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MAINTENANCE OF PITOT-STATIC SYSTEMS OF TRANSPORT AIRCRAFT

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.

2. REFERENCES:

1. "Pitot-Static Systems"; Patton and Bryan, Civil Aeronautics Administration, Airplane and Equipment Engineering Report No. 46, (Undated, circa 1950).

2. "The Effect of Flow Disturbances on Airspeed Static Vent Readings"; Dunlap and Lapin, Douglas (internal memo) A250-AERO-243, July 1954.

3. "An Investigation of the Effect of Random Fuselage Wall Irregularities on Flush Static Pressure Port Calibrations"; Werner and Teigen, WADC Technical Report 57-365 (AD 130805), April 1957.

4. "Effects of Some Dimensional Variables on the Calibration Characteristics of Static Pressure Sources"; Teigen, WADC Technical Report 59-596 (AD 266373), June 1959.

2. (Continued):

5. “Fuselage Skin Irregularities in the Vicinity of Fuselage Static Pressure Ports”; De Leo and Hagen, Rosemount Engineering Co., 1961.

6. “Effects and Control of Installation Irregularities on Flush Static Systems”; Stratton, Douglas Report LB 30765, December 1961.

7. “Aircraft Skin Contour Measurements Adjacent to Flush Static Ports on Military Transport Type Aircraft”; De Leo, Hagen and Thompson, Rosemount Engineering Co., Technical Report 4622B, April 1962.

8. “Recommendation on Flush Static Port Maintenance”; Anderson, United Air Lines Report F-829B, August 1963. (Superseded by Refs. 9 and 30)

9. “Recommendation on Maintenance of Pitot-Static Systems of Transport Aircraft”; Air Transport Association of America, Recommendation 34-10-4, December 1969.

10. “Evaluation of Factors Affecting the Calibration Accuracy of Aircraft Static Pressure Systems”; De Leo et al, (U.S.) Air Force Systems Command, Technical Report SEG-TR-65-35 (AD 621678, N66-13623), July 1965.

11. “The Effects of Installation Irregularities on Flush Static Systems and the Means of Eliminating Them”; Stratton, Autonetics Publication 554-A-18, Undated.

12. “The Influence of Pressure System Leakage on Aircraft Static Pressure Measurements”; De Leo and Hagen, Rosemount Engineering Co. Report 76111, Undated.

13. “Relation of Static System Leakage to Altitude Error”; Wheatley, United Air Lines Report F-1096A, Rev. June 1967.

14. “Pitot and Static Pressure Systems, Installation and Inspection of”; Anonymous, (USAF Specification) MIL-P-26292, January 1959. (Ref. 9 proposed revision.)

15. “Recommendation on Design of Pitot-Static Systems for Transport Aircraft”; Anderson, United Air Lines Report F-1242, May 1970.

16. “Recommendation on Design of Pitot/Static Systems for Transport Aircraft”; Air Transport Association of America, June 1970.

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.

2. (Continued):

19. “Wind Tunnel Test Results of Protruding Static Taps for Pressure Compensation”; Hansen, Douglas (internal memo) A250-AERO-60-29, January, 1960.

20. “The Measurement of Pressure Altitude on Aircraft”; Gracey, NACA TN 4127, October 1957.

21. “Measurement of Static Pressure on Aircraft”; Gracey, NACA Report 1364, 1958.

22. “Flight Calibrations of Fuselage Static Pressure Vent Installations for Three Types of Transports”; Silsby and Stickle, NASA TN D-1356, May 1962.

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.

24. “Douglas Five-Probe Differential Pressure Head Proposal for the ATA Conference, Washington, D.C.”; Price, Douglas Technical Memorandum TM-AERO-F-1785, February 1960.

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.

27. “Lo-lag Trailing Cone System”; Watson, Douglas Technical Memorandum TM-4099, February 1966.

28. “Flight Test Procedures for Static Pressure Systems Installed in Subsonic Transport Aircraft”; Society of Automotive Engineers, ARP921, July 1971.

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30. “Maintenance of Pitot-Static Systems of Transport Aircraft”; Anderson, United Air Lines Report F-1119B, October 1967.

31. “Bibliography on Altimetry, Static Pressure Measurement and Barometry”; Anderson, United Air Lines Report F-780, Rev. 1962.

32. “Experimental Evaluation of TRU-42/A Pitot Tube Damage (REC Model 851C)”; Lemmerman and Malin, Rosemount Engineering Company, Report 8673, Undated (c. 1967).

33. “Waviness and Mismatch Quality Standards: Static Ports”; Douglas Aircraft Division Attachment 1 to DQS C 4.2-3R, May 1968.

2. (Continued):

34. "Operation, Maintenance and Data Processing Procedures for the DC-8 Trailing Cone Kit"; Douglas Aircraft Division, DR-66, (undated).

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.)

38. "Performance Report on Static Air Source on Air Carrier Turbojet Aircraft"; Air Transport Association, October 1966.

39. "The Influence of Aerodynamic Cleanness of Aircraft Static Port Installations on Static Position Error Repeatability"; Douglas Aircraft Co. Report No. DAC-67485, November 20, 1968.

40. "Installation Static Trailing-Cone Calibration System", DC-8 Service Bulletin No. 34-101, Douglas Aircraft, June 1969.

41. "DC-8 Airspeed Static Position Error Repeatability," Mabry and Brumby, Douglas Paper 5517, Undated (circa 1969).

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.

4.6.2.4 If after an apparently satisfactory low-range test, the behavior of the instruments is still such as to suggest leakage, a full range test should be made.

The design of some instrument cases is such that the cabin pressure tends to loosen the gasket seal between the glass and bezel, rather than to tighten it. With instrument cases of this type, a full-range test may reveal leakage not detectable by a low-range test.

4.6.3 Full Range Leakage Test: At each major airframe overhaul, or biennially, a full-range leakage test including all components normally connected to the system should be performed. This may be done in conjunction with a system calibration check if desired. A full-range test should also be made before and after any flight calibration of pitot-static systems.

CAUTION: Where instruments are connected to two systems (e.g. an autopilot air data sensor connected to the co-pilot's pitot system and the auxiliary static system) it may be necessary to take both systems to the test altitude and airspeed together, or to disconnect such instruments to avoid over-pressuring or reverse-pressuring them. When two or more are taken up, they must be isolated from each other during the time the leakage rates are being read.

4.6.3.1 The pressure in the pitot AND static systems should be reduced until the altimeter reaches the test altitude; the pressure in the pitot system must be greater than that in the static system, and at the test altitude the airspeed indicator or machmeter should be brought to 60% of the maximum operating airspeed or mach number, V_{MO} or M_{MO}, for the test altitude. After closing off the system and the test equipment, the leakage in a 1-minute period should not exceed 1% of the test airspeed, nor 2% of the test altitude. When high test altitudes are used, the pitot pressure may be below ambient; a leak in the pitot system may appear as an increase rather than a decrease of airspeed.

NOTE: Where the total area of the static port openings is less than .024 sq inch (15.6 sq mm), less static system leakage may be tolerable. See Note in 4.6.2.2.

4.6.3.2 Test Altitudes: A test altitude should be applied which will produce a pressure differential across the static tubing which is at least equal to maximum cabin differential pressure. This will vary with the type of airplane and with the field evaluation, and may be calculated as needed. Typical values for a sea-level field, in round numbers, are:

TABLE 1

Approximate Maximum Cabin Differential Pressure		Test Altitude
Negligible (Unpressurized Aircraft)		3,000 feet
2.5 psi	(176. gm/sq cm)	5,100
4.2	(296.)	9,000
5.5	(387.)	12,400
8.5	(597.)	22,000

4.6.4 Leakage of cabin pressure around a static port fitting may also be demonstrated by pressurizing the airplane to, say, .5 psi, (35. gm/sq cm) and then applying a bubble-type leak detector to the gap between the fitting and the skin.

5. PITOT AND PITOT-STATIC TUBES:

5.1.1 Because it is much easier to obtain accurate total pressure than accurate static pressure, it is usual to assume that errors of airspeed measurement are chargeable to defect of static pressure rather than pitot. Almost invariably, pitot errors are negative, whether due to poor choice of location, misalignment, leakage to ambient or excessive size of water drain hole. Whether leakage of cabin air pressure into a pitot system will cause a positive or a negative error can be calculated from the airspeed and the cabin differential pressure.

5.1.2 Tubes may be provided with static pressure ports as well as total pressure entries. Such pitot-static tubes are usually used where a flush static port installation would not be satisfactory, or where aerodynamic compensation for static pressure error is needed.

5.1.3 The inspections described herein should be made at each major airframe overhaul, or at two year intervals, unless experience indicates a longer interval would be satisfactory.

5.2 Alignment:

The function of a tube to pick up total or stagnation pressure requires that it be outside of the airplane boundary layer and pointed into the wind. Because the local wind direction changes as the body angle (or angle of attack) changes, tubes are sometimes pointed slightly downward to partially compensate for the high body-angle typical of approach and landing conditions.

The alignment of the tube with respect to the airplane should be specified in the Maintenance Manual for each airplane type. The tolerances should also be specified there; if not, the following should be used:

a. Pitot tubes of the blunt form, ±1°. A blunt pitot tube, for this purpose, is considered one in which the outer surface at the nose is a cone of 30° or greater apex angle, or any ogival or other shape of equal or greater bluntness, and the lip or wall between the inner and outer diameters is of the order of 0.02 inch (0.5 mm) or greater.

b. Pitot tubes of the sharp form, ±2°. A sharp pitot tube, for this purpose, is considered one in which the outer surface at the nose is a cone of 15° or smaller apex angle, or any ogival approximation of equal or greater sharpness, and the lip or wall between the inner and outer diameters at the entry is of the order of 0.005 inch (0.13 mm) or less.

c. Pitot tubes of the cylindrical form, ±2°. A cylindrical pitot tube for this purpose is considered one in which the outer surface, from the nose aft is substantially cylindrical, and a thin lip is formed with the base of the internal conical entry chamber.

d. Pitot-static tubes of any form, ±1°.

A full treatment of this subject can be found in Ref. 18.

5.3 Inspection:

5.3.1 Pitot tubes should be inspected for damage, erosion or other defects. Discoloration or slight flaking of the plating are not causes for removal, but the following conditions are:

a. At the entry: blunting of the lip to 0.03 inch (0.8 mm) or more at any one place, or to 0.02 inch (0.5 mm) all around, unless a greater bluntness was originally designed into the tube. (Ref. 32)

b. At the entry and for 2 inches (51 mm) aft, or within 1 inch (25.4 mm) of the drain hole: chips, gouges, dents, blisters or other defects more than 0.03 inch (0.8 mm) deep or high by 0.06 inch (1.5 mm) long or wide.

c. In the portion more than 2 inches (51 mm) aft of the entry: defects deeper or higher than 0.09 inch (2.3 mm).

d. In the mast portion (if any): defects deeper or higher than .15 inch (3.8 mm).

5.3.2 Pitot-static tubes should be inspected for damage, erosion or other defects. Discoloration is not cause for removal, but the following conditions are:

a. At the entry: blunting of the lip to 0.03 inch (0.8 mm) or more at any one place, or to 0.02 inch (0.5 mm) all around, unless a greater bluntness was originally designed into the tube.

b. At the static holes: Burring or deformation exceeding 0.003 inch (0.08 mm) in any dimension.

c. In the rest of the tubular portion: Defects deeper or higher than 0.010 inch (0.25 mm).

d. In the mast portion (if any): defects deeper or higher than 0.15 inch (3.8 mm).

5.4 Drainage:

5.4.1 Pitot (and pitot-static) tubes are usually provided with one or more drain holes so that rain or other water may be discharged overboard, and not enter the system. Each drain hole should be examined to assure that it is not obstructed nor burred. In clearing a hole or removing burrs, care must be taken to avoid enlarging the hole, for this could lead to negative pressure error.

5.4.2 The hoses and tubing leading from each pitot (and pitot-static) tube should be inspected as described in Section 4.5. Special attention should be given to the slope of lines to assure free drainage either into a sump (if fitted) or to the tube's own drain.

5.5 Skin Surface:

The smoothness required of the skin surface near pitot-static tubes should be specified in the Maintenance Manual for each type of airplane. The tolerable departures from contour should also be specified; if not, the following should be used:

The point on the skin closest to the static ports of the tube should be noted, and a square area extending 12 inches (or 30 cm) forward and 12 inches (or 30 cm) aft and above and below marked out as described for flush static ports in 6.3.1.4.

Using a straightedge and gauge as described in 6.3.1.4, clearances greater than the following are cause for corrective efforts:

A tube whose axis is 4 inches (10.2 cm) from the skin, 0.16 inch (4.1 mm).

A tube whose axis is 5 inches (12.7 cm) from the skin, 0.20 inch (5.1 mm).

A tube whose axis is 6 inches (15.2 cm) or more, 0.24 inch (6.1 mm).

Where the pitot-static tube is mounted on a baseplate intended to be recessed into and flush with the skin surface, these limits also apply to the baseplate.

5.6 Protective Covers:

Protective covers should be used to prevent insects and other foreign matter from entering pitot tubes while airplanes are laid up, or idle for longer than the usual turnaround, maintenance or overhaul work periods. Each cover should have a brightly colored streamer attached, to minimize any possibility of overlooking removal before flight.

6. SURFACE MEASUREMENT OF FLUSH STATIC PORTS:

6.1 General:

The measurement of departures of airplane skin surface from contour is difficult and tedious to do in a comprehensive, scientific manner. References 3-5, 7 and 10 describe measurement equipment and procedures at a first-order simplification: i.e., as dial indicator depth readings from a temporarily attached reference straight-edge, at discrete intervals. For the purposes of transport operators, a second-order simplification may suffice, and this is described in this section.

The tolerances given in this section are based upon an intuitive synthesis of manufacturing drawings, examination of undamaged airplanes, References 2-5, 7, 10 and 29 and a small amount of experience in recalibrating ports after skin rework. They are suggested for interim use until limits based on windtunnel studies and flight tests are established.

6.2 Tooling:

6.2.1 CAUTION: Tools of the type listed below have very sharp corners and edges, particularly when new. The corners and edges must be slightly rounded with fine abrasive cloth before these tools are used on airplane skin.

6.2.2 Spring-tempered steel rule 24 inches long, approximately 1.25 inch wide and 0.045 inch thick, or 60 cm long, approximately 32 mm wide and 1 mm thick.

For use on skin of compound curvature the stiffness of the rule is critical; it must be flexible enough to not deflect the airplane skin when held flat against it, yet stiff enough to not be deflected itself when a thickness gauge is placed between it and the skin.

It may be desirable to rig a rectangular frame a little larger than 24 x 24 inches (or 60 x 60 cm) to hold the rule in place against the skin, the frame being held to the airplane skin by vacuum cups at the corners.

6.2.3 Flexible spring tempered steel rule 6 inches long approximately 0.5 inch wide and 0.020 inch thick; or 15 cm long, approximately 12 mm wide and 0.5 mm thick.

6.2.4 Thickness gauge, with narrow blades; approximately 0.25 inch or 6 mm wide at ends.

6.2.5 Taper type thickness gauge (e.g. Starrett No. 270, 0.010 to 0.150 inch and 0.30 to 4 mm).

6.3 Procedure and Tolerances:

6.3.1 Flush Ports in Flat or Simple - Curved Areas:

6.3.1.1 Hose and Tubing Preload: It may be found in thin-skinned airplanes that the hose or tubing attached to the static port fitting is exerting sufficient force on the fitting so as to deflect the skin. This should be corrected before attempting any other corrective work or calibration.

6.3.1.2 Port Fitting Flushness (Refs. 2, 11 and 19): With a thickness gauge measure the elevation of the face of the static port fitting above the surface of the surrounding skin, or its depression below it (Figures 1 and 2). This should be done at two or three points, for the elevation or depression may not be uniform. It may be found that the hole in the skin is burred so that the port may only appear to be depressed.

Elevation of the port fitting above the skin by 0.002 inch (0.05 mm) or more, or depression of 0.005 inch (0.13 mm) or more is cause for corrective efforts, unless it was done intentionally by the airframe builder as part of the calibration.

The heads of flush rivets used to attach the port fitting to the skin and doublers should be shaved if they protrude more than 0.002 inch (0.05 mm) above the skin.

6.3.1.3 Gap Between Fitting and Skin: When the hole in the skin is appreciably larger than the fitting, an annular or crescentic gap may be left. Fitting installation drawings usually call for such gaps to be filled, but it is not unusual to find unfilled gaps 0.03 inch (0.76 mm) or wider. The pressure effects of such gaps are not known.

The presence of a gap of 0.04 inch (1.02 mm) or wider is cause for corrective efforts.

6.3.1.4 Gross Measurement of Surrounding Areas (Refer to Figure 3): Identify the Captain's and Copilot's static port fittings and note the midpoint between them. At a point a little more than 12 inches (or 30 cm) above and a little more than 12 inches (or 30 cm) forward of the midpoint, place a piece of pressure-sensitive tape as a marker. In like manner place three more markers to define the square area within which measurements will be taken as shown in Figure 3.

Hold the 24 inches (or 60 cm) rule on edge against the skin and parallel to a waterline (on a perfect, constant-section fuselage the edge of the rule should touch skin along its entire length). Try this at several waterline locations within the area bounded by the tape markers while watching for clearance between the rule and the skin. Insert the taper gauge or a thickness gauge blade in the largest clearances found.

On piston-engined airplanes, clearance of 0.080 inch (2.03 mm) at any point in this area is cause for corrective efforts. On turbine-engined airplanes, clearance of 0.040 inch (1.02 mm) at any point in this area is cause for corrective efforts.

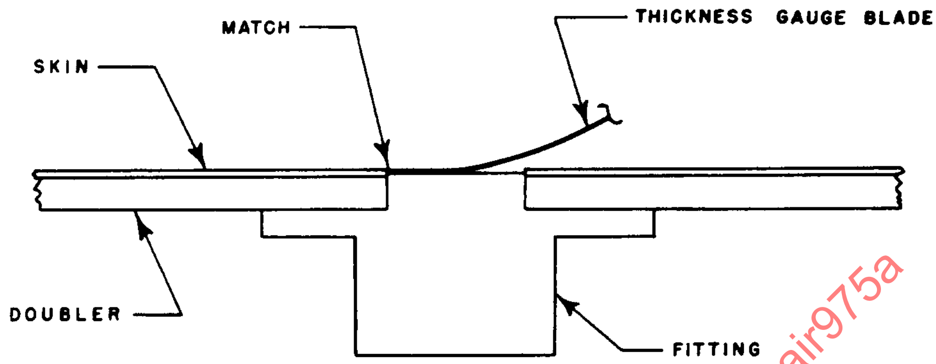

FIGURE 1 - Measurement of Port Fitting Depression
(Sectional View)

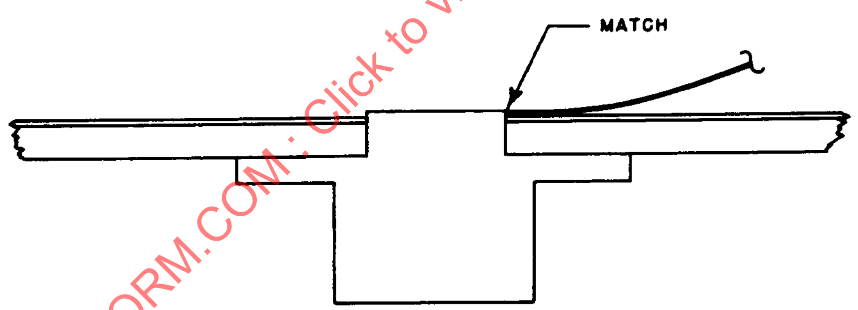

FIGURE 2 - Measurement of Port Fitting Elevation
(Sectional View)

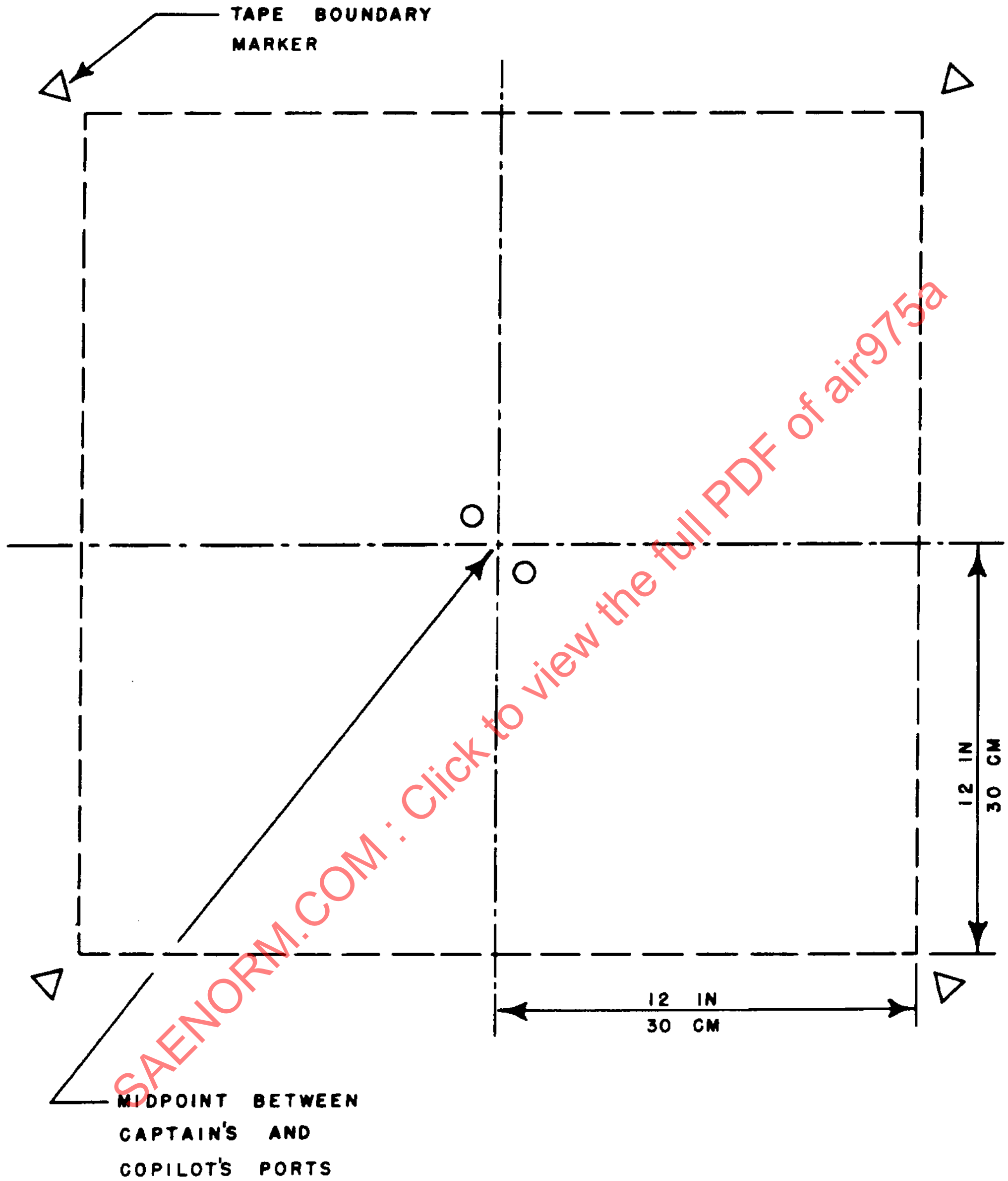

FIGURE 3 - Gross Measurement Zone

6.3.1.4 (Continued):

Irregularities, such as skin laps, oval-head rivets, etc., which were included in the detail design of the airplane, and which were present in the particular airplanes used by the airframe builder to determine the “approved” calibration, should be disregarded.

6.3.1.5 Fine Measurement of Surrounding Area (Refer to Figure 4): Hold the 6 inches (or 15 cm) rule on edge against the skin, parallel to a waterline and centered over the Captain’s static port fittings. Try this at various waterline locations within the limits of 3 inches (or 7.5 cm) above and below the center of the fitting while watching for clearance between the rule and the skin. Insert a thickness gauge blade in the largest clearances found.

On piston-engined airplanes, a clearance of 0.015 inch (0.38 mm) at any point in this area is cause for corrective efforts. On turbine-engined airplanes, clearance of 0.010 inch (0.25 mm) at any point in this area is cause for corrective efforts.

6.3.2 Flush Ports in Compound-Curved Areas: This is done in the same manner as on flat or simple-curved areas, except that the rule is laid flat to the skin and flexed to conform to its curvature. If the rule is wide, or if the curvature of the skin is considerable in the direction perpendicular to the length of the rule, one edge only may be held against the skin and used as a reference for the thickness gauge.

CAUTION: Do not allow the rule to deflect the skin.

6.3.3 Small Raised Port Plates: Gross measurements should be made above and below the plate. For measurements forward and aft of the plate a special rule with a clearance notch for the plate may be used on a flat or simple-curved area. Fine measurements should be made over the entire face of the plate, irrespective of the limits shown in Figure 4.

6.4 Recording:

6.4.1 Whenever static ports are calibrated, it is desirable to record the condition of the adjacent surface. Perhaps the most definitive way to record the shape of a surface, or in this instance its departure from ideal, would be by means of contour lines. While this method may be the best for research work, it is quite impracticable for commercial air carrier use, and a less elegant method must suffice.

6.4.2 Figure 5 shows a recording form for gross measurements in terms of clearance between the reference rule and the skin. In most instances the reference rule will contact the skin at two or more points, which may be indicated on the form by the letter C. The larger clearances, for example those greater than 0.030 inch (0.76 mm), may be written in at the appropriate locations. In like manner clearances greater than 0.010 inch (0.25 mm) in the inner zone may be noted on a form such as shown in Figure 6. Both forms should be used for any one pair of ports on one side of an airplane.

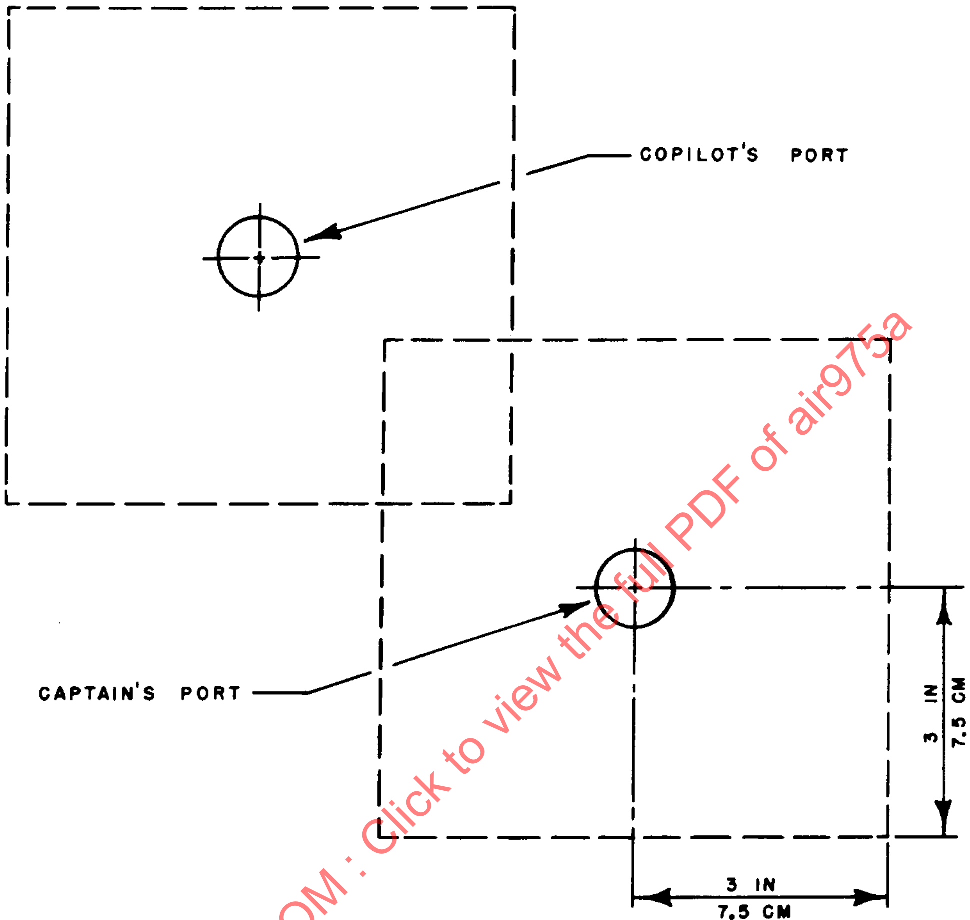

FIGURE 4 - Fine Measurement Zones

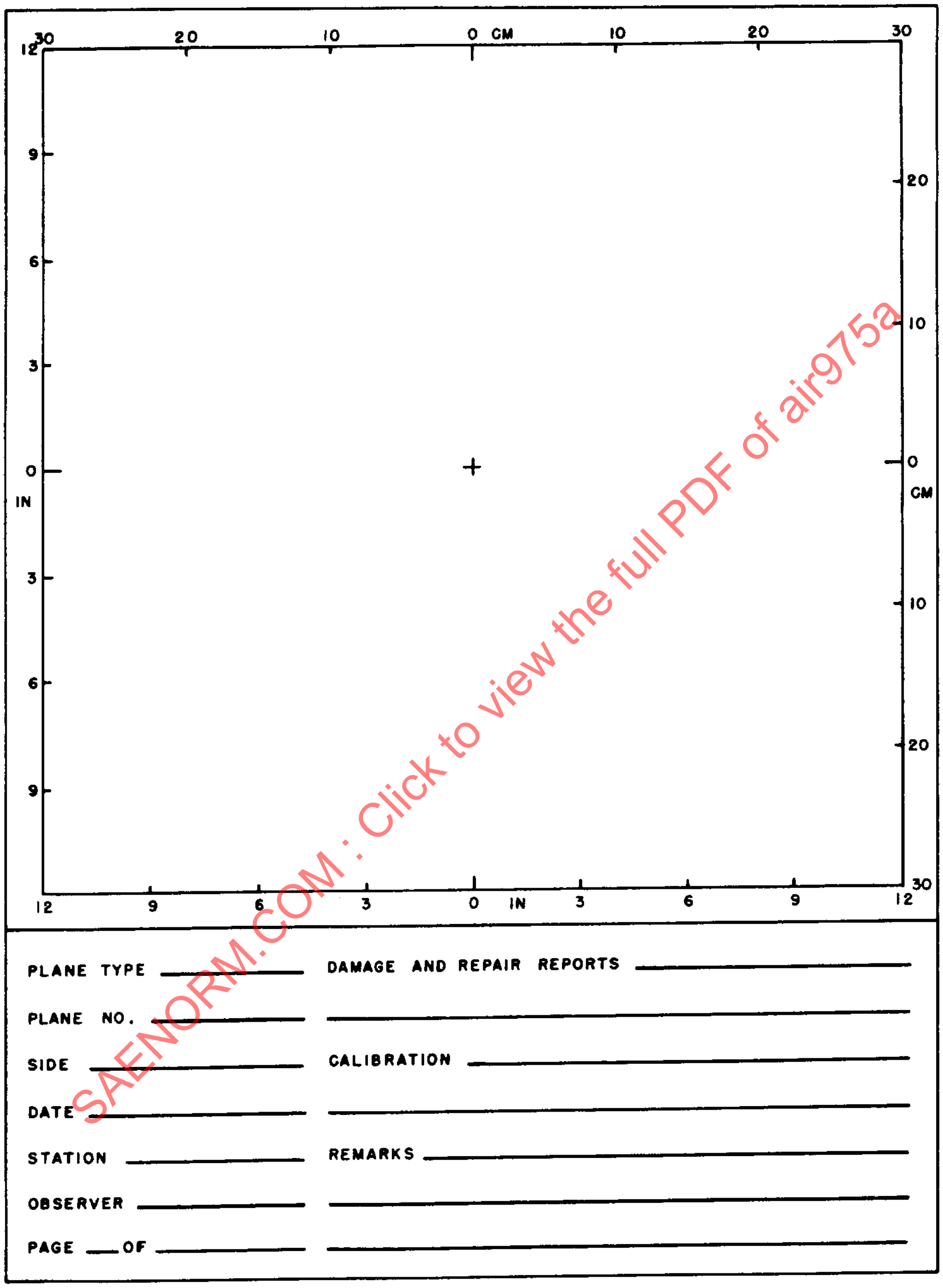

FIGURE 5 - Recording Form for Gross Measurements

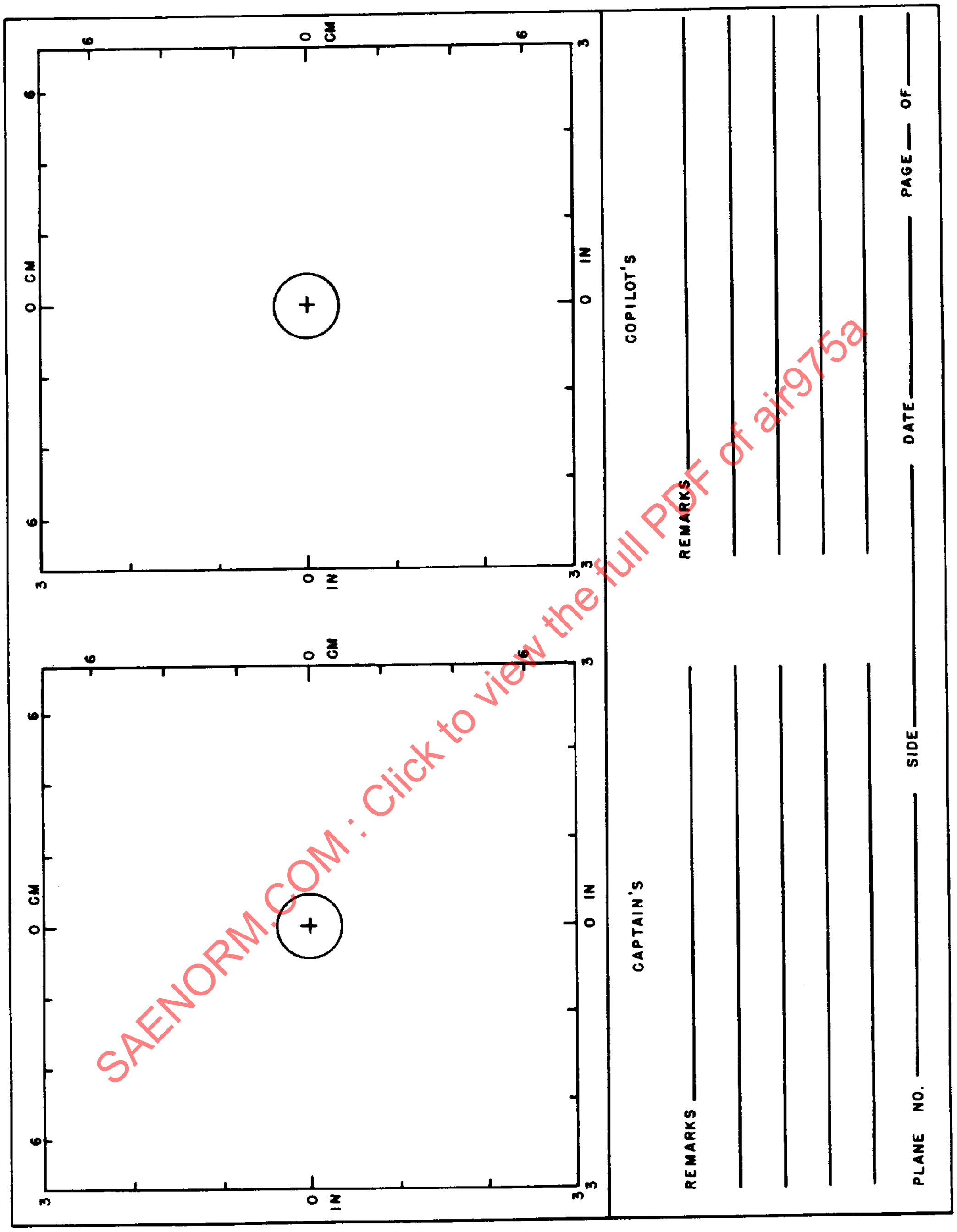

FIGURE 6 - Recording Form for Fine Measurements

7. REPAIR METHODS - FLUSH STATIC PORTS:

NOTE: Most or all of this information should be included in the builder's Structural Repair and Maintenance Manuals for each type of airplane.

7.1 Craftsmanship:

Sheet-metal work at and around the static ports should be done only by mechanics of exceptional skill and experience. At critical phases of the work, as for example when straightening a bent piece of structure could result in cracking it, the guidance of an engineer qualified in structural aspects is recommended.

7.2 Bumping:

Where it is found that there is a small elevation or depression whose depth exceeds the allowance given in 6.3, consideration may be given to bumping the skin closer to contour. To minimize the risk of stretching the skin, or of cracking it or some of the substructure, it is preferable to undercorrect rather than to chance overcorrection. It should also be recognized that what is a depression while the airplane is unpressurized may 'oilcan' to a protuberance when cabin pressure is applied. In some instances it may be necessary to install shims between the skin and substructure.

7.3 Filling:

7.3.1 Dents may be filled until a permanent repair can be made. Fillings may show a tendency to crack after a time due to cabin pressure acting on the skin; they also prevent observation of the origin or growth of skin cracks. Although the adhesion of the filling material should be good enough to keep it in place, it would seem prudent to anchor large fillings with screws after the material has hardened. Fillings should be inspected at short intervals.

The Structural Repair Manuals for some airplanes include procedures for patching skin with fibreglass cloth and epoxy resin. Presumably these materials could be used for filling dents.

NOTE: Good results have been obtained with the proprietary product "Met-L-It" (Fr. "Colmetal", Sp. "Qemetal") (R. M. Hollingshead Corporation, Camden and Toronto). The "No. 4" kit contains filler in sheet form, referred to as 'fibre', together with filler in paste form and solvent.

The instructions in the kit may be supplemented to call for filling large dents first with small pieces of fibre, then with increasingly larger ones, in the manner of contour lines on a map. The external surface and the edge feathering are done with the paste material.

7.3.2 Because of the possibility of ingestion of fillings which may become dislodged, the use of fillings is NOT recommended for airplanes with aft-fuselage-mounted engines.

7.4 Surface Patches:

Static ports are usually in areas of the fuselage which are considered ‘critical’ as to aerodynamic cleanness. For this reason as well as for port calibration, surface patches should be used only temporarily.

Surface patches with unbevelled edges and/or non-flush rivets should not be installed within the limit shown on Figure 7. Surface patches with bevelled edges and flush rivets should not be installed within the limit shown on Figure 8.

7.5 Flush Patches:

While flush patches may theoretically be installed at any distance from the static ports if they meet all the smoothness requirements of Section 6.3, in practice it may in some instances be preferable to install a larger patch encompassing the ports, so that the joints and riveting may be kept farther from the ports.

7.6 Installation of New Skin:

7.6.1 Reskinning is usually done according to original manufacturing drawings. In some cases the smoothness tolerances are not very stringent, or may not even be stated. Every effort should be made to obtain the smoothest possible final surface, nevertheless.

7.6.2 Where the damage is extensive enough to require installation of a new piece of skin at or near the static port region, the frames, stringers, intercostals and/or other members should be straightened, doubled, replaced or shimmed as required so that the design contour and smoothness will be matched as closely as possible.

Where the skin is thin in proportion to the stiffness of the structure to which it is to be riveted, consideration should be given to using somewhat thicker skin to assure greater smoothness. There may, however, be structural reasons for not doing this; if so, they should govern.

Where the skin being replaced is of compound curvature, or milled to various thicknesses, or is otherwise special, the piece should be obtained from the airframe builder.

7.6.3 To assure the smoothest result, the rivet holes in the new skin should be located by placing it against and drilling it to match the substructure to which it is to be riveted. Using the removed piece of skin to locate rivet holes while away from the airplane is likely to result in wrinkles at installation.

Doublers under the skin at the static port area should also be replaced, and must be pre-formed to the prescribed curvature before installation.

Static port fittings should also be replaced and made flush. Efforts to salvage old doublers and fittings usually result in a slightly wavy surface with the face of the port fitting recessed.

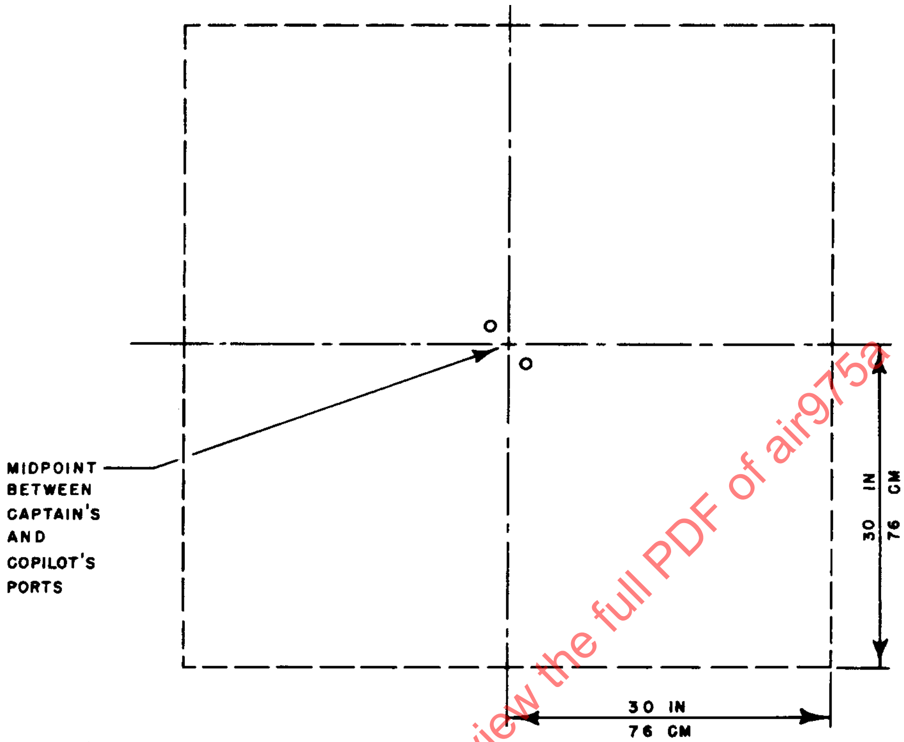

FIGURE 7 - Rough Surface Patch Limit

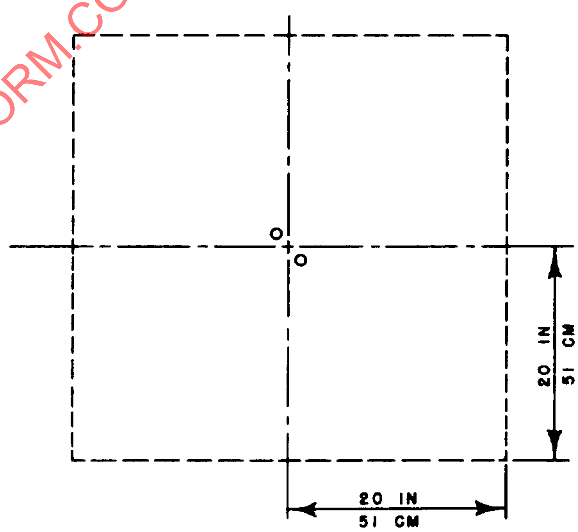

FIGURE 8 - Fair Surface Patch Limit