

CHAPTER 4

JET AIRCRAFT FUEL AND FUEL SYSTEMS

The purpose of the aircraft fuel system is to deliver a uniform flow of clean fuel under constant pressure to the engine under all operating conditions. To accomplish this task, the fuel system must be properly maintained. The Aviation Machinist's Mate (AD) is responsible for maintaining and troubleshooting the fuel system, understanding the different types of fuels and their characteristics, and knowing the different types of aircraft and engine fuel systems and their various parts. In general, aircraft fuel systems are divided into two categories-the aircraft fuel system and the engine fuel system. The aircraft fuel system consists of fuel tanks, float-operated transfer valves, selector and shutoff valves, and fuel tank boost pumps.

The engine fuel system includes some combination of different parts. These parts are filters, fuel control units, engine-driven fuel pumps, flow dividers, pressurizing valves, drain valves, afterburner fuel controls, and fuel nozzles or injectors. The jet engine fuel system usually includes an emergency system to supply fuel to the engine in case of main system failure. In some cases, the emergency system is a duplicate of the main system. However, in others the emergency system is not fully automatic and must be controlled by the pilot. For the non-automatic type emergency system, the pilot must accelerate and decelerate slowly, or there will be danger of rich blowout, lean blowout, stall, or overheating of the combustion and turbine areas.

The aircraft fuel system and engine fuel system as well as the type, designation, and requirements of the aircraft fuels, are discussed in this chapter.

LEARNING OBJECTIVES

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

1. Discuss the types of fuels used in aviation.
2. Identify the operational properties required in aviation fuels.
3. Describe a typical aircraft fuel system.
4. Describe fuel system components and inspection procedures.
5. Identify fuel sampling and contamination procedures.
6. Discuss the major safety precautions and the basic procedures for fuel cell removal and installation.
7. Describe external fuel tank components and their operations.
8. Discuss fuel system components and their operations.



When working around or with jet fuels always wear your proper Personal Protective Equipment (PPE) due to the following hazards; Slight to Moderate Irritant, Effects Central Nervous System Harmful or Fatal If Swallowed, Moderate fire hazard. Avoid breathing vapors or mists. May cause dizziness and drowsiness. May cause eye irritation and skin irritation (rash). Long-term, repeated exposure may cause skin cancer.

TYPES OF JET FUEL

The U.S. Military grades of jet fuel are designated by the letters JP followed by a number. The grade number merely shows the approximate sequence the fuel specifications were accepted by the military. North Atlantic Treaty Organization (NATO) codes show compatible fuel standards. When changing to a different fuel, it is usually unnecessary to drain out the old fuel. Some aircraft prohibit fuel mixing or require different settings on some fuel components (fuel controls) when switching fuel grades.

JP-4

JP-4 (NATO Code F-40) is an alternate fuel to JP-5 for United States Navy (USN) jet aircraft used at shore stations only. It is never used on ships. Its low vapor pressure reduces fuel tank loss and vapor lock tendencies. Its fuel density is 6.5 pounds per gallon (ppg), and its flash point is below 0 degrees Fahrenheit (°F). When switching to JP-4 from JP-5, engine operating characteristics may change. Changes include easier starting, slower acceleration, lower operating temperature, and shorter range.

JP-5

JP-5 (NATO Code F-44) is the Navy's primary jet fuel. It is relatively safe to store, is thermally stable, and has high heat content per gallon. JP-5 is a kerosene-type fuel with a vapor pressure close to 0 pounds per square inch (psi). Its high flash point makes it safe for shipboard handling. In fact, it is the only jet aircraft fuel used aboard ships. It has a lower tendency to vaporize than the more volatile grades. The vapor-air mixture in tanks or containers above its liquid surfaces generally will be too lean to be ignited until the surface of the liquid reaches a temperature of about 140 °F.

JP-8

JP-8 (NATO Code F-34) is similar to JP-5 in most characteristics, except flash point and freeze point. JP-8 is available only in Europe. JP-8 represents significant advantages over JP-4 in fuel handling and operational safety. However, like JP-4, its flash point is lower than shipboard safety standards. The disadvantages of cost, availability, and low temperature starting problems prevent it from replacing JP-4.

Commercial Fuel

Common commercial fuels used include types A, A-1, and B. Commercial fuels are authorized for use in military aircraft when JP fuel is not available. The characteristics of commercial fuel are similar to military fuels. A-1 is designated NATO code F-34, or equal to JP-8. Jet A is equal to JP-5, and Jet B is equal to JP-4.

OPERATIONAL PROPERTIES OF FUELS

Due to the wide range of operating conditions and high rate of fuel consumption, jet engines require specific fuels to operate efficiently and maintain a reasonable engine service life. Various grades of jet fuels were developed to meet specific operating or handling characteristics. A study of the basic characteristics of turbine fuels will help you understand the importance of delivering the proper fuel to the aircraft. Such a study is also valuable in understanding the need for safety and caution in handling these fuels. This section includes basic characteristics of engine fuels.

Characteristics

Aircraft engine fuels are petroleum products manufactured from crude oil by oil refineries. They are classified as inflammable liquids. Any material easily ignited that burns rapidly is inflammable. Under proper conditions, fuel can explode with force similar to dynamite. Death can result if the vapors of

fuel are inhaled in sufficient quantities. Serious skin irritation can result from contact with the fuel in the liquid state. In liquid form, aircraft fuels are lighter than water, and in vapor form they are heavier than air. Consequently, water in the fuel usually settles to the bottom of the container.

Vapors of these fuels, when released in the air, tend to remain close to the ground, thus increasing the danger to personnel and property. From a safety and health standpoint, aircraft engine fuels must be handled with caution.

In the selection of a fuel, several factors must be considered. Because one fuel cannot have all the requirements to the greatest degree, the fuel selected is a compromise of various factors. Specific properties of fuels are determined through testing. These tests determine the volatility, density, heating value, combustion, safety, and handling characteristics of the fuels. There are hundreds of tests that determine the physical, chemical, and performance properties of fuel. We limit this discussion to the most common and important ones, as follows:

- Volatility (vapor pressure and distillation)
- Flash point and fire point
- Heat energy content
- Viscosity
- Handling characteristics
- Combustion products
- Effects of additives and impurities
- Freeze point

Volatility

Volatility measures the ability of a liquid to convert to a vaporous state. Fuel must vaporize and the vapor must be mixed in a given percentage of air for it to burn or explode. Only fuel-air mixtures within the flammable range will burn (*Figure 4-1*).

Volatility of a fuel affects starting, range, and safety. A highly volatile fuel helps the engines start easier, especially at low temperatures or under adverse

conditions, and has less range due to fuel evaporation in flight. The fuel has a higher tendency to vapor lock and is more susceptible to a fire during a crash. The volatility of a petroleum fuel is usually measured in terms of vapor pressure and distillation.

The vapor pressure shows the tendency to vaporize at specific temperatures. Vapor pressure is measured in a Reid vapor pressure test bomb. In the test, one volume of fuel and four volumes of air are contained in a sealed bomb fitted with a pressure gauge. The container and fuel are heated to 100 °F and shaken; then, the pressure on the gauge is read. The pressure shown on the gauge is known as the Reid vapor pressure (RVP) and is expressed in psi. A highly volatile fuel helps engines start easier, especially at low temperatures or adverse conditions. The distillation measurement for volatility measures the amount of fuel boiled off at specific temperatures. Because turbine fuels are a mixture of hydrocarbons (gasoline and kerosene), they have a wide range of boiling points. This test records the boiling ranges. The military specification for fuels will give these temperatures and the percentages of the fuel allowed to boil off to meet the desired standards.

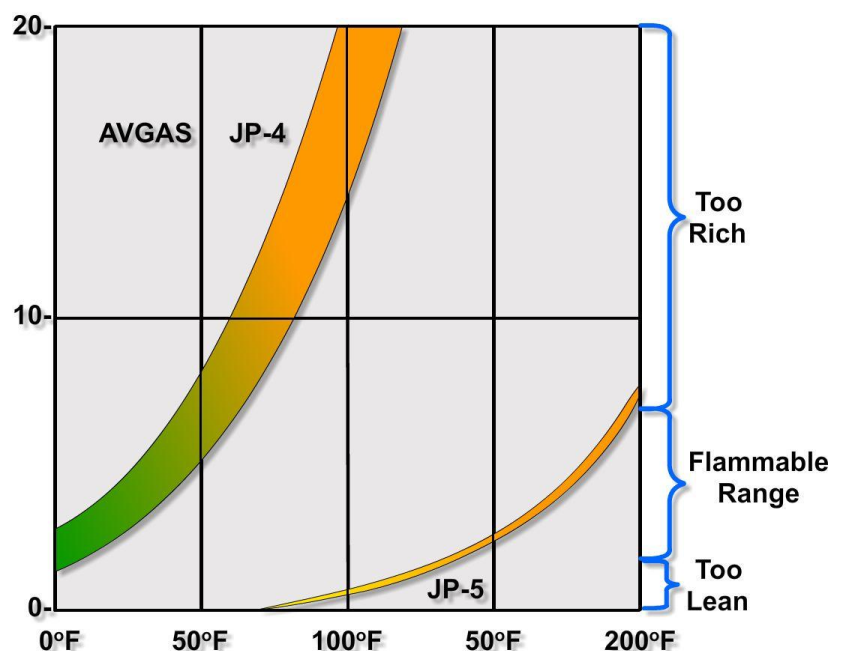


Figure 4-1 — Vaporization of aviation fuels at atmospheric pressure.

Flash Point and Fire Point

The flash point is the temperature at which the fuel vaporizes enough to ignite with an outside heat source. The flash point of a fuel is an index of its potential safety for handling and storage. Ships require at least a 140 °F flash point for storage and safety reasons. The fire point is the temperature at which the vapors continue to burn without an outside heat source.

Heat Energy Content

For aircraft engine use, it is important that the fuel contain as much heat energy (thermal value) as possible, both per unit weight and per unit volume. The thermal value is the amount of heat produced as a result of complete combustion and is expressed in calories or British thermal units (Btu).

Thermal value per unit of weight increases as gravity increases. Energy content and density influence fuel selection when range or payloads are the limiting factors. All these factors are important to understand when the aircraft will be weight-limited rather than volume-limited.

Viscosity

Is the internal resistance of a liquid that tends to prevent it from flowing. Turbojet engine fuels should be able to flow through the fuel system and strainers under the lowest operating temperatures to which the engine will be subjected. Fuel viscosity and density also have considerable effect on nozzle performance, especially when varied over a wide range. The most important fuel property influencing nozzle performance is viscosity. It affects drop size, flow range, and spray angle. Changes in fuel density affect fuel flow.

Handling Characteristics

For a fuel to have satisfactory handling characteristics, it must be noncorrosive and should not clog fuel filters, even at very low temperatures. The fuel should not produce vapor lock in the fuel tanks or various fuel pumps or slugging out of the fuel tank vents (Slugging is the process by which liquid fuel is carried along with vaporized fuel when the vapor escapes to the atmosphere). As much as possible, the fuel should have enough of the properties of a lubricant to avoid significant wear of the fuel-metering pumps.

Combustion Products

Aircraft fuels must have a minimum tendency to form solids or carbon on combustion. A loss in the efficiency of the engine results when these deposits build up in the engine.

Additives, Impurities, and Their Effects

Only materials that will be effective when added in a maximum concentration of 5 percent are considered as liquid additives. Beyond this concentration, the material may be considered as a fuel.

Gum inhibitors used in military gas turbine fuels are the same as those used for military aviation gasolines. In aviation gasoline, gum is almost always completely soluble and becomes apparent only when the gasoline is evaporated. Both soluble and insoluble gum, especially the insoluble form can be expected to have serious effects on the fuel system of turbine engines. The fuel-metering pumps, fuel pumps, and fuel filters are likely to be seriously affected by insoluble gum. The soluble type can cause difficulty in the fuel system at points where microscopic leakage occurs and exposes thin films of fuel to air, and thus to evaporation. The microscopic fuel leaks will usually appear at fuel valves.

Certain aircraft require a minimum concentration of fuel system icing inhibitors (FSIIs). These are put in the fuel to prevent icing in the airframe fuel system, engine filter, or engine fuel control. FSII

materials are considered to be dangerous before they are added to fuel; therefore, shipboard injection is not approved.

Freeze Point

The freezing point of a fuel is the temperature at which solid particles begin to form in the fuel. These particles are waxy crystals normally held in suspension in the fuel. These particles can readily block the filters in an aircraft fuel system. The fuel almost always becomes cloudy before the solid particles form. This cloud is caused by dissolved water coming out of the solution and freezing.

AIRCRAFT FUEL SYSTEM

Aircraft fuel system maintenance is the responsibility of more than one work center. For instance, ADs remove and install bladder and self-sealing fuel cells. Personnel of the Aviation Structural Mechanic (AM) rating perform the repairs on integral tanks. Personnel from the Aviation Ordnance (AO) rating usually help in the installation and removal of external tanks (drop tanks). To maintain the aircraft fuel system pertaining to the AD rating, you must be familiar with the aircraft fuel system as well as the engine fuel system.

To meet the particular needs of the various types of aircraft, fuel tanks vary in size, shape, construction, and location. Sometimes a fuel tank is an integral part of a wing. Most often fuel tanks are separate units, configured to the aircraft design and mission.

Fuel Tank Construction

The material selected for the construction of a particular fuel tank depends upon the type of aircraft and its mission. Fuel tanks and the fuel system in general are made of materials that will not react chemically with any fuels. Fuel tanks that are an integral part of the wing are of the same material as the wing. The tank's seams are sealed with fuel-proof sealing compound. Other fuel tanks may be synthetic rubber self-sealing cells or bladder-type cells that fit into cavities in the wing or fuselage of the aircraft.

Fuel tanks must provide access for the inspection and repair of the tank. This requirement is met by installing access panels in the fuselage and wings. Fuel tanks must be equipped with sumps and drains to collect sediment and water. The construction of the tank must be such that any hazardous quantity of water in the tank will drain to the sump, so the water can be drained from the fuel tank. The AD should be familiar with the different types of fuel tank/cell construction as described in the following paragraphs.

Self-Sealing Fuel Cells

A self-sealing cell is a fuel container that automatically seals small holes or damage caused during combat operations. A self-sealing cell is not bulletproof, merely puncture sealing. As illustrated in *Figure 4-2*, the bullet penetrates the outside wall of the cell, and the sticky, elastic sealing material surrounds the bullet. As the bullet passes through the cell wall into the cell, the sealant springs together quickly and closes the hole. Now some of the fuel in the tank comes in contact with the sealant and makes it swell, completing the seal. In this application, the natural stickiness of rubber and the basic qualities of rubber and petroleum seal the hole. This sealing action reduces the fire hazard caused by leaking fuel. It keeps the aircraft's fuel intact so the aircraft may continue operating and return to its base.

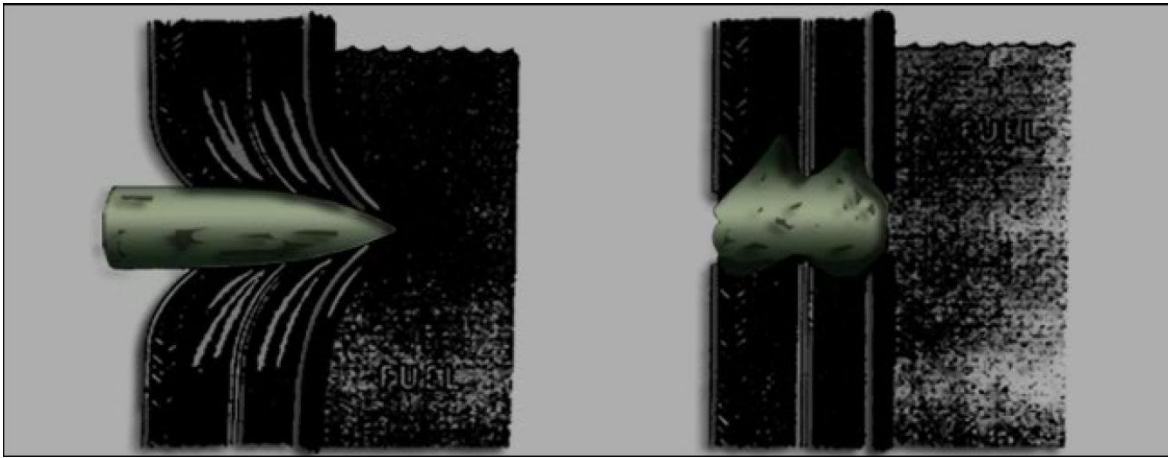


Figure 4-2 — Bullet sealing action.

The most commonly used types of self-sealing fuel cells are the standard construction type and the type that uses a bladder along with the self-sealing cell. Of the two, the standard construction cell is used the most. It is a semi-flexible cell, made up of numerous plies of material.

The combination bladder and self-sealing cell is made up of two parts. One part is a bladder-type cell, and the other part is identical to the standard construction cell. The Combination cell is designed to self-seal holes or damage in the bottom and the lower portions of the side areas. The bladder part of the cell (non-self-sealing) is usually restricted to the upper portion. This type of cell is also semi-flexible.

Self-Sealing Cell (Standard Construction)

There are four primary layers of materials used in the construction of a self-sealing cell. These layers are the inner liner, nylon fuel barrier, sealant, and retainer. All self-sealing fuel cells in service contain these four primary layers of materials. If additional plies are used in the construction of the cell, they will be related to one of the primary plies.

The inner liner material is the material used inside the cell. It is constructed of Buna N synthetic rubber. Its purpose is to contain the fuel and prevent it from coming in contact with the sealant. This will prevent premature swelling or deterioration of the sealant.

Buna rubber is an artificial substitute for crude or natural rubber. It is produced from butadiene and sodium and is made in two types, Buna S and Buna N. The Buna S is the most common type of synthetic rubber. It is unsuitable for use as inner liner material in fuel cells. It causes the petroleum fuels used in aircraft to swell and eventually dissolve. The Buna N is not affected by petroleum fuels, making it ideal for this application. However, the Buna N is slightly porous, making it necessary to use a nylon barrier to prevent the fuel from contacting the sealant.

The nylon fuel barrier is an unbroken film of nylon. The purpose of the nylon fuel barrier is

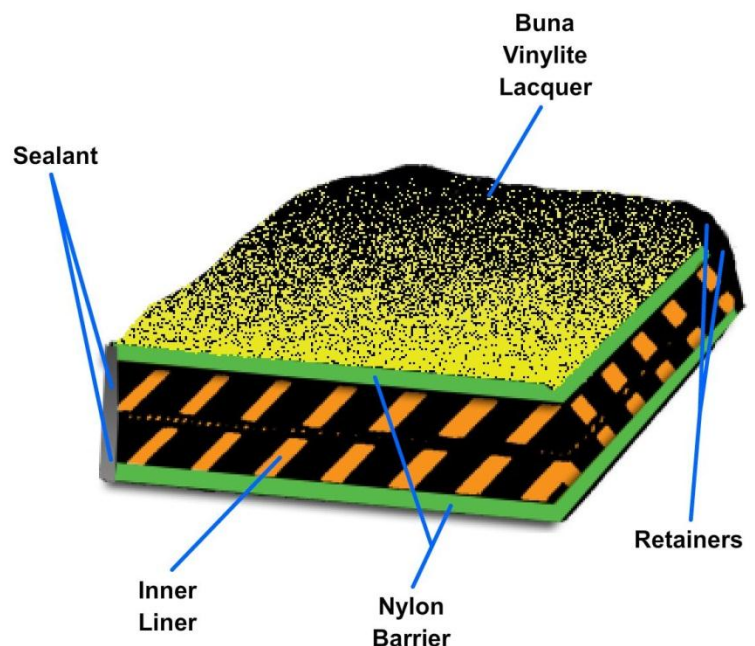


Figure 4-3 — Self-sealing fuel cell (standard construction).

to prevent the fuel from diffusing farther into the cell. The nylon is brushed, swabbed, or sprayed in three or four hot coats to the outer surface of the inner liner during construction.

The sealant material is the next material used in fuel cell construction. It remains dormant in the fuel cell until the cell is ruptured or penetrated by a projectile. The function of the sealant is to seal the ruptured area to keep the fuel from flowing through to the exterior of the fuel cell (*Figure 4-3*).

The mechanical reaction results because rubber, both natural and synthetic, will “give” under the shock of impact. This reaction will limit damage to a small hole in the fuel cell. The fuel cell materials will allow the projectile to enter or leave the cell, and then the materials will return to their original position. This mechanical reaction is almost instantaneous.

The chemical reaction takes place as soon as fuel vapors penetrate through the inner liner material and reach the sealant. The sealant, upon contact with fuel vapors, will extend or swell to several times its normal size. This reaction effectively closes the rupture and prevents the fuel from escaping. The sealant is made from natural gum rubber.

The retainer material is the next material used in fuel cell construction. The purpose of the retainer is to provide strength and support. It also increases the efficiency of the mechanical action by returning the fuel cell to its original shape when punctured. It is made of cotton or nylon cord fabric impregnated with Buna N rubber.

Self-Sealing Cell (Nonstandard Construction)

One variation from the standard construction, self-sealing fuel cell previously discussed has four primary layers—an inner liner, a nylon fuel barrier, two sealant plies, and three retainer plies.

The cords in the first retainer ply run lengthwise of the cell. The cords in the second retainer run at a 45-degree angle to the first. The cords in the third retainer run at a 90-degree angle to the second. The outside is coated with Buns-Vinylite lacquer to protect the cell from spilled fuel and weathering. Baffles and internal bulkheads are used inside the cell to help retain the shape of the cell and prevent sloshing of the fuel. They are constructed of square woven fabric impregnated with Buna N rubber. Flapper valves are fitted to some baffles to control the direction of fuel flow between compartments or interconnecting cells. They are constructed of Micarta, Bakelite, or aluminum.

These plies, baffles, internal bulkheads, and flapper valves with the necessary fittings and combinations make up a typical self-sealing fuel cell.

Bladder-Type Fuel Cells

A non-self-sealing fuel cell is commonly called a bladder-type cell. It is a fuel container that does not self-seal holes or punctures. The advantage of using a bladder fuel cell results from the saving in weight. Some of the other advantages are the simplicity of repair techniques and the reduced procurement costs over self-sealing fuel cells.

Bladder-type cells are usually made of very thin material to give minimum possible weight. They require 100-percent support from a smooth cavity. The cell is made slightly larger than the cavity of the aircraft for better weight and distribution throughout the aircraft’s fuel cavity structure. The thinner wall construction increases the fuel

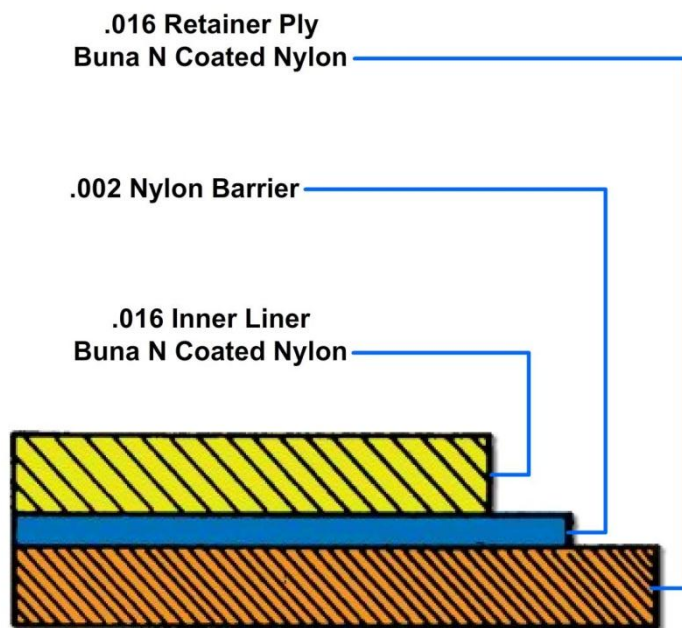


Figure 4-4 — Bladder cell construction.

capacity over the self-sealing cells, thus increasing the range of the aircraft. Many of our aircraft formerly equipped with self-sealing cells have been changed to bladder-type cells. There are two types of bladder fuel cells—rubber type and nylon type.

Rubber-Type Bladder Cells

The rubber-type bladder cells are made in the same manner as self-sealing cells. They have a liner, nylon barrier, and retainer ply. The sealant layers are omitted. All three plies are placed on the building form as one material in this order—liner, barrier, and retainer. *Figure 4-4* illustrates this type construction.

The inner liner may consist of Buna N rubber, Buna N-coated square woven fabric (cotton or nylon), or Buna N-coated cord fabric. The purpose of the inner liner is to contain the fuel and provide protection for the nylon barrier. The nylon barrier consists of three to four coats of nylon applied hot by brush, swab, or spray. The purpose of the nylon barrier is to keep fuel from diffusing through the cell wall. The retainer consists of Buna N-coated square woven fabric (cotton or nylon) or cord fabric. The purpose of the retainer ply or plies is to lend strength to the fuel cell and provide protection for the nylon fuel barrier.

Nylon-Type Bladder Cell (Pliocel)

Nylon bladder cells differ in construction and material from the Buna N rubber cells. This type of cell may be identified by the trade name “Pliocel” stenciled on the outside of the cell. The Pliocel construction consists of two layers of nylon woven fabric laminated with three layers of transparent nylon film.

The repair of this type of cell must be accomplished by entirely different methods and with different materials. The adhesive and Buna N rubber used to repair the rubber-type bladder cell cannot be used on the nylon-type cell.

FUEL SYSTEM COMPONENTS AND INSPECTION PROCEDURES

The maintenance of the aircraft and engine fuel system is primarily the responsibility of the AD rating. Besides fuel cell repairs, some of these maintenance tasks that are the responsibility of the AD are discussed in the following paragraphs. These tasks include inspecting, cleaning, replacing fuel parts, and rigging and adjusting various fuel system controls.

Fuel System Component Inspection

Periodically, the entire fuel system must be inspected for wear, damage, and leaks. Fuel system parts must be inspected for security of mounting, leaks, and loose connections. Maintenance should be limited to such items as the tightening of connections to eliminate leaks and the replacement of defective units. Repairs involving the disassembly of units are made at overhaul maintenance activities.

Additionally all units must be securely mounted and all connections tight and properly safetied. Boost pumps should be used to build up pressure to check for leaks.

Pumps

The boost pump should be checked periodically for proper operation and correct pressure output. The pump assemblies must be checked for leaks, the condition of the fuel, and the condition of the electrical connections. The drain lines must be free of traps, bends, and restrictions.

Main-Line Strainer

The main-line strainer must be drained at each preflight inspection to eliminate any water and/or sediment. The screen must be removed and cleaned at the intervals specified in the applicable technical publications. The sediment removed from the housing should be examined thoroughly. Particles of rubber are often early warnings of deterioration of hose or self-sealing tanks. The strainer must be checked for leaks and damaged gaskets.

Fuel Lines and Fittings

The lines must be inspected to see that they are properly supported and that the nuts and clamps are securely tightened. A hose-clamp torque wrench should be used to tighten hose clamps to the proper torque. If this wrench is unavailable, the clamp should be tightened finger tight plus the number of turns specified for the hose and clamp. Clamps should be tightened only when the engine is cold. If the clamps do not give a seal at the specified torque, the clamp, the hose, or both should be replaced. After a new hose has been installed, the hose clamps should be checked daily and tightened if necessary. When this daily check shows that cold flow (the flowing of the rubber from the clamping area) has ceased, the clamps should be inspected at the less frequent periods specified for hose clamps throughout the system. The hose should be replaced if the plies have separated, if there is excessive cold flow, if there are signs of chafing, or if the hose is hard and inflexible. Permanent impressions from the clamps in the tube or cover stock indicate excessive cold flow. Hose that has collapsed at the bends as a result of misaligned fittings or lines should be replaced. Some hose tends to flare at the ends beyond the clamps. This is not an unsatisfactory condition and does not indicate leakage. At each engine change, all hose connections forward of the firewall should be inspected and defective hoses replaced.

Selector Valves

Selector valves should be rotated and checked for free operation, excessive backlash, and accurate pointer indicators. If the backlash is excessive, the entire operating mechanism should be checked for worn joints, loose pins, and broken drive lugs. Defective parts in the operating mechanism must be replaced. The cable control systems should be inspected for worn or frayed cables, damaged pulleys, and worn pulley bearings.

High-Pressure Fuel Lines

Because the fuel lines installed on the discharge side of the engine-driven fuel pump are subjected to high pressures, you should take special care when inspecting for leaks and damage. The lines must be properly connected; otherwise, units such as the governor and barometric control will not function correctly and may be seriously damaged.

Combustion Chamber Drain Valve

The engine must be turned up to check the operation of the drain valve. If fuel does not run from the overboard drain after shutdown, the cause should be determined.

High-Pressure Filter

The high-pressure filter must be inspected for security of mounting, leaks, and proper safetying. The filter element must be removed, cleaned, and inspected at regular intervals. Regardless of their condition, filter elements must be discarded at the period(s) specified in authorized maintenance instructions. Whenever the element is removed, the housing should be cleaned and the seals should be replaced.

Fuel Nozzles

Periodically, the fuel nozzles and screens must be removed and inspected. The screens should be cleaned and defective nozzles replaced. The inner surface of the exhaust cone must be inspected for heavy streaks—discoloration of the metal due to overheating. These inspections are rough checks for a combustion chamber in which the fuel nozzle is not functioning properly.

SAMPLING PROCEDURES

Fuel samples are taken from the fuel cell low point drains as specified in the applicable Maintenance Requirement Card (MRC) deck.

1. Ensure exterior of low-point drain is cleaned prior to sampling.
2. Drain off 1 pint from low-point drain, using a 1-quart, clear glass or polyethylene container.
3. Inspect sample for loose drops of water puddled under fuel.
4. If water is detected, discard sample and repeat steps 1 and 2 until no water is found.
5. Swirl the sample by briskly rotating the container.
6. If water is present under the swirling vortex, draw another sample and re-inspect.
7. Inspect fuel sample for any discoloration, cloudiness, and loose sediment under the swirling vortex.
8. If small amounts of particulate material are noted, discard the sample, draw another sample, and re-inspect.
9. If relatively large quantities of water or foreign matter are noted, or small amounts persist from one or more cell drains, perform the following:
 - Keep the fuel sample.
 - Immediately notify maintenance control, which will ground the aircraft and notify the quality assurance division to perform an investigation to determine the source of contamination.
 - If the source of contamination is not isolated to the aircraft, notify the cognizant fuel handling activity. The source of contamination must be identified. See *table 4-1* for types of contamination and limits.

NOTE

Obtain fuel samples prior to refueling. Only trained personnel shall take fuel samples; personnel taking samples must have clean hands and equipment. Improper containers and poorly drawn or mishandled samples result in meaningless or misleading results.

Table 4-1 — Visual Contamination Table

TYPE CONTAMINANTS	APPEARANCE	CHARACTERISTICS	EFFECTS ON AIRCRAFT	ACCEPTA-BILITY LIMITS FOR DELIVERY TO AIRCRAFT
A. Water				
1) Dissolved Water	Not visible.	Fresh water only. Precipitates out as a cloud when fuel is cooked.	None unless precipitated out by cooling of fuel. Can then cause ice to form on low-pressure fuel filters if fuel temperature is below freezing.	Any amount up to saturation.
2) Free Water	Light cloud. Heavy cloud. Droplets adhering to sides of bottle. Gross amounts settled in bottom.	Free water may be saline water or fresh water. Cloud usually indicates water in fuel emulsion.	Icing of fuel system—usually low-pressure fuel filters. Erratic fuel gage readings. Gross amounts of water can cause flame-outs and/or corrosion of components.	Zero—fuel must contain no visually detectable free water.
B. Particulate Matter				
1) Rust	Red or black powder, rouge, or grains. May appear as dye-like material in fuel.	Red rust (Fe2O3) — nonmagnetic. Black rust (Fe3O4) —magnetic. Rust generally comprises major constituent of particulate matter.	Will cause sticking, and sluggishness or general malfunction of fuel controls, flow dividers, pumps, nozzles, etc.	*Refer to Note
2) Sand or Dust	Crystalline, granular, or glass-like.	Usually present and occasionally constitutes major constituent.	Will cause sticking, and sluggishness or malfunction of fuel controls, flow dividers, pumps, nozzles, etc.	*Refer to Note
3) Aluminum or Magnesium Compounds	White or gray powder or paste.	Sometimes very sticky or gelatinous when wet with water. Usually present.	Will cause sticking and sluggishness or malfunction of fuel controls.	*Refer to Note

NOTE

If dark, stringy, or fibrous material that tends to float in the fuel is noted in any sample, forward the sample(s) to the nearest Navy Petroleum Laboratory for microbiological growth determination.

TYPE CONTAMINANTS	APPEARANCE	CHARACTERISTICS	EFFECTS ON AIRCRAFT	ACCEPTA-BILITY LIMITS FOR DELIVERY TO AIRCRAFT
C. Micro- biological Growth	Brown, gray, or black. Stringy or fibrous.	Usually found with other contaminants in the fuel. Very lightweight; floats or "swims" in fuel longer than water droplets or solid particles. Develops only when free water is present.	Fouls fuel quantity probes, sticks flow dividers, makes fuel controls sluggish.	Zero.
D. Emulsions				
1) Water-in-Fuel Emulsions	Light cloud. Heavy cloud.	Finely divided drops of water in fuel. Same as free water cloud. Will settle to bottom in minutes, hours, or weeks depending upon nature of emulsion.	Same as free water.	Zero—fuel must contain no visually detectable free water.
2) Fuel and Water or "Stabilized" Emulsions	Reddish, brownish, grayish, or blackish. Sticky material variously described as gelatinous, gummy, like catsup, or like mayonnaise.	Finely divided drops of fuel in water. Contain rust or microbiological growth, which stabilizes or "firms" the emulsion. Will adhere to many materials normally in contact with fuels. Usually present as "globules" or stringy, fibrous-like material in clear or cloudy fuel. Will stand from days to months without separating. This material contains one-half to three-fourths water, a small amount of fine rust or microbiological growth, and one-third to one-half fuel.	Same as free water and sediment, only more drastic. Will quickly cause filter plugging and erratic readings in fuel quantity probes.	Zero.
E. Miscellaneous				
1) Interface Material	Lacy bubbles or scum at interface between fuel and water. Sometimes resembles jellyfish.	Extremely complicated chemically. Occurs only when emulsion and free water is present.	Same as microbiological growth.	Zero—there should be no free water.
2) Air Bubbles	Cloud in fuel.	Disperse upward within a few seconds.	Same as microbiological growth.	Any amount.

NOTE

Particles large enough to be visible should rarely be present. At the most, the total sediment should be a spot of silt. If any appreciable contamination is found, the test must be repeated.

Measuring Contamination

How do you determine how much contamination is too much? First, you have to understand the units of measurements used to identify contamination. The two units for measuring contamination are microns for solids and parts per million (ppm) for water.

There are about 25,400 microns in 1 inch. *Figure 4-5* gives you a microscopic view of human hair compared with small particle contaminants.

The reference for water contamination is ppm. If you take a 32-ounce sample bottle and fill it 3 1/4 inches from the bottom, you have about 500 cubic centimeters (cc). Break the 500 cc down into one million little pieces. You now have 1 ppm. Of course, you must use accurate surveillance equipment to perform measurements that small. Normally, the organizational maintenance level does not require this precise testing and inspection. Instead, the organizational level visually inspects fuel samples for contamination.

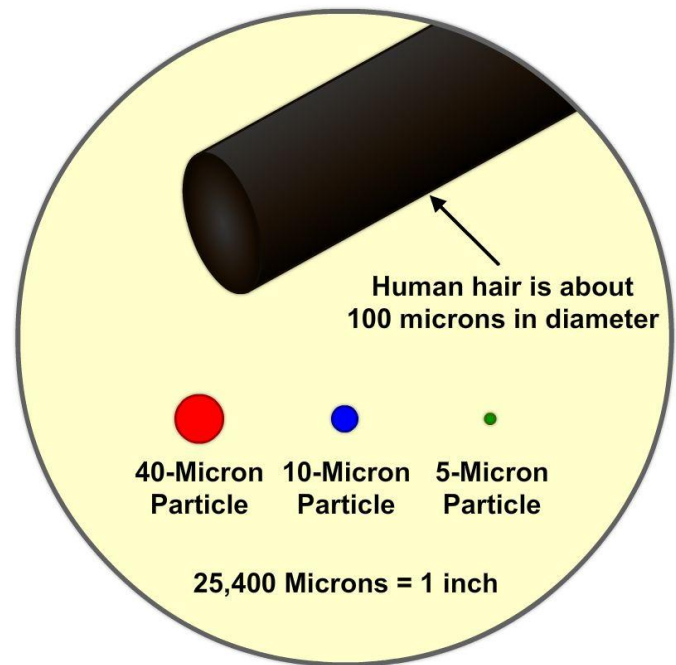


Figure 4-5 — Enlargement of small particles in comparison to human hair.

FUEL CONTAMINATION

The complex fuel systems of modern aircraft do not function properly if the fuel is contaminated with dirt, rust, water, or other foreign matter. Very small quantities of water may form into ice at altitude, affecting small fuel control orifices. Contaminated fuel has caused aircraft accidents with a tragic loss of life and valuable aircraft. This means clean fuel is a LIFE-OR-DEATH matter with aviation personnel.

Besides being deadly, contaminants are also sneaky. A certain type of emulsion resulting from water and rust particles can adhere to the sides of aircraft's fuel cells and go undetected, even with fuel sampling. It will continue to build up until parts of it wash off, blocking fuel filters, lines, or fuel control passages. Contamination causes unnecessary man-hours in troubleshooting and fixing fuel problems and possible engine failure.

In addition to causing extra maintenance and engine failure, fuel contamination causes serious delays in flight operations. Contaminated fuel must be tracked back to the source of contamination and the problem corrected. Until the cause of contamination is found and corrected, the contaminated system cannot be used. The fuel system may be a mobile refueler, air station hydrant refueling system, or the entire fuel system of an aircraft carrier. Contaminated fuel could affect one aircraft or the operation of an entire air wing.

Types and Limits of Contamination

Acceptable fuel is clean and bright with no visually detected free water. The terms clean and bright have no relation to the natural color of the fuel. Jet fuels are not dyed and vary from clear, water white to straw-yellow in color. Clean means the absence of any cloud, emulsion, visible sediment, or free water. Bright means the fuel has a shiny, sparkling appearance. A cloud, a haze, specks of particulate matter, or entrained water indicates contaminated fuel that cannot be used. Steps must be

taken to find the source of contamination and correct it. *Figure 4-6* shows unacceptable sample examples.

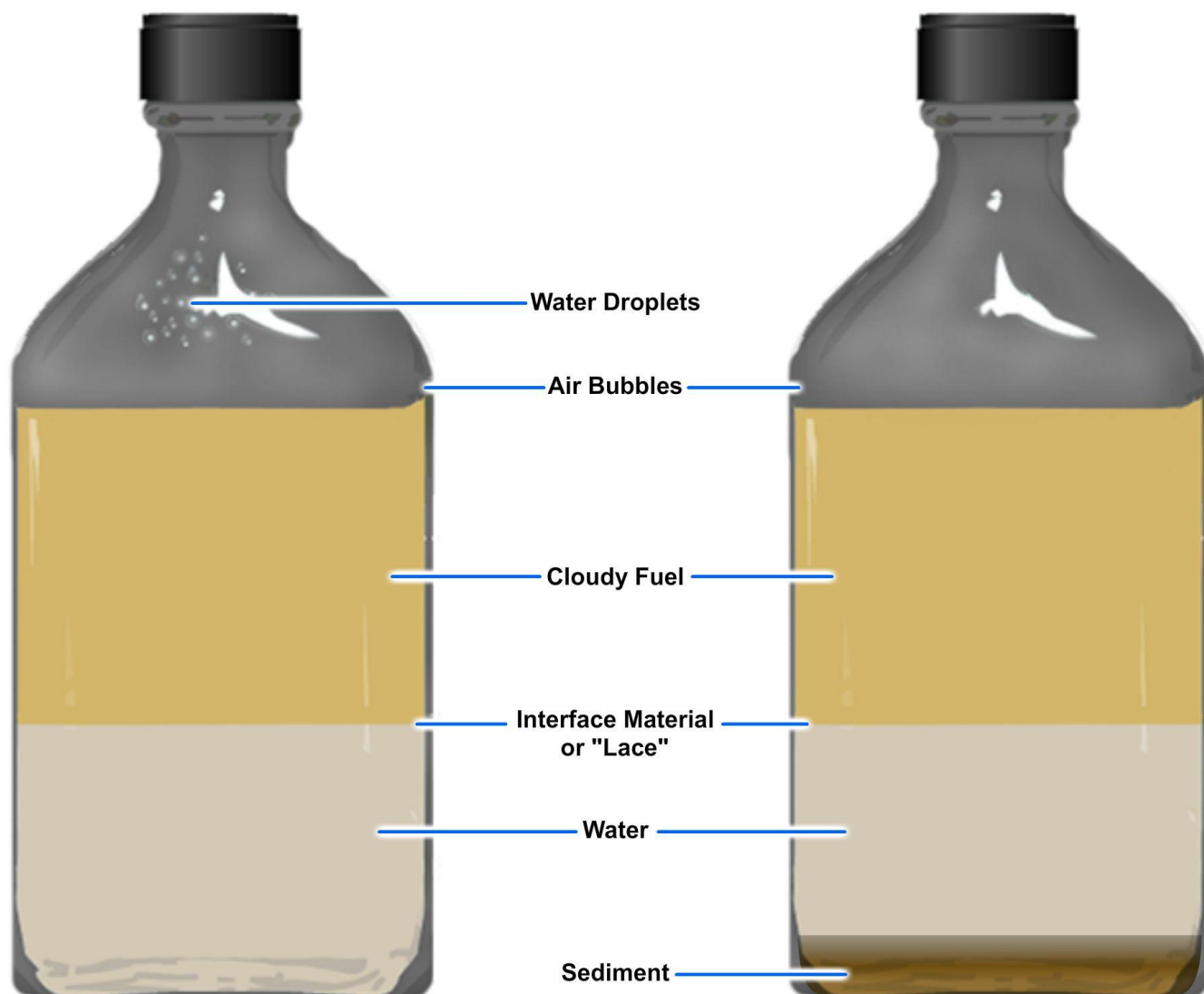


Figure 4-6 — Samples of JP-5 showing unacceptable fuel sample examples.

Water

Water in fuels is either fresh or saline and present as dissolved or free water. Dissolved water is water in the fuel NOT visible. Free water is a cloud, emulsion, droplets, or gross amounts in the bottom of the container. Any form of free water can result in icing, corrosion, or malfunctioning of fuel system parts. Saline water will cause corrosion faster than fresh water.

Sediment

Sediment appears as dust, powder, fibrous material, grain, flakes, or stain. Specks or granules of sediment indicate particles in the visible size of about 40 microns or larger. In a clean sample of fuel, sediment should not be visible except upon the most meticulous inspection. Sediment or solid contamination is either course or fine.

Course sediment is 10 microns or larger in size. Course particles can clog orifices and wedge in sliding valve clearances and shoulders, causing malfunction and excessive wear. They can also clog nozzle screens and other fine filter screens throughout the fuel system. Fine sediments are less than 10 microns and are not visible as distinct or separate particles. They appear as a dark shellac-like surface on sliding valves.

Microbiological Growth

Microbiological growth consists of living organisms that grow at a fuel/water interface. These organisms include protozoa, fungus, and bacteria. Fungus is the major constituent causing many of the problems associated with biological contamination of jet fuels. Fungus is a vegetable life that holds rust and water. It is also a stabilizing agent for fuel-water emulsion. Microbiological growth can develop wherever free water exists in the fuel tanks. Traces of metallic elements are also necessary, but water is the key ingredient. Remove free water and growth ceases. Microbiological growth is a brown, black, or gray color and has a stringy, fibrous-like appearance. It clings to glass and metal surfaces, causing problems such as severe corrosion or erratic operation of fuel system components. Microbiological growth causes erroneous readings in fuel quantity systems, sluggish fuel control operation, and clogged filters. It is more prevalent in tropical and semitropical locations because of higher temperatures and humidity. Fuel suspected of microbiological contamination must not be defueled into a clean system.

Preparation for Fuel Cell Maintenance

Before any maintenance is performed on a fuel tank/cell, a check of the applicable aircraft maintenance manual is required. If the aircraft maintenance manual is not specific enough to cover the type of maintenance that is required, refer to the Aircraft Fuel Cell and Internal/External Tank manual, NA 01-1A-35, for additional information. If you find conflicting information between the specific fuel system portion of the aircraft maintenance manual and the NA 01-1A-35, the procedures in the NA 01-1A-35 manual take precedence.

To protect personnel from the health hazards associated with aviation fuels, protective clothing and equipment are required and should be the first priority before starting any fuel cell maintenance. Specific items such as respirators, coveralls, proper shoes, and safety goggles are usually available for use by personnel. All of these are required to work with aviation fuel cells or tanks. NA 01-1A-35, Appendix B, contains specific information on all of the required safety equipment.

Defueling, Depuddling, Purging

Prior to an inspection, entry of personnel, or repair of any fuel tank/cell, specific functions must be accomplished. These functions are discussed in the following paragraphs. A definition of each function is provided to allow you to become familiar with it.

1. Defueling. Defueling is the process of removing fuel from the aircraft tank/cell.
2. Depuddling. Depuddling is the process of removing residual fuel from cells/tanks after defueling and low-point draining. Depuddling is a necessary step prior to air purging when a nontoxic and noncombustible atmospheric state is required in a fuel cell or tank.
3. Purging. Purging is the process for removing fuel vapors capable of producing a combustible or toxic atmosphere.

Before you perform any defueling, depuddling, or purging on an aircraft, you must park it in an area specifically authorized for such operations. You must be familiar with the safety precautions and procedures listed in the maintenance instruction manuals and NAVAIR wing and squadron instructions.

Defueling

General precautions for defueling aircraft include the following:

1. Position the aircraft at least 100 feet from any building or smoking area or in the designated defueling area.
2. Inspect fire extinguishers for serviceability. Man extinguishers at all times.

3. Park the defueler as far from the aircraft as possible. Park it heading away from the aircraft in case you need to move the defueler in an emergency.



All the required grounding and bonding cables must be attached before the aircraft or defueler tanks are opened. Bonding and grounding wires must be attached to clean, unpainted, conductive surfaces to be effective.

4. Always ground the aircraft to an approved grounding point. Bond the aircraft to the defueler. Ground the grounding cable for the nozzle to a metal part remote from the tank/cell. This action will minimize static electricity between the nozzle and the aircraft. Then, attach the bonding cable from the nozzle to the aircraft.
5. Personnel requirements are one person to man each fire extinguisher, one person to operate the defueler, and one person to operate the aircraft defueling panel. Additionally, one person must operate the fuel system control panel inside the aircraft, if applicable.
6. Once defueling is complete, drain remaining fuel from low-point drains into an approved safety container.



Do not defuel aircraft in the vicinity of an electrical storm. No maintenance of any type will be allowed on the aircraft during defueling.

Depuddling

Depuddling of the aircraft fuel tank/cell is a hazardous operation because it requires the entry or partial entry of personnel into an aircraft tank/cell. They remove any residual fuel that was not removed from the tank/cell during defueling. In an effort to minimize the hazards associated in depuddling, all maintenance personnel are required to work in pairs. One person should remain outside the tank/cell to act as a safety observer while the other enters the tank/cell to do the depuddling. The following general safety precautions apply to depuddling: The aircraft battery connector and aircraft power receptacle should always be tagged with an appropriate warning placard; power is NOT to be applied to the aircraft under any circumstances. Before you perform any depuddling, refer to the aircraft maintenance manual and NA 01-1A-35 for the proper support equipment that must be used.

NOTE

The two individuals should always be connected by a safety line in case of an emergency.

When you purge a tank/cell, attach an approved air blower to the tank/cell and ensure that all personnel remain clear of the removed access panel. After allowing approximately 30 minutes for the blower to remove the toxic vapors, stop the air blower and have the tank/cell tested by a gas-free engineer to ensure the tank/cell is safe for personnel to initiate depuddling. If after this time a “safe” condition is not reached, reinstall the air blower for at least an additional 15 minutes and have the test repeated. Continue the venting and testing, if necessary, until the tank/cell can be certified safe for personnel. The air inside the tank/cell has to be certified and documented as safe. The outside safety observer and the individual who is going to enter the tank/cell should obtain all the necessary protective clothing and equipment and proceed with the depuddling.

The next step in depuddling is to remove all the necessary access panels and covers required. Then, immediately after entering the tank/cell, the individual must cap or seal all openings leading from other possible sources of fuel or fuel vapors. Depuddling can be accomplished by using an approved explosion-proof vacuum cleaner. You can also use a cellulose sponge or cheesecloth to remove the residual fuel from the tank/cell.

Purging

When you perform maintenance on a fuel tank/cell, the next step is purging. There are four approved methods you may use to purge the aircraft fuel tank/cell. They are the air blow, air exhaust, oil purge, and JP-5 method.

The air blow purging method uses an air blower and ducting to force fresh outside air into the tank/cell. The air exhaust purge method uses an air blower and ducting to draw fresh outside air through the tank/cell. The oil purge method uses lubricating oil, MIL-PRF-6081 Grade 1010, to dilute the fuel vapors in the defueled tank/cell. The oil purge method is the most desirable of the three methods. This method must be used when performing extensive repairs to the aircraft other than maintenance solely related to the fuel system. The oil purge method will normally keep the tank/cell safe for personnel for approximately 10 to 15 days. The JP-5 method uses JP-5 fuel to dilute and help remove all residues from low flash point fuels including JP-4 or aviation gasoline (AVGAS).

NOTE

In all methods of purging, it is mandatory that the tank/cell be certified. Certification is done by a gas-free engineer, who documents the tank/cell as being safe for personnel or safe for hot work.

FUEL CELL REMOVAL AND INSTALLATION

General fuel cell removal and installation procedures are discussed in the following paragraphs. These procedures are applicable to the removal and installation of all fuel cells. However, the latest technical publications must be used for actual removal and installation of fuel cells on any naval aircraft.

Removal

After the aircraft is defueled, depuddled, and purged, the following steps should be accomplished for the removal of the cell:

1. Remove required access covers.
2. Remove all interior parts, lines, clamps, fittings, and plates from cell.

NOTE

Clean dust covers must be installed on all open tubes, ports, and disconnected electrical plugs and receptacles.

3. Cap or plug all lines, fittings, and parts removed from the cell to prevent contamination.
4. Place removed items in a separate container for each cell, and identify with cell number and aircraft bureau number.
5. If possible, locate and mark with yellow crayon (SS-C-635) any damaged areas showing evidence of leakage.
6. Disconnect cell fittings and interconnects.

7. Untie and remove lacing cords. If a cord is cut during removal, retain old cord to determine length of replacement cord.
8. Remove the screws or hangers that secure the cell to the cavity. Install lifting device if necessary.

The cell must be handled very carefully to prevent abrasions, cuts, and punctures. Tape should be applied to sharp edges of all cavity openings to eliminate chafing of the cell upon removal.

If necessary, the cell may be collapsed and strapped in a folded position. Bends should not occur at any of the fittings.

Carefully remove the cell, observing the following precautions:

- a) Do not pull the cell by its fittings.
- b) Carefully guide the protruding fittings past all obstructions.
- c) If the cell binds while removing it, do not force it. Stop to determine the cause of the trouble and remedy it before continuing. Sprinkle the cell with talc or other suitable powder if it becomes necessary to squeeze the cell around or between structural members.
- d) Do not pry on rubber fittings or on the cell with sharp instruments; use large wooden paddles.

When removal of the cell is necessary because of major repairs or other reasons, the cell should be inspected. You then reinstall it, provided it is fit for further service in the aircraft. Fuel cells should be removed when signs of leakage appear. These signs are rubber particles in the strainer, loose seams, loose or cracked fittings, or swollen sealants. If the cell is considered to be repairable beyond organizational level, it should be crated and sent to the nearest fuel cell repair activity.

When a fuel cell remains empty for more than 72 hours, a thin coat of oil, Specification MIL-PRF-6081, Grade 1010, is applied to the inner liner. This process should be accomplished whether the cell is installed or removed from the aircraft for storage. The oil will act as a temporary plasticizer, and it will prevent the inner liner from drying out and cracking.

Fuel cells that are to be returned to storage until repairs can be accomplished at a later date should have a coating of oil, Specification MIL-PRF-6082, Grade 1065. It is applied to the interior of the cell. This heavier type of oil will act as a preservative over a sustained period. Oil should not be applied to the interior of self-sealing cells that have exposed sealant. It is applied when the exposed area has been covered with an oil-resistant tape. Although complete coverage of the cell interior is necessary, preservative oil should not be allowed to puddle in the bottom of the cell.

Handling Procedures

Always carry or haul fuel cells carefully. The purpose of carrying or handling fuel cells is to protect the outside (retainer ply) wall. It serves to support the shape of the cell and protect the self-sealing (sealant) layer underneath it from fuel spillage. The cord construction and lacquer coating must be cautiously safeguarded.

To avoid any undue damage to the cell during handling, follow the following instructions:

1. Always transport the cell by a well-padded truck or dolly, or by hand carrying.
2. Never use any of the cell fittings for handholds while carrying the cell.
3. Never allow the cell to be dragged or rolled on the deck.
4. Before placing the cell on the deck, spread an appropriate barrier material on the area where the cell will be placed.

5. Never place the cell on a bench, pallet, or table where parts of the cell are allowed to overhang.
6. If the cell were removed during cold weather, warm the cell to at least 60 degrees Fahrenheit (°F) 16 degrees Celsius (°C) before collapsing or folding.
7. Never use unnecessary force or pressure to compress a collapsed cell into a small package. The undue pressure will produce sharp folds that damage the cell.
8. Never allow the cell to be folded across or beside any of the cell fittings.
9. Never leave a self-sealing cell in a collapsed condition for a period longer than 1 hour. Bladder-type fuel cells may be left collapsed for a longer period of time, providing the cell is not walked on, severely creased, or abused.
10. Always install protective caps on the cell hanger receptacles while the cell is removed from the aircraft.

When uncrating a fuel cell, you must always follow the opening instructions on the crate or shipping container. These instructions are provided for your use to prevent possible damage to the cell and to preserve the crate/shipping container for future use. Before removing the cell from the container, you should be sure that a clean, smooth surface, larger than the cell itself, has been cleared and protected with an appropriate barrier material before unfolding the cell. Fuel cells that have been stored for a long time can shrink or become distorted. Cells in this condition will be difficult for you to install, and they often cause misalignment of the cell fittings with the aircraft fittings. To restore a shrunken or distorted fuel cell to its original condition, you should soak the cell in water. The length of time required for soaking will normally depend on the condition of the cell. Normally, 72 hours is enough, as long as the water temperature remains at least 70 (°F) 21 (°C). Soaking time can be reduced by placing the cell in an air-circulating oven at a maximum temperature of 120 (°F) 49 (°C) for about 4 hours. It must also be maintained at high humidity.

**WARNING**

Fuel cells are easily damaged. Use caution when cutting nylon lacing cords.

NOTE

Bladder-type fuel cells and nylon Pliocels are much more delicate than self-sealing cells and require extremely careful handling. However, the handling precautions are the same as for self-sealing cells.

Installation

The steps outlined below are generally followed when installing a fuel cell in an aircraft.

1. Check the cell to make certain that it is the proper one for the cavity.
2. Tape all cell openings.
3. Inspect the fuel cell cavity for cleanliness and loose bolts, nuts, etc.; make certain there are no sharp metal or protruding edges that may damage the cell during or after the installation of the fuel cell.
4. Tape or otherwise protect the edges of the fuel cell if necessary.
5. Apply talc or other suitable powder to the outer surface of the cell and the cell cavity to make it easier to move the cell into position.

6. If necessary, collapse or fold the cell as required, and secure it with webbed straps. The cell should be warmed to room temperature.
7. When applying straps, place them and the buckles so they are easily accessible after the cell is installed.
8. Guide the fuel cell into the cavity, making sure it is installed in the right direction. Wooden paddles with rounded edges may be used to guide the cell into the cavity; never use tools with sharp edges or points.
9. If any binding occurs, determine the trouble and remedy it before damage is caused to the fuel cell. Be very careful that protruding fittings are not damaged.
10. Remove straps if the cell was collapsed; then check the interior of the cell to make certain that no tools or foreign materials were left inside.
11. Install all fittings and components. New seals and gaskets must be used.

NOTE

The use of any sealing compounds on rubber fuel cell fittings is prohibited. Sealing compounds may be used only on connections when the adjoining surfaces are metal.

Torquing Requirements

One of the main causes of fuel leaks is improper torquing of bolts used to secure fuel cell access covers, access plates, and cell fittings. Overtorquing or improper torquing sequence causes excessive rubber cold flow, warps fitting plates, and in some cases, breaks the metal insert in fuel cell fittings. It is important that torquing be performed properly.

Before the bolts are installed, threads should be inspected for burrs or other defects that could damage cell fitting inserts or give incorrect torque readings. Threaded cell fittings should be inspected to ensure that they are not filled with rust-preventive compound or dirt. Presence of such foreign material will result in incorrect torque values.

All bolts should be fully installed finger tight before they are torqued. Bolts should be of proper length. A bolt that is short will not safely engage the mated part; one that is too long will bottom out, giving incorrect torque values and causing leaks.

Each work package (WP) that requires removal and installation of a fuel cell access cover specifies required torque values and refers to the applicable bolt torque sequence for securing the part.

Testing

When a new or repaired fuel cell is installed in an aircraft, it should be tested for possible leaks before it is filled with fuel. The air pressure test is the best method of determining if any leaks exist. This test consists of applying air pressure to a sealed cell and checking for the existence of leaks with a mercury manometer. Further details on this type of testing can be found in the specific aircraft maintenance instruction manual (MIM).

EXTERNAL FUEL TANK SYSTEM DESCRIPTION

External fuel systems increase range or mission by providing additional fuel for increased range or tanking. The external fuel system consists of the fuel (drop) tanks, a transfer system, and a jettison system.

External Fuel Tank

The 150 and 300-U.S.-gallon Aero 1C, the 300-U.S.-gallon Aero 1D, and the 330-U.S.-gallon FPU-8/A external fuel tanks are droppable, streamlined, metal containers. *Figure 4-7* shows a FPU 8/A. These tanks are carried under the wing to supplement the internal fuel supply for extended range. Threaded suspension lugs are provided on the top of the tank to accommodate the installation of adapter fittings. These adapter fittings are used to connect the fuel tank to the aircraft fuel system and the fuel tank air pressurization system. The tank is equipped with a refuel transfer shut-off valve and an air pressure and vent shutoff valve. The pressure-fueling float switch is a float-operated device that shuts off fuel flow when the external fuel tank is filled to capacity. This is an electrical connector provided on the top of the tank for connecting the float switch electrical wiring to the aircraft wiring. The air pressure and vent shutoff valve vents the tank to the atmosphere during the pressure fueling procedure. However, the valve is also used with the external fuel tank air pressurization system. This valve uses engine bleed air as a means of pressurizing the tank and forcing fuel into the wing tank, or tanker store. A gravity filler port is provided to accomplish gravity fueling when pressure fueling equipment is not available.

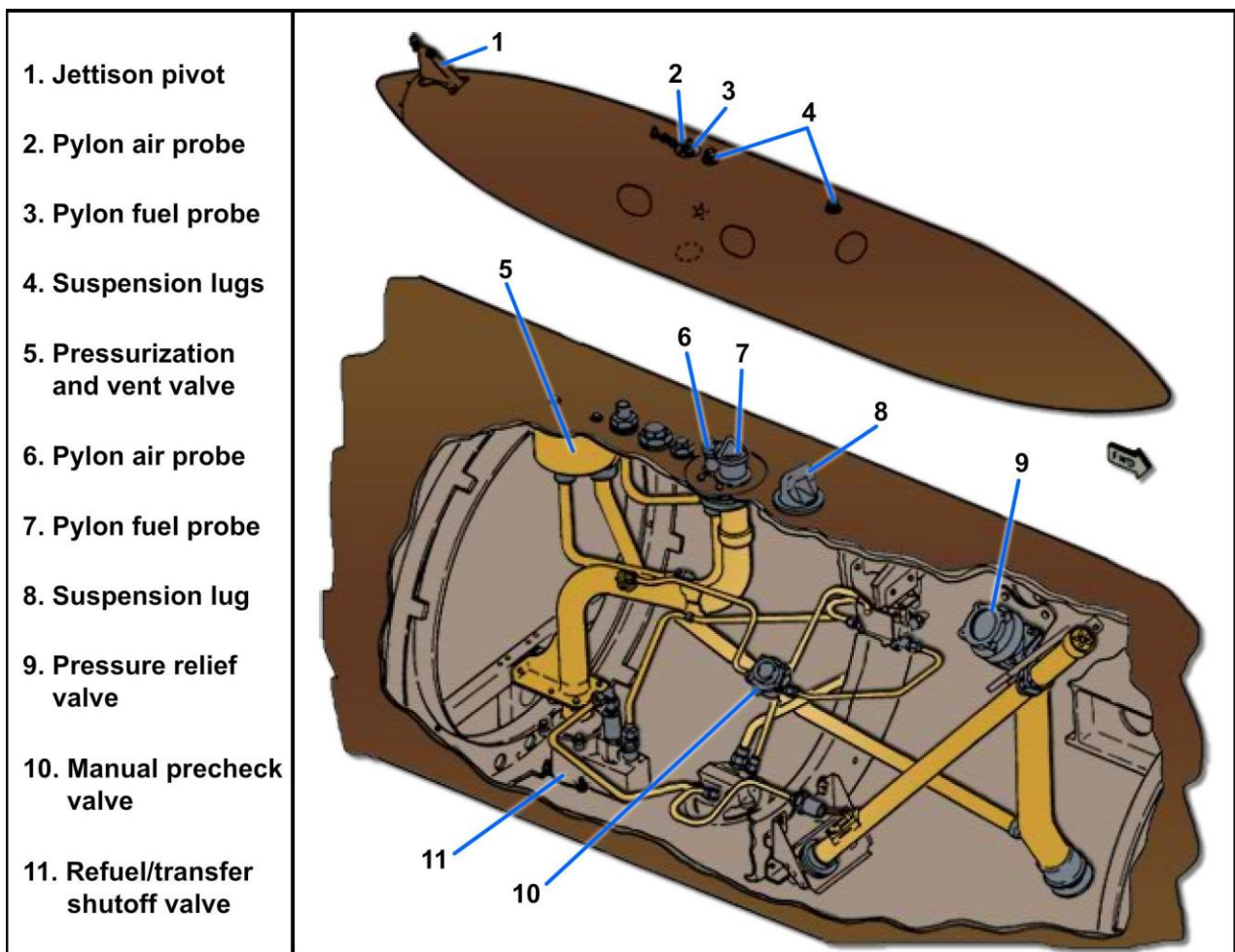


Figure 4-7 — External fuel tank (FPU-8/A) (with cutaway view).

External Fuel Transfer

External fuel tank pressurization and transfer is accomplished with regulated engine bleed air. An external tank pressure regulator maintains 15 to 18 psi air pressure to each of the external tanks. Once the tank is pressurized, fuel then transfers through the refuel/transfer shutoff valve into the refueling manifold. External fuel is then transferred to any of the fuel tanks that will accept the fuel. The refuel/transfer valve will close automatically when the external tank is empty.

The external tank air pressure regulator closes when there is weight on the wheels or when the in-flight refueling probe is extended. Closing the regulator prevents the tanks from being pressurized while the aircraft is on the ground, during an arrested landing, or during in-flight refueling.

External Fuel Tank Jettison

The external fuel tanks can be selectively jettisoned or all jettisoned at one time, such as during an emergency situation. The external tank to pylon fuel/air coupling valves will automatically close the fuel transfer and air pressurization tubes once the tanks are jettisoned.

FUEL SYSTEM COMPONENTS

Common fuel tank parts include pumps, strainers, fuel quantity indicators, valves to control fuel level or routing, and vents and drains. These parts provide capabilities for fueling, defueling, and fuel system management.

Pumps

The aircraft fuel system uses transfer pumps and boost pumps to deliver a continuous supply of fuel to the engine(s) under all operating conditions.

Transfer Pumps

Fuel transfer pumps are installed in the fuel system to pump fuel from the various tanks of the aircraft to the main or sump tank. There are several different types of transfer pumps; common ones are electrically driven or ejector-type motive-flow pumps (*Figure 4-8*). Since the type of pump may differ

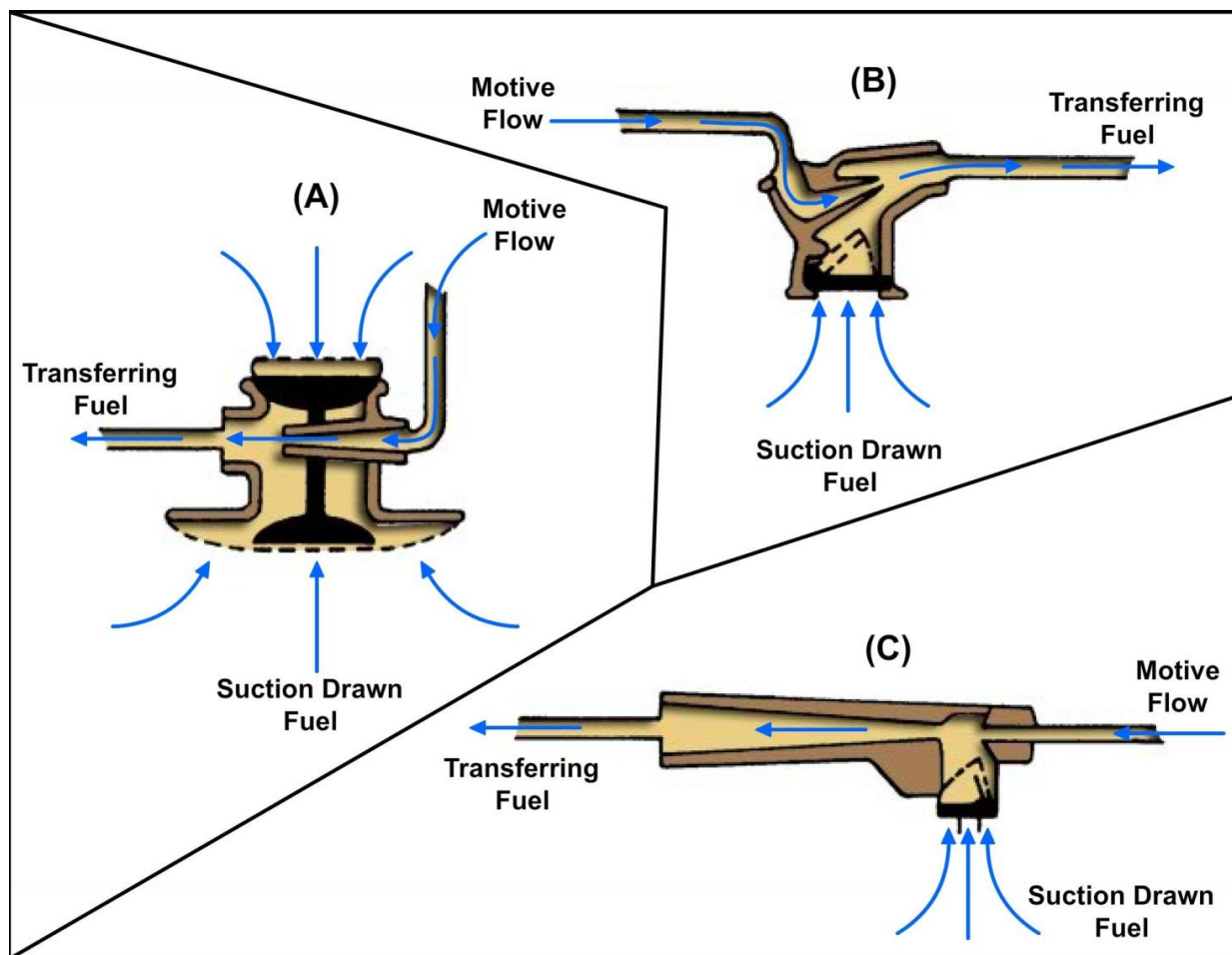


Figure 4-8 — Ejector pumps. (A) Dual seat; (B) single seat; (C) wing transfer.

from one aircraft model to another, the applicable MIM should be consulted for proper identification and maintenance.

Boost Pumps

All Navy fixed-wing aircraft use pressure feed fuel systems. The basic source for this pressure is the engine-driven pump. Auxiliary fuel pumps or booster pumps are required in every pressure feed system. They are needed to supply fuel pressure for starting the engine and to supply fuel to the priming system. They are also used as an emergency pump in case of failure of the engine-driven unit. The submerged boost pump is essentially an integral unit composed of a centrifugal pump and an electric motor. A screen is provided to protect the pump from foreign matter. A submerged boost pump is shown in (Figure 4-9).

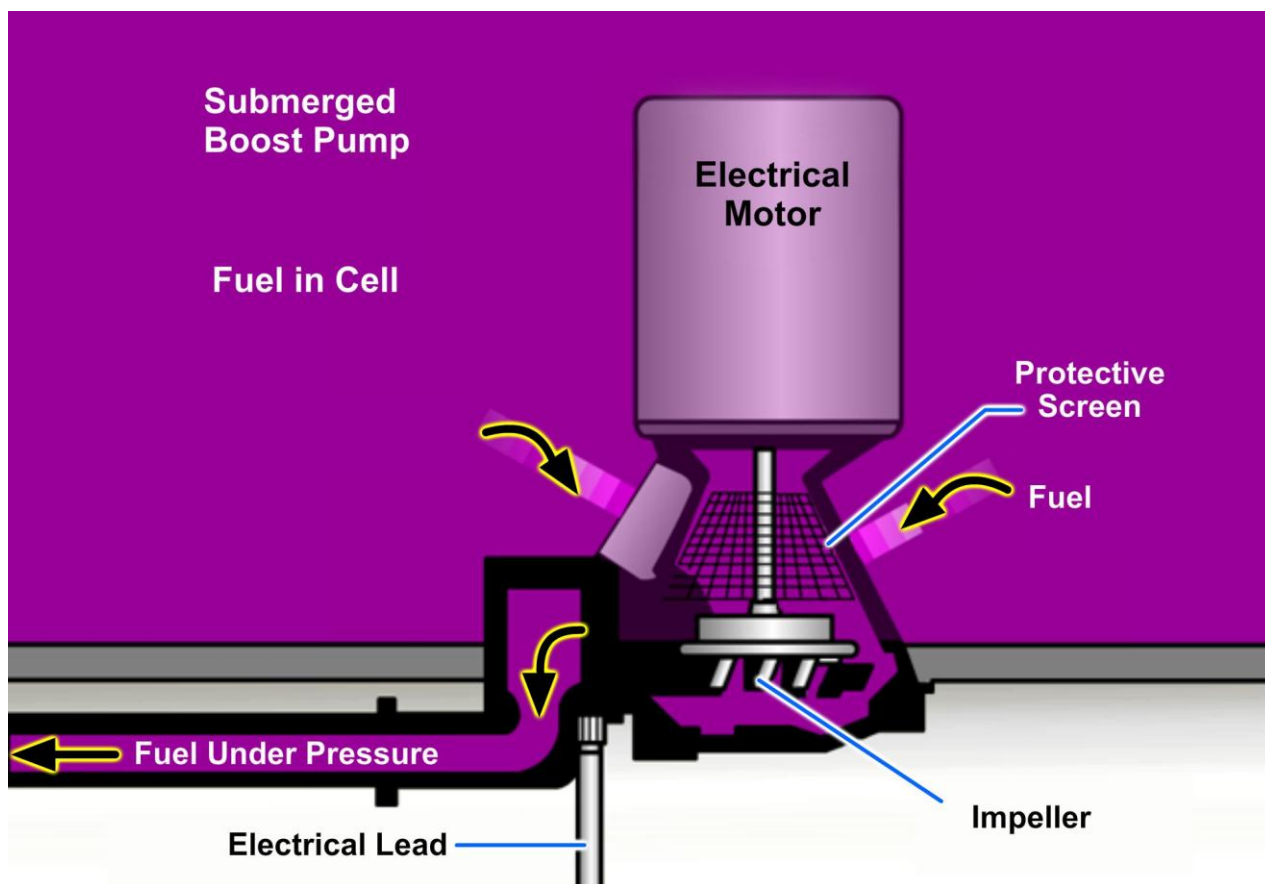


Figure 4-9 — Submerged boost pump.

Strainers

Strainers are installed in the tank outlets and frequently in the tank filler necks. These strainers are of fairly coarse mesh and prevent only the larger particles from entering the fuel system. Other strainers are provided in the fuel inlets and in the fuel lines themselves. The latter are fine-mesh strainers.

Fuel Quantity Indicators

Quantity-indicating units will vary. A fuel counter or indicator, mounted on the instrument panel, is electrically connected to a flow meter installed in the fuel line to the engine. The fuel counter is similar in appearance to an automobile speedometer. When the aircraft is serviced with fuel, the counter is automatically set to the total number of pounds of fuel in all tanks. As fuel passes through the

measuring element of the flow meter, it sends electrical impulses to the fuel counter. These impulses actuate the fuel counter mechanism in such a way that the number of pounds passing to the engine is subtracted from the original reading. Thus, the fuel counter continually shows the total quantity of fuel (in pounds) remaining in the aircraft. However, there are certain conditions that cause the fuel counter indication to be inaccurate. Any fuel remaining in the droppable tanks when they are jettisoned is indicated on the fuel counter as fuel still available for use. Any fuel that leaks from a tank or a fuel line upstream of the flow meter is not counted. Any fuel supplied to the engine by the emergency pump is not counted.

Some continuous-flow fuel systems have a fuel quantity gauge for each tank or group of interconnected tanks. If the system has a main tank with auxiliary tanks feeding into it, a fuel quantity gauge is normally for the main tank. In this type of system, the pilot relies on the indication of the fuel counter (flow meter). All fuel in the auxiliary tanks is transferred to the main tank and fed to the engine. When all fuel except that in the main tank has been consumed, the fuel quantity gauge provides a more reliable indication of the fuel still available. The accuracy of its indication is not affected by the conditions listed in the preceding paragraph. That is, leakage and emergency system supply.

The fuel quantity gauge normally used in aircraft is an electronic (capacitor) type for measuring aircraft fuel capacity in pounds. Normally, the capacitor-type fuel gauge is used without a flow meter, although most engines have provisions for installing one if it is required. A low-level switch is incorporated in the fuel level transmitter. This switch turns on an indicator light in the cockpit when the fuel in the tank drops to a specific low level. This signal informs the pilot that the fuel supply is almost exhausted.

Aircraft Fuel Valves

Valves are used to regulate and control the flow of fuel in the aircraft and engine fuel systems. Some of these valves are discussed in the following paragraphs.

Shutoff Valves

Shutoff valves are two-position (open and closed) valves. The manually operated type is installed to shut off the fuel while a unit in the system is being removed or replaced. Electrically operated shutoff valves control flow during fuel transfer and when fuel is being bypassed because of a defective or damaged unit. *Figure 4-10* shows a motor-operated shutoff valve, commonly referred to as a gate valve.

Fuel Level Control Valves

Fuel level control valves control fuel levels in a tank during ground fueling or fuel transfer to the main tank.

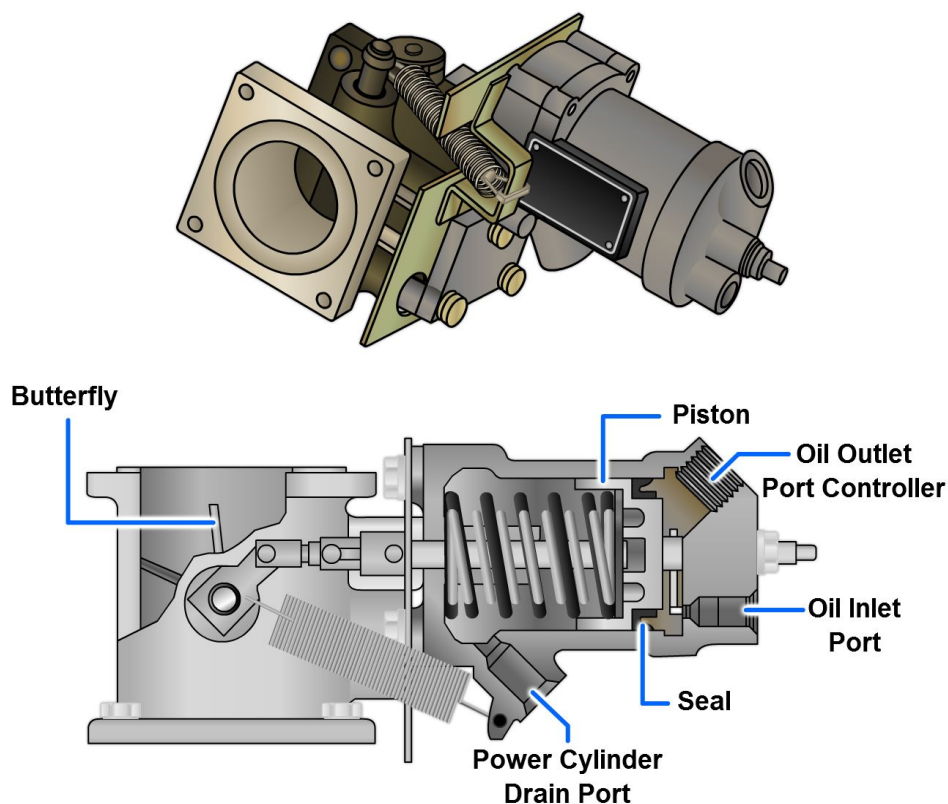
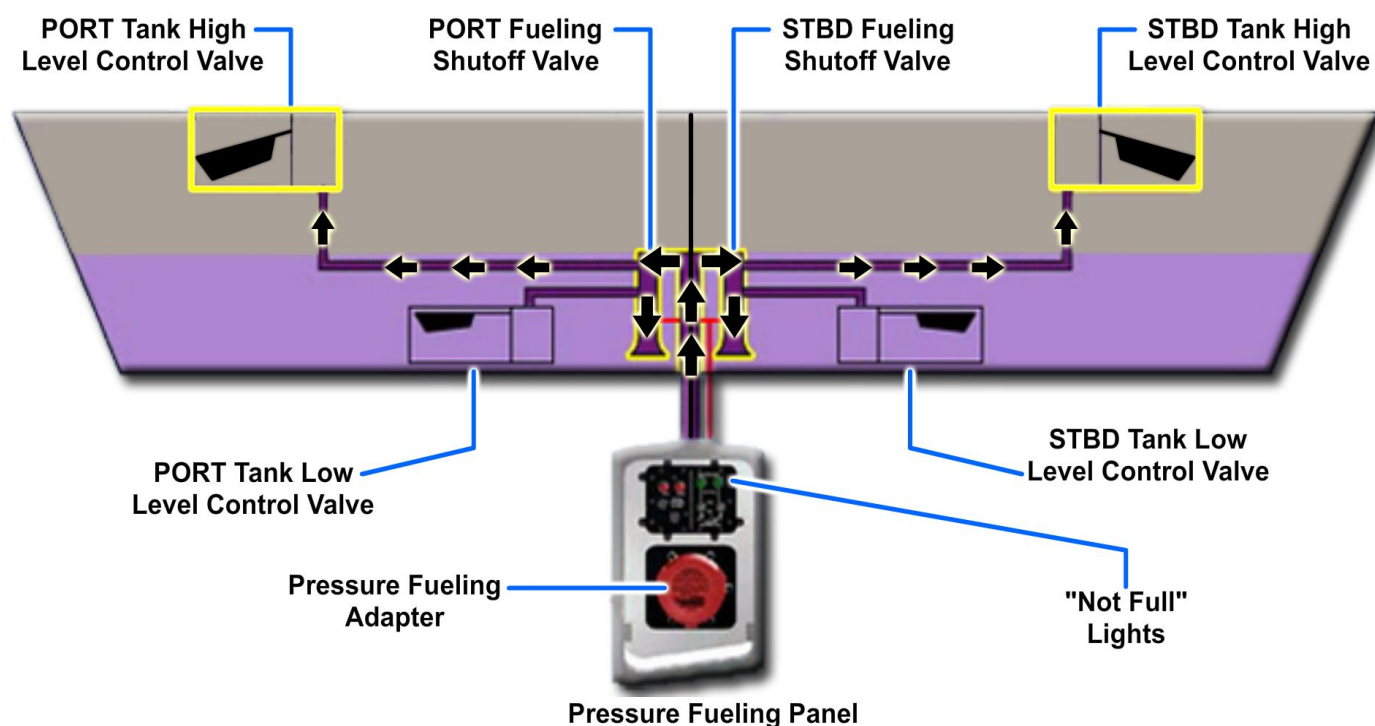


Figure 4-10 — Motor-operated shutoff valve (Gate valve).

There is one fuel level control valve for each tank, auxiliary tank, or group of interconnected tanks. When used for fuel transfer, the valves are located at different levels in the main tank. Fuel is then transferred from the auxiliary tanks in the order designed by the manufacturer. During normal operation of the fuel system, the boost pumps for all the tanks are turned on before the engine is started. Each auxiliary tank boost pump continues to operate until the tank is emptied; then the fuel pressure warning light comes on and the boost pump is turned off by the pilot. Thus, fuel is delivered under boost pump pressure to each fuel level control valve. The fuel then remains in the tank or group of tanks to which it is connected.

In the sectional views of the valve in *Figure 4-11*, note how the float rises and lowers with the fuel level. When the fuel level in the main tank is high, the float is raised. This action closes the pilot valve and lifts the ball check from its seat. Fuel, under boost pump pressure, then passes through the main valve stem into the valve body. Note how the fuel pressure exerted against the bottom surface of the synthetic rubber diaphragm holds the main valve closed. This action prevents fuel from entering the main tank from the transfer lines.

When the fuel level in the main tank drops, the float moves downward. *Figure 4-11* shows how this action allows the ball check to seat in the main valve stem, and then shuts off the fuel pressure in the bottom side of the diaphragm. The pilot valve opens and permits fuel to drain from the main valve body. As the pressure on the under surface of the diaphragm is relieved, the main valve opens to admit fuel from the auxiliary tank.



Interaction Available

Figure 4-11 — Fuel level control valves.

Check Valves

Check valves are installed in the fuel system wherever fuel flow in one direction is required. Fuel pressure in the direction of flow—Indicated by an arrow on the valve—forces the valve open against spring pressure. Spring force and reversal of fuel flow close the valve. This is a one-direction valve. It is important that the valve be installed so that the arrow points in the desired direction of flow.

In some turbojet engine fuel systems, there is a check valve between the fuel control and the fuel dump valve. The check valve remains closed until a certain pressure is reached in the fuel line. A

bypass to the top of the dump valve transmits this bypass pressure. Then, upon engine starting, the controlled fuel pressure builds up. The dump valve is then actuated to close the drain port and open the flow into the fuel manifolds. The check valve remains fully open during engine operation.

Selector Valves

In the continuous-flow system, selector valves are not used for tank-to-engine selection during normal operation. However, in many installations there are selector valves to enable the pilot or mechanic to control the fuel flow for special purposes. These include fuel integrity checks, shutting off fuel to the engine, bypassing fuel components to allow manual operations in emergency conditions, and cross-feeding fuel to different tanks or engines to prevent an unbalanced fuel load.

Fuel Lines and Fittings

The fuel lines between the various tanks and between the tanks and the engine-driven pump are of the conventional type. They consist of metal tubing or flexible hose. There are drain cocks at low points in the lines so that any water that collects at these locations may be drained. A quick disconnect fitting is often installed in the main fuel line to the engine. This fitting permits quick disconnection of the main fuel line when an engine change is performed.

The line connecting the various fuel system units installed on the engine are made of either metal tubing or flexible hose. Because these lines and fittings must withstand the high pressures encountered on the discharge side of the engine-driven fuel pump, special types are used.

Lightweight Hose Assemblies

The lightweight engine hose assembly is designed for continuous operating temperatures of -40 to $+300$ °F. The inner tube is seamless and is of a specially formulated synthetic compound. The reinforcement and cover are of stainless steel wire braid and consist of a partial inner braid and a full-coverage outer braid. This hose can be identified by the bright wire braid outer cover with red markings. These markings are repeated 6 inches apart.

This hose is designed for aircraft power plant and airframe fuel and oil lines. It is widely used in jet engines. It is flexible, lightweight, and has the ability to withstand high operating temperatures where maximum fire resistance is a prime consideration. This hose may be used in submerged applications.

The fitting on this type of hose uses a lip-seal principle, instead of compression, to affect a fluid seal. This lip-seal is formed during assembly by a sharp knifelike spur, which cuts an annular flap in the hose inner tube. Fitting retention against blow-off is affected by the cutting action of the spur. Separating the wire braid, this is then gripped between the nipple and the socket. These fittings must be marked with a painted stripe to detect hose push out after assembly or proof test.

Rigid Tubing

The majority of rigid tubing used in naval aircraft is manufactured from aluminum. However, exposed lines and lines subject to abrasion or intense heat are made of stainless steel. Therefore, you will be concerned more with stainless steel lines. Whenever an engine fuel line requires replacement, the normal procedure is to obtain from supply a preformed line with fittings attached. If a line must be manufactured locally and installed on an engine or component, the original line must be duplicated as exact as possible. *Figures 4-12 and 4-13* show a few of the correct and incorrect methods of installing metal tubing and flexible hose.

Bulkhead Fitting

Bulkhead fittings must be properly installed. To ensure proper installation of the fitting shown in *Figure 4-14*, the mechanic must check to see that the bulkhead has the required thickness for which the fitting was designed.

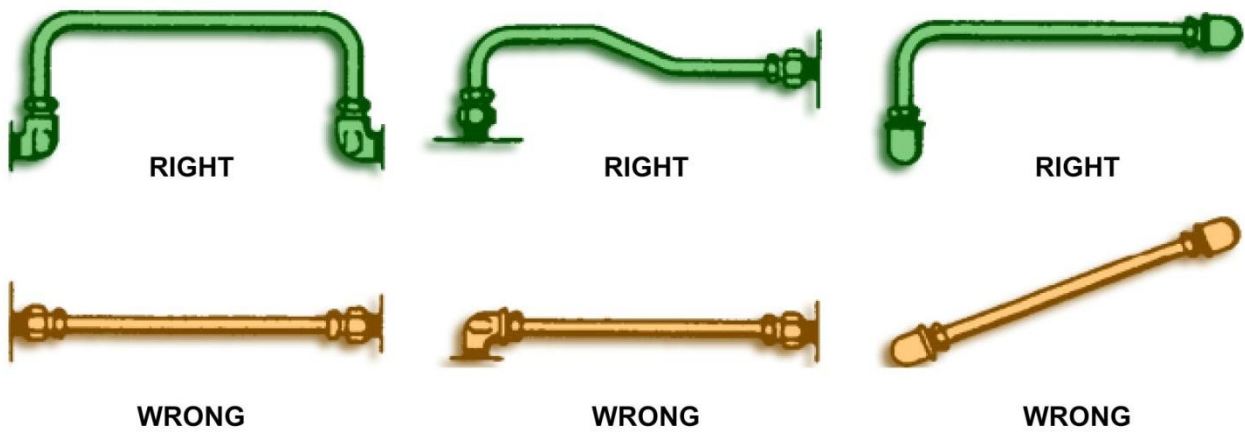


Figure 4-12 — Correct and incorrect methods of installing tubing.

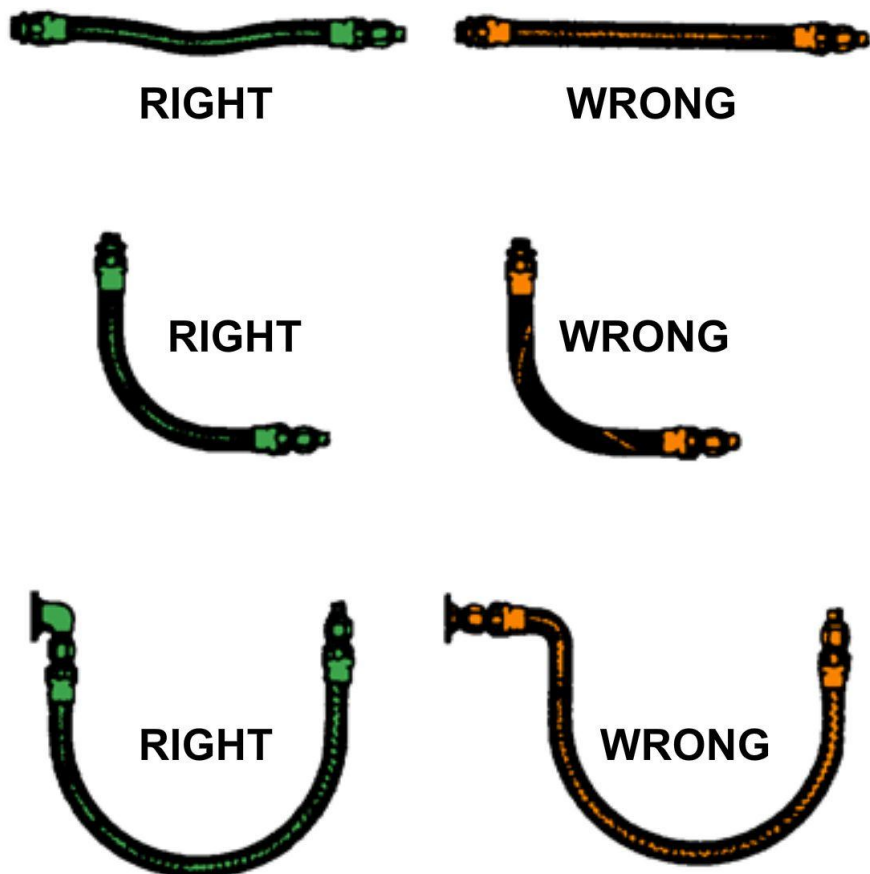


Figure 4-13 — Correct and incorrect installation of flexible hose.

Fitting with O-Ring Seal

To prepare a fitting with an O-ring, assemble the nut on the fitting end until the washer face of the nut lines up with the upper corner of the seal groove. The O-ring seal should be lubricated sparingly with petrolatum and placed on the fitting groove so it contacts the nut. Then screw the fitting (and nut simultaneously) into the boss until the seal contacts the boss chamfer and the nut contacts the boss. Before tightening the locknut, position the fitting direction by turning it three-fourths turn or turning it out one-fourth turn. Assemble the fluid line to the fitting end. Holding the fitting stationary in the selected position, tighten the locknut (*Figure 4-14*).

Fitting with O-Ring Seal and Seal Ring

Start with the threads of the fitting, the O-ring seal, and the seal ring which should be coated sparingly with petrolatum or hydraulic fluid. Work the seal ring, with the smooth (hair) side toward the O-ring seal, into the counter bores of the nut. Then, turn the nut down until the O-ring seal is pushed firmly against the lower threaded section of the fitting. Install the fitting into the boss. Then, keep the nut turning with the fitting until the O-ring contacts the boss. This point can be determined by a sudden increase in torque. With the fitting in this position, put a wrench on the nut to prevent its turning; then turn the fitting in 1 1/2 turns. Position the fitting by turning in not more than one additional turn. Hold the fitting and turn the nut down tight against the boss. Slight extrusion of the ring is not considered detrimental (*Figure 4-14*).

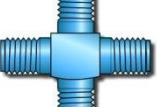
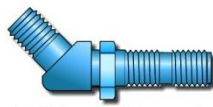
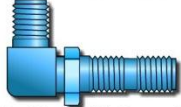
MS 21904 - Elbow  90 Degree	MS 21905 - Tee 	MS 21906 - Cross 	MS 21902 - Union 
MS 21900 - Adapter  Flareless to AN Flared Tube	MS 21916 - Reducer  External Thread	MS 21913 - Plug 	MS 21914 - Cap Assembly (Steel Only)  Pressure Seal
MS 21915 - Bushing  Screw Thread Expander	MS 21907 - Elbow  Bulkhead Universal 45 Degree	MS 21908 - Elbow  Bulkhead Universal 90 Degree	MS 21903 - Union (Long Type)  Bulkhead & Universal
Example of Code: MS 21900 - 4 D Prefix - Military Specification Design Part NO. - Adapter, Flareless tube to an Flared tube Size of fitting in 16ths Inch - (4/16 inch) Material - Aluminum Alloy	MS 21901 - Adapter (Long Type)  Flareless Tube to AN Flared Tube Bulkhead	MS 21921 - Nut  Use only with 21922 Sleeve	MS 21922 - Sleeve (Steel Only)  Use only with 21921 Nut

Figure 4-14 — Fuel line fittings; bulkhead fitting; universal fitting, elbows, plugs, caps.

Fuel Drains

So the moisture content can be checked and moisture drained from the fuel system, the drain valve(s) is/are installed in the low point (or points) in the system (or units).

Figure 4-15, frames 1 through 6, shows six different types of fuel drain valves used on aircraft.

The valve shown in *frame 1* is usually located in the boost pump or in the low-point drain. This fitting needs to be pushed up and held to have it in the OPEN position. To close the valve, release the plunger.

The valve shown in *frame 2* is usually found in the main fuel filter drain. To open this type of drain, rotate the bar counterclockwise to lock it in the OPEN position. To close the drain, rotate the bar in the clockwise direction.

The valve shown in *frame 3* is usually located in the inboard or outboard compartment low-point drain. To open and lock it in the OPEN position, insert a screwdriver in the slot and turn it clockwise, about 90 degrees. To close this valve, turn the screwdriver counterclockwise.

The fuel drain valve shown in *frame 4* can be opened by inserting a screwdriver in the slot, pushing in, and holding it, which will allow fuel to flow. It can be closed by releasing the screwdriver.

The fuel drain shown in *frame 5* is for the aft boost pump drain. It can be opened and locked in the OPEN position by rotating it in the counterclockwise direction. Rotating it in the clockwise direction will close the valve.

The valve shown in *frame 6* is usually found in the low-point drain, forward sump cell, and is opened by pushing and holding. It is closed by releasing the plunger.



Figure 4-15 — Fuel drain valves (frames 1-6).

Interaction Available

Fuel Control Operation

The hydro-mechanical fuel control, shown in *Figure 4-16*, is a lightweight, high-capacity, fuel-flow-metering unit. It is designed to permit selection of a desired engine jet thrust level. It also provides automatic compensation through the full range of thrust for the ambient operating conditions encountered during flight. Engine thrust during ground operation and under various flight conditions is controlled by a single power lever. The fuel control also regulates fuel for engine starting and shutdown. The variables sensed by the fuel control are power lever angle, burner pressure, high-pressure compressor speed, and compressor inlet temperature. By using these variables the fuel control accurately governs the engine's steady state, selected through a speed-governing system of the proportional or droop type. The fuel control also uses these same variables to control fuel flow for acceleration and deceleration. The fuel control consists of a fuel-metering system and a computing system. The metering system regulates fuel supplied to the engine by the engine-driven fuel pump to provide the engine thrust demanded by the pilot. Fuel regulation is also controlled by engine operating limitations, as sensed and scheduled by the fuel control computing system. The computing system senses and combines various operational parameters to govern the output of the metering system of the fuel control under all engine operating conditions.

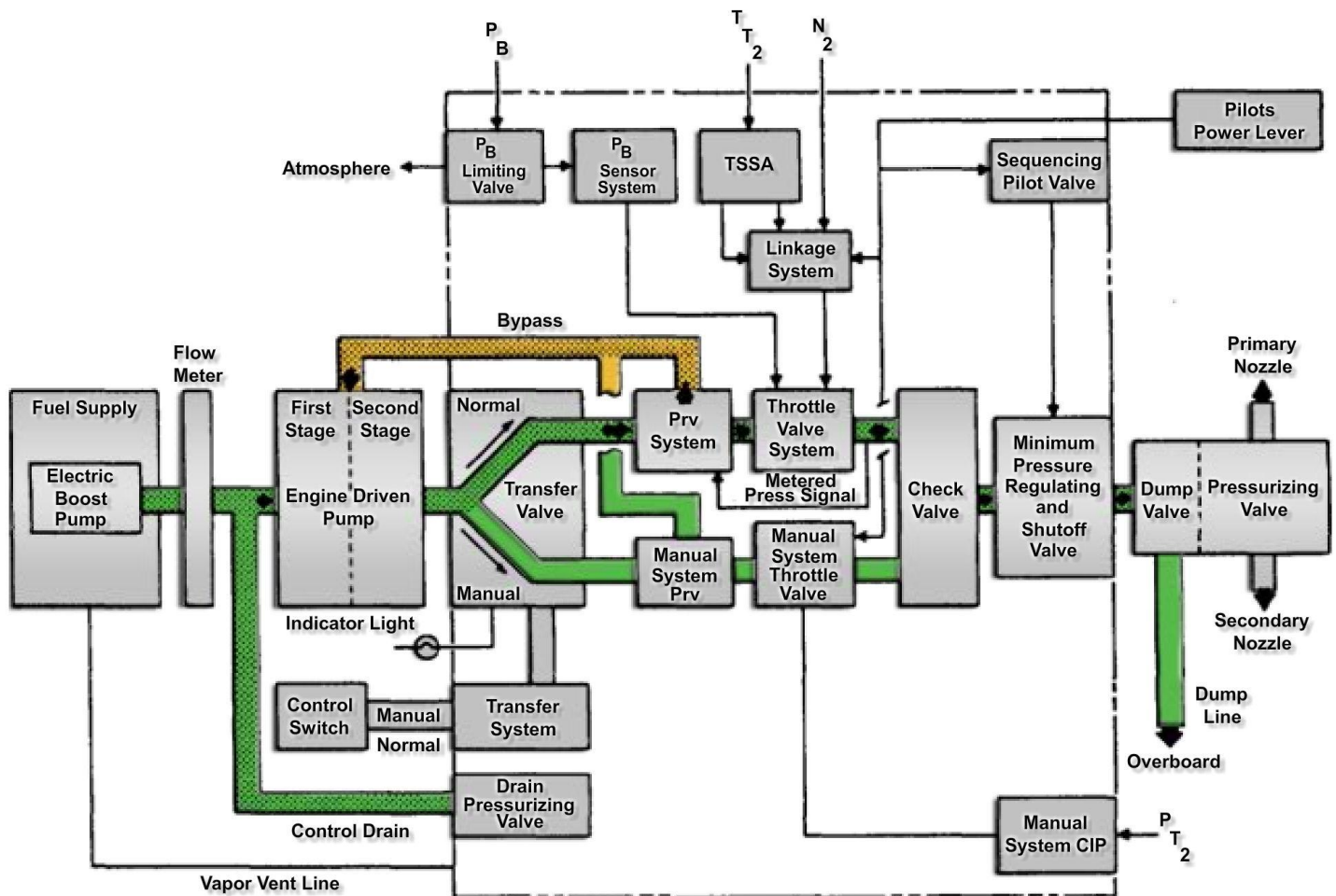


Figure 4-16 — Fuel control schematic.

High-pressure fuel is supplied to the control inlet from the engine-driven pump. At the inlet of the control, the fuel is filtered by a coarse (80-mesh) screen and a fine (40-micron) screen. The coarse screen protects the metering system from large particles of fuel contaminants. If this screen becomes clogged, a filter relief valve will open, permitting continued operation with unstrained fuel. The fine screen protects the computing system against solid contaminants. This screen is self-cleaning. It traps particles by removing the high-velocity of the fuel flowing past the screen into the metering section.

Next, the fuel encounters the pressure-regulating valve, which is designed to maintain a constant pressure differential across the throttle valve. All high-pressure fuel in excess of that required to maintain this pressure differential is bypassed to the pump inner stage by the pressure-regulating valve. This valve is servo controlled. The actual pressure drops across the throttle valve orifice and is compared, by the sensor, with a selected pressure drop, and any error is hydraulically amplified. The amplified error positions the pressure-regulating-valve spring, altering the force balance of this valve so that sufficient high-pressure fuel is bypassed to maintain the selected pressure drop. The pressure-regulating-valve sensor also incorporates a bimetallic disc to compensate for any variation in the specific gravity of the fuel, which results from fuel temperature change.

The high-pressure fuel, as regulated by the pressure-regulating valve, then passes through the throttle valve. This valve consists of a contoured plunger. The computing system of the control positions the plunger within a sharp-edged orifice. By virtue of the constant pressure drop maintained across the throttle valve, fuel flow is a function of the plunger position. An adjustable stop limits the motion of this plunger in the decrease fuel direction to permit minimum fuel flow.

The final part to act upon the metered flow prior to its exit from the control is the minimum pressure and shutoff valve. This valve is designed to shut off the flow of metered fuel to the engine when the power lever is in the OFF position. The metered flow then causes the power-lever-operated sequencing valve to transmit a high-pressure signal to the spring side of the shutoff valve. This signal forces the latter against the seat, thus shutting off the flow of fuel to the engine. When the power lever is moved out of the OFF position, the high-pressure signal is replaced by pump inner stage pressure. Then, metered fuel pressure is increased sufficiently to overcome the spring force. The valve opens, and fuel flows to the engine. Thereafter, the valve will provide a minimum operating pressure within the fuel control. This ensures that adequate pressure is always available for operation of the servos and valves at minimum flow conditions.

The power-lever-operated sequencing valve also incorporates a windmill bypass feature, which functions when the shutoff valve is closed. This feature bleeds throttle valve discharge flow to the fuel pump inner stage to increase the throttle valve pressure drop and opens the pressure-regulating valve. Damage to the fuel pump from excessive pressure is thus prevented during engine wind milling. The sequencing valve functions in both the normal and manual operating systems. The following designators are used in the description of the computing system of the fuel control. These designators should be referred to during study of the fuel control.

- N2 High-pressure compressor rotor speed revolutions per minute (RPM)
- TT2 Compressor inlet temperature
- PB Burner can pressure
- WF/PB Ratio of metered fuel flow to burner can pressure

The computing system positions the throttle valve to control steady-state engine speed, acceleration, and deceleration. These actions are accomplished by using the ratio WF/PB as a control parameter. Throttle valve positioning of this parameter is achieved through a multiplying system whereby the WF/PB signal is used for acceleration or deceleration. The steady-state speed control is multiplied by a signal proportional to PB to provide the required fuel flow.

PB is sensed in the following manner: A motor bellows is internally exposed to PB and the resulting force is increased by the force of an evacuated bellows of equal size. It is directly connected to the motor bellows. The net force, absolute burner pressure, is transmitted through a lever system to a set of rollers having a position proportional to WF/PB. These rollers ride between the bellows-actuated lever and a multiplying lever. The force proportional to PB is thus transmitted through the rollers to the multiplying lever. Any change in the roller position (WF/PB) or the PB signals upsets the equilibrium of this lever. The signal changes the position of a flapper-type servo valve, which is supplied with regulated high-pressure fuel through a bleed air orifice. The resulting change in servo pressure between the two orifices is controlled by the position of a piston attached to the throttle valve plunger. The motion of this piston compresses or relaxes a spring that will return the multiplying lever to its equilibrium position. An adjustable minimum-ratio stop on the WF/PB signal controls engine deceleration. This arrangement provides a linear relationship between decreasing WF and PB, which results in blow out- free decelerations.

An adjustable maximum-ratio stop on the WF/PB signal controls engine acceleration. This stop is positioned by an acceleration-limiting cam. The cam is rotated by a speed-sensing servo system and translated by a TT2-sensing servo system. The cam is so contoured as to define a schedule of WF/PB versus engine speed for each value of TT2 that will permit engine accelerations. This revolution avoids engine over temperature and surge limits without compromising engine acceleration time.

A burner pressure limiter incorporated in the fuel control senses burner pressure with respect to ambient pressure. When this differential exceeds a preset maximum, the pressure will relay a signal to the burner pressure motor bellows. The action reduces bleeding through the limiter valve to

ambient pressure, causing a limitation on fuel flow preventing burner pressure from exceeding a maximum, safe value.

A flyweight-type, engine-driven, speed-sensing governor controls movement of the speed servo piston through a pilot valve. When N2 speed changes, the flyweight force varies and the pilot valve is positioned to meter either low- or high-pressure fuel to the speed servo piston. The motion of the piston repositions the pilot valve until the speed-sensing system returns to equilibrium. The piston incorporates a rack that meshes with a gear segment on the three-dimensional acceleration cam to provide the speed signal for acceleration limiting. This piston position is also used to indicate actual engine speed, and it is connected by a droop lever to a droop cam.

The temperature-sensing bellows and servo assembly are connected through a lever and yoke assembly to the acceleration-limiting cam. The position of this servo piston is indicative of TT2 and is used to translate the acceleration cam. It integrates the temperature and speed signals. The position of the speed-set cam is also translated by the servo piston by means of a cross-link to the acceleration cam. Engine steady-state condition is a function of N2 speed, TT2, PB, and power lever position.

In the event that the primary control system malfunctions, the manual system may be engaged by operating a switch in the cockpit. It then energizes the manual transfer solenoid to close the flapper valve. The flapper valve will remain in the closed position because of residual magnetism, regardless of whether or not the solenoid is continuously energized. Servo action positions the shuttle valve to direct pump discharge pressure to the spring side of the manual and normal system transfer valve. This pressure, combined with spring pressure, positions the valve to close off the primary operating system and direct high-pressure fuel to the manual system.

Engine Fuel System

Fuel from the aircraft fuel system is supplied to the engine-driven fuel pump through the engine fuel supply hose. The engine fuel supply hose is the last link between the aircraft fuel system and the engine fuel system. Fuel from the engine-driven fuel pump is directed to the fuel control. Then, it is regulated and distributed to the combustion chambers. Components of the engine fuel system are discussed in the following paragraphs, along with operation.

Fuel Valves

Fuel valves in the engine fuel system aid in starting, stopping, and safety factors. Valves may differ slightly from engine to engine, and they may be called by different nomenclature, although they perform identical functions.

Fuel-Pressurizing Valve

The fuel-pressurizing valve is usually required on jet engines. It incorporates a duplex-type fuel nozzle to divide the flow into primary and secondary manifolds. At the low fuel flows required for starting and altitude idling, all the fuel passes through the primary line. As the fuel flow increases, the valve begins to open the main line. At maximum flow, the main line passes about 90 percent of the fuel.

Fuel-pressurizing valves will usually, through incorporation of spring-loaded inlet check valves, trap fuel forward of the manifold, giving a positive cutoff. This cutoff prevents fuel from leaking into the manifold and through the fuel nozzles, thereby eliminating after-fires and carbonization of the fuel nozzles. Carbonization occurs when low combustion chamber temperatures cause incomplete burning of the fuel.

An example of this arrangement is the fuel-pressurizing and dump valve. This valve performs two major functions, as indicated by its name. During engine operation, it divides metered fuel flow into

two properly pressurized portions, primary and secondary. During engine shutdown, it provides a dump system that connects the fuel manifolds to an overboard drain. The features of the fuel-pressurizing and dump valve are shown in *Figure 4-17*.

The fuel-pressurizing and dump valve is connected to the fuel manifold. The dump valve is composed of an inlet check valve, a 200-mesh fuel inlet screen, a pressurizing or flow-dividing valve, and a manifold dump or drain valve.

Flow Divider

A flow divider performs essentially the same function as a pressurizing valve. It is used, as the name implies, to divide flow to the duplex fuel nozzles. It is not unusual for units performing the same functions to be called different names on different engines or by different manufacturers.

Drain Valves

Drain valves drain residual fuel from the various parts of jet engines where accumulated fuel is most likely to present operating problems. The chance of a fire hazard exists in a combustion chamber if fuel accumulation occurs during shutdown. Residual lead and gum deposits from evaporated fuel cause problems in fuel manifolds and fuel nozzles.

In some instances, the function of draining fuel manifolds is accomplished by an individual unit known as a drip or dump valve. This type of valve may operate by pressure differential or by solenoid (*Figure 4-18*).

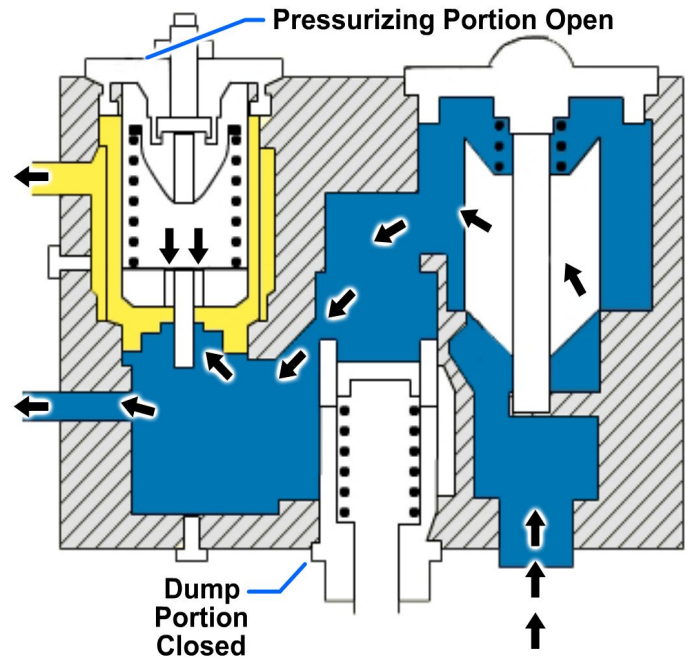


Figure 4-17 — Fuel-pressurizing and dump valve.

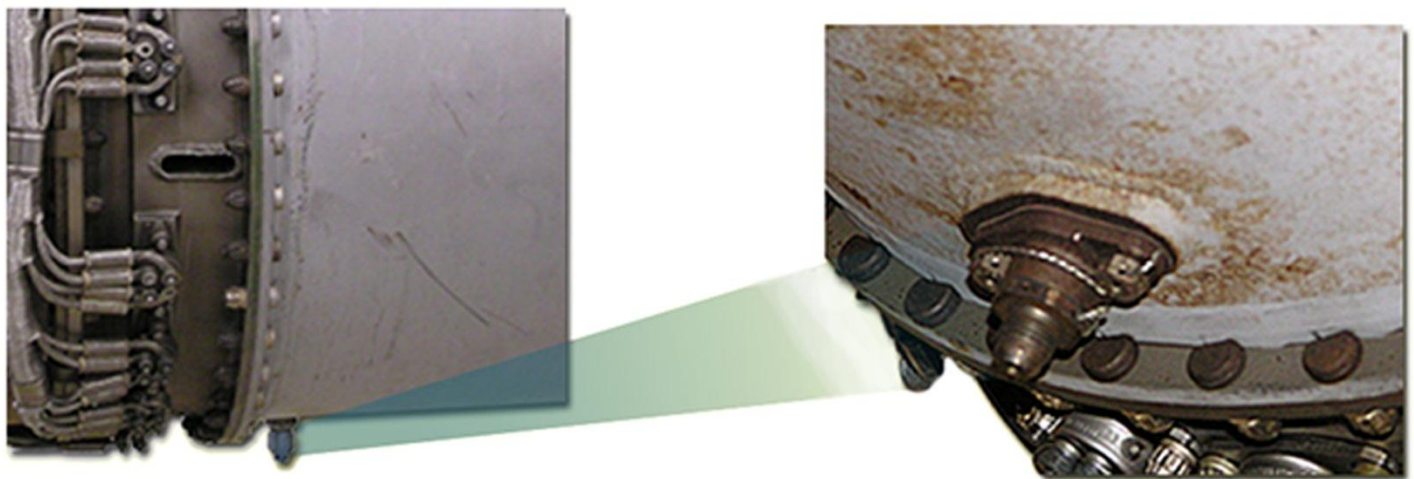


Figure 4-18 — Drain valve.

The combustion chamber drain valve drains raw fuel that accumulates in the combustion chamber. It drains after each shutdown when the engine fire has gone out, draining all fuel that collected during a

false start. The can-type combustion chambers drain fuel, by gravity, down through the flame tubes or interconnector tubes until it gathers in the lower chambers. The chambers are fitted with drain lines to the drain valve. In the basket annular-type combustion chamber, the fuel drains through the air holes in the liner and collects in a trap in the bottom of the chamber housing. A typical combustion chamber drain valve is shown in *Figure 4-18*.

When the fuel collects in the drain lines, the drain valve allows the fuel to drain when pressure in the combustion chamber manifold is reduced to near atmospheric pressure. The drain valve is spring-loaded in an open position. It is closed as pressure within the manifold and lines to the burner's increases above that of the spring tension trying to keep the valve open. It is imperative that this valve be in good working condition to drain accumulated fuel after each shutdown. Otherwise, a Hot Start during the next starting attempt or an After-fire after shutdown may occur.

FUEL SPRAY NOZZLES AND FUEL MANIFOLDS

In jet engines, the fuel spray nozzle's function is to inject fuel into the combustion area in a highly atomized, precisely patterned spray. It then burns evenly and in the shortest possible space and time. It is very important that the fuel be evenly distributed by the spray to prevent the formation of any hot spots in the combustion chambers. For this reason, the spray should be well centered in the flame area of the liners. Fuel nozzle types vary between engines; mostly fuel is sprayed into the combustion area under pressure through small orifices in the nozzles. The nozzles generally used are of the vaporizing orifice type and include the simplex and the duplex configurations. The duplex nozzle usually requires a dual manifold and a pressurizing valve or flow divider. This is to divide primary and secondary fuel flow. The simplex nozzle requires only a single manifold for proper fuel delivery.

Simplex Fuel Nozzle

The simplex fuel nozzle was the first type of nozzle used in turbojet engines, but it was replaced in most installations with the duplex nozzle, which gives better atomization at starting and idling speeds. The simplex nozzle is still being used to a limited degree. A simplex nozzle is shown in *Figure 4-19*. Each of the nozzles of the simplex type consists of a nozzle tip, an insert, and a strainer made of a fine-mesh screen and a support.

Duplex Fuel Nozzle

The duplex fuel nozzle is the type of nozzle most widely used in present-day engines. Its use requires a flow divider, which gives a desirable pattern of spray for combustion over a wide range of operating pressures. A nozzle of this type is shown in *Figure 4-20*.

The primary fuel entry line of the duplex nozzle is smaller than the secondary entry line. This feature permits fuel within the primary line to reach a comparatively high degree of pressure and atomization during starting and altitude idling conditions. The secondary fuel entry line also starts supplying fuel when engine RPM raises fuel pressure to a predetermined level—usually after engine RPM is stabilized after a start.

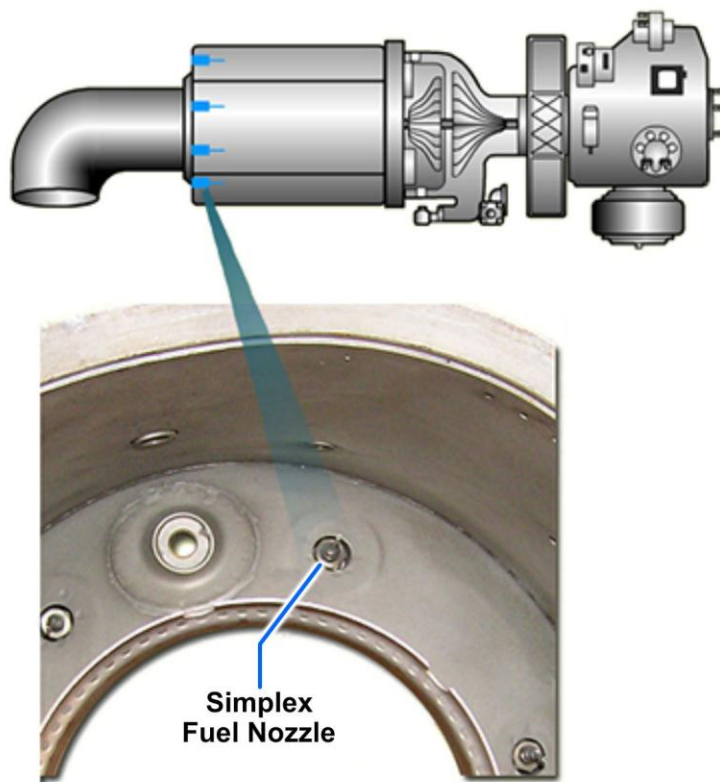


Figure 4-19 — Simplex fuel nozzle.

The single manifold of the simplex nozzle does not have the above-mentioned feature and must supply fuel under all operating conditions. Therefore, duplex nozzles provide better low-speed performance than simplex-type nozzles.

At sufficient pump outlet pressure, the pressurizing valve or flow divider allows fuel to enter the main or secondary line. The spray orifice will increase its spray angle because of the increased fuel flow and pressure. *Figure 4-20* shows the spray angle of a typical duplex nozzle.

The duplex nozzle may be represented in many configurations, depending upon the type of combustion chamber installation. Therefore, the nozzle parts will vary between duplex nozzles of various engines. *Figure 4-21* shows a duplex and simplex nozzle spray patterns.

Fuel Selectors

Fuel selectors are designed to control the flow of fuel in all aircraft fuel systems. Construction and flow control are similar for most valves used in modern aircraft. The construction of the selector is basically a ported body housing a rotor. Control for these valves can be manual or electrical. Graphite sealing discs are arranged on the rotor so that the ports are sealed or opened in sequence by rotation of the rotor. The ends of the rotor bores in the body are closed by top and bottom caps with O-rings. The rotor stem extends through the top cap with an O-ring seal to prevent leakage. This stem is rotated by an electrical actuator assembly or by either a handle or a yoke for manual actuation. Where manual actuation is used, the top cap incorporates a spring-loaded ball and a stop pin to index the various rotor positions.

The motor-operated gate valve provides a means of controlling the flow of fuel to various parts of the fuel system. It is designed as an open-and-closed valve and is motor operated. The gate or sliding portion of the valve slides between O-rings or other suitable sealing devices in the body of the valve. On some models, an indicator is attached to the gate to show the position of the valve while installed in the system. Some of these valves have a cable and drum between the motor and valve mechanism to provide for manual override. This mechanism may be used if the electrical motor is defective.

DUPLEX FUEL NOZZLES



Figure 4-20 — Duplex fuel nozzle.

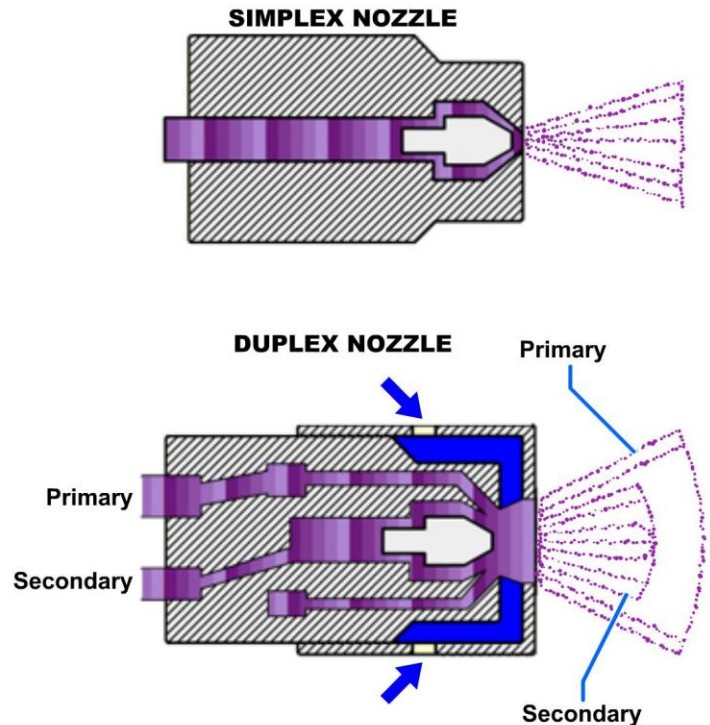


Figure 4-21 — Simplex/Duplex nozzle spray pattern.

Figure 4-22 shows a motor-operated gate valve with a manual-override mechanism. The installation and rigging of motor-operated gate valves are similar to those of the fuel selector valves. However, the motor-operated gate valves that have no manual override require no adjustment on installation.

Filters

The three most common types of filters in use are the micro-filter, the wafer screen filter, and the plain screen mesh filter. The individual use of each of these filters is dictated by the filtering treatment required at a particular location.

Micro-Filter

The micro-filter (Figure 4-23) has the greatest filtering action of any present-day filter, and it is rated in microns. (A micron is a thousandth part of 1 millimeter.) The porous cellulose material, frequently used in the construction of filter cartridges, removes foreign matter measuring 10 to 25 microns. The minute openings make this type of filter susceptible to clogging; therefore, a bypass valve is a necessary safety factor.

Since the micro-filter does such a thorough job of removing foreign matter, it is especially valuable between the fuel tank and engine. The cellulose material also absorbs water, preventing it from passing through the pumps. If water does seep through the filter—and this happens occasionally when filter elements become saturated with water—the water can and does quickly damage the working elements of the fuel pump and control units. These elements depend solely on the service fuel for their lubrication. To reduce water damage to pumps and control units, periodic servicing and replacement of filter elements are imperative.

The most widely used filters are the 200-mesh and the 35-micron filters. They are used in fuel pumps and fuel controls and between the fuel pump and fuel control where removal of microscopic particles is needed. These filters, usually made of a fine-mesh steel wire, are a series of layers of wire.

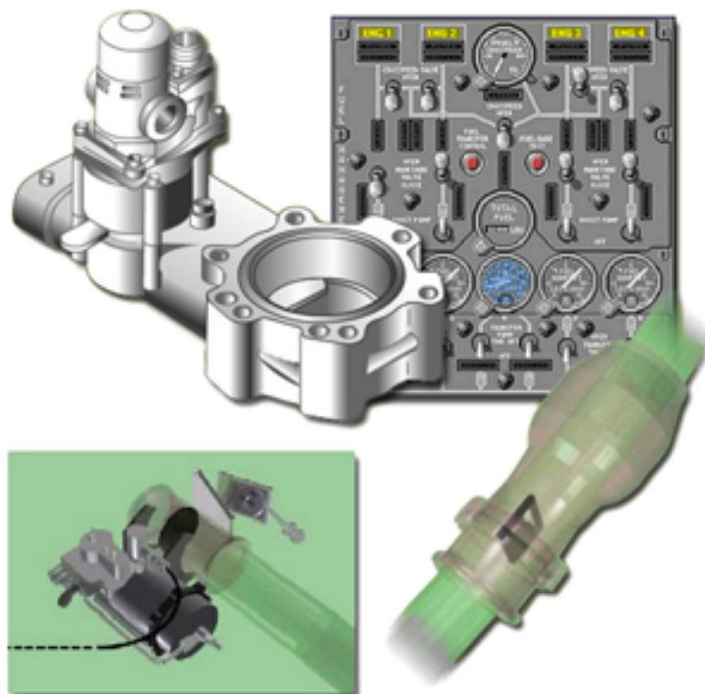


Figure 4-22 — Motor-operated gate valve and override.

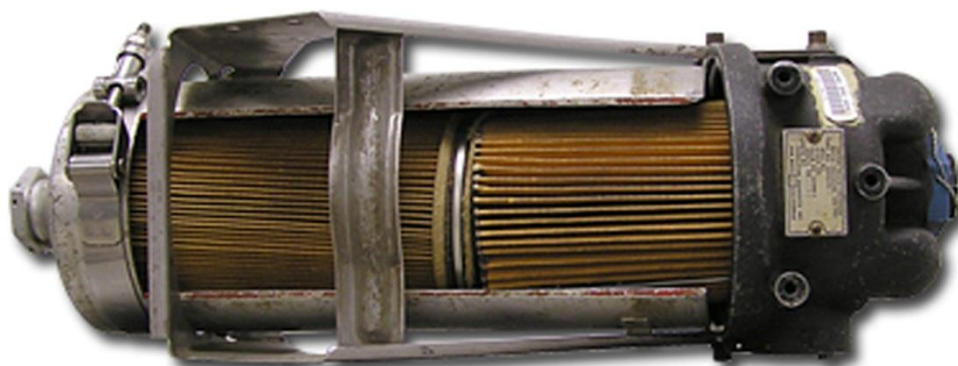


Figure 4-23 — Aircraft fuel filter (micro-filter).

Wafer Screen Filter

The wafer screen filter, shown in *Figure 4-24*, has a replacement element made of layers of screen discs of bronze, brass, and steel. This type of filter can remove minute particles. It also has the strength to withstand high pressure.

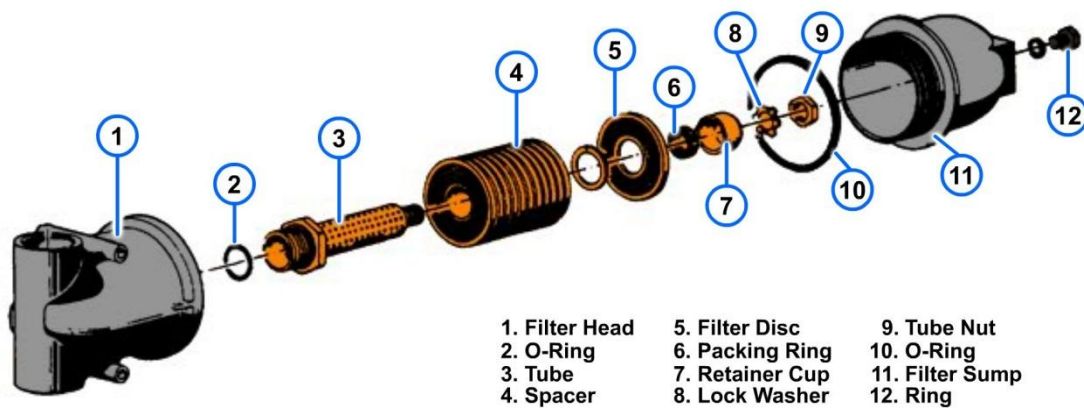


Figure 4-24 — Wafer screen filter.

Plain Screen Mesh Filter

The plain screen mesh filter is the most common type. It has long been used in internal combustion engines of all types for fuel and oil strainers. In present-day turbojet engines, it is used in units in which filtering action is not so critical, such as in fuel lines before the high-pressure pump filters. The mesh size of this type of filter varies greatly according to the purpose for which it is used.

Engine-Driven Pumps

Engine-driven fuel pumps deliver a continuous supply of fuel at the proper pressure during operation of the aircraft engine. The engine-driven fuel pumps must be capable of delivering the maximum needed flow at high pressure to obtain satisfactory nozzle spray and accurate fuel regulation.

Fuel pumps for engines are generally positive displacement gear, piston, or rotary vane types. The term positive displacement means that the pump will supply a fixed quantity of fuel to the engine.

These pump types may be divided into two groups—constant displacement and variable displacement. Their use depends on the fuel control system used to regulate the flow of fuel to the fuel controls.

Gear-Type Pumps

Gear-type pumps have straight-line flow characteristics. However, fuel requirements vary with flight or ambient air conditions. Hence, a pump of adequate capacity at all engine operating conditions will have excess capacity over most of the range of operation. This characteristic requires the use of a pressure relief valve for disposing excess fuel. A constant-displacement gear-type pump is illustrated in *Figure 4-25*.

Variable-Displacement Pump

The variable-displacement pump system differs from the constant-displacement pump system. Pump displacement is changed to meet varying fuel flow requirements; that is, the amount of fuel that is discharged from the pump can be made to vary at any one speed. With a pump of variable flow, the applicable fuel control unit can automatically and accurately regulate the pump pressure and delivery to the engine.

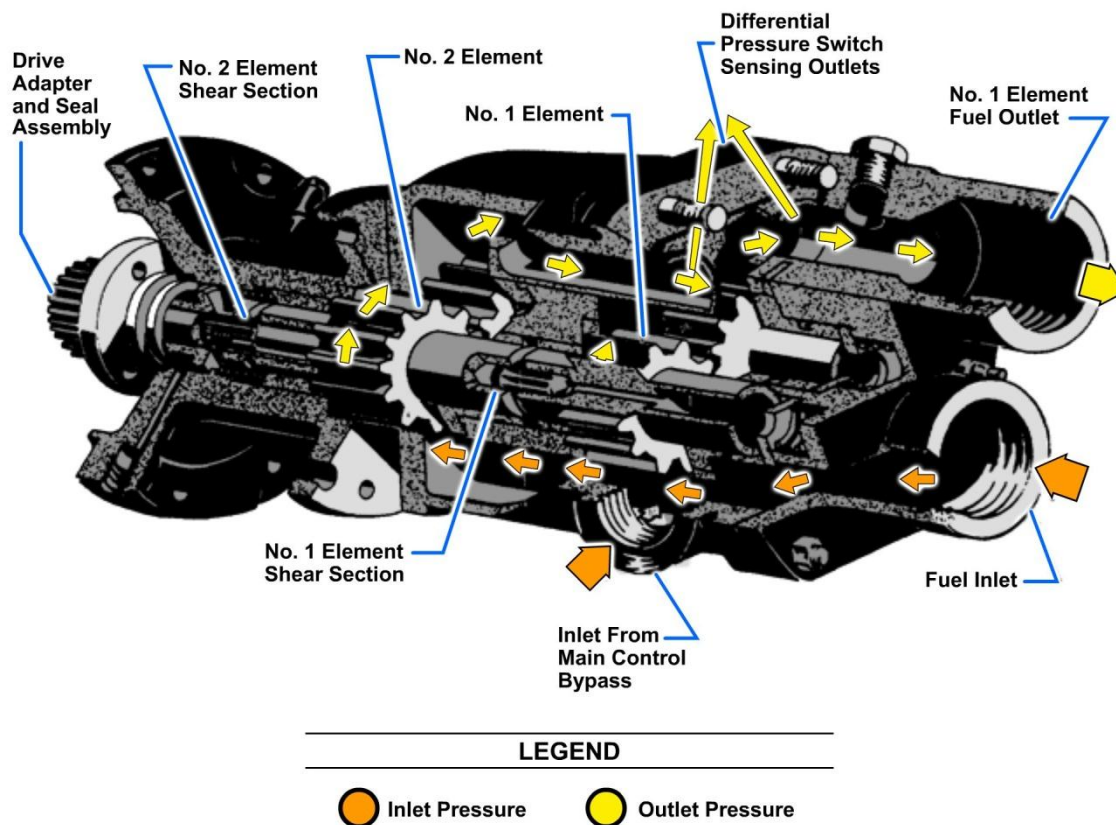


Figure 4-25 — Cutaway view of a dual-element gear-type pump.

Where variable-displacement pumps are installed, two similar pumps are provided, connected in parallel. Either pump can carry the load if the other fails during normal parallel operations. At times, one pump is not enough to meet power requirements. Pump duplication increases safety in operation, especially in takeoffs and landings.

The positive-displacement, variable-stroke type of pump incorporates a rotor, a piston, a maximum speed governor, and a relief valve mechanism. A variable-stroke pump is shown in *Figure 4-26*.

An engine-driven rotary-vane type of pump

Figure 4-27 shows the engine-driven fuel pump is turned by a gear train in the accessory section of the engine. Constant pressure is maintained by a spring-loaded pressure relief valve.

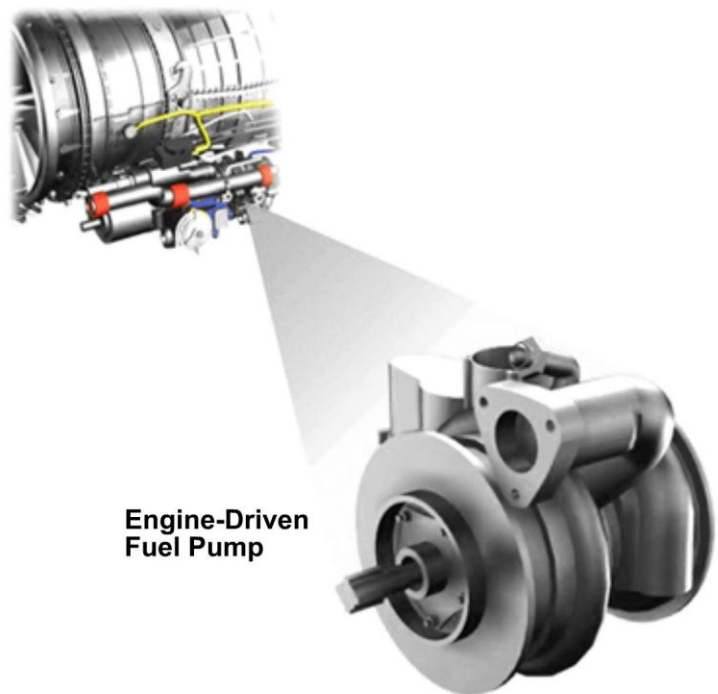


Figure 4-26 — Variable-displacement fuel pump.

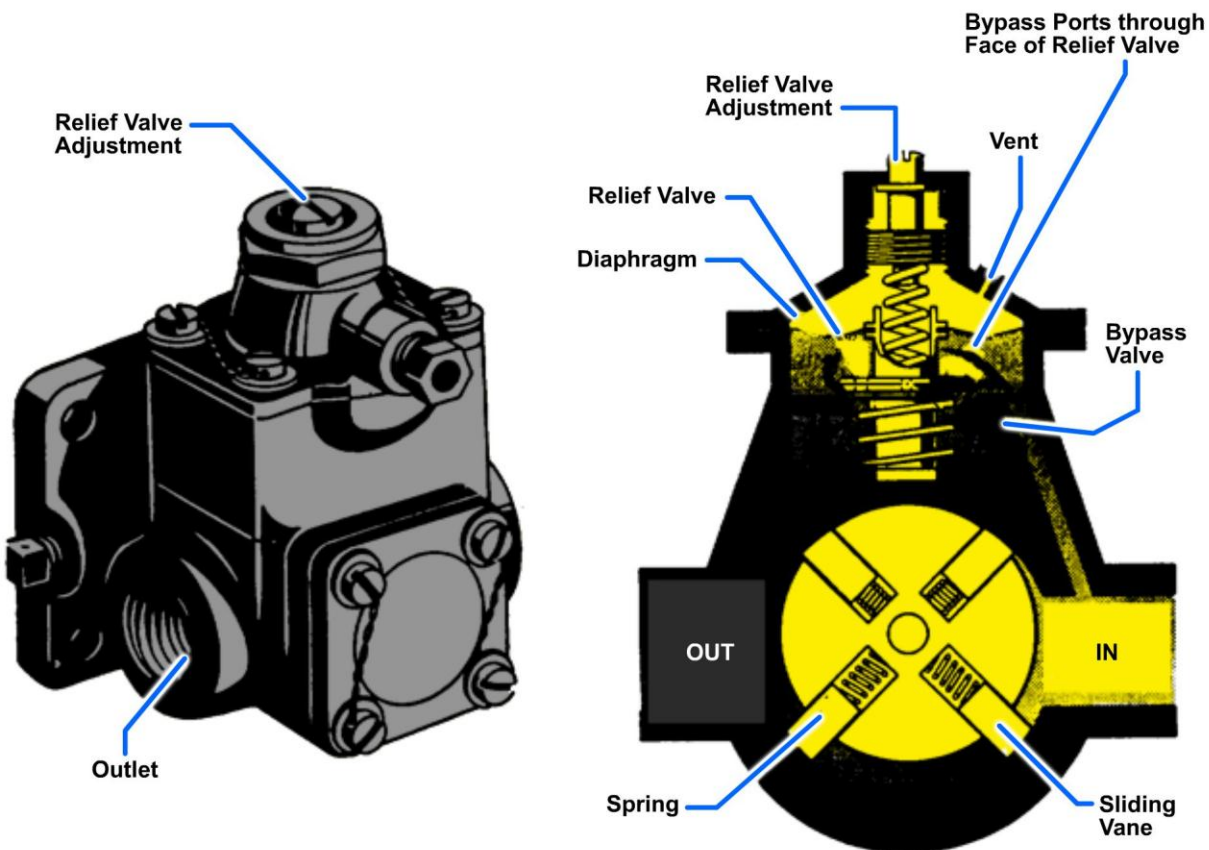


Figure 4-27 — Engine-driven, rotary-vane type of pump.

Fuel is bypassed before the engine is started, when the engine-driven fuel pump is not turning. An auxiliary fuel booster pump delivers fuel under pressure. Fuel pumped by the booster pump will pass through the stationary engine-driven pump; it is necessary to incorporate a bypass valve in the engine-driven pump. Both the fuel pressure relief valve and the bypass valve may be contained in the same mechanism.

Refer to Fluid Power, Naval Education and Training (NAVEDTRA 12964), for a detailed description of the principles of operation of the various types of pumps.

Fuel System Maintenance

The most important consideration when working on any fuel system maintenance task is the safety of personnel. Aircraft fuels are extremely hazardous because of the explosive and toxic dangers that are always present. The health hazards associated with aviation fuels (breathing of vapors, spilling on skin or in the eyes, or swallowing) must be avoided. It is not possible to describe all the potential problems or dangers that may arise in the performance of any type of fuel system maintenance. As an AD, it is your responsibility to be thoroughly aware of all the safety practices and procedures that must be strictly followed.

Fuel vapors are very harmful when they are inhaled. It takes only a very small percentage of these vapors to cause very serious effects on personnel. Fuel vapors are heavier than air and will collect in the lower areas of the fuel tank/cell. Unless these vapors are removed by the use of forced-air ventilation, they can present a hazard for an indefinite period. Personnel should avoid inhaling these vapors and should always be alert to recognize the first signs of the toxic effect of breathing these vapors. The symptoms of inhalation include nausea, dizziness, and headaches. If a person should experience these symptoms during fuel system maintenance, immediately stop and move the individual to a source of fresh air. If the individual appears to be completely overcome by the vapors, get prompt medical attention. When working with any type of aviation fuel, personnel should always avoid prolonged contact with the fuel. If a person's clothing becomes saturated, he or she should

remove them as soon as possible and wash off the affected areas with soap and water. It is essential to know the location of approved eyewash stations and how they are used.

Fuel Leak Analysis

In modern aircraft, the fuel systems are designed to operate satisfactorily under all conditions, such as acceleration and deceleration, temperature, pressure, and flight attitudes. However, no matter how good the design, the fuel system will not function as designed if it is not maintained properly. A significant number of fuel leaks can be attributed to incorrect maintenance procedures used in installing fuel tanks/cells, components, lines, and fittings. By referring to the applicable aircraft maintenance manual and learning the general procedures discussed in this section, you will have little difficulty in locating the source of an aircraft fuel leak.

Location of Leaks

Leak source analysis is the process of using the aircraft maintenance manual, fuel system schematic diagrams, installation diagrams, and troubleshooting charts. The most common method of analysis is the methodical process of elimination to isolate the source of a fuel leak. In addition, you should first screen the Aircraft Discrepancy Book (ADB) to possibly save many man-hours looking for a leak. The review of a prior fuel system discrepancy may reveal that spilled fuel was not properly cleaned or components were improperly installed. Never assume that the first leak you find is the only leak in the system. Completely check and test the entire fuel system as directed by the applicable maintenance manual.

Severe leaks in the tank/cell drain system are caused by a rupture, loose interconnecting fittings, or cut or distorted O-rings. These leaks can usually be detected immediately after refueling the tank/cell. Dripping leaks are usually found at fuel system plumbing connections. Leaks are caused by undertorquing or overtightening lines, hoses, or fittings. Never assume that the leaks can usually be detected by operating the fuel transfer pump/boost pump to pressurize the fuel system. Intermittent leaks are most often caused by loose cell fittings or connections. Fuel quantity probes that are mounted on the high side of the tank/cell usually leak when the aircraft is in a climb or descent. In some cases, servicing the fuel tank/cell to capacity may aid in locating these types of leaks.

Fuel Dye to Locate Leaks

The use of colored dye to detect hidden fuel leaks is a practical means you can use in fuel system leak source analysis. The dyed fuel will leave a stain that can be traced back to the source of the fuel leak. (The use of dyed fuel is particularly useful in checking for leakage, especially near the engine's hot section where high temperatures prevent the fuel from leaving a wet spot.) When aid in the troubleshooting of fuel leaks, a logbook entry in the miscellaneous history section of the aircraft logbook should be made. The fuel color, resulting from the use of dye, can be disregarded in fuel sample analysis. Additionally, a similar entry should be made for aircraft serviced with dyed fuel. You should always select a dye color that will provide the highest visibility in the area where the leaking fuel is suspected. The appropriate information for ordering the dye can be found in NA 01-1A-35, Appendix A. The addition of unmixed dye to empty fuel systems should always be avoided because it can cause deterioration of the cell lining. The dye should always be added to the fuel, rather than fuel added to the dye. For information and correct procedures for the use of dyes in fuel system leak detection, refer to the proper maintenance manual.

NOTE

Do not return the colored fuel to bulk tanks or trucks, as there is sufficient dye in a 2-ounce can to color 10,000 gallons of fuel.

A very small leak may require an hour or more for color to appear. If no coloration appears after a reasonable waiting period, fill the tank to the two-third level. Add another 2 ounces of dye for each 100 gallons of fuel added. Wait as before. Again, if no coloration appears after a reasonable waiting period, repeat the process at full tank capacity. The dye will leave a stain, which can be traced to the source of the leak even after the tank unit has been emptied.

The colored fuel is suitable for use in aircraft engines since the dye does not have a harmful effect on the usefulness of the fuel. If you do not empty the aircraft fuel tank to repair the leak, the dyed fuel can be burned in the engine. Fuel from tanks tested with dye will remain colored until the tanks have been filled and emptied several times. Stains on the aircraft structure or clothing can be removed with aircraft fuel or an approved dry cleaning solvent.

NOTE

Never use more than one 2-ounce can of dye to each 100 gallons of fuel.

Rigging and Adjusting

This section covers some of the basic inspections and procedures to be used in the rigging and adjusting of fuel controls, fuel selectors, and fuel shutoff valves. Inspect all bell cranks and rod bearings for looseness, cracks, and corrosion. Particular attention should be given to the rod and bell cranks where the bearing is staked. This area is subject to stress cracking and corrosion. The adjustable rod ends should be inspected for damaged threads and the number of threads remaining after final adjustment. The drums should be inspected for wear, and the cable guards should be checked for proper positioning. If the cables have been loosened, the tension should be set.

While rigging the fuel selector, power control, and shutoff valve linkages, you should follow the step-by-step procedures for the particular aircraft model being rigged. The cables should be rigged with the proper tension with the rigging pins installed. The pins should be removed without any binding; if they are hard to remove, the cables are not rigged properly and should be rechecked. The power lever should have the proper cushion at the IDLE and FULL POWER positions. The pointers or indicators on the fuel control should be within limits. Also, the fuel selectors must be rigged so that they have the proper travel and will not restrict the fuel flow to the engines. You must take all of these things into consideration while rigging or adjusting the parts of the fuel system.

Rigging the fuel control of a turbojet engine is an exacting job. The power lever assembly and its related linkage provide manual control of the engine thrust. The power lever assembly is located in the cockpit, and its related mechanical linkage connects it with the fuel control unit of the engine. Positioning the power lever at any selected setting mechanically actuates the linkage to the fuel control unit, resulting in the desired engine thrust. One of the common types of flight controls is the cable and rod system. In this system, you will find bell cranks, push-pull rods, drums, fairleads, flexible cables, and sheaves. All of these parts make up the control system and must be adjusted or rigged from time to time. The most difficult type of rigging is to rig on the multi-engine jet aircraft, the power levers must be together or married at all power settings.

The rigging of the proper control cables and push-pull rods is usually accomplished at the factory, and no rigging is required except when a part has been changed. The control system that would concern you the most is at the fuel control and throttle quadrant (*Figure 4-28*).

Before starting the adjustment of the power controls at the engine, you should make sure that the power lever is free from binding. Use a tensiometer to ensure correct cable tension. If the power controls do not have full throw or are binding, the entire system should be checked and the discrepancies repaired before adjusting the power control system. Low cable tension may cause sluggishness or insufficient travel of the control. High cable tension may result in damaged pulleys, bell cranks, and cables, or vibrations in the controls.

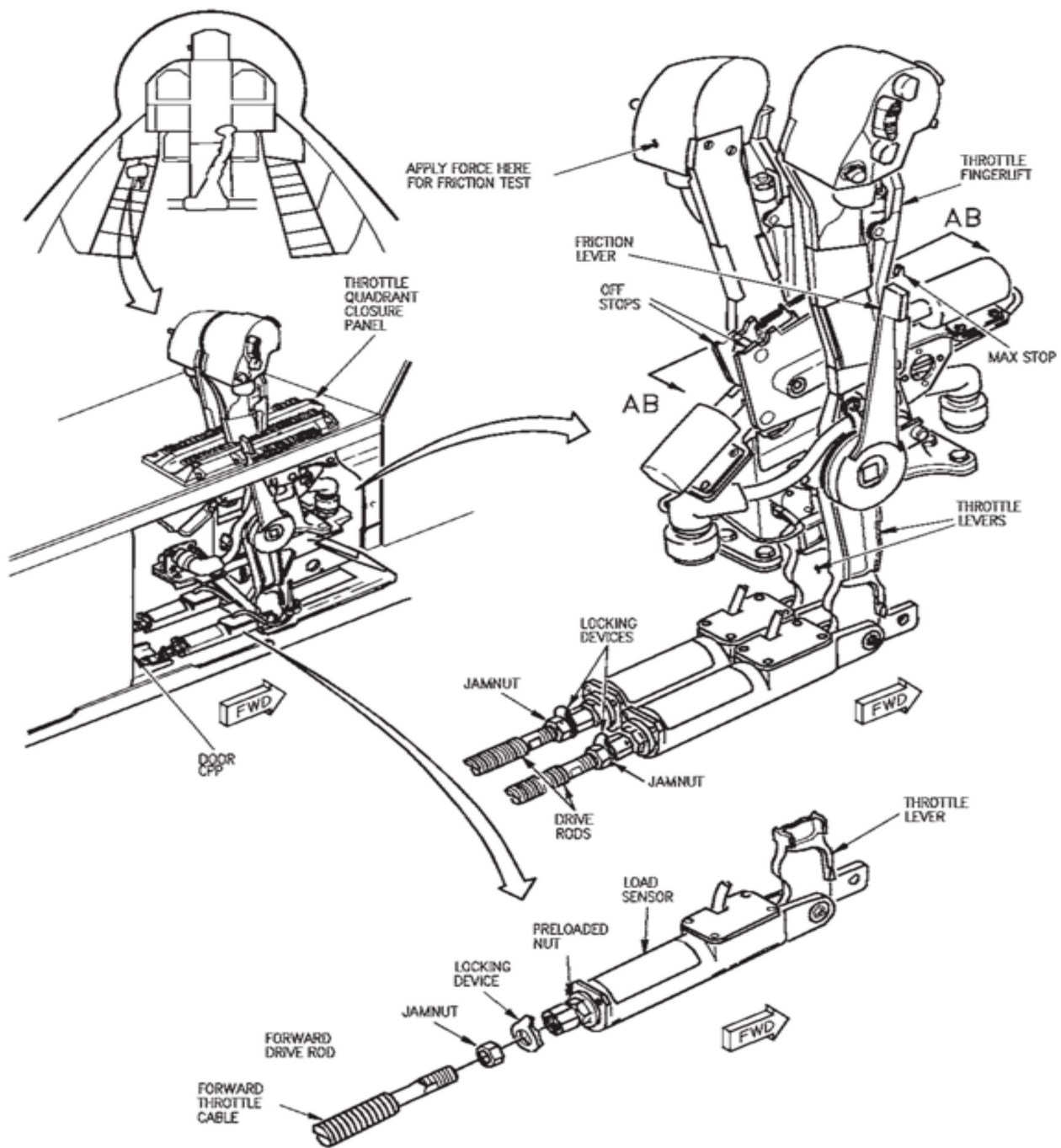


Figure 4-28 — Engine power control rigging.

End of Chapter 4

Jet Aircraft Fuel and Fuel Systems

Review Questions

- 4-1. What does volatility measure?
- A. The ability of a liquid to convert to a vaporous state
 - B. The ability of a vapor to convert to a vaporous state
 - C. The ability of a liquid to convert to a liquid state
 - D. The ability of a vapor to convert to a liquid state
- 4-2. Flashpoint is the temperature at which what substance vaporizes enough to ignite from an outside heat source?
- A. Oil
 - B. Water
 - C. Fuel
 - D. Hydraulic fluid
- 4-3. Viscosity is the internal resistance that prevents the flow of a substance in what state?
- A. Solid
 - B. Liquid
 - C. Gas
 - D. Vapor
- 4-4. What is the NATO code for JP- 5?
- A. F-40
 - B. F-42
 - C. F-43
 - D. F-44
- 4-5. A-1 commercial fuel carries what NATO designation?
- A. F-34
 - B. F-40
 - C. F-44
 - D. F-50
- 4-6. Specified by your Maintenance Requirement Card (MRC) deck, fuel samples are taken from what drain point on the aircraft?
- A. High point drains
 - B. Side point drain
 - C. Nose point drain
 - D. Low point drain

- 4-7. How many primary layers of materials are used in the construction of a self-sealing cell?
- A. One
 - B. Four
 - C. Six
 - D. Eight
- 4-8. What are the two types of bladder fuel cells?
- A. Plastic, leather
 - B. Plastic, rubber
 - C. Nylon, plastic
 - D. Rubber, nylon
- 4-9. Where are check valves installed?
- A. Wherever fuel needs to be checked
 - B. Wherever fuel flow is recommended
 - C. Wherever fuel flow in one direction only is required
 - D. Wherever fuel flow in any direction is required
- 4-10. What fuel nozzle is the most widely used in present day engines?
- A. Duplex
 - B. Simplex
 - C. Triplex
 - D. Quadplex
- 4-11. The purpose of a flow divider is to divide fuel flow to what type of fuel nozzle?
- A. Simplex fuel nozzle
 - B. Duplex fuel nozzle
 - C. Triplex fuel nozzle
 - D. Quadplex fuel nozzle
- 4-12. What are the three most common fuel filters used in jet engines today?
- A. Micro, wafer, waffle mesh
 - B. Micro, wafer, plain mesh
 - C. Screen mesh, waffle, wafer
 - D. Wafer, screen mesh, micron
- 4-13. The purpose of the fuel pump is to deliver a continuous supply of what substance at the proper pressure?
- A. Air
 - B. Oil
 - C. Water
 - D. JP-5

4-14. What is the most common fuel used in Naval Aviation?

- A. JP 2
- B. JP 3
- C. JP 4
- D. JP 5

4-15. Which of the following is a purpose for defueling an aircraft?

- A. To check the aircraft hydraulics
- B. To tow the aircraft
- C. To repair the aircraft's fuel cell
- D. To complete the aircraft's daily inspection

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