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ARROW
HYDRAULICS SYSTEM

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

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ARROW 2

UTILITY HYDRAULIC SYSTEM

REPORT NO. 72/SYSTEMS 19/26

JUNE 1957

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

COMPILED BY D. Royston.   APPROVED BY Alan R. Bulay

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

MALTON — ONTARIO

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1. Introduction

1.1 System Principles

The ARROW 2 aircraft is to be equipped with a utility hydraulic system to operate landing gear, steering, wheel brakes, speed brakes, armament equipment, and an emergency alternating current power pack. In the design of the system, the size and weight of each item has been reduced to the minimum consistent with the high degree of reliability, the latter being considered essential.

1.1.1 System Pressure

A nominal system working pressure of 4000 psi has been chosen. This provides standardization within the aircraft of many components and fittings between the utility system and the flying controls system, for which the need for a 4000 psi system is dictated by physical size and maximum control actuator response requirements. The pressure chosen also enables the use of comparatively small landing and steering gear actuators which would otherwise require excessive space.

1.1.2 System Temperature

An optimum system working temperature of 250°F has been chosen. This temperature is high enough to keep the need for heat exchangers to a minimum. At the same time indications are that the latest sealing materials, when used with existing sealing techniques and MIL-O-5606 fluid, will prove entirely adequate at this temperature.

1.2 Design Provisions for System Reliability

1.2.1 Pump Duplication

The utility hydraulic system is powered by two pumps each delivering approximately 20 (US) GPM at 3250 RPM; one is mounted on each of the engine-driven gearboxes to ensure maximum system reliability. Stoppage of one engine, or failure of a single pump, will not cause failure of operation of any of the utility sub-systems.

1.2.2 Emergency Operation

To protect against a system hydraulic line failure, provision is made for emergency release of the landing gear by the use of a 5000 psi nitrogen storage bottle. For the same case, emergency brake power is supplied from an accumulator which is tapped off the normal system through a check valve.

1.3 Detail Design

In the detail design of the hydraulic circuits several innovations have been introduced to ensure proper functioning of the system, with a minimum of maintenance, during operation under the most adverse environmental conditions. These innovations are noted below.

1.3.1 Air-less Circuit

The principle of an "air-less circuit" has been adopted, i.e.

a circuit in which the air inclusion is kept to a minimum. A compensator is used, instead of the usual reservoir. Stored fluid is kept in the compensator under constant pressure, there being no direct contact between fluid and air.

1.3.2 Line Fittings

To provide greater line resistance to fatigue, MS-type flareless fittings, up-rated to 4000 psi working pressure, have been used in preference to the AN flared type. This feature parallels mandatory requirements on all new designs in the USAF and USN and therefore contributes to standardization. (See Fig. 1.8)

1.3.3 Flexible Connections

To avoid the problems normally associated with the use of flexible hoses, swivel joint fittings have been used extensively in the system. These have gained a favourable reputation on 3000 psi systems, and few new problems are expected at the 4000 psi operating pressure.

2. Design Objectives

The design objectives of the utility hydraulic system are as noted in the following paragraphs.

2.1 General

2.1.1 To provide hydraulic power for the following:

(a) Extension and retraction of landing gear

(b) Operation of speed brakes

(c) Operation of nose wheel steering

(d) Operation of wheel brakes

(e) Raising and lowering of missiles in the armament pack

(f) Emergency alternating current power pack

(g) Primary pressurization of the flying control system compensators

(h) Pressurization of the utility system compensator

2.1.2 To provide duplication of hydraulic engine-driven power sources so that failure of one engine, or of one pump, will not result in failure of the utility hydraulic system.

2.1.3 To provide a high degree of system reliability consistent with design for small size and low weight.

2.1.4 To permit operating temperatures to a maximum of 250°F for the system, (with local hot spots up to 275°F) thereby reducing the size of the heat exchangers in the system.

2.1.5 To use currently available sealing techniques and MIL-O-5606 hydraulic fluid.

2.1.6 To provide utility sub-systems with as much irreversibility as possible, by paying special attention to the elimination of air from the hydraulic fluid.

2.1.7 To provide relatively high pump inlet pressure to overcome the effects of low temperature and suction line losses, and in so doing, to improve pump reliability.

2.1.8 To provide a high pressure nitrogen system for emergency release of the landing gear in the event of failure of the utility hydraulic system.

2.1.9 To provide a system which will meet the operations and design requirements of RCAF specification AIR 7-4, which in turn calls for the design requirements of CAP 479, "Manual of Aircraft Design Requirements for the Royal Canadian Air Force", the requirements of the United States Air Research and Development Command Manual No. 80-1, "Handbook of Instructions for Aircraft Designers", and publications and specifications referred to therein.

2.2 Landing Gear Hydraulic Sub-system

2.2.1 To retract the gear, after making the selection, in not more than 5 seconds at fluid temperatures down to -20°F and in not more than 30 seconds at a fluid temperature of -65°F.

2.2.2 To lower the landing gear, including doors, and lock all down-locks by the normal system in not more than 15 seconds at fluid temperatures down to -20°F, and in not more than 30 seconds at -65°F.

2.2.3 To lower the landing gear by emergency means in not more than 15 seconds at fluid temperatures down to -20°F, and in 30 seconds at -65°F, at angles of yaw up to ±5°.

2.2.4 To raise and lower the landing gears at all airspeeds up to 250 knots E.A.S. for yaw angles up to ±10°.

2.2.5 To provide actuators which will withstand the airloads on the doors in their partially downlocked, or fully downlocked, positions at all airspeeds up to 250 knots E.A.S. and for yaw angles up to ±25°.

2.2.6 To prevent inadvertent retraction of the landing gear while the weight of the aircraft is resting on the gear.

2.2.7 To keep the use of sequence valves to a minimum but, where their use is necessary, to ensure

(a) that they are connected by rigid, positively operating linkages, which cannot deform from their installed position because of vibration or inertia loads.

(b) that they will require little or no adjustment, and will be protected from jamming due to foreign matter thrown into them by the slip-stream or spinning wheels.

2.2.8 To provide a landing gear actuating system in which the control lever, after selecting a gear retraction or extension, can be reversed with the gear in any intermediate position, whereupon the gear will return to the last position selected.

2.2.9 To ensure, in the emergency landing gear lowering sub-system, the greatest possible reliability consistent with minimum possible weight penalty, by providing separate pneumatic lines directly to the transfer valves, by-pass valves, uplock release jacks and shuttle valves.

2.2.10 To release locks in advance of main actuator movement without the use of sequence valves, by designing the lock release jacks to operate at a lower effective line pressure.

2.2.11 To prevent inadvertent release of uplocks on landing gear or doors, by preventing the locks from releasing under maximum pressure build-up and surges which can occur in the system return lines.

2.3 <u>Speed Brakes Sub-system</u>

2.3.1 To extend, retract, or hold the speed brakes at any position by hydraulic actuation.

2.3.2 To extend the speed brakes upon moving the selector switch lever to the SPEED BRAKE EXTEND position, until the air-loads balance the hydraulic forces or until the speed brakes are full out.

2.3.3 To hold the speed brakes in their immediate position on moving the selector switch lever to HOLD position, providing that the airloads on the speed brakes are not increased.

2.3.4 To provide overspeed relief, within the speed brake selector valve, so that increasing airloads will cause extended speed brakes to "blow in" until a new pressure-airload equilibrium is reached.

2.4 Nose Wheel Steering Sub-system

2.4.1 To provide nose wheel steering by hydraulic actuation to facilitate ground handling at all speeds up to nose wheel liftoff speed.

2.4.2 To permit the nose wheel to be swivelled, and steered, to turn the aircraft on a circle with a 30 foot radius.

2.4.3 To provide a ratio of nose wheel turn to steering control movement, which will provide smooth handling at high speeds and sufficient response at taxiing speeds to permit the high rate, small radii, turns necessary for parking, etc.

2.4.4 To use rudder control motion for steering control and to allow free rudder pedal motion when steering is not in action.

2.4.5 To provide sufficient damping to the angular motion of the nose wheels for the prevention of shimmy, with and without nosewheel steering engaged.

2.4.6 To allow the steered gear to caster normally with sufficient shimmy damping, at any time that steering power is released, either because of normal operation or steering system failure.

2.4.7 To provide a self-centering device to insure proper alignment of the nose wheels during retraction and extension.

2.5 Wheel Brakes Hydraulic Sub-system

2.5.1 To provide a normal braking system which will allow differential and proportional braking using brake pressures up to 2550 psi, to meet the deceleration rates required under landing or aborted take-off conditions.

2.5.2 To provide an emergency braking system which will

(a) have similar pedal travel, pedal input force curves and braking characteristics to those of the normal braking system, except that the maximum pressure available is 1500 psi.

(b) automatically take over from the normal braking system when the normal utility system pressure falls to 900 psi, or less, due to utility system failure or shutdown of the engines.

(c) provide for a limited number of brake applications as may be required during towing, using stored energy from the emergency brake accumulator.

2.5.3 To provide parking brake operation by mechanically holding the brake pedals in the BRAKES ON position by the action of the parking brake handle.

2.5.4 To provide automatic "anti-spin" brake application during landing gear retraction.

2.6 Armament Pack Hydraulic Sub-systems

2.6.1 To provide a hydraulic sub-system, contained within the armament pack, which will power a SPARROW 2 missile installation.

2.6.2 To provide a hydraulic sub-system which can be quickly disconnected from the main system during "turnaround" to allow rapid change of armament packs.

2.7 Emergency Alternating Current Power Pack

To provide emergency A.C. power during double engine flame-out (including the single engine seized case), sufficient to operate the flying control damping system, telecommunication equipment and certain flight instruments required to fly the aircraft from the time of double engine flame-out till engine relight. The primary source of power is one or both wind-milling engines.

3. Description of System

3.1 Power Circuit

The power circuit, Fig. 1.13 is composed of the pumps, pressure regulating valve, heat exchangers, heat exchanger control valves, filters, main system accumulator, emergency brake accumulator, compensator, pressure switches, pressure control valve, and the ground service connections. The power circuit can be divided into two,

(a) The unloading circuit

(b) The loaded circuit as described below.

3.1.1 Unloading Circuit

During periods when there is no hydraulic demand, the pumps pump through the unloading circuit. This circuit consists of both pumps, the pressure regulator valve, the air to oil heat exchanger, the fuel to oil heat exchanger, by-pass control valve, thermal by-pass valve, low pressure filter, and the compensator. (see Figs. 1.14, 1.15, 1.16).

3.1.2 Loaded Circuit

During periods of hydraulic demand, the pumps deliver their full flow through the pressure regulator and thence simultaneously into the appropriate sub-circuit and into the main accumulator. When the main accumulator pressure builds up to a maximum of 4350 psi, the pressure regulator diverts the pump flow into the unloading circuit. Sub-circuit flow will continue during this period, the pressure being maintained by the accumulator. When the accumulator discharges sufficient oil into the sub-system to cause the accumulator pressure to drop to approximately 3850 psi, then the pressure regulator valve diverts the pump flow back into the appropriate sub-circuit and main accumulator. This process is repeated until the component operated by the sub-circuit completes its travel. (see Fig. 1. 17).

3.1.3 Temperature Control

Temperature control of the hydraulic fluid is achieved by the air to oil and fuel to oil heat exchangers. It should be noted, that since the heat exchanger circuit forms part of the unloading circuit, then heat exchange is achieved only when the pumps are unloaded, which will be 75% to 90% of the flight time.

The heat exchanger circuit provides for the three flight cases described below.

3.1.3.1 Extreme Cold Conditions

(Encountered during the first part of a flight.)

To prevent excessive pressure buildup in the heat exchangers for this flight case, the fluid must by-pass the heat exchangers, as shown in Fig. 1. 14. During this period there will be a small flow through the heat exchangers, to ensure that they are scoured out prior to the time they are required for cooling.

3.1.3.2 Periods of Low Fuel Flow

(Encountered during cruise back from a mission).

During these periods, the fuel is relatively hot due to aerodynamic heating during the high speed combat portion of the flight. Therefore, to avoid overheating the fuel the hydraulic oil by-passes the fuel to oil heat exchanger and all the cooling is achieved in the air to oil heat exchanger. (See Fig. 1.15).

3.1.3.3 Periods of High Air Inlet Temperatures to the Air/Oil Heat Exchanger

(Encountered during supersonic flight).

During these periods, and also during periods of low ram air flow at relatively high air temperature, the hydraulic system relies on the fuel to oil heat exchanger to maintain temperature control of the hydraulic fluid. The flow pattern is shown in Fig. 1.16. The operation of the system is such, that on an increasing fluid temperature of 213°F at the thermal control valve return port, fluid from the air to oil heat exchanger is gradually diverted into the fuel to oil heat exchanger. Complete diversion is obtained when this temperature reaches 230°F. (See Figs. 1.15 and 1.16).

3.1.4 Pump Suction Pressurization (Figs. 1.4 and 1.5)

Pump suction line pressurization is achieved by the compensator. Fluid pressure of approximately 1500 psi from the pressure reducing valve section of the pressure control valve acts on a small piston in the lower end of the compensator. This force is transmitted to a larger piston thus producing a lower pressure of 90 psi in the fluid in the top of the compensator, pressurizing the pump suction as well as the return lines.

During periods when more fluid enters the compensator than leaves it, (e.g. during speed brake extension, missile linkage retraction, system fluid expansion, etc.) the fluid volume in the low pressure (90 psi)end of the compensator increases, forcing fluid out of the high pressure (1500 psi) end, through the service relief valve, back into the low pressure side of the compensator. This action maintains the low pressure end of the compensator substantially at 90 psi.

A relief valve, designed to relieve at 220 psi, is fitted in the dome at the top of the low pressure end of the compensator. Should this valve open, any air trapped in the dome will be discharged prior to the discharge of fluid.

A manually operated bleed valve is provided in the low pressure end of the compensator. In addition to providing an airbleed for servicing, this valve also enables surplus fluid to be drawn off if the compensator is over-full.

A special rod, calibrated for temperature and filling level, is provided for insertion through an access hole in the bottom of the compensator to determine the piston position.

3.1.5 Cockpit Pressure Indication (Fig. 1.12)

There are two pressure warning switches in the utility hydraulic system. These switches sense hydraulic pressure and are wired to amber warning lights in the pilot's cockpit.

3.1.5.1 Utility Hydraulics Pressure Switch

This switch is downstream of the pressure regulator in the line feeding into the sub-systems. The associated amber light comes on when the system hydraulic pressure falls to 1000 psi and goes out on increasing pressure at 3000 psi.

3.1.5.2 Emergency Brakes Pressure Switch

This switch is in the emergency brake line upstream of the brake control valve. The associated amber warning light comes on when the emergency brake accumulator pressure falls to 1600 psi and goes out on increasing pressure at 3000 psi.

3.1.6 System Pressure Relief (Fig. 1.7)

In the event that the pressure regulator fails, such that hydraulic oil is delivered continuously into the sub-systems, the system relief valve section of the pressure control valve will by-pass the pump flow to the return side of the system. The full flow pressure differential setting of the relief valve is 4750 psi.

3.1.7 Reduced Pressure Circuit (Fig. 1.1 and 1.7)

The emergency brakes and compensator (utility and flying control), pressurization operate at 1500 psi, originating at the pressure reducing valve section of the pressure control valve.

3.1.8 Filtration

All pressurized fluid, including that from ground servicing hydraulic power units, passes through a master high pressure filter of 40 (US) GPM capacity. The nose wheel steering sub-system has a 4 GPM high pressure type filter to protect the steering control valve. The armament pack sub-system has a 40 (US) GPM high pressure filter to protect the valves and the missile lowering jacks. All return fluid, including that from the pressure control unit (Fig. 1.1) and the compensator filling connection, passes through the 40 (US) GPM low pressure bowl-type filter on the bottom of the compensator (See Fig. 1.4 and Fig. 1.1). The 40 GPM filters are equipped with a self-sealing device which allows filter element replacement without draining of the system. All filters are of the 10 micron type and are equipped with relief valves to by-pass fluid around the filter element if the pressure drop across the element exceeds 50 psi.

3.1.9 Ground Servicing (Fig. 1.1)

Two ground service connections are provided, one on the pressure side and the other on the return side of the system. By connecting a ground power hydraulic unit, the system may be operated by an external source of power without operating the aircraft pumps. The low pressure service connection may also be used as a filling point for the system. The filter in the return line of the main flow path protects the pumps from any foreign matter which may enter the system during filling operation.

3.2 Landing Gear Sub-system

3.2.1 Landing Gear Description

The ARROW 2 aircraft has a tricycle landing gear consisting of a forward retracting nose gear with dual wheels, and main gear with two-wheeled bogies, which retract inboard and forward into the wing. The gear with their associated units are described in more detail in this section. The layout and activation of the doors is covered in Section 3.2.2.

In Section 3.2.3 the operation of the landing gear is described in detail, including the function of the landing gear selector valve, by-pass valve, shuttle valves, transfer valves and the pneumatic shut-off valve.

3.2.1.1 Nose Gear (Fig. 4.2)

3.2.1.1.1 General

(a) Upper Leg

The nose gear consists of a cantilevered strut, Y-shaped at the upper attachment points with a jack pickup lug and drag strut pickup on the starboard side of centerline. The drag strut, which has a mechanical downlock, is hydraulically unlocked to jack-knife upwards on retraction. A microswitch on the upper link is actuated in the downlocked position to indicate NOSE GEAR DOWN AND LOCKED on the cockpit landing gear indicator.

As both ends of the strut are self-aligning, a free-swivelling "dog-leg" hydraulic connection is required. A fairing door, hinged along the rear of the bay, is attached to the leg by links, near the forward edge.

(b) Lower Leg

The liquid spring shock strut is fully extended by a pneumatic spring during landing gear retraction. The lower portion of the gear, including shock strut, scissors and co-rotational nose wheels, can be turned as far as 55° on either side of centerline. (See Section 3.4 - NOSE WHEEL STEERING SUB-SYSTEM). Steering and shimmy damping is provided by a steering jack and valve and associated linkage on the forward side of the leg. Steering is hydraulically powered and is cable controlled from the pilot's rudder pedals.

3.2.1.1.2 Nose Gear Operation

The nose gear jack, on the forward face of the navigator's bulkhead, retracts to raise the gear upward and forward into the nose wheel well. The final portion of the jack retraction stroke is snubbed by an internal damper. On extension, the gear is allowed to "free fall" with a "runaround" circuit between the two ports on the gear jack. Outflow at the "UP" port is restricted by an orifice to slow down the gear during extension and the gear is snubbed at the end of the stroke by an internal damper.

3.2.1.1.3 Nose Gear Uplock

The nose gear uplock has a spring loaded hook which is hydraulically (or in emergency landing gear extension, pneumatically) unlocked to allow the nose gear to extend. The nose door sequencing valve is mounted on the uplock and actuated by the gear uplock roller which lifts a separate valve striker.

3.2.1.2 Main Gear (Fig. 2.14)

3.2.1.2.1 General

(a) Upper Main Gear Structure

The main gear trunnion lies between the front and centre wing spars at an angle of approximately 45° to the aircraft centerline. The main gear strut and the backstay are hung from this pivot which has a detachable coupling to enable removal from the spar pickup housings.

(b) Main Gear Leg Fixed Fairing

A large fairing door, to cover the outboard portion of the wheel well, is attached to the main strut and backstay by spring loaded collars. In the down position this fairing door lies at about 45° to the line of flight. A small pivot door, hinged to the wing outboard of the pivot, is opened by a linkage attached to it.

(c) Sidestay

A telescopic sidestay, attached to the midpoint of the main strut by means of a universal joint, has an internal downlock mechanically engaged and hydraulically unlocked, at the start of an UP selection. Due to the compound rotation of the upper joint, a 4-swivel special dogleg hydraulic connection is required. A microswitch, in series with one on the downlock in the main leg, is actuated when the sidestay is downlocked. When both switches are operated, a GEAR DOWN & LOCKED signal is given in the cockpit.

(d) Gear Shortening Mechanism

There is a shortening and twisting mechanism halfway down the leg which aligns the bogie beam and tie rod with the main strut backstay and sidestay to allow the gear to fit within the wing on retraction. It is mechanically driven by the gear rotation about the trunnion. The lower rotating portion of the gear is locked torsionally in the full down position, actuating the gear downlock microswitch mentioned in the last paragraph. During the first 9^{o} of retraction from the down position, no shortening or twisting occurs. For the next $5\frac{1}{2}^{o}$ the gleason teeth of the anti-rotation lock are disengaged with 0.65" of shortening. After the initial $14\frac{1}{2}^{o}$ retraction, twisting starts at the rate of 5^{o} per 1" of shortening up to a figure of 8.15" of shortening. No further twist takes place during the final 0.35" shortening travel.

(e) Shock Strut

Below the shortening mechanism are located the torque scissors and the shock strut, which is a liquid spring type. A recuperator mounted on the brake torque link replenishes the fluid level in the strut when necessary while the gear strut is fully extended.

(f) Bogie Beam and Tie Rod

The bogie beam, at each end of which is mounted a wheel and brake assembly, pivots about the bottom of the shock strut. Brake torque reaction links connect the brake discs to the strut above the bogie pivot. A spring loaded telescopic tie rod, with self-aligning ends, is attached between the upper leg and the horn on the forward end of the bogie. As soon as the aircraft weight comes off the wheels, the tie rod extends, tipping the forward end of the bogie down to the correct position for stowage.

3.2.1.2.2 Gear Retraction

The main gear retraction jack, located outboard of the main pivot, is attached to a lug on the backstay. The jack extends to raise the gear. The final portion of the gear retraction stroke is snubbed by an internal damper. Both ends of the jack have self-aligning bearings to cater for the flexibility of the structure and the pivot. Both ports of the jack are located at the head end. Spherical swivel joints are used in the two swivel dogleg hydraulic connections.

3.2.1.2.3 Gear Extension

The gear is allowed to "free-Fall" with a "runaround" circuit between the two ports on the jack. Outflow from the jack is restricted by an orifice in the HIGH PRESSURE port to slow down the gear extension. The final portion of the jack retraction (gear extension) stroke is snubbed by an internal damper.

3.2.1.2.4 Gear Uplock

The main gear uplock hook supports the stowed gear by means of an uplock roller on the aft side of the strut. In the uplock mounting case there is an uplock hook, spring loaded to the locked position, a hydraulic uplock release jack, and a door closing sequence valve, operated by a cam for protection from uplock roller overtravel. The uplock release jack is normally operated hydraulically from the GEAR JACK DOWN line, but on emergency landing gear down selection the tandem standby piston is operated pneumatically.

3.2.1.3 Sequencing

Each landing gear selection is divided into two phases:

UP SELECTION GEARS RETRACT AND LOCK UP
DOOR JACKS UNLOCK AND DOORS CLOSE
IN LOCKED UP POSITION

DOWN SELECTION DOORS OPEN AND LOCK DOWN
GEARS UNLOCK AND EXTEND TO
LOCKED DOWN POSITION

In any gear bay, the final movement of the unit in motion in the first phase, trips a mechanically operated sequence valve to start the second phase in operation, (regardless of the relative position of the corresponding units in the other bays). At any stage the selection may be reversed.

3.2.2 Landing Gear Door-Layout and Actuation

3.2.2.1 Nose Door

The nose gear door is hinged along the right side of the nose gear bay. In the GEAR UP condition, there is a gap between this door, and the fairing door attached to the leg which permits discharge of ventilating air from the nose gear bay and the compartments adjacent to it. The door is opened and closed by a single door jack.

3.2.2.1.1 Nose Door Jack

Due to the slope of the hinge line of the door the lower jack attachment point moves rearward during jack extension, requiring the use of self-aligning bearings at each end of the jack. The jack has an internal multi-stage downlock automatically released at the start of DOOR CLOSING. The gear-lowering sequence valve mounted nearby is linked to the door and is mechanically actuated when the door is locked open.

3.2.2.1.2 Nose Door Uplock Release Jack

Two uplock rollers, on the left edge of the nose door, engage uplock hooks interconnected through an uplock release jack with an internal return spring. Normal hydraulic and emergency pneumatic uplock release operation is provided by tandem annular pistons.

3.2.2.1.3 "Nose Gear Up and Locked" Microswitch

A microswitch, close to the door uplock hooks, is actuated by the door as it is locked up, causing the "UP" signal to show for the nose gear on the pilot's indicator panel.

3.2.2.2 Main Gear Door

The main door has a piano-hinge along the lower edge of the wing root rib and lies close to the fuselage side in its fully locked down position. It is designed to support the undercarriage in certain flight cases where the gear is raised off its uplock hook due to wing deflection.

3.2.2.2.1 Main Door Jack Assembly

The main door jack has a multi-stage internal downlock which is automatically released as pressure builds up in the DOOR CLOSING hydraulic line. In this installation, the rod end pivot point is fixed and the cylinder barrel travels during jack acutation.

Two mounting brackets attach the jack assembly to the wing root rib. The upper bracket, which terminates at its outboard end in a lug between the fork end of the piston rod, has a locking device which prevents the pivot bolt from shifting axially or rotating.

The stationary pivot bolt, has internal drillings, permitting the UP and DOWN lines to be connected directly to the flareless male end bosses. Two separate internal hydraulic passages lead down to either side of the piston.

The jack assembly will be supplied complete with non-interchangeable brackets.

3.2.2.2.2 Main Door Uplock Release Jacks

There are five uplock rollers on the perimeter of the door which engage hooks in the wheel well. In two cases, a pair of hooks are linked together and unlocked by a single uplock release jack. The third jack has only one hook to unlock. These jacks are designed to operate at a lower pressure than the door jack, hence the locks can be released before the pressure buildup in the door jack puts an additional load on the hooks.

3.2.2.2.3 "Main Gear Uplocked" Microswitch

A microswitch is actuated by each door. When it is locked up, an "UP" signal appears for that particular gear on the pilot's indicator panel.

3.2.3 Operation - Detail Description (Fig. 2.2 through Fig. 2.8)

3.2.3.1 On Ground (Power On) (Fig. 2.2)

Under this condition, the landing gear selector lever is normally in the DOWN position, and with the weight of the aircraft on the main gear, the ground safety microswitches on the gear scissors are actuated, removing power from the safety release solenoid and preventing the landing gear lever from being moved to the UP position.

With the selector lever in the DOWN position, the landing gear solenoid selector valve has electrical power applied to the DOWN solenoid, pressurizing the DOWN PRESSURE lines in the landing gear system, and also making pressure available for nose wheel steering (See Fig. 4.1 and 2.9).

Each gear downlock microswitch is depressed, giving a DOWN signal for that particular gear on the pilot's indicator panel.

Each free-fall gear has only return line pressure on each side of its actuator piston. The transfer valve connects both ports of the actuator to system return via the landing gear UP line.

Each door jack is extended and held in position by an internal mechanical downlock

3.2.3.2 Take-Off, Up Selection (Fig. 2.3 and Fig. 2.4)

When the selector lever is moved to its UP position, power is applied to the UP solenoid on the selector valve.

As pressure rises in the UP lines, the gear downlocks release; then, at a higher pressure, the gears start to retract.

In each wheel bay, the final travel of the gear to its uplock position operates a door-closing sequence valve, applying pressure to the door jack, which releases its internal downlock and closes the door.

3.2.3.3 In Flight (Fig. 2.5)

When all three landing gear doors are locked up, the landing gear selector valve is automatically de-energized. This puts the valve in the NEUTRAL position, and the landing gear UP and DOWN lines are connected to system return.

Should any of the door UP locks inadvertently unlock, the landing gear selector valve is immediately automatically selected to the "UP" position until the three doors are relocked, when it again becomes de-energized.

3.2.3.4 Normal Down Selection (Fig. 2.7 and Fig. 2.8)

When the pilot moves the landing gear selector lever from UP to DOWN, pressure builds up in the DOWN lines, operating the door uplock release jacks. At a higher pressure the door jacks extend, opening the doors.

After a door jack has extended beyond the first downlock stage, (which prevents subsequent blow-back beyond that point, but not further extension) it actuates a gear-lowering sequence valve permitting pressure to build up in the DOWN line to the gear. The gear uplock is then released.

Pressure on the SYSTEM DOWN port of the transfer valve connects both sides of the gear jack with return via the SYSTEM UP port, thus providing a "run-around" circuit. The gear falls under gravity and assisting airloads, with its extension rate limited by the fixed orifice in the jack. An internal damper snubs the final portion of the gear extension. The nose gear jack extends so that the rod displacement volume flows into the transfer valve via the SYSTEM UP port. The main gear jack retracts, and the piston rod displacement volume flows out of the transfer valve into the UP lines. As long as electrical power is available, power is continuously applied to the DOWN solenoid on the selector valve until the next UP selection.

When the weight of the aircraft depresses the main wheel struts at least 3/4", the ground safety microswitches are actuated. (See 3.2.3.1.1). When the nose gear is supporting aircraft weight, the circuit for nose wheel steering can be completed. (See 3.4).

3.2.3.5 Emergency Landing Gear Extension (Fig. 2.6)

When a stop on the landing gear selector panel is pushed aside, the lever can be moved into the EMERGENCY DOWN position. The lever then opens a shut-off valve mechanically, supplying nitrogen at a pressure of 5000 psi to the EMERGENCY DOWN lines.

In the gear bays, nitrogen pressure operates three gear uplock release jacks, three gear transfer valves, seven gear door uplock release jacks, and via shuttle valves, three door jacks. This starts the landing gear and the doors in operation at about the same time. Each gear then falls in the same manner as for normal operation.

When EMERGENCY LANDING GEAR DOWN is selected, an emergency by-pass valve shuts off the line from the UP port of the selector valve and by-passes the landing gear UP lines around the selector valve to the main utility return. This arrangement ensures that an emergency landing gear down selection can still be made in the event of the landing gear selector valve being jammed mechanically in an UP selection, even though there is no hydraulic or electrical system failure.

3.2.4 Landing Gear Position Indicator Lights

An individual green light for each landing gear is provided on the pilot's instrument panel to signal that the applicable landing gear is locked DOWN.

An individual red light for each landing gear is provided on the pilot's instrument panel to signal that the pertinent landing gear is neither locked UP nor locked DOWN.

The corresponding red and green lights, for each individual landing gear, are out when the applicable landing gear door is UP and locked.

A single red light is provided on the landing gear selector lever. This light will show steady red when the landing gear is in motion or if a downlock or uplock inadvertently unlocks.

This light is out when the landing gear is locked UP or locked DOWN.

This same light will show flashing red when both throttles are back, the aircraft is below 10,000 feet and UP landing gear is still selected. This is the warning to prevent an inadvertent wheels-up landing.

NOTE: The term landing gear has been used in the general sense and includes both landing gear leg and landing gear door as applicable.

3.3 Speed Brakes Sub-system (Fig. 3.1)

3.3.1 General

Two speed brakes, located on the underside of the aircraft just aft of Sta. 485, can be extended, retracted or held in any intermediate position by two hydraulic jacks, controlled by a valve which is operated by a three-position switch on the inboard throttle lever.

3.3.2 Extension

The speed brakes will extend when the selector switch is placed in SPEED BRAKE EXTEND position.

3.3.3 "Blow In" Relief

If increasing airloads raise the jack pressure above the cracking setting of the integral relief in the selector valve, the speed brakes will "blow in", relieving the pressure until a new jack force/hinge moment equilibrium is reached.

3.3.4 Hold

The speed brakes will hold at the position attained when the selector switch is placed in the HOLD position.

3.3.5 Retraction

The speed brakes will retract when the selector switch is put in the speed brake retract position. Power is kept on the valve retract solenoid when both the speed brakes are fully retracted.

3.4 Nose Wheel Steering Hydraulic Sub-system (Fig. 4.1 through Fig. 4.6)

3.4.1 Nose Wheel Steering Control

Nose wheel steering is accomplished by a double-ended hydraulic jack mounted on the bottom of the nose wheel strut. The jack is operated by a steering control valve, mechanically linked to the pilot's rudder pedals.

To obtain steering, the nose gear scissors microswitch must be de-actuated by weight on the nose gear, and the pilot must depress the steering selector button on his stick grip to open the solenoid operated selector valve.

This sends high pressure fluid to the control valve, and thence to the jack, which will then respond to the pilot's rudder pedal movements. A follow-up mechanism returns the control valve spool to neutral when the nose wheels have reached a position corresponding to the rudder pedal position. (See Fig. 4.6).

3.4.2 Steering Angle

The nose wheels can be steered through an angle of 55° on either side of centerline, enabling the aircraft to be turned on a 30' turning radius as shown on Fig. 4.3.

3.4.3 Control Disconnection - Hydraulic

Movement of the rudder pedals actuates the spool of the steering control valve through an internal hydraulic clutch when pressure is available from the steering selector valve. To engage the clutch the rudder pedal position must be synchronized with the nose wheel position.

When steering has not been selected by the pilot, or when the nose gear scissors are fully opened, the electrical circuit is interrupted and the selector valve is in the NORMAL position. With no hydraulic pressure, the steering valve is automatically declutched, allowing free rudder pedal movement. This also permits the nose wheel to caster under ground reaction forces, when towing, or when taxiing with brakes only, without using steering.

3.4.4 Mechanical Control Run

From the rudder pedal quadrant in the nose wheel well, cables run back toward the navigator's bulkhead. One pulley is located forward, the other to the rear of the bulkhead. The cables run down to a mechanical disconnect pulley on the nose gear pivot axis at the centerline of aircraft, which keeps the cables taut while the gear is moving from an extended to a retracted position. On the leg itself, the two cables run down to the mechanical follow-up linkage on the steering valve.

3.4.5 Shimmy Damping

When steering is not being used, the system pressure is shut off at the unpowered solenoid selector valve. Both ports on the control valve are connected to system return.

When shimmying forces displace the piston, building up pressure at the one end of the jack, the fluid has to pass through the restrictor at that end, up through the control valve spool and the return pressure passage, then down through the other one-way restrictor in the free flow direction. Centering springs inside the steering jack help return the wheels to a neutral position.

Shimmy damping is also available when nose wheel steering is engaged.

3.4.6 System Plumbing Connections

The pressure for nose wheel steering is drawn off the landing gear DOWN line in the nose wheel bay. This line has pressure on it at all times on the ground while the engines are running.

Inside the PRESSURE port, on the steering control valve, is a 4 GPM high pressure filter which protects the steering control valve, and the steering jack downstream of it.

The return line from the steering control valve passes through the solenoid selector valve before teeing into the NOSE GEAR UP line. This line is normally connected to system return when the aircraft is on the ground. During an UP selection, system pressure is applied through the return ports on the solenoid valve and into all the fluid passages in the control valve and jack. This assists in centering the wheels before retraction of the nose gear is complete.

3.5 Wheel Brakes Hydraulic Sub-system (Fig. 5.1 and Fig. 5.2)

3.5.1 General Description

Differential and proportional braking is provided by toe pressure on the pilot's rudder pedals actuating two brake control valves via cable runs to the top rear of the armament bay. Brake pressure lines are routed from the valves to the wheel bays and down the main landing gear legs to the brake units on the two-wheeled bogies.

3.5.2 Special Features

3.5.2.1 An anti-spin braking circuit automatically applies the brakes during UP selection of the gear.

3.5.2.2 An emergency braking system provides differential and proportional braking in the event of failure of normal utility pressure, without any additional action on the part of the pilot.

3.5.3 Braking Pressures

Each brake control valve has two sections, a normal and an emergency section. Utility system pressure, nominally at 4000 psi, is supplied to the NORMAL port, and a nominal 1500 psi from the reduced pressure circuit of the utility hydraulic system is supplied to the EMERGENCY port.

For normal braking, increasing the toe pressure on the rudder pedals gives increasing brake pressure up to a maximum of 2550 psi. The 1500 psi maximum available pressure in the emergency condition is sufficient for effective braking at aircraft landing weights.

3.5.4 Brake Units (Fig. 5.3)

The brakes are of the multiple disc type. Pressure is applied by several pistons, with spring loaded return to overcome the system return pressure when braking pressure is released.

Wheels and tires may be changed without disturbing the brake lines.

3.5.5 Brake Lines on Main Gear Leg (Fig. 5.2)

Swivel fittings are used in the brake lines on the main gear to cater for geometry changes. Due to the shortening and rotation of the lower half of the gear, and the restricted installation space, a swivelling, sliding trombone assembly is also required.

3.5.6 Pressure Warning Lights

If the pressure in the normal utility system falls below 1000 psi, the UTILITY warning light will glow in the cockpit. At about the same time, the by-pass spool in the brake control valve shifts over to provide emergency braking. If the pressure in the emergency braking accumulator should fall below 1600 psi the EMERGENCY BRAKING warning light will glow, indicating that emergency braking will not be available.

3.6 Armament Hydraulic Sub-system

Full details of this system are given in brochure 72/Systems 19/40.

3.7 Alternating Current Power Pack

This power pack provides A.C. power during double engine flame-out. It supplies 1.4 KVA at 115 volts 400 C.P.S. for the aircraft damping system, telecommunication and certain flight instruments.

It consists of an alternator driven by a constant speed hydraulic motor fed from the 4000 psi main hydraulic pressure line.

Its operation is controlled by a solenoid stop valve in the pressure line to the hydraulic motor. This valve is wired so that normally the solenoid is de-energized and the valve closed.

On failure of the normal A.C. power supply, this valve is energized causing it to open. Pump pressure then drives the hydraulic motor which, in turn, drives the alternator thus producing A.C. power.

The valve is wired through the nose gear leg scissors switch to prevent needlessly energizing this valve on the ground when the engines are off. The scissors switch is wired through the ground test switch to provide for ground testing of the A.C. power pack.

3.8 Ground Servicing (Figs. 1.1 and 1.2)

3.8.1 Requirements - General

Ground equipment must be attached to the external disconnect couplings of the aircraft hydraulic systems to perform the following servicing tasks:

1. Filling of the utility hydraulic and flying control hydraulic systems.

2. Refilling the compensators after they have been bled of any entrapped air.
3. Operating of any one of the systems (without running the engines) for checkout or trouble shooting.
4. Recharging both 200 cubic inch floating piston accumulators in the utility system.

3.8.2 Ground Servicing Equipment Requirements

The following two units are required to perform the servicing tasks listed above:

1. A mobile hydraulic power unit, complete with motor driven pumps, reservoir, pressure gauges and hose connections to couple up to the aircraft systems. This equipment is to recharge the accumulator and to power each hydraulic system when the engines are shut down.
2. A hydraulic charging and bleeding trailer consisting basically of a hand pump with hose connections and self-sealing couplings. This equipment is required for filling the compensators on any of the three aircraft systems.

APPENDIX I

PUMP CIRCUIT

Avro Part No.	No. Per A/C	Description	Spec. No.	Vendor
7-1956-23	1	Filter - 40 GPM	E 353	Parmatic Eng.
7-1956-37	1	Compensator	E 316	Loud Machine Works
7-1956-353	1	Valve - By-pass Control	E 469	Garret Mfg.
7-1956-383	1	Valve - By-pass	E 471	Garret Mfg.
7-1956-569	1	Valve - Shut Off	E 510	Marotta Valve
7-1958-12	2	Accumulator	E 210	Sprague Eng.
7-1958-51	1	Valve - Pr. Regulator	E 462	Electrol Inc.
7-1994-12	1	Valve - Dump	E 342	Vinson Mfg.
7-1956-15027	1	Heat Ex. Oil-Air		Garret
7-1956-15028	1	Heat Ex. Oil-Air		Garret
7-1958-15021	1	Valve - Pr. Control	E 569	Vinson
7-1958-15023	2	Pump - Const. Delivery	E 458	Vickers

LANDING GEAR

Avro Part No.	No. Per A/C	Description	Spec. No.	Vendor
7-1900-11	6	Valve - Sequence	E 308	Adel
7-1952-12	1	Jack - N/G Door	E 331	Jarry Hydr.
7-1952-13	1	Valve - Emergency L/G	E 313	W. Kiddie
7-1952-14	1	Bottle - Air Storage	E 335	W. Kiddie
7-1952-16	3	Valve - Shuttle	E 315	Hydra Power
7-1952-22	2	Elbow - Swivel	E 310	Barco Mfg.
7-1952-24	1	Jack - N/G Door Uplock	E 381	Fairey Aviation

Avro Part No.	No Per A/C	Description	Spec. No.	Vendor
7-1952-25	2	Elbow - Swivel	E 310	Barco Mfg.
7-1952-29	2	Elbow - Swivel	E 310	Barco Mfg.
7-1952-31	1	Valve - Pneumatic	E 396	Aviation Elec.
7-1952-194	1	Valve - Fixed Orifice	E 499	Gar Precision
7-1952-195	1	Valve - Flow Regulator	E 430	Gar Precision
7-1952-203	1	Swivel Joint	E 361	Barco Mfg.
7-1952-204	1	Swivel Joint	E 361	Barco Mfg.
-205	1	Swivel Joint	E 361	Barco Mfg.
7-1962-23	2	Jack - M/G Door	E 320	Dowty Equip.
-65	2	Valve - Flow Controller	E 430	Gar Precision
-67	2	Valve - Fixed Orifice	E 499	Gar Precision
7-1952-15021	3	Valve - Transfer		Aviation Elec.
-15025	1	Jack - N/G	E 568	Jarry
-15023	1	Valve - N/W Steering Selector		Jarry
7-1956-15011	1	Valve - L/G Selector	E 564	Weston
7-1962-15023	2	Jack - M/G Up-lock	E 305	Dowty
-15025	6	Jack - M/G Door Up-lock	E 304	Dowty
-15021	1	Jack - M/G L.H.	E 570	Jarry
-15022	1	Jack - M/G R.H.	E 570	Jarry
WHEEL BRAKES				
7-1954-11	1	Valve - Brake Control	E 314	Hydra Power
7-1992-107	2	Valve - Shuttle	E 467	Hydra Power

Avro Part No.	No. Per A/C	Description	Spec. No.	Vendor
SPEED BRAKES				
7-1956-7	2	Jack - Speed Brakes	E 357	Jarry Hydr.
7-1956-13	1	Valve - Selector	E 359	Weston Hydr.

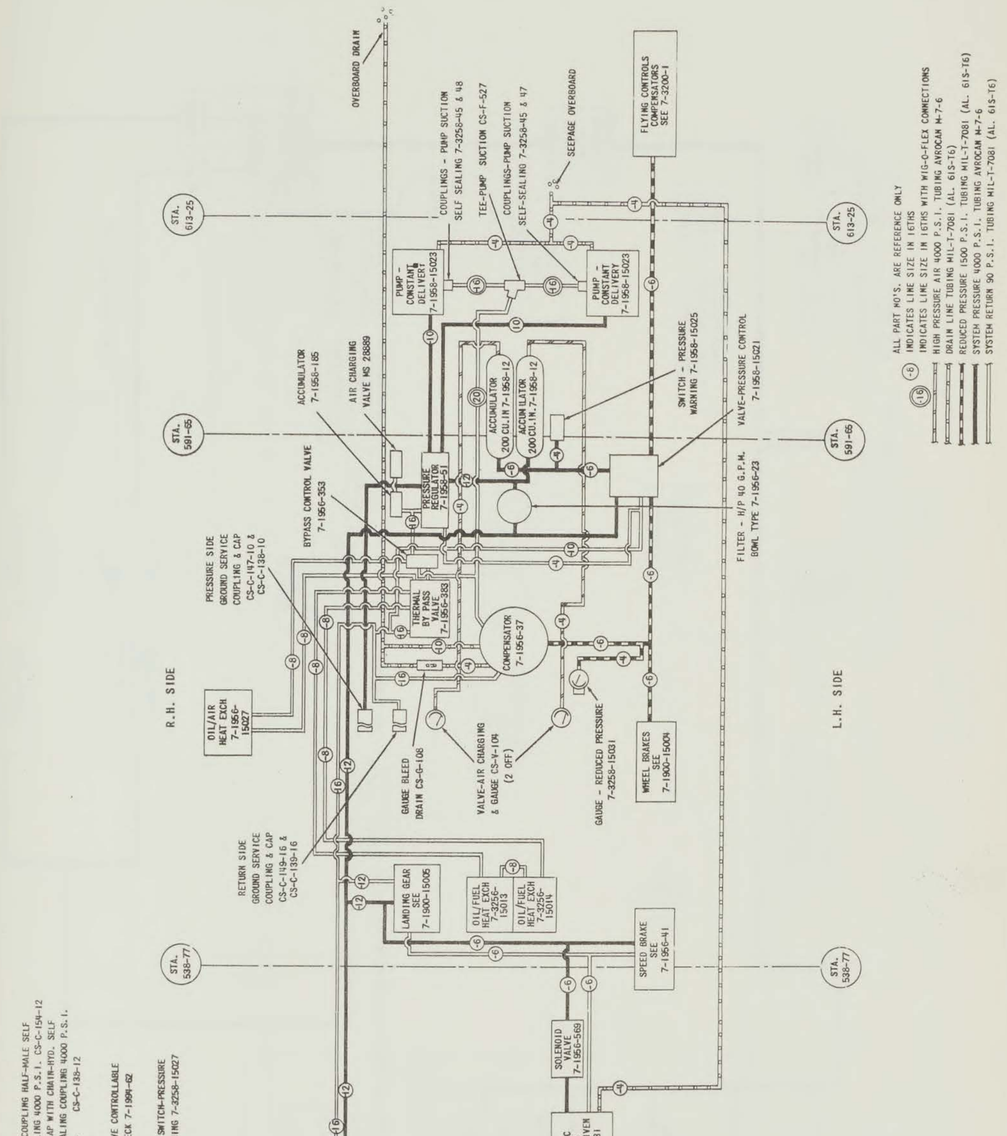

FIG. 1.1 DIAGRAMMATIC UTILITY HYDRAULIC SYSTEM

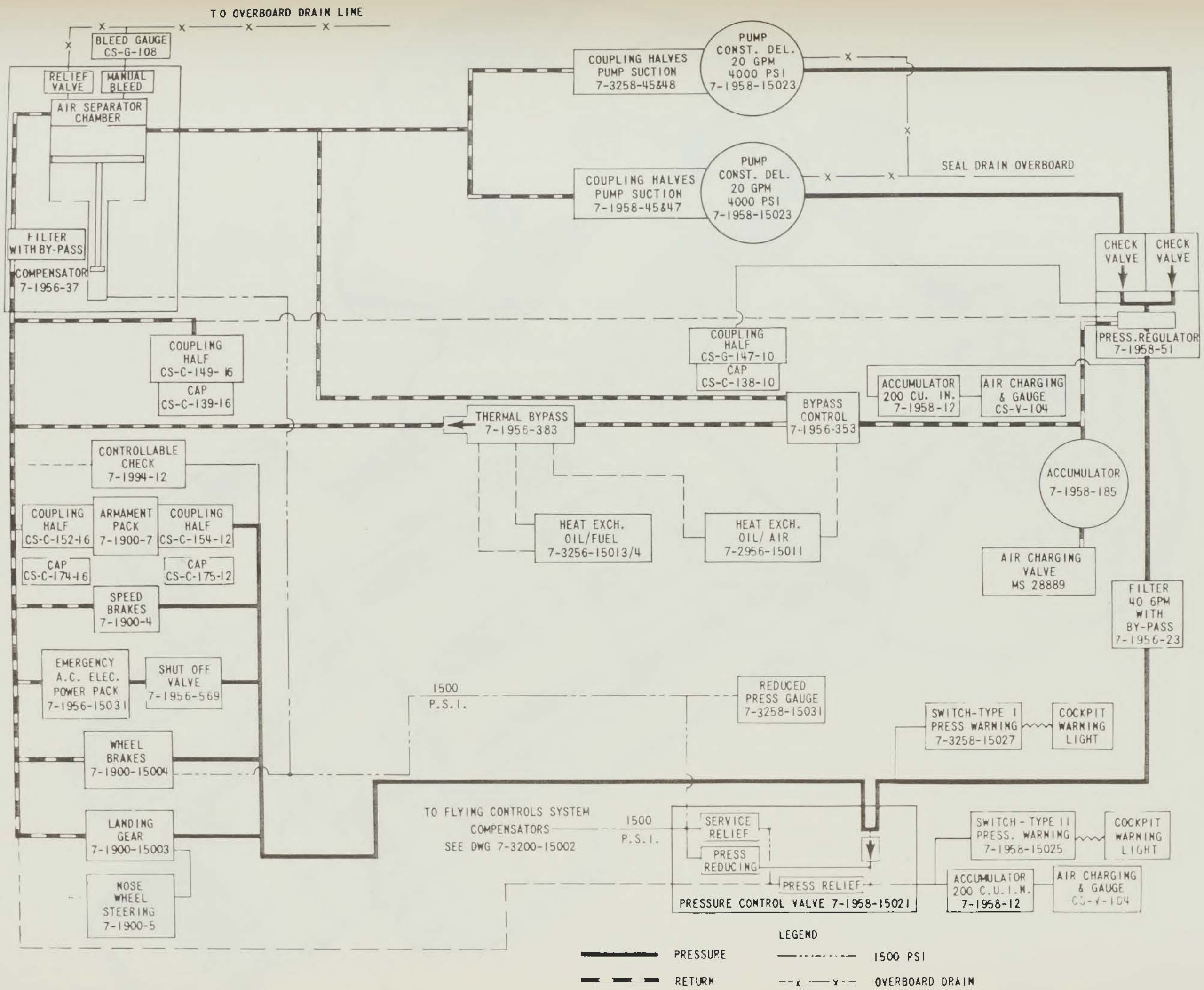

FIG. 1.2 UTILITY HYDRAULIC SYSTEM

AVRO ARROW

SECRET

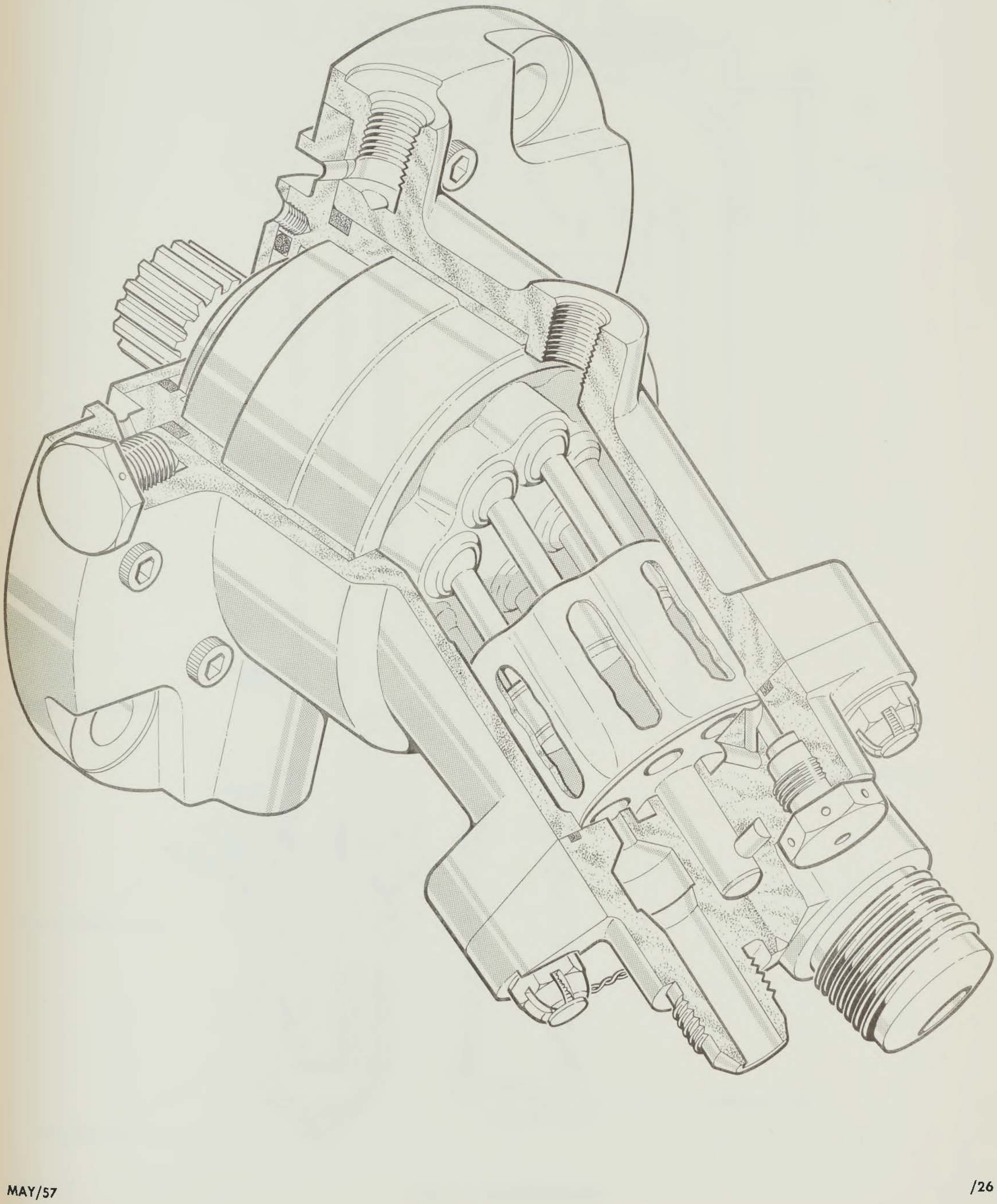

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FIG. 1.3 FIXED DISPLACEMENT PUMP

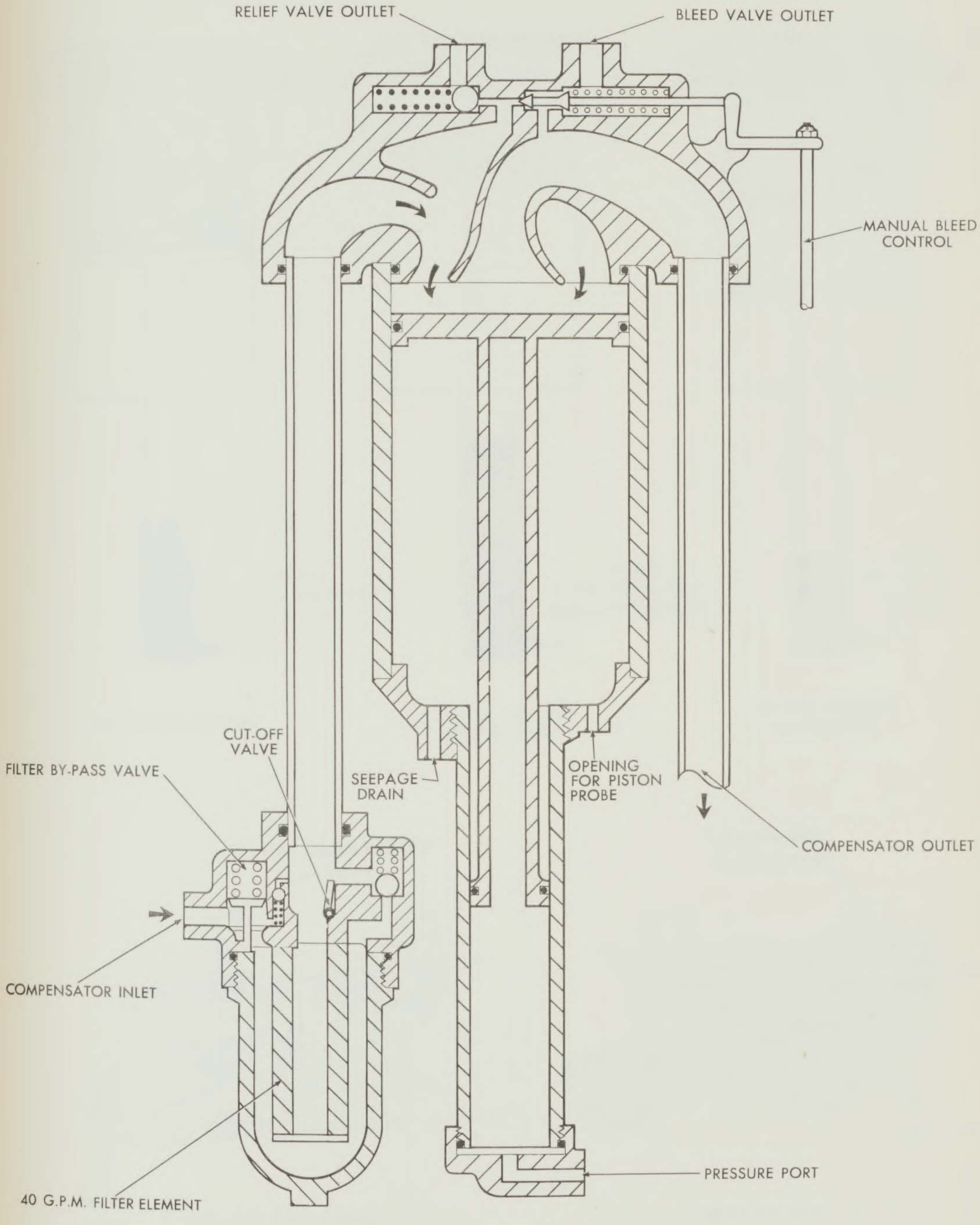


FIG. 1.4 COMPENSATOR

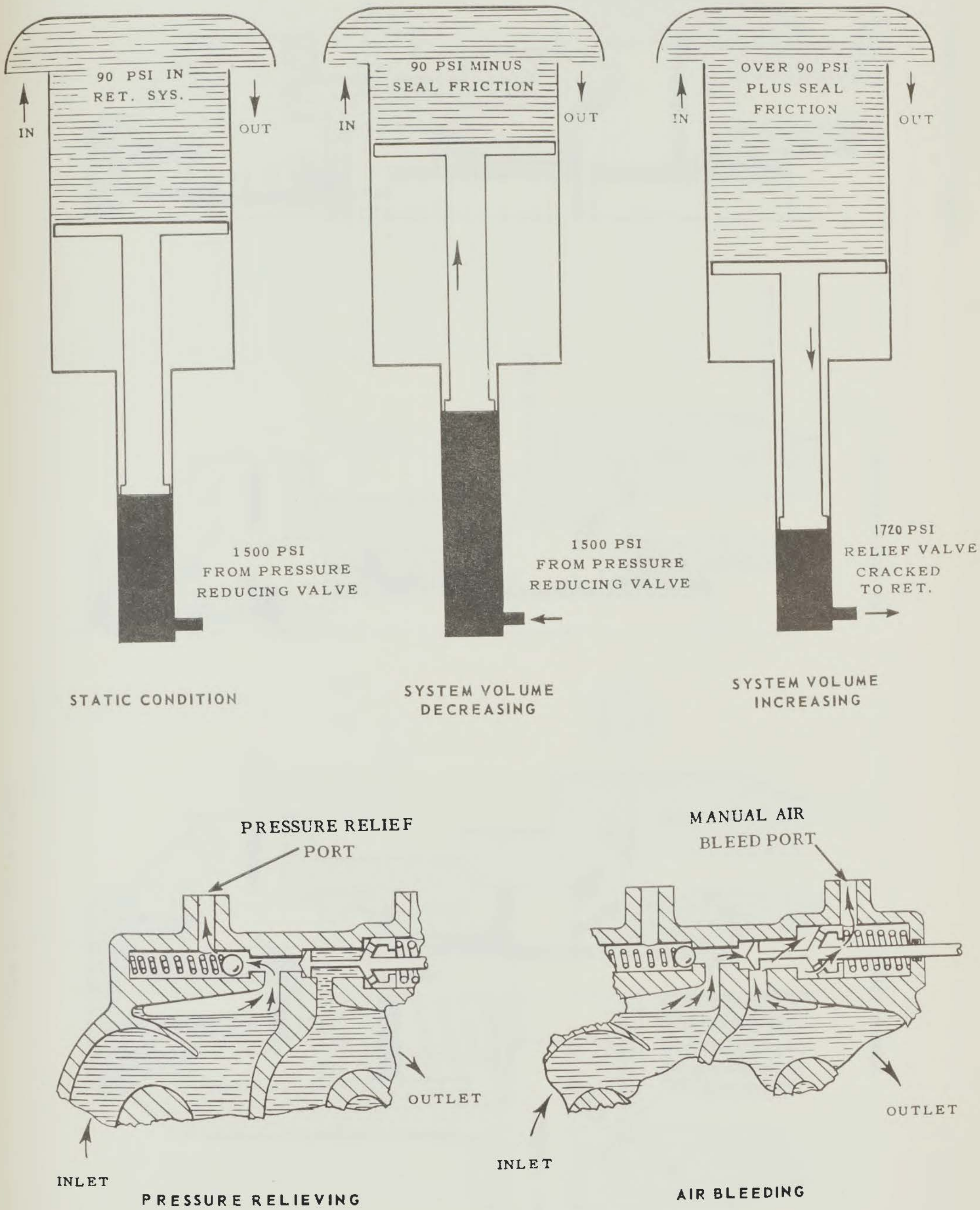


FIG. 1.5 UTILITY HYDRAULIC SYSTEM COMPENSATOR FUNCTIONING

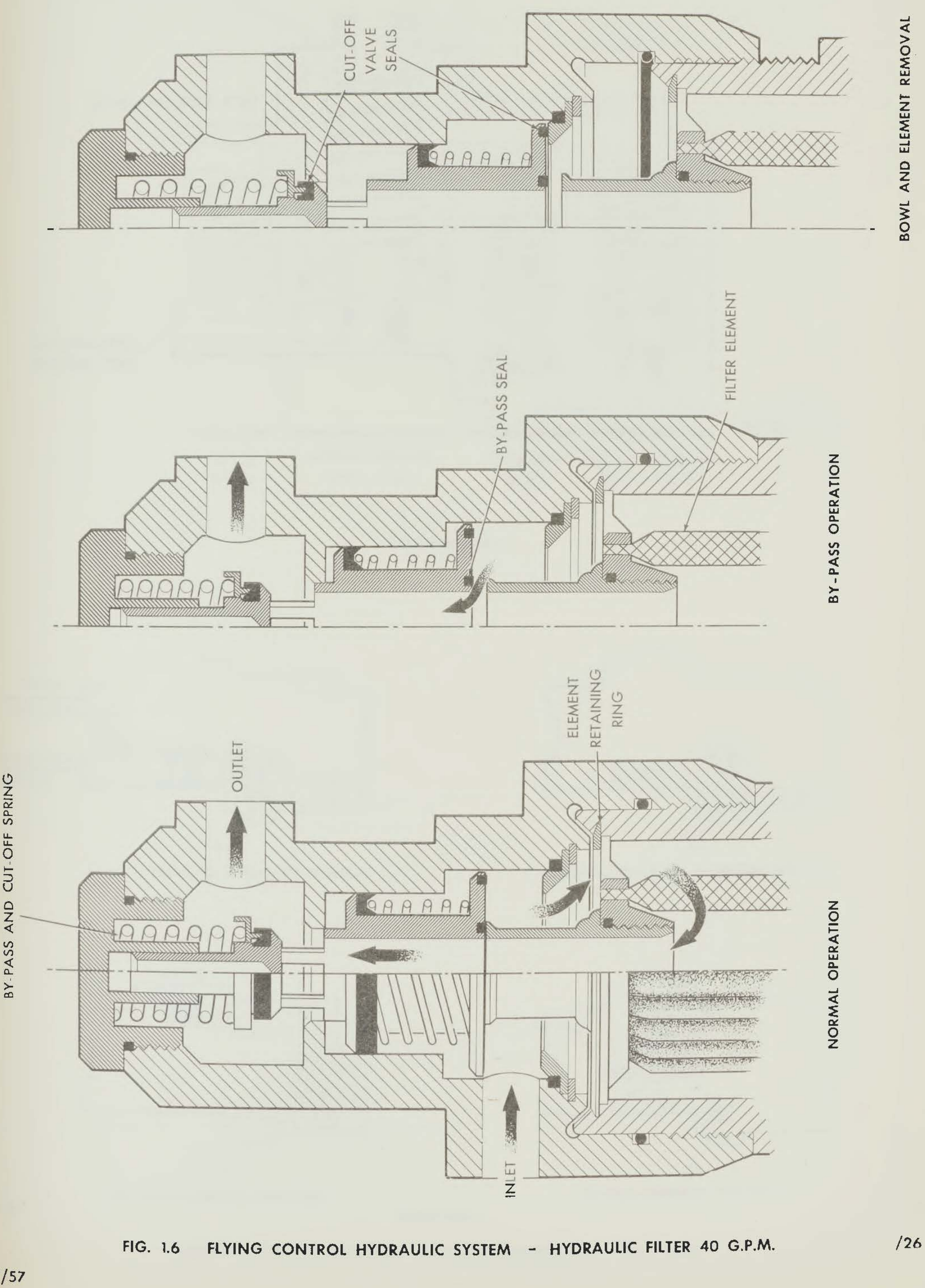
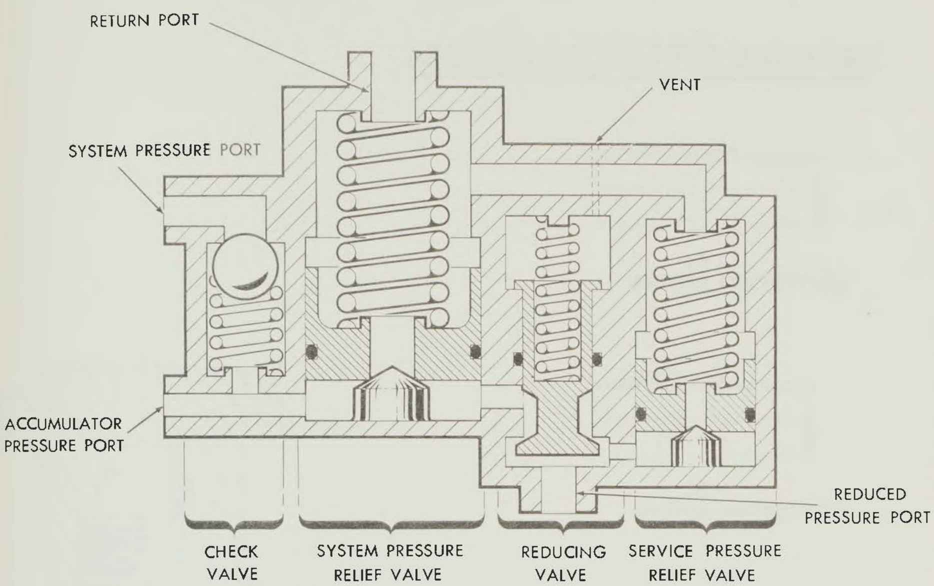
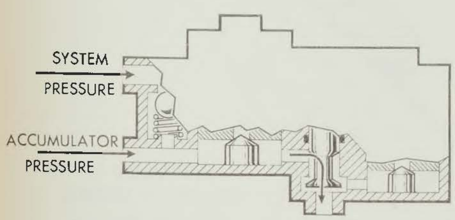


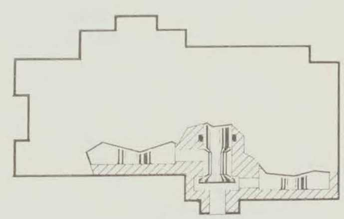
FIG. 1.6 FLYING CONTROL HYDRAULIC SYSTEM - HYDRAULIC FILTER 40 G.P.M.



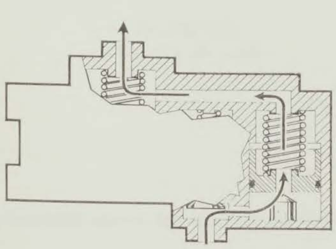
DIAGRAMMATIC



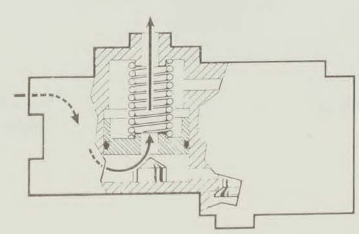
(A)
REDUCED PRESSURE RISING TO NORMAL



(B)
SYSTEM & REDUCED PRESSURES NORMAL



(C)
REDUCED PRESSURE RELIEVING

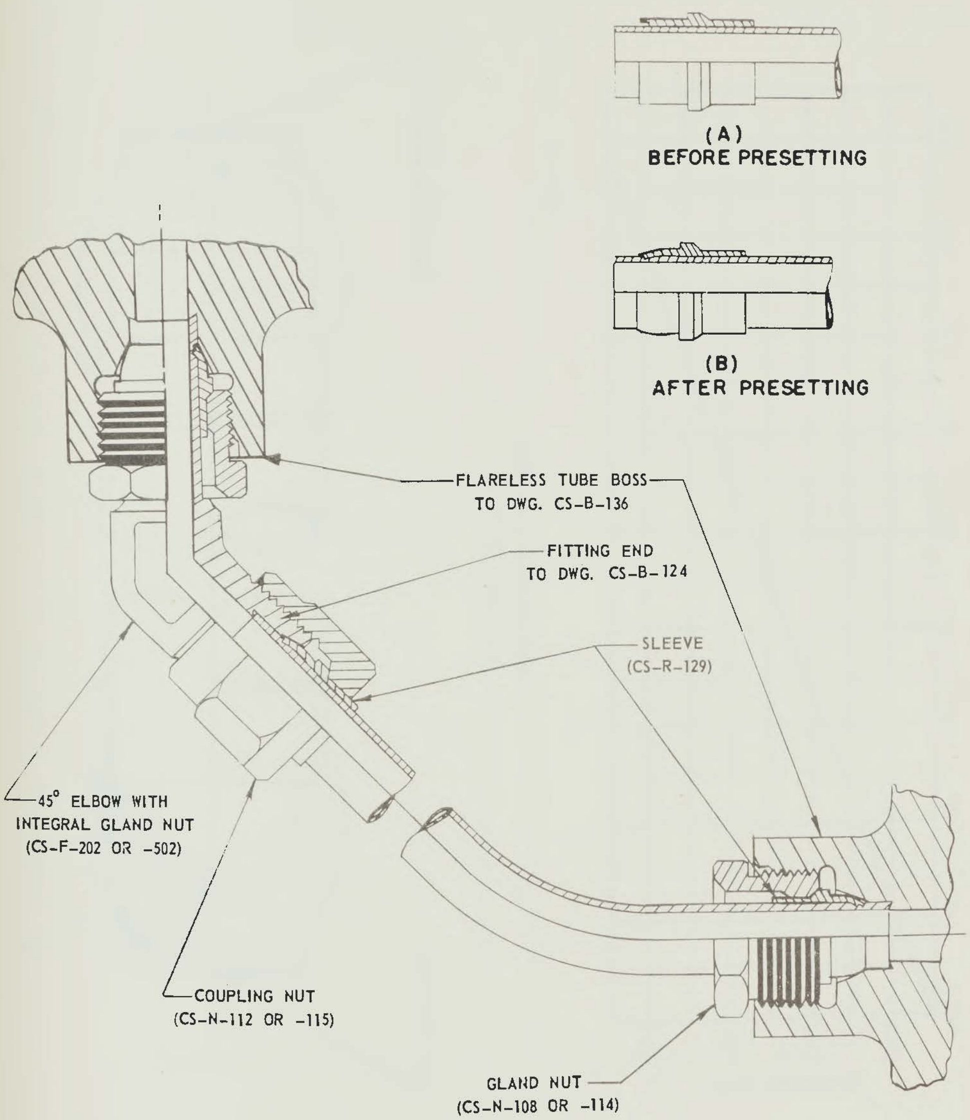


(D)
SYSTEM PRESSURE RELIEVING

OPERATION

FIG. 1.7 UTILITY HYDRAULIC SYSTEM - PRESSURE CONTROL VALVE

ASSEMBLY OF SLEEVE AND TUBE



NOTE: CS NUMBERS REFER TO AVRO STANDARD DRAWINGS.

FIG. 1.8 FLARELESS TUBE CONNECTIONS

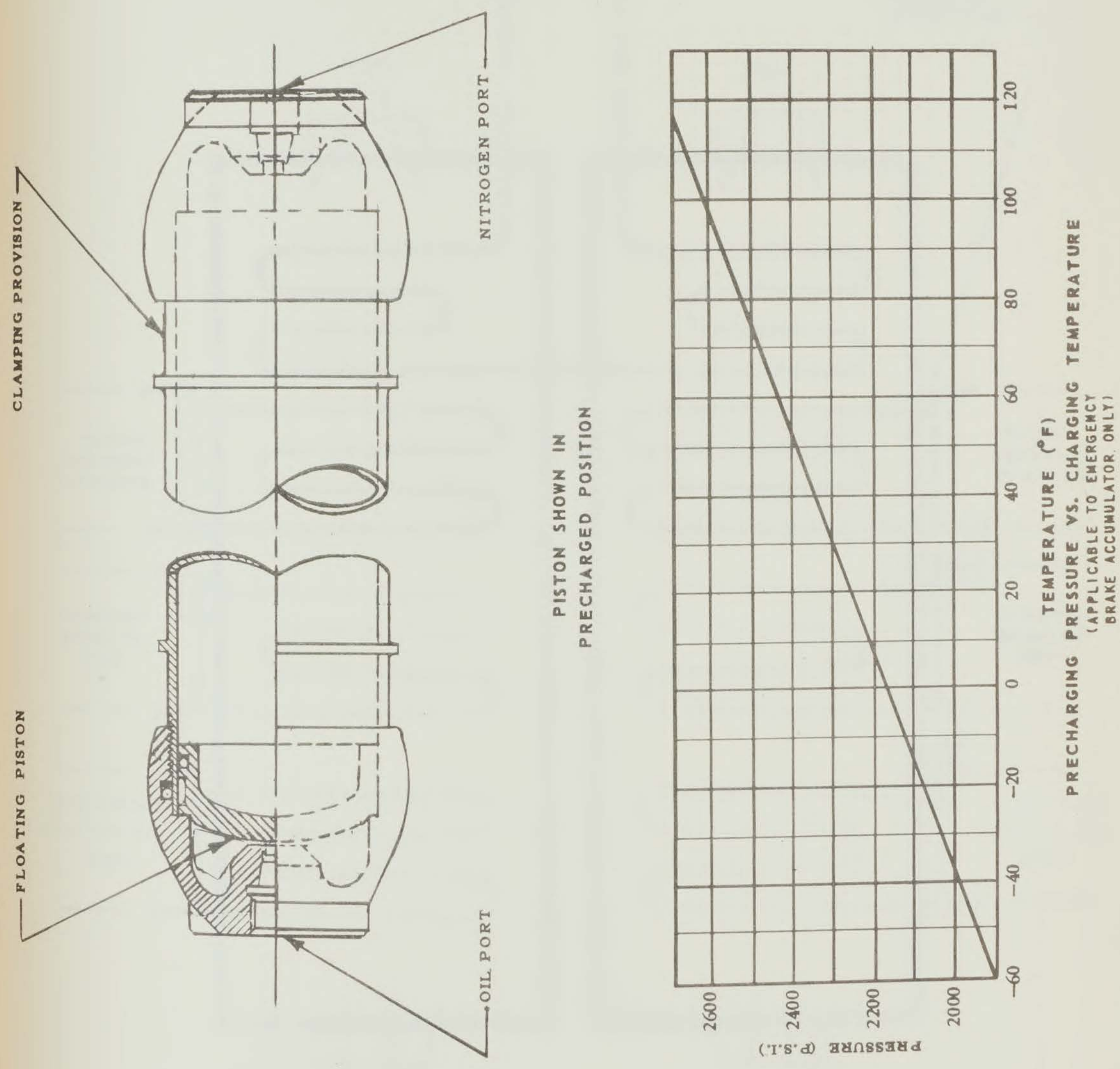


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FIG. 1.9 ACCUMULATOR - FLOATING PISTON TYPE

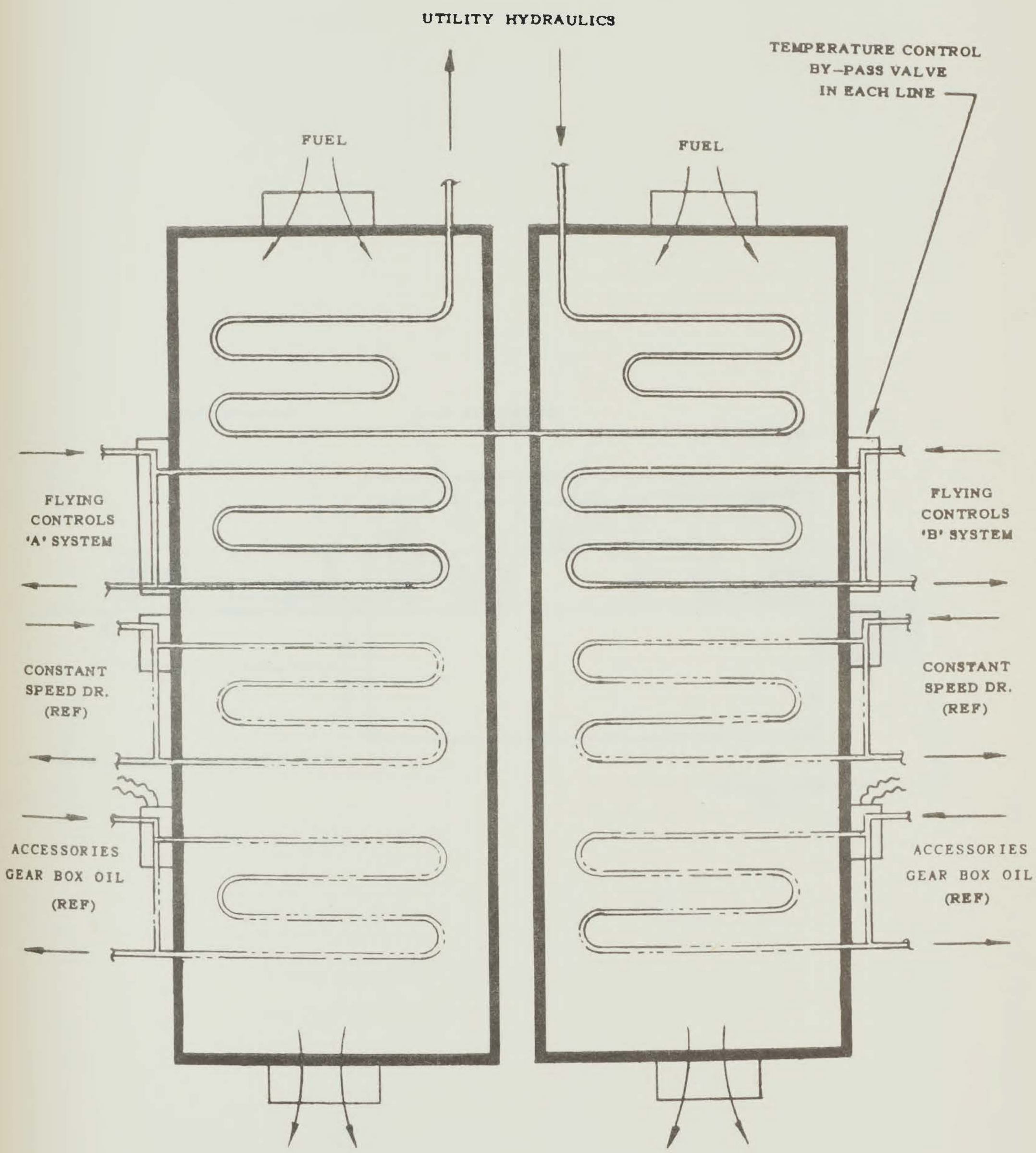

FIG. 1.10 HEAT EXCHANGER OIL TO FUEL

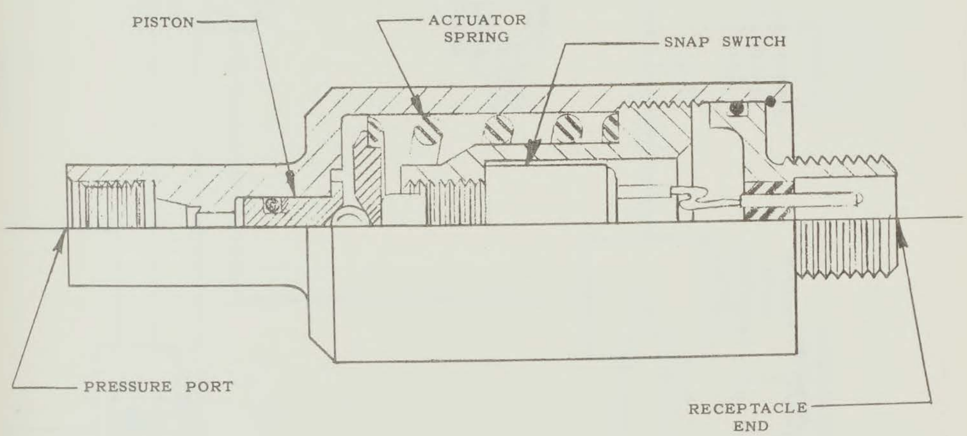

FIG. 1.11 HYDRAULIC PRESSURE SWITCH

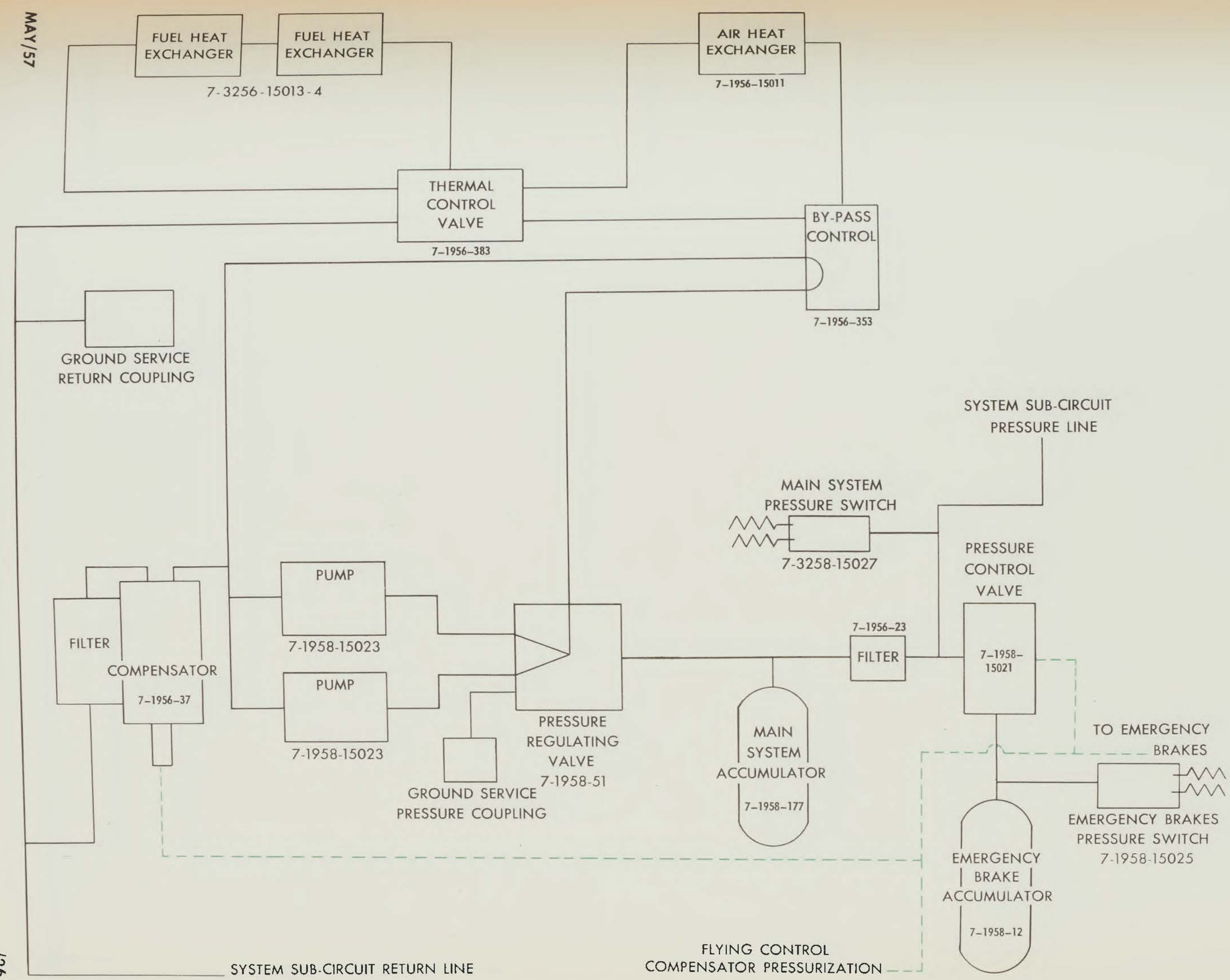

FIG. 1.12 POWER CIRCUIT BLOCK DIAGRAM

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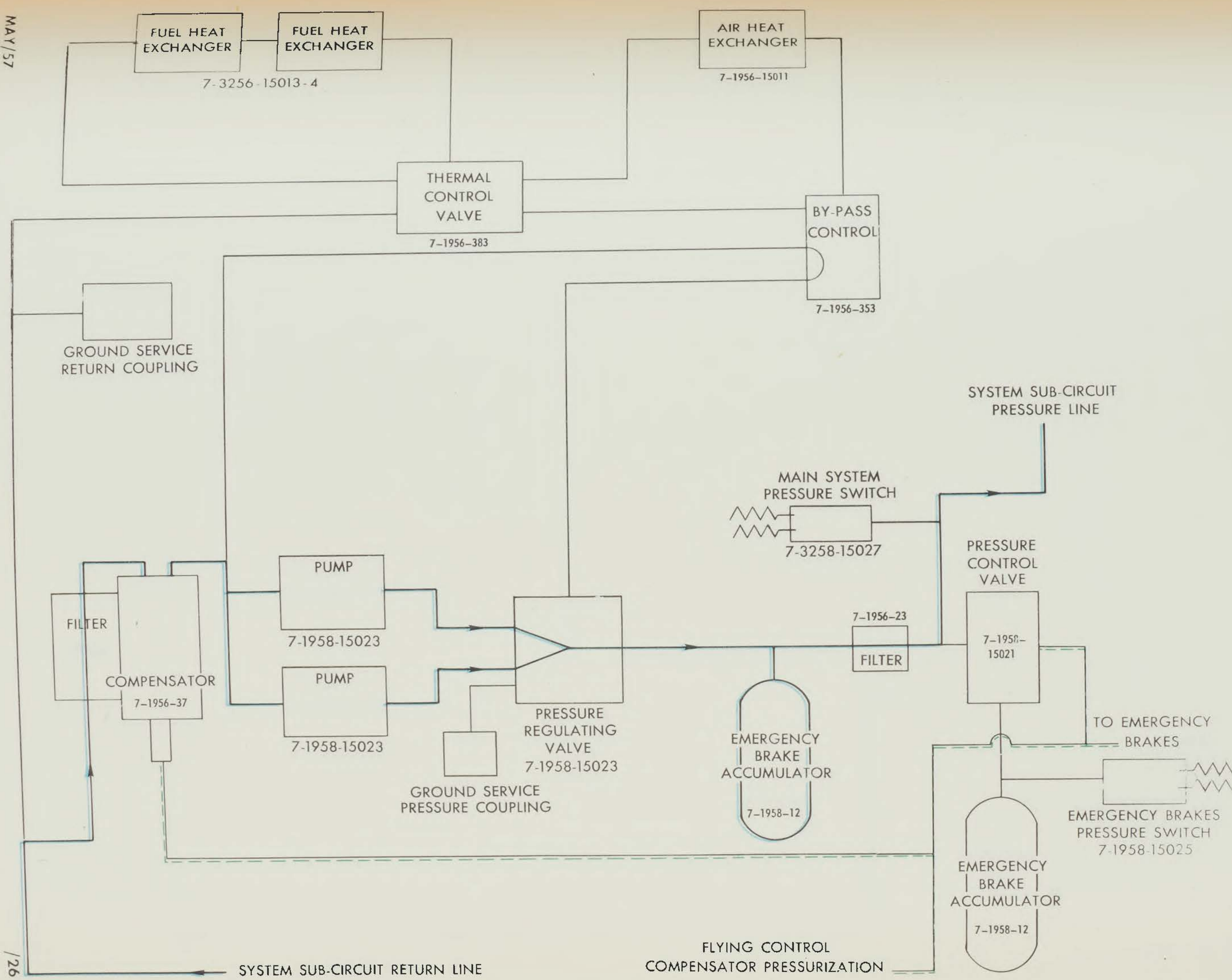


FIG. 1.13 FLOW PATTERN IN THE LOADED CIRCUIT

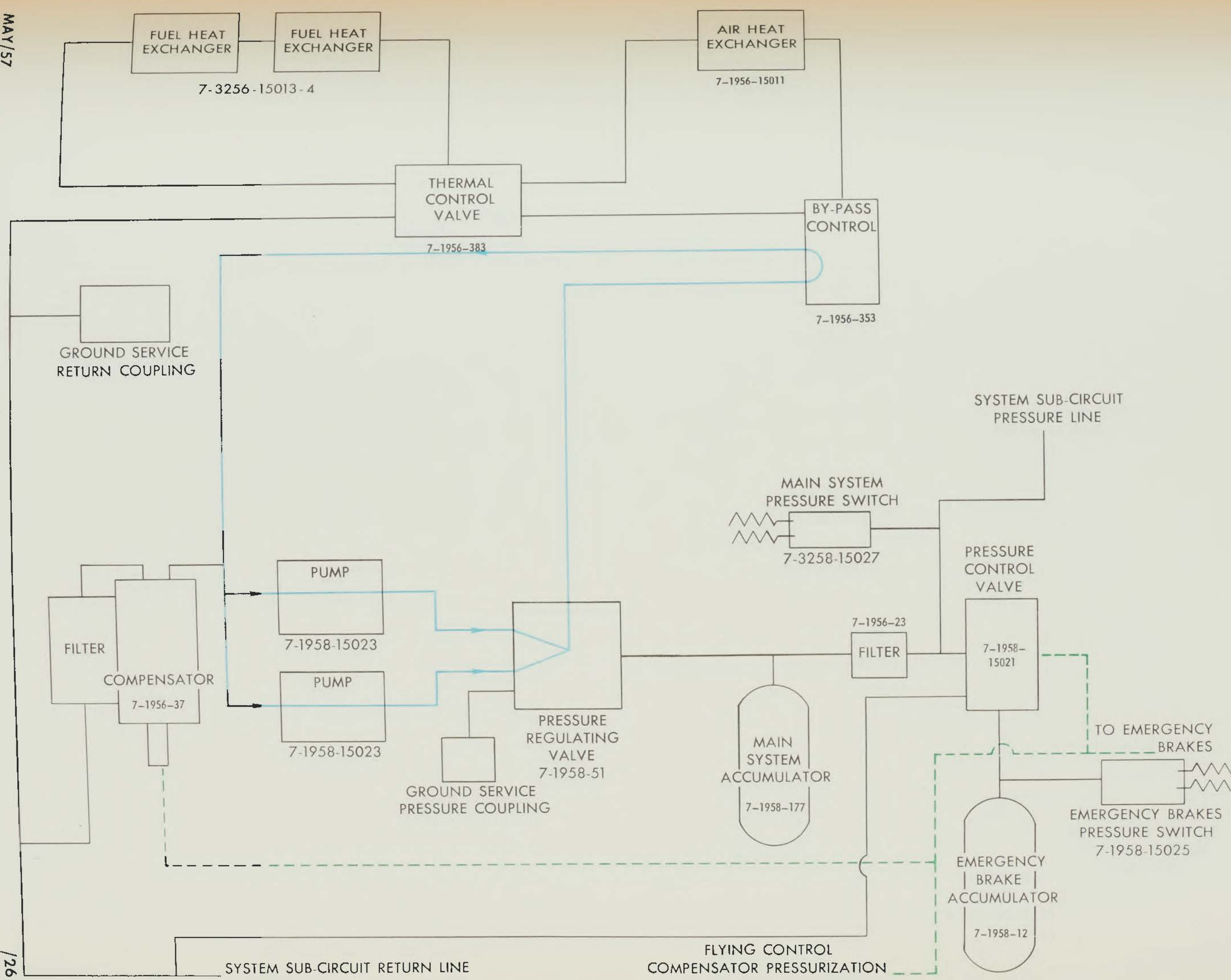


FIG. 1.14 TYPICAL FLOW PATTERN UNLOADING CIRCUIT -65°F TO +90°F

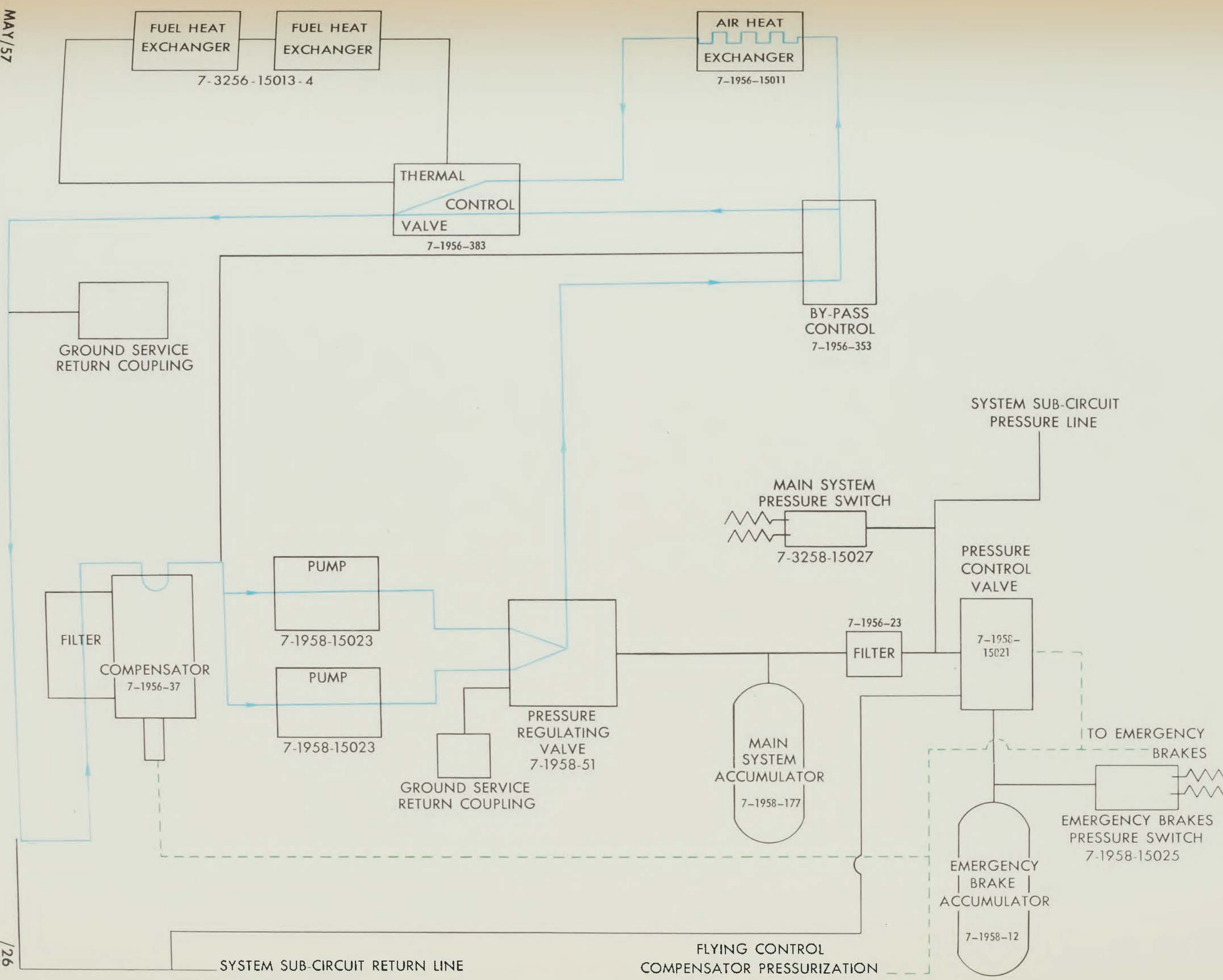


FIG. 1.15 TYPICAL FLOW PATTERN UNLOADING CIRCUIT 90°F TO 213°F PUMP INLET TEMPERATURE

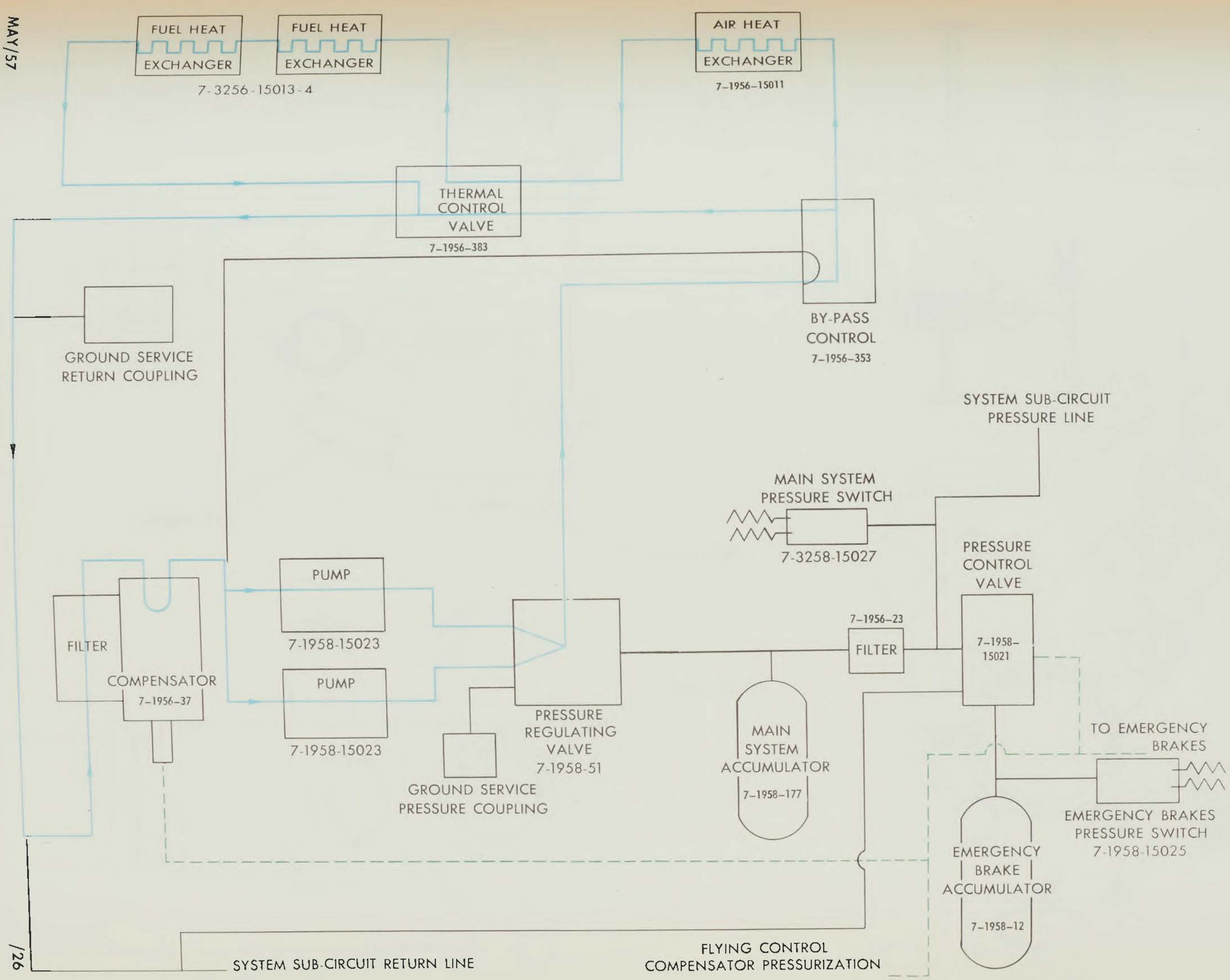


FIG. 1.16 TYPICAL FLOW PATTERN UNLOADING CIRCUIT 214°F TO 230°F PUMP INLET TEMPERATURE

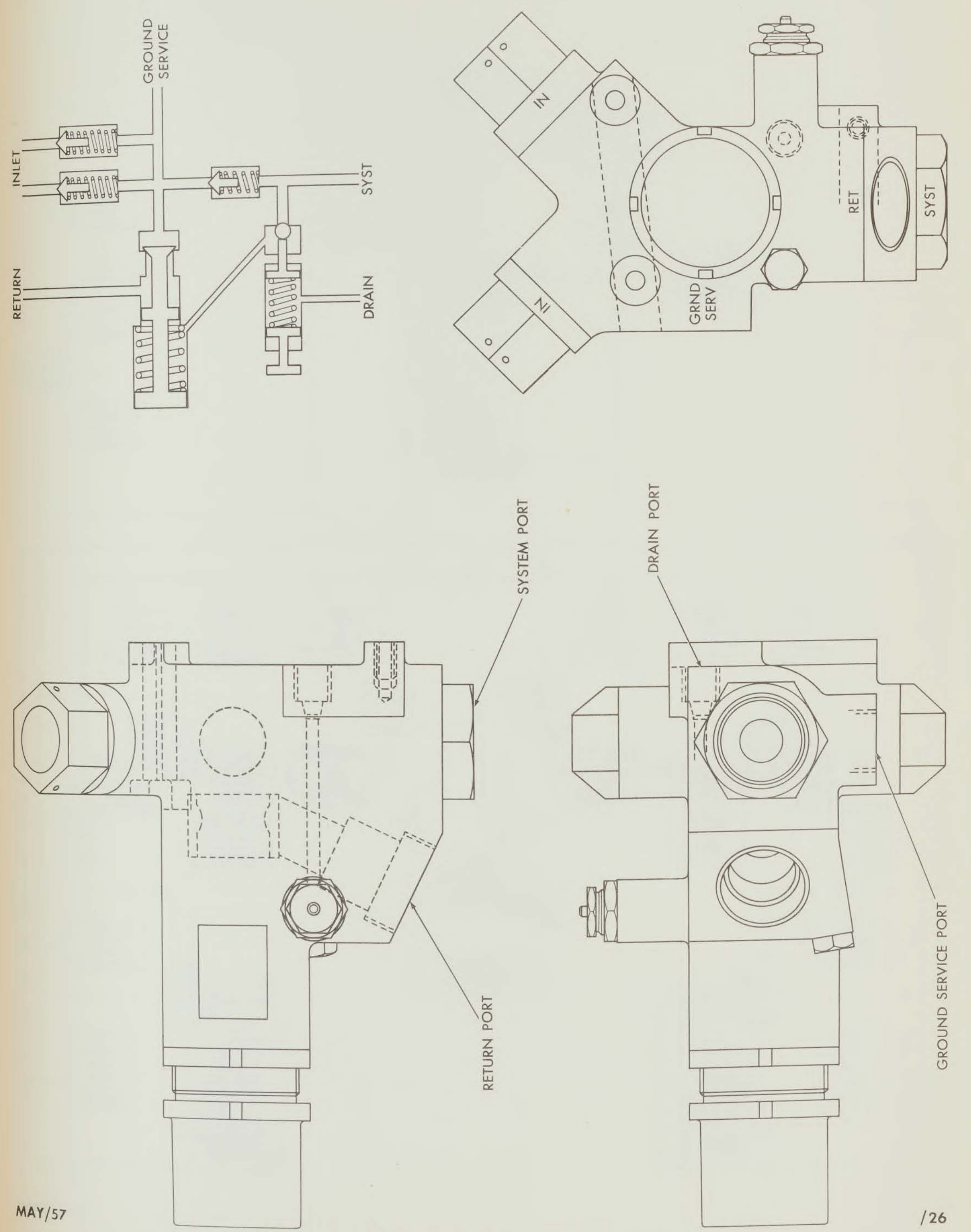


FIG. 1.17 PRESSURE REGULATING VALVE

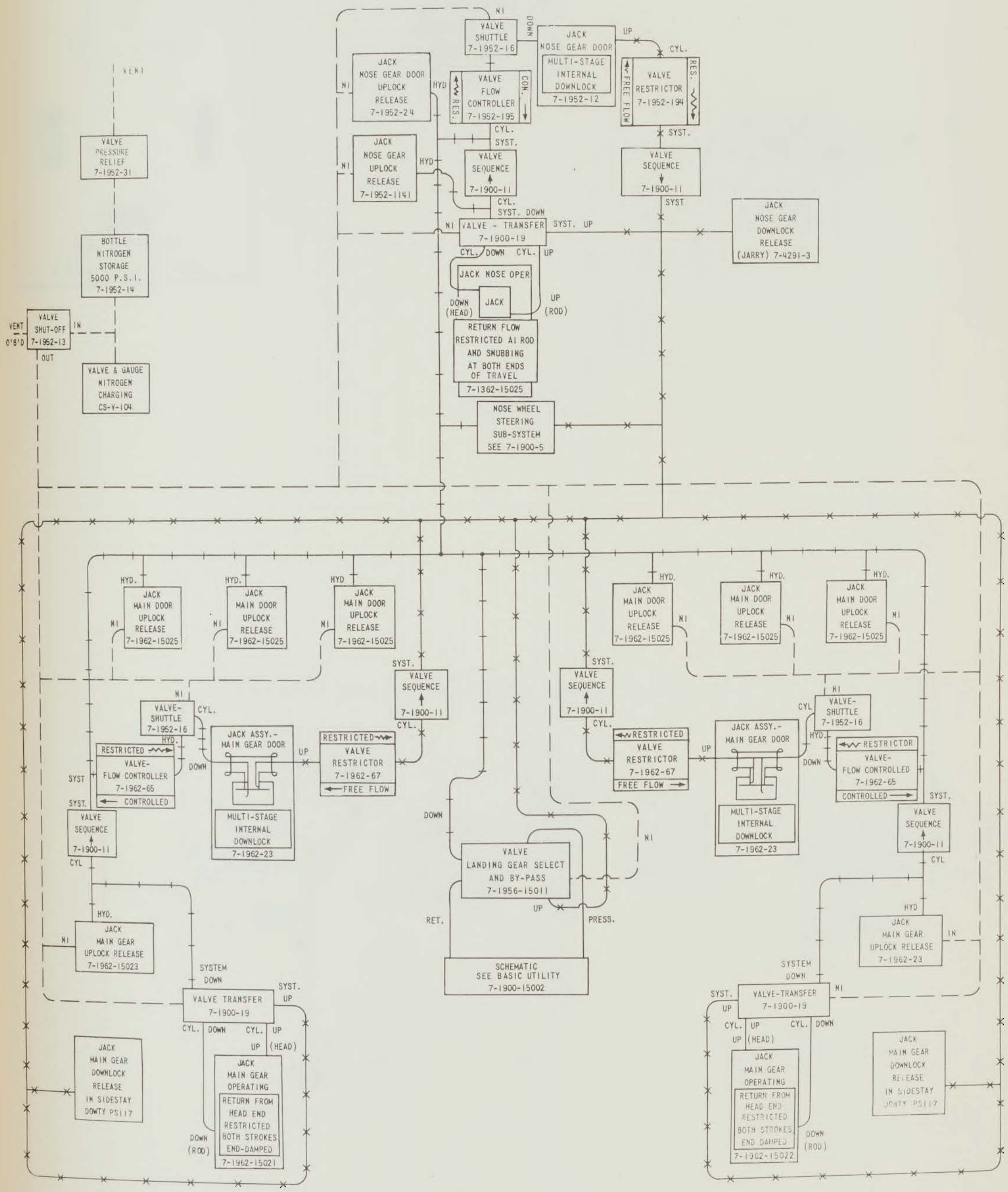


FIG. 2.1 SCHEMATIC LANDING GEAR SUB-SYSTEM

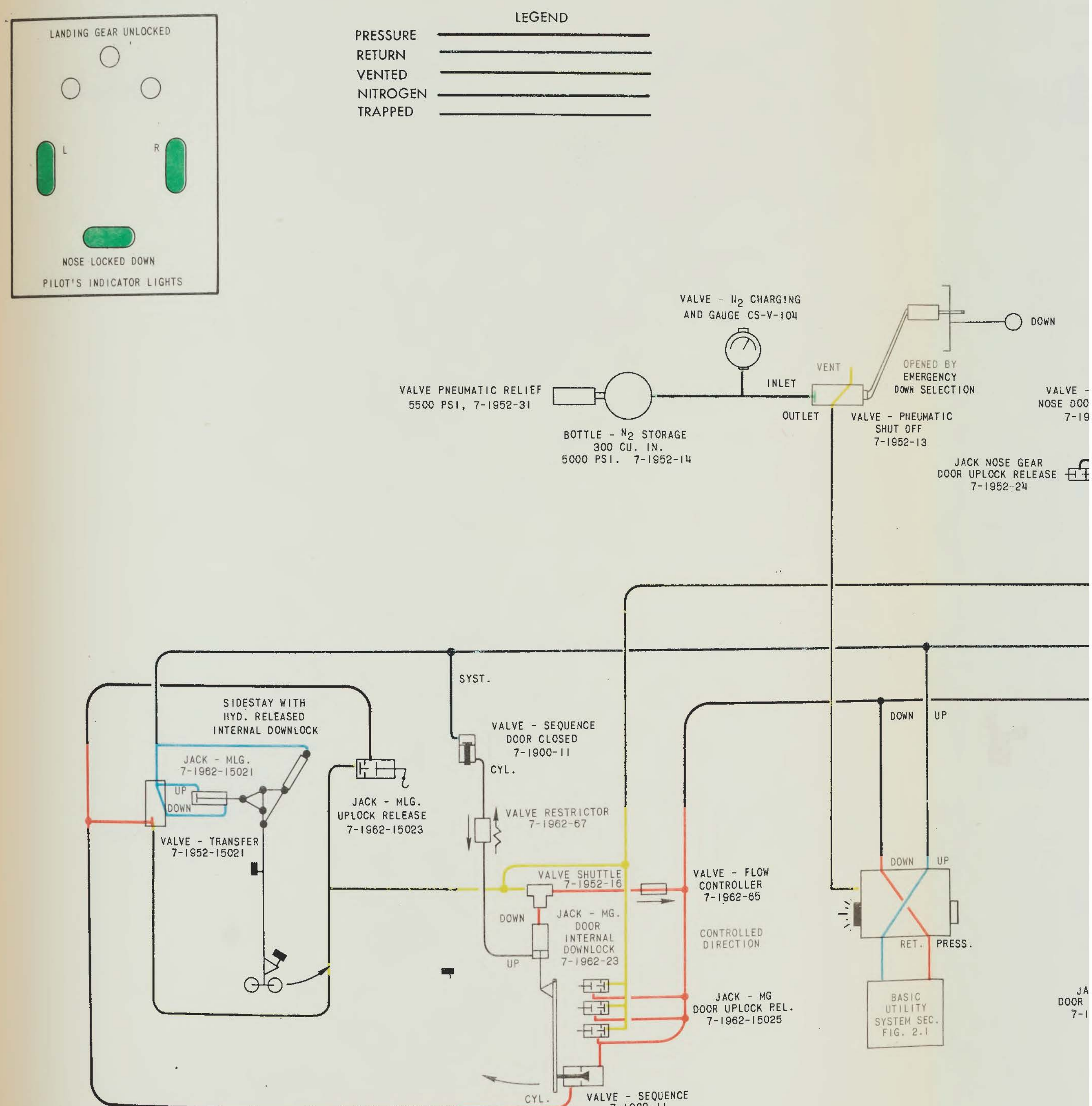


FIG. 2.2 ON GROUND-DOORS AND GEAR LOCKED DOWN

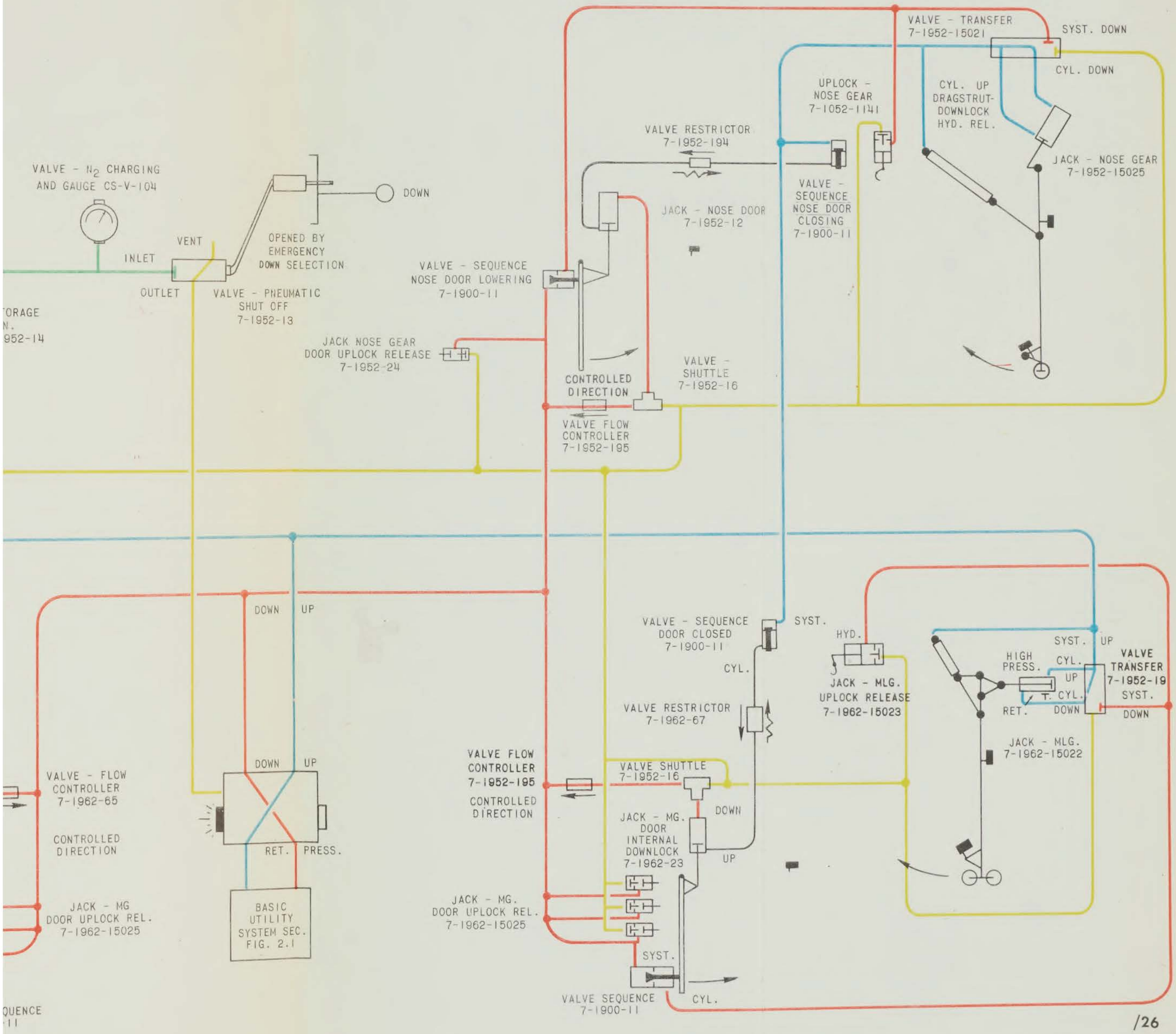


FIG. 2.2 ON GROUND-DOORS AND GEAR LOCKED DOWN

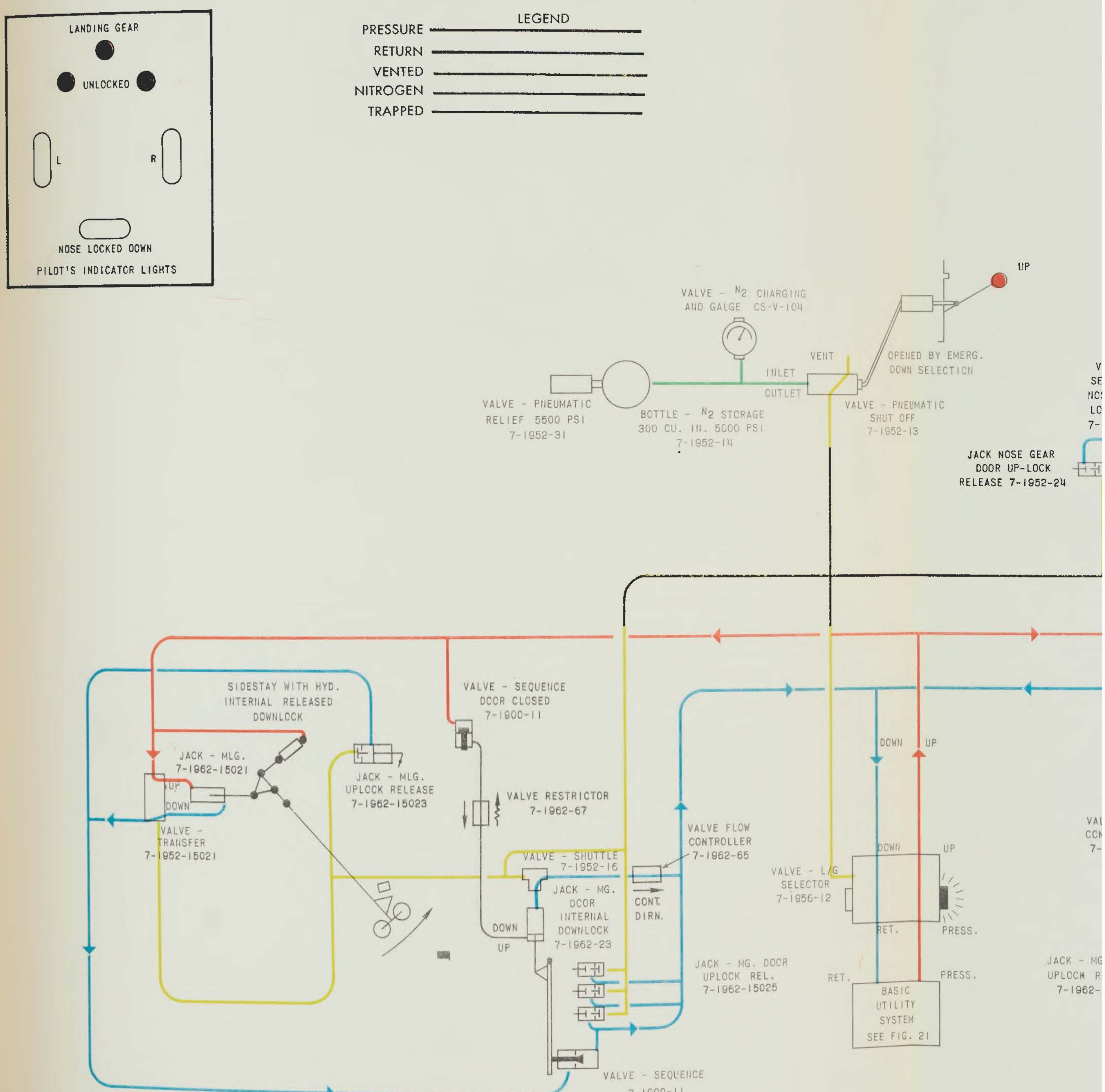


FIG. 2.3 UP SELECTION-DOORS LOCKED DOWN, GEARS RETRACT

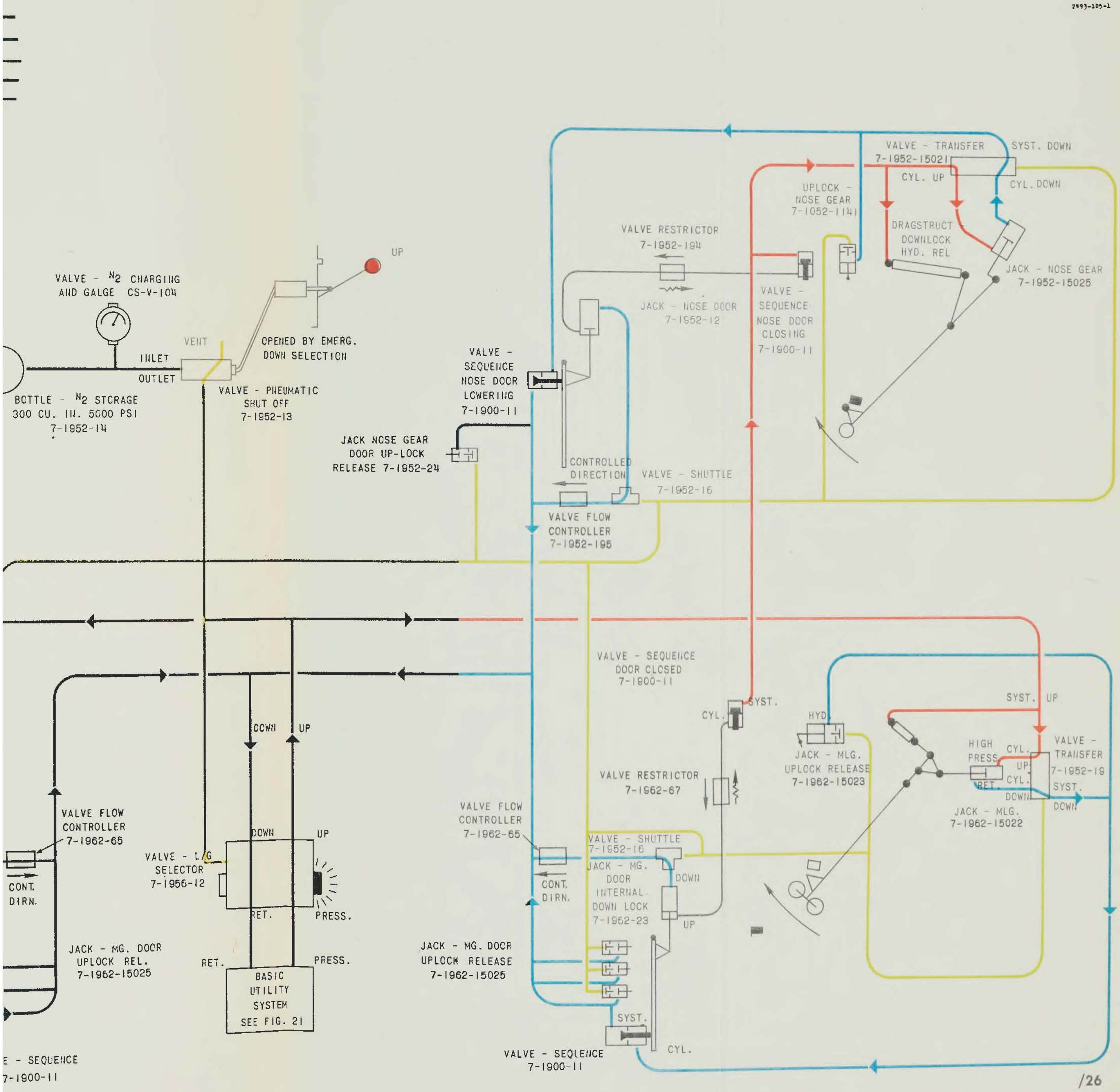


FIG. 2.3 UP SELECTION-DOORS LOCKED DOWN, GEARS RETRACTING

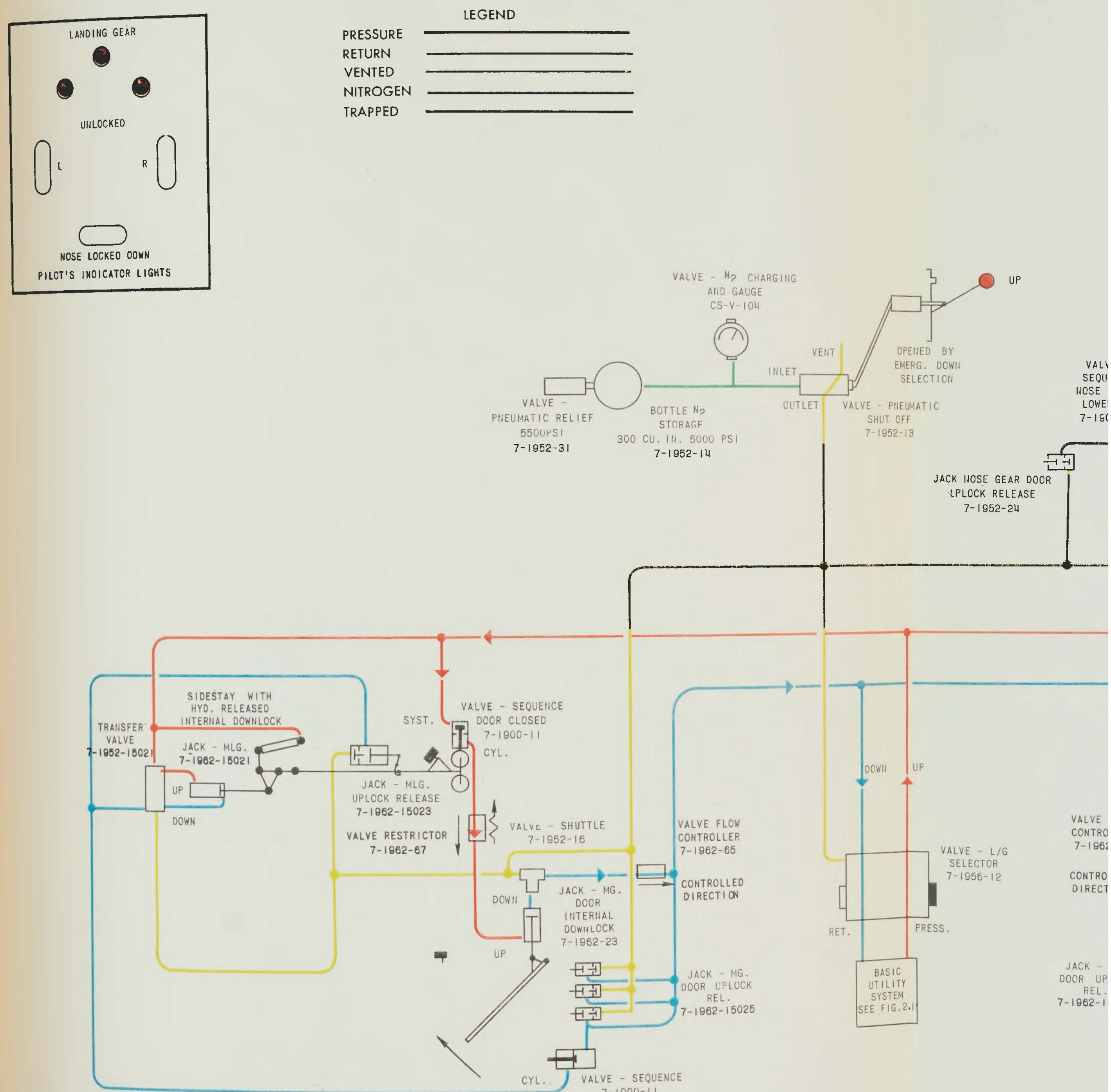


FIG. 2.4 UP SELECTION- GEARS UPLOCKED, DOORS CLOSING

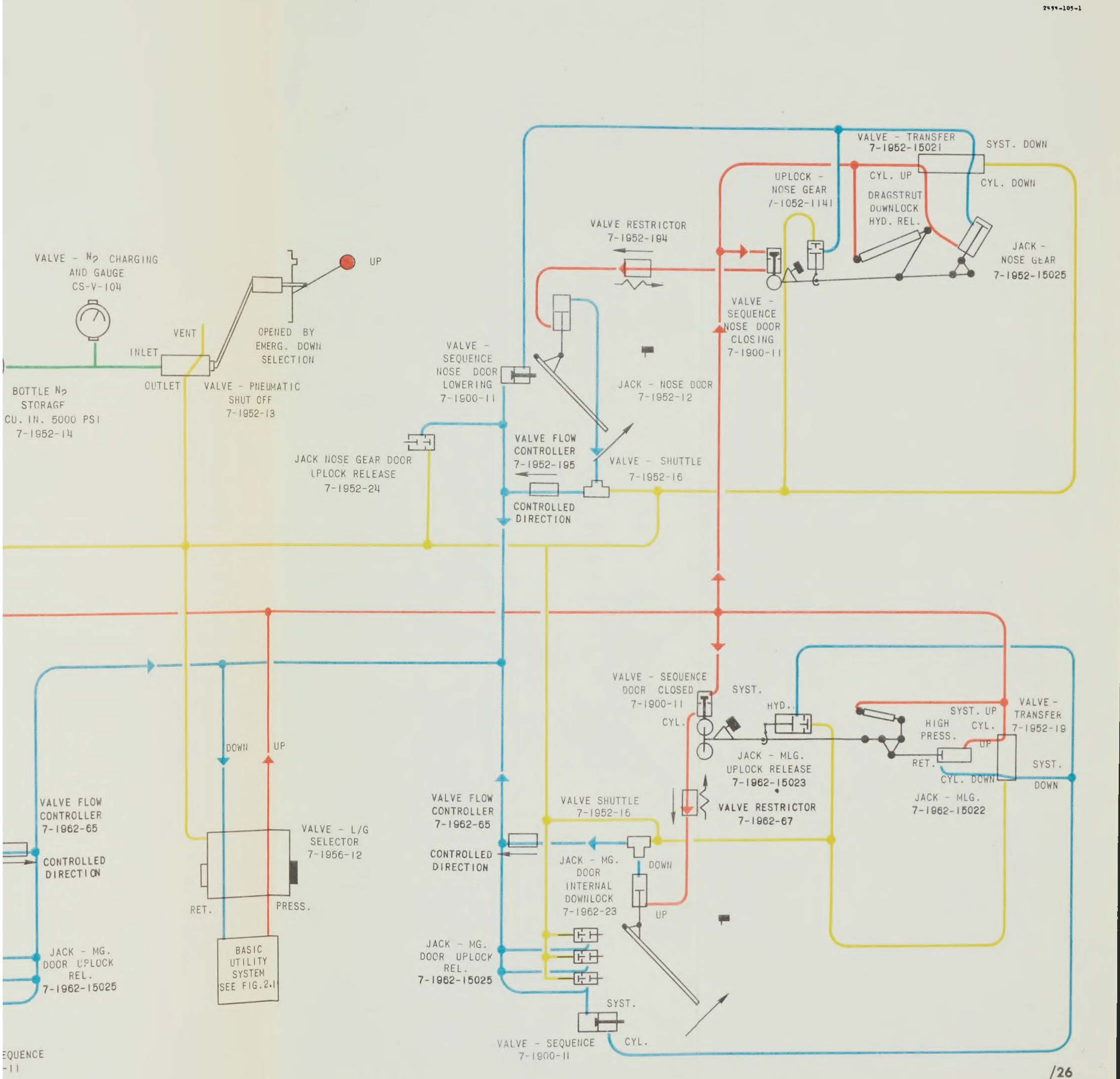


FIG. 2.4 UP SELECTION- GEARS UPLOCKED, DOORS CLOSING

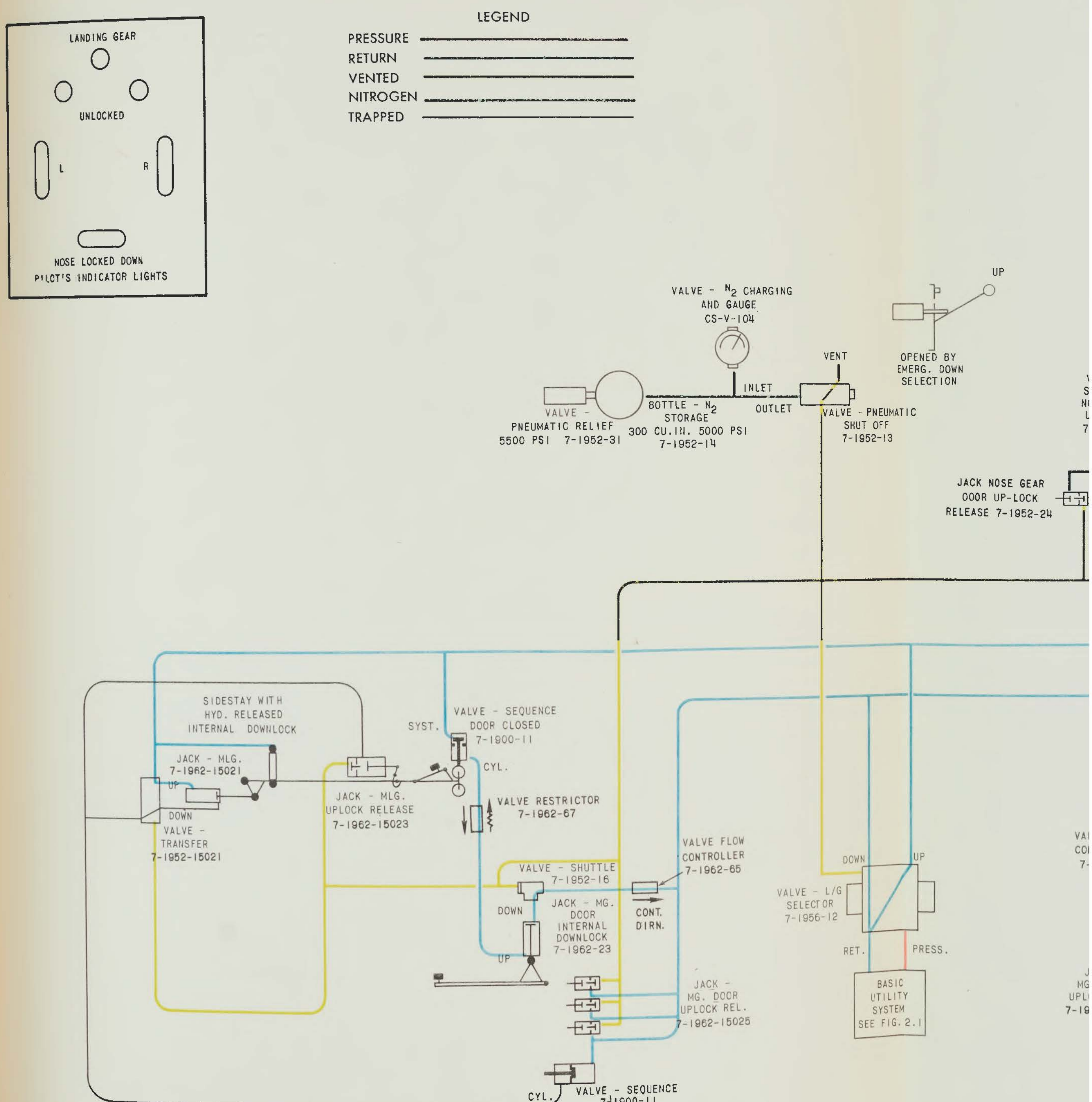
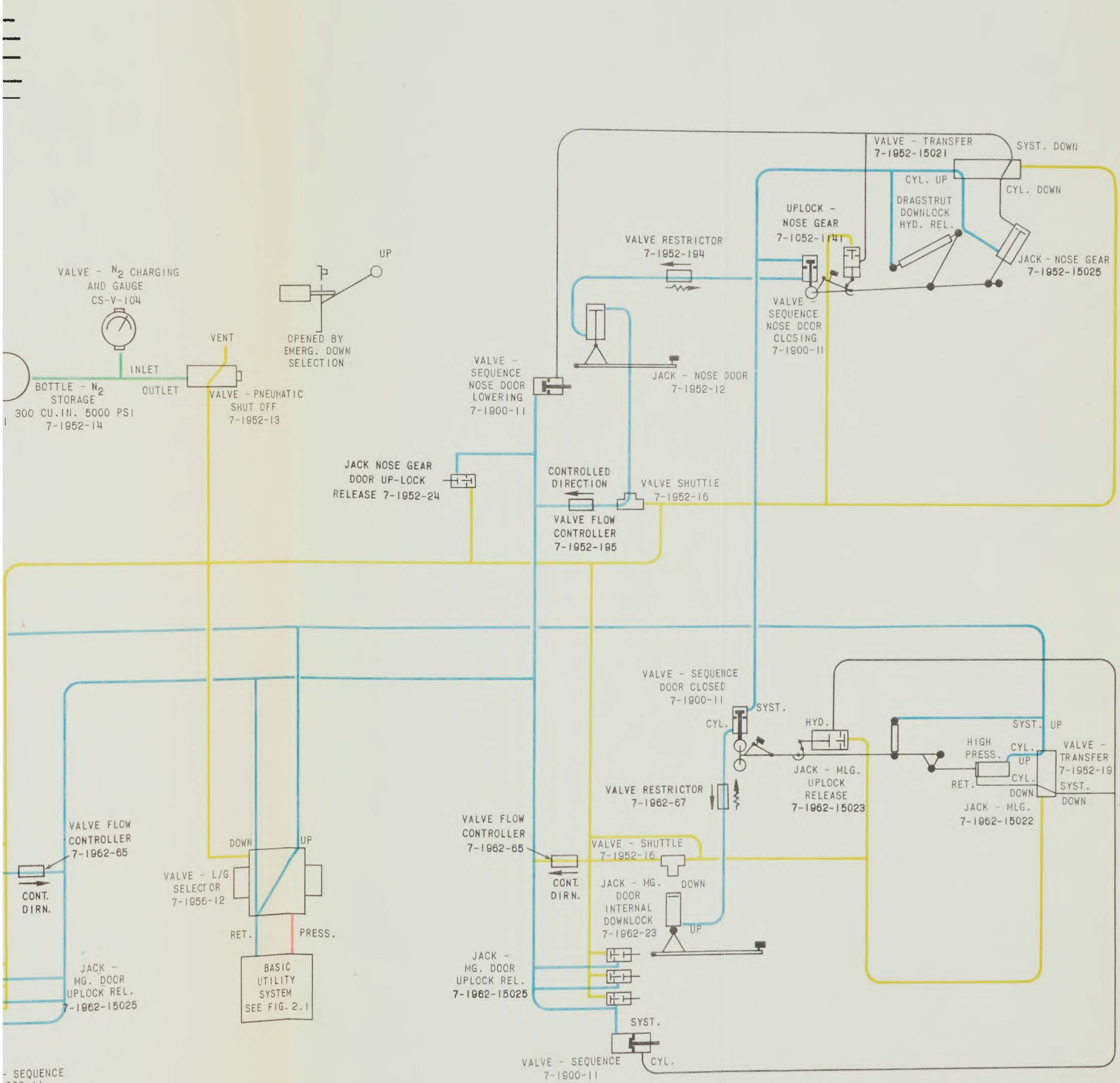


FIG. 2.5 IN FLIGHT-GEAR UPLOCKED, DOORS CLOSED AND LOCKED, SELECTOR VA



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LIGHT-GEAR UPLOCKED, DOORS CLOSED AND LOCKED, SELECTOR VALVE IN NEUTRAL

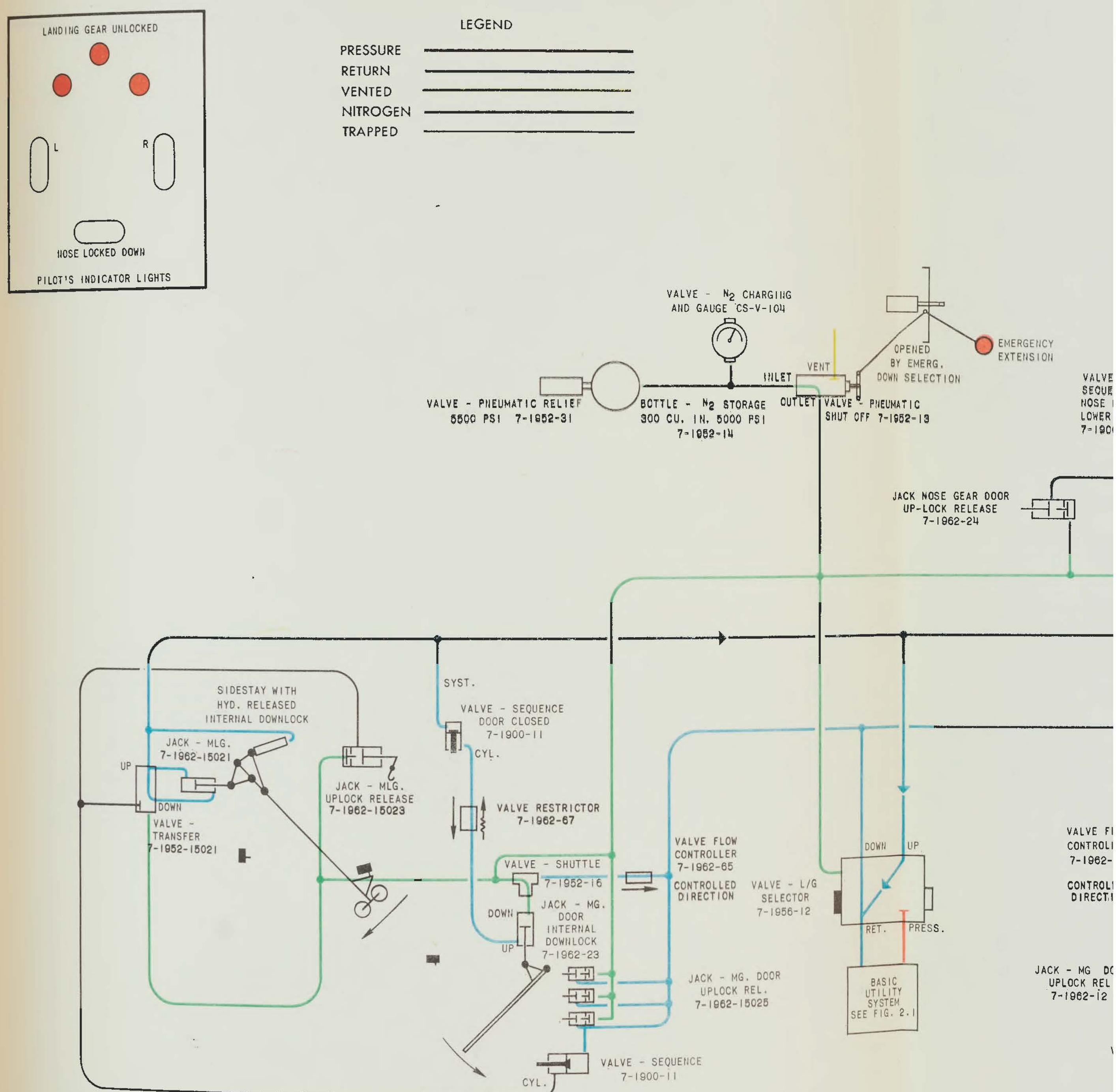

FIG. 2.6 EMERGENCY LANDING GEAR DOWN SELECTION
ALL UPLOCKS RELEASED TOGETHER, BOTH GEARS AND DOORS IN MOTION

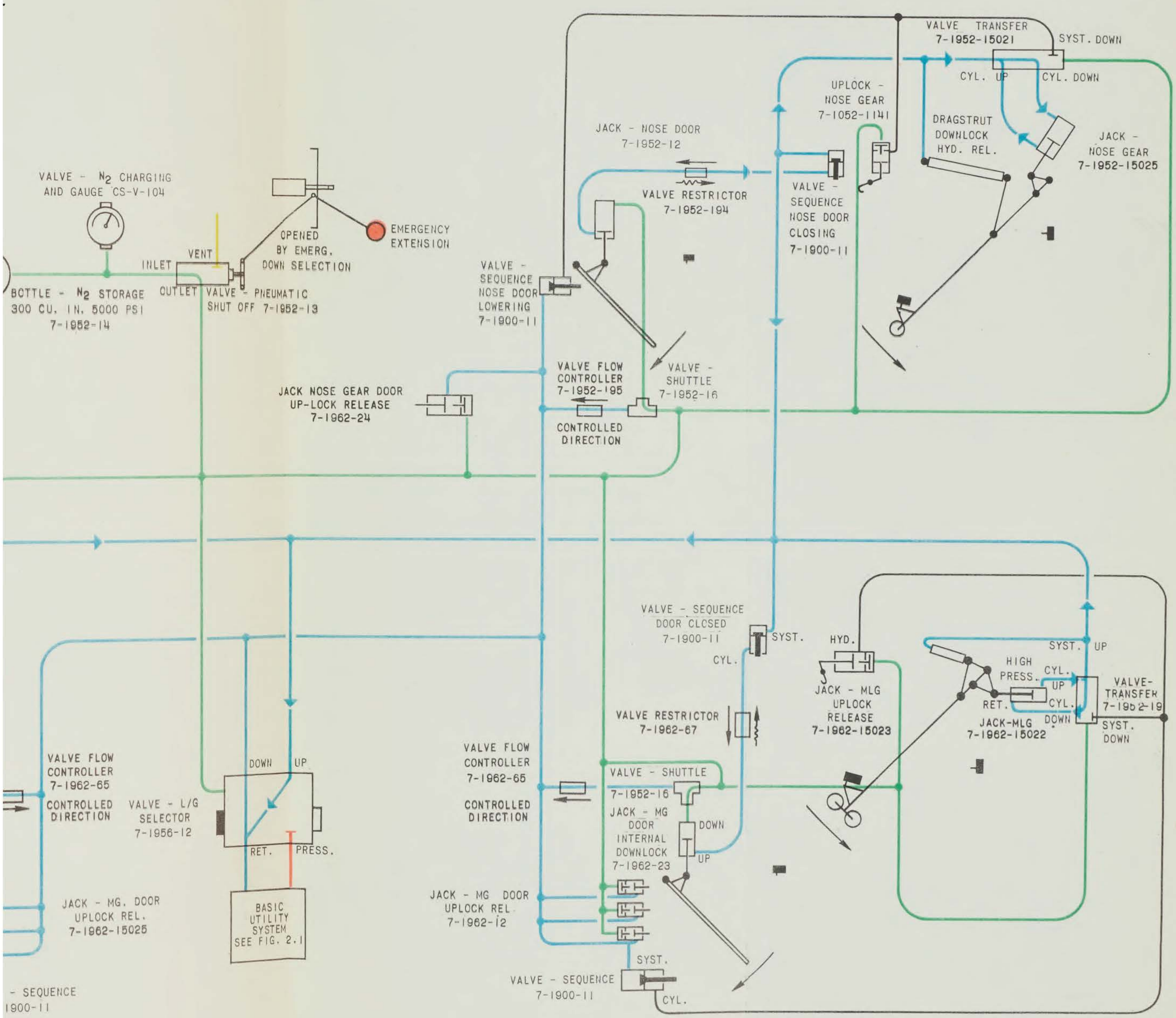

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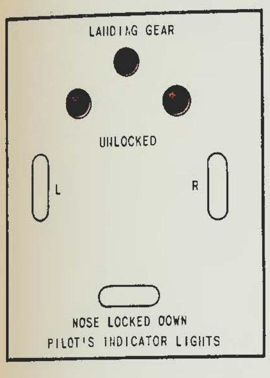
FIG. 2.6 EMERGENCY LANDING GEAR DOWN SELECTION
ALL UPLOCKS RELEASED TOGETHER, BOTH GEARS AND DOORS IN MOTION



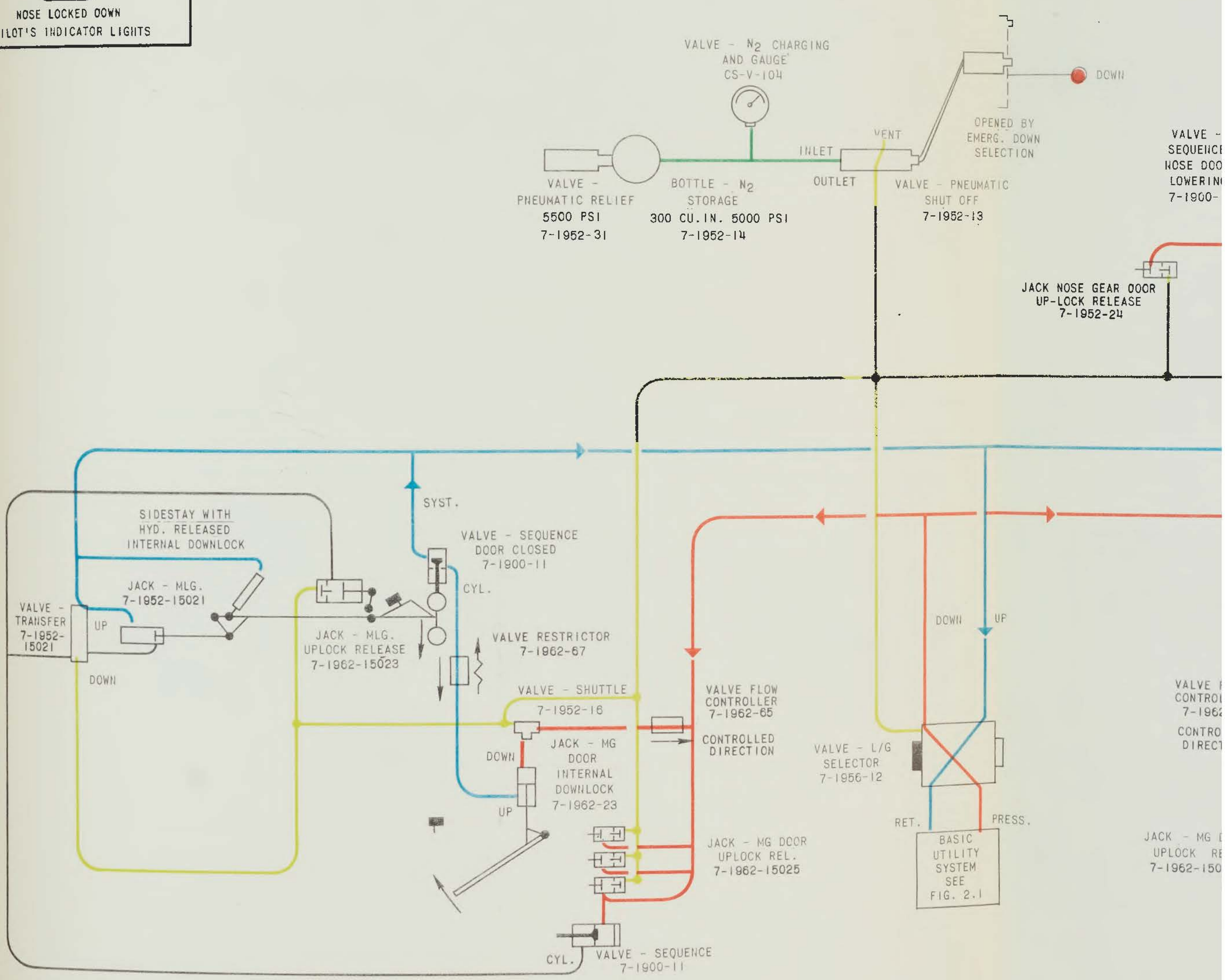
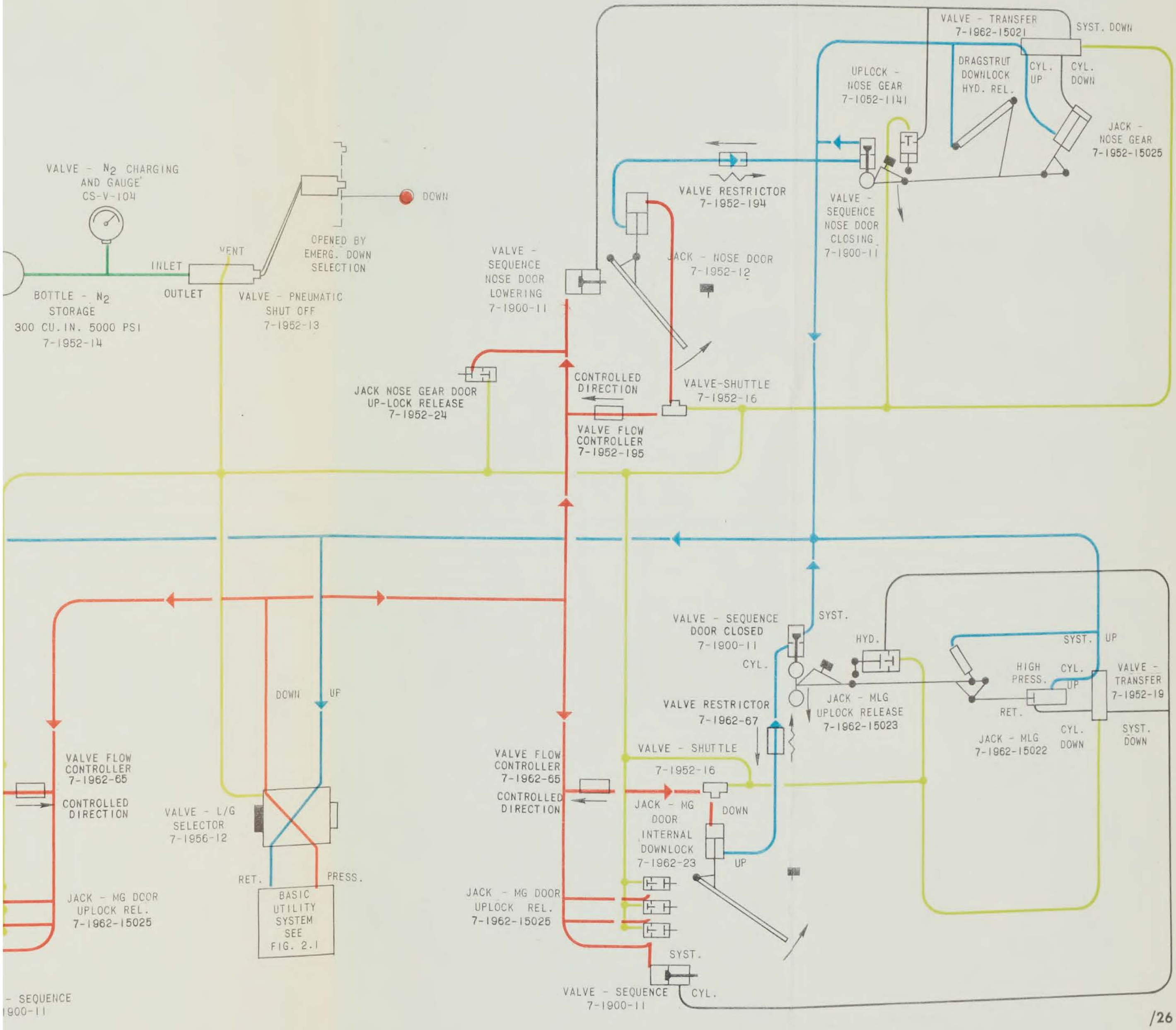


FIG. 2.7 DOWN SELECTION-DOORS OPENING, GEARS ON UPLOCKS



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G. 2.7 DOWN SELECTION-DOORS OPENING, GEARS ON UPLOCKS

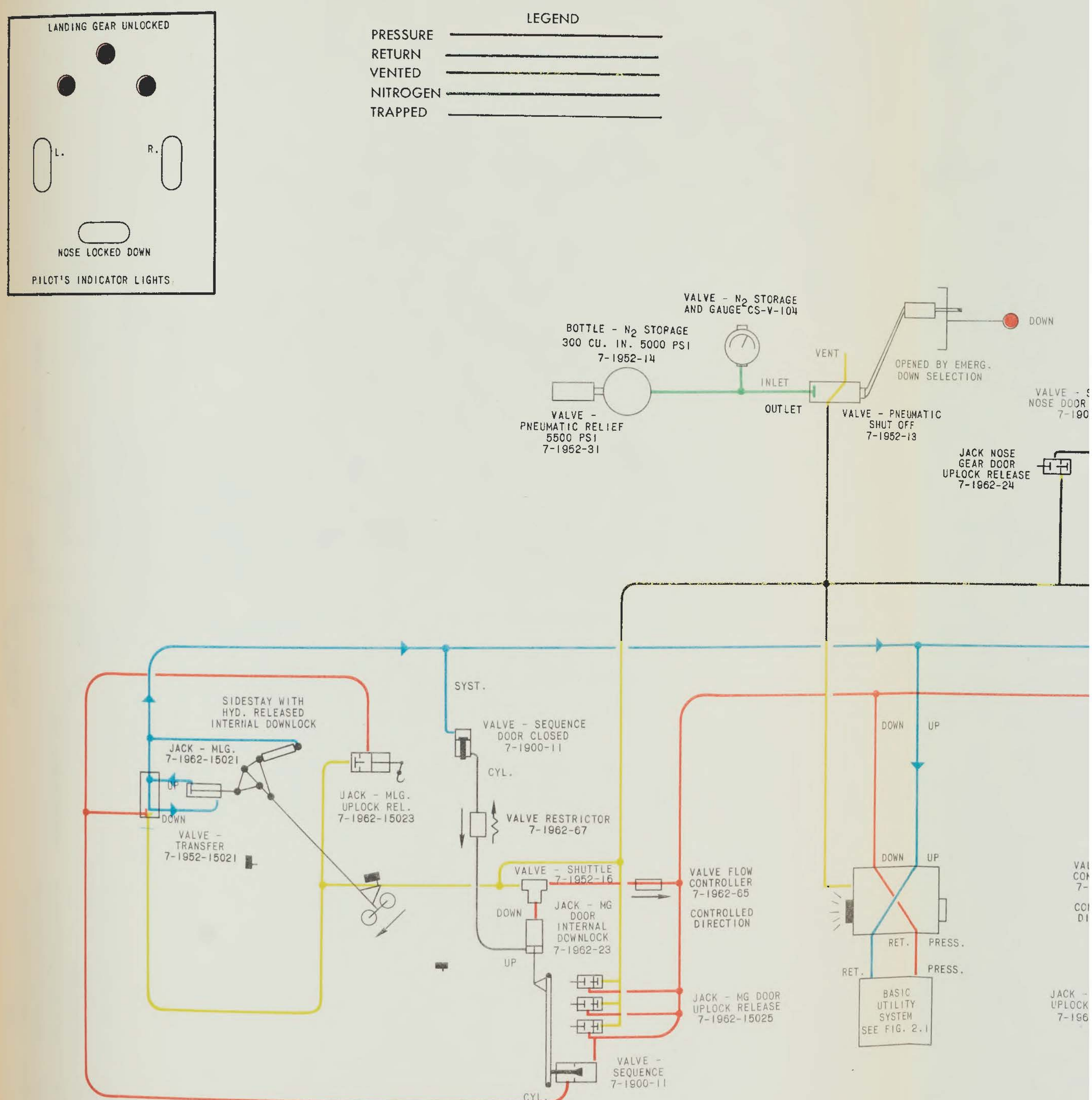

FIG. 2.8 DOWN SELECTION-DOORS LOCKED DOWN, GEARS FALLI

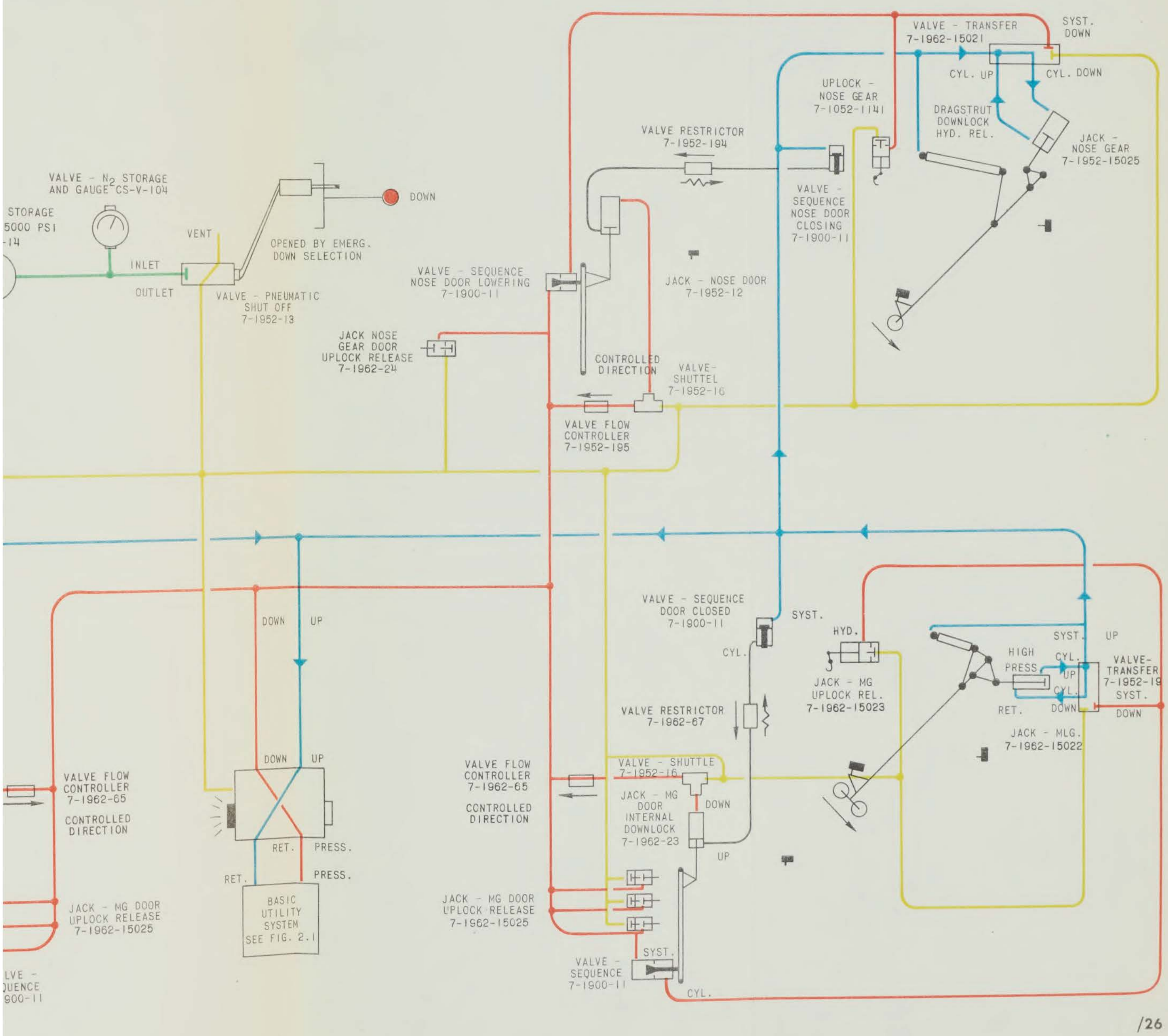

FIG. 2.8 DOWN SELECTION-DOORS LOCKED DOWN, GEARS FALLING

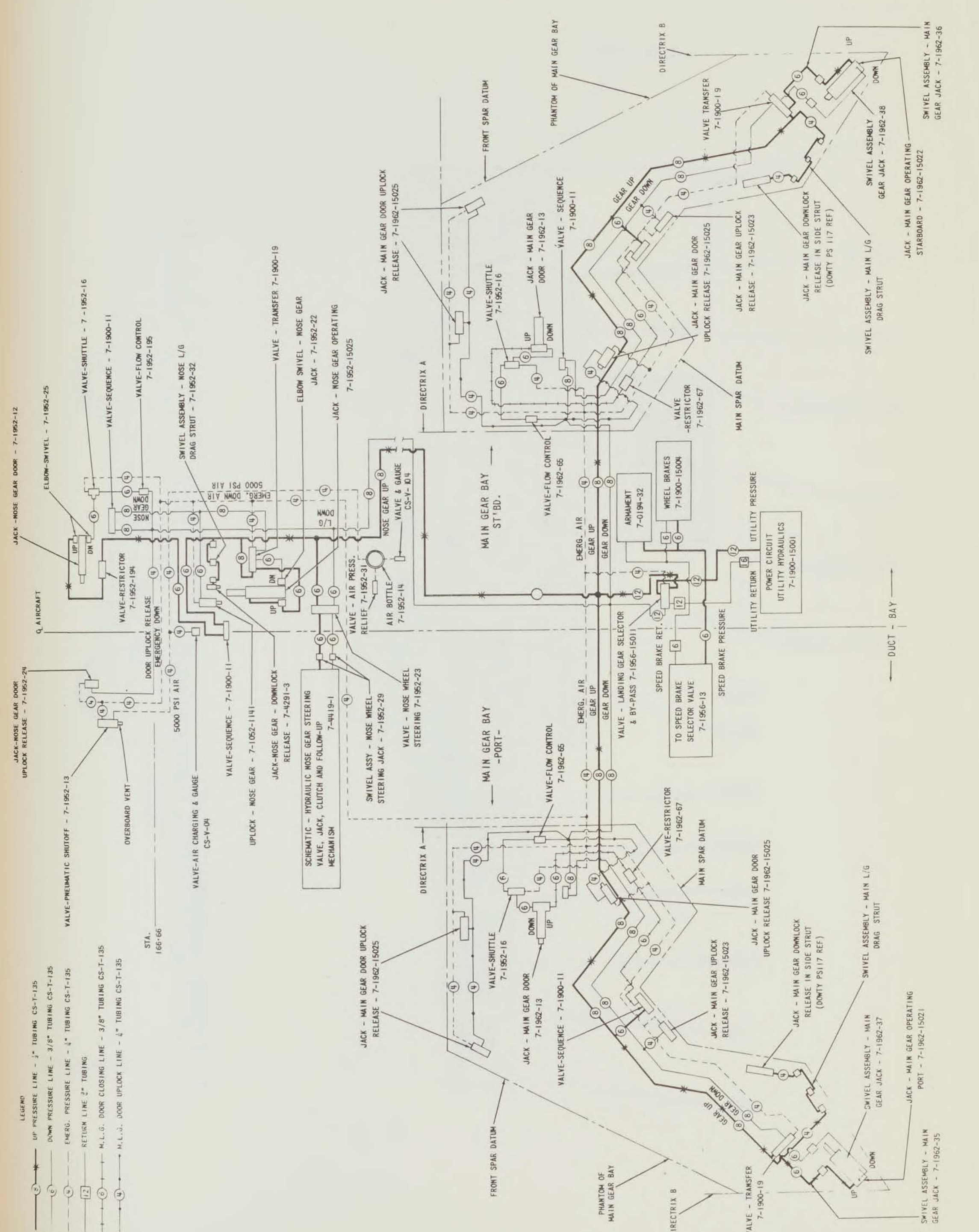

FIG. 2.9 DIAGRAMMATIC-LANDING GEAR

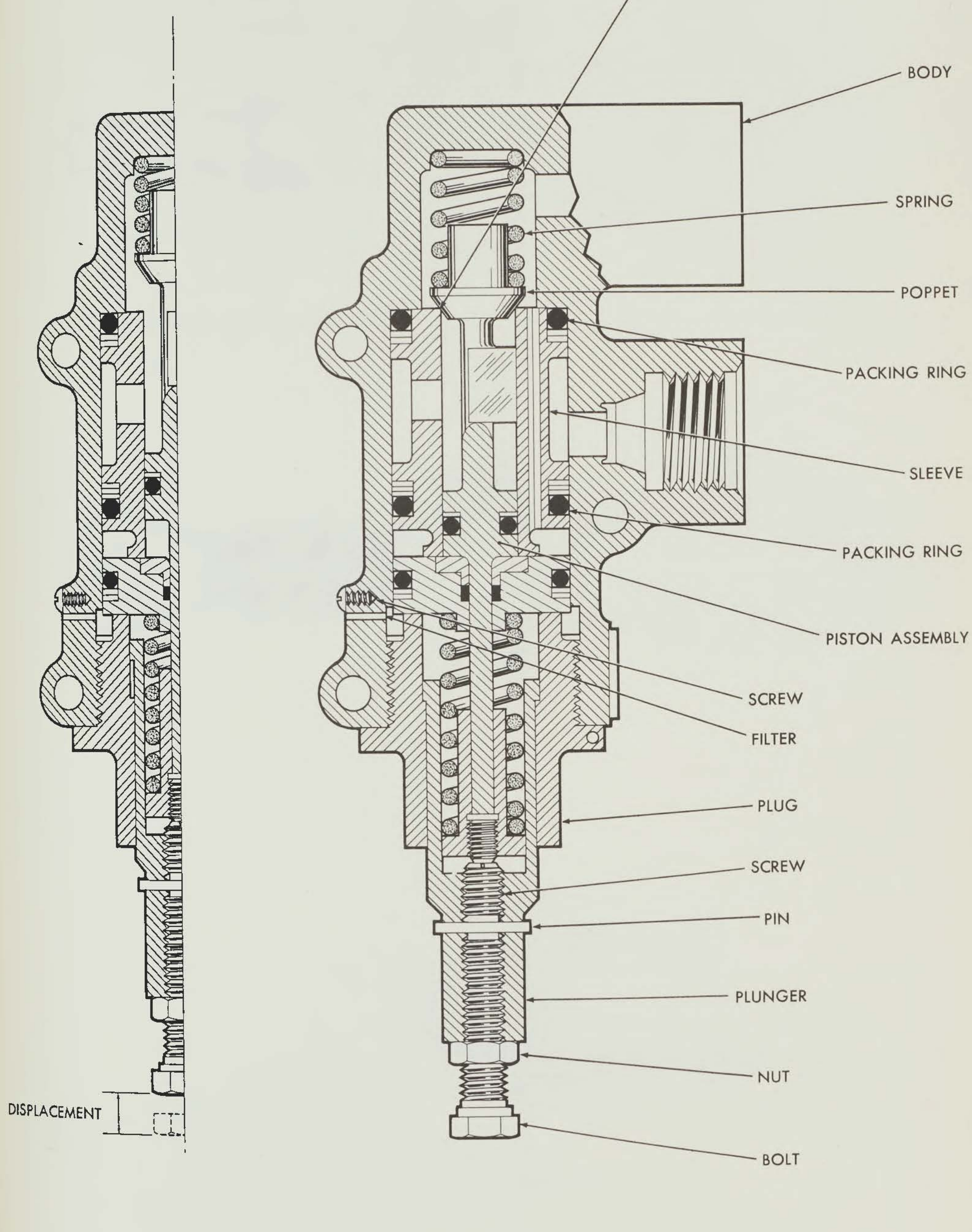

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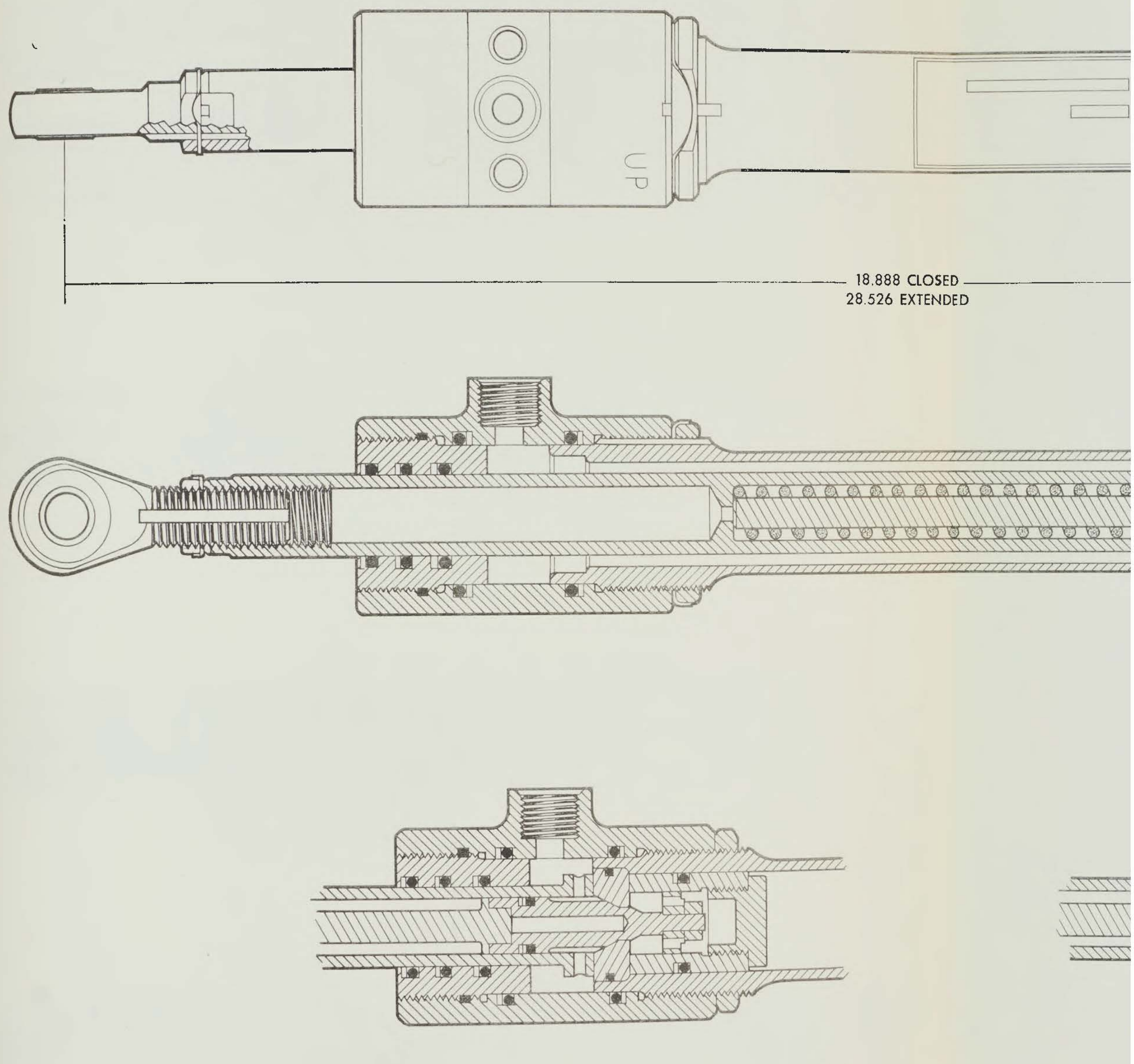
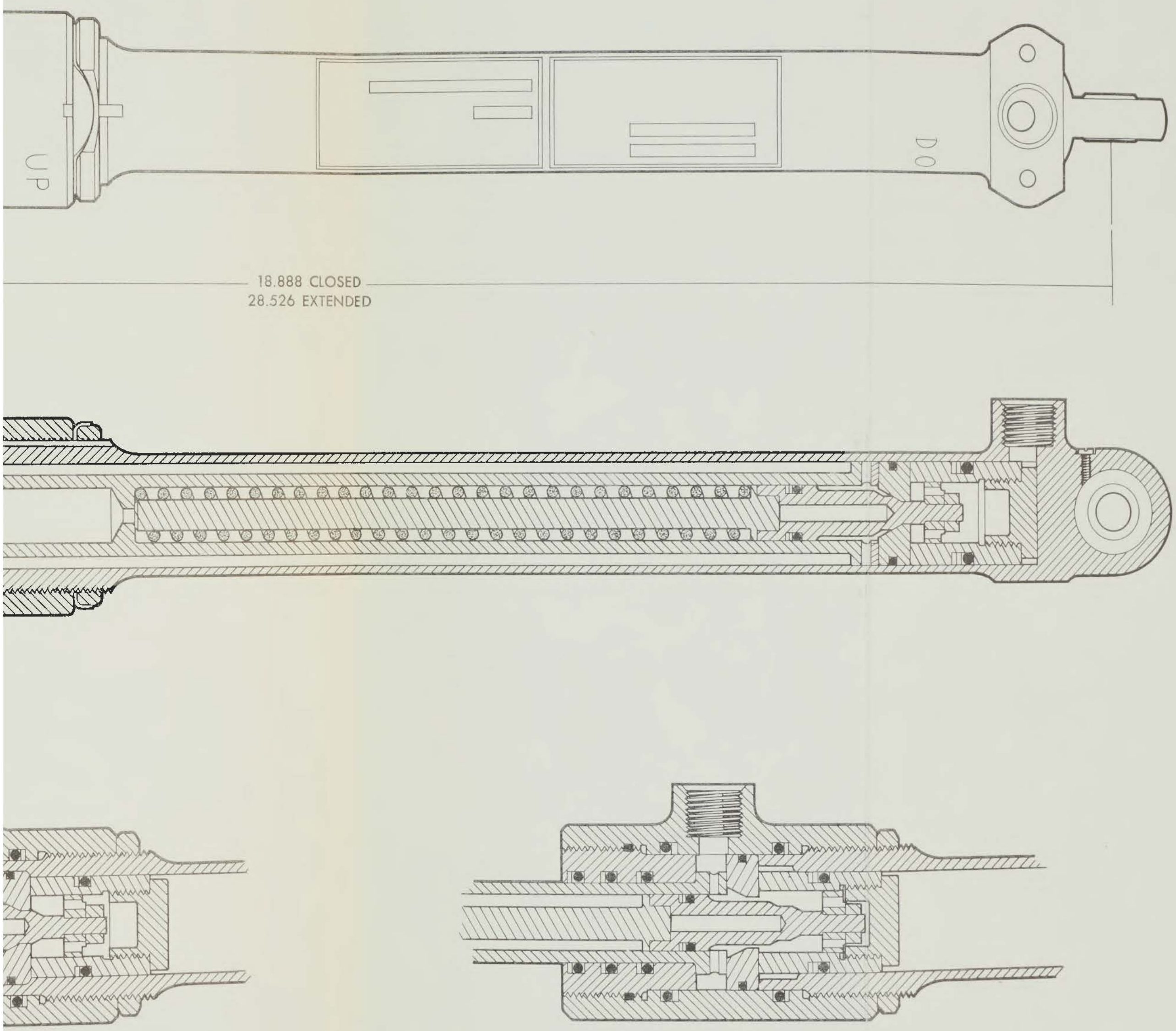
FIG. 2.10 SEQUENCE VALVE



LOCKED IN BLOWBACK POSITION

FIG. 2.11 JACK-NOSE GEAR DOOR
WITH INTERNAL DOWNLOCK



K POSITION

FULLY EXTENDED & LOCKED POSITION

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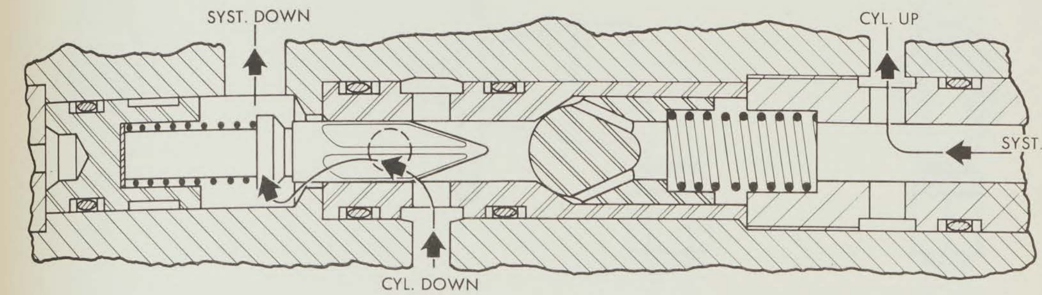
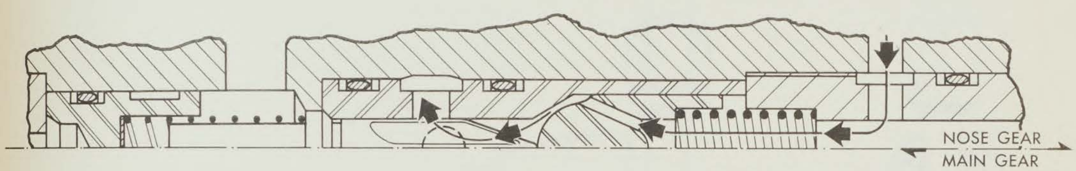
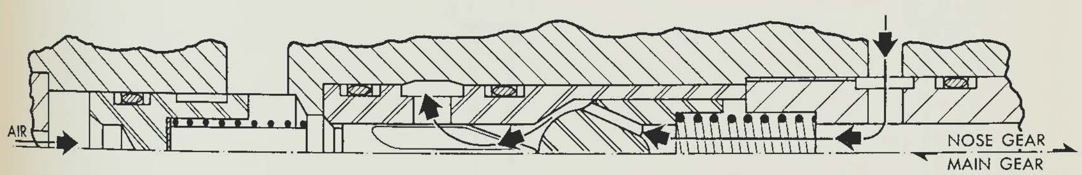
FIG. 2.11 JACK-NOSE GEAR DOOR
WITH INTERNAL DOWNLOCK



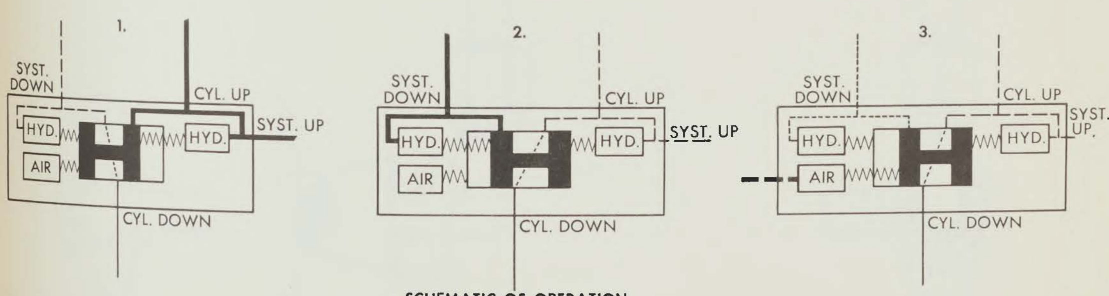
1. UP SELECTION



2. DOWN SELECTION



3. EMERGENCY DOWN



SCHEMATIC OF OPERATION

FIG. 2.12 TRANSFER VALVE

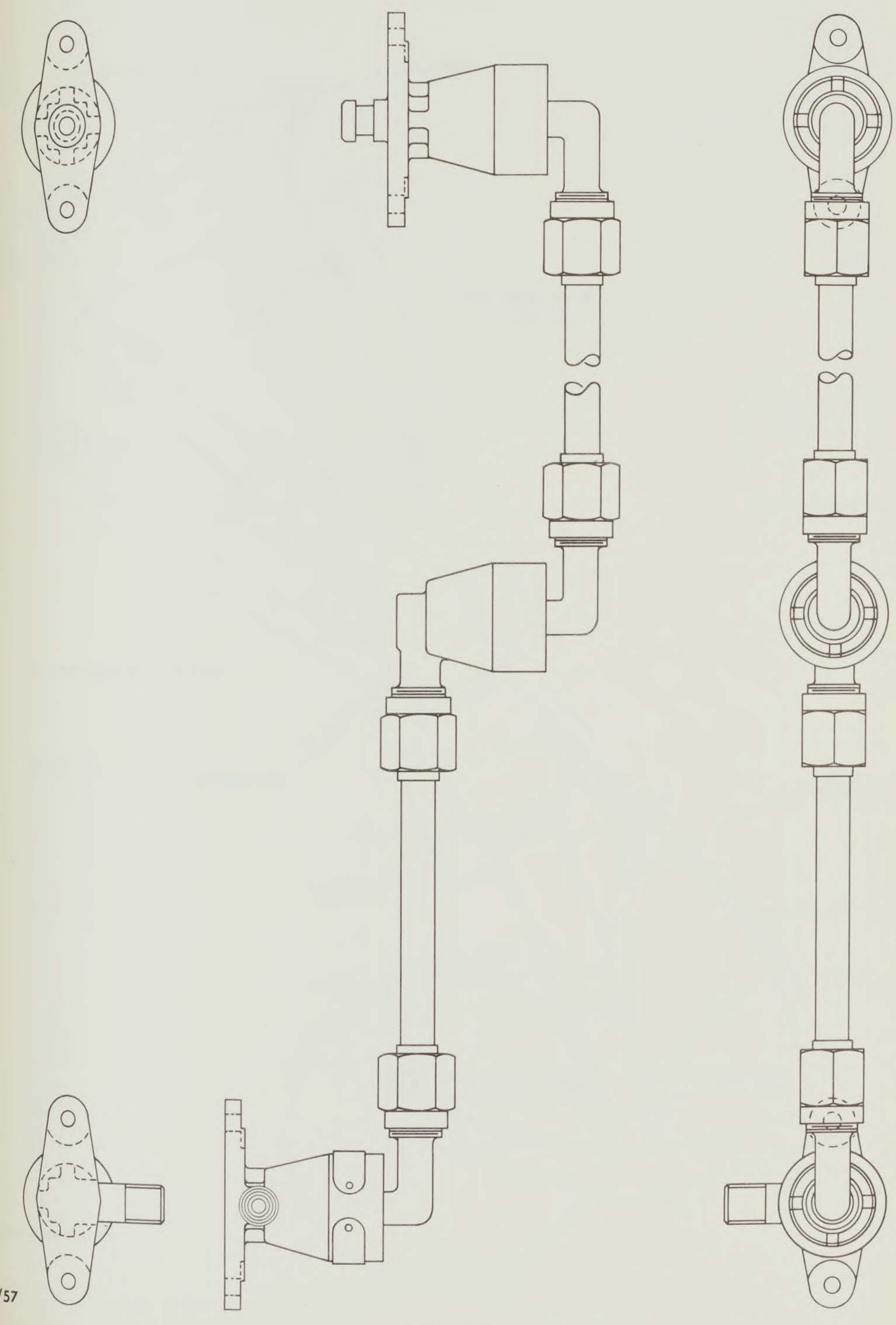


FIG. 2.13 DOGLEG SWIVEL ASSEMBLY FOR DOWNLOCK RELEASE—NOSE GEAR

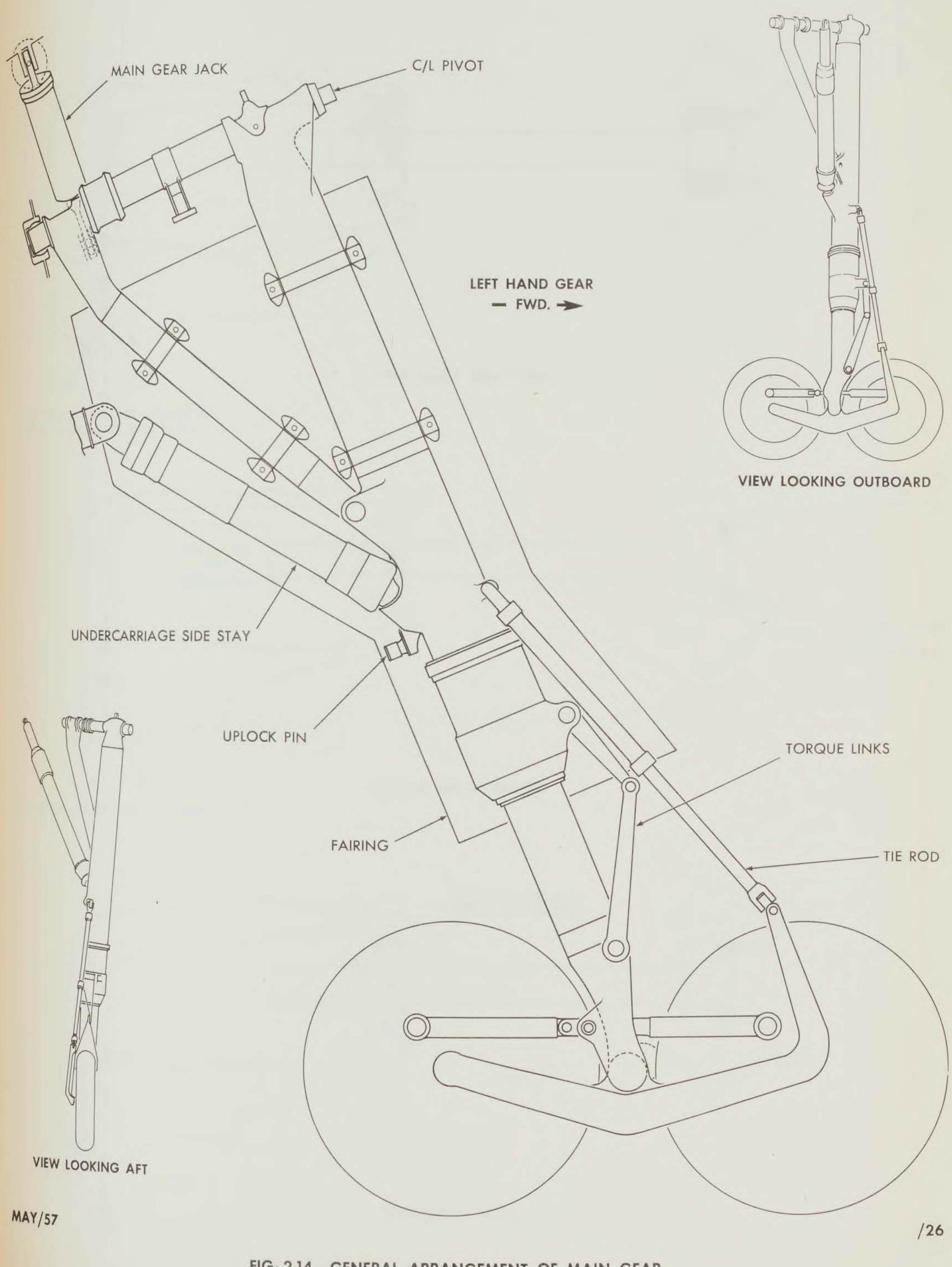


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FIG. 2.14 GENERAL ARRANGEMENT OF MAIN GEAR

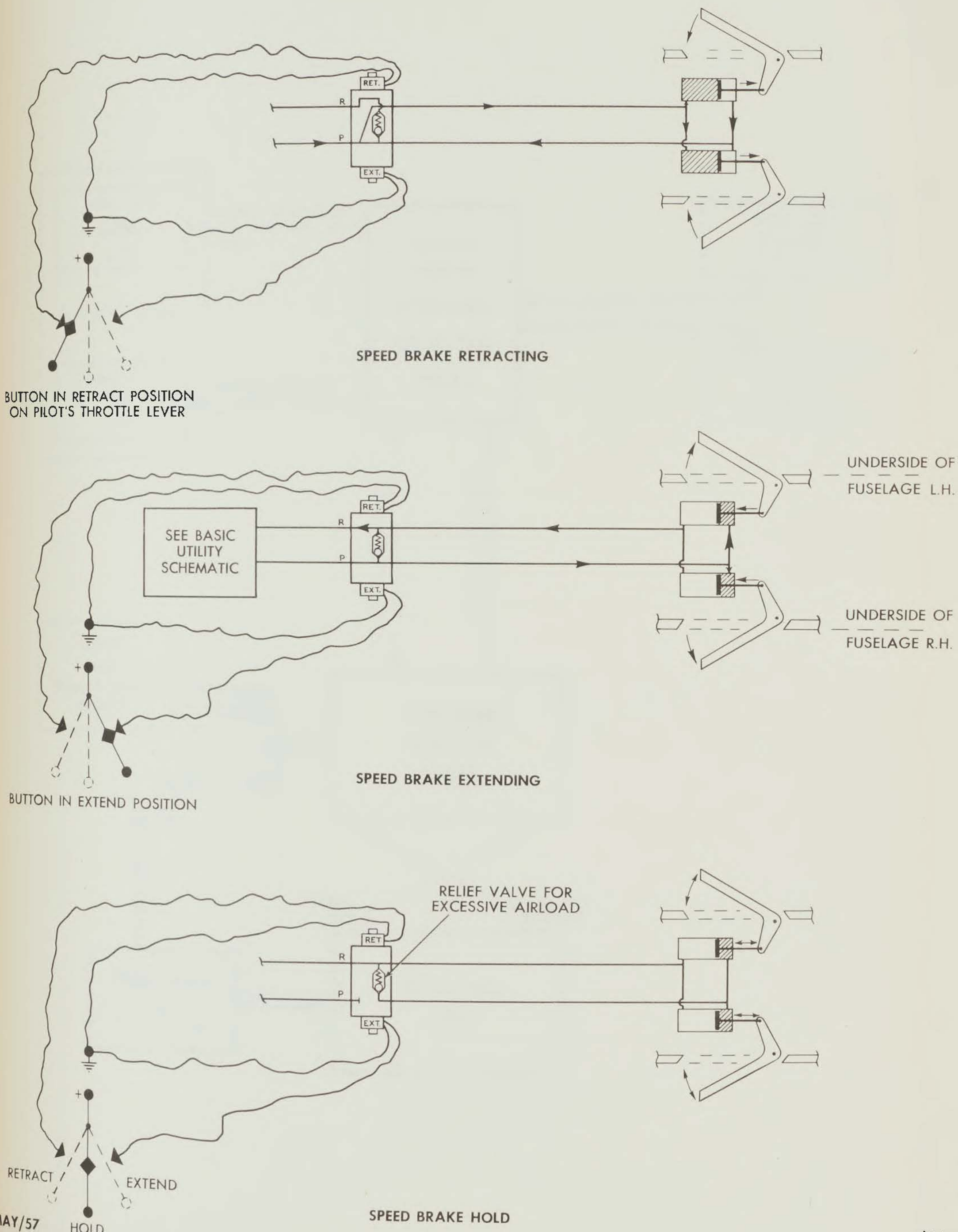

FIG. 3.1 SPEED BRAKE SCHEMATIC

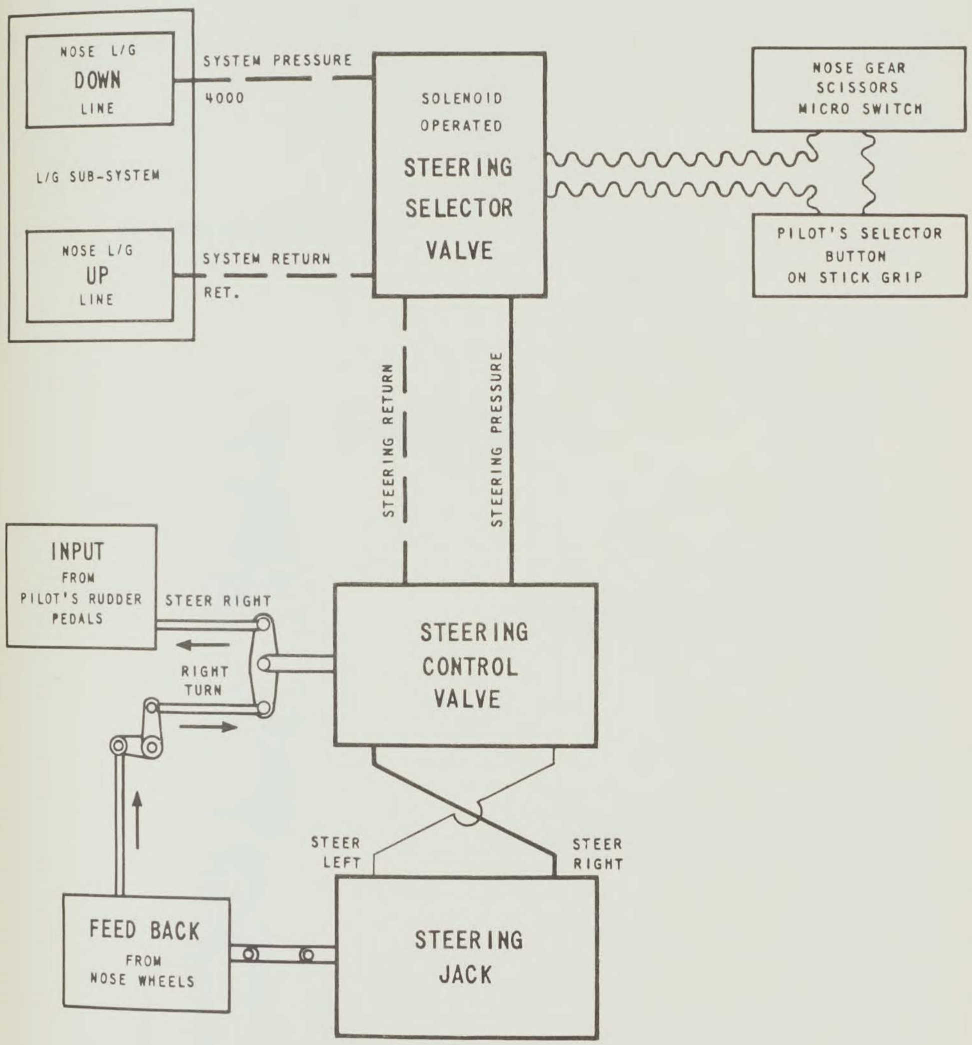

FIG. 4.1 BASIC SCHEMATIC NOSE-WHEEL STEERING

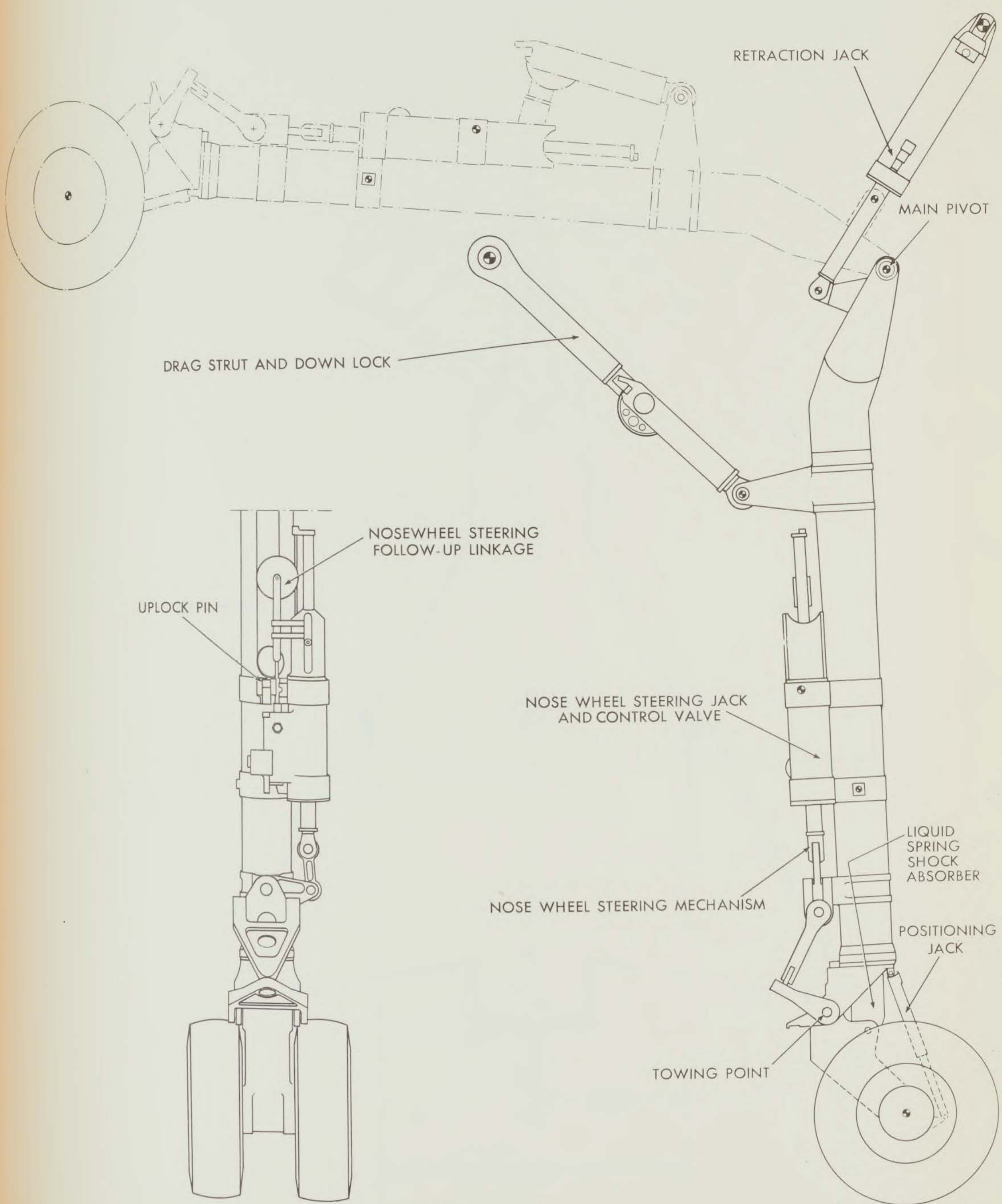

FIG. 4.2 GENERAL ARRANGEMENT OF NOSE GEAR

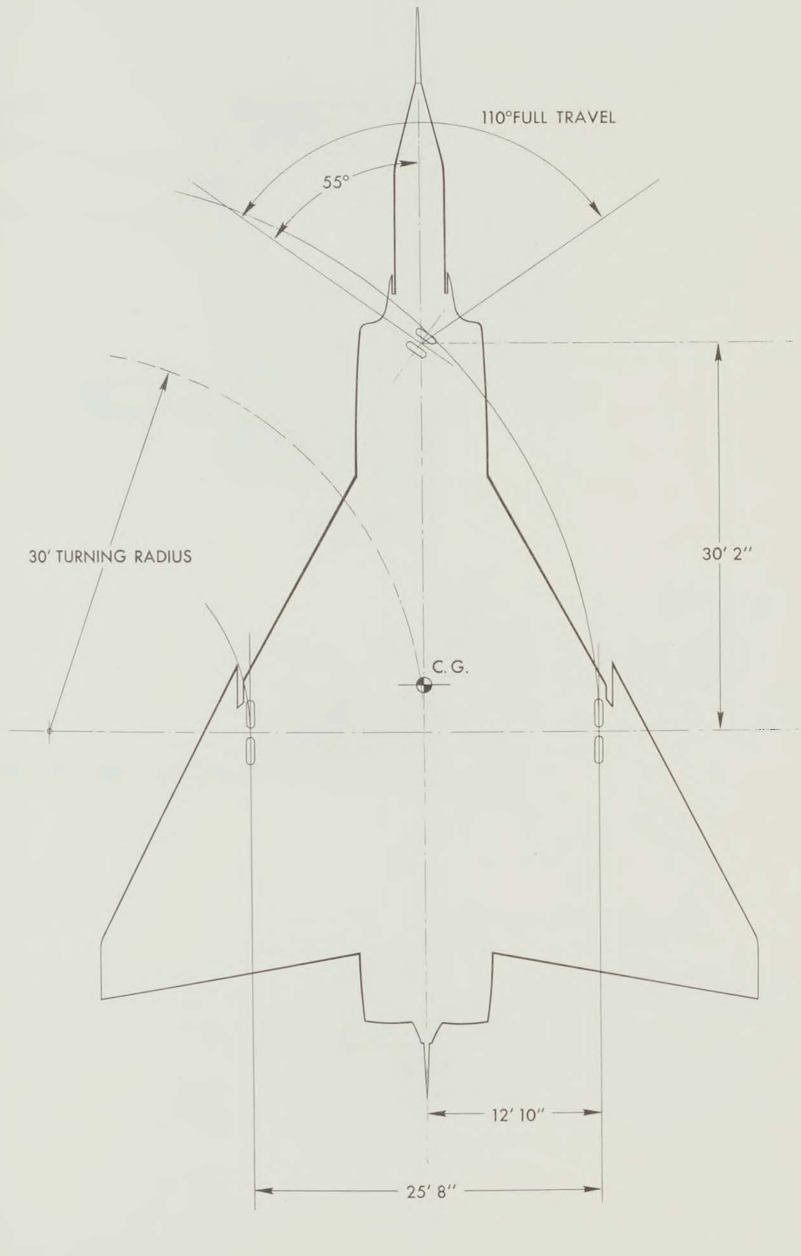

FIG. 4.3 GEOMETRY OF NOSE WHEEL STEERING

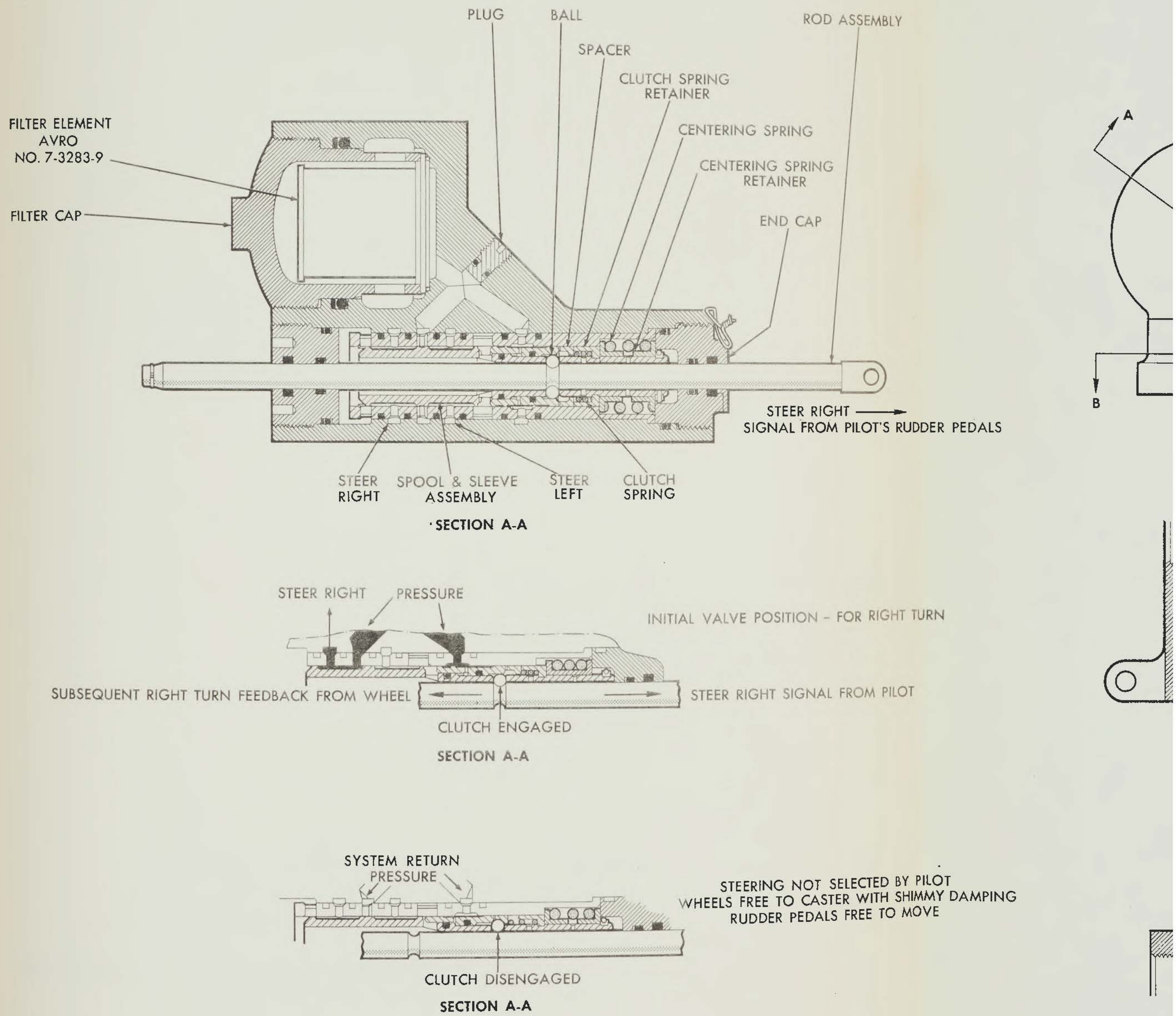

FIG. 4.4 NOSE WHEEL STEERING CONTROL VALVE

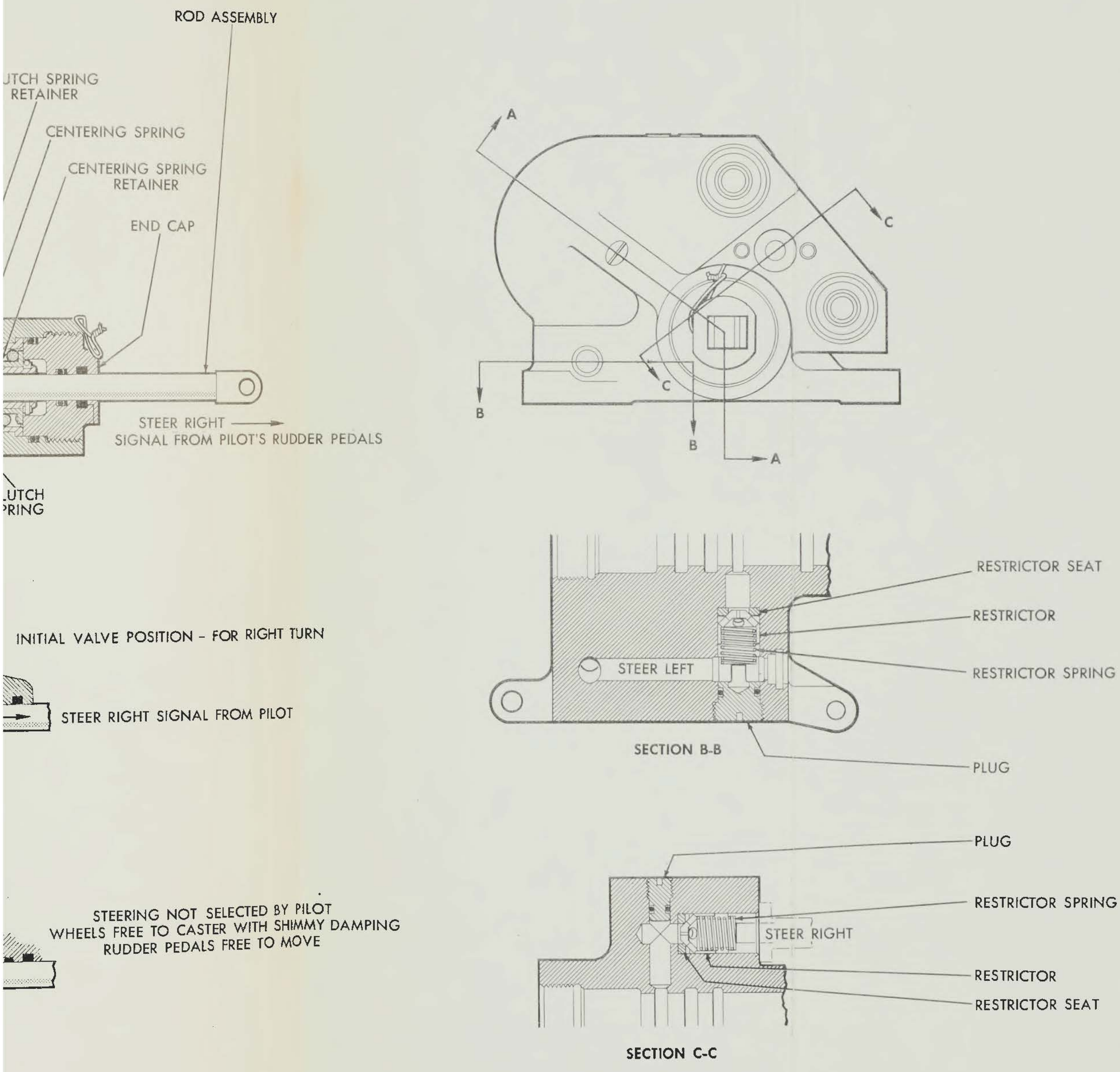

FIG. 4.4 NOSE WHEEL STEERING CONTROL VALVE

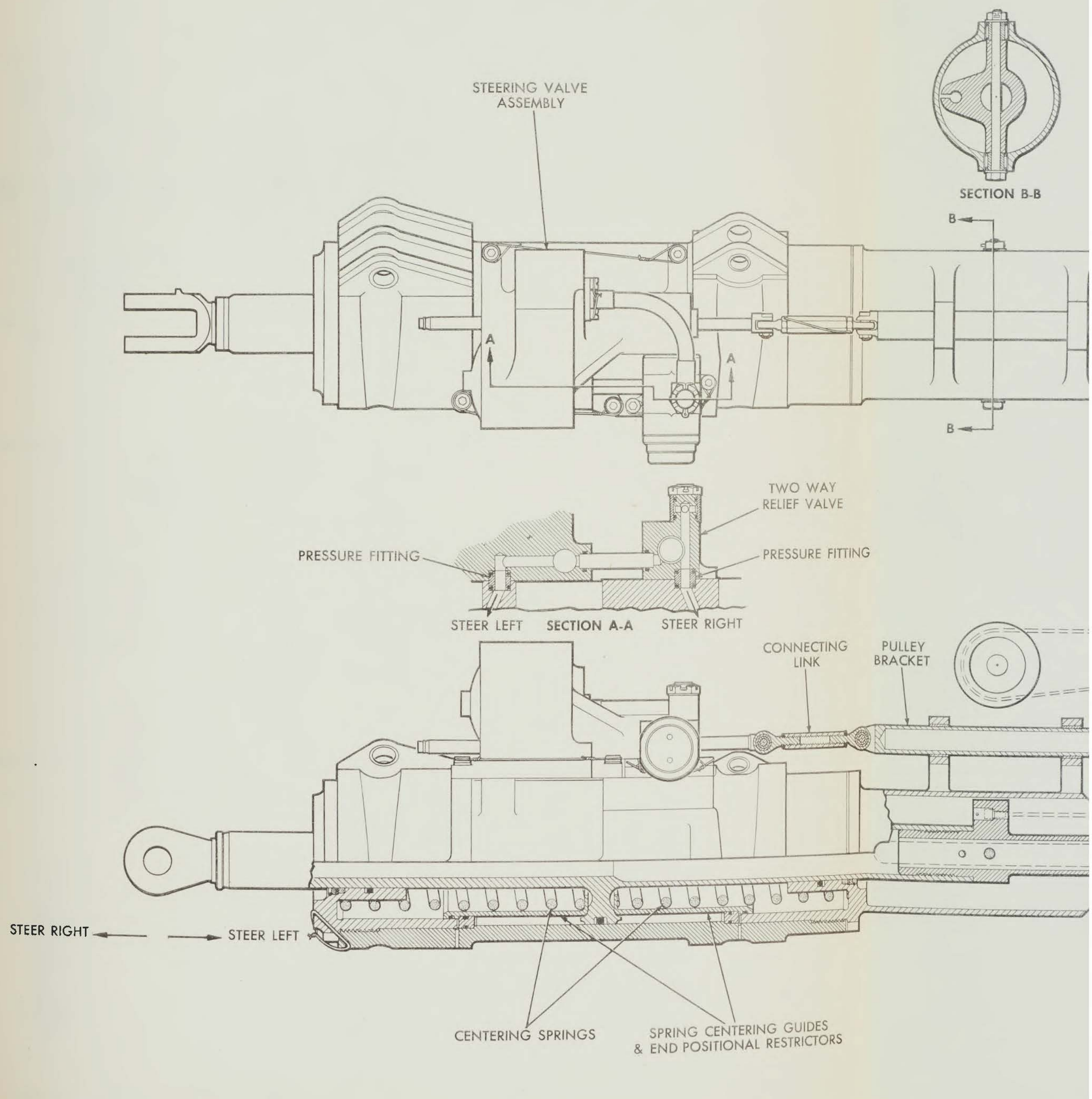

FIG. 4.5 STEERING JACK AND CONTROL VALVE

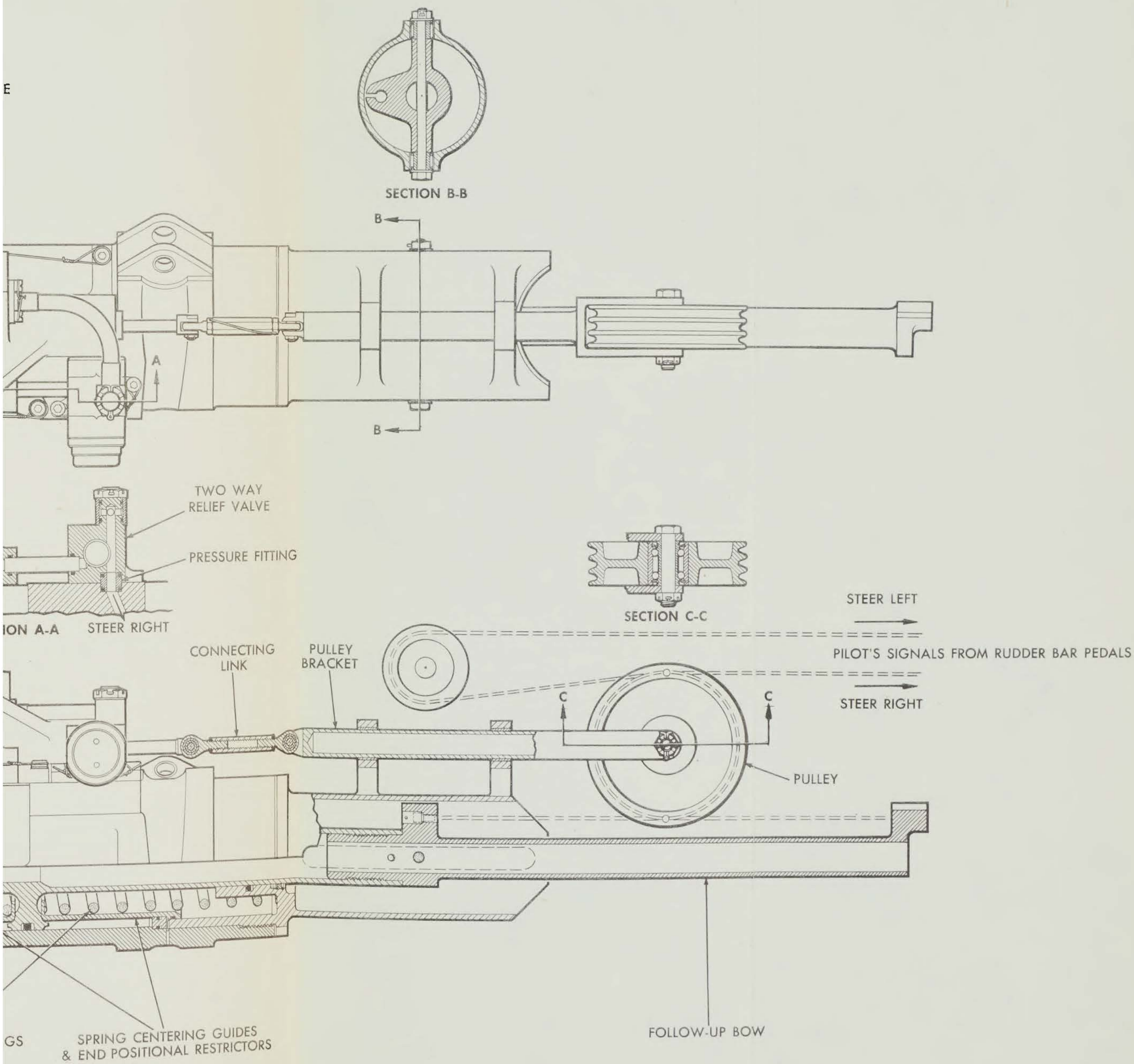

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FIG. 4.5 STEERING JACK AND CONTROL VALVE

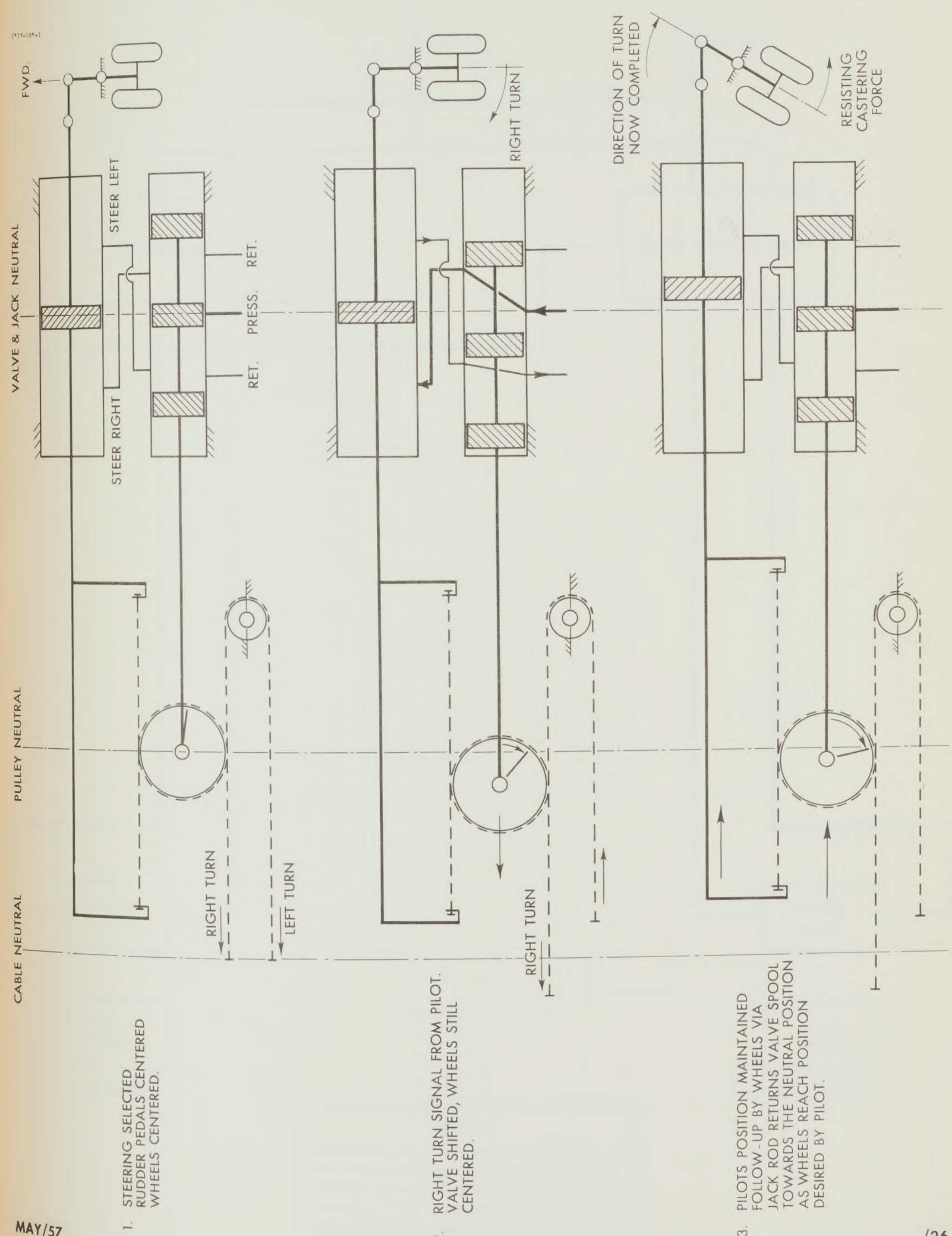

FIG. 4.6 SCHEMATIC OF NOSE WHEEL JACK & VALVE (SHOWING MECHANICAL OPERATION)

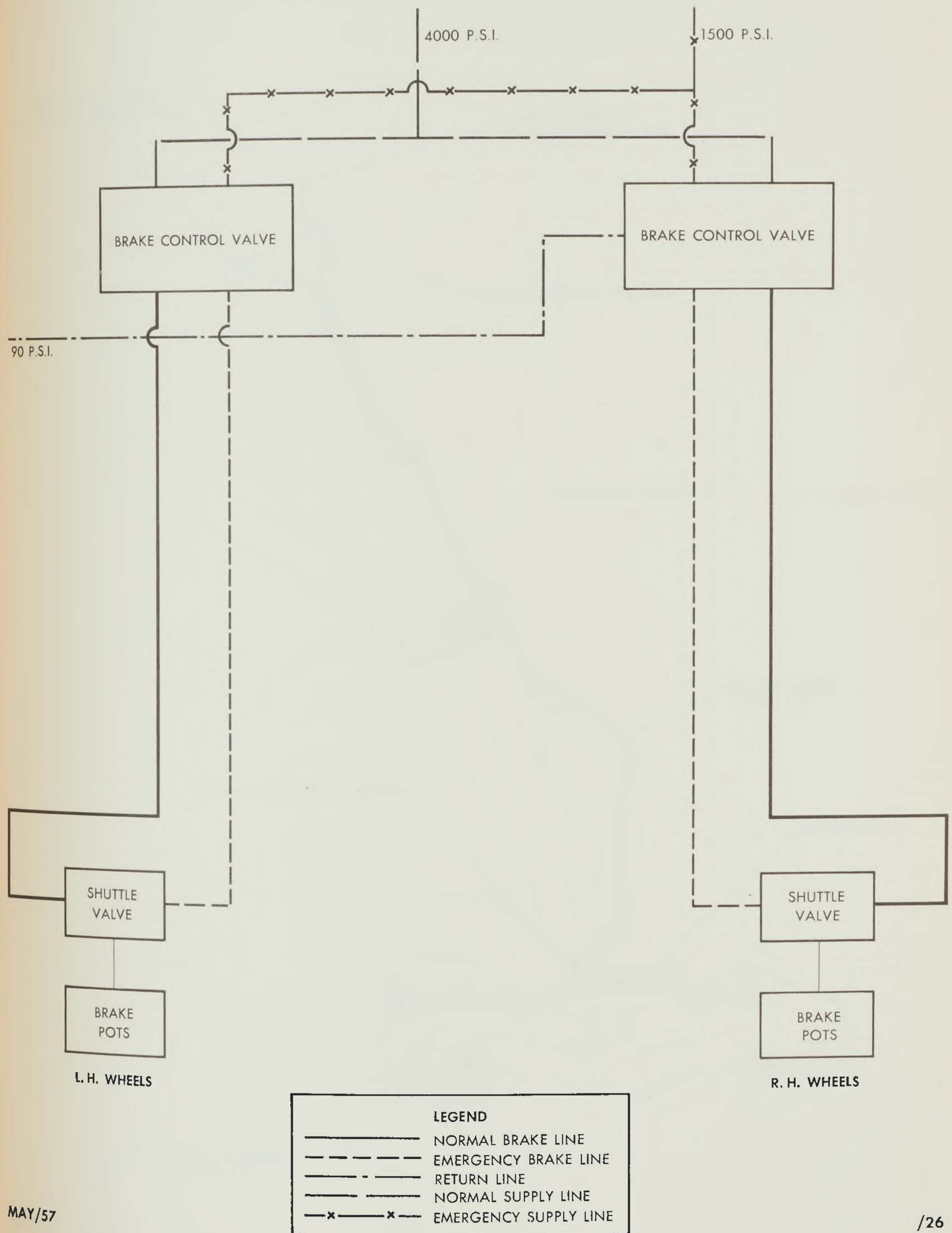

FIG. 5.1 SCHEMATIC — WHEEL BRAKES

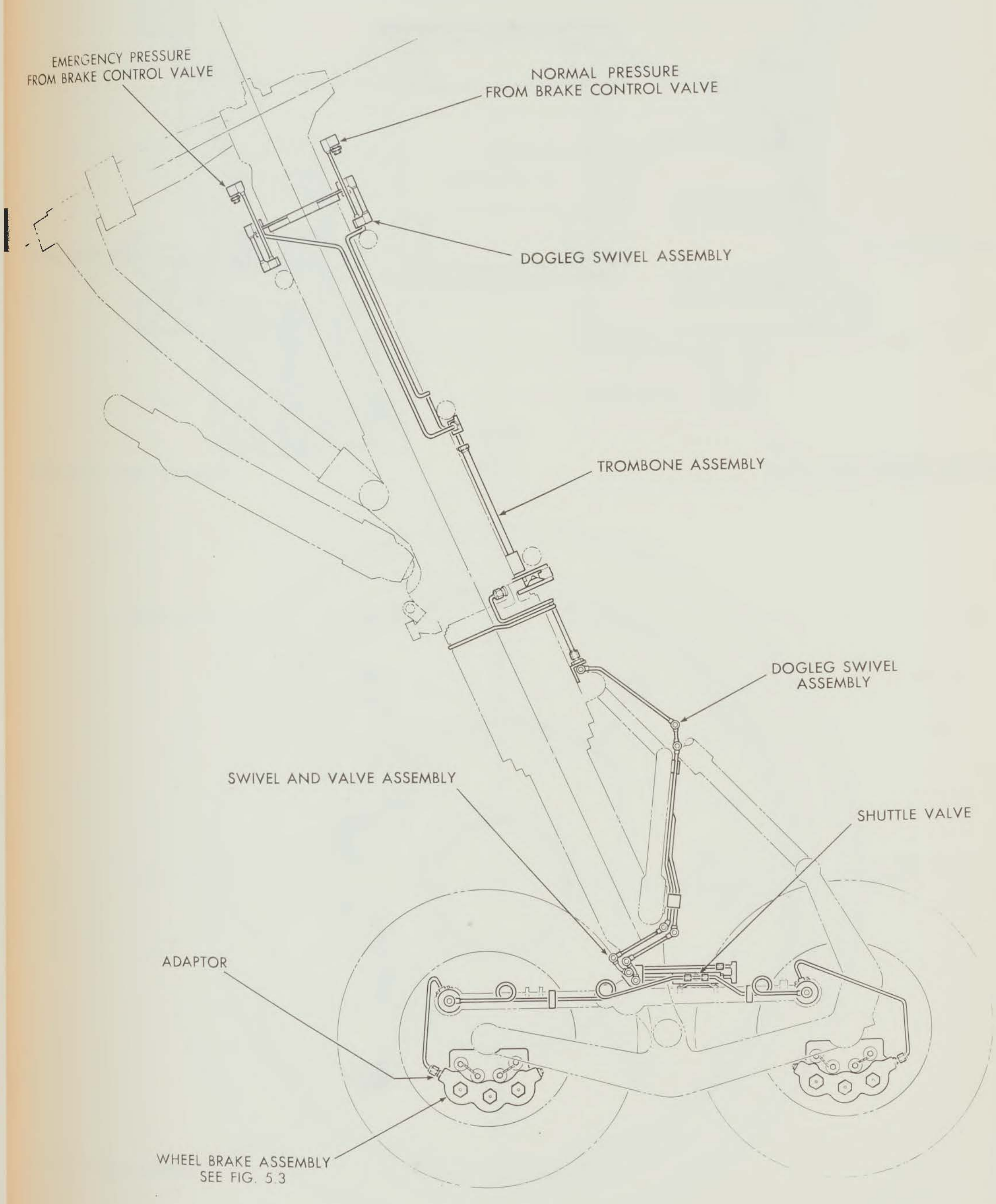

FIG. 5.2 WHEEL BRAKE SUB - SYSTEM

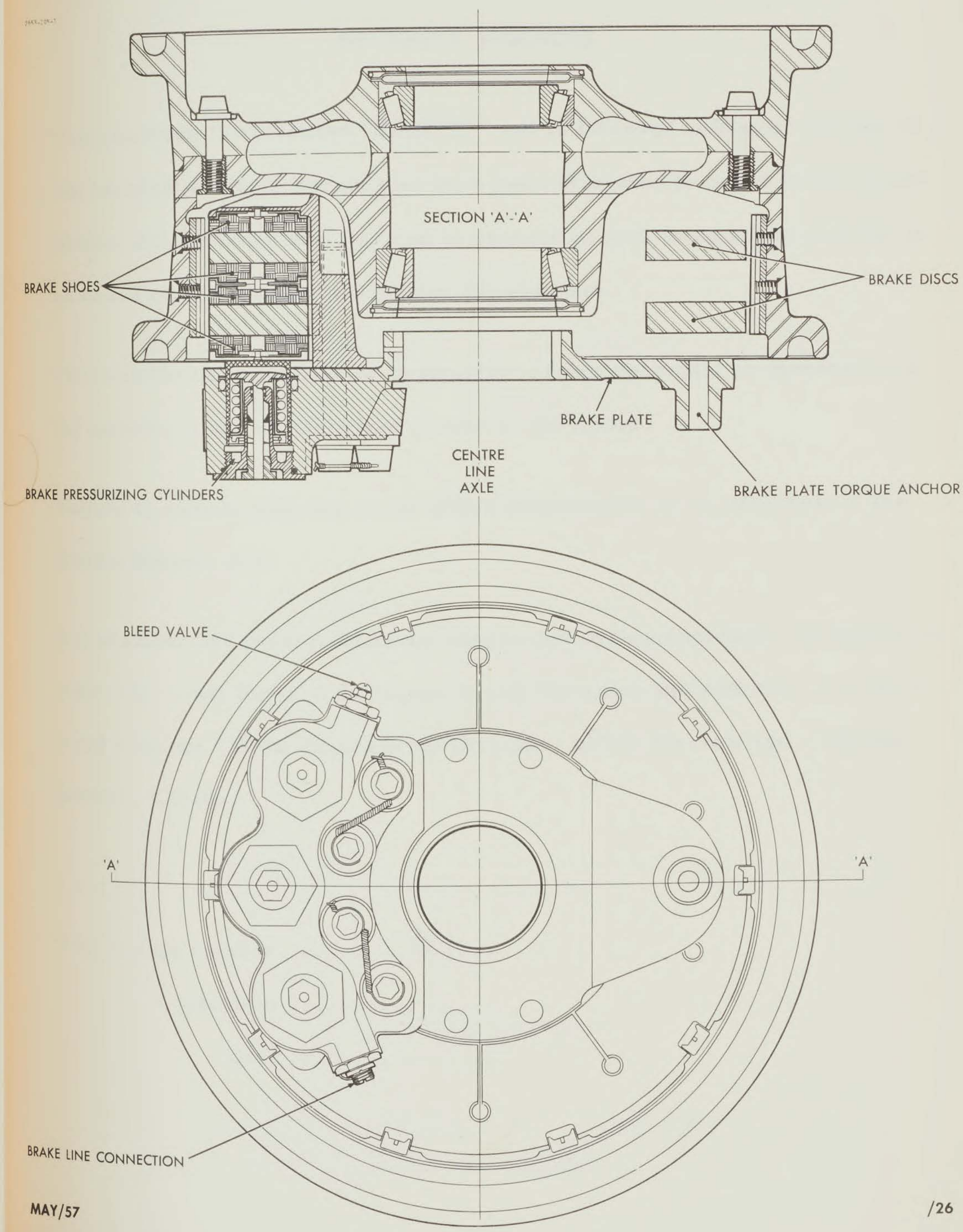

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FIG. 5.3 WHEEL BRAKE ASSEMBLY

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Date ....

ARROW 2
FLYING CONTROLS HYDRAULIC SYSTEM

REPORT NO. 72/SYSTEMS 32/25

JUNE 1957

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

COMPILED BY D. Royston. APPROVED BY Alan R Buley

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

MALTON — ONTARIO

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1. Introduction

1.1 Flying Control Requirements

The Arrow 2 aircraft will be equipped with a fully powered flying control system. This is the only practical way to cope with high surface loads resulting from stability and controllability requirements.

With fully powered controls, the power required to operate the surfaces is derived from the engines; the pilot's effort is only that required to overcome the operating loads of the surface control actuator valves, the control linkage friction, and the forces of the artificial feel systems. The control system may be described as irreversible. There is therefore, no feed-back of aerodynamic forces to the pilot and hence no natural feel of aircraft response through the controls.

1.2 System Considerations

1.2.1 Powered Controls

Hydraulic means of transmitting power to the control surface actuators has been chosen as the most suitable, and a system pressure of 4000 psi has been selected in order to meet the high response requirements and actuator size limitations imposed by the aircraft performance and configuration. To achieve a degree of reliability comparable to the highly developed mechanical systems used in the past, the powered control system is duplicated, the two systems being identified as "A" and "B" respectively, and confined to the operation of the ailerons, elevators and rudder. The aileron and elevator parallel and differential servos receive power from the "B" system only. The duplication covers input power to the pumping system, the pumps, the hydraulic circuits and the rams of each surface actuator. It is arranged that adequate flying control power is available in the event of the failure of one engine or one hydraulic system.

1.2.2 Astra I Scanner Drive

The "A" flying controls hydraulic system has a secondary function, in that it also supplies high pressure fluid to power the Astra I scanner drive hydraulic sub-system.

1.3 Special Design Features

Certain innovations in the detail design of the hydraulic circuits ensure proper functioning of the system, with a minimum of maintenance, during operation under the most adverse environmental conditions. Some of these innovations are noted below.

1.3.1 Air-Less Circuit

The principle of an "air-less circuit" has been adopted, i.e. a circuit in which the air inclusion is kept to a minimum. Compensators are used instead of the usual reservoirs. In the compensators stored fluid is kept constantly under pressure, there being no direct contact of the fluid with air.

1.3.2 High Fluid Temperature

Drag considerations dictate the desirability of using the fuel supply as a heat sink for dissipating heat generated by the hydraulic systems. This is precluded, under low fuel consumption conditions, by fuel temperature limitations at engine inlets. It is, therefore, necessary to utilize ram air cooling under these conditions. For efficient heat exchange the hydraulic fluid must be operated at as high a temperature as is practicable, and 275°F has been established as the upper limit in order to permit the use of standard MIL-O-5606 fluid and of sealing materials and techniques which are in a satisfactory state of development.

1.3.3 Line Fittings

To provide greater line resistance to fatigue, MS-type flareless fittings, up-rated to 4000 psi working pressure, have been used in preference to the AN flared type. This feature parallels mandatory requirements on all new designs in the USAF and USN and therefore contributes to standardization. (See Fig. 2.8).

1.3.4 Flexible Connections

To avoid problems normally associated with the use of flexible hoses and, in particular, those associated with the high operating temperatures and pressures of this system, flexing steel lines have been used extensively wherever relative motion has to be catered for.

1.4 Selection of Line Sizes

The line sizes selected for the hydraulic circuits are based on full flow and full control effectiveness with a fluid temperature of 0^{o}F.

This operating condition has been chosen as a satisfactory compromise between the system operational characteristics and weight and space-saving considerations.

It was considered impracticable to size the lines for full flow and control effectiveness at -65^{o}F because of the weight and space penalties involved, since fluid cooling is necessary after a few minutes of operation to keep the system temperature below 250^{o}F.

NOTE: Information on the Flying Control Actuators and Servos is given in Brochure 72/Systems 15/28 entitled: "DESCRIPTION OF ARROW 2 FLYING CONTROL SYSTEM".

2. Design Objectives

The design objectives for the flying control hydraulic system are:

2.1 To provide an irreversible hydraulic system to move the control surfaces individually or in combination meeting the following maximum rate and hinge moment requirements at fluid temperatures down to 0°F:

(a) Elevators - 60,000 lb. - ft. at 40°/sec.

(b) Ailerons - 25,000 lb. - ft. at 35°/sec.

(c) Rudder - 12,000 lb. - ft. at 40°/sec.

2.2 To provide adequate control power for flight (with limited manoeuverability) under the following conditions:

(a) Fluid temperature as low as minus 20°F.

(b) Asymmetric flight due to single engine operation.

(c) Failure of one of the duplicated flying controls hydraulic systems.

2.3 To restrict system operating temperatures to a maximum of 250°F (with temperatures up to 275°F in local sections of the circuit) by the use of heat exchangers, to permit the use of currently available sealing techniques and MIL-O-5606 hydraulic fluid.

2.4 To provide a high degree of system reliability, through the use of pump inlet pressurization, to overcome cavitation tendencies at low temperature and high altitude.

2.5 To provide a system which will meet the requirements of RCAF Specification AIR 7-4, which in turn calls for the design requirements of CAP 479, "Manual of Aircraft Design Requirements for the Royal Canadian Air Force" and ARDCM 80-1, "Handbook of Instructions for Aircraft Designers".

3. Description of System

3.1 Simplified Schematic

Fig. 1.2 shows a simplified schematic of one of the flying control hydraulic systems. The primary flow path is indicated by heavy lines, the solid portion representing the pressure side and dotted portion representing the return side of the closed circuit. Secondary paths are indicated by thin lines, and the ground power unit is shown in phantom lines.

3.1.1 Primary Flow Path

Variable delivery pumps supply filtered hydraulic fluid to the flying control valves and actuators. Returning fluid passes through a heat exchanger to a compensator and from there enters the pump. The system is of the airless type, with the compensator fulfilling the function of a pressurized reservoir.

3.1.2 Secondary Flow Paths

The two principle secondary flow paths, as shown in Fig. 1.2, are as follows:

(1) The path through the pressure relief valve protects the system from excessive rises in pressure.

(2) The path through the pressure reducing valve supplies standby pressure to the compensator in case of failure of the normal pressure supply from the Utility System.

3.2 Filtration

All pressure fluid flowing to the flying control actuators passes through a 40 (US) gpm 10 micron filter. The aileron and rudder actuators, being remote from this filter, are provided with further protection for their valves by filters close to the actuators. All return fluid passes through a filter mounted on the compensator inlet. (See Fig. 2.0).

3.3 Temperature Control

The pump inlet temperature is maintained below 230°F by the use of heat exchangers in the circuit upstream of the compensator. Energy losses in the hydraulic circuit, (principally in the pumps and control valves) are transferred, in part, to the hydraulic fluid, resulting in a rise in temperature.

The maximum fluid temperature at the inlet to the heat exchangers will be +250°F, but localized heating up to +275°F may occur. Under these conditions the outlet temperature will not exceed 230°F. These operating conditions have been taken into consideration in the design of units, seals and in selecting MIL-O-5606 as the hydraulic fluid.

3.4 Ground Service Connections

Two ground service connections are provided, one on the pressure side and the other on the return side of the system. This permits the system to be operated by an external source of power without operating the pump or the compressor. The low pressure service connection is also used as a filling point for the system. A filter in the return line of the main flow path protects the pumps from any foreign matter which may be introduced when filling the system.

3.5 System Warm Up Times (Fig. 3.1)

If the aircraft has been cold soaked on the ground, it will be necessary to warm up the hydraulic oil before take-off to obtain adequate control power for flight. This is done by manual movements of the cockpit control during engine running. An approximate measure of the time required to warm up to operating temperature from cold soak ambient air temperatures of -20, -40 and -65°F is given in Fig. 3.1.

3.6 Astra I Scanner Drive Sub-System

Power for the Astra I Scanner drive hydraulic system is obtained from the flying controls hydraulic system ("A"). High pressure fluid is taken from the supply line for the rudder unit, at a point downstream of the main filter. The fluid is then passed through a stop valve, and a check valve, into the hydraulic motor end of a hydraulic transformer unit. This unit is part of the Astra I hydraulic system and is basically a 4000 psi hydraulic motor mechanically driving a 1000 psi constant delivery pump. A flow regulator is installed in the motor to prevent the removal of more than

3.5 gpm flow from the flying controls system. An 80 cu.in. accumulator is "T" jointed into the 4000 psi supply line, downstream of the check valve, to supply the hydraulic motor during peak flying control flow requirements. The solenoid operated stop valve receives its electrical supply from the main D.C. bus; therefore on double engine flame-out this valve will close, preventing the removal of power from the flying control system. The stop valve can also be de-energized on the ground to prevent scanner system operation during testing of the flying control hydraulic system.

4. Description of Main Components

4.1 Compensator (See Figs. 2.0 and 2.1)

4.1.1 Purpose

The compensator is a variable volume, air-less pressure vessel, designed to keep the pump inlet under pressure at all times. It compensates for volumetric changes in the flying controls hydraulic system due to the thermal expansion and leakage. It also serves as an air separator. The low pressure filter, on the inlet of the compensator filters, return fluid before it reaches the main compensator chamber.

q 4.1.2 Physical Description (See Fig. 2.0)

The compensator consists of a large bore cylinder, of 475 cu. in. capacity, with a coaxial small bore cylinder rigidly attached. A large diameter piston with a hollow stem allows the main cylinder volume above the piston to be pressurized by system reduced pressures which are imposed on the hollow stem area in the small cylinder.

4.1.3 Pressurization

There are two pressure connections on the small cylinder arranged so that either one will function in the event of failure of the other. Reduced pressure at 1500 to 1600 psi, from the utility system pressure control valve, provides the normal means of pressurizing the small cylinder through the central stand pipe. In the bottom of the chamber is a floating piston, which is pressurized at 1250 psi from the flying controls hydraulic system pressure control valve. On failure of the normal pressure source, the alternative pressure forces the floating piston against the end of the hollow stem to maintain pressurization in the low pressure chamber. (The stand pipe maintains the separation between the systems.)

4.1.4 Relief Valve

A relief valve, designed to relieve at 220 psi, is fitted in the dome at the top of the main chamber. Should this valve open, any air trapped in the dome will be discharged prior to discharge of fluid.

4.1.5 Bleed Valve

A manually operated bleed valve is provided in the low pressure end of the compensator. In addition to providing an air-bleed for servicing, this valve also enables surplus fluid to be drawn off if the compensator is over-full.

4.1.6 Functioning of Compensator (See Fig. 2.1)

4.1.6.1 Volume of System Decreasing

As the hydraulic system cools down, its total volume decreases, reducing the system return pressure acting on the top of the piston. (See detail (b) Fig. 2.1). When the pressure falls to the point where the hydraulic force plus the seal friction is insufficient to balance the 1500 psi pressurization in the small cylinder, the piston will rise to re-establish pressure equilibrium.

4.1.6.2 Volume of System Increasing (See detail (c) of Fig. 2.1)

When the volume of the system increases, the pressure in the head of the compensator increases until it is sufficient to overcome the hydraulic force on the high pressure piston area, plus the seal friction. The piston then moves down, discharging fluid from the high pressure chamber at 1720 psi. through the relief valve, until a pressure balance is re-established.

4.1.6.3 Failure of Normal Pressurization (Between reducing valve and compensator) (see detail (d) in Fig. 2.1)

When the normal (utility system) fluid pressure falls to a value less than 1250 psi, the stand-by system pressure moves the floating piston upwards, until it contacts the rim of the hollow piston rod and thus restores return line pressurization. Due to higher seal friction and the reduced effective area of the small cylinder (bore area minus the central stem area), the effective pressurization in the top chamber in this stand-by condition is reduced to approximately 75 psi. As the system volume increases, the pressure in the small cylinder increases to 1800 psi before fluid is released through the relief valve.

4.1.6.4 Failure of Normal Pressurization (With line from reducing valve to compensator intact) (See detail (e) of Fig. 2.1)

Pressure will be transmitted to the low pressure chamber, from the stand-by system, through the column of fluid trapped on the normal high pressure supply side of the smaller piston.

If the system return pressure increases and the resulting pressure rise in the lower cylinder exceeds 1720 psi, the trapped fluid will be discharged through the utility relief valve, permitting the floating piston to contact the hollow piston stem. The compensator will then operate in the manner described in paragraph 4.1.6.3 above.

4.1.7 Compensator Servicing

Providing the system is filled correctly initially and no leakage occurs, the compensator will be completely full only if the maximum system temperature is reached. For every mean fluid temperature within the design temperature range there is a corresponding piston position that indicates a full system. A constant reading piston position indicator, calibrated in degrees of temperature, is fitted to each compensator to indicate the volume of the contained fluid. Comparison of the actual system temperature (determined within acceptable limits from a thermometer in an insulated mounting on a hydraulic component in the aircraft), with the piston indicator reading, gives the required information on system volume.

4.2 Variable Delivery Pump (See Fig. 2.2 & 2.3)

4.2.1 Pump Drive

Each flying control hydraulic system incorporates two identical pumps, one of which is driven through a geared drive from the L.H. main engine, and the other from the R.H. main engine.

4.2.2 Pump Inlet Pressure

The inlet pressure to each pump is maintained at a nominal value of 90 psi by the compensator. The pumps will operate satisfactorily with any inlet pressure from 30 to 130 psi, and will withstand intermittent operation with inlet pressure down to 2 psi absolute.

4.2.3 Delivery Rate

The pumps are of the variable displacement type, with integral outlet pressure sensing unit which varies the delivery rate to meet the system demands as reflected in pressure drop. This unit is set to maintain a nominal 4000 psi outlet pressure. Available delivery rate varies directly as the engine speed, reaching a maximum of approximately 20 (US) gpm, per pump, at 3250 rpm (equivalent to full engine rpm). The pumps will withstand an overspeed up to 3900 rpm in the event of engine malfunction.

4.2.4 Pump Inlet Connection

The system return is connected to the pump through a quick disconnect self-sealing coupling. This prevents loss of system fluid, and minimizes the possibility of air inclusion in the system when the pump is removed for servicing.

4.2.5 Pump Delivery Manifold

The outputs from the two pumps in each system are united in a manifold, which incorporates a check valve in each inlet. In the event of one pump failure, the check valve in the respective manifold inlet will prevent the reverse flow of fluid through the inoperative pump. The check valves also prevent reverse flow through both pumps during operation of the ground servicing unit.

4.2.6 Pump Case Drain

A pump case drain line from each pump is connected to the system return line upstream of the heat exchangers. This drain line provides for disposal of the internal leakage from the pump, thus providing the necessary lubrication and cooling of the pump mechanism. This port also serves for case filling after pump installation, as it is located at the highest point in the casing to prevent entrapment of air.

4.3 Filters

4.3.1 Filter - Bowl Type, High Pressure, 40 (US) GPM (See Fig. 2.6)

4.3.1.1 Purpose

High pressure 40 (US) gpm filters are located in the pressure side of the system, downstream of the pumps and ground servicing coupling. These filters protect the flying control valves and actuators and the automatic flight command (parallel) servos. They are the master high pressure filters and are designed to provide filtration down to 10 micron size.

4.3.1.2 Self-Sealing Provisions

The filter bowl and element can be removed without completely depressurizing the system, provided pressure on the high pressure side is reduced to the normal return pressure (approx. 90 psi). When the bowl is being removed, internal valves in the filter head move to positions which prevent loss of any appreciable amount of fluid and the consequent entry of air into the system lines.

4.3.1.3 Relief Valve Operation

The relief valve is set for 50 ±5 psi cracking pressure differential across the filter element. Should excessive clogging of the element cause the pressure drop to exceed this valve it will be bypassed.

In normal conditions, i.e. when the clogging does not exceed a certain allowable value (equivalent to blocking off 25% of the filter element area), the filter is designed to work without by-passing in the following conditions:

(1) at rated flow at all temperatures above $0^{\circ}F$,

(2) at 50% of the rated flow at all temperatures above $-20^{\circ}F$,

(3) at 7.5% of rated flow at all temperatures above -65°F.

4.3.1.4 Filter Element

The 40 gpm filter elements used in the flying controls system filters are of the cleanable, re-usable type.

4.3.2 Filter - Bowl Type, Low Pressure, 40 (US) GPM (See Fig. 2.6)

This filter is installed in the return side of the system, mainly to protect the pumps. It is placed upstream of the compensator to ensure a positive pressure at the pump inlet. It is mounted on the inlet of the compensator to filter particles of 10 microns and larger from the fluid returning from relief valves, pump case drains, actuators, and ground servicing connection, thus protecting the pumps and the compensator. The low pressure filters are equipped with self-sealing valves and relief valves, to provide the same operating and servicing facilities as specified for the high pressure filters in paragraph 4.3.1.2 and 4.3.1.3 above. This filter will use the same element of 40 (US) gpm capacity developed for the high pressure filter.

4.3.3 Filter - Secondary High Pressure (See Fig. 2.5)

4.3.3.1 Purpose in System

Due to the long lines separating the main 40 (US) gpm. high pressure filter from the rudder and aileron actuators, additional filtration protection is provided near these units, by means of individual filter assemblies of 4 and 7 (US) gpm nominal capacity, respectively. After the initial cleansing of the system, it is anticipated that these filters will require infrequent servicing, as the main filter, which is more readily accessible, will retain most of the contaminants.

4.3.3.2 Filter Element

The filter elements are made from the same material as the main 40 gpm high pressure filter elements and are designed to provide protection from particles down to 10 microns. They will be re-usable after cleaning.

4.3.3.3 By-Pass Relief Valve

Each filter assembly incorporates a by-pass relief valve, so that undue restriction of flow through the filter element will result in flow being by-passed around the element. The relief valve is set to open when the pressure drop across the element exceeds 50 $\pm$ 5 psi.

4.4 Pressure Control Valve (See Fig. 2.4)

The three valves described below have been combined into one unit to simplify piping, conserve space and reduce the number of mounting points. This unit is termed the pressure control valve.

4.4.1 System Pressure Relief Valve

The pressure relief valve is set to crack at a maximum pressure differential of 4370 psi which, with the normal pressure of 90 psi in the return side of the system, gives an actual pressure of 4460 psi. The valve provides full flow relief at a pressure of 4750 psi.

4.4.2 Pressure Reducing Valve

The pressure reducing valve reduces normal system pressure to a nominal value of 1250 psi for emergency pressurization of the flying controls system compensator.

4.4.3 Service Relief Valve

A service relief valve is provided to permit relief flow of fluid from the high pressure side of the compensator when fluid is forced into the low pressure side. It is set to crack at a pressure differential of 1800 psi.

4.5 Accumulator - 25 Cubic Inch, Floating Piston Type (See Fig.2.7)

4.5.1 Purpose in System

Whenever the control valve of an actuator is moved from its neutral position there is a demand for high pressure fluid. The accumulator with its nitrogen charge can supply this demand momentarily faster than the pump, thus giving quicker control response. The accumulator will be recharged by the pump when the demand has been met. It also provides damping for pressure surges and pulsations caused by rapid valve operation. Tests have proven that a 25 cu. in. accumulator is adequate to perform both these functions.

4.6 Switch - Hydraulic Pressure (See Fig. 2.12)

4.6.1 General Description

The switch body has a hydraulic port at one end and an electrical connection at the other. Inside the case a pressure-sensitive mechanism actuates a snap-action type electrical switch, which has a wide range between snap and reset. A warning light glows in the cockpit when system pressure falls too low and actuates this pressure switch.

4.6.2 Pressure Settings

The switch contacts close as the system pressure falls to 1000 psi and open when the system pressure rises to 3000 psi or higher. In normal flight manoeuvres, the cockpit warning light should not glow, even momentarily, unless system failure occurs.

4.7 Heat Exchanger (Figs. 2.10 and 2.11)

4.7.1 Heat Source

The high powered pumps and actuators generate large quantities of heat in the hydraulic fluid which is circulating through them. Little heat can be transferred to the surrounding air because of the high ambient temperatures which may be encountered. Therefore, a heat sink is required to keep the fluid temperature from exceeding 275°F. The fluid temperature at the pump inlets must not exceed 230°F, in order that sufficient cooling capacity is available for the minimum fluid flow case.

4.7.2 Heat Sinks

The principal heat sink is the oil to air heat exchanger. The cooling air is bled off of the engine intake and is vented overboard after passing through the heat exchanger. A secondary heat sink is the oil to fuel heat exchanger, downstream of the oil to air one, which transfers the residual heat load into the fuel being delivered to the engines.

4.7.3 Oil-to-Air Heat Exchanger

This heat exchanger has a relief valve by-pass which opens at low temperatures and allows the fluid to by-pass the main exchanger passages. This occurs when the high viscosity due to low temperature causes a pressure drop through the heat transfer surfaces in excess of 10 psi. For cold starting, the low flow circulation through the main exchanger passages and the high flow circulation through the by-pass passages rapidly heats the whole exchanger, to provide full heat exchange capacity when the system fluid temperature has risen to 275°F at the heat exchanger inlet.

4.7.4 Oil-to-Fuel Heat Exchanger

The oil-to-fuel heat exchanger serves to carry the extra cooling load that cannot be handled by the primary oil-to-air heat exchanger.

This exchanger has a by-pass relief valve which, for low temperature operation, will permit the main part of the flow to short-circuit the oil-to-fuel heat transfer surfaces if the pressure drop through them is in excess of approximately 3 psi.

A special feature of this valve is a thermostatic element which is sensitive to fluid outlet temperature. At maximum temperature the by-pass valve closes, forcing the main flow through the heat transfer area. Thus the secondary heat exchanger shares the load with the oil-to-air heat exchanger when the latter is overloaded.

4.8 Expansion Couplings (Fig. 2.9)

Expansion couplings have been incorporated where necessary on long straight runs in hydraulic lines, to relieve stresses due to structural flexing or thermal expansion and contraction. A system of internal passages and carefully dimensioned pressure areas ensure that each unit is hydraulically balanced for any degree of expansion.

Ground Servicing (See Fig. 1.2)

5.1 Requirements - General

Equipment must be attached to the external disconnect couplings of the aircraft hydraulic systems to perform the following servicing tasks:

1. Filling of the flying control and utility hydraulic systems.
2. Refilling the compensators after they have been bled of any entrapped air.
3. Operation of any one of the systems for checkout or troubleshooting without running the engines.

5.2 Ground Servicing Equipment Requirements

The following two units will be required to perform the servicing tasks listed above:

1. A mobile hydraulic power unit, complete with motor driven pump, reservoir, pressure gauges and hose connections to couple to the aircraft systems. This equipment is to recharge the accumulator and to power each hydraulic system when the engines are shut down.
2. A hand pump with hose connections and self-sealing couplings, adapted for temporary support on the aircraft or on the ground servicing unit. This is required for filling the compensators in any of the three aircraft systems.

5.3 Disconnect Self-Sealing Couplings and Accumulators

Due to the fact that most self-sealing couplings cannot be attached or detached while pressure remains in the system, it is necessary to relieve all pressure prior to disconnecting. The emergency braking and compensator-pressurizing accumulator of 200 cu. in. capacity, being isolated by a check valve in the pressure control valve, is unaffected when the utility system pressure is released.

5.4 Protection of the Aircraft Hydraulic Systems (See Fig. 1.2)

5.4.1 Filters

To prevent the introduction of foreign material into the hydraulic fluid during connecting and disconnecting self-sealing couplings, no fluid is permitted to enter the main system components (valves, compensators and pumps) without first passing through the main high pressure or the main low pressure filter. High pressure fluid from the ground servicing unit enters the main line upstream of the pumps and their check valves, and then passes through the main high pressure filter.

5.4.2 Filling Connection Location

To fill the system, fluid is pumped in through the system return self-sealing coupling at the inlet to the filter attached to the compensator, hence the added fluid is filtered before it reaches the compensator. An additional filter upstream of the hand pump provides further protection for the aircraft hydraulic systems.

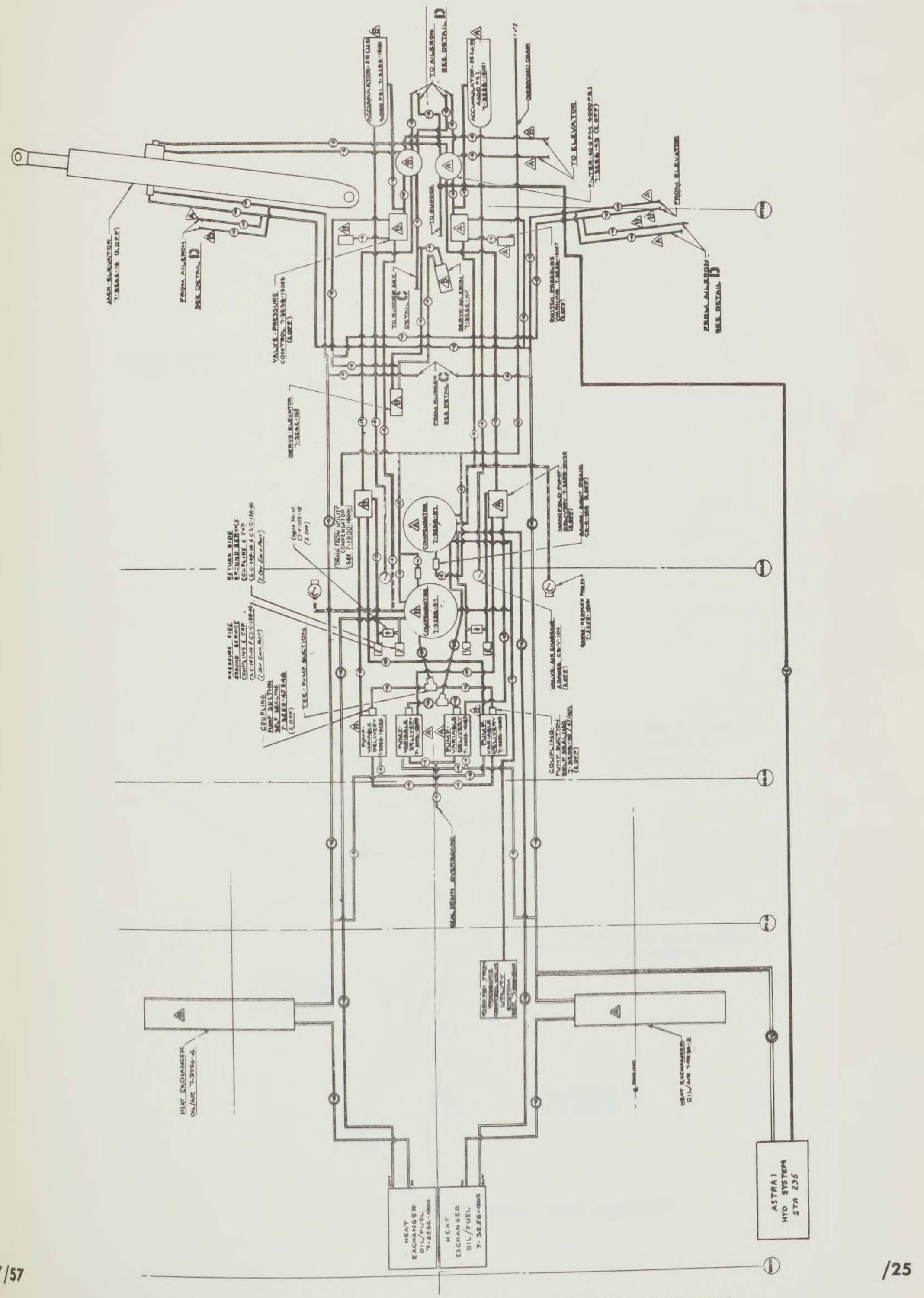

FIG. 1.0 DIAGRAMMATIC FLYING CONTROLS HYDRAULICS SYSTEM

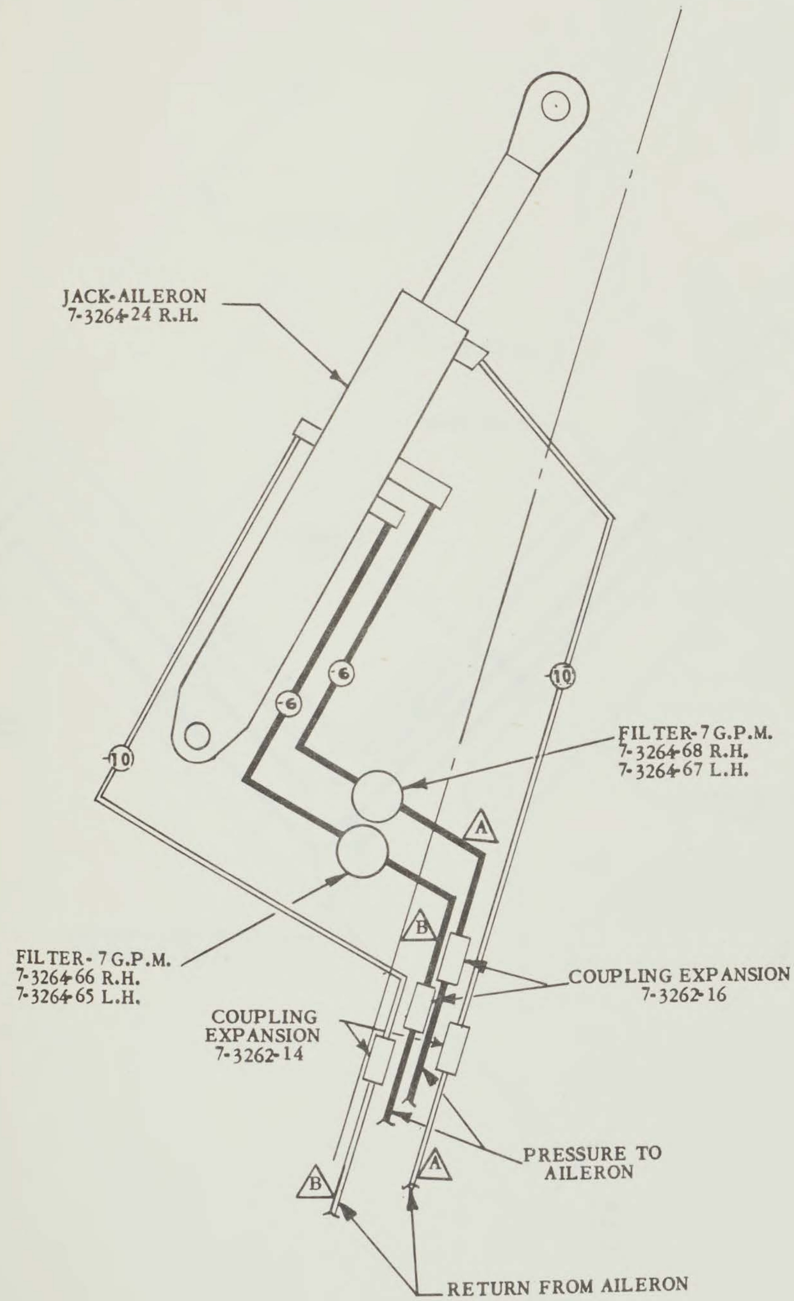

FIG. 1.0.1 DIAGRAMMATIC FLYING CONTROL HYDRAULIC SYSTEM (OUTER WING)

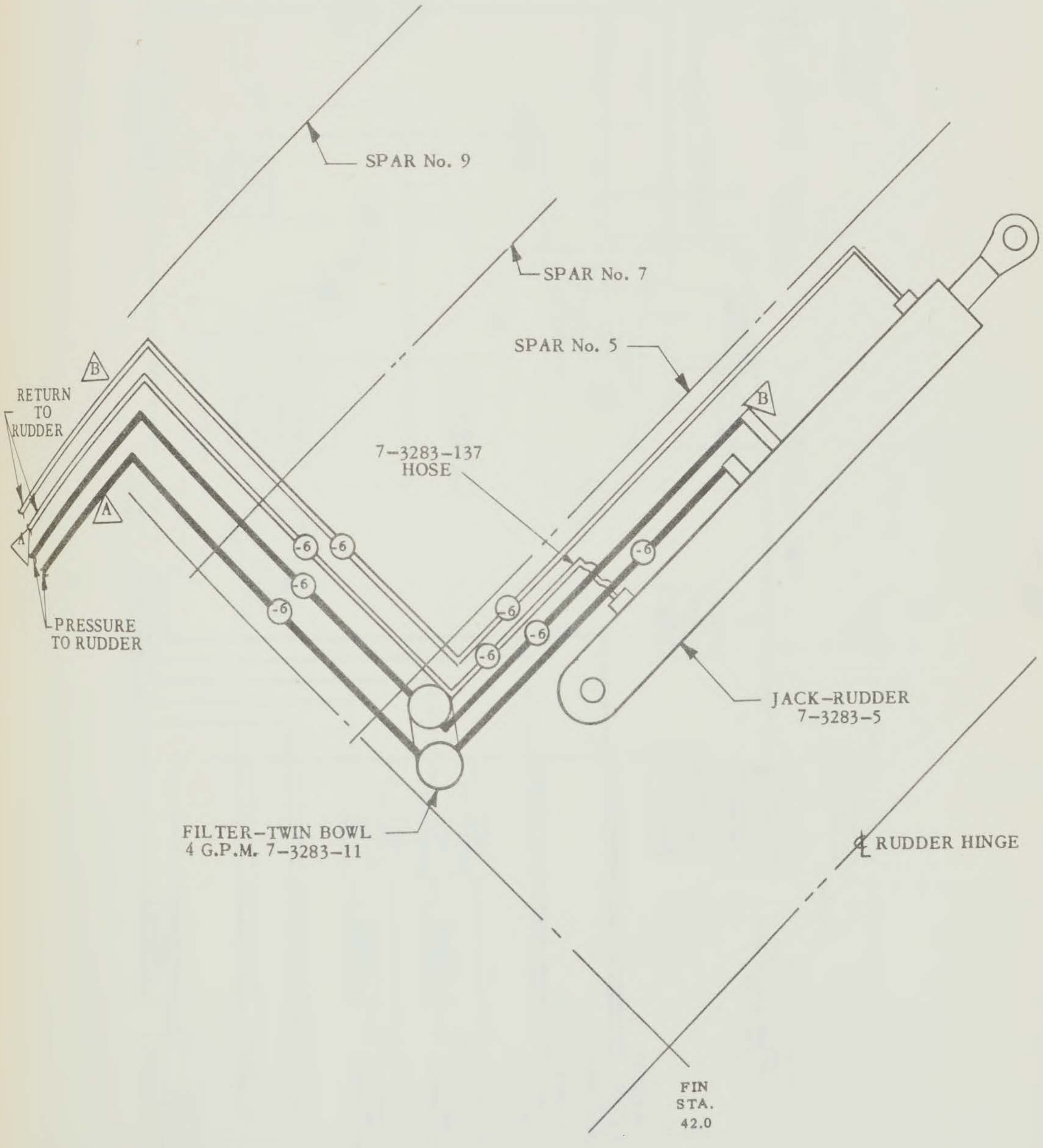

FIG. 1.0.2 DIAGRAMMATIC FLYING CONTROL HYDRAULIC SYSTEM (FIN)

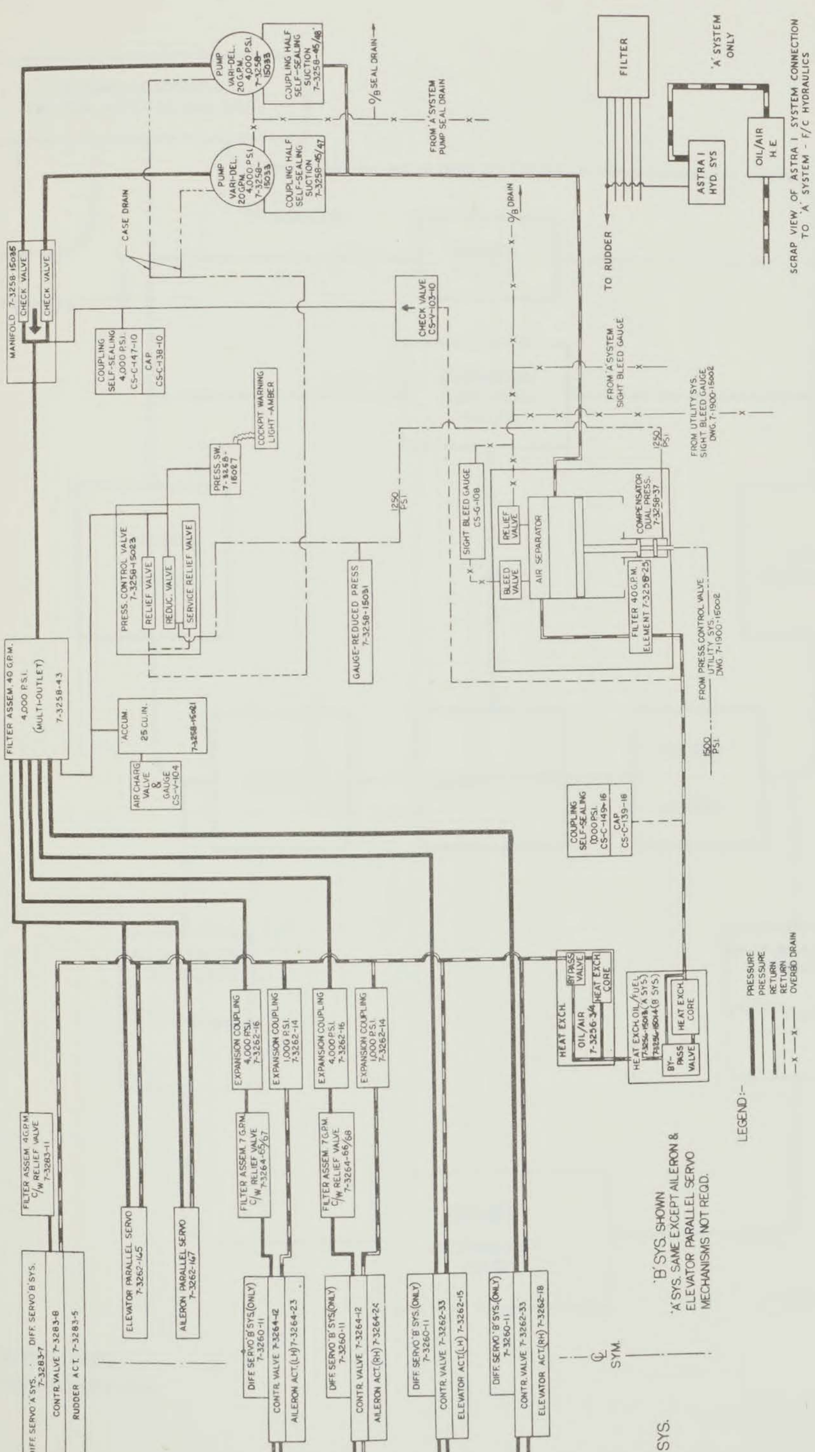

FIG. 1.1 SCHEMATIC FLYING CONTROLS HYDRAULIC SYSTEM

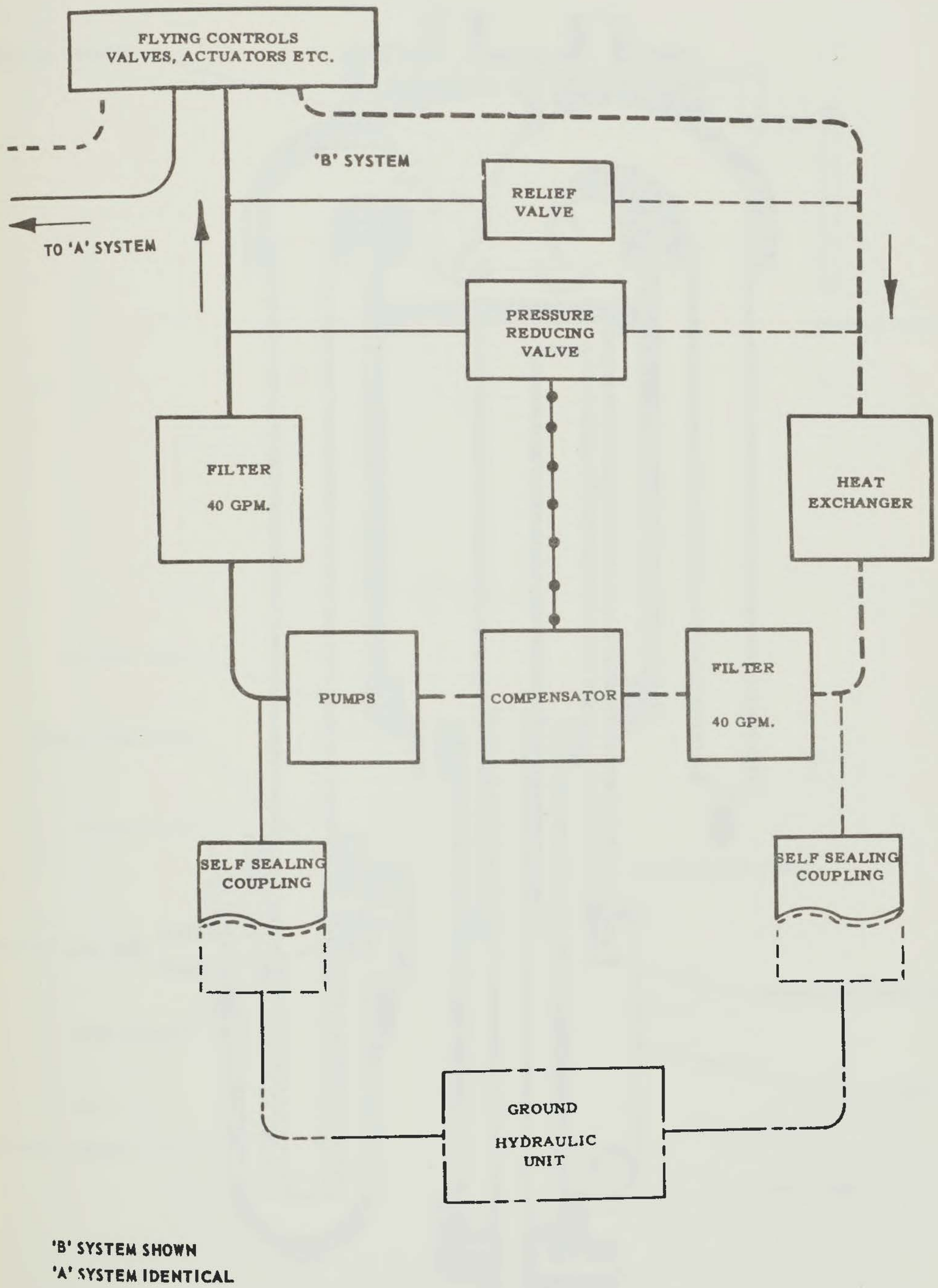

FIG. 1.2 SIMPLIFIED SCHEMATIC FLYING CONTROLS HYDRAULIC SYSTEM

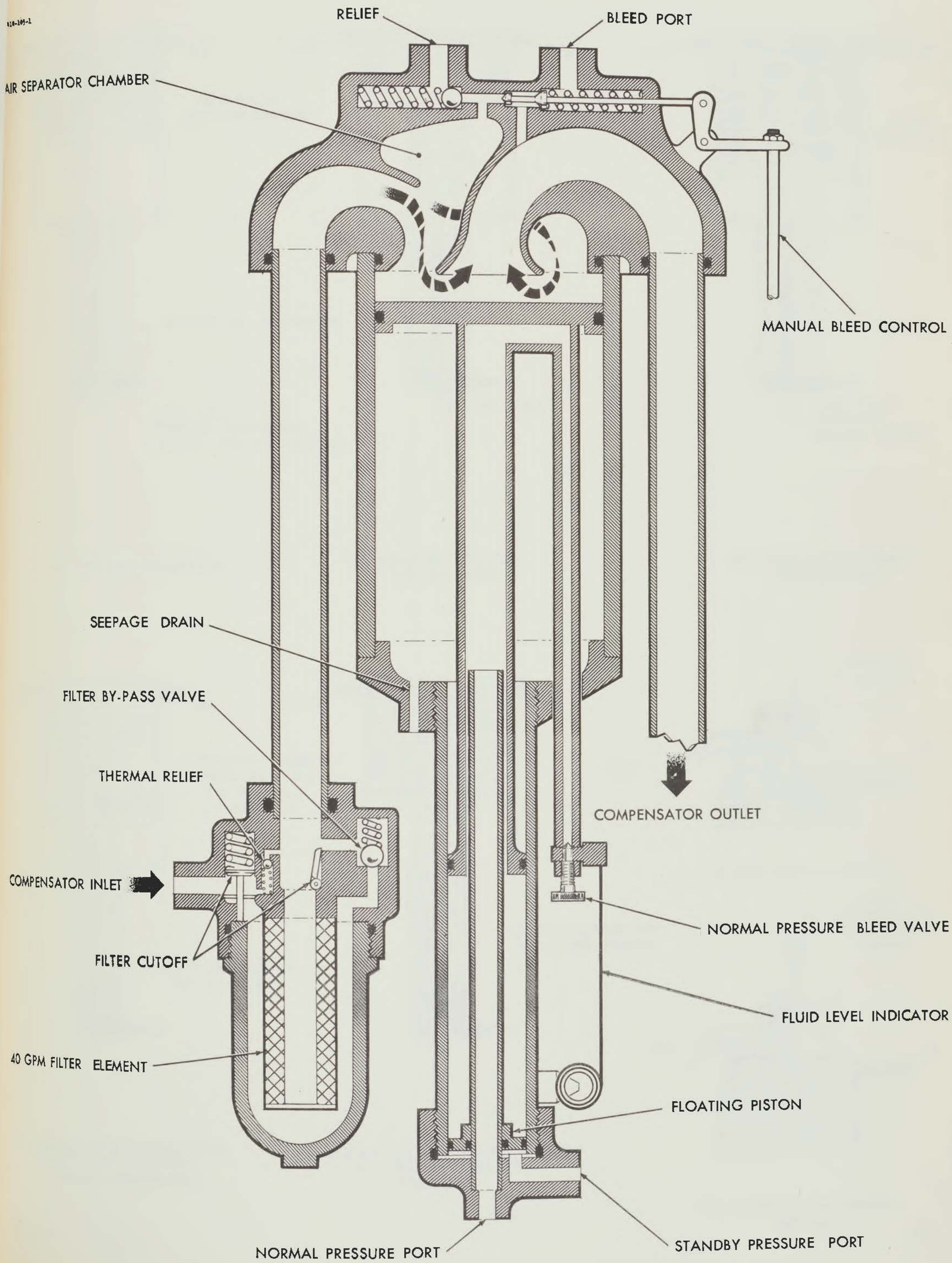

FIG. 2.0 FLYING CONTROL HYDRAULIC SYSTEM - COMPENSATOR

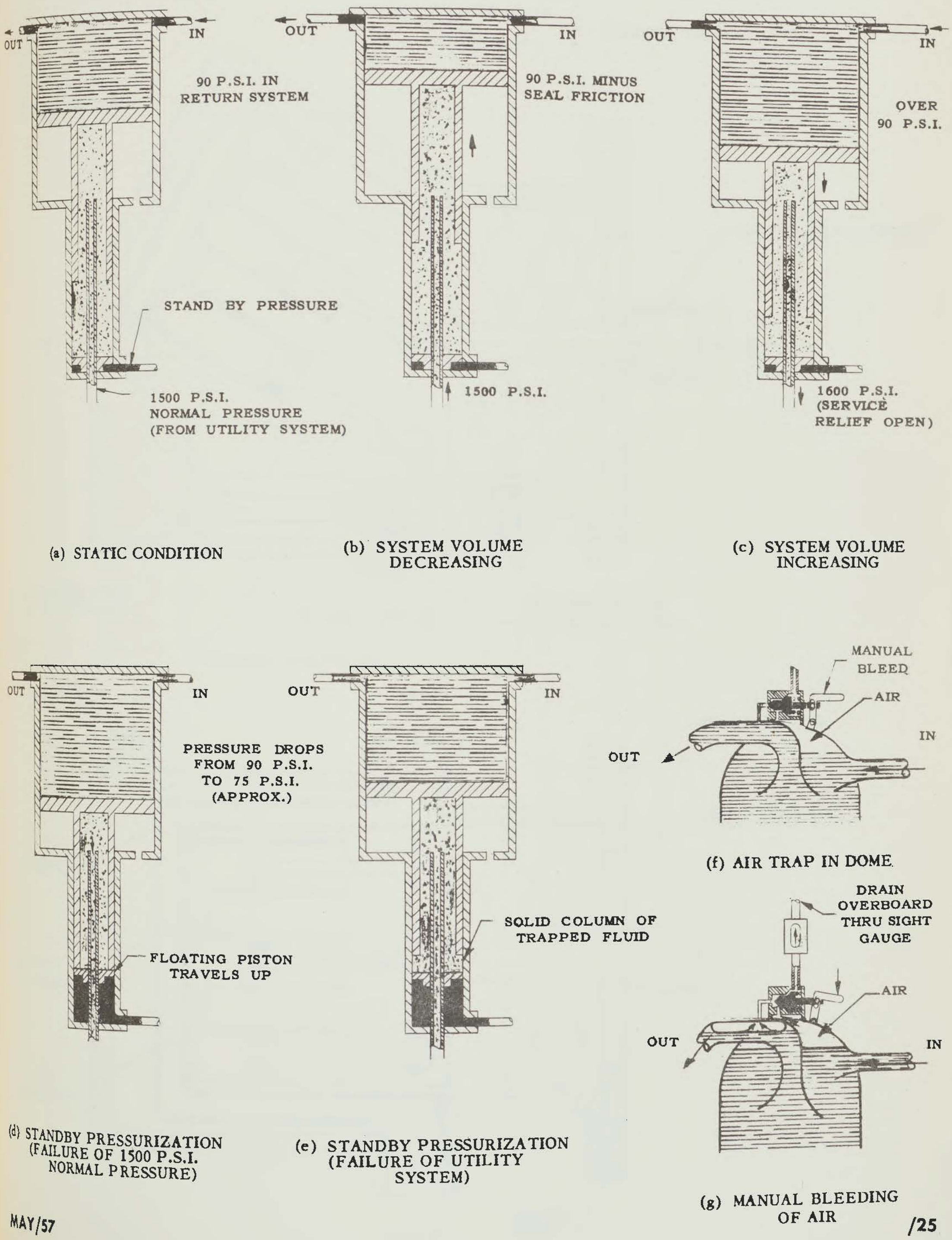

FIG. 2.1 FLYING CONTROLS COMPENSATOR FUNCTIONING

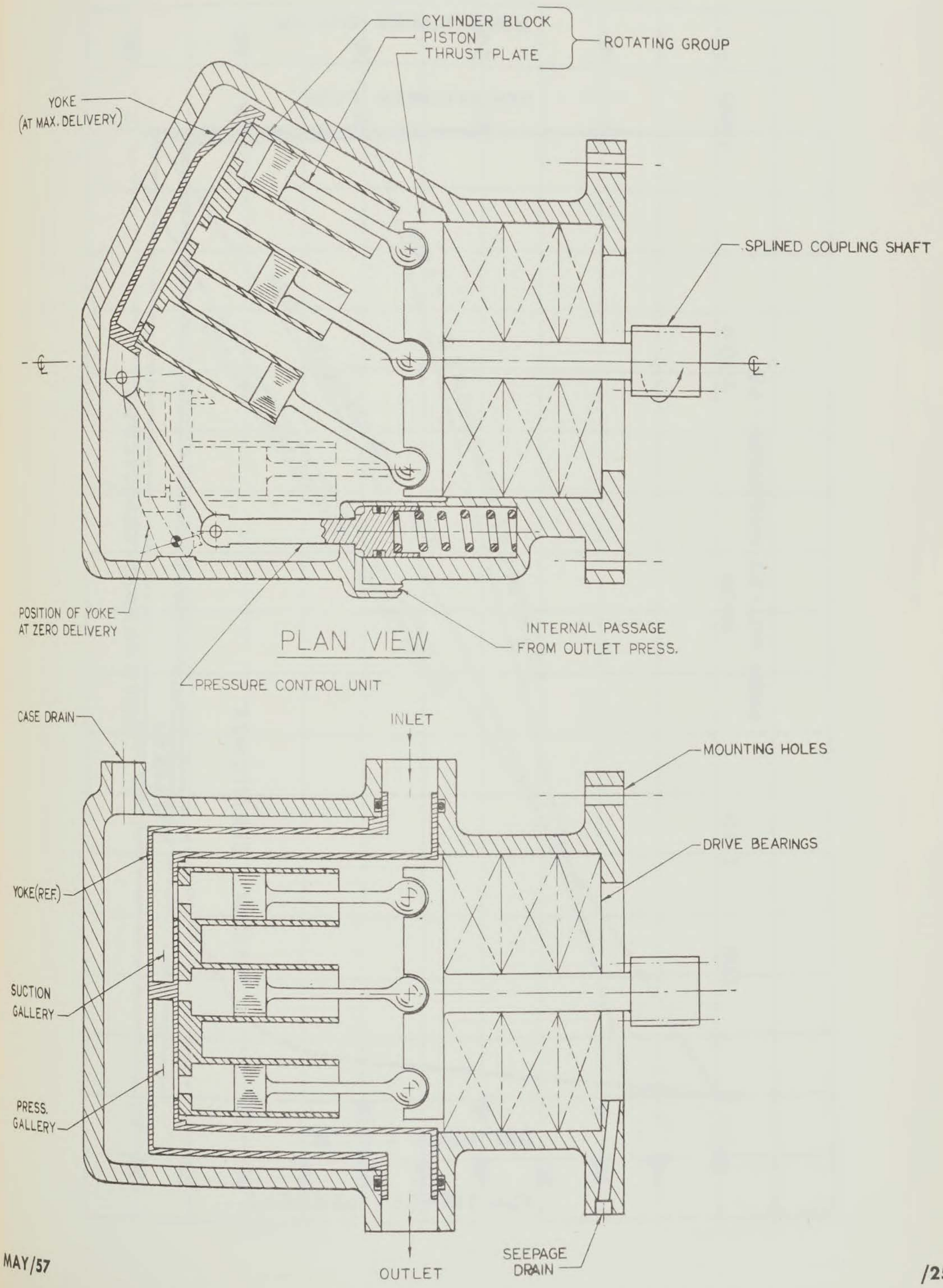

FIG. 2.2 - VICKERS - VARIABLE DEL. PUMP (DIAGRAMMATIC)

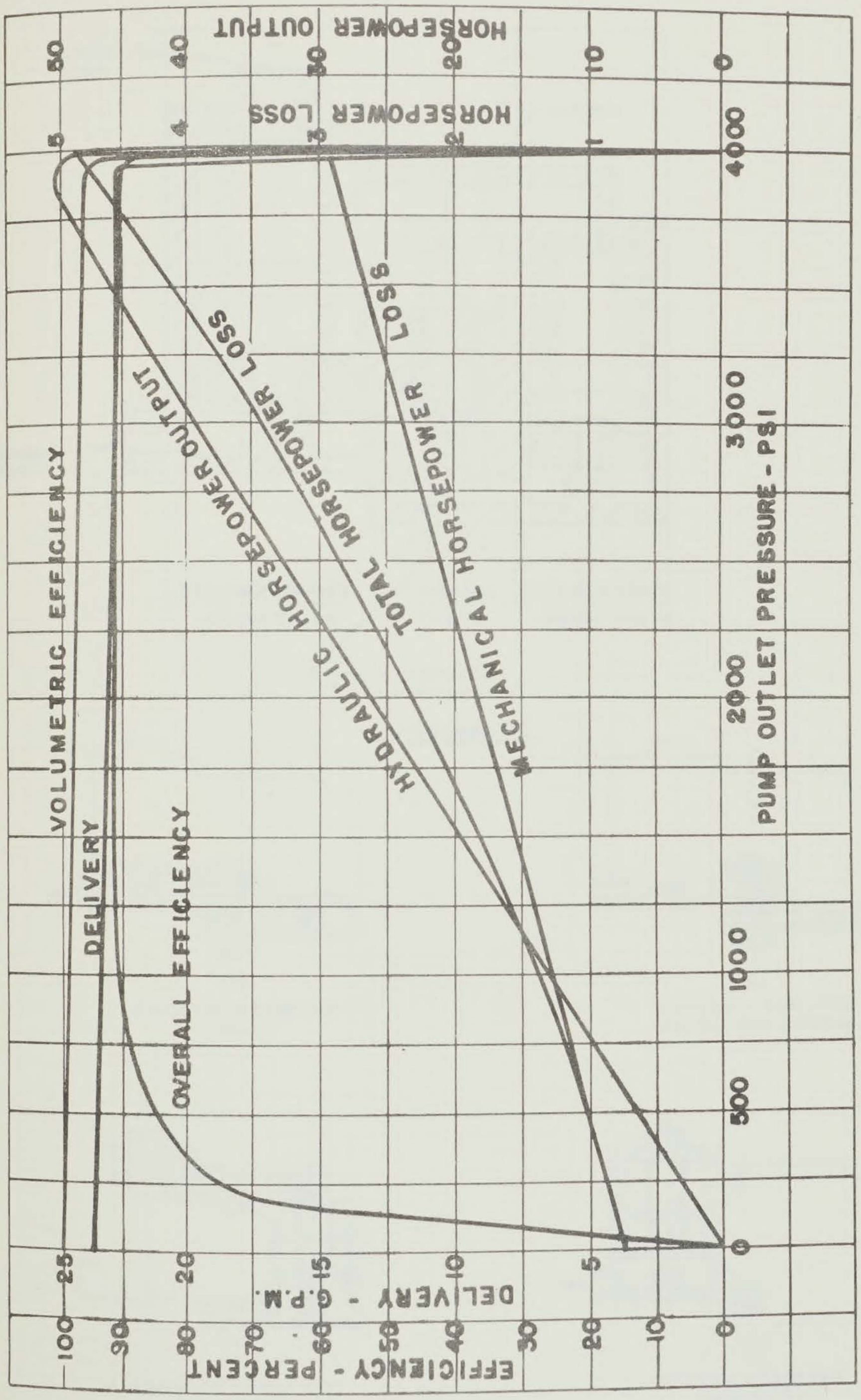

FIG. 2.3 CALCULATED PERFORMANCE CURVES FOR VICKERS 7-3258-15033 VARIABLE DELIVERY PUMP

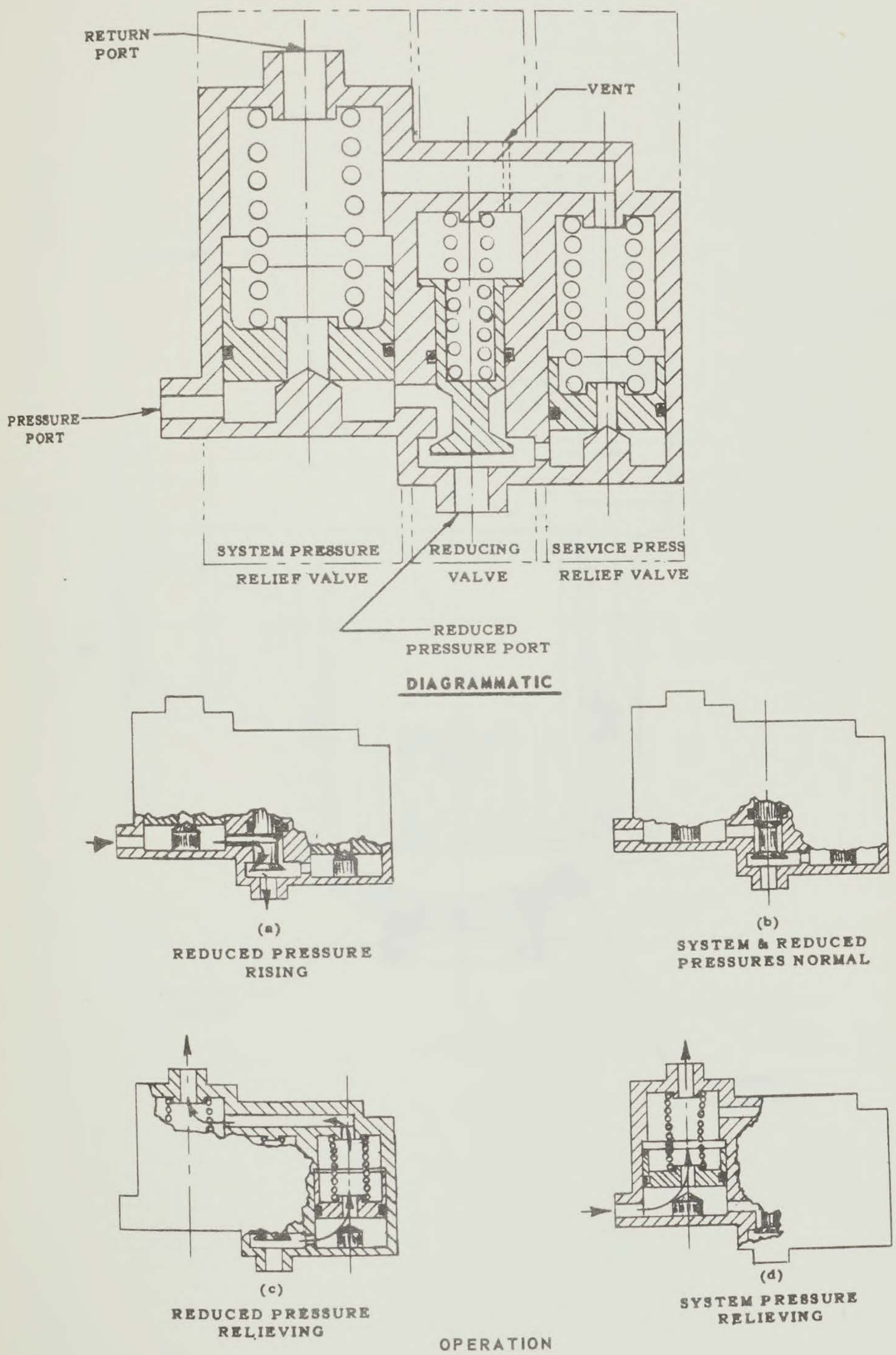

FIG. 2.4 PRESSURE CONTROL VALVE

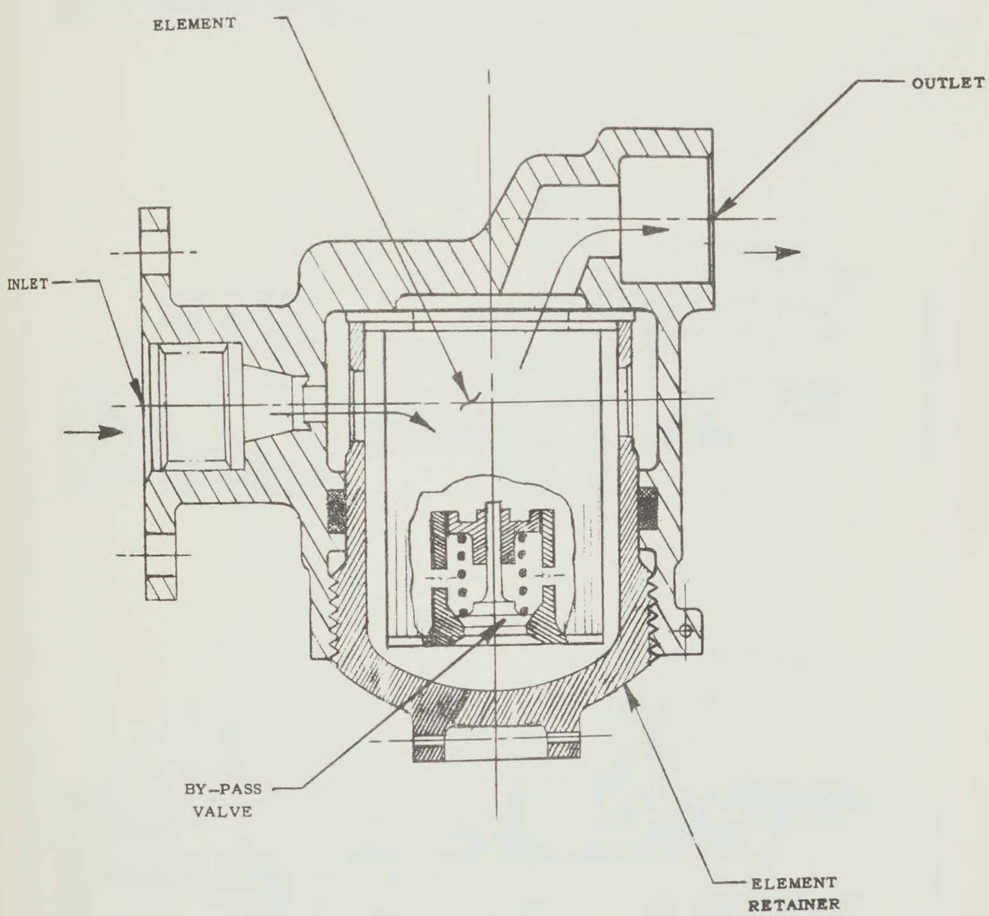

FIG. 2.5 HYDRAULIC FILTER 7 GPM

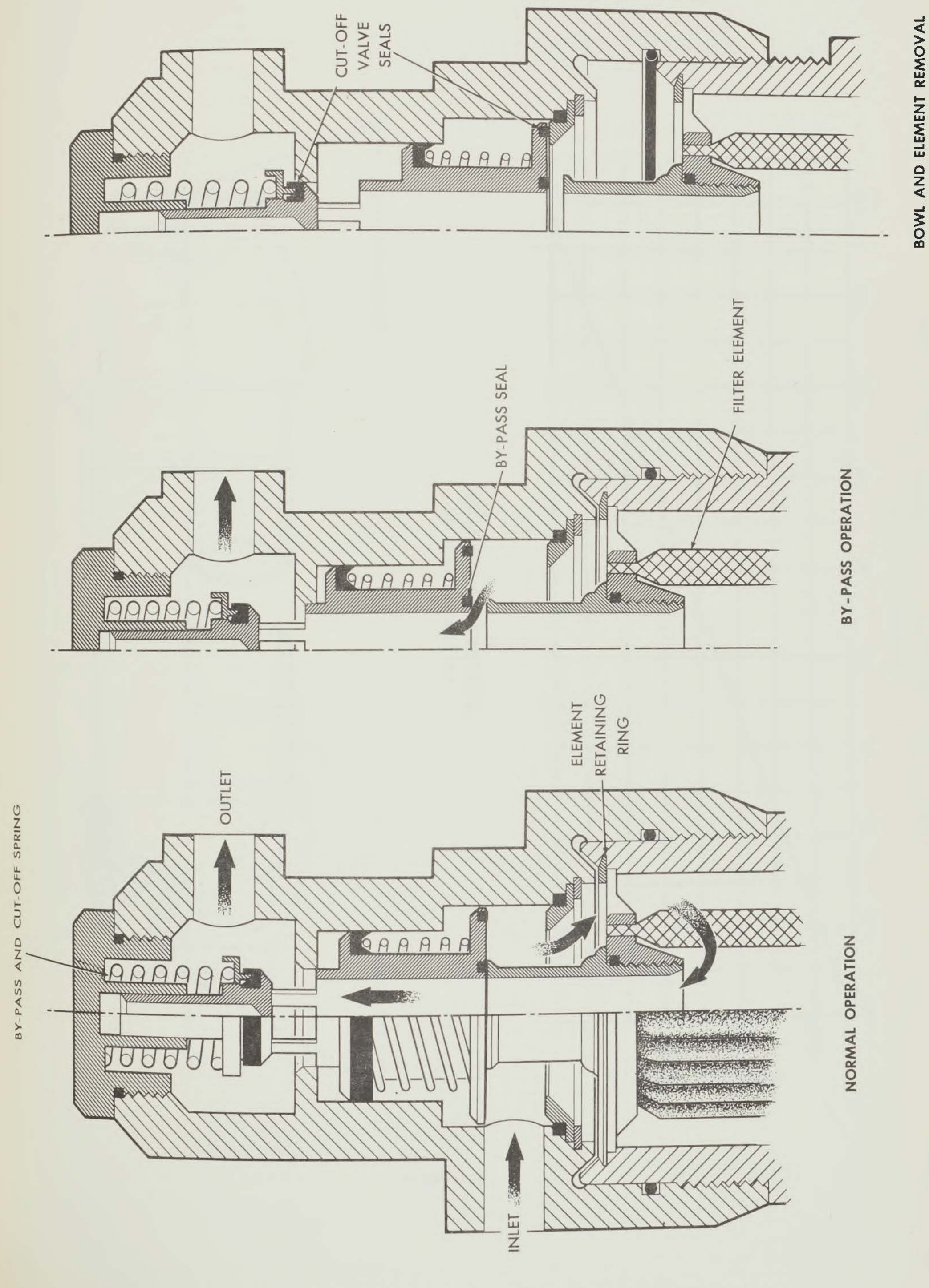

FIG. 2.6 FLYING CONTROL HYDRAULIC SYSTEM - HYDRAULIC FILTER 40 G.P.M.

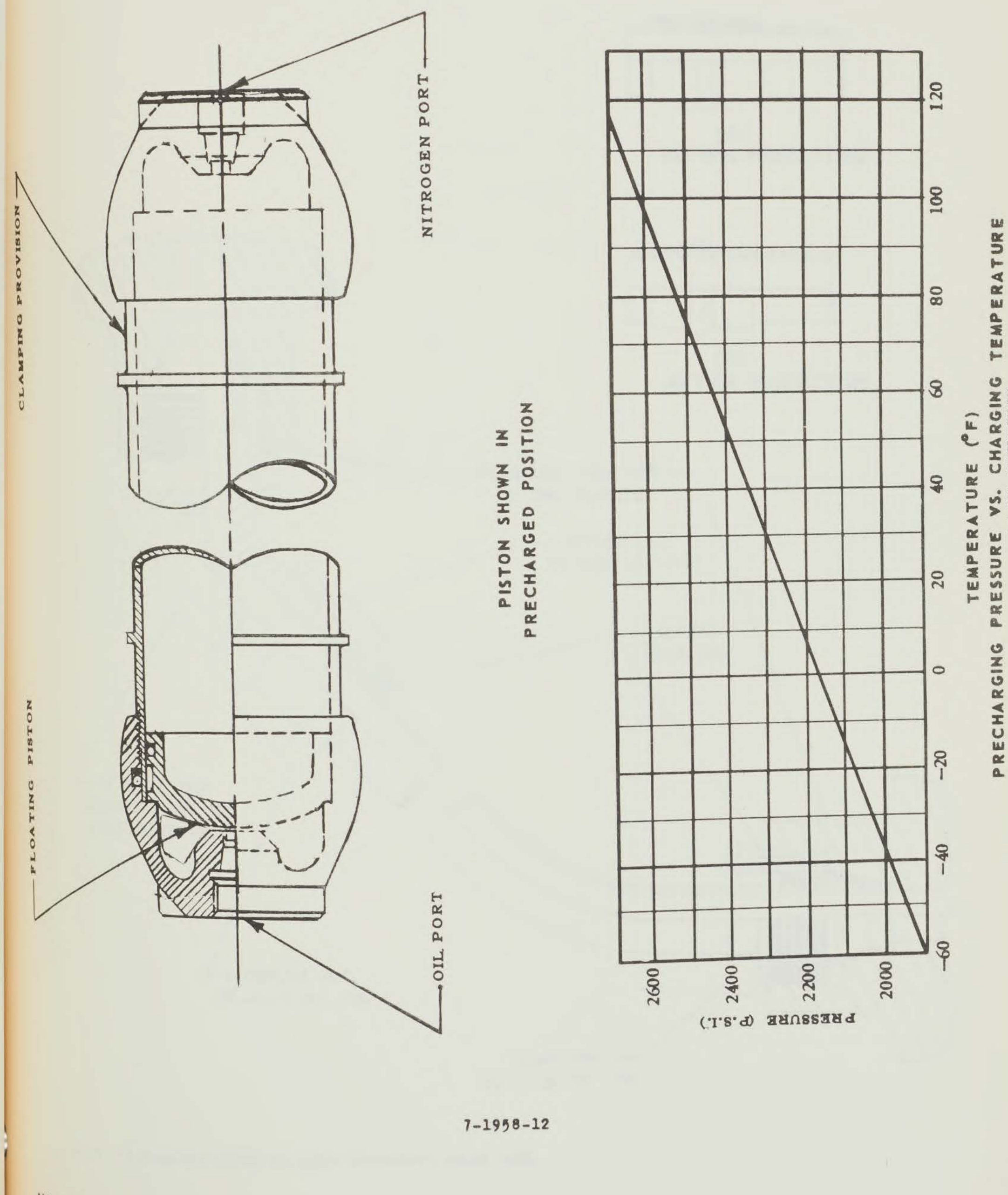

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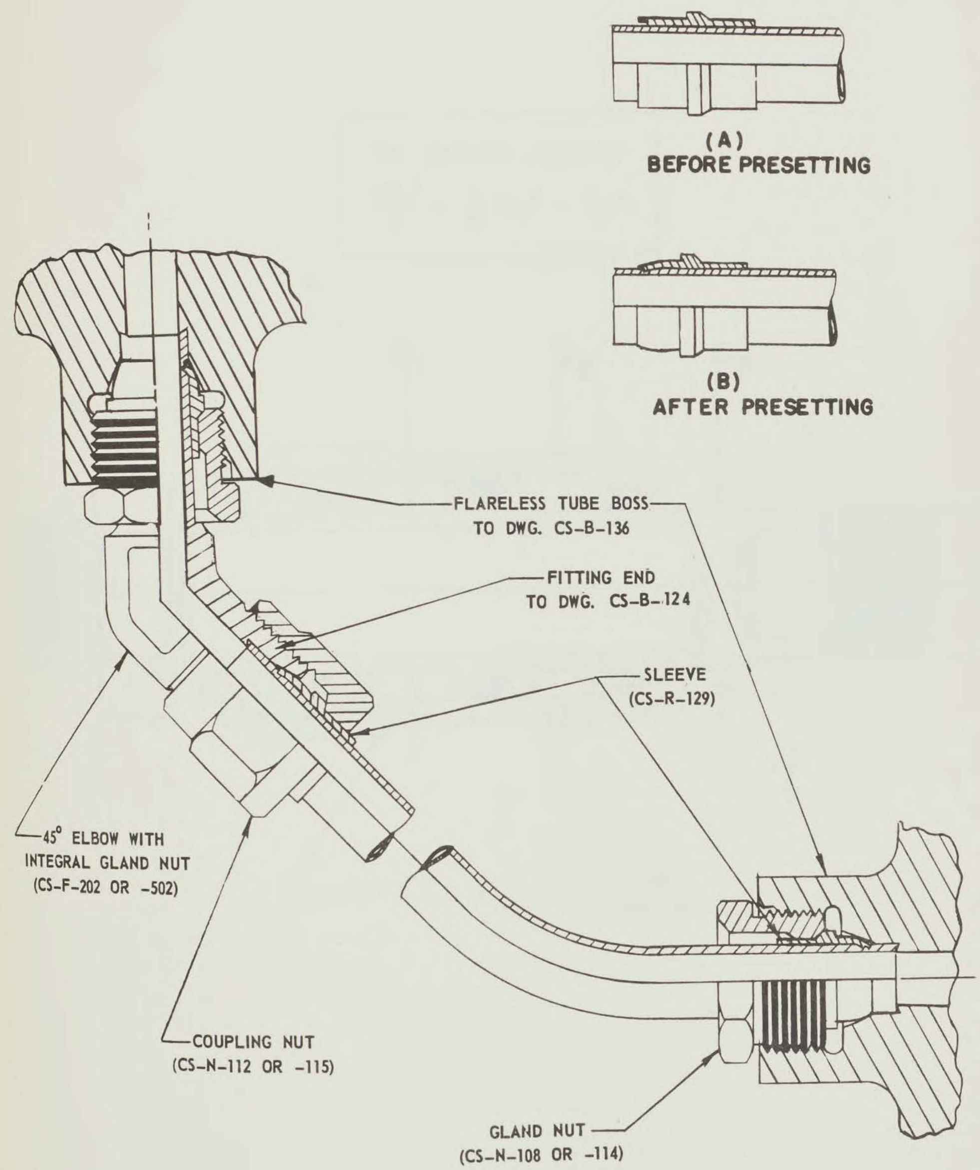
FIG. 2.7 ACCUMULATOR - FLOATING PISTON TYPE

ASSEMBLY OF SLEEVE AND TUBE



NOTE: CS NUMBERS REFER TO AVRO STANDARD DRAWINGS.

FIG. 2.8 FLARELESS TUBE CONNECTIONS

For Hydraulic Balance:

$$\frac{\pi D_1^2}{4} = \frac{\pi}{4}(D_2^2 - D_3^2)$$

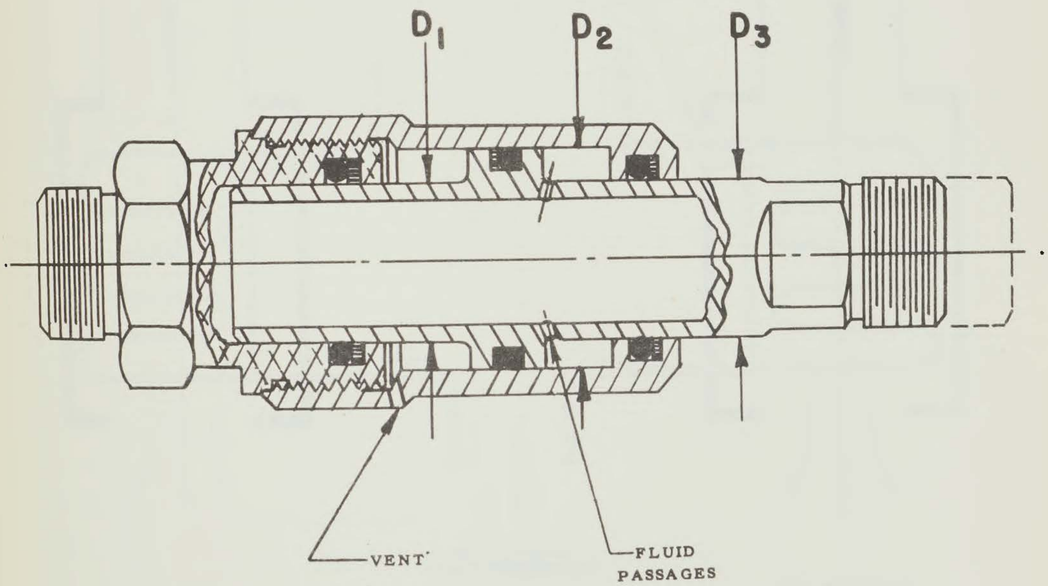


FIG. 2.9 EXPANSION COUPLING (BALANCE TYPE)

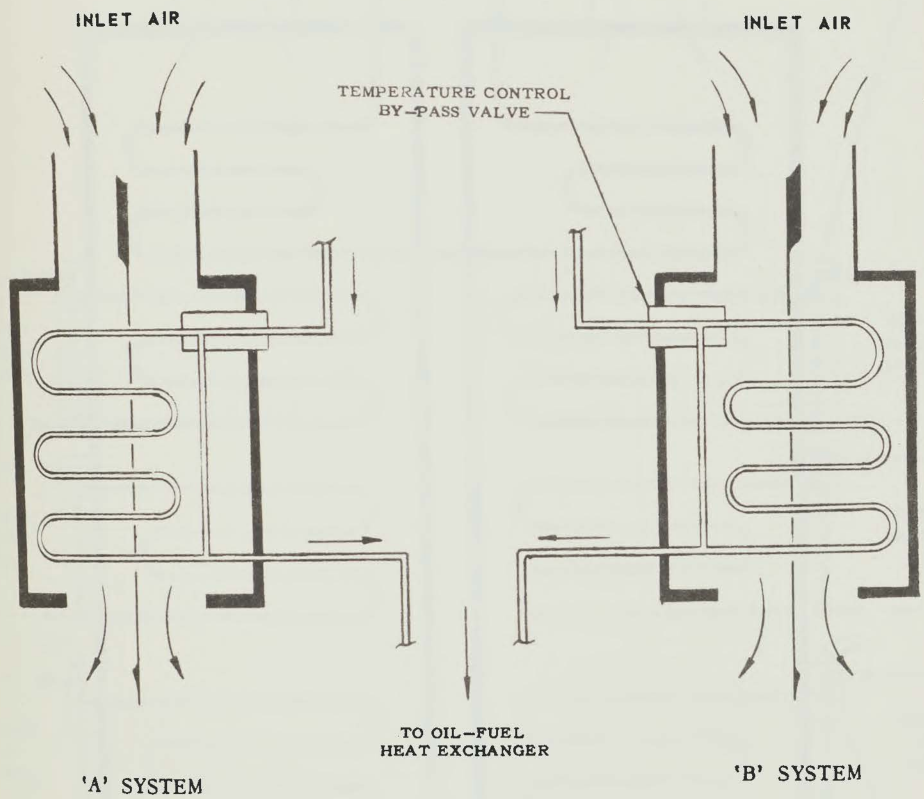


FIG. 2.10 HEAT EXCHANGER OIL TO AIR

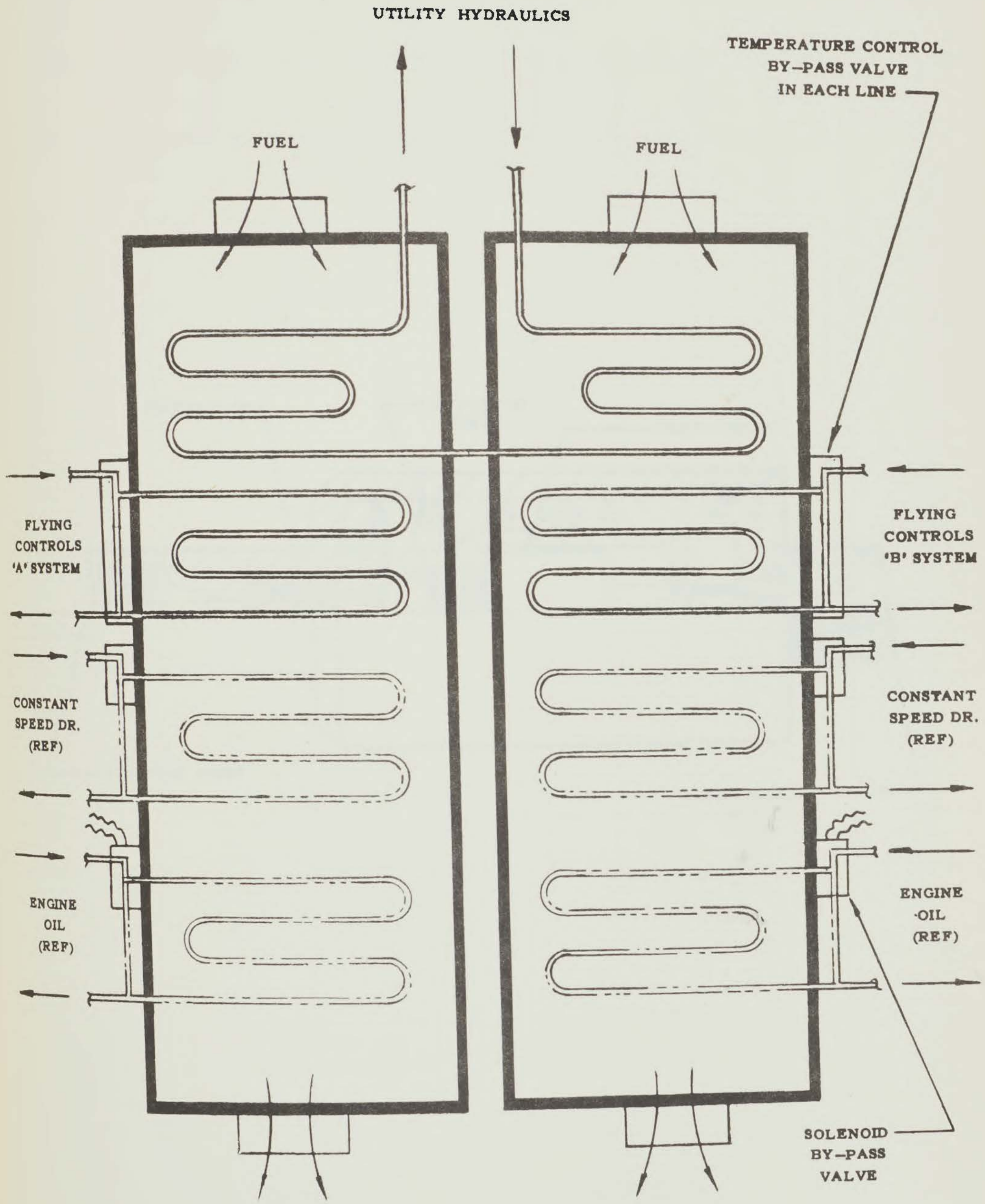


FIG. 2.11 HEAT EXCHANGER OIL TO FUEL

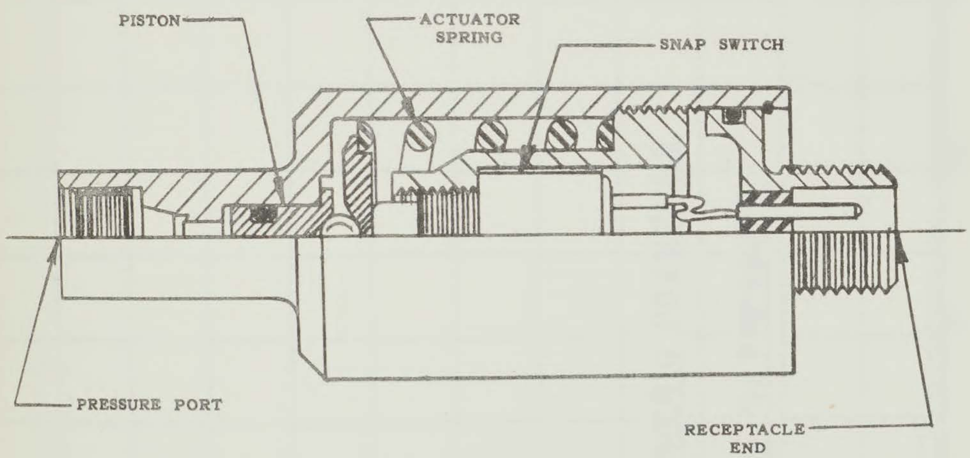


FIG. 2.12 HYDRAULIC PRESSURE SWITCH

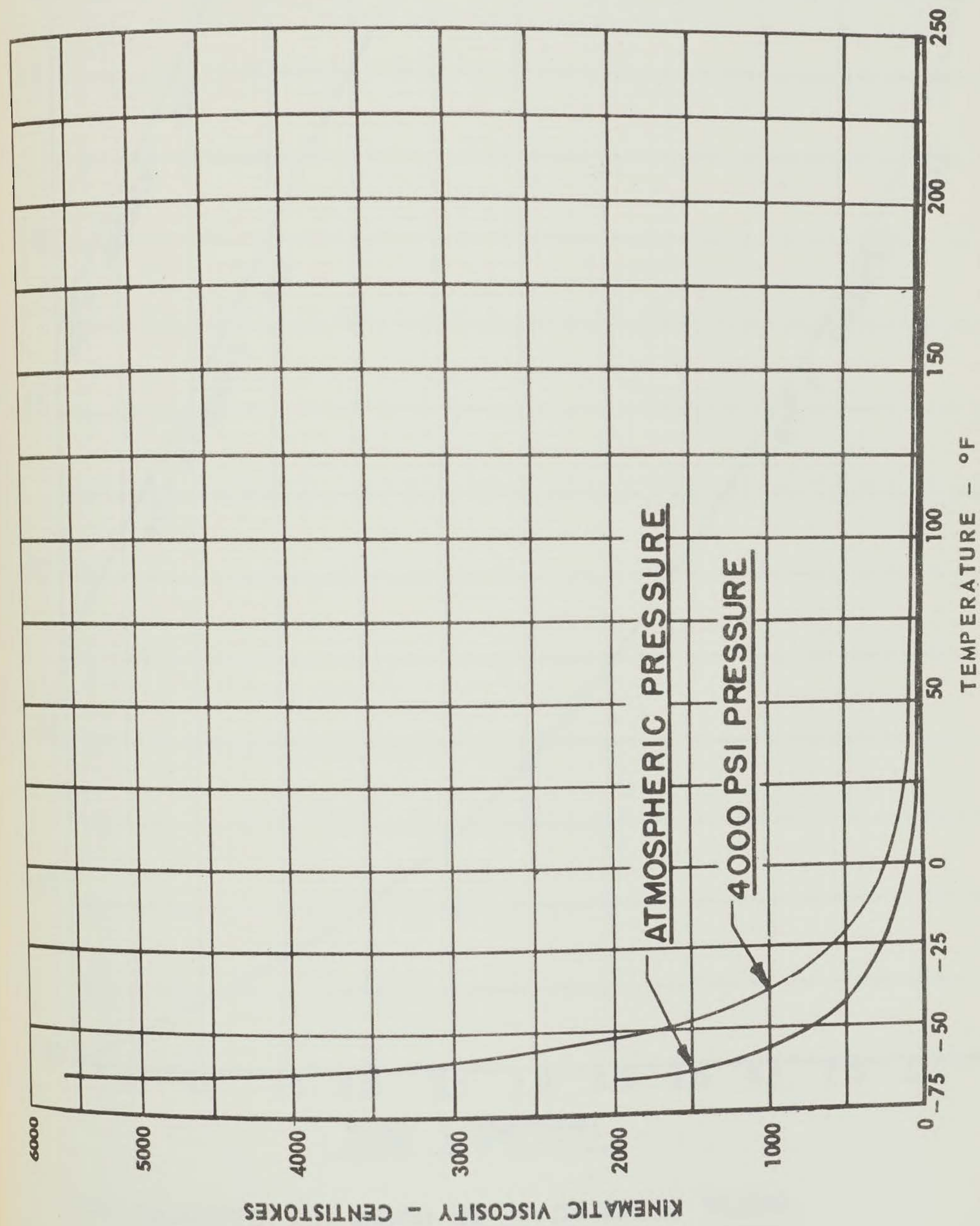
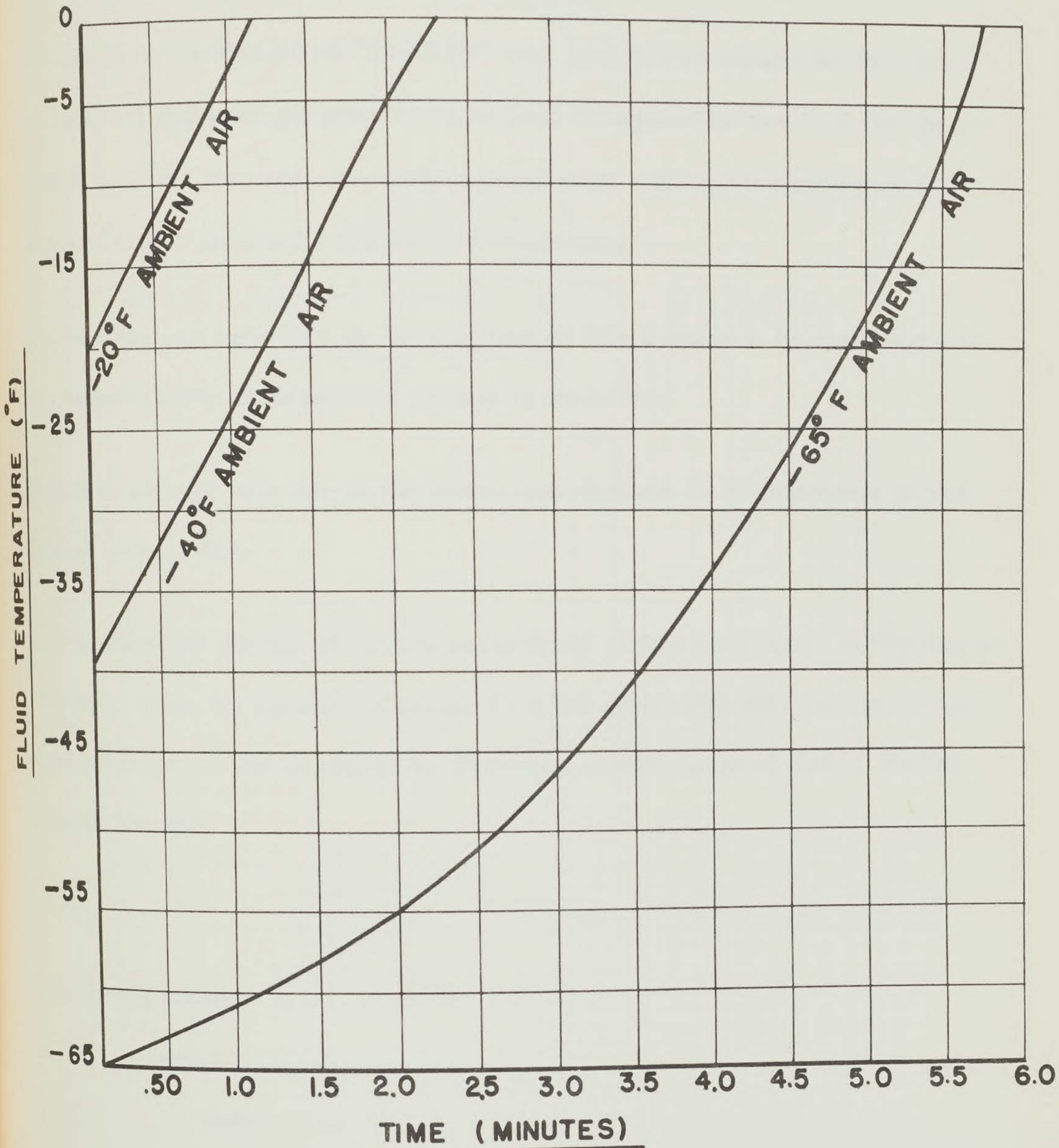


FIG. 3.0 KINEMATIC VISCOSITY VS TEMPERATURE



TIME REQUIRED TO WARM UP HYDRAULIC FLUID

FIG. 3.1 FLYING CONTROLS - GRAPH OF TIME REQUIRED TO WARM UP HYDRAULIC FLUID VS HYDRAULIC FLUID TEMPERATURE

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Date ....

ARROW 2
ARMAMENT HYDRAULIC SYSTEM

REPORT NO. 72/SYSTEMS 19/40

JUNE 1957

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

COMPILED BY D. Royston.   APPROVED BY Alan R. Buley

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

MALTON — ONTARIO

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1. General Description of the Sparrow 2D Armament Hydraulic System

1.1 The armament installation consists of four Sparrow 2D missiles stowed in pairs abreast. One outboard missile and one inboard missile, on opposite sides of the aircraft centre line, form a pair. The two pairs of missiles are staggered, one pair being referred to as the forward missiles, the other the aft missiles.

1.2 Each pair of missiles, and its associated equipment, is hydraulically linked and operated independently of the other pair.

1.3 The armament hydraulic system is a sub-system of the utility hydraulic system and, as such, has a nominal operating pressure of 4000 p.s.i. and a zero flow return pressure of 90 p.s.i. As a sub-system, it is completely contained within the armament pack. It is connected to the utility hydraulic system by two self-sealing, quick disconnect couplings mounted on the right hand side of the forward face of the bulkhead at aircraft station 485.

1.4 Each missile installation has the following hydraulically actuated equipment:

(a) Missile wing doors

(b) Missile fin doors

(c) Missile up-lock

(d) Missile extension and retraction mechanism (comprising a front jack and a rear jack)

(e) Drag link doors (aft missiles only).

1.5 The missiles may be extended in any one of the following modes:

Mode 1 - The two aft missiles only

Mode 2 - The two forward missiles only

Mode 3 - All four missiles.

NOTE: Mode 3 is actually modes 1 and 2 operated simultaneously.

2. System Requirements

2.1 To provide a limited number of modes for extending the missiles as described in Section 1.5.

2.2 To provide sequences of operation for operational and training missions as well as for ground servicing.

2.2.1 Operational mission sequence requirements for any extension mode are as follows:

(a) Lower missiles

(b) Fire missiles

(c) Retract empty launchers to their secondary up position (i.e. launcher in contact with bottom skin seals)

NOTE: The forward missiles must be fired before the aft missiles in mode 3. If any missile of mode 1 or mode 2 is hung up, it will automatically be jettisoned. If a forward missile of mode 3 is hung up, the aft missile will be jettisoned and their launchers retracted to allow for the jettisoning of the forward hung up missile.

2.2.2 Training mission sequence requirements for any extension mission are as follows:

(a) Lower missiles

(b) Fire missiles

NOTE: The jettisoning of hung up missiles is not automatic, but must be done by action of the pilot.

(c) Retract empty launchers to their secondary up position, or retract unfired missiles to full up position.

NOTE: Retraction of launchers in associated pairs is automatic, whether the missiles are fired or jettisoned. However, retraction of an unfired missile and the other empty launcher of the pair must be by deliberate action of the pilot. In mode 3 if one of the forward missiles is hung up, the aft missile will not fire. However, all four launchers may be retracted to full up position and the aft missiles re-lowered, with a mode 1 selection, and fired. Jettisoning of the forward hung up missile will jettison the aft missiles first. (See note in Section 2.2.1).

2.2.3 Ground operation sequence requirements are the same as for training mission, except that the firing signal and jettison signal can not be supplied to the armament pack.

2.3 To lower all four missiles at once, in minimum time, without cavitation.

2.4 To limit maximum terminal velocities.

2.5 To limit the initial and final loading on the missile to 10 "g", both on extension and retraction.

3. Sequence of Operation

3.1 Operational mission (see Fig. 6.6.1, 6.2 and 6.3)

Origin of Signal	Hydraulic Operations for Selected Mode 1, 2, or 3
Fire control	Operates door selector valves for selected mode. Wing and fin doors open. For Mode 1 and 3 drag line doors also open.
Doors "full open" limit switches.	Actuates compensating valves, placing the forward and aft missile jacks in series.
Limit switches on compensating valve spools.	Missile up-lock jacks unlock.
Limit switches on up-locks (both up-locks must be open)	Actuates missile selectors. Missiles are extended.
As each missile approaches the extended position, limit switches are actuated by the front jack shroud.	The compensating valve associated with each missile is operated, putting the jacks in parallel.

Origin of Signal	Hydraulic Operations for Selected Mode 1, 2, or 3
Limit switches are actuated by compensating valve spools	Door selector valves are actuated, closing wing and fin doors (drag link doors for aft missiles, remain open). Missile up-locks are closed.
Missiles are fired and hung-up missiles are jettisoned.	Note: for order of firing or jettisoning see note in Section 2.2.1.
As each missile leaves its launcher it actuates a "Missile Released" limit switch. It also mechanically operates the secondary up stops.	As the second missile leaves its launcher both compensating valves go into series position.
When both compensating valve spools of a missile pair are in series: Note: for mode 3, this signal, from forward missile compensators, fires the aft missile.	Missile door selector valve operates the door jacks, opening wing and fin doors, and up-locks are re-opened.

Origin of Signal	Hydraulic Operations for Selected Mode 1, 2, or 3
Doors "full open" limit switch.	Missile selector operates, retracting launchers to secondary up position.
Launcher in secondary up position.	Wing, fin and drag link doors close (modes 1 and 3) Wing and fin doors (mode 2).

Note: A hung-up forward missile in a mode 3 selection is jettisoned by the closing of the aft missile drag link doors, thus beginning the forward launcher retracting cycle.

3.2 Training Mission

The sequence of operation for a training mission is the same as that for an operational mission, except that there is no automatic jettison of hung up missiles. Therefore, the pilot must decide whether to retract or jettison the hung-up missiles. This is done by deliberate switch selection.

3.2.1 Retraction of Missiles

The actuation of the cockpit switch opens the doors of the selected mode. When the doors are fully open, the limit switches activate the compensating valves into series and retraction begins. Since the secondary up stop of a hung up missile is not rotated, the missile and launcher will be retracted to the full up position, while the empty launcher will retract to the secondary up stop. If a forward missile is hung up in a Mode 3 selection, the aft missiles will not fire (see Note in Section 2.2.2).

3.3 Ground Operation

The lowering sequence of operation is the same as that of a training mission, except that the fire control system signal to open the wing fin and drag link doors is replaced by a signal from the "lower" contacts of the ground service switch for the applicable pair of missiles or empty launchers. The missiles or empty launchers will remain down until a "raise" selection is made on the ground service switch. Then the normal training mission retraction sequence will follow, the missile being retracted to the full up position and empty launchers to their secondary up stops.

3.4 Manual Jettison

A means is also provided to dump the missiles if necessary when the aircraft is in the air. This may occur on either operational or training missions, therefore any number of the four missiles may remain on the launchers. With a "Jettison" selection of hung up or unfired missile(s), the doors open and the launchers are lowered. If both forward and aft missiles are hung up, all four launchers will lower. When the launchers reach their fully extended position the hung up missile(s) will be jettisoned (aft first in the case of all four being lowered). A normal "missile released" retraction will then occur.

4. Components - Their Description and Purpose in the Circuit

NOTE: It has been decided that there should be two restrictor valves incorporated in the drag link door jacks system. This change will not be shown on the schematics, and is, therefore, not mentioned in the brochure. At present, the brochure indicates that there is only one restrictor.

4.1 Restrictors

A restrictor is an orifice having a given pressure drop for a given flow and temperature. There are two types of restrictors installed, one having the same flow-pressure characteristic in each direction (two way restrictor); the other, a given flow characteristic in one direction and a free flow in the opposite direction.

4.1.1 Wing, Fin, and Drag Link Door Restrictors

These are two way restrictors each having the same purpose in the circuit, that is, they limit the operating speed of the doors. The drag link doors restrictor, however, has a different flow characteristic than the wing and fin door restrictors. When the doors are opening, the restrictors decrease the pressure acting on the head end of the jack, thereby decreasing the opening speed. When the doors close, the flow is restricted on leaving the head end of the jack, thus giving a lower pressure differential, resulting in slower door closing speeds.

4.1.2 Missile Jack Restrictors

There are three separate restrictors installed for each jack, and a fourth is incorporated in the flow regulator. One restrictor is installed at the "down" port of the rear jack and is used during extension and retraction, having the same flow characteristics in each direction. When a missile is lowered, the restrictor decreases the pressure on the extension area of the rear jack,and reduces the pressure build-up through the flow regulator on the retraction area of the front jack. In the retraction case, it restricts the flow from the jack, causing pressure build-up on the rear jack "down" port, while the flow regulator restrictor decreases the pressure on the "up" port of the front jack, resulting in lower piston velocities. The other two restrictors are installed at the "up" and "down" ports of the compensating valve. Each has a given flow characteristic one way, to build up back pressure on the jacks, and free flow the other way, so that when one restrictor is building up pressure the other is allowing free flow. The restrictor placed at the valve "up" port maintains a given rear jack piston velocity during the parallel operating portion of the extension stroke, when no damping exists on the jack. The restrictor at the valve "down" port serves the same purpose for the front jack during retraction.

4.2 Door Jacks and Up-lock Release Jacks

The wing, fin and drag link door operating jacks are all identical, standard piston type, and have no dampers or internal locks. The up-lock release jacks are similar to the door jacks, except for size and shape. The rod ends of the jacks are under pump pressure at all times, and piston movement is a result of the equal fluid pressures acting on the differential area, between the head and rod ends.

4.3 Missile Front Jack (Fig. 1)

The front jacks of forward and aft missiles are similar in construction and differ only in size. Each consists of three concentric tubes, two fixed and one movable. It has a damper and damping holes which serve to reduce the movable tube velocity of both front and rear jacks (hydraulically interconnected - see Section 4.5), during the last portion of the extension stroke. The area contained between the inner and outer fixed tubes is the extension area, and that between the inner fixed tube and movable tube is the retraction area. The swept volume of the extension area is equal to the swept volume of the rear jack retraction area (see Section 4.4).

During extension, the flow of fluid is from the rear jack, through the down port, and into the space between the inner and outer fixed tubes. The return flow is from the space between inner fixed tube and movable tube, through the damper holes, then through the centre of the fixed tube to the up port. This jack, together with the rear jack, forms the missile extension mechanism.

4.4 Missile Rear Jack (Fig. 2)

The rear jacks of both forward and aft missiles differ only in size. This type of jack consists of five concentric tubes, three fixed and two movable. It has a damper and damping holes which serve to reduce the velocity of both front and rear jacks during the last portion of the retraction stroke. The area contained between the outer and second fixed tubes is the retraction area, and that contained between the movable tubes is the extension area. During extension the flow is from the missile selector, through the down port, through the inner fixed tube, down the inner movable tube and past the check valve into the space between the movable tubes. The return fluid flows from the retraction space, through the space between the second and inner tubes to the up port and then to the front jack down port. For retraction it is the opposite, except that the fluid by-passes the check valve and flows through the damping holes to return through the inner movable and fixed tubes.

4.5 Compensating Valve (Fig. 4)

There is one compensating valve installed for each missile operating circuit. The valves for the forward and aft missiles are of the same type and differ only in size.

These valves are essentially four way, two position valves, actuated by pilot pressure supplied from a source external to the valve. Each is composed of a spool with slots to direct the flow, detents at each end to hold the spool in position in case of pilot pressure failure, and a pilot pressure valve at each end to position the spool. The pilot pressure valves are operated by solenoids. Also incorporated in this valve are two limit switches used to operate other equipment in the armament system (see Section 3.1).

The prime function of this valve, is to change the flow pattern to the forward and aft missile jacks from a normal series connection to a parallel connection, near the end of their extension or retraction strokes. This parallel connection is required to correct any mis-alignment that may occur during the series connected portion of the stroke. It also allows the application of full pump pressure to both jacks at the up or full down positions and holds the launchers (missiles on or off) against maximum loads.

4.6 Selector Valves (Fig. 5)

All selector valves used are of the four way, two position type, differing in size and slightly different in the flow pattern. Each valve is pilot pressure operated through pilot valves and solenoids, the pilot pressure being applied to one of two pistons. These pistons in turn position the valve slide, to produce the flow pattern required. In the case of door selector valves, wing and fin doors and drag link doors (shown in Fig. 45), the valve slide configuration is such that pressure is applied at the rod end port at all times, changing the flow to the head end port only.

The missile selector valves are similar in construction, but are different in size. The valve slide directs pump pressure to the down port and return pressure at the up port for extension, then reverses the flow pattern for retraction. The door selector and the missile selector valves have incorporated in them a check valve, a thermal relief valve and two detents. The check valve prevents fluid from flowing back through the pressure port, thereby holding the missiles and doors in the up position. The detents hold the slide in the selected position in case of hydraulic or electrical failure. Excessive pressure due to temperature changes is prevented by the thermal relief valve. The missile up-lock release selector valve is based on the same principle as above, but has only one pilot pressure valve and one solenoid. The pistons, therefore, are of different sizes. The flow pattern is similar to that of the door selector valve.

4.7 Flow Regulator (Fig. 3)

The flow regulators are essentially variable orifice restrictors which limit the maximum flow of fluid in one direction, normally allowing free flow in the opposite direction. One is installed for each missile to limit the maximum piston velocity attainable by both front and rear jacks during extension. The flow regulators, used in the armament pack, incorporate fixed orifice restrictors in the normal free flow direction, which are used in conjunction with restrictors at the outlet ports of the rear jacks. (see Section 4.1.2).

4.8 Thermal Relief Valve

A thermal relief valve has been incorporated in the system to prevent an excessive build up of pressure after the armament pack is removed from the aircraft.

APPENDIX I

Avro Part No.	Description	No. Per A/C	Spec. No.	Manufacture
7-1956-23	Filter 40 G. P. M.	1	E 353	Parmatic
7-1994-27	Jack, Door, Wing Fins and Drag Links	10	E 516	Electrol
7-1994-28	Jack - Launcher Up-Lock Release	4	F 529	
7-1994-29	Front Jack, Forward Missile	2	E 528	
7-1994-31	Rear Jack, Forward Missile	2	E 527	
7-1994-32	Front Jack, Aft Missile	2	E 528	
7-1994-33	Rear Jack, Aft Missile	2	E 527	
7-1994-34	Valve - Missile Selector (Forward)	1	E 524	
7-1994-35	Valve-Door Selector	3	E 522	
7-1994-36	Valve Up-lock Selector	2		
7-1994-37	Valve Compensating	4	E 509	
7-1994-39	Flow Regulator 4 G. P. M. (Forward Missile)	2	E 519	
7-1994-41	Valve Restrictor (Wing and Fin Doors)	2	E 518	
7-1994-42	Valve Restrictor (drag link doors)	1	E 518	
7-1994-43	Flow Regulator 16 G. P. M. (aft missile)	2	E 517	

Avro Part No.	Description	No. Per A/C	Spec. No.	Manufacture
7-1994-47	Valve Missile Selector (Aft)	1	E 524	
7-1994-52	Valve Manifold Assy.	1	E 522	
7-1994-44	Manifold	1		
7-1994-26	Manifold (drag link doors)	1		
7-1994-53	Valve Manifold Assy.	1	E 522	
7-1994-55	Valve Restrictor	1	E 533	
7-1994-61	Valve Restrictor	1	E 533	
7-1994-71	Valve Restrictor	2	E 499	
7-1994-72	Valve Restrictor	2	E 499	
7-1994-73	Valve Restrictor	2	E 499	
7-1994-74	Valve Restrictor	2	E 499	
7-1994-76	Valve-Thermal Relief	1	E 578	
CS-C-200-12	Coupling Halves (Pressure)	1		
CS-C-201-16	Coupling Halves (Return)	1		

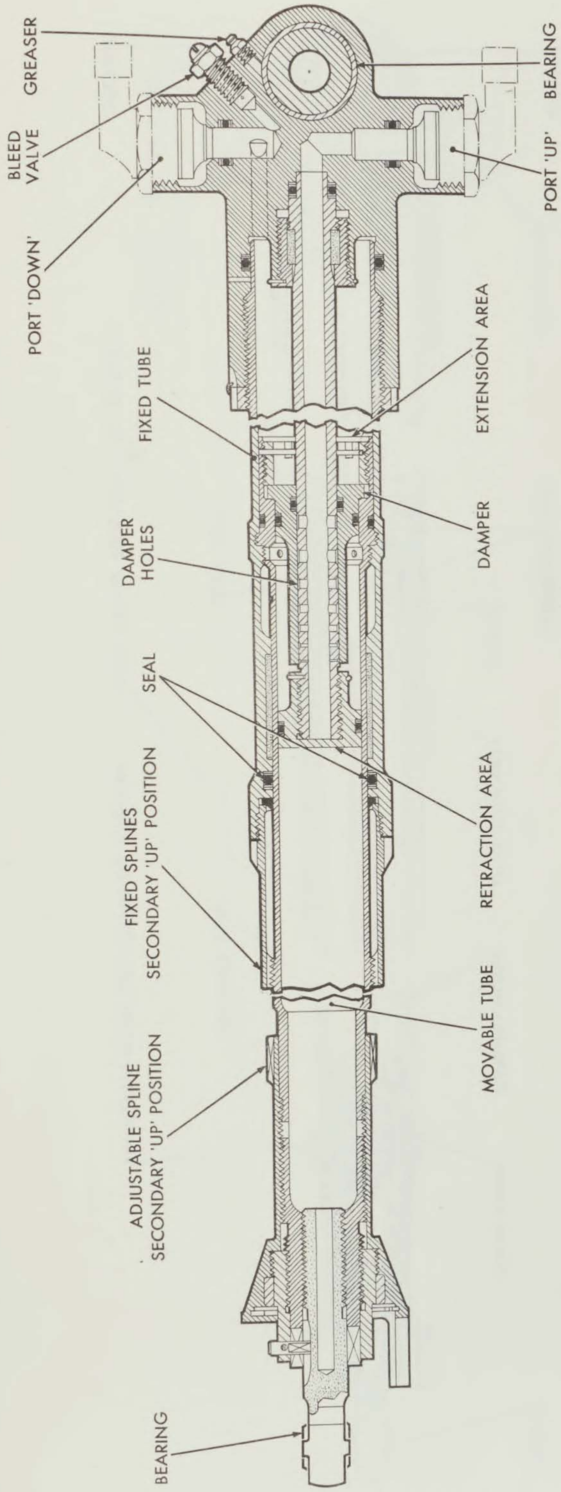


FIG. 1 TYPICAL FORWARD JACK - ARMAMENT PACK

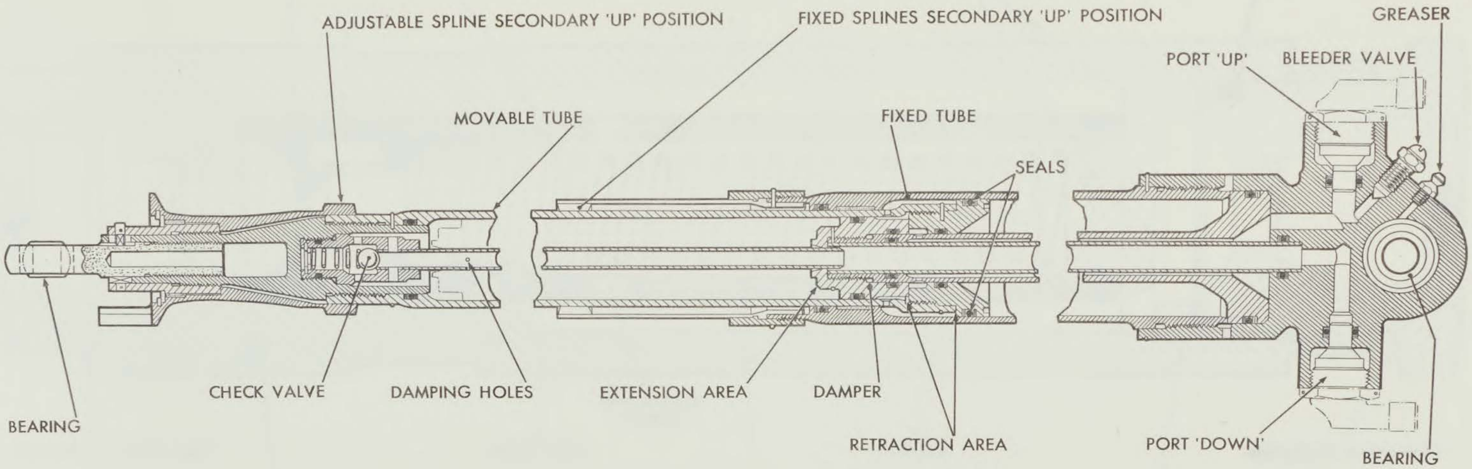


FIG. 2 TYPICAL REAR JACK - ARMAMENT PACK

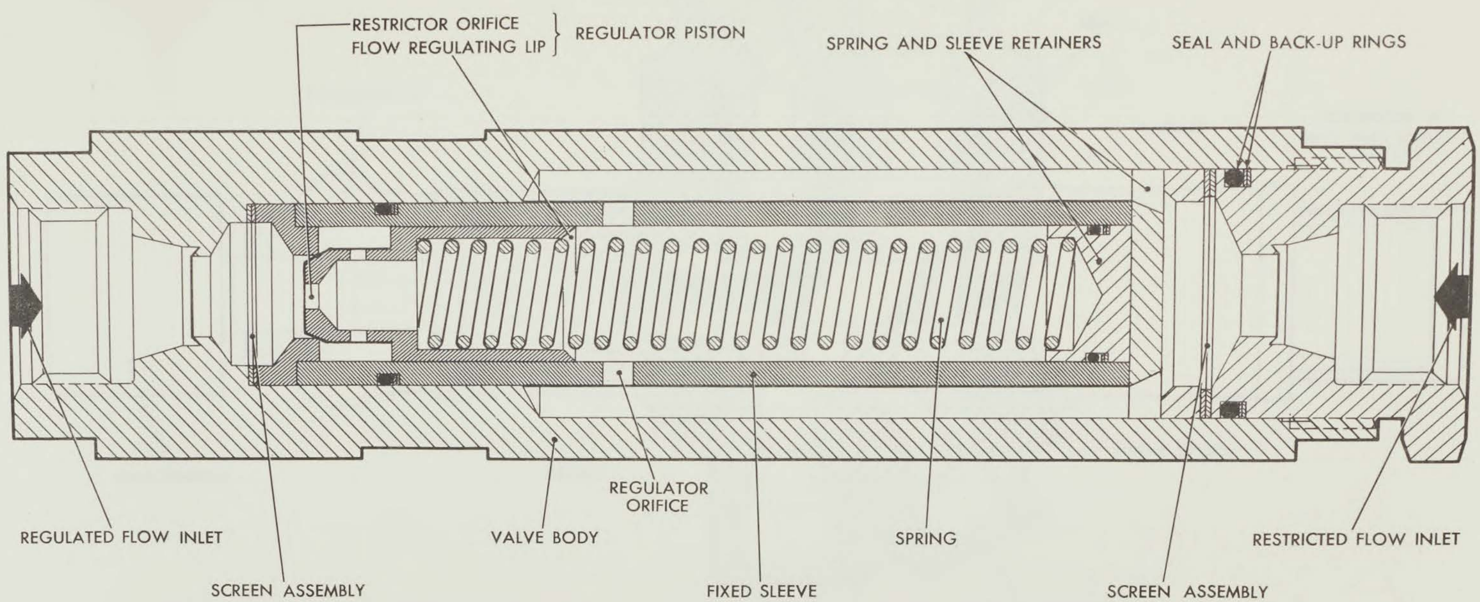


FIG. 3 FLOW REGULATOR

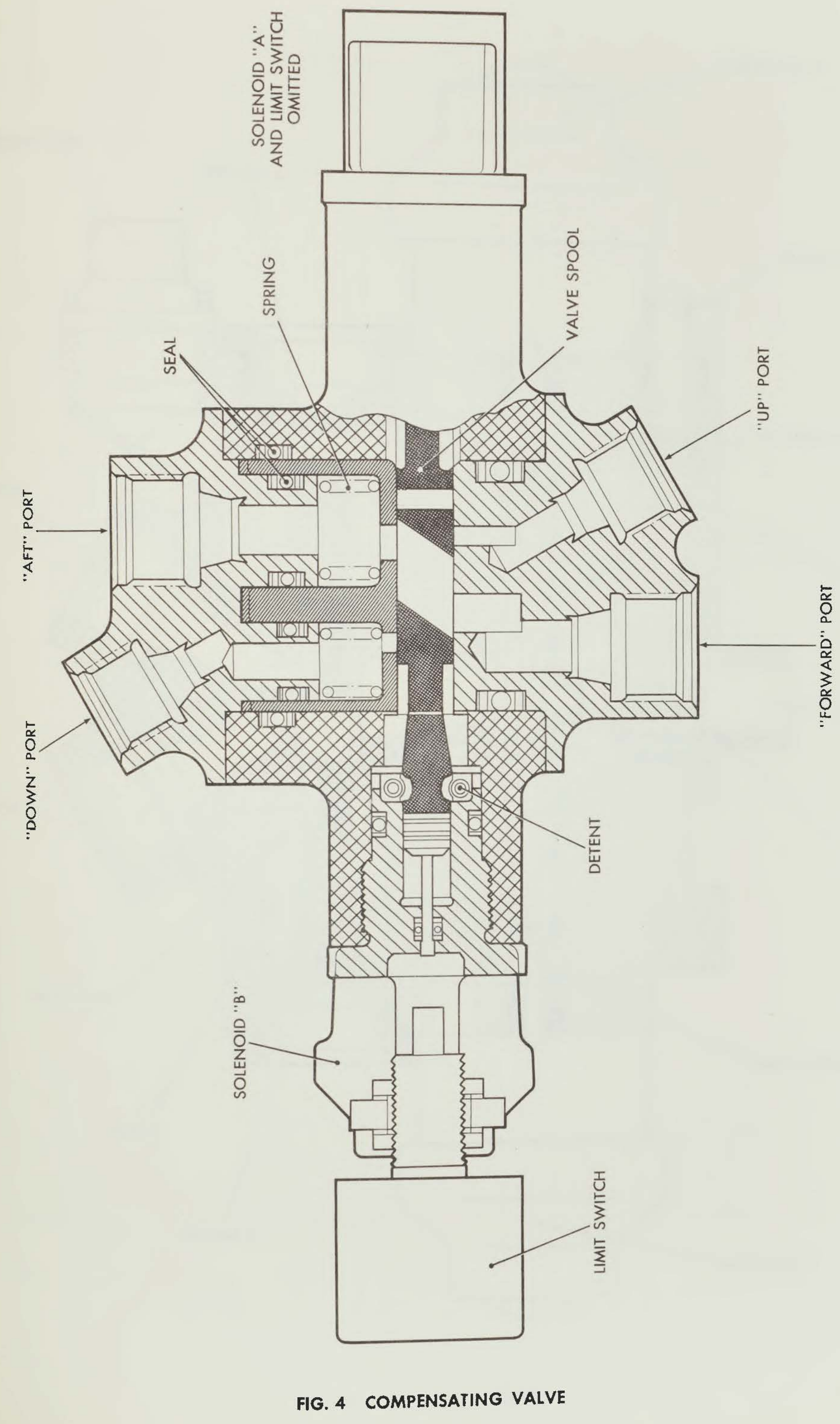


FIG. 4 COMPENSATING VALVE

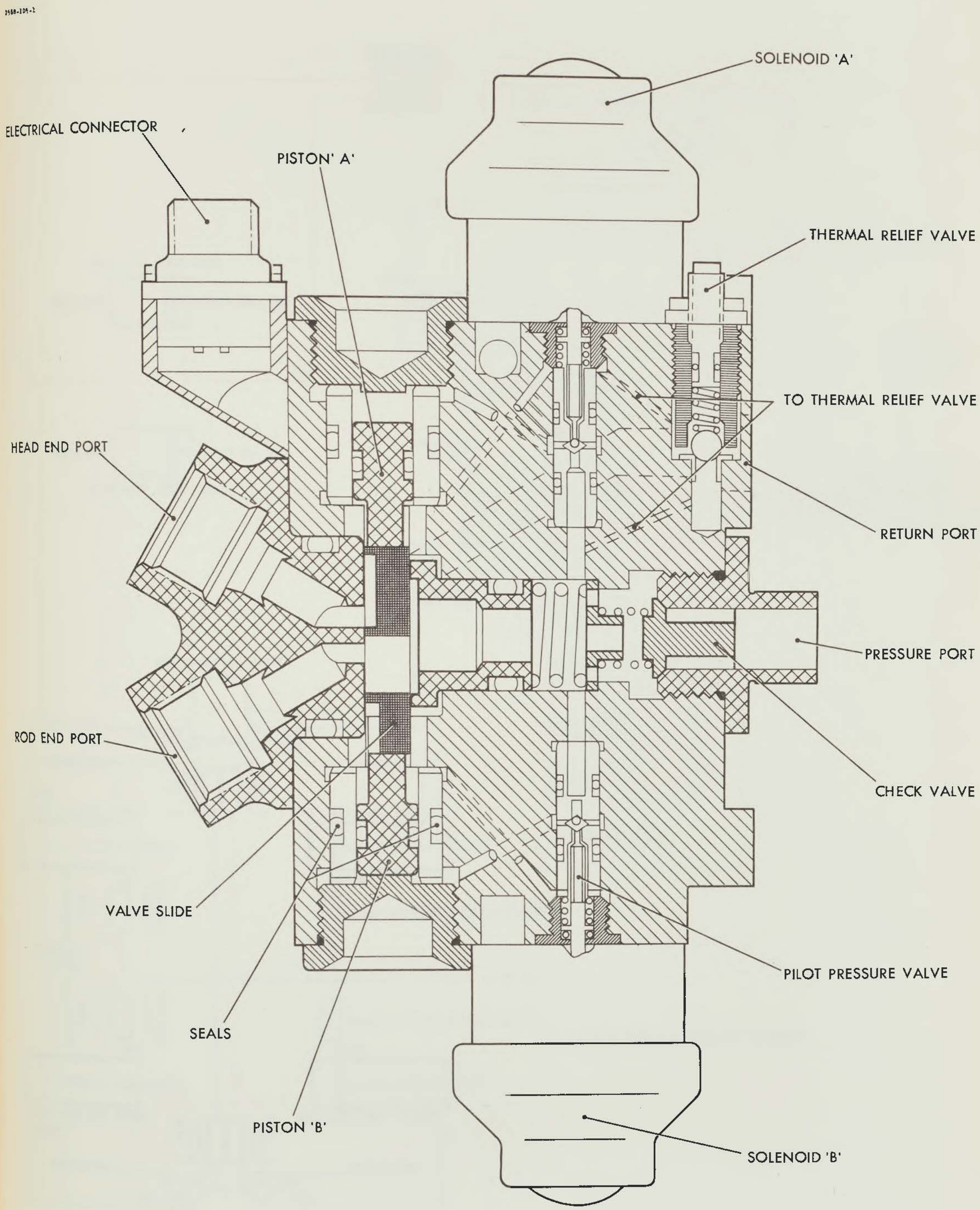


FIG. 5 SELECTOR VALVE

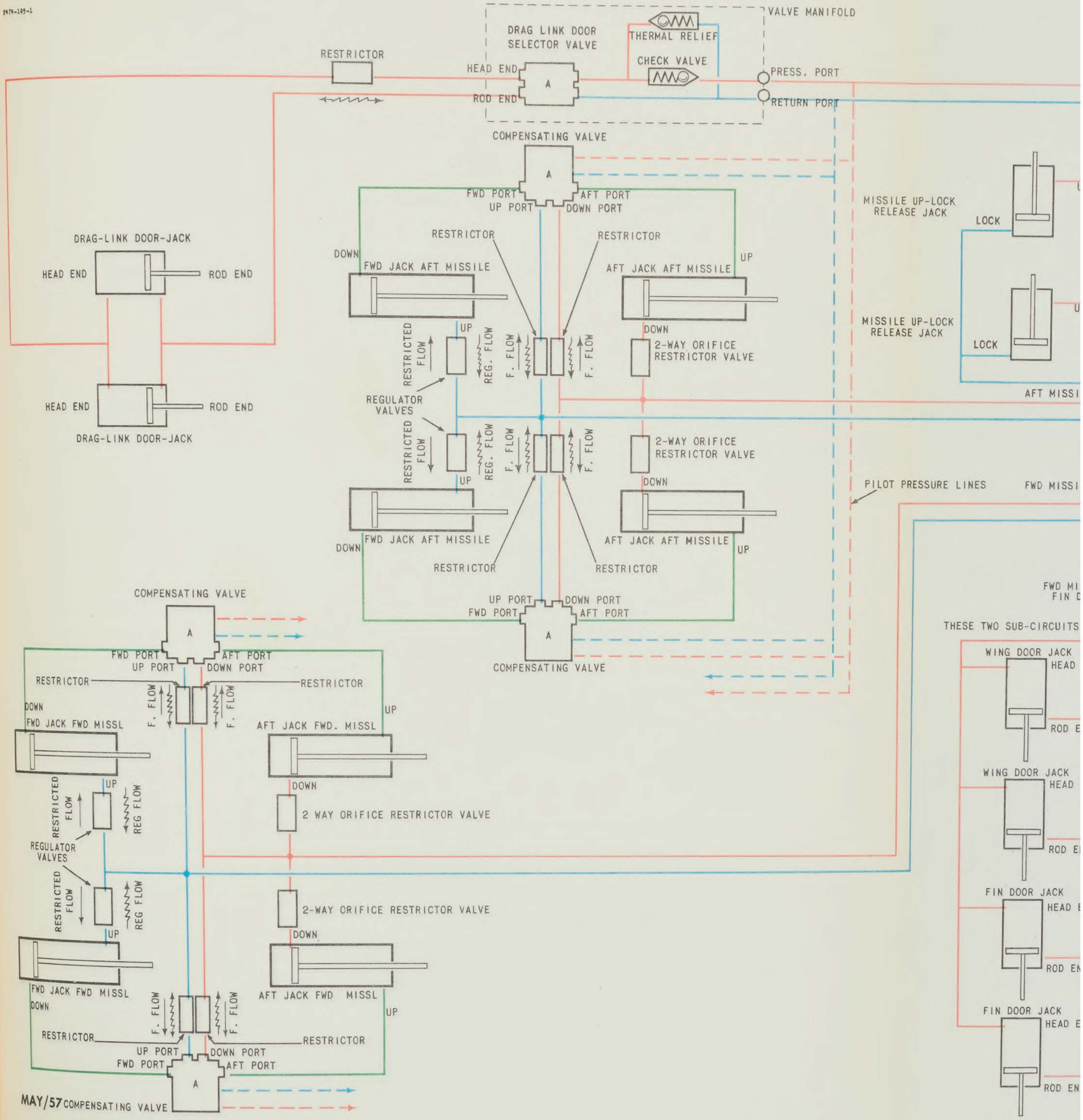
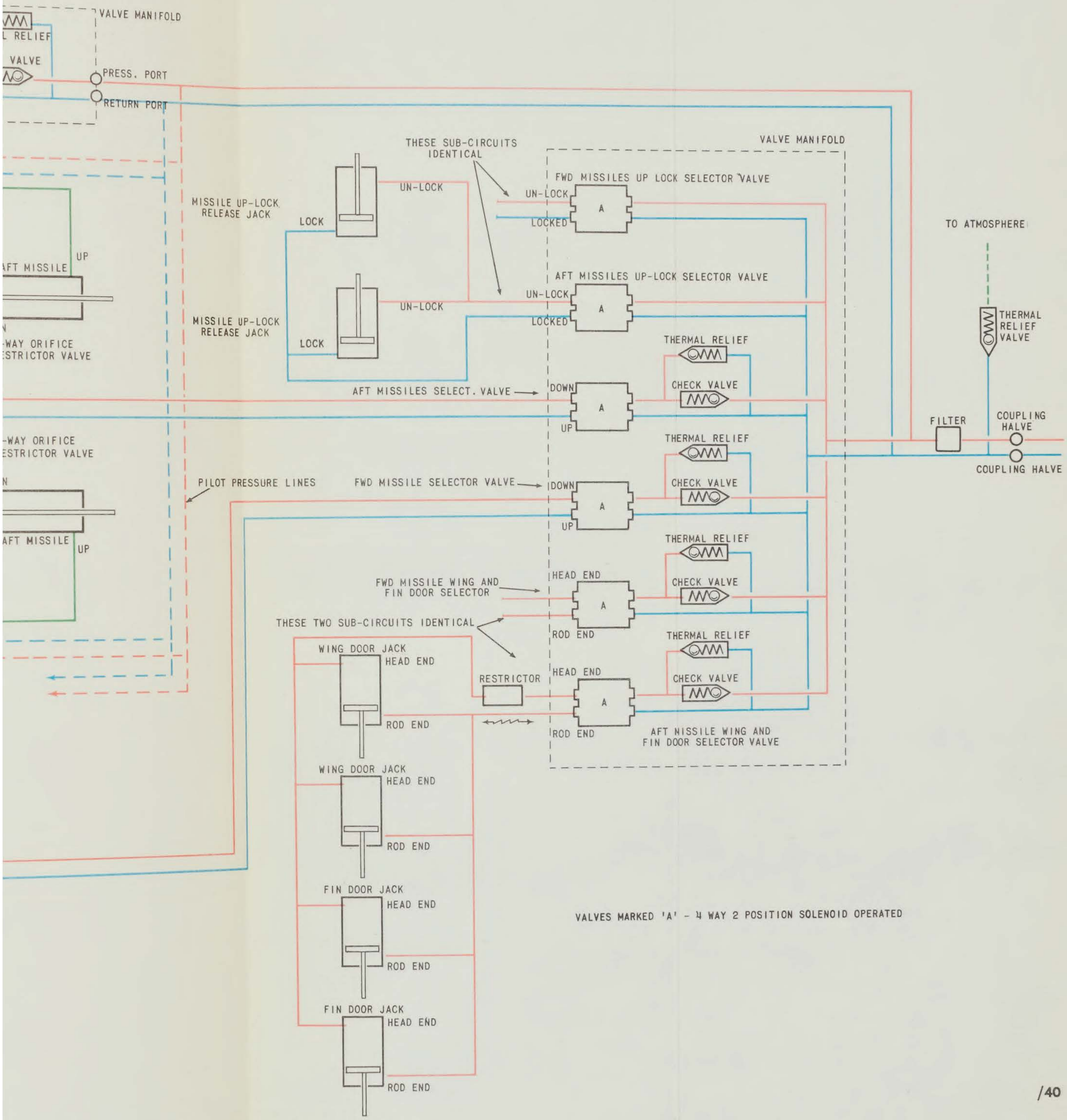


FIG. 6 SCHEMATIC, MISSILES EXTENDING IN SERIES - DOORS OPEN



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6 SCHEMATIC, MISSILES EXTENDING IN SERIES - DOORS OPENED

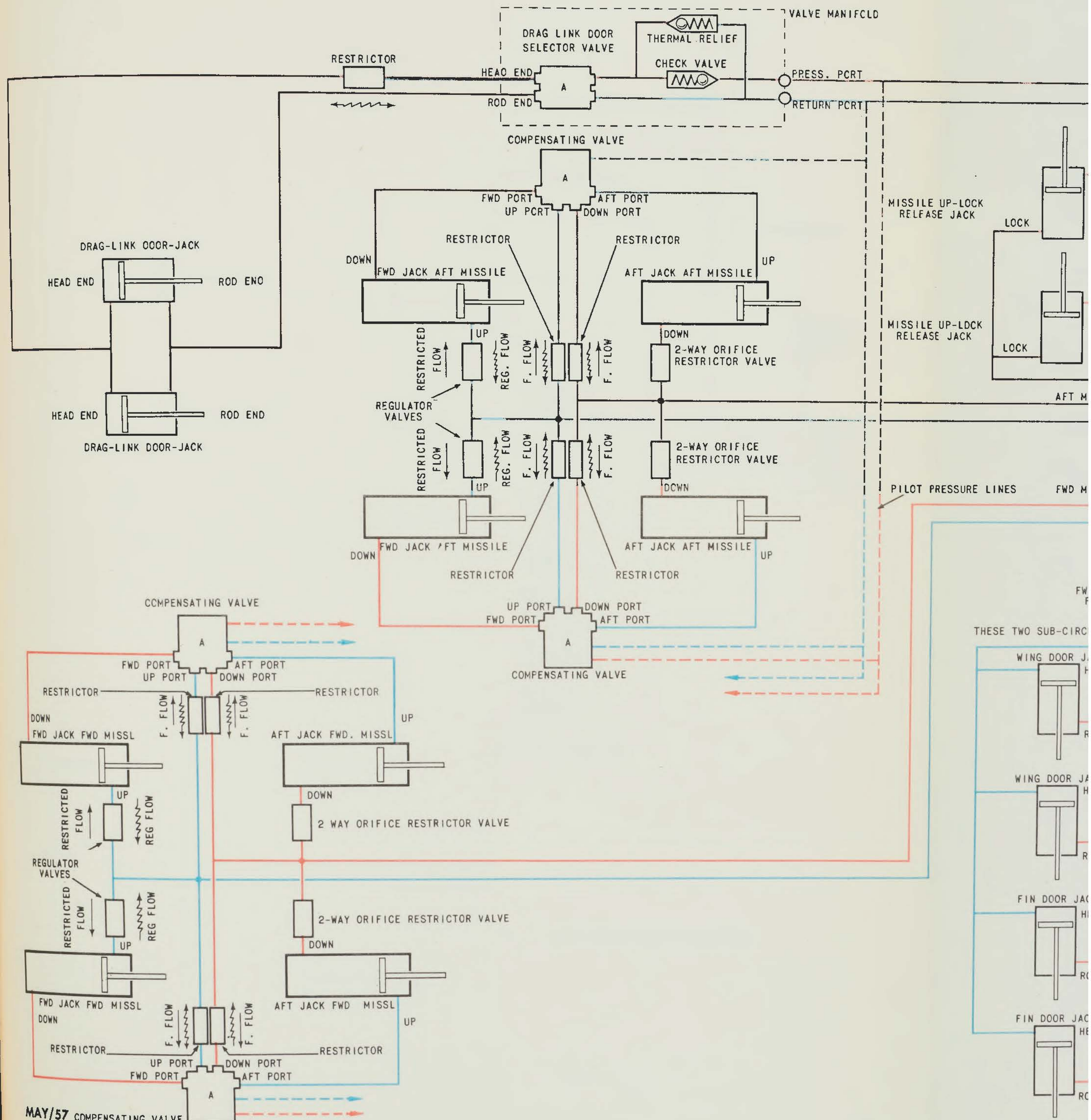
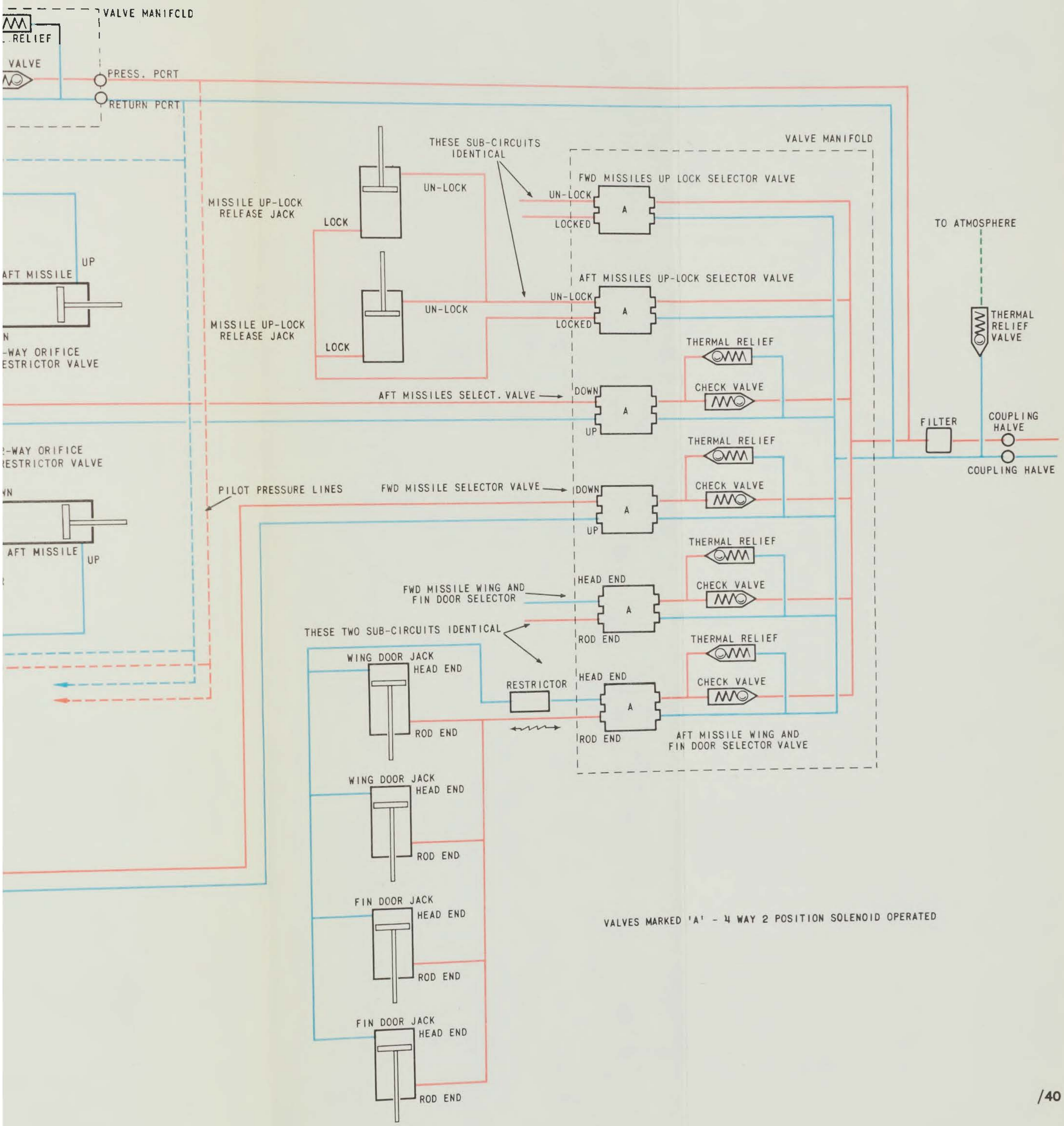


FIG. 7 SCHEMATIC, MISSILES EXTENDING IN PARALLEL - DOORS CL



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SCHEMATIC, MISSILES EXTENDING IN PARALLEL - DOORS CLOSING

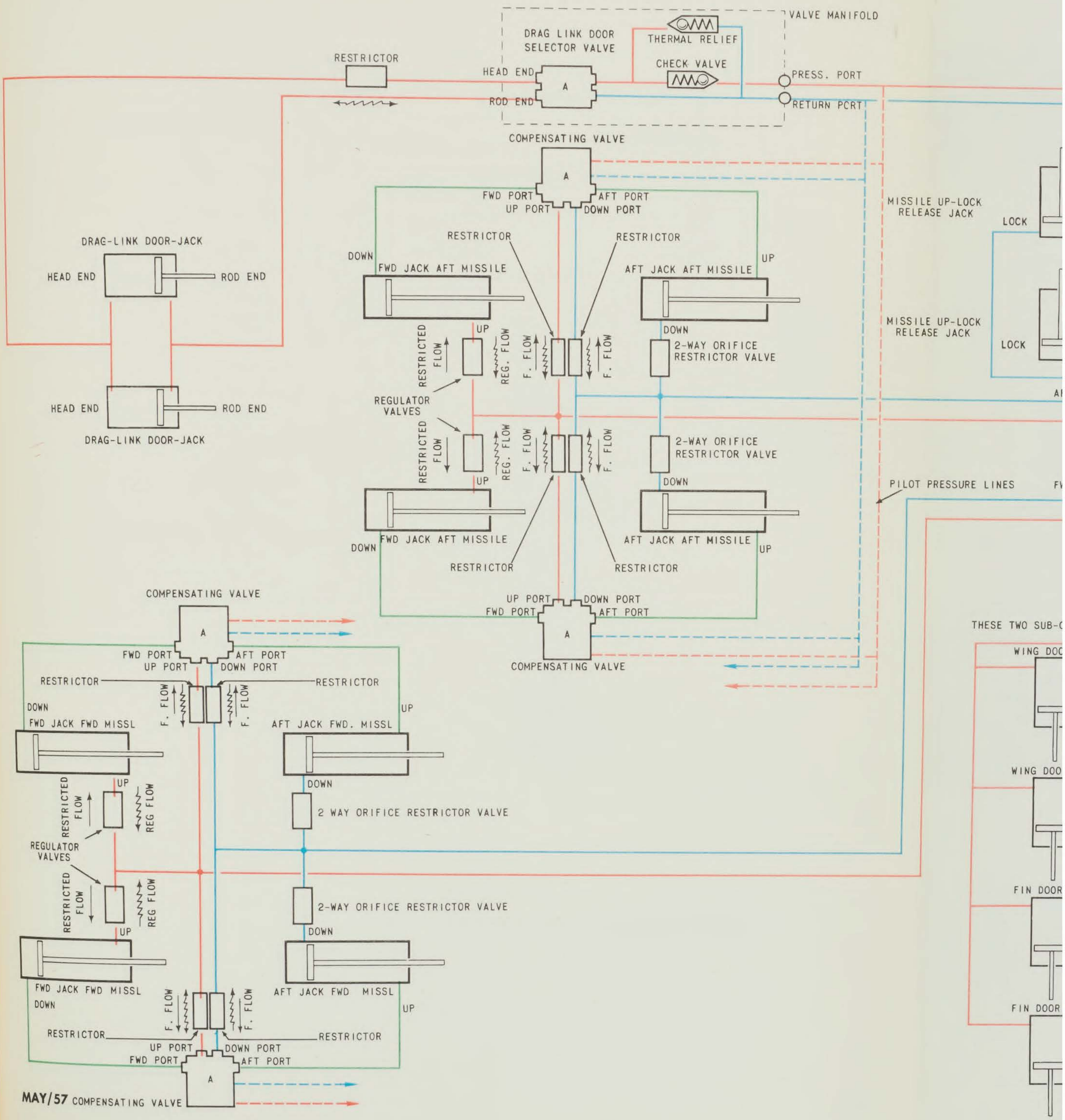
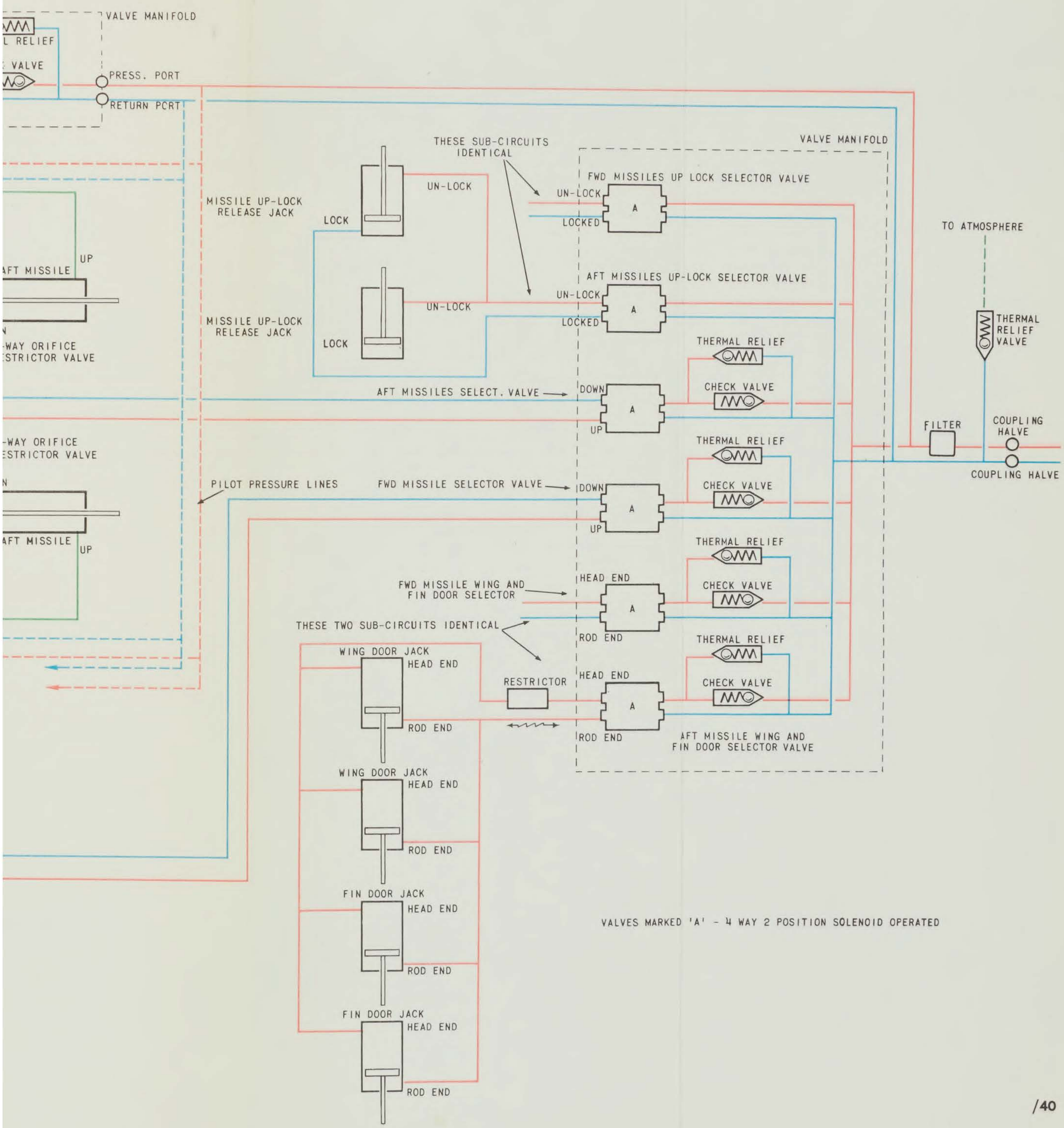


FIG.8 SCHEMATIC, MISSILES RETRACTING IN SERIES - DOORS C



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SCHEMATIC, MISSILES RETRACTING IN SERIES - DOORS OPENED

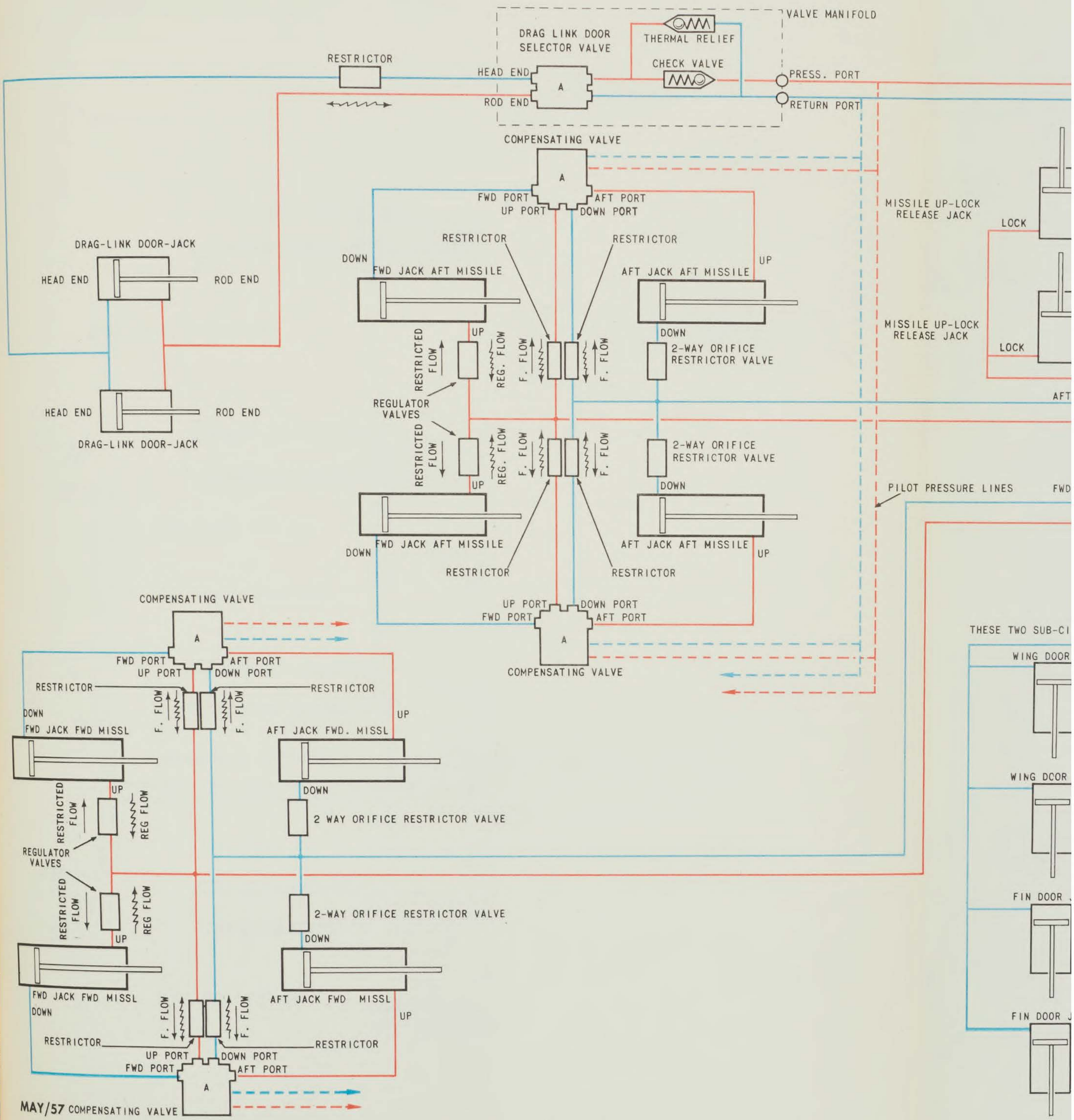
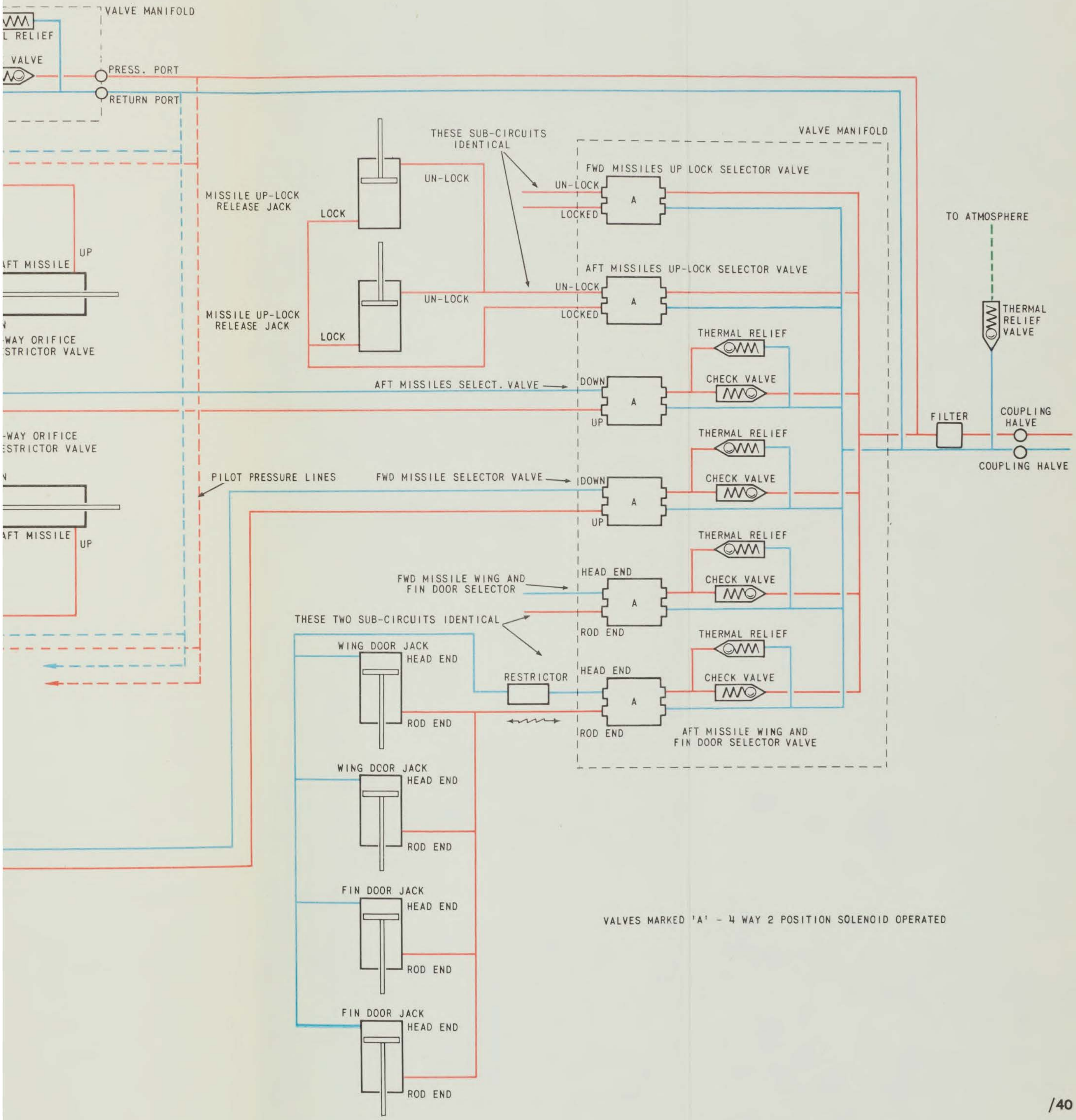


FIG. 9 SCHEMATIC, MISSILES OR LAUNCHERS RETRACTING IN PARALLEL - I



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IC, MISSILES OR LAUNCHERS RETRACTING IN PARALLEL - DOORS CLOSING

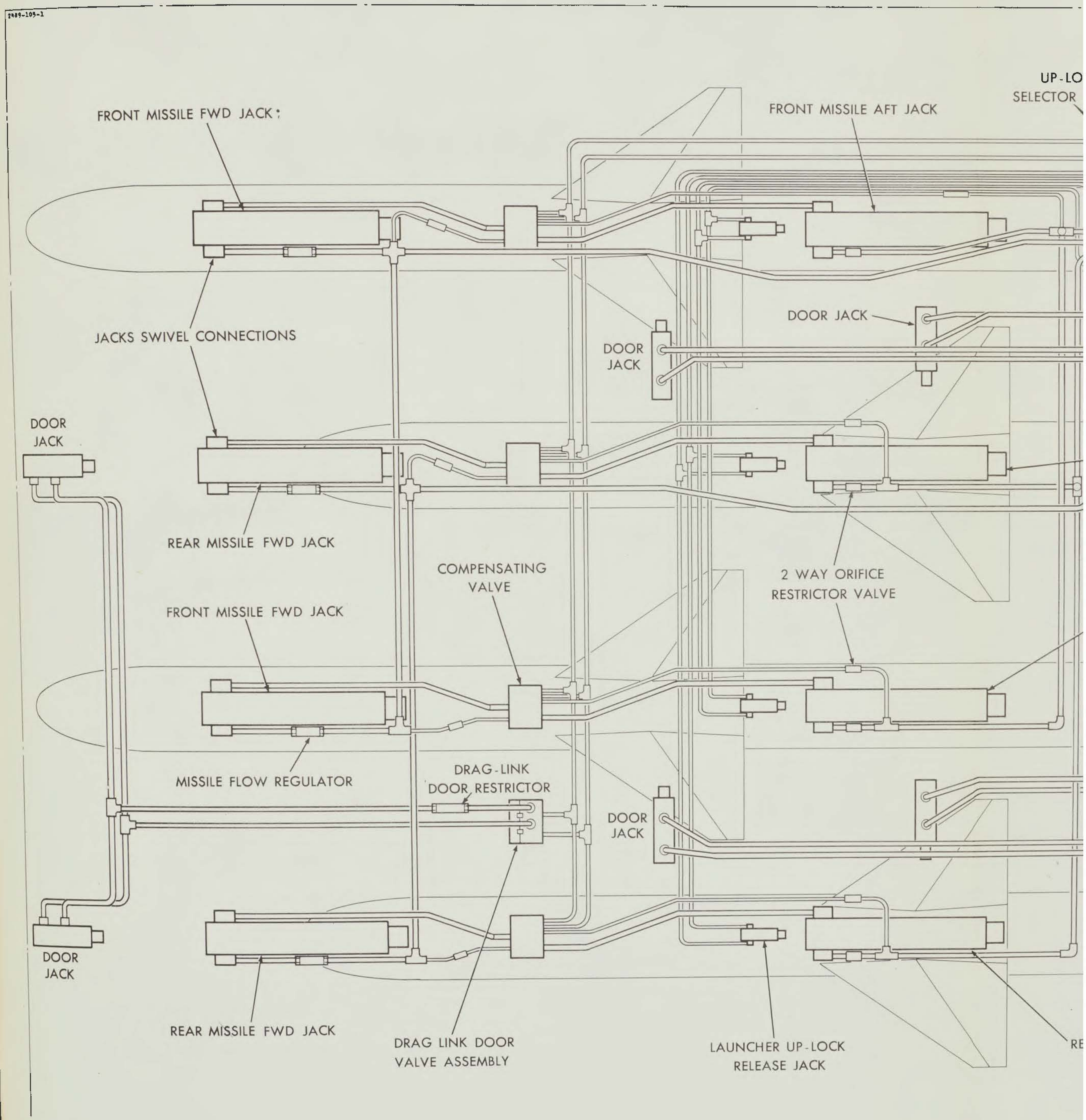

FIG. 10 DIAGRAMMATIC OF ARMAMENT HYDRA

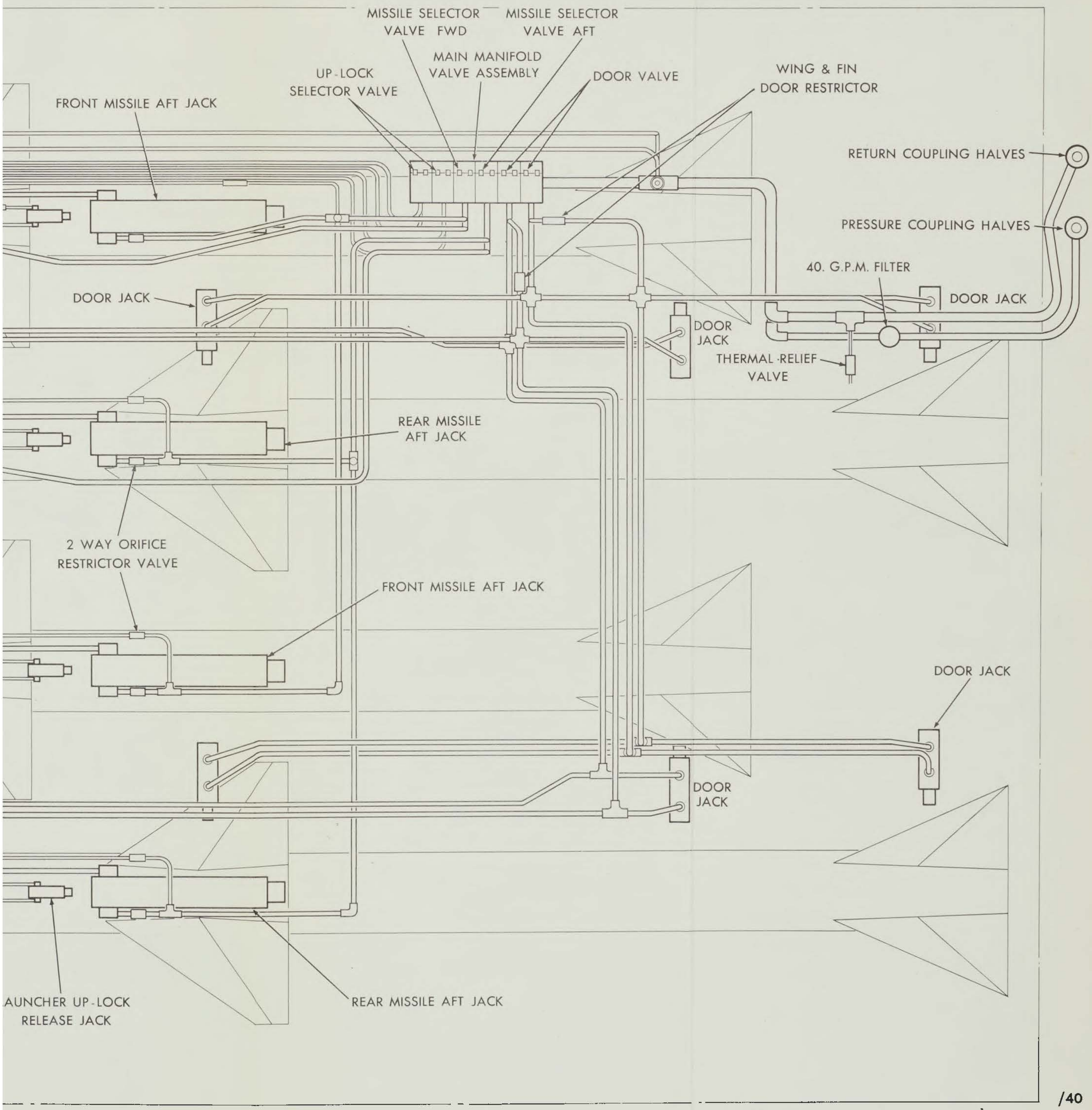

FIG. 10 DIAGRAMMATIC OF ARMAMENT HYDRAULICS