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Maintenance of Pitot-Static Systems of Transport Aircraft

RATIONALE

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1. SCOPE:

In efforts to increase the accuracy and reliability of altimetry, speed measurement and other aspects of air data, a great deal of attention and money have been expended on new and refined pressure transducing and computing systems and on the standards by which they are calibrated. So much progress has been made in this that the limiting factor is, or may soon be, the sensing and transmitting in the aircraft of the pressures to be transduced. Until the appearance of References 1-13 and 18 there was little guidance available on the maintenance of pitot and static systems. This report presents what information is available, suggests limits, and lists the principal original papers on the subject.

1.1 Purpose:

To set forth in a single document the principles and practices for maintenance of pitot and static pressure systems of transport aircraft.

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9. "Recommendation on Maintenance of Pitot-Static Systems of Transport Aircraft"; Air Transport Association of America, Recommendation 34-10-4, December 1969.
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17. "Design and Installation of Pitot-Static Systems for Transport Aircraft"; Society of Automotive Engineers, ARP920, October 1968.
18. "Wind-Tunnel Investigation of a Number of Total Pressure Tubes at High Angles of Attack; Subsonic, Transonic and Supersonic Speeds"; Gracey, NACA Report 1303, 1957.

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23. "Flight Calibration of Aircraft Static Pressure Systems"; De Leo and Hagen, FAA SRDS Report RD-66-3, (Clearinghouse PB-170-763) (Rosemount Engineering Co. Report 76431) February 1966.
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25. "Evaluation of New Methods for Flight Calibration of Aircraft Instrument Systems"; De Leo and Hagen, WADC Technical Report 59-295 (Part III) (AD 268780) September 1961.
26. "Trailing Cone Reference System"; Watson, (included in) Douglas Report DEV 3674, November 1964.
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35. "Specification for Aircraft Static System Flight Test by Trailing Cone Method"; Air Transport Association, (Attachment 2 to) Operations Memorandum 66-134, November 1966.
36. "DC-8 Airspeed Static Position Error Repeatability"; Mabry and Brumby, Douglas Aircraft Division, Paper 5517, (Undated; c. 1968).
37. ICAO Circular 81-AN/68 - Aeroplane Static Pressure System - Uniform Method of Calibration of Position Error. (International Civil Aviation Organization, Montreal, Canada.)
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3. BACKGROUND:

- 3.1 All aircraft are fitted with pitot or pitot-static tubes for the sensing of pitot (or total) pressure. The accuracy of a tube may depend in part on its alignment on the airplane and on the condition of the tube itself at and near the entry (or nose). Very little information has been available to guide the operator in maintaining tubes. This Aerospace Information Report (AIR) endeavors to provide guidance.
- 3.2 Most transport aircraft now in service or soon to enter service sense static pressure for the altitude and speed instruments at flush ports mounted in the fuselage skin. It has long been known that the repeatability of the pressure sensing at such ports is largely dependent upon the contour and smoothness of the surrounding skin; as the requirements for accuracy of altimetry have become more stringent, this has become a matter of increasing concern.

During the course of their service lives, airplanes accumulate damage and minor surface deformation, some of which is in the static port area. In most instances, Structure Repair Manuals for the various aircraft do not adequately detail the special requirements of these areas, and repairs which would be quite smooth enough in other fuselage areas, may lead to excessive pressure sensing errors. Comparison of information for various airplanes shows less agreement than would be expected.

3.2 (Continued):

This AIR endeavors to establish comparatively simple methods of measuring and setting limits on surface irregularities on existing airplanes, and to lend support to the instrument engineer who has to plead for exceptional sheet metal work and for test flight time.

- 3.3 There is need for more wind-tunnel studies to establish a firmer basis for the kinds of tolerances this AIR sets. While the effects of long-wavelength sinusoidal waviness and protrusion or recession of port fittings have been well analyzed, the effects of step discontinuities, narrow gaps, and irregular roughness need study.

Some types of aircraft now in service have skin in the static port region so thin that it can be expected to bulge or quilt slightly between supporting members. The amount of this quilting, and its effect, if any, on static pressure sensing should also be the subject of studies.

- 3.4 For recommendations on the design of pitot-static systems of new aircraft, or for the retrofit of old ones, References 10, 15-17 should be consulted.
- 3.5 It is emphasized that this AIR is tentative, and in some areas intuitive in nature, and that while it offers guidelines it should in no way be considered binding or mandatory.
- 3.6 The Maintenance and Overhaul Manuals for each type of airplane should contain information equivalent to this AIR, suitably adapted for that type of airplane. Where adequate specific information is available, it should be given more weight than a general recommendation such as this one.

4. LEAKAGE:

4.1 General:

- 4.1.1 Leakage, particularly of cabin air pressure into a pitot or static system is not an unusual occurrence. Large leaks are immediately apparent from the behavior of the instruments. Small leaks, however, may be so minor that their effect may be erroneously ascribed to instrument tolerances or to static port irregularities, etc. It goes without saying that for routine airplane operation, leakage must be held below a certain limit, and that prior to calibration of a pitot-static system leakage should be completely eliminated.
- 4.1.2 Purging and proof-pressure testing, while not part of leak testing should in some circumstances precede leak testing.
- 4.1.3 Where Government regulations set more stringent requirements, they shall prevail.

4.2 Tooling:

- 4.2.1 For occasional leak testing, as after replacement of an instrument, the airplane's own instruments may be used, although it is more convenient to have a test set which need consist only of a simple airspeed indicator with a hand-pump, a pitot adapter, a static adapter and appropriate lengths of tubing.
- 4.2.2 Special test sets for calibration checks of pitot-static instruments and system leak tests are available in various degrees of elaborateness. Basically they consist of pumps, altimeters, airspeed indicators and regulating and shutoff valves. In some models a machmeter and/or rate-of-climb indicator may be included; in some, the instruments may be calibrated in pressure terms, rather than in feet and knots.
- 4.2.3 Suitable adapters allowing connection of the test equipment to the airplane system should be available. For pitot system tests it is preferable to connect the test equipment by an adapter fitted over the tube. For static systems it is preferable that the connections be made at the static ports, rather than some other point in the plumbing, as for example a drain, for this would leave one point untested after removal of the test equipment. The static port adapter, at least for use where the inside of the skin at the static port location is exposed to cabin pressure, should be large enough to include the annular gap between the face of the port fitting and the surrounding skin so that any leakage path for cabin air pressure would be detected.

It is usual to connect the adapter to the port on one side and to use tape to blank off the corresponding port on the other side of the airplane. When using this method, something should be placed between the face of the port fitting and the tape to prevent sealing of the orifices by the tape, so that if there is leakage between the port fitting and the skin it will be detected as flow into the piping. (A coin of about the same diameter as the fitting might be suitable.)

CAUTION: Large pieces of colored tape should be used so as to minimize the possibility of their being forgotten.

4.3 Purging:

At each second airframe overhaul or at three-year intervals (unless the operators' inspections indicate that a longer interval would be satisfactory), the instruments should be disconnected and the plumbing blown with dry air or dry nitrogen at a pressure of about 50 psi (3.52 kg/sq cm), unless a lower pressure is recommended by the airframe builder, in the direction from the instruments towards the ports and drains. Hoses which show signs of deterioration and could shed bits of lining should be removed beforehand. If there is reason to suspect that there is much solid material in the lines, they should be disconnected from port fittings of the "salt shaker" type so that the material may escape.

CAUTION: Failure to disconnect instruments will result in damage to them.

It may be necessary to restrain hoses from whipping and to prevent blasts of air from reaching the disconnected instruments.

4.4 Proof-Pressure Tests:

If the necessity is indicated by the operator's experience, after major modification, replacement of several sections of plumbing or otherwise at the discretion of the operator, the system should be disconnected from all instruments, plugged and pressurized with dry air or nitrogen to a pressure of about 100 psi (7.03 kg/sq cm) for 5 minutes, unless a lower pressure is recommended by the airframe builder.

4.5 Visual Inspection:

- 4.5.1 At each major airframe overhaul or at two year intervals all pitot and static tubing in vulnerable and accessible locations should be visually inspected for chafing, kinks, cracks and other damage, and for dips which could form water traps, and appropriate corrective action taken.
- 4.5.2 At each major airframe overhaul or at two year intervals all pitot and static hoses should be visually inspected for chafing, kinks, and other damage, and should be felt for softening, embrittlement or other deterioration, and replacement or other corrective action taken. Hoses in tension or capable of being placed in tension, as by the action of a hinged panel, should be rearranged or replaced by longer ones.

4.6 Leak Testing:

4.6.1 The following principles should be observed in all pitot-static leak testing:

- a. Leak testing should be done AFTER all other inspection and work on the system has been completed.
- b. A diagram of the system should be at hand so it will be clear what is being included in the test, so that the probable leak point can be inferred from the behavior of the instruments, and so as to reduce the danger of applying excessive or reverse pressure of any instrument.
- c. Before connecting it to the airplane, the test equipment should be capped off and tested to ensure that it has no leaks of its own.
- d. Connection of the test equipment should be made outside of the airplane; i.e., at the pitot tubes and at the static ports. Use of interior drain or test fittings for this purpose is not desirable, for the capping or plugging of them remains untested after removal of the test equipment.
- e. Full-range testing should be done only by persons thoroughly familiar with the airplane and its instruments and with the test equipment. Others should make only low-range tests.
- f. The pressure in the pitot system must always be equal to or greater than that in the static system, i.e., negative airspeed must be avoided.

4.6.1 (Continued):

- g. The excess of pitot over static pressure must not exceed the range of the airspeed indicator or machmeter.
- h. The rate of change of static pressure should not exceed the range of the rate-of-climb indicator.
- i. The rate of leakage must be determined for each system separately. Rates of two or more systems parallel are not valid because the added volume of a system which happens to be tight can reduce the apparent leakage rate of a faulty system connected to it.
- j. At the conclusion of testing a double-check should be made to assure that the system has been restored to its normal flying configuration, e.g., tapes removed from static ports and pitot tube drain holes, plugs and caps replaced, selector valves in normal positions, etc.

4.6.2 Low Range Leakage Test: After each instance in which a connection in the pitot or static system has been broken to permit the replacement of instruments, hoses, or tubing, or for other reasons, a low-range leakage test should be performed. Quick-disconnects, even if provided with self-sealing valves, should not be exempted from this requirement unless the operator's experience shows otherwise.

4.6.2.1 Pitot System: Leaving the static system vented to ambient, pressure should be applied to the pitot system until the airspeed indicator reads 250 knots, and the system and tester closed off. In a 1-minute period the leakage of each system separately should not exceed 2.5 knots. The pressure should be released slowly.

4.6.2.2 Static System: Leaving the pitot system vented to ambient, the pressure in the static system should be reduced until the airspeed indicator reads 250 knots or the altimeter reads 3000 ft above field altitude, and the system and tester closed off. In a 1-minute period the leakage of each system separately should not exceed 2.5 knots or 60 feet. The vacuum should be released slowly.

NOTE: These rates apply to typical flush port systems having two port fittings, each with seven holes of .047 inch (1.2 mm) diameter totaling .012 sq inch (7.8 sq mm), or other arrangement of equal or greater area. Where the total is less, as in some installations using pitot-static tubes, less leakage may be tolerable. Ref. 13 gives a method for determining this.

4.6.2.3 In instances where it would be impracticable to make a leakage test after breaking and making one or two connections, it may be acceptable to have an inspector or another mechanic check the connection, as for example by putting a wrench on the nut and feeling whether it had been torqued up.