JUNE 1957

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ARROW 2
FUEL SYSTEM

REPORT No. 72/SYSTEMS 16/21

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

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ARROW 2
FUEL SYSTEM

REPORT NO. 72/SYSTEMS 16/21

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This brochure is intended to provide an accurate description of the system(s) or service(s) for purposes of the Arrow 2 Mock-up Conference, and is not to be considered binding with respect to changes which may occur subsequent to the date of publication.

COMPILED BY ______ APPROVED BY Alan R. Buley

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

MALTON — ONTARIO

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

1. Design Objectives

1.1 General

To meet the requirements of AIR 7-4, CAP 479 and ARDCM 80-1.

1.2 Detailed

To provide for the following:

1.2.1 Sufficient internal storage capacity to meet engine requirements for both the 200 nautical mile mission and the 300 nautical mile mission, as stipulated in Paragraphs 3.6.1.1 and 3.6.1.2 of AIR 7-4.

1.2.2 Sufficient external storage capacity to extend the range of the aircraft to meet the 1500 nautical mile ferry mission requirement, as stipulated in Paragraph 3.7.1 of AIR 7-4.

1.2.3 An engine supply sub-system capable of supplying the maximum fuel demand of any power plant contemplated for use in the aircraft.

1.2.4 A transfer sub-system capable of transferring fuel from tributary tanks to the engine supply sub-system at rates up to the maximum demand for all operational attitudes of the aircraft.

1.2.5 A pressurization sub-system capable of preventing fuel boiling under all altitude and temperature conditions to be experienced by the aircraft.

1.2.6 A refueling sub-system to allow refueling for the primary mission, as described in Paragraph 3.6.1.1 of AIR 7-4,

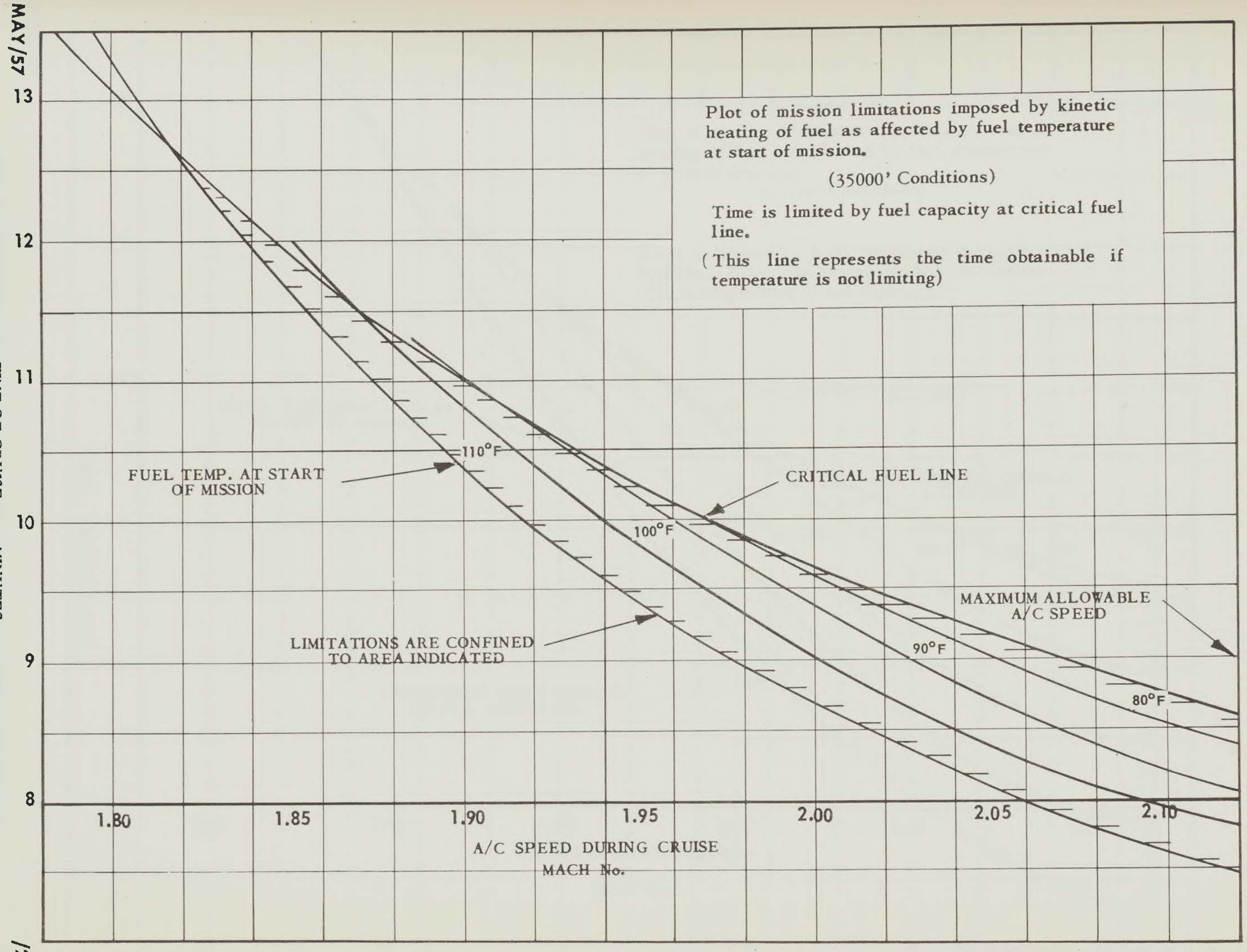


FIG. 1.1 MISSION LIMITIATONS IMPOSED BY KINETIC HEATING (35,000 FT.)

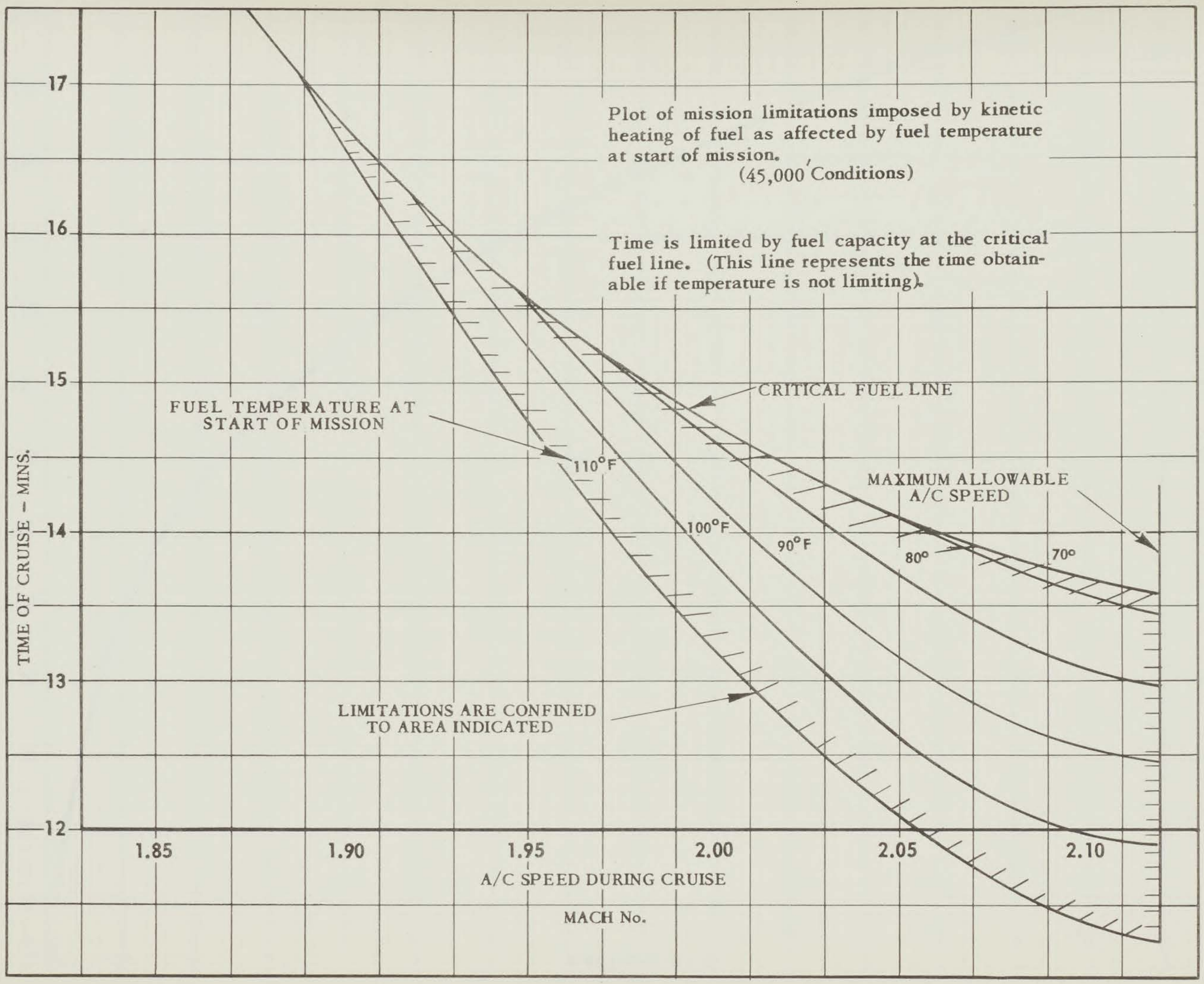
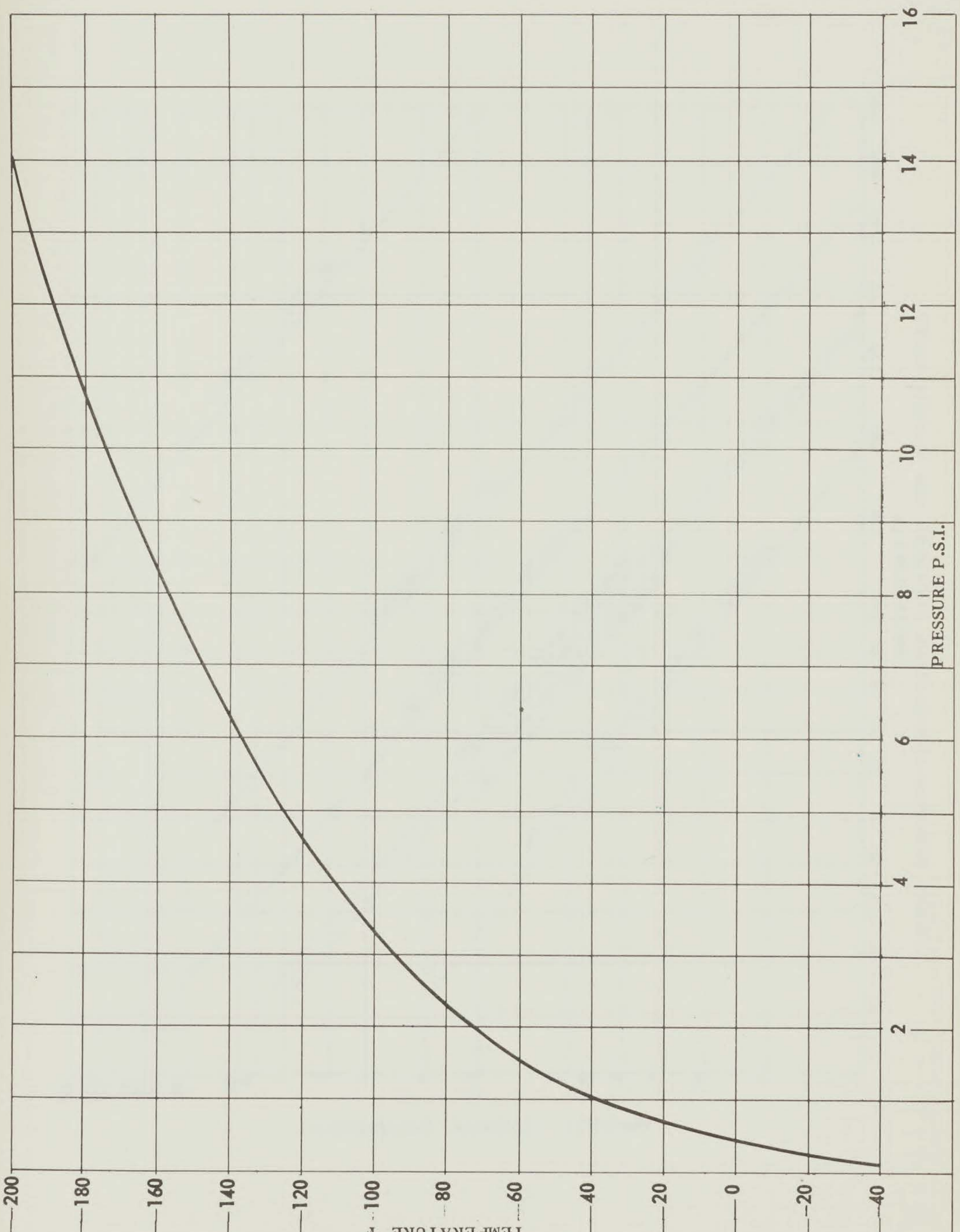
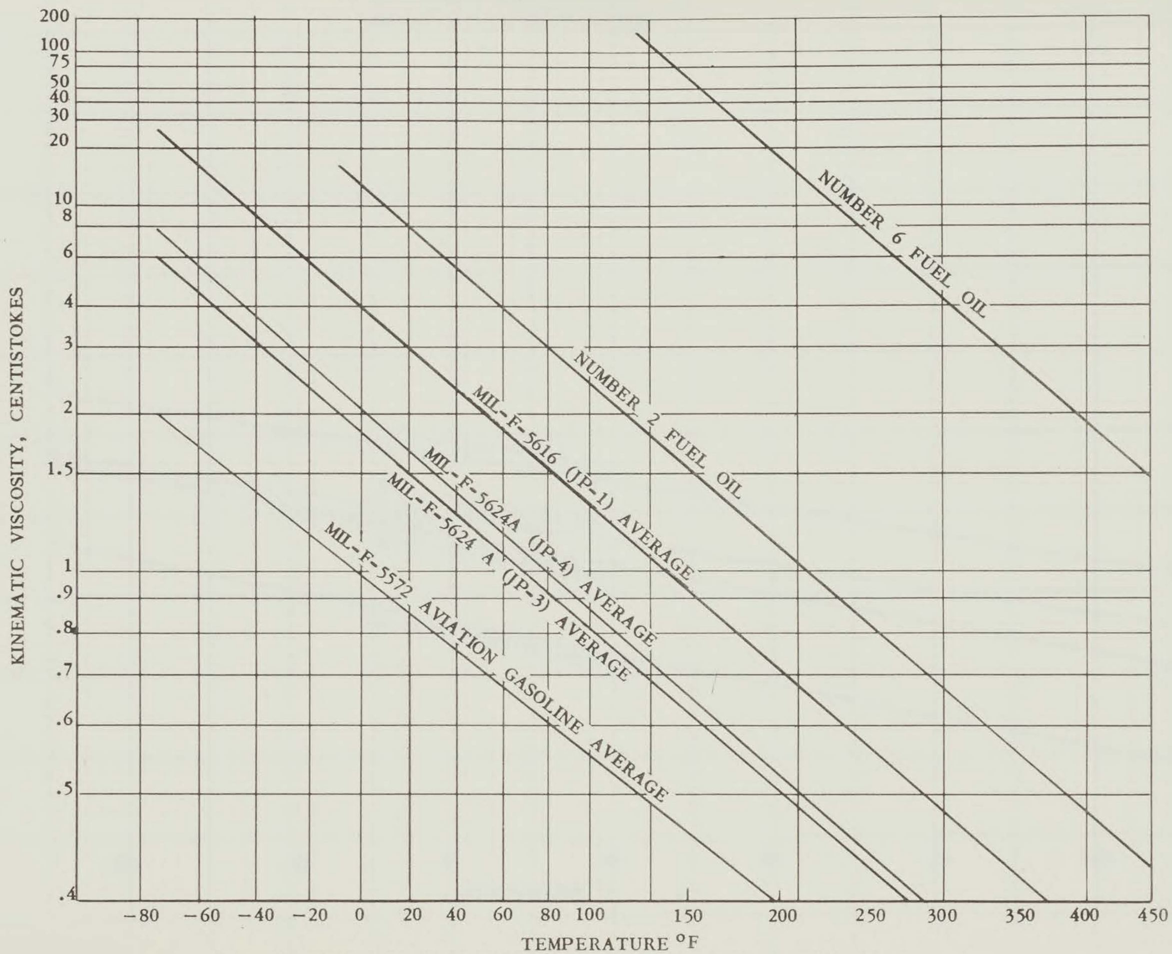


FIG. 1.2 MISSION LIMITATIONS IMPOSED BY KINETIC HEATING (45,000 FT.)



VARIATION OF VAPOUR PRESSURE WITH TEMPERATURE – JP4 FUEL

FIG. 1.3 VARIATION OF VAPOUR PRESSURE WITH TEMPERATURE - JP4 FUEL



A.S.T.M. VISCOSITY–TEMPERATURE RELATIONS FOR SEVERAL FUELS

FIG. 1.4 VISCOSITY VARIATION WITH TEMPERATURE

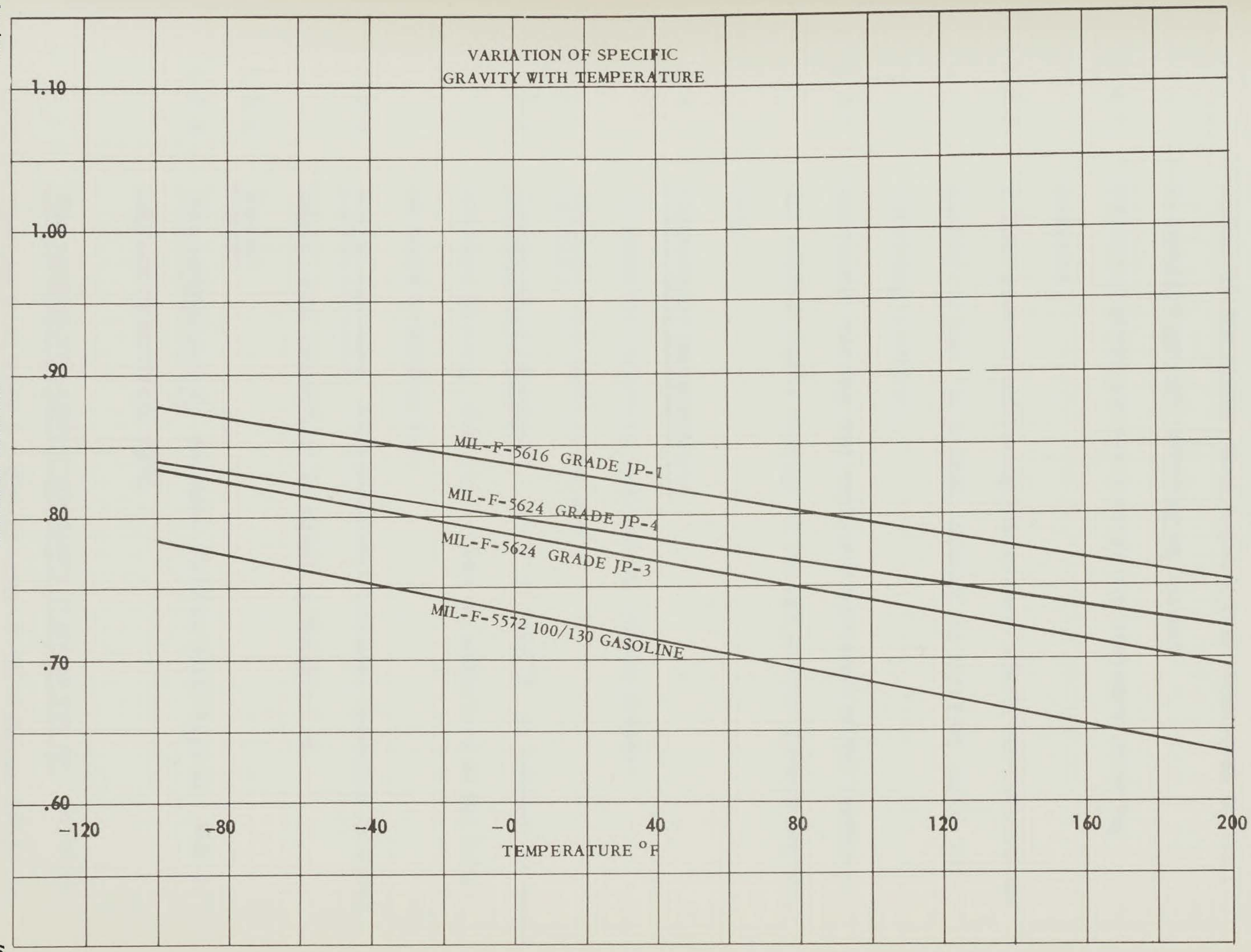


FIG. 1.5 VARIATION OF SPECIFIC GRAVITY WITH TEMPERATURE

within the ten minute turn-around time stipulated, by the use of standard ground refueling equipment.

1.2.7 Defueling of the system through the pressure refueling adaptors.

1.2.8 A fuel quantity indicating sub-system which will indicate the quantity of fuel, in pounds, aboard the aircraft, under all operating conditions.

1.2.9 Automatic warning and continued operation of the system in the event of battle damage or failure of vital system components.

1.3 Operational Requirements

To meet the following operational requirements:

1.3.1 Altitude: Sea level to 60,000 ft.

1.3.2 Temperature (Ambient): -65°F to +248°F, as induced by aerodynamic heating, with limitations on endurance at the latter as noted in Section 1.4.

1.3.3 Flight Attitudes: All operational attitudes including inverted flight, with limitations as shown in Section 1.4.

1.3.4 Fuels:

1.3.4.1 The normal use of: Aviation Turbine Fuel Type II 3-GP-22 (MIL-F-5624 Grade JP4).

The emergency combat and ferry mission use of: Aviation Turbine Fuel Type I 3-GP-23 (MIL-F-5616 Grade JP1).

<u>The emergency ferry mission use of:</u> Aviation Fuel 3-GP-25 (MIL-F-5572 100/130 Gasoline).

1.4 <u>Flight Limitations</u>

To impose an absolute minimum of flight limitations.

1.4.1 Inverted flight duration - 15 seconds of operation at maximum fuel flow to each engine at sea level.

1.4.2 Duration at maximum speed, as outlined by Figs. 1.1 and 1.2.

1.4.3 Long range ferry mission: The maximum speed of the aircraft with the long range tank installed is limited to Mach No.0.95

2. General Layout and Description

2.1 Introduction

Due to the conditions of high temperature, high altitude and high rates of fuel flow inherent in the supersonic performance characteristics of the Arrow 2, the design of the fuel system has of necessity, involved a number of unprecedented refinements. The requirement for virtually complete automatic operation, in a system of tanks distributed over some two-thirds of the total length of the aircraft, has added to the need for new measures to ensure an adequate and reliable fuel system.

From the outset it was apparent that a relatively high degree of pressurization of all fuel tanks was demanded, to prevent boiling of fuel in a system which must function at pressure altitudes up to 60,000 feet, and in conditions of aerokinetic heating up to fuel temperatures as high as 185°F. A system using J.P.4 fuel under these conditions would not tolerate, at any point, pressures lower than 10 psi (absolute).

Fuel flow demands of the order of 80,000 lbs/hr. per engine, call for pipe diameters as high as three inches, and fifteen H.P. booster pumps. Electrical, air turbine, and hydraulic drives for the fuel booster pumps were considered and rejected, for various reasons, in favour of shaft drive from the

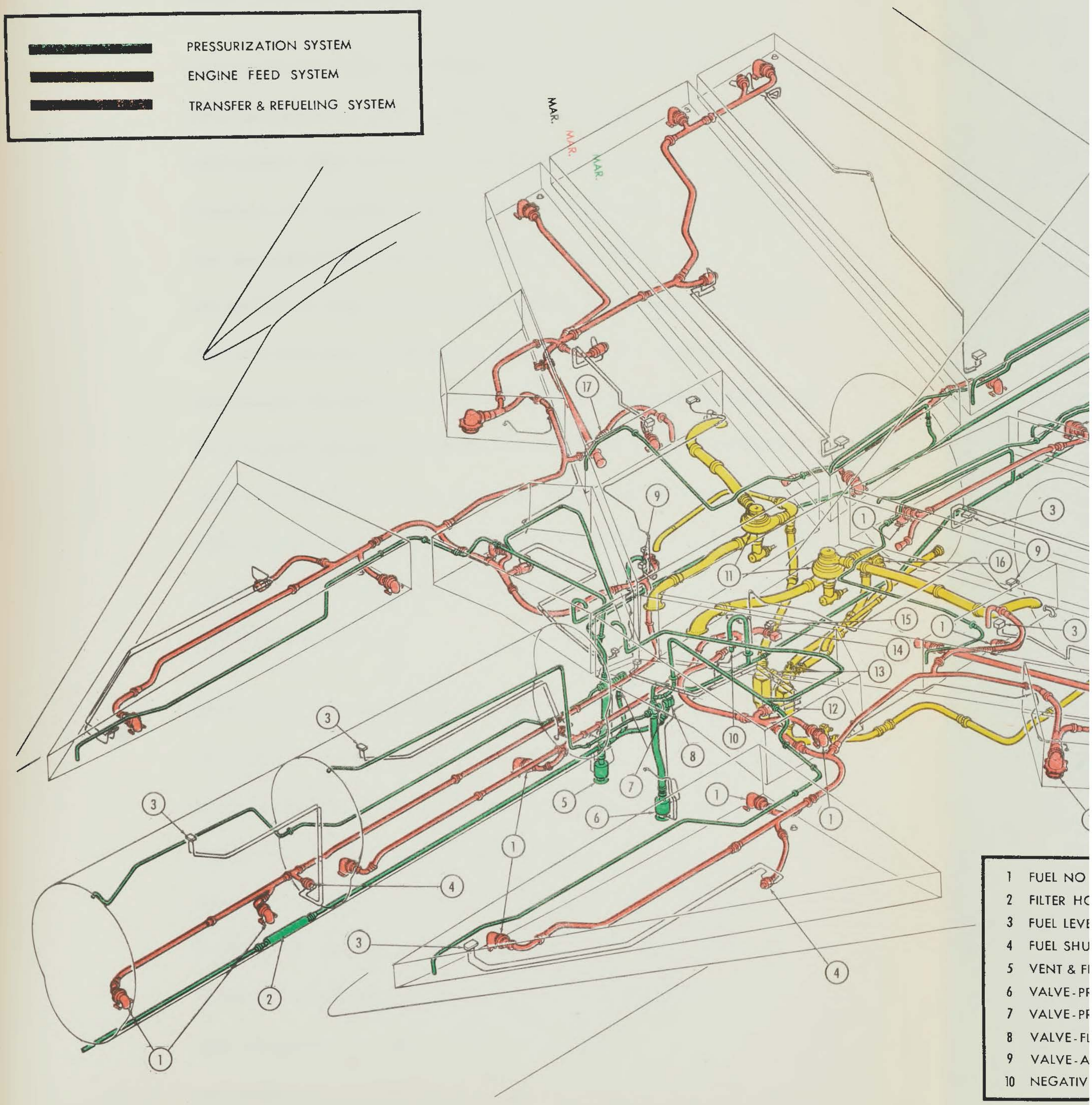
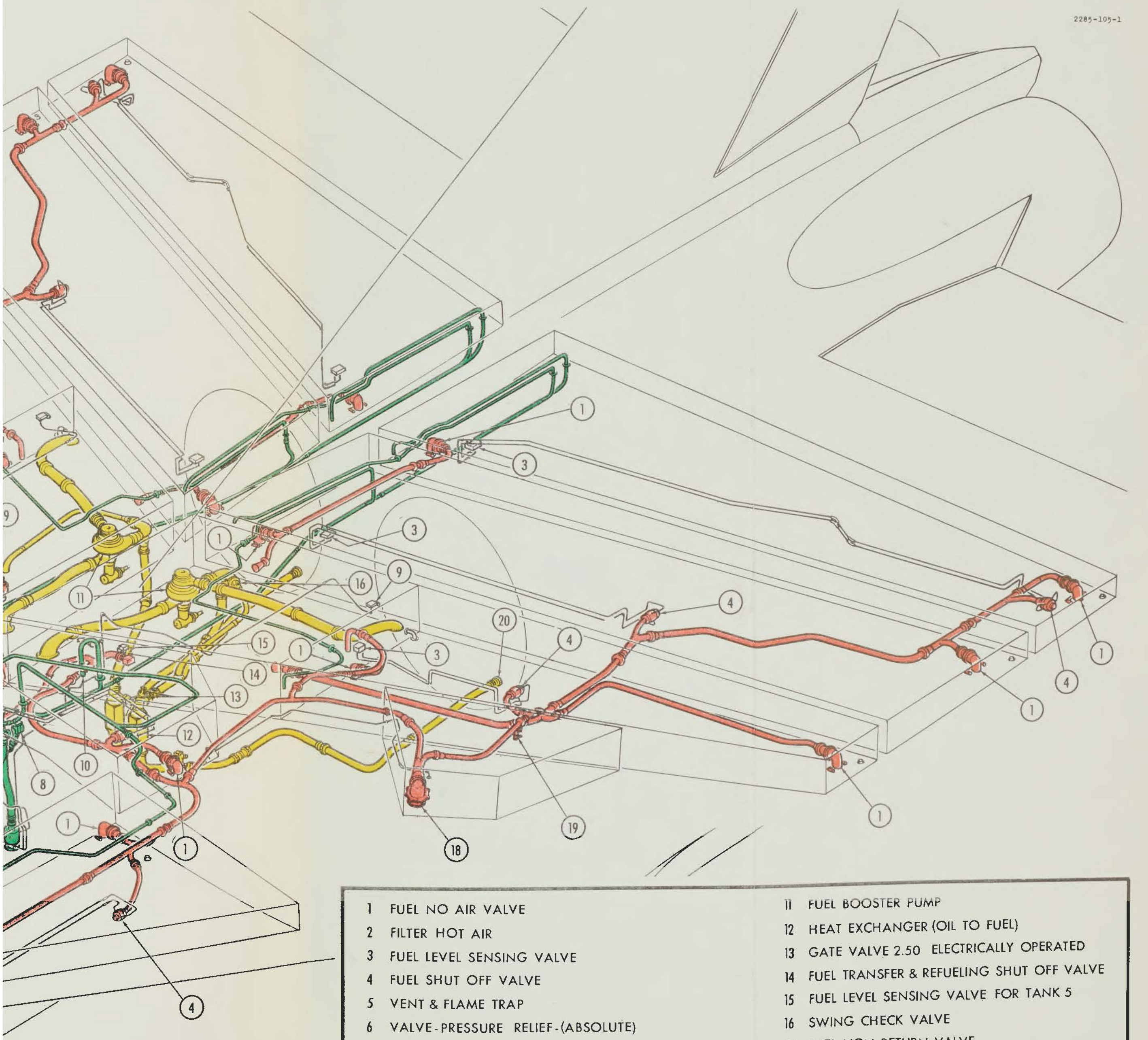


FIG. 2.1 FUEL SYSTEM - GENERAL ARRANGEMENT



1	FUEL NO AIR VALVE	11	FUEL BOOSTER PUMP
2	FILTER HOT AIR	12	HEAT EXCHANGER (OIL TO FUEL)
3	FUEL LEVEL SENSING VALVE	13	GATE VALVE 2.50 ELECTRICALLY OPERATED
4	FUEL SHUT OFF VALVE	14	FUEL TRANSFER & REFUELING SHUT OFF VALVE
5	VENT & FLAME TRAP	15	FUEL LEVEL SENSING VALVE FOR TANK 5
6	VALVE-PRESSURE RELIEF-(ABSOLUTE)	16	SWING CHECK VALVE
7	VALVE-PRESSURE REGULATOR (ABSOLUTE)	17	FUEL NON RETURN VALVE
8	VALVE-FLOW LIMITER-AIR	18	ADAPTOR PRESSURE FUEL SERVICING
9	VALVE-AIR RELEASE	19	GATE VALVE 2.50 MANUALLY OPERATED
10	NEGATIVE "G" & LOW VALVE-LEVEL AIR ADMISSION	20	ENGINE CONNECTION

FIG. 2.1 FUEL SYSTEM - GENERAL ARRANGEMENT

engine driven accessories gear boxes.

Fuel transfer from the widely distributed tributary tank system presented problems of some difficulty, in view of the inherently long shallow form of the wing tanks. Due to the pronounced anhedral of the thin delta wing of this aircraft, the normal points of fuel pick-up were of necessity at the aft outboard ends of the cells, where depth was insufficient for conventional mechanical pumps. In the interest of functional simplicity it was decided to effect the transfer of fuel from tributary tanks to the centrally located collector tanks by means of air pressure, regulated to a constant absolute value of 19 psi. Absolute pressurization precludes, the need for exhausting or inhaling of air from fuel tanks during climb or descent.

Evaluation of the aerodynamic characteristics of the Arrow 2 has indicated the desirability of reducing the static margin of the aircraft during the combat phase of the mission. The objective is to counteract the aft shift of centre-of-pressure that occurs in the transition from subsonic to supersonic flight, and thereby achieve a noticeable reduction in trim drag with a consequent increase in performance. To achieve this reduction in static margin, the aircraft fuel will be scheduled to transfer from individual tanks to the collector tank in a predetermined sequence. During cruise-out to combat, this schedule will cause a progressive shift aft of the aircraft C.G.

The nature of the aircraft's fuel system is such that elaborate precautions are necessary to minimize the inclusion of air due to changes of attitude causing uncovering of the fuel pick-up points in the tributary tanks. For this purpose a special fuel-no-air valve is mounted at the entry to the pick-up pipes in each tank. As a further measure "air release" valves are mounted in the collector tanks to discharge overboard any unwanted air evolving from the fuel, without reducing the tank pressure below the fuel vapour pressure.

No provision for gravity refueling has been made as it is assumed unlikely that the aircraft will be flown from bases at which pressure refueling tenders are not available. This assumption is made in view of the fact that the same tender will be a requirement for engine starting.

2.2 Layout

The fuel system consists of two almost symmetrical sub-systems: The port sub-system consisting of the aft fuselage tank together with six wing tanks, normally feeding the port engine, and the starboard sub-system consisting of the forward fuselage tank together with six wing tanks, normally feeding the starboard engine. Both fuselage tanks are of "double bubble" cross section and bladder type design. All wing tanks are of the integral type.

2.2.1 Fuselage Tanks

The fuselage tanks occupy the space between the engine intake ducts above the armament bay, from station 315 to station 480.

2.2.2 Wing Tanks

The wing tanks occupy the entire inner wing from the front spar to the rear spar, with the exception of a compartment forward of the main spar into which the main landing gear retracts.

2.2.3 External Tank

To increase the range of the aircraft to meet the requirements of the ferry mission, an external tank is provided which supplies fuel to both the right and left hand sub-systems. This tank is quickly detachable on the ground and is jettisonable in flight.

2.3 Normal Operation of the System

2.3.1 Engine Feed

Fuel is supplied from each sub-system to its respective engine by means of a booster pump, which is shaft driven by the engine and located in the collector tank of its respective sub-system. The booster pumps have inlets from

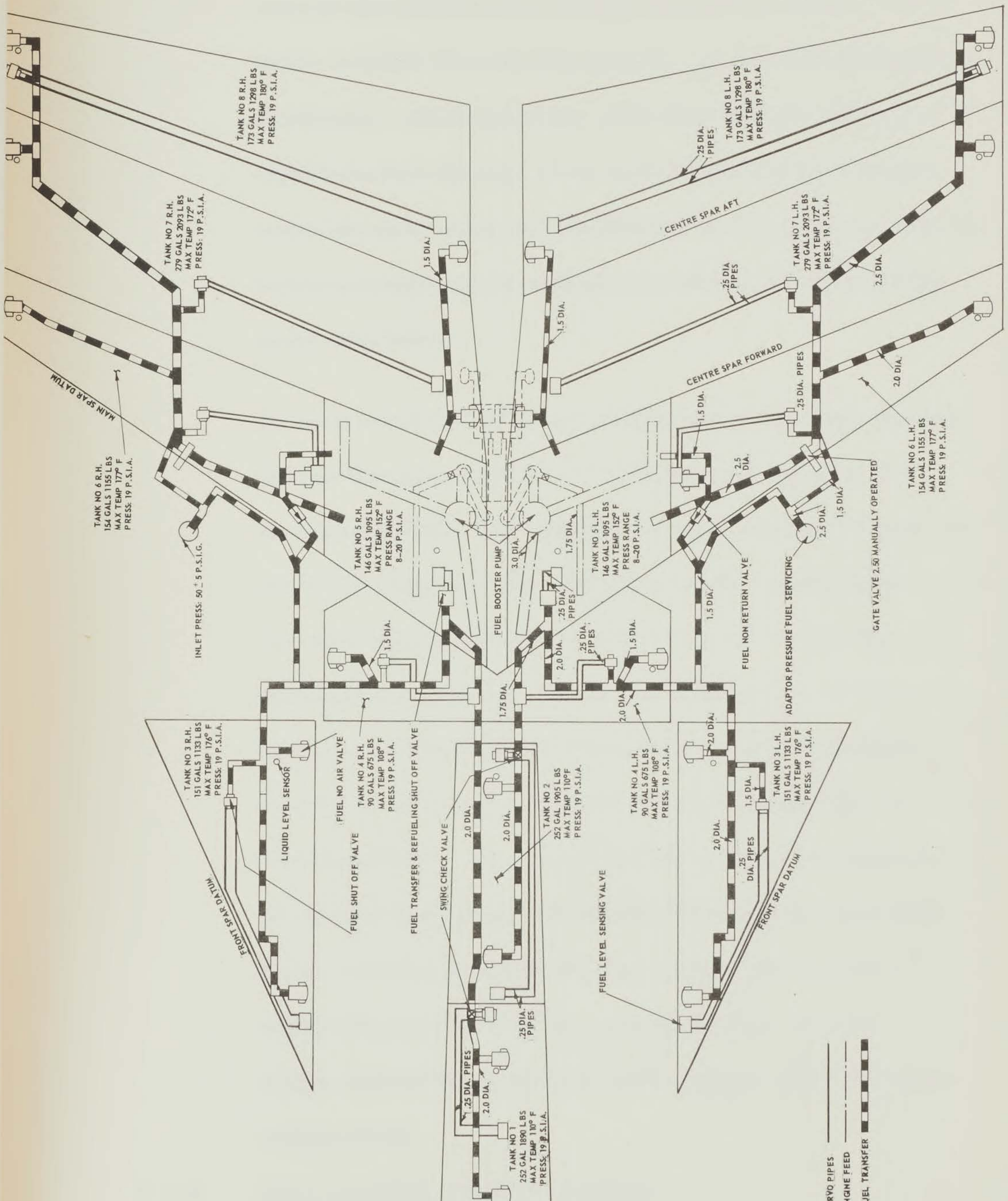


FIG. 2.2 FUEL TRANSFER AND ENGINE FEED SYSTEM

each of the extreme fore and aft corners of the collector tanks in order to cater for negative 'g' and extreme attitude conditions. Each pump has sufficient capacity to supply the maximum fuel demand of its own engine and afterburner, under the most adverse conditions, or to supply the requirements of both engines with partial afterburning under the same conditions.

Downstream of the booster pumps, fuel from each system passes through a gate valve that prevents pressure from an empty system from interfering with transfer of fuel from the other system in the event of a booster pump failure. The fuel then passes through an oil to fuel heat exchanger (See Brochures 72/Systems 32/35 and 72/Systems 19/26) at the entrance to which the two systems are cross-connected through a motor operated gate valve, normally kept in the closed position. The fuel then flows to each engines' fuel connection through an electrically operated low pressure cock, which is provided for the purpose of isolating the engine for servicing or for emergency fuel shut-off. A single connection is made to each engine within the engine compartment.

2.3.2 Fuel Transfer and C.G. Control

Until flight experience has demonstrated the adequacy of the damping system the fuel control system will, in addition to meeting the normal combat requirements, provide the facility for maintaining the C.G. between normal design limits (i.e. 28-31% MAC). When the damping system reliability has been proven, this additional feature will only be necessary for flights involving immediate or rapid landing after take-off, such as training and other non-combat flights.

A C.G. master switch on the Master Refueling Panel is operated to obtain either of the two transfer sequences, according to the C.G. shift desired. There will be no provision for switching transfer patterns in flight. Normal combat transfer sequence with the furthest possible aft C.G. shift will be:

R.H. 1, 3, 4, 6, 7, 8, 5

L.H. 2, 3, 4, 6, 7, 8, 5 (Ref. Fig. 2.4)

The alternative mission sequence will be selected to maintain the C.G. between the 28-31% MAC limits and the best transfer sequence will be decided at a later stage.

All tributary tanks are drained through fuel-no-air valves which are situated in the extreme corners of each tank. Control of the draining sequence is achieved by mounting a thermistor type level switch in each tributary tank, at a fuel level just above that which would shut off the last

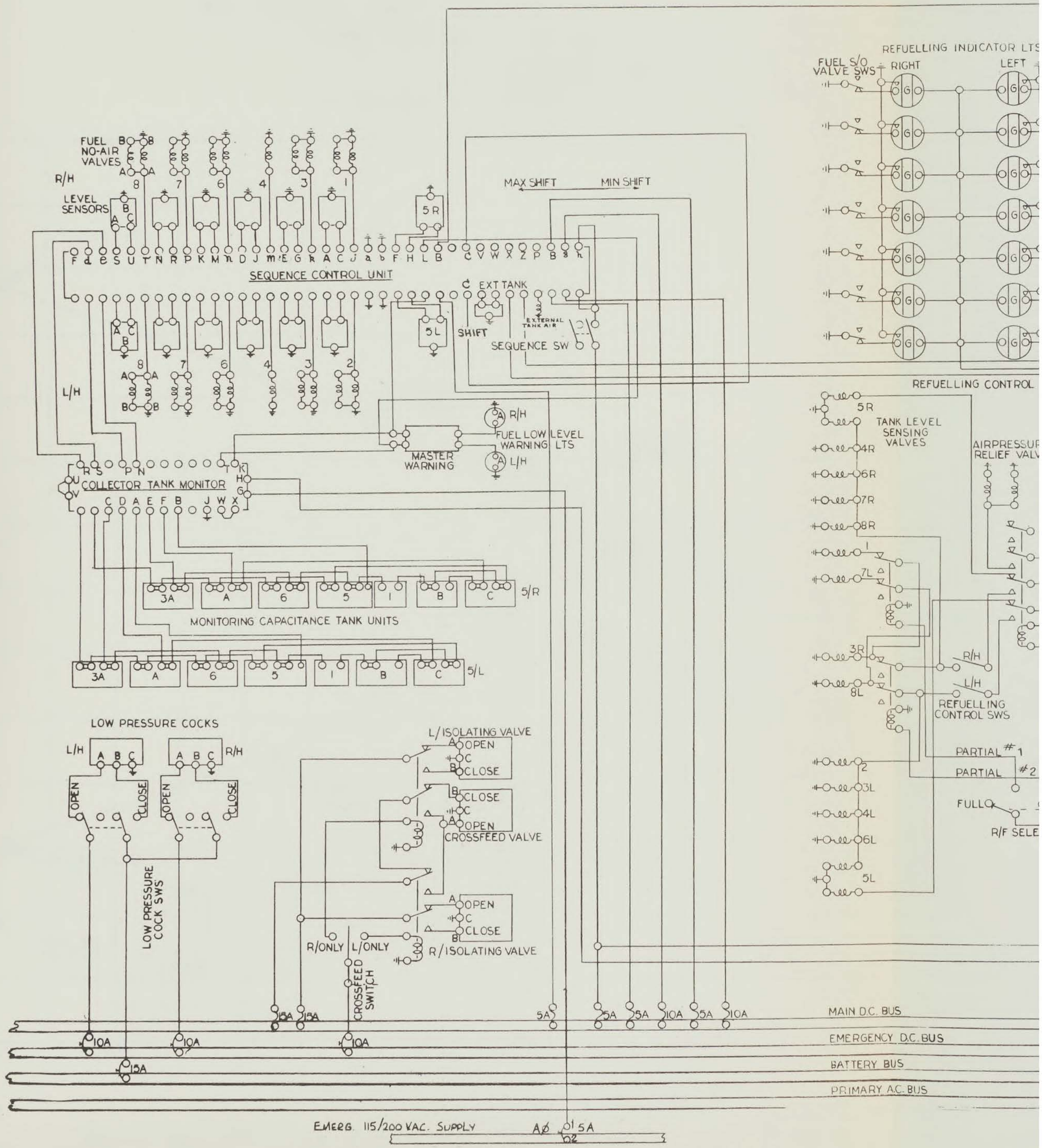
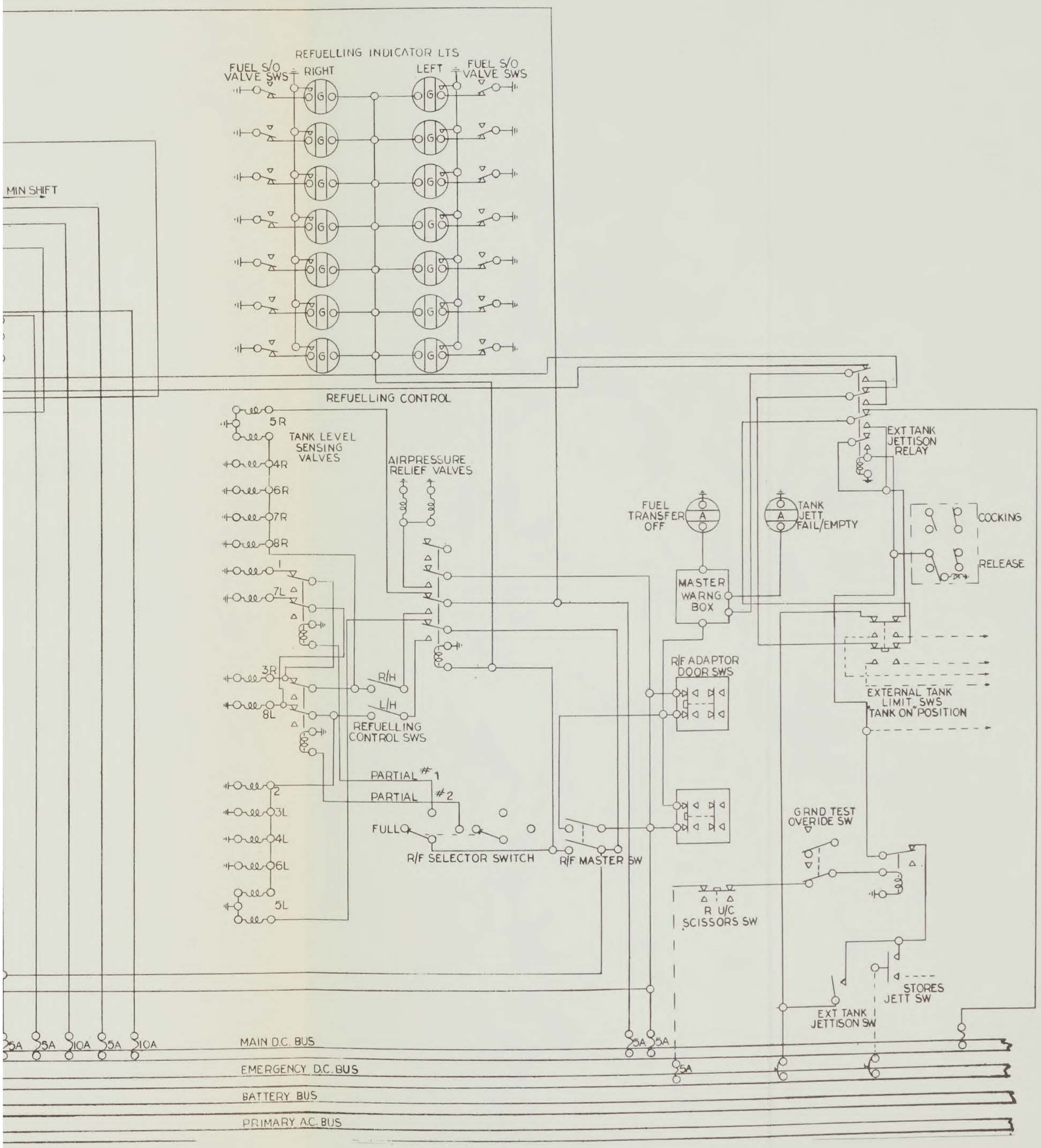


FIG. 2.3 FUEL CONTROL ELECTRICAL WIRING DIAGRA



2.3 FUEL CONTROL ELECTRICAL WIRING DIAGRAM

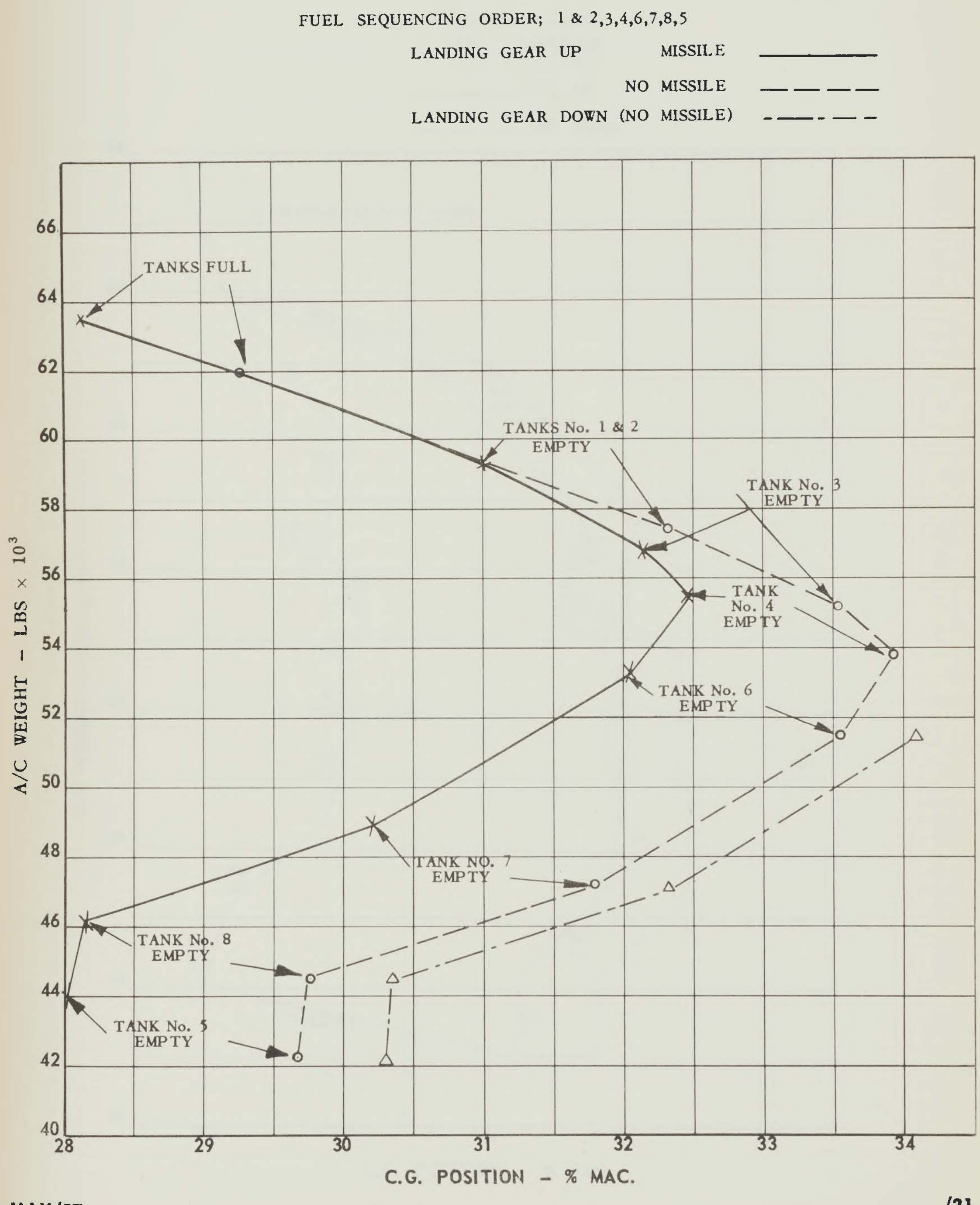


FIG. 2.4 C.G. SHIFT VS FUEL CONSUMPTION - NORMAL SEQUENCE

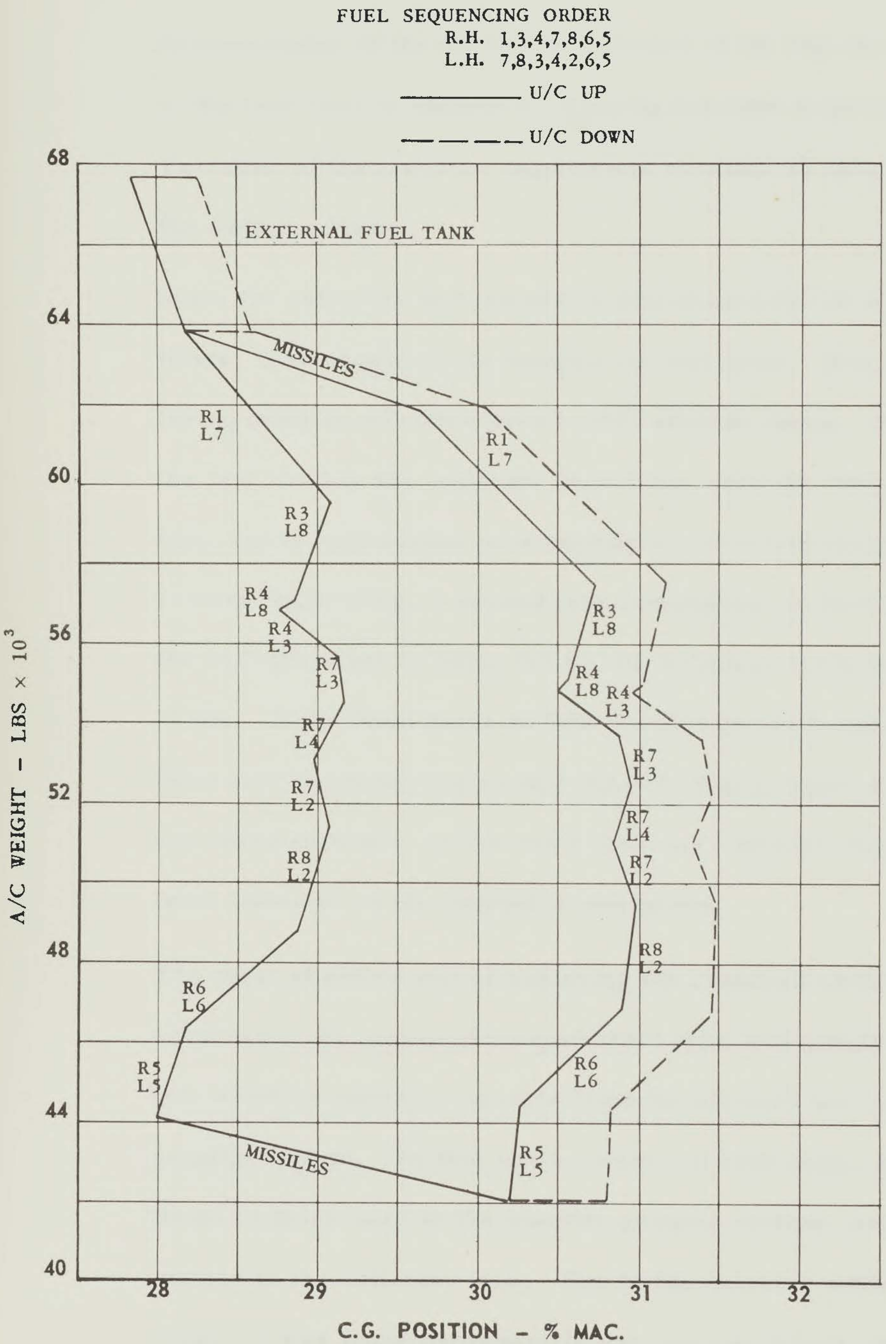


FIG. 2.5 C.G. SHIFT VS FUEL CONSUMPTION - ALTERNATIVE SEQUENCE

fuel-no-air valve in the tank. This level switch controls the de-energizing of the over-ride solenoid of the fuel-no-air valve in the tank next in sequence, allowing transfer to proceed. Variation of the transfer sequence is possible by re-orientating the switch outputs.

Since the collector tank should be maintained full at all times, it is necessary to monitor its fuel level. The monitoring must be affective over a $\pm 80^{\circ}$ attitude range. When the fuel level in the collector tank drops until the tank is 90% full, due to high engine consumption or incorrect transfer system functioning, a second tank commences to feed so that the collector tank is being fed by two tributary tanks instead of one. If the level drops to 70% of collector tank capacity a third tank is introduced so that three tributary tanks are feeding simultaneously, at the same time the collector tank low level indicator in the cockpit is energized.

The most effective way of achieving the required switching accuracy is by means of a capacitance type fuel gauging system which is entirely separate from the aircraft fuel quantity gauging system. To this end a number of tank units, additional to those used in the quantity gauging system, are located in the collector tank. Due to the extreme attitude range, it was found necessary to use one set of tank units for the condition from cruise to 80° nose up and another set from cruise to 80° nose down. A single attitude sensor operating two double pole-double throw relays, is common to both the left and right tank systems.

When the collector tank fuel is above the 90% level the tributary tanks drain singly in the pre-selected sequence, until the sensor in the first tank to drain is exposed to air. This sensor then balances a bridge circuit and energizes a relay, removing the 28 V-DC from the next valve coil, opening it and allowing the next tank in sequence to drain, the fuel-no-air valve in the first tank now being closed. Any basic sequence can be chosen by initially connecting the fuel-no-air valve over-ride solenoid coils to a control unit. If at any time the fuel transfer rate lags behind the engine demand, and the collector tank fuel level drops to 90% of tank capacity, then the contact switch of the true volume fuel gauge in the tank closes, energizing a relay which causes the tanks to drain two-at-a-time instead of singly. The additional tank drained being the one following in normal sequence. When the collector tank fuel again rises above the 90% level, the abnormal two-at-a-time sequence is interupted and the normal sequence resumed. Similarly, if the fuel in the collector tank falls below the 70% level, yet another relay is energized. This changes the "two-at-a-time" draining sequence to "three-at-a-time" and at the same time a cockpit warning lamp is illuminated.

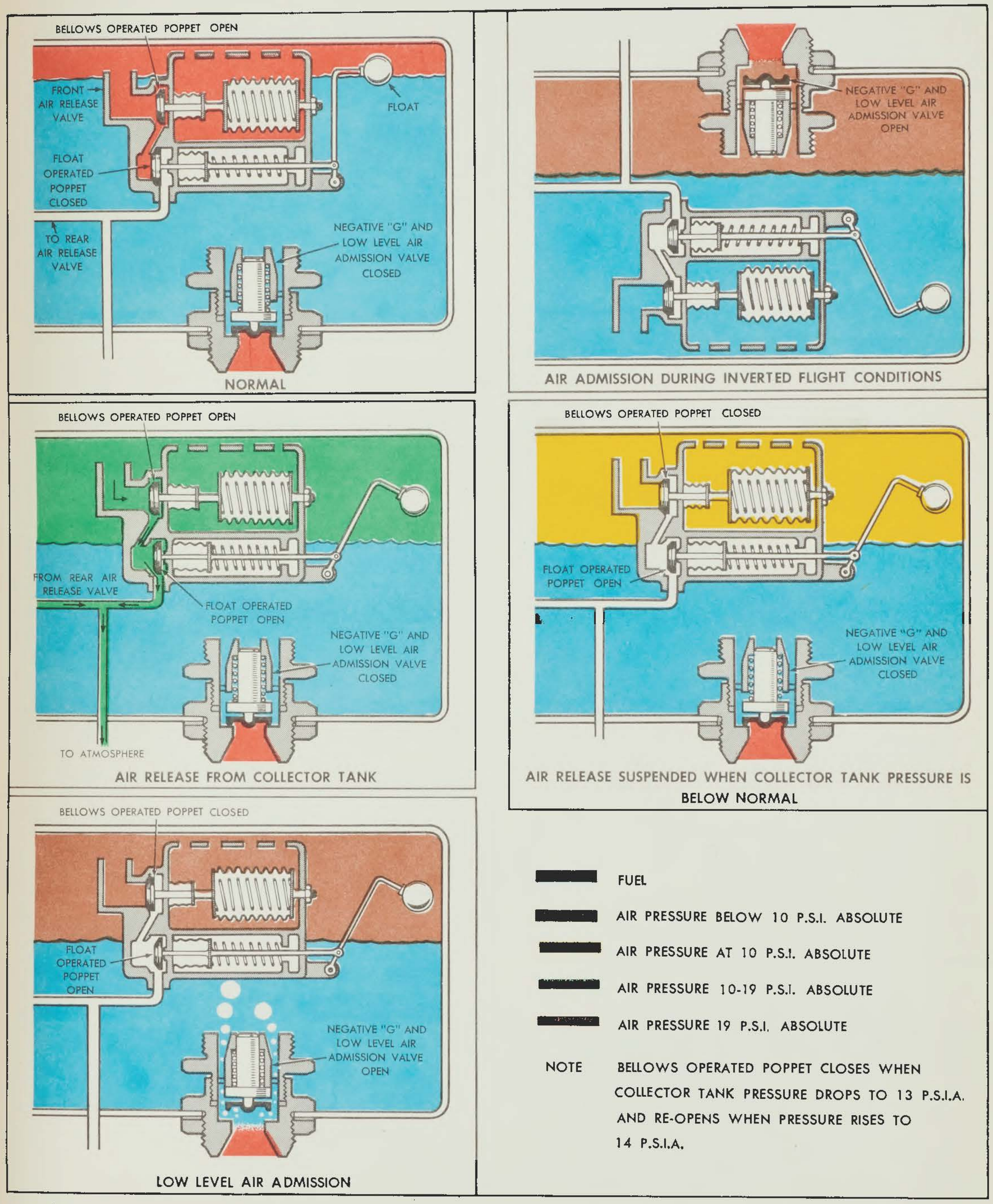


FIG. 2.6 COLLECTOR TANK AIR ADMISSION AND AIR RELEASE

If the collector tank fuel drops to an unsafe level below the 70% level, due to incorrect functioning of the monitoring system, a thermistor level switch sensor, which operates independently of the monitoring system, causes the tributary tanks to drain "two-at-a-time" in addition to illuminating the cockpit warning lamp.

Air which is held in solution in the fuel or which has leaked into the system is separated from the fuel by the booster pumps and discharged overboard from the collector tanks through air release valves situated in two extreme corners of each tank. The booster pumps are equipped with air extraction devices to minimize cavitation or stalling.

Operation of the fuel transfer system is automatic, requiring no attention from the pilot whatsoever.

2.3.3 Tank Pressurization

Engine bleed air, taken from the air conditioning system downstream of the ram air heat exchanger, is used for tank pressurization to prevent fuel boiling and to achieve transfer.

The pressure in all internal tanks, with the exception of the collector tank, is regulated to a nominal 19 psi (absolute) which is sufficient to overcome all fuel flow losses and hydrostatic heads, and to prevent fuel boiling.

For the sake of simplifying this description the internal fuel system will be regarded as two sub-systems, namely, the starboard wing plus the forward fuselage tank, and the port wing plus the aft fuselage tank.

The fuel system derives air from a high pressure manifold connected to the downstream side of the air conditioning and pressurizing system heat exchanger. The air is passed through a hot air filter to the two sub-systems, each of which incorporates a flow limiter and a pressure regulator. From the downstream side of each regulator a branch pipe leads overboard through a pressure relief valve, the overboard outlets being protected from the effects of missile blast by flame traps at the points of exit through the aircraft skin.

The relief valves, together with the upstream flow limiters, protect the system from a regulator failure by allowing sufficient air to flow overboard to maintain the correct pressure at the inlet to each tank. The pipe sizes are such as to prevent an excessive loss of air from a damaged tank, so that resultant drop in pressure in all other tanks in the system is avoided.

Air is supplied to the collector tanks during negative 'G' operation and during the final emptying of the collector tanks

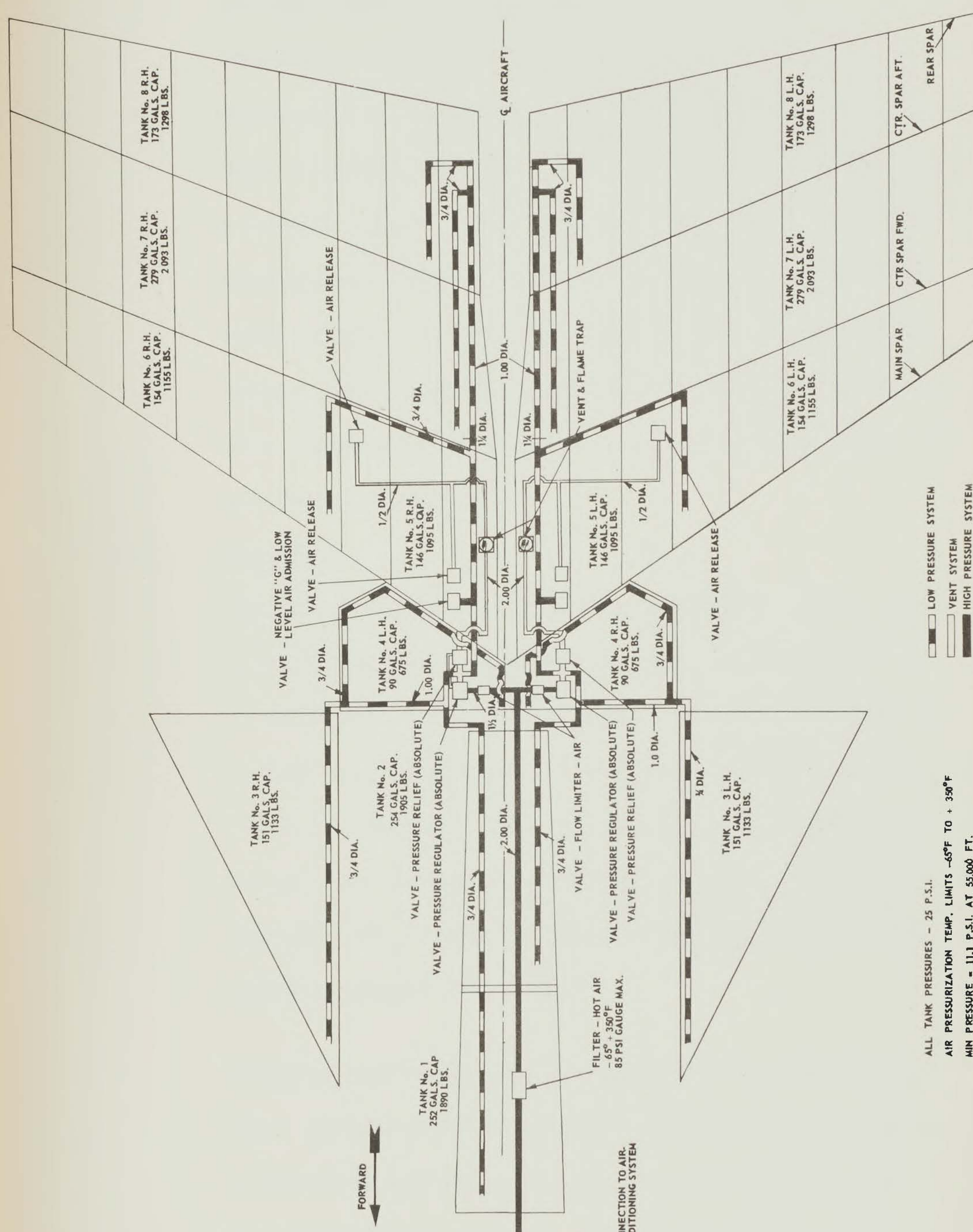


FIG. 2.7 PRESSURIZATION DIAGRAMMATIC FUEL SYSTEM

through negative 'g' and low level air admission valves. These valves limit the pressure difference between the collector tanks and the tributary wing tanks to 12 psi, leaving an absolute pressure in the collector tanks sufficient to prevent the fuel boiling at its maximum temperature. This air, upon resumption of normal flight conditions, with fuel flowing into the collector tanks, is discharged to atmosphere through the air release valves. The air is discharged by an artificial low pressure sink, obtained by using engine bleed air to create a low pressure by venturi action.

2.3.4 Refueling

The aircraft is refueled through two standard, $2\frac{1}{2}$ inch (nominal size) pressure refueling adaptors. One adaptor being located on each side of the aircraft, just aft of the main landing gear wells. Fuel is conducted from this point to all tanks, flow being prevented from entering the collector tanks via the normal transfer pipe by means of a mechanically operated shut-off valve, which is closed by the action of opening the refueling adaptor access door.

A partial refueling setting is required for the primary mission. This becomes a problem since certain combinations of full and empty tanks can produce an aircraft C.G. location unsuitable for take-off. The solution is to provide a

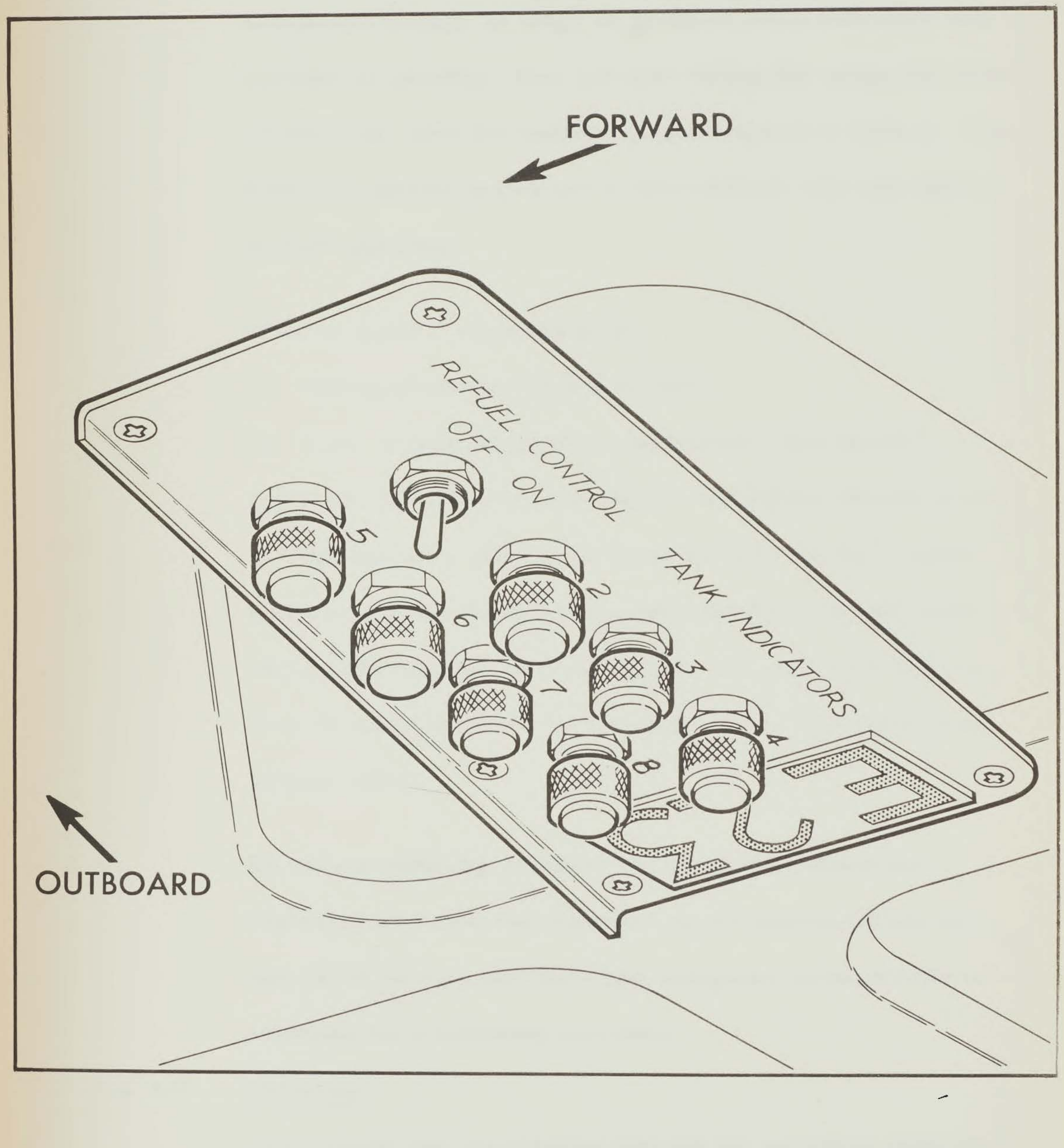


FIG. 2.8 REFUELING CONTROL AND SIGNAL PANEL

number of alternative fuel loads which keep the C.G. within desired limits. These alternatives are provided by first completely filling, as large or group of tanks from both sub-systems as possible, then partially filling the remaining tanks as required, until the desired quantity of fuel is aboard. The Refueling Master Switch has a "Full Refuel" and two "Partial Refuel" positions.

"Partial Refuel" selection gives:

(1) Filling of selected group of tanks.

(2) Flow in remaining tanks, controlled at the bowser.

If the full fuel capacity is required, the Master Switch is set to "Full Refuel". Fuel is fed to each tank, via the normal transfer system, through servo operated fuel shut-off valves which are energized to remain open. As each tank fills its shut-off valve is closed by the action of its associated level sensing valve.

To reduce refueling pressure requirements, electrical overrides have been incorporated on all pressurization system relief valves, and these are energized automatically on selecting for a refueling operation.

2.3.5 Defueling

The aircraft may be defueled through the pressure refueling adaptor by selecting "Defuel" on the refueling control panel, then applying air pressure to a ground connection located in the pressurization line, forward of the air filter. The applied pressure causes transfer of fuel from the tributary tanks to the adaptor. Suction at the refueling nozzle is required for defueling the collector tank.

2.3.6 Fuel Quantity Indicating System

Two independent, capacitance type fuel gauging sub-systems are provided; one to indicate the weight of fuel in the right-hand fuel tank system, and the other, the weight of fuel in the left-hand fuel tank system.

The capacitor-type fuel quantity gauging system is an electronic fuel measuring device which indicates fuel in pounds.

Basically, the transistorized system used on this aircraft is a two-unit system, consisting only of an indicator and a "tank unit", which constitutes a re-balancing capacitance bridge. The "tank-unit" is actually several capacitance sensing units, located in each fuel tank and connected in parallel.

A change in fuel quantity causes a change in tank unit capacitance in one leg of the bridge, which unbalances the bridge. This out-of-balance condition results in a voltage signal which is amplified by a phase sensitive, transistorized amplifier

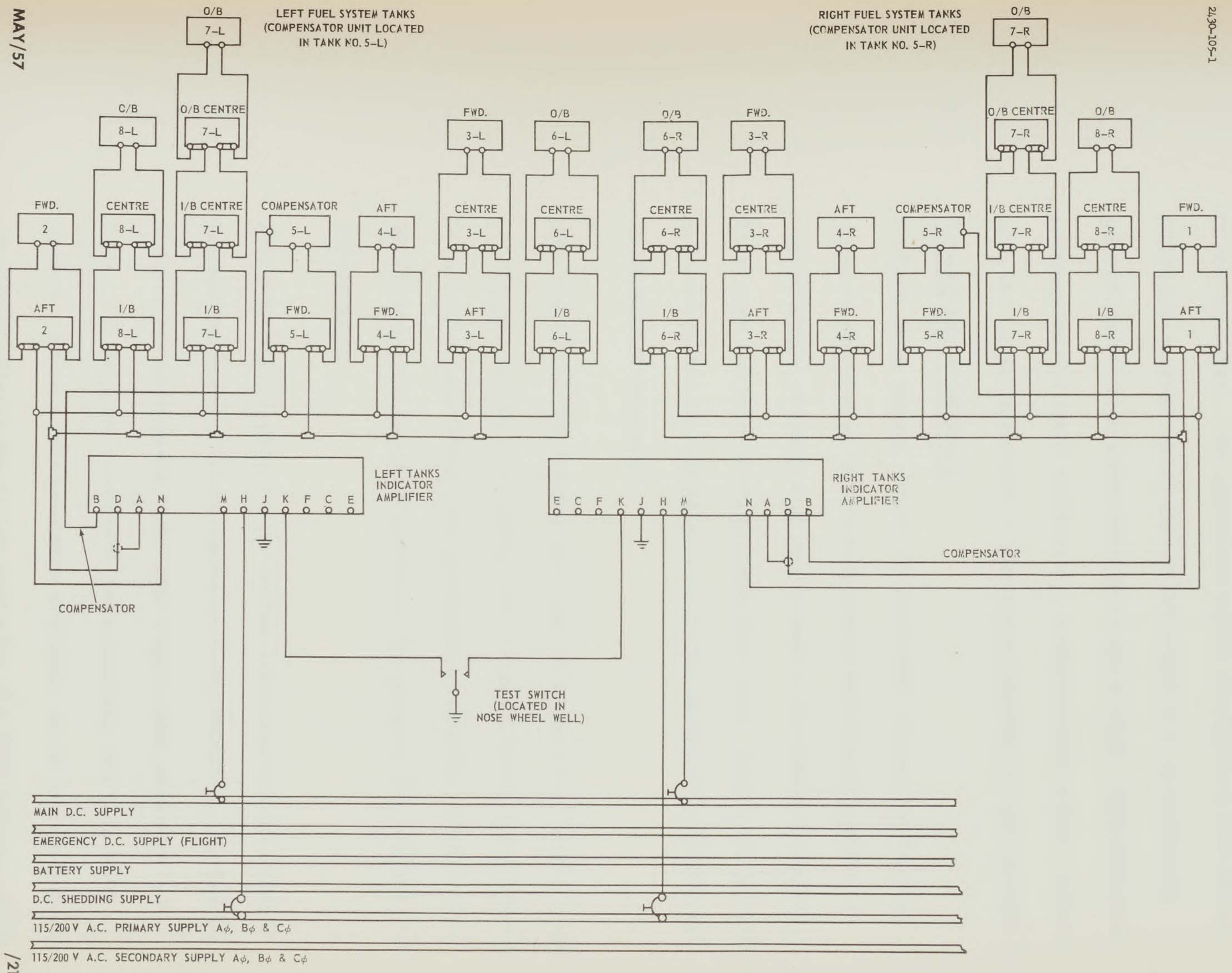


FIG. 2.9 FUEL QUANTITY—ELECTRICAL WIRING DIAGRAM

in the indicator. The amplified signal energizes a two-phase indication motor, which drives the wiper of a re-balancing potentiometer to restore balance in the bridge. The indicator pointer, on the same shaft as the potentiometer wiper, rotates with the wiper to provide a continuous reading of fuel quantity.

2.4 Emergency Provisions

Failure of an engine, which automatically means the slowing down or stopping of the corresponding fuel booster pump, or direct failure of the pump, will result in fuel being consumed from only one side of the aircraft at a time. However, adequate aileron control is available to cater for the worst possible aircraft lateral unbalance.

The fuel in the inoperative sub-system becomes available when the operative side is emptied, and its pump discharge pressure falls to the point where tank pressure is capable of delivering fuel through the by-pass system of the pump in the inoperative sub-system.

The pilot will be expected to refrain from opening the throttle beyond sea level military rating on being warned by an amber light on his instrument panel that engine inlet pressure has fallen. If the light continues, the crossfeed valve must be opened. Failure of a pressure regulator in the pressurization system is catered for by the provision of a flow limiter on the upstream side of the regulator, to limit the air flow to a value slightly above the normal maximum demand. In addition, an air pressure relief valve limits the air pressure at the inlet to the tank system.

The small pipe sizes restrict air pressurization loss from battle damaged tanks.

A thermistor type low level warning switch that operates independently of the sequencing control, is mounted in the collector tanks at a level below that of the 'three tanks transferring', or 70% level signal of the monitor unit.

2.5 Long Range Provision

To meet the requirements of the long range ferry mission, a single tank of five-hundred gallons capacity is installed on the under-side of the fuselage. (See Fig 2. 10). Fuel transfer is effected by means of an extension of the aircraft pressurization system, of 19 psi (absolute) nominal pressure, and the Series Sequencing System.

The drop tank is the first tank in the sequence and thus the first to drain; the addition of the drop tank now means that all tanks in the aircraft internal fuel system are connected, through their fuel-no-air valve solenoid coils, to the Sequence Control Units.

Dry disconnect valves and spring loaded couplings, break transfer and pressurization lines automatically when the tank is dropped. Non return valves fitted inside the aircraft also ensure there can be no air or fuel escape.

Filling is accomplished by hand through the top of the drop tank.

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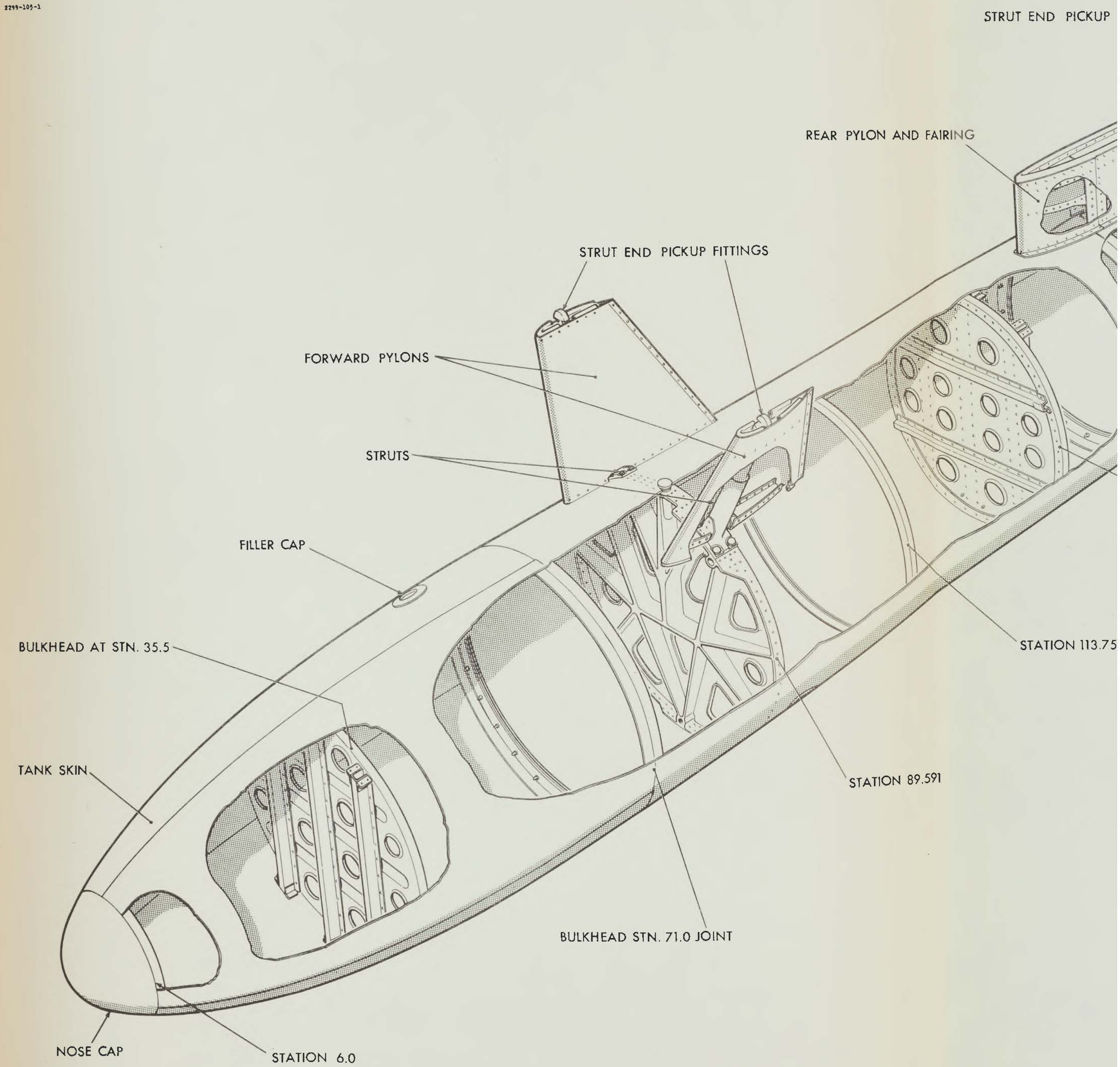

FIG. 2.10 DROP TANK - GENERAL ARRANGEMENT

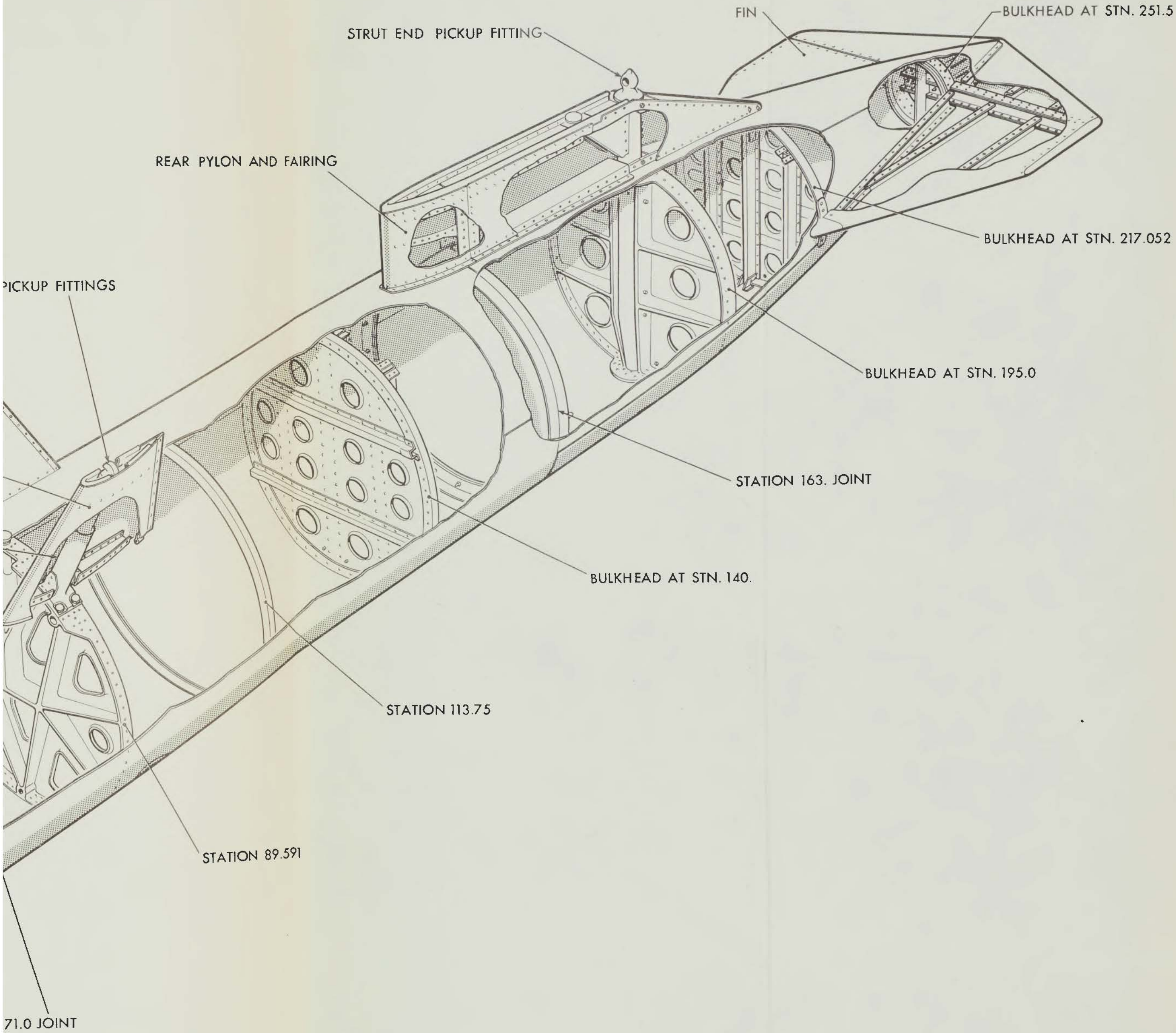

FIG. 2.10 DROP TANK - GENERAL ARRANGEMENT

3. Description of Main Components

3.1 Engine Supply Sub-System (See Fig. 3.1)

3.1.1 Pump-Fuel Booster

3.1.1.1 Purpose

To provide sufficient pressure at the inlet to the engine driven fuel booster pump, to suppress boiling and prevent subsequent vapor lock.

3.1.1.2 Description - (See Fig. 3.2)

The pump has two separate pumping elements as an integral unit, each having its own repriming element. The repriming elements are sliding vane type vacuum pumps having four blades each. Each pump has its own inlet and discharge scroll. Air leakage from one element to the other during repriming is practically eliminated by labyrinth seals on the back side of the impellers, and flapper type check valves located in each scroll immediately before the common discharge point. Light spring loads keep the check valves of the element closed during repriming operations to prevent air leakage from element to element, which would defeat any repriming efforts.

Repriming is accomplished by creating a slight vacuum within the element to be reprimed. This causes fuel to rise in the inlet line to the impeller, for restoration of fuel pump performance. To ensure that the fuel rises to and within the impeller for successful repriming, the inlet of each vacuum

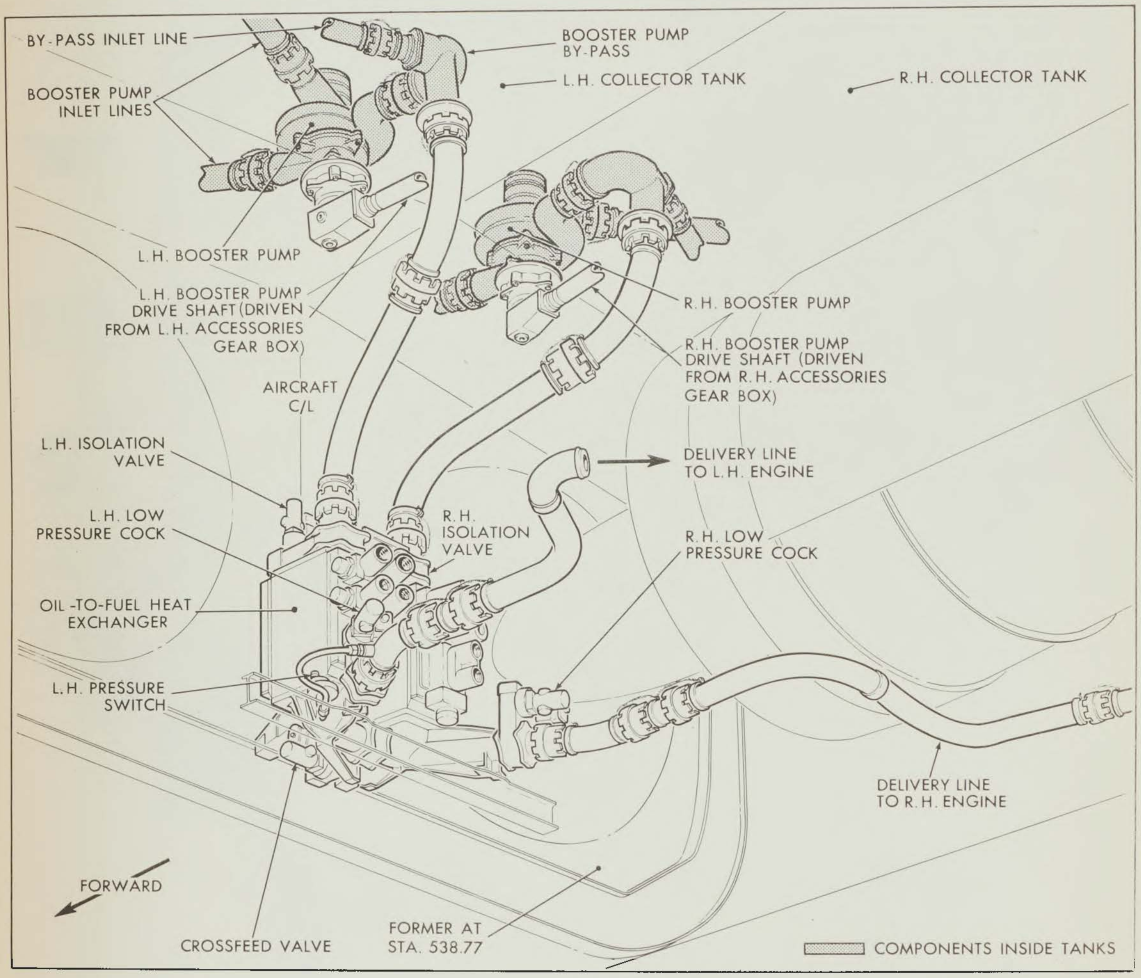

FIG. 3.1 ENGINE SUPPLY SUB-SYSTEM

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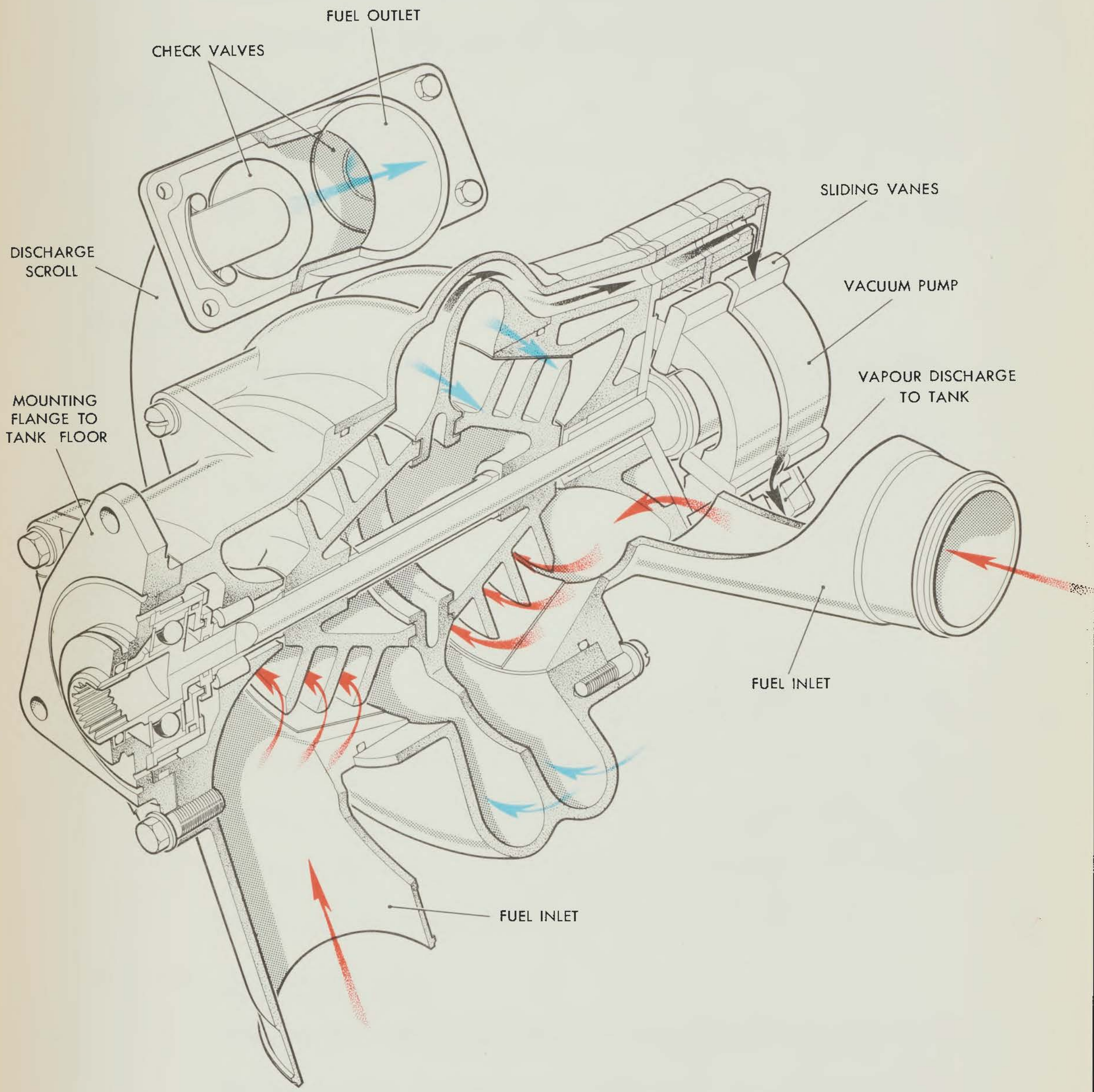

FIG. 3.2 FUEL BOOSTER PUMP

pump is connected to the discharge scroll of the element with which it is associated. The discharge from the vacuum pumps is fed directly back into the tank in which the pump is mounted.

3.1.1.3 Rating

Each pump is capable of delivering fuel at the rate of 100,000 lbs. per hour, with a pressure rise through the pump of 15 psi, and only one of the two inlets covered by fuel.

3.1.1.4 Power

The power required to drive the pump is obtained from the aircraft accessories gear box through a shaft drive. Each pump derives its power from the engine on its respective side of the aircraft. There is no mechanical linkage between the two sides.

3.1.1.5 Emergency Provisions

To provide for failure of a pump or its drive, an aircraft mounted by-pass has been incorporated which is capable of delivering fuel into the engine feed line, downstream of the pump, at rates up to the demand of a single engine on military rating at sea level. This by-pass is closed by a check valve, to prevent recirculation with the pump operating.

3.1.1.6 Ground Checking

The booster pumps may be checked during engine run-up tests by opening the refueling access door. This action shuts-off transfer from the tributary tanks to the collector tanks, and in doing so reduces the collector tank pressure to atmospheric.

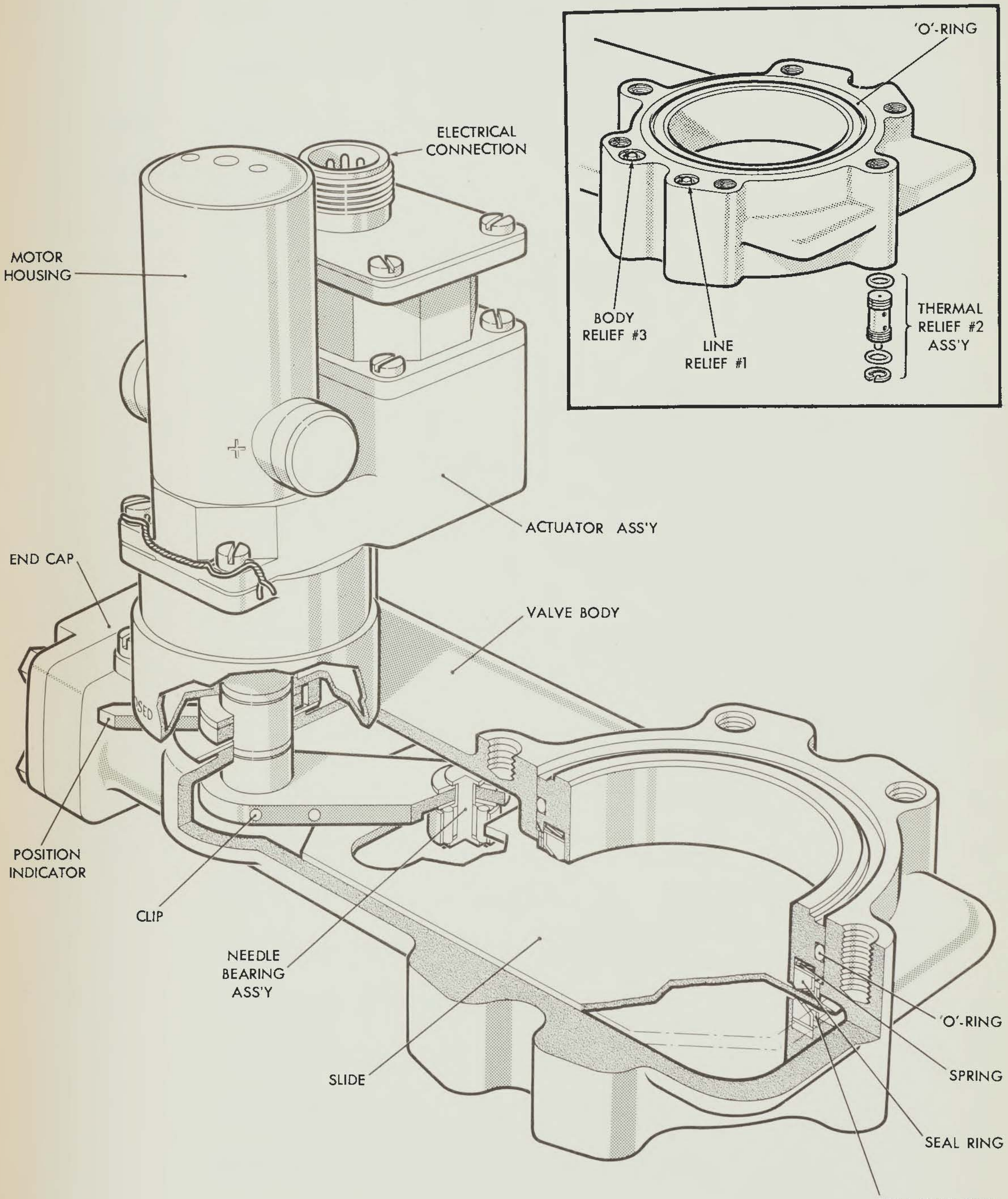

FIG. 3.3 MOTOR OPERATED GATE VALVE

If the booster pump is operating the engine inlet fuel pressure conditions will not trigger the low pressure warning light.

3.1.2 Valve - Fuel Shut Off, Motor Operated

3.1.2.1 Purpose

This valve provides a positive, remote method of closing a fuel line against flow in either direction.

Five such valves are used in the system, two serving as low pressure fuel cocks at the point of entry of the engine fuel supply line into the engine compartment; a third is used to close the cross-feed line isolating the two engine feed systems, one from the other, during normal operation. The remaining two valves close the empty sub-system when one pump has failed and the other side has emptied, to allow unrestricted transfer from the sub-system transferring through the failed booster pump by-pass.

3.1.2.2 Description (See Fig. 3.3)

These valves are of the sliding gate type powered by a reversible 28 volt D.C. motor, acting through a gear train. Overtravel of the motor is allowed for by the use of a clutch which disengages when the slide reaches the end of its travel. Limit switches cut the power supply to the motor at the same time so that power is required only whilst the valve is being moved from open to closed and vice versa. Thermal relief ports are incorporated to prevent damage caused by thermal expansion either within the valve body itself or on either side of the gate.

The valve is capable of opening or closing fully within one second, under all environmental conditions, at voltages of 27 1/2 and 30 volts D.C. and within two seconds at 18 volts D.C.

3.1.2.3 Power Requirements

This valve is designed to operate in an 18-30 volts D.C. system, it should also be capable of operating at 14 volts D.C. It draws a seven amp current only during movement of the slide.

3.1.3 Switch, Engine Inlet Pressure

3.1.3.1 Purpose

This switch provides a signal in response to pressure changes in the engine inlet line.

3.1.3.2 Description

Refer to Fig. 3.4.

3.1.3.3 Operation

The switch is adjusted to operate on increasing pressure (open electrical circuit) at 18.3 nominal psi (absolute), and the contacts close on decreasing pressure at 17.3 nominal psi (absolute).

3.1.3.4 Power Requirements

As this unit operates as a switch only, it requires no external power.

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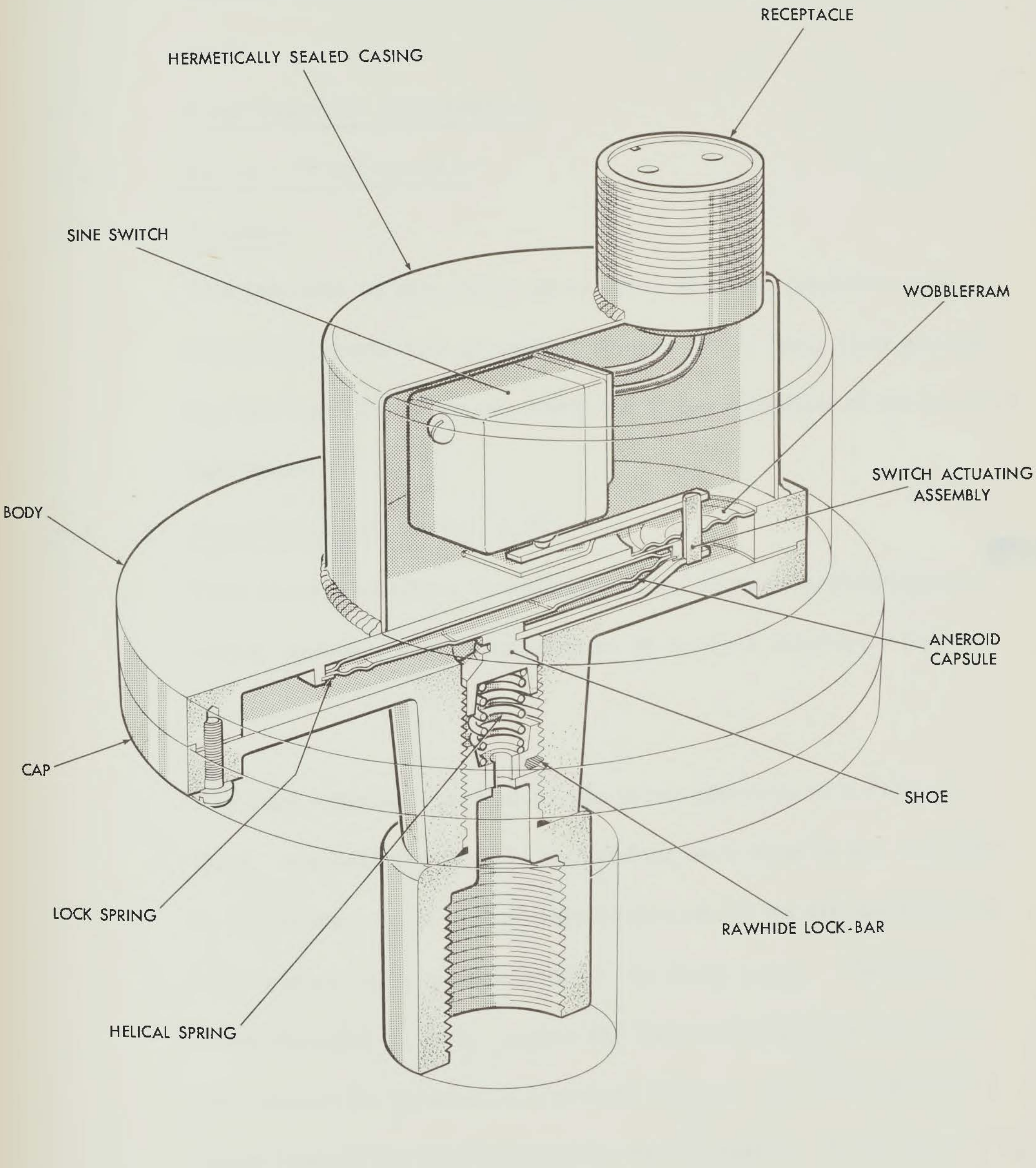


FIG. 3.4 ENGINE INLET SWITCH

It is designed to function in an 18-30 volt D. C. system and is capable of making or breaking up to a five ampere resistive load.

3.2 Fuel Transfer Sub-system

3.2.1 Valve - "Fuel-No-Air"

3.2.1.1 Purpose

The function of this valve is to close the fuel transfer lines when their ends are no longer immersed in fuel, thus preventing the ingress of the air used for pressurization of the aircraft fuel tanks.

3.2.1.2 Description (See Fig. 3. 5)

This is essentially a float-controlled, servo-operated piston valve, opening when signalled to do so by a float type fuel sensor.

The fuel sensing element of the valve consists of a divided float, one half of which is located on each side of the fuel inlet to the valve. It is completely balanced, in an air medium, by a weight on the opposite side of the pivot point. The float, when covered by fuel, upsets the balance and since the float mechanism is pivoted in a gimbal system, the float is free to move toward the fuel surface in any direction. A spring in the linkage tends to retain the floats in a neutral position when they are in air. The tension on this spring is adjusted so that just over half of the float must be immersed in order to

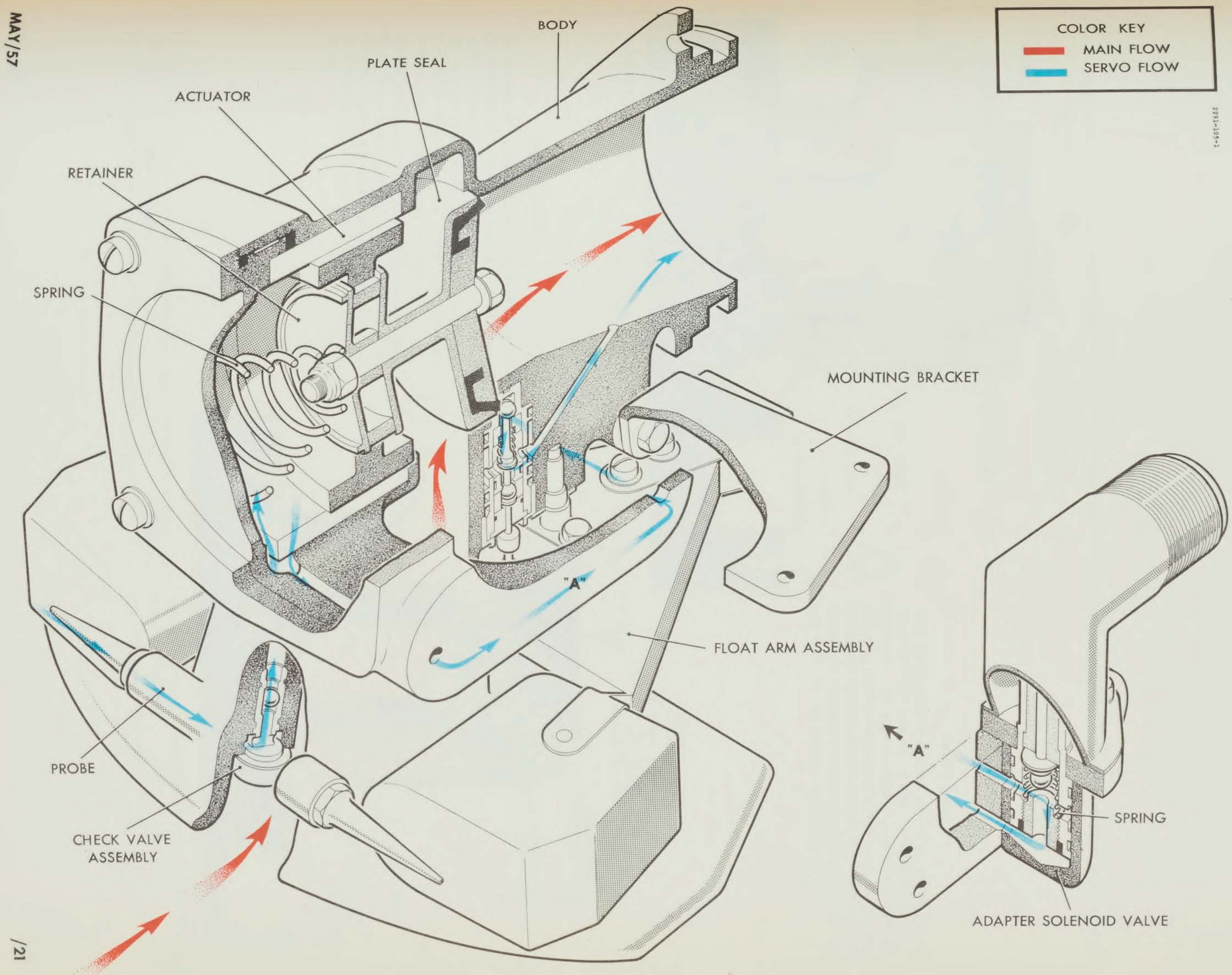
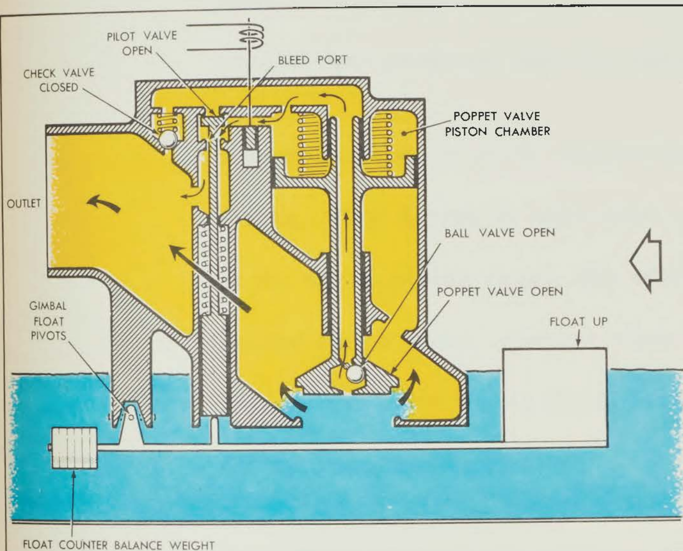
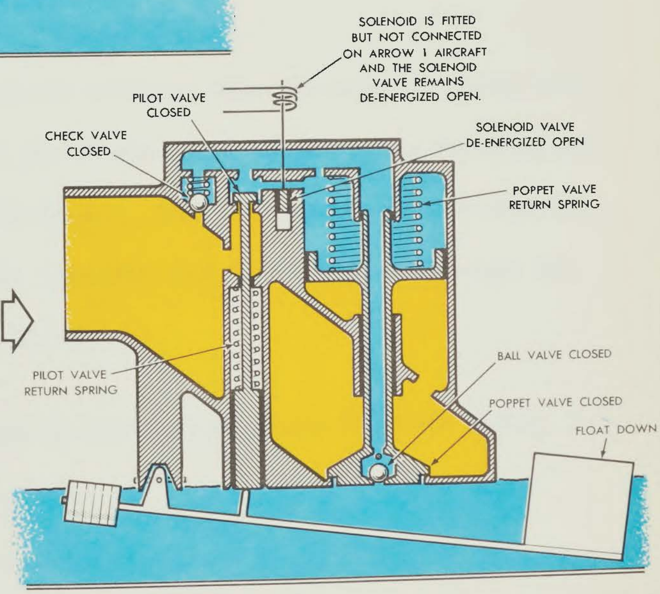


FIG. 3.5 FUEL NO AIR VALVE



VALVE OPEN

WHEN THE LEVEL OF FUEL IS ABOVE THE BASE OF THE FUEL NO-AIR VALVE, THE FLOAT IS IN THE UP POSITION, RETAINING THE PILOT VALVE OPEN. THIS ALLOWS UNRESTRICTED BLEED FLOW PAST THE OPEN BALL VALVE THROUGH THE OPEN PILOT VALVE TO THE VALVE OUTLET. THE RESULTING REDUCED PRESSURE IN THE PISTON CHAMBER ALLOWS THE INCOMING FUEL PRESSURE TO OPEN THE POPPET VALVE AND PERMIT FUEL TO TRANSFER THROUGH THE VALVE.



VALVE CLOSED

WHEN THE LEVEL OF FUEL DROPS TO THE BASE OF THE VALVE, THE FLOAT IS LOWERED TO THE DOWN POSITION AND THE PILOT VALVE CLOSES. THIS SHUTS OFF BLEED FLOW, TRAPPING FUEL IN THE POPPET VALVE PISTON CHAMBER. THE RESULTANT PRESSURE BUILD UP, AIDED BY THE POPPET VALVE RETURN SPRING, CLOSES THE POPPET VALVE, PREVENTING A FLOW OF AIR THROUGH THE VALVE.

A LIGHTLY SPRING-LOADED CHECK VALVE IS OPENED BY REFUELLING PRESSURE DURING REFUELLING, TO ALLOW THE PRESSURE TO BE FELT WITHIN THE POPPET VALVE PISTON CHAMBER. THIS RETAINS THE POPPET VALVE CLOSED, PREVENTING REFUELLING FLOW THROUGH THE VALVE.

FUEL AT REDUCED PRESSURE — FUEL AT TANK PRESSURE

FIG. 3.6 FUEL NO AIR VALVE SCHEMATIC

displace it from its mean position.

The movement of the float is translated by a rocker arm into linear movement of a servo valve, which controls the admission of tank pressure into the servo piston chamber.

The main valve is of the poppet type, operated by a servo piston. The design is such that, with pressures on both sides of the servo piston equal, the valve operates as a spring loaded check valve, opening when the downstream pressure falls to the point where the differential pressure overcomes the action of the spring.

Fuel flows through the orifices, then through the check valve assembly into the piston chamber, thence to the solenoid and pilot valve to downstream. The solenoid valve assembly is normally open for transfer and is controlled through the Sequence Control Unit.

An alternative type of valve arrangement is shown in Fig. 3.6.

3.2.2 Monitor-Collector Tank

This section to be added at a later stage

3.2.3 Sequence Control Unit

This section to be added at a later stage.

NOT AVAILABLE AT PRESENT

FIG. 3.7 COLLECTOR TANK MONITOR

NOT AVAILABLE AT PRESENT

FIG. 3. 8 SEQUENCE CONTROL UNIT

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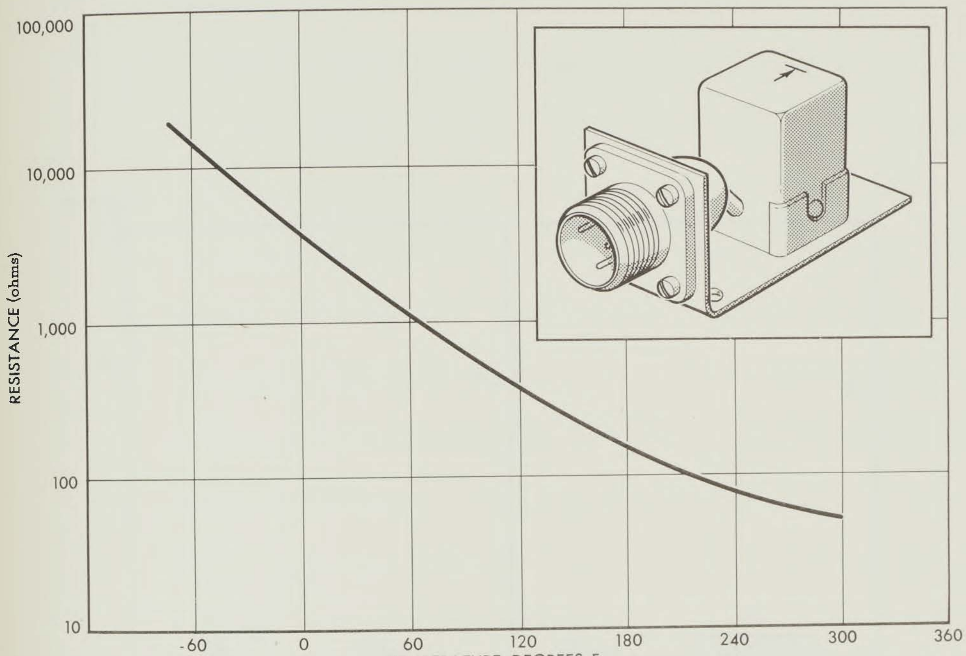
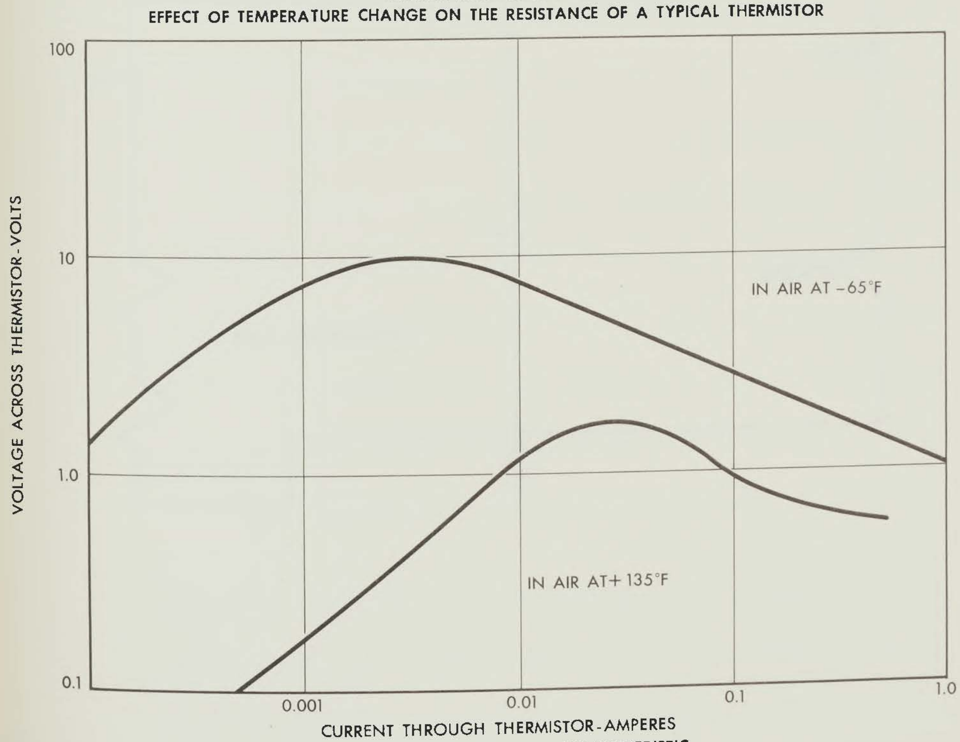


EFFECT OF TEMPERATURE CHANGE ON THE RESISTANCE OF A TYPICAL THERMISTOR



VOLTAGE-CURRENT OR POWER CHARACTERISTIC

FIG. 3.9 LIQUID LEVEL SENSOR

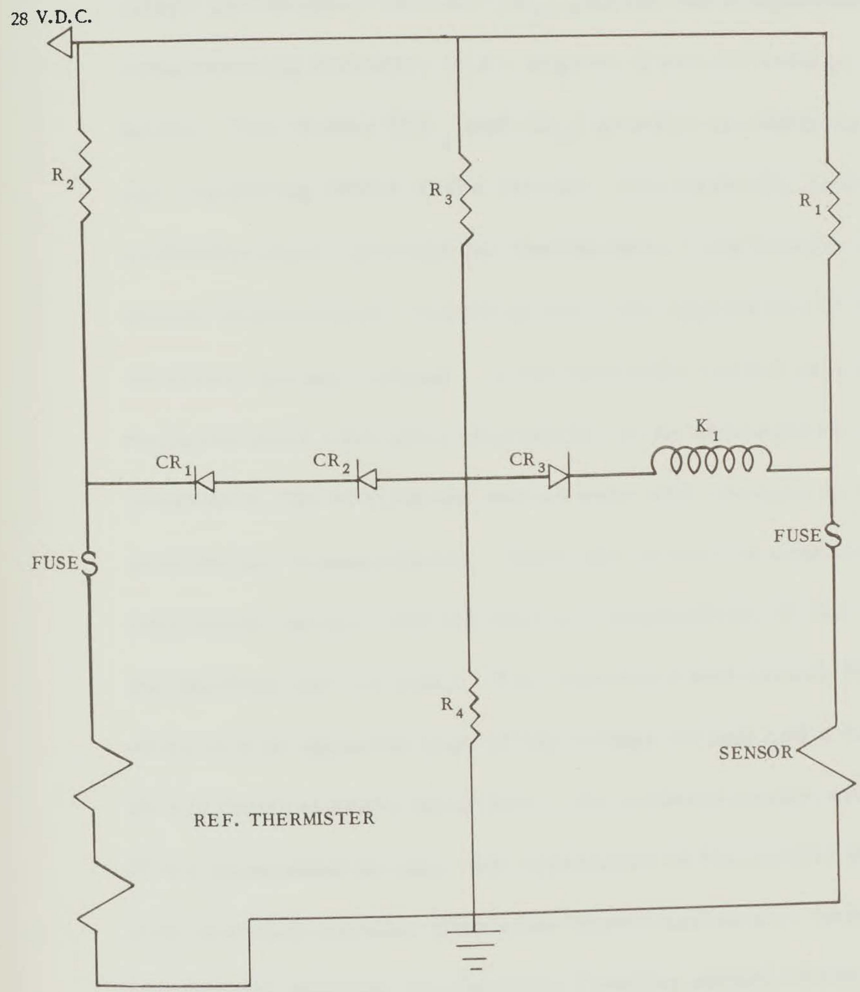


FIG. 3.10 THERMISTER BRIDGE CIRCUIT

The sensor, plus the bridge balancing resistors (R_1, R_3, R_4), provide the basic bridge circuit. The relay (K_1) is operated from the unbalance signal in the bridge. The reference thermisters and balance resistor (R_2) provide the temperature compensating circuitry and a degree of circuit voltage regulation. The diodes (CR_1 and CR_2) provide an additional voltage regulating effect to the circuit. Hermetically sealed protective fuses prevent the thermistors from heating to an unsafe temperature, resulting from the application of an incorrect bridge voltage. A hermetically sealed case also encloses each reference thermistor in an atmosphere of air (therefore, its resistance varies only with changes in the ambient air temperature). Since the sensor is exposed, its resistance varies with the thermal conductivity of the surrounding medium (air or fuel). The reference and sensor thermistors are in opposite legs of the bridge circuit and a small direct current heats them above the ambient temperature. When immersed in fuel, the resistance of the sensor thermistor becomes greater than when immersed in air, because of the greater thermal conductivity (cooling effect) of fuel.

With the sensor in fuel, the voltage drop across it is increased and the voltage potential difference across relay K_1 is such that current flow is prohibited by the diode CR_3. Thus, with the sensor in fuel the relay is de-energized. When the sensor is exposed to air its resistance decreases, accompanied by a decrease in the voltage drop across it and current is permitted to flow through relay K_1. Thus, when the sensor is in air the relay is energized.

3.2.4.4 Power Requirement

With a nominal 28 VDC supply, the power requirements are 8 1/2 watts nominal, 9 watts max. The units have a contact rating of two amps inductive, and have two isolated circuits on the control relay, ie. a single-pole double-throw relay switch.

3.3 Refueling and Defueling Sub-system

3.3.1 Cap - Pressure Fuel Servicing

3.3.1.1 Purpose

The primary function of this unit is to protect the pressure refueling adaptor from dust. It is also used as a secondary seal against fuel leakage through the refueling adaptor.

3.3.1.2 Description (See Fig. 3.11)

The cap consists of an outer shell containing a bayonet lock, mating with jaw ring MS-29514 and frozen grips to facilitate locking and unlocking. An internal sealing chamber uses the servo principle to load the seal which seats on the adaptor face, so that, if the seal on the adaptor is faulty, internal system pressure is incapable of lifting the seal from its seat. The seal member is free to rotate within the outer housing so

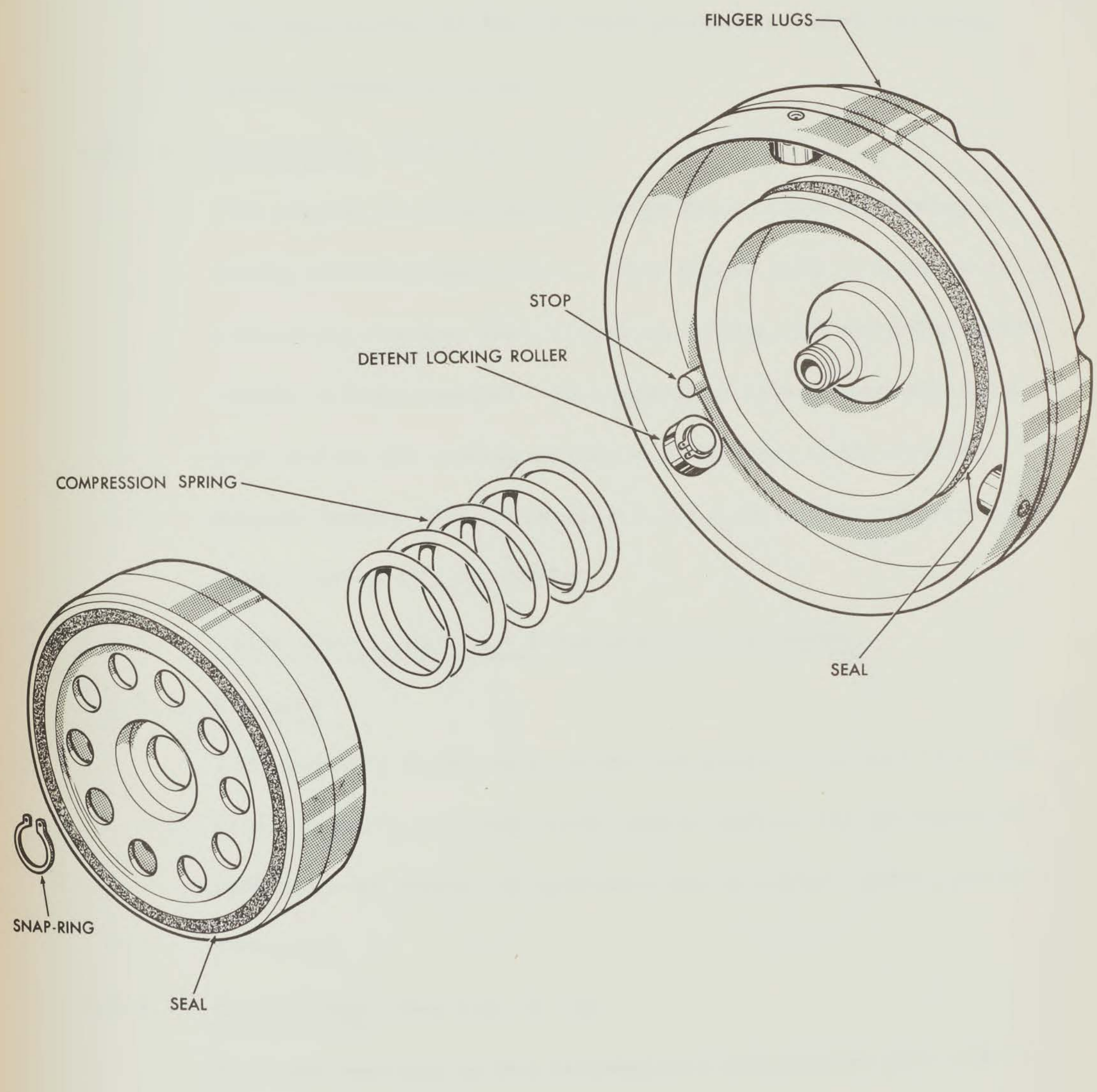


FIG. 3.11 CAP-PRESSURE FUEL SERVICING

that no rotation of the seal on its seat is required in locking or unlocking the cap.

3.3.2 Adaptor-Pressure Fuel Servicing

3.3.2.1 Purpose

This unit serves as the aircraft ground pressure refueling system connection point.

3.3.2.2 Description (See Fig. 3.12)

The adaptor is essentially a large case elbow containing a spring loaded poppet valve. This poppet acts as a check valve preventing reverse flow of fuel out of the unit when the mating nozzle is disconnected. The poppet is raised manually by a push rod on the mating nozzle to admit fuel to the system. The adaptor mates with a standard 2 1/2 inch nozzle conforming to Specification MIL-N-5877A.

3.3.3 Valve-Level Sensing - Pressure Fuel Servicing

3.3.3.1 Purpose

This valve is designed to sense the pressure of fuel in a tank at the correct tank full level, and to initiate the operation of a tank shut-off valve, by hydraulic servo action, during pressure refueling.

3.3.3.2 Description (See Fig. 3.13)

The unit consists of two isolated and independent pilot valves each controlling the flow in a separate bleed passage from a tank shut-off valve. Each of the pilot valves is operated by a

PRESSURE FUEL SERVICING CAP ADDED

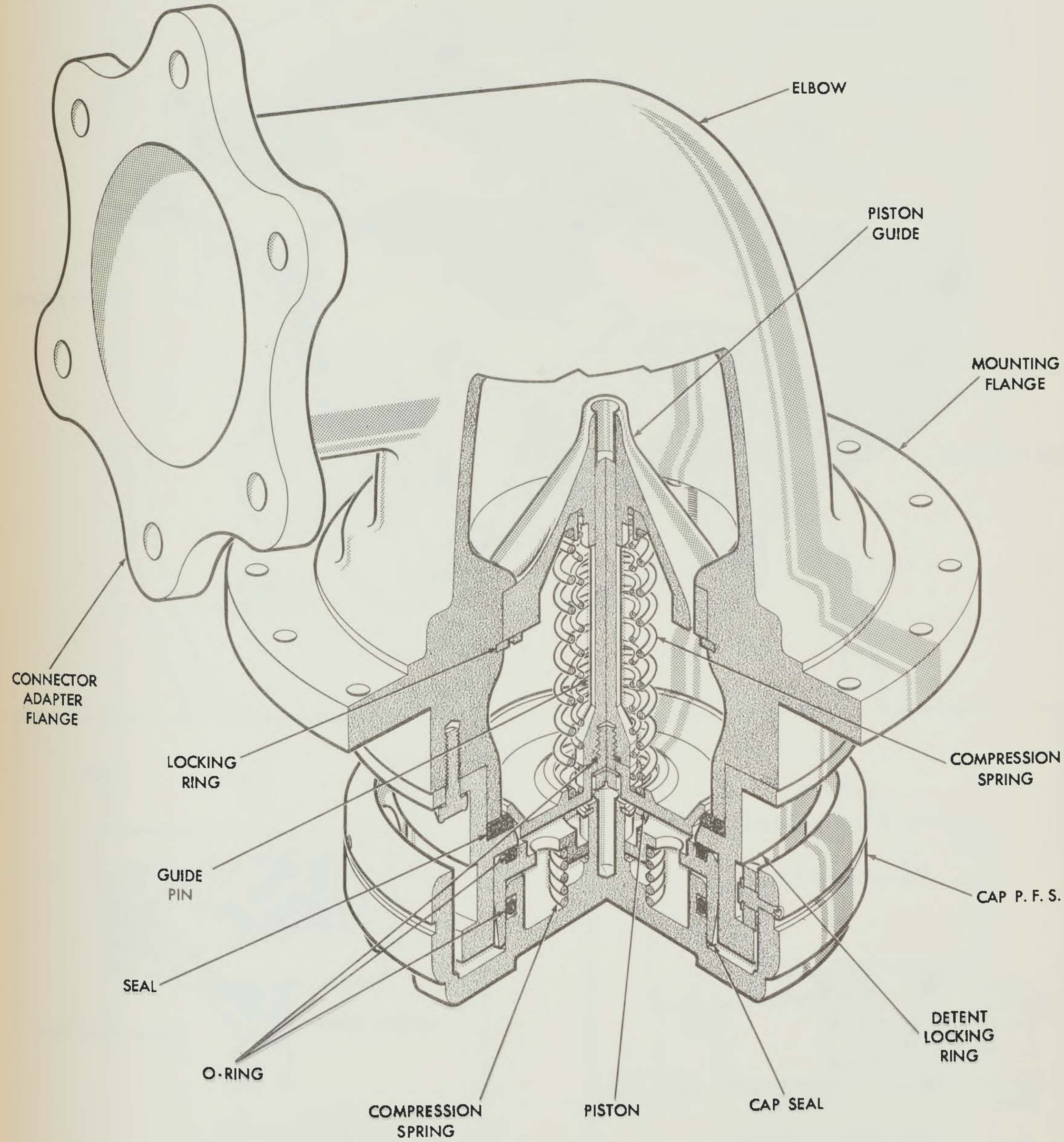


FIG. 3.12 ADAPTER-PRESSURE FUEL SERVICING

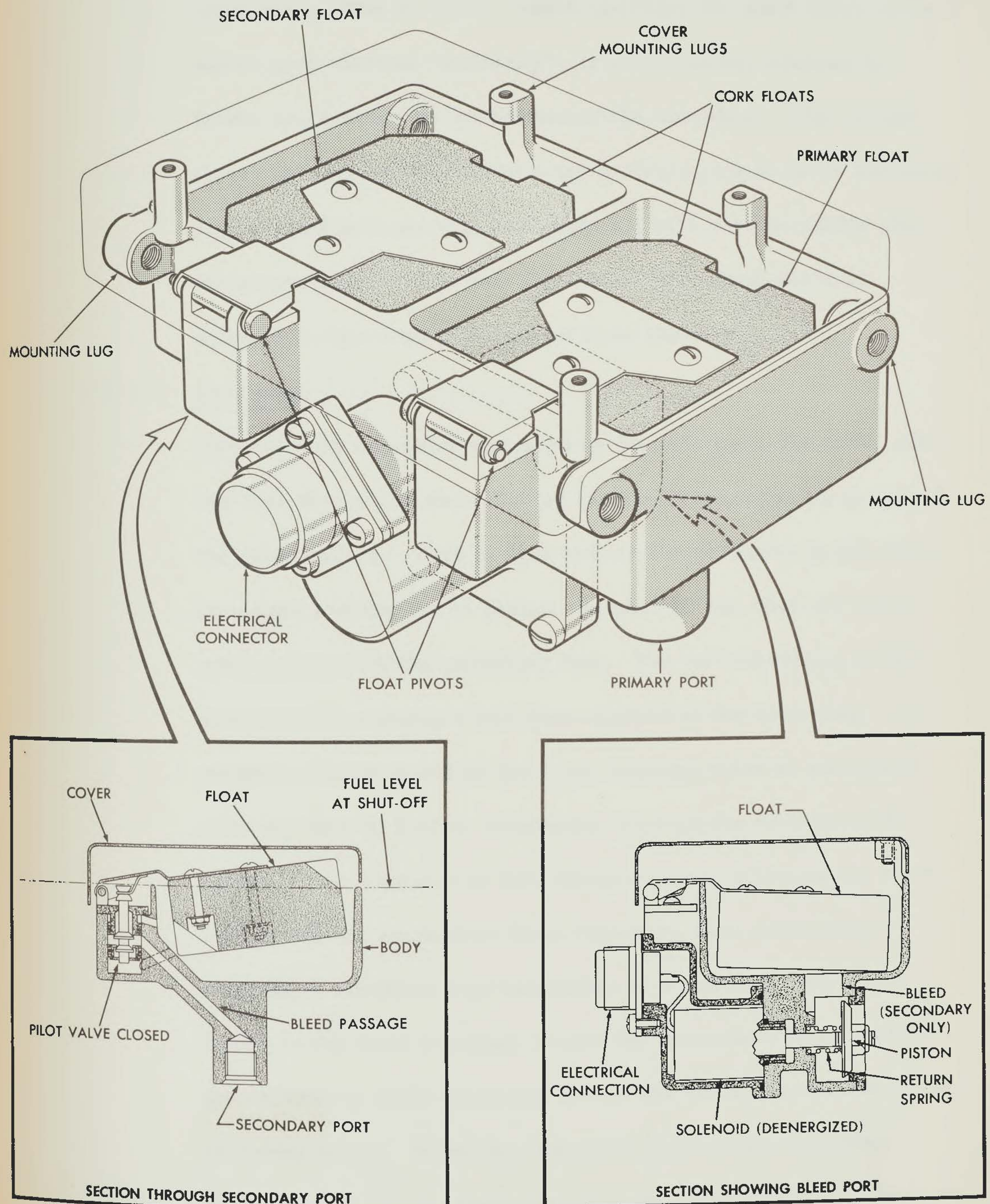


FIG. 3.13 VALVE-LEVEL SENSING-PRESSURE FUEL SERVICING

coated cork float, and the floats are contained in separate float chambers. One of these, which operates the pilot valve in the servo port marked "Primary", is permanently drained by fairly large holes in the bottom of the chamber. The second float chamber is drained through a single poppet valve normally held closed by a spring, but provided with a solenoid for electrical operation. The fuel flow from both bleed ports is allowed to flow into this second float chamber.

3.3.3.3 Operation

The valve is normally operated by fuel rising in the tank, lifting both floats and thus closing the bleed passages by means of the pilot valves. This in turn raises the pressure in the bleed passages and the servo piston chamber of the shut-off valve, which closes off the refueling line. For pre-checking of the system after pressure has been applied at the refueling adaptor, the solenoid on the level sensing valve is energized allowing flow of fuel to commence through the tank shut-off valves. The solenoid is then de-energized, allowing the servo flow to fill the secondary float chamber, thus artificially creating a condition representative of a full fuel tank. The filling of the float chamber raises the secondary float, closes the secondary pilot valve and closes the secondary piston of the refueling valve. When the indicator light on the refueling control panel glows, indicating that the system has operated satisfactorily the solenoid on the level sensing valve is re-energized allowing the tank to fill. This pre-checking solenoid also affords a means of shutting off the system prior to complete filling of the tanks, during partial refueling.

3.3.3.4 Power Requirements

The pre-checking solenoid is the only electrically operated portion of this unit. It has been designed to operate in an 18-30 volt D.C. system drawing a one-half ampere current.

3.3.4 Valve-Shut Off - Pressure Fuel Servicing

3.3.4.1 Purpose

The function of this valve is to control the admission of fuel to each individual fuel tank aboard the aircraft during pressure refueling.

3.3.4.2 Description (See Fig. 3.14)

This valve is servo operated by means of dual pistons mounted back to back.

Servo pressure is applied to the face of the primary, or up-stream, piston through a spring loaded check valve. This servo pressure is then metered into the chamber behind each piston through slots milled in the valve guide spindle. The pressure is then allowed to escape from each piston chamber through servo ports extending radially from the valve body. Working in conjunction with the secondary piston is a switch assembly which makes contact when the secondary piston is in its closed position.

3.3.4.3 Operation

Valve Operation

The pistons are normally held in the closed position by light springs when no pressure is applied at the inlet. As the pressure at the inlet to the valve is raised it is also imposed on the back face of each servo piston, through the metering slots. Because of the differential areas involved, increased inlet pressures induce greater tendencies to close. The valve is opened by releasing the pressure behind the pistons. This is done by opening the servo bleed passages, which are large by comparison with the inlet passage in the metering slots. The valve is closed again merely by closing the servo bleed ports. If the inlet pressure should fall below outlet pressure, the valve is prevented from opening by the check valve at the inlet to the servo system.

In the Arrow 2 fuel system each of these valves is used in conjunction with a level sensing valve (ref. section 3.3.3.) which serves as the control on the opening and closing of the bleed passages controlling the opening and closing of the main valve.

Pre-checking of the system is accomplished in the initial stages of pressure refueling by energizing the solenoids on the

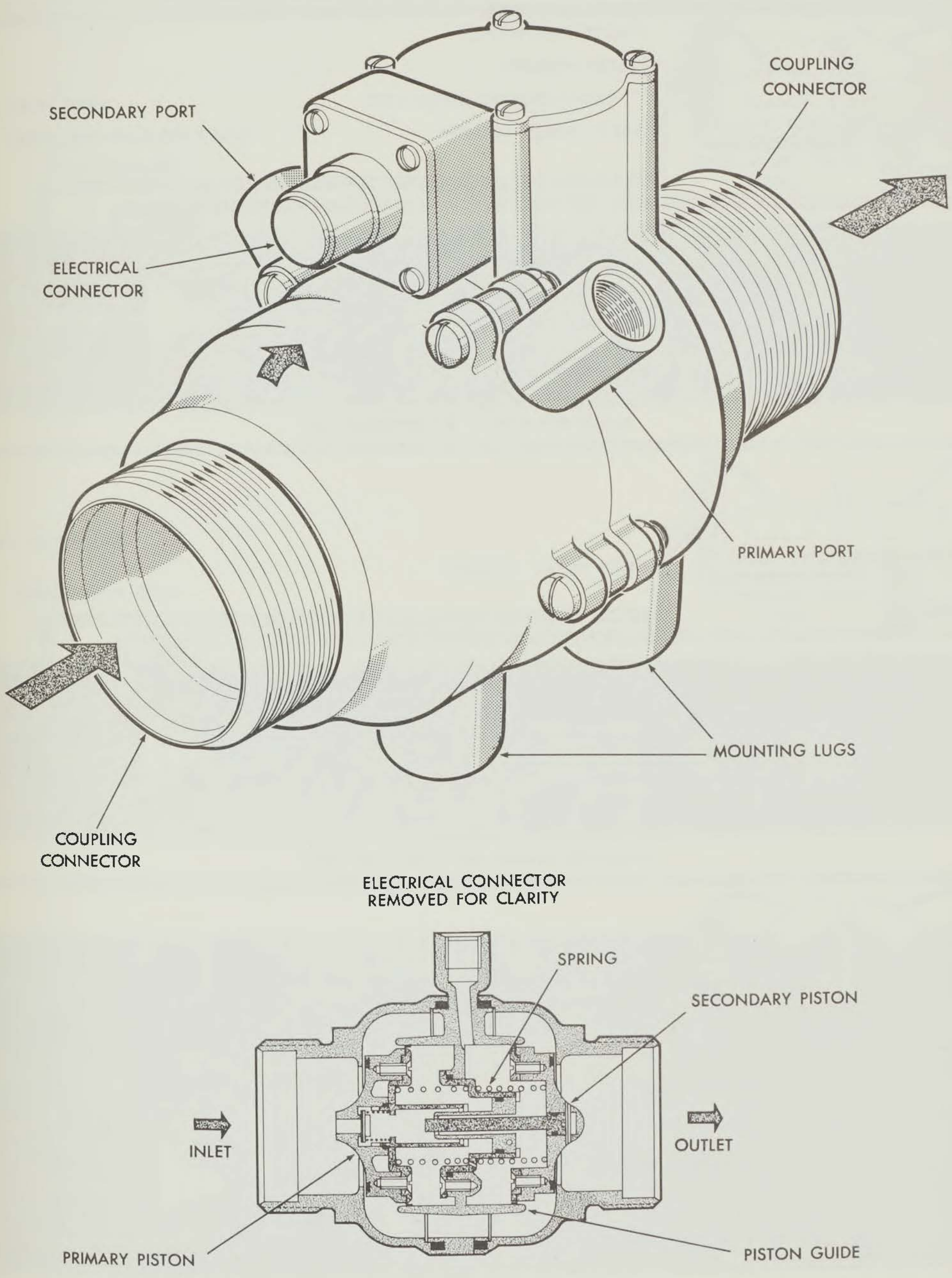


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FIG. 3.14 VALVE-SHUTOFF-PRESSURE FUEL SERVICING

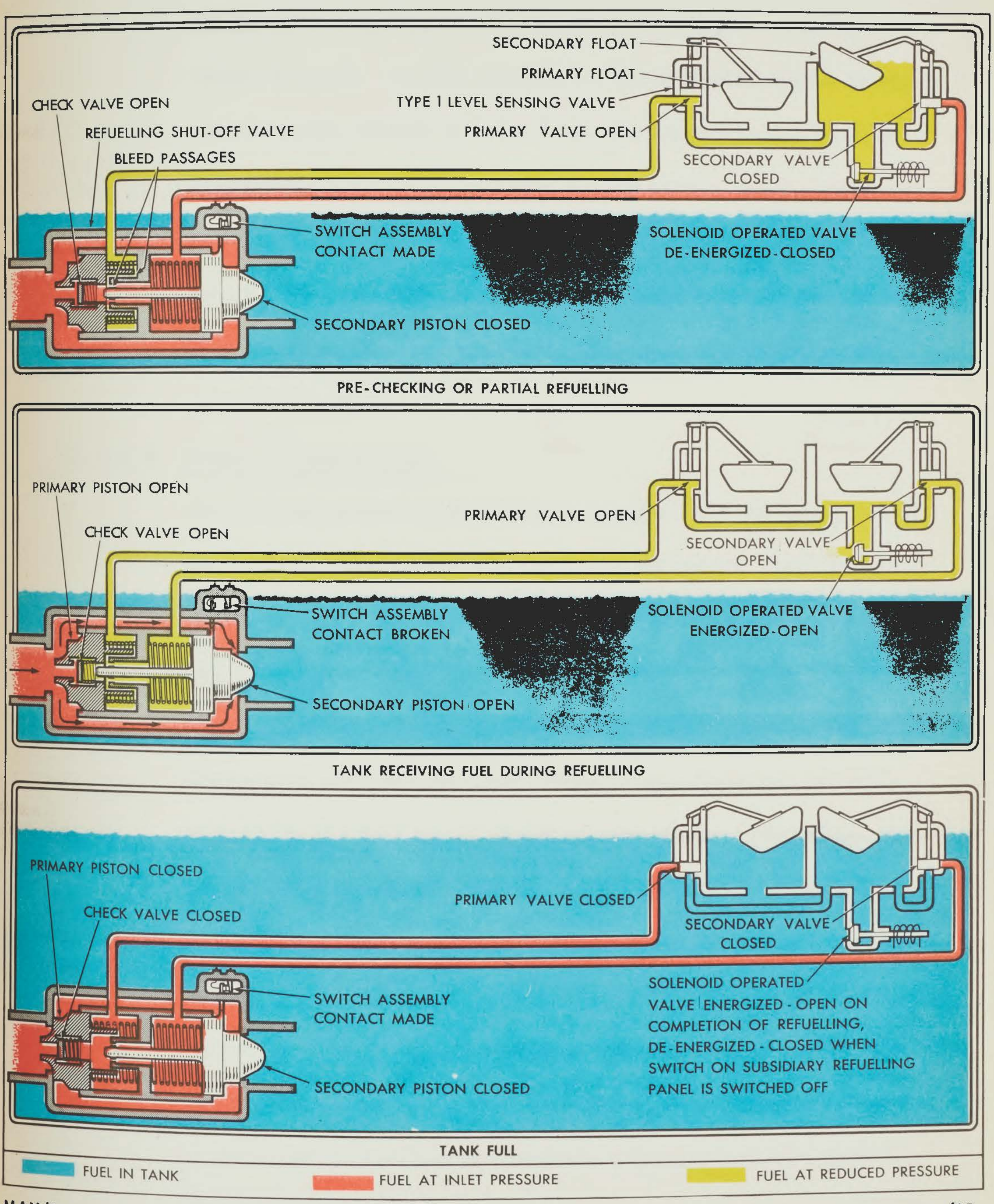

FIG. 3.15 OPERATION OF REFUELING SHUT-OFF VALVES AND TYPE 1 LEVEL SENSING VALVES

level sensing valves to start the fuel flowing. This releases the pressure in the piston chambers allowing the shut-off valves to open. At this time all of the indicator lights on the control panel should be off. When the solenoids are then de-energised, the servo flow fills the secondary float chambers, causing the secondary valves to close. The appearance of all seven lights on each control panel is evidence that the system is functioning correctly and that it is safe to proceed with normal refueling.

3.3.4.4 Power Requirements

No external power of any kind is required for the operation of this valve. The switch element is designed for functioning in an 18-30 volt D.C. system and is capable of making and breaking a lamp load only.

3.3.5 Valve-Combined Transfer and Refueling Shut-Off (See Fig. 3.16)

This valve permits controlled flow in one direction and prevents reverse flow out of the Collector Tank. The valve, for its refueling function, incorporates a primary and secondary means of closure, each of which operates by hydraulic servo action. It is remotely controlled by a dual, fuel level sensing valve, through the medium of two hydraulic bleed pipes. The valve closes when either or both of the bleed pipes are closed. In its transfer function the hydraulic servo pipes are opened directly to the tank.

NOT AVAILABLE AT PRESENT

FIG. 3.16 VALVE - COMBINED TRANSFER AND REFUELING SHUT-OFF

NOT AVAILABLE AT PRESENT

FIG. 3.17 VALVE - DUEL TANK LEVEL SENSING - COLLECTOR TANK

3.3.6 Valve-Level Sensing - Collector Tank (See Fig. 3.17)

This incorporates a solenoid operated over-ride device intended primarily for use with the Combined Transfer and Re-fueling Shut-off Valve. (Ref. Section 3.3.5)

The valve senses the rising level in the collector fuel tank and close the bleed lines of a hydraulic servo operated shut-off valve. It also includes primary and secondary operating devices, each of which is capable of controlling the closure of a separate bleed passage. The secondary operating device incorporates a pre-check feature for testing the operation of the valve and the shut-off control of the secondary bleed port, during refueling. A solenoid operated over-ride is provided to control both primary and secondary bleed ports, so that when energised it will break the bleed lines and permit fuel to exit into the tank and when de-energized allow normal float operated control.

3.3.7 Valve - Non Return - Defueling

3.3.7.1 Purpose

The purpose of this unit is to allow defueling from the collector tank and yet to prevent fuel from entering through an uncontrolled inlet during refueling.

3.3.7.2 Description (Refer to Fig. 3.18)

The valve is an in-line, spring loaded type. A dished washer and silicone sealing washer (LS 53) are positioned over a

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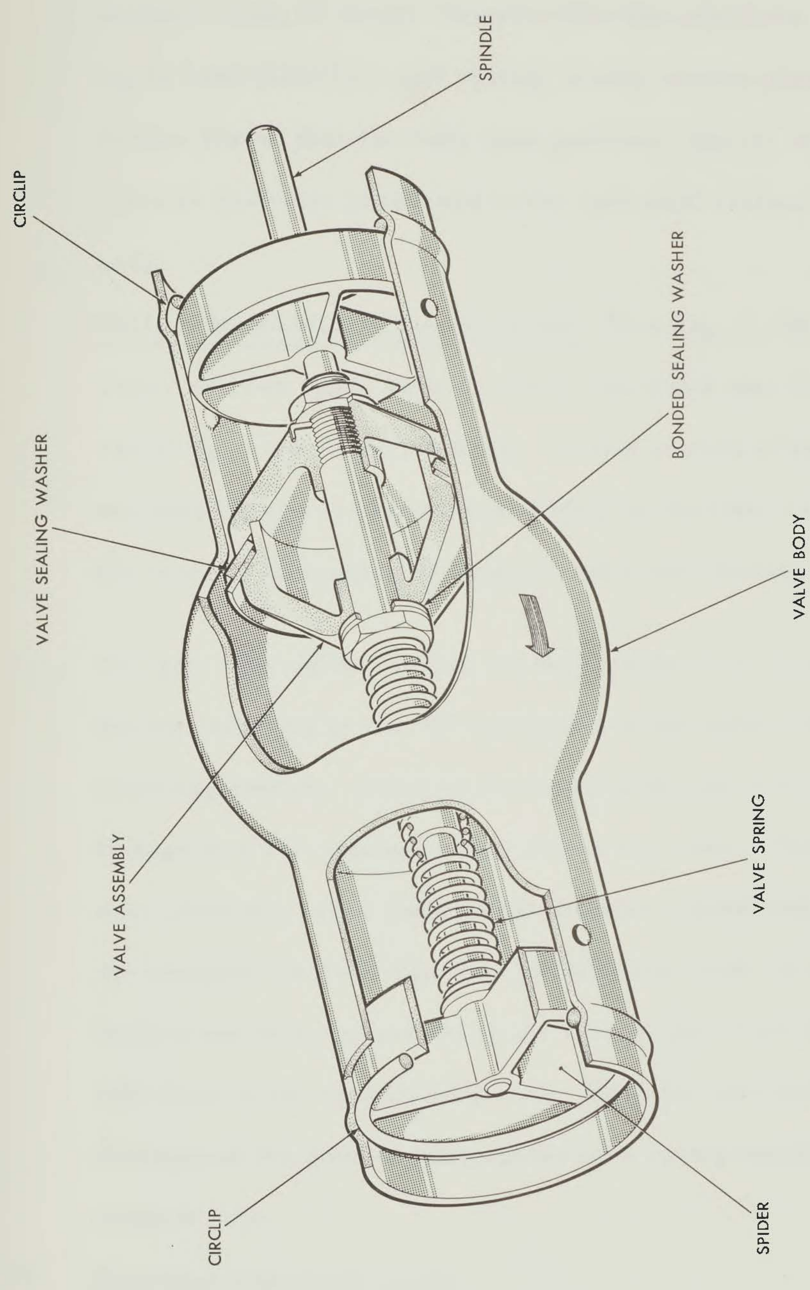

FIG. 3.18 NON-RETURN VALVE

spigot on the base of one conically shaped valve half, both washers being of larger diameter than the pipe bore. Opening is controlled by a coil spring, a stop washer preventing further travel than the fully open position, that is, when the valve is centrally positioned in the spherical section of the body.

3.3.8 Valve - Mechanically Operated Gate (See Fig. 3.19)

There are two inlets through which fuel could pass during refueling of the Collector Tank. So that control of level can be achieved one is shut off completely by the Gate Valve and the other is controlled by Shut-off and Level Sensing Valves.

The gate type valve shutting off the transfer line, is closed during refueling by the 70° movement of the access door to the refueling adaptor, which is transmitted through mechanical linkage to a 90° rotation which closes the valve. The access door latch pin, when locked shut actuates a limit switch to de-energize the Fuel Transfer Off warning light. If either door is not shut, or not correctly locked, the "Fuel Transfer Off" light in the cockpit comes on. Once the door lock is disengaged the door is fully opened by a spring loaded door support arm.

3.3.9 Refueling and Signal Panel

The Refueling Control and Signal Panel is located outboard of the Refueling Access Door in each main landing gear well, and

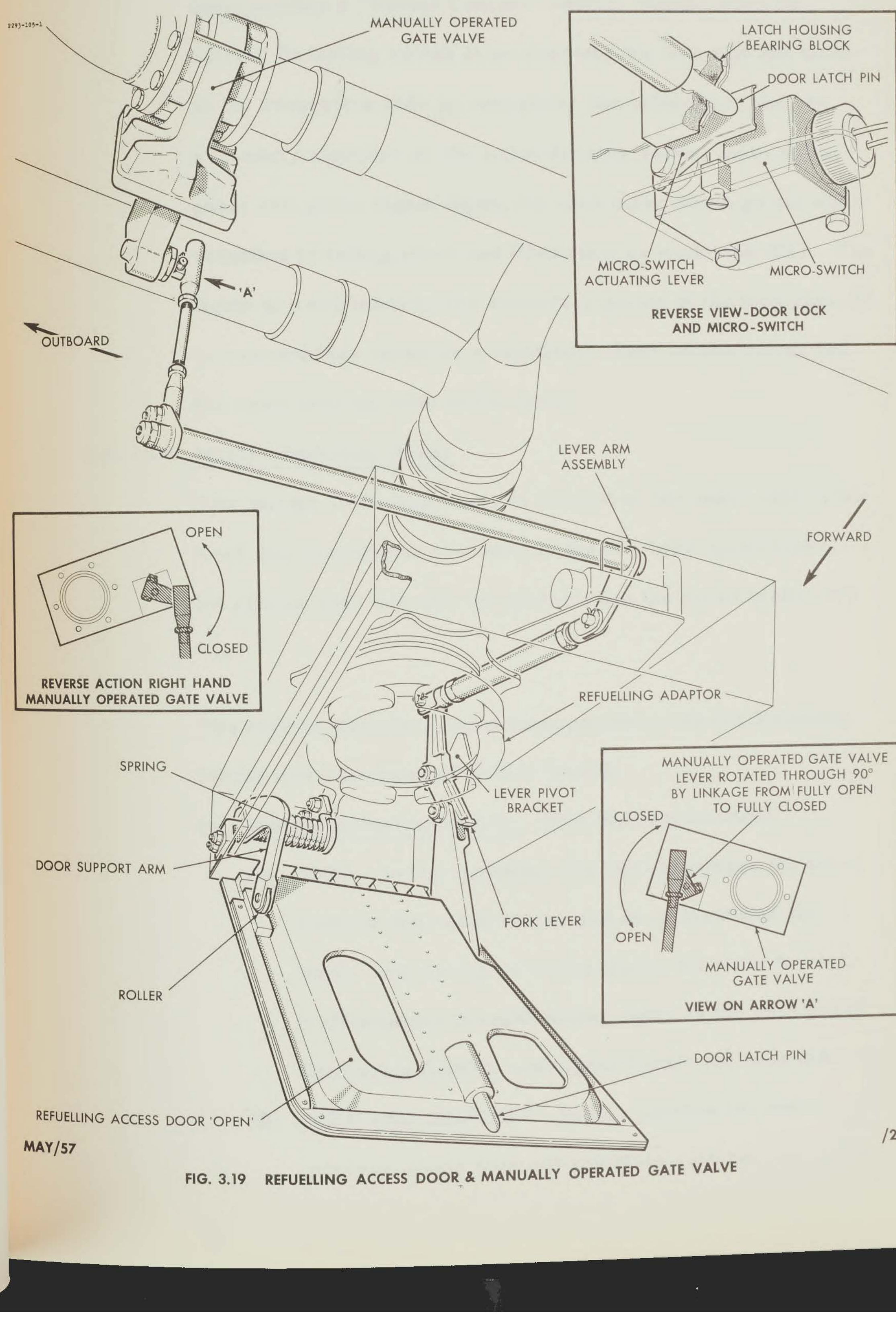

FIG. 3.19 REFUELLING ACCESS DOOR & MANUALLY OPERATED GATE VALVE

incorporates a "Refuel Control" switch, which, when the Master Refueling switch is on controls the flow into the tanks on its respective side by energizing the solenoid in the secondary chamber of the Level Sensing Valve. Also on the panel are green signal lights for each tank, which go out when refueling is taking place and illuminate as each tank fills. The lights are activated by the secondary piston of the tank shut off valves and thus serve as a functional check on the valves and the level sensing units in the tanks.

3.3.10 Master Refueling Panel

The Master Refueling Panel is located on the under side of the Duct Bay immediately forward of the left hand speed brake, its access door can only be opened when the speed brakes are "IN".

The Master Refueling Panel incorporates a Master Refueling Switch and a Refueling Selector Switch.

(a) Master Refueling Switch. This has two positions.

(I) "ON" - In this position, the switch engages the solenoids in the relief valves and de-pressurizes the tanks, and during refueling allows the tanks to vent. It illuminates the tank signal lights on the subsiduary "Refueling Control and Signal Panel" for each side.

(II) "OFF AND DEFUEL" - In this position the switch removes power from all refueling switches and lights.

(b) Refueling Selector Switch. This switch has three positions.

(I) "PARTIAL" - There are two "Partial" positions of the switch; "Partial 1" leaves one Level Sensing Valve in each system de-energized and "Partial 2" leaves two Level Sensing Valves in each system de-energized.

(II) FUEL REFUEL - In this position the switch energizes all Level Sensing Valves and tanks fill at random.

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

3.4 Pressurization Sub-System

3.4.1 Limiter - Air Flow

3.4.1.1 Purpose

The function of this device is to limit the flow of air in the pressurization piping leading to the air pressure regulators (Ref. section 3.4.2) to within the capabilities of the corresponding air pressure relief valve (Ref. section 3.4.5), which comes into use in the event of failure of an air pressure regulator.

3.4.1.2 Description (See Fig. 3.20)

These units are essentially convergent-divergent nozzles with the throat diameter chosen such that choking occurs with sonic velocity at the throat, at the maximum flow requirement of

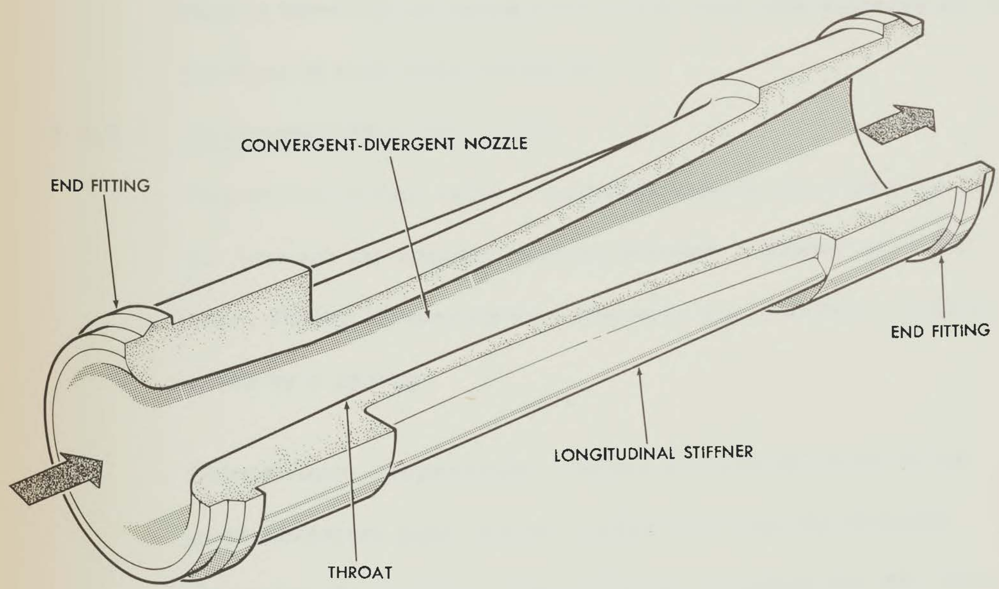

FIG. 3.20 LIMITER-AIR FLOW

the line in which they are located.

3.4.1.3 Since no moving parts are involved no external controls or power are required.

3.4.2 Valve - Air Pressure Regulator - Absolute Reference (19 psia.)

3.4.2.1 Purpose

The function of this unit is to regulate the pressure of the engine bleed air entering each of the wing tank systems for the purpose of tank pressurization.

3.4.2.2 Description (See Fig. 3.21)

Regulation in this valve is accomplished by throttling the inlet air through the annular opening between a sleeve valve and seat. Power to operate this sleeve is derived from a bellows aided by a spring.

Downstream air pressure, sensed at a remote point in the pressurization pipe system, is fed back into the chamber enclosing the bellows. The reference pressure for this valve is sealed inside the bellows after evacuation.

A plate valve, held in place by a light spring, closes the passage between the valve housing and the valve seat, in the event that pressure falls below outlet pressure.

3.4.2.3 Operation

The evacuated bellows and spring are adjusted to balance with

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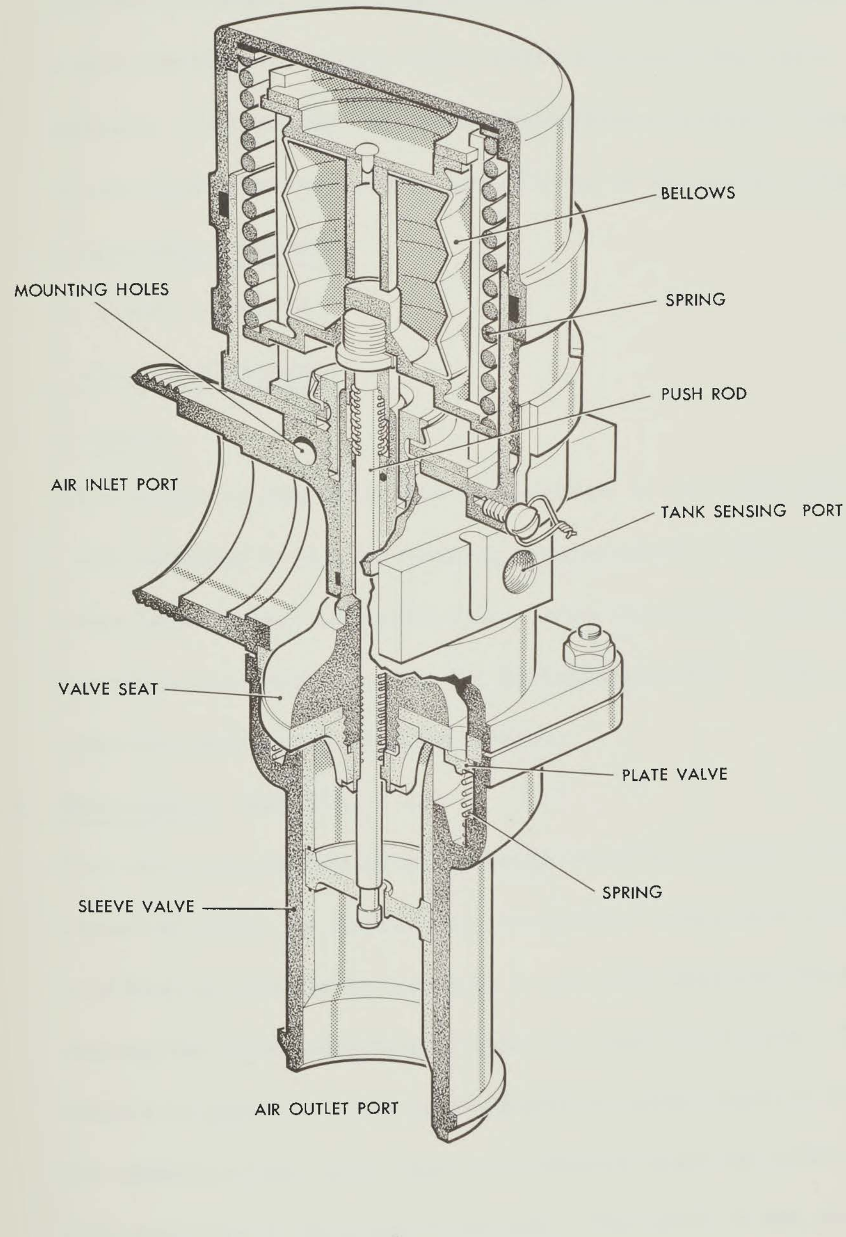


FIG. 3.21 VALVE-AIR PRESSURE REGULATOR

a 19 psi (absolute) pressure in the bellows chamber. Any drop in downstream pressure reduces the pressure in the bellows chamber, resulting in an expansion of the bellows, and a movement of the sleeve valve which increases the valve opening. Conversely, a rise in downstream pressure results in contraction of the bellows and closing of the sleeve valve.

3.4.2.4 Power Requirements

No power required.

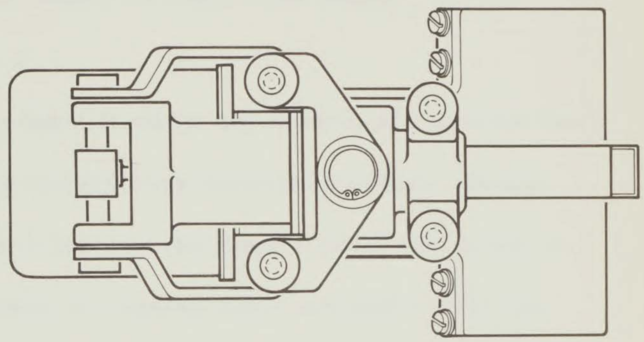
3.4.3 Valve - Air Release

3.4.3.1 Purpose

This device serves as a means of escape for air from the aircraft collector tanks, preventing displacement of fuel from these tanks by accumulation of air evolved from the fuel and air which has entered normally through operation of the collector tank pressurization system.

3.4.3.2 Description (See Fig. 3.22)

The valve consists of an air passage which is capable of being closed by either or both of two completely independent poppets. The first of these is operated by a specially designed float, making the valve sensitive to collector tank fuel levels. The second is operated by an aneroid bellows which ensures that the opening of the valve does not suddenly cause the collector tank pressure to drop below normal. The inlet to the valve is shrouded to minimise leakage through the valve due to



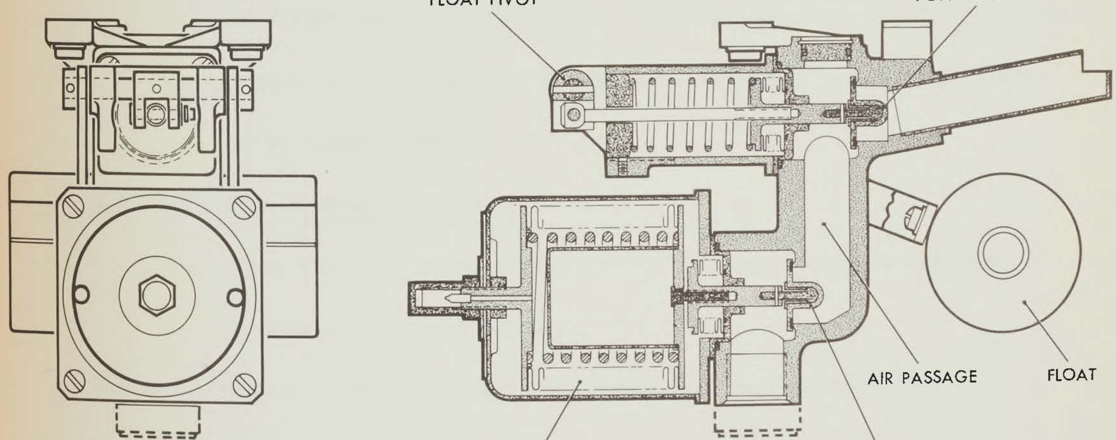


FIG. 3.22 VALVE - AIR RELEASE

fuel sloshing. The outlet is piped overboard.

3.4.3.3 Operation

The level sensing poppet is under the control of a special float, designed to have no weight when immersed in fuel. Hence when the fuel level is low and the float is in air its weight is sufficient to overcome the spring which normally holds the poppet closed. As the fuel level rises the float weight decreases allowing the spring to close the poppet.

Pressure control is operated by an aneroid bellows which expands as tank pressure falls, completely closing the poppet at a tank pressure of 10 psi. At any pressure above 11 psi the poppet is wide open, allowing the valve to operate only in the level control mode.

3.4.3.4 Power Requirements

This valve is completely automatic, requiring no exterior controls or power supply.

3.4.4 Valve - Negative "g" and Low Level Air Admission

3.4.4.1 Purpose

The function of this valve is to ensure that pressure in the collector tank never falls below the vapour pressure of the fuel, when the transfer system ceases to function.

3.4.4.2 Description (See Fig. 3.23)

This device is essentially a relief valve, admitting air into the collector tank from the wing pressurization system when the pressure differential between the wing tanks and collector tank exceeds 10 psi.

3.4.4.3 Operation

As collector tank pressure falls, due to cessation of fuel transfer, the spring holding the poppet off its seat is overcome, allowing it to return and air to enter.

3.4.4.4 Power Requirements

The valve is completely automatic requiring no external controls or power supply.

3.4.5 Valve - Air Pressure Relief, Absolute Reference

3.4.5.1 Purpose

The function of this valve is to protect the wing tanks from over pressurization through failure of an air pressure regulator. It also serves as a convenient means of releasing air from the tanks during ground pressure refueling.

3.4.5.2 Description (See Fig. 3.24)

This unit is essentially an air pressure regulator, designed to regulate upstream pressure. It consists of a main valve operated by a servo piston employing a "bellofram" sealing arrangement. The valve piston position is controlled by the pressure behind the servo piston which in turn is controlled by a servo bleed with a fixed inlet orifice and a variable outlet orifice.

The outlet orifice is adjusted by the relationship between

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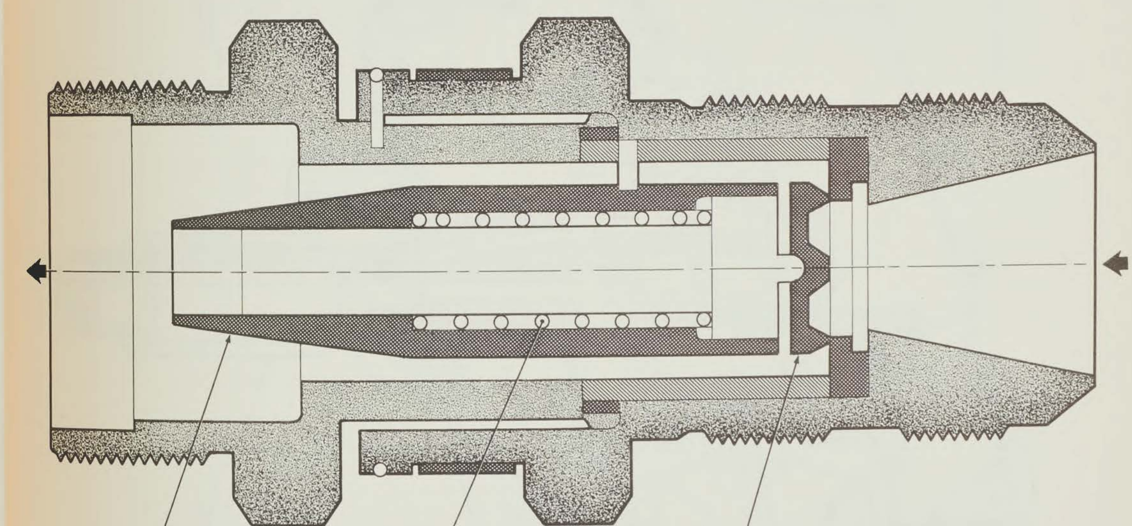

FIG. 3.23 VALVE - NEGATIVE "G" AND LOW LEVEL AIR ADMISSION

2441-105-1

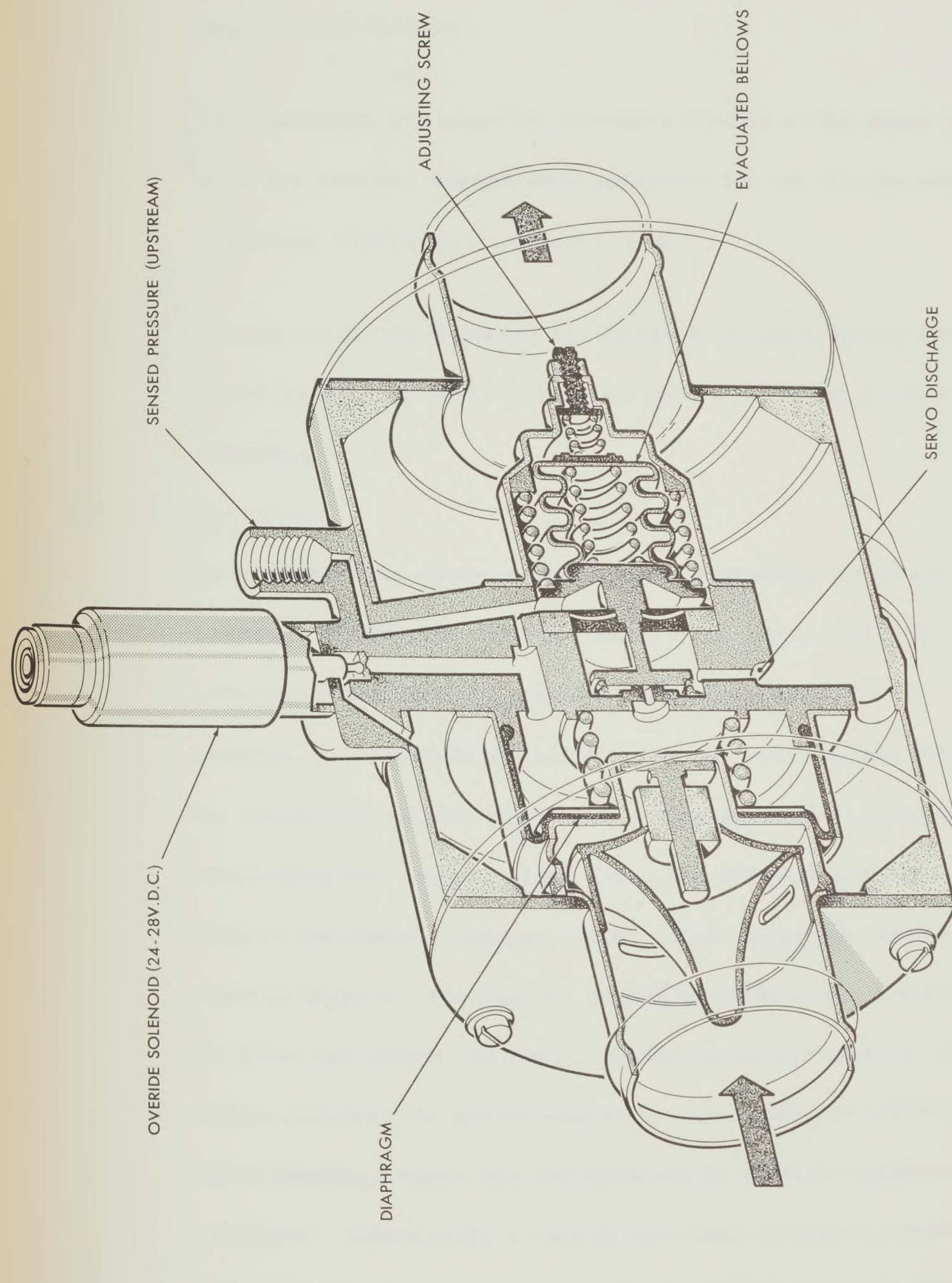

FIG. 3.24 VALVE-AIR PRESSURE RELIEF (ABSOLUTE)

upstream pressure and the absolute pressure in the permanently sealed bellows.

The upstream pressure is remotely sensed at the same point used for sensing downstream pressure for the air pressure regulator (reference section 3.4.2.).

A solenoid is provided for the purpose of interrupting normal servo balance so that air may be released during pressure refueling.

3.4.5.3 Operation

Operation of the valve is achieved by admitting air at upstream pressure both to the chamber behind the piston and to the exterior of the aneroid bellows. The movement of this bellows, in response to variations in the relationship between its inside and outside pressure, is transmitted to a poppet controlling the release of air from the piston chamber. A drop in upstream pressure results in an expansion of the aneroid bellows, causing the poppet to restrict the release of air from the piston chamber. As the pressure rises in the piston chamber the piston and main valve move to reduce the valve opening, which has the tendency to restore upstream pressure. Conversely a rise in upstream pressure results in enlarging the escape orifice from the piston chamber, thus causing a drop in pressure in this chamber, resulting in increased valve opening.

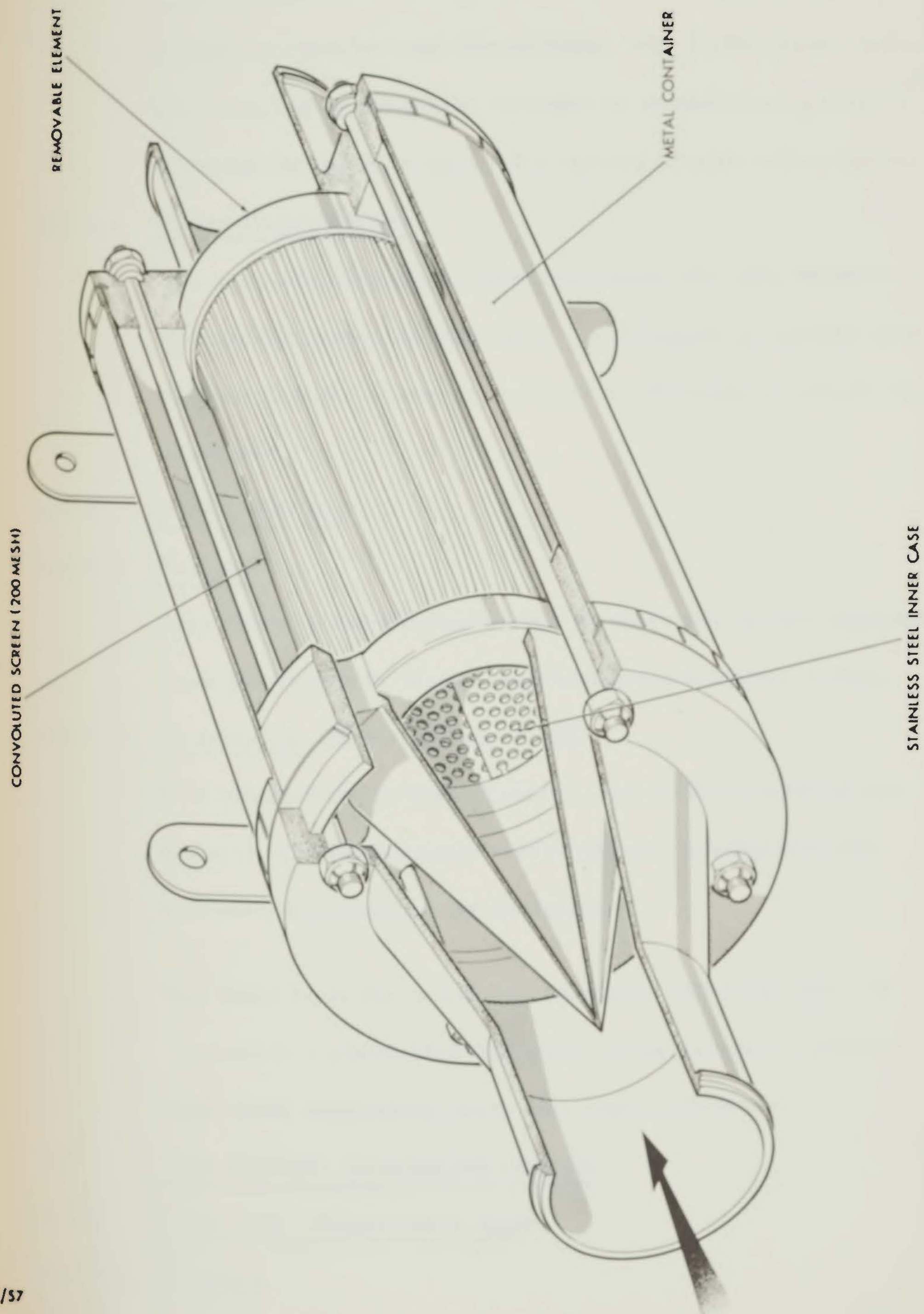

FIG. 3.25 HOT AIR FILTER

The solenoid override opens a relatively large passage between the piston chamber and downstream, which effectively reduces the pressure in the piston chamber to downstream pressure, allowing the valve to open fully against a weak return spring.

3.4.5.4 Power Requirements

The override solenoid, which constitutes the sole requirement for external power in this valve, is designed to operate in an 18-30 volt D.C. system. It draws a .35 ampere current while energized.

3.4.6 Filter, Hot Air

3.4.6.1 Purpose

This filter is intended primarily to filter the hot air supplied from the engine to the aircraft fuel pressurization system.

3.4.6.2 Description (Refer to Fig. 3.25)

It is situated in the high pressure line from a manifold connected to the downstream side of the air conditioning and pressurizing system heat exchanger.

The filter is of the removable element, 300 CFM type. It consists of a convoluted 200 mesh screen around a stainless steel inner supporting case, in a metal container.

3.5 Fuel Contents Gauging Sub-system

3.5.1 Tank Unit - Capacitance Type

3.5.1.1 Purpose

Tank units are lightweight, internally mounted sensing elements of the fuel gauge system.

3.5.1.2 Description (See Fig. 3.26)

A tank unit is essentially a capacitor consisting of two cylindrical tubes, mounted to maintain concentricity and electrically insulated from one another. The inner tube is a cylinder of constant diameter, composed of insulating plastic on which are coated two metallic patterns. One of these metallic patterns, together with the metallic outer tube, forms a capacitor which is connected in one leg of the null balancing bridge in the indicator power unit. The other metallic pattern is grounded to reduce fringing of the capacitance field. In this way the capacitance versus height relationship of the units in the tank can be matched to the volume versus height relationship for the tank. Due to the fact that aircraft fuel tanks are almost invariably of irregular cross section it is necessary to design the tank units to suit each individual installation. Connectors on the tank unit provide external electrical connections.

3.5.1.3 Operation

The capacitance of any capacitor depends upon three factors: The area of the plates, the distance between the plates, and the material between the plates (the dielectric). Since the tank unit is rigidly constructed, the first two factors are always constant. Therefore, the capacitance of the tank unit can be varied only by changes in the dielectric. When such a

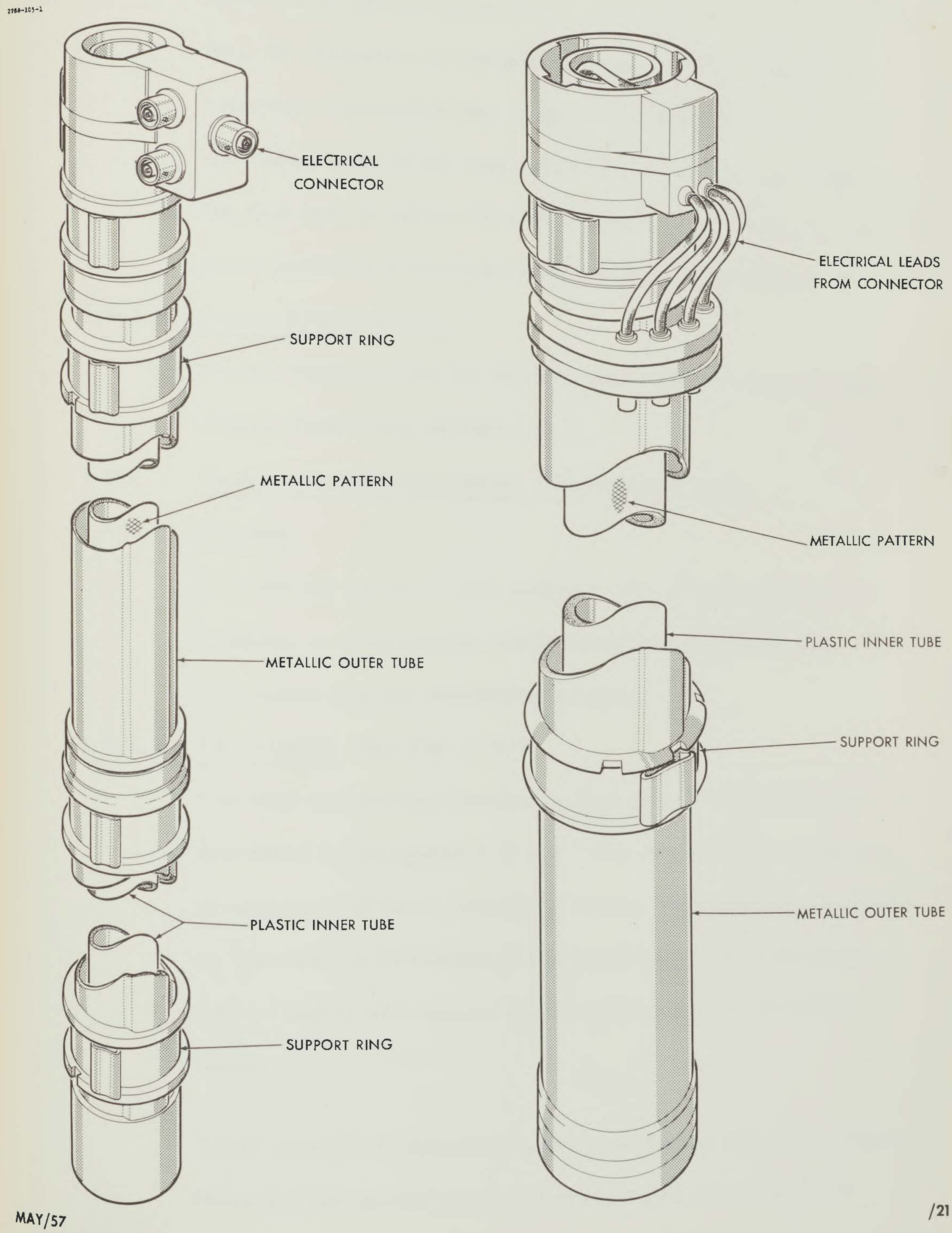

FIG. 3.26 UNIT-TANK CAPACITORS

capacitor is placed vertically in a fuel tank which is partly full, its dielectric is composed of fuel and air. Since the dielectric constant of fuel is approximately twice that of air, the capacitance of the tank unit is about twice as great when the fuel tank is full as when it is empty. Any change in fuel mass produces a corresponding change in capacitance.

3.5.1.4 Power Requirements

Power requirements for this unit are supplied from the Indicator, (reference section 3.5.3).

3.5.2 Tank-Unit and Compensator - Capacitance Type

3.5.2.1 Purpose

This device serves a dual purpose, it is a tank unit and, in addition, a compensator which introduces fuel deviation correction into the measuring system.

3.5.2.2 Description (See Fig. 3.27)

The tank unit portion consists of two concentric tubes and is as described in paragraph 3.5.1.2. The compensator assembly is composed of three concentric tubes, separated and insulated by spacers. It is located at the lower end of the combination unit so that it will remain immersed with a minimum fuel level.

Three electrical receptacles are provided on this unit. Two of these are the normal tank unit receptacles while the third carries the signal from the compensator.

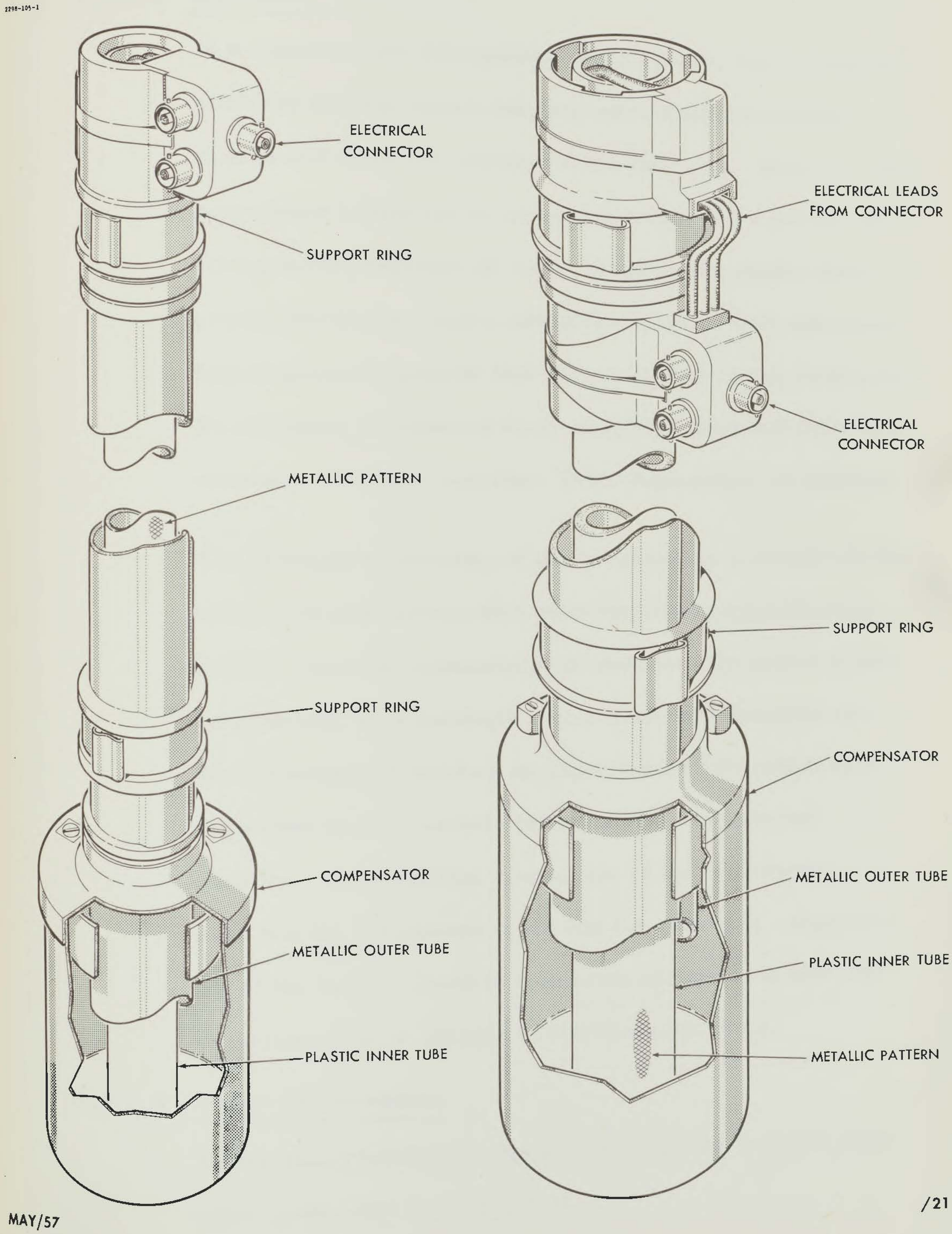

FIG. 3.27 TANK UNIT-COMPENSATOR

3.5.2.3 Operation

In a capacitor type fuel quantity gauge system, fuel indication accuracy depends upon a constant correlation between the density and dielectric constant of the fuel used. However, this correlation is affected by changes in temperature and by variations in the properties of fuels. Engineering studies have proved that the per cent of effective change in dielectric constant is generally greater than the per cent of change in density. To minimize the effect of these variations upon fuel indication accuracy, a special capacitor (the compensator) is utilized.

The principle of operation of the compensator is similar to that of the tank unit because both units function as variable capacitors. Since the compensator is located at the lowest usable level of fuel, it is completely immersed until the tanks are almost empty. Therefore its capacitance is dependant upon variations in fuel characteristics rather than upon fuel quantity. The electrical connections of the compensator are such that its capacitance is fed into the reference - capacitor leg of the bridge circuit to counteract deviations in tank unit capacitance due to changes in fuel characteristics.

3.5.2.4 Power Requirements

Power requirements for this unit are supplied from the indicator (reference Section 3.5.3).

3.5.3 Indicator - Fuel Quantity

The purpose of this unit is to provide the pilot with an indication of the quantity of fuel remaining in each of the aircraft fuel systems.

3.5.3.1 Description (See Fig. 3.28)

The non-sensitive type indicator used in this system is actually a composite unit consisting of a normal indicator portion containing the dial, pointer and operating motor, and a power unit portion containing the capacitance bridge network and the amplifier circuit controlling the operation of the pointer operating motor.

The unit has been designed for the exclusive use of transistors, making possible complete hermetic sealing. Electrical connections are made through a multipin receptacle at the rear of the unit. The indicator is equipped with a standard transmitting potentiometer.

Fuel quantity is presented on a standard two inch diameter dial graduated from zero to eleven thousand and five hundred pounds, over three hundred and twenty degrees of pointer travel.

3.5.3.2 Operation

The tank units, all wired in parallel, form one leg of capacitance bridge. As the quantity of fuel in the tanks varies so

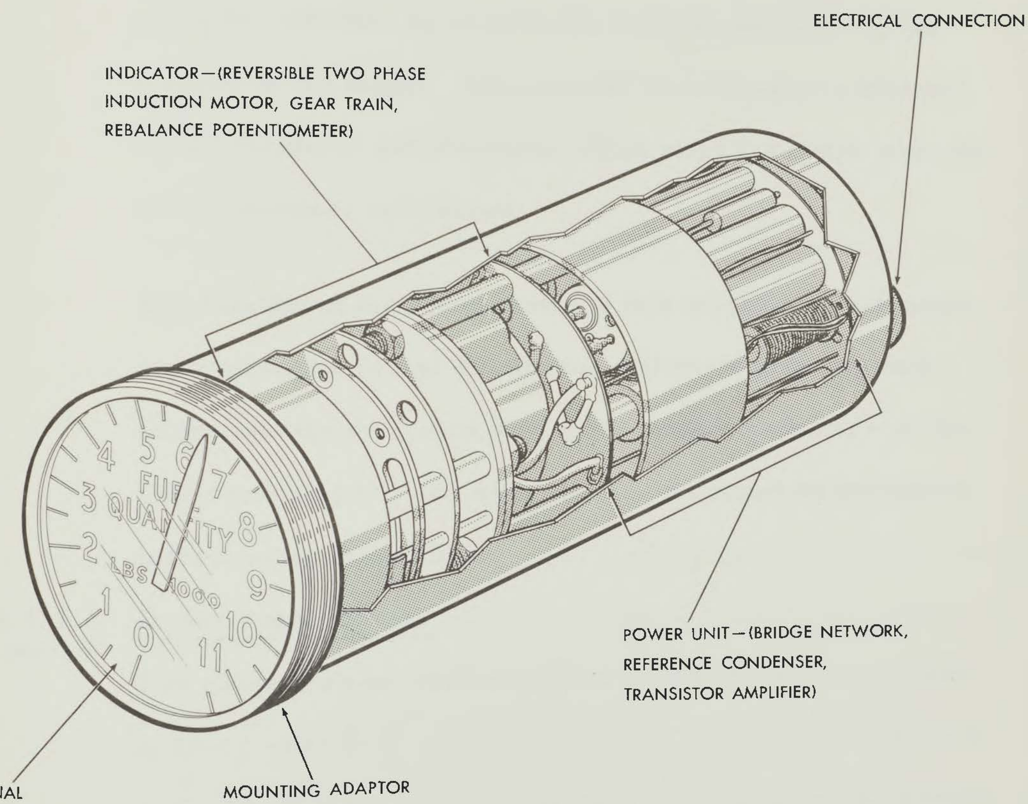

FIG. 3.28 INDICATOR-FUEL QUANTITY

will the total capacitance of the tank units. This variation in capacitance will result in a voltage signal across the corners of the bridge network of varying polarity, dependent on whether the quantity of fuel is increasing or decreasing. This voltage signal is used, through the amplifier to energize the motor, to move the indicator up or down the scale as dictated by the polarity of the signal. Movement of the indicator is followed by the rebalance potentiometer which stops the motor when the bridge becomes rebalanced.

The function of the compensator in this circuit is to introduce a variation due to fuel density and dielectric property variations into the reference side of the bridge, as occurs on the side containing the tank units, so that its effect on the instrument reading is nullified.

3.5.3.3 Power Requirements

The gauge systems each require a supply of electrical power at 18-30 volts D.C. and 102-124 volts, 400 cycles per second A.C. Each of the two systems draws 0.4 watts at 18-30 volts and 4 watts at 102-124 volts, 400 cycles per second.

3.6 Miscellaneous

3.6.1 Valve - Non-Return - Swing Check

For relief of refueling pressures on the fuel-no-air valves and their associated mountings in the fuselage tanks, check valves are mounted in the fuel lines and attached directly to the bulkheads, preventing flow of fuel from the refueling lines back into the transfer lines, thus causing thrust loads associated with refueling shut-off to be imposed on the bulkheads at Stations 392 and 478.

Check valves also close the Booster Pump by-pass to prevent recirculation while the pumps is operating.

3.6.2 Valve - Fuel and Condensate Drain

3.6.2.1 Purpose

These valves are the means of draining condensate from the aircraft fuel tanks and in some cases draining residual fuel from the tanks.

3.6.2.2 Description (Refer to Fig. 3.29)

Both Condensate and Drain valves are operated from outside the aircraft. The external surfaces of the valve assembly are flush with each other and with the aircraft skin outer surface.

The unit is basically a poppet type valve, opened against a spring until an aperture is exposed.

3.6.3 Couplings and Piping (Refer to Fig. 3.30)

Couplings are assembled over standard beads on the fuel piping and "O"-rings of standard dimensions are incorporated in the couplings for effective sealing. They allow an installation misalignment of at least three degrees in any direction, between tube centre lines, and an axial offset of one sixteenth of an inch between tube centre lines. Flexure allowance is an angle of thirty minutes in any direction from the installed position. Each flexible coupling provides for three-sixteenths variation in tube gap and a minimum of one-thirty-second of an inch axial movement in either direction from the installed position. The couplings are capable of operating with all combinations of restraint from full restraint to no resetraint.

Clips for support of single pipes are selected from CS-C-166 or 167 using cushions to CS-C-185. The "C" type clip (CS-C-166) is used on rigid structures with small variations in temperature. The clamp type clip (CS-C-167) is used where a sliding motion between tube and support may be necessary to permit structural flexure or differential expansion and contraction.

Piping is generally of WWT 787, non heat treated 52S Light Alloy, chosen because of high strength qualities at elevated temperatures. Bending, handling, shear strength at the coupling and pipe bead wear were the main considerations in determination of pipe thickness. Thicknesses chosen were .028" for diameters up to three quarters of an inch and .035"-minimum wall thickness for diameters from three quarters to two and a half inches.

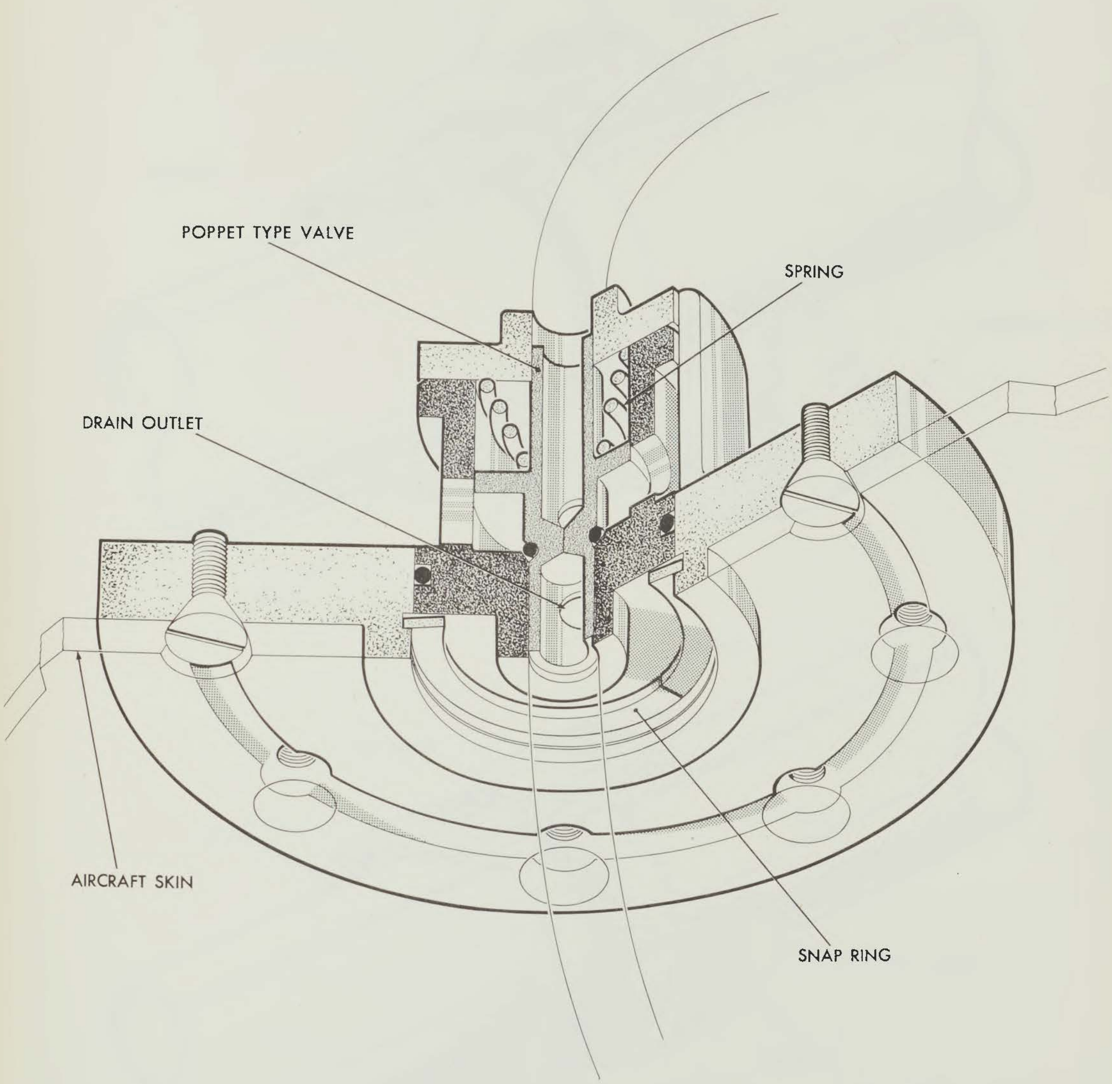

FIG. 3.29 FUEL AND CONDENSATION DRAIN VALVE

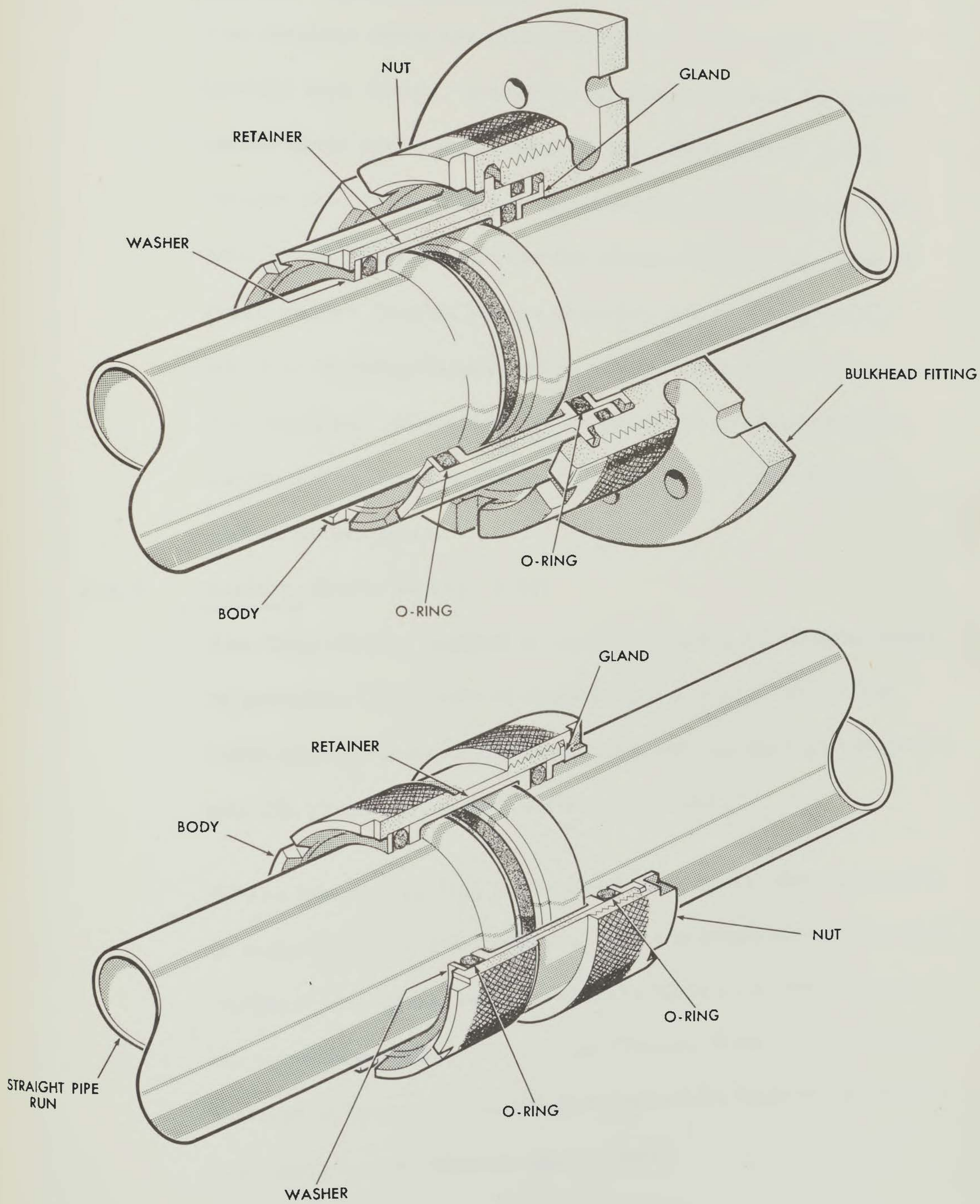

FIG. 3.30 COUPLING-FLEXIBLE FUEL

3.6.4 Fuel Cells - Bladder Type (Refer to Fig. 3.31)

The fuselage tanks are of double bubble cross section and bladder type design, occupying the space between the engine intake ducts above the armament bay, from station 315 to station 480. The cells are manufactured in accordance with MIL SPEC TG396-A and consist of non self sealing, Buna N type, rubber flexible linings installed in a fuel tank cavity which is an integral part of the aircraft fuselage structure. The tanks are subjected to 25 psi absolute pressure and are supported by hangers and by two rows of tie rod fittings at eleven inches pitch.

3.6.5 Sealing (Refer to Fig. 3.32)

The Chan-O-Seal method is used for sealing all integral tanks. In principle it consists of machining a groove in one of the inter-faying surfaces and injecting a non-curing type compound into the groove from the outside of the tank.

Where internal sealing is required and access after assembly is restricted, the old method of faying surface application of a curing type sealant together with the filleting of the corners has been resorted to. In certain "Danger Zone" areas a combination of both methods has been called for in order to form a secondary line of defence against leaks.

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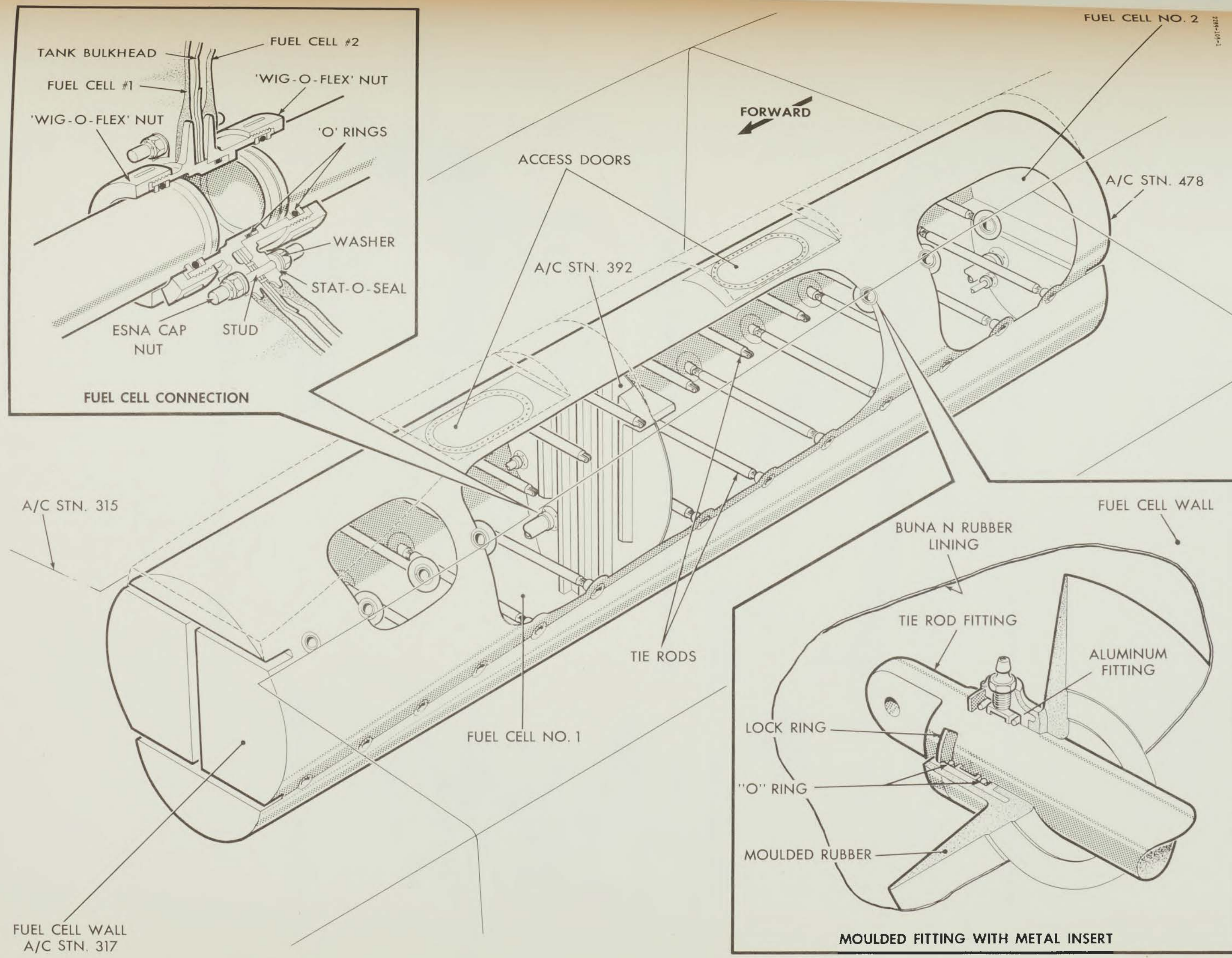

FIG. 3.31 BLADDER TYPE FUEL CELLS

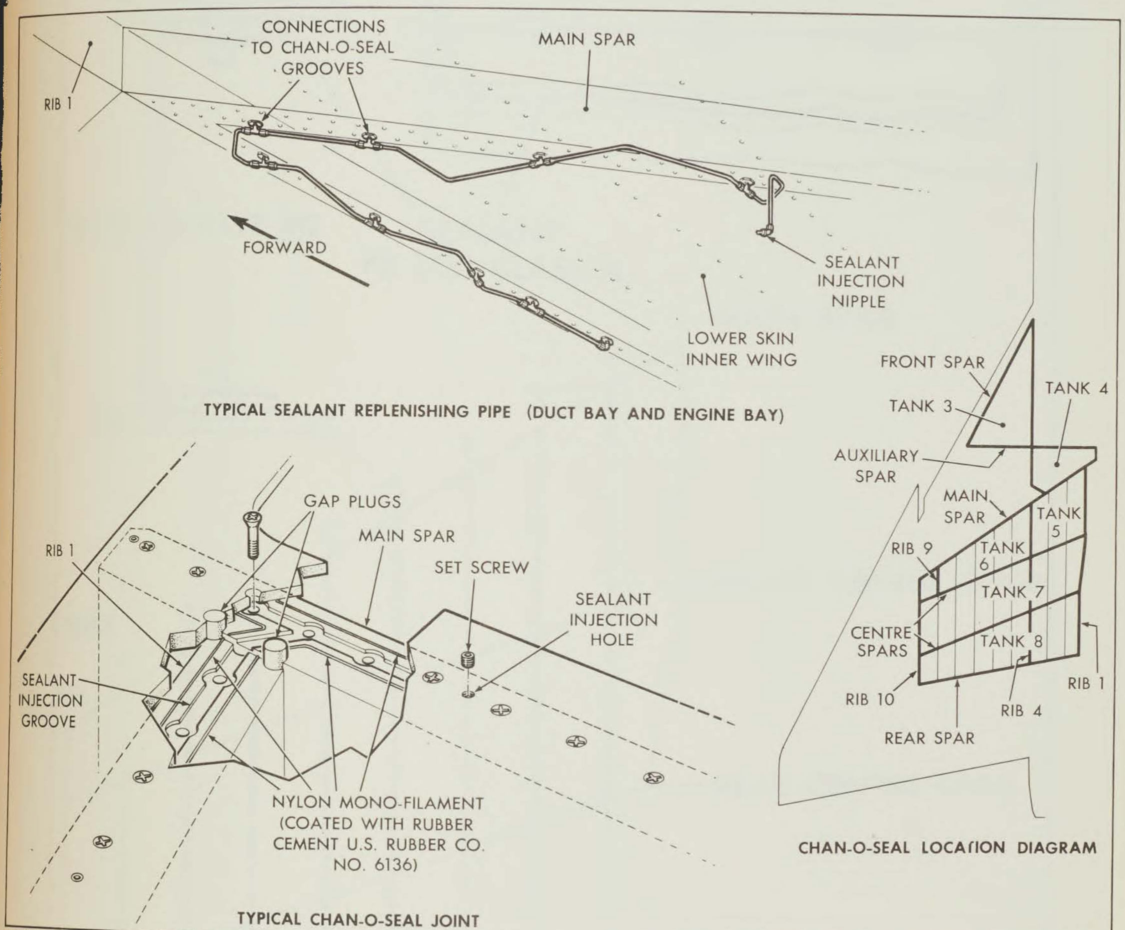

FIG. 3.32 SEALING—INTEGRAL TANKS

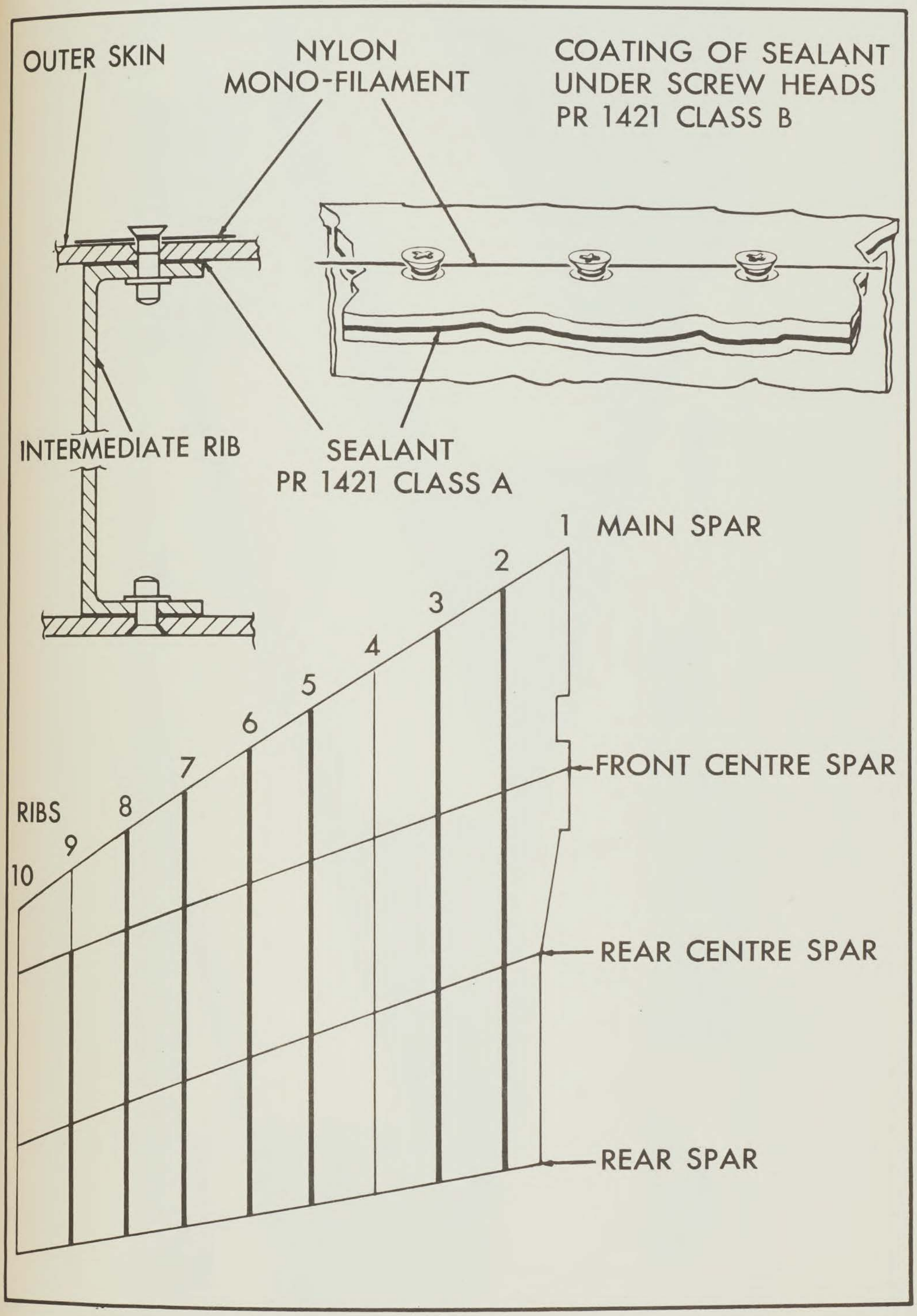

FIG. 3.33 SEALING OF INTERMEDIATE RIBS—INNER WING

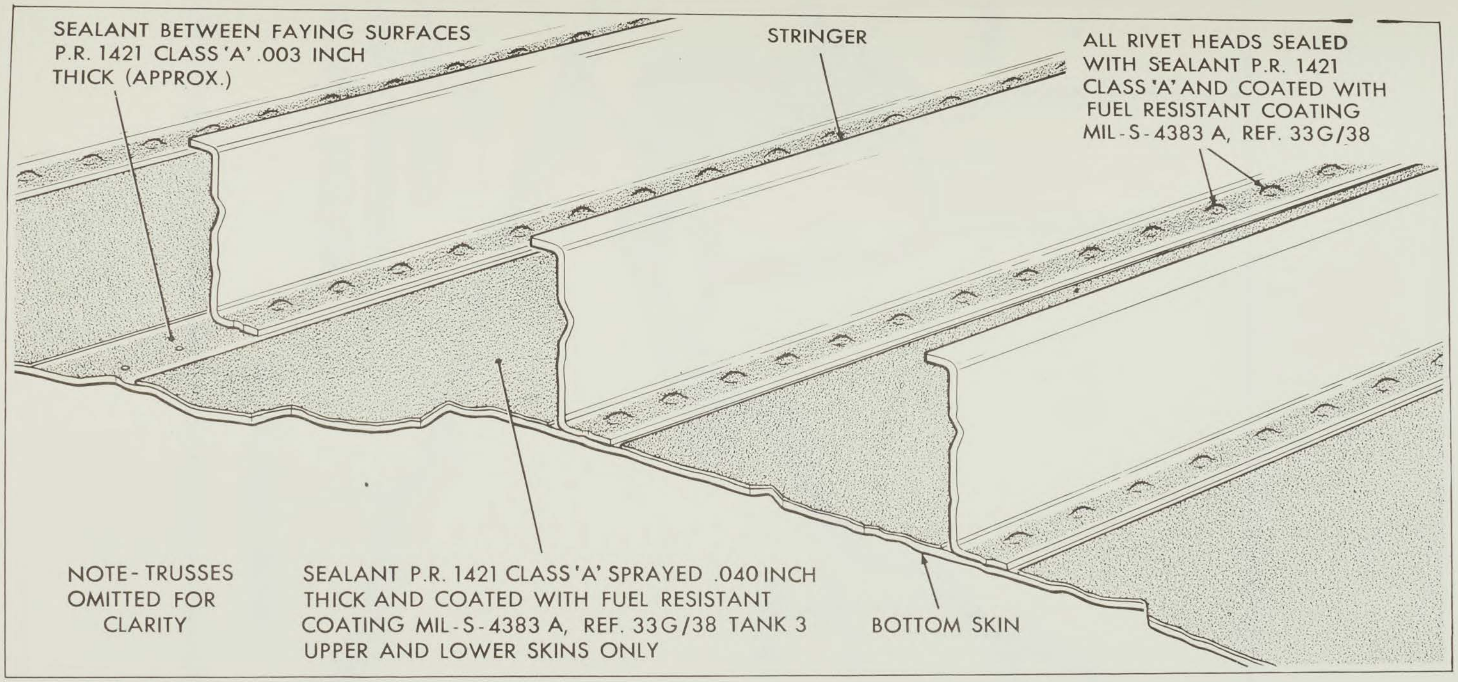

FIG. 3.34 SEALING OF STRINGERS—TANKS 3 AND 4

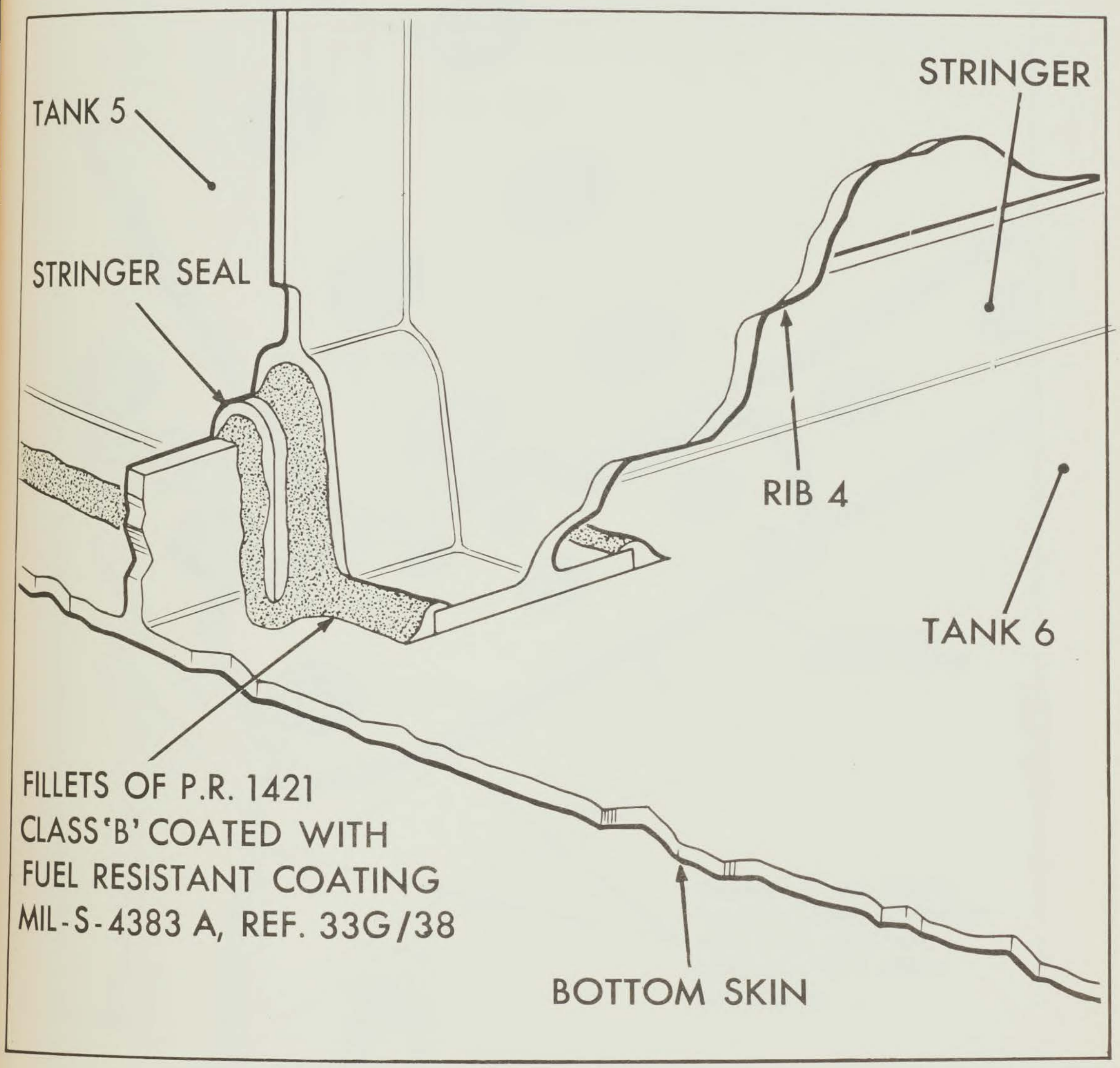

FIG. 3.35 INTERNAL FILLETING

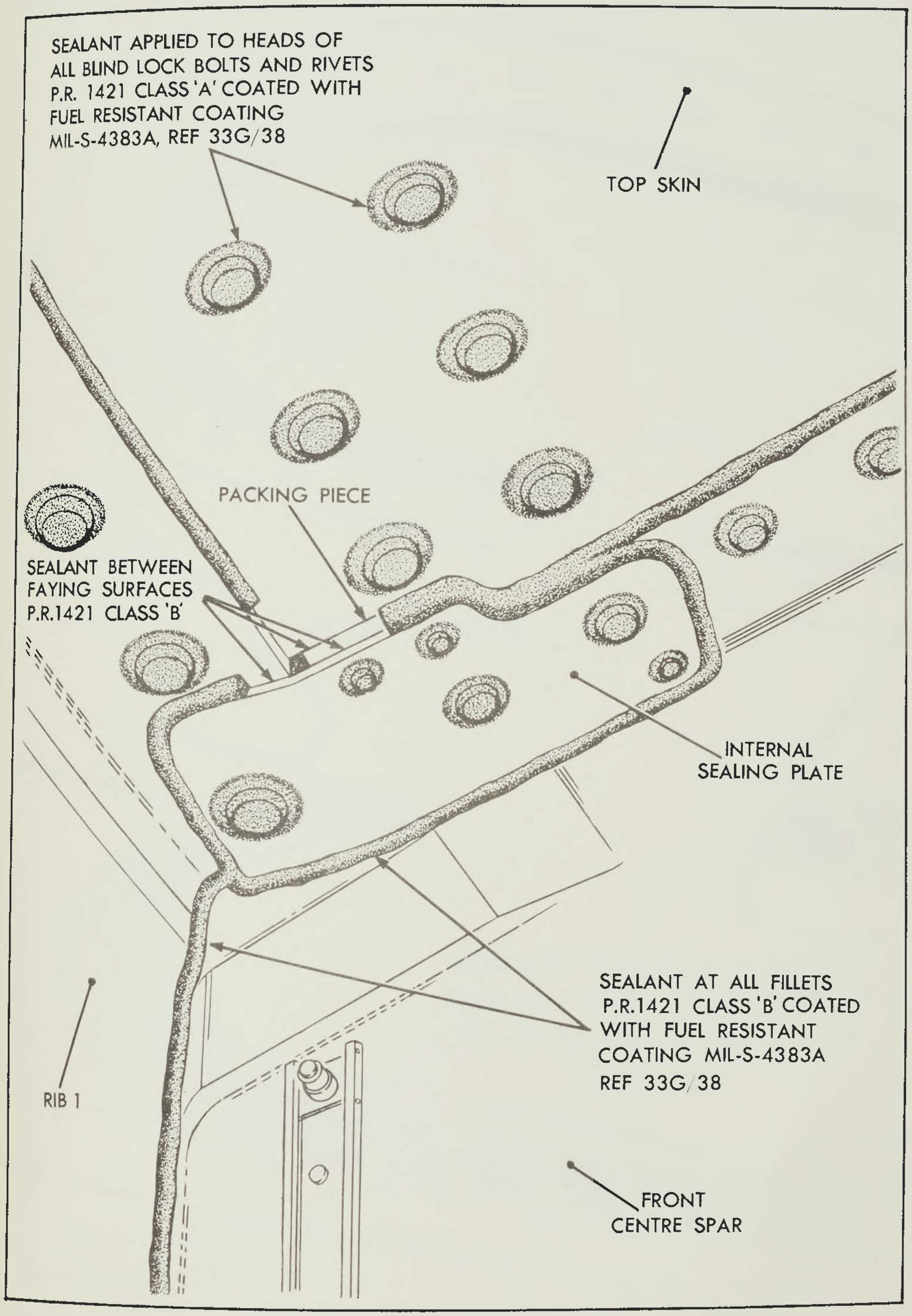

FIG. 3.36 TYPICAL SEALING AT TANK BOUNDARY JOINTS

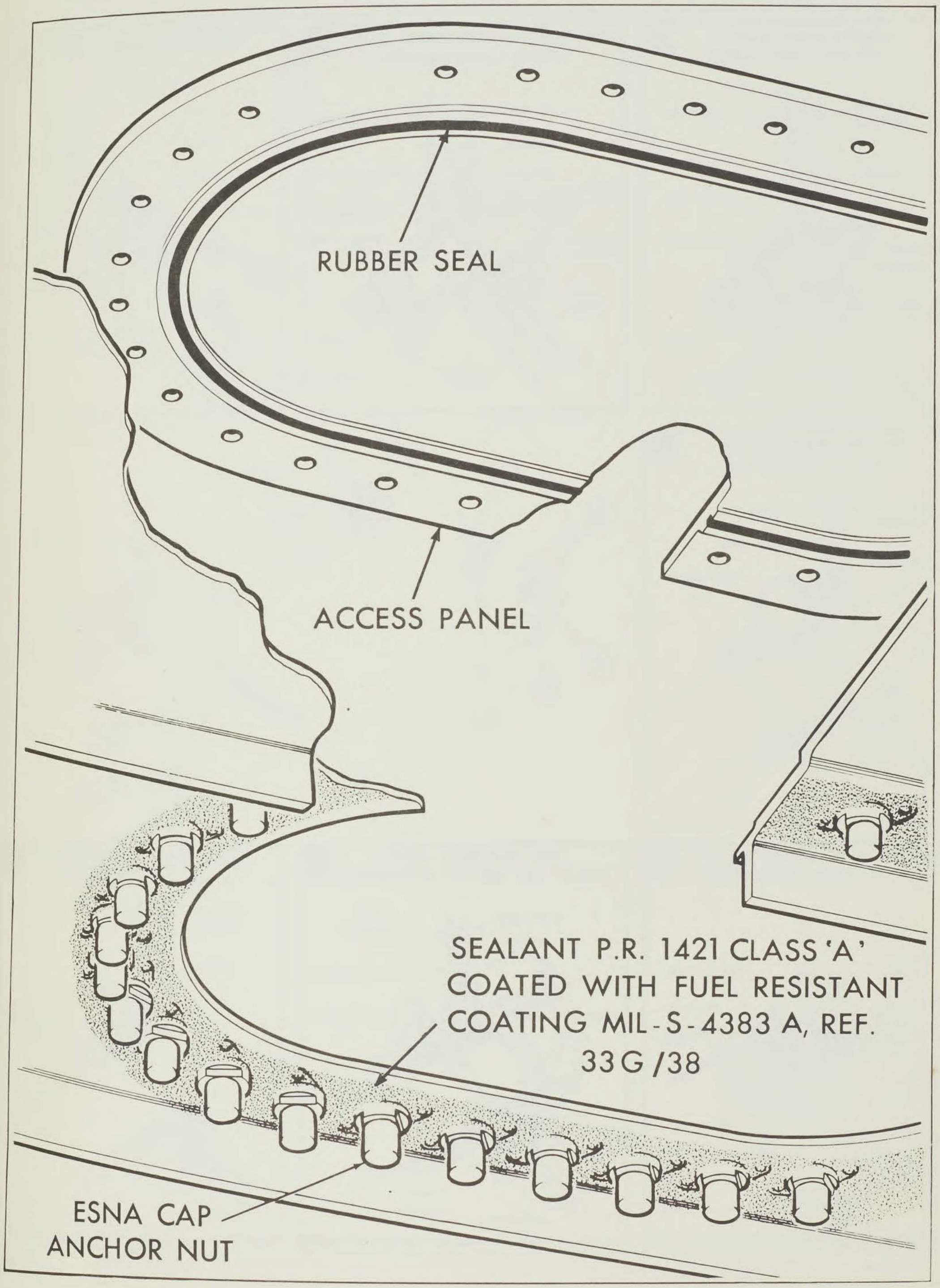

FIG. 3.37 TYPICAL ACCESS DOOR SEALING—INNER WING

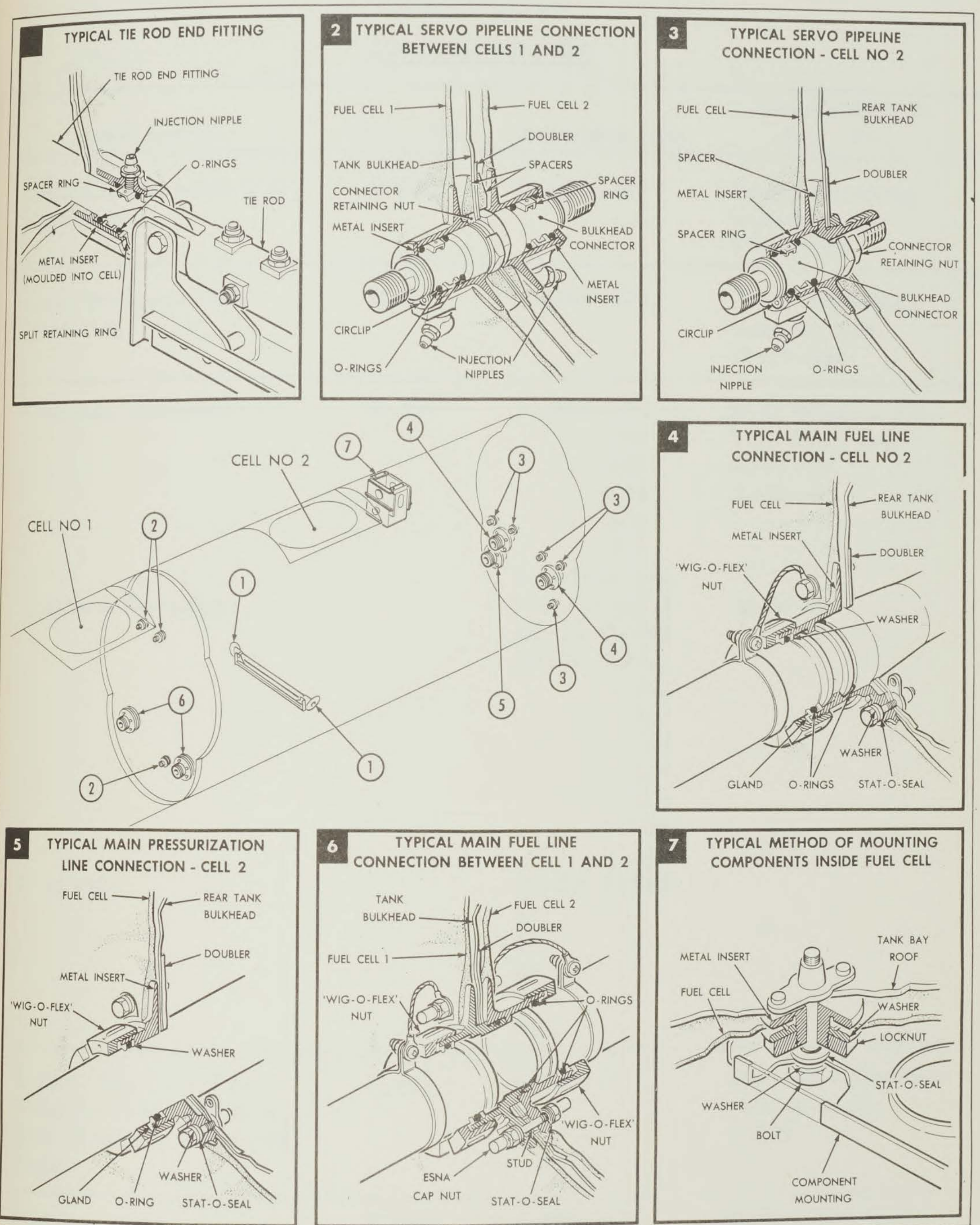

FIG. 3.38 SEALING OF FUEL CELLS CONNECTION—FUSELAGE TANKS

Description	Spec. No.	Avro Drg. No.	Manufacturer's Drg. No.
Fuel Cells	E 370	7-1754-5	Dominion Rubber
		7-1754-6	Co. Ltd.,
			FCB 60249
Fuel Distribution Control	E 503		Minneapolis-
		7-1662-1007	Honeywell Reg. Co.
Tank Units		1011	Ltd.
		1013	FG 220A
		1015	
		1023	
		1021	FG 120K
		1017	FG 150K
Collector Tank Monitor		7-1654-257	
Sequence Control Unit		7-1654-258	
Fuel Gauging System	E 323		Minneapolis-
		7-1662-605	Honeywell Reg. Co.
Tank Units		-607	Ltd.
		-611	
		-635	
		-637	
		-641	
		-803	
		-805	FG 200
		-811	
		-813	
		-815	
		-817	
		-821	
		-825	
		-827	
		7-1662-807	FG 250
		7-1662-985	FG 120
Indicator		7-1252-14	JG 130A
Pump, Fuel Booster	E 203	7-1662-583	Pesco Products
		-584	Div. Berg-Warner
			Corp.
			XO 23234-010
			-011
Switch, Fuel Pressure Engine Inlet	E 422	7-1656-51	Hydra-Electric
			20004

APPENDIX 1

EQUIPMENT LIST

Description	Spec. No.	Avro Drg. No.	Manufacturer's Drg. No.
Adaptor, Pressure Fuel Servicing	E 243	7-1662-447	Flight Refueling, Canada, Ltd. 07-01-050
Cap, Pressure Fuel Servicing	E 271	7-1662-471	Flight Refueling, Canada, Ltd. 07-01-060
Coupling, Flexible	E 259	7-1662-393	E. B. Wiggins Oil Tool Co., Inc.
		-395	A11V-16
		-397	A11V-48
		-625	
		-663	
		-971	
		16-CS-C-142	
Bulkhead Coupling		7-1662-15018	A21V-40
		40-CS-C-142	
		CS-C-140-12	
		-16	
		-20	
		-24	
		-28	
		-32	
		-40	
		-48	
Boss type		16-CS-C-172	
		20	
		24	
		28	
		32	
		40	
Filter, Hot Air, Fuel Pressurization (Removable Element, 300 CFM Type)	E 348	7-1654-7	Purolator Products Canada, Ltd. 44722
Flexible Hose	E 535	7-1600-47	Resistoflex Corp.
Flow Limiter, Air	E 300	7-1656-227	

Description	Spec. No.	Avro Drg. No.	Manufacturer's Drg. No.
Switch Low Level, Fuel	E 362		Minneapolis-Honeywell
Sensor		7-1662-981	SK 62678 (FG56G)
Valve, Air Pressure Regulator Absolute, 25 psi	E 227	7-1600-20	Hymatic Eng. Co. P 2352
Valve, Air Pressure Relief Absolute	E 288	7-1656-	Hamilton Standard Div. -Windsor Locks HS. 503993
Valve, Air Release	E 225	7-1600-19	Manning Maxwell and Moore, Inc. 141 RL 42
Valve, Combined Transfer and Refueling	E 538	7-1662-15017	
Valve, Dual Tank Level Sensing	E 337	7-1600-12	Schulz Tool & Mfg. Co. 2-355-51
Valve, Element Swing Check	E 366	7-1662-707	Essex Mfg. Co. Inc., 215000
Valve, Fuel and Condensate Drain	E 368	7-1656-8	Auto-Valve, Inc. 1550 B1
		7-1662-12	1575 B2
		-183	1575 B1
		-185	1540 C
		-186	1541 C
		-189	1550 B2
Valve, Fuel No Air	E 201	7-1600-45	Flight Refueling, Canada, Ltd. 37-07-001 Aero Supply Mfg. Co. Inc. 31-1865-000
Valve, Fuel Shut-off Electric Motor operated 28 V. D.C.	E 233	7-1600-61	General Controls AV16B-1287

Description	Spec. No.	Avro Drg. No.	Manufacturer's Drg. No.
Valve, Gate, Manually operated	E 428	7-1662-15015	General Controls
Valve, Neg."g" & Low Level Air Admission	E 270	7-1662-7	Hymatic Eng. Co. P 2134
Valve, Non Return	E 543	7-1662-15021	Flight Refueling, Canada, Ltd. SKC. 129
Valve, Tank Shut-off Pressure Fuel Sensing	E 311	7-1600-11	Schulz Tool & Mfg. Co. 7-355-51