

CHAPTER 6

ENGINE AND AIRCRAFT RELATED SYSTEMS

An Aviation Machinist's Mate (AD) deals with a large variety of aircraft systems. As an AD you need knowledge of hydraulics and electricity because of these different systems. You must be familiar with such systems as ignition, start, bleed-air, and auxiliary power unit systems. This chapter introduces you to basic hydraulics, electricity, and the related systems that the AD regularly maintains.

LEARNING OBJECTIVES

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

1. Discuss the operating principles of hydraulic systems.
2. Identify the sources and prevention of contamination.
3. Recognize systems using fuel for hydraulic control.
4. Recognize aircraft power plant electrical systems.
5. Identify the different types of ignition systems.
6. Identify the types and operation of jet engine starters.
7. Recognize the procedures for safe operation of aircraft starting equipment.
8. Discuss the purpose of the bleed-air systems.
9. Recognize the use of the auxiliary power unit (APU).

BASIC HYDRAULICS

Hydraulics is the science of liquid pressure and flow. In its application to aircraft, hydraulics is the action of liquids under pressure used to operate various mechanisms. All modern naval aircraft use hydraulic systems and hydraulic components.

The word *hydraulics* is from the Greek word for water. Hydraulics originally meant the study of physical behavior of water at rest and in motion. Today the meaning includes the physical behavior of all liquids. A liquid is any fluids whose particles have freedom of movement among themselves but remain separate. In aviation, hydraulics usually means the "red fluid" used to operate landing gear and flight control or propeller systems. Hydraulics applies to fuel and oils systems, too, so a knowledgeable AD must be familiar with hydraulic principles.

Pascal's law states that "any force applied to a confined liquid transmits undiminished in all directions." This pressure acts at right angles to the walls of the container and exerts equal forces on equal areas. A 100-pound force will result from 5 pounds per square inch (psi) of pressure exerted against a 20-square-inch area. *Figure 6-1* shows a simple hydraulic mechanism that demonstrates these principles in operation.

A liquid has a definite volume but no definite shape. If you put a liquid into a container, it assumes the shape of that container. Since liquids are almost incompressible, they transmit pressure well. Although the application of large forces will cause a small decrease in the volume, this decrease is negligible. For more detailed information on the principles of hydraulics, study the training manual *Fluid Power*, NAVEDTRA 12964.

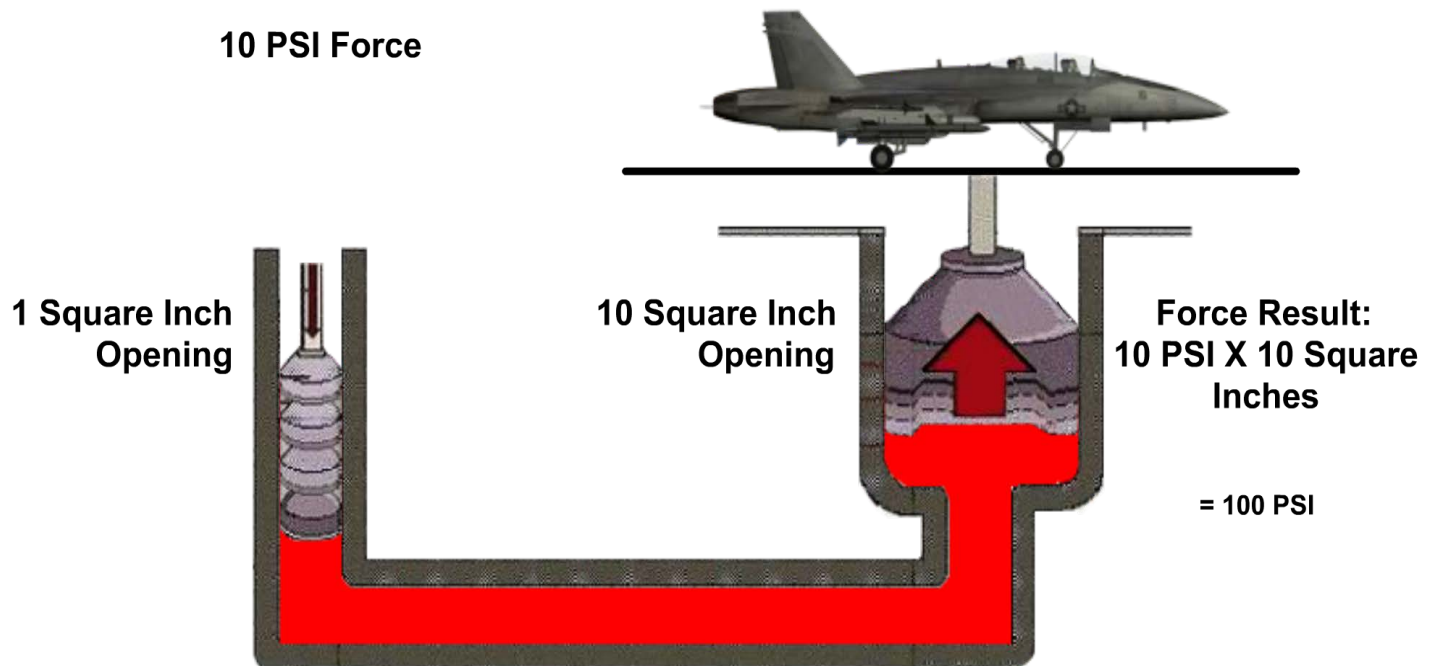


Figure 6-1 — Simple hydraulic mechanism.

Hydraulic Fluids

Petroleum-based liquids are the most widely used fluids in hydraulic systems. Refined hydraulic fluid is clear in color. Red dyes are added to this fluid so that hydraulic system leaks are easier to find and identify. Special petroleum based fluids are used for certain applications. For example, MIL-PRF-83282B is the hydraulic fluid approved for use in, and in the servicing of, navy aircraft hydraulic systems. MIL-PRF-6083C is the approved hydraulic fluid for the preservation, packaging, and use in hydraulic test benches.

Contamination

Experience has shown that trouble in a hydraulic system occurs whenever the hydraulic fluid becomes contaminated. The nature of the trouble—whether a simple malfunction or the complete destruction of a component—depends to some extent on the type of contaminant.

Two general classes of contaminants are abrasives and non-abrasives. Abrasives include core sand, weld splatter, machining chips, and rust. Non-abrasives are contaminants resulting from oil oxidation and the soft particles that are worn or shredded from seals and other organic components. Oil-oxidation products, usually called sludge, have no abrasive properties. Nevertheless, sludge may prevent proper operation of a hydraulic system by clogging the valves, orifices, and filters.

The mechanics of the destructive action by abrasive contaminants is clear. When the size of the particles circulating in the hydraulic system is greater than the clearance between moving parts, the clearance openings act as filters. Hydraulic pressure pushes these particles into the softer materials. This results in blocked passages or scratches on finely finished surfaces from movement between parts. These scratches result in internal component leakage and decreased efficiency.

Abrasive particles contained in the system are not flushed out. New particles are continually created as friction sludge acts as an effective catalyst to speed up oxidation of the fresh fluid. A catalyst is a substance that, when added to another substance, speeds up or slows down chemical reaction. The catalyst itself is not changed or consumed at the end of the reaction.

Origin of Contaminants

The contaminants in hydraulic systems can be traced to four major sources.

1. Particles originally contained in the system. These particles originate during fabrication of welded-system components, especially reservoirs and pipe assemblies. Proper design and cleaning reduce the presence of these particles. For example, parts designed using seam-welded, overlapping joints reduce contamination. Parts designed using arc welding of open sections increase contamination. Parts designed with hidden passages, beyond the reach of sandblasting, are the main source of core sand contamination.
2. Particles introduced from outside forces. Particles enter hydraulic systems at points where the liquid or working parts of the system are in temporary contact with the atmosphere. Struts and piston rods are constantly exposed to the atmosphere. The most common danger areas are at the refill and breather openings and at cylinder rod packings. Contamination results from carelessness during servicing and cleaning. Particles of lint from cleaning rags can cause abrasive damage in hydraulic systems, especially to closely fitted moving parts. Rust or corrosion present in a hydraulic system usually can be traced to improper storage of materials or parts. Proper preservation of stored parts helps to reduce corrosion.
3. Particles created within the system during operation. Contaminants created during system operation are of two general types—mechanical and chemical. Mechanical particles are formed by the wearing of parts in frictional contact, such as pumps, cylinders, and packing gland parts. These worn particles can vary from large chunks of packings to steel shavings of microscopic size, which system screens cannot filter.
4. Particles introduced by foreign liquids. Water is the most common foreign fluid contaminant, especially in petroleum-based hydraulic fluid. Water enters through condensation of atmospheric moisture and normally settles at the bottom of the reservoir. Fluid movement in the reservoir disperses the water into fine droplets. These water droplets form an oil-water-air emulsion because of the mixing action created in the pumps and passages. This emulsion normally separates during the rest period in the system reservoir.

The chief source of chemical contaminants in hydraulic fluids is oxidation. Chemical contamination forms as a result of the high pressure and temperatures acting with the catalytic action of water, air, copper, or iron oxides. Oil oxidation products appear first as organic acids, gums, and varnishes. These products combine with dust particles and appear as sludge. Oxidation products that dissolve in liquid increase a liquid's resistance to flow. Products that do not dissolve in liquid form sediments and precipitates—especially on colder elements such as heat exchanger coils. A precipitate is a solid substance that was chemically separated from a solution.

Liquids containing antioxidants have little tendency to form gums under normal operating conditions. However, as the temperature increases, resistance to oxidation diminishes. Hydraulic fluids that are subjected to high temperatures above 250 degrees Fahrenheit (°F) will break down, leaving particles of asphaltene suspended in the liquid. The red fluid changes to brown, and is referred to as decomposed liquid. This explains the importance of keeping the hydraulic fluid temperature below specified levels. The second chemical reaction that can produce impurities in hydraulic systems allows liquids to react with certain types of rubber. This reaction causes the structure of the rubber to change, turning it brittle, and causing the rubber to fall apart. Make sure that system fluids are compatible with the seals and hoses, and that those parts are appropriate for the system.

Contamination Control

Filters provide adequate control of the contamination problem during all normal hydraulic system operations. Contamination controls from outside sources are the responsibility of maintenance personnel. Therefore, take all precautions to be sure contamination is held to a minimum during

service and maintenance. Do not reuse fluid drained from hydraulic systems or equipment. Do not use hydraulic fluid stored in open containers. Hydraulic fluid absorbs dust and grit from the air, resulting in contamination problems. Keep hydraulic parts and servicing equipment clean. Should the system become contaminated, minimize damage by taking prompt maintenance action.

HYDRAULIC SYSTEM MAINTENANCE

Hydraulic system maintenance consists of inspecting for leaks and contamination, and replacing parts. External leaks, where fluid is escaping from a cylinder, valve, or fitting, are usually easy to find.



WARNING

A pinhole leak in a 3,000-psi hydraulic system can force fluid through your skin. Do not use your hand to feel for a leak.

Inspect the area around the leak; a leak may not be directly above the accumulation of fluid. Fluids often follow the structure or tubing to a lower point before dropping off. When you notice leaks, trace them to the source and then repair or replace the bad unit or part.

Internal leaks are caused by fluid under pressure slipping past an unseated valve or worn packing ring. Normally, fluids flow into the return line back to the reservoir. The signs of internal leakage are sluggish operation of an actuating system or a drop-off in system pressure. A drop in gauge pressure or an indication of insufficient pressure on the gauge may be caused by an internal leak. When internal leakage is suspected or known to be in the hydraulic system, the symptoms should be noted to aid in locating the leak. Follow the aircraft technical instruction for specific troubleshooting and maintenance procedures. For more information on hydraulic maintenance procedures, consult the *Aviation Hydraulics Manual*, NAVAIR 01-1A-17.

Fuel as a Hydraulic Fluid

Fuel, and the means to regulate fuel pressure, is readily available within the aircraft. It is an ideal fluid to use for hydraulic control of systems. Especially those systems controlling certain engine functions, such as compressor guide vane variable geometry actuation, and operation of the afterburner variable nozzles.

Fuel pressure hydraulically operates the inlet guide vanes (IGVs) and the bleed valve ring. The vane control and the bleed-air system prevent compressor surges during low revolutions per minute (rpm) range operation. The system uses engine fuel pressure as control and hydraulic force to vary the angle of the high-pressure compressor variable IGVs. Fuel pressure is used to operate the high-pressure compressor bleed air valve (*Figure 6-2*). This action decreases the airflow through the rear stages of the compressor. Compressor surge and choking caused by increased air velocity is prevented.

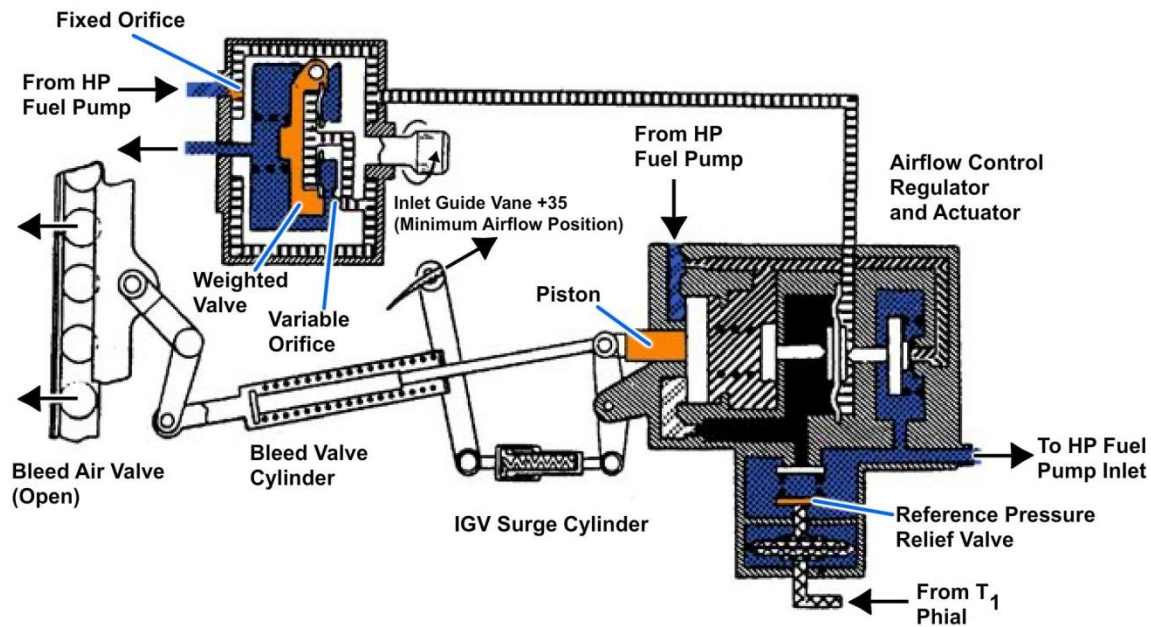


Figure 6-2 — Bleed-air and vane control system.

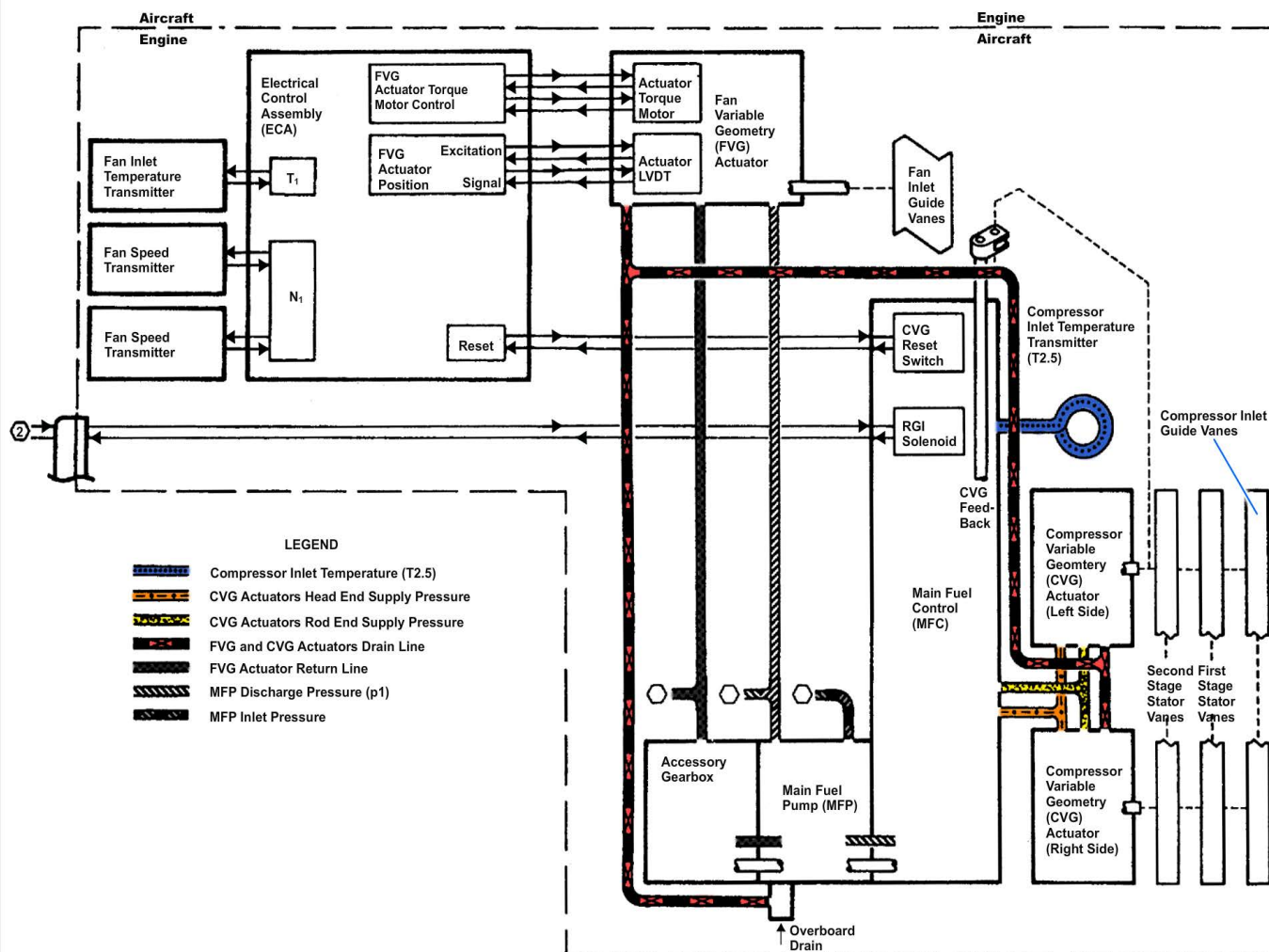


Figure 6-3 — Fan and compressor variable geometry systems.

Variable Inlet Guide Vanes and Stators

The F404-GE-400, installed in the F/A-18 uses air-variable IGVs and variable stators. These systems are the fan variable geometry (FVG) system and the compressor variable geometry (CVG) system. Compressor IGV and stator angle are changed by setting the CVG pilot valve to direct fuel pressure to two CVG actuators. A torque motor in the single FVG actuator sets the CVG pilot valve (*Figure 6-3*).

Variable Exhaust Nozzles

The convergent-divergent geometry of the variable exhaust nozzle provides the optimum exhaust throat area. The action of the variable exhaust nozzle is achieved by close tolerance overlapping seals, which bridge adjacent leaf segments to provide a relatively smooth surface contour. The GE-F404/414 installed in the F-18 Hornet and Super Hornet aircraft uses the hydraulic action of fuel to position the variable exhaust nozzles (*Figure 6-4*).



Interaction Available

Figure 6-4 — Variable exhaust nozzle actuation.

BASIC ELECTRICITY

You should be familiar with the aircraft electrical system in general. You must become familiar with the different engine electrical systems and components that support your type of engine. Some of the electrical systems that ADs maintain include ignition, starting, thermocouple, temperature control, and constant-speed drive (CSD) systems. To understand the operation of these systems, you must understand basic electricity. The following paragraphs cover some of the basic facts and laws that will be helpful in understanding electrical principles.

Electricity is a form of energy. Energy is the ability of a body to do work. It does not occupy space, but it can be measured. There are two forms of electricity—static and dynamic. Static electricity is electricity at rest. It is produced by friction, which causes one body to give up electrons to another. The body that lost the electrons will have a positive charge. The body that gained the electrons will have a negative charge. As a result, the positively charged body will try to gain electrons. The negatively charged body will try to cast off its surplus electrons to an oppositely charged body or a neutrally charged body. Lightning is an example of static electricity during the discharge of electrons. Dynamic electricity is electricity in motion. This is the most useful form of electricity, and it is produced, controlled, and measured with relative ease. It is called electricity in motion because it will flow along a definite path, called a circuit. Static electricity will remain in the body containing it until discharged.

There are three methods of producing electricity. These methods are heat, chemical, and mechanical means. When two dissimilar metals in contact with each other are heated, an electron flow takes place between them. Thermocouples are a good example of this flow. The storage battery is a good example of converting chemical energy into electrical energy. The mechanical means of producing electricity will be of the most interest to you. The generator and magneto are two methods used to mechanically produce electricity.

There are three types of current that these mechanical devices produce. They are direct, pulsating direct and alternating current. Direct current (dc) is current that always flows in the same direction. Pulsating direct current (dc) is direct current that is interrupted by a set of breaker points. The current will flow in one direction when the circuit closes. When the circuit is open, the current cannot flow and its value, or voltage, drops to zero until the circuit closes again.

Alternating current (ac) is current that changes direction in the circuit, flowing first in one direction and then in the other. A cycle is two complete alternations within a period of time. The hertz (Hz) indicates one cycle per second. For example, one cycle per second is 1 hertz. The standard unit of electricity used in the United States is 60 Hz ac.

The electromotive force is the force that causes electrons to flow from atom to atom in a conductor. Electrons flow from atoms with an excess of electrons to atoms with less electrons. The practical electrical units are the volt, the ampere, and the ohm. The volt is the unit of electromotive force necessary to cause electrons to flow in a circuit. The ampere is the rate of flow of these electrons in a conductor. The ohm is called the unit of electrical resistance. This resistance varies according to the kind of material used as a conductor, the length of the conductor, and the cross-sectional area of the conductor. Resistance also varies with temperature. Other factors being equal, the resistance increases if the length of the conductor is increased, and decreases if the cross-sectional area of the conductor is increased. Resistance increases as the temperature increases.

Ignition, Starting, Bleed Air, and Auxiliary Power Unit Systems

As an AD, your primary responsibility is to maintain power plants and related systems. You should know that engine systems support the entire aircraft. Engine systems support more than just the engine. This means that the maintenance of these systems is the responsibility of more than one work center. Electrical or pneumatic systems that other work centers help maintain include ignition, starting, bleed-air, and auxiliary power units (APU).

Aircraft Ignition Systems

Jet engine ignition systems are simple compared to automobile ignition system. They are simple because jet engine ignition systems require no ignition timing. Since jet engine combustion is a self-sustaining process, a spark is needed only during the start cycle. After combustion starts, the ignition system may be turned off. However, some aircraft use continuously operating ignition systems to

ensure an immediate relight in case of flameout. Pressure switches or mechanical linkages that automatically reactivate the ignition system are also used in some aircraft for the same reason.

The ignition systems on all jet engines are basically the same, but terminology varies between engine manufacturers. The part that goes in the combustion chamber to supply spark is called a spark plug, an igniter plug, or a spark igniter. They may look a little different and maybe called by different names, but they all do basically the same job. Modern jet engines require an ignition system with a high voltage and high heat spark.

The high-energy, capacitor-discharge ignition system is the most widely used ignition system. It provides a high-tension spark capable of blasting carbon deposits and vaporizing large amounts of fuel. This high-energy system makes starts with carbon-fouled igniter plugs possible, and it also helps in air restarts at high altitude. Classified as ac or dc systems and they use either a high- or low-voltage capacitor.

High-Energy, Capacitor-Discharge DC Ignition System

The ignition exciter gets its input from the low voltage dc supply of the aircraft electrical system (*Figure 6-5*). The ignition system has three major components. The system consists of one ignition exciter and two lead assemblies. The exciter unit is hermetically sealed to protect internal components from moisture, foreign matter, pressure changes, and adverse operating conditions. This type of construction eliminates the possibility of flashover at high altitude due to pressure change and ensures positive radio noise shielding. The complete system, including leads and connectors, is built to ensure adequate shielding against leakage of high-frequency voltage. High-frequency leakage would interfere with radio reception of the aircraft. The system's primary purpose is to supply energy to spark the high-energy, capacitor-discharge system and igniters.



Figure 6-5 — Typical sealed ignition exciter box.

Figure 6-6 is a functional schematic of the system. You should refer to this figure when studying the theory of operation of a capacitor discharge system. This schematic shows a cam operated breaker point. Most modern systems have had all mechanical parts replaced with electronic solid-state devices. System operation is discussed in the following paragraphs.

A 24-volt dc input voltage is sent to the input receptacle of the exciter. The voltage first goes through a noise filter. This filter blocks conducted noise voltage from feeding back into the aircraft electrical system. This input voltage operates a dc motor, which drives one 16-lobe and one 1-lobe cam. The input voltage is also sent to two breakers actuated by the 16-lobe cam.

From the breakers, a rapidly interrupted current is sent to the autotransformer. When the breaker closes, the flow of current through the primary winding of the transformer generates a magnetic field. When the breaker opens, the flow of current will stop. The collapse of the field induces a voltage in the secondary windings. This voltage causes a pulse of current to flow into the storage capacitor through a rectifier. This rectifier limits the flow to a single direction. With repeated pulses, the storage capacitor thus assumes a charge, up to a maximum of approximately 4 joules (J). One joule per second (J/sec) equals 1 watt of power.

The storage capacitor connects to the spark igniter through the triggering transformer and through a normally open contactor. When the charge on the capacitor has built up, the contactor closes by the

mechanical action of the single-lobe cam. A portion of the charge flows through the primary of the triggering transformer and the capacitor connected in series with it. This current induces a high voltage in the secondary, which ionizes the gap at the spark igniter. Thus, when the spark igniter conducts, the storage capacitor discharges the remainder of its accumulated energy through it. Energy also comes from the charge from the capacitor that is in series with the primary of the triggering transformer.

The spark rate at the spark igniter varies in proportion to the voltage of the dc power supply. This varying voltage affects the rpm of the motor. Since both cams are geared to the same shaft, the storage capacitor always accumulates its store of energy from the same number of pulses before discharge.

The use of the high-frequency triggering transformer, with a low-reactance secondary winding, holds the discharge time duration to a minimum. This concentration of maximum energy in minimum time achieves an ideal spark for ignition. This spark is capable of blasting carbon deposits and vaporizing globules of fuel.

The capacitor, constructed integrally with the exciter unit, is sealed separately in its own case. All high voltage in the triggering circuits is isolated from the primary circuits. The complete exciter is sealed against the escape or entry of air. This type of construction protects all parts from adverse operating conditions and eliminates flashover at altitude. This design also shields against leakage of high-frequency voltage that could interfere with radio reception in the aircraft.

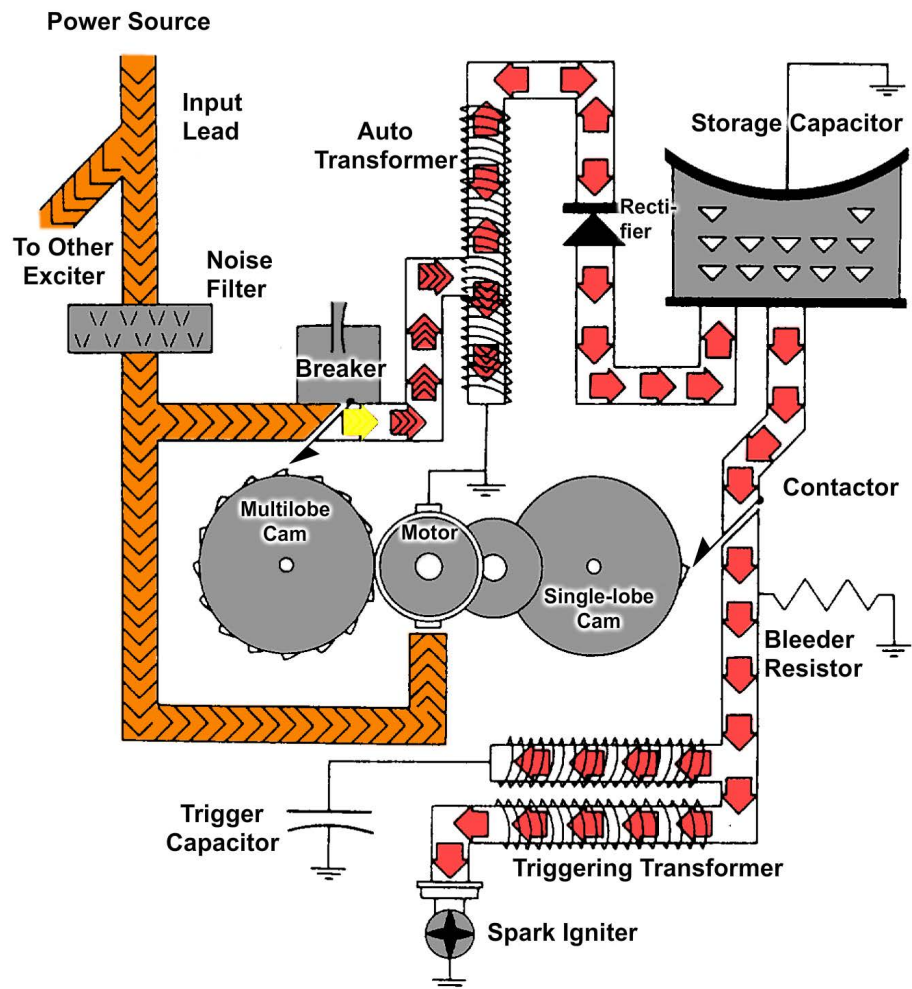


Figure 6-6 — Functional schematic diagram of a capacitor-discharge-ignition system.

High-Energy, Capacitor-Discharge AC Ignition System

The ignition system is an automatic, intermittent duty, at-powered, electronic capacitor discharge system (Figure 6-7). It is used for initiating engine combustion during aircraft armament firing, during starting, and for automatic re-ignition in case of engine flameout. The ac ignition system consists of an ignition exciter, a control amplifier, leads, ignition plugs, and an alternator stator.

Engine Ignition Exciter

The exciter is a dual-circuit and dual-output unit that supplies a high-voltage, high-energy electrical current for ignition. The exciter consists of a radio frequency interference filter. The exciter also contains power, rectifier, storage, and output elements. The exciter is on the forward part of the compressor section of the engine.

Engine Control Amplifier

The amplifier is the electronic control center of the engine. It controls the function of the ignition system as well as other engine functions. The amplifier is mounted on the accessory section under the compressor area aft of the engine front frame.

Engine Ignition Leads and Igniter Plugs

The ignition leads are high-tension cables that transmit electrical current from the exciter to the igniter plugs. The igniter plugs are located in the combustion chamber housing.

Engine Alternator Stator

The alternator is an engine-driven, single-phase, ac electrical-output unit on the engine accessory gearbox. It supplies the engine with electrical power independent of the aircraft electrical system. It contains three sets of windings. Two windings supply electrical power to the ignition exciter, and the third winding supplies electrical power to the control amplifier.

Ignition Operation

The operation of an ignition system is explained in the following paragraphs refer to figure 6-7.

Starting procedures call for the ignition switch ON, the engine cranking for starting, and the throttle advanced to the 10-degree power lever angle (PLA) position. At that time, current flows from the alternator stator to power the control amplifier. Simultaneously, the PLA ignition switch in the fuel control closes. The gas generator speed (N_g) logic circuit will close the ignition relay to provide

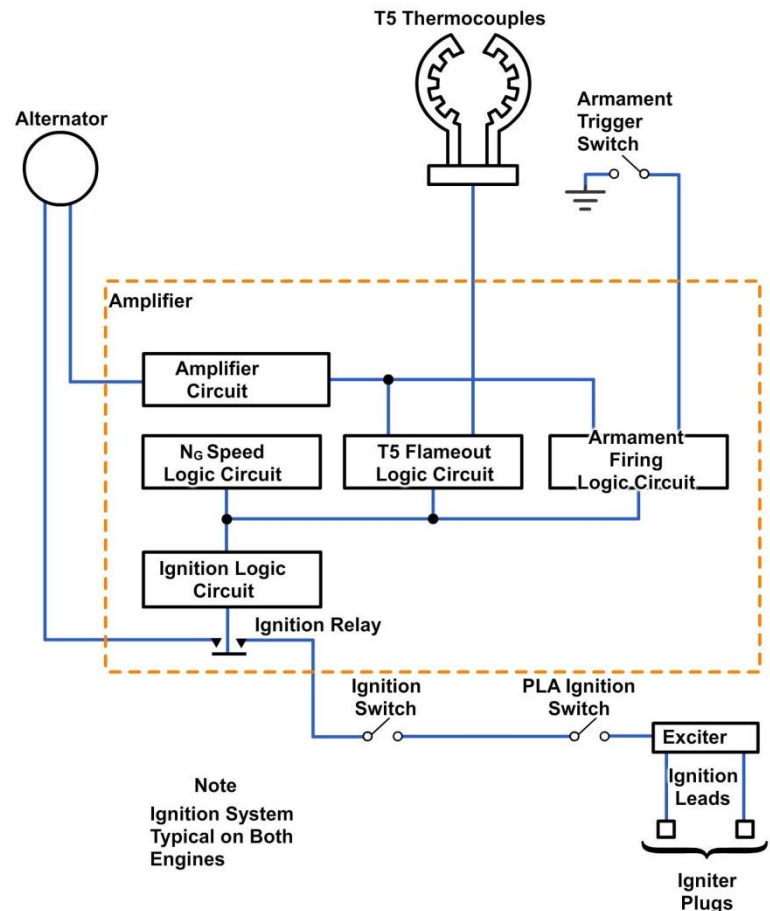


Figure 6-7 — Jet engine electronic ignition system.

ignition whenever the Ng is within the 10 to 48 percent Ng range. With the relay closed, a circuit is completed from the alternator stator ignition windings, through the ignition exciter, to the igniter plugs. Current flows from the alternator, through the control amplifier, to the ignition exciter. At the ignition exciter, current increases and discharges as a high-voltage output, this is conducted through the igniter cables to the igniters. Current crossing the gaps in the igniters produces a continuous high-intensity spark to ignite the fuel mixture in the combustion chamber. When engine speed reaches 8,500 rpm Ng and inter turbine temperature (ITT) reaches operating range, a Temperature (T1) signal is generated. This signal goes from the T1 temperature detectors through the T1 circuit, and to the control amplifier ignition logic circuit. The control amplifier ignition relay opens and ignition stops. Combustion then continues as a self-sustaining process.

Ignition is automatically reactivated when either a flameout occurs or when aircraft armament is fired. When T1 temperature drops in excess of 800 °F (427 °C) from T1 selected by PLA, a signal transmitted from the T1 detectors causes the control amplifier T1 flameout logic to close the amplifier ignition relay. This activates ignition system operation. Ignition continues until engine operating temperature is again attained and the 800 °F temperature error signal is canceled. This action causes the control amplifier to end ignition operation.

An armament-firing protection circuit prevents flameout from armament gas ingested by the engine. When the aircraft armament is fired, the armament-firing logic circuit is activated by a signal from the armament trigger switch. The amplifier logic then causes ignition operation to be activated. Ignition operation ends after a 1-second time delay in the amplifier logic following release of the armament firing trigger.

Ignition System Maintenance

The only maintenance performed at the organizational level is cleaning and replacement of ignition parts. Ignition parts are sealed units and must be replaced as complete assemblies.

Degrease spark igniters and clean the outer shell with a wire brush. If deposits exist on the ceramic tip and on the center and ground electrodes, remove them by light abrasive blasting. However, this abrasive blast should not be used on the ceramic barrel surface. Clean the ceramic barrel of the igniter with a soft swab and a suitable solvent. Dry the igniter with compressed air. Visually inspect the barrel and shell threads. If necessary, clean the barrel and shell threads with a die. Visually inspect the exposed ceramic section. Any cracks are cause for rejection.

The functional testing of the capacitor discharge ignition system is a simple operation.

Perform a dry run of the engine (operate the ignition system). Listen at the tailpipe. You can determine if the unit is working by listening for the spark. Another way is to remove the spark igniters, leave them hanging on the high-tension leads, and operate the ignition system. The spark can be seen at the plug if the unit is working. The spark should be brilliant and accompanied by a sharp report.

Safety Precautions

1. Ignition must be off for at least 5 minutes before working on the system.
2. Avoid contact with an energized ignition system.
3. Short igniters to ground with an insulated tool.
4. Make sure no volatile vapors are present before energizing spark igniters during testing and checking.
5. Apply a ground to exciter to dissipate energy stored in capacitors.



WARNING



You should pay particular attention while performing this test. Do not come into contact with the igniter plugs or leads while the power is on in the ignition system. Some systems have voltages up to 28,000 volts or more. These high voltages could cause serious injury or death. Prevent fuel or fuel fumes from gathering under the engine while the igniter plugs are being ground tested.

Starting Systems

Starting a jet engine requires rotating the compressor fast enough to begin the engine combustion cycle. Starting systems must be capable of providing both high starting torque and high speed. High starting torque is required to overcome the large amount of weight of the engine rotor. High speed is required to increase rotor rpm until the rotor is self-sustaining. There are several ways to accomplish these objectives. The following paragraphs describe four methods. They are the air turbine starter, the electrical starter, hydraulic starter or, bleed air engine to engine start (dual engine).

Air Turbine Starter

The air turbine starter is a lightweight unit for starting engines with compressed air. The starter is a turbine air motor equipped with a radial inward-flow turbine wheel assembly, reduction gearing, splined output shaft, and a quick detaching coupling assembly (*Figure 6-8*).

Compressed air, supplied to the scroll inlet, is sent to the turbine wheel by the nozzle in the scroll assembly. The reduction gear system transforms the high speed and low torque of the turbine wheel to low speed and high torque at the output shaft. An over-speed switch mechanism is used to limit maximum rotational speed. When the desired starter rotational speed is reached, the fly weights in the governor assembly will open the limit switch. This section sends a signal that shuts off the supply of air. At a higher, predetermined rotational speed, the overrunning clutch assembly disengages the output shaft from the rotating assembly.



Figure 6-8 — Air turbine starting system.

Electrical Starters

Electrical starters are 28-volt dc series wound motors, designed to provide high starting torque. Their use is limited to small engines because of the high current drain on the electrical source and their heavy weight. Electrical starters develop a lot of heat while cranking. Starter damage from heat is prevented by observing maximum cranking time and time intervals between start attempts.

Hydraulic Starters

Hydraulic starters, like electrical starters, are energy-limited starting systems. Energy-limited starting systems are designed to start the engine in a short time period, and are limited to small engines. They make ideal starters for APUs.

Components include a high-pressure accumulator and a variable displacement motor. The variable displacement motor permits high torque to be applied without exceeding cutoff speed limits. A small electric motor or hand pump charges the accumulator. The accumulator then supplies power to the starter.

Bleed-Air Systems (Engine)

It is important to understand what is meant by bleed air and where bleed air comes from. Bleed air is tapped off of pressurized air from the engine compressor section. On some engine configurations, the air is bled from more than one area of the compressor. This design gives a source for high- and low-pressure air to suit whatever requirements a particular system may have. Other engines have only one source of bleed air available from each engine. That source is often tapped from the last stage of compression on each engine. The engine has a number of different uses for the air pressure it generates while operating. Besides thrust, bleed air can be used for engine starting, seal pressurization, and anti-icing.

Cross-bleed Air Engine Starting System

Most aircraft in the fleet using two or more engines employ a cross-bleed starting system (*Figure 6-9*). This system provides regulated air pressure from one engine to start the remaining engine(s). The first engine must be started by an external source of air pressure. External sources may be auxiliary power units or ground support equipment. Subsequent engines can then be started using bleed air

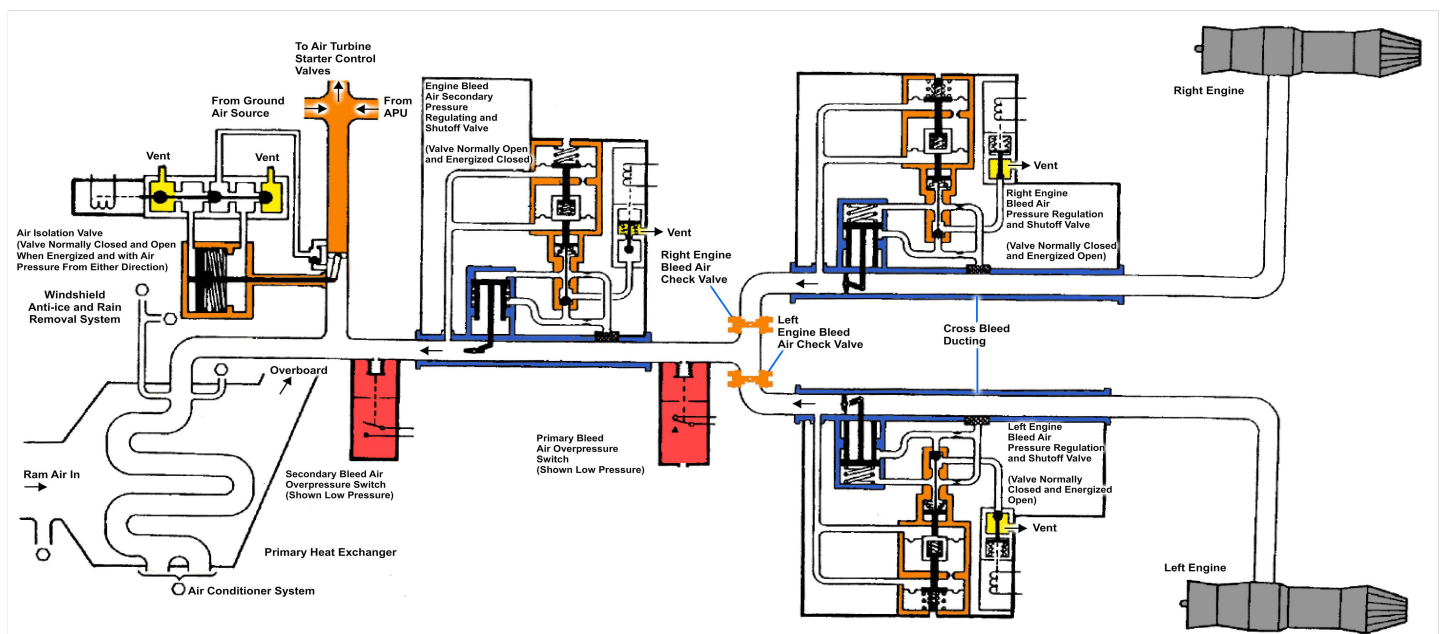


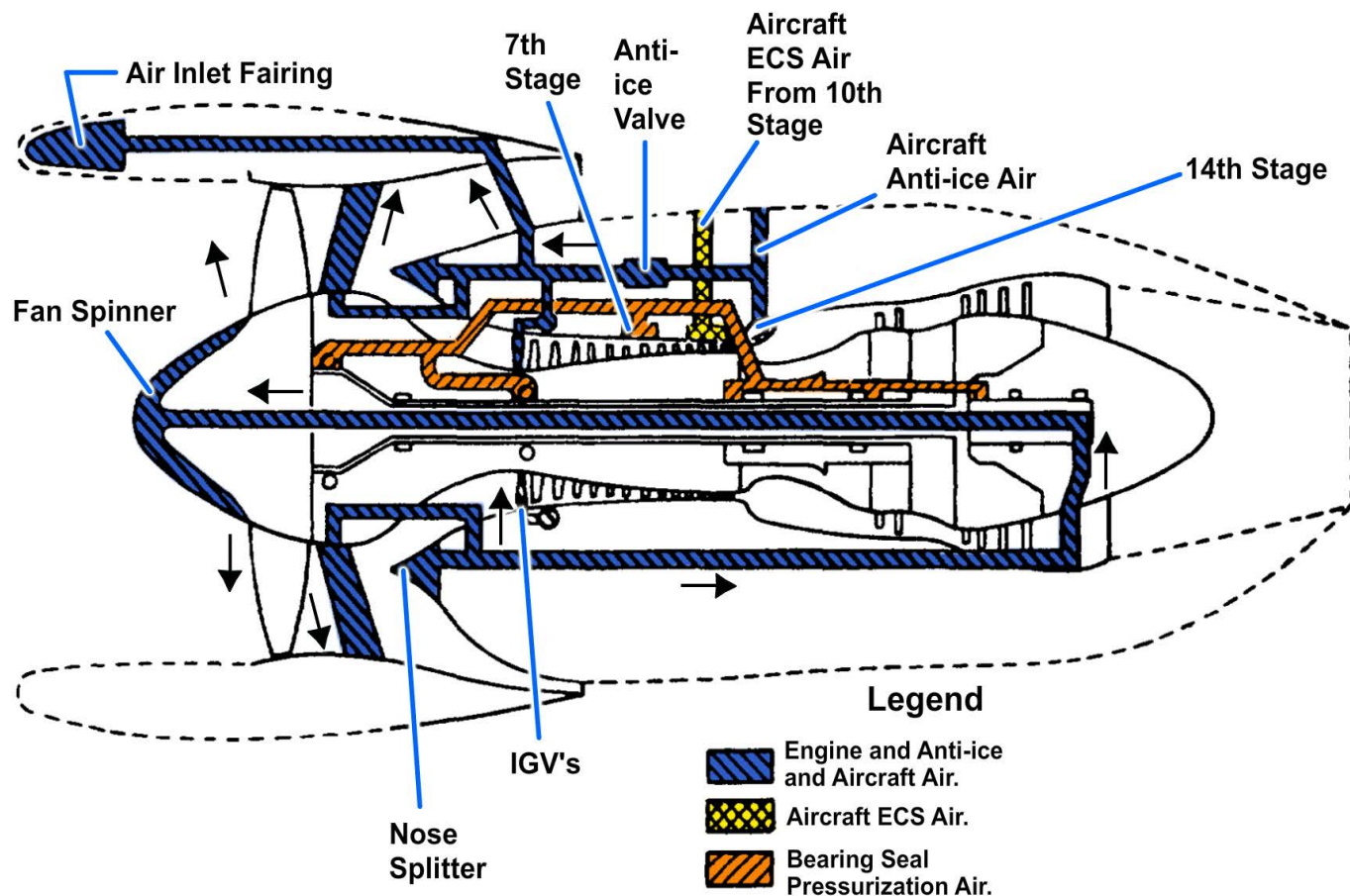
Figure 6-9 — Bleed air systems.

from the running engine. Opening the cross-bleed air valves allows regulated bleed air from the running engine to supply air to the other engines' starters.

Compressor bleed-air valves reduce the load on the compressor, making it easier for the starter to turn the compressor. During starts, air is bled from the compressor through ports on the compressor housing. The bleed valves are held open by compressor air pressure until the engine starts. After starting, the speed-sensitive valve directs compressor discharged air to close the bleed valves.

Oil and Seal Pressurization System

Primary air pressure, bled from the compressor, controls oil leakage on non-rubbing labyrinth or clearance-type bearing seals. These bearings use the differential in sump pressures to keep oil loss to a minimum. The sump scavenge pump capacity is greater than that of the oil system pressure pump. Not only does the sump scavenge pump scavenge all the oil in the sump area; it also scavenges air in the sump, creating a lower air pressure than that of the area surrounding the bearing sump. This action allows the compressor bleed air external from the sump to flow from outside the sump area across the bearing seal, preventing oil leakage in the opposite direction. The airflow also helps cool the bearings (*Figure 6-10*).



Interaction Available

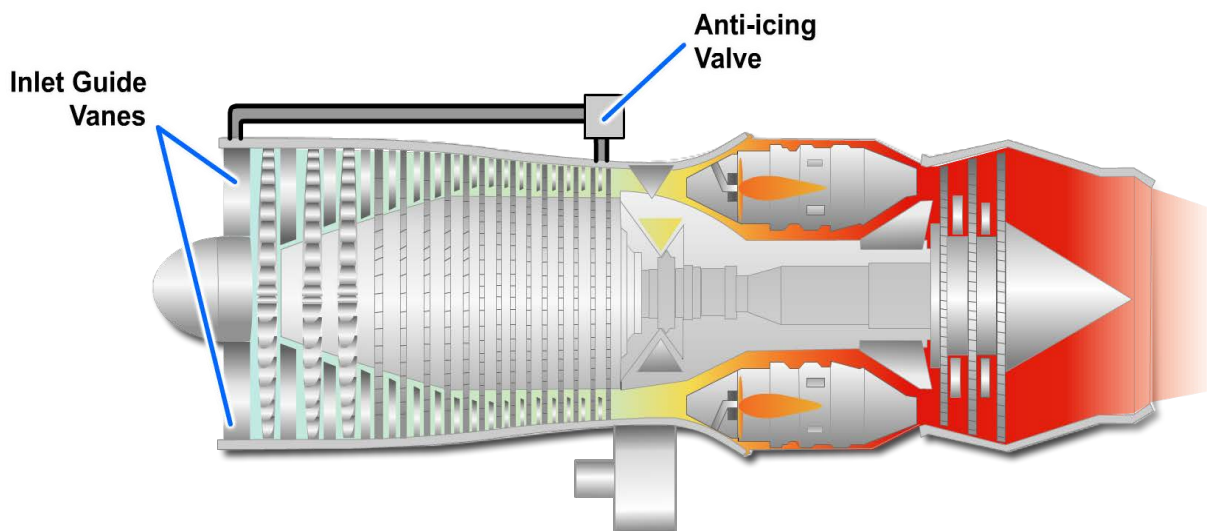
Figure 6-10 — Engine bleed-air distribution.

Anti-icing System

The guide vanes of a turbine-powered engine are used to direct the flow of inlet air into the compressor section. The air is coldest at this point and is subject to icing. The biggest problem resulting from ice forming at this point is the blockage of inlet air, which causes air starvation, and thus engine failure. Another problem is the possibility of inducing chunks of ice into the engine. Engine anti-icing systems prevent these problems if turned on prior to entering an icing condition.

Icing will not normally occur in supersonic flight because heat caused by the friction of the aircraft passing through the air is sufficient to prevent ice from forming.

Many types of anti-icing systems are in use today. All systems use bleed air from the engine to perform the anti-icing function. The use of bleed air causes engine power loss. Anti-icing will be used only when absolutely necessary. Some aircraft use a reversible electric motor to open and close an air valve to supply the needed air. Other aircraft use an electrical solenoid to control a pneumatic anti-icing valve (*Figure 6-11*).



Interaction Available

Figure 6-11 — Inlet guide vane anti-icing system.

When the aircraft routinely flies in adverse weather conditions, a fail-safe system may be used in the system. The solenoid-actuated air valve is electrically actuated closed. If the switch is turned on, or if electrical power is lost, the valve is spring-loaded to the open position. Some systems use anti-ice for the complete inlet duct, while in other systems only the guide vanes are anti-iced.

Bleed-Air Systems (Aircraft)

There are a several aircraft systems that rely on engine bleed air to operate (*Figure 6-12*). These systems include air-conditioning and pressurization, electronic equipment cooling, windshield washing, anti-icing, and anti-g systems. The bleed-air system also pressurizes fuel tanks, hydraulic reservoirs, and radar waveguides on several types of aircraft.

In addition to supplying aircraft systems with bleed air, some aircraft manufacturers use it to provide extra lift to the wings. Design engineers devised a system to duct engine bleed air across the leading edge of the wing to increase the lift, generating airflow. This system decreases the aircraft stall speed and increases its slow flight capability, which is desirable during aircraft carrier landings.

Aircraft Deicing and Anti-icing Systems

On foggy days (visible moisture in the air), ice can form on aircraft leading edge surfaces at altitudes where freezing temperatures start. Water droplets in the air can be super cooled to below freezing temperature without actually turning into ice. Ice forms when these droplets are disturbed in some manner. This unusual occurrence is partly due to the surface tension of the water droplet not allowing it to expand and freeze. However, when the aircraft surfaces disturb these droplets, they immediately turn to ice on the aircraft surfaces. The ice may have a glazed or rime appearance. The glazed ice is smooth and hard to detect visually. The rime ice is rough and easily noticeable. Frost forms as a result of water vapor being turned directly into a solid. It can form on aircraft surfaces in two ways. It

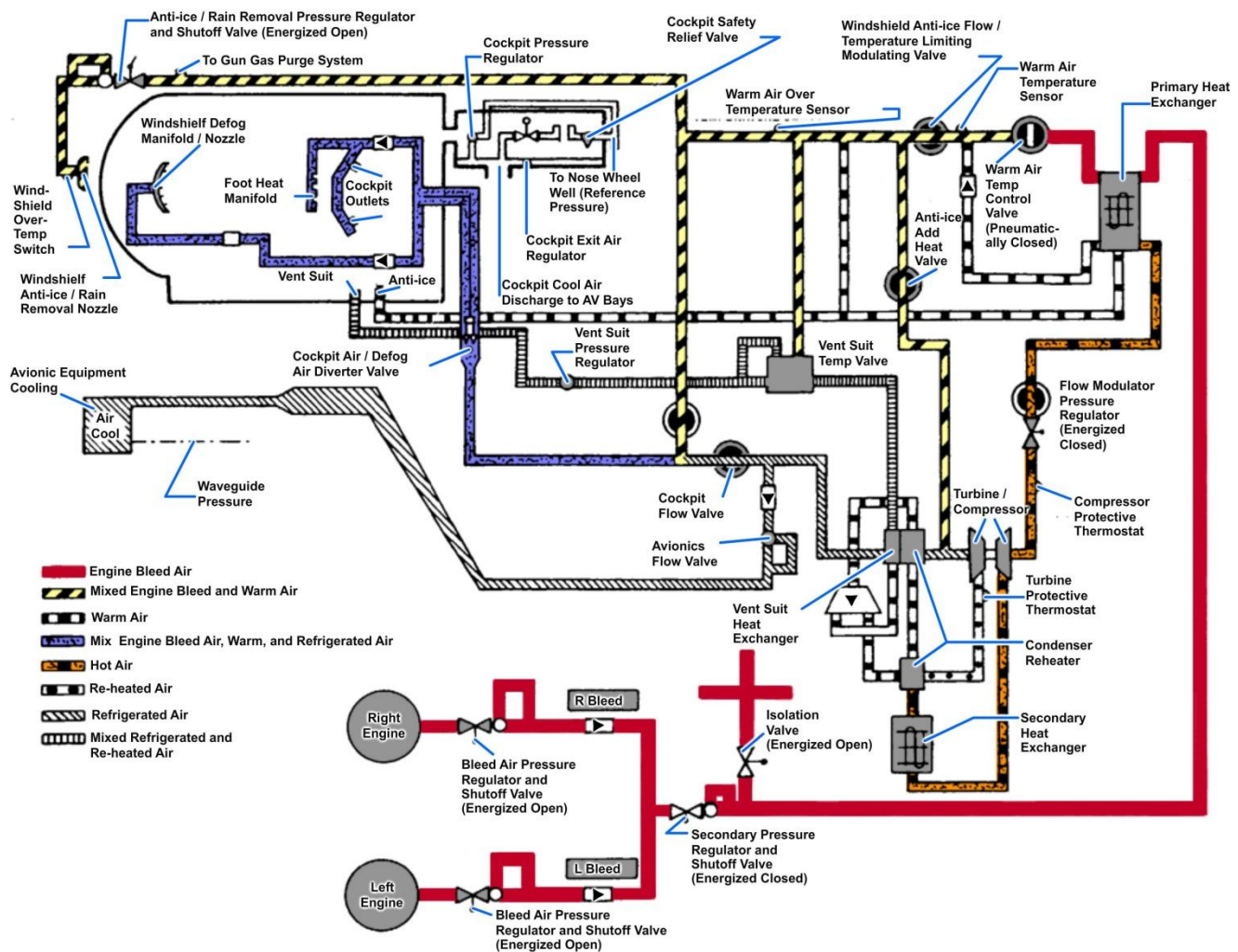


Figure 6-12 — Environmental control systems.

can collect on aircraft parked outside overnight when the temperature drops below freezing and the proper humidity conditions exist. It can form on aircraft surfaces when the aircraft descends rapidly into warm, moist air after flying at higher cold altitudes. In this case, frost forms because of the cold air coming off the aircraft structure as it warms up.

The shape of the wing may be changed drastically because of the formation of ice or frost. Control of the aircraft may become difficult as the lift characteristics of the wing change. Uneven distribution of ice generates an unbalanced aircraft condition. Enough ice to cause an unsafe condition can form in a very short period of time. Thus, some method of ice removal or prevention is necessary.

Presently, there are two methods for eliminating or preventing ice. One method, deicing, employs a mechanical system to break up and remove the ice after it has formed. The second method, anti-icing, uses

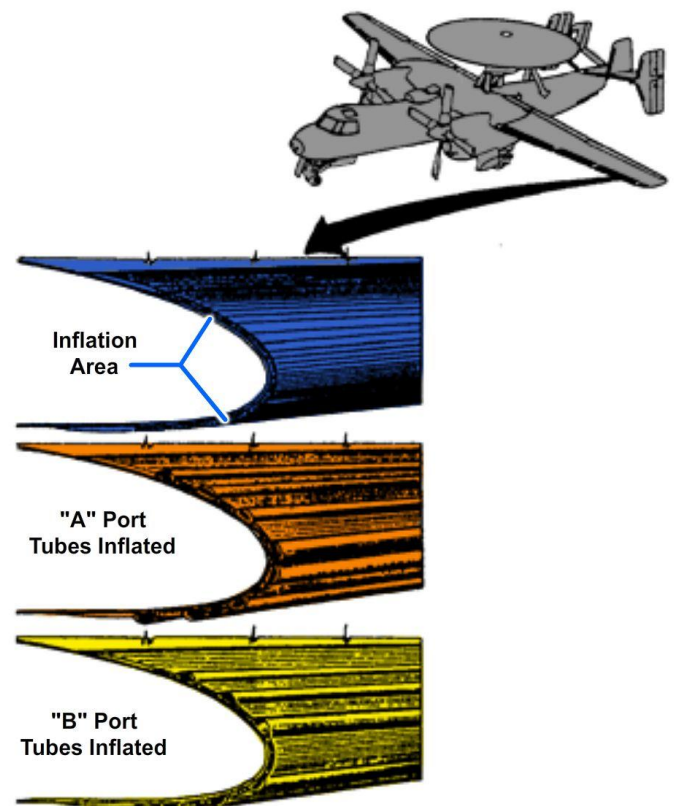


Figure 6-13 — Deicer boot.

heated bleed air to prevent the formation of ice. The deicing systems are common to older aircraft. The anti-icing systems are common to newer aircraft. Both systems use bleed air to accomplish their function.

As shown in *Figures 6-13 and 6-14*, the deicing system uses bleed air to inflate the rubber boots along the leading edge of the wing. The cells or tubes of the deicer boots are inflated and deflated alternately by pressure and suction causing a wavelike motion, which cracks the formed ice and allows it to be carried away by the airstream. The system is pneumatically operated, electrically controlled, and regulated by a pressure regulator and relief valve. Suction and pressure gauges provide a means of monitoring the system operation.

The anti-ice system shown in *Figure 6-15* is a combination of both deice and anti-ice systems, and is called an ice protection system. Using bleed air, temperature sensors, thermostatic switches, and various types of valves, ice protection requirements are met.

Aircraft Fuel Systems

The pressurization and vent system provides regulated bleed air pressure to all fuel tanks. This prevents fuel boil-off at high altitude and provides a means to transfer fuel between tanks. This system also provides pressure relief of the fuel tanks during ascent and vacuum relief of the tanks during descent if the pressurization system fails.

Internal tanks are pressurized anytime the engine is running, provided that electrical power is on, the refueling probe is retracted, the tail hook is up, and weight is off the wheels.

Fuel transfer from external tanks to the main aircraft tanks using bleed air is also available, if the above conditions are met. During emergencies, troubleshooting, or checking fuel transfer after installing external tanks, an OVERRIDE switch is installed that defeats all conditions except that the tail-hook must be up.

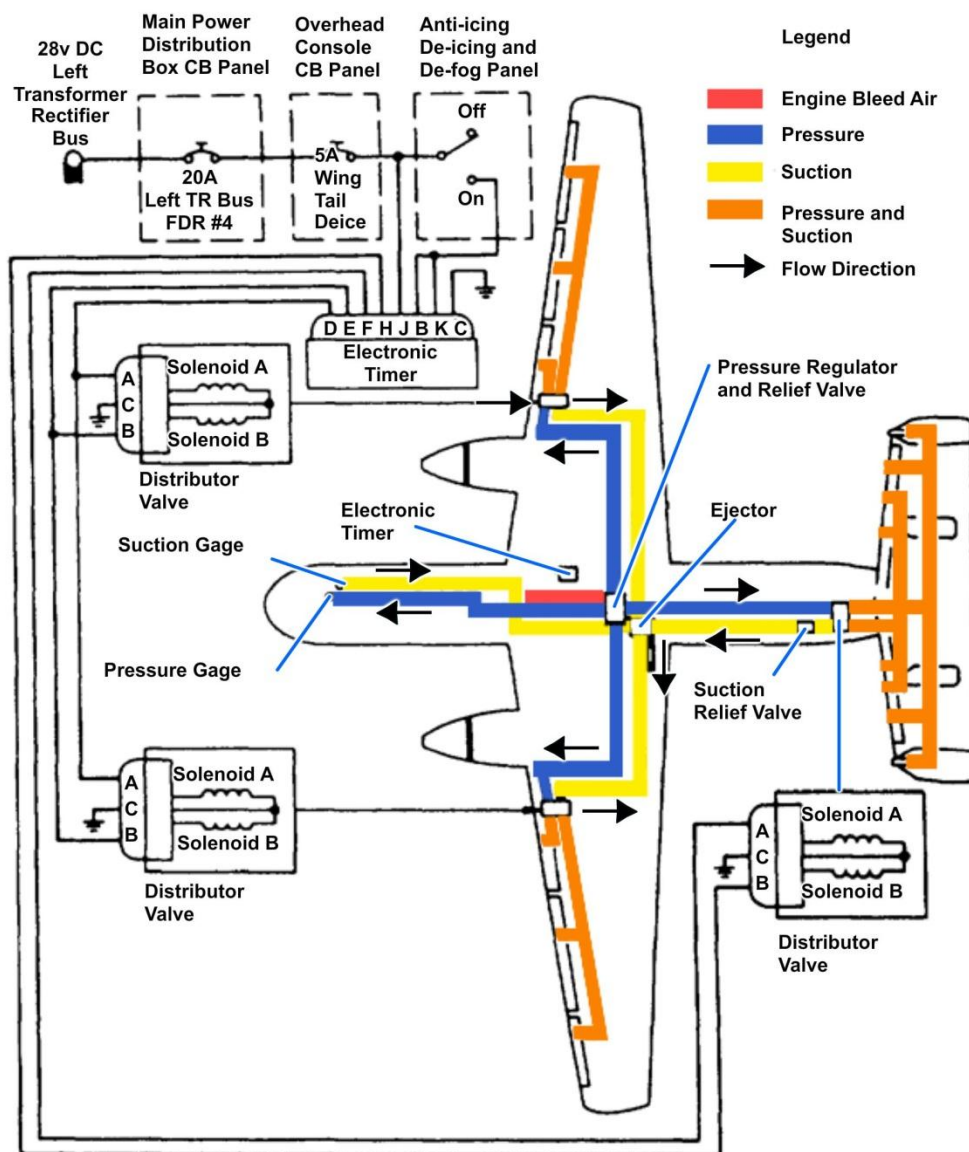
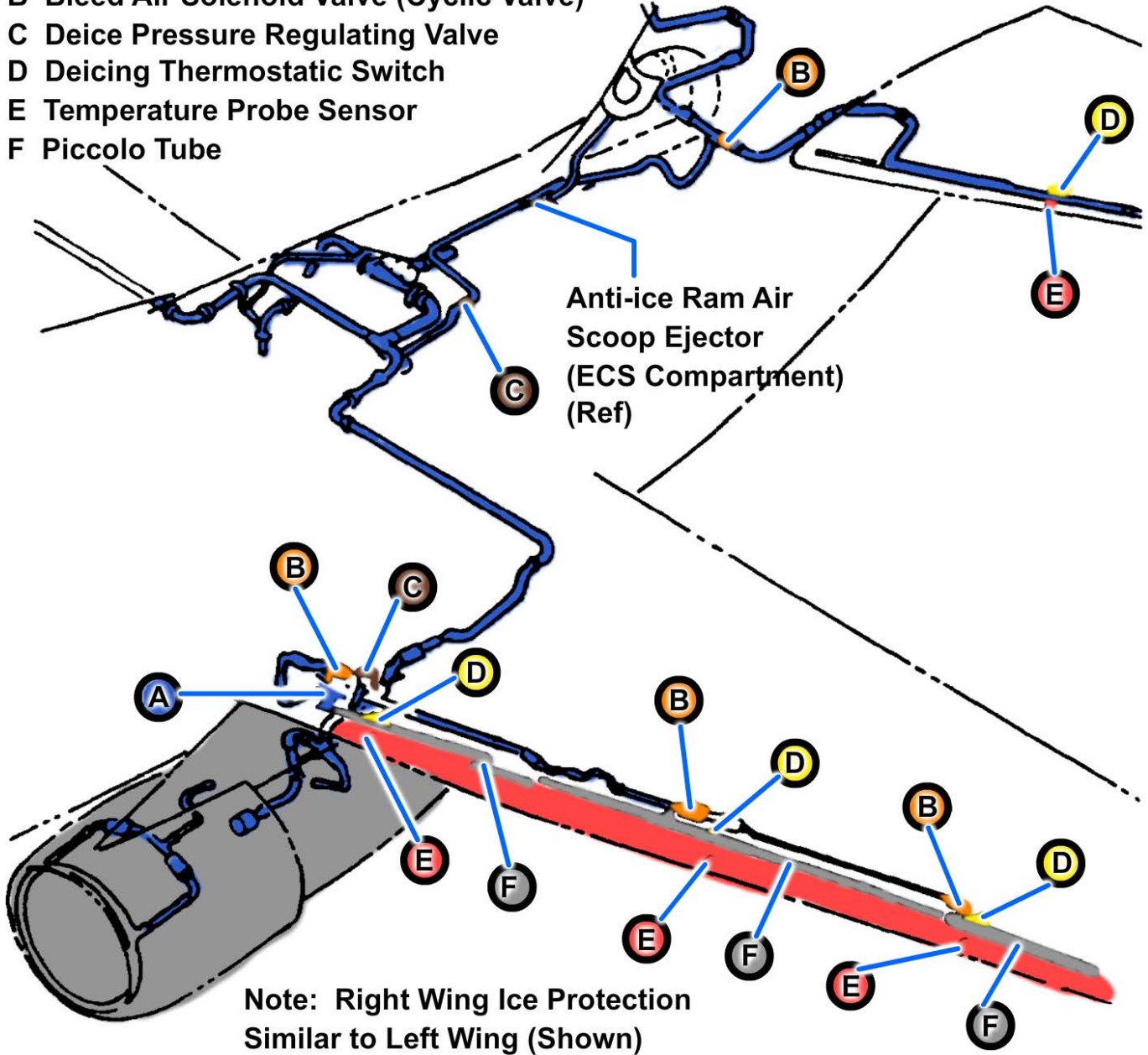


Figure 6-14 — Deicing system.

- A Deicing Temperature Control Regulator Valve
- B Bleed Air Solenoid Valve (Cyclic Valve)
- C Deice Pressure Regulating Valve
- D Deicing Thermostatic Switch
- E Temperature Probe Sensor
- F Piccolo Tube



Interaction Available

Figure 6-15 — Ice protection system.

Auxiliary Power Units (APU's)

Several types of aircraft now in the fleet have an onboard APU. APUs are small, self-contained jet engines that are started either electrically through onboard batteries or hydraulically through a hydraulic starter motor (*Figure 6-16*).

In the past, APUs were too large and too heavy for practical use in tactical combat aircraft. Their use was limited to the larger land-based aircraft with missions such as patrol, cargo, transport, or special projects. Advancements in technological design and metallurgy have produced small, lightweight, yet efficient APUs. These advancements have enabled newer carrier-borne aircraft, such as the SH-60

and the tactical F/A-18, to operate aboard ship without the requirement for flight deck support equipment. This places less demand on the flight deck crews, and makes the flight deck a somewhat safer working environment.

The use of an APU makes the modern jet aircraft completely self-sufficient. Aircraft having air turbine starters can use compressed air from the APU to start engines. They also supply electrical and hydraulic power, as well as air conditioning during ground maintenance. The aircraft is independent of the need of ground power units to carry out its mission. There are many types and configurations of gas-turbine units.

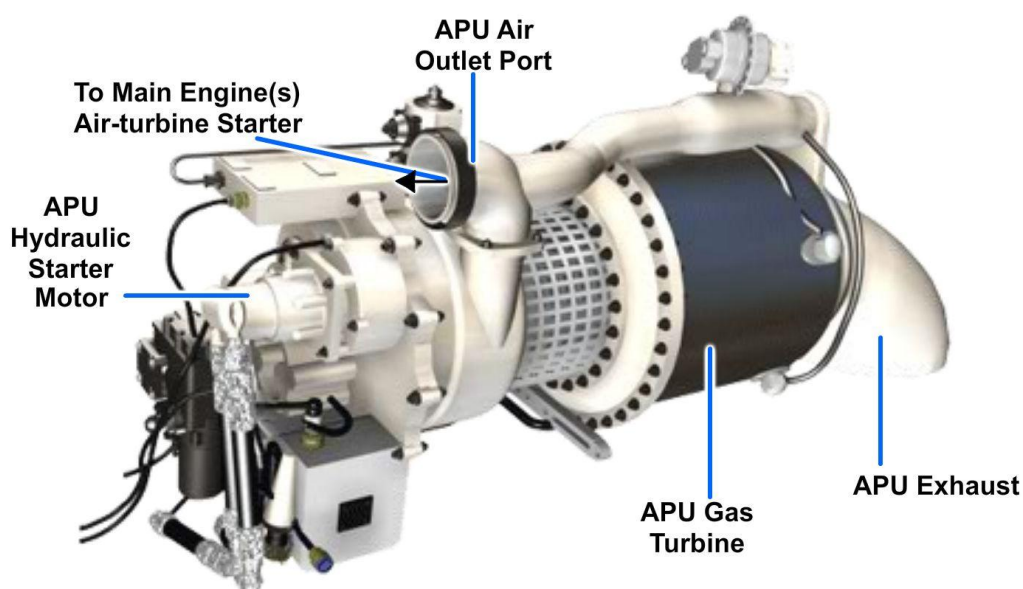


Figure 6-16 — Typical onboard auxiliary power unit (APU).

Maintenance performed on APUs can be almost as extensive as that performed on aircraft main engines. The major difference, other than the size, is that most APUs use centrifugal flow compressors instead of axial flow. The nomenclature of many of the components may be the same. However, the component itself may not look or operate in the same manner because of the basic function of the unit.

Authorized repairs for organizational activities include minor component replacements and adjustments. Common repairs include inlet/exhaust door actuator maintenance, bleed-air shutoff valve maintenance, and generator replacement. Maintenance on the ignition system, generator, oil tank, oil pressure switch, oil cooler, and scavenge oil filter, or major inspections may require APU removal because of the APU location. Major APU inspections and repairs are performed by the supporting Fleet Readiness Center (FRC) shore-based or Aircraft Intermediate Maintenance Department (AIMD) sea-based under the Auxiliary Power Unit and Support Equipment Gas Turbine Engine Management Program.

End of Chapter 6

Engine and Aircraft Related Systems

Review Questions

- 6-1. What is the science of hydraulics?
- A. Air speed pressure and flow
 - B. Liquid pressure and flow
 - C. Lubrication pressure and flow
 - D. Water pressure and flow
- 6-2. What is the MILSPEC designation for hydraulic fluid?
- A. MIL-L-23699
 - B. MIL-PRF-23699
 - C. MIL-H-83282
 - D. MIL-PRF-83282
- 6-3. How many major sources of hydraulic contamination are possible?
- A. One
 - B. Two
 - C. Three
 - D. Four
- 6-4. What design type is a Variable-Area Exhaust Nozzle?
- A. Convergent-divergent design
 - B. Convergent-single design
 - C. Dual-single design
 - D. Dual-divergent design
- 6-5. Electricity is a form of what?
- A. Energy
 - B. Lift
 - C. Power
 - D. Resistance
- 6-6. What is alternating current?
- A. Current that pulsates
 - B. Current that changes direction
 - C. Current that stays in one direction
 - D. Current that is static

- 6-7. What are the two forms of electricity?
- A. Alternating and direct
 - B. Direct and static
 - C. Static and tempo
 - D. Static and dynamic
- 6-8. What type of aircraft ignition system is most widely used?
- A. High energy analog discharge ignition system
 - B. High energy bottomless discharge ignition system
 - C. High energy capacitor discharge ignition system
 - D. High energy frequency discharge ignition system
- 6-9. What component supplies high voltage current for aircraft ignition?
- A. Engine control amplifier
 - B. Engine ignition exciter
 - C. Engine control module
 - D. Engine spark plug
- 6-10. What are the three major components of an ignition system?
- A. One Spark plug and two lead assemblies
 - B. One Lead assembly and two spark plugs
 - C. One Spark plug and two ignition exciters
 - D. One Igniter exciter, leads, and igniter plug
- 6-11. What type of engine is ideal for hydraulic starters?
- A. Auxiliary power unit (APU)
 - B. Turbofan engine unit
 - C. Turboprop engine unit
 - D. Turboshift engine unit
- 6-12. What type of starter is powered by an accumulator?
- A. Bleed air starter
 - B. Compressor starter
 - C. Electric starter
 - D. Hydraulic starter
- 6-13. What does the anti-ice system use to perform its anti-icing function?
- A. Engine air turbulence
 - B. Engine bleed air
 - C. Engine electricity
 - D. Engine hydraulics

6-14. Presently, how many methods are used to deice an aircraft?

- A. Two
- B. Four
- C. Six
- D. Eight

6-15. What are the methods used to deice an aircraft?

- A. Bleed air and electrical
- B. Bleed air and hydraulics
- C. Bleed air and mechanical
- D. Bleed air and vibrations

6-16. What system makes the modern jet aircraft completely self-sufficient?

- A. Accumulator
- B. APUs
- C. AIMDs
- D. FRCs

6-17. What division performs major overhaul repair and inspections on the APU?

- A. Depot level engine division
- B. FRC level engine division
- C. GE level engine division
- D. NADEP level engine division

6-18. What system relies on bleed air from the engine to operate?

- A. Air-conditioning
- B. Brakes
- C. Ejection seats
- D. Flight controls

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