ORION

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ORION

FUELING, DEFUELING, AND FUEL TRANSFER . . 4
THE FUEL SYSTEM 5
AUXILIARY FUEL 6
TANK VENTING 7
QUANTITY INDICATING 8
PRESSURE FUELING 9
DETAILED OPERATION—FUELING AND PILOT VALVES 10
DEFUELING 12
THE FUELING OPERATION 12
FUEL LOADING 14
GENERAL SERVICE INFORMATION 16
FUEL TRANSFER SYSTEM 19
INTEGRATED FUELING INSTRUCTION 24

P-3 FUEL FEED SYSTEM 26
FLIGHT STATION CONTROLS AND INDICATORS . 27
CROSSFEED 29
LOW PRESSURE PUMPING SYSTEM OPERATION . . 29
HIGH PRESSURE PUMPING SYSTEM OPERATION . 33
COMPONENT DETAIL AND MAINTENANCE . . . 34

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FRONT AND BACK COVERS In November of 1967, Patrol Squadron 5 completed their 25th year of operation, flying — as they have always done — the latest development in Lockheed ASW aircraft.

Commissioned VB-135 in 1942 at Whidbey Island, they operated both PV-1's and PV-2's in WW II. Their frequent and audacious all-weather raids on Japan were aptly symbolized by "The Blind Foxes" appellation they adopted at that time.

After the war, the squadron began peacetime operation from our Eastern Seaboard as VPML-5, then, shortly after receiving P-2's fitted with the Navy's first MAD gear in 1948, they adopted their current "MAD FOXES" emblem, and were re-designated VP-5. As a unit of Fleet Air Wing 11, they have since retained Jacksonville, Florida, as the "foxes' den", but have ranged far afield on a great variety of assignments in the course of this long tenure.

In the 1950's, they extended their hunting grounds over the North Atlantic and beyond, operating at various times in this period from Iceland, Italy, Newfoundland, Malta, Norway, the Azores, and Morocco. Their records for these globe-trotting years include two CNO Safety Awards, suggesting that the Mad Foxes are indeed "crazy — like a fox."

Although their ASW operations continued to range far afield on occasion in the early 1960's, world events at their doorstep kept them close to home much of the time. In 1961, VP-5 aided in recovering America's first two pioneer astronauts, Alan Shepard and Virgil Grissom, after their historic sub-orbital flights, and they were also instrumental in the recovery of Walter Shirra following his 6-orbit mission in 1962. Later that year, VP-5 was the first unit ordered into action to enforce the quarantine on shipment of offensive military equipment to Cuba.

Transition from P-2's to P-3's began in June 1966 and the squadron that won the coveted "E" for battle efficiency with their veteran Neptunes in 1964 became an even greater asset to the Navy's ASW capability. They demonstrated this most convincingly in the course of a recent 6-month deployment to Sangley Point, Republic of the Philippines. Despite their heavy schedule entailing more than 9000 hours of flight in support of our efforts in Viet Nam, they returned to Jacksonville winner of yet another CNO Safety Award.

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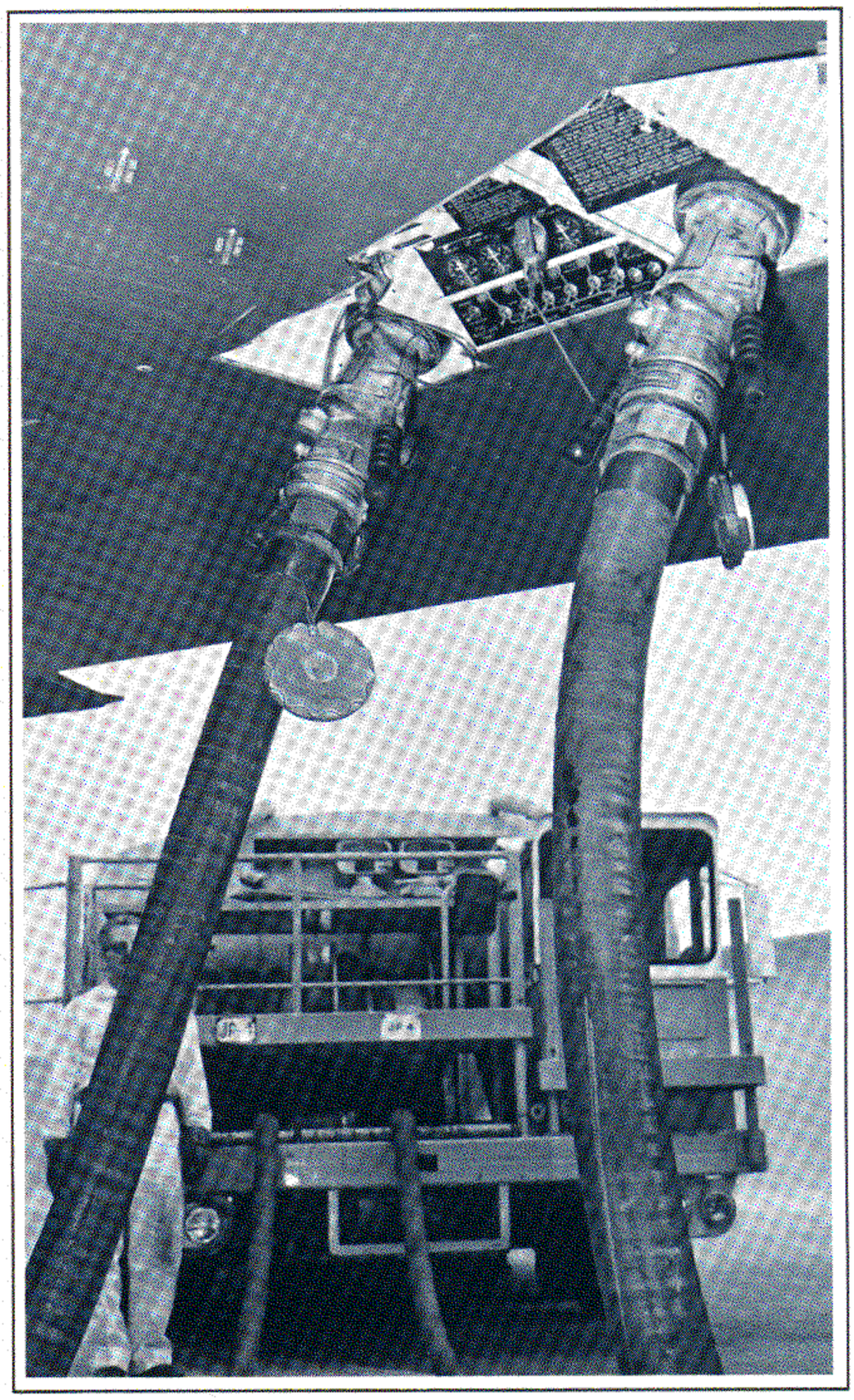
FOREWORD

The first article of this issue is an updated reprint of Orion Service Digest Issue 2. In the many months Issue 2 has been out-of-print, thousands of copies have been requested by enterprising personnel, most of whom wished to acquire a complete set of Digests for their personal reference file. Re-issuing the text will put the information, if not the original magazine, in their files together with information on an allied topic — The Fuel Feed System — the subject of the second article of this issue. Those unfamiliar with the P-3 are urged to read both articles, for discussions closely affiliated to Engine Feed are contained in the first article and are not repeated in the second.

We should mention here that a simple fuel dump system is now being incorporated in production aircraft as part of a major modification program to equip the P-3 for operation at higher gross weight. In view of the small percentage of operating aircraft equipped with this facility and the fact that its inclusion in no way alters the normal procedures and functions described here, we have deferred discussion of fuel dumping for a future article devoted to the provisions for high gross weight operation.



FUELING DEFUELING AND FUEL TRANSFER

INTRODUCTION

OUR SUBJECT SYSTEMS occupy a position of overlapping interest between the areas and functions usually associated with maintenance and those associated with operation. This is attributable to an integrated design, wherein a single manifold and its associated components serves multiple purposes. There are many inherent advantages in respect to simplification and weight-saving with such a design, and it follows that, when three sub-systems are so closely-knit, everyone concerned with one of them is unavoidably concerned with the other two, and should know something of the design and operation of all three.

The histories of most mass-produced, pressure-fueled aircraft provide proof that when great quantities of fuel are pumped into — or out of — aircraft tanks through a closed system, serious accidents can occur, sometimes entailing destruction of aircraft and fatalities. The Orion design offers a high degree of protection against such occurrences, but certainly operators who bring to the job a thorough knowledge of the devices they operate greatly enhance the margin of safety. For this reason, we strongly recommend that fueling, defueling, and fuel transfer operations be performed by an ADJ or better-qualified rate especially schooled on the design. However, it is recognized that experienced service personnel may not be available in isolated instances, and in such cases this article will help to guide the inexperienced.

Of course, Digest information should not be regarded as a substitute for official publications, but as a convenient supplement to them. The Maintenance Instruction Manuals, the Maintenance Requirement Cards, and the NATOPS Operating Manuals are revised as necessary to reflect changes in design and techniques, and should always be consulted as final authority.

THE FUEL SYSTEM is comparatively simple, considering that it serves a long-range, four-engine aircraft. As shown in Figure 1, tankage extends from wing-tip to wing-tip, and from the wing front spar beam to the aft spar beam. These tanks are integral, that is, they are created by sealing the primary wing structure and providing chordwise bulkhead partitions to separate the tanks.

In addition to the integral tanks, a bag-type (bladder-cell) tank is installed in the belly forward of the wing center section, immediately aft of the bomb bay. For most purposes, this tank may be regarded as an extension of the integral center-section tank — indeed the two compartments are identified collectively as No. 5 Tank. In this article, we will use this nomenclature where the context allows, but since it is often necessary to distinguish between the two compartments, we will then refer to the center section compartment as No. 5 Ctr. Tank, and the fuselage bag compartment as No. 5 Fus. Tank.

Maximum fuel capacity of the aircraft is 9200 U.S. Gallons. This corresponds to 59,800 lb of JP-4 fuel at its nominal density of 6.5 lb per gallon. JP-4 is considered to be the normal fuel for the Orion. JP-5 is an acceptable alternate fuel, but it is a somewhat denser fuel — indeed a full load of cold JP-5 could weigh 65,000 lb or more — and the extra weight can be an important factor in respect to loading and operating limitations.

Tanks 1 and 2, in the left wing, and 3 and 4, in the right wing are engine-feed tanks; each tank normally supplies fuel to the corresponding engine. These four tanks are of nearly equal capacity (10,439 lb in each outboard tank; 10,861 lb in each inboard tank) so that there is little occasion to cross feed engines unless engines are shut down in flight.

Engine Feed. Normally, the feed line to each engine is pressurized by an ac electric motor-pump mounted in an open-top surge box at the inboard lower-aft

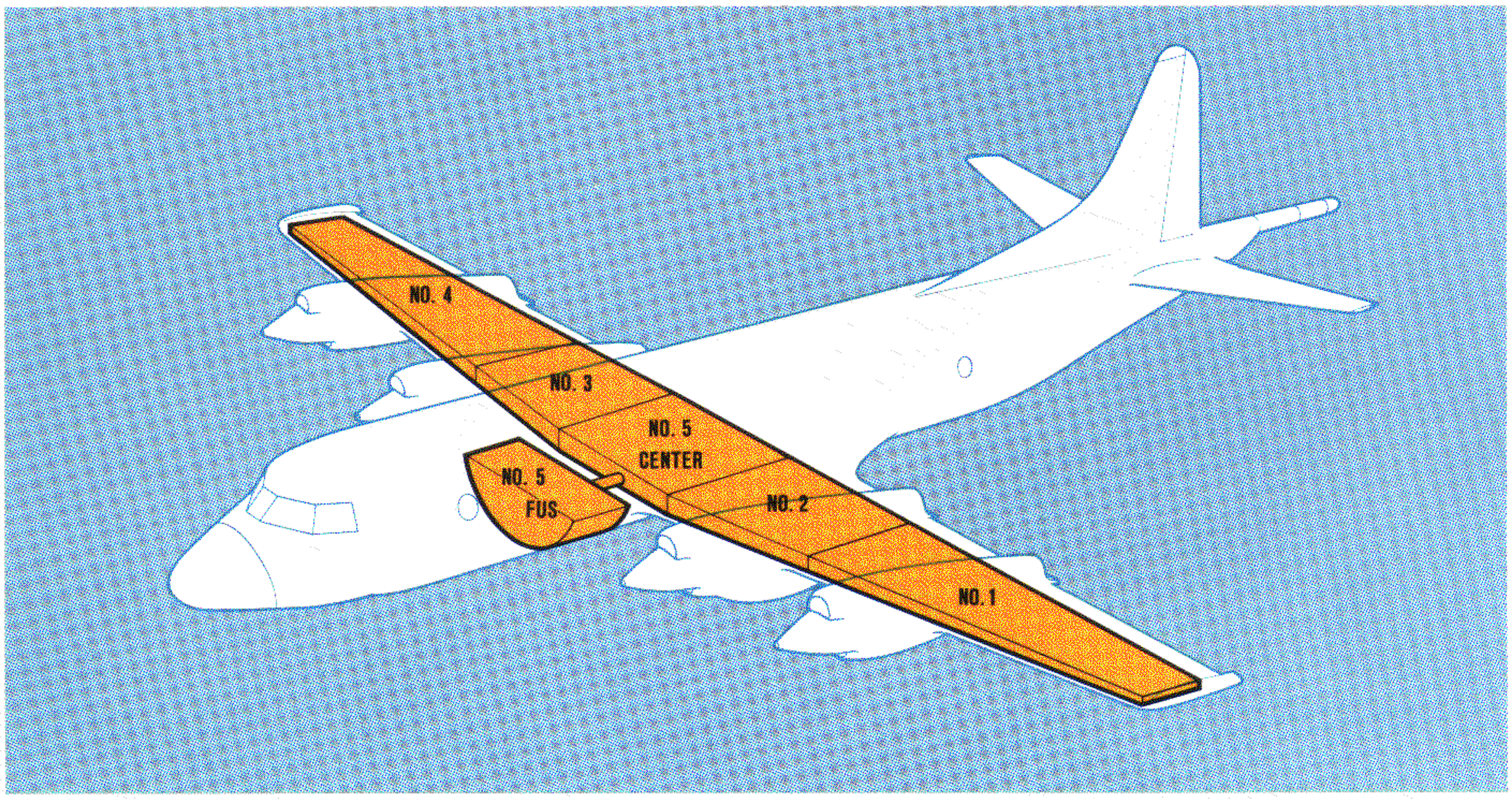


Figure 1 Orion Fuel Tanks

corner of each engine-feed tank. These pumps have dual pumping elements of the centrifugal tapered screw type. One element scavenges fuel from a low point forward of the surge box, keeping the surge box flooded, thus ensuring that little fuel is unusable even in a prolonged nose-down descent such as the normal approach attitude. The other pumping element, the booster element, in turn maintains pressure constantly in the engine feed line so that normally a pressurized supply will be provided for a third centrifugal pump mounted on — and driven directly by — the engine.

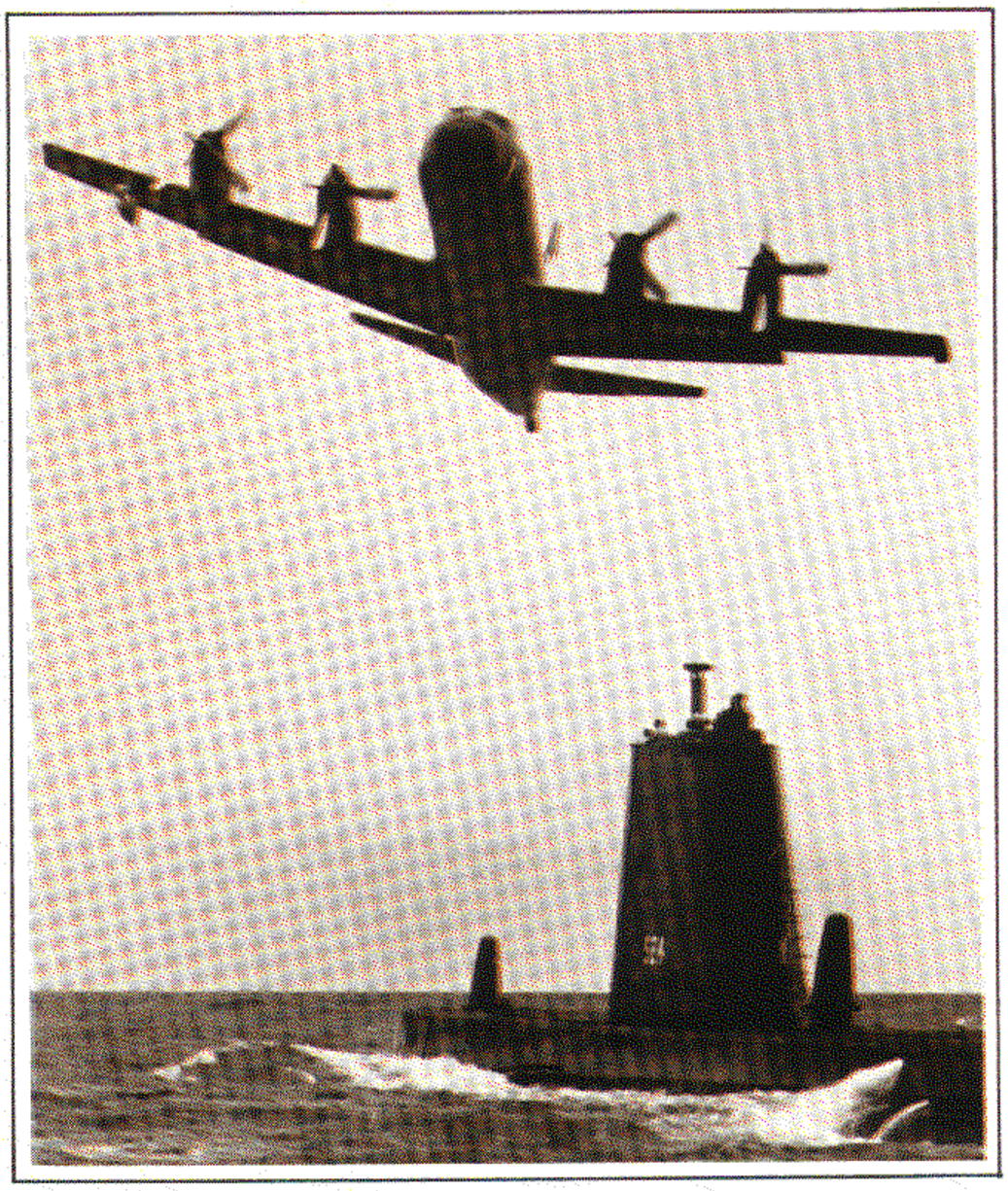
The fuel feed system has been carefully designed so that engine feed can be maintained in the event a motor pump or its power supply fails. If the booster-scavenge pump is inoperative, the engine-driven boost pump can draw fuel through a bypass line directly from the surge-box (thus by-passing the inoperative booster-scavenge pump). Each surge-box has a flap-

per check valve in its forward wall that allows tank fuel to gravity-flow to the bypass inlet of the engine-feed line.

The four engine-feed systems are tapped, as shown in the Figure 2 diagram, by a cross-feed system which has five electrically operated valves: four cross feed shutoff valves, and one cross-ship cross feed shutoff valve. The output of each tank-mounted boost pump is more than adequate for two-engine supply, and it can be directed through the cross feed system to supply any combination of engines. There is no provision for transferring fuel from any engine-feed tank to another tank.

Conventional filler-wells are provided for the four engine-feed tanks, so that these tanks can be serviced when pressure-fueling is unavailable, and a dip stick can be used at the filler-wells to determine fuel quantity manually.

Auxiliary Fuel. No. 5 Tank capacity (17,199 lb. of JP-4) accounts for about 29% of the maximum fuel supply, but it is regarded as an auxiliary tank that is fueled for flights which are too long to utilize the engine feed tanks alone. It has no filler well for



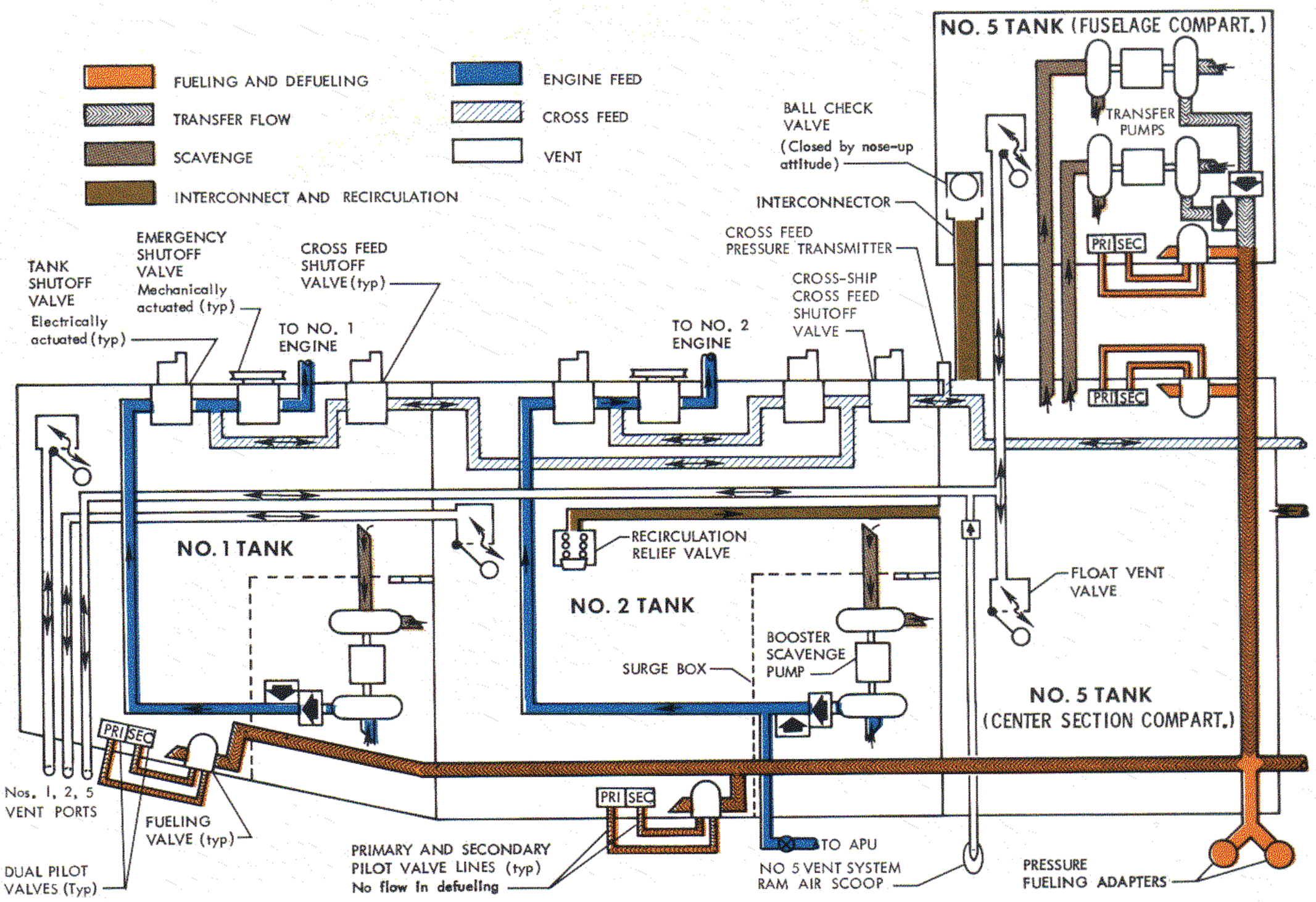


Figure 2 Fuel Tank Plumbing and Flow Schematic. Right wing tanks do not incorporate a Cross-ship Shutoff valve or Tank 5 vent lines, but are otherwise identical to the left wing tanks.

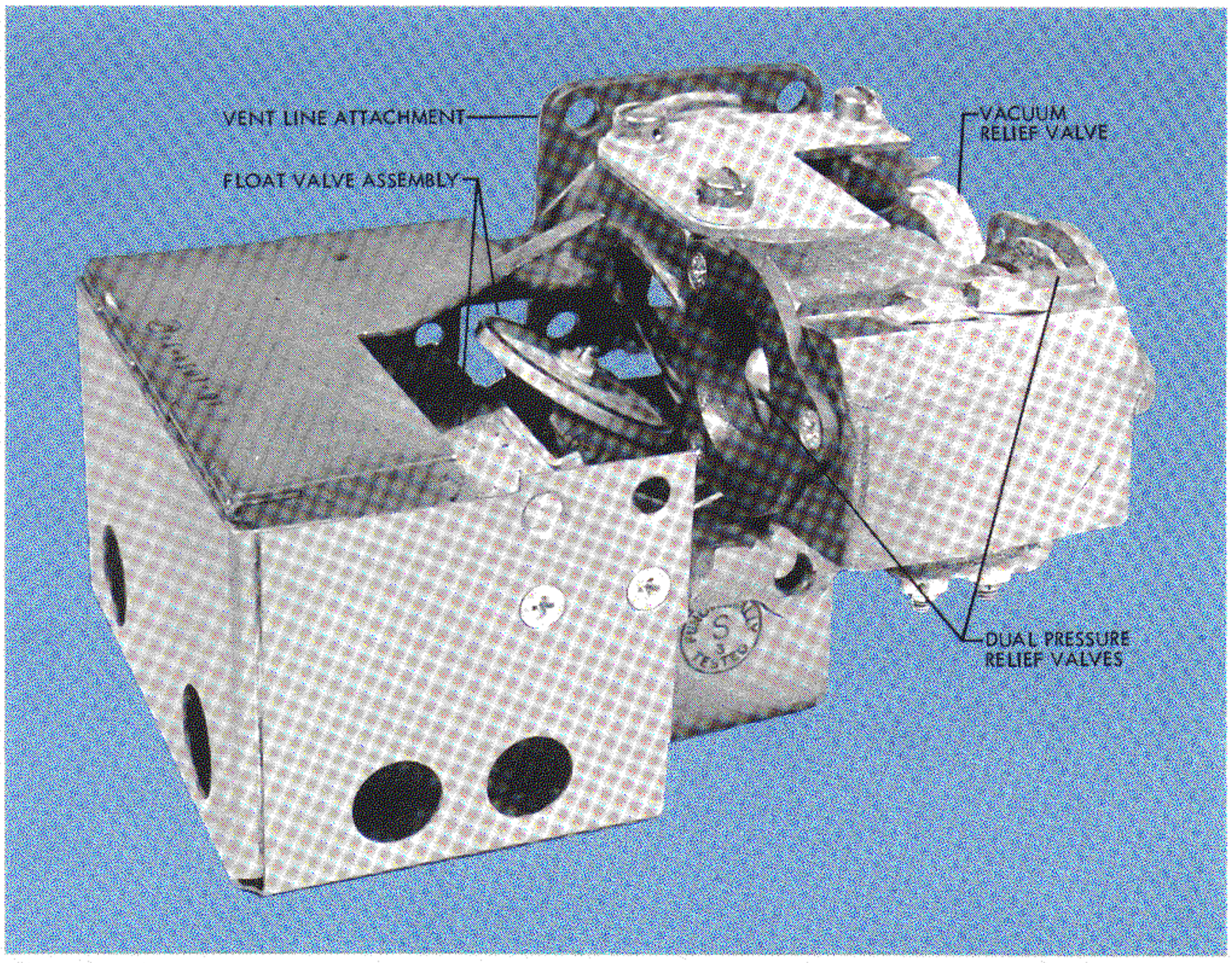


Figure 3
Float Vent Valve Assembly

gravity fueling. A sight-gauge type slip tube is mounted in the bottom of the No. 5 Ctr. Tank for manual measurement of fuel quantity.

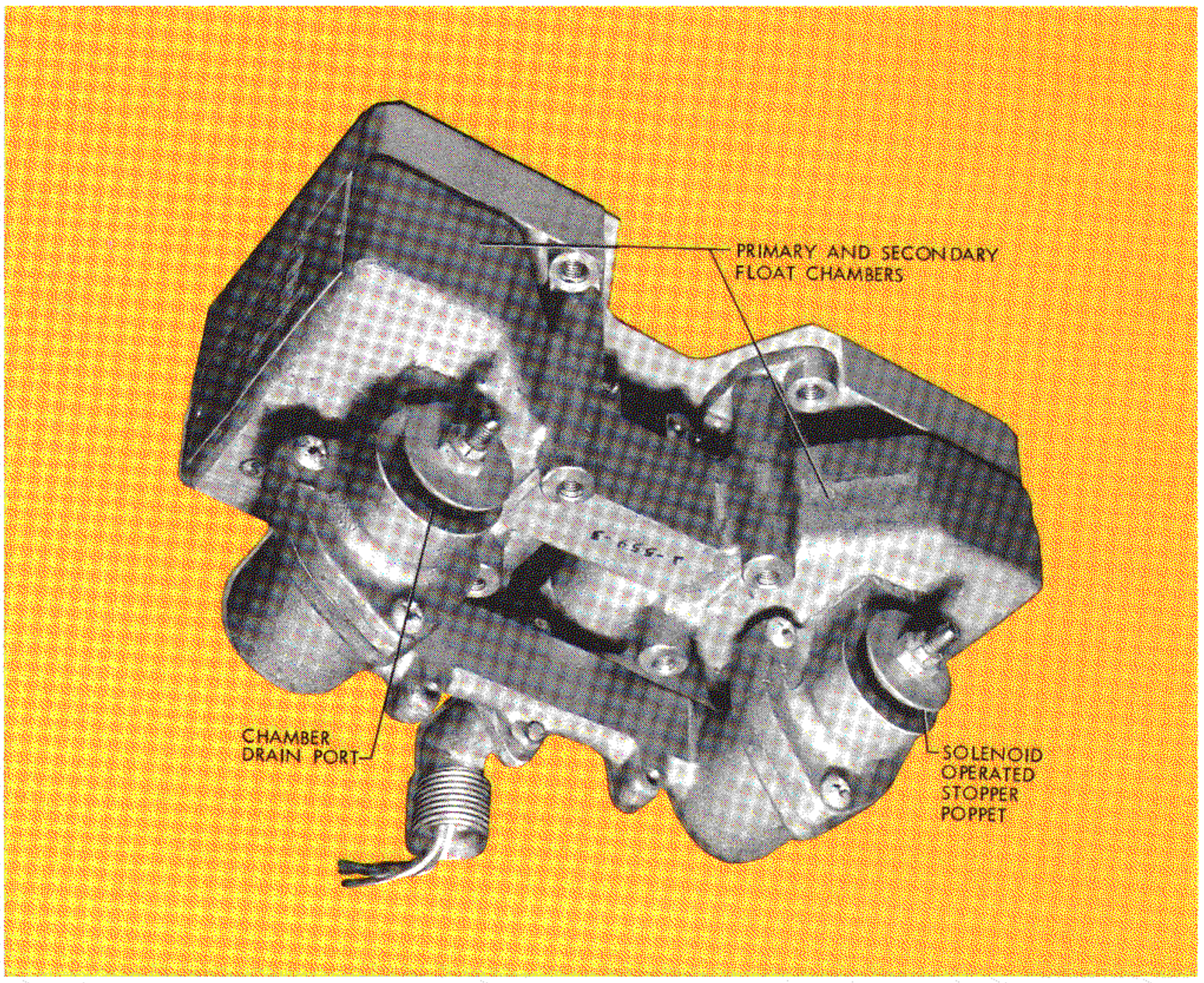
When fuel is carried in the No. 5 Tank, it is expended as quickly as possible by transferring it continuously into the four engine-feed tanks during the early part of the flight. Two transfer pumps — identical to the booster-scavenge pumps used in the engine feed systems — are used to transfer the No. 5 Tank fuel. They are mounted at the low point of the No. 5 Tank, which, as can be seen in Figure 1, is the bottom of the No. 5 Fus. Tank. This area may be regarded as a surge box for the transfer system. Fuel above the level of the interconnect can flow freely into the No. 5 Fus. Tank from the No. 5 Ctr. Tank, and in addition the scavenge elements of the two transfer pumps work constantly during fuel transfer, scavenging No. 5 Ctr. Tank to maintain a head of fuel at the booster elements of the transfer pumps. The booster elements pump the auxiliary fuel to the engine feed tanks, utilizing the pressure fueling manifold and the engine-feed tank fueling valves for the purpose. These four fueling valves are controllable from the flight station Fuel Management Panel, where, for obvious reasons, they are identified as Nos. 1, 2, 3, and 4 Transfer Valves.

Tank Venting, always a vital system on aircraft, is especially important on pressure fueled aircraft such as the Orion. Vent valve assemblies are located in domes atop the two No. 5 Tank compartments, and at the top outboard end of each wing tank. Vent plumbing is routed outboard from the valve assemblies through the wing tanks to discharge ports, fitted with flame-arresters, mounted in the bottom wing skin near the tip.

The vent valve assemblies have float operated valves that close to prevent fuel surges from being spilled during turning maneuvers, and open to allow free venting when the tank is less than full. When the tank is full, the free vent is blocked by the float valve, but pressure and vacuum relief valves in each vent valve assembly crack (open) at plus 1.2 psi and minus 0.1 psi, respectively, to limit tank differential pressure.

The two No. 5 vent lines are interconnected, and plumbed to a port at the left wing tip. The No. 5 Fus. Tank is, of course, located in an unpressurized area of the fuselage. Negative internal pressure, so small as to be insignificant to an integral tank, will collapse a bag tank, and No. 5 Tank vent is designed to ensure that this does not occur. Ram air is admitted through a scoop just forward of the inboard end of the left wing flap, ducted forward through a check-valve, and discharged into the No. 5 vent line. Ram air from the intake will circulate through the vent line and overboard at the wing tip vent port, but due to a restrictor in the line a small back pressure will be maintained in the No. 5 Fus. bag at all times

Figure 4
Dual Pilot Valve Assembly



during flight. During the maneuver most likely to collapse the bag — a rapid descent from high altitude — the positive pressure in its vent line ensures that pressure in the bag will never lag significantly behind the increasing atmospheric pressure.

Quantity Indicating is of the capacitor probe type. Multiple probes — 5 in each outboard tank, 3 in each inboard tank, 3 in No. 5 Tank — are top mounted in the wing tanks, bottom mounted in the No. 5 Tank. Indicators for the five tanks are provided on a Fueling Control Panel at the pressure fueling facility and on the Fuel Management Panel in the flight station. The latter panel also has a drum-type totalizer. All the quantity indicators are calibrated in pounds.

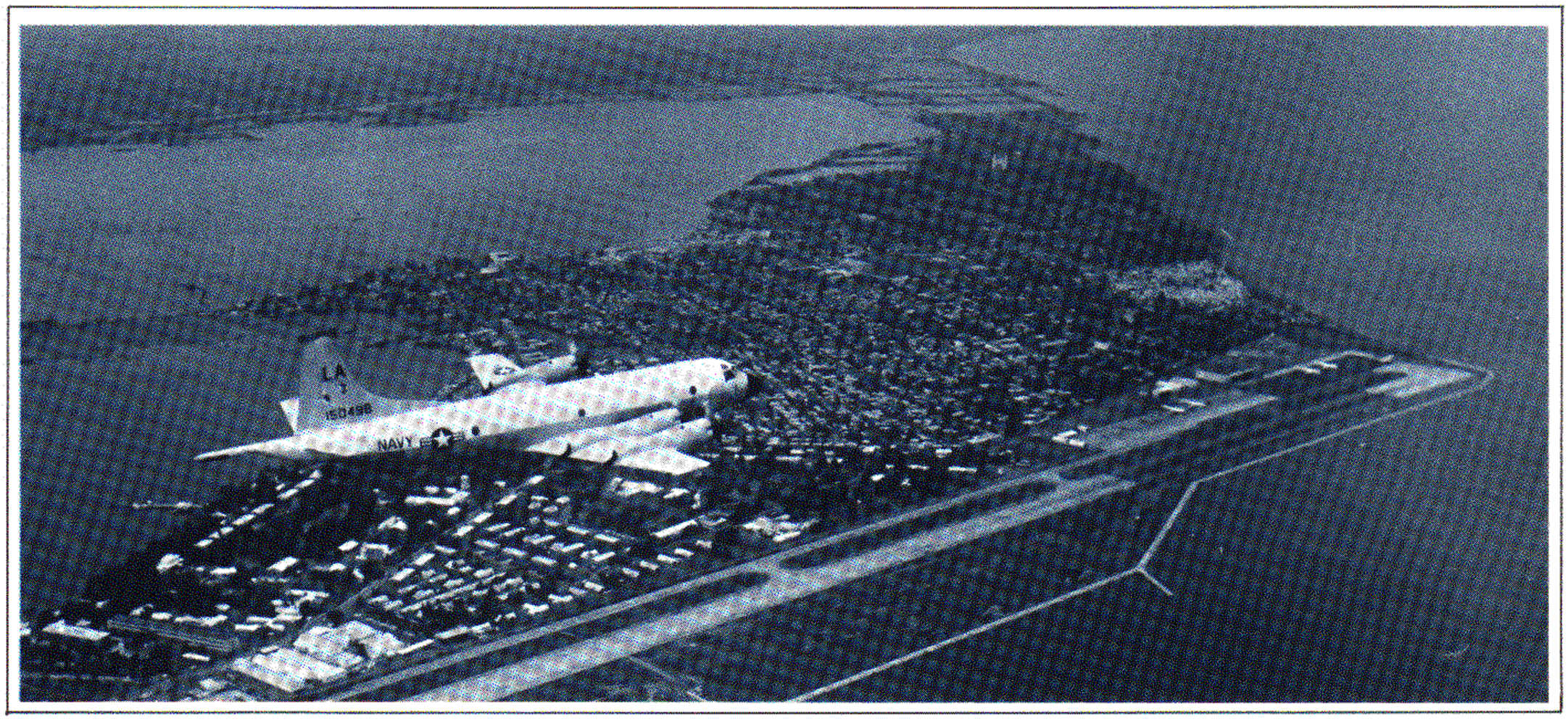
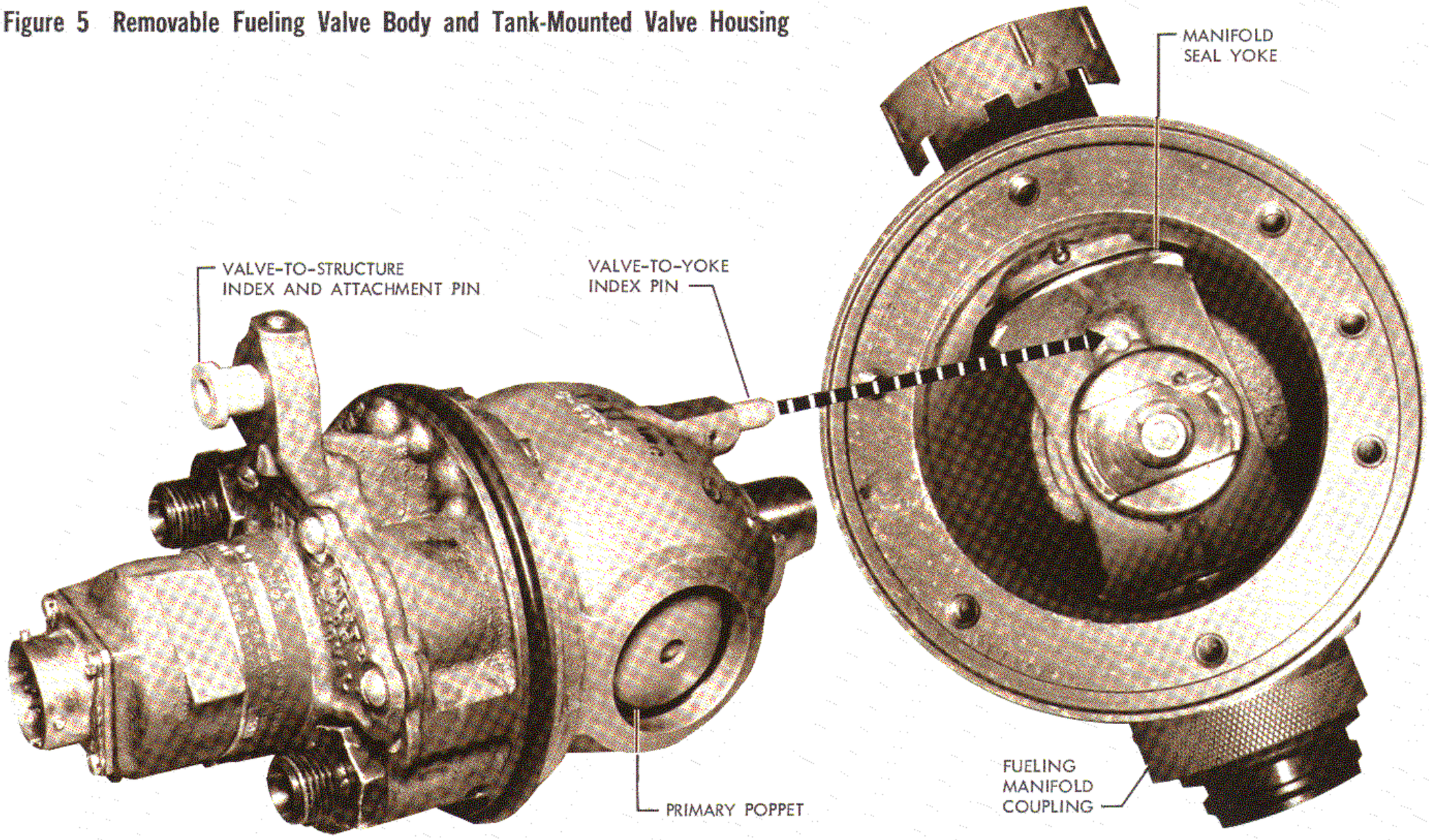


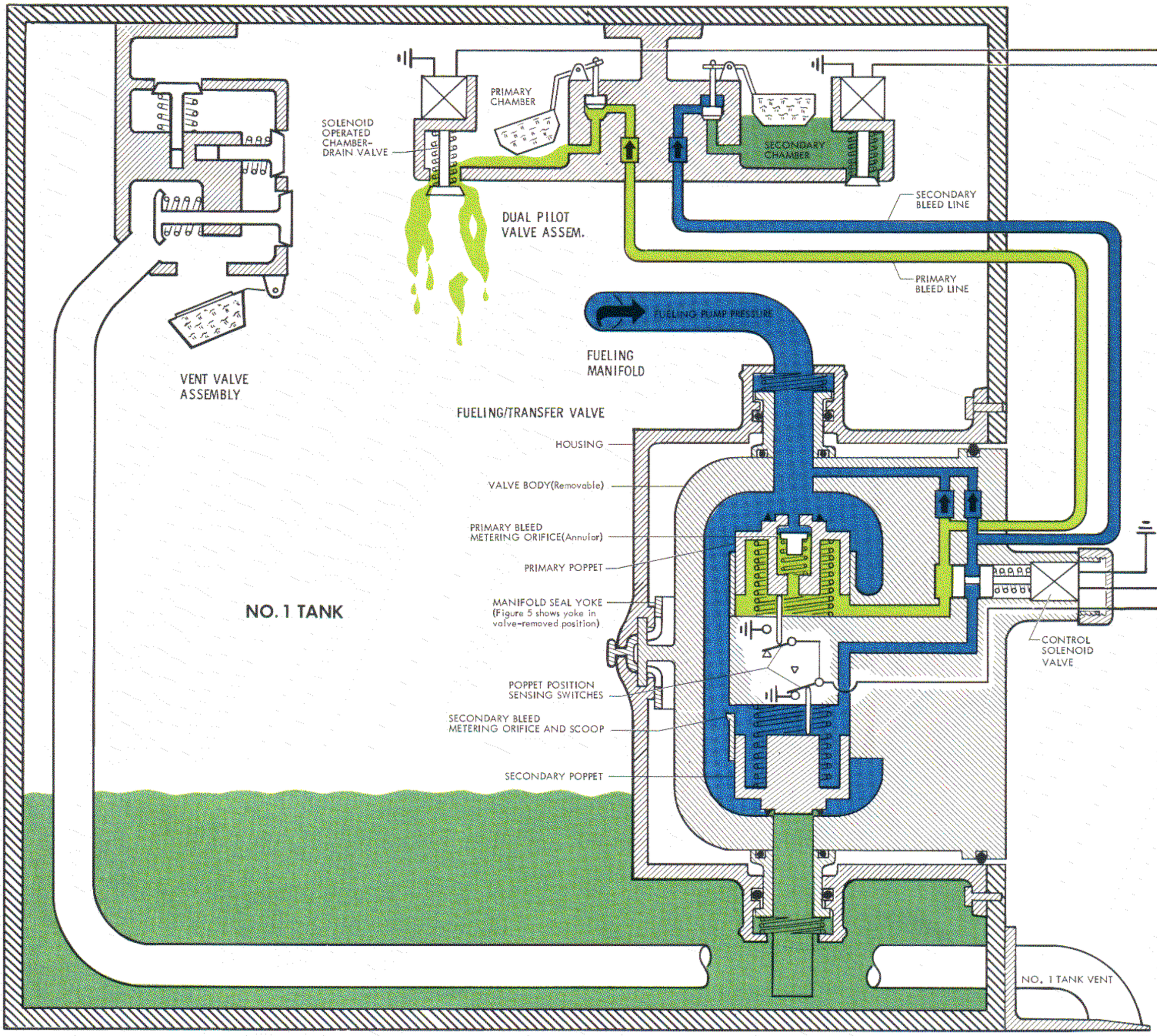
Figure 5 Removable Fueling Valve Body and Tank-Mounted Valve Housing



PRESSURE FUELING

The pressure fueling facility shown on the title page is located inboard of No. 3 Engine in the lower aft wing-to-fuselage fillet. The two fueling connectors, suitable for MS29520 Type D-1 hose nozzles, allow accelerated servicing when two fuel trucks are available. The two supply lines are joined into a single large diameter tube which passes into No. 5 Ctr. Tank through the aft shear beam web as shown in Figure 2. Inside the No. 5 Ctr. Tank the main tube is joined to a fueling manifold which has three branches — a left, right, and forward branch. The left and right branches run spanwise inside the wing tanks to fueling valve housings bolted to the aft shear beam in each engine-feed tank. The forward branch goes to a fueling valve housing for the No. 5 Ctr. Tank mounted on the forward shear beam. It continues through the forward beam, a dry bay, and enters the No. 5 Fus. Tank through the aft tank bulkhead and bag wall, terminating at the No. 5 Fus. fueling valve housing which is mounted on the aft bulkhead. (Actually, tubing continues on to the two transfer pumps, but these lines carry no flow in fueling or defueling and are not a part of the fueling manifold). An open tube extends from each fueling valve housing to the bottom of the respective tank, enabling almost all of the fuel to be removed when the valves are used for defueling.

The fueling valves are identical units. They are spring loaded to the closed position, have a solenoid valve for manual control, and a dual pilot valve control which provides two separate and automatic closure controls for the fueling valve when the tank is full. The design is such that pressure (either positive or vacuum) must be applied to the fueling manifold before the valves can be opened, and no valve can be opened by positive manifold pressure if its tank is already full. Fueling valves utilizing a similar theory of operation have been used for years on other pressure-fueled airplanes, but the Orion fueling valves are somewhat different in their "plug-in" design which allows a valve to be removed without defueling the tank. The valve body, containing all the moving parts, can be turned in the permanently mounted housing (this positions the temporary sealing yoke shown in Figure 5 to block the flow of fuel from the fueling manifold) and extracted through the access hole in the shear beam or tank bulkhead. This plug-in concept is used with most of the tank-mounted components on the Orion in order to simplify routine maintenance. It is an especially valuable feature of the fueling valves, for these valves must function properly for normal defueling, and if a malfunctioning valve could not be removed as described, defueling to effect a minor repair would be an onerous task.



DETAILED OPERATION — FUELING AND PILOT VALVES

The tank-mounted components of one engine-feed tank and the principal electrical circuitry concerned with the fueling, defueling, and transfer operations are shown in simplified schematic form in Figure 6. The vent system is entirely automatic and mechanical, and is shown only for purposes of reference and orientation.

The Fueling and Defueling placards adjacent to the Fueling Control Panel contain the procedural steps necessary to enable a relative stranger to the Orion to accomplish either task. It is highly desirable, however, that the operator understand the reasons for these steps so that he can do the job safely and intelligently in every circumstance, and the key to such understanding lies in knowing the details of operation of the fueling valve.

The body of the fueling valve contains two poppets designated as primary and secondary, which are arranged in series, that is, fuel must first pass the primary, then the secondary poppet before it is discharged into the tank.

In effect, the poppets are floating pistons, lightly spring loaded to the closed position. In order to open the valve it is necessary to reduce the pressure force on the inner face of each poppet below the pressure

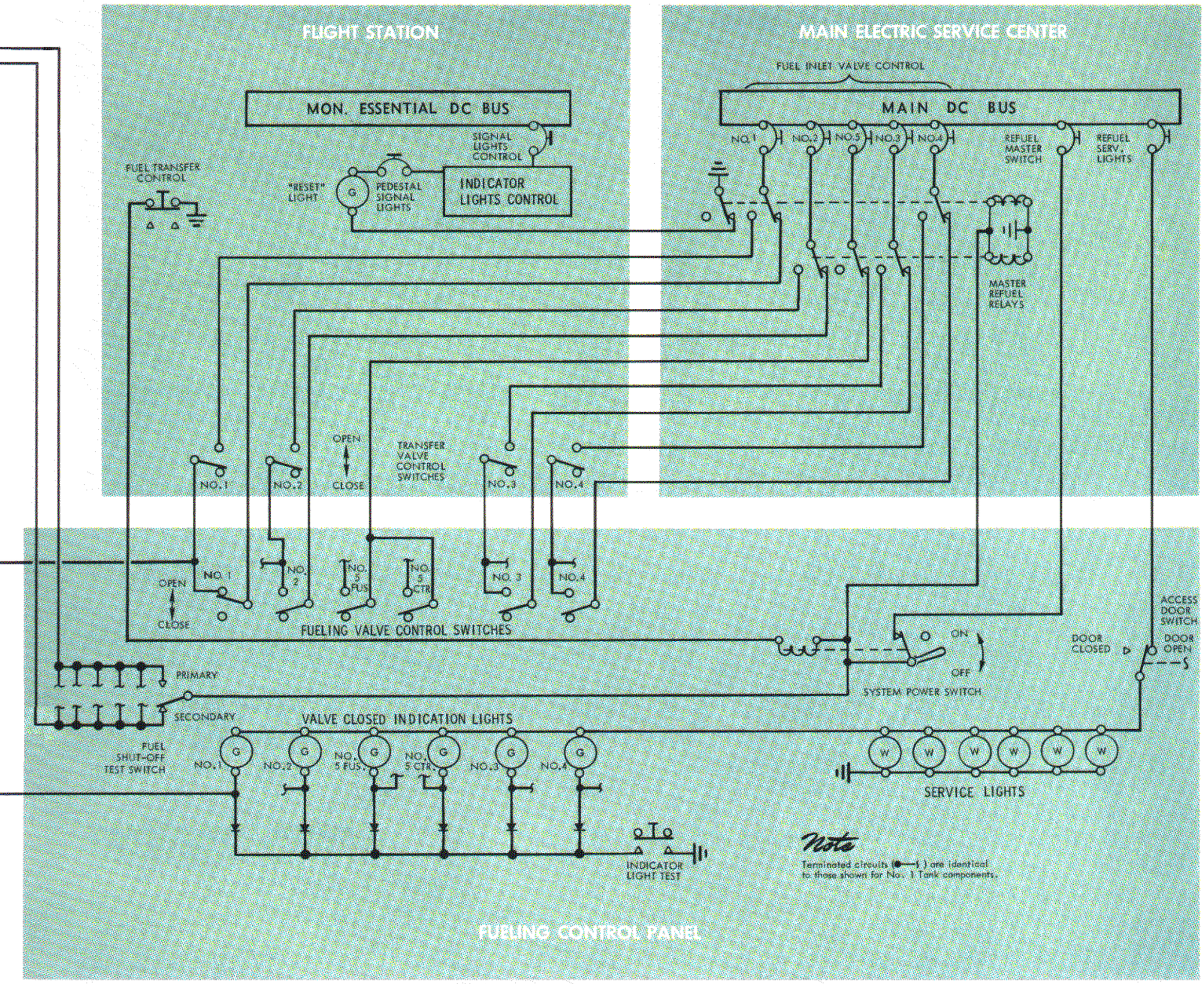


Figure 6 Fueling/Transfer Valve Master Schematic. Condition shown is the conclusion of the Secondary Fuel Shutoff Test, just prior to fueling.

force (or the sum of two pressure forces) acting on the outer poppet face (or faces). During fueling, this is done by allowing a metered bleed of fuel to flow freely from the cavity behind each poppet and spill into the tank through the float chamber drains of a dual pilot valve assembly mounted at the top of the tank. If either or both of these bleeds are blocked, one or both poppets will close and stop the fueling flow to that tank.

The fueling valve control solenoid operates a valve which blocks both bleeds (and, therefore, fueling flow) when the solenoid is de-energized, or allows both bleeds to flow to the pilot valve when the solenoid is energized by turning the Fueling (or Transfer) Valve Control Switch to "OPEN."

When the tank approaches full, the rising fuel floods the two pilot valve float chambers and the float operated valves close, blocking both bleeds and causing both fueling valve poppets to close.

To enable the operator to test that the automatic fill-and-shutoff feature is operable without filling the tank, a Fuel Shutoff Test switch is provided. By selecting "PRIMARY" or "SECONDARY," the operator plugs the related float chamber drains by means of solenoid operated stopper valves. When the bleed fills the chambers, the floats will rise and shut off fueling flow exactly as if the fuel tanks were full. This is the situation pictured in Figure 6. The sec-

ondary bleed has filled the float chamber and full fueling pressure has been trapped behind the secondary poppet, causing it to close and stop the fueling flow even though the primary bleed continues to flow and the primary poppet is open.

Note that a postion sensing switch provided for each poppet closes when the poppet is closed; opens when the poppet is opened. The switches are wired in parallel so that when either switch (either poppet) is closed, a green Valve Closed Indication light on the Fueling Control Panel will be illuminated.

DEFUELING. Examination of the Figure 6 schematic will reveal that if defueling suction is applied to the fueling manifold, the fueling valves will operate just as they do in fueling, except that the bleed flow from behind the two poppets is drawn through individual passages (fitted with check valves) in order to create a low pressure (a negative gauge pressure) behind the poppets. The pilot valves have no function in defueling except that they contain check valves which prevent air from being drawn backwards through the pilot valve bleed lines and "spoiling" the partial vacuum behind the poppets. Two other check valves of importance to defueling are discussed under "Fuel Transfer System Design."

About 10 in. Hg (minus 5.0 psig) suction is required to open the fueling valves for defueling, but once flow is established, a substantially lesser vacuum will suffice to hold them open.

THE FUELING OPERATION

The fueling operator should be thoroughly familiar with the controls at his command, and understand the import of reactions he will observe on the indicators at the Fueling Panel. The Fueling Placard mounted adjacent to the panel cannot accommodate *every* item pertinent to *every* replenishment (nor is it revised as publications are changed to incorporate new and more accurate information), and the competent operator will allow for factors not specified on the placard. The following discussion is broadened to include these factors.

Both ac and dc power are required for the pressure fueling operation; ac for the quantity gauging system, dc for the controls and indication lights. An external power source is preferred, of course, but if necessary an internal generating source can be utilized as described in the "General Information and Servicing MIM." Unneeded electrical and electronic components should be de-energized. Radar gear is regarded to be particularly hazardous as an ignition source (none should be operated within 120 feet of the aircraft during fueling operations) and of course all potential ignition sources should be removed, especially from the vicinity of the tank vent ports at the wing tips. Monitors should be posted at the vent ports to ascertain that the initial fuel input expels vapor freely.

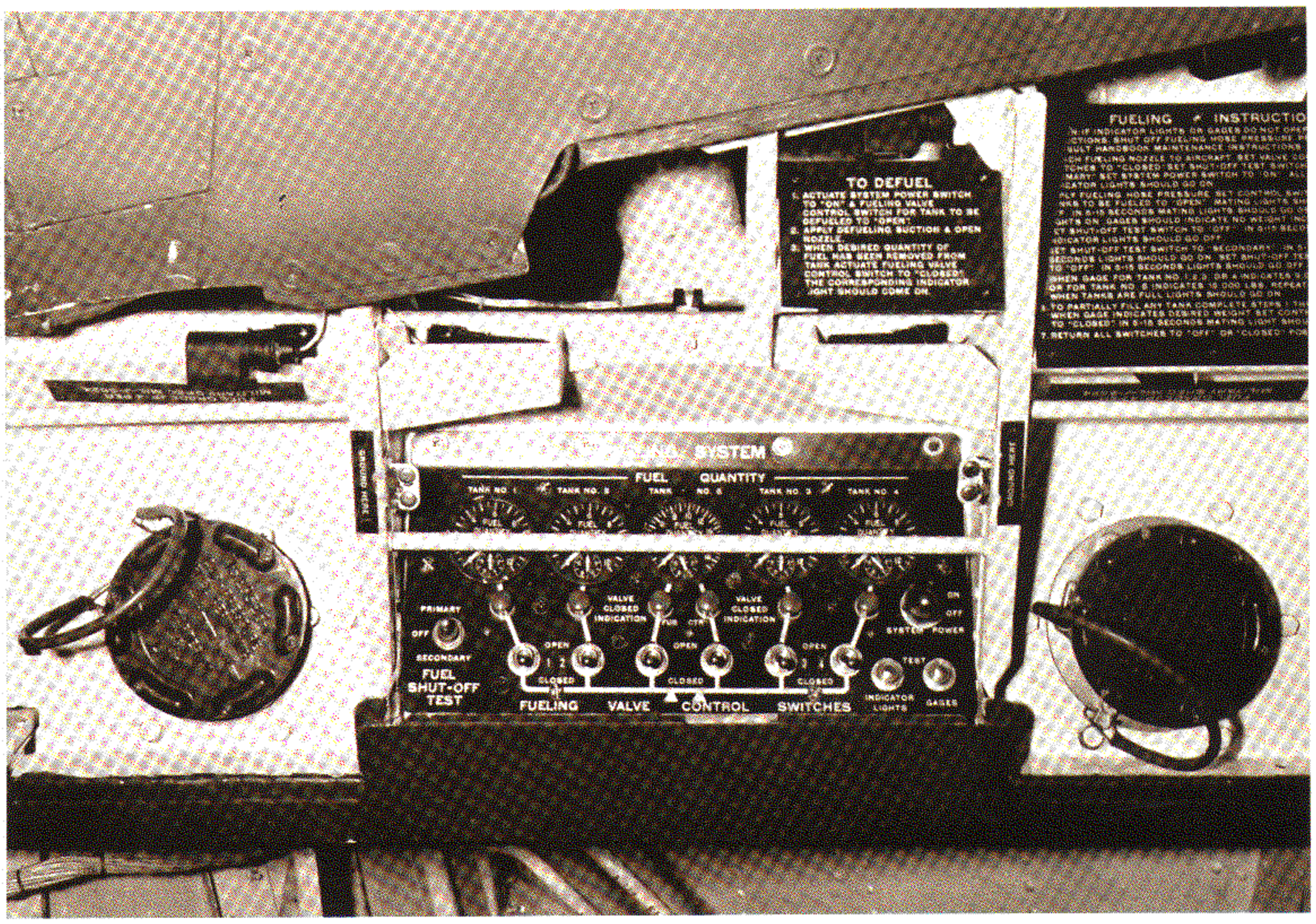


Figure 7
Fueling Control Panel

After opening the Fueling Panel access door, the operator should first ensure that all switches are in the "OFF" or "CLOSED" position.

As shown on the Figure 6 schematic, an access door switch automatically illuminates the white service lights and provides power to the six green Fueling Valve Closed Indication lights for the individual fueling valves. Since the two spring loaded poppets and their position sensing switches in each fueling valve should be closed at this time, all the green indicator lights should illuminate immediately when the access door is opened.

An unlit lamp can be tested for defects by pressing the Indicator Light Test switch provided for that purpose. If an unlit lamp responds to the Test switch, it is an indication, but not positive proof, of serious trouble in the related fueling valve. The poppets seat on rubber, and generally they are seated securely by full fueling manifold pressure acting, together with the spring load, on the large inner face of the poppet. If the fueling valve was last closed during defueling or very low-pressure fueling, the poppets may be effectively closed, but they may have closed so softly that the position sensing switches did not close. If the fuel level in the related tank is low enough so that there is no danger of accidentally overflowing the tank, the valves can be seated securely by applying pressure to the fueling manifold, being ready to remove it immediately if the quantity gauge indication rises, proving that the fueling valve is indeed open. Needless to say, a jammed-open fueling valve must be remedied before pressure fueling, or before flight if the flight requires transfer from the No. 5 Tank.

A Gauge Test switch is also provided on the Fueling Control Panel. Pressing this switch will introduce an artificial signal into the quantity measuring portion of the five gauge circuits, causing the indicators to drive to the empty stop (a point slightly below the zero reading). Note that the test proves whether or not the instruments are operable; it cannot prove the accuracy of the readings.

Static electrical bonds should be in place *before* fueling nozzles are attached. With fueling pressure and electrical power available, the initial responsibility of the fueling operator is to thoroughly test the operation of the fueling valve/pilot valve arrangement described previously.

As shown in Figure 6, local control of the fueling valve solenoids is obtained by selecting the System Power switch "ON," and the Fuel Shutoff Test switch that is used to manipulate the dual pilot valve solenoids is armed also when System Power is "ON." The Test switch is a momentary type switch that is spring loaded to "OFF." It must be held in position during the shut-off test. When held at "PRIMARY," the Test switch will close the primary chamber drain valves in all six pilot valves.

When fueling pressure is applied, the Indication lights may "blink" off and then back on almost immediately if there is air in the fueling valve. A valve which allows an appreciable fueling flow to enter the tank when its Control switch is at "CLOSED" is obviously uncontrollable from both the manually operated Fueling Valve and Transfer Valve switches.

Having proven fueling valve controllability, while holding the Test switch at "PRIMARY" the operator must select "OPEN" at the Fueling Valve Control Switches of those tanks with which the fueling operation is concerned in order to test the automatic shutoff function. Obviously, this will always include tanks requiring fuel, and it will include *all* fueling valves if fuel is to be added to No. 5 Tank.

Selecting "OPEN" at the Fueling Valve Control Switches opens the primary and secondary bleed lines to the pilot valves in the selected tanks (see Figure 6). As fueling pressure, which has until now been trapped behind the primary poppets, bleeds off,* the primary poppets will be unseated. Fueling pressure will gain access to the body of the valves, initiating the secondary bleeds. The secondary bleeds, allowed to flow freely from their metering orifice to the pilot valves, will not create pressure behind the secondary poppets. Therefore, when full fueling pressure acts upon the annular-land surface of the secondary poppets, the poppets will open, and fuel will flow into the tanks. Since both poppets are open, both poppet position sensing switches in each valve will be open, extinguishing the Valve Closed Indication lights for the selected tanks.

Assuming the Test switch is held at "PRIMARY," in about 5 to 15 seconds the primary bleeds will have filled the applicable primary float chambers, and the bleed flow will be shut off at the float valves. Full fueling pressure will build up behind the primary poppets and their spring load will force the poppets closed, illuminating the Valve Closed Indication lights.

If all 6 Valve Closed Indication lights are not illuminated 15 seconds after the test began, the operator must terminate fueling immediately. Fuel flow

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** Of course, if a tank is being tested which is already full, neither of the float operated pilot valves will permit bleed flow, both poppets in the fueling valve will remain closed, and the valve closed Indication light will remain illuminated throughout the test period. When testing Tanks 1 through 4 preparatory to fueling Tank 5, this will be the case with any tanks which are actually full.*

into the tanks is continuous while testing is in progress (indeed as much as 300 lbs may enter the tank in 15 seconds), it is never safe to assume that a tank will accept the fuel, and flow must be stopped immediately if there is evidence that the automatic shutoff on a tank is inoperative.

After proving the Primary shutoff function, the operator then selects "Secondary" at the Fuel Shutoff Test switch and repeats the test.

If a light indicates a malfunction, but the quantity gauge indicates that the fueling valve is operating properly, the trouble is most likely a maladjusted poppet position sensing switch.

If one fueling valve poppet operates correctly and the other one does not, the trouble may lie either in the fueling valve or in the pilot valve. A method of pinpointing the trouble is given under "General Service Information."

If the valves and indication lights have all responded properly, the operator may then proceed to fuel the tanks as required, first selecting "CLOSED" at the Fueling Valve Control switch of any tanks which have been tested but which do not require fuel. As explained later, the No. 5 Ctr. control switch should be closed at this time if less than 4000 lb is to be carried in No. 5 Tank.

As fueling commences, the appropriate Valve Closed lights should be extinguished, the inflow of fuel should register on the quantity gauges, and the vent monitors should report a satisfactory vapor flow from the related vent ports.

The initial check of the automatic shutoff is made before any appreciable amount of fuel is added to the tanks. This ensures that a check will be made, even though the tanks are being "topped off" only, or that only a small amount of fuel is to be added. In many cases, however, well over a thousand gallons of fuel will be added after the initial shutoff test was made. The head of fuel in the tank, against which the secondary poppet must close, is now greatly increased, and a test made at this time will be more representative of the pressure differentials which exist when the pilot shutoff must operate. Then too, if a solid contaminant has been carried into a valve with the high-rate fueling flow, the valve may have been jammed open after the initial test was made. Therefore, the operator should repeat the "SECONDARY" Fuel Shutoff Test when the tanks approach full (9000 lb for the engine-feed tanks; 16,000 lb for No. 5 Tank).

When tanks are to be only partly filled, set the Fueling Valve Control Switches to "CLOSED" when the desired level is indicated on the fuel gauge, but if tanks are to be completely filled, allow the pilot valves to close the fueling valves automatically. Turbulence, pressure fluctuations, etc. can cause the Valve Closed Indication lights to blink on and off before the tank is completely full. Wait until the cycling stops before removing fueling pressure or turning Fuel Valve Control Switches to "CLOSED." When fueling is complete, observe that all Valve Closed Indication lights are illuminated, then set all switches to "CLOSED" or "OFF."

FUEL LOADING. When fuel is loaded into No. 5 Tank, there is one simple rule that must be observed. *If 4000 lb or less fuel is to be carried in No. 5 Tank, all of it must be loaded through the No. 5 Fus. fueling valve.*

A combination of factors involving the tank design and the requirements of the transfer system makes this obligatory, and we will digress to briefly explain these factors.

The interconnect between the No. 5 Ctr. and Fus. Tanks is located a few inches above the floor of the No. 5 Ctr. Tank for two reasons: First, it is necessary that cutouts in the wing front shear beam be well clear of the spar caps in this highly stressed member. Second, belly landings experienced by other aircraft with fuselage fuel tanks indicates that when tank interconnect ports are located in the tank floor (necessitating that the interconnect be routed below the level of the tank adjacent to the belly skin), the entire contents of both tanks are much more likely to be spilled, greatly increasing the fire hazard if such an emergency arises. Thus the location of the interconnects on the P-3A was chosen as optimum for strength, safety, and utility.

The Transfer System is discussed in more detail in the following pages, but in the present context it is important to realize that both transfer pumps are mounted on the bottom of No. 5 Fus. Tank; one at the forward end, one at the aft end. These pumps must be primed, that is, the pumping elements must be immersed before fuel can be scavenged from No. 5 Ctr. Tank and transferred to the engine-feed tanks.

Because of weight limitations, there will be many instances in which No. 5 Tank will be only partly fueled, and, unlike the engine-feed tanks, No. 5 Tank will ordinarily be completely empty when the airplane is to be fueled. The importance of this lies in the fact that there will generally be no residual fuel in No. 5 Fus. Tank to prime the transfer pumps. The Fueling Control Panel has a fueling valve control for No. 5 Ctr. Tank and one for No. 5 Fus. Tank, and a single No. 5 Tank quantity gauge which reports the combined content of the two compartments. Note that the fueling operator does not have individual

quantity gauges to ascertain the fuel levels in the two compartments, and since the levels may vary considerably unless both compartments are filled to the level of the interconnect, the one simple rule must be followed during fueling to ensure that No. 5 Tank fuel will always be apportioned in such a way that the transfer pumps will be effective. We reiterate: *If 4000 lb or less fuel is to be carried in No. 5 Tank, the fuel should be loaded through the No. 5 Fus. fueling valve.* Otherwise, the transfer system may be completely useless, or it may function sporadically, depending upon the exact circumstances.

On the Orion every available cubic inch of tankage space is devoted to fuel storage, indeed less than 0.4% of the engine-feed tank volume is unused for fuel. Since JP-4 expands more than this (about 0.5%) per 10°F rise in temperature, it is inevitable that if the tanks are completely filled with cool fuel quite some time before takeoff on a hot day, the tanks will overflow through the vent ports at the wing tips — an obviously undesirable situation.

If maximum fuel load is to be carried and the fuel is appreciably cooler than ambient temperature, the tanks must be filled as near to takeoff time as possible to circumvent the thermal expansion overflow.

The thermal expansion overflow can be avoided if a less-than-maximum fuel load is to be carried by terminating fueling to the engine-feed tanks when the fuel level in each tank is 1000 lb below full, and loading 4000 lb extra fuel into No. 5 Tank to compensate for the shortage in the four engine-feed tanks.* In such a case, take particular care to load the compensatory fuel through the No. 5 Fus. fueling valve. The compensatory fuel must be transferred from No. 5 Tank into the engine-feed tanks shortly before take-off to obtain the minimum wing load in flight, and, as explained under "Transfer System

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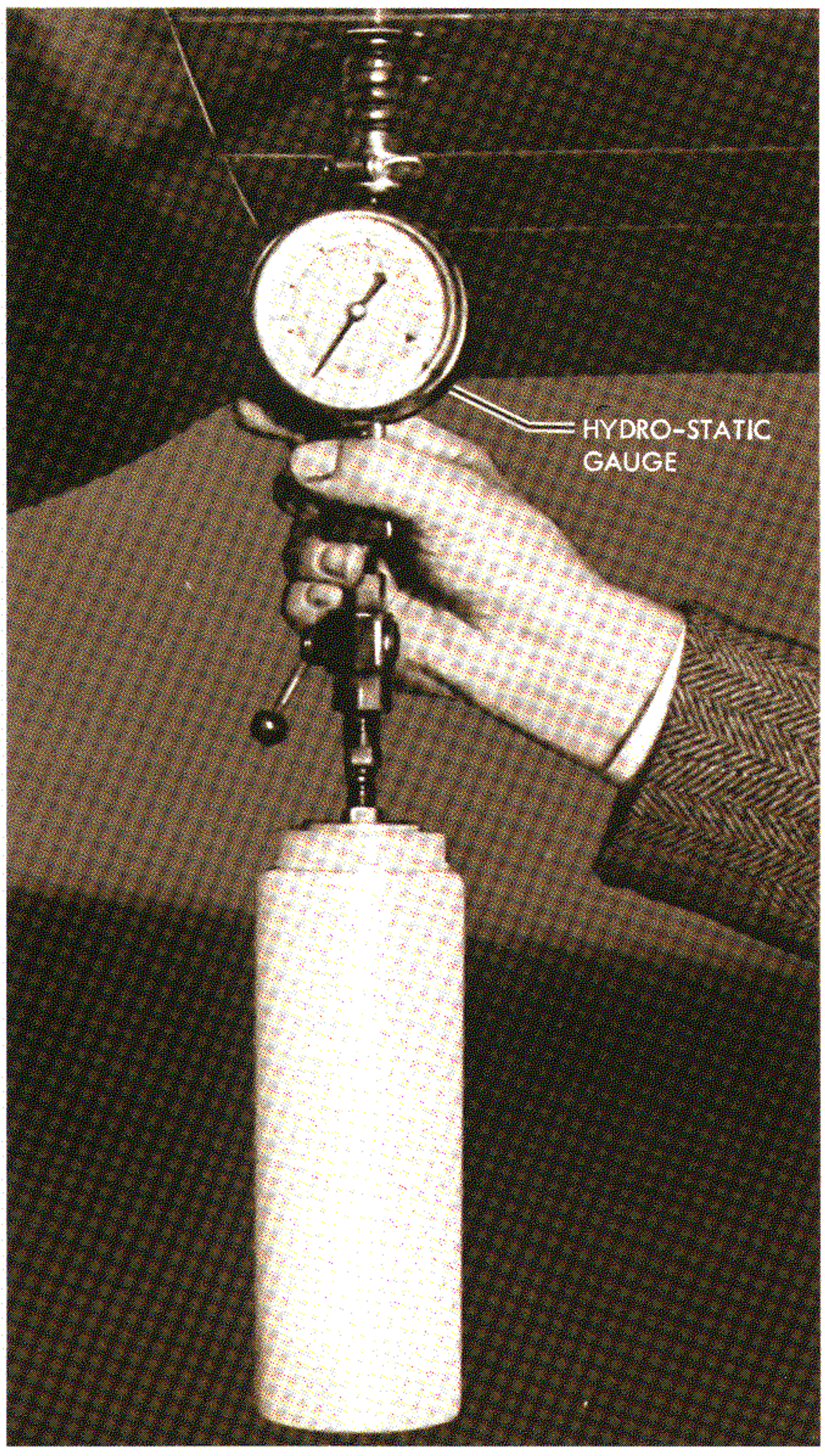
* *The 1000 lb deletion from the engine-feed tanks is calculated to allow for the most unfavorable conditions, i.e., cold fuel, a hot day, and a 5° ramp slope. It will require about a half hour to transfer 4000 lb of fuel, as must be done before takeoff. Under more favorable conditions a lesser fuel deletion will provide ample expansion space and the pre-takeoff fuel transfer will require proportionately less time.*

Design," the greatest head of fuel obtainable must be provided for the transfer pumps if the fuel is to be transferred at a high flow rate.

Of course, the best procedure would be to simply keep the compensatory fuel in the fuel truck and arrange to "top-off" the tanks with the fuel truck pumps just before takeoff.

The quantity gauges are calibrated to read pounds, and the indicating system is compensated to adjust automatically to variations in fuel density, but all such systems are inherently less accurate at high levels than at low, and it is well to be alert for evidence of gross inaccuracy during servicing. There are a variety of means by which gauge accuracy can be tested — the most direct and precise method being the traditional one of filling an empty tank by increments of known gallonage with fuel of known density.



In cross-checking the accuracy of the quantity indicating gauges by any other method, due allowance must be made for the inaccuracies inherent to the alternate means of measurement.

The tank dip-stick and the sight gauge offer a means of direct measurement, but as explained later, these cannot be used at all tank levels. Also, the dip-stick is subject to error; being calibrated to measure JP-4 of nominal density in a level aircraft. Consequently it tends to yield deceptively low readings with JP-5, and if the aircraft is not laterally level, stick readings will be too high in the low wing tanks and vice versa.

The Hydro-Static Pressure Tester recently introduced provides a means of cross-checking engine-feed tank quantity that can be employed at all tank levels and is near-ideal in respect to convenience. This device, which actually samples hydro-static pressure on the water-drain valve (at the lowest point in the tank), is calibrated to read directly in pounds avoirdupois, with a separate scale for the inboard and outboard tanks. Again, total accuracy is not to be expected, and best accuracy is obtained with a level aircraft. The lateral attitude of the aircraft can be checked on an inclinometer mounted conveniently just forward of the Fueling Control Panel on later aircraft. Accuracy on the pressure gauge deteriorates in the reverse manner from the errors of the stick gauges, that is, deceptively low readings will be observed in the low wing tanks. If the aircraft is more than 2 degrees from level, the gauge will be too inaccurate to be of practical use.

GENERAL SERVICE INFORMATION

As stated previously, the wing tanks are almost completely filled during pressure fueling, possibly to a level higher than the caps on the wing top filler wells, depending upon the exact point at which the pilot valves close. For this reason the Orion should not be pressure fueled with the filler caps removed unless suitable precautions are taken to prevent overflow. Also, anyone attempting to "dipstick" the engine-feed tanks after they have been pressure fueled to capacity should be prepared for overflow when the caps are loosened.

We do not recommend that over wing filling and dipsticking be done as a matter of course, for traffic on the wings takes a steady toll of minor damage, and some contamination will inevitably enter the tanks through the open filler-wells. If it is necessary to walk on the wings, put down walk-way mats, wear wing socks, and *never* lean ladders against a wing.

Due to wing dihedral, the filler-wells must be located near the high outboard end of the engine-feed

tanks. Consequently, dipsticking through the filler-wells will yield no reading unless the inboard tanks contain 4225 lb (650 gallons) or more fuel; the outboard tanks 8775 lb (1350 gallons) or more.

WARNING

High rate fueling flow can generate high static electrical charges in the fuel. In the Orion integral tanks, these charges should dissipate quickly, but to be certain that there is no potential for static sparks and explosions, the dipstick should not be used for at least three minutes after fueling has been terminated.

As mentioned previously, the bottom of No. 5 Fus. Tank and the No. 5 Ctr. Tank are both somewhat lower than the interconnect between the two compartments. Since there is but one sight gauge for the tank, true fuel measurement can only be taken manually when the fuel level is higher than the interconnect (more than 4000 lb, total content).

If a Fuel Shutoff Test reveals that a fueling valve does not respond properly to the pilot valve, it is sometimes difficult to determine whether the pilot valve or the fueling valve is at fault. As shown in Figure 2, the pilot valve lines are routed outside the tanks where they are readily accessible. By opening the appropriate line and either allowing the bleed to flow freely or blocking it while the fueling manifold is pressurized, the trouble can be traced to either the fueling or the pilot valve, but:

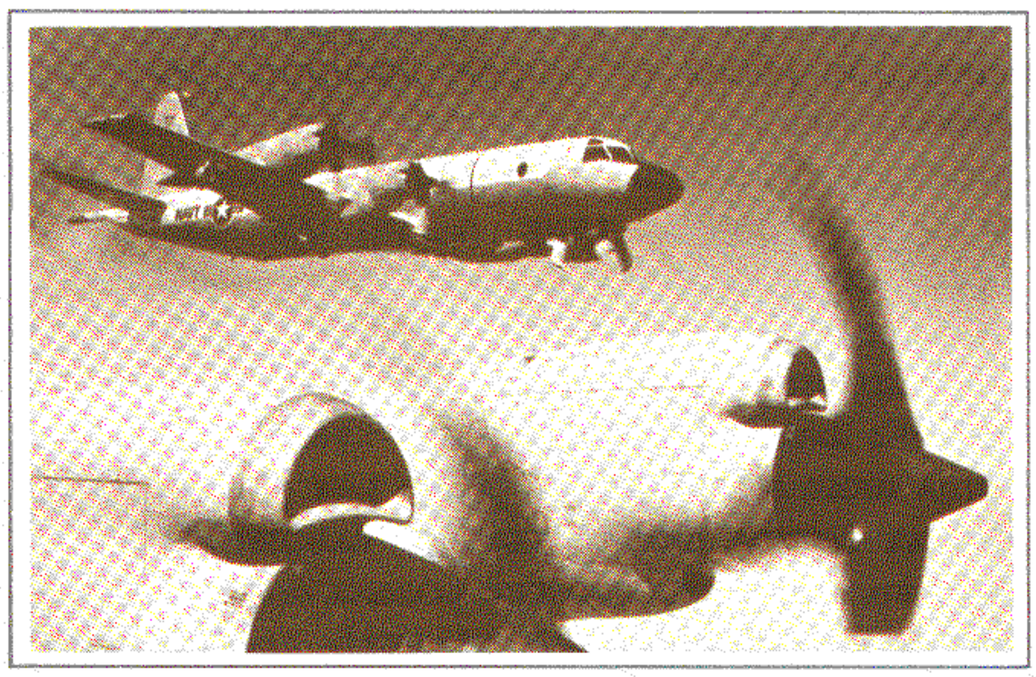
WARNING

TANKS OVERFILLED BY PRESSURE FUELING WILL ALMOST CERTAINLY BE OVERPRESSURIZED, AND EVEN IF THE TANK DOES NOT RUPTURE, THE WING MAY BE SERIOUSLY DAMAGED.
DO NOT INDUCE FUELING FLOW BY OPENING BLEED LINES UNLESS PROPER PRECAUTIONS ARE TAKEN TO PREVENT OVERFLOWING THE TANK.

The exposed pilot valve lines allow a good deal of time to be saved when trouble shooting is necessary, but because of the inherent chance that a tank will be overfilled, this procedure should *not* — repeat *not* be attempted by anyone other than an experienced mechanic who is familiar with fueling systems in general, and this one in particular.

If an unexpected delay is experienced after the tanks are filled, fuel may drip from the wing tip vents due to thermal expansion of the fuel. This constitutes a fire hazard, and it is also likely to dissolve and erode a black-top surface. We suggest, therefore, that ample containers suitable for storage and disposal of flammable waste be kept available, and that these be secured in position to catch the overflow before, not after, the overflow occurs.

Defueling Problems generally stem from the use of low capacity pumps or fueling hoses that collapse when used for defueling. Little can be done about collapsed fueling hose except to replace it with hose that will support the maximum vacuum the pump will generate, but the fueling operator (or to be more accurate, the defueling operator) can generally compensate for relatively inefficient pumping equipment. Bear in mind that: the head of fuel in the tank aids in opening the fueling valves; a better vacuum is



needed to open the valves than is needed to keep them open; the fueling valves farthest from the fueling facility will have the least vacuum to operate on after defueling flow has been initiated. Any or all of these factors may be important when defueling multiple tanks. If trouble is encountered in opening many valves in sequence, they can generally be opened by setting all the Valve Control Switches to "CLOSED," then setting them to "OPEN" simultaneously. A valve which tends to close as the head of fuel in its tank diminishes will often perform perfectly if it is interchanged with a valve nearer the Fueling Panel.

Note that each pilot valve contains two check valves (12 in all) and that the transfer system incorporates two check valves of a unique design (see Figure 11). If any of these valves fail to seat properly, defueling from one or all tanks may be difficult or impossible due to air back-flowing and "spoiling" the fueling manifold vacuum needed to open the fueling valves. As before, the pilot valve lines can be blocked to facilitate trouble shooting.

SUMP DRAINING is closely related to the fueling operation, and although it is beyond the scope of this article to explore fully the many problems associated with water contaminated fuel, we would be remiss if we did not point out some aspects that make sump draining particularly important on a turbo-prop patrol plane such as the Orion.

In the course of a long range, turbine powered, Navy patrol mission, ranging from the warm humidity of near sea level atmosphere to the extremely cold upper atmosphere, some atmospheric water vapor will condense within the fuel tanks; more will be absorbed directly by the jet fuel (which has a much higher affinity for water than does avgas) and free water will settle and accumulate on the tank floor. As specified on the Maintenance Requirement Cards, every fuel tank sump must be drained at each Daily and Preflight inspection, but we feel that draining for maximum effect is largely a matter of good judgment, and the ground crew can often make additional timely sump drainings, bearing in mind that:

> The maximum amount of water will be drained when the tank fuel is cold (but not so cold as to freeze water) and has not been disturbed for a long period of time. Conversely, the least water will be removed if sumps are drained when fuel is warm (warm fuel tends to absorb free water from the sumps and hold it in solution), or agitated (fuel pumps tend to emulsify the water and fuel). When warm, dry fuel is added to the tanks, the residual fuel will be both warmed and agitated but nevertheless a post-fueling sump drain can sometimes avert an accident. If the added fuel was badly water-contaminated, the residual fuel may cool it enough to cause water to precipitate.

The higher incidence of water in jet fuel tanks, due to the natural causes mentioned previously, has given rise to a phenomenon that can become truly troublesome to maintenance of tank mounted components and the jet-fuel tanks themselves. Micro-

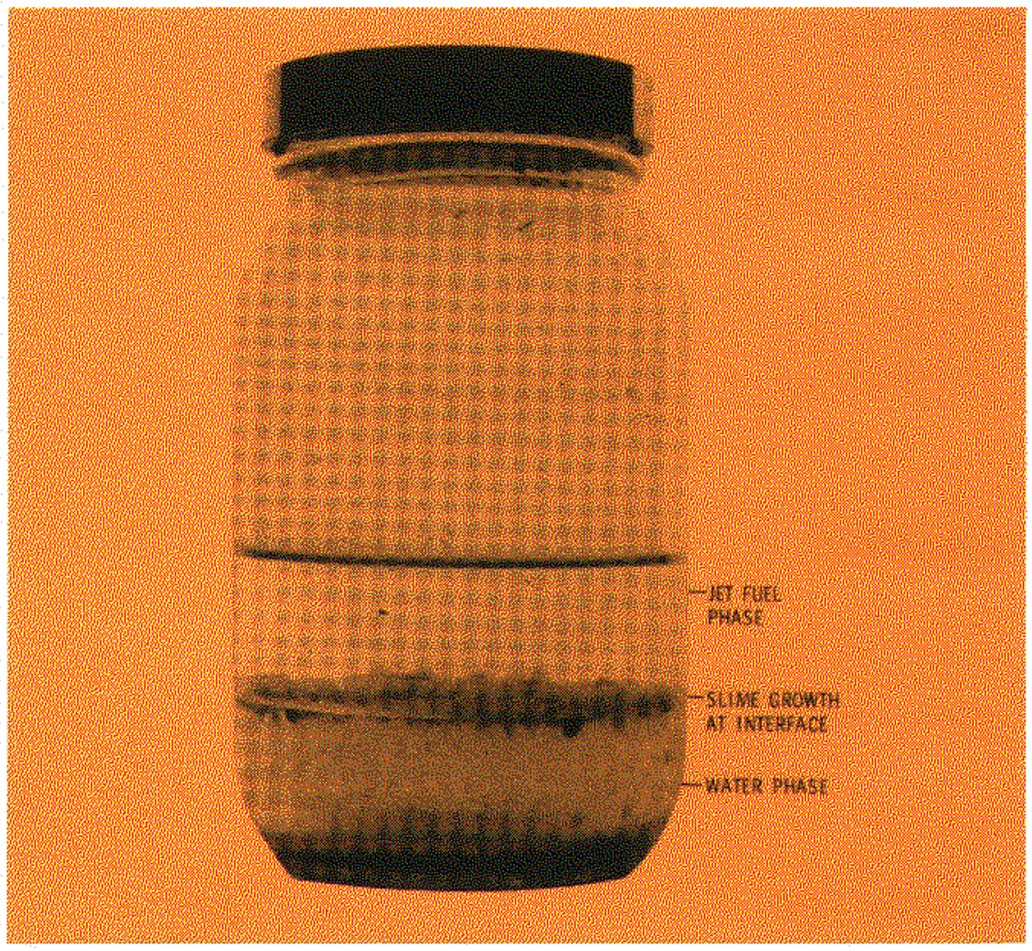


Figure 8 "Green Slime" Cultured in Sump Drain Sample

scopic spores live and propagate in the free water accumulations in jet fuel tanks, growing eventually to form a slimy mat — familiarly known as "green slime," although it is more likely to be of a brownish hue. Note that once the mat-like colony has formed it may adhere, generally (though not necessarily) to the tank floor, and it cannot be removed by draining fuel. In some cases, the colonies penetrate the protective coating applied to integral tanks at the factory, and a corrosive process takes place causing pits and craters to form that are extremely dangerous in such vital primary structural members. In other cases, screens and filters have been clogged with slime, and tank quantity probes made inaccurate.

Thus, frequent and effective sump draining is required not only to eliminate the usual hazards of water in engine fuel, but also as an extremely important part of preventive maintenance on the Orion. The "green slime" problem can be reduced or eliminated if all the free water in which the spores incubate is removed by sump draining.

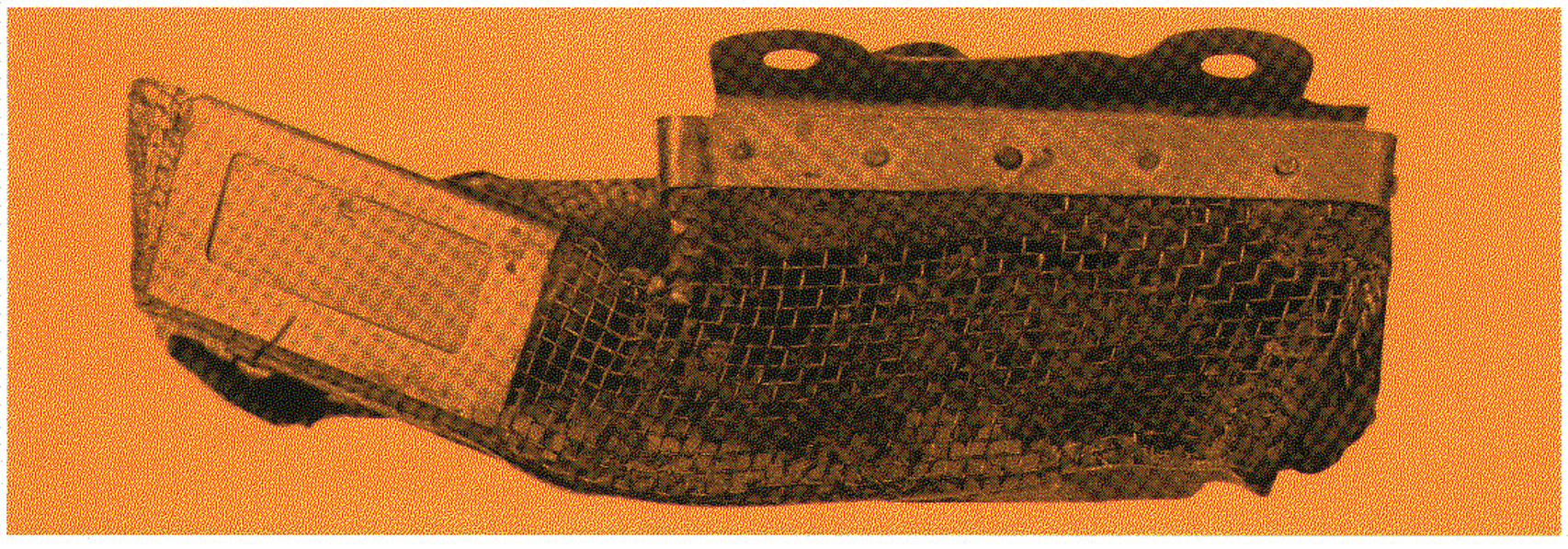


Figure 9 Booster Pump Intake Screen from Contaminated Fuel Tank

FUEL TRANSFER SYSTEM

DESIGN. Figure 10 shows a profile view of the two No. 5 Tank compartments and the transfer pumps and plumbing in schematic form. Orientation is essentially correct, but we have exaggerated certain features to more clearly illustrate some important aspects.

As mentioned previously, the two transfer pumps are identical to the booster-scavenge pumps used in the engine-feed tanks for reasons of interchangeability. They are mounted somewhat differently, however. The engine-feed tank pumps are bottom-mounted, but they are removable through the wing top, and they are provided with plug-in type mounts in order that a pump requiring maintenance after flight can be easily replaced, generally without removing any fuel. Access to the No. 5 Tank is, of necessity, from the bottom, and the transfer pumps are somewhat more difficult to replace.

As mentioned previously, the No. 5 Fus. Tank is, in effect, a surge box for the auxiliary fuel. The two scavenge elements of the transfer pumps draw fuel into No. 5 Fus. Tank from the bottom of No. 5 Ctr. Tank. The booster elements (the lower elements of the two pumps) then draw fuel through their screened inlets and pump it through check valves (in a dual check valve assembly) into the fueling manifold and to the four engine-feed tank fueling valves. Maximum transfer pressure is limited to about 13-psi by pressure relief-bypass valves, one of which is located in each pump's booster discharge line between the pump and the dual check valve assembly.

The dual check valve is of interesting design for, as an examination of the Figure 2 schematic reveals, if they were ordinary check valves they would allow an uncontrollable flow from No. 5 Fus. Tank if defueling suction was applied to the fueling manifold, and it would be impossible to defuel any of the other

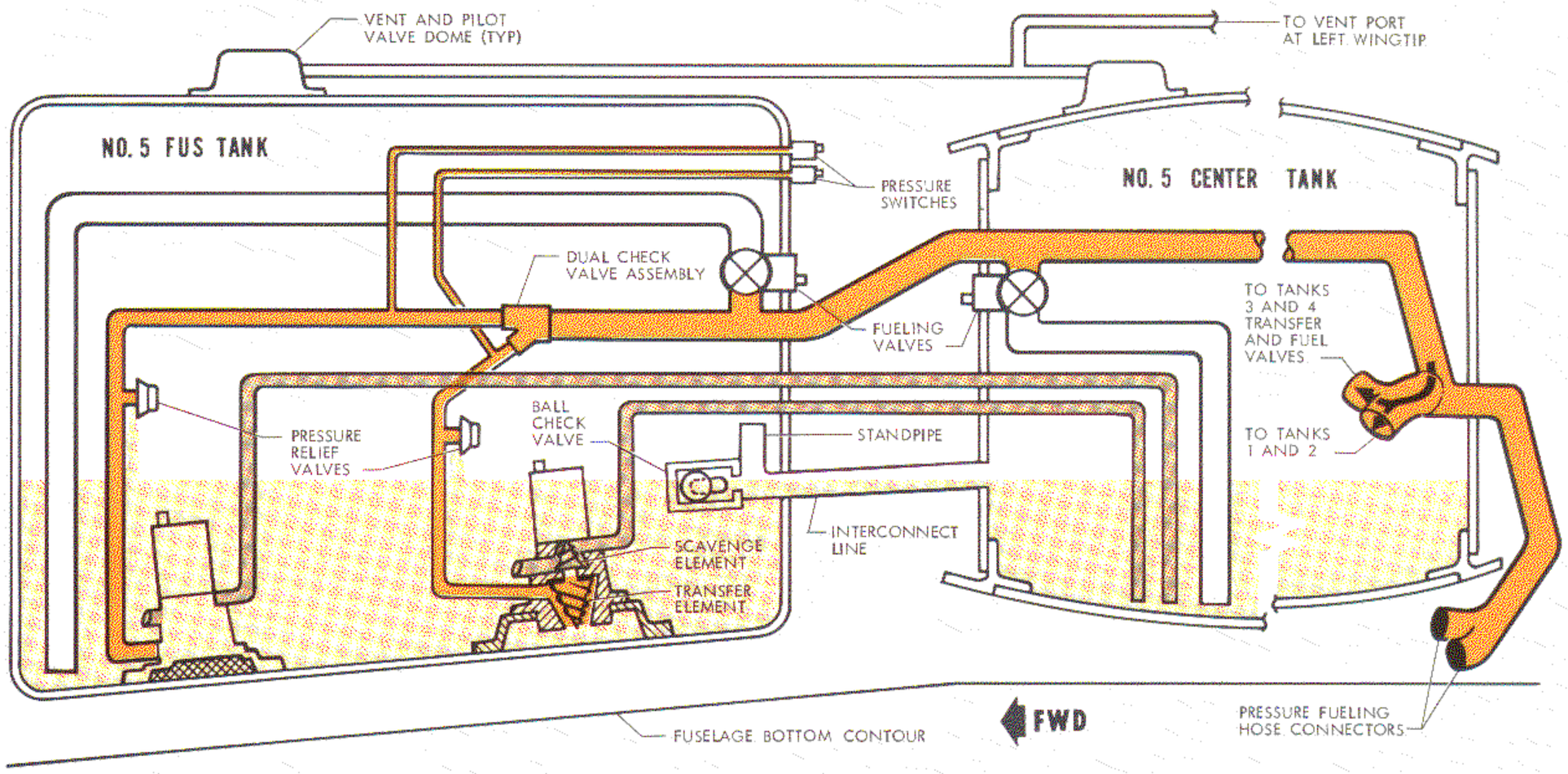


Figure 10 Schematic of Transfer System Operation with No. 5 Tank Fuel at the 4000-lb. Level

As shown in Figure 10, the scavenge and the booster elements of the two pumps are both centrifugal screw type elements, mounted on the same drive shaft; the booster element being the larger of the two. The scavenge elements are rated to pump 2000 lb per hour against a 5-psi back pressure; the booster elements are rated to pump 5000 lb per hour against an 18-psi back pressure, and since they are not positive displacement pumps, they will supply proportionately more fuel when operating against a lesser back pressure.

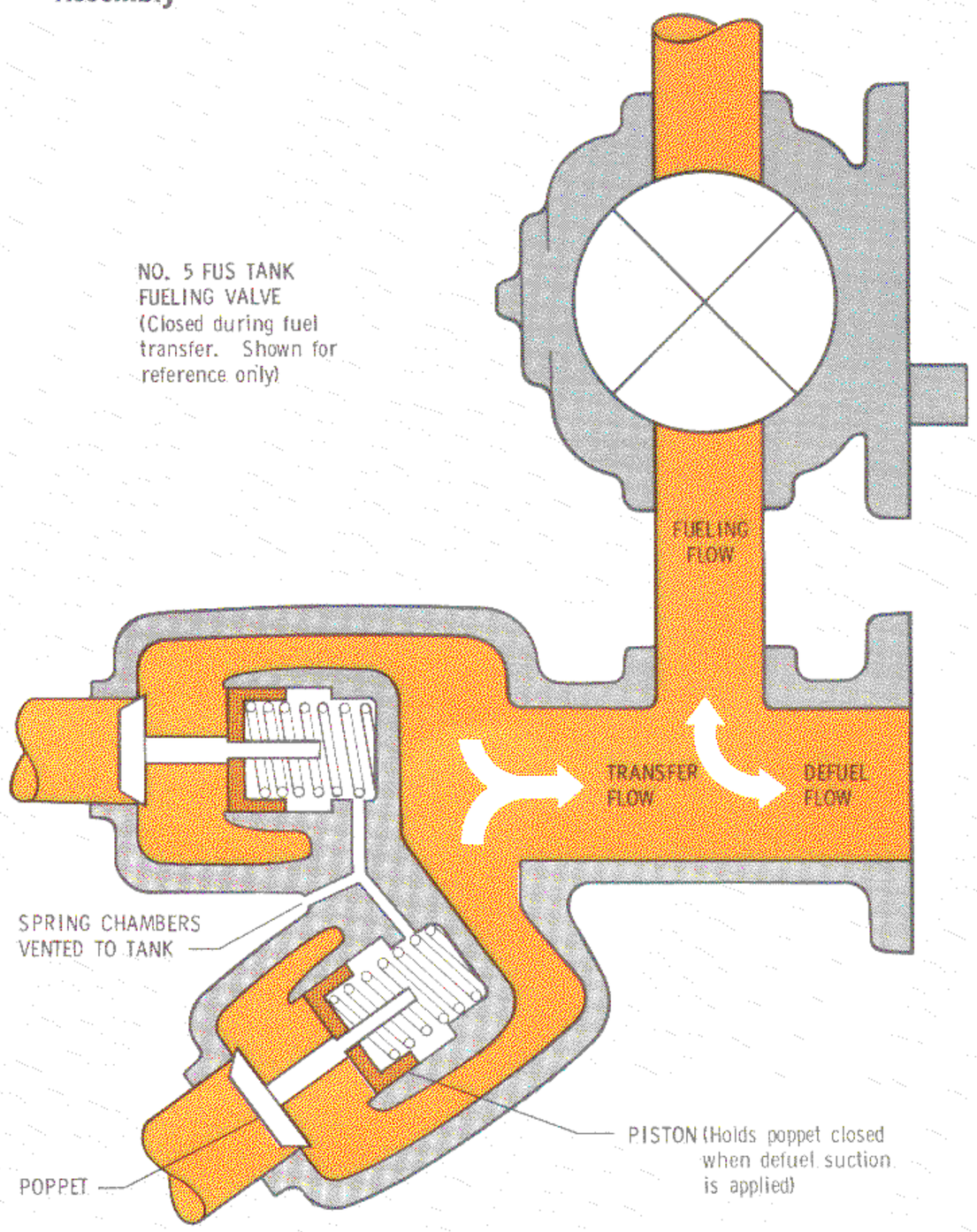
tanks. A cross-section schematic of one of these check valves is shown in Figure 11. The function of the valve can be seen, but in summation we may say that these valves will open only when pressure in the boost pump lines is higher than pressure in the No. 5 Fus. Tank. They will not open in response to low pressure (suction) in the fueling manifold.

If the transfer valves (Nos. 1, 2, 3, and 4 fueling valves) are closed and the transfer pumps are running, the booster discharge will bypass through the pressure relief valves back into No. 5 Fus. Tank, but

the scavenge elements will continue to draw fuel from No. 5 Ctr. Tank into the No. 5 Fus. Tank. This excess will flow freely back to No. 5 Ctr. Tank, by-passing the ball-check valve (shown in Figure 10) if the aircraft attitude is level. A 6° nose-up attitude will cause the ball-check valve to seal off the normal interconnect flow in order that the transfer system "surge box" not be drained so low that the pumps cavitate. With the ball-check valve seated, No. 5 Fus. Tank fuel cannot return to No. 5 Ctr. Tank unless it is above the top of the standpipe (see Figure 10) which is teed into the interconnect line just aft of the ball-check valve assembly.

If the four transfer valves are open and the fuel level in the four engine-feed tanks is considerably less-than-full, the valves will accept fuel at a high flow rate. The high capacity booster elements of the transfer pumps may succeed in evacuating considerably more fuel from the No. 5 Fus. Tank than the scavenge pumps replace. In this case flow through the interconnect from No. 5 Ctr. Tank will make up the difference so long as there is a head of fuel in No. 5 Ctr. Tank. But if there is less than about 2000 lb of fuel in No. 5 Ctr. Tank, it will not gravity-flow through the interconnect and the aft transfer pump's booster element may cavitate. This situation is depicted in Figure 12, and (as mentioned previously in the "Fuel Loading" section) it is evident that if a small No. 5 Tank fuel load is to be transferred rapidly, the fueling operator must load all of it through

Figure 11
Tank 5
Dual Check Valve
Assembly



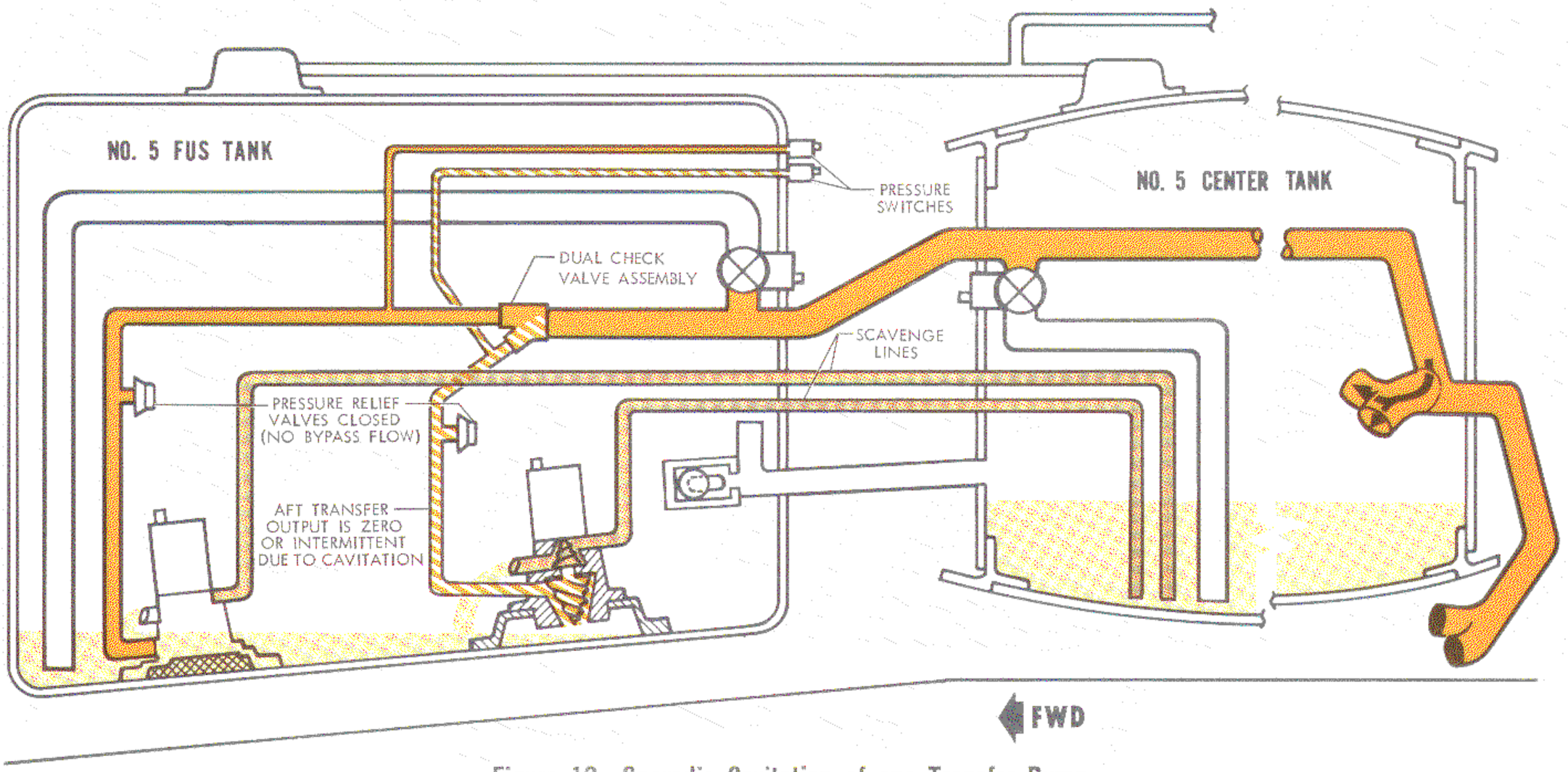


Figure 12 Sporadic Cavitation of one Transfer Pump

the No. 5 Fus. Tank fueling valve to ensure that this tank has the maximum attainable fuel content when the transfer operation is initiated.

Two switches, located on the Fuel Management Panel in the flight station, control the transfer pumps. So long as the pumps maintain working pressure, advisory lights, adjacent to the two Transfer Pump control switches, will be extinguished. When the No. 5 Tank fuel has been transferred, the transfer pumps will cavitate; pressure switches will sense that output pressure has fallen below 3 psi, and the advisory lights will be illuminated.

The transfer pumps could supply higher pressure, but they are purposely limited by the relief valves in their discharge lines as part of a triple-safety scheme to ensure that the engine-feed tanks are never over-pressurized. If both the primary and the secondary automatic shutoff should fail to modulate the flow into the engine-feed tanks (the transfer valves should admit just enough fuel to replace that being used by the engines) the short, large-diameter vent lines for the outboard tanks can easily discharge the excess fuel from the pressure-limited transfer system without overpressurizing the tanks. The inboard tank vent lines are necessarily about 25 feet longer than the outboard vent lines, and it is questionable that they alone could carry off the necessary flow of fuel without imposing a higher tank pressure than the normal maximum for which the wing structure was designed. For this reason, Tanks No. 2 and 3 are fitted with a recirculation valve — a pressure relief valve which cracks at 1.2 psi — and a recirculation tube which will carry excess transfer input back to the No. 5 Ctr. Tank.

The flight crew can check that the transfer operation is proceeding as it should by observing the reaction of the fuel quantity gauges, but we have not provided valve position indicating lights in the flight station for the four transfer valves. The valves cycle open and closed during in-flight transfer due to the action of the pilot valves, and four blinking advisory lights would be more disconcerting than informative.

Since time-lapse is required to check the transfer operation by observing the quantity gauges, it is conceivable that a flight could be under way before the crew discovers that the transfer valves are not operable from the flight station because someone neglected to turn "OFF" the System Power switch at the Fueling Control Panel. For this reason the Fuel Management panel has a "RESET" advisory light, and we have provided a self-latching type System Power switch whose holding coil can be de-energized by pressing a "Fuel Transfer Control" button on the Fuel Management panel (see Figure 13). When its holding coil is momentarily de-energized, the System Power switch returns to "OFF," de-energizing the master refuel relays. When these relays are de-energized, control power for the four engine-feed tank fueling valves is shunted to the Transfer Valve switches at the flight station, both No. 5 Tank fueling valve control circuits are disarmed, and the "RESET" advisory light is extinguished.

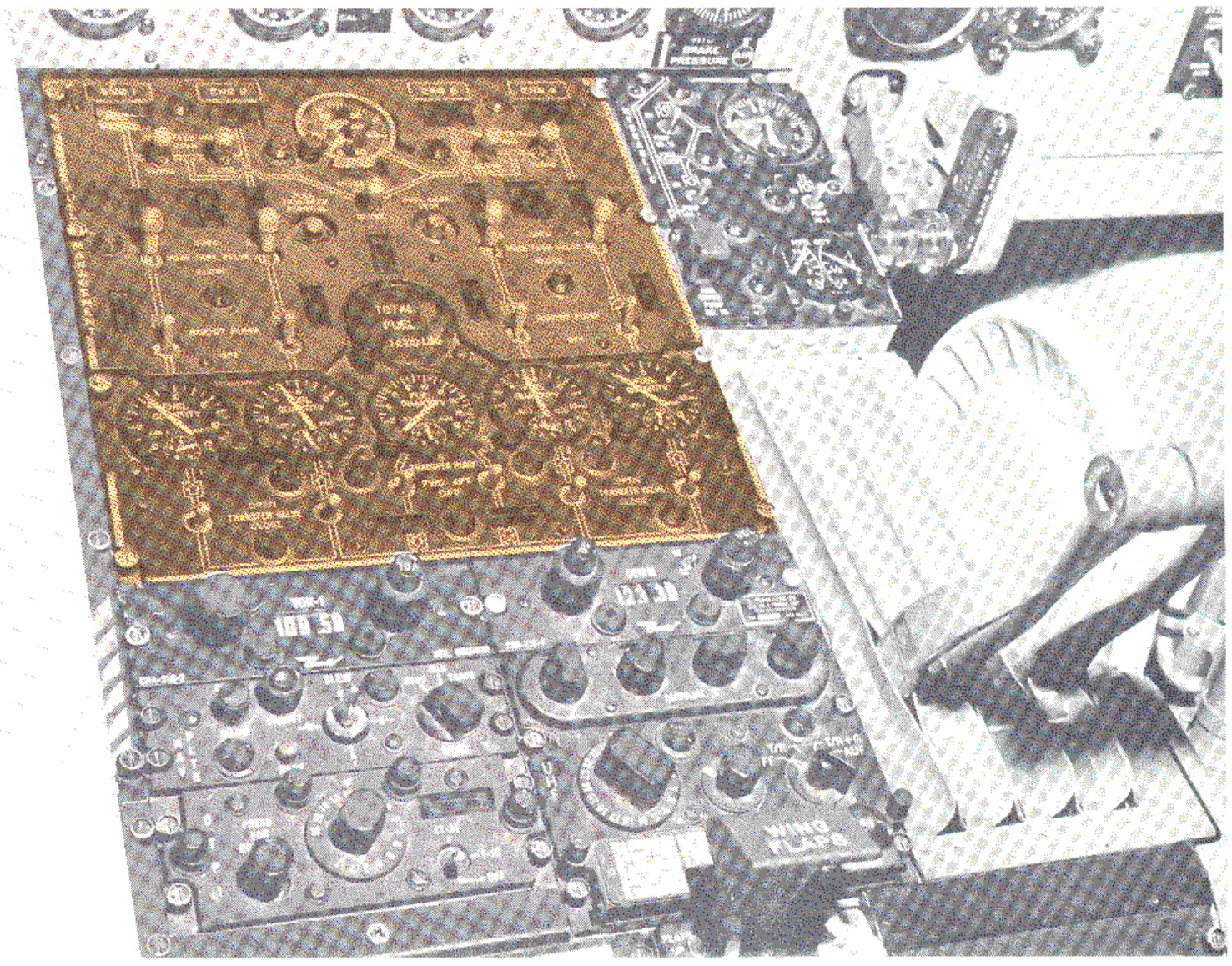


Figure 13
Pilot's View of
Fuel Management Panel

OPERATION Operation of the transfer system is surprisingly simple in comparison to the complicated procedures required on most long range aircraft.

If No. 5 Tank has been fueled, the flight crew will turn the Transfer Pump switches to "ON" and the Nos. 1, 2, 3, and 4 Transfer Valve switches to "OPEN." The transfer system will replenish the engine-feed tanks as fuel is expended by the engines, so that Tanks 1, 2, 3, and 4 will be kept completely full until No. 5 Tank is emptied.

It is important from a structural strength standpoint to complete the fuel transfer as quickly as possible. The simple, semi-automatic operation, maintaining at all times the maximum amount of fuel in the wing, was devised in early design work as one of the factors upon which the strength of the wing was predicated. Fuel weight in the wing subtracts from the wing air loads to produce the net loads for which the wing is designed. Fuel carried in No. 5 Tank which could be transferred into the wing imposes an unnecessarily high stress level in straight-and-level (1g) flight, and this unnecessary stress is multiplied when multi-g maneuvers are executed or gust loads are encountered. Common sense determines a single general rule that applies without exception: *Never carry fuel in No. 5 Tank that can be transferred into the engine-feed tanks.*

The "Aircraft Operating Limitations" (Section 1, Part 4 of the NATOPS Flight Manual) includes a "Zero Fuel Weight" computation wherein mission loading is checked to ensure that the span-wise distribution of useful load is not prejudicial to the reserve strength of the wing. As noted in that discussion, the Orion's "3-g" wing could be reduced to a "2.1-g" wing if operated with maximum No. 5 Tank fuel, and minimum fuel in the engine feed tanks.

During ground transfer system operation, it sometimes happens that when No. 5 Tank contains about 4000 lb of fuel which is to be transferred into four engine-feed tanks simultaneously, the high transfer rate will empty the fuel from No. 5 Fus. Tank faster

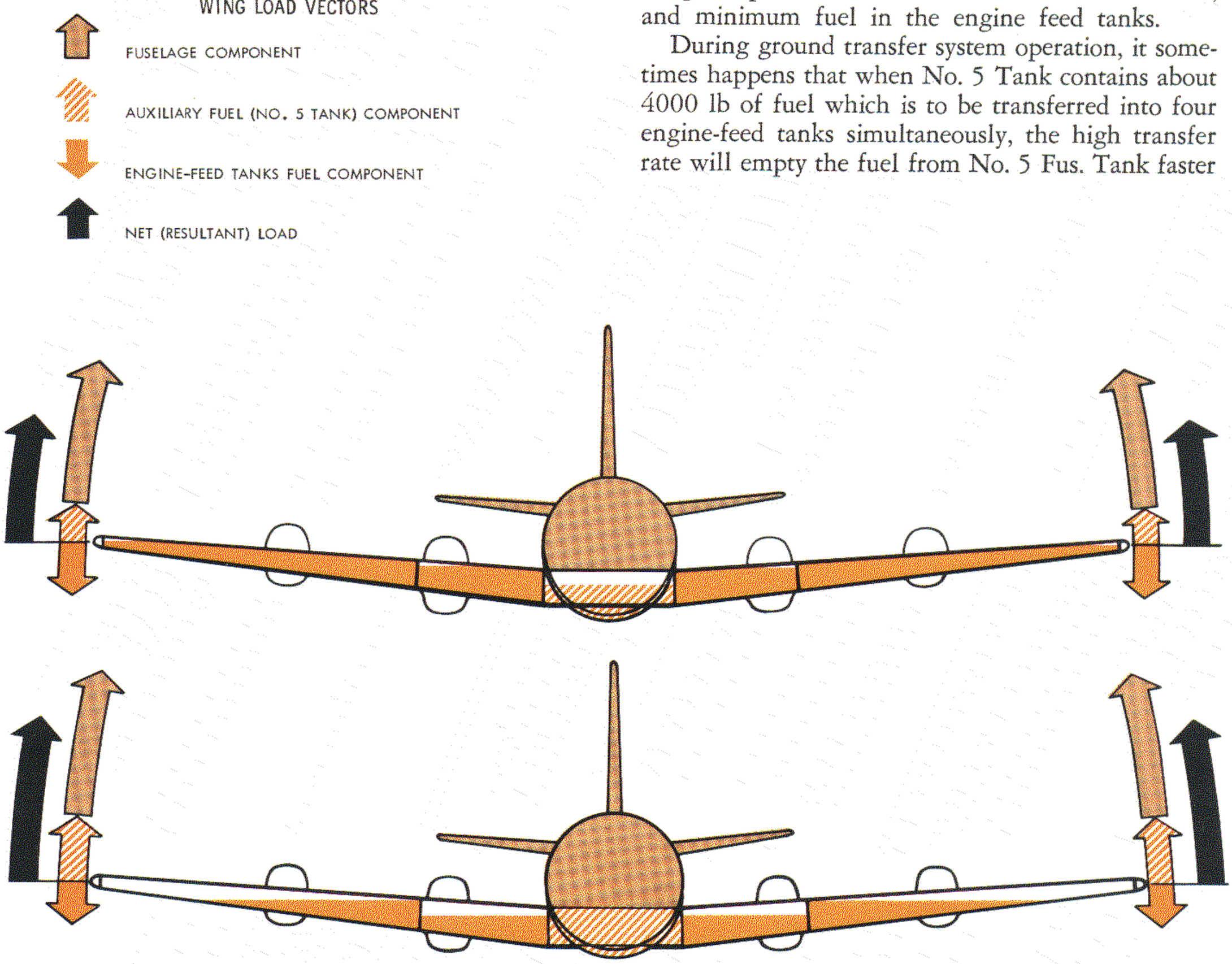


Figure 14 Effect of Fuel Weight Distribution on Wing Load In-flight, Carrying About 80% of Maximum Fuel in Both Cases. Moment arrows show principle; are not to scale.

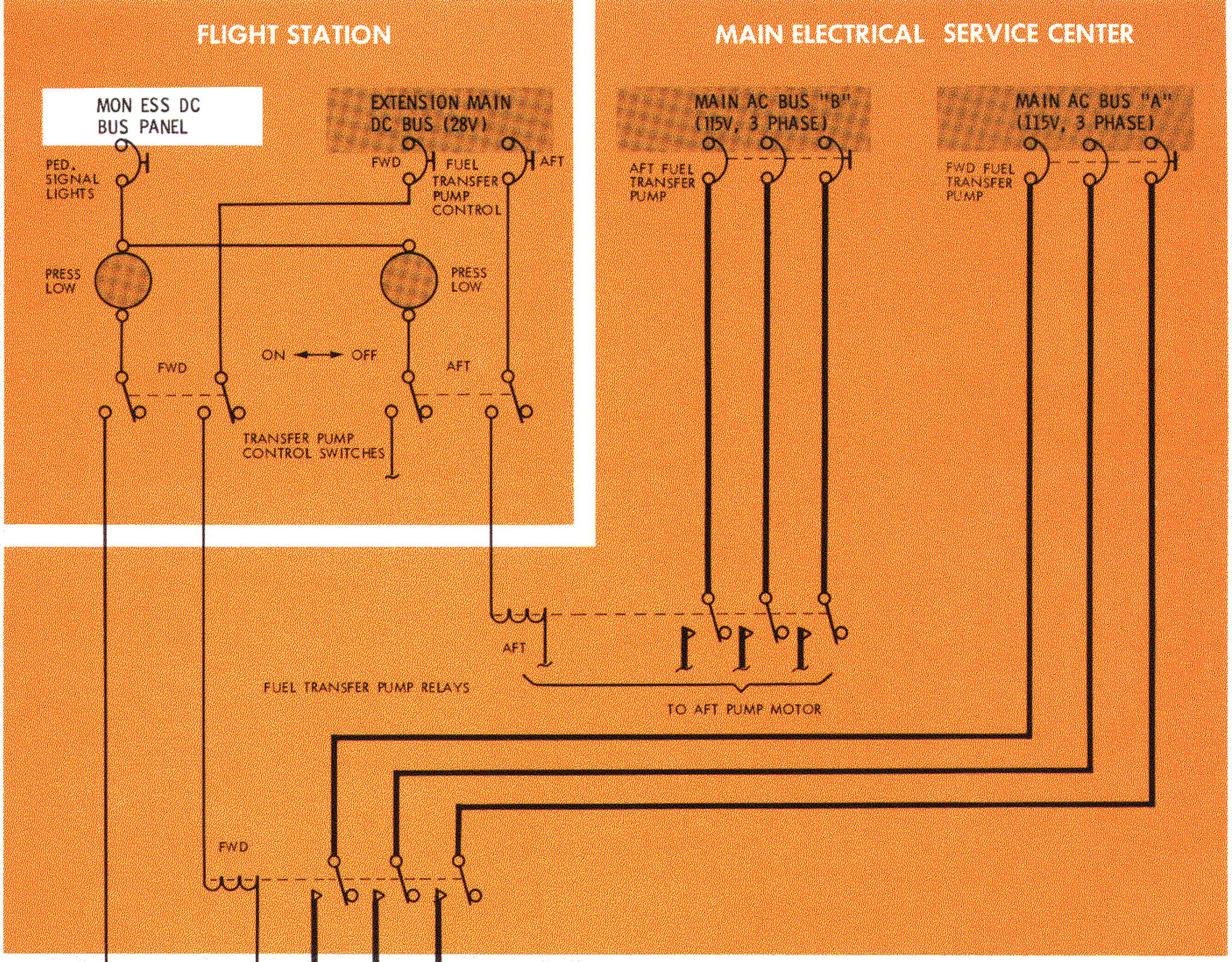


Figure 15 Transfer Pump Power, Control and Warning Circuits

than the scavenge pumps can replace it. If this situation continues for some time, the aft transfer pump (which is the highest of the two transfer pumps), will cavitate, causing the "PRESS LOW" advisory light to come on, and the operator may conclude that the pump is malfunctioning. If this occurs, we suggest that the operator turn all the Transfer Valve switches to "CLOSED" for a short period. This will allow the scavenge pump elements to recover the head of fuel, and the "PRESS LOW" light will be extinguished. In a few minutes, the scavenge pumps will provide a sufficient head of fuel, and the fuel transfer can be resumed.

This situation will not occur in flight if the No. 5 Tank has been properly loaded, for in normal operation, the transfer system will carry off only enough flow to replace the combined engine-feed flow; a smaller flow than that provided by the scavenge pumps.

The situation *can* occur in flight if No. 5 Tank has been loaded improperly, or if one Transfer pump is inoperative. In either case, closing the transfer valves for a short period and keeping the pumps (or pump) operating will recover the head of fuel in No. 5 Fus. Tank as previously described.

Engineering Flight Tests proved that, should a malpractice or malfunction result in the cavitation of both transfer pumps while fuel remains in No. 5 Tank, a period of nose-down flight will bring most of the residual fuel from No. 5 Ctr. Tank into the No. 5 Fus. Tank, and the transfer flow will be re-established.

INTEGRATED FUELING INSTRUCTION

Fueling procedures are given on the Fueling Panel placard, in the Maintenance Requirement Cards, and on a full-page chart in the "Ground Handling and Servicing MIM." These vary slightly in detail, but are alike in format, in that a "core" procedure is given which the operator is expected to modify as necessary to accomplish the intent of auxiliary directions given in related MIM text, NOTES, and WARNINGS. For example, the placard procedure does not instruct the apportioning of small fuel loads in No. 5 Tank. The MIM procedural chart carries that information together with precautions regarding alternate loading to prevent thermal overflow, but special procedures required in the event of a preliminary indication of valve malfunction, and provisions to test engine-feed tank automatic shutoff when fueling No. 5 Tank alone are to be found only in the MIM text and do not appear on the procedural chart or placard.

The "integrated instruction" which follows is designed to incorporate the intent of the basic check procedure and allow for the many variables described in the official publications.

In the interest of providing a brief, practical instruction, we have retained only those elements of procedure pertaining to safety, and presented an abridged valve testing technique to eliminate some chance of confusion. Those familiar with the fueling operation will note some departures from standard, and to explain these we have interjected commentary between pertinent elements.

FUELING INSTRUCTIONS

Fueling aircraft not scheduled for immediate takeoff to more than 9400 lb each in Tanks 1 thru 4 or 16,200 lb in Tank 5 may incur hazardous thermal-expansion overflow from tank vents. If mission loading requires more than 9000 lb in any of Tanks 1 thru 4, it is permissible to fuel excess into Tank 5 up to 16,000 lb to avoid vent-drip provided that excess is transferred to Tanks 1 thru 4 before takeoff.

This "Prologue" information warrants consideration prior to fueling in every case in warm climates, and in cold climates too if aircraft are to be taken into the comparatively warm environment of a hangar after refueling. As noted previously, if fuel in full tanks warms as much as 10°F, overflow is to be expected.

PRE-FUELING CHECK

No operating radar within 120 ft — Monitors posted at proper wing-tip tank vents — Static grounds attached — Gages Test switch drives all fuel gages below zero — Indicator Lights Test switch illuminates all green Valve Closed Indication lights.

These are routine checks that safeguard the fueling operation and, of course, testing of the lights and gauges proves not only their operability but also the prerequisite ac and dc power supply needed for the fueling operation.

FUELING

WARNING — TERMINATE FUELING IMMEDIATELY IF NO AIR FLOW FROM VENTS IS DETECTED AS FUELING COMMENCES OR IF GREEN VALVE CLOSED INDICATION LIGHTS FAIL TO PERFORM AS STATED.

1. With all Fueling Valve Control switches at "CLOSED" and System Power "OFF", attach fueling nozzles and apply 10 psi fueling pressure. SHUT OFF FUELING HOSE PRESSURE IMMEDIATELY UNLESS ALL 6 GREEN (VALVE CLOSED INDICATION) LIGHTS ARE ILLUMINATED.

This step is a basic one, in which the operator determines that the manual shutoff function on every fueling valve is operable. Experience has shown that some valves may not close positively enough to illuminate their indicator lights while fueling manifold pressure is zero. This is of little concern in itself, for a small positive pressure should seat the valves positively. But it should be noted that a jammed-open valve that is totally uncontrollable would give the same indication, and if the related tank is already near full, there is immediate hazard of overpressurizing the tank if a high rate fuel flow is permitted for even a few seconds. For this reason the MIM requires that a preliminary check be made with low fueling pressure in such circumstances. An integrated instruction must allow for such adversity, and specify that only 10 psi pressure be utilized until valve controllability is proven. Also, the lower pressure at this point in the procedure is additionally advantageous in that the pressure-operated fueling valves are proven with a pressure level more nearly representative of Transfer System pressure, and the reduced pressure minimizes the amount of fuel added to tanks before the automatic shutoff function is proven.

2. Select "OPEN" at Fueling Valve Control switches of tanks to be fueled or of all tanks if Tank 5 is to be fueled. Hold Fuel Shutoff Test switch at "PRIMARY" and System Power switch "ON" for 15 seconds while observing green lights, then select "OFF" at both switches. Green lights of all selected tanks except lights of full tanks must extinguish momentarily. All 6 green lights must be illuminated before System Power "OFF" selection.

The wording of this step differs from comparable steps in other procedures in that it ensures that wing tank automatic shutoff will be tested each time Tank 5 is fueled, and describes the reaction of every indicator light in the event a valve on a full tank has been selected "OPEN." Note that the sequence of items ensures that the test time on all valves will begin at the same instant, and the operator is instructed to shut off all "VALVE OPEN" power after the count of 15. Thus, the operator will automatically shut off fuel flow first, and can then ponder in safety any apparent malfunctions.

3. Increase fueling pressure to 50 (± 5) psi, check that all green lights remain illuminated and gages show no weight increase.

4. Select "CLOSED" at Fueling Valve Control switches of tanks not requiring fuel. Hold Fuel Shutoff Test switch at "SECONDARY", select System Power switch "ON". Green lights of fueling valves selected "OPEN" must extinguish, then illuminate within 15 seconds.

This step terminates testing of fueling valves for tanks not actually requiring fuel for the reason that completing the test cycle under full fueling pressure may introduce an appreciable quantity of fuel into a tank already filled to the desired level. As before, the order of events in this step ensures that the fuel shutoff test on all valves will be made coincidentally.

5. Select "CLOSED" at No. 5 CTR. Control switch if Tank 5 requirement is for less than 4000 lbs. Release Fuel Shutoff Test switch to "OFF", and observe weight increase on gages.

6A. If no tank is to be completely filled, when desired weight is indicated in each tank, select "CLOSED" at related Fueling Valve Control switch, check that green light illuminates and quantity indication stabilizes.

6B. If any tank is to be filled, when first of Tanks 1 thru 4 gages reaches 9000 lb or Tank 5 gage reaches 16,000, hold Fuel Shutoff Test switch to "SECONDARY" and check that green lights are illuminated within 15 seconds. Release Fuel Shutoff Test switch to "OFF". For full tanks, allow tanks to fill and shut off automatically. For part full tanks, select "CLOSED" at related Fueling Valve Control switch when desired weight is indicated, check that green light illuminates and quantity indication stabilizes.

7. Turn System Power switch "OFF", check that all green lights are illuminated, turn Fueling Valve Control switches "CLOSED", detach fueling nozzles. ▲▲

P-3 FUEL FEED SYSTEM

INTRODUCTION

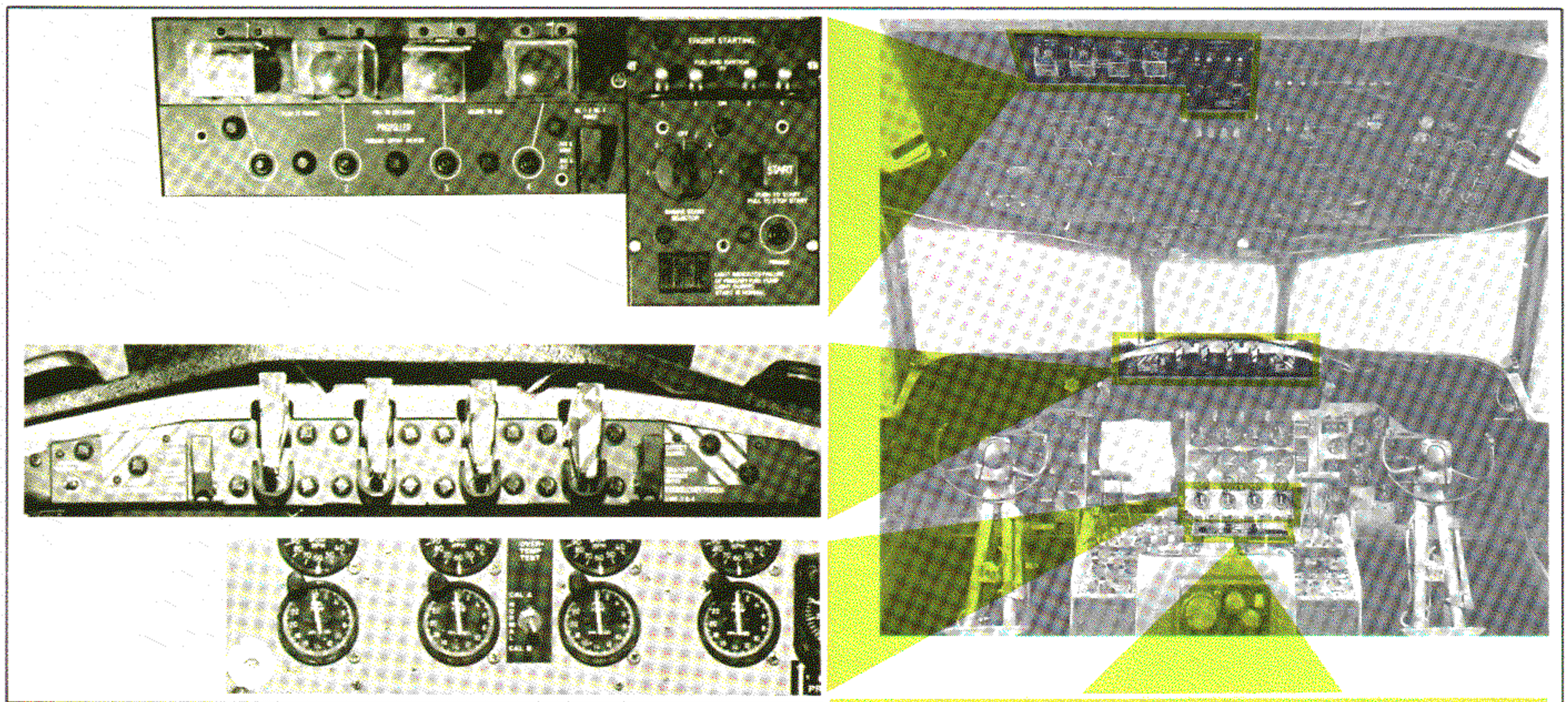
SIMPLICITY OF OPERATION and maintenance, which were primary design objectives throughout the P-3, are exemplified in the fuel system. The straight wing structure, compartmented to provide near-equal tankage aft of each engine, contributes greatly to the operational simplicity. The combined capacity of these engine-feed tanks is ample for most missions, and the near equality of volume makes it unnecessary to cross-feed engines if they are utilized equally.

Maintenance simplicity was achieved by designing for commonality of components and by anticipating repair requirements. Spares variety is minimized, be cause most components requiring regular maintenance can be used interchangeably in a number of locations. With few exceptions, tank-mounted components can be removed and replaced without draining and entering the tank.

The combined engine-feed tank capacity can be augmented as much as 37% for extreme-range missions by utilizing No. 5 tankage for temporary storage. The fuel transfer system continually replenishes engine feed tanks from the No. 5 supply as fuel is used from them in the first stage of the mission. No. 5 Tank fuel can only be utilized in this way, whereas the contents of the engine-feed tanks can only be used for immediate consumption, for the fuel feed and crossfeed system is designed to prevent fuel being transferred from one tank to another. It does allow any tank to supply any combination of engines, one of which will normally, but not necessarily, be the corresponding engine. A scavenge system in each tank ensures that nearly all fuel is usable.

Tank-mounted motor pumps boost fuel to supply mechanically driven pumps on each engine's fuel control assembly. The fuel pumps, screens, and filters throughout the fuel system are provided with bypasses so that failure or blockage will not interrupt engine feed. A heat exchanger located upstream of each engine's filters and fuel control, utilizes warm engine oil to heat the feed flow as necessary to maintain it at an optimum temperature, well above the temperature at which ice might accumulate on filters and sensitive metering devices.

A capacitance type fuel quantity system indicates the weight of fuel in each tank on individual dial indicators; a drum-type totalizer provides a running total of fuel remaining. Fuel flow to each engine is measured by a mass type flowmeter and indicated in pounds of flow per hour. Pressure switches and position sensing switches installed at key points operate advisory lights to inform the crew of immediate or potential trouble in the fuel system.



FLIGHT STATION CONTROLS AND INDICATORS

Fuel system controls and indicators for the management of fuel reserves are located on the Fuel Management Panel, where they are accessible from all flight deck stations. Control switches are oriented along a simple flow diagram embossed on this panel, together with advisory lights that monitor component function.

Figure 1 shows this panel, to which we have added an extension incorporating rudimentary symbols portraying the typical controls and indicators pertaining to fuel feed to an individual engine. Beginning with this engine's feed-tank quantity gauge and proceeding forward along the diagram, the components concerned with direct tank-to-engine feed flow are:

1. The tank Boost Pump switch, accompanied by a "BOOST" advisory light that illuminates when the tank feed line is not under positive pressure.
2. A Main Tank Valve switch, accompanied by a "TANK" advisory light that illuminates when the position of this motor actuated valve does not coincide with the selected position. From this point, fuel proceeds to the corresponding engine-driven pumps through an Engine Fuel Shutoff valve — a mechanically actuated valve operated by the Emergency Engine Shutdown handle, which is shown in Figure 1 but is not on the Management Panel diagram.
3. A "PRESS LOW" light which will illuminate if the engine-driven boost pump does not add more than 19 psi to the initial pressure supplied by the tank-mounted pump.

Figure 1 Fuel Management Panel. Inset shows continuation of flow via typical controls and indicators to engine fuel nozzles.

MONITORABLE ESSENTIAL DC BUS

EXTENSION MAIN DC BUS

SIGNAL LIGHT CONTROL

PEDESTAL SIGNAL LIGHTS

SIGNAL LIGHT CONTROL BOX

NO. 2 FUEL BOOST PUMP CONT.

MONITORABLE ESSENTIAL AC BUS

ØA

ØB

ØC

FUEL TANK NO. 2 SHUTOFF VALVE CONT

CROSSFEED VALVE NO. 2

FORWARD LOAD CENTER

G BOOST G

G TANK G

G X FEED G

FUEL MGMT PANEL

NO. 2 BOOST PUMP

OFF

OPEN

CLOSE

NO. 2 MAIN TANK VALVE CONT SWITCH

OPEN

CLOSE

NO. 2 CROSSFEED VALVE

MAIN LOAD CENTER

MAIN AC BUS B

ØA

ØB

ØC

FUEL BOOST NO. 2

NO. 2 FUEL BOOST PUMP RELAY

ENLARGEMENT OF NO. 2 TANK SHUTOFF VALVE (TYPICAL OF ALL MOTOR ACTUATED FUEL VALVES)

CLOSE

NO. 2 FUEL TANK

BOOSTER PRESSURE LINE

APU FUEL MANUAL SHUTOFF VALVE

DIFFUSER

NO. 2 BOOSTER/ SCAVENGE PUMP

THERMAL SWITCH

SURGE BOX

CHECK VALVES

SCAVENGE PUMP SUCTION LINE

NO. 2 BOOSTER PRESSURE SWITCH

FLAPPER CHECK VALVE

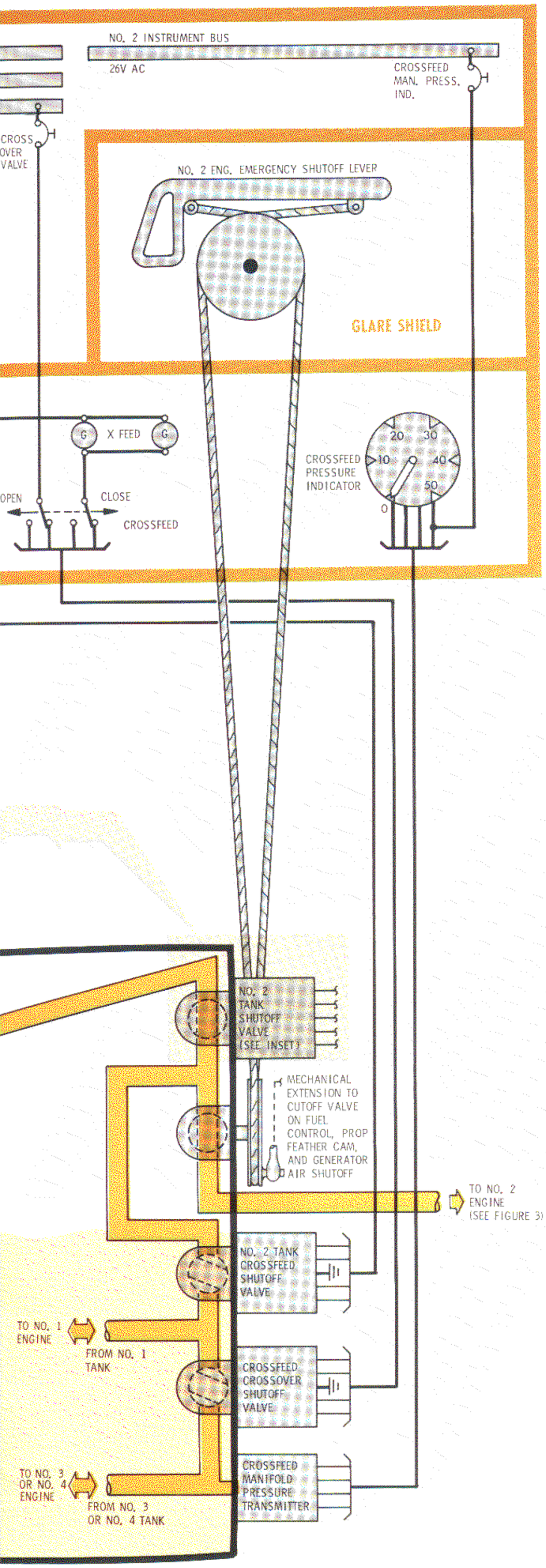


Figure 2
Tank-mounted Fuel Feed Components of No. 2 Tank and Related Control and Indicator Schematic

4. A "FILTER" light which illuminates when pressure drop across the engine's low-pressure filter elements indicates their useful life has nearly expired.

Continuing, beyond the Fuel Management Panel diagram:

5. An advisory light on the Engine Start Panel (overhead) will illuminate if the primary element of a dual, high pressure pumping system in the engine fuel control fails during engine operation.
6. A Fuel Cutoff valve, which is mechanically actuated (together with the Emergency Shutoff valve mentioned previously) by the Emergency Engine Shutdown Handle. This valve also has a motor actuator that is energized to shutoff fuel flow by means of a switch operated by the Emergency Handle, and also by actuating the Prop Feather switch to "FEATHER" or selecting "OFF" at the engine's Fuel and Ignition switch.
7. A Flowmeter, calibrated in pounds per hour, whose transmitter is located immediately upstream of the fuel nozzles manifold.

CROSSFEED As shown on the Fuel Management Panel diagram, fuel can be diverted from a point immediately downstream of the Main Tank Valve to any engine via the Crossfeed System by opening the appropriate valves. These are motor-actuated valves, that are identical to the Main Tank valves and incorporate identical advisory facilities, that is, each control switch is accompanied by an advisory light that illuminates when the valve position does not coincide with the selected switch position. A Crossship Crossfeed shutoff valve is provided. Closing this valve separates the left wing crossfeed system from the right wing system, and it is then possible to crossfeed simultaneously on both wings without danger of an inadvertent transverse shift of weight.

Note that the Fuel Crossfeed Pressure indicator is plumbed into the right-wing crossfeed system. The performance of a specific tank-mounted boost pump can be determined by directing its output alone to this point of the crossfeed system.

LOW PRESSURE PUMPING SYSTEM OPERATION

To support the following discussions of the individual Fuel Feed System components, we have divided them between two Mechanical/Hydraulic/Electrical schematics, Figure 2 showing tank mounted components, Figure 3 showing the continuation of flow into the nacelle and to the fuel nozzles.

In normal operation, flow begins at the inlet of the scavenge pump element, a centrifugal type element which continually draws fuel into the surge box at the rate of about 2700 pounds per hour from the forward part of the tank floor. One of these dual-element motor-pumps is located within the open-top surge box at the aft-inboard corner of each engine-feed tank. The scavenge/surge box arrangement maintains a constant head of fuel at the second pump element inlet — the tank boost pump. Of course scavenge pump output in excess of engine consumption spills over the top of the surge box.

If the boost/scavenge pump is inoperative, the flapper type check valve in the forward wall of the surge box will admit fuel, ensuring that the level within the box will be equal to the general level of tank fuel surrounding it or higher if tank fuel surges away from the box due to maneuvers.

The booster element is also a centrifugal type pump. It is the first in a series of pumps which feeds an engine fuel control or, in the course of crossfeeding, the pumping systems of multiple engine fuel controls may be fed by a single tank boost pump.

The boost pump inlet flow is taken from a screened enclosure at the bottom of the surge box. It is characteristic of the centrifugal type pump that its output flow and pressure vary inversely, that is, a high demand is supplied at relatively low pressure and vice versa. The pump is rated to deliver 30 psi maximum at no flow, 18 (plus or minus 3) psi at 5000 lb per hour flow. A pressure switch, mounted on the aft side of the rear beam adjacent to the pump, monitors pump output pressure. The switch is set to actuate at a very low pressure (2 psi with decreasing pressure), and illuminate the "BOOST" warning light adjacent to the pump control switch on the fuel management panel to warn that the pump is not fulfilling its function. A "BOOST" light indicates loss of the scavenge function in that tank also, for the scavenge element is driven by the boost pump motor.

Failure of a tank mounted pump does not prevent use of tank fuel, for an engine-driven boost pump can draw fuel from the surge box through the check valve in the pump by-pass line shown in Figure 2. Of course, it is best to feed none but the corresponding engine while the tank-mounted pump is inoperative, and a later section of the article discusses related operating techniques.

The power control circuit for each boost/scavenge pump motor is routed through a thermal switch in the motor case. This switch opens and de-energizes the motor if case temperature exceeds 400°F. This is well above normal operating temperature for these fuel-cooled components, and a thermal trip is certain indication of a serious malfunction. For this reason, the switches are designed to reset at a temperature below —60°F, necessitating that the motor pump be removed and chilled in dry-ice to reset the switch. This feature is intended to ensure that a motor-pump that has malfunctioned will never be put back into operation without thoroughly investigating both the pump motor and its control and power supply circuits.

Figure 2 Schematic shows the point in No. 2 Tank feed line from which fuel is taken for the APU. Normally of course, No. 2 Tank fuel will be drawn through the by-pass check valves during ground operation, and supplied under pressure by the No. 2 Tank boost pump during flight. Note, however, that the APU actually has access to the crossfeed system and can, if necessary, utilize fuel from any engine feed tank. This is convenient for ground operation to prevent the APU from depleting fuel reserve from No. 2 Tank, but it will require use of a boost pump in the tank chosen as alternate.

The booster pumps deliver pressure to the tank shut-off valve, and if this valve is opened, tank fuel is available to the corresponding engine, or it can be directed through the crossfeed manifold to any other engine as required for fuel management. To reduce the possibility of external fuel leaks, all fuel valves and all plumbing connections of components discussed heretofore are inside the tanks. Engine supply from the emergency engine shutoff valve passes through the front shear beam into the nacelle, and enroute to the engine driven fuel pumps it is taken through a heater-strainer unit as shown in Figure 3. The heater portion of this unit uses warm engine oil to heat the fuel to an optimum temperature, and the fuel is strained through a screen before it enters the engine driven centrifugal booster pump, which is located immediately downstream.

At normal engine rpm, the engine-driven centrifugal pump will add about 30 psi to whatever pressure the tank-mounted boost pump supplies at its inlet. Since the inlet pressure may vary considerably (depending upon flow demand made on the tank-mounted pump) the device that measures performance of the engine-driven pump is a differential pressure switch, plumbed to measure pressure rise across the pump. The switch unit, which is mounted at the side of the heater-strainer assembly, is set to close and illuminate the "PRESS LOW" light on the Fuel Management Panel if pressure rise across the pump is less than 19 to 20 psi.

The system design permits the engine-driven boost pump to draw fuel from the engine-feed tank without the aid of the tank-mounted pump if the pump is inoperative. The fuel feed system is planned to minimize cavitation tendencies, but the laws of fluid dynamics dictate that any unpressurized pump suc-

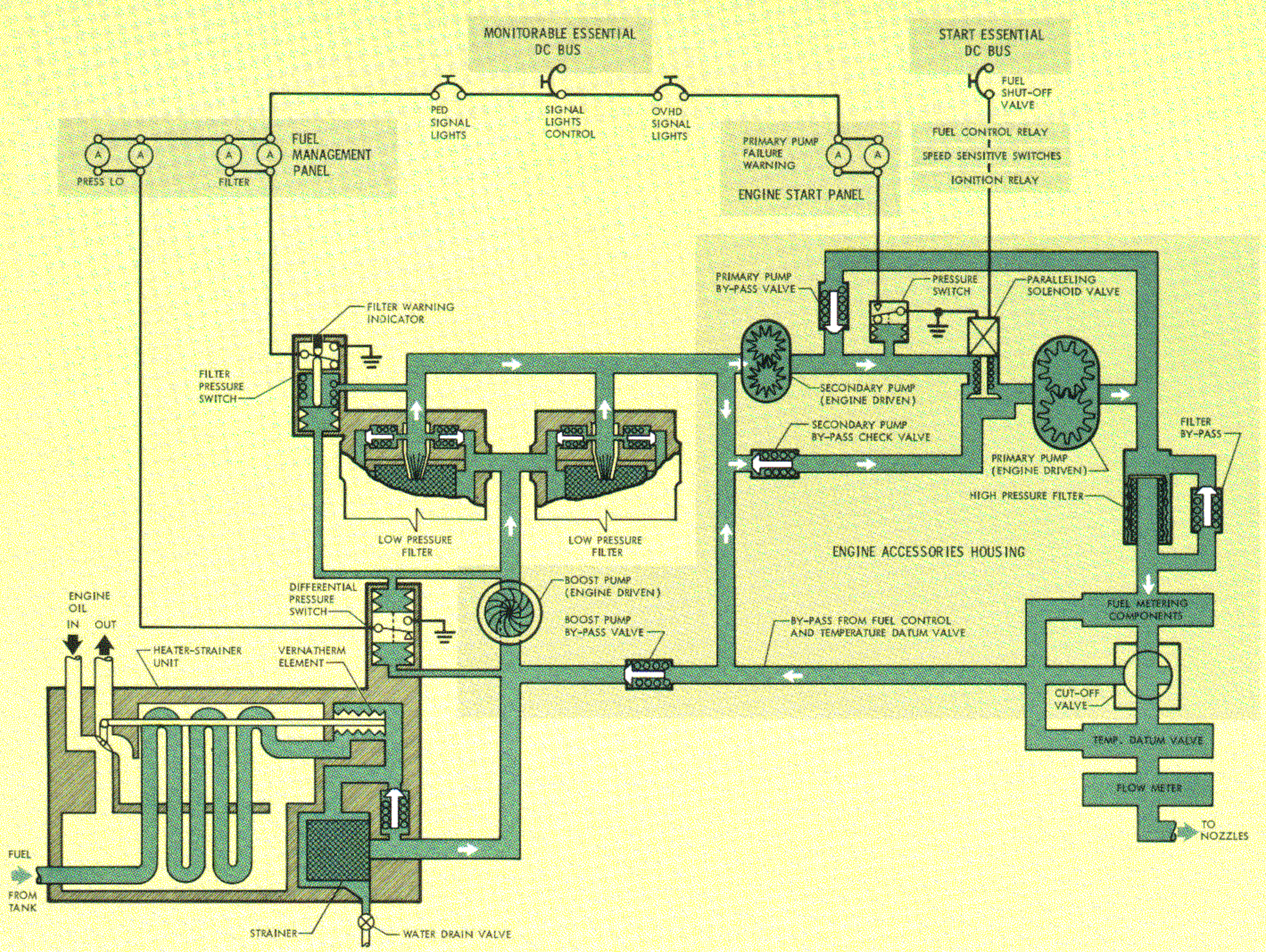


Figure 3 Nacelle-mounted Fuel Pumping/Filtration Schematic

tion line may cavitate under some conditions. The P-3 has demonstrated that its engine-driven boost pumps are capable of supplying sufficient fuel from a stable tank supply to meet any power demand in level flight at any altitude within its operating range. But as described in the NATOPS Emergency Operating procedures, a booster/scavenge pump malfunction after takeoff may be troublesome, and some special understanding of causative factors will be of help to the operator who encounters fuel-feed cavitation problems unexpectedly.

As mentioned, in level flight the mild suction required to lift a stable fuel of relatively low volatility such as the P-3 uses will not induce cavitation. However, certain transient conditions, singly or in combination, may do so. The most adverse combination of factors will be encountered during a rapid climb to high altitude with heat-soaked wing tank fuel. Climb attitude produces a less-favorable relationship between tank level and the engine booster inlet, climb power necessitates a high fuel flow, and pressure drop in the pump suction line will be maximum. At the same time, the heat soaked fuel under rapidly decreasing atmospheric pressure may produce vapor bubbles which will be ingested and enlarged by the suction in the engine-feed line, and the "PRESS LOW" light will illuminate when the engine driven pump cannot compress the aerated fuel to 19 psi above pressure in the tank feed line.* The resulting power loss will be gradual, as a rule, and can be immediately recovered by crossfeeding from a tank with an operating boost pump. The situation may right itself, as atmospheric pressure changes less rapidly with increasing altitude and as the aeration process slows in the cooling fuel, and tank-to-engine operation can generally be resumed after a short period of crossfeed operation. The period can be shortened by alleviating such of the causative factors as the mission allows, i.e., reduced power, level flight, and/or lower altitude will serve to alleviate the condition.

The initial crossfeed operation should be kept minimum, for the amount of usable fuel in the tank

** Tests indicate that this switch setting provides a considerable forewarning of impending engine power loss. Usually the "PRESS LOW" light illuminated about 1000 feet lower than the altitude at which starvation became evident.*

with the inoperative boost pump is indeterminate, and lateral load problems and diminished operating range can result if a large discrepancy in tank level is permitted to develop.

One further consideration to flight with a failed booster-scavenge motor-pump concerns loss of the scavenge function. With scavenging, unusable fuel is negligible; without it, some fuel will drain forward and become unusable during a prolonged nose-down descent. For example, a test made at 10° nose-down showed 1950 lb unusable from inboard tanks, 780 lb unusable from outboard tanks. Further tests showed that practically all of this fuel could be used by executing pull-ups occasionally, thus periodically filling the surge boxes.

In normal operation, the tank mounted pump serves as a back-up for the engine driven boost pump, for it will force sufficient fuel through a failed engine driven boost pump bypass to maintain a supply of fuel at positive gauge pressure at the inlets of the two engine driven high pressure pumps. Maintaining this positive pressure supply at the high pressure pumps is the purpose of all the components we have discussed heretofore.

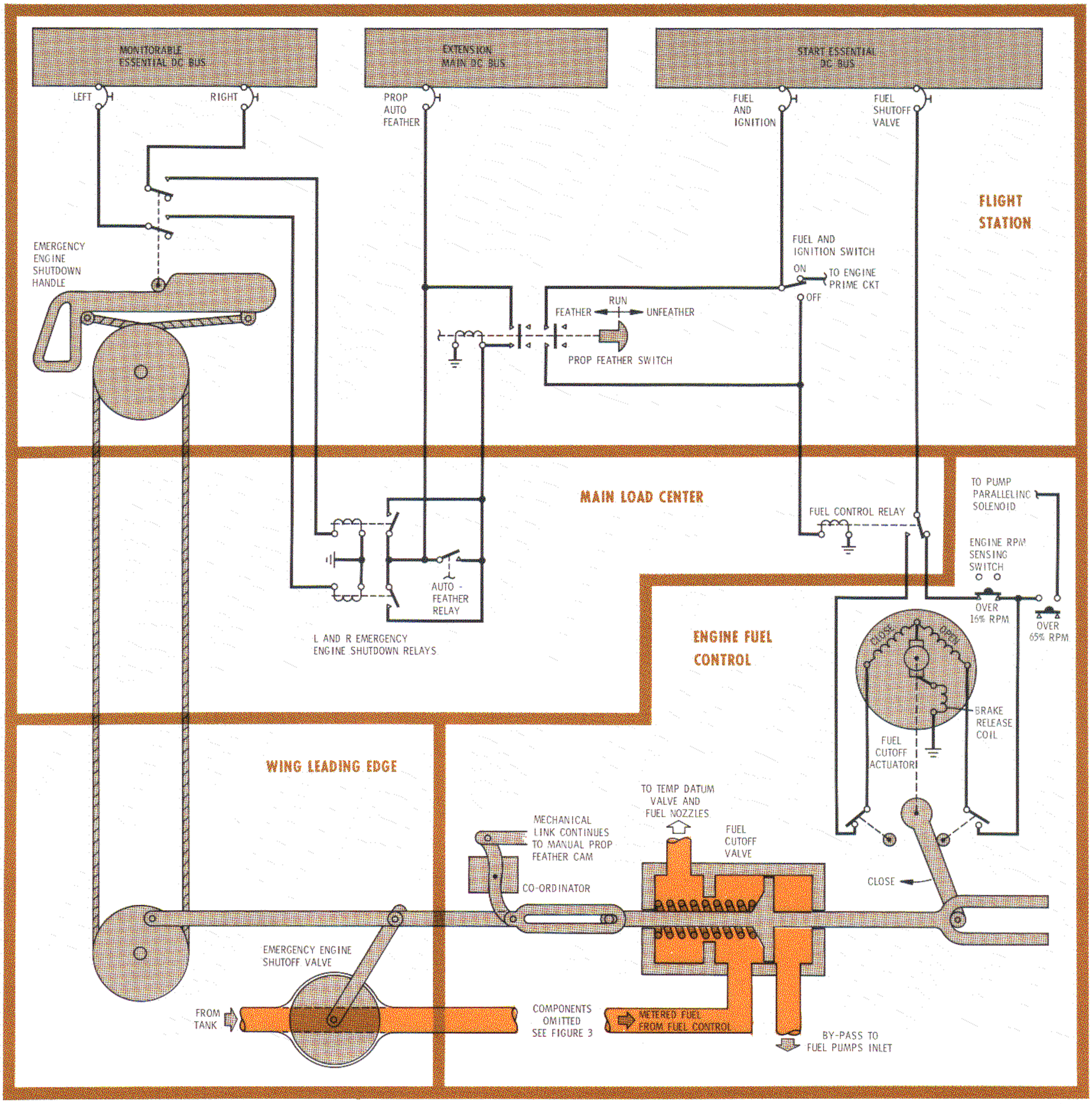


Figure 4 Simplified Schematic of Fuel Cutoff Provisions

HIGH PRESSURE PUMPING SYSTEM OPERATION

The high pressure pumps are gear type pumps (see Figure 3) identified as Primary and Secondary. At normal engine operating speed, either pump will produce sufficient pressure and flow for engine operation, but it should be noted that the primary pump is somewhat larger than the secondary and has, therefore, a slightly greater capacity. Note also that the two pumps are in series so long as the normally open "paralleling" solenoid valve is de-energized, routing the discharge of the secondary pump to the inlet of the primary pump. This is the normal "series" configuration when the engine is operating. When the pumps are thus connected in series, the secondary pump is actually idling, for its discharge is not sufficient to satisfy the demand of the primary pump, and consequently there will be a small pressure drop across the secondary pump. The balance of the flow needed to satisfy the primary pump demand will be drawn from the boost pump discharge through the secondary pump bypass check valve. The discharge of the primary pump passes through the high pressure filter to the engine fuel control; the secondary pump is active, but in a standby capacity for it is not contributing to the pressurized flow.

If the primary pump fails partially or completely so that its demand drops to less than the output of the secondary, pressure will build up in the lines between the pumps. Pressure between the pumps will: 1) close the pressure switch and illuminate the "Primary Pump Failure" advisory light on the Engine Start panel in the flight station and, 2) open the primary pump bypass check valve. Thus the secondary pump will automatically assume the duty of the primary pump in the event of a primary pump failure, and the crew is advised of this failure.

The primary and secondary pumps are "sized" to produce sufficient output for operation on a single pump at normal engine speed, but at starting speed the supply may be marginal, particularly if a start is to be made in cold weather. To ensure an adequate supply under the most adverse conditions, the pumps are "paralleled" for a period of time as the engine accelerates during the start. An engine driven flyweight switch in the speed sensing control closes and energizes the paralleling valve solenoid (closing the valve) when cranking speed exceeds 16%. This valve diverts the secondary pump discharge in the same manner as a primary pump failure would, and the output of both pumps is available to the fuel control for light-off. When engine speed increases to about 65% after light-off, a speed sensing control switch will again open the circuit to the paralleling solenoid valve, and the secondary pump will be retired to "standby" (series) configuration.

Note that there will be pressure in the secondary pump discharge line while the pumps are put in parallel to ensure a starting flow, so that the Primary Pump Failure light in the flight station will be illuminated while engine speed is between approximately 16% and 65%. Thus during a start, the light does *not* indicate a failed primary pump, but is a normal indication that the two pumps are effectively plumbed in parallel to ensure the fuel flow needed for a light-off at cranking speed. Conversely, a Primary Pump Failure light that does *not* glow at any time when the related engine is started would indicate a failed secondary pump.

Either of the high pressure pumps has capacity to supply more than enough fuel to maintain rated turbine inlet temperature, and the function of the engine's fuel control assembly is to "trim" off the unneeded flow and return it to the system upstream of the high pressure pumps. The fuel that is metered to the combustion chamber nozzles is measured by a flow-meter which senses the inertia of the flow without obstructing it, and transmits a signal which is translated into lb/hr at the flight station gauge.

MANUAL-ELECTRIC FUEL CUTOFF Normal engine shutdown is accomplished by selecting "OFF" at the Fuel and Ignition switch. This operates a motor-actuated valve in the engine fuel control which blocks the metered fuel flow to the engine and bypasses it back to the inlet of the high-pressure pumps. The valve action is quite rapid (less than .5 seconds from open to close) and the bypass feature allows fuel to recirculate through the high pressure pumps during the coast-down interval.

The NATOPS Manual cautions against turning the Fuel and Ignition switch "ON" during the coast down interval. Extreme overtemperature damage can result if the engine is re-supplied with fuel while it is decelerating, for without the aid of a starter or a windmilling propeller the engine may be unable to accelerate to normal operating speed.

The fuel cutoff valve can be operated to "close" by purely manual-mechanical means by pulling the Emergency Engine Shutdown handle, and, as shown in Figure 4, the electrical cutoff is also activated in the Emergency Shutdown (via the Emergency Engine Shutdown relays and the Feather switch). Figure 4 is a greatly simplified schematic arranged to portray clearly the inter-relationship of both the automatic and manual, mechanical and electrical controls which are instrumental in allowing or pre-

venting fuel flow to an engine. It can be seen that normal shutdown via the Fuel & Ignition Switch is made by direct motor actuation of the Fuel Cutoff valve; opening of the valve is also purely electrical, but can occur only if the Emergency Engine Shutdown handle is in its normal position and engine rpm is in excess of 16%. Shutdown by all other means induces simultaneous propeller feathering — both functions being performed by electrical means only unless the Emergency Shutdown handle is pulled, in which case the electrical actuation of both functions is accompanied by manual/mechanical actuation as well.

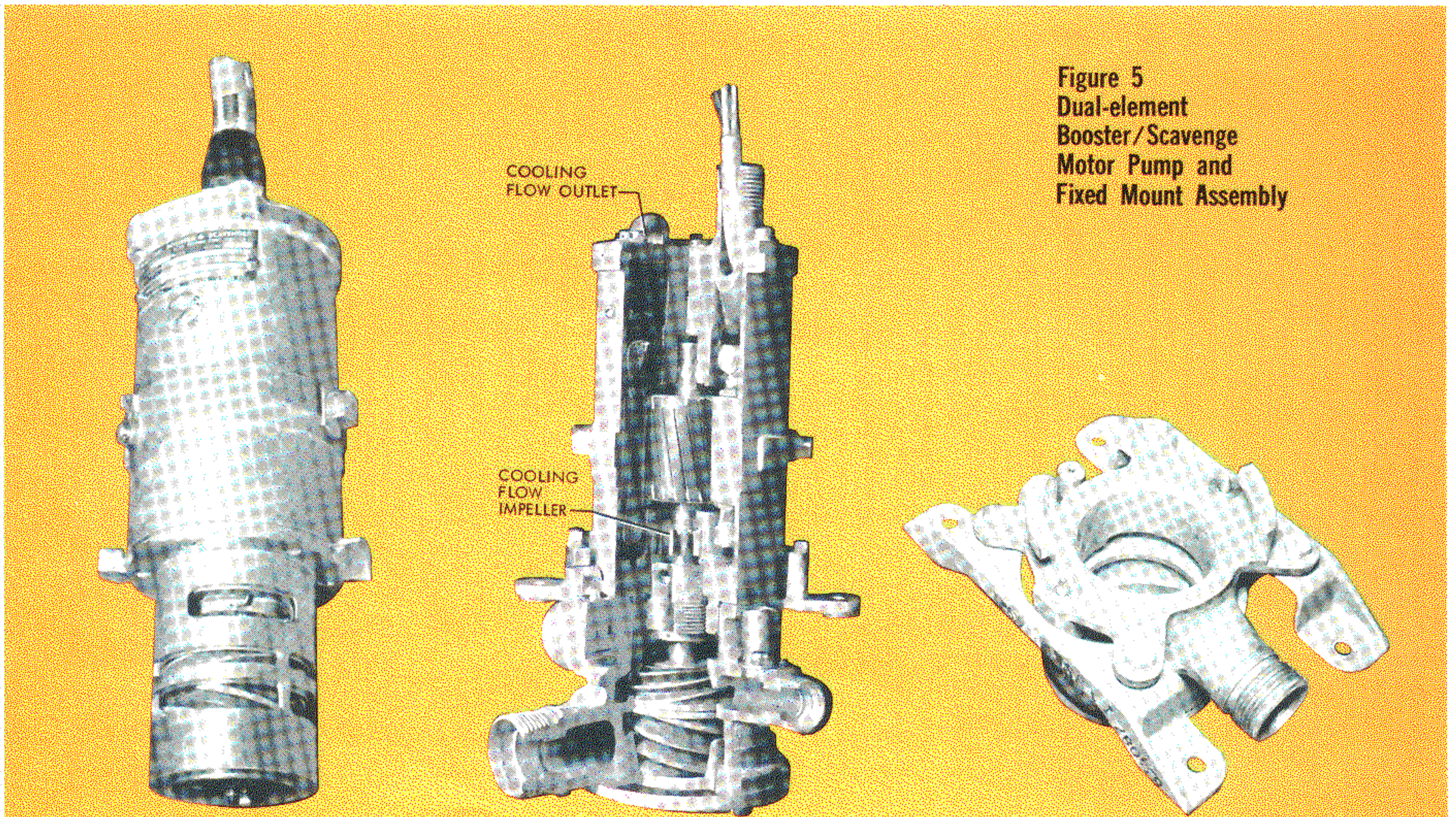


Figure 5
Dual-element Booster/Scavenge Motor Pump and Fixed Mount Assembly

COMPONENT DETAIL AND MAINTENANCE

TANK-MOUNTED PUMPS The pumping elements of the tank-mounted fuel motor-pumps are plugged into inlet housings mounted permanently inside the tanks. Booster motor-pumps are removed through an access door in the upper wing skin near the aft-inboard corner of each tank. A special tool (LAC Tool No. 829121-1) is used to extract and install these motor-pumps. The tank's fuel should be at the 3015 pound level or lower before the inboard tank boost pumps are serviced and at the 4355 pound level or below before the outboard tank boost pumps are serviced. Above these levels the access doors may be in contact with the fuel.

A fuel heater and strainer unit is mounted transversely below each engine fuel control near the engine oil cooler radiator. All oil from the engine is routed to this unit before it enters the cooling radiator, and all fuel passes through the unit enroute to the engine mounted boost pump and the fuel strainers. Fuel entering the unit flows first through heat exchanger tubing as shown in Figure 3. Exiting from the heat exchanger the fuel flows around a Vernatherm power element (thermostat) and through a 60-mesh strainer. If the fuel is below 40°F the Vernatherm unit will port a full flow of engine oil through the heat exchanger muff to warm the fuel. As the fuel becomes warmer, valves operated by the Vernatherm unit will bypass a part of the oil flow around the heat exchanger until fuel temperature reaches approximately 70°F, at which time all engine oil will bypass the heat exchanger.

The 60-mesh screen in the unit will remove water droplets from the fuel, and a small sump is provided to accumulate water which can then be drained off through a manually operated valve. Of course the

screen will trap other forms of contamination in addition to water and it should be removed periodically for cleaning.

FUEL MANAGEMENT VALVES The four tank shutoff valves and the five crossfeed manifold shutoff valves are all mounted in the web of the front shear beam. The valve bodies are identical; motor actuated valves are interchangeable and mechanically actuated valves are interchangeable. All of the valves have provisions to dissipate thermal expansion pressure in either direction when the valve is closed so there will be no danger of over pressurizing feed lines or any other components regardless of the valve's position in the system. The crossfeed and main tank valves are motor operated, the engine Emergency Shutoff valves are mechanically operated. The housings of all these plug type valves are plumbed permanently inside the tanks; the moving parts and the actuators are accessible in the wing leading edge and can be removed for servicing without draining or opening the fuel tanks. When these valves are dismounted for servicing, Maintenance Manual procedures should be followed closely to avoid damaging the seals or losing fuel. The removable plugs fit inside a ported sleeve, permanently installed in the valve housing. When the

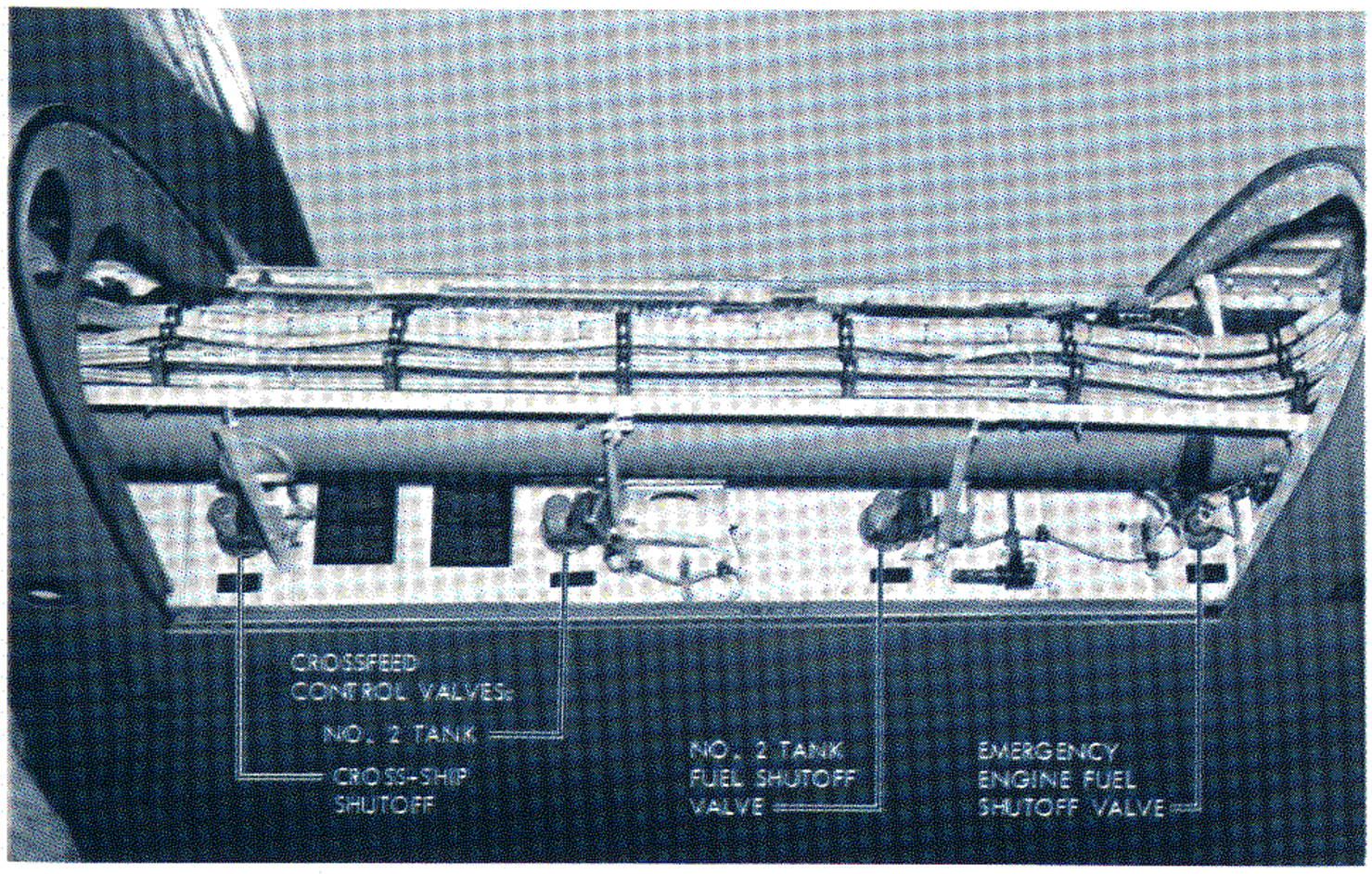
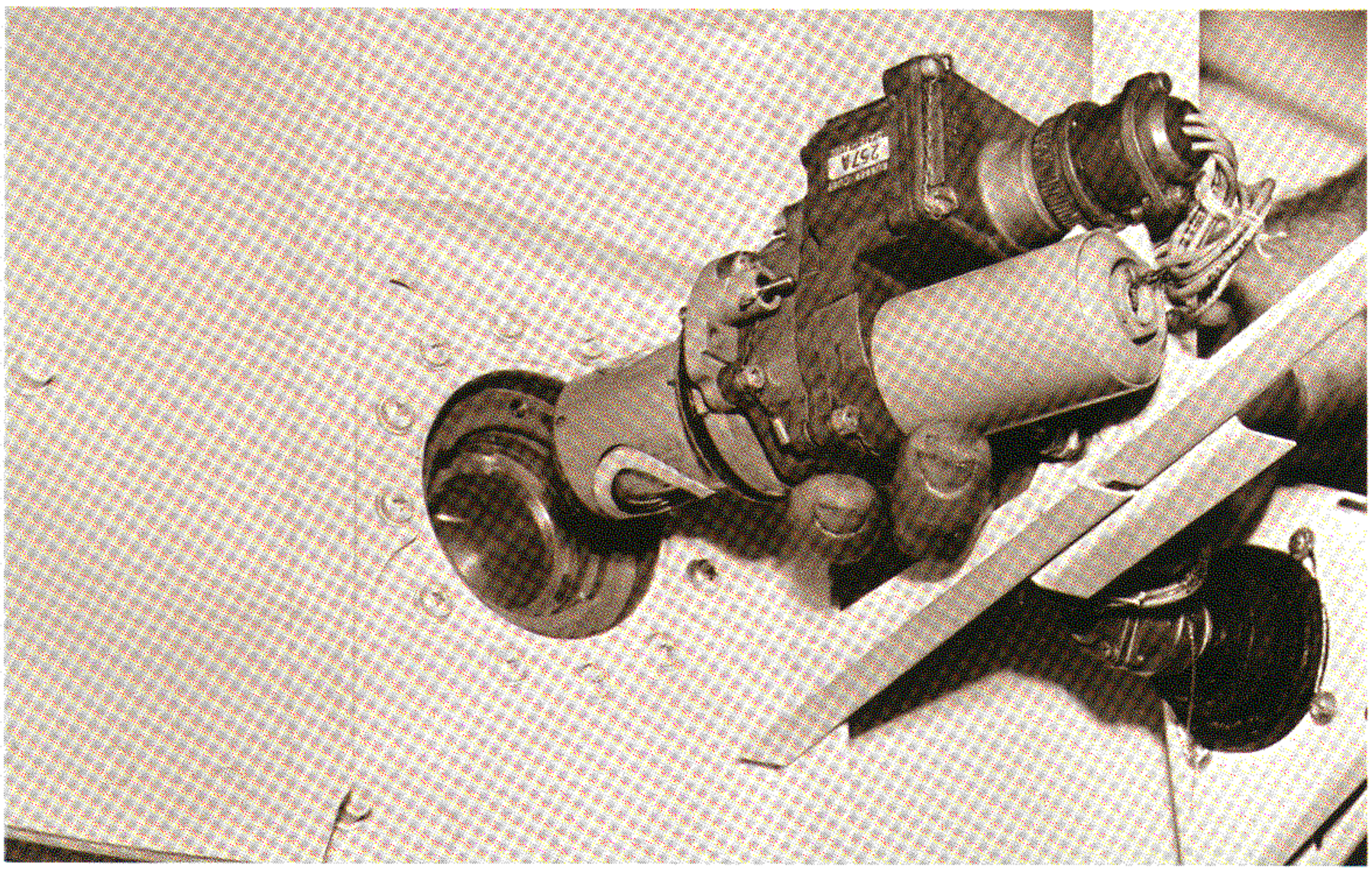


Figure 6
No. 2 Tank Fuel Management Valves — Wing Leading Edge Removed



valve is mounted and in the open position, the plug ports, the sleeve ports, and the valve body ports are aligned horizontally. When the valve is turned off, the plug rotates 90° ccw so that the plug ports are vertical. When the plug is to be removed, a lock screw is removed, an indexing pin is lifted and the plug, together with its actuator, is turned an additional 90° ccw. This rotates the sleeve ports to the vertical position so that the sleeve serves as a shutoff, and it aligns a combination of keys and keyways inside the valve so that the plug can be withdrawn from the sleeve.

The plug is tightly sealed to the sleeve bore, and high friction may be encountered when withdrawing the plug, particularly the first ⅜″ which withdraws the main O-ring seal. An impact wrench, LAC Tool No. 823739-1, is provided to aid in withdrawing mechanically operated valves.

By following the removal and installation procedures carefully, fuel loss will be limited to the small quantity contained in the plug when it is withdrawn, regardless of the fuel level in the tanks. Note, however, that the first step in removing the valve plug is a 90° ccw rotation of the entire assembly, which turns the sleeve to its off position, and the last step in the installation procedure is a cw rotation to turn the sleeve to its on position. *Do not turn the components cw at any time unless the plug is completely bottomed in the sleeve.* There may be a considerable head of fuel in the lines and tanks above the valve, and if the valve sleeve is inadvertently turned on when there is no effective plug seal, a truly hazardous flood of fuel may be expected.

FLOWMETERS The fuel flow indicating system installed on the P-3 is quite accurate, and measures the mass of flow rather than volume. Consequently it reports the weight of flow per hour to the engine regardless of the density of the fuel, or which fuel is being used.

Figure 7 shows a schematic of the system, all components of which are energized from phase B

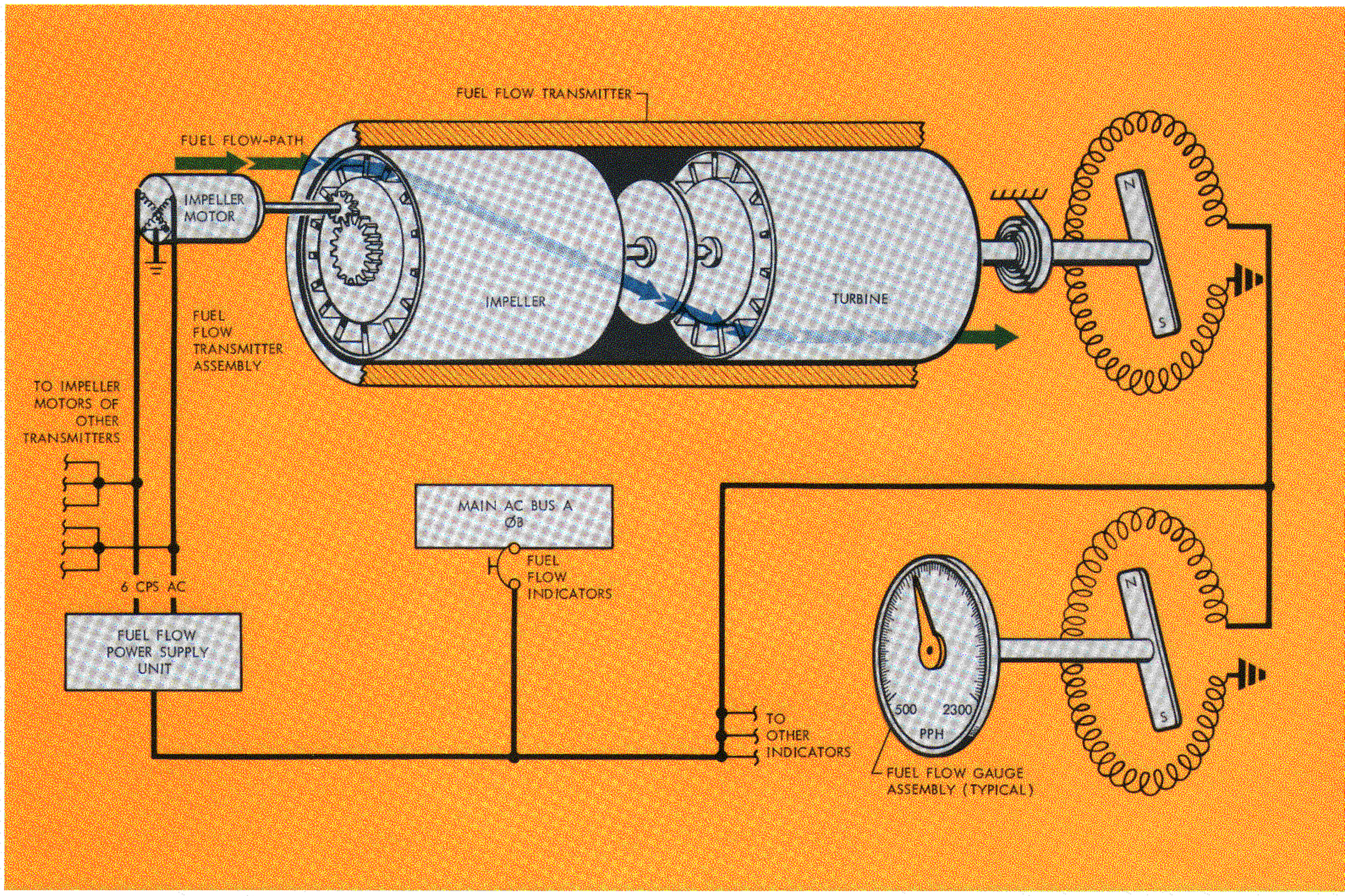


Figure 7 Flowmeter Power, Transmitter, and Indicator Schematic

of Main AC Bus A through the Fuel Flow Indication circuit breaker. The four synchro transmitter/indicator branches of the system utilize the power directly and in conventional fashion. However, the 400-cps bus power is altered by the Fuel Flow Power Supply unit in the Main Load Center to provide a 6-cps output* which is used to drive a low speed motor in each transmitter assembly, one of which is mounted at the right side of each engine.

The transmitter motor turns an impeller turbine near the inlet of the assembly at constant rpm. The impeller is not a pump, that is it does not produce a flow, but it does impart a swirl to the fuel flow. The swirling fuel impinges on the blades of a stator turbine downstream of the impeller, and the helical flow is straightened in passing through the stator turbine. As its name implies, the stator turbine does not revolve, but it is restrained only by a torsion spring so it can yield to the momentum of the swirling fuel, rotating and coming to rest at whatever position the torque imparted by the swirling fuel is balanced by spring force. The synchro system "picks off" the angular position of the stator turbine and reflects the displacement at the indicator hand of the fuel flow gauge in the flight station. Gauge calibrations range from 0 to 2300 lb/hr. The system requires little regular maintenance, but it should be noted that the entire system remains operational and the motor-impeller assembly rotates continuously so long as Main AC Bus A is energized. The flowmeter is cooled and lubricated by fuel, and can be damaged if operated without it. For this reason it is necessary that the power unit be de-energized by pulling the Fuel Flow Indicator circuit breaker when maintenance requires draining any transmitter.

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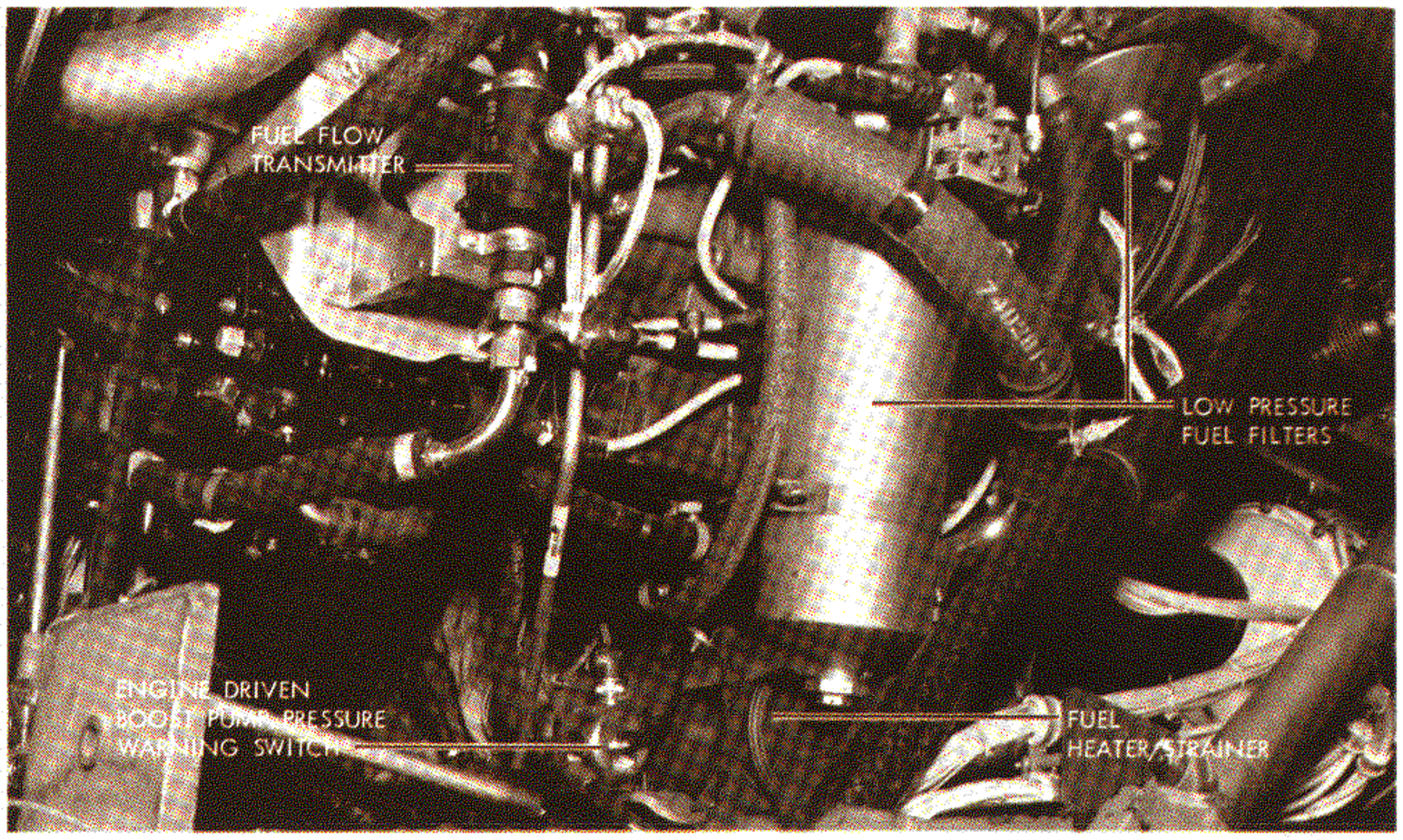
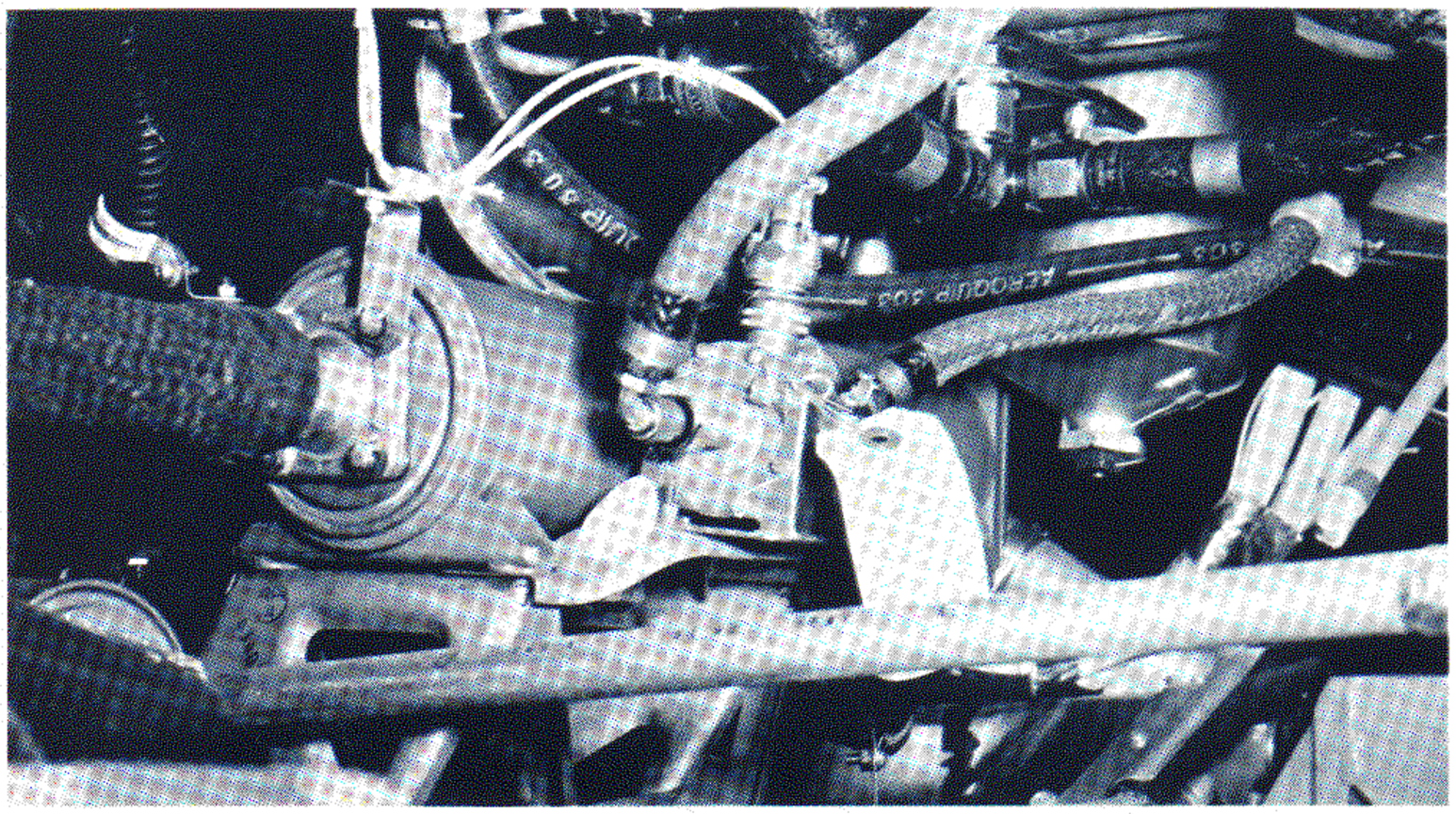
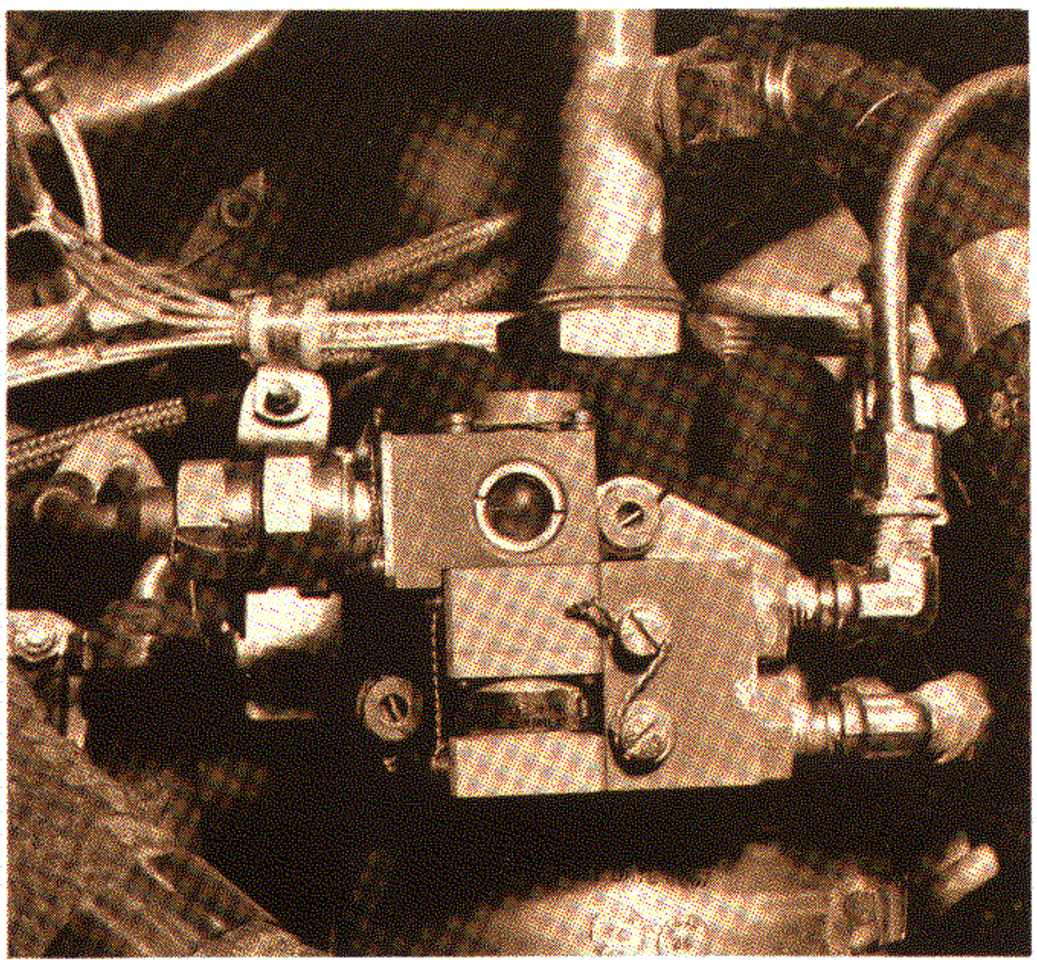
* *Beginning with BUNO 152187, the 6-cps power is obtained by use of transistor-switching circuits instead of the motor-driven, commutator-switching arrangement used previously. The two types of power supply units are both physically and functionally interchangeable, the only difference being the substitution of solid-state components for the moving components in the earlier model.*

Figure 8
Fuel-feed Components in Lower Nacelle Viewed From Aft-right and Aft-left. Filter warning indicator on aft filter monitors both assemblies.







LOW PRESSURE FUEL FILTERS The two low pressure filter housings mounted on the right side of the engines each contain two paper elements, rated at 5 microns. As shown in Figure 3, the two housings are connected in parallel, and both contain bypass valves that begin to pass flow when pressure drop across the elements reaches about 11 psi. A switch assembly mounted atop the aft filter is set to actuate when flow through the filters is impeded to the extent of 7.5 psi and illuminates the "FILTER" light on the Fuel Management Panel. At the same time, a red indicator visible through a small window in the switch assembly will be actuated. Both components latch in position, providing lasting evidence after the engine is shut down that filter maintenance is required. The switch and mechanical indicator are both reset manually at the time new elements are installed. ▲▲

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