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ORION

HYDRAULIC POWER SYSTEM

POWER SYSTEM AND COMPONENT DESCRIPTIONS

HYDRAULIC SYSTEM LINE MAINTENANCE

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FRONT AND BACK COVERS On 4 January 1963, four officers and ten enlisted men of VP-31, assembled in Hangar 3 at Moffett Field, were designated Detachment Alfa and charged with training NAVAIRPAC Orion flight crews. Their venture was implemented with a 2-bicycle motor pool and an office richly appointed with a telephone and boxes. The lack of tools was bothersome (a congenital flat tire often grounded half of the motor pool) but, until April, this handicap was neatly offset by a lack of aircraft.

From its humble origin, Detachment Alfa grew rapidly, and its record for training and operation during the balance of 1963 attests to much individual enthusiasm and talent. After transitioning from P-2's to P-3's themselves, under the tutelage of Lockheed instructors, they organized their own training facilities and enrolled VP-19's flight crews for transition training in July. Later, classes of Replacements matriculated, and Detachment Alfa settled to its primary task. In all, their 1963 alumni numbered 51 Pilots, 49 Flight Engineers, and 95 Electronics Operators.

Similarly, the Detachment's maintenance personnel transitioned smoothly from bicycles to P-3's in April, and readily accommodated a growing stable of Orions delivered, singly, in June, July, and November. By year's end their charges had flown 2253 accident-free hours, landed 4266 times, and their Schedule Reliability record was an amazing 99.57%; purer than Ivory soap.

The operations included some extracurricular duties (WestPac Inspection Tours) wherein Alfa claimed a fair operating area by flying non-stop across the North Pacific to Japan. Later, they circumnavigated their lake. The latter flight, we hasten to add, was not non-stop, but on both these excursions the flight crews proved P-3 flexibility by doing their own service and maintenance. Thus, when the famous California weather threatened December's flight-training schedule, Alfa confidently deployed 3 Orions and a skeleton maintenance crew to Fallon, Nevada for a week. They found no submarines there.

The front cover shows that Alfa flies neat formation, and, in our opinion, their insignia (see back cover) indicates exquisite taste.

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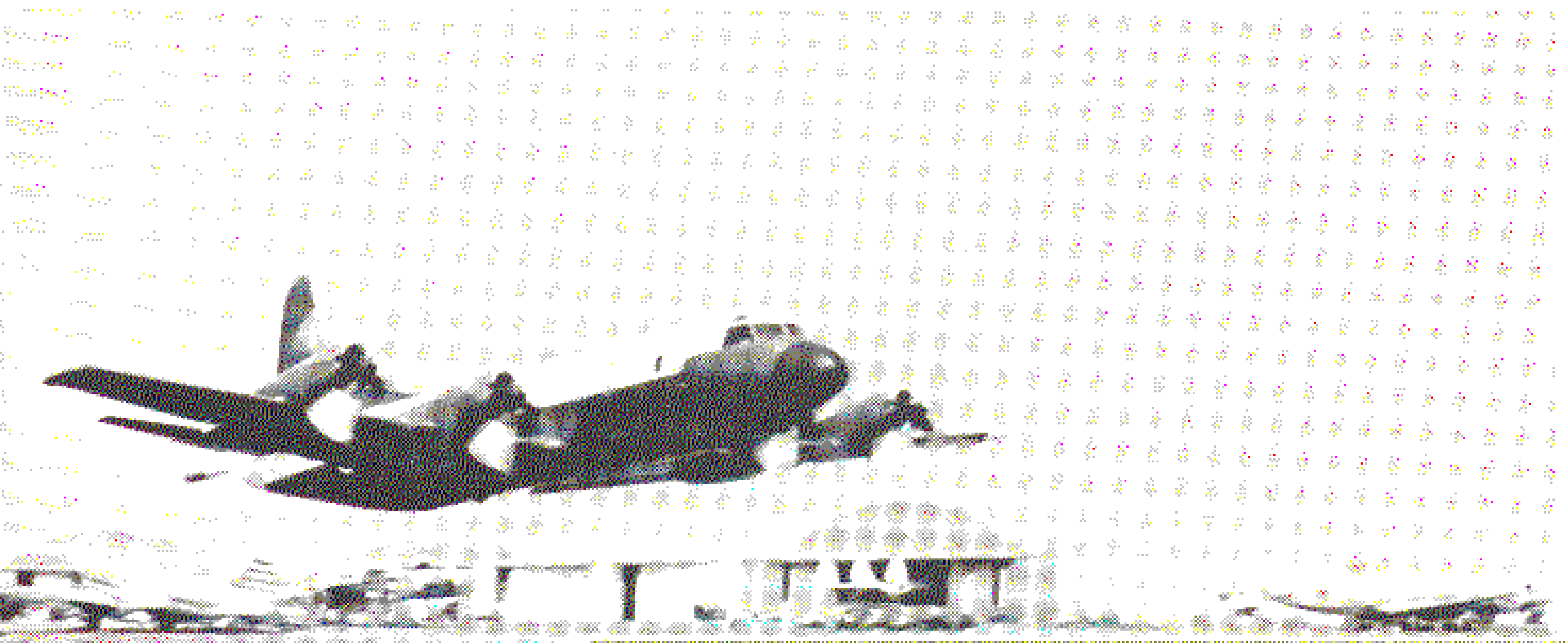
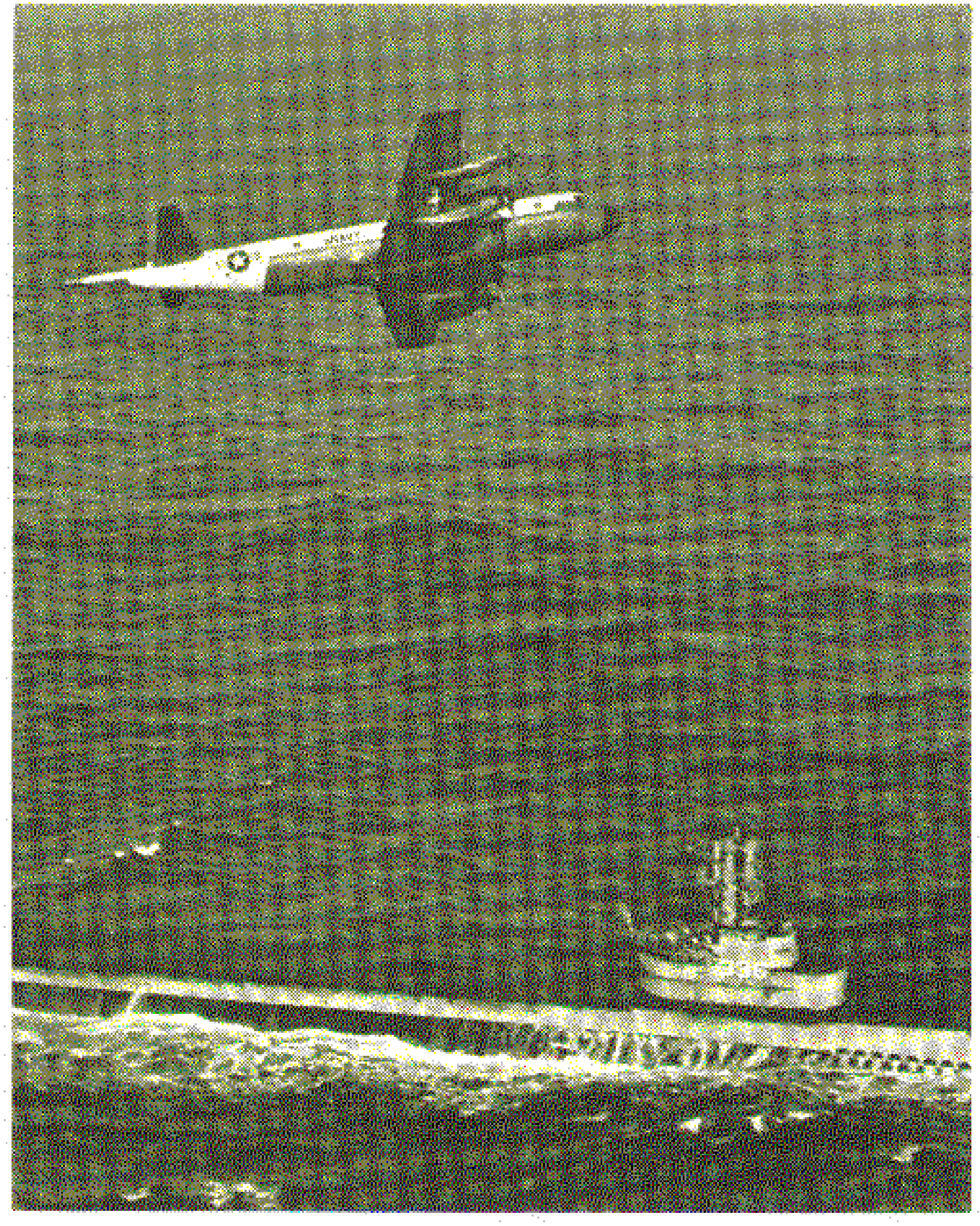
P-3 ORION
HYDRAULIC POWER SYSTEM



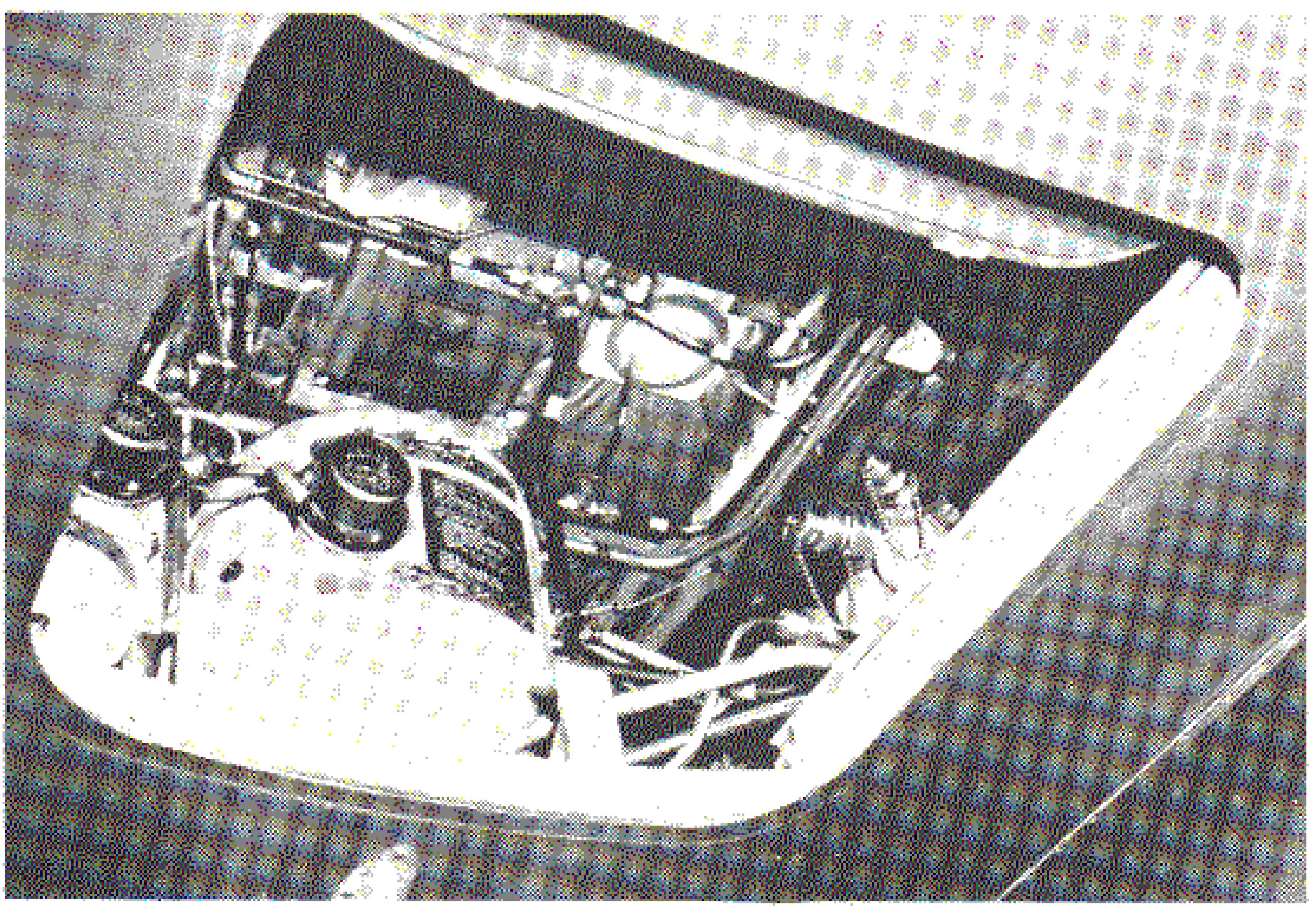


INTRODUCTION

IN OUR SYSTEM-BY-SYSTEM coverage of the P-3 Orion, the hydraulic power system follows on logically from the Issue 3 description of the electrical power and bus transfer system. In a sense, the Orion hydraulic power system is an electric accessory, and it is the connecting link between the electric system and the many actuating systems that use hydraulic power for normal operation. Some of these actuating systems are discussed in this article, but we have not discussed the landing gear actuation, brakes, and steering, nor the wing flap and flight control systems, for these are complex and important enough to warrant separate articles. However, the general layout of *all* the actuating systems, as well as the power system components, is shown on the Master Hydraulic Schematic on the fold-out pages of this magazine.

To gain a clear perspective of the hydraulic power system and the way in which it is integrated, it is helpful to know some of the considerations that enter into the "philosophy" of the design.

DESIGN PHILOSOPHY The design was taken, almost totally, from the Electra transport. Early in the Electra preliminary design program a thorough study was made to provide the new transport with a hydraulic system that would be superior in all respects to previous designs. Pumping configurations using engine-driven pumps, electrically-driven pumps, and combinations of the two were analyzed for their competence to supply normal needs and their ability to continue operation despite adverse combinations of failures and malfunctions. The most favorable configuration, and the one used on the Orion today, was three variable-displacement



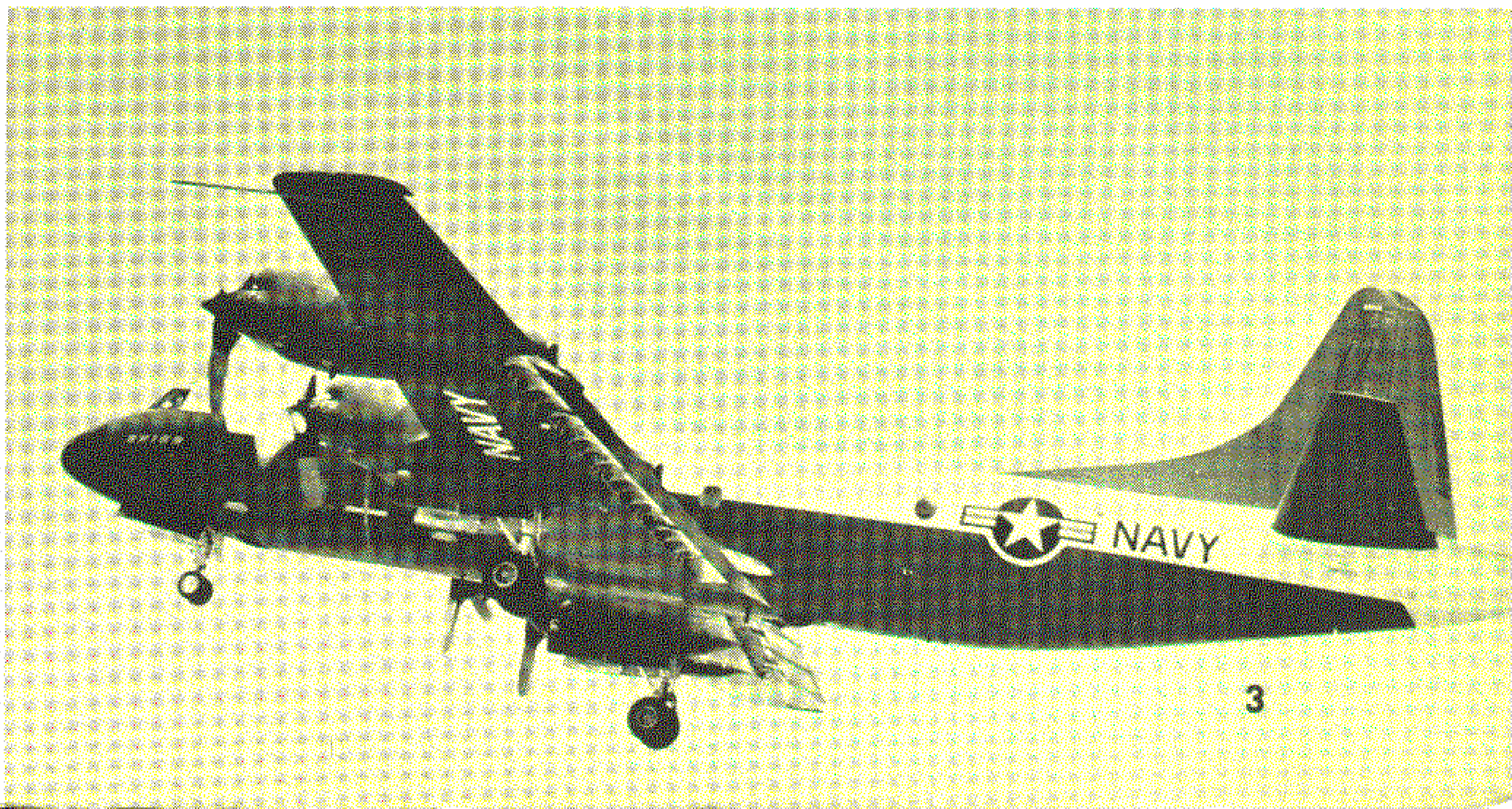
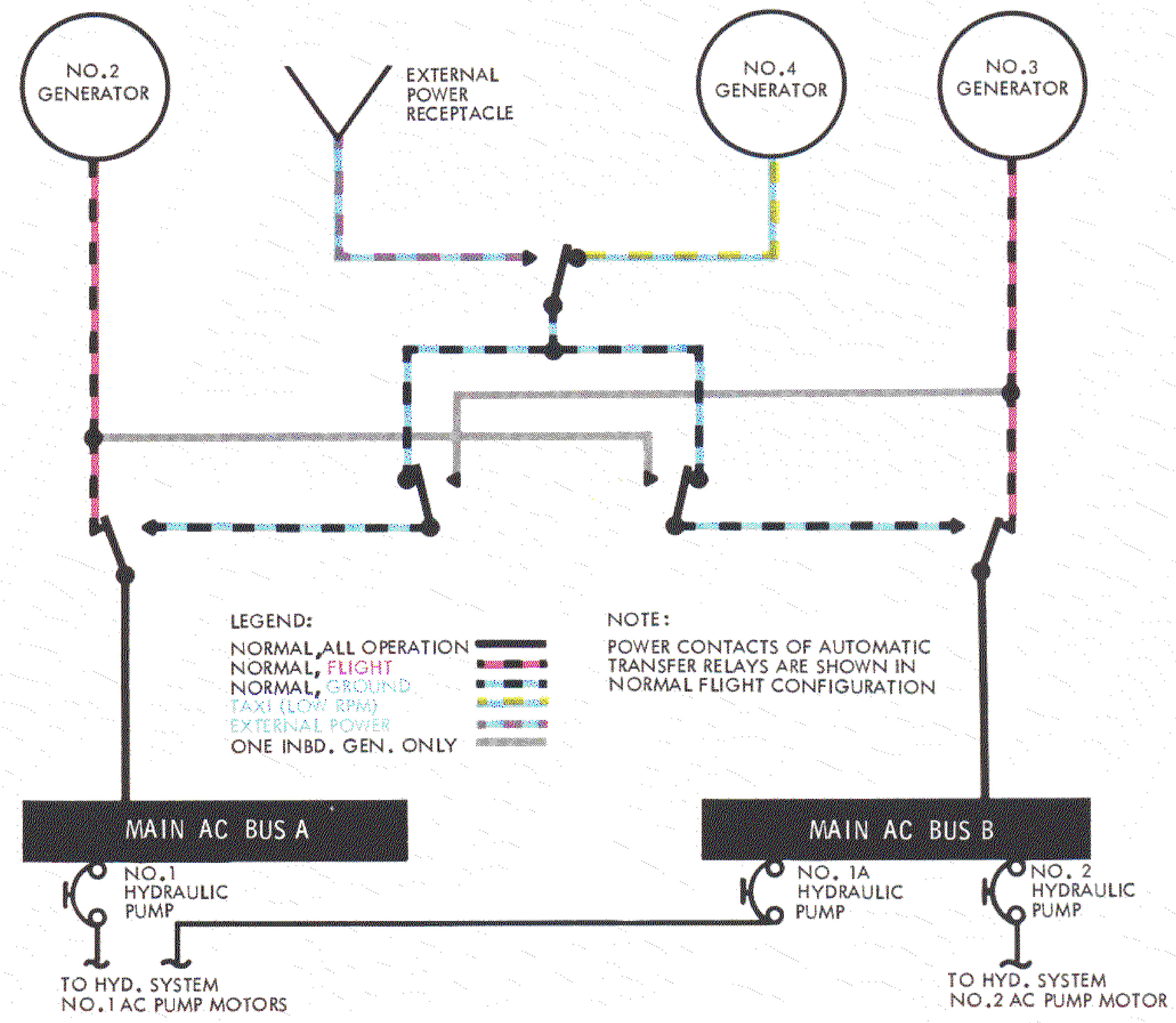
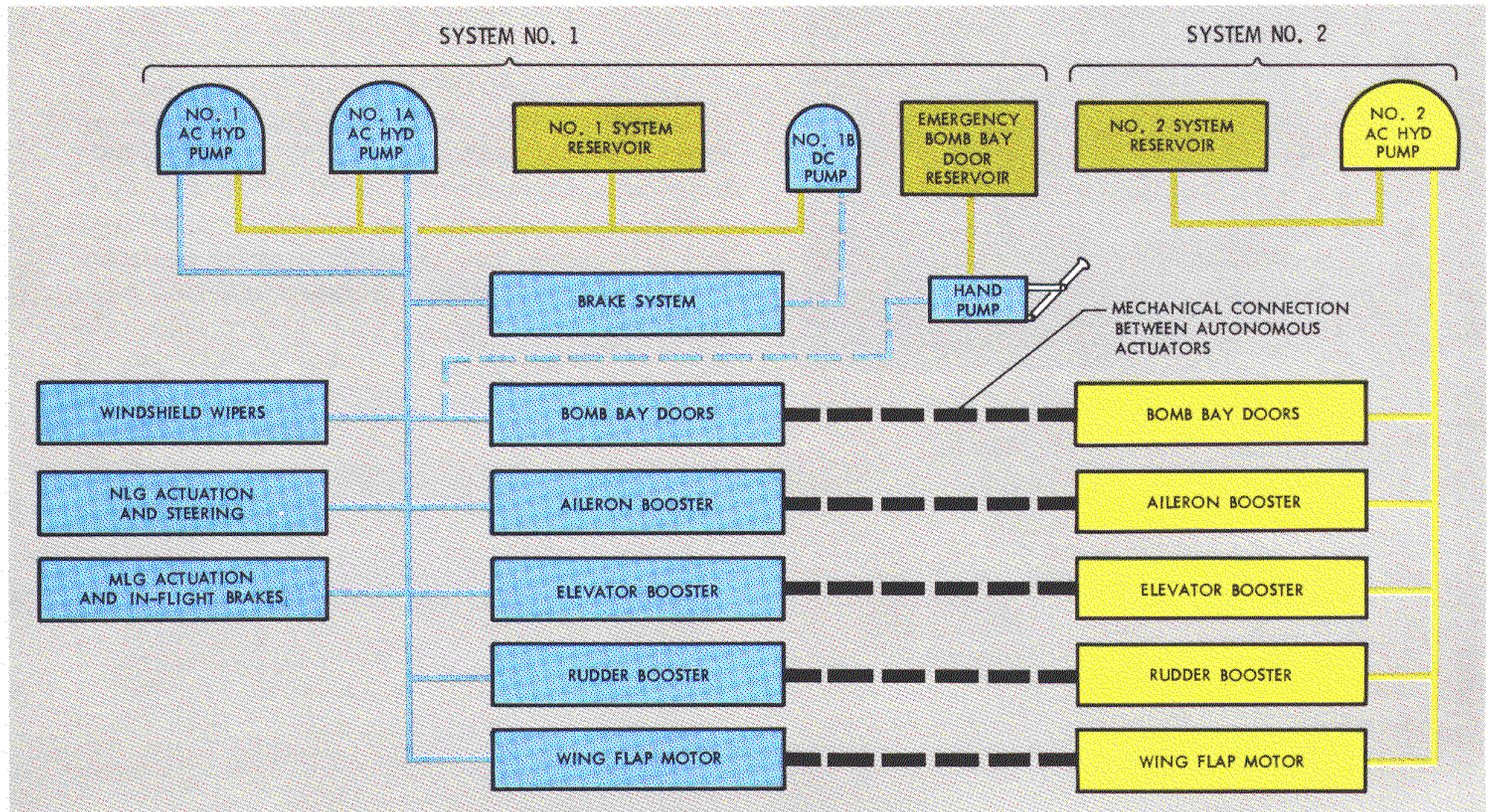


Figure 1
Scheme of Electric and Hydraulic Power Support for Hydraulically Actuated Functions



AC MOTOR PUMP ELECTRICAL SUPPORT



HYDRAULIC ACTUATOR SUPPORT

high-capacity ac electric motor driven pumps, powering two completely separate 3000-psi systems for normal operation, with a small dc-electric motor driven pump (No. 1B) of low enough capacity to operate off the aircraft battery, providing brake power for ground handling. The original system installed on the Electra has needed minor modification only, and years of use in all types of operation have proven that the preliminary design study yielded a sound conclusion.

Many factors entered into this determination. Perhaps the most influential factors were certain shortcomings inherent in a design which utilizes engine-driven hydraulic pumps on multi-engine aircraft. If one or more engines are lost on take-off or are shut down in flight, hydraulic system power is lost or system capacity is reduced at the very time the full capacity may be needed to meet an emergency situation. The pumps and hydraulic lines must be located in an engine fire zone, and are directly subjected to the wearing effects of engine vibration. Further, the nacelle-mounted components are less convenient for ground maintenance, and are completely inaccessible for emergency in-flight maintenance.

At first glance, the advantages gained by making the hydraulic systems dependent on electrical power would appear to be predicated on a rather dubious proposition, for with a conventional electric power system an electrical problem would automatically become a hydraulic problem as well. This is not true of the Orion electric system. As the Issue 3 description of the automatic bus transfer system explained, any two of the three engine-driven generators can be inoperative without affecting the power supply to the two Main AC Buses which support the hydraulic pump motors, and even the loss of power—or deliberate de-energization—of one main bus or of two transformer-rectifiers would not deprive the aircraft of *any* of its hydraulically operated functions.

In practice, many fringe benefits derive from the use of motor-driven pumps. Pump operation is not dependent upon the operation of specific engines; indeed, all pumps can operate from any generator or from an external electrical power source. Although each system has connectors for a ground test hydraulic "gig", it is not necessary to use them for ground test work, and neither is it necessary to run engines to check hydraulic functions. Except for the rare circumstance which necessitates the use of a gig and the occasional need to replace components and replenish the reservoirs, the system is closed against contamination—a real gain in view of some bitter experiences on past designs in which the frequent use of ground test gigs often resulted in contaminated hydraulic systems or a transference of a local contamination from one aircraft to many others.

The status of hydraulic power on the Orion is rather difficult to assess. It is a great deal more than a convenience, but it is backed up by so many purely manual "emergency" systems that hydraulic power is something less than a necessity. The aircraft evolved from the general philosophy that few —and preferably none—of the aircraft systems and components should be so indispensable that a single malfunction would result in an emergency situation. Thus, although the hydraulic power systems normally provide power for all the functions shown in Figure 1, those functions that qualify as indispensable to the safe completion of a mission can all be performed adequately—if not so handily—with manual power and/or pilot skill. Except for flap actuation, there is at least one, and generally more than one, alternate means by which all the important functions can be performed in the unlikely event that all hydraulic power is lost in flight. As regards flaps, landing the Orion without them is so little more difficult than a normal landing that there is little justification for an alternate means of actuation.

However, it is unlikely that a flaps-up landing will be necessitated because of hydraulic problems. The flaps, and all the functions supported by the No. 2 System, have the extra protection afforded by two separate and independent hydraulic systems powering dual hydraulic actuators. Although both systems are used normally, all these actuating systems will perform satisfactorily from either the No. 1 or No. 2 System alone. As can be seen in Figure 1, all the hydraulic functions on the aircraft are operable from the No. 1 System. This is the principal system and it is served by two pumps designated as Pumps 1 and 1A.* The No. 2 System has a single pump (Pump 2) and serves a limited number of important functions that would be impaired to some extent if *all* hydraulic power were lost in flight, thereby providing protection against the type of failure (such as the loss, contamination, or blockage of the system's oil supply) that can incapacitate *any* hydraulic system—even a two-pump system.

**The small dc motor-pump, No. 1B, is generally considered to be part of the No. 1 Hydraulic System, but its output is used solely for brake actuation, and we will discuss it in connection with the power brake system in a future issue of the Orion Service Digest.*

GENERAL DESCRIPTION Generally speaking, high pressure lines are corrosion resistant steel (Type 304, 1/8 hard), low pressure lines are 6061-T6 aluminum, and drain lines are nylon. Flareless fittings and tube connectors (MS 21900 Series) are used throughout, except that the nylon tubes are flared, and utilize the AN-800 Series fittings.

MIL-H-5606 oil is used; "O"-rings are MS 28775 and MS 28778 except for a few outsize Lockheed Standard rings for which, at present, there are no Military Standard equivalents.

Extensive use is made of teflon-lined hoses. In construction these differ from conventional rubber hoses in that the stainless steel wire braid that supports the pressure load is external and is not embedded in the hose wall. The teflon liner has no more structural strength than rubber, but the material has excellent qualities in that it does not deteriorate with age, is immune to corrosion and vibration/pulsation damage, and the exposed wire braid is easily inspected for serviceability. Teflon hoses are more vulnerable than rubber hoses in respect to abrasion and sharp bends, and therefore they should not be used as substitutes for the rubber hoses that *are* installed on the Orion.

Nearly all of the hydraulic power system components are located in the hydraulic service center, arranged as shown in Figure 2, together with most of the control and selector valves and some of the actuators for the various actuating systems. This service center is just aft of the wing, and it is a cabin pressure area, accessible through a hatch in the cabin floor in flight, and through a belly hatch from the ground. System No. 1 components are located on the left side of the service center; No. 2 components are on the right.

System oil is used to cool the electrical motors which drive the three main pumps. A part of the pump suction flow from the reservoir is diverted and forced through a cooling jacket around the stator windings of the motors, through the case of the high pressure pumps, and thence through a heat exchanger (such as the one shown in Figure 3) which is immersed in fuel inside the adjacent inboard fuel tank. Pumps 1 and 1A share a single heat exchanger in the No. 2 Tank; Pump 2 utilizes an identical assembly mounted on the floor of No. 3 Tank. The heat exchangers are the only hydraulic power system components that are not in the hydraulic service center.

POWER SYSTEM AND COMPONENT DESCRIPTIONS

RESERVOIRS The two hydraulic systems have individual reservoirs, in accordance with the design aim of having isolated and independent systems. The No. 1 system serves a large brake accumulator plus a number of linear actuators for the landing gear whose oil capacities vary according to the position of their pistons. No. 1 is much the larger of the

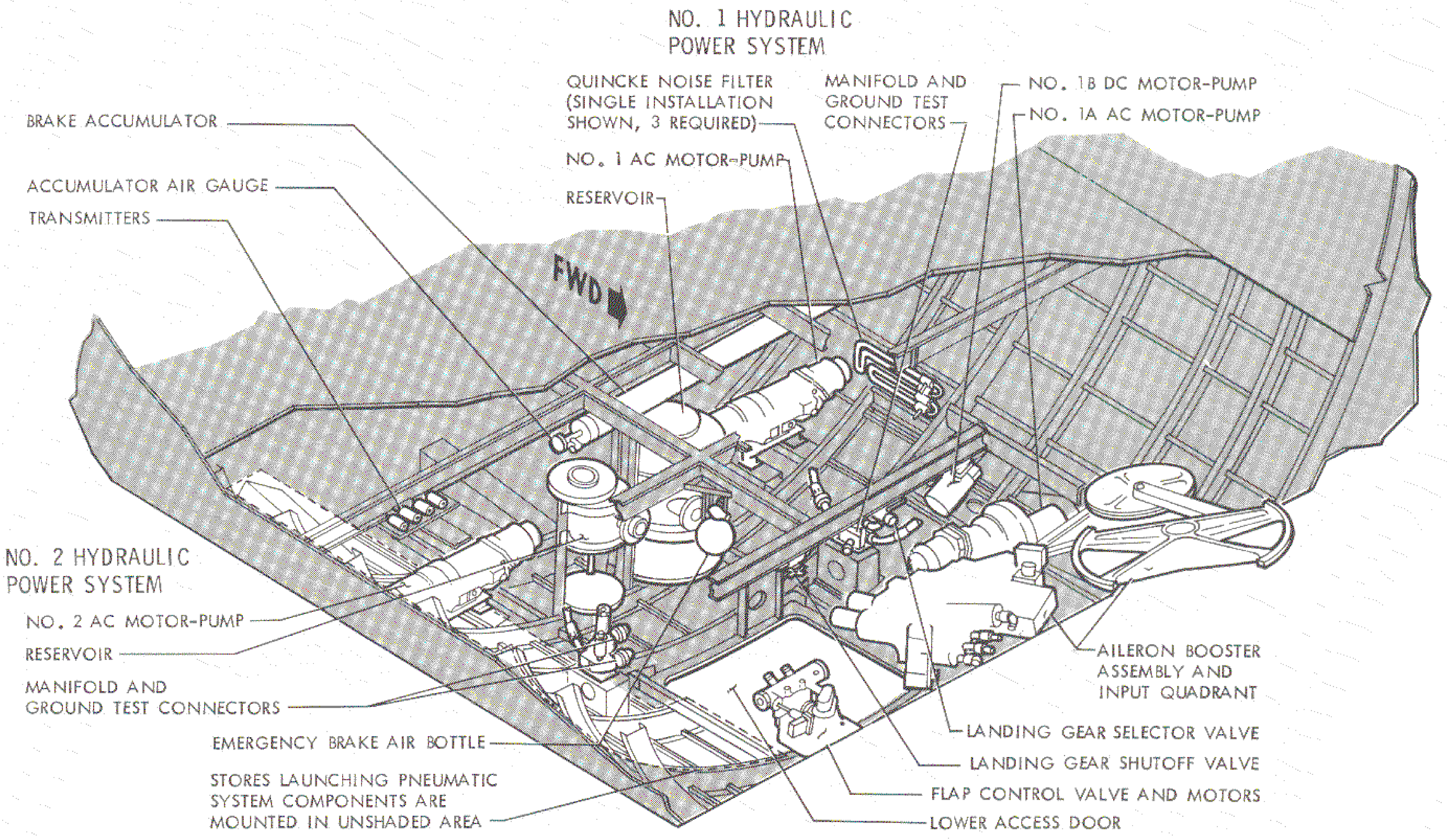


Figure 2 Hydraulic Service Center

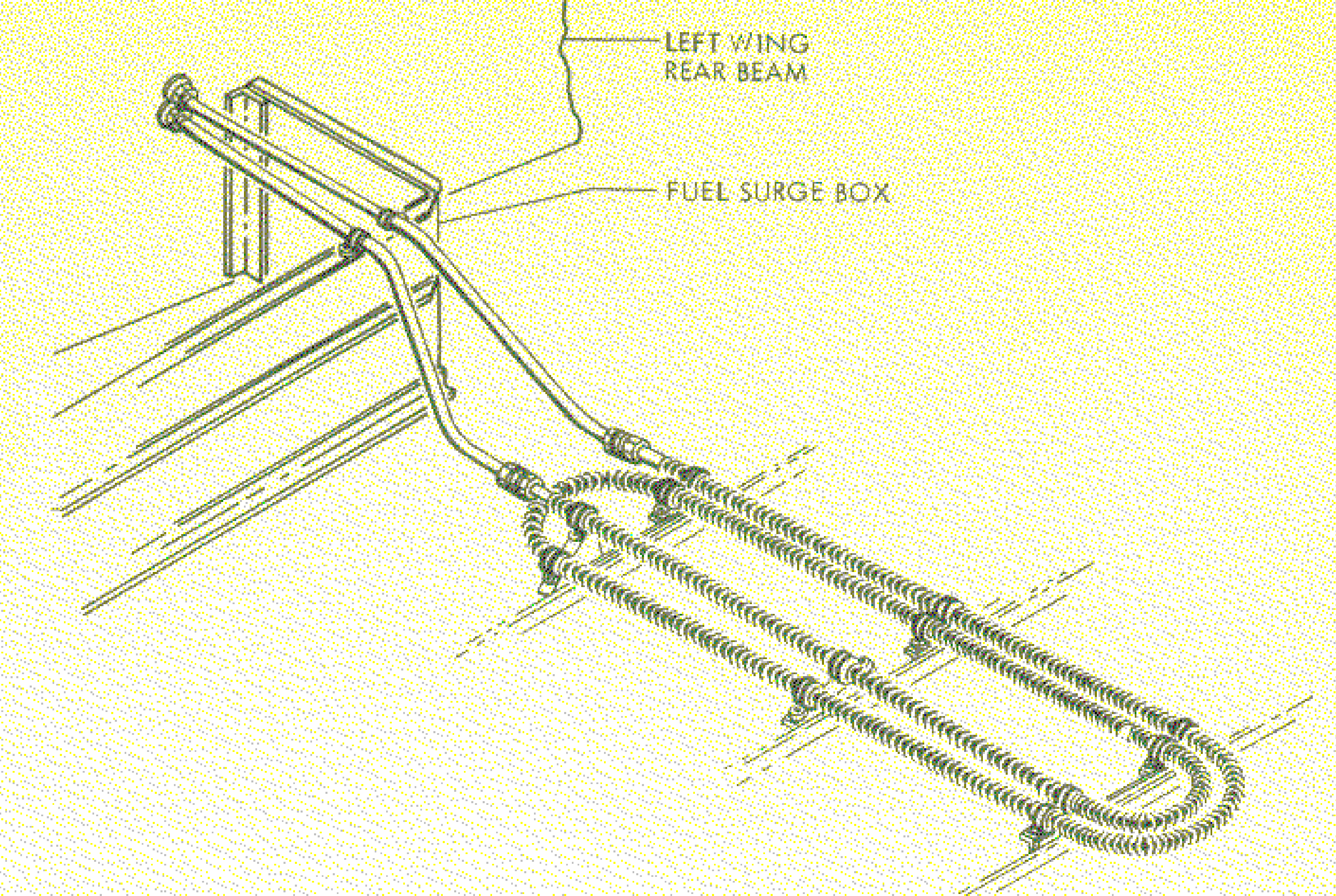


Figure 3 Number 1 System Hydraulic Oil-to-Fuel Heat Exchanger

two reservoirs to allow for these variables. It is normally serviced with the landing gear down, in which case it may contain a maximum of 5.6 U.S. Gallons with an empty brake accumulator or 5 gallons with a fully charged accumulator; the reservoir must be refilled if the level falls 0.8 gallons (to 4.8 or 4.2 gallons as applied to the above instances). No. 2 System serves only one variable capacity system — the bomb-bay doors — and the few cubic inches of oil involved is considered to be negligible. The reservoir is full at 1 gallon, and must be serviced if the level falls one quart (to ¾ gallons).

The reservoirs are of similar construction, incorporating a float type quantity indicator for direct reading and a potentiometer (whose wiper is positioned by the linkage for the direct reading gauge) that operates a remote indicator in the flight station. The latter is a dual-needle gauge, (see Figure 4) with a 0-to-5.6 gallon scale for No. 1 Reservoir and a 0-to-1 gallon scale, graduated in quarts, for No. 2 Reservoir.

Filler well assemblies, attached to the reservoir bodies by Marman clamps, incorporate a filler neck, a snap-lock cap, and a 200-mesh screen. These subassemblies are identical, despite the different sizes of the reservoirs. The filler well assemblies are removed to gain access to the internal reservoir components, and each assembly, when it is installed, loads a spring which retains a large filter seated in the pump suction port.

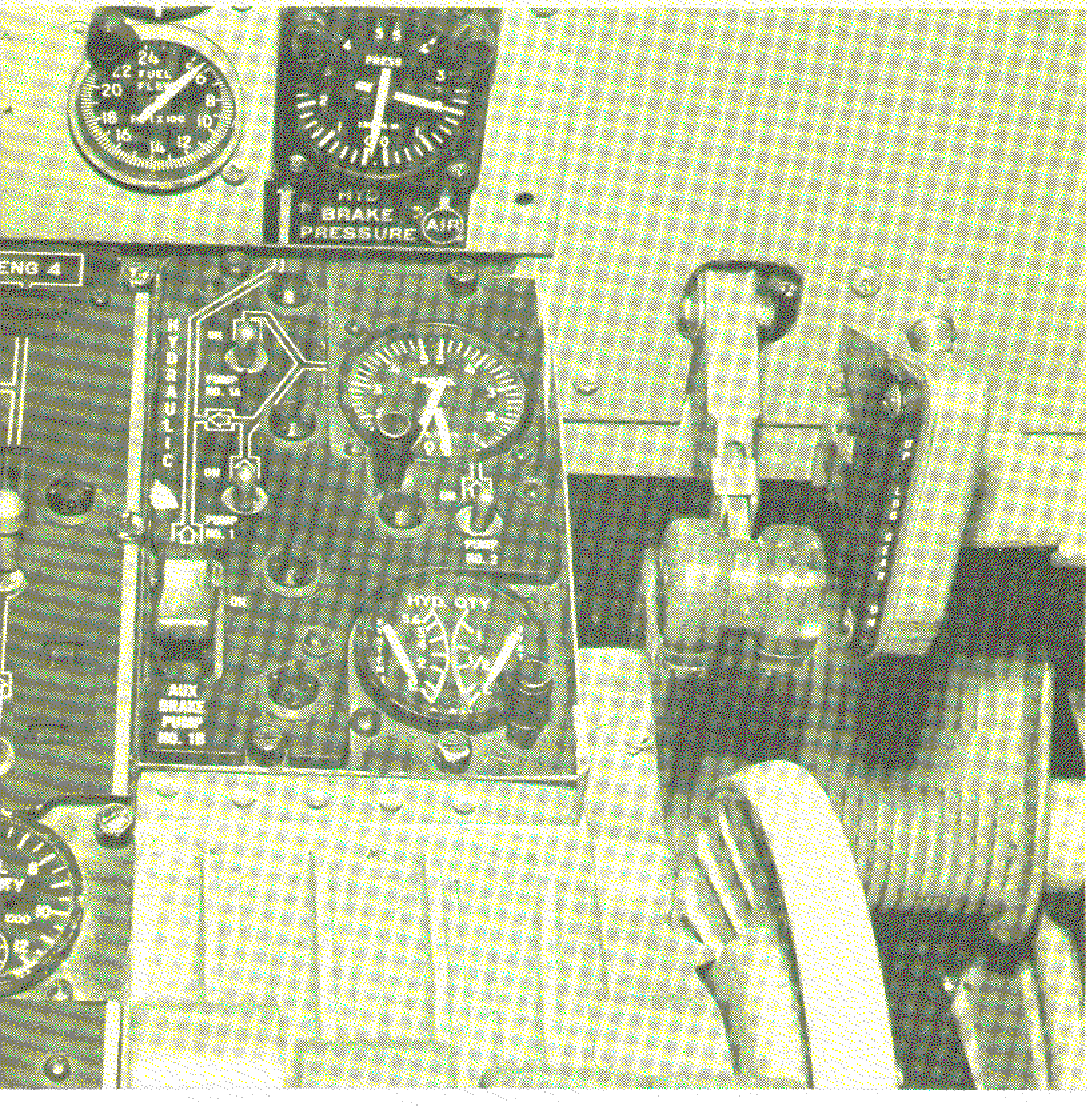


Figure 4
Hydraulic Systems Controls and Indicators

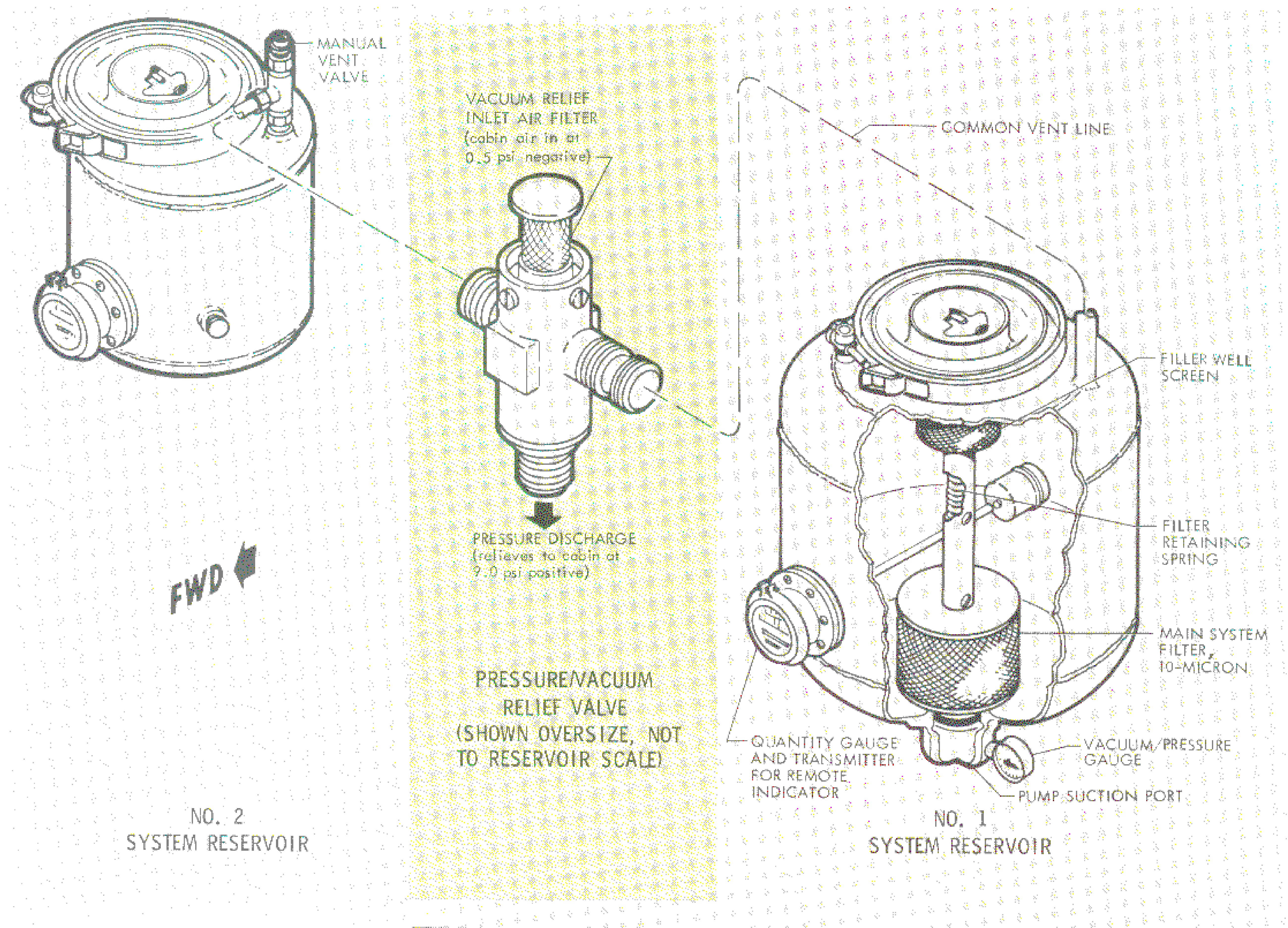


Figure 5
Reservoirs and Related Components

These cylindrical filters have walls of exceedingly-fine, intricately-woven wire screen, folded in a pattern of deep, length-wise convolutions. This "accordion pleated" arrangement provides strength and an immense filtering area. No. 1 filter is the largest, for its filtering area must accommodate two pump suction flows. This filtering media, which is used also in high pressure applications throughout the systems, is discussed in the "Hydraulic System Line Maintenance" section.

The two systems are kept completely separate insofar as the transfer of oil from one system to another is concerned, but the air spaces of the reservoirs are interconnected by their vent lines through the body of a pressure/vacuum relief valve which serves both systems. The vacuum and the pressure relief poppets both sense cabin pressure (any air entering the reservoir must pass through the screen shown in Figure 5), and they are set to ensure that reservoir pressure will never deviate more than 12 psi above or 1 psi below the existing cabin pressure.

Due to the disproportionate spread between the vacuum and pressure relief settings, the valve serves a secondary purpose. If cabin pressure becomes higher than reservoir pressure (due to changes such as thermal contraction of reservoir air, withdrawal of oil from the reservoirs by actuators, or descent to levels of higher atmospheric pressure), the comparatively weak vacuum relief poppet will readily admit air, but when the situation reverses (due to thermal expansion of reservoir air, a refund of oil from variable capacity actuators, or ascent to levels of lower atmospheric pressure) the comparatively strong pressure relief poppet will not allow a like mass of air to escape. Thus, in flight, the pressure/vacuum relief valve acts as a sort of automatic, pressure-limited air pump that promotes the delivery of oil to all system pumps. Generally, there will be some internal reservoir pressure which must be dissipated before doing any sort of maintenance work which requires opening the system, for even a small pneumatic pressure will expel a great deal of oil needlessly. A manually operated valve, located on the vent line at the No. 2 Reservoir, is provided to bleed off residual pressure.

When the pumps are not operating, reservoir pressure registers on a direct reading gauge, calibrated from plus 15 to minus 15 psi, tapped into the pump suction boss at the bottom of each reservoir. The gauge taps are downstream of the reservoir filters, and when pumps are operating the gauges indicate the pressure in the pump suction lines.

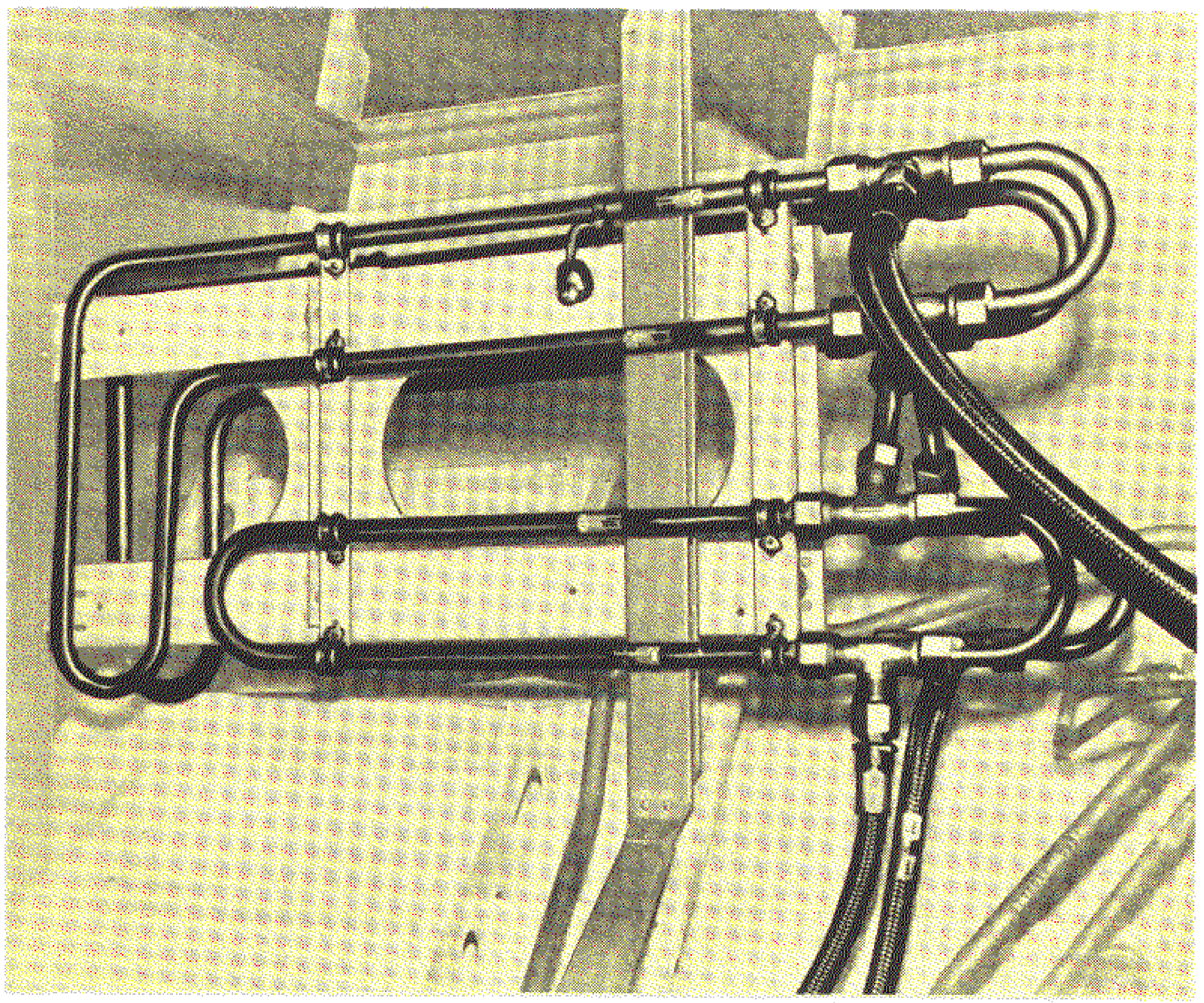


Figure 6A
Dual "Quincke"
Noise Damper Installation
for No. 1 System Pumps

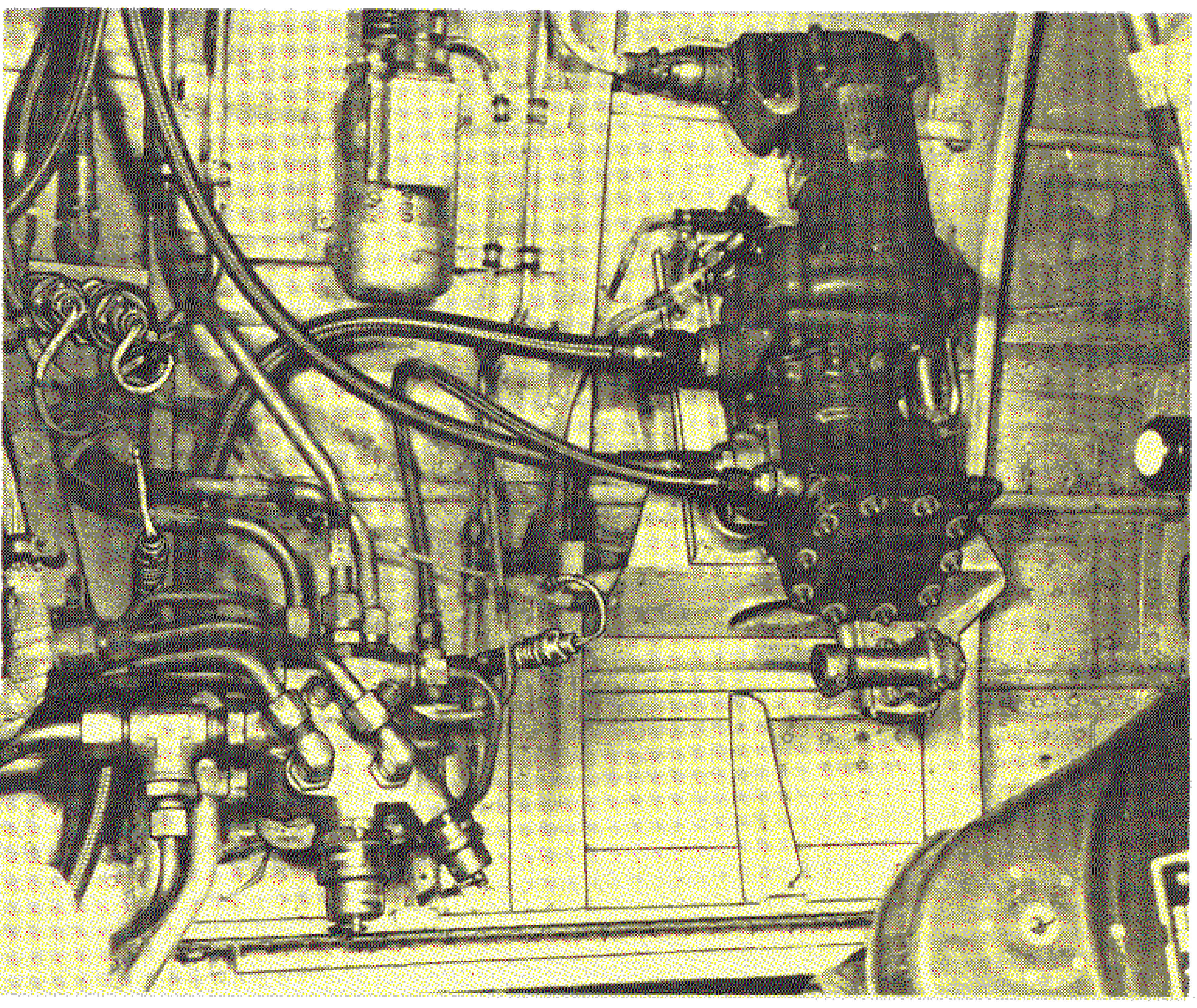


Figure 6B
View Through Cabin Access Hatch
of Number 1 System Manifold
(Service Center Assembly) and No. 1A Pump

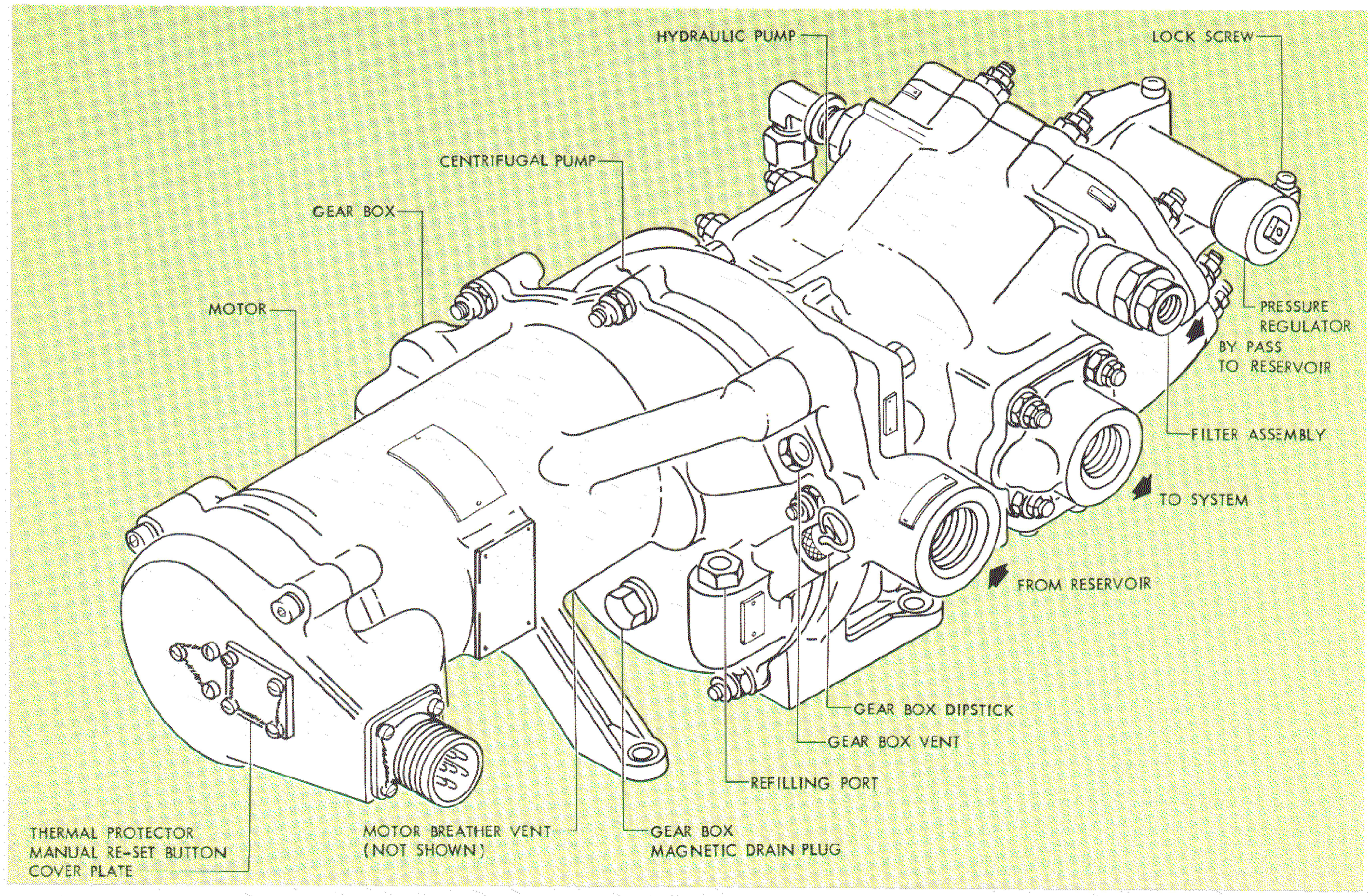


Figure 7 AC Motor-Pump

MANIFOLD ASSEMBLIES A few inches below its reservoir, the No. 1 suction line is divided by means of a special "wye" fitting into two large-diameter supply lines for the Nos. 1 and 1A pumps. A branch off the 1A Pump suction line is connected to a manifold (also known as a service center assembly) mounted at the left side of the belly access hatch. The manifold provides a source of supply for the small dc motor pump (No. 1B) and a quick-disconnect for hydraulic gig suction. There is a similar assembly at the other side of the hatch for the No. 2 System, but this is a much smaller unit, serving only the No. 2 hydraulic system gig connectors and the hydraulic power output of the No. 2 Pump.

These manifold assemblies, shown in Figure 6, were designed for the Electra system to reduce the complexity of plumbing, and to house power system accessories in a single assembly, easily detached for overhaul and bench testing. Many of the elements necessary to channel, filter, and monitor oil flows to and from multiple pumps operating in parallel are contained in the manifolds, and there are plug-in ports for others. The original design concept is somewhat diluted on the Orion, for with the addition of an access hatch in the cabin floor (there was no such hatch on the Electra), the manifolds, especially the No. 1 System manifold, made all too convenient steps, and it was necessary to move some of the more fragile protuberances to safer locations. The assemblies themselves were not moved, for at no other location would they provide such strong and ideally accessible attachments for separate hydraulic gig connections for the two systems.

In the following pages, the discourse follows along the power system flows from pump-suction to return, and we will encounter and further discuss the components of these manifolds together with other power system components in the order of flow.

ELECTRICALLY-DRIVEN PUMPS The main pump suction lines are ¾-inch hoses which bypass the manifolds and discharge into the center of a centrifugal pump scroll located between the main (high pressure) pump case and the motor reduction gear box of each pump assembly (see Figure 7). The scroll houses a centrifugal type booster pump mounted directly on the main pump shaft. The constant speed motor turns the pump shaft through

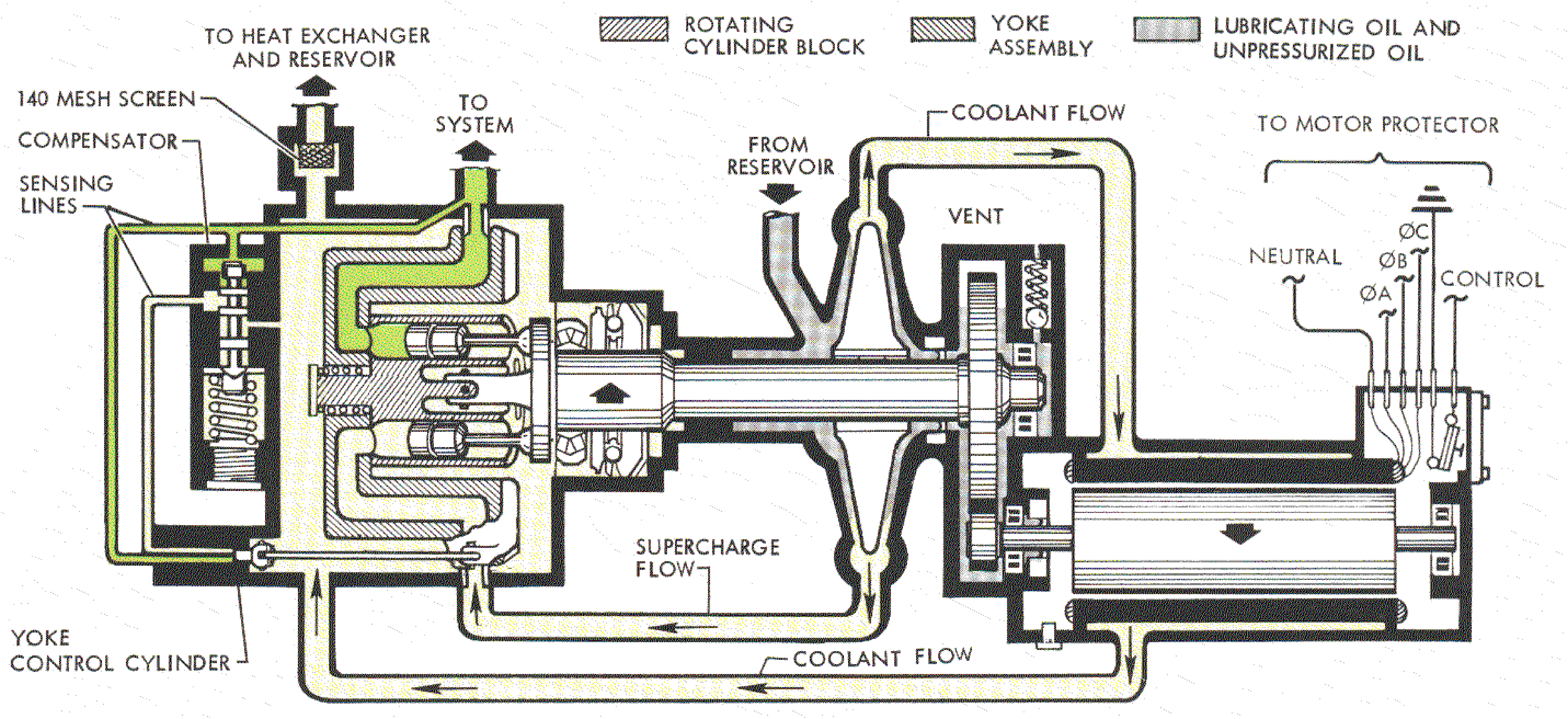


Figure 8 Motor-Pump Schematic

reduction gears at 3200 rpm, which is sufficient to boost the oil pressure about 15 to 20 psi above the existing reservoir pressure. The output of this integral pump is taken from two taps (see Figure 8) on opposite sides of the scroll housing.

One tap provides a constant flow of oil for motor cooling (about 2 gpm) through an internal passage. Baffles direct this flow through the hollow-walled motor case, after which it is shunted via an external line into the case of the high pressure pump. This constant flow through the low pressure chamber of the main pump cools and lubricates all its moving parts, picks up whatever "blow-by" oil escapes past the high pressure pump pistons, and is discharged through a coarse-screen filter cartridge installed in the case drain port. Since most motor-pump troubles generate heat, the coolant flow temperature at this point is a measure of the motor-pump's condition. A thermal switch, installed just down-stream of each pump, is set to close and illuminate an "OIL HOT" light, identified with the pump number, on the flight station center instrument panel if temperature reaches 177 (plus or minus 5) degrees F.

Pumps 1 and 1A coolant flows are combined (after passing through check valves in the No. 1 System manifold that prevent back-flow through an inactive pump) and the combined flow is routed through the heat exchanger in No. 2 Fuel Tank back to No. 1 Reservoir. The No. 2 System has only one coolant flow, of course, and it is routed directly from the pump to the heat exchanger in the No. 3 Fuel Tank and back to No. 2 Reservoir.

The second tap off the centrifugal pump scroll provides oil at positive pressure at the intake of the high pressure pump.

As can be seen in the Figure 8 schematic, the Vickers motor-driven variable displacement design is similar to their engine-driven designs. The rotating assembly consists of a base plate, to which nine piston rods are jointed, that turns in a fixed plane, carrying with it a cylindrical, 9-piston block fitted inside a non-rotating yoke. The yoke is pivot-mounted to the pump case and has an offset (crank) attachment for a compensator piston rod that controls the yoke's attitude. If the yoke is not deflected, the cylindrical block containing the pistons will rotate in a plane parallel to the base plate, thus producing no stroke, or the yoke can be tilted to displace the pistons, reaching maximum stroke when the yoke is tilted 30° from the plane of rotation of the base plate.

The pump compensating mechanism receives a feed-back signal of system pressure and adjusts the pump output by tilting the yoke more or less to provide more or less flow. Whereas engine driven pumps are generally rated to produce a given pressure and flow at a nominal drive speed, the Orion motor-driven pumps have a fixed rotational speed and a special compensating mechanism that enables the pump to provide 6 gpm at 2950-to-3000 psi, or to provide more flow as system pressure drops, reaching a maximum flow of 8 gpm at 2200 psi. This is known as "constant horsepower" compensation. As the name implies, it maintains an essentially constant load on the drive motor during high

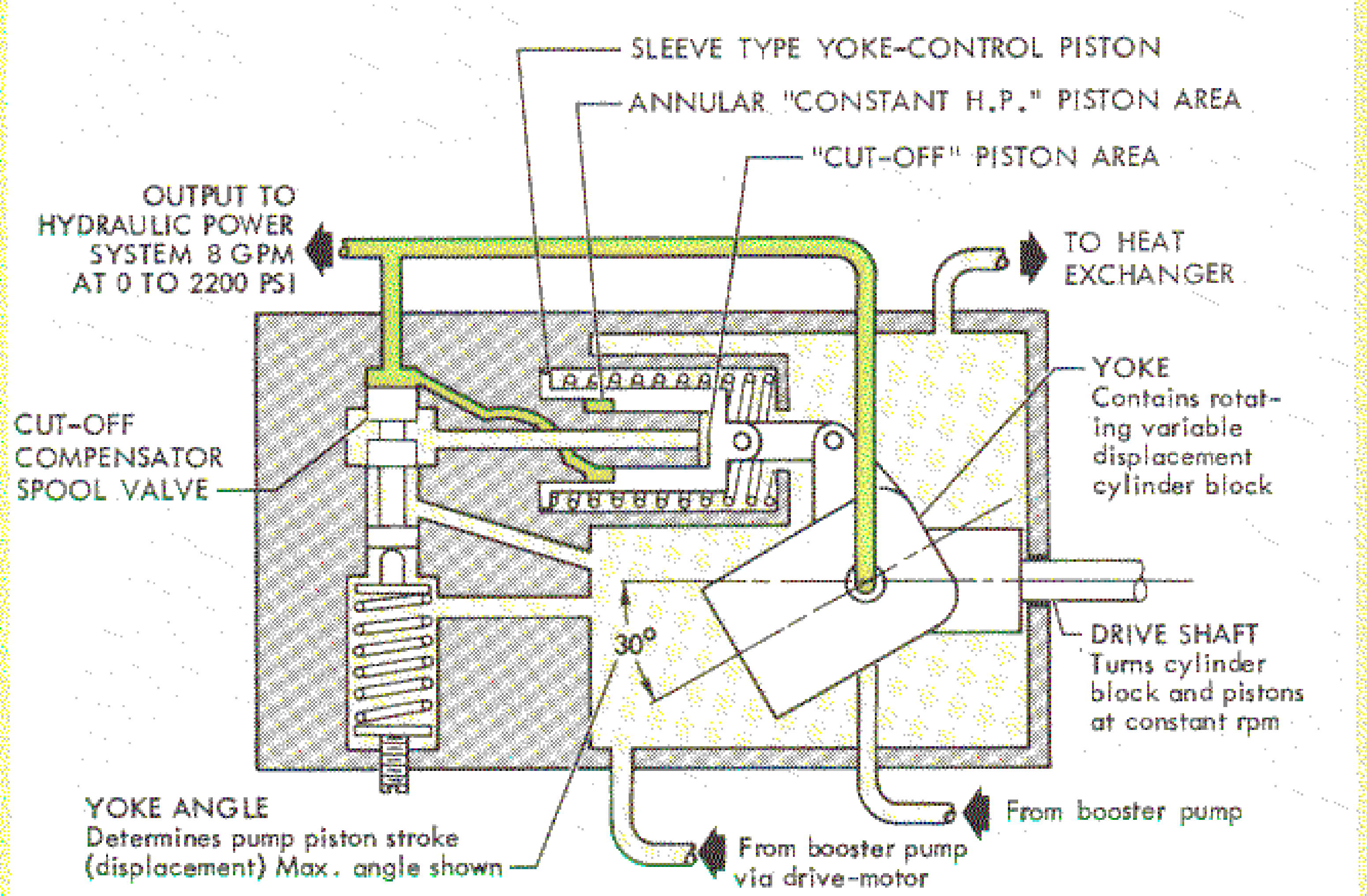


Figure 9A Compensation, Full Flow Position

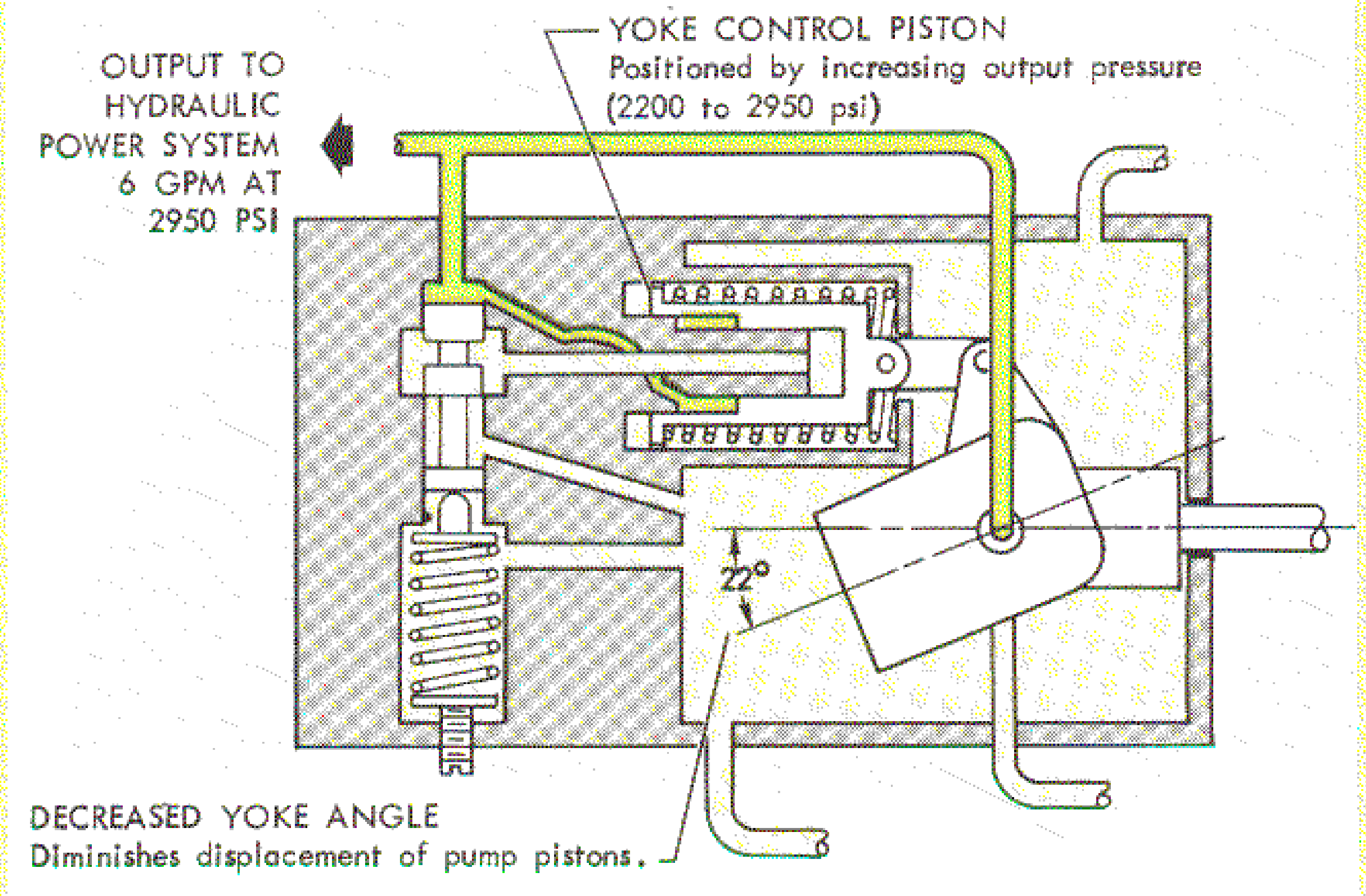


Figure 9B—Compensation, Reduced Flow Position

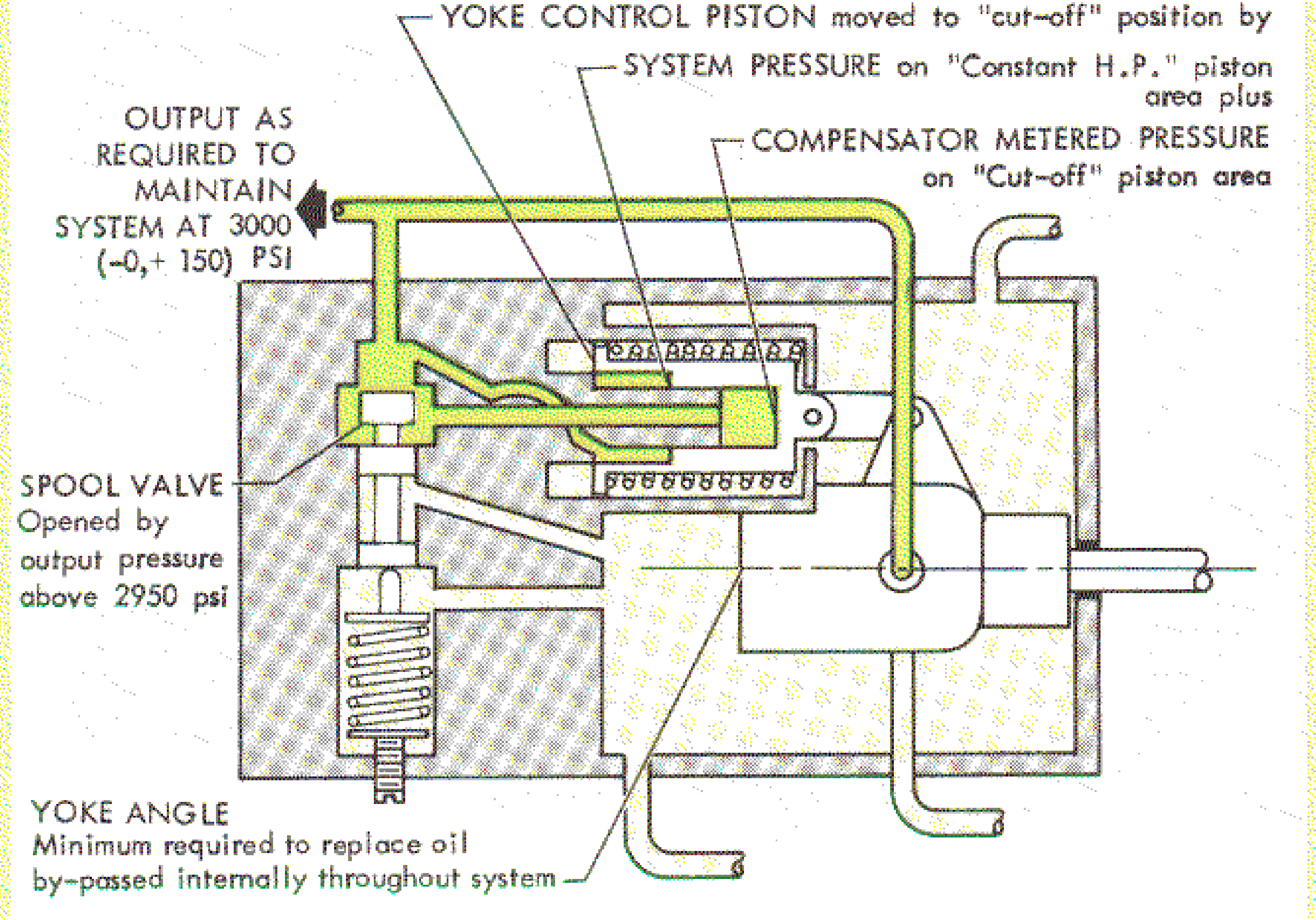


Figure 9C Compensation, Minimum Flow Position

demand periods while the pump is providing accelerated flow. The accelerated flow enables the system to maintain normal speed of many actuators in use simultaneously, even though their combined demand exceeds 6 gpm per pump. (This assumes, of course, that the actuators are working against normal loads so that none of them "stall" due to the slightly reduced system pressure.)

Figures 9a, 9b, and 9c show the three phases of pump compensation in a pressure-buildup order, starting at low pressure and increasing to full system pressure. This is the sequence of events that will occur in practice if a No. 1 System pump is energized with the brake accumulator empty.

A. As shown in Figure 9a, the yoke control piston is spring loaded to hold the displacement yoke at its maximum displacement angle of 30°. This spring is opposed by the existing system pressure, which acts at all times on the "constant horsepower" piston area, but the hydraulic force will not be sufficient to move the yoke control piston until the actuating pressure (system pressure) builds up to 2200 psi. Thus the cylinder block will be canted to its maximum angle, and the pump will deliver its maximum flow, 8 gpm, when system pressure is less than 2200 psi.

B. As shown in Figure 9b, the yoke control piston *will* respond to system pressure fluctuations in the 2200 to 2950 psi range. Assuming that system pressure is steadily increasing as the accumulator fills, the displacement yoke angle will decrease from the 30° full displacement angle, which produces an 8-gpm flow at 2200 psi, to approximately 22° which will produce 6 gpm at 2950 (plus 50, minus 0) psi.

C. As shown in Figure 9c, the spring load on the compensator spool will be overcome by system pressure in excess of 2950 psi, and the displaced spool will meter pressure to the "cutoff" area of the yoke control piston. This pressure will act in tandem with the "constant hp" force on the piston, and with increasing pressure the piston will move rapidly from the 22° displacement angle at 2950 psi to approximately 0° at 3000 (plus 150, minus 0) psi.

Thus when full system pressure exists, the hydraulic power output will be the minimum required to replace oil leaked internally and the consumption of electrical power is reduced.

QUINCKE NOISE-DAMPING ASSEMBLIES From the pump high-pressure port, flow is directed through a noise damping network of tubes which breaks up the pressure impulses (see Figure 6A). The use of this simple type of damper—named for its originator, Quincke—is made possible by the constant speed feature of the pumps which produces a pressure "ripple" whose wave frequency is constant, (as opposed to the wide band of frequencies "broadcast" by variable speed engine-driven pumps) and has a predictable amplitude. The branch tubes of this network are carefully dimensioned, shaped, and arranged to divide the steady incoming waves into fractional pulses which tend to cancel one another when they meet at the downstream tube junctions. Thus the pump ripple is made to baffle itself, and little noise "telegraphs" out through the pressure line branches to the various actuators.

Pump pressure is routed from the Quincke assembly to the associated service center manifold. A low pressure warning switch tapped into this line will close when output pressure falls to about 2000 psi, and illuminate a "HYD PRESS" light, identified with the pump designation, in the flight station. The circuit for each light is routed through one pole of the pertinent pump control switch, so the light functions only when the switch is selected "ON."

HIGH-PRESSURE FILTERS In the system manifold, high pressure input passes first through a check valve and then through a high pressure filter for each pump. When a hydraulic gig is attached to either system manifold, pressure input enters at a point between the check valve and filter (the No. 1A Pump filter is used in the No. 1 System manifold), and a relief valve for each of the three pumps is also tapped in at this point.

The filter elements are rated 10-micron nominal, and are of the same convoluted screen design as the reservoir filters, but are much smaller and stronger.

All relief valves on the Orion are identical and interchangeable, including the one that protects the small-capacity 1B pump system. They are of the in-line cartridge type. Their outlet ports are plumbed directly to return, and they are adjusted to crack at 3450 psi, reseat at 3200 psi, and are capable of passing 8 gpm at less than 3450 psi.

PRESSURE GAUGES System pressures register in the flight station on separate halves of a dual remote gauge (see Figures 4 and 10) operated by separate transmitters mounted at the top of the service center. Pressure sensing lines for the transmitters are tapped into the system main lines just downstream of the system manifolds.

These remote indicator circuits—and the synchro type circuits of other aircraft instruments that register increments of pressure or position—utilize 400 cycle power derived from the Monitorable Essential AC Bus, stepped down through two transformers to the two 26-volt AC Instrument Buses located in the flight station. The Systems 1 and 2 remote pressure indicator circuits are powered by the No. 1 and No. 2 Instrument buses, respectively. Although the hydraulic pressure indicators show *system* pressure, the performance of a specific No. 1 System pump can readily be determined by deactivating its companion pump.

MAIN MOTOR-PUMP ELECTRICAL POWER AND CONTROL

Except for bus support, the power and control circuits of the three ac pump motors are identical. Pumps 1A and 2 are powered by Main AC Bus B; No. 1 Pump from Main AC Bus A. This division of power sources for the principal hydraulic system (No. 1) ensures that all actuators will continue to receive hydraulic power in the event that one of the main buses is de-energized. However, this may entail some reduction in system capacity and slower actuator response during peak loads, especially if Bus B is de-energized, deactivating the No. 2 Pump in addition to the No. 1A Pump.

Pump control power is also divided between two buses—Nos. 1 and 2 Control circuit breakers are on the Extension Main DC Bus; No. 1A on the Monitorable Essential DC Bus—ensuring that an electrical malfunction that disables one, or even two, transformer-rectifiers will not result in loss of hydraulic power due to loss of control at the pump relay.

The relay panels in the main electrical service center mount a power relay together with a component known as a motor protector for each of the ac motor pumps. Turning "ON" a pump control switch energizes a series circuit that can be traced (in Figure 10) through the relay solenoid, one pole of a 2-pole RESET switch in the motor protector, the contacts of a latching relay (also in the motor protector), and thence to ground through a thermal switch inside the pump motor housing.

The thermal switch can also be manually reset. If the pump motor case over-heats to about 380° F, the thermal switch opens the control circuit, thereby opening the power circuit at the pump relay. A thermal trip could be due to a simple hydraulic problem easily found and repaired — even in flight, perhaps — in which case the thermal switch may be reset after removing a small access plate on the end of the motor. The motor must cool to 200° F

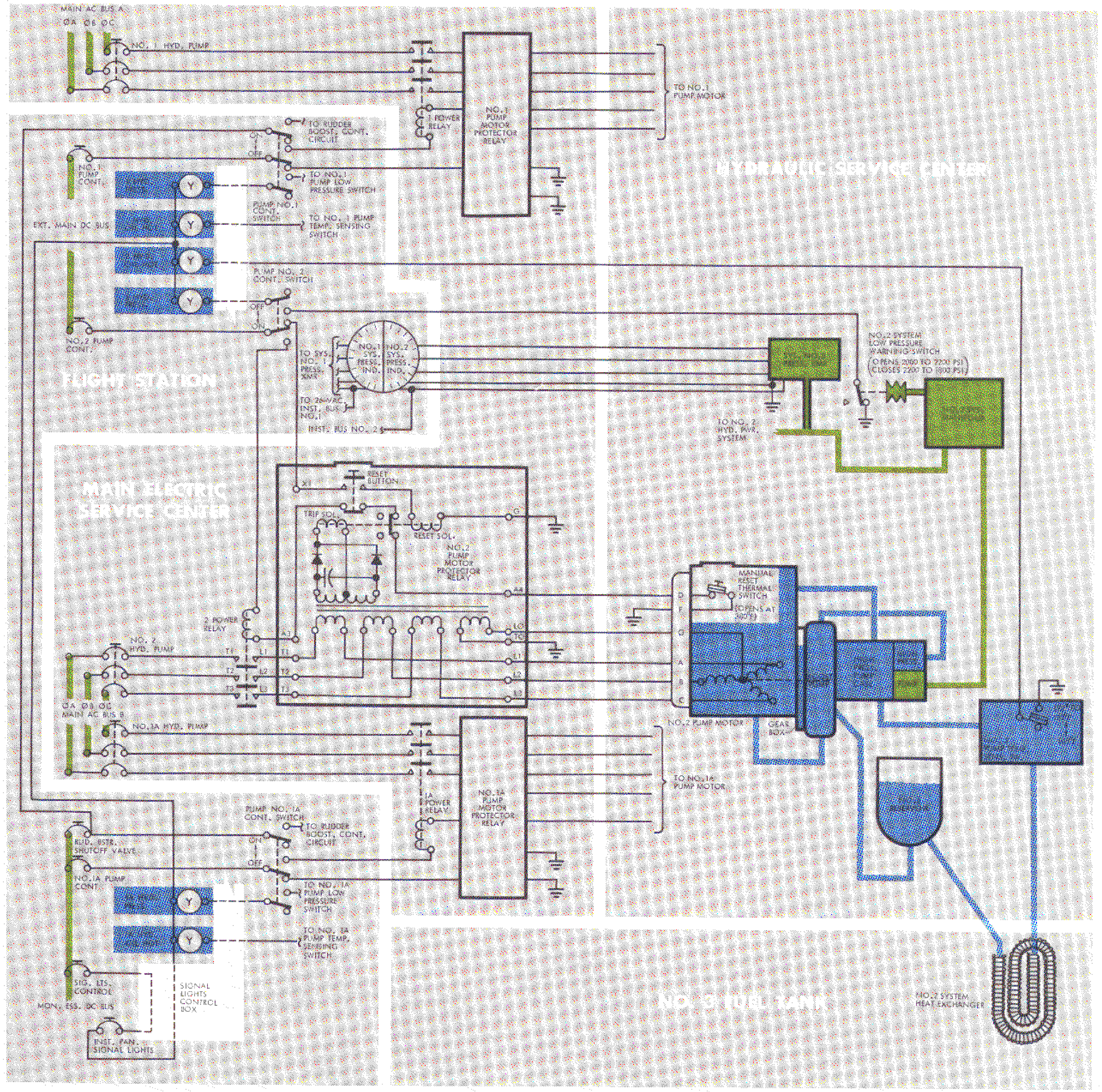
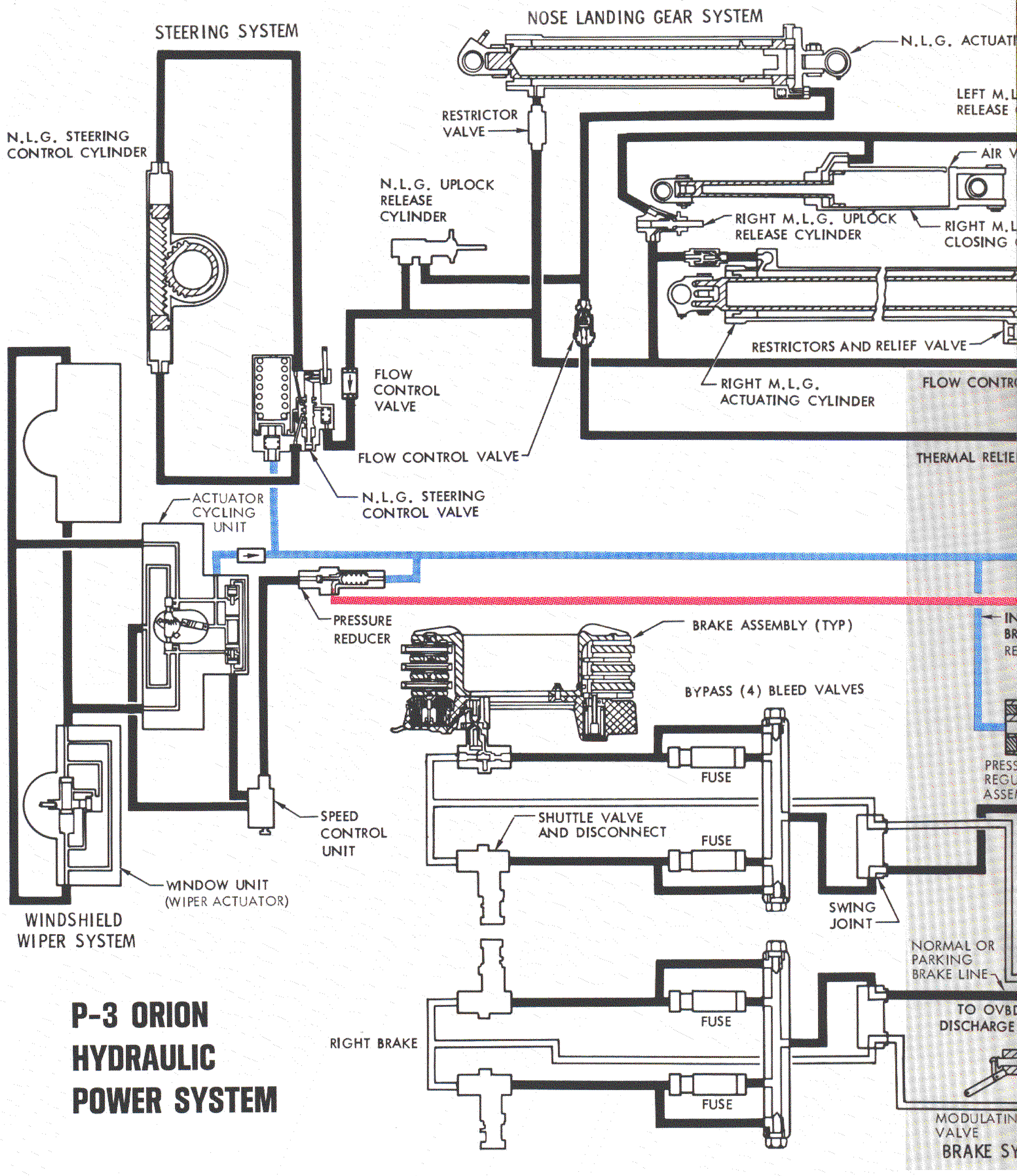


Figure 10
Hydraulic Systems
Control and Power
Schematic

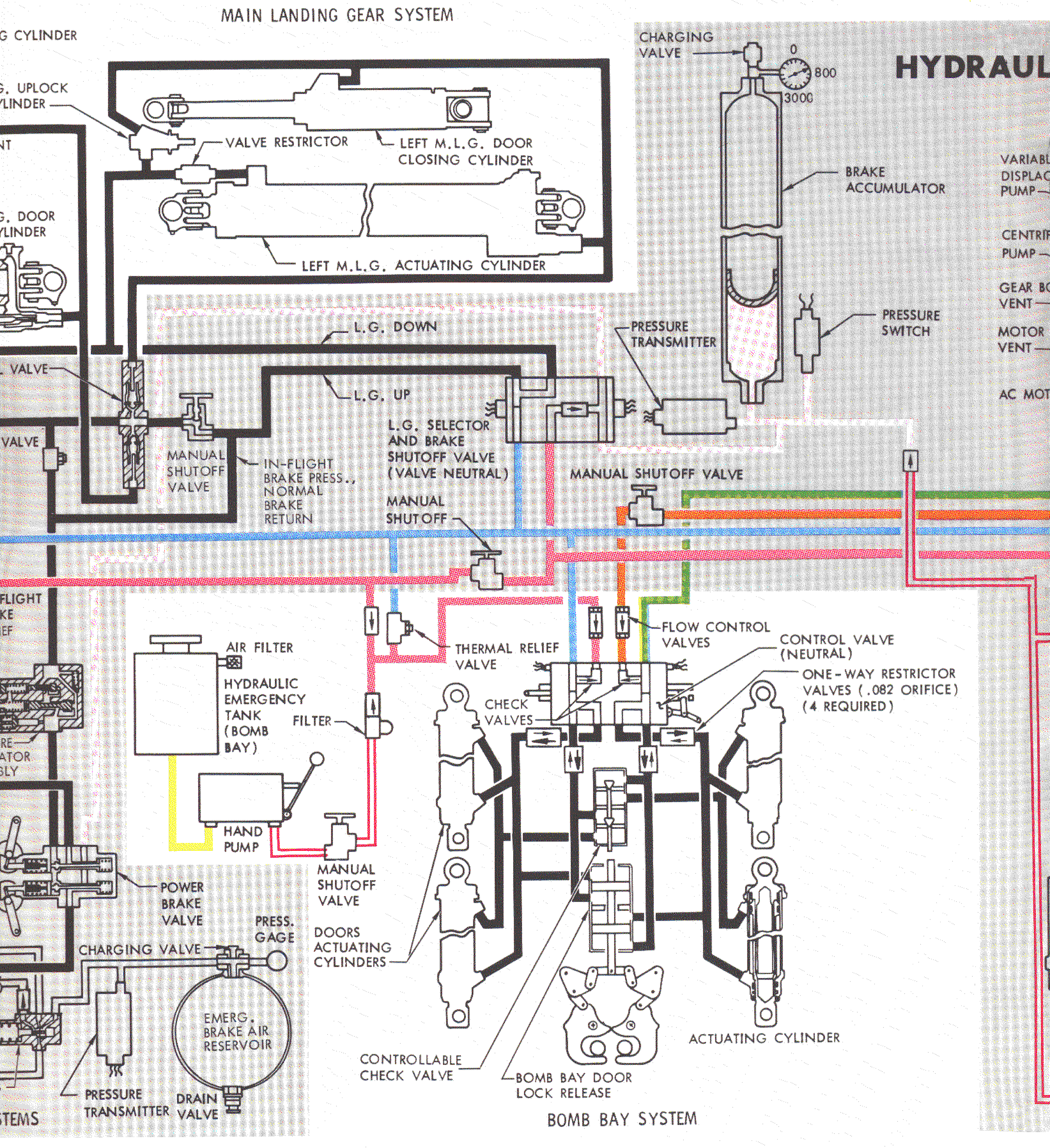
before the switch can be reset, and we recommend that the switch not be reset a second time if it trips again.

The motor protector's function is to open the control circuit at the latching relay if certain faults occur in the motor itself, or between the motor protector and the motor. The three phases of power input *to* the pump motor and the ground lead *from* the motor are routed through separate primary windings of a transformer in the motor protector. If a fault, either phase-to-ground or phase-to-phase, is sensed, ac current is generated in the secondary winding of the transformer. This current is rectified and impressed on the "trip" solenoid of the latching relay, which opens the circuit (and it is mechanically latched open) when the error signal reaches a predetermined intensity. Note that the protector is designed to care for phase-to-phase or phase-to-ground faults in the motor or in the ac circuits between the protector and the motor — it does not protect against single-phase open circuits. Faults between the generating source and the motor protector are cared for by the generator control and bus-transfer circuitry, circuit breakers, or ground power protective circuits.

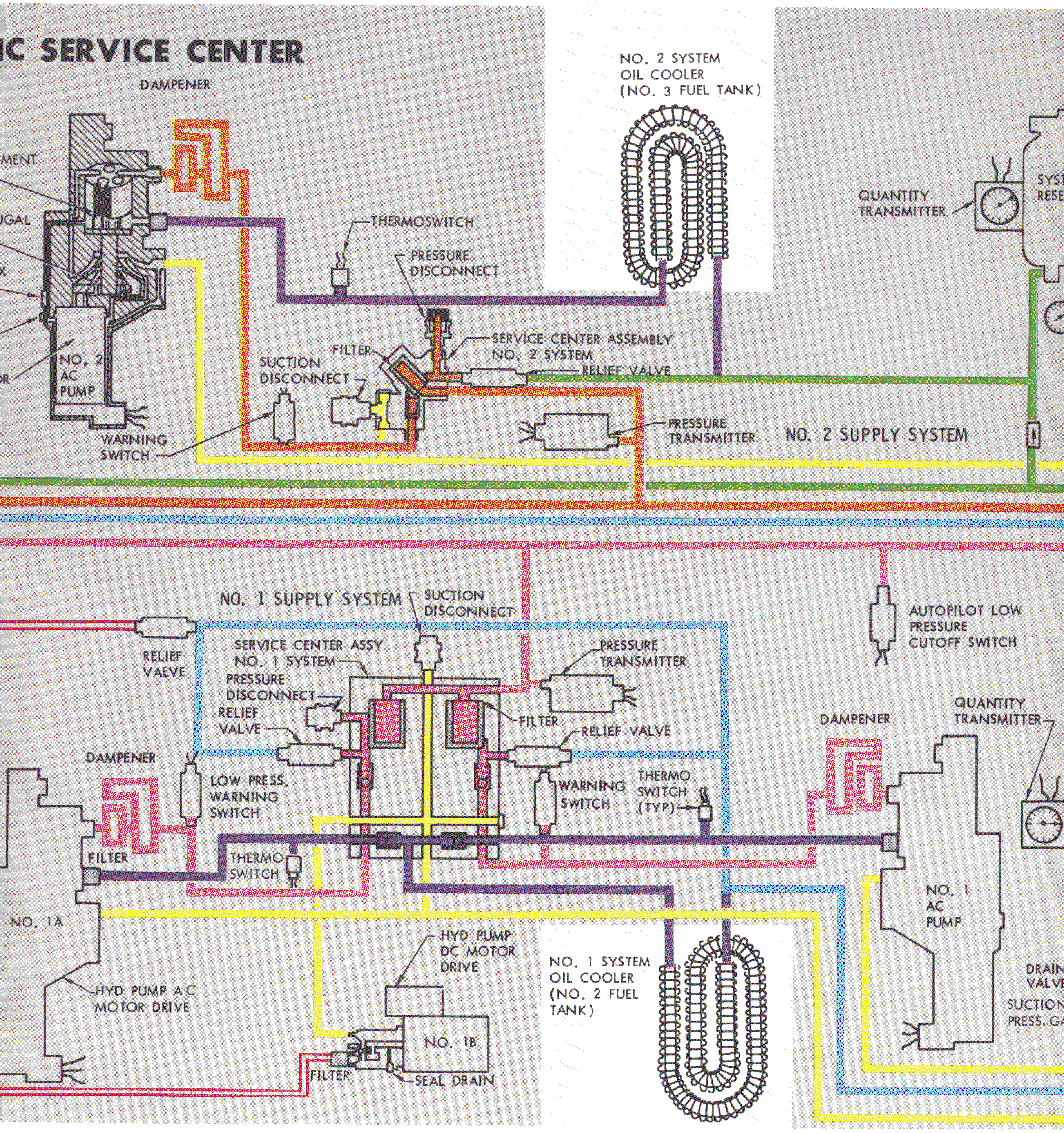
After a trip has occurred and the fault that caused it has been corrected, it is necessary to carry out a simple resetting procedure to restore motor pump operation. The pump control switch must first be turned "OFF". This energizes a contact of the reset button at the motor protector. The reset button — which is reached by removing the terminal cover from the motor protector — is then momentarily depressed, energizing a circuit through the "reset" solenoid of the latching relay, restoring the control circuit to operability.

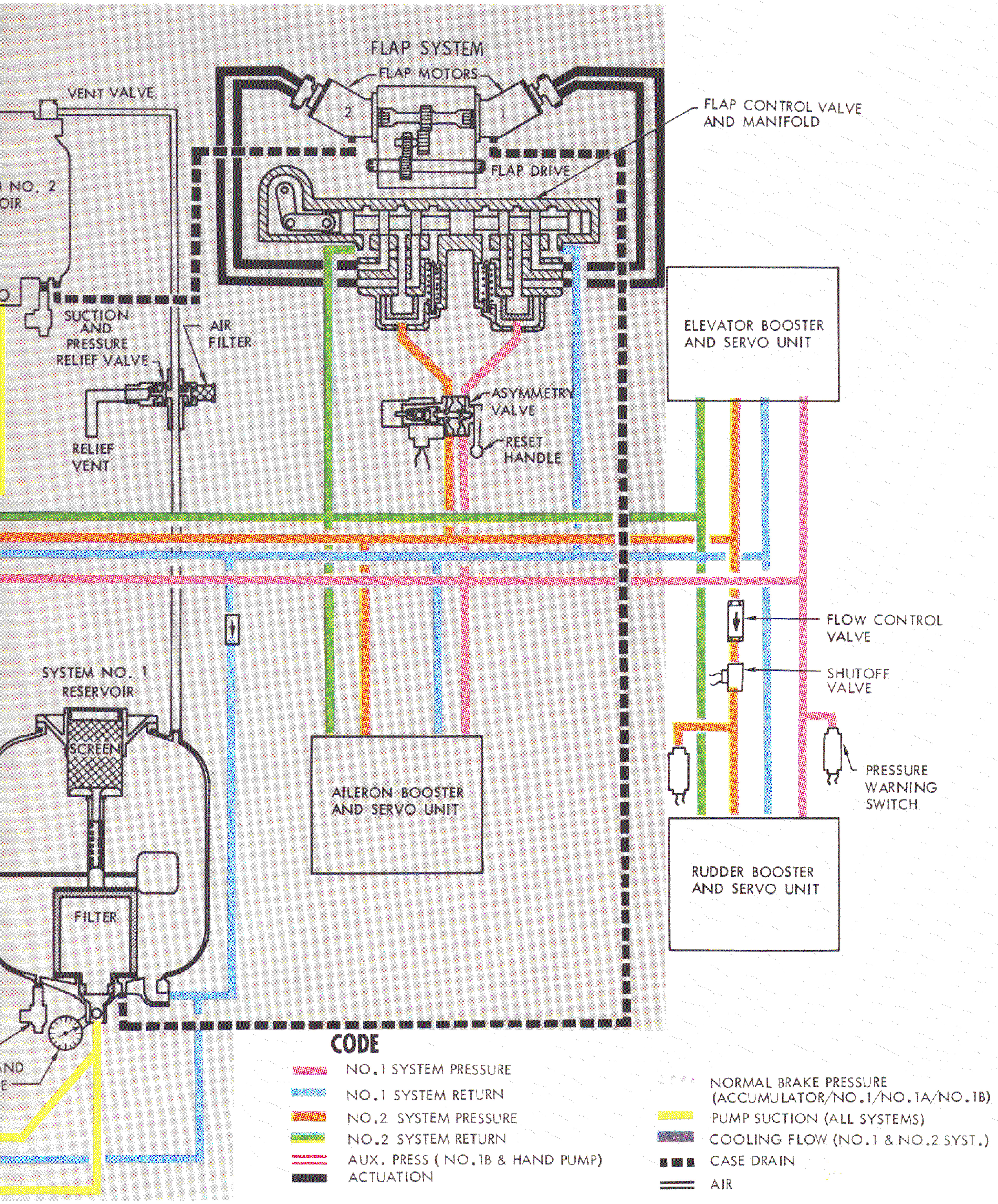


P-3 ORION HYDRAULIC POWER SYSTEM


MAIN LANDING GEAR SYSTEM
HYDRAUL
G CYLINDER
G. UPLOCK
YLINDER
NT
G. DOOR
YLINDER
VALVE RESTRICTOR
LEFT M.L.G. DOOR
CLOSING CYLINDER
LEFT M.L.G. ACTUATING CYLINDER
CHARGING
VALVE
0
800
3000
BRAKE
ACCUMULATOR
PRESSURE
SWITCH
PRESSURE
TRANSMITTER
VARIABL
DISPLAC
PUMP
CENTRIF
PUMP
GEAR BO
VENT
MOTOR
VENT
AC MOT
L.G. DOWN
L.G. UP
VALVE
VALVE
MANUAL
SHUTOFF
VALVE
IN-FLIGHT
BRAKE PRESS.,
NORMAL
BRAKE
RETURN
L.G. SELECTOR
AND BRAKE
SHUTOFF VALVE
(VALVE NEUTRAL)
MANUAL
SHUTOFF
MANUAL SHUTOFF VALVE
FLIGHT
KE
EF
AIR FILTER
HYDRAULIC
EMERGENCY
TANK
(BOMB
BAY)
FILTER
THERMAL RELIEF
VALVE
FLOW CONTROL
VALVES
CONTROL VALVE
(NEUTRAL)
ONE-WAY RESTRICTOR
VALVES (.082 ORIFICE)
(4 REQUIRED)
CHECK
VALVES
RE
ATOR
BLY
HAND
PUMP
MANUAL
SHUTOFF
VALVE
POWER
BRAKE
VALVE
PRESS.
GAGE
CHARGING VALVE
DOORS
ACTUATING
CYLINDERS
EMERG.
BRAKE AIR
RESERVOIR
ACTUATING CYLINDER
CONTROLLABLE
CHECK VALVE
BOMB BAY DOOR
LOCK RELEASE
PRESSURE
TRANSMITTER
DRAIN
VALVE
STEMS
BOMB BAY SYSTEM

IC SERVICE CENTER




FLAP SYSTEM
FLAP MOTORS
2
1
VENT VALVE
FLAP CONTROL VALVE AND MANIFOLD
NO. 2
OIR
FLAP DRIVE
SUCTION AND PRESSURE RELIEF VALVE
AIR FILTER
ELEVATOR BOOSTER AND SERVO UNIT
ASYMMETRY VALVE
RESET HANDLE
RELIEF VENT
FLOW CONTROL VALVE
SHUTOFF VALVE
SYSTEM NO. 1 RESERVOIR
SCREEN
AILERON BOOSTER AND SERVO UNIT
PRESSURE WARNING SWITCH
RUDDER BOOSTER AND SERVO UNIT
FILTER
ND
E
CODE
NO.1 SYSTEM PRESSURE
NO.1 SYSTEM RETURN
NO.2 SYSTEM PRESSURE
NO.2 SYSTEM RETURN
AUX. PRESS (NO.1B & HAND PUMP)
ACTUATION
NORMAL BRAKE PRESSURE (ACCUMULATOR/NO.1/NO.1A/NO.1B)
PUMP SUCTION (ALL SYSTEMS)
COOLING FLOW (NO.1 & NO.2 SYST.)
CASE DRAIN
AIR

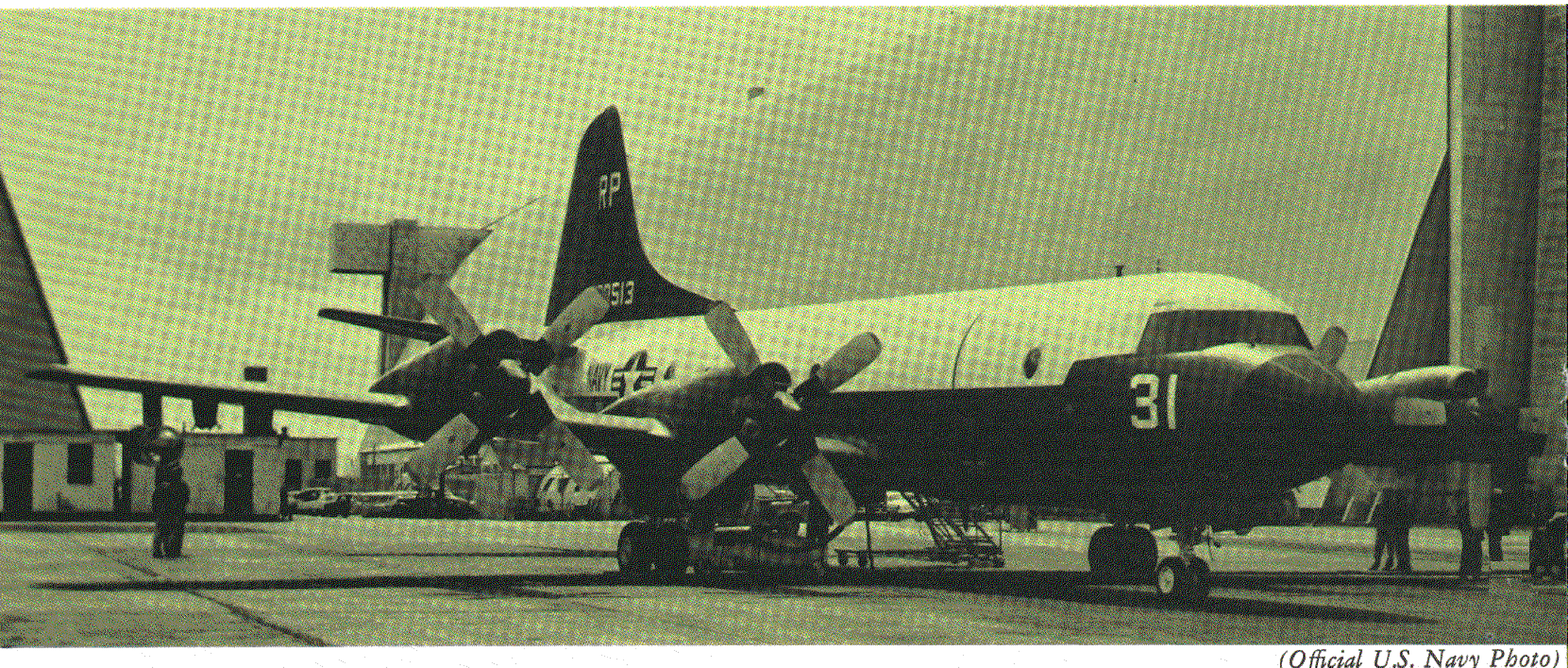
When the Orion was first introduced into service, the failure rate of the pump motors was disproportionately high in comparison to the failure rate of pump motors on the Electra transport, even though the motor pumps and the hydraulic systems they serve are nearly identical. It is fairly certain that the chief reason for this was that the electrical power carts in use at some Naval facilities at that time were not able to supply the relatively high amperage requirements of the Orion, and when the amperage of a power supply generator is overdrawn, voltage through the motor protector drops uniformly in all three phases. The motor protector is designed primarily for use with the aircraft generation systems. These are self-controlled systems that will automatically reject a generator that produces under— or over— voltage. Power from the external receptacle will be rejected by the aircraft system *only* if its phase sequence is incorrect, for there is no under/over voltage protection in the P-3 ground power circuit. Tests show that a pump motor of this type can be ruined in a few seconds if input voltage drops when the pump is activated. We urge, therefore, that only ground power carts such as the NC-12 or 12A be used with the Orion. These ground power units have sufficient capacity to carry the maximum bus load without voltage loss, and on the NC-12A, the voltage and frequency of power delivered to the aircraft bus is constantly monitored by a "protective package" which will promptly disconnect the power unit from the aircraft buses if a dangerous frequency or voltage develops, just as the aircraft generation systems do when the engines are running.

HYDRAULIC SYSTEM LINE MAINTENANCE

Squadrons phasing out Neptunes and phasing in Orions will find some shift in emphasis and technique in regard to hydraulic maintenance, stemming from three principal differences in hydraulic system design. These are: the use of liquid-cooled motor pumps, the use of filters without by-pass provisions, and the flareless (MS) plumbing fittings.

GROUND OPERATION OF SYSTEM PUMPS In line maintenance, there is no need to make ground-check engine runs, and comparatively little need for hydraulic gigs, because the liquid-cooled motor pumps allow completely representative operational checks to be made very conveniently, utilizing external electrical power. However, statistics (compiled by our Statistical Group from field service reports) show that the pump service life in terms of flying hours has not been as good in Orion experience as it is with the nearly identical Electra system, suggesting a possible abuse of some sort during ground operation.

As mentioned previously, motor damage results when ground power is used, if the power source is inadequate to support the total aircraft load and maintain bus voltage during the critical pump-starting period. In this regard, note also that the capacity of the power source in continuous operation (as indicated on its name-plate) is not the only criterion for judging its adequacy, for if the extension cable to the airplane is too long, Grand Coulee Dam itself could not properly support an Orion bus. The



(Official U.S. Navy Photo)

NC-12A power unit has a line-drop compensating capability, which was described in Orion Service Digest Issue 5, and full advantage should be taken of this feature to procure long service life from the aircraft components.

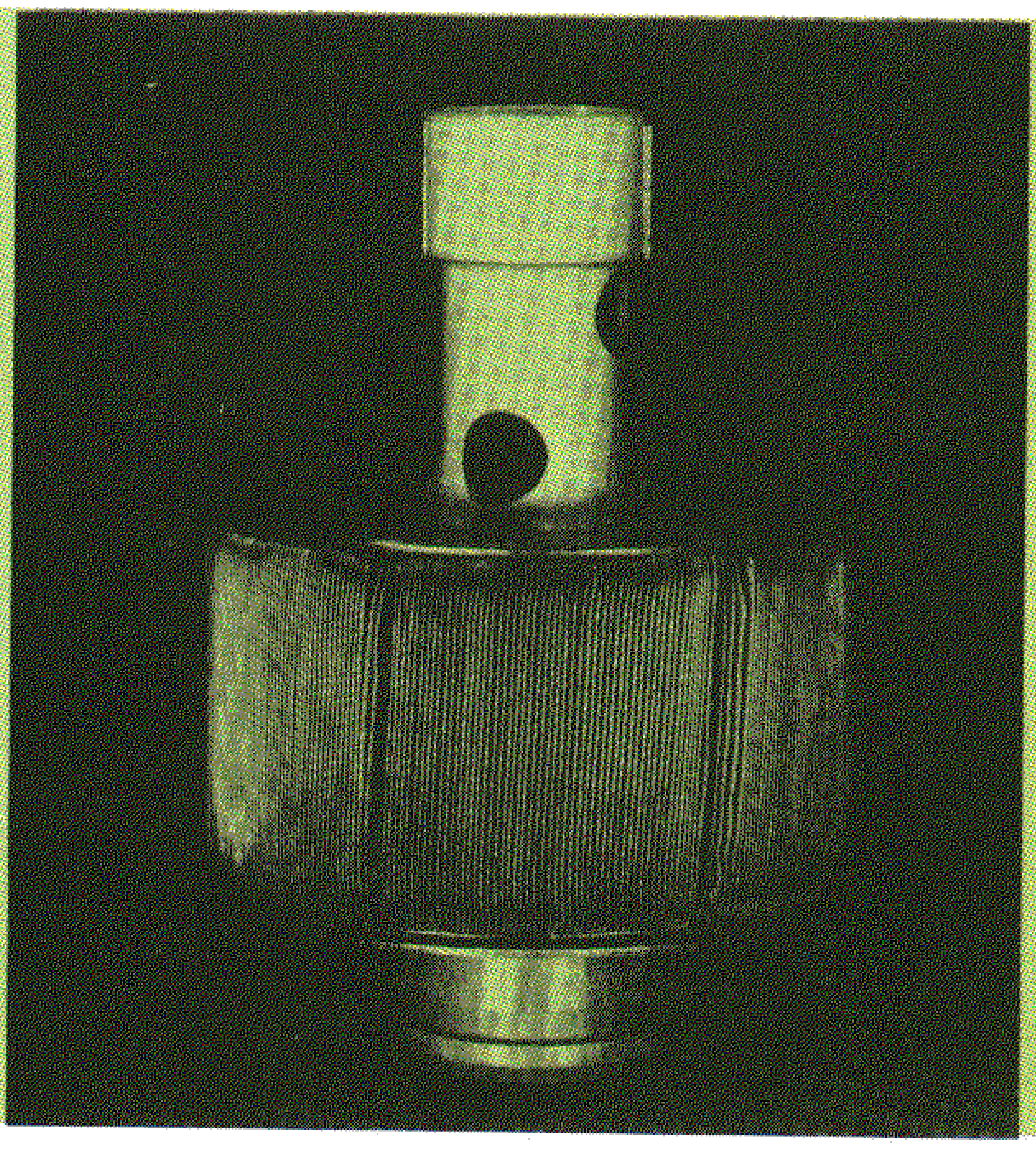
When the pumps are to be used, it is not good technique to energize two or more of these powerful motors simultaneously, nor to cycle them "ON" and "OFF" after only a few seconds of operation. After a pump is started, it is best to allow it to run for a minute or so to dissipate the heat built-up during the start.

It is evident that aircraft operating time is not an accurate measure of pump operating time. Each hour of unnecessary ground-running time reduces the pump's chance to fulfill its projected operating life and consequently increases the incidence of pump failure. Maintenance crews, aiming to promote trouble-free operation, defeat their purpose if they run pumps more — or more pumps — than absolutely necessary to make ground checks. However, we recommend that the aircraft pumps always be used instead of a ground test gig unless circumstances arise which make it clearly unwise to do so. Obviously, no pump should be used when fuel in the adjacent inboard tank is too low (less than 1000 lbs) to provide adequate cooling, and the aircraft pumps should not be used to flush a system that has been contaminated in some way.

The reduction gear boxes of the three ac motor pumps are lubricated with MIL-H-5606 hydraulic oil. The level of this oil should be checked and replenished as necessary, and the oil should be changed at the intervals specified on the Maintenance Requirement Cards.

CHECKING AND CLEANING FILTERS Another possible source of pump trouble can be avoided by exercising reasonable vigilance in checking the condition of the reservoir filters. Reservoir filters that intercept pump suction flow are particularly effective on the Orion, for the flow rate at this point is not only higher than at any other, it is also continuous — never less than coolant flow (2 gpm per pump) plus normal flight control booster demand (about 1 gpm per system). Such repetitious filtering maintains system oil of exceptional purity, but the myriad microscopic particles removed from the oil may accumulate quite rapidly on the filter element, for it is axiomatic that an efficient filtering arrangement will clog more rapidly than an inefficient one.

The designers elected to provide no filter bypass provisions on the Orion, for these are apt to defeat the purpose of a filter — at the very time it is most needed — by allowing abrasives shed from a single deteriorated component to migrate, fouling orifices and abrading components throughout the aircraft. Instead, much design effort was spent in ensuring the principal functions with a second power system and/or dependable manual emergency systems. The multitude of back-up provisions makes it unlikely that the interruption of flow at any one filter would jeopardize the operation, and a bypass for contaminated oil would be the greater evil.



Number 2 System Reservoir Filter

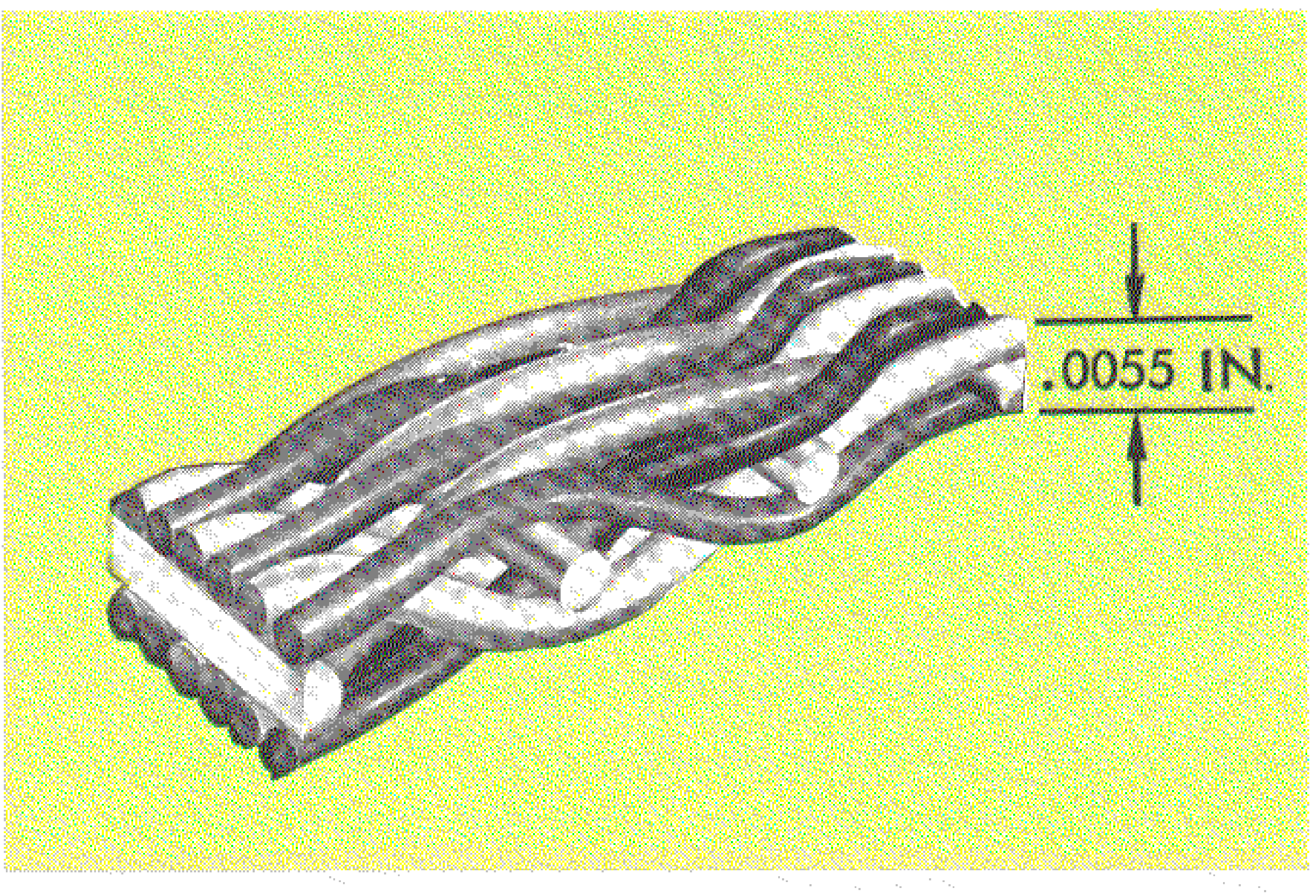


Figure 11 Enlarged Detail of "Dutch Twill" Screen Weave

The filtering medium used on all the Orion filters is an almost incredibly intricate screen, woven in the "Dutch Twill" pattern shown in Figure 11, and despite a few thousand holes per square inch, the screen appears to be opaque. It is rated as a 10-micron nominal, 25-micron absolute filter. To define this capability in meaningful terms: If 100 particles measuring 4 to 8 ten-thousandths of an inch (10 to 20 microns) in cross section were dropped into pure fluid, a 10-micron filter will intercept at least 98 of these in one pass. Particles whose smallest diameter is 25-microns or more will not pass. A 40-micron particle is regarded to be the smallest which can be seen without magnification. The screen has two particularly desirable qualities. The tough stainless steel wire does not shed — becoming a source of contamination rather than a cure for it — and the weave pattern provides curved filtering passages able to trap fine hair-like particles that would penetrate a straight passageway.

Unfortunately, the "wedging" of particles in the screen makes it difficult to clean the filters, and they cannot be cleaned by ordinary means. Ultrasonic cleaning is the only method known to be effective. In this method, the elements are immersed in a succession of trichloroethylene baths which carry high-frequency wave impulses, creating a pulsing cavitational suction at the surface of the filter that removes particles from the filter pores. After cleaning, the integrity of the element is checked by administering a small internal air pressure while the screen is wet and submerged in a specified test fluid. The surface tension property of this fluid creates a film strong enough to support the air pressure *if* every pore in the element is within tolerance. After an element has been cleaned and has passed the integrity test, the effectiveness of the cleaning is checked by determining that a given pressure gradient will force a given flow of super-clean oil through the element.

Note that this pressure drop test is the only accepted method of determining cleanliness. An element can be totally clogged by microscopic particles and yet appear to be perfectly clean. Visual inspection, even with a microscope, is inadequate, for particles may lodge deep in the screen and/or in the convolutions. Even the pressure drop test does not prove that the element is completely clean, but it does prove that it is not unacceptably dirty.

The reservoir filters are of primary concern, for blockage at the reservoir will affect all the functions served by that system. Operational experience with reservoir filters shows that there is a wide variation in the filters' useful life between cleanings due to variables in cleaning effectiveness and in the nature and amount of contaminants entering, or generated in, the hydraulic system. Therefore, the practice of replacing filters on a time basis cannot in itself ensure trouble free operation. The condition of the reservoir filters can be checked quite easily, and they should be checked frequently, by determining the pressure drop across the elements while pumps are operating. The viscosity of the oil is important when this test is made. Oil in the reservoirs should be no less than 100° F (definitely warm to the touch) and therefor this check is made most conveniently after flight, before the oil cools.

1. Open reservoir vent valve to relieve any existing pressure and lock the valve open (or loosen a reservoir filler cap) to maintain zero air pressure during the balance of the procedure.
2. Record reading from pump suction gauges mounted at each reservoir outlet with no pumps operating.
3. Start all three ac motor-pumps (one at a time).
4. Clear the flaps for operation and run flaps in either direction.
5. Record reading from pump suction gauges while flaps are running and compare with previous readings. If second reading at either reservoir is more than 1-psi below the previous reading, the filter element is not trustworthy for further use.

Experience and laboratory tests have proven that filters which present a 1-psi restriction to the modest flow induced by flap operation are badly silted.

Beyond this point, flow restriction will increase rapidly, causing pumps to cavitate when a high demand is made on the system, severely shortening the lives of the pumps.

Other filters and/or screens are strategically positioned throughout the power and actuating systems to protect individual components, particularly those in which flow-control orifices are used. Periodic cleaning will suffice for these. They are ordinarily less susceptible to clogging and will give evidence of imminent trouble by slowing actuation time.

FLARELESS TUBE-FITTINGS The third major innovation — the use of MS flareless fittings — is not a new aviation development, but ex-Neptune squadrons may have had little experience with them, and they do require some special techniques in maintenance. This type connector provides exceptionally leak-free, long-lived hydraulic systems, requiring little maintenance in mending leaks and replacing tubing. When the need does arise, however, the repairman should understand the sealing principles of the flareless fitting and the necessity for careful use of wrenches on the tubing nuts.

Unlike the flared type fitting — in which the tube flare accepts the tapered fitting end and seals directly to it — the flareless type fitting accepts the tube end plus a hardened metal sleeve which effects a seal at two annular points of contact; one on the tube, one inside the fitting (see Figure 12). At the time of manufacture, the fitting port is first deeply counterbored large enough to accept the unflared tube end, and a 24° counter sink is run almost to the bottom of the bore, providing a tapered mouth large enough to accept one end of the sleeve. When installed, the nut forces the sleeve deeper into the funnel-shaped mouth of the fitting and, as the sleeve end is made to constrict, a cutting lip is imbedded in the tube periphery, providing a perfect annular seal at this point. Further tightening causes the sleeve to bow slightly until a second annular seal is effected between the sleeve periphery and the bell-mouth of the fitting. After torquing, the bowed sleeve acts as a spring-lock for the nut which will retain it against the loosening effect of vibration, and there is little chance that a connection will ever develop a leak if it is assembled and installed correctly.

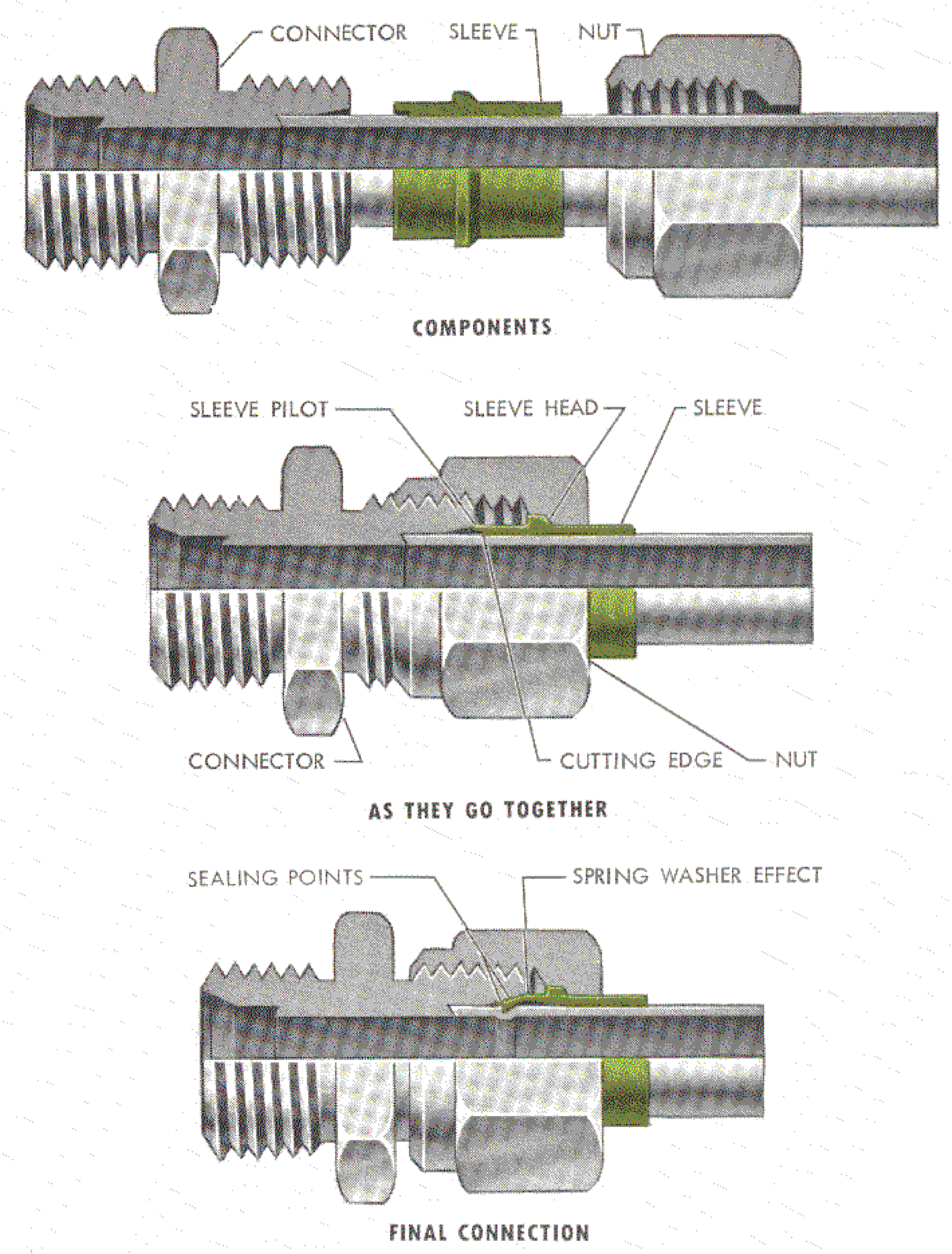


Figure 12 Flareless Tube Connector Assembly

To obtain uniformly high quality tube assemblies in production line work at Lockheed, special machines with close-tolerance dies and carefully controlled pneumatic rams are used to "preset" the sleeves on tube-ends, ensuring that sleeves of all sizes are given the optimum permanent bite according to tube material and wall thickness. The tube assemblies are then installed with torque-wrenches, applying a measured force to obtain the optimum bow of the sleeve for sealing and nut retention. *We recommend that the factory Standards* be observed in maintenance work also whenever possible,* but one of the attractive features of the flareless fitting is that a field repair good enough for temporary duty can be made without special tools, either for presetting or installation — indeed, both operations can be done with an ordinary end wrench. After a replace-

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**Lockheed MPS (Manufacturing Process Standards) 3019, 7640, and 7662. These resulted from an exhaustive program of Research tests, and they contain dimensional tolerances for machining as well as the fabrication techniques for tube assembly and installation which have enabled us to build consistently high-quality hydraulic systems with the flareless fittings. The vendors who supply connector parts to Lockheed (Weatherhead and Parker) have always maintained the machining tolerances we require, and we know that these parts, assembled to our Standards procedures, will always yield exceptionally good results. We strongly recommend that repairs, especially extensive repairs, be made to factory Standards if time and circumstance will allow. We realize, however, that this is often impractical and sometimes impossible in the field, and the simpler procedures which follow are given as an alternative for local repair at fields of limited facilities.*

ment tube of proper material and wall thickness has been bent, cut — reasonably square — to size, and cleaned, the sleeves can be set on a simple vise-held tool (see Figure 13) or, if necessary, they may be set directly on the aircraft fittings. In making such a repair, the case-hardened tool, or aircraft fitting, substitutes for the presetting tool die, the nut for its ram. The installer tightens down the nut, keeping count of rotation to approximate the sleeve presetting force and also the installation torque (which is obtained by use of a torque wrench at the factory).

Proceed as follows:

Ideally, the field repair will be made with the presetting tool or a steel connector fitting clamped in a vise. (The fittings tend to swell and gall the nuts when used for presetting; never use aluminum connectors, steel connectors should not be used more than 5 times). Lubricate the fitting threads, the bell-mouth and the sleeve with MIL-H-5606 hydraulic oil. The tube end is inserted squarely into the tool or fitting, and the tube should be rotated slowly between thumb and fingers while the nut is turned down until the cutting lip of the collar seizes on the tube. This establishes a starting point. From this point, turn the nut one and one-sixth turns (7 wrench flats) to preset the sleeve. In all likelihood, this will provide an acceptable sleeve "bite" on all tubes used on the Orion, but note that thick-walled steel tubes may sometimes chip the sleeve's hardened steel cutting lip, permitting leakage between the tube and sleeve. Should this occur, we suggest that a second tube be made up, presetting to one turn (instead of the customary 1 and 1-sixth) or slightly less.

After presetting, back the nut off and inspect the sleeve. Much of the bow will disappear when the nut pressure is relieved, but the leading end of the sleeve should be permanently set with the cutting lip imbedded deeply enough to retain the sleeve on the tube. It may be possible to rotate the sleeve in some cases, but it will *not* be possible to slide the sleeve lengthwise more than 1/64" if the cutting lip has made an acceptably clean groove. Check that the barrel section of the sleeve which seals against the fitting bell-mouth has no visible blemishes. Pressure test — using twice the operating pressure or 500 psi, whichever is greater — to ensure the connections are leak-free and provide a good safety margin.

When plumbing an assembled tube, be sure it is clean and, again, well lubricated with MIL-H-5606 oil. Turn the nut on the fitting with a wrench until a sudden sharp rise in torque is encountered. This point of resistance is not difficult to detect, but it will necessarily be overshot at first, and the nut should be backed-off and returned cautiously to establish exactly the point of rapid torque rise. At this point, the sleeve lip will have bottomed in the tube groove, and further tightening the nut exactly one wrench flat (one-sixth turn) will bow the sleeve and seat it in the fitting bell-mouth. If a connection leaks, the nut should be tightened further, *not more than one additional wrench flat*, and pressure tested again.

A small leak, either during pressure test or in service, may be due to a tiny score that can be polished out by repeatedly tightening and loosening the connection, but it is not likely that *anything* will be gained by tightening a connector more than two wrench flats (1/3 turn) past the high-torque threshold, in fact it is quite likely that the connection will be ruined. When the nut is overtightened, the tube may collapse under the sleeve bite, the cutting lip may be chipped, or the sleeve barrel may buckle. In some cases, an overtightened fitting may hold against static pressure, but will leak when subjected to vibration and dynamic pressure in service. It is preferable to fabricate a new tube assembly if a leak persists after repetitious tightening to the maximum permissible limit.

Table 1 lists the torque values used at Lockheed when new tubes are installed on the production line. We recommend that torque wrenches be used as normal procedure for field installation too, if the connection is accessible enough. We believe that torque-tightening may be especially valuable in field maintenance in case a connection leaks due to inadequate presetting. In such a case, the sleeve bow is not properly developed, but the sleeve has been deformed to some extent, and it is no longer possible to establish a valid starting point either for preset rotation (to complete the preset) of for installation. Obviously, the safest course will be to reject such a tube assembly, but in line maintenance this is not always practicable. By tightening the nut to the applicable torque value, the nut will probably pass the point reached by position tightening, but there is no chance of over-tightening and there *is* some chance that a seal will be effected. If so, an assembly has been saved that must otherwise be rejected out of hand or might be ruined by "desperation" tightening.

Table 1
Torque Values for
Installing Flareless
Tube Assemblies

WRENCH TORQUE FOR 304-1/8 H STEEL TUBES (S)**

SIZE — OUTSIDE DIAMETER	WALL THICKNESS	WRENCH TORQUE IN. LBS.	
		MIN.	MAX.
3/16	.016	90	110
3/16	.020	90	110
1/4	.016	110	140
1/4	.020	110	140
1/4	.035	140	170
3/8	.020	170	230
3/8	.028	200	250
1/2	.020	300	400
1/2	.028	400	500
1/2	.035	500	600
5/8	.020	300	400
5/8	.028	500	600
5/8	.035	600	700
5/8	.042	700	850
3/4	.028	650	800
3/4	.049	800	960
1	.020	800	950
1	.065	1600	1750
WRENCH TORQUE FOR 304-1A OR 347-1A STEEL (SA)**			
1/4	.020	90	110
5/16	.020	100	120
3/8	.042	145	175
1/2	.028	300	400
1/2	.049	500	600
1	.035	750	900
WRENCH TORQUE FOR 6061-T6 TUBES (A)**			
1/4	.035	110	140
5/16	.035	125*	170*
3/8	.035	145	175
1/2	.035	270	330
1/2	.049	320	380
5/8	.035	360	440
5/8	.049	425	525
3/4	.035	380	470
1	.035	750	900
1-1/4	.035	900	1100

* FOR DRI-LUBED NUTS

** THE LAST SYMBOLS INK-STAMPED ON FLARELESS TUBE ASSEMBLIES IDENTIFY WALL THICKNESS AND MATERIAL, eg, 035S MEANS .035 THICK, 304-1/8 H STEEL

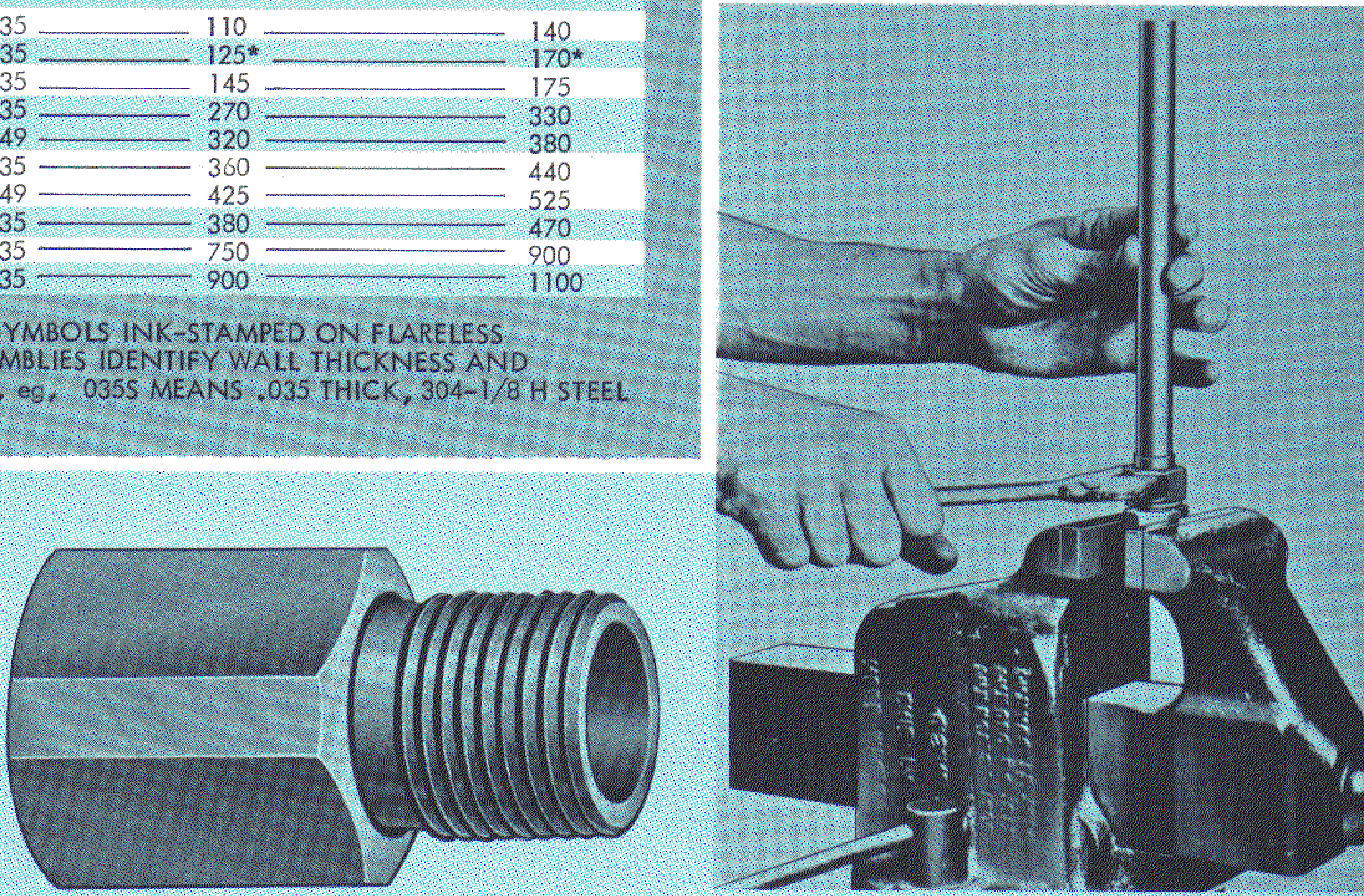


Figure 13 Vise-Held Presetting Tool and Hand-Tool Assembly Technique

DAMAGE ISOLATION DURING FLIGHT

An inspection of the layout of the hydraulic system master schematic reveals the interesting fact that, except for the rudder/elevator booster pressure lines, it is possible to block off any or all pressure lines emanating from the service center by closing manual shutoff valves or by operating selector valves. Hence, there is only one inaccessible line per system that is unavoidably pressurized when pumps are energized, and if the need should ever arise, an enterprising crew that is familiar with the system could effect an in-flight remedy for a leak at almost any point.

It is, of course, the pilot's prerogative to determine whether or not the situation warrants attempting an in-flight repair to regain the use of the system rather than simply deactivating a hydraulic power system whose reservoir has been seriously depleted. The latter course would probably be chosen in the case No. 2 System was involved, for all its functions are operable from No. 1 System. The complete loss of No. 1 System would be of a more serious nature, and in the following discussion we have invented a theoretical situation to illustrate the general possibility for taking corrective action in-flight after oil loss has made the primary hydraulic power system inoperative—a subject that is traditionally interesting to military aircrew members.

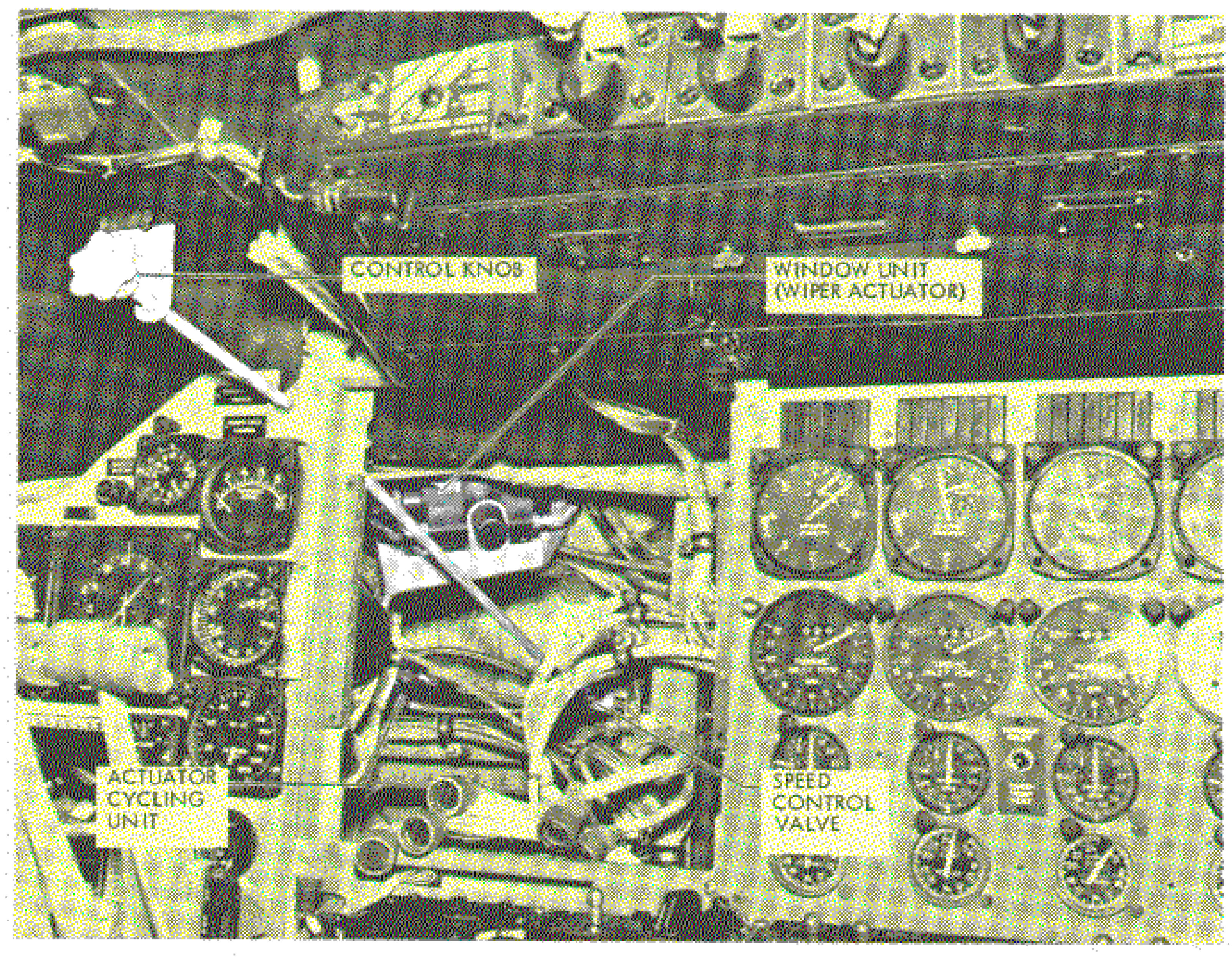
If we assume No. 1 Reservoir oil has been seriously depleted through a leak in the windshield wiper system and both No. 1 System pumps have been shut down, there are some foreseeable effects on the balance of the mission which the pilot can assess. Cruise will be essentially normal, for the output of No. 2 Pump will be sufficient for normal operation of the three flight control boosters unless flaps and bomb bay actuators are used simultaneously in conjunction with the boosters. However, some functions are not operable from No. 2 Pump, for instance, an emergency gear extension will be necessary before landing; the hydraulically powered nosewheel steering system will be inoperative after landing. Normal braking with the rudder toe-pedals will be available, but limited to the power stored in the brake accumulator plus whatever the dc motor driven pump (No. 1B) can glean from the reservoir. In addition to this, emergency braking from the air reservoir is available, but this produces uniform drag at all main wheels which offers no aid to steering.

On the other hand, a leak in the windshield wiper system can be isolated, either by closing the wiper control valve or by closing the No. 1 System bomb bay door shut-off in the service center. If clean, extra oil is aboard, the reservoir can easily be replenished and the system re-activated. If oil level is marginal, the following points suggest remedies: a single No. 1 System pump may operate successfully even though two-pump operation causes cavitation; about ¾ gallon of oil can be transferred from the Emergency Reservoir into the No. 1 Reservoir by using the hand pump to cycle the bomb bay doors; landing gear extension produces a net gain in reservoir level.

WINDSHIELD WIPER SYSTEM

Hydraulic pressure for the windshield wiper system is taken from the No. 1 Hydraulic System through a pressure reducer which delivers oil to the wiper control valve at 2000 psi. A relief valve function of the pressure reducer is designed to relieve actuating pressure in excess of 2075 psi. The control valve is mounted forward of the Pilot's station on the pressure bulkhead and has a needle valve stem connected by a jointed drive shaft to the windshield wiper control knob at the top of the Pilot's instrument panel. When the needle valve is unseated, pressure from the pressure reducer is ported through a balance line to sensing pistons in an automatic cycling four-way valve.

As the control valve stem is screwed further out, actuating oil will be metered to the actuating pressure inlet port of the four-way valve and pass through the four-way valve to the inboard end of both windshield wipers' actuating cylinders (assuming that the wipers are in their outboard "parked" position). The pistons in the actuating cylinders are actually reversible pressure operated racks meshed with pinion gears on the wiper shafts so that linear motion of the pistons is translated into rotary motion of the shafts. The pistons will move when relatively low pressure builds up downstream of the cycling valve and disengages a sprag type parking clutch on the wiper shafts. Pressure will increase as the pistons are slowed by hydraulic dampers (dash pots) near the end of their travel. When this pressure builds up within 200 psi of the pressure furnished through the balance lines to the sensing pistons in the four-way valve, the valve will trip and actuating pressure will be ported to the outboard ends of the two actu-



Windshield Wiper System Components, Viewed Through Pilot's Instrument Panel

ating cylinders, reversing the actuating pistons and returning the wipers outboard.

The speed of the wipers is determined by the flow of oil metered to the system through the manually adjusted needle valve. As the needle valve is turned toward "OFF" the wipers will slow accordingly, and when the actuating pistons move at greatly reduced speed the dash pots which normally cause cycling pressure to build up will become less effective and the pistons inboard travel will be greater. The increased piston travel will drive the wipers outboard and down off the windshield where they will not obstruct vision. The wipers should be parked while they are off the glass. This is done by turning the control knob full "OFF" while the wipers are off the windshield, thereby blocking pressure from the system. The loss of pressure will allow the sprag clutches on the wiper shafts to engage, and these clutches will prevent the airstream from blowing the wipers inboard.

BOMB BAY DOORS SYSTEM

The clam-shell type bomb bay doors are operable from either of the hydraulic power systems or from a hand pump. As shown in Figure 14, there are four identical actuators, one at each end of each door. In keeping with the general layout plan of components in the service center, the No. 1 System powers the left door actuators; the No. 2 System powers the right door actuators. Normally, both systems will operate in unison, but the No. 1 and 2 actuators at the forward end and at the aft end of the bomb bay are inter-connected by leverage arrangements (shown in Figure 14) so that either the left (No. 1) or the right (No. 2) pair of actuators can operate both doors. As can be seen, this is the case when the emergency hand pump is used. Hand pump pressure works only through the No. 1 (left side) actuators to open and close the doors, and it utilizes also the No. 1 half of three "tandem" components, two of which are mounted above the door uplock latches. These two are at the forward end of the bay, on the aircraft centerline. The other tandem component, the door control valve, is also on the forward bulkhead, but it is at the upper left corner. This is a dual, pilot-operated, 4-way valve, which can also be operated manually from within the cabin.

Figure 14 is a mechanical/electrical/hydraulic schematic, which portrays the entire system and all its controls except for the automatically programmed jettison system which is, for obvious reasons, interconnected with the bomb bay door electrical control at the points indicated. The components are shown greatly simplified for the sake of clarity, but the scheme of operation is essentially as portrayed.

The following discussion traces the course of events as they occur in a single door cycle, that is, from doors up-and-locked to doors open, and back to doors up-and-locked. To illustrate the entire capability of the system, we will assume the doors are being operated from the flight station, as they normally are, but that No. 1 Hydraulic System only is being used. Note that the control valve is shown in its neutral position, as it normally is in flight when not in use.

The pilot initiates "BOMB BAY OPEN" by selecting that position of the door control switch on the Pilots Armament Control Panel. This shunts 28-volt dc power, taken from the Armament Power No. 1 circuit breaker on the Extension Main DC Bus and the series of circuit breakers shown, through the REMOTE-LOCAL switch, which is normally in its closed (REMOTE) position as shown, and to two solenoids — one for each hydraulic system — on the control selector valve. The solenoids operate the two small "door open" pilot valves within the selector, and of course only No. 1 will be effective in this case, for we are assuming that No. 2 has no hydraulic pressure to work with.

The No. 1 "open" pilot valve ports full system pressure to the "door open" spool cylinder on the No. 1 half of this 2-system control spool, driving it up to its "open" position, where it engages a detent. This detent is strong enough to hold the spool at "open" (full up) without the aid of hydraulic pressure, which adds a positive and continuous force to maintain the selected spool position. The displaced control spool directs system pressure to the valve's No. 1 "OPEN" port and also opens a path for oil to return from the No. 1 door actuating system to the No. 1 reservoir. Incidentally, note that there is no return line to the emergency reservoir. When the hand pump is used, it utilizes the No. 1 actuation ports, and emergency oil is ultimately transferred to the No. 1 System reservoir.

From the No. 1 "OPEN" port of the control valve, pressure reaches the No. 1 halves of two related components, the controllable check valve and the uplock actuator. However, pressure is checked by the controllable check valve until the door uplock hooks are unlocked, an action done almost instantly by the uplock actuating cylinder. The inset at the upper right of Figure 14 shows the components related to the uplock as they are when the hooks are in the unlocked position. It can be seen that the attachment at the lower end of the uplock actuator piston rod unlocks the two hooks, and when they are unlocked the upper end of the actuator rod strikes the controllable check valve control rod, forcing open the valves for both power systems and allowing "opening" pressure to reach the door actuators. Thus, the controllable check valve is actually a mechanical sequencing device that prevents the door actuators from inflicting opening force on the doors while they are locked closed.

With the doors unlocked and the controllable check valves open, pressure in the door actuating cylinders (in this example, only the No. 1 actuators) commences to open the doors. Note, at this point, that all flow from the power system is controlled by a 4-gpm flow control valve at the inlet to the selector valve and return flow is being metered through a restrictor-check valve at the selector valve. Thus, the door actuator pistons are trapped between positive system pressure and positive back pressure while the doors are in motion, and wind buffeting is prevented.

We should mention here some items which are important to the system at this point but which are omitted from the schematic for the sake of simplicity.

As the No. 1 (left side) actuators work through the reciprocal-lever linkage to drive the right hand door open, the No. 2 actuator pistons are also drawn toward open, and they discharge oil at one port and attempt to draw oil (from No. 2 power system) in at the other. Since we are assuming in our example that oil is not being pumped in No. 2 System, cavitation (vapor pockets) might be created by the suction except for a check valve inside the selector between pressure and return. Suction in the pressure line draws open the check valve, and oil discharged from one port of the actuating cylinders "runs around" to the other port. These "run around" valves are provided for both power systems, but are not shown on Figure 14.

The other item not shown is a limit switch circuit that operates advisory lights, informing the Pilot when the doors are neither open nor closed (by means of a "DOORS" light) and informing both the Pilot and the Tactical Coordinator when the doors are full open (by means of an "OPEN" light at each position).

The doors are full open when the actuator pistons bottom, and they are held open by continual "door-open" pressure until the pilot selects "CLOSE" at the Bomb Bay control switch.

Selecting "CLOSE" powers a circuit, not used in the "OPEN" function, through parallel-connected limit switches which complete the circuit to the Bomb Bay Door Control Relay coil. When the relay contacts close, 28-volt dc power is impressed on No. 1 and No. 2 "door close" pilot valve solenoids. The resulting hydraulic action is essentially the same as before, except that door close pressure is ported directly to the door actuators and return flow passes in the reverse direction through the controllable check valve, which is held open by the unlocked position of the uplock actuator. Pressure also reaches the "lock" port of the uplock actuator at this time, but it produces no action because the linkage between the uplock piston rod and the hooks is in the over-center position schematized in the Figure 14 inset. Thus, despite the locking force on their actuator, the hooks remain open as the doors travel closed until the uplock lug on both doors strike the upper jaws of the hooks. This double blow moves the hooks enough to "break" the over-center lock of the linkage, and the lock actuator becomes effective. As the uplock actuator piston drives down, the hooks rotate—helping to pull the doors up snug—and the hook linkage is again forced past center to provide a mechanical lock. The hook limit switches open when both hooks are fully locked, the Bomb Bay Door Control relay is de-energized, and all power, both electric and hydraulic, is removed from the actuating system.

Gravity and airloads tend to open the door, but this force, working back through hooks and the over-center linkage, tends only to pull the lock actuator pistons more firmly against the cylinder bottoms.

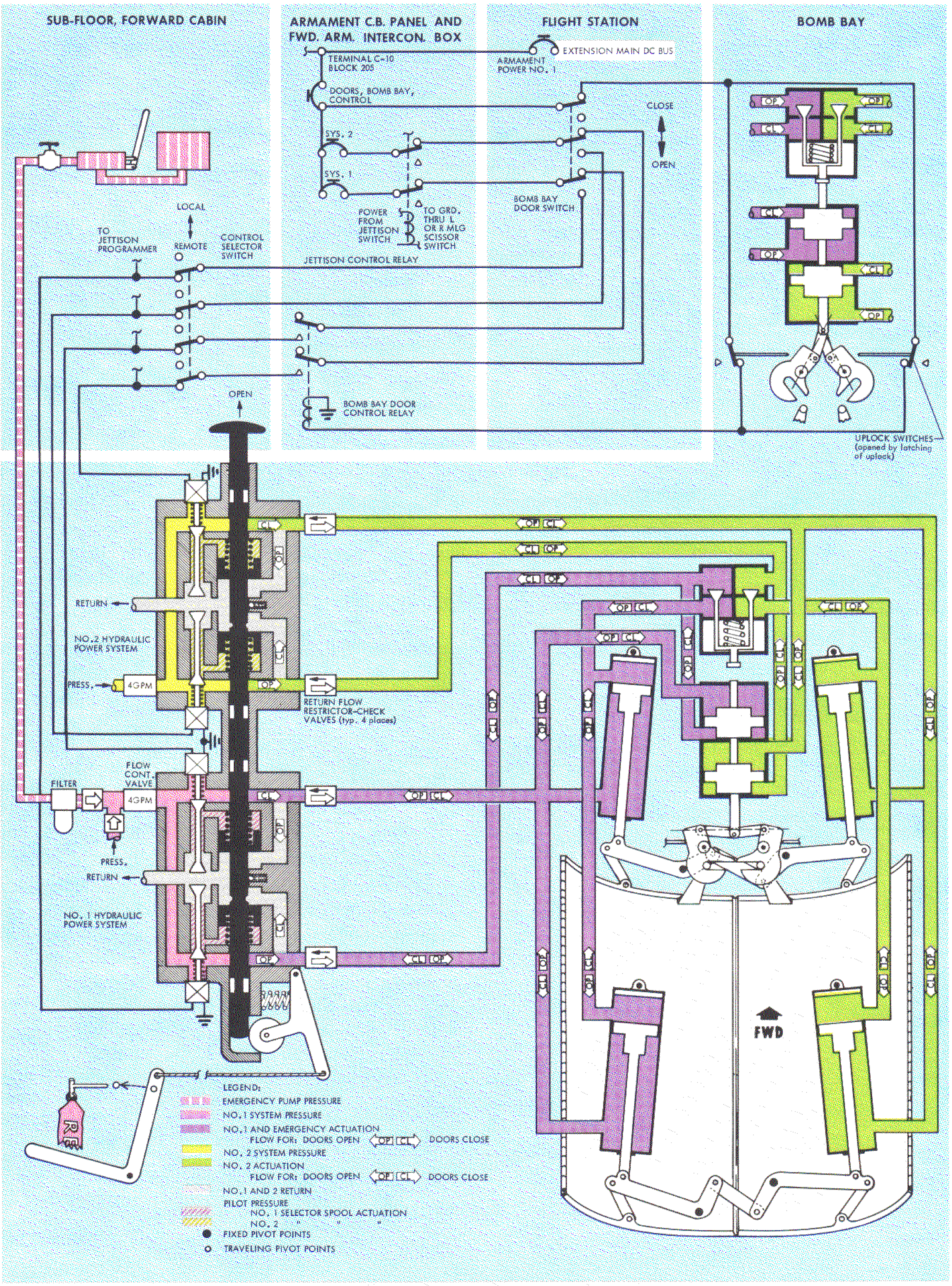


Figure 14 Bomb Bay Doors Systems Master Schematic

EMERGENCY DOOR ACTUATION SYSTEM This system is designed to allow a one-shot operation of the doors, even though no power, either hydraulic or electric, is available. To open the bomb bay doors manually, the operator first opens a door in the floor near the radio operators station. This sub-floor compartment, which is a cabin pressure area, contains the LOCAL-REMOTE switch and the manual control handle for the bomb bay door selector (4-way) valve. By selecting LOCAL at the switch the operator disconnects the flight station control of the selector valve, ensuring that someone does not succeed in restoring electrical power momentarily which might inadvertently reverse the Emergency operation in progress. This would nullify whatever part of the door cycle the operator had accomplished, and also expend that part of the small (¾-gallon) Emergency Reservoir supply already used. Note that the LOCAL-REMOTE switch does not prevent the jettison system from operating the selector. It is assumed that the most important, but not the only, possible reason for an emergency door actuation would be to manually jettison bomb-bay stores. If the pilot does initiate the jettison cycle, it should have every chance to automatically over-ride the manual door cycle, whether this aids or defeats the pump operator's immediate intent.

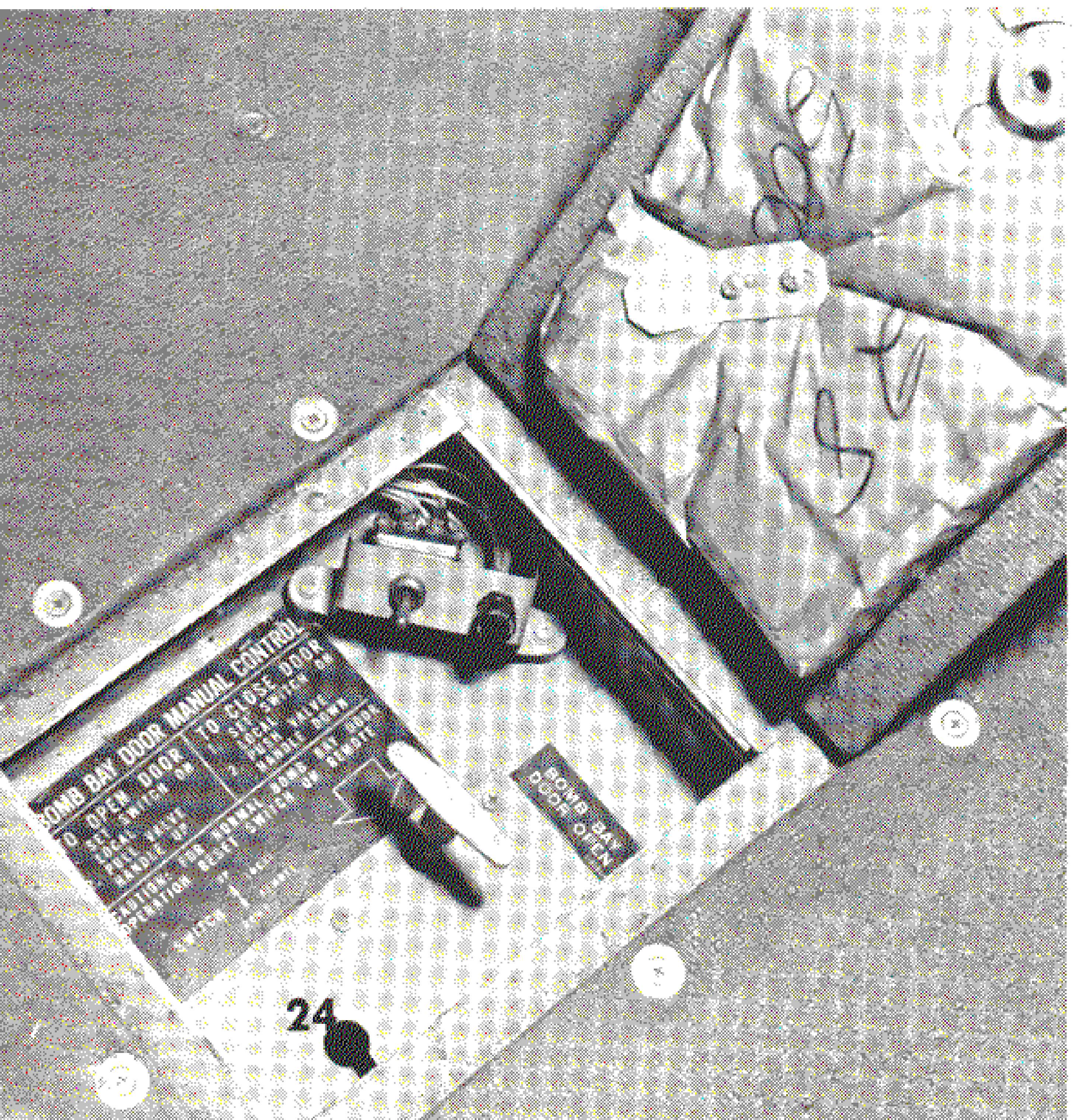
With the control switch in LOCAL, the operator pulls the door selector handle up to open the doors. (As mentioned previously, detents on the door selector valve spool will hold it in this position.) He then opens a second floor access door located to the right of the valve control door, opens the manual shut-off valve (see Figures 14 and 15), inserts the pump handle in its jack and pumps open the doors. As mentioned before, the No. 1 actuators and the No. 1 ports of the "tandem" hydraulic components are utilized by the Emergency system. Return oil goes to the No. 1 System Reservoir, not the Emergency Reservoir.

Note that, with the selector manually positioned, if hydraulic power should become available in either system while the operator is using the hand pump, it will automatically aid whichever function (door open or close) he is performing.

Hydraulic pressure is used in normal operation to hold the doors in their full open position, and of course in emergency operation it will be necessary for the operator to maintain a continual pressure with the hand pump to ensure that the doors do not creep towards close.

Closing the doors with the emergency system is a two-man operation, for one man must hold the door selector valve down in close position while the other operates the hand pump. No detent was provided to hold the selector mechanically in close position, for should the valve be inadvertently left in this position during ground maintenance work, someone might be cut off at the hip pockets by the closing of the clam-shell type doors if either hydraulic power system was pressurized. As explained previously, the door uplock hooks latch mechanically when the doors are full closed, and it is not necessary to maintain hand-pump pressure in the door actuator cylinders after the doors are locked up.

A positive safety-pinned lock is provided (see Figures 14 and 16) which prevents the selector spool from going down to its "CLOSE" position, ensuring that the doors are never closed inadvertently while the airplane is on the ground. The insertion point for the safety-pin is located just forward of the left door, so that the crewman must stand clear of the doors, but in full view of them, to insert or remove the safety pin. ▲ ▲



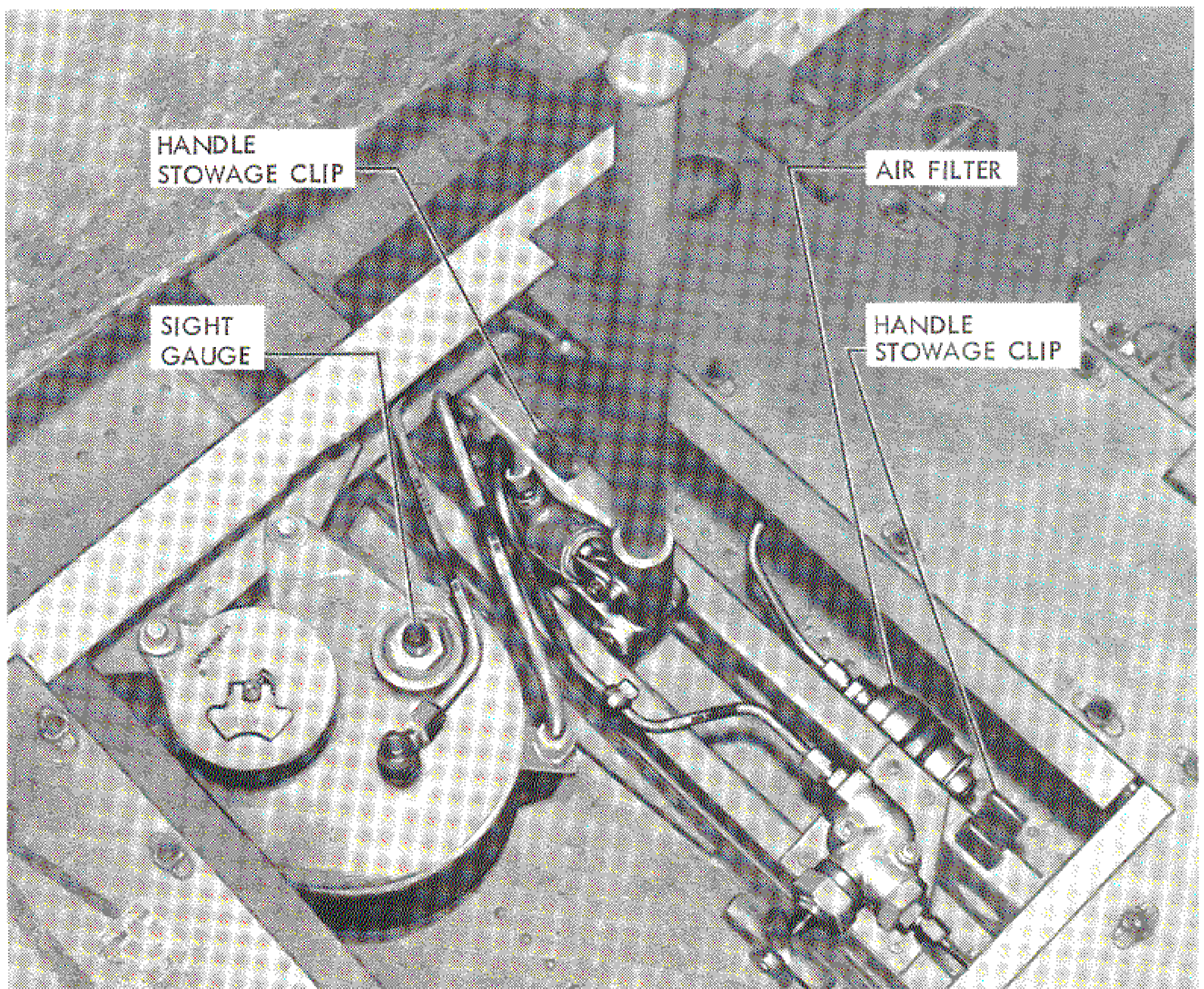


Figure 15
Emergency Bomb Bay Doors Control and Pumping System (located in sub-floor between forward observation stations)

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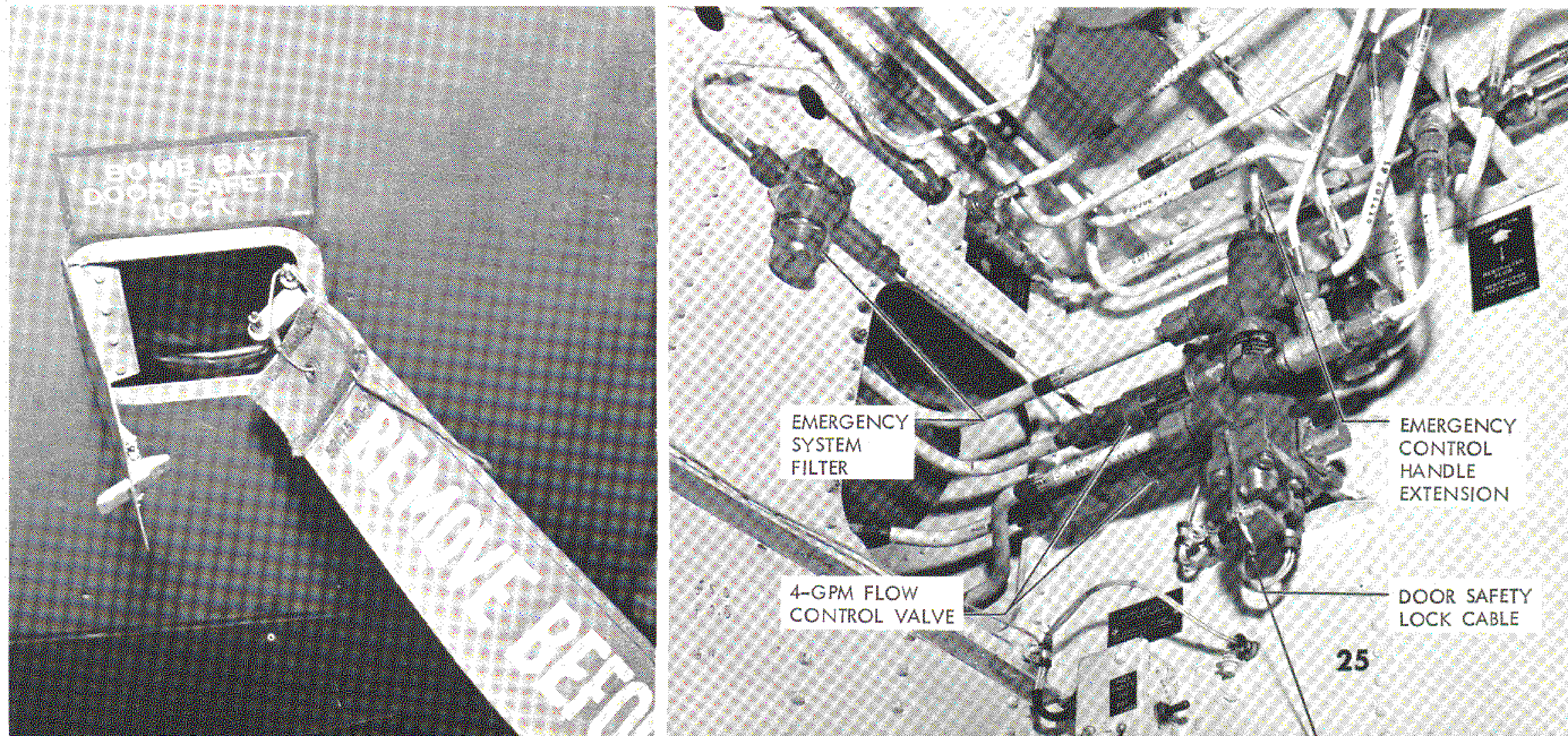
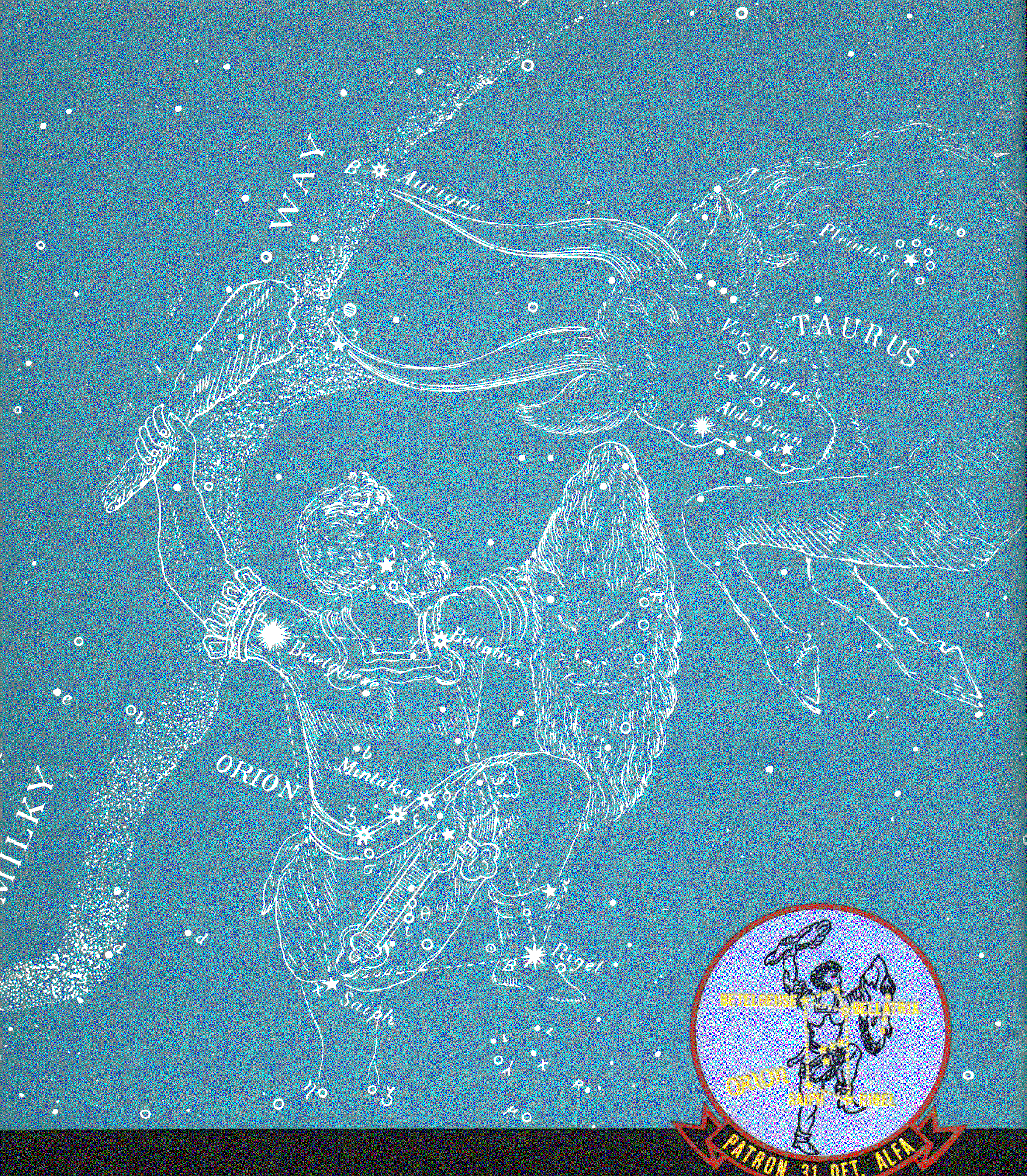


Figure 16
Door-Open Safety and General View of Door Selector and Related Installations (at left forward bomb bay)



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