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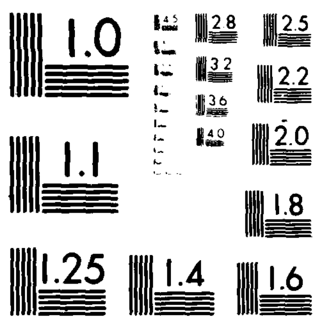

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FLYING QUALITIES EVALUATION RU-21A CEFIRM LEADER AIRPLANE

FINAL REPORT

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Airborne sensor equipment	Pilot workload

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The United States Army Aviation Engineering Flight Activity conducted a flying qualities evaluation of the RU-21A CEFIRM LEADER airplane, manufactured by Beech Aircraft Corporation. Flight tests, conducted at the Beech facility in Wichita, Kansas, on 9 and 10 October 1974, encompassed 6.8 flight hours. Testing was conducted to evaluate the handling qualities of the RU-21A CEFIRM LEADER airplane within the contractor-developed flight envelope. The design changes

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20. Abstract

incorporated in the RU-21A CEFIRM LEADER aircraft produced no significant change in the aircraft handling qualities. The contractor's flight envelope was determined to be acceptable and it is recommended that the RU-21A CEFIRM LEADER supplement to the operator's manual incorporate stall airspeed data on the results of these tests. Five shortcomings were determined but need not be corrected until future designs. They are, in order of importance: excessive right aileron displacement required during the approach and landing sequence, ineffective lateral trim system, inaudible stall warning at high power settings, early activation of the artificial stall warning system, and high pilot workload in airspeed and altitude retention. Within the scope of this evaluation, the flight handling qualities of the RU-21A CEFIRM LEADER airplane are acceptable.

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INTRODUCTION

BACKGROUND

1. In 1969 four RU-21A, three RU-21B, and two RU-21C aircraft were modified by Beech Aircraft Corporation (BAC) and Fairchild Hiller Aircraft Service Division in support of classified CEFIRM LEADER mission requirements. These modifications were comprised of internal mission equipment racks and external antenna configurations but did not alter the basic aircraft dimensions. The RU-21A CEFIRM LEADER aircraft have been utilized for airborne sensor equipment evaluations since December 1969. The latest modification of the aircraft, accomplished in 1974 at the BAC facility at Wichita, Kansas, in response to United States Army Security Agency mission requirements, involves major external modifications as described in paragraph 3. The BAC conducted an airworthiness investigation of the CEFIRM LEADER aircraft through flight testing and engineering analysis. The United States Army Aviation Engineering Flight Activity (USAAEFA) was directed by the United States Army Aviation Systems Command (AVSCOM) to qualitatively evaluate the handling qualities of the modified CEFIRM LEADER aircraft prior to releasing the aircraft for mission suitability testing (ref 1, app A). Henceforth, the term "RU-21A CEFIRM LEADER" will denote the latest version of CEFIRM LEADER aircraft, as described in paragraph 3 and appendix B.

TEST OBJECTIVE

2. The objective of this test was to evaluate the airplane handling qualities that might have been influenced by the airframe modifications. Test results were to substantiate BAC flight test and engineering analysis data from which the RU-21A CEFIRM LEADER aircraft airworthiness and operational flight envelope were determined.

DESCRIPTION

3. The test aircraft, serial number 67-18113, was a production RU-21A modified to the present RU-21A CEFIRM LEADER configuration by installation of 18-inch wing tip extensions; installation of wing-tip pod antennas; removal of the wing high-frequency dipole antennas; installation of 8.50 x 10, 10-ply main landing gear tires; and modified nacelle doors to accommodate the larger landing gear tires. Figure 1 of appendix B is a three-view drawing of the aircraft showing areas of structural modification. The maximum gross weight had been increased to 10,200 pounds. Mission equipment racks were installed but no mission equipment was on board. The basic RU-21A is an unpressurized, low wing, all-metal airplane powered by two T74-CP-700 turboprop engines. A complete description of the basic RU-21A is contained in the operator's manual (ref 2, app A).

TEST SCOPE

4. A limited flying qualities evaluation of the RU-21A CEFIRM LEADER airplane was conducted at the BAC facility at Wichita, Kansas, on 9 and 10 October 1974. Four test flights were conducted for a total of 6.8 hours. All tests were conducted with an aircraft engine start gross weight of 10,250 pounds ballasted to the aft center-of-gravity (cg) limit. The flight envelope limits of the operator's manual and the safety-of-flight release (ref 3, app A) were observed during this evaluation. Handling qualities were evaluated against the requirements of military specification MIL-F-8785B(ASG) (ref 4, app A) and the modified Cooper-Harper Handling Qualities Rating Scale (HQRS), shown in appendix D, was used to rate aircraft handling qualities during certain critical flight tasks. A summary of the test configurations is presented in table 1 and test conditions are shown in table 2.

Table 1. Test Configurations.

Configuration	Gear	Flaps	Power	Propeller Speed (rpm)
Cruise (CR)	Up	Up	PLF[1], 170 KIAS[2]	1900
Glide (G)	Up	Up	Idle	[3]1900
Power approach (PA)	Down	35%	PLF, 120 KIAS	2000
Landing (L)	Down	100%	Idle	[3]2200
Waveoff (WO)	Down	100%	Topping[4]	2200
Takeoff (TO)	Down	Up	Topping	2200

[1]PLF: Power for level flight.
[2]KIAS: Knots indicated airspeed.
[3]Propeller speed at trim prior to reducing power to idle.
[4]During these tests, the topping power was N_1 limited at the test altitudes.

Table 2. Test Conditions.

Test Description	Density Altitude (ft)	Outside Air Temperature (°C)	Gross Weight (lb)	Center-of-Gravity Location (in.)	Indicated Airspeed (kt)	Configuration
Static lateral-directional stability	6920	11	9340	160.1	120	CR
	6940	12	9800	159.7	170	
	7400	12	10,040	159.6	120	PA
Static lateral-directional stability	7260	14	9640	159.8	170	CR
	7260	14	9860	159.7	120	PA
Dynamic longitudinal stability	7040	12	9480	159.9	120	CR
	7260	14	9800	159.7	170	
	7140	13	9940	159.6	120	PA
Dynamic lateral-directional stability	7040	12	9400	160.0	120	CR
	7260	14	9720	159.8	170	
	7140	13	9860	159.7	120	PA
Roll performance characteristics	7260	14	9840	159.7	170	CR
	7260	14	9800	159.7	120	PA
Stall characteristics	10,020	2	9940	159.6	100	TO
	10,180	2	10,100	159.4	120	CR
	10,800	2	9880	159.7	100	PA
	6180	10	10,140	159.3	100	PA
	10,180	2	10,000	159.6	120	G
	10,800	2	9760	159.8	100	L
	6180	10	10,080	159.4	100	WO
	11,020	4	9680	159.8	100	WO
Single-engine characteristics	11,140	5	10,150	159.3	170	CR
	11,140	5	10,120	159.4	120	TO
	7400	13	10,080	159.4	120	TO

TEST METHODOLOGY

5. Engineering flight test techniques prescribed in reference 5, appendix A, were used during this evaluation. Elevator and rudder control positions were measured by cloth tape measures, while aileron control deflections were measured in degrees of wheel deflection. Elevator forces were measured by a hand-held 50-pound force gage. Aileron and rudder forces were estimated. A calibrated sensitive airspeed indicator and altimeter were installed. Power parameters were observed on calibrated aircraft instruments. An airspeed calibration was conducted by BAC and the data from this calibration were used to determine the calibrated airspeeds plotted in appendix C. All data were hand-recorded and data reduction was accomplished manually. The aircraft takeoff weight and longitudinal cg location were determined prior to commencing flight testing. Weighing was accomplished using electronic scales located under the aircraft jack points with the crew on board at their designated stations. All test condition weights were calculated utilizing a calibrated production cockpit fuel flow instrument and recorded time. The test condition cg's were read from a cg loading diagram provided by BAC.

RESULTS AND DISCUSSION

HANDLING QUALITIES

General

6. The handling qualities of the RU-21A CEFIRM LEADER were qualitatively evaluated, with the airplane at near maximum gross weight and aft cg limits, against the requirements of MIL-F-8785B(ASG). No deficiencies and five shortcomings were found. The shortcomings are excessive right aileron displacement required during the approach and landing sequence, ineffective lateral trim system, inaudible stall warning at high power settings, early activation of the artificial stall warning system, and high pilot workload in airspeed and altitude retention.

Static Longitudinal Stability

7. The static longitudinal stability characteristics of the RU-21A CEFIRM LEADER were evaluated at the conditions shown in table 2. The aircraft was trimmed in steady-heading coordinated level flight at the desired trim airspeed. While maintaining constant power and trim settings, the airspeed was stabilized at 5 to 10-KIAS increments up to 30 KIAS greater or less than the trim airspeed. Longitudinal control forces and positions were measured and test results are presented in figures 1 through 3 of appendix C.

8. The static longitudinal stability, as indicated by the variation of stick force with airspeed about the trim airspeed, was positive in both the CR and PA configurations. Stick force gradients were more shallow on the low-speed side of trim than on the high-speed side of trim. At airspeeds approaching a stall in the PA configuration, the stick force gradient became essentially neutral. Though static longitudinal stability in the WO configuration was not specifically tested, stall testing revealed that in the WO configuration the stick force gradient actually reversed and near-zero stick force was required at 60 KIAS (para 24). Static longitudinal stability, as indicated by the variation of elevator control column position with airspeed, was slightly positive in the CR configuration. In the PA configuration, the elevator control position gradient was neutral. Although during this test a 60-KIAS band around trim required only 1/4 inch of control displacement, the shallow control position gradients were not objectionable, due to the positive elevator force cues to airspeed variation from trim. The static longitudinal stability of the CEFIRM LEADER airplane at an aft cg position did not meet the requirements of MIL-F-8785B(ASG), paragraph 3.2.1.1, in that in the PA configuration, an aft trim position of the elevator control was not required to maintain an airspeed slower than trim and a forward elevator control position was not required to maintain an airspeed faster than trim airspeed. Within the scope of this test, the static longitudinal stability of the RU-21A CEFIRM LEADER is satisfactory because of the adequate force cues.

Static Lateral-Directional Stability

9. Static lateral-directional stability characteristics were qualitatively evaluated using steady-heading sideslip, aileron-only turns, and rudder-only turns. Though not a standard test for lateral-directional handling qualities, the capability of the aircraft to be turned with wings level was evaluated. This maneuver is used to turn the aircraft during certain mission profiles. Due to the absence of acceptable sideslip angle indication, no quantitative data were taken.

10. The static directional stability as indicated by the variation of rudder pedal deflection and force with sideslip angle was positive. The rudder pedal force and displacement were essentially linear with sideslip angle up to full rudder deflection sideslips right and left. Positive effective dihedral was indicated by the requirement for aileron force and control displacement into the sideslip (*ie*, right aileron required in a right sideslip). Aileron control displacement and force appeared to be essentially linear with sideslip angle. Side-force characteristics, as indicated by the variation of bank angle with sideslip, were positive and the side forces as sensed by the pilot provided excellent cues of the out-of-trim flight condition.

11. Lateral-directional handling qualities were further evaluated during aileron-only turns, rudder-only turns, and wings-level turns. During aileron-only turns, no measurable adverse or proverse yaw was encountered. During normal maneuvering the aircraft was flown virtually as a two-control (aileron and elevator) airplane, with only minimal rudder compensation required when rapid bank angle changes were made. Rudder-only turns revealed strong effective dihedral, in that bank angle was easily controlled by rudder application. Wings-level turns were made in the CR and PA configurations. In the CR configuration, full-rudder deflection turns were possible, with no adverse flying qualities other than the effect of the strong side forces creating an uncomfortable ride for the passengers. Nearly full opposite aileron was required to maintain wings level. No adverse pitch coupling was noted. In the PA configuration, wings-level turns were limited by aileron authority prior to reaching full rudder deflection. At these large wings-level sideslip angles, forcing the rudder to the stop set up what appeared to be a divergent Dutch-roll type oscillation. This oscillation presented no problem, in that it occurred at a point well beyond the normal maneuver limits and recovery was immediately effected when rudder pressure was partially released. The static lateral-directional characteristics of the RU-21A CEFIRM LEADER were qualitatively judged to have met the requirements of MIL-F-8785B(ASG) and are satisfactory.

Dynamic Longitudinal Stability

12. The short-period mode of the RU-21A CEFIRM LEADER was evaluated by elevator control pulses and doublets. The short-period characteristics were essentially deadbeat with no observable overshoot in aircraft attitude. The short-period characteristics of the RU-21A CEFIRM LEADER are acceptable.

13. The phugoid mode was evaluated by varying the airspeed 15 KIAS above and below the trim airspeed, followed by a slow elevator control release to a zero stick force condition. The phugoid mode of the RU-21A CEFIRM LEADER was oscillatory in both the CR and PA configurations and the initial tendency of the aircraft was to return to trim after releasing elevator control force, indicating that the elevator force static stability was stable. In the CR configuration at a 170-KIAS trim airspeed, the phugoid oscillation was lightly damped. In the CR configuration at a 120-KIAS trim airspeed, the phugoid oscillation approached neutral stability, and in the PA configuration trimmed at 120 KIAS, the character of the phugoid mode was oscillatory divergent. Phugoid mode frequency and damping characteristics are shown in table 3. Throughout this test program, the phugoid mode was continually excited. This tendency to be easily excited, coupled with the low phugoid damping, made longitudinal trim difficult to establish with precision. Airspeed variations of 3 to 5 KIAS were common in all phases of flight where the pilot was not tightly in the control loop to suppress the incipient phugoid oscillation. This tendency precluded accurate determination of a trim airspeed band for the RU-21A CEFIRM LEADER; however, qualitatively, the trim airspeed band was approximately 2 KIAS either side of the trim airspeed. The tendency for the phugoid mode to be easily excited will require the pilot to concentrate his efforts on controlling airspeed during instrument flight to avoid excessive airspeed and altitude excursions (HQRS 4). The high pilot workload in airspeed and altitude retention due to an easily excited phugoid oscillation is a shortcoming which should be corrected in future designs. The phugoid oscillation characteristics meet the requirements of MIL-F-8785B(ASG) under Level 1 (CR, 170 KIAS), Level 2 (CR, 120 KIAS), and Level 3 (PA at 120 KIAS). Within the scope of this test, the longitudinal dynamic stability characteristics of the RU-21A CEFIRM LEADER are acceptable.

Table 3. Phugoid Mode Characteristics.

Configuration	Trim Indicated Airspeed (kt)	Period (sec)	Damping Ratio (nondimensional)	Undamped Natural Frequency (radians/sec)
CR	170	46.2	0.087	0.137
CR	120	35.3	0.008	0.178
PA	120	32.9	-0.020	0.191

Dynamic Lateral-Directional Stability

Dutch-Roll Characteristics:

14. The Dutch-roll characteristics of the test aircraft were qualitatively evaluated at the conditions shown in table 2, utilizing the rudder pedal doublet technique. At a 170-KIAS trim airspeed in the CR configuration, the Dutch-roll period was 3.5 seconds and the roll-to-yaw ratio was estimated to be 1:1.5. The oscillation was moderately damped, returning to trim conditions after four to six overshoots. At the 120-KIAS trim airspeed in the PA configuration, the Dutch-roll period was 4.5 seconds and the roll-to-yaw ratio was estimated to be 1:2. The longer period and larger yaw excursion as compared to roll probably is a function of decreased directional stability at 120 KIAS, as compared to the 170-KIAS condition; however, the Dutch-roll oscillation remained noticeably damped. Pilot inputs were not necessary to suppress the Dutch roll during any phase of testing; however, purposely exciting the Dutch roll tended to excite the spiral mode to the right. Within the scope of this test, Dutch-roll characteristics of the RU-21A CEFIRM LEADER are satisfactory.

Spiral Stability:

15. The spiral stability characteristics of the RU-21A CEFIRM LEADER were evaluated by establishing trimmed level flight conditions, then stabilizing in a 20-degree bank angle, using rudder only. After the bank angle was established, the rudder pedal was slowly returned to trim and the resulting tendency of the aircraft to increase or decrease bank angle was noted. In an effort to determine precise lateral trim, spiral stability was evaluated at different aileron trim settings. At all conditions tested up to full-left-wing-down aileron trim, the aircraft exhibited a tendency to decrease bank angle in turns to the left and increase bank angle in turns to the right. This was indicative of either insufficient aileron trim to establish precise lateral trim conditions, or a shift in the spiral stability between right and left turns. The rates of convergence and divergence were, however, essentially equal at a given aileron trim setting and very slow. The aircraft seemed to possess sufficient friction in the aileron control system to allow aileron displacement to trim the aircraft in hands-off level flight. However, sideslips or gusts can upset this balance, requiring pilot effort to restore wings-level flight (HQRS 3). Within the scope of this evaluation, the spiral stability of the RU-21A CEFIRM LEADER is satisfactory.

Roll Performance

16. The roll performance characteristics of the RU-21A CEFIRM LEADER were evaluated at the conditions shown in table 2. These tests were initiated by trimming the aircraft in wings-level flight and then establishing a 60-degree bank angle turn. From a stabilized 2g turn, maximum-deflection opposite aileron was applied and the time to roll from a 45-degree bank angle to the opposite 45-degree bank angle was determined. Elevator and rudder control inputs were not utilized. At both the 170-KIAS and 120-KIAS trim airspeeds, the time required to roll through a

90-degree bank angle was 3.5 seconds for rolls to the right and 3.0 seconds for rolls to the left. During the 90-degree roll attitude change, the roll rate was essentially constant. Roll-to-pitch or roll-to-yaw coupling was not noticeable and there were no adverse handling qualities. Within the scope of the test, the roll performance characteristics of the RU-21A CEFIRM LEADER are satisfactory.

Stall Characteristics

17. Dual and single-engine stall characteristics were evaluated at the conditions listed in table 2. Stalls were initiated from the specified trim conditions by accomplishing a slow (1 knot per second) deceleration to the stall. Stall was defined by an uncontrollable roll or pitch-down airplane motion, depending on the configuration and power setting. Test results are presented in table 4. The RU-21A CEFIRM LEADER supplement to the operator's manual should be adjusted to reflect the stall airspeed data of table 4.

18. Stalls in the CR configuration were characterized by activation of the stall warning horn at approximately 15 to 18 KIAS above the stall airspeed, followed by an airframe buffet which increased in severity as the stall was approached. Airframe buffet onset occurred approximately 3 to 5 KIAS above the stall. The premature activation of the artificial stall warning device is a shortcoming, in that it occurs so early that the operational pilot may tend to ignore it. Additionally, the stall warning device is a horn which sounds in the cockpit. During stalls at high power settings with an associated high noise level in the cockpit, the stall warning horn was virtually inaudible, a shortcoming which should be corrected in future aircraft. The airframe buffet provided excellent cues to the impending stall; however, a rapid deceleration to a stall would minimize this characteristic. All flight controls remained effective during the approach to stall and no reduction in longitudinal control force was noted. The stall itself was defined by a rapid left roll. Roll attitudes of 30 to 60 degrees, left wing down, were reached during recovery with no power reduction. Stall recovery was immediate upon release of aft wheel pressure and wings-level flight was regained by application of right aileron control. The roll following the stall was minimized by applying up to full right rudder pedal during the recovery or by reducing the power to idle as the stall occurred (HQRS 3).

19. Accelerated stalls in the CR configuration were accomplished in 30-degree bank left and right turns. The stall and recovery was essentially the same as in the wings-level CR configuration. The stall was left-wing-down in both right and left turns, with a higher apparent roll rate developed in the right turning stall (HQRS 3). During the approach to the turning stall, increasing aileron into the turn was required to maintain the desired angle of bank, indicating a tendency of the aircraft to roll out of the turn as stall airspeed was approached. This is an enhancing characteristic that provides an extra stall warning and would tend to reduce the severity of unintentional stalls.

Table 4. RU-21A CEFIRM LEADER Stall Airspeeds.

Configuration	Gross Weight (lb)	Center-of-Gravity Location (in.)	Pressure Altitude (ft)	Stall Warning Horn Indicated Airspeed (kt)	Buffet Indicated Airspeed (kt)	Stall Indicated Airspeed (kt)
CR	10,100	159.4	9500	92	80	77
G	10,000	159.6	9500	94	90	78
TO	9940	159.6	11,000	78	78	74
PA	9880	159.7	10,000	79	62	61
	10,140	159.3	5500	85	65	64
L	9760	159.8	10,000	78	73	67
WO	9680	159.8	10,000	66	55	54
	10,080	159.4	5500	65	54	54
CR	10,060	159.4	9500	101	89	[1]84
	10,020	159.5	9500	96	81	[2]78
CR[3]	10,150	159.3	10,000	Note[5]	Note[5]	[4]84
TO[3]	10,100	159.4	10,000	Note[5]	Note[5]	[4]83
	10,080	159.4	6200	Note[5]	Note[5]	[4]84

[1]30-degree left bank angle turn.
[2]30-degree right bank angle turn.
[3]Left engine inoperative and feathered, right engine at topping power.
[4]Stall airspeed below minimum-control airspeed.
[5]Not recorded.

20. Wings-level stalls in the G configuration were characterized by unmistakable airframe buffet, beginning 12 KIAS above the stall and increasing in severity as the stall point was approached. This buffet, felt through the airframe and elevator control, produced a porpoising effect as the stall point was approached, making a precise definition of the stall airspeed difficult. This characteristic did, however, provide excellent cues to an impending stall (HQRS 2).

21. Stalls in the TO configuration were characterized by an extremely nose-high (over 15 degrees) attitude and excellent warning in the form of airframe buffet occurring 4 KIAS above stall airspeed. The stall was characterized by a slow drop of the left wing and recovery was immediate on release of aft wheel pressure with virtually no altitude loss. Stick forces were light but positive (HQRS 1).

22. In the PA configuration, the airframe buffet was very mild; occurring only 1 KIAS above stall airspeed, the buffet was not a sufficient stall warning. The pilot must rely on the inadequate electronic stall warning system in the PA configuration. The stall was characterized by a more violent left roll in this configuration than in any other configuration. A normal stall (rate of deceleration greater than 1 knot per second) was accomplished to evaluate pilot cues and reaction time during PA stalls. This stall resulted in the aircraft rolling 110 degrees to the left and pitching to an attitude 60 degrees below the horizon before the pilot could react. This resulted in a zero-g condition and excessive altitude loss during recovery. The rapid roll and pitch-down were controlled by application of full right rudder and full right aileron at the first sign of airframe buffet. However, this is not a normal stall recovery procedure. Due to the inadequate stall warning margin, the operational pilot could not be expected to apply these controls in a timely manner to preclude the roll tendency in an inadvertent PA stall. While this characteristic is hazardous, the stall, occurring at 61 to 64 KIAS, is well below the airspeed band in which power approaches are flown. Thus, this characteristic should not normally be encountered. A discussion of the consequences of PA stalls should be included in the operator's manual and the maneuver should be demonstrated or discussed in detail during U-21 transition training. A proposed NOTE discussing PA stalls is presented below.

NOTE

> Power-on stalls with gear and flaps extended on the RU-21A CEFIRM LEADER may result in the aircraft rolling past a 90-degree left bank angle and pitching nose down. This results in altitude losses on the order of 1000 feet prior to recovery. The stall occurs at a low airspeed (64 KIAS) and the warning buffet occurs only 1 knot prior to the stall. Large attitude excursions and altitude losses may be avoided either by reducing power to low idle at the stall or by application of full right rudder and right aileron as the buffet is detected. Power approaches below 70 KIAS should be avoided.

23. Stalls in the L configuration were mild and were characterized by a pitch oscillation, due to a cyclic-type airframe/elevator buffet. As in the G configuration stalls, this oscillation/buffet precluded a precise determination of stall airspeed but provided excellent stall warning. The aircraft was controllable to the stall; however, when the aircraft was held on the verge of the stall, there was a tendency for pilot inputs to increase the amplitude of the oscillation, forcing the aircraft to stall (HQRS 2).

24. Stalls in the WO configuration were characterized by an oscillatory motion in pitch during stall entry. Elevator forces became lighter as airspeed was decreased to reach a minimum (near-zero) aft wheel force at 60 KIAS. From this airspeed, increasing aft control was required to stall the aircraft but elevator control forces remained light (HQRS 3).

25. Single-engine stalls with either engine feathered were essentially the same as dual-engine stalls. Recoverv was accomplished by standard stall recovery techniques, including going to flight-idle on the operative engine (HQRS 3).

26. Within the scope of this test and the operating limits prescribed for the RU-21A CEFIRM LEADER airplane, the stall characteristics are satisfactory. The stall characteristics of the RU-21A CEFIRM LEADER failed to meet the requairements of the following paragraphs of MIL-F-8785B(ASG):

a. Paragraph 3.4.2.1.1 - Perceptible airframe or control buffet warning of impending stall did not occur at a minimum of 5 knots above stall speed in the CR, PA, TO, and WO configurations.

b. Paragraph 3.4.2.1.1 - Artificial stall warning device activates in excess of 10 knots above stall speed.

c. Paragraph 3.4.2.1.1 - Pitch oscillations in excess of ±2 degrees of pitch attitude occur during the approach to power-off stalls in the G configuration and during the approach to power-on stalls in the WO configuration.

d. Paragraph 3.4.2.1.3 - After a brief delay, recovery from PA stalls was not possible without excessive altitude loss.

Single-Engine Characteristics

27. The single-engine handling qualities of the RU-21A CEFIRM LEADER were evaluated with either the left or right engine shut down and propellers feathered. Data showing minimum trim airspeeds and minimum control airspeeds are presented in table 5. Single-engine flight characteristics were excellent. The aircraft could be trimmed throughout a normal single-engine approach and only light rudder forces were required to maintain trim during the landing flare and power reduction. Within the scope of this test, the single-engine characteristics of the RU-21A CEFIRM LEADER are satisfactory.

Table 5. Minimum Trim Airspeed and Minimum Control Airspeed.[1]

Configuration	Inoperative Engine	Minimum Trim Indicated Airspeed[2] (kt)	Minimum Control Indicated Airspeed (kt)	Gross Weight (lb)	Center-of-Gravity Location (in.)	Pressure Altitude (ft)
CR	Right	110	80	10,150	159.3	10,000
	Left	110	86	10,150	159.3	10,000
TO	Right	98	82	10,120	159.4	9000
	Right	98	80	10,080	159.4	5500
	Left	103	86	10,100	159.4	10,000
	Left	107	90	10,080	159.4	6200

[1]Operative engine at topping power.
[2]Minimum trim airspeed is established with respect to rudder trim.

Longitudinal Trim Changes

28. Longitudinal trim changes caused by power changes and flap and gear operation were evaluated during a typical approach and landing sequence. From a trim airspeed of 170 KIAS at 5000 feet pressure altitude, torque was reduced to 500 foot-pounds (ft-lb) and altitude was held constant. Level flight was established at 118 KIAS, requiring a 22-pound pull force on the elevator control. After retrimming at 118 KIAS and extension of the approach flaps (35 percent), a 3-pound elevator control push force was required to maintain level flight. Landing gear extension caused no apparent trim change but airspeed was reduced. The aircraft was retrimmed with landing gear down and flaps at the approach setting at 120 KIAS (940 ft-lb torque required). From this condition, landing flaps were extended (100 percent), requiring a 3-pound pull force to maintain airspeed at 120 KIAS. After retrimming the longitudinal force to zero at 100 KIAS, power was retarded to low-idle in the L configuration. Eleven pounds of pull force were required to maintain 100 KIAS. The longitudinal trim changes during the landing sequence were satisfactory.

Lateral Trim Changes

29. Lateral trim changes due to power changes and flap and gear operation were evaluated by maintaining 100 KIAS in the CR configuration and noting the lateral control displacement (in degrees) required to maintain wings level. Extension of the landing gear and a power adjustment to maintain 100 KIAS required 10 degrees of right aileron control displacement. Extension of approach flaps required an additional 9 degrees of right control rotation for a total displacement of 19 degrees, right, of the CR trim point. Extending full flaps and a power adjustment to maintain 100 KIAS and level flight required an additional 4 degrees of right control rotation, giving a total of 23 degrees right control displacement. A power reduction to establish a 500-foot-per-minute rate of descent did not change the right aileron requirement. The requirement for excessive right aileron displacement during the approach and landing sequence is a shortcoming which should be corrected when practical. Approximately 8 to 10 pounds of right aileron force were required to maintain 110 KIAS with gear and flaps extended. This force was uncomfortable and distracting to the pilot. Approaches were conducted in right crosswind components of 8 to 10 knots and moderate turbulence with no excessive difficulty. A rigging check of the test aircraft revealed all controls rigged within limits. This requirement to hold a significant right aileron control displacement and force during landings is a shortcoming. Future CEFIRM LEADER aircraft should be checked with regard to this phenomenon. If these aircraft exhibit the same tendency, further investigation is recommended.

Trimmability

30. The capability to trim the aircraft to a given airspeed and zero control force was evaluated throughout this test. For all configurations tested, longitudinal and directional control forces could be trimmed to zero (dual engine) throughout the flight envelope. Longitudinal, lateral, and directional trim controls were conveniently located. Longitudinal and directional trim were effective and easy to use, but lateral trim was ineffective, since the right aileron control force of 8 to 10 pounds could not be trimmed to a lower value during the approach and landing sequence. The inability to trim laterally during the landing sequence is a shortcoming which should be corrected as soon as possible. Additionally, lateral trim could be operated from full right to full left in level flight with no discernible change in lateral control force. The tendency of the aircraft to be easily excited to a long-period oscillation greatly degraded longitudinal trimmability (HQRS 4) and the airspeed retention ability of the aircraft; however, the aircraft trimmability characteristics are acceptable, except during the landing sequence.

ANTENNA VIBRATIONS

31. The tip pod antennas installed on the RU-21A CEFIRM LEADER were visually monitored throughout this test program. No visible antenna vibration or oscillation was noted. Within the scope of this test, the tip pod antenna configuration is satisfactory for flight.

CONCLUSIONS

GENERAL

32. The following conclusions were reached upon completion of testing:

a. Within the scope of this evaluation, the handling qualities of the RU-21A CEFIRM LEADER were not significantly altered from the basic RU-21A and are acceptable.

b. The contractor-proposed flight envelope for the RU-21A CEFIRM LEADER is acceptable.

c. Five shortcomings were identified during this evaluation.

SHORTCOMINGS

33. The following shortcomings were identified:

a. Pilot workload in airspeed and altitude retention is high, due to an easily excited and lightly damped phugoid oscillation (para 13).

b. The artificial stall warning device activates at an airspeed too high above the stall airspeed (para 18).

c. The stall warning horn may not be audible at high power settings, due to cockpit noise (para 18).

d. The aileron control must be held in an excessive right aileron displacement during the approach and landing sequence (para 29).

e. A right aileron control force of 8 to 10 pounds, due to trim changes associated with power adjustments, gear extension, and flap extension, could not be trimmed to a lower value during the approach and landing sequence (para 30).

SPECIFICATION COMPLIANCE

34. The handling qualities of the RU-21A CEFIRM LEADER met the requirements of MIL-F-8785B(ASG) against which they were tested except as listed below.

a. Paragraph 3.2.1.1 - The elevator position versus airspeed gradient was neutral in the PA configuration (para 8).

b. Paragraph 3.4.2.1.1 - A perceptible airframe or control buffet stall warning did not occur at a minimum of 5 KIAS above stall airspeed in power-on configurations (paras 18 through 25).

c. Paragraph 3.4.2.1.1 - The artificial stall warning activates in excess of 10 KIAS above stall airspeed in most configurations (paras 17 and 18).

d. Paragraph 3.4.2.1.1 - Pitch attitude oscillations in excess of ±2 degrees occurred during the approach to stall (paras 20, 23, and 24).

e. Paragraph 3.4.2.1.3 - After a brief delay, recovery from PA stalls was not possible without excessive altitude loss (para 22).

RECOMMENDATIONS

35. The RU-21A CEFIRM LEADER should be released for operational use within the limits defined by the operator's manual and the safety-of-flight release.

36. Correct the shortcomings listed in paragraph 33 in future aircraft.

37. The RU-21A CEFIRM LEADER supplement to the operator's manual should be adjusted to reflect the stall airspeed data of table 4.

38. A demonstration or thorough discussion of the rapid roll and pitch-down tendency of the RU-21A in PA stalls should be included in the U-21 transition training syllabus (para 22).

39. The following NOTE should be incorporated in the RU-21A CEFIRM LEADER supplement to the operator's manual:

NOTE

> Power-on stalls with gear and flaps extended on the RU-21A CEFIRM LEADER may result in the aircraft rolling past a 90-degree left bank angle and pitching nose down. This results in altitude losses on the order of 1000 feet prior to recovery. The stall occurs at a low airspeed (64 KIAS) and the warning buffet occurs only 1 knot prior to the stall. Large attitude excursions and altitude losses may be avoided either by reducing power to low-idle at the stall or by application of full right rudder and right aileron as the buffet is detected. Power approaches below 70 KIAS should be avoided.

40. Future RU-21A CEFIRM LEADER aircraft should be checked for the requirement to hold significant right lateral control during the approach and landing sequence. If future aircraft require this right lateral control displacement, further testing should be accomplished to determine corrective action (para 29).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-EFI, 20 August 1974, subject: Test Directive for CEFIRM LEADER, Project No. 75-03.

2. Technical Manual, TM 55-1510-209-10/1, *Operator's Manual, Army Model U-21A, RU-21A, and RU-21D Aircraft*, with Change 2, 1 August 1972.

3. Message, AVSCOM, AMSAV-EFI, 9-21, 031815Z Oct 74, subject: Safety-of-Flight Release for CEFIRM LEADER (RU-21A) Aircraft.

4. Military Specification, MIL-F-8785B(ASG), *Flying Qualities of Piloted Airplanes*, 7 August 1969, with Interim Amendment 1, 31 March 1971.

5. Flight Test Manual, Naval Air Test Center, FTM No. 103, *Fixed Wing Stability and Control*, 1 August 1969.

APPENDIX B. DESCRIPTION

1. The RU-21A CEFIRM LEADER airplane has the general structure of the RU-21A airplane. Major modifications are listed below.

a. Maximum gross weight for takeoff increased from 9650 to 10,200 pounds.

b. Main landing gear tires changed to 8.50 x 10, 10-ply.

c. Nacelle landing gear doors modified to accommodate the larger tires.

d. Eighteen-inch spanwise section added to each wing tip.

e. High-frequency dipole antennas removed from wing.

f. GUARDRAIL I-type antennas (22-1/2 [illegible]n diameter by 102 inches long) installed on wing tips.

2. A three-view drawing showing areas of structural modification is included as figure 1. Photos 1 through 3 show the aircraft and structural details of the tip extension and pod assembly.

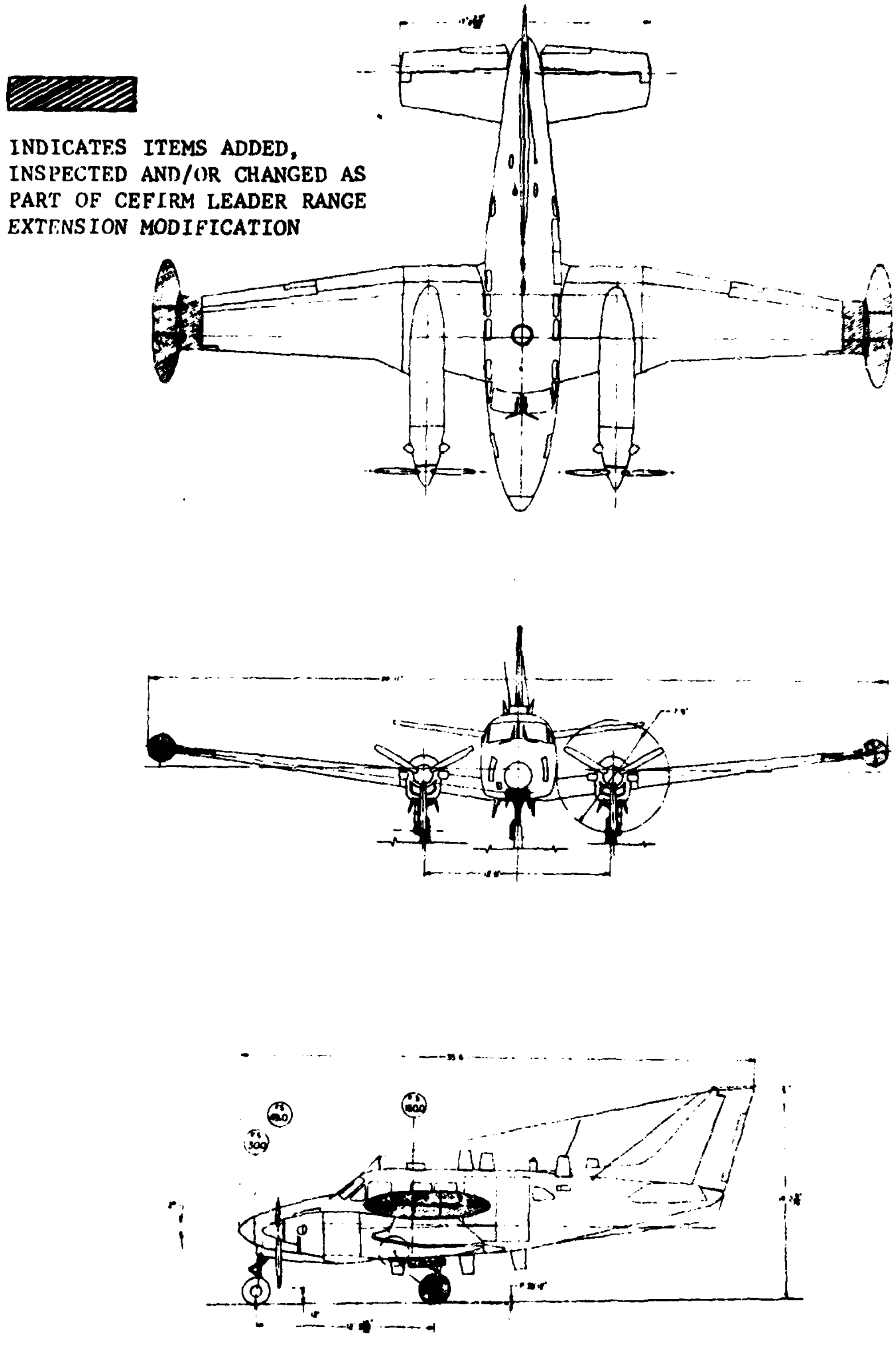


Figure 1. Three-View Drawing, RU-21A CEFIRM LEADER.

Photo 1. RU-21A CEFIRM LEADER Airplane.

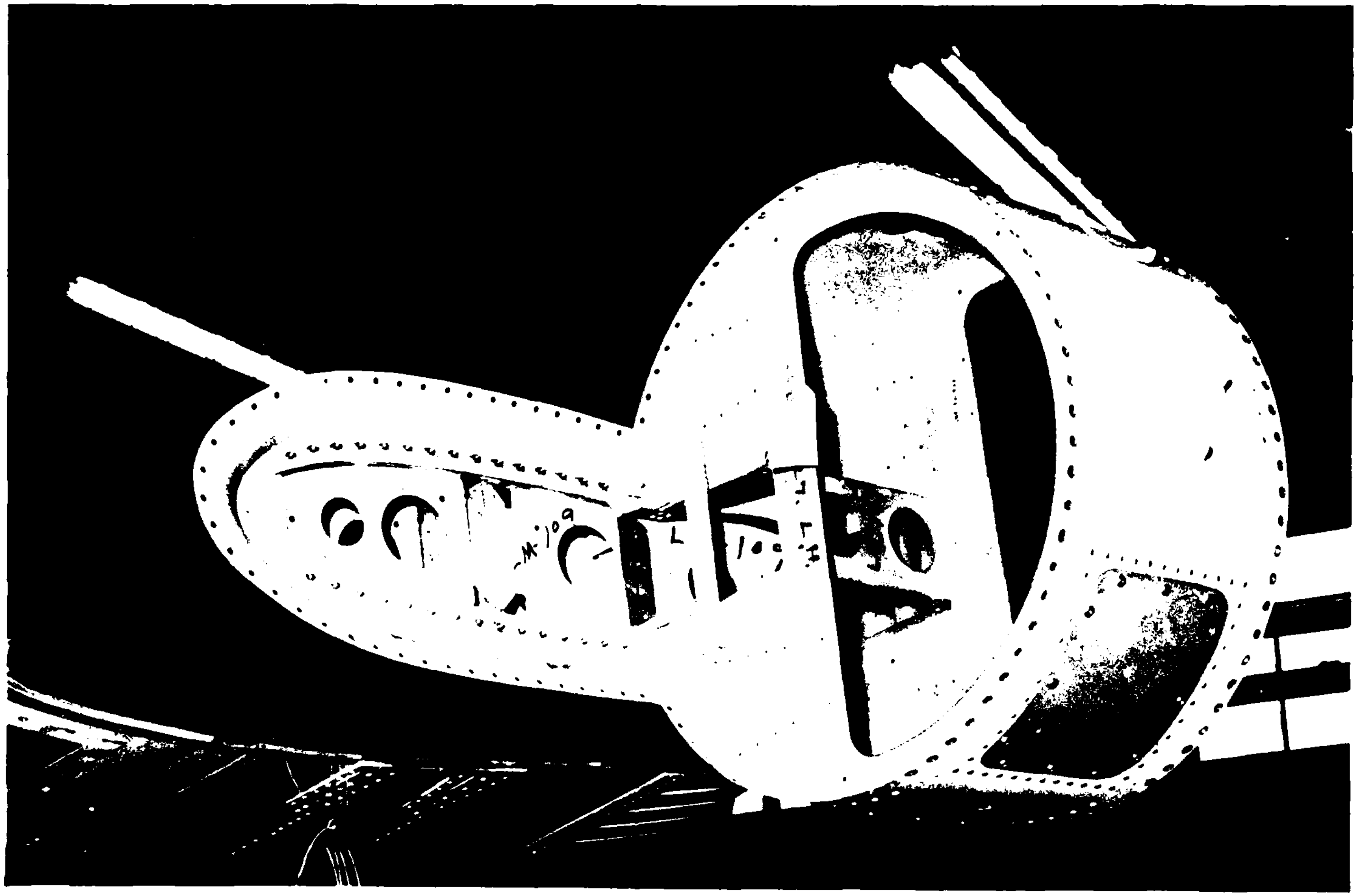


Photo 2. Detail of Wing-Tip Antenna Structure.

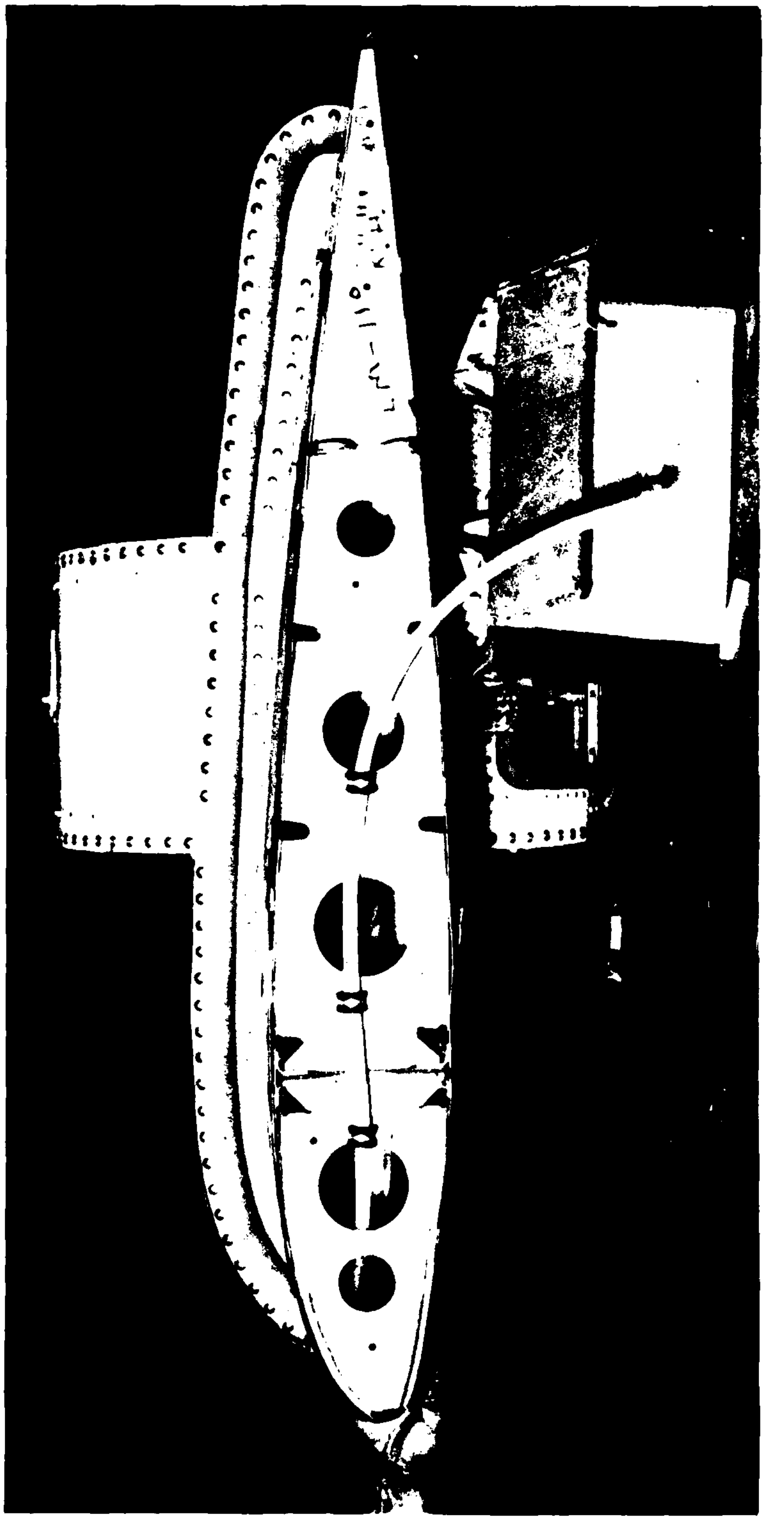


Photo 3. Wing-Tip Extension and Pod Assembly (right wing).

APPENDIX C. TEST DATA

FIGURE 1
Static Longitudinal Stability
RU-21A S/N 67-18113

Avg Gross Weight ~LB	Avg CG Location ~IN	Avg Density Altitude ~FT	Avg OAT ~°C	Configuration	Flight Condition
9340	160.1(AFT)	6920	11.0	Cruise	Level Flight

NOTE: Shaded symbols denote trim

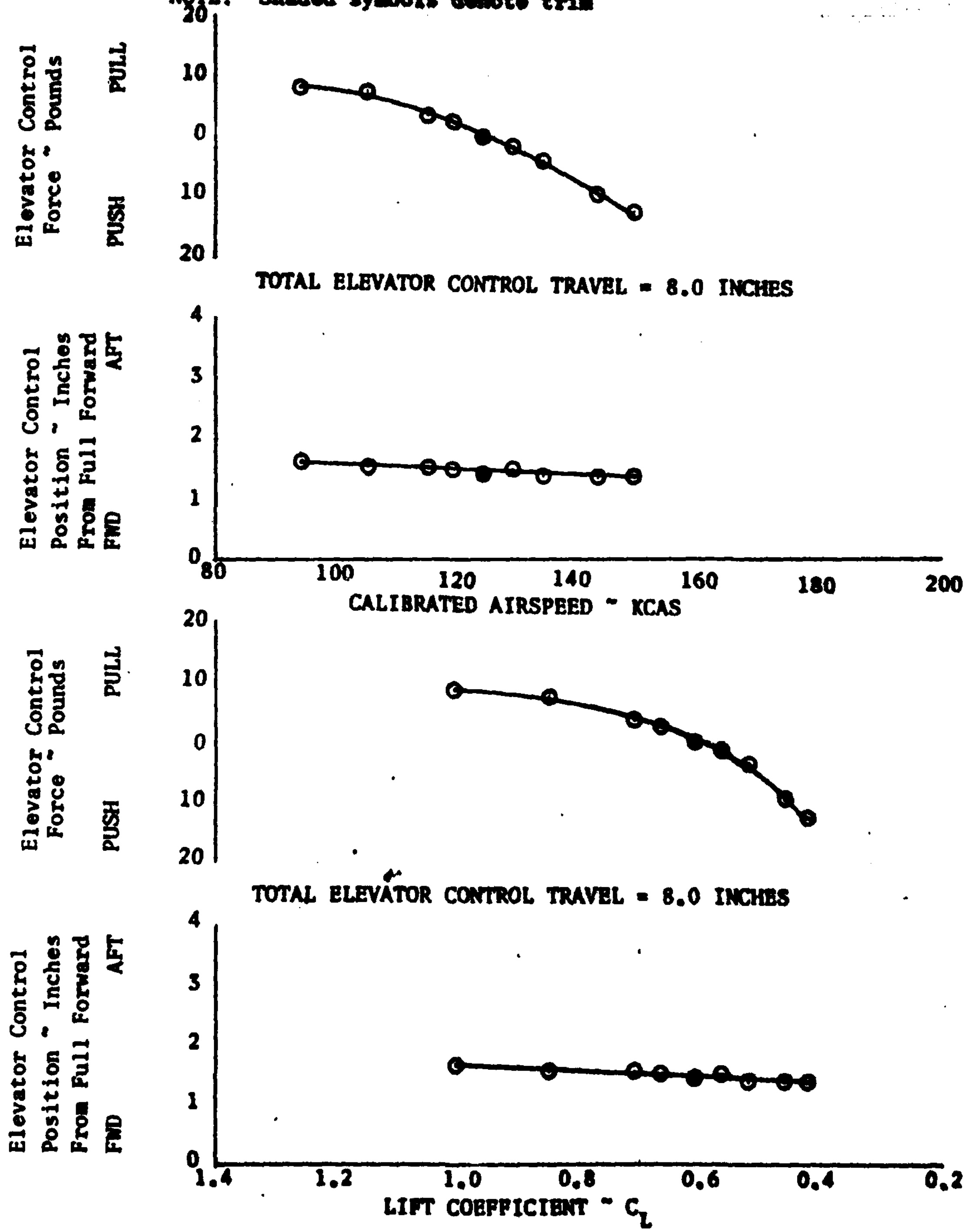


FIGURE 2
Static Longitudinal Stability
RU-21A S/N 67-18115

Avg Gross Weight ~LB	Avg CG Location ~IN	Avg Density Altitude ~FT	Avg OAT ~°C	Configuration	Flight Condition
9800	159.7 (AFT)	6940	12.0	Cruise	Level Flight

NOTE: Shaded symbols denote trim

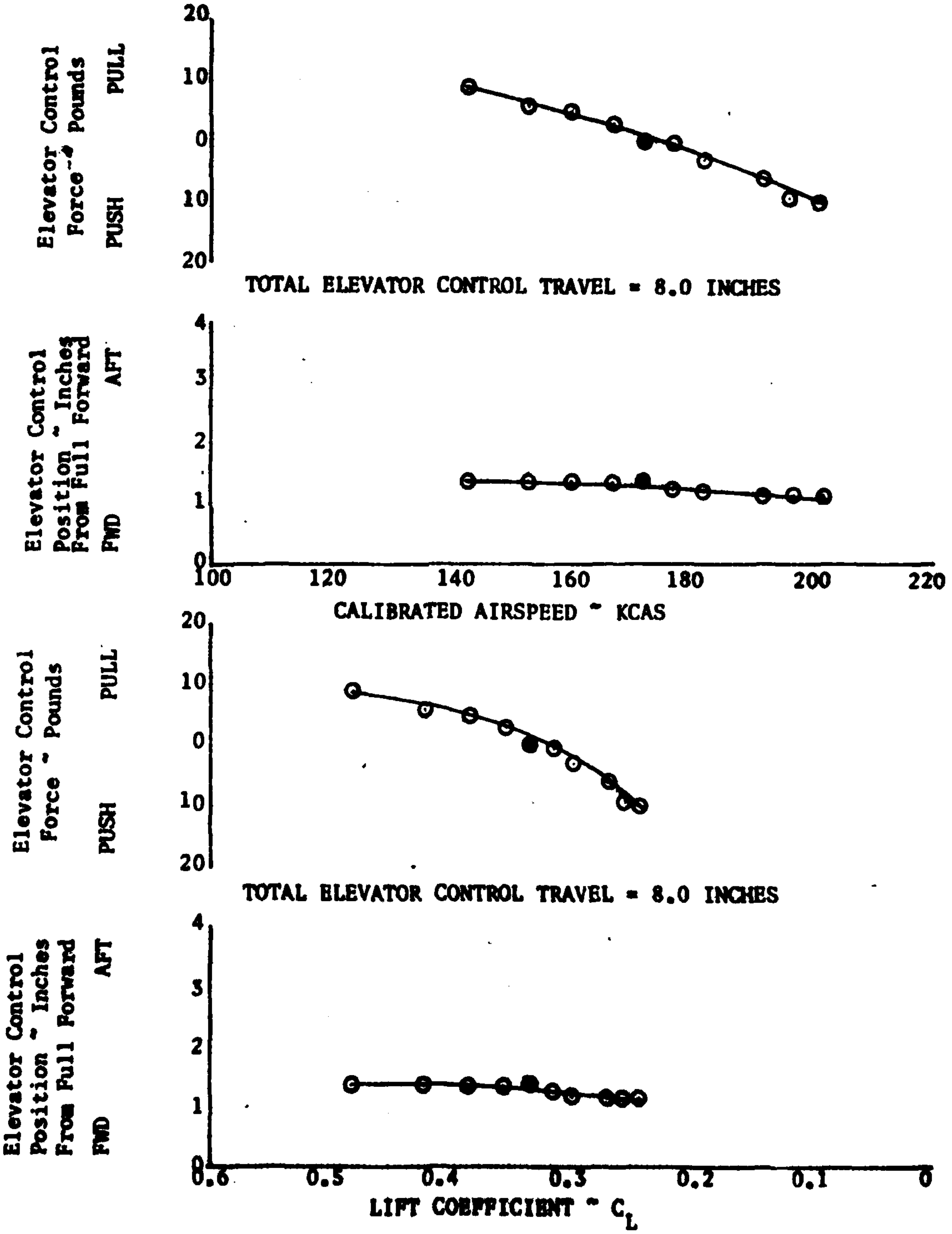
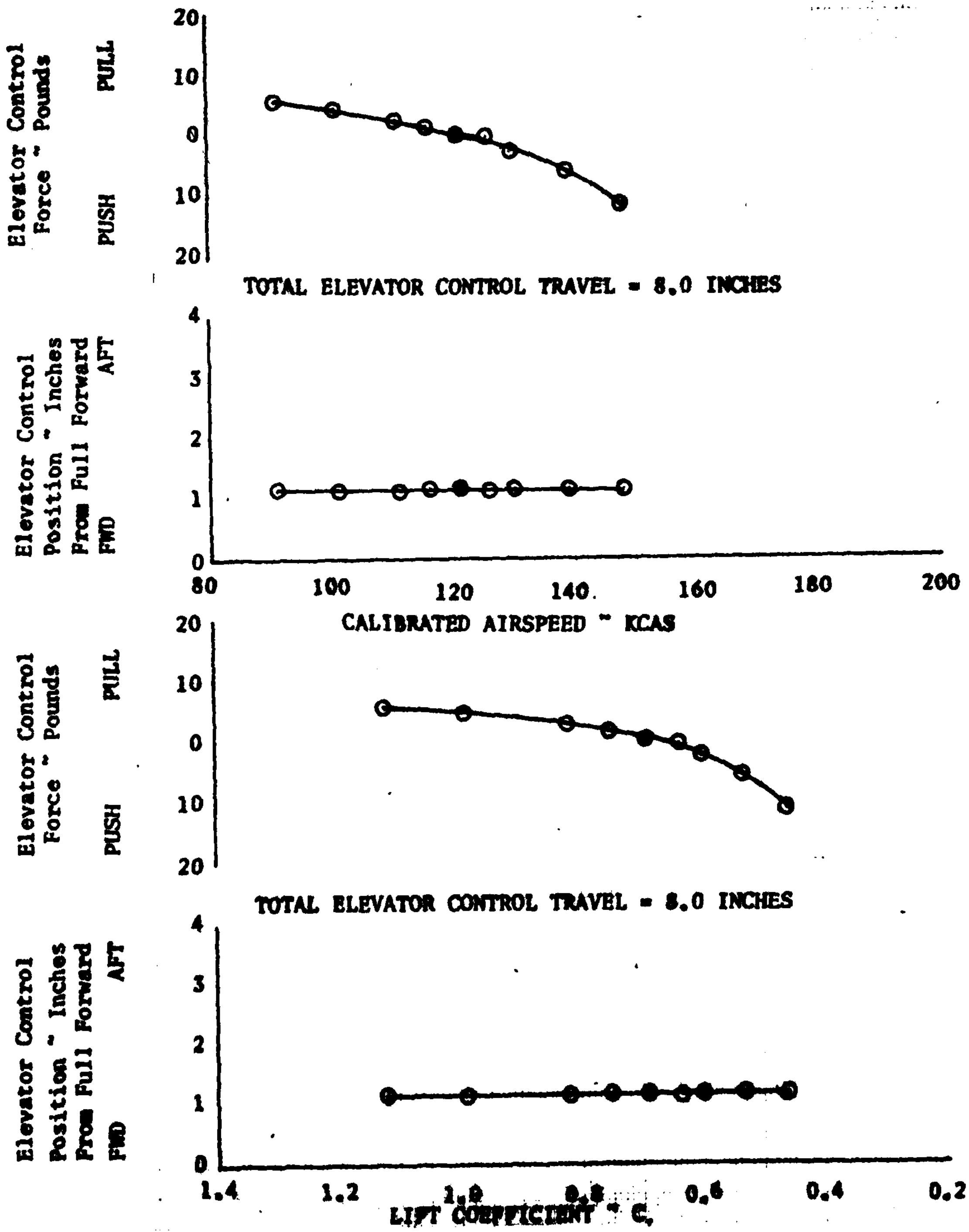


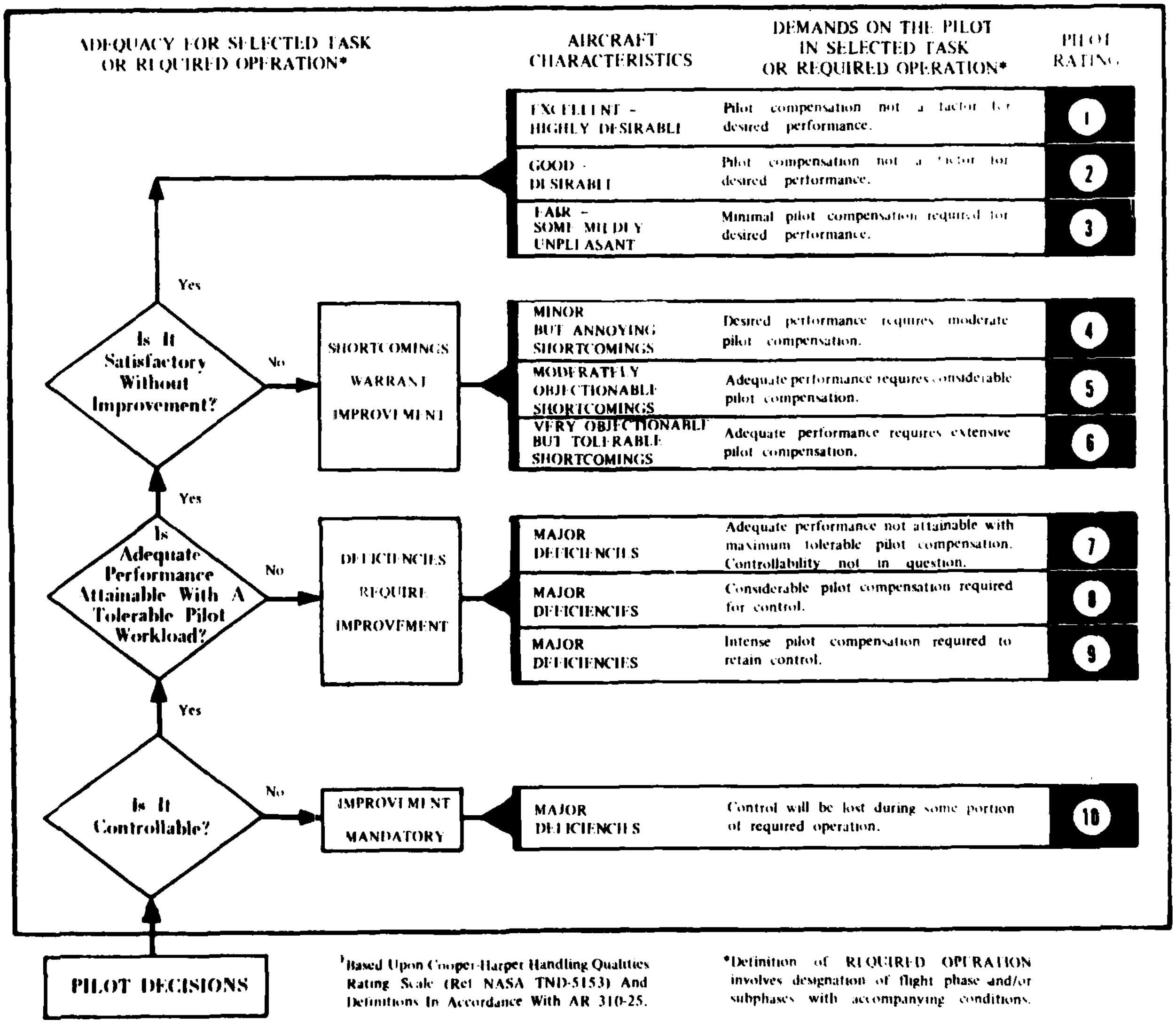
FIGURE 3
Static Longitudinal Stability
RU-21A S/N 67-18118

Avg Gross Weight ~LB	Avg CG Location ~IN	Avg Density Altitude ~FT	Avg OAT ~°C	Configuration	Flight Condition
10040	159.6(AFT)	7400	12.0	Power Approach	Level Flight

NOTE: Shaded symbols denote trim



APPENDIX D.
HANDLING QUALITIES RATING SCALE



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

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

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