

## CHAPTER 12. AIRCRAFT AVIONICS SYSTEMS

### SECTION 1. AVIONICS EQUIPMENT MAINTENANCE

**12-1. GENERAL.** There are several methods of ground checking avionics systems.

**a. Visual Check.** Check for physical condition and safety of equipment and components.

**b. Operation Check.** This check is performed primarily by the pilot, but may also be performed by the mechanics after annual and 100-hour inspections. The aircraft flight manual, the Airman's Information Manual (AIM), and the manufacturer's information are used as a reference when performing the check.

**c. Functional Test.** This is performed by qualified mechanics and repair stations to check the calibration and accuracy of the avionics with the use of test equipment while they are still on the aircraft, such as the transponder and the static checks. The equipment manufacturer's manuals and procedures are used as a reference.

**d. Bench Test.** When using this method the unit or instrument is removed from the aircraft and inspected, repaired, and calibrated as required.

**e. Electromagnetic Interference (EMI).** For EMI tests, refer to chapter 11 paragraph 11-107 of this AC.

**12-2. HANDLING OF COMPONENTS.** Any unit containing electronic components such as transistors, diodes, integrated circuits, proms, roms, and memory devices should be protected from excessive shocks. Excessive shock can cause internal failures in any of these components. Most electronic devices are subject to damage by electrostatic discharges (ESD).

**CAUTION:** To prevent damage due to excessive electrostatic discharge, proper gloves, finger cots, or grounding bracelets should be used. Observe the standard procedures for handling equipment containing electrostatic sensitive devices or assemblies in accordance with the recommendations and procedures set forth in the maintenance instructions set forth by the equipment manufacturers.

**12-3.—12-7. [RESERVED.]**



## SECTION 2. GROUND OPERATIONAL CHECKS FOR AVIONICS EQUIPMENT (ELECTRICAL)

**12-8. GENERAL.** When the operating or airworthiness regulations require a system to perform its intended function, the use of the Technical Standard Order (TSO) equipment or the submission of data substantiating the equipment performance is strongly recommended. An operation check of avionics is the responsibility of the pilot in command. However, it is recommended that after replacement of equipment during 100 hour or annual inspections, an operational check of avionics equipment be performed. The accomplishments of these checks must be done in accordance with the recommendations and procedures set forth in the aircraft's flight manual instructions published by the avionics equipment manufacturers.

### 12-9. INSPECTION OF AVIONICS SYSTEMS.

**a.** The inspection shall include the following:

(1) Inspect the condition and security of equipment including the proper security of wiring bundles.

(2) Check for indications of overheating of the equipment and associated wiring.

(3) Check for poor electrical bonding. The bonding requirements are specified by equipment manufacturers. Installation cabling should be kept as short as possible, except for antenna cables which are usually pre-cut or have a specific length called out at installation. Proper bonding on the order of 0.003 ohms is very important to the performance of avionics equipment.

(4) Check to assure that the radios and instruments are secured to the instrument panel.

(5) Check that all avionics are free of dust, dirt, lint, or any other airborne contaminants. If there is a forced air cooling system, it must be inspected for proper operation. Equipment ventilation openings must not be obstructed.

(6) Check the microphone headset plugs and connectors and all switches and controls for condition and operation. Check all avionics instruments for placards. Check lightening, annunciator lights, and cockpit interphone for proper operation.

(7) The circuit breaker panel must be inspected for the presence of placarding for each circuit breaker installed.

(8) Check the electrical circuit switches, especially the spring-load type for proper operation. An internal failure in this type of switch may allow the switch to remain closed even though the toggle or button returns to the OFF position. During inspection, attention must be given to the possibility that improper switch substitution may have been made.

#### **b. Inspect antennas for:**

(1) broken or missing antenna insulators

(2) lead through insulators

(3) springs

(4) safety wires

(5) cracked antenna housing

(6) missing or poor sealant at base of antenna

(7) correct installation

(8) signs of corrosion, and

(9) the condition of paint/bonding and grounding.

(10) Check the bonding of each antenna from mounting base to the aircraft skin. Tolerance: .1 ohm, maximum.

(a) Test Equipment:

1 1502B Metallic Time Domain Reflectometer or equivalent.

2 Thruline Wattmeter.

(b) Perform the antenna evaluation check using the domain reflectometer to determine the condition of the antenna and coax cables. Refer to manufacturer's maintenance procedures.

(c) Use thruline wattmeter as needed for addition evaluation. Refer to manufacturer's maintenance procedures. Check for the following:

1 Resistance.

2 Shorts.

3 Opens.

c. **Inspect the static dischargers/wicks for:**

(1) physical security of mounting attachments, wear or abrasion of wicks, missing wicks, etc.,

(2) assurance that one inch of the inner braid of flexible vinyl cover wicks extends beyond the vinyl covering,

(3) assurance that all dischargers are present and securely mounted to their base,

(4) assurance that all bases are securely bonded to skin of aircraft in order to prevent the existence in voltage level differences between two surfaces,

(5) signs of excessive erosion or deterioration of discharger tip,

(6) lighting damage as evidenced by pitting of the metal base, and

(7) megohm value of static wick itself as per manufacturer's instructions. It should not be open.

**d. Subsequent inspection** must be made after a maintenance action on a transponder. Refer to Title 14 of the Code of Federal Regulations (14 CFR) part 91, sections 91.411 and 91.413.

**e. Inspection of the emergency locator transmitter operation**, condition and date of the battery.

**f. Perform a function check** of the radio by transmitting a request for a radio check. Perform a function check on navigation equipment by moving the omni bearing selection (OBS) and noting the needle swing and the TO/FROM flag movement.

## 12-10. COMMUNICATION SYSTEMS.

Ground operation of communication systems in aircraft may be accomplished in accordance with the procedures appropriate for the airport and area in which the test is made and the manufacturer's manuals and procedures. Check system(s) for side tone, clarity of

transmission, squelch, operations using head phones, speaker(s), and hand microphone. If a receiver or transmitter is found to be defective, it should be removed from the aircraft and repaired.

#### **12-11. VHF OMNI-DIRECTIONAL**

**RANGE (VOR).** A VOR operates within the 108.0 to 111.85 MHz, and 112.0 to 117.95 MHz frequency bands. The display usually consists of a deviation indicator and a TO/FROM indicator. The controls consist of a frequency selector for selecting the ground station and an OBS, which is used for course selection. An ON/OFF flag is used to determine adequate field strength and presence of a valid signal. There are numerous configurations when integrated into flight directors and/or when using a slaved compass system, which uses an additional indicator that points continually to the selected omni station regardless of OBS selection. In order to determine the accuracy specified in a functional check, a ground test set must be used in accordance with the manufacturer's specifications. For the purpose of this inspection/maintenance activity, the following operational check can be accomplished to determine if the equipment has the accuracy required for operation in instrument flight rules (IFR) environment. Verify audio identification, OBS operation, flag operation, radio magnetic indicator (RMI) interface, and applicable navigation (NAV) switching functions. The operational check is also published in the AIM, section 1-1-4. This check is required by 14 CFR part 91, section 91.171 before instrument flight operations.

**12-12. DISTANCE MEASURING EQUIPMENT (DME).** The operation of DME consists of paired pulses at a specific spacing, sent out from the aircraft (this is what is called interrogation), and are received by the ground station, which then responds with paired pulses at the specific spacing sent by the aircraft, but

at a different frequency. The aircraft unit measures the time it takes to transmit and then receive the signal, which then is translated into distance. DME operates on frequencies from 962 MHz to 1213 MHz. Because of the curvature of earth, this line-of-sight signal is reliable up to 199 nautical mile (NM) at the high end of the controlled airspace with an accuracy of 1/2 mile or 3 percent of the distance. DME inspection/maintenance on the aircraft is most commonly limited to a visual check of the installation, and if there have been previously reported problems, the antenna must be inspected for proper bonding and the absence of corrosion, both on the mounting surface, as well as the coax connector. Accuracy can be determined by evaluating performance during flight operations, as well as with ground test equipment. If a discrepancy is reported and corrected, it is good practice to make the accuracy determination before instrument flight. Tune the DME to a local station, or use the proper ground test equipment to check audio identification, and DME hold function verify correct display operation.

#### **12-13. AUTOMATIC DIRECTION**

**FINDER (ADF).** The ADF receivers are primarily designed to receive nondirectional beacons (NDB) in the 19 to 535 kHz amplitude modulation (AM) broadcast low band. The receivers will also operate in the commercial AM band. The ADF display pointer will indicate the relative bearing to a selected AM band transmitter that is in range. An ADF system must be checked by tuning to an adequate NDB or commercial AM station. Verify proper bearing to station, audio identification and tone/beat frequency oscillator (BFO), correct operation in closed circuit (LOOP) and sense modes. Note the orientation of the selected station to the aircraft using an appropriate chart. Observe the ADF relative bearing reading, and compare to the chart. Slew the needle and observe how fast (or slowly) it returns to the reading. ADF performance may

be degraded by lightning activity, airframe charging, ignition noise and atmospheric phenomena.

**12-14. INSTRUMENT LANDING SYSTEMS (ILS).** The ILS consist of several components, such as the localizer, glide slope, marker beacon, radio altimeter, and DME. Localizer and glide slope receivers and marker beacons will be discussed in this section.

**a. Localizer receiver operates** on one of 40 ILS channels within the frequency range of 108.10 to 111.95 MHz (odd tens). These signals provide course guidance to the pilot to the runway centerline through the lateral displacement of the VOR/localizer (LOC) deviation indicator. The ground transmitter is sighted at the far end of the runway and provides a valid signal from a distance of 18 NM from the transmitter. The indication gives a full fly left/right deviation of 700 feet at the runway threshold. Identification of the transmitter is in International Morse Code and consists of a three letter identifier preceded by the Morse Code letter I (two dots). The localizer function is usually integral with the VOR system, and when maintenance is performed on the VOR unit, the localizer is also included. The accuracy of the system can be effectively evaluated through normal flight operations if evaluated during visual meteorological conditions. Any determination of airworthiness after reinstallation before instrument flight must be accomplished with ground test equipment.

**b. The glide slope receiver operates** on one of 40 channels within the frequency range 329.15 MHz, to 335.00 MHz. The glide slope transmitter is located between 750 feet and 1250 feet from the approach end of the runway and offset 250 to 650 feet. In the absence of questionable performance, periodic functional flight checks of the glide slope system would be an acceptable way to ensure continued system performance. The functional flight test

must be conducted under visual flight rules (VFR) conditions. A failed or misleading system must be serviced by an appropriately-rated repair station. Ground test equipment can be used to verify glide slope operation.

**c. Localizer/Glide Slope (LOC/GS) may have self test function,** otherwise the proper ground test equipment must be used. Refer to manufacturer's or aircraft instruction manual.

**12-15. MARKER BEACON.** Marker beacon receivers operate at 75 MHz and sense the audio signature of each of the three types of beacons. The marker beacon receiver is not tunable. The blue outer marker light illuminates when the receiver acquires a 75 MHz signal modulated with 400 Hz, an amber middle marker light for a 75 MHz signal modulated with 1300 Hz and, a white inner marker light for a 75 MHz signal modulated with 3000 Hz. The marker beacon system must be operationally evaluated in VFR when an ILS runway is available. The receiver sensitivity switch must be placed in LOW SENSE (the normal setting). Marker audio must be adequate. Ground test equipment must be used to verify marker beacon operation. Marker beacon with self test feature, verify lamps, audio and lamp dimming.

**12-16. LONG RANGE NAVIGATION (LORAN).** The LORAN has been an effective alternative to Rho/Theta R-Nav systems. Hyperbolic systems require waypoint designation in terms of latitude and longitude, unlike original R-Nav (distance navigation) systems, which define waypoints in terms of distance (Rho) and angle (Theta) from established VOR or Tacan facilities. Accuracy is better than the VOR/Tacan system but LORAN is more prone to problems with precipitation static. Proper bonding of aircraft structure and the use of high-quality static wicks will not only produce improved LORAN system performance, but can also benefit the very high frequency

(VHF) navigation and communications systems. This system has an automatic test equipment (ATE).

**NOTE: Aircraft must be outside of hangar for LORAN to operate.**

Normally self test check units, verification of position, and loading of flight plan will verify operation verification of proper flight manual supplements and operating handbooks on board, and proper software status can also be verified.

**12-17. GLOBAL POSITIONING SYSTEM (GPS).** The GPS is at the forefront of present generation navigation systems. This space-based navigation system is based on a 24-satellite system and is highly accurate (within 100 meters) for establishing position. The system is unaffected by weather and provides a world-wide common grid reference system. Database updating and antenna maintenance are of primary concern to the GPS user.

**NOTE: Aircraft must be outside of hangar for ground test of GPS.**

**12-18. AUTOPILOT SYSTEMS.** Automatic Flight Control Systems (AFCS) are the most efficient managers of aircraft performance and control. There are three kinds of autopilot; two axes, three axes, and three axes with coupled approach capability. Attention must be given to the disconnect switch operation, aural and visual alerts of automatic and intentional autopilot disconnects, override forces and mode annunciation, servo operation, rigging and bridle cable tension, and condition. In all cases the manufacturer's inspection and maintenance instructions must be followed.

**12-19. ALTIMETERS.** Aircraft conducting operations in controlled airspace under instru-

ment flight rule (IFR) are required to have their static system(s) and each altimeter instrument inspected and tested within the previous 24 calendar months. Frequent functional checks of all altimeters and automatic pressure altitude reporting systems are recommended.

**a. The tests required must be performed by:**

(1) The manufacturer of the aircraft on which the tests and inspection are to be performed.

(2) A certificated repair station properly equipped to perform those functions and holding:

(a) An instrument rating Class I.

(b) A limited instrument rating appropriate to the make and model of appliance to be tested.

(c) A certified/qualified mechanic with an airframe rating (static system tests and inspections only). Any adjustments shall be accomplished only by an instrument shop certified/qualified person using proper test equipment and adequate reference to the manufacturer's maintenance manuals. The altimeter correlation adjustment shall not be adjusted in the field. Changing this adjustment will nullify the correspondence between the basic test equipment calibration standards and the altimeter. It will also nullify correspondence between the encoding altimeter and its encoding digitizer or the associated blind encoder.

**b. Examine the altimeter face** for evidence of needle scrapes or other damage. Check smoothness of operation, with particular attention to altimeter performance during decent.

**c. Contact an appropriate air traffic facility** for the pressure altitude displayed to the controller from your aircraft. Correct the reported altitude as needed, and compare to the

reading on the altimeter instrument. The difference must not exceed 125 feet.

**12-20. TRANSPONDERS.** There are three modes (types) of transponders that can be used on various aircraft. Mode A provides a (non altitude-reporting) four-digit coded reply; Mode C provides a code reply identical to Mode A with an altitude-reporting signal; and Mode S has the same capabilities as Mode A and Mode C and responds to traffic alert and collision avoidance system (TCAS)-Equipped Aircraft.

**a. Ground ramp equipment** must be used to demonstrate proper operation. Enough codes must be selected so that each switchposition is checked at least once. Low and high sensitivity operation must be checked. Identification operation must be checked. Altitude reporting mode must be demonstrated. Demonstrate that the transponder system does not interfere with other systems aboard the aircraft, and that other equipment does not interfere with transponder operation. Special consideration must be given to other pulse equipment, such as DME and weather radar.

**b. All transponders** must be tested every 24-calendar months, or during an annual inspection, if requested by the owner. The test must be conducted by an authorized avionics repair facility.

**12-21. EMERGENCY LOCATOR**

**TRANS- MITTERS (ELT).** The ELT must be evaluated in accordance with TSO-C91a, TSO-C126 for 406 MHz ELT's, or later TSO's issued for ELT's. ELT installations must be examined for potential operational problems at least once a year (section 91.207(d)). There have been numerous instances of interaction between ELT and other VHF installations. Antenna location should be as far as possible from other antennas to prevent efficiency losses. Check ELT antenna installations in close proximity to other VHF antennas for suspected interference. Antenna patterns of

previously installed VHF antennas could be measured after an ELT installation. Tests should be conducted during the first 5 minutes after any hour. If operational tests must be made outside of this time frame, they should be coordinated with the nearest FAA Control Tower or FSS. Tests should be no longer than three audible sweeps.

**12-22. INSPECTION OF ELT.** An inspection of the following must be accomplished by a properly certified person or repair station within 12-calendar months after the last inspection:

**a. Proper Installation.**

(1) Remove all interconnections to the ELT unit and ELT antenna. Visually inspect and confirm proper seating of all connector pins. Special attention should be given to coaxial center conductor pins, which are prone to retracting into the connector housing.

(2) Remove the ELT from the mount and inspect the mounting hardware for proper installation and security.

(3) Reinstall the ELT into its mount and verify the proper direction for crash activation. Reconnect all cables. They should have some slack at each end and should be properly secured to the airplane structure for support and protection.

**b. Battery Corrosion.** Gain access to the ELT battery and inspect. No corrosion should be detectable. Verify the ELT battery is approved and check its expiration date.

**c. Operation of the Controls and Crash Sensor.** Activate the ELT using an applied force. Consult the ELT manufacturer's instructions before activation. The direction for mounting and force activation is indicated on

the ELT. A TSO-C91 ELT can be activated by using a quick rap with the palm. A TSO-C91a ELT can be activated by using a rapid forward (throwing) motion coupled by a rapid reversing action. Verify that the ELT can be activated using a watt meter, the airplane’s VHF radio communications receiver tuned to 121.5 MHz, or other means (see NOTE 1). Insure that the “G” switch has been reset if applicable.

**d. For a Sufficient Signal Radiated From its Antenna.** Activate the ELT using the ON or ELT TEST switch. A low-quality AM broadcast radio receiver should be used to determine if energy is being transmitted from the antenna. When the antenna of the AM broadcast radio receiver (tuning dial on any setting) is held about 6 inches from the activated ELT antenna, the ELT aural tone will be heard (see NOTE 2 and 3).

**e. Verify that All Switches are Properly Labeled and Positioned.**

**f. Record the Inspection.** Record the inspection in the aircraft maintenance records according to 14 CFR part 43, section 43.9. We suggest the following:

I inspected the Make/Model \_\_\_\_\_ ELT system in this aircraft according to applicable Aircraft and ELT manufacturer’s instructions and applicable FAA guidance and found that it meets the requirements of section 91.207(d).

Signed: \_\_\_\_\_  
Certificate No. \_\_\_\_\_  
Date: \_\_\_\_\_

**NOTE 1: This is not a measured check; it only indicates that the G-switch is working.**

**NOTE 2: This is not a measured check; but it does provide confidence that the antenna is radiating with sufficient power to aid search and rescue. The signal may be weak even if it is picked up by an aircraft VHF receiver located at a considerable distance from the radiating ELT. Therefore, this check does not check the integrity of the ELT system or provide the same level of confidence as does the AM radio check.**

**NOTE 3: Because the ELT radiates on the emergency frequency, the Federal Communications Commission allows these tests only to be conducted within the first five minutes after any hour and is limited in three sweeps of the transmitter audio modulation.**

**12-23. FLIGHT DATA RECORDER.** The flight data recorder is housed in a crush-proof container located near the tail section of the aircraft. The tape unit is fire resistant, and contains a radio transmitter to help crash investigators locate the unit under water. Inspection/Operational checks include:

**a. Check special sticker** on front of the flight data recorder for the date of the next tape replacement, if applicable.

**b. Remove recorder magazine** and inspect tape for the following:

(1) broken or torn tape,

(2) proper feed of tape, and

(3) all scribes were recording properly for approximately the last hour of flight.

**c. Conditions for tape replacement** (as applicable):

(1) There is less than 20 hours remaining in the magazine as read on the *tape remaining* indicator.

(2) Tape has run out.

(3) Broken tape.

(4) After hard landings and severe air turbulence have been encountered as reported by the pilots. After the same tape has been in use 1 year (12 months), it must be replaced.

(5) Ensure that a correlation test has been performed and then recorded in the aircraft records.

**d. Refer to the specific** equipment manufacturer's manuals and procedures.

**e. The state-of-the art Solid-State Flight Data Recorder (SSFDR)** is a highly flexible model able to support a wide variety of aeronautical radio, incorporated (ARINC) configurations. It has a Built-In Test Equipment (BITE) that establishes and monitors the mission fitness of the hardware. BITE performs verification after storage (read after write) of flight data and status condition of the memory. These recorders have an underwater acoustic beacon mounted on its front panel which must be returned to their respective manufacturer's for battery servicing. For maintenance information refer to the equipment or aircraft manufacturer's maintenance instruction manual.

**12-24. COCKPIT VOICE RECORDERS (CVR).** CVR's are very similar to flight data recorders. They look nearly identical and operate in almost the same way. CVR's monitors the last 30 minutes of flight deck conversations and radio communications. The flight deck conversations are recorded via the microphone monitor panel located on the flight deck. This panel is also used to test the system and erase the tape, if so desired. Before operating the

erase CVR mode, consult the operational manual of the manufacturer for the CVR.

**a. Playback is possible** only after the recorder is removed from the aircraft.

**b. Refer to the specific** equipment manufacturer's manuals and procedures.

**c. The Solid State Cockpit Voice Recorder system** is composed of three essential components a solid state recorder, a control unit (remote mic amplifier), and an area microphone. Also installed on one end of the recorder is an Under water Locator Beacon (ULB). The recorder accepts four separate audio inputs: pilot, copilot, public address/third crew member, and cockpit area microphone and where applicable, rotor speed input and flight data recorder synchronization tone input. For maintenance information refer to the equipment manufacturer's maintenance manual.

**12-25. WEATHER RADAR.** Ground performance shall include antenna rotation, tilt, indicator brilliance, scan rotation, and indication of received echoes. It must be determined that no objectionable interference from other electrical/electronic equipment appears on the radar indicator, and that the radar system does not interfere with the operation of any of the aircraft's communications or navigation systems.

**CAUTION: Do not turn radar on within 15 feet of ground personnel, or containers holding flammable or explosive materials. The radar should never operate during fueling operations. Do not operate radar system when beam may intercept larger metallic objects closer than 150 feet, as crystal damage might occur. Do not operate radar when cooling fans are inoperative. Refer to the specific Ra**

**dar System equipment manufacturer's manuals and procedures.**

**12-26. RADOME INSPECTION.** Inspection of aircraft having weather radar installations should include a visual check of the radome surface for signs of surface damage, holes, cracks, chipping, and peeling of paint, etc. Attach fittings and fastenings, neoprene erosion caps, and lightning strips, when installed, should also be inspected.

**12-27. DATA BUS.** Data Buses provide the physical and functional partitioning needed to enable different companies to design different avionics boxes to be able to communicate information to each other. It defines the framework for system(s) intergration. There are several types of data bus analyzers used to receive and review transmitted data or to transmit data to a bus user. Before using an analyzer, make sure that the bus language is compatible with the bus analyzer. For further information refer to ARINC specifications such as 429 Digital Information Transfer System, Mark 33 which offers simple and affordable answers to data communications on aircraft.

**12-28. ELECTRIC COMPATABLITY.** When replacing an instrument with one which provides additional functions or when adding new instruments, check the following electrical ( where applicable) for compatibility:

- a. Voltage (AC/DC).
- b. Voltage polarity (DC).
- c. Voltage phase (s) (AC).
- d. Frequency (AC).
- e. Grounding (AC/DC).
- f. System impedance matching.
- g. Compatibility with system to which connected.

**12-29.—12-36. [RESERVED.]**



### SECTION 3. GROUND OPERATIONAL CHECKS FOR AVIONICS EQUIPMENT (NON ELECTRICAL)

**12-37. COMPASS SWING** must be performed whenever any ferrous component of the system (i.e. flux valve compensator, or Standby Compass) is installed, removed, repaired, or a new compass is installed. The magnetic compass can be checked for accuracy by using a compass rose located on an airport. The compass swing is normally effected by placing the aircraft on various magnetic headings and comparing the deviations with those on the deviation cards. Refer to CFR14, 23.1327, 14 CFR 23.1547, and the equipment or aircraft manufacturer's manual.

**a.** A compass swing must be performed on the following occasions:

- (1) When the accuracy of the compass is suspected.
- (2) After any cockpit modification or major replacement involving ferrous metal.
- (3) Whenever a compass has been subjected to a shock; for example, after a hard landing or turbulence.
- (4) After aircraft has passed through a severe electrical storm.
- (5) After lightning strike.
- (6) Whenever a change is made to the electrical system.
- (7) Whenever a change of cargo is likely to affect the compass.
- (8) When an aircraft operation is changed to a different geographic location with a major change in magnetic deviation. (e.g., from Miami, Florida to Fairbanks, Alaska.)

(9) After aircraft has been parked on one heading for over a year.

(10) When flux valves are replaced.

**b. Precautions.**

(1) The magnetic compass must be checked for accuracy in a location free of steel structures, underground pipes or cables, or equipment that produces magnetic fields.

(2) Personnel engaged in the compensation of the compass shall remove all magnetic or ferrous material from their possession.

(3) Use only nonmagnetic tools when adjusting the compass.

(4) Position the aircraft at least 100 yards from any metal object.

(5) All equipment in the aircraft having any magnetic effect on the compass must be secured in the position occupied in normal flight.

**c. Compass Swing Procedures.**

(1) Have the aircraft taxied to the NORTH (0°) radial on the Compass Rose. Use a hairline sight compass (a reverse reading compass with a gun sight arrangement mounted on top of it) to place the aircraft in the general vicinity. With the aircraft facing North and the person in the cockpit running the engine(s) at 1000 rpm, a mechanic, standing approximately 30 feet in front of the aircraft and facing South, "shoots" or aligns the master compass with the aircraft center line. Using hand signals, the mechanic signals the person in the cockpit to make additional adjustments to align the aircraft with the master

compass. Once aligned on the heading, the person in the cockpit runs the engine(s) to approximately 1,700 rpm to duplicate the aircraft's magnetic field and then the person reads the compass.

**NOTE: (1) For conventional gear aircraft, the mechanic will have to position the magnetic compass in the straight and level position or mount the tail of the aircraft on a moveable dolly to simulate a straight and level cruise configuration. (2) Remember the hairline sight compass is only intended to be used as a general piece of test equipment.**

(2) If the aircraft compass is not in alignment with the magnetic North of the master compass, correct the error by making small adjustments to the North-South brass adjustment screw with a nonmetallic screw driver (made out of brass stock, or stainless steel welding rod). Adjust the N-S compensator screw until the compass reads North ( $0^{\circ}$ ). Turn the aircraft until it is aligned with the East-West, pointing East. Adjust the E-W compensator screw until it reads  $90^{\circ}$ . Continue by turning the aircraft South  $180^{\circ}$  and adjust the N-S screw to remove one-half of the South's heading error. This will throw the North off, but the total North-South should be divided equally between the two headings. Turn the aircraft until it is heading West  $270^{\circ}$ , and adjust the E-W screw on the compensator to remove one-half of the West error. This should divide equally the total E-W error. The engine(s) should be running.

(3) With the aircraft heading West, start your calibration card here and record the magnetic heading of  $270^{\circ}$  and the compass reading with the avionics/electrical systems on then off. Turn the aircraft to align with each of the lines on the compass rose and record the com

pass reading every  $30^{\circ}$ . There should be not more than a plus or minus  $10^{\circ}$  difference between any of the compass' heading and the magnetic heading of the aircraft.

(4) If the compass cannot be adjusted to meet the requirements, install another one.

**NOTE: A common error that affects the compass' accuracy is the mounting of a compass or instruments on or in the instrument panel using steel machine screws/nuts rather than brass hardware, magnetized control yoke, structural tubing, and improperly routed electrical wiring, which can cause unreasonable compass error.**

(5) If the aircraft has an electrical system, two complete compass checks should be performed, one with minimum electrical equipment operating and the other with all electrical accessories on (e.g. radios, navigation, radar, and lights). If the compass readings are not identical, the mechanic should make up two separate compass correction cards, one with all the equipment on and one with the equipment off.

(6) When the compass is satisfactorily swung, fill out the calibration card properly and put it in the holder in full view for the pilot's reference.

**d. Standby (wet) Compass.** Adjustment and compensation of the Standby Compass may also be accomplished by using the "compass swing" method.

## 12-38. PNEUMATIC GYROS.

**a. Venturi Systems.** The early gyro instruments were all operated by air flowing out of a jet over buckets cut into the periphery of the gyro rotor. A venturi was mounted on the outside of the aircraft to produce a low pressure, or vacuum, which evacuated the instrument case, and air flowed into the instrument through a paper filter and then through a nozzle onto the rotor.

(1) Venturi systems have the advantage of being extremely simple and requiring no power from the engine, nor from any of the other aircraft systems; but they do have the disadvantage of being susceptible to ice, and

when they are most needed, they may become unusable.

(2) There are two sizes of venturi tubes: those which produce four inches of suction are used to drive the attitude gyros, and smaller tubes, which produce two inches of suction, are used for the turn and slip indicator. Some installations use two of the larger venturi tubes connected in parallel to the two attitude gyros, and the turn and slip indicator is connected to one of these instruments with a needle valve between them. A suction gage is temporarily connected to the turn and slip indicator, and the aircraft is flown so the needle valve can be adjusted to the required suction at the instrument when the aircraft is operated at its cruise speed. (See figure 12-1.)

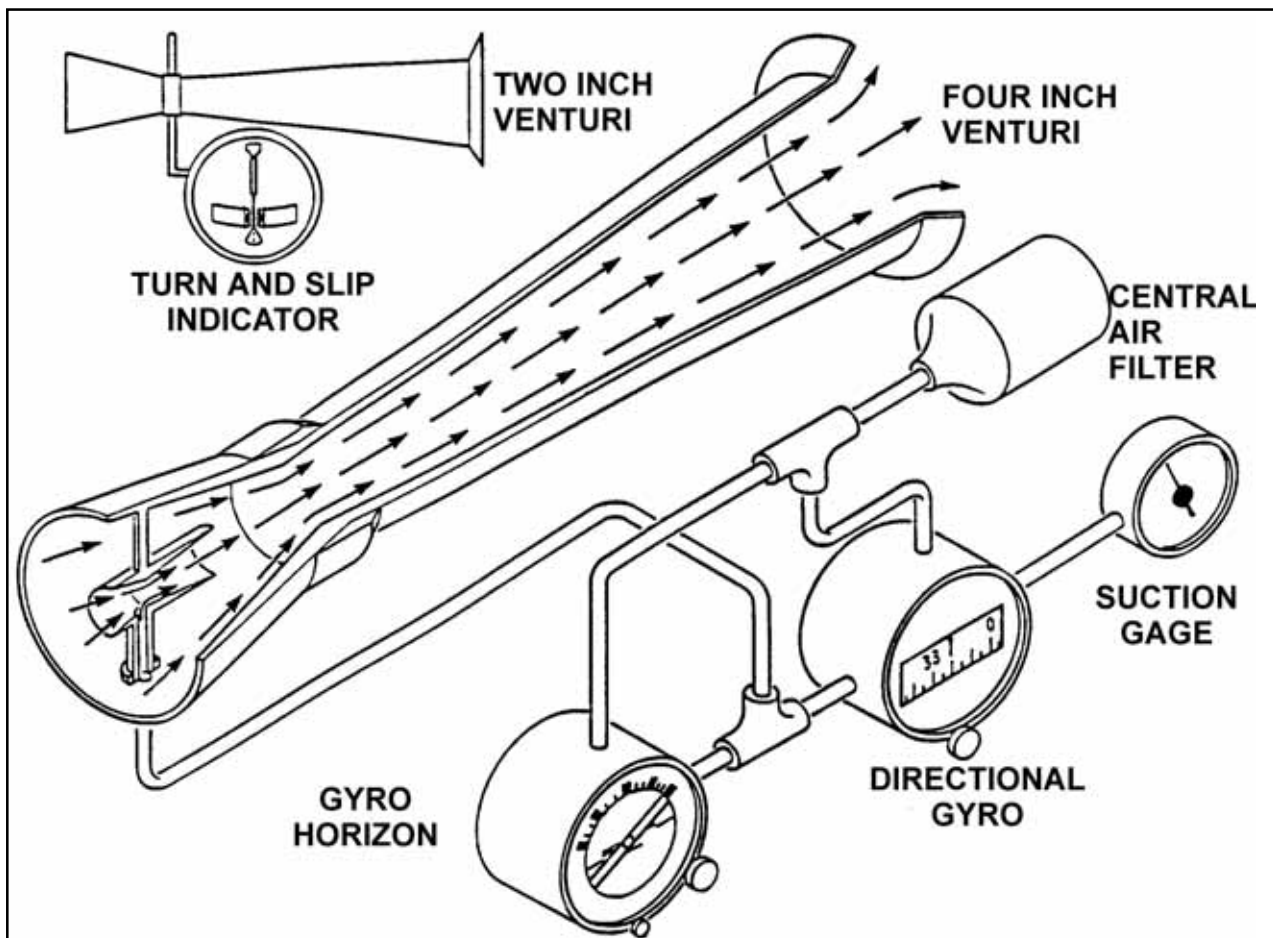


FIGURE 12-1. Venturi system for providing airflow through gyro instruments.

**b. Vacuum Pump Systems.** In order to overcome the major drawback of the venturi tube, that is, its susceptibility to ice, aircraft were equipped with engine driven vacuum pumps and the gyro instruments were driven by air pulled through the instrument by the suction produced by these pumps. A suction relief valve maintained the desired pressure (usually about four inches of mercury) on the attitude gyro instruments, and a needle valve between one of the attitude indicators and the turn and slip indicator restricted the airflow to maintain the desired 2 inches of suction in its case. Most of the early instruments used only paper filters in each of the instrument cases, but in some installations a central air filter was used to remove contaminants from the cabin air before it entered the instrument case.

(1) The early vacuum pumps were vane-type pumps of what is called the *wet* type—one with a cast iron housing and steel vanes. Engine oil was metered into the pump to provide sealing, lubrication, and cooling, and then this oil, along with the air, was blown through an oil separator where the oil collected on baffles and was returned to the engine crankcase. The air was then exhausted overboard. Aircraft equipped with rubber deicer boots used this discharge air to inflate the boots. But before it could be used, this air was passed through a second stage of oil separation and then to the distributor valve and finally to the boots. (See figure 12-2.)

(2) The airflow through the instruments is controlled by maintaining the suction in the instrument case at the desired level with a suction relief valve mounted between the pump and the instruments. This valve has a spring-loaded poppet that offsets to allow cabin air to enter the pump and maintain the correct negative pressure inside the instrument case.

(3) The more modern vacuum pumps are of the dry type. These pumps use carbon vanes and do not require any lubrication, as the vanes provide their own lubrication as they wear away at a carefully predetermined rate. Other than the fact that they do not require an oil separator, systems using dry air pumps are quite similar to those using a wet pump. One slight difference, however, is in the need for keeping the inside of the pump perfectly clean. Any solid particles drawn into the system through the suction relief valve can damage one of the carbon vanes, and this can lead to destruction of the pump, as the particles broken off of one vane will damage all of the other vanes. To prevent particles entering the relief valve, its air inlet is covered with a filter, and this must be cleaned or replaced at the interval recommended by the aircraft manufacturer.

**c. Positive Pressure Systems.** Above about 18,000 feet there is not enough mass to the air drawn through the instruments to provide sufficient rotor speed, and, to remedy this problem, many aircraft that fly at high altitude use positive pressure systems to drive the gyros. These systems use the same type of air pump as is used for vacuum systems, but the discharged air from the pump is filtered and directed into the instrument case through the same fitting that receives the filtered air when the vacuum system is used. A filter is installed on the inlet of the pump, and then, before the air is directed into the instrument case, it is again filtered. A pressure regulator is located between the pump and the in-line filter to control the air pressure so only the correct amount is directed into the instrument case.

**System Filters.** The life of an air-driven gyro instrument is determined to a great extent by the cleanliness of the air that flows over the rotor. In vacuum systems, this air is taken

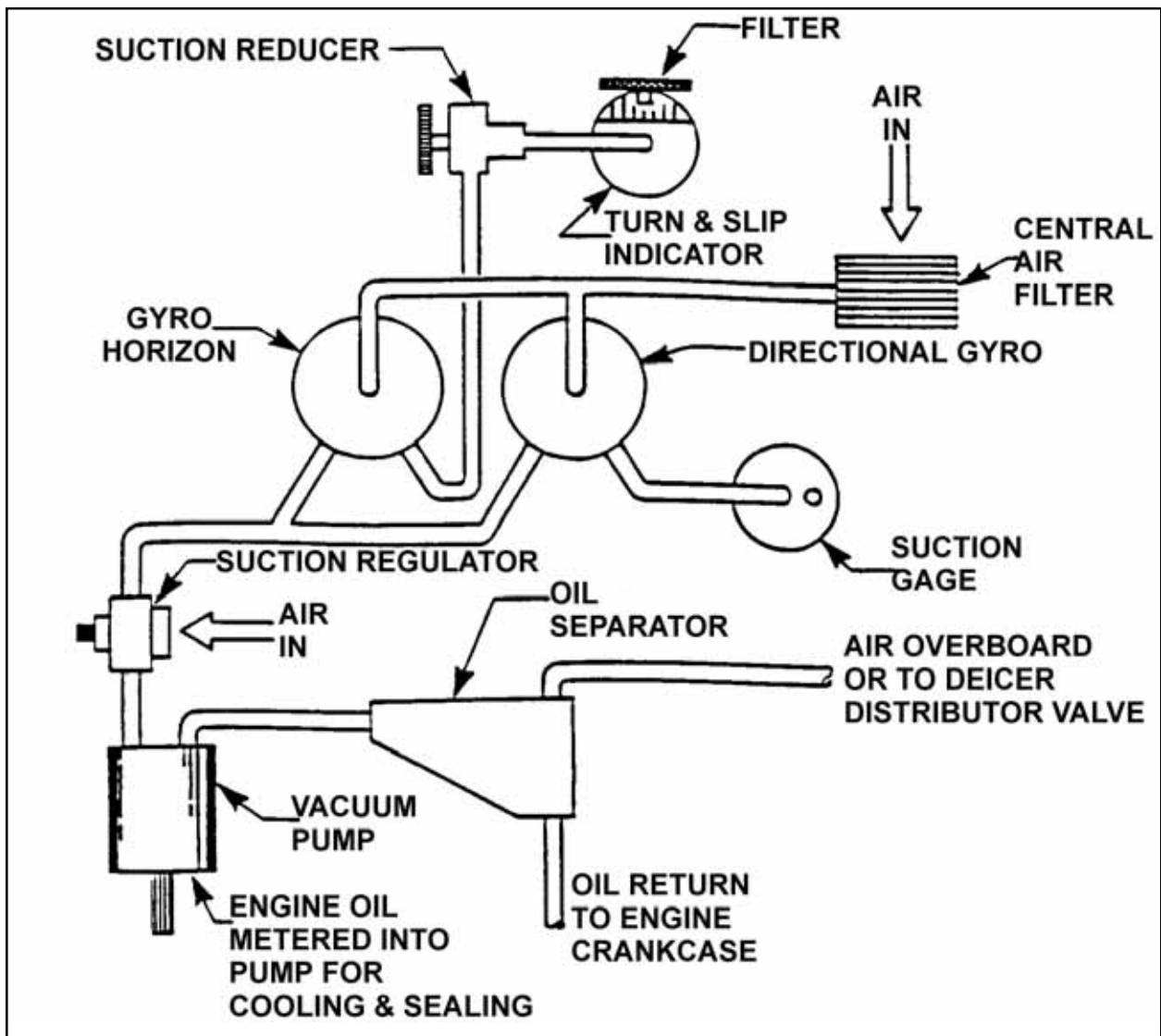


FIGURE 12-2. Instrument vacuum system using a wet-type vacuum pump.

from the cabin where there is usually a good deal of dust and very often tobacco smoke. Unless all of the solid contaminants are removed from the air before it enters the instrument, they will accumulate, usually in the rotor bearings, and slow the rotor. This causes an inaccurate indication of the instrument and will definitely shorten its service life. Dry air

pumps are also subject to damage from ingested contaminants, and all of the filters in the system must be replaced on the schedule recommended by the aircraft manufacturer, and more often if the aircraft is operated under particularly dusty conditions, especially if the occupants of the aircraft regularly smoke while flying. (See figures 12-3 and 12-4.)

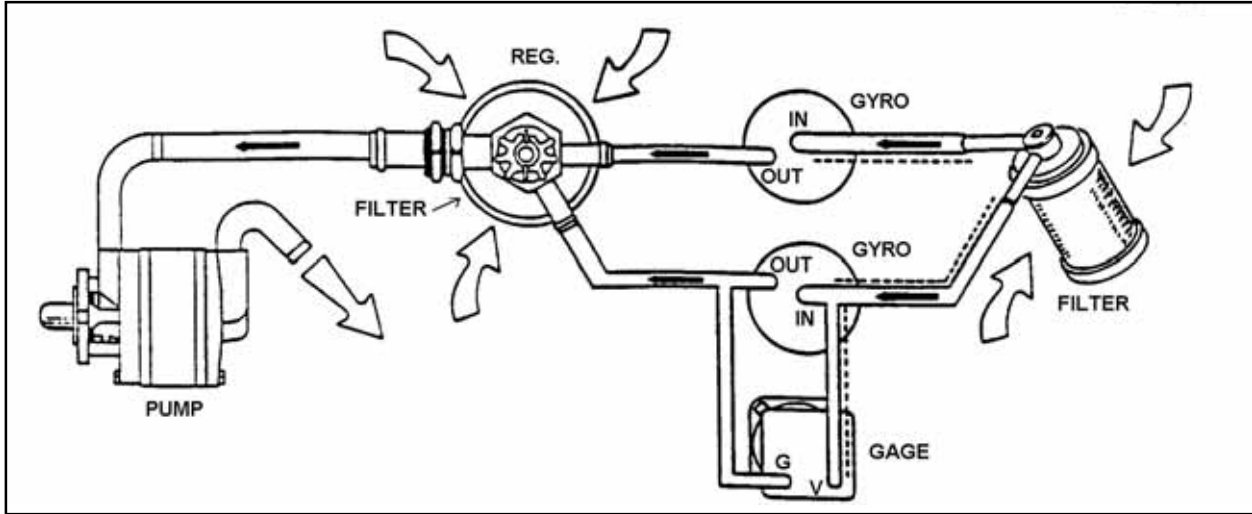


FIGURE 12-3. Instrument vacuum system using a dry-type air pump.

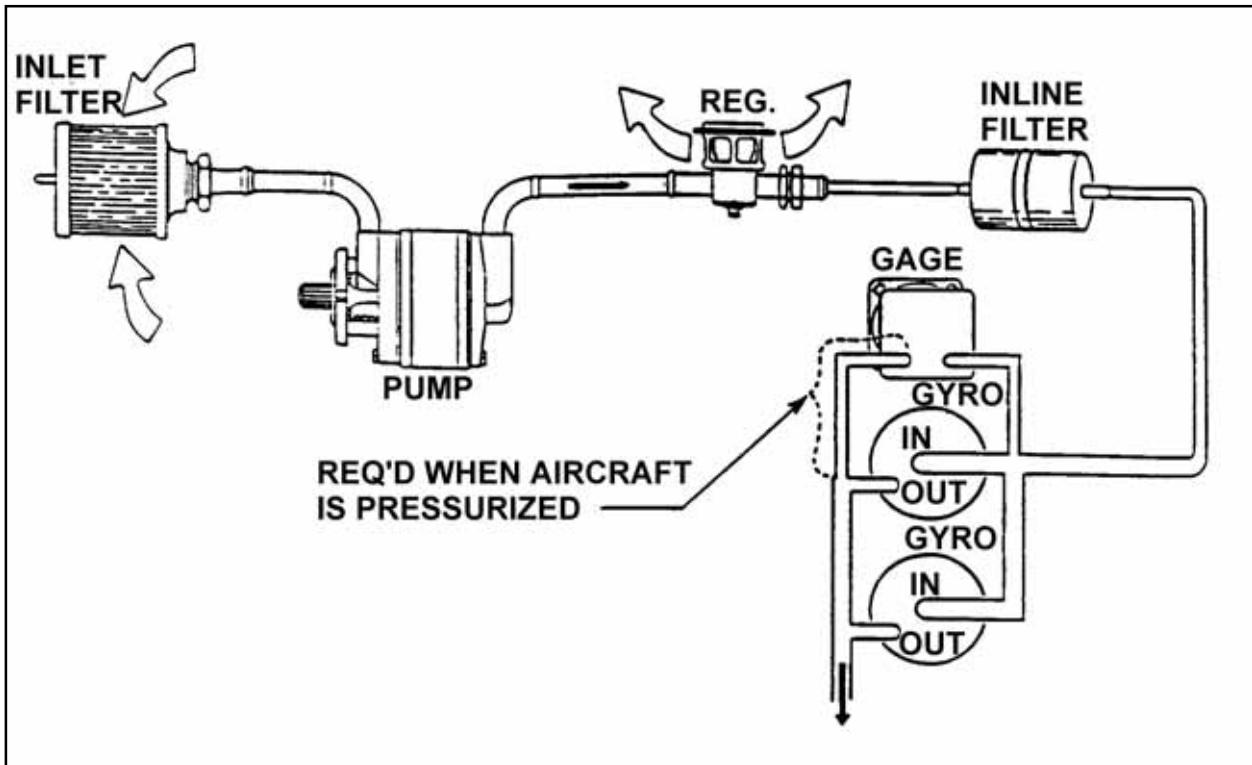


FIGURE 12-4. Instrument pressure system using a dry-type air pump.

12-39.—12-50. [RESERVED.]

## SECTION 4. PITOT/STATIC SYSTEMS

**12-51. GENERAL.** In order for the pitot-static instruments to work properly, they must be connected into a system that senses the impact air pressure with minimum distortion and picks up undisturbed static air pressure.

Pitot pressure is ram air pressure picked up by a small open-ended tube about a ¼-inch in diameter that sticks directly into the air stream that produces a pressure proportional to the speed of the air movement. Static pressure is the pressure of the still air used to measure the altitude and serves as a reference in the measurement of airspeed.

Airspeed requires pitot, altimeter, rate of climb, and transponder-required static.

**12-52. SYSTEM COMPONENTS.** The conventional design of the pitot system consists of pitot-static tubes or pitot tubes with static pressure parts and vents, lines, tubing, water drains and traps, selector valves, and various pressure-actuated indicators or control units such as the altimeter, airspeed and rate-of-climb indicators, and the encoding altimeter connected to the system. (See figure 12-5.)

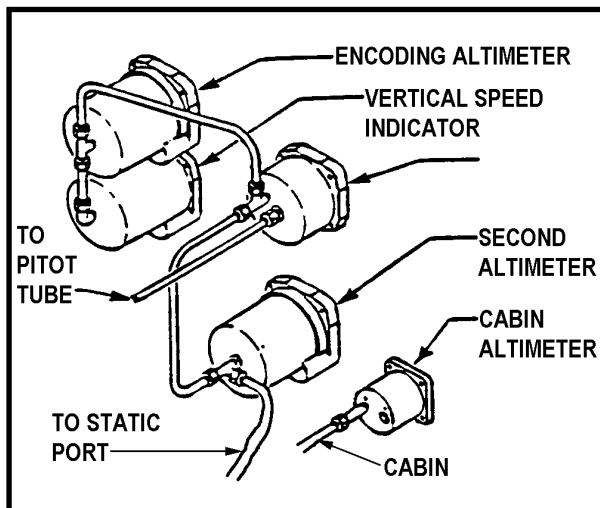


Figure 12-5. Pitot/static system for a small aircraft.

**12-53. PITOT/STATIC TUBES AND LINES.** The pitot tube (see figure 12-6) is installed at the leading edge of the wing of a single-engine aircraft, outside the propeller slipstream or on the fuselage of a multiengine aircraft with the axis parallel to the longitudinal axis of the aircraft, unless otherwise specified by the manufacturer.

**12-54. STATIC PORTS AND VENTS** (more modern trend) should be mounted flush with fuselage skin. One port is located on either side of the fuselage, usually behind the cabin.

Inspect for elevation or depression of the port or vent fitting. Such elevation or depression may cause airflow disturbances at high speeds and result in erroneous airspeed and altitude indications.

**12-55. HEATER ELEMENTS.** A heating element is located within the tube head to prevent the unit from becoming clogged during icing conditions experienced during flight. A switch in the cockpit controls the heater. Some pitot-static tubes have replaceable heater elements while others do not. Check the heater element or the entire tube for proper operation by noting either ammeter current or that the tube or port is hot to the touch. (See figure 12-6.)

### 12-56. SYSTEM INSPECTION.

a. **Inspect air passages** in the systems for water, paint, dirt or other foreign matter. If water or obstructive material has entered the system, all drains should be cleaned. Probe the drains in the pitot tube with a fine wire to remove dirt or other obstructions. The bottom static openings act as drains for the head's static chamber. Check these holes at regular intervals to preclude system malfunctioning.

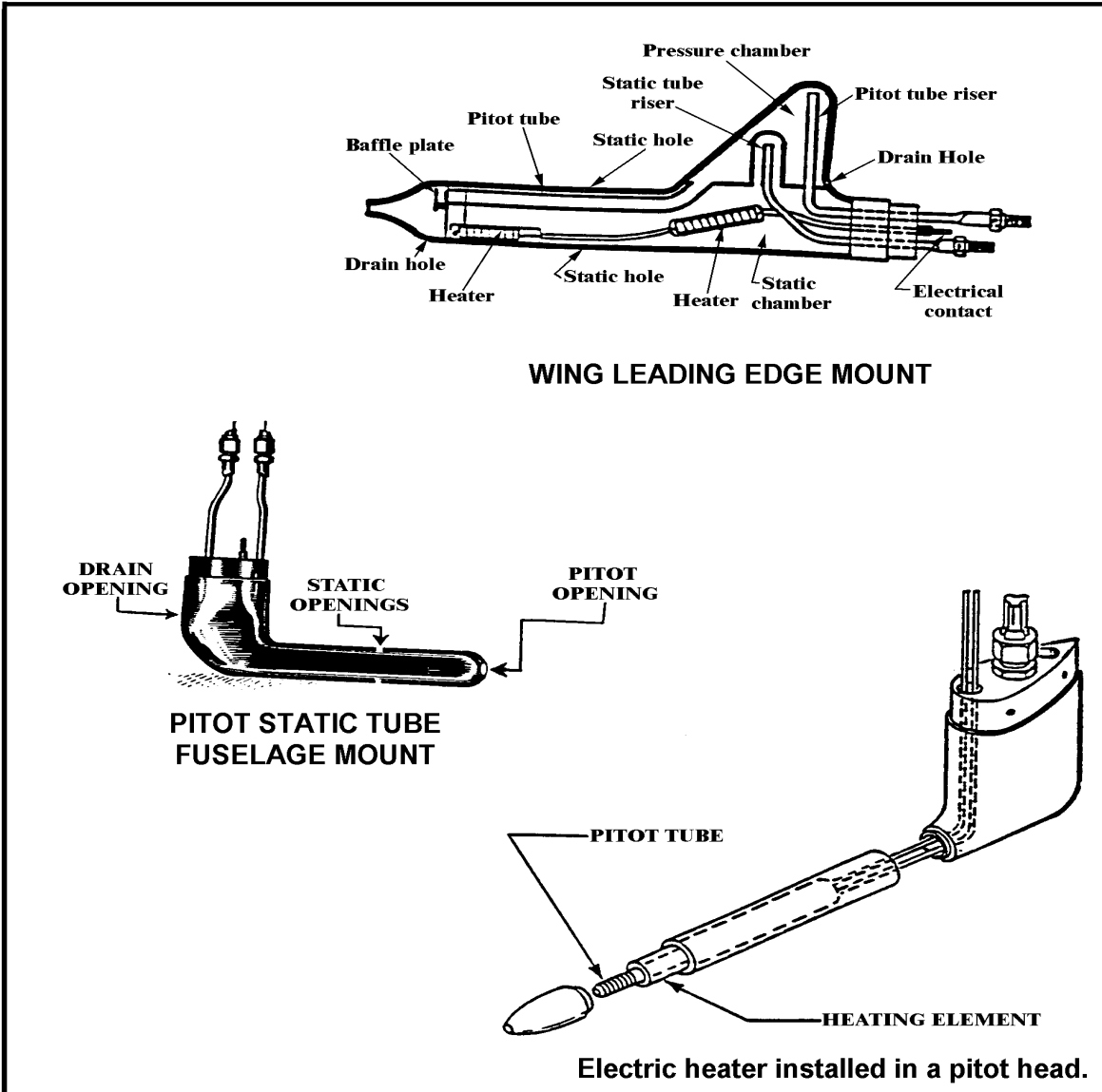


Figure 12-6. Pitot/Static Tube Head

**b. Check to ensure the water drains freely.** If a problem is experienced with the pitot-static system drainage or freezing at altitude, and the tubing diameter is less than 3/8-inch, replace it with larger tubing.

**c. Check the pitot tube for corrosion.**

(1) The pitot probe should not have any corrosion within 1/2-inch of the probe tip.

(2) Make sure there is no flaking which forms pits and irregularities in the surface of the tube.

**NOTE:** It is essential that the static air system be drained after the airplane has been exposed to rain.

#### 12-57. SYSTEM LEAK TEST.

**a. Pitot-static leak tests** should be made with all instruments connected to assure that no leaks occur at instrument connections. Such tests should be accomplished whenever a connection has been loosened or an instrument replaced.

**b. After the conclusion of the leak test,** return the system to its normal flying configuration. Remove tape from static ports and pitot drain holes and replace the drain plug.

**12-58. STATIC SYSTEM TESTS** must comply with the static system tests required by 14 CFR 91.411 and be performed by an appropriately-rated repair station with the appropriate test equipment.

If the manufacturer has not issued instructions for testing static systems, the following may be used:

**a. Connect the test equipment** directly to the static ports, if practicable. Otherwise, connect to a static system drain or tee connection and seal off the static ports. If the test equipment is connected to the static system at any point other than the static port, it should be made at a point where the connection may be readily inspected for system integrity. Observe maintenance precautions given in paragraph 12-60 of this section.

**b. Do not blow air through the line** toward the instrument panel. This may seriously damage the instruments. Be sure to disconnect the instrument lines so no pressure can reach the instruments.

**c. Apply a vacuum** equivalent to 1,000 feet altitude, (differential pressure of approximately 1.07 inches of mercury or 14.5 inches of water) and hold.

**d. After 1 minute, check** to see that the leak has not exceeded the equivalent of 100 feet of altitude (decrease in differential pressure of approximately 0.0105 inches of mercury or 1.43 inches of water).

**12-59. TEST PITOT SYSTEM** in accordance with the aircraft manufacturer's instructions. If the manufacturer has not issued in-

structions for testing pitot systems, the following may be used:

**a. Seal the drain holes** and connect the pitot pressure openings to a tee to which a source of pressure and manometer or reliable indicator is connected.

**b. Restrain hoses** that can whip due to applied pressure.

**c. Apply pressure** to cause the airspeed indicator to indicate 150 knots (differential pressure 1.1 inches of mercury or 14.9 inches of water), hold at this point and clamp off the source of pressure. After 1 minute, the leakage should not exceed 10 knots (decrease in differential pressure of approximately 0.15 inches of mercury or 2.04 inches of water).

**CAUTION: To avoid rupturing the diaphragm of the airspeed indicator, apply pressure slowly and do not build up excessive pressure in the line. Release pressure slowly to avoid damaging the airspeed indicator.**

**d. If the airspeed indicator reading declines,** check the system for leaky hoses and loose connections.

**e. Inspect the hoses** for signs of deterioration, particularly at bends and at the connection points to the pitot mast and airspeed indicator. Replace hoses that are cracked or hardened with identical specification hoses. Any time a hose is replaced, perform a pressure check.

**Warning: Do not apply suction to pitot lines.**

**12-60. MAINTENANCE PRECAUTIONS.** Observe the following precautions in all pitot-static system leak testing:

**a. Before any pitot/static system is tested**, determine that the design limits of instruments attached to it will not be exceeded during the test. To determine this, locate and identify all instruments attached to the system.

**b. A system diagram** will help to determine the location of all instruments as well as locate a leak while observing instrument indications. If a diagram is not available, instruments can be located by tracing physical installation.

**c. Be certain that no leaks exist** in the test equipment.

**d. Run full range tests** only if you are thoroughly familiar with the aircraft instrument system and test equipment.

**e. Make certain** the pressure in the pitot system is always equal to, or greater than, that in the static system. A negative differential pressure across an airspeed indicator can damage the instrument.

**f. The rate of change or the pressure applied** should not exceed the design limits of any pitot or static instruments connected to the systems.

**g. When lines are attached** to or removed from the bulkhead feed-through fitting or at a union, ensure the line attached to the opposite end is not loose, twisted, or damaged by rotation of the fitting. Such fittings normally are provided with a hex flange for holding the fitting.

**12-61. REPLACING LINES.** If necessary to replace lines, observe the following installation:

**a. Attach lines** at regular intervals by means of suitable clamps.

**b. Do not clamp lines** at end fittings.

**c. Maintain the slope of lines** toward drains to ensure proper drainage.

**d. Check the lines** for leaks.

**12-62. RELOCATON OF PITOT TUBE.** If pitot tube relocation is necessary, perform the relocation in accordance with the manufacturer's recommendations and consider the following:

**a. Freedom of aerodynamic disturbances** caused by the aircraft.

**b. Location protected** from accidental damage.

**c. Alignment with the longitudinal axis** of the aircraft when in cruising flight.

**12-63. TROUBLESHOOTING THE PITOT/STATIC PRESSURE SYSTEM.**

**a. If instruments** are inoperative or erratic operation occurs, take the following action:

**Table 12-1. Color codes for pitot-static systems.**

CODE ABBR.	DEFINITION	COLOR
PP	PITOT PRESSURE	NATURAL
SP	STATIC PRESSURE (PILOT)	RED
	STATIC PRESSURE (CO-PILOT)	GREEN
	STATIC PRESSURE (CABIN)	YELLOW
	STATIC PRESSURE (STANDBY)	BLUE

(1) Check for clogged lines. Drain lines at the valves (especially after aircraft has been exposed to rain). Disconnect lines at the instruments and blow them out with low-pressure air.

(2) Check lines for leaks or looseness at all connections. Repair as required.

**b. If the pitot heating element(s) are operative,** check the following:

(1) Are circuit breaker(s) tripped?

(2) Reset the circuit breaker to determine if:

(a) The system is OK, or

(b) The circuit breaker trips again, if so:

1. Check the wiring continuity to the ground. If the switch(s) is defective, repair as necessary.

2. Check the heating element; replace it if it is defective.

**12-64.—12-69. [RESERVED.]**



## SECTION 5. AVIONICS TEST EQUIPMENT

**12-70 GENERAL.** Certificated individuals who maintain airborne avionics equipment must have test equipment suitable to perform that maintenance.

### 12-71 TEST EQUIPMENT CALIBRATION STANDARDS.

**a. The test equipment calibration standards** must be derived from and traceable to one of the following:

(1) The National Institute of Standards and Technology.

(2) Standards established by the test equipment manufacturer.

(3) If foreign-manufactured test equipment, the standards of the country, where it was manufactured, if approved by the Administrator.

**b. The technician** must make sure that the test equipment used for such maintenance is the equipment called for by the manufacturer or equivalent.

(1) Before acceptance, a comparison should be made between the specifications of the test equipment recommended by the manufacturer and those proposed by the repair facility.

(2) The test equipment must be capable of performing all normal tests and checking all parameters of the equipment under test. The level of accuracy should be equal to or better than that recommended by the manufacturer.

(3) For a description of avionics test equipment used for troubleshooting, refer to the equipment or aircraft manufacturing instruction manual.

**12-72 TEST EQUIPMENT CALIBRATION.** Test equipment such as meters, torque wrenches, static, and transponder test equipment should be checked at least once a year.

**c. National Institute of Standards and Technology** traceability can be verified by reviewing test equipment calibration records for references to National Institute of Standards and Technology test report numbers. These numbers certify traceability of the equipment used in calibration.

**d. If the repair station** uses a standard for performing calibration, that calibration standard cannot be used to perform maintenance.

**e. The calibration intervals** for test equipment will vary with the type of equipment, environment, and use. The accepted industry practice for calibration intervals is usually one year. Considerations for acceptance of the intervals include the following:

(1) Manufacturer's recommendation for the type of equipment.

(2) Repair facility's past calibration history, as applicable.

**f. If the manufacturer's manual** does not describe a test procedure, the repair station must coordinate with the manufacturer to develop the necessary procedures, prior to any use of the equipment.

**12-73 – 12-83. [RESERVED.]**




## CHAPTER 13. HUMAN FACTORS

**13-1. HUMAN FACTORS INFLUENCE ON MECHANIC’S PERFORMANCE.** To accomplish any task in aviation maintenance at least three things must be in evidence. A mechanic must have the tools, data, and technical skill to perform maintenance. Only recently has the aviation industry addressed the mechanic job functions, pressures, and stress, by identifying those human factors (HF) that impact the mechanics performance.

**13-2. THE FAA AVIATION SAFETY PROGRAM** has condensed these HF reports

into a personal minimums checklist, which asks the mechanic to answer 10 ‘yes or no’ questions before the maintenance task is begun and 10 ‘yes or no’ questions after the task is completed. If the mechanic answers “NO” to any of the 20 questions, the aircraft should not be returned to service. We have provided the checklist in figure 13-1 for your evaluation and review. A color copy of the checklist is available from any Flight Standards District Office. Just ask for the Airworthiness Safety Program manager.




Airworthiness Aviation  
Safety Program  
Federal Aviation  
Administration

### MAINTENANCE

"PERSONAL MINIMUMS" CHECKLIST

✓ Before the task

	DO I HAVE THE KNOWLEDGE TO PERFORM THE TASK?
	DO I HAVE THE TECHNICAL DATA TO PERFORM THE TASK?
	HAVE I PERFORMED THE TASK PREVIOUSLY?
	DO I HAVE THE PROPER TOOLS AND EQUIPMENT TO PERFORM THE TASK?
	HAVE I HAD THE PROPER TRAINING TO SUPPORT THE JOB TASK?
	AM I MENTALLY PREPARED TO PERFORM THE JOB TASK?
	AM I PHYSICALLY PREPARED TO PERFORM THE TASK?
	HAVE I TAKEN THE PROPER SAFETY PRECAUTIONS TO PERFORM THE TASK?
	DO I HAVE THE RESOURCES AVAILABLE TO PERFORM THE TASK?
	HAVE I RESEARCHED THE FAR'S TO ENSURE COMPLIANCE?



Airworthiness Aviation  
Safety Program  
Federal Aviation  
Administration

### After the task

	DID I PERFORM THE JOB TASK TO THE BEST OF MY ABILITIES?
	WAS THE JOB TASK PERFORMED TO BE EQUAL TO THE ORIGINAL?
	WAS THE JOB TASK PERFORMED IN ACCORDANCE WITH APPROPRIATE DATA?
	DID I USE ALL THE METHODS, TECHNIQUES, AND PRACTICES ACCEPTABLE TO INDUSTRY?
	DID I PERFORM THE JOB TASK WITHOUT PRESSURES, STRESS, AND DISTRACTIONS?
	DID I REINSPECT MY WORK OR HAVE SOMEONE INSPECT MY WORK BEFORE RETURNING TO SERVICE?
	DID I MAKE THE PROPER RECORD ENTRIES FOR THE WORK PERFORMED?
	DID I PERFORM THE OPERATIONAL CHECKS AFTER THE WORK WAS COMPLETED?
	AM I WILLING TO SIGN ON THE BOTTOM LINE FOR THE WORK PERFORMED?
	AM I WILLING TO FLY IN THE AIRCRAFT ONCE IT IS APPROVED FOR THE RETURN TO SERVICE?

**FIGURE 13-1.** Personal Minimum’s Checklist

