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Aircraft Fuel Systems Craftsman

Volume 2. Fuel Subsystems and Components

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Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For Weighted Airman Promotion System (WAPS) Specialty Knowledge Test (SKT) purposes, the examinee should check the *Enlisted Promotions References and Requirements Catalog* to determine the correct references to study.

AS A FUEL SYSTEMS CRAFTSMAN, it is important that you understand the theory of operation of fuel systems or subsystems, particularly on the aircraft to which you are assigned. Any decent mechanic can remove and replace a component; however, having the knowledge of how the components function within the systems and how the systems operate, can usually save you from replacing a component that may be perfectly serviceable. Do you know someone in your shop that other people seem to go to when they are having difficulty isolating a problem on an aircraft? This individual probably knows the fuel system inside and out, yet this information did not simply fall into his or her lap. This craftsman probably devoted many hours to studying the aircraft technical data, and more likely, volunteered for work on a regular basis to learn quickly. The challenge for you as a journeyman and future craftsman is this: learn all you possibly can about aircraft fuel systems. If you do, then you will become the “someone” to whom others come to for assistance.

This second volume of career development course (CDC) 2A674, *Aircraft Fuel Systems Craftsman*, describes various fuel subsystems and components found on different types of aircraft. Considering the number and different types of airframes within your Air Force specialty code (AFSC), we will refer to representative systems to convey an overview of their operations; while systems on each type of airframe may work a bit differently than on other airframes, they each possess many similar general characteristics. As a result, a good understanding of representative systems will help you as you gain experience in your specific airframe spelled out in the Career Field Education and Training Plan (CFETP).

Unit 1 covers engine feed on the F–16 fighter and KC–135 tanker, as well as the crossfeed systems on the KC–135.

Unit 2 deals with the fuel transfer systems on the F–16 fighter and C–5 Galaxy, as well as the jettison systems on the C–5 Galaxy and bomber aircraft. While the fuel transfer system provides the capability to transfer fuel from one storage area to another on the same aircraft, the jettison system provides for fuel to be dumped or jettisoned during emergency situations.

Unit 3 addresses the ground refueling and defueling systems on the F–16 fighter and the C–5 Galaxy. It also addresses the aerial refueling system on bomber aircraft. As the name implies, a ground refueling and defueling system permits an aircraft to receive fuel from a ground fuel truck, as well as return the fuel to the same type of truck. Aerial refueling, on the other hand, allows the aircraft to receive fuel while in flight from a tanker aircraft.

Unit 4 considers the tank scavenge and manifold scavenge systems, which are both critical to aircraft flight. For example, a tank scavenge system is designed to ensure continual flow of fuel to the aircraft engines and to expedite the removal of water from low areas of the fuel tanks. The manifold scavenge system, on the other hand, is used to expel unusable fuel from a manifold and route it to a fuel tank, which allows the fuel transfer systems we discuss in unit 2 to properly perform their functions.

Unit 5 discusses a cargo aircraft vent system and a fighter aircraft pressurization system. Both of these systems are crucial to the safe operation of an aircraft. For example, a vent system prevents over pressurization and rupture of fuel tanks. On the other hand, a pressurization system helps to keep fuel from boiling at high altitudes, provides for fuel to be “pushed” along during fuel transfers, and prevents the rupture or collapse of fuel cells.

Unit 6 covers the F–16 fighter fuel quantity indicating system, and provides an overview of the B–1B fuel heat exchanger system.

Foldouts 1 through 8 are provided to enhance this CDC. Whenever the text refers to one of the foldouts, please turn to that foldout.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information provided in this volume.

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For Guard and Reserve personnel, this volume is valued at 12 hours and 3 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Please read the menu for Unit 1 and begin ➔

Unit 1. Engine Feed and Crossfeed Systems

THIS IS THE FIRST UNIT of the second volume of career development course (CDC) 2A674, *Aircraft Fuel Systems Craftsman.* As you can see by the title, this unit deals with engine feed and crossfeed systems. It would be impractical and beyond the scope of this CDC to cover all the fuel systems on all the aircraft in the Air Force inventory; however, the information that we present can be applied (in the most part) to just about any aircraft using a fuel system. As representative examples, we use four primary aircraft during our discussions. We will use the F–16 aircraft for presenting fighter aircraft fuel system information. For cargo aircraft, we will refer to the C–5 aircraft. The B–1B Bomber will be the representative system for our bomber aircraft. Finally, for the tanker aircraft, our reference will be the KC–135. Although the size and function of different aircraft can vary from one to another, the fuel systems basically function the same.

1–1. Engine Feed Systems

Just as the human heart is responsible for pumping vital fluids through the body, the engine feed (ENG FEED) system is responsible for routing vital fluids to the engine(s) of an aircraft. The engine feed system is considered the “heart” of the fuel system. Without it, the aircraft is not capable of flight.

In this section, we begin to lay the firm foundation for all future discussions about aircraft fuel systems. The following are the six major subject areas as they apply to the engine feed system:

- Operational theory of the engine feed system on a single-engine fighter aircraft.
- Operational theory of the engine feed system on a multi-engine tanker aircraft.
- Pumps used in a typical engine feed system.
- Check valves.
- Shutoff valves.
- Troubleshooting the fighter engine feed system.

201. Operational theory of the engine feed system on a single-engine fighter aircraft

At the present time, the F–16 is the most widely used single-engine fighter aircraft in the Air Force inventory. Refer to foldout (FO) 1 during this lesson. The engine feed system (FO 1, fig. 6) provides adequate filtered fuel to the engine during all operating flight conditions. When the ENG FEED selector switch is in the NORM position, boost pumps in the forward (FWD) and aft reservoir tanks pump the fuel through the engine feed line to the fuel-flow proportioner (FFP). After fuel flows through the FFP, a small amount is routed to the engine electronic control (EEC) for cooling purposes and then returns to the reservoir tanks. The remainder of the fuel passes through a heat exchanger for cooling hydraulic systems A and B, the electric generator, and the accessory drive gearbox/jet fuel starter. From there, fuel flows through an electrically operated shutoff valve, which controls the flow of fuel to the engine. Fuel flows through the fuel-flow transmitter to operate the fuel-flow indicator, through a fuel filter and on to the engine for consumption. With this overview in mind, let us look at the 10 major components in the engine feed system. They are as follows:

- Engine feed switch.
- Boost pumps.
- Crossfeed valve.
- FFP.
- Jet fuel starter (JFS).
- EEC fuel cooling shutoff valve (SOV).
- Heat exchanger.
- Main engine fuel SOV.
- Fuel-flow transmitter.
- Ground fuel pump advisory panel.

ENGINE FEED switch (ENG FEED)

The ENG FEED switch is a four-position rotary switch, with the following positions:

- OFF.
- NORMAL.
- AFT.
- FORWARD.

The switch allows you to select which fuel pumps you want to operate. If you turn the switch to the NORMAL position, all of the fuel pumps will operate. This is the position that is normally selected during flight. If you turn the switch to the AFT or FORWARD position, only the pumps in the aft or FWD tanks will operate depending on which position you have selected. This can be quite handy when transferring fuel or correcting a fuel imbalance, as we will discuss in more detail later.

Boost pumps

Refer to FO 1, figure 6. Starting at the reservoir tanks, there are two boost pumps in the FWD reservoir tank and one boost pump in the aft reservoir tank. In the FWD reservoir tank, one boost pump is located on the bottom of the tank for normal engine feed. The other boost pump is located near the top of the tank to ensure that fuel is supplied to the engine when the aircraft is in inverted flight. The aft reservoir tank has one boost pump located at the bottom of the tank for normal engine feed. All three boost pumps are dual-impeller, electrically driven pumps that supply a positive flow of fuel to the engine feed manifold.

A pressure switch is installed on each boost pump. This switch lights up an indicator light on the ground fuel pump advisory panel to let the ground crew know that the boost pumps are in operation. As fuel is pumped out of the reservoir tanks, the fuel enters the engine feed manifold. Using figure 6 on FO 1, follow this manifold as it leaves the tank. The first components you see are a fuel strainer and a boost pump line which supply the fuel bleed pressure to operate the turbine pumps and the scavenge ejector pumps. The fuel that is used to operate these pumps eventually returns to the reservoir tanks. Now follow the engine feed manifold over to the crossfeed valve.

Crossfeed valve

The crossfeed valve is a fuel pressure-operated gate valve. The fuel pressure that operates the valve is controlled by the crossfeed control solenoid valve that diverts fuel pressure to the crossfeed valve poppet, allowing the valve to open. The solenoid valve is electrically controlled by the engine feed switch on the fuel control panel. The crossfeed valve *opens* when the engine feed switch is placed to the FWD or AFT position. The valve is used for single-tank feed of the engine and for fuel transfer.

Fuel-flow proportioner

The FFP is located in the A-I tank and ensures that fuel flows equally from the two reservoir tanks. This component consists of twin constant-displacement pumps on a common shaft, driven by hydraulic power from hydraulic system A. Fuel is supplied to the inlet ports of the FFP by the pumps in the reservoir tanks. Regardless of the difference in pressure or flow from the reservoir tanks, the output pressure from the FFP is 40–50 pounds per square inch gauge (psig). A pressure switch is installed to sense the differential pressure between the aft reservoir and the output side of the FFP and sends a signal to an indicator light on the ground fuel pump advisory panel.

If the pump in the FFP malfunctions, an internal bypass system within the FFP allows fuel to flow to the engine. As fuel leaves the FFP, the two manifolds join to make one common manifold. The next component down the engine feed line is the defuel receptacle, which is not used for engine feed, but is discussed later in a separate unit. Now, follow the engine feed manifold down to the line that goes to the jet fuel starter.

Jet fuel starter

As the name implies, the main purpose of the JFS is to supply fuel to the engine for starting. The JFS is a combustion-driven turbine, which receives its fuel supply from the engine feed manifold. It is operated by a switch in the cockpit.

Engine electronic control fuel cooling shutoff valve

The EEC SOV is a dual-operated, gate-type valve. The valve allows a small amount of fuel to be routed through the EEC for cooling of the electronic equipment and is then routed back to the reservoir tanks. The EEC shutoff valve is controlled by the MASTER switch located on the pilot’s left console. The next component down the engine feed manifold is the heat exchanger.

Heat exchanger

The main purpose of the heat exchanger is to cool the oils of the hydraulic systems, the integrated drive electrical generator, and the oil for the accessory drive gearbox and jet fuel starter. A thermally actuated valve in the heat exchanger outlet prevents the fuel from exceeding 200 degrees Fahrenheit (° F). The valve actually opens at 185° F to allow fuel to return to the tanks, which increases fuel flow through the heat exchanger and prevents the temperature of the fuel in the heat exchanger from exceeding 200° F. Just downstream of the heat exchanger is the engine-fuel shutoff valve.

Main engine-fuel shutoff valve

This shutoff valve is a butterfly-type valve. It is electrically controlled by the MASTER switch on the fuel panel and manually controlled by a handle. The purpose of the main shutoff valve is to control the flow of fuel to the engine. When the MASTER switch is OFF, the shutoff valve is CLOSED, stopping the flow of fuel to the engine. With the MASTER switch ON, the shutoff valve is OPEN, allowing fuel flow to the next component, the fuel-flow transmitter.

Fuel-flow transmitter

The fuel-flow transmitter is a standard-type transmitter that sends a signal to the fuel-flow indicator on the pilot’s instrument panel. From there, the fuel flows to the engine for consumption. Earlier, we stated that the F–16 has two separate fuel systems. Each system supplies fuel through the engine feed manifold to the FFP.

Fuel quantity gauge

The fuel quantity gauge gives the pilot or maintenance personnel the ability to see how much fuel is onboard the aircraft. It has two pointers, one for the aft system and one for the forward system that shows the amount of fuel contained in each system. The gauge also has a totalizer, which shows the amount of the two systems added together. This number is found at the bottom of the gauge.

Fuel imbalance

Think back in the previous paragraph when we were discussing the fuel quantity gauge. Aside from the functions that we already discussed, this gauge gives the pilots another useful indication: it provides them with the ability to know when they are in danger of getting a fuel imbalance. A fuel imbalance occurs when there is too little or too much fuel in either the forward or aft system. How do you think you could correct a fuel imbalance caused by having too much fuel in the forward system? Do you remember our discussion of the ENG FEED switch? By placing the ENG FEED switch to the FWD position, only the pumps in the forward system will operate. The crossfeed valve will also open, allowing fuel from the forward system to be transferred to the aft system to correct the fuel imbalance.

When the fuel imbalance is corrected, the ENG FEED switch is moved to the NORMAL position. The boost pump in the aft reservoir tank and the transfer pump in the A–I tank starts. At the same time, the crossfeed solenoid valve de-energizes, allowing the crossfeed valve to CLOSE. Now, normal engine feed will start from both reservoir tanks.

Ground fuel pump advisory panel

As we stated earlier, there is a ground fuel pump advisory panel located on the bottom centerline structure of the aircraft near the forward end of the right main landing gear door (FO 1, fig. 2). The panel contains seven lights and one switch. An indicator light marked FFP lights up when the pressure from the FFP is correct. The other lights (marked 1–5) are for each of the five electric fuselage pumps.

- Light 1 is for the F–l transfer pump.
- Light 2 is for the aft reservoir tank boost pump.
- Light 3 is for the aft reservoir tank top-mounted boost pump.
- Light 4 is for the aft reservoir tank bottom-mounted boost pump.
- Light 5 is for the A–I tank transfer pump.

The FFP light illuminates when the pump is operating and proper pressure is present. Also, there is a red light for engine over speed and a fuel hot test switch that is used to check the fuel hot circuitry.

202. Operational theory of the engine feed system on a multi-engine tanker aircraft

In this lesson, we will cover the aircraft engine feed system for a tanker-type aircraft. You will find there are a few differences in this system that are not contained in the engine feed systems for other types of aircraft.

The tanker aircraft we will cover, can feed any or all engines using three separate fuel pump pressure systems. Refer to FO 2. As you can see, there are three systems that provide engine feed. They are as follows:

- The main tank boost pump system—supplying fuel under boost pump pressure.
- The boost pump override system—supplying fuel from the center wing tank.
- The air refueling (A/R) pumps system in the body tanks—supplying fuel to the engine manifold.

Each of the latter two systems has a greater output pressure than that of the main tank boost pumps. Consequently, when either is operating, it overrides the main tank boost pumps (C) and shuts off the flow of fuel from the discharge lines by closing the dual check valves (D) installed downstream of these pumps.

The boost pumps serve as a backup system under these operating conditions:

- If the boost pumps are running at the same time as the A/R pumps (H) or override pumps (E), the boost pumps resume engine fuel supply when the other pumps are turned off, pressure is reduced, or the corresponding tanks are depleted of fuel.
- Fuel flow to the engine is controlled by an electric motor-driven fuel shutoff valve (A).

Body tank fuel

Fuel from the body tanks is directed to the engine manifold when the A/R pumps are operating and the A/R to engine manifold SOV (I) is opened. Through the interconnected manifold lines, fuel from the body tanks can be used for any one or all of the engines.

The main tank boost pumps are not supplying fuel to the engine manifold when the A/R pumps are operating. This is true because A/R pump pressure is greater than boost pump pressure. This causes the dual check valves in the boost pump discharge line to close and shut off fuel flow to the pumps.

To ensure sufficient fuel feed to the engines, both boost pumps for each main tank should be on for takeoff, landing, and any other high-power operations. If necessary, one boost pump can feed more than one engine when high power is not required. Placing the override pump switches on the pilot’s fuel-management panel (FMP) (FO 2, left of FWD body tank gauge) to ON, starts the override pumps which, due to their greater output pressure, overrides boost pump pressure and supplies fuel to the engine or engines selected.

Center wing tank

Engine selection for fuel from the center wing tank is made by opening the tank to manifold valves. This is done through the operation of the applicable switches on the pilot’s FMP. For example, let us say we want to use center wing tank fuel for all four engines. To do this, all tanks to manifold valves (B) must be open.

The center wing tank fuel is normally depleted before the main tank fuel because of the higher output pressure of the pumps in the center wing tank.

Transferring fuel in flight

Fuel cannot be transferred from one main tank to another while the aircraft is in flight; however, the reserve tank fuel can be transferred by gravity flow into main tanks numbers 1 and 4 if it is desired to use reserve tank fuel for engine fuel feed. Fuel in the upper deck tank can be transferred by gravity flow into the aft body tank for engine fuel feed.

203. Pumps used in a typical engine feed system

The three types of pumps used in engine feed systems are as follows:

- Centrifugal boost.
- Dual-impeller.
- Quick-change electrically driven.

Centrifugal boost pump

The centrifugal-type fuel pump is suitable for boost, transfer, or air refueling operations. The primary purpose of the pump is to pressurize fuel in a manifold. Fuel can then be directed to the engine, another fuel tank, or to a receiver aircraft. As the name implies, the centrifugal-type pump operates by centrifugal force. Figure 1–1 illustrates this concept. You can see that fuel enters the pump near the inner portion of the rapidly rotating impeller (A). As the fuel is caught in the impeller and spun rapidly, the weight of the fuel causes it to develop an outward force or pressure. The impeller rotates at a high speed, and the weight of the fuel throws it to the outer circle of the impeller. Air is forced to the inner portion of the impeller because it is lighter than the fuel. It collects and rises to the surface of the fuel to become a part of the vented air. These pumps have one distinct advantage over other types of pumps. There is no contact between the rotating impeller and the stationary housing of the pump body (B), so they tend to run cooler.

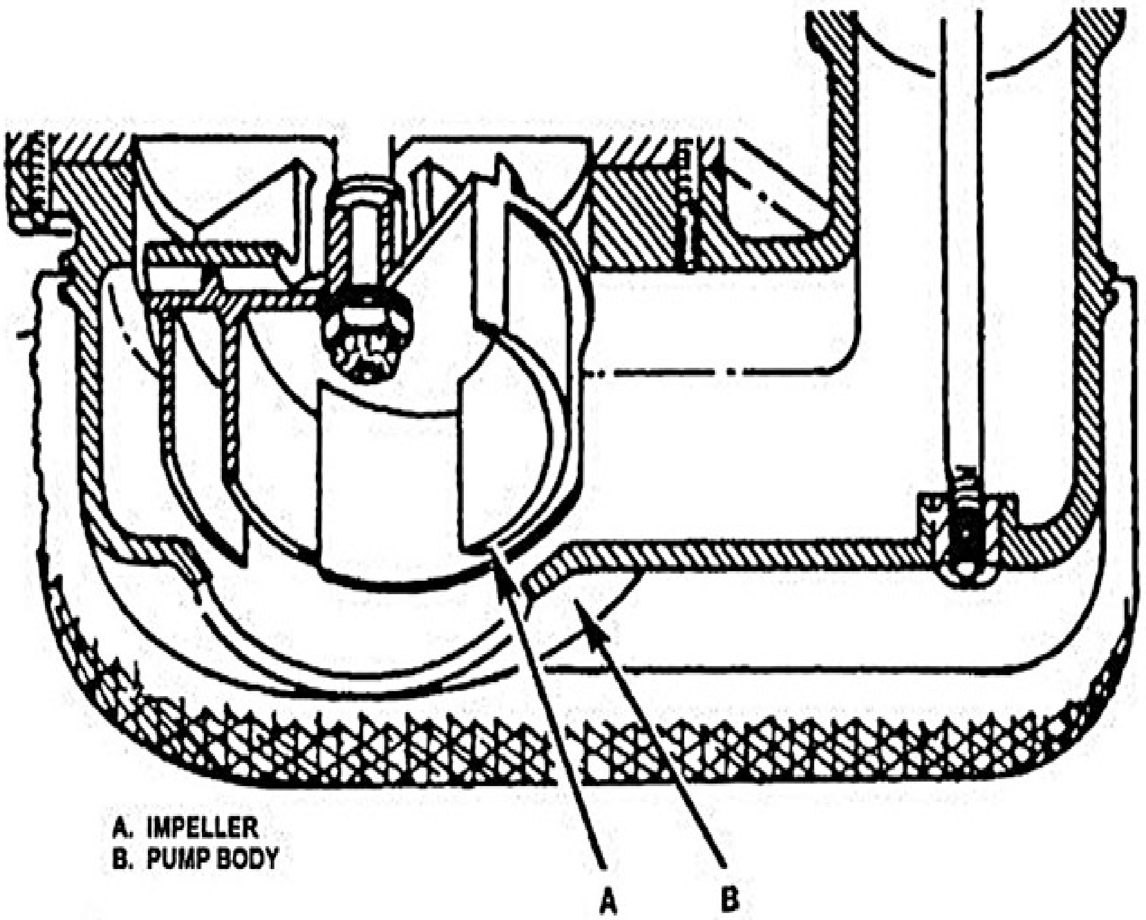

Figure 1–1. Centrifugal-type pump.

Centrifugal-type pumps have variable displacement. For example, the pressure output of a typical pump may be 15 pounds per square inch (psi) pressure at zero flow, and yet vary from 6- to 15-psi pressure at a flow of 3,900 pounds per hour (pph). The output pressure characteristics for a particular pump are engineered into the pump by different designs of the impeller and pump body to meet the system requirements. The output pressure and flow ratings of pumps are greater than the system needs. This provides an ample supply in case of a single pump failure. The centrifugal-type pump is not self-priming; therefore, it is installed at a location where fuel flows to the inlet of the pump.

Many pumps incorporate a spring-loaded flapper, which is used as a bypass valve. Locate item F in figure 1–2. During normal pump operation, fuel pressure holds the valve closed. However, when the pump is inoperative, the weight of the fuel in the tank forces the flapper open and the fuel bypasses the impeller section. An inlet screen is also installed to prevent debris from holding the valve open. An open valve causes fuel to be discharged back into its own tank.

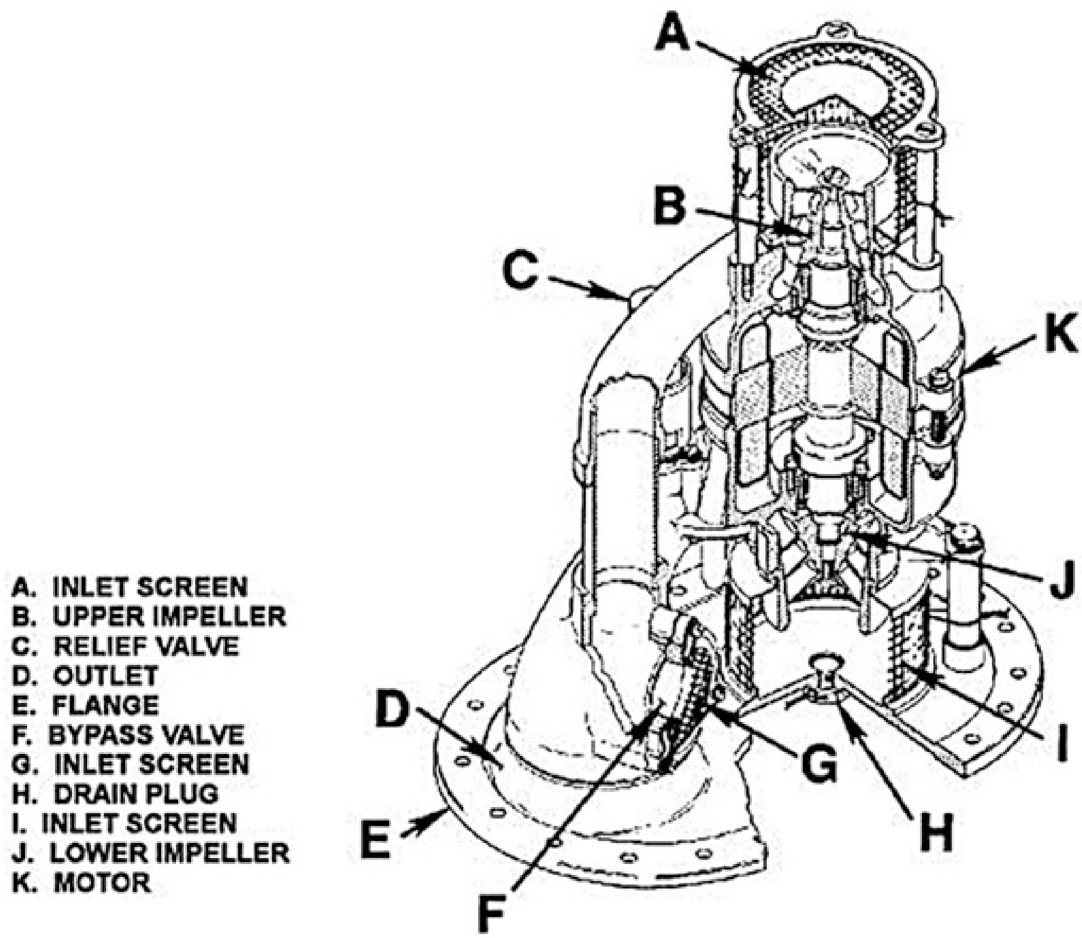

Figure 1–2. Dual-impeller pump.

Dual-impeller pump

Notice in figure 1–2 that there are two inlet wire mesh screens (A and I) covering the pump impellers. These are used to prevent large debris such as tools, nuts, bolts and cheesecloth from entering either impeller (B or J). In some instances, the function of the upper impeller (B) is to supply fuel to the engines during inverted flight or negative G (gravity) conditions. Both impellers are driven by the same electrical motor (K). There is also a pressure relief valve (C) to prevent pressure buildup in the outlet (D) and related tubing when the valves are closed downstream. The mounting flange (E) permits pump removal without requiring you to enter the tank. The bypass valve (F) permits gravity flow to the engines. To prevent foreign objects (FO) from holding the bypass valve open, an inlet screen (G) is provided. The drain plug H) is normally a quick-shutoff type valve that's operated remotely, rather than with the screw plug shown.

Quick-change electrically driven pump

Boost pumps on some older model aircraft require tank entry before replacement. This operation is time-consuming, and there are always hazards present when tank entry is required. To overcome this danger and reduce the time needed to replace a pump, quick-change type pumps are being incorporated on some aircraft. Figure 1–3 shows a cross-sectional view of a quick-change, bottom-mounted, completely submerged fuel pump. It has provisions for the removal and replacement of the complete motor and impeller unit from the top of the fuel tank without either physically entering or completely defueling the tank.

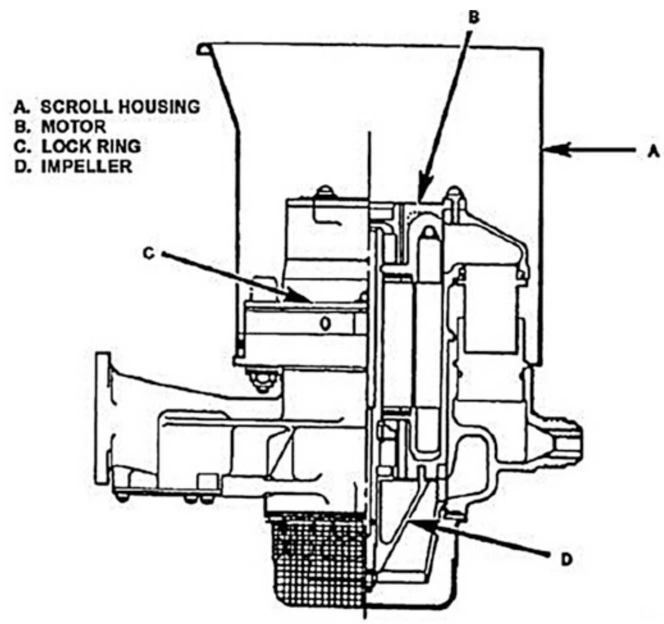

Figure 1–3. Quick-change centrifugal pump.

The pump is set in a scroll housing (A) which is attached to the bottom of the fuel tank. The scroll housing serves as a reference guide when the pump is moved. The motor (B) and impeller (D) are held and locked to the housing by a lock ring (C). To remove the pump, the access plate located directly above the pump in the top surface of the wing is removed first. Then the pump removal tool (fig. 1–4) is grounded with a grounding wire (A) and inserted through the opening until the guide plate (C) is seated in the access opening. When the tool is lowered further (sliding through the guide plate), it can enter the scroll housing. It is guided by the tongue (B), which must follow in a guide slot in the scroll housing. The removal tool engages the lock ring (C) (fig. 1–3).

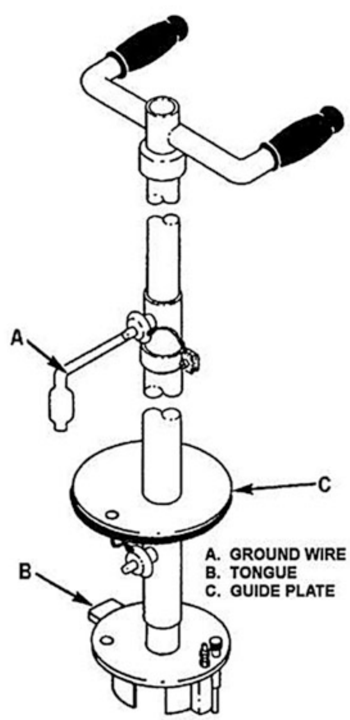

Figure 1–4. Pump installation and removal tool.

Downward pressure on the tool depresses a spring-loaded safety lug in the lock ring so that a portion of a turn counterclockwise turns the lock ring to disengage the pump from the scroll housing. At the same time, the spring-loaded safety lug locks the tool to the pump motor and the impeller unit. The tool, pump motor, and impeller can then be withdrawn through the access opening.

To install a new pump motor and impeller unit, reverse the removal steps. The tool cannot be separated from the unit until you have completely locked the ring. It is not possible to install the wrong pump. The installation guide, which is a part of the permanently mounted base unit, allows only the installation of the correct motor unit. The time required to remove and replace this type pump is probably less than the time it took you to read its description. This pump requires no special tools to install.

204. Check valves and shutoff valves

In this section, we will discuss the various types of check valves and SOVs. It is important to know how the different types of each operate and where and when they are used. When you are troubleshooting a malfunction, knowing how the valves operate can save a lot of time replacing components that are not broke. No matter the airframe you work, there will be check valves and SOVs.

Check valves

Two main types of check valves are flapper and pressure loaded. They are used to control the direction of fuel flow and prevent the reverse flow of fuel through an inoperative boost pump. Most check valves are designed to prevent them from being installed backwards in the fuel line. They may have different size fittings on the ends. In addition, an arrow symbol stamped on the valve body shows the direction of fuel flow. Pay close attention to the arrow; ensure you install the check valve properly.

Flapper check valve

A flapper check valve is shown in figure 1–5. This type is used when the gravity flow through the valve is undesirable. Gravity flow or pump pressure opens the flapper valve. The flapper (A) is closed by a spring (B) which has slight pressure. Many flapper check valves have *top* or *hinge* stenciled on the valve body. On these valves, the hinge of the flapper is at the stenciled location. If the spring should break, the valve still performs the function of preventing reverse flow of fuel. The arrow (A) (flapper valve) indicates the direction of fuel flow. The valve body (B) (spring) provides a housing for the valve.

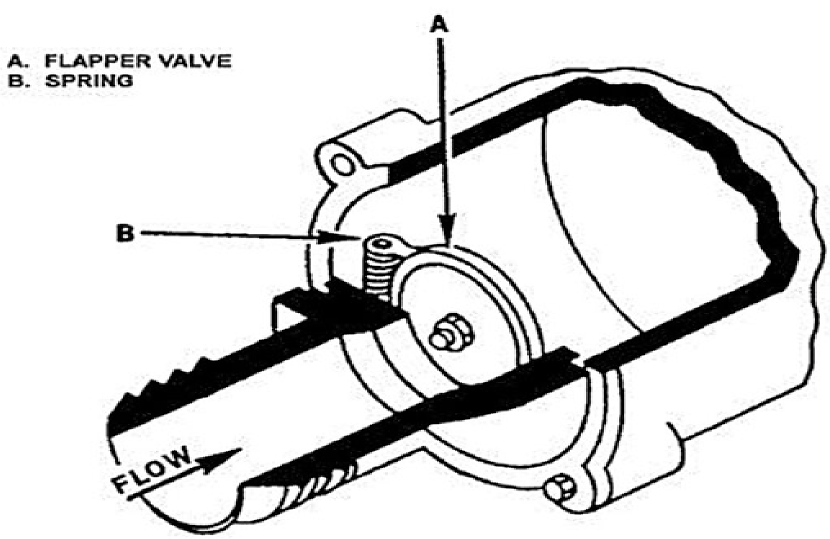

Figure 1–5. Check valve.

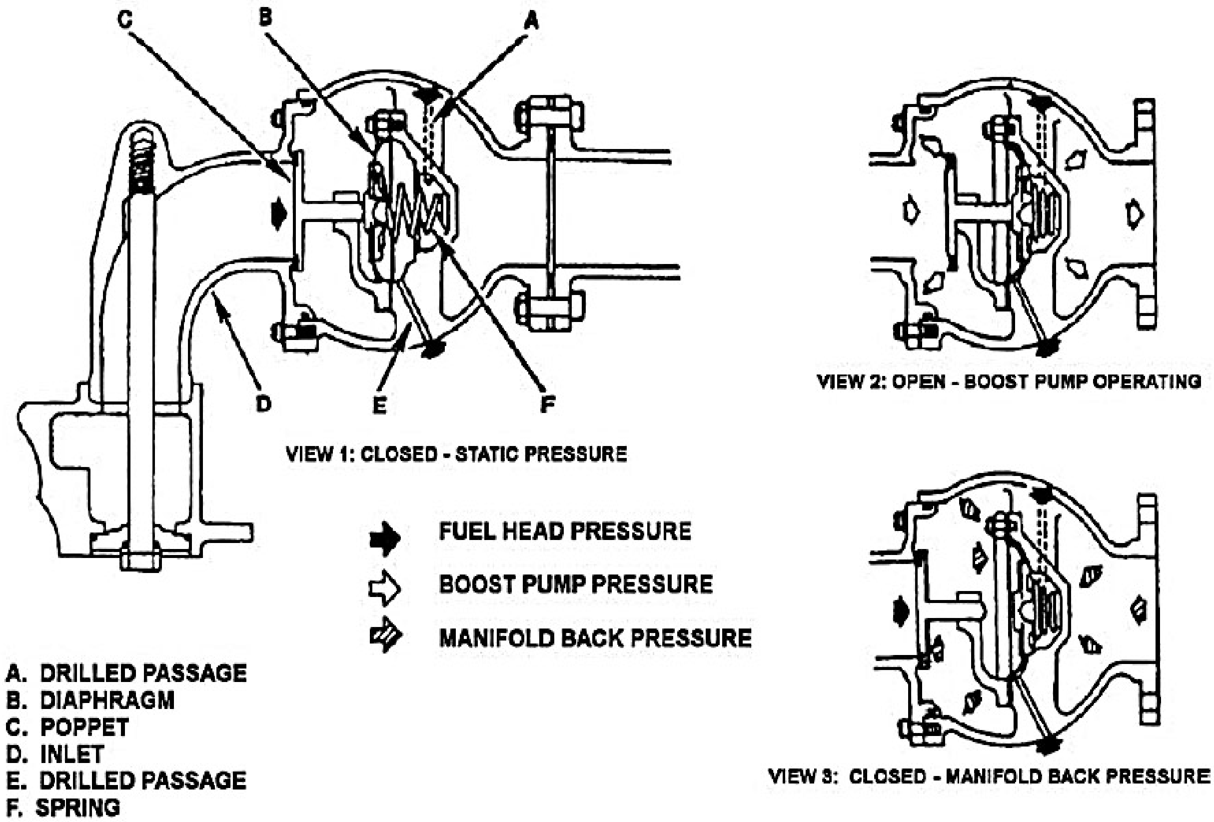

Figure 1–6. Pressure-loaded check valve.

Pressure-loaded type

A pressure-loaded check valve is shown in figure 1–6. This type is used where gravity flow through the valve is not desirable. Pressure-loaded check valves are opened by pump pressure only. When the pump is not operating, the poppet (C) is seated (view 1). Gravity flow or head pressure at the inlet (D) to the valve will try to force the poppet from its seat. Since the valve is submerged in fuel, head pressure also enters through the drilled passages (A and E). The combined forces of the spring (F) and the fuel pressure entering the drilled passages act on the diaphragm (B) and keep the poppet closed. When the pump is operating, pressure at the inlet (D) opens the poppet (C). This moves the diaphragm (B) to the right, compresses the spring (F), and allows fuel through the valve (view 2). When manifold back pressure is equal to or greater than pump pressure, there’s no flow (view 3). In this condition, reverse flow of fuel is prevented because the poppet is seated.

Drilled hole

Some pumps may be out of fuel sooner than others because of their location. When this occurs, it is called a dry pump. On some check valves, there may be a small hole drilled in the center of the flapper. Some pumps require fuel for cooling and lubrication. The drilled hole allows some fuel to return from other parts of the system to lubricate a dry pump. It may also be used to help relieve a small amount of fuel pressure in the fuel manifolds.

Shutoff valves

Shutoff valves are normally used to control the flow of fuel or air through a manifold or into a tank. We will discuss the two major types of shutoff valves. They are as follows:

- Sliding gate.
- Disc-type.

Sliding gate shutoff valves

The sliding gate shutoff valve is very common to fuel systems. These valves have the advantage of being able to control a large flow of fuel in the manifold. They have a full-bore open throat, which offers no restriction to fuel flow when the valve is open. They are also relatively small and lightweight for the size of line they can control. Their primary disadvantage is not being able to withstand extreme pressures. There are sliding contacts between the sealing surfaces, and they are more likely to leak due to wear. The sliding gate SOVs can be operated electrically or manually.

Shutoff valve operation

The valve shown in figure 1–7 is an electrically actuated unit. The motor (A) is usually operated on direct current. The gearing is positive action and opens or closes the valve in one second or less. There is no provision in the electrical motor circuit to allow partial opening and closing of the unit. Limit switches are provided to prevent over travel, which could cause straining of the gears and valve.

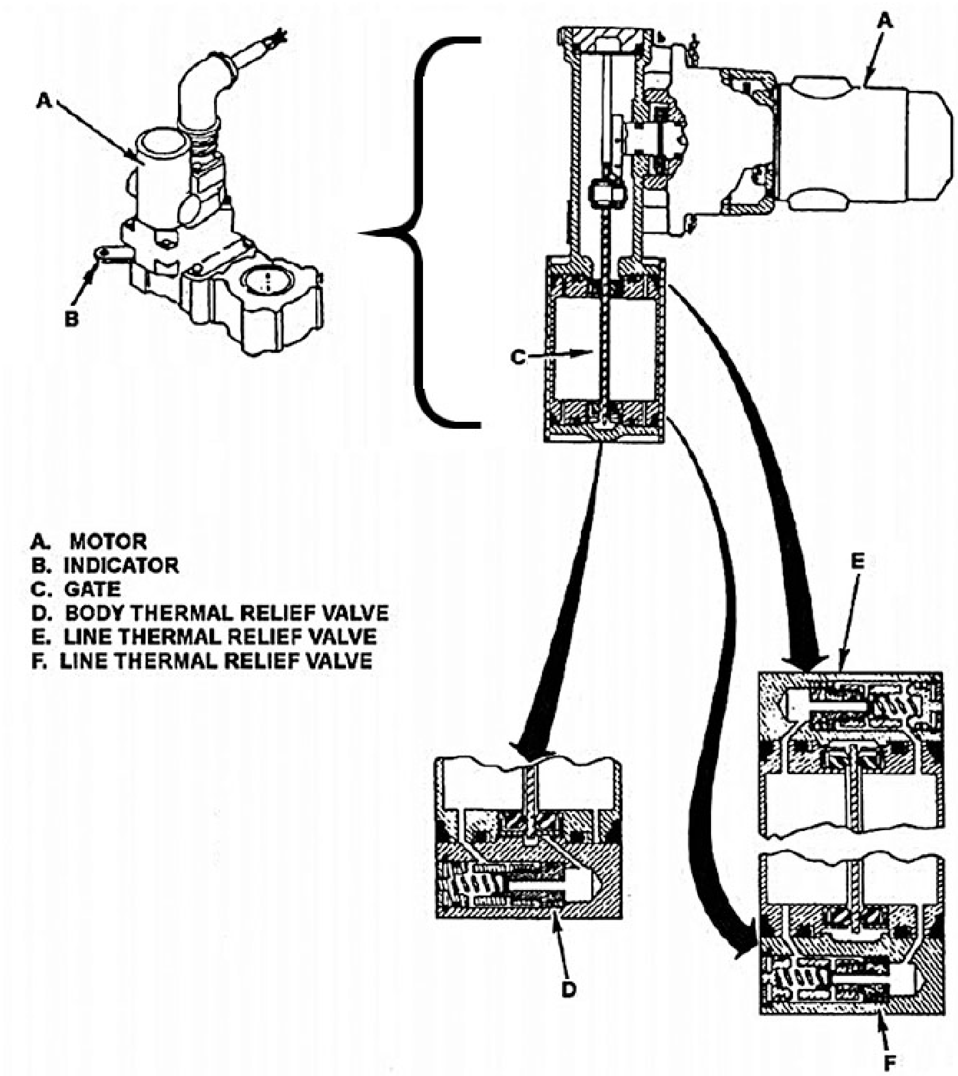

Figure 1–7. Motor-operated sliding gate valve.

A clutch is used to disconnect the motor and gear train so that the valve can be manually operated. The visual indicator (B) is normally used as a manual handle. The cross-sectional view shows that the gate (C) slides up and down in a slot formed by the sealing surfaces much as you might slide a playing card in the saw slot of a tube, which was sawed through.

The valve stops flow in either direction. In the CLOSED position, fluid pressure applied to one side presses the gate more tightly against the seal on the other side. To prevent excessive pressures from building up in trapped lines or within the body of the valve, there are usually three spring-loaded thermal relief valves incorporated in the sliding gate valve body. The two line thermal relief valves (E and F) allow excessive pressure on each side of the valve to bypass the gate. The body thermal relief valve (D) relieves the excessive pressure built up in the sliding gate cavity when the valve goes to the CLOSED position. These relief valves are preset to open at some pressure higher than normal operating pressure but lower than any pressure, which could damage the valve or seals. For example, if normal line pressure is 40 psi, and if 80 psi might damage the gate or seals, the relief valves would probably be set to begin opening at 55 psi.

Disc-type valves

A typical example of a disc valve, also referred to by the name “butterfly,” is shown in figure 1–8. As you can see in the illustration, the main seal between the disc (D) and the valve body (C) is an O-ring-type seal (E) located in a groove in the disc. The thermal relief valves are installed in the disc. A position indicator (B) is incorporated to determine by a visual inspection the position of the valve. Provisions are usually made to permit removal and replacement of the motor (A) without draining the lines or removing the valve body.

Since the disc remains in the line of flow and takes up a portion of the cross-sectional area, these valves do not offer full flow. To compensate for this, most valves are of a larger diameter (bore) through the valve body. In this manner, the flow through the valve remains relatively constant.

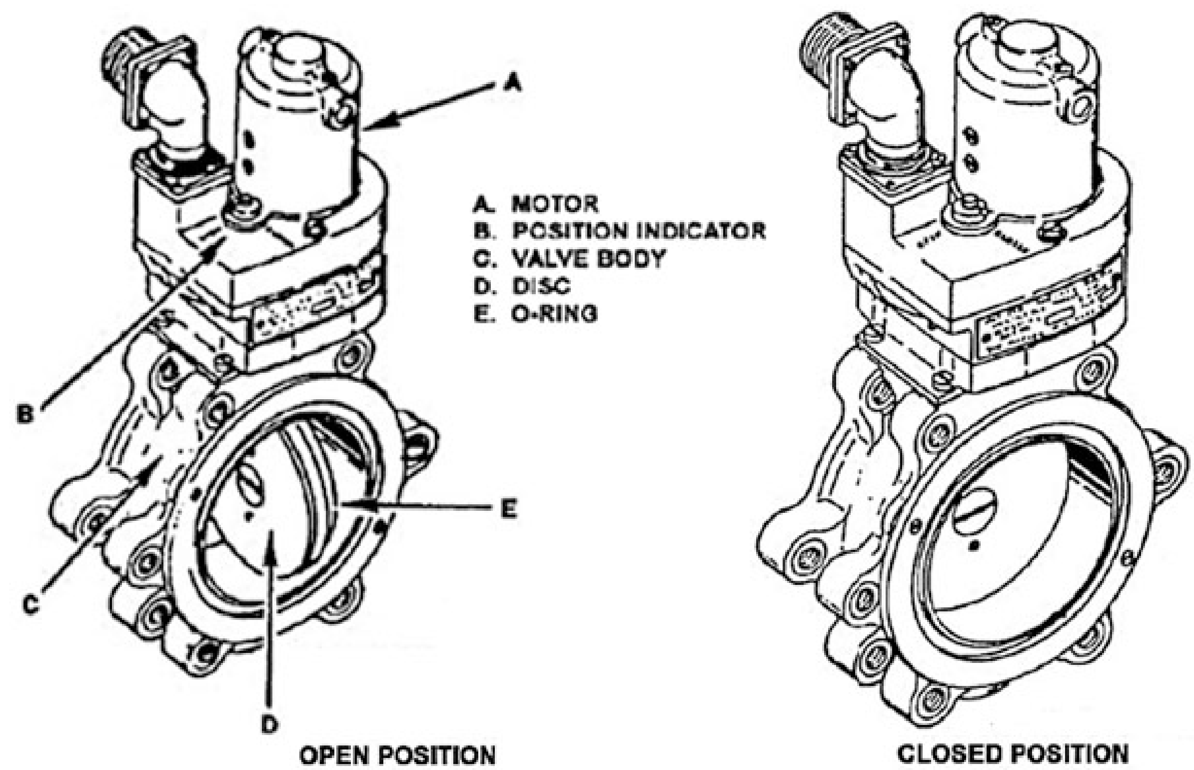

Figure 1–8. Disc (butterfly) valve.

205. Performing operational checks and troubleshooting the fighter engine feed

As we stated earlier, there are several components that make up the engine feed system on a fighter aircraft. A number of these components cause few problems other than a fuel leak. Components such as the engine feed manifold itself, the engine electronic control, or the heat exchanger, can be checked for fuel leaks by simply using the boost pumps to pressurize the manifold and looking for leaks. When you are called out to troubleshoot an aircraft, sometimes you will begin by performing an operational check on the system. After you troubleshoot for the faulty component and you replace the defective component, you will then be required to do an additional operational check. This is required prior to the aircraft's next mission.

Another problem that can arise is a fuel imbalance of the two fuel systems, but this can be corrected by the pilot in-flight. The boost pumps or the FFP can also cause an engine feed problem, which would be noticed by the ground crew before flight while observing the ground fuel pump advisory panel.

When a boost pump malfunction is indicated, you have to troubleshoot the system to determine whether the pump is inoperative, a pressure switch is bad, or the problem is with the indicating system.

When you start troubleshooting, first check the direct pressure reading of the suspected bad boost pump. If the pressure is low or zero, check power to the pump. If power is available, the pump itself is defective and needs replacing. If power is not available, the pump may be good; troubleshoot the electrical system to the pump to see if it is defective

Let us say the boost pump has the proper pressure reading on a direct reading gauge. According to the technical order (TO), your next step is to check the pressure switch. Since you know the boost pump pressure is correct, your next step is to check for continuity of the pressure switch. With the pump on, the pressure switch should be closed. If the pressure switch circuit is open, the switch is defective. If the circuit is CLOSED, the problem is in the indication system. This would require more in-depth troubleshooting of the indication system and may require assistance from other specialists such as instrument or electrical journeyman or craftsman.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

201. Operational theory of the engine feed system on a single-engine fighter aircraft

1. How many boost pumps are used to pressurize the fuel in the engine feed manifold?

2. How many boost pumps are used to ensure fuel flows to the engine during inverted flight?

3. What components make up the engine feed system on a fighter aircraft?

4. How is the FFP powered?

5. Explain how the JFS operates.

6. How would the pilot correct a fuel imbalance caused by having too much fuel in the forward system?

202. Operational theory of the engine feed system on a multi-engine tanker aircraft

1. What are the three separate engine fuel pump pressure systems used on a tanker aircraft?

2. How do the override pumps and air refueling pumps override the main tank boost pumps?

3. What component controls the flow of engine fuel from the fuel feed system?

4. What valve must be open on a tanker aircraft to feed the engines using the A/R pumps?

5. What action must be taken to feed the engines from the reserve tanks on a tanker aircraft?

203. Pumps used in a typical engine feed system

1. List three uses of a centrifugal-type pump.

2. What is the distinct advantage of a centrifugal pump over the other types?

3. Where is the centrifugal pump installed?

4. What is the purpose of the spring-loaded flapper used on some pumps?

5. What is the purpose of the wire mesh screens covering some pump impellers?

204. Check valves and shutoff valves

1. Name two types of check valves.

2. What is the primary function of an installed check valve?

3. What symbol is stamped on the body of check valves to prevent them from being installed backwards?

4. What is the purpose of the drilled hole in the center of a check valve flapper?

5. Why are sliding gate shutoff valves installed in a manifold?

6. What is the primary disadvantage of a sliding gate shutoff valve?

7. What are the locations and types of valves used to relieve excessive pressure in a sliding gate valve?

8. Name two types of shutoff valves.

205. Performing operational checks and troubleshooting the fighter engine feed system

1. In the event of a fuel leak on a fighter engine feed system, which components would you check?

2. If the ground crew found a boost pump indication malfunction, what steps would you take to troubleshoot the system?

1–2. Crossfeed System

The crossfeed system is designed to help prevent a possible engine flameout by providing an alternate fuel supply source should a problem occur with the engine feed tanks. While the engine feed system on a multi-engine aircraft is used to feed an engine from its “respective” main tank, the crossfeed system may be used to feed any engine from any tank on the aircraft. Consequently, this system is not found on single-engine fighter-type aircraft.

206. Tanker crossfeed system—theory of operation

The crossfeed system on a tanker aircraft is fairly simple. Refer to FO 2 during our discussion of the system. Notice that there are four main tanks. Number 1 and 2 main tanks are on the left wing, and number 3 and 4 main tanks are on the right wing. These are called main tanks because they directly feed their respective engines. In other words, the number 1 main tank feeds number 1 engine, and so forth. In normal flight operation, this is an ideal situation; however, what do you think would happen if the aircraft were hit by small arms fire and the number 4 main tank sustained enough damage to leak fuel? Without the option of using the crossfeed system, the tank would eventually empty and the number 4 engine would flame out. To prevent this from happening, fuel from number 3 main tank can come through the crossfeed system to feed the number 4 engine.

Using the boost pumps (C) in number 3 main tank, the fuel manifold is pressurized to the number 3 engine manifold valve (upper valve located inside the inboard dry bay), and the number 3 fire wall shutoff valve (also in the dry bay, directly below the engine manifold valve). When the fire shutoff valve is open (which is anytime the respective engine is running), fuel is supplied from number 3 main tank to number 3 engine. When the number 3 engine manifold valve is opened, number 3 main tank boost pumps provide the fuel pressure to allow fuel to enter the crossfeed manifold and flow to the number 4 engine manifold valve (B). When this valve is open, fuel flows through a dual check valve to the number 4 fire shutoff valve (A). Since the fire wall shutoff valves are always open any time the engines are operating, fuel is available to the number 4 engine. By opening the appropriate valves, fuel can be routed to the crossfeed manifold to feed any engine from any main tank.

207. Performing operational checks and troubleshooting the crossfeed system

The crossfeed system does not use many components; therefore, troubleshooting a malfunction is normally not very difficult. Although each aircraft’s crossfeed system may be slightly different by design, the system generally uses the same basic components. Elements to be considered are as follows:

- Boost pumps.
- Shutoff valves.
- Check valves.
- Pressure switches.

Boost pumps

If the boost pumps are inoperative, no pressure is available to route fuel through the manifolds. Therefore, if the problem is a lack of pressure in the system, the boost pumps may likely be the problem. This does not necessarily mean that the pump itself is bad, for the problem may be the relay, boost pump switch, or faulty wiring. Some electrical system troubleshooting may be required to isolate the root cause.

Shutoff valves

Other than leaking internally or externally, the only other common problem with shutoff valves is that they fail to open or fail to close. Since the majority of shutoff valves are motor operated, that is where the problem usually lies. A shutoff valve motor, like any other motor, wears out after a period of time. An experienced mechanic normally can distinguish between a healthy valve motor and one, which is near failure, simply by listening to it. Additionally, an inoperative shutoff valve will often “trip” a circuit breaker. This happens because the motor shorts internally, no longer providing resistance in the circuit. As a result, the circuit overloads, and “trips” the respective breaker.

Another possible problem with the shutoff valve may be foreign object damage (FOD) stuck in the valve, preventing it from closing. Sometimes this situation can be remedied by applying boost pump pressure to each side of the valve in turn (if possible) and cycling the valve open and closed a few times. The pump pressure may flush the foreign object out of the valve, allowing it to close.

Check valves

Check valves rarely become stuck closed due to their design. However, they may become stuck in the OPEN position, which keeps them from doing their intended job—preventing reverse flow of fuel. In the crossfeed system, the effects of a check valve stuck open are usually minimal.

Pressure switch

A pressure switch is normally connected directly to a centrifugal pump or fuel manifold. The switch "senses" pressure, low pressure, or no pressure, and sends a signal to an indicator light on the FMP. Before you begin troubleshooting, it is important you ensure that this light is working. If you are attempting to check out a pump and the light does not work, you might assume that the pump is inoperative when in fact it is putting out sufficient pressure. If the light works with other pumps but not the pump you suspect as being inoperative, the pump is most likely inoperative.

As you can see, troubleshooting is simply a process of elimination. The more you know about a system and its components, the easier it is to determine the problem. When troubleshooting a malfunction, always remember to consult the applicable aircraft technical order.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

206. Tanker crossfeed system—theory of operation

1. What valves must be open to crossfeed the number 4 engine from the number 3 main tank?

2. Where does the fuel pressure come from when the crossfeed system is in use?

3. Which shutoff valves are open any time the engines are running?

4. What manifold must fuel be routed to feed any engine from any main tank to?

207. Performing operational checks and troubleshooting the crossfeed system

1. Which four components should you consider when you are troubleshooting the crossfeed system?

2. When you are troubleshooting a problem where no pressure is available to permit crossfeed to occur, what are the possible causes of the problem?

3. What is the normal result of a shorted shutoff valve motor?

4. What effect on the crossfeed system might an inoperative check valve have?

5. What component aids in troubleshooting by sending a signal to an indicator light on the fuel-management panel?

Answers to Self-Test Questions

201

1. Three.
2. One; located near the top of the forward reservoir tank.
3. Engine feed switch; boost pumps, crossfeed valve, FFP, JFS, EEC SOV, heat exchanger, main engine fuel SOV, fuel-flow transmitter, and ground fuel pump advisory panel.
4. By hydraulic power from hydraulic system A.
5. It is a combustion-driven turbine, which receives its fuel from the engine feed manifold, and is started by a switch in the cockpit.
6. By placing the ENG FEED switch to the FWD position, allowing fuel from the forward system to be transferred to the aft system.

202

1. Main tank boost pump system, the boost pump override system, and the A/R pumps system.
2. The greater output pressure of the override and A/R pumps will close the dual check valves of the main tank boost pumps, shutting off the flow of fuel from the discharge lines.
3. An electric motor-driven fuel shutoff valve.
4. The A/R to engine manifold SOV.
5. The reserve tank fuel must be transferred by gravity flow into main tanks numbers 1 and 4.

203

1. A boost pump, transfer pump, or an air refueling operations.
2. There is no contact between the impeller and the pump body.
3. At a location where fuel can flow to the inlet of the pump.
4. It is used as a bypass valve.
5. To prevent large items such as tools, nuts, bolts, and cheesecloth from entering the fuel impeller.

204

1. Flapper and pressure-loaded.
2. It controls the direction of fuel flow by preventing the reverse flow of fuel.
3. An arrow on the valve body that shows the direction of fuel flow.
4. It allows fuel to return from other parts of the system to lubricate a dry pump.
5. To control the flow of fuel in the manifold.
6. They cannot withstand extreme pressures.
7. Two in the line and one in the body; thermal relief valves.
8. Sliding gate and disc-type.

205

1. The engine feed manifold, engine electronic control, and heat exchanger.
2. Take a direct pressure reading of the suspected bad boost pump. If the pressure is zero or near zero, check power to the pump. If power is available, the pump is defective and needs replacing. If power is not available, troubleshoot the electrical system to the pump.

206

1. The number 3 engine manifold valve, the number 4 engine manifold valve, and the number 4 fire shutoff valve.
2. From main tank boost pumps.
3. The fire shutoff valves.
4. The crossfeed manifold.

207

1. Boost pumps, shutoff valves, check valves, and pressure switches.
2. Inoperative boost pump, relay, switch, or faulty wiring.
3. The motor will trip its respective circuit breaker.
4. The effect would be minimal if the check valve is stuck open.
5. Pressure switch.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (201) What type of pump is used for engine feed in the forward (FWD) and aft reservoir tanks of a fighter aircraft?
   a. Dual-impeller, turbine-driven.
   b. Single-impeller, turbine-driven.
   c. Dual-impeller, electrically driven.
   d. Single-impeller, electrically driven.

2. (201) To correct a fuel imbalance caused by too much fuel in the forward fuel system of a fighter aircraft, you would place the ENGINE FEED switch in the
   a. AFT position.
   b. FWD position.
   c. NORMAL position.
   d. BALANCE position.

3. (202) Fuel flow to the engine on a tanker aircraft is controlled by
   a. an electric motor-driven shutoff valve.
   b. an electric motor-driven shuttle valve.
   c. a manually operated shutoff valve.
   d. a manually operated shuttle valve.

4. (202) To use body tank fuel to feed the engines on a tanker aircraft, the
   a. air refueling pumps must be operating.
   b. main tank pumps must be operating.
   c. alternate pumps must be operating.
   d. override pumps must be operating.

5. (202) To feed *all* engines from the center wing tank on a tanker aircraft, the
   a. gravity feed valve must be opened.
   b. override wing valves must be opened.
   c. tank to manifold valves must be opened.
   d. air refueling to engine manifold valves must be opened.

6. (202) How is fuel transferred from the reserve tank on a tanker aircraft *during flight*?
   a. Air pressure.
   b. Gravity flow.
   c. Boost pump pressure.
   d. Override pump pressure.

7. (203) The output pressure and the flow ratings of a centrifugal pump are greater than the amount the system needs to
   a. provide an ample supply of fuel in case of a single pump failure.
   b. prevent fuel boiling and evaporation in the wing tanks at high altitudes.
   c. provide fuel to the engines during negative Gs or inverted flight conditions.
   d. prevent the reverse flow of fuel from a pump with a greater pressure output.

8. (203) When fuel supply is required during negative gravity conditions,
   a. a rotary-vane centrifugal pump is used.
   b. a dual-impeller centrifugal pump is used.
   c. an in-line ejector centrifugal pump is used.
   d. a top-mounted pump centrifugal pump is used.

9. (203) For ease of maintenance, the type of centrifugal pump designed to be installed from the top of the fuel tank is a
   a. rotary-vane pump.
   b. dual-impeller pump.
   c. quick-change pump.
   d. top-mounted electrically driven pump.

10. (203) Which item would you use as a reference guide for the removing tool when installing a quick-change pump?
   a. Guide plate.
   b. Guide tongue.
   c. Scroll housing.
   d. Spring-loaded safety lug.

11. (203) Which is an advantage of the quick-change electrically driven fuel pump?
   a. Requires no special tools to install.
   b. It is possible to install the wrong pump.
   c. Increases the time required for pump changes.
   d. Requires either physically entering or completely defueling the tank.

12. (204) The flapper on a flapper-type check valve is opened by
   a. spring pressure.
   b. hydromechanical action.
   c. gravity flow or pump pressure.
   d. an electrical impulse to the flapper mechanism.

13. (204) What type of seal is found between the disc and valve body on a disc-type valve?
   a. V-ring.
   b. O-ring.
   c. Gasket.
   d. Metal-to-metal.

14. (205) If you suspect leaking, the *best* method for troubleshooting a fighter engine feed system component is to
   a. operate the component, while looking for leaks.
   b. pressurize the manifold with fuel and look for leaks.
   c. stand-test with fuel for 30 minutes and look for leaks.
   d. pressurize the manifold with air and listen for leaks.

15. (205) You are troubleshooting a boost pump problem on a fighter aircraft. To do this properly, your *first* step is to check for
   a. power to the boost pump.
   b. a pressure switch reading.
   c. continuity of the pressure switch.
   d. a direct pressure reading of the pump.

16. (206) Which tanks are the engines on a tanker aircraft directly fed from?
    a. Main.
    b. Body.
    c. Fuselage.
    d. Auxiliary.

17. (206) On a tanker aircraft, where must fuel be routed to feed any engine from any *main* tank?
    a. Forward body tank.
    b. Crossfeed manifold.
    c. Transfer manifold.
    d. Center wing tank.

18. (207) You are troubleshooting a malfunction of the crossfeed system on a tanker aircraft when you determine there is no pressure available to route fuel to the crossfeed manifold. The *most* probable cause of this malfunction is
    a. a stuck open check valve.
    b. a malfunctioning boost pump.
    c. an inoperative pressure transmitter.
    d. foreign object damage stuck in a shutoff valve.

19. (207) You are troubleshooting a malfunction in the crossfeed system when you determine the circuit breaker for a shutoff valve continues to "pop." The *most* probable of this malfunction is
    a. a defective circuit breaker.
    b. the valve motor has shorted out.
    c. there is too much pressure in the system.
    d. an open in the circuit shutoff valve circuit.

20. (207) Which component is designed to sense low pressure and send a signal to an indicator light?
    a. Light.
    b. Gauge.
    c. Pressure switch.
    d. Pressure transmitter.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Fuel Transfer and Jettison Systems

IN THE PREVIOUS UNIT, you learned that the engine feed and crossfeed systems are vital to the operation of an aircraft. As you would expect, there are other systems that are also vital to aircraft operation. In this unit, we will look at two such systems: the transfer and jettison systems found on many types and models of aircraft.

Since aircraft normally have many fuel storage areas, there must be a way to move fuel from one storage area to another, and the transfer system serves this purpose. Fuel is transferred for a number of reasons: to empty a tank, to perform maintenance, to move it to another tank where it can be defueled, or move it to a main tank to replenish fuel that is used by the engines.

The fuel jettison system is used in emergency situations to permit fuel to be jettisoned or dumped from the aircraft to reduce the aircraft weight. We will cover the operation of both systems in this unit.

2–1. Transfer Systems

The primary purpose of a transfer system is to move fuel from one tank to another on an aircraft. If an aircraft has more than one fuel tank, it also has a transfer system. In this section, we will cover the transfer systems on both the fighter and cargo aircraft. Our lesson will cover four specific areas, which are as follows:

- Fighter transfer system operation.
- Troubleshooting the fighter transfer system.
- Cargo transfer system operation.
- Operational checkout of the cargo transfer system.

208. Fighter transfer system operation

Fighter aircraft are equipped with two independent methods of transferring fuel from the storage tanks to the reservoir tanks for engine feed. The primary transfer method is by siphon and air pressure. A power transfer method is also provided to augment the fuel transfer and to scavenge the tanks to minimize the amount of unusable fuel. In addition to these two methods, fuel may also be transferred from external sources.

Siphoning and air pressure method

There are two separate fuel systems used in the siphon and air pressure method. First, let us discuss the forward fuel system, and then we will look at the aft fuel system.

Forward fuel system

As fuel from the FWD reservoir tank is used by the engine, it creates a siphoning action, causing fuel to flow through a standpipe that interconnects the top of the FWD reservoir tank with the bottom of the F–2 tank (FO 1, fig. 4). The fuel that leaves the F–2 tank is replaced with fuel from the F–1 tank through an interconnecting standpipe. Fuel that leaves the F–1 tank is replaced by fuel from the right wing tank. This arrangement of interconnecting standpipes and air pressure causes the right wing tank to empty first, followed by the F–1 tank, the F–2 tank, and the FWD reservoir tank.

Aft fuel system

The aft fuel system empties in a similar fashion.

As fuel is used from the aft reservoir tank, it is replaced with fuel from the A–1 tank through a standpipe. Fuel that leaves the A–1 tank is replaced by fuel from the left wing tank. This will cause the left wing to empty first, followed by the A–1 tank, then the aft reservoir tank.

Air pressure required to assist the siphoning action is supplied to the wing tanks from the internal fuel tank vent and pressurization valve at 4.7 to 6.4 psi. Since the siphoning action depends on the absence of air in the reservoir tanks, air ejectors are provided to expel excess air from the reservoir tank, should some enter during maneuvers or other adverse conditions. The air ejectors are controlled by a thermistor switch near the top of each reservoir tank and use air pressure from the environmental control system (ECS) for operation.

When the reservoir tank is full of fuel, the thermistor switch provides a signal to energize the air ejector control solenoid valve CLOSED. When the fuel level in the reservoir tank drops the thermistor switch will de-energize the air ejector solenoid to OPEN, allowing air pressure from the ECS to cause the air ejector to expel air from the reservoir tank. Once the air is removed, fuel will cover the thermistor switch, and will energize the ejector control solenoid to CLOSE, stopping the operation.

Power transfer method

The power transfer system provides a backup system to the siphon and air pressure transfer, using six pumps to complete its function. This system has two electric transfer pumps, two turbine transfer pumps, and two scavenge pumps. The two electric pumps are standard centrifugal-type with a pressure switch that sends a signal to an indicator light on the ground fuel pump advisory panel. The pump is controlled by the ENG FEED switch located on the fuel control panel. One electric pump is located in the F–1 tank and the other is in the A–1 tank.

The two turbine-type pumps are centrifugal pumps powered by fuel pressure from the engine feed manifold. There is one turbine pump located in the right wing tank and another in the left wing tank. There are two scavenge pumps. They are standard-type ejector pumps located in the F–2 tank for scavenging residual fuel. The ejector pumps are powered by fuel pressure from the engine feed manifold.

The electric pump in the F–1 tank will transfer fuel to the FWD reservoir tank. If the FWD reservoir tank is full of fuel, the excess fuel will back flow through the standpipe to the F–2 tank. If the F–2 tank is full, the excess fuel will flow through the connecting standpipe back into the F–1 tank, then to the right wing tank if the F–1 tank is full.

The electric pump in the A–1 tank will transfer fuel into the aft reservoir tank. If the aft reservoir tank is full, the excess fuel will back flow through the standpipe into the A–1 tank, then into the left wing tank. The turbine pump, located in the right wing tank, will transfer fuel into the F–2 tank. If the F–2 tank is full, the excess fuel will back flow into the F–1 tank, then into the right wing tank. The turbine pump located in the left wing tank will transfer fuel into the A–1 tank. If the A–1 tank is full, the fuel backflows through the standpipe into the left wing tank. As stated before, the power transfer method is a backup system to the siphon and air pressure method, and ensures there will be fuel supplied to the reservoir tanks for engine feed.

External transfer

Fuel is transferred from the external tanks to the internal wing tanks by air pressure supplied by engine bleed air. This bleed air is cooled by the air-conditioning system and is regulated to 19 to 24 psi by the external vent and pressurization valve located in the vent tank.

Each external wing tank transfers to its respective wing. When the external centerline tank is installed, it will transfer first into both wing tanks. With the external tank select switch in NORM, fuel from the centerline tank will enter the refuel manifold (FO 1, fig. 3). The refuel/transfer control solenoid valve is energized CLOSED, preventing fuel pressure from entering the sensing line to the high-level shutoff shuttle valve. With the shuttle valve (spring loaded) in the transfer position, the sensing line from the high-level shutoff float valve to the external tank transfer valve will be OPEN.

Now fuel from the centerline tank will enter each internal wing tank, keeping them full until the centerline tank is empty. At the same time, the centerline tank will send a signal through the refuel/transfer valve to the external wing tanks and will energize the refuel/transfer valves CLOSED, allowing the centerline tank to transfer first.

When the centerline tank is empty, the refuel/transfer valve will close, preventing air from entering the internal wing tank. At the same time, the signal to the external wing tanks will be de-energized to allow them to transfer into the internal wing tanks.

When the external wing tanks are empty, the refuel/transfer valve will close to prevent air from entering the internal wing tank. A float switch is located in the vent tank to provide a means of stopping fuel transfer from the external tanks. If fuel backs up through the wing vent lines into the vent tank (due to failure of a wing float valve or an external tank transfer shutoff valve), fuel will raise the float, sending a signal to the refuel/transfer valve in the external centerline and wing tanks to close the valve. Stopping fuel transfer will prevent the tank from overfilling and venting overboard.

209. Troubleshooting the fighter transfer system

Many of the malfunctions that occur in the fighter transfer system are related to the vent and pressurization system. Often there are transfer pump problems that will occur, but instead of repeating what we have already covered under the engine feed system troubleshooting, now let us discuss the vent and pressurization-related transfer problems.

The most common problem is that no external tanks transfer when the select switch is in NORM position, but the external wing tanks will transfer when the select switch is in the WING FIRST position. The most probable cause for this discrepancy is an inoperative centerline refuel/transfer valve. However, the first component you would probably suspect as malfunctioning is the vent and pressurization valve. On fighter aircraft, there is only one vent and pressurization valve for all the external tanks. Since the external wing tanks did transfer with the select switch in WING FIRST, you know this valve must be operable.

The problem would seem to be with the centerline tank. The next component you would check is the manual shutoff valve. When the centerline tank is removed, the manual shutoff valve will stop fuel flow through the manifold. If the manual shutoff valve is closed, the fuel will not flow out of the centerline tank. If the valve is open, there is another problem.

The next item to check is the cannon plugs to ensure they are properly installed on the centerline tank. Next, use a direct-reading gauge to check for proper pressure to the centerline tank. If the pressure is 19 to 25 psi, the only component left is the refuel/transfer valve in the centerline tank. The next step would require you to remove and replace the refuel/transfer valve.

If none of the external tanks transferred in either NORM or WING FIRST position, the vent and pressurization valve is most likely inoperative.

210. Cargo transfer system operation

Refer to the fuel systems schematic and FMP on FO 3 while we cover the cargo transfer system. The cargo aircraft shown on the foldout has a total of 12 fuel tanks, 6 per wing. All fuel is stored within the wings. There are four main fuel tanks that feed the engines, four auxiliary tanks, and four extended range tanks. The aircraft is capable of holding approximately 330,000 pounds of fuel when all tanks are filled to capacity. All tanks contain two boost pumps and a fuel level control valve.

The transfer system on a cargo aircraft is used to move fuel from one tank to another during engine feed operation and to facilitate maintenance inside a fuel tank. You must always maintain the balance of the aircraft when you are transferring fuel. In other words, the fuel quantity in the left wing should be about equal to the fuel quantity in the right wing. Consult the aircraft technical order for specific guidance on maintaining aircraft balance during transfer operations.

Main tanks

Fuel from a main tank can be transferred to another main tank or to an auxiliary or extended range tank. Refer to FO3 while we simulate transferring fuel from the number 1 main tank to the number 1 auxiliary tank.

Turn on the boost pumps (N) in the number 1 main tank to pressurize fuel in the manifold through the check valve. Since you are not feeding the engines, the firewall shutoff valve (K) should be closed. Opening number 1 isolation valve (M) will allow fuel to flow into the main wing manifold. Trace the line to the number 1 auxiliary tank fuel level control valve (F). This valve is actually a dual-fuel level control valve, which like most other fuel level control valves, operates hydromechanically and is controlled by a solenoid. When you open the valve, fuel flows into the tank. By observing the quantity indicator for number 1 main tank, you can determine when all fuel has been transferred.

Auxiliary tanks

Let us transfer fuel from the number 1 auxiliary tank to the number 1 main tank using FO 2. Again, the boost pumps in number 1 auxiliary tank will pressurize the manifold and open the check valves downstream. Notice that no other valves need to be opened for fuel to flow to the fuel level control valve in the number 1 main tank. When this valve is opened, fuel should flow into the tank. Again, you would observe the fuel quantity indicator to determine when the tank is empty. When you are transferring from an extended range tank you can also use similar procedures.

Extended range tanks

If you have to remove the fuel from an extended range tank, you could transfer it to a main, auxiliary, or the other extended range tank. For our discussion, let us transfer from the number 1 extended range tank to the number 4 main tank. Although this transfer scenario would seldom be performed, it will demonstrate the capability of the transfer system to move fuel from one end of the aircraft to another.

Either or both pumps in the extended range tanks may be used to supply the needed pressure. Turning ON the pumps in the number 1 extended range tank will pressurize the left outboard section of the wing manifold to the left separation valve (D). You will need to open this valve to route fuel to the center separation valve (C). The entire left wing manifold should be pressurized. Open the center separation valve and fuel is routed to the right separation valve (E). Note the location of the fuel level control valve for the number 4 main tank. The right separation valve must also be open to route fuel to the tank. With this valve open, fuel flows to the number 1 main tank fuel level control valve. Open the fuel level control valve and fuel begins to flow into the tank. Whenever possible, fuel should be transferred rather than defueled. The defueling operation requires more personnel and is limited to certain types of repair areas.

211. Operational checkout of the cargo transfer system

In our last lesson, we covered the system operation and components of the cargo transfer system. In this lesson, we cover the procedures required to perform an operational check of the system.

Pump checkout

Using FO 3, locate the fuel pressure transmitter (O) in the left wing fuel manifold. This component senses fuel pressure and transmits a signal to an indicator on the fuel-management panel (FMP). Also, locate the four pressure switches on either side of the left and right separation valves. These switches can also be used to determine if a pump is operating satisfactorily by sending a signal to a PRESS LOW indicator light on the fuel-management panel.

Notice the fuel pressure indicators immediately below the left and right crossfeed valve switches on the FMP. When you operationally check a pump, fuel should be routed to the transmitter for this indicator to determine if the pump is operating within an acceptable output pressure range. Also, notice the four PRESS LOW indicator lights directly below the left and right separation valves. As previously stated, fuel can be routed to the pressure switches for these lights to determine adequate pump output pressure. However, the pressure indicators provide a more accurate reading.

Using both the fuel system schematic and the FMP, we will operationally check the outboard pump in the number 1 auxiliary tank. The first step should always be to ensure the tank has enough fuel to completely cover the pump. The applicable fuel system technical order will specify the amount. Often a pump will seem to have failed to check out, simply because the tank does not contain enough fuel.

Verifying that the number 1 auxiliary tank contains adequate fuel, you would then turn on the outboard pump to pressurize the manifold. Notice that fuel is routed to the outboard left wing pressure switch. The PRESS LOW light on the FMP should extinguish, indicating good pump pressure. Notice the fuel line on the right side of the left separation valve leading to the pressure indicator. Open the left separation valve to route fuel to the pressure transmitter for this indicator. If the pump is good, the indicator should read 36 (plus or minus [±] 12) psi.

Valve checkout

To perform a valve checkout, use a source of pressure from a pump and route it through the valve to be checked. For example, let us say we are checking the left separation valve. Turn on either pump in the number 1 auxiliary tank. Fuel is pressurizing the manifold up to the left separation valve, but since the valve is CLOSED, there should be no reading on the pressure indicator because the transmitter is on the inboard side of the valve. If pressure indicated the valve is not CLOSED, it is possible that it may have failed in the OPEN position or may be leaking internally and will require troubleshooting.

NOTE: Any valve on the aircraft can be checked out using pressure indicators, PRESS LOW lights, or both.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

208. Fighter transfer system operation

1. Explain the siphoning and air pressure transfer of the FWD fuel system.

2. What is the purpose of the thermistor switch?

3. How is excess air expelled from the reservoir tanks?

4. How many pumps are used to transfer fuel on a fighter aircraft?

5. Which pump transfers fuel to the FWD reservoir tank?

6. How are the external tanks pressurized, and to what pressure?

7. What is the sequence of transfer from the external tanks with the selector switch in NORM?

8. Explain how the fuel in the centerline tank transfers.

209. Troubleshooting the fighter transfer system

1. What is probably the most common transfer problem on the fighter aircraft?

2. Explain what you would check if all external tanks did not transfer in NORM position, but external wing tanks did with the select switch in WING FIRST position.

210. Cargo transfer system operation

1. How is the fuel level control valve operated and controlled in the transfer system?

2. When transferring fuel, how can you determine when all fuel has been transferred?

3. What tanks on a cargo aircraft could you transfer fuel from a main tank to?

211. Operational checkout of the cargo transfer system

1. What component senses fuel pressure and sends a signal to an indicator on the fuel-management panel?

2. How many pressure switches are installed in the main manifold to determine if pumps are operating properly?

3. What should be your first step when you are operationally checking a boost/transfer pump?

4. In addition to the fuel pressure indicators, what other means may you use to check out pump pressure?

5. What pressure would be considered acceptable when you are operationally checking a boost pump on the cargo aircraft?

6. Explain how you would operationally check a valve in the transfer system?

2–2. Fuel Jettison/Dump Systems

There is one fuel subsystem that nearly all aircraft have but is seldom used—the fuel jettison/dump system. The jettison system, or dump system, as it is sometimes called, is used to dump fuel from the aircraft while it is in flight. This may become necessary if an aircraft with a heavy payload loses engine power. Having the capability to dump fuel in such a situation may mean the difference between a safe emergency landing and a mishap. In this section, we cover the jettison systems on both the cargo and bomber aircraft.

212. Cargo aircraft fuel jettison/dump system

The fuel jettison system on the cargo aircraft is comprised of a combination of fuel lines, valves, and pumps. This system is designed to allow the aircrew to “dump” fuel overboard during an in-flight emergency. This will reduce the gross weight of the aircraft so an emergency landing can be made. The cargo aircraft fuel jettison system that we will discuss has the capability to jettison approximately 1,380 gallons of fuel per minute.

To give you the information, you need to understand the basic operation of this system. That is why we will cover the following three subject areas:

- Components.
- Operational check.
- Malfunctions.

Components

For this discussion, refer to FO 3, figure 1. A fuel jettison mast and shutoff valve are mounted in the trailing edge of the wing, outboard of the flaps on each side of the airplane (item P). The jettison mast is simply an extension of the main fuel manifold. Jettisoning is done by opening the jettison and side separation valves and operating all boost pumps in the auxiliary and extended range fuel tanks. The boost pumps are capable of providing the required jettison rate.

Although, the normal jettison procedure for reaching gross landing weight does not require jettison of the main tank fuel, it is possible to jettison from the main fuel tanks for ditching operations. The location of the jettison mast assures fuel discharge will clear all parts of the aircraft and no fuel vapors will enter any portion of the aircraft to create a hazard. A flame arrestor screen is installed in the jettison mast for two reasons. One is to prevent the introduction of foreign objects from entering the fuel system. Second, if an aircraft is dumping fuel and it happens to catch fire, the screen does not allow the flames to go through it and into the aircraft.

Fuel dump valves control the fuel flow through the jettison system. The valve interfaces with the fuel dump mast and the fuel transfer system. One valve is located in each wing on the fuel dump line outside the tanks. These valves can be found in the rear flapwell area of the No. 1 and No. 4 main tanks.

There are two guarded toggle JETTISON switches, located at the two lower corners of the flight engineer's FMP (FO 3, fig. 1). The switch covers are red and contain a small drilled hole to which thin safety wire is attached to prevent accidental operation of the system. In the event of an emergency, the safety wire is thin enough to allow the switch cover to be forced open.

Operational check

Performing an operational check of the fuel jettison system is a fairly simple process; however, while it may be simple, it's also dangerous because of the potential for a sizable fuel spill. A hose and clamp is required. They must be long enough to reach from the two jettison masts to an approved fuel container—such as a fuel bowser. To prevent the hose from accidentally coming out of the bowser, some fuel shops have a locally fabricated hose assembly that connects to a fitting on the bowser.

To perform the operational check of the right wing jettison system, position a person at the jettison mast. Secure the hose to the maintenance stand in such a manner as to provide sufficient length to reach the jettison mast. The weight of the hose is supported by the stand. Attach the hose to the jettison mast and secure it with a clamp. Secure the other end of the hose to the fuel container.

Place the AUX 4 boost pump switch to the ON position. There should be no fuel flow from the right jettison mast, since the valve is closed. Place the right JETTISON switch in the JETTISON position. Fuel should flow from the right jettison mast. Return the right JETTISON switch to the CLOSED position and AUX 4 boost pump to OFF. Fuel should stop flowing out of the jettison mast except for a small amount of residual fuel that should also stop after a few minutes.

Malfunctions

Since this system is very seldom used and is comprised of only a few components, malfunctions do not often occur. Ironically, probably the most common problem arises after an operational check of the system. A small stream of fuel continues to flow out of the jettison mast for some time after the jettison valve has been CLOSED. This is because, the valve stays closed for such a long period of time that the o-ring seals retain their compressed shape after the valve is opened. Keep in mind that one side of this valve is constantly exposed to the elements via the jettison mast that is open to the atmosphere; hence, the o-ring seals have a tendency to dry out over time.

Usually though, this problem can be corrected by cycling the valve open and closed a few times (without any boost pumps on) and simply waiting for the fuel to stop flowing out of the jettison mast after the valve is finally closed. If fuel still continues to flow out after a longer than usual period of time, or if the stream of fuel does not gradually get smaller, the valve will have to be removed and the seals replaced.

Another problem that may arise is foreign objects stuck in the screen at the end of the jettison mast, blocking fuel flow through the mast. However, this is very uncommon.

213. Bomber aircraft fuel dump system

The fuel dump system on the bomber is very similar in operation to the jettison system on the cargo aircraft. As with the cargo aircraft jettison system, the bomber's fuel dump system also permits the jettisoning of fuel overboard for weight reduction in flight.

Fuel dump shutoff valves are located in each wing tip to enable fuel dumping. The shutoff valve body is a two-inch butterfly-type valve mounted in the dry bay, outboard of the fuel tank. The shutoff valves are connected to the fuel transfer lines and overboard outlets by fuel dump lines.

The guarded two-position DUMP switch on the FMP controls the fuel dump operation. Placing this switch to the DUMP position will open the dump shutoff valve, provided the landing gear is in the airborne (UP) position. This safety feature prevents the accidental dumping of fuel while the aircraft is on the ground.

The opening of the shutoff valves enables fuel to be dumped overboard as a function of the fuel transfer system. Fuel transferred from the aircraft tanks is routed through the ballast tank isolation valve into the wing transfer lines through the dump valves, then overboard. The dump operation is in effect when the dump valves are opened and any fuel transfer pump is in operation. Placing the DUMP switch back to the NORM position will close the shutoff valve and end the dump operation. The bomber aircraft has the capability of dumping fuel overboard at a maximum rate of 3,800 pounds per minute.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

212. Cargo aircraft fuel jettison/dump system

1. Which valves must be opened to jettison fuel from the auxiliary and extended range tanks on the cargo aircraft?

2. When is it possible to jettison fuel from the main tanks?

3. Explain the reason for the location of the jettison mast?

4. Why is performing an operational check on the jettison system dangerous?

5. What is the most common jettison system malfunction? Explain.

213. Bomber aircraft fuel dump system

1. What is the purpose of the bomber aircraft fuel dump system?

2. What type of valve is the fuel dump shutoff valve on the bomber aircraft, and where is it located?

3. What safety feature prevents the accidental dumping of fuel while the aircraft is on the ground and the dump switch is placed to the DUMP position?

4. In addition to the dump valve, what valve must be opened to transfer fuel from a fuel tank to the wing transfer lines to be dumped overboard?

5. How is the dump valve closed?

Answers to Self-Test Questions

208

1. As fuel from the FWD reservoir tank is used by the engine, it creates a siphoning action, causing fuel to flow through a standpipe that interconnects the top of the FWD reservoir tank with the bottom of the F–2 tank. The fuel that leaves the F–2 tank is replaced with fuel from the F–1 tank through an interconnecting standpipe. Fuel that leaves the F–1 tank is replaced by fuel from the right wing tank.
2. Controls the operation of the air ejectors.
3. By air ejectors.
4. Six.
5. The electric transfer pump in the F–1 tank.
6. By engine bleed air pressure; 19 to 24 psi.
7. The centerline tank will empty first, then the external wing tanks.
8. Fuel from the centerline tank will enter each internal wing tank via the refuel manifold, keeping them full until the centerline tank is empty.

209

1. No external tanks transfer when the select switch is in the NORM position, but the external wing tanks will transfer with the select switch in WING FIRST.
2. First, check to ensure the manual shutoff valve is not CLOSED. If the valve is open, check the cannon plugs to ensure they are properly installed on the centerline tank. Next, use a direct-reading gauge to check for 19 to 25 psi to the centerline tank. If pressure is good, the only component left is the refuel/transfer valve in the centerline tank.

210

1. Operated hydromechanically and controlled by a solenoid.
2. Observe the fuel quantity indicator in the tank in which fuel is being transferred from.
3. To another main tank, an auxiliary tank, or an extended range tank.

211

1. Fuel pressure transmitter.
2. Four.
3. Ensure the tank contains enough fuel to completely cover the pump, as per the applicable tech data.
4. PRESS LOW indicator lights.

5. 36 (±12) psi.
6. Close the valve and use a pump to pressurize one side of the valve. The pressure switch or transmitter sensing line on the other side should send no reading to the pressure indicator. If the valve is CLOSED, there should not be a pressure indication on the light or gauge. If pressure indicated the valve is not CLOSED, it is possible that it may have failed in the OPEN position or may be leaking internally and will require troubleshooting.

212

1. The jettison valve and side separation valve.
2. For ditching operations.
3. It assures fuel discharge will clear all parts of the aircraft and no fuel fumes will enter any portion of the aircraft to create a hazard.
4. Potential for a sizable fuel spill.
5. Fuel continues to leak out of the jettison mast after an operational check of the system. This is because the infrequent use of the jettison valve causing the seals to remain compressed after the valve is opened.

213

1. The system permits the jettisoning of fuel overboard for weight reduction in flight.
2. A two-inch butterfly valve, located in the dry bay, outboard of the fuel tank.
3. The dump shutoff valve will not open unless the landing gear is in the airborne (UP) position.
4. The ballast tank isolation valve.
5. By placing the DUMP switch back to the NORM position.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

21. (208) The purpose of the power transfer method on a fighter aircraft is to
    a. pressurize the tanks only.
    b. augment fuel transfer only.
    c. pressurize and scavenge the tanks.
    d. augment fuel transfer and scavenge the tanks.

22. (208) Which fighter aircraft tank will empty *first* during fuel transfer of the forward (FWD) fuel system?
    a. F–1.
    b. F–2.
    c. Right wing.
    d. FWD reservoir.

23. (208) How many pumps are used in the power transfer system on a fighter aircraft?
    a. Two.
    b. Three.
    c. Four.
    d. Six.

24. (208) On a fighter aircraft, what type of pumps are the scavenge pumps and where are they located?
    a. Ejector-type; located in the F–2 tank.
    b. Turbine-type; located in the F–2 tank.
    c. Ejector-type; located in the F–1 tank.
    d. Turbine-type; located in the F–1 tank.

25. (209) You are troubleshooting a problem on a fighter aircraft. You find that *none* of the external tanks transferred fuel with the select switch in NORM position; however, the external wing tanks *did* transfer fuel with the select switch in WING FIRST position. The *most* probable cause of this malfunction is the
    a. inoperative wing float valve.
    b. external transfer shutoff valve is bad.
    c. external vent and pressurization valve is bad.
    d. centerline refuel/transfer valve is inoperative.

26. (210) While transferring fuel from an auxiliary tank on a cargo aircraft, in order to determine if the auxiliary tank is empty, you would observe the
    a. pressure gauge.
    b. fuel no-flow light.
    c. fuel quantity indicator.
    d. low-level warning light.

27. (211) Which indication shows that a boost pump on a cargo aircraft is putting out sufficient pressure?
    a. Pressure indicator reads 20 pounds per square inch (psi).
    b. PRESS LOW light extinguishes.
    c. Pressure indicator reads 16 psi.
    d. PRESS LOW light illuminates.

28. (212) To prevent the introduction of foreign objects into the fuel transfer system of a cargo aircraft, the jettison mast is equipped with a
    a. flame arrestor screen.
    b. safety wire device.
    c. check valve.
    d. flapper.

29. (212) Which type of fuel valves control the flow of fuel through the jettison system?
    a. Vent.
    b. Refuel.
    c. Transfer.
    d. Dump.

30. (213) What safety feature in the bomber aircraft fuel dump system prevents the accidental dumping of fuel while the aircraft is on the ground?
    a. The DUMP switch cover is safety-wired closed.
    b. The landing gear must be in the airborne (UP) position.
    c. The DUMP switch is spring-loaded to the OFF position.
    d. A shorting plug must be connected for the dump valve to open.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Refueling and Defueling Systems

IN SOME RESPECTS, an automobile and an aircraft have a lot in common. For example, both must have the capability of being fueled or refueled before going on a long trip or a long mission. Unlike an automobile, most aircraft have many tanks. On an aircraft, a ground refueling system is used to selectively fill any or all tanks while the aircraft is on the ground. Unlike an automobile, aircraft are also equipped with a defuel system. As the name implies, the defuel system permits fuel to be taken off the aircraft for maintenance, weight and balance, or other reasons as deemed necessary. Most aircraft can be refueled in midair. This is done through an aerial refueling system, permitting the aircraft to receive fuel without mission interruption; thus, giving the aircraft a virtually unlimited flying range.

3–1. Ground Refueling and Defueling Systems

As we mentioned in our introduction, the ground refuel system is used to fill any or all tanks on an aircraft. Conversely, many maintenance tasks on fuel systems require the removal of fuel from the aircraft or from selected fuel tanks. The defuel system we mentioned earlier is used for that purpose.

Depending on the base and the type of aircraft, you may be required to perform refuel and defuel operations. As a fuel systems mechanic, you must have a working knowledge of the system to operationally check and troubleshoot the system should a malfunction occur.

To give you the knowledge you need to understand refuel/defuel systems, we cover the following four subject areas:

- Components used in the ground refueling system.
- Operation of the cargo ground refueling and defueling systems.
- Fighter ground refueling system.
- Troubleshooting the fighter ground refueling system.

214. Components used in the ground refueling system

The components that are commonly found in a ground refueling system include the following:

- Single-point receptacles (SPR).
- Fuel-flow indicator switches.
- Float switches.
- Fuel-level control valves.
- SOV.

Since we covered SOVs in a previous unit, we only cover the first four components in this lesson.

Single-point receptacle

An illustration of the SPR is shown in figure 3–1, and it is a spring-loaded poppet valve. The valve is OPENED when the refueling nozzle is inserted into the receptacle and the nozzle lever is pushed forward to the "OPEN" position. It closes by spring tension when the refueling nozzle lever is pulled back to the spring-loaded "CLOSED" position.

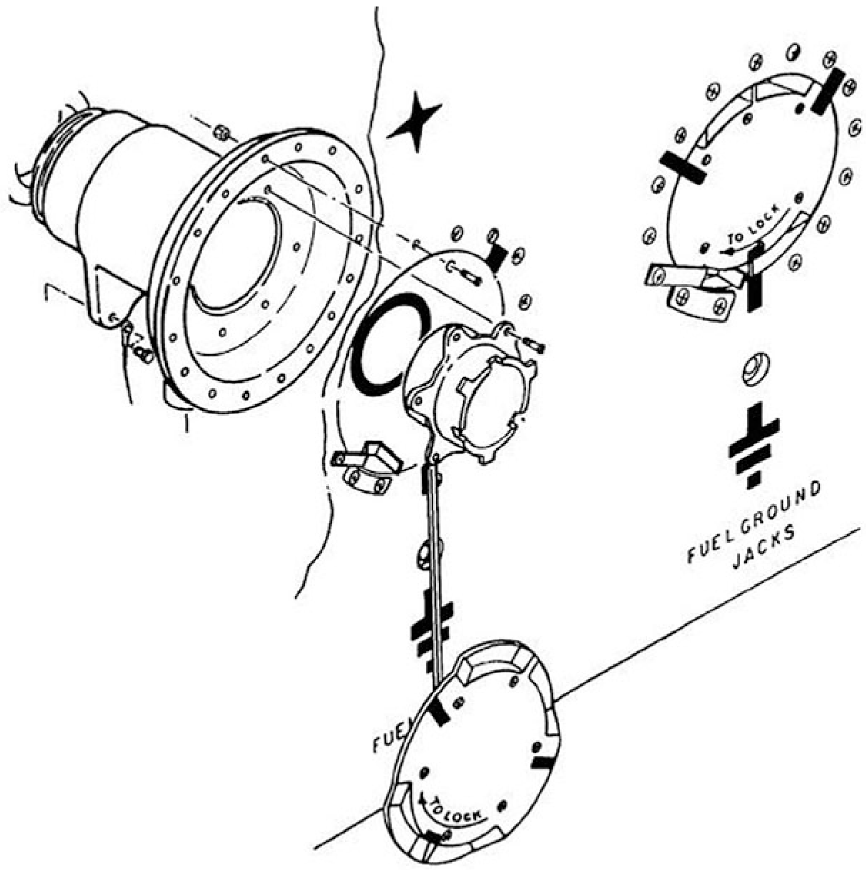

Figure 3–1. Single-point receptacles.

Fuel-flow indicating switches

A cutaway illustration of a fuel-flow indicating switch is shown in figure 3–2, and the switch is used to indicate a flow- or no-flow condition. Sufficient fuel flow through the fuel manifold from the left side causes the vane (C) to swing to the right. The striker arm (B) contacts the microswitch (A) in the head of the unit. This breaks the electrical circuit and indicates fuel flow. When flow is stopped by either a closed valve downstream or an empty fuel tank, the vane (C) moves to the position shown in figure 3–2. The microswitch then completes the electrical circuit and gives an indication of no flow.

NOTE: A fuel-flow indicating switch may be used in a system to indicate refueling shutoff using these same principles of operation.

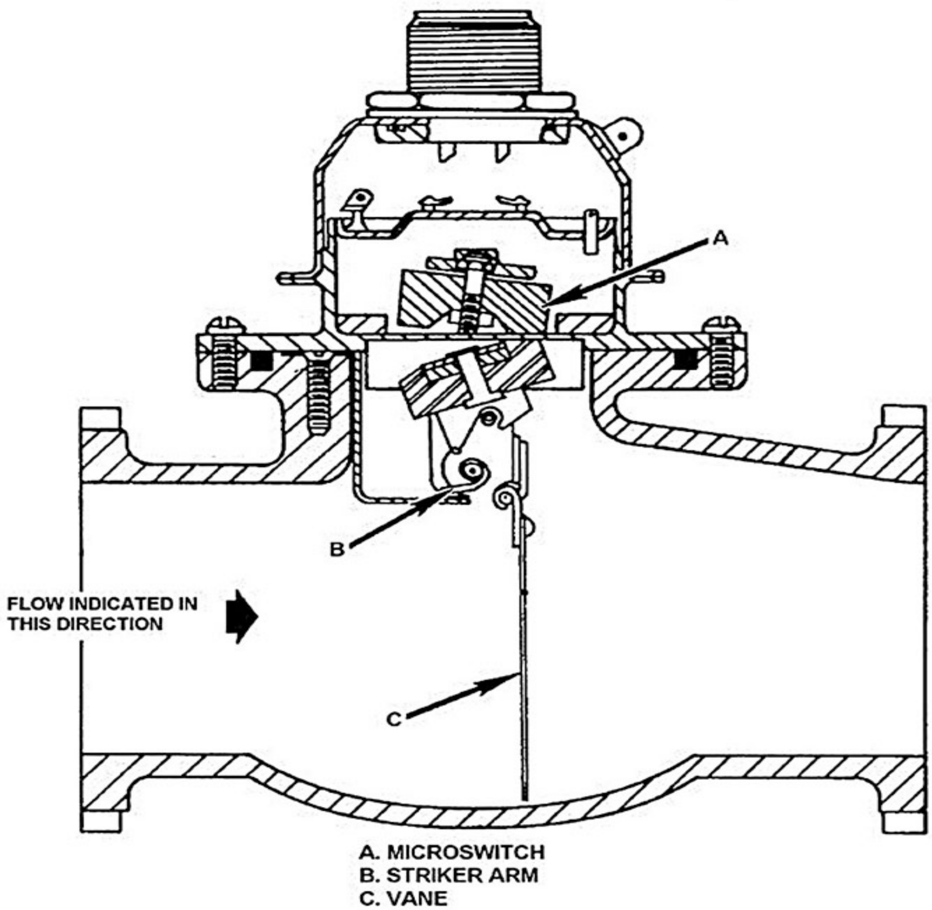

Figure 3–2. Fuel-flow indicating switch.

Float switches

A cutaway illustration of a float switch is shown in figure 3–3. These switches are located inside a fuel tank or are attached to the fuel manifold. They are actuated by the fuel level. Upon actuation, the float switches control other electrically operated units. When used in a system designed for automatic pump shutoff when all the fuel is depleted, the float switch will be located at the lowest point in the system and at the same level as the pump. After all of the fuel is removed by the pump, the float switch will then automatically stop the pump. Look at figure 3–3. When the float (B) is raised, a circuit is completed across the microswitch (A). But when depletion of fuel causes the float to drop, the circuit is broken across the microswitch, causing the fuel pump operation to stop.

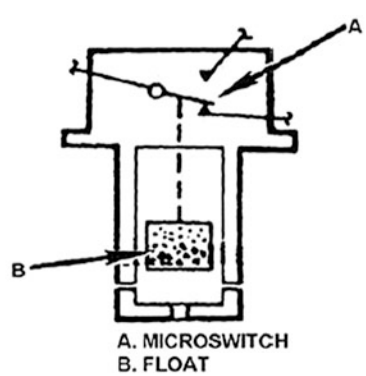

Figure 3–3. Float switch.

Fuel-level control valves

Fuel-level control valves permit the automatic control of fuel level during the filling of a tank. This type of valve permits refueling any tank from a single point because each tank does not have to be monitored, because the valve will automatically stop the flow of fuel into a tank prior to overflow. In this way, a fuel-level control valve makes refueling a safer operation (if the valve is operating properly).The hydromechanical principle is used to operate these valves. Figure 3–4 shows a few simple examples. Refer to view 1, and you will see that if equal pressures are applied to both sides of the diaphragm (A), the diaphragm remains in the center position. If a spring (B) is installed to aid the pressure of one side, as in view 2, the diaphragm moves to the left as shown. If the pressure is equal on both sides but one side has a larger area, the total force on the side with the larger area results in the diaphragm moving to the right, as shown in view 3.

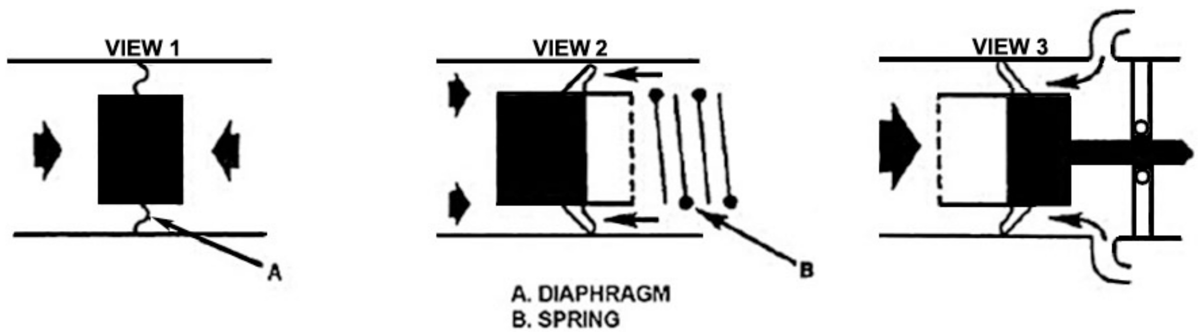

Figure 3–4. Hydromechanical principle.

Piston-type fuel-level control valve

Figure 3–5 illustrates a piston-type fuel-level control valve, which also uses the hydromechanical principle for operation and control. Fuel pressure pushes the piston (A) open, which allows fuel to enter the tank. Some of the fuel passes through the piston, pushing the pilot valve (B) open to allow fuel flow into the tank. When the tank is nearly full, the float (C) rises and closes the pilot valve to prevent fuel from flowing through it. Fuel pressure inside is now equal to the pressure holding the piston open. With the aid of a spring (D), the piston closes and prevents more fuel from entering the tank.

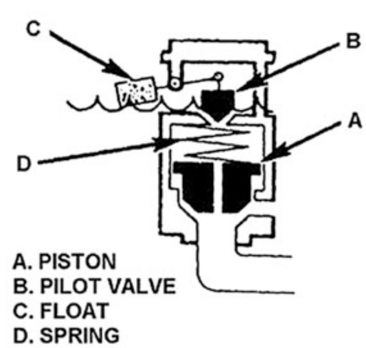

Figure 3–5. Piston-type fuel-level control valve.

Diaphragm-type fuel-level control valve

A cutaway illustration of a diaphragm-type fuel-level control valve is shown in figure 3–6. This type of valve is operated hydromechanically and controlled electrically. Fuel pressure (E) pushes the diaphragm (D) open and allows fuel to enter the tank. Fuel passes through the orifice in the center of the diaphragm, the float-controlled pilot valve (C), and the outlet (G). When the float rises, a hydromechanical operation takes place within the valve, shutting off fuel flow.

The solenoid (A) is used to electrically control the valve. Without electrical power, the solenoid poppet (H) is forced downward by the spring (I). As you can see, the poppet is holding the float linkage (F) in a position to prevent fuel from passing through the pilot valve. When you apply electrical power to the solenoid, it raises the poppet and compresses the spring. This allows the float to move freely to any position, depending on the fuel level. When the tank is full, the float is up and stops fuel from entering the tank. The float is down any time the tank is less than full and power is not applied to the solenoid. Therefore, the valve remains closed until you decide to allow fuel to enter the tank.

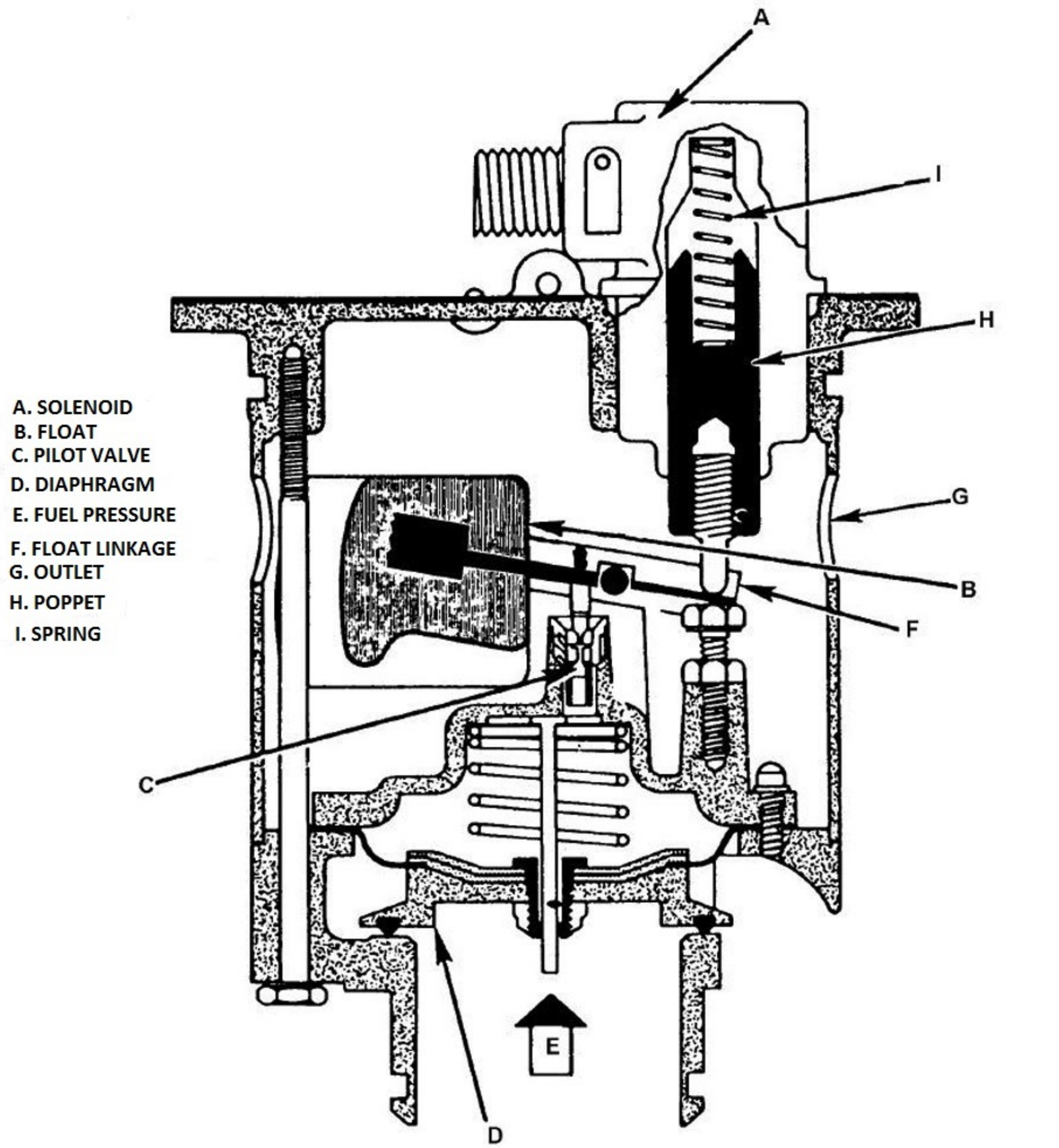

Figure 3–6. Diaphragm-type fuel-level control valve.

Dual-float fuel-level control valve

Figure 3–7 shows a cutaway view of a dual-float fuel-level control valve. As the name implies, it is a dual-mechanism that has a primary system and a secondary system. Either system can perform the total function of the valve, which provides a double safety factor. Keep in mind that tank entry is required to remove and replace this particular valve because it is bolted to the manifold.

The valve is installed in the tank with the pilot valve at the desired level. The valve controls the fuel entering the tank by way of the refuel system. In some instances, this valve may also control fuel entering the tank by way of the transfer system. The poppet valves (E and Q on fig. 3–7) are spring-loaded to the CLOSED position. They can be opened by the electric solenoids located directly above each respective valve. The floats (A and D) control the pilot valves (C and P) by closing the valves when the fuel level in the float chambers rises to the level shown in the illustration. There are two conditions in which fuel in the chambers will rise to this level.

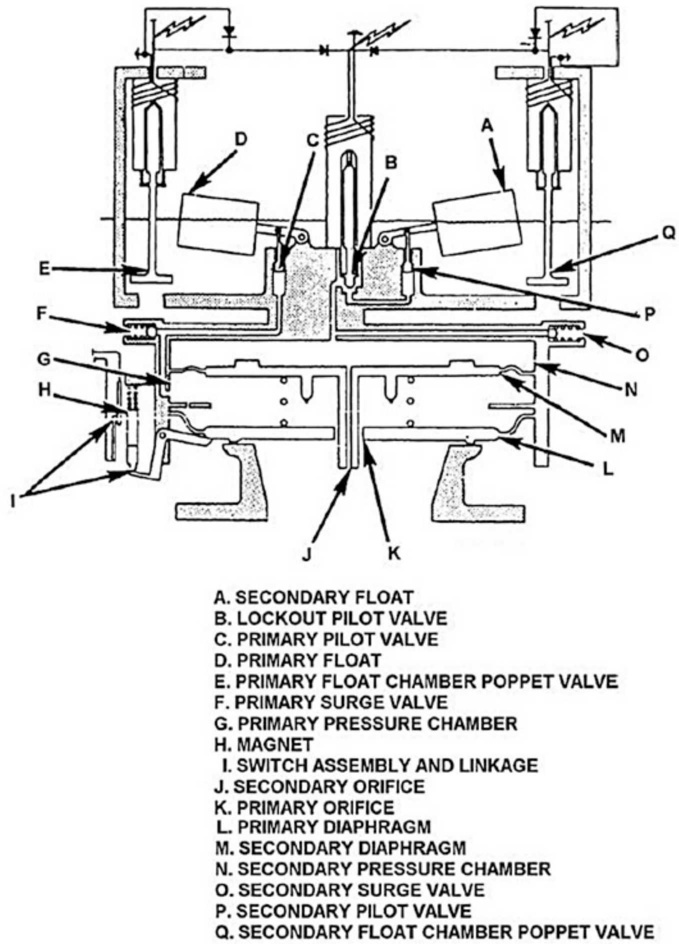

Figure 3–7. Dual-fuel level control valve.

One is when there is a full tank. This occurs because of the openings in the float chambers above the float level. Whether the poppet valves (E and Q) are open or not—when the tank is filled to the level of the openings—fuel enters the float chambers and causes the floats to rise.

The other condition of the fuel-level control is an OFF condition. This occurs when no electricity flows through the solenoids and allows the poppet valves (E and Q) to be CLOSED. In this condition, as soon as fuel pressure is applied to the fuel line, fuel is forced through the primary orifice (K), over to the left to the passageway starting at the pressure chamber (G), and out the primary pilot valve (C). Fuel fills the chamber to the point shown, where the float (D) rises and closes the pilot valve (C). Even without the secondary system, when valve C closes, fuel under fueling pressure would continue to enter the primary pressure chamber (G). Because of the greater area, it would force the primary diaphragm (L) down and shut off fuel flow to the tank.

Whether the primary system functions normally or fails to function at all, the secondary system is fully capable of controlling the total action of the fuel-level control. Fuel under refuel pressure enters the secondary orifice (J), the secondary pressure chamber (N), and up the drilled passageway, and through the lockout pilot valve (B) to the secondary pilot valve (P). Since the secondary float chamber poppet valve (Q) is CLOSED (OFF), the secondary float (A) closes valve P. Fuel pressure then builds up in the secondary pressure chamber (N). Pressure in the chamber (N) moves the secondary diaphragm (M) down. The fingers seen on either side of the primary orifice (K) push the primary diaphragm (L) closed to shut off fuel flow into the tank. By examining the figure, you can see that if the lockout pilot valve (B) is CLOSED (no power to the solenoid), pressure builds in the secondary pressure chamber (N) even though there is no fuel in the secondary pilot float chamber. In case of a leaking secondary (and primary) float chamber poppet valve; the action of the lockout pilot valve still gives positive shutoff action. When the primary diaphragm valve is CLOSED, the magnet (H) is moved and closes the switch assembly (I). This circuit is used to electrically control the valve in the CLOSED position. The surge valves (O and F) relieve excessive pressure due to fuel surge as the valve closes.

Any one portion of the valve could malfunction because of dirt, ice, or other small debris. This is why it is essential that an operational check of the unit be performed during the filling of a tank or after the valve has been replaced.

Fuel must be flowing into the tank when you conduct an operational check of the valve, shown in figure 3–7 .The primary solenoid valve is energized and the primary float chamber poppet valve seats. This closes off the chamber and allows the fuel level to raise and actuate the primary float (D). When the primary float rises, the primary pilot valve (C), which is linked to the float (D), closes off the passage. This trapped fuel pressure in the primary pressure chamber (G) becomes equal to inlet pressure. The primary diaphragm shuts off fuel flow since the area on the upper side of the diaphragm is greater. The diaphragm is also aided by the spring. When the primary diaphragm closes, it contacts the linkage and closes the switch assembly (I). This completes an indicator circuit that indicates the valve is closed. An operational check of the secondary side is performed following similar procedures as the primary, but in this case you de-energize the secondary float chamber poppet valve (Q).

215. Operation of the cargo ground refueling and defueling systems

There are two methods that can be used to refuel cargo and most other types of aircraft. The first and most common method is the SPR method. The primary advantage of this method is that it allows all fuel tanks to be refueled from a single connection.

The second method is the filler cap or “over the wing” method. This method is slow and more dangerous than the SPR method because of the free-falling fuel creating static electricity and the presence of fuel vapors in the tank. This type of refueling is conducted as a last resort and will not be covered in this CDC.

General description of single-point receptacle method

As previously stated, the SPR method allows the tanks to be filled from a single point on the aircraft. The SPR receptacles are located in the fairing forward of the main landing gear wheel wells. Removal of caps in the fairing exposes the receptacles (fig. 3–1). This aircraft has a total of four SPRs—two on each side of the fuselage, which permit the aircraft to be refueled from one to four refuel trucks at the same time. Each SPR is capable of a maximum flow of 600 gallons per minute (gpm) at a nozzle pressure of 45–55 psig.

During refueling operations, any or all of the aircraft fuel tanks may be filled at the same time by selective control. Fuel-level control valves automatically shut off fuel flow when the tanks are filled to maximum level, leaving approximately 3 percent air space above fuel level. All single-point refueling (SPR) operations are controlled from the fuel-management panel.

System components

Using FO 3, figures 1 and 2, let us look at the components in a cargo aircraft ground refueling system.

Single-point receptacle

The SPR (A) is a spring-loaded poppet valve. It is OPENED by engaging the lever on the refueling nozzle and is CLOSED by spring tension when the lever is retracted.

Refuel isolation valves

Refuel isolation valves (B) are located at the top point of the 4-inch refueling line. They connect the refuel manifold to the main refuel (wing) manifold in the center section of the aircraft. There are two valves—left and right; they are controlled by the left and right ground refuel (GRD REFUEL) valve switches on the flight engineer's FMP. Switch positions are refuel (REF), which opens the valve to permit refuel; OFF, which closes the valve; and DRAIN, which will be covered shortly.

Center separation valve

The center separation valve (C) is a motor-operated fuel shutoff valve located in the center of the 3-inch main (wing) manifold. The valve separates the fuel manifold into two halves, preventing imbalance during crossfeed operation. The valve is controlled by the center SEPARATION switch on the FMP.

Left and right separation valves

The left separation valve (D) is located in the left outboard wing dry bay and the right separation valve (E) is located in the right outboard wing dry bay. These valves are butterfly-type and separate the fuel system in each wing. They are controlled by the left- and right-SEPARATION switches on the FMP.

Fuel-level control valves

Fuel-level control valves (F) are located in each tank on the aircraft to stop fuel flow into the tank when desired. These valves have dual systems, primary and secondary, which operate independently of one another. The valve senses fuel level with floats, and the solenoids provide electromechanical means of lifting the floats to open and close the primary and/or secondary valve. These valves should be operationally checked during the first few minutes of a ground refueling operation.

Each fuel-level control valve may be closed to stop fuel flow at a desired quantity during refueling by closing the appropriate MAIN tank—FILL rotary switch on the FMP or by placing the appropriate auxiliary or extended range tank REF switch on the FMP in the CLOSED position. The primary and secondary sides of the valves may alternately be CLOSED by placing the PRECHECK switch to PRIMARY (PRI) or SECONDARY (SEC) position.

Single-point receptacles drain/transfer pump

This pump (G) is located in the 4-inch fuel line on each side of the aircraft next to the SPR receptacles. Each pump scavenges the residual fuel from its respective manifold after refueling. The pumps are controlled by the GRD REFUEL switches on the FMP. The switch is placed to the DRAIN position to start the pump.

Single-point receptacles drain valves

SPR drain valves (H) are also located in the 4-inch drain line just upstream of the drain pump, next to the SPR receptacle. The purpose of these valves is to shut off the gravity flow to the manifold of its respective SPR drain pump. The valves are energized when the GRD REFUEL switch is placed to the DRAIN position. The valves also provide thermal relief features that relieve in either direction to the low-pressure side of the valve. A manual drain valve (I) is also used for removing excess fuel and is attached to the SPR drain/transfer pump.

Fuel (wing) manifold drain valves

A 1-inch manifold drain valve (J) is located at the aft inboard end of No. 1 and No. 4 main fuel tanks. When in the OPEN position, these drain valves allow fuel in the wing manifold to gravity flow to the vent box. The valves are opened by positioning the LINE DRAINS switch to MANF. Let us simulate a ground refuel operation using foldout 3.

Refuel system operation

For our simulated refuel, we will use the left side refuel manifold. The refueling nozzle is connected to either of the two SPRs (A). We will be refueling the entire aircraft; as a result, many valves will have to be OPENED. Foldout 3, figures 1 and 2 will be used.

Follow the left refuel manifold from the SPR down to the LH refueling isolation valve (B). Opening this valve will allow fuel to flow from the refuel manifold to the main (wing) manifold; the same thing occurs with the RH refueling isolation valve.

At this point, fuel is available to the fuel-level control valves for No. 2 AUX, 2 main, 1 extended range, and 2 extended range tanks on the left wing. Opening the left separation valve will route fuel to Nos. 1 main and 1 AUX tank. Now let us go back to the center separation valve (C). Opening this valve will allow fuel to be routed to Nos. 3 main, 3 AUX, 3 extended range, and 4 extended range tanks. Opening the right separation valve will make fuel available to the remaining two tanks. By opening the fuel level control valves for all 12 tanks, refueling will take place.

Just as with the transfer system, fuel level in the tanks being refueled can be selected using the FMP. It is also important to note that the primary and secondary sides of the fuel-level control valves should be operationally checked during the first few minutes of the refueling operation, to ensure that they will stop fuel flow into the tank when the desired level is reached.

Defuel system operation

On most aircraft, the defuel operation is very similar to the transferring of fuel from tank to tank. The centrifugal pumps are used to pressurize the fuel and route it through the appropriate manifolds, to the SPR, and off the aircraft. The cargo aircraft is no exception.

Let us simulate defueling the left wing tanks to the LH refuel manifold/SPR. The first step in the defueling process is to turn on the pumps in all tanks to be defueled. We need to pressurize fuel in the manifold and route it to the LH refueling isolation valve. Notice that the No. 2 AUX and No. 2 extended range tank boost pumps can pressurize fuel down to the LH ground refueling isolation valve (B) without opening any additional valves. However, this is not true of the other left wing tanks.

Follow the fuel manifold from the No. 1 main tank boost pumps. Fuel is routed past the firewall shutoff valve (K) for No. 1 engine, which will remain CLOSED during defuel. Fuel is also routed to the left crossfeed valve (L) that may also remain CLOSED. The next valve that must be opened is the No. 1 isolation valve (M). Opening this valve allows fuel to flow to the left separation valve (D). When the left separation valve is OPENED, fuel will flow to the LH refueling isolation valve, then to the SPR.

Use this same procedure of tracing the fuel system schematic to determine which valves must be open to defuel the remaining tanks on the left wing.

As with the refueling and transfer operations, the fuel balance must be monitored to ensure a wing-heavy condition does not develop during defuel.

216. Fighter ground refueling system

The refuel system on the fighter aircraft is somewhat different than that of the cargo. This aircraft has seven internal and three external tanks (FO 1, fig. 1). The internal tanks are the left and right wing tanks, F–1, F–2, A–1, FWD reservoir, and aft reservoir tanks in the fuselage. All of these tanks are integral-type fuel tanks except the F–1 tank, which is a bladder cell. The external tanks are two 370-gallon externally mounted wing tanks and a 300-gallon externally mounted centerline tank.

It takes approximately four minutes to refuel the internal tanks and an additional minute to fill the externals when installed. A manually operated fuel SOV installed in the plumbing between the refuel manifold and each external fuel tank provides the capability of selective refueling of the external tanks. This aircraft has two SPRs; one is used for refuel and one for defuel.

Refuel system components

Let us look at the components used in this system, starting with the component through which fuel enters the aircraft.

Single-point receptacles

The refuel receptacle is located on the lower left side of the fuselage just forward of the wing trailing edge. It is a conventional adapter such as used on other aircraft, permitting the use of a standard refueling nozzle. The refuel receptacle is opened by the refueling nozzle. It is self-sealing and closes when the nozzle is removed.

Refuel shutoff valves

Two refuel shutoff valves (one in each reservoir tank) control fuel flow from the refuel manifold to the reservoir tanks during refueling. The refuel shutoff valve is a poppet-type pressure-actuated valve.

Refuel/transfer float valves

Two refuel/transfer float valves provide control functions during refueling and during external tank transfer. The primary function of the refuel-transfer float valves is to control the refuel shutoff valves and the external tank-transfer shutoff valves that control the flow of fuel.

Refuel shuttle valves

Two refuel shuttle valves (one in each reservoir tank) provide control functions for refueling of the aircraft and external tank transfer of fuel. The refuel shuttle valve consists of a housing, four ports, two check valves, and a poppet. The shuttle valve located in the forward reservoir controls the refuel shutoff valve in the forward reservoir and the external tank-transfer shutoff valve in the right wing. The shuttle valve located in the aft reservoir controls the refuel shutoff valve in the aft reservoir and the external tank-transfer shutoff valve in the left wing.

The shuttle valve poppet is actuated by fuel pressure from the refuel manifold. The shuttle-valve control port to the refuel shutoff valve is blocked by the position of the poppet to prevent fuel from the external tanks entering the reservoir tanks.

Wing pylon fuel disconnect valves

The wing disconnect valves provide fuel connections between the pylon/tank and the wing integral tank. The fuel disconnect valve is installed in each wing fuel disconnect adapter. Each valve provides sealing of the pylon tank fuel line at the wing disconnect when the external pylon/tank is installed. Each valve provides a method of sealing the aircraft wing integral tank when the external pylon/tank is removed. Each fuel disconnect valve is a spring-loaded poppet-type valve which provides positive shutoff.

Wing pylon/tank assembly selective refueling fuel shutoff valve

This is a manually operated ball (globe)-type valve. The valve is installed in the fuel pylon in the fuel supply line between the wing pylon fuel disconnect valve and wing pylon external tank. The purpose of the valve is to provide selective refueling of the external wing pylon fuel tank.

Aircraft centerline tank selective refueling fuel shutoff valve

This valve is also a manually operated ball-type valve. Its purpose is to provide selective refueling of the external centerline tank. Positioning the valve to the CLOSED position permits the internal tanks to be refueled without refueling the external centerline tank.

Performing an operational check

Unlike most other aircraft, when ground refueling a fighter there is no requirement for power unless you need a fuel quantity reading. As previously stated, one SPR is used to refuel this aircraft. It is located at the lower left fuselage just forward of the wing trailing edge.

With the refuel hose connected to the SPR (FO 1, fig. 3), fuel pressure of approximately 60 psi is supplied to the refuel manifold during refueling. Fuel from the refuel manifold is routed through the de-energized refuel/transfer solenoid valve to the poppet of the refuel shuttle valve in each reservoir. The fuel pressure moves the poppet to provide an open passage from the refuel shutoff valve through the refuel shuttle valve and to the line outlet whose opening is blocked or unblocked by the refuel/transfer float valve in each wing. The opening is unblocked when the wing is not full of fuel (the float valve is down).

Refuel manifold fuel pressure acting on the refuel shutoff valves causes the shutoff valves to open. Also, the poppet in the refuel shuttle valves is blocking the fuel passage that controls the external tank transfer shutoff valves and the valves remain CLOSED, preventing fuel from the refuel manifold from entering the wing tanks.

Fuel from the refuel manifold flows through the refuel shutoff valves into the forward and aft reservoirs. Also, all external tanks will be receiving fuel from the refuel manifold through the fuel disconnect valves. The forward and aft fuel systems are refueled simultaneously.

Refueling sequence

As previously stated, there are two separate fuel systems. We will cover the FWD system first, then the aft.

Forward fuel system

As fuel enters the FWD reservoir tank (FO 1, fig. 3) through the refuel shutoff valve, the reservoir tank will fill. When it is full, a standpipe at the top of the FWD reservoir tank will allow fuel to flow into the F–2 tank. When the F–2 tank is full, the standpipe at the top of the F–2 tank will allow fuel to flow into the F–1 tank. When the F–1 tank is full, the standpipe at the top of the F–1 tank will allow fuel to flow into the right wing tank. When the right wing tank is full, the fuel level will raise the float of the high-level shutoff float valve located near the top of the wing tank. With the float raised, the fuel bleed pressure will stop. This will cause back pressure in the sensing line to CLOSE the refuel shutoff valve in the FWD reservoir tank, which completes the refueling operation of the FWD fuel system.

Aft fuel system

The aft fuel system operates similar to the FWD system. Fuel entering the aft reservoir tank through the refuel shutoff valve will fill the tank. When the aft reservoir tank is full, the standpipe located at the top of the tank will allow fuel to flow into the A–1 tank. When the A–1 tank is full, the standpipe will allow fuel to flow into the left wing. When the left wing tank is full, the float on the high-level shutoff valve will rise, causing a back pressure through the sensing line that will CLOSE the refuel valve in the aft reservoir tank. This will complete the aft fuel system refuel operation. Now with the FWD and aft fuel systems refueled, let us move on to the external tanks.

Centerline tank

The 300-gallon centerline tank receives fuel from the refuel manifold. The fuel pressure will OPEN the refuel/transfer valve located at the bottom of the tank, allowing fuel to enter the centerline tank.

Since there are no bulkheads or compartments, the fuel will fill the tanks from the bottom to the top. When the fuel level reaches the refuel float valve located at the top of the tank, fuel will raise the float, causing the refuel/transfer valve to CLOSE, completing the refuel operation of the centerline tank.

External wing tanks

The 370-gallon external wing tank also receives fuel from the refuel manifold. Fuel pressure will OPEN the refuel/transfer valve, allowing fuel into the tank. The 370-gallon tanks have two bulkheads that divide the tank into three sections. The nose section will fill first; then fuel will flow through a standpipe to the tail section. When the tail section is full, the fuel will flow through a standpipe to the center section. When fuel reaches the refuel float valve, the fuel will raise the float, causing the refuel/transfer valve to CLOSE. This will complete the refuel operation of the 370-gallon tanks. With the FWD and aft fuel systems completed, the centerline tank refueled, and the left- and right- external tanks full, the refuel operation of the aircraft is complete.

217. Troubleshooting the fighter ground refueling system

There is no specific set of steps or procedures to follow when troubleshooting the refuel system or components on all aircraft. Because of the many types of aircraft and the variety of problems that could arise in the systems, always refer to the applicable aircraft technical order when troubleshooting.

However, as a fuel systems craftsman, you will be expected to know the typical components and operating principles of a refuel system on all types of aircraft. From an earlier section, you learned the typical components that are found in a fighter-type aircraft refuel system and the operating principles of that system. With this information, you would be expected to evaluate any discrepancy involving the system and choose the most probable cause. You should not, however, jump to a conclusion or make a hasty decision and start replacing components just yet. Simply because you have selected a probable cause does not guarantee that what you have chosen is indeed the problem.

Specific troubleshooting steps from the applicable aircraft technical order must be followed to provide the exact location of a malfunction. Many maintenance personnel have cursed themselves after spending many long, hard hours removing and replacing a component they thought was defective, only to find out later that a broken or loose wire connection was the cause of the malfunction.

A good example of this on a fighter aircraft-refueling system would be a discrepancy that stated fuel vented overboard and the refueling operation would not stop. The most probable cause would be that the refuel shutoff valve is inoperative. Troubleshooting steps outlined in the applicable aircraft technical order could prove that there is a broken sensing line from the float valve to the refuel shutoff valve.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

214. Components used in the ground refueling system

1. What switch indicates a flow- or no-flow condition?

2. What is the purpose of a fuel-level control valve?

3. Upon what principle does a fuel-level control valve operate?

4. Upon what principle does the piston-type of fuel-level control valves operate?

5. Outline the operation of the piston-type fuel-level control valve.

6. How is the diaphragm-type valve controlled?

7. Can the dual-float fuel-level control valve be replaced from outside or inside the fuel tank?

8. What is the purpose of the dual floats on a dual-float valve?

215. Operation of the cargo ground refueling and defueling systems

1. What is the primary advantage of the SPR method of ground refueling?

2. What is the maximum fuel-flow capability of each SPR on the cargo aircraft refuel system?

3. What location are all single-point refueling operations controlled from?

4. After the selected tanks on the cargo aircraft are refueled, how much air space is left at the top of each tank?

5. How is the SPR OPENED and CLOSED?

6. Which valves connect the ground refueling manifold/SPR to the main (wing) manifold?

7. During ground refueling, what action could you take to alternately close the primary and secondary sides of the fuel-level control valves of the tanks taking fuel?

8. What valve, when opened, will allow fuel to flow from the SPR to the main (wing) manifold?

9. In addition to the fuel-level control valves and a refueling isolation valve, what valves must be OPENED to permit refueling of all tanks on the cargo aircraft?

10. What components should be checked during the first few minutes of the refueling operation?

11. What is the first step in defueling a cargo aircraft?

12. Which fuel tanks can supply fuel directly to the LH refueling isolation valve without opening additional valves?

216. Fighter ground refueling system

1. What component(s) control fuel flow from the refuel manifold to the reservoir tanks during refuel?

2. What is the primary function of the refuel/transfer float valves?

3. Where are the refuel shuttle valves located?

4. What type of valve is the wing pylon/tank assembly selective refueling fuel shutoff valve?

5. What sequence are the FWD fuel system tanks refueled in?

6. When the aft fuel system is refueled, what component will cause the refuel shutoff valve to CLOSE?

7. Which component in the external wing tanks causes the refuel/transfer valve to CLOSE when the tank is full?

217. Troubleshooting the fighter groundrefueling system

1. As an aircraft fuel systems craftsman, what would you be expected to do if a discrepancy should develop on an aircraft refueling system?

2. During the refueling operation of a fighter aircraft, fuel begins to vent overboard and the refueling shutoff valve will not close. What would be the most probable cause for this malfunction?

3–2. Aerial Refueling System

The aerial refueling system is often considered to be one of the most complicated fuel subsystems. This is because of the interaction with other aircraft systems such as the hydraulic and electrical systems. When the system is operating normally, an operational check may be fairly easy. However, when a malfunction occurs, it may sometimes be difficult to troubleshoot. Let us look at the aerial refueling system on a bomber aircraft, starting with some of the major components used in the system.

218. Components of the bomber aerial refueling system

Refer to FO 4 during this lesson for location and visual identification of A/R components. The first component covered will be the Universal Aerial Refueling Receptacle Slipway Installation (UARRSI).

Universal Aerial Refueling Receptacle Slipway Installation

The UARRSI is located just forward of the windshield, and provides a means for the aircraft to receive fuel during flight. The unit is named “universal” because the same unit is used on other types of aircraft, such as the A–10.

The UARRSI line is connected to the fuel transfer system. The UARRSI consists of a receptacle, a hydraulically actuated slipway door, and a signal/voice amplifier. The slipway door is opened by a hydraulic actuator. The actuator is activated by pulling down on the T-handle located on the aerial refuel panel (FO 4, fig. 2). Insertion of the tanker nozzle into the UARRSI trips a nozzle contact switch and the receptacle toggles latch the nozzle in the receptacle.

Aerial refuel windshield center post lights

The aerial refueling light system is composed of two advisory lights and one caution light. The lighting matrix is located on the windshield center post (FO 4, fig. 2). The blue READY/ nose wheel steering (NWS) advisory light is located on top of the lighting matrix and provides system status information for aerial refueling. This light allows the pilot and copilot to know if all conditions are satisfied prior to aircraft hookup. The light extinguishes when the boom nozzle is seated into the receptacle.

The green LATCHED advisory light is located in the center of the lighting matrix. It illuminates when the hydraulic toggle latches have latched the boom nozzle into the refueling receptacle.

The amber disconnect (DISC) caution light illuminates when the tanker refueling boom is removed from the refueling receptacle. The light extinguishes when the trigger switches on the flight control sticks are actuated to the first detent after disconnect, or by pushing the slipway door handle up.

The annunciator lights knob on the aerial refuel panel controls the light intensity. The knob functions only when the pull refuel slipway door T-handle is extended.

Aerial refuel panel

The AERIAL REFUEL panel is located on the forward crew compartment center overhead panel (FO 4, fig. 2). The panel provides controls for use during aerial refueling and reverse (REV) aerial refueling. The panel contains the intensity controls for the external (EXT) aerial refueling wing inspection lights, the annunciator lights on the windshield center post, the slipway lights, and the override (ORIDE), REV, and normal mode (NORM MODE) switches. Also controlled by the panel are the ORIDE and OPEN/UNLK caution lights. The PULL REFUEL T-handle is also part of the panel.

Slipway lights

The aerial refuel slipway lights (FO 4, fig. 1) are located on either side of the slipway receptacle installation. The lights illuminate the receptacle to assist the tanker boom operator during conditions of low visibility.

Hydraulic accumulator

The aerial refuel hydraulic accumulator is a piston type that is precharged with nitrogen gas to 1,800 psi on one side of the piston and hydraulic system pressure on the opposite side. The main hydraulic pump for hydraulic system No. 3 supplies 3,000 psi pressure for the accumulator. The A/R hydraulic accumulator is serviced at the aerial refuel accumulator service panel in the nose wheel well.

Accumulator dump and relief valve

The A/R accumulator dump and relief valve is a two-way, two-position valve with provisions for thermal relief and pressure-to-return. The pressure-to-return positions are marked OPEN and CLOSE. The valve is spring-loaded to the CLOSED position. When the manual control handle is set to the OPEN position, the valve directs accumulator pressure to hydraulic system No. 3 reservoir. The thermal relief valve cracking pressure is 3,500 psi minimum and full flow is 15 cubic centimeters per minute (cc/min) at 3,750 psi maximum. The relief valve will reset as pressure decreases to 3,110 psi minimum.

Aerial refuel pressure reducing valve

This valve regulates system pressure. The valve consists of the inlet, return, and outlet ports. The valve automatically reduces hydraulic operating pressure to the three ports to the following predetermined values: 4,000 psi to the inlet port, 200–500 psi to the return port, and 2,800 psi to the outlet port.

Aerial refuel pull-to-refuel handle

The pull-to-refuel handle (FO 4, fig. 1) is a T-shaped handle connected to a control cable. Depressing the trigger on the T-handle will allow the handle to be pulled down to the REFUEL position, releasing the trigger and locking the T-handle in the REFUEL position. Pulling the T-handle down to the OPEN position will mechanically unlock the slipway door locks and the slipway door will open.

The aerial refueling electrical circuitry is also energized when the T-handle is pulled down to the OPEN position. When the T-handle is pushed up to the CLOSED position, hydraulic pressure is supplied to close and lock the slipway door. At the same time, the air refueling electrical circuitry will be de-energized.

Aerial refuel pull-to-refuel switch

This component is a cam-operated switch that is actuated when pulling the T-handle previously covered. When the switch is actuated, the aerial refueling circuitry is energized.

Aerial refuel pressure switch

This switch is located in the A/R manifold (FO 4, fig. 1). The switch opens and closes as the fuel pressure varies to signal correct manifold pressure to the aircraft electrical multiplex (EMUX) system.

With increasing fuel pressure, the switch will close at 75–85 psi at a temperature range of –65° F to 160° F. With decreasing fuel pressure, the switch will open at 60–70 psi. The pressure switch includes a positive drift-free mechanism for adjusting both operating pressures plus or minus 10 psi from the normal operating range.

Reverse aerial refuel fuel shutoff valve

The reverse A/R fuel SOV is a motor-operated 4-inch butterfly-type valve, which opens or closes to control fuel flow. The valve body is mounted on the right side of the forward fuselage tank with the actuator mounted on the outside of the tank. A position indicator on the actuator may be used to determine whether the valve is OPEN or CLOSED, and may also be used as a valve manual override lever.

219. Bomber aerial refueling system operation

The aerial refuel panel (FO 4, fig. 2) provides control for use during aerial refueling and reverse aerial refueling. It contains aerial refueling lighting controls, mode switches, and caution lights. The slipway door T-handle protrudes from a cutout portion of the panel.

Initiating aerial refueling

Placing the MODE switch of the aerial refuel panel in the NORM position and pulling down on the PULL REFUEL T-handle with locking trigger depressed initiates the aerial refueling process. This action sends NORM and PULL REFUEL HANDLE OUT signals to the EMUX; command output signals are then generated by EMUX. When electrical power is supplied to the aerial refuel power supply, the following events occur:

- Slipway doors are mechanically unlocked, allowing the spring-loaded slipway door to begin opening by spring action. The opening door actuates the door CLOSED and locked switch to CLOSED, illuminating the OPEN/UNLK light.
- The aerial refueling amplifier, which includes the sequence signals and intercom function, activates.
- Slipway lights are energized.
- Slipway door manual valve is OPENED, pressurizing the OPEN side of the slipway door hydraulic actuator and opening the slipway door.

When the slipway door reaches the fully OPEN position, the door open switch is actuated. This results in the illumination of the blue READY/NWS advisory light on the windshield center post. The aircraft is now ready for mating to the tanker-refueling boom.

When the boom nozzle on the tanker aircraft enters the refueling receptacle and actuates the contact switch, seven events are triggered:

- Toggle latches are hydraulically actuated, latching the boom into the receptacle.
- Induction coils in the receptacle and boom make contact, allowing aerial refueling signals and intercom (voice communication) to function between the tanker and receiver aircraft.
- The fuel center of gravity management system (FCGMS) opens all fill valves and ballast isolation valve, and turns off all transfer pumps, provided the appropriate switches on FUEL MGT panel are in the AUTO position.
- Green LATCHED advisory light illuminates. (After LATCH switch is deactivated.)
- Blue READY/NWS advisory light extinguishes.
- A latched signal is transmitted to the tanker by refuel amplifier.
- The FCGMS is set to control CG location by regulating fuel flow into tanks No. 1 and 4. The refueling process may now begin.

When aerial refueling is performed in the normal mode and refueling is complete, a disconnect is initiated manually by the tanker boom operator or by the receiver aircraft pilot or copilot depressing the aerial refuel disconnect and reset trigger on the stick grip to the first detent. In the event that a high-pressure condition occurs or the boom travel limits are exceeded, an automatic disconnect occurs. Regardless of where the disconnect signal originates, the latch solenoid valve is de-energized. This action hydraulically unlocks the toggle latches, causing the following four secondary events to occur:

- DISC caution light illuminates.
- LATCHED advisory light extinguishes.
- Tanker intercom is disconnected from receiver intercom system.
- FCGMS is switched from aerial refueling to transfer mode.

Completing the aerial refueling operation

After manual disconnect, pressing the pilot or copilot trigger switch to the first detent resets the UARRSI and signal amplifier and causes the READY/NWS light to illuminate. After automatic disconnect, a signal amplifier reset permits recycling of the air refueling functions.

The final series of aerial refueling events is initiated by pushing the slipway door handle, with the locking trigger depressed, up into its original (CLOSED) position. This results in the following:

- When the slipway door manual valve is mechanically CLOSED, permitting the hydraulic pressure to go to the CLOSED side of the slipway door hydraulic actuator. The slipway door closes. Aerial refueling power is turned OFF. This results in the READY/NWS and slipway lights extinguishing and the UARRSI amplifier de-energizing.

- When the slipway door reaches the fully CLOSED position, the door closed switch is actuated, which activates the door locks to the LOCKED position and causes the OPEN/UNLK caution light to extinguish.

With the PULL REFUEL T-handle down and the MODE switch in the ORIDE mode or in the event of system failure, a command is sent to EMUX. EMUX then generates the command output signals, supplying electrical power to the aerial refueling power supply. The following events then occur:

- The override mode is activated, allowing disconnection from the refueling tanker only by means of the pilot or copilot trigger switches.
- The ORIDE caution light on the AERIAL REFUEL panel illuminates.
- In the event of system malfunction, the A/R ORIDE caution light on the main caution panel illuminates. Illumination of the A/R ORIDE light indicates that the aerial refueling system is in the override mode but that the override mode has not been selected (ORIDE MODE switch not in ORIDE position). Illumination of the A/R light also causes the ORIDE caution light on the AERIAL REFUEL panel to illuminate. Selection of the ORIDE MODE switch extinguishes the A/R ORIDE caution light.

Reverse aerial refueling

This aircraft has the provisions for reverse aerial refueling. Fuel can be transferred back to the tanker through the boom. The MODE-REV switch on the aerial refuel panel controls the reverse aerial refueling operation. In the REV mode, the reverse aerial refueling valve is OPENED, providing a fuel-flow path from the aircraft to the tanker boom. Fuel from the aircraft is then transferred by manually operating the fuel transfer system and fill valves. The reverse aerial refueling valve is OPENED by setting the MODE switch to REV. Placing the switch to REV supplies reverse aerial refueling valve open signals to EMUX. However, the valve will not open unless the PULL REFUEL T-handle is out.

220. Troubleshooting the bomber aerial refueling system

As you have learned from this lesson, the aerial refuel system on this bomber aircraft is a fairly complicated system. Attempting to troubleshoot a malfunction without consulting the applicable fault-reporting/fault-isolation manual may cause you to replace perfectly good components. Where older aircraft have only a portion of the maintenance manual devoted to troubleshooting, this aircraft has a complete fault-reporting manual and a rather large fault diagnostics chapter in the general series manual for fuel systems. With the use of this information and the aircraft computer system, there should be no guesswork involved in isolating a system malfunction. Let us look at what is involved in troubleshooting this aircraft.

Central Integrated Test System

The Central Integrated Test System (CITS) is a computer system that monitors the conditions and configurations of 36 of the aircraft systems both in flight and on the ground. The CITS system is specific to the B–1 bomber. The CITS control and display panel (FO 5, fig. 1) is located in the center of the aft crew station. CITS displays system malfunctions to the crew and records the faults for later troubleshooting. In addition, CITS can isolate malfunctions down to the line replaceable unit (LRU) or further, to the shop replaceable unit (SRU) inside the LRU. When a malfunction is detected, CITS assigns and records a CITS maintenance code (CMC) for that malfunction.

Central Integrated Test System maintenance code

The CMC is an alphanumeric code that identifies a particular problem in a particular system. For instance, a CMC of 28372 reads “Nozzle contact relay-wrong status.” The first two digits of a CMC identify the aircraft system containing the malfunction; in this example, the first two digits (28) identify the fuel system. The last three digits (372) identify the malfunction. The CMC can be converted into a fault isolation code using the fault code index in the system’s general system (GS) technical order. Most CMCs correspond to a fault code (FO 5, fig. 2).

Fault codes

The fault codes used are six, seven, eight, or 10 digits and direct the craftsman from the fault to a procedure that will resolve the problem. A six- or eight-digit fault code merely identifies the fault or problem. When the fifth digit is an A through W, a diagram is provided to isolate the fault.

A seven-digit code will identify the faulty LRU. The craftsman proceeds directly to the job guide and performs the required maintenance action. A 10-digit code will identify the bad subsystem, component, or SRU, and will also tell what action is required to fix the problem.

Fault code index

The fault code index contains all fault codes that pertain to the system. The index is divided into two parts. Part 1 contains fault codes corresponding to CMCs (FO 5, fig. 2). Part 2 contains all other fault codes (FO 5, fig. 3).

Fault identification diagrams

The fault identification diagrams (FO 5, fig. 4) identify crew-observable faults during flight, and ground crew faults not detected by the CITS. The diagrams are basically flow charts for troubleshooting. Flight observable fault symptom paths can be retraced by maintenance personnel to identify how the flight crew arrived at the fault code. Each fault identification diagram has only one entry point where the basic fault is given.

Fault isolation diagram

Fault isolation diagrams (FO 5, fig. 5) are used to isolate and correct a fault. Use the fault code to locate the correct fault isolation diagram. The fault code is located in the upper left of the diagram and identifies the flow chart entry point. You must perform the tasks as indicated until the flow chart terminates at a REMEDY block, GO TO block, or NORMAL block. Now let us look at the troubleshooting procedures for an aerial refuel malfunction by creating a problem scenario.

Troubleshooting procedures

Picture this: the aircraft is scheduled for an aerial refueling mission in a few hours, and you and a coworker are sent out to operationally check the A/R system. Refer to FO 6 during this troubleshooting scenario.

You arrive at the aircraft and proceed with the operational (OPS) check. During the check, you discover that when you insert the A/R tester into the A/R receptacle, you do not get a LATCHED light on the aerial refuel panel but *did* get a latched light on the A/R tester. From the information given in the previous lesson and from your own experience, you know there is a malfunction. The tester however, appears to be physically latched in the receptacle.

Locate the fault identification diagram containing the appropriate fault (FO 6, fig. 1) by observing the fault code at the upper right corner of the diagram. Now locate the specific discrepancy in this diagram. You should find it in block 3. Since you did *not* get a LATCHED light, follow the diagram to block 6. With the A/R tester simulating the tanker aircraft, the answer to this question is yes. Follow the line down and to the right. Fault code *28–25–AM* is given for this discrepancy. Now that you have a fault code—what is next?

Notice that the fault code contains six digits. This means that further troubleshooting is required. Also, notice that the fifth digit in the code is between A through W, indicating that a fault isolation diagram exists for this fault. Locate this diagram in the general series TO by scanning the fault codes at the top left section of the diagrams. The diagrams are numbered numerically, using the fault codes. Once you have found the page with the fault code 28–25-AM (FO 6, fig. 2), verify the fault by looking at the statement at the bottom of the page. The statement should accurately describe the malfunction. Notice that it reads “No Latched Light with A/R Nozzle Latched.” This is the needed diagram.

Locate the entry point directly below the fault code. This is block 1 and is where we will start the isolation procedure. Block 1 contains the question, “With test set latched, does center post LATCHED light come on?” Since the latched light did not illuminate, the answer is no. If it did illuminate, the system would be normal, as indicated by block 2. However, since the light did not illuminate, follow the line to the right to block 3. This block tells you to enter parameter monitor codes (PMC) to verify that the command to light the LATCHED light was received by the EMUX. You would now go to the CITS control and display (CCD) panel in the aft crew station and enter the PMCs requested by block 3. As a result, CITS will display a value on the CCD panel. In this case, the value will be *BIT 03 = ON or BIT 03 = OFF*.

The question at the bottom of block 3 reads “*Does display read BIT 03 = OFF?”* If the answer is no, follow the line to the right to block 9. Notice that this block instructs you to repair wiring. This is called a remedy block, and is a termination point of the fault isolation diagram. Of course, additional troubleshooting may be required to isolate the faulty wiring.

If the answer to the question in block 3 was yes, follow the line down to block 4, where you are instructed to enter another code that will verify the status of the light relay. Again, the question reads, “*Does display read BIT 03 = ON?”* If the answer is yes, the problem is in the wiring; if the answer is no, go to block 5. Block 5 instructs you to replace a relay, then re-enter the PMC you entered in block 4. If the display does not read *BIT 03 = ON*, you are instructed to replace the UARRSI.

If the display *does* read *BIT= ON*, go to block 6 and enter the PMCs indicated.

If the display reads *BIT = ON*, and the latched light is illuminated, the system is normal, as indicated by block 8. Apparently, replacing the relay fixed the problem.

Now, if only troubleshooting a problem with your car was so easy! As you can see, by using fault identification and isolation diagrams, troubleshooting is simply a matter of following a preplanned "action tree", entering codes (PMC) and answering questions until a remedy to the problem is indicated. Remember that the CITS system as discussed is only applicable to the B-1 bomber.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

218. Components of the bomber aerial refueling system

1. What three parts make up the UARRSI?

2. Explain how the slipway door on the UARRSI is opened.

3. Where is the aerial refueling lighting matrix on the bomber aircraft located?

4. Which light on the lighting matrix allows the pilot and copilot to know if all conditions are satisfied prior to aircraft connection?

5. Where is the aerial refuel panel located on the bomber aircraft?

6. Which valve in the aerial refueling system directs accumulator pressure to hydraulic system No. 3 reservoir when the manual control handle is set to the OPEN position?

7. Explain what events are initiated when the pull-to-refuel handle is pulled down to the OPEN position.

219. Bomber aerial refueling system operation

1. What action initiates the aerial refueling process?

2. Explain what events occur when electrical power is supplied to the aerial refuel power supply.

3. After boom and receptacle connection, what components allow aerial refueling signals and intercom between tanker and receiver to take place?

4. What indication should you receive when the tanker’s boom enters the refueling receptacle and actuates the contact switch?

5. What conditions would result in an automatic disconnect of the boom and receptacle?

6. What four secondary events should occur after the boom and receptacle are disconnected?

7. After a manual disconnect is initiated, what action resets the UARRSI and signal amplifier, resulting in the illumination of the READY/NWS light?

8. What switch controls the reverse aerial refueling operation?

220. Troubleshooting the bomber aerial refueling system

1. What computer system on the bomber aircraft monitors the conditions and configurations of the aerial refueling system both in flight and on the ground?

2. What do the first two digits of a CITS maintenance code identify?

3. When interpreting a fault code, what would indicate that a fault-isolation diagram is provided?

4. What would a seven-digit fault code identify?

5. What type of diagram would identify an aerial refueling malfunction discovered by the flight crew that was *not* detected by CITS?

6. What aerial refueling discrepancy is identified by fault code 28–25–AM?

7. During fault isolation of an aerial refueling malfunction, where would you enter a PMC?

Answers to Self-Test Questions

214

1. Fuel-flow indicating switch.
2. To permit the automatic control of fuel level during the filling of a fuel tank.
3. Hydromechanical.
4. Hydromechanical.
5. Fuel pressure pushes piston open and fuel enters tank; fuel passes through piston, pushes pilot valve open, and into tank; when tank is nearly full, float rises and closes pilot valve; fuel pressure inside valve is now equal to the pressure holding the piston open; spring pressure helps close the piston valve to prevent fuel from entering the tank.
6. Electrically.
7. Inside; it requires tank entry.
8. They provide a double safety factor.

215

1. It allows all fuel tanks to be refueled from a single connection.
2. 600 gallons per minute.
3. The fuel-management panel.
4. Approximately three percent.
5. By engaging the lever on the refueling nozzle; by spring tension when the lever is retracted
6. Refuel isolation valves.
7. Placing the PRECHECK switch first to PRI, then SEC position.
8. The LH or RH refuel isolation valve.
9. The center separation valve, as well as the left- and right-separation valves.
10. The primary and secondary fuel-level control valves should be operationally checked to ensure they will stop the flow of fuel into the tank when the desired level has been reached.
11. Turn on the pumps in all tanks to be defueled.
12. No. 2 AUX and no. 2 EXT RG tanks.

216

1. Two refuel shutoff valves.
2. They control the refuel shutoff valves and the external tank-transfer shutoff valves.
3. There is one in each reservoir tank.
4. A manually operated ball-type (globe) valve.
5. The FWD reservoir tank will fill first, then the F–2 tank, F–1 tank, and right wing tank.
6. The high-level shutoff valve.
7. The refuel shutoff valve.

217

1. To know the typical components and operating principles of a refuel system on all types of aircraft; to evaluate any discrepancies involving the system; and choose the most probable cause.
2. Refuel valve is inoperative.

218

1. A receptacle, slipway door, and signal/voice amplifier.
2. The slipway door is opened by pulling down the T-handle on the aerial refuel panel, which activates a hydraulic actuator that opens the door.
3. The windshield center post.
4. The blue READY/NWS advisory light.

5. On the forward crew compartment center overhead panel.
6. The accumulator dump and relief valve.
7. The slipway doors will unlock and open, and the aerial refueling electrical circuitry is energized.

219

1. Placing the MODE switch of the aerial refuel panel in the NORM position and pulling down on the PULL REFUEL T-handle.
2. The slipway doors begin to open, causing the OPEN/UNLK light to illuminate; the aerial refueling amplifier activates; the slipway lights are energized; and the slipway door manual valve is opened, pressuring the OPEN side of the slipway door hydraulic actuator and opening the slipway door.
3. Induction coils.
4. The green LATCHED light illuminates and the blue READY/NWS light extinguishes.
5. A high-pressure condition occurs or the boom travel limits are exceeded.
6. The DISC caution light illuminates, the LATCHED light extinguishes, tanker and receiver intercom systems are disconnected, and the FCGMS is switched from aerial refueling to transfer mode.
7. Pressing the pilot or copilot trigger switch to the first detent.
8. The MODE-REV switch on the aerial refuel panel.

220

1. The CITS.
2. The aircraft system containing the malfunction.
3. When the fifth digit is an A through W.
4. The faulty LRU.
5. A fault-identification diagram.
6. “No latched light with A/R nozzle latched.”
7. CITS control and display panel in the aft crew station.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

31. (214) Using fuel-level control valves makes refueling a safer operation because the valves will
    a. signal the refueling monitor when to stop the fuel flow.
    b. shut down the refueling vehicle if the tanks start to overflow.
    c. provide an automatic refueling of a tank to any desired level.
    d. automatically stop the flow of fuel into a tank prior to overflow.

32. (214) What principle is used to operate fuel-level control valves?
    a. Static.
    b. Venturi.
    c. Pressure.
    d. Hydromechanical.

33. (214) What part of a piston-type fuel-level control valve prevents fuel from entering the tank?
    a. The float.
    b. A spring.
    c. A pilot valve.
    d. The diaphragm.

34. (215) *Approximately* what percent of air space is left at the top of the tanks of a cargo aircraft after ground refueling?
    a. 1.
    b. 3.
    c. 5.
    d. 7.

35. (215) Which cargo aircraft components should be operationally checked during the first few minutes of a ground refueling operation?
    a. Fuel-level control valves.
    b. Separation shutoff valves.
    c. Refueling isolation shutoff valves.
    d. Single-point receptacle drain pump and valve.

36. (215) To allow fuel to flow from a cargo aircraft single-point receptacle to the main wing manifold during ground refueling, the
    a. single-point receptacle drain valve must be open.
    b. center separation valve must be open.
    c. refuel isolation valve must be open.
    d. right separation valve must be open.

37. (216) Which fuel tank on the fighter aircraft contains a bladder cell for fuel storage?
    a. A–1.
    b. F–1.
    c. Aft reservoir.
    d. Foward reservoir.

38. (216) When the forward (FWD) fuel system on the fighter aircraft is refueled, what tank will fill *first*?
    a. F–1.
    b. Left wing.
    c. Right wing.
    d. Reservoir.

39. (216) What is the refueling sequence for the aft fuel system on a fighter aircraft?
    a. Aft reservoir, A–1 tank, then left wing tank.
    b. A–1 tank, aft reservoir, then left wing tank.
    c. Left wing tank, A–1 tank, then aft reservoir.
    d. Left wing tank, aft reservoir, then A–1 tank.

40. (217) You are preparing to troubleshoot a problem on the ground refueling system for a fighter aircraft. To do this properly, you would
    a. refer to the applicable aircraft technical order.
    b. select a probable cause and remove the easiest component first.
    c. select a probable cause and remove the most difficult component first.
    d. make a list of the possible causes of the problem and begin replacing the components on your list.

41. (218) The reverse aerial refueling shutoff valve is a
    a. motor-operated butterfly valve.
    b. cable-operated butterfly valve.
    c. motor-operated gate valve.
    d. cable-operated gate valve.

42. (219) Which condition will result in an *automatic* disconnect of the boom and receptacle during aerial refueling on a bomber aircraft?
    a. Low-pressure condition exists.
    b. Boom travel limits are exceeded.
    c. Fuel center of gravity is off balance.
    d. Reset trigger on pilot's stick is pressed.

43. (220) When a system malfunction on a bomber aircraft is detected by the Central Integrated Test System (CITS), a
    a. fault code is generated.
    b. CITS isolation code is generated.
    c. fault identification diagram is generated.
    d. CITS maintenance code (CMC) is generated.

44. (220) You are troubleshooting a malfunction in a bomber aerial refueling system. The fault code for the malfunction is 28–25–*AM*. What does the letter "*A*" indicate?
    a. The faulty system or subsystem only.
    b. A fault isolation diagram is provided.
    c. The faulty component within the system.
    d. Corrective action required to fix problem.

45. (220) You are troubleshooting a problem on a bomber aircraft. At a certain point, the fault isolation diagram requests that you enter a parameter monitor code (PMC). To comply with the request, you would enter the code on the
    a. Central Integrated Test System (CITS) control and display panel in the aft crew station.
    b. CITS control and display panel on the windshield center post.
    c. system status panel on the windshield center post.
    d. system status panel in the aft crew station.

Please read the unit menu for unit 4 and continue ➔

Student Notes

Unit 4. Tank Scavenge and Manifold Scavenge Systems

IN PREVIOUS UNITS we covered engine feed and crossfeed systems, fuel transfer and jettison systems, as well as refueling and defueling systems. In this unit, we continue to build your knowledge base by covering examples of the tank and manifold scavenge systems you will encounter on the job. The tank and manifold scavenge systems we discuss are used on aircraft for two entirely different purposes. First, the tank scavenge system is used to ensure an uninterrupted flow of fuel to the aircraft engines and to facilitate the removal of water from low areas of the fuel tanks. In contrast, the manifold scavenge system is used to remove unusable fuel from a manifold and route it to a fuel tank. A particular aircraft may have one or both of these systems, depending on its designed mission. Most cargo aircraft will have both.

4–1. Tank Scavenge System

We will begin this section with a scenario. A jet-powered aircraft is equipped with a wing tank that is as long and wide as a small living room. A boost pump is located in the center of the tank, and the tank itself is about 1/4 full of fuel. During flight, the aircraft goes into a hard left bank and fuel sloshes to the left side of the tank, leaving the pump uncovered. In this situation, you should know what will happen next—engine flameout!

Of course, there are ways to prevent this situation or solve this problem. To solve this problem on the B–52 aircraft, engineers equipped each main tank with four boost pumps. These pumps were installed in various areas of the tank. This configuration ensures that fuel will be picked up by at least one or two pumps, regardless of the level of fuel in the tank or the aircraft attitude (nose up, left bank, etc.).

Some of the larger and more modern aircraft (such as the C–5 or C–17) are equipped with up to 12 rather large fuel tanks. In these instances, it would be both economically and mechanically infeasible to have multiple pumps in each tank. For this reason, the tank scavenge system we discuss in this section was designed. We will cover the following three major subject areas during our discussions:

- Operation and components of the tank scavenge system.
- Performing operational checks of the tank scavenge system.
- Tank scavenge system malfunctions.

221. Components and operation of the tank scavenge system

The purpose of the tank scavenge system is to ensure an uninterrupted flow of fuel to the engines during abnormal operating conditions such as noncoordinated turns, wind gusts, steady side slips, negative gravities (G), and nose up or down attitudes. The scavenge system is also designed to pick up any water that settles at the low points of the tank due to condensation. The system allows this water to be burned by the engine.

The tank scavenge system is found primarily on cargo-type aircraft because of the large size of the fuel tanks. The system consists of jettison or ejector pumps, surge boxes, sump low-level sensors, low-level warning lights, and various fuel lines and manifolds.

Jet or ejector pumps

All fuel tanks on the cargo aircraft, including the vent boxes, are equipped with ejector- or jet-type pumps (FO 3, item S). These jettison/ejector pumps are also illustrated in figure 4–1. They operate from boost-pump bleed pressure and have variable displacement. A small line is tapped off the boost pump to provide this pressure. Fuel flows through this line to the inlet (A) of the jettison/ejector pump. As this fuel passes through the jettison pump and exits the outlet port (C), it creates suction at the pickup port (B), which is normally facing downward, only a small distance from the bottom of the tank. Fuel is then drawn into the pickup port and added to the fuel coming from the boost pump. This is known as the Venturi principle.

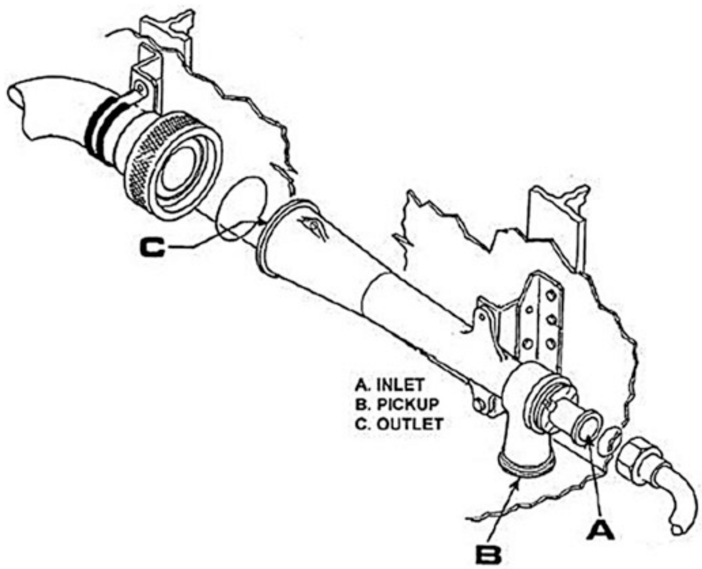

Figure 4–1. Jet/ejector pump.

The jettison/ejector pumps have no moving parts to wear out, and are installed in several different areas of the tank, thus ensuring fuel is picked up from any area. The pump in figure 4–1 is installed in the lower corner of the tank. In contrast, the pump in figure 4–2 is mounted on a tank bulkhead and has many pickup tubes, which are routed to various areas of the tank. The fuel that is picked up by these jettison pumps is eventually routed to the surge box, as shown in the schematic on FO 3, item T.

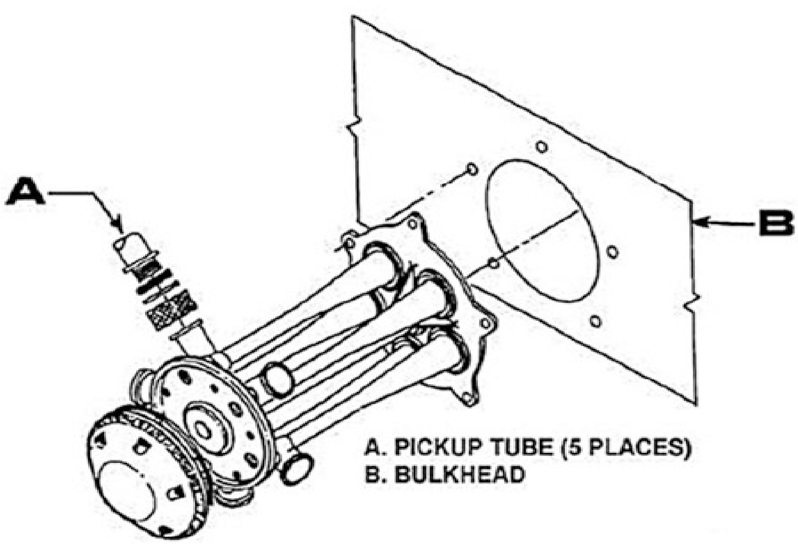

Figure 4–2. Jettison pump (bulkhead-mounted).

Since you cannot see the scavenge system while it is working, it is sometimes difficult to grasp the Venturi theory of its operation. For a commonplace example of the Venturi principle in action, let us drain a waterbed using a drain kit. Water pressure coming from a faucet is routed to one side of a “T” fitting and exits the other side. This flowing water/pressure produces suction at the third side of the “T” fitting which is connected to the waterbed mattress. The suction causes the water to be drawn out of the mattress. After water starts flowing out of the mattress, you can shut off the faucet, thus stopping the water pressure into the “T” fitting. When you do, the water from the mattress will still continue to drain. This is a good example of the Venturi principle at work.

Surge boxes

A surge box is shown by on FO 3, item T. Surge boxes are located in all fuel tanks on the cargo aircraft illustrated on the foldout. The surge boxes in the outboard and inboard main tanks have a capacity of 275 and 205 gallons respectively. Surge boxes in the auxiliary and extended range tanks have a capacity of 50 gallons to provide approximately five minutes of usable fuel to the engines at cruise power fuel consumption.

These surge boxes are equipped with flapper valves that permit the inflow and prevent the outflow of fuel from the sumps. The surge boxes, combined with the ejector pumps, keep the boost-pump inlet submerged at all times. All main tanks and auxiliary tanks No. 2 and 3 have 30-gallon sump boxes (tanks) in their surge boxes to also enclose the boost pumps.

Sump low-level sensors and warning lights

The sump low-level sensors are located inside the surge/sump boxes of the outboard main tanks (No. 1 and No. 4) only. They are attached to the fuel-quantity probes inside the sump boxes. The MAIN 1 or MAIN 4 SUMP LOW lights on the fuel-management panel (FO 3, fig. 2 item C) illuminate when the sump low-level sensors determine that a fuel condition of less than 1,600 pounds of fuel remain in the surge/sump box (approximately 3/4 full). The MAIN SUMP LOW light on the pilot’s annunciator panel also illuminates when either the MAIN 1 or MAIN 4 SUMP LOW lights on the fuel-management panel illuminate.

When the tank scavenge system is operating properly, the jettison pumps in various areas of the tank should be picking up fuel and routing it to the surge/sump box. The flapper valves in the box should be letting fuel in and keeping it in, resulting in the sump being full regardless of the fuel level in the tank or the attitude of the aircraft (nose up, left bank, etc.). The MAIN 1 or MAIN 4 SUMP LOW lights should only illuminate if there is a problem.

222. Performing operational checks of the tank scavenge system

Refer to the fuel systems schematic on FO 3 as we simulate an OPS check of the tank scavenge system in the No. 1 main tank. The first step in an OPS check of the tank scavenge system is to OPS check the fuel-quantity indicating system and the sump low-level warning system to ensure the MAIN SUMP LOW lights are working properly. Remember, these indicators and lights are the only means of determining proper system operation.

Next, you must ensure the tanks that you are checking contain more than 12,000 pounds of fuel. With the tank fuel level at 12,000 pounds, the sump will be full regardless of the condition of the flapper valves or the scavenge ejector system.

Your next step is to ensure all switches are set correctly in accordance with the applicable aircraft technical order. Begin to transfer fuel from the No. 1 main tank to any other tank you select until 7,000 pounds of fuel remain. The sump low-level warning light should illuminate when fuel capacity is between 9,000 and 12,000 pounds. This indicates that the sump box is no longer full, and the low-level warning system is working.

Now close the left isolation valve (M) and turn on *only* the outboard (O/B) boost pump in No. 1 main tank. Since the isolation valve is closed, no fuel is being transferred; however, the boost pump is

operating. Therefore, the scavenge system is also operating. The light should extinguish in less than five minutes. If it does not, the scavenge system is not operating properly.
Turn off the O/B boost pump and open the isolation valve (M). Begin transferring fuel from No. 1 main tank. The sump low-level warning light should illuminate again before the fuel level in the tank reaches 6,000 pounds.

Next, close the left isolation valve and turn on the inboard boost pump for No. 1 main tank. The sump low-level warning light should extinguish in less than five minutes. If it does not extinguish in less than five minutes, troubleshoot the system using the applicable fault isolation manual.

NOTE: Always remember to return the system to normal configuration after performing an operational check.

223. Tank scavenge system malfunctions

The jettison/ejector pumps have no moving parts; hence, it would seem there would be no possible way for a malfunction to exist. However, other factors come into play that can interfere with the correct operation of the system. For example, the boost pumps contain inlet “finger” screens that are designed to keep debris and FO from being drawn into the pump. If the screens become covered with debris, the ejector pumps will not operate at full efficiency. You can inspect these screens without performing a tank entry.

NOTE: There are some components, however, that can only be visually inspected by entering the tank.

As is often the case, the ejectors themselves may also become clogged with FO. Pieces of sealant, cheesecloth, sponge material, lint, etc., are common examples of FO. Remember, there are several jettison/ejector pumps in the same tank; however, the obstruction of the inlets of only one or two may have a noticeable effect on the system. This is why it is important to clean the inside of the fuel tanks after maintenance.

Another component to consider is the sump box. Any defects in this box, such as cracks, missing fasteners, or inoperative flapper valves, may allow fuel to flow out. Remember, the fuel level in the sump box should almost always be higher than that in the main section of the tank.

The sump low-level sensors may also be inoperative. Usually this would only be the case if the corresponding low-level warning light either remains illuminated all the time, or does not illuminate at all. In any event, always follow the applicable aircraft fault isolation manual to avoid unnecessary maintenance.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

221. Components and operation of the tank scavenge system

1. What is the purpose of the tank scavenge system on a cargo aircraft?

2. Why is the tank scavenge system used primarily on cargo aircraft?

3. Explain how jet pumps/ejector pumps operate in the scavenge system.

4. Where does the fuel that is picked up by the jet/ejector pumps go?

5. What part of the scavenge system encloses the boost pumps?

6. Where are the sump low-level sensors located?

7. At what fuel level will the MAIN 1 or MAIN 4 SUMP LOW lights illuminate?

222. Performing operational checks of the tank scavenge system

1. What is your first step when you are operationally checking the tank scavenge system?

2. Besides the fuel-quantity indicating system, what indication will you see to let you know the tank scavenge system is working properly?

3. What fuel level will the sumps be full, regardless of the condition of the flapper valves or ejector system?

4. What should you always remember to do after performing an operational check?

223. Tank scavenge system malfunctions

1. What components are attached to the boost pumps and may have an adverse effect on the tank scavenge system if they become clogged with debris?

2. What types of defects may cause the tank scavenge system to operate poorly?

3. What would most likely be the problem if the sump low-level warning light on the fuel-management panel never went out?

4–2. Manifold Scavenge System

Another system that is found primarily on large aircraft is the manifold scavenge or manifold drain system. This system is very important after a refueling or defueling operation; after these operations, the manifolds may be full of fuel, as they can hold hundreds of gallons of fuel. In addition, the manifolds often pass near the cargo compartment of the aircraft. In this configuration, the fuel may present a safety hazard, if it is not removed. Also, the fuel trapped in the manifold is unusable unless it is returned to a tank. For these two very important reasons, the manifold scavenge system is used to remove this residual fuel.

224. Cargo aircraft manifold drain systems

In this lesson, we will look at the manifold drain system on a cargo aircraft. Our example actually has the following three separate drain systems:

- Main (wing) manifold drain system.
- Aerial refueling manifold drain system.
- Ground refueling manifold drain system.

NOTE: The simplest of the three is the main manifold drain system.

Main manifold drain system

Refer to FO 3 for the locations of system components and switches/controls. The main (wing) manifold spans from the left wing jettison mast to the right wing jettison mast. A 1-inch motor-operated main manifold drain valve (J) is located at the aft inboard end of No. 1 and No. 4 main tanks. When they are in the OPEN position, these drain valves allow the fuel in the wing manifold to gravity flow into the vent box. Both valves are 115-volts (V), ac motor operated. The valves are operated by positioning the line drain switch on the fuel-management panel to the MANIF position.

Aerial refueling manifold drain system

This system was designed to remove the fuel from the aerial refueling manifold after an air refueling mission or operational checkout. It consists of a 1-inch manifold drain valve (Q) which prevents gravity flow of fuel to the drain during aerial refueling and a drain pump (R) which scavenges residual fuel from the manifold and routes it to the left or right inboard main tank through a check valve. The drain pump is a rotary-vane type that has positive displacement. Figure 4–3 shows a typical rotary vane pump. The pump consists of an electric motor and a shaft with rotary (circular) vanes at the end. A rotary vane pump is said to have positive displacement because its input is equal to its output. It does not pressurize a manifold like a centrifugal pump; however, the rotary vanes move fuel from the inlet to the outlet (fig. 4–3). The motor on this type of pump is not fuel resistant; therefore, it will never be submersed in fuel the way a centrifugal pump is.

After a refueling operation, the LINE DRAIN switch on the FMP is placed to the AIR REF position. In this position, electrical power is made available to the drain valve and pump. The drain valve opens and the pump operates. Fuel is scavenged after approximately six to eight minutes or until the pump unloads. The LINE DRAIN switch must then be placed back to the center OFF position to turn the pump off and close the valve.

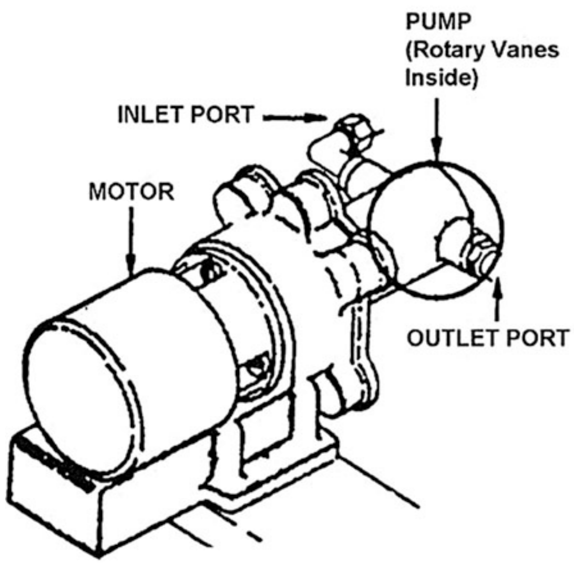

Figure 4–3. Rotary vane scavenge pump.

Ground refueling manifold drain system

The ground refueling manifolds are scavenged by the same type of components as the aerial refueling manifold. A SPR manifold drain pump (FO 3, item G) is located in the $^3/_4$-inch fuel line on each side of the aircraft next to the SPRs. Each pump scavenges residual fuel from its respective manifold after refueling. An SPR manifold drain valve (H) is installed in the drain manifold to shut off the gravity flow to the manifold of its respective SPR drain pump. The pumps are operated by placing the GRD REFUEL switches to the DRAIN position. A SPR manifold manual drain valve (I) is also used for removing excess fuel and is attached to the SPR drain pump.

225. Troubleshooting the manifold drain system

As far as malfunctions are concerned, the manifold drain system is probably one of the simplest systems to troubleshoot, mostly because of the small number of components involved. The most common malfunction in this system is that the left or right SPR manifold does not drain after a refuel operation. Refer to the fuel systems schematic on FO 3 while we run through a troubleshooting scenario on the cargo aircraft.

The first step in the troubleshooting process is to gain access to the applicable SPR manifold drain shutoff valve (H) and disconnect the cannon plug to the valve's actuator motor. With the applicable circuit breakers CLOSED, place the GRD REFUEL switch to the DRAIN position. Use a multimeter and take a reading at the applicable pins on the cannon plug. There should be 115 V, alternating current (ac) available to the pins named in the applicable troubleshooting or fault isolation manual. If not, the problem is with the electrical system. The GRD REFUEL switch may be defective, the circuit breaker may be bad, or the wiring itself may be faulty. Further troubleshooting with an electrician's assistance will be required.

If 115 V, ac is present at the appropriate pins on the cannon plug, you know that the electrical system is okay from the switch to the valve motor. The next step in the process is to observe the manual override (position indicator) lever on the shutoff valve (H) to determine whether the valve is in the OPEN or CLOSED position. If the lever is in the CLOSED position, the valve actuator motor is inoperative and did not open even though power was available to it.

If the lever is in the OPEN position, the problem is not with the valve. Reconnect the cannon plug to the valve's actuator motor and disconnect the cannon plug from the SPR manifold drain pump (G). As before, check for 115 V, ac on the applicable pins of the cannon plug. If 115 V, ac is present, the pump is inoperative. If 115 V, ac is not present, there is an electrical problem, which will require further troubleshooting.

Remember that these are general troubleshooting procedures presented in this CDC unit and that you should ALWAYS consult the applicable aircraft technical order when attempting to isolate a malfunction.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

224. Cargo aircraft manifold drain systems

1. How many separate manifold drain systems are found on the cargo aircraft?

2. What component allows fuel to drain from the main (wing) manifold to a vent box?

3. What component scavenges fuel from the aerial refueling manifold, and where is the fuel routed?

4. Explain the procedures for scavenging the air refueling manifold on the cargo aircraft.

225. Troubleshooting the manifold drain system

1. What is the most common malfunction affecting the manifold drain system on the cargo aircraft?

2. What should be your first step when you are troubleshooting a problem with the manifold drain system?

3. After placing the GRD REFUEL switch to DRAIN, you take a voltage reading at the applicable pin on the cannon plug of the SPR manifold drain valve. The reading is 0.003 V, ac. Where do the problems lie, and what components should you check next?

4. How do you determine whether the SPR manifold drain valve is in the OPEN or CLOSED position?

Answers to Self-Test Questions

221

1. To ensure an uninterrupted flow of fuel to the engines during abnormal operating conditions such as noncoordinated turns, wind gusts, steady side slips, negative G, and nose up or down attitudes.
2. Because of the large size of the fuel tanks.
3. Jet pumps/ejector pumps operate using the Venturi principle, fuel from boost-pump bleed pressure flows through the inlet of the jettison/ejector pump as it exits the outlet port it creates suction at the pickup port. Fuel at the bottom of the tank is then drawn into the pickup port and added to the fuel coming from the boost pump. This is the Venturi principle.
4. To the surge box.
5. The surge/sump box.
6. Inside the surge/sump boxes of the outboard main tanks (No. 1 and No. 4) only. They are attached to the fuel-quantity probes inside the sump boxes.
7. When less than 1,600 pounds of fuel remain in the surge/sump box (approximately $^3/_4$ full).

222

1. Operationally check the fuel-quantity indicating system and the sump low-level warning system.
2. The MAIN SUMP LOW warning lights.
3. The sumps should be full with 12,000 pounds of fuel remaining in the outboard main tanks.
4. Return the system to normal configuration.

223

1. Inlet “finger” screens.
2. Obstruction or clogging of the inlets with foreign objects such as pieces of sealant, cheesecloth, sponge material, lint, etc. In addition, other defects can include cracks, missing fasteners, or inoperative flapper valves.
3. The corresponding sump low-level sensor would likely be inoperative.

224

1. Three.
2. A 1-inch manifold drain valve.
3. A rotary vane-type drain pump. The fuel is routed to the applicable left or right inboard main tank.
4. Place the LINE DRAIN switch on the fuel-management panel to the AIR REF position. This opens the drain valve and operates the pump. Fuel is scavenged after approximately six to eight minutes or until the pump unloads. After this, return the LINE DRAIN switch to the center (OFF) position to turn the pump off and close the valve.

225

1. The left or right SPR manifold does not drain after a refuel operation.
2. Gain access to the applicable SPR manifold drain shutoff valve and disconnect the cannon plug to the valve’s actuator motor.
3. The problem lies with the electrical system. Items that should be checked include the GRD REFUEL switch, circuit breaker, or the wiring itself. In either case, further troubleshooting of the electrical system is required.
4. By visually observing the valve’s position indicator/manual override lever.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

46. (221) On a cargo aircraft, the SUMP LOW lights for the main tanks 1 and 4 *normally* illuminate at less than how many pounds of fuel?
    a. 1,000.
    b. 1,600.
    c. 2,000.
    d. 2,600.

47. (222) You can determine whether the tank scavenge system on a cargo aircraft is operating properly by checking the
    a. sump low lights only.
    b. fuel quantity indicators only.
    c. sump low lights and the fuel quantity indicators.
    d. fuel-pressure indicators and the fuel quantity indicators.

48. (223) Which situation could have a negative effect on the operation of the tank scavenge system?
    a. Low-boost pump pressure.
    b. Trapped fuel in surge box.
    c. Jet pump control inoperative.
    d. Boost-pump inlet screens clogged.

49. (223) What effect, if any, would a missing flapper valve in the sump box have on the operation of the tank scavenge system?
    a. None.
    b. Fuel would be stuck in the sump box.
    c. Undesired fuel would flow into the sump box.
    d. Fuel would be allowed to flow out of the sump box.

50. (224) How is the fuel drained from the main wing manifold of a cargo aircraft after a defuel operation?
    a. Gravity flow.
    b. Ejector pump.
    c. Rotary vane pump.
    d. Poppet drain valve.

51. (225) When troubleshooting a manifold drain system, the *best* method you can use to determine whether or *not* the single-point receptacle manifold drain shutoff valve has opened is to
    a. observe the manual override lever.
    b. observe the cannon plug position.
    c. listen to the actuator motor for the valve.
    d. take a voltage reading at the cannon plug.

52. (225) While troubleshooting a problem with the manifold drain system on a cargo aircraft, it seems that the single-point receptacle (SPR) manifold does *not* drain after a refueling operation. You place the GRD REFUEL switch to the DRAIN position and then take a voltage reading at the applicable pins on the cannon plug for the SPR drain shutoff valve. You determine that 115 volt (V), alternating current (ac) is present and that the manual override level is in the CLOSED position. In this situation, the malfunctioning component is *most* likely
   a. faulty wiring.
   b. the GRD REFUEL switch.
   c. an inoperative shutoff valve actuator.
   d. the applicable circuit breaker.

Please read the unit menu for unit 5 and continue ➔

Student Notes

Unit 5. Vent and Pressurization Systems

AS THE TITLE IMPLIES, this unit is about the fuel vent and pressurization systems you may encounter on the job. These systems are extremely important to the safe operation of an aircraft. To see how, let us consider the following brief scenario: let us say you have a 55-gallon drum and you want to fill it with water, but your drum has only one opening. This opening is equipped with a fitting connected to a heavy-duty, high-pressure water hose. You connect the hose to a high-pressure water source and begin filling the drum. What happens next will depend on certain conditions. If the water pressure you are using is high enough, the drum may rupture. Now, let us apply this overpressure situation to the fuel tanks on an aircraft. No doubt, the results of over pressurization would be deadly. To prevent this from occurring, aircraft are equipped with some types of vent systems.

In addition to a vent system, some aircraft types are equipped with a fuel pressurization system. These systems are designed to serve several purposes. For example, the system may prevent fuel from boiling at high altitudes, permit the transfer of fuel, or prevent the rupture or collapse of fuel cells.

Larger aircraft such as the B–52, C–17, and C–130 are not capable of inverted flight; thus, they only require a vent system. Due to the altitudes at which they fly and to support inverted flight, fighter and some fighter/bomber-type aircraft require both a vent and pressurization system.

Some aircraft such as the C–5 use a “pressurized” vent system. Although there are several varieties of these systems, all are based on the fact that the fuel tanks must “breathe.”

In this unit, we will cover the specific purpose and operation of the cargo vent system and the fighter pressurization system.

5–1. Fuel Tank Vent System

In our introduction, we used the example of an over pressurized barrel. We stated that aircraft fuel tanks are protected from over pressurization by the fuel tank vent system. In this section, you will learn about the operation of the vent system used on cargo aircraft. In addition, you will gain knowledge of the vent float valves used in this system.

226. Cargo aircraft vent system operation

To understand the concept of the vent system, you must first comprehend the effects of altitude on pressure. As altitude increases, pressure decreases. Therefore, if an aircraft had enclosed fuel tanks with no vent or pressurization system and the aircraft ascended, the outside “external” pressure would decrease while the internal tank pressure remained the same. Since there is no way for the internal pressure to be relieved to equalize with the external pressure, the fuel tanks would eventually rupture. This scenario illustrates the importance of a vent or pressurization system.

With these thoughts in mind, let's turn our attention to the following three major subjects of this lesson:

- Purpose of the vent system.
- Vent system description.
- Vent boxes.

Purpose of the vent system

The vent system on an aircraft prevents the rupture or collapse of a fuel tank due to excessive positive or negative pressure. In this regard, the fuel vent system on the cargo aircraft protects the wing and tank structures against differential pressures that are present during refueling, defueling, and climb and descent of the aircraft. The vent system also prevents spillage of fuel overboard during normal ground and flight maneuvers as it compensates for pressure changes. We will use FO 8 in the discussion for this lesson.

Vent system description

The fuel tanks in each wing are vented by a common system that serves all tanks on one side of the aircraft, as shown in FO 8. This venting system also prevents inter-tank transfer or overboard spillage of fuel during flight or ground maneuvers. Each fuel tank is vented by a vent line with an upturned bellmouth inlet near the inboard tank end. The inlets are located immediately below the upper surface of the wing skin. Opposite ends of the vent lines discharge into the vent boxes or their interconnecting lines. Open ends of the vent lines are positioned so that fuel expansion will not flood the vent system when the aircraft is in climb or level flight attitude. The vent system terminates in a 100-gallon vent box (view B) in each outboard main wing tank. The vent box vents into the atmosphere only when the tank pressure exceeds a preset tolerance above or below the ambient atmospheric pressure. Venting is controlled by a vent valve (18) in each vent box. Each vent valve vents through a duct (19) that is connected to an opening in the lower surface of the wing.

Vent boxes

Any fuel that enters the vent lines will drain into the vent boxes and be scavenged into the outboard main tanks by ejector or jettison pumps. A vent box overfill float switch (17) is located in each vent box and will actuate when the vent box is approximately half-filled with fuel. The float switch will then illuminate the VENT FILL indicator light on the fuel-management panel. The fuel vent boxes are located in the aft inboard corner of each outboard main tank. The vent boxes are pressurized by the introduction of nitrogen into each tank and excess positive or negative pressure is controlled by the vent valve located in each vent box. The vent box and six fuel tanks in each wing are interconnected and pressurized through the vent lines. The No. 1 main tank vent line (8) is a U-shaped manifold that originates in the upper inboard end of the No. 1 main tank and terminates in the vent box. The No. 1 auxiliary tank vent line (6) originates in the upper inboard end of the No. 1 auxiliary tank. The remaining four tanks also have vent lines that originate at the upper inboard ends of their respective tanks, but they join together into a common vent manifold (4) that terminates in the vent box. This system of interconnecting vent lines is typical of the vent system on most cargo and tanker aircraft.

Vent float valves

Vent float valves are commonly found on cargo, tanker, and heavy bomber aircraft. A vent float valve is a simple component, consisting of a float, linkage, and poppet. Figures 5–1, 5–2, and 5–3 show examples of typical vent float valves in different positions.

When an aircraft goes into a climb, fuel flows to the aft portion of the tank. On aircraft with more than one vent opening per tank, one of the openings is usually located in the aft portion of the tank. Unless there is some way to stop the fuel, it will enter the manifold and eventually make its way overboard. To prevent this from happening, use the vent float valve, shown on figure 5–1. As the fuel flows to the aft portion of the tank, the hinge linkage (B) and the float (C) rise with the fuel level to seat the poppet (A). During level flight conditions or when the aircraft is on the ground, the float should be in the LOWERED position, as shown in figure 5–2. This position will allow ambient air to enter and leave the tank through the vent opening.

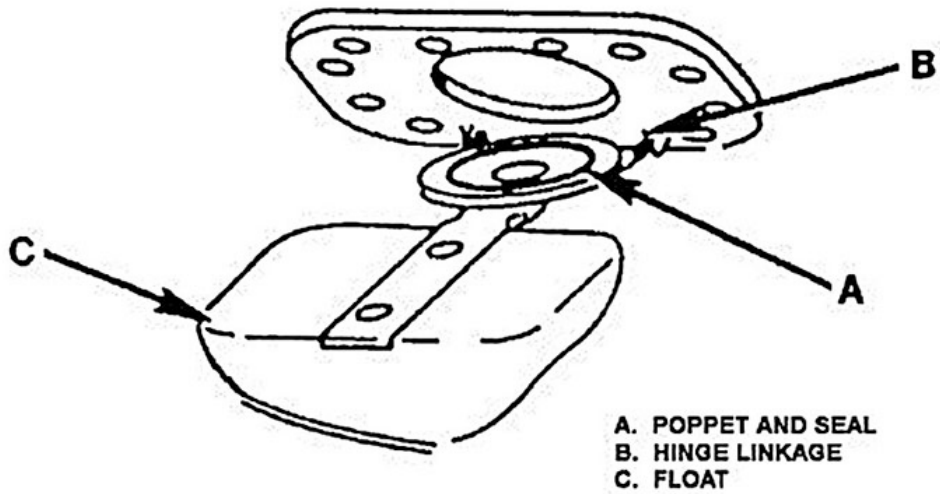

Figure 5–1. Vent float valve (OPEN position).

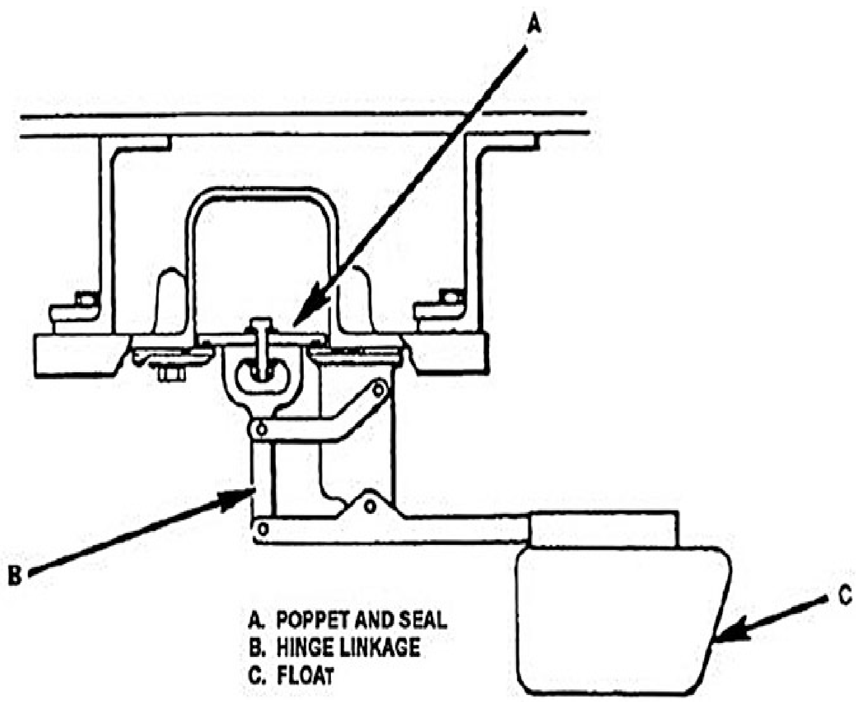

Figure 5–2. Vent float valve (CLOSED position).

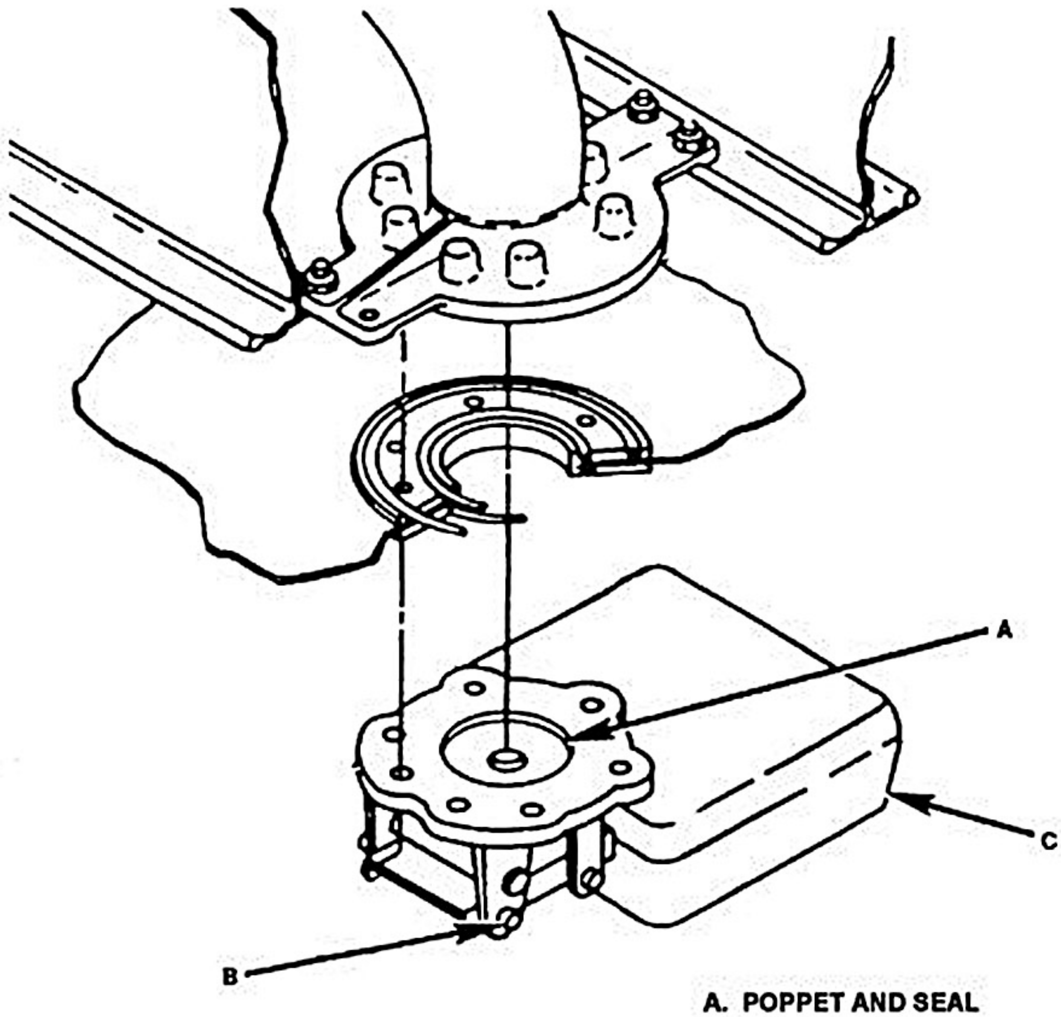

Figure 5–3. Vent float valve.

227. Vent system operational check out and troubleshooting

Depending on the aircraft you are working, the methods used to perform an operational check of the vent system will vary. It may not always be a faulty component causing the venting. As we know, vent lines are installed inside the fuel tanks. There could be a bad o-ring on one of the manifolds. You may be able to perform pressure checks on the vent lines and look for leaks. There may also be some components in the vent system that you can eliminate by performing operational checks. Always refer to the applicable aircraft technical order when performing operational checks. Having a thorough knowledge of how the vent manifolds and components are routed through the fuel tanks will aid in troubleshooting a malfunction. In many cases, performing an operational check will involve refueling the aircraft and waiting to see if the aircraft will vent.

When you are called out to troubleshoot a venting problem, be sure to get a good turnover. Ask plenty of questions; did it happen during refuel, in-flight, early in the morning, late afternoon, and when was the aircraft last refueled are all good questions. Depending on the answers to your questions, you will be able to determine the approach to take in your troubleshooting procedures. Regardless of the symptoms, always refer to the applicable aircraft technical order.

Since the valve operates through mechanical linkage, you must be careful not to mishandle or bend the unit because a malfunction can result. Another problem is sometimes caused when condensation freezes the valve. As an aircraft's altitude changes, the air temperature also varies. With this change in temperature, the fuel vapors surrounding the valve linkage condense and may freeze. This can cause the valve to temporarily malfunction. If the vent float valve should become stuck in the OPEN position, fuel may enter the vent manifold and eventually vent overboard.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

226. Cargo aircraft vent system operation

1. What is the purpose of the vent system on the cargo aircraft?

2. Within each fuel tank, where is the vent manifold bellmouth located?

3. How are the open ends of the vent lines positioned inside the tank?

4. At what location do all fuel tank vent manifolds terminate?

5. Under what conditions will the vent valve open to vent the wing into the atmosphere?

6. What component is installed inside the vent box to send a signal to illuminate a VENT FILL light on the fuel-management panel?

7. What is the basic purpose of a vent float valve?

8. What three parts make up a vent float valve?

9. In what position should the float on a vent float valve be when the aircraft is in a level flight attitude?

227. Vent system operational check out and troubleshooting

1. What two problems may cause the valve to malfunction?

2. What condition may result from a vent float valve becoming stuck open?

5–2. Pressurization System

As we stated in the introduction to this unit, the pressurization system on an aircraft may serve several purposes. For example, the system may prevent fuel from boiling at high altitudes, permit the transfer of fuel, or prevent the rupture or collapse of fuel cells.

In this section, we will cover the following three major subject areas as they apply to the pressurization system:

- Purpose and components of the vent and pressurization system on fighter aircraft.
- Operation of the fighter vent and pressurization system.
- Troubleshooting the fighter vent and pressurization system.

228. Fighter aircraft vent and pressurization purpose and components

In previous lessons, we discussed cargo aircraft systems. The vent and pressurization on a fighter aircraft is just as important. The vent and pressurization system on a fighter aircraft is a closed system, the aircraft changes altitude faster and also flies inverted, the closed system prevents fuel from coming out of the vent mast. The pressurization system will suck air in or let it out to make up for changes in altitude. The pressure inside the tank must be equal to or greater than the atmospheric pressure on the outside of the tank. We will cover the components, system operation, and troubleshooting of the fighter aircraft vent and pressurization system.

Purpose

The four primary purposes of a pressurization system on the fighter aircraft include the following:

- Provide positive air pressure to transfer fuel from the external tanks to the wings and assist in the internal tank transfer.
- Prevent negative pressure from collapsing the F–1 tank cell during fuel transfer or certain flight maneuvers.
- Minimize boiling of fuel in all tanks at high altitudes.
- Inert the fuselage tanks during combat to prevent ignition of fuel vapors inside the fuel tanks should the tank be hit by small arms fire.

The internal and external vent and pressurization system is illustrated in FO 1, figure 5. The system shown is used on fighter aircraft to provide internal and external fuel tank pressurization and venting control. The internal tanks are pressurized and vented through the internal vent and pressurization valve. The valve has two pressure schedules (normal and combat). Air from the ECS is allowed to flow into the tanks if the pressure falls below the control value.

Energizing the solenoid of the internal vent and pressurization valve initiates the combat pressure schedule. This is done by either placing the AIR REFUEL switch to OPEN or by placing the TANK INERTING switch to TANK INERTING.

The external tanks are pressurized, regulated, and vented by the external vent and pressurization valve. This valve regulates the air pressure in the external tanks. A solenoid in the pressurization valve permits air pressure in the external tanks to be dumped when the solenoid is energized. The solenoid is energized when the air refuel switch is placed to OPEN. Internal air pressure in the external tanks is also dumped when the pressurization source drops below 6 psi. At engine shutdown, tank pressure is dumped, permitting ground refueling of the external tanks.

Components

The vent and pressurization system has several components you should become familiar with. These are shown in FO 1, figure 5 and include the following:

- Internal tank vent and pressurization valve.
- External tank vent and pressurization valve.
- Remote-sensing pressure relief valve.
- Negative pressure relief valve.
- Fuel-tank manual depressurization valve.
- Ground-air service connector.

Internal tank vent and pressurization valve

This valve is located in the vent tank. As previously stated, the valve has two pressure schedules (normal and combat). Air from the ECS is allowed to flow into the tank if the pressure falls below the control value. If tank pressure exceeds the control value, it is vented overboard. Air exits the aircraft at the vent outlet on the lower surface of the left wing. Ambient pressure is sensed on the left side of the aircraft.

External tank vent and pressurization valve

The external tanks are pressurized, regulated, and vented by this valve. Also located inside the vent tank, this valve regulates 19–24 psi.

Remote-sensing pressure relief valve

This valve is also located in the vent tank. It is a poppet-type safety valve. The relief valve provides a backup means of relieving pressure should the internal vent and pressurization valve fail. It opens when the tank pressure is between 7 and 9 psi.

Negative pressure relief valve

A separate negative pressure relief valve is mounted in the upper fuselage surface and provides a backup means of allowing air into the vent tank should the tank come under a negative pressure (vacuum) condition. The opening pressure of the valve is 0.75 psi. The negative pressure relief valve is a spring-loaded poppet-type valve.

Fuel-tank manual depressurization valve

This poppet-type valve is located above the vent tank and is used to manually depressurize the internal and external fuel tanks.

Ground-air service connector

The fuel-tank pressurization ground-air service connector is located in the right main landing gear wheel well. With the use of a special adapter, you can apply ground air from an external air source to assist in troubleshooting or performing operational checks.

229. Fighter aircraft vent and pressurization system operation

Again, refer to FO 1, figure 5. All vent and pressurization system components are located in the vent tank just forward of the air refueling receptacle. Air for the pressurization system is supplied from engine bleed air at 60–70 psi. The air is cooled by the ECS. Air in the pressurization line will go through two check valves to prevent fuel from entering the ECS.

External tanks

Follow the pressurization line into the vent tank where the line "T"s off. At this point, the air will go to the Halon flow control valve and to the external tank vent and pressurization valve.

The air will then enter the externals through the external vent and pressurization valve forcing fuel out and transferring it to the wing tanks. If the air pressure going to the externals is above 26 psi, the vent part of the tank vent and pressurization valve will relieve the excess pressure. This excess air will vent overboard through the vent line to the bottom of the left wing. A solenoid in the vent and pressurization valve permits pressure in the external tank to be dumped before air refueling and after engine shutdown, permitting ground refueling of the external tanks.

Internal tanks

For internal tank operation, go back to where the air line "T"s off to the Halon control valve. This valve is used for the tank inerting system. With the TANK INERT switch in the OFF position, air passes through the Halon flow control valve and will enter the internal tank vent and pressurization valve. The pressurization part of the valve will reduce the air pressure to a normal or combat pressure schedule.

With the air refueling switch CLOSED and the INERT switch OFF, the solenoid in the internal vent and pressurization valve will de-energize and regulate the engine bleed air pressure to normal pressure (4.7–6.4 psi). This air pressure will enter and pressurize the vent tank, and then be routed to each wing tank. The air that enters the wing tank will place a positive pressure on the fuel and will prevent the fuel from vaporizing at high altitudes.

When the air pressure is above 7 psi, the vent part of the vent and pressurization valve will open. This will allow excess air pressure through the vent line to vent overboard at the bottom of the left wing. The combat pressure will be used when the pilot places the tank inerting switch to the TANK INERT position.

Tank inerting

The fuel tank inerting system prevents ignition of fuel vapors inside the fuel tank should the tank be hit by small arms fire. It is to be used ONLY in combat situations. The system uses Halon as an inerting agent. Halon is a fluid that prevents combustion when mixed with air. Thirteen pounds of Halon is stored in the Halon reservoir tank located in the left main wheel well.

The system is activated by positioning the fuel inerting switch to TANK INERT. This opens a normally closed shutoff valve (A) between the Halon reservoir tank and the Halon flow control valve. The Halon flow control valve is located in the vent tank. The valve regulates the Halon pressure at the outlet port of the valve to approximately 5 psi.

The Halon mixture will enter the internal tank vent and pressurization valve where a solenoid will energize and the air pressure will be reduced from normal pressure to 1–3 psi combat pressure. The air/Halon mixture will then enter the wing tanks. A second shutoff valve (B) opens for 20 seconds and discharges 1.69 pounds of Halon directly into the aft end of the A–1 tank, the aft end of the F–1 tank, and the outboard end of each wing tank. At the end of 20 seconds, the second shutoff valve (B) will close, allowing a mixture of Halon to enter the internal tank vent and pressurization valve. This Halon mixture will continue until the pilot switches the inerting switch to the OFF position.

When the air refuel switch is selected or during engine shutdown, the solenoid in the internal vent and pressurization valve will de-energize, allowing the internal tank to vent air to a pressure of below 6 psi. This completes operation of the tank inerting system.

230. Troubleshooting the fighter aircraft vent and pressurization system

One of the most common problems in a fighter aircraft is the failure of a vent and pressurization valve to energize or de-energize. For example, if all the external tanks failed to transfer, the most probable cause would be that the external vent and pressurization valve failed to open, preventing air pressure from entering the external tanks.

The first thing to check is the switch positions. If all switches are set correctly, take a pressure reading at the external tank. If there is no pressure in the external tank, you could assume that the external vent and pressurization valve is faulty. To verify your assumption, check to see if power is available to the vent and pressurization valve solenoid. If power is available, the valve is obviously faulty and will have to be replaced.

If power is not available, an electrical problem exists which could be a faulty relay or switch. This would require additional troubleshooting of the electrical system.

Internal tank pressurization problems are usually more difficult to find because there are no indications of a malfunction. Normally, the only time you will find an internal vent and pressurization problem is during a phase inspection or operational check. If you find the pressure in the internal tank is below normal, you may think the internal vent and pressurization valve is faulty. Before you replace the valve, check the switches for correct positioning and also check for power at the solenoid of the internal vent and pressurization valve.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

228. Fighter aircraft vent and pressurization purpose and components

1. What are the four primary purposes of the pressurization system on the fighter aircraft?

2. What are the two pressure schedules of the internal tank vent and pressurization valve?

3. What should occur if pressure in the internal tanks falls below the control value?

4. What action would you take to initiate the combat pressure schedule of the internal vent and pressurization valve?

5. What happens to the pressure in the external tanks at engine shutdown?

6. Where is the internal tank vent and pressurization valve on the fighter aircraft located?

229. Fighter aircraft vent and pressurization system operation

1. What should normally occur if the air pressure routed to the external tanks is greater than 26 psi?

2. What is normal pressure for the internal tanks?

3. What is the purpose of the fuel tank inerting system?

4. What is considered combat pressure for the internal tanks?

230. Troubleshooting the fighter aircraft vent and pressurization system

1. What would be the most probable cause if *all* the external tanks on a fighter failed to transfer?

2. How would you troubleshoot the problem stated in question #1?

3. What can you safely assume when there is power available to a solenoid on a vent and pressurization valve, and the valve does not function?

4. During what period of time are internal tank vent and pressurization malfunctions *normally* detected?

Answers to Self-Test Questions

226

1. It protects the wing and tank structures against differential pressures that are present during refueling, defueling, and climb and descent of the aircraft. The vent system also prevents inter-tank transfer and overboard fuel spillage.
2. Near the inboard tank end, immediately below the upper surface of the wing skin.
3. In such a way so that fuel expansion will not flood the vent system when the aircraft is in a climb or level flight attitude.
4. In a 100-gallon vent box.
5. When the tank pressure exceeds a preset tolerance above or below the ambient atmospheric pressure.
6. A float switch.
7. It prevents fuel from entering the vent manifold.
8. A float, linkage, and poppet.
9. LOWERED.

227

1. The mechanical linkage may become damaged or frozen.
2. Fuel may enter the vent manifold and eventually vent overboard.

228

1. Provide positive air pressure to transfer fuel from external tanks to the wings and assist in the internal tank transfer; prevent negative pressure from collapsing the F–1 tank cell during fuel transfer or certain flight maneuvers; minimize boiling of fuel at high altitudes; and inert the fuselage tanks during combat.
2. Normal and combat.
3. The internal tank vent and pressurization valve will OPEN, letting air from the ECS into the tanks.
4. Place the AIR REFUEL switch to OPEN or place the TANK INERTING switch to TANK INERTING.
5. The pressure is dumped, permitting ground refueling of the external tanks.
6. At the poppet-type valve in the vent tank.

229

1. The vent part of the vent and pressurization valve will relieve the excess pressure.
2. 4.7 to 6.4 psi.
3. It prevents ignition of fuel vapors should the tank be hit by small arms fire in combat situations.
4. 1–3 psi.

230

1. The external vent and pressurization valve failed to open.
2. First, check the switch positions. Next, take a pressure reading at the external tank. If no pressure is present, check power to the vent and pressurization valve solenoid. If power is available, the valve is inoperative. If no power is available, further troubleshooting is required on the electrical system.
3. The valve is faulty and will have to be replaced.
4. During a phase inspection or operational check.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

53. (226) The vent system on a cargo aircraft is used to
    a. assist in fuel transfer.
    b. pressurize external tanks.
    c. aid in the collapse of a cell.
    d. prevent overboard fuel spillage.

54. (226) On a cargo aircraft, the bellmouth inlet of the vent manifold in a fuel tank is located at the
    a. inboard end below the upper surface of the wing skin.
    b. inboard end above the upper surface of the wing skin.
    c. outboard end below the upper surface of the wing skin.
    d. outboard end above the upper surface of the wing skin.

55. (226) On a cargo aircraft vent system, the individual tank vent manifolds terminate
    a. in the vent box.
    b. at the boil port.
    c. in the No. 2 main tank.
    d. at the ram air duct.

56. (227) The vent float valve operates by means of
    a. an electric solenoid.
    b. mechanical linkage.
    c. flight controls.
    d. fuel pressure.

57. (227) Which condition *could* result in the malfunction of a vent float valve?
    a. Overfilling the fuel tank.
    b. Rough handling of the valve.
    c. Operating the valve in a “dry” tank.
    d. Loose electrical connections to the valve.

58. (228) Which fighter aircraft cell is protected from collapsing by the pressurization system?
    a. F–1 tank.
    b. F–2 tank.
    c. A–1 tank.
    d. Forward reservoir tank.

59. (228) Which action will initiate the combat pressure schedule of the internal vent and pressurization valve on a fighter aircraft?
    a. Open the fuel tank manual depressurization valve.
    b. Place the air refuel switch to the STANDBY position.
    c. Place the tank inert switch to the TANK INERTING position.
    d. Allow pressure in the internal tanks to fall below the control value.

60. (229) The internal tank vent and pressurization valve on a fighter aircraft is located in the
    a. forward reservoir tank.
    b. left wing tank.
    c. A–1 tank.
    d. vent tank.

61. (230) What would be the *most* probable cause if *all* the external tanks on a fighter aircraft failed to transfer?
    a. Vent and pressurization valve stuck open.
    b. Vent and pressurization valve stuck closed.
    c. Remote sensing pressure relief valve inoperative.
    d. Refuel/transfer valve failed in the centerline tank.

62. (230) When will internal tank vent and pressurization problems on a fighter aircraft *normally* be discovered?
    a. In flight.
    b. Immediately after flight.
    c. During a phase inspection.
    d. During an end-of-runway inspection.

Please read the unit menu for unit 6 and continue ➔

Student Notes

Unit 6. Fuel Quantity Indicating and Heat Exchanger Systems

THE FUEL QUANTITY indicating system in an automobile performs a very necessary function; that is, it senses the amount of fuel in the tank and reports this amount to a gas gauge on the dashboard. This indication lets the driver know when it is time to refuel. In a like manner, all Air Force aircraft are equipped with a fuel quantity indicating system. Like the automobile, this system is designed to sense the amount of fuel available and report this amount via an indicator or light in the cockpit or flight deck. Unlike an automobile, an aircraft has several fuel tanks and additional components which make the system somewhat complicated.

To give you the information you need to successfully work these systems, we will cover the theory of operation of the fuel quantity indicating system of the fighter aircraft.

We will also cover some basic fundamentals of the heat exchanger system. We will look at the functions and components of the system. Our objective is not to make you an expert; however, we want to provide you with enough information to be able to identify heat exchangers and there purpose in the fuel system.

6–1. Fuel Quantity Indicating System

The fuel quantity indicating system is another fuel system that is similar in purpose and function from one aircraft to another, yet slightly different as far as the operation of the system and the names given to components. For example, the fuel indicating system (as it is called on the fighter aircraft) is designed to provide a fuel-hot temperature indication. The system also measures and displays internal and external aircraft fuel quantities and senses fuel level for control and operation of air ejectors and fuel low lamps on the caution light panel.

In this section, we will look at the following two subsystems of the typical fuel quantity indicating system on a fighter aircraft:

- The fuel quantity measuring subsystem.
- The fuel-level sensing subsystem.

231. Fighter fuel quantity measuring subsystem

The fuel quantity measuring subsystem provides an indication of fuel remaining and the location of that fuel in the aircraft. To give you the information you need to work on this subsystem, we will cover the following four major subject areas:

- Components.
- Theory of operation.
- Theory of capacitance.
- Fuel quantity select switching network.

Components

The fuel quantity measuring subsystem consists of the following components:

- Fuel quantity indicators.
- Fuel quantity select panel.
- Fuel quantity control unit.
- Capacitance-type tank units.

Fuel quantity indicator

The fuel-quantity indicator (fig. 6–1) is located on the right side of the instrument panel of both forward and aft cockpits. The indicator has dual pointers marked forward right (F/R) and aft left (A/L) that indicate fuel remaining in the forward (right) and aft (left) fuselage tanks, respectively. The indicator also includes a totalizer window that continuously displays the total fuel in all tanks.

Fuel quantity select panel

This panel is illustrated in figure 6–1. It is located on the pilot's right instrument panel (forward cockpit). The two switches mounted on the panel include the following:

1. The fuel quantity selector switch.
2. The external fuel tanks switch.

Fuel quantity selector switch

The fuel quantity selector switch is a six-position rotary switch that provides a means of selecting the fuel quantity in a particular fuel tank system. The switch positions are marked TEST, NORM, reserve (RSVR), INT, WING, EXT WING, and EXT CTR.

External fuel tanks switch

The external fuel tanks switch is a two-position toggle switch with positions marked NORM and WING FIRST. The switch provides selection for sequencing external fuel tank transfer.

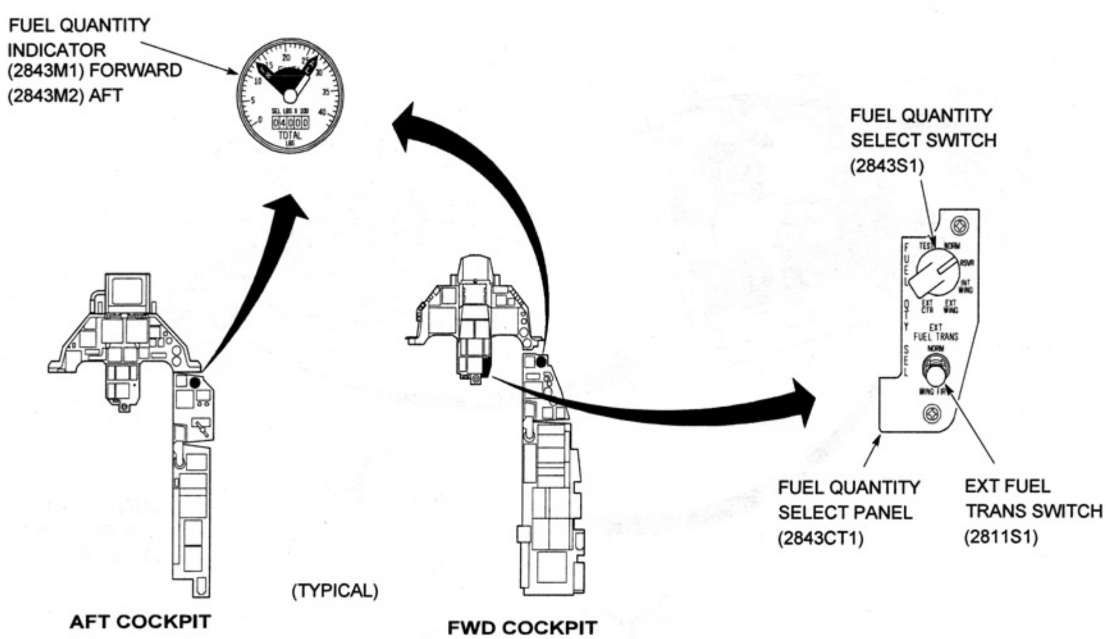

Figure 6–1. Fuel quantity indicator/select panel.

Fuel quantity control unit

An illustration of the fuel-quantity control unit is shown in figure 6–2. A panel must be removed to gain access to the unit. The control unit contains circuitry to provide the fuel quantity measuring functions and correct fuel quantity displays.

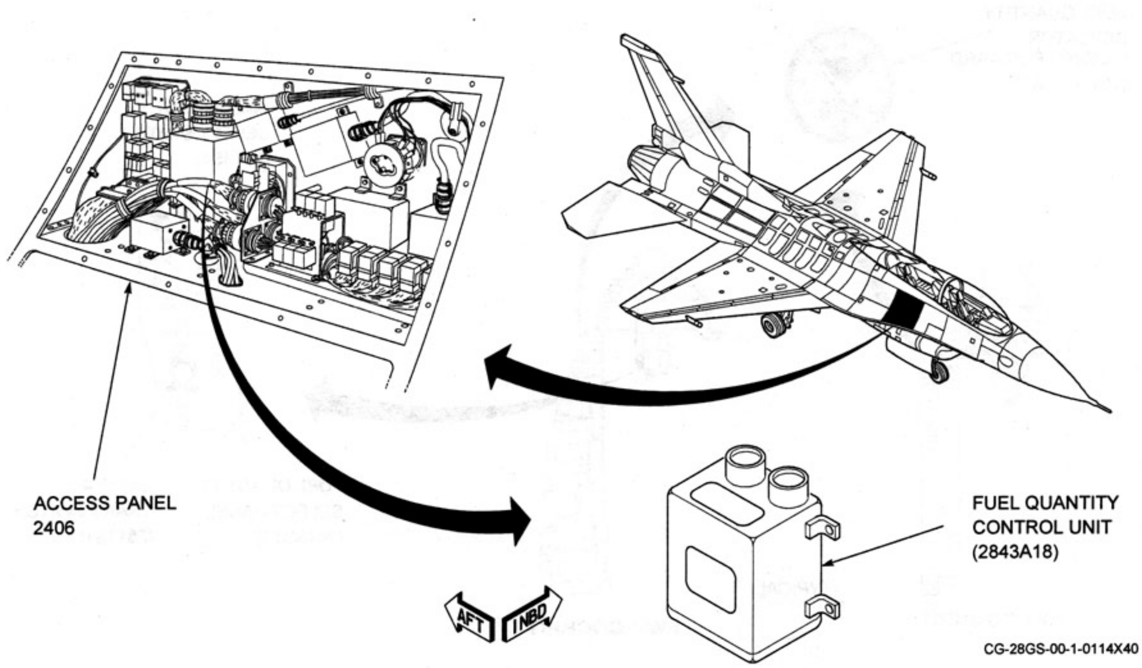

Figure 6–2. Fuel quantity control unit.

Capacitance-type tank units

Twenty-four tank units are used to measure the internal and external aircraft fuel quantities. Examples are shown in figure 6–3. The fuselage and external fuel tanks use internally mounted tank units, while the wing tanks use flange-mounted tank units. Each tank unit consists of two concentric metal tubes (one inside another), a potted assembly of two diodes and a fixed capacitor, a terminal block, and mounting brackets.

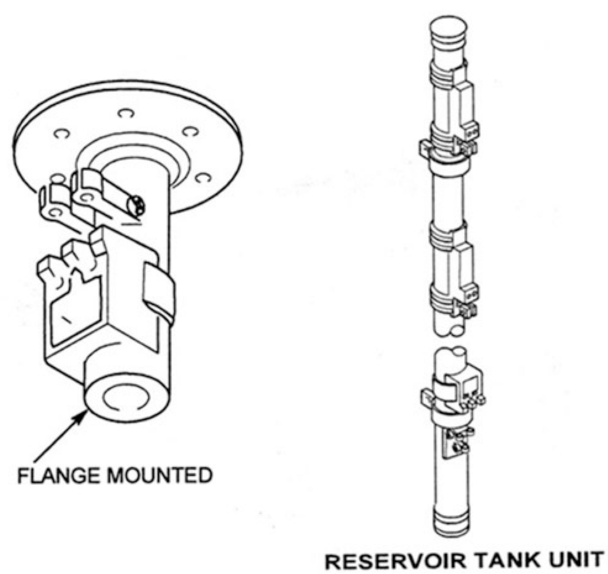

Figure 6–3. Capacitance tank units.

Theory of operation

The fuel quantity measuring subsystem uses an ac voltage source for system operation. The FUEL QUANTITY circuit breaker, mounted on the right ac power panel, protects the fuel quantity control unit. A power supply inside the control unit provides both ac and direct current (dc) voltage required for fuel quantity measuring system operation. A six kilohertz (KHz) oscillator provides voltage to the tank units.

Theory of capacitance

The quantity of usable fuel in the aircraft is sensed by the capacitance tank units located in the tanks. How these tank units operate appears to remain a mystery to many fuel systems personnel. The tank units (fig. 6–4) are basically two concentric cylinders (a cylinder placed exactly in the center of another cylinder), electrically isolated from one another, that form the plates of capacitors. This leads us to the question, what is a capacitor?

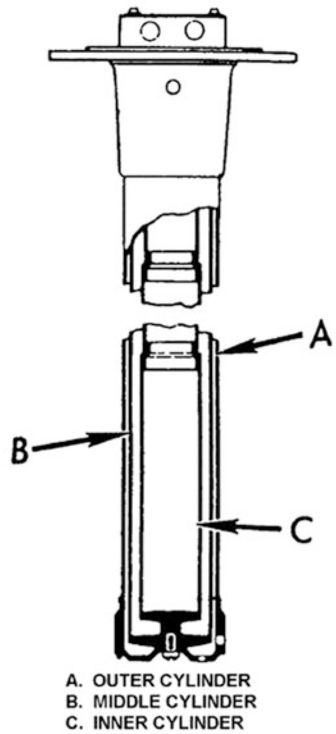

Figure 6–4. Capacitance tank unit.

A capacitor is a physical device composed of two pieces of conducting material separated by an insulating material. In this case, the insulating material (dielectric) is either fuel or air. As fuel rises in the tank, the fuel replaces the air between the two tubes of the capacitance tank unit, changing the capacitance. This change in capacitance provides a signal to the control unit that is proportional to fuel quantity.

The tank unit inner cylinder is designed to obtain a linear relationship between fuel mass and tank unit capacitance. In other words, the inner cylinder is cone-shaped; so visualize a cone-shaped cylinder placed exactly in the center of a slightly larger cylinder that has small holes along its length to let fuel into it. Now, because of the cone-shaped inner cylinder, the fuel mass or amount of fuel between the inner and outer cylinders will vary along the length of the tank unit. When the fuel mass varies, so does the tank unit capacitance. Now, let us take a look at how the signal from the capacitance tank unit ends up displayed on an indicator.

A high-frequency (6 KHz) voltage is applied to each tank unit. Each tank unit also contains two diodes connected in opposing polarity (one negative and one positive). A diode in a circuit is similar to a check valve in a manifold—it allows current to flow in one direction only. The positive signals from the tank unit are routed through the control unit, fed into an amplifier, then to a tank indicator channel A/L or F/R. The negative signals from the tank unit are sent to the control unit, which inverts the signals before sending them to an amplifier as positive signals, then to the total fuel channel.

Fuel quantity select switching network

The fuel quantity select switching network consists of relays used to provide the capability of selecting the desired tank system to be displayed on the fuel quantity indicator. The fuel quantity select switch, located on the fuel quantity select panel (fig. 6–1), is used to select the tank system to be monitored. As previously stated, this switch has the following six positions:

TEST

With the switch in the TEST position, the fuel quantity indicator A/L and F/R pointers drive to 2,000 pounds. The total digital readout will drive to 6,000 pounds. This indicates that the system is working properly.

NORM

With the switch in the NORM position, the A/L pointer indicates the sum of fuel in the aft reservoir and aft fuselage tank (A1). The F/R pointer indicates the sum of fuel in the forward reservoir and forward fuselage tanks (F1 and F2).

RSVR

With the switch positioned to RSVR, the A/L pointer indicates the amount of fuel in the aft reservoir and the FR pointer indicates the amount of fuel in the forward reservoir.

INT WING

With the switch in this position, the A/L pointer indicates the amount of fuel in the left wing tank and the FR pointer indicates the amount of fuel in the right wing tank.

EXT WING

When the switch is positioned to EXT WING, the A/L pointer indicates the amount of fuel in the left external wing tank and the F/R pointer indicates the amount of fuel in the right external wing tank.

EXT CTR

With the switch in this position, the A/L pointer drops to zero and the F/R pointer indicates fuel in the external centerline tank.

NOTE: The TOTAL digital readout displays total fuel on the aircraft in all switch positions except TEST.

232. Fuel-level sensing subsystem components and operation

The fuel-level sensing subsystem provides fuel-level sensing and control operation of air ejector valves and the fuel low-caution lights. First, we will take a look at the major components of the subsystem, and then we will cover the theory of operation.

Major components

This subsystem consists of the following four major components:

- Fuel-level sensors.
- Fuel-level control unit.
- Air ejector valves.
- Fuel low-caution lights.

Fuel-level sensors

Each sensor consists of a single thermistor mounted on the tank units in the reservoir tanks (fig. 6–5). The purpose of the sensors is to detect when fuel drops below specific levels in the reservoir tanks. There are two types of sensors, ejector control sensors and low-level sensors. The ejector control sensors are located near the top of each tank unit and will uncover at a fuel quantity of approximately 440 pounds. Ejector control sensors are located on the tank units in the forward and aft reservoir tanks. The fuel low-level sensors are mounted on each reservoir tank unit.

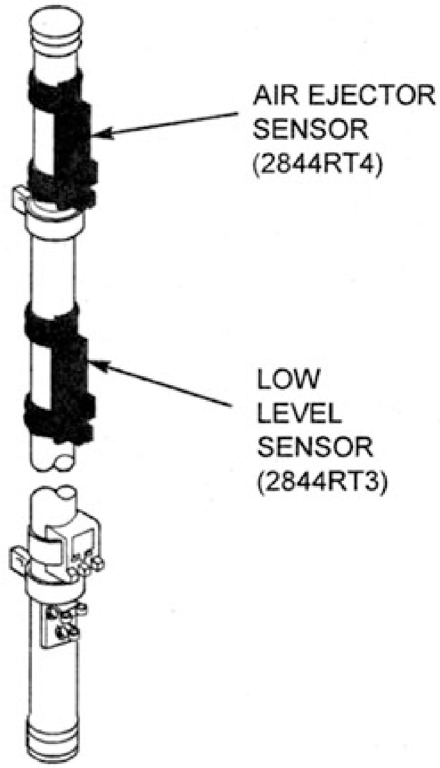

Figure 6–5. Fuel-level sensor.

Fuel-level control unit

The control unit (fig. 6–6) is located in the right strake equipment area under an access panel. The unit contains circuitry to provide the fuel-level sensing functions and correct fuel-level sensing displays. The control unit provides air ejector valve control and operation. It contains self-test circuitry and a fault detection circuit.

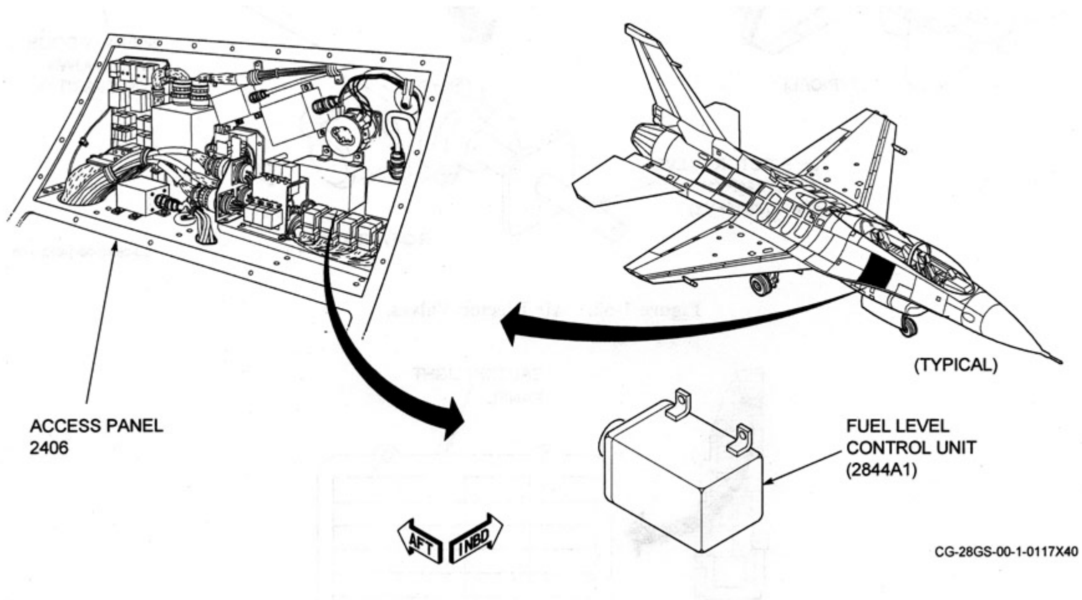

Figure 6–6. Fuel-level control unit.

Air ejector valves

The air ejector valves (fig. 6–7) are located in the aerial refuel well and are solenoid-operated pneumatic valves. The valves allow air pressure from the ECS to cause the ejector pump to expel air from the reservoir tank to aid suction fuel feed.

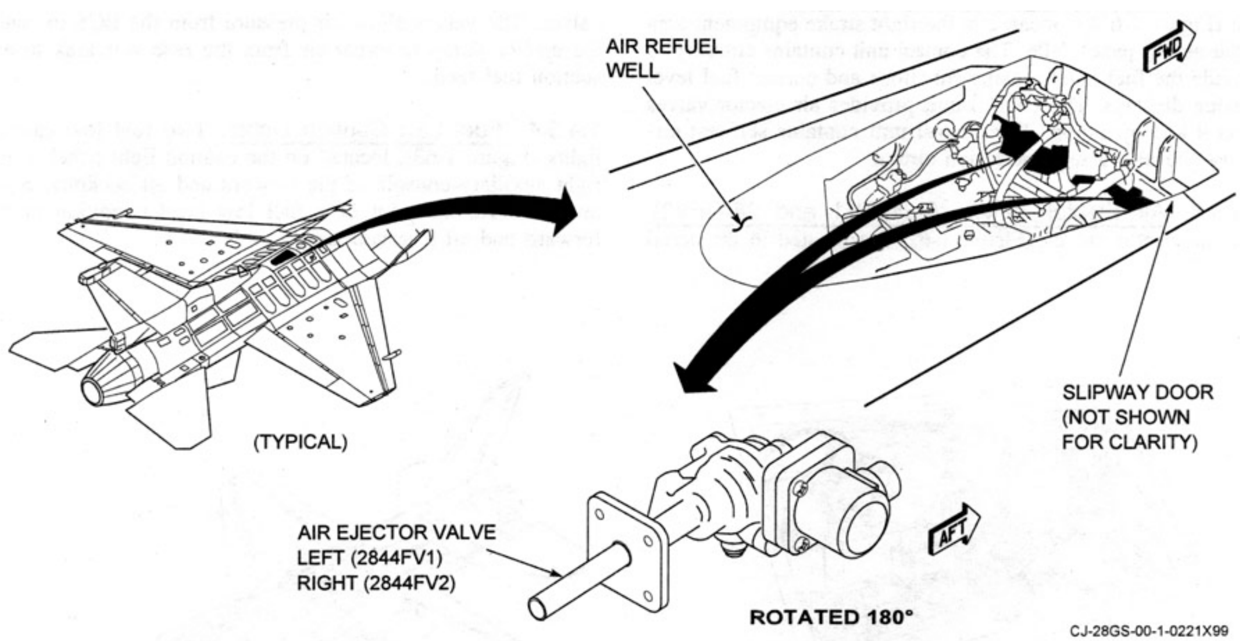

Figure 6–7. Air ejector valves.

Fuel low-caution lights

Two fuel low-caution lights (fig. 6–8), located on the caution light panel on the right auxiliary console of the forward and aft cockpits, come on to inform the pilot of a fuel low-level condition in the forward and aft reservoir tanks.

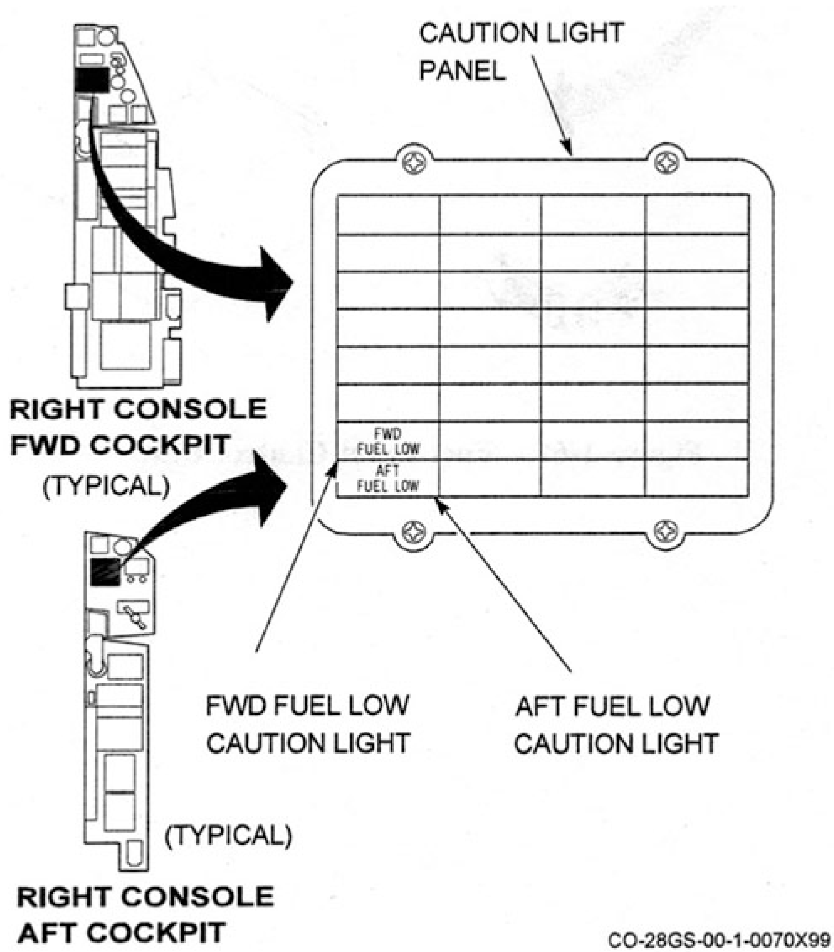

Figure 6–8. Fuel low-caution lights.

Theory of operation

The fuel-level sensors consist of a single thermistor mounted on the tank units in the reservoir tank. When the thermistor is not covered with fuel, it heats up, resulting in lower resistance. When the thermistor is covered with fuel, it is able to dissipate a greater amount of heat, resulting in a decrease in temperature and an increase in resistance.

Fuel-level sensing uses dc voltage to operate the caution light panel FWD FUEL LOW and AFT FUEL LOW lights. The FUEL-LEVEL SENSING circuit breaker, mounted on the right strake dc power panel, permits application of 28 V, dc to the control unit for fuel-level sensing and air ejector control and operation.

The fuel-level sensors are installed so that the forward and aft reservoir tank sensors will uncover at a specified fuel level. The sensor is mounted on the tank unit in each reservoir tank. The control unit provides power to the sensor. When the sensor in the forward reservoir is uncovered, a lower resistance is supplied to the control unit, which applies 28 V, dc to the FWD FUEL LOW light on the caution light panel. The operation is similar for the aft fuel sensor except that the AFT FUEL LOW light illuminates.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

231. Fighter fuel quantity measuring subsystem

1. What components can be found in the fuel quantity measuring subsystem?

2. Briefly describe the fuel quantity indicator.

3. What two switches are located on the fuel quantity select panel in the forward cockpit?

4. How many tank units are used to measure internal and external aircraft fuel quantities?

5. Briefly describe the construction of a capacitance tank unit.

6. What type of voltage is applied to each tank unit?

7. Where are the positive signals from the tank units routed?

8. Explain what should occur when the fuel quantity select switch is placed to the TEST position.

232. Fuel-level sensing subsystem components and operation

1. What function does the fuel-level sensing subsystem serve?

2. Name the two types of fuel-level sensors.

3. Where are the fuel low-level sensors located?

4. What components allow air pressure from the ECS to cause the ejector pump to expel air from the reservoir tank to aid suction fuel feed?

5. What component provides power to the fuel low-level sensors?

6–2. Heat Exchanger System

Earlier in the introduction to this unit, we stated that we did not want to make you into an expert on heat exchangers; however, we stated that we wanted to provide you with enough information to be able to understand how the heat exchanger system operates and the components involved within the fuel system. To give you the information that you need to build a foundation for understanding the heat exchanger system and how its components tie into the fuel system, we will cover the following two major subject areas:

- The Heat Exchanger System theory of operation.
- Heat Exchanger components.

233. Bomber heat exchanger system operation

Heat exchangers (HX) help transfer heat throughout several aircraft systems using fuel to dissipate the heat. Heat exchangers are also used to help cool hot fuel not burned by the engines. We will use the B–1B has our example here. Refer to FO 7 for component location, during this lesson.

Fuel Heat Sink (fuel cooler heat exchangers) operations

The Fuel Heat Sink sub-subsystem on the B–1B consists of separate left and right fuel-cooling scoop actuating cylinders, control valves for control of the cylinders, and accumulator control valves for porting accumulator pressure to the scoop actuating cylinders. Fuel cooler heat exchangers are air-to-fuel HXs (FO 7, item #4) that are used to cool fuel prior to returning the fuel to the main tanks (TK6L/R). On the ground, an electrical fuel cooler blower is used for fuel cooling. A blower inlet door is opened to provide the blower a source of ambient air. Ambient air is routed across the fuel cooler HX and overboard through the fuel cooler ram air scoop. In flight, below 370 knots indicated airspeed (KIAS), ambient ram air is inducted through the fuel cooler ram air scoop, across the fuel cooler HX and overboard through the fuel cooler ram air exhaust door. Above 370 KIAS, the scoops are commanded CLOSED. Control of the ram air scoop, ram air exhaust door, fuel cooler blower, and blower inlet door is automatic. A switch, located on the FMP labeled AUTO and CL, provides for override of the automatic function and can be used to close the ram air scoop by setting the switch to CL.

The Fuel Heat Sink sub-subsystem removes heat from the fuel-cooling loop. The fuel-cooling loop circulates main tank fuel through liquid-to-fuel heat exchangers, where it absorbs heat from the air recirculation coolant loop (ACL), liquid coolant loop (LCL), and intercooler coolant loop (ICL), as well as three integrated drive generators (IDG), four accessory drive gearboxes (ADG), and four hydraulic systems. Heated fuel then flows through fuel-to-air fuel heat sink heat exchangers, where it is cooled by ram air (in flight) or blower driven ambient air (ground operations).

Fuel-cooling loop operations

The B–1B has two separate fuel-cooling loops, which supply fuel from the main tanks as a heat sink for other aircraft fluid systems. Flow for each cooling loop is provided by its respective cooling loop pump located in the main tanks. Flow for each cooling loop is first routed through a fuel filter, then through five heat exchangers two in tank 1 and three in tank 3.These heat exchangers use fuel to cool avionics equipment, accessory drive gearboxes, integrated drive generators, and the hydraulic systems. Hot fuel is either delivered to the engines/auxiliary power units or passed through a fuel/air heat exchanger, and back into the main tanks. A cooling loop crossfeed valve allows one cooling loop pump to supply flow to both cooling loops if one cooling loop pump should fail. If both cooling loop pumps should fail, the boost pumps will provide cooling flow under low-engine demand.

234. Bomber heat exchanger components

In this lesson, we covered the B–1B heat exchangers that are connected with the fuel system, as well as the cooling loops. The cooling loops provide filtered fuel to the heat exchangers that are used to cool avionics equipment, accessory drive gearboxes, integrated drive generators, and the hydraulic system.

Heat exchangers

Heat exchangers include the intercooler coolant loop, air recirculation coolant loop, liquid coolant loop, fuel cooler, IDG, ADG, and hydraulic heat exchangers.

Intercooler coolant loop

The ICL absorbs heat from the air in the intercooler heat exchangers of the crew and stores refrigeration units, and transfers the heat to the fuel-cooling loop. There are two ICL heat exchangers, one in each cooling loop, in tank 1B and tank 1C. ICL also flows through a liquid-to-liquid (fast warm-up) heat exchanger, where it warms the LCL liquid when the LCL is below normal operating temperature (FO 7, item #5).

Air recirculation coolant loop

The ACL absorbs heat from the air in the air recirculation-loop heat exchangers and transfers the heat to the fuel cooling loop. One ACL heat exchanger is located in tank 1C. When the fuel does not cool it sufficiently, the ACL receives additional cooling in the regenerative refrigeration (REGEN). All ACL flows through the REGEN heat exchangers, and the REGEN throttles are modulated as required to cool the ACL to its operating temperature (FO 7, item #5).

Liquid coolant loop

The avionics LCL absorbs heat from avionics LRUs by flowing through the LRUs. LCL also absorbs heat from the precooled bleed air entering the oxygen-generating unit. Like the ACL it is cooled by the fuel cooling loop and, if required, by REGEN 1 and 2, except the LCL is directed around or through the REGEN heat exchangers as required to be cooled to its proper operating temperature. One LCL heat exchanger is located in tank 1B (FO 7, item #5).

Fuel cooler

The fuel cooler heat exchanger is a liquid to air type HX consisting of a metal housing, core baffles, and fuel inlet/outlet ports. The fuel enters the HX fuel inlet port and is circulated through the HX inside stainless steel tubing. Fins and baffles inside the tubing absorb hear from the fuel. Cool ambient air from the ram air scoop or blower passes through the HX and across the tubing. As the air crosses the tubing, heat is transferred to the air, the air is vented overboard through exit louvers during flight. The cooled fuel exits the HX through the outlet port. For ground fuel cooling, the ram air scoop and ground-cooling door are both open. The blower draws air from the overwing fairing cavity, blows it through the HX, and out of the ram air scoop (FO 7, item #4).

Integrated drive generators

A constant speed drive (CSD) and an ac generator are mechanically coupled and mounted together as one assembly called an integrated drive generator. The IDG heat exchangers use cooling loop fuel to disperse heat in the IDG oil. The IDG heat exchangers are located in the forward section of tank 3b and 3c, tank 3b for IDG's No. 1 and No. 2, and the tank 3c IDG heat exchanger for IDG No. 4 (FO 7, item #3).

Accessory drive gearboxes

Accessory drive gearboxes heat exchangers are also located in the forward section of tank 3B and 3C, just below the IDG heat exchangers. The ADG heat exchangers work exactly like the IDG heat exchangers, except they provide cool oil for the accessory drive gearboxes, which are the link between the aircraft engines and the CSD/IDG. There is a left (TK 3B) ADG H/X that serves the No. 1 and No. 2 ADGs and a right (TK 3C) ADG H/X that provides cool oil for the No. 3 and No. 4 ADG (FO 7, item #2).

Hydraulic heat exchangers

The hydraulic heat exchanger is a liquid-to-liquid, dual-core assembly that uses cooling loop fuel from the main fuel tanks as a heat sink to cool the hydraulic fluid in the main No. 1 and No. 2 hydraulic subsystems. The fluid-to-fuel heat exchanger maintains the hydraulic fluid in the main No. 1 and No. 2 subsystems below 275 degrees F. Hydraulic fluid temperature is controlled by a thermal bypass valve in each subsystem. This heat exchanger is located in the forward section of tank 3B (on FO 7, item #1).

The other hydraulic heat exchanger is located in the right side of the aft intermediate fuselage fuel tank (TK 3C). The heat exchanger cools the hydraulic fluid in the main No. 3 and No. 4 subsystems; otherwise, it is physically and functionally identical to the system No. 1 and No. 2 heat exchanger (on FO 7, item #1).

The fuel-cooling loop

The main purpose of the fuel-cooling loop sub-subsystem is to route fuel through heat exchangers to draw heat from other aircraft systems, acting as a heat sink. The heated fuel is delivered to the engine and if not needed is returned to the main tank (TK6). The cooling loop also provides fuel to the auxiliary power unit (APU) during ground maintenance. Fuel filters are provided to prevent heat exchanger clogging. Tanks 6L/R (main tanks) contain one cooling loop pump each connected between the engine feed check valve housings and the respective cooling loop lines.

Cooling loop lines are routed from the cooling loop pumps past the crossover valve and by-pass valves junctions through the fuel filters on through the heat exchangers to the engine feed/return junctions. Fuel is then routed to engine feed lines, or to fuel cooler (fuel-to-air) heat exchangers. The fuel cooler heat exchangers cool the fuel prior to being routed through the cooling loop return valves back to the respective main tank.

Major components

The major components are cooling loop pumps, cooling loop filters, cooling loop return valves, cooling loop crossover valve, and GROUND COOL switch.

Cooling loop pumps

The cooling loop pumps provide fuel flow, using TK 6 fuel, through aircraft heat exchangers (IDG, ADG, Hydro, ACL, ICL, LCL and Fuel Cooler HX) to keep system fluids cooled. The heated fuel is then delivered to the engines or returned to tanks 6L/R through the fuel cooler heat exchanger (air-to-fuel) depending on engine fuel demand. The cooling loop pump provides pressure feed for APU operations and cooling. The pumps are used to defuel the main tanks (TK6) for ground maintenance. The pump is pressure fed with fuel from two boost pumps mounted in the same tank. It can also be suction fed from the tank bottom if the fuel-level depletes below the boost pump inlets. TK6 fuel quantity has to be greater than 500 pounds for the cooling loop pump to run on the ground. When defueling or transferring fuel from the main tank using manual mode, shut the pumps off before reaching 500 pounds to prevent the pumps from running dry and premature pump bearing failure. The engine 1 or 4 START switch controls the left pump and 2 or 3 START controls the right pump. With APU power, only the left pump is on. If it fails, then the right pump will run. With external power connected both pumps will run. Circuit breakers for the left and right cooling loop pumps are in individual power control assemblies (PCA) installed in the aft crew compartment and main wheel well equipment bays. These circuit breakers must be OPENED and CLOSED in the proper sequence to prevent damage to the aircraft. The correct sequence for opening all fuel pump circuit breakers is as follows:

1. Open phase A.
2. Open phase B.
3. Open phase C.

The correct sequence for closing pump circuit breakers is as follows:

1. Close phase C.
2. Close phase B.
3. Close phase A.

Cooling loop filters

The cooling loop fuel filters remove contaminants from the fuel, prior to the fuel flowing through the heat exchangers. This prevents heat exchanger clogging. Cooling loop filter housings/elements are located in line with cooling loop lines, within the forward intermediate fuselage tank (TK 2) and are accessible from the intermediate weapons bay side wall. A manual shutoff valve is provided on the inlet side of the filter as well as a check valve on the outlet to facilitate element change out without defueling.

Cooling loop return valves

The cooling loop return fuel shutoff valve controls fuel flow return to each main tank (TK6 L/R). When the valve is OPEN, fuel is allowed to return to the mains and cooling loop back pressure is reduced. Closing the valve increases the cooling loop back pressure to the set point of the return pressure relief valve and forces the heated fuel to the engines. The cooling loop return valves are located inside the tank 3 shelf at the top of each main wheel well. The actuator includes a redundant position status for EMUX monitoring and a visual position indicator for local monitoring (FO 7, item #6).

Cooling loop crossover valve

The cooling loop crossover fuel-shutoff valve provides a means to cross connect the left and right cooling loop systems. This allows for a single pump providing fuel flow through both loops to cool the system fluids. The cooling loop crossover valve is installed in the tank 6L on the aft bulkhead. The valve is normally open on the ground and closed for airborne operations (FO7, item #8).

GROUND COOL switch

The GROUND COOL switch provides a means to cycle the ground refuel/defuel valve during ground operations. The switch is in the crew compartment on the FUEL MGT panel. It is a two position switch, OFF or GND COOL. The switch is normally in the OFF position. When positioned to GND COOL with landing gear on the ground, EMUX logic provides open command to the ground refuel/defuel valve.

This permits hot main tank fuel to be pumped to an open tank so it can be replaced by cooler fuel from any other tank.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

233. Bomber heat exchanger system operation

1. What are heat exchangers used for?

2. What component is the fuel first routed to in the cooling loop?

3. What is the purpose of the cooling loop crossfeed valve?

234. Bomber heat exchanger components

1. What is the minimum fuel quantity needed in TK6 to safely operate the cooling loop pumps?

2. What is the correct sequence for opening and closing fuel pump circuit breakers?

3. Where are the cooling loop filters located?

Answers to Self-Test Questions

231

1. Fuel quantity indicators, fuel quantity select panel, fuel quantity control unit, and capacitance-type tank units.
2. The indicator has dual pointers marked FR and AFT, which indicate fuel remaining in the forward and aft fuel systems, and a totalizer window that continuously displays the total fuel in all tanks.
3. The fuel quantity selector switch and the external fuel tanks switch.
4. 24.
5. Each unit consists of two concentric metal tubes, a potted assembly of two diodes and a fixed capacitor, a terminal block, and mounting brackets.
6. A high-frequency (6 KHz) voltage.
7. Through the control unit, an amplifier, then to a tank indicator channel.
8. The fuel quantity indicator AL and FR pointers drive to 2,000 pounds. The total digital readout will drive to 6,000 pounds.

232

1. It provides fuel-level sensing and control operation of air ejector valves and the fuel low-caution lights.
2. Ejector control sensors and low-level sensors.
3. They are mounted on each reservoir tank unit.
4. Air ejector valves.
5. The control unit.

233

1. To help transfer heat throughout several aircraft systems using fuel to dissipate the heat.
2. Flow for each cooling loop is first routed through a fuel filter.
3. It allows one cooling loop pump to supply flow to both cooling loops if one cooling loop pump should fail.

234

1. TK6 fuel quantity has to be greater than 500 pounds for the cooling loop pump to run on the ground.
2. (1) The correct sequence for opening all fuel pump circuit breakers is as follows:
   1. Open phase A.
   2. Open phase B.
   3. Open phase C.

(2) The correct sequence closing pump circuit breakers is as follows:

1. Close phase C.
2. Close phase B.
3. Close phase A.

3. Cooling loop filter housings/elements are located inline with cooling loop lines, within the forward intermediate fuselage tank (TK 2) and are accessible from the intermediate weapons bay sidewall.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

63. (231) What feature of a fighter fuel quantity indicator will indicate the sum of fuel in all tanks on the aircraft?
    a. Probe.
    b. Totalizer.
    c. Tank unit.
    d. Compensator.

64. (231) The positive signals from the capacitance tank units on the fuel quantity indicating system for a fighter aircraft are routed through
    a. a control unit, an amplifier, to an indicator channel.
    b. an amplifier, indicator channel, to a control unit.
    c. a control unit, indicator channel, to an amplifier.
    d. an amplifier, control unit, to an indicator channel.

65. (231) On a fighter aircraft, the TOTAL digital readout displays the total fuel on the aircraft with the fuel quantity select switch in all positions *except*
    a. RSVR.
    b. TEST.
    c. NORM.
    d. EXT CTR.

66. (232) On a fighter aircraft, the fuel low-level sensors are located in the
    a. A–1 and F–1 tanks.
    b. reservoir tank units.
    c. left and right internal wing.
    d. left and right external wing.

67. (232) When the thermistor head on a fuel-level sensor for a fighter aircraft is covered with fuel, there will be
    a. an increase in temperature and resistance.
    b. a decrease in temperature and resistance.
    c. an increase in temperature and a decrease in resistance.
    d. a decrease in temperature and an increase in resistance.

68. (233) Which heat exchangers cool fuel prior to returning it to the main tanks?
    a. Air recirculation coolant loop (ACL) heat exchangers.
    b. Intercooler coolant loop (ICL) heat exchangers.
    c. Fuel cooler heat exchangers.
    d. Hydraulic heat exchangers.

69. (233) What happens if both cooling loop pumps should fail?
    a. Both cooling loop pumps will never fail at the same time.
    b. Heat exchangers cease to operate and the air conditioner starts to overheat.
    c. The boost pumps provide cooling flow during low-engine demand.
    d. Tank 3 pumps reverse direction and provide fuel flow through both cooling loops.

70. (234) What fuel quantity (in pounds) in TK6 (main tanks) must be maintained to prevent the cooling loop pumps from running dry?
a. 300.
b. 400.
c. 500.
d. 600.

Student Notes

Glossary of Abbreviations and Acronyms

° F	degrees Fahrenheit
±	plus or minus
A/L	aft left
A/R	aerial refueling/air refueling
ac	alternating current
ACL	air recirculation coolant loop
ADG	accessory drive gearbox
APU	auxiliary power unit
cc/min	cubic centimeters per minute
CCD	Central Integrated Test System control and display
CDC	career development course
CITS	Central Integrated Test System
CMC	Central Integrated Test System maintenance code
CSD	constant speed drive
dc	direct current
DISC	disconnect
ECS	environmental control system
EEC	engine electronic control
EMUX	electrical multiplex
ENG FEED	engine feed
EXT	external
F/R	forward right
FCGMS	fuel center of gravity management system
FFP	fuel-flow proportioner
FMP	fuel-management panel
FO	foldout/foreign object
FOD	foreign object damage
FWD	forward
G	gravity
GRD REFUEL	ground refuel
gpm	gallons per minute
GS	general system
HX	heat exchanger
ICL	intercooler coolant loop

IDG	integrated drive generator
JFS	jet fuel starter
KHz	kilohertz
KIAS	knots indicated airspeed
LCL	liquid coolant loop
LRU	line replaceable unit
NORM MODE	normal mode
NWS	nose wheel steering
O/B	outboard
OPS	operational
ORIDE	override
PCA	power control assembly
PMC	parameter monitor code
pph	pounds per hour
PRI	primary
psi	pounds per square inch
psig	pounds per square inch gauge
REF	refuel
REGEN	regenerative refrigeration
REV	reverse
RSVR	reserve
SEC	secondary
SOV	shutoff valve
SPR	single-point receptacle or single-point refueling
SRU	shop replaceable unit
TO	technical order
UARRSI	Universal Aerial Refueling Receptacle Slipway Installation
V	volt

Student Notes

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