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14. ABSTRACT
This Test Operations Procedure (TOP) describes the test requirements, objectives, responsibilities, and techniques/methodologies required to perform pitot-static system calibrations. This TOP is used for rotary-wing and fixed-wing aircraft. The TOP will facilitate test planning, execution, and data collection using two techniques (trailing device and pace) and the equipment required to complete pitot-static system calibrations. Variations in platform requirements are discussed within this TOP. These guidelines, along with platform specific capabilities and requirements, will enable the tester to develop a comprehensive testing strategy.

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TEST OPERATIONS PROCEDURE

Test Operations Procedure (TOP) 7-3-057 10 April 2007
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PITOT-STATIC SYSTEM CALIBRATIONS

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1. SCOPE.

1.1 Introduction.

This pitot-static Test Operations Procedure (TOP) is used for rotary-wing and fixed-wing aircraft. The TOP will include two techniques (trailing device and pace) and the equipment required to complete pitot-static system calibrations. This TOP will facilitate test planning, execution, and data collection. Variations in platform requirements are discussed within this TOP. These guidelines, along with platform specific capabilities and requirements, will enable the tester to develop a comprehensive testing strategy.

1.2 Trailing Device Methodology Theory.

The trailing device method discussed in this TOP is restricted to rotary-wing aircraft. This method requires a calibrated pitot-static source (trailing device) to be suspended below the aircraft on a cable. The aircraft being calibrated will perform a speed sweep under preplanned conditions. Possible conditions include: level flight, climbs, descents, external configuration changes, and changes in sideslip. The calibrated pitot-static data are then compared directly to the aircraft pitot-static data collected. The airspeed and altimeter position error corrections for a given flight condition are determined by subtracting the source airspeed and altitude from the airspeed and altitude indicated by the aircraft pitot-static system. The trailing device should be suspended outside the downwash of the aircraft (minimum of 1 1/2 to 2 rotor diameters). The pressures from the trailing device are transmitted through tubes to the helicopter where they are converted to accurate pressure altitudes and calibrated airspeeds by sensitive, calibrated instruments. Since the pressures from the source are transmitted through tubes to the helicopter for conversion to airspeeds and altitudes, no error is introduced by trailing the source below the helicopter.

1.3 Pace Methodology Theory.

The pace method discussed in this TOP can be used for both rotary-wing and fixed-wing aircraft. This method requires a second aircraft with a calibrated pitot-static system to fly in close formation with the aircraft under test. The aircraft being calibrated will perform a speed sweep under the preplanned conditions as the formation lead. The flight formation will be close enough to accurately perceive position, rate of closure, or separation, but outside the flow field (downwash and vortices) of the aircraft under test. Both aircraft are flown at the same altitude so that both airspeed and altitude data can be collected. The conditions flown may be limited by the capabilities of the different aircraft. The calibrated pitot-static data are compared directly to the test aircraft pitot-static data collected. The airspeed and altimeter position error corrections for a given flight condition are determined by subtracting the calibrated airspeed and altitude from the airspeed and altitude indicated by the test aircraft pitot-static system.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

2.1.1 Trailing Device Equipment.

The trailing device calibration system consists of the following components:

a. Trailing Device. A typical trailing device is shown in figure A-1 (Appendix A). The cable attachment bracket and pivot pin are located so that, when the device is suspended by the pivot pin, the device hangs horizontally or slightly nose down. The pivot pin goes through the eyelet of the cable. The device has four fins at the extreme rear, oriented 45 degrees from the vertical, so that no fin is directly behind the cable attachment bracket. The pitot and static ports are connected by surgical tubing to the semirigid tubing of the cable and tubing assembly. It is important that the surgical tubing be routed behind the pivot and up to the semirigid tubing. The trailing device calibration is determined through wind tunnel testing. The trailing device should be stored between uses in a protective case to prevent nicks and scrapes.

b. Cable and Tubing Assembly.

The cable is 3/16-in., 7- by 19-twisted strand, 4,200-lb tensile strength stainless steel cable. At each end, the cable is looped around an eyelet and secured with two fittings. The eyelet center-to-eyelet center length is determined as a function of the rotor diameter. The cable should be no shorter than 1 1/2 to 2 times the rotor diameter. Cables shorter than this length will cause the trailing device to remain within the downwash of the rotor, contributing to position error of the trailing device and aerodynamic instability. Cables longer than the length identified lead to a greater chance of instability at lower airspeeds.

The pitot and static lines are 3/16-in. outside diameter semirigid tubing. The tubing is secured to the cable and is in a triangular configuration. The cable forms the leading edge with the two tubes side by side behind the cable. The top 6 to 8 feet of the cable and tubing assembly may be wrapped with a protective material such as electrical tape to minimize damage caused by chaffing against the aircraft.

c. Attachment/Release System.

The attachment system is dependent on the aircraft and the onboard systems. The attachment system must securely hold the trailing device, cable, and tubing to the aircraft throughout the flight. The key component of the attachment system is the slip fitting. Polyflow tubing is installed over the slip fittings. If the cable is released, the slip fitting will release the tubing.

The release system is dependent on the aircraft and the onboard systems. The release system must be able to jettison the tubing, cable, and trailing device reliably and rapidly.

Examples of previous attachment/release systems:

(1) On the OH-58D, AH-64D, and AH-6M, the attachment/release system used was the weapons pylon. The assembly was mounted to a heavy plate that was jettisoned by the wing stores jettison (Figures A-2 and A-3).

(2) On the HH-60G, the attachment/release system used was the cargo hook. The slip fittings were located on the hook. The release system was that of the cargo hook.

(3) On the CH-47D, the attachment/release system used required a manual release. Framework was mounted to the center cargo hole that contained a hand lever to release the assembly (Figures A-4 and A-5).

d. Sensitive Airspeed and Altimeter Indicators.

The sensitive airspeed indicators should have 1-kt divisions from zero to 100 kt and 2-kt divisions above 100 kt. This allows reading to the nearest one-half knot from zero to 100 kt and to the nearest knot above 100 kt. Sensitive altimeters should have 20-ft divisions. This allows reading to the nearest 10 ft.

e. Ground Handling Equipment.

The launch/recovery person should wear hearing and eye protection to prevent injury from downwash and noise. The recovery person should wear heavy rubber gloves to prevent injury from the possibility of static electrical discharge.

2.1.2 Pace Equipment.

The pace calibration system consists of a specially outfitted and calibrated pace aircraft. These pace aircraft generally have specially designed, separate pitot/static systems which have been calibrated with the most precise methods available. The sensitive airspeed and altimeter indicators should be held to the standards discussed for the trailing device indicators (see paragraph 2.1.1d).

2.2 Instrumentation.

2.2.1 Indicator Sensitivity and Calibration.

All airspeed and altitude indicators being used for the calibration effort should receive a calibration to attain the instrument corrections needed for data reduction. The instrument calibration will identify the delta between the airspeed/altitude calibration input set point and the airspeed/altitude indicated. When performing hysteresis calibrations, the indicators must be put on a “shaker” or tapped constantly to settle out.

Sensitive airspeed indicators should have 1-kt divisions from zero to 100 kt and 2-kt divisions above 100 kt. This allows reading to the nearest one-half knot from zero to 100 kt and to the nearest knot above 100 kt. The calibration should be accomplished in 5-kt increments increasing from 20 kt to the maximum allowable airspeed. Hysteresis should be checked by reducing airspeeds from the maximum. Allowable hysterisis is ±1 kt below 100 kt and ±2 kt above 100 kt.

Sensitive altimeters should have 20-ft divisions. This allows reading to the nearest 10 feet. Starting at sea level, increase indicated altitude to 5,000 ft in 500-ft increments. Record input and observed altitudes at each increment. Increase altitude to 15,000 feet in 1,000-ft increments. Reduce input altitude stopping at the same points gathered going up; record input and output altitudes at each increment. Allowable hysteresis is ±20 feet. See Federal Aviation Regulations FAR Part 43 Appendix E - Altimeter System Test and Inspection for general methods and procedures[1*].

2.2.2 Leak Checks.

Ensure the pitot-static leak check equipment calibration range is within the pressure ranges of the indicators being calibrated.

Allowable leak rates for a complete trailing device system installed on an aircraft are 2.0 kt/min at 100 kt after tapping the airspeed indicator and 20 fpm at 1,000 feet above ambient after tapping the altimeter.

2.2.3 Airspeed System Dynamic Response and Pitot/Static Balance.

If climb and descent performance data are to be collected, then the pitot/static system needs to be "balanced." To check the balance, attach a fixture to the trailing device that vents the pitot and static ports together. Apply a pressure change to simulate 3,000 feet per minute climb rate. Airspeed should not change more than ±15 kt at the point of primary measurement, in this case the trailing device airspeed indicator. Adjust the balance by adding volume to the pitot or static side as necessary. The location, size, and configuration of the ballast will affect the dynamic response throughout the system. Note: 15 kt at zero airspeed is a pressure differential equivalent to about 1 knot error at 100 kt. The same considerations hold true for an air-data/nose boom installation.

Adding instrumentation transducers (thus volume) to the primary aircraft pitot/static system can affect the balance of the system under test. Perform a balance test before and after a modification if climb and descent data are to be collected. In this case, the object is to maintain the original aircraft system balance at the primary airspeed instrument regardless of its value.

[*] Superscript numbers correspond to those in Appendix G, References.

3. REQUIRED TEST CONDITIONS.

3.1 Trailing Device Test Planning.

A large number of data points can be obtained in a relatively short time by using the trailing device method of pitot-static system calibration. Data can be obtained during level, climbing, and descending flight.

The trailing device is a sensitive instrument and must be handled and stored with the greatest care. During launch and retrieval, the device must not be allowed to touch the ground; even small nicks or scratches can change its calibration. The trailing device, cable and tubing assembly, and indicators must always be stored in the boxes provided and must not be subjected to a damp, dusty, corrosive, or otherwise hostile environment.

Calibration sheets should be obtained for the trailing device and each indicator, and the calibrations must meet the acceptance requirements.

Once the trailing device is installed, ensure that both the trailing device and aircraft system(s) under test pass a pitot-static leak check. The cable should be no shorter than 1 1/2 to 2 times the rotor diameter of the test aircraft.

Take special care to ensure that the complete release system functions properly and that the cable and tubing assembly cannot jam or hang up with the cable being pulled in any direction.

Schedule the test aircraft and the chase aircraft for testing. If possible, use a chase aircraft similar in performance to the test aircraft. Schedule a radio frequency that will allow launch and retrieval personnel to use handheld radios to talk with crews of the test and chase aircraft to enhance safety. Ensure the test aircraft has out-of-ground effect hover performance available during launch and retrieval of the trailing device. The trailing device must be launched and recovered at a location clear of buildings and other aircraft. Schedule the test aircraft crew, chase aircraft crew, and ground crew for a preflight briefing to delineate duties during the flight.

3.2 Pace Test Planning.

A large number of data points can be obtained in a relatively short time by using the pace method of pitot-static system calibration. Data can be obtained during level, climbing, and descending flight.

Schedule the test aircraft, pace aircraft, and chase aircraft for testing. The test aircraft and pace aircraft must have similar performance for the flight regimes being calibrated. If possible, use a chase aircraft similar in performance capabilities. Schedule a radio frequency for communication between the three aircraft. Schedule the test aircraft crew, pace aircraft crew, and chase aircraft crew for a preflight briefing to delineate duties during the flight.

4. TEST PROCEDURES.

4.1 General.

The calibration of pitot-static pressure systems can be accomplished by determining the errors in each system independently or simultaneously. The procedures discussed in this section could be used to collect data on each system under test. Each technique has particular safety considerations. Risks for each technique have been identified in appendix B.

4.2 Trailing Device Technique.

4.2.1 Preflight Briefing.

The preflight briefing should have the test aircraft crew, chase aircraft crew, and the launch and recovery ground crew in attendance. The preflight brief will cover the duties of each crew during the flight. The subjects should include but are not limited to the following:

a. Radio frequencies to be used during launch, recovery, and in-flight.

b. Launch and recovery procedures to include radio communications and personnel responsibilities. The trailing device must be launched and recovered at a location clear of buildings and other aircraft. Minimize the risk of accident and injury. The trailing device should not touch the ground and should be held by the launch/recovery person during liftoff and landing.

c. Brief the crew of the chase aircraft to assist in launch and recovery effort.

d. In-flight testing procedures to include radio communications, conditions to be tested, and data point order.

e. Brief the crew of the chase aircraft to monitor motion and position of the trailing device relative to test aircraft throughout the flight.

f. Brief the crew of the chase aircraft to position the chase aircraft for best surveillance of the test aircraft, cable and tubing assembly, and trailing device consistent with safety of the chase aircraft.

4.2.2 Preflight Inspection.

The complete system must be thoroughly inspected before use. The preflight inspection includes:

a. Check trailing device nose for nicks and scrapes (even small nicks near the static ports can change the calibration of the device.)

b. Check pitot and static ports are clear of any obstructions.

c. Check the fins for proper alignment (straight).

d. Ensure all fasteners of the device segments are tight and secured with adhesive/sealant.

e. Inspect cable for fraying, especially at the ends.

f. Check cable eyelets and fittings are in place and undamaged.

g. Verify lacing is snug and at the proper spacing.

h. Check the pneumatic lines near the release mechanism and near the device do not kink when the cable and tubing assembly is pulled aft to the in-flight position.

i. Check that the release mechanism can release the cable with the cable pulled at any angle with substantial force (i.e., the cable will not hang-up when the release mechanism is activated).

j. Verify the airspeed and altimeter indicators/instrumentation have current calibrations.

k. Verify the pitot-static system(s) to be calibrated and the trailing device system have been leak checked.

4.2.3 Launch Procedures.

Use the following procedures to launch the trailing device:

a. The cable and tubing assembly will be stretched on the ground to the front of the aircraft (directly off the nose or to 45 degrees off the nose) within the pilot's view. The launch personnel should be holding the trailing device before the aircraft lifts off the ground.

b. Verify communications with the chase aircraft and spotter before lift-off. The launch and recovery personnel rely on the spotter to abort the procedure if unsafe circumstances arise. The spotter should remain in communication with the test aircraft while observing the launch and recovery personnel.

c. At lift-off, the test aircraft will slowly ascend vertically as the launch personnel walk toward the aircraft. The launch personnel will carry the trailing device beneath the aircraft and allow the aircraft to lift the trailing device clear of his/her grasp.

d. The spotter will use radio communication with the test aircraft to call out the height of the device.

e. Once the trailing device has been released, the aircraft will continue to ascend vertically to a safe hover height. At the safe hover height, allow the cable to untwist and the trailing device to stop spinning before transitioning to forward flight.

f. After transition to forward fight, follow the join-up procedure discussed in the brief to join-up with the chase aircraft.

4.2.4 In-Flight Procedures.

Use the following procedures to obtain data:

a. Set altimeters to 29.92 in.-Hg.

b. Stabilize the test aircraft and trailing device at the desired test point.

c. With the aircraft and trailing device stabilized at the desired test point:

(1) Operate instrumentation required to record data.

(2) If using an analog gauge, tap indicator to minimize the effects of friction, backlash, and hysteresis.

(3) Read and record indications of all pitot-static instruments as quickly as practicable.

d. The chase aircraft will maintain observation of the trailing device from the launch through recovery, informing the test aircraft of changes in trailing device stability.

4.2.5 Recovery Procedures.

Use the following procedures to recover:

a. Verify recovery personnel and spotter are in place and prepared for recovery. The recovery personnel should be wearing the protective gear and have the grounding hook ready. The spotter should have radio communications with the test article.

b. Bring the aircraft to a high hover with the spotter calling out the trailing device height.

c. The spotter will marshal the aircraft over the retrieval personnel.

d. Slowly descend vertically until the retrieval personnel catches the trailing device with the grounding hook to dissipate the static electricity from the trailing device and cable.

e. When the retrieval person has control of the trailing device, the aircraft will continue to descend slowly. The retrieval person will walk away from the aircraft, keeping the cable and tubing assembly from being dragged and clear of the aircraft.

4.3 Pace Technique.

4.3.1 Preflight Briefing.

The preflight briefing should have the test aircraft crew, chase aircraft crew, and pace aircraft crew in attendance. The preflight brief will cover the duties of each crew during the flight. The subjects should include but are not limited to the following:

a. Radio frequencies to be used during launch, recovery, and in-flight.

b. Launch and rendezvous procedures.

c. Formation procedures.

d. In-flight testing procedures to include radio communications, conditions to be tested, and data point order.

e. Brief the crew of the chase aircraft to monitor motion and position changes between the pace aircraft and the test aircraft.

f. Brief the crew of the chase aircraft to position the chase aircraft for best surveillance of the aircraft relative positions.

4.3.2 Preflight Inspection.

The complete system must be thoroughly inspected before use. The preflight inspection includes:

a. Check pitot and static ports are clear of any obstructions.

b. Verify the airspeed and altimeter indicators/instrumentation have current calibrations.

c. Verify the test and pace pitot-static systems have been leak checked.

4.3.3 In-Flight Procedures.

Use the following procedures to obtain data:

a. Set altimeter in test and pace aircraft to 29.92 in.-Hg.

b. Stabilize the lead aircraft at the desired test point. Communicate to the second aircraft when approaching stable.

c. When the lead aircraft calls approaching stable, the second aircraft should tighten the formation to the briefed separation (formation separation distances between data points can be increased to reduce pilot workload).

d. The lead aircraft will communicate when stable. The second aircraft will communicate when to start the data collection after it is stable with the proper separation and without a closure/separation rate from the lead aircraft (both the test aircraft and the pace aircraft should be at the same altitude).

e. With both aircraft stabilized at the desired test point:

(1) Operate instrumentation required to record data.

(2) If using an analog gauge, tap indicator to minimize the effects of friction, backlash, and hysteresis.

(3) Read and record indications of all pitot-static instruments as quickly as practicable.

5. DATA REQUIRED.

A representative flight data card for acquiring pitot-static data using a calibrated pitot-static system is presented in Appendix C. The data card is presented as an example to illustrate the data acquisition procedure. The data card used in a given calibration may differ in details from this example. The data to be collected in-flight include airspeed and altitude of both the calibrated system and system under test. Outside air temperature, sideslip angle, aircraft configuration, and flight regime data are also required to complete the data collection. Care must be taken to ensure that operator's manual airspeed limits, presented in terms of ship system airspeed, are not exceeded. When using multiple position error corrections, a minimum of two overlap points should be used to ensure correlation. An example of multiple position error corrections would be the use of a trailing device to calibrate airspeeds from 40 to 120 kt and the pace method used to calibrate from 110 to 170 kt. A second example would be if the pace aircraft had multiple position error corrections for multiple configurations to be used (landing gear up/down, flaps up/down, etc.). The data reduction procedure is presented in Appendix D.

6. PRESENTATION OF DATA.

Data should be presented in such a way as to identify the difference between indicated airspeed and calibrated airspeed for each configuration and pitot-static system being calibrated. Results can be presented in the format found in Figure E-1 (Appendix E). The plot identifies the conditions that the data were flown, the configuration, and the individual pitot-static system. Calibration plots similar to the example would need to be produced for each system calibrated. The example plot is the calibration for aircraft pitot-static system. If a non-standard pitot-static system (instrumented boom mounted on the aircraft for test purposes) is being calibrated and reported on, precautions need to be made to ensure the calibration information from the non-standard installation is not used for the standard system operator manual corrections. A "NOT FOR HANDBOOK USE" note should be placed on any non-standard installation plots.

APPENDIX A. TRAILING DEVICE FIGURES.

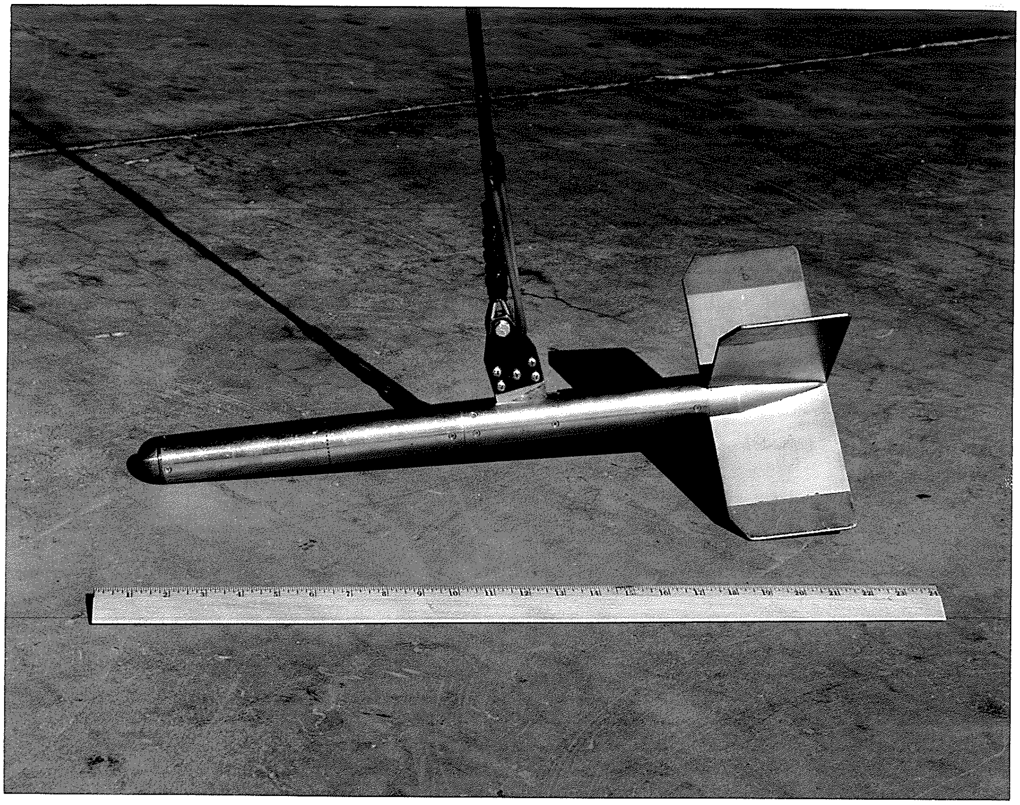


Figure A-1. Trailing Device

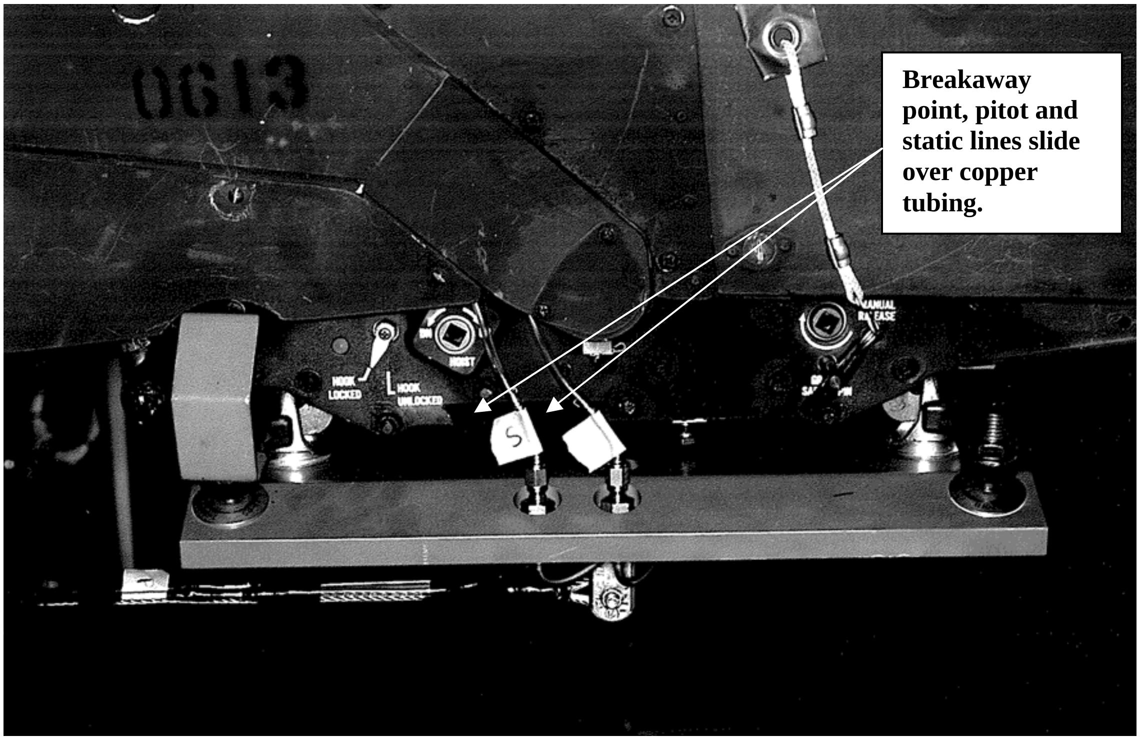


Figure A-2. AH-64 Weapons Pylon Mount

Figure A-3. AH-64 Weapons Pylon Mount (bottom)

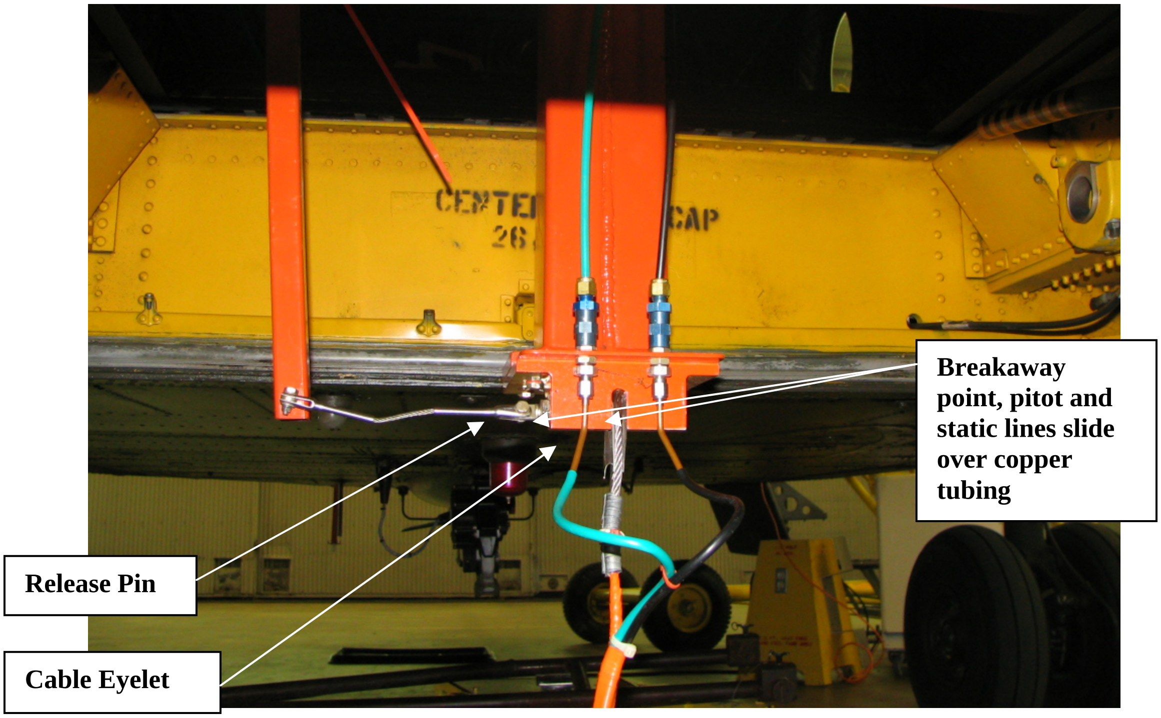


Figure A-4. CH-47D Attachment/Release System (bottom of the aircraft)

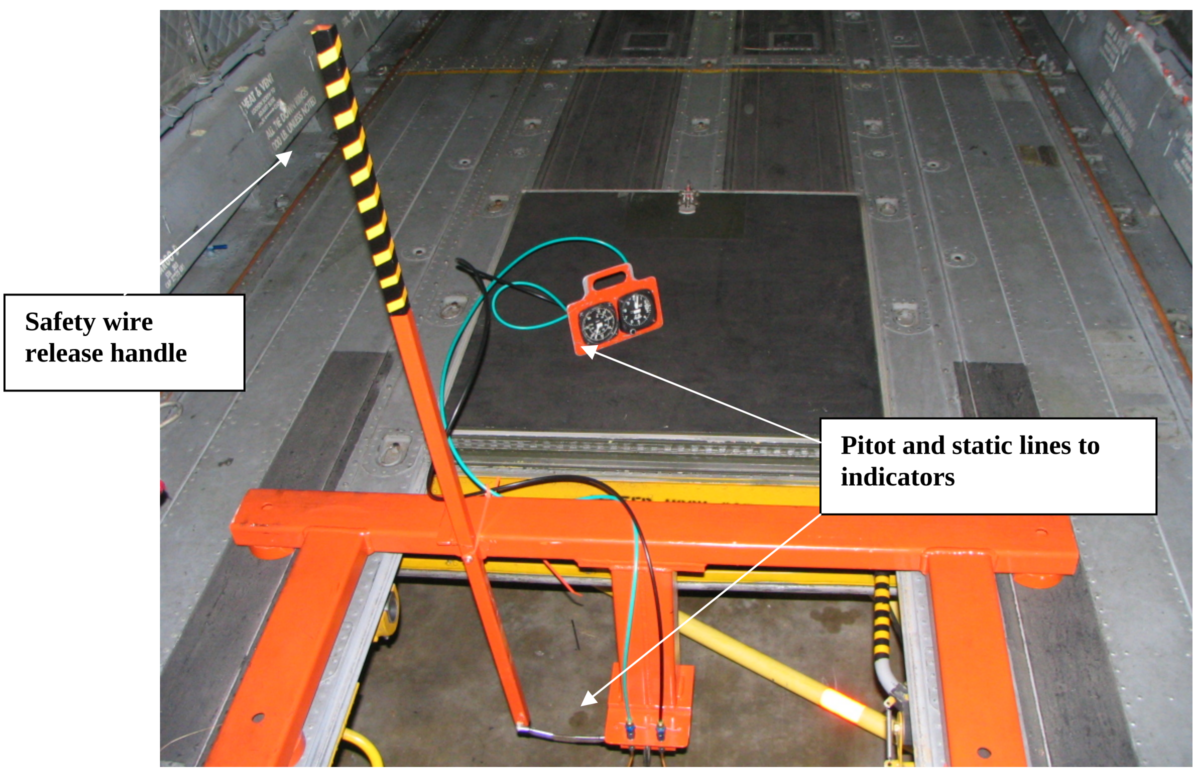


Figure A-5. CH-47D Attachment/Release System (Cabin)

APPENDIX B. SAFETY/RISK MANAGEMENT.

1.1 General

The highest level of concern for safety should be maintained throughout the test program. Human and materiel resources should be protected and conserved by the early identification, evaluation, and correction of any system hazards that may appear during the conduct of these tests. Hazards identified during the safety testing should be classified as to severity and probability in accordance with (IAW) MIL-STD-882D[2]. The hazards identified in this section are the typical hazards in performing these tests. Each calibration performed should be evaluated for the possibility of additional hazards. The test team should incorporate a gradual buildup in all test maneuvers and should evaluate trends to prevent exceeding aircraft- or test-imposed limits. Specific variables affecting safety are discussed in this section.

1.2 Training/Currency

The crew will consist of two qualified and current experimental test pilots. Additional crew should be minimized in accordance with aircraft, safety, or data collection requirements.

1.3 Aircraft

The test director (TD) will inspect the test aircraft to ensure ingress/egress routes are not impaired by equipment installation. All crewmembers will perform egress drills before the start of the test. A quality assurance inspector will inspect all nonstandard items installed on the test aircraft before start of the test.

1.4 Risks Identified for Use of the Trailing Device

1.4.1 Injury to Ground Crew During Launch and Recovery of the Trailing Pitot-Static Device

During launch and recovery, the pitot-static device apparatus is handled by ground personnel to ensure that the pitot-static device does not contact the ground. Ground personnel could be struck by the pitot-static device during recovery or could become entangled in the cabling during launch or recovery operations. In addition, ground personnel could be injured by a high voltage discharge from the pitot-static device (due to static electrical buildup) during recovery.

Suggested actions taken to mitigate the risk.

(a) A briefing of procedures should be conducted before flight.

(b) The ground crew should wear flight helmets and gloves.

(c) The person designated to retrieve the pitot-static device during recovery should wear heavy rubber gloves to protect from static electricity and should use a grounded hook to discharge the static electricity.

(d) An observer on the ground should be in radio contact with the flight crew during launch and recovery operations.

1.4.2 Damage to Aircraft due to Contact with the Trailing Pitot-Static Device Assembly During In-Flight Operations

Each use of the trailing device must be considered a new development. Small differences in attachment and handling have caused large differences in the stability of the trailing device. The onset of uncontrolled motion of the trailing device, cable, and tubing assembly is often rapid and occurs with little warning. The results of this uncontrolled motion can be serious. If the trailing device separates from the cable, the cable can become entangled in the main or tail rotor. The trailing device also can develop oscillations great enough to cause contact with the aircraft. The trailing device is sensitive to turbulence where uncontrolled motion of the trailing device and cable assembly could occur without any prior indication.

Suggested actions taken to mitigate the risk.

(a) A visual chase is highly suggested. The chase aircraft should be positioned such that it would not be struck by the trailing device or become entangled with the cable and tubing assembly should the trailing device happen to disintegrate or separate from the cable or if the trailing device and cable and tubing assembly are jettisoned. The chase aircraft should not be positioned behind or below the test aircraft.

(b) The chase aircraft should maintain a position that allows the best observation of the test aircraft, cable and tubing assembly, and trailing device in accordance with the safety requirements above.

(c) The cable and tubing assembly should be watched closely by the chase flight crew to detect the onset of whipping motions. “Whipping” of the cable and tubing assembly is usually a prelude to trailing device instability.

(d) The trailing device should be watched closely to detect the onset of any rolling, pitching, vertical oscillation, or fore and aft oscillations. At the onset of any of these motions, the chase aircraft crew should advise the test aircraft crew immediately.

(e) The test aircraft should not engage in any maneuvering flight when towing the trailing device.

(f) The flight crew should thoroughly brief the emergency procedures to include crew coordination duties associated with the malfunction of the trailing device assembly before flight.

(g) Testing should be conducted only in smooth air conditions.

1.4.3 Damage to Aircraft due to Contact of the Trailing Pitot-Static Device Assembly with an Obstacle During Transition from Launch and Recovery

When the trailing device is launched or recovered, the aircraft will ascend/descend vertically. The aircraft will transition between a high hover and forward flight or between forward flight and a high hover as the situation requires. The potential exists for an inadvertent contact of the trailing device with an obstacle during these transitions when flying near the ground.

Suggested actions taken to mitigate the risk.

(a) A visual chase is highly suggested. The chase aircraft should maintain a position that allows the best observation of the test aircraft, cable and tubing assembly, and trailing device.

(b) The flight crew should thoroughly brief the emergency procedures to include crew coordination duties associated with the malfunction of the trailing device assembly before flight.

1.5 Risk Identified for Use of Pace

1.5.1 Midair Collision with Pace Aircraft

Pace operations will place two aircraft in close proximity. The potential exists for inadvertent contact between aircraft, resulting in loss of the test aircraft or pace aircraft and/or injuries to the crew due to the possibility of one or both aircraft being unable to recover.

Suggested actions taken to mitigate the risk.

(a) A thorough briefing of the flight maneuvers, a breakaway briefing, and communication procedures should be conducted with all crews present before each flight.

(b) Pace aircraft should be flown by a qualified and current pilot trained to perform pace procedures.

(c) Two-way communication between aircraft should be maintained at all times.

APPENDIX C. EXAMPLE AIRSPEED CALIBRATION DATA CARDS.

SET ALTIMETER TO 29.92!!!!!			Chase: xxx							
Flt No: xx			Date: x/x/20xx		Page 1 of 1				Freq: xxx.x, xxx.x	
		Start	Trailing Device		Ship		OAT		Configuration – 1	
Evt	Pt	Time	kt	ft	kt	ft		Pt	Test Condition	
								1	House Keeping	
									Level Flight	
									5000 ft Boom Altitude	
								2	40 kt Boom Airspeed	
								3	50 kt Boom Airspeed	
								4	60 kt Boom Airspeed	
								5	70 kt Boom Airspeed	
								6	80 kt Boom Airspeed	
								7	90 kt Boom Airspeed	
								8	100 kt Boom Airspeed	
								9	110 kt Boom Airspeed	
								10	120 kt Boom Airspeed	
								11	115 kt Boom Airspeed	
								12	105 kt Boom Airspeed	
								13	95 kt Boom Airspeed	
								14	85 kt Boom Airspeed	
								15	75 kt Boom Airspeed	
								16	65 kt Boom Airspeed	
								17	55 kt Boom Airspeed	
								18	45 kt Boom Airspeed	

APPENDIX D. DATA REDUCTION.

A representative table for reducing pitot-static data acquired using a calibrated system is presented in table D-1. This form is presented as an example to illustrate the data reduction procedure. The form used for reducing data from a given calibration may differ in details from this example. The example table is set up for a single calibrated source and a single source under test. The process remains the same for multiple sources. Theory and definitions are detailed in the U.S. Naval Test Pilot School-Flight Test Manual No. 106[3]. The atmospheric constants define within this section pertain to the 1962 U.S. Standard Atmosphere[4].

Table D-1. Pitot-Static System Calibration Data Reduction Process

Data Reference		Calibrated Pitot-Static Source					Pitot-Static Source Under Test			Position Error
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
Pt[1]	Evt[2]	V_{ind}[3]	ΔV_{ic}[4]	V_{ic}[5]	ΔV_{pc}[6]	V_{cal}[7]	V_{ind}	ΔV_{ic}	V_{ic}	ΔV_{pc}

NOTES:

[1]Pt – Point (from the test data card)
[2]Evt – Event (from the test data card)
[3]V_{ind} – indicated airspeed
[4]ΔV_{ic} – instrument correction airspeed delta
[5]V_{ic} – instrument corrected airspeed
[6]ΔV_{pc} – position correction airspeed delta
[7]V_{cal} – calibrated airspeed

Step 1

Transcribe readings from the data card to the data reduction table columns *(1)*, *(2)*, *(3)*, and *(8)*.

Step 2

Calculate instrument corrected airspeed for all pitot-static systems for each test point as follows and enter in V_{ic} columns *(5)* and *(10)*:

$$V_{ic}\ (5) = V_{ind}\ (3) + \Delta V_{ic}\ (4)$$
$$V_{ic}\ (10) = V_{ind}\ (8) + \Delta V_{ic}\ (9)$$

The instrument correction is determined from an instrument calibration before or during the pitot-static leak check. Note: some instrumentation systems provide V_{ic} data directly negating Step 2.

Step 3

Calculate calibrated airspeed of the calibrated system for each test point as follows and enter in the V_{cal} column *(7)*:

$$V_{cal}\,(7) = V_{ic}\,(5) + \Delta V_{pc}(6)$$

Step 4

Calculate position error for the system under test for each test point as follows and enter in ΔV_{pc} column *(11)*:

$$\Delta V_{pc}\,(11) = V_{cal}\,(7) - V_{ic}\,(10)$$

Step 5

Once the position error has been evaluated for each data point of the system under test, the trend lines can be determined and an equation for the trend lines can be calculated for future use. For the example data figure E-1, the equations are:

$$\Delta V_{pc} = 11.44348 - 0.11145 * V_{ic} + 0.0000965026 * V_{ic}^2 \text{ (Example Only)}$$
$$V_{cal} = 12.13316 + 0.871 * V_{ic} + 0.00017927 * V_{ic}^2 \text{ (Example Only)}$$

Step 6

Calculate the pressure difference between the system calibrated airspeed and the system instrument corrected airspeed. The equations are as follows:

$$q_c = Pa_{ssl} * (((\gamma - 1) / 2 * (V_{cal} / a_{ssl})^2 + 1.0)^{(\gamma / (\gamma-1))} - 1)$$
$$q_{ci} = Pa_{ssl} * (((\gamma - 1) / 2 * (V_{ic} / a_{ssl})^2 + 1.0)^{(\gamma / (\gamma-1))} - 1)$$
$$\Delta P = q_c - q_{ci}$$

Where:
q_c = calibrated impact pressure (in.-Hg)
q_{ci} = instrument corrected impact pressure (in.-Hg)
Pa_{ssl} = ambient pressure standard day sea level = 29.92125 in.-Hg
$\gamma = 1.4$
a_{ssl} = speed of sound standard day sea level = 661.4786 kt
ΔP = pressure difference (in.-Hg)

Step 7

Calculate the calibrated pressure altitude. The equation is as follows:

$$Exp = R * h_{ssl} * g_c / g_{ssl}$$
$$Hp_{cal} = T_{ssl} / h_{ssl} * (1.0 - ((Pa - \Delta P) / Pa_{ssl})^{Exp})$$

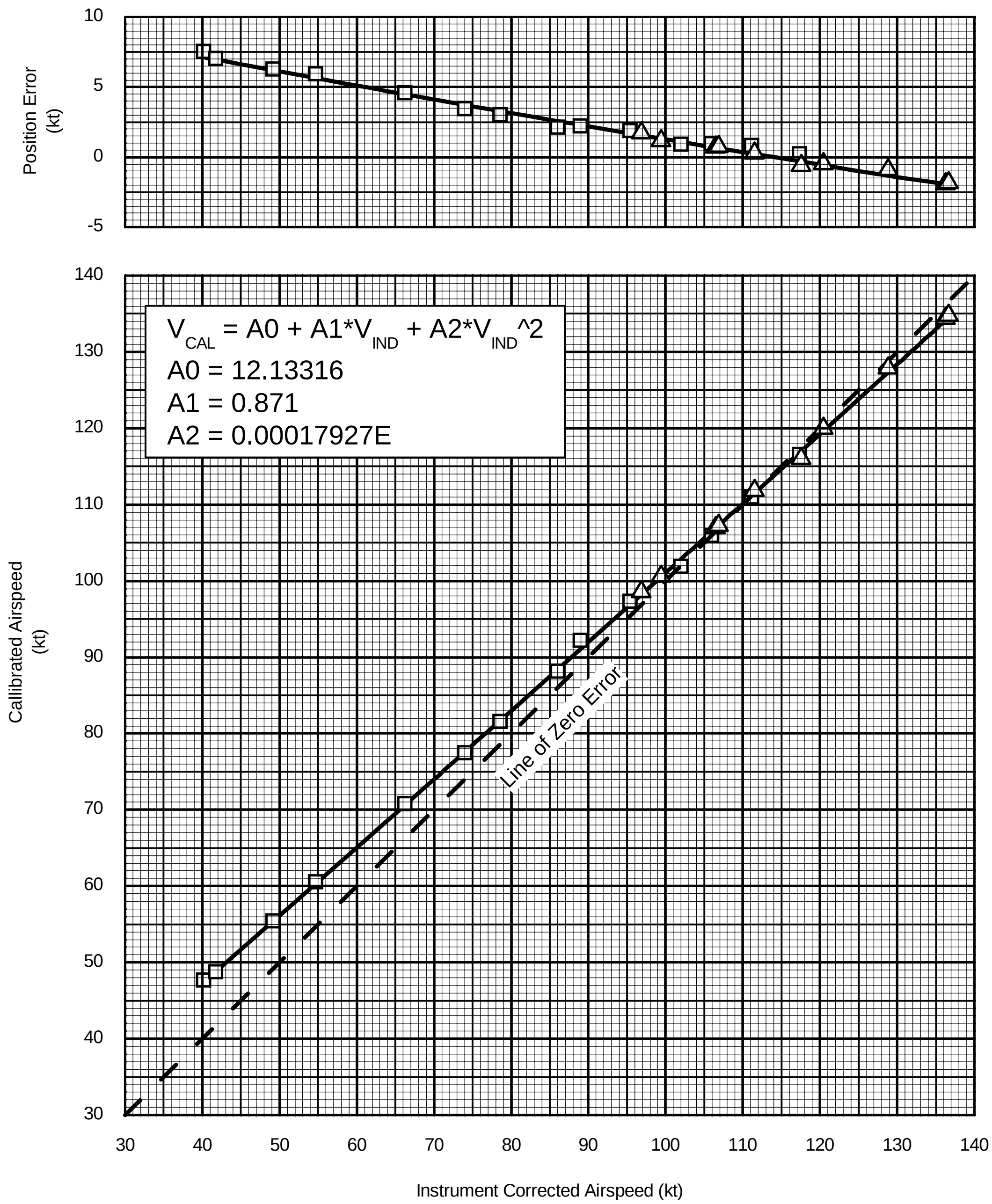
Where:
Exp = exponent
R = engineering gas constant = 96.0340 ft-lb_f/lb_m-K
h_{ssl} = standard day temperature lapse rate = 0.0019812 K/ft
g_c = gravitational constant (lb_m/slug) ~ 32.17 (lb_m/slug)
g_{ssl} = gravitational constant standard day sea level = 32.17 (lb_m/slug)
Hp_{cal} = calibrated pressure altitude (ft)
T_{ssl} = air temperature standard day sea level = 288.15 K
Ps = instrument corrected static pressure (in.-Hg)
ΔP = pressure difference (in.-Hg)
Pa_{ssl} = ambient pressure standard day sea level = 29.92125 in.-Hg

APPENDIX E. EXAMPLE DATA PRESENTATION.

Figure E-1
Ship Airspeed Calibration
UH-60 USA S/N XX-XXXXX

Symbol	Avg Gross Weight (lb)	Avg CG Location (FS)	Avg Density Altitude (ft)	Avg OAT (deg C)	Avg Rotor Speed (%)	Calibration Method
□	16,800	352.2	6,900	12.0	100	Trailing Device
△	20,470	350.7	8,970	9.0	100	Pace

Notes: 1. Configuration: Clean, Doors Closed, Windows Closed, ALQ-144 Removed
2. Condition: Level Flight; Ball Centered



APPENDIX F. GLOSSARY.

h_{ssl}	standard day temperature lapse rate
a_{ssl}	speed of sound standard day sea level
Avg	average
CG	center of gravity
Evt	event
Exp	exponent
FS	fuselage station
FTM	flight test manual
g_c	gravitational constant
g_{ssl}	gravitational constant standard day sea level
Hp_{cal}	calibrated pressure altitude
IAW	in accordance with
MIL-STD	military standard
OAT	outside air temperature
Ps	instrument corrected static pressure
Pa_{ssl}	ambient pressure standard day sea level
Pt	point
ΔP	pressure difference
q_c	calibrated dynamic pressure
q_{ci}	instrument corrected dynamic pressure
R	engineering gas constant
TD	test director
TOP	Test Operations Procedures
T_{ssl}	air temperature standard day sea level
V_{ind}	indicated airspeed
V_{ic}	instrument corrected airspeed
V_{cal}	calibrated airspeed
ΔV_{pc}	position correction airspeed delta

APPENDIX G. REFERENCES.

1. Federal Regulation, FAR, *Federal Aviation Regulation*, 20 August 2007.

2. Military Standard, MIL-STD-882D, *Department of Defense, Standard Practice for System Safety*, 10 February 2000.

3. Flight Test Manual, USNTPS-FTM-No. 106, *Rotary Wing Performance*, USNTPS, NAWC, 31 December 1995.

4. Report, *US Standard Atmosphere*, prepared under sponsorship of the National Aeronautics and Space Administration, United States Air Force, and the United States Weather Bureau, 1962.

Comments, recommended changes or any pertinent data which may be of use in improving this publication should be forwarded to the following address: Test Business Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road, Aberdeen Proving Ground, MD 21005-5055. Phone (410) 278-1486, DSN 298-1486. Technical information may be obtained from the preparing activity: Flight Test Directorate (TEDT-AC-FT) US Army Aviation Technical Test Center, Building 30137, Cairns Army Airfield, Fort Rucker, AL 36362-5276. Phone: (334) 255-8149, DSN: 558-8149. Additional copies are available from the Defense Technical Information Center, 8725 John J. Kingman Road, STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.