2A-28-10: General

The G550 fuel system consists of two wing fuel tanks, a series of pumps and lines to supply fuel to the engines and APU, and indicators to monitor the aircraft fuel state. See Figure 1 through Figure 3.

The total usable capacity of fuel tanks is 41,300 pounds, or 6,118 U.S. gallons at a standard fuel weight of 6.75 pounds per gallon. The international equivalent is 18,734 kilograms or 23,158 liters.

The fuel tanks can be filled from a single-point pressure fueling adapter or through tank fill openings on top of each wing. Fuel is drawn from the tanks and pressurized for distribution to the aircraft engines and/or APU by boost pumps mounted on the rear wall of each tank. Sensors mounted within the fuel tanks provide information for cockpit display windows enabling the flight crew to monitor fuel quantity and fuel tank temperature.

The fuel system is divided into the following subsystems:

- 2A-28-20: Fuel Wing Tanks
- 2A-28-30: Fuel Distribution System
- 2A-28-40: Fuel State Indications

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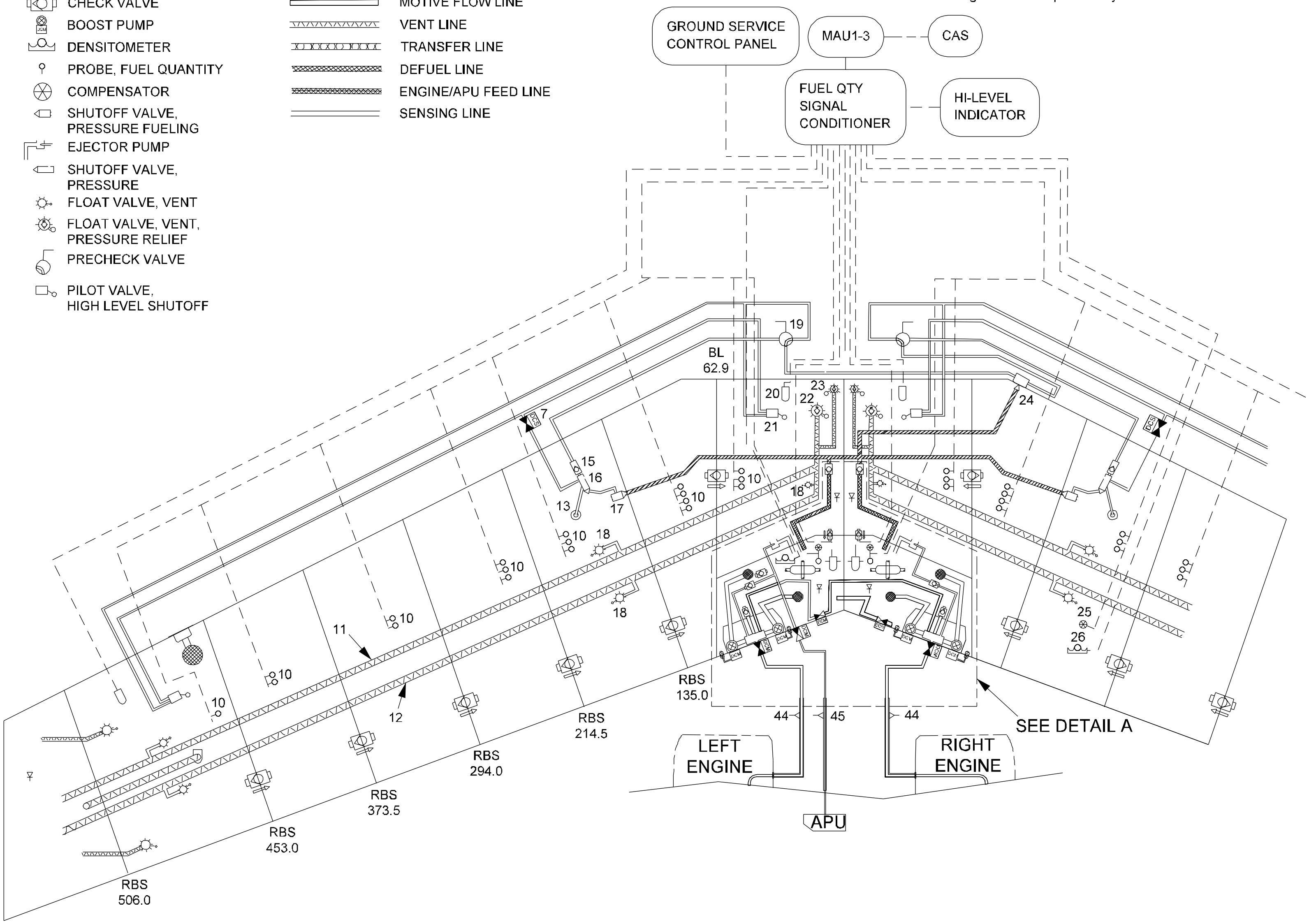
NOTE

1. SYSTEM IS SYMETRICAL ABOUT BL 0.0 EXCEPT FOR:
   - PRESSURE FUELING / DEFUELING ADAPTER AND LINES
   - INTERTANK SHUTOFF VALVE AND LINES
   - CROSSFLOW SHUTOFF VALVE AND LINES
   - APU SUPPLY LINES
   - DESITOMETERS
   - COMPENSATORS
2. BAFFLE RIBS ARE LOCATED AT BL 62.9, RBS 135.0, RBS 214.5, RBS 294.0, RBS 373.5 AND RBS 453.0
3. See Figure 3 for component key.

SOLENOID VALVE, N.C.
SOLENOID VALVE, N.O.
MOTOR VALVE, N.C.
MOTOR VALVE, N.O.
LOW LEVEL SENSOR
HIGH LEVEL SENSOR
CHECK VALVE
BOOST PUMP
DENSITOMETER
PROBE, FUEL QUANTITY
COMPENSATOR
SHUTOFF VALVE, PRESSURE FUELING
EJECTOR PUMP
SHUTOFF VALVE, PRESSURE
FLOAT VALVE, VENT
FLOAT VALVE, VENT, PRESSURE RELIEF
PRECHECK VALVE
PILOT VALVE, HIGH LEVEL SHUTOFF
ADAPTER, GRAVITY FUELING
ADAPTER, PRESSURE FUELING / DEFUELING
HEAT EXCHANGER, HYDRAULIC OIL
DRAIN VALVE
FUELING LINE
MOTIVE FLOW LINE
VENT LINE
TRANSFER LINE
DEFUEL LINE
ENGINE/APU FEED LINE
SENSING LINE



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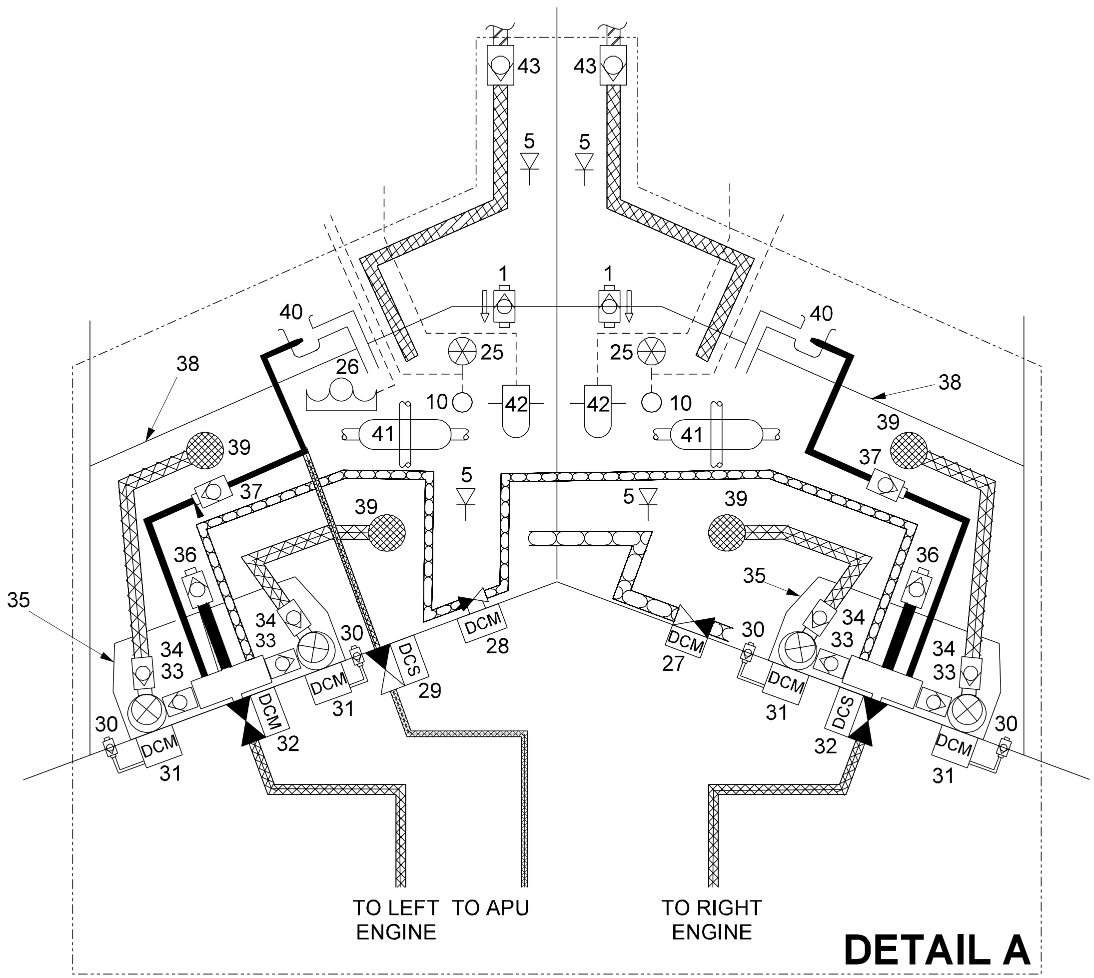
Fuel System Block Diagram (Full Wing View)
Figure 1



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Fuel System Block Diagram (Hopper View)
Figure 2

INDEX NO.	NOMENCLATURE
1	FUELING CHECK VALVE
2	VENT FLOAT/NON-RELIEVING VALVE (AIR PASSAGE)
3	VENT FLOAT/NON-RELIEVING VALVE (VENT DUCT)
4	OVERBOARD VENT AND RAM AIR INLET
5	WATER/FUEL DRAIN VALVE
6	VENT PLENUM
7	HIGH FUEL LEVEL SENSOR, OUTBOARD
8	PRESSURE FUELING HIGH-LEVEL PILOT VALVE, OUTBOARD
9	GRAVITY FUELING ADAPTER AND SCREEN
10	FUEL QUANTITY PROBES
11	FORWARD VENT DUCT
12	AFT VENT DUCT
13	PRESSURE FUELING AMBIENT PRESSURE PORT
14	PRESSURE FUELING SOLENOID SHUTOFF VALVE
15	PRESSURE SENSING CHECK VALVE
16	PRESSURE SENSING VALVE
17	PRESSURE FUELING SHUTOFF VALVE
18	VENT FLOAT DRAIN VALVE
19	PRESSURE FUELING MANUAL PRECHECK VALVE
20	HIGH FUEL LEVEL SENSOR, INBOARD
21	PRESSURE FUELING HIGH-LEVEL PILOT VALVE, INBOARD
22	VENT FLOAT/PRESSURE RELIEF VALVE, 3-INCH
23	VENT FLOAT/PRESSURE RELIEF VALVE, 1-INCH
24	PRESSURE FUELING/DEFUELING ADAPTER
25	COMPENSATOR
26	DENSITOMETER
27	INTERTANK SHUTOFF VALVE
28	CROSSFLOW SHUTOFF VALVE
29	APU FUEL SHUTOFF VALVE
30	VAPOR RETURN CHECK VALVE
31	FUEL BOOST PUMP
32	ENGINE FUEL SHUTOFF VALVE
33	PUMP DISCHARGE CHECK VALVE
34	PUMP SUCTION CHECK VALVE (HELD OPEN BY PUMP SUCTION PORT)
35	FUEL BOOST PUMP MANIFOLD
36	PUMP SUCTION BYPASS CHECK VALVE
37	FUEL EJECTOR PUMP MOTIVE FLOW CHECK VALVE
38	FUEL HOPPER
39	FUEL BOOST PUMP FILTER SCREEN
40	FUEL EJECTOR PUMP
41	HYDRAULIC FLUID HEAT EXCHANGER
42	LOW FUEL LEVEL SENSOR
43	DEFUELING SUCTION CHECK VALVE
44	ENGINE FUEL LINE DRAIN VALVE
45	APU FUEL LINE DRAIN VALVE

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Fuel System Block Diagram (Component Key)
Figure 3

2A-28-20: Wing Fuel Tanks

1. General Description:

The aircraft wing fuel tanks are integral to the wing structure. Fuel is contained within most of the interior of the wing, with the tank dimensions defined by the front wing spar, rear wing spar and the upper and lower wing skin. The interior of the wing is coated with a sealant during manufacturing to prevent fuel leakage.

The shape of the wing accommodates the installations necessary for efficient operation of the fuel system. The tank area near the wing root has the largest volume and houses the fuel boost pumps and fuel feed lines. With wing dihedral of three degrees (3°), fuel within the wing will always flow towards the wing root, ensuring that the fuel boost pump inlets will be adequately supplied until all usable fuel has been consumed. To prevent the outward movement of fuel during flight maneuvers involving turns, the six wing ribs within the tank that form the contour of the wing are fitted with baffles hinged to open only in the direction of the wing root. The wing ribs also contain a series of holes above the baffles to allow fuel to flow outboard during single-point pressure fueling, since the single-point access is located near the wing root. A second set of holes penetrate the wing ribs below the baffles to allow residual fuel and any accumulated water to drain inboard to the wing root as fuel quantity decreases. Both sets of holes are of small diameter (0.25 inches) so that flow rates through the holes are smaller than the flow rate through the larger rib baffle.

The following installations are contained within each fuel tank structure:

- Left and Right Fuel Hoppers
- Over-Wing (Gravity) Fueling System
- Gravity Water / Fuel Drain System
- Fuel Ventilation System
- Fuel Filtration System

2. Description of Subsystems, Units and Components:

A. Fuel Hoppers:

Each wing tank has a internal compartment at the wing root, termed a hopper, at the lowest point of the tank. Each compartment is formed by the rear wing spar, the rib at the centerline of the fuselage, an outboard wing rib located sixty-two point nine (62.9) inches from the fuselage centerline and a wall located forty-three and one half (43½) inches forward of the rear spar. The outboard wing rib and the forward wall have baffles directing fuel into the hopper, and drain holes for residual fluids. See the illustration in Figure 4.

The aft wing spar serves as the mounting surface for the boost pumps, fuel shut off valves, the crossflow and intertank valves and temperature sensors. The outside of the aft wing spar is accessible from the main landing gear wheel wells, and the fuel system components in the hoppers are mounted through openings in the spar, allowing the components to be replaced without emptying the fuel tanks.

Each hopper can contain 190 U.S. gallons or 1,283 pounds of fuel (the international equivalents are 719 liters or 583 kilograms). The intake lines supplying the boost pumps are installed along the bottom of the hoppers ensuring that all possible fuel can be extracted from the tanks.

The wing tank hopper also houses a heat exchanger to cool hydraulic system fluid. The right wing tank cools the left hydraulic system fluid, the left tank cools the right hydraulic system fluid. The heat exchangers are located on the bottom of each hopper, with hydraulic system lines entering and exiting the hopper through the aft wing beam. The heat exchangers act as radiators, with a set of tubing coils within baffles to transfer heat to the fuel in the wing tank. The hydraulic fluid is hot due to the pressurization of the system pumps, while aircraft fuel is cooled by the large surface area of the wing tanks encountering low temperatures at higher altitudes. The transfer of heat from hydraulic fluid to fuel both preserves the pressure transmitting characteristics of hydraulic fluid and aids in maintaining aircraft fuel at temperatures that prevent high viscosity.

B. Over-Wing (Gravity) Fueling:

An over-wing (gravity) fueling adapter assembly is installed on the top of each wing near the wing tip. The adapter has a locking fuel cap and a sleeve intake into the wing tank. The sleeve is fitted with a screen filter to prevent foreign objects from entering the tank during fueling. A grounding jack is installed on the wing leading edge near the over wing opening for prevention of electrical sparks or shorts during the fueling process. As fuel is pumped into the tank from a truck or underground facility, the fuel flows inboard through the baffles in the wing ribs to the hopper at the lowest point of the tank. The tank is filled from inboard to outboard and fuel quantity must be monitored at the fuel truck or hose outlet at underground tanks unless the aircraft is powered and manned, in which case the aircraft fuel gages may be used to monitor quantities. If the aircraft gages are used to determine fuel quantity, the aircraft should be level, otherwise an imbalance between wing tanks will occur.

Both wing tanks should be filled simultaneously. If both tanks cannot be filled at the same time, fueling should alternate from wing tank to wing tank to avoid the maximum fuel imbalance limit of two thousand (2,000) pounds. (See Figure 5.) Procedures for over-wing (gravity) fueling are presented in Chapter 9: Handling and Servicing.

C. Gravity Water / Fuel Drains:

Each wing tank is equipped with three drain valves located in the lower skin of each wing. One outboard drain near the wing tip to empty the fuel ventilation plenum and two inboard drains empty the hopper and the portion of the fuel tank forward of the hopper. The drains are operated manually and serve to drain any water that has infiltrated the aircraft fuel due to rain seepage or contamination. (Any water would accumulate at the bottom of the fuel tank since the specific gravity of water is heavier than the specific gravity of petroleum based fuels.) (See Figure 5.)

D. Fuel Ventilation System:

The fuel ventilation system provides a means for the flow of ambient air into and out of the wing fuel tanks. When the aircraft is fueled, fuel fills the volume of the tanks displacing air, and conversely as fuel is used from the tanks, air replaces the fuel consumed to fill the tank void.

Ventilation is accomplished by a system of vent tubes and float valves that spans the length of each wing fuel tank. At the wing tip, just outboard of the fuel tank is an empty chamber or plenum, plumbed to an air vent scoop on the lower section of the outboard wing leading edge. Two vent tubes connected to the plenum run the length of the fuel tank at the top, just below the wing upper skin. The inboard ends of the vent tubes are joined together at a common manifold just forward of the fuel hopper. The common manifold is connected to two (2) vent / float valves: one vent / float valve is three (3) inches in diameter, the other is one (1) inch in diameter. When the inboard section of the fuel tank is not full of fuel, the hinged floats of the valves drop down, providing an air passage from the inboard section of the fuel tank out through the vent tubes to the plenum at the wing tip and out to the ram air vent on the wing leading edge.

If the inboard section of the tank is to be filled with fuel during servicing (inboard fuel levels are dependent upon total fuel carried in the tank), the hinged float of the valves will remain open to permit the flow of air out of the inboard section of the tank until the rising fuel level pushes the float closed. Since inboard or lower section of the wing tank is filled first, another set of vent / float valves positioned adjacent to the air plenum at the wing tip are necessary to continue venting the wing during refueling. Each of the two vent / float valves is connected to one of the vent tubes along the top of the wing, and both act in the same manner as the two inboard vent / float valves. They provide a passage for air to exit the tank as fuel fills the tank. The outboard location of the vent / float valves enables air ventilation until the tanks are full, at which time the floats of the valves close.

The four vent / float valves operate in the opposite manner as fuel is consumed from the tank. As the aircraft takes off with full fuel tanks, the engines are supplied with fuel at a high rate by the boost pumps drawing fuel from the bottom of the tank hopper and pressurizing the fuel into the engine supply lines. The two inboard vent / float valves incrementally open to admit air to the tank as fuel is withdrawn from the tanks by the boost pumps. Forward aircraft speed forces air into the vent scoop on the wing leading edge, and the air pressure flows through the plenum at the wing tip, inboard through the vent tubes and to the vent / float valves, assisting in opening the valves. As fuel is consumed from the inboard section of the tank, fuel in the outboard section of the tank flows inboard through the rib baffles towards the hopper as space becomes available. As fuel levels in the outboard section of the wing fall, the two outboard vent / float valves open to provide additional air to fill the tank space vacated by the fuel. Aircraft turns and banks after takeoff will result in either the inboard or outboard vent / float valves opening or closing depending upon fuel levels and aircraft attitudes but ventilation air will remain available.

The ventilation system also provides a secondary function for the fuel tank. If a fueling malfunction overfills the tank, the pressure of the increasing volume of fuel will overcome the hinge action of the vent / float valves forcing them open. Fuel will then flow into the valves and out the vent tubes to the plenum chamber. If fuel continues to overpressure the tank, the plenum will fill with fuel and then spill out of the ram air inlet in the wing leading edge, providing a relief from the overpressure and preventing structural damage to the wing tank. The outboard vent plenum also acts as an expansion chamber for wing fuel. If the aircraft fuel tanks are filled and the aircraft subsequently is exposed to high temperatures and/or solar heating prior to departure, the fuel volume within the tanks will expand even though the weight of the fuel remains unchanged. The expanding fuel will force open the vent / float valves and expand out to the plenum that provides sufficient space for at least a two percent (2%) increase in fuel volume.

If circumstances result in fuel filling the vent system, a drain valve in the bottom of the plenum can be opened to empty the plenum.

NOTE:

Any fuel in the plenum should be drained prior to takeoff to prevent environmental damage from fuel spilling from the ram air opening.

Any fuel remaining in the vent tubes will drain back into the fuel tank through three vent / float drains located on the underside of the tubes and positioned within the inboard one third (1/3) of the fuel tank.

E. Fuel Filtration:

The fuel system is protected from foreign particles by three filters in each tank. One filter prevents the entry of contaminants during over wing fueling. Two other filters are fitted into the fuel boost pump intakes at the bottom of the fuel hoppers. The mesh of the filters block the entry of particles into the fuel system but have no effect on liquid contaminants.

3. Controls and Indications:

A. Crew Alerting System (CAS) Messages:

The following CAS message is displayed if the fuel quantity in the two wing tanks differs by one thousand (1,000) pounds:

Area Monitored:	CAS Message:	Message Color:
Fuel Quantity inputs to MAU #1 and #2	Fuel Imbalance	Blue

4. Limitations:

A. Flight Manual Limitations:

(1) **G550** Usable Fuel Capacities:

Left Tank	Right Tank	Total
20,650 lb (9,367 kg)	20,650 lb (9,367 kg)	41,300 lb (18,734 kg)
3,059 gal (11,579 lit)	3,059 gal (11,579 lit)	6,118 gal (23,158 lit)

NOTE:

It is possible to upload fuel in excess of 41,300 lb (18,734 kg). This is permitted as long as the maximum ramp weight and/or the maximum takeoff weight is not exceeded (max ramp weight = 91,400 lb / 41,458 kg and max takeoff weight = 91,000 / 41,277 kg) and the loaded aircraft center of gravity is within limits.

(2) **G500** Usable Fuel Capacities:

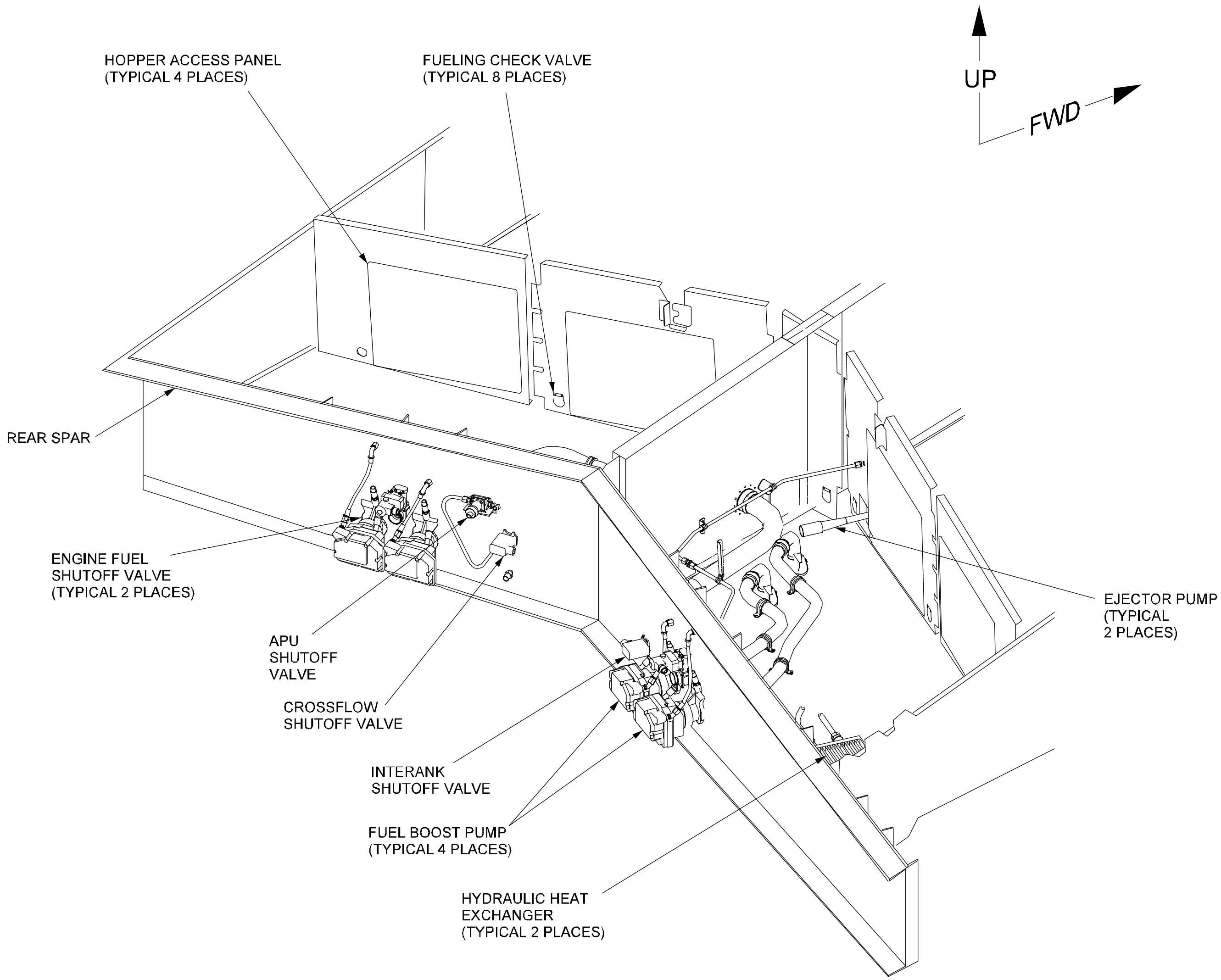
Left Tank	Right Tank	Total
17,600 lb (7,983 kg)	17,600 lb (7,983 kg)	35,200 lb (15,966 kg)
2,607 gal (9,868 lit)	2,607 gal (9,868 lit)	5,214 gal (19,736 lit)

NOTE:

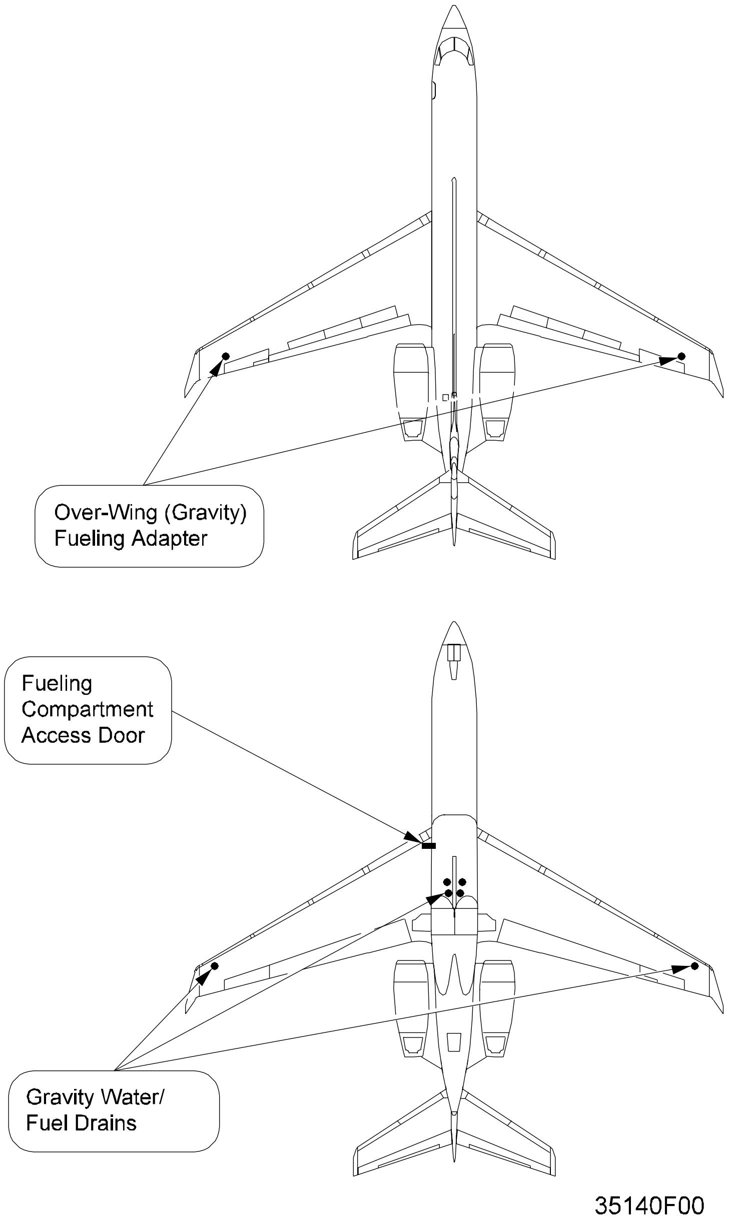
It is possible to upload fuel in excess of 35,200 lb (15,966 kg). This is permitted as long as the maximum ramp weight and/or the maximum takeoff weight is not exceeded (max ramp weight = 85,500 lb / 38,782 kg and max takeoff weight = 85,100 lb / 38,600 kg) and the loaded aircraft center of gravity is within limits.

NOTE:

G500 fueling operations are limited to pressure refueling only. Gravity refueling is not permitted.



Fuel Tank Hoppers
Figure 4



Fueling Adapters and Drains
Figure 5

2A-28-30: Fuel Distribution

1. General Description:

Fuel distribution for aircraft operation involves several distinct features directed toward supplying the engines with the correct amount of usable fuel. The aircraft tanks may be filled using a single point pressure fueling system. If fuel quantity needs to be reduced, or the tanks emptied, three methods are available for removal of fuel from the wing tanks. Fuel within the tanks is supplied to the engines by pressurizing the fuel with tank boost pumps. To compensate for an inflight engine failure, either engine may be supplied with fuel from either tank, and fuel balance between the tanks may be accomplished though opening a valve common to both tanks. The fuel system includes a means to maintain the temperature in the fuel tanks within a specified range. Fuel distribution incorporates the following elements:

- Single Point Pressure Fueling
- Defueling
- Fuel Crossflow and Intertank Transfer System
- Fuel Boost Pumps
- Engine and APU Fuel Distribution
- Fuel Temperature Indication and Heated Fuel Return System

2. Description of Subsystems, Units and Components:

A. Single Point Pressure Fueling:

Both left and right fuel tanks may be filled from a single fueling point within a panel located in the right wing forward fuselage fairing. The fueling panel opens to provide access to a fueling receptacle and two valves used to check the automatic shutoff features of the pressure fueling system. When opened, the panel face swivels downward, and contains the printed operating instructions for pressure fueling, a red high level warning light and a test pushbutton for the light. The fueling panel contains neither fuel gages nor a means to control the quantity of fuel to be loaded on the aircraft. Instead, the Fuel Quantity Panel (FQP) mounted on the inboard side of the Left Electronics Equipment Rack (LEER), is used to preselect the amount of fuel to be added to the aircraft tanks.

The FQP is powered by the Ground Service bus and provides the indications and controls necessary to pressure fuel the aircraft. The panel incorporates a digital readout of the fuel quantity in each tank, an indication of the amount of fuel to be loaded on the aircraft, a tank high level warning signal, and two selector switches. The left switch tests and resets the panel, selects the automatic refueling function or closes the pressure fueling shutoff valves. When the test and reset switch is set to the TEST/RESET position, the FQP performs a built-in test (BIT) of the system, and annunciates any malfunctions on the digital display screen. The system then resets. The center OFF position of the switch closes the pressure refueling shutoff valves electrically, and the AUTO REFUEL position opens the pressure fueling shutoff valves. The right switch has two positions: INCR and DECR to adjust the final fuel quantity to be transferred into the aircraft tanks with the pressure fueling function.

After the desired fuel quantity has been selected with the FQP, the shutoff control features of the pressure fueling system are operationally checked prior to fueling. Pressure fueling shutoff may be initiated either mechanically or electrically, but both employ the action of a pressure sensing valve installation to interrupt the flow of fuel into the aircraft tanks.

During pressure fueling, the truck nozzle is inserted into the aircraft adapter and fuel is routed from the adapter into a manifold flowing into each tank. Within each tank the fuel passes through the pressure fueling shutoff valve and into the tank, filling the tank from inboard to outboard. To control the operation of the fueling shutoff valve, a small amount of fuel is also routed through a system of control lines. The control lines first pass through a pressure sensing valve with a diaphragm. One side of the diaphragm is vented to atmospheric pressure through a line that exits on the bottom of the aircraft wing. The other side of the diaphragm is plumbed to the fuel control line. As long as the ventilation system of the tank is unobstructed, the pressure within the tank will be equal to atmospheric pressure as the tank is filled. Any blockage of the tank vents would result in a rise in pressure from the increasing volume of fuel, and the pressure sensing valve would detect the difference and close, shutting off the flow of fuel at the shutoff valve.

If atmospheric and tank pressures remain in balance fuel in the control lines continues through an electrically operated solenoid valve. The solenoid valve may be closed by electrical signals from three sources:

(1) The fuel quantity system when the preselected total fuel quantity has been reached.

(2) The FQP when the left TEST/RESET and AUTO REFUEL switch is placed in the center OFF position

(3) The REMOTE FUELING pushbuttons labelled L SHUTOFF and R SHUTOFF above the FUEL SYSTEM panel on the cockpit overhead (see Figure 6.

If the solenoid valve is closed by electrical signals from any of these sources, pressure will build up in the fuel control line, exceeding atmospheric pressure, and causing the pressure sensing valve to close the fueling shutoff valve.

If the solenoid valve remains open, fuel in the control line flows into the inboard and outboard vent / float valves. As long as the vent / float valves are open, the control fuel flows through the valves and empties into the wing tank. As the fuel level within the tank rises, the inboard vent / float valve will close, and control line fuel is prevented from freely flowing through the valve. However, the outboard vent / float valve remains open until the tank is almost full, so the control line fuel will continue to flow though the outboard valve into the tank. When the outboard vent / flow valve closes as the tank reaches full, the control line fuel no longer has an exit path to the tank, and the resulting pressure build up will cause the closure of the fueling shutoff valve.

Prior to pressure fueling, the action of the pressure sensing valve and the vent / float valves is checked. Adjacent to the pressure fueling adapter inside the fueling panel are two identical valves, one for each wing tank. The valves may be manually turned to three positions: PRE-CHECK FLOAT, PRE-CHECK TANK PRESS or FUEL. The two pre-check functions of the valve use a separate system of fuel lines (independent of the fuel control line) to activate the vent / float valves and the pressure sensing valve in each wing. Pressure fueling is first selected on with the FQP, then each tank pre-check valve is manually turned to the PRE-CHECK FLOAT position. In this position, the valve opens to port pressurized fuel to fill the chamber housing the vent / float valve, simulating a rising fuel level. As both vent / float valves close, the pressure build up in the control fuel line will close the pressure sensing valve and the fueling shutoff valve stopping the flow of fuel into the tank. The pre-check valve is then rotated to the FUEL position relieving the pressure built up in the line to the vent / float valves and allowing pressure fueling to continue. Lastly, the pre-check valve is turned to the PRE-CHECK TANK PRESS position, sending fuel to the tank side of the diaphragm on the pressure sensing valve, causing the valve to close and interrupting pressure fueling. The pre-check valve may then be turned to the FUEL position to restore pressure fueling flow.

The cockpit control switches are then checked. The L SHUTOFF pushbutton on the REMOTE FUELING section of the FUEL SYSTEM panel is selected in with the blue legend within the pushbutton illuminated CLSD. The flow of pressurized fuel into the left tank is interrupted by electrically closing the solenoid valve in the control fuel line, increasing pressure in the pressure sensing valve and closing the fueling shutoff valve. The pushbutton is then selected to the open position (legend in the pushbutton extinguished) and the flow of fuel into the left tank resumes. The R SHUTOFF pushbutton is tested in the same manner to verify the electrical control of the solenoid valve in the right fuel tank.

Once all pressure fueling shutoff features have been successfully tested, pressure fueling can be completed, loading fuel on board the aircraft until reaching the preselected level. When fuel reaches the preselected level, an electrical signal is sent by the FQP to close the solenoid valve.

If a unlikely series of malfunctions occurs, and none of the shutoff features of the pressure fueling system stop the flow of fuel into the aircraft tanks, a high level sensor in each tank will signal the illumination of the red warning light on the inboard face of the fueling panel. The pressure fueling operator should then immediately stop the flow of fuel into the aircraft by using the control lanyard or emergency shutoff at the fuel truck.

B. Defueling:

Removal of fuel from the aircraft may be accomplished by three methods. Depending upon the circumstance, a combination of the methods may yield the most satisfactory results. The methods are:

(1) Attaching the pressure fueling nozzle into the adapter at the fueling panel and applying suction instead of pressure at the fueling truck. Two defueling lines (one for each tank) are connected to the pressure fueling inlet lines, but separated from the lines by one way check valves that remain closed under fueling pressure. When suction is applied to the fueling inlet lines, the check valves open, and fuel is siphoned from the aircraft. The inlets of the defueling lines are located on the bottom of the fuel hoppers at the lowest point of the fuel tanks in order to remove the maximum amount of fuel possible from the tanks. However, approximately eleven (11) gallons or forty-two (42) liters of fuel will remain within the tanks using this method. The water / fuel drains must be opened to remove residual fuel if the tank is to be totally emptied.

Suction defueling is the common method of reducing the amount of fuel on board the aircraft if operational circumstances require a reduction in aircraft takeoff gross weight.

(2) Connecting a one (1) inch hose from the drain fitting on the fuel supply line to each engine and using fuel truck suction to draw fuel through the boost pump intake lines. This method results is less residual fuel in the tanks, but is much slower, since a one (1) inch line is used, and only one tank at a time may be emptied.

(3) Using the same one (1) inch line connected to the engine fuel line drain fitting and fuel truck, but powering the boost pumps to pressurize the engine supply line. This method is faster than method number two (2), and leaves the least amount of fuel in the tanks, since the boost pumps operate the ejector pump to induce greater fuel scavenging.

NOTE:

Prior to defueling the aircraft into a fuel truck, ensure that the capacity of the truck will accommodate the amount of fuel to be removed from the aircraft.

C. Fuel Crossflow and Intertank Transfer:

In normal flight operations, each engine consumes fuel from the respective side tank (i.e. left engine from left tank), however, malfunctions may require different fuel feed requirements. If both boost pumps in one tank fail, the engine corresponding to that tank must be fed from the opposite tank. Feeding both engines from one tank will cause an unbalance in the quantity between tanks, and if not corrected, exceed the aircraft limitation of two thousand pounds (2,000 lbs.) between tanks. The same imbalance would occur at a slower rate if one engine fails, and the remaining operating engine is fed only from the tank corresponding to that engine. Two sets of lines and valves are installed between the fuel tanks to provide alternate fuel feed paths to maintain fuel flow to the engines while maintaining fuel balance between tanks.

The crossflow line and valve is plumbed between the manifolds housing the two boost pumps within the hoppers of each tank, and allows an engine to be supplied with pressurized fuel from the opposite side tank. In the event of an engine failure, the remaining engine can be fed alternately from the onside fuel tank, then from the tank on the side of the inoperative engine to maintain fuel balance. Feeding an engine from the opposite side tank is accomplished by first opening the crossflow valve, turning on the boost pumps in the opposite side tanks, and then turning off the boost pumps in the onside tank. The crossflow valve can also compensate for the loss of both boost pumps within a tank.

The valve is selected open with a pushbutton switch, labelled X FLOW on the FUEL SYSTEM panel on the cockpit overhead. When the pushbutton is depressed, the white line legend within the switch is illuminated, completing the illustrated diagram between the tanks shown on the panel. The crossflow valve is powered by the left essential DC bus, and valve position is monitored by MAU #1. When the valve is open, MAU #1 relays the position to the Monitor and Warning System (MWS) that in turn generates a blue advisory Crew Alerting System (CAS) message of “Fuel

Crossflow Valve Open" for display on the CAS window, and illustrates the direction of fuel feed with a green arrow on the Fuel synoptic display window (the green arrow will point towards the tank with the greatest number of operating boost pumps).

To enable balancing fuel between tanks in the event of dual boost pump failure within a tank, an intertank line and valve are installed between the two fuel tank hoppers. The valve is opened with the INTER TANK pushbutton switch on the FUEL SYSTEM panel on the overhead. Depressing the switch will open the valve and the white line legend will illuminate within the switch completing the diagram line between tanks shown on the panel. The intertank valve is also powered by the left essential DC bus, but is position monitored by MAU #2. When the valve is open a blue advisory CAS message of "Fuel Inter Tank Valve Open" is displayed, and the valve is illustrated open on the Fuel synoptic window display. Opening the intertank valve only provides a path for fuel flow through the line connecting the hoppers of the fuel tanks. Since boost pump operation cannot provide the motive force to transfer fuel from tank to tank, the fuel balancing procedure requires that the aircraft be flown slightly out of trim in the yaw axis to induce fuel migration through the intertank valve. The out of trim condition will produce sufficient lateral force to cause fuel from the tank with the greater quantity to flow into the tank with the lesser quantity.

The same combination of intertank valve operation and out of trim condition is used to balance fuel between tanks when fuel tank temperature is low, since all boost pumps are required to be selected on when fuel temperature reaches zero degrees centigrade (0°C) or below.

For a full description of the procedures for operation of the crossflow and intertank valves, see section 05-14-00: Fuel System Abnormal / Emergency Procedures.

D. Engine and APU Fuel Supply Valves:

The engines are supplied pressurized fuel from the manifolds housing the dual boost pumps in each tank. The fuel is routed through a shutoff valve located on the aft wing beam at each tank. The shutoff valves are powered by the essential DC buses, left essential DC for the left engine and tank, right essential DC for the right engine and tank. The operation of the valves is controlled by the engine fire handles on the forward section of the cockpit center pedestal. Pulling out a fire handle will close the shutoff valve feeding fuel to the selected engine. For maintenance purposes, the valves may also be closed manually by using the position indicating lever on the valve body at the aft wing beam section in the main wheelwells.

The APU receives pressurized fuel from the left boost pumps and tank. A shutoff valve is installed in the APU fuel line at the left tank, and accessible through the left main wheelwell. The valve is controlled by the APU MASTER switch on the cockpit overhead, and is also powered through the relay in the switch, using right battery bus or left essential bus DC.

The shutoff valves for the engines and APU are accessible from the wheel wells, and can be removed without defueling the aircraft.

E. Fuel Boost Pumps:

The aircraft fuel tanks are equipped with four identical and interchangeable boost pumps, two in each tank. The boost pumps are located within the tank hoppers to ensure a positive supply of fuel to the pumps. The boost pump intakes are covered with filter screens to prevent the ingestion of foreign objects or particles that could damage the pumps.

The boost pumps are designated main or alternate, with the main pumps installed in the inboard position, and alternate pumps outboard. Both main and alternate pumps are required to be selected on at all times, unless pumps in a tank are switched off to balance fuel between tanks. The main and alternate pumps are selected on with MAIN and ALT pushbutton switches on the FUEL SYSTEM panel on the overhead. The amber OFF legend in a switch will illuminate if the pump is selected off or if the pump is inoperative. The pumps are equipped with pressure sensors to monitor pump performance. When a pump is initially powered, the OFF legend will be illuminated until an operating pressure of sixteen psi plus or minus two (16 psi ±2) is reached. The OFF legend will illuminate with the switch on if pump pressure drops to nine psi plus or minus one point five (9 psi ±1.5). Both main and alternate boost pump pressure sensors are monitored by MAU #1 and MAU #2 and subsequently by the MWS to provide CAS messages relating to boost pump pressures. The main and alternate boost pumps are electrically powered from different sources to enhance redundancy. The power sources are tabulated below:

Boost Pump	Power Source
Left Main	Left Essential DC
Left Alternate	Left Main DC
Right Main	Right Essential DC
Right Alternate	Right Main DC

The pressure produced by the boost pumps is also used to provide fluid flow through the ejector pump in each tank. The ejector pump incorporates a small diameter line from the pressurized boost pump manifold plumbed to extend forward in the tank to a position in front of the intake baffle to the tank hopper. The ejector directs a stream of high pressure fuel into the mouth of a wider opening plumbed back into the hopper. The velocity of the fuel ejected from the pump induces the flow of a larger volume of fuel into the hopper, thus assisting in the movement of fuel into the boost pump intakes.

Should both boost pumps fail, a separate line in the boost pump manifold , termed the suction bypass line, enables the engine to siphon fuel from the bottom of the hopper using the engine mounted fuel pumps. If the crossflow valve is open, boost pump pressure from the opposite side tank will be higher than engine suction pressure and the engine will be fed from the opposite tank.

F. Fuel Temperature Indication and Heated Fuel Return System:

The temperature of the fuel in the tanks is monitored to ensure that it remains within limitations. Two temperature bulbs, one in each tank, are mounted on the aft wing spar and penetrate into the fuel hoppers. The bulbs contain an element with an electrical resistance that varies with temperature. The resistance in the bulbs is monitored by the MAUs (left tank by MAU #1, right tank by MAU #2) and converted to a proportional voltage that is then translated into a digital format for display by the MWS. The temperature display range is from minus seventy to plus three hundred degrees centigrade (-70°C to +300°C) with an accuracy of plus or minus five degrees centigrade (±5°C). Fuel tank temperature is displayed on the Fuel synoptic 2/3 window, Summary synoptic 2/3 window and the Secondary Engine 1/6 window displays.

When operating at high altitudes or in extreme latitudes, the temperature of the aircraft fuel supply must be increased in order to ensure that fuel viscosity remains low enough for the fuel to flow freely through tank components and the engine Fuel Management Unit (FMU). Fuel in the wing tanks is warmed by a Heated Fuel Return System (HFRS) that diverts a part of the fuel supplied to the engine back to the tanks. The fuel returned to the tanks is drawn off after it has passed through a heat exchanger with the engine oil system where hot oil is cooled by engine fuel. As a result, the temperature of the fuel is raised to approximately fifty degrees centigrade (50°C). The hot fuel is returned to the fuel tanks and distributed throughout the wing by a system of pipes with multiple small holes. Although the volume of hot fuel returned is much smaller than the cold fuel within the tank, the temperature difference is significant enough to warm the tank fuel to within the range to maintain required fuel viscosity.

The flow of hot fuel back to the tank is controlled by three switches: one on the cockpit overhead and one at each engine. The FUEL RETURN OFF / AUTO pushbutton switch on the overhead FUEL SYSTEM panel provides flight crew control of the HFRS. When selected to the AUTO (or on) position, the return of fuel from the engine is managed by the Full Authority Digital Engine Control (FADEC) on each engine. The engine FADECs receive fuel tank temperature from the temperature probes fitted into each wing tank through the aft wing beam at the hopper. If the temperature within a wing tank is equal to or below zero degrees centigrade (≤ 0°C), the FADEC will open a Fuel Return To Tank (FRTT) valve at the engine, porting hot fuel back to the tank. When tank fuel temperature rises, equaling or exceeding ten degrees centigrade (≥ 10°C), the FADEC will close the valve, retaining the fuel within the engine FMU circulation. The operation of the FRTT valves are monitored by the MAUs, with MAU #1 communicating with the cockpit overhead switch and the FRTT valve of the left engine, and MAU #2 linked to the FRTT valve of the right engine. HFRS status is reported by the MAUs to the MWS that in turn formulates CAS messages appropriate to the operating condition and generates the graphic display of HFRS operation on the Fuel synoptic window. The Fuel synoptic window will display the HFRS only when the system is operating. The system is represented by a line and a valve between the respective tank and engine, shown in cyan. If the system is selected on and a malfunction exists, the line and valve are represented in amber.

The operation of the HFRS is limited to fuel system normal operating parameters and also by aircraft performance requirements, since the fuel returned to the tank must be in excess of the flow consumed by the engines as scheduled by the power levers and FADEC. For the FADEC to open the FRTT valve, the following conditions must be valid:

- The cockpit overhead switch selected to AUTO

- The engine fire handle stowed (not pulled)
- Engine low fuel pressure not indicated
- Engine low fuel quantity not indicated
- Engine fuel flow requirement less than 2,250 pounds per hour
- Fuel filter not blocked
- Fuel crossflow valve closed
- Fuel temperature should be at or below 0°C
- Electrical power to the FRTT valve available

3. Controls and Indications:

(See Figure 6.)

A. Circuit Breakers (CBs):

The following CBs protect the fuel distribution system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L MAIN PUMP CONT	LEER	A-3	L ESS DC Bus
L MAIN FUEL PUMP	Left PDB	N / A	L ESS DC Bus
R MAIN PUMP CONT	REER	A-14	R ESS DC Bus
R MAIN FUEL PUMP	Right PDB	N / A	R ESS DC Bus
L ALT PUMP CONT	LEER	A-2	L MAIN DC Bus
L ALT FUEL PUMP	Left PDB	N / A	L MAIN DC Bus
R ALT PUMP CONT	REER	A-15	R MAIN DC Bus
R ALT FUEL PUMP	Right PDB	N / A	R MAIN DC Bus
FUEL X-FLO VLV	LEER	B-2	L ESS DC Bus
FUEL INTER-TANK VLV	LEER	C-3	L ESS DC Bus
R FUEL S/O	REER	B-14	R ESS DC Bus
L FUEL S/O	LEER	B-3	L ESS DC Bus
L FUELING S/O	REER	A-16	GND SVC Bus
R FUELING S/O	REER	C-16	GND SVC Bus
FUEL RETURN	LEER	C-2	L MAIN DC Bus

B. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the fuel distribution system:

Area Monitored:	CAS Message:	Message Color:
Pressure in boost pump manifold	Fuel Pressure Low L-R	Red
Fuel tank temperature below -37°C or above +54°C	Fuel Tank Temperature	Red
Alternate fuel boost pump pressure	Alt Fuel Pump Fail L-R	Amber
Boost pump control logic (only one pump on with crossflow valve open above 41,000 ft.)	Fuel Boost Pump	Amber

Area Monitored:	CAS Message:	Message Color:
Fuel tank temperature between -35°C and -36°C or tank temperature above -35°C at an altitude above 35,000 ft. with fuel quantity indicating more than 1,000 lbs in either or both tanks, but only 1,000 lbs. remaining in hopper	Fuel Tank Temperature	Amber
Main fuel boost pump pressure	Main Fuel Pump Fail L-R	Amber
Fuel quantity differs between tanks by more than 1,000 lbs.	Fuel Imbalance	Blue
Intertank valve	Fuel Inter Tank Valve Open	Blue
Heated fuel return	Fuel Return Fail L-R	Blue
Crossflow valve	Fuel Crossflow Valve Open	Blue

4. Limitations:

A. Flight Manual Limitations:

(1) **Boost Pumps:**

(a) Operation:

All operable boost pumps must be selected ON for all phases of flight unless fuel balancing is in progress.

(b) When fuel tank temperature is less than 0°C:

All boost pumps shall remain ON. If fuel load balancing is required when fuel tank temperature is less than 0°C, comply with Section 1-03-80: Fuel Load Balancing (quoted below as item 2).

(2) **Fuel Load Balancing:**

(a) Maximum fuel imbalance for takeoff is 1000 lb.

(b) Maximum fuel imbalance in flight is 2000 lb.

(c) Proceed with fuel load balancing before the imbalance exceeds 1000 lb.

(d) When the Fuel Tank Temperature is less than 0°C, fuel balancing shall be accomplished using the intertank valve and establishing a small sideslip (approximately ½ trapezoid). Move the rudder trim arrow in the direction of the "heavy" tank, which will create a slight wing down condition toward the "light tank".

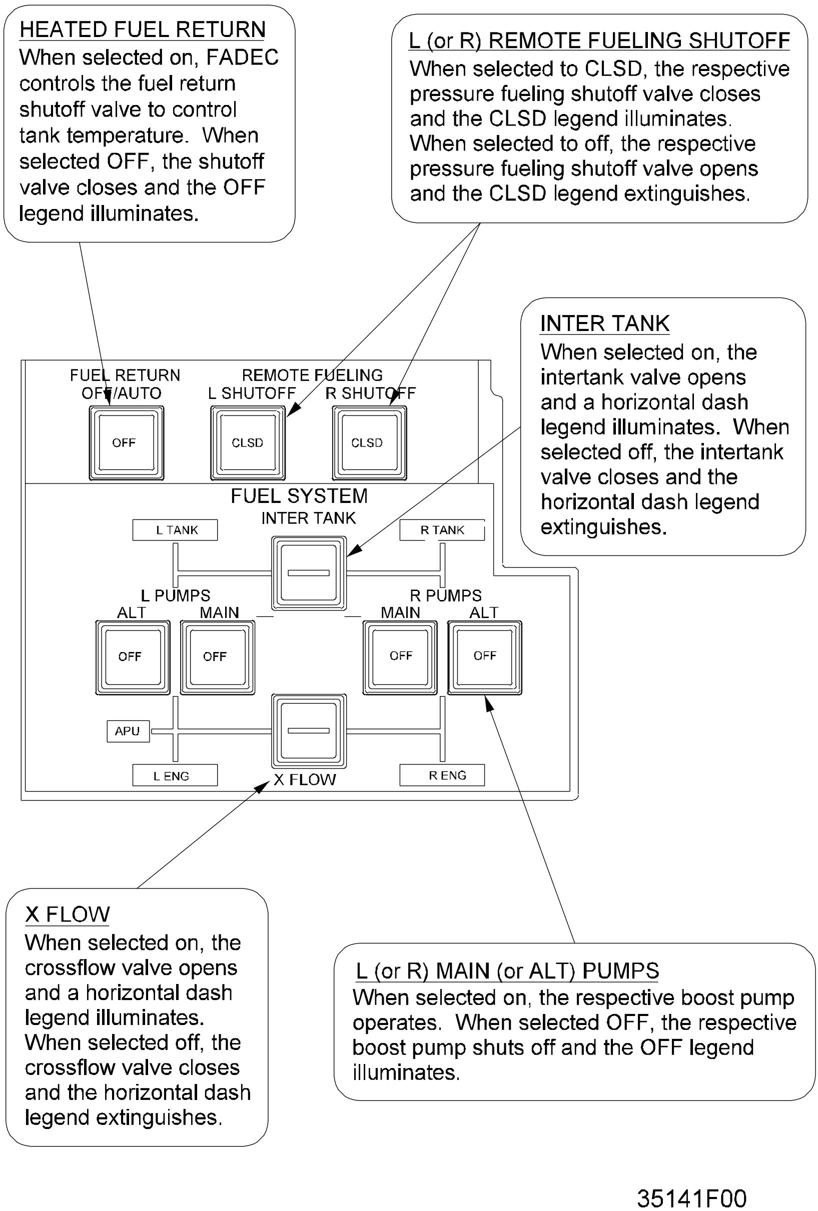
(3) **Fuel Tank Temperature:**

(a) Fuel temperatures of +54°C or greater will cause a red "Fuel Tank Temperature" warning message to be displayed on the Crew Alerting System (CAS).

(b) Fuel temperatures of -35°C to -36°C will cause an amber "Fuel Tank Temperature" caution message to be displayed on the CAS.

(c) Fuel temperatures less than or equal to -37°C will cause a red “Fuel Tank Temperature” warning message to be displayed on the CAS.

(d) When fuel tank temperature is at or below -30°C in flight with less than 5,000 lbs total fuel remaining, the airplane shall be descended to an altitude where SAT is -60°C or warmer and maintained at a minimum speed of M .80.



Fuel System Control Panel
Figure 6

2A-28-40: Fuel State Indication

1. **General Description:**

Indications of the fuel quantity within the wing tanks are derived from the Fuel Quantity Signal Conditioner (FQSC) located in the Left Electronics Equipment Rack (LEER). The FQSC transmits to and receives signals from fuel quantity probes installed in each wing, modifies the data for differences in environmental and chemical properties of the fuel, and determines the amount of fuel in the tank. The fuel quantity of each tank is provided to the Fuel Quantity Panel (FQP) installed on the face of the LEER and to Modular Avionics Units (MAUs) #1 and #2 for communication to the Monitor and Warning System (MWS) that generates the graphic display of fuel quantity on cockpit display windows. A secondary quantity indication is provided to Multi-function Control and Display Unit (MCDU) #1 for crew use in performance initialization of the flight plan and to monitor fuel management during flight.

NOTE:

Aircraft configured in accordance with JAR specifications have the option of displaying fuel quantities in kilograms (Kg.)

CAUTION

WHEN REFUELING THE AIRCRAFT AT LOCATIONS WHERE THE FUEL VENDOR MAY BE UNFAMILIAR WITH AIRCRAFT REQUIREMENTS, REVIEW THE FOLLOWING SECTIONS OF THE AIRCRAFT LIMITATIONS PRIOR TO FUELING: 01-12-20, APU FUEL GRADES AND FUEL TEMPERATURES, 01-12-30, ENGINE FUEL GRADES, AND 01-12-40, FUEL ADDITIVES.

2. **Description of Subsystems, Units and Components:**

   A. **Fuel Quantity Probes:**

Each wing tank has nineteen (19) fuel quantity probes positioned throughout the tank. The probes are placed in positions that allow determination of fuel quantity for the full range of tank capacity, from full to lowest usable level. The probes are connected through a wiring harness that enters the tank through the forward wing spar The harness leads from the wing inboard, through the fuselage and up to the FQSC unit in the LEER.

The probes measure quantity as a function of electrical capacitance. The FQSC transmits a low voltage signal (nominally 5 volts) to each probe through a wire in the harness and measures the capacitance through another wire in the probe. The ends of the two wires are separated by a fixed distance so that the capacitance between the wires is dependent upon the characteristics of the medium between the wires. The capacitance is higher when the probe is immersed in fuel and lower when the probe is exposed to air. The FQSC receives the capacitance signals from all probes in the wing and converts the combined signal to fuel quantity.

Two separate probes are installed within the wing to provide high fuel level and low fuel level signals to the FQSC. The high level probe is positioned near the tip of the wing so that when fuel quantity has reached tank capacity, the probe will be immersed and provide a high capacitance signal. The high fuel level signal is provided to the external refueling panel at the right wing root in order to illuminate the high level warning light on the panel door (see Figure 9). The low level probe is installed in the hopper, near the lowest level of the tank. When the fuel level drops to expose the probe to air, the capacitance falls and a low level signal is provided to the FQSC. The low level probe is positioned so that the low fuel level signal will occur at approximately six hundred fifty pounds (650 lbs) or two hundred ninety-five kilograms (295 kg) with volume equivalents of ninety-six gallons (96 gal) or three hundred sixty-three liters (363 L) at standard densities.

To refine the fuel quantity reading derived from the capacitance signals of the tank probes, two other types of sensors are installed in the tank. Each tank has a densitometer that determines the density of the fuel in the tank to improve the weight calculation of the FQSC. The densitometers are electromechanical oscillators that vibrate at a frequency proportional to the density of the medium surrounding the oscillator. The FQSC translates the frequency to density. The left tank densitometer is located in the tank hopper to monitor existing fuel density and the right tank densitometer is located outboard in the wing tank to measure fuel density as it is loaded in the tank.

Each wing also has a compensator sensor placed in the fuel hopper to calculate the dielectric constant of the fuel. The dielectric constant is dependent upon the chemical makeup of the fuel, and different fuel brands or types have different additives that effect the dielectric constant. The right wing has an additional compensator outside of the hopper to determine the constant as fueling is in progress. The FQSC adjusts the capacitance reading of the fuel quantity probes using the dielectric constant reading from the compensator sensor.

B. Fuel Quantity Signal Conditioner (FQSC):

The FQSC processes signals from the wing tank fuel probes, densitometers and compensators to provide accurate fuel quantity data for aircraft displays and control of the automatic refueling process. The FQSC uses twenty-eight volt (28 V) DC power either from the ground service bus while the aircraft is on the ground (weight-on-wheels) or the right emergency bus while in the air. The fuel quantity probes and sensors in each wing are separately powered through dedicated circuit breakers, with a total of four circuit breakers feeding the FQSC: left and right ground and left and right air.

The Fuel Quantity Panel (FQP) is powered and controlled by the FQSC through direct wire connections. During automatic refueling, the FQSC compares the preselected fuel quantity entered on the FQP with the amount of fuel in the wings tanks and provides an open signal to the fueling solenoid valves until the preselected and actual fuel quantities match. The FQSC then closes the solenoid valves.

Quantity readings are furnished to MAU #1 and #2 by the FQSC over ARINC 429 bus connections. The MAUs forward data to the MWS for generating fuel quantity displays and Crew Alerting System (CAS) messages. The FQSC provides fuel quantity information to MCDU #1 through a separate ARINC 429 bus. An illustration of the FQSC interfaces is contained in Figure 7.

C. Fuel Quantity Displays:

An indication of aircraft fuel quantity is presented on eight (8) displays:

(1) The Fuel Quantity Panel (FQP) - located on the inboard upper side of the LEER, indicates left, right and total fuel quantity, and high level warnings for each tank on a digital display screen. Beneath the screen are two switches used to control the automatic refueling of the aircraft. The left switch, in the down position tests and then resets the fuel quantity display, in the up position initiates the automatic fueling of the aircraft by opening the fueling solenoid valves in each wing or closes the solenoid valves when selected to the center position. The right switch, in the up position increases the preselected fuel load and decreases the desired fuel load in the down position. The panel is shown in Figure 8.

(2) Multi-Function Control and Display Unit (MCDU) #1:

- If an electrical malfunction reduces the available electrical power supply to emergency batteries only, MCDU #1 will automatically revert to a display of fuel quantity (adjacent to LSKs 6L and 6R) and engine performance parameters.
- During normal operations, fuel quantity information from the FQSC is shown on PERFORMANCE INIT page 5/5 of the MCDU at Line Select Key (LSK) 1L, displayed in small characters. If the displayed quantity is not acceptable to the flight crew, a manual entry of fuel quantity may be made with the keyboard of the MCDU. If a manual entry is made, the fuel quantity will be displayed in large characters. Fuel quantity is also displayed during flight on pages 1/2 and 2/2 of FUEL MGT. The quantity displayed on these pages is obtained by subtracting cumulative fuel used from fuel flow indications from the fuel quantity initially displayed or entered on the PERFORMANCE INIT 5/5 page. If fuel flow indications are faulty, the flight crew may manually update the fuel quantity on the FUEL MGT 1/2 page or manually enter a fuel quantity on the PERFORMANCE INIT using current quantity indications.

NOTE:

For more information, see sections 2B-19-00 through 2B-30-00.

(3) FUEL synoptic 2/3 window display

(4) SUMMARY synoptic 2/3 window display

(5) GROUND SERVICE system 1/6 window display

(6) SECONDARY ENGINE system 1/6 window display

(7) ALTERNATE PRIMARY ENGINE system 1/6 window display if the secondary engine system window is not currently displayed.

(8) COMPACTED ENGINE system 1/6 widow display in the event of a Display Unit failure.

3. Controls and Indications:

(See Figure 7 through Figure 9.)

NOTE:

Full descriptions of synoptic and system window displays are presented in Section 2B-07-00.

The fuel quantity system may be tested with the FUEL pushbutton switch on the SYSTEM TEST panel on the upper left section of the cockpit overhead. Depressing the pushbutton will illuminate the amber TEST legend in the switch and result in the following indications:

- A fuel quantity of seven thousand pounds (7,000 lbs) in each tank (left and right) and a total fuel quantity of fourteen thousand pounds (14,000 lbs) displayed on whichever of the above listed synoptic or system pages currently selected for view on cockpit display units
- An amber caution message of “Fuel Level Low L-R” on the CAS window display

A. Circuit Breakers (CBs):

The following CBs protect the fuel indication system:

Circuit Breaker Name:	CB Panel:	Location:	Power Source:
L FUEL QTY (AIR)	REER	B-15	Right emergency battery bus
R FUEL QTY (AIR)	REER	B-16	Right emergency battery bus
L FUEL QTY (GND)	REER	C-14	Ground service bus
R FUEL QTY (GND)	REER	C-15	Ground service bus

B. Crew Alerting System (CAS) Messages:

The following CAS messages are associated with the fuel indication system:

Area Monitored:	CAS Message:	Message Color:
Fuel Quantity in Hopper 650 lbs or less	Fuel Level Low L-R	Amber
Fuel Quantity difference of 1,000 lbs or more between tanks	Fuel Imbalance	Blue
Fuel Quantity Measurement	FQMS Maintenance Required	Blue
Fuel Quantity Signal Conditioner	FQSC Channel Fail, L-R	Blue

4. Limitations:

A. Flight Manual Limitations:

When fuel tank temperature is at or below -30°C in flight with less than 5000 lb of total fuel remaining, descend the aircraft to an altitude where the Static Air Temperature (SAT) is -60°C or warmer and maintain a minimum speed of Mach 0.80.

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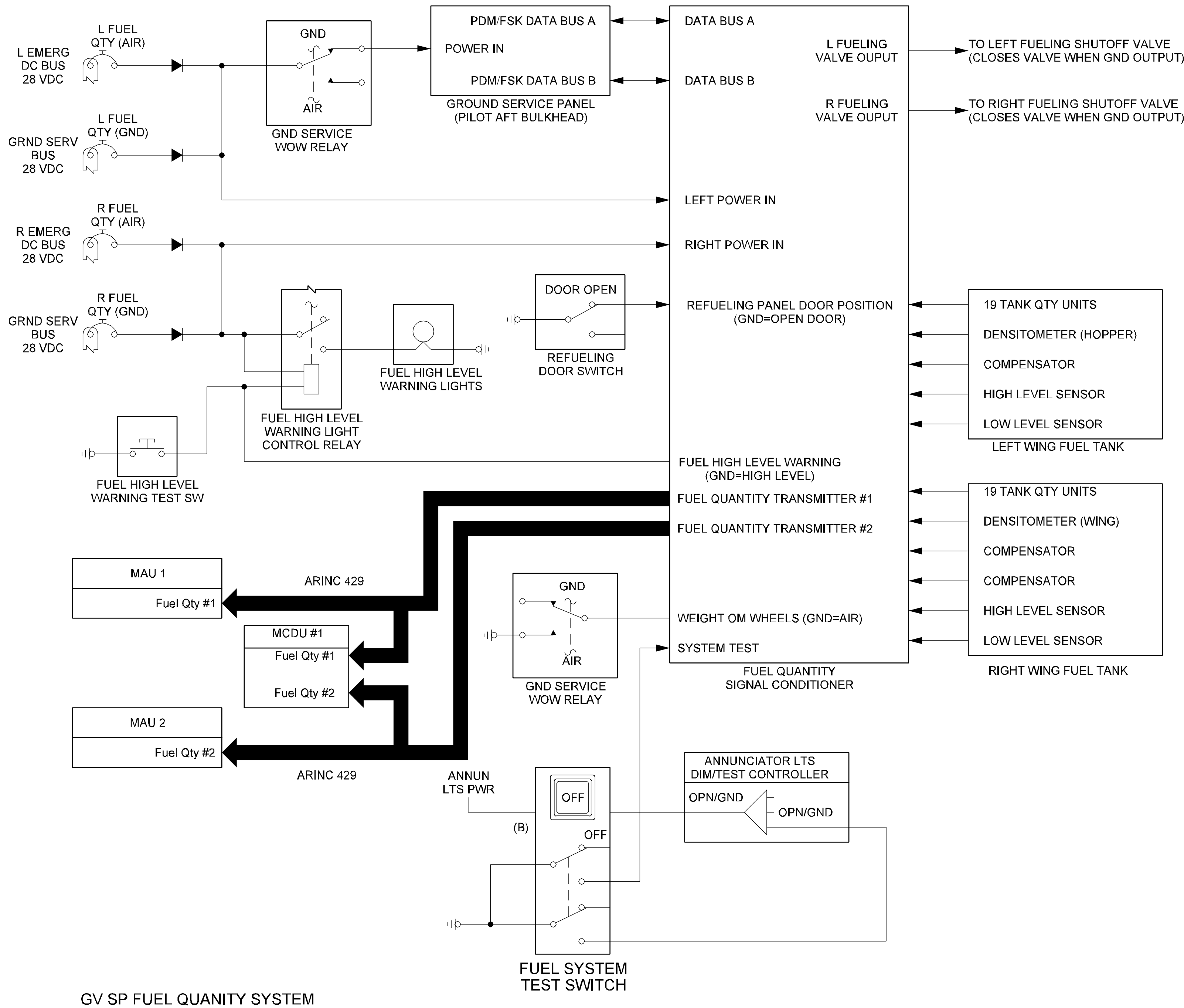
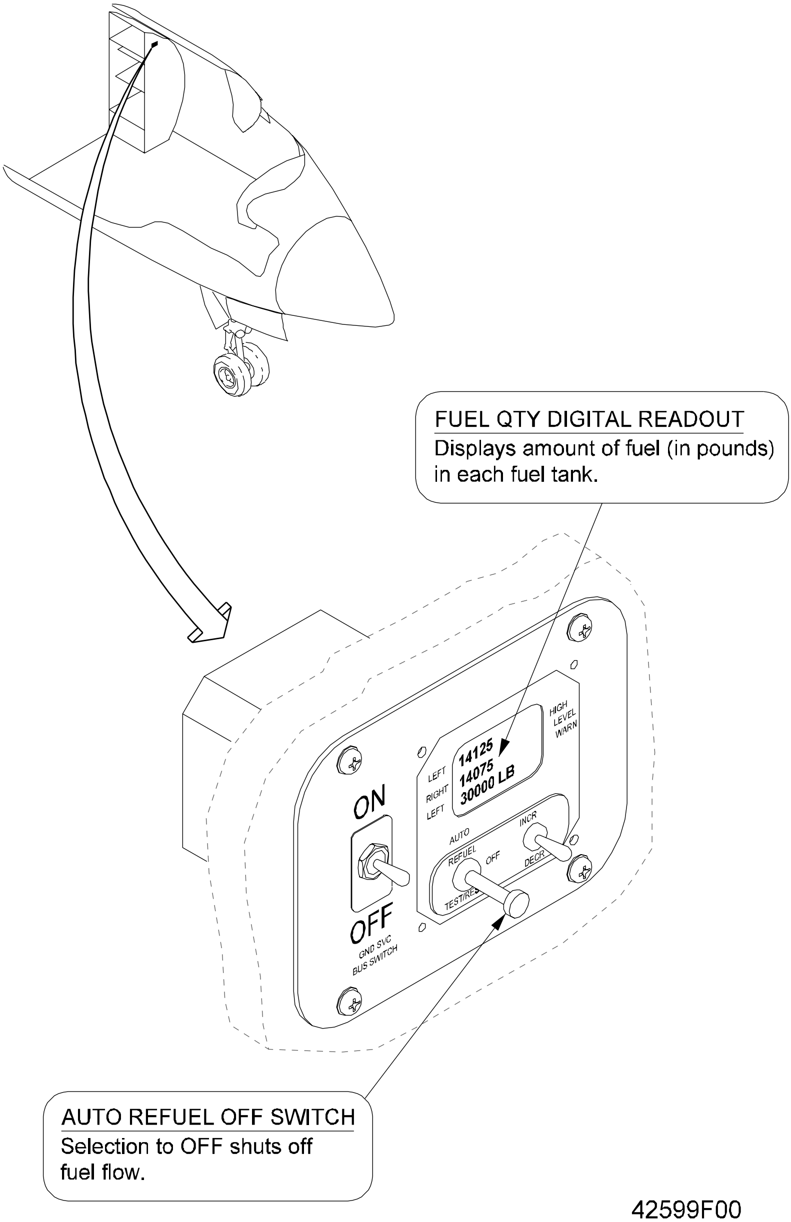
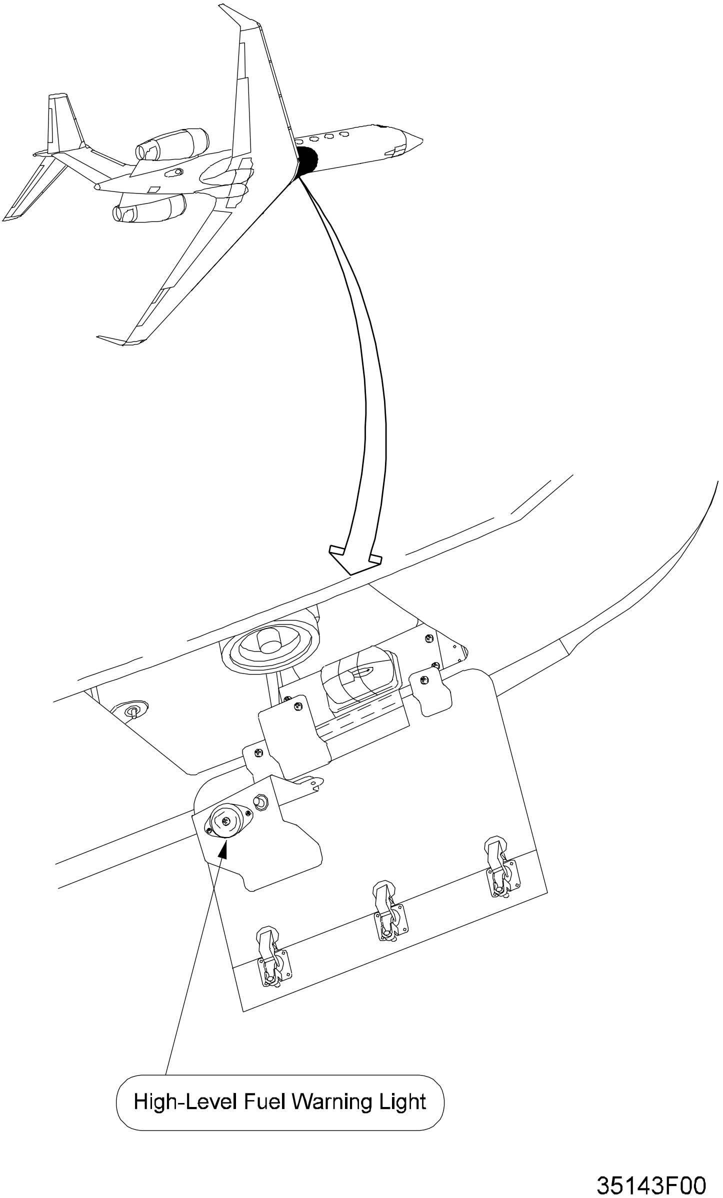


FQSC Block Diagram
Figure 7



FUEL QTY Panel
Figure 8



Fueling Compartment Access Door
Figure 9