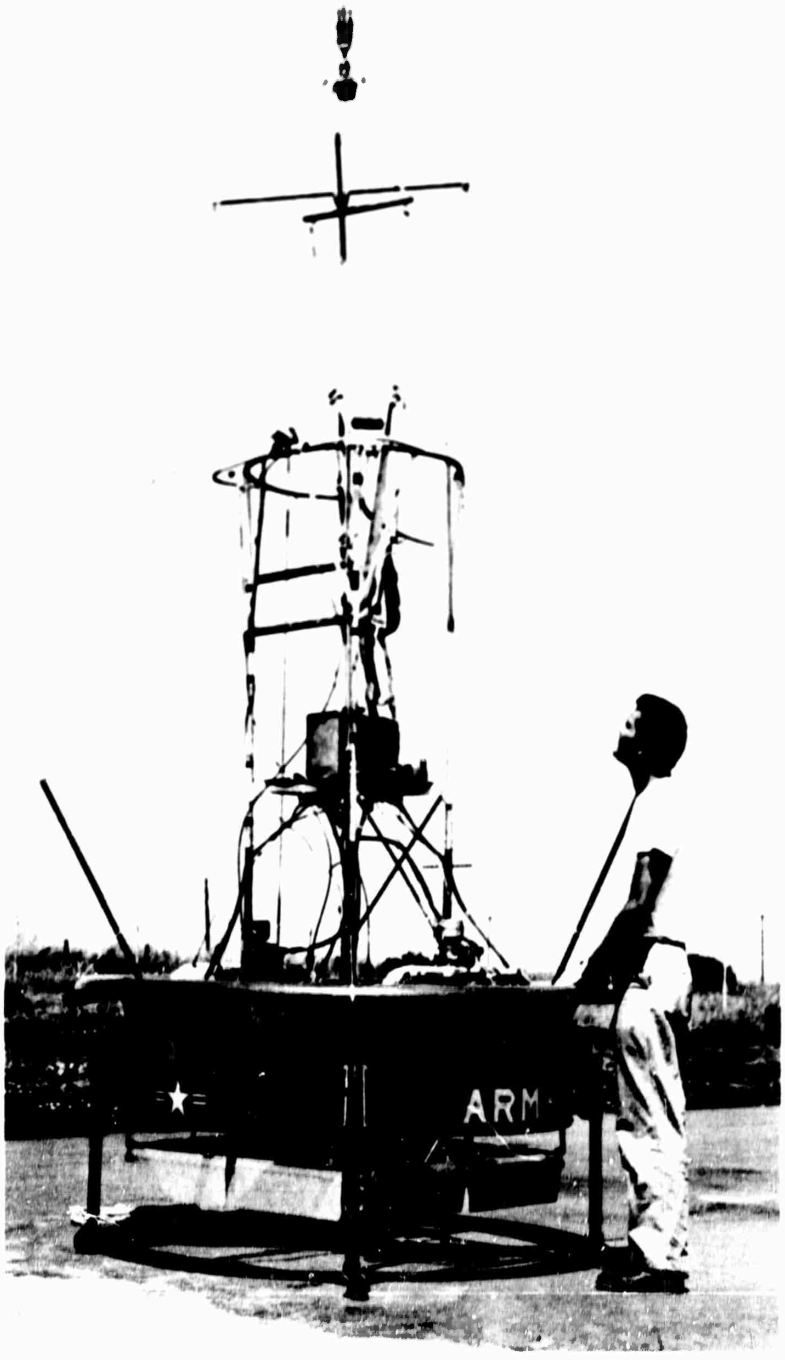

FIGURE 8

MODEL 1031-A
MAXIMUM C.G. ELEVATION

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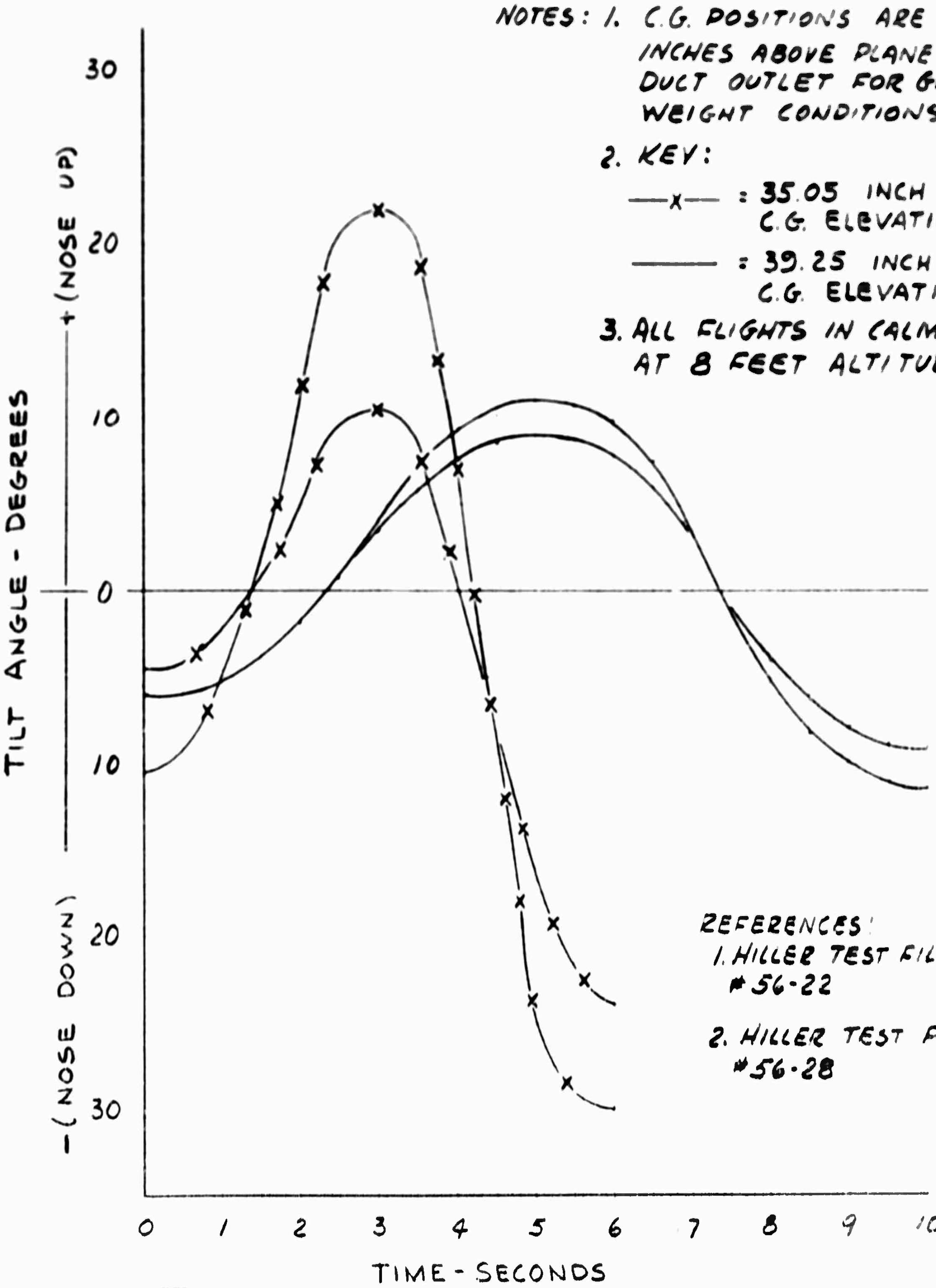
TILT ANGLE vs TIME
(VARIOUS VERTICAL C.G. POSITIONS)



NOTES: 1. C.G. POSITIONS ARE IN INCHES ABOVE PLANE OF DUCT OUTLET FOR GROSS WEIGHT CONDITIONS

2. KEY:

—x— : 35.05 INCH C.G. ELEVATION

——— : 39.25 INCH C.G. ELEVATION

3. ALL FLIGHTS IN CALM AIR AT 8 FEET ALTITUDE

REFERENCES:

1. HILLER TEST FILM #56-22
2. HILLER TEST FILM #56-28

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FIG 9

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MODEL 1031-A PLATFORM GEOMETRY

DECOUPLING ROLL FROM PITCH TESTS

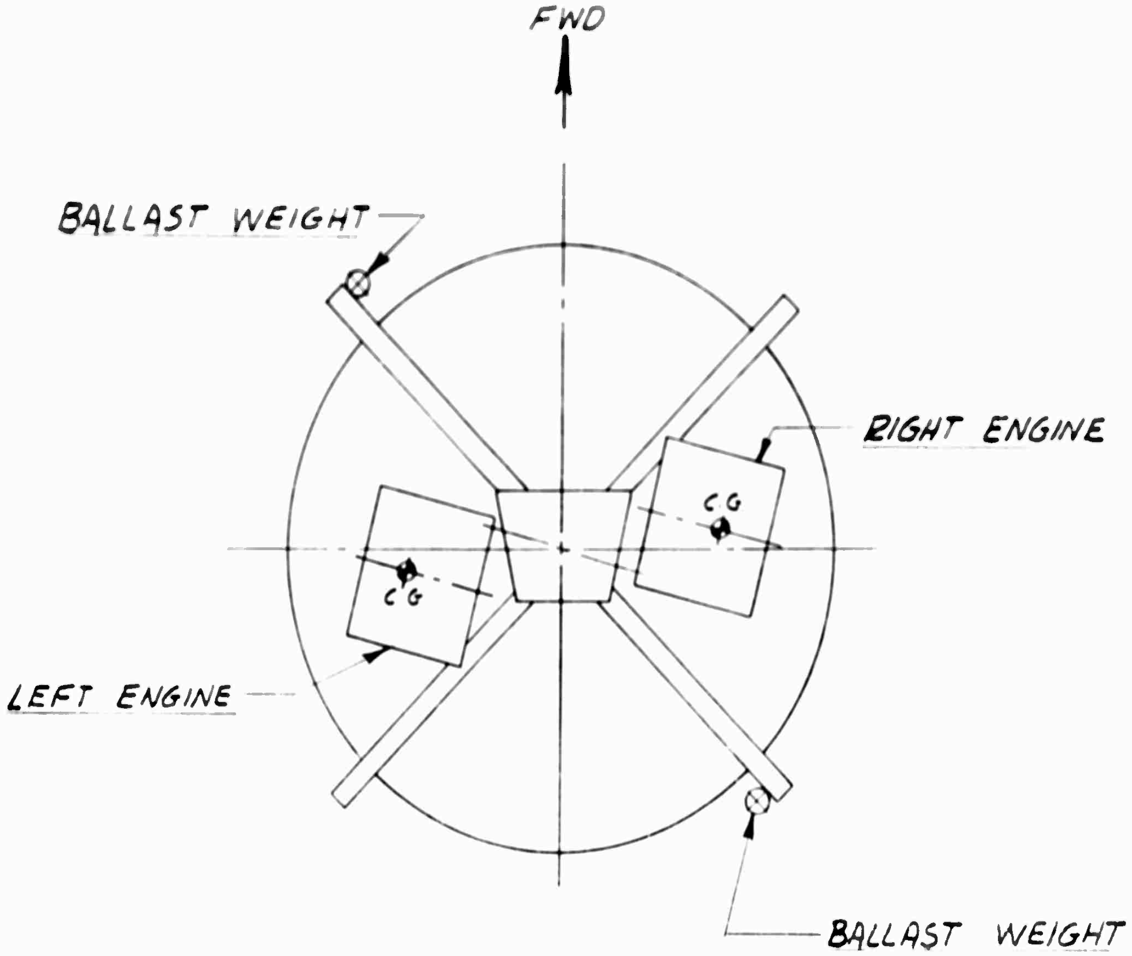

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FIG. 10

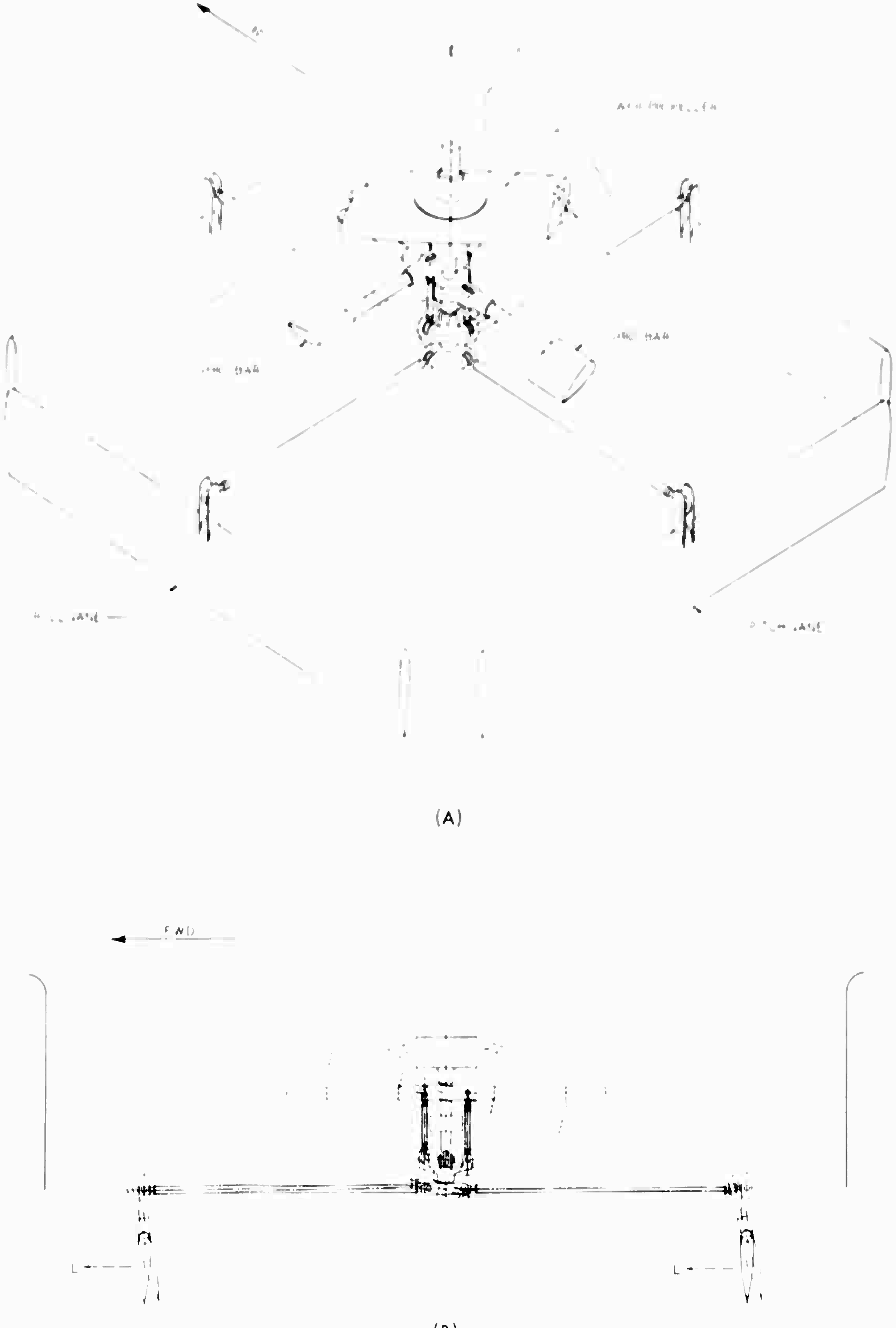


FIGURE 11

SKETCH - GYRO-BAR STABILIZER

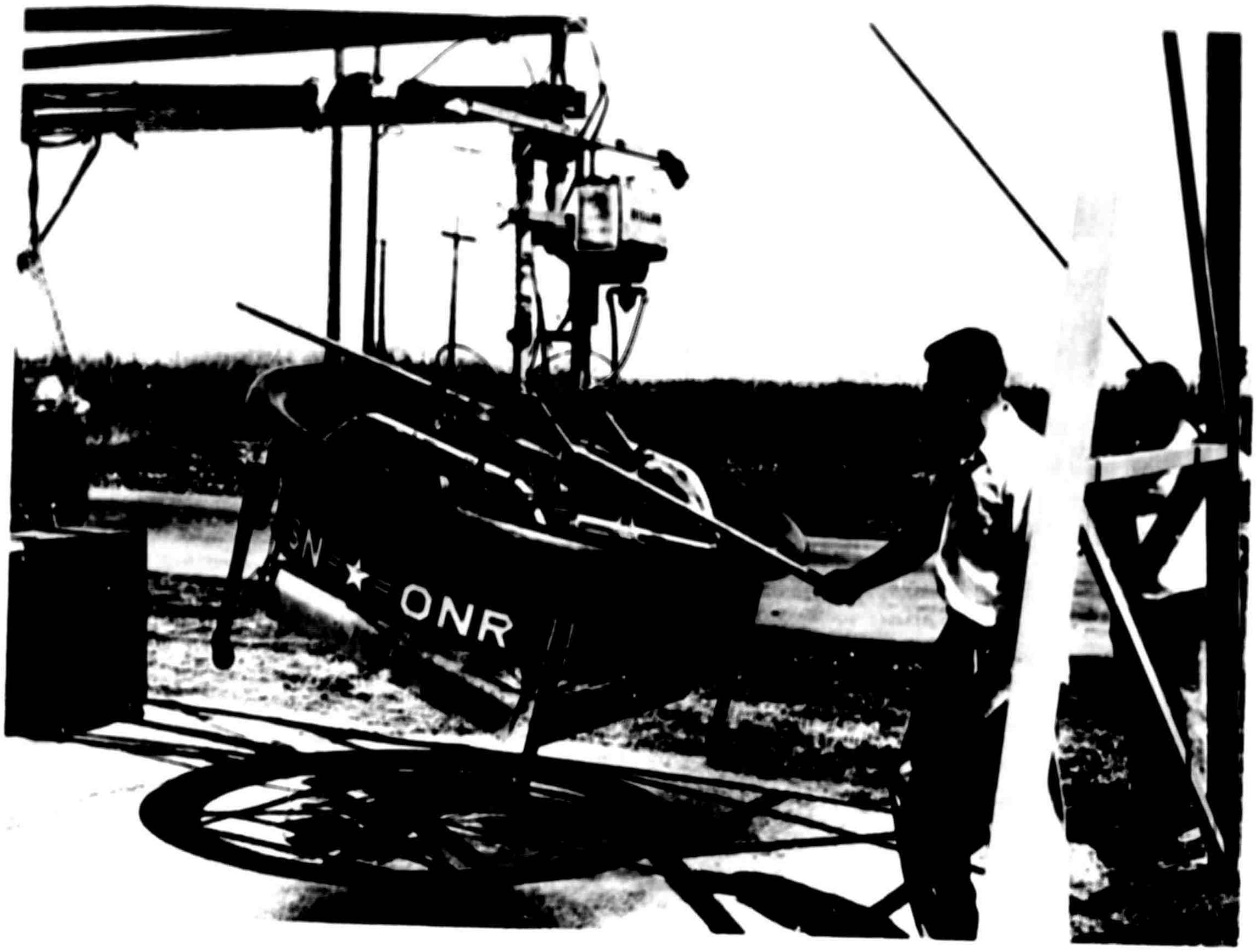


FIGURE 12

FORCED AND FREE OSCILLATION-STATIC STAND

FIGURE 13

PLATFORM TILT ANGLE POTENTIOMETER INSTALLATION

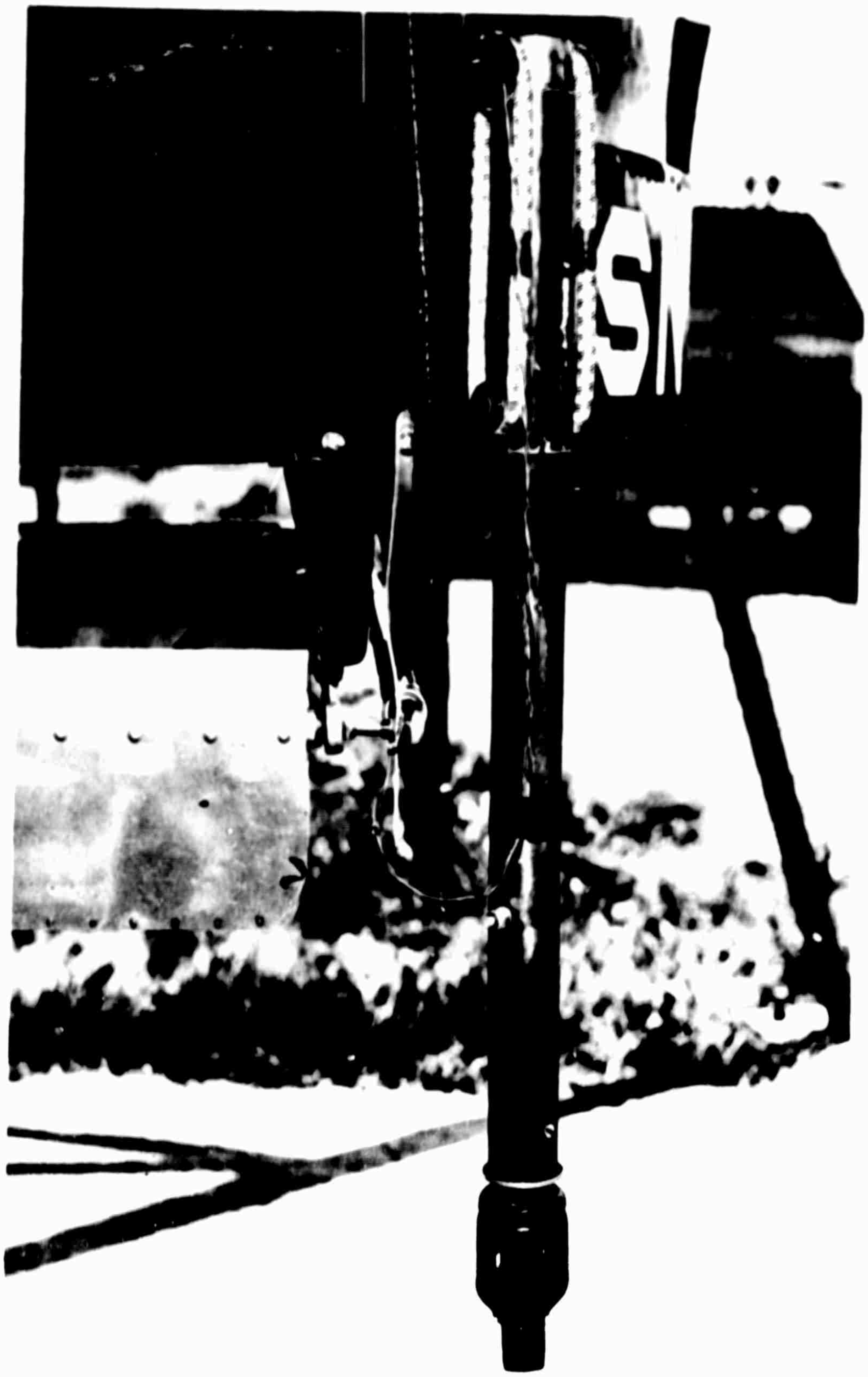


FIGURE 14

DUCT VANE ANGLE POTENTIOMETER INSTALLATION

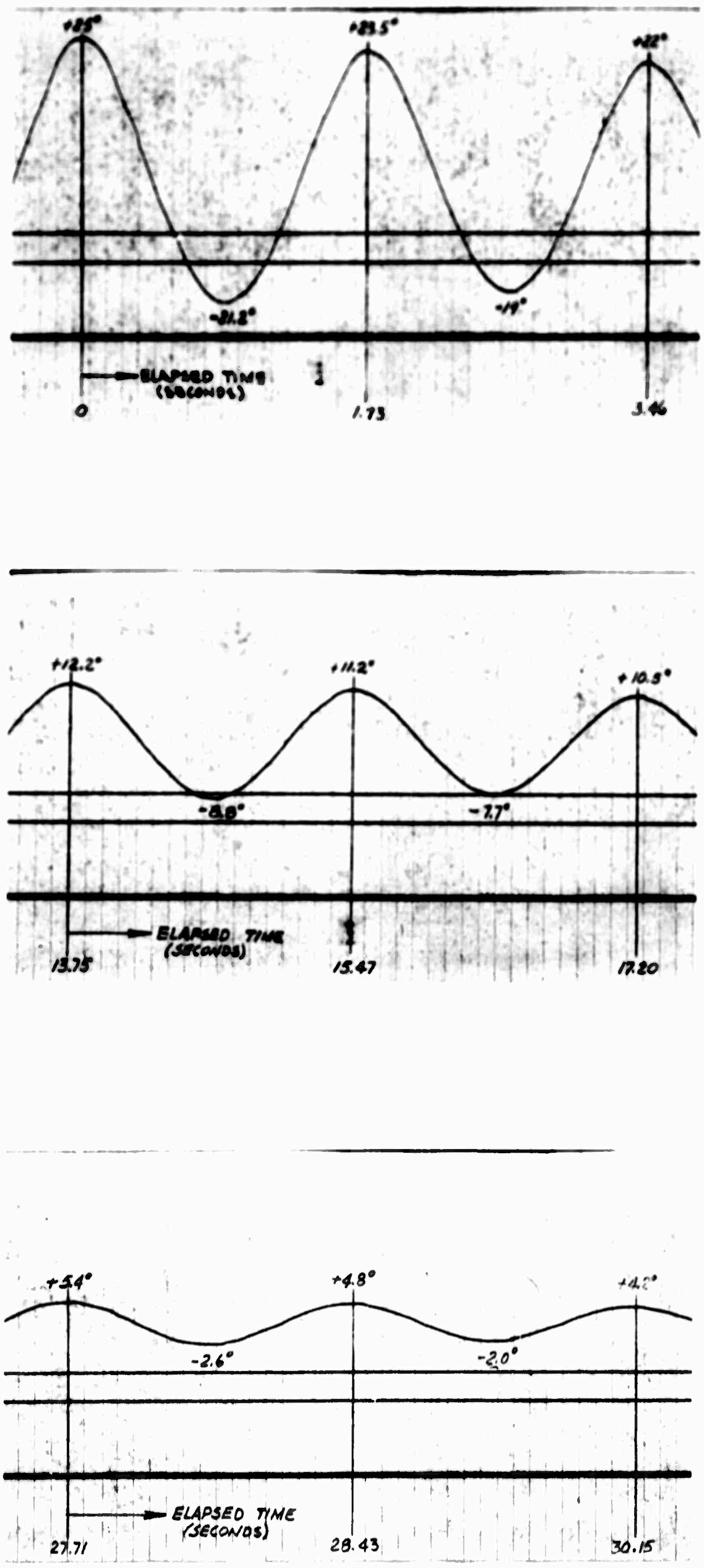


FIGURE 15

UNDAMPED FREE OSCILLATION TRACE-POWER OFF

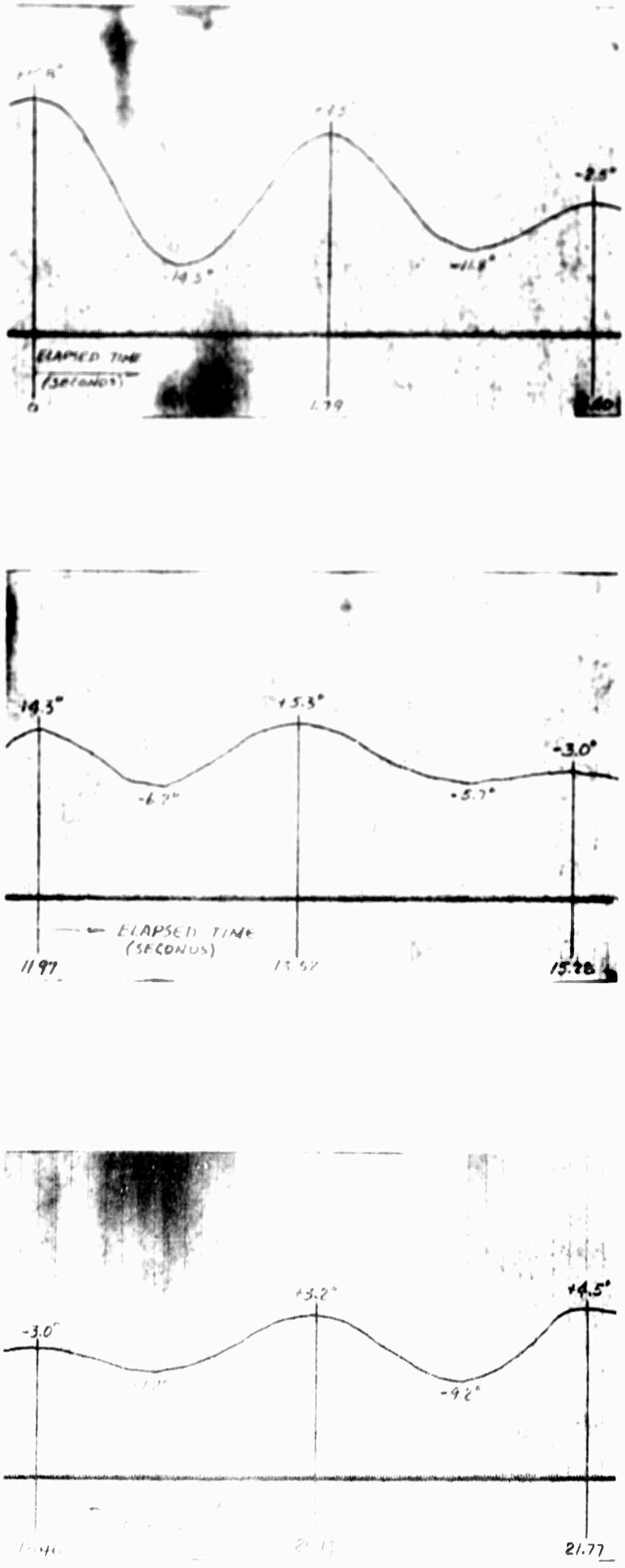


FIGURE 16

UNDAMPED FREE OSCILLATION TRACE-POWER OFF

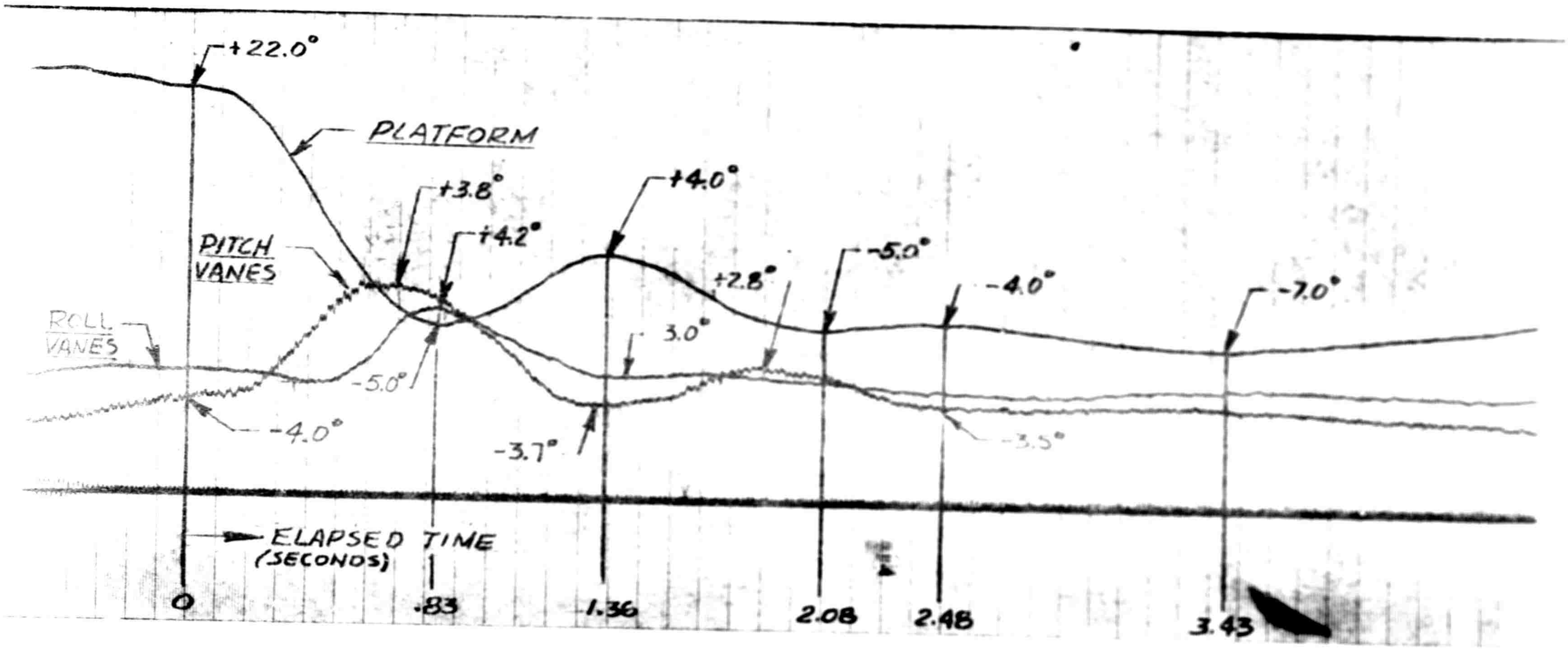


FIGURE 17

DAMPED FREE OSCILLATION TRACE - GYRO-PADDLE STABILIZER DEVICE

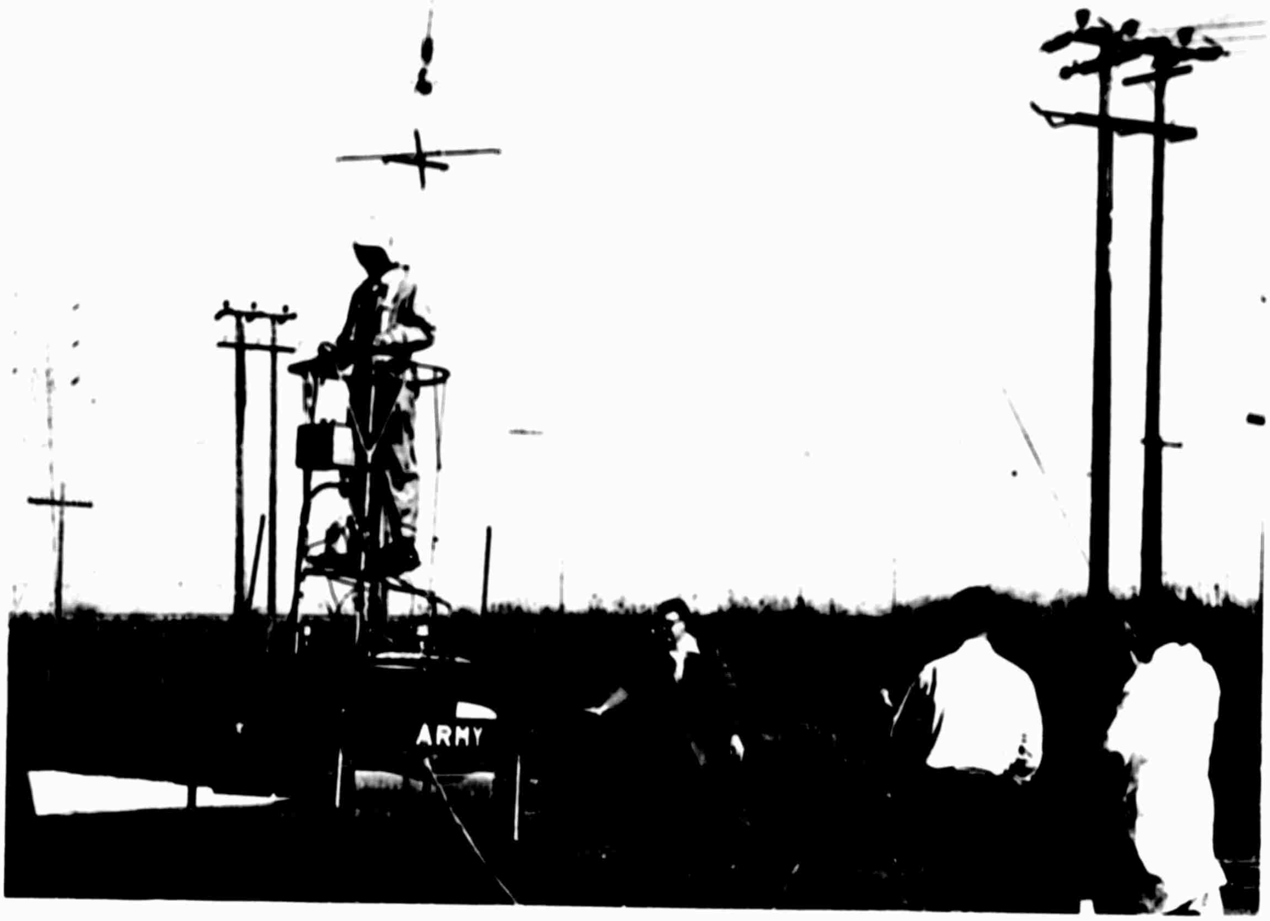
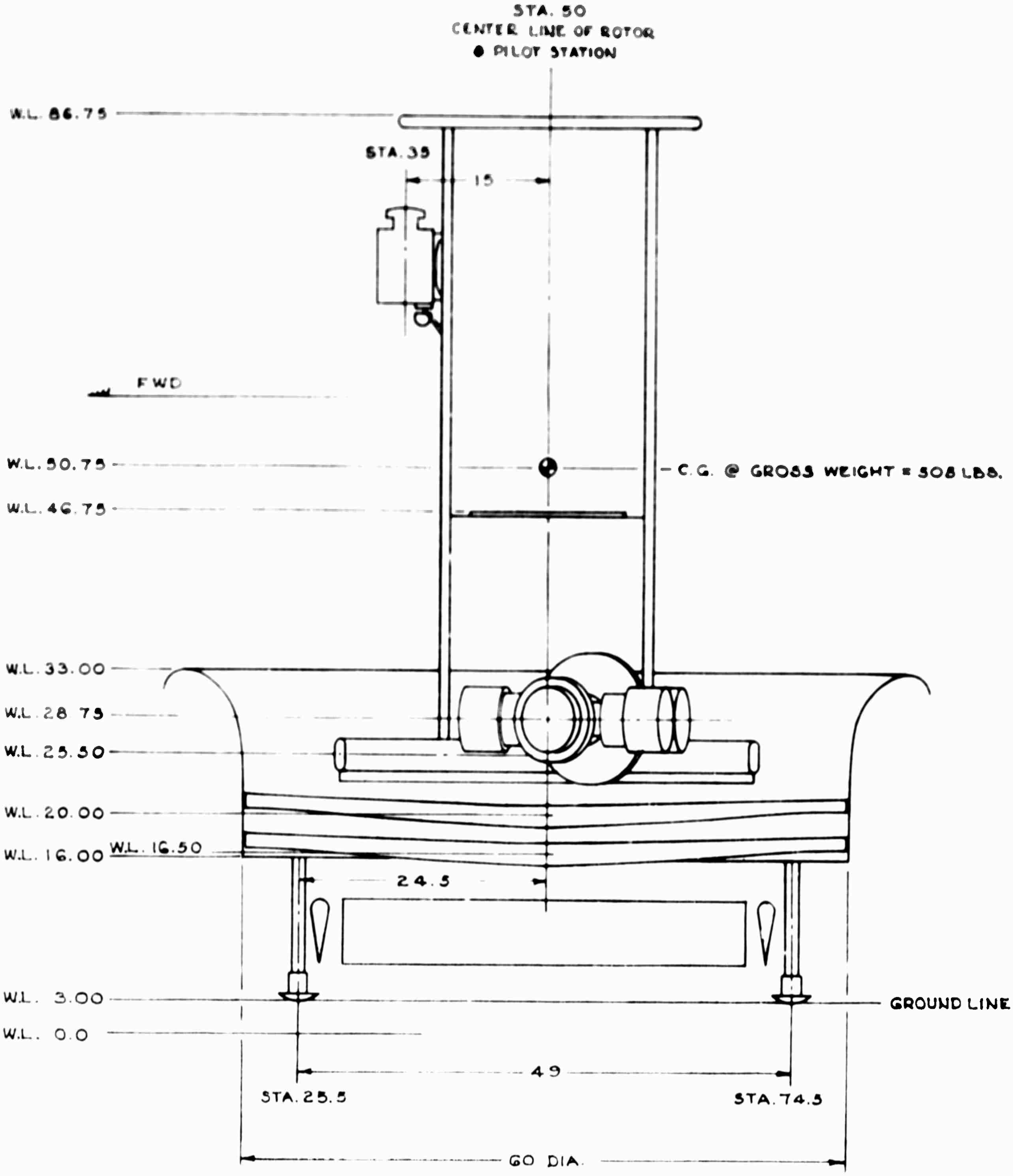


FIGURE 18

FREE OSCILLATION - TETHER TEST



GENERAL ARRANGEMENT
MODEL 1031-A
PHASE III FINAL CONFIGURATION

FIG. 19

	NAME	DATE	HILLER HELICOPTERS	PAGE Figure 20
PREPARED	C.H. Dessin	11/30/56	TITLE SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr 13[illegible]	MODEL 1031-A
CHECKED				
APPROVED				REPORT NO [illegible]

PITCHING MOMENT vs AIRSPEED FOR LEVEL FLIGHT TRIM

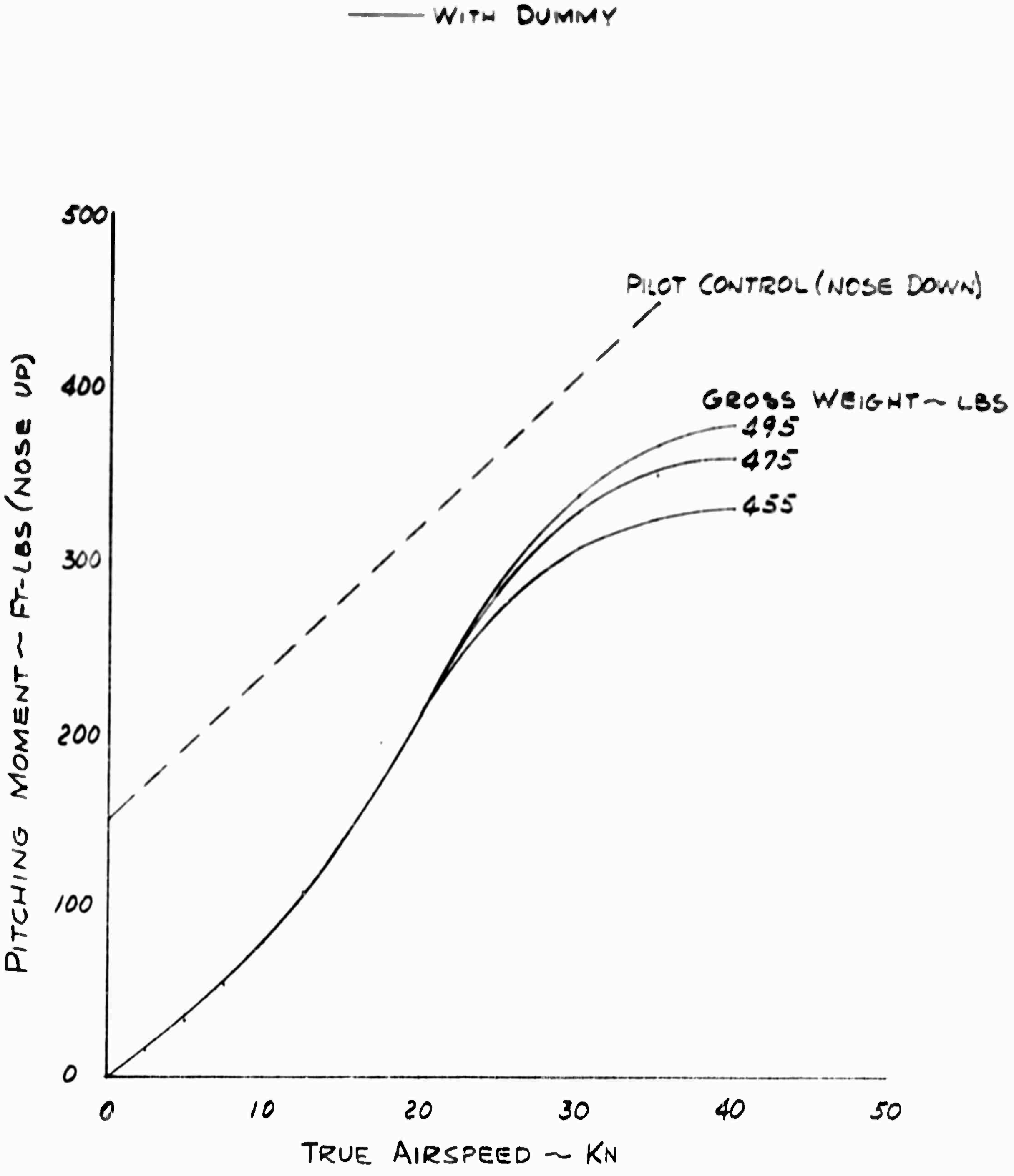


FIG. 20

PREPARED	NAME C.H. Dessin	DATE 11/30/56	HILLER HELICOPTERS	PAGE [illegible]
CHECKED			TITLE SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr [illegible]	MODEL 1031-A
APPROVED				REPORT NO. [illegible]

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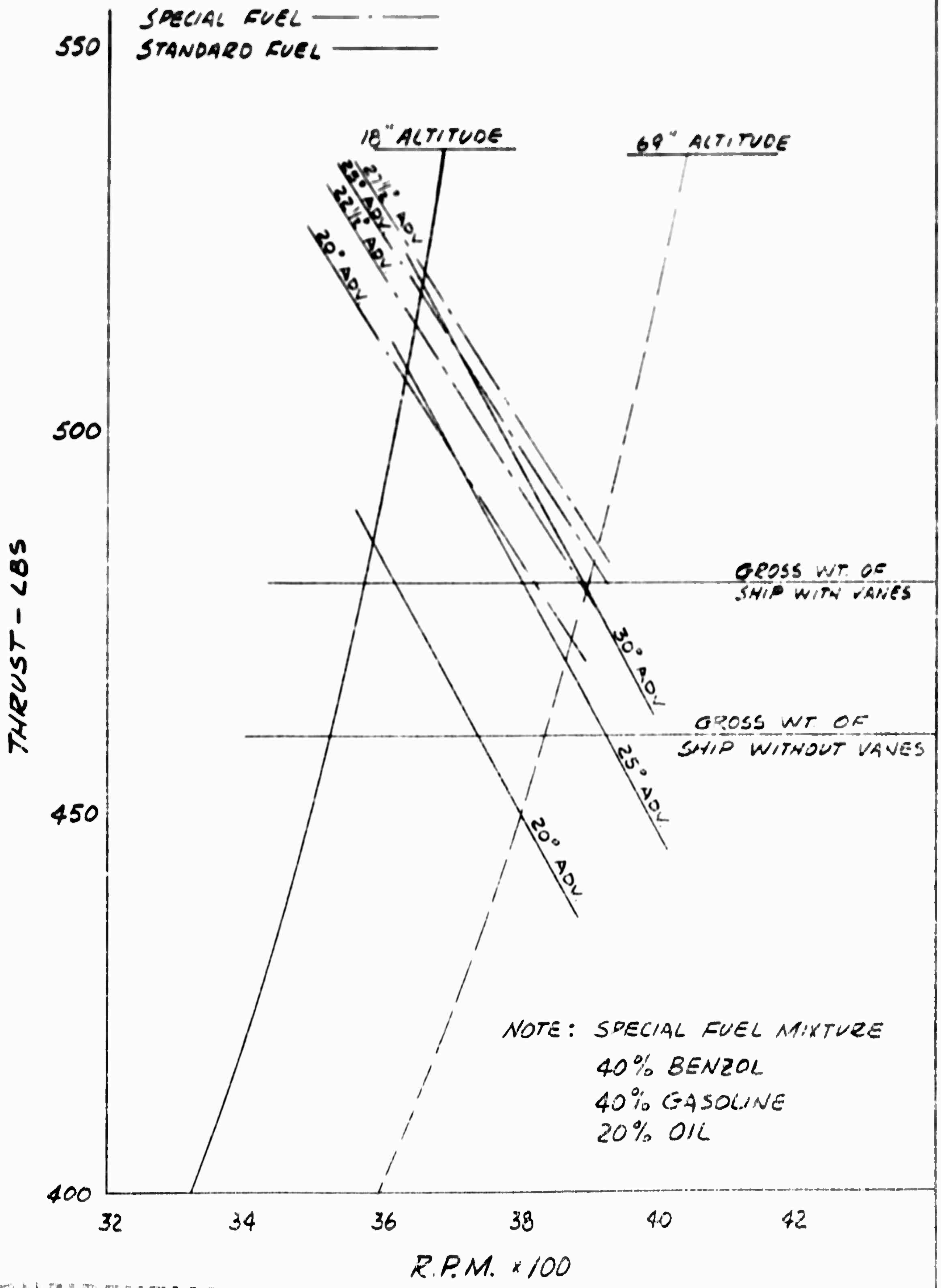
STATIC THRUST vs ENGINE SPEED
(FULL THROTTLE AND VARIOUS SPARK ADVANCES)



NOTE: SPECIAL FUEL MIXTURE
40% BENZOL
40% GASOLINE
20% OIL

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FIG. 2.1

PREPARED	NAME C.H. Dassin	DATE 11/30/60	HILLER HELICOPTERS	PAGE	[illegible]
CHECKED			TITLE SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr [illegible]	MODEL	[illegible]
APPROVED				REPORT NO	[illegible]

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STATIC THRUST vs. VANE ANGLE
(25° B.T.C. SPARK ADVANCE)

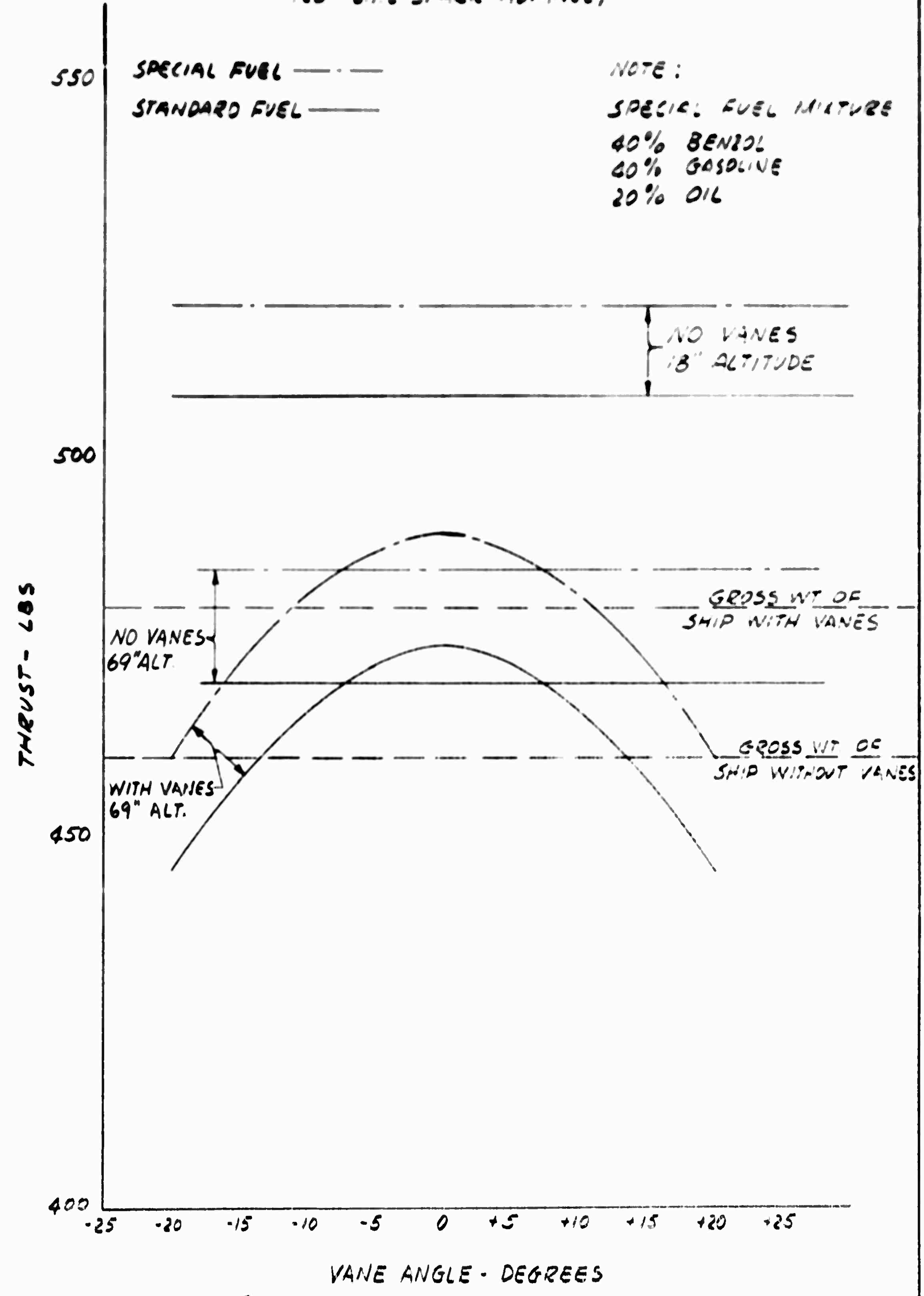

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FIG. 22

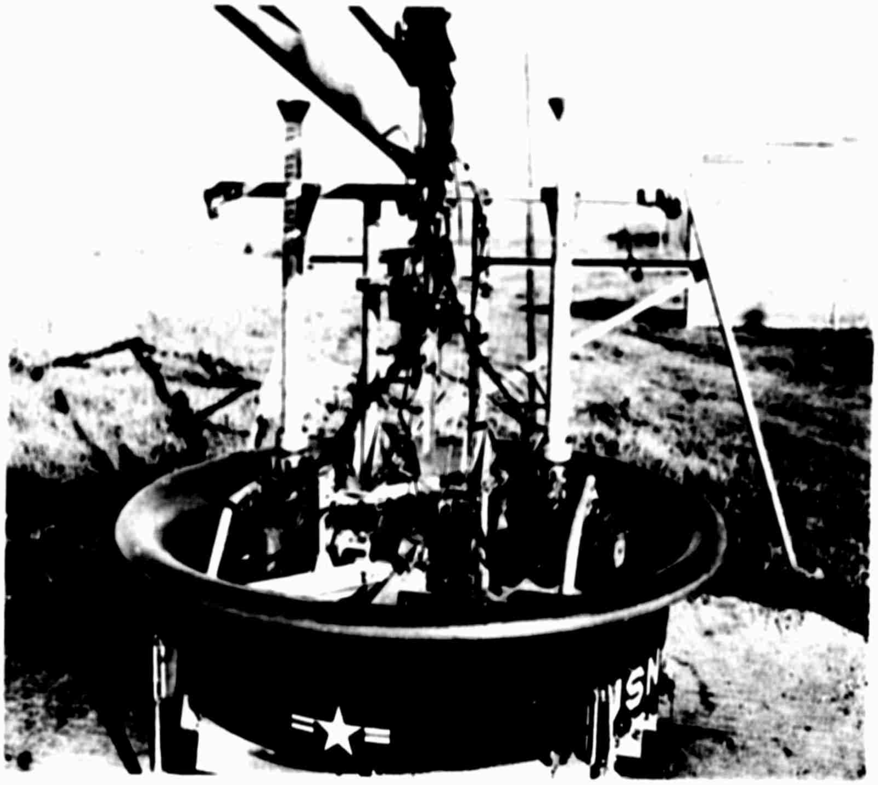

FIGURE 23

TUNED CARBURETOR AIR INTAKE STACKS

PREPARED	NAME C.H. Dessin	DATE 11/30/56	HILLER HELICOPTERS	PAGE Figure 2[illegible]
CHECKED			TITLE SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr 1357(00)	MODEL 1031-A
APPROVED				REPORT NO 56-110

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STATIC THRUST vs ENGINE SPEED
(NELSON 40 & 42 H.P. ENGINES)

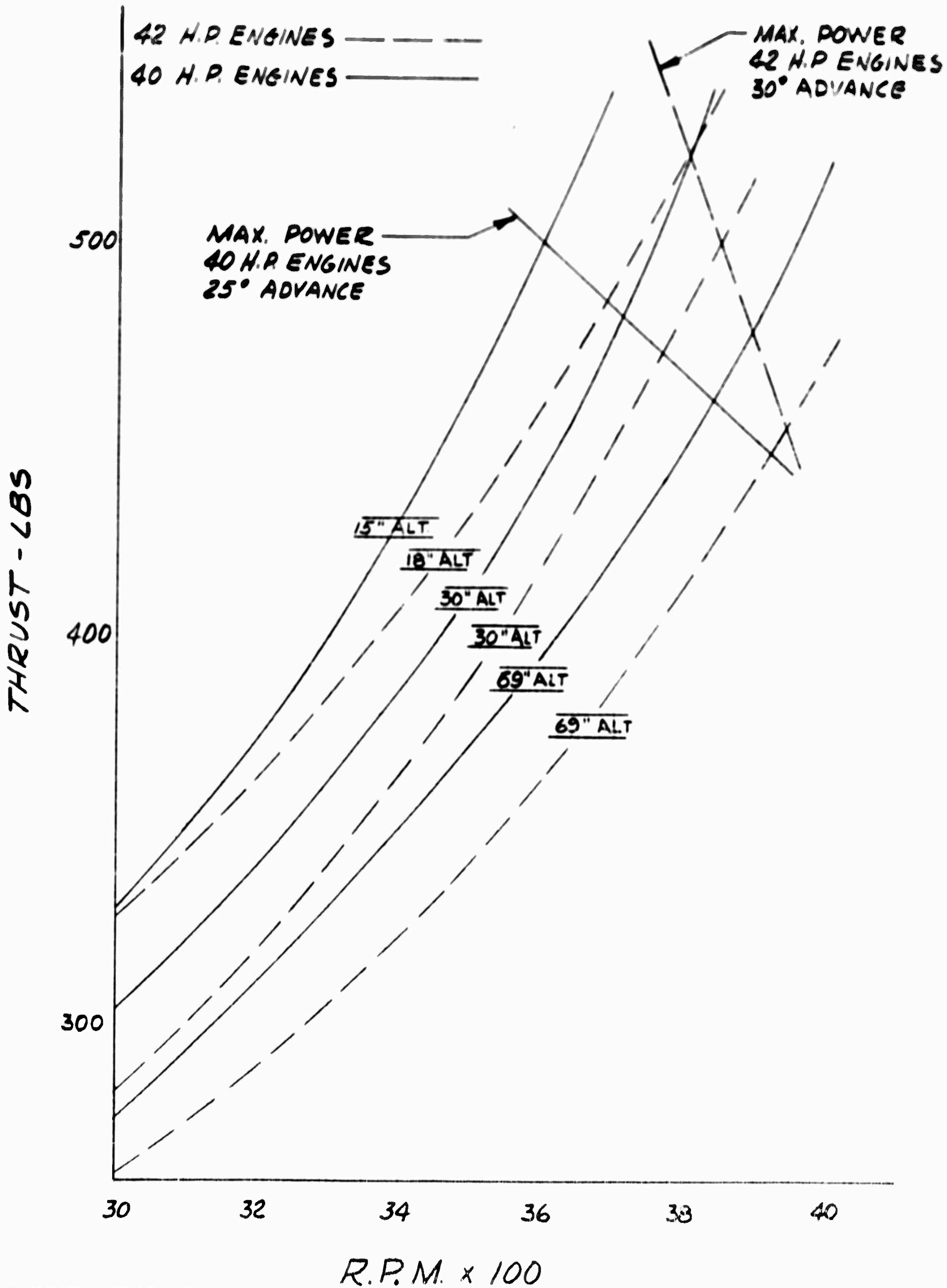

FIG. 24

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60-028

	NAME	DATE	HILLER HELICOPTERS	PAGE Figure 25
PREPARED	C.H. Dessin	11/30/56	TITLE SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr 1357(00)	MODEL 1031-A
CHECKED				REPORT NO 56-110
APPROVED				

PERCENT THRUST INCREASE

vs

DIVERGENT NOZZLE LENGTH

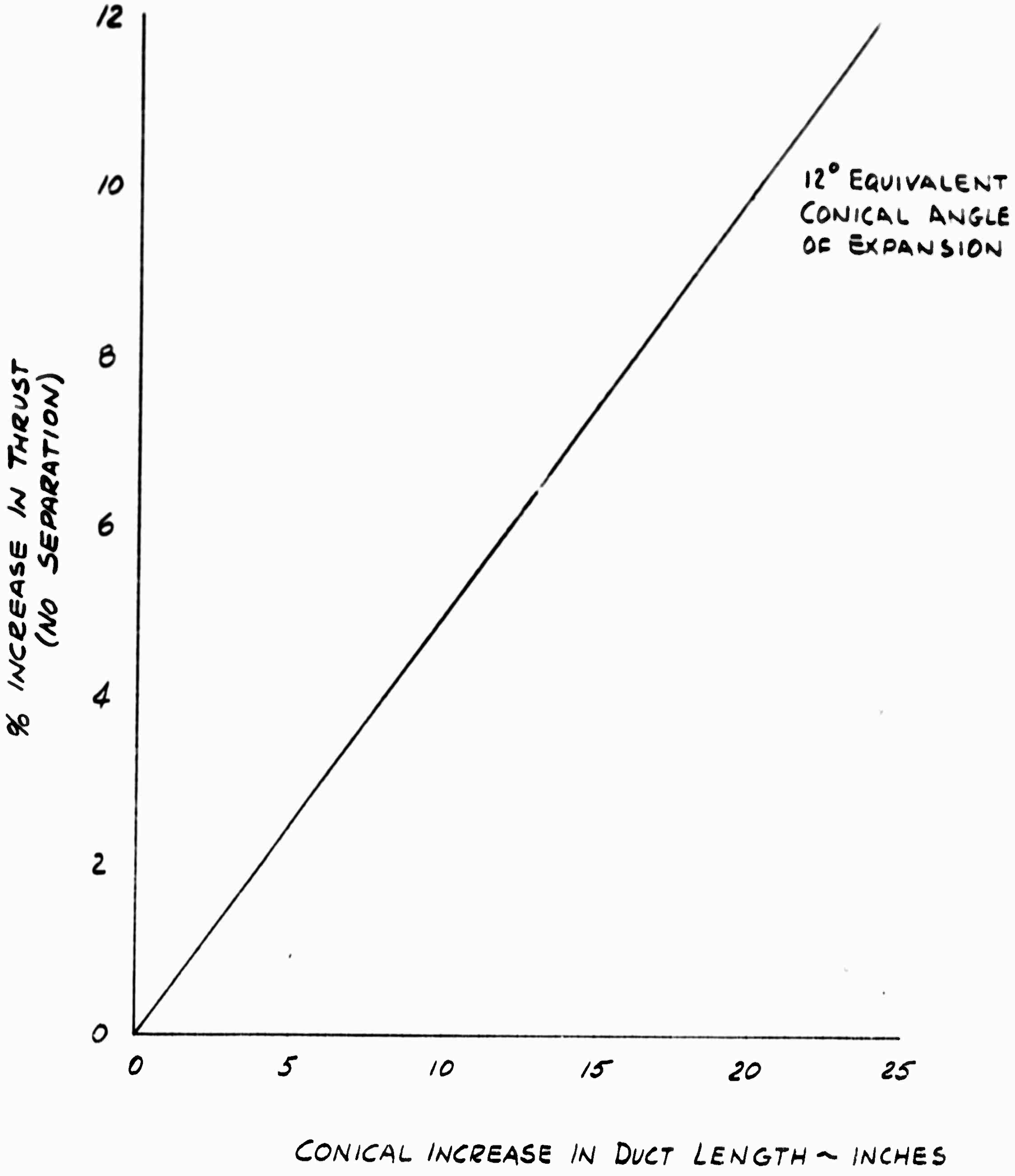

FIG. 25

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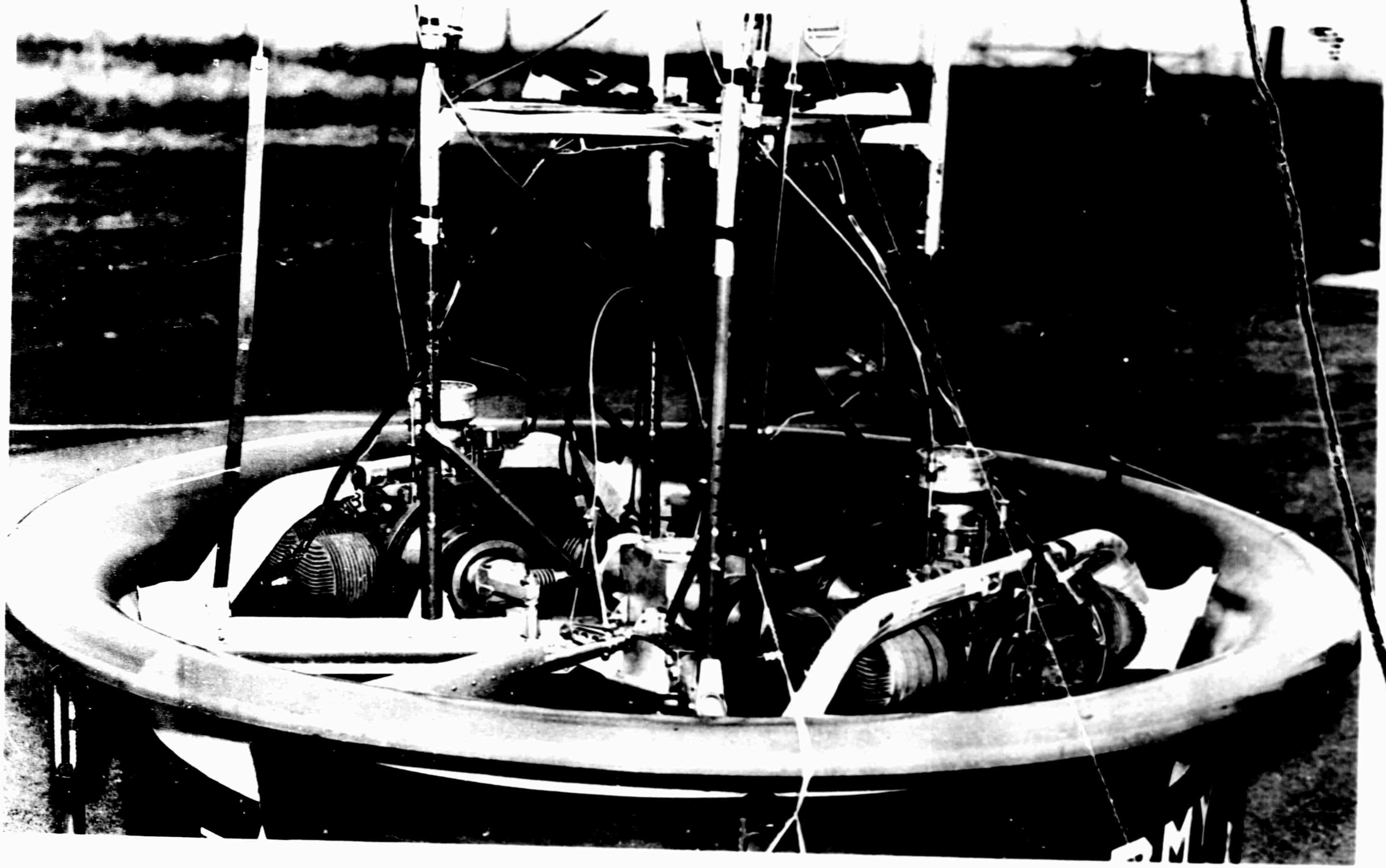

FIGURE 26

AERODYNAMIC FAIRING C DUCT INLET

APPENDIX I

PHASE I DATA

APPENDIX I

EXPLANATION OF KINESTHETIC CONTROL

The human body is in unstable equilibrium when standing erect on a solid surface. Man's upright position is maintained by the constant exertion of balanced moments and forces produced by the muscles, tendons, and joints of the body. The proper balance is maintained by an instinctive sense whose end organs lie in the muscles, tendons, and joints and are stimulated by body tensions.

For the case of a man standing on a fixed surface, if he leans forward, his weight is supported on the balls of his feet which result in a moment about his ankles resisting the tendency to fall forward as shown in Figure AI-1a.

For the case of a man standing on an airborne platform in flight, the forces on the man's body are similar; however, the force reacting at the balls of the feet is provided by the platform. This force will occur at some tilt angle of the machine and the tilted thrust vector will pass ahead of the center-of-gravity of the system creating a correcting moment as shown in Figure AI-1b. It then appears that the same instinctive reflex responses which stabilize a person standing on the ground will function in the same sense to stabilize a person on the airborne platform. Because of the magnitude of the thrust vector, the restoring moment will be of larger magnitude for the person on the airborne platform.

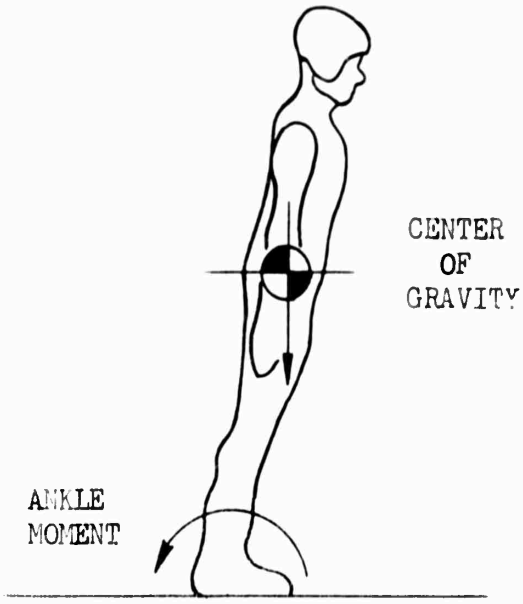

FIGURE AI-1a

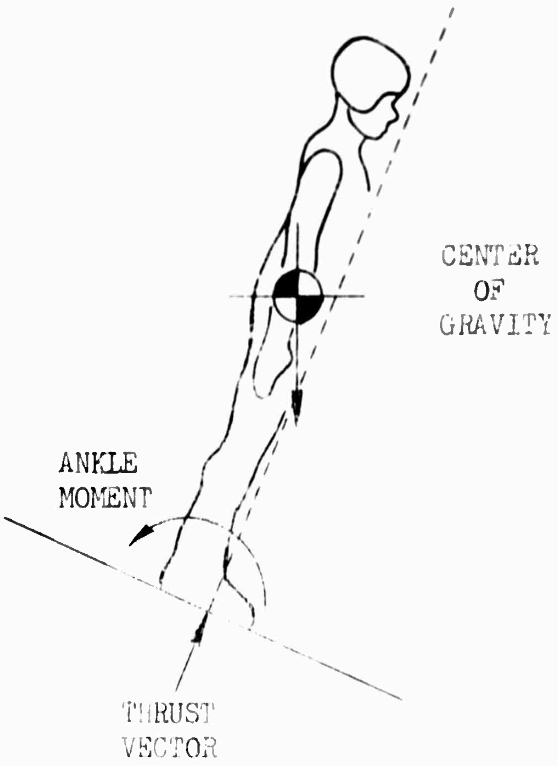

FIGURE AI-1b

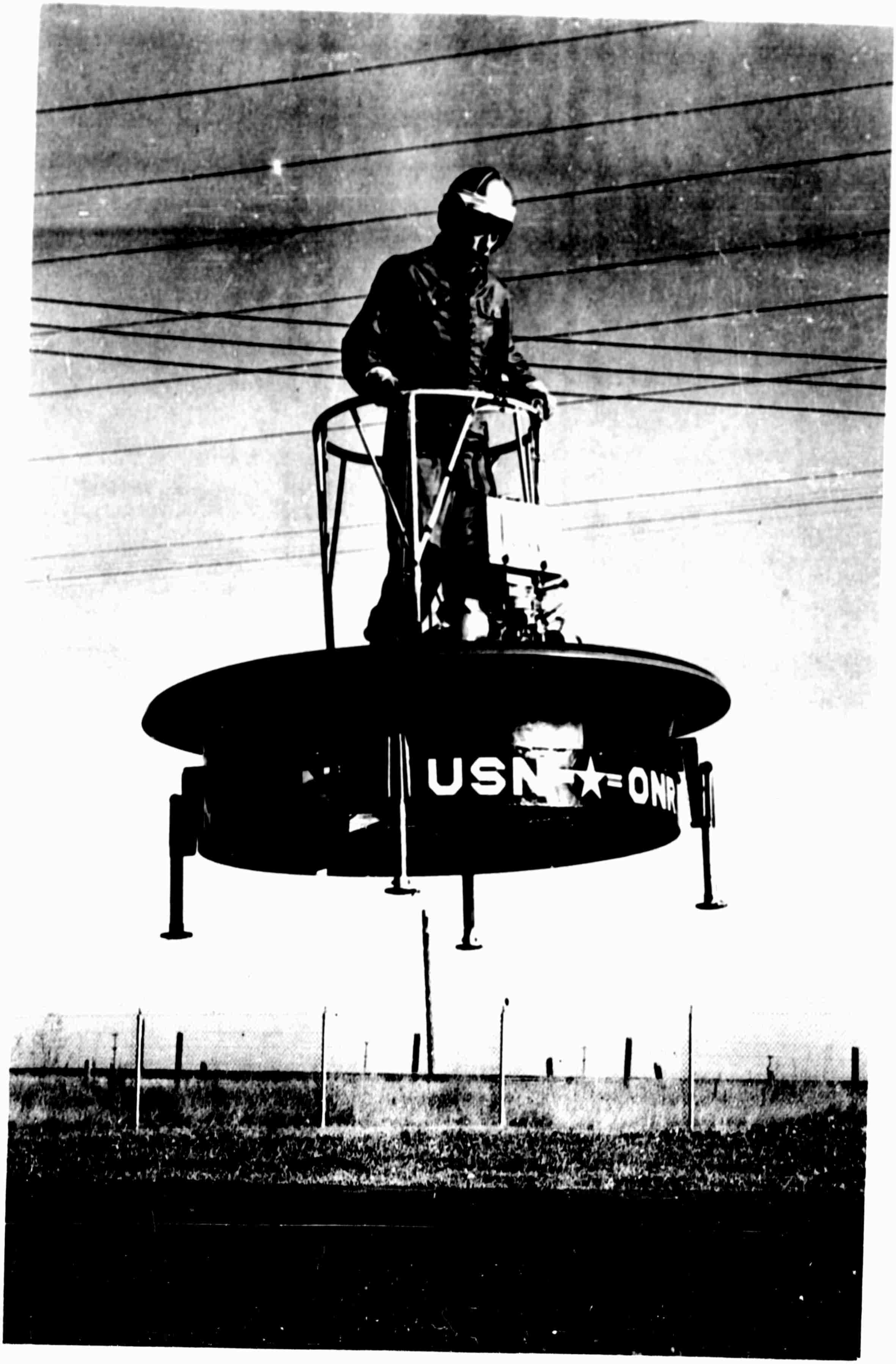

FIGURE AI-2

FIRST FREE-FLIGHT OF
MODEL 1031 PLATFORM ON 4 FEBRUARY 1956

APPENDIX II

PHASE II DATA

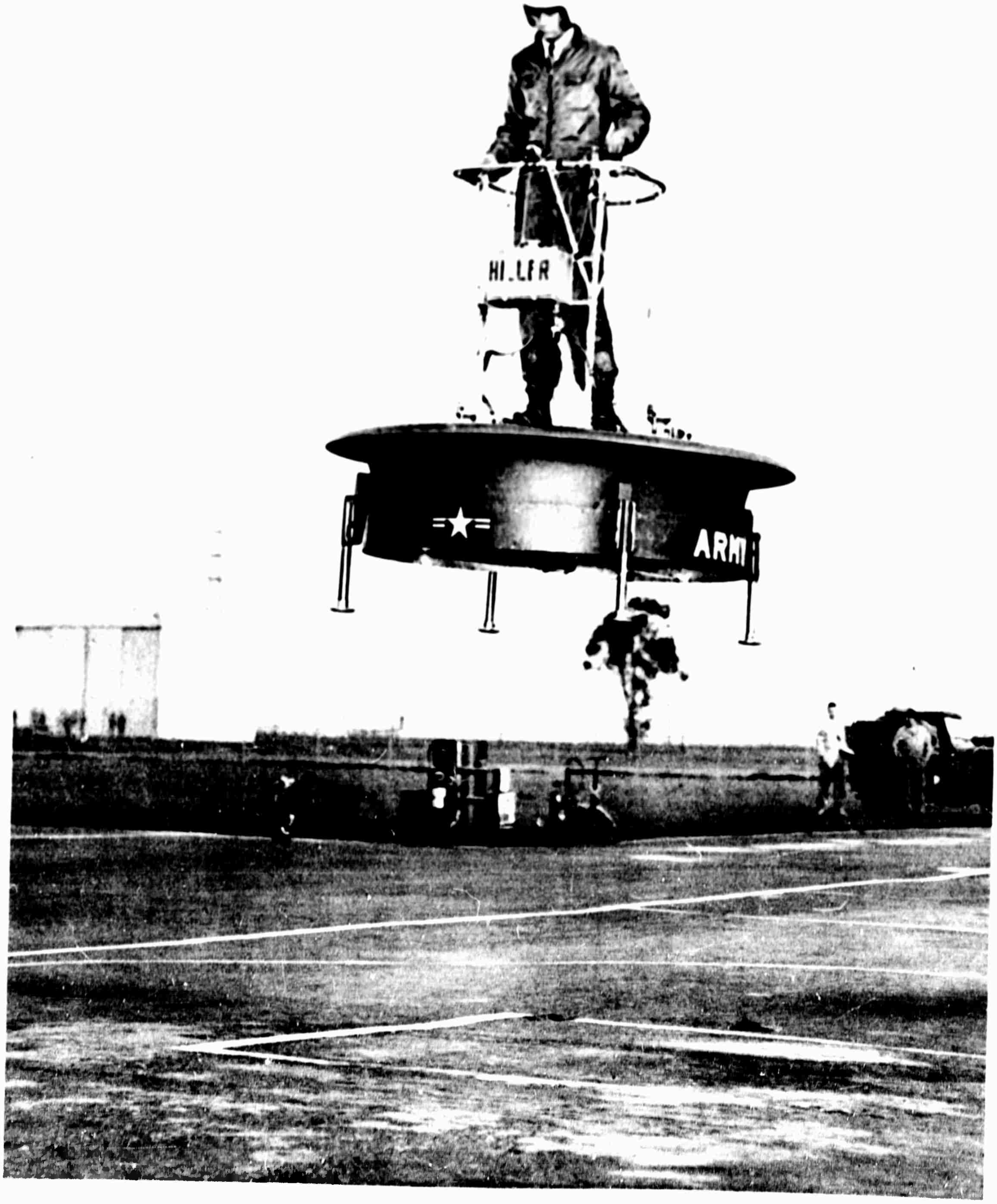

FIGURE AII-1

FREE-FLIGHT OF MODEL 1031-A

APPENDIX III

TETHER TEST STAND MODIFICATIONS

PHASE III

Appendix III

TETHER TEST STAND MODIFICATIONS

The tether test stand, used for all tethered flight tests of the platform, was modified during the month of June 1956 to provide for a larger run between towers and flights at out-of-ground effect altitudes.

As shown in Figure AIII-1, the distance between towers was increased from 80 feet to 120 feet and the tether cable height was raised from 22 feet to 32 feet. The additional 20 feet of ground surface between the new tower location and the original black-top surface was finished with concrete paving. Tether cable support towers were increased in height by the addition of a 10 foot long, 4 inch diameter steel pipe. The pipe with cross arms extending laterally 5 feet from the center of the towers were welded atop the original structure. The vertical extension was stiffened against side loads by a brace cable anchored with turnbuckles to the base of the tower with the cables passing over the cross arm and top of the vertical extension. Figure AIII-2 shows the completed, modified tether rig.

This rework of the tether test rig was undertaken in order to provide sufficient height to permit out-of-ground effect tethered flights scheduled for the exploration of stability characteristics.

Figure AIII-1

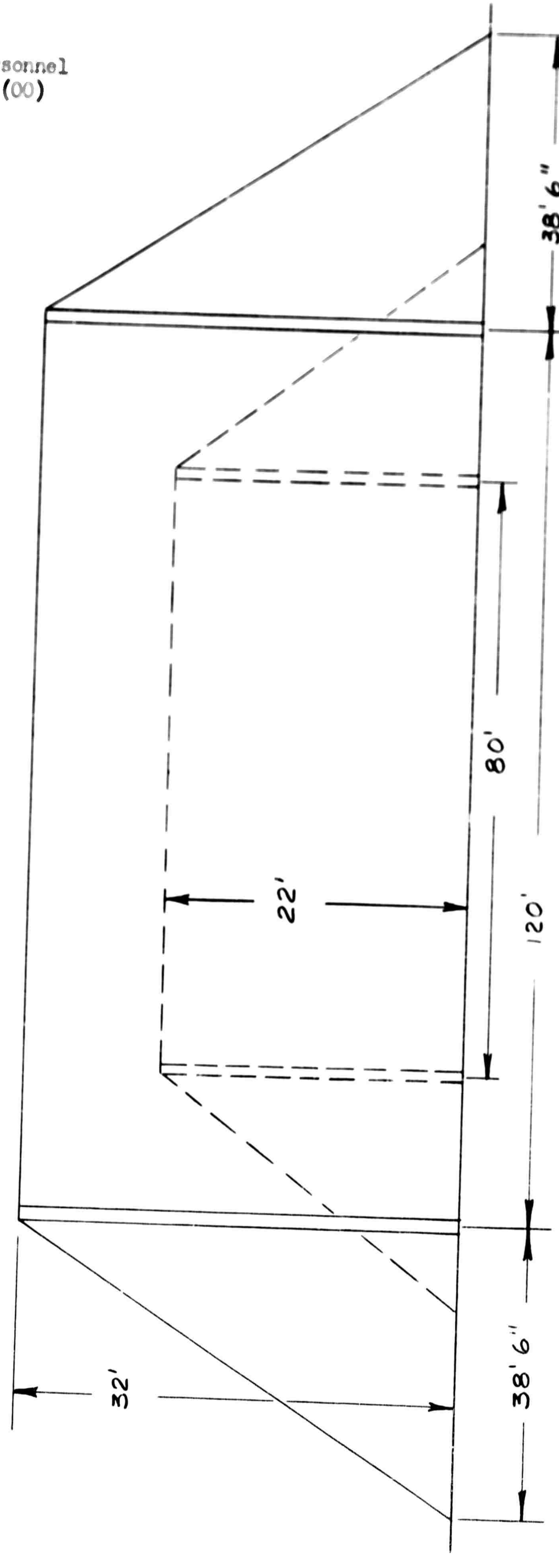

FIGURE AIII-1

COMPARISON OF NEW AND OLD
TETHER TEST STAND DIMENSIONS

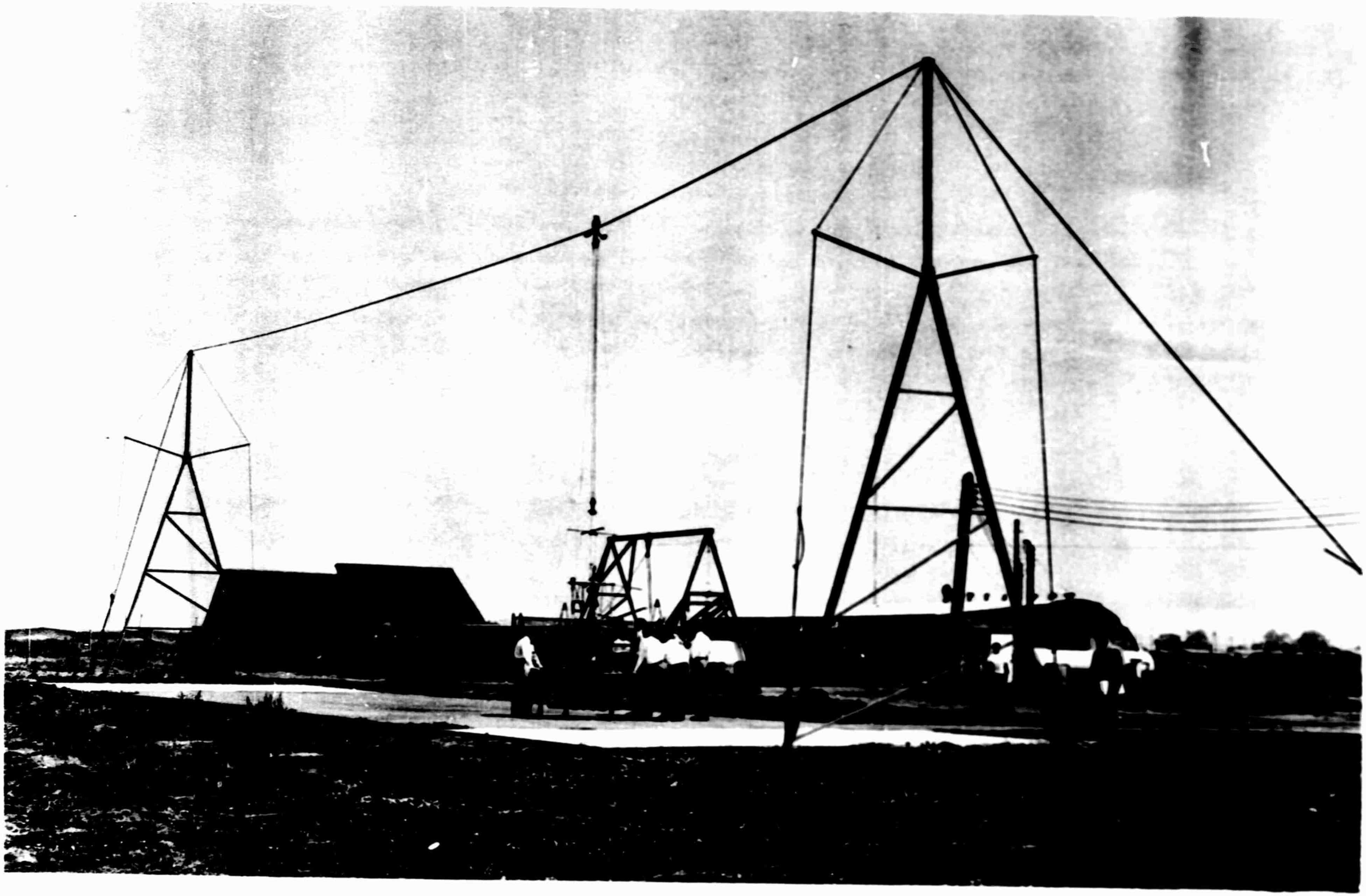

FIGURE AIII-2

MODIFIED TETHER RIG

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APPENDIX IV

SUMMARY AIRCRAFT AND ENGINE LOG

PHASE I, II, AND III

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APPENDIX IV

SUMMARY AIRCRAFT AND ENGINE LOG

Phase	Model Designation	TOTAL HOURS PER PHASE					Remarks
		Air-Frame	Fwd Engine		Aft Engine		
			Serial No.	Hours	Serial No.	Hours	
I	1031	30:37	1	30:14	2	7:00	10-12-54 - No. 4 cylinder of No. 2 engine froze. Eng. temp. above 420° F. Standard fuel. Replaced piston and assigned Serial No. 2a.
					2a	22:31	
II	1031	14:20	1	13:02	2a	13:52	8-24-55 - No. 4 cyl. of No. 1 engine burned. Stalling engine. Standard fuel. Outside air temp 68° F. Replaced piston and assigned Serial No. 1a.
	1031A	11:19	Right Engine		Left Engine		
			1a	11:53	2a	11:42	
III	1031A	24:50	1a	9:11	2a	9:10	11-23-55 - Engines reworked by vendor to 42 HP configuration and assigned Serial Nos. 205 and 206.
			205	11:58	206	15:30	
			213	2:56			
			204	:46			
Sub-Total Model 1031		44:57	1	43:16	2	7:00	9-6-56 - No.2 cyl. eng. Serial 205 had badly burned piston. Standard fuel. Outside air temp. 65°F. On 3 previous flights, a 40-50% benzol fuel mixture with 32-35° spark advance had been used. Engine Serial 213 installed.
					2a	36:23	
Sub-Total Model 1031A		36:09	1a	21:04	2a	20:52	10-19-56 - Crankshaft adjacent to No. 2 cylinder, eng. ser. 213, cracked causing crankshaft housing to crack. Std. fuel. 30° spark advance. Outside air temp. 65°F.
			205	11:58			
			213	2:56	206	15:30	
			204	:46			
Grand Total Phases I, II, III		81:06	1	43:16	2	7:00	Minor items of trouble on engines include starter cable and handle breakage, ignition wire clip breakage and carb. attach studs loosening. Engine hard to start on a number of occasions.
			1a	21:04			
			205	11:58	2a	57:15	
			213	2:56	206	15:30	
			204	:46			

APPENDIX V

SUMMARY TEST LOG

PHASE III

TABLE I
SUMMARY TETHER TEST LOG - DUCT OUTLET VANES

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Pressure (In.H_2O)	Wind Vel. (MPH)	Linkage Ratio	Duration (Min)	Pilot	Remarks
3-21	H-1	60	-	10-15	-	2	Johnston	Ground run to check engine operation.
3-22	H-2	50	30.12	0	1:1	5	"	Outlet vanes with tilting floorboard. 24 - 36 inches maximum altitude. Belts slipping flt. H-4. Tension increased.
"	H-3	60	"	0-2	"	4	"	
"	H-4	"	"	2-3	"	3	"	
"	H-5	"	"	3-5	"	4	"	1 gal. 50% benzol-gas mixture added to 1 gal. standard gas. Slight increase in power.
3-24	H-6	50	30.17	0	"	10	"	50% benzol-gas mixture. Change in linkage ratio did not show noticeable improvement.
"	H-7	52	"	0	1.92-1	5	"	
"	H-8	54	"	0	2.7-1	5	"	
"	H-9	56	"	0	3.84-1	3	"	Vane connections reversed. No good. 50% benzol-gas mixture.
"	H-11	60	"	0-3	"	6	"	Two vanes removed; no noticeable improvement in control. 75% benzol-25% gas mixture. Eng. surge.
"	H-10	58	"	"	"	8	"	Vane control direction rigged for design condition. 50% benzol-gas mixture.
"	H-12	62	"	"	"	5	"	25% benzol-75% gas mixture.
3-27	H-13	60	30.36	10-20	2.75-1	4	"	Two aft vanes only connected with reversed control. No noticeable improvement.
"	H-14	"	"	"	5.5-1	4	"	Stiffer bungees on floorboard helped considerably. Control motions per original design. Pilot controlled platform in winds with concentrated effort.
"	H-15	"	"	"	3.38-1	3	"	
"	H-16	"	"	"	"	3	"	
"	H-17	"	"	"	"	4	"	
"	H-18	"	"	"	5.5-1	4	"	
3-28	H-19	"	30.16	0	"	3	"	Additional familiarization flights did not improve pilot technique nor result in improved confidence and/or feel.
"	H-20	65	"	0-2	"	4	"	

TABLE I (CONTINUED)

1956 Date	Flt. No.	Air Temp (°F)	Barom. Pressure (In.H_2O)	Wind Vel. (MPH)	Linkage Ratio	Duration (Min)	Pilot	Remarks
3-29	H-21	60	30.14	0-3	5.5-1	4	Johnston	Fixed floorboard with tilting ring to control movement of vanes. Spark advanced to 27½° on Flts. H-22 thru H-32.
"	H-22	"	"	0	"	4	"	
"	H-23	"	"	0-3	"	3	"	
"	H-24	"	30.05	20-25	"	2	"	Control cable clip came loose.
"	H-25	"	"	"	"	4	"	Hard to fly in gusts. - Pilot senses attitude of ship thru his feet - very fatiguing.
3-30	H-26	"	30.06	15-25	"	6	"	Two vanes and single bungee. Platform controlled in winds. Better than tilting floor control. Still not instinctive.
"	H-27	55	"	"	"	6	"	
4-2	H-28	50	30.08	0-3	"	5	"	
4-3	H-29	65	30.14	10-20	"	4	"	
4-4	H-30	55	-	0	-	5	"	
"	H-31	60	30.14	10-20	-	5	Schneider	
4-5	H-32	60	30.16	0	-	10	"	Ground run to check velocity of air over duct.

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TABLE II

SUMMARY TETHER TEST LOG - VERTICAL CENTER OF GRAVITY LOCATION

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	Vert. CG (In)*	Pilot's Floor (In)*	Duration (Min)	Pilot	Remarks
4-18	I-1	60	30.02	0	32.5	21.75	3	Johnston	Felt good in calm air. Easier to start and stop.
"	I-2	65	"	0	-	"	3	"	Ship displaced downward with pilot rigid. Ship moved fwd, then back, with increasing angle of tilt. Ship tends to roll to right.
"	I-3	"	"	0	-	"	7	"	
"	I-4	70	29.98	10-15	-	"	5	"	
4-19	I-5	55	30.13	0	33.60	27.75	6	"	Period of oscillation increased. Yaw and roll to right more noticeable on 12" floor height. 50 benzol fuel mixture used on Flt. I-9. Spark advanced to 27° on Flt. I-10.
"	I-6	"	"	0	34.0	28.75	7	"	
"	I-7	58	"	0-3	34.32	29.75	7	"	
"	I-8	60	"	"	34.65	30.75	6	"	
"	I-9	65	"	10-20	"	"	7	"	
4-20	I-10	55	"	0	34.73	31.00	7	"	
"	I-11	60	"	0-3	35.10	31.75	8	"	
"	I-12	65	"	3-5	33.60	27.75	7	"	Floor boards returned to 9" location. Period of oscillation faster than with higher locations.
"	I-13	70	30.05	5-10	35.10	31.75	7	"	Vibrations measured.
4-23	I-14	50	30.01	15-20	"	"	5	"	Pilot able to fly into wind without much trouble. Adjusted carburetor without noticeable improvement.
"	I-15	"	"	"	30.50	18.75	5	"	Pilot likes feeling of ship better at low floor location. Floor at orig. design level.
4-26	I-16	55	29.92	0-5	35.10	31.75	4	Major Cockrell	Gusts made first flight difficult. One yaw rope used.
"	I-17	"	"	"	"	"	2	Johnston	Ignition lead broke.
"	I-18	60	-	"	"	"	4	"	Maximum altitude about 3'
"	I-19	"	"	0-10	"	"	7	Major Cockrell	Better flt. than I-16. 2 yaw ropes used.
"	I-20	55	30.12	0-5	"	"	6	Dessin	Ignition lead broke.
4-27	I-21	"	"	0-10	"	"	5	"	Gusty winds caused oscillations to build up. Pilot tried to stand straight rather than go with ship.

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TABLE II (CONTINUED)

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	Vert. CG (In)*	Pilot's Floor (In)*	Duration (Min)	Pilot	Remarks
6-6	K-1	50	30.06	0-5	35.10	31.75	6	Johnston	Decoupling weights added to left fwd and right aft legs, Flts. K-2 and K-3. Ship showed less tendency to roll when displaced. Period of oscillation decreased as height of floor increased.
"	K-2	"	"	"	"	"	5	"	
"	K-3	"	"	"	"	"	6	"	
6-7	K-4	55	30.02	0	35.45	32.75	6	"	
"	K-5	60	30.03	0	35.85	33.75	4	"	
6-8	K-6	"	30.06	0	36.25	34.75	6	"	
"	K-7	"	"	0	"	"	6	"	Decoupling weights removed. Ship displaced to determine minor axis of inertia.
"	K-8	"	"	0	36.60	35.75	6	"	Period of oscillation decreased as height of floor increased in this series of tests. Ship still stable with high floor position. Max. altitude about 6'.
"	K-9	"	"	0-3	37.00	36.75	6	"	
6-12	K-10	50	30.05	0-3	"	"	5	"	
"	K-11	55	30.06	"	37.40	37.75	5	"	
"	K-12	57	"	"	37.75	38.75	5	"	
"	K-13	60	"	"	38.12	39.75	5	"	
"	K-14	"	"	"	38.50	40.75	7	"	
"	K-15	"	"	"	38.90	41.75	5	"	
6-14	K-16	"	30.00	0	38.90	"	10	"	
"	K-17	"	"	0-5	39.25	42.75	8	"	Decoupling weights reinstalled for this flt. Oscillation quite slow.
"	K-18	"	"	"	"	"	8	"	Decoupling weights removed. Stable, but has tendency to yaw.
6-15	K-19	50	30.04	0-3	"	"	5	Dessin	Marked improvement in pilot's feel of ship between Flts. K-19 and K-22.
"	K-20	55	"	0	"	"	9	"	
"	K-21	60	"	0	"	"	13	"	
"	K-22	63	"	0	"	"	6	"	

*Inches above duct outlet.

TABLE III
SUMMARY TETHER TEST LOG - GYRO PADDLE STABILIZER

1956 Date	Flt. No.	Air Temp (^oF)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	Ip (Slug-Ft^2)	Linkage Ratio (+)	Vert. CG (*)	Pilot Floor (*)	Duration (Min)	Pilot	Remarks
7-17	M-1	74	30.02	5-10	.010	.65-1	36.50	10.75	4	Johnston	Yaw vanes require adjustment for increased torque of gyro.
"	M-2	75	"	"		"			4	"	Altitude limited to 1' at max.throttle Little motion of vanes - high friction evident.
"	M-3	"	"	"		1:1			5	"	
7-18	M-4	55	29.99	0-5		"			8	"	Friction of stabilizer system reduced, more vane action, very lazy oscillation and reduced amplitude when externally tilted with pilot fixed. Lape 1st training flt M-5 good. Hiller flt M-6 good. Lape much improved on M-7.
"	M-5	70	"	5-10		"			8	Lape	
"	M-6	"	"	"		"			6	Hiller	
"	M-7	"	"	"		"			5	Lape	
"	M-8	"	"	"		"			4	Johnston	
7-19	M-9	60	30.02	0		"			6	"	Oscillation tests. Ship tends to drift to right. Rigging of vanes will be Checked. Ship drifts slowly when externally tipped. No oscill. with pilot fixed. No evident sensitivity to 5 MPH winds.
"	M-10	"	"	"		"			4	"	
"	M-11	65	"	"		"			5	Lape	
"	M-12	"	"	0-5		"			5	"	
7-20	M-13	"	30.12	"		"			4	Johnston	Left engine rough. Check ignition system.
"	M-14	"	"	0		"			4	"	Left engine rough. Recheck points.
"	M-15	70	30.02	5-10		"			6	"	Engines OK. Smooth slow fwd flight in gusts.
7-23	M-16	"	"	0-5		"			5	"	Check-out of ship prior to Lape training flight.
"	M-17	"	"	"		"			2	Lape	Left engine balky; no start. Suspect carburetor.
"	M-18	75	"	10-15		"			2	Munro	Ground check of engine starting operation.
7-24	M-19	70	"	5-10		"			5	Lape	Training flights. Very good in gusty winds.
"	M-20	"	"	"	↓	"	↓	↓	0	"	

(*) Inches above duct outlet.
(+) Vane angle/bar angle.

TABLE III (CONTINUED)

1956 Date	Flt. No.	Air Temp (°F)	Barom. Press. (In.H$_2$0)	Wind Vel. (MPH)	I_p (Slug-Ft^2)	Linkage Ratio (+)	Vert. CG (*)	Pilot Floor (*)	Duration (Min)	Pilot	Remarks
7-25	M-21	60	29.98	0	.010	1:1	38.50	40.75	7	Lape	Training flight - very good.
"	M-22	65	"	0		"			6	"	Training flt. - 1st with Lape operating throttle.
"	M-23	65	"	0-3		"			6	"	Pilot technique good. Externally excited oscillations damped out rapidly with pilot fixed.
"	M-24	68	"	"	↓	"			10	"	
7-30	M-25	60	30.04	0	.016	"			8	"	Heavy gyro-paddle produced no noticable change in oscill. damping. Yaw vanes require adjustment to correct additional torque of gyro.
"	M-26	"	"	0-5		"			4	"	
"	M-27	65	"	"		"			6	"	
"	M-28	70	"	5-10		"			6	"	Right engine running rough.
7-31	M-29	60	30.05	0		"			1	"	Points adjusted, engines run smooth. Broke spark plug clip.
"	M-30	65	"	0-5		"			7	"	Good flt. Deflections in vanes noted.
8-7	M-31	60	"	0		1.25:1			7	Johnston	Vanes stiffened - linkage ratio increased.
"	M-32	70	"	0		"			6	Lape	Eng. rough. Vane movement improved.
"	M-33	"	"	0-5		"			4	"	Training flight.
"	M-34	75	"	15-20		"			3	Johnston	No power. High ambient temp. blamed.
8-8	M-35	55	30.03	0		"			2	Lape	No power. Broken breaker point found on left engine.
"	M-36	70	30.04	10-15		"			2	"	Barmotive rep. assisted in checking out ignition and carb. on engines. Timing, float level and spark plug gaps adjusted more accurately. Plug cap set at .020" instead of .025".
"	M-37	"	"	"		"			7	"	
8-9	M-38	60	30.08	0		"			2	"	No left eng. start. Accelerator pump shaft bent.
"	M-39	"	"	"		"			7	"	Good flight. Engine start and run after shaft fix.
8-10	M-40	65	30.04	"		"			5	"	Good training flight.
"	M-41	70	"	"		"			2	"	Demonstration for J. Carlson, TC Pro Engr.
"	M-42	"	"	"	↓	"	↓	↓	6	Johnston	" " " "

TABLE III (CONTINUED)

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	I_P (Slug-Ft^2)	Linkage Ratio (+)	Vert. CG (*)	Pilot Floor (*)	Duration (Min)	Pilot	Remarks
8-24	0-1	75	30.01	5-10	.016	1.25:1	38.50	40.75	7	Lape	Lightweight landing gear (alum) a: floor support structure installed. Altitude 3 feet.
8-28	0-2	60	29.90	0	|	"	|	|	5	"	Attitude gyro and potentiometers installed. Oscillograph records of free oscillation and damping effect of gyro-paddle stabilizer system.
"	0-3	65	"	0	|	"	|	|	3	"	
"	0-4	70	"	0-3	|	"	|	|	3	"	
"	0-5	"	"	5-15	|	"	|	|	4	"	
8-30	0-6	60	30.02	0	↓	"	|	|	5	"	Good training flt with heavy gyro.
"	0-7	65	"	0-3	.010	"	|	|	6	"	Good training flt with light gyro.
"	0-8	70	"	0-5	0	0	↓	↓	6	"	Unsteady flight with gyro removed and vanes locked.
"	0-9	"	"	10-15	0	0	37.00	36.75	6	"	Improved control over Flt. 0-8.
8-31	0-10	60	30.03	0	.016	1.25:1	"	"	6	"	Good flt. in hover and translation. Lazy oscillation.
"	0-11	"	"	"	.010	"	"	"	6	"	Good flight. No apparent change with light gyro.
"	0-12	"	"	"	0	0	"	"	6	"	Hover and fwd flight requires close pilot coordination with gyro-paddle removed and vanes locked.
9-4	0-13	"	30.00	0	0	0	30.50	18.75	5	"	Test to check stab./control of orig. Model 1031A design.
"	0-14	65	"	"	.016	1.25:1	"	"	5	"	Gyro-paddle stab. shows marked improvement in stability for original design vert. c.g. position.
"	0-15	"	"	0-3	"	"	"	"	6	Johnston	
"	0-16	70	"	5-10	.010	"	34.75	30.75	3	Lape	Good hover and fwd flt control and stability. Pilots prefer floor height as tested.
"	0-17	"	"	10-15	"	"	"	"	3	Johnston	
9-5	0-18	60	30.02	0	"	"	"	"	5	Lape	Familiarization flights to confirm pilot's opinion of floor location in calm air.
"	0-19	"	"	"	"	"	"	"	3	Johnston	
"	0-20	65	"	"	"	"	"	"	5	"	
"	0-21	70	"	5-15	"	"	"	"	6	Lape	Good handling characteristics in flt in wind with 5 MPH gusts. Altitude power limited to 1 ft.
"	0-22	"	"	"	"	"	"	"	5	Johnston	

TABLE III (CONTINUED)

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	Ip (Slug-Ft^2)	Linkage Ratio (+)	Vert. CG (*)	Pilot Floor (*)	Duration (Min)	Pilot	Remarks
9-6	0-23	60	30.09	0	.010	1.25:1	34.75	30.75	5	Lape	Spark advanced 35°. Benzol-gas mix. No additional thrust realized.
"	0-24	"	"	0	"	"	"	"	7	"	Spark 32°, increased amount of benzol in fuel mixture. No additional thrust realized. Max.temp. 255°C.
"	0-25	65	"	0	"	"	"	"	2	Johnston	Carb. adjusted for more lean regular fuel mixture at 30° spark advance. Cylinder No. 2 burned on right engine.
9-10	0-26	"	-	-	-	-	-	-	13	Lape	Ground test only to check new engine temp at max. power.
"	0-27	"	-	5	.010	1.25:1	34.75	30.75	5	"	Check of thrust performance. Max. altitude 2 ft.
9-11	0-28	50	-	0	"	"	"	"	4	Johnston	Check thrust performance. Max. alt. 3 ft.
"	0-29	"	-	0	"	"	"	"	5	Lape	" " " " "
"	0-30	66	-	5-15	"	"	"	"	4	Johnston	Max. altitude 3 ft. Power surge-belt tension and dressing required. OK for free flight by pilot.

(+) Vane angle/bar angle.
(*) Inches above duct outlet.

TABLE IV

SUMMARY TETHER TEST LOG - MISCELLANEOUS FLIGHTS

1956 Date	Flt. No.	Air Temp. (°F)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	Gyro Bars	Pilot Floor	Duration (Min)	Pilot	Remarks
9-25	Q-1		29.94	5-10	H	12	4	Johnston	Shakedown of ship with new props. installed. Reducing tip clearance. External Cables installed to true up duct. Increased max. alt. approx. 1' for fwd flt conditions.
9-26	Q-2	65		0	H	12	4	Lape	
"	Q-3		30.02	0	H	12	6	Capt. Reid	Very good flight.
"	Q-4	68	"	3-5	H	12	5	Lape	Demonstration.
10-17	S-1	65		0	H	12	5	Lape	Shakedown of ship prior to free flight.
"	S-2	"		0	H	12	4	Lape	
10-19	U-1	"		2-5	H	12	5	Col. Seneff	Good flight - Engine trouble at end of flight.
10-26	W-1	62		5	H	12	5	Maj. Ritter	Had difficulty getting feel of ship. Improved on 2nd flight.
"	W-2	65		5	H	12	5	"	
"	W-3	"		5	H	12	5	Maj. Kilmer	Good flight but wind giving some trouble.
"	W-4	"		5	H	12	5	Dessin	Checkout flights for Project Engineer and Test Engineer to obtain feel of ship in final configuration.
"	W-5	"		5	H	12	5	"	
"	W-6	"		5	H	12	5	Munro	

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TABLE V
SUMMARY FREE FLIGHT TEST LOG

1956 Date	Flt. No.	Air Temp (^oF)	Barom. Press. (In.H_2O)	Wind Vel. (MPH)	I_p (Slug-Ft^2)	Pilot Floor (*)	Duration (Min)	Pilot	Remarks
9-12	P-1	55	-	0-1	.010	30.75	6	Johnston	Good flight. Altitude about 4'.
"	P-2	"	-	0-1	"	"	5	"	Good fwd flights; good maneuvers.
"	P-3	"	-	0-1	"	"	5	Lape	Pilot's 1st solo; good low-speed fwd flight.
9-13	P-4	"	-	0	-	30.75	6	Johnston	Gyro bars, vanes removed this flt.only. Propeller rubbed, cutting inner aluminum ring.
9-14	P-5	54	-	0	.010	"	5	"	Pilot prefers feel of ship with gyro bars and vanes than in previous flight.
"	P-6	"	-	0	"	"	6	Lape	Definite improvement over Flt.P-3 by pilot.
"	P-7	"	-	0-5	"	30.75	6	Johnston	This series of tests was run to determine which configuration felt best to pilot. Configuration chosen was with heavy gyro bars and vanes with floor at 12" elevation. Max. altitude in fwd. flt. about 3'. Free flights discontinued with effort expended to obtain higher altitude. Pilot Lape showed remarkable improvement on each succeeding flight.
9-18	P-8	65	-	0	"	40.75	4	"	
"	P-9	"	-	0	"	"	5	"	
9-19	P-10	60	-	0	"	"	4	"	
"	P-11	"	-	0	"	"	6	Lape	
"	P-12	58	-	0	.016	"	5	Johnston	
"	P-13	"	-	0	"	"	4	Lape	
"	P-14	59	-	0	"	30.75	5	Johnston	
"	P-15	"	-	0	"	"	5	Lape	
9-26	R-1	70	30.02	5-10	"	"	6	Johnston	New propellers installed with reduced tip clearance. Max. altitude about 4' in fwd flight and 10' in hover.
"	R-2	"	"	"	"	"	6	Lape	
"	R-3	"	"	"	"	"	6	Johnston	
10-19	T-1	55	-	0	.016	"	6	"	Demonstration for Col. Seneff. Good fwd flts with speeds approx. 15-20 MPH. Pilot Lape showed continued improvement in handling ship.
"	T-2	"	-	0	"	"	6	Lape	
"	T-3	"	-	0	"	"	5	Johnston	
10-25	V-1	57	-	0	"	"	5	Lape	Check-out of ship with new engine installed.
10-26	V-2	"	-	0	"	"	5	Lape	Demonstration for Maj.Ritter and Kilmer. Obtained alt. about 10' in hover; dropped off to about 4' in fwd.flt. Lape good fwd flt and maneuverability.
"	V-3	"	-	0	"	"	5	Johnston	

(*) Inches from duct outlet.

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	NAME	DATE	HILLER HELICOPTERS	
PREPARED	C.H. Dessin	11/30/56		PAGE A VI
CHECKED			TITLE: SUMMARY REPORT PHASE III AIRBORNE PERSONNEL PLATFORM CONTRACT Nonr 1357(00)	MODEL 1031-A
APPROVED				REPORT NO. 56-110

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APPENDIX VI

PILOT TRAINING LOG
PHASE III

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APPENDIX VI
PILOT TRAINING LOG

1956 Date	Flt. No.	Flight Time (Min)		Total Time (Hrs:Min)		Purpose			Remarks
		Tethered	Free	Tethered	Free	Training	Test	Demon.	
7-18	M-5	8		:08		x			All flights with Pilot Lape aboard. Flts M-5 thru M-21 using remote throttle operator. Took pilot short while to get used to ship. Flt M-7 was very good flight.
"	M-7	5		:13		x			
7-19	M-11	5		:18		x			
"	M-12	5		:23		x			
7-23	M-17	-		:23					Left engine would not start.
7-24	M-19	5		:28		x			
"	M-20	6		:34		x			
7-25	M-21	7		:41		x			Good flight. Calm air.
"	M-22	6		:47		x			1st flt with pilot throttle. Good flight.
"	M-23	8		:55		x	x		
"	M-24	10		1:05		x	x		
7-30	M-25	8		1:13		x	x		
"	M-26	4		1:17		x	x		
"	M-27	-		1:17					Could not start left engine.
"	M-28	6		1:23		x	x		
7-31	M-29	1		1:24		x	x		Right engine ignition lead broke.
"	M-30	7		1:31		x	x		Good flight in light breeze.
8-7	M-32	6		1:37		x	x		
"	M-33	4		1:41				x	Demonstration for Gen. Browning.
8-8	M-35	-		1:41					Broken breaker point in left engine.
"	M-36	2		1:43			x		Left engine erratic.
"	M-37	7		1:50			x		
8-9	M-38	-		1:50					Left engine would not start.
"	M-39	7		1:57			x		Good flight.
8-10	M-40	5		2:02			x		Very smooth flight in calm air.
8-24	0-1	7		2:09			x		

PILOT TRAINING LOG (CONTINUED)

1956 Date	Flt. No.	Flight Time (Min)		Total Time (Hrs:Min)		Purpose			Remarks
		Tethered	Free	Tethered	Free	Training	Test	Demon.	
8-28	0-2	5		2:14			x		
"	0-3	3		2:17			x		
"	0-4	3		2:20			x		
"	0-5	4		2:24			x		
8-30	0-6	5		2:29			x		
"	0-7	6		2:35			x		Pilot felt pretty good on this flight.
"	0-8	6		2:41			x		
"	0-9	6		2:47			x		Good control of ship in spite f wind.
8-31	0-10	6		2:53			x		
"	0-11	6		2:59			x		
"	0-12	6		3:05			x		Vanes locked - ship sensitive.
9-4	0-13	5		3:10			x		" " , low floor. Ship quite sensitive.
"	0-14	5		3:15			x		
"	0-16	3		3:18			x		
9-5	0-18	5		3:23			x		
"	0-21	6		3:29			x		Good flts in winds up to 15 MPH.
9-6	0-23	5		3:34			x		
"	0-24	7		3:41			x		
9-10	0-26	13		3:54			x		Checkout of ship with new engine installed.
"	0-27	5		3:59			x		
9-11	0-29	5		4:04			x		
9-12	P-3		5		:05	x			1st solo free-flt - hover and slow fwd flt. Handled ship very well.
9-14	P-6		6		:11	x	x		Pilot showed marked improvement with each flight. Was able to increase speed of fwd flights and to demonstrate maneuvers that more experienced pilot performed.
9-19	P-11		6		:17	x	x		
"	P-13		4		:21	x	x		
"	P-15		5		:26	x	x		
9-26	Q-2	4		4:08			x		Check-out of ship with new propellers.
"	Q-4	5		4:13				x	Demonstration for Capt. Reid.
"	R-2		6		:32			x	Demonstration for Capt. Reid.

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PILOT TRAINING LOG (CONTINUED)

1956 Date	Flt. No.	Flight Time (MIN)		Total Time (HRS:MIN)		Purpose			Remarks
		Tethered	Free	Tethered	Free	Training	Test	Demon.	
10-17	S-1	5		4:09			x		Checkout of ship.
"	S-2	4		4:13			x		Checkout of ship.
10-19	T-2		6		:38			x	Demonstration for Col. Seneff.
10-25	V-1		5		:43		x		Checkout of ship with new engine.
10-26	V-2		5		:48			x	Demonstration for Major Ritter and Major Kilmer.

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