

AEROSPACE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard



ARP920

REV.
A

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DESIGN AND INSTALLATION OF PITOT-STATIC SYSTEMS FOR TRANSPORT AIRCRAFT

FOREWORD

Changes in the revision are format/editorial only.

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) covers the design and installation requirements for pitot-static systems.

1.1 Purpose:

The purpose of this Aerospace Recommended Practice is to present recommendations for the design and installation of pitot and static systems for transport type aircraft. This document also makes recommendations for several system configurations and sets forth the acceptable quality control requirements and the means by which they are to be controlled.

2. REGULATORY DOCUMENTS:

2.1 Federal Aviation Administration Documents:

The following document, of the issue in effect on date of application for certification, forms a part of this Aerospace Recommended Practice to the extent noted herein: Federal Aviation Regulation: Part 25 - Airworthiness.

Standards: Transport Category Airplanes. In the event of conflict between this document and FAR, Part 25, the regulatory document should apply.

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2.2 Applicable Documents:

The following documents, of the issue in effect on the date of application for certification, form a part of this Aerospace Recommended Practice to the extent noted herein:

2.2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS390 Pitot or Pitot-Static Pressure Tubes, Electrically Heated (Turbine Powered Sub-Sonic Aircraft)

AS393 Airspeed Tubes - Electrically Heated

ARP921 Flight Test Procedures for Subsonic Transport Pitot-Static Systems

ARP975 Maintenance Procedures for Pitot-Static Systems for Transport Aircraft

2.2.2 Federal Aviation Administration Publications: Available from FAA, 800 Independence Avenue, SW, Washington, DC 20591.

Part 25 Airworthiness Standards: Transport Category Airplanes

AC 43-203 Advisory Circular - Altimeter and Static System Tests and Inspections

2.2.3 Radio Technical Commission for Aeronautics Publications: Available from RTCA, 1140 Connecticut Ave., NW, Suite 1020, Washington, DC 20036.

120-61/00-108 Environmental Test Procedures for Airborne Electronic Equipment

2.2.4 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-1247 Identification of Pipe, Hose, and Tube Lines for Aircraft, Missile, and Space Systems

3. GENERAL REQUIREMENTS:

3.1 Materials and Workmanship:

3.1.1 Materials: Materials should be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in aircraft.

3.1.2 Workmanship: Workmanship should be consistent with high grade aircraft manufacturing practice.

3.2 Compatibility of Components:

If individual components of the pitot-static systems recommended herein are individually acceptable, but require matching for proper operation, they should be identified in a manner that will assure proper matching.

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3.3 Environmental Conditions:

The following environmental conditions have been established as design requirements unless more severe requirements are specified by the airframe manufacturer. The means of maintaining and testing to the following criteria are not covered in this recommended practice.

- 3.3.1 Temperature: When installed in accordance with the manufacturer's instructions, the individual components of the pitot-static system (i.e., sump valves, normal-to-alternate switching valves, etc.) should function over the range of ambient temperature shown in Column A below and should not be adversely affected following exposure to the range of temperature shown in Column B below.

TABLE 1

TABLE 1A - Reciprocating Engine Powered Aircraft

Instrument Location	A	B
Heated Areas (Temperature Controlled)	0 to 55 °C	-50 to 71 °C
Unheated Areas	0 to 55 °C	-50 to 71 °C
Non-Pressurized	-46 to 71 °C	-50 to 71 °C

TABLE 1B - Turbine Powered Aircraft (Subsonic)

Instrument Location	A	B
Pressurized Areas (Temperature Controlled)	0 to 60 °C	-50 to 71 °C
Non-Pressurized	-54 to 71 °C	-62 to 71 °C

TABLE 1C - Turbine Powered Aircraft (Supersonic)

Instrument Location	A	B
Pressurized Areas (Temperature Controlled)	0 to 60 °C	-50 to 71 °C
Non-Pressurized Areas - No Temperature Control	-54 to 260 °C	-62 to 260 °C

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- 3.3.2 Altitude: When installed in accordance with the manufacturer's instructions, the component should function and should not be adversely affected following exposure to a pressure and temperature range equivalent to -1000 to the maximum certificated altitude for the aircraft. The component should not be adversely affected when subjected to an ambient pressure of 50 inches (1280 mm) and 0.8 inch (20.51 mm) of mercury absolute.
- 3.3.3 Vibration (Reciprocating Engine Powered Aircraft): When installed in accordance with the manufacturer's instructions, the component should function and should not be adversely affected when subjected to vibrations of the following characteristics.

TABLE 2

Instrument Location in Airframe	Cycles Per Second	Maximum Double Amplitude (Inch)	Maximum Acceleration
Wings and Empennage	5-2000	0.010	.25 g
Fuselage	5-55	0.020	3.0 g
Panel (Vibration Isolated)	5-55	0.010	1.5 g

- 3.3.3.1 Vibration (Turbine Powered Subsonic Aircraft): When installed in accordance with the manufacturer's instructions, the component should function and should not be adversely affected when subjected to vibrations of the following characteristics:

TABLE 3

Instrument Location	Frequency Cycles Per Second	Maximum Double Amplitude (Inch)	(Peak) Maximum Acceleration
Wings, Empennage	5-2000	.030	5.0 g
Fuselage	5-2000	.020	3.0 g
Flight Deck Area	5-2000	.010	.25 g

- 3.3.4 Humidity: The component should function and should not be adversely affected following exposure to any relative humidity in the range from 0 to 95% at a temperature of approximately 70 °C.
- 3.3.5 Explosion Category: The system component, when intended for installation either in uninhabited areas of non-pressurized aircraft or in non-pressurized areas of pressurized aircraft, should not cause an explosion when operated in an explosive atmosphere. The component should meet the requirements applicable to the explosion category below. Specifically, any component which can be an ignition source and is intended for installation in an area in which combustible fluid or vapor may result from abnormal conditions, e.g. fuel line leakage, should meet the requirements of Category I. If the intended location is an area where combustible fluid or vapor can occur during normal operation, e.g. fuel tank, the instrument component should meet the requirements of Category II listed below:

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TABLE 4

Category	Definition
I	Explosion proofed: case not designed to preclude flame or explosion propagation.
II	Explosion proofed: case designed to preclude flame or explosion propagation.
III	Hermetically sealed.
IV	Instrument not capable of causing an explosion.

- 3.3.6 Fire Hazard: The system should be so designed as to safeguard against hazards to the aircraft in the event of malfunction or failure and the maximum operating temperature of surfaces of any instrument component contacted by combustible fuel or vapor should not exceed 200 °C due to self heating.

All materials should be non-combustible and should not liberate gases or fumes which will result in such corrosion as to cause malfunction of equipment, nor should toxic gases or fumes that are detrimental to performance of the aircraft or health of personnel be liberated under the operating conditions specified herein.

- 3.3.7 Radio Interference: The system should not be a source of objectionable interference under operating conditions at any frequencies used on the aircraft, either by radiation, conduction or feedback in any electronic equipment installed in the same aircraft as the instruments in accordance with RTCA Report 120-61/DO-108, latest revision.

- 3.3.8 Magnetic Effect: The magnetic effect of the system components should not adversely affect the performance of other instruments installed in the same aircraft.

3.4 General System Design and Installation:

Each aircraft should be fitted with a minimum of two pitot and three static systems. Static ports or systems should be provided in manifold pairs and so designed and installed as to minimize the effects of aircraft sideslip (YAW). Figures 1, 2 and 3 show system configurations which have been approved for use in specific aircraft and which may be used as a guide to the system designed.

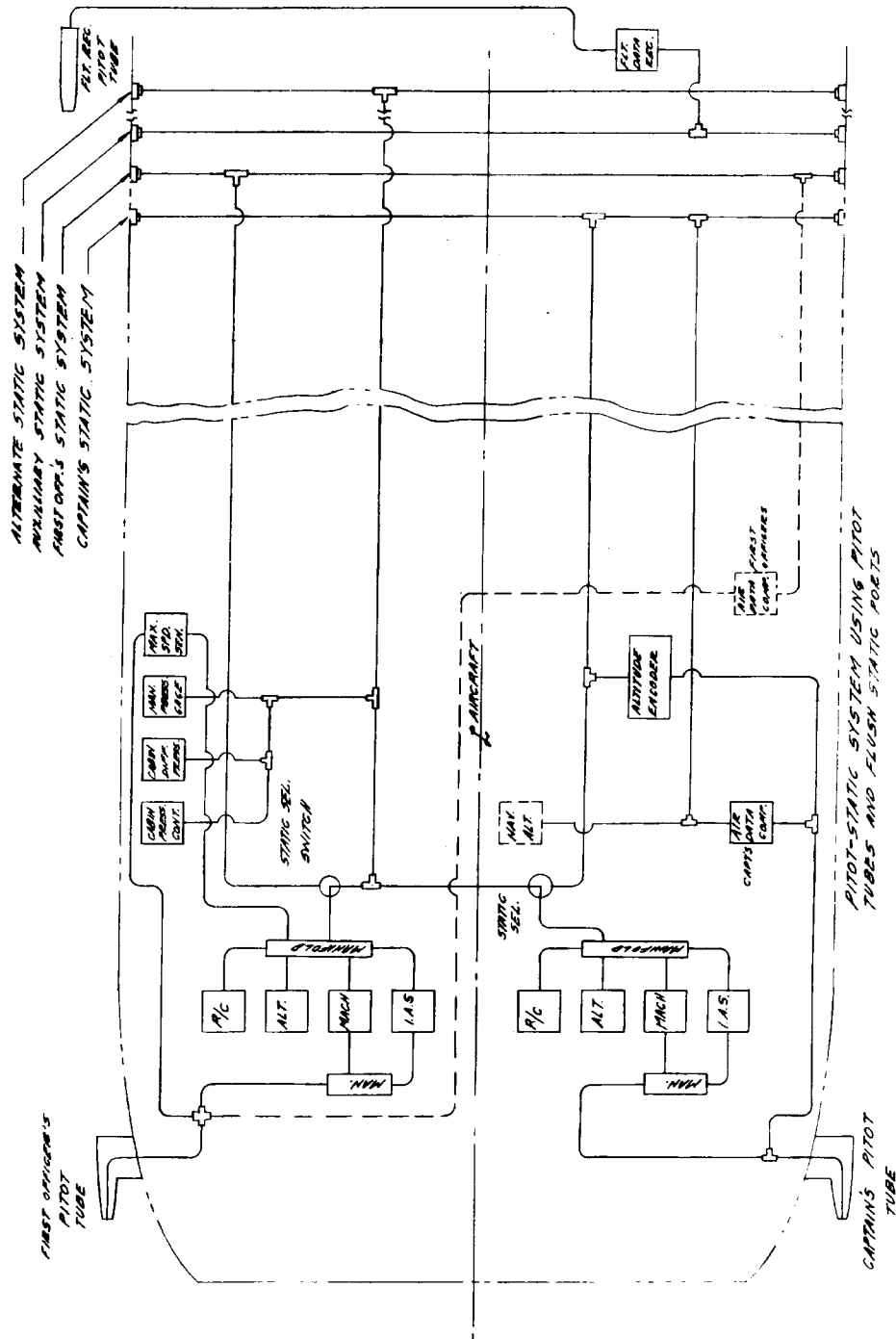


FIGURE 1 - Schematic - Pitot-Static System

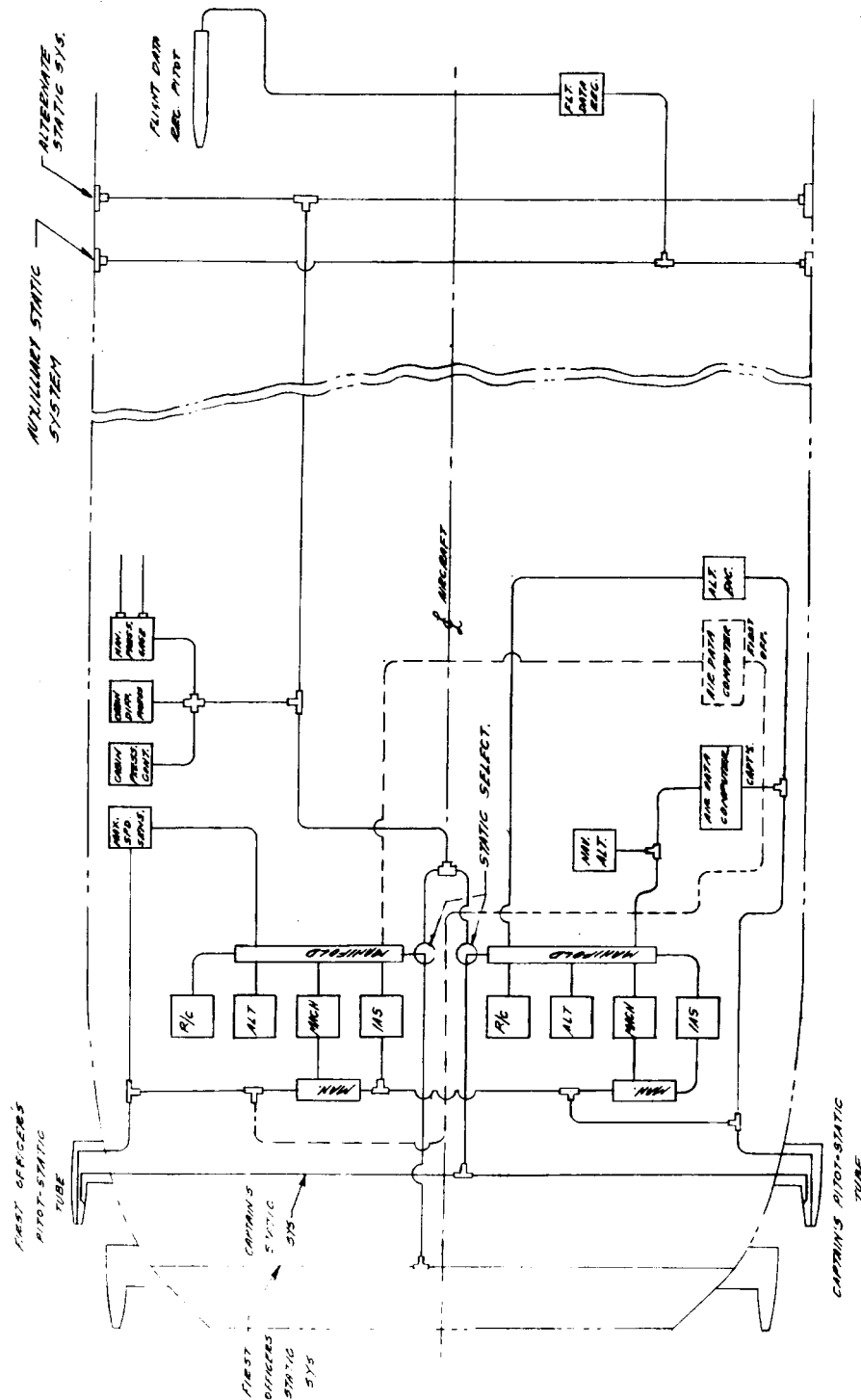


FIGURE 2 - Schematic - Pitot-Static System Using Pitot-Static Tubes

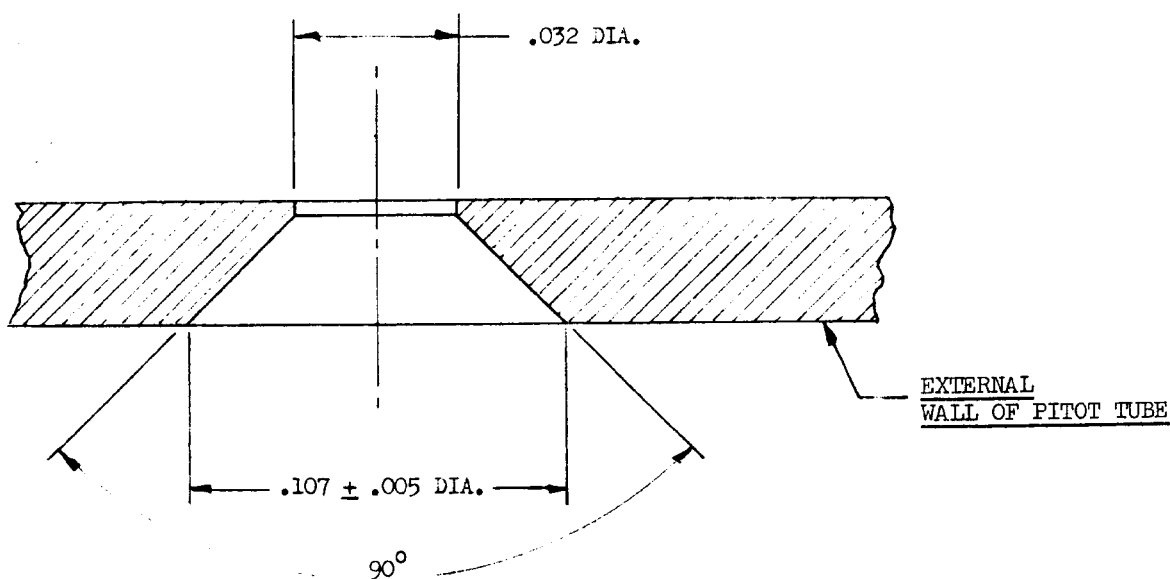


FIGURE 3 - Drain Hole Cross Section

3.4.1 Pitot (Total Pressure) System: Each aircraft should be equipped with a minimum of two pitot systems. These systems should be identified as:

- a. Pitot System (Pilot's)
- b. Pitot System (First Officer's)
- c. Auxiliary Pitot System (if required by paragraph 3.4.1.3)

3.4.1.1 Captain's Pitot System: The captain's pitot system should be connected to his airspeed indicator. In aircraft equipped with machmeters, air data computers and/or altitude encoders, the captain's equipment should be connected to his pitot system. In aircraft equipped with only one air data computer and/or altitude encoder, it should be connected to the captain's pitot system.

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- 3.4.1.2 First Officer's Pitot System: The first officer's pitot system should be connected to his airspeed indicator. In aircraft equipped with machmeters, maximum allowable speed switch, air data computers and/or altitude encoders, the first officer's equipment should be connected to his pitot system.

In aircraft equipped with automatic flight control systems (autopilots), flight data recorders and pitch trim compensators, etc. such equipment may be connected to the first officer's pitot system. However, means must be provided to permit either manual or automatic disconnect of such auxiliary equipment from the basic system supplying pitot pressures to the first officer's airspeed and Mach indicators in the event of a failure in any of the auxiliary equipment or a leak in the associated plumbing.

- 3.4.1.3 Auxiliary System(s): Should an additional independent auxiliary pitot system(s) be installed, such auxiliary system should be connected to the automatic flight control system, flight data recorder, pitch-trim compensators and any other equipment that may require pitot pressure. Should equipment connected to auxiliary static systems require pitot (dynamic pressure) inputs, such auxiliary pitot systems should be installed.

- 3.4.2 Static System: Each aircraft should be equipped with a minimum of three static systems. These systems should be identified as: captain's, first officer's and alternate. Should additional static systems beyond the ones specified be used, they should be identified as auxiliary systems in terms of the use to which they are put (e.g., "Autopilot Static System", etc.).

Caution should be exercised, however, to avoid connecting too many systems to each static system. The number of transducers which can be connected to each system is dependent upon their volume and the resultant effect upon lag (see paragraph 3.6.4) when connected thereto.

- 3.4.2.1 Captain's Static System: The captain's static system should be connected to his altimeter, airspeed indicator, and rate of climb indicator if installed. The captain's static system should also be equipped with a selector valve permitting transfer of the captain's instruments to the alternate static system. In aircraft equipped with machmeters, air data computers and/or altitude reporting systems, the captain's equipment should be connected to his static system. In aircraft equipped with only one air data computer and/or altitude reporting system, it should be connected to the captain's static system.
- 3.4.2.2 First Officer's Static System: The first officer's system should be connected to his altimeter, airspeed indicator and rate of climb indicator. The first officer's static system should also be equipped with a selector valve permitting transfer of the first officer's instruments to the alternate static system. In aircraft equipped with machmeters, maximum allowable speed switch, air data computers and/or altitude reporting systems, the first officer's equipment should be connected to his static system.

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- 3.4.2.3 Alternate Static System: For purposes of reliability, an alternate static system should be installed in each aircraft. The alternate system should be provided with independent captain and first officer's selector valves to permit the system to be independently or simultaneously connected to the captain and first officer's flight instruments in lieu of their primary system (see paragraph 3.4.2.1 and 3.4.2.2).
- 3.4.2.4 Auxiliary Static System(s): Auxiliary static systems are identified as any static system installed in the aircraft other than those previously identified as the captain's, first officer's and alternate systems. As many auxiliary static systems as deemed absolutely necessary to insure aircraft safety should be used in the aircraft. The auxiliary static system(s) may be used to provide static pressure to the autopilot, flight data recorder, pitch-trim compensator, cabin pressure controller¹, cabin differential pressure gauge, etc. or any combination thereof. Each auxiliary static system should be identified.
- 3.5 Specific System Design:
- 3.5.1 Pitot (Total Pressure) Systems:
- 3.5.1.1 Accuracy: The total pressure as measured by either the captain or first officer's and/or auxiliary pitot systems should not differ from the true pitot (total) pressure by more than 1.0% at any speed, altitude, angle of attack, angle of sideslip or aircraft configuration within the approved operating envelope of the aircraft. In addition, the first officer's or auxiliary pitot systems should not differ from the captain's system by more than 0.5% when the aircraft is flying so as to exhibit no detectable sideslip.
- 3.5.1.2 Pitot Tubes: Pitot (total) pressure should be obtained either from a pitot or pitot-static pressure tube or probe. In addition to the requirements specified herein, their basic design should meet the requirements of AS393 or AS390.
- a. Pitot Tube Total Pressure Entry: The shape of the tube's entry should be such as to minimize errors due to the local airflow into and around the tube.
 - b. Anti-Icing/De-Icing
 - 1. Pitot Tube Anti-Icing/De-Icing: Each pitot or pitot-static tube should be provided with an internal anti-icing/de-icing heater. Such anti-icing/de-icing should be accomplished by either electrical or pneumatic means, and should be so located and of sufficient heat that when activated it will meet the performance requirements of AS390 and AS393.

¹A separate static system should be provided for cabin pressure control equipment of the bleeding type (see paragraph 3.5.2.4).

3.5.1.2 (Continued):

2. **Strut Anti-Icing/De-Icing:** Where a strut or mast is employed for mounting of the pitot or pitot-static tube, an electrical or pneumatic heater should be provided in the leading edge if needed to maintain system accuracy and to prevent or eliminate the build-up of ice. The strut anti-icing/de-icing heater should be connected so as to operate concurrently with the pitot or pitot-static tube anti-icing/de-icing system.
3. **Ground Operation of Anti-Icing/De-Icing Heaters:** The pitot or pitot-static tube and mast anti-icing/de-icing heater systems should be designed such that no damage to the tube or mast should result from allowing power to be applied to the heaters for a period of 5 hours at any time when the aircraft is on the ground.
4. **Heater Power Monitoring:** Some means should be provided to indicate to the flight crew that electrical current, if used, is being used by the anti-icing/de-icing heaters.
- c. **Drainage Provisions:** The pitot or pitot-static tube should include water drainage provisions. Such drainage provisions should be in the form of holes so located as to allow drainage when the aircraft is on the ground. A tube which is otherwise symmetrical about its axis should have the mounting holes arranged asymmetrically so as to assure that the tube can only be installed with the drain hole(s) at the bottom.

The diameter of the drain hole(s) should be such as to reduce the blocking effect of capillary action of water in the drain holes. The cross-sectional shape of the drain holes should be such as to prevent them from causing an error in excess of the total system error of paragraph 3.5.1.1. An example of such a drain hole cross section is shown in Figure 3.

- 3.5.1.3 **Pitot Tube Location:** Each pitot or pitot-static tube should be so located as to provide pitot (total) pressure and static pressure (as applicable) with a minimum of interference effects from the aircraft. The mounting location selected should be as free as possible from the effects of boundary layer, angle of attack or angle of sideslip, access doors, radomes, landing gear doors, landing flaps, fluids draining from the aircraft or similar conditions. The pitot or pitot-static tube should be so located as to minimize the possibility of damage due to encounters with ground equipment or personnel. They should also be so located as to minimize their use as handles or steps by maintenance or flight personnel.
- a. **Pitot Tube Spacing:** Pitot or pitot-static tubes should be spaced a sufficient distance apart so that a single object (such as a bird) cannot occlude or damage more than one tube, nor should the flow field or wake of one tube affect the flow field or accuracy of another tube.
 - b. **Accuracy of Pitot Tube Mounting Provisions:** When the pitot (pitot-static) tube is attached directly to the aircraft structure, the mounting provisions of both the tube and the aircraft structure should be held to sufficiently close tolerances to allow routine replacement of the tubes without the need for special aligning procedures or tools such as templates, bubble protractors, etc.

3.5.1.3 (Continued):

When the pitot (pitot-static) tube is mounted on a boom or mast which would normally be considered an integral part of the aircraft, the mounting provisions of both the tube and the mating portion of the boom or mast should be held to sufficiently close tolerances to allow routine replacement of the tube without the need for special aligning procedures or tools.

NOTE: Where a boom or mast is provided as part of the airplane, a simple means should be provided for checking its alignment.

3.5.2 Static Pressure Systems - General System Design:

3.5.2.1 Static Pressure Accuracy:

- a. Federal Aviation Regulation Accuracy Requirements - Paragraph 25.1325 of Part 25 of the Federal Aviation Regulations specified the accuracy requirements for static systems as required by the Federal Aviation Administration (see Figure 4).
- b. Operator's Accuracy Requirements: The operator's requirements for static system accuracy are somewhat more severe than that noted above. Precise measurement of altitude and airspeed is also necessary for efficient, economical operation of the aircraft. Therefore, static position errors should not exceed those specified herein and illustrated in Figures 5 and 6.
 1. ± 25 ft or one quarter of one percent (.25%), whichever is greater, throughout the performance envelope of the aircraft up to a Mach number of 0.90 if compensated (see Figure 6).
 2. ± 125 ft throughout the operating envelope of the aircraft if uncompensated (see Figure 5).
 3. $\pm 0.20 \Delta p/q_{cm}$ between a Mach number of 0.90 and a Mach number of 1.10 (uncompensated). $\pm 0.020 \Delta p/q_{cm}$ if compensated.
 4. $\pm 0.010 \Delta p/q_{cm}$ above a Mach number of 1.10.

The design goal for the gradient of position error should be equal to or less than:

- a. 1.5 knots per 10 knots of airspeed in the speed range between $1.2 V_S$ and V_{Fe} , with landing flaps.
- b. 50 ft per 0.025 Mach number up to M_{Mo} plus 0.01 Mach number.

NOTE: To accomplish the above accuracies, fixed aerodynamic compensation may be necessary and is permitted. See paragraph 3.5.2.2a(9) through 3.5.2.2a(11).

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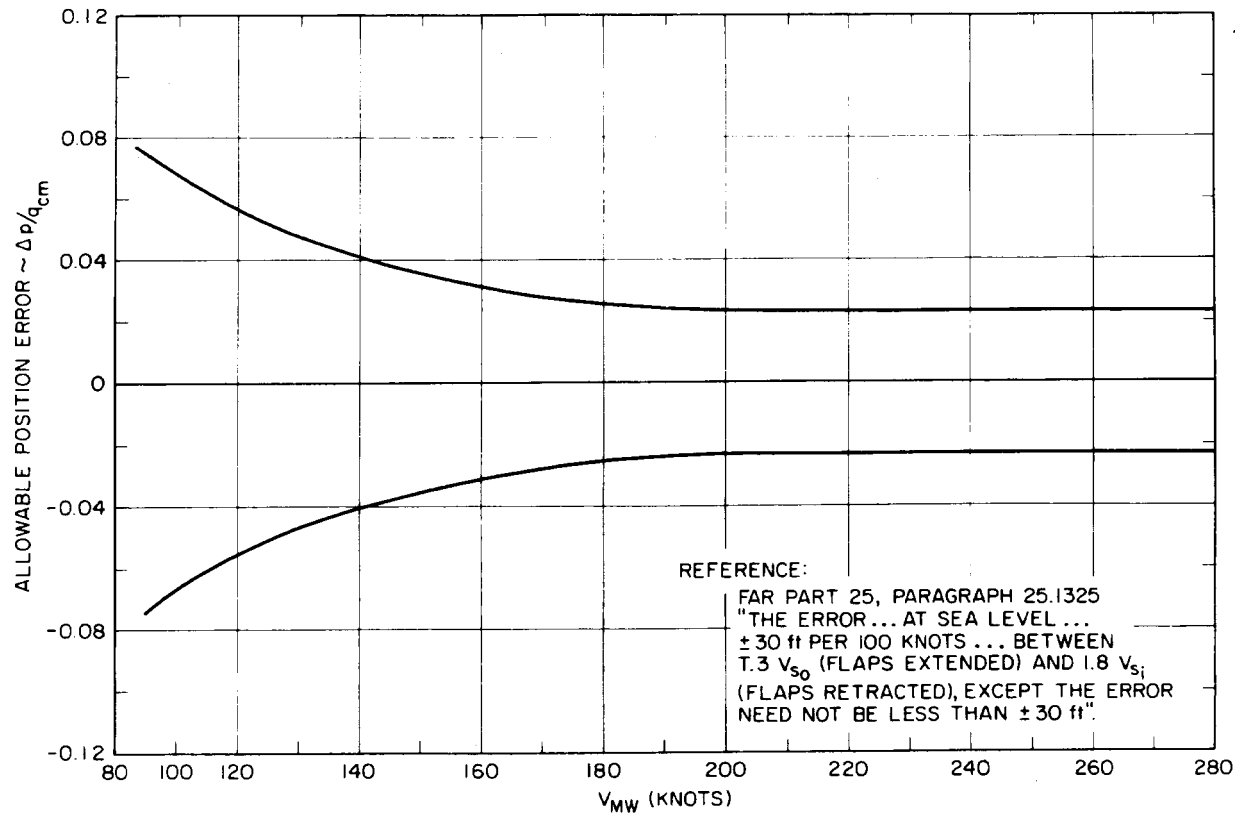


FIGURE 4 - FAA Allowable Static Port Altitude Error

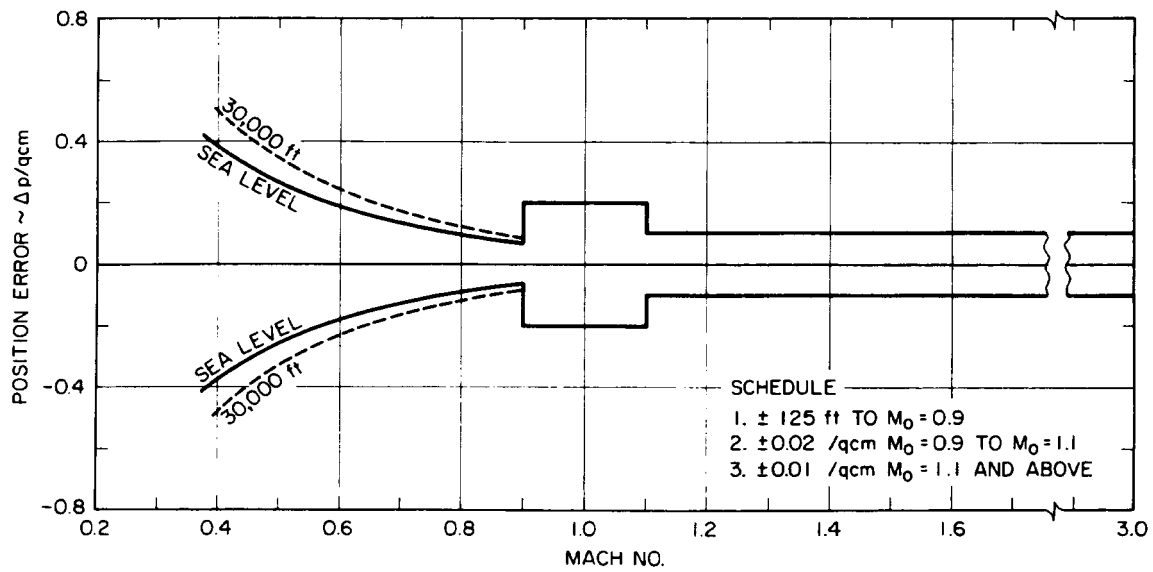


FIGURE 5 - Static Position Error Schedule
Illustrated Example

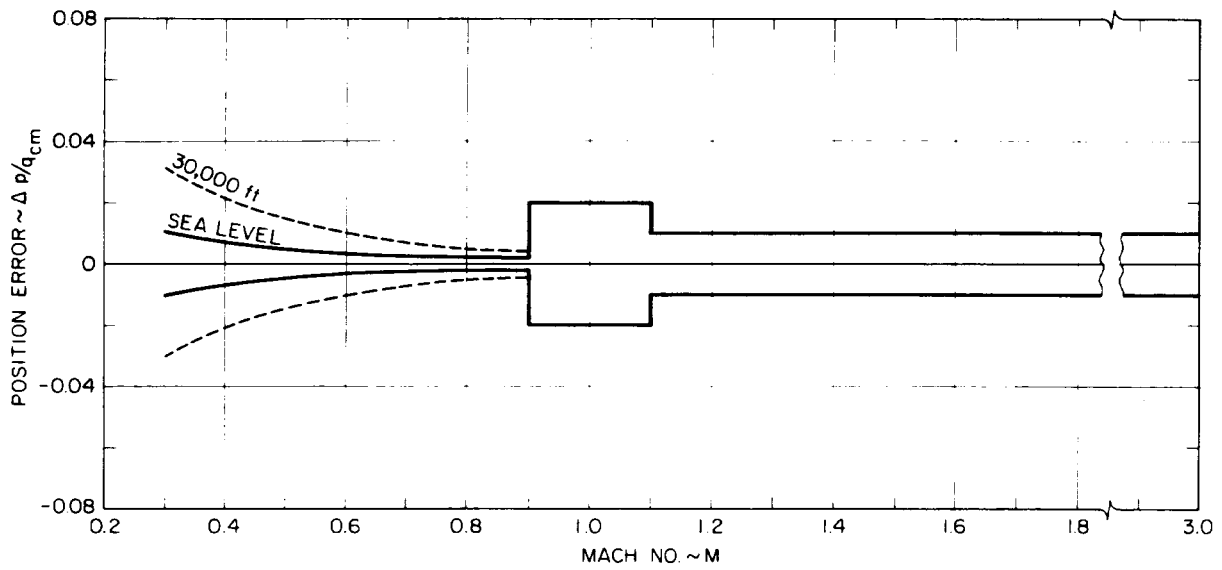


FIGURE 6 - Static Position Error Schedule
Variable Aerodynamic Compensation