SECRET

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ARROW FUEL SYSTEM

GENERAL

1. 1. **REQUIREMENTS**

The requirements of the fuel system for the ARROW are that the fuel management shall be as far as possible automatic; that the minimum movement of the C of G results from the transfer of fuel; that maximum engine power is available (full fuel flow) regardless of the aircraft speed, altitude or attitude. The fuel system is constructed therefore to:

(a) Function under all conditions of speed, attitude, altidude and temperature from sea level to 60,000 ft.

(b) Allow for engine fuel requirements up to 90,000 lbs per hour per engine.

(c) Allow for aerodynamic heating of fuel up to 185°F.

(d) Proportion fuel to the engine so that, as th tanks empty, the minimum movement of the C of G results.

(e) Allow for full or partial refuelling under pressure to permit a minimum turnround time.

2. **LAYOUT OF TANKS**

(i) The whole fuel system is sub-divided into two almost similar sides. Each sub-system is designed to supply fuel to the engine on that side, but a crossfeed connection is provided so that if only one engine is in use, all the fuel carried may be used. The whole system is pressurized to effect transfer and to prevent boiling of fuel at altitude.

(ii) There is a total of fourteen tanks in the whole system, each engine being fed by one of the fuselage tanks and six of the integral wing tanks. These are divided as follows:

(a) RIGHT HAND ENGINE

Tank No.	1	277 Gals. =	2133 lb.	(calculated at 7.7 lb/gal.)
	3	151	1162.5	
	4	90	693	
	5	147	1124	
	6	154	1186	
	7	279	2148.5	
	8	173	1332	
		1270 Gals.	9779 lb.	

(b) LEFT HAND ENGINE

Tank No.	2	281 Gals. =	2164 lb.	(calculated at 7.7 lb/gal.)
	3	151	1162.5	
	4	90	693	
	5	147	1124	
	6	154	1186	
	7	279	2148.5	
	8	173	1332	
		1274 Gals.	9810 lb.	

THE TOTAL TANK CAPACITY IS 2544 Gals = 19589 lb.

(iii) The quantity of fuel in each sub-system is registered on the two gauges in the front cockpit. The gauging of fuel is derived from capacitance units fitted in each tank. (This subject is dealt with under "Electrics").

(iv) Tanks No. 1 (R.H. engine) and NO. 2 (L.H. engine) are located in the fuselage, mounted in tandem between sta. 315 and 485, and are a rubber cell type. The remaining tanks are an integral part of the inner wing, between the front and rear spars, and collectively occupy all this space except for the wheel wells of the main landing gear. An additional fuel load of 500 gallons may be carried in a jettisonable belly tank fitted under the fuselage which feeds by air pressure (30 p.s.i. absolute) into each of the collector tanks.

Each sub-system transfers fuel by air pressure to tank No. 5, the collector tank, which, through an engine driven booster pump, delivers fuel to the engine on its respective side.

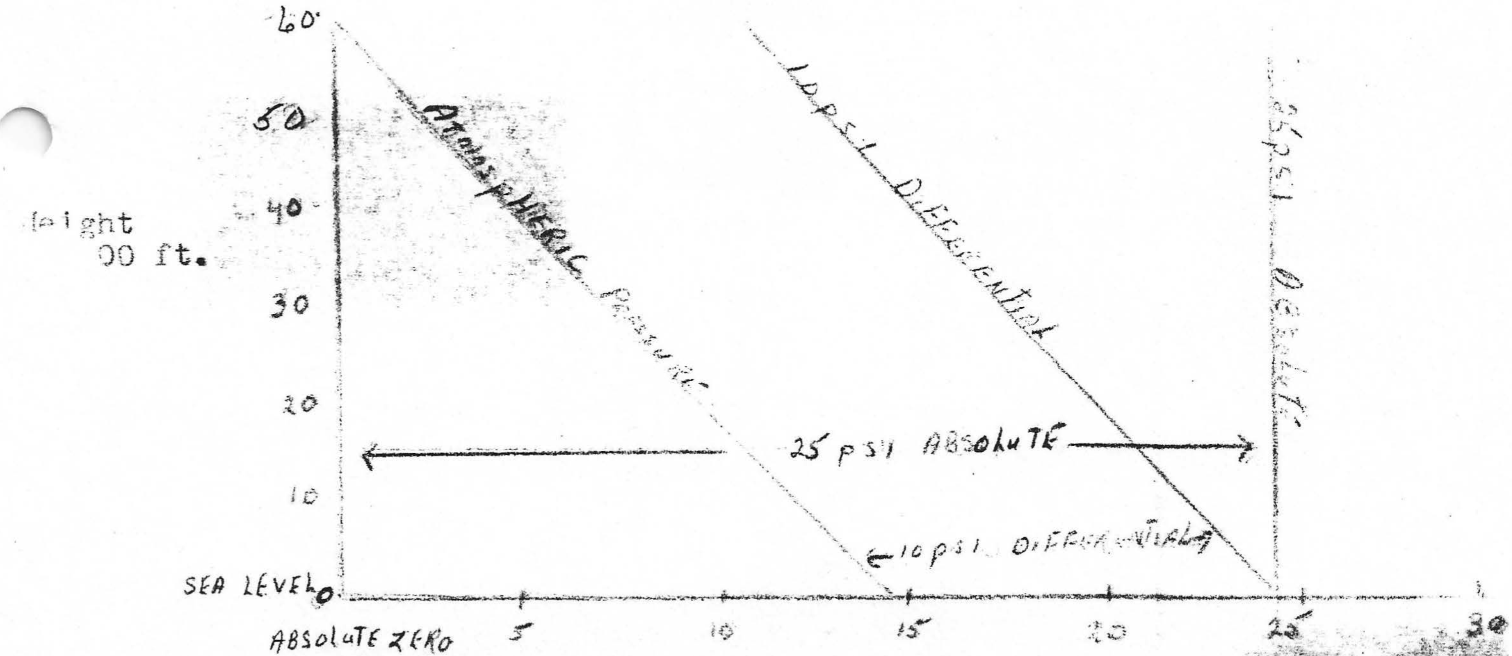
Fuel and condensate drain valves are fitted into each wing tank. These valves are for draining off accumulations of water and can be used for draining residual fuel. The valves are fitted in that, part of each tank which, when the aircraft is on the ground, is lost and collects residual liquid. The valves are operated manually from the exterior, by pushing up the flush fitting cap of the lower part of the valve with a draining pipe-end. In the fuselage tanks drains are fitted in each tank and in the space between the tank and the tank floor, from the drains the residual liquid is piped off to the flame trap in the duct bay. Drainage is achieved by the same method as used for the wing tanks.

3. PRESSURIZATION

(i) To pressurize the fuel system, two values of air pressure are used, and a third value is used to actuate Vent Intake Control Valves in the fuselage tanks.

(a) ABSOLUTE AIR PRESSURE The wing tanks are all metal construction and can withstand a high level of pressurization. A pressure of 25 p.s.i. absolute is used. This pressure is measured against absolute zero. A hand-held pressure gauge which "indicates" zero is actually allowing for the pressure of the atmosphere which, at sea level is about 14.7 p.s.i. Thus a gauge fitted to a tank which is then pressurized so that the gauge reads 10.3 p.s.i. is only reading the value of pressure above the existing atmospheric pressure. The absolute pressure is the sum of the gauge pressure and the atmospheric pressure. In the example; 14.7 p.s.i. atmospheric +10.3 p.s.i. gauge = 25 p.s.i. absolute. As altitude is gained, atmospheric pressure falls but the gauge reading increases so that the sum of the two = 25 p.s.i. absolute.

(b) DIFFERENTIAL AIR PRESSURE The fuselage tanks are rubber cells encased in the sheet metal of the fuselage and cannot withstand a very high degree of pressurization for these tanks a pressure of 10 p.s.i. differential is used. This pressure is measured against the atmospheric pressure. Thus a gauge fitted to a tank pressurized to 10 p.s.i. differential will read 10 p.s.i. differential at all levels, but the actual pressure in the tank, if measured against the absolute zero, decreases in value as the atmospheric pressure reduces with altitude.



(ii) The air supply for the tank pressurization system is taken at 85 p.s.i. differential from the aircraft air-conditioning system at the output of the air-to-air heat exchanger. Downstream of the heat exchanger a high pressure relief valve is fitted as part of the air conditioning system. The high pressure air is then passed through a hot air filter, from the outlet of which it is piped to the absolute and differential pressure regulators.

(iii) A take-off from the 85 p.s.i. differential air supply line is also taken to an 18 p.s.i. differential regulator which provides air to the Vent Intake Control Valves in the fuselage tanks.

(iv) After the engines are started it takes approximately 1/2 minute to pressurize the tanks to 18 p.s.i. absolute, and $2\frac{1}{2}$ minutes to reach 25 p.s.i. absolute.

FUSELAGE ~~WING~~ TANKS

4. PRESSURIZATION

(i) A take-off from the high pressure air supply line at 85 p.s.i. differential provides high pressure air to the inlet of a differential Air Pressure Regulator, which regulates the supply to the fuselage tanks at 10 p.s.i. differential. The outlet line from the differential Air Pressure Regulator divides to supply regulated pressure to the two tanks through one or more of the three Vent Intake Control Valves. These valves, two mounted at the top and one at the bottom of each tank, are fitted to prevent fuel from entering the pressurization lines whilst venting, and are fitted in these positions to allow pressurization and venting to take place regardless of the attitude of the aircraft.

(ii) To prevent over pressurization of the tanks, in case of failure of the differential Air Pressure Regulator, a flow limiter is fitted at the regulator inlet which limits the air flow to slightly above normal maximum demand, and a differential air relief valve, fitted at the regulator outlet, relieves excess pressure.

(iii) In the event of damage to one of the tanks, pressure is maintained in the other by flow limiters fitted in the pressure supply lines to each.

5. PRESSURIZING COMPONENTS

(i) DIFFERENTIAL AIR PRESSURE REGULATOR

This valve regulates the pressure of the pressurizing air fed to the fuselage tanks to a value of 10 p.s.i. differential. High pressure air, from the air-to-air heat exchanger, enters the unit and passes through the annular opening around the sleeve valve and past the spring loaded plate valve to the tank. The sleeve valve is kept in the open position by the spring which surrounds the ambient reference bellows in the sensing chamber. The sleeve valve is connected to the sensing unit by a connecting rod which ends in the pressure plate forming the lower end of the bellows. Under the pressure plate is a chamber containing air at tank pressure. The balance of the tank pressure air against the pressure plate, and ambient air in the bellows, controls the opening of the sleeve valve. As tank pressure increases relative to ambient air, as in a climb, it stands to close the sleeve valve, and when the tank pressure reaches 10 p.s.i. differential, it overcomes the air pressure in the bellows and the force of the surrounding spring, closing the sleeve valve completely and prevents further pressurization of the tank. If the pressure rises above 10 p.s.i. differential, as in a rapid descent, the spring loaded plate valve rises and blocks the air passage to prevent loss of pressurization. The excess tank pressure is relieved through the differential air pressure regulator, (refer para 5 iv).

(ii) FLOW LIMITER

The purpose of these units has already been described. The units themselves are convergent-divergent ducts with the neck diameters chosen to choke the air flow at the maximum flow requirement of the line in which they are located.

(iii) VENT INTAKE CONTROL VALVE (AIR/NO FUEL VALVE)

The purpose of this valve is two fold. To allow the air pressure from the differential air pressure regulator to pressurize the tank to 10 p.s.i. differential and to prevent air in the tank from exceeding this value during a climb by allowing the excess pressure to pass back through the relief valve and vent to atmosphere. The type 2 design of the valve, two of which are fitted in each tank, one at the top aft and one at the bottom forward, is such that with no air pressure applied it remains closed by a combination of fuel pressure and the force of the spring seating the valve at the outlet of the pressurization line. Through the jet assembly of the unit, servo air pressure, at 18 p.s.i. differential, is directed into the servo pressure chamber. This pressure acts on the pressure plate, which is connected to the valve, and overcomes the force of the spring in the fuel chamber. The air pressure moves the pressure plate to open the valve provided only that the servo pressure from the jet assembly is available to act on the pressure plate. If the unit is immersed in fuel, the jet assembly, being also immersed, is obstructed by fuel to such an extent that the spring in the fuel chamber re-asserts itself and closes the valve.

In the Type 1 design, fitted forward at the top of the tank and not normally immersed in fuel, the valve is positioned inside the pressure line and is opened by the 18 p.s.i. differential acting in the servo pressure chamber, in this case positioned under the return spring. Fuel pressure helps keep the valve closed by forcing it down. The greater area of the servo piston as compared to the lower surface of the inlet valve overcomes any tendency for the valve to be forced open by fuel pressure.

Venting from the tank is effected by the tank pressure reversing the flow in the pressurization lines. One or more valves, not being immersed in fuel, are kept open by the 18 p.s.i. differential pressure through the jet assembly.

In both types of unit, the valve has a spring loaded relief mechanism at the valve end of the connecting rod from the pressure plate, so that if the 18 p.s.i. differential regulator fails, inward venting can take place through Type 2 units and outward venting through Type 1 units.

(iv) DIFFERENTIAL AIR PRESSURE-RELIEF VALVE

This valve protects the fuselage tanks from over pressurization during a climb or in the event of failure of the differential air pressure regulator valve. Provision is also made to allow it to open during refuelling.

The unit consists of three air chambers, containing ambient air, upstream air pressure and metered upstream air pressure; a main valve, kept closed by the force of a spring and the pressure of metered upstream air; a poppet valve, kept closed by the springs in the ambient air chamber, but moved to open in response to the diaphragm between the ambient air and upstream air pressure chambers.

The pressure of ambient air and the spring force in the ambient air chamber is sufficient to overcome the pressure in the upstream air pressure chamber, thus keeping the poppet valve closed. The pressure of metered upstream air and the force of the main valve return spring maintains the main valve closed. A rise in upstream air pressure overcomes the ambient air pressure and spring force, and allows the poppet valve to open. The pressure in the metered air chamber escapes to atmosphere and cannot be immediately replaced due to the metering orifice; inlet pressure overcomes the force of the main spring and opens the main valve. As soon as the inlet pressure, and consequently the upstream pressure, falls below 10 p.s.i. differential the poppet valve closes again, pressure builds up in the metered upstream air pressure chamber, and the main valve shuts. The valve has a permanent bleed, which stabilizes the functioning of the pressure regulator and also serves to allow pressurizing air to escape when the aircraft is on the ground. Tank pressure returns to atmospheric pressure after about 20 minutes on the ground.

In the event of the pressure regulator failing, the valve will open when tank pressure exceeds 10.5 p.s.i. differential.

During refuelling, the override solenoid is energized, air in the metered air chamber is allowed to escape to atmosphere, and inlet pressure forces the main valve open.

This valve also allows the escape of excess fuel, due to fuel expansion, when the tanks are full.

6. TRANSFER

(i) The pressurizing air in the fuselage tanks, maintained at 10 p.s.i. differential forces the fuel into one or both of the Fuel/No Air Valves fitted at the pick up points of the transfer line, and along the transfer line to the electrically driven transfer pumps. These pumps boost the transfer pressure from 10 p.s.i. differential to match the transfer pressure of the wing tank system which is at 25 p.s.i.

absolute. The outlet fuel pressure of the transfer pumps is regulated by a fuel pressure regulator valve to 25 p.s.i. absolute. In the event of the regulator failing an override provision permits pressures in excess of 28-30 p.s.i. absolute to be fed back to its associated fuselage tank.

In the event of the transfer pump failing, fuel is by-passed through the shut-off and by-pass valve fitted in parallel across the inlet of the pump and the outlet of the regulator. Pump failure is sensed by a differential pressure switch fitted in para lel with the pump which completes one of the "FUEL PROP" warning light circuits, and the "FUEL PROP" warning light in the cockpit comes on.

NOTE: The electrical input to the transfer pumps is controlled by a scissor switch on the port main undercarriage; supply is made available only when the landing gear is retracted.

The solenoid-operated valves in the servo line, between the shut-off and by-pass valves and the level sensing valve, are also controlled by the scissor switch in the port main undercarriage. The solenoids are energized when the landing gear is retracted and the transfer pump is functioning. (The function of the solenoids is explained in para 7 (v) and the level sensing valve is explained under refuelling).

7. TRANSFER COMPONENTS

(i) FUEL/NO AIR VALVE

Two of these valves are located at the bottom, fore and aft, of each fuselage tank. Provided they are covered with fuel the valves remain open and the pressure of air forces fuel into the transfer lines. As soon as a valve becomes directly exposed to pressure of air the inlet closes and no air enters the fuel transfer lines.

The valve is constructed to:-

(a) Open when immersed in fuel

(b) Close if air is likely to enter the transfer lines, either due to low fuel level in the tank or aircraft atitude.

(c) Act as a check valve during refuelling.

The unit consists of a float operated poppet valve, which closes one or both of the fuel bleed passages and a hollow shafted valve unit incorporating a fuel-operated piston. The operation of the unit depends upon the fuel pressures acting on the piston, the pressures being dependent upon the position of the poppet valve controlled by the float. The solenoid operated stop valve is not required and is left de-energized, the poppet it controls being open.

With the float up in fuel, the poppet valve is also up and the upper port closed. Tank pressure forces fuel up the hollow shaft of the main valve to the back of the piston, but this fuel is allowed to escape to the downstream side of the valve through the bleed passage under the poppet valve. With downstream pressure on both sides of the piston, and downstream pressure on top of the valve, the greater tank pressure is able to overcome the force of the weak return spring and open the fuel valve. If the fuel level falls, the float mechanism closes the lower port of the poppet valve preventing fuel escaping from the back of the piston, which, being of greater surface area than the fuel valve surface area, forces the valve shut. When the fuel level rises again the pressure at the back of the piston is released and the valve opens. During refuelling the unit acts as a check valve; fuel is forced under pressure through the spring loaded ball valve and acts on the top face of the piston, but cannot escape through the hollow shaft due to the ball valve housed in the main valve. Pressures on both sides of the piston balance, and fuel pressure, acting on the top of the fuel valve, closes it.

In inverted flight, the return spring of the float operated poppet valve moves the poppet valve to close the fuel escape, and no fuel transfers. The float is counter balanced to have no weight in air, and thus, when immersed in fuel, the return spring of the poppet valve controls the function of the unit and closes the main valve.

In the controlled C of G system, where no fuel flow proportioner is incorporated, the function of the valve is also regulated by the solenoid operated stop valve. With the stop valve solenoid energized the fuel escape is blocked regardless of the position of the float and due to the build up of pressure on the top surface of the piston, the fuel valve closes. With the solenoid de-energized the unit works normally.

(11) TRANSFER PUMPS

The transfer pumps, one fitted in the line between each fuselage tank and its respective side of the sub-system, are electrically driven fuel pumps which function at a working pressure of 50 p.s.i. differential. These pumps come into operation only when the aircraft main gear is retracted. In order to test the functioning of the pumps on the ground, press-to-check buttons are provided at the master refuelling control panel. If the pumps are working, the buttons will light up. The pumps are driven by a 200 volt, three phase 400 c.p.s. motor. Failure of either pump in flight is indicated by a differential pressure switch, fitted in parallel with the pump, which actuates the "FUEL DROP". warning light in the cockpit. A low-level sensing unit, mounted on the aft Fuel /No Air Valve in each fuselage tank, causes the respective transfer pump to be switched off when transfer from the tank is complete.

(iii) FUEL PRESSURE REGULATOR

The unit consists of a spring-loaded piston-action main valve, governed by a 25 p.s.i. absolute bellows type sensing unit, which controls the pressure in the fuel chamber at the back of the piston, and thus controls the opening of the valve.

Inlet pressure forces the valve to open, and fuel also enters the fuel chamber through the check valve in the eye of the main valve. Fuel in the chamber is allowed to bleed away to the outlet side through the graduated orifice, the opening of which is controlled by the pressure sensing bellows. If the downstream pressure exceeds 25 p.s.i. absolute the bellows begins to contract and close the graduated orifice. Pressure in the fuel chamber forces the main valve towards the closed position, and the fuel pressure passing through the unit is reduced. At 27 p.s.i. absolute downstream pressure contracts the bellows sufficiently to close the graduated orifice completely and the valve closes. In practice, the valve assumes a position, governed by the bellows, such that the outlet pressure remains at a constant 25 p.s.i. absolute.

(iv) SHUT-OFF AND BY-PASS VALVE

The valve has two pistons, spring loaded and mounted back to back on hollow spindles; each piston can close the valve but both must be open to open the valve. When fuel pressure is applied, fuel flows to the piston chambers through the eye and hollow spindle of the primary valve. This pressure, acting on the larger surface at the back of the primary valve, forces the piston to stay firmly closed. When the pressure is released in the primary chamber, fuel pressure at the inlet overcomes the spring force and opens the primary valve, fuel flows through the body of the unit, and, acting on the larger front face of the secondary valve, opens it allowing fuel to pass back to the tank. This operation occurs when the regulator fails and fuel pressure is too high at the outlet of the transfer-pump and fuel-pressure-regulator combination. If the transfer pump fails, pressure downstream is virtually nil and flow occurs in the reverse direction.

Fuel pressure in the primary piston normally keeps the valve closed, the fuel in the secondary chamber is allowed to bleed away through the return-to-tank line. In order to permit automatic function of the valve as a return-line to tank in the event of the pressure regulator failing "open" the by-pass over-ride system is incorporated.

(v) FUEL BY-PASS OVER-RIDE

In the event of the pressure regulator failing in the open position, downstream pressure would be much in excess of 25 p.s.i. absolute. To prevent damage to the system the excess pressure is fed back to the tank through the shut-off and by-pass valve. To open the by-pass valve, the pressure in the primary piston chamber must be released. The servo line from the primary chamber to the level sensing valve, which normally controls the shut-off valve, is passed through a bellows pressure-sensing unit in which downstream pressure is felt by the bellows. At normal pressures the bellows are expanded and keep a poppet valve shut which prevents the release of pressure from primary chamber. If downstream pressures rise above 28 p.s.i. absolute the bellows collapse and, by opening the poppet valve, allows the pressure in the primary chamber to escape. Fuel pressure at the inlet of the two-way shut-off valve can then open the primary piston and pass back to the tank.

Between the two-way shut-off valve and the level sensing unit of each fuselage tanks are two solenoid-operated poppet valves. These have the effect of switching the servo lines from the by-pass over-ride unit and the common return-to-tank line, used in flight, to individual primary and secondary servo lines to the level sensing unit, used during refuelling. The solenoids are energized in flight when the circuit through the undercarriage scissor switch is completed as the undercarriage is retracted. During refuelling the solenoids are de-energized.

The refuelling application of the by-pass and shut-off valves and the level sensing units are described in para. 15 (iv).

SUMMARY OF THE FUSELAGE FUEL TANK ARRANGEMENTS

The foregoing paragraphs detail the operation of the fuselage tank pressurization and transfer, and gives a break down and function of each component.

To summarize the whole of the fuselage system, now that all the controlling units are known, will unify the arrangements into a working system.

High pressure air, from the aircraft air conditioning system, is tapped off the air-to-air heat exchanger and fed to both the fuselage tanks at a constant pressure of 10 p.s.i. differential through the DIFFERENTIAL PRESSURE REGULATOR. This air pressure enters the tanks through one or more of the three VENT INTAKE CONTROL VALVES fitted in each tank, which serve also to allow pressure in excess of 10 p.s.i. differential as occasioned by climbing, to vent to atmosphere through the DIFFERENTIAL AIR PRESSURE-RELIEF VALVES. Fuel, under 10 p.s.i. differential, is forced into the FUEL/NO AIR VALVES, two of which are fitted at the bottom of each tank, and passed along the transfer lines to the FUEL TRANSFER PUMPS. These pumps are fitted to match the fuselage tank transfer pressure to the wing tank pressure which is at 25 p.s.i. absolute. The outputoof these pumps is regulated by the FUEL PRESSURE REGULATOR to 25 p.s.i. absolute. From the fuel pressure regulator fuel passes to the fuel flow proportioner and to the collector tank, which are described in para. 11 (ii), and para. 12 respectively. A FLOW LIMITER is fitted in the fuselage tank pressurizing line to prevent excess pressure in the event of a faulty differential air pressure regulator, and two others are fitted in the individual lines to each tank so that in the event of damage to one, pressure is maintained in the other.

In parallel with the transfer pump and fuel pressure regulator, a SHUT-OFF AND BY-PASS VALVE, used as a by-pass in the event of a pump failure, is fitted to allow fuel to transfer by a combination of gravity, tank pressure and suction from the fuel flow proportioner, and a differential pressure switch across the pump actuates the "FUEL PROP" warning light in the pilot's cockpit. In the event of the pressure regulator failing "open", the shut-off and by-pass valve acts as a return-to-tank and is governed by the FUEL BY-PASS OVER-RIDE which releases the pressure in the primary chamber when downstream pressure exceeds 28 p.s.i. absolute.

WING TANKS

8. PRESSURIZATION

The wing tanks, being an integral part of the inner wing, are of all metal construction and can be more highly pressurized than the fuselage tanks without fear of damage. This has the advantage of being able to dispense with certain components required in the fuselage tanks to permit venting, minimizes weight, and also allows for transfer of fuel for maximum engine demands at all altitudes.

The source of air pressure for the wing tanks is the same as for the fuselage tanks, but the line is divided upstream of two flow limiters, one for sub-system and two absolute air pressure regulators set at 25 p.s.i. absolute. The pressurizing air is fed into the wing tanks, exclusive of the collector tank, through sized supply lines, which, in the event of damage to a tank, act as flow limiters, and ensure that sufficient pressure is available for the remainder. Over pressurization, in the case of a failed absolute air pressure regulator, is prevented by fitting an absolute air pressure relief valve, downstream of the regulator, which permits excessive pressure to escape to atmosphere.

9. PRESSURIZING COMPONENTS

(i) FLOW LIMITER

The flow of pressurizing air from the high pressure supply line is restricted, by the flow limiters, (described in para. 5 (ii)), to slightly above normal maximum demand. If the absolute air pressure regulator fails the tanks will not become over pressurized. The air supply lines to each of the wing tanks are sized so that in the event of a wing tank being damaged the pressure to the other tanks is maintained and transfer continues.

(ii) ABSOLUTE AIR PRESSURE REGULATOR

This valve regulates the high pressure air from the flow limiters to a constant absolute value of 25 p.s.i. absolute. Its functioning is precisely the same as the differential air pressure regulator, (described in para. 5(i)), but in this case the "bellows" are sealed, and designed to contract at pressures in excess of 25 p.s.i. absolute. Working against the force of the spring surrounding the bellows and the pressure of air sealed in the bellows, if the downstream pressure exceeds 25 p.s.i. absolute the sleeve valve begins to close and reduces the volume of air passing through the valve, preventing further pressurization.

(iii) ABSOLUTE AIR PRESSURE RELIEF VALVE

This valve is identical in construction and function to the differential air pressure relief valve, (described in para. 5 (iv)), but in this case a sealed bellows exposed to upstream air pressure reacts to open the poppet valve when upstream air pressure reaches 25.5 p.s.i. absolute.

During refuelling the solenoid is energized, and the volume of air in the tank, being replaced by fuel, is allowed to escape to atmosphere.

10. TRANSFER

The fuel transfer pressure of 25 p.s.i. absolute forces fuel into the transfer lines by way of Fuel/No Air Valves fitted in the tanks on the inlets of the transfer lines. In tanks 6,7,and 8 the transfer lines have two inlets, inboard and outboard, which allows for the wing anhedral. Tanks 3 have two inlets, fore and aft, and tanks 4 have only one. The fuel passes from the Fuel/No Air valves at the inlets to the transfer lines to the flow proportioner units of each sub-system. These units proportion the fuel of their associated sub-systems at a rate of flow arranged so that all the tanks empty at the same time, and so that, during flight, the Centre of Gravity of the aircraft remains relatively constant.

The wing tanks are so shallow on the outboard sides, that it is impractical to fit fuel pumps. Collection of fuel from these sides is necessitated by the anhedral, the transfer has therefore been arranged through the Fuel/No Air valves into which fuel is forced by pressurizing air.

11. TRANSFER COMPONENTS

(i) FUEL/NO AIR VALVE

The function and operation of this valve is the same as has already been detailed. (Paragraph 7 (i)). Two valves are fitted in each of the wing tanks with the exceptions of No. 4 tank which has only one. No. 5 (collector) tank has no Fuel/No Air valve since all the fuel is delivered to this tank from all the others for feeding through booster pumps to the engine.

The anhedral of the wings demands that fuel may be collected from the outboard as well as from the inboard sides of the tanks, the Fuel/No Air valves have therefore been fitted at the ends of laterally mounted transfer lines in tanks 6, 7, and 8, and on the outboard side fore and aft in tank 3. The only Fuel/No Air valve in tank 4 is fitted on the outboard side. The transfer line from tank 3 is common also to tank 4.

(ii) FLOW PROPORTIONER

The flow proportioner consists of five fuel chambers each with a seperate inlet. Tanks 6, 7, and 8 have separate chambers in the unit, as also do tanks 1 and 2; the right hand flow proportioner accepting fuel from fuselage tank 1 and the left hand from tank 2. Tanks 3 and 4, having a common transfer line, have also a common fuel chamber in each flow proportioner. The chambers are of uniform diameter but are sized laterally accordingly to the tank, or tanks, from which they accept fuel. In each metering chamber, ganged on a common shaft, are fitted metering vanes, which all rotate at the same speed by the pressure of fuel entering the inlets. By rotating at the same speed, the vanes proportion the fuel taken from each tank, and the amount of fuel taken from each tank is governed by the lateral width of the chambers which are sized directly as the capacity of the associated tank; thus all tanks empty together. On the outlet side of the metering vanes the fuel transfer line becomes common and passes directly to the collector tank on its own side of the system.

Each flow proportioner unit is fitted with an electric motor-operated by-pass, which is signalled to open by a low level sensor unit in its respective collector tank, or, by the "BULK FUEL" selector switch on the master refuelling panel. The refuelling function of the unit is described in para. 14.

In the event of jamming or seizing of the metering vanes, transfer to the collector tank ceases, and fuel for the engine is only available from the collector tank itself. When the level of fuel in the collector tank has dropped sufficiently, a low level sensor signals the electric motor in the by-pass of the flow proportioner and motors "open" the by-pass. Fuel from each inlet by-passes the metering vanes and flows directly to the common transfer line and the collector tank. Once the by-pass has been signalled to open, a lock-on feature keeps it so until the aircraft power supply is switched off. As soon as aircraft or ground power, supply is switched on again, the lock-on is automatically released and the by-pass will close. Malfunctioning of a flow proportioner must, therefore, be checked before power is applied; a mechanical indicator on each unit indicates the by-pass in the "by-pass" or "metering" position.

When the low level sensor signals the by-pass motor, a "LOW LEVEL" light for that tank comes "on" in the Pilot's warning light panel of the pilot's cockpit, and the "FUEL PROP" light also comes on as the by-pass opens. (See fuel warnings on page 29).

SUMMARY OF THE WING FUEL TANK ARRANGEMENTS

The same source of high pressure air is used for the wing tank as for the fuselage tanks, but as these tanks are integral of the inner wing the pressure is maintained at 25 p.s.i. absolute by the ABSOLUTE AIR PRESSURE REGULATORS. This air enters the wing tanks through individual pressurizing lines which are sized to maintain pressure in the other tanks should one sustain damage. FLOW LIMITERS are fitted upstream of the air pressure regulators so that, in the event of a regulator failing, air is still available to the tanks at a slightly higher pressure than normal, and the excess pressure escapes overboard through the ABSOLUTE AIR PRESSURE RELIEF VALVES. Fuel, under 25 p.s.i. absolute is forced into the transfer lines through the FUEL/NO AIR valves, which are fitted laterally in tanks 6, 7, and 8, fore and aft in tank 3 and of which there is only one in tank 4, and passes along the transfer lines to the FLOW PROPORTIONER UNIT. The flow proportioner, through sized fuel chambers and co-axially mounted metering vanes, proportions the amount of fuel taken from the fuselage and wing tanks on its own side of the sub-system, and passes it to its associated collector tank. The metering vanes of the flow proportioner are rotated by fuel pressure only. If one of the vanes should become jammed fuel flow from all the tanks of the sub-system ceases. This results in the level of fuel in the collector tank falling until it is low enough for the level sensor in the tank to signal the FLOW PROPORTIONER BY-PASS motor to the "by-pass" position. The low level sensor actuates the "LOW LEVEL" light on the Pilot's Warning Light Panel, and the "FUEL PROP" light comes on as the by-pass is opened. Once the by-pass has opened, the lock-on feature keeps it open for the remainder of the flight.

THE COLLECTOR TANKS AND ENGINE FEED

12. PRESSURIZATION

Fuel from all the tanks of a sub-system is delivered to the collector tank. An engine-driven booster pump in each tank passes fuel to the engine on its own side. Fuel delivered to the collector tanks is at the pressure of the rest of the system, but the level of fuel will vary to some extent upon the demands of the booster pumps and also because of aircraft attitudes which result in the Fuel/No Air valves closing in the other tanks. In view of these variations of fuel level it can be seen that variations of pressure will also occur, since the tanks are not pressurized directly to 25 p.s.i. absolute as is the rest of the system.

During an interruption of transfer the fuel level in the collector tanks will fall and pressure will decrease as fuel is used. To prevent fuel from falling below fuel vapour pressure arrangement is made to allow air to enter the tanks as the pressures fall, and for the air to escape again as fuel recommences to transfer and pressures rise.

The pressures in the collector tanks vary between 25 p.s.i. absolute at no flow, and 15 p.s.i. absolute at full flow. At idling the pressures remain at approximately 23 p.s.i. absolute.

(i) NEGATIVE "G" AND LOW LEVEL AIR ADMISSION VALVE

This valve is fitted at the bottom of the collector tank and is supplied with air pressure from the wing tank pressurization system at 25 p.s.i. absolute. It consists of a spring loaded valve which remains closed against the inlet pressure of 25 p.s.i. absolute provided the tank pressure is maintained above 11 p.s.i. absolute. Once the differential pressure across the valve exceeds 14 p.s.i. absolute, the 25 p.s.i. absolute at the inlet of the valve opens it, and air bubbles up through the fuel and repressurizes the tank. Under negative "G" or inverted flight conditions fuel transfer ceases because the Fuel/No Air valves shut, and in the inverted flight attitude the only difference is that both sides of the valve are directly affected by air pressure; 25 p.s.i. absolute at the inlet, and tank pressure at the outlet.

(ii) AIR RELEASE VALVE

These valves, of which there are two in each collector tank, one forward and inboard, one aft and outboard to allow for any aircraft attitude are fitted to allow the air admitted by the "Negative "G" and Low Level Air Admission" valve, to escape again once transfer is resumed and the fuel level rises. The unit consists of two poppet valves which open or close in the air release line. One is controlled by a float, and closes when the float is up, and the other is controlled by air, or fuel, pressure acting on a sealed bellows which closes the valve at a pressure of <u>less</u> than 13 p.s.i. absolute and opens it at pressures <u>greater</u> than 14 p.s.i. absolute. Both poppet valves must be open to allow the release of air, but either closing prevents the air escaping. The outlet air from the valve is piped to a point downstream of the Differential Air Pressure Regulator and escapes to atmosphere.

As the fuel level falls, during an interruption of transfer, the float poppet opens, and the pressure in the tank decreases, closing the bellows poppet as the pressure falls below 13 p.s.i. absolute. A further drop in pressure to below 11 p.s.i. absolute results in air being admitted through the Negative "G" valve. When transfer is resumed, the fuel level rises and tends to compress the air in the tank, and as the pressure reaches 14 p.s.i. absolute the bellows contract, and open the poppet valve to allow the air to escape. Once the fuel level has risen sufficiently to operate the float poppet, it closes, and no further air escape can take place.

In inverted flight with no transfer taking place, all Fuel/No Air valves being shut, the only fuel available to the engine is that which is in the collector tank and pressure will fall to below 13 p.s.i. absolute as it is used; at 11 p.s.i. absolute pressurizing air enters from the "Negative "G" and Low Level Air Admission" valve. <u>The inverted flight li it is for 15 seconds</u>.

NOTE: If more than 15 seconds of inverted flight is maintained, and more than 65% of the fuel available for inverted flight is used from the collector tank, the low level sensor unit in the tank will signal the fuel proportioner by-pass to "by-Pass" which due to its lock on feature, will remain in the "By-Pass" position for the remainder of the flight. (See para. 11 (ii)).

The float of the float operated poppet is designed to have no weight in fuel, so that in inverted flight, the return spring surrounding the poppet closes the valve and prevents fuel escape up the air release line. This would otherwise be open to atmosphere until the pressure in the tank had fallen below 13 p.s.i. absolute to close the bellows operated valve.

13. TRANSFER AND ENGINE FEED

(i) BOOSTER PUMPS

The delivery of fuel to the collector tank has already been described (para. 11 (ii)). In each collector tank is fitted a booster pump to provide sufficient fuel pressure at the inlet to the engine fuel pumps to prevent boiling and the subsequent vapour lock. The pumps increase the delivery pressure to a minimum of 15 p.s.i. differential above the collector tank pressure. There are two inlet pipes to the booster pump, one from the forward inboard side of the tank, and one from the aft outboard side. Each inlet supplies fuel to the eye of one of the two impellers, mounted back to back on a common web, which is driven by a shaft from the accessory gear box of the engine on the side it serves. Each pump is capable of delivering fuel at the rate of 100,000 lbs per hour (12.987 gals. per hour at 7.7 lbs/gal.) with a pressure rise of 18 p.s.i. differential and only one of the two inlets covered by fuel. Each booster pump is fitted with an automatic priming device to dispel air and vapour from the fuel.

In the event of a booster pump failing, a separate by-pass inlet, with a non-return valve incorporated, to prevent the booster pump, when working, from passing fuel back to the tank, is provided to allow engine feed to continue by a combination of collector tank pressure, gravity, and suction from the engine fuel pump. This by-pass is capable of delivering fuel at rates up to the demands of one engine on military rating at sea level.

(ii) FUEL SHUT-OFF VALVES AND CROSSFEED

The control of fuel to the engine, after it has been boosted through the collector tank, is governed by five electrically-driven Shut-Off valves. All the valves are located on the oil-to-fuel heat exchanger, through which, in separate chambers for each side, the fuel from each collector is passed before entering the engine fuel pumps. Two valves, referred to as isolating valves, one for each sub-system, are located at the inlet to the heat exchanger and serve to shut off fuel from one or other of the sub-systems. A third valve is located at the bottom of the heat exchanger and serves as a crossfeed, so that fuel from the right hand sub-system can be used in the left hand engine, the left hand isolating valve being closed. The reverse condition can also be imposed. The two remaining valves are located at the separate outlets from the heat exchanger to each engine, and serve as low pressure fuel cocks to isolate the engine from the fuel system in cases of fire emergency and for engine servicing.

The isolating valves are controlled by a crossfeed switch located in the cockpit; it has the positions:

(a) NORMAL - Each engine being fed by its own sub-system; both isolating valves open and crossfeed neutral.

(b) RIGHT ONLY - Each engine being fed by the right hand sub-system; left hand isolating valve is shut, crossfeed from the right.

(c) LEFT ONLY - Each engine being fed by the left hand sub-system; right hand isolating valve is shut, crossfeed from the left.

If only one engine is in use, fuel can be used from either side to feed the live engine by manipulation of the crossfeed control in conjunction with the engine Low Pressure fuel cocks.

The valves are sliding gate type valves, powered by a reversible 28 volt D.C. motor acting through a gear train, which can fully open or close within one second.

Downstream of each low pressure cock is fitted a pressure switch which switches on the "ENG. FUEL PESS" light on the master warning panel when engine feed pressure falls below 17.3 $\pm$ .05 p.s.i. absolute and switches the light out when pressure reaches 18.3 $\pm{}^{1.0}_{0.5}$ p.s.i. absolute.

ARROW REFUELLING

14. GENERAL DESCRIPTION

The aircraft is refuelled through two refuel adaptors, one for each sub-system, which are located i wheel well of the main landing gear. Two refuelling t are required to refuel in the minimum time, but it is in order to refuel one side at a time. Refuelling cont is kept by three electric refuelling panels; one maste and one refuelling control and signal panel for each s system.

The aircraft can be either fully or partiall refuelled. In either case the fuel passes from the ad to the Flow Proportioner Unit, but, iffull refuelling desired, the by-pass is opened and the tanks fill at r If partial refuelling is required, the by-pass is left and fuel is proportioned through the Flow Proportioner each tank. In this latter case the quantity of fuel t delivered is assessed by subtracting the contents show the gauges in the front cockpit from the total require and all tanks will have a quantity of fuel proportione them so that the C of G remains within limits.

The supply of fuel to the various tanks, dur refuelling, is mainly carried in the same piping syste that, during flight, transfers fuel from the tanks to Flow Proportioner. However, to prevent damage to tank maintaining the refuelling pressure of 50 p.s.i. absol after the tanks have filled, the supply to each tank i off automatically by Tank Shut-Off Valves in the suppl which are governed by a Level Sensing Valve in each ta The only tanks which have a separate refuelling line are the collectors. The refuelling lines provided have a shut-off valve and its associated level sensing valve, and is fed directly from the refuelling point, thus the collector tanks are always filled, and filled first. The normal transfer pipes from the Flow Proportioners to the coll tanks are shut by a manually operated Gate-Valve linke to the access door to the refuelling adaptors in the w wells.

15. REFUELLING COMPONENTS

(1) REFUELLING ACCESS DOOR AND MANUALLY-OPERATED GAT

The gate type valve, shutting off the transf line, is closed during refuelling by the 70° movement the access door to the refuelling adaptor being transm through mechanical linkage to a 90° rotation which clo the valve. The access door latch pin, when locked sh engages a micro-switch in the "FUEL PROP" warning ligh circuit. If either door is not shut, or not correctly the "FUEL PROP" light in the cockpit comes on, and warns the occupant that one or both of the gate valves has been left shut, preventing the transfer of fuel to the collector tank from taking place. Once the door lock is disengaged, the door is fully opened by the spring loaded door support arm.

(ii) MASTER REFUELLING PANEL

The master refuelling panel is located on the under side of the duct bay immediately forward of the left hand speed brake, the access door to which can only be opened when the speed brakes are "IN".

The master panel incorporates a master refuelling switch, and a refuelling selector switch.

(a) MASTER REFUELLING SWITCH This switch has two positions:

(i) ON In this position, the switch energizes the over-ride solenoids in the relief valves and vents the tanks to atmosphere. It also brings on the refuelling indicator on the subsiduary "Refuelling Control & Signal Panel" for each side. (Other functions are explained under "ELECTRICS").

(ii) OFF & DEFUEL In this position the switch over rides all refuelling switches and lights.

(b) REFUELLING SELECTOR SWITCH This switch has three positions:

(i) PARTIAL There are two "partial" positions of the switch, in either of which the by-pass motors of the flow proportioners are motored shut and fuel is proportioned into the tanks. (The two positions are for the Mk II controlled C of G system where each position selects certain tanks to refuel).

(ii) FULL REFUEL In this position the Flow Proportioner by-passes are motored to "by-pass" and tanks fill at random.

Incorporated on the Master Panel are two tank pump indicator buttons for checking the respective transfer pumps (see para. 7 (ii)), and also a ground test safety over-ride switch for switching on the transfer pumps on the ground.

The Master Refuelling Switch is provided with a guard which prevents the access door from being closed with the master switch left "ON".

(iii) REFUELLING CONTROL AND SIGNAL PANEL

The refuelling control and signal panel, located outboard of the refuelling access door in each main landing gear well, incorporates a "REFUEL CONTROL" switch, which controls the flow into the tanks on its respective side by energizing the solenoids in the secondary chambers of the level sensing valves. Also on the panel is one green signal light for each tank, which goes out when refuelling is taking place and comes on as the tank fills. The lights are activated by the secondary piston of the tank shut-off valves and thus serve as a functional check of the valves and the level sensing units in the tanks.

(iv) REFUELLING SHUT-OFF VALVE & LEVEL SENSING VALVE

The refuelling and shut-off valve consists of a primary and secondary piston, and a switch assembly, attached to the secondary piston, which completes the circuit to its associated green warning light on the Refuelling Control and Signal Panel, when the piston is seated and the valve closed. The construction of the valve is similar to the two-way shut-off and by-pass valve (described in para. 7 (iv)) but has a check valve in the primary piston to prevent reverse flow. The chambers are interconnected by a bleed port and the valves are normally held closed by lightly loaded springs in each chamber.

There are two basically similar types of level sensing units. The Type 1 unit is used in the wing tanks and the Type 2 in the fuselage tanks.

The Type 1 unit consists of a primary and secondary valve controlled by floats in the primary and secondary float chambers. The primary chamber is permanently drained to the tank, the float rising only when the tank proper is full. The secondary chamber is drained through a solenoid-operated poppet valve, controlled by the "REFUEL CONTROL" switch, which allow drainage to tank only when the solenoid is de-energized. Servo lines from the two chambers of the shut-off valve are connected to the secondary float chamber, but the line from the primary piston chamber is routed through the primary side of the level sensing unit in such a way, that the primary float-operated valve can block the primary servo line when the tank is full.

By energizing the solenoid in the level sensing valve secondary chamber, drainage from this chamber is stopped and fuel, bleeding through the shut-off valve, fills the secondary chamber by way of the servo lines. When the secondary chamber fills and the float rises, the float operated poppet valve blocks the servo line and pressure in the secondary piston chamber increased to the point where the secondary shut-off piston closes, regardless of the level of fuel in the tank. This operation is used to pre-check the functioning of the tank shut-off valves. When the tanks are being filled, the action of the primary float operated valves, of the level sensing units, blocking the primary servo lines, increases pressure in the primary piston chambers and automatically closes the shut-off valves when the tanks are full. During filling, but after pre-checking, the solenoids are left de-energized and the secondary float chambers are allowed to drain so that pressure in the secondary piston chamber is released and the shut-off valves are allowed to re-open. Refuelling can then be completed.

The type II Unit is used with the By-pass and Shut-off valve in conjunction with the by-pass over-ride. The type II valve is similar to the Type I valve, but has different flow requirements. Due to the indirect circuit between the shut-off valve and the level sensing units, of the fuselage tanks, the servo lines are of a slightly larger size than in the wing tanks. This resulted in the secondary chamber of the level sensing unit filling too rapidly and the drain port was not large enough to allow the fuel in the float chamber to be dumped to allow the valve to re-open after pre-checking. In the Type II level sensing unit the primary servo line is passed to the primary chamber and is not passed through to the secondary chamber but drains to the tank. In this way only the secondary servo line flow is used to fill the secondary float chamber and the flow rate is still slightly greater than the flow of the combined primary and secondary servos in the normal valves, but is not too large to flood the secondary float chamber permanently regardless of the solenoid poppet valve position.

(v) TWO WAY SHUT-OFF VALVE

A two way shut-off valve, located in each collector tank, operates in the same manner as the refuelling shut-off valves, but also allow reverse flow through the valves for use during defuelling. The construction of the valve is the same as the refuelling shut-off valve with the following exceptions:

(a) There is no check valve in the primary piston.

(b) A check valve is fitted in each servo line.

A drop in pressure at the inlet of the two way shut-off valve is felt in the piston chamber, this closes the check valves in the servo lines and allows the fuel to open the piston valves and to flow in the reverse direction.

16. PRE-CHECKING

(a) Carry out refuelling safety precautions in accordance with the latest instructions.

(b) Switch the master refuelling switch on the master refuelling panel to ON. This energizes "open" the over-ride solenoids in the relief valves, which dissipates the pressure in the tanks, and prevents further pressure from entering the the tanks, in the event of the air conditioning pressure rig being in operation. The fuel by-pass over-ride solenoids, which when energized interconnect the servo lines from the refuelling shut-off and by-pass valves to the return to tank line, are left de-energized for refuelling the fuselage tanks, and the servo lines are connected from the shut-off valves to the level sensing units.

(c) Check that the seven green lights on each refuelling control and signal panel come on. This will indicate that the shut-off valve in each tank is closed.

(d) Switch the selector switch on the master refuelling panel to FULL. This motors the flow proportioner by-pass to the open position.

(e) Open the refuelling access door in each main landing gear well, remove the cap from the pressure refuelling adaptor, and attach the refuelling nozzle to the adaptor. The action of opening the access door closes the manually operated gate valve, shutting off the transfer line to the collector tank.

(f) With the refuelling tender pressure adjusted to 25 p.s.i. indicated on the gauge, open the refuelling nozzle. Check the signal lights remain on.

(g) Pre-check the closing of the shut-off valves immediately after opening the refuelling nozzle, by switching ON the refuel control switch on each refuelling control and signal panel. Ensure that the signal lights go out. Switching ON the refuel control switch energizes the solenoids open in the level sensing valves, the incoming fuel opens the shut-off valves and fuel flow into the tanks commences. The opening of the shut-off valves causes the signal lights to go out.

(h) Pre-check the closing of the shut-off valves immediately after the signal lights go out by switching OFF the refuel control switches. Ensure that the signal lights come on. Switching Off the refuel control switches de-energizes and closes the level sensing valve solenoid operated poppet valves and the shut-off valves close, causing the signal lights to come on.

(j) Close the refuelling nozzle immediately after pre-checking and switch the refuelling selector switch to either PARTIAL REFUEL selection. This causes the flow proportioner by-pass to be motored closed.

NOTE During pre-checking, the refuelling selector switch must be in the FULL position. Consequently the flow is not proportioned to maintain C of G. It is therefore important, during partial refuelling, that a minimum of fuel enters the tanks during pre-checking.

17. PARTIAL REFUELLING

Prior to partial refuelling, the amount of fuel remaining in the tanks must be obtained from the gauges in the front cockpits, (registered in pounds) and subtracted from the total amount of fuel required to arrive at the quantity of fuel to be delivered to the aircraft.

Ensure that refuelling selector switch has been switched to either "PARTIAL REFUEL" positions, and proceed as follows:

(a) Switch the refuel control switch ON, and with the tender pressure re-adjusted to 50 p.s.i. indicated on the gauge, re-open the refuelling nozzle. The incoming fuel pressure opens the shut-off valves, the signal lights go out, and refuelling commences.

(b) When the refuelling tender gauges indicate that the required amount of fuel has been delivered, shut off the refuelling tender pumps and switch the refuel control switch on each refuelling control and signal panel to OFF. This de-energizes the solenoids in the level sensing valves to the closed position and the pressures in the shut-off valves equalize, closing the shut-off valves and causing the signal lights to come on.

(c) Remove the refuelling nozzles from the adaptors, replace the caps on the adaptors and close the access door.

CAUTION The refuelling access doors control the manually operated gate valves, which in turn control the transfer flow into the collector tanks. It is therefore essential to ascertain that both refuelling access doors are properly closed on completion of refuelling.

(d) Switch the master refuelling switch on the master refuelling panel OFF. This de-energizes the solenoids in the relief valves and air pressure regulators, closing off the vents to atmosphere, and allowing pressurization air to enter the tanks. With this selection all signal lights on the refuelling control and signal panels go out, and all refuelling switches are over-ridden.

(e) Close the master refuelling panel access door.

18. FULL REFUELLING

After pre-checking, the procedure for full refuelling is the same as the procedure for partial refuelling with the following exceptions:

(a) Switch the selector switch on the master refuelling panel to FULL. This will motor the flow proportioner by-pass to the open position. This selection is maintained throughout the full refuelling sequence.

(b) The level sensing valves in the tanks will cause the tank shut-off valves to close automatically when the tanks are filled. The lights on the refuelling control and signal panels will come on when the shut-off valves close, indicating that the tanks are full.

19. DEFUELLING

The aircraft is defuelled through the refuelling adaptor in each main landing gear well. Defuelling from the wing storage tanks and the fuselage tanks is effected by tank pressurization forcing the fuel through the transfer lines, assisted by suction from the tender pumps. An external source of air pressure is necessary to pressurize the tanks to achieve this.

Defuelling from the collector tanks, which are not pressurized by air, is by suction through the two way shut-off valves. As the level in the collector tank drops, air is admitted through the negative "G" and low level air admission valve to take the place of the displaced fuel.

The refuelling master switch remains in the OFF and DEFUEL position for defuelling, therefore no selection is necessary. Residual fuel may be drained through fuel and condensate drain valves located in the bottom skin of the inner wing for the wing tanks and at a flame trap in the bottom of the duct bay for the fuselage tanks.

NOTE: An added fuel and condensate drain valve is fitted at the bottom of the duct bay, which drains the space between the fuselage tanks and the tank floors, providing a convenient method of checking for leakage from the fuselage tanks.

FUNCTION TESTING

20. 1. TESTING THE FUEL PRESSURIZATION SYSTEM

Pressure gauge adaptors are provided at six check points in the fuel pressurization system to obtain pressure readings for the function tests described in subsequent paragraphs, and to assist in trouble shooting the system:

(a) One in each fuselage tank access panel.
(b) One in the line at the outlet of the differential pressure regulator in the duct bay.
(c) One in the line at the outlet of each absolute pressure regulator in the engine bay.
(d) One at the outlet of the servo pressure regulator in the duct bay.

The following tests must be carried out in sequence shown, with the aircraft defuelled.

2. DIFFERENTIAL AND ABSOLUTE AIR RELIEF VALVES FUNCTION TEST

To function test the differential and absolute air relief valves proceed as follows:

(a) Connect three 0-25 p.s.i. pressure gauges, one at the pressure gauge adaptor at the outlet of the differential pressure regulator, and one at the adaptor at the outlet of each absolute pressure regulator.

(b) Disconnect and blank off the outlet pressure sensing lines at the differential and absolute pressure regulators.

(c) If the master refuelling panel access door is open, ensure that the master refuelling switch is in the OFF AND DEFUEL position.

(d) Connect the ground pressure rig to the fuel pressurization ground test connection and apply pressure, progressively raising the pressure from 0-65 p.s.i.g. over a period of five minutes.

(e) Check the pressure at each gauge during pressure build up. The reading on the gauge at the differential pressure regulator outlet must be from 10.5-11 p.s.i.g., and the reading on the gauge at the outlet of each absolute pressure regulator must be from 26-27 p.s.i. absolute minus Barometric Pressure in p.s.i..

NOTE In order to determine absolute pressures accurately, the barometric pressure for the day (in p.s.i.) must be added to the observed readings on the pressure gauges.

CAUTION Should the pressure reading on any of the gauges exceed the minimum relieving pressure by two p.s.i. during pressure build up, the air supply must be shut off immediately and the defective relief valve must be replaced before the test is continued.

(f) Shut off the air supply at the ground pressure rig.

(g) Remove blanking and reconnect the outlet pressure sensing lines to the differential and absolute pressure regulators.

3. AIR PRESSURE REGULATOR FUNCTION TEST

With the three 0-25 p.s.i. gauges remaining in the positions described in para. 2 (a) and the ground pressure rig connected, proceed with the air pressure regulator function tests as follows:

(a) Connect an added 0-25 p.s.i. pressure gauge to the adaptor at the outlet of the servo pressure regulator

(b) Ensure the master refuelling switch is in the OFF AND DEFUEL position.

(c) From the ground pressure rig apply pressure until gauge reads 50-85 p.s.i.

(d) When the pressure reading becomes constant on each gauge, reduce the pressure at the ground pressure rig to 18 p.s.i..

(e) Check that the readings on the gauges are within the following limits:

(i) On the gauge at the outlet of the differential pressure regulator 9.75-10.5 p.s.i..

(ii) On the gauges at the outlets of the absolute pressure regulators -24.75-26 p.s.i. absolute minus barometric pressure in the p.s.i.

(iii) On the gauge at the outlet of the servo pressure regulator - 14.5-16 p.s.i.

(f) Progressively increase the pressure reading at the ground pressure rig from 15 p.s.i. to 85 p.s.i. over a period of five minutes.

(g) The readings on the gauges must remain the same as laid down in (e). This provides a check that each regulator is functioning correctly through a wide range of inlet pressures.

(h) Turn off the air supply, switch the master refuelling switch ON and a low two minutes for the tanks to depressurize.

(j) Switch the master refuelling switch to OFF AND DEFUEL.

(k) Apply constant pressure from the ground pressure rig at gauge reading of 90 p.s.i..

(m) Check that the pressure build up at each gauge to the pressures laid down in (e) takes less than two minutes. This provides a check that the regulators are fully opening to admit air into the tanks during pressure build up.

NOTE The relief valves should remain closed while function testing the air pressure regulators. A small bleed flow from the relief valves however, is normal when maximum regulation pressures are reached.

(n) Shut off the air supply at the ground pressure rig, and switch the master refuelling switch ON to depressurize the tanks.

(p) Remove the 0-25 p.s.i. pressure gauge from the adaptor at the outlet of the servo pressure regulator.

4. AIR PRESSURE REGULATOR & RELIEF VALVE OVER-RIDES FUNCTION TESTS

With the three 0-25 p.s.i. gauges remaining in the positions described in para. 2 (a), and the ground pressure rig connected, proceed with the air pressure regulator and relief valve over-rides function tests as follows:

(a) Connect the electrical external power supply.

(b) Ensure that the master refuelling switch is in the On position.

(c) Apply a constant indicated pressure of 85 p.s.i. from the ground pressure rig.

(d) Check that the reading on each gauge remains at zero for a period of three minutes. This provides a check that the regulator over-rides are shutting off the air supply to the tanks during refuelling.

(e) Switch the master refuelling switch to OFF AND DEFUEL and allow three minutes for the tanks to pressurize.

(f) Check that the pressure readings on the gauges rise to the pressures laid down for the differential and absolute regulators in para 3 (e). This provides a check that the regulator over-rides are opening to allow the tanks to pressurize and the relief valve over-rides are closing the vents to atmosphere.

(g) Switch the master refuelling switch On.

(h) The reading on the gauges must fall to zero in less than two minutes. This provides a check that the relief valve over-rides are opening satisfactorily to provide vents to atmosphere during refuelling.

(j) Turn off the ground pressure rig.

FUEL SYSTEM FAULTS AND REMEDIES

WARNING LIGHTS

	TROUBLE	PROBABLE CAUSE	REMEDY
1.	FUEL PROP light reported on in flight, but LOW LEVEL warning lights did not come on	A fuel transfer pump is inoperative	Establish which fuel transfer pump is defective by switchi on the ground test override switch and operating tank pump indicator buttons on the master refuelli panel. Replace defective pump
2.	FUEL PROP light reported on in flight with a LOW LEVEL light on temporarily	Relevant flow proportioner jammed	Check each flow proportioner positio indicator before ground power is switched on. Reset flow proportioner by switching on ground power and function test for recurring o jamming. Replace flow proport ioner if defective
3.	FUEL PROP light reported on immediately prior to take-off	Refuelling access doors not properly closed, or defective access door micro switch. Master refuelling switch inadvertently left on. A flow proportioner jammed.	Ensure refuelling access doors are properly closed, replace micro-switch if defective. Switch off master refuelling switch ar close access door. Function test flow proportioners and replace if defective
4.	A ENG FUEL PESS light reported on in flight but low level light did not come on.	Relevant booster pump inoperative	Replace defective booster pump or dri mechanism.

FUEL SYSTEM FAULTS AND REMEDIES

PRESSURIZATION

	TROUBLE	PROBABLE CAUSE	REMEDY
5.	Differential air relief valve relieving continuously	Differential pressure regulator failed Differential relief valve failed	Establish which valve [illegible] failed by checking regulator outlet pressu[illegible] at regulator test poin[illegible] with tanks pressurized. Excessive pressure indicates regulator failed. Normal pressu[illegible] or less indicates relief valve failed. Replace defective regul[illegible] ator or relief valve.
6.	An absolute air relief valve relieving continuously	Relevant absolute regulator failed Relevant absolute valve failed	Establish which valve has failed by checking regulator outlet pressu[illegible] at regulator test poin[illegible] with tanks pressurized. Exwessive pressure indicates regulator failed. Normal pressur[illegible] or less indicates reli[illegible] valve failed. Replace defective regulator or relief valve.
7.	Fuselage tanks air pressure does not vent to atmosphere when master refuelling switch is switched ON	Solenoid in differential air relief valve override inoperative. Override circuitry defective.	Replace differential air relief valve. Rectify electrical fault.
8.	Wing tanks air pressure does not vent to atmosphere when master refuelling switch is	Solenoid in relevant absolute air relief valve override inoperative. Override circuitry defective	Replace defective absolute air relief valve. Rectify electrical fault.

FUEL SYSTEM FAULTS AND REMEDIES

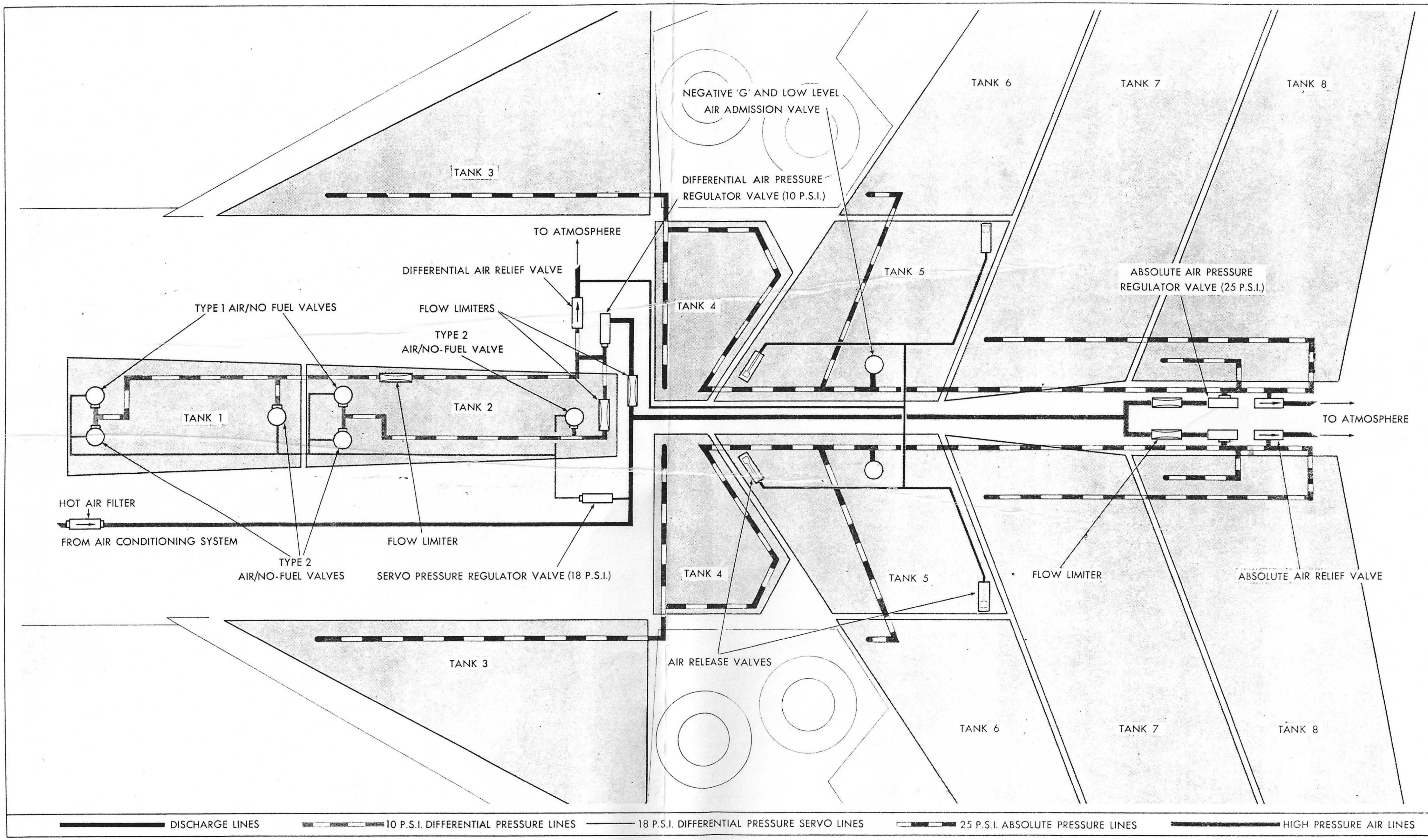
VENTING

	TROUBLE	PROBABLE CAUSE	REMEDY
9.	Evidence of excessive fuel being vented to atmosphere in the area of the duct bay flame trap during flight.	Air/no fuel valve(s) inoperative	Replace defective air/ fuel valve(s).
		Fuselage tanks fuel and condensate drain valve leaking.	Replace defective fuel and condensate drain valve.
		15 p.s.i. servo pressure regulator failed.	Replace defective serv pressure regulator.
		Defective air release valve(s).	Replace defective air release valve(s).
10.	Fuselage and wing tanks air pressure does not vent to atmosphere, and tank indicator lights do not come on when master refuelling switch is switched ON	Master refuelling switch or circuit defective	Replace defective master switch or loca and rectify electrica fault.

FUEL SYSTEM FAULTS AND REMEDIES

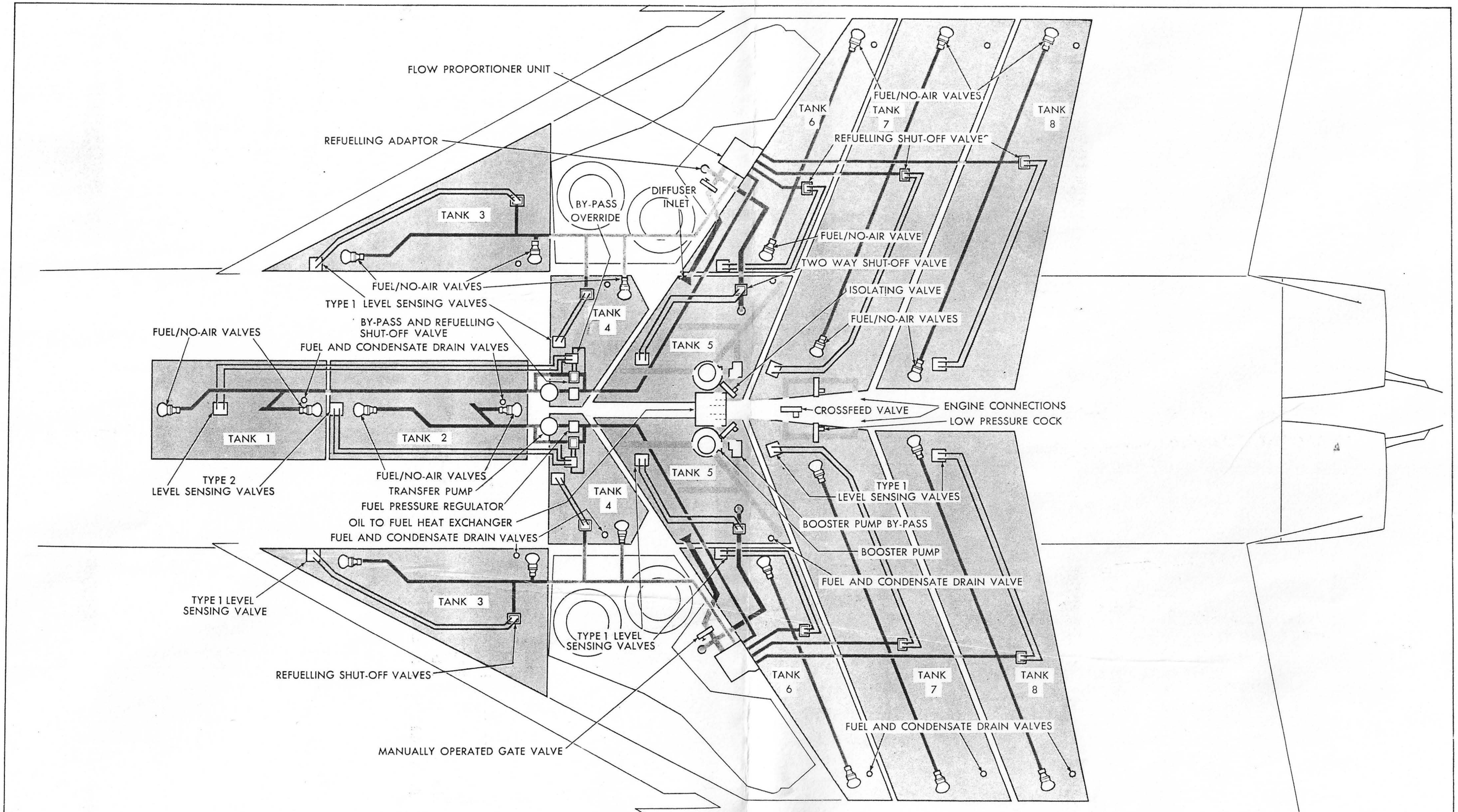
REFUELLING

	TROUBLE	PROBABLE CAUSE	REMEDY
11.	A tank indicator light does not come on during refuelling pre-checking	Relevant shut-off valve not closing	
		Defective Shut-off valve	Replace defective shut off valve.
		Solenoid in level sensing valve inoperative or float mechanism defective.	Replace defective leve sensing valve.
		Light bulb or electrical circuitry defective	Replace light bulb, locate and rectify electrical fault.
12.	A tank indicator light does not go out during refuelling pre-checking.	Relevant shut-off valve not opening	
		Defective shut-off valve.	Replace defective shut off valve.
		Solenoid in level sensing valve inoperative, or float mechanism defective.	Replace defective lev sensing valve.
		Override solenoid in override valve inoperative if it is fuselage tank indicator light.	Function test override valve and replace if defective.
13.	Fuel is discharged when operating aft fuel and condensate drain valve in duct bay.	A fuselage tank is leaking.	Determine source of leak and rectify.



7M1-5401-4

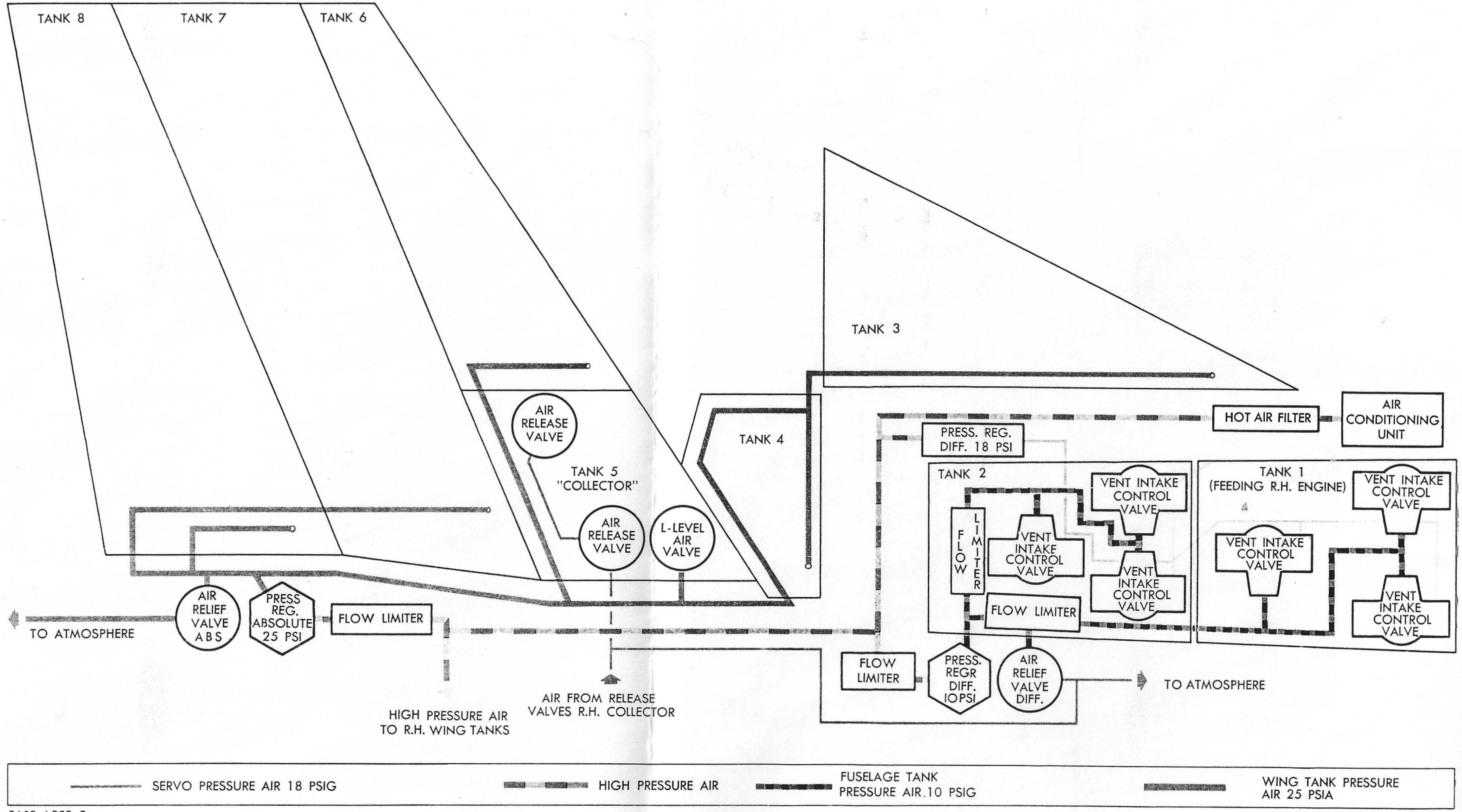
FUEL SYSTEM - TANK PRESSURIZATION SCHEMATIC



FUEL SUPPLY LINES — ENGINE FEED LINES — SERVO LINES

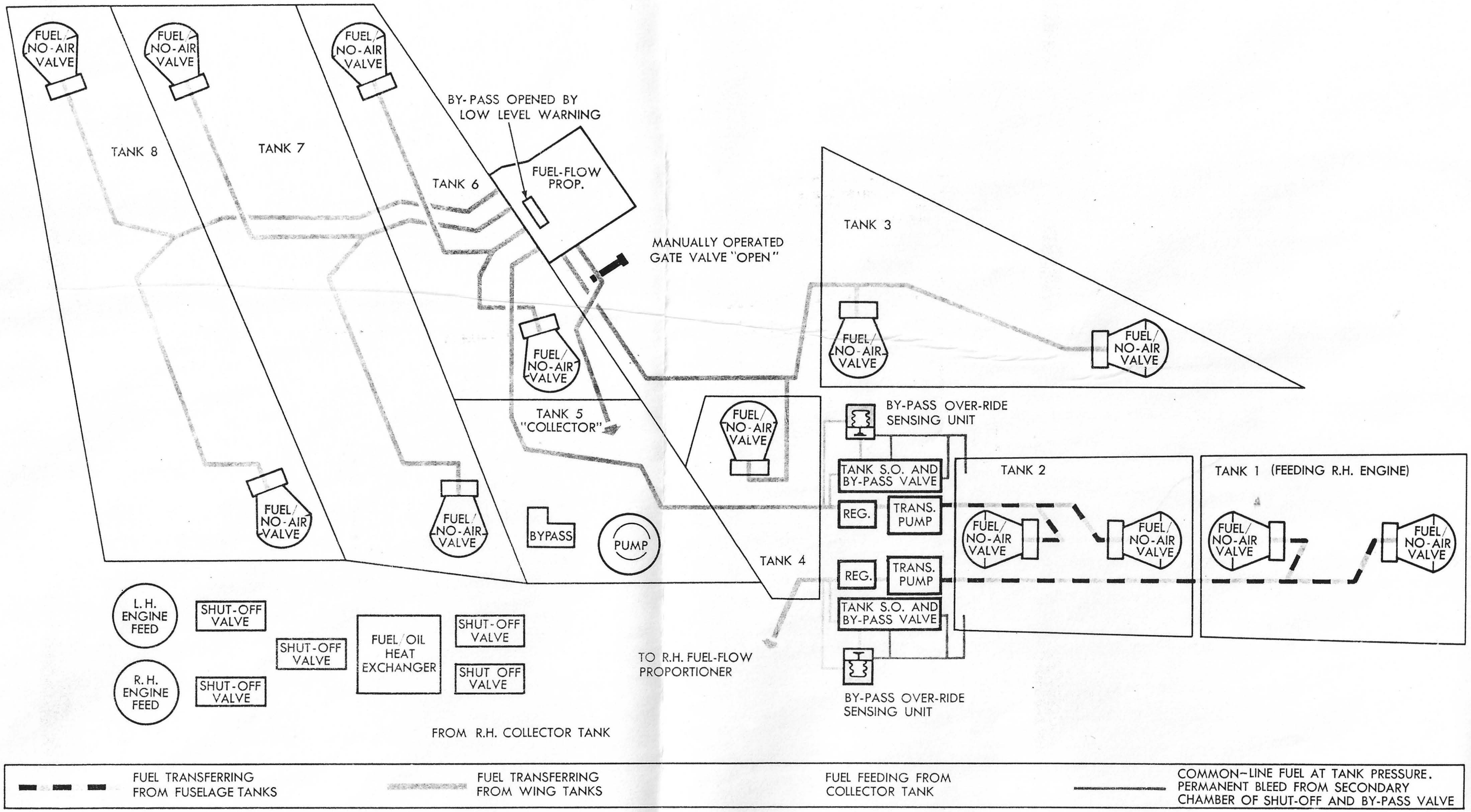
7M1-3402-4

FUEL SYSTEM - FUEL FLOW SCHEMATIC



C105-LD35-3

ARROW 1
FUEL SYSTEM TANK PRESSURIZATION
SECRET

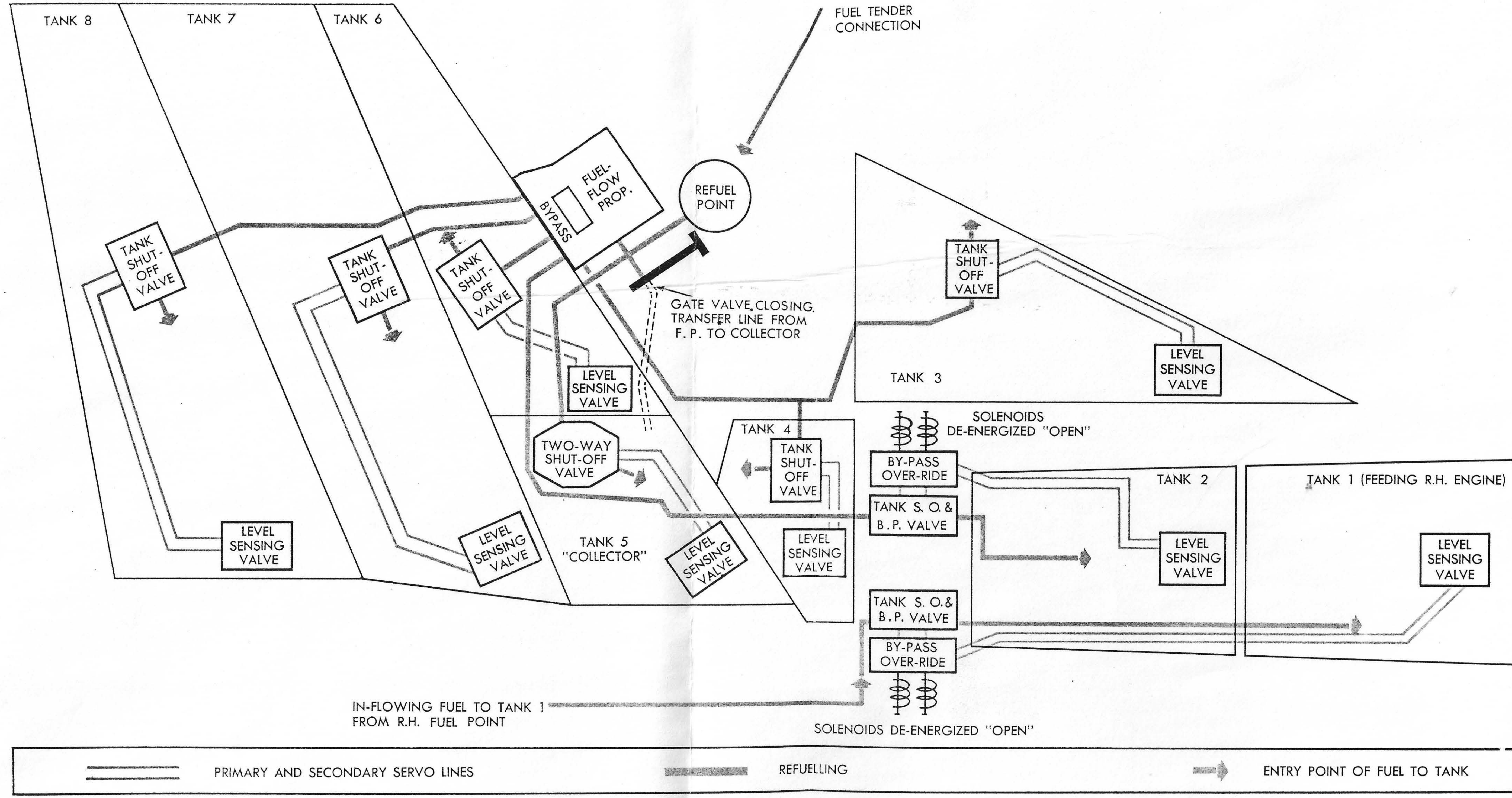


C105-LD36-3

ARROW 1

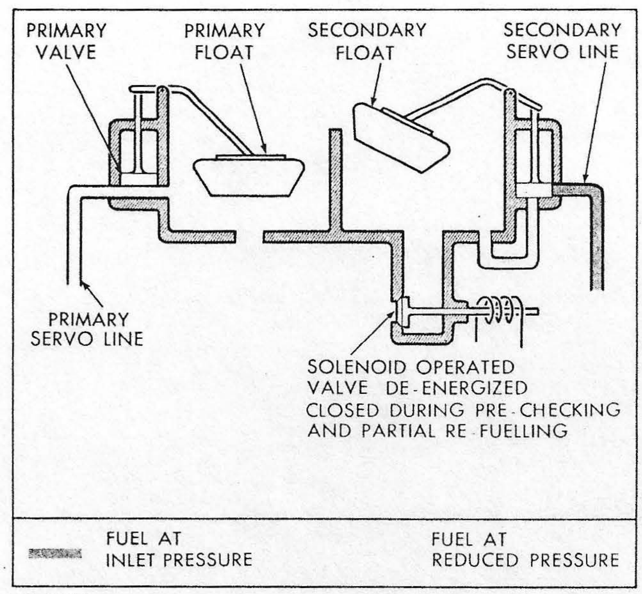
FUEL SYSTEM ENGINE FEED AND TRANSFER

SECRET



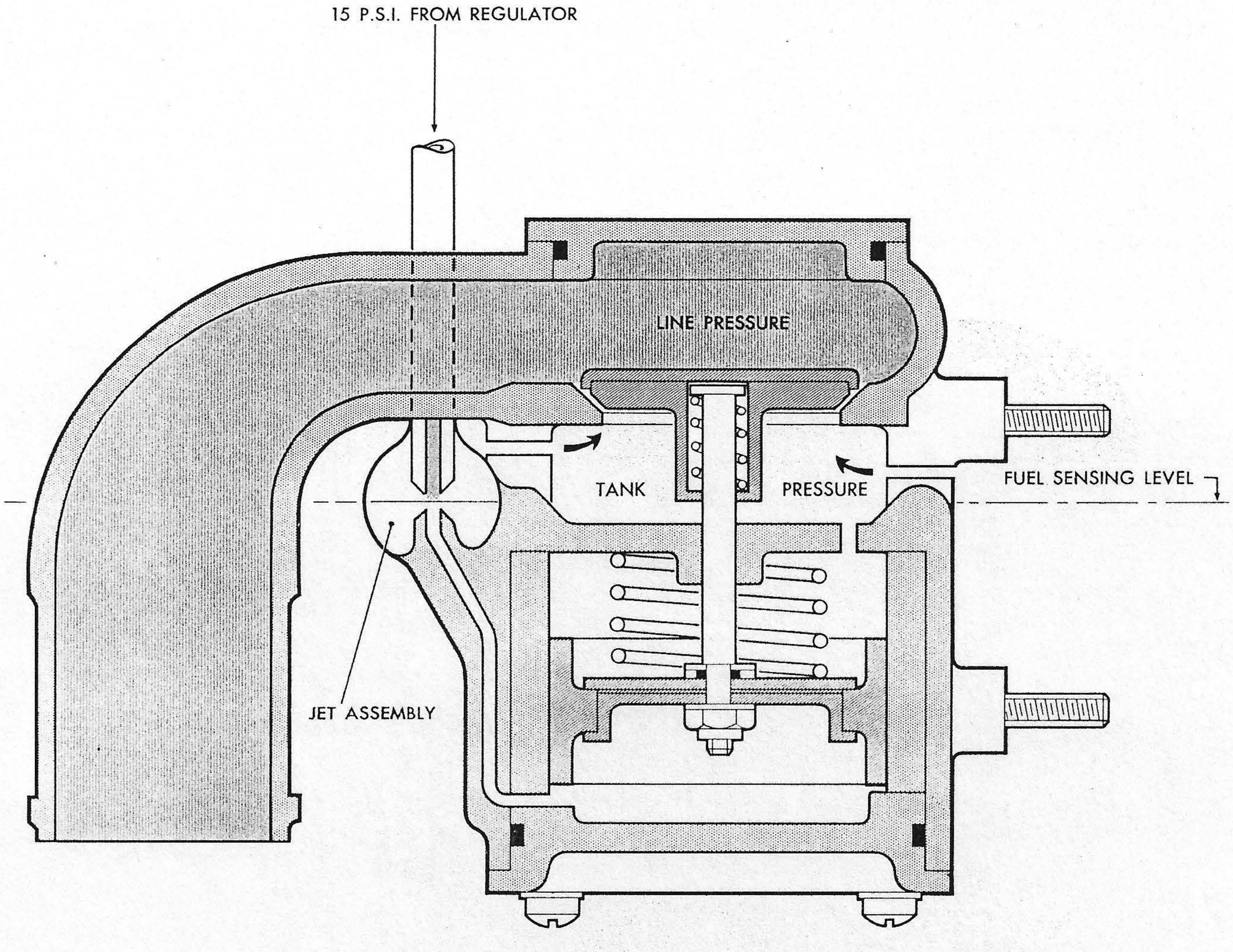
C105-LD34-3

ARROW 1
FUEL SYSTEM REFUELLING
SECRET



7M1-3434-1

TYPE 2 LEVEL SENSING VALVE SCHEMATIC

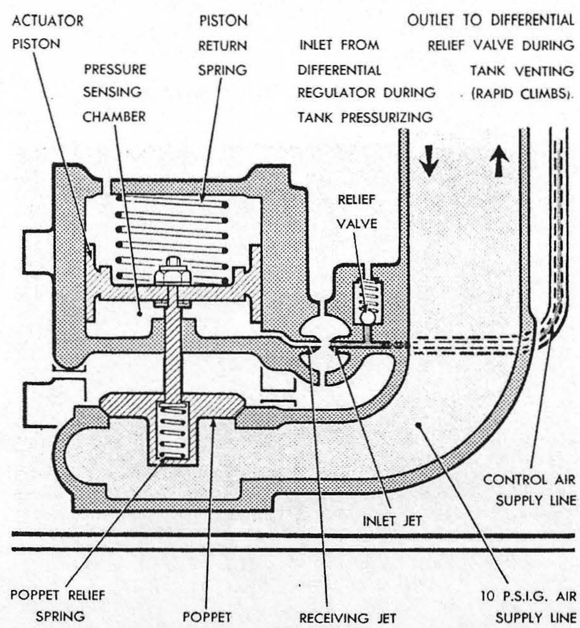


C105-LD-94-1

VENT-INTAKE-CONTROL VALVE TYPE 1

CF105 — FUEL SYSTEM

SECRET



DESCRIPTION

THE LOWER TYPE 2 VALVE IS NORMALLY IMMERSED IN FUEL AND THE AFT TYPE 2 VALVE IS IMMERSED IN FUEL DURING CLIMBS. DURING IMMERSION THE FUEL ISOLATES THE RECEIVING JET FROM THE INLET JET, PREVENTING 18 P.S.I. AIR PRESSURE FROM ENTERING THE PRESSURE SENSING CHAMBER. THE PISTON RETURN SPRING AIDED BY THE FUEL HEAD HOLDS THE POPPET ON ITS SEATING, PREVENTING FUEL FROM ENTERING THE 10 P.S.I.G. AIR SUPPLY LINE.

WHEN THE VALVE BECOMES UNCOVERED BY FUEL DUE TO A CHANGE IN ATTITUDE OF FLIGHT OF THE AIRCRAFT, THE 18 P.S.I.G. AIR PRESSURE PASSES FROM THE INLET JET TO THE RECEIVING JET INTO THE PRESSURE SENSING CHAMBER, COMPRESSING THE PISTON AGAINST ITS SPRING AND OPENING THE POPPET.

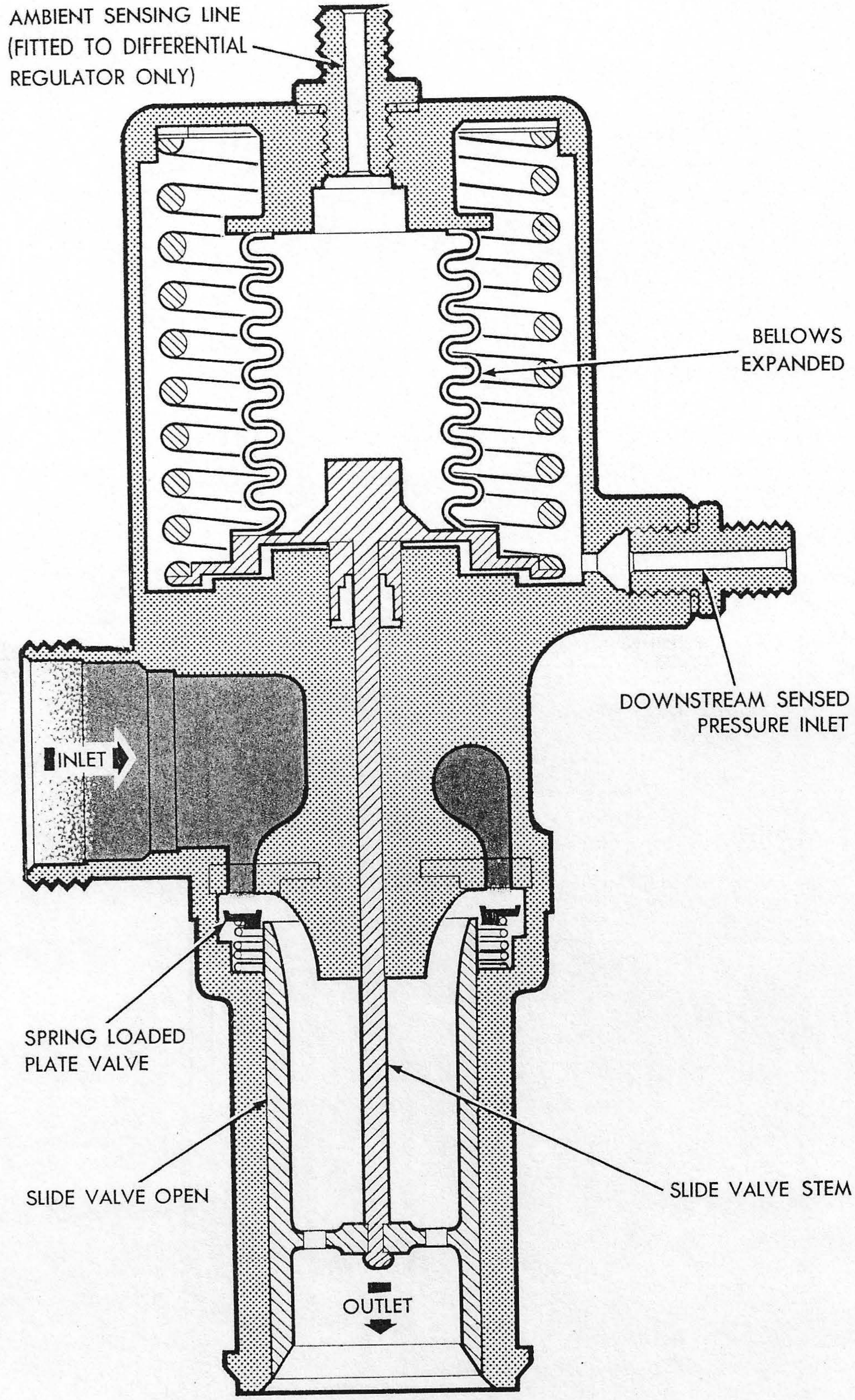
IN THE EVENT OF A DROP IN TANK PRESSURE, THE POPPET WILL OPEN AGAINST THE POPPET RELIEF SPRING SHOULD 10 P.S.I.G. SUPPLY LINE PRESSURE EXCEED TANK PRESSURE BY 1.5-1.75 P.S.I.

A RELIEF VALVE IS FITTED IN THE CONTROL AIR SUPPLY LINE TO RELIEVE EXCESS PRESSURE WHICH WOULD CAUSE THE VALVE TO OPEN EVEN WHEN IMMERSED IN FUEL.

AIR AT 10 P.S.I.G   AIR AT 18 P.S.I.G.   FUEL

7M1-3421-2

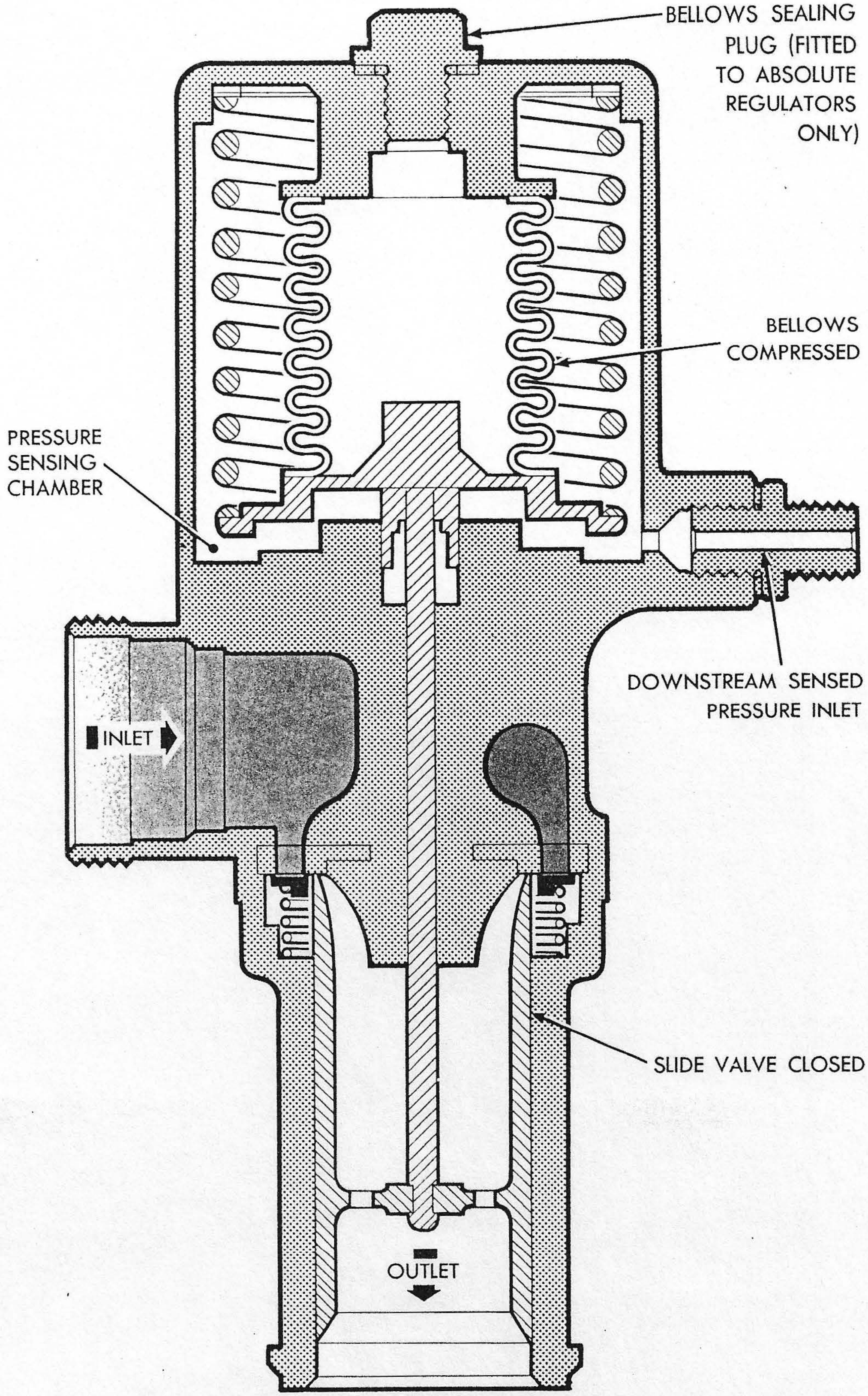
TYPE 2 AIR/NO-FUEL VALVE SCHEMATIC



▭	AMBIENT AIR PRESSURE
▭	HIGH PRESSURE AIR (85 P.S.I.G.)
▭	FUSELAGE TANK PRESSURIZING AIR AT 10 P.S.I.G.

EXTRACT FROM 7M1-3417-1.

DIFFERENTIAL AIR PRESSURE REGULATOR SCHEMATIC

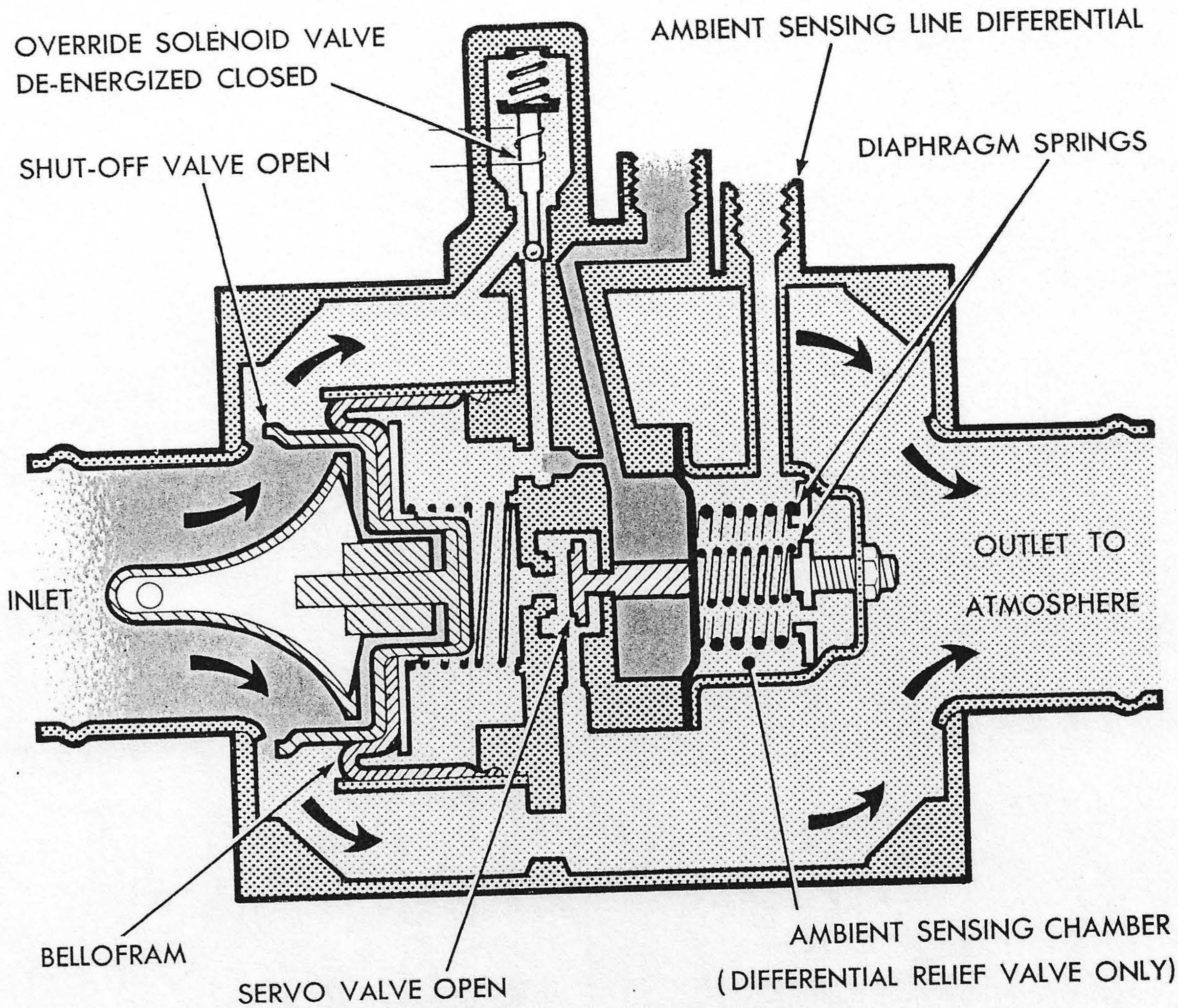


HIGH PRESSURE AIR (85 P.S.I.G.)

WING TANK PRESSURIZING AIR AT 25 P.S.I.A.

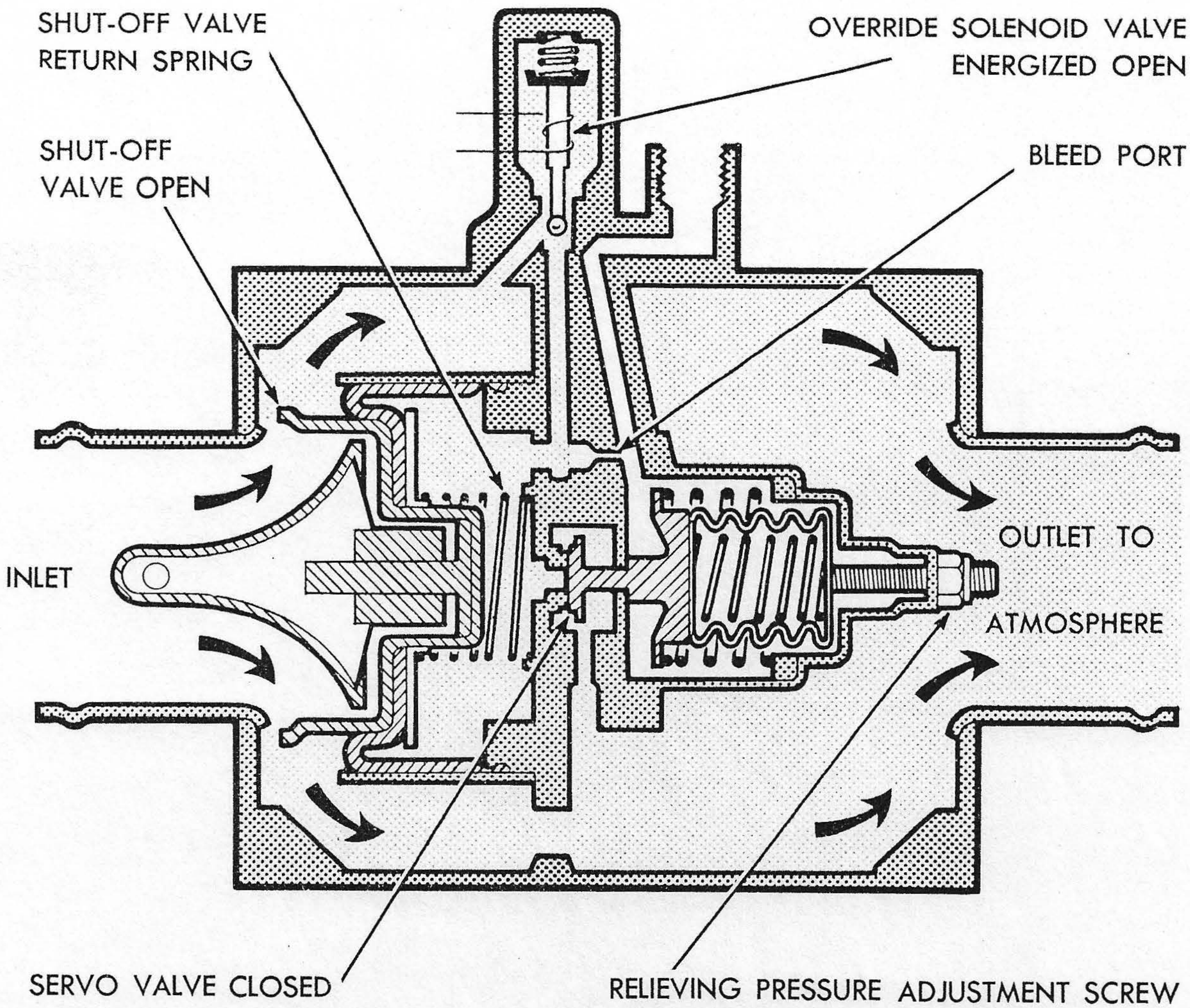
EXTRACT FROM 7M1-3417-1

ABSO[illegible] AIR PRESSURE REGULATOR SCHEMATIC



▭	AIR AT ATMOSPHERIC PRESSURE
▭	TANK PRESSURE AIR IN EXCESS OF 10 P.S.I.G. (RELIEF VALVE OPENS AT 10.5 - 11 P.S.I.G.) EXTRACT FROM 7M1-3418-1

DIFFERENTIAL AIR PRESSURE RELIEF VALVE

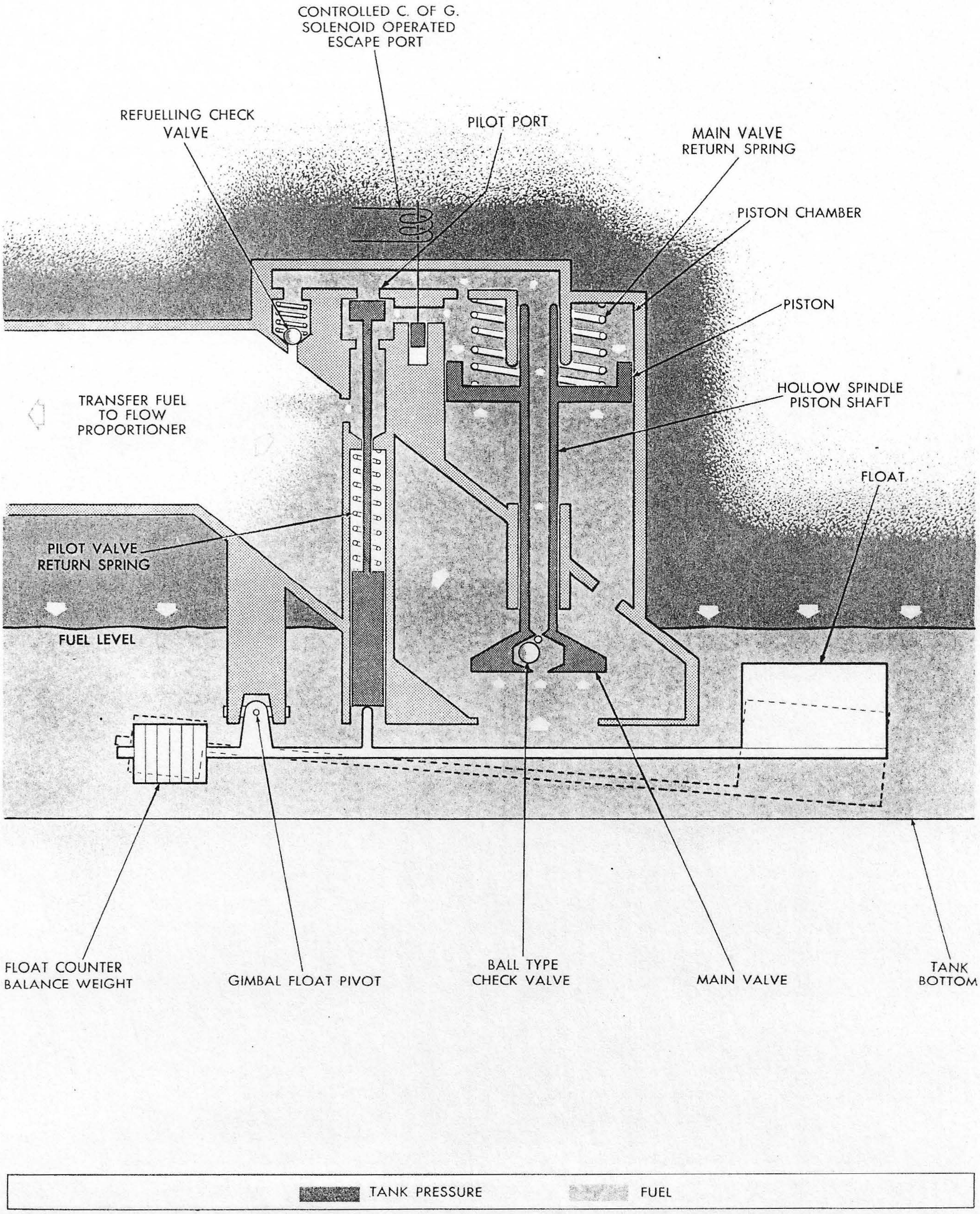


AIR AT ATMOSPHERIC PRESSURE

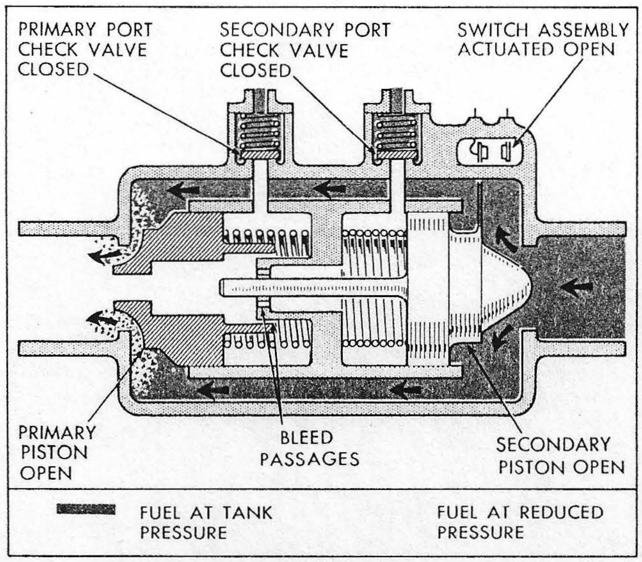
TANK PRESSURE AIR IN EXCESS OF 25 P.S.I.A. (RELIEF VALVE OPENS AT 26 - 27 P.S.I.A.)

EXTRACT FROM 7M1-3418-1

ABSOLUTE AIR PRESSURE RELIEF VALVE SCHEMATIC

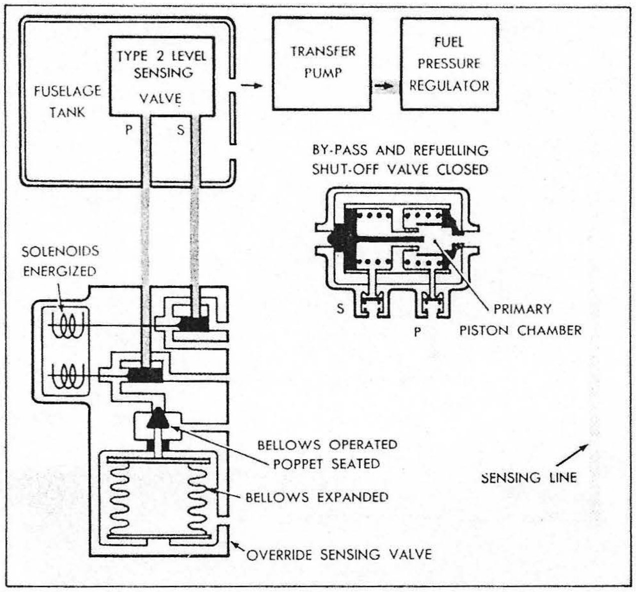


FUEL/NO AIR VALVE (ARROW)



7MI-3411-2

TWO WAY SHUT-OFF VALVE - REVERSE FLOW SCHEMATIC

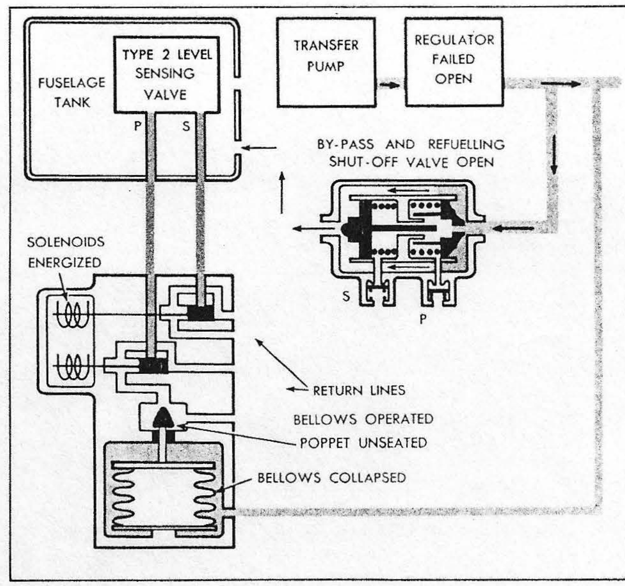


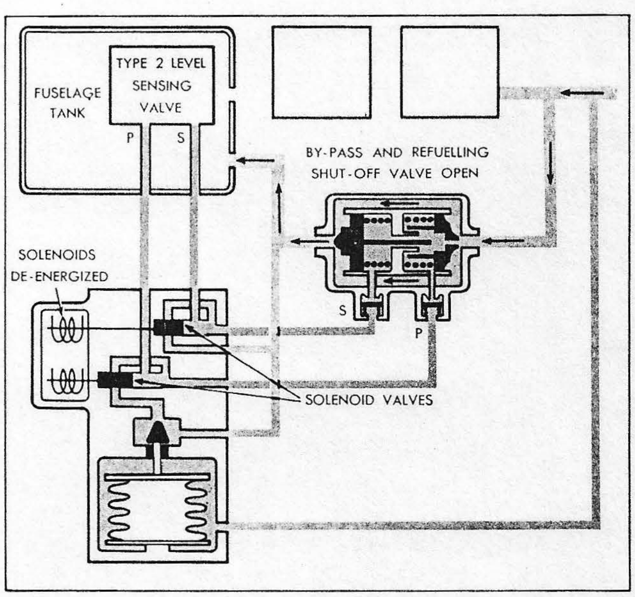
NORMAL

DURING NORMAL OPERATION, THE SOLENOIDS ARE ENERGIZED WHEN THE TRANSFER PUMP IS SWITCHED ON, AND THE SOLENOID VALVES CLOSE OFF THE PRIMARY AND SECONDARY SERVO LINES TO THE LEVEL SENSING VALVE, AND OPEN THE PRIMARY AND SECONDARY SERVO LINES FROM THE BY-PASS AND REFUELLING SHUT-OFF VALVE. THE OUTLET PRESSURE OF 25 P.S.I.A. IS INSUFFICIENT TO CONTRACT THE BELLOWS, SO THE BELLOWS OPERATED VALVE REMAINS CLOSED. THIS BLANKS OFF THE PRIMARY SERVO LINE AND TRAPS FUEL IN THE PRIMARY CHAMBER OF THE BY-PASS AND SHUT-OFF VALVE WHICH PREVENTS THE VALVE FROM OPENING AND FEEDING FUEL BACK TO THE TANK.

REGULATOR FAILED OPEN

IF THE REGULATOR FAILS, IT FAILS IN THE OPEN POSITION AND THE FUEL OUTLET PRESSURE RISES. AT 28 P.S.I.A., THE PRESSURE BEGINS TO OPEN THE BELLOWS VALVE AND AT 30 P.S.I.A. IT IS FULLY OPEN. THIS ALLOWS THE FUEL TRAPPED IN THE PRIMARY CHAMBER OF THE BY-PASS AND SHUT-OFF VALVE TO DISSIPATE, AND THE VALVE TO OPEN AND BY-PASS EXCESS FUEL BACK TO THE TANK.





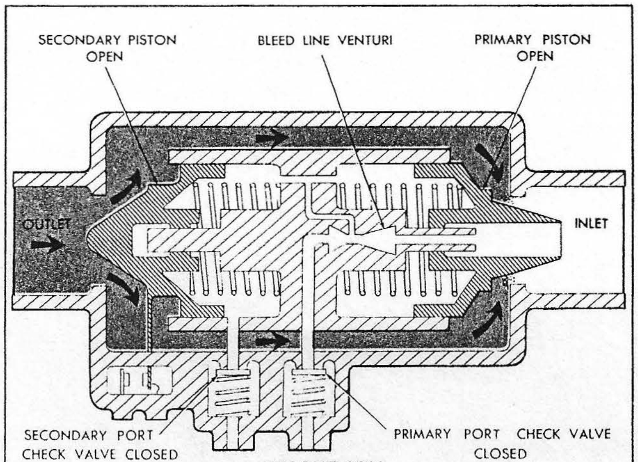
REFUELLING

DURING REFUELLING, THE TWO SOLENOID VALVES ARE DE-ENERGIZED. THIS OPENS THE PRIMARY AND SECONDARY SERVO LINES TO THE LEVEL SENSING VALVE, AND CLOSES THEM TO THE OVERRIDE SENSING VALVE. THE LEVEL SENSING VALVE AND THE BY-PASS AND SHUT-OFF VALVE NOW CONTROL REFUELLING. SEE PARA. 74

FUEL AT 25-28 P.S.I. | FUEL IN EXCESS OF 28-30 P.S.I. | FUEL AT REDUCED PRESSURE | REFUELLING SERVO LINES AT REDUCED PRESSURE

7MI-3416-3

BY-PASS OVERRIDE SCHEMATICS



DESCRIPTION

WHEN THE TRANSFER PUMP IS INOPERATIVE, PRESSURE AT THE VALVE INLET IS BELOW TANK PRESSURE. THIS REDUCED INLET PRESSURE IS FELT WITHIN THE PRIMARY AND SECONDARY PISTON CHAMBERS AND CLOSES THE CHECK VALVES. PRESSURE AT THE VALVE OUTLET NOW OPENS THE SECONDARY PISTON, ALLOWING THE PRESSURE TO OPEN THE PRIMARY PISTON, AND THE BY-PASS FLOW TO COMMENCE.

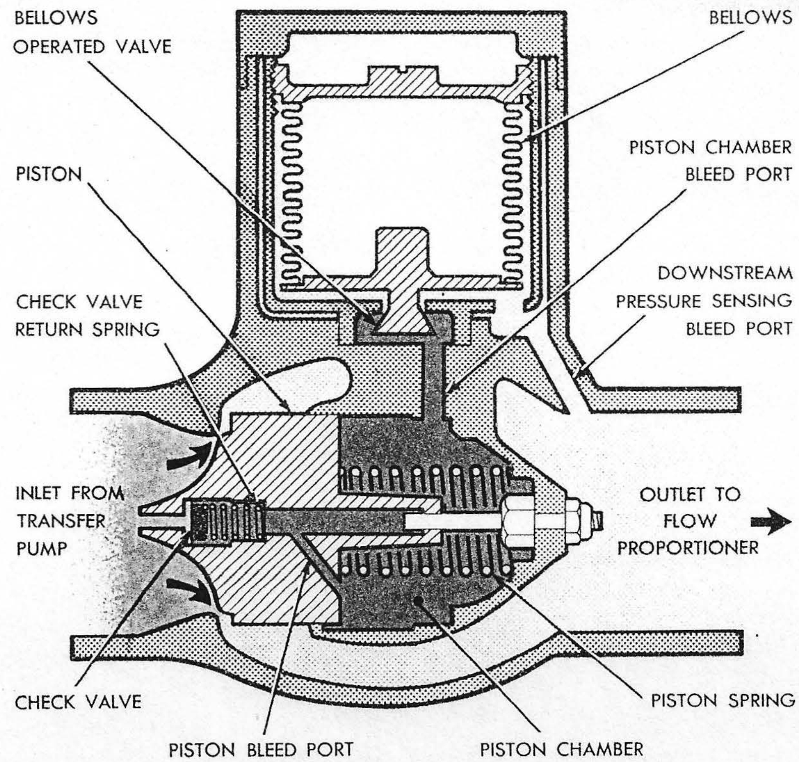
THE PRIMARY PISTON IS MAINTAINED IN THE OPEN POSITION BECAUSE OF THE DIFFERENCE IN PRESSURE BETWEEN THE FUEL ACTING ON THE FACE OF THE PISTON, AND THE FUEL AT THE INLET.

NOTE

THE BLEED LINE VENTURI IS FITTED IN THE PRIMARY BLEED LINE TO ENSURE QUICK OPENING OF THE VALVE DURING OVERRIDE OF THE FUEL PRESSURE REGULATOR (SEE FIG. 16). THE PRESSURE IN THE PISTON CHAMBERS IS DERIVED FROM THE THROAT OF THE VENTURI. THIS REDUCES THE PRESSURE IN THE PISTON CHAMBERS TO BELOW INLET PRESSURE.

FUEL AT FUSELAGE TANK PRESSURE — FUEL AT REDUCED PRESSURE

BY-PASS FLOW THROUGH THE BY-PASS AND REFUELLING SHUT-OFF VALVE



DESCRIPTION

FUEL DELIVERED BY THE TRANSFER PUMP OPENS THE PISTON AND CHECK VALVE AGAINST THE RETURN SPRINGS. THE FUEL THEN FLOWS PAST THE PISTON TO THE FLOW PROPORTIONER, AND ALSO PAST THE CHECK VALVE THROUGH THE BLEED PORT INTO THE PISTON CHAMBER.

OUTLET PRESSURE IS SENSED IN THE BELLOWS CHAMBER, AND WHEN THE PRESSURE RISES TO 25 P.S.I.A., THE BELLOWS START TO COLLAPSE AND CLOSE THE BELLOWS OPERATED VALVE. THE VALVE FULLY CLOSES AT 27 P.S.I.A.

THE BELLOWS OPERATED VALVE RESTRICTS THE BLEED FLOW FROM THE PISTON CHAMBER, AND THE RESULTANT BACK PRESSURE, ASSISTED BY THE RETURN SPRING MOVES THE PISTON TOWARDS ITS SEATING TO RESTRICT FUEL DELIVERY AND MAINTAIN THE OUTLET PRESSURE AT 25-27 P.S.I.A.

THE CHECK VALVE PREVENTS REVERSE FLOW SHOULD THE INLET PRESSURE FALL BELOW THE OUTLET PRESSURE.

FUEL AT TRANSFER PUMP DELIVERY PRESSURE

FUEL AT 25-27 P.S.I.A.

PRESSURE VARYING BETWEEN 25 P.S.I. AND INLET PRESSURE DEPENDING UPON PISTON POSITION

7M1-3419-1 BLACK

FUEL PRESSURE REGULATOR SCHEMATIC

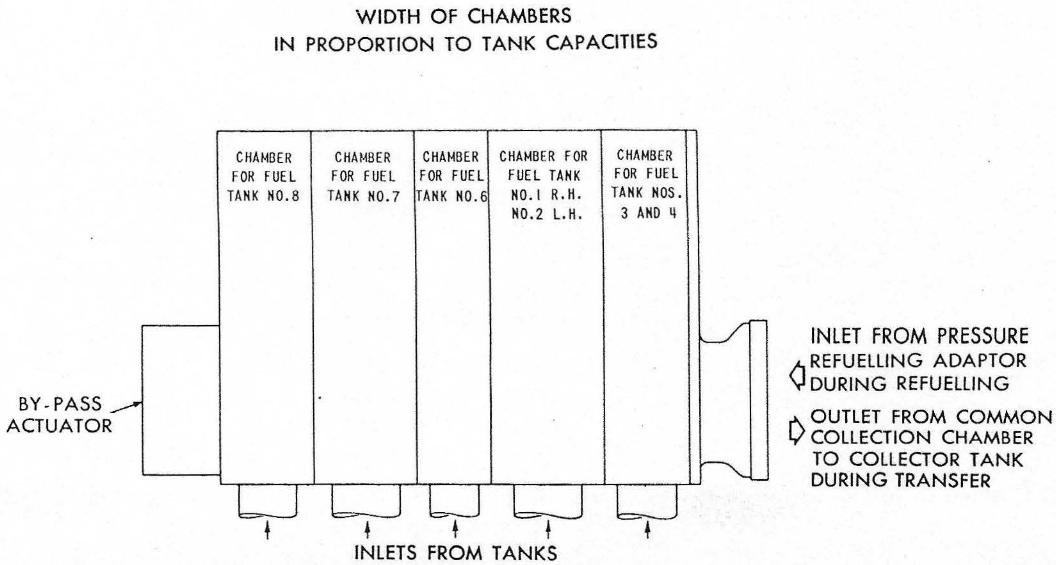
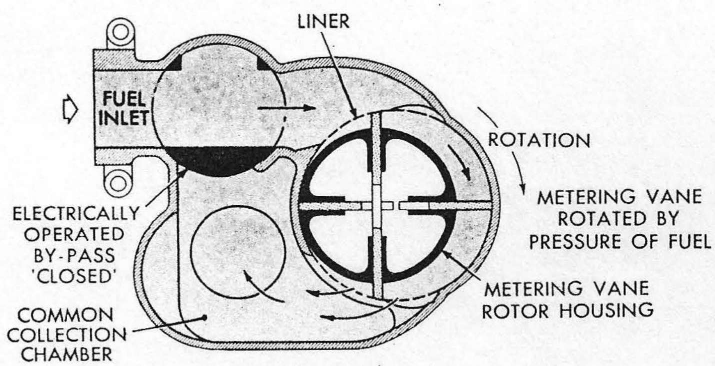
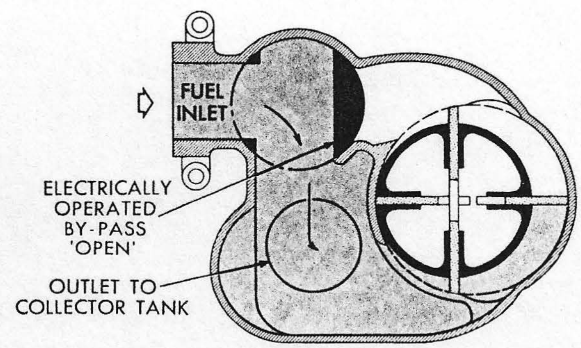


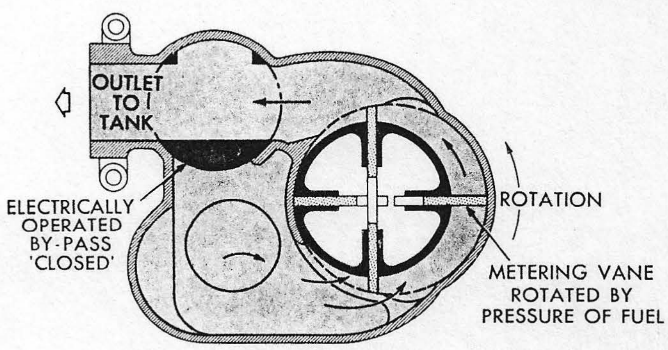
DIAGRAM OF COMPLETE FLOW PROPORTIONER



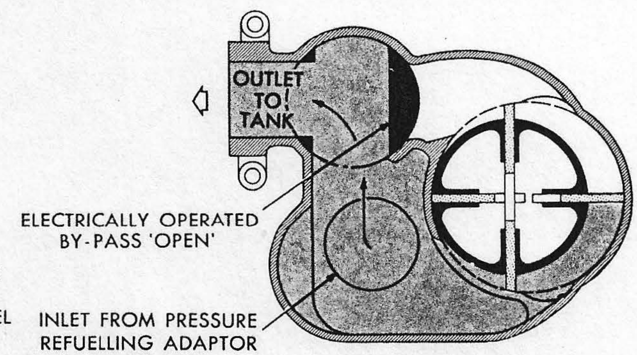
NORMAL TRANSFER



EMERGENCY TRANSFER



PARTIAL REFUELLING



FULL REFUELLING

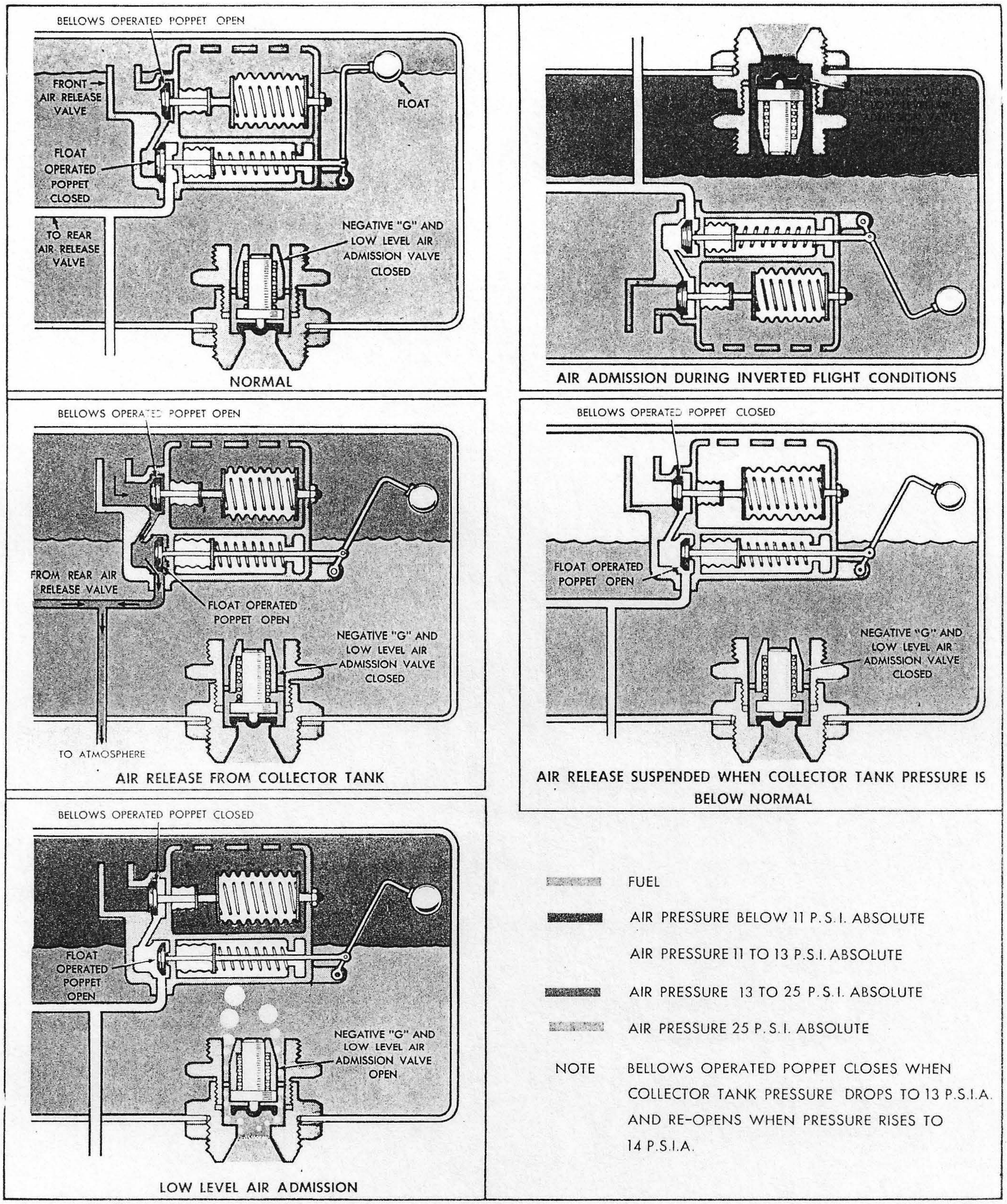
CROSS SECTION DIAGRAMS TYPICAL FOR EACH CHAMBER

FUEL UNDER PRESSURE	RESIDUAL FUEL AT METERING VANE INLET

C-105-LD-83-1

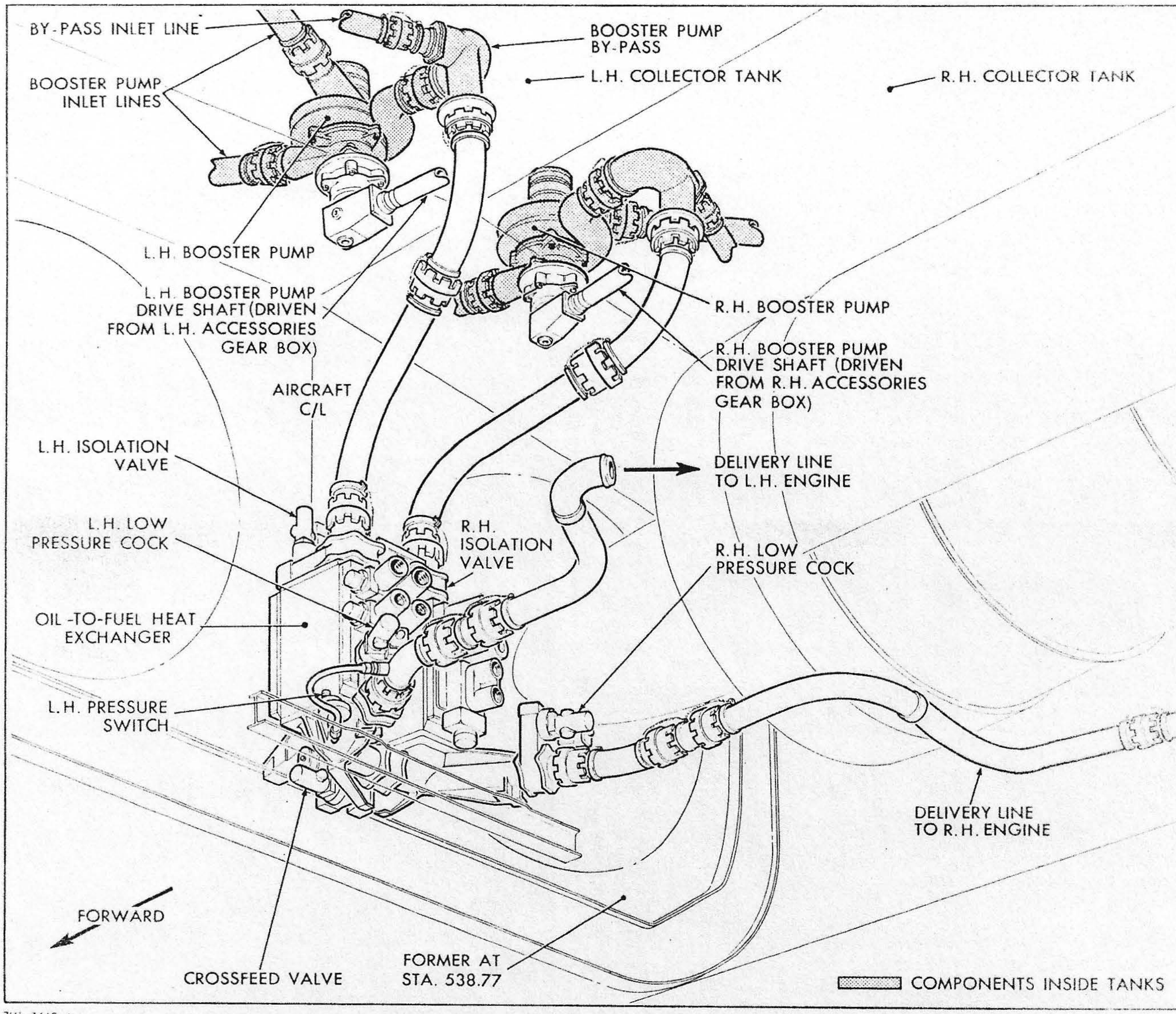
FUEL FLOW - PROPORTIONER UNIT

SECRET



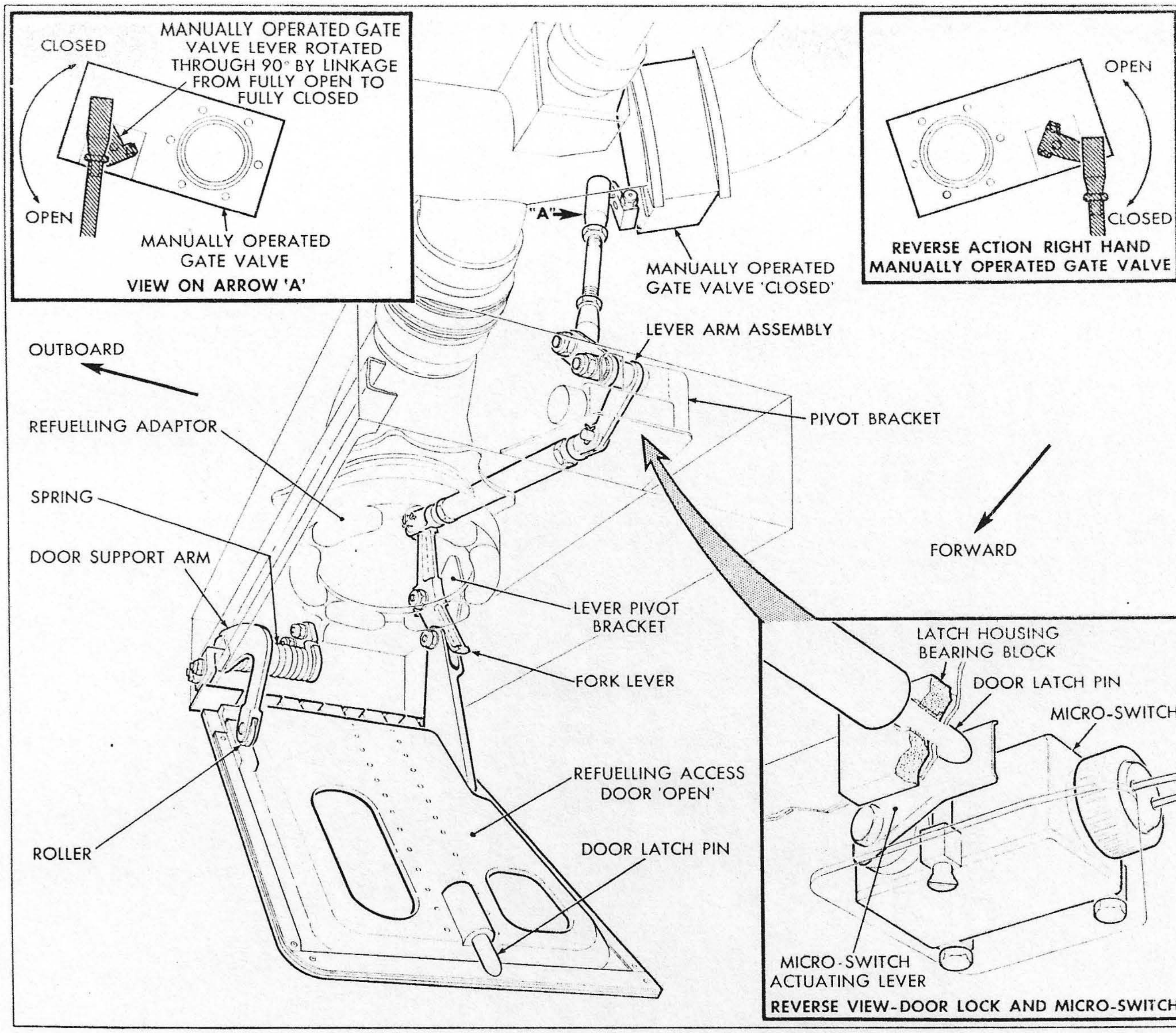
7M1-3404-2 BLACK

COLLECTOR TANK - AIR ADMISSION AND AIR RELEASE DIAGRAMS



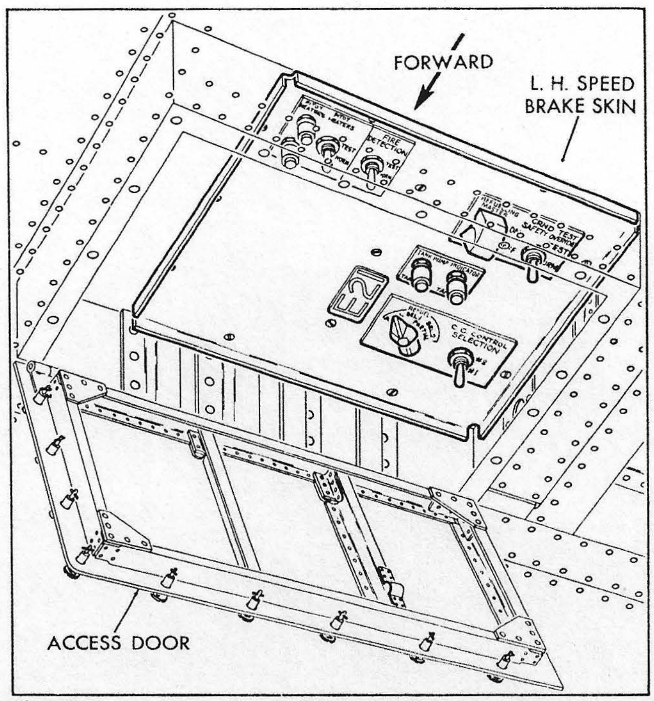
7M1-3415-1

LAYOUT OF ENGINE FEED COMPONENTS



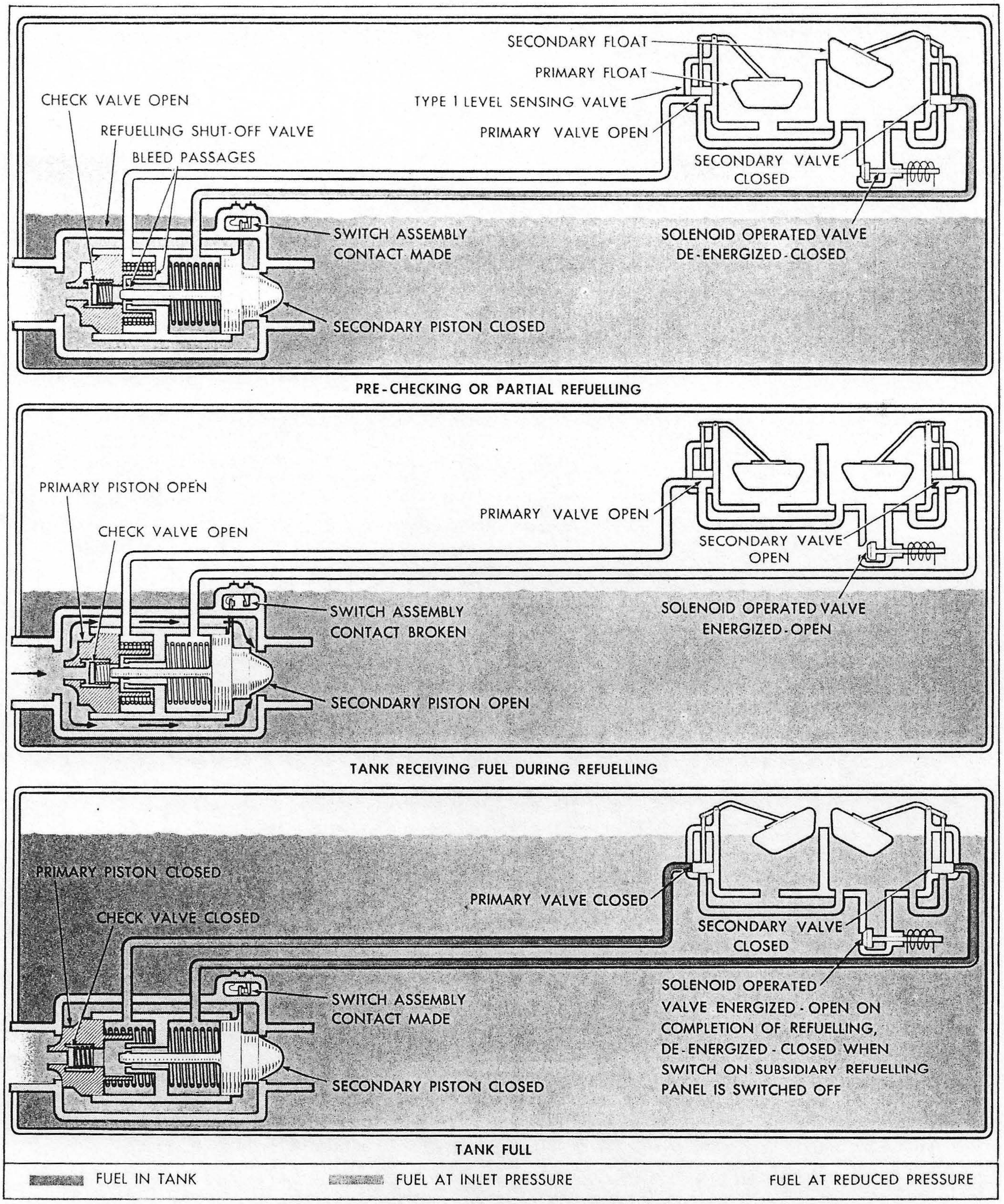
7M1-3407-1

REFUELLING ACCESS DOOR AND MANUALLY OPERATED GATE VALVE



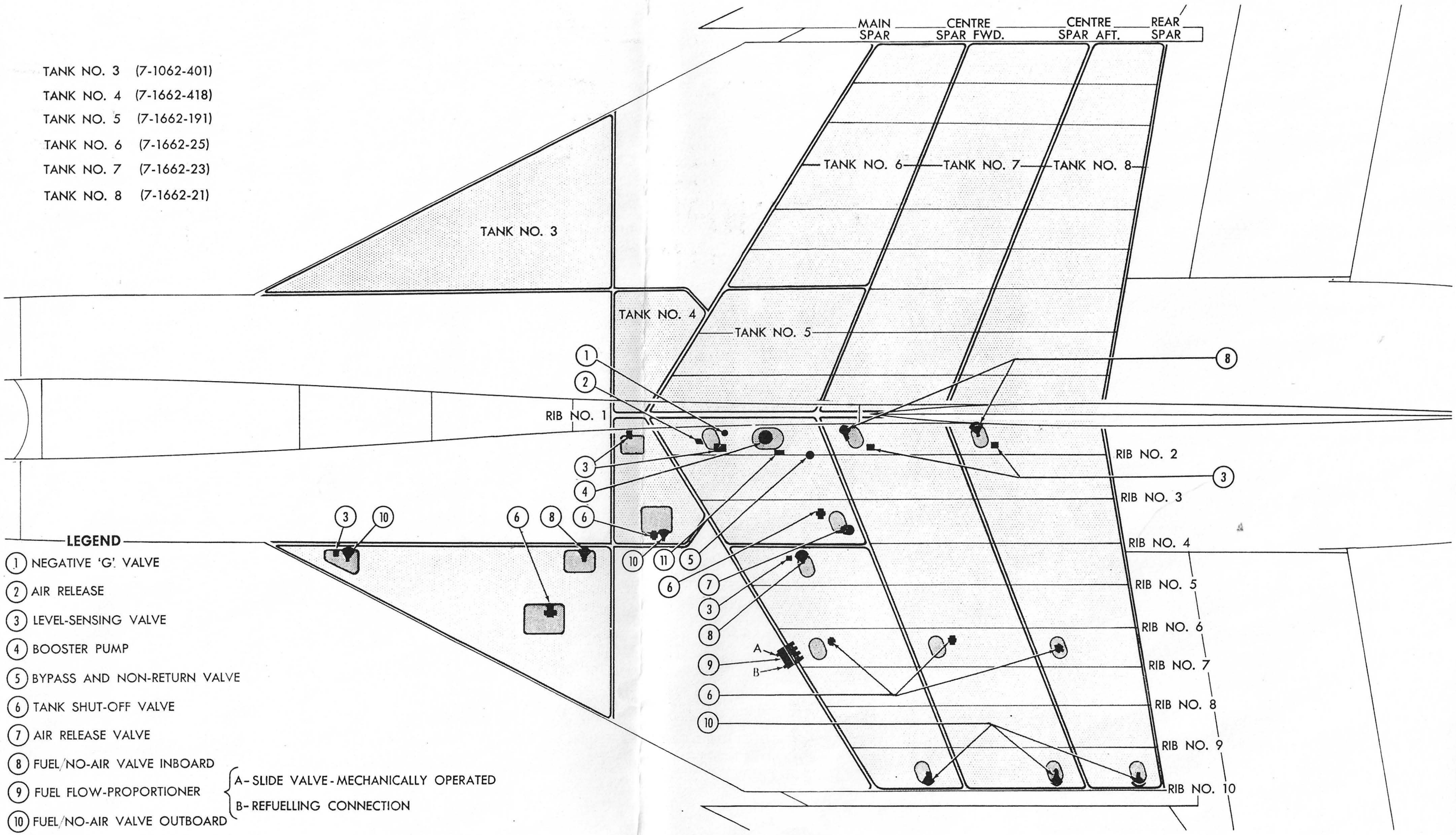
7MJ-3406-1

REFUELLING AND TEST PANEL



OPERATION OF REFUELLING SHUT-OFF VALVES AND TYPE 1 LEVEL SENSING VALVES

TANK NO. 3 (7-1062-401)
TANK NO. 4 (7-1662-418)
TANK NO. 5 (7-1662-191)
TANK NO. 6 (7-1662-25)
TANK NO. 7 (7-1662-23)
TANK NO. 8 (7-1662-21)



LEGEND

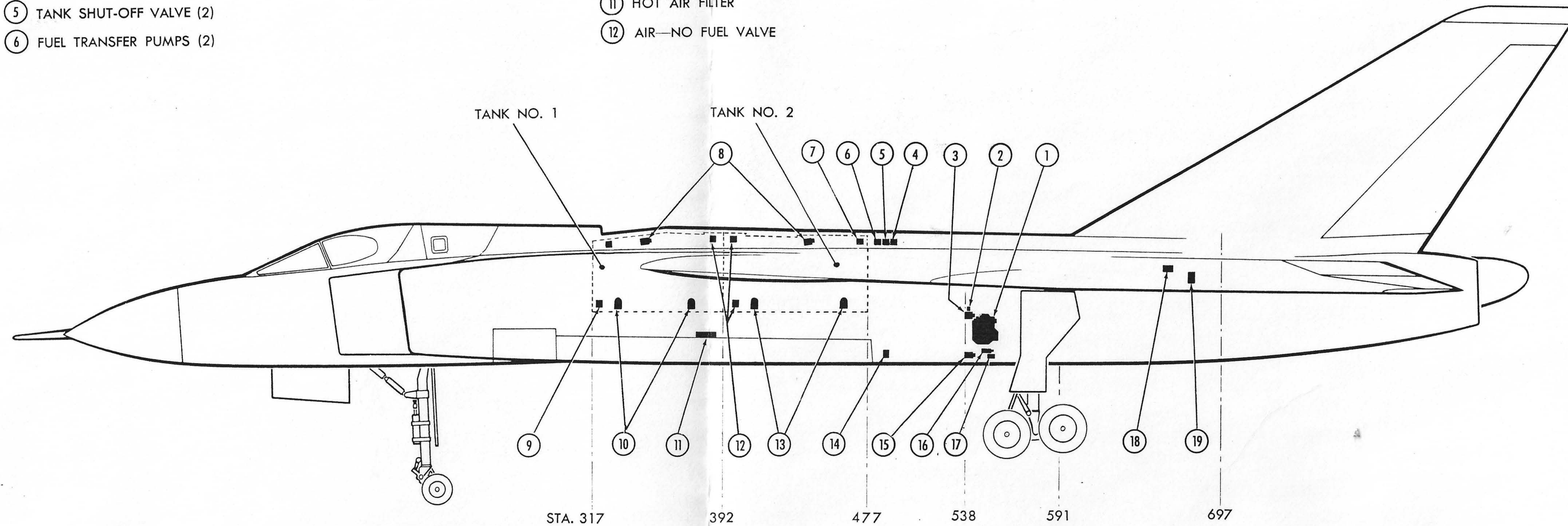
1. NEGATIVE 'G' VALVE
2. AIR RELEASE
3. LEVEL-SENSING VALVE
4. BOOSTER PUMP
5. BYPASS AND NON-RETURN VALVE
6. TANK SHUT-OFF VALVE
7. AIR RELEASE VALVE
8. FUEL/NO-AIR VALVE INBOARD
9. FUEL FLOW-PROPORTIONER { A- SLIDE VALVE-MECHANICALLY OPERATED; B- REFUELLING CONNECTION }
10. FUEL/NO-AIR VALVE OUTBOARD
11. LIQUID LEVEL SENSER

C105-LD-63-1

FUEL SYSTEM COMPONENT LOCATION DIAGRAM
WING

SECRET

1. OIL-FUEL HEAT EXCHANGER
2. BOOSTER PUMP LOW PRESSURE WARNING SWITCH (2) (BETWEEN FUEL ISOLATING VALVES—ITEM 3)
3. FUEL ISOLATING VALVE (2)
4. FUEL PRESSURE REGULATOR VALVE
5. TANK SHUT-OFF VALVE (2)
6. FUEL TRANSFER PUMPS (2)
7. AIR—NO FUEL VALVE
8. LEVEL SENSING VALVE
9. AIR—NO FUEL VALVE
10. FUEL—NO AIR VALVE
11. HOT AIR FILTER
12. AIR—NO FUEL VALVE

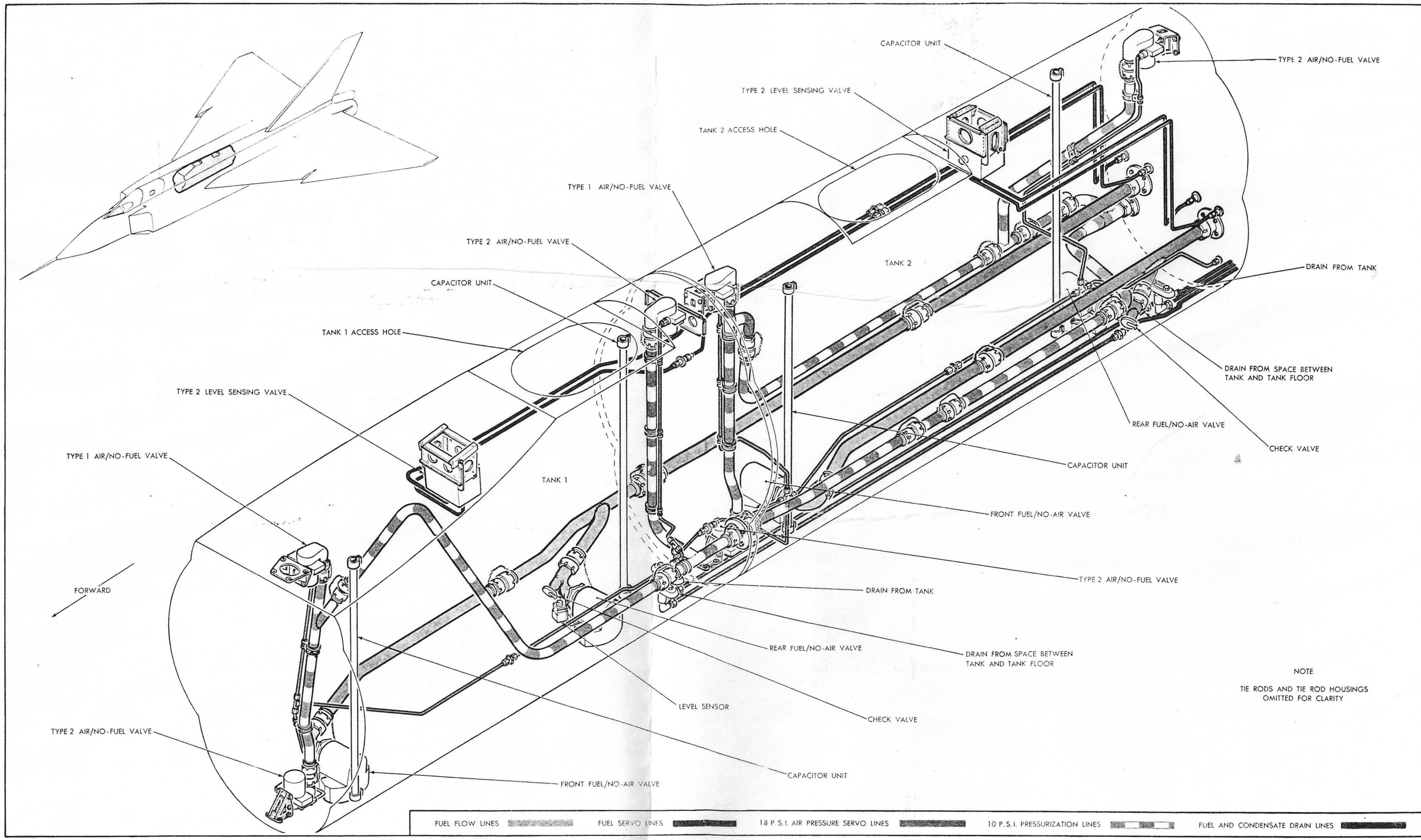


13. FUEL—NO AIR VALVE
14. AIR PRESSURE RELIEF VALVE—DIFFERENTIAL
15. FUEL CROSSFEED VALVE
16. FUEL LOW PRESSURE COCK (2)
17. ENGINE LINE LOW PRESSURE WARNING SWITCH (2)
18. AIR PRESSURE RELIEF VALVE—REGULATOR (2)
19. AIR PRESSURE RELIEF VALVE—ABSOLUTE (2)

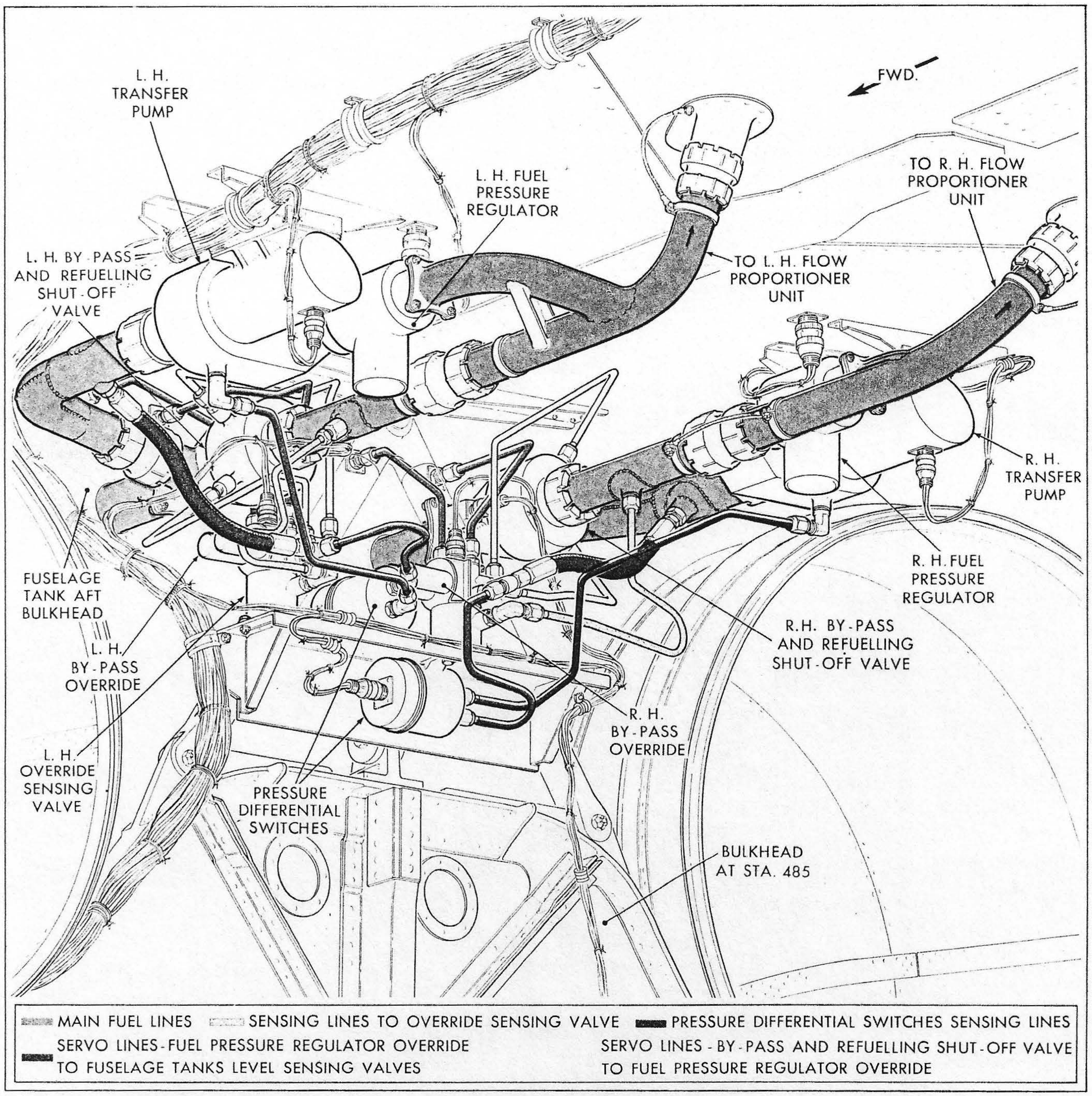
C105-LD-64-1

FUEL SYSTEM – COMPONENT LOCATION DIAGRAM
FUSELAGE

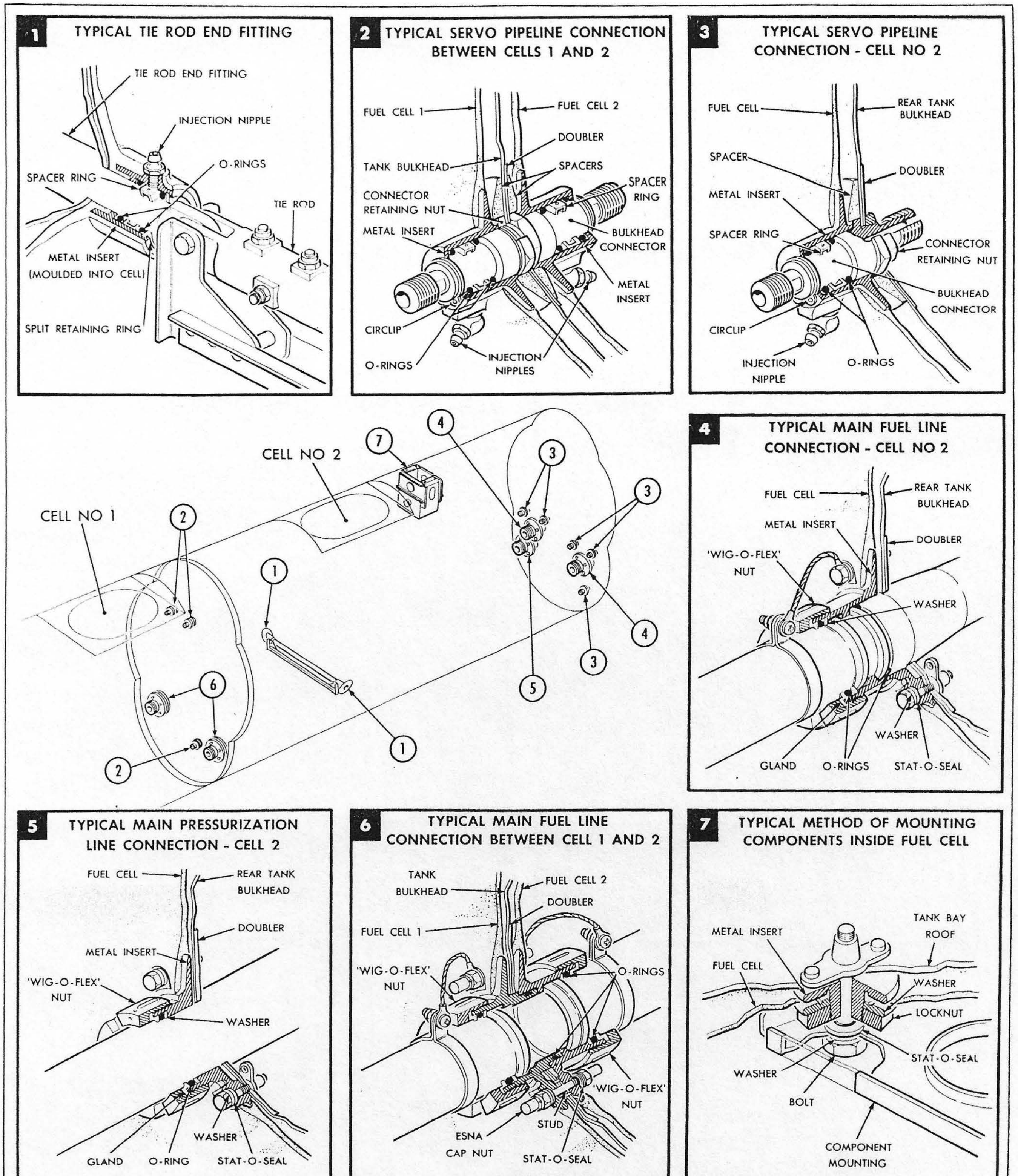
SECRET



LAYOUT OF FUSELAGE TANKS COMPONENTS

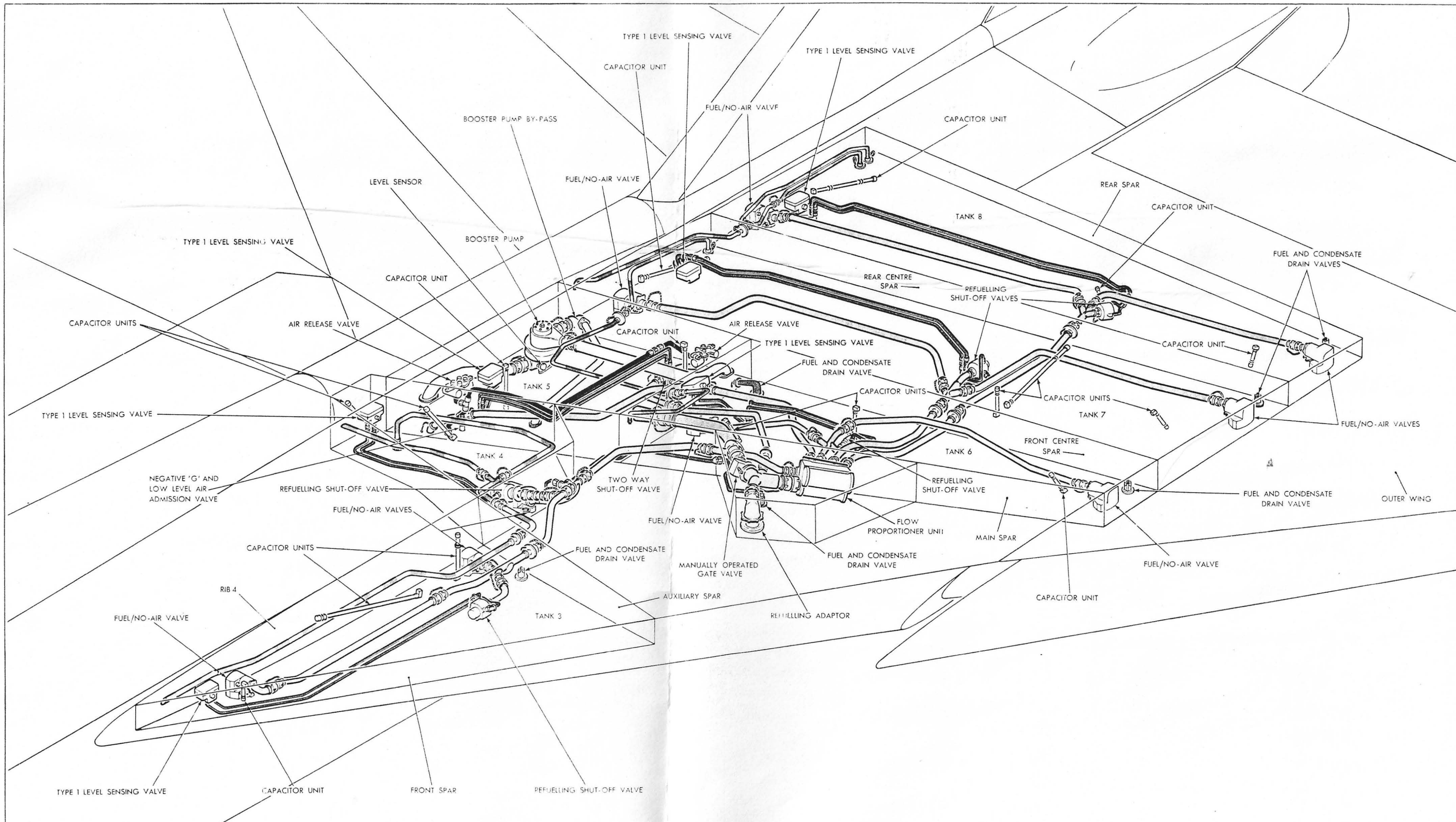


FUSELAGE TANKS TRANSFER LINES AND COMPONENTS



7M1-3431-1

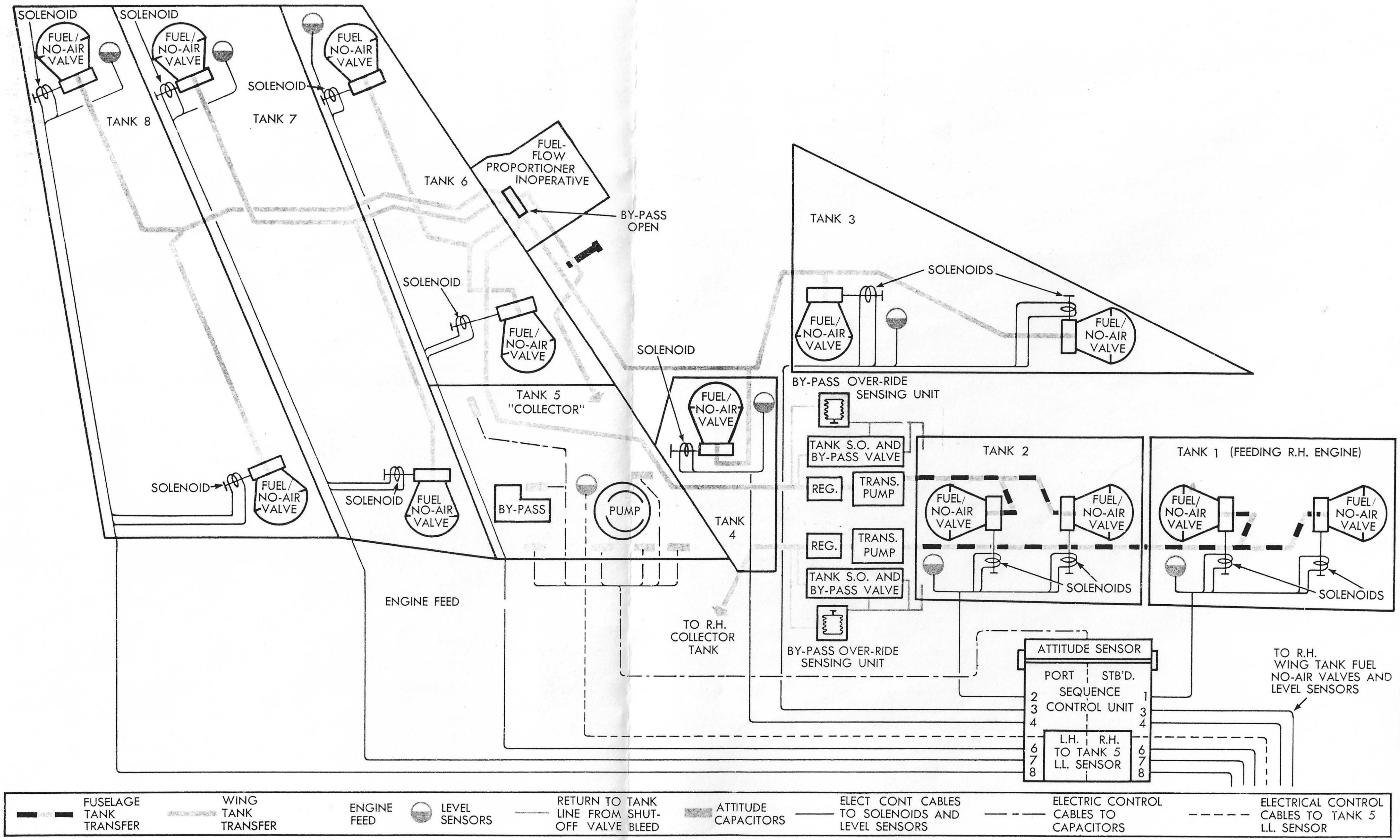
SEALING OF FUEL CELL CONNECTIONS
FUSELAGE TANKS



FUEL FLOW LINES — FUEL SERVO LINES — ENGINE FEED LINES — FUEL AND CONDENSATE DRAIN LINES — 23 P.S.I. ABSOLUTE PRESSURIZATION LINES — AIR DISCHARGE LINES

TMI-3410-2

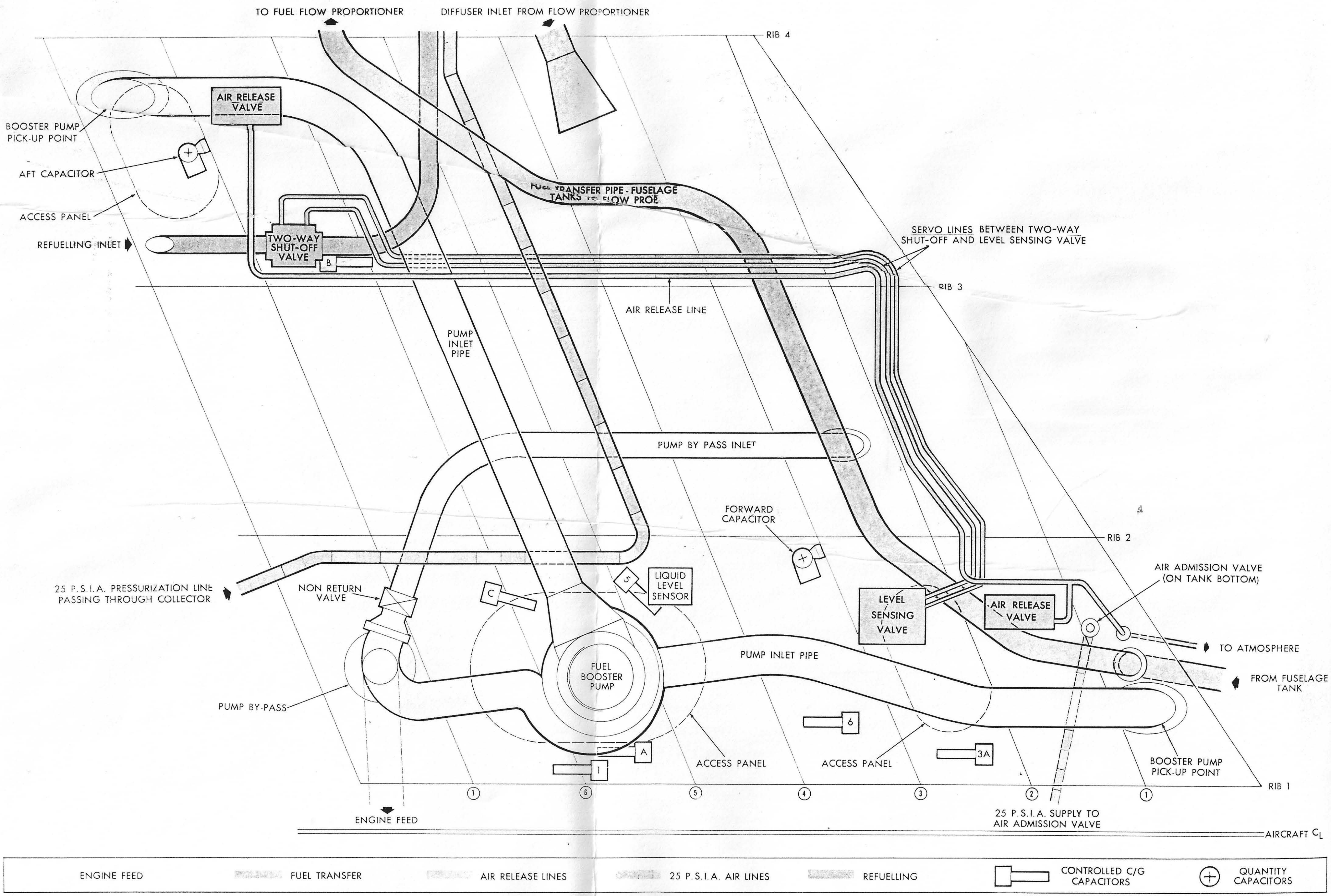
LAYOUT OF WING TANK COMPONENTS



C105-LD108-1

ARROW 1
COMPOSITE FUEL SYSTEM

–SECRET



COLLECTOR TANK COMPONENTS - FUEL SYSTEM (FLOW PROPORTIONER AND CONTROLLED C/G)

SECRET