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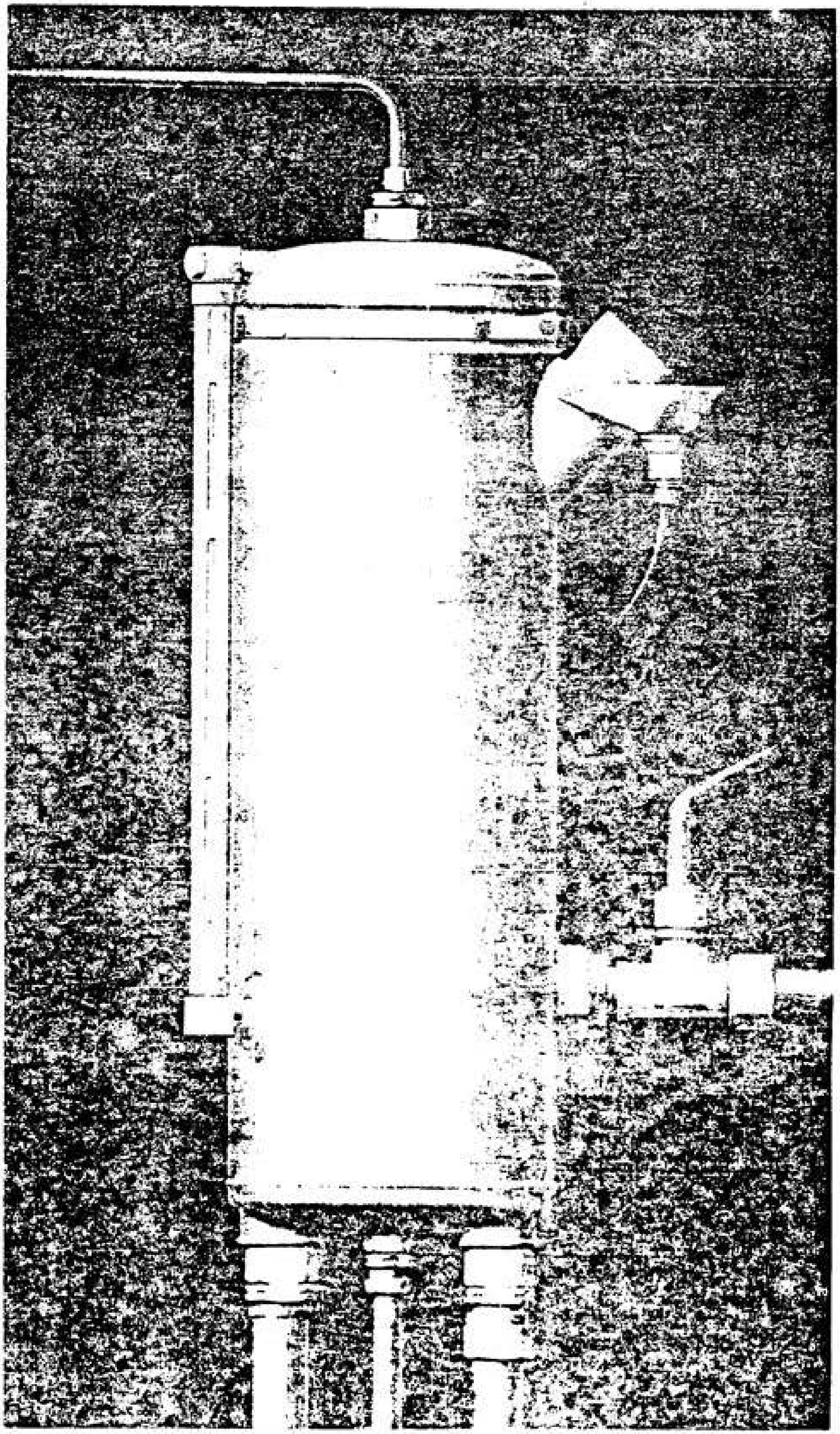
STARLIFTER TRAINING MANUAL • VOLUME V



HYDRAULIC

Customer Training Department • Lockheed - Georgia Company • Marietta, Georgia 3

STARLIFTER TRAINING MANUAL

VOLUME V

HYDRAULICS

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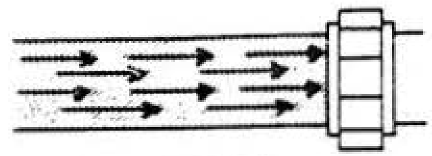
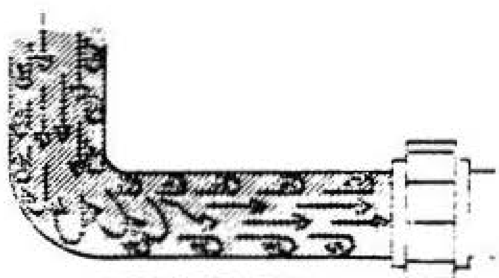
LAMINAR FLOW.

When a liquid is forced through a constant-diameter tube at low velocity, the flow is smooth and even and the fluid's particles tend to move in a parallel stream. The portion of liquid that touches the tube's walls is slowed down because of friction. This means the liquid near the center of the tube moves at a higher velocity than does the liquid near the wall of the tube. However, as long as the velocity remains low, the flow will continue smooth because of the low resistance.

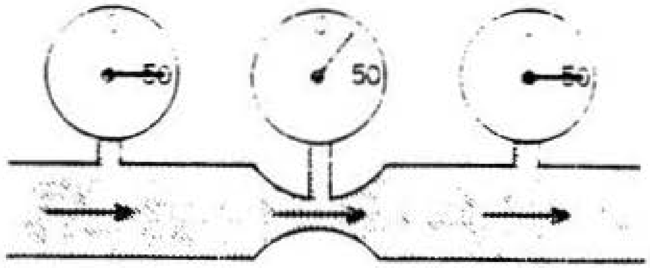

LAMINAR FLOW

TURBULENT FLOW.


TURBULENT FLOW

Resistance to a moving liquid is proportional to its velocity. When the velocity passes a critical point, the resistance increases until turbulent flow results.

The velocity of a liquid in a tube is inversely proportional to the pressure in the tube. Should the liquid pass around a bend or through an orifice or restrictor, or should the tube's diameter suddenly decrease, the pressure decreases and the volume decreases. This increased velocity, in turn, can increase the resistance until turbulent flow results.



FLUID FLOW THROUGH ORIFICE

Resistance increases can also be caused by the following:

1. An increase in the area of the tube's surface in contact with the liquid. A long tube of a given diameter will offer more resistance than a short tube of the same diameter.

2. An increase in the degree of roughness of the tube's interior surface.

3. An increase in the viscosity of the liquid.

DEFINITIONS OF HYDRAULIC TERMS.

AREA	The measure of a surface, usually given in square inches. The information is used in determining the force of an actuator or piston.
FORCE	The push or pull on an object which tends to change its motion. Force is usually measured in pounds. In hydraulics, force is computed from pressure pushing against the area of a piston.
UNIT PRESSURE	The amount of force on a unit area, usually one square inch. Unit pressure is usually abbreviated PSI (pounds per square inch), or LBS/IN^2.
STROKE (LENGTH)	A measurement of distance, usually expressed in inches. It represents the distance a piston moves in a cylinder.
EXPANSION AND CONTRACTION	In general, liquids expand when they are heated. They contract when they are cooled. If a liquid is confined so that it cannot escape when it is heated, pressure on the walls of the container increases. If the liquid is cooled, under the same conditions, the pressure decreases. This is defined as thermal expansion and contraction.

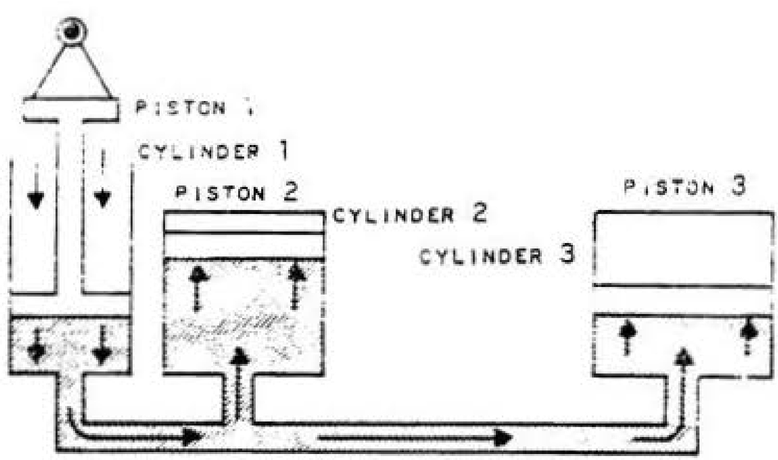
VOLUME (DISPLACEMENT)	A measure of quantity or amount. Volume is usually expressed in terms of cubic inches and abbreviated IN^3. The volume represents the amount of fluid in a reservoir. It also can represent the amount of fluid displaced or pushed by a pump or piston in a cylinder.
VISCOSITY	The property which causes a liquid to resist a change in shape and flow.

PASCAL'S LAW.

Pascal's law states:

> When a force is applied to a confined body of fluid, the resultant pressure is transmitted equally and undiminished in all directions.

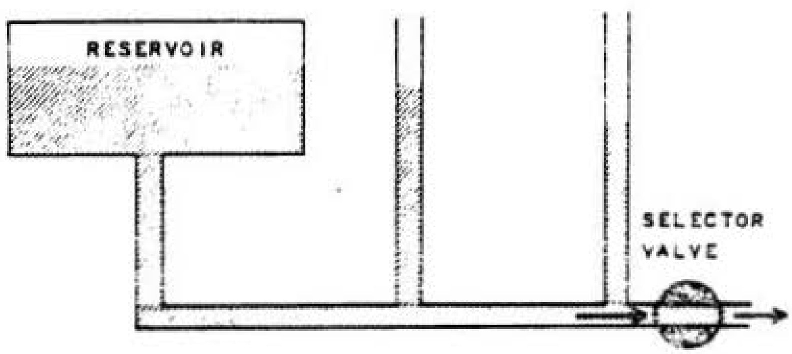
In hydraulics, Pascal's law applies to liquids that are confined and are not moving.



KINETIC ENERGY LOSS
(CONFINED LIQUID)

Consider the illustration. When a force is put on the piston on the left, the pressure is uniformly transmitted throughout the entire system. This pressure is applied to the walls of the cylinders and tubes. This is true, however, only so long as pistons 2 and 3 do not move. If they do move, the result is a difference in pressure. Liquid then flows from cylinder 1 to cylinder 2. Pascal's law does not apply. But when pistons 2 and 3 stop moving, the liquid stops flowing, the pressure equalizes, and Pascal's law again applies.

As liquid flows through a tube, the pressure decreases if the length of the tube is increased. In the next illustration, assume that the level in the two tubes is the same when there is no flow. As soon as the selector valve is opened, the liquid moves. The level of the liquid in the tube farthest from the reservoir decreases more than the fluid level of the tube nearest the reservoir.



KINETIC ENERGY LOSS
(UNCONFINED LIQUID)

RELATIONSHIP OF FORCE, AREA, AND PRESSURE.

The terms "force," "area," and "pressure" have a definite mathematical relationship. The relationship of the factors may be expressed as follows: force equals the area in square inches times the pressure in pounds per square inch. Stated another way,

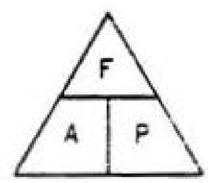
$$\text{Force} = \text{Area} \times \text{Pressure}$$

or

$$\text{Area} = \frac{\text{Force}}{\text{Pressure}}$$

or

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$



RELATIONSHIP OF FORCE, AREA, AND PRESSURE

This formula is usually found in a triangular form. Whenever any two factors are known, the third can be calculated.

EXAMPLE 1: The area of a piston is 3 IN.^{2} (square inches). Pressure is 50 PSI (pounds per square inch). What force can the cylinder produce?

ANSWER: The formula says that the force is equal to the area times the pressure:

$$\text{Force} = \text{Area} \times \text{Pressure}$$

Since the area is 3 IN.^{2}, and the pressure is 50 PSI,

$$\text{Force} = 3 \times 50$$

or

$$\text{Force} = 150 \text{ LBS}$$

EXAMPLE 2: The force of a piston is 200 LBS. The area of the piston is 4 IN.^{2}. What is the pressure?

ANSWER: In this case, the pressure is found by dividing the force by the area:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Since the force is 200 LBS, and the area is 4 IN.^{2},

$$\text{Pressure} = \frac{200}{4}$$

or

$$\text{Pressure} = 50 \text{ PSI}$$

EXAMPLE 3: The pressure in a cylinder is 3,000 PSI. The force is 9,000 LBS. What is the area of the piston?

ANSWER: The formula says that the force divided by the pressure gives the area.

$$\text{Area} = \frac{\text{Force}}{\text{Pressure}}$$

Since the force is 9,000 LBS, and the pressure is 3,000 PSI,

$$\text{Area} = \frac{\text{Force}}{\text{Pressure}}$$

Since the force is 9,000 LBS, and the pressure is 3,000 PSI,

$$\text{Area} = \frac{9,000}{3,000}$$

or

$$\text{Area} = 3 \text{ IN.}^2$$

These relationships must be understood to learn the function of a hydraulic system. A hydraulic pump must supply enough liquid under pressure to operate actuators. The actuators must be made to supply the force needed to move aircraft components such as flaps and landing gear.

There is another formula in hydraulics that must be understood. This formula concerns the relationship between volume, area, and length. <u>The volume is equal to the area times the length.</u> Stated another way,

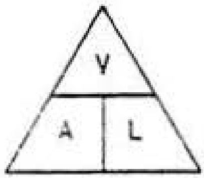
$$\text{Volume} = \text{Area} \times \text{Length}$$

or

$$\text{Area} = \frac{\text{Volume}}{\text{Length}}$$

or

$$\text{Length} = \frac{\text{Volume}}{\text{Area}}$$



RELATIONSHIP OF VOLUME, AREA, AND LENGTH

This relationship can also be placed in triangular form. If two are known the third can be calculated.

EXAMPLE: If the area of a piston is 2 $IN.^2$ and its length of travel if 5 IN., what volume is displaced?

ANSWER: The formula says that the volume equals the area times the length.

$$\text{Volume} = \text{Area} \times \text{Length}$$

Since the area is 2 $IN.^2$ and the length is 5 IN.,

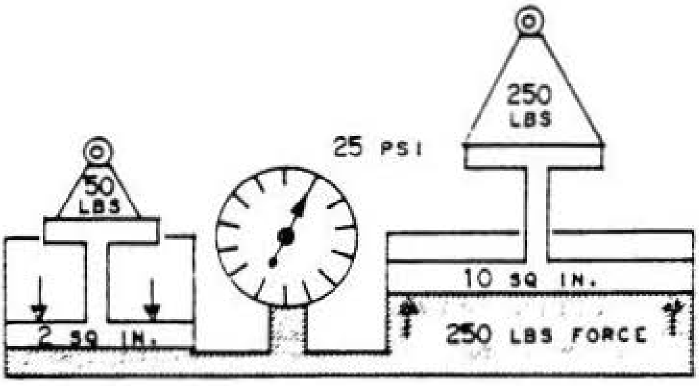
$$\text{Volume} = 2 \times 5$$

$$\text{Volume} = 10 \text{ Cubic Inches}$$

In like manner, the area or length can be found by using this formula.

MECHANICAL ADVANTAGE (MA).

One of the most important tools the design engineer can use is mechanical advantage. Mechanical advantage lets him accurately determine the size of actuating cylinders and pistons and the distance the pistons must move to operate a mechanism. Why is unit size so important in designing a hydraulic system? It is important because space in an airplane is limited. Operating units must be designed to be as strong as necessary but as small and light in weight as possible.



MECHANICAL ADVANTAGE

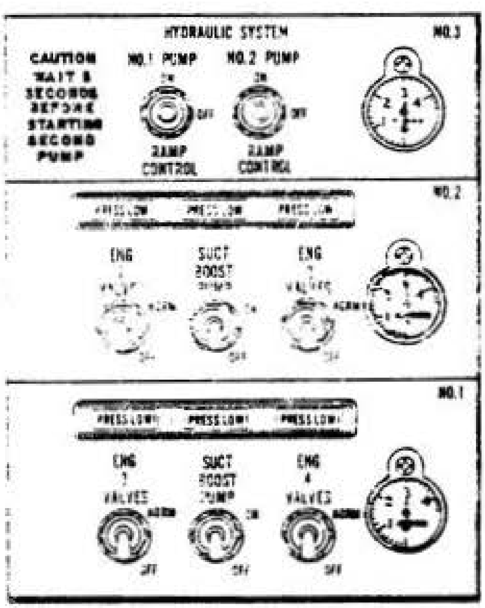
When the 50-pound weight rests on the small piston that has an area of 2 square inches, the fluid pressure becomes 25 PSI. This is found by dividing the weight, or force, by the area. The 25-PSI pressure shows in the gage. When this pressure acts through the hydraulic fluid on the 10-square-inch area of the piston, which is under the 250-pound weight, the weight is supported.

This gain in force (from 50 pounds to 250 pounds) is done by increasing area only and not fluid pressure. It shows the idea of mechanical advantage which is used in many hydraulic devices. Mechanical advantage (MA) is expressed as a ratio. In the above illustration, it is five to one or 5:1. In hydraulics, mechanical advantage can be explained as the ratio between two pistons with regard to the following factors: area, force, and stroke (distance traveled).

The mechanical advantage ratio serves as a useful shortcut in hydraulics. Suppose an 800-pound weight must be raised by using a 40-pound force on there is a 1,200-PSI system provided for emergency extension of the nose landing gear. This system is designated as hydraulic system No. 4 and is pressurized by a hand pump.

HYDRAULIC SYSTEM NO. 1.

Hydraulic system No. 1 is powered by two variable-volume hydraulic pumps connected in parallel and driven by engines No. 3 and No. 4. The only functions of system No. 1 are to supply hydraulic power to one of the two aileron actuating cylinders in each wing, to one of the two rudder actuating cylinders, and to one of the three elevator actuating cylinders. The reservoir and a majority of the components of this system are located in a service center which is located on the right side of the cargo compartment. Ground test connections are provided in the forward end of the right wheel well so that a hydraulic test stand may be connected for ground testing the flight controls.

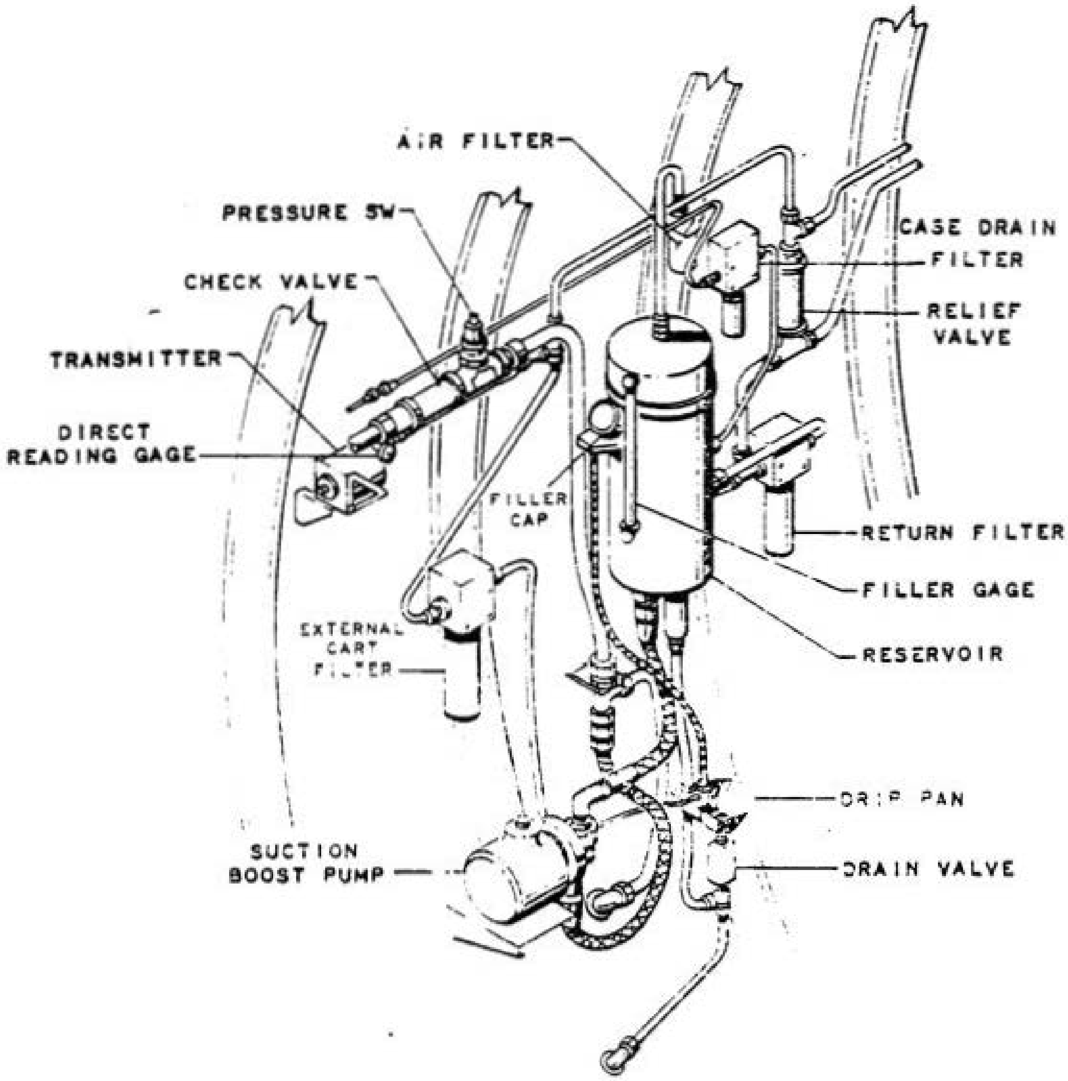


HYDRAULIC SYSTEMS CONTROL PANEL

The hydraulic systems control panel is located in the lower left corner of the flight engineer's panel. This panel is divided into three sections, one section for each 3,000-PSI power system. Control and indication components for hydraulic system No. 1 are located on the lower section of the panel. These components are two engine valves switches, one suction boost pump switch, three low-pressure warning lights, and a pressure indicator. The indicator dial is graduated in increments of [illegible] PSI from 0 to 4,000 PSI.

No. 1 system's reservoir contains approximately 2.4 gallons of fluid when properly serviced. All reservoirs in the airplane are of the nonpressurized type and can be serviced at any time during flight or ground operation. A sight gauge and index marks on the reservoir are provided to allow proper servicing. The reservoir is vented to the cargo compartment through a vent line and air filter.

A suction boost pump is mounted below and slightly forward of the reservoir to provide an adequate supply of hydraulic fluid to the No. 3 and No. 4 engine-driven pumps. This centrifugal pump is driven by an A-C motor and is controlled by a

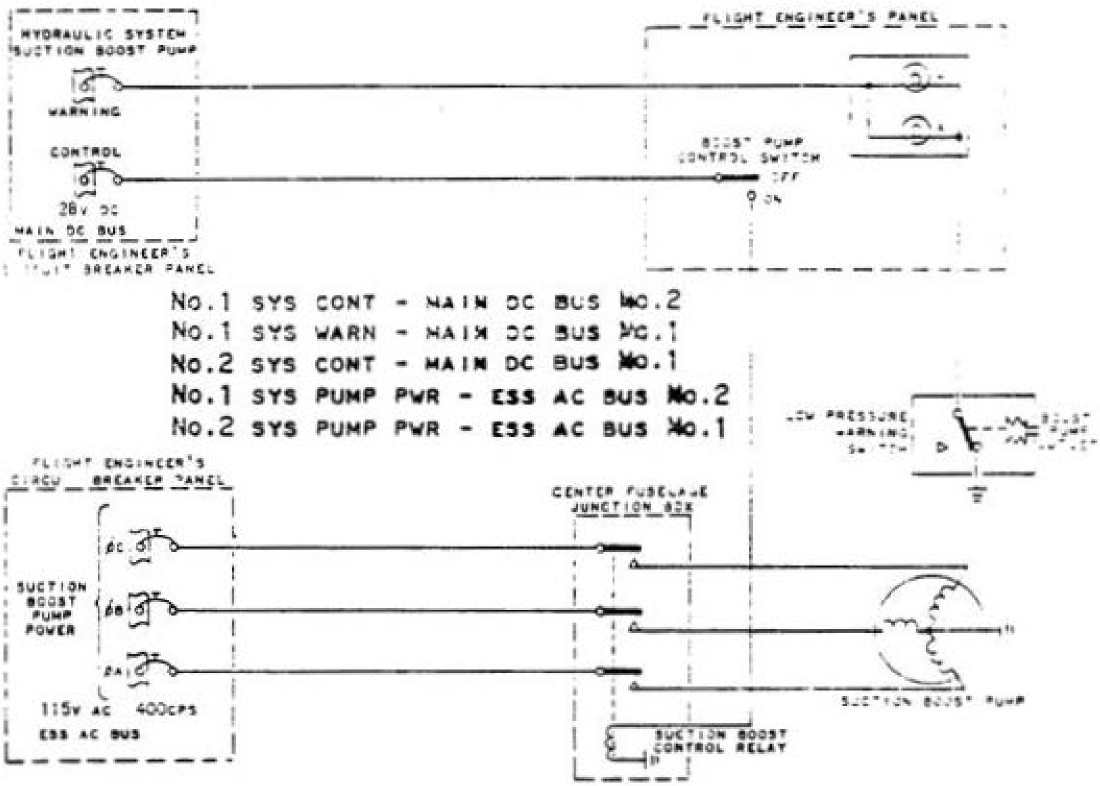


HYDRAULIC SYSTEM SERVICE CENTER NO.1

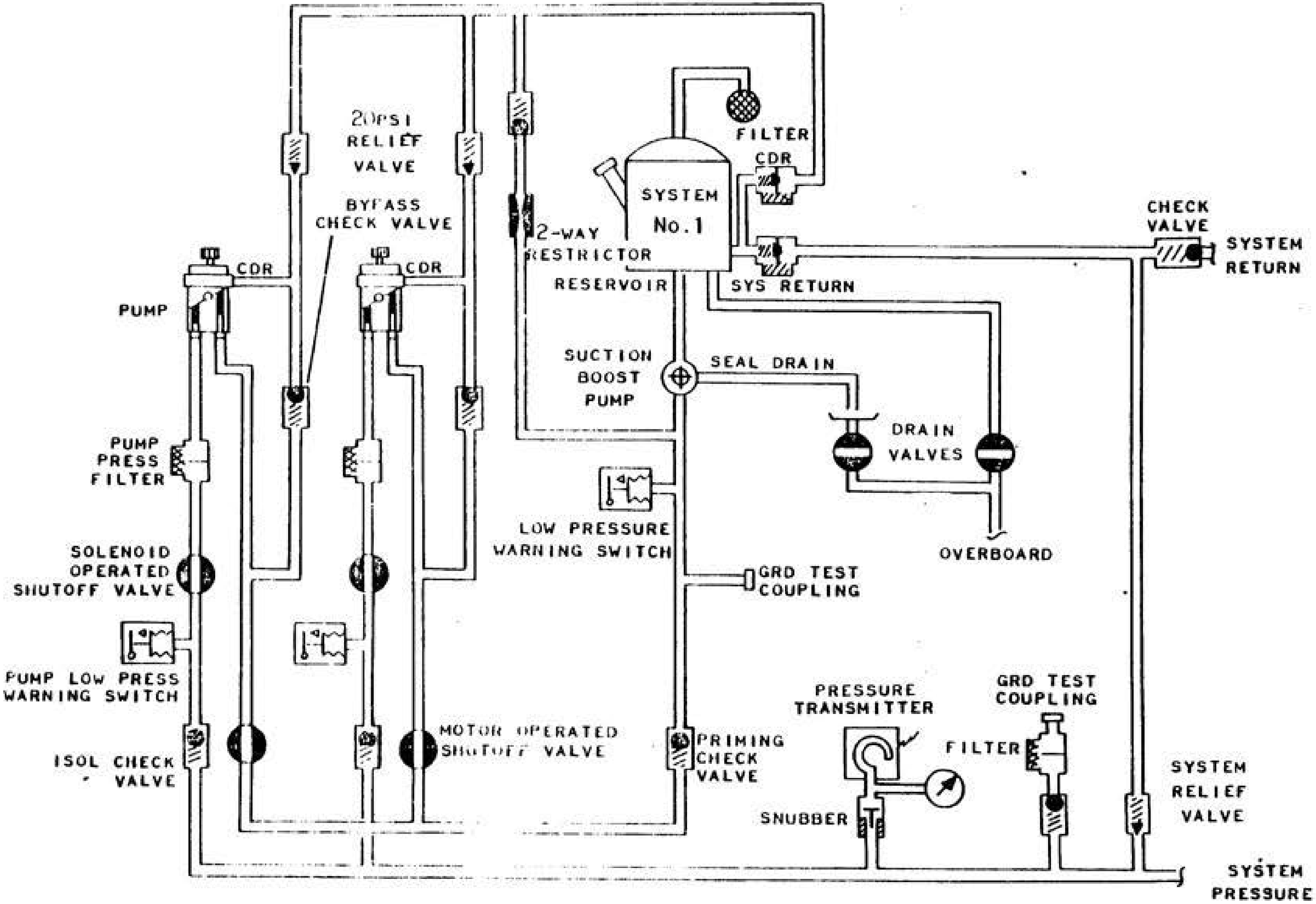
switch on the flight engineer's panel. The suction boost pump is capable of delivering 0 to 19.2 gallons-per-minute flow at pressures between 70 and 110 PSI. Adequate cooling of the boost pump is ensured by a bypass line routed from the pump's outlet port to the reservoir. Flow to the reservoir is controlled by a restrictor. To help prevent a possible failure of the engine-driven pumps, the suction boost pump should be turned on prior to engine start and cut off only after the completion of the engine run.

Discharge pressure of the suction boost pump is sensed by a low pressure warning switch located above the pump. This switch is adjusted to illuminate an amber warning light on the hydraulic systems control panel when pump discharge pressure is less than 20 PSI. The light will extinguish and stay extinguished when the pressure is above 30 PSI.

A one-way check valve located in the supply line downstream of the low-pressure warning switch, prevents flow back into the reservoir when the suction boost pump is turned off. This check valve, which is commonly referred to as the priming check valve, holds a prime or head of hydraulic fluid to the engine pumps.



SUCTION BOOST PUMP ELECTRICAL SCHEMATIC



NO.1 POWER SECTION HYDRAULIC SCHEMATIC

At this point the supply line leaves the service center and is routed through the leading edge of the right wing. Because the components for No. 3 and No. 4 engines are identical in function and operation, only those for one engine will be discussed.

Six hydraulic components for each engine-driven pump are located in the leading edge of the wing directly aft of the engines. These components are:

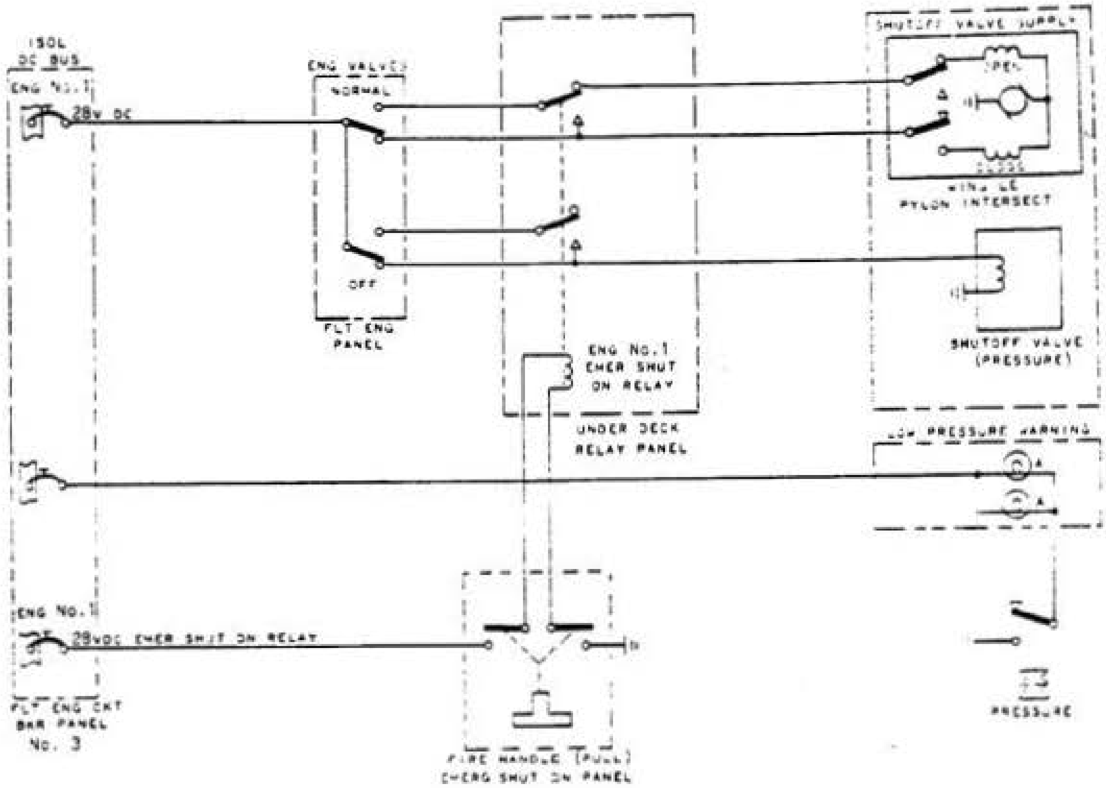
1. Supply shutoff valve
2. Pressure shutoff valve
3. Low-pressure warning switch
4. Isolation check valve
5. 20-PSI relief valve
6. Bypass check valve

All of the components, except the isolation check valves, are located aft of their associated engine. Both of the isolation check valves are located aft of No. 4 engine.

The supply shutoff valve is a motor-operated, gate-type valve which in normal use requires 28-volts DC to drive it open or closed. This valve can be operated in three ways to control supply fluid to the engine-driven pumps. Normally the flight engineer controls the valve electrically with the engine valves switch which is located on the hydraulic systems control panel. In case of an engine fire or failure, the pilot can pull the FIRE EMERGENCY handle which closes the valve electrically. Maintenance personnel can open or close the valve by positioning the valve's manual-override lever when electrical power is off.

The pressure shutoff valve is a solenoid-actuated valve that is spring loaded to the open position and is closed when 28-volt D-C electrical power is applied to the solenoid. When the valve is closed, output of the engine-driven pump is blocked by the valve. Actuation of this valve is simultaneous with the actuation of the supply shutoff valve since both are controlled by the same engine valves switch and by the same FIRE EMERGENCY handle.

Outlet pressure from the engine-driven pump is sensed by a low-pressure warning switch installed downstream of the pressure shutoff valve. This switch is adjusted to make and break the electrical circuit to its associated PRESS LOW light, located on the hydraulic control panel, at 1,350 (± 150) PSI. When the pump pressure decreases to 1,200 PSI, the amber light will be illuminated. As the pump pressure increases to 1,500 PSI, the amber light will be extinguished.



ENGINE PUMP SHUTOFF AND WARNING ELECTRICAL SCHEMATIC

The isolation check valve is a one-way check valve located in the pressure line downstream of the low-pressure warning switch. This valve serves two purposes, to prevent reverse flow through an inoperative pump and to prevent the pressure from one engine pump from actuating the low-pressure warning switch of the other engine pump in its system.

The two remaining components ensure proper cooling and lubrication for the engine-driven pumps under all operating conditions. A 20-PSI relief valve is installed in the case drain line of the engine pump. When the engine is running and the engine valves switch is in the "NORM" position, case drain flow will be directed back to the reservoir through the 20-PSI relief valve. When the engine is running and the engine valves switch is in the "OFF" position, the 20-PSI relief valve will close. Case drain flow will then be directed to the depressurized supply line of the engine pump through the bypass line and bypass check valve. This run-around action prevents pump cavitation. The bypass check valve, which is a one-way check valve, also prevents the suction boost pump output from bypassing the engine-driven pump when the boost pump is operating and the supply shutoff valve is open.

An engine-driven pump is mounted on the accessory gearboxes of No. 3 and No. 4 engines. Each pump is a nine-piston, variable-volume unit that supplies flow to and controls pressure within the No. 1 hydraulic system. These pumps are connected in parallel so a single pressure-line source supplies fluid to all subsystems.

Flow capacities for one engine-driven pump, based on 90-percent volumetric efficiency, are:

ENGINE POWER	FLOW IN GPM
Take-off	23.5
Cruise	21
Idle	12.3

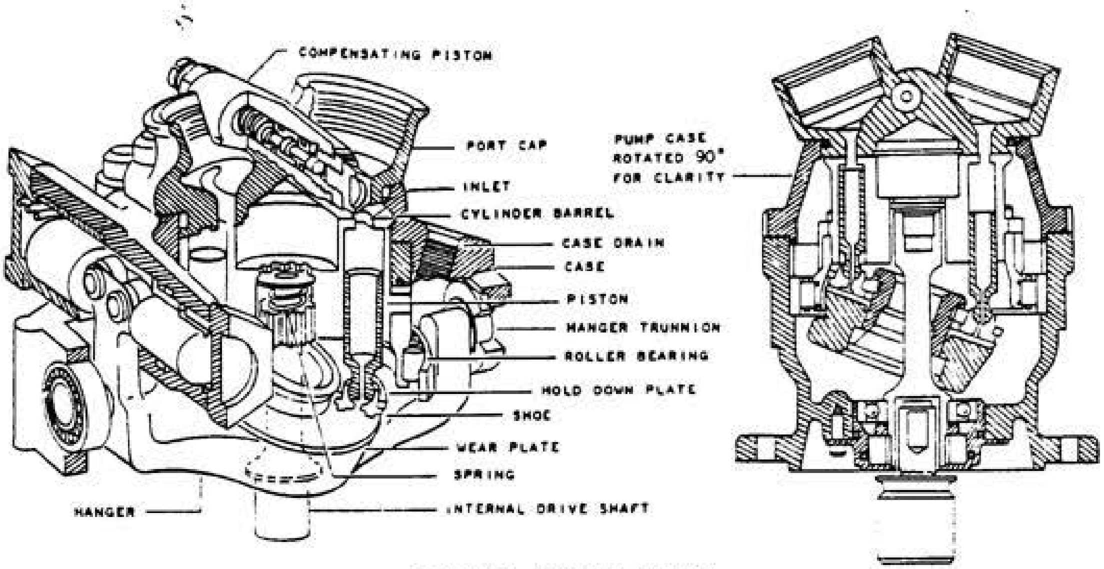
Pump displacement begins to decrease rapidly at 2,800 PSI and continues to decrease until a system operating pressure of 3,000 PSI is reached. At 3,000 PSI, the pump displacement is zero.

The heart of the pump is a revolving cylinder barrel containing nine pistons with bronze shoes. All of the piston shoes contact a variable-angle wear plate. As the pump's drive shaft turns the cylinder barrel, the pistons are forced to reciprocate when the wear plate is tilted. A hold-down plate, engaging the enlarged base of the piston shoes, ensures a positive return of each piston during the intake stroke

Varying the angle of the wear plate changes the displacement of the pump. The angle can be changed by moving a trunnion-mounted hanger that has the wear plate pinned to it. Hanger movement is controlled by the pressure compensator which regulates volume delivered in accordance with system demand. By regulating the flow, a predetermined pressure can be maintained.

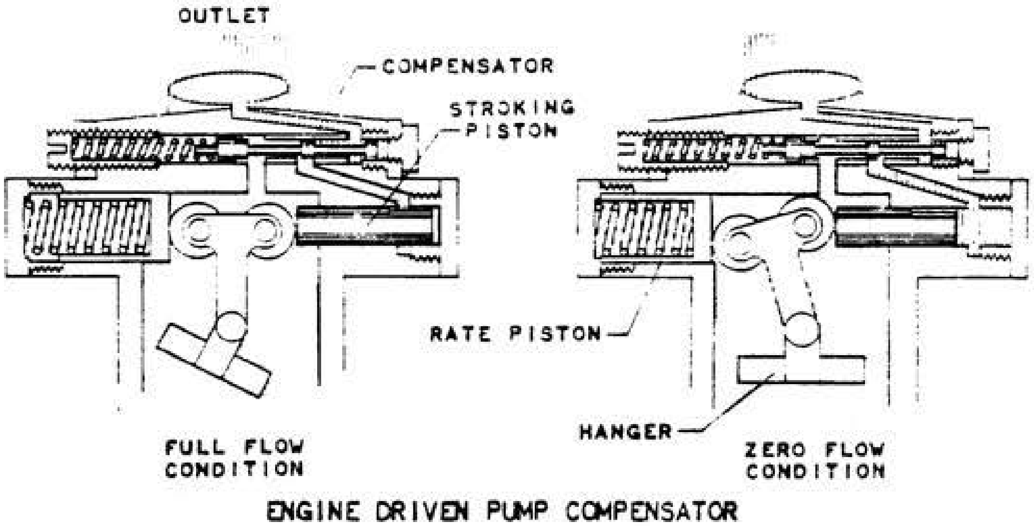
Hydraulic fluid from the supply line enters the revolving cylinder barrel as the pistons are retracting and then is discharged under pressure as the pistons are forced into their bores. System pressure is directed to the spring-loaded-closed spool of the pressure compensator. When system pressure exceeds the spring load, the spool moves and directs the fluid into a stroking cylinder. The stroking piston then moves the hanger to a smaller angle which reduces the volume delivered to maintain the desired pressure. When system pressure is less than the spring load, the stroking piston retracts and allows the hanger to move to a greater angle which increases the volume delivered.

Axial thrust of the pistons against the wear plate during the power stroke is balanced hydraulically. System-pressure fluid is admitted to an undercut area in the face of



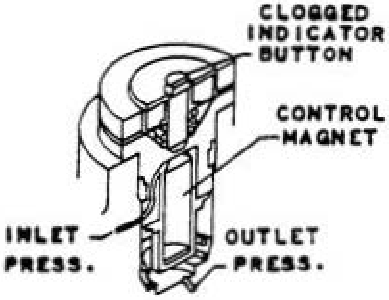
ENGINE DRIVEN PUMP

the piston shoe through a hole in each piston and piston shoe. This pressure, applied to the undercut area which is slightly less than the piston area, effectually balances the force so that the shoe is supported on a fluid film at all times. This balance is controlled to such a degree that there is no excessive leakage and high volumetric efficiency is maintained. The axial thrust of the cylinder barrel is also balanced against the port plate hydraulically. These features eliminate the need for anti-thrust plates or bearings.



ENGINE DRIVEN PUMP COMPENSATOR

Only one other item, exclusive of plumbing and fittings, is located on the engines. A high-pressure filter is installed downstream of the engine-driven pumps on the right side of each engine. All of the hydraulic filter elements in the airplane are made from corrosion resistant steel, and filter to 25 microns absolute and 10 microns (0.00039) nominal. Also, all in-line hydraulic filters incorporate an anti-cavitation check valve which seats only when the filter bowl is removed. As an aid to determine the condition of the filter element, a clogged indicator button is incorporated in the filter housing.



DETAILED VIEW

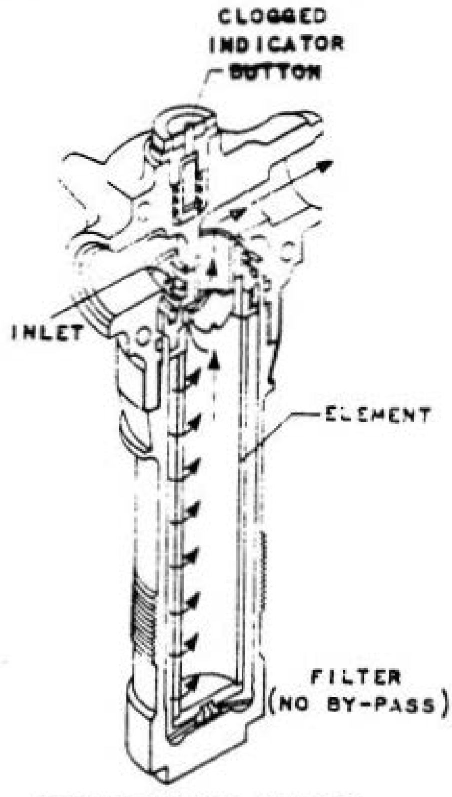
CLOGGED INDICATOR BUTTON

The clogged indicator button, painted red, is controlled by the difference between inlet and outlet pressure of the filter being felt on a control magnet. As the filter becomes contaminated, the outlet pressure will drop accordingly. Inlet pressure is felt on the top of the control magnet, and outlet pressure is felt on the base of the control magnet. When inlet pressure is approximately 70 PSI above outlet pressure (70 PSID), the control magnet moves down and loses its magnetic hold on the button's magnet. A spring will then move the clogged indicator button into view above the filter body. Because the filter does not have a bypass feature, the element must be removed and cleaned as soon as possible. After cleaning the element, the indicator button will have to be reset manually.

Pressure lines from both engine-driven pumps terminate at a common pressure line in the wing leading edge directly aft of No. 4 engine. From this point, the pressure line is routed aft through the engine pylon and then into the cargo compartment by way of the wing trailing edge. All of the remaining components for this power system are located at the No. 1 service center. These components are:

1. Snubber and direct-reading indicator
2. Pressure transmitter
3. System relief valve
4. Filters

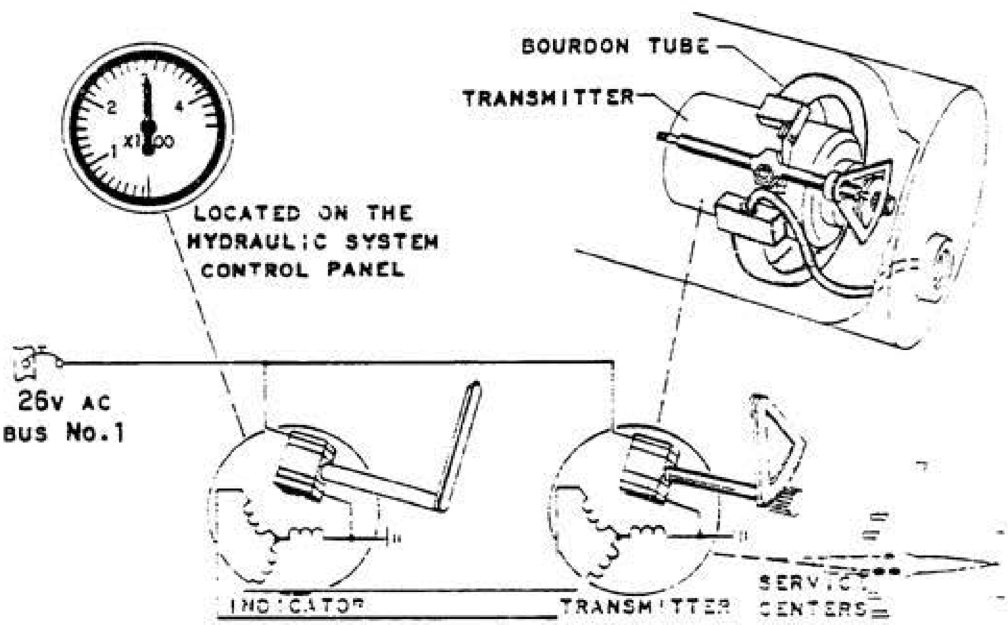
A snubber and a direct-reading indicator are installed just upstream of each pressure transmitter for the



HYDRAULIC OIL FILTER

three hydraulic systems. The snubber acts as a surge damper to prevent erratic indication and possible damage to the indicator and transmitter. The indicator dial is graduated in increments of 1,000 PSI from 0 to 4,000 PSI.

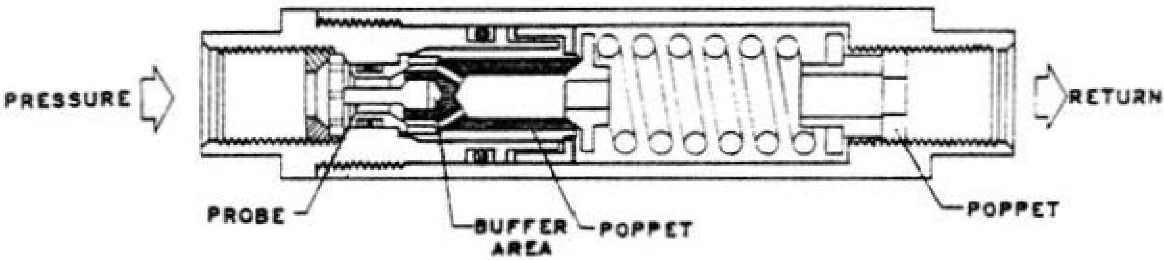
Signals from the pressure transmitter are sent to the pressure indicator which is located on the hydraulic systems control panel. The transmitter consists of a Bourdon tube mechanically linked to the rotor of an A-C synchro. The indicator consists of another A-C synchro with its rotor attached to the pointer of the indicator. Both synchros have their stators and rotors connected in parallel, and both rotors are excited by 26 volts AC.



HYDRAULIC PRESSURE INDICATION

As pressure is increased, the Bourdon tube will straighten until the difference in hydraulic force is balanced by the elastic resistance of the tube's material. These movements displace the transmitter's rotor which causes a change in the voltage induced and a shift of magnetic-field strength in the legs of the stator windings. Because the transmitter and indicator stators are connected in parallel, this change will also be reflected in the stators of the indicator. The rotor of the indicator then rotates and aligns itself with the changing magnetic field of the stators. As pressure decreases, the tube will respond and seek its original position.

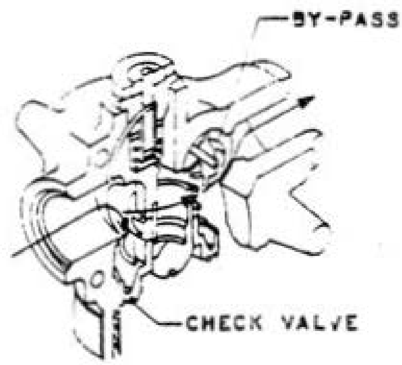
The system relief valve is provided to protect the system from excessive pressure in the event that the engine-driven pumps fail to compensate. The valve consists of a poppet set by a spring, a stationary probe, and two ports. One port of the valve is connected to the pressure line, and the other port is connected to the system return line. If system pressure reaches 3,560 PSI, the poppet will unseat and allow the output of the pumps to move through the valve back to the reservoir. After the poppet unseats, system pressure must drop to approximately 3,150 PSI before the poppet will reseat. As the poppet reseats, fluid must be forced out of the buffer area in front of the probe. This feature enables the valve to work smoothly without chattering. The valve is capable of bypassing 32 gallons-per-minute when it is fully open.



SYSTEM RELIEF VALVE

Two filters are used to filter the hydraulic fluid returned to the reservoir. One filter is installed in the system return line, and the other filter is installed in the engine-pump case drain line. These filters are identical except for their size and flow volume.

As the filter element becomes contaminated, the pressure drop across the filter increases. When the pressure drop reaches approximately 70 PSI, a clogged indicator button extends from the top of the filter body. These filters also have an internal bypass feature. Inlet pressure is felt on the face side of the bypass valve which is spring loaded against its seat. Outlet pressure is felt on the spring-loaded side of the bypass valve. When the pressure drop across the filter reaches approximately 100 PSI, enough hydraulic force is created to unseat the valve. At this time hydraulic fluid bypasses the filter element and goes directly to the reservoir.



FILTER BY-PASS

Another filter, identical to the one on the engine, is installed in the pressure line downstream of the quick-disconnect fitting for the ground test stand. This filter removes contamination from the fluid before it can enter the hydraulic system.

HYDRAULIC SYSTEM NO. 2.

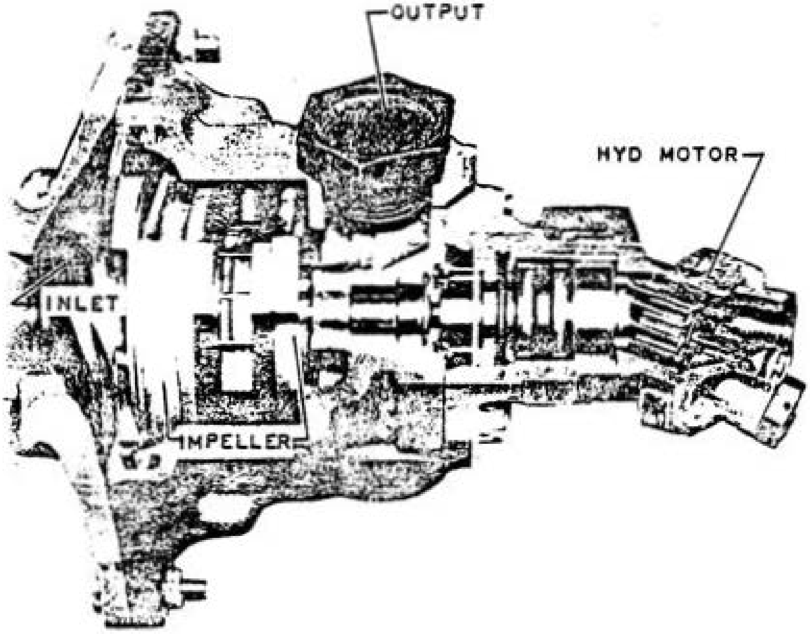
With the exception of being equipped with two suction boost pumps, hydraulic system No. 2 is the same in basic design and content as hydraulic system No. 1. It is powered by two variable-volume hydraulic pumps connected in parallel and driven by engines No. 1 and No. 2. System No. 2 supplies hydraulic power to the following: one of the two aileron actuating cylinders in each wing, one of the rudder actuating cylinders, one of the three elevator actuating cylinders, one motor of the wing-flap drive system, one-half of the dual tandem actuators for the wing spoilers, and one-half of the spoiler cable actuator. This system also supplies power for normal operation of the following: landing gear, wheel brakes, nose gear steering, horizontal stabilizer trim, emergency generator, control-column pusher actuator, and the hydraulic-motor-driven suction boost pump.

Control and indication components for hydraulic system No. 2 are located on the middle left section of the hydraulic systems control panel. This section contains the same components as the section for system No. 1.

The reservoir and a majority of the components for this system are located in a service center on the left side of the cargo compartment. Manually-operated interconnect valves are provided to allow hydraulic power from system No. [illegible] to be delivered to system No. 2 during ground checkout. Ground test connections are located in the forward end of the left wheel well for use with a hydraulic test stand.

The reservoir contains approximately 4.2 gallons with the landing gear down and approximately five gallons with the landing gear up. Two one-way check valves are installed in the reservoir's vent line. One check valve allows cargo compartment air pressure to be felt on the fluid in the reservoir but prevents fluid from entering and contaminating the vent filter. The other check valve allows fluid to leave the reservoir in the event of an overfilled condition during ground checkout but, when seated, it prevents foreign particles from entering the reservoir.

Two suction boost pumps are provided for the No. 2 hydraulic system. They ensure positive inlet pressure to the engine-driven pumps under all flow requirements. One of the pumps is identical to the electrically-driven pump used in system No. 1 and is located below the reservoir. The other, a hydraulically-driven pump is mounted on the bottom of the reservoir.



HYDRAULICALLY DRIVEN SUCTION BOOST PUMP

This suction boost pump receives fluid under pressure to drive the hydraulic motor section of the boost pump. A restrictor in the pressure line prevents over-speeding of the pump. The motor consists of a nine-piston assembly driven in and out of a barrel assembly. When the pressure from the engine-driven pumps reaches approximately 500 PSI, the hydraulic motor section of the pump begins to turn the boost section, and flow starts toward the inlet side of the engine-driven pumps. The pump has a rated flow of 21 gallons-per-minute at a pressure of 75 PSI to 110 PSI. When the pressure exceeds 110 PSI, the hydraulic motor will stall. As system demand causes a flow, the pressure is decreased and the cycle starts again.

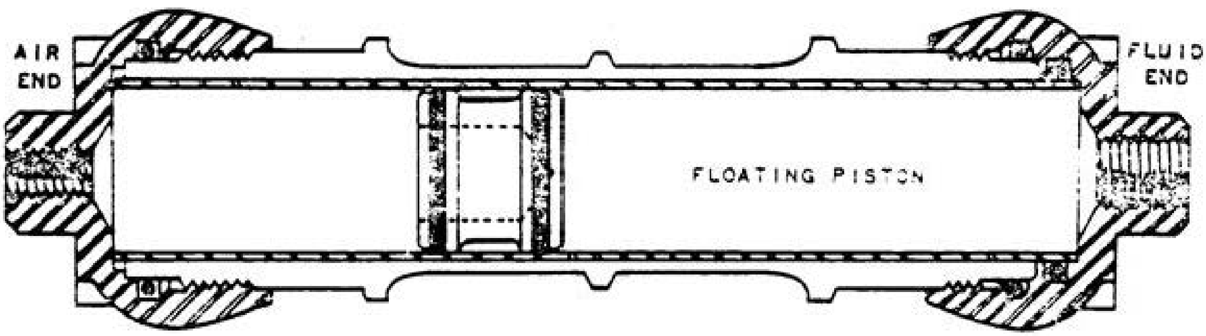
Approximate filter settings in PSID for No. 2 system are:

	CLOGGED BUTTON	BYPASS VALVE
Pump Pressure	70	-
Ground Test Stand	70	-
System Return	70	100
Case Drain Return	28	40

HYDRAULIC SYSTEM NO. 3.

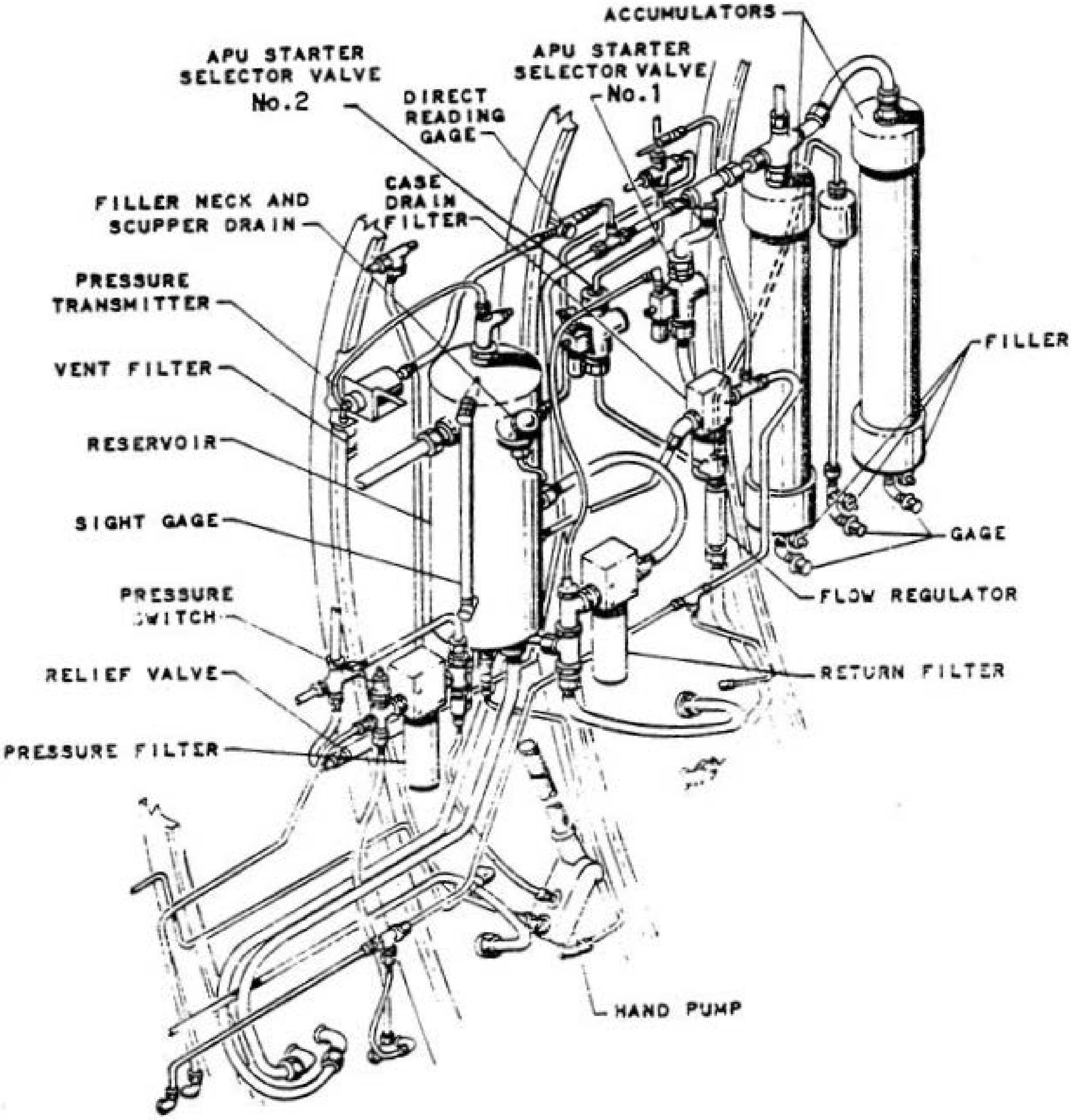
Hydraulic system No. 3 is powered by two electrically-driven, variable-volume pumps connected in parallel. This system supplies hydraulic power for normal operation of the following: the cargo doors and ramp system, the APU (auxiliary power unit) starter, one motor of the wing flap drive system, one-half of the dual tandem actuators for the wing spoilers, one-half of the spoiler cable actuator, and one control-column pusher actuator. This system also supplies power for emergency operation of the wheel brakes, the third actuator for the elevator, and the aileron servo tab lockout mechanism.

Except for the electrically driven pumps and the control panels, all of the power-system components are located in a service center on the left side of the cargo compartment just forward of service center No. 2. The reservoir contains approximately five gallons of fluid when properly serviced. Manually operated interconnect valves are provided to allow hydraulic power from system No. 3 to be delivered to system No. 2 during ground checkout. Two 400 cubic-inch, piston-type accumulators are installed at the No. 3 service center to store a reserve supply of fluid under pressure to start the APU and to provide emergency brakes when the high-pressure pumps are inoperable. A handpump is incorporated to charge the accumulators and to permit manual operation of the cargo doors and ramp system.

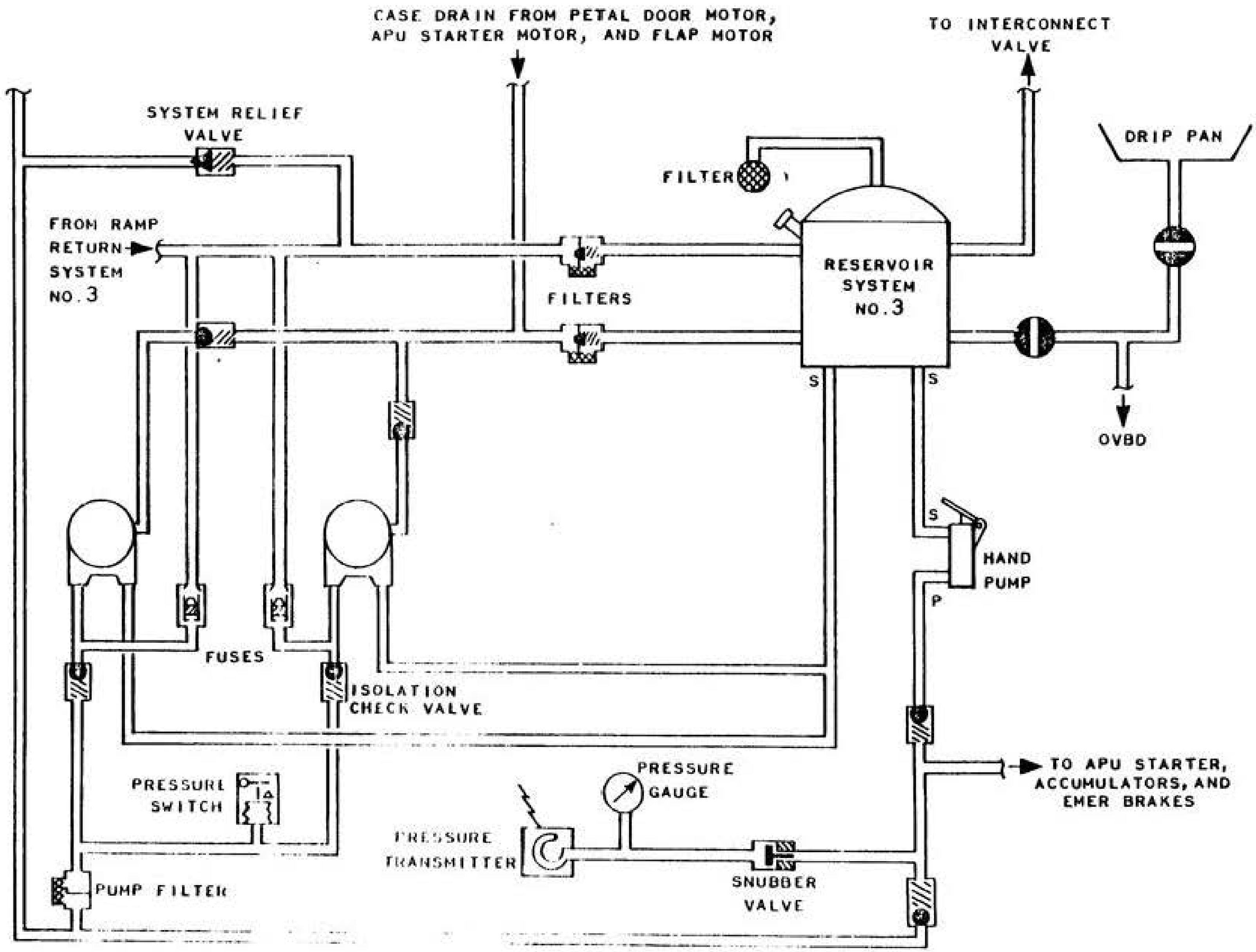


PISTON-TYPE ACCUMULATOR

The control and indication components for hydraulic system No. 3 are located on the upper section of the hydraulic systems control panel which is in the lower left corner of the flight engineer's panel. This section contains a pressure indicator and two pump switches. The pressure indicator will indicate system pressure, and a green PRESS ON light on the pilots' main instrument panel will illuminate



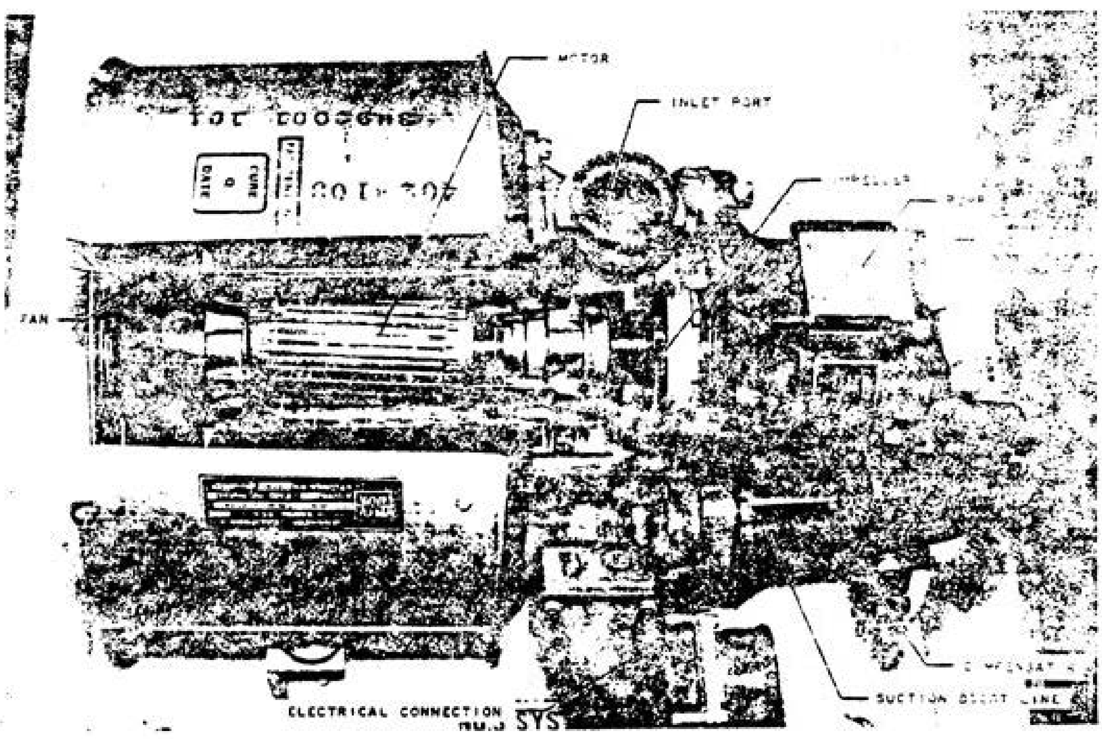
HYDRAULIC SERVICE CENTER NO.3



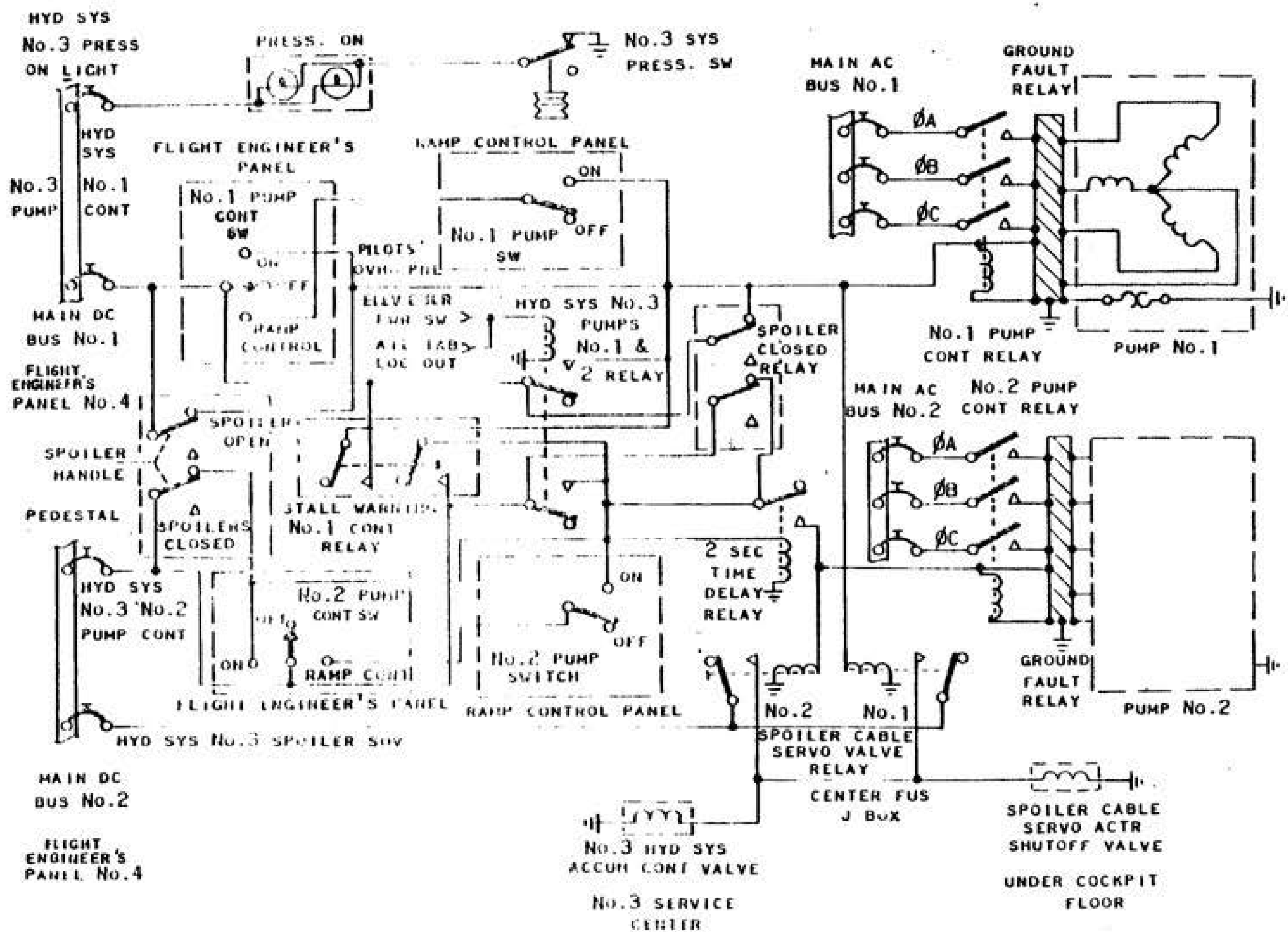
NO. 3 POWER SECTION HYDRAULIC SCHEMATIC

when the pressure is above 1,500 PSI. Each pump switch on the hydraulic system control panel has three positions which are: "ON," "OFF," and "RAMP CONTROL." Switches for the pumps are also located on the ramp control panel in the cargo compartment, but they are operative only when the flight engineer's switches are in the "RAMP CONTROL" position. The switches on the ramp control panel have two positions which are: "ON" and "OFF." In addition to the switches on the two control panels, the pumps will automatically start through the electrical circuitry of the aileron, elevator, wing spoiler, and stall warning systems. A time-delay relay is incorporated in the No. 2 pump circuitry to prevent overloading the electrical system when both pumps are scheduled to start simultaneously.

The No. 3 system pumps are located in the forward end of the left wheel well. They are variable-volume pumps driven by air-cooled A-C motors. Each pump has three major sections which are enclosed by a housing and cover assembly. These major sections are: an electric motor with attached fan, an impeller-type boost pump, and an axial piston pump. The boost pump, located between the motor and axial piston pump, receives fluid from the reservoir. This fluid is pressurized to approximately 40 PSI and then delivered to the inlet of the axial piston pump. The axial piston pump is identical in operation to the engine-driven pumps.



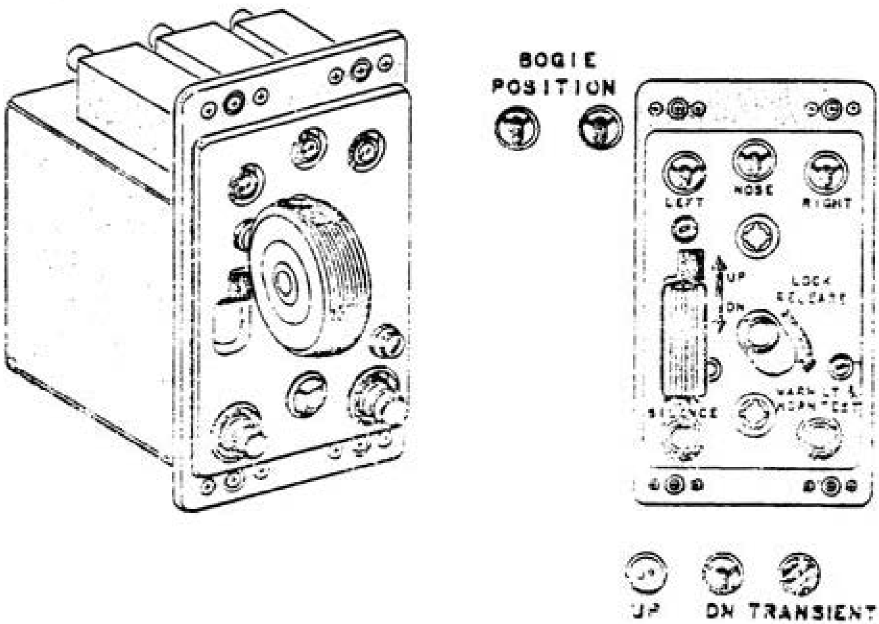
NO.3 HYDRAULIC SYSTEM ELECTRICAL MOTOR-DRIVEN PUMP



NO.3 POWER SECTION ELECTRICAL CONTROL SCHEMATIC

Hydraulic pressure for landing gear retraction and extension is provided by the No. 2 hydraulic system. In the event of No. 2 hydraulic system failure, the main gear may be manually released to free fall. An engage mechanism is provided for manually positioning the drag link to the down-locked position. Emergency extension of the nose gear is accomplished by hydraulic pressure from the No. 4 hydraulic system.

The gear can be extended or retracted by placing the selector handle, located on the landing gear control panel, in the desired position. Separate indicators are provided to show extension or retraction of each gear. A "wheel" appears in the indicator window when the gear is down and locked. When the gear is up and locked, the word "UP" is displayed. The intermediate position is indicated by a "barber pole" symbol. Two red warning lights in the selector handle are illuminated during any unsafe condition.



CONTROL PANEL

Each main gear assembly includes the following:

1. An air-oil shock strut
2. An axle beam and axle assembly links
3. Torque arms

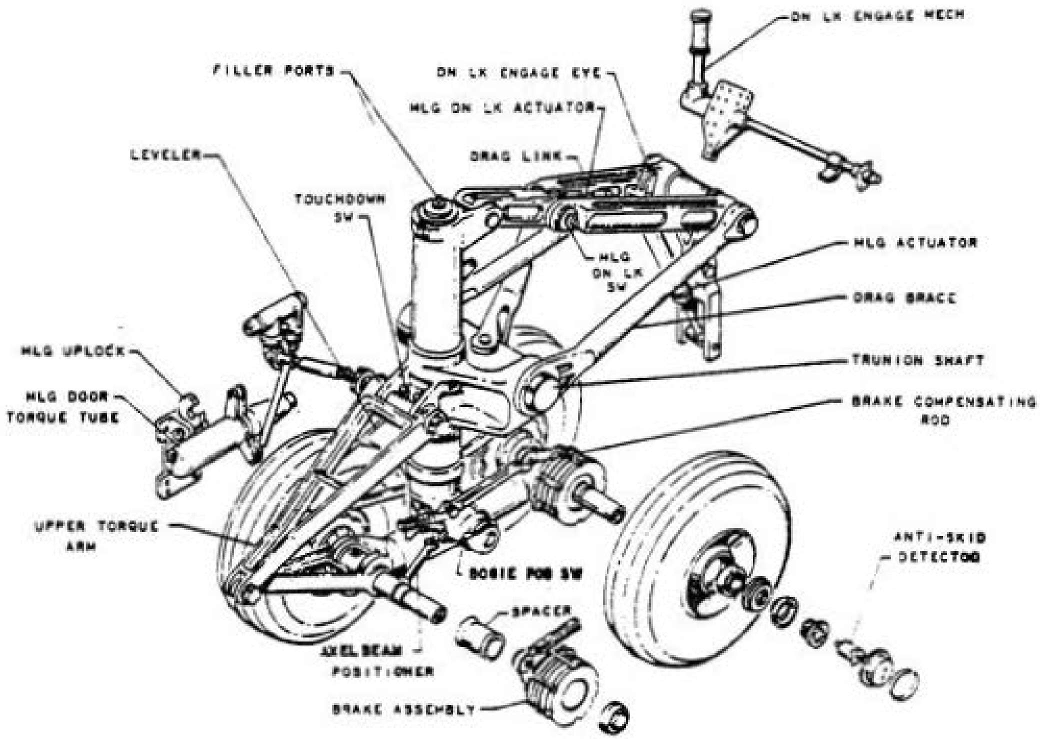
4. Drag braces
5. Drag links and downlock assembly
6. Uplock assembly
7. Leveler rod assembly
8. Axle beam positioner cylinder and reservoir
9. Actuating cylinder
10. Wheels and tires
11. Wheel brake assemblies
12. Brake Compensating rods
13. Door uplock

The nose landing gear assembly consists of the following:

1. Air-oil shock strut
2. Axle
3. Torque arms
4. A drag link with an up-down lock assembly
5. Actuating cylinder
6. Wheels with tires

MAIN LANDING GEAR SYSTEM.

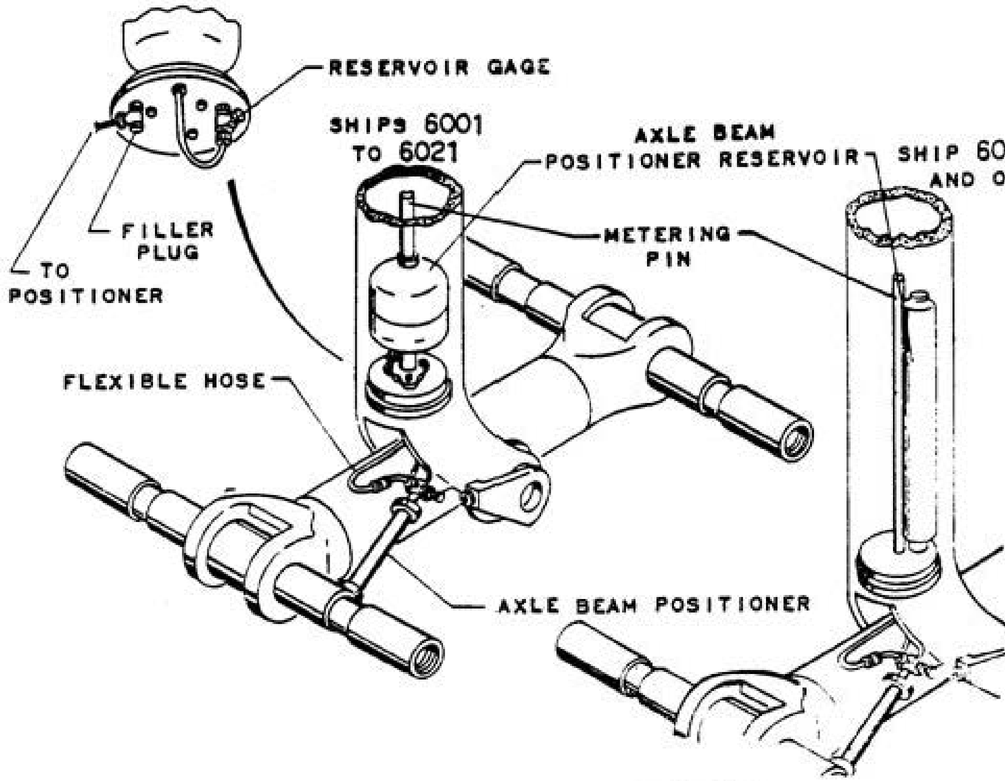
The two main landing gear shock struts provide a means of attaching the main gear assemblies to the aircraft, and provide shock absorption during taxiing, take-off, and landing. The shock strut is a conventional air-oil-type which is trunnion mounted to the airplane. Primarily, it consists of a piston assembly and an outer cylinder assembly. The strut piston will extend 28 inches under a no-load condition; but in the final static position under design gross weight, it will compress to three inches extended. The shock strut compression stroke is designed to meet certain unusual requirements of the StarLifter. In order to minimize fuselage bending loads, the main landing gear has been placed as close as possible to the most aft center of gravity position. The overhang of the fuselage aft of the main landing gear and the small ground clearance, limits the tail-down angle during take-off or landing. To overcome this, a two-step action of the shock strut was developed. By setting the stroke at 28 inches, the wheels are placed sufficiently below the fuselage to permit an 11-degree tail-down angle at touchdown impact. The first 17 inches of compression may be quite rapid, and the tail down angle limit at this point is approximately eight degrees. Beyond 17 inches of compression the shock strut will allow the airplane to sink much slower until the static condition on the weight carried is reached. During this time the airplane will rotate downward as in any landing so that the tail clearance is ample.



MAIN LANDING GEAR COMPONENTS

The axle beam and axle assembly provides a means of mounting the brake and wheel assemblies to each main gear. The [illegible]-type axle beam has a pair [illegible] lugs on each end which serve as mounts for the axles. A hollow bolt, which provides the pivot point for the axle beam assembly, attaches the beam assembly to the shock strut piston yoke. The axles are threaded internally on each end which eliminates the need for thread protectors when replacing wheel and tire assemblies. An anti-rotation spacer assembly, incorporating tow rings and jack pads, is installed on each end of the axle beam and provides for the centering of the axles.

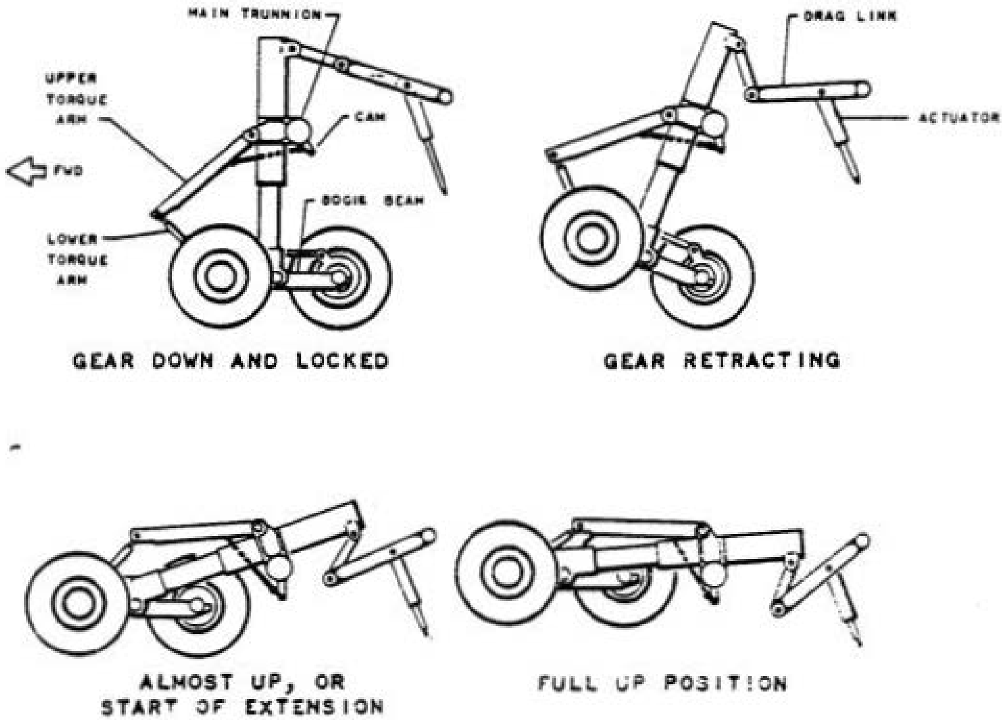
The axle beam positioner cylinder is an air-oil cylinder attached between the axle beam and the shock strut piston. This keeps the axle beam approximately perpendicular to the longitudinal axis of the shock strut while in the extended position for landing, and during part of the extension and retraction cycle. It also provides a degree of snubbing action to prevent oscillations of the axle beam during landing, taxiing, and take-off. A positioner-cylinder air-bottle reservoir provides approximately 75 cubic inches of additional air for the positioner cylinder. The bottle is located



AXLE BEAM POSITIONER RESERVOIR

in the lower hollow area of the shock strut piston. It is made of stainless steel and is precharged to approximately 2,000 PSI. The bottle has an air pressure gauge and an air filler valve, and is connected to the positioner cylinder by means of a high pressure flexible hose. It is flange-mounted internally to the lower piston cover plate with standard bolts and plate nuts.

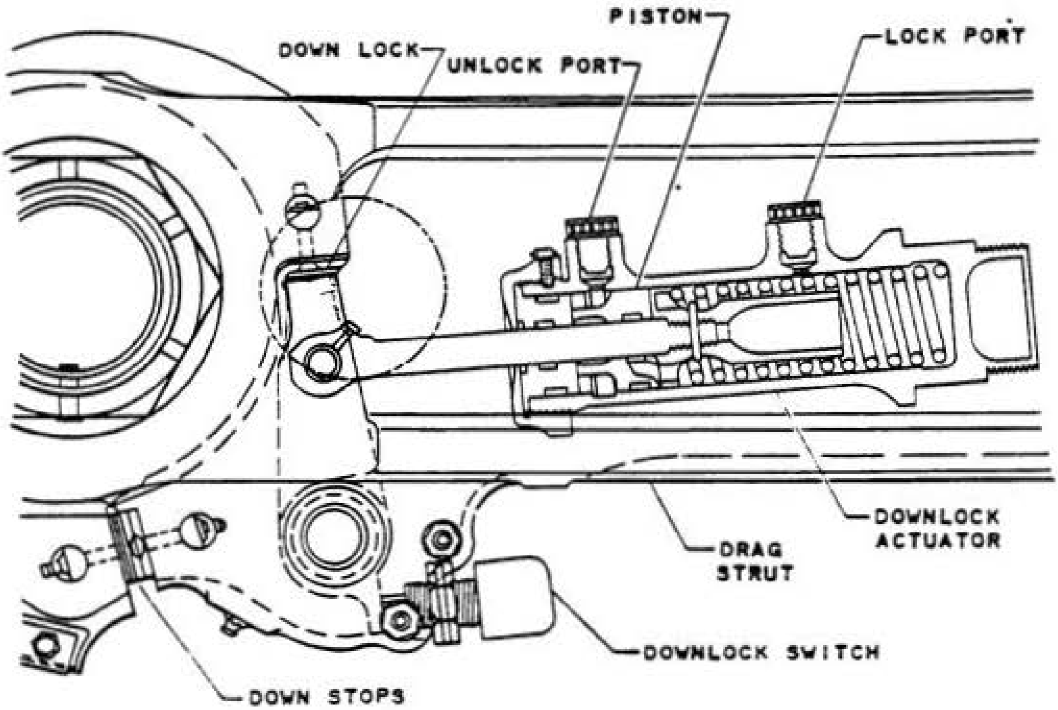
An upper torque arm and a lower torque arm are located on each main gear to maintain wheel alignment. The upper torque arm is mounted to lugs on the shock strut cylinder, and the lower torque arm is attached to the forward axle. The torque arms are secured to each other at their apex by a ball and socket joint. A leveler rod assembly is attached between a lug on the upper torque arm and a lug on the drag brace at the shock strut trunnion. During gear retraction the leveler rod linkage will cause the axle beam to rotate about its pivot point so that during approximately the last 20 degrees of strut rotation the axle beam assumes and maintains a position parallel to the stowed position. During gear extension the leveler rod linkage



MAIN LANDING GEAR LEVELER

maintains the axle beam position parallel to the retracted position for approximately the first 20 degrees of downward strut movement to provide clearance for the main gear doors. The drag link provides for the retraction and extension of the main gear, and incorporates the downlock.

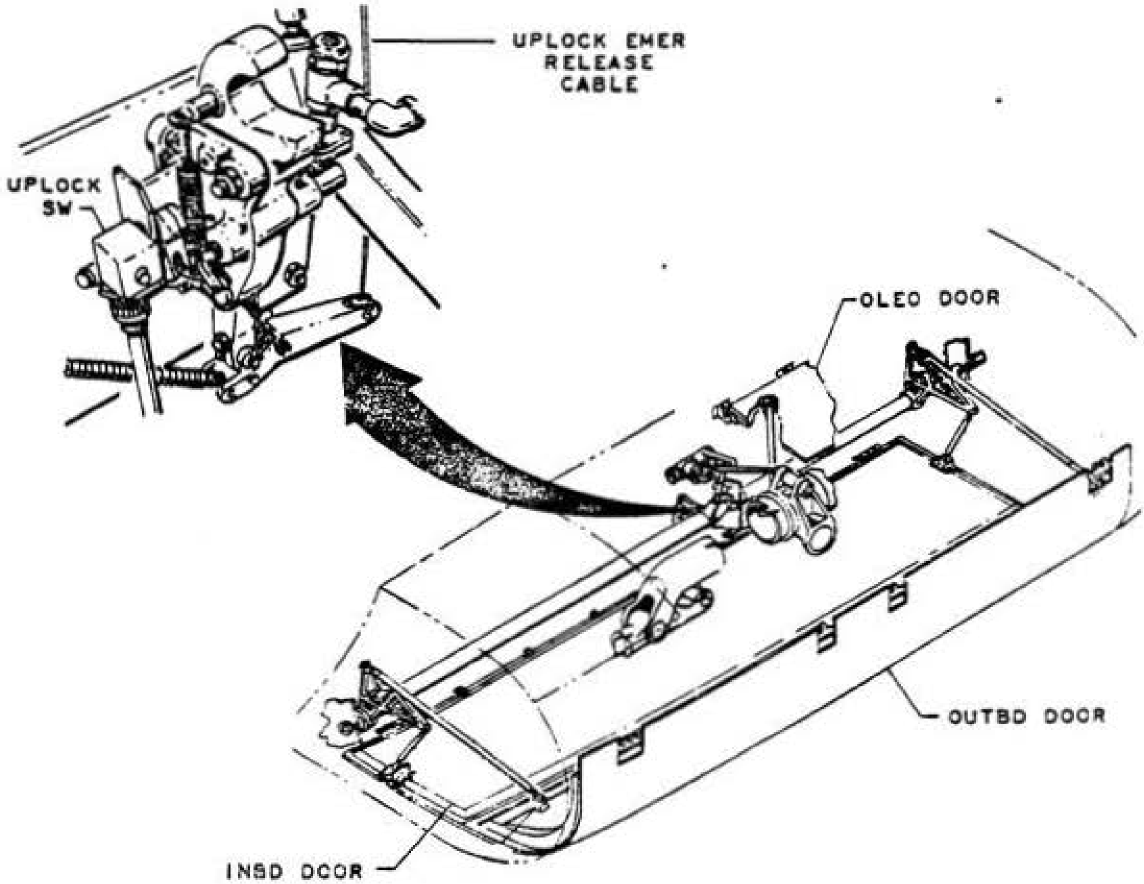
The drag link assembly consists of a single forward link attached to the shock strut cylinder and two aft drag links attached to the fuselage. The forward link and two aft links are connected by a knee bolt. The main landing gear actuator is attached between the two aft drag links and pivots the drag link assembly at the knee joint to extend and retract the main gear. The main landing gear downlock is located at the knee joint of the drag link assembly. The downlock consists of a "chocking" lever, a spring-loaded hydraulic actuator, a cam on the forward drag link, and a downlock switch. The spring load holds the "chock" under the cam of the forward drag link preventing the drag link assembly from folding. During gear retraction, hydraulic pressure is applied to the downlock actuator thereby moving the "chock" aft and allowing the drag link assembly to fold.



MAIN LANDING GEAR DOWNLOCK

Each main landing gear pod is provided with three doors; an outboard door, an inboard door, and an oleo door. The outboard door is hinged to the pod and swings down and outboard. It is linked to the forward and aft ends of the door torque tube which rotates, through a bellcrank linkage attached to the landing gear strut assembly, as the gear is extended or retracted. The inboard door is hinged to the pod and swings down and inboard. It is linked to the torque tube at the forward and aft ends. The oleo door is hinged to the pod on the inboard side and swings up and inboard. It is linked by a single push rod fastened to the main gear trunnion lugs.

The actuating linkage of the main landing gear doors is provided to transfer the motion of the shock strut for opening and closing the doors during the retraction and extension of the main gear. The linkage for the lower doors is connected, through a link which connects two ball joints, to the main gear upper attach pin.



MAIN LANDING GEAR DOORS AND UPLOCK

Motion is then transferred to the doors by bellcranks, torque tubes, and pushrods. As the gear is retracted or extended, motion is transferred through a bellcrank and pushrod to the torque tubes extending the length of the wheel well. The doors are driven by pushrods connected to the torque arms at the forward and aft ends of each lower door. The oleo door is actuated by a single pushrod connected to the main landing gear trunnion lug.

A main landing gear uplock assembly is installed in each main landing gear pod. Each uplock assembly locks the associated landing gear and the pod doors through an interlinked torque tube assembly. The door torque tube, rather than the gear, is locked when rotated to the gear up position.

The uplock assemblies are mechanical overcenter locks and are normally released by a hydraulic actuator. In the event of a failure of the hydraulic release mechanism, they are released manually by a cable rigged lever.

The upward motion of the landing gear is transmitted through the linkage to rotate the door torque tube, which in turn is linked to the pod doors. As the torque tube rotates, a lever arm and roller contacts the open uplock and forces the uplock head through a small arc to the locked position. The lever arrangement snaps past center and locks the uplock head.

For hydraulic release, the hydraulic release cylinder actuator rod extends and contracts a cam which rotates and moves the fulcrum of the locking levers to the open position. A spring maintains the lock open and in readiness for the next closing cycle.

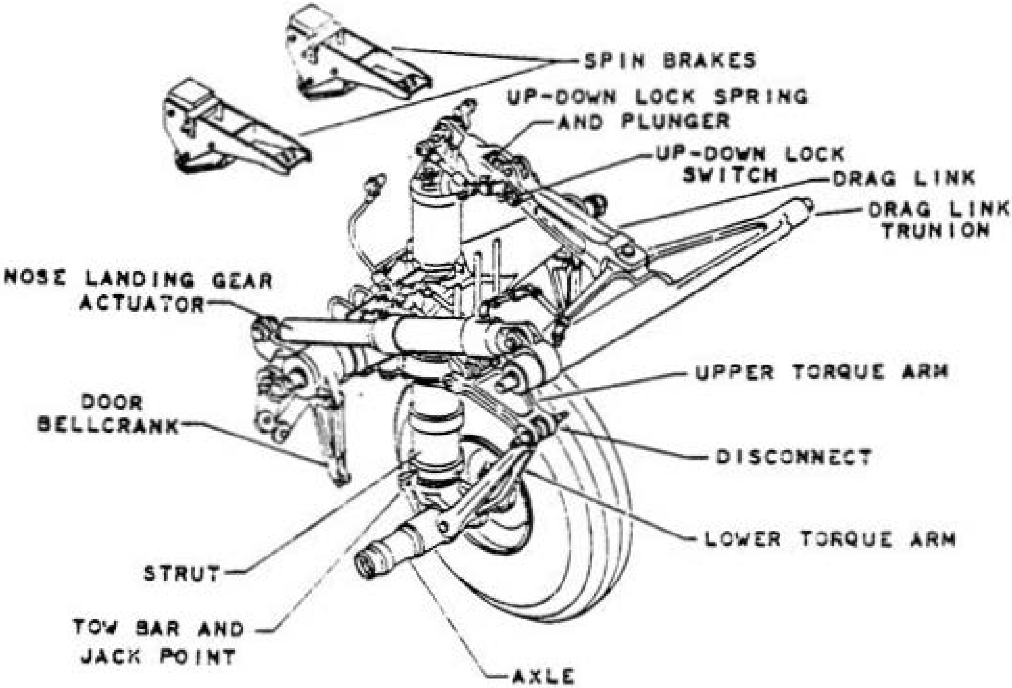
The left and right main landing gear door uplocks prevent the leading edge of the doors from gapping when the aircraft is in flight. The uplocks are located at the forward edges of the main gear doors. When the aircraft is on the ground, the landing gear doors are open and the door uplock actuator is pressurized to the unlocked position. The door uplock actuator is sequenced to the locked condition when the landing gear goes into the uplock position. The door uplock is held in the locked position by overcenter linkage. When the landing gear control handle is put in the "DN" position, pressure is applied to the door uplock actuator to release the uplock. In case of No. 2 hydraulic system failure, the door uplock may be released manually by pulling a T-handle located in the cargo compartment.

Brake compensating rods are attached from each brake assembly to the shock strut to prevent pitching of the axle beam assembly during braking. As the aircraft is braked, the forward force tends to cause the forward wheels to dip and the rear wheels to rise. This motion is restricted by the brake compensating rods which transmit the force to the strut instead of to the axle beam, causing an even braking action of the wheels.

NOSE LANDING GEAR SYSTEM.

The nose gear strut assembly is a combination air-oil type to provide shock absorption during taxiing, take-off, and landing. The strut is filled with hydraulic fluid and compressed air through filler valves on top of the cylinder. O-ring seals and backup rings form packings that seal the internal sliding surfaces. The shock strut trunnion ends are mounted in self-aligning spherical bearings in the fuselage structure. The steering control valve, steering cylinders, steering cable, and torque arms are attached to the strut.

The nose gear torque arms act as an antirotation connection link, connect the strut piston to the cylinder, and provide a means for steering the nose gear. The upper

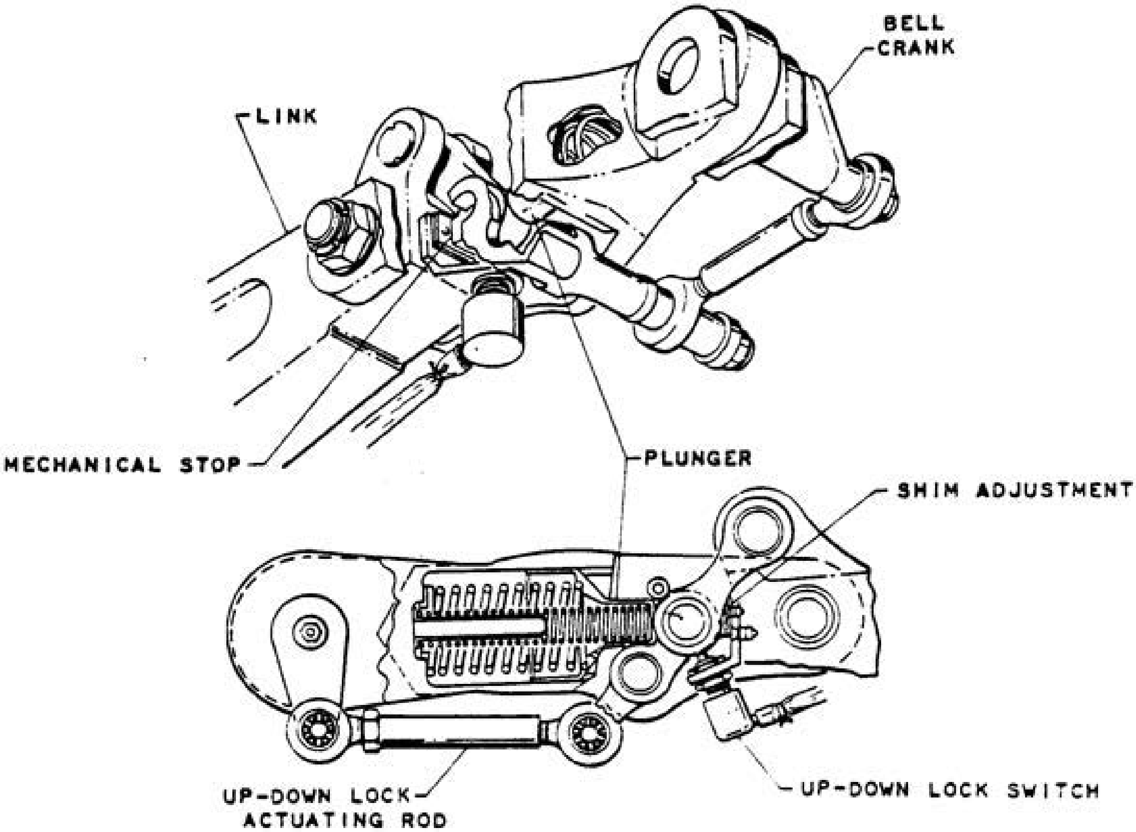


NOSE LANDING GEAR COMPONENTS

torque arm is bolted at the upper mount lug on the shock strut cylinder and the lower torque arm is bolted to the strut piston lugs. Both torque arms are fitted with bushings at each mounting lug. A quick disconnect at the apex provides a common pivot for the torque arms.

The nose gear drag link, which contains the up-down lock mechanism, transmits the nose gear drag loads from the shock strut to the fuselage. The drag link is jointed near the center and folds while the nose gear is in transit. As hydraulic pressure is applied to the nose gear actuating cylinder, pressure is also applied to the up-down lock actuating cylinder. The nose gear drag link is attached to the top of the shock strut and to the drag link trunnion. The drag link locks straight and nearly horizontal in the extended position. In the retracted position the top of the strut is rotated aft and downward until the drag link is straight and in a nearly vertical position.

The nose gear up-down lock mechanism is incorporated in the drag link assembly, and the actuating cylinder is mounted on the nose gear shock strut. The cylinder is connected to the mechanism through bellcranks and a pushrod. The gear is locked in either the up or the down position by two cranks forced into an overcenter position. The cranks are forced into the overcenter position by the combination of a spring

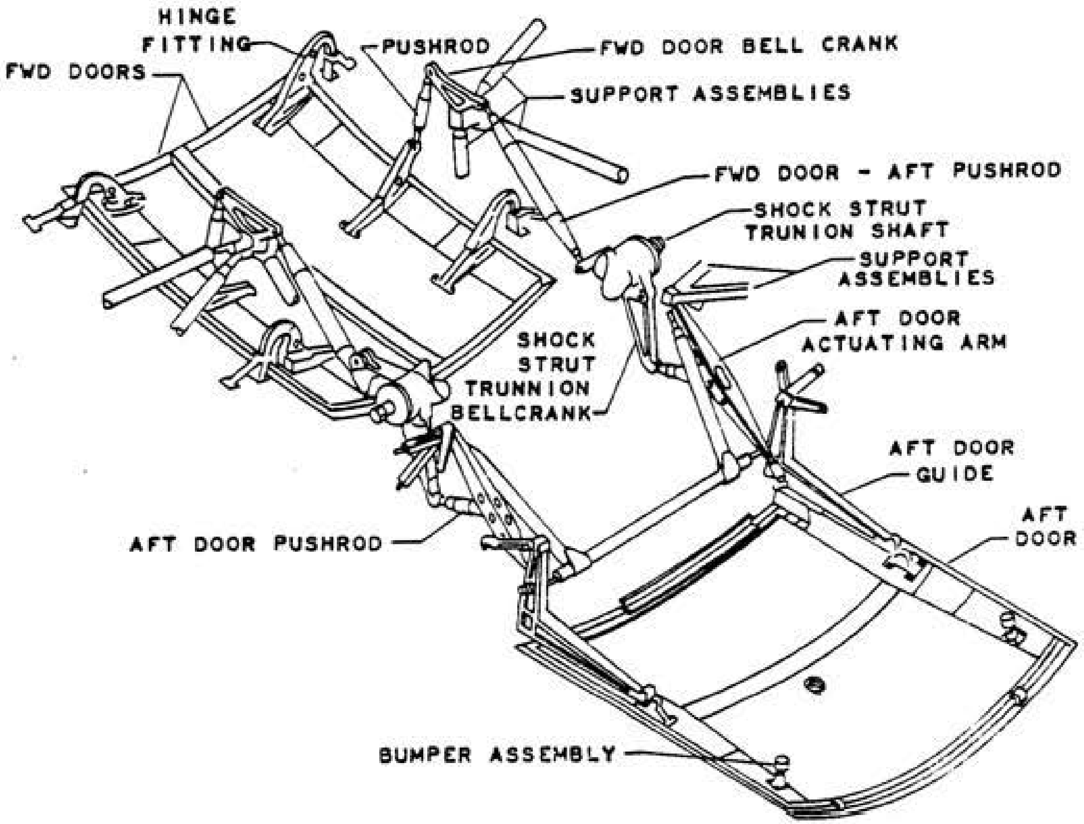


NOSE LANDING GEAR UP-DOWN LOCK

and the hydraulic pressure to the actuating cylinder; they are maintained in the locked position by the spring assembly. Hydraulic pressure to the unlock side of the actuating cylinder unlocks the up-down lock mechanism.

The nose gear actuator is a typical hydraulically actuated, double-acting, cylinder and piston assembly. The cylinder is attached to the drag link trunnion and to a bellcrank on the shock strut trunnion. The actuator is extended to lower the gear and retracted to raise the gear.

The nose gear doors enclose the nose wheel well when the gear is in the retracted position. The doors open and close in conjunction with the nose landing gear through a system of adjustable pushrods and bellcranks. The doors consist of two clamshell doors covering the forward section and one single door covering the aft section. When the gear is in the up position, all doors are closed and are preloaded. The clamshell doors move downward and outboard as the gear extends, and then back



NOSE LANDING GEAR DOORS

to the closed position when the gear is down. The aft door moves down and back under the fuselage, and remains in this position until the gear is retracted. Bumpers on the aft door contact the fuselage to provide additional support for the door.

The door actuating mechanism transfers the motion of the nose gear shock strut, for opening and closing the nose landing gear doors during extension and retraction of the nose gear. The linkage for each forward door is connected to the strut trunnion bellcrank. The motion is then transferred through arms, rods, and bellcranks to the doors. The aft door linkage consists of one rod and two arms for each side of the door. The rod is connected to the strut trunnion bellcrank and then to an arm, which is connected to the door on one end and a support on the other end. The other arm on each side of the door provides support and acts as a guide for the aft end of the door.

The nose landing gear spin brake stops the nose wheel from spinning when the gear is in the retracted position. When the nose gear is retracted, the tire comes in contact with the brake lining. The wheel assembly gradually stops rotating due to the friction generated between the tire and spin brake. The brake assembly is attached to the forward upper section of the nose wheel well and consists of a bracket, brake lining, and a strap. The spin brake is attached to upper structure of the nose wheel well by a hinge at the aft end and at the forward end by a pin and two retaining clips. The clips are slotted to allow the forward end of the assembly to move up and down approximately 0.4 inch. The flexible neoprene strap, in conjunction with the slotted clips, allows for differences that may occur in the tire and brake contact point.

HYDRAULIC OPERATION.

The landing gear system is hydraulically operated by pressure from the No. 2 hydraulic system. Four solenoid actuated valves are provided to direct hydraulic pressure for landing gear operation. The four valves are: the nose landing gear selector valve, the main landing gear selector valve, the main landing gear downlock selector valve, and the main landing gear door uplock selector valve. All four of the selector valves have manual override provisions which allow manual positioning of the valves in the event of electrical failure. All four valves are solenoid-pilot operated. When one of the solenoids of a valve is energized, the pilot portion of the valve directs hydraulic fluid under pressure to position the control spool. The positioning of the control spool directs hydraulic fluid under pressure to the various components for operation.

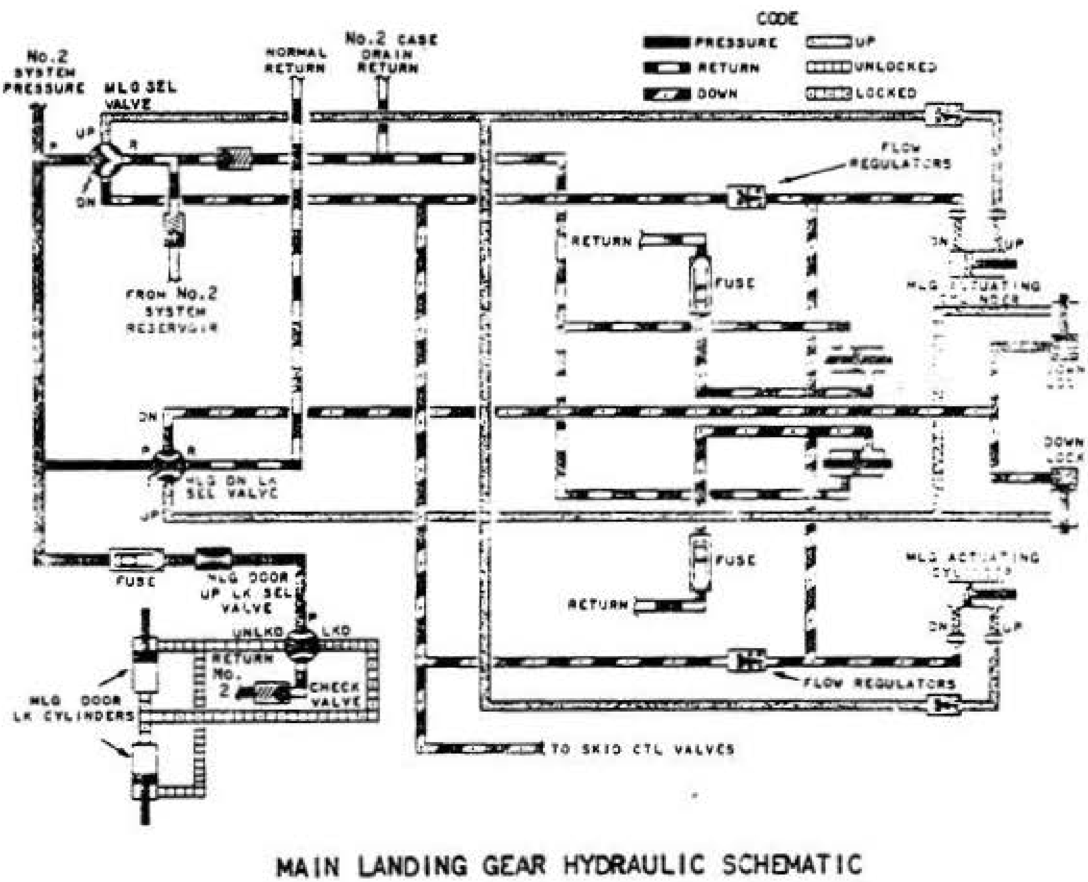
The main landing gear selector valve is located on the left side of the cargo compartment aft of the No. 2 hydraulic system service center. When the up solenoid is energized, fluid is directed to the rod side of the main landing gear actuators.

Main landing gear retraction speed is controlled by flow regulators in the up line. During retraction, the face side of the main landing gear actuators are connected to system return through the selector valve. When the down solenoid is energized, the control spool is positioned to direct hydraulic fluid under pressure to both the rod side and the face side of the main landing gear actuators. Because of the greater effective area of the face side, the actuators will extend. Main landing gear extension speed is controlled by flow regulators installed in the lines to the face side of the actuators.

During the extension cycle, hydraulic fuses connected between the line to the face side of the actuators and the return line allow 40-cubic inches of fluid to pass to return. This allows pressure on the rod side of the actuators to raise the main gear slightly which allows the gear uplocks to unlock. When 40 cubic inches of fluid have passed to return, the fuses shut off, pressure builds up on the face side of the actuators, and the main gear is extended.

The main gear downlock selector valve is located on the left side of the cargo compartment aft of the No. 2 hydraulic system service center. During the gear retraction cycle this valve directs No. 2 hydraulic system pressure to the downlock actuators to remove the "chocking lever" from under the cam of the drag link which allows the drag link to fold. During extension, fluid is directed to the face side of the downlock actuators to force the "chocking lever" of the downlock under the cam when the drag links straighten.

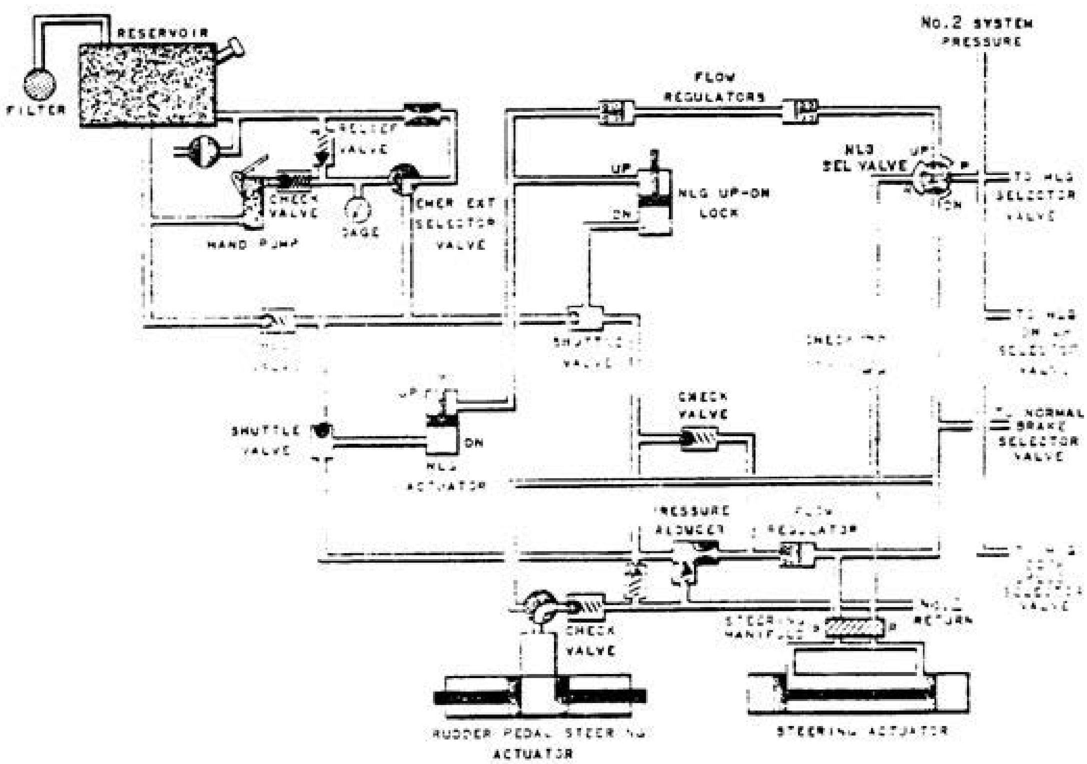
The main landing gear door uplock selector valve is located on the left side of the cargo compartment between the No. 2 and No. 3 hydraulic system reservoirs.



MAIN LANDING GEAR HYDRAULIC SCHEMATIC

This selector valve directs hydraulic fluid under pressure to lock and unlock the external main landing gear door locks. A hydraulic fuse is installed in the pressure line to the main landing gear door uplock selector valve to prevent depletion of the No. 2 hydraulic system fluid in the event a downstream line breaks.

The nose landing gear selector valve is located in the electronics compartment beneath the flight station floor. This valve directs hydraulic fluid under pressure to the nose landing gear up-down lock and to the nose landing gear actuator. A pressure reducer in the nose landing gear down line reduces pressure to approximately 800 PSI for nose gear extension. A flow regulator is also installed in the downline to control extension speed. Two flow regulators are installed in the up line; one is used during gear extension and the other is used during gear retraction to control the speed of actuation.



NOSE LANDING GEAR HYDRAULIC SCHEMATIC

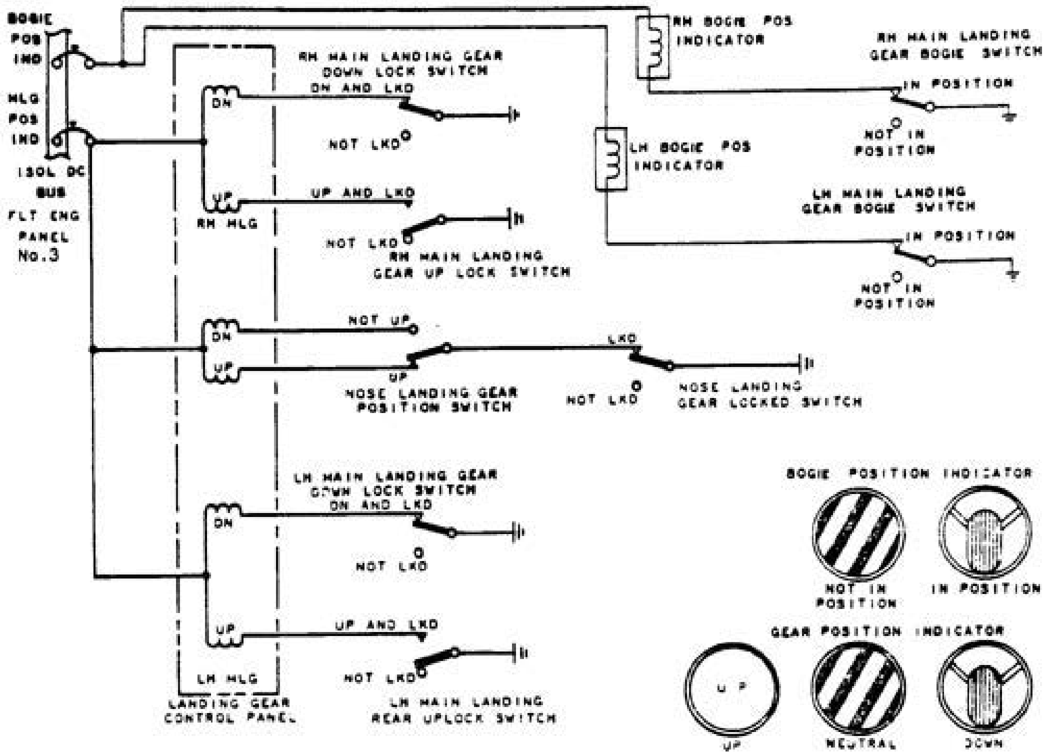
A ground is provided to the up solenoid of the main landing gear selector valve and the main gear downlock selector valve by the deenergized contact of the main gear up and locked relay.

The ground circuit for the nose landing gear selector valve up solenoid is completed in parallel through the nose gear lock switch when it is in the not locked position and the nose landing gear position switch is in the not up position. This causes the selector valves to direct hydraulic pressure to the unlock side of the downlock actuators and to the retracting side of the gear actuators. When the nose gear is up and locked, the ground will be removed from the up solenoid of the nose gear selector valve and it will deenergize. When the main gear is up and locked, the main gear up and locked relay will energize and remove the ground from the main gear selector valve and the main gear downlock selector valve. The energized contacts of the main gear up and locked relay provide power to energize the lock solenoid of the main gear door uplock selector valve. The main gear door overcenter lock switches break the circuit to the lock solenoid when the door lock linkage is locked overcenter.

Moving the landing gear control handle to the "DN" position will apply electrical power from the isolated D-C bus through the control handle switch to the down solenoid of the main and nose gear selector valves and the main gear downlock selector valve. Hydraulic pressure is applied to both the extension and retraction sides of the gear actuators. Because of the larger area of the extension side, the gear will move to the extend and downlocked position. When the landing gear control handle is placed to "DN," the main gear up and locked relay will deenergize and the main gear door uplock selector valve unlock solenoid will be energized. As long as the control handle is in the "DN" position, the electrical circuit is completed to the selector valves and the landing gear system will remain pressurized.

When the airplane settles on the wheels and the compression of the shock strut actuates the touchdown switches to the ground position, a spring-loaded plunger locks the control handle in the "DN" position. The lock prevents the control handle from moving out of the "DN" position accidentally. When the airplane is airborne, the ground circuit for touchdown relay No. 1 is completed through both touchdown switches in series which are actuated to the air position. The touchdown relay, in the air position, completes the ground circuit for the landing gear control handle release solenoid, which automatically unlocks it. Actuation of the touchdown switches to the ground position will complete the electrical ground circuit for touchdown relays No. 2 through No. 7, and opens the electrical ground circuit for touchdown relay No. 1.

Located on the landing gear control panel are three individual flay-type indicators to show the position of each gear. The indicators show miniature wheels and tires



LANDING GEAR POSITION INDICATOR ELECTRICAL SCHEMATIC

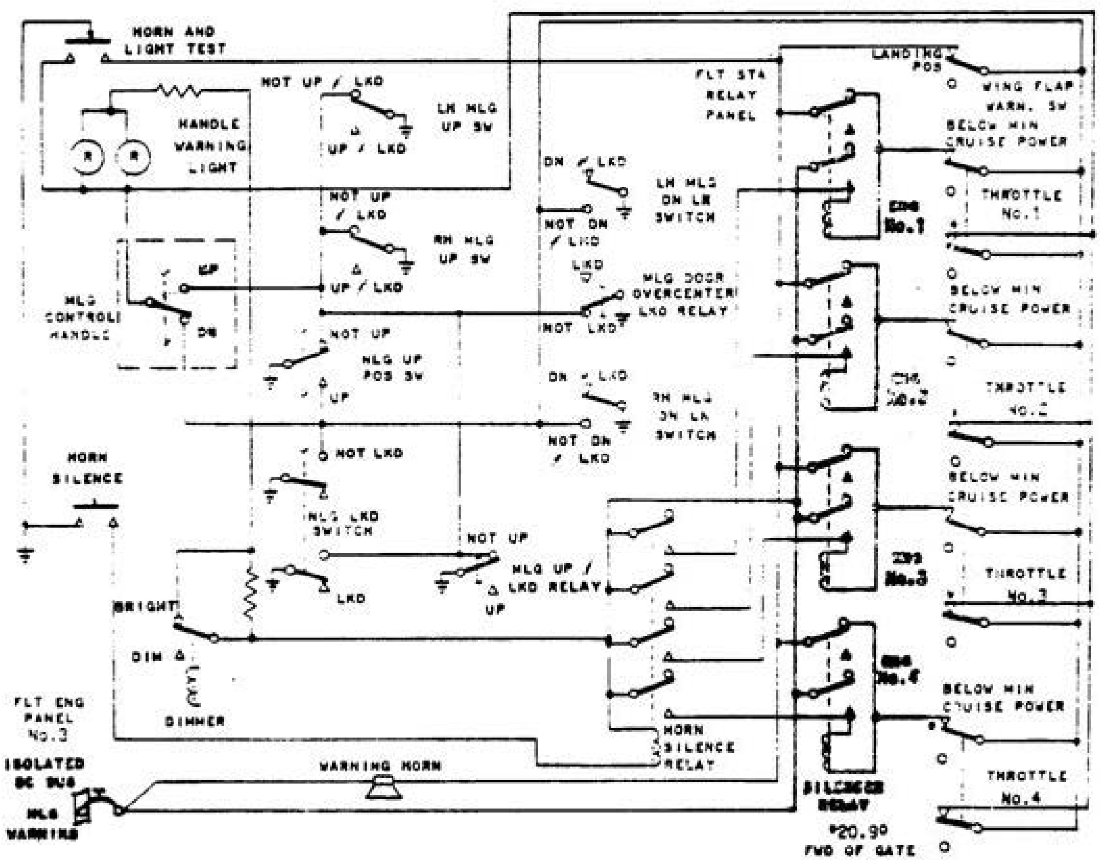
in the gear down and locked position, and the word "UP" when the gear is up and locked. When the gear is in an intermediate position, the indicators will show a diagonally striped area.

Electrical power is supplied from the isolated D-C bus to each of the three position indicators. When the main gear is fully extended, the downlock switches are actuated to the locked position and the electrical ground circuit for each indicator coil is completed. When the nose gear is fully extended, the lock switch is actuated to the locked position and the nose gear position switch is actuated to the not-up position. The electrical ground circuit for the nose gear indicator coil is completed through both switches in series. The coil for each indicator is then energized which causes the miniature wheels and tires to appear on each indicator. When the main landing gear is fully retracted, the uplock switch for each main gear is actuated to the locked position completing the electrical ground circuit to the up coil of its respective indicator. When the nose gear is fully retracted, the lock switch is actuated to the locked position and the nose gear position switch is actuated to the up position, completing the electrical ground circuit to the up coil of the nose gear indicator.

The up coil for each indicator is then energized, causing "UP" to be seen on each indicator. When the landing gear is neither extended nor retracted, the up and down coils for all indicators are deenergized, causing a diagonally striped area to appear on the indicators.

Bogie position indicators for the left and right bogie assemblies are located on the bogie position indicator panel which is located on the pilots' center instrument panel to the left of the landing gear control panel. A miniature tire and wheel will appear on the indicator when the respective bogie is in position for landing. Barber poles will appear when the bogie is not in position. The circuit is completed to the indicator coil when the respective bogie switch is in position and open when the switch is not in position.

A red light in the landing gear control handle illuminates when the gear is neither fully extended nor fully retracted. A ground circuit for the light is provided by the



LANDING GEAR WARNING ELECTRICAL SCHEMATIC not-up and locked position of the main landing gear uplock switches; the not-up position of the nose landing gear position switch; the not-locked position of the nose landing gear lock switch; a deenergized contact of the main landing gear up and locked relay; and a deenergized contact of the main landing gear door overcenter locked relay during retraction. During extension, ground circuits are provided by the not-locked position of the nose landing gear lock switch and the not-locked position of the main landing gear downlock switches.

A warning horn in the flight station sounds if a throttle is retarded below minimum cruise power when the gear is not down and locked. If the warning horn circuit is activated by retarding a throttle, the light in the control handle also illuminates. The warning horn can be turned off by depressing the HORN SILENCE button, but the light remains illuminated until the gear is down and locked or until the throttle is advanced beyond minimum cruise power.

The warning horn is provided a ground circuit through the deenergized contact of the silencer relay, the throttle switch in series for each engine, and the gear downlock switches. All four engine silencer relay and throttle switch circuits are in parallel. The ground from the gear downlock switches to the light in the handle is provided through the throttle switches only.

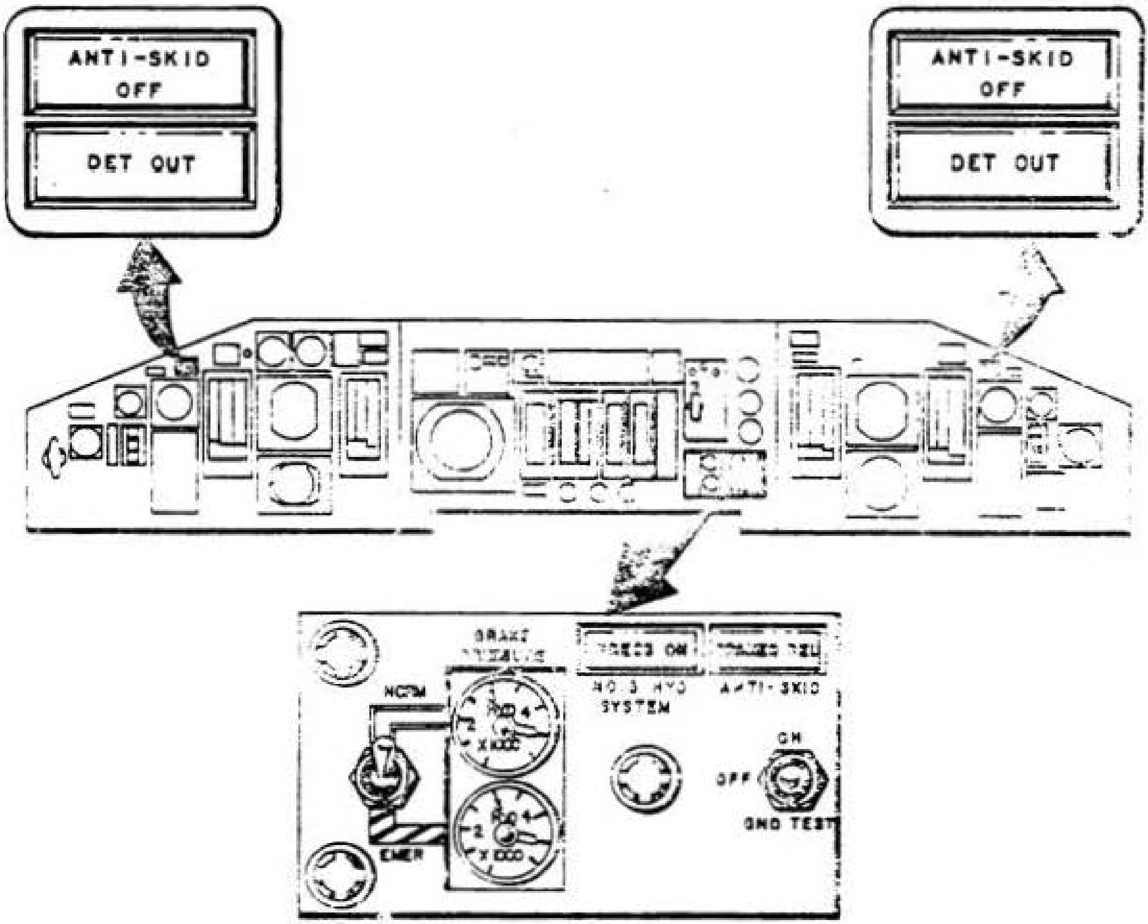
Pressing the HORN SILENCE button energizes the horn silencer relay. Through the energized contacts of the horn silencer relay, all four silencer relays are energized. Energizing the silencer relays breaks the ground circuit to the warning horn. Through their own contacts, 28-volts DC is applied to the four silencer relays. The silencer relay, which has the ground circuit through the throttle switch, remains energized when the button is released.

The warning horn also sounds if the flap control handle is moved to select the landing position for the flaps and the gear is not down and locked. The HORN SILENCE button will not silence the horn if the horn has been turned on by the wing flap warning switch. In order to silence the horn, the gear must be down and locked or the flap control lever must be moved to select less than landing position flaps.

MAIN WHEEL
BRAKE AND ANTI-SKID SYSTEM

GENERAL DESCRIPTION.

The StarLifter is equipped with a hydraulic power brake system which provides normal and emergency braking capability. Anit-skid protection may be selected but operates only when the normal brake system is used. A method is also provided for setting the brakes when parking the aircraft.



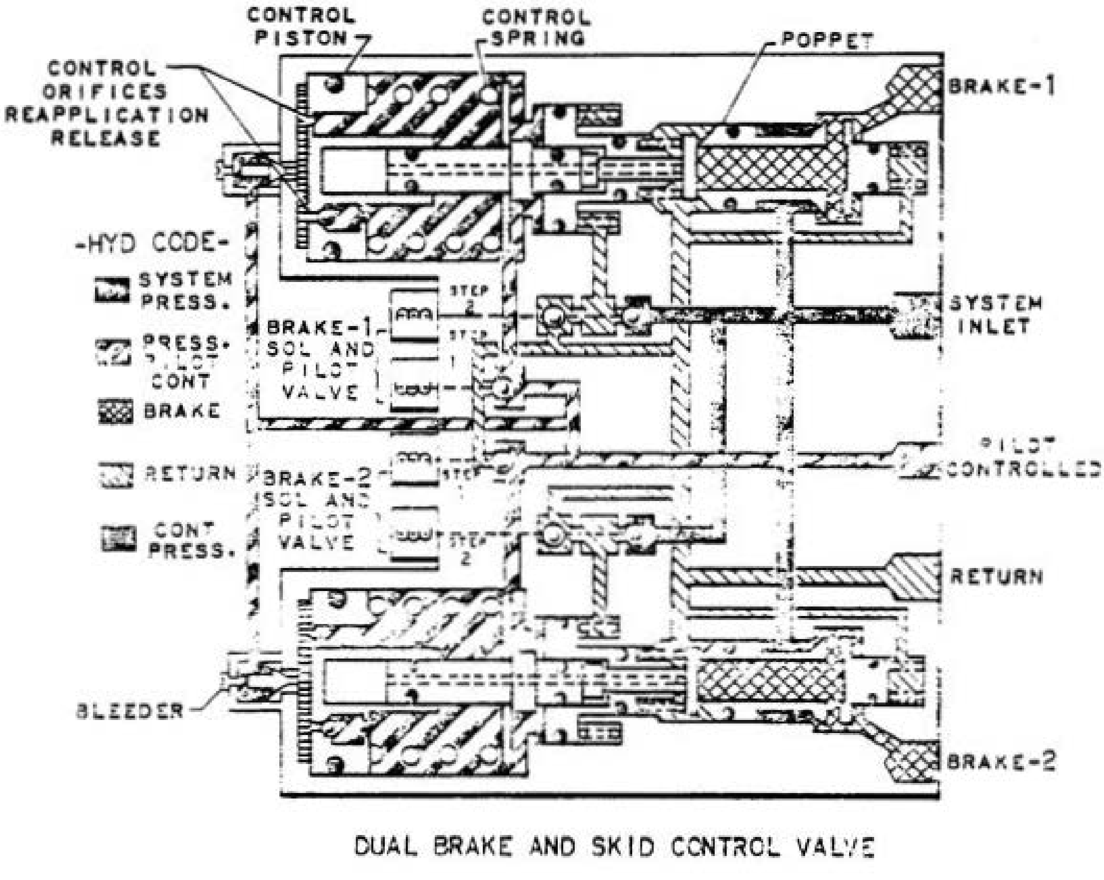
BRAKE AND ANTI-SKID SYSTEM CONTROL PANEL AND INDICATOR LIGHTS opilot's brake linkages are interconnected by torque tubes and bellcranks which ermit brake application from either position. The left pedals actuate the valve ear the pilot's outboard pedal, and the right pedals actuate the valve near the opilot's outboard pedal.

ach dual-pilot metering valve consists of two identical piston and sleeve metering ssemblies which are fitted into a dual-bore housing. Both pistons are actuated t the same time by movement of the brake pedals. Although both pistons are ctuated at the same time, pressure is applied through only one-half of the valve, epending on the system selected.

he pilot metering valves are pressure reducers whose output pressure is controlled by pedal movement as applied by the pilot or copilot. Force on the valve lunger causes the spool to move forward and align the spool's forward port with he pressure inlet port. As the spool moves forward, the spool's aft port is closed y the spool moving inside the sleeve. This stops fluid from moving into the return ort. A pressure buildup is then felt at the skid control valve if "NORM" is selected, r at the main metering valve if "EMER" is selected and also on the forward end of e main metering valve spool. The pressure build up, moves the spool aft, and ompresses the spring between the two forces. The pressure build up continues ntil the force generated by the pressure against the end of the spool equals the orce of the compressed spring. At this time both the pressure and return ports of e spool are covered and pressure at the skid control valve is maintained as set y pedal position. An increase in pedal force causes a corresponding increase in essure until the forces are again equal. A decrease in pedal force causes the eater force, generated by pressure against the end of the spool, to move the spool t until the metering pressure is connected to return through the hollow spool. The ressure decreases until the forces are again equal. When the valve is in the brake-ff position, the outlet port is connected to return and the inlet port is blocked.

our skid control valves are installed in the normal brake system. The skid control lves are located in the cargo compartment, two on each side aft of the hydraulic stem service centers. The valves have two functions: as metering valves and as id control valves. Two valves are contained in each valve body, and each of the lves provides both metering and skid control for a wheel. Metered fluid from e pilot metering valve enters an anti-skid valve and is directed to the control ston. As pressure builds up on the control piston, the spool is moved to overme the control spring. This movement unseats the metering poppet which ports draulic pressure from the main landing gear down line into the brake assemblies. e amount of poppet opening depends upon the pressure from the pilot metering lve.

Upon first application of pilot-controlled pressure to the control piston of the skid control valve, the valve metering poppet opens fully to supply fluid from the inlet port to the brake port. This assures fast flow of fluid into the brakes and low pressure braking action starts. In order to allow brake response to low pilot-controlled pressure up to approximately 200 PSI, a preload piston is employed to load the preload spring onto the metering poppet. Above 200 PSI the control piston, acting through the control spring, controls the brake pressure. At pressure above 200 PSI, the solenoid valve meters brake pressure into the brakes at a predetermined rate that requires approximately 1.5 seconds for full brake pressure to be applied. The relatively slow buildup of brake pressure assures that skid control can take place before there is severe overshoot of brake pressure.



DUAL BRAKE AND SKID CONTROL VALVE

As pressure builds up in the brake assembly, the preload piston is moved back which compresses the preload spring; and from this point, further movement of the preload piston compresses the control spring. When the force generated by pressure on the preload piston and the control spring tension are equal, the metering poppet will be closed which shuts off inlet pressure. When pilot-controlled pressure is removed by releasing the brake pedals, the pressure in the brake assembly moves the preload piston back further, and fluid flows between the preload piston and the metering poppet to return.

The skid control portion of the metering valve is solenoid-operated with two steps of operation. Each step is controlled by a solenoid-operated pilot valve which modulates both brake pressure release and reapplication to provide brake retarding force and to prevent skidding. The first step provides modulated brake pressure by controlling its increase or decrease to a relatively low rate of pressure change. The second step provides rapid, and complete brake release followed by rapid return of pressure to a value slightly less than the pressure existing at the time of release.

With the step 1 and 2 solenoids deenergized and upon initial application of brakes, the metering poppet is closed. When pilot-controlled pressure reaches 25 to 100 PSI in the control cylinder, the force on the control piston is sufficient to initiate metering action.

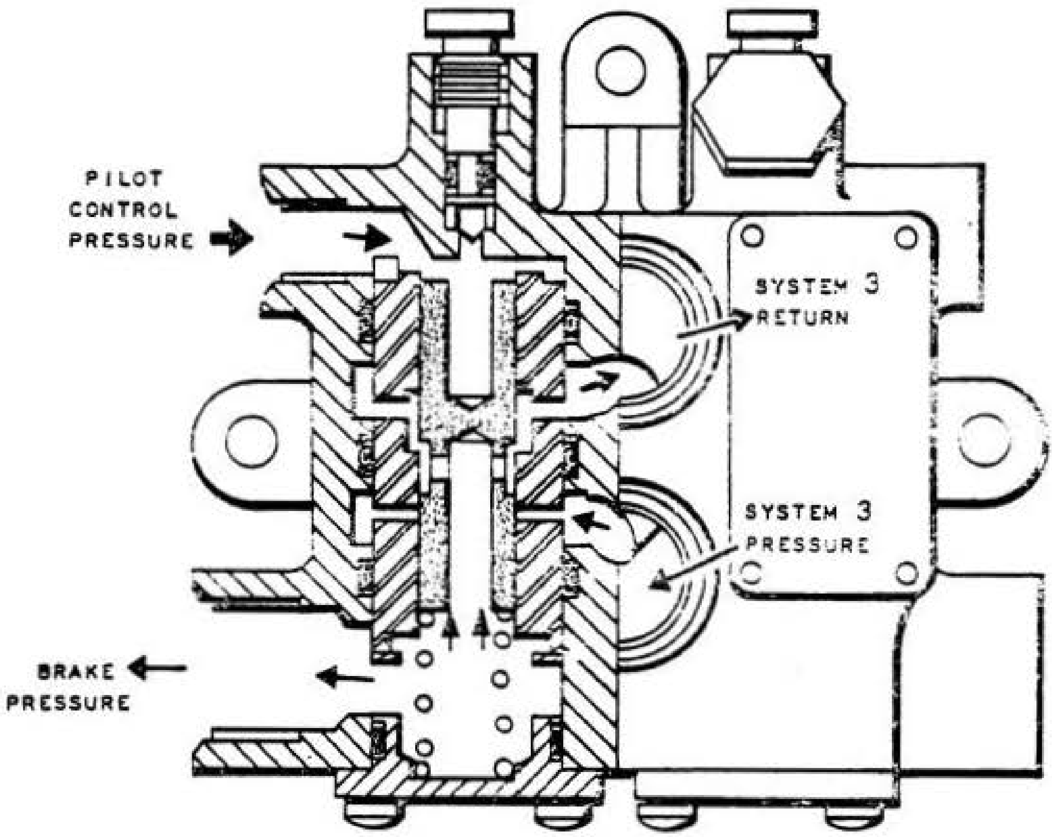
When the step 1 solenoid is energized, the related pilot valve is actuated to shut off the pilot-controlled pressure and to allow the flow of fluid out of the control cylinder. The metering poppet return seat opens to system return and allows the brake pressure to be reduced proportionately with the decreasing spring force, which is dictated by the position of the control piston. Brake release time is shorter than application time; this is accomplished by using a control orifice which has a check valve that permits fluid flow through it only during brake release.

When the step 2 solenoid is energized, the related pilot valve directs full system pressure to the preload piston causing it to move rapidly and open the metering poppet return seat, which allows release of the brake pressure. At the same time, the control spring force is being reduced by fluid flow out of the control cylinder through the step 1 pilot valve. The longer the release lasts, the lower the pressure will be at which metered reapplication starts.

Pressure reapplication occurs when both step 1 and step 2 solenoids are deenergized. Pilot-controlled hydraulic fluid flows through the step 1 pilot valve to the control cylinder and the preload piston. Fluid flows from the rod end to the head end of the control piston through the control orifice. The control piston moves to increase the control spring load at a rate dictated by the size of the orifice. This causes opening of the metering poppet to a degree such that the brake pressure on the return seat always balances the increasing spring force.

The dual main metering valve for emergency brake operation is installed in the cargo compartment aft of the No. 2 hydraulic system service center. The metered pressure output from one-half of each of the dual-pilot metering valves is routed to the main metering valve. One-half of the main metering valve is for the left brakes and the other half is for the right brakes.

The main metering valve pressure output is controlled by pressure from the pilot metering valves. Control pressure is applied to the end of the spool and forces it to move which aligns the opening in the spool with the pressure port. As pressure builds up in the brake assemblies, this pressure is also felt on the outlet end of the spool and it generates a force which opposes the force generated by the control pressure. The spool is forced to move back and the pressure port is closed

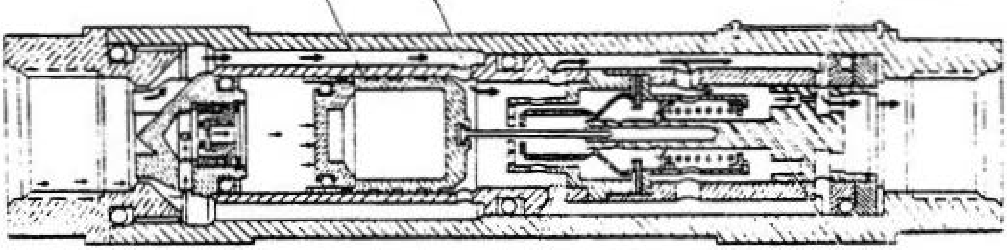


EMERGENCY BRAKE MAIN METERING VALVE

to prevent a further build up of pressure to the brake assemblies. When the brake pedal is released, control pressure is reduced and allows the spring tension and pressure at the outlet port to move the spool back to port the pressure from the brake assemblies to return.

Manifolds, shuttle valves, and hydraulic fuses are installed in the cargo compartment on each side aft of the hydraulic system service centers.

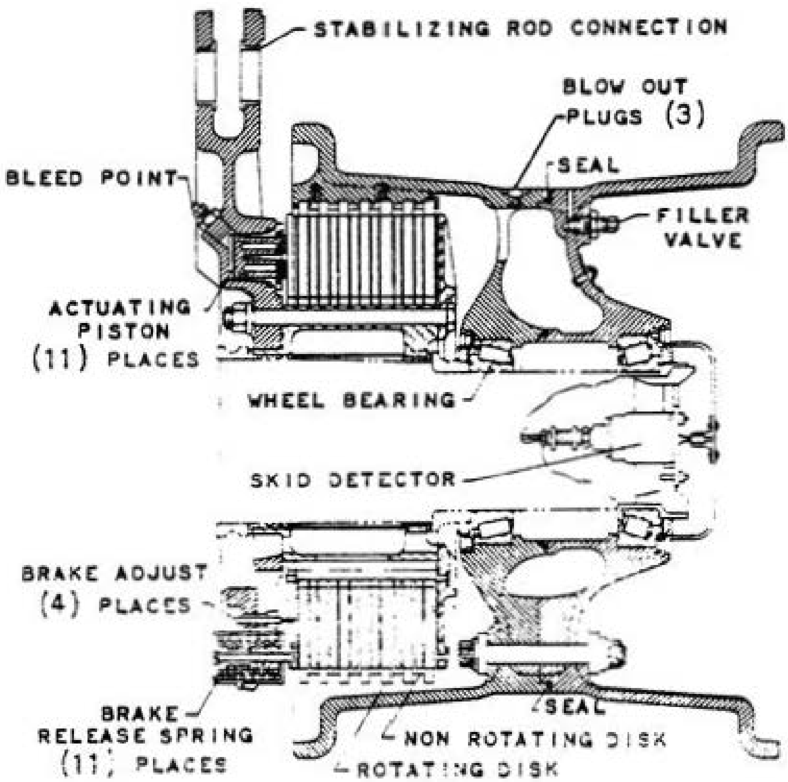
Eight hydraulic fuses are installed in the normal brake system. The hydraulic fuse is a valve that blocks a hydraulic pressure line when fluid is passed in excess of the calibrated capacity of the fuse. Once closed, the fuse will remain closed until its piston is unseated by reverse fluid flow. Without this protection, the failure of a hydraulic line or component downstream from the valve could cause complete loss of fluid in the system. The calibrated capacity of the fuses is 20 cubic inches of fluid. The fuses have a totalizing capability which allows them to sum the amount of fluid which passes through.



HYDRAULIC FUSE

During landing gear retraction the main landing gear wheels are braked by return fluid from the main landing gear system. The restricted fluid in the return line is felt through the skid control valves into the brake assemblies.

A multiple-disk, manually-adjusted brake is installed on each main wheel. Hydraulic fluid under pressure pushes eleven equally-spaced pistons against a non-rotating disk. This action compresses a disk assembly. Half of the disks within the assembly rotate with the wheel. The other half, spaced alternately between the rotating disks, are non-rotating. Each non-rotating disk is sintered iron, which provides friction against the steel rotating disks. The rotating disks are held in place by means of retainer blocks which are splined to the wheel assembly. Compressing the disks provides the braking action by pressing the non-rotating disks which cannot move. Eleven brake release spring-loaded devices are fastened to the inner non-rotating disk. When hydraulic pressure is released from the piston, the spring-loaded device pulls the disk away, allowing the wheels to turn. Four manual adjustment screws provide a means of compensating for normal wear of the brakes. A bleed plug is provided to remove the air from the brake assembly.



WHEEL BRAKE ASSEMBLY

ANTI-SKID.

The anti-skid control system is primarily based on controlling the skid in its beginning stage. Skid control is provided over a speed range covering the maximum landing speed to a minimum taxi speed of approximately 15 knots. Below 15 knots the anti-skid system is inoperative.

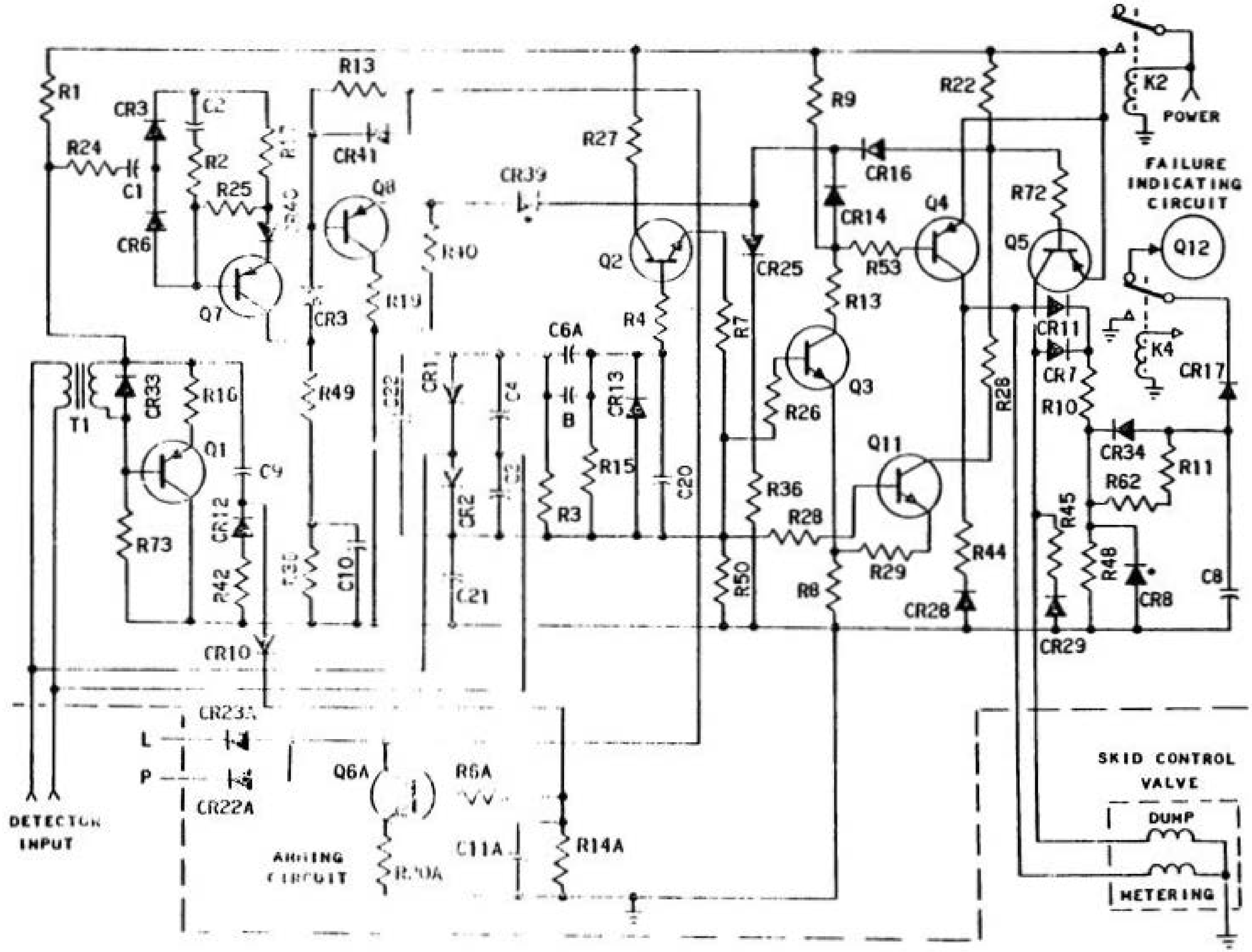
The arming of the locked wheel circuits causes the step 1 and the step 2 solenoids to energize in the skid control valves and prevents pressure from being applied to the wheel brakes. The BRAKES REL light on the brake pressure and anti-skid panel will be illuminated. After touchdown, each locked-wheel control circuit is armed through the locked-wheel arming circuit.

This circuit receives its energy signal from the rotation sensing circuit and is energized as long as any one wheel is rotating at a speed in excess of 15 knots.

When the wheels begin to rotate above 100 RPM after the aircraft touches down, both the locked-wheel sensing circuit and the rate-sensing circuit begin to control braking action. When the anti-skid detector supplies a changed signal, the rate-sensing circuit energizes the step 1 control circuit. This control circuit will amplify the signal and energize the step 1 power circuit which energizes the step 1 solenoid of the skid control valve. The skid control valve then releases some of the pressure being applied to tne wheel brake and allows the wheel to turn which prevents a skid. If the signal change is great enough, the step 2 control circuit will energize the step 2 power circuit after a short time delay. The step 2 solenoid of the skid control valve "dumps" the applied hydraulic pressure to the wheel brake and sends the fluid to the system return which removes braking action. As the wheel begins to pick up speed, the step 2 solenoid is deenergized and skid protection is again available. The skid control valve will meter pressure to the wheel brakes to give maximum braking without skid or locked wheels until the aircraft slows below approximately 15 knots.

The apparent skid is detected in the rate sensing circuit which receives alternating current from the detector alternator. This current is rectified into direct current; it is then filtered and sent to a deceleration sensing circuit. The output of this circuit is amplified by a transistor amplifier which drives two power transistors for step 1 and step 2 brake release. Two levels of sensitivity which operate these two steps are provided in a sensitivity-ratio control circuit which produces two different voltage levels for the signal to the power transistors. The step 1 power transistor receives the higher signal voltage resulting in reduced sensitivity for step 2. A time delay of approximately 0.1 second in the operation of step 2 is provided by a capacitance time-delay circuit at the input to the step 2 power transistor.

A locked wheel is detected by the rotation-sensing circuit which is part of the locked-wheel control system. This system uses the current supplied from the secondary of a transformer whose primary is connected to the detector alternator. This current is amplified by a transistor amplifier stage and then rectified and filtered to provide D-C voltage to a transistor circuit which drives the power transistors. When a wheel comes to a low speed or stops and the locked-wheel arming circuit is energized, the locked-wheel control circuit causes step 1 and step 2 brake release power transistors



ANTI-SKID CONTROL CIRCUIT

to be energized and allows fast brake release.

The anti-skid DET OUT light illuminates as an indication of single brake release that continues for more than 2.5 seconds. A failure that causes a continuous release of brake pressure will result in the K1 relay becoming energized after about 2.5 to 3.0 second time delay. The relay normally closed contacts provide a grounding circuit for the first failure indicating light. If there are no other brakes with a continuous release, skid control continues for all other wheels.

Failures that result in a continuous release of two or more brakes for more than 3.5 to 4.5 seconds will turn the power off the control system to revert the brakes to manual control. A continuous brake release of two or more brakes for 3.5 to 4.5 seconds, causes the K3 relay to pull-in and short out the K2 relay. When the K2 relay drops out, the power is removed from the skid control circuit and a ground is provided to illuminate the ANTI-SKID OFF lights.

NOSE GEAR STEERING

GENERAL DESCRIPTION.

The nose landing gear (NLG) steering system contains a steering column and steering wheel, a steering actuator, and a steering control valve; it also contains the necessary pulleys, chains, and cables to interconnect the steering components. The components contained in the rudder pedal steering linkage consist of a hydraulic connecting actuator and the levers and sprockets required to interconnect the rudder pedal steering function with the steering wheel steering function. Pressure for the steering system is supplied by the No. 2 hydraulic system through the nose landing gear selector valve and associated tubing.

Turning the steering wheel or depressing the rudder pedals, causes the steering control valve to direct pressure to the appropriate end of the actuating cylinder. This cylinder turns the nose wheels in the selected direction. A maximum of 80-degrees rotation left or right is possible through the wheel steering system. A maximum of eight-degrees rotation left or right is possible by depressing the rudder pedals. When the load is removed from the nose gear, centering cams within the strut returns the nose wheels to the line-of-flight position in preparation for retraction of the gear.

THE SYSTEM.

The steering wheel and column assembly is located forward and to the left of the pilot's position. The steering column assembly consists of an upper and lower assembly with a gearbox and indicator between the two sections. The gearbox reduces the effort required to initiate steering movement from the steering wheel and the indicator indicates position of the nose wheel in relation to the line-of-flight.

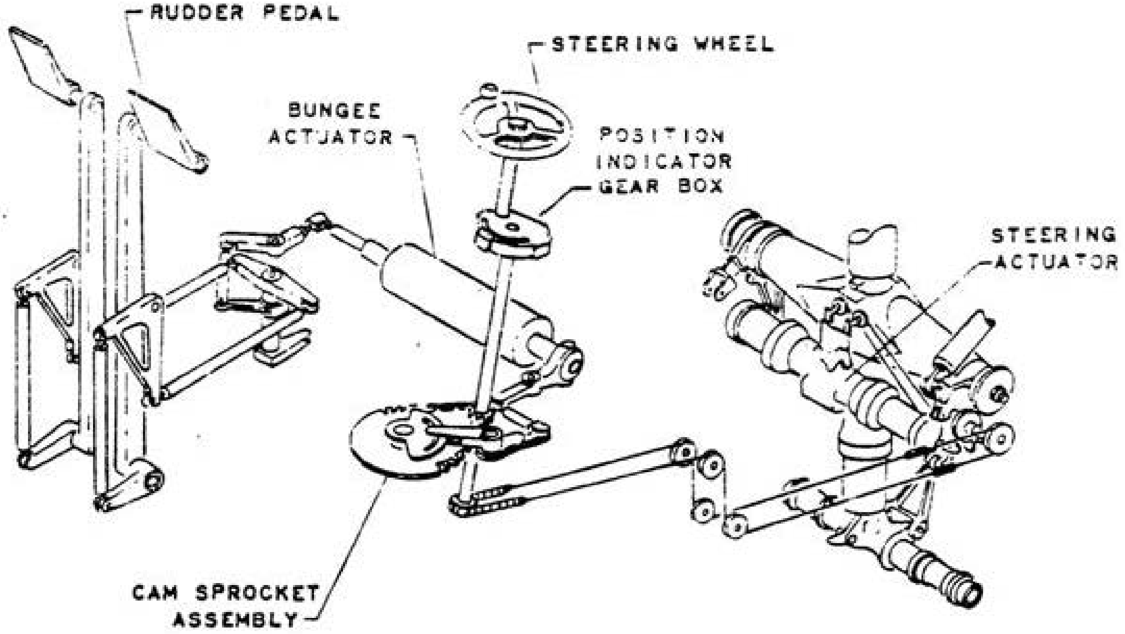
The rudder pedal steering assembly is connected to the lower portion of the steering column. Rudder pedal movement is transmitted to the steering column by bellcranks, a hydraulic-spring "bungee" actuator, a cam and sprocket, and a roller chain. The rudder system connects to the steering system through the hydraulic-spring "bungee" actuator which also serves as a clutch between the two systems.

Operation of the rudder pedals will provide eight degrees of steering either side of straight ahead. Further deflection of the nose wheel has to be made by rotating the steering wheel. The "bungee" actuator has a lost motion which allows unrestricted castering of two degrees either side of center.

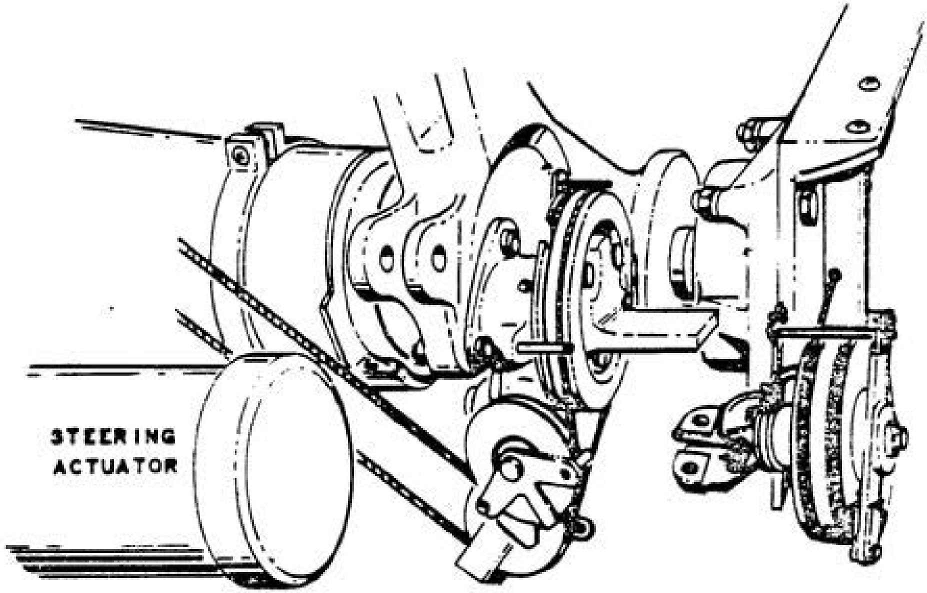
No. 2 hydraulic system pressure is directed into the "bungee" actuator when the aircraft is on the ground and/or when the main landing gear wheel speed is above 50 knots. Hydraulic pressure applied to the "bungee" actuator causes it to become a fixed link capable of transmitting rudder pedal movement to the steering column. However, the springs in the "bungee" actuator will compress allowing the rudder pedals to be held and the nose wheel to be steered by the steering wheel.

Upon take-off and when the main wheels have decreased in speed to below 50 knots, hydraulic pressure is removed from the "bungee" actuator. Removal of hydraulic pressure increases the lost motion in the "bungee" actuator thereby disconnecting the rudder system from the steering system.

When the nose landing gear is extended, movement of the steering column is transmitted through a sprocket attached to the lower end of the steering column. Rotational movement of the sprocket is transmitted to the control cable by a bicycle-type chain attached to the cable ends. The cable, in turn, is attached to the output pulley and disconnect assembly. This assembly is secured to the wheel well structure



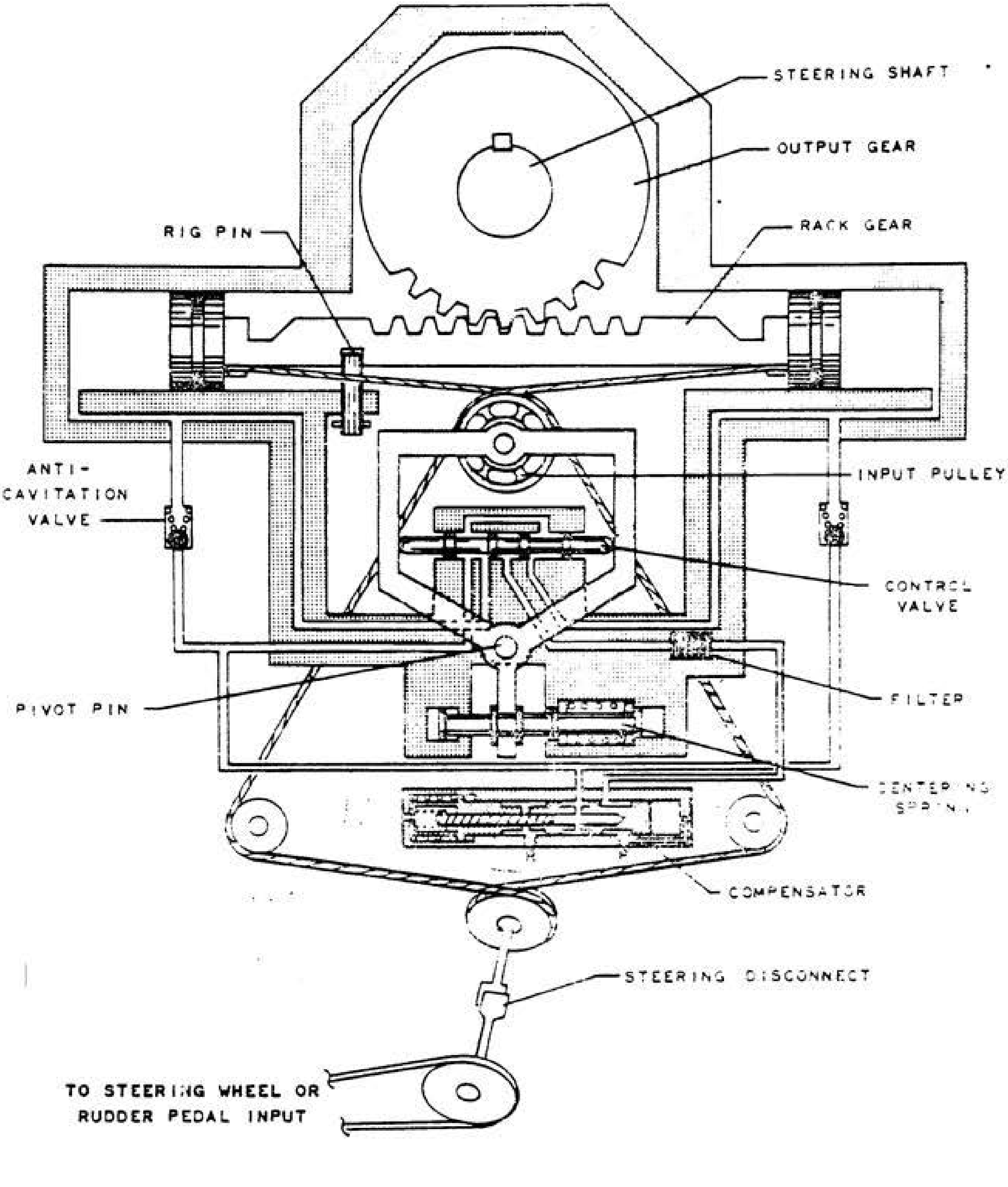
NOSE GEAR STEERING CONTROL LINKAGE



NOSE STEERING DISCONNECT

near the NLG trunnion. When the NLG is retracted, movement of the gear separates the disconnect assembly, and the steering column is locked in the neutral position. Locking the steering column in neutral assures that the two halves of the disconnect assembly engage when the NLG is extended. Cables from the disconnect assembly transmit movement to the steering control valve on the nose strut.

The nose wheels are steered by two horizontally opposed cylinders mounted forward on the shock strut. The pistons are connected to a rack gear which engages a sector gear arranged to convert reciprocal motion to rotary motion in a sleeve extending below the steering cylinders. The sector gear is connected by torque links to the axle housing. Steering motion is initiated through a control valve, operated by the steering control wheel or the rudder pedals, which directs fluid under pressure to the right or left cylinder to rotate the wheels in the direction desired. Fluid flow is shut off by a self-cancelling control arrangement when the desired steering angle is reached. Hydraulic pressure is available to the steering system only when the landing gear control handle is in the "DN" position and No. 2 hydraulic system pressure is available.



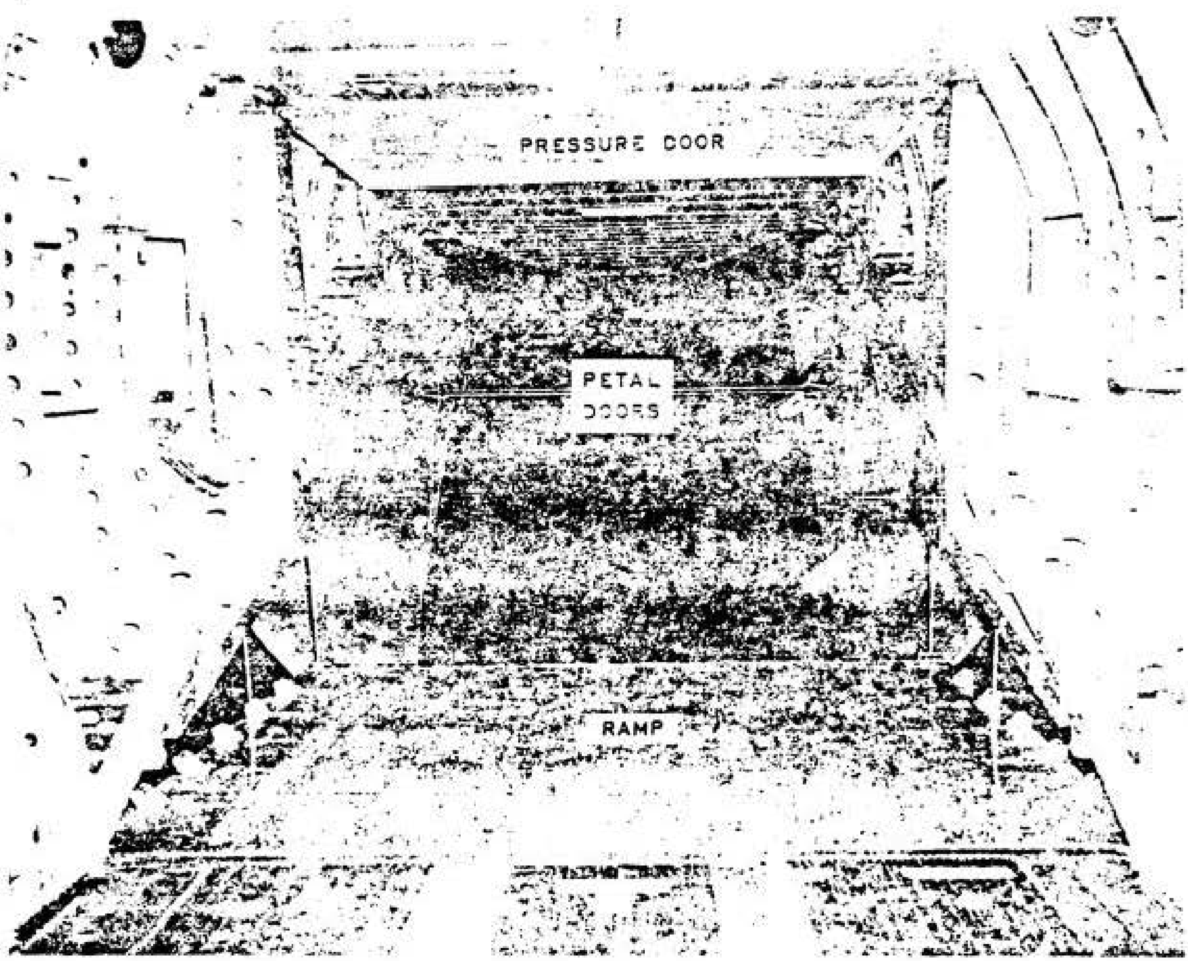
STEERING CONTROL MANIFOLD

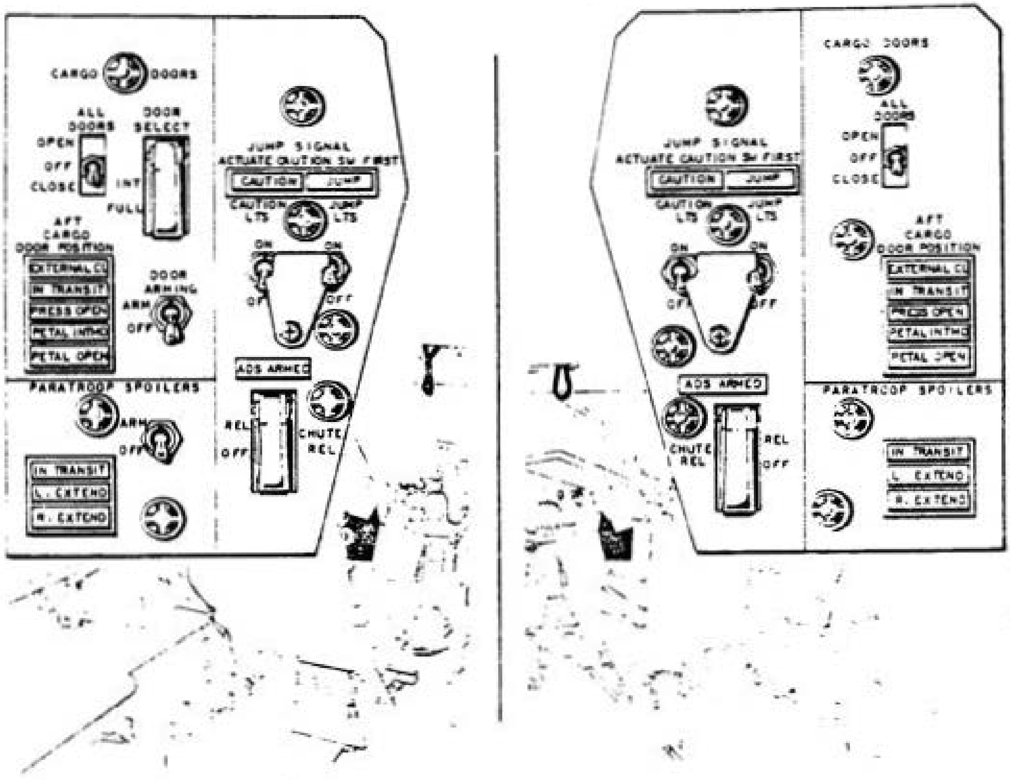
Rotation of the steering column applies a tension load to one input cable and causes the opposite cable to relax, initiating a rotation within the input pulley and link steering servo actuator assembly. Rotation of the input pulley and link positions the hydraulic control valve to connect pressure to one actuating cylinder cavity while connecting the opposite cavity to the hydraulic system return. Hydraulic pressure applied against the actuating piston moves the piston and rack gear causing rotation of the output gear and nose landing gear wheels. Continual rotation of the steering column will hold the control valve and input linkage in this position, causing the wheels to turn until the rotation of the steering column is stopped or until the 80-degree limit is reached. When the input motion from the steering column is stopped, the steering piston equalizes the tension load of the input cables and moves the control valve and input linkage to a neutral position. Should the castering torque load become sufficient to create a slight movement in the steering piston, it will position the control valve to direct pressure into the cylinder against the piston, driving it back to the selected position. In the absence of input loads, the input centering mechanism will hold the control valve in a neutral position allowing interflow between the actuating cylinder cavities by way of the return passages and allowing the nose gear wheels to rotate in response to castering loads. The interflow or by-pass cavities also provide dampening for nose wheel shimmy.

CARGO RAMP, PRESSURE DOOR, AND PETAL DOORS

GENERAL DESCRIPTION.

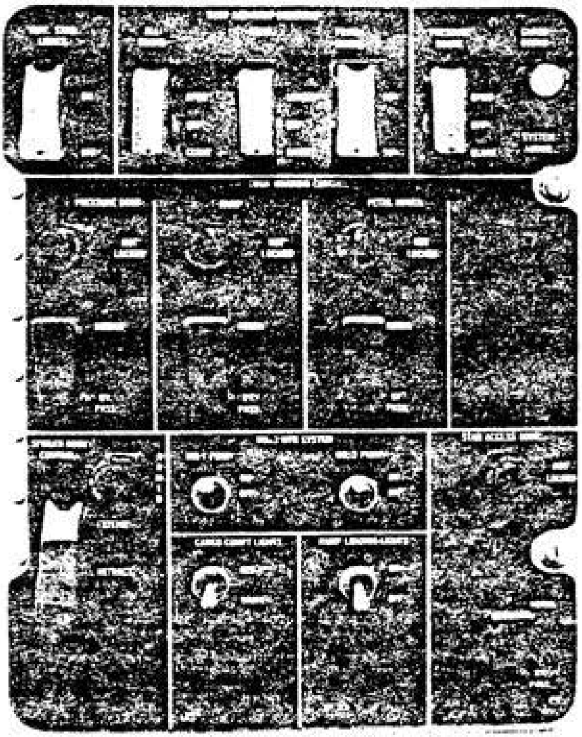
The StarLifter is equipped with two hydraulically actuated clamshell-type petal doors, a pressure door, and a cargo ramp. Hydraulic pressure for operation of the doors and ramp system is supplied by the No. 3 hydraulic system.





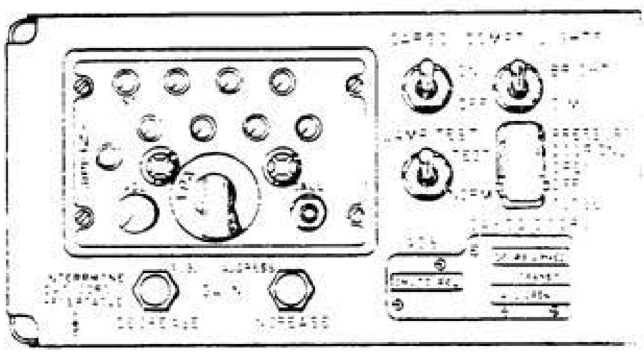
PARADROP AND ADS CONTROL PANELS

There are four separate control panels from which the doors and ramp system can be operated. The pilot's paradrop and aerial delivery system (ADS) control panel, the copilot's paradrop and ADS control panel, the DOOR AND RAMP CONTROL PANEL and the crew door interphone and public address (PA) panel. The pilot's and copilot's paradrop and ADS control panels are located in the flight station. From these panels, all of the doors and the ramp may be operated in flight only. The DOOR AND RAMP CONTROL PANEL is located aft of the left paratroop door. From this panel, all of the doors and the ramp may be opened or closed on the ground, and all doors and the ramp may be closed in flight. The crew door interphone and PA control panel is located aft of the crew entry door. This panel contains a PRESSURE DOOR ONLY switch that will open or close the pressure door in flight or on the ground.



DOOR AND RAMP CONTROL PANEL

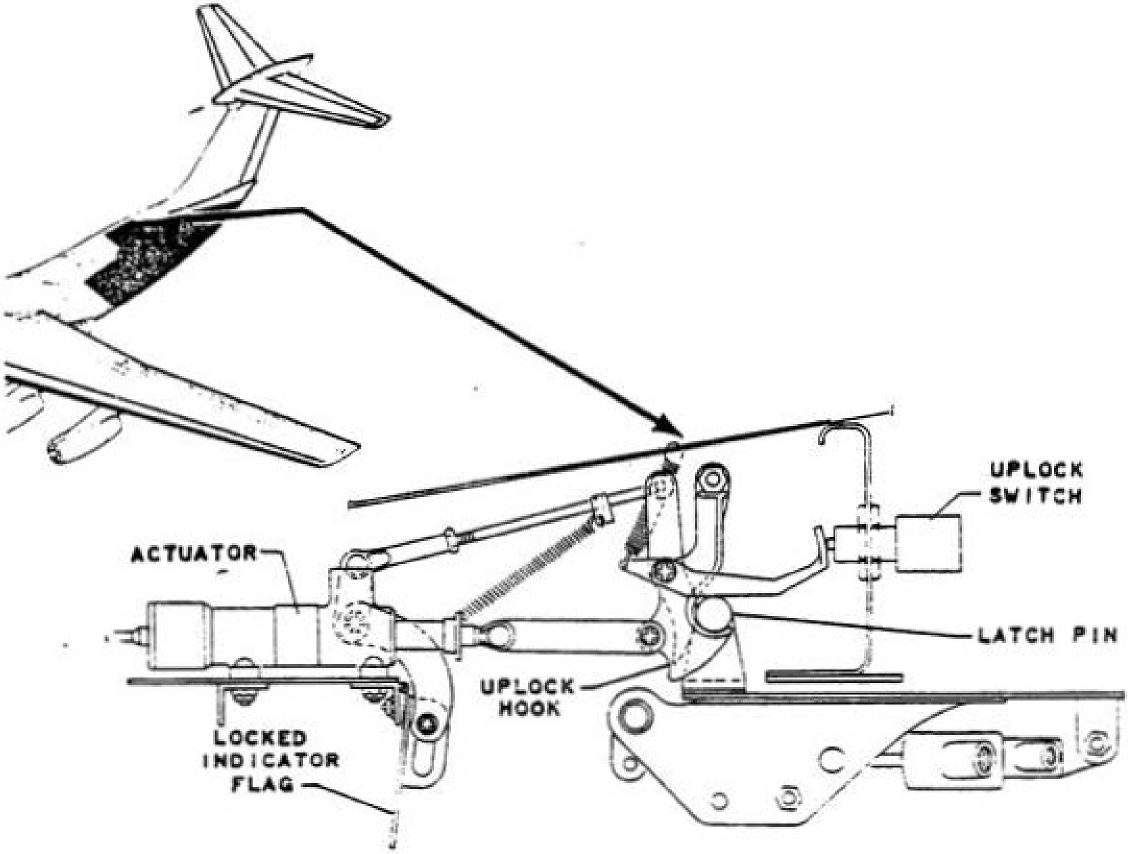
The petal doors have three open positions: 38 degrees, 65 degrees, and 80 degrees. The 80-degree position is for ground use only. The pressure door has one open position: full open. The cargo ramp may be stopped in any position from full up to 13 degrees below horizontal. However, for airdrops the ramp is restrained horizontally by a pair of stop links. The ramp may be lowered to rest on the ground, for loading vehicles, by disconnecting the stop links.



CREW DOOR INTERPHONE AND PA CONTROL PANEL

THE SYSTEM

PRESSURE DOOR - The aft pressure door is approximately ten feet wide and seven feet high and provides the aft closure for the cargo compartment. The aft pressure door opens in conjunction with the petal doors and the cargo ramp to provide an unobstructed opening into the rear of the cargo compartment. The pressure door is hinged at the top. When the pressure door is closed, it latches to the ramp which is in the up position. A single hydraulic actuator, which is attached near the top of the pressure door and to the aft fuselage overhead deck, opens and closes the door.



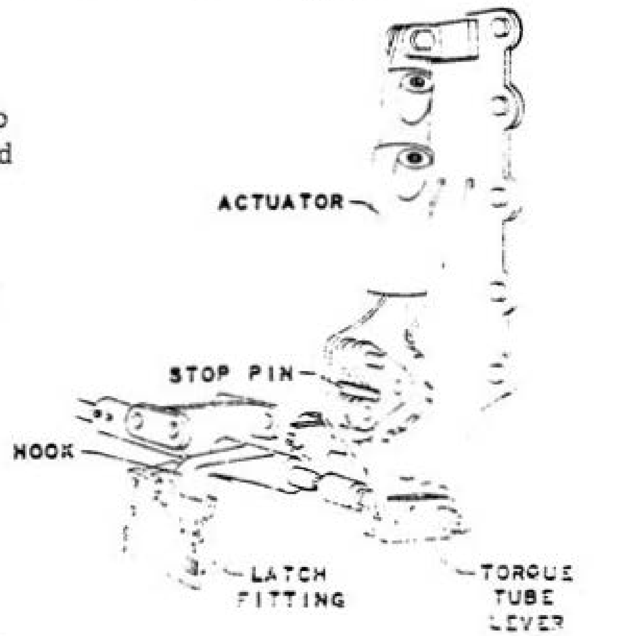
PRESSURE DOOR UPLOCK

A spring-locked and hydraulically-released uplock, which is mounted in the aft fuselage overhead deck, locks the pressure door to the open position. A latch pin, which is bracket mounted to the aft side of the pressure door, strikes the uplock hook and moves it aft as the pressure door nears the full open position. As the door reaches the full open position, a spring in the hydraulic actuator forces the hook under the latch pin and locks the door. With the door in the full open position the latch pin positions two levers: one lever displays a visual locked indicator flag and the other actuates the pressure door uplock switch. The pressure door uplock switch is used in the system to control the indicator lights and to sequence the movement of the ramp and the petal doors. To release the uplock mechanism, hydraulic pressure is directed to the uplock actuator. The actuator retracts and pulls the hook from under the latch pin. As the door moves down, the locked indicator flag is retracted and the uplock switch moves to the not locked position.

Two pressure-door-lock actuators are installed in the door to operate the 13 hooks which latch the pressure door to the ramp. One actuator is installed on each side near the bottom of the pressure door. Two torque tubes, one having six hooks and one having seven hooks are connected to the actuators. As the actuators extend, they rotate the torque tubes which position the hooks into the latch fittings on the aft upper end of the ramp. When the hooks engage the latch fittings, the actuating linkage is overcenter locked. Two mechanically actuated locked indicators protrude inside the cargo compartment from the lower center of the pressure door as a visual indication for the locked condition. Retracting the pressure door lock actuators brings the actuating linkage out of overcenter locked and disengages the hooks from the latch fittings.

Two pressure door locked switches are actuated when the hooks engage the ramp latch fittings. The switches are mounted on the aft end of the ramp and are actuated by the innermost hook on each torque tube. The pressure door locked switches are used in the indicator lights circuits and in the doors and ramp system control circuits.

Two pressure door unlocked switches are installed on the bottom of the pressure door. They are located near the center of the door at the ends of the torque tubes. These switches are individually actuated by corresponding cams on the torque tubes. The switches are used in the doors and ramp system control circuits.

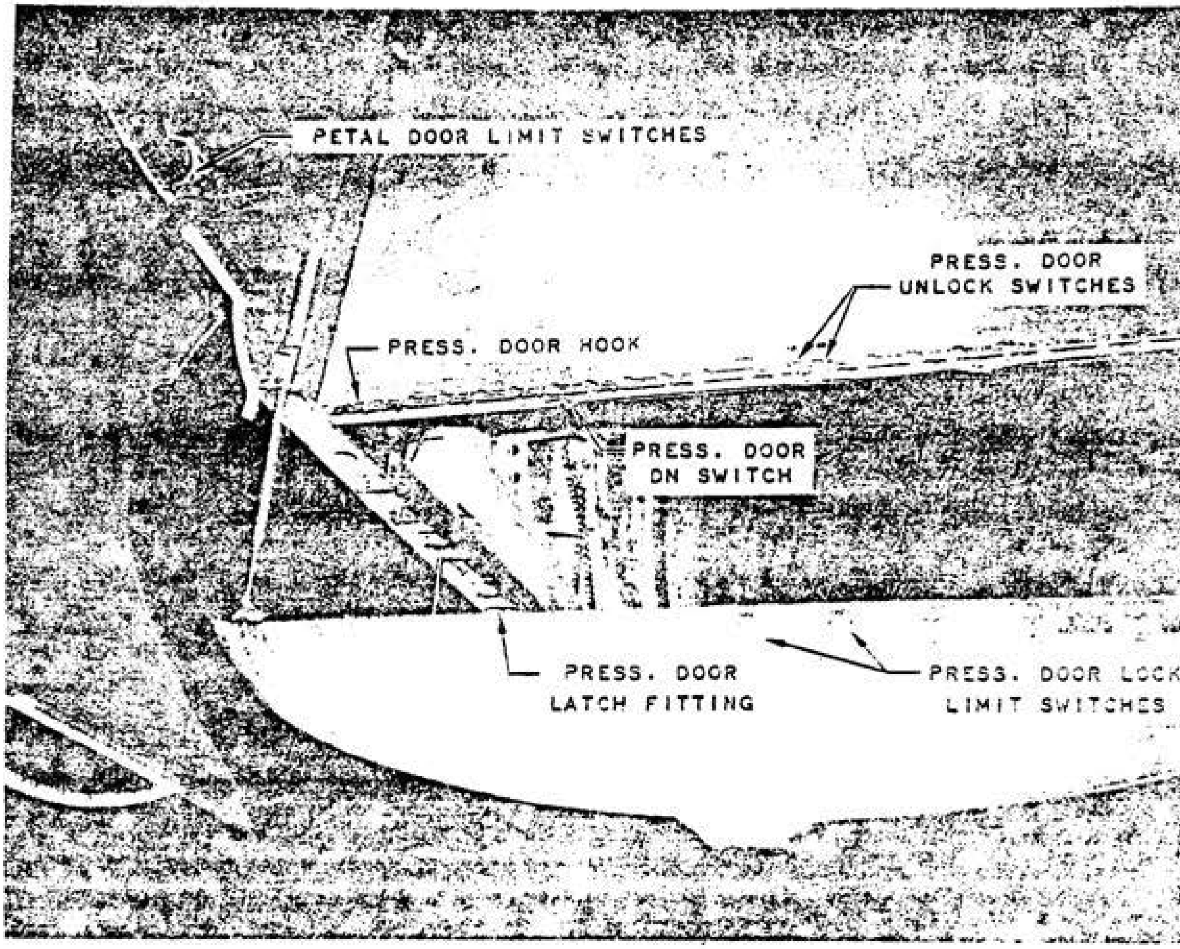


PRESSURE DOOR LOCK ACTUATOR AND LOCKS

Two pressure door down switches are mounted on the pressure door and are actuated when they make contact with the aft end of the ramp. These two switches are used in the control circuit to permit the pressure door to be locked when it is down against the ramp and in position.

RAMP

A cargo ramp, approximately nine feet wide and ten feet long, provides cargo floor level and ground loading access to the full width of the cargo compartment.



[illegible] AND DOOR COMPONENTS

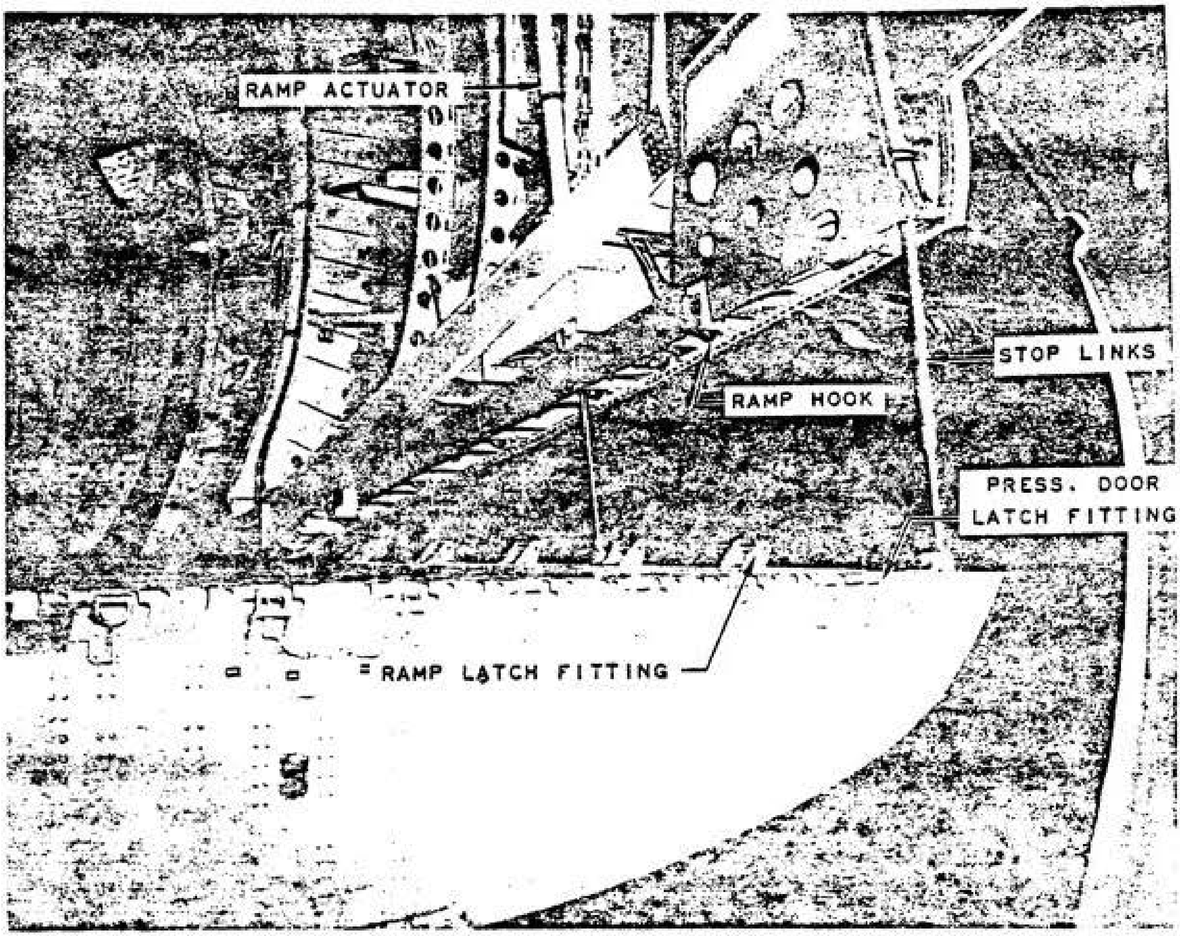
[illegible]

[illegible] in the [illegible] sitions. [illegible]

[illegible] rotates [illegible] each hook.

A visual [illegible] in [illegible] at each hook station. [illegible]

Two [illegible] switches, one left and one right, are install[illegible] near the [illegible] ends of the ramp lock torque tubes. The ramp [illegible]

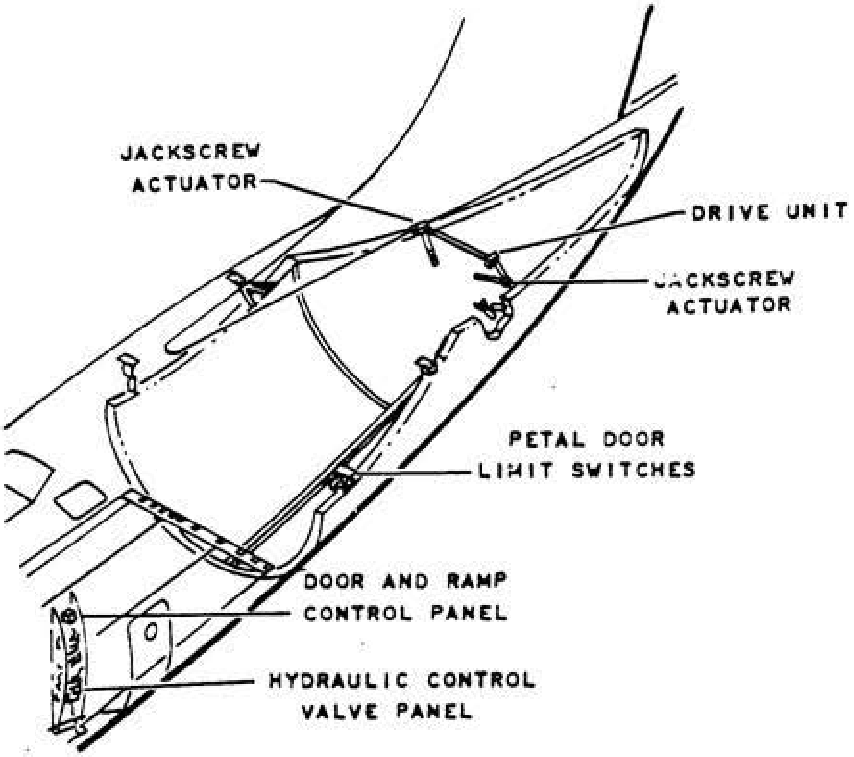


RAMP COMPONENTS

actuated by the aft most latch fitting when the ramp is [illegible] [illegible] in the [illegible]

Four ramp lock switches are installed [illegible] ramp lock torque tubes. When the torque tubes have rotated to the locked position, [illegible] in the indicator lights circuits.

A spring-loaded catch assembly holds the actuator attach pin which prevents vibration from unlocking the ramp. The slotted end of the actuator allows the retracting motion of the actuator to first release the catch assembly and then to engage the attach pin which rotates the torque tubes to unlock.

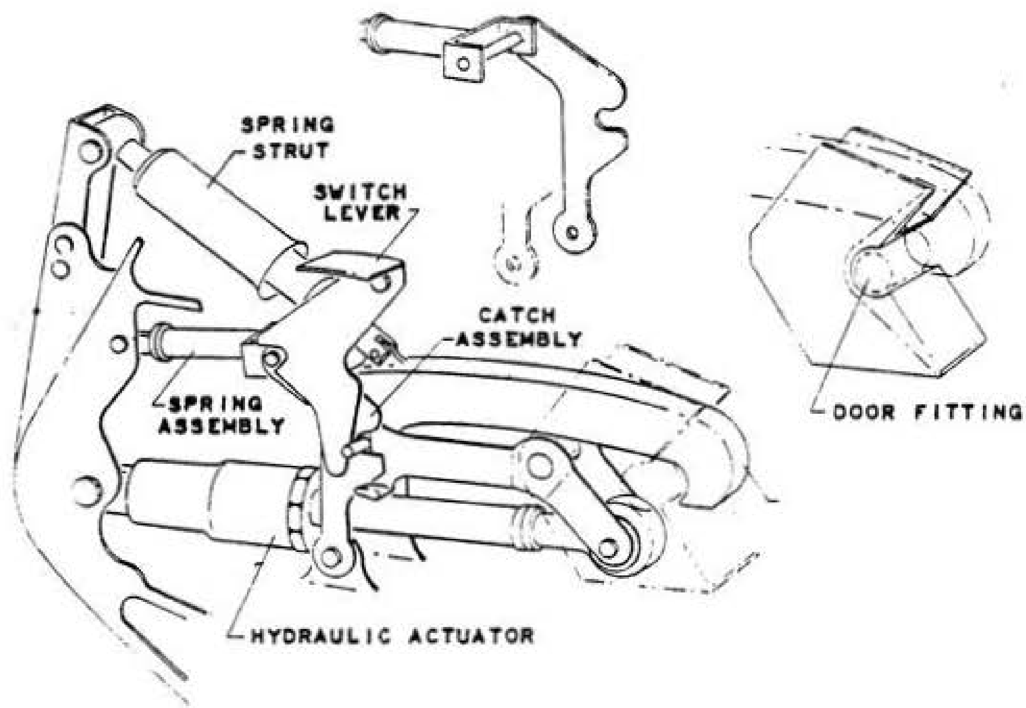


PETAL DOOR COMPONENTS

doors are hinged, on their upper edges, to the aircraft structure and open outward to 38, 65, or 80 degrees. The doors are actuated by a single hydraulic motor and gear box driving two jackscrew actuators, one for each door.

The drive motor and gear box assembly is located along the center line of the aircraft in the aft fuselage area. A reversible hydraulic motor, a reduction gear box, and a hydraulic limit valve make up the drive assembly. The hydraulic limit valve is positioned by rotation of the gear box. When the gear box has rotated an equivalent of the 65-degree door open position, the limit valve will stop the flow of hydraulic fluid to the drive motor. The limit valve may be by-passed by putting the PETAL DOORS switch, located on the DOOR AND RAMP CONTROL PANEL, in the "80°" position which causes the petal doors to open to the 80-degree position. Provisions are made for attaching a handcrank to the gear box for manual operation of the petal doors.

The housings for the jackscrew actuators are gimbel mounted to aircraft structure. Self-aligning bearings attach the jackscrews to the petal doors. A torque tube connects each jackscrew actuator to the gearbox assembly. Mechanical stops are provided to limit extension and retraction of the jackscrews, but the stops do not make contact if the electrical control circuit is functioning properly.



PETAL DOOR LOCKS

Two hydraulically-actuated latching mechanisms with locking hooks are provided on the lower inboard edge of the left petal door. When the petal doors are closed, the locking hooks are rotated to engage corresponding fittings on the right petal door and to lock the doors in the closed position.

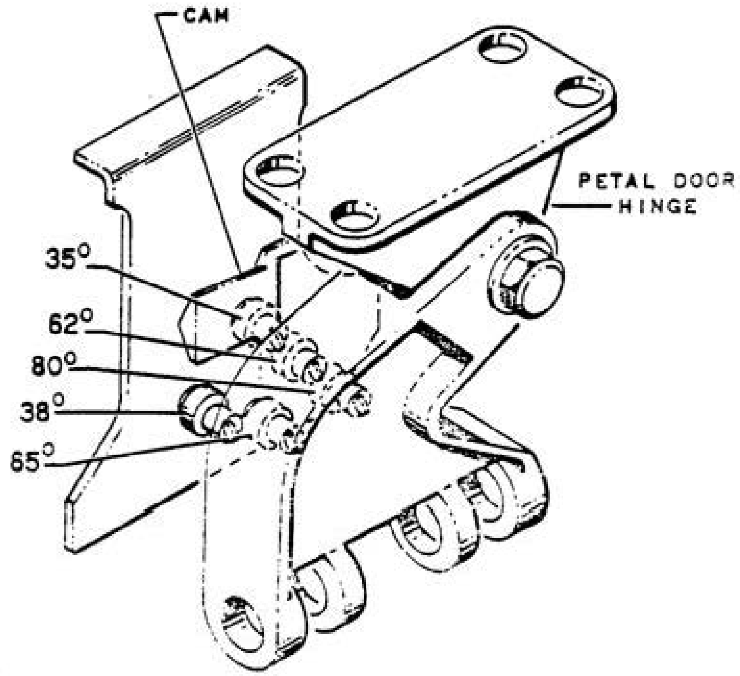
Each of the petal door locks is operated by a double acting hydraulic actuator which extends to lock and retracts to unlock. A spring strut, attached to the locking hook, positions the hook to engage the latch fitting on the right petal door when the actuator extends. When the hooks are fully locked, the actuating linkage goes overcenter and is held there by a catch assembly.

A petal door overcenter locked switch is installed at each petal door lock and is actuated by a switch lever when the actuator arm attach pin is in the notch of the catch assembly. The petal door overcenter locked switches are used in the indicator lights circuits.

A notch in the spring-loaded catch assembly receives the actuator arm attach pin; this prevents vibration from unlocking the hooks. As the actuator retracts, a cam on the actuator arm moves the catch assembly back to release the attach pin and allows the locking hooks to rotate to the unlock position.

A petal door unlocked switch is installed at each lock assembly. These switches are actuated by the locking hooks when the hooks are in a fully unlocked position. The length of the spring strut causes the end of the hook to move up and actuate the unlocked switch when the actuator is fully retracted. Hydraulic pressure is maintained on the retract side of the actuators when it is necessary to hold the petal door unlocked switches in the actuated position. The petal door unlocked switches are used in the doors and ramp system control circuits.

Five petal door limit switches are installed at the forward hinge of the left petal door. A cam, attached to the door, actuates one of the switches at each of the following petal door positions: 35 degrees, 38 degrees, 62 degrees, 65 degrees, and 80 degrees. The petal door limit switches are used in the indicator lights and doors and ramp control circuits. The 35-degree and 62-degree switches are used in the indicator lights circuits. The 38-degree, 65-degree, and the 80-degree switches are door travel limit switches.



PETAL DOOR LIMIT SWITCHES

A petal door closed switch, installed at each petal door lock assembly, is actuated by a lever which contacts the right petal door when the doors are closed. The petal door closed switches are used in the doors and ramp system control circuit.

HYDRAULIC OPERATION.

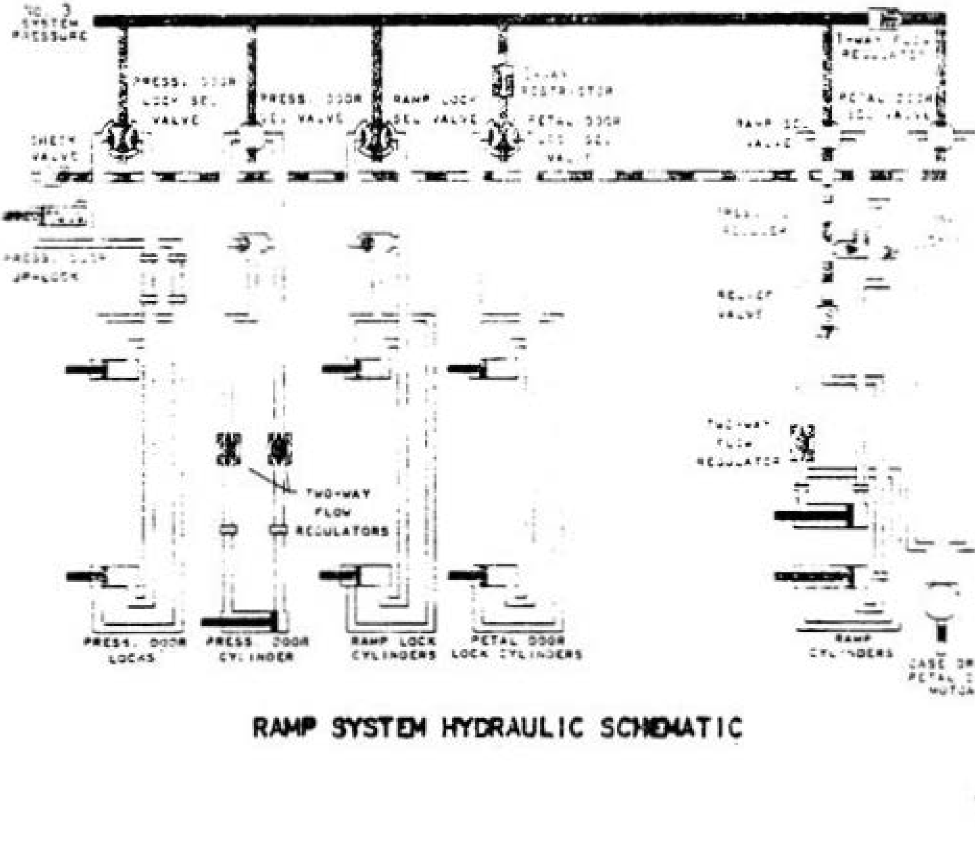
Six solenoid operated valves are used to direct hydraulic flow for operation of the doors and ramp system. These valves are:

1. Pressure door actuator control valve
2. Pressure door lock control valve
3. Ramp control valve
4. Ramp lock control valve

5. Petal door control valve
6. Petal door lock control valve

All six valves are located on a valve panel aft of the DOOR AND RAMP CONTROL PANEL and are designed to permit manual operation when electric power is not available.

The pressure door actuator control valve directs the flow of hydraulic fluid to the "open" or "close" side of the pressure door actuator. A pressure door shuttle valve is provided to separate the "open" and "close" sides of the pressure door actuator during the door-opening cycle, and to connect the "open" and "close" sides of the actuator during the door-closing cycle. The shuttle valve is installed between the "open" and "close" lines from the pressure door actuator to the pressure door actuator control valve. Two pressure door flow regulators are used to regulate the speed of the pressure door, during the opening and closing cycles, by controlling the flow rate of hydraulic fluid to the pressure door actuator. The flow regulators are installed in the lines between the shuttle valve and the pressure door actuator. The pressure door lock control valve directs the flow of hydraulic fluid to "lock" and "unlock" the pressure door and to release the pressure door uplock.



RAMP SYSTEM HYDRAULIC SCHEMATIC

The ramp control valve directs the flow of hydraulic fluid to the up or down side of the ramp actuators. A ramp pressure-reducing valve reduces the hydraulic pressure to 410 PSI at the down side of the ramp actuators. The pressure reducing valve is installed in the upper portion of the control valve panel. A flow regulator controls the speed of the ramp, during the lowering and raising cycles, by regulating the flow rate of the hydraulic fluid to or from the ramp actuators. The flow regulator is installed in the up line between the ramp actuators and the ramp control valve. The ramp lock control valve directs the flow of hydraulic fluid to the lock or unlock side of the two ramp lock actuators.

The petal door control valve directs the flow of hydraulic fluid to the open or close side of the petal door drive motor which operates the jackscrew-type door actuators through a central gearbox and torque tube arrangement. A petal door flow regulator in the pressure line regulates the flow of hydraulic fluid to the control valve, thus regulating the speed of the petal door drive motor. The petal door lock control valve directs the flow of hydraulic fluid to the lock or unlock side of the petal lock actuators.

ELECTRICAL CONTROL AND OPERATION.

The doors and ramp are normally controlled electrically from either of the paradrop and ADS control panels or from the DOOR AND RAMP CONTROL PANEL. Only the pressure door may be electrically controlled from the interphone and PA control panel. Indication and warning lights for the doors and ramp are located on the four control panels, on the navigator's panel, and on the annunciator panel in the flight station.

PARADROP AND ADS CONTROL PANELS

Both the pilot's and the copilot's paradrop and ADS control panels contain an ALL DOORS switch with "OPEN," "OFF," and "CLOSE" positions. Placing this switch in the appropriate position will cause the doors and the cargo ramp to open or close simultaneously. The pilot's panel also contains a two-position DOOR ARMING switch with "ARM" and "OFF" positions; it must be in the "ARM" position before any door movement will occur. Also on the pilot's panel is a DOOR SELECT switch with "INT" and "FULL" positions. The position of the DOOR SELECT switch determines the position to which the petal doors will open. In the "INT" position, the doors open to 38 degrees, and in the "FULL" position, the doors open to 65 degrees.

DOOR AND RAMP CONTROL PANEL

Doors and cargo-ramp control switches located on the DOOR AND RAMP CONTROL PANEL are as follows: an ALL DOORS switch, a PETAL DOORS switch, a PRESSURE DOOR switch, and a RAMP switch. This panel also contains control switches for the No. 3 hydraulic system pumps.

The ALL DOORS switch has "OPEN" and "CLOSE" positions to simultaneously control all doors. The RAMP switch has "LOWER" and "RAISE" positions to control ramp position and the PETAL DOORS switch has "80°" and "55°" positions for selection of the amount of petal door opening on the ground. The PRESSURE DOOR switch has three positions: "OPEN," "OFF," and "CLOSE." This permits independent operation of the pressure door.

CREW DOOR INTERPHONE AND PA CONTROL PANEL

The PRESSURE DOOR ONLY switch, on the crew door interphone and PA panel, has three positions: "OPEN," "OFF," and "CLOSE." It is the only switch on the panel which will affect door movement. This switch permits ground or in flight operation of the pressure door, if the static line "A" frame actuators are not installed when the system is armed by the DOOR ARMING switch.

When the ALL DOORS control switch on the pilot's or copilot's paradrop and ADS panel is in the "CLOSE" position, the close relay is energized and power is supplied through the energized door-sequence relay to the close solenoid of the petal door actuator control valve. With the petal doors open, the petal doors actuator limit switch provides a ground path for the close solenoid of the petal door actuator control valve through the door-sequence relay through the energized close relay and the ramp-down switches. The close solenoid is now energized which positions the petal door actuator control valve to close; hydraulic pressure is now ported to the petal door drive motor. The petal doors start to close and when they reach the 80-degree or the 55-degree position, the applicable limit switch opens. As the limit switch, selected by the DOOR SELECT switch, is opened, the all open relay is deenergized and the magnetic coils are energized. This holds the ALL DOORS control switch in the "CLOSE" position; however, the ALL DOORS control switch must be held manually in the "CLOSE" position until the magnetic coils are energized.

When the petal doors are completely closed, the petal doors closed switches are actuated to complete the ground circuit for the lock solenoid of the petal door lock control valve. Hydraulic pressure is then ported to the lock sides of the petal door lock actuators to lock the petal doors. The petal door actuator limit switch, when actuated, breaks the ground circuit of the door sequence relay and causes it to deenergize. When deenergized, the door sequence relay directs power to the up solenoid of the ramp control valve. Hydraulic pressure is then directed to the retract or up side of the ramp actuators.

When the ramp is in the full up position, the ramp up switches are actuated. One switch grounds the lock solenoid of the ramp lock control valve; the other provides a path for power which is supplied through the close relay to energize the lock solenoid. Hydraulic pressure is then ported to both ramp lock actuators which lock the ramp in the closed position.

When the ramp is up and locked and the petal doors are closed and locked, a circuit is completed through the ramp locked switches and the petal doors locked overcenter switches to the PRESSURE DOOR switch. From the PRESSURE DOOR switch the circuit is completed through the pressure door down switches and the static line "A" frame retract switches to energize the unlock solenoid of the pressure door lock control vlave.

When the static line "A" frame actuators are installed in the aircraft, only the PRESSURE DOOR switch on the DOOR AND RAMP CONTROL PANEL will close the pressure door. If the static line "A" frame actuators are not installed in the aircraft, adapter plugs are installed in the actuator connectors. When the adapter plugs are installed, the pressure door will close and lock in sequence without using the PRESSURE DOOR switch.

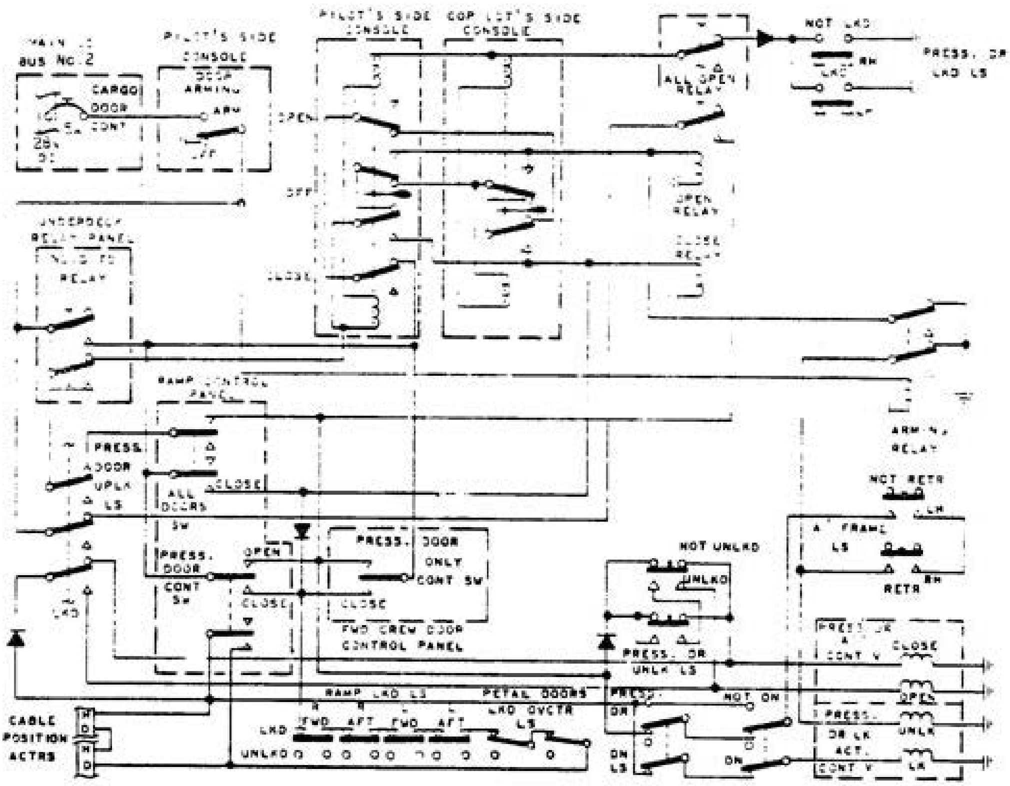
The circuit to the pressure door actuator control valve open solenoid is completed through the pressure door uplock switch. Hydraulic pressure is ported to the pressure door actuator which preloads the pressure door to the open position. It is also ported to the unlock sides of the pressure door lock actuators and to the pressure door uplock actuator, which releases the spring-loaded pressure door up-lock mechanism.

When the pressure door uplock is released, the pressure door uplock switch is actuated. This breaks the circuit to the pressure door actuator control valve open solenoid and makes the circuit to the close solenoid. The close solenoid is then energized and hydraulic pressure is ported to the down side of the pressure door actuator to lower the pressure door. When the pressure door reaches the closed position, the pressure door down switches are actuated which breaks the circuit to the pressure door lock control valve unlock solenoid and energizes the lock solenoid. This ports hydraulic pressure to the lock sides of the pressure door lock actuators. The locks are actuated and the pressure door is locked in the closed position. When the pressure door is locked in the closed position, both pressure door downlock switches are opened. This releases the ALL DOORS control switch, on the paradrop and ADS control panels, to the "OFF" position and removes the power from the doors and ramp control circuits.

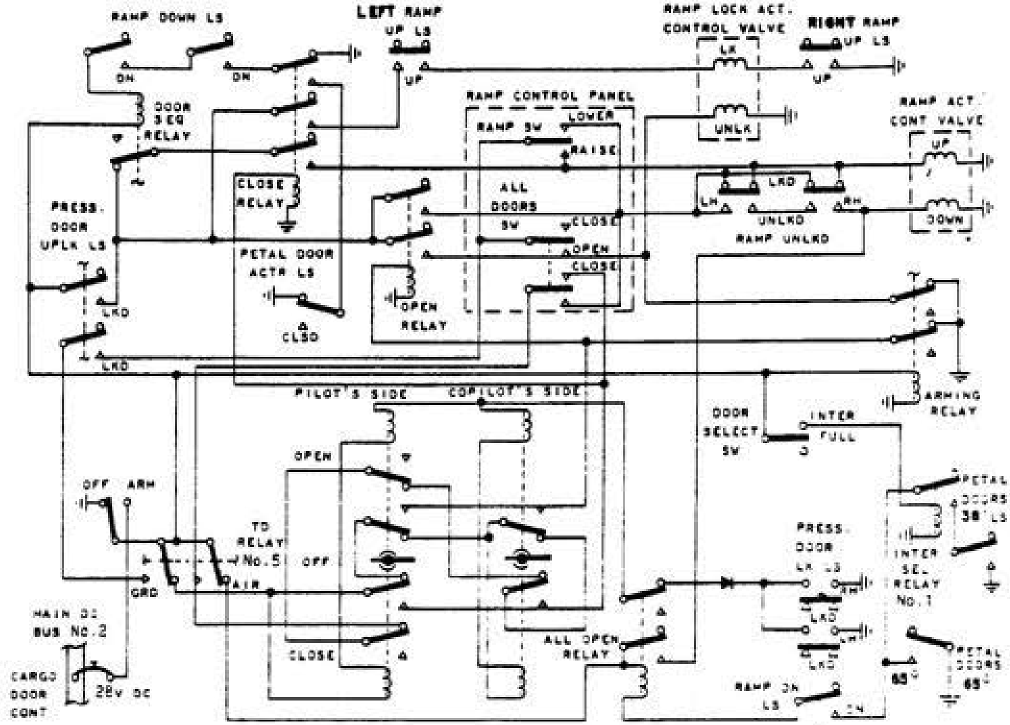
GROUND OPERATION OF THE DOORS AND RAMP.

When the DOOR ARMING switch is in the "ARM" position, power is supplied to the DOOR SELECT switch. Power is supplied through touchdown relay No. 5 to the PRESSURE DOOR ONLY control switch, to the PRESSURE DOOR control switch, and to the ALL DOORS switch on the DOOR AND RAMP CONTROL PANEL. Power is also supplied through the pressure door uplock switch to the ALL DOORS control switch on the DOOR AND RAMP CONTROL PANEL. The ALL DOORS control switches on the paradrop and ADS control panels are not connected into the control circuitry when the aircraft is on the ground and touchdown relay No. 5 is energized.

When the ALL DOORS switch, on the DOOR AND RAMP CONTROL PANEL, is held in the "OPEN" position, the pressure door is hydraulically preloaded to the closed



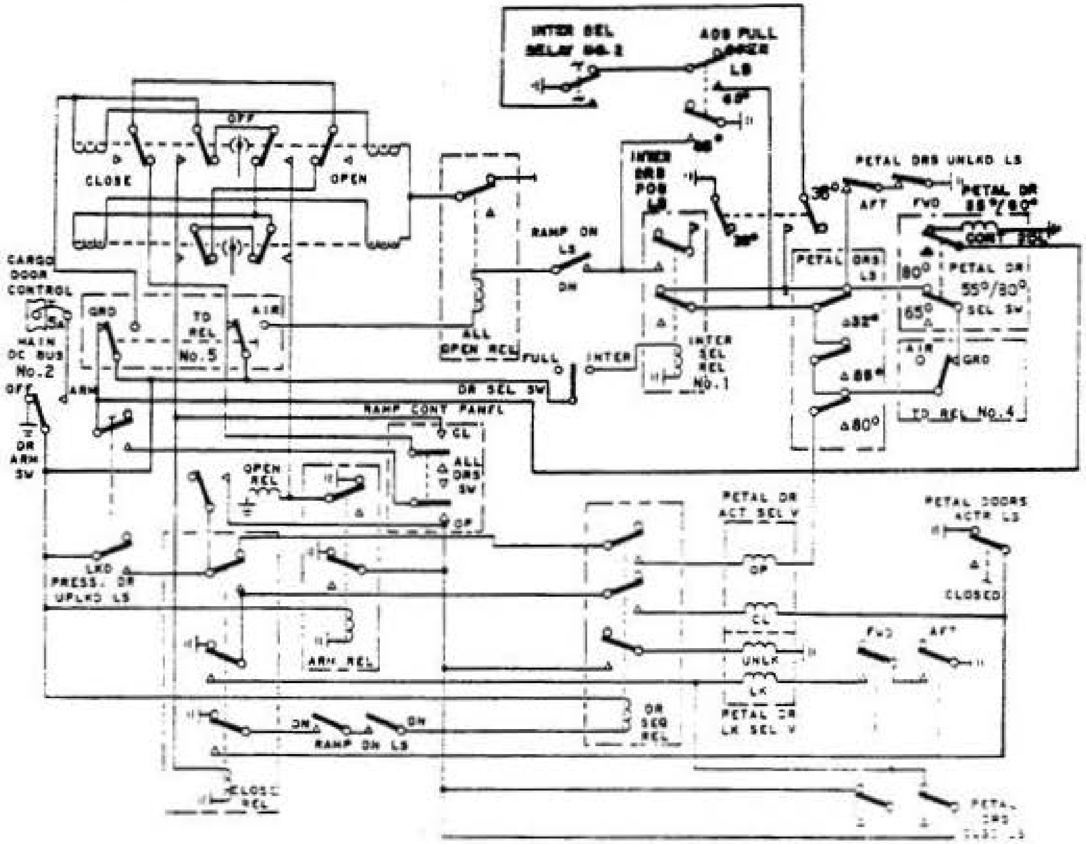
PRESSURE DOOR CONTROL SCHEMATIC



RAMP CONTROL SCHEMATIC

position and unlocked. When unlocked, hydraulic pressure is applied to the open port of the pressure door actuator, opening the pressure door. Electrical power is provided to the close solenoid of the pressure door actuator control valve through the not-unlocked contacts of the pressure door unlock switches. At the same time power is supplied through the pressure door [illegible] line "A" frame retract switches to the unlock solenoid of the pressure door lock actuator control valve. When the pressure door unlocks from the ramp, the pressure door unlock switches remove the electrical power from the close solenoid and [illegible] it to the open solenoid of the pressure door actuator control valve.

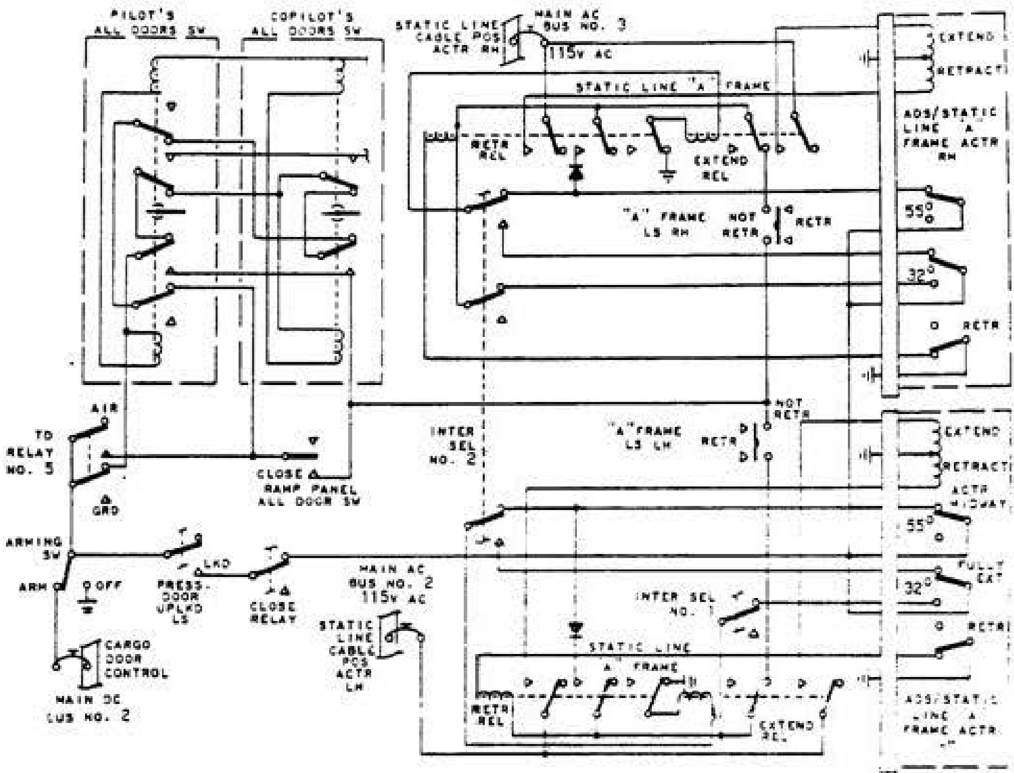
While the pressure door is opening, the up solenoid of the ramp actuator control valve is energized through the open contacts of the ALL DOORS switch and the locked contacts of the ramp unlock switches. The ramp is hydraulically preloaded. When the pressure door is locked in the up position, the pressure door uplock switch is actuated to cut off power to the pressure door lock and actuator control valves Power is then supplied through the ALL DOORS switch to energize the unlock solenoid of the ramp lock control valve. Hydraulic pressure is then ported to the retract sides of the ramp lock actuators to unlock the ramp. When the ramp is unlocked, the ramp unlock switches are actuated to deenergize the up solenoid of the ramp control valve and to energize the down solenoid. Hydraulic pressure is then ported to the down side of both ramp actuators to lower the ramp.



PETAL DOOR CONTROL SCHEMATIC

When the ramp reaches the horizontal position with the ramp stop links installed, the ramp down limit switches and the deenergized close relay provide a ground for the door sequence relay. Power is supplied to the unlock solenoid of the petal door lock actuator valve from the ALL DOORS switch through the energized door sequence relay.

Hydraulic pressure is ported to the unlock sides of the petal door lock actuators which unlock the petal doors. When the petal doors are unlocked, the petal door unlock switches are actuated to complete the ground circuit of the petal door control valve open solenoid. Two ground paths are available for the petal door control valve open solenoid. One ground is available through the petal door 80-degree limit switch, the 55-degree limit switch, the 32-degree limit switch, and the petal doors unlocked limit switches. The second ground, available only when the "80°" position is selected, is through the 80-degree limit switch, through TOUCHDOWN relay No. 4, and through the "80°" position of the PETAL DOORS select switch. With the open solenoid of the petal door control valve energized, hydraulic pressure is ported to the open side of the petal door drive motor which drives the petal doors open.



ADS/STATIC LINE ELECTRICAL SCHEMATIC

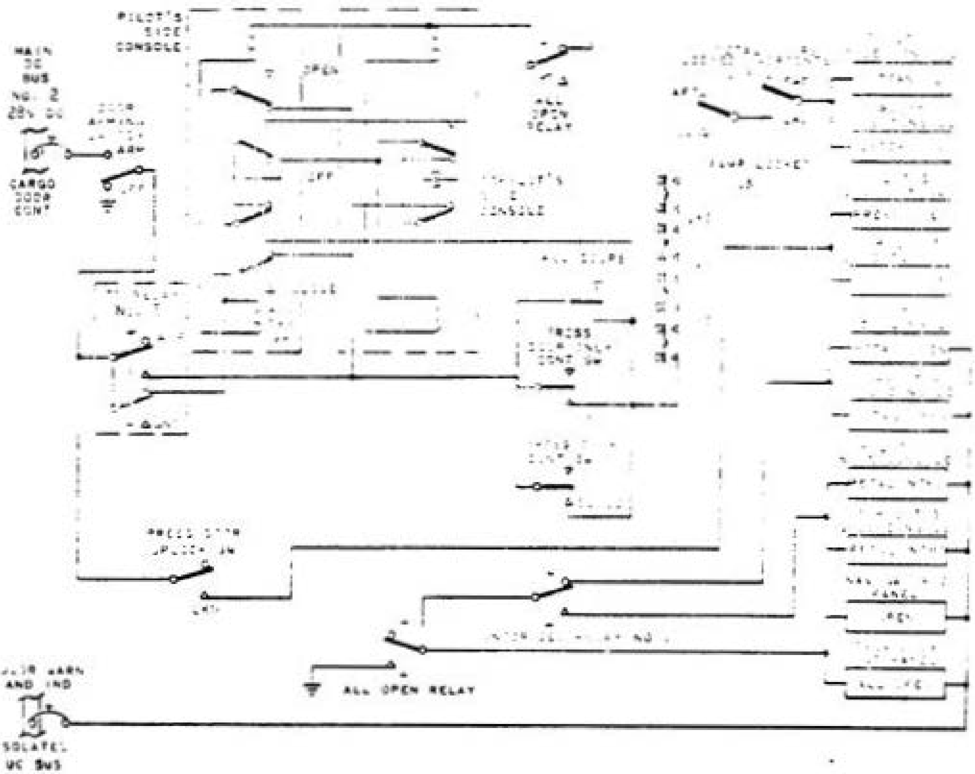
As the petal doors reach the selected position, the applicable limit switch actuates deenergizing the open solenoid of the petal door control valve; this stops the flow of hydraulic fluid to the petal door drive motor. When the ramp is lowered to the horizontal position and the petal doors are open to the selected position, the ALL DOORS control switch is released. If the ramp is to be lowered to the ground, the RAMP control switch is momentarily positioned to "RAISE" so the ramp stop links may be disconnected. After the ramps stop links are disconnected, the RAMP control switch is positioned to "LOWER." This energizes the down solenoid of the ramp control valve and ports hydraulic fluid into the down side of both ramp actuators which lower the ramp. The RAMP control switch must be held in the "LOWER" position until the ramp is lowered to the desired position.

When the petal doors are to be opened to the 80-degree position, the PETAL DOORS 55/80-degree switch is positioned to "80°." This bypasses the petal door 35-degree and 65-degree limit switches and energizes the petal door control solenoid valve on the petal door drive assembly. When the petal doors reach the 65-degree position, the petal door control valve reduces the flow of hydraulic fluid to the petal door motor and slows the speed of travel between the 65-degree and the 80-degree positions. When the petal doors reach the 80-degree position, the petal door 80-degree limit switch is actuated to break the petal door control valve open solenoid circuit. The solenoid is deenergized, which closes the valve and stops the petal door drive motor.

When the ALL DOORS control switch is positioned to "CLOSE," the opening sequence is reversed. The operation of the doors and ramp system is the same when controlled from the ALL DOORS switch on the DOOR AND RAMP CONTROL PANEL as when controlled from the ALL DOORS switch on the paradrop and ADS control panel. The ALL DOORS switch on the DOOR AND RAMP CONTROL PANEL must be held in position until the operation is complete.

CARGO RAMP, PRESSURE DOOR, AND PETAL DOORS INDICATOR LIGHTS.

Indication and warning lights for the doors and ramp are located on the pilot's and copilot's paradrop and ADS control panels, the crew door interphone and PA control panel, the DOOR AND RAMP CONTROL PANEL, and the navigator's ADS panel.

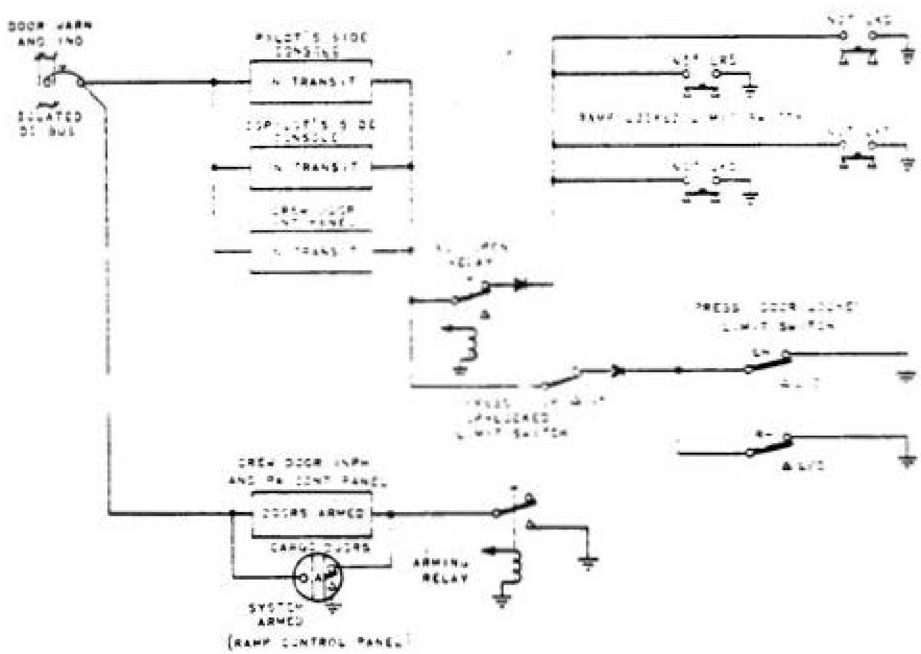


CARGO DOOR SYSTEM INDICATING SCHEMATIC

Paradrop and ADS control panels each contain an EXTERNAL CL light, an IN TRANSIT light, a PRESS OPEN light, a PETAL INTMD light, and a PETAL OPEN light. The EXTERNAL CL lights illuminate when the petal doors and ramp are closed-and-locked and electrical power is being applied to the pressure door close circuit. These lights remain on until the pressure door is closed-and-locked and the switch being used to close the pressure door is released to the "OFF" position. During the opening cycle the IN TRANSIT lights illuminate when the pressure door locked limit switches are actuated. These lights stay on until the ramp and petal doors are completely open and the all open relay is energized removing the ground for the light circuit. During the closing cycle the IN TRANSIT lights illuminate as soon as the petal doors start to close and remain on until the pressure door has locked to the ramp.

The PRESS OPEN lights illuminate when the pressure door is locked in the open position.

The PETAL OPEN lights illuminate when the petal doors reach the end of their travel and the all open relay is energized. The position of the DOOR SELECT switch on the pilot's paradrop and ADS control panel determines whether the PETAL



CARGO DOOR SYSTEM INDICATING SCHEMATIC

INTMD light or the PETAL OPEN light illuminates. The navigator's ADS panel contains an OPEN light which will be illuminated when the doors reach the end of their travel and the all open relay is energized.

The crew door interphone and PA control panel contains an ARMED light, an IN TRANSIT light, and an ALL OPEN light. The ARMED light illuminates when the DOOR ARMING switch is positioned to "ARM" and the arming relay is energized to complete the circuit. Because the IN TRANSIT light is in parallel with the IN TRANSIT lights on the pilot's and copilot's paradrop and ADS control panels, they will all be illuminated and extinguished at the same time. When the all open relay is energized, the ALL OPEN light illuminates. The all open relay is energized when the pressure door, the petal doors, and the ramp are open to the desired positions.

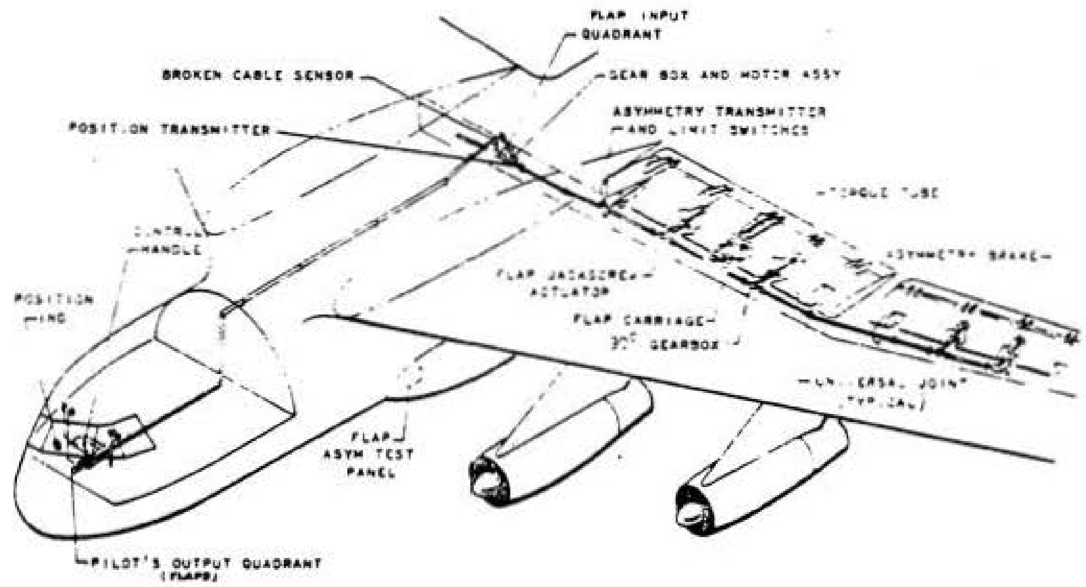
The DOOR AND RAMP CONTROL PANEL contains a CARGO DOORS SYSTEM ARMED light, a PETAL DOORS NOT LOCKED light, a RAMP NOT LOCKED light, and a PRESSURE DOOR NOT LOCKED light. Illumination of the CARGO DOORS SYSTEM ARMED lights occurs when the DOOR ARMING switch is positioned to "ARM" and the arming relay is energized. The RAMP NOT LOCKED light illuminates when the ramp is unlocked. When the pressure door is unlocked, the PRESSURE DOOR NOT LOCKED light illuminates. The PETAL DOORS NOT LOCKED light illuminates when the petal door is not locked.

WING FLAPS

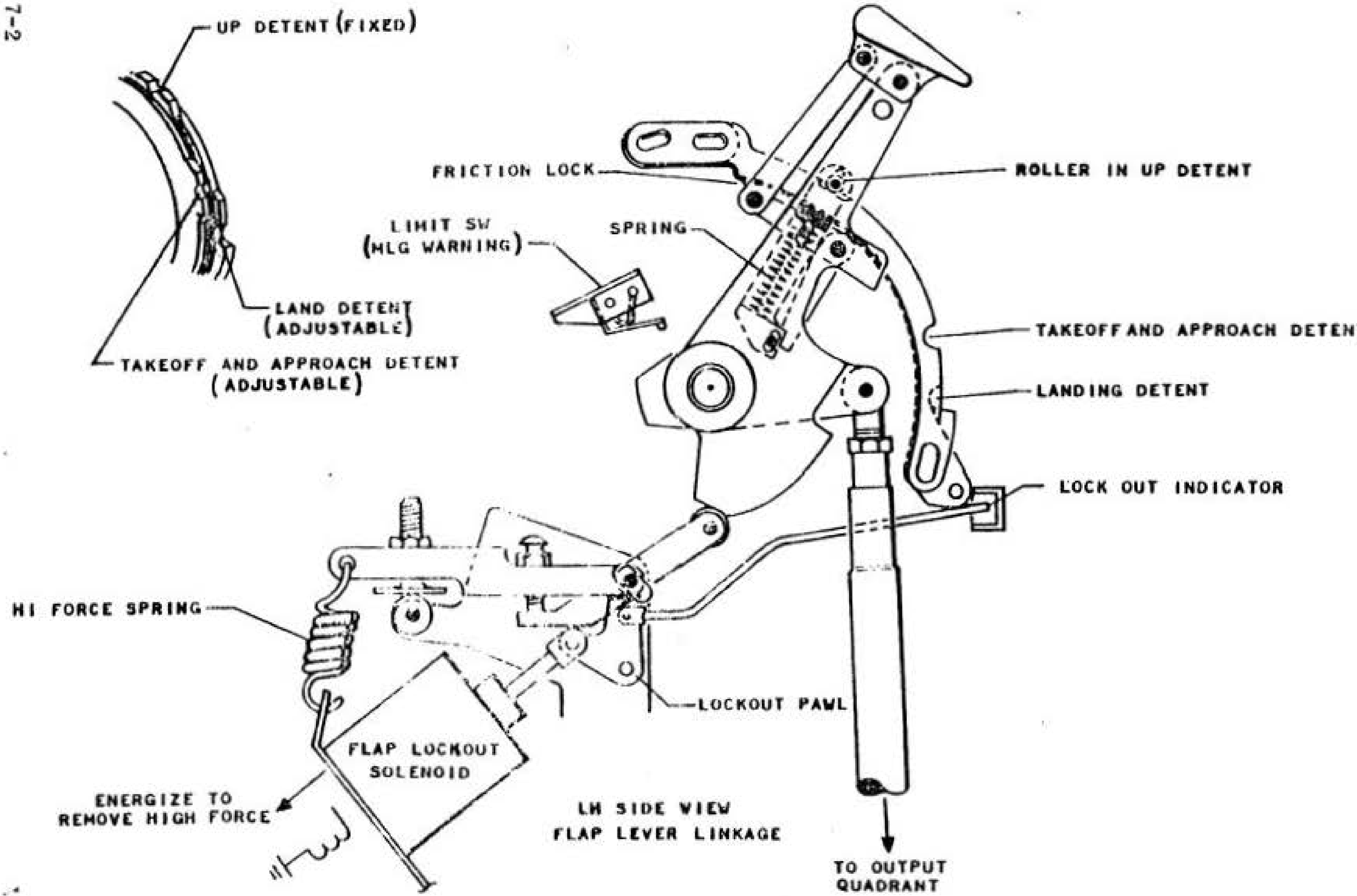
GENERAL DESCRIPTION.

Aircraft wing flaps provide increased-attitude control during low-speed maneuvers. Improved control is accomplished by changing the camber and area of the wing into a high-lift configuration. The increase in lift permits landing and take-off at lower speeds. Other advantages are the ability to use shorter runways and greater safety while operating over obstructions around airports.

Double-slotted, Fowler-type flaps are used on the StarLifter. Two surfaces on each wing extend from the wing root to the aileron. Surface deflection is manually controlled from the flight station. The flaps are mounted on carriages which roll on curved tracks. The tracks extend aft from the trailing edge of the wing structure. Jackscrew actuators are used to extend and to retract the



FLAP SYSTEM INSTALLATION



FLAP CONTROL HANDLE LINKAGE

flaps. Two hydraulic motors are mounted on a gearbox which drives the jackscrews by means of torque tubes. A flap asymmetry system monitors flap operation and automatically stops flap movement if one section of the flaps lags or leads its counterpart.

THE SYSTEM.

Degree and direction of flap travel are governed by the flap control handle which is located on the center console. Each movement of the flap control handle must be preceded by tilting the aft end of the handle knob up. This procedure allows a serrated shoe to move away from a serrated track and unlocks the handle. The serrated shoe and track allows infinite positioning of the handle. The handle has three detented positions: "UP," "TAKEOFF AND APPROACH," and "LANDING." Tilting the flap handle knob also frees a roller from the detent which is holding the handle. Only the take-off and landing detent tracks are adjustable.

A lockout solenoid imposes a high breakout force to the flap control handle when the spoilers are being used in flight. The spoiler control handle incorporates a similar restraining feature when the flaps are being used in flight. This feature prevents inadvertent operation of the flaps while the spoilers are in use, but the high handle force may be overridden in the event of a malfunction. The lockout solenoids are located within the control pedestal and must be energized to remove the high force from the handles. When a high-force condition exists, a lockout indicator for the affected handle can be seen protruding through the throttle quadrant cover. During ground operation the flaps and spoilers may be operated simultaneously.

A landing gear warning switch is closed by the flap control handle at approximately 90 percent of the flap control handle position. When all of the gears are not down and locked and the landing gear warning switch is actuated, a warning horn will blow and continue to blow until the gear is down and locked or the warning switch is opened.

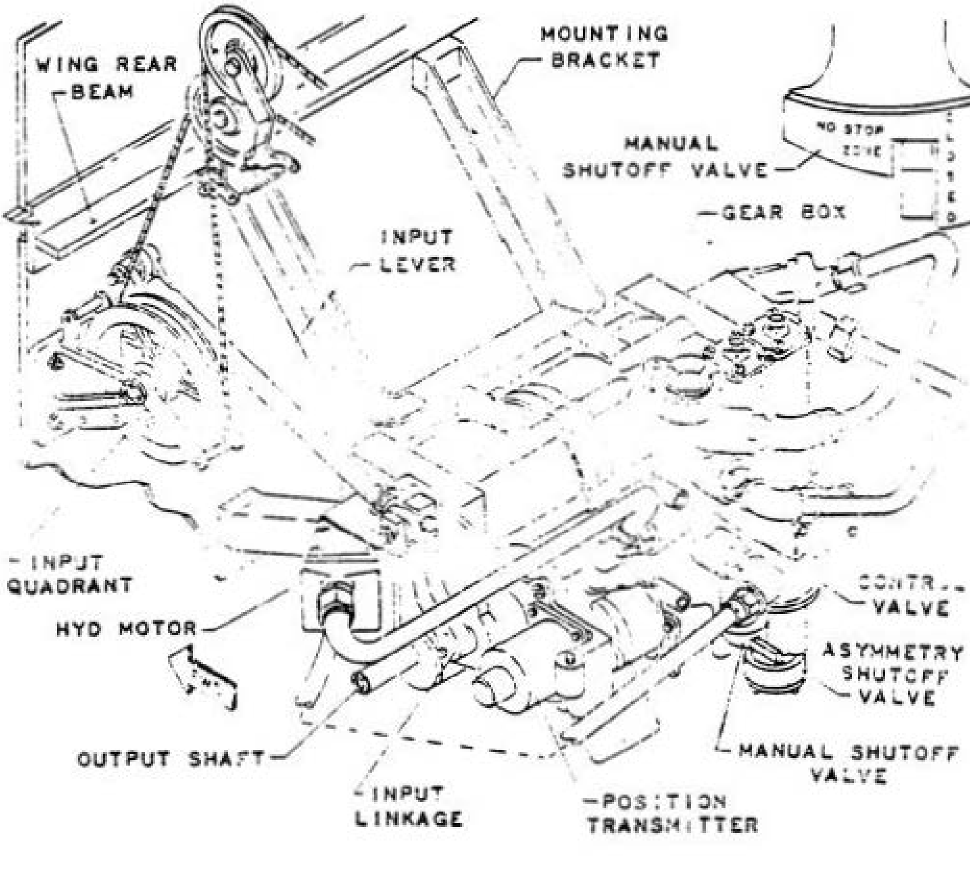
Movement of the flap control handle transmits the input signal to the [illegible] a single closed-loop cable system and mechanical linkage. The flap control handle can be placed in any position without waiting for the flap system to follow up. In addition to the three detented and decaled positions, convenient reference marks are located at the 25 and 50 percent extension positions on the flap select scale.

A failed-cable detector assembly is located above the flap input quadrant. The input quadrant is mounted on the aft face of the wing rear beam inside the cargo compartment. If a cable were to break, the spring would force the striker plate to contact and actuate the detector switch. The switch would then close the asymmetry shutoff valve in the gearbox and prevent the flap actuation that would result from cable stretch in the remaining cable.

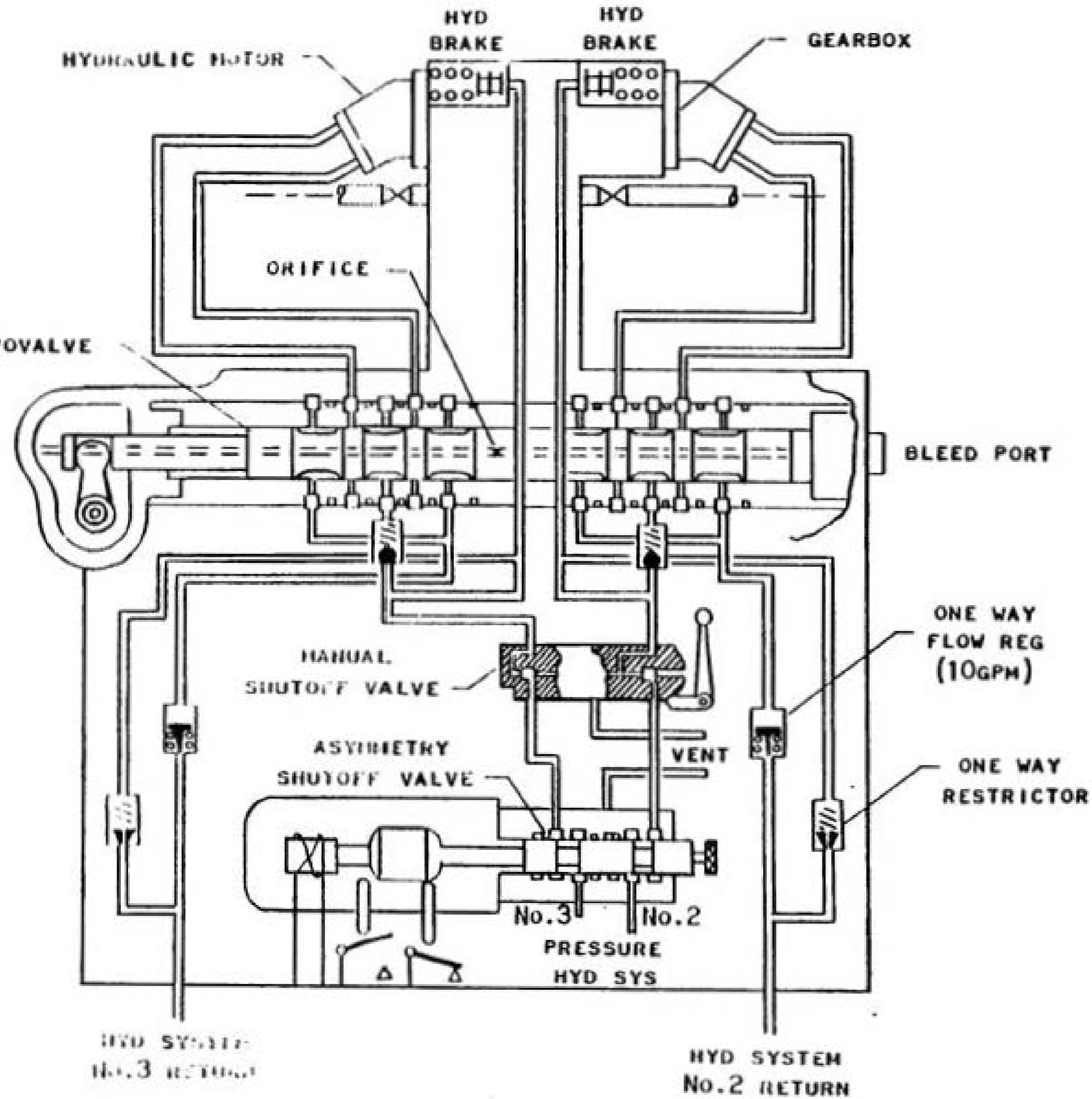
A motor and wing-flap gearbox assembly is mounted on the wing rear beam adjacent to the flap input quadrant. Major components in this assembly are:

1. Two hydraulic motors
2. Hydraulic manifold
3. Gearbox
4. Position transmitter

Normally the gearbox is driven by both hydraulic motors which are nine-piston reversible motors. The No. 2 hydraulic system supplies power for one motor and



FLAP INPUT QUADRANT AND GEARBOX INSTALLATION



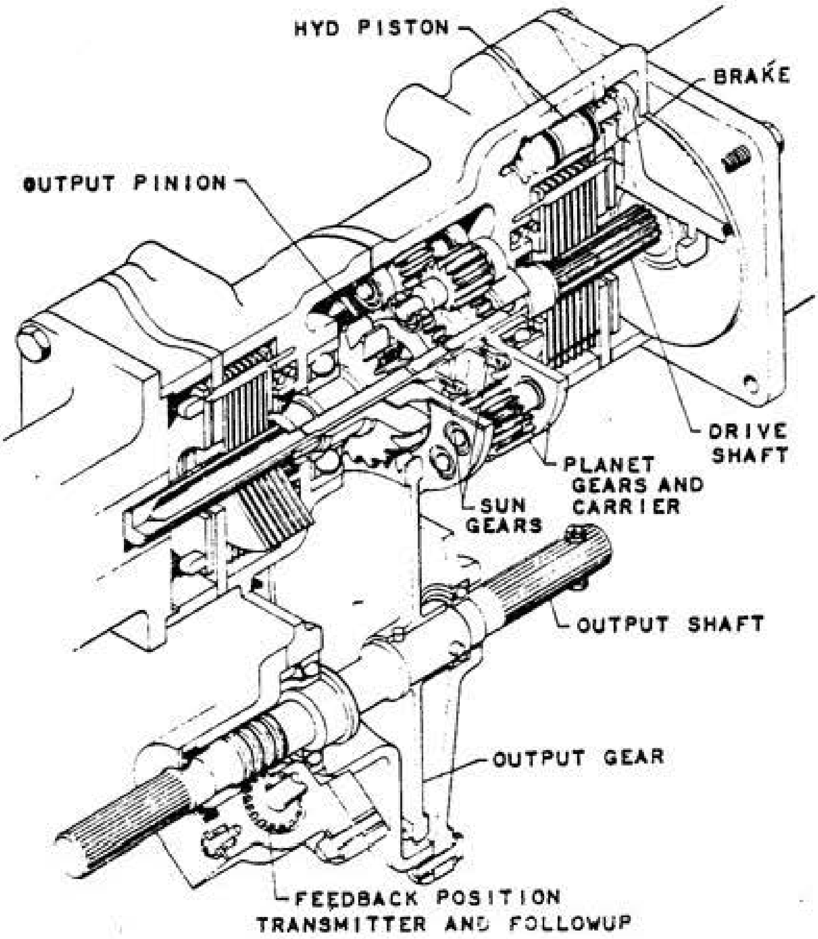
FLAP HYDRAULIC CONTROL

the No. 3 hydraulic system supplies power for the other motor. During one motor operation, maximum system torque is available because of the mechanical advantage gained in the differential gearbox; but the flaps are driven at one-half the normal operating speed. Motor speed is controlled by flow control valves installed in the return lines from the motors.

The hydraulic manifold contains a solenoid-operated shutoff valve, a manual shutoff valve, and a servovalve. Hydraulic pressure to the manifold is first routed through the solenoid-operated shutoff valve designated as the asymmetry shutoff valve. This valve is energized closed when an asymmetrical condition exists, when the FLAP ASYMMETRY TEST switch is actuated, or when the failed-cable detector switch is actuated. When the asymmetry shutoff valve is energized, the solenoid releases a spring-loaded valve spool which shuts off all hydraulic flow to the manifold. A visual indicator to show actuation and a manual reset knob for the solenoid are external parts of the valve. From the asymmetry shutoff valve, pressure is routed to the manual shutoff valve. This manual shutoff valve isolates the flaps from both hydraulic systems. The tandem servovalve is located downstream of the manual shutoff valve and provides synchronized control of fluid flow to and from the hydraulic motors.

The flap gearbox is a sun and planetary-gear differential assembly. Both of the hydraulic motors spline into and drive a sun gear. The planetary gear train contains three pairs of planetary gears, which are bearing mounted to a carrier that has the output pinion bolted to it. A gear reduction takes place between the output pinion and the output gear. The planetary gears mesh with each other and with the sun gears. When both motors are driving the gearbox, the planetary gears lock together because of counteracting torques. This causes the planetary carrier to turn at the same speed as the sun gears. During one-motor operation, the planetary gears rotate around the stationary sun gear of the inoperative motor. The planetary carrier then rotates at one-half the speed of the driving motor. This reduces flap speed to one-half the normal operating speed.

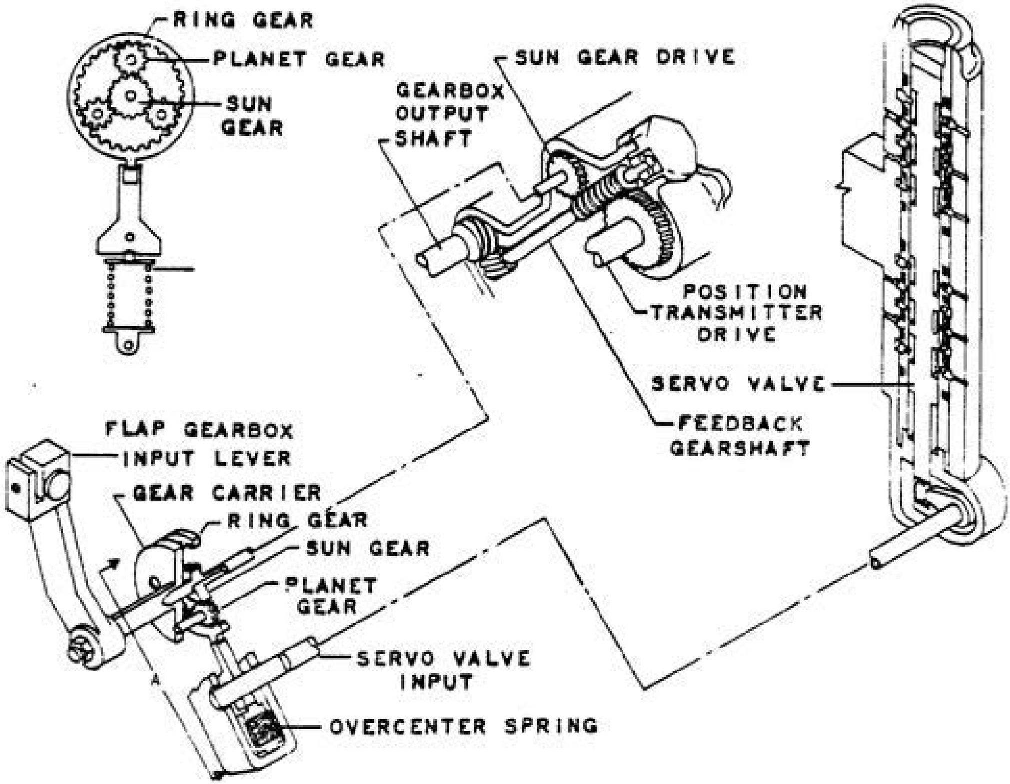
Two spring-applied and hydraulically-released brake assemblies are incorporated in the gearbox. If hydraulic pressure to one motor is lost, the associated brake automatically locks that motor's drive shaft. Brake application is accomplished through spring force exerted on a series of friction disks. Half of the disks are splined to the motor drive shaft and the other half of the disks are pinned to the gearbox case. Brake release is accomplished by hydraulic pressure moving a piston which, through the action of a lever and release pin, compresses the brake springs. This action allows the friction disks to move apart and the motor drive shaft to rotate freely. The brake holding torque is sufficient to prevent the shaft



FLAP GEARBOX

from rotating under full stall torque of the opposite driving motor. Check valves and one-way restrictors in the hydraulic manifold ensure proper brake operation in the event of a hydraulic system failure.

To prevent damage to the gearbox brakes during flap operation with the interconnect valves open, a flap ground-test shutoff valve is incorporated. This manually-operated shutoff valve, located adjacent to the flap drive gearbox, is installed in the pressure line to the No. 3 system flap motor. The normally open valve must be closed if the No. 3 hydraulic system is used to pressurize the No. 2 hydraulic system for the flap operation. Neglecting to close the valve will result in dragging brakes and eventual failure due to insufficient flow from the No. 3 hydraulic system pumps for two motor operation.

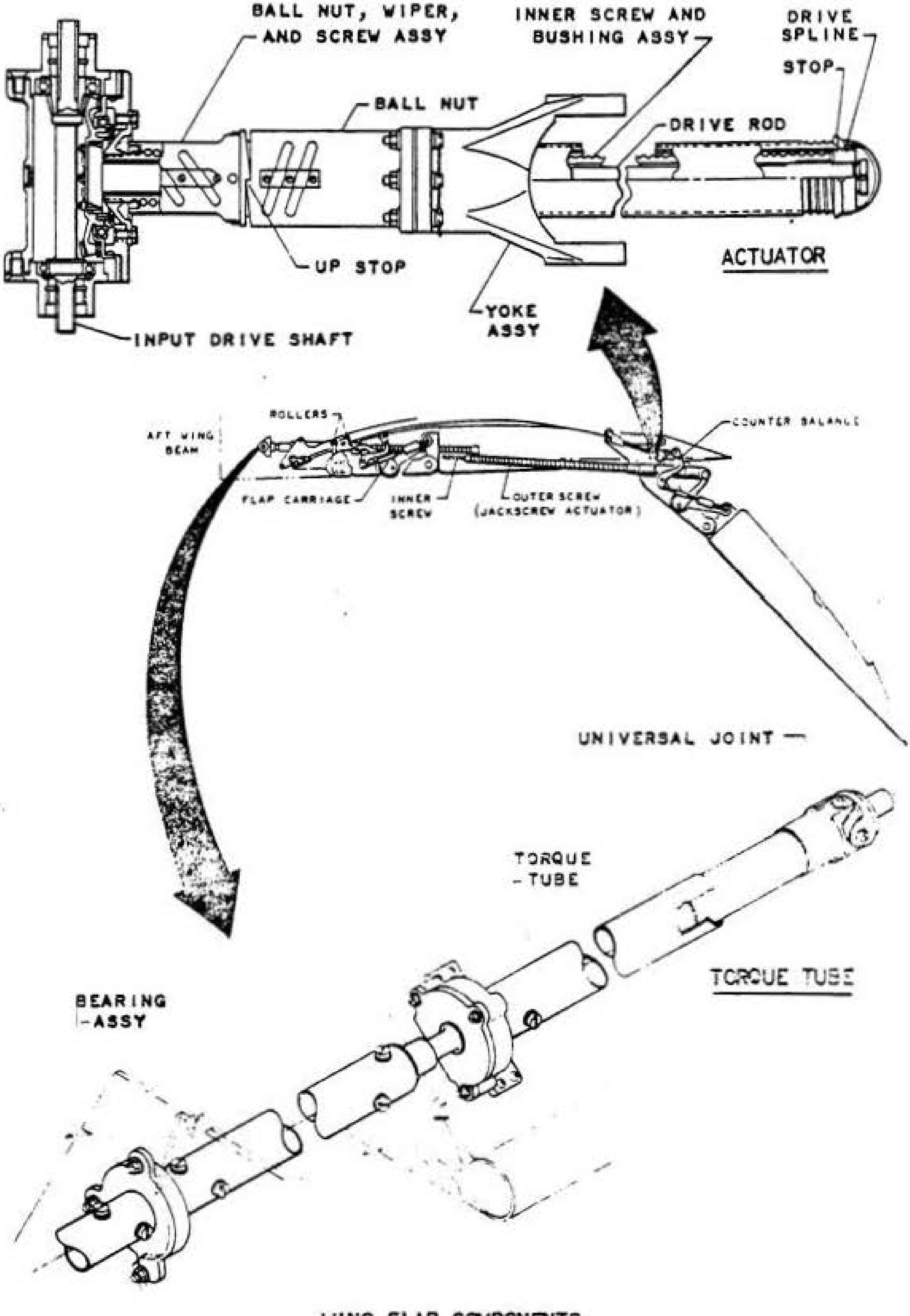


FLAP FOLLOWUP MECHANISM

Motion from the input quadrant is transferred to the gearbox input lever by means of a pushrod. The input lever is coupled to a planetary gear carrier of the flap followup mechanism. Input lever movement rotates the carrier, causing the planetary gears to revolve around the sun gear and drive the planetary ring gear. Displacement of the ring gear positions the servovalve in the hydraulic manifold to direct fluid to the hydraulic motors. A feedback gear-shaft connects the gearbox output shaft to the sun gear. Rotation of the sun gear causes the planetary gears to rotate about their pivot on the planetary carrier and to rotate the ring gear in the opposite direction of the control lever input. This feedback centers the servovalve and stops flap movement.

The flap position transmitter is coupled to the feedback gearshaft. Flap position is relayed to an indicator on the pilots' center instrument panel.

A torque tube drive, from the motor-driven gearbox, is routed along the trailing edge of each wing. This drive is routed through the gearbox of each flap actuator. A solenoid brake is attached to the gearbox of each of the outboard actuators. The torque tubes are supported by bearings and are coupled by universal joints.



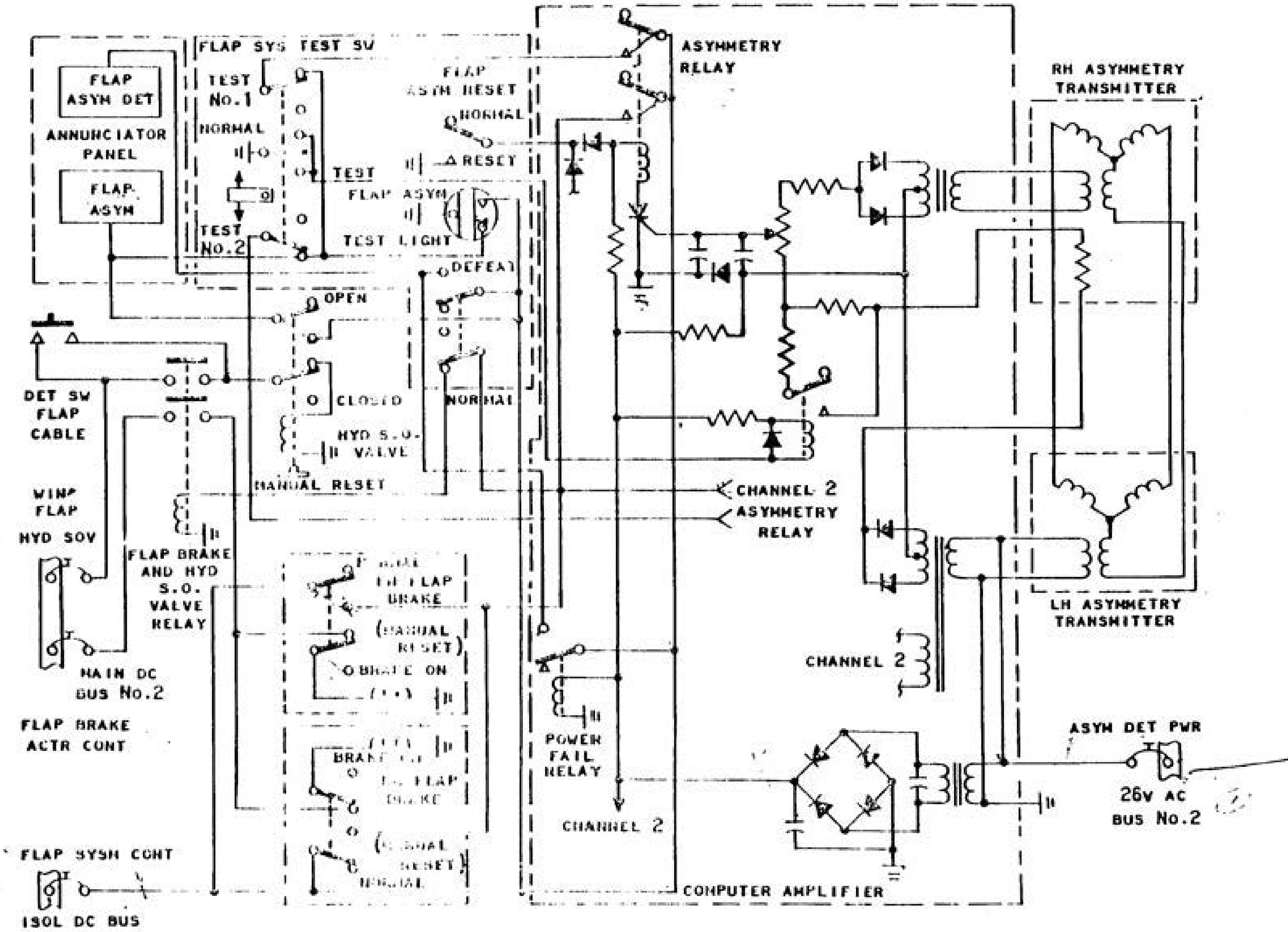
WING FLAP COMPONENTS

Two jackscrew actuators are used to drive each section of the flaps. Each flap actuator consists of a 90-degree gearbox and a jackscrew assembly. The output pinion of the 90-degree gearbox is connected to the forward end of the actuator drive shaft. This drive shaft extends aft through the non-rotating inner screw and engages internal sliding splines of the outer screw. The rotating outer screw is pinned to the forward ball nut which travels on the fixed inner screw. The actuator yoke is bolted to the non-rotating ball nut which engages the outer screw. An adjustable arm connects the flap surfaces to the yoke. As the drive shaft rotates the outer screw in the extend direction, the outer screw and the yoke-ball nut assembly move aft simultaneously. Total flap extension is the sum of the travel of the outer screw on the inner screw and the travel of the yoke on the outer screw. Reverse rotation of the drive shaft reverses the operation to retract the flaps.

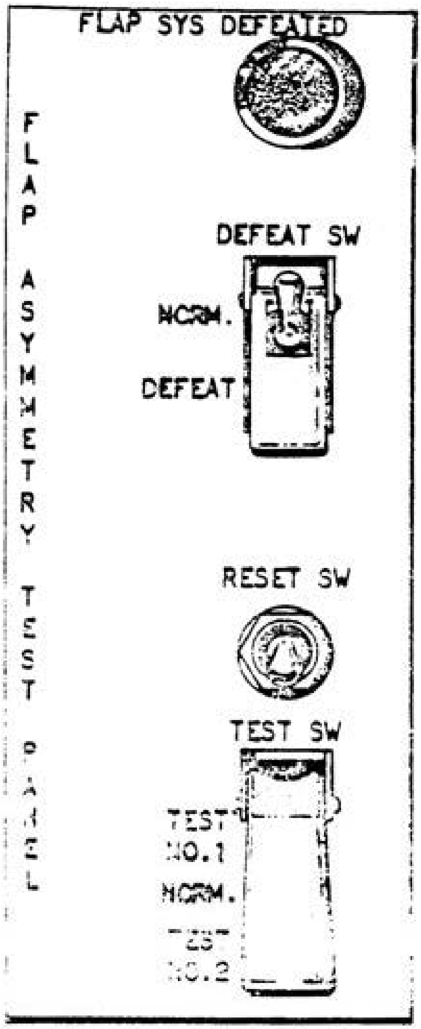
ASYMMETRY PROTECTION.

A flap asymmetry system provides protection against asymmetrical operation of the wing flaps. The detection section of this system monitors flap position by means of two transmitter-control transformer synchro loops. A transmitter synchro is located at the inboard track of each left side flap section and is driven by a chain and cable assembly. A corresponding control transformer is located at the inboard track of each right side flap section and is also driven by a chain and cable assembly. The transmitter-control transformer synchro loops are connected outboard to outboard and inboard to inboard. The computer-amplifier located in the cargo compartment compares the input to the transmitter to the output of the corresponding control transformer. In this way the position of the flaps sections is compared. As the flaps move symmetrically, maximum inductive coupling is maintained and the output of the control transformers is the same as the input to the transmitters. If one section of the flaps lags or leads its counterpart, the electrical difference between their transmitter input and control transformer output would produce an asymmetry signal. The computer-amplifier output would then cause the solenoid-operated hydraulic shutoff valve to close the brakes, to apply at both outboard actuators, and would illuminate the FLAP ASYM warning light on the annunciator panel and the flap asymmetry test light on the FLAP ASYMMETRY TEST PANEL. The asymmetry system can be reset only on the ground because additional flap travel in flight could possibly increase an asymmetrical condition beyond the corrective capabilities of the aileron system. The circuitry of the asymmetry system includes a power failure monitoring circuit that illuminates the FLAP ASYM DET light on the annunciator panel when the system is not functioning.

A FLAP ASYMMETRY TEST PANEL is located in the APU compartment. The panel consists of a TEST SW, a test light, a RESET SW, and a DEFEAT SW. To check the



FLAP ASYMMETRY CONTROL

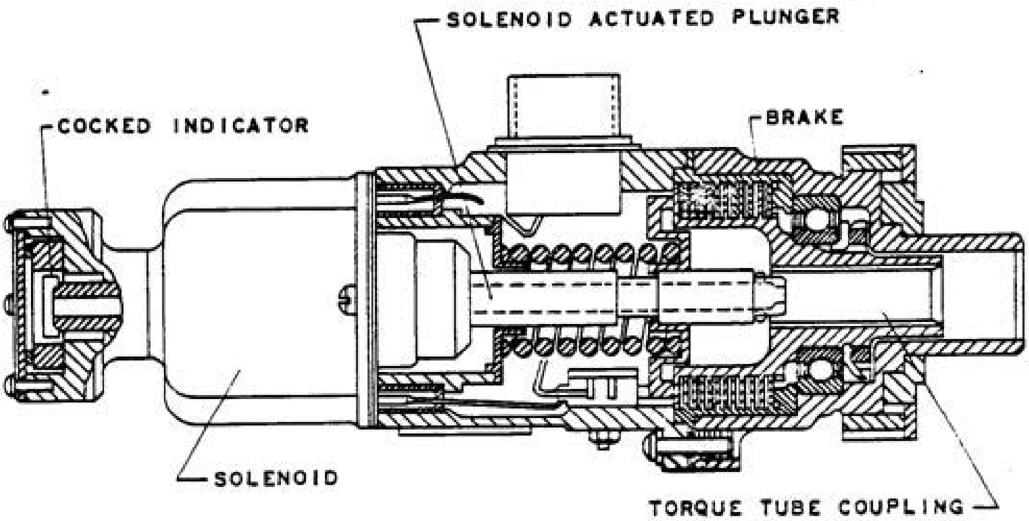


FLAP ASYMMETRY TEST PANEL

asymmetry system, first pressurize the No. 2 and No. 3 hydraulic systems from different power sources; then put the flaps in motion. Next, momentarily place the ASYMMETRY TEST switch to the "TEST NO. 1" position which controls the outboard flaps' channel in the computer-amplifier. The asymmetry brakes should engage and the solenoid-operated hydraulic shutoff valve should close, to stop all flap movement. When flap movement stops, the FLAP ASYM light on the annunciator panel and the test light on the asymmetry test panel will illuminate.

To reset the system, first place the DEFEAT SW in the "DEFEAT" position which will remove the electrical power from the asymmetry brakes and from the hydraulic shutoff valve. Then manually reset the shutoff valves and asymmetry brakes. The flaps will then continue to the position previously selected. After the valve and brakes have been reset, placing the RESET SW to the "RESET" position momentarily will break a holding circuit within the computer-amplifier. When the DEFEAT SW is returned to the "NORM" position, the test light and the FLAP ASYM light will be extinguished. To check the inboard flaps' channel in the computer-amplifier, repeat the previous procedures using the "TEST NO. 2" position of the TEST SW instead of the "TEST NO. 1" position.

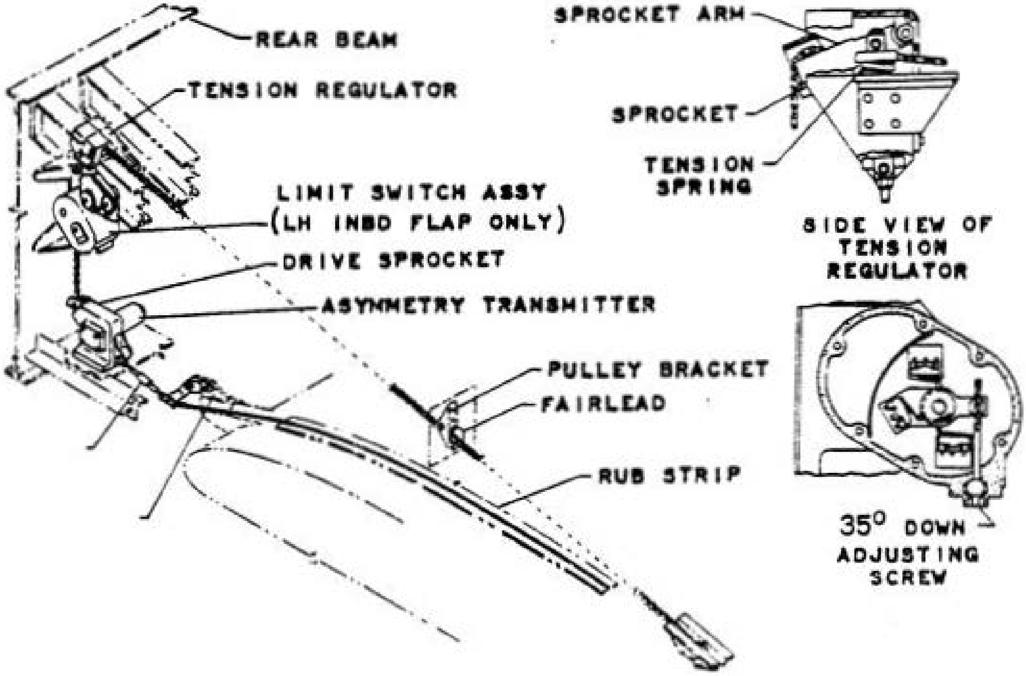
The solenoid-operated asymmetry brakes are connected to the through shafts of the outboard flap actuators' gearboxes. When the solenoid is energized by the asymmetry system, a compression spring is released to apply the disk-type brakes and a switch is opened to remove power from the solenoid. If a malfunction causes one brake to lock, the opposite brake will automatically lock. The brake has a manual reset knob and a visual indicator to show brake position.



FLAP ASYMMETRY BRAKE

Each flap asymmetry-transmitter drive consists of a chain, a cable, a tension regulator, and a synchro. The chain and cable are attached to the flap surface. The chain is routed over the synchro and tension regulator sprockets mounted in the flap well, and the cable is routed over a pulley mounted to the structure of the wing trailing edge. A tension regulator maintains proper chain and cable tension throughout the flap travel range.

A limit switch assembly is connected to the left inboard asymmetry-transmitter drive. Limit switches are provided for the full-up, 20 degrees down, and 35-degrees down flap positions. When the full-up limit switch is actuated (flaps not-up position), a high force is applied to the spoiler handle and maximum trim



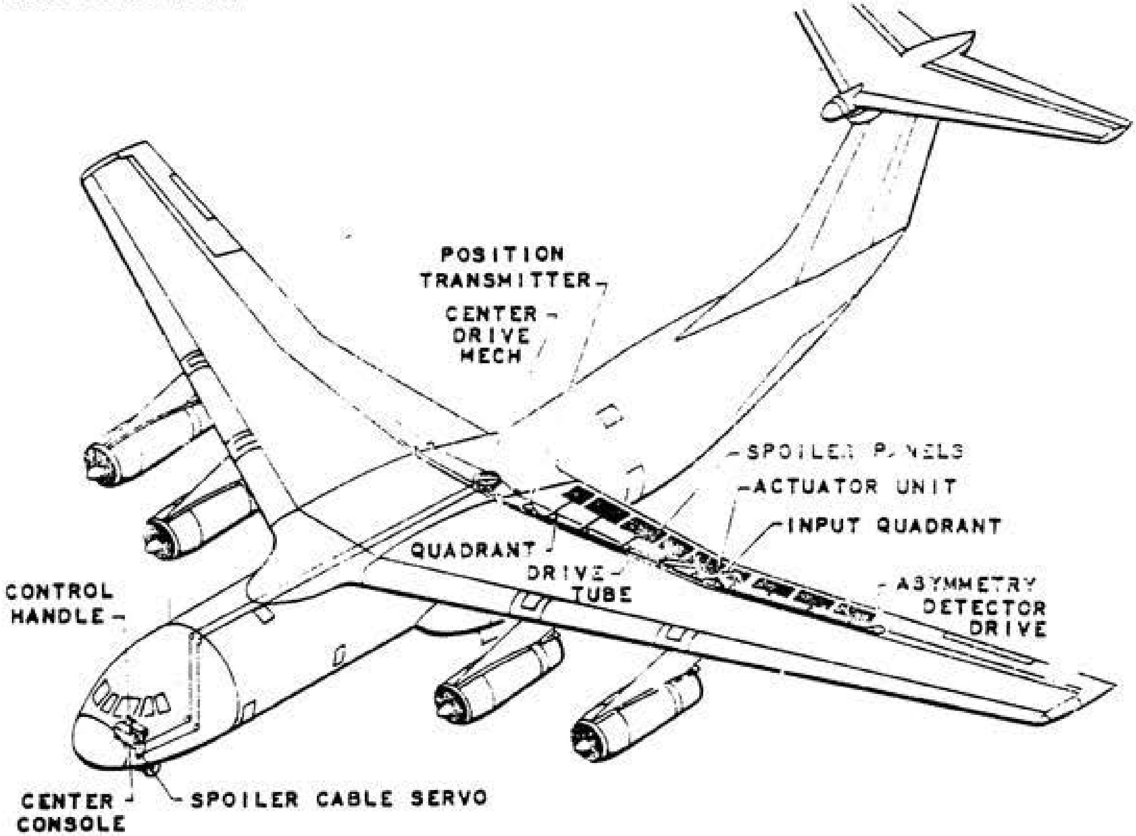
WING FLAP ASYMMETRY TRANSMITTER DRIVE

is available for the horizontal stabilizer. The 20-degree limit switch is used in the automatic flight control system to increase the gain from the autopilot when the flaps are in the 20-degrees down to the full-down range. The 35-degree limit switch is used in the take-off warning system.

WING SPOILER SYSTEM

GENERAL DESCRIPTION.

Hydraulically-actuated, lift-spoiling panels are installed on the upper and lower surfaces of the aircraft wings. The spoilers are used during a rejected take-off to reduce speed and shorten aircraft roll. In flight, spoilers are used as a speed brake to reduce speed for a high rate of descent or simply to slow the aircraft down. During landing, spoilers are used to spoil the effective extra lift created by the flaps so the aircraft may be stopped in relatively short distances.



SPOILER CONTROLS INSTALLATION

The spoiler system is controlled by manual movement of the spoiler control handle on the center console. The system also may be armed to operate automatically at touchdown or in the event of a rejected take-off. Arming the system is accomplished by positioning a rotary SPOILER SELECT switch on the center console and by pulling the spoiler control handle outward.

A spoiler actuator unit is located on each wing and is attached to the wing rear beam where the trailing edge starts to sweep back. Each spoiler actuator unit contains two tandem hydraulic actuators. One of the actuators drives the spoiler panels located inboard of the actuator unit, and the other actuator drives the spoiler panels located outboard of the actuator unit. The movement of the actuators is transmitted to the spoiler panels by mechanical linkage. A drive tube is threaded onto each actuator and is connected by cables to a drive quadrant for each spoiler panel in the group. The spoiler panels are connected to the drive quadrants by push-pull rods.

There are 36 spoiler panels on the wings. The spoiler panels are in two groups, inboard and outboard, with each group containing upper and lower panels. There are five upper and five lower panels on each inboard wing and four upper and four lower panels on each outboard wing.

During flight, the tandem actuators for both spoiler actuator units use pressure from the No. 2 and No. 3 hydraulic systems. For ground operation the inboard actuators use No. 2 hydraulic system pressure and the outboard actuators use No. 3 hydraulic system pressure. In the event either hydraulic system fails during ground operation, the spoiler actuator unit will automatically change operation so that both inboard and outboard actuators will operate from the remaining hydraulic system.

An asymmetry detection system is provided on the outboard drive tubes to ensure that the outboard spoiler panels on one wing do not lead or lag the outboard spoiler panels on the other wing. Should an asymmetrical condition occur beyond the allowable limits, the sensing system causes all spoiler panels to close.

Spoiler position indication is provided by a dual pointer indicator on the center instrument panel. The indicator also has a "LOCKED" and "UNLKD" flag.

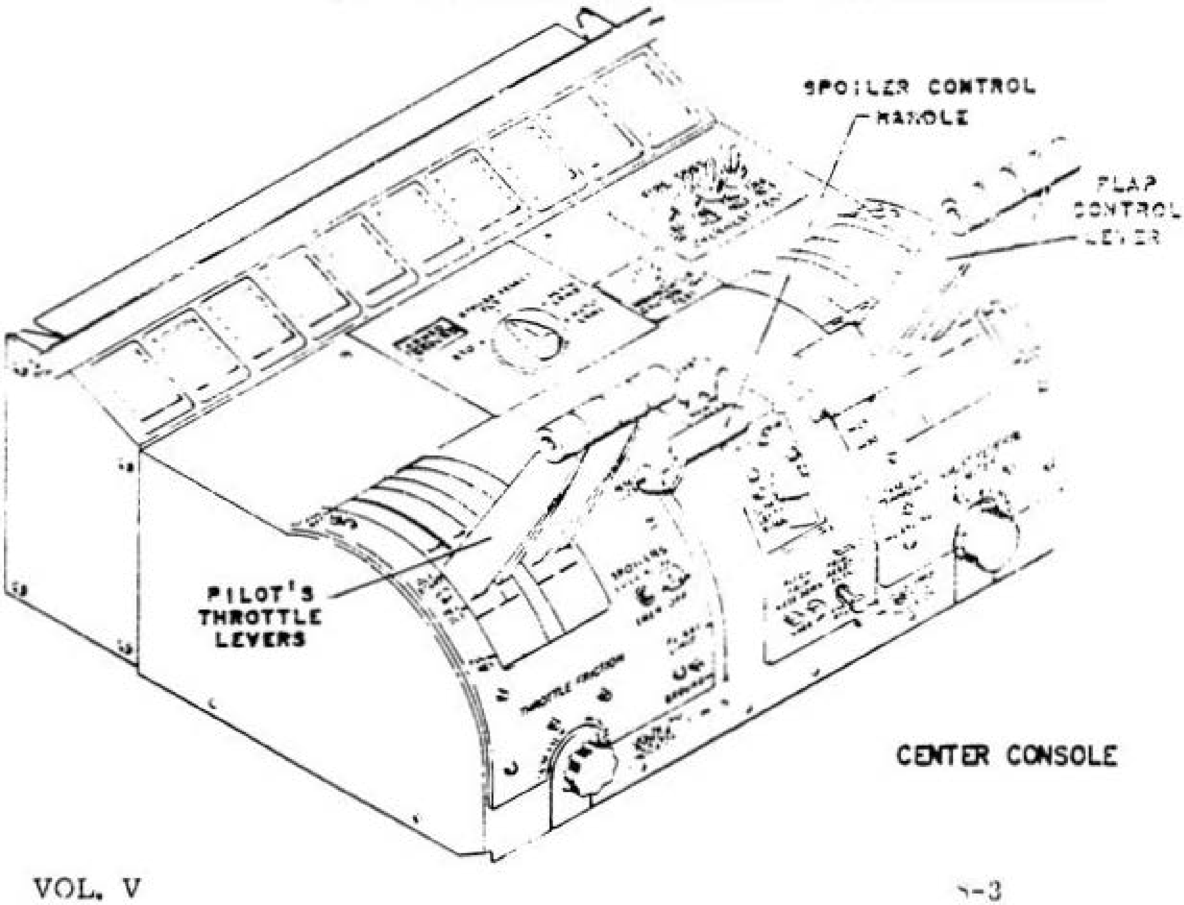
An ARMED light on the center console illuminates when the system is armed for automatic operation. A GROUND light, which is also located on the center console, illuminates to indicate the system is set up for ground operation. The GROUND light does not illuminate when the "FLIGHT" mode is selected.

DETECTOR lights are located on the copilot's side panel for indication of proper asymmetry detector operation. The annunciator panel contains SPOILER ASYM lights.

A three-position spoiler emergency retract and off switch is located on the center console. The three switch positions are: "EMER RETRACT," "NORM," and "EMER OFF." Positioning the switch to "EMER RETRACT" simulates an asymmetrical condition and causes all spoiler panels to close. For normal spoiler operation, the switch will be in the "NORM" position. Positioning the switch to "EMER OFF" simulates an asymmetrical condition and will shut off all hydraulic pressure to the spoiler actuator units when all of the spoiler panels are closed.

SYSTEM OPERATION.

The spoiler input control system contains: a spoiler control handle and a rotary SPOILER SELECT switch which are located on the center console, a hydraulic spoiler cable servo located beneath the center console, and a center drive assembly located on the wing rear beam. A closed-loop cable



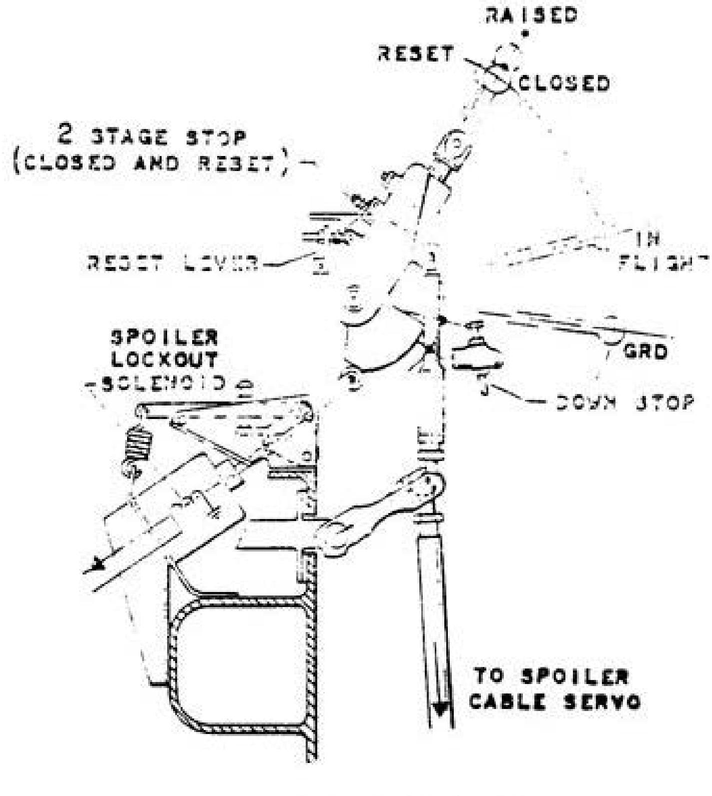
CENTER CONSOLE

system connects the hydraulic cable servo and the center drive assembly. The closed-loop cable system is routed from the center drive assembly out each wing to the input quadrant of the spoiler actuator unit.

The mode of spoiler operation is selected by positioning the SPOILER SELECT switch. The operational modes are: "AUTO LAND," "MAN LAND," "FLIGHT," and "RTO."

In "MAN LAND" and "FLIGHT" modes, the hydraulic-cable servo positions the input system in response to manual selections from the spoiler control handle. In "AUTO LAND" and "RTO" modes, electrical circuits control the hydraulic cable servo to position the input system. The spoiler handle will follow the movement of the hydraulic cable servo in "AUTO LAND" and "RTO" modes.

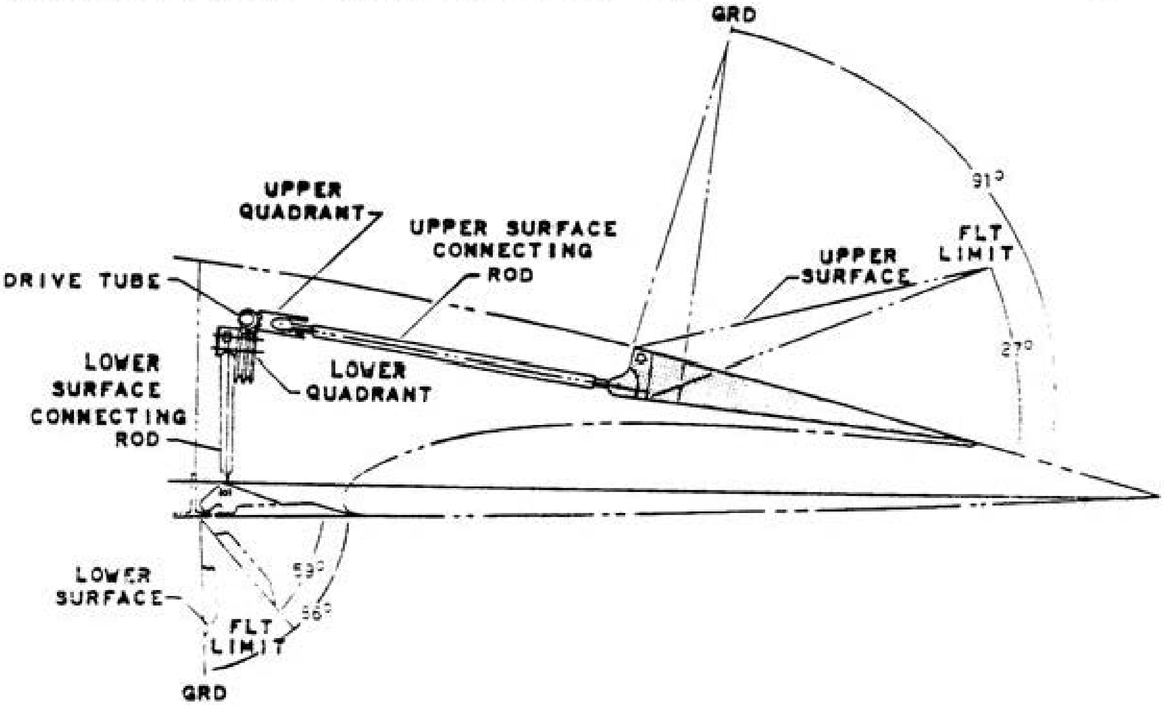
The spoiler control handle is detented at two positions: "CLOSED" and "FLIGHT LIMIT." Spoiler control handle travel is approximately 42 degrees from the "CLOSED" to the "FLIGHT LIMIT" position and approximately 65 degrees from the "CLOSED" to the "GROUND" position.



SPOILER HANDLE POSITIONS

The positions of the spoiler panels when the spoiler control handle is in the "FLIGHT LIMIT" detent position will be as follows: the upper panels deflected 27 degrees and the lower panels deflected 59 degrees. When the SPOILER SELECT switch is positioned to "FLIGHT," a positive mechanical stop will not permit the spoiler control handle to be moved beyond the "FLIGHT LIMIT" position. The amount of spoiler panel deflection, up to the flight limit, is selective by positioning the spoiler control handle.

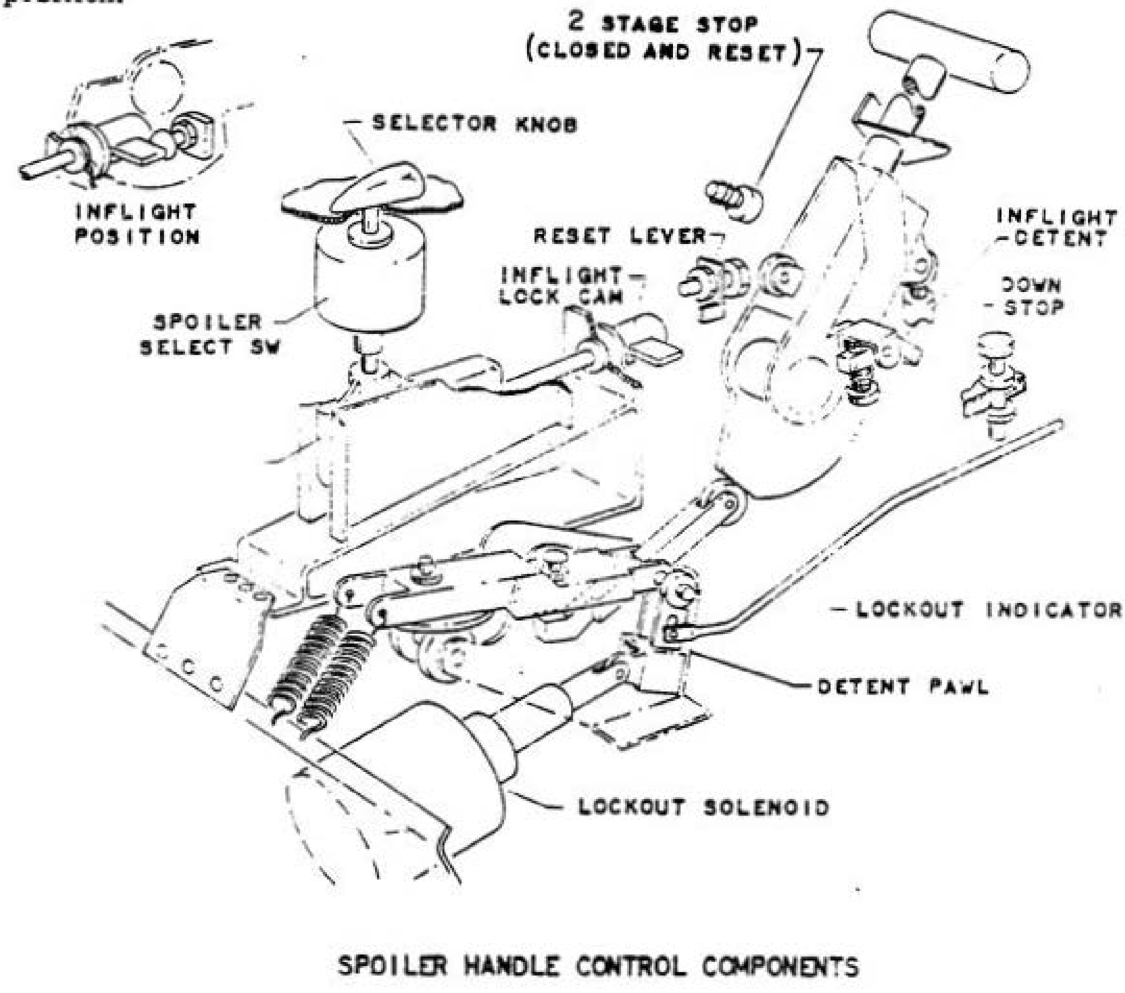
When the SPOILER SELECT switch is positioned to "MAN LAND," "AUTO LAND," or "RTO," the flight limit mechanical stop is removed and the spoiler control handle may be moved to the "GROUND" position. In the "GROUND" position the upper panel deflection will be 90 degrees and the lower panel deflection will be 86 degrees.



SPOILER PANEL DEFLECTION

The spoiler control system incorporates a high-force detent mechanism on the spoiler handle at the "CLOSED" position to prevent inadvertent movement of the spoiler control handle while the flaps are extended. Likewise, the flap control system incorporates a high-force detent mechanism at the "RETRACTED" position to prevent inadvertent operation of the flaps while the spoiler panels are deployed. The high-force detent mechanism is actuated to low force by energizing a detent solenoid and is spring-loaded back to high force when the solenoid is deenergized. With the SPOILER SELECT switch in the "FLIGHT" position, the detent solenoid is energized when the wing flaps are in the full-up position and the spoiler control handle is lifted. Moving the wing flaps down will actuate the flap position relay to deenergize the spoiler handle detent solenoid and the spring will move the mechanism to high force. The detent solenoid is also energized by placing the SPOILER SELECT switch in "AUTO LAND," "MAN LAND," or "RTO" and lifting the spoiler control handle, which will allow both flaps and spoilers to be operated at the same time.

When the detent solenoid is deenergized, the detent pawl is the pivot for the detent lever. As an attempt is made to move the handle from the "CLOSED" position, the spoiler spring detent must be overcome using a short fulcrum arm because the cam detent is not a constant radius with the handle in the "CLOSED" position.



SPOILER HANDLE CONTROL COMPONENTS

When the detent solenoid is energized, the detent pawl is moved from under the detent lever; and the detent stop bolt near the spring attach point becomes the pivot. Changing the moment arm decreases the break out force on the spoiler control handle.

To operate the spoilers with any mode selected, the spoiler control handle must be lifted. A spoiler lift handle interconnecting mechanism is located within the center console and consists of a switch operator and switches, a selector pin, and an interconnect cam.

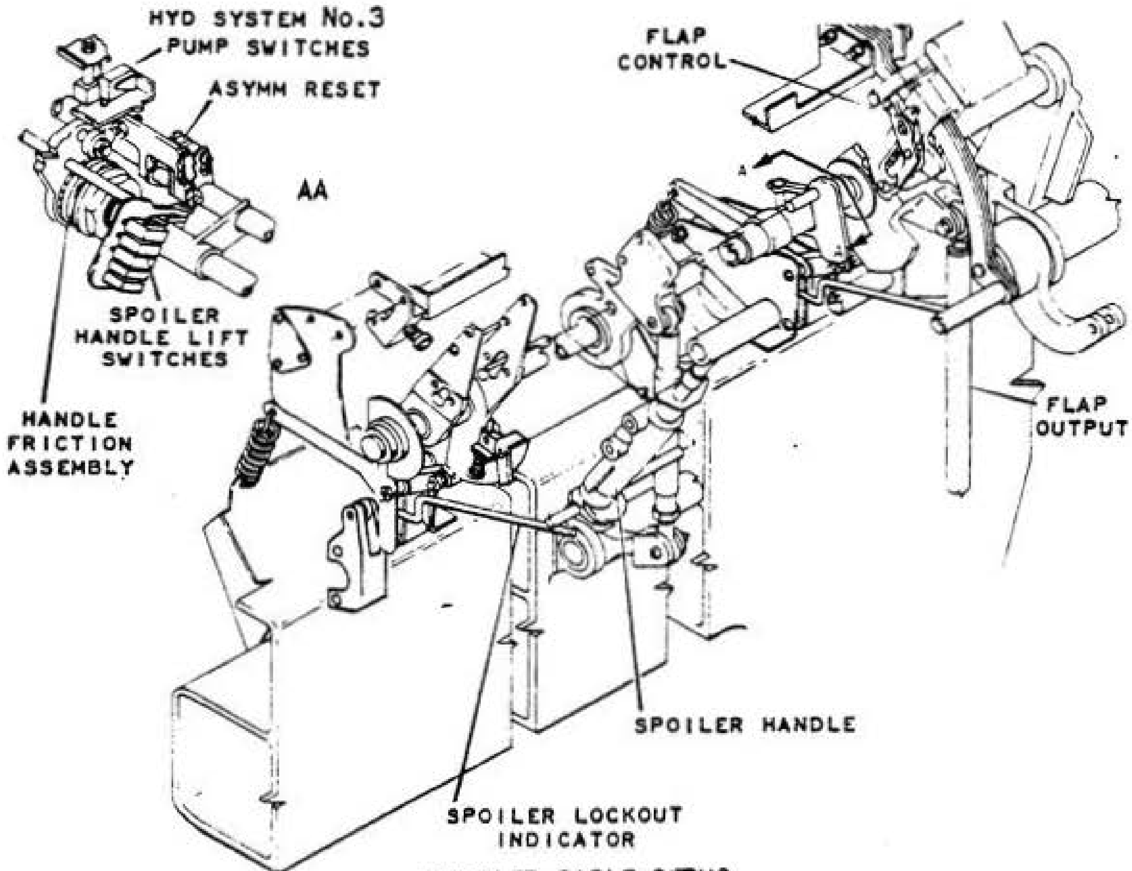
The spoiler control handle shaft fits into a tubular necked interconnecting cam. A selector pin driven through the spoiler control handle shaft extends through diagonal slots in the interconnecting cam. Because of the diagonal slots, the interconnecting cam is forced to rotate as the spoiler control handle is raised and lowered. The rotation of the interconnecting cam, when the spoiler control handle is lifted, slides a pin to the right. This actuates the switches which arm the system for automatic operation and energize the high force detent solenoid.

A cam roller is located on the forward face of the handle housing to operate handle position switches. The handle position switches control a circuit to the No. 3 hydraulic system pumps. As the handle is moved approximately two degrees out of the "CLOSED" position, the pumps are turned on. When the handle is returned to the "CLOSED" position and the spoiler panels are closed and locked, the pumps will stop.

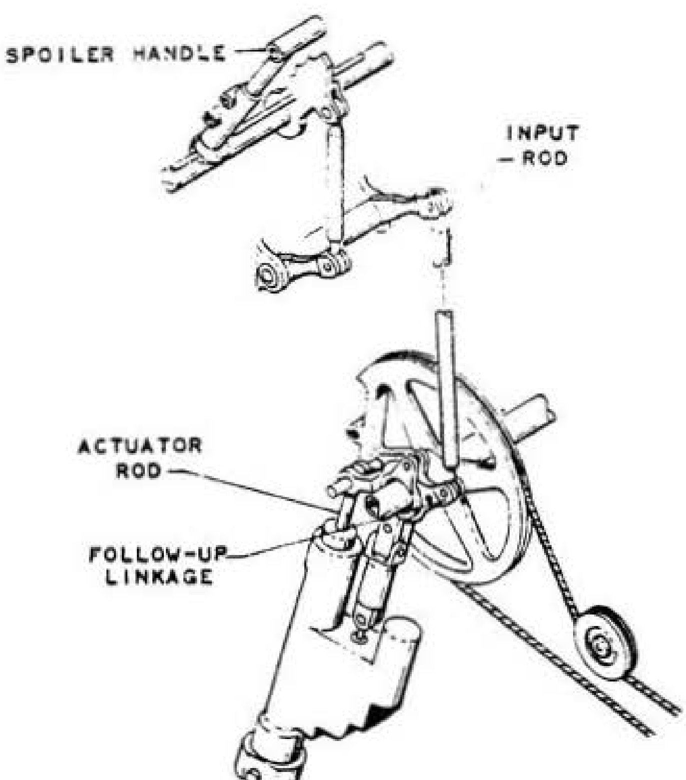
The spoiler asymmetry system must be reset to restore operation if the spoilers are closed by an asymmetrical condition or by the use of the emergency retract and off switch.

The asymmetry reset mechanism is operated by moving the handle forward past the "CLOSED" position. As the handle is moved past the "CLOSED" position, a cam roller on the handle housing strikes the reset switch operator and moves the reset lever which actuates the switches. The spoiler handle is moved to "RESET" against the force of a spring until a positive mechanical stop is contacted. The mechanical stop prevents damage to the reset spring and switches.

Two different devices are provided to apply friction to the spoiler control handle. One applies friction to the handle pivot and the other to the handle idler lever. Both are washer and checknut devices. After an adjustment, the checknuts are lockwired in place.



SPOILER CABLE SERVO



SPOILER HANDLE LINKAGE

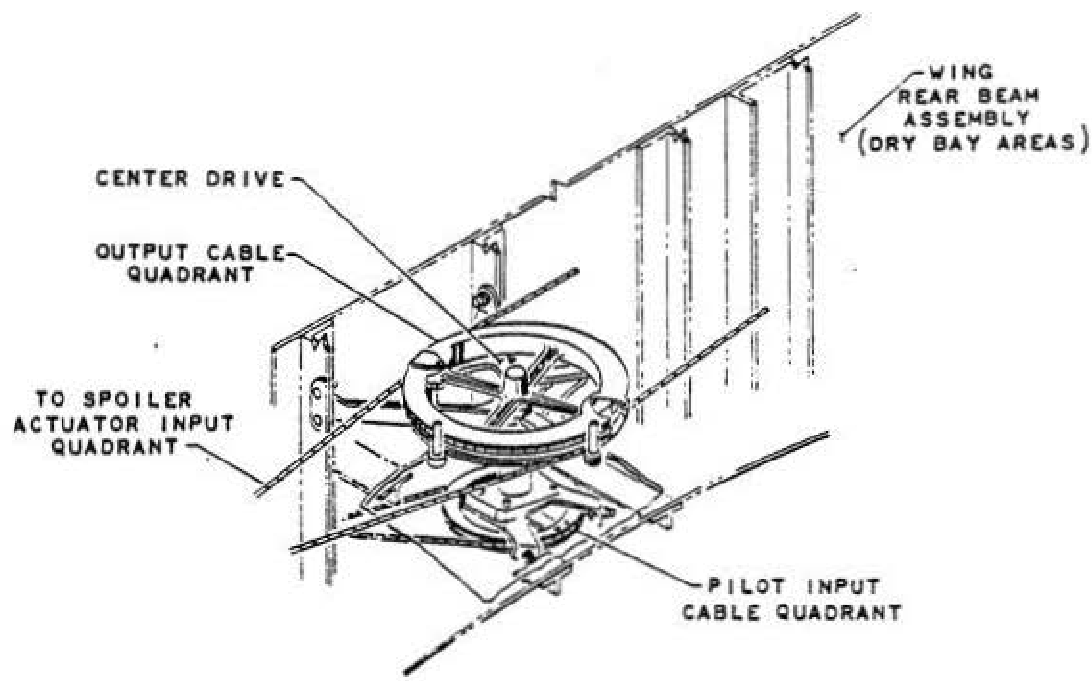
The SPOILER SELECT switch consists of a select knob, a wafer switch, a 90-degree gear box, a cam selector, and the flight limit stop for the spoiler handle. Rotation of the SPOILER SELECT switch, for operational mode selection, positions the wafer switches and the 90-degree gear box. The 90-degree gear box output shaft positions the selector cam in or out of the path of the stop on the spoiler control handle. With "FLIGHT" selected, the spoiler control handle is stopped at "FLIGHT LIMIT." With "RTO," "AUTO LAND," or "MAN LAND" selected, the stop is moved out of the path of the spoiler control handle; and the handle may be moved to the "GROUND" position.

A spoiler-cable servo and a cable-drive quadrant are located under the floor below the center console. The spoiler-cable servo is a tandem hydraulic actuator with a tandem servo control valve. The unit also contains two solenoid operated valves which direct pressure to two pistons that are used for automatic spoiler deployment ("AUTO LAND" and "RTO"). Both or either No. 2 or No. 3 hydraulic system pressures will operate the spoiler-cable servo.

In the "FLIGHT" or the "MAN LAND" mode, the spoiler control handle is moved manually. Movement of the spoiler control handle positions the tandem servo control valve of the spoiler cable servo to direct pressure to the spoiler cable servo actuator. The spoiler cable servo actuator is attached to the cable drive quadrant and moves the cable system in response to spoiler control handle movement. An input feedback system centers the tandem servo control valve and stops actuator movement when the actuator has moved a distance proportional to spoiler control handle movement. The input lever of the spoiler cable servo attaches at one end to the input linkage from the spoiler control handle, at the other end to the cable drive quadrant, and near the mid point to the servo control valve. Spoiler control handle movement causes the servo control valve to move when the drive quadrant is stationary. As the actuator moves the drive quadrant, the [illegible] input lever is used as the pivot or hinge and the servo control valve is neutralized when the input motion is stopped.

Although the cable drive quadrant attach bolt goes through the input lever, the [illegible] is not close, this allows the servo control valve to move before the attach bolt is contacted.

The two solenoid valves of the spoiler cable servo are energized open under the following conditions: on touchdown when the aircraft wheel speed is above 50 knots and "AUTO LAND" has been selected, or if "RTO" is selected and the throttles are placed to REVERSE IDLE with wheel speed above 50 knots. Opening the valves causes pistons to position the servo control valve and direct pressure to the cable servo actuator which drives the spoiler input system and deploys the spoilers to the ground position.

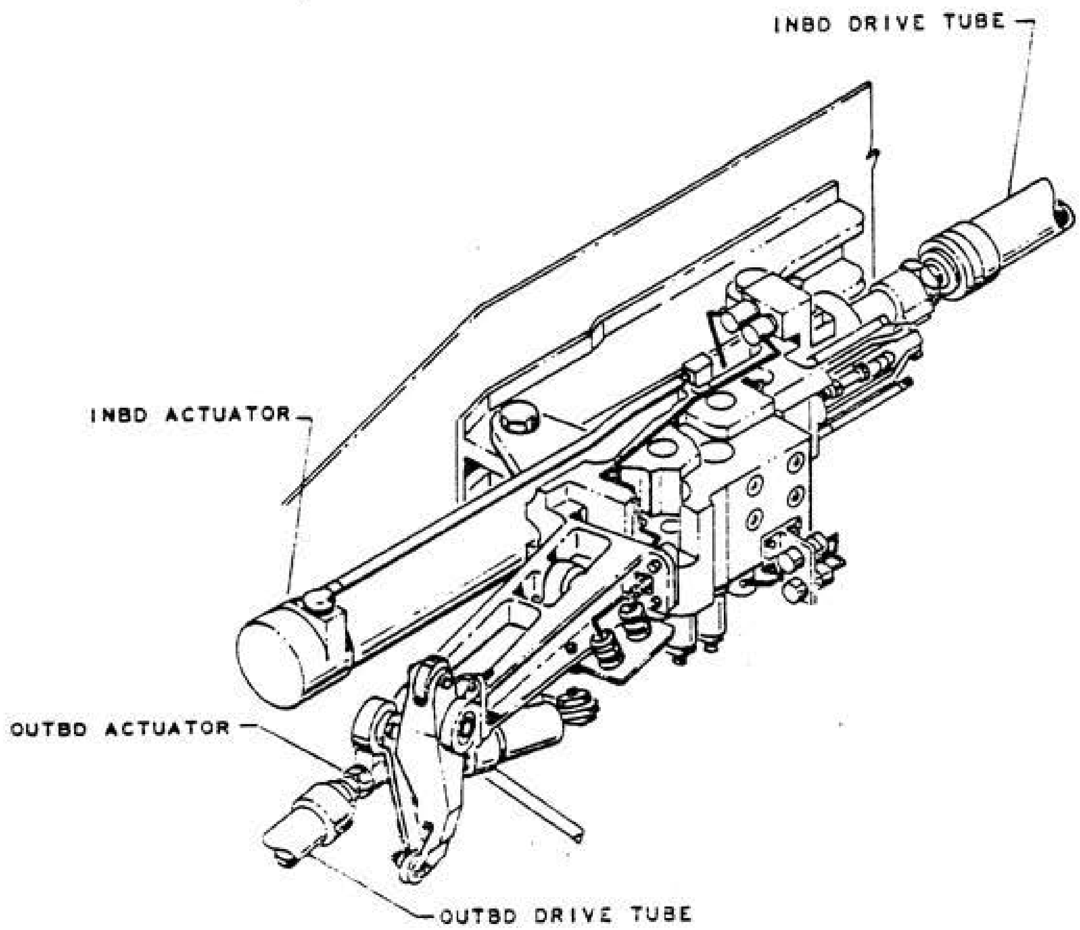


SPOILER CENTER DRIVE QUADRANT

The center drive mechanism consists of two pulleys connected by a shaft. Cables from the spoiler-cable servo-drive quadrant connect to one pulley, and from the other pulley a closed-loop cable system is routed out each wing and attaches to the input quadrant of each actuator unit. The pulley to which the cables from the spoiler-cable servo-drive quadrant attach is inside the pressurized area, and the output pulley is inside the center wing dry bay area. The shaft connecting the two pulleys is pressure sealed.

Input motion, transmitted from the center drive assembly through the closed loop cable system, positions the input followup mechanism at the actuator units. The input followup mechanism is connected to the servo control valves of the actuator units. The followup mechanism positions the servo control valves which direct fluid to the primary and auxiliary cylinder of each tandem actuator. Feedback motion from the movement of the tandem actuators to the input followup mechanism returns the servo control valves to neutral when the spoiler panels have moved a distance proportional to input movement.

The input system is connected by spring bungees to the servo control valves of the actuator units. The spring bungees prevent overloading the input linkage when the spoiler cable servo moves the input system to the ground position very fast while

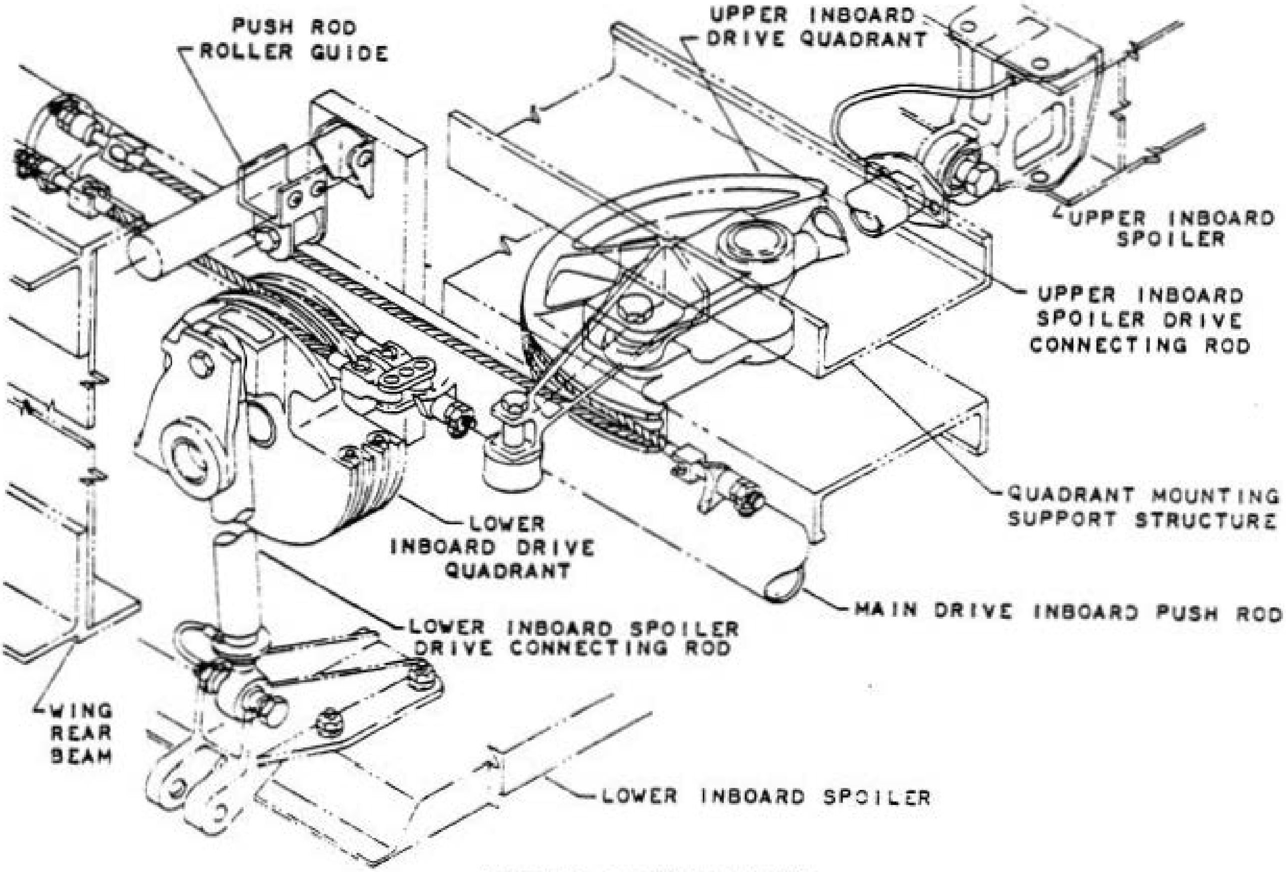


LEFT SPOILER ACTUATOR UNIT

in the "AUTO LAND" and "RTO" modes. The spring bungees will allow the spoiler panels to move toward close on "blowdown" due to air loads or to close and lock in the event of an asymmetrical condition, without movement of the spoiler control handle.

The spoiler output system consists of an inboard and an outboard drive tube driven by each actuator unit, and a drive quadrant and a push-pull rod at each of the spoiler panels.

The drive tubes consist of short segments of large-diameter, heat-treated, alloy-steel tubing joined together by threaded fittings which provide length adjustment of each tube segment to facilitate rigging of the system. The opening and closing cables, which connect the drive tubes and drive quadrants, are attached to lugs on the drive tubes with adjustable connectors.

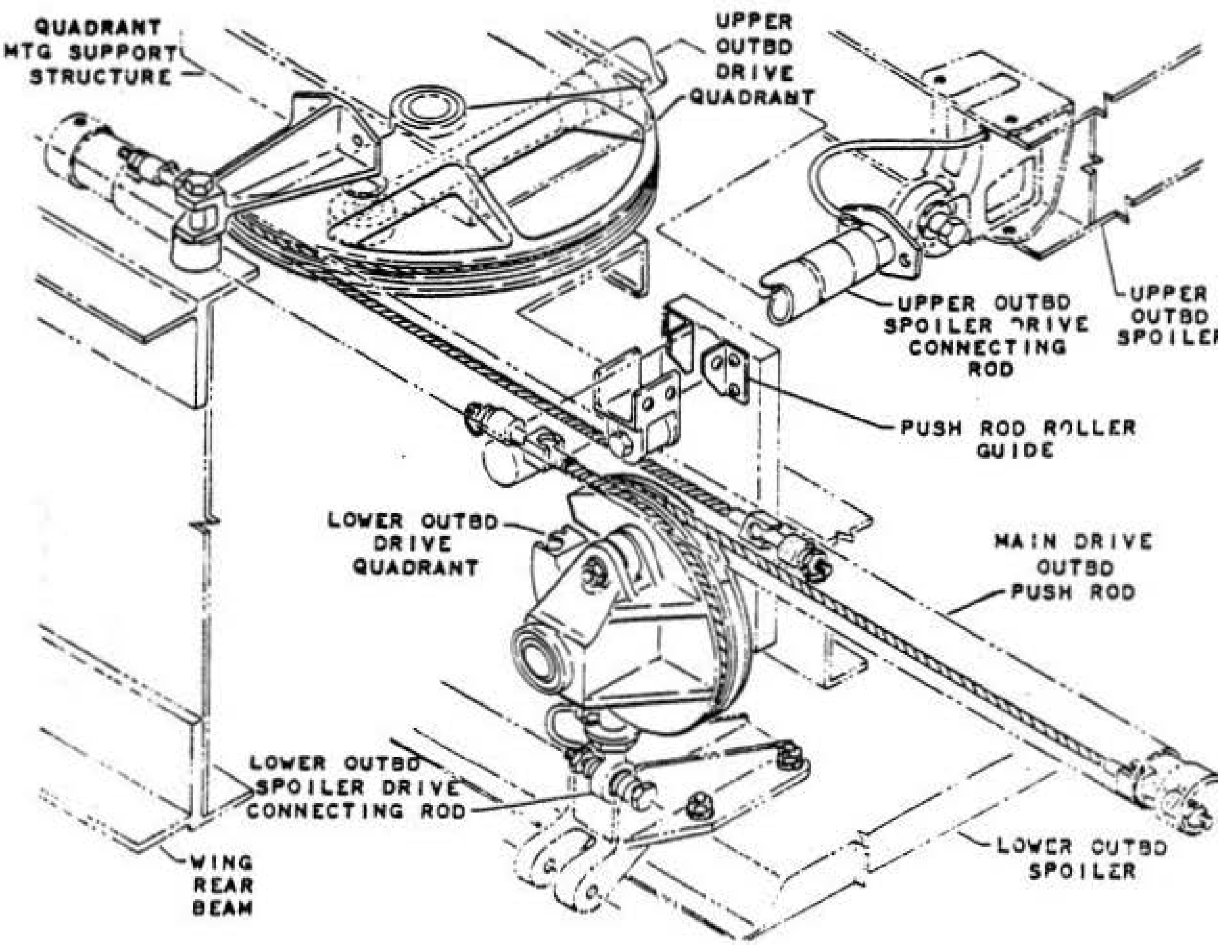


INBOARD SPOILER DRIVE

Actuator motion transmitted by the drive tubes is transferred through the cables to the drive quadrants. Each drive quadrant operates through a push-pull rod, attached to a bell crank on the spoiler panel, to move the spoiler panel.

At the flight limit position, the spoiler panels are held open by the force of the hydraulic actuators. When the spoiler panels are deployed to the ground position, the push-pull rods' attach points on the lower spoiler panels' drive quadrants are driven overcenter, imparting a mechanical block on the output system.

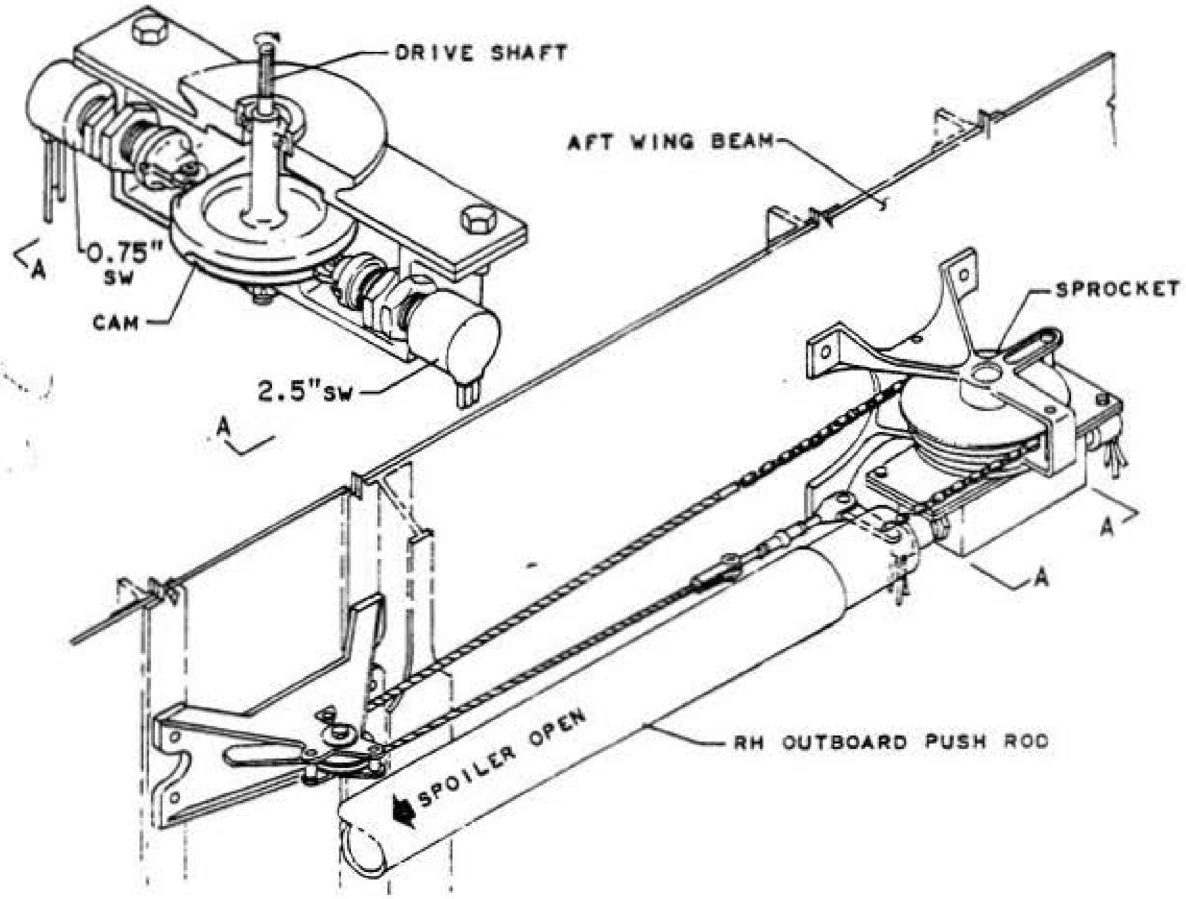
All spoiler panels are locked closed mechanically by driving the push-pull rods' attach points overcenter. The inboard drive tubes position both the upper and the lower inboard spoiler panels. Hydraulic actuators drive the inboard drive tubes in an outboard direction to open the spoiler panels. The outboard drive tubes position both the upper and the lower outboard spoiler panels. Outboard drive tubes are moved in an inboard direction to open the spoiler panels. All drive tubes are tension loaded while the spoilers are opening.



OUTBOARD SPOILER DRIVE

The asymmetry detection system is comprised of two dual switch, cam operated detectors which monitor outboard spoiler position during the first 2.5 inches of outboard drive tube travel. These detectors are located near the end of the outboard drive tubes and are attached to the wing rear beam. Cams which operate the detectors are rotated by drive tube movement through a cable, chain, and sprocket drive. Two switches on each detector are actuated as the cams rotate. One switch is actuated open when the drive tube has traveled 0.75 inch and the other switch is actuated closed when the drive tube has traveled 2.5 inches. Outboard drive tube travel is compared by electrically connecting the 0.75 inch travel switch on one wing to the 2.5 inch travel switch on the opposite wing. If one drive tube travels 2.5 inches before the opposite drive tube has moved 0.75 inch, an electrical circuit is completed to relays to deenergize the asymmetry pilot valve solenoids in the actuator units which causes all spoiler panels to close.

A synchro position transmitter is attached to the wing rear beam near the end of each inboard drive tube and is driven by a cable, chain, and sprocket in response

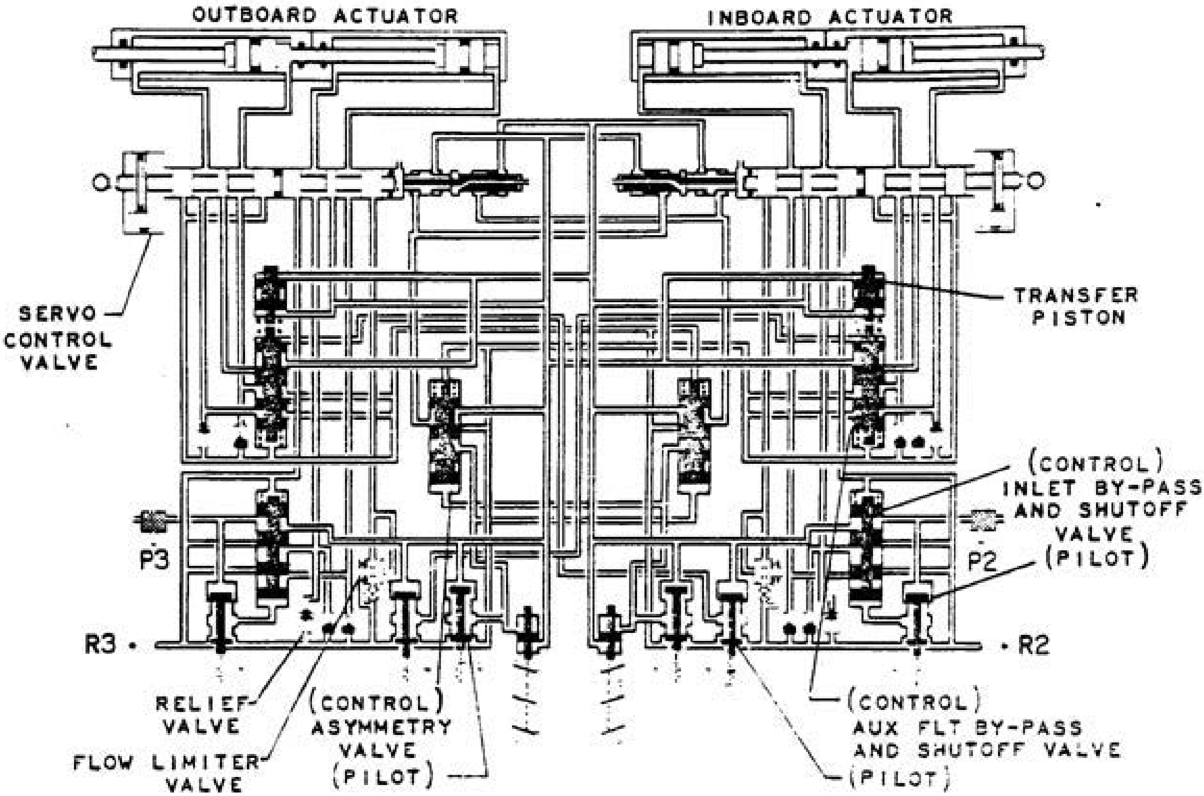


ASYMMETRY DETECTOR DRIVE

to inboard drive tube travel. Spoiler position is indicated on a dual pointer indicator on the center instrument panel.

A dual-tandem spoiler actuator unit is located on each side of the aircraft and is attached to the wing rear beam. Internally, each actuating unit manifold contains two tandem actuating cylinders, two tandem servo control valves, filter relief valves, anticavitation valves, flow limiter valves, and check valves. The acutator units also contain inlet by-pass and shutoff valves, auxiliary flight by-pass and shutoff valves, and asymmetry valves.

Each tandem actuator is divided into two cylinders, a primary cylinder and an auxiliary cylinder. No. 2 hydraulic system pressure is supplied to the primary cylinders of the inboard tandem actuators and to the auxiliary cylinders of the outboard tandem actuators. No. 3 hydraulic system supplies the primary cylinders



ACTUATOR UNIT (INTERNAL)

of the outboard tandem actuators and the auxiliary cylinders of the inboard tandem actuators.

For in flight spoiler operation, fluid is supplied to all four of the tandem actuators from both the No. 2 and the No. 3 hydraulic systems. Both the primary and auxiliary cylinders of each tandem actuator are used because of the high force required for in flight spoiler operation.

For ground operation, only the primary cylinders of the tandem actuators are used. The inboard tandem actuators are supplied by the No. 2 hydraulic system and the outboard actuators are supplied by the No. 3 hydraulic system.

Hydraulic fluid from both the No. 2 and the No. 3 hydraulic systems is routed through dual manually-operated shutoff valves in the wings before entering the actuator unit. The dual manual shutoff valves are located adjacent to the actuator units and the handle for each valve is accessible on the ground only.

All hydraulic fluid entering the actuator units is passed through micronic filters on the actuator units. A clogged filter indicator button is provided for monitoring filter contamination by extending to indicate a differential pressure across the filter element.

Pressure distribution from both the No. 2 and No. 3 hydraulic systems is routed through inlet by-pass and shutoff valves as the fluid leaves the filters. The inlet by-pass and shutoff valves are electrically deenergized open for spoiler system operation.

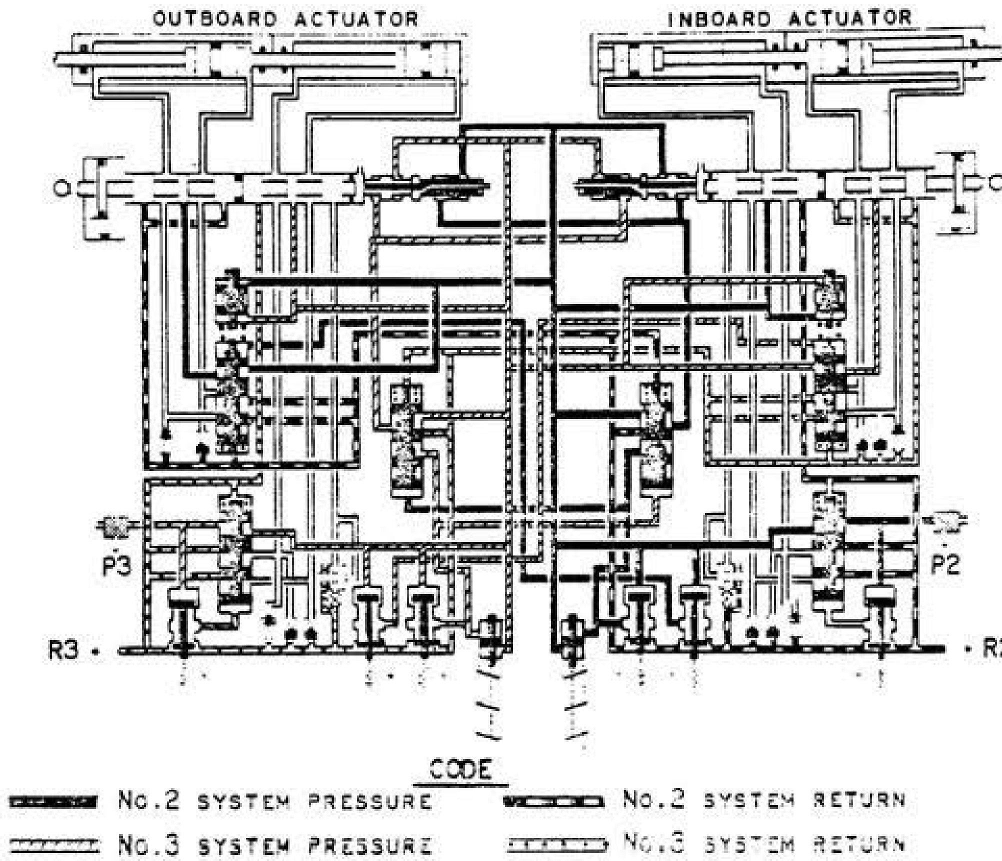
IN FLIGHT OPERATION.

For normal flight operation, hydraulic pressure is available to both dual tandem spoiler actuator units from the No. 2 and No. 3 hydraulic systems.

No. 2 and No. 3 hydraulic system pressures are available at the servo control valves. Pressure comes to the servo control valves directly from the inlet by-pass and shutoff valves and is applied to the primary cylinders of the actuators. No. 2 hydraulic system pressure will be available to the inboard primary cylinders and No. 3 hydraulic system pressure to the outboard primary cylinders.

The auxiliary flight by-pass and shutoff valves are electrically energized open in flight by placing the landing gear handle in the "UP" position. This allows No. 2 and No. 3 hydraulic system pressures to the servo control valves to be applied to the auxiliary cylinders of the actuators. The route of the fluid from the inlet by-pass and shutoff valves is through the auxiliary flight by-pass and shutoff valves' pilot spools, to the control spools of the auxiliary by-pass and shutoff valves. The pressure on the control spools will override the valve closing springs and cause the valves to open. No. 2 hydraulic system pressure will be available to the outboard auxiliary cylinders and No. 3 hydraulic system pressure to the inboard auxiliary cylinders.

If either the No. 2 or the No. 3 hydraulic system were to fail in flight, the remaining system would supply all four actuators. Each actuator unit would have one actuator operated by the primary cylinder and the other operated by the auxiliary cylinder. Whether it would be the inboard or the outboard actuators which would be operating on the primary or auxiliary cylinder, would be determined by which hydraulic system had failed. If the No. 2 hydraulic system failed, the primary cylinders of the outboard actuators and the auxiliary cylinders of the inboard actuators would be used. If the No. 3 system failed, the primary cylinders of the inboard actuators and the auxiliary cylinders of the outboard actuators would be used. The auxiliary bypass and shutoff valves' control spools for the failed system would close and connect the auxiliary cylinder of the actuators to return. The failed systems' primary cylinders would be connected

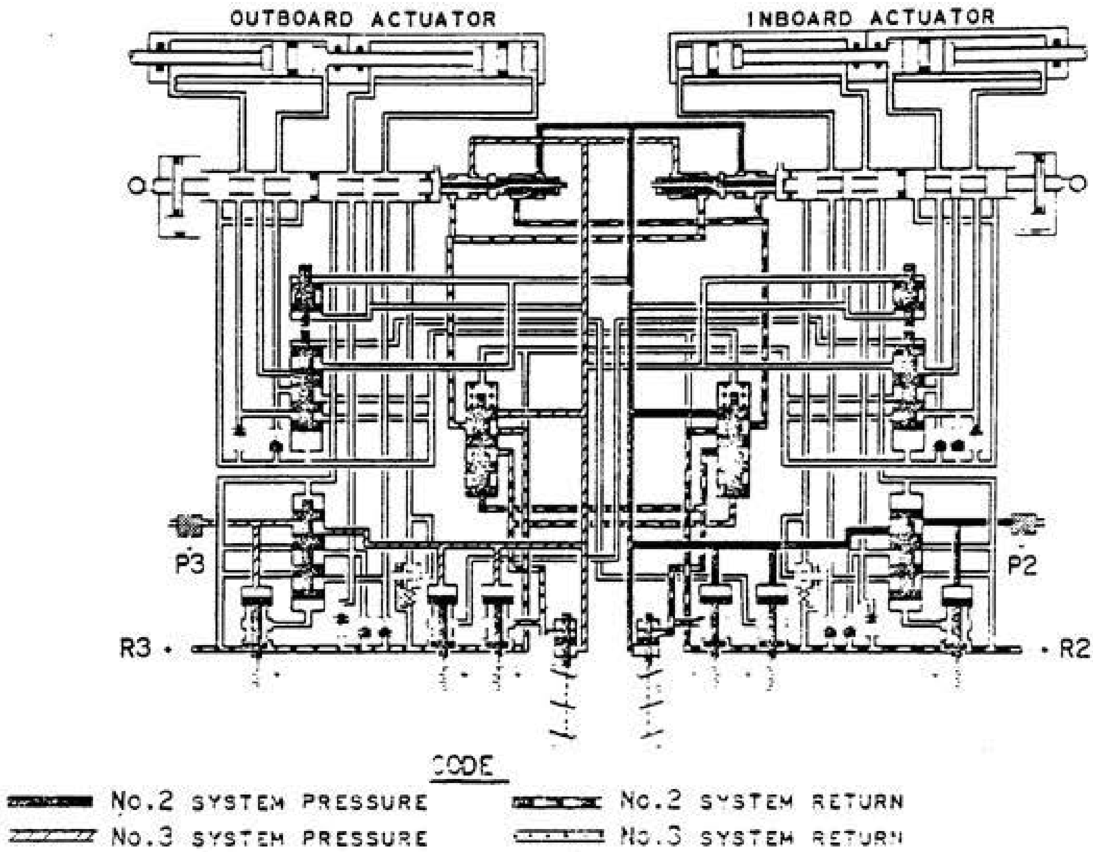


NORMAL FLIGHT OPERATION

to return by the servo control valve. If the inoperative cylinder of an actuator tends to cavitate, suction would pull fluid through the anticavitation valves into the inoperative cylinders.

GROUND OPERATION.

For normal ground operation, the auxiliary flight by-pass and shutoff valves' pilot valves are deenergized by placing the landing gear handle in the "DN" position. This removes pressure from the control spools of the auxiliary flight by-pass and shutoff valves and allows them to close. No. 2 hydraulic system pressure will be shut off to the outboard actuators' auxiliary cylinders and No. 3 hydraulic system pressure will be shut off to the inboard actuators' auxiliary cylinders. Pressure will be available only to the primary cylinders of the actuators: No. 2 hydraulic system pressure to the inboard primary cylinders and No. 3 hydraulic system pressure to the outboard primary cylinders.



ASYMMETRY OPERATION

ASYMMETRY OPERATION.

An asymmetry system is incorporated to automatically close all spoiler panels if one outboard drive tube moves 2.5 inches and the other outboard drive tube has not moved 0.75 inch during the opening cycle. Closure pistons inside the actuator units position the servo control valves to the spoiler close position and hydraulic pressure closes and locks the spoiler panels.

The portion of the asymmetry system in each actuator unit consists of two switch pistons, four closure pistons, and two solenoid operated valves; each valve consists of a pilot valve and a control valve assembly. The switches which are operated by the switch pistons are mounted externally on the actuator unit.

No. 2 hydraulic system pressure is applied to one closure piston at each inboard actuator servo control valve and to one closure piston at each outboard actuator servo control valve. No. 3 hydraulic system pressure is applied to closure pistons in the same manner. This pressure is routed directly from the inlet by-pass and shutoff valves and is applied to the end of the closure pistons to move the servo control valves to the spoilers close position. When spoiler panel position is symmetrical within the allowable limits, No. 2 and No. 3 hydraulic system pressure is directed to the opposite ends of the closure pistons to create a hydraulic balance. With a hydraulically balanced condition there is no closure piston force available to position the servo control valves.

The balance pressure is directed to the closure pistons from the inlet by-pass and shutoff valves by positioning the asymmetry valves' control spools. The asymmetry valves' control spools are positioned open by hydraulic pressure which is directed by the electrically energized pilot valves. The asymmetry pilot valve solenoids are energized when spoiler panel position is symmetrical within the allowable limits.

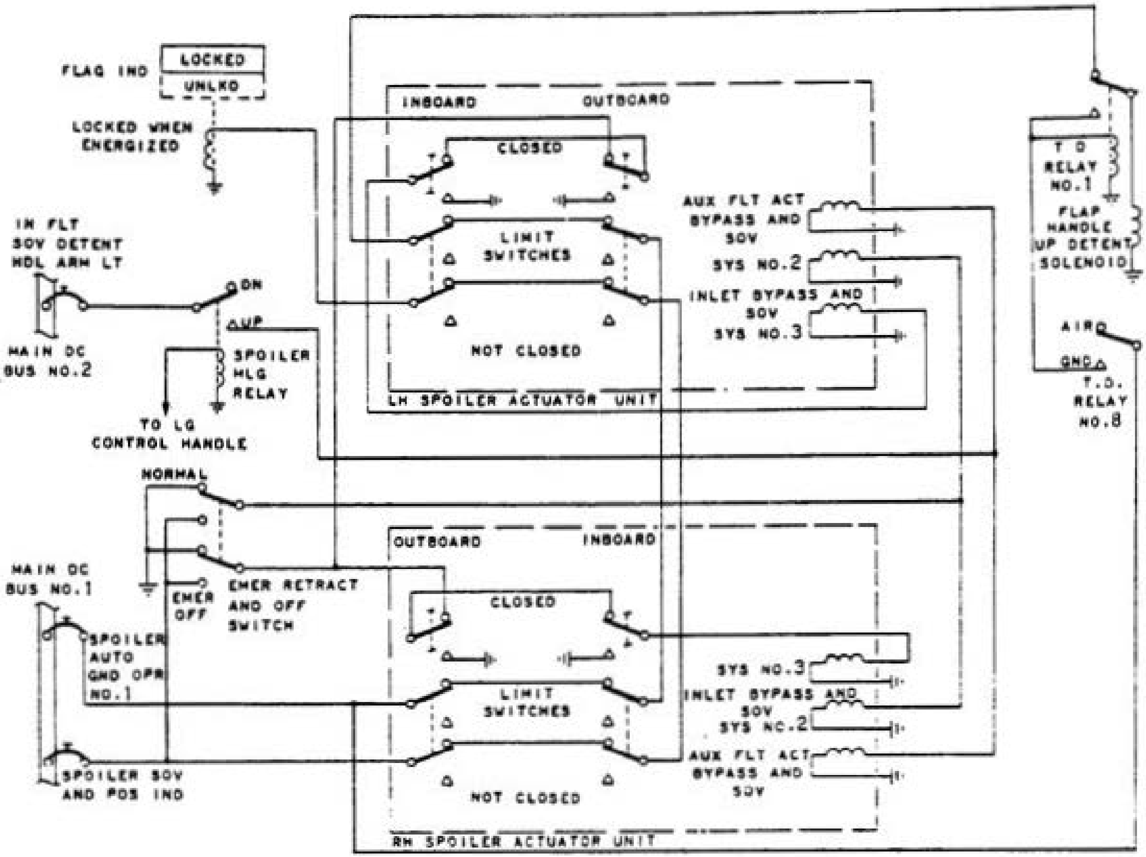
Both No. 2 and No. 3 hydraulic system pressure is applied to each asymmetry valves' control spool. The control spool assemblies are designed so both No. 2 and No. 3 hydraulic system pressures must be lost to the control spool assemblies before they can close.

All asymmetry pilot valve solenoids will deenergize in the event of an asymmetrical condition. Deenergizing the pilot valve solenoids allows the control spools to shutoff the balance pressure to the closure pistons and connect the balance side of the closure pistons to return. Pressure on the opposite ends of the closure pistons moves the closure pistons against the servo control valves and positions them to the spoiler close position.

ELECTRICAL.

The electrical portion of the spoiler system consists of three basic functions which are somewhat interrelated. These basic functions are: control, automatic operation, and the asymmetry function.

The No. 2 and No. 3 hydraulic systems inlet by-pass and shutoff valves on the actuator units are normally deenergized open. 28-volts DC is required to close the inlet by-pass and shutoff valves which shut off hydraulic pressure to the actuator units. The control voltage is provided by positioning the emergency retract and off switch on the center console to "EMER OFF." When "EMER OFF" is selected, the inlet by-pass and shutoff valves in the No. 2 hydraulic system pressure lines will close immediately. The inlet by-pass and shutoff valves for No. 3 hydraulic system pressure will be energized closed when both actuators of the actuator unit have fully extended thereby closing and locking the spoiler panels.



SPOILER ELECTRICAL CONTROL

Limit switches, mounted on each of the actuator units, are actuated when the actuators are bottomed out while closing the spoiler panels. The limit switches are part of the No. 3 system inlet by-pass and shutoff valve circuits and are also part of the No. 3 hydraulic system pump circuits. During spoiler system operation, the No. 3 system pumps are turned on when the spoiler control handle is moved from the "CLOSED" position. When the spoiler control handle is returned to the "CLOSED"position, the switches will turn off the No. 3 hydraulic system pumps after the actuators have driven all spoiler panels closed and locked. If an actuator were to move from the closed position in flight, the pumps would be turned on automatically to aid in closing the panels. The actuator limit switches, wired in series, control a LOCKED, UNLKD flag on the position indicator on the center instrument panel.

Anytime the No. 3 hydraulic system pumps are turned on, two control valves are opened for spoiler operation. The spoiler cable servo selector valve opens and allows No. 3 hydraulic system pressure to be used to position the spoiler cable servo; the accumulator control valve also opens and connects the two No. 3 hydraulic system accumulators into the system pressure manifold. To minimuze leakage of the accumulators, both of these valves are closed when the No. 3 hydraulic system pumps are off.

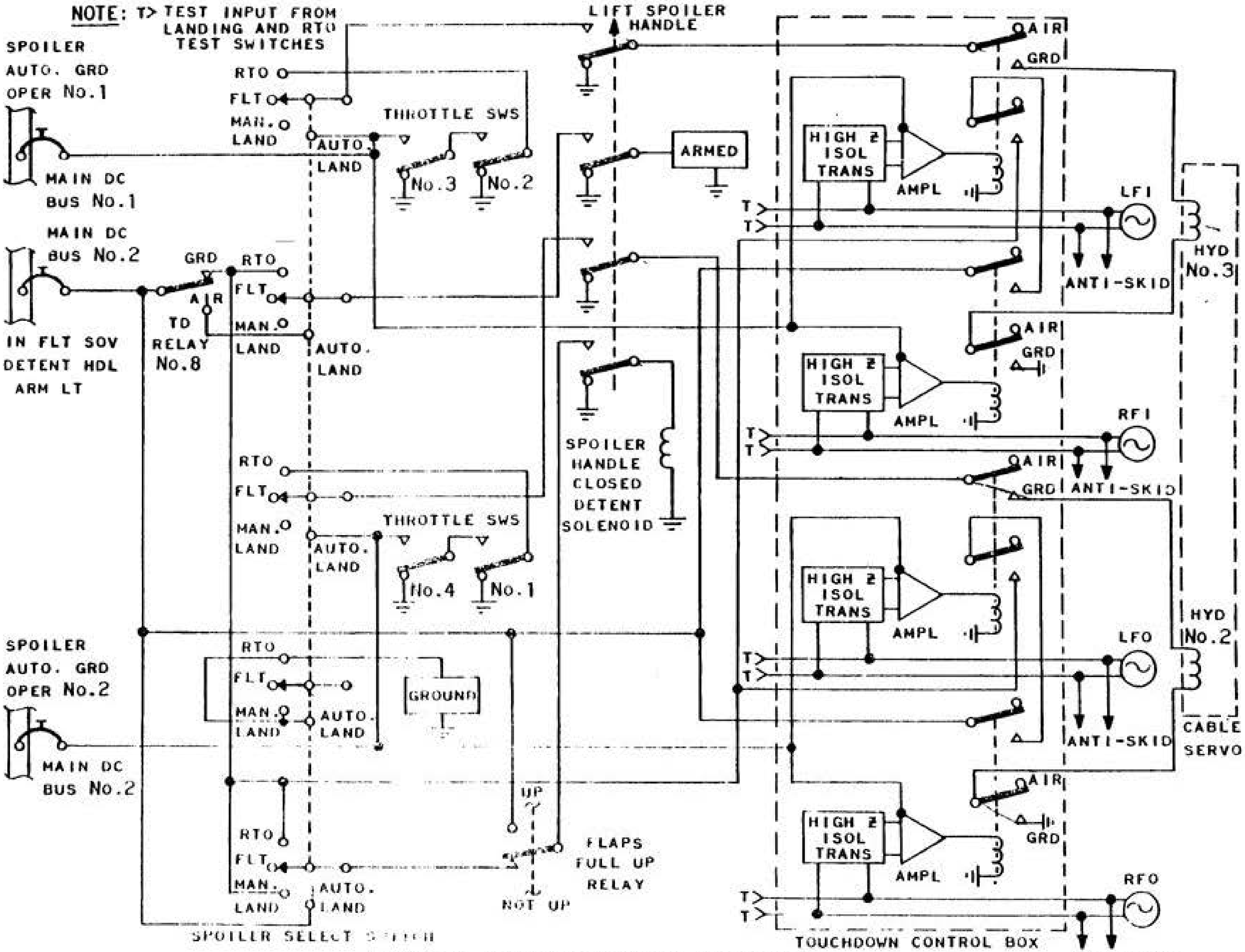
The auxiliary flight by-pass and shutoff valves in the actuator units are energized open by placing the landing gear handle to "UP". When the landing gear handle is placed to "DN", the auxiliary flight by-pass and shutoff valves deenergize and close the valves.

The spoiler system may be armed to deploy automatically on landing or in the event of a rejected take-off. For automatic deployment on landing, the SPOILER SELECT switch is positioned to "AUTO LAND" and the spoiler control handle is lifted. At touchdown, when the rotational speed of the wheels as sensed by the anti-skid detectors is 50 knots or above, the spoiler panels will deploy to the ground position.

When armed for "AUTO LAND," an ARMED light and a GROUND light on the center console will illuminate. The spoiler control handle high-force detent solenoid will be energized to low force when "AUTO LAND" is selected, and the spoiler control handle is lifted. Although the flap position relay is in the high-force detent solenoid circuit, it does not have a function when "AUTO LAND" is selected. If the high-force detent solenoid fails to energize, the cable servo force can override the detent even with only No. 2 hydraulic system pressure.

When "AUTO LAND" is selected and the spoiler control handle is lifted, voltage is supplied to relay contacts inside the touchdown control box. The touchdown control box is located inside the cargo compartment on the right side aft of the No. 2 hydraulic system service center. The control box contains four high impedance transformers, four amplifier circuits, and four relays. Output from the forward wheel anti-skid detectors is fed to the touchdown control box as part of the automatic deployment system. When wheel speed is 50 knots or above, the relays inside the touchdown control box will energize and complete the circuits to the solenoids of the spoiler cable servo. No. 2 and No. 3 hydraulic system pressures are directed to the spoiler cable servo actuator to position the input system for ground deployment. The forward outboard anti-skid detectors control the No. 2 hydraulic system solenoid of the spoiler cable servo, and the forward inboard detectors control the No. 3 hydraulic system solenoid.

For automatic deployment in the event of a rejected take-off, "RTO" is selected and the spoiler control handle is lifted. If wheel rotation speed is above 50 knots and if either No. 1 and No. 4 or No. 2 and No. 3 throttles are positioned to "REVERSE IDLE," the spoiler panels will deploy to the ground position.



AUTOMATIC SPOILER ELECTRICAL OPERATION

The ARMED light and the GROUND light will illuminate as an indication of system armed for RTO, and the spoiler control handle high force detent will be removed.

The operation of the touchdown control box is the same for RTO and AUTO LAND except that the voltage provided to the relay contacts goes through the throttle switches for RTO.

When "MAN LAND" is selected and the spoiler handle is lifted, the GROUND light illuminates and the high force detent solenoid is energized. The spoiler control handle is used to manually position the input system.

With "FLIGHT" selected the high force detent solenoid is energized when the spoiler handle is lifted provided the flaps are full up. No light indication is provided for "FLIGHT" selection and the handle is positioned manually.

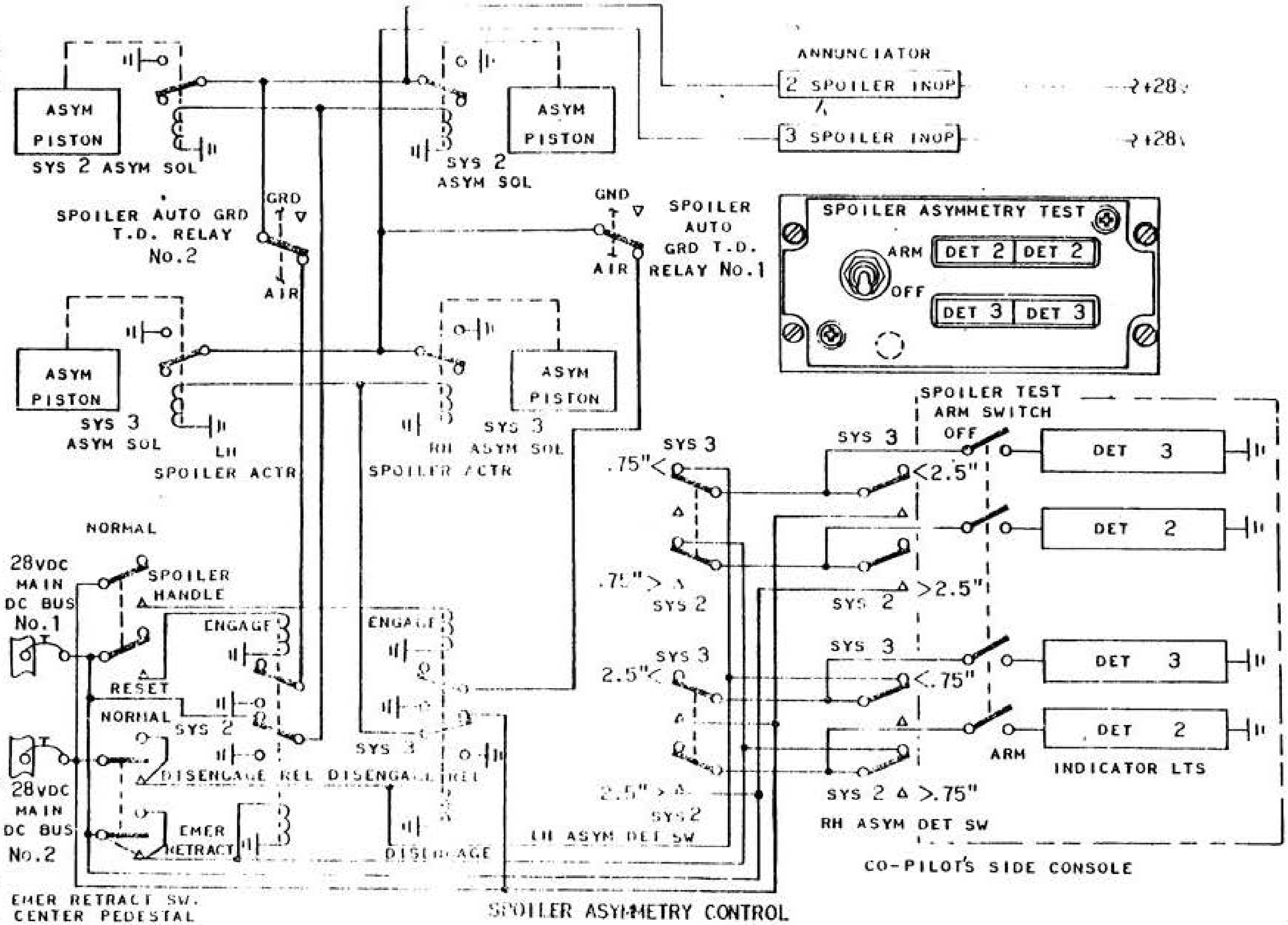
A test panel located on the copilot's side panel provides a means of simulating wheel speed above 50 knots. By using the test switches and arming the system, the automatic deployment operations can be checked with the aircraft parked.

The asymmetry detection switches are actuated as the cams rotate. One switch of each detector is actuated open when the drive tube has traveled 0.75 inch and the other switch is actuated closed when the drive tube has traveled 2.5 inches. Outboard drive tube travel is compared by electrically connecting the 0.75 inch travel switch on one side to the 2.5 inch travel switch on the opposite side. If one drive tube travels 2.5 inches before the opposite drive tube has moved 0.75 inch, an electrical circuit is completed to disengage relays which deenergize the asymmetry pilot valve solenoids in the actuator units and cause all spoiler panels to close.

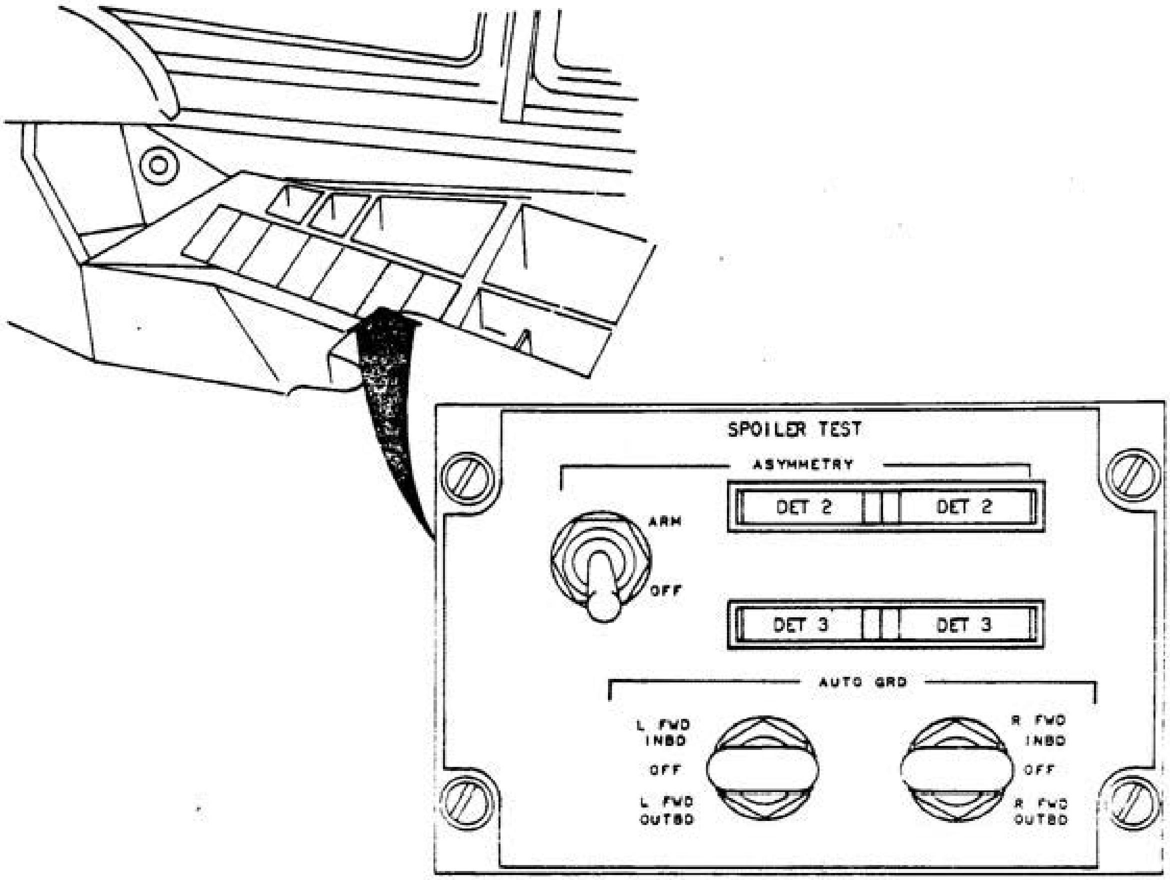
DETECTOR lights located on the spoiler asymmetry test panel illuminate to indicated proper detector switch operation the first 2.5 inches of drive tube travel.

In the event of an asymmetrical condition, the asymmetry pistons inside the actuator units position switches to illuminate spoiler asymmetry lights on the annunciator panel.

To restore system operation after an asymmetry closure the spoiler control handle is moved forward past the "CLOSED" position which will energize the engage/ disengage relays.



SPOILER ASYMMETRY CONTROL

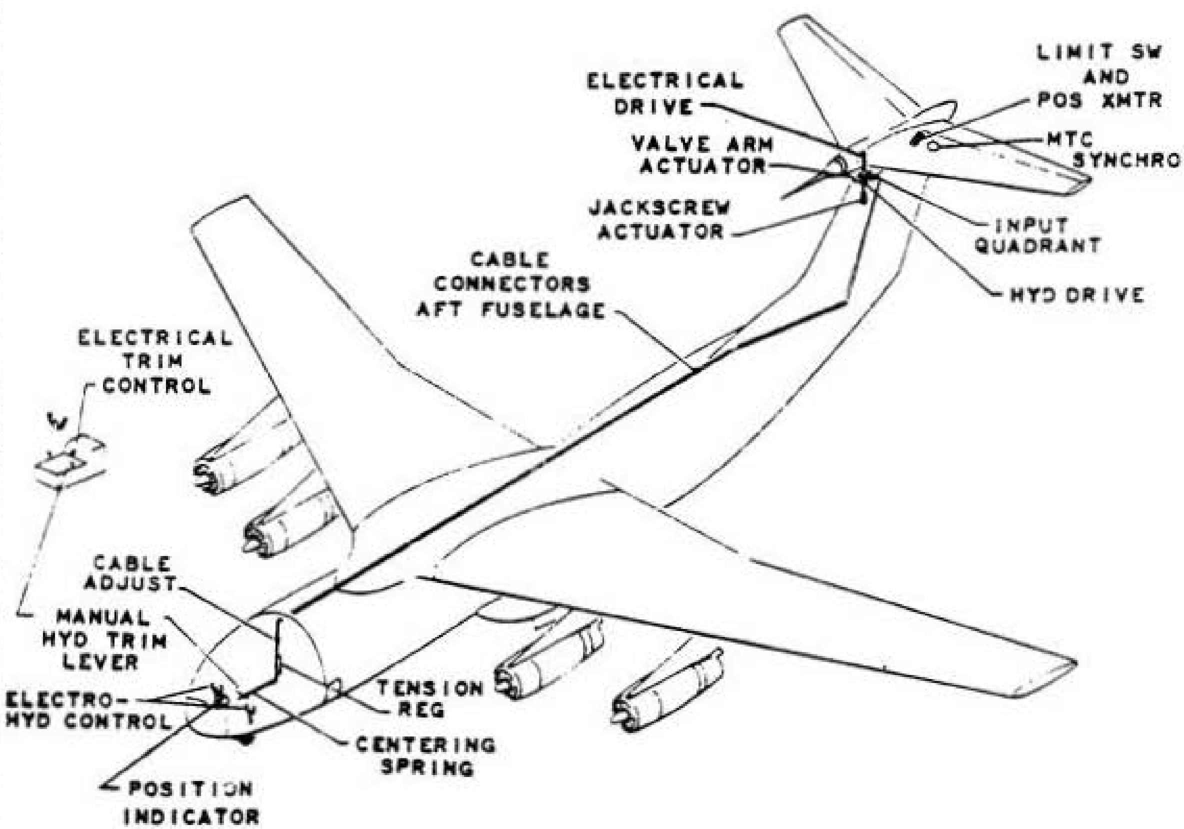


ASYMMETRY TEST PANEL

PITCH TRIM SYSTEM

GENERAL DESCRIPTION.

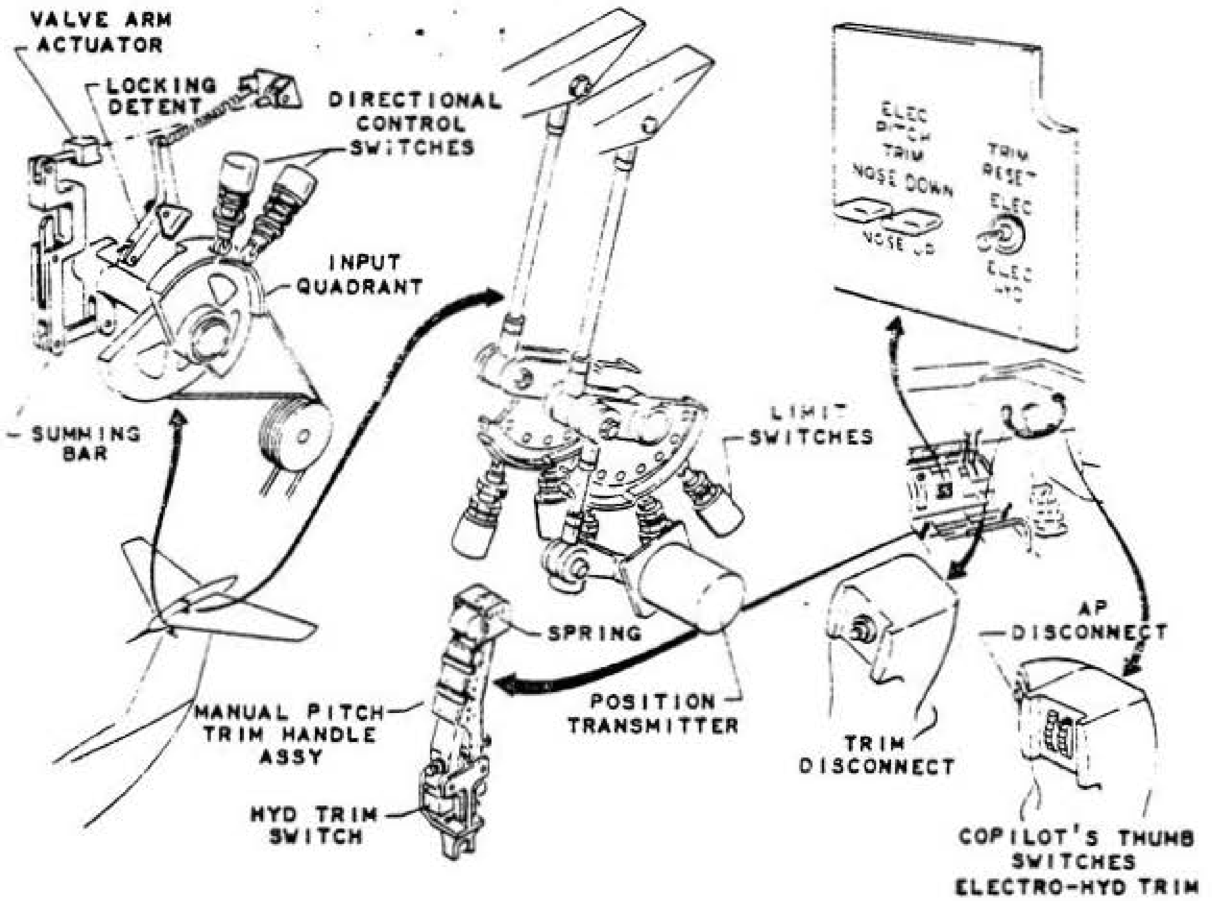
Trimming the aircraft about the pitch axis is accomplished by movement of the horizontal stabilizer. The pitch trim system includes the horizontal stabilizer, the horizontal stabilizer actuator, the electro-hydraulic trim control system, the manual-hydraulic trim control system, the electrical trim control system, the electrical power circuits, and the horizontal stabilizer position indication system.



CONTROLS INSTALLATION

The rear spar of the horizontal stabilizer is attached by pivots to the top of the vertical stabilizer. Pitch trim is accomplished through angular rotation of the horizontal stabilizer around the pivot axis to change the control surface angle of attack. Upward movement of the horizontal stabilizer leading edge produces nose-down trim of aircraft attitude, and downward movement of the stabilizer leading edge produces nose-up trim. The pitch trim system supplements the elevator control system but is completely independent of elevator control surface movements. The angular trim range of the horizontal stabilizer is approximately four degrees above the neutral position to 12.5 degrees below neutral.

Pitch trim corrections may be made by operating either of the following: electro-hydraulic trim control switches located on the pilot's or the copilot's control wheel, the manual-hydraulic control levers, or the electrical trim control switches located on the center console. Electrical signals from the autopilot or Mach trim compensator systems will produce trim corrections when these systems are operating. A disconnect button is located on the inboard grip of the pilot's and copilot's wheels to disengage the trim control systems. These systems are reset by positioning the



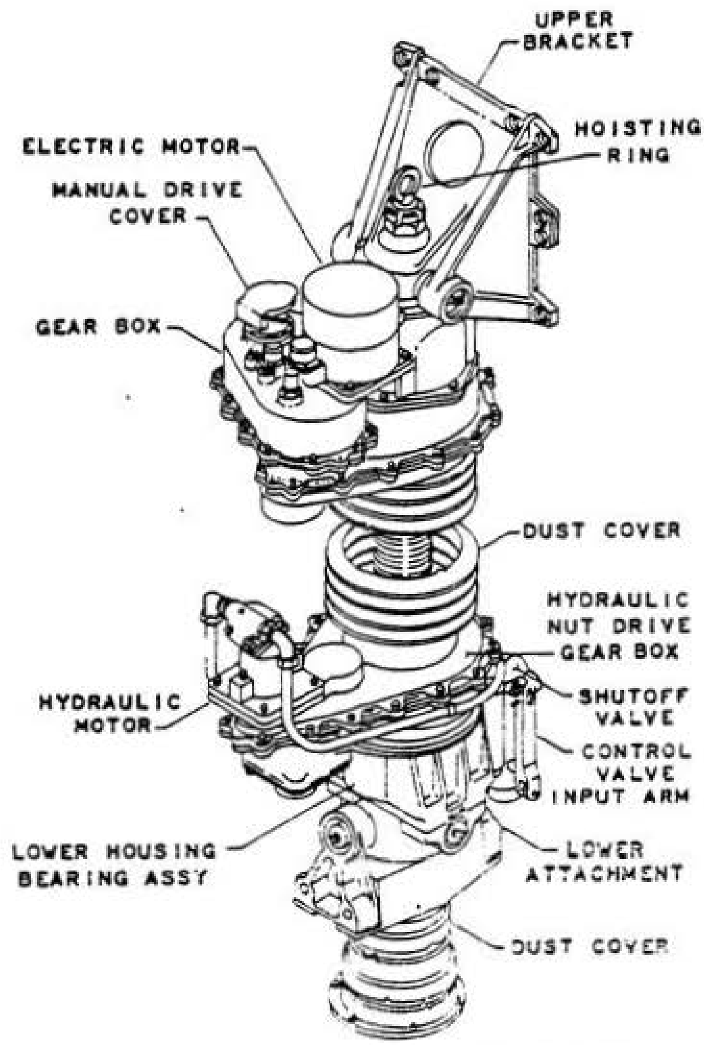
CONTROL SWITCHES

reset switch, located on the center console, to "ELEC" for the electrical trim control system and to "ELEC-HYD" for the electro-hydraulic trim control system. An autopilot disconnect button is located on the outboard grip of the pilot's and copilot's control wheels and is used to disengage the automatic pitch trim mode of the autopilot.

THE SYSTEM.

The horizontal stabilizer actuator, a linear screwjack type actuator, is mounted vertically. The upper attach fitting of the actuator is bolted to the forward spar of the horizontal stabilizer, and the lower attach fitting is bolted to a shelf on the forward spar of the vertical stabilizer. Two completely independent drive systems are used, an electromechanical and a hydromechanical drive unit. The electromechanical drive unit is located at the top of the actuator assembly and is driven by an electric motor. This assembly, consisting of a gear train and dual clutch arrangement, turns the jackscrew. The hydromechanical unit is located at the lower end of the actuator assembly and is driven by a hydraulic motor. This assembly consists of a gear train and a rotating nut which is turned by the gear train. The rotating nut, through which the jackscrew is threaded, is restrained from vertical movement by thrust bearings. Pitch trim is accomplished by rotating the screw within the nut (electromechanical drive) or by rotating the nut around the jackscrew (hydromechanical drive). Either mode of operation will cause the jackscrew to extend or retract.

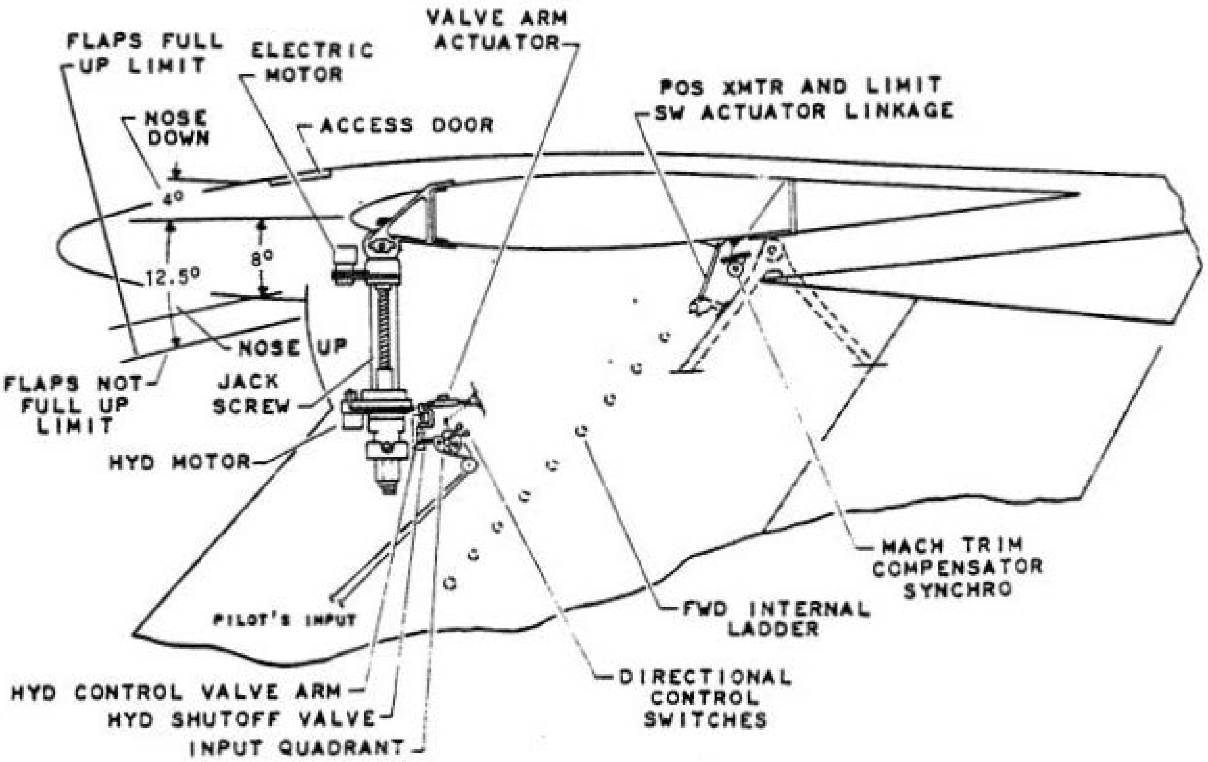
The hydromechanical drive unit of the stabilizer actuator can be controlled by either the electro-hydraulic trim control system or by the manual-hydraulic trim control system since both systems are connected to the flow control valve, of the hydromechanical drive, by a summing bar linkage. Input motion from either trim control system can be transferred to the valve lever by the summing bar linkage while the other trim control system remains static. Components included in the electro-hydraulic trim control system are as follows: dual switches on the outboard grip of the pilot's and copilot's wheels, a solenoid-controlled hydraulic actuator connected to the summing bar linkage, a Mach trim compensator disengage relay, an autopilot disengage relay, and three stabilizer position limit switches. The pair of trim switches on either control wheel can be used to operate the electro-hydraulic trim control system. Simultaneous operation of both switches of either pair to the "NOSE UP" or "NOSE DN" positions, provides power and ground to the respective solenoid in the hydraulically operated control valve actuator. It is impossible for the set of switches on one control wheel to electrically override the switches on the other control wheel. As the control valve actuator extends or



HORIZONTAL STABILIZER TRIM ACTUATOR

retracts, the summing bar linkage and the control valve are positioned to drive the stabilizer to a corresponding position. Operation of the control wheel trim switches in either direction also deenergizes the hydraulic shutoff valve, on the stabilizer actuator, to the open position and disengages the autopilot and Mach trim compensator systems.

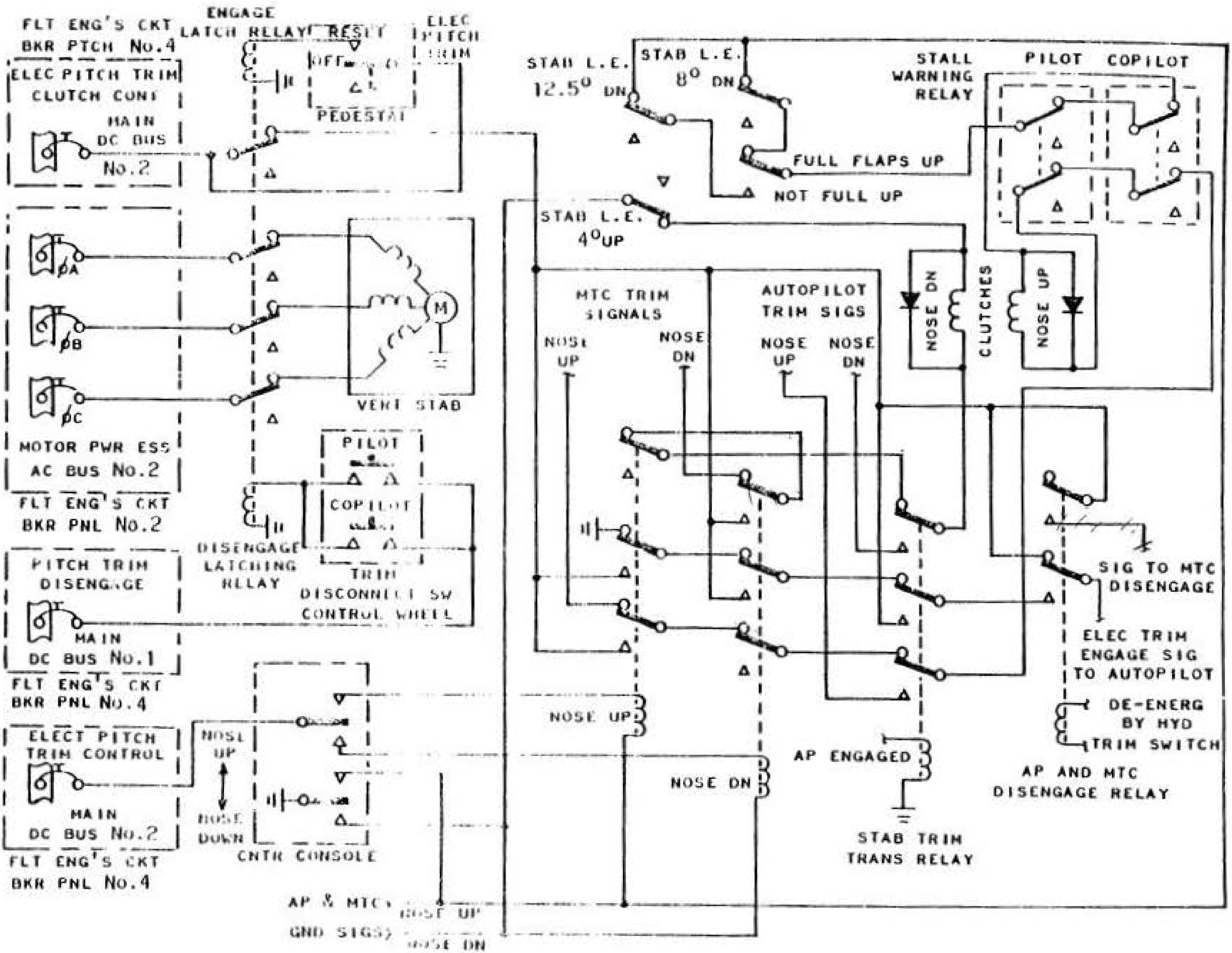
There are six limit switch assemblies mounted in the vertical stabilizer and connected by mechanical linkage to the horizontal stabilizer. Two sets of contacts are used in three of these switch assemblies, one set for the electro-hydraulic trim control system circuits and one set for the manual-hydraulic trim control system circuits. The limit switches associated with the electro-hydraulic trim control switches, when actuated, interrupt the power circuit to the corresponding



EMPENNAGE INSTALLATION

control valve actuator solenoid to stop stabilizer actuator operation. The nose-down limit switch actuates when the horizontal stabilizer leading edge reaches the four-degrees-above-neutral position. One of the nose-up limit switches is actuated when the horizontal stabilizer leading edge reaches the eight-degrees-below-neutral position if the flaps are fully retracted. If the flaps are not fully retracted, the flap position relay transfers the nose-up power circuit to the 12.5 degrees nose-up limit switch circuit. This circuit is actuated when the stabilizer leading edge reaches a position 12.5 degrees below the neutral position.

The pilot and copilot are each provided with a pitch trim control lever. These levers, located on the center console, are connected to the stabilizer actuator summing bar by mechanical linkage and cables. The summing bar linkage permits either the electro-hydraulic or the manual-hydraulic control system to introduce control motions to the stabilizer actuator flow control valve while the other control system remains static. Each control lever has a switch that is actuated to the open position when the fore and aft sections of the control lever



ELECTRICAL TRIM CONTROL SCHEMATIC

handle are squeezed together. If either lever switch is open, the hydraulic shut-off valve at the stabilizer actuator is deenergized to the open position and pressure is admitted to the flow control valve. The displacement of the control levers in either direction from the neutral position results in a proportional displacement of the flow control valve. The rate of stabilizer actuation is therefore proportional to the amount of control lever displacement. Operating either control lever switch also deenergizes the pitch trim disengage relay of the autopilot and Mach trim systems to disconnect these systems from the stabilizer actuator.

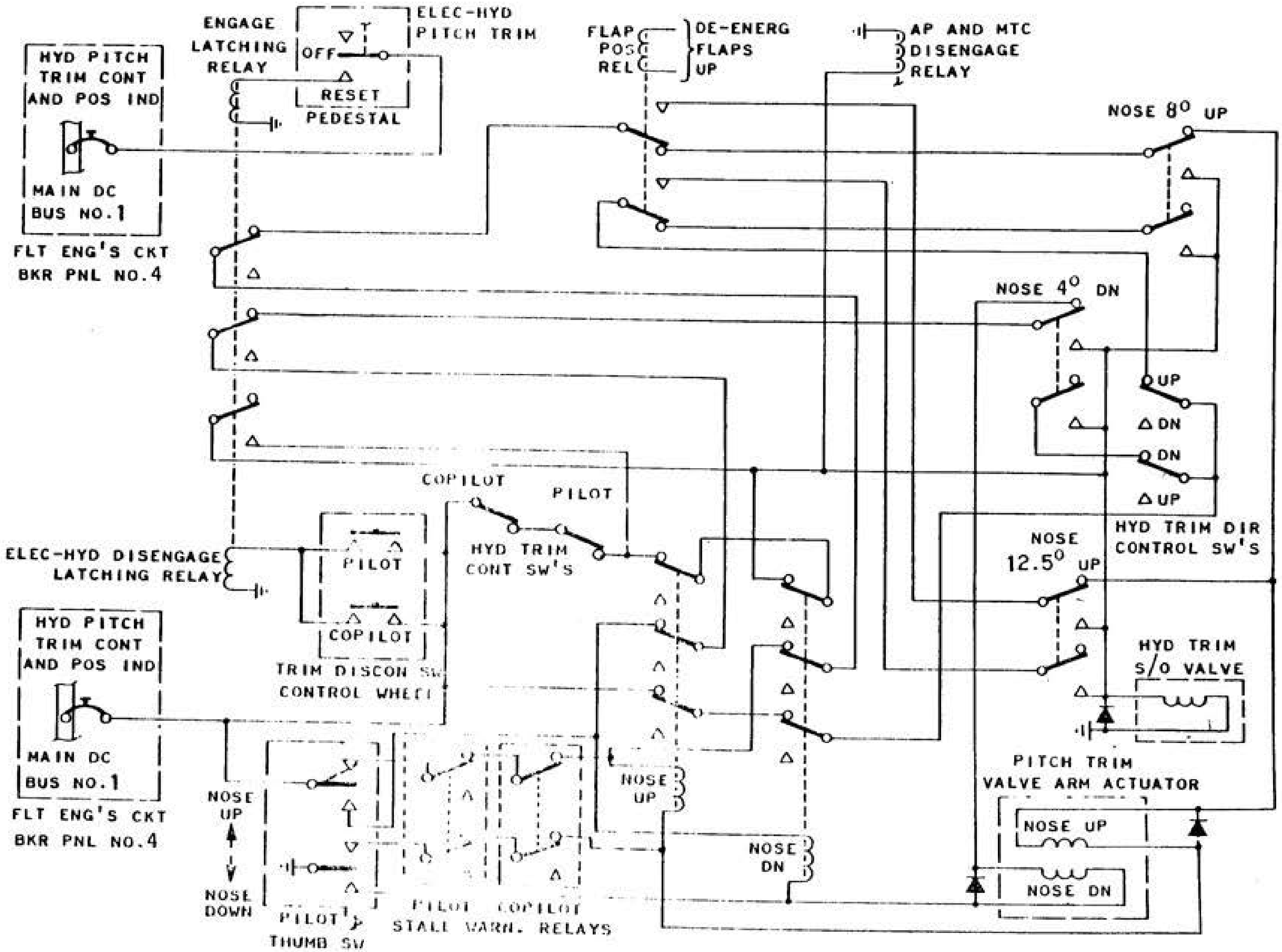
The electromechanical drive unit of the stabilizer actuator is controlled by the electrical trim control system, and by the autopilot or Mach trim compensator system if these systems are operating. The electrical trim control system includes: dual ELEC PITCH TRIM control switches on the center console, two clutch relays, a transfer relay, two counter-rotating clutches, three stabilizer position limit switches, and a trim disconnect relay. Also the trim disconnect switches on the control wheels and the trim reset switch on the center console are shared with the electro-hydraulic trim control system. Simultaneous operation of the two electric pitch trim switches to the "NOSE UP" or "NOSE DN" positions connects power and supplies a ground for the clutch relay corresponding to the direction of switch operation. The clutch relay function is to connect electrical power to the corresponding actuator clutch and to connect a disengage signal to the Mach trim compensator system. Both circuits are routed through a transfer relay. The transfer relay switches the control of the trim system from pilot to autopilot and directs a disengage signal to the Mach trim compensator system when the autopilot system is engaged. The autopilot system then furnishes power and a ground circuit for trim operation. The autopilot is disengaged when the pilot energizes one of the hydraulic trim control systems. The three limit switches associated with the electrical trim control system are mounted in the vertical stabilizer and are actuated by linkage connected to the horizontal stabilizer. The nose-down limit switch actuates when the horizontal stabilizer leading edge reaches a position four degrees above the neutral position to interrupt the ground circuit to the nose-down clutch. If the flaps are fully retracted, one of the nose-up limit switches actuates when the stabilizer leading edge reaches a position eight degrees below the neutral position to interrupt the nose-up clutch ground circuit. If the flaps are not fully retracted, the flap position relay routes the ground circuit of the nose-up clutch circuit through the limit switch which actuates when the stabilizer leading edge is 12.5 degrees below the neutral position. The Mach trim compensator system is connected to the electrical trim control system at the clutch relays. When connected, the Mach trim system furnishes power and a ground circuit for the motor clutch being operated. The Mach trim system is disengaged when the autopilot is engaged, when the pilot energizes a clutch relay, and when the pilot energizes one of the hydraulic trim control systems.

Either of the trim disconnect switches, one on the inboard grip of each control wheel, can be used to disconnect the electro-hydraulic trim control system and the electrical trim control system. The switch disconnects the electrical trim system by completing a power circuit to the trim disengage solenoid of the electrical trim disengage relay. Actuation of this self-latching relay interrupts the power circuits to the clutch relays, interrupts the power circuits to the electric motor of the stabilizer actuator, and disconnects the autopilot and the Mach trim compensator systems. Moving the trim reset switch to the "ELEC" position connects power to the reset coil of the electric trim disengage relay to return the relay to the normal operating position. Both disconnect switches and the reset switch are momentary-contact type switches. Both of the electrical trim disengage relay solenoids are normally deenergized.

The electromechanical drive unit is driven by a three-phase, 400-cycle A-C motor that is powered from the essential A-C bus. The motor runs continually until disconnected by the TRIM DISC switch on the pilot's or copilot's control wheel. Two 28-volt magnetically-operated clutches, rotating in opposite directions, engage the motor to the gear train. Engagement of one clutch extends the jackscrew and engagement of the other clutch retracts the jackscrew. Only one clutch can be engaged at a time. A dual trim switch arrangement is provided on the center console for electrical trim control corrections. Both switches have to be actuated simultaneously to complete the electrical circuit. One switch provides a ground and the other switch supplies 28 volts from the main D-C bus. These switches are spring-loaded to the off position and are momentary in the "NOSE UP" or "NOSE DOWN" positions. Trim correction signals also come from the autopilot and Mach trim compensator systems. These signals also energize the actuator extend or retract clutch. Since this is a slow rate unit as compared with the hydromechanical drive unit, a more precise trim setting can be made for longitudinal control.

The hydromechanical drive unit is powered by a hydraulic motor using pressure from the No. 2 hydraulic system. A reduction gear drive, meshed to the motor output gear, turns the rotating nut which causes the jackscrew to move up or down. Maximum rate of trim change is approximately five times faster than electromechanical drive operation. The stabilizer can also be actuated manually for ground maintenance by engaging drive devices to drive sockets located on either gearbox. Speed and direction of motor rotation is controlled by means of the hydraulic flow control valve, which is located at the horizontal stabilizer trim actuator assembly.

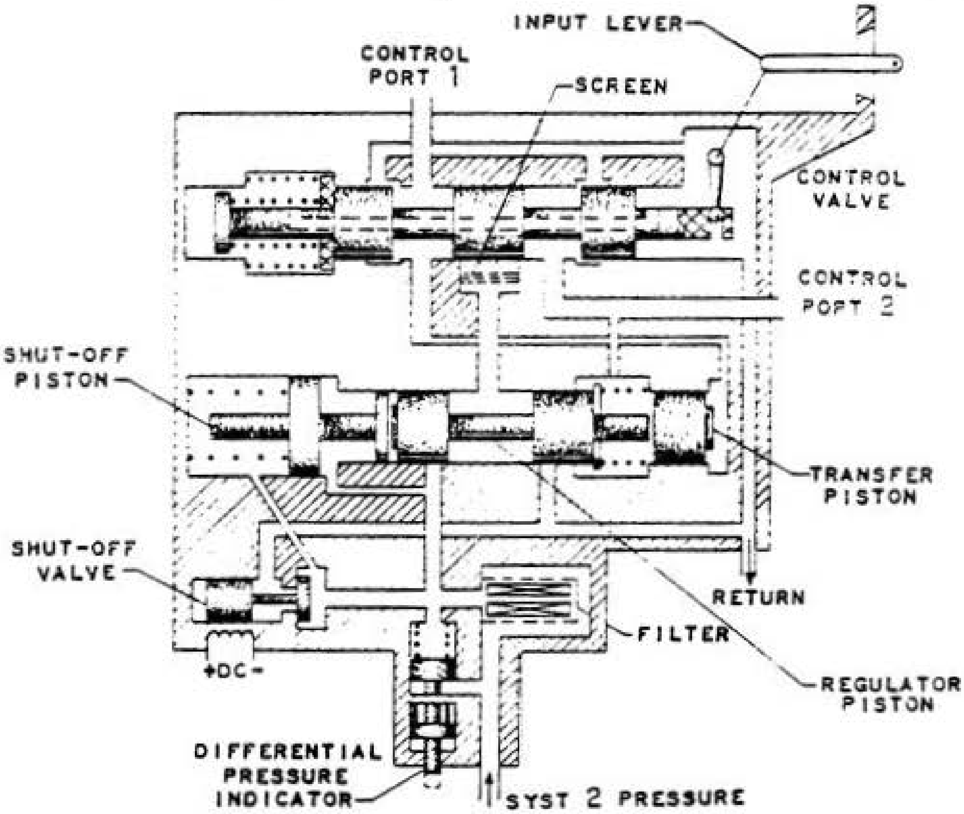
The hydraulic flow control valve is attached to the horizontal stabilizer actuator assembly. It is mechanically connected to the flow control valve actuator and is connected by mechanical linkage and cables to the pilot's and copilot's trim



ELECTRO-HYDRAULIC TRIM CONTROL SCHEMATIC levers. In the valve assembly is a 28-volt DC shutoff valve, a pressure line filter, and a filter clog indicator button. The flow control valve is a modulating type valve which controls the amount and direction of hydraulic oil flow to the hydraulic motor. When the valve spool is in the neutral position, the pressure port is blocked and both motor control ports are opened to system return.

The 28-volt DC solenoid-operated hydraulic shutoff valve is a component of the stabilizer actuator hydromechanical drive unit. This valve is normally energized to the closed position by electrical power from the No. 1 main D-C bus. The valve is deenergized to the open position when the electro-hydraulic trim switch on one of the control wheels is operated to activate the electro-hydraulic trim control system. The valve is also deenergized to the open position when the fore and aft sections of either the pilot's or the copilot's trim control lever is squeezed together.

The manual-hydraulic trim control system is provided with two directional control switches, one up and one down, which are actuated by cams on the stabilizer actuator input cable quadrant. Electrical power for the hydraulic shutoff valve operation is routed through these normally closed directional control switches and also



FLOW CONTROL VALVE

the associated position limit switches. Rotation of the input quadrant in either direction opens the corresponding directional control switch to route power to the hydraulic shutoff valve through the corresponding position limit switches.

The hydraulic filter portion of the flow control valve assembly filters hydraulic fluid upstream from the shutoff and modulating sections of the valve assembly. The filter has a micronic filter element without a bypass feature. Should the filter element become dirty or clogged, a red indicator button will extend about 1/4 inch. The indicator button is located adjacent to the filter at the bottom of the flow control valve assembly.

The horizontal-stabilizer-trim limit switches are mounted on a bracket assembly which is attached to the vertical stabilizer. The limit switches are actuated by cams which are mechanically linked to the horizontal stabilizer. Movement of the stabilizer, up or down, rotates the cams; and the switch contacts will open when travel limits are reached. Six limit switch assemblies are used. Three assemblies for the electro-hydraulic and manual-hydraulic trim control system and three assemblies for the electrical trim control system. Each of the hydraulic system limit switch assemblies contains a switch for each of the hydraulic trim control systems. The limit switches are actuated at one of the trim range limits of approximately four-degrees nose-down regardless of wing flap positions, eight-degrees nose-up if the flaps are fully retracted, or at 12.5-degrees nose-up if the flaps are not fully retracted. Limit switches associated with the electro-hydraulic trim control system, when actuated, interrupt the power circuit to the corresponding control valve actuator solenoid to stop stabilizer actuator operation. Limit switches associated with the manual-hydraulic trim control system, when actuated, connect power to the hydraulic shutoff valve solenoid to close the valve and stop horizontal stabilizer actuator operation. Limit switches associated with the electrical trim control system, when actuated, interrupt the ground circuits of the corresponding motor clutches to stop horizontal stabilizer actuator operation.

The horizontal stabilizer trim position transmitter is mounted on the limit switch bracket assembly and is mechanically linked to the limit switch cam by a positioning arm and linkage rod.

The horizontal stabilizer trim position indicator is mounted on the center instrument panel. The indicator pointer shows the position of the horizontal stabilizer in degrees of travel from neutral.

When the autopilot is engaged, a relay will isolate the console dual trim switches and the Mach trim compensator system from trim correction functions. Through the energized contacts of the transfer relay, up or down signals from the autopilot will now be applied to the appropriate electromechanical motor clutch for autopilot trim corrections. When either of the hydraulic trim control systems is used and the autopilot is engaged, a relay will energize which will disengage the autopilot and at the same time apply power to disconnect the Mach trim compensator. This assures the pilot of hydromechanical trim at all times.

PRIMARY FLIGHT CONTROLS AND TRIM SYSTEMS

GENERAL DESCRIPTION.

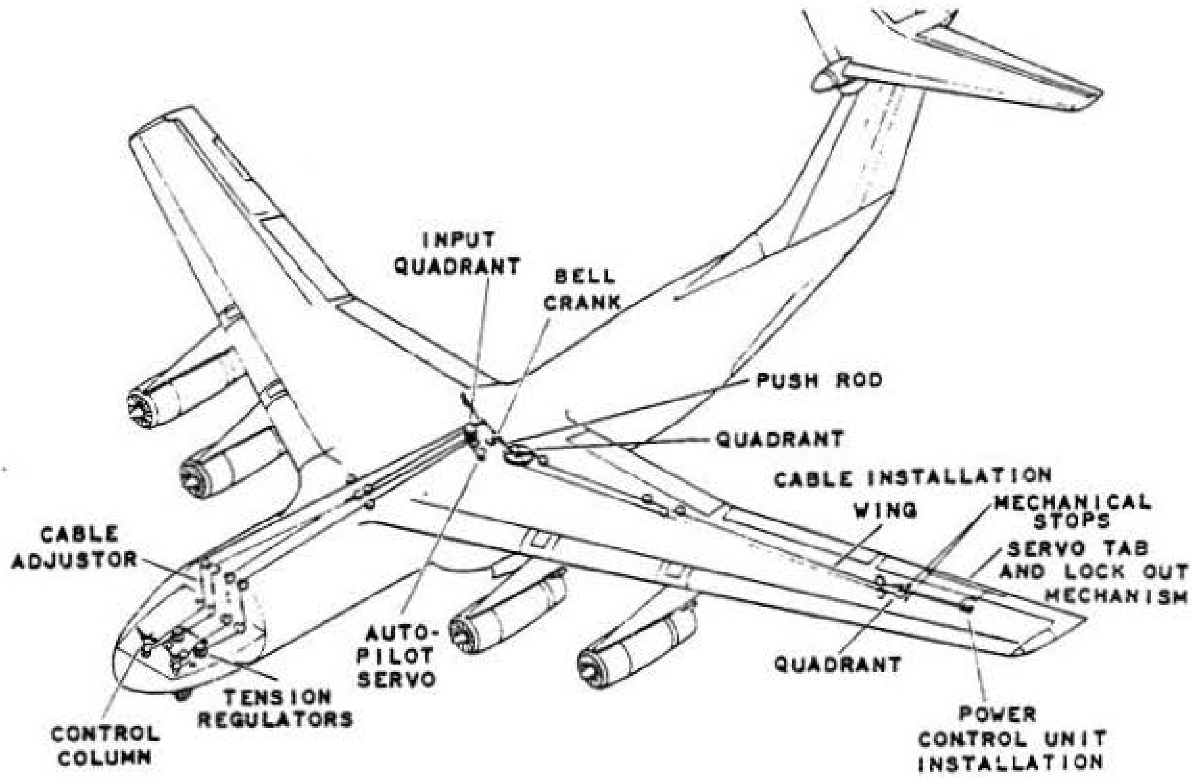
The primary flight control systems consist of the ailerons, the rudder, the elevators, and the associated power and control components of each. They are utilized for maintaining attitude and directional control of the aircraft. The ailerons are controlled by turning the control wheel. The elevators are controlled by fore and aft movement of the control column. The rudder is controlled by pushing the rudder pedals. Two complete sets of controls are provided, one for the pilot and one for the copilot. Either set can be used for aircraft control. Output from the cockpit controls is transmitted to the flight control power units through mechanical linkages and cables.

Two types of control cables are used. One is aircraft flexible twisted-steel-wire cable. The other is Lockclad cable. Lockclad is standard twisted-steel-wire cable with aluminum tubing swaged around it. This type of cable has two advantages. One is that the cable's coefficient of expansion is nearer that of the aircraft's fuselage than the standard steel-wire cable. With temperature changes, the cables expand or contract by almost the same amount as the fuselage. The other advantage is that Lockclad cable is more rigid. There is less cable sag and fewer supports are needed for a given length of cable.

Each flight control cable system has tension regulators to compensate for changing temperatures. The regulators are located under the flight deck. Each regulator consists of two metal quadrants which are mounted on a common shaft and are connected together by a compression spring assembly. The regulator takes in or lets out cable as required to maintain the desired tension in the attached cables. A scale on each regulator is used to rig the cable tension in relation to ambient temperature.

AILERONS

The ailerons are located on the rear beam of the outer wing sections and form part of the trailing edges of the outer wing section. The ailerons, one on each wing, are simultaneously deflected up or down; but they move in opposite directions to produce a rolling movement about the longitudinal axis of the aircraft.

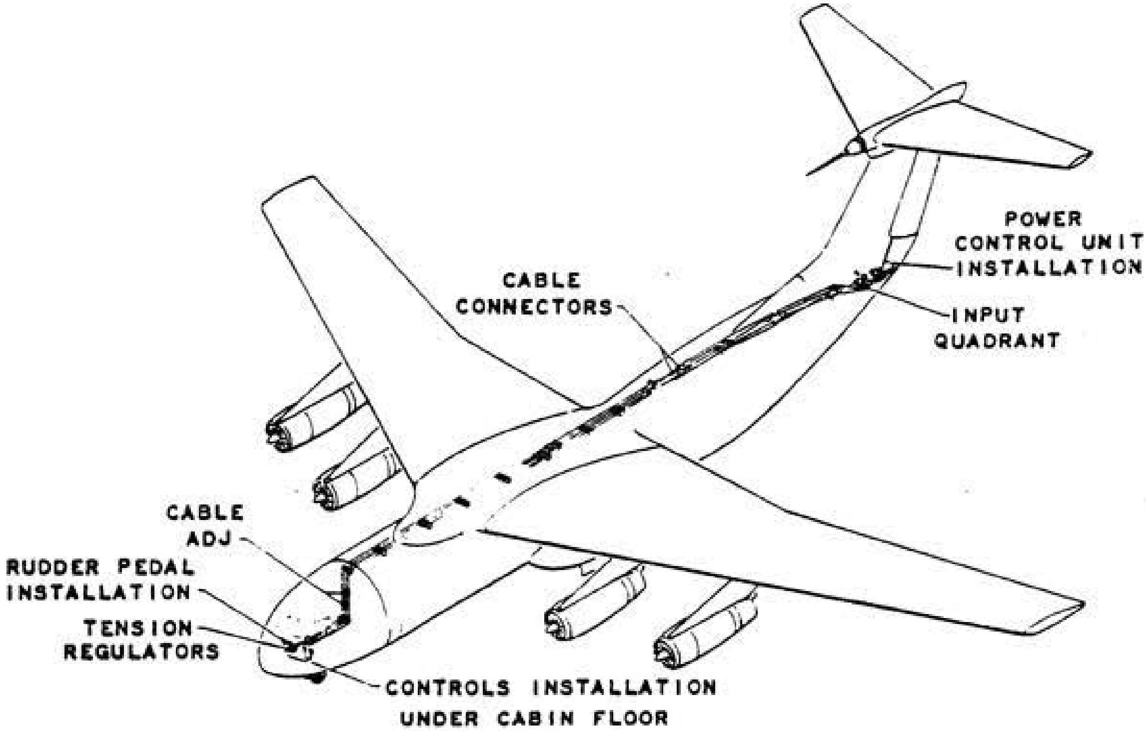


AILERON CONTROL INSTALLATION

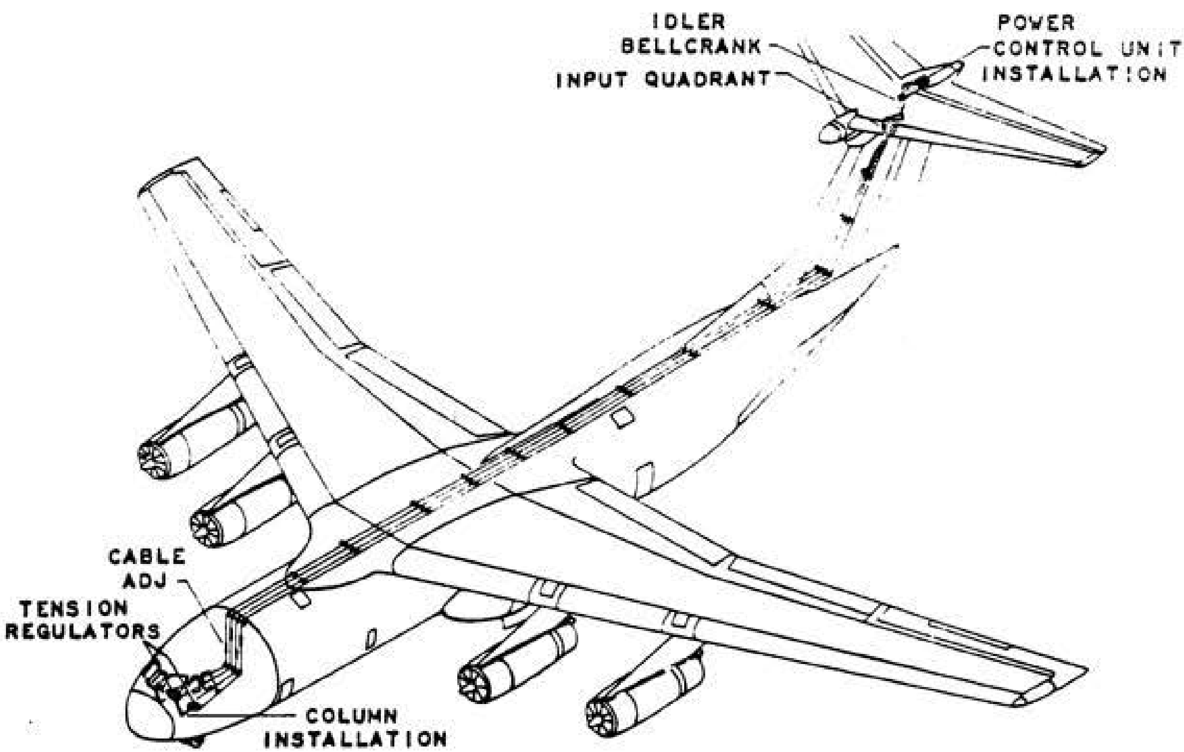
Each aileron is normally actuated by a power control unit which is controlled by the pilot's or copilot's control wheel and is powered by the No. 1 and No. 2 hydraulic systems. A servo tab is hinged to the center section of each aileron rear beam and forms the trailing edge of the aileron in this area. The servo tabs remain faired with the ailerons during normal power-on operation. When selected for operation, the servo tabs move up or down in response to control wheel rotation. An electrical trim system positions the aileron power control units' input system for longitudinal trim.

RUDDER

The rudder is hinged to the vertical stabilizer and is used to control the aircraft about the yaw axis. The rudder is actuated by a power control unit which is controlled by the pilot's or the copilot's rudder pedals and is powered by the No. 1 and No. 2 hydraulic systems. Operating pressure of the rudder power control unit is changed as a function of airspeed. Reduced hydraulic pressure is used during high speed flight. For low speed flight faster response of the rudder is required; therefore, a higher pressure is used. An electrical trim system positions the rudder power control unit's input system for directional trim.



RUDDER CONTROLS INSTALLATION



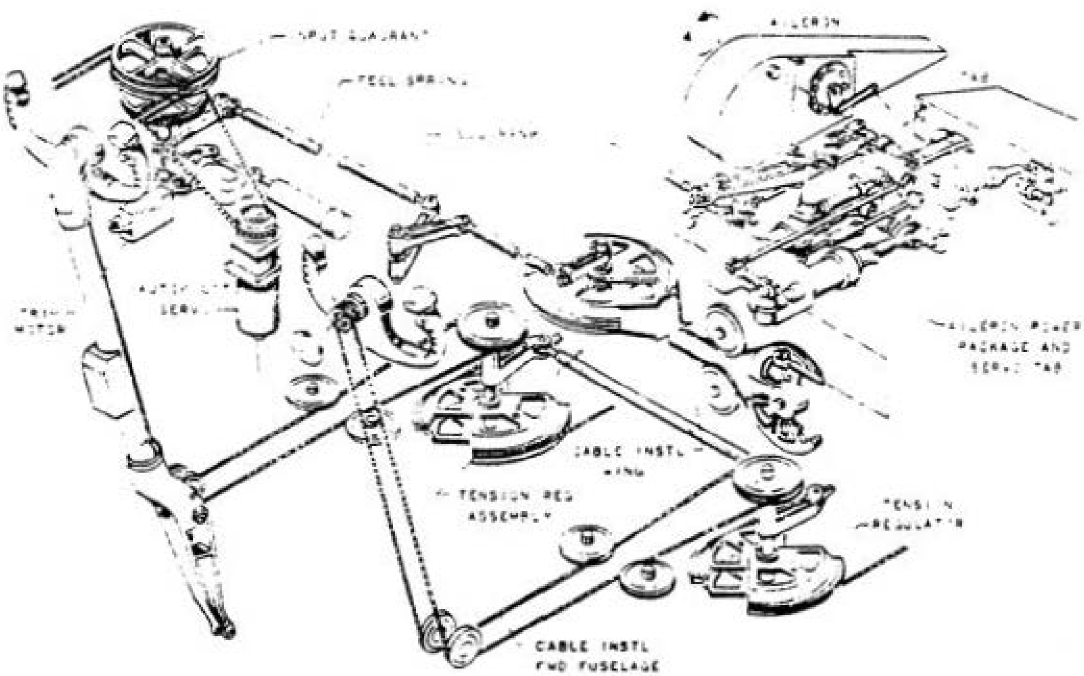
ELEVATOR CONTROLS INSTALLATION

ELEVATORS

The elevators are located on the rear beam of the horizontal stabilizer on both sides of the stabilizer bullet. The elevators are simultaneously deflected upward or downward into the airstream to produce a nose-up or nose-down attitude of the aircraft. The elevators are hydraulically actuated by a power control unit mounted between the elevator torque tube shafts in the bullet. During normal operation, the actuators powered by the No. 1 and No. 2 hydraulic systems move the elevators. If either one of the hydraulic systems becomes inoperable, the elevators can be controlled with the remaining system; however, the No. 3 hydrualic system and the emergency actuator can be used with the remaining system to provide dual hydraulic system control. If both the No. 1 and No. 2 hydraulic systems become inoperable, the elevators can be controlled with the No. 3 hydraulic system and the emergency actuator.

AILERON CONTROL SYSTEM.

A pair of cables link each control wheel to a tension regulator input quadrant below the flight deck. A pulley is splined to each control wheel hub and is accessible through a removable cover at the top of the control column. Ball-terminal ends on the upper cable ends are installed in ball sockets in the pulleys



AILERON CONTROL SYSTEM

servo and the aileron trim actuator also connect to the input quadrant. Input motions from these control sources can rotate the input quadrant in either direction from neutral. Rotary motion of the input quadrant is transferred by push-pull rods, bellcranks, and cables to displace the servo control valves in the power control units during normal power-on operation and to operate the servo tabs during power-off operation.

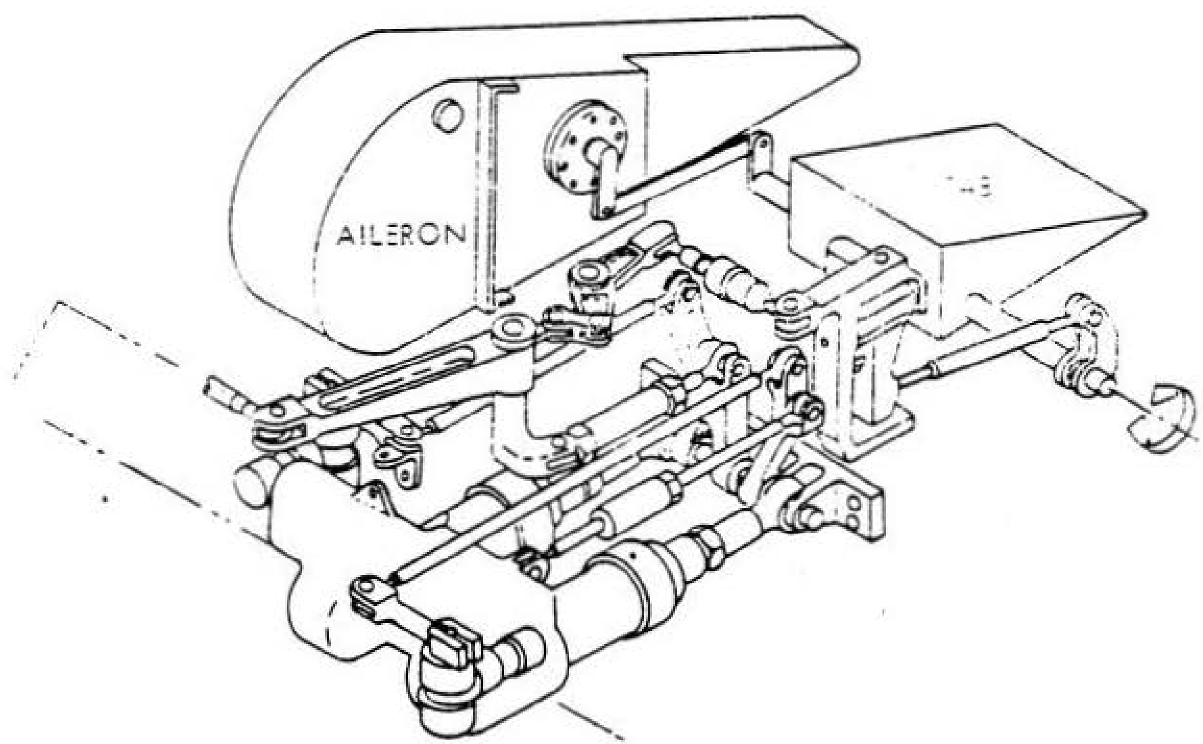
Normal power-on operation of the ailerons does not provide a resisting force or "feel" indication of the magnitude of the forces required to displace the ailerons into the airstream. Without this "feel" force there is a tendency to overcontrol the aircraft and subject the aileron hinges and wing structure to greater forces than are necessary. A double acting spring cartridge is connected to the input quadrant assembly to resist quadrant rotation. The resisting force of this spring provides an artificial "feel" force at the control wheels. The aileron trim actuator is connected to the input quadrant through the "feel" spring linkage and is used to shift the neutral position of the input quadrant. This actuates the aileron power control units to provide lateral trim. In addition to providing "feel," the artificial "feel" spring returns the aileron system to neutral trim when the control wheels are released.

In each wing, a cable quadrant transfers motion from the input quadrant assembly through cables, which are supported and guided along the aft side of the wing rear beam, to a power control unit input cable quadrant. Ball-terminal ends attach the cables to the wing cable quadrants and to the power control unit input cable quadrants. Adjustable mechanical stops are provided at each input cable quadrant.

A power control unit is mounted on the aft side of the rear beam at each aileron in each wing. The principal components of the power control unit are as follows: dual actuators, a tandem servo control valve, a valve input and feedback linkage, an override spring, a centering spring, and hydraulic control components attached to or contained within the hydraulic manifold. The power control units hydraulically actuate the ailerons in response to input control movements from the control wheels, the autopilot servomotor, or the aileron electric trim actuator. In each power control unit, one of the actuators is powered by the No. 1 hydraulic system and the other actuator is powered by the No. 2 hydraulic system. During normal operation, each actuator provides one-half of the force required to operate the attached aileron. However, either actuator is capable of providing the entire operating force if the hydraulic system to the other actuator fails. The left and right aileron power control units move simultaneously but in opposite directions.

The piston of each of the actuators is attached to a common bracket bolted to the aileron front beam. The forward actuator cylinder ends are connected to the hydraulic manifold which forms the cylinder end. The tandem servo control valve, in the hydraulic manifold, directs and modulates fluid from the No. 1 hydraulic system to one actuating cylinder and fluid from the No. 2 hydraulic system to the other actuating cylinder. Since the actuating piston ends attach to the lower section of the aileron front beam and since the aileron hinges are located near the top of the aileron front beam, extension and retraction of the pistons rotates the aileron to raise or lower the aileron trailing edge. Hydraulic snubber arrangements at both ends of the actuators reduce shocks at the ends of the piston strokes.

One end of the servo control valve is mechanically connected to the input and followup linkage, and the other end is mechanically connected to the centering spring linkage. As the input linkage displaces the valve in either direction from the neutral position, the valve interconnects hydraulic passageways to direct hydraulic flow to and from the actuators. As the followup linkage moves with the aileron, the valve returns toward the neutral position. When the aileron reaches the position corresponding to the preselected input position, the valve reaches the neutral position to stop hydraulic flow to the actuators. This stops the aileron movement.



POWER CONTROL UNIT, SERVO TAB, AND LINKAGE

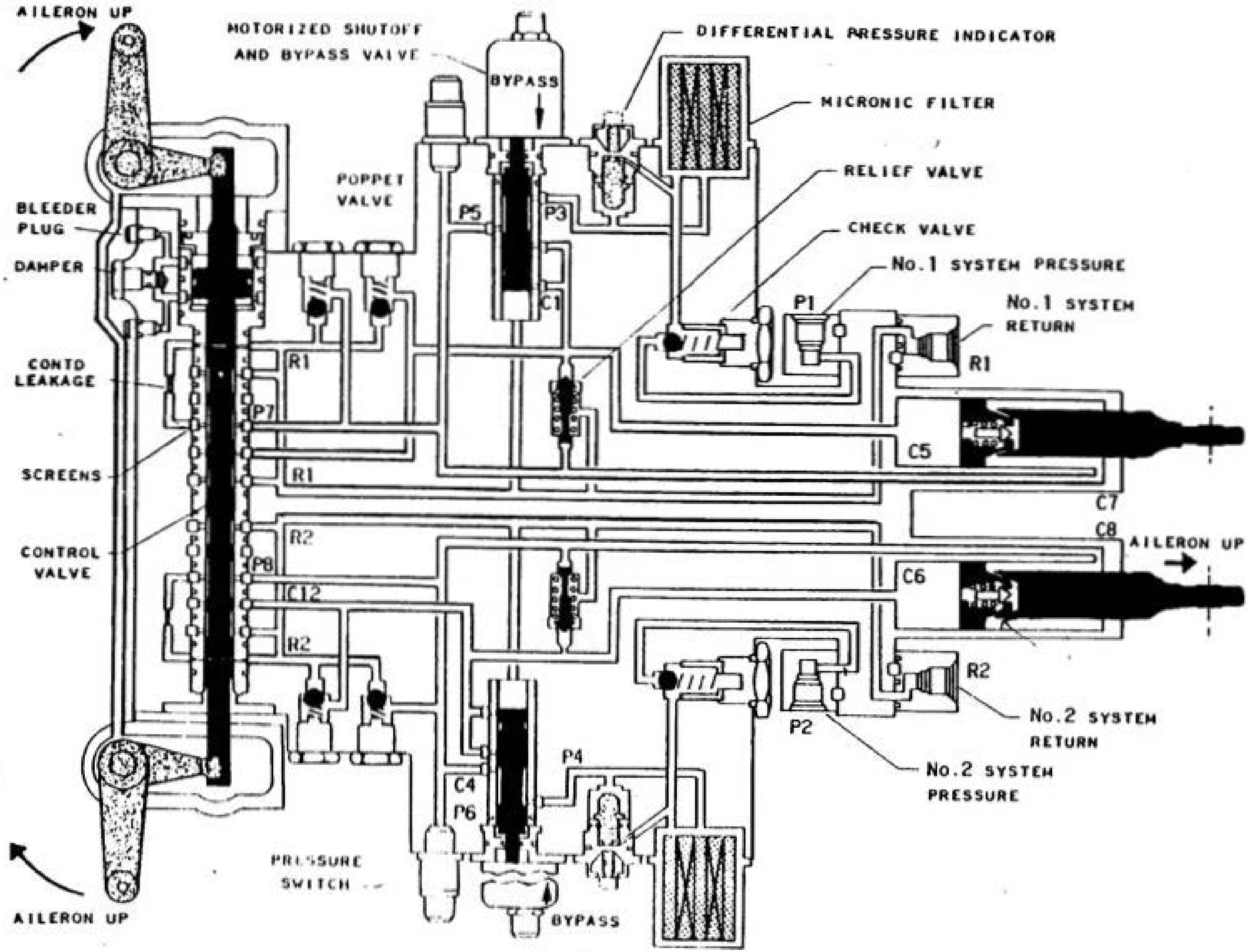
The centering spring linkage, connected to the opposite end of the servo control valve from the input and feedback linkage, stores energy as the valve is displaced from neutral. If the input linkage should fail, the centering spring linkage would return the servo control valve and the aileron to the neutral positions. The centering spring would prevent the power control unit from moving the aileron to an extreme up or down position if the input linkage should fail.

A controlled leakage arrangement, of one gallon per minute, at each hydraulic system section of the servo control valve permits flow through the power control unit when the valve is in the neutral position and the hydraulic systems are pressurized. This provides a continuous supply of warm fluid to the power control unit, which is located in an unheated area, to prevent sluggish operation. A piston and orifice at one end of the servo control valve provides hydraulic snubbing and damping action to protect the valve and the system from excessively rapid actuation.

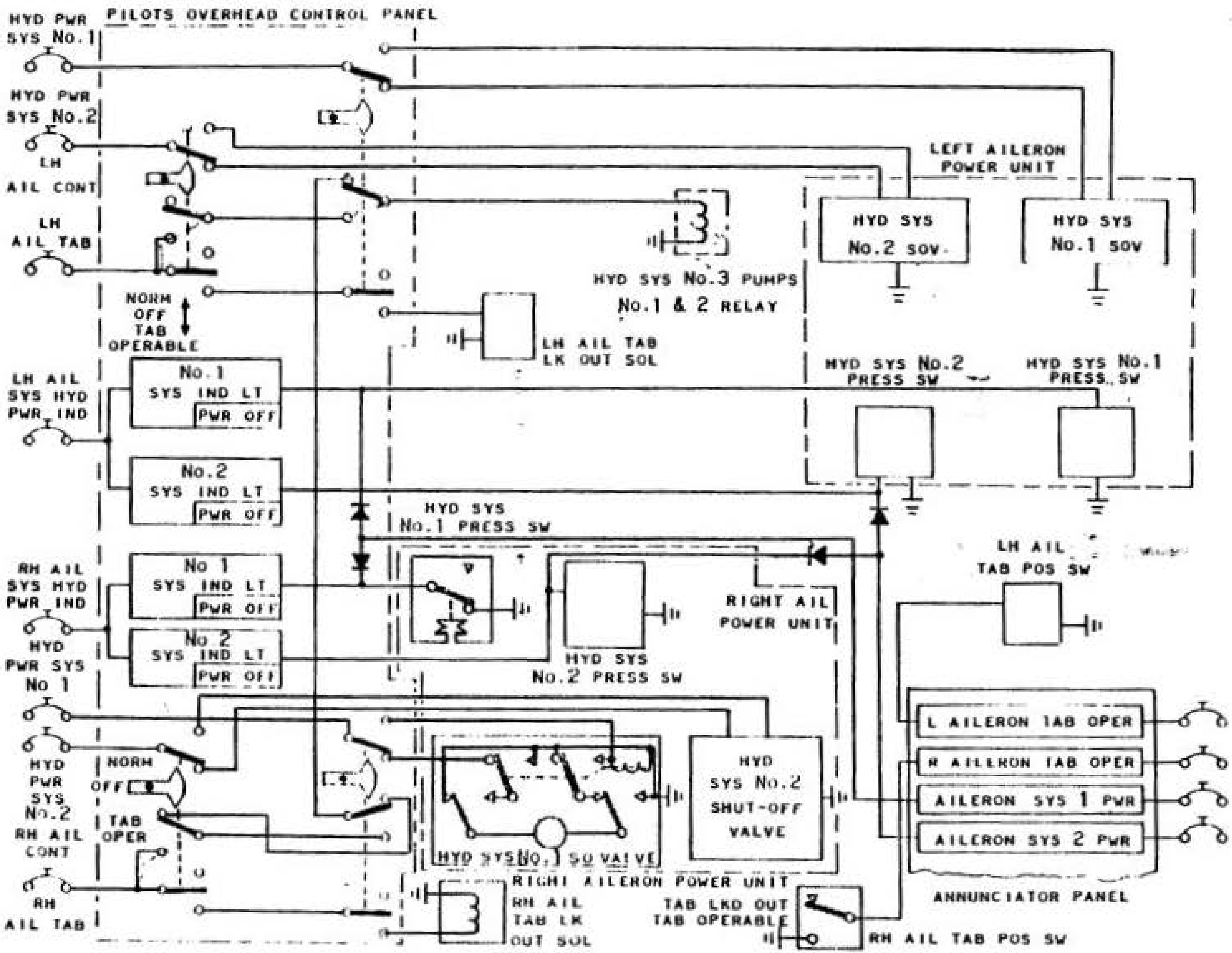
A no-bypass type micronic filter is installed in the pressure inlet line of each hydraulic system in the aileron power control unit. A differential pressure indicator senses the pressure drop across the filter element and releases a "pop-up" indicator button that protrudes when the filter is obstructed.

Two combination shutoff and bypass valves are installed in the hydraulic manifold, one downstream of each filter element. In the normal or open positions, the valves direct system pressure to the servo control valve and to the rod side of the actuators. In the shutoff and bypass positions, the valves block the hydraulic pressure inlet lines and connect both ends of the actuators together and to return. The interconnection of the actuator ends provides a low resistance path for fluid interchange when the hydraulic system is depressurized. The valves are controlled by the AILERON SYS switches on the pilots' overhead panel.

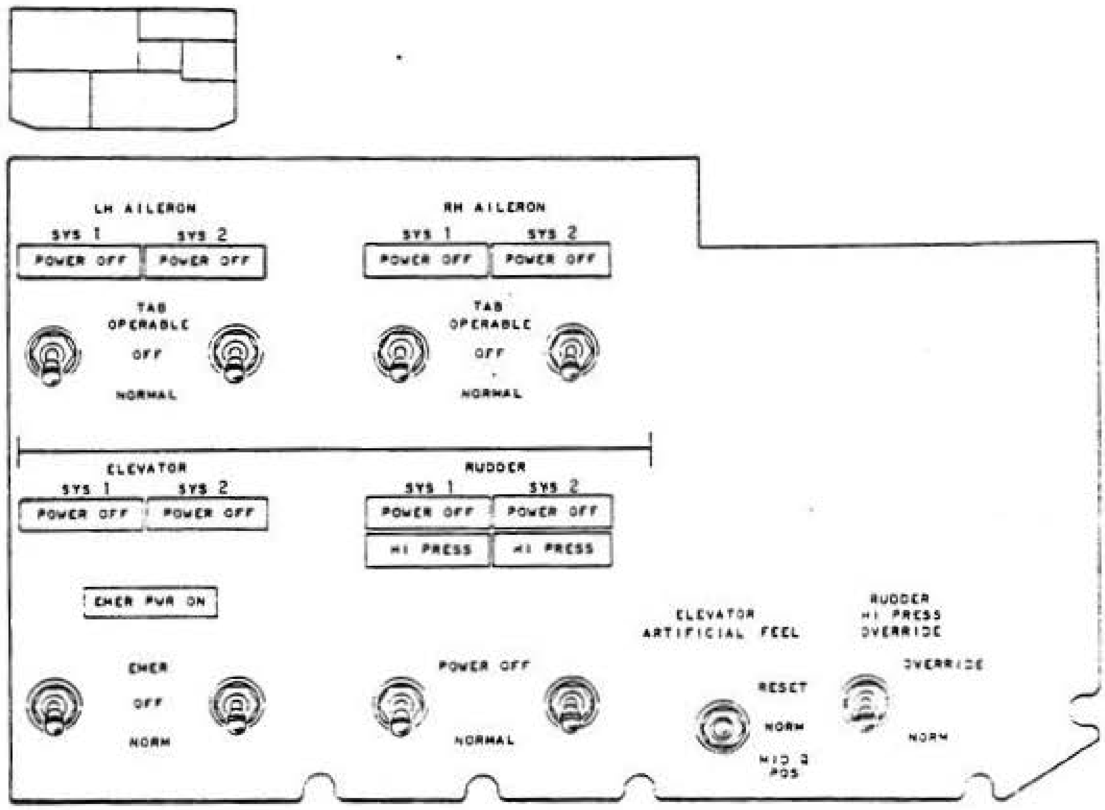
Two pressure operated switches, one for each the No. 1 and No. 2 hydraulic systems, are mounted on the hydraulic manifold of each power control unit to sense line pressures between the servo control valve and the shutoff and bypass valves. The switches are actuated when hydraulic pressure is low. This provides a ground to the associated AILERON SYS "POWER OFF" lights on the pilots' overhead panel and to the AILERON SYS PWR lights on the annunciator panel which causes these indicator lights to illuminate.



POWER CONTROL UNIT SCHEMATIC



AILERON ELECTRICAL CONTROL



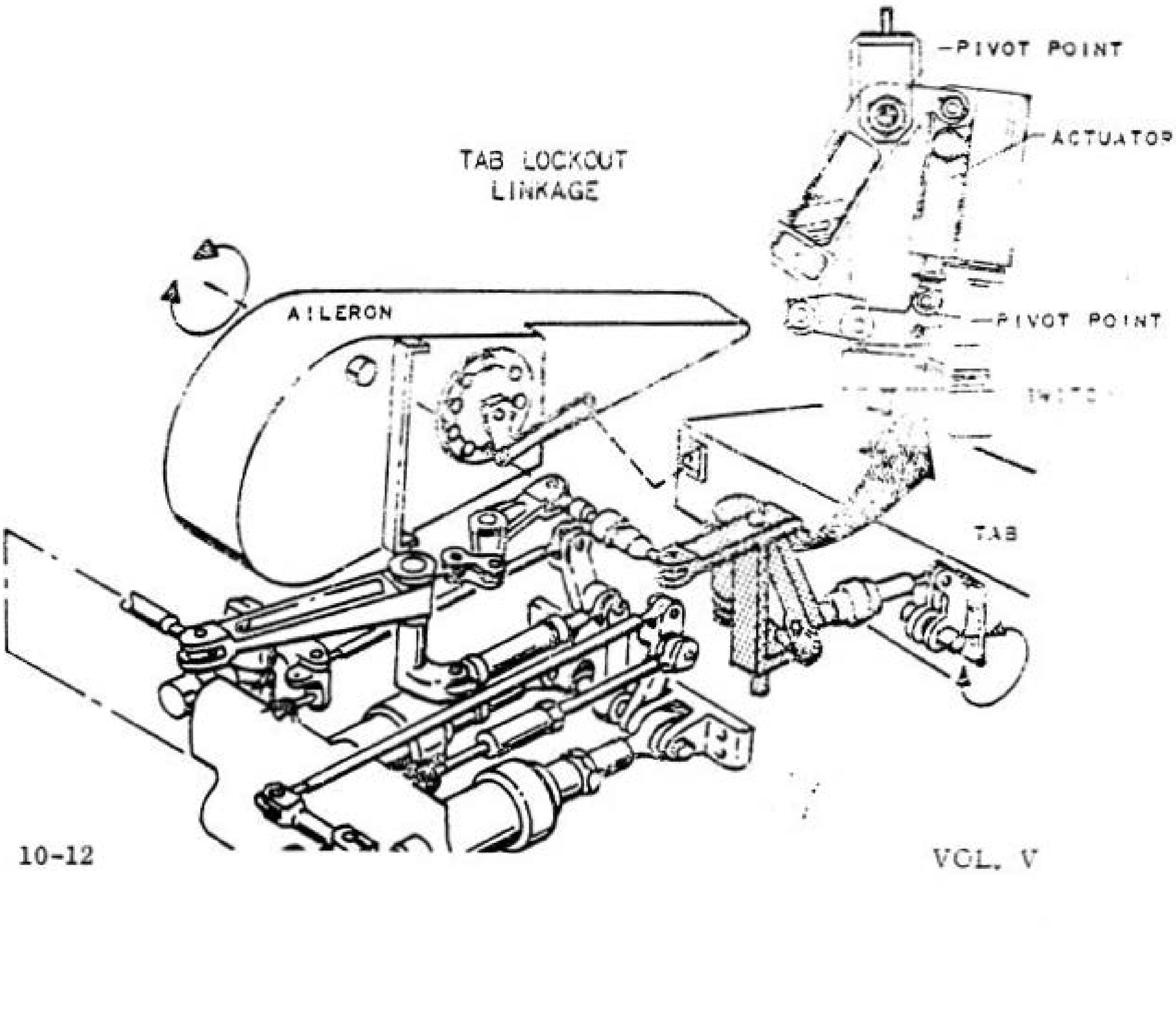
PILOTS' OVERHEAD PANEL

During normal operation, hydraulic pressure is maintained on the rod side of the power control unit actuators. Movement of the servo control valve ports the face side of the actuators to system pressure or to system return. Moving the valve for aileron down connects the face side of the actuators to return and allows the already pressurized retract side of the actuators to move the aileron down. Moving the valve for aileron up directs pressure to the face side of the actuators also and because of the difference in area the actuators extend and move the ailerons up. When the valve is centered, the port to the face side of the actuators is blocked and fluid is trapped.

A load limiting relief valve is installed in each actuator rod. If the aileron surface load is great enough to cause a pressure difference of approximately 2,900 PSI greater on the rod side than on the face side of the actuators, the valve opens and allows fluid to pass from the rod side to the face side of the actuator. A load limiting relief valve is also installed between the face side of each aileron actuator and system return which allows fluid to pass if differential pressure exceeds approximately 2,700 PSI. Anticavitation poppet valves installed in the manifold prevent cavitation of the actuators when they are operated with power off, while the shutoff and bypass valves are in the normal open position.

A servo tab, similar to the aileron in design and construction, forms the trailing edge of the central section of each aileron. The servo tab provides manual aileron capability in the event No. 1 and No. 2 hydraulic systems fail. The servo tab is mechanically linked to the aileron power control unit input system, but it is locked out and does not deflect during normal power-on operation. The left or right servo tab may be selected to operate by the LH AILERON SYS or RH AILERON SYS switch on the pilots' overhead panel.

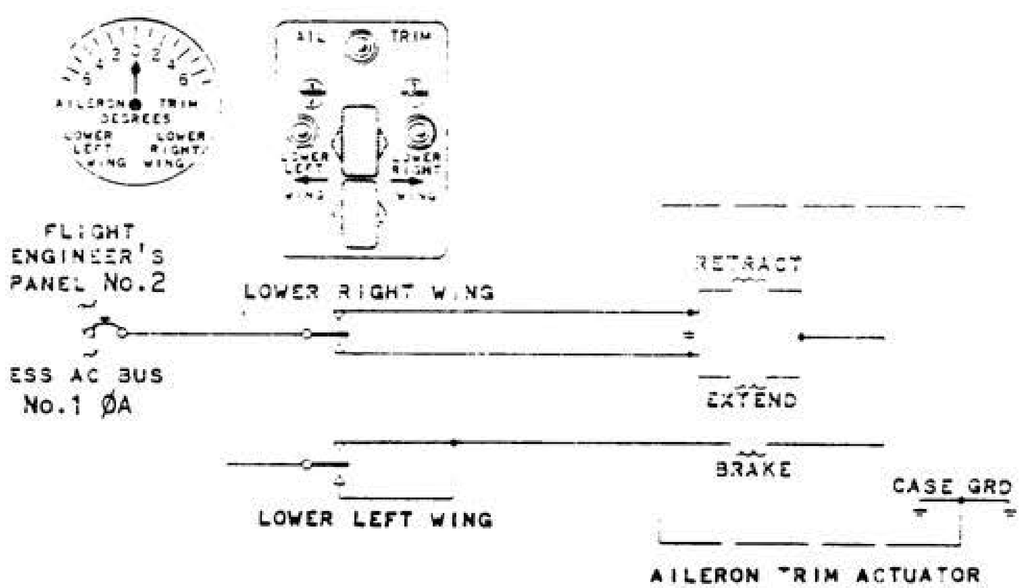
A bellcrank and push-pull rod linkage connect the power control unit servo control valve input linkage to the tab lockout mechanism. The tab lockout mechanism is located inside the aileron and is connected to the servo tab by a push-pull rod. A spring cartridge, which is part of the tab lockout mechanism, holds the servo tab connecting rod attach point at the pivot of the tab lockout mechanism. When "TAB OPERABLE" is selected, an actuator powered by No. 3 hydraulic system pressure overcomes the spring cartridge and moves the attach point away from the tab lockout pivot providing a moment arm to transmit input motion to the servo tab.



Greater control wheel movement is required for full servo tab deflection than for full normal power-on aileron deflection. The input to the power control unit's servo control valve is connected by a spring "bungee" to prevent damage to the valve when it is bottomed out during servo tab operation. Two viscous dampers mounted on each aileron and attached to the servo tab hinge fitting prevent servo tab flutter.

TRIM.

Aileron trim is accomplished by positioning the aileron power control units' input system. The aileron trim actuator is attached to aircraft structure and to the artificial feel spring lever arm at the input quadrant. The trim actuator motor is controlled by two AIL TRIM switches on the center console. The trim actuator changes the neutral position of the input system by moving the artificial feel spring. This displaces the servo control valves of the power control units which drive the ailerons to the new neutral position. A trim position transmitter is located on the trim actuator and sends position information to the trim indicator on the pilots' center instrument panel.



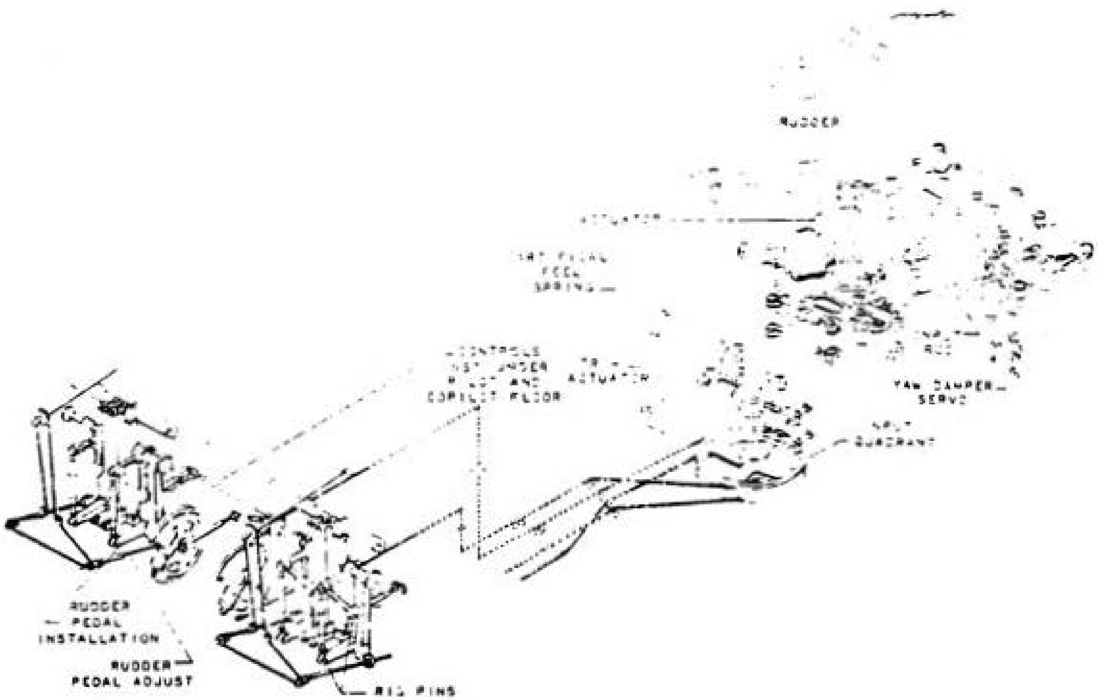
AILERON TRIM ELECTRICAL

RUDDER CONTROL SYSTEM.

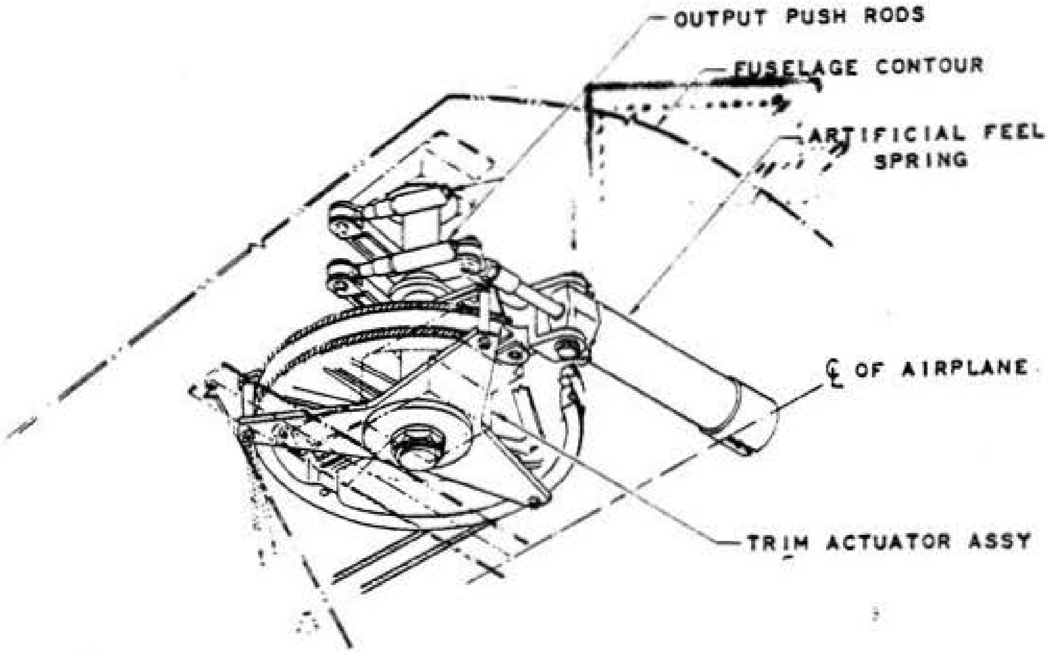
The rudder pedals are connected by push-pull rods and levers to cable tension regulators under the flight deck floor. The pilot's and copilot's rudder pedals are interconnected through mechanical linkage at the tension regulators. Mechanical stops restrict the movement of the rudder pedals to the amount necessary to provide full travel under design limit operating loads.

A separate cable system connects each of the two tension regulators to an input quadrant assembly located near the rudder power control unit at the rudder surface yoke. The rudder trim actuator also connects to the input quadrant. Input motions from these control sources can rotate the input quadrant in either direction from neutral. Rotary motion of the input quadrant is transferred by push-pull rods and bellcranks to displace the servo control valve in the power control unit.

Normal power-on operation of the rudder system does not provide a resisting force or "feel" indication of the magnitude of forces required to displace the rudder into the airstream. Without this "feel" force, there is a tendency to over-control the aircraft and subject the rudder hinges and stabilizer structure to greater forces than are desired. A double acting spring cartridge is connected to the input quadrant assembly to resist quadrant rotation. The resisting force of



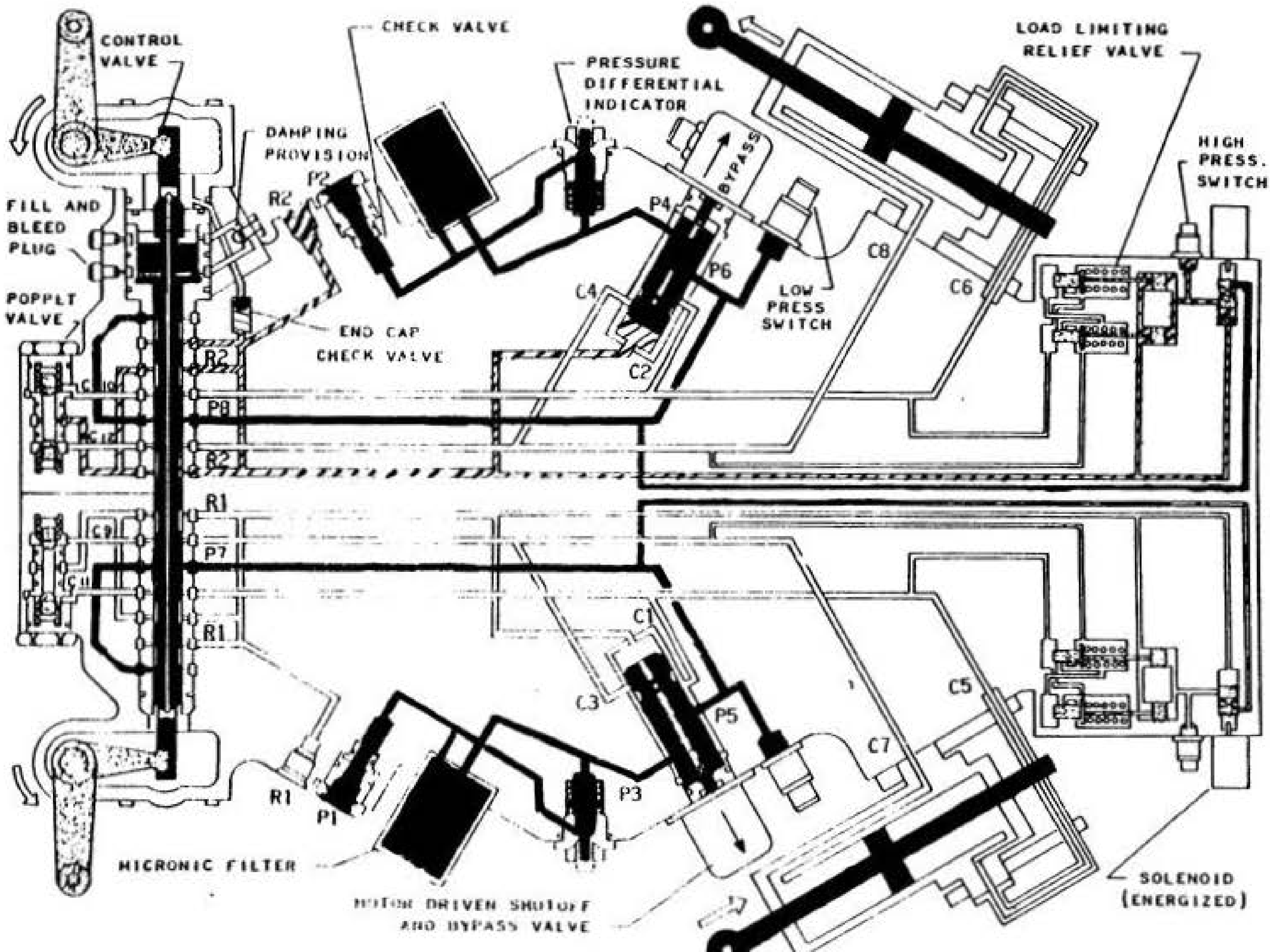
RUDDER CONTROL SYSTEM



RUDDER INPUT QUADRANT

this spring provides an artificial "feel" force at the rudder pedals. The rudder trim actuator is connected to the input quadrant through the "feel" spring linkage and is used to shift the neutral position of the input quadrant. This trims the rudder power control unit to provide directional trim. In addition to providing "feel" the artificial "feel" spring returns the rudder system to netural trim when the rudder pedals are released.

A dual push-pull rod and bellcrank system connects the input quadrant to the servo control valve of the power control unit. The power control unit is located at the rudder torque tube yoke. Components of the power control unit are as follows: dual balanced actuators, a tandem servo control valve, valve input and feedback linkage, and hydraulic control components attached to or contained within the hydraulic manifold. The piston of each actuator connects to the rudder torque tube through a yoke on the torque tube. The actuator pistons attach on opposite sides of the torque tube and operate together to position the rudder. One actuator retracts while the other actuator extends. The power control unit actuates the rudder in response to input control movements from the rudder pedals, the rudder trim actuator, and the yaw damper servo motors. The yaw damper servo motors are mounted on the power control unit and position the servo control valve independently of the input linkage. In operation the yaw rate gyro senses when the aircraft begins to yaw and sends an electrical signal to the yaw damper computer. The computer amplifies



POWER CONTROL UNIT SCHEMATIC

these signals to a level sufficient to drive the servo motors. The motors cause the power control unit to deflect the rudder in a direction which stops the aircraft from yawing.

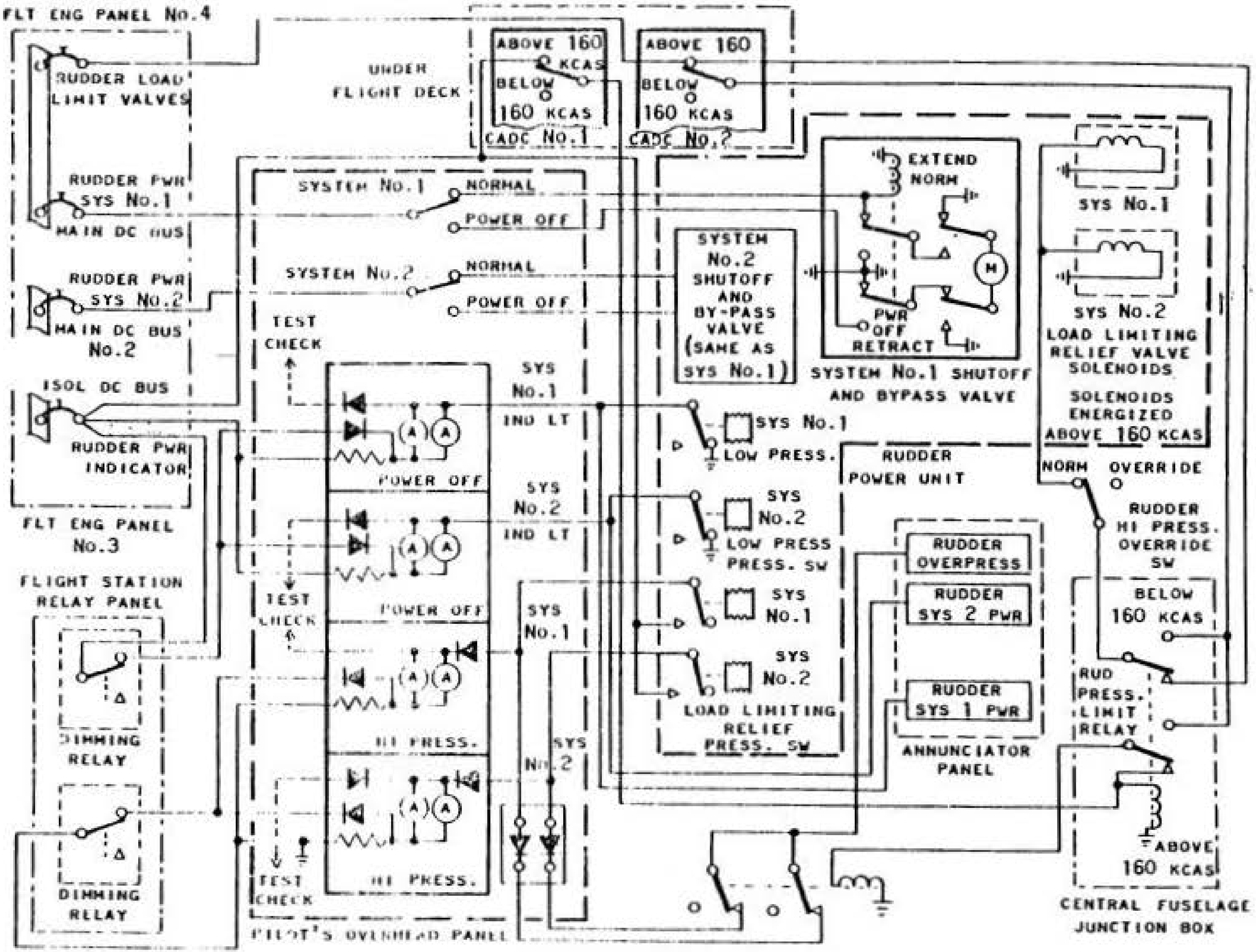
In the power control unit, one of the actuators is powered by No. 1 hydraulic system pressure and the other actuator is powered by No. 2 hydraulic system pressure. During normal operation, each actuator provides one-half of the force required to operate the rudder. However, either actuator is capable of providing the entire operating force if the hydraulic system of the other actuator fails. The actuators have internal stops to limit the control surface travel and snubbers to reduce shock resulting from slamming of the surface through full throw operation during ground checkout. The snubbers slow the actuator speed the last one-half inch of travel before contacting the internal stops.

A controlled leakage arrangement, of one-half gallon per minute, at each hydraulic system section of the servo control valve permits flow through the power control unit when the valve is in the neutral position and the hydraulic systems are pressurized. This provides a continuous supply of warm fluid to the power control unit, which is located in an unheated area, to prevent sluggish operation. A piston and orifice at one end of the servo valve provides a hydraulic snubbing and damping action to protect the valve and the system from excessively rapid actuation.

A no-bypass type micronic filter is installed in the pressure inlet line of each hydraulic system in the rudder power control unit. A differential pressure indicator senses the pressure drop across the filter element and releases a "pop-up" indicator button that protrudes when the filter is obstructed.

Two combination shutoff and bypass valves are installed in the hydraulic manifolds, one downstream of each filter element. In the normal or open positions, the valves direct system pressure to the tandem servo control valve. In the shutoff and bypass position the valves block the hydraulic pressure inlet lines and connect both ends of the actuators together and to return. The interconnection of the actuator ends provides a low resistance path for fluid interchange when the hydraulic system is depressurized. The valves are controlled by the RUDDER SYS switches on the pilots' overhead panel.

Two pressure operated switches, one for the No. 1 and one for the No. 2 hydraulic systems, are mounted on the hydraulic manifold of each power control unit to sense line pressures between the servo control valve and the shutoff and bypass valves. The switches are actuated when hydraulic pressure is low. This provides a ground to the associated RUDDER SYS "POWER OFF" lights on the pilots' overhead panel and to the RUDDER SYS PWR lights on the annunciator panel which causes these indicator lights to illuminate.



RUDDER ELECTRICAL CONTROL

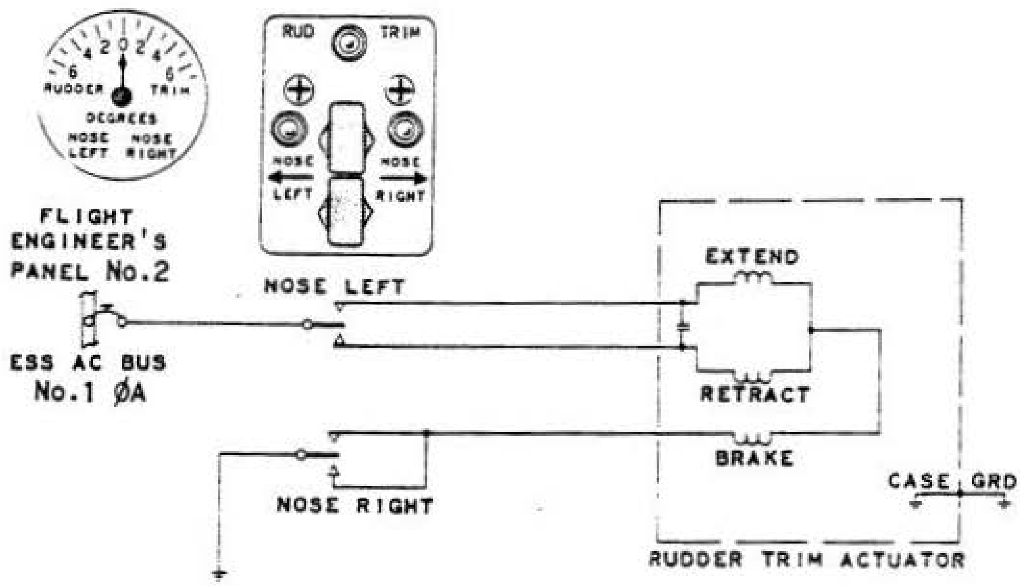
Above 160 knots computed air speed, the pressure to the power control unit actuators is limited to 900 PSI. Below 160 knots computed air speed, pressure to the actuators is allowed to reach 2,450 PSI. Load limiting relief valves inside the power control unit changes the unit's maximum operating pressure in response to an electrical signal from the central air data computer (CADC). A load limiting relief valve is connected between each side of each actuator and the applicable system's return line. A solenoid-operated pilot valve is provided for each of these load limiting relief valves. When deenergized, the pilot valves direct system pressure to the piston ends of the load limiting relief valves; this assists the springs and causes a higher pressure to be required to unseat the valves. Above 160 knots computed air speed, the pilot valve solenoids are energized by the CADC to close off system pressure to the relief valve pistons which allows the valves to open at the lower pressure.

A pressure switch for each hydraulic system is located in the manifold and will sense the pressure between the load limiting solenoid pilot valves and the load limiting relief valve pistons. The pressure switches control a HI PRESS light on the pilots' overhead panel for each system and a RUD OVERPRESS light on the annunciator panel. Anytime pressure at the load limiting relief valve pistons exceeds 1,650 PSI, the HI PRESS light for that system will illuminate. The RUD OVERPRESS light will illuminate if the pressure at the load limiting relief valve pistons reaches 1,650 PSI and the aircraft is above 160 knots computed air speed.

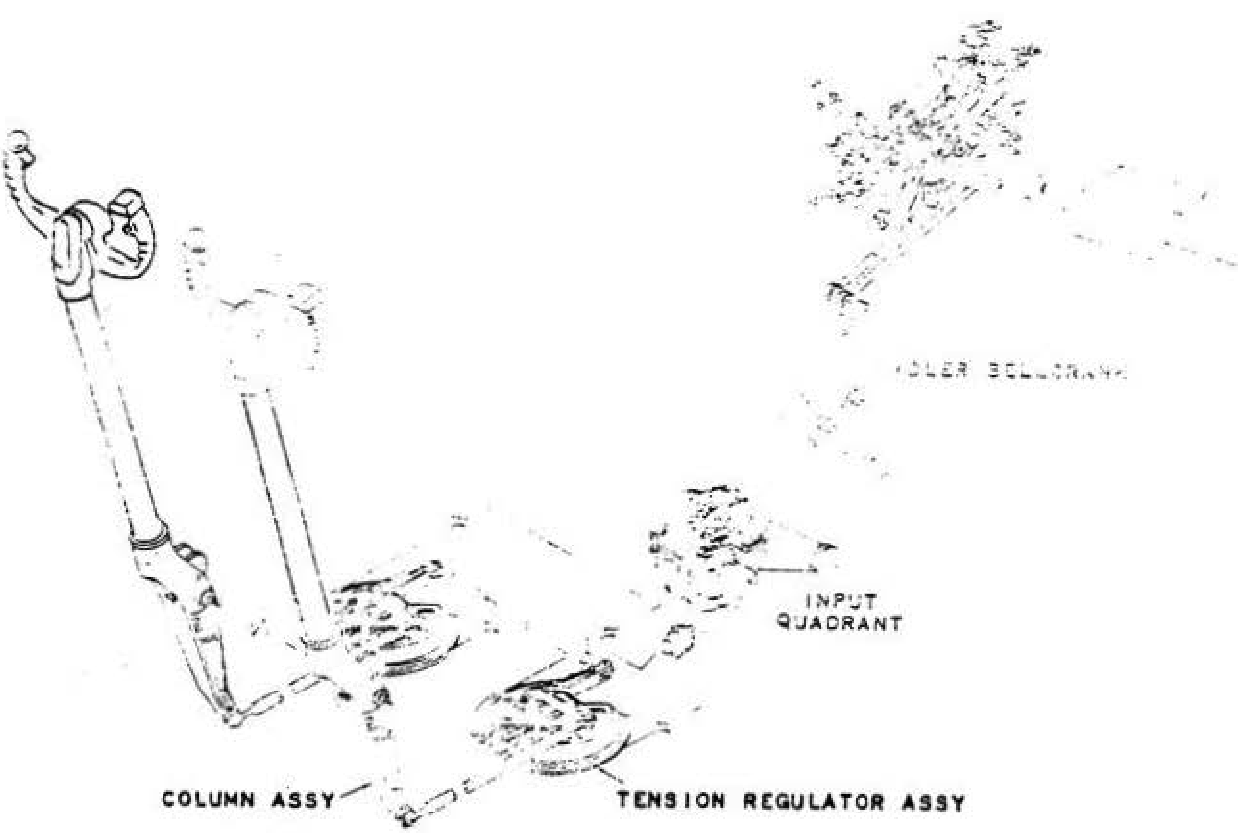
A RUDDER HI PRESS OVERRIDE switch on the pilots' overhead panel provides control of the load-limiting relief valve's pilot-valve solenoids. When the RUDDER HI PRESS OVERRIDE switch is placed to "NORMAL," the CADC has control of the load-limiting relief valve's pilot valves. When the switch is placed to "OVERRIDE," the pilot valves will be deenergized and the [illegible] power control unit will be operated by high pressure.

TRIM.

Rudder trim is accomplished by positioning the rudder power control unit's input system. The rudder trim actuator is attached to aircraft structure and to the artificial feel spring lever arm at the input quadrant. The trim actuator motor is controlled by the two RUD TRIM switches on the center console. The trim actuator changes the neutral position of the input system by moving the artificial feel spring. This displaces the servo control valve of the power control unit which drives the rudder to the new neutral position. A trim position transmitter is located on the trim actuator and sends position information to the trim indicator on the pilots' center instrument panel.



RUDDER TRIM ELECTRICAL



ELEVATOR CONTROL SYSTEM

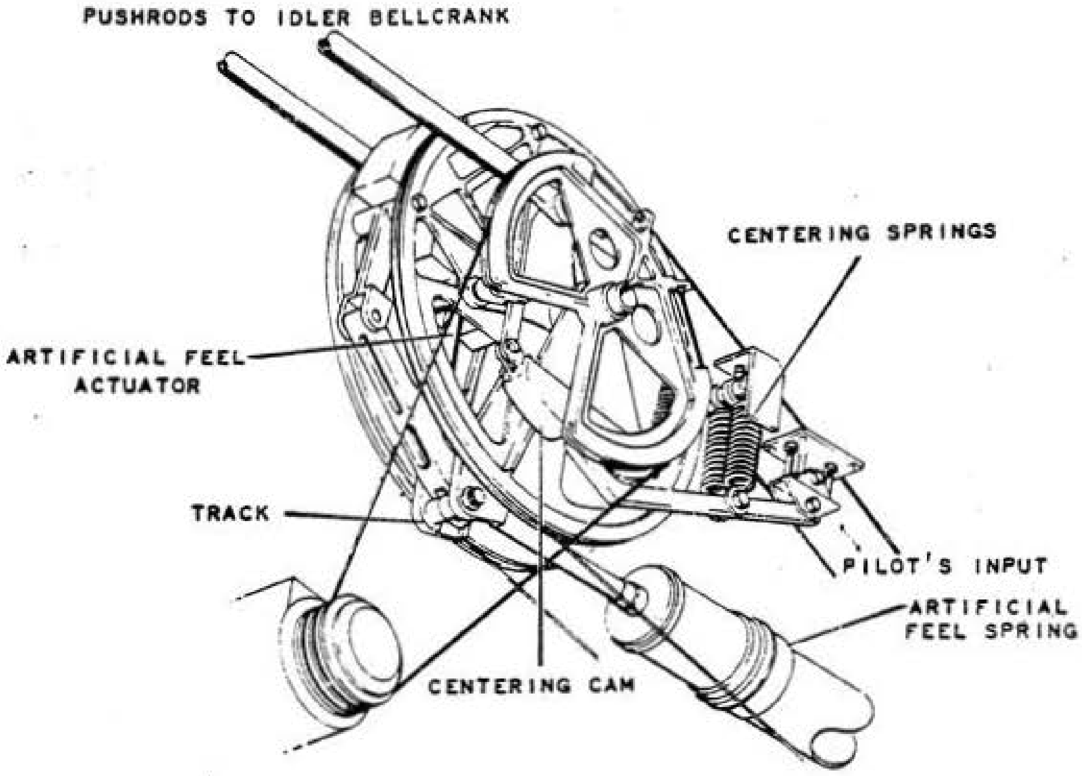
ELEVATOR CONTROL SYSTEM.

Each control column is connected to a cable tension regulator by a push-pull rod. The pilot's and copilot's elevator controls are interconnected through a push-pull rod attached to the input bellcranks of the tension regulators. Mechanical stops restrict the movement of the control columns to the amount necessary to provide full travel under design limit operating loads. The ~~control columns are~~ equipped with bobweights which in conjunction with the artificial feel spring provides a slight forward column movement at positive "G's" and a slight aft column movement at negative "G's."

A separate cable system connects each tension regulator to an input quadrant assembly in the empennage. The elevator autopilot servo motor also connects to the input quadrant assembly. The input quadrant assembly consists of two large cable quadrants for attaching the cable system from the tension regulators and a third smaller cable quadrant for connecting the autopilot servo motor cables. All three quadrants are mounted on a common shaft. The location of the input quadrant and power control unit near the horizontal stabilizer pivot point is such that the relationship between the control column position and elevator attitude is affected a negligible amount when the horizontal stabilizer attitude is changed for pitch trim.

An artificial feel "Q" spring is mounted between the two large cable quadrants. One end of the feel spring attaches to aircraft structure and the other end attaches to the input quadrant assembly. The attach point of the "Q" spring on the quadrant assembly is mounted in a track and is adjustable from the quadrant center by an electric "Q" actuator also mounted between the input quadrants. This "Q" system actuator is an electric motor-driven jackscrew controlled by the CADC. The actuator moves the point of the "Q" spring attachment on the quadrant toward and away from the center. This adjusts the length of the input lever arm through which the "Q" spring force is applied to the elevator input system, varying the artificial "feel" load into the control system as a function of airspeed. The input system neutral position will be changed slightly as the position of the spring attach point is changed. The attach point of the spring is moved away from the center of the input quadrant as airspeed increases and a slight nose up input will be induced into the elevator system. As airspeed decreases the spring attach point will be moved toward the center of the input quadrant and a slight nose down input will be induced into the elevator system.

An elevator input neutral detent device is provided at the input quadrant assembly to provide a positive neutral feel. The device consists of a spring-loaded lever and roller assembly attached to aircraft structure and a notched cam located on the input quadrant assembly. When the input system is neutral, the roller on the spring-loaded

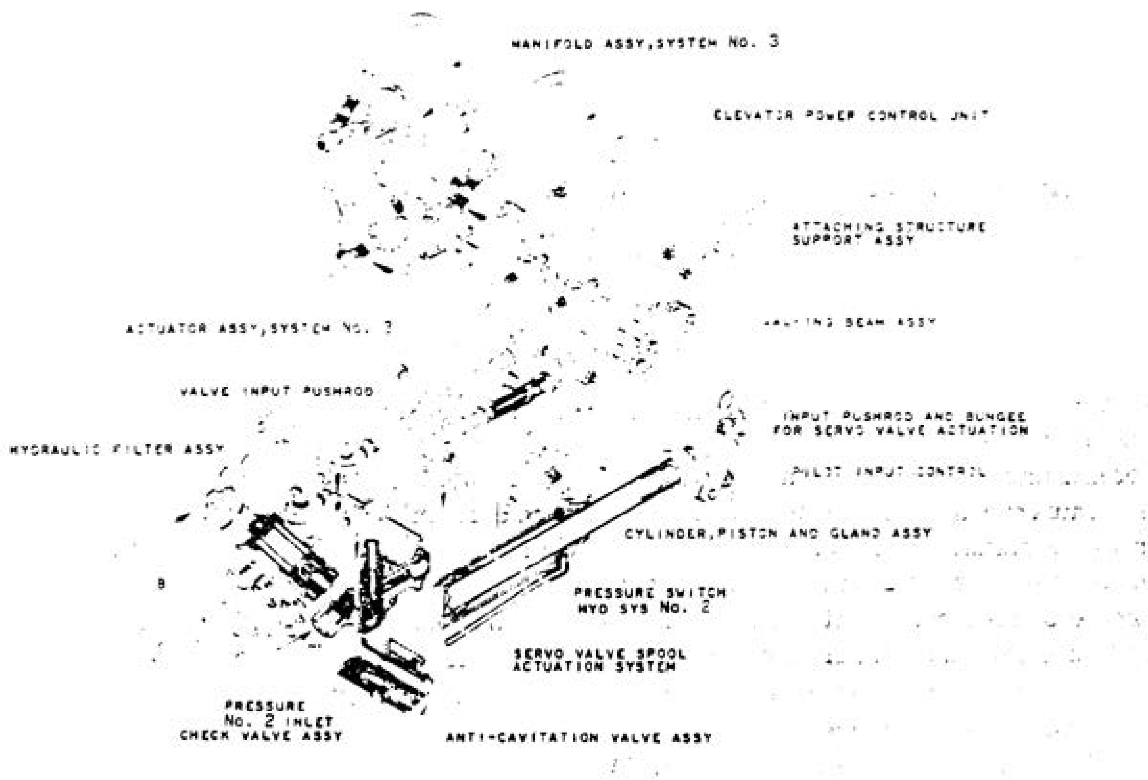


ELEVATOR INPUT QUADRANT

lever fits into the notch on the cam. The cam is moved as the "Q" actuator changes the position of the "Q" spring attach point on the input quadrant so that the neutral detent will encompass the induced input.

A potentiometer geared to the "Q" actuator motor provides an electric signal proportional to the quantity of "Q" spring force being put into the input system. This signal is compared to an electrical signal from one CADC and if a difference exists, the motor is driven in the direction which will eliminate the difference. A second potentiometer, gaged to the motor controlling potentiometer, produces a signal which is compared in a signal comparator to a signal from the other CADC. A difference in these signals will cause the signal comparator to complete an electrical circuit to the elevator artificial feel malfunction relay. Electrically energized, the elevator artificial feel malfunction relay will electrically deenergize the "Q" actuator motor and complete the circuit for the ELEV FEEL MALFUNC light on the annunciator panel. If a malfunction occurs during flight the actuator may be either left at the position the malfunction occurred, or the ELEVATOR ARTIFICIAL FEEL switch on the pilots' overhead panel may be moved to the "MID-Q POS" This will cause the actuator to drive the spring attach point to an intermediate position. No other selection can be made during flight, but with touchdown relay No. 2 in the ground position, the circuit can be completed to the "Q" actuator motor through the ELEVATOR ARTIFICIAL FEEL switch in the "RESET" position. This will bypass the malfunction relay and drive the "Q" actuator to the position of the controlling CADC.

The elevator power control unit is mounted in the horizontal stabilizer between the inboard ends of the elevator torque tubes. The unit hydraulically actuates the elevators in response to input control movements from the control columns or from the autopilot servo motor. Dual output rods transmit elevator control commands from the input quadrant assembly to an idler bellcrank. The bellcranks are pivot mounted to the power control unit's output lever and are connected at one end to the idler bellcrank and at the other end to the power control unit's servo control valves. The actuators of the power control unit attach to the output lever. Actuator drive is transmitted from the output lever to the elevators by a separate push-pull rod to a horn on each elevator torque tube. At the same time, the output lever motion operates the servo control valve linkage in the direction that tends to neutralize the



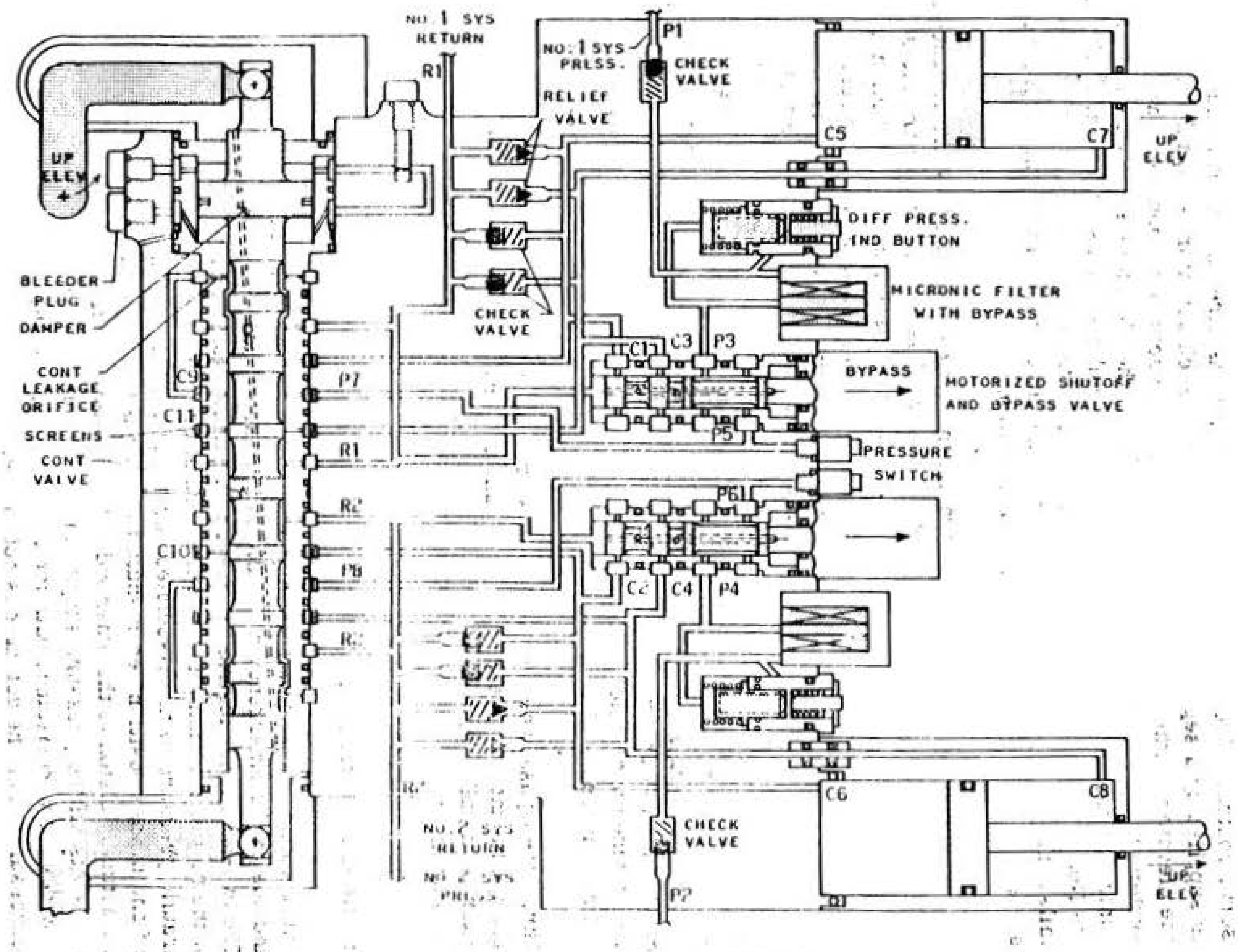
POWER CONTROL UNIT

servo control valves. The power control unit has three actuators. Each actuator is supplied by a separate hydraulic system. Each actuator is capable of operating the elevators without assistance from the other actuators; however, two hydraulic systems are usually used in unison to operate the elevators so that uninterrupted control is assured if one of the operating hydraulic systems should fail. Normally, the No. 1 and No. 2 hydraulic systems operate the elevators but if either system fails, the remaining system may be operated in conjuction with the emergency system powered by the No. 3 hydraulic system.

The power control unit has two hydraulic manifolds with internal and attached hydraulic components to control and modulate the flow of the three hydraulic systems to the respective actuators. The lower side-by-side actuators, used for normal operation of the elevators, share a common (main) manifold and a tandem servo control valve with dual hydraulic control components which connect the No. 1 hydraulic system to one actuator and the No. 2 hydraulic system to the other actuator. The main manifold forms the forward end of the actuating cylinders and is attached by pivots to the forward section of the power control unit frame. The upper actuator, used for backup and emergency operation of the elevators, is connected by flexible hose to a separate hydraulic (emergency) manifold which is mounted on the main manifold. The emergency manifold has its own servo control valve with internal and attached hydraulic components, similar to those of the main manifold, which controls hydraulic flow from the No. 3 hydraulic system to the emergency actuator.

Three no-bypass type micronic filters, two mounted on the main hydraulic manifold and one mounted on the emergency manifold, protect the power control unit. One filter is installed in the pressure inlet line of each hydraulic system, upstream of the shutoff and bypass valve, to filter all fluid entering the unit. A differential pressure indicator senses the pressure drop across the filter and releases a "pop-up" indicator button which protrudes from the manifold housing and indicates that the filter is obstructed.

Three combination shutoff and bypass valves, two on the main hydraulic manifold and one on the emergency hydraulic manifold, are included in the power control unit. The two-position, electric motor-driven valves extend into the pressure inlet lines of the respective manifolds. In the normal or open positions, the valves port hydraulic pressure to the associated servo control valves. In the emergency or shutoff and bypass position, each shutoff and bypass valve ports fluid from one side of the actuator piston to the other side of the piston through the system return line and also shuts off the pressure supply line. The interconnection of the cylinder ends provides a low resistance path for fluid interchange when the hydraulic system is depressurized or the actuator is not in use.



POWER CONTROL UNIT SCHEMATIC

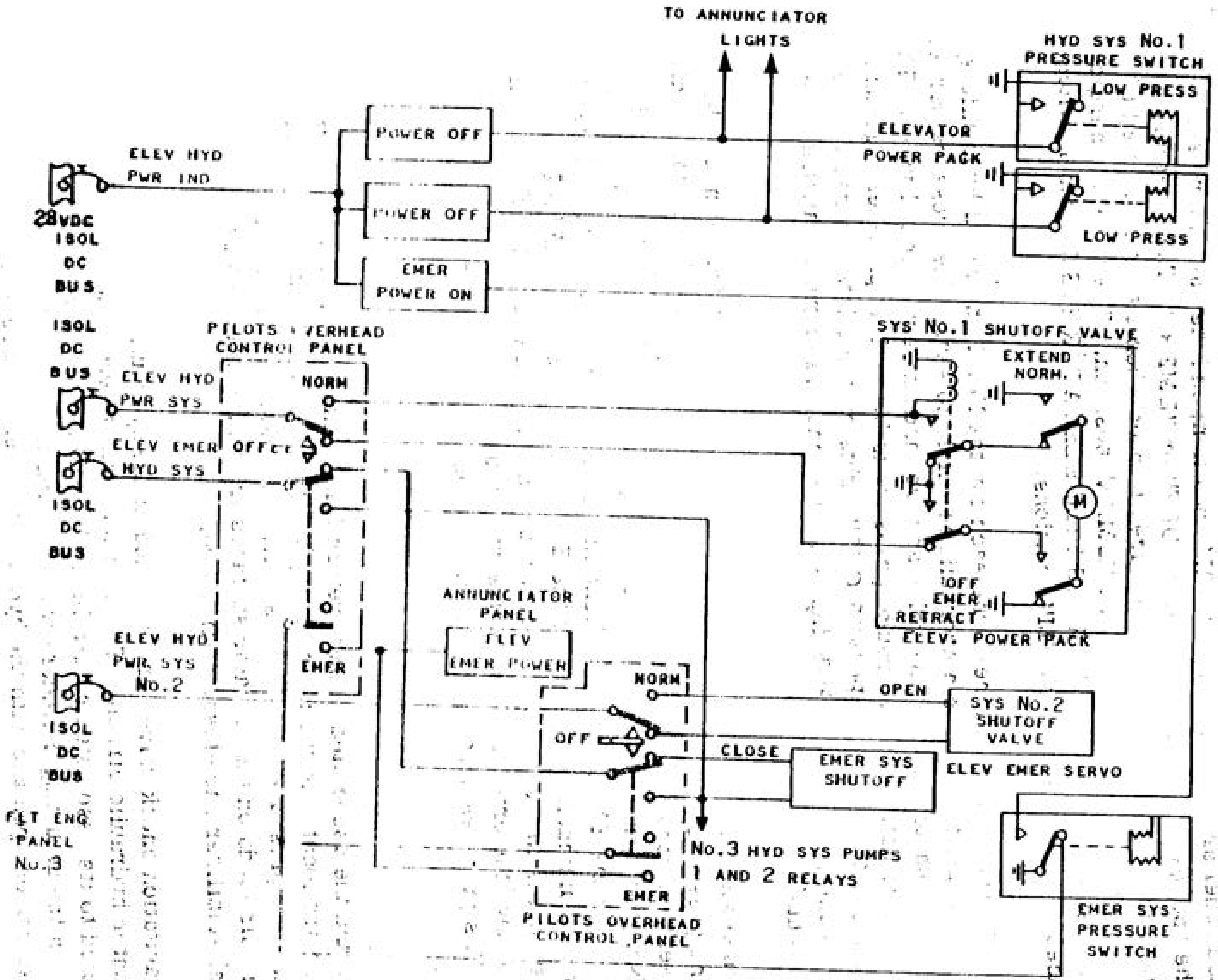
No. 1 and No. 2 hydraulic system shutoff and bypass valves are energized open when the ELEVATOR SYS 1 and ELEVATOR SYS 2 control switches on the pilots' overhead panel are placed in the "NORM" position; and they are energized closed when the applicable switch is placed to "OFF" or "EMER." The emergency, or No. 3 hydraulic system, valve is energized to open when either or both ELEVATOR SYS 2 switches are placed in the "EMER" position. The valve is energized to close when both the ELEVATOR SYS 1 and ELEVATOR SYS 2 control switches are placed in the "OFF" or "NORM" positions.

Two pressure-operated switches, one each for the No. 1 and No. 2 hydraulic systems, are mounted on the main hydraulic manifold to sense line pressure between the associated shutoff and bypass valve and the tandem servo control valve. The switches are actuated when hydraulic pressure is low. This provides a ground to the associated ELEVATOR SYS "POWER OFF" lights on the pilots' overhead panel and to the associated ELEV SYS PWR lights on the annunciator panel causing these indication lights to illuminate.

A pressure-operated switch is mounted on the emergency hydraulic manifold to sense line pressure between the No. 3 hydraulic system shutoff and bypass valve and the servo control valve. The switch actuates when the shutoff and bypass valve admits No. 3 system pressure to the servo control valve and provides a ground connection for the EMER PWR ON light on the pilots' overhead panel. This causes the light to illuminate. When either the ELEVATOR SYS 1 or ELEVATOR SYS 2 control switch is in the "EMER" position and the pressure from the No. 3 hydraulic system is low, the emergency pressure switch actuates to the low pressure position. This provides a ground connection to the ELEV EMER PWR light on the annunciator panel and causes the light to illuminate.

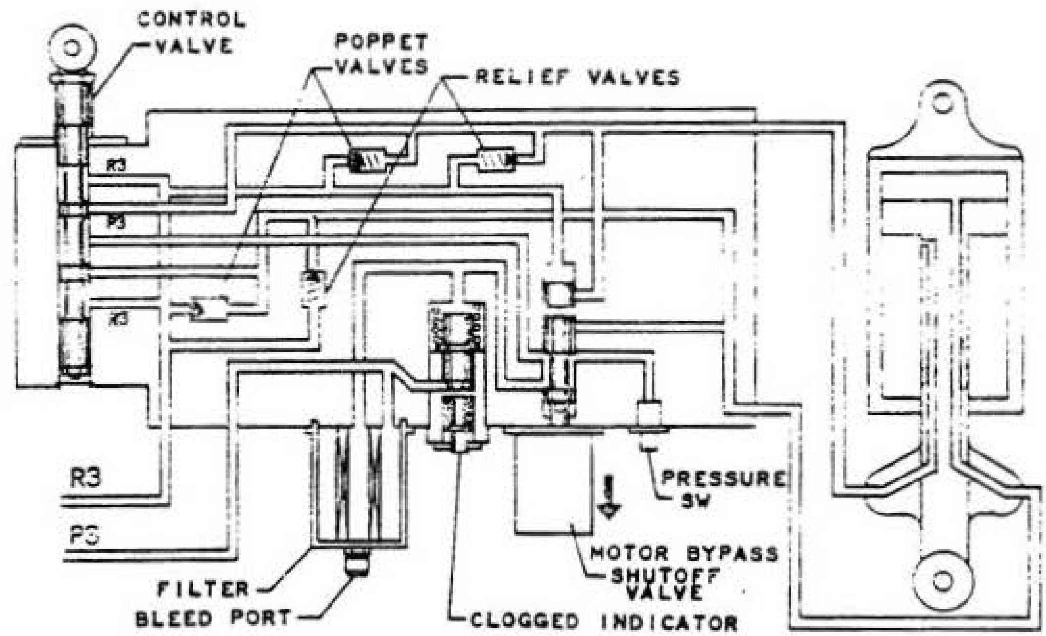
A pressure relief valve is connected between the supply line to each end of each actuator, and the associated system return line. Six pressure relief valves are used, four are located in the main hydraulic manifold and two in the emergency manifold. The pressure relief valves relieve excessive pressure from the actuators to prevent air loads on the elevator surfaces from developing excessive loads on the horizontal stabilizer and elevator structure.

Six anticavitation check valves are installed in the hydraulic manifolds, two for each actuator hydraulic circuit. The hydraulic line to each end of each actuator is connected to its associated return line. The check valves open to prevent cavitation in the actuating cylinders while cycling the elevators with the shutoff and bypass valves open and with the hydraulic systems depressurized.



ELEVATOR ELECTRICAL CONTROL

Both the main and emergency hydraulic manifolds contain a servo control valve to direct and modulate the hydraulic flow to and from the actuators in response to control movements. The tandem main servo control valve interconnects hydraulic passageways in the main hydraulic manifold to provide pressure and return lines of the No. 1 hydraulic system to one of the lower actuators and the pressure and return lines of the No. 2 hydraulic system to the other lower actuator. The emergency servo control valve interconnects passageways in the emergency manifold to connect pressure and return lines of the No. 3 hydraulic system to the upper (emergency) actuator. Both ends of the main servo control valve and one end of the emergency servo control valve are mechanically connected to the input quadrant assembly. As the input linkage displaces the valves in either direction from the neutral position, hydraulic flow from the pressurized hydraulic systems begins to move the elevators. As the power control assembly output lever moves, the linkage returns the servo control valves toward the neutral position. When the elevators reach the position preselected by the control movements, the servo control valves reach the neutral position to stop further hydraulic flow and elevator movement.



ELEVATOR EMERGENCY SERVO

The main servo control valve has a one gallon-per-minute controlled leakage feature at each hydraulic system section of the valve. This permits flow through the power control unit when the valve is in the neutral position and the hydraulic systems are pressurized. It also provides a continuous supply of warm fluid to the power control unit, located in the unheated empennage, to prevent sluggish operation. A piston and orifice arrangement at one end of the main servo control valve provides hydraulic snubbing and damping action.