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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.

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ENGINEERING DIVISION

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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.

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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 <u>Landing Gear Hydraulic Sub-system</u>

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.

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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 <u>Armament Pack Hydraulic Sub-systems</u>

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 air-bleed 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

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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° of retraction from the down position, no shortening or twisting occurs. For the next $5\frac{1}{2}^{\circ}$ the gleason teeth of the anti-rotation lock are disengaged with 0.65" of shortening. After the initial $14\frac{1}{2}^{\circ}$ retraction, twisting starts at the rate of 5° 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 <u>Gear Retraction</u>

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 <u>Gear Extension</u>

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 <u>Gear Uplock</u>

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

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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

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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.

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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.

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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.

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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

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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.
6 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.

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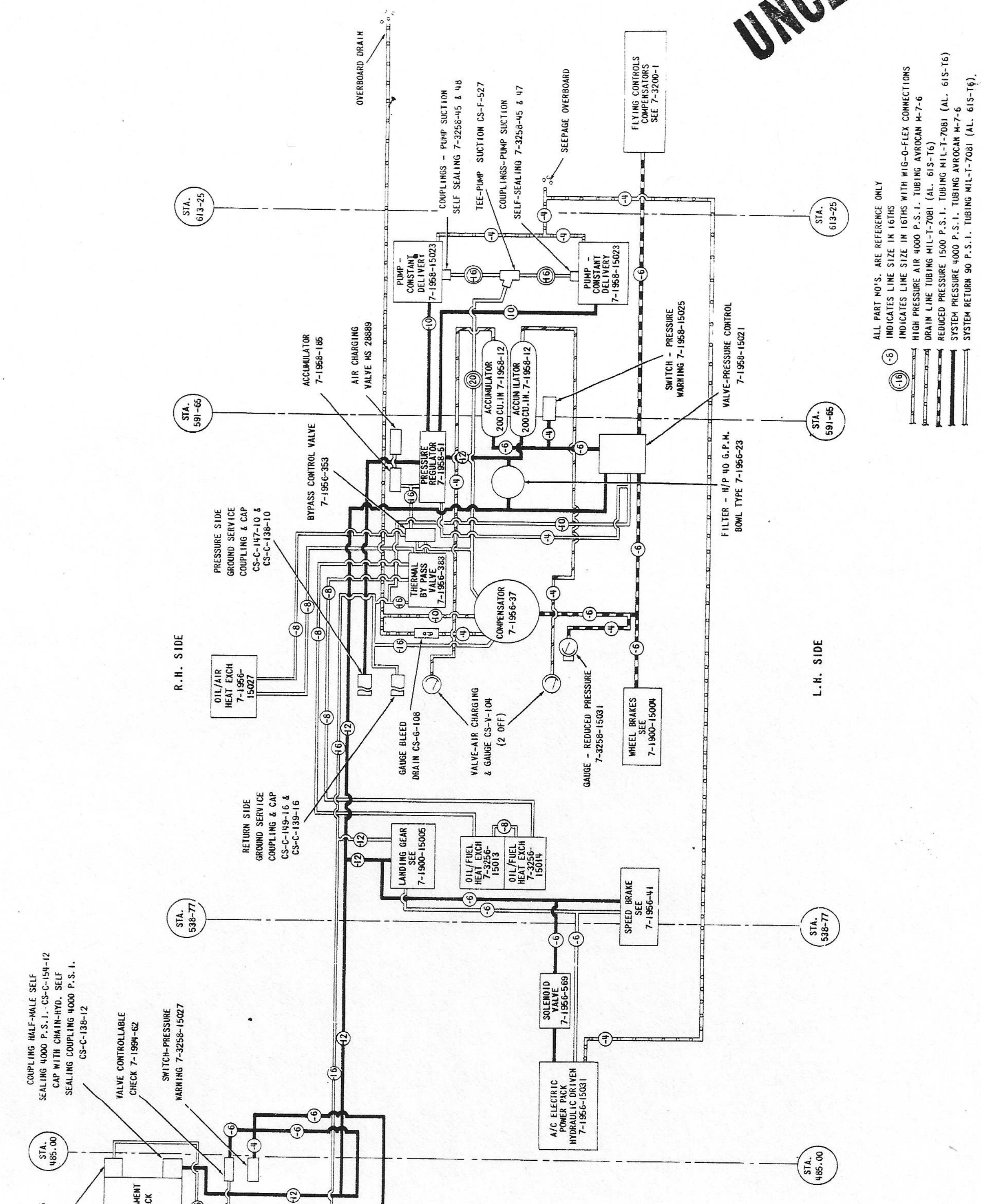

FIG. 1.1 DIAGRAMMATIC UTILITY HYDRAULIC SYSTEM

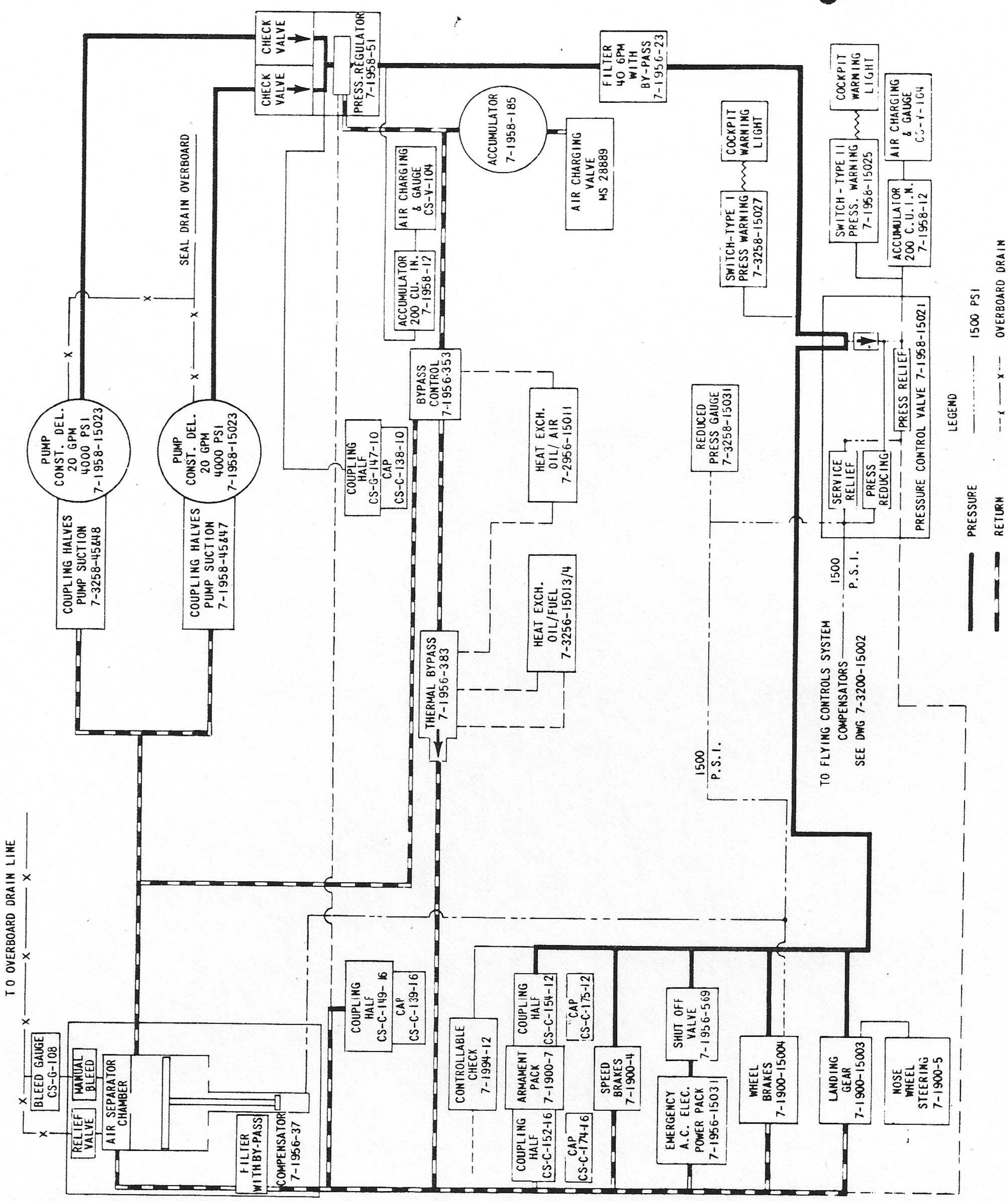

FIG. 1.2 UTILITY HYDRAULIC SYSTEM

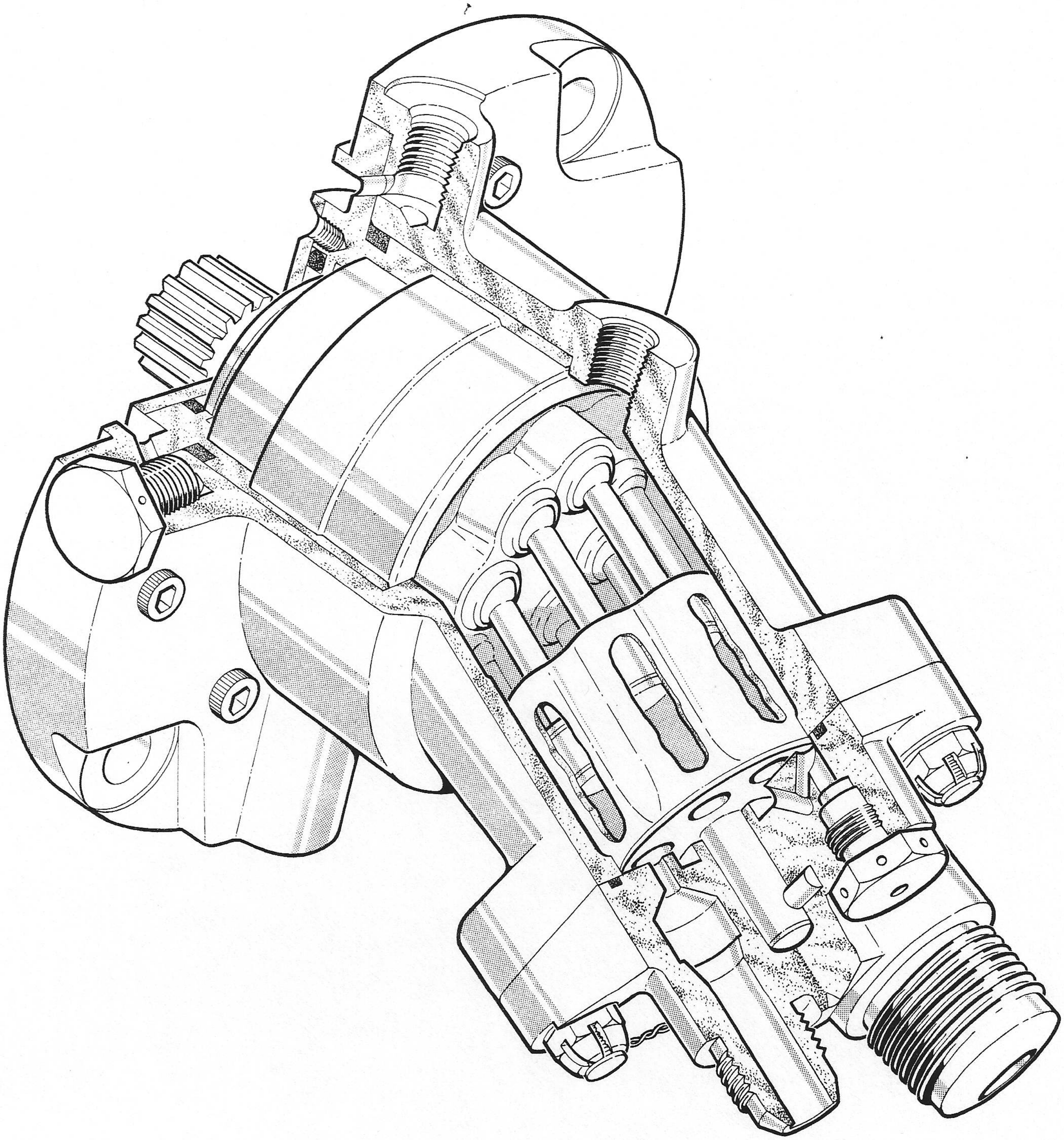

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FIG. 1.3 FIXED DISPLACEMENT PUMP

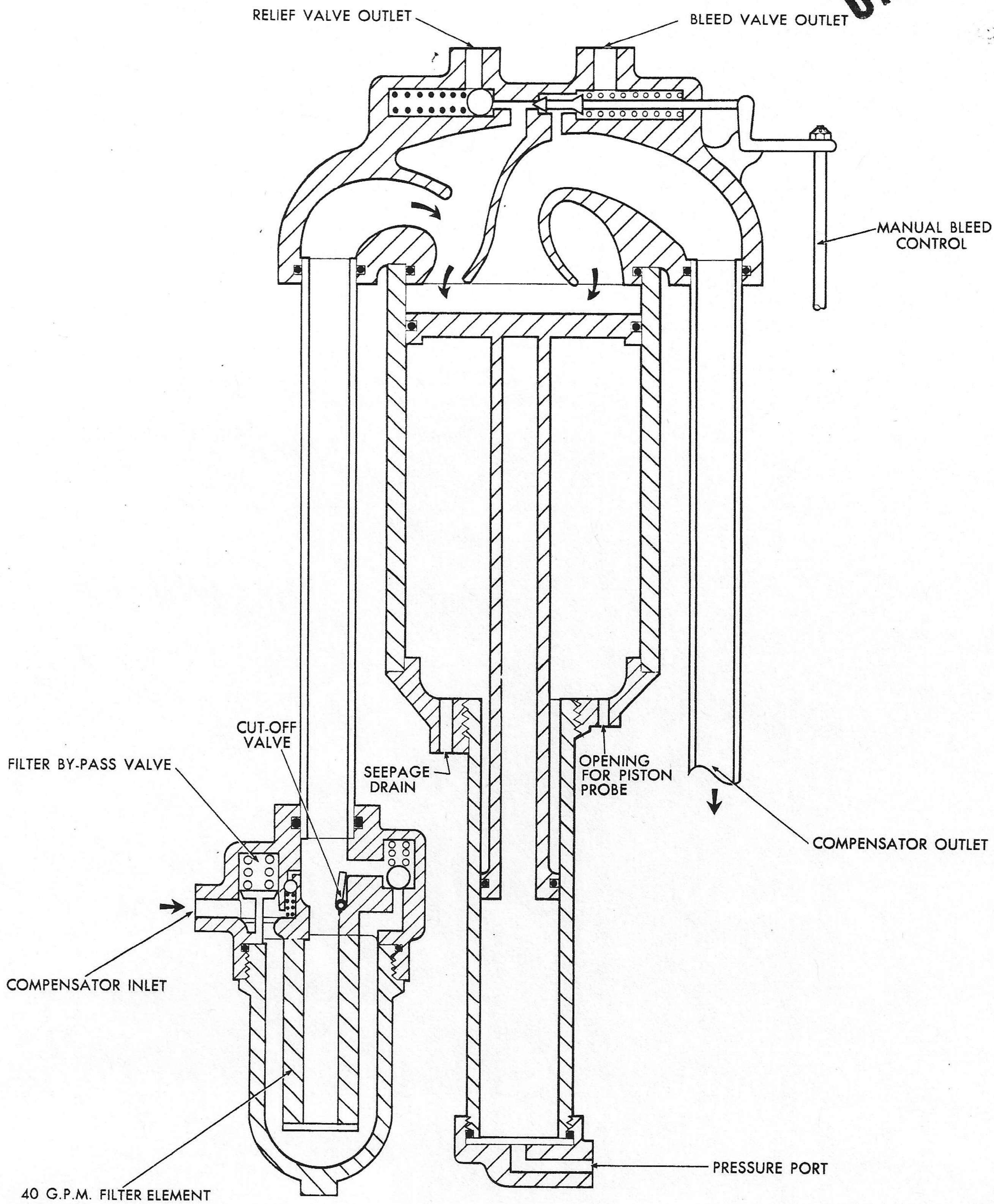
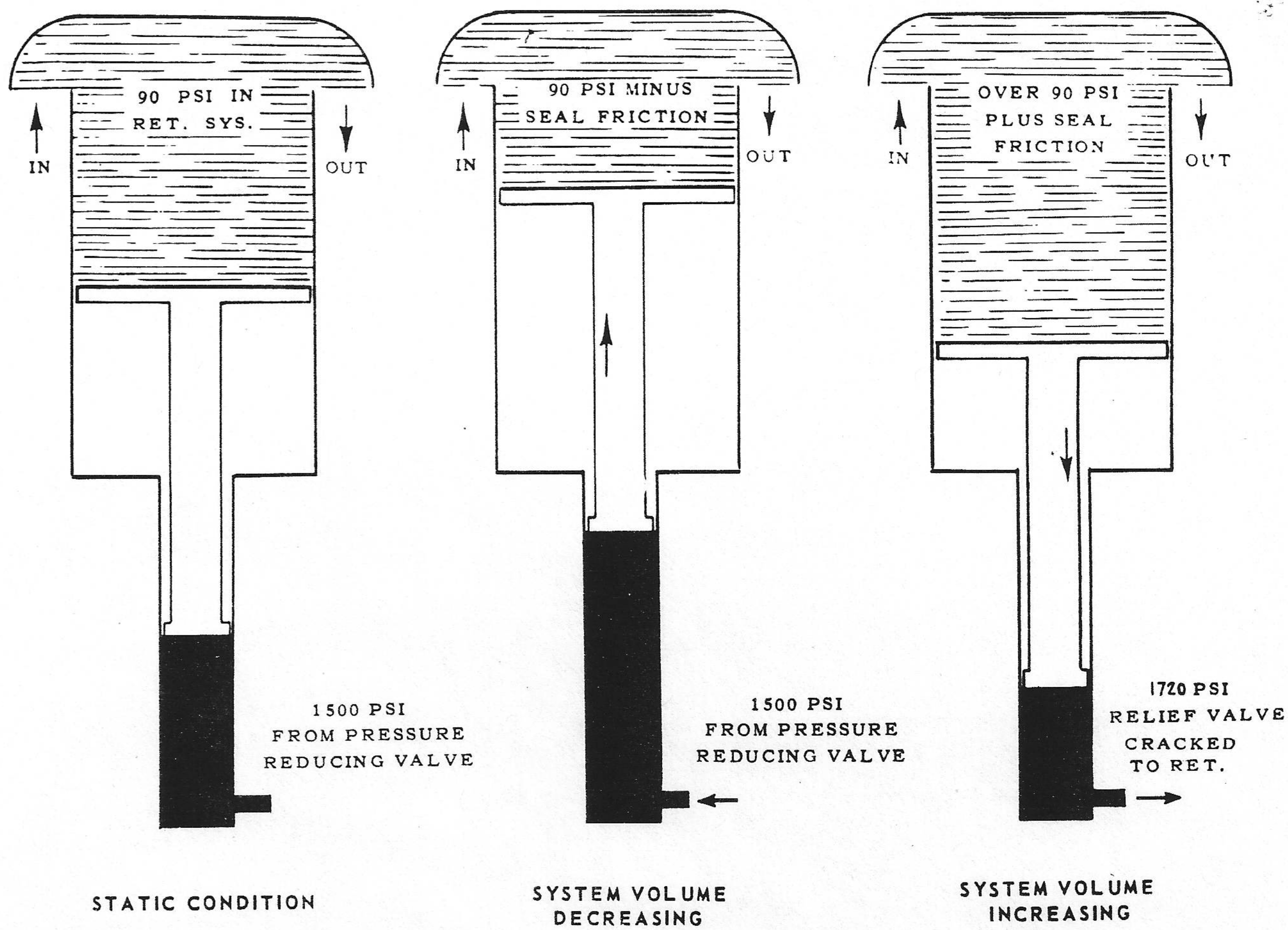


FIG. 1.4 COMPENSATOR



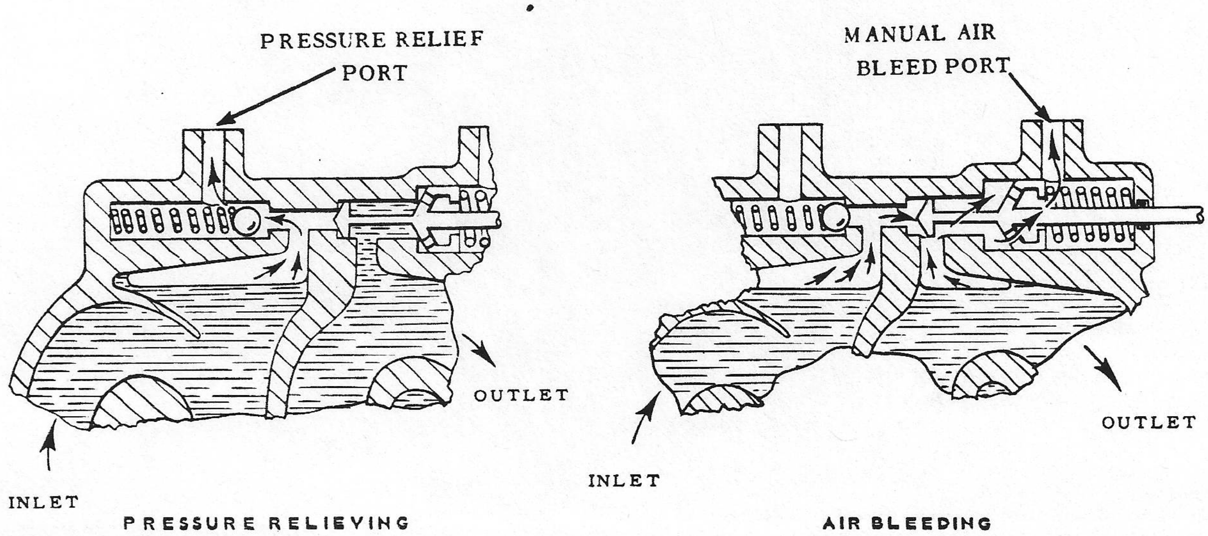


FIG. 1.5 UTILITY HYDRAULIC SYSTEM COMPENSATOR FUNCTIONING

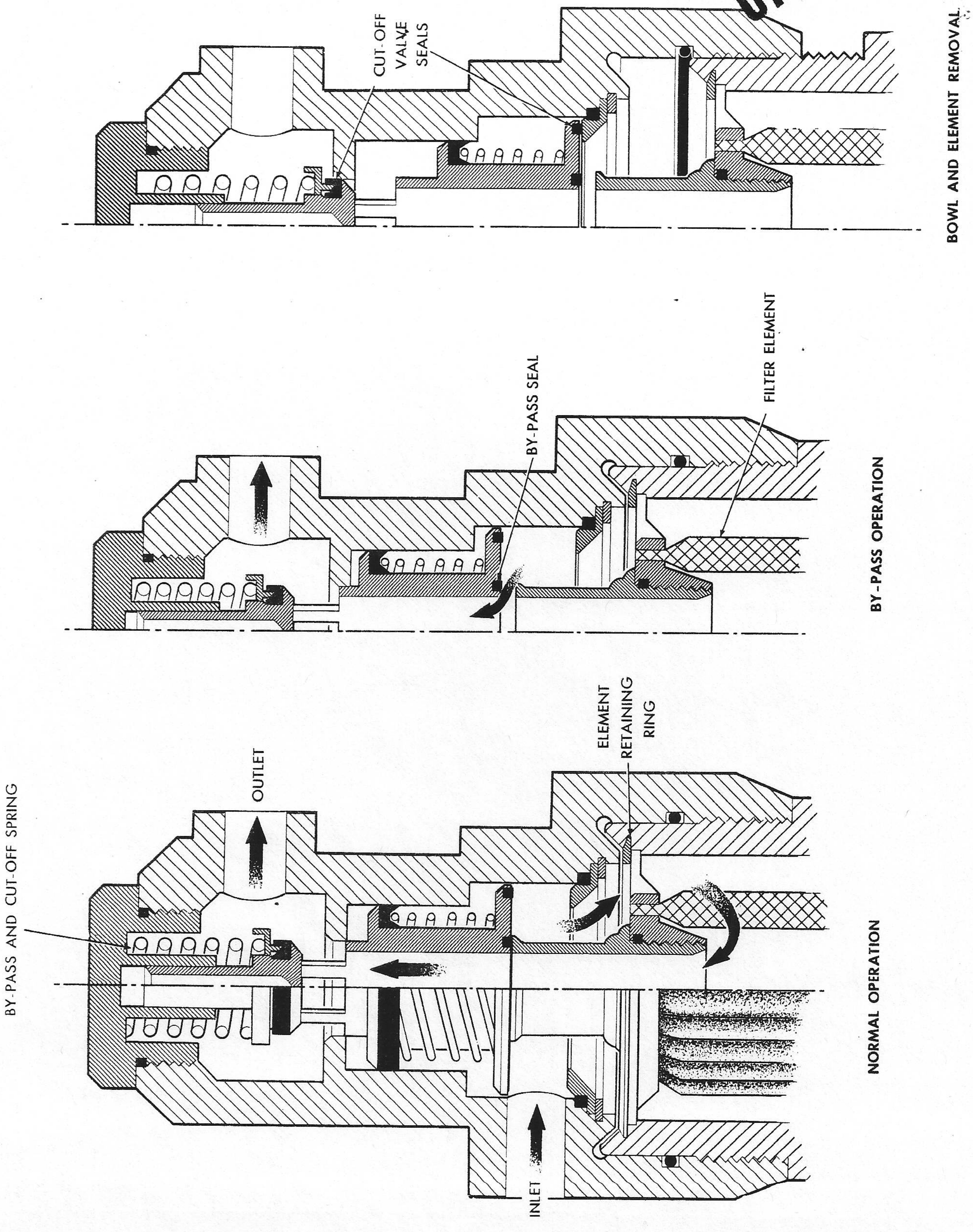


FIG. 1.6 FLYING CONTROL HYDRAULIC SYSTEM - HYDRAULIC FILTER 40 G.P.M.

UNCLASSIFIED

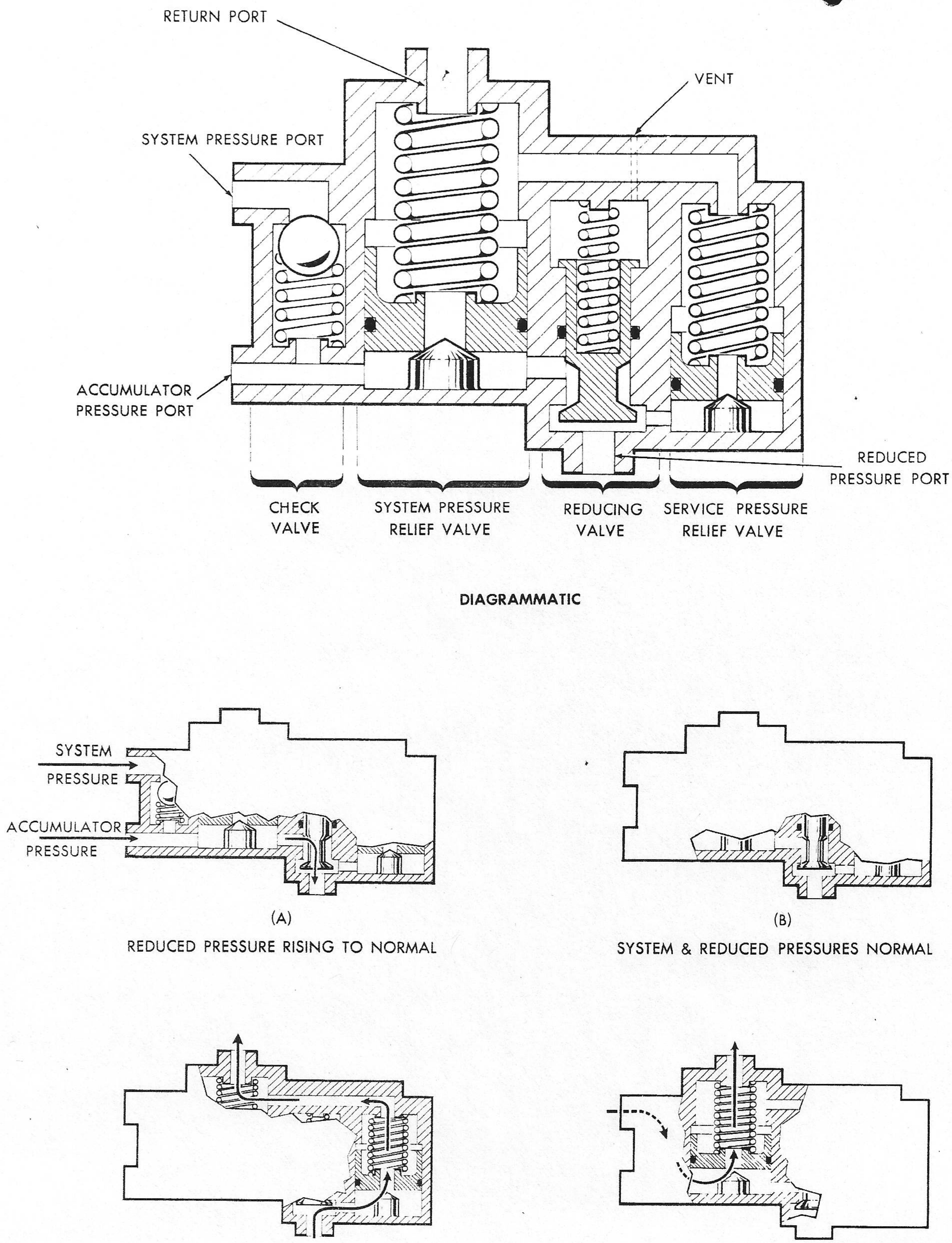
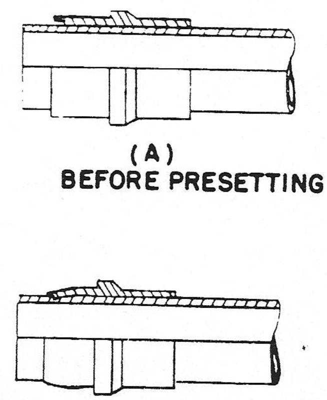
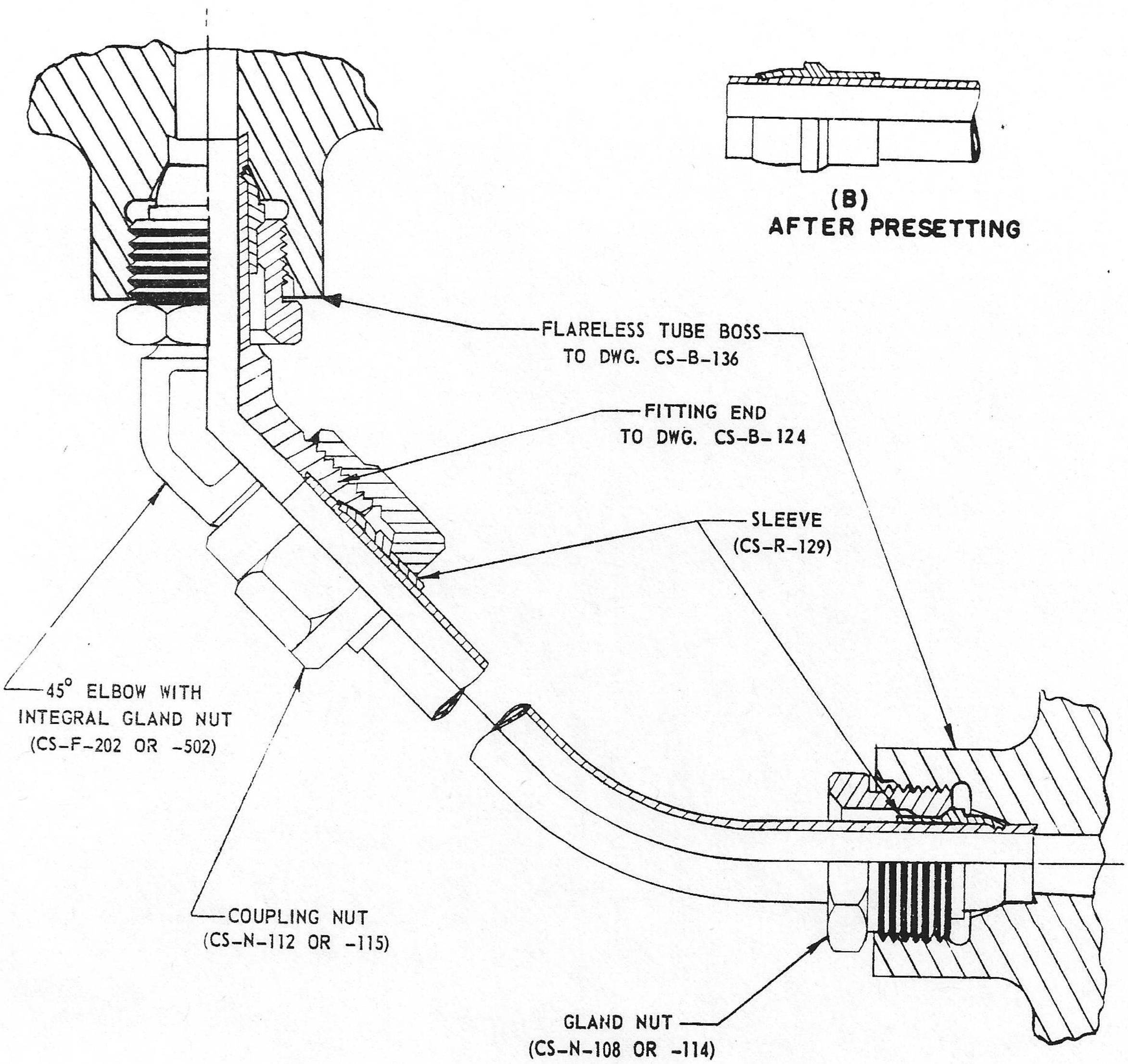


FIG. 1.7 UTILITY HYDRAULIC SYSTEM - PRESSURE CONTROL VALVE

ASSEMBLY OF SLEEVE AND TUBE





NOTE: CS NUMBERS REFER TO AVRO STANDARD DRAWINGS.

FIG. 1.8 FLARELESS TUBE CONNECTIONS

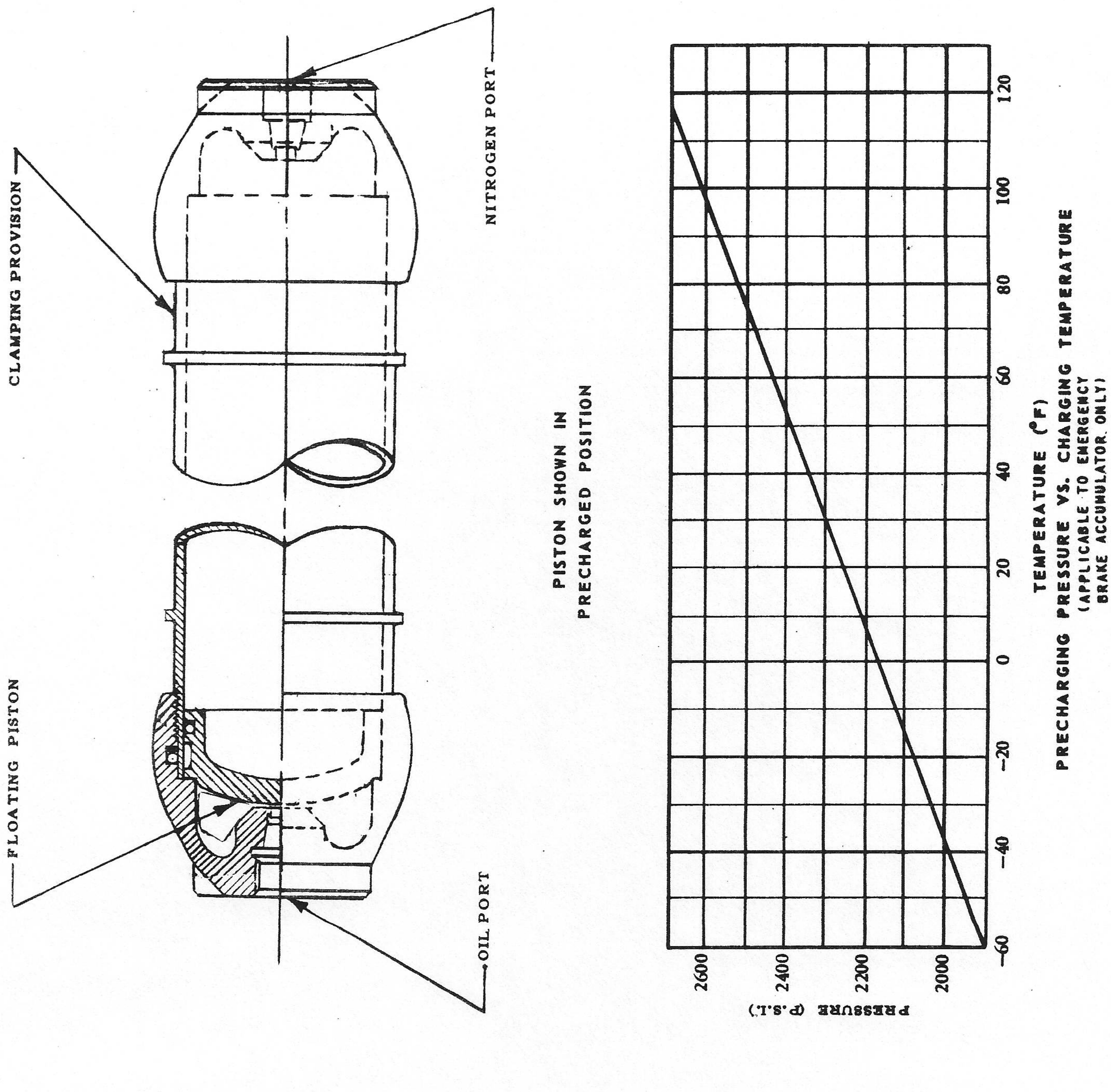


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FIG. 1.9 ACCUMULATOR - FLOATING PISTON TYPE

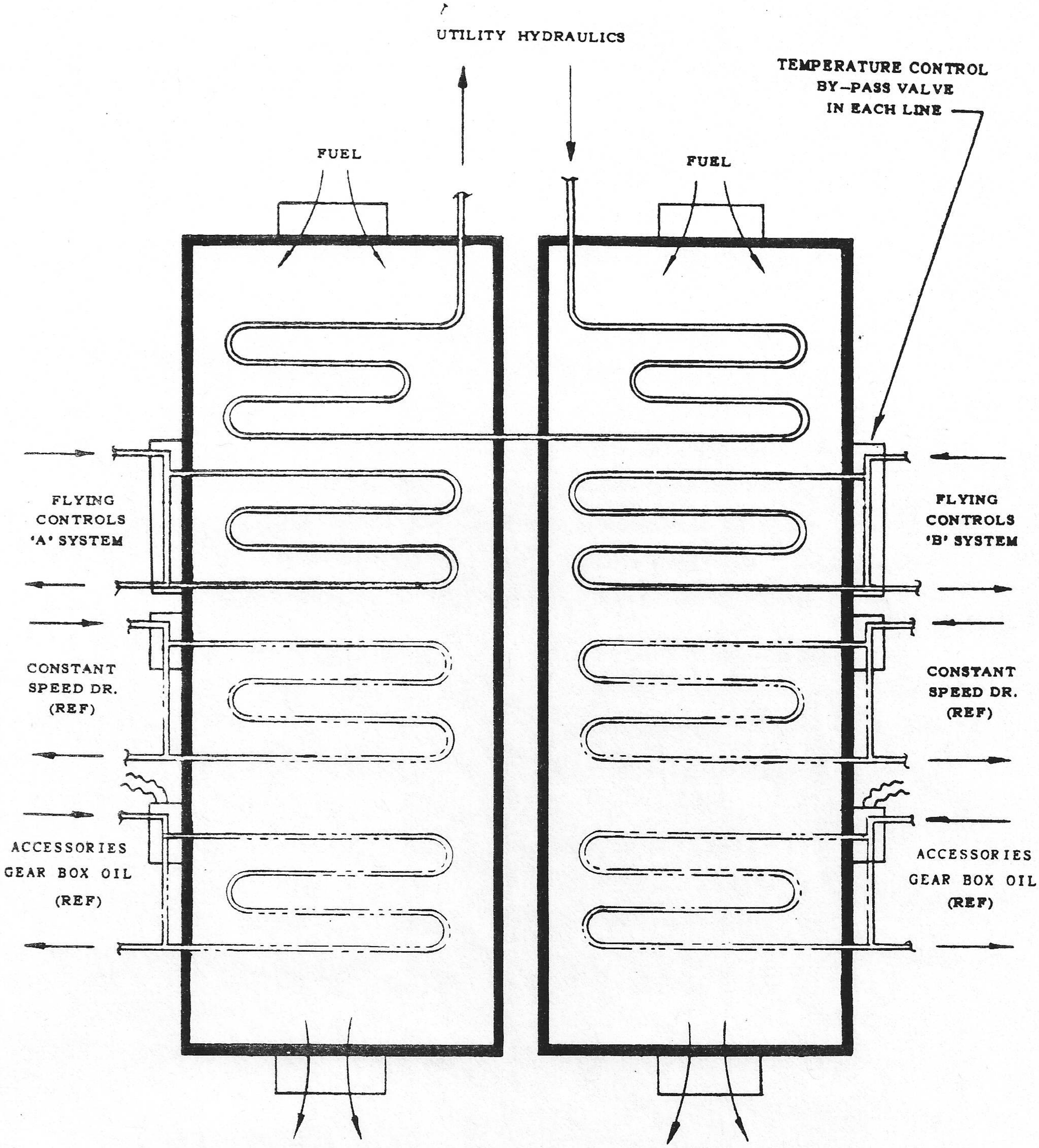

FIG. 1.10 HEAT EXCHANGER OIL TO FUEL

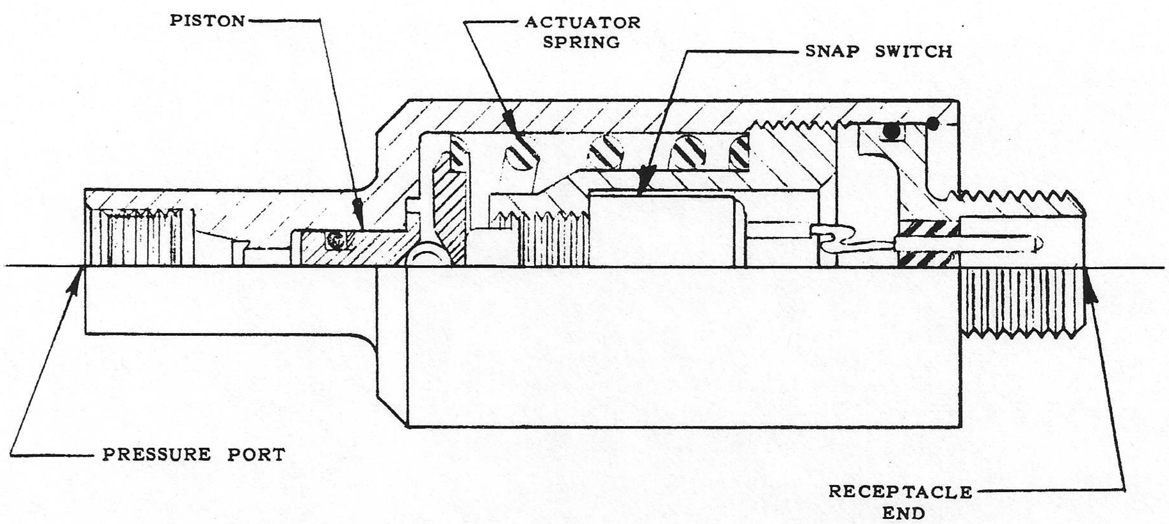

FIG. 1.11 HYDRAULIC PRESSURE SWITCH

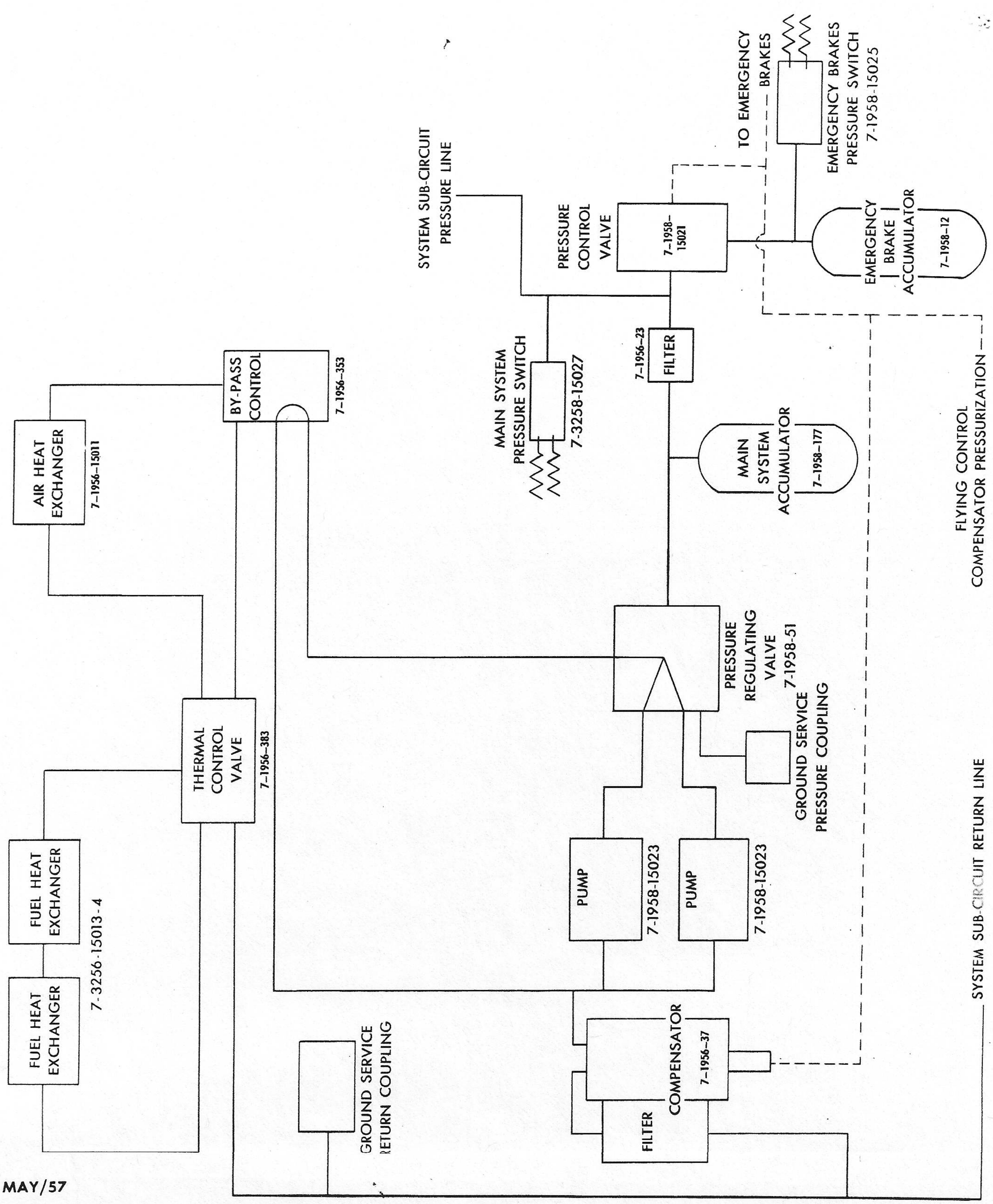

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FIG. 1.12 POWER CIRCUIT BLOCK DIAGRAM

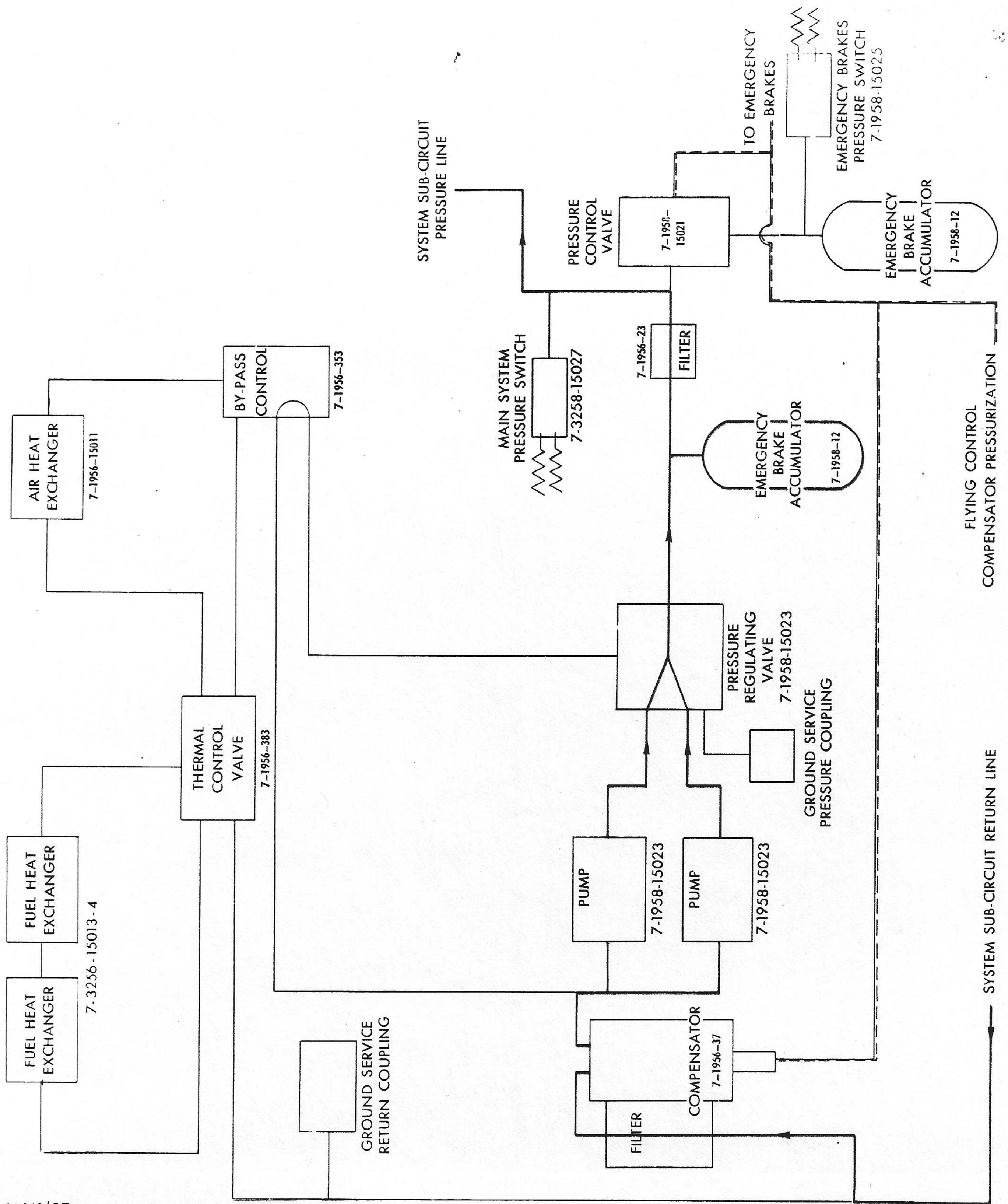


FIG. 1.13 FLOW PATTERN IN THE LOADED CIRCUIT

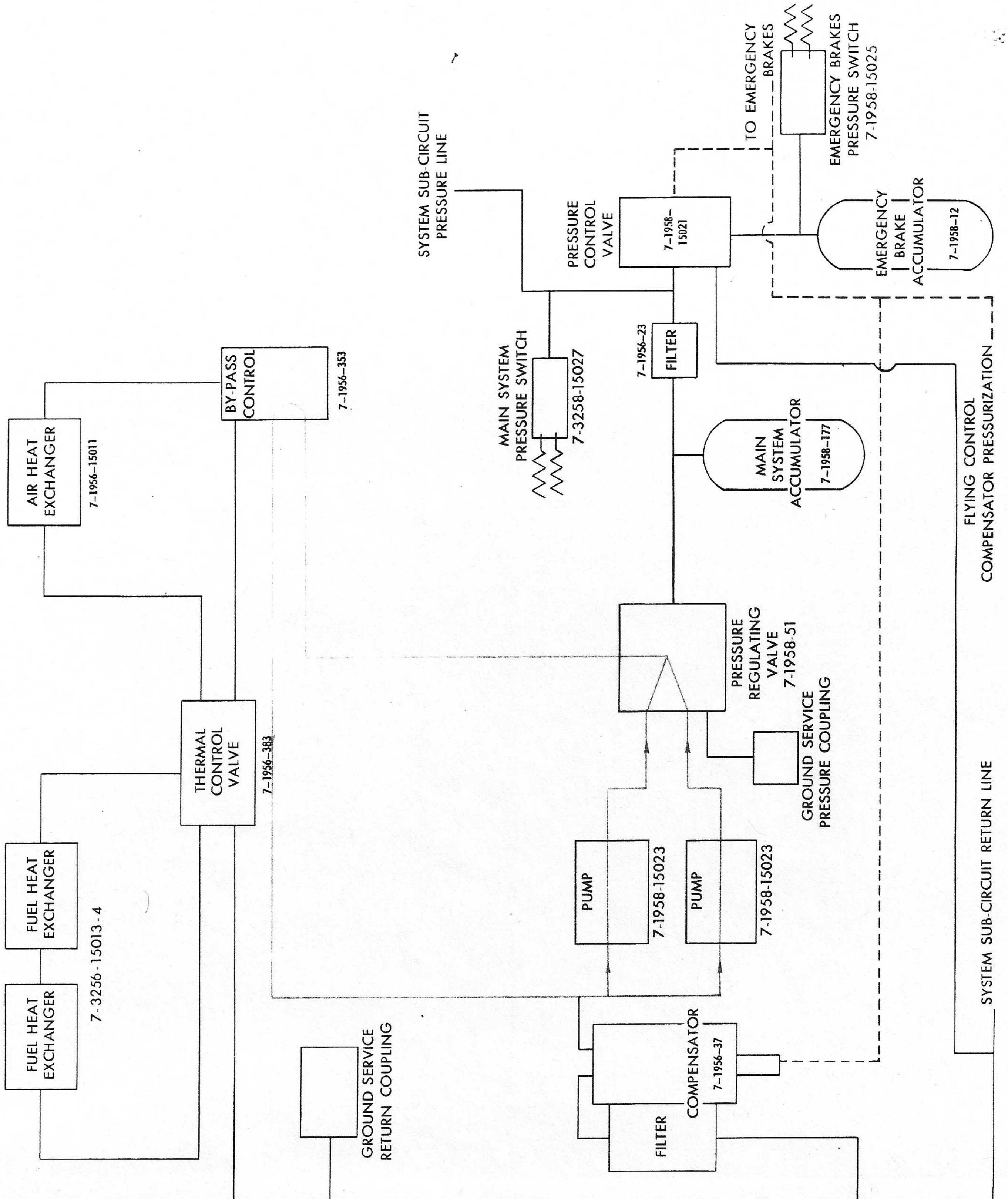


FIG. 1.14 TYPICAL FLOW PATTERN UNLOADING CIRCUIT -65°F TO +90°F

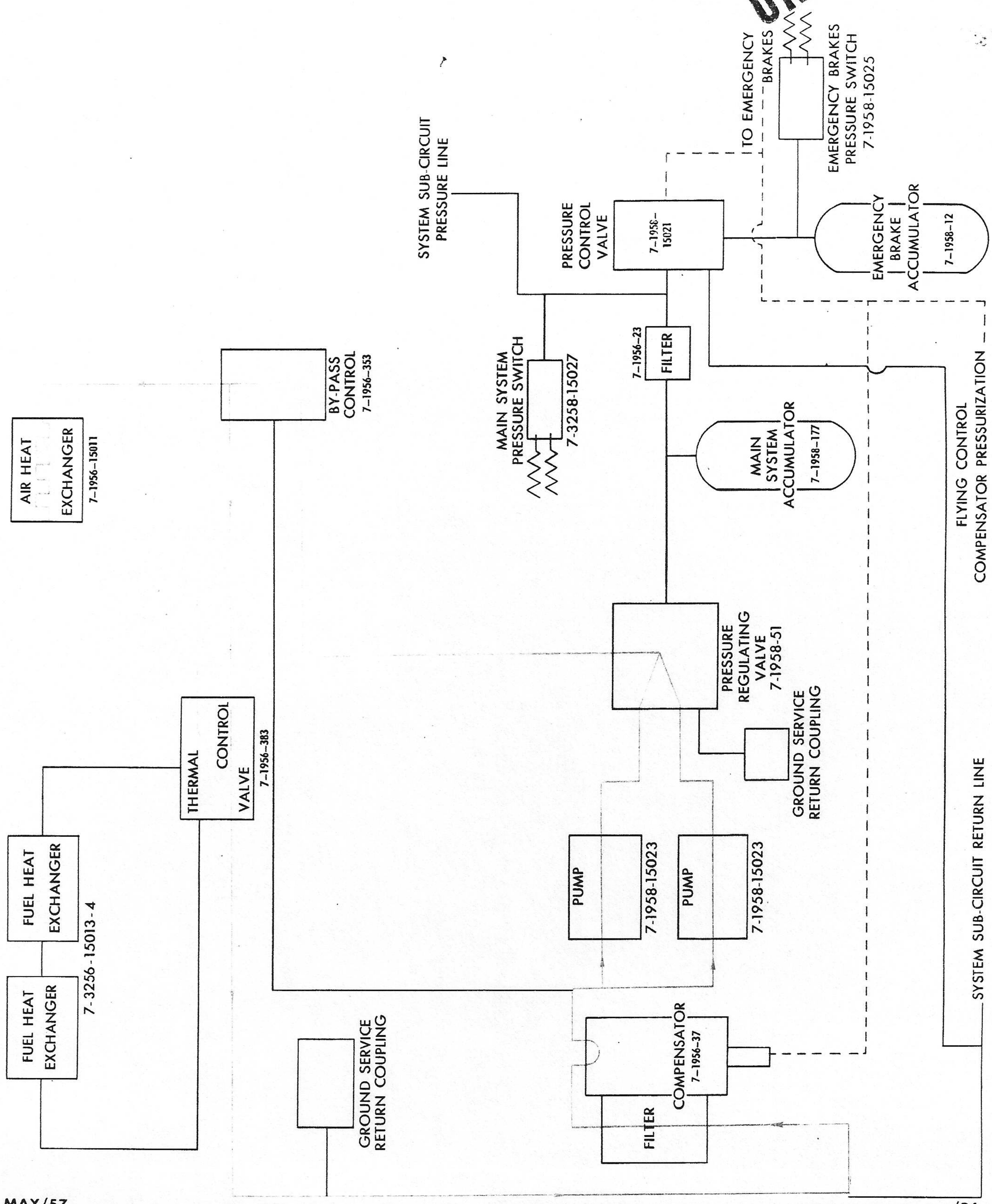


FIG. 1.15 TYPICAL FLOW PATTERN UNLOADING CIRCUIT 90°F TO 213°F PUMP INLET TEMPERATURE

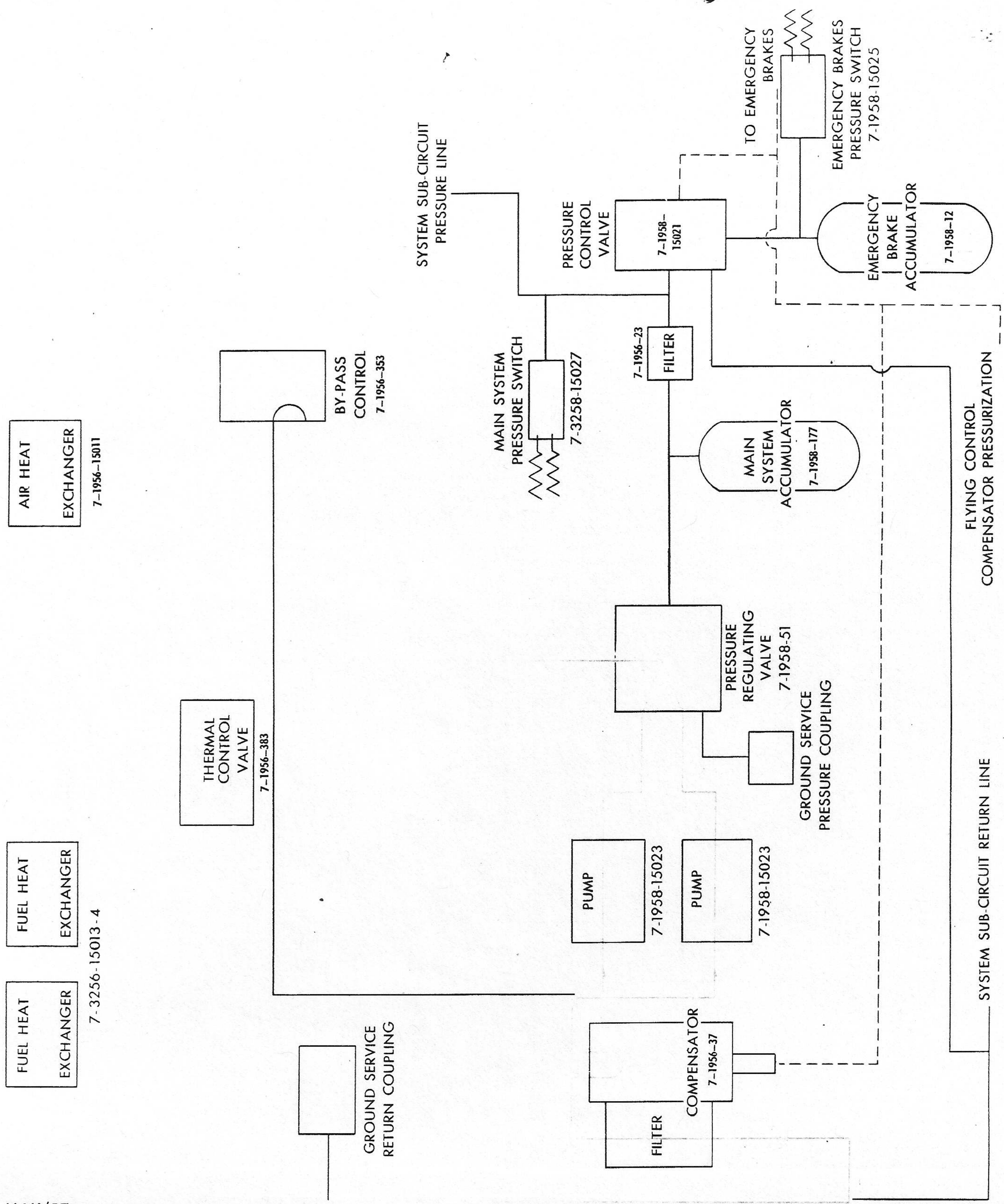


FIG. 1.16 TYPICAL FLOW PATTERN UNLOADING CIRCUIT 214°F TO 230°F PUMP INLET TEMPERATURE

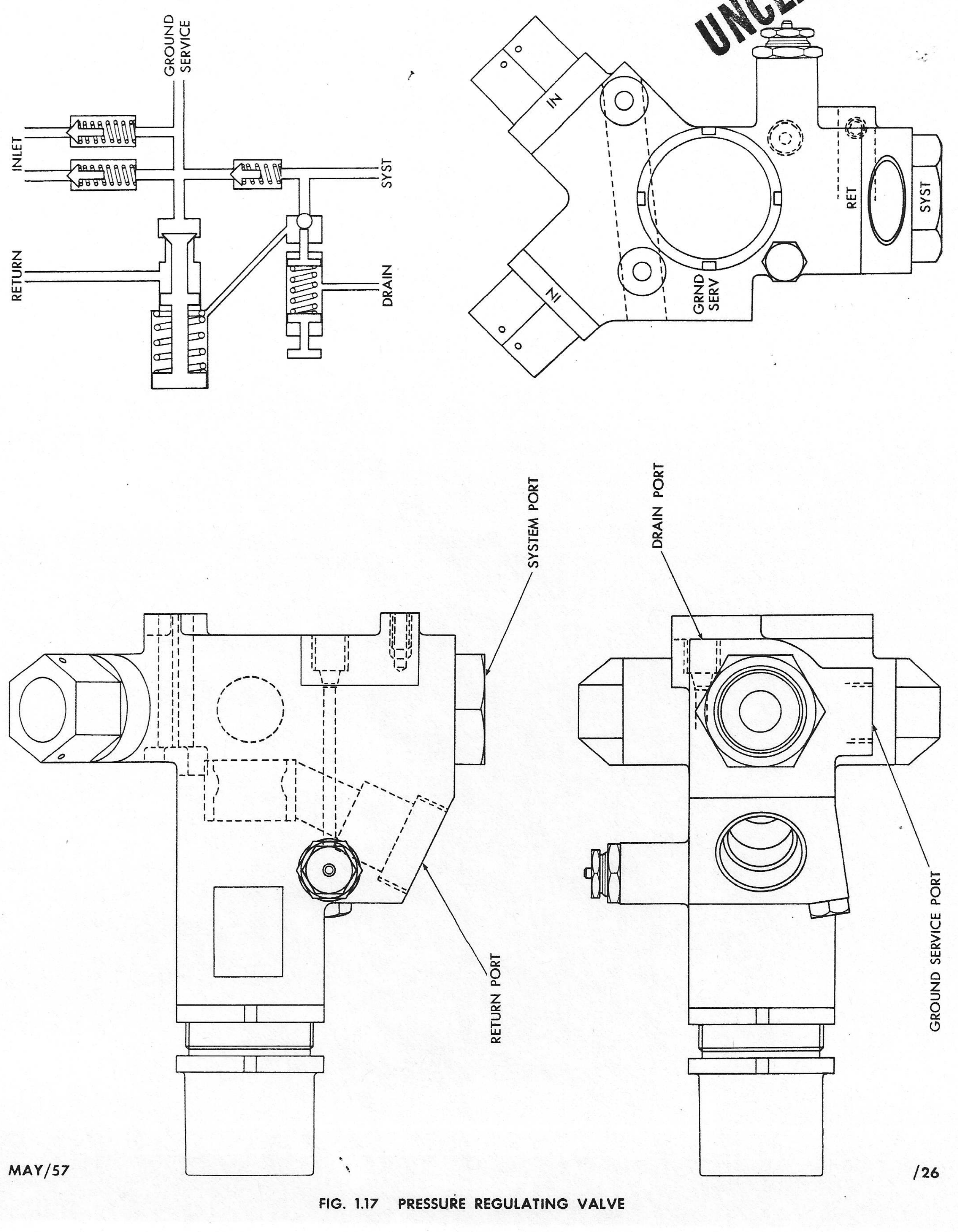


FIG. 1.17 PRESSURE REGULATING VALVE

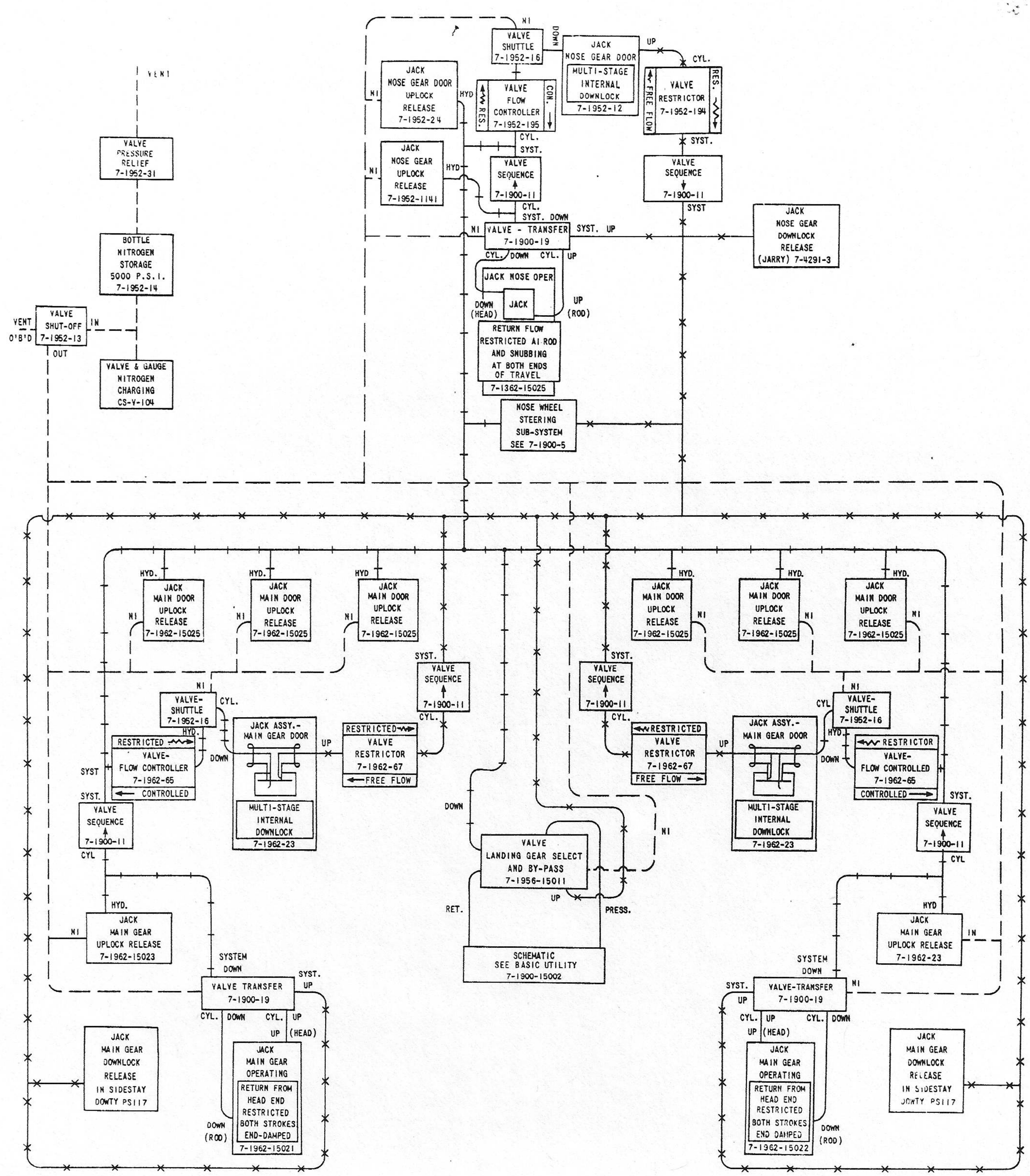


FIG. 2.1 SCHEMATIC LANDING GEAR SUB-SYSTEM

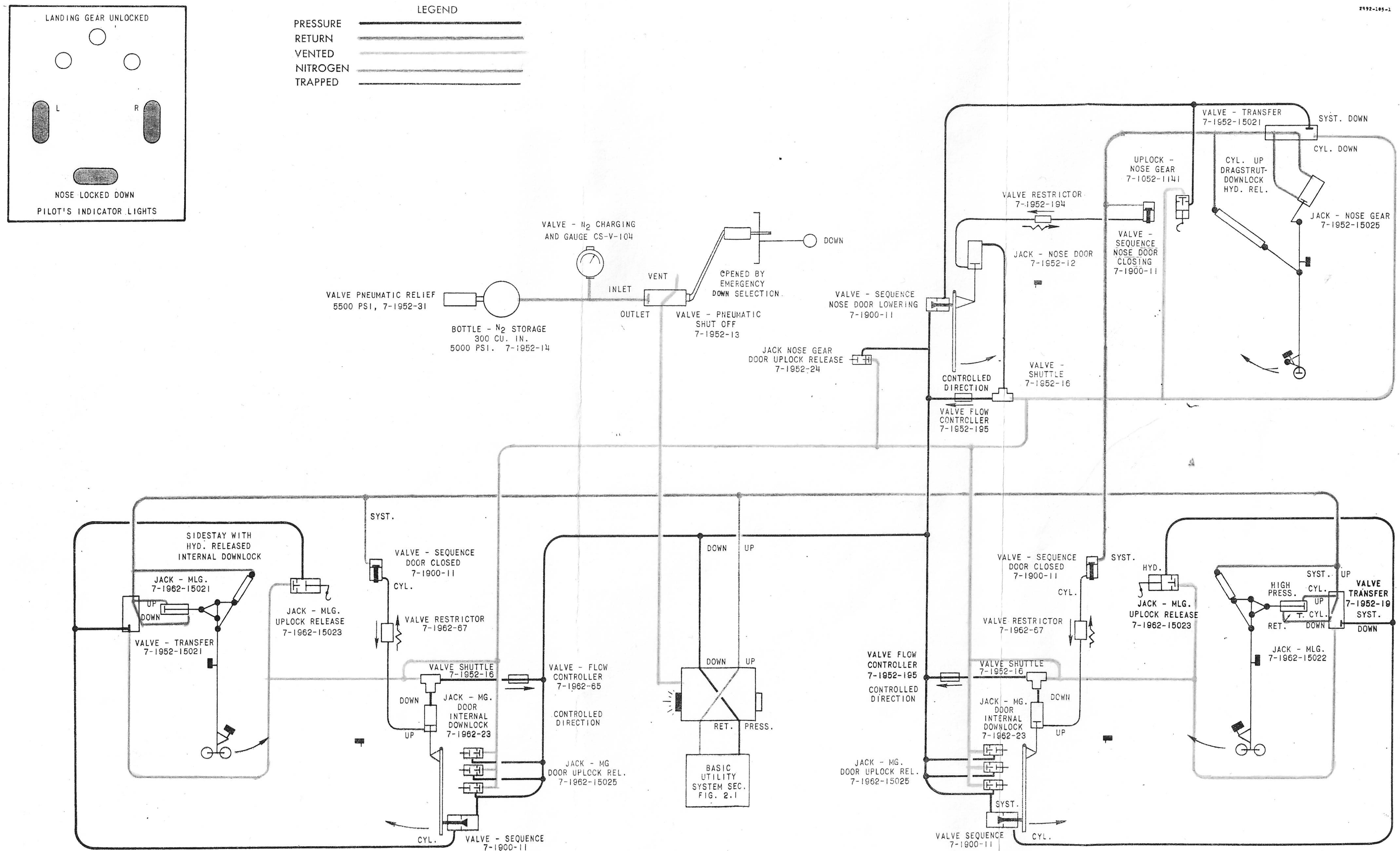


FIG. 2.2 ON GROUND-DOORS AND GEAR LOCKED DOWN

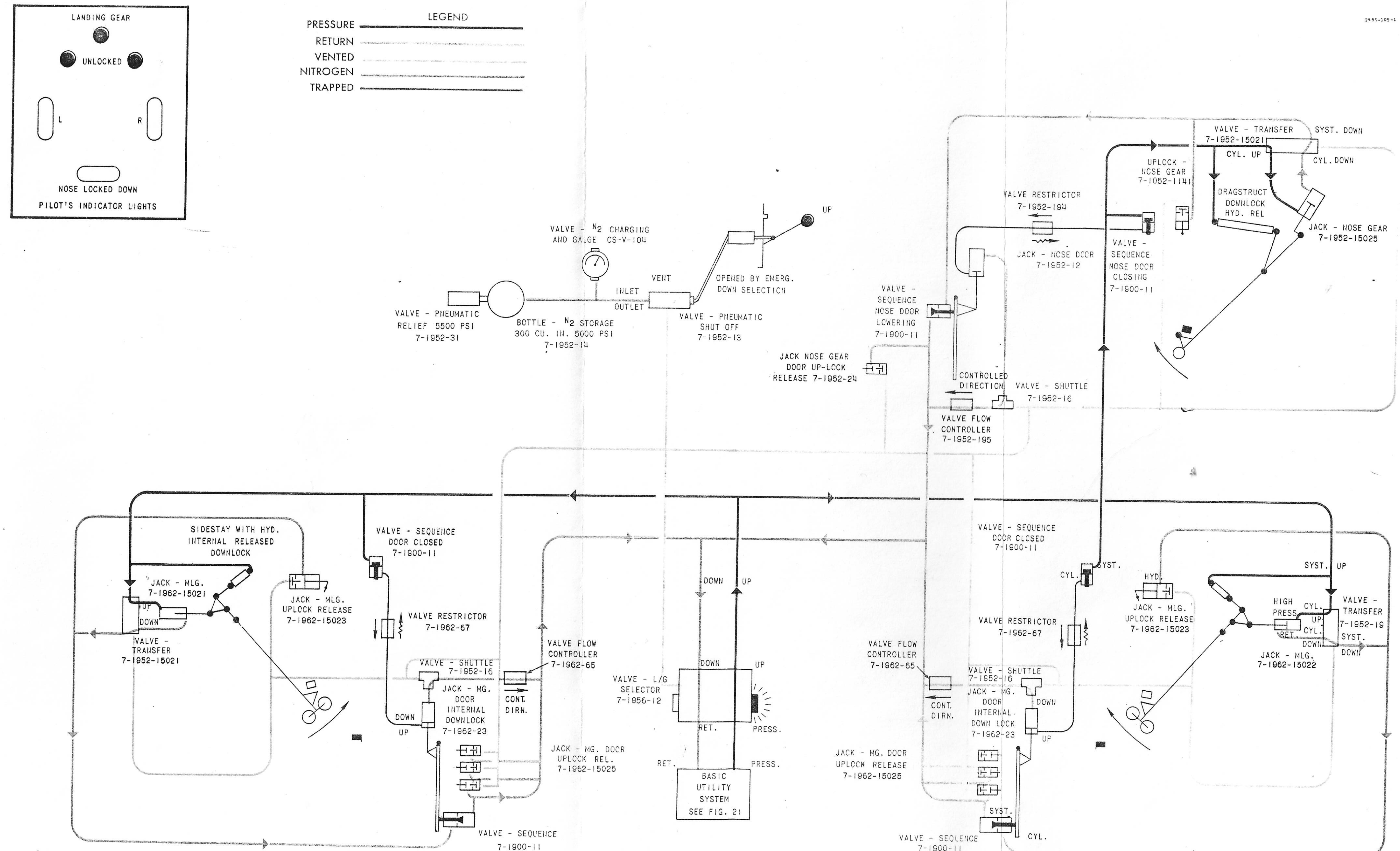


FIG. 2.3 UP SELECTION-DOORS LOCKED DOWN, GEARS RETRACTING

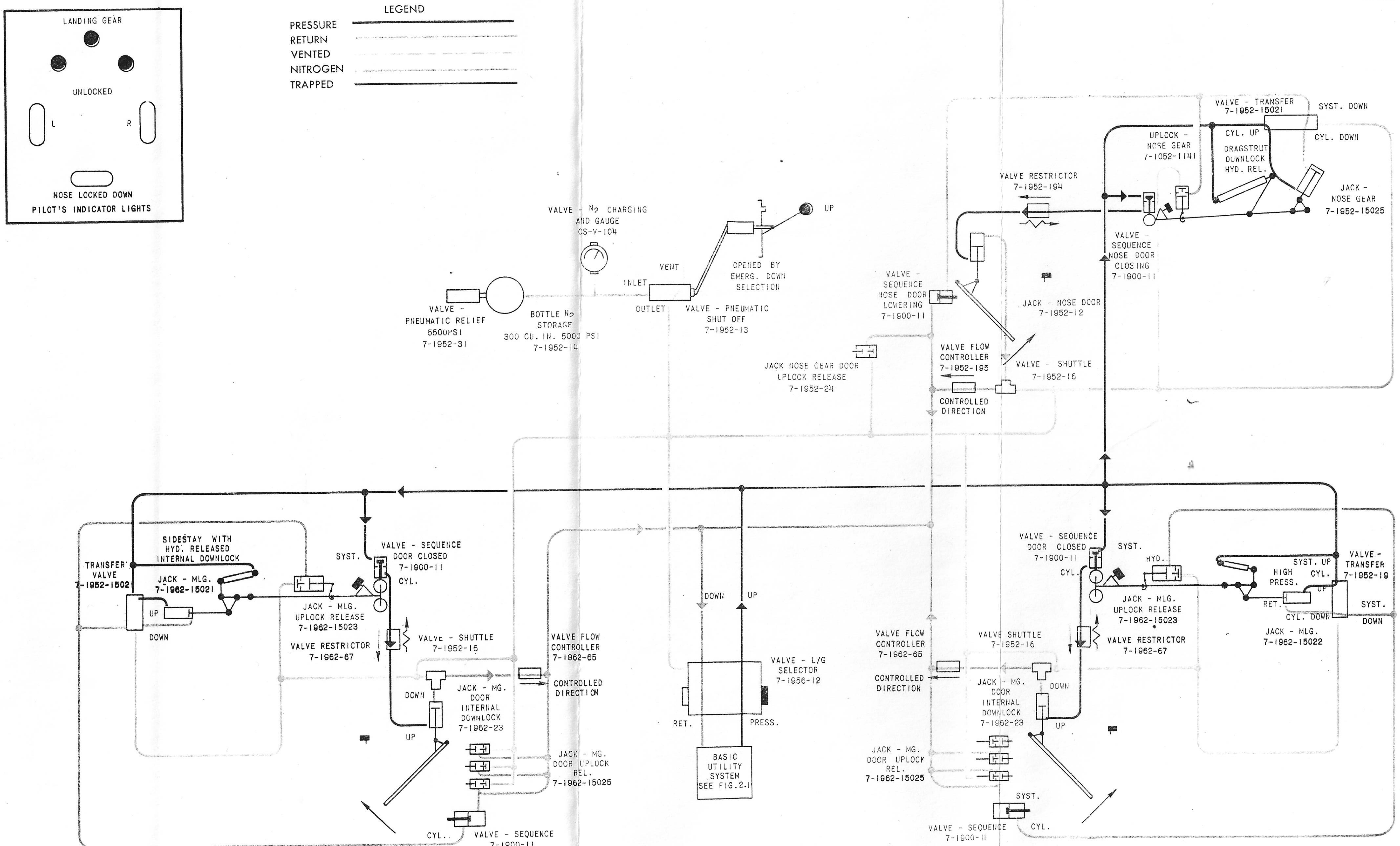
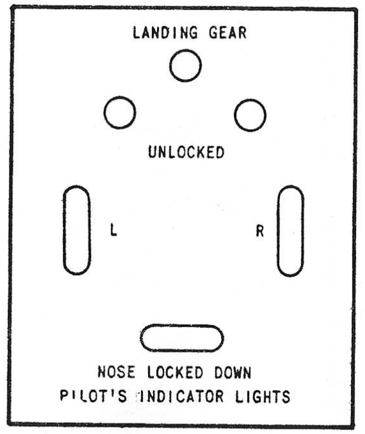


FIG. 2.4 UP SELECTION - GEARS UPLOCKED, DOORS CLOSING



LEGEND

PRESSURE
RETURN
VENTED
NITROGEN
TRAPPED

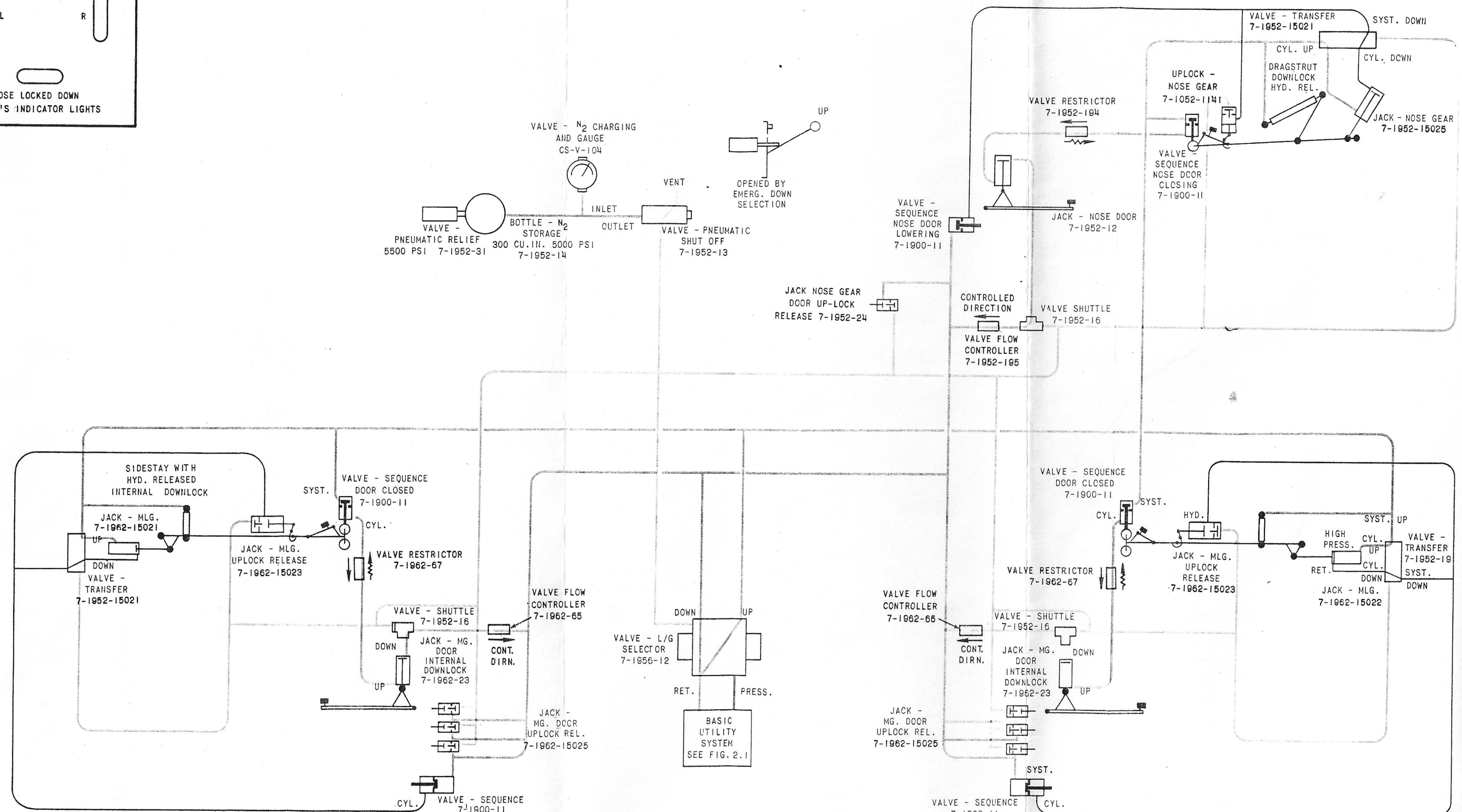


FIG. 2.5 IN FLIGHT-GEAR UPLOCKED, DOORS CLOSED AND LOCKED, SELECTOR VALVE IN NEUTRAL

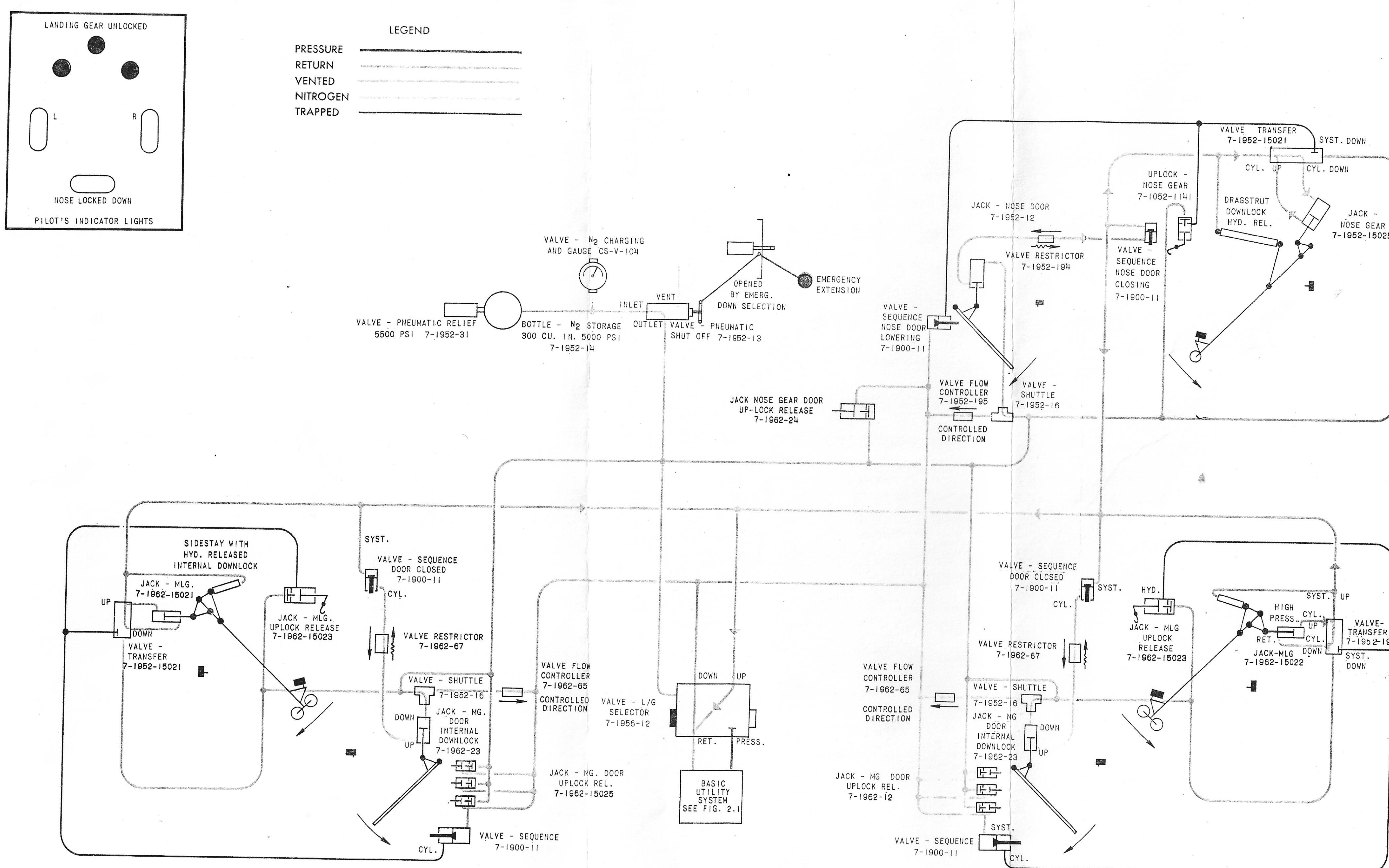


FIG. 2.6 EMERGENCY LANDING GEAR DOWN SELECTION
ALL UPLOCKS RELEASED TOGETHER, BOTH GEARS AND DOORS IN MOTION

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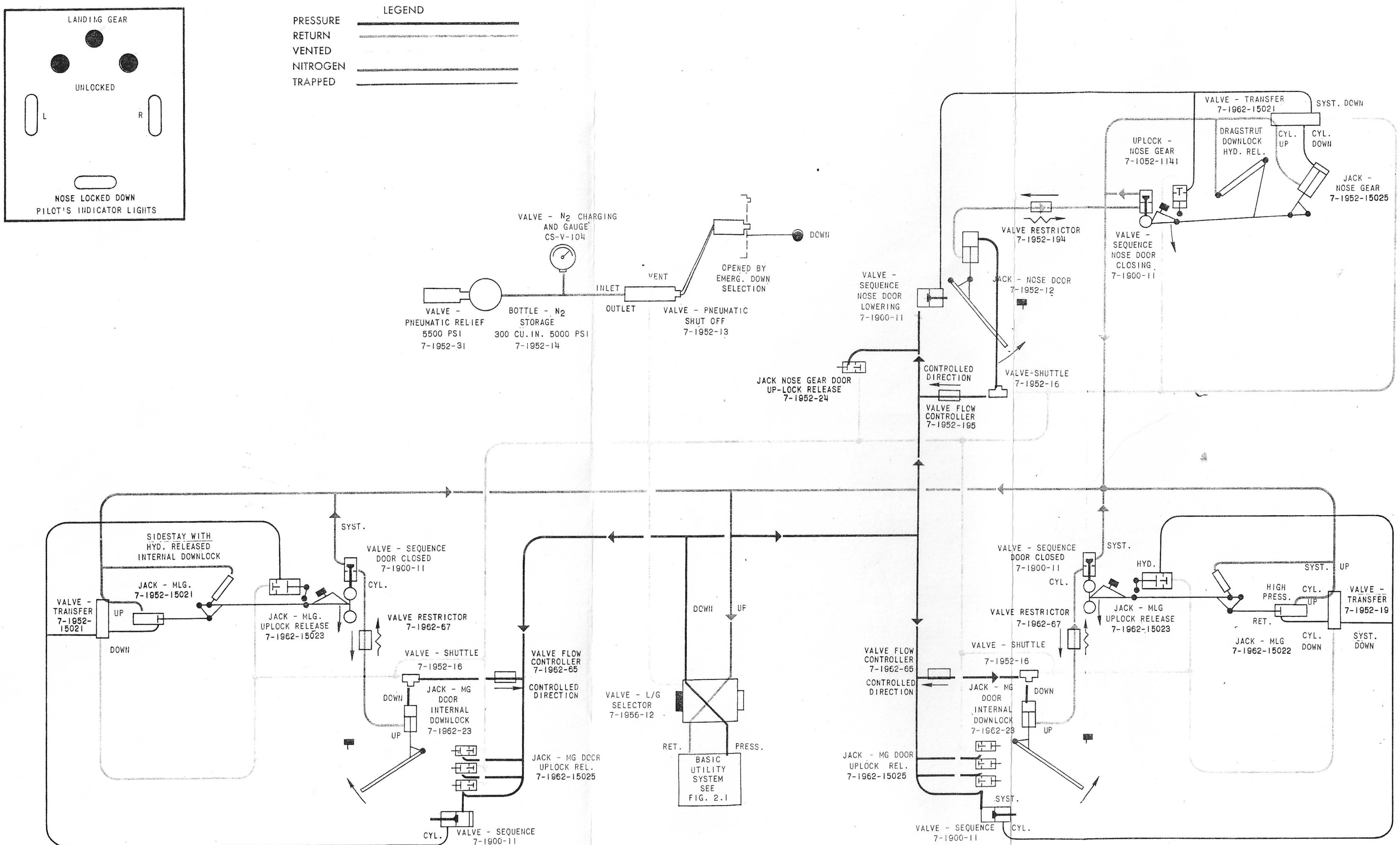

FIG. 2.7 DOWN SELECTION-DOORS OPENING, GEARS ON UPLOCKS

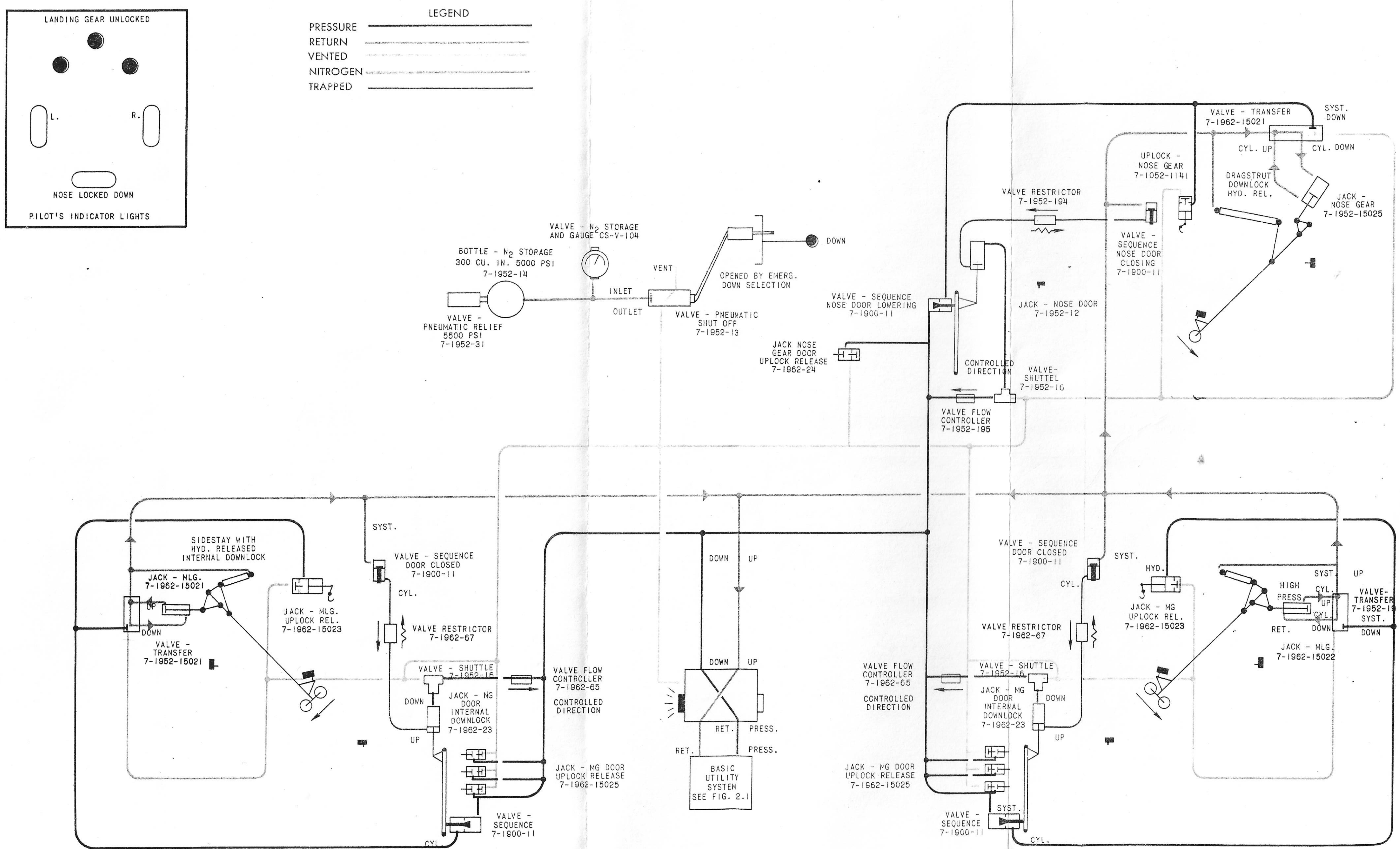

FIG. 2.8 DOWN SELECTION-DOORS LOCKED DOWN, GEARS FALLING

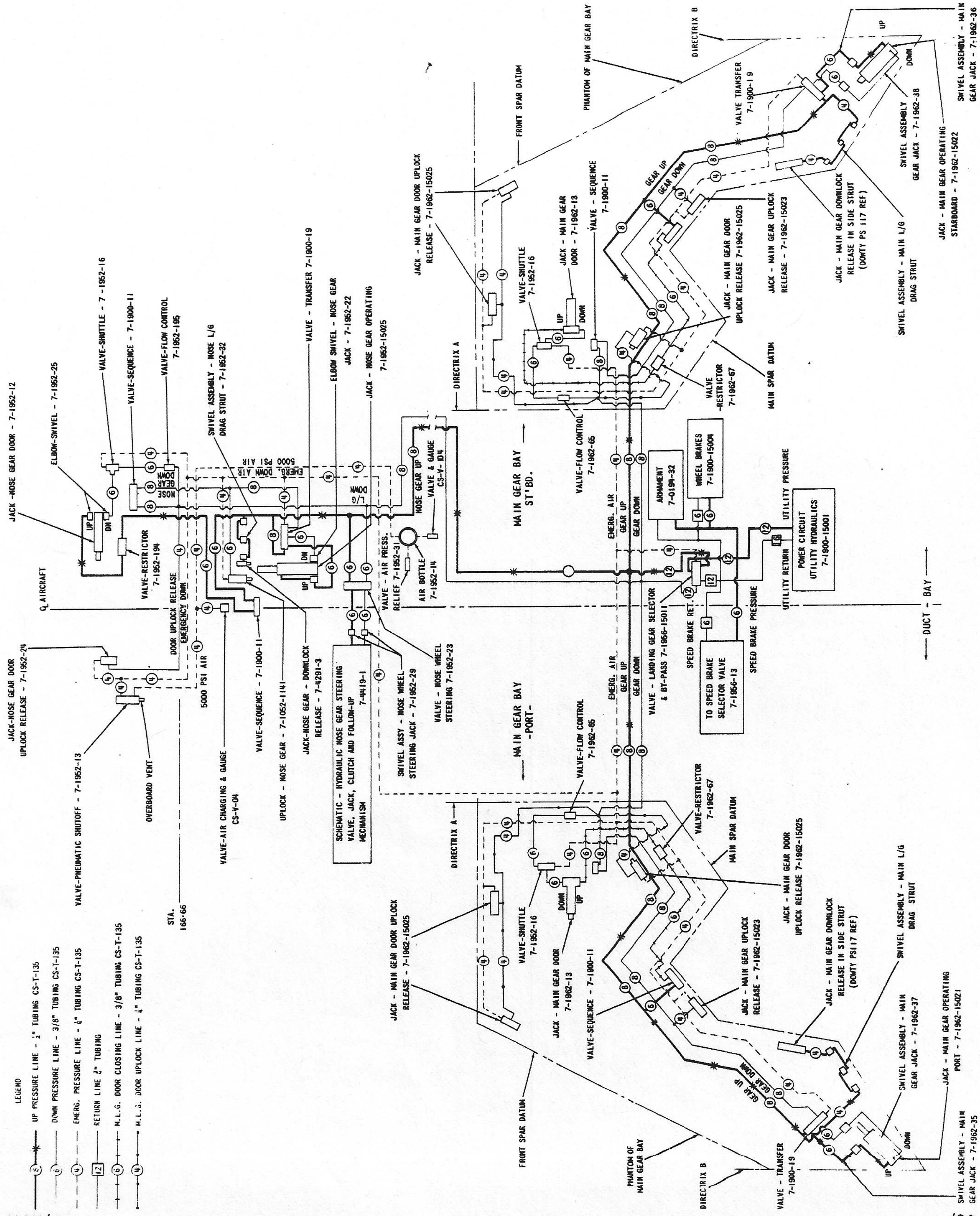

FIG. 2.9 DIAGRAMMATIC-LANDING GEAR

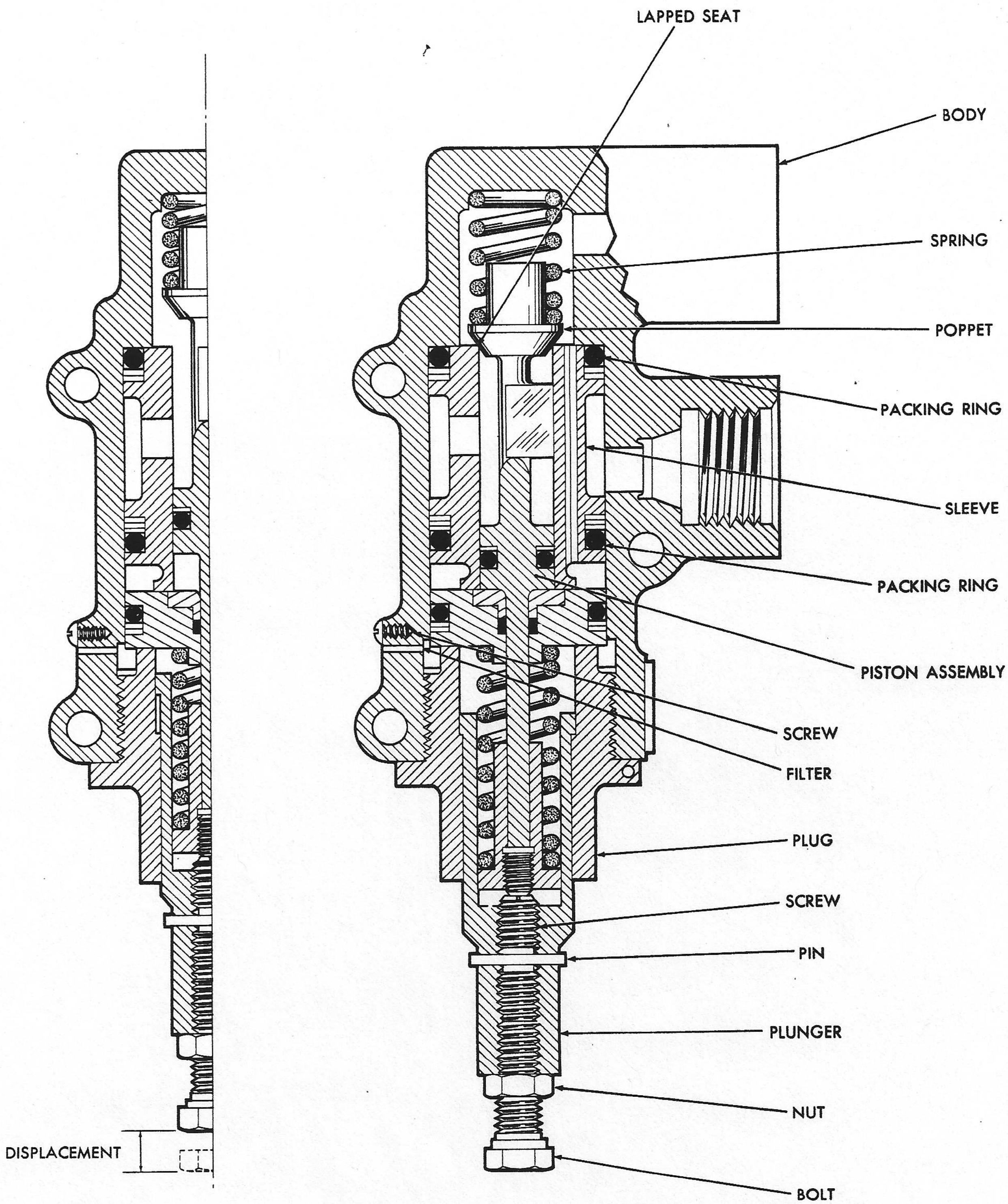

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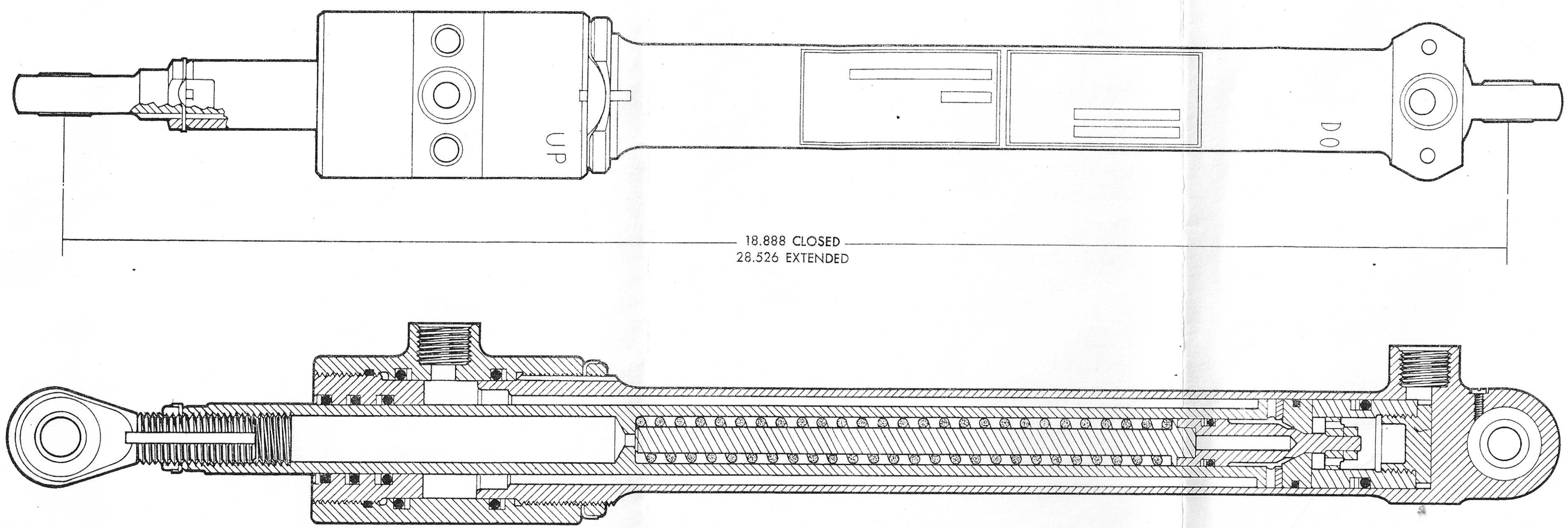
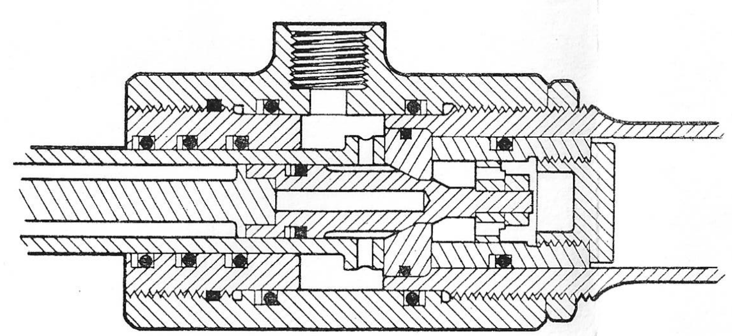
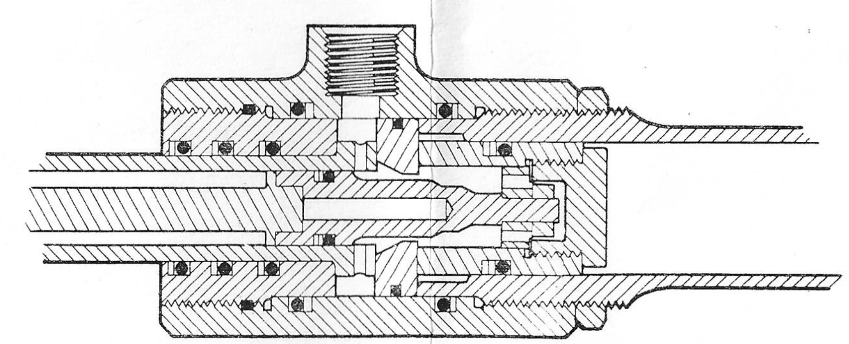
FIG. 2.10 SEQUENCE VALVE





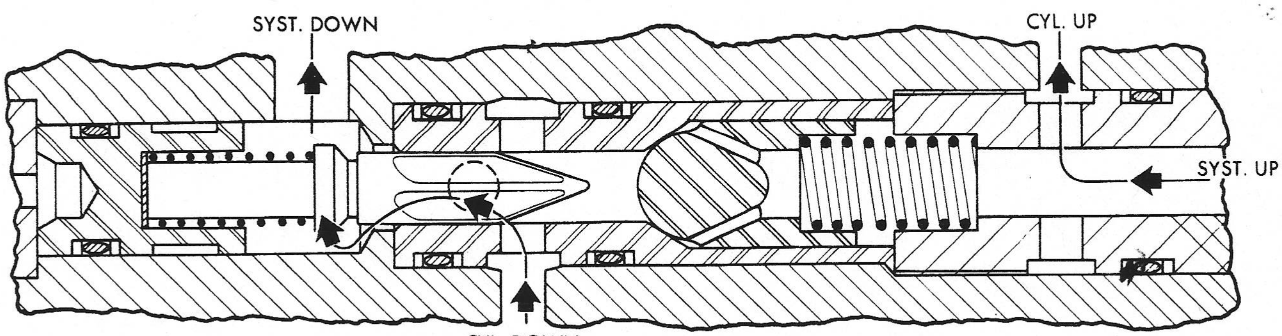
LOCKED IN BLOWBACK POSITION



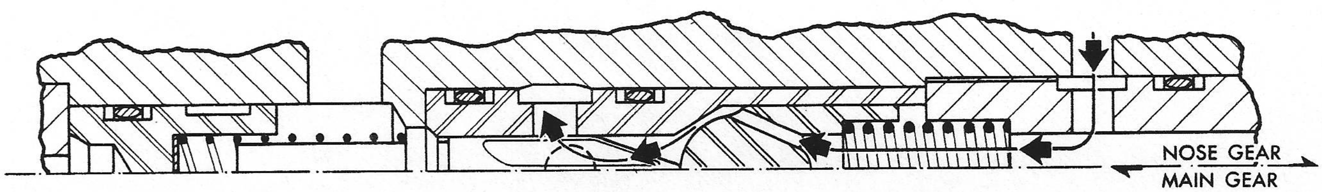
FULLY EXTENDED & LOCKED POSITION

FIG. 2.11 JACK-NOSE GEAR DOOR
WITH INTERNAL DOWNLOCK

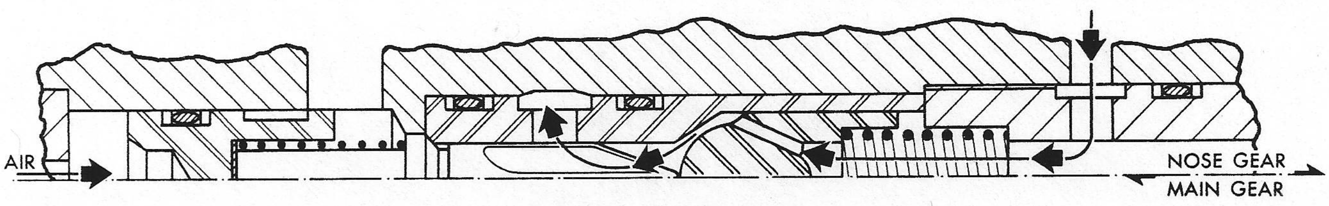
2524-104-1



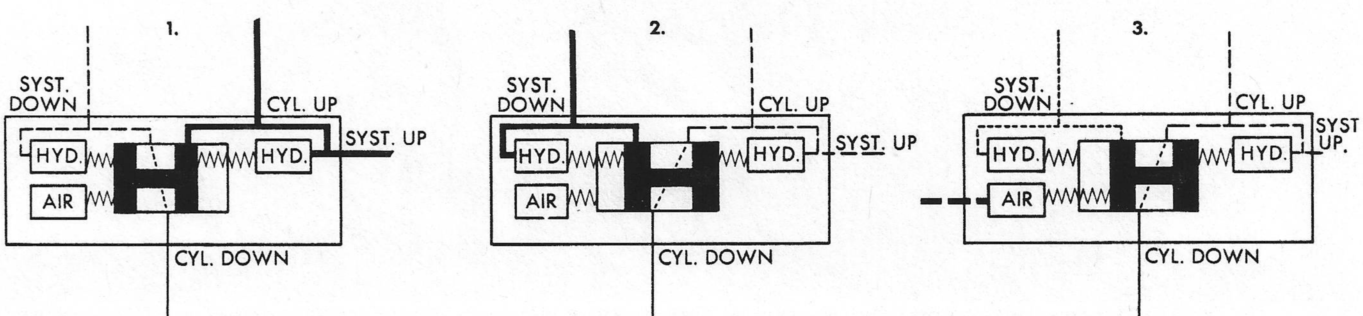
1. UP SELECTION



2. DOWN SELECTION



3. EMERGENCY DOWN



SCHEMATIC OF OPERATION

FIG. 2.12 TRANSFER VALVE

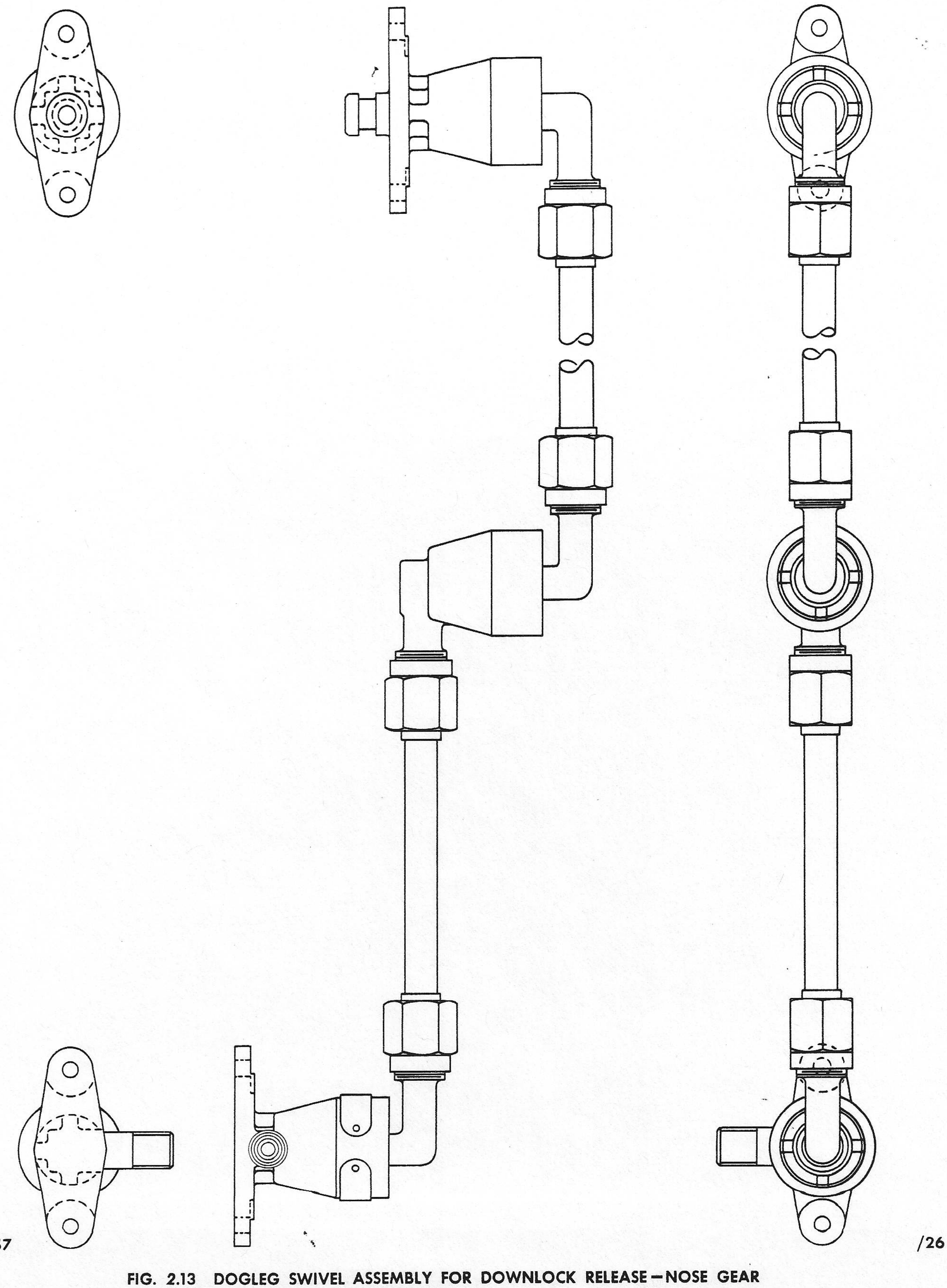


FIG. 2.13 DOGLEG SWIVEL ASSEMBLY FOR DOWNLOCK RELEASE—NOSE GEAR

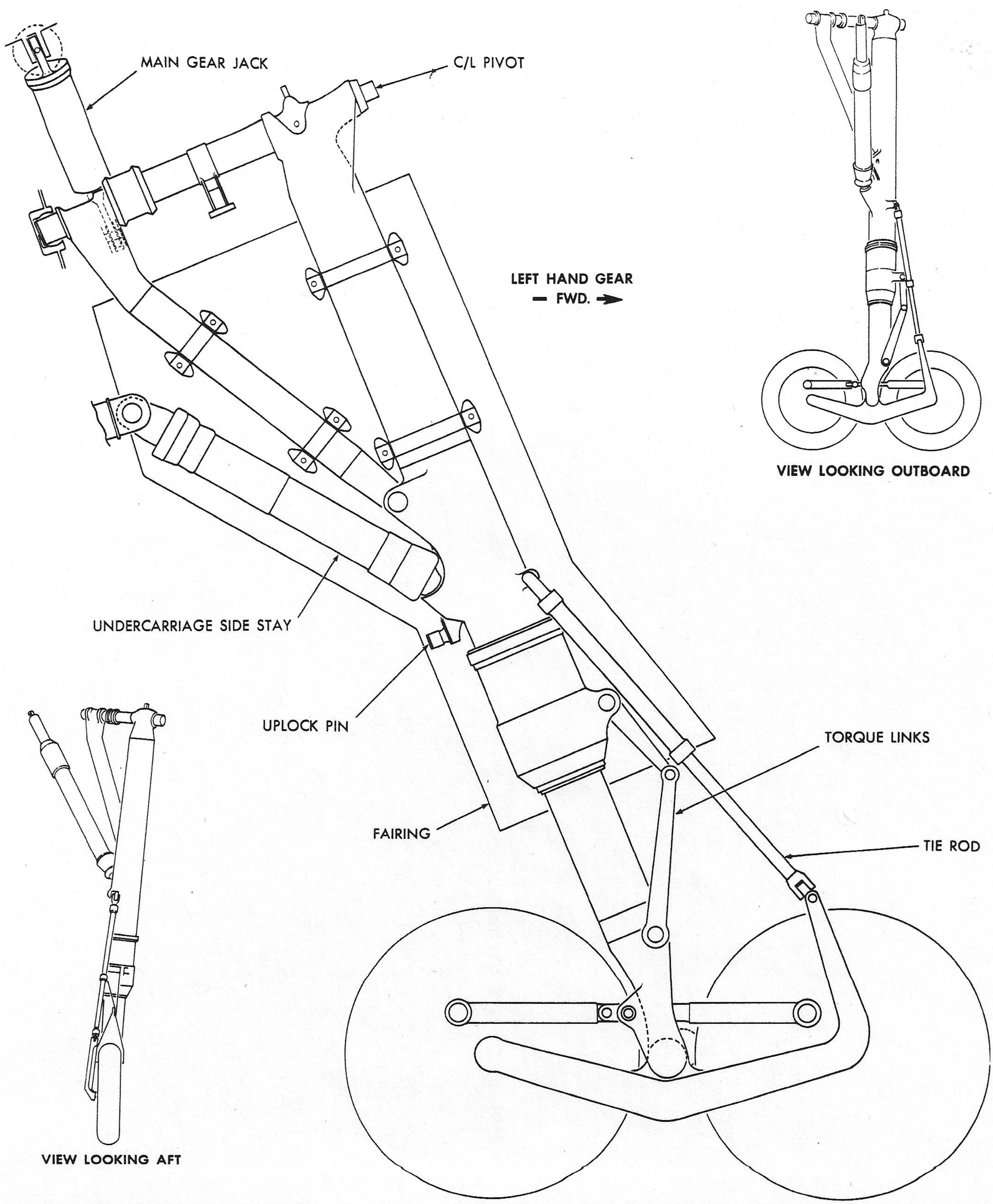


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FIG. 2.14 GENERAL ARRANGEMENT OF MAIN GEAR

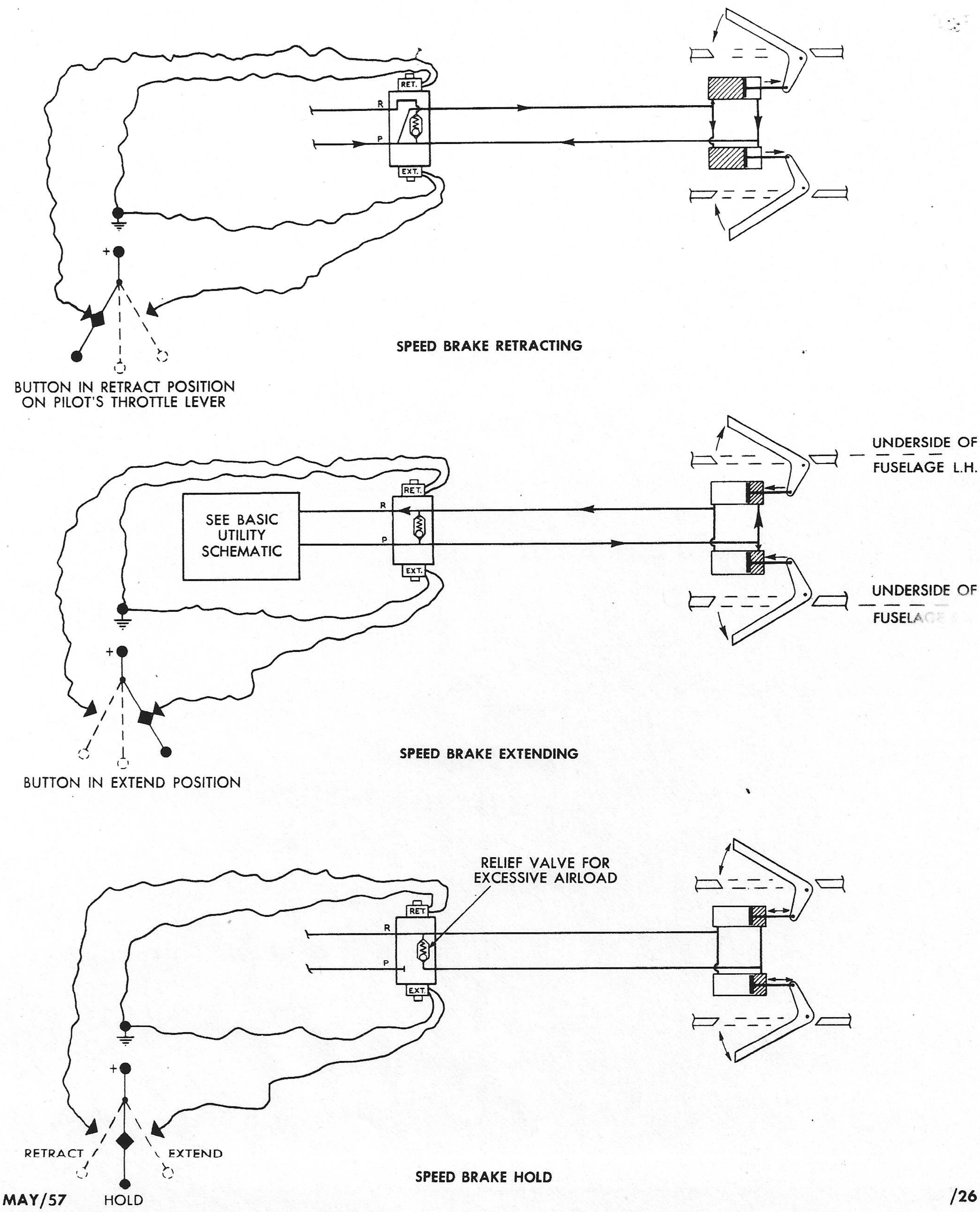

FIG. 3.1 SPEED BRAKE SCHEMATIC

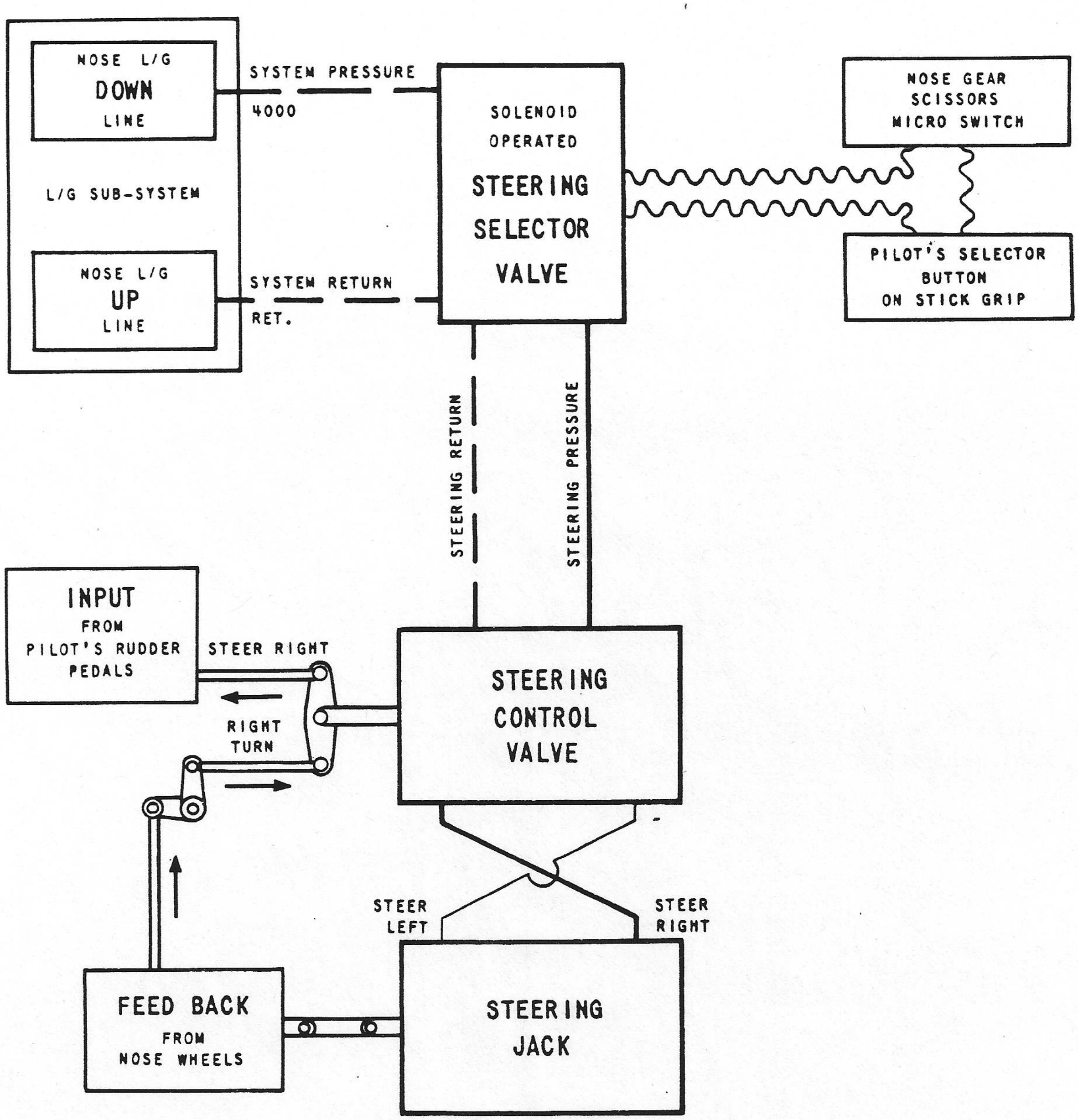

FIG. 4.1 BASIC SCHEMATIC NOSE-WHEEL STEERING

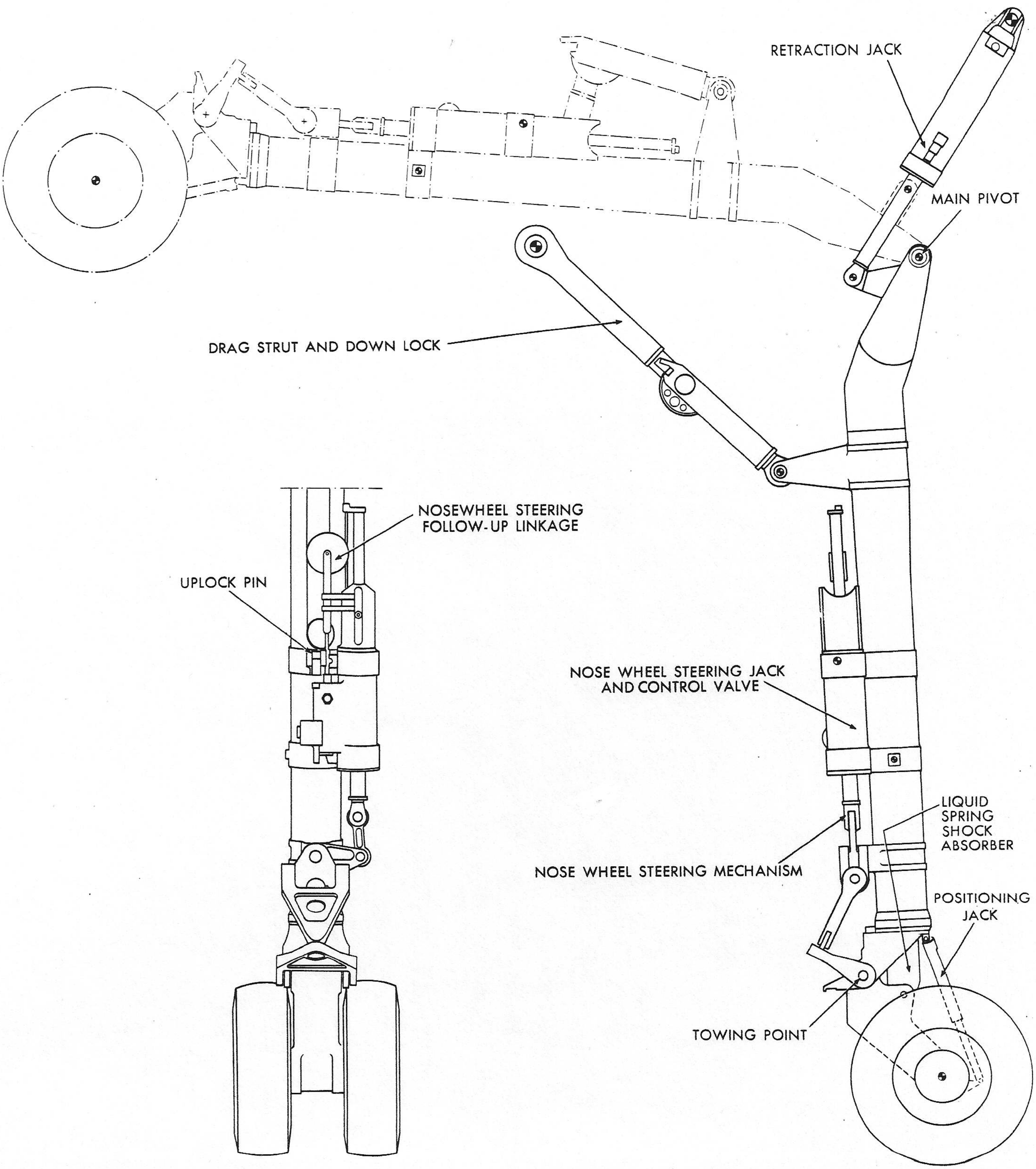

FIG. 4.2 GENERAL ARRANGEMENT OF NOSE GEAR

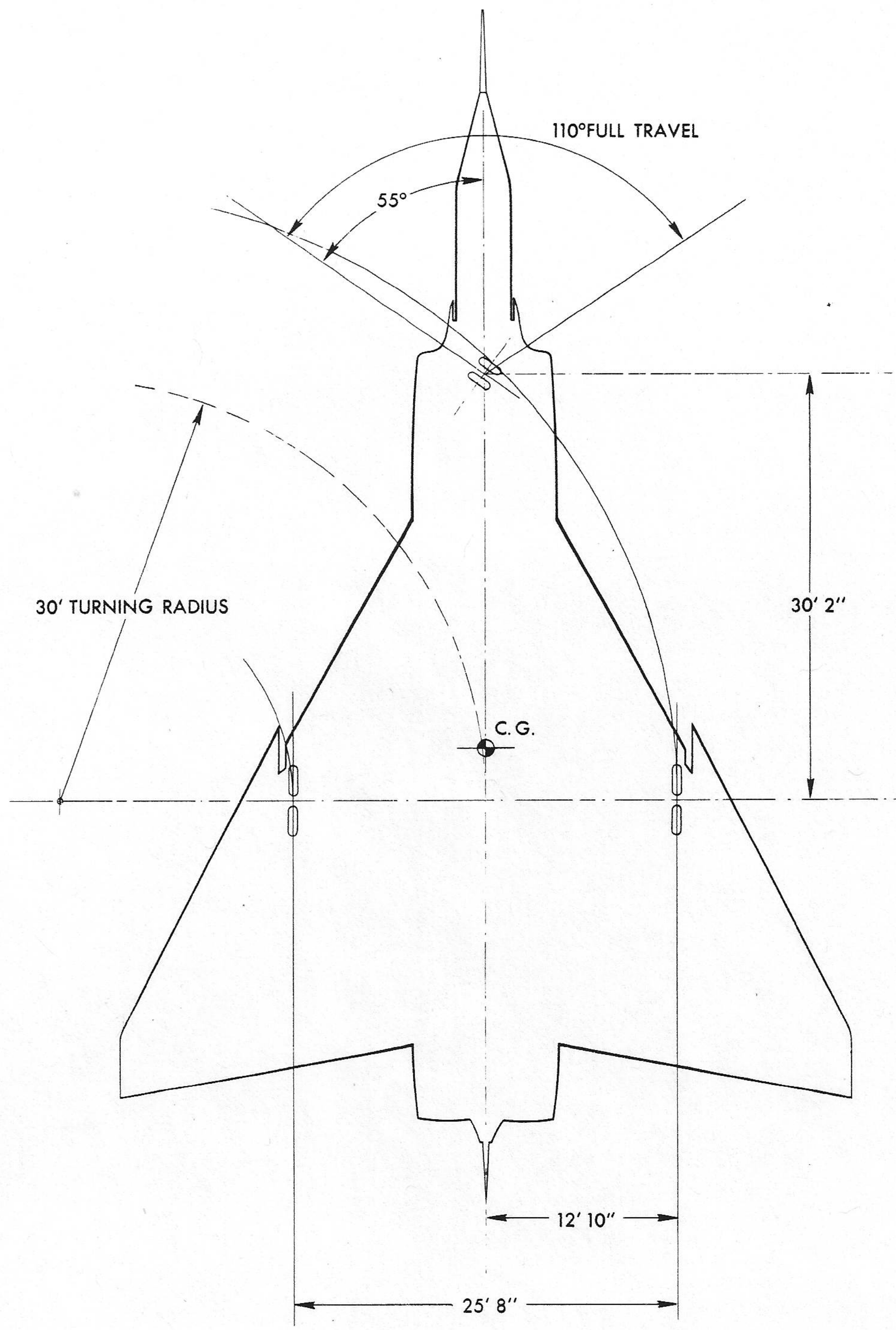

FIG. 4.3 GEOMETRY OF NOSE WHEEL STEERING

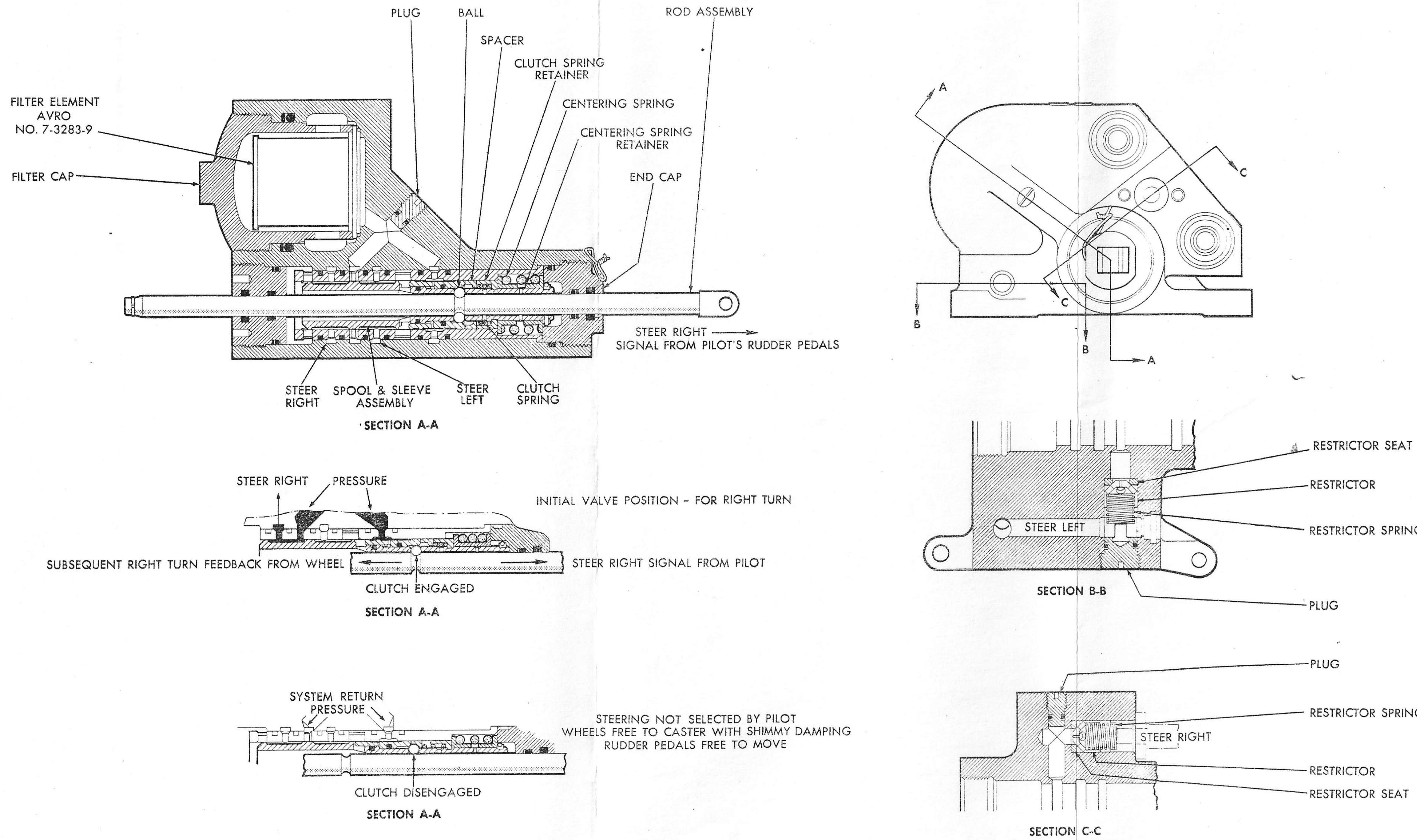

FIG. 4.4 NOSE WHEEL STEERING CONTROL VALVE

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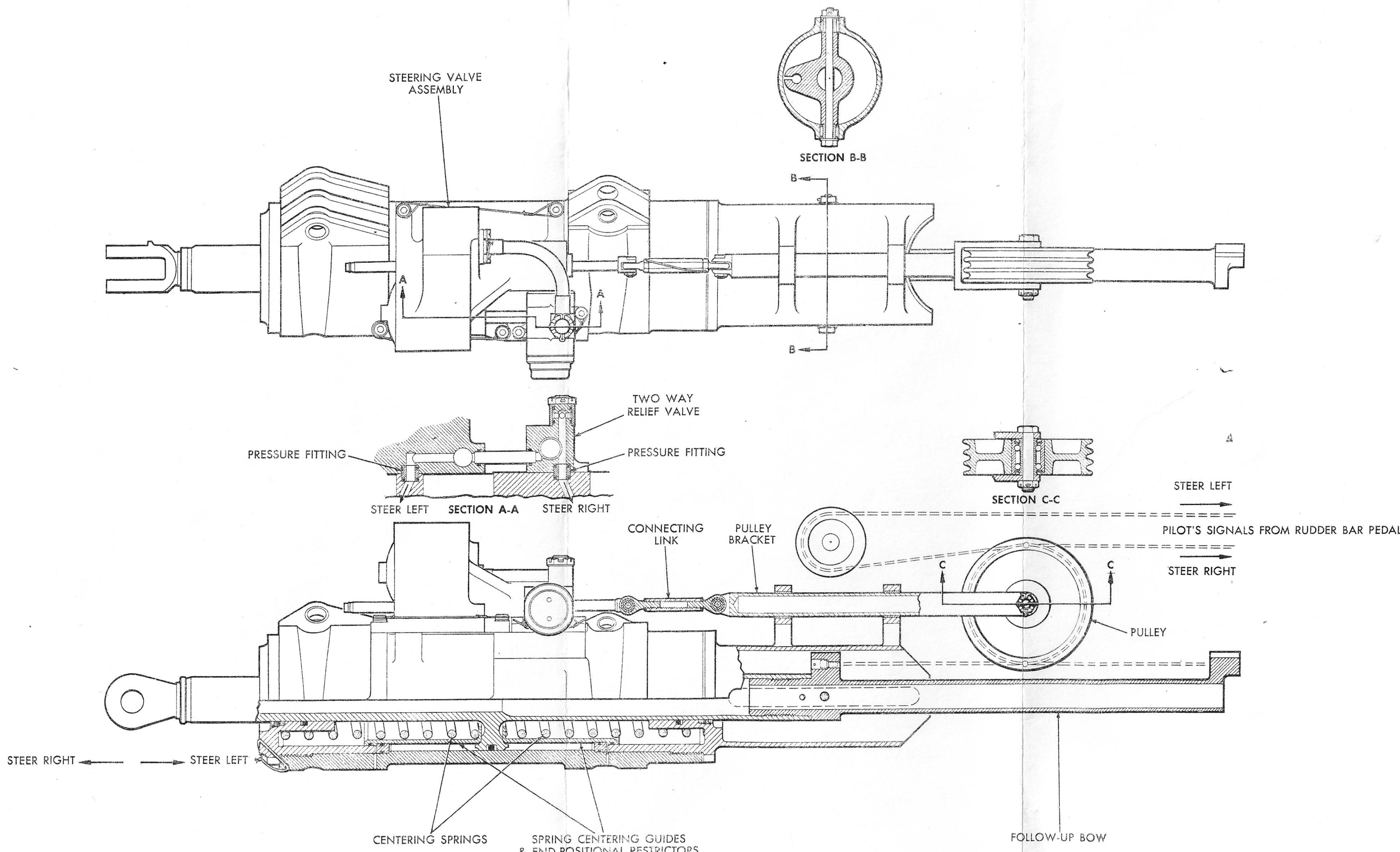

FIG. 4.5 STEERING JACK AND CONTROL VALVE