Dr. Norbert Cheung's Series in Electrical Engineering

Level 5 Topic no: 3

Hydraulic Components and Systems

Contents

Reference:

WL Green, "Aircraft Hydraulic Systems – An introduction to the analysis of systems and components," John Wiley and Sons, 1985.

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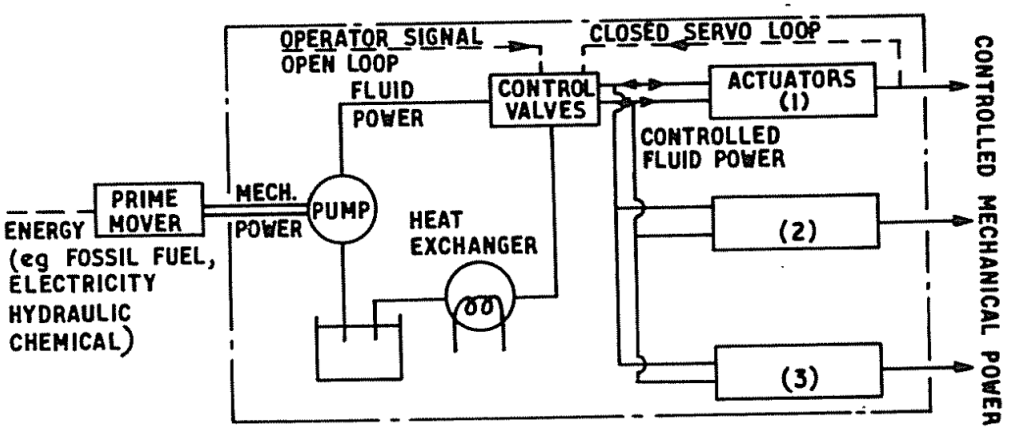
1. Introduction

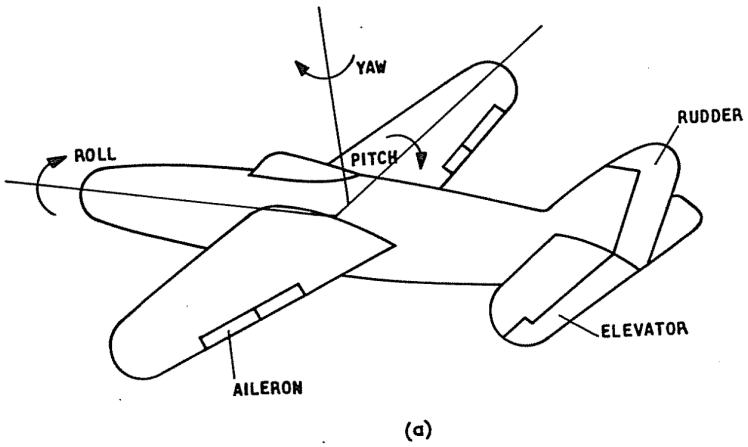
- Fluid power engineering is concerned with the design and assembly of equipment to control the application of mechnical power at places and times where it is required.
- The raw power is derived from the pump of the electric motor or heat engine.
- The power is transmitted to the motor in terms of flow and pressure.
- The power flow is controlled by the valves, and this power flow is fed into hydraulic actuators, which in turn converted in rotary or linear motion.
- The actuators are electrically controlled by torque motors or solenoids.



- Usually only one prime mover and pump is needed, in order to control many actuators (neglecting backup system).
- The hydraulic actuator may have a closed look link (either mechanical or electrical) to the servo valve.

2. Use of Hydraulic Servo in Flight Systems

- In primary flight control: aileron, elevator, rudder
- In general utility services: undercarriage lowering and retraction; wing landing flaps; bomb and cargo doors; air brakes; nose wheel steering; etc.
- In primary flight services, the output actuators are duplicated.



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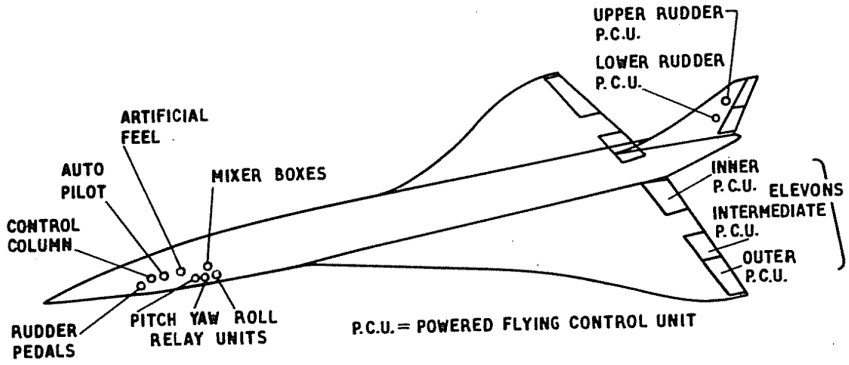
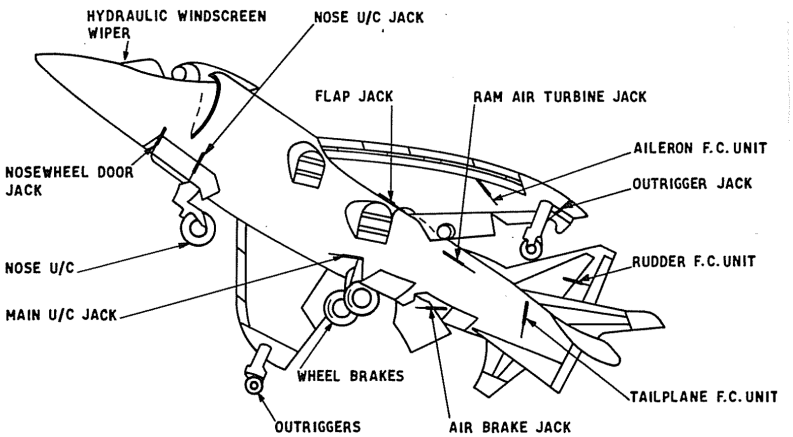
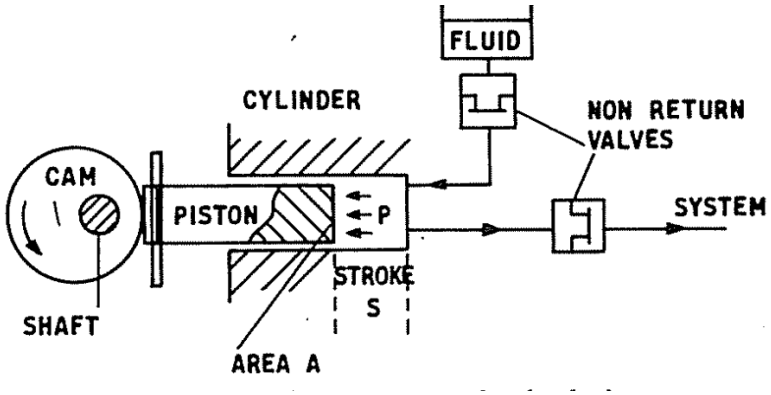


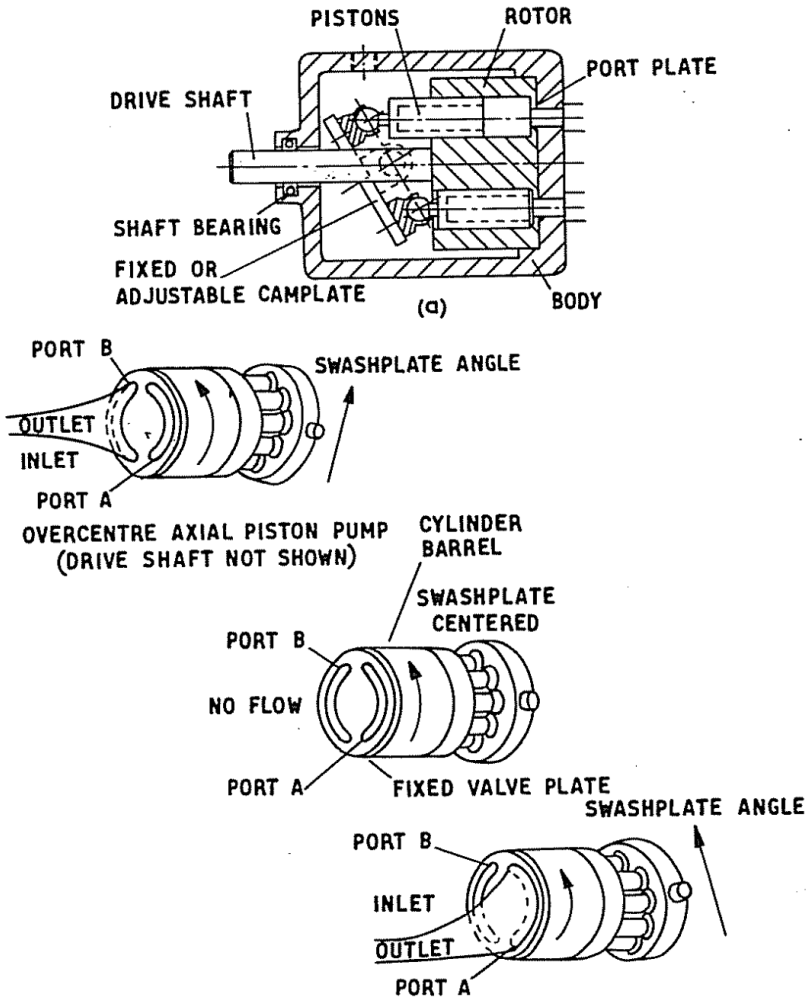


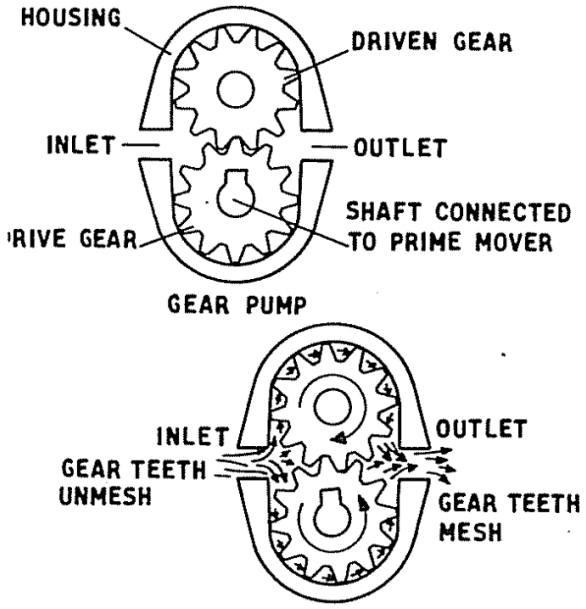
3. Hydraulic Servo Pumps

- Powered by electric induction motor, or by a linkage from the mechanical heat engine.



- In most aircraft, a swash type pump is installed. It has a flexibility of directing the flow of fluid by setting the angle of the swash plate.

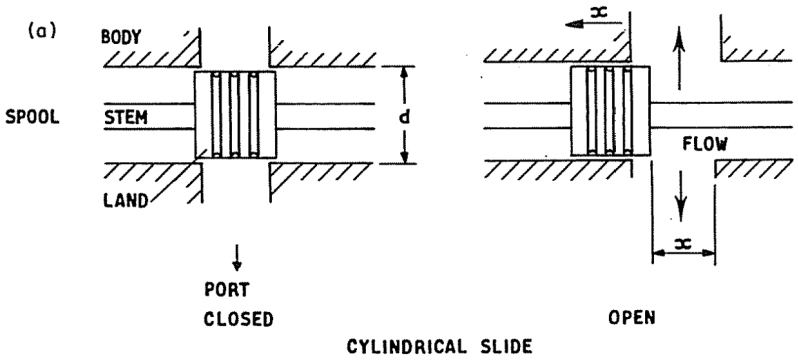




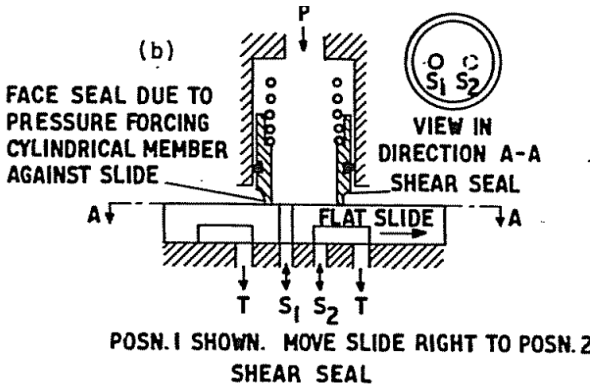
- Other pump used in aircraft includes the gear pump. It has an advantage of simplicity and reliability.
- In aircraft system, the main concern is weight and reliability. The cost is secondary.

4. Hydraulic Servo Valves

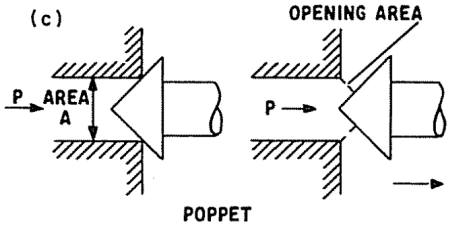
- The valve use cylindrical slide to control the opening and closing of fluid



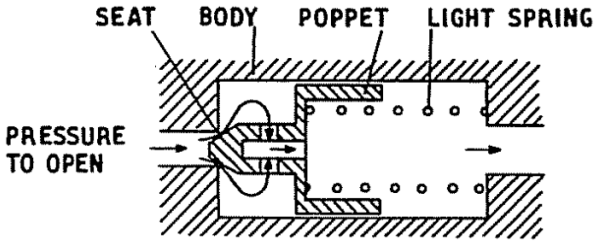
- A flat slide can be used to control of flow direction, as shown in the picture below.

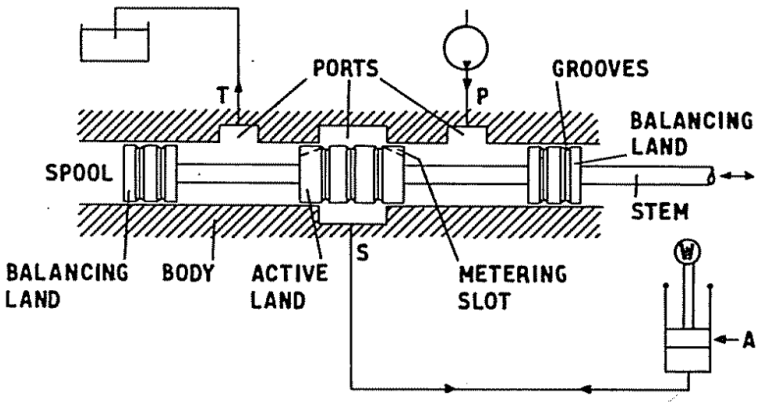


- A poppet can be used to control the open and close of the valve.

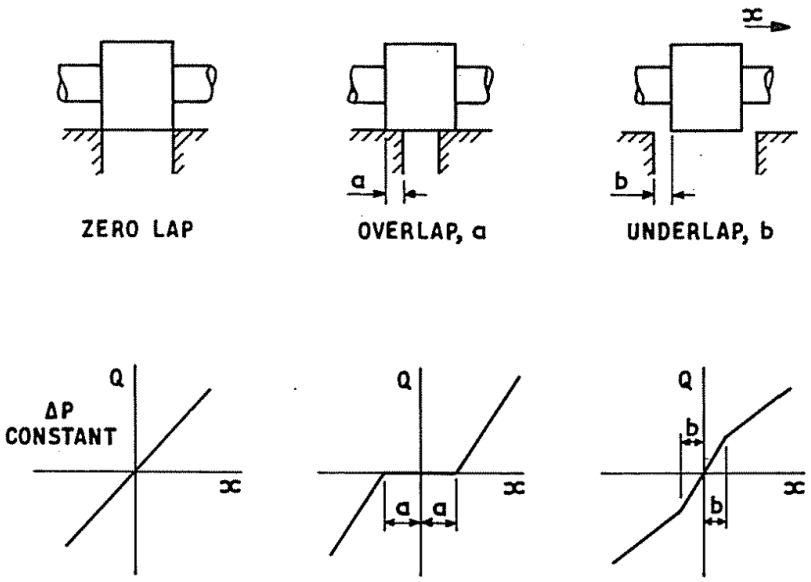


- Analogous to diodes, hydraulic systems need valves to restrict the direction flow.

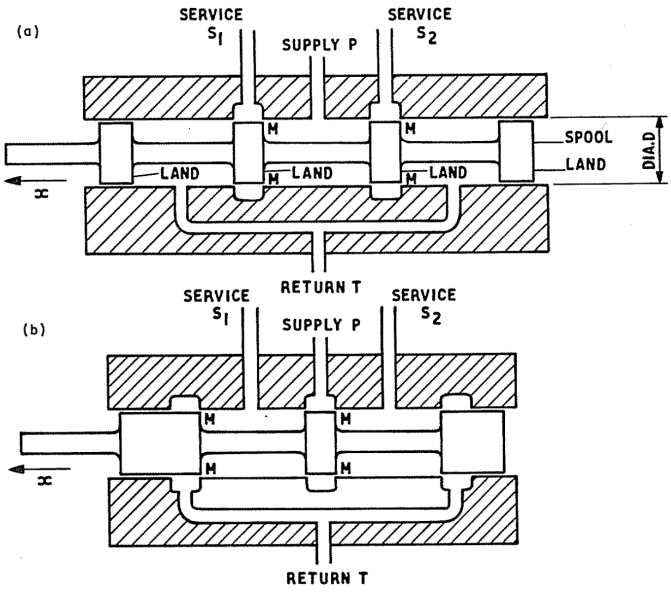




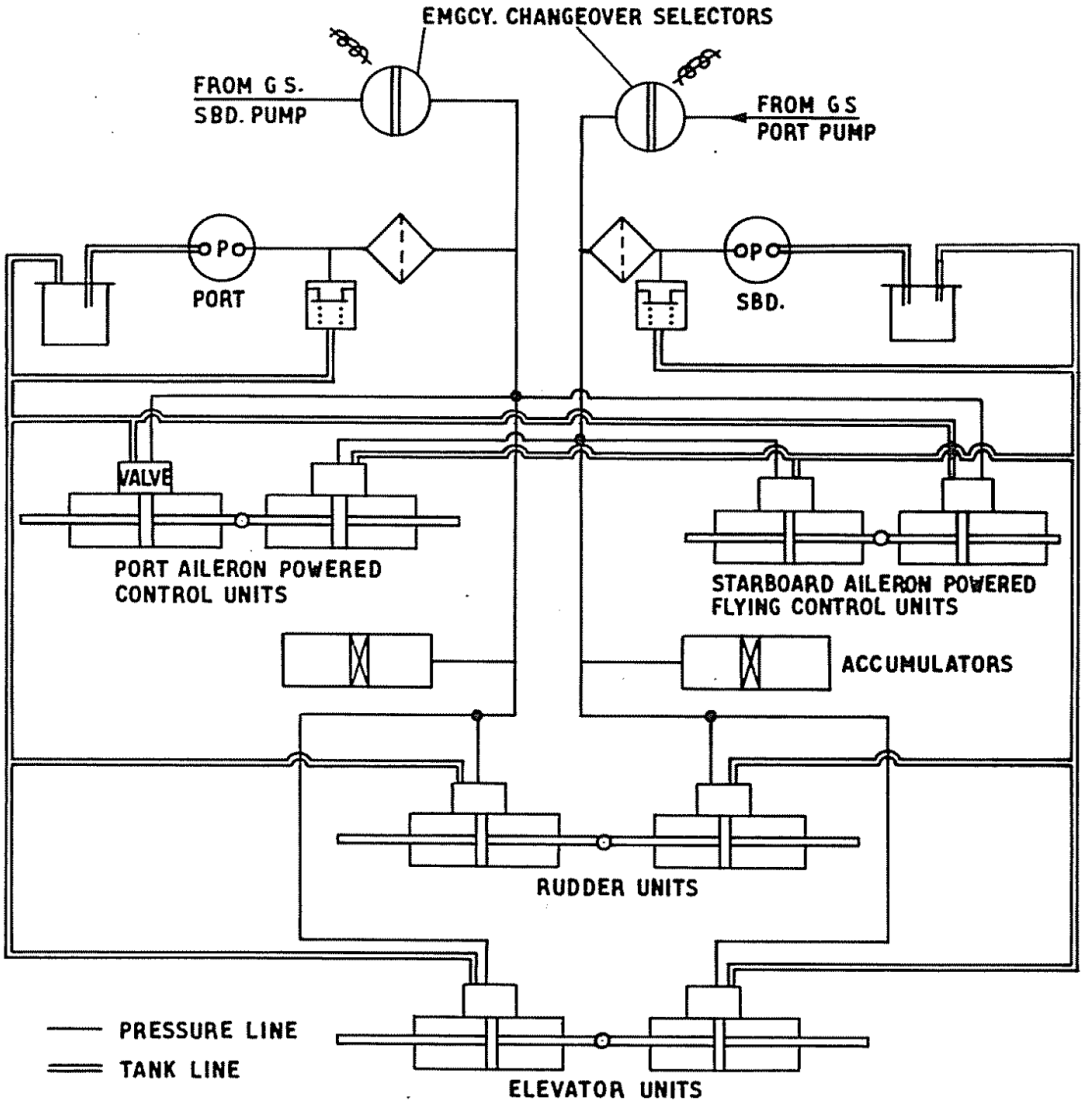
- Servo can also be classified as over-lap, zero-lap, and under-lap. Each has its own characteristics as shown in the diagram below.



- As an example, figure below shows two typical zero-lap servo valve elements.

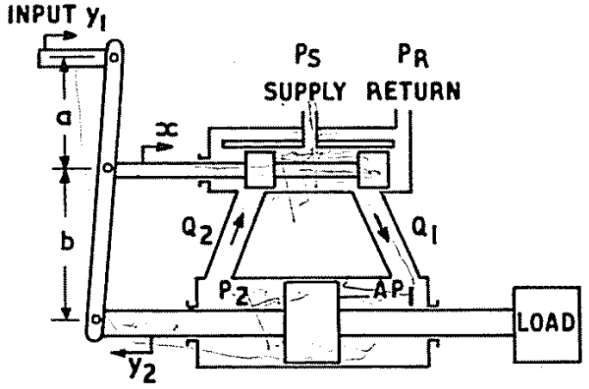


- Figure below shows the typical hydraulic system of an aircraft.
- For safety purpose, the system is duplicated.
- Normally, the two systems will be operating as the same time.
- When emergency happens, the failure system will be "disconnected" from the control, including the mechanical linkages.
- For vertical take-off aircrafts, there are usually three circuits avalible.

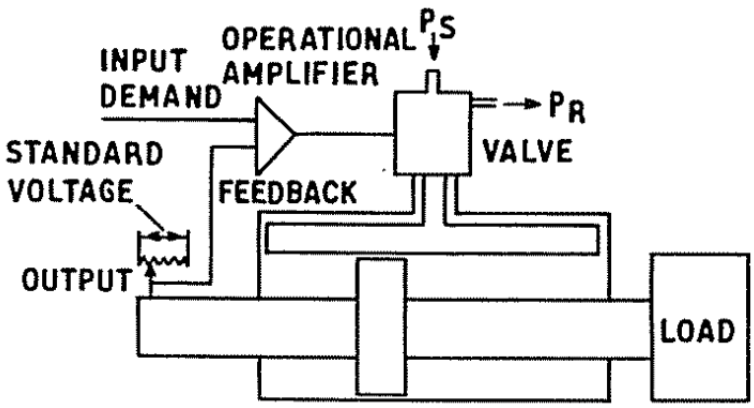


5. Feedback in Hydraulic Servo Systems

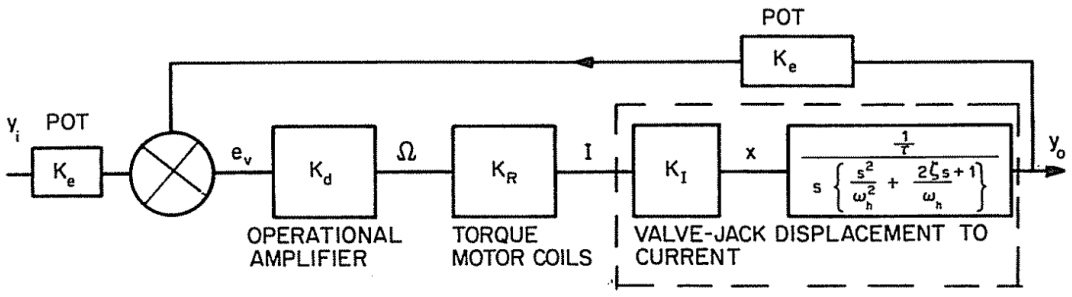
- The feedback can be a simple mechanical link (as in power steering in cars), or by electrical sensors and actuators (as used in most aircrafts).



A Hydraulic Servo with Mechanical Lever

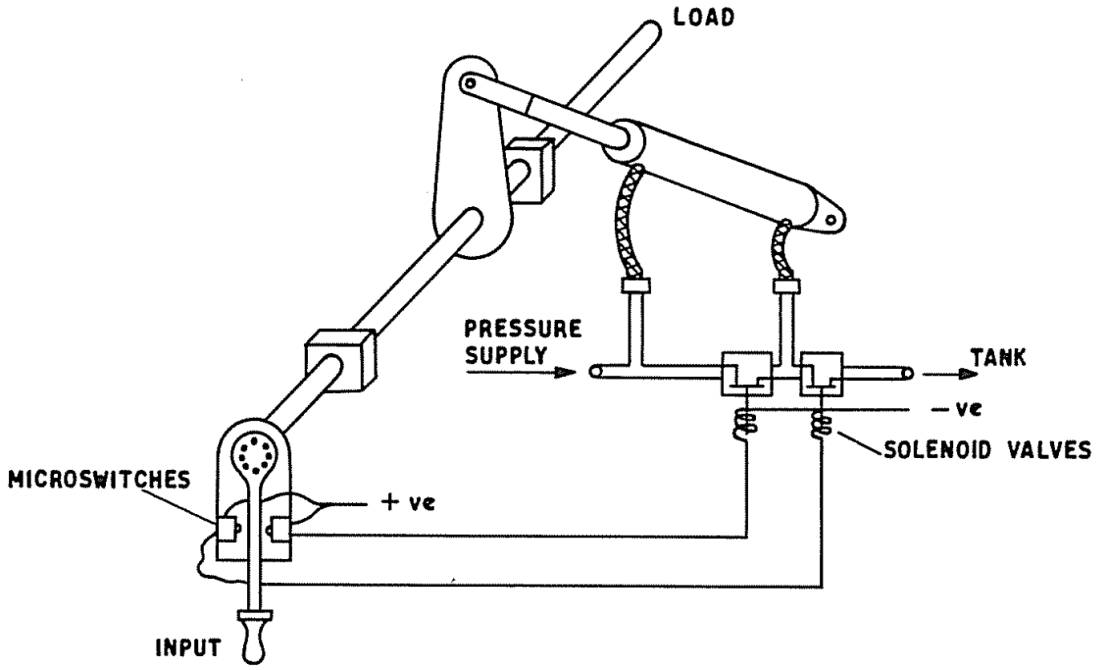


An Electro-hydraulic Servo System



Block Diagram of the Electro-hydraulic Servo System

- For high inertia mechanics with slow response (e.g. nose wheel steering), the on-off servo control is used.
- This type of system is also called the bang-bang servo system.
- The valves are either fully opened or fully closed. After the valve is fully opened, the mechanics will travel to the destination. Once it reaches the destination it will be fully closed.

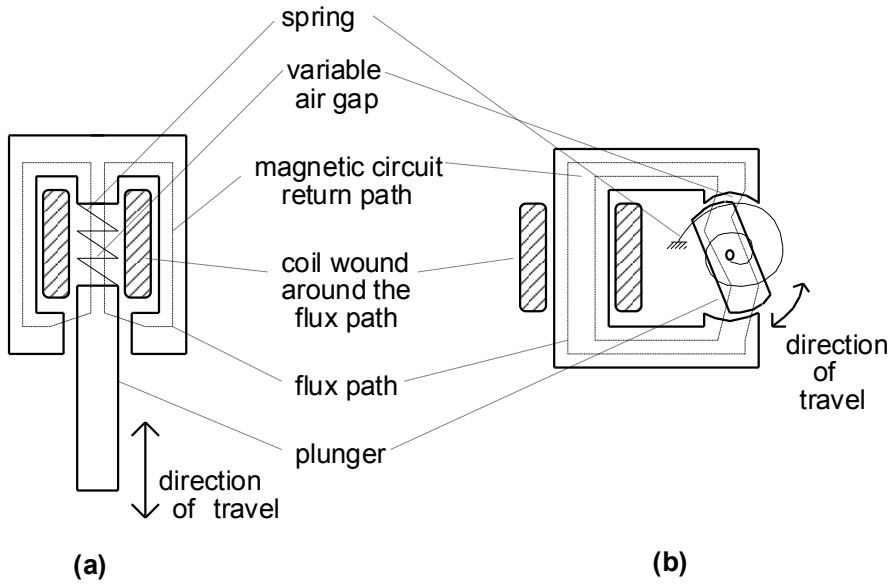


6. Construction of Solenoid Actuators

- Solenoid exists in two forms. In the first form the plunger of the solenoid moves in and out in a discrete manner. In the second form solenoid exists as a rotary device and travels between two discrete angular positions.
- To minimise the holding current, a coil with a large number of turns is wound on the stator. Therefore the inductance of a typical solenoid is relatively large.
- The solenoid works on the principle of reluctance variation, and has a variable magnetic circuit. When the coil is energised, the flux produces force in such a manner that it reduces the reluctance of the magnetic circuit.
- The force produced by the magnetic field acts in one direction.

The force in the other direction is provided by a spring. Only one coil is present on a solenoid.

- Since there is a large variation of force at different plunger positions, therefore most solenoids have short travel strokes. A typical stroke length is 5-10mm for linear travel solenoids, and 30-60 degrees for rotary devices.



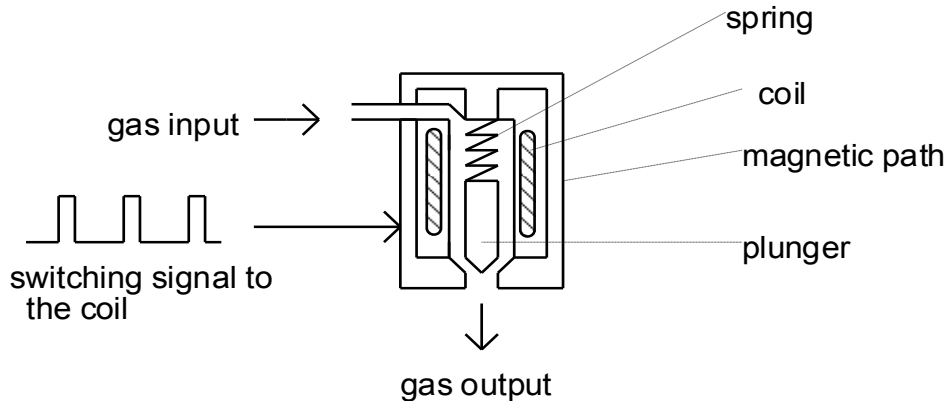
Structure of linear motion solenoid and rotary motion solenoid.

Solenoids and Proportional Actuators

The structure and operation principles of a number of commonly used proportional actuators are investigated. They are:

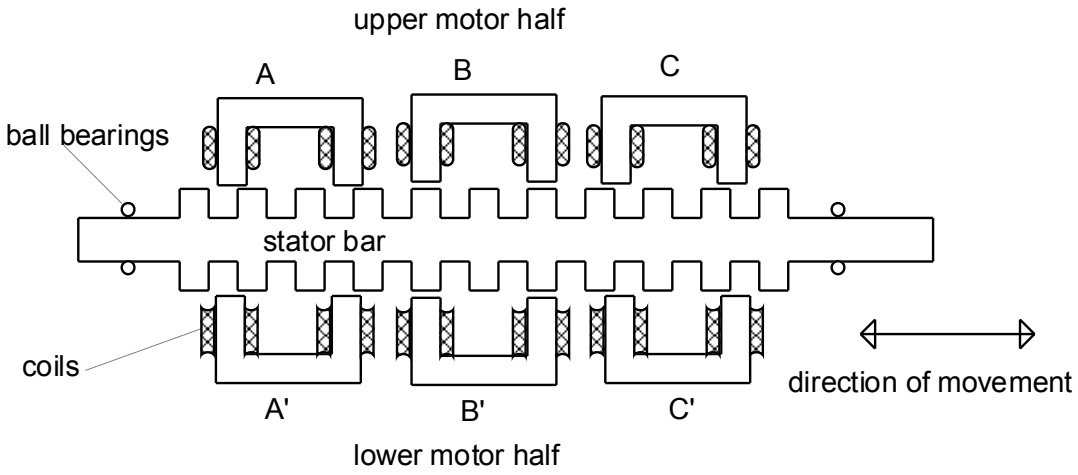
i. Bang bang controlled solenoid
ii. Stepping motor proportional actuator
iii. Short stroke moving coil proportional actuator
iv. Proportional actuator driven by torque motor
v. d.c. motor

- Bang bang controlled solenoids are normally used in low cost applications when precision is not required.
- A typical example is the fuel injection system in engines.
- Proportional control of gas flow is achieved by varying the on/off duty ratio.
- Implementing proportional control is low in cost,
- Disadvantages: limited life cycle, low precision, poor performance, low reliability.



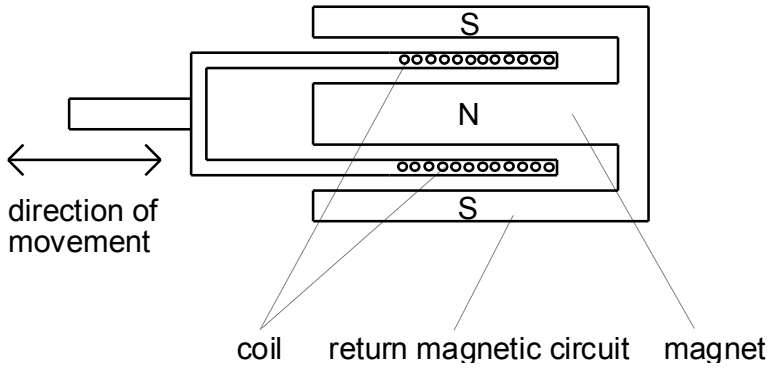
Bang bang controlled solenoid

- Stepping motors driven proportional actuators are commonly employed in proportional fluid valves.
- They are more complex in constructions than solenoids and they come in larger sizes.
- Stepping motors do not produce smooth trajectory motions, and the travel advances incrementally.
- Many stepping motor controllers operate in open loop mode.
- There is no provision of error correction when slipping occurs.



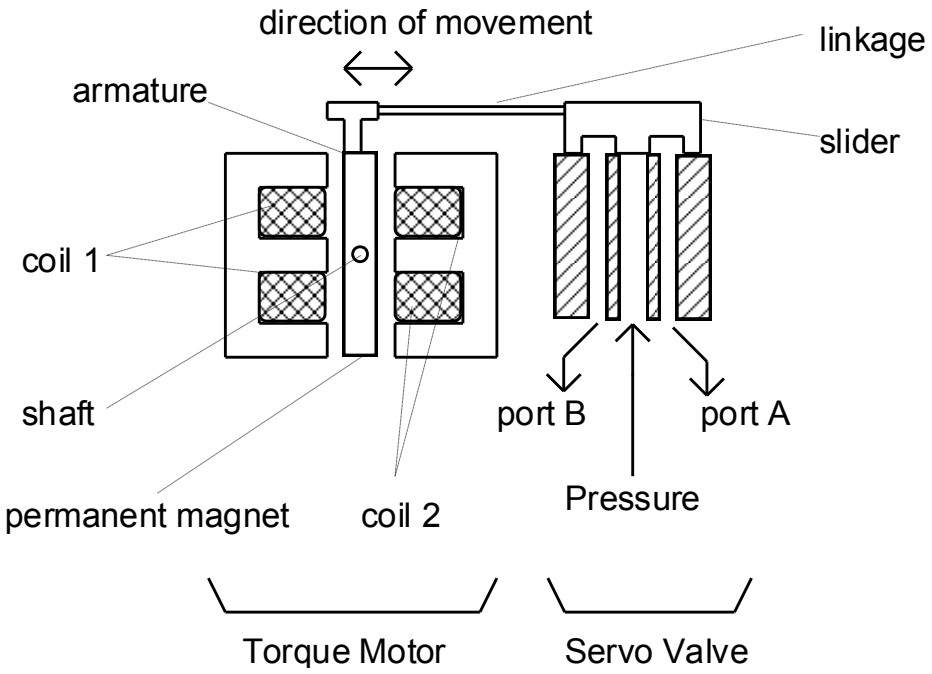
A three phase stepping motor with linear travel

- Moving coil motor is the most popular form of motion device in proportional actuators.
- Positioning systems, hydraulic servo valves, and other high end applications in which precise control over the trajectory path is required.
- Moving coil actuator has a linear control characteristic; its force depends on current only, and it can be controlled in both directions.
- It is more expensive to produce than a solenoid, because of the permanent magnet, the structure of the moving coil, and the precision alignment between the plunger and the stator.
- This also makes it less robust and more susceptible to damage.



A moving coil proportional actuator

- The torque motor uses two differential coils to produce a limited stroke linear motion actuator.
- It is usually found in expensive proportional valves.
- The actuator consists of a permanent magnet and two coils; the amount of deflection on the armature depends on the difference of current of the two coils.
- The magnetic circuit of the actuator is designed to deflect the armature at an angle which is linear with the current difference of the two coils.
- The design also ensures that saturation is absent on the magnetic circuit.
- The structure of the actuator is complex, and linkage is required for the connection to the servo valve.
- Magnetic circuit is large and bulky, because it needs to avoid flux saturation in the magnetic path.
- It also needs to provide a linear relation between current and deflection.



A single stage servo valve

- The fifth type of proportional actuator uses d.c. motor as the motion device.
- Permanent magnet d.c. motor is an unlimited stroke rotary device
- The motor is commutated directly through a pair of brush
- For some proportional actuators, the brushes are eliminated by using brushless d.c. motors.
- Proportional actuators driven by d.c. motors can be found in electro-hydraulic servo, positioning systems, and many other applications.
- However, they have complex structures, dedicate moving parts, and are generally more expensive than solenoids.

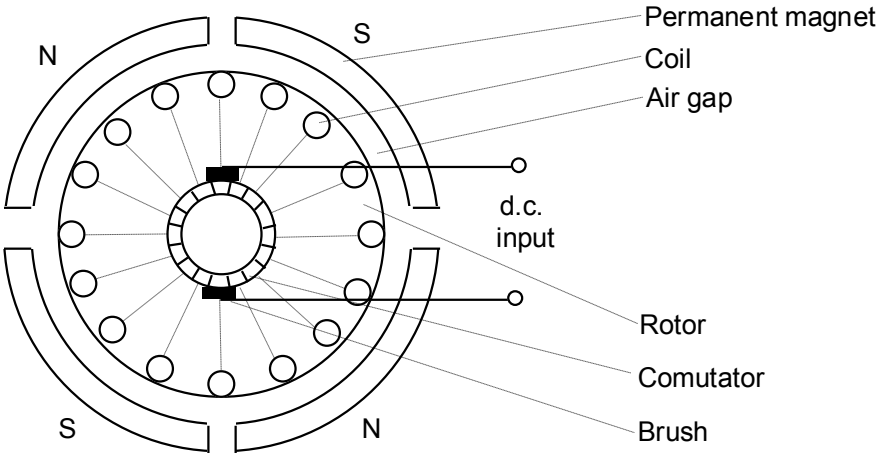
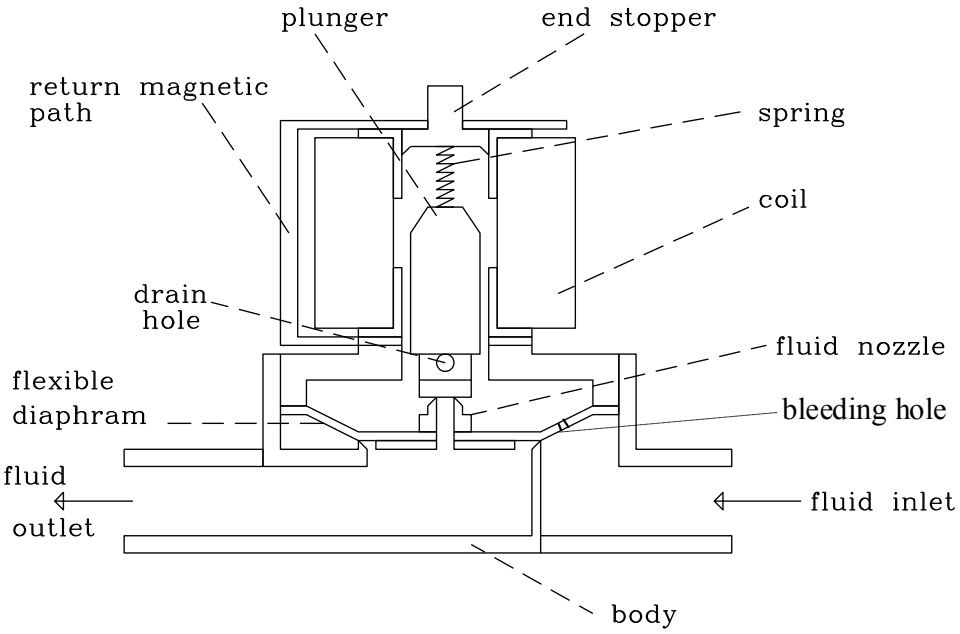


Figure 2-6 Cross section of a d.c. motor

- The two stage solenoid valve is an integration of a switching solenoid and a two stage valve.
- The plunger controls the position of the flexible diaphragm, which in turn controls the flow of fluid.
- The diaphragm has a nozzle in the centre and a smaller bleeding hole at one side.
- The plunger is hollowed, and has a drain hole by the side to assist the movement of the plunger when it is surrounded by fluid. Note that the plunger acts as the valve directly and no mechanical linkage is required.



Make/Model	Goyen Controls/20BW2 d.c.
Type	Two stage switching solenoid valve
Stroke length	10mm
Operating voltage	24V d.c.
Maximum current	0.6A
Resistance	40Ω
Inductance	0.35-1.1H
No of turns of coil	2240

A two stage solenoid valve and its characteristics

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