

CHAPTER 9

POWERPLANT TROUBLESHOOTING

Efficient maintenance of any aircraft depends upon the operating and maintenance personnel's familiarity with the aircraft and its associated parts. You must have a thorough knowledge of the engine and know its normal operating conditions. You should know the oil pressures, fuel pressure, rpm limits, and exhaust temperatures throughout the entire engine operating ranges. In addition to knowing the normal engine conditions, you should understand the effects of atmospheric conditions on the engine. You must consider such things as air temperatures and pressure, fuel temperatures, and wind effects.

CHAPTER OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize general engine troubleshooting procedures.
2. Identify common engine problems.
3. Identify general engine troubleshooting steps.
4. Recognize the types of gas turbine test equipment.
5. Identify the types of troubleshooting drawings and diagrams
6. Discuss the purpose and types of borescopes used today.
7. Discuss the purpose of the materials used in engine field cleaning.

GENERAL ENGINE TROUBLESHOOTING

All aircraft maintenance activities are plagued by repeat discrepancies. These discrepancies show up repeatedly on the same aircraft. They show up even after being signed off as previously corrected. There are many possible causes for repeat discrepancies. The most common cause is poor troubleshooting procedures.

It is often unsafe to assume that the engine is completely repaired when some obvious corrective measure has been taken to correct a malfunction. Never be hasty in assuming any conclusions. Do not confuse cause and effect. For example, low oil pressure, in itself, is not truly a trouble. It is only an indication that a problem exists. The true cause of which is the trouble.

The preceding paragraph emphasizes the importance of tracing an abnormal indication to its source. Do not be satisfied that restoration to a normal condition is accomplished by some obvious adjustment. Adjusting the oil pressure relief valve setting may not be the only correction or the correct step for a low oil pressure discrepancy. Refer to *Table 9-1* for possible low oil pressure causes. Invariably, there is a reason for an abnormal engine indication. You must know the reason and make sure that proper corrective measures are taken before the discrepancy is signed off. Proper corrective measures require the use of time-proven methods, not guesswork.

NOTE

Always refer to the appropriate maintenance instruction manual (MIM) for powerplant troubleshooting procedures.

As previously stated, to troubleshoot intelligently, you must know the system and the function of each component in the system. You must have a mental picture of the location of each component in

relation to other components in the system. Studying schematic diagrams of the system is one way to establish this mental picture.

Table 9-1 — Oil Pressure Troubleshooting Chart

TROUBLE	CAUSE	CORRECTIVE ACTION
High oil pressure.	Low oil temperature. Improper setting of relief valve. Defective pressure indicator.	Check temperature indicator. Check grade of oil. Reset pressure relief valve. Replace with new or serviceable indicator.
Low oil pressure.	High oil temperature. Clogged oil filter. Improper setting of relief valve. Defective pressure pump. Defective pressure indicator. Low oil level. Viscosity of oil is too light. Air leak in the supply line.	Check temperature indicator. Remove and replace oil filter. Reset pressure relief valve. Repair or replace pump. Replace with new or serviceable indicator. Fill oil tank to the proper level. Drain system; refill with correct grade of oil. Locate and eliminate air leak.

General Safety Procedures

In the performance of your duties, you may come across many potentially dangerous conditions and situations. When working, there is one rule to stress strongly—SAFETY FIRST. Whether you are working in the shop, on the line, or during a flight, you should always follow prescribed safety procedures. When working on or near aircraft, there is the danger from the jet blast, intake duct, propeller, or rotor blades. Because of these dangers, you need to develop safe and intelligent work habits. You should become a safety specialist, trained in recognizing and correcting dangerous conditions and unsafe acts.

You should study the cardiopulmonary resuscitation (CPR) training section of *Basic Military Requirements*, NAVEDTRA 14325, and *Standard First Aid Training Course*, NAVEDTRA 10081. These texts provide valuable information, but they do not replace training. It is your responsibility to get first aid training, including CPR. Personal CPR training is available at many Navy medical facilities. Many local fire stations and Red Cross agencies also offer this type of training. It is important for you to be currently certified in the special skills of CPR when troubleshooting electrical systems, ignition systems, or fuel systems.



WARNING

Do not perform CPR unless you have had the proper training.

COMMON ENGINE PROBLEMS

The need for troubleshooting is indicated by poor engine performance or system operation. The MIM for an aircraft or engine contains specific information for understanding and troubleshooting engine problems. Understanding the cause of common engine problems will not only help you avoid common problems it will make you a better maintainer and troubleshooter during your career as an Aviation Machinists Mate (AD).

Air System

All personnel should clearly understand that any obstruction or interruption of the air as it moves through the engine will affect the entire operation of the engine. Entrance of foreign matter into the air system is one of the main causes of service trouble. As the foreign matter passes rearward, it causes improper combustion, blockage of cooling air passages, and combustion section damage. The turbine section and the afterburner section may also become damaged.

Compressor Section

The compressor section of the turbojet engine is subject to a variety of service troubles from foreign object damage (FOD) passing through the compressor. Small pebbles, nuts, bolts, and washers can cause damage to the compressor rotor blades and stator vanes. Damage severe enough to warrant complete overhaul of the engine may result from the ingestion of foreign matter.

Combustion Chamber and Turbine Section

High temperatures take place in the combustion and turbine sections. Few major service troubles occur when maximum temperature and maximum rpm limits are closely monitored. Hot starts, over-temperatures, and exceeding maximum rpm will cause extensive service troubles in the combustion and turbine sections.

Fuel System

The fuel system of the gas turbine engine begins at the engine-driven fuel pump. The system ends with delivery of fuel to the combustion chambers through fuel nozzles in the form of highly atomized spray. Common service troubles are wrong types of fuel, water or other foreign matter in the fuel, defective fuel-boost pumps, and clogged fuel filters.

Lubrication System

Using the proper grade of oil when replenishing the oil supply is an essential requirement used to avoid lubrication system troubles. Gas turbine engines have few moving parts, but the speed, at which the parts move, especially the rotor, requires constant lubrication to the bearings. Oil starvation for a short period of time can result in having to remove the engine for overhaul.

TROUBLESHOOTING PROCEDURES

Troubleshooting procedures are similar in practically all applications. Troubleshooting is the logical or deductive reasoning procedure used when determining what is causing a particular system malfunction. There are ten steps involved in good deductive troubleshooting.

1. Conduct a visual inspection. This inspection should be thorough and searching. Check all lines, units, mechanical linkages, and parts for evidence of leaks, looseness, material condition, and proper installation. During this visual inspection, check all systems for proper servicing. Check reservoirs for proper servicing levels, accumulators for specified preload, etc.

2. The aircraft discrepancy book (ADB) and the visual information display system/maintenance action forms (VIDS/MAFs) are invaluable troubleshooting tools. The type of flight and previous maintenance actions may give an indication of the engine's problem. You may save many man-hours of troubleshooting an engine discrepancy by first screening the ADB for prior maintenance. You may find prior maintenance that has contributed to the cause of the new problem. You may find improperly performed maintenance, and trends of prior malfunctions.
3. Conduct an operational check. Check the malfunctioning system or subsystem for proper operation. This includes checking the mechanical movement of throttles and linkages for the correct movement without binding. Check for the proper sequence of operation and speed, and whether a complete cycle was obtained. Sometimes an operational check requires special test equipment or engine turn up to check out the system properly.
4. Classify the trouble. Discrepancies usually fall into four basic categories. They are the hydraulic, pneumatic, mechanical, and electrical types. Using the information gained from steps 1 and 2, you must determine under which classification the malfunction occurs. Something affecting normal flow of fluid would be classified as a hydraulic malfunction. The flow of fluid may be affected by external and internal leakage, total or partial restriction, or improper lubrication.
5. Something affecting the normal flow of compressed gases is classified as a pneumatic malfunction. This type of fault stems from the same general sources as the hydraulic malfunctions mentioned in the previous paragraph.
6. Many units that operate hydraulically or pneumatically use mechanical linkage. If a discrepancy in the linkage exists, it will affect the system's operation. Many mechanical discrepancies are found during visual inspections. Common mechanical problems are worn linkages, broken linkages, improperly adjusted linkages, or improperly installed linkages.
7. You must be able to determine if the electrical system is functioning normally. Common electrical problems are complete power failure, circuit failure, or component failure. Electrical components have circuit breakers and switches to operate or control them. Check the obvious things such as tripped circuit breakers or switches in the wrong position. Although Aviation Electricians Mate (AEs) normally troubleshoots electrical problems, sometimes you will work with them on a problem. Learn to read electrical schematics and use a multimeter so you can trace electrical power requirements throughout the affected system.
8. Isolate the discrepancies. This step calls for sound reasoning. A full and complete knowledge of engine theory, as well as a complete understanding of the affected system, is necessary. During this step you must use knowledge and known facts to determine where the malfunction exists in the system. Usually the trouble can be pinned down to one or two areas. Eliminate those units that could not cause the known symptoms and those that can be shown to operate normally.
9. Accomplish the isolating and correcting of engine discrepancies by comparing symptoms with probable cause. Begin with the most obvious and proceed to the less likely causes. A combination of several small maladjustments or malfunctions may contribute to a single complex discrepancy.
10. Correct the discrepancies. Accomplish this step only after the trouble has been definitely located. Malfunctions are corrected by servicing, adjustments, and part replacement. Part replacement is often needed to correct a malfunction, but you never use part replacement as a method of troubleshooting. Each year, thousands of dollars' worth of engine parts are returned to overhaul activities with labels stating that they are faulty. Upon completion of test and check by the overhaul activity, many parts show no defect. This practice is wasteful and very expensive. Another problem occurs when mechanics replace a major assembly, but the

problem could have been corrected by replacing a subassembly. The replacement of an entire unit when only a small part is at fault reflects poor maintenance practices. When troubleshooting, remember you are working with equipment that is both expensive and scarce. Replace equipment only after it is thoroughly tested and determined to be faulty.

Troubleshooting Errors

There are certain errors that you should avoid if you are to become an effective troubleshooter. These errors may result from faulty procedures or by the way you think about your work. A report entitled “A Preliminary Investigation of Troubleshooting” lists common troubleshooting practices to avoid. The report indicates that you should avoid making the following common errors:

1. Checking parts of the system that had nothing to do with the cause of the symptom.
2. Ignoring part of a system because you did not know that the unit was a possible cause of the symptom.
3. Making a difficult check when a simple one would have done the job.
4. After isolating the engine trouble between two points, making further checks beyond, rather than between, these points. Sometimes making a check between two points despite the fact that no engine trouble was found between them would cost additional man hours without much success, omitting a check even though you know it is related to the situation.
5. Attempting to remember a lot of information and failing; this finding points out the necessity of writing down all information during checks, and using the maintenance manuals, not your memory, for troubleshooting steps.

The report pointed out that troubleshooters sometimes made errors because of previous experience in similar situations. When they analyze and repair the engine trouble successfully, they have a feeling of satisfaction. They then tend to repeat the same procedures, even when the procedures are not relevant to the present engine trouble. Similarly, if the mechanic tried certain checks in the past and they did not fix the problem, the mechanic is reluctant to use them again, even when they provide information needed to correct the problem.

To become an expert troubleshooter, you must know the function of each part and how the operation of one part or system affects another. A good way to learn engine systems and the different relationships is to study schematics and diagrams. Trace out all the systems you work on, and recognize normal readings. Learn how to use test equipment and read schematics before you are required to troubleshoot a problem.

Diagrams, Drawings, and Charts in Troubleshooting

The diligent use of the applicable MIM is essential in preventing poor troubleshooting procedures. The MIM for each aircraft provides troubleshooting aids that cover the six steps listed in the previous section. These manuals provide a variety of troubleshooting aids. *Figure 9-1* shows examples of troubleshooting chart formats. These charts list a definite sequence of action for a problem, according to the probability of failure and ease of investigation. These charts supply the trouble, probable cause, and the corrective action for some of the more common malfunctions.

The MIM also contains schematics and diagrams for use in troubleshooting. Diagrams of the various electrical circuits, fuel systems, and lubrication systems are very useful in isolating discrepancies. There are many types of diagrams, but those most important for troubleshooting include schematics and pictorials. There are some MIMs that combine different types of diagrams to provide more information. To understand how a system or component of the aircraft functions, you must be able to read these diagrams.

Probable Cause	Isolation Procedure	Corrective Action
STEP f TROUBLE: ROTODOME DOES NOT ROTATE		
RADAR PWR, LEFT TR BUS FDR, and RIGHT TR BUS FDR ACFT 28 vdc circuit breakers not engaged, 87CB36, 77A5CB19, 77A5CB17, 43A40CB5	Check circuit breakers.	Engage circuit breakers.
Failure in rotodome system	Operate rotodome, using external hydraulic power (NAVAIR 01-E2AAA-2-1, WP035 00).	If rotodome does not operate with hydraulic power, check hydraulic components. If rotodome operates with hydraulic power, check electrical system.
Rotodome rotation constant-speed motor	Replace motor with one known to operate properly (WP019 00).	If normal operation results after replacement, forward defective component to next higher maintenance level.
Rotodome rotation selector valve, 40L1	Replace valve with one known to operate properly (WP017 00).	If normal operation results after replacement, forward defective component to next higher maintenance level.
Rotodome rotation selector valve solenoid	Check for 28 vdc at pin B on valve electrical plug, 40L1P1.	If 28 vdc is obtained, replace valve (WP017 00).
ANT ROT switch (On aircraft serial no. 158638 through 160011, part of Radar Set Control C-8764/APS-120 40A11. On aircraft serial no. 160012 through 163028, part of Radar Set Control C-10024/APS-125 39A11 (used on APS-125 or APS-138 radar). On aircraft serial no. 163029 through 163848 and 163850 through 164107, part of Radar Set Control C11475/APS-139 9A11.)	Check for 28 vdc at pin B on radar set control plug, 40A11P2, 39A11P2.	If 28 vdc is obtained, replace control box (NAVAIR 01-E2AAA-2-18.2, WP268 00).
RADAR PWR circuit breaker, 87CB36	Check for 28 vdc at inlet side of circuit breaker.	If 28 vdc is obtained, replace circuit breaker. If 28 vdc is not obtained, refer to NAVAIR 01-E2AAA-2-4, WP003 00.
OFF push-switch 40A43	Check for 28 vdc at pin R of OFF switch connector 40A43P2.	If 28 vdc is not obtained, replace push-switch (NAVAIR 01-E2AAA-2-4, WP003 00).
System wiring	Check continuity of wiring.	Repair or replace wiring.
Rotodome rotation and support mechanism gearbox	Check for clutch slippage (WP021 00).	If clutch adjustment does not obtain correct torque values, replace gearbox. Forward defective component to next higher maintenance level.
	Check output drive assembly for wear or damage.	If output drive assembly is worn or damaged, replace it (WP021 00).

Figure 9-1 — Examples of troubleshooting chart formats (1, 2, 3, and 4).

Schematic diagrams enable maintenance personnel to trace the path of electrical circuits, fuel systems, and lubrication systems of aircraft. Schematic diagrams use symbols for a graphic representation of the assembly or system. Some of the mechanical symbols used in schematics are shown in *Figure 9-2*. A complete listing can be found in the *Military Standard, Mechanical Symbols for Aeronautical, Aerospace, and Spacecraft Use, Part 2*, MIL-STD-17B-2. Electrical components or circuits use the standard electrical symbols shown in *Figure 9-3*. Look at this figure and notice the electrical symbols for FUSE, SPLICE, GROUND, and POLARITY.

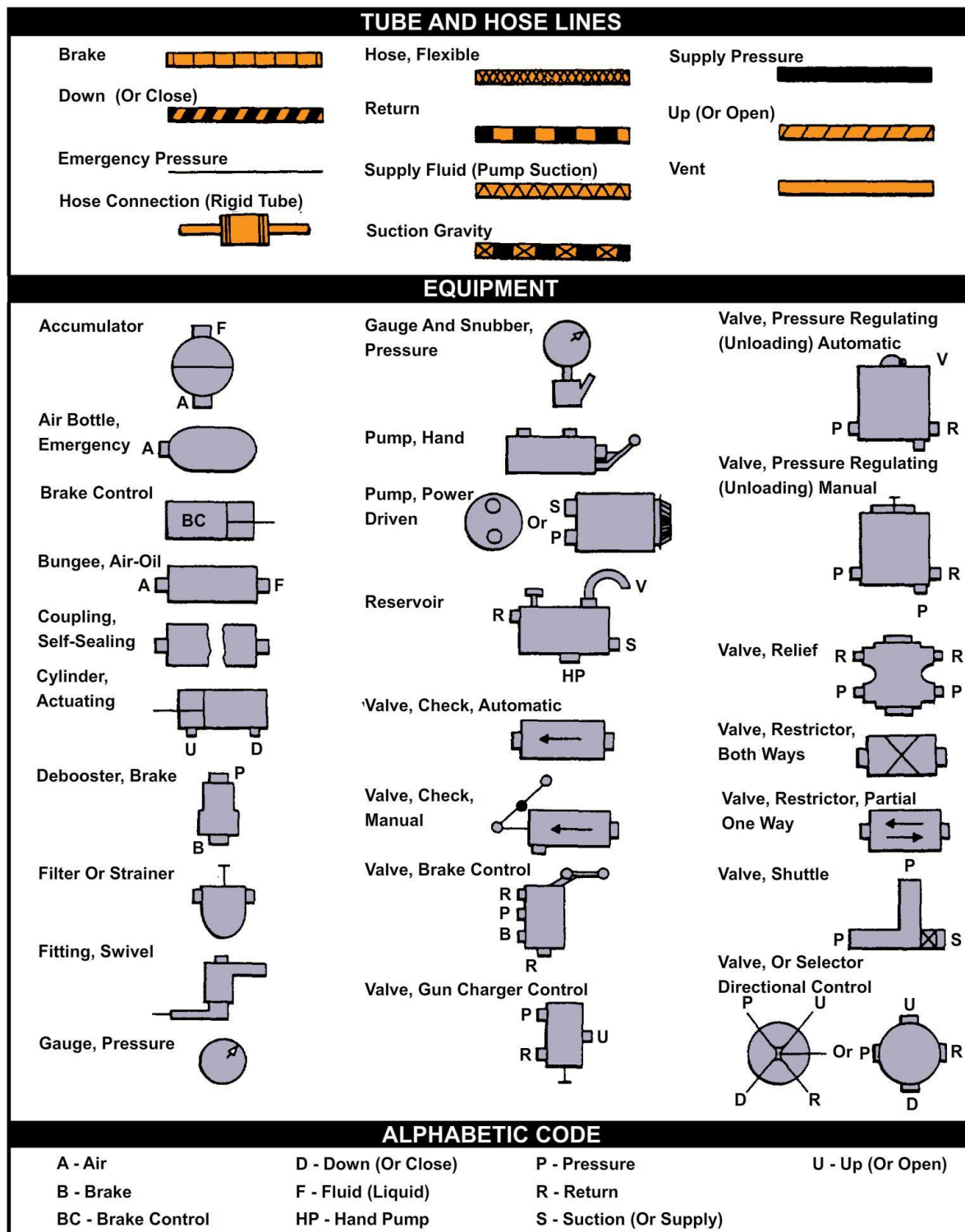


Figure 9-2 — Aeronautical mechanical symbols.

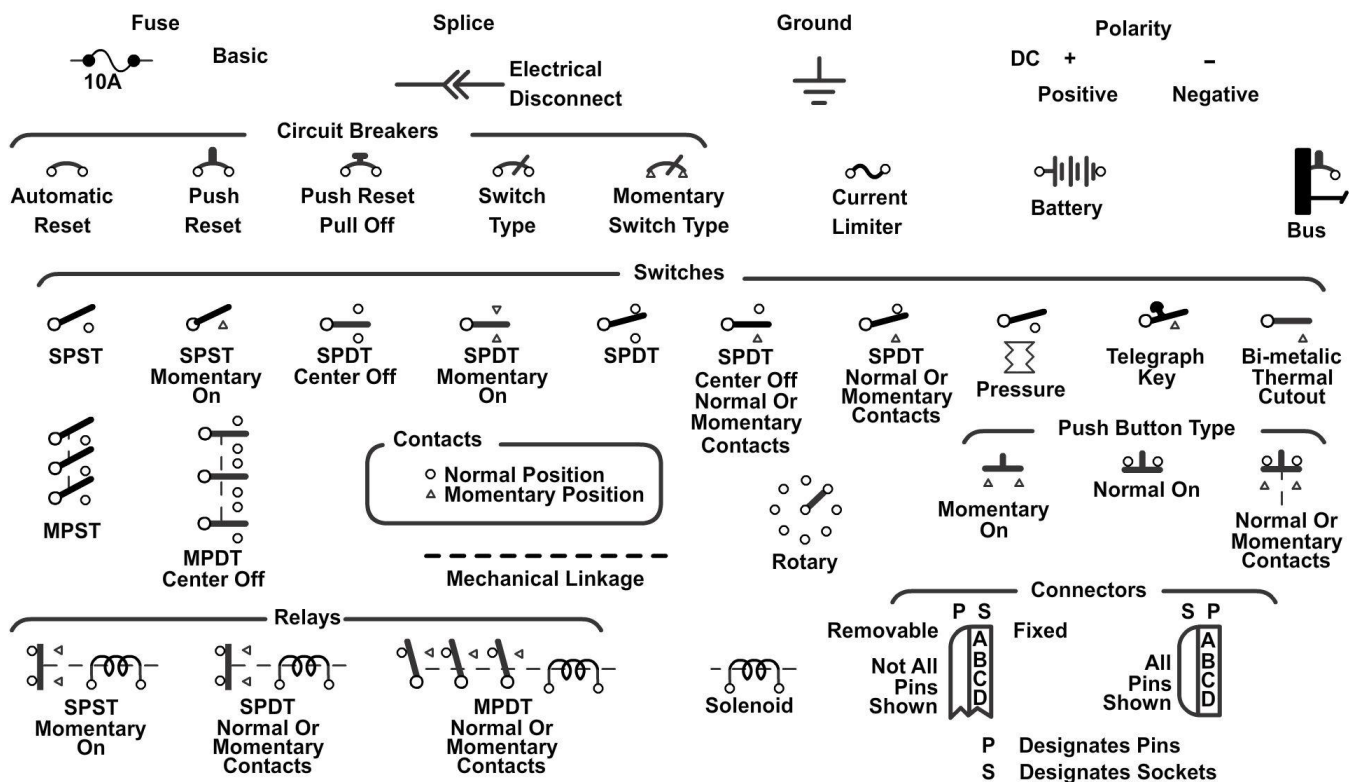


Figure 9-3 — Electrical symbols.

Schematic diagrams show the relationship of each part to other parts in the system. They do not always indicate the physical location of the part. *Figure 9-4* is a schematic diagram that shows the flow of fuel of a turbojet engine fuel control. It shows the flow of fuel from the fuel pump through the fuel control, the fuel distributors, and the internal fuel tubes. Fuel from the internal fuel tubes enters the

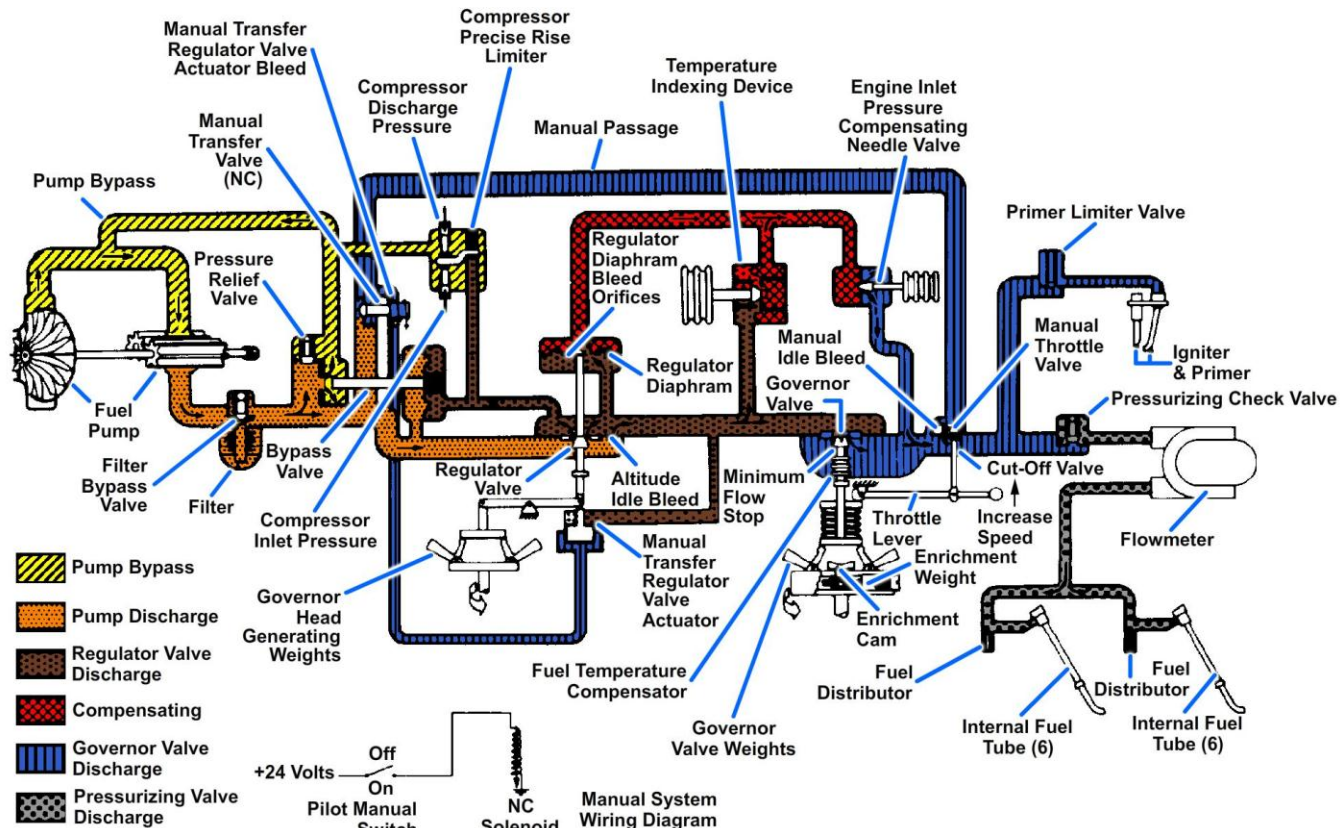


Figure 9-4 — Fuel control schematic.

combustion chambers through fuel lines to the fuel manifold. Each part is illustrated and identified by name. The arrows show the direction of flow through each line and component within the fuel control.

Pictorial diagrams show location, function, and appearance of parts and assemblies. This diagram is sometimes called an installation diagram. Pictorial diagrams are valuable for locating and identifying parts (*Figure 9-5*). Other uses for this type of drawing are the disassembled or exploded view and the cutaway. Cutaway drawings show the internal construction of parts, and exploded views show how the various parts of a component are assembled. *Figure 9-6* shows a cutaway drawing, and *Figure 9-7* shows an exploded view drawing.

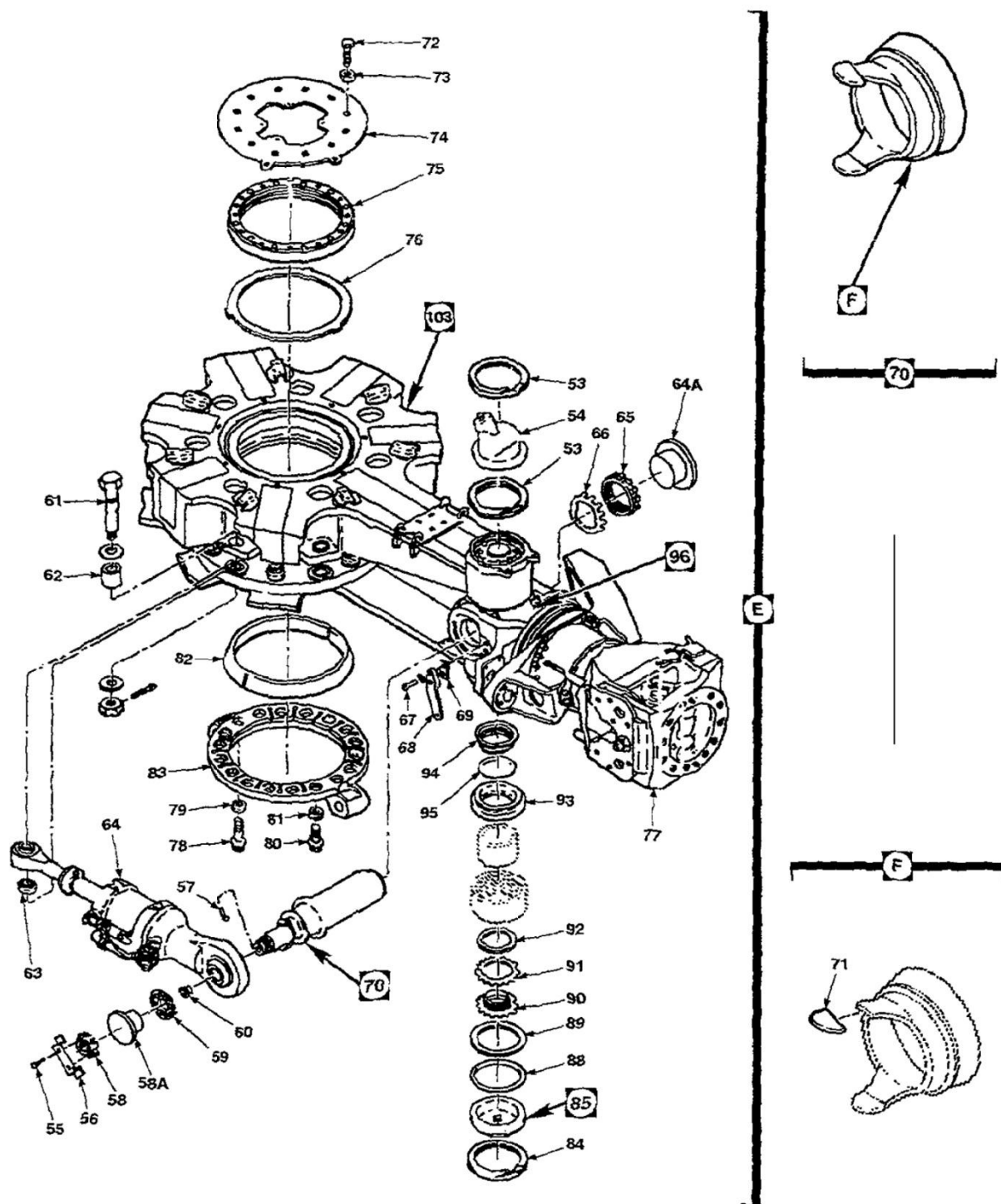


Figure 9-5 — Pictorial diagram of an H-53 main rotor head hub assembly.

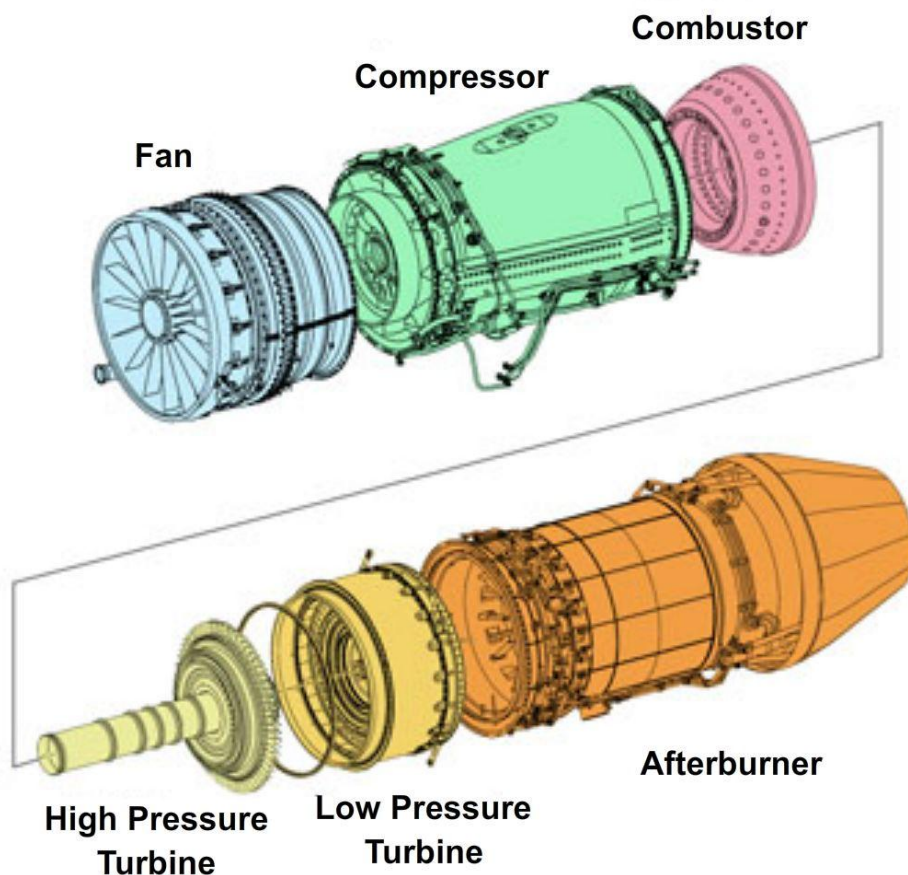


Figure 9-6 — Major engine sections view.

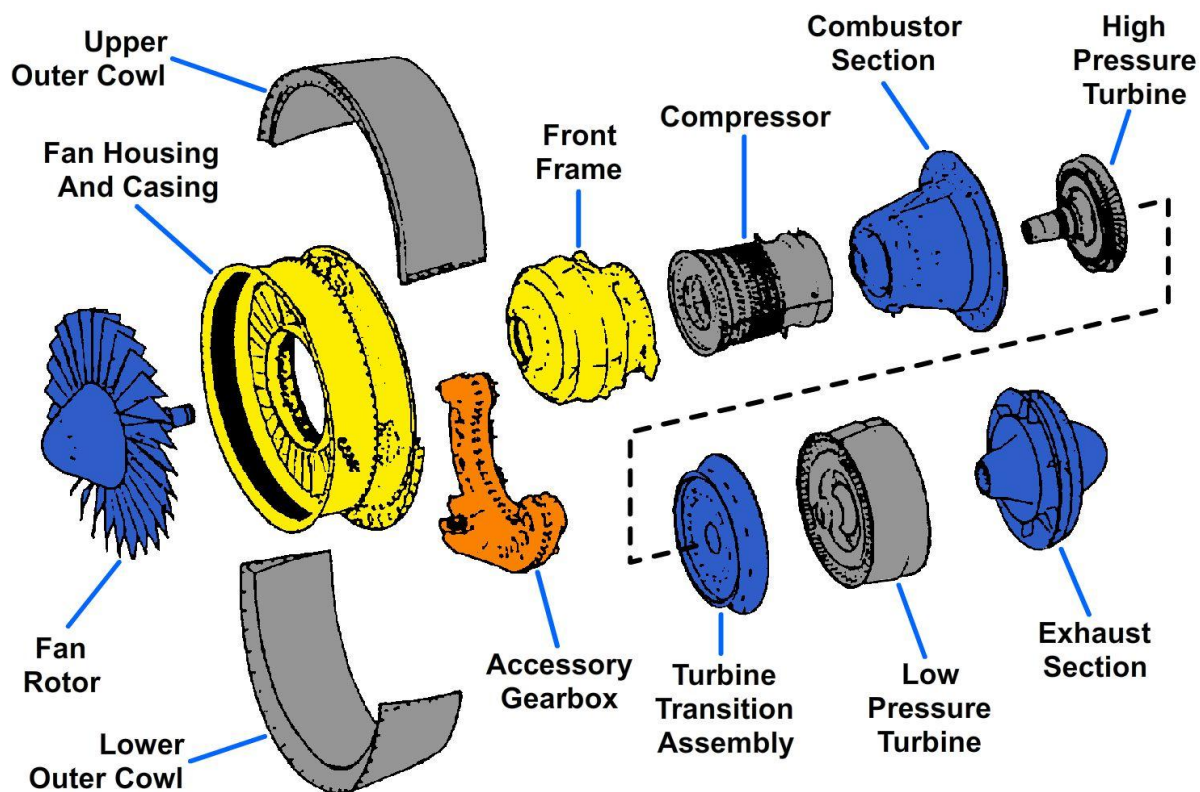


Figure 9-7 — Turbofan exploded view.

Fluid Line Identification

You can identify fluid lines in aircraft by markers made up of color codes, words, and geometric symbols. These markers identify each line as to function, content, primary hazard, and direction of flow. *Figure 9-8* lists the various types of fluid lines and indicates the color code and symbol for each line. *Figure 9-9* shows the markers used for rocket fuel lines.

FUNCTION	COLOR	SYMBOL
Fuel	Red	
Rocket Oxidizer	Green, Gray	
Rocket Fuel	Red, Gray	
Water Injection	Red, Gray, Red	
Lubrication	Yellow	
Hydraulic	Blue, Yellow	
Solvent	Blue, Brown	
Pneumatic	Orange, Blue	
Instrument Air	Orange, Gray	
Coolant	Blue	
Breathing Oxygen	Green	
Air Conditioning	Brown, Gray	
Monopropellant	Yellow, Orange	
Fire Protection	Brown	
De-icing	Gray	
Rocket Catalyst	Yellow, Green	
Compressed Gas	Orange	
Electrical Conduit	Brown, Orange	
Inerting	Orange, Green	

Figure 9-8 — Fluid line color codes and symbols.

In most instances, fluid lines are marked by the use of 1-inch tape or decals, as shown in *Figure 9-9*. On lines 4 inches or larger in diameter, lines in an oily environment, hot lines, and some cold lines, steel tags replace tape or decals (*Figure 9-9*). On lines in engine compartments, where there is a possibility that tapes, decals, or tags can be drawn into the engine intake, paint is used.

Reading *Figure 9-9*, from left to right, the line function is indicated by color code (red), (FUEL), and symbols (four-pointed star). Content of the line is indicated by name (FUEL). The primary hazard is indicated by the word FLAM. Direction of flow is indicated by arrows. Two-headed arrows are used to show reversible flow. In addition, certain lines may have a special code for lines that have a specific function within a system. Some examples include drain, vent, pressure, and return lines.

There are four general classes of hazards found in connection with fluid lines. These hazards are shown by special fluid line markings.

1. Flammable material (FLAM). The hazard marking FLAM is used to identify lines containing materials known as flammable or combustible materials.
2. Toxic and poisonous materials (TOXIC). The word TOXIC identifies lines that contain materials that are extremely hazardous to life or health.
3. Anesthetics and harmful materials (AAHM). The AAHM markings identify lines containing materials that produce anesthetic vapors and all liquid chemicals that are hazardous to life and property. These materials do not produce dangerous quantities of fumes or vapors.
4. Physically dangerous materials (PHDAN). The PHDAN marking identifies lines that carry a material that is not dangerous within itself but is asphyxiating in confined areas. The material in the line may be in a dangerous physical state of high pressure or temperature.

Aircraft and engine manufacturers are responsible for the original installation of identification markers, and maintenance personnel are responsible for replacement as necessary. Tapes and decals are placed on both ends of a line and at least once in each compartment through which the line passes. In addition, identification markers are found next to each valve, regulator, filter, or other accessory within a line. Location requirements are the same for tapes and decals as they are for tags and paint.

Additional information is listed in *Aviation Hose and Tube Manual*, NAVAIR 01-1A-20. Complete instructions for installing fluid line identification markers are contained in MIL-STD-1247C.

GAS TURBINE TEST EQUIPMENT

You will find that certain test equipment will prove invaluable in troubleshooting engine systems. We will briefly discuss the necessary test equipment available for maintaining aircraft systems. More detailed information can be found in the technical manual for the particular piece of equipment.

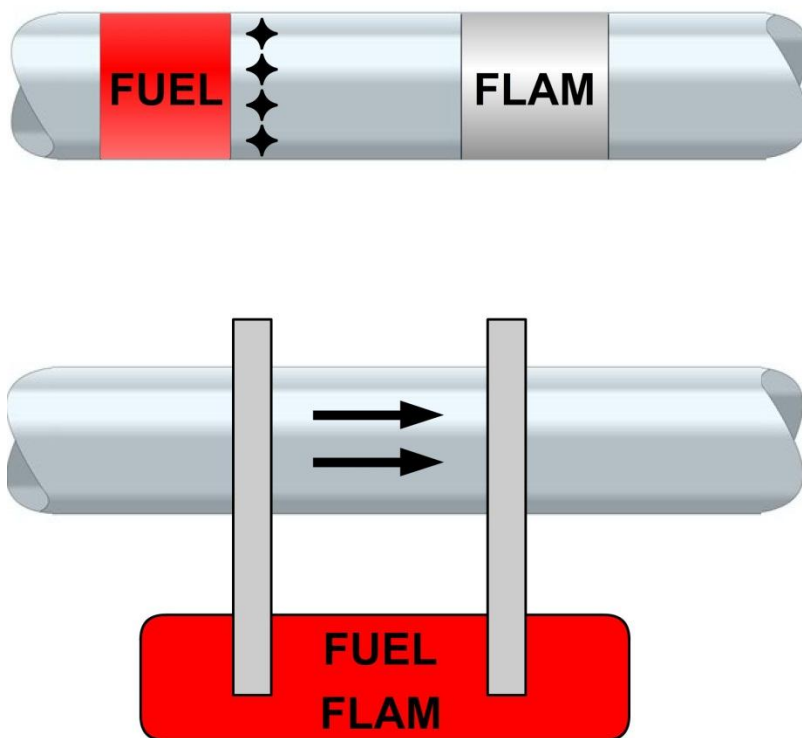


Figure 9-9 — Fluid line identification group, using tape and decals; and using metal tags.

Electrical Test Equipment

During troubleshooting, you will often measure voltage, current, and resistance. Although AEs normally troubleshoot and repair electrical systems, you should have knowledge of basic electricity and test equipment. This information will increase your troubleshooting abilities since there are few aircraft systems independent of electrical operations. In addition, many troubleshooting charts call for continuity checks that a properly trained AD can easily accomplish.

General Rules for Electrical Test Meters

Always connect an ammeter in series—never in parallel. Always connect a voltmeter in parallel—never in series. Never connect an ohmmeter to an energized circuit. On test meters, select the highest range first, and then switch to lower ranges as needed.

When you use an ohmmeter, select a scale that gives a near-midscale reading. Midscale is the point where the meter is most accurate. Do not leave the multimeter selector switch in a resistance position when the meter is not in use. The leads may short together, discharging the internal battery. There is less chance of damaging the meter if the switch is on a high at-volt setting, or in the OFF position. Meters that have an OFF position dampen the swing of the needle by connecting the meter movement as a generator. This prevents the needle from swinging wildly when moving the meter.

NOTE

Only authorized personnel may repair and maintain electronic and electrical equipment because of the chance of injury, the danger of fire, and possible material damage. To use electrical test equipment correctly, you need to have a working knowledge of basic electricity. You should adhere to the special and general rules for the handling of electrical devices.

View the meter from directly in front to eliminate parallax error. Observe polarity when measuring DC voltage or current. Do not place meters in the presence of strong magnetic fields. Never measure the resistance of a meter or a circuit with a meter in it. The high current required for ohmmeter operation may damage the meter. This also applies to circuits with low-filament current tubes and to some types of semiconductors.

When you are measuring high resistance, do NOT touch the test lead tips or the circuit because it may cause body resistance to shunt the circuit, creating an erroneous reading. Connect the ground lead of the meter first when making voltage measurements. Work with one hand whenever possible.

Multimeter

The process of fault detection often leads beyond visual inspection and power checks. Use a voltmeter to find out if a power circuit is delivering power to the proper place. However, the voltmeter will not identify what is wrong. An ohmmeter is a better instrument for identifying the problem. With the ohmmeter, you can find opens, shorts, grounds, or incorrect resistance values. With schematics you can trace circuits until you isolate the trouble.

The multimeter contains circuitry that allows it to be a voltmeter, an ammeter, or an ohmmeter. A multimeter is often called a volt-ohmmeter (VOM).

The VOM does have two disadvantages—it can load the circuit under test, and the meter movement is easy to damage through improper testing procedures.

Two common multimeters are the Fluke 83V and the Fluke 8840A. (See *Figures 9-10 and 9-11.*)

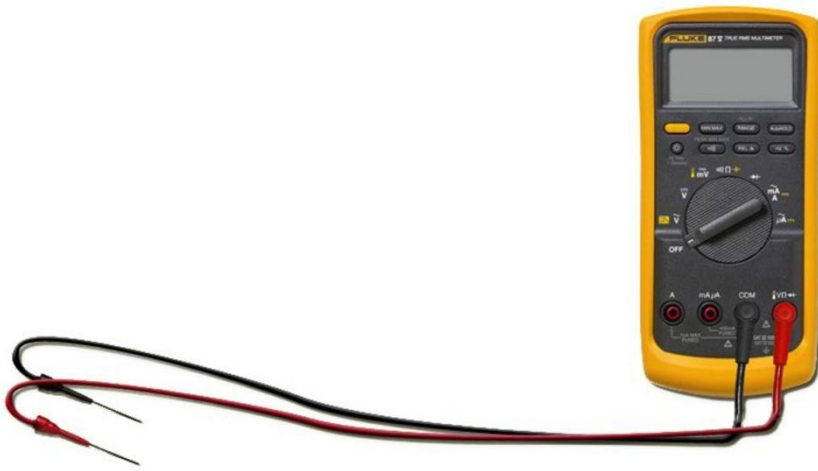


Figure 9-10 — Fluke 83V multimeter.



Figure 9-11 — Digital multimeter, fluke 8840A



Figure 9-12 — Ohmmeter.

Ohmmeter

Use an ohmmeter to measure circuit continuity and total or partial circuit resistance. An ohmmeter is shown in *Figure 9-12*. Before measuring the resistance of an unknown resistor or electrical circuit, the test leads of the ohmmeter are first shorted together, with the leads shorted, calibrate the meter for proper operation on the selected range. When the variable resistor is adjusted properly, with the leads shorted, the pointer of the meter will come to rest exactly on zero. This reading indicates zero resistance between the test leads. When the test leads of an ohmmeter are separated, the pointer of the meter will return to the left side of the scale. This happens because of the interruption of current and the spring tension action on the movable coil assembly.

After you adjust the ohmmeter for zero reading, it is ready to be connected in a circuit to measure resistance. The power switch of the circuit to be measured should always be in the OFF position. Circuit voltage applied across the meter could damage meter movement.

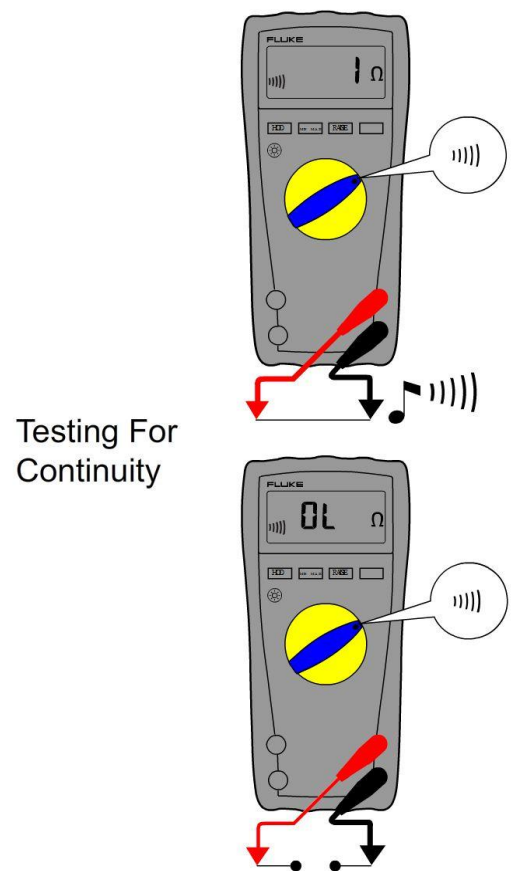
Connect the test leads of the ohmmeter across (in series with) the circuit to be measured. The current produced by the meter must now flow through the circuit being tested. A reading obtained from the

ohmmeter between zero and infinity shows the number of ohms of resistance in that circuit. An infinity reading shows there is an open circuit.

In open circuits, current flow stops. The cause may be a broken wire, defective switch, etc. To detect open circuits, be sure to perform a continuity test, which will tell if the circuit is complete or continuous.

Figure 9-13 and Figure 9-14 shows a continuity test with a multimeter. Figure 9-14 shows both plugs are disconnected, and the ohmmeter is connected in series with conductor or A, which is under test. The power should be off. When checking conductors A, B, and C, the current from the ohmmeter flows through plug 2 (female), conductor A, B, or C, to plug 1 (female). From plug 1, current passes through the jumper to the chassis, which is grounded to the aircraft structure. The aircraft structure serves as the return path to the chassis of unit 2 and completes the circuit through the series-connected ohmmeter.

The ohmmeter shows a low resistance because no break exists in conductors A, B, or C. However, checking conductor D reveals an open. The ohmmeter shows maximum resistance because current cannot flow in an open circuit. With an open circuit, the ohmmeter needle is all the way to the left, since it is a series-type ohmmeter (which reads right to left). When you have finished using the ohmmeter, turn the ohmmeter switch OFF to conserve the batteries.



Testing For Continuity

Figure 9-13 — Simple continuity meter check.

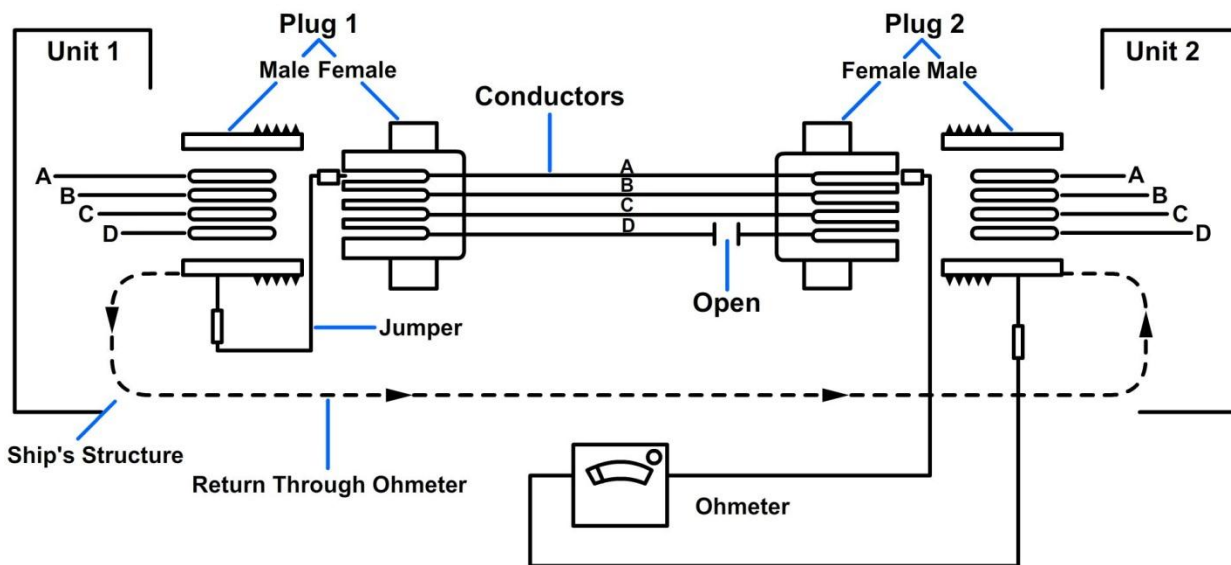


Figure 9-14 — Continuity test.

High-Voltage Insulation Tester

The high-voltage insulation tester detects or measures leakage of high-voltage insulation.

The high-tension voltage tester is composed of four sections. They are as follows:

- A vibrator inverter, which converts a 24-volt DC source to 110-120 volts AC.

- A voltage control, which controls the amount of high voltage applied to the test circuit.
- A step-up transformer, which steps up the low voltage from the vibrator inverter or 110-volt source to high voltage.
- A rectifier that changes ac to dc. The test leads are connected to the rectifier dc output side.

To calibrate the high-voltage tester, follow these four steps:

1. Set the microampere and kilovolt meters to indicate ZERO when the machine is OFF.
2. With the current ON, connect the test leads.
3. Move the voltage control until the needle is about one-sixteenth inch past 10, 000 volts. Then set the test voltage limiter gap. If it is properly adjusted, the neon light will not flash at the test voltage setting.
4. Adjust the excess current indicator to flash on and off continually when the microampere meter shows a leakage in excess of 100 microamperes.

When operating the high-voltage tester, be sure to perform a continuity test with an ohmmeter before you apply the high-voltage insulation test. To hook up the high-voltage tester, follow these steps:

1. Ground the high-voltage insulation tester to a good local ground with the grounding lead.
2. Connect the red high-voltage test lead to the high-voltage side of the part to be tested.
3. Connect the black ground test lead to the ground side of the part to be tested.



The insulation tester operates on high voltages that are dangerous. Always discharge the ground circuits before you touch them. Always connect the ground lead to a good earth ground before you turn the tester on. When testing a lead, connect the tester to the lead before you turn the test voltage switch on. Be safe. Operate the equipment and secure the leads with one hand only.

BORESCOPE INSPECTION

You will find borescope inspection requirements listed in the periodic maintenance inspection cards (PMIC) for scheduled or conditional inspections. Borescopes provide illumination of internal areas of aircraft engines or engine parts. This illumination allows for internal inspections that require minimum disassembly, such as the removal of port covers or thermocouples.

Types of Borescopes

The rigid borescope assembly (*Figure 9-15*) allows for inspection of internal engine conditions having a direct access. Another type of borescope has a flexible probe and is commonly known as a fiber-optic borescope, or fiberscope. The probe on the fiber-optic scopes can be snaked around, behind, and into areas impossible to reach with the rigid scope (*Figure 9-16*).

The advantage of the flexible probe is that many areas can now be inspected without opening the engine. The probe can be worked back through the compressor from the front of the engine. It can also be inserted through a fuel nozzle opening and worked back to the turbine area to as close as one-quarter of an inch from the surface being inspected. Being able to assess possible damage at that close a range has a distinct advantage over the rigid type of borescope. A fiber-optic borescope

and an inspector experienced in its use could make the difference between wasting the man-hours spent rejecting a perfectly good engine or obtaining more flight hours from that same engine after damage was suspected.



Interaction Available

Figure 9-15 — Rigid borescope.



Interaction Available

Figure 9-16 — Fiber-optic borescope.

Borescope Use

Know your equipment. Borescopes are easily damaged and have different characteristics. For example, optical characteristics of the small borescope magnify and distort all areas other than the turbine blade leading edge. This often results in what appears to be an alarming vane condition. Know and be able to locate all inspection areas or ports on your engine. *Figure 9-17* shows an example of inspection ports and areas that you can inspect from that port.

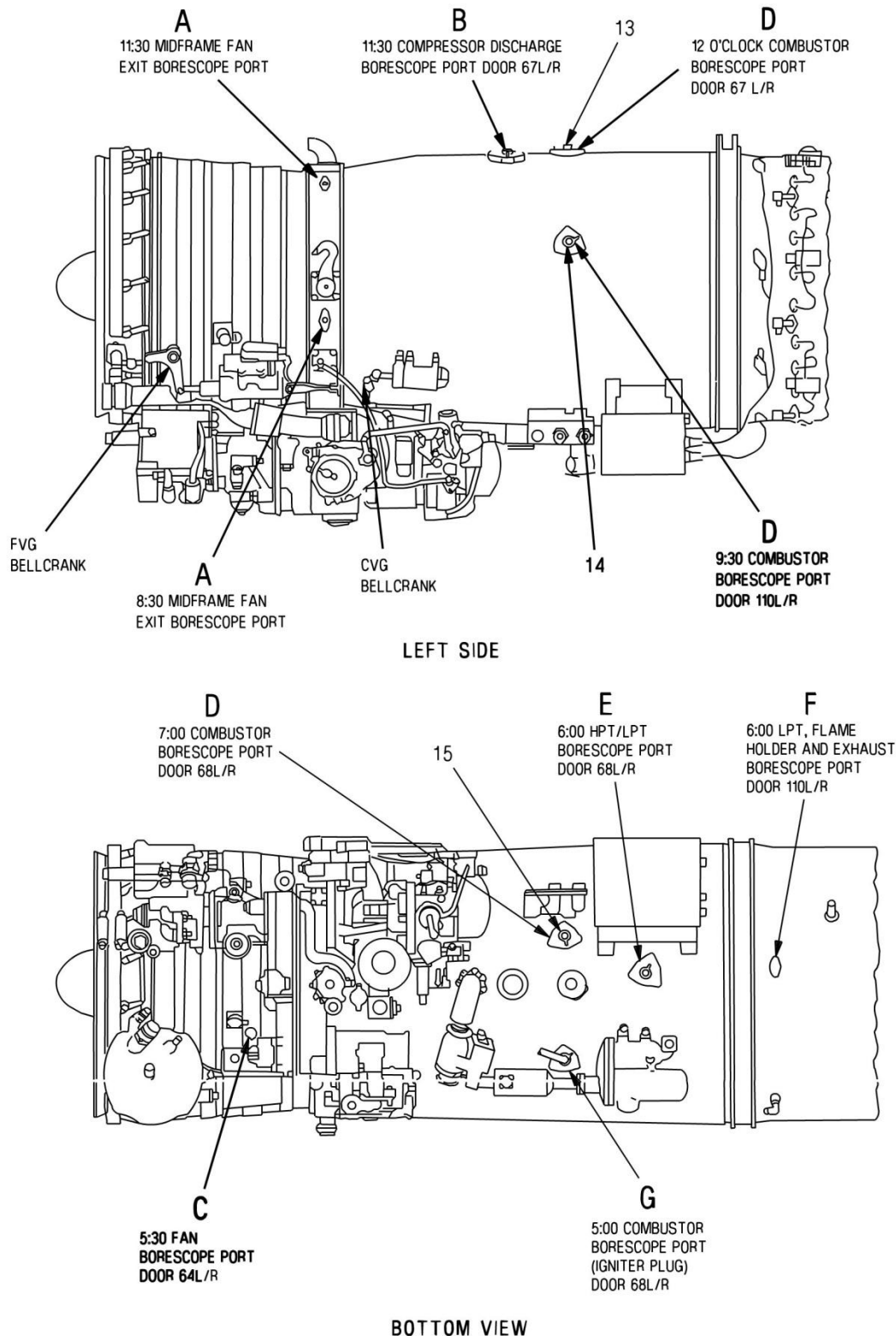


Figure 9-17 — Engine inspection ports.

Establish internal reference points. Pictorial and cutaway diagrams help establish these reference points. When the probe is in the inspection port, it is easy to lose your sense of direction. Some borescopes have an index mark on the eyepiece to show direction.

Scan the inspection area thoroughly and in an orderly manner. Compressor cracks can be difficult to detect because of small close parts, rotating the engine too fast, or deteriorated borescope optics. Note and evaluate factors including stage, area, magnitude, direction, and adjacent material conditions. Some inspection cards instruct you to mark or bend an 18-inch length of lock-wire, and then insert the wire through an adjacent inspection port. You can then use this wire as a gauge to measure vane cracks while viewing through the borescope.

Figures 9-18 and 9-19 show different engine parts seen through a borescope. You must know the terms to describe the damage found. Then compare this information with serviceability limits in the MIM. Record all information (Figure 9-20).

Report your conclusions and recommendations. Carefully read and follow the procedures in your aircraft maintenance manuals for borescoping. Different procedures are required for different types of engines to prevent damage or to inspect properly. For example, on the turboprop engine, the turbine blade inspection is made easier by releasing the propeller brake. This makes it possible to rotate the turbine smoothly in both directions. On turbofan engines, you should not borescope if there is a possibility that wind can rotate the fan rotor.

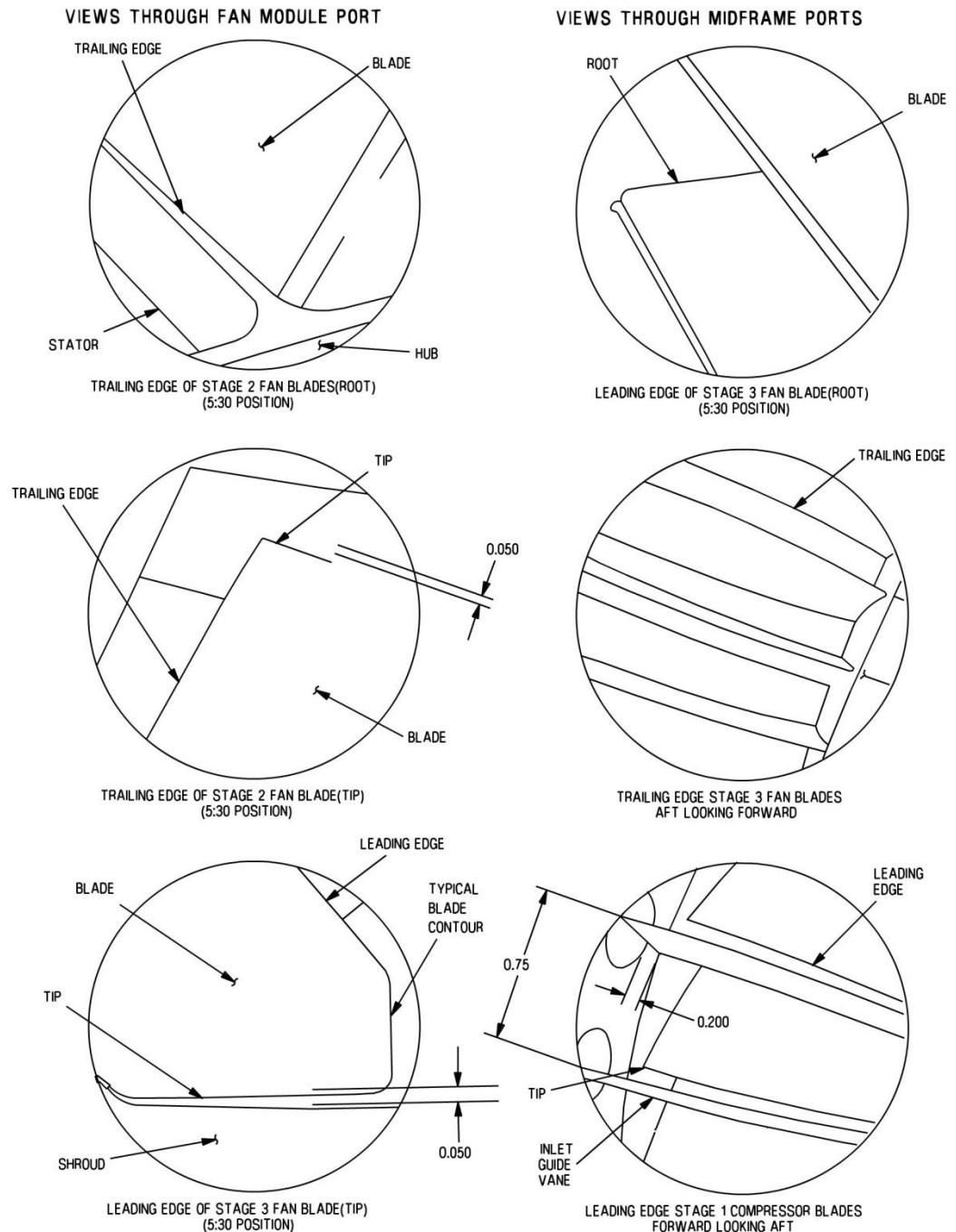
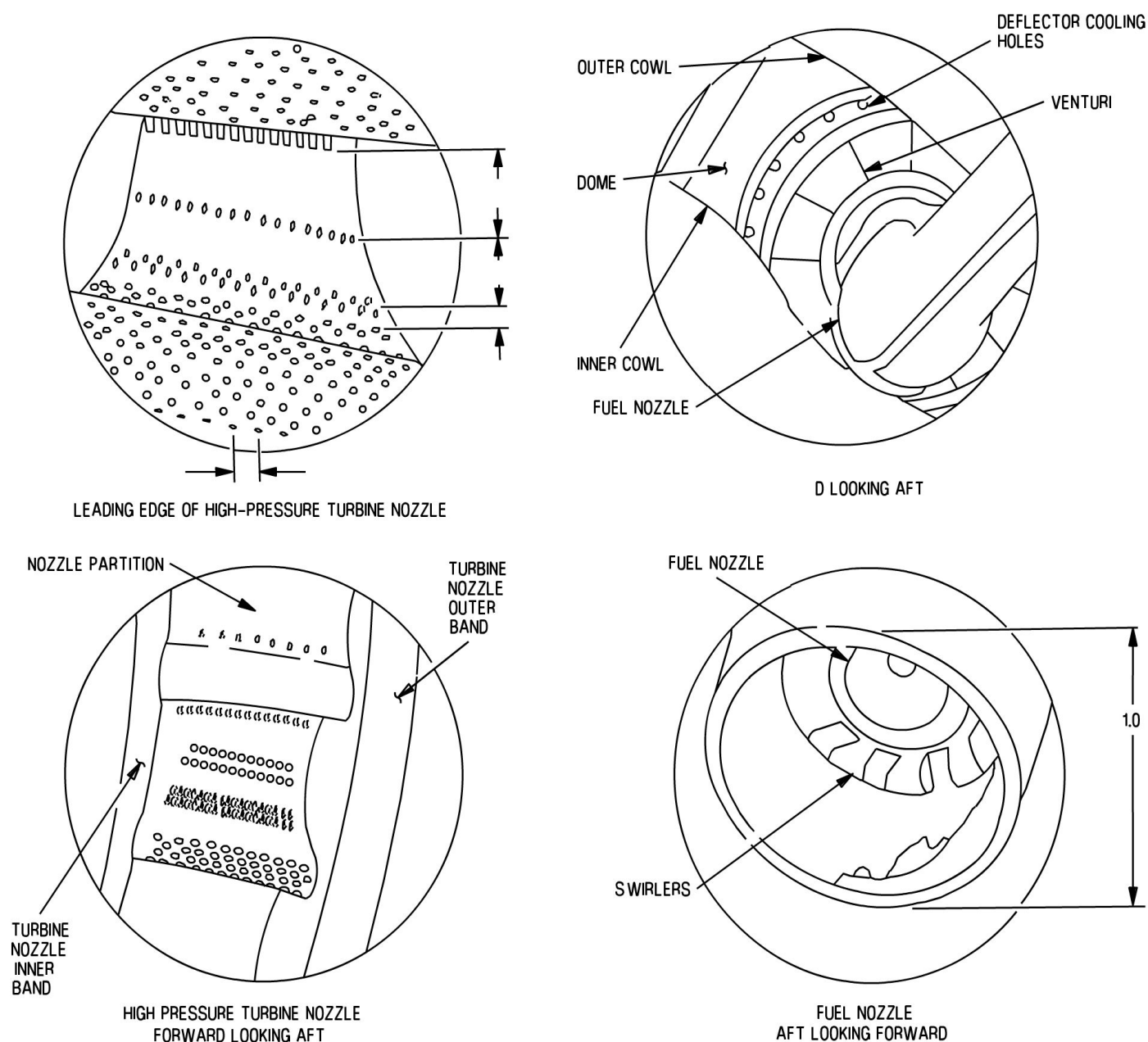


Figure 9-18 — Borescope views of compressor and fan blades sections.

Although water washing is not required before borescoping, it helps clean the engine so you get the best possible evaluation. Dirt and small carbon particles may obscure small cracks or pitting that could be missed in a dirty engine. Water washing also improves engine performance by removing sulfidation.



LEGEND

ALL DIMENSIONS
ARE IN INCHES

**Figure 9-19 — Borescope views of combustion section and turbine blades
(1, 2, 3).**

Inspect	Max Usable Limits	Corrective Actions
NOTE Max usable limit - The limit which is allowable without repairing or replacing part Corrective action - What must be done before part or engine is serviceable.		
a. Combustion liner dome for:		
(1) Cracks	None allowed.	Replace Engine (WP003 00).
(2) Torn Metal	None allowed.	Replace Engine (WP003 00).
b. Stage 7 compressor rotor blades for:		
(1) Cracks	None allowed.	Replace Engine (WP003 00).
(2) Torn metal	Any amount, within limits in areas (dimensions) A and B, figure 15.	Replace Engine (WP003 00).
(3) Missing tip corners	None allowed. Go to figure 14 for difference between a missing tip corner and a rework chamfer.	Replace Engine (WP003 00).
(4) Missing pieces of airfoil	None allowed.	Replace Engine (WP003 00).
(5) Nicks, pits, dents and scratches on leading and trailing edges	Any number within limits in areas (dimensions) A and B, figure 15.	Replace Engine (WP003 00).
(6) Curled edges on tips of blades	0.140 inch of blade length. Not more than ten blades affected.	Replace Engine (WP003 00).
(7) Smooth dents on airfoil surface of blade	1. Any number on leading/trailing edges, but do not exceed limits of figure 15. Not more than 10 blades affected.	1. Replace Engine (WP003 00).
	2. At locations other than leading and trailing edges, any number of smooth dents allowed on outer 0.500 inch of airfoil, 0.030 inch deep any number of blades.	2. Replace Engine (WP003 00).
(8) Erosion on leading or trailing edge	Any amount, 0.070 inch.	Replace Engine (WP003 00).

Figure 9-20 — Basic borescope maintenance inspection criteria.

Engine Water Washing

Engine water washing consists of applying an emulsion of demineralized water and cleaning liquids. Field cleaning of this nature is often accomplished as a desalination wash to remove salt deposits when operating in salt-laden air. Field cleaning may be done as a performance recovery wash to remove dirt and other deposits.

Specific steps to follow in cleaning a particular engine are found in the maintenance instructions for the particular engine. These steps generally include blocking some lines and ports and removing any equipment in the inlet duct. This is done to prevent damage by the cleaning material. The engine is then motored over for specific periods of time while the cleaning compound is fed into the inlet duct. After cleaning, the engine must be returned to its original configuration. The engine is dried by running it. Engine performance for trend analysis is often checked after engine washing.

NOTE

Always refer to the appropriate MIMs prior to the start of any engine water washes.

End of Chapter 9

Powerplant Troubleshooting

Review Questions

- 9-1. What is the recommended maintenance procedure if oil pressure is low on a gas turbine engine?
- A. Remove and replace air inlet
 - B. Remove and replace engine
 - C. Remove and replace fuel filter
 - D. Remove and replace oil filter
- 9-2. What is the most common error in troubleshooting procedure?
- A. Viewing the Aircraft Discrepancy Book (ADB)
 - B. Reviewing the aircrafts maintenance instruction manual (MIM)
 - C. Omitting a step even though you know its related to the problem
 - D. Asking your supervisor for help
- 9-3. What is the purpose of an electrical schematic diagram?
- A. Shows an exploded view of a component
 - B. Trace the path of electrical circuits
 - C. Shows an internal view of a component
 - D. Traces the path of fluid flow
- 9-4. What do fluid line markers identify?
- A. Function, content, primary hazard, and direction of flow
 - B. Length, function, content, and primary hazard
 - C. Width, direction of flow, content, and function
 - D. Material type, content, function, and direction of flow
- 9-5. How is a multimeter connected in a circuit?
- A. Directly
 - B. Parallel
 - C. Polarity
 - D. Series
- 9-6. What is the purpose of a multimeter?
- A. Allows the technician to measure volts, amps, and ohms from one unit
 - B. Allows the technician to measure high voltage, amps, and ohms from one unit
 - C. Allows the technician to measure exhaust gas temperature, ohms, and volts from one unit
 - D. Allows the technician to measure outside air temperature, volts, and amps from one unit

- 9-7. What are the two most common borescopes used in naval aviation maintenance?
- A. Big and small
 - B. Fiber-optic and rigid
 - C. Internal and external
 - D. Straight and curved
- 9-8. What color is used on the tapes that identify aircraft fire protection lines?
- A. Blue
 - B. Brown
 - C. Green
 - D. Red
- 9-9. What does a blue and yellow circle identify on fluid line identification?
- A. Compressed gas
 - B. Electrical conduit
 - C. Hydraulic
 - D. Rocket fuel
- 9-10. What is the purpose of a borescope?
- A. To identify electrical current in an engine
 - B. To identify fuel pressure of an engine
 - C. To identify internal damage in an engine
 - D. To identify lubrication pressure of an engine
- 9-11. How is the engine dried after engine water wash has been performed?
- A. Blow-dried
 - B. Drip-dried
 - C. Dried by heat lamp
 - D. Running it
- 9-12. Which of the following is an advantage of engine water washing?
- A. Increased engine performance
 - B. Increased maintenance man-hours
 - C. Increased aircraft down time
 - D. Increased aircraft log book entries

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