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EDWARDS AIR FORCE BASE, CALIFORNIA

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SUBJECT: USAATA Test Report No. 63-6

TO: See Distribution

1. This letter transmits the final report on subject test.

2. In accordance with your request, one copy of the report entitled, "Flying Qualities and Performance Evaluation of the Breguet 941 Turbo-prop Troop Transport" is inclosed.

FOR THE COMMANDER:

1 Incl
as

E. C. CARVELL
Administrative Officer

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ATA-TR-63-6

FLYING QUALITIES AND PERFORMANCE EVALUATION OF THE BREGUET 941 TURBO-PROP TROOP TRANSPORT

January 1964

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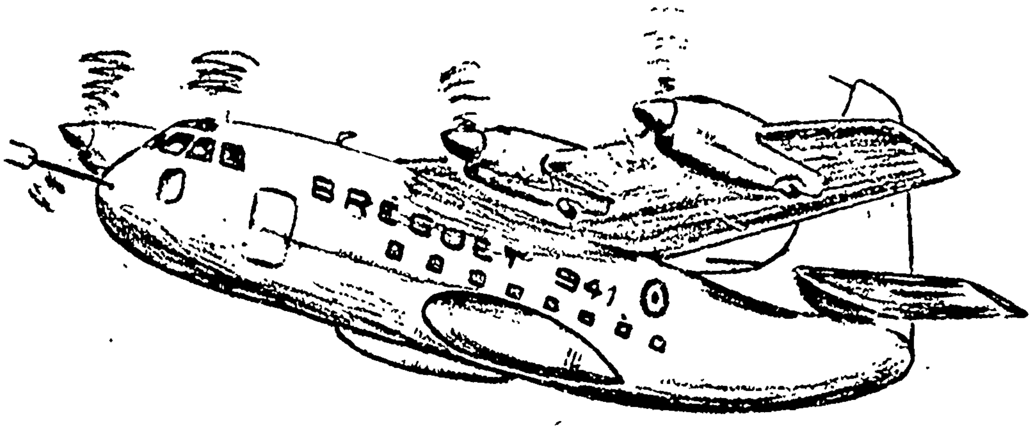
ATA-TR-63-6

FLYING QUALITIES AND PERFORMANCE EVALUATION OF THE BREGUET 941 TURBO-PROP TROOP TRANSPORT

January 1964



U. S. ARMY
AVIATION TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA
TEST AND EVALUATION COMMAND
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UNITED STATES ARMY

Project Pilot
Michael N. Antoniou
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FLYING QUALITIES AND PERFORMANCE EVALUATION
OF THE BREGUET 941 TURBO-PROP
TROOP TRANSPORT

SUMMARY

1. This report presents the results of performance observations and a qualitative stability and control evaluation of the Breguet 941 prototype STOL troop/cargo transport conducted by the U. S. Army Aviation Test Activity, Edwards Air Force Base, California. Testing was performed at Mont De Marsan, France during November 1963. The airplane, of all metal high wing configuration, is powered by four turbo-prop power plants and uses the deflected slipstream principle to attain STOL performance. All propellers are interconnected by shafting so as to eliminate engine-out asymmetric thrust.

2. Results indicate that the Breguet 941 prototype has good potential for use as a medium STOL troop/cargo transport. STOL performance appears to be comparable to medium STOL airplanes now in service use and under development by the U. S. Army. Conventional performance (rate of climb, cruise speed and range) appears to exceed that of medium STOL transports now in service use and should be comparable to that projected for the medium STOL transport now being developed (based on contractor data). Airplane configuration and contractor information indicate that service ceiling of the prototype is limited to 18,000 ft.

3. General cockpit configuration is satisfactory, but numerous detail design deficiencies will require a cockpit mock-up

[redacted]

for correction. Ground handling qualities are acceptable except that power adjustments to modulate taxi speed require excessive pilot attention. Engine exhaust and fuel fumes are present in the cockpit during all ground operations to an excessive degree.

4. STOL take-off and landing characteristics are generally satisfactory. Techniques used to obtain STOL performance require no unusual degree of skill or pilot effort. It appears that further refinement of contractor recommended techniques is possible and will produce an improvement in STOL performance over that obtained in this evaluation. Engine-out characteristics are particularly compatible with the STOL capability of the airplane due to the use of the propeller cross-shaft system. Controlled flight at STOL speeds is possible following asymmetric power failure and the complete STOL take-off and landing sequence can be completed under asymmetric thrust conditions. Propeller cross-shafting should be considered for use in other STOL multi-engine airplanes of interest to the U. S. Army.

5. In the STOL configuration, longitudinal flying qualities are satisfactory, but both lateral and directional characteristics are unsatisfactory due to weak static lateral-directional stability and low damping of dynamic lateral-directional oscillations. Flying qualities during the transition from the STOL take-off configuration to the clean climb configuration are unsatisfactory due to the method and fast rate of operation of the flaps and due to excessive pitch trim changes during the transition sequence. In the climb

[redacted]

[redacted]

and cruise configurations, longitudinal flying qualities are unsatisfactory due to weak static and dynamic stability coupled with strong elevator control power, but both lateral and directional flying qualities are acceptable.

6. In the cruise configuration maneuvering stability is unacceptable due to very low "stick force/g" gradients and transient g instability in sudden pull-ups.

7. Lateral and directional control power obtained with the spoiler-differential propeller pitch combination was satisfactory in all clean configurations and was particularly satisfactory in the STOL configurations. This control concept offers a substantial improvement in lateral and directional controllability over that obtained in comparable STOL airplanes (CV-2B) now in service use. This control concept should be considered for application to future STOL airplanes developed for the U. S. Army.

8. Further evaluation of the Breguet 941 is recommended following conversion of the prototype into a production configuration.

[redacted]

ATA-TR-63-6

FLYING QUALITIES AND PERFORMANCE EVALUATION OF THE BREGUET 941 TURBO-PROP TROOP TRANSPORT

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PART I

FLYING QUALITIES AND PERFORMANCE EVALUATION OF THE BREGUET 941 TURBO-PROP TROOP TRANSPORT

FLIGHT EVALUATION

INTRODUCTION

Authority

1. Authority for the conduct of this evaluation was received from the Commanding General, U. S. Army Test and Evaluation Command by Confidential message number C-2092, dated 4 October 1963.

Background

2. The Breguet 941, prototype STOL troop transport was developed by the French firm, "Société Anonyme des Ateliers d'Aviation, Louis Breguet" as a follow-on to the Breguet 940, an experimental flight research STOL vehicle which first flew in May, 1958. The Breguet 941 prototype, which first flew in June 1961, incorporates design concepts which were developed through the Breguet 940 program. Up to the present time, no production models of the airplane have been built and, in fact, the Breguet 941 prototype which was used for this evaluation remains the only flying article which the company has produced in the 941 series. After completion of contractor tests on the airplane in 1962, the prototype was turned over to the French Air Force for testing equivalent to the U. S. Air Force Category II tests. These tests were completed in the Spring of 1963. At that time, a ten hour flight evaluation of the airplane was conducted by National Aeronautics Space Administration (NASA) personnel of the AMES Research

Center and U. S. Air Force (USAF) personnel from Edwards Air Force Base, California. Following various modifications to the airplane, a joint NASA/USAF/French Air Force evaluation was conducted during September, 1963 at the French Air Force Test Center at Mont de Marsan, France. Following fixes made to the airplane as a result of this evaluation, a joint USAF/French Air Force evaluation was conducted during November 1963 at which time the U. S. Army was invited to participate. Army participation in this program formed the basis for this report. The airplane is presently undergoing the French equivalent of the U. S. Army service tests conducted by the U. S. Army Aviation Test Board. On 6 December 1963, the single prototype is scheduled to be bailed back to the manufacturer where it will be modified into a production configuration incorporating all fixes generated up to the end of service tests. Modification into production configuration is expected to be complete by April, 1964.

Purpose

3. The purpose of this evaluation was to evaluate the flying and ground handling qualities of the Breguet 941 prototype as a STOL troop/cargo transport and to determine the effectiveness of several unusual design features which are incorporated in the airplane. Due to the limited time which was allocated to the U. S. Army from the U. S. Air Force/French program and because no performance measuring equipment was available at the test site, no performance

measurements were made during the single evaluation flight. However, STOL performance of the airplane was evaluated as a result of STOL tests which were observed by the U. S. Army representative. The performance observations are included in Part II of this report.

Description of the Airplane (See Figure 1)

4. The Breguet 941 prototype is an all-metal high wing, four engine, tri-cycle gear, troop/cargo assault airplane designed for STOL operations from unprepared surfaces. It is manufactured by the Societe Anonyme des Ateliers D'Aviation, Louis Breguet, Toulouse, France. The airplane utilizes the deflected slipstream principle to obtain STOL performance. Basic design concept was to use the deflected slipstream principle coupled with a control system and a power train which would give satisfactory flying qualities and flight safety in the speed regimes possible through use of this principle. This design concept is reflected in the employment of the following major devices on the airplane:

a. Double slotted, full span flaps incorporating a slot in the leading edge of the forward flap section. The flaps produce very high lift coefficients for take-off and high drag coefficients for landing.

b. The propeller location is such that approximately 90% of the wing is immersed in the propeller slipstream.

c. The propellers are interconnected by steel cross-shafting such that the failure of an engine does not produce an uncontrollable condition during STOL operations.

d. The four individual engine throttles are mechanically linked to a single power lever so that power adjustments are accomplished by manipulation of a single control.

e. Wing mounted spoilers and differential outboard propeller pitch are used to obtain satisfactory lateral and directional control at STOL speeds.

f. A two piece rudder is employed which can be activated at the pilot's option for supplementary directional control at STOL speeds.

g. A hydraulically boosted, irreversible control system is incorporated about all three axes thereby permitting the use of artificial feel systems to obtain desired handling qualities.

h. A movable stabilizer is used as a trimming device in the low speed range to accommodate the large longitudinal trim changes produced by airspeed variation and flap deflection in this airplane.

5. The Breguet 941 prototype has a span of 76.7 ft., a length of 77.9 ft. and a height (at the top of the vertical stabilizer) of 30.7 ft. The cargo compartment is 36.6 ft. long, 8.5 ft. wide and 7.4 ft. high, exclusive of the rear ramp. The aircraft is unpressurized. Maximum gross weight at which the prototype has been flown is 44,000 lb, which is the design STOL weight. Power is supplied by four Turbomeca Turmo IIID free turbine engines rated at 1200 SHP each driving three

bladed, 14 ft. 9" Breguet-Ratier constant speed, reversing propellers. Total fuel capacity, carried in wing cells, is 2642 U. S. gallons.

6. The retractable tri-cycle landing gear (See Figure 5), hydraulically actuated, consists of dual, tandem wheel main gears and a twin wheel nose gear. The nose wheel incorporates power steering and a shimmy damper. Length of the nose wheel strut can be varied on the ground to adjust aircraft attitude for ease of cargo handling through the clam shell doors at the rear of the fuselage. Each main gear wheel is mounted on an independent, swiveling strut incorporating hydraulic shock absorbers so that independent wheel action is obtained for improved rough field handling. Hydraulic disc brakes and an anti-skid device are employed on each main gear wheel. The main gear retracts into "blister" type nacelles on the side of the fuselage while the nose gear retracts aft into the fuselage.

7. The hydraulically actuated, double slotted, full span flaps are built in eight spanwise sections, four sections per wing, in order to minimize asymmetric lift following failure of any one section. The two inboard sections on each wing deflect through a maximum angle of 98° while the two outboard sections on each wing deflect through a maximum angle of 72°.

8. The cargo compartment of the airplane contains seats for 56 troops or provisions for 24 stretchers. (See Figure 2). Cargo or troops are loaded through an aft clamshell door and a ramp which can be adjusted to truck bed level or lowered to the ground

for wheeled vehicle entry, (See Figure 3). Clamshell doors are hydraulically actuated. (The doors on the prototype were restricted from operation in flight) Tie-down rings are incorporated in the floor of the cargo compartment for lashing of cargo. No provisions are incorporated for heating the cargo compartment. A door, incorporating a ladder, is installed on the left forward side of the cargo compartment for crew entry and exit.

9. Cockpit of the airplane contains stations for a crew of three. Pilot and co-pilot seats are located side by side. A flight engineers seat is located behind the co-pilots seat with access to various engine and environmental controls located on the right side of the cockpit.

Propeller/Cross-shaft System (See Figure 4)

10. The propeller/cross shaft system is comprised of the following major components:

a. The four turbine powerplants with their associated power trains and reduction gearing.

b. The propeller housings containing the propellers and hydraulically (engine oil) actuated propeller pitch controls.

c. The cross shaft system consisting of:

(1) Flexible steel shafting, mounted in hydraulically damped bearings, between each outer and inner engine.

(2) Two linked flexible steel shafts between the inner engines, mounted in fixed bearings.

(3) Four angle gear drives linking the flexible cross-shaft to the reduction gearing on each engine.

(4) A free wheeling unit incorporated in the power train of each engine.

(5) A pilot controlled clutch designed to disconnect a malfunctioning propeller from the drive system and feather it.

(6) Shear necks designed to shear following seizure of one of the angle gear drives.

(7) A cross shaft governor control located at the center of the cross-shafting and sensitive to cross-shaft RPM. This governor is used to control the speed of the cross shaft and therefore all propellers.

(8) A pilot actuated cross shaft brake located at the ends of the cross shaft.

(9) A master, pilot actuated, cross-shaft speed control lever used to set cross shaft and therefore propeller RPM by means of the cross shaft governor.

Cross-Shaft System

11. Primary purpose of the cross/shaft system is to assure a continuous flow of power to all four propellers following failure of one or more engines. This eliminates the airplane control problems normally encountered following failure of an engine when operating below minimum single engine control speeds. Additionally, due to the aerodynamics of a propeller system, failure of one engine where all four propellers continue to operate, produces a net loss in

thrust of only 17% compared to the 25% loss which is obtained when an engine fails on a conventional four engine airplane.

12. Under normal operating conditions, where each engine is driving its own propeller, the cross-shaft rotates in a non-loaded condition at approximately 6000 RPM (take-off) or as selected by the pilot. In the event of failure of an engine, the free wheeling device incorporated in the engine power train automatically disconnects the failed engine from the propeller power train. Power from the remaining engines is then absorbed by the cross-shaft by means of a shaft running from the angle gear drive to the engine reduction gearing through the center of the free wheeling unit.

13. In the event of failure of a propeller such as overspeeding or an out of balance condition due to battle damage, the propeller can be disconnected from the drive system by means of a pilot actuated mechanical dog clutch. Feathering is then accomplished by means of the feathering circuits in the propeller pitch control housing. The power from the corresponding engine is then available to drive the remaining three propellers.

14. Seizure of any of the angle gear drives connecting the cross shaft to the propellers would produce seizure of the cross shaft system. To preclude this happening, a shear neck

installed between the cross shaft and each angle gear drive is designed to shear following angle gear drive seizure. Under those conditions, the engine associated with the angle gear drive failure would continue to drive its own propeller while the other engines would retain cross-shaft capability.

Propeller System

15. Pilot command signals for RPM changes are produced by manipulation of the cross-shaft speed control which, through a mechanical linkage, resets the cross-shaft governor control. The constant speed unit in the cross-shaft governor then relays a mechanical signal to the four propeller pitch actuators where a change in propeller pitch is hydraulically accomplished. Propeller pitch change produces a change in propeller RPM and therefore cross-shaft RPM since the two are interconnected. The selected RPM is then maintained by the constant speed unit in the cross-shaft governor control. Since all propellers are connected to the cross shaft propeller, synchronization of all propellers is automatically accomplished.

16. In addition to the constant speed mode of operation described above, the propellers are capable of operation in three additional modes:

a. Differential Pitch Mode - This mode is activated through mechanical linkage to the cross shaft governor when the flaps are lowered to the STOL configuration (i.e., 45° deflection or more). In this mode, lateral deflections of the control stick are transmitted to a mixing unit in the cross-shaft governor. The governor mixing unit, through mechanical/servo linkage then activates the outboard propeller pitch controls such that differential propeller pitch is obtained between the two outboard propellers. Maximum propeller pitch differential that can be obtained with lateral control stick movement in this mode is 3 degrees. The differential pitch which is produced induces a yawing and rolling effect and is therefore used to supplement lateral and directional control in the STOL speed regime.

b. Transparency Mode - This mode is utilized in STOL approaches to obtain zero thrust and high induced drag in order to obtain steep approach angles at slow speed. In this mode, activated by the pilot, the outboard propeller pitch is set to obtain zero thrust slipstream velocities over the outer wing. This produces a higher required airplane angle of attack for a given set of approach conditions (i.e., sink rate and approach speed) which in turn produces increased induced drag enabling the pilot to select high angles of approach without a build-up in airspeed (This system was not in operation on the prototype test airplane).

c. Reversal Mode - This mode, utilized for STOL landings, is designed to destroy wing lift following touch-down, thereby immediately increasing the weight of the airplane on the wheels and improving braking efficiency. Additionally, aerodynamic braking due to the reverse thrust is obtained. In this mode, all propellers are placed in reverse pitch by a pilot command signal transmitted through the mixing unit in the cross-shaft governor to the propeller pitch control units. The pilot reverse thrust command is obtained by lifting the power lever handle approximately one inch and then pulling the handle inboard until an electrical circuit is closed. The reversing mode is such that when the handle is returned to the forward thrust position, only the inboard propellers will return to positive thrust blade angles. The outboard propellers are then returned to forward thrust blade angles by means of a momentary type toggle switch located on the power lever handle which activates the outboard propeller pitch change circuits.

17. The direction of rotation of the propellers is unique. The left inboard and right outboard propellers turn clockwise. The right inboard and left outboard turn counter clockwise. The direction of rotation of the outboard propellers was selected in order to decrease the induced drag caused by the wing tip vortices.

Flight Control System

18. The flight control system on the Breguet 941 prototype is irreversible about all three axes and is powered by dual operating hydraulic servos. Pilot control inputs are transmitted through

mechanical linkage to the respective servos which then actuate the control surface. An artificial feel system consisting of spring bungees and a bobweight is used to produce control force gradients.

a. Longitudinal Control System - The primary longitudinal control surfaces consist of a stabilizer-elevator. Fore and aft movement of either the pilot's or co-pilot's interconnected control sticks is transmitted through mechanical linkage to servos which then actuate the elevator. Longitudinal trim is obtained by electrically changing stabilizer incidence by means of a switch located on the control sticks. On the prototype test airplane, stabilizer incidence could not be changed above approximately 130 kts. IAS. At airspeeds in excess of 130 kts. IAS, longitudinal trim was obtained by re-centering the longitudinal feel springs by means of a separate toggle switch. A positive bobweight is employed on the control stick to provide maneuvering stability (stick force per g). Weight of the bobweight, in unaccelerated flight, is offset by an additional spring.

b. Lateral Control System - The lateral control system consists of wing mounted spoilers which are used at all speeds and the differential propeller pitch mode which is activated in the STOL configuration. Lateral movement of either control stick is mechanically transmitted to servos which cause the respective spoiler to deflect upward into the slipstream (i.e., left stick would cause the left spoiler to deflect). This produces a loss of lift on the associated wing causing a roll in that direction. In the STOL configuration, initial propeller differential pitch is obtained as lateral stick displacement exceeds one half the total travel. Further stick displacement results in increasing differential pitch until the maximum of 3 degrees is obtained at full lateral deflection. Lateral trim is obtained by electrically deflecting one spoiler by means of a cockpit toggle switch.

c. Directional Control System - Primary directional control is obtained by means of a single vertical stabilizer to which is attached a two piece rudder. For normal operations the forward rudder segment is electrically locked in the neutral position. For STOL operations, the forward segment may be unlocked to supplement the directional control available from the rear segment in the STOL speed range. Movement of either set of interconnected cockpit control pedals is transmitted by mechanical linkage to servos which actuate the rudder segment(s). Additionally, in the STOL configuration, differential outboard propeller pitch up to a maximum differential pitch of 3 degrees is obtained as the rudder pedals are displaced thus providing additional directional control power. Rudder force gradients are obtained by means of spring bungees installed in the rudder linkage. Directional trim is obtained by electrically re-centering the spring bungees by means of a toggle switch in the cockpit.

19. Angle of attack system - The Breguet 941 prototype has an angle of attack indicating system coupled with para-visual lights, installed in the cockpit. The angle of attack indicators and para-visual system are designed for use in STOL approaches where indicated airspeeds are not reliable in this airplane. A stall warning stick shaker, activated by the angle of attack system, is installed, but was inoperative. The angle of attack system consists of pressure sensors located on each side of the fuselage coupled with transducers to produce the electrical signal for the angle of attack indicators. Each pilot is furnished with an indicator. Para-visual lights, activated by the angle of attack system, are installed above the instrument panel in the pilots field of vision. Each pilot is furnished with a set of lights. The para-visual installation consists of three lights, amber, green and red, mounted in a vertical row. Amber indicates an airplane angle of attack of less than zero degrees. Green indicates an angle of attack of from zero degrees to three degrees while red indicates an angle of attack of from three degrees to thirteen degrees.

Flying Qualities and Performance Evaluation of the Breguet 941
Turbo-prop Troop Transport

Scope of Evaluation

20. Scope of this evaluation was necessarily limited due to the time available in which to accomplish the evaluation flight. STOL flying qualities and flying qualities which were noted to be marginal while observing the USAF evaluation team were therefore given priority.

21. One flight of 1:20 duration was flown, during which the Breguet 941 prototype was evaluated in the STOL, CLIMB and CRUISE, configurations. Take-off gross weight was 40,000 lb and Center of Gravity was in the mid position at 29.8% MAC (C.G. range is from 25.0% to 35.0%). Airfield pressure altitude at take-off was 500 ft. mean sea level with an airfield ambient temperature of plus 4°C. Surface wind was calm. Test altitude band ranged from 500 ft. mean sea level to 7000 ft. mean sea level during the evaluation. Airspeed ranged from 42 kts. IAS (+28° angle of attack) to 200 kts. IAS. Maximum normal acceleration obtained was +2.1g. The forward rudder segment was locked throughout the evaluation.

22. The following tests were conducted:

a. Cockpit evaluation

b. Ground handling qualities

c. Control system break out forces

d. STOL take-off characteristics

e. CLIMB characteristics

f. CRUISE configuration stability and control characteristics

g. STOL configuration stability and control characteristics

h. Engine out characteristics

i. STOL landing characteristics

j. Flying qualities at high angles of attack

Method of Evaluation

23. Test methods utilized in this evaluation were as prescribed in the AGARD Flight Test Manual, USAF Stability and Control Flight Test Manual, and "Pilot Techniques for Stability and Control Tests" by Doyle. Since no stability and control or performance instrumentation were installed in the test airplane, the evaluation was entirely qualitative in nature.

RESULTS AND DISCUSSION

Cockpit Evaluation

24. The airplane which was evaluated was a prototype and therefore contained many switches and controls which were installed for flight test purposes only. The cockpit design had not been finalized into production configuration. Flight controls, instruments, placards and electronic equipment were all of French design. A detailed cockpit analysis under these conditions was not practical.

The following discussion will deal with general cockpit configuration. Observations regarding specific items will be made where the nature of the item was such that it was not affected by the prototype configuration of the airplane. Procurement of this airplane by the U. S. Army should be preceded by a complete cockpit mock-up to assure design in accordance with the Handbook of Instructions for Aircraft Designers (HIAD) and Army requirements.

25. Entrance to the airplane was made through the crew door located on the left forward side of the fuselage. Size of the entrance door was satisfactory. Entrance into the cockpit was made by means of steps leading into the flight engineer's station behind the pilots' seats. General cockpit layout was such that engine and propeller instruments, airplane and engine environmental controls and various electrical switches mounted on the right side of the cockpit aft of the co-pilot's seat were visible only to the flight engineer sitting at the flight engineer's station. The cockpit of the prototype was apparently designed for use by a three-man crew. The flight engineer's duty, other than starting and stopping the engines, was to monitor the instruments and controls at the flight engineer's station (similar to present U. S. Army crew chief functions). The provision for a third crew member in the cockpit of this airplane with

control operating duties is not necessary. It is probable that controls and instruments now located at the flight engineer's station could be relocated where they would be accessible to the pilot or co-pilot and that the pilot/co-pilot could accomplish starting and shut-down procedures, thereby reducing the minimum crew required to operate the airplane to two personnel.

26. Entry into the pilots' seats was somewhat restricted due to the relatively narrow space between the seat and the center control console. Seat adjustment range was satisfactory both fore and aft and up and down, but an overhead handhold is needed to assist the up and down adjustment. Arm rests were not provided on the pilots' seats. Since the airplane is capable of remaining airborne for over 10 hours and to enhance overall pilot comfort, arm rests should be installed.

[27. Visibility from the cockpit was excellent due to extensive use of glassed areas, overhead "eyebrow" panels and floor level glassed panels. Horizontal plane visibility arc was approximately 235° from the left rear quarter around to the right rear quarter. The remaining 125° of visibility arc was blocked by the rear of the cockpit and the wings. Visibility was comparable to that of the CV-2B DeHavilland "Caribou".]

28. Location of the control stick relative to the seat was satisfactory. Control stick length was satisfactory and maximum control stick displacements were easily obtained. Power lever length, location and throw range were satisfactory. Rudder pedal location and pedal adjustment range was satisfactory. Location of the nose wheel steering control on the pilot's left console was unsatisfactory since the power lever was also located to the left of the pilot's seat, making it necessary for the pilot to remove his left hand from the power lever to obtain nose wheel steering control during taxi and take-off. Additionally, it was impossible to use nose wheel steering during STOL landings since power lever reversing manipulations were required. Relocation of the nose wheel steering control would be desirable for improved service use. It is recommended that incorporation of nose wheel steering into the rudder pedals be studied for production versions of this airplane.

29. Separate flap control switches are provided on the pilot's left console and on the center console for use by the co-pilot. These switches are of the three position, spring loaded, instantaneous type. A flap position indicator is located on the main instrument panel. In order to make a flap adjustment, it is necessary for the pilot to depress the flap switch, while monitoring the flap position indicator

until the desired flap setting has been obtained. This is awkward, time consuming and places an unnecessary load on the pilot. A "follow-up" type switch with detents for the various primary flap deflections would be more desirable. Correction of this deficiency would be desirable prior to service use. A third flap control, located on the power lever handle, is used for go-around from a STOL configuration approach. Activation of this switch, coupled with application of take-off power, automatically reduces flap deflection from 98° to 70° and provides an automatic longitudinal trim input into the control stick feel spring system to compensate for the nose down pitching moment induced by the flap retraction. The location and operation of the STOL go-around flap control is satisfactory considering the flying qualities of the airplane during the go-around sequence.

30. The stabilizer incidence trim control is located on the pilot's control stick. Since, in the prototype test airplane, stabilizer trim is usable only to 130 kts. IAS, the longitudinal feel spring trim is utilized for trimming when operating above that speed. Longitudinal feel spring trim, lateral spoiler trim and directional feel spring trim are located on the pilot's left console and are duplicated on the center console for use by the co-pilot.

Location of the trim switches on the left console is such that they are awkward and difficult to use. Correction of this deficiency would be desirable prior to service use. A four-way switch located on the pilot's control stick incorporating stabilizer trim and lateral spoiler trim would be a more desirable arrangement. Directional and longitudinal feel spring trim could then be located on the center console. If production versions of the airplane incorporate a stabilizer which is trimmable throughout the speed range of the airplane, complete removal of the longitudinal feel spring trim system would be desirable. Three trim warning lights are employed on the center console to indicate that the trim systems are set for take-off. A light is illuminated when the respective trim system is not at take-off setting and is extinguished as the trim control is manipulated to bring the particular trim system into the take-off setting range. The take-off setting ranges for the trim controls are quite small and an unsatisfactory amount of trim control manipulation is required to obtain a "lights out" condition. Employment of "gauge and pointer" type trim position indicators would eliminate this deficiency and would be desirable in this airplane.

31. The landing gear handle, located on the upper forward center console is easily accessible to both pilots. A flashing warning light in the gear handle was satisfactory in warning the pilot of a gear up

condition. However, the light is activated whenever the gear is up and the flaps are down. This would be disconcerting when executing an instrument approach pattern or other slow speed maneuver, particularly at night, and correction of this deficiency would be desirable prior to, service use. A warning light cut-off switch would alleviate this problem. An annunciator panel, located on the central instrument panel was of sufficient size and brilliance to be an effective initial warning device. Various other warning lights were scattered in what appeared to be a random pattern throughout the cockpit and were not of sufficient brilliance to be effective. Centralization of these lights and an increase in brilliance would be desirable.

32. Several engine emergency controls and the propeller feathering controls are located on the aft upper control console such that the pilots would be required to shift head and body positions to activate them. Relocation of these controls to a more favorable position would be desirable.

33. In summary, general cockpit layout of the Breguet 941 prototype is satisfactory and the major flight controls are favorably located. Elimination of a third crew member as a control operator is possible. Several secondary flight control systems and miscellaneous auxiliary controls are poorly located and their mode of operation is undesirable. A large percentage of the cockpit control and instrument

design does not conform with the requirements of HIAD. A cockpit mock-up would be required prior to service acceptance of the airplane.

Ground Handling Characteristics

34. Pre-starting checks were accomplished by the French Air Force flight engineer occupying the third cockpit seat. Pre-starting checks seemed to be logical and orderly (they were made in French) consisting of the usual items associated with pre-starting of turbine engines (i.e., fuel pressure checks, power control positions, electrical power, etc.). The actual engine starts, also accomplished by the flight engineer, were simple and easily accomplished. Using external electrical power, a momentary type switch was depressed activating the engine starter. As the engine compressor reached minimum light-off speed of approximately 20% RPM, the throttle for the particular engine on the center console was advanced from idle cut-off to ground idle. Engine light-off then occurred followed by compressor acceleration to a ground idle speed of approximately 60% RPM on an automatic fuel control schedule. Engine starting sequence was #3, #1, #2 and #4. Due to the cross-shaft system, all four propellers begin to turn as the first engine is started. This places high inertia loads on the engine so that the first engine started is most susceptible to compressor stall during the acceleration cycle from idle cut-off to ground idle speed. This problem was not encountered on the evaluation flight.

Following start of the first engine, the other engines were started and stabilized at ground idle speed. This was accomplished easily by means of detents on the center console throttle quadrant corresponding to the ground idle position. Entire starting sequence from beginning of the pre-start check to stabilization of all engines at ground idle consumed five to seven minutes. Individual engine throttles are mechanically linked to the power lever by means of mechanical locks installed on each individual throttle handle. Minimum engine speed at which a throttle can be locked to the power lever is flight idle speed (approximately 80% RPM).

35. The power produced by a single engine at flight idle speed was sufficient for taxiing on a hard surface and this procedure was used with #3 engine in the flight idle position, locked to the power lever and #1, #2, and #4 at ground idle. The parking brake, a "pull to lock" type located under the left instrument panel was easily released and taxi was initiated by manipulating the power lever located at the pilot's left hand. Brake sensitivity and effectiveness were satisfactory and, when not using the nose wheel power steering, light differential braking was adequate in accomplishing medium to large radius turns. Nose wheel power steering, when used, was effective in producing turns of all radii, but there was a tendency to over-control the power steering wheel. This was due to the high sensitivity of the wheel coupled with the low force required to turn the wheel. Correction of this deficiency would be desirable.

36. It was found that, even with one engine at flight idle, too much power was developed for satisfactory taxi speeds. In order to avoid riding the brakes, French Air Force technique, which was used, was to place the power lever in the reverse thrust position at flight idle power, causing all four propellers to go into the reverse mode. As described in paragraph 16 (c), returning the power lever handle to the forward thrust position causes only the inboard propellers to return to positive thrust. Positive thrust of the inboard propellers is then cancelled out by reverse thrust of the outboard propellers. Using the outboard propeller pitch toggle switch on the power lever handle, the pitch of the outboard propellers is then "beeped" to a pitch setting such that the net thrust produced by the inboard and outboard propellers is in a forward direction and of sufficient magnitude to produce satisfactory taxi speed without brake riding. This procedure was necessary several times as the airplane was taxied to the runway due to ground slope changes, turning requirements, etc. Since this procedure required the pilot to use his left hand and since the power steering wheel also required the left hand, the operation was awkward, difficult to perform satisfactorily. Some other means of modulating taxi thrust should be investigated and/or the nose wheel power steering should be activated by rudder pedal movement.

37. Riding qualities of the airplane were evaluated on hard surfaces only. Due to the relatively narrow tread of the main gear (11.8 ft) and the shock absorption qualities of the landing gear system, some lateral "rocking" was observed while taxiing on the concrete taxi surfaces, but the "rocking" produced was not objectionable and no difficulty was experienced in controlling the airplane. Shock absorption qualities are such that a very "soft" spongy ride was produced. This type of shock absorption coupled with the narrow tread gear would probably tend to degrade ground handling qualities when operating from rough terrain and/or in high wind conditions.

38. Fuel and exhaust fumes were very evident in the cockpit during ground operations. This may be due to the circulation pattern of the engine exhaust flow. Correction of this deficiency is considered mandatory prior to service use.

Flying Qualities

Control System Breakout Forces

39. Definition - Breakout force is defined as that force which the pilot must apply to a flight control in order to produce an initial airplane reaction. Breakout forces are caused by friction in the control system linkage and by the inertia of the control system itself.

40. Control system breakout forces were qualitatively estimated in flight. The following values were obtained:

a. Longitudinal and lateral - less than 2 pounds.

b. Directional - 3 to 4 pounds

The low breakout forces obtained were satisfactory considering the low control force gradients which were obtained in the stability and control evaluation, since high breakout forces coupled with low control force gradients would cause the pilot to tend to overcontrol the airplane.

STOL Take-off Characteristics

41. Three STOL take-offs were accomplished. STOL take-off techniques used were those which were developed by the contractor and the French Air Force. At the request of the French project pilot, no attempt was made to vary take-off techniques to check flying qualities variations. Take-offs were made at a gross weight ranging from 39,000 lbs to 40,000 lbs. Center of Gravity position was at 29.8% MAC. On two of the take-offs, a STOL flap setting of 45° was used throughout the take-off and the STOL climb. On the third take-off, a flap setting of 35° was used until just prior to lift-off at which time flap deflection was increased to 60°. Wind was calm for all take-offs.

42. Pre-take-off checks were quickly accomplished using a printed check list. Time required for pre-take-off checks was one half

to one minute. All four engines were brought up to flight idle speed and locked into the power lever. Cross-shaft/propeller speed was set at 95% RPM by means of the cross-shaft speed control and the stabilizer incidence was positioned at +3 degrees. Line up on the runway was easily accomplished using power steering and light differential braking.

43. Constant 45° Flap STOL Take-offs - All engines were set at take-off power by means of the power lever. Brakes were adequate to hold the airplane at 100% power. Although the airplane was restrained by the brakes, lateral stick deflections and rudder pedal inputs caused differential propeller pitch operation which produced yawing and rolling movements in the airplane with zero forward speed (static on the runway). Acceleration following brake release was extremely rapid. Due to the short period of time in which the airplane was on the ground and due to the extremely low speed at which directional and lateral control became effective, nose wheel steering was not required for directional control which was obtained primarily through use of lateral control stick inputs supplemented by small rudder pedal inputs as required (similar to techniques employed in the OV-1 'Mohawk'). Precise directional control was possible in this airplane using this method and the method was not awkward or difficult to use. Although primary directional control by use of rudder inputs was also

possible at low speeds, high rudder control power coupled with low rudder force gradients made precise directional control difficult to obtain since there was a tendency to overcontrol rudder inputs. Higher rudder force gradients during take-off would be desirable in this airplane.

44. Longitudinal control was maintained in the neutral position until an indicated airspeed of 50 knots was obtained and then was pulled to the full aft position. Pull force required at the full aft position was approximately five pounds and was satisfactory. With the C.G. at 29.8% MAC, minimum nose wheel lift-off speed was 55 kts. IAS followed immediately by airplane lift-off. Rate of airplane rotation at lift-off was such that no difficulty was encountered in checking rotation at an angle of attack of approximately 7-10 degrees which produced an indicated airspeed of 65-70 kts. and a climb angle of 10-15 degrees as the airplane passed through 50 ft. It is probable that, considering the control characteristics and thrust available in this airplane, the climb sequence through 50 ft. could be accomplished consistently at airspeeds of 55-60 kts. thereby further reducing distances required to clear 50 ft. Gear retraction was initiated at approximately 75 ft. No trim change was observed as the gear was retracted. Some small improvement in distance over 50 ft. would probably be obtained if the gear were retracted immediately after lift-off.

45. Flap retraction was commenced at an altitude of 200-300 ft. at an indicated airspeed of 70 kts. Flap retraction was very fast. Flaps retracted at a rate of 7-10 degrees per second and produced a strong nose down pitch trim change of 40 pounds as they retracted. Additionally, as the flaps were retracted, high sink rates were produced with the airplane held at a constant climb attitude. Maximum sink rate obtained was approximately 800 FPM and was probably due to the inability of the airplane to accelerate quickly enough to offset the large loss of lift obtained with flap retraction. Because of the strong nose down pitch trim change, the high sink rates produced and the fact that the pilot had to monitor flap retraction due to the design of the flap control switch (see paragraph 29), flap retraction immediately after take-off or at low altitude was not practical or safe. This was not satisfactory since the capabilities of the airplane and the pilot were compromised. Correction of this deficiency would be mandatory prior to service use of this airplane. A mechanical tie-in between the flaps and the horizontal stabilizer (similar to the CV-2B "Caribou") would probably alleviate the pitch trim change deficiency. A reduction in flap retraction rate and the use of a "follow-up" type flap control would probably reduce the high sink rate characteristic. As a result of the above characteristics, flap retraction, commenced at 200-300 ft. was

accomplished in a series of "milking" operations requiring approximately five separate flap actions and consuming approximately one to two minutes. Control about all axes was satisfactory throughout the transition to the clean climb configuration. Small random lateral trim changes were obtained as the flaps were retracted and the airplane accelerated to climb speed, but were not of sufficient magnitude to be objectionable.

46. <u>35° Flap STOL Take-off with Flap Actuation to 60° at Lift-off</u> - Take-off sequence using 35° flap was unchanged from the 45° case up to the point of lift-off except that airplane acceleration seemed to be slightly higher. As the airplane reached 45-50 kts. IAS, the co-pilot "popped" the flaps down to 60°. Lift-off occurred immediately at 50-55 kts. with the airplane in a level altitude and the control stick full aft. As the airplane rotated after lift-off, the control stick was moved forward to a position midway between neutral and full aft to establish an initial rotation rate and was then pulled aft slightly to increase rotation rate such that airspeed passing through 50 ft. was 55-60 kts. This technique seemed to produce the shortest distance over 50 ft. and was not difficult to perform. Lateral and directional control was satisfactory and no difficulty was encountered in maintaining wings level, steady heading flight. Climb to 75-100 ft. was made at 60 kts. IAS where the gear was retracted followed by climb to 300 ft. where flap retraction sequence was commenced. Flap sequence was unchanged from the 45° case.

Climb Characteristics

47. Climb characteristics were evaluated at a climb airspeed of 125 kts. IAS in the clean configuration. Compressor speed was 95%, propeller RPM was 95% and the C.G. was at 29.8% MAC.

48. Visibility during the climb, at a climb attitude of approximately 5 to 10 degrees, was satisfactory. Static longitudinal stability was weakly positive in this configuration and longitudinal control power was moderate to strong. This combination resulted in poor pilot "feel" for the trim airspeed control position and as a result, the airplane was difficult to trim and to maintain at the desired trim airspeed. This was unsatisfactory and would be tiring to the pilot in prolonged climbs. Correction of this deficiency would be desirable prior to service use. Static lateral and static directional stability was positive with increasing amounts of positive lateral and directional control force and deflection required as side slip angle was increased. Dynamic lateral-directional stability was positive with the airplane displaying pilot induced dutch roll characteristics which damped in approximately two to three cycles after pilot inputs ceased. Lateral control power (rate of roll) was satisfactory using lateral inputs of 50% of the available lateral stick travel. Lateral control forces were light, but satisfactory. Adverse yaw produced during the rudder-fixed rolls was moderate, but could be eliminated with coordinating rudder.

Cruise Configuration Stability and Control

49. CRUISE configuration stability and control was evaluated at 6000 ft. mean sea level at an indicated trim airspeed of 160 kts. Compressor speed was set at 95% and propeller speed was set at 85%. C.G. was at 29.8% MAC. Ambient temperature was -5°C. At this speed the horizontal stabilizer was locked at +6° and the longitudinal force feel system was used for trim.

50. Static longitudinal stability was neutral in this configuration and longitudinal control power was very strong making it extremely difficult to maintain the desired trim speed due to pilot overcontrolling and a tendency for the airplane to "wander" away from trim. During prolonged cruising, this condition would be very tiring to the pilot. This was unsatisfactory and correction of this deficiency would be mandatory prior to service use of this airplane. A reduction of longitudinal control power in this configuration would be desirable and would help to alleviate this deficiency.

51. Dynamic longitudinal stability, evaluated using positive and negative stick pulses, produced a long period phugoid oscillation which showed no tendency to damp. Additionally, stick pulses produced a change in the mean airplane attitude due to the neutral static stability characteristic. The non-damping characteristic of the phugoid oscillation was not satisfactory for a transport airplane of this type and correction of this deficiency is considered mandatory prior to service use of this airplane.

52. Static longitudinal stability was also checked at 5000 ft. mean sea level at 200 kts. IAS in the CRUISE configuration. At this speed, static stability appeared to be slightly negative. That is, longitudinal control position and control force gradients tended to reverse slopes as airspeed was varied away from the trim airspeed of 200 kts. IAS. This characteristic was unsatisfactory and should be corrected prior to service use of this airplane.

53. Lateral and directional stability and control was evaluated under the conditions described in paragraph (48) above. Lateral and directional flying qualities were satisfactory. Lateral and directional control displacement and control force increased approximately linearly as side slip angle was increased. Rudder forces obtained were moderate and were satisfactory. Lateral forces were light, but satisfactory. The airplane displayed positive dihedral effect, (ability to "pick up" a wing with rudder). Side slips produced a small nose up pitch trim change of negligible magnitude which was acceptable. The lateral-directional dynamic dutch roll oscillation was controllable and damped in approximately two cycles when pilot inputs ceased. Side force characteristics of the airplane were satisfactory in that increasing side slip angle required increased bank angle to maintain steady heading flight.

54. Lateral control effectiveness (rate of roll) was satisfactory. One half lateral control deflection inputs produced roll rates which were more than adequate for an airplane of this type. Lateral control force was light, but positive and increased with increasing deflections. Adverse yaw produced was small in magnitude and easily controllable using coordinating rudder. The spoiler installation appeared to give adequate lateral power in this airplane at cruising airspeeds.

55. Rate of operation and effectiveness of the longitudinal feel spring trim system and the lateral spoiler trim was satisfactory in the CRUISE configuration. Effectiveness of the directional trim system was also satisfactory, but lag in the rate of operation induced a pilot tendency to overcontrol directional trim inputs. Correction of this deficiency would be desirable prior to service use.

STOL Configuration Stability and Control

56. Take-off Configuration - STOL take-off configuration flying qualities were evaluated at 5000 ft. mean sea level at an indicated trim airspeed of 60 kts. with flaps set at 45° and power

set for take-off. C.G. was at 29.8% MAC. Static longitudinal stability was weakly positive in this configuration, but was satisfactory since strong control force gradients during STOL take-off operations are not desirable due to the considerable control stick "juggling" that is inherent in the maneuver. Stick pulses produced a neutrally damped phugoid dynamic oscillation. Considering the short period of time in which the airplane would be in the STOL configuration during actual service operations, the neutrally damped phugoid was acceptable. Longitudinal control power was moderately strong and was satisfactory. Longitudinal power was sufficient to produce acceptable rotation rates and to obtain desired attitudes quickly and precisely. Lateral and directional stability was weakly positive in this configuration. Very low lateral and directional forces were required to produce large side slip angles. Side force characteristics were weak with very small bank angles required to maintain steady heading side slips. These characteristics are marginally satisfactory and should be improved prior to service use of the airplane, since they degraded the pilot's ability to maintain coordinated flight. Pilot induced lateral-directional "Dutch Roll" dynamic oscillations were of long periods and damped satisfactorily in approximately three cycles. Lateral control power (rate of roll) was particularly satisfactory in this configuration. One half control deflection rolls produced large bank angles within one second. Adverse yaw was moderate, but could be controlled due to good rudder power. Rate of roll is considered very satisfactory considering the low speed and the configuration.

57. Landing Configuration - STOL landing configuration flying qualities were evaluated at 5000 ft. mean sea level at an indicated trim airspeed of 55 kts. with flaps set at 98° (full deflection) and power set for approach (92%). C.G. was at 29.8% MAC. Flying qualities in this configuration were very similar to those obtained in the take-off configuration. Longitudinal static stability remained weakly positive, but was acceptable due to the numerous longitudinal control stick inputs that are required during a STOL approach. In this configuration, the dynamic phugoid oscillation appeared to be weakly damped and was satisfactory. Longitudinal control power was moderate and this coupled with the weakly positive static stability was acceptable. Longitudinal control power was sufficient to produce airplane response such that no difficulty was encountered in adjusting airplane altitude as would be required during a STOL approach. Lateral and directional static stability displayed the same characteristics as those obtained in the take-off configuration and were again considered marginally satisfactory, the correction of which would be desirable prior to

service use. Lateral-directional dynamic stability (Dutch Roll Oscillation) was unsatisfactory in this configuration and would degrade the pilot's ability to maintain steady heading during a STOL approach in rough air. Dynamic "dutch roll" oscillations, when induced by the pilot, displayed very low damping with a tendency for residual oscillations to continue. Correction of this deficiency would be desirable prior to service use. Lateral and directional control power was again very satisfactory in this configuration. Bank angle obtained in one second using one half lateral control deflection was large. Rudder power was sufficiently strong so that, although moderate adverse yaw developed in the rolls, it could be quickly coordinated. Lateral and directional control power are considered very satisfactory considering the low speed and the configuration.

Maneuvering Stability

58. Maneuvering flying qualities (stick force per g characteristics) were evaluated at 7000 ft. mean sea level at a trim airspeed of 160 kts. IAS in the CRUISE configuration by means of the wind-up turn technique. Maximum normal acceleration obtained was two g's, the present limit on the airplane. Stick force per g gradient obtained was positive, but very weak. Stick force at two g's was estimated at 5 pounds pull force. Aft stick

deflection from the trim position required to obtain two g's was very small. Additionally, the airplane displayed "g jump" qualities with sudden aft control stick inputs. That is, there was a tendency to exceed the g which had been commanded by the control stick input. Following the maneuvering stability evaluation, the evaluating pilot, in attempting to level the airplane from a 200 kt. IAS descent, inadvertently obtained 2.1 g's with a very small aft stick application. These maneuvering characteristics were unsatisfactory and dangerous considering the type of airplane and its strength limits. Service pilots, particularly under conditions of stress, as in combat, could easily apply stick forces and stick displacements that would result in normal accelerations exceeding the limits of the airplane. Correction of this deficiency prior to service use is considered mandatory. It is probable that re-design of the control stick bobweight system would alleviate this characteristic.

Engine-Out Characteristics

59. In order to evaluate the effectiveness of the cross-shaft system, engine out characteristics were evaluated at 5000 ft. mean sea level in the STOL take-off and climb (clean) configurations. With the airplane in the STOL take-off configuration (45° flaps, gear down, take-off power) at a trim airspeed of 65 kts., the left

outboard (#1) engine was retarded to ground idle (zero thrust). The only trim change obtained was a slight nose down pitch which was easily corrected. Rate of climb decreased, but remained positive (approximately 500 FPM). There was no apparent lateral-directional trim change. A second engine (#2) was then retarded to zero thrust on the same side as the first. Still in the take-off configuration, the airplane maintained altitude at an indicated airspeed of 70 kts. with no apparent lateral-directional trim change. No difficulty was experienced by the pilot in maintaining wings level, steady heading flight. Gear and flaps were then retracted and the airplane was allowed to accelerate to 120 kts. IAS where a rate of climb of approximately 300-400 FPM was obtained. Although large pitch trim changes were required as flaps were retracted and the airplane accelerated, only small random lateral-directional trim changes were obtained. Engine-out characteristics of the airplane were considered particularly satisfactory from a safety and flying qualities standpoint considering the STOL capability of the airplane.

STOL Landing Characteristics

60. Three STOL landings were accomplished. STOL landing techniques used were those which were developed by the contractor and the French Air Force. At the request of the French project

pilot, no attempt was made to vary take-off techniques to check flying quality variations. Landings were accomplished at a weight of 39,000 pounds with the C.G. at 29.8% MAC (mid position). Flap setting used for all landings was 98° and full reverse thrust was employed on each touchdown. Wind was calm.

61. Basic approach technique used was a power approach at a constant angle of attack of 3°, varying power as required to maintain desired glide path angle (similar to the approach technique used in the OV-1 "Mohawk"). At a 3° angle of attack in the landing configuration, the test airplane was apparently very near the bottom of the power required curve since moderate (±3°) changes in angle of attack on final approach produced only small variations in sink rate. This characteristic was used to vary flight path angle without resort to excessive power manipulation. Use of the single power lever rather than four throttles to manipulate engine power was an asset in reducing pilot workload during the approach. Some lateral-directional overcontrolling was experienced due to the weak lateral-directional static stability in this configuration, but good lateral-directional control power enabled the pilot to maintain a wings level, coordinated approach. However, pilot "feel" for coordinated flight was degraded due to the

low lateral-directional static stability and side force levels, causing inadvertent small angle side slips to develop due to pilot control inputs.

62. Entry into the traffic pattern was made at 120-130 kts. IAS using power for level flight. Following landing gear extension at 120 kts. IAS, power was reduced to approximately 85% to slow the airplane. As airspeed decelerated to 100 kts. IAS flaps were lowered to 45°. Airplane deceleration to 70 kts. was rapid following flap extension and a large rapid nose up pitch trim change was obtained requiring approximately 20 pounds of push force to maintain desired attitude until re-trimming could be accomplished. This was unsatisfactory and correction of this deficiency would be desirable prior to service use. As the airplane decelerated to 70 kts. IAS, approximately 90% power was applied to maintain level flight with the flaps extended. Landing check list was completed quickly and turn onto base leg was accomplished. Visibility during the turn was satisfactory. Flaps were then lowered to 70° causing a nose up pitch trim change of approximately 10 pounds and a reduction in airspeed to 60-65 kts. Turn onto final approach was accomplished easily. Lateral control power was very satisfactory in obtaining precision turns and the rudder

was effective in maintaining "ball-centered" conditions. Flaps were lowered to 98° on final approach and power was set at 92%.

63. A slight nose down pitch trim change was obtained as flaps were lowered, but was easily corrected using stabilizer trim. Airspeed decelerated to 55 kts. IAS, final approach speed, at an angle of attack of +3°. Rate of descent was 500-600 FPM. A mechanical safety, employed on the power lever handle to guard against inadvertent application of reverse thrust while airborne, was disengaged as the airplane descended through 200 ft. Angle of approach at this time was approximately 8°. Since airplane angle of attack was maintained at +3°, attitude of the airplane with reference to the ground was approximately 5° nose down. After setting the power lever for reverse operation, approach was continued down to a height of approximately 20 ft. above ground level at which time the airplane was rotated to an attitude just above level attitude. Stick force required to perform the rotation was low, approximately 5 pounds, but no over-rotational tendencies were observed. Elevator power was sufficient to produce the flare precisely and appeared to be strong enough to rotate the airplane at considerably lower speeds. As the airplane was flared, sink rate was reduced to approximately 400 FPM. As the airplane

settled to within 3-5 ft. of the ground, slight "floating" was produced (possibly due to the deflected slipstream and ground effects) which required a reduction in power of 1-2% to effect touchdown immediately. Power was not reduced to settings lower than 85% approximately, since due to the slow acceleration characteristics of the turbine engine at low engine speeds, power would not be immediately available following application of reverse thrust and the landing roll would consequently be increased.

64. As contact with the ground occurred at approximately 200-300 FPM, reverse thrust was selected by means of the power lever handle and take-off power in reverse was obtained by pushing the power lever to the take-off position (full forward). This direction of movement was not awkward and was aided by the deceleration of the airplane. As reverse thrust was selected, the control stick was placed in the neutral position and heavy braking was applied. Airplane deceleration was very rapid. Although power steering could not be used during the landing roll-out due to the necessity for manipulating the power lever, directional control was easily maintained by differential braking and rudder inputs. As the airplane continued to decelerate, moderate lateral "rocking" and weak longitudinal pitching was observed. This was

due to the design and shock absorption characteristics of the main gear and it is possible that this characteristic would be undesirable when operating from rutted or unprepared surfaces. Stronger damping in the shock absorber system might alleviate this characteristic and produce more ground stability. As the airplane came to rest, the power lever was retarded to flight idle and the forward thrust position was selected with the power lever handle. Since only the two inboard propellers return to forward thrust in this airplane (see paragraph 16c) no residual forward movement was obtained as forward thrust was selected. This characteristic was desirable. The outboard propellers were then "toggled" into the forward thrust position by means of the switch on the power lever handle and the reversing guard was engaged.

65. During landing approaches, the ability of the pilot to maintain a desired angle of attack was degraded by the angle of attack system operation and by the para-visual light operation. Angle of attack indications and light indications were not calibrated so that a satisfactory angle of attack as displayed on the gauge produced an unsafe condition (red) on the lights and vice versa. In addition, there was a measurable lag in light operation with changing angle of attack which made attitude control difficult. Angle of attack gauge indications, while more responsive than

the lights tended to fluctuate considerably, making instrument interpretation difficult. An additional deficiency was that pilot and co-pilot systems were not cross-calibrated and considerable variations in the two systems were observed. Correction of these deficiencies would be desirable prior to use of the system as a primary approach reference.

Characteristics at High Angles of Attack

66. A very brief evaluation of flying qualities at high angles of attack was made in the landing configuration. The purpose of the evaluation was to determine whether higher angles of attack could be safely used during STOL approaches. Weight ranged between 39,000 and 40,000 pounds. C.G. position was 29.8% MAC. Flaps were set at 98° and the landing gear was lowered. Power was varied as necessary to produce stabilized flight. Altitude ranged from 7000 to 6000 ft.

67. Angle of attack was gradually increased to a maximum of 28°. At this angle of attack, 95% power produced a sink rate of 500 FPM. Attitude was such that visibility in an angle of attack range up to 20° would be adequate for landing. Longitudinal and lateral-directional stability was weak, but control power about all axes was satisfactory and the pilot was able to maintain controlled

flight with no unusual difficulty up to the maximum angle of attack which was obtained (28°). The handling qualities and sink rates obtained indicate that STOL approaches could be accomplished at angles of attack in excess of 3° safely, thereby reducing air and ground distances to values lower than those obtained in this evaluation.

CONCLUSIONS

68. It is concluded that flying qualities of the Breguet 941 prototype airplane are suitable for service use except as stated below:

a. Correction of the following deficiencies is mandatory prior to service use:

(1) Excessive fuel and exhaust fumes are present in the cockpit during ground operations (paragraph 38).

(2) Flap retraction and extension is excessively fast (paragraph 45).

(3) Pitch trim change due to flap retraction is excessively large (paragraph 45).

(4) Static longitudinal stability is too weak in the CRUISE configuration (paragraph 50).

(5) Damping of the longitudinal phugoid oscillation is excessively weak in the CRUISE configuration (paragraph 51.).

(6) Maneuvering stick force gradients are too low in the CRUISE configuration (paragraph 58).

(7) The airplane exhibited g instability in sudden pullups (paragraph 58).

b. Correction of the following deficiencies would be desirable prior to service use:

(1) Cockpit configuration requires a three man crew (paragraph 25).

(2) An over-head handhold to aid in adjustment of the pilots and co-pilots seat is needed (paragraph 26).

(3) Pilot and co-pilot seats are not equipped with arm rests (paragraph 26).

(4) The nose wheel steering power control wheel is awkwardly located (paragraph 28).

(5) Design of the flap control switch requires excessive pilot attention (paragraph 29).

(6) Location of the trim controls makes them awkward and difficult to use (paragraph 30).

(7) One of the two longitudinal trim systems should be eliminated if possible (paragraph 30).

(8) The trim position light indicating system requires too much pilot manipulation (paragraph 30).

(9) The landing gear warning system does not incorporate a cut-out switch (paragraph 31).

(10) Various warning lights are not favorably placed in the cockpit and are of inadequate brilliance (paragraph 31).

(11) Various engine and propeller emergency controls are located so that they are difficult to reach (paragraph 32).

(12) The nose wheel power steering control is too sensitive (paragraph 35).

(13) Modulation of taxi speed by use of reverse thrust is awkward and requires excessive manipulation. (paragraph 36).

(14) Landing gear shock absorption system would probably degrade ground handling qualities on rough terrain or in high wind (paragraph 37).

(15) Rudder force gradients are too low for adequate pilot feel during take-off (paragraph 43).

(16) Static longitudinal stability is too weak in the CLIMB configuration (paragraph 47).

(17) Elevator control power is too strong in the CRUISE configuration (paragraph 50).

(18) Rate of operation of the directional trim control is too slow (paragraph 55).

(19) Static lateral-directional stability was weak in the STOL Take-off and Landing configurations (paragraph 56 & 57).

(20) Dynamic lateral-directional damping was very weak in the STOL Landing configuration (paragraph 57).

(21) Pitch trim change due to flap extension is too large (paragraph 62).

(22) Angle of attack gauge and para-visual light indications are difficult to interpret (paragraph 65).

69. The following characteristics of the Breguet 941 prototype enhanced its suitability for service use and should be considered for future designs:

a. Low speed lateral and directional control effectiveness is particularly well suited to the STOL mission.

b. Engine-out characteristics are an asset to the accomplishment of the STOL mission of the airplane.

c. Pilot techniques required to obtain STOL performance were easily accomplished due to the STOL flying qualities of the airplane and the relative simplicity of the techniques themselves.

70. The following general conclusions were made:

a. Incorporation of nose wheel power steering control into the rudder pedals should be considered (paragraph 28).

b. Airplane characteristics during a "go-around" from a STOL approach were demonstrated by the French project pilot using the automatic pitch trim change system to compensate for flap retraction from 98° to 70°. Airplane response and controllability appeared satisfactory, but should be evaluated prior to service use (paragraph 29).

c. Location of a four way trim control switch on the control stick should be considered (paragraph 30).

d. Employment of "gauge and pointer" type trim indicators would be desirable in this airplane (paragraph 30).

e. A cockpit mock-up should be accomplished to determine cockpit suitability (paragraph 33).

f. It is probable that STOL take-off and landing distances over 50 ft could be reduced by a change in technique (paragraphs 44 and 66).

g. It is probable that re-design of the control stick bobweight system would improve maneuvering stability (paragraph 58).

RECOMMENDATIONS

71. It is recommended that the Breguet 941 prototype be considered for service use as a STOL troop/cargo transport.

72. It is recommended that:

a. Deficiencies (1) through (7) listed in paragraph 68a be corrected prior to further evaluation of the airplane.

b. Deficiencies (1) through (22) listed in paragraph 68b be corrected prior to acceptance for service use.

c. Incorporation of nose wheel power steering into the rudder pedals be considered.

d. Location of trim controls on the control stick be considered.

e. "Gauge and pointer" type trim indicators be employed.

f. A cockpit mock-up review be conducted if the airplane is considered for service use.

g. STOL take-off and landing techniques be evaluated with a view toward improving performance.

h. Re-design of the control stick bobweight system be considered in order to improve maneuvering stability.

i. Further evaluation of the airplane be carried out following conversion of the prototype into production configuration.

j. Further evaluation be expanded to the limits of the airspeed-altitude-weight-Center of Gravity envelope of the airplane.

k. Flight test instrumentation be provided, as practicable, to measure performance, stability and control parameters in future evaluation of the airplane.

l. The devices employed in the Breguet 941 prototype to obtain favorable engine out characteristics and good STOL controllability be considered for application to other STOL vehicles being evaluated by the U. S. Army.

FLIGHT NO. 3

TAKE-OFF DISTANCE				LANDING DISTANCE			
No.	Ground	Est. Air	Total (over 50')	No.	Ground	Est. Air	Total (over 50')
#1	620 ft.	300 ft.	920 ft.	#1	540 ft.	300 ft.	840 ft.
#2	610 ft.	250 ft.	860 ft.	#2	520 ft.	300 ft.	820 ft.
#3	625 ft.	250 ft.	875 ft.	#3	550 ft.	250 ft.	800 ft.

3. Take-off and landing distances observed appear to be slightly superior to those obtained with the CV-2B "Caribou" and those anticipated for the CV-7A. However, this performance was obtained at maximum gross weights ranging from 4000 to 5000 pounds under the design STOL weight of 44,000 pounds for this airplane. It is probable that at the STOL design weight of 44,000 pounds, STOL performance of the Breguet 941 prototype would be comparable to that of the CV-2B and the CV-7A.

4. The evaluating pilot was informed by the French Air Force project pilots and by Breguet personnel that production versions of the airplane would have larger engines producing 1500 SHP each for take-off. This would increase total horsepower over that presently installed in the prototype by 1200 SHP. An increase in horsepower of this magnitude should produce significant improvement in take-off and landing distance and would probably result in superior STOL performance

at 44,000 pounds over that obtained in the CV-2B and that projected for the CV-7A at their respective design STOL gross weights. A comparison of Breguet performance data based on the large engine installation and CV-7A performance data shows that at their respective STOL design gross weights, the Breguet 941 production version STOL performance would be superior to CV-7A STOL performance by approximately 300 ft. in landing distance and 200 ft. in take-off distance (over 50 ft.). Additionally, Breguet personnel stated that an increase in wing span of approximately four feet was being considered for the production version. An increase in wing area of this magnitude would also favorably affect STOL performance.

Conventional Performance (See Figures 6,7 & 8)

5. Climb performance - Climb performance of the prototype was qualitatively evaluated as adequate for the mission of the airplane. Rate of climb in the clean configuration at sea level at a gross weight of 40,000 pounds was 1500-2000 FPM. Installation of larger engines and wing extension in the production version should significantly improve rate of climb.

6. Service ceiling - Service ceiling of the airplane, although not observed, is probably relatively low due to the high wing loading of the airplane (50 lb/ft^2). Breguet personnel stated that the

service ceiling was 18,000 ft. This is marginally adequate for an airplane of this type. Installation of larger engines and wing extension should significantly improve the service ceiling of the production version. Breguet performance data for the production version indicates a service ceiling of 26,000 ft. at a weight of 44,000 pounds at maximum continuous power.

7. Speed Capability - A true cruise airspeed of 185 kts. was observed in the prototype at 5000 ft mean sea level at 39,000 pounds gross weight. Installation of larger engines and wing extension should improve cruising speed capability. Breguet performance data for the production version indicates a cruising speed of 215 kts. TAS at 10,000 ft. Maximum level flight speed at sea level is quoted at 254 kts. and at 10,000 ft. is given as 260 kts.

8. Range - Breguet performance data indicates that the production version of the airplane would have a maximum range of 1675 nautical miles (N.M.) at 10,000 ft. cruising at 215 kts. TAS. This is with no extra tankage provided and allowing a fuel reserve. Take-off weight under these conditions would be 47,250 lbs. With extra tankage on board, take-off weight would be 58,400 lbs. and range would be 2500 N.M. A specific range of 0.11 N.M./LB is quoted at 215 kts. TAS at 44,000 lbs. gross weight.

9. STOL Assault Mission Profile - Breguet performance data indicates that the production version airplane would be capable of performing a STOL take-off at 44,000 lbs. with a payload (troops/cargo) of 6,600 lbs. with sufficient fuel to climb to and cruise at 10,000 ft., at 215 kts. for 160 N.M. Descent would then be made to sea level and a 100 N.M. penetration executed at 215 kts. TAS followed by a STOL landing at the mid-point destination. A return trip cargo load of 6600 lbs. would then be loaded, a STOL take-off accomplished and the return profile flown to home base without refueling at the midpoint.

10. Weight Data - Breguet data indicated the following production version weights:

a. Empty weight - 28,924 lbs.

b. Empty weight plus maximum fuel - 46,561 lbs. (not including extra tankage).

c. Design take-off assault (STOL) weight - 44,092 lbs.

d. Design take-off logistic weight - 52,911 lbs.

e. Design take-off ferry weight - 58,422 lbs.

f. Design maximum cargo payload - 16,500 lbs.

11. Airplane Strength (See Figure 9) - At the STOL gross weight of 44,000 lbs., maximum normal acceleration is given at 3.5 g's and the design landing sink speed limit is given at 13 ft/sec.

12. Flotation Characteristics - Undercarriage index of the nose gear and main gear of the airplane is 9 and 15 respectively. Observation of the airplane on rain-soaked sod surfaces showed flotation characteristics similar to the CV-2B "Caribou". California Bearing Ratio measurements were not taken since measuring equipment was not available. Airplane flotation was satisfactory on surfaces that were estimated to have a California Bearing Ratio of from 3 to 5. Conversation with the French project pilots revealed that one sod surface on which the airplane operated satisfactorily had a French California Bearing Ratio rating of 3. The equivalency of this value to the U. S. Value is unknown. The airplane was observed to make 20 taxi runs over this surface following its tracks on each run. At the end of 20 runs, the main gear had left ruts approximately 3 inches deep and the nose gear had left ruts 2 inches deep. The airplane was maneuvering successfully as the runs were terminated.

Miscellaneous Data

13. Cost - French project pilots estimated the cost of the production version at between 2.0 and 2.5 million dollars per airplane. Breguet personnel quoted a price of 1.5 million dollars per airplane in a lot of 100 minus radio equipment.

14. Cross-shaft Reliability - Breguet reported that the cross-shaft had been bench run for 5000 hours with no difficulty and that the cross-shaft installed on the test airplane had operated for 500 hours with no maintenance problem. French Air Force personnel verified this statement.

15. Engine Reliability - A total of 23 Turbomeca engines had been replaced for various reasons since the airplane commenced flying. The airplane had accumulated a total time of 520 hours at the time of this evaluation.

16. Breguet personnel stated that actuation of the rear cargo doors was rapid and that three jeeps had been off-loaded in one minute and thirty seconds from door opening to door closing. Cargo door actuation was not observed since the cargo doors were inoperative at the time of the evaluation.

17. Cargo compartment evaluation was difficult since a large amount of test equipment was installed. However, numerous tie-down rings were located on the cargo compartment floor and folding troop seats were installed. Breguet personnel stated that production versions would incorporate non-skid floors and an integral cargo roller system.

18. The McDonnell Aircraft Corporation representative (McDonnell has license rights on the airplane) stated that McDonnell would

increase the interior width of the airplane by 6 inches and increase the maximum payload capability to 17,500 lbs. if the airplane was produced in the U.S. He also stated that 1500 SHP T-58 engines would be substituted for the 1200 SHP Turbomeca engines installed in the prototype.

19. Pilot training should pose no unusual problems for this airplane.

20. An increase in maintenance man hours will probably be required to maintain this airplane over those expended on the CV-2B and over those anticipated for the CV-7A due to the numerous subsystems employed in this airplane and the complexity of these systems.

21. Systems complexity in this airplane is such that a thorough systems reliability evaluation should be accomplished prior to acceptance of the airplane.

22. From a political and psychological standpoint, considering recent U. S. Air Force-Army controversy over the allegation that the Army is procuring aircraft too large for its mission, the Breguet 941 has the distinct advantage of being small in exterior size. Wingspan is approximately 20 ft. shorter than the 96 ft. wingspan of the CV-2B "Caribou" and the fuselage length and tail height are approximately the same as the CV-2B. That is to say, the airplane has dimensions such that it "looks" suitable, from the standpoint of size, to be an Army airplane.

Flying Qualities and Performance Evaluation of the Breguet 941
Turbo-prop Troop Transport

23. The U. S. Air Force (Colonel Burrows of the Tactical Air Command) showed considerable interest in the airplane and made many favorable comments.

Reviewed and Approved By:

Richard J. Kennedy Jr.

RICHARD J. KENNEDY, JR.
Lieutenant Colonel, TC
Commanding

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1. U. S. Naval Test Pilot School, "Stability and Control Techniques" by Doyle.
2. U. S. Air Force Experimental Test Pilot School, "Handbook for Stability and Control Testing".
3. U. S. Naval Test Pilot School, "Performance Testing Manual".
4. "Breguet 941 Technical Presentation" by Avions L. Breguet, dated June, 1963.
5. Model Specification, "Prototype Tactical Transport Airplane (STOL) Caribou II (CV-7A), dated 20 September 1962, with Addendum.
6. T.M. 55-1510-206-10, "Operator's Manual AC-1 Aircraft", dated June, 1962.

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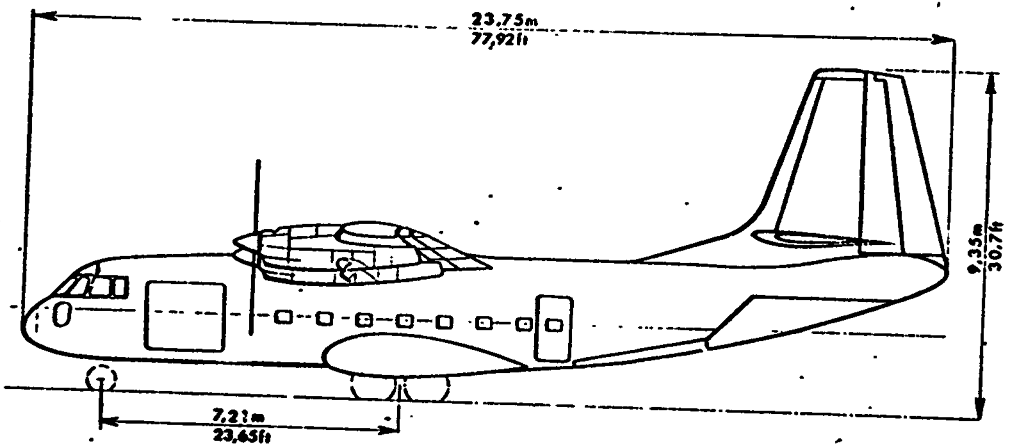

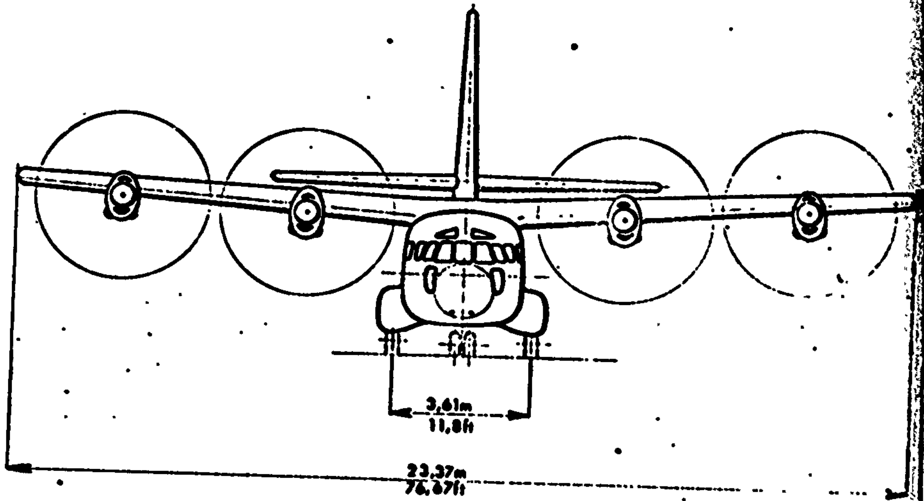

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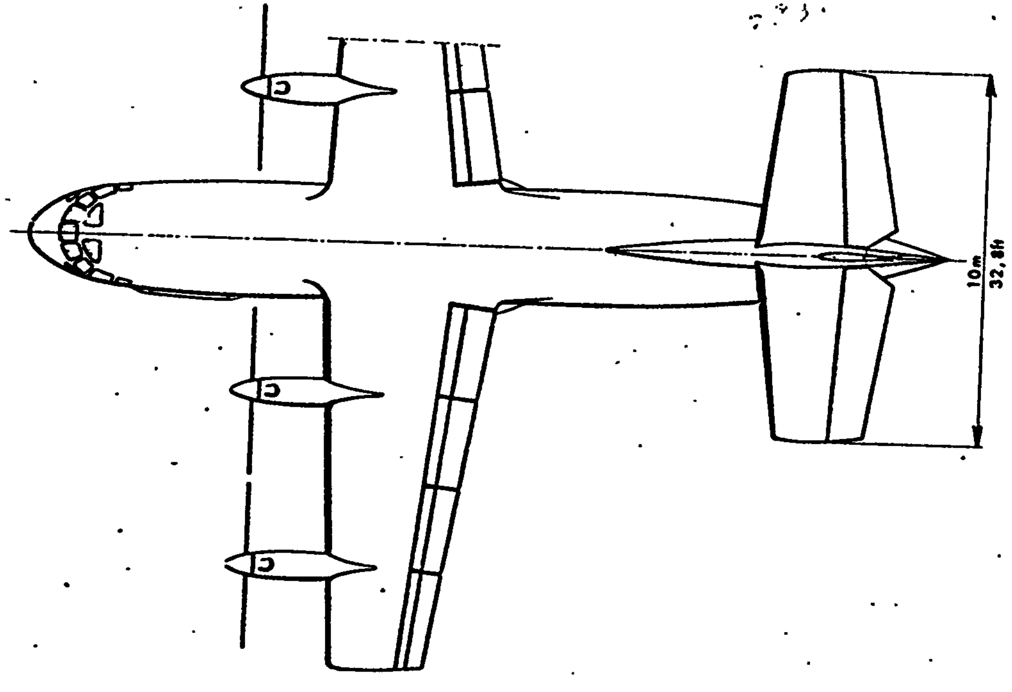

BREGUET 941

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TYPICAL LOADING FOR OFFICIAL USE ONLY CHARGEMENT TYPE

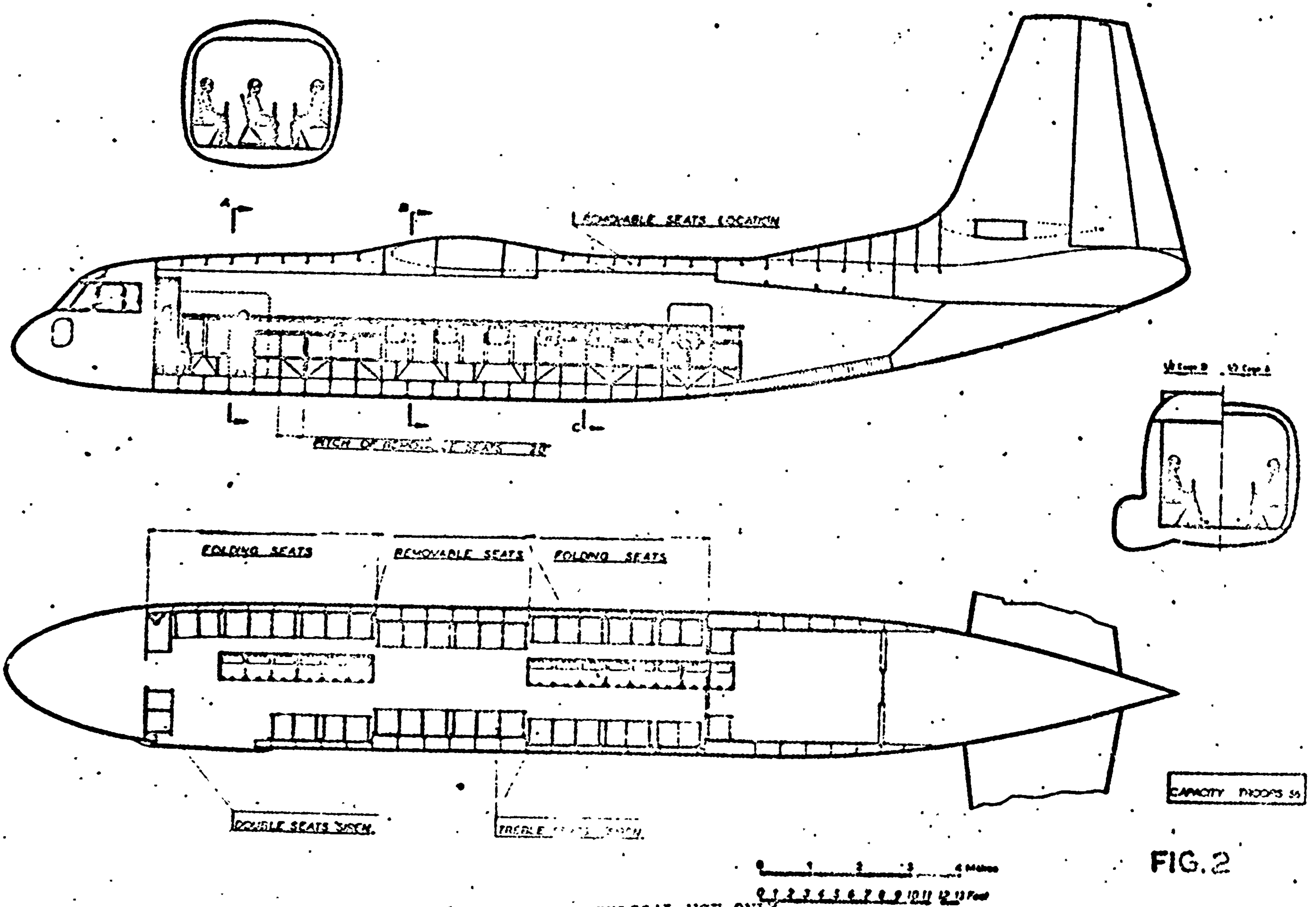

FIG. 2

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REAR DOORS AND RAMP

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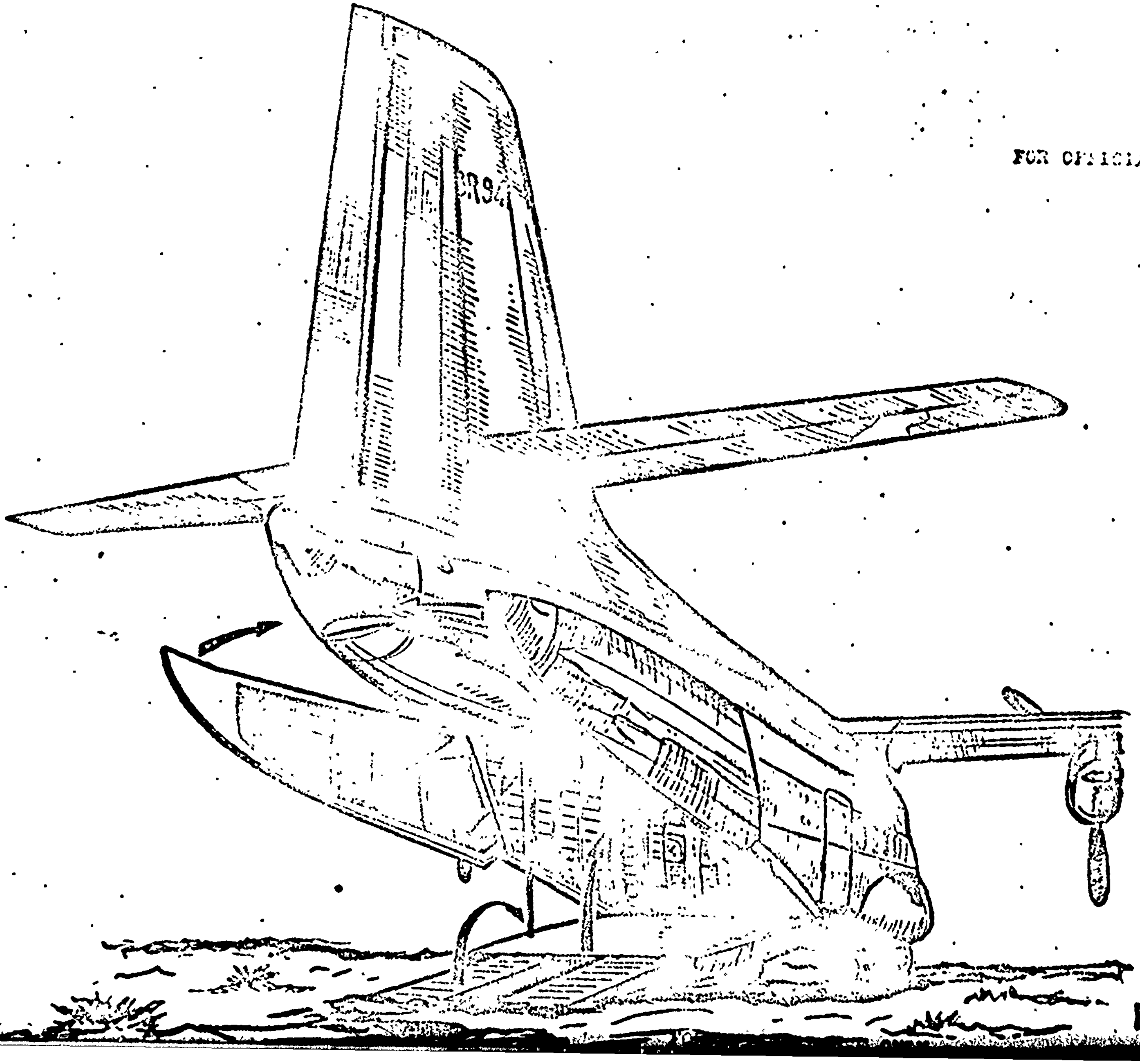

FIG. 3

INTERCONNECTING SHAFT

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TRANSMISSION

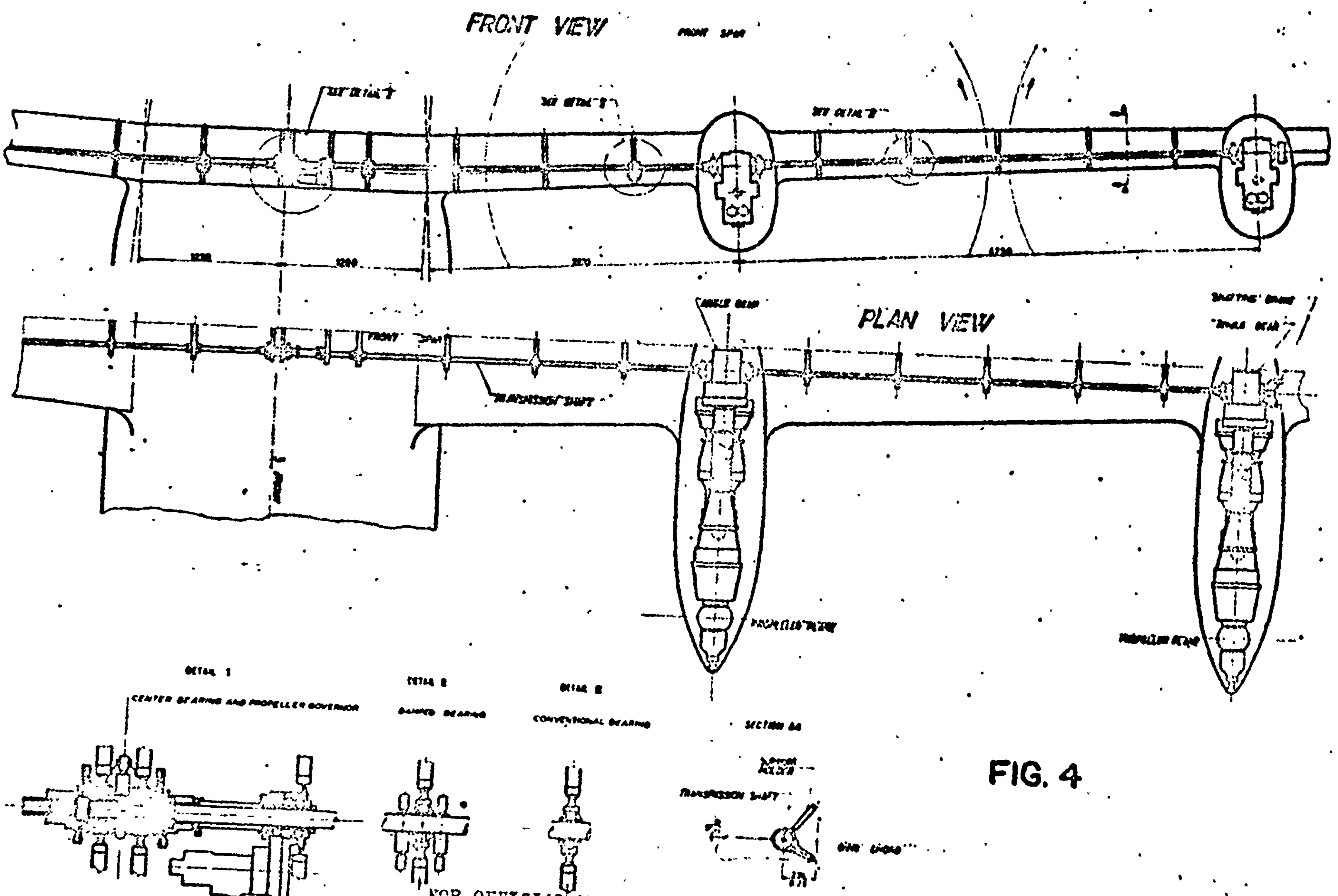

FIG. 4

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LANDING GEAR

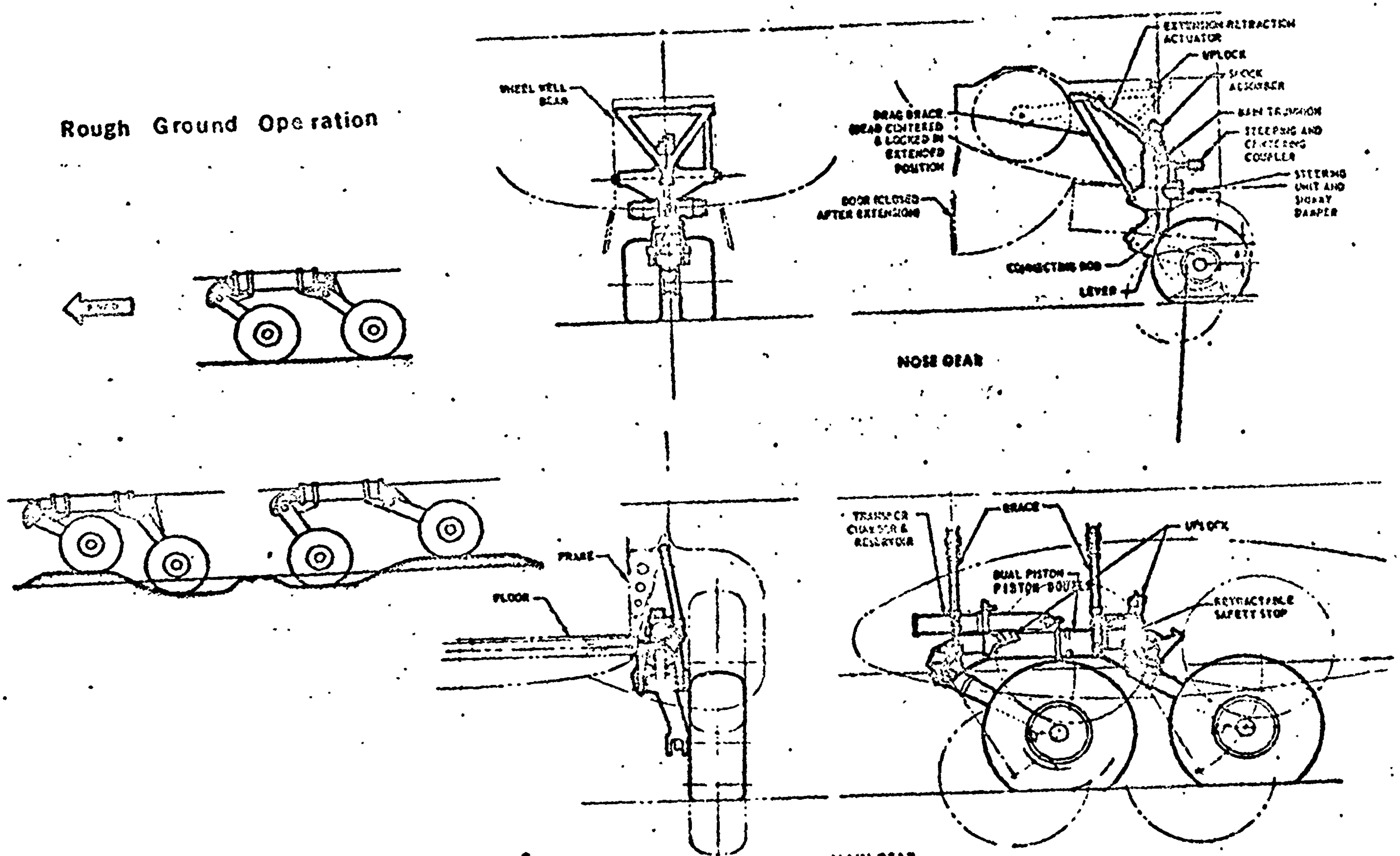

FIG. 5

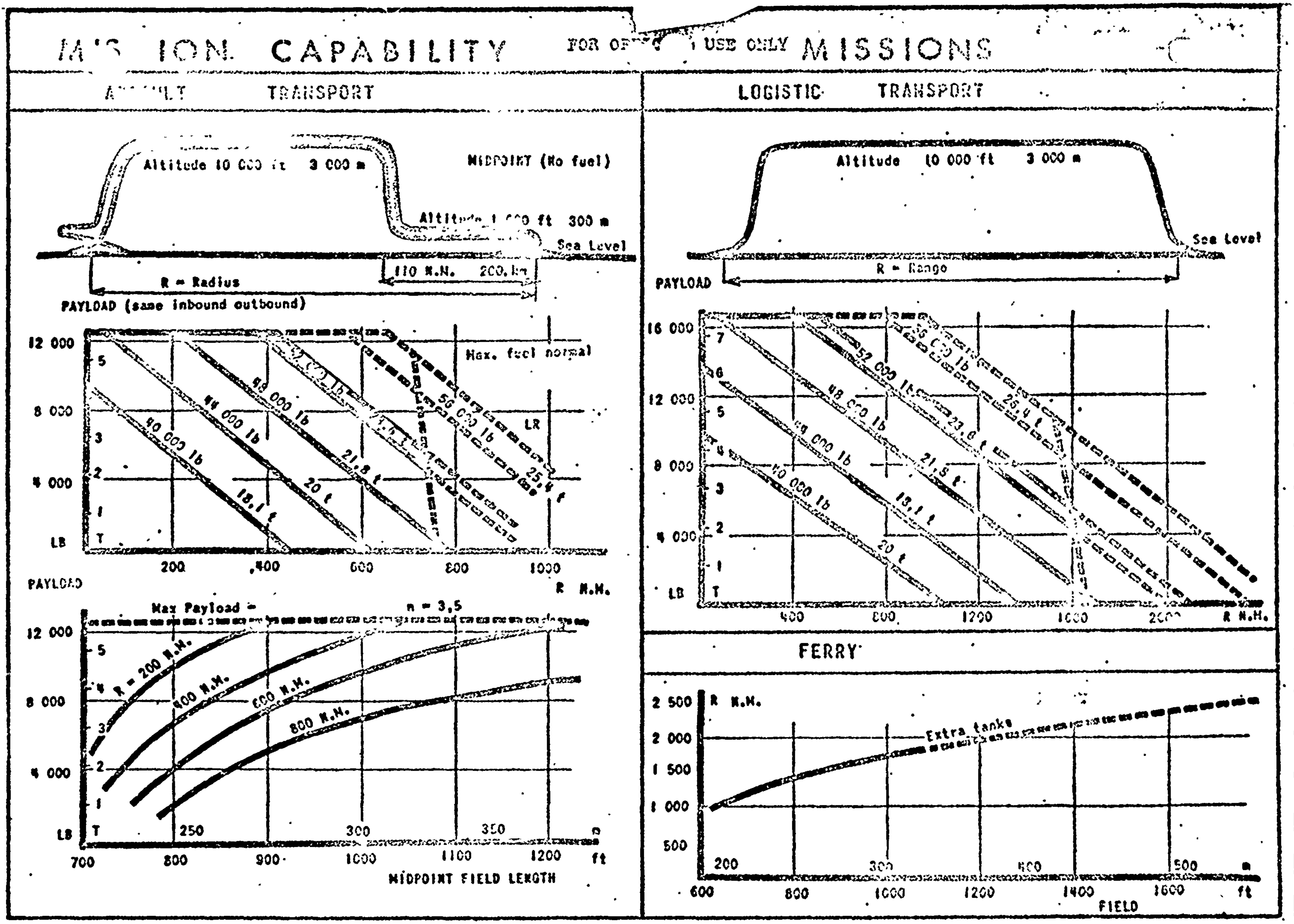

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FIG. 6

PERFORMANCE

PERFORMANCE SUMMARY

MAXIMUM PAYLOAD

Assault Mission	5,500 kg	12,100 lbs
Logistic Mission	7,500 kg	16,500 lbs

TAKE-OFF (Grass field) (See p. 18 definition of Mission profiles)

Assault (TOGW - 20,000 kg - 44,000 lbs)

- Four engine(over 10.5m-35 ft)	250 m	820 ft
- Four engine climb slope	24 %	

Logistic (TOGW - 24,000 kg - 52,900 lbs)

- Four engines(over 10.5m-35 ft)	425 m	1,394 ft
- Three engine climb slope	9 %	

Long Range (TOGW - 26,500 kg - 58,400 lbs)

- Four engines(over 10.5m-35 ft)	540 m	1,750 ft
- Three engine climb slope	9 %	

CRUISE

- Maximum cruise speed		
- Sea level	470 km/h	254 kts
- at 3,000 m - 10,000 ft	480 km/h	260 kts
- Normal cruise speed at 3,000 m - 10,000 ft	400 km/h	215 kts
- Mean cruise consumption at 3,000 m - 10,000 ft	2.18 kg/km	8.7 lbs/NM

LANDING (On Grass Field)

As indicated, the landing curve shown on the opposite page corresponds to decreasing rates of descent.

Landing distance from 15 m - 50 ft to stop :

-at 19,000kg (41,900lbs), V_z 4 m/s (800 ft/mn) 225 m - 738 ft
-at 21,000kg (46,300lbs), V_z3,6m/s (720 ft/mn) 270 m - 885 ft
-at 24,000kg (52,300lbs), V_z2,8m/s (560 ft/mn) 375 m -1,230 ft

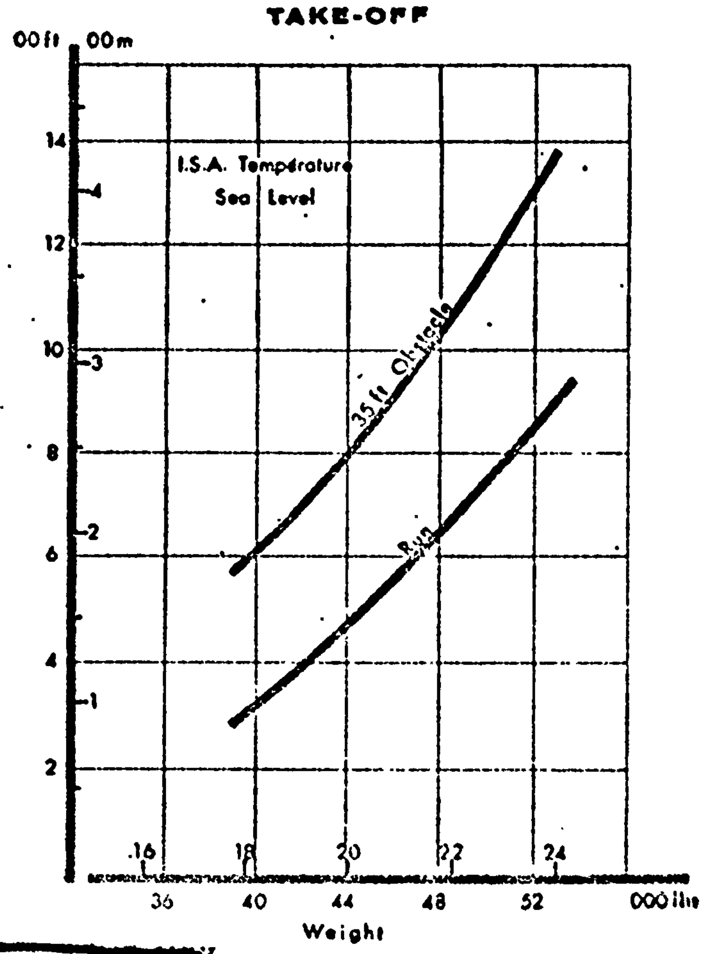

FIG.7

LANDING DISTANCE

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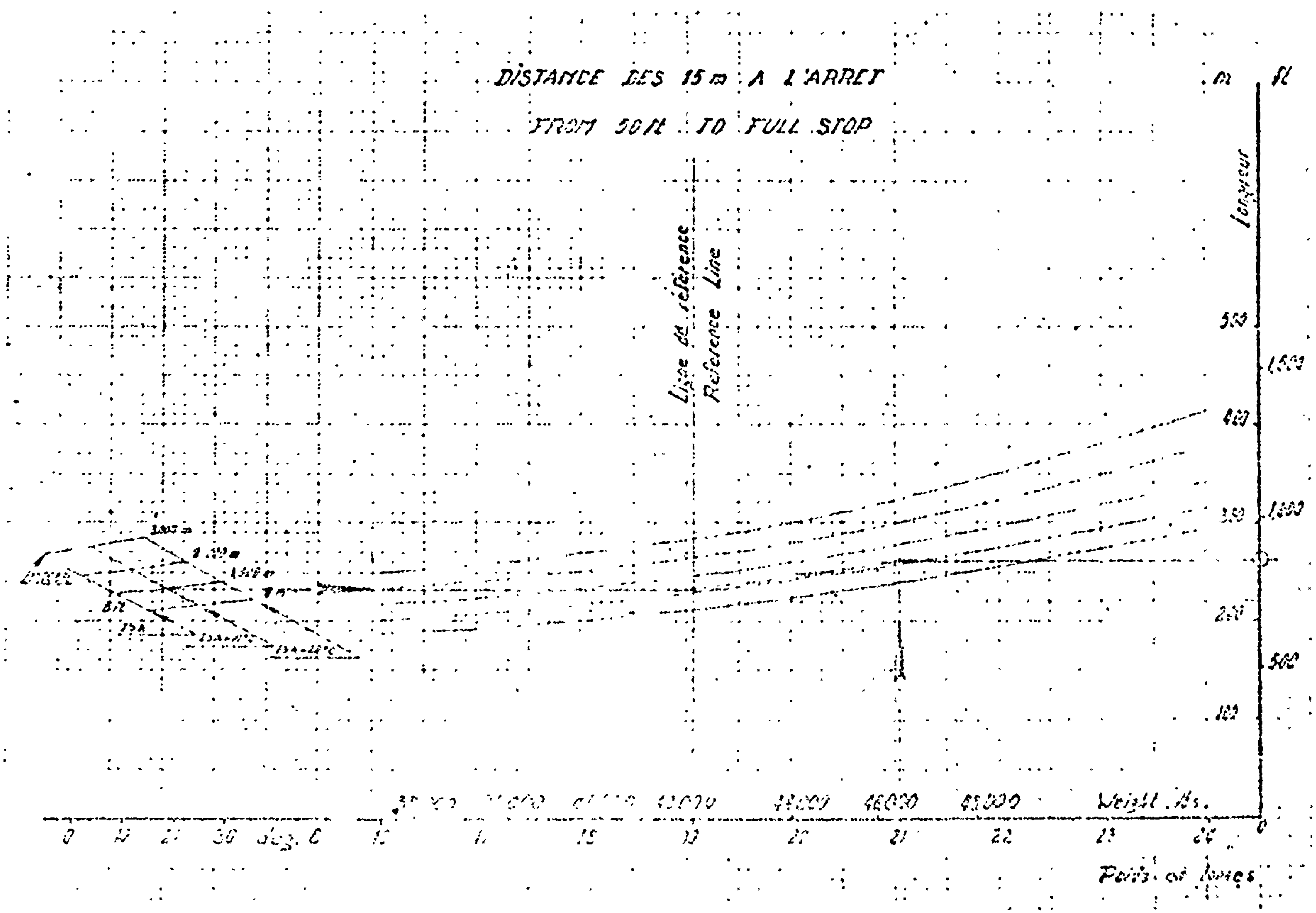

FIG. 8

FLIGHT ENVELOPE

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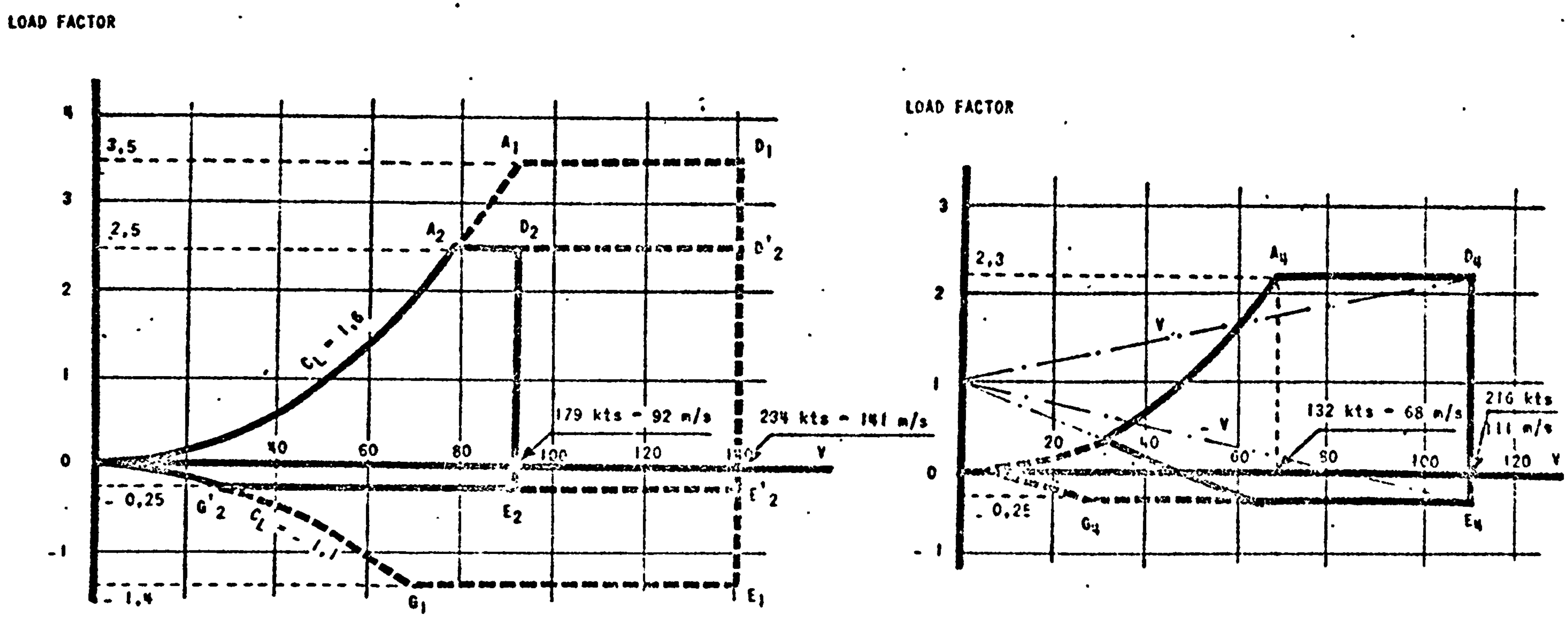
BASIC MANEUVER ENVELOPE

BASIC GUST ENVELOPE

AIRCRAFT WEIGHT 44 000 lbs

CRUISE CONFIGURATION



$OA_1\ D_1\ G_1$ { Symmetrical maneuver

$OA_2\ D'_2\ E'_2\ G'_2$ { Non symmetrical maneuver

V - EQUIVALENT AIRSPEED

V = GUST VELOCITY = 50 ft/s

[redacted]

FIG. 9

[redacted]

Flying Qualities and Performance Evaluation of the Breguet 941
Turbo-prop Troop Transport

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