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AEFA Project No. 87-13

# VERIFICATION OF THE PRODUCTION SAFE FLIGHT INSTRUMENT CORPORATION OV/RV-1D STALL WARNING SYSTEM

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Final Report

AEFA

Approved for public release, distribution unlimited.

AVIATION ENGINEERING FLIGHT ACTIVITY
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A Safe Flight Instrument Corporation (SFIC) stall warning system and prototype normal acceleration (g) limit aural warning device were evaluated on an OV-1D(C) at Edwards Air Force Base, California, from 17 to 25 August 1988. Fifteen productive test flight hours were completed. The tests were conducted with the Louvered Scarfed Shroud Suppresser (LSSS) not installed due to excessive engine nacelle and firewall temperatures previously encountered with the YT53-L-704 engines. Interchangeability of the SFIC stall warning system between aircraft was demonstrated by the good correlation of data between Grumman's test on aircraft SN 67-18922 and U.S. Army Aviation Engineering Flight Activity's (AEFA's) test on aircraft SN 62-5867 for LSSS not installed. Additionally, Grumman's data shows adequate warning margin for LSSS on. There were, however, inadequate stall margins with LSSS not installed for dual-engine unaccelerated stalls, drop tanks only, and no-stores configurations. Single engine warning margins were inadequate, especially with the right engine operating near maximum power. Accelerated stall warning margins were satisfactory for all wing stores configurations. If the SFIC system is installed on operational aircraft without LSSS, the SFIC system should be adjusted to provide approximately 3 knots more warning margin for low power stalls. The SFIC system should be installed on OV/RV-1D aircraft because of inadequate aerodynamic stall warning.

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However, to enhance pilot operational capabilities a system should be developed that provides continuous angle of attack information. The g limit aural warning device was evaluated during conduct of accelerated stalls and evasive maneuvers. The system provides adequate warning for relatively slow increases in g, but is inadequate for aggressive maneuvering above the maneuvering speed. The system was not adjustable for the various g limits associated with different wing stores configurations.

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# INTRODUCTION

## BACKGROUND

1. The Safe Flight Instrument Corporation (SFIC) stall warning system was previously evaluated on the OV-1D(C) by the U.S. Army Aviation Engineering Flight Activity (AEFA) (ref 1, 2, and 3, app A). Further development work by SFIC and Grumman Aircraft Corporation (GAC) has been completed and verification of the production stall warning system characteristics was necessary prior to a production decision. The U.S. Army Aviation Systems Command directed AEFA to evaluate the production SFIC system (ref 4). GAC's flight test report is contained in FTD-134-67.11 (ref 5).

## TEST OBJECTIVES

2. The objective of this test was to evaluate the production SFIC stall warning system. An additional objective was to evaluate a prototype normal acceleration (g) limit aural warning system.

## DESCRIPTION

3. The OV-1D(C) Serial Number 62-5867 is a two-place, midwing observation/surveillance aircraft equipped with two YT53-L-704 Lycoming gas turbine engines each rated at 1800 shaft horsepower at sea level standard day conditions. The test aircraft had AN/ALQ-136(V)2 wing tip antennae installed and a production SFIC stall warning system. The test was conducted without the Louvered Scarfed Shroud Suppresser installed due to engine firewall temperature limitations with the YT53-L-704 engines. Other configurations included the side looking airborne radar and the 147(V)1 infrared countermeasure pod. A detailed description of the aircraft is contained in appendix B and in the operator's manual (ref 6).

a. The SFIC stall warning system consists of a lift transducer (vane), lift computer, pendulous accelerometer, rudder pedal shaker and stall warning tone generator. The lift transducer provides an electrical signal to the lift computer which is proportional to the lift coefficient ratio, CL/CL max. A more detailed description of the SFIC system is included in appendix B.

b. The g limit aural warning system provides an audible tone through the intercom system above pre-determined g levels. As g levels increase above the predetermined levels the tone repetition rate of the interrupted tone increases until at the limit g the tone becomes continuous. A more detailed description of the g alert system is included in appendix B.

## TEST SCOPE

4. Testing was conducted at Edwards Air Force Base, California between 17 and 25 August 1988. Nineteen flights and 20 flight test hours (15 productive flight hours) were flown. Dual- and single-engine unaccelerated stall and dual engine accelerated stall evaluations were conducted in accordance with the test plan (ref 7), and within the limits

of the operator's manual and airworthiness release (ref 8). Tests were conducted in the configurations listed in table 1 at the conditions listed in table 2. No adjustments to the warning system were made during the tests. Stall warning margins were compared to the requirements of MIL-F-8785C (ref 9) and with the data from Grumman's test (ref 5). The stall warning aural tone was compared to MIL Standard 411D (ref 10).

## TEST METHODOLOGY

5. Established engineering flight test techniques and data reduction procedures were used during this evaluation (refs 11 and 12). The test methods are briefly described in the Results and Discussion section of this report. A more detailed description of the test techniques and data analysis methods may be found in appendix D. Data were hand recorded in the cockpit, on magnetic tape on-board the test aircraft, and via telemetry to the Real-Time Data Acquisition and Processing System (RDAPS) facility. Telemetry displays in the RDAPS facility were used to monitor critical parameters in flight. Appendix C contains listings of the test instrumentation. An airspeed calibration (fig. C-1), and weight and balance check were conducted prior to start of the flight tests. Fuel cell calibration and flight control rigging checks performed during previous stall tests were used for this evaluation. A Handling Qualities Rating Scale (fig. D-1) was used to augment pilot comments relative to the aircraft handling qualities.

Table 1. Aircraft Configuration

| Aircraft Configuration | Landing Gear Position | Flap Setting (deg) | Power Setting | |
|---|---|---|---|---|
| | | | Dual-Engine Stall | Single-Engine Stall |
| Takeoff (TO) | Down | 15 | Flight Idle and 1200 shp | 1200 shp |
| Cruise (CR) | Up | Zero | | |
| Go-Around (GA) | Up | 15 | | |
| Landing (L) | Down | 45 | | |

Table 2. Test Conditions[2]

| Test | Trim Airspeed (KIAS) | Takeoff Gross Weight (lb) | Longitudinal Center of Gravity[2] (FS) | Aircraft Configuration | Store Configuration |
|---|---|---|---|---|---|
| Dual Engine | 1.2 $V_{S1}$[3] | 15,000 | 160.3 | TO<br>CR<br>GA<br>L | None |
| | | 17,200 | 160.8 | | Two (2) 150 gallon drop tanks |
| | | 18,300 | 158.9 | | SLAR[4], two (2) 150 gallon drop tanks, AN/ALQ-147(V)1 (store Station 6) |
| Single-Engine Stall | $V_{yse}$[5] | 15,000 | 160.3 | | None |
| | | 17,200 | 160.8 | | Two (2) 150 gallon drop tanks |
| | | 18,300 | 158.9 | | SLAR, two (2) 150 gallon drop tanks, AN/ALQ-147(V)1 (store Station 6) |
| Dual-Engine Accelerated Stall | 1.4 $V_{S1}$ | 15,300 | 160.3 | TO[6]<br>CR[7] | None |
| | | 17,200 | 150.8 | | Two (2) 150 gallon drop tanks |
| | | 18,300 | 158.0 | | SLAR, two (2) 150 gallon drop tanks, AN/ALQ-147(V)1 (store station 6) |
| Mission Maneuvers | 160 | 15,500 | 157.6 | CR | SLAR |

NOTES:

[1]All tests were conducted at approximately 10,000 feet Hp with the AN/ALQ 136(V)2 antenna wing tips installed, and without the Louvered Scarfed Shroud Suppressor installed.
[2]These longitudinal centers of gravity represent normal mission centers of gravity for the configurations noted.
[3]$V_{S1}$: Dual engine power OFF stall airspeed for a specific aircraft configuration. Operator's manual recommended takeoff trim setting was used for the TO aircraft configuration.
[4]SLAR: Side Looking Airborne Radar.
[5]$V_{yse}$: Single engine best rate of climb airspeed.
[6]Tests were conducted at 1.7 g.
[7]Tests were conducted at 2.0 g and 2.5 g.

# RESULTS AND DISCUSSION

## GENERAL

6. The stall warning characteristics of the production Safe Flight Instrument Corporation (SFIC) system were evaluated without the Louvered Scarfed Shroud Suppresser (LSSS) installed in the configurations shown in table 1 and at the test conditions shown in table 2 of the Introduction. The LSSS was not installed because of excessive engine firewall and nacelle area skin temperatures experienced during previous tests (ref 3, app A). Interchangeability of the SFIC system between aircraft was demonstrated by the good correlation between Grumman's test on aircraft serial number 67-18922 and the U.S. Army Aviation Engineering Flight Activity's aircraft serial number 62-5867 for LSSS not installed. Additionally, Grumman's data shows adequate warning margin for LSSS on. Dual engine stall warning margins with LSSS removed do not meet MIL-F-8785C criteria for all configurations. Stall warning margins for the drop tanks only and no-stores configurations are inadequate in some flight conditions. A warning will be required in the handbook if the SFIC system is installed on aircraft without LSSS. If the SFIC system is installed on operational aircraft without LSSS, the SFIC system should be adjusted to provide approximately 3 knots more warning margin for low power stalls. Single engine stall warning margins are unsatisfactory and will require a warning in the handbook if the SFIC system is installed. Accelerated stall warning margins met MIL-F-8785C (ref 9) criteria and are satisfactory. System effectiveness is slightly degraded by the high noise and vibration levels at high rpm/high power settings. The test aircraft, serial number 62-5867, exhibits a pedal oscillation in the flaps down configurations with power settings above 35 to 40 percent torque (ref 1 and 2). This oscillation also reduces SFIC system stall warning effectiveness in the Takeoff (TO), Landing (L), and Go-Around (GA) configurations. The OV-1D(C) stall warning system was evaluated during mission maneuvers and provided adequate tactile and aural warning of impending stall during conduct of these maneuvers. Aerodynamic buffet onset provides some warning of impending stall in some configurations, but in other combinations of power and flap settings there is no buffet. Consequently, airframe buffet is not a reliable warning of impending stall. The SFIC stall warning system provides some stall warning for all configurations even though in some cases the margins are inadequate. The SFIC aural warning tone did not meet the guidelines of MIL Standard 411D, although it was satisfactory as an effective artificial stall warning signal. In the absence of adequate stall warning, the incorporation of any stall warning system is better than none at all. However, to enhance pilot operational capabilities a system that provides continuous angle of attack information should be developed.

## DUAL-ENGINE UNACCELERATED STALL WARNING

### General

7. Dual-engine unaccelerated stall warning margins were evaluated in the aircraft configurations shown in table 1 and at the conditions shown in table 2 of the Introduction. Stalls were also conducted at 1/2 ball width out of trim, left and right, to determine the effect of sideslip on stall warning margins. Flight control trim tabs were set for each aircraft configuration as defined in appendix D. For most conditions buffet onset was followed by artificial stall warning. The stall was defined by an uncommanded

pitching, rolling or yawing or some combination of the three. Recovery from the stalled condition was easily effected by relaxation of aft stick pressure. There were insignificant differences in SFIC stall warning margins with either left or right sideslip. The SFIC stall warning margins for drop tanks only and the no-stores configurations were unsatisfactory, did not meet MIL-F-8785C requirements, and are a shortcoming. However, the SFIC system does provide some warning and therefore a margin of operational safety not available without the SFIC system. The following warning should be placed in the handbook:

**WARNING**

"The SFIC stall warning system does not provide adequate (5 knots) warning for all combinations of power, wingstores and flap settings with LSSS off, therefore, the pilot must take immediate stall preventive action at first indication of artificial warning."

**All-Stores**

8. Artificial stall warning margins for the all-stores dual engine unaccelerated stalls are presented in figure E-1, appendix E. The SFIC stall warning margins for the dual-engine unaccelerated stalls in the all-stores configuration varied from four and one-half knots calibrated airspeed (KCAS) at flight idle power to 14 KCAS at maximum power. For the approach configuration the maximum speed for warning onset allowed by paragraph 3.4.2.1.1.1 of MIL-F-8785C was exceeded by nearly two knots, while stall warning margin was approximately one-half knot less than the required five knots for some configurations. The SFIC stall warning system failed to meet MIL-F-8785C requirements at all conditions, but is satisfactory for the all-stores configuration.

**Drop Tanks**

9. Artificial stall warning margins for the drop tanks only unaccelerated stalls are presented in figure E-2. The SFIC stall warning margins for the dual-engine unaccelerated stalls for the drop tanks only configuration varied from 2.8 KCAS in the landing configuration at flight idle power to 18 KCAS in the landing configuration at maximum power. The stall warning margins for the drop tanks only configuration dual engine unaccelerated stalls do not meet the requirements of paragraph 3.4.2.1.1.1 of MIL-F-8785C in that the stall warning margin was two knots less than the five knots required. The stall warning margins for the drop tanks only dual-engine unaccelerated stalls are unsatisfactory. The artificial stall warning margin for the dual engine, drop tanks only, unaccelerated stalls is a shortcoming. However, the SFIC system provides a margin of stall warning not available without the SFIC system. If the SFIC system is installed, the warning discussed in paragraph 7 should be placed in the handbook.

**No-Stores**

10. Artificial stall warning margins for the no-stores dual engine unaccelerated stalls are presented in figure E-3. The SFIC stall warning margins for the dual-engine unaccelerated stalls for the no-stores configurations varied from two KCAS in the cruise

configuration at flight idle power to 17 KCAS for the landing configuration at maximum power. The stall warning margins for the no-stores configuration do not meet the requirements of paragraph 3.4.2.1.1.1 of MIL-F-8785C in that the stall warning margin was three knots less than the five knots required. The stall warning margins for the no-stores dual-engine unaccelerated stalls are unsatisfactory. The artificial stall warning margins for the dual engine, no-stores configuration unaccelerated stalls are a shortcoming. However, the SFIC system provides a margin of stall warning not available without the SFIC system. If the SFIC system is installed the warning discussed in paragraph 7 should be incorporated in the handbook.

**Effect of Side-Slip**

11. Dual engine unaccelerated stalls with sideslip data are presented in figures E-1 through E-3. The stalls were conducted with 1/2 ball width out of trim both left and right. This resulted, for some configurations in up to 12 degrees of sideslip at the stall. There were insignificant changes in stall warning margin with sideslip, either left or right, for all wing stores configurations.

## SINGLE-ENGINE UNACCELERATED STALL WARNING

**General**

12. The SFIC single-engine unaccelerated stall warning margins were evaluated in the aircraft configurations shown in table 1 and at the conditions shown in table 2 of the Introduction. Evaluations were conducted with both left and right engines individually shut down and feathered and with the power lever at ground idle with the propeller at maximum rpm to simulate an uncontrollable propeller. These conditions were evaluated to determine if there were propeller effects on the stall warning system, since the stall warning vane is located on the outboard portion of the right wing. The aircraft was decelerated at one knot indicated airspeed per second or less, until the stall occurred. The most significant effect (insufficient margin) was with the left engine inoperative (either windmilling or feathered) and the right engine operating at maximum power. There was no significant difference in single-engine warning margins with the left propeller windmilling or feathered. Single-engine stall warning margins do not meet MIL-F-8785C criteria and are a shortcoming. The following warning should be incorporated in the handbook if the SFIC system is installed.

**WARNING**

> "The SFIC stall warning system does not provide adequate (5 knots) warning during single-engine operation. The pilot must take immediate stall preventive action at first indication of artificial warning. Additionally, the SFIC system will not give warning of impending minimum control speed with the critical engine inoperative."

**All-Stores**

13. Artificial stall warning margins for the single engine all-stores configuration are presented in figure E-4. The SFIC stall warning margins for the single-engine unaccelerated stalls for the all-stores configuration varied from approximately one and one-half KCAS in the cruise configuration with the left propeller windmilling and the right engine at maximum power to 12 KCAS in the cruise configuration with left engine maximum power, and right propeller windmilling. The SFIC stall warning margins for the single-engine all-stores configuration do not meet the requirements of paragraph 3.4.2.1.1.1 of MIL-F-8785C in that the stall warning for some conditions was only one and one-half knots. The artificial warning for the all-stores single engine configuration is unsatisfactory and is a shortcoming. However, the SFIC system provides a margin of stall warning not available without the system. The warning discussed in paragraph 12 should be incorporated in the handbook if the SFIC system is installed.

**Drop Tanks Only**

14. Artificial stall warning margins for the single engine, drop tanks only configuration are presented in figure E-5. The SFIC stall warning margins for the single-engine unaccelerated stalls for the drop tanks only configuration varied from approximately 3 KCAS for the GA configuration (right engine at maximum power, left propeller windmilling) to 9 KCAS for the Cruise (CR) configuration (left engine at maximum power and right propeller windmilling). The stall warning margins for the single-engine drop tanks only configuration did not meet the requirements of paragraph 3.4.2.1.1.1 of MIL-F-8785C in that the minimum warning margin was 2 knots less than the 5 knots required. The artificial warning margin for the drop tanks only single engine configuration is unsatisfactory and is a shortcoming. However, the SFIC system provides a margin of stall warning not available without the system. The warning discussed in paragraph 12 should be incorporated in the operator's manual if the SFIC system is installed.

**No Stores**

15. Artificial stall warning margins for the single engine no-stores configuration are presented in figure E-6. The SFIC stall warning margins for the single-engine unaccelerated stalls for the drop tank only configuration varied from two KCAS in the GA configuration (right engine at maximum power, left engine propeller feathered) to approximately 12 KCAS in the GA configuration (left engine at maximum power and right propeller windmilling). The stall warning margins for the single-engine no stores configuration do not meet the requirements of paragraph 3.4.2.1.1.1 of MIL-F-8785C in that the stall warning margin was 3 knots less than the 5 knots required. The unsatisfactory warning margins are a shortcoming. However, the SFIC system provides a margin of stall warning not available without the system. If the SFIC system is installed the warning discussed in paragraph 12 should be incorporated in the handbook.

## DUAL-ENGINE ACCELERATED STALL WARNING

16. Dual-engine accelerated stall warning margins were evaluated in the aircraft configurations shown in table 1, at the conditions in table 2 of the Introduction. Most of

the dual-engine accelerated stalls were performed using left wind-up turns since post stall gyrations from accelerated stalls typically result in a right roll. Normal accelerations at stall varied from 1.7 to 2.5 g's.

17. A summary of dual engine accelerated stall warning margin is presented in figure E-7. Stall warning margin is presented in percent of coefficient of lift at stall. During performance of mission evasive maneuvers, the pilot could maneuver the aircraft to limit g (with the g warning system providing adequate warning) or to just below stall (with adequate warning provided by the stall warning system). The aircraft was easily prevented from stalling by reducing the severity of the maneuver (HQRS 2). The dual-engine accelerated stall warning margins for all configurations meet the requirements of MIL-F-8785C and are satisfactory.

18. Mil Standard 411D (ref 10) requires a stall aural warning tone to be an interrupted 400 Hertz (Hz) signal varying from one cycle per second at activation to ten cycles per second at the point of stall. The SFIC aural warning tone did not meet the guidelines of Mil Standard 411D although it was satisfactory as an effective artificial stall warning signal.

## ACCELERATION g LIMIT AURAL WARNING SYSTEM

19. A prototype normal acceleration g limit warning system was installed and qualitatively evaluated during this stall warning test. The pilot could select either a single or dual interrupted tone. The g alert onset could be pilot selected at 2.5 or 3 g. The dual interrupted tone was preferred as it was more readily distinguishable from the stall warning tone. The pilots preferred to have alert onset adjusted at the 3g level to avoid numerous nuisance alerts. The g alert warning system provided adequate warning for relatively slow, smooth increases to the g limit, but did not provide adequate warning during aggressive maneuvering above the maneuvering speed. The inadequate warning of impending limit g during aggressive maneuvering is a shortcoming. The 400 Hz tone was satisfactory by itself, but became difficult to differentiate from the stall warning when both were activated. The warning system tone should be evaluated in conjunction with a full-up Aircraft Survivability Equipment suite and stall warning system to determine if the proliferation of tones results in auditory saturation. A voice synthesis stall and g alert warning system should be evaluated. The g alert system should have an adjustable g limit for different load configurations.

## EXHAUST SHROUD BUCKLING

20. The left engine exhaust shroud became buckled and warped, apparently due to exhaust temperatures encountered during low speed, high powered flight. A picture of the distorted shroud is shown in figure E-9. This distortion indicates that a potential exhaust shroud overtemperature condition exists with T53-L-704 engine operation. The instrumented right engine firewall temperatures did not approach AVSCOM provided limit temperatures (315 degrees Centigrade). The exhaust shroud (non-LSSS) should be evaluated at YT53-L-704 operational temperatures at low speeds and high power to determine if the temperatures will cause shroud life reduction.

# CONCLUSIONS

## GENERAL

21. The Safe Flight Instrument Corporation (SFIC) stall warning system provided unsatisfactory warning for some stores configurations and flight conditions, however, the system provides a margin of safety not available without the system installed.

22. Interchangeability of the SFIC system was demonstrated by the good correlation of data between Grumman's test on aircraft serial number 67-18922 and the U.S. Army Aviation Engineering Flight Activity's aircraft serial number 62-5867 for LSSS not installed.

## SPECIFIC

23. The SFIC stall warning margins are satisfactory for the dual engine all stores configuration (para 8).

24. The SFIC stall warning margins for dual engine accelerated stalls (all configurations) are satisfactory (para 16).

25. There were insignificant changes in stall warning margin with side slip, either left or right, for all wing stores configurations (para 11).

26. The g alert system provided adequate warning for relatively slow, smooth increases to the g limit, but did not provide adequate warning during aggressive maneuvering (para 19).

27. The left engine exhaust shroud buckled and warped, apparently due to exhaust temperatures encountered during low speed, high power stalls (para 20).

## SHORTCOMINGS

28. The following shortcomings were identified and are listed in decreasing order of relative importance.

a. The inadequate stall warning margins for dual engine unaccelerated stalls for the Louvered Scarfed Shroud Suppressor (LSSS) off, drop tanks only and no-stores configurations (para 9 and 10).

b. The inadequate stall warning margins for single engine operation in all wing stores configurations (para 12, 13, and 14).

c. The inadequate warning of impending limit g during aggressive maneuvering provided by the g alert system (para 19).

## SPECIFICATION COMPLIANCE

29. The SFIC stall warning system failed to meet the following requirements of MIL-F-8785C:

a. Paragraph 3.4.2.1.1.1 in that the SFIC warning margins for the dual engine unaccelerated stalls, LSSS off, drop tanks only and the no-stores configuration are three knots less than required (paras 9 and 10).

b. Paragraph 3.4.2.1.1.1 in that the SFIC stall warning margins for single engine operation in all configurations were three knots less than required (para 12, 13, and 14).

30. The SFIC aural warning system failed to meet the following requirements of MIL STD 411D in that the aural stall warning tone was not an interrupted 400 Hertz audio signal varying from one cycle per second at activation to ten cycles per second at the point of stall (para 18).

## RECOMMENDATIONS

31. Install the Safe Flight Instrument Corporation Stall Warning System (SFIC) (paras 7, 8, 9, 10, 12, 13, 14, 15 and 16.

32. If the SFIC system is installed on operational aircraft without Louvered Scarfed Shroud Suppressor (LSSS), the SFIC system should be adjusted to provide approximately three knots more warning margin for low power stalls (para 6).

33. A system that provides continuous angle of attack information should be developed (para 6).

34. The following warning should be placed in the handbook (para 7):

**WARNING**

> "The SFIC system does not provide adequate stall warning for all combinations of power, wing stores, and flap settings with LSSS off, therefore, the pilot must take immediate stall preventive action at first indication of artificial warning."

35. The following warning should be incorporated in the handbook if the SFIC system is installed (para 12):

**WARNING**

> "The SFIC stall warning system does not provide adequate (5 knots) warning during single engine operation. The pilot must take immediate stall preventive action at first indication of artificial stall warning. Additionally, the SFIC system will not give warning of impending minimum control speed with the critical engine inoperative."

36. The warning system tone should be evaluated in conjunction with a full up Aircraft Survivability suite and stall warning system to determine if the proliferation of tones results in auditory saturation (para 19).

37. The g alert system should have an adjustable g limit for different load configurations (para 19).

38. A voice synthesis system should be evaluated for the stall warning and g alert systems (para 19).

39. The exhaust shroud (non-LSSS) should be evaluated at YT53-L-704 operational temperatures at low speeds and high power to determine if the temperatures will reduce shroud life (para 20).

## APPENDIX A. REFERENCES


1. Final Report, AEFA Project No. 84-13, *Evaluation of the OV-1D Stall Warning Characteristics*, January 1986.

2. Final Report, AEFA Project No. 85-16, *Evaluation of the Safe Flight Instrument Corporation Stall Warning System for the OV-1D Aircraft*, February 1986.

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## APPENDIX B. DESCRIPTION

### DESCRIPTION

1. The OV-1D(C) test aircraft, serial number 62-5867 (figs. B-1 and 2) is a two-place, twin engine turboprop aircraft featuring a mid-wing, triple vertical stabilizers, and tricycle landing gear. Seven external store stations, (one on the fuselage, six on the wings) are used to carry a variety of surveillance pods and/or fuel tanks. For this program, the aircraft was tested in three wing stores configurations: no stores, two 150 gallon drop tanks installed (drop tanks only configuration); and with two 150 gallon drop tanks, AN/ALQ-147A(V)1, with the Side Looking Airborne Radar (SLAR) boom installed (the ALL-STORES configuration). The Louvered Scarfed Shroud Suppresser (LSSS) was not installed. The AN/ALQ-136(V)2 wing tip antennas (fig. B-3) and a production Safe Flight Instrument Corporation (SFIC) stall warning system was installed. A more detailed description of the basic OV-1 aircraft is contained in the operator's manual (ref 6, app A).

2. The production (SFIC) stall warning system consisted of the following components: a lift transducer, lift computer, pendulous accelerometer, rudder pedal shaker, and stall warning tone generator. The lift transducer is an electromechanical device consisting of a movable vane and mounting plate which incorporates integral anti-icing heaters. The anti-icing heaters are activated through the aircraft pitot heat switch. The lift transducer was mounted on the right wing (fig. B-3). The spanwise location of the center of the lift transducer vane was at right wing station 274.0. The chordwise location of the center of the lift transducer vane was on the lower surface of the wing leading edge 5.375 inches forward of the forward edge of the skin line on the bottom of the wing (where the wing skin and deice boot join). This corresponds to 6.531 inches forward of the forward edge of the skin line on the top of the wing (where the wing skin and deice boot join). These dimensions were measured along the surface of the wing deice boot. During flight, the vane position is determined by airflow stagnation point location on the wing and is a function of local airflow which varies with changes in angle of attack of the wing. The lift transducer provides an electrical signal to the lift computer which is proportional to the lift coefficient ratio, CL/CLmax. The flap position transmitter is an electro-mechanical device which supplies flap position information to the lift computer. The flap position transmitter is connected to the flap system and automatically supplies flap position information to the lift computer to compensate for the effect of flap position on lift coefficient. A landing gear switch automatically disables artificial stall warning and supplies low heat to the anti-icing heaters of the lift transducer when the aircraft pitot heat switch is ON, and the aircraft is on the ground. The pendulous accelerometer transmits a signal to the lift computer as a function of variation of aircraft pitch attitude, normal acceleration and longitudinal acceleration. The stall warning activation schedule is presented in figure B-4. A block diagram of the stall warning system is shown in figure B-5. The lift transducer, flap position transmitter and pendulous accelerometer supply signals to the lift computer which activates the rudder shaker and audio tone at a predetermined margin prior to the aircraft reaching an aerodynamic stall. The rudder pedal shaker was mounted on the pilot's left rudder pedal. A 400 Hertz audio tone at +12 decibel milliwatts activates simultaneously with the rudder shaker to provide an aural stall warning signal to the intercom system. The tone volume can be neither decreased nor disabled by the flight crew. The stall warning system incorporates a self-test switch which

allows the pilot to check the system on the ground or in flight. When the aircraft is on the ground, a solenoid in the lift transducer actuates to push the vane forward and simulate a stall condition activating the rudder shaker and stall warning tone. Actuating the self-test switch in flight introduces an electrical test signal simulating forward movement of the lift transducer vane causing rudder shaker and stall warning tone activation. A more detailed description of the SFIC stall warning system can be found in the SFIC Pre-Stall Warning System Pilot's Guide (ref 14).

3. The g limit aural warning system is intended to improve pilot awareness of aircraft fatigue stress levels by providing an audible tone through the intercommunications system above pre-determined g levels. For this test, a cockpit control unit was provided which allowed selection of warning initiation at the 2 1/2 or 3 g level. The test pilot could select single or dual interrupted tone, and adjust tone volume. As g levels increased above the selected initiation level the repetition rate of the interrupted tone increased until at 4 g the tone became continuous. A self test switch activated the tone to verify that the system was operational. The g alert system was installed in accordance with Grumman Technical Bulletin, TB 134-ST-TB-85, 21 August 1987 (ref 15).

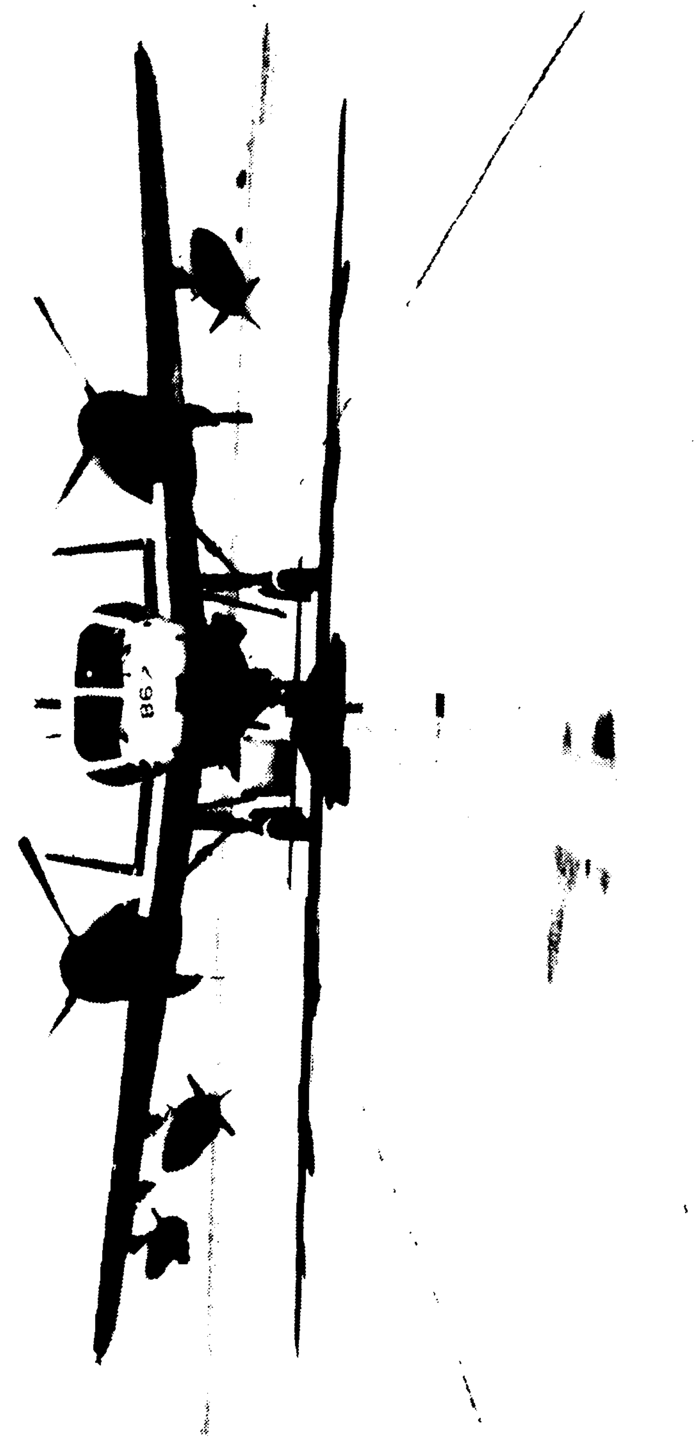


Figure B-1. All Stores Frontal View

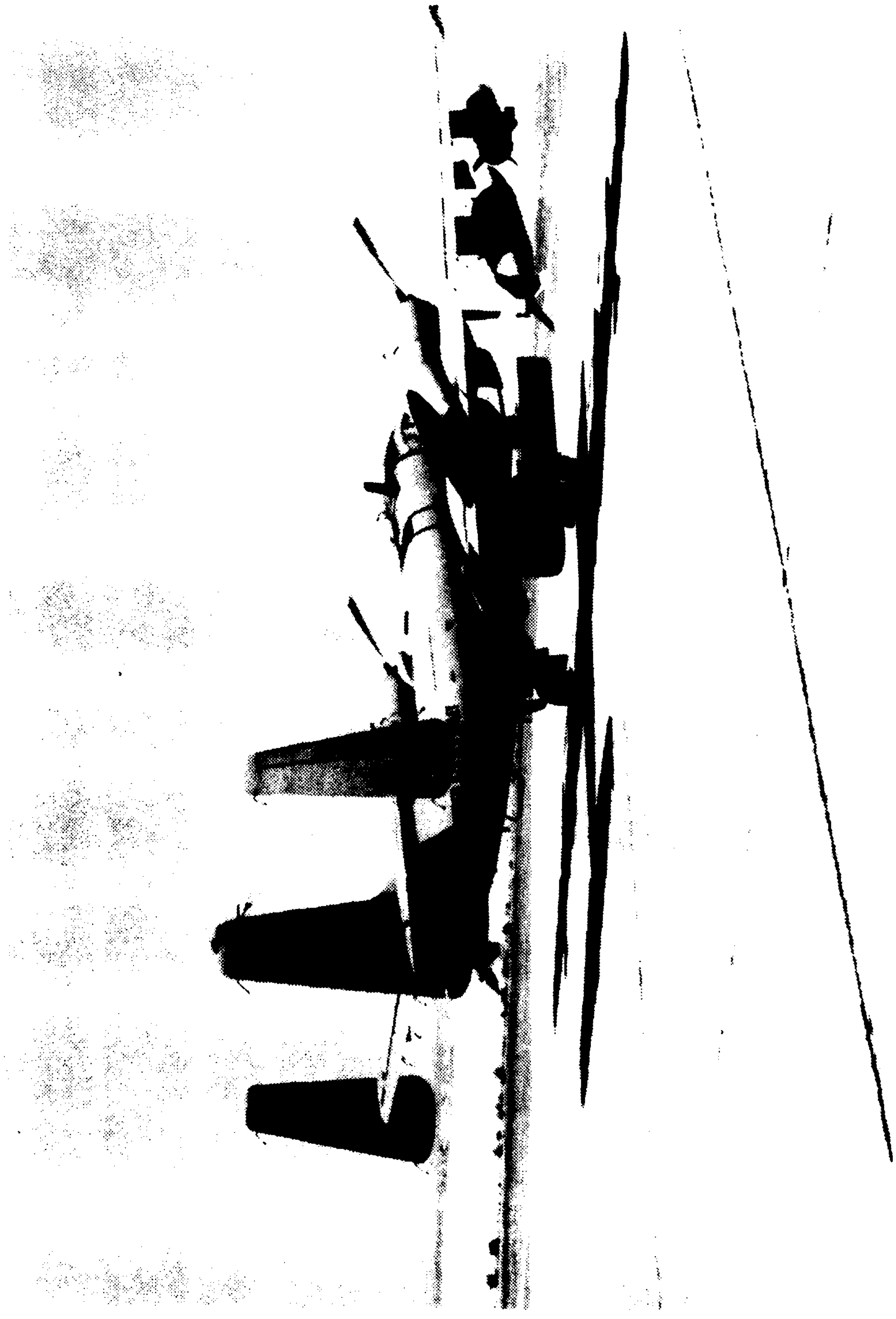


Figure B-2. All Stores Quarter View

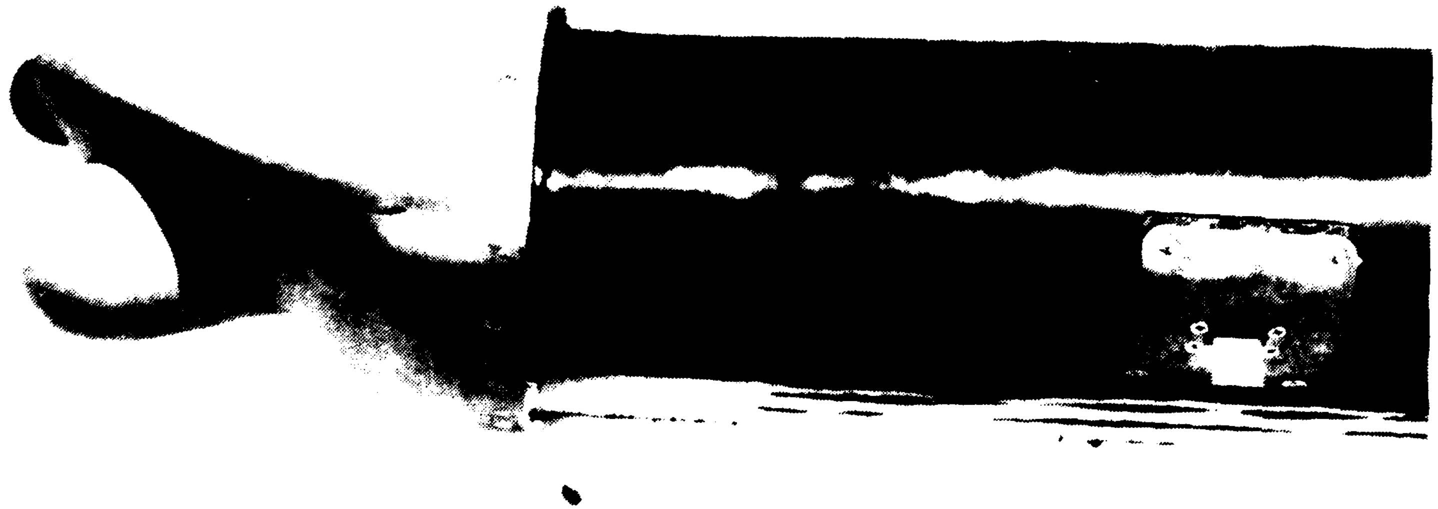


Figure B-3. OV-1D(C) Right Wing Tip (Front View)

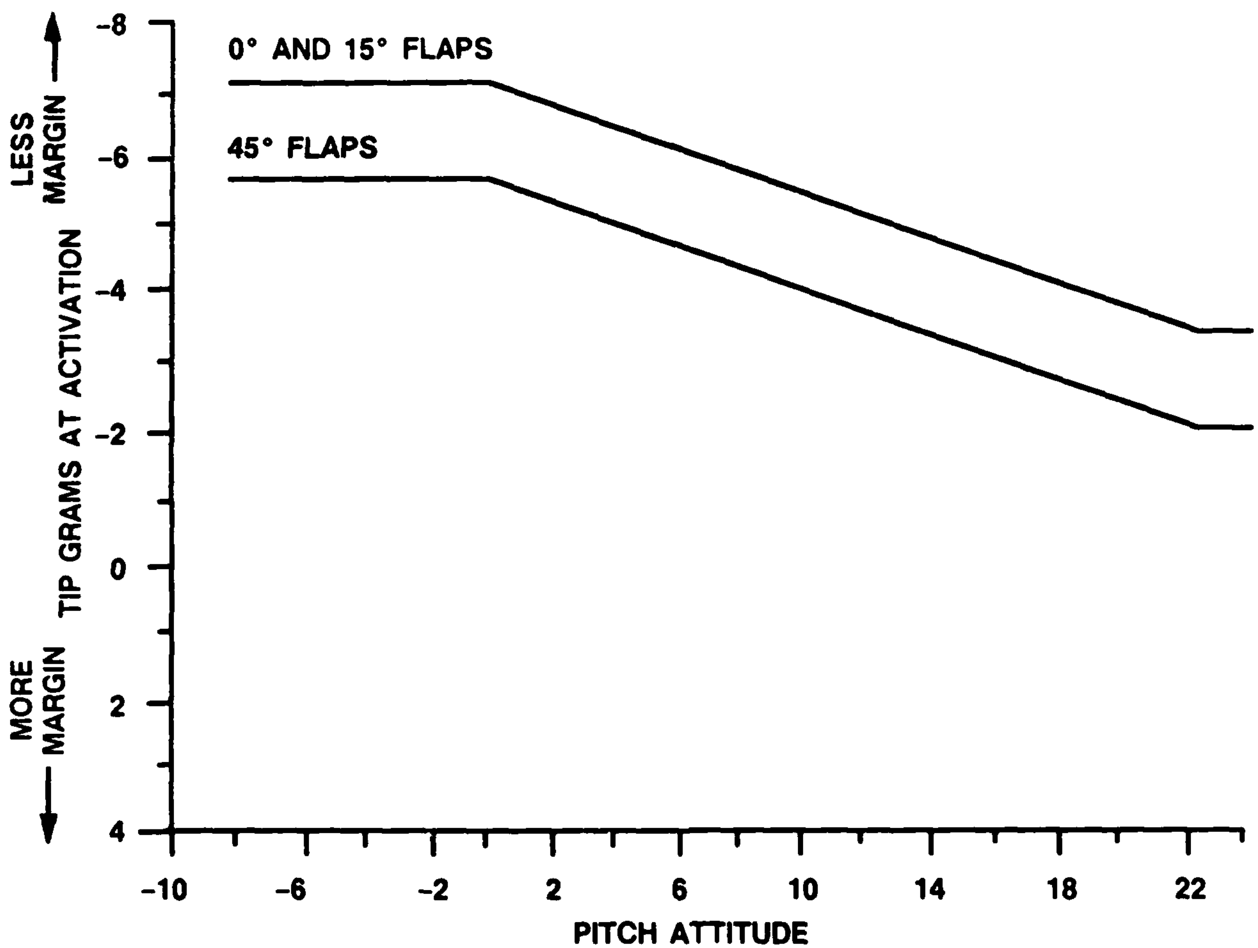



Figure B-4. Stall Warning Schedule 4

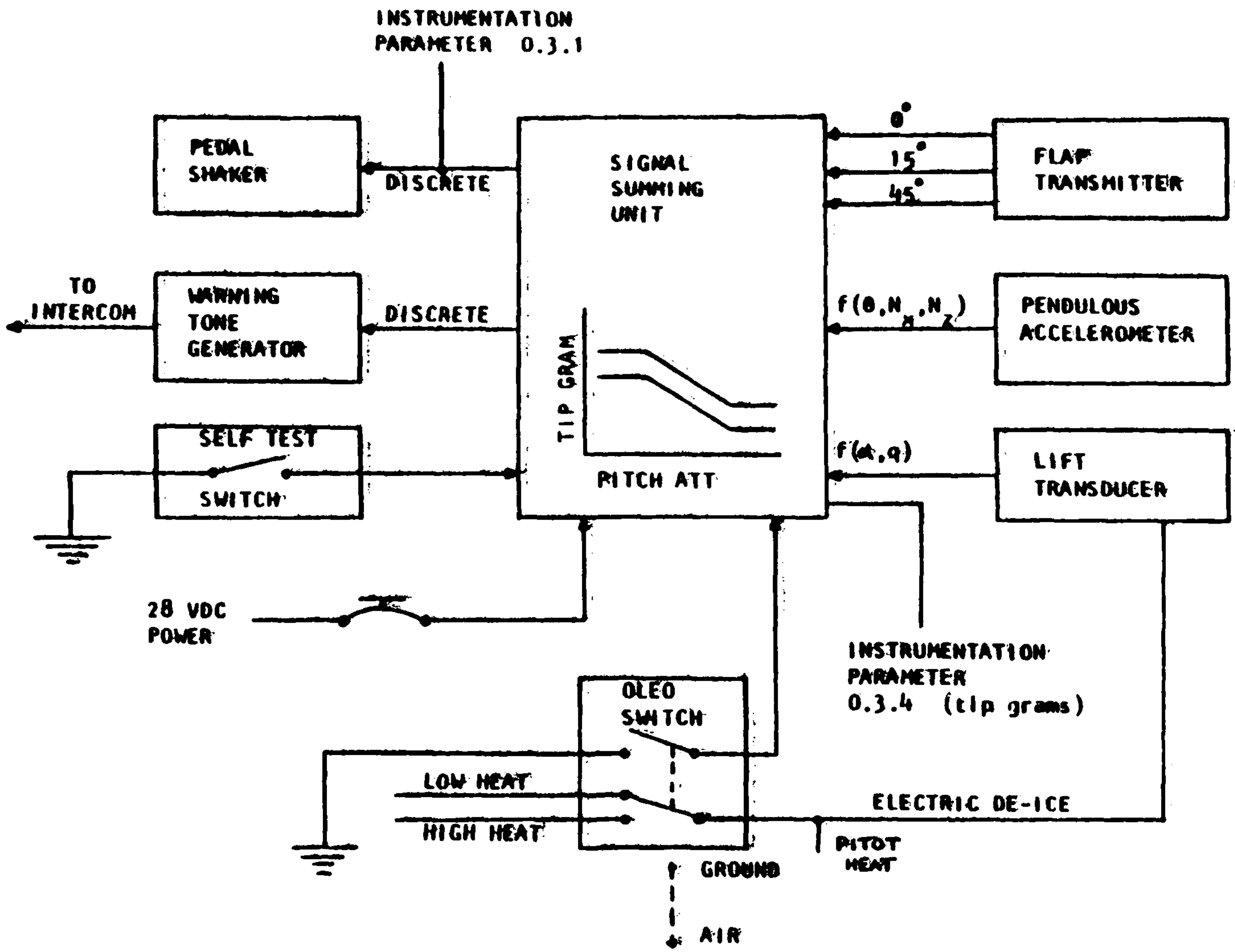



Figure B-5. SFIC Stall Warning System

## APPENDIX C. INSTRUMENTATION

1. Instrumentation for this evaluation was calibrated, installed and maintained by the US Army Aviation Engineering Flight Activity personnel. Flight test data were recorded on magnetic tape onboard the test aircraft and via telemetry to the Real-Time Data Acquisition and Processing System facility. An instrumented boom was installed to provide pitot and static pressure, side-slip, and angle of attack data. The boom system airspeed calibration is shown in figure C-1.

2. The following test instrumentation was used in addition to the standard aircraft instruments:

**Cockpit Panel**

Engine fuel flow (left and right)
Engine fuel totalizer (left and right)
Airspeed (ship and boom)
Altitude (ship and boom)
Ambient air temperature
Angle of attack (boom system)
Angle of sideslip (boom system)
Normal acceleration (cg)
Time code

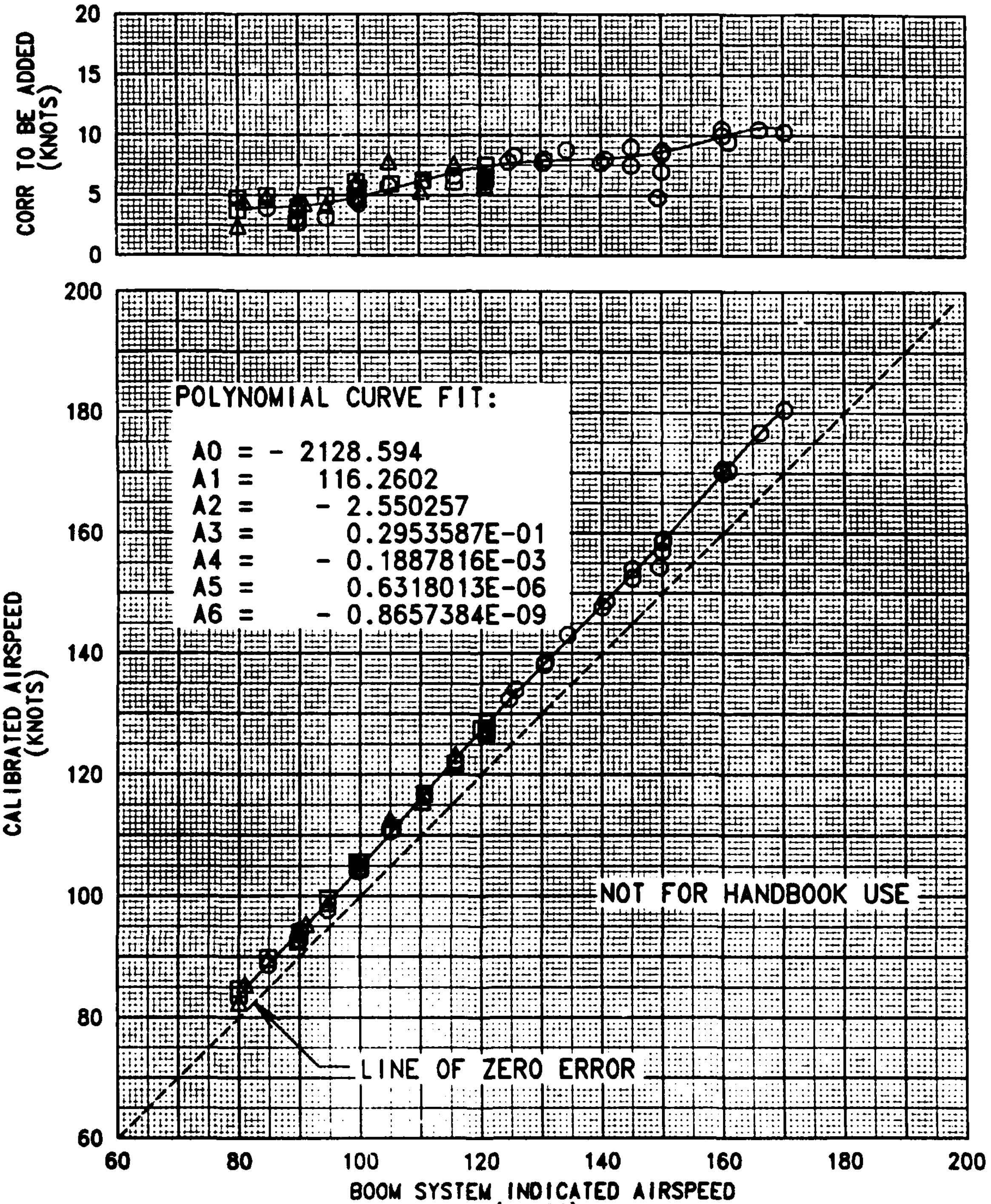
**Magnetic Tape**

Airspeed (ship and boom)
Pressure Altitude (ship and boom)
Total air temperature
Longitudinal control position
Lateral control position
Directional control position
Safe Flight Instrument Corporation (SFIC) lift transducer (volts)
SFIC pendulous accelerometer output
Angle of attack (boom system)
Angle of sideslip (boom system)
Pitch attitude
Roll attitude
Heading
Pitch rate
Roll rate
Yaw rate
Center of gravity normal acceleration
Pilot's directional pedal force (left and right)
Exhaust gas temperature (left and right)
Fuel flow (left and right)
Fuel totalizers (left and right)
Propeller speed (left and right)
Gas generator speed (left and right)
Engine torque (left and right)

Throttle position (left and right)
Left outboard aileron position
Right rudder position
Center rudder position
Time

FIGURE C-1
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
OV-1D(C) USA S/N 62-5867

| SYM | AVG GROSS WEIGHT (LB) | AVG CG LOCATION LONG (FS) | AVG CG LOCATION LAT (BL) | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG PROP SPEED (RPM) | TEST METHOD | AIRCRAFT CONFIGURATION |
|---|---|---|---|---|---|---|---|---|
| ○ | 16200 | 158.2(FWD) | 3.6 RT | 8210 | 17.5 | 1450 | T34 PACE | CRUISE |
| □ | 15550 | 157.8(FWD) | 3.6 RT | 10040 | 13.0 | 1660 | T34 PACE | TAKE-OFF |
| △ | 15230 | 157.6(FWD) | 3.6 RT | 10060 | 13.0 | 1655 | T34 PACE | LANDING |



## APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

### TEST TECHNIQUES

1. Unaccelerated stalls were initiated from trimmed level flight at 1.2 times the power-off stall speed ($V_{s1}$) for dual-engine unaccelerated stalls in the cruise, go-around and landing configuration and at single-engine best rate of climb speed for single-engine stalls. In the takeoff configuration operator's manual recommended trim settings were used. The unaccelerated stalls were performed wings-level at an airspeed reduction rate of one knot per second or less. Accelerated stalls were conducted by trimming the aircraft at 1.4 Vsl. The accelerated stalls were performed at a constant g while decreasing the airspeed at approximately 2 knots per second in left windup turns. Aircraft stall was identified from the time history data as the point of maximum lift coefficient. Calibrated stall airspeed was defined as the boom calibrated airspeed at stall. A Handling Qualities Rating Scale was used to augment pilot comments relative to the aircraft handling qualities (fig D-1).

### DATA ANALYSIS METHOD

#### Airspeed Determination

2. Instrument corrected airspeeds ($V_{ic}$) using the Pulse Code Modulation (PCM) system were obtained through the equation:

$$V_{ic} = a_o \left[ 5 \left[ (Q_{ic} / P_o + 1)^{2/7} - 1 \right] \right]^{1/2}$$

where:

$a_o$ = Standard day, sea level speed of sound, knots
$P_o$ = Standard day, sea level static pressure, in-Hg
$Q_{ic}$ = instrument corrected differential pressure, in-Hg

3. Boom calibrated airspeeds (Vcal) were obtained by correcting Vic for position error ($\Delta V_{pc}$).

4. Equivalent airspeeds (Ve) were obtained through the equation:

$$V_e = a_o \left[ 5\delta \left[ (Q_c / P_c + 1)^{2/7} - 1 \right] \right]^{1/2}$$

where:

$\delta$ = Pc/Po
$P_c$ = Ambient test static pressure, in-Hg
$Q_c$ = Calibrated differential pressure, in-Hg

$$= P_o \left[ \left[ 0.2 \left[ V_{cal} / a_o \right]^2 + 1 \right]^{7/2} - 1 \right]$$

**Coefficient of Lift Determination**

5. Test lift coefficients were obtained through the equation:

$$CL = \frac{(2)(W)(n)}{\varrho_o((Ve)(1.6878))^2 360}$$

where:

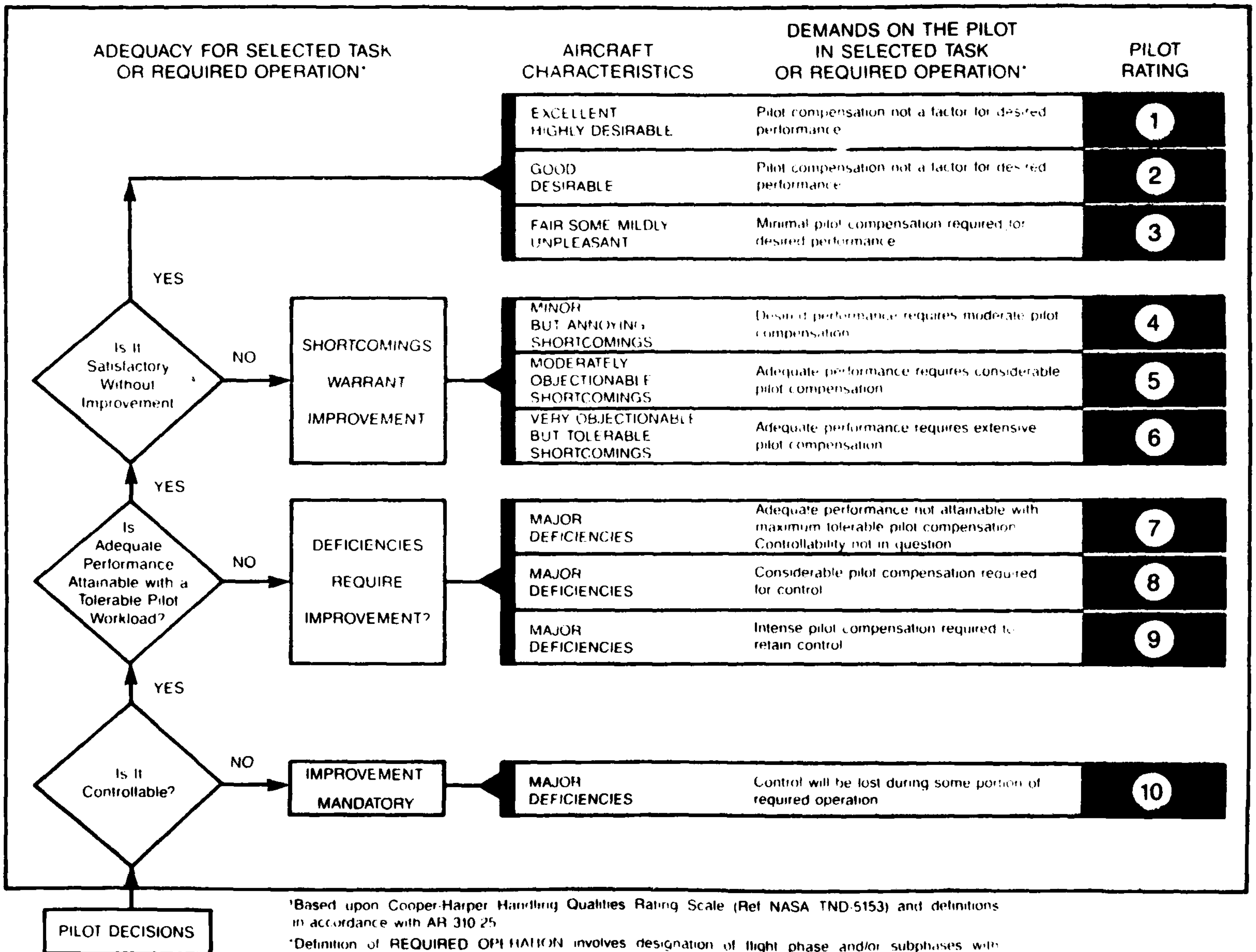
W = aircraft gross weight
n = normal load factor
$\varrho_o$ = standard day, sea level density, slugs/ft$^3$
360 = wing surface area, ft$^2$

## AIRSPEED CALIBRATION

6. The test boom pitot-static system was calibrated using the aircraft pace method to determine the airspeed position error and is presented in figure C-2.

## WEIGHT AND BALANCE

7. Prior to flight testing, a weight and balance determination was conducted on the aircraft using calibrated floor scales located under the aircraft landing gear. The aircraft basic weight and center of gravity with the safe flight stall warning system, side looking airborne radar, two drop tanks, and airspeed boom and yaps head was 13,337 pounds and fuselage station 160.66.




*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

Figure D-1. Handling Qualities Rating Scale

## APPENDIX E. TEST DATA

| Figure | Figure Number |
| --- | --- |
| **Index** | |
| Dual-Engine Unaccelerated Stall Warning Summary | E-1 through E-3 |
| Single-Engine Unaccelerated Stall Warning Summary | E-4 through E-6 |
| Dual-Engine Accelerated Stall Warning Summary | E-7 |
| Ship System Airspeed Calibration | E-8 |
| **Photo** | |
| Exhaust Shroud | E-9 |

## FIGURE E-1
## DUAL ENGINE UNACCELERATED STALL WARNING SUMMARY
### OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| □ | TAKEOFF/APPROACH | 15 | DOWN |
| ○ | CRUISE | 0 | UP |
| △ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: SIDE LOOKING AIRBORNE RADAR, TWO 150 GALLON DROP TANKS, AND AN/ALQ-147(V)1.
2. AVERAGE GROSS WEIGHT = 17,320 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 158.5.
4. OPEN SYMBOLS DENOTE BALL CENTERED CONDITION.
5. SHADED LEFT SYMBOLS DENOTE ONE-HALF BALL LEFT CONDITION.
6. SHADED RIGHT SYMBOLS DENOTE ONE-HALF BALL RIGHT CONDITION.
7. UNFLAGGED SYMBOLS DENOTE FLIGHT IDLE POWER.
8. FLAGGED SYMBOLS DENOTE MAXIMUM AVAILABLE POWER (1200 SHP).
9. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

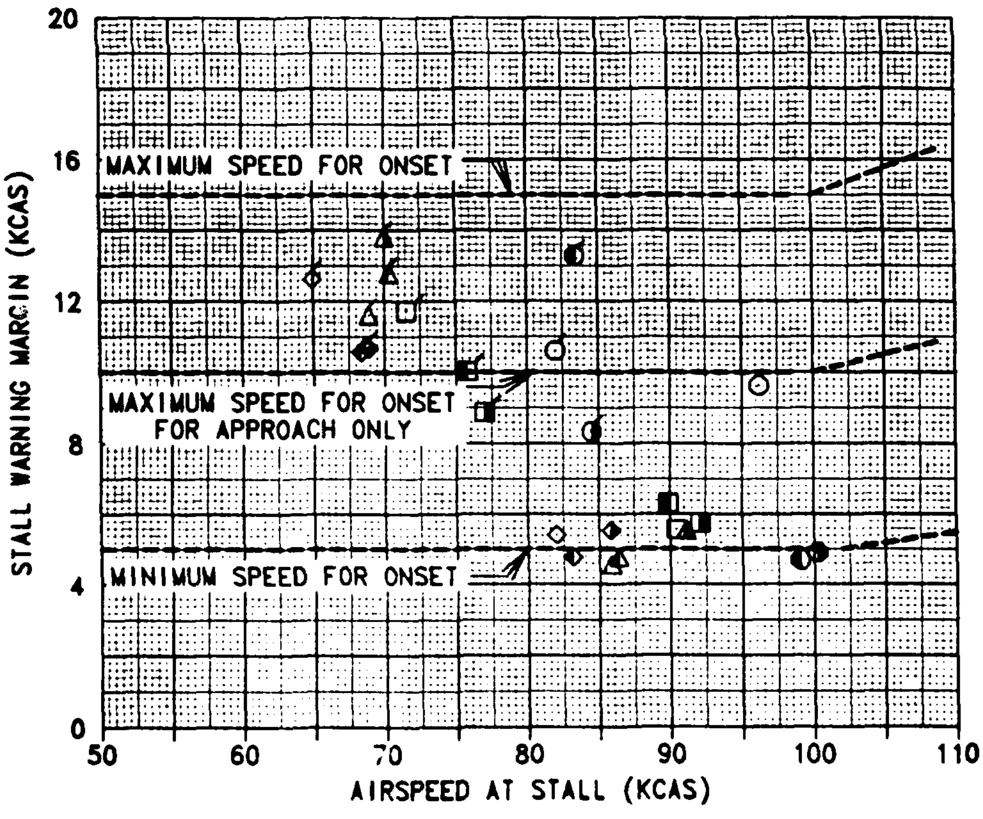


FIGURE E-2
DUAL ENGINE UNACCELERATED STALL WARNING SUMMARY
OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| ⊡ | TAKEOFF/APPROACH | 15 | DOWN |
| ⊙ | CRUISE | 0 | UP |
| △ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: TWO 150 GALLON DROP TANKS
2. AVERAGE GROSS WEIGHT = 15,780 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 160.3.
4. OPEN SYMBOLS DENOTE BALL CENTERED CONDITION.
5. SHADED LEFT SYMBOLS DENOTE ONE-HALF BALL LEFT CONDITION.
6. SHADED RIGHT SYMBOLS DENOTE ONE-HALF BALL RIGHT CONDITION.
7. UNFLAGGED SYMBOLS DENOTE FLIGHT IDLE POWER.
8. FLAGGED SYMBOLS DENOTE MAXIMUM AVAILABLE POWER (1200 SHP).
9. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

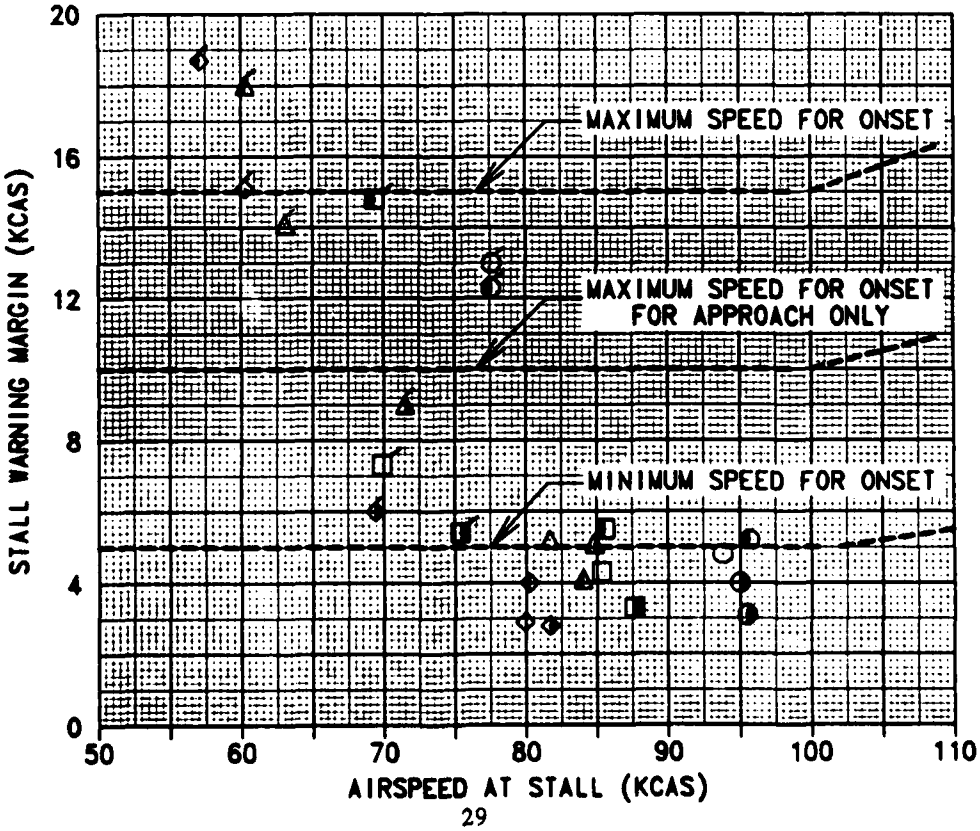


FIGURE E-3

DUAL ENGINE UNACCELERATED STALL WARNING SUMMARY

OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| □ | TAKEOFF/APPROACH | 15 | DOWN |
| ○ | CRUISE | 0 | UP |
| △ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: NO EXTERNAL STORES
2. AVERAGE GROSS WEIGHT = 13,080 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 160.2.
4. OPEN SYMBOLS DENOTE BALL CENTERED CONDITION.
5. SHADED LEFT SYMBOLS DENOTE ONE-HALF BALL LEFT CONDITION.
6. SHADED RIGHT SYMBOLS DENOTE ONE-HALF BALL RIGHT CONDITION.
7. UNFLAGGED SYMBOLS DENOTE FLIGHT IDLE POWER.
8. FLAGGED SYMBOLS DENOTE MAXIMUM AVAILABLE POWER (1200 SHP).
9. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

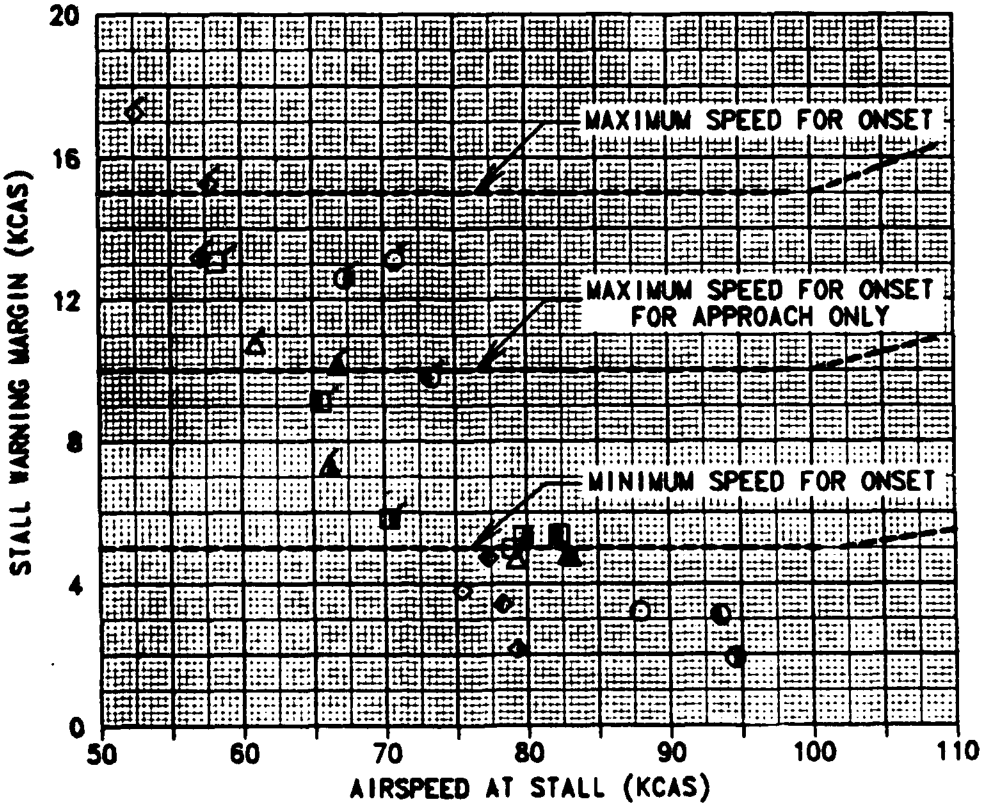


FIGURE E-4
SINGLE ENGINE UNACCELERATED STALL WARNING SUMMARY
OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| ⊡ | TAKEOFF/APPROACH | 15 | DOWN |
| ⊙ | CRUISE | 0 | UP |
| Δ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: SIDE LOOKING AIRBORNE RADAR, TWO 150 GALLON DROP TANKS, AND AN/ALQ-147(V)1.
2. AVERAGE GROSS WEIGHT = 17,070 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 158.3.
4. OPEN SYMBOLS DENOTE NUMBER ONE ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
5. SHADED SYMBOLS DENOTE NUMBER TWO ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
6. UNFLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE AT GROUND IDLE AND PROPELLER WINDMILLING.
7. FLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE SHUTDOWN AND PROPELLER FEATHERED.
8. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

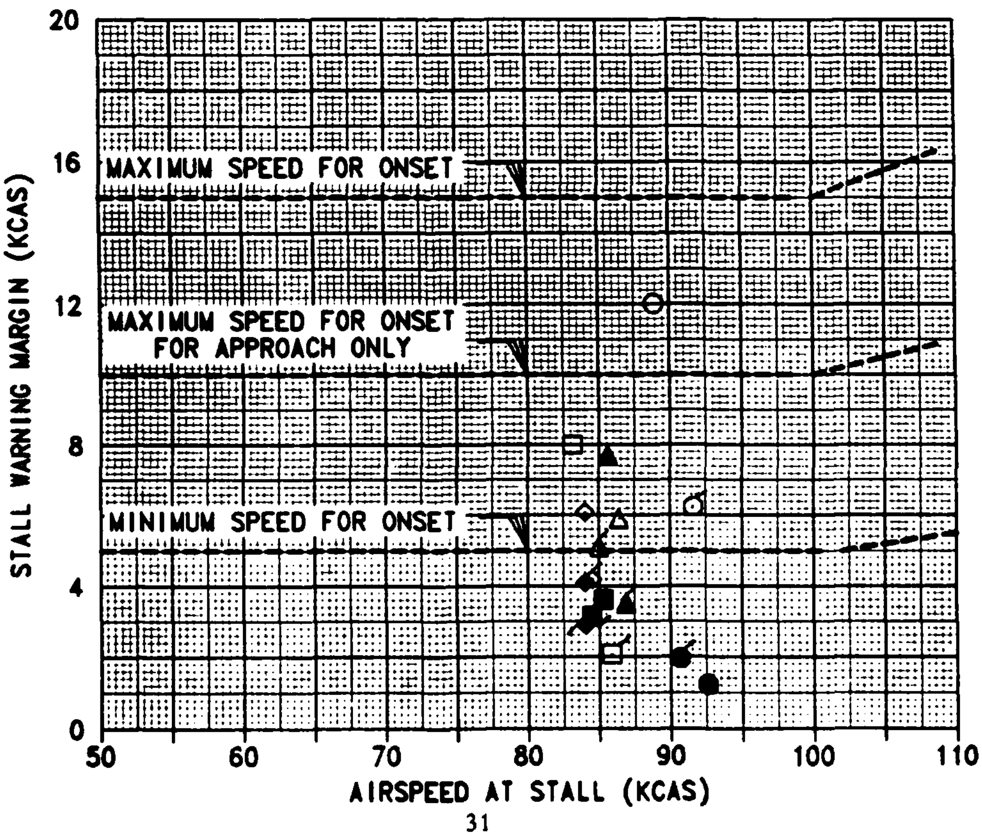


FIGURE E-5
SINGLE ENGINE UNACCELERATED STALL WARNING SUMMARY
OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| □ | TAKEOFF/APPROACH | 15 | DOWN |
| ⊙ | CRUISE | 0 | UP |
| △ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: TWO 150 GALLON DROP TANKS.
2. AVERAGE GROSS WEIGHT = 16,470 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 160.6.
4. OPEN SYMBOLS DENOTE NUMBER ONE ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
5. SHADED SYMBOLS DENOTE NUMBER TWO ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
6. UNFLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE AT GROUND IDLE AND PROPELLER WINDMILLING.
7. FLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE SHUTDOWN AND PROPELLER FEATHERED.
8. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

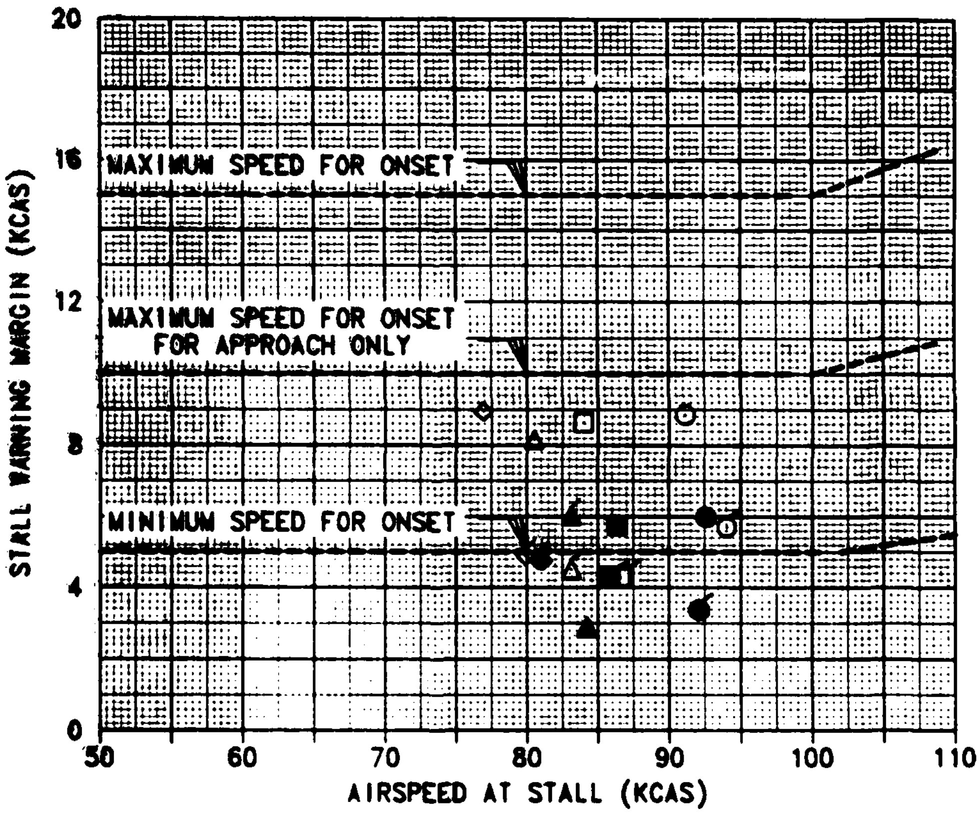


FIGURE E-6

SINGLE ENGINE UNACCELERATED STALL WARNING SUMMARY

OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| □ | TAKEOFF/APPROACH | 15 | DOWN |
| ⊙ | CRUISE | 0 | UP |
| △ | GO-AROUND | 15 | UP |
| ◇ | LANDING | 45 | DOWN |

NOTES:
1. EXTERNAL STORES CONFIGURATION: NO EXTERNAL STORES.
2. AVERAGE GROSS WEIGHT = 13,990 POUNDS.
3. AVERAGE LONGITUDINAL CENTER OF GRAVITY = FS 160.1.
4. OPEN SYMBOLS DENOTE NUMBER ONE ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
5. SHADED SYMBOLS DENOTE NUMBER TWO ENGINE AT MAXIMUM AVAILABLE POWER (1200 SHP).
6. UNFLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE AT GROUND IDLE AND PROPELLER WINDMILLING.
7. FLAGGED SYMBOLS DENOTE INOPERATIVE ENGINE SHUTDOWN AND PROPELLER FEATHERED.
8. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.

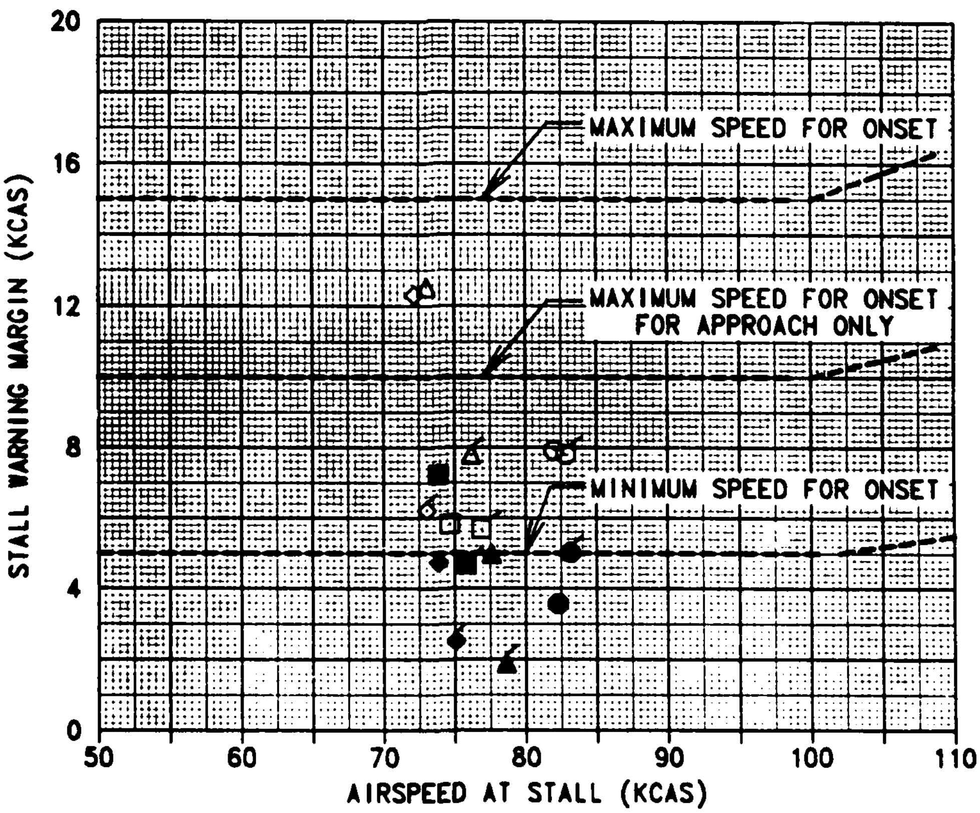


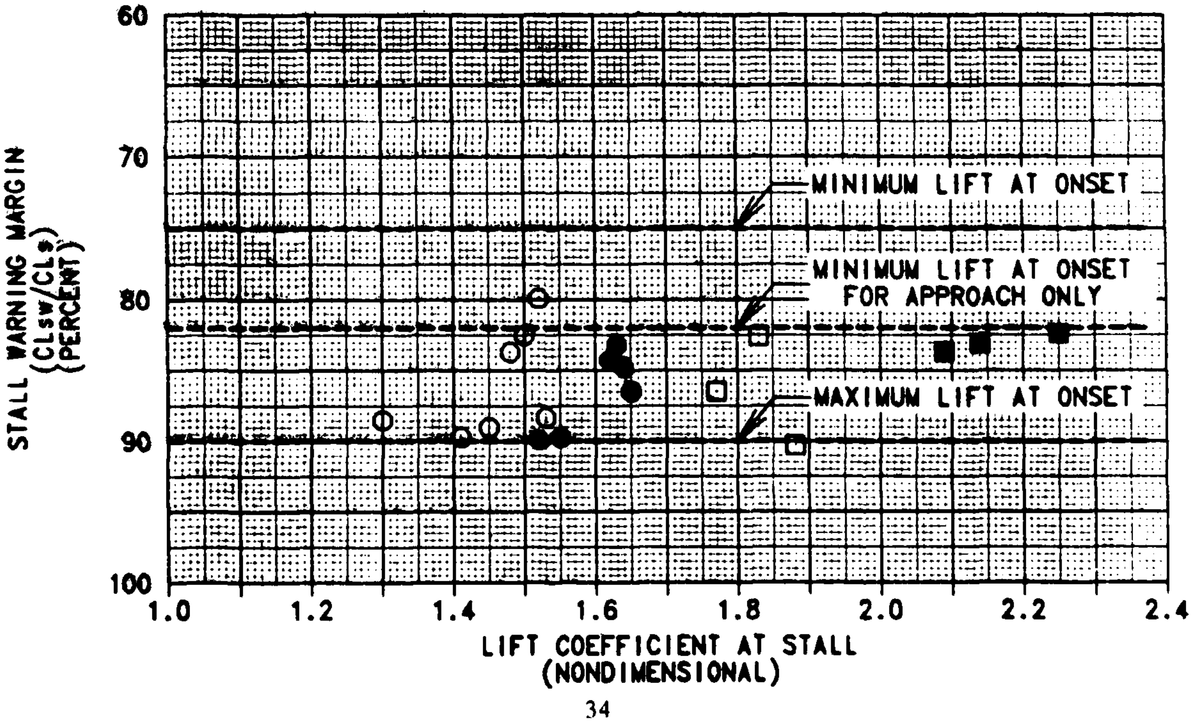
FIGURE E-7
## DUAL ENGINE ACCELERATED STALL WARNING SUMMARY
OV-1D(C) USA S/N 62-5867

| SYMBOL | AIRCRAFT CONFIGURATION | FLAP POSITION (DEGREES) | GEAR POSITION |
|---|---|---|---|
| □ | TAKEOFF/APPROACH | 15 | DOWN |
| ○ | CRUISE | 0 | UP |

NOTES: 1. TESTING CONDUCTED AT THE FOLLOWING CONDITIONS:

| AVERAGE GROSS WEIGHT (LB) | AVERAGE LONG. CENTER OF GRAVITY (FS) | STORES CONFIGURATION |
|---|---|---|
| 13720 | 160.2 | NO STORES |
| 16570 | 160.6 | TWO 150 GALLON DROP TANKS |
| 17010 | 158.3 | SIDE LOOKING AIRBORNE RADAR, TWO 150 GALLON DROP TANKS, AND AN/ALQ-147(V)1 AT STORE STA. 6 |

2. OPEN SYMBOLS DENOTE FLIGHT IDLE POWER.
3. SHADED SYMBOLS DENOTE MAXIMUM AVAILABLE POWER (1200 SHP).
4. DASHED LINES DENOTE MILITARY SPECIFICATION LIMITS AS PER MIL-F-8785C.
5. ALL STALLS PERFORMED USING LEFT WIND-UP TURNS.



## FIGURE E-8
## SHIP SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
### OV-1D USA S/N 62-05867

| SYM | AVG GROSS WEIGHT (LB) | AVG CG LOCATION LONG (FS) | AVG CG LOCATION LAT (BL) | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG PROP SPEED (RPM) | TEST METHOD | AIRCRAFT CONFIGURATION |
|---|---|---|---|---|---|---|---|---|
| ⊙ | 16200 | 158.2(FWD) | 3.6 RT | 8210 | 17.5 | 1450 | T34 PACE | CRUISE |
| ⊡ | 15550 | 157.8(FWD) | 3.6 RT | 10040 | 13.0 | 1660 | T34 PACE | TAKE-OFF |
| Δ | 15230 | 157.6(FWD) | 3.6 RT | 10060 | 13.0 | 1655 | T34 PACE | LANDING |

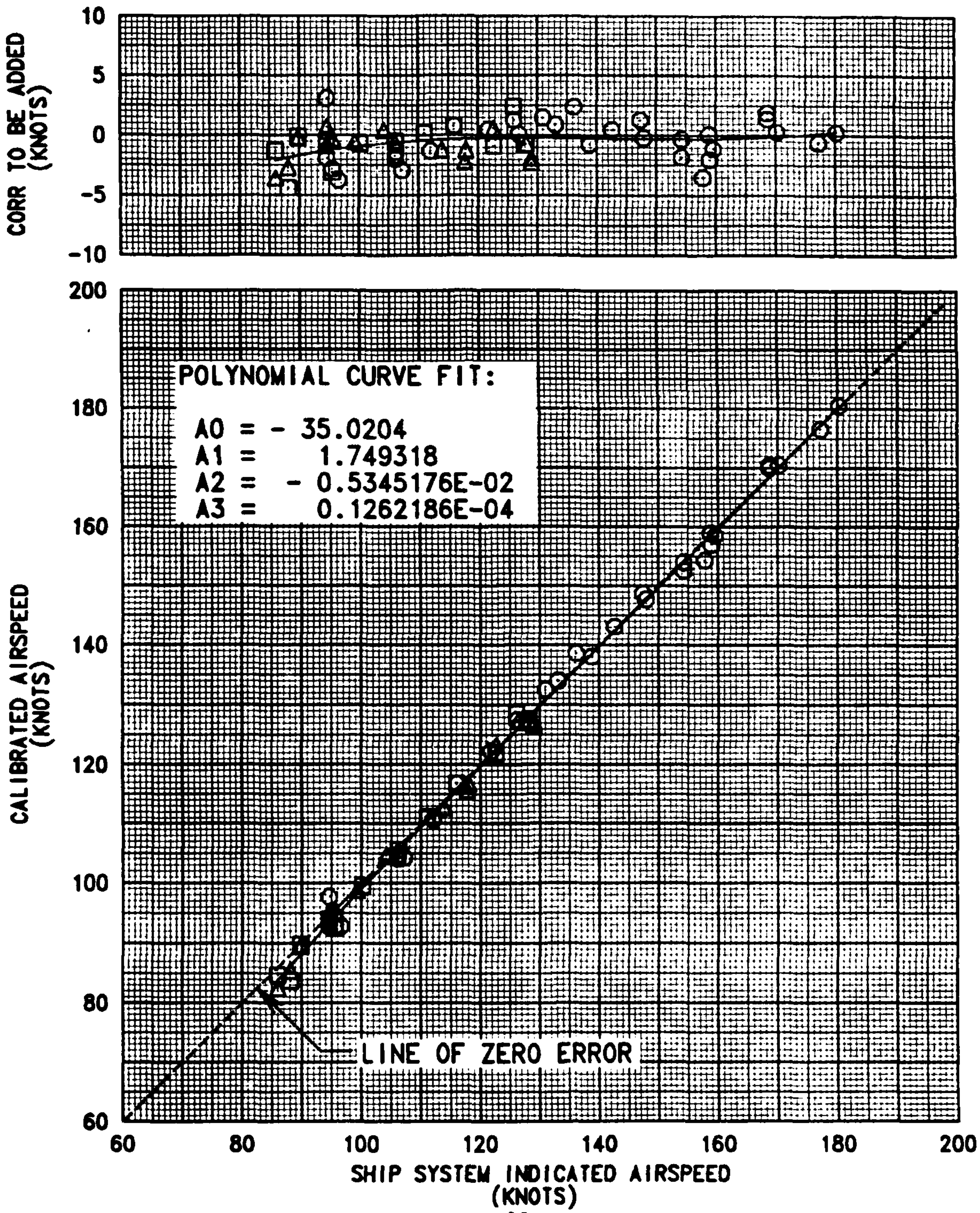


Figure E-9. Engine Exhaust Shroud

## DISTRIBUTION

| | |
|---|---|
| HQDA (DALO-AV) | 1 |
| HQDA (DALO-FDQ) | 1 |
| HQDA (DAMO-HRS) | 1 |
| HQDA (SARD-PPM-T) | 1 |
| HQDA (SARD-RA) | 1 |
| HQDA (SARD-WSA) | 1 |
| US Army Material Command (AMCDE-SA, AMCDE-P, AMCQA-SA, AMCQA-ST) | 4 |
| US Training and Doctrine Command (ATCD-T, ATCD-B) | 2 |
| US Army Aviation Systems Command (AMSAV-8, AMSAV-Q, AMSAV-MC, AMSAV-ME, AMSAV-L, AMSAV-N, AMSAV-GTD) | 8 |
| US Army Test and Evaluation Command (AMSTE-TE-V, AMSTE-TE-O) | 2 |
| US Army Logistics Evaluation Agency (DALO-LEI) | 1 |
| US Army Materiel Systems Analysis Agency (AMXSY-RV, AMXSY-MP) | 8 |
| US Army Operational Test and Evaluation Agency (CSTE-AVSD-E) | 2 |
| US Army Armor School (ATSB-CD-TE) | 1 |
| US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH) | 5 |
| US Army Combined Arms Center (ATZL-TIE) | 1 |
| US Army Safety Center (PESC-SPA, PESC-SE) | 2 |
| US Army Cost and Economic Analysis Center (CACC-AM) | 1 |
| US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library) | 3 |

| | |
|---|---|
| US Army Aviation Research and Technology Activity (AVSCOM) Aviation Applied Technology Directorate (SAVRT-TY-DRD, SAVRT-TY-TSC (Tech Library) | 2 |
| US Army Aviation Research and Technology Activity (AVSCOM) Aeroflightdynamics Directorate (SAVRT-AF-D) | 1 |
| US Army Aviation Research and Technology Activity (AVSCOM Propulsion Directorate (SAVRT-PN-D) | 1 |
| Defense Technical Information Center (FDAC) | 2 |
| US Military Academy, Department of Mechanics (Aero Group Director) | 1 |
| ASD/AFXT, ASD/ENF | 2 |
| US Army Aviation Development Test Activity (STEBG-CT) | 2 |
| Assistant Technical Director for Projects, Code: CT-24 (Mr. Joseph Dunn) | 2 |
| 6520 Test Group (ENML) | 1 |
| Commander, Naval Air Systems Command (AIR 5115B, AIR 5301) | 3 |
| Defense Intelligence Agency (DIA-DT-2D) | 1 |
| School of Aerospace Engineering (Dr. Daniel P. Schrage) | 1 |
| Headquarters United States Army Aviation Center and Fort Rucker (ATZQ-ESO-L) | 1 |