Contents

INTRODUCTION TO HYDRAULIC SYSTEM

PRINCPLES OF HYDRAULICS

The name 'Hydraulics' has been taken from the Greek word 'HYDOR' meaning water and 'AULOS' meaning pipe. For the first time 'Hydraulics' was put to use by the person who converted the energy of flowing water into useful mechanical energy, by means of the water wheel. Later on the idea of Industrial Hydraulics or Oil Hydraulics emerged. It is the science of transmitting energy through the medium of pressurized fluid. Advancement of this science started when Pascal discovered a fundamental law called Pascal's law which states: "Pressure generated at one point in a confined liquid, acts actually in all directions and acts perpendicular to the surface of the container". The law helped in developing this new field of hydraulics, dealing with power transmission, control of mechanical motion and characteristics of fluids under pressure. The developments resulted into the use of network of high-pressure of fluid pipes from the pressure generating station i.e. pump to the application points through the controlling system. In this process various auxiliaries like valves, accumulators and seals etc. were invented. Now-a-days, the principle of oil hydraulics are applied for power transmission and control and very successfully replaced even mechanical and electrical drives in some machine-tools and equipment.

The logical and sequential arrangement of various elements to obtain the desired function through fluid is called hydraulic system. Oil hydraulic systems can be built using readily available standard elements together with electrical/ pneumatic interface to perform any complicated sequence of operation. The system is more widely used in machine tools as principal and feed movement drives providing rotary as well as translatory motion with stepless regulation of feed and speed rate , speed changing devices, automatic control of machine cycle, etc. The innovation of electro hydraulic servo valve and proportional valves, which could conveniently interface with electrical and electronic measuring and signaling devices, led to the popular use of electro- hydraulic servo drives in CNC machines. The latest is the application of electro-hydraulic stepping motors with hydraulic torque amplifiers for feed drives in an open loop configuration. This extensive use of hydraulic system is due to their capability of providing infinitely variable speed over a wide range, smooth reversal of moving machine members, automatic overload protection, easy lubrication, etc. Among their shortcomings is leakage of hydraulic fluid through seals and gaps, ingress of air into fluid, effect of temperature and time on fluid properties, etc.

Pascal's Law

PRESSURE APPLIED ON A CONFINED FLUID IS TRANSMITTED

UNDIMINISHED IN ALL DIRECTIONS AND ACTS WITH EQUAL FORCE ON

EQUAL AREAS AND AT RIGHT ANGLES TO THEM (If a force F is applied on a

piston of area A, (over a confined fluid) then it gives a pressure P = F/A. This pressure will be uniform in the entire confined fluid at rest.

ADVANTAGES OF HYDRAULIC SYTEMS

Due to limitations of other power transmission system such as electrical, electromechanical and pneumatic etc. hydraulic power transmission is preferred. Large forces can be transmitted to long distances with high pressure stability and quick response. There are multiple application possibilities which is suitable for use where large forces with infinitely

variable speeds are to be applied in given directions. Hydraulic equipments give smooth operation for longer period with very less maintenance cost. Normally oil contamination control and leakage control may give long life to hydraulic components.

Other advantages of hydraulic system are:

1. **Highly compact**- Power to weight ratio is very high. A hydraulic motor weighs about

   1/7 th of an electric motor of same power
2. **Precise control**- depending on different requirements we can get exact speed, force and position of user,
3. **Over load protection**- in case there is over load in pipe line or user, there is provision of relief valve set at a certain maximum pressure to take care of it,
4. **Suspension of load for long period**- by providing a pilot operated non-return valve in pipeline, load may be suspended for a longer period,

5. **Flexibility in design**- As per needs of production, scheme of hydraulic circuit may be changed easily only with addition of a few components,

6. **Easy maintenance**- its maintenance is easy. Only oil contamination control will fulfill major portion of maintenance work. For this monitoring of set parameters and inspections of pipe lines, religiously is necessary

7. **Variable Speed Controls**: - We can get infinitely variable speeds and positions as per need of users.

8. **Stalling of loads**:- The loads can be stalled to zero speed without any damage to the equipments

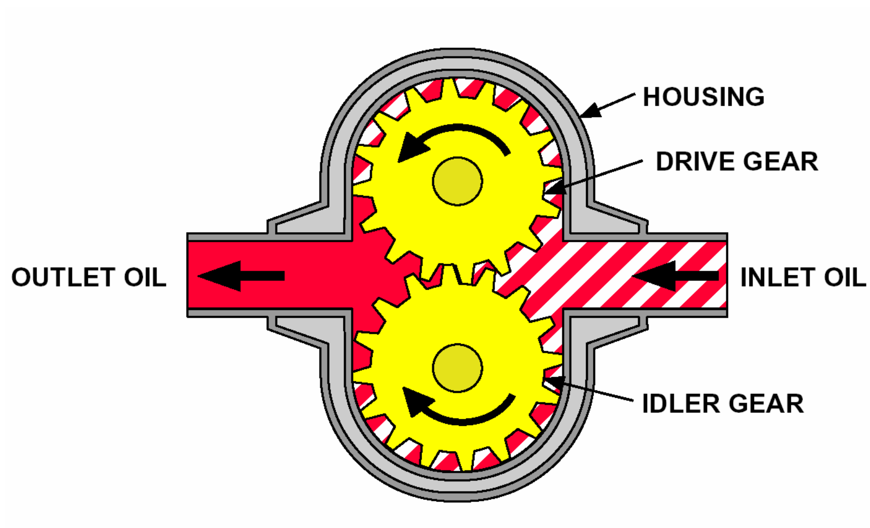
DISADVANTAGES OF HYD.SYSTEM

- Expensive.
- High maintenance cost
- Susceptible to leakage (fire hazard)
- Vulnerable to dirt (difficult to maintain cleanliness)
- Trouble shooting is difficult and time consuming.
- Trained person required**.**

COMPONENTS OF HYDRAULIC SYSTEM AND THEIR FUNCTIONS

POSITIVE DISPLACEMENT PUMPS

A pump, in a hydraulic system, is a device to transmit force from one source to another point. It does not create any power, but transmits the power from source like electric motor or engine to hydraulic fluid. By its mechanical action, the pump creates a partial vaccum in the inlet side. This vaccum gets filled up with the hydraulic fluid, by gravity or by the atmospheric pressure. After the inlet chamber of the pump is filled with fluid, the mechanical action of the pump forces that fluid further into the system through the outlet pipe line.



BASIC CHARACTRISTICS OF PUMPS

Positive displacement pumps are used as power generating elements. Base on the geometry of the pumping mechanism these pumps are either fixed or variable displacement type.

Hydrostatic or displacement pumps provide a given amount of fluid for every stroke, revolution or cycle. Their output except for leakage losses is independent of outlet pressure making them well suited for use in the transmission of power. Selection of pumps is made based on the following performance characteristics.

Pump rating: Pumps are generally rated by their maximum operating pressure capability and their output in gallon per minute or liter/min. at a given drive speed. **Pressure rating:** The pressure rating of a pump is determined by the manufacturer based reasonable service life expectancy under specified operating conditions. Operating at higher pressure may result in reduced pump life or more serious damage.

Displacement: The flow capacity of a pump can be expressed as its displacement per revolution or by its output in liter per minute. Displacement is the volume of liquid transferred in one revolution. It is equal to the volume one pumping chamber multiplied by the number of chambers that pass the outlet per revolution.

Volumetric efficiency: In theory, a pump delivers an amount of fluid equal to its displacement each cycle or revolution. In reality the actual output is reduced because of internal leakage or slipping. As pressure increases, the leakage from the out let back to the in let or to the drain increases and volumetric efficiency decreases

HYDRAULIC FLUIDS

Fluids for hydraulic systems are subject to a wide range of pressure, velocities and temperatures.

During the operation of the system the temperature of the hydraulic fluid changes owing to its heating and cooling. In the suction line the supply of liquid is affected by the vacuum formed in the suction end of the pump. In the pressure piping the fluid is subjected to high pressure.

Hydraulic fluids have to fulfill following functions.

1. To effect transmission of energy.
2. To lubricate the elements.
3. Prevent formation of sludge gum and varnish.
4. To carry away the heat generated in the system.
5. To seal moving parts.
6. Separate out water.
7. To inhibit rust and corrosion.
8. Depress teaming.

Refined mineral oil is the best pressure liquid. Grades with the smallest variation of viscosity due to temperature changes are best suited for this purpose. The oil should not contain impurities and components, which produce saponifying fats, acids, asphalt etc.

Oil with a higher viscosity should be used in cases when leakages are high i.e. at high temperatures and pressure, or with large clearance in packing due to wear. Also high viscosity oil should be used in the system with low flow rate. It is recommended to use low viscosity oils in high-speed drives regard less of the considerable leakage losses. Here the use of viscous oils may give rise to the jamming of parts such as vanes of vane-pumps, pistons, and valves when the force moving them is unable to overcome friction.

RESERVOIR AND FILTER

Reservoir is a very important part of the hydraulic system. It primarily serves as a supply source for hydraulic system fluid. It is from the reservoir that the pump draws fluid for various operations and to which the fluid is returned when the actuator discharge the same. Its construction assists in the separation of air and contaminants from the fluid and helps dissipate heat generated within the system. Tank is the main constituent of the reservoir.

TANK

When the hydraulic fluid passes through the system, it gets heated due to its frictional losses and pressure drops through a number of pipelines and valves. If this heat is not taken away, it will have a very harmful effect. In general tank capacity is taken 3 to 4 times the capacity of the pump. If the suction lines are not well dipped into the fluid, it will result in foaming, cavitation and formation of whirl-pools around the suction strainer. So the lowest level of oil should not be allowed to go lower than 30cm (or 3×ID of suction pipe) above the inlet mouth of suction pipe of the pump. At least 100mm airspace should be left above the oil level in a tank to allow easy escape of any bubbles. Drain lines, however, are often piped in above oil level to eliminate back pressure and siphoning.

It is preferable to bring each line separately into the tank rather than through a common header. Otherwise flow in one common header will create back pressure into the common return line, interfering with the operation of some hydraulic components. Since the level is required to be checked regularly, the oil level indicator is located conveniently. Return lines usually are cut at an angle of approximately 45° at the bottom so that the flow is directed towards the walls of the tank and away from the pump intake line for maximum heat dissipation.

Baffle plates are provided in the tank between inlet lines and return line to prevent continuous circulation of the same fluid again and again. In the first compartment the flow is made to change its direction suddenly with the result that any particles contained in the oil are separated by centrifugal force and settle by gravity on the bottom. The change of direction also separates air absorbed by the oil. Baffle plate top is kept at 2/3 of the height of the fluid level. So that oil freed from mechanical impurities in the first compartment can freely flow into second compartment. Each compartment has its separate drain plug for removing dirt.

A hole is provided at the top of the tank for inlet and exit of air, as the oil level in the tank goes up and down during various operations. The reservoir is usually provided with an air breather at the top cover plate for filtering the incoming air. A replaceable fine mesh wire screen (10μm rating) is installed in the air breather to keep fine foreign matter out of the reservoir when new fluid is added. The size of the breather must be large enough to maintain atmospheric pressure in the reservoir. When excessive moisture is likely to go inside the tank along with atmospheric air, an air drier is installed in the air breather. For filling the liquid a gauge with 0,1 ×0,1mm in used.

Above the tank, a plate of adequate strength is provided upon which the pump and electric motor is mounted. This plate eliminates misalignment between the pump and the electric motor and is isolated far above the tank top to allow a flow of air, to carry away the heat radiated through the thinner metal of the tank top.

The tank should periodically be cleaned thoroughly with kerosene oil with the help of sponge. Inside, the reservoir I painted with a sealer to minimize oxidation which may be caused by condensation. It is preferable to flush with a solvent compatible with the hydraulic oil before filling the oil.

STRAINERS AND FILTERS

Potential trouble due to oil-borne contamination can be minimized by proper initial cleaning and filtration.

Sources of contaminants are listed below.

(i) Residual dirt and scale remaining from the fabrication time of the components.
(ii) Dirt introduced during assembly or servicing.
(iii) Dirt Carrie of by air movements into the reservoir as the fluid level changes.
(iv) Decomposed products of the hydraulic fluid and wear particle from the system and components.
(v) Sealant from Teflon tapes etc.
(vi) Metallic particle from moving surfaces
(vii) Non metallic particle from elastomer seals.
(viii) Sand from rags and clothing.
(ix) Paint
(x) Fiber from filters.

Generally contaminants will include particles of silicas, metals, elastomers and fibers of textile material. A filter is required to provide maximum restriction to the passage of contamination, while offering minimum resistance to flow of the system fluid. Filters and strainers are necessary to reduce the level of contaminants in the system so as to eliminate the following adverse effects.

(a) Plugging of orifices
(b) Scoring of polished surfaces
(c) Damage to seals

(d) Accelerated wear of relatively moving parts

(e) Sitting and wear critical edges as in servo valves leading to loss of control.

A filter is a device where the primary function is the retention by some porous medium, of insoluble contaminant from a fluid. A strainer is nothing but coarse filter. Normally the term used to describe a strainer is MESH (no. of holes per linear inch) size and to describe filter is micron. In strainer fluids flow in straight line while in filter it flows in cured path. Strainer is described by wire mesh (no of holes per linear inch) and filter by microns (0,001mm). Strainers are made of fine wire mesh (normally not more than zero) wrapped around metal frames and remove particles of 74µ and above.

Figure 5.28 Hydraulic oil filter element construction

Figure 5.27 Hydraulic system filters

PRESSURE CONTROLLING ELEMENTS

The control devices control the pressure and the displacement, velocity and acceleration of the mechanism. These are links between the generating and converting elements and are called valves. They are basically assemblies of one or more flow restricting elements, which fall into three main classes: -sliding (spool and plate) seating (puppet, ball and flapper) and flow dividing.

One sided pressure acting on valves can produce excessive frictional force. In order to reduce this force 0,2 × 0,2 mm cross section circular grooves are turned on cylindrical valve pistons at intervals of 2 or 3mm. The same objective can be achieved by drilling axial and radial holes connecting symmetrically located spaces serving the same purpose.

Pressure controls are designed for limiting the pressure in any part of the system, for unloading a pump when the present pressure is reached, for building up back pressure in the exhaust line of a reciprocating or rotary hydraulic motor, for bleeding off surplus flow from the pump to maintain a constant pressure in the system, and for reducing the pressure.

PRESSURE CONTROL

Pressure control valves are usually named for their primary function, such asrelief valve, sequence valve, brake valve etc.

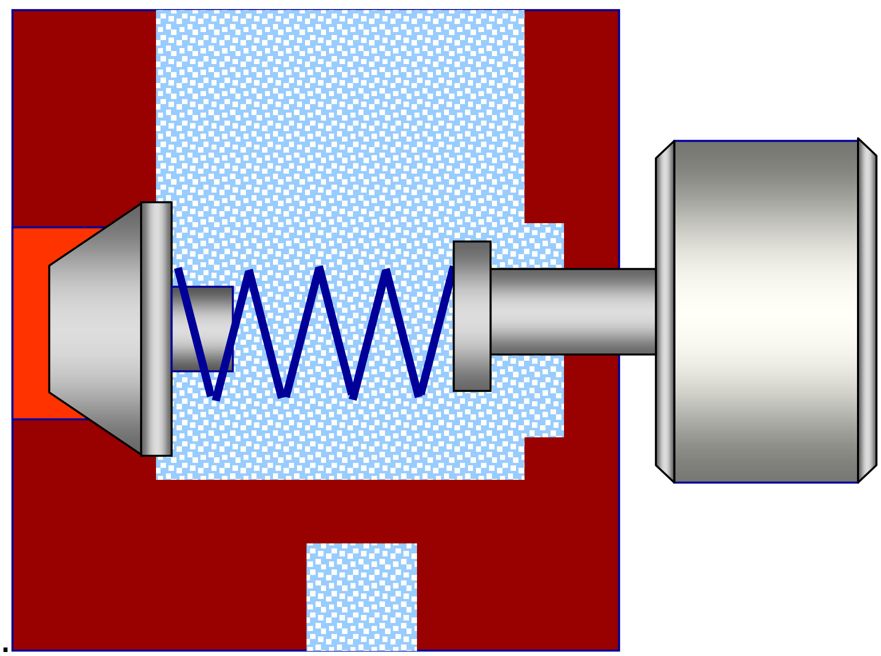
RELIEF VALVES

Relief valves protect the other elements in the system from excessive pressure bydiverting the excess fluid to the tank when the system pressure tends to exceed the set level. In principle valve are of two types (a) simple direct acting relief valve (b) compound relief valve.

The direct acting type of relief valves has a ball, poppet or a sliding spool working against a spring. The preload on the spring determines the systems pressure and can be adjusted by screw.

The pressure, at which the valve first begins to divert flow, is called the cracking pressure. As flow through the valve increases, the poppet is forced farther off its seat causing increased compression of spring and the pressure. When the valve is fully open to by-pass the full rated flow is full flow pressure. The difference between full flow pressure and cracking pressure is called pressure override.

In some cases pressure override is objectionable. It can result in considerable wasted power due to the fluid lost through the valve before its maximum setting is reached. Ball and poppet valves suffer from high pressure over ride and tendency to chatter. Spool type relief valves of the direct acting type provide smooth and stable operation with superior pressure flow characteristics



Direct acting type relief valve

For handling high flow rates at medium and high-pressure balance piston type pilot operated (compound) valve is considered better design. A typical design of the valve is given in the figure 8.The piston of this valve has a small axial hole, which links the upper and lower of valve body. This valve consists of two stages- a small poppet type relief valve for determining the pressure and main spool valve for handling the flow.

If the pressure in the system increases above the set value, the fluid passes from the pressure line through the hole in the side of main piston, into the upper chamber. The restricted flow through the orifice into the upper chamber results in pressure differential on the main piston there by lifting it off to by pass the flow to reservoir. The light spring acting on the piston restores it to original position when the system pressure falls below the set value. The light return spring causes the low pressure differential for dumping the flow.

The valve can be remotely controlled through channels (vent connection) which connect the upper space of the valve with the auxiliary control valve (pilot valve). When the pilot valve is actuated by hand, solenoid operated direction control valve, or by the cams of a machine table, the upper space of the valve is connected to the atmosphere and the valve operates at low, nearly atmosphere pressure. If no remote control is required these channels are closed by plugs.

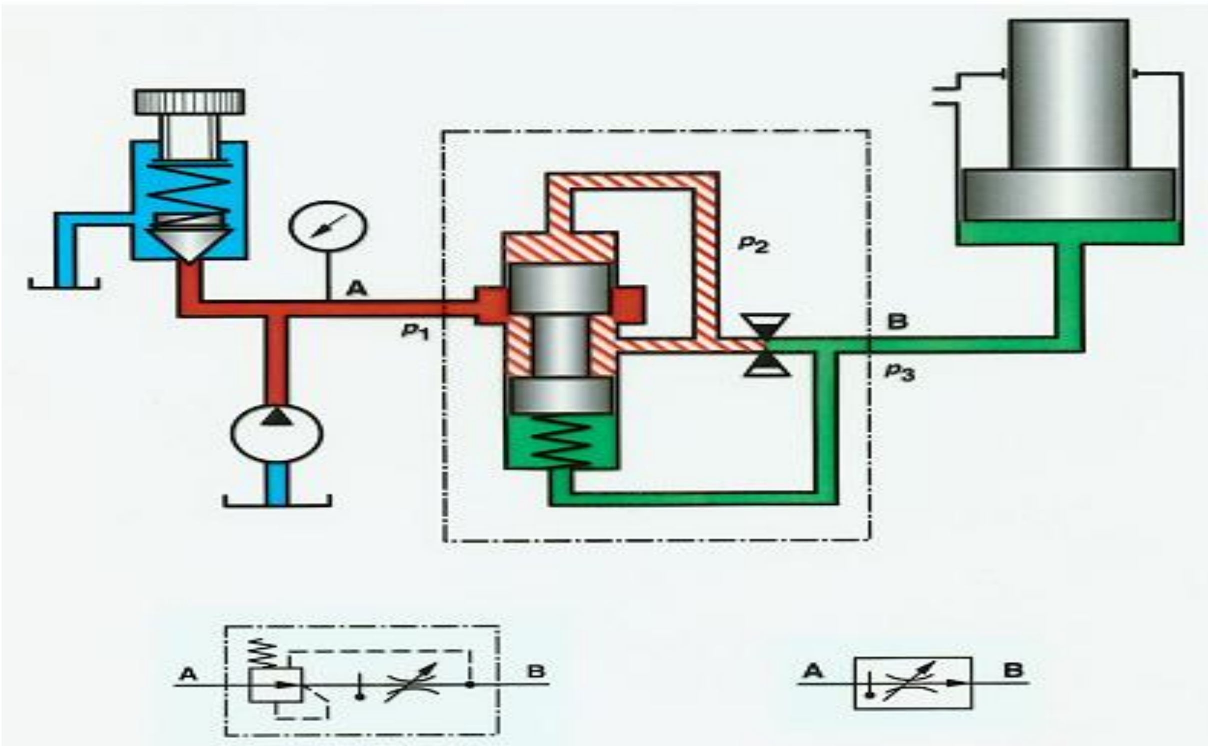
Pilot operated (compound) balance piston type valves are also manufactured simple spool type in place of having poppet seating type of piston. Here the secondary system or exhaust is not opened at the bottom the piston but at the side in the middle of the valve. Ports at the bottom of the piston and at the top of the piston are connected together through an axially drilled hole in the piston and also with the primary system (high-pressure line). Pressure at the top of the valve is further controlled by pilot valve, which has a spring-loaded ball on its seal.

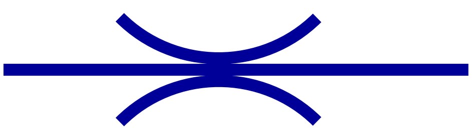
SIMPLE FLOW CONTROL VALVES

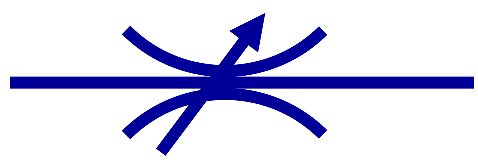
A needle type throttle valve is adjusted by moving a needle in the axial direction.

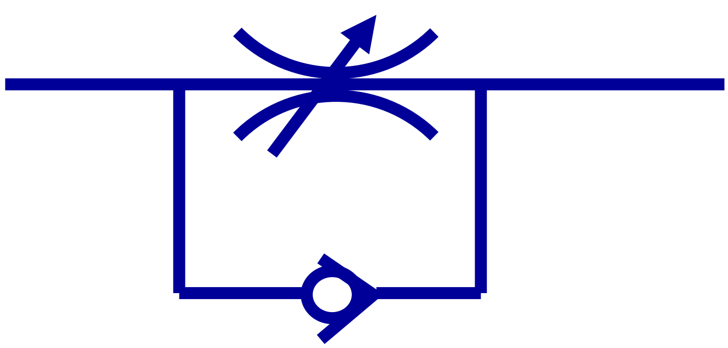
In the rotary type flow control valve, the orifice cut along the length of the sleeve is gradually opened or cut out by the rotation of the spool. Adjustment of the flow rate is done manually, turning handle on the face of the valve. The handle must be locked when the adjustment is complete. The best results are obtained when the ratio of the periphery of the passage to its area is small, the passage short and their bends smooth. In some cases throttle valves are used in which the area of oil passage is constant but its length is variable. In such cases the fluid flows along a long volute channel cut on a plug moving in a smooth cylindrical hole.

The rate of flow through any orifice depends upon the pressure difference between inlet and outlet sides. The pressure at the outlet port is created by the work load.





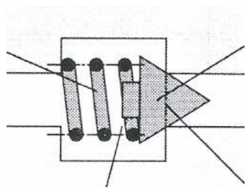




FLOW CONTROL VALVES

CHECK VALVE

A check valve can function as either a directional control or a pressure control. It is nothing more than a directional valve. It permits free flow in one direction and blocks flow in the other. That is why it is also called as "Non-return valve'. The check valve consists of a valve body a poppet or ball. The valve is closed in one direction by the pressure and opened in the other direction after overcoming spring force.



FUNCTION OF CHECK VALVES

Functions of check valve can be summarized in following lines.

(i) To minimize or eliminate leakage.

(ii) To hold load against gravity i.e. as counter balance valve or along with counter balance valve.

(iii) To create backpressure.

(iv) To ensure minimum system pressure.

(v) To isolate pumps or valves.

DIRECTIONAL CONTROL VALVE

These valves are used to steer the flow to selected direction in a hydraulic system. A direction control valve does this by changing the position of internal moving parts.

The directional control valve is generally required to accomplish following functions:

- To start, stop, accelerate, decelerate and change the direction of motion of a hydraulic cylinder or motor.
- To permit free flow from the pump to the reservoir at low pressure, when the pump delivery is not needed into the system.
- To vent the relief valve by either electrical or mechanical control.
- To isolate certain branch of the circuit.

The directional valves are mainly classified into two categories.

(I). Rotary spool type.
(II). Sliding spool type.

HYDRAULIC CYLINDERS AND MOTORS

Hydraulic actuators perform function opposite to the hydraulic pumps. They convert hydraulic energy back to mechanical energy to perform useful work. Actuators can be classified as

(1) Linear actuator such as cylinder or ram.

(2)Rotary actuator-hydraulic motors.

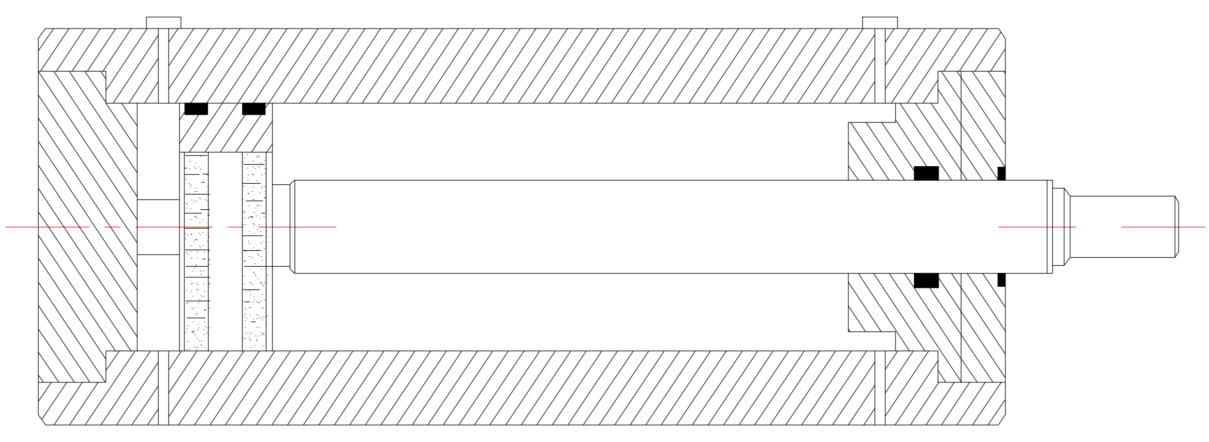
HYDRAULIC CYLINDERS

Hydraulic cylinders provide a linear motion and most commonly used of hydraulic drives. Hydraulic cylinders are broadly classified into two categories.

(a) Single acting cylinders.
(b) Double acting cylinders.

Single acting cylinder applies force only in one direction. The return motion is accomplished by releasing the pressure when the piston is moved back to its original position by a spring or some external force.

Double acting cylinder is operated by hydraulic fluid in both directions and it is capable of a power stroke either way. In such cylinders, fluid ports are fitted to each end, to function alternately as inlet and outlet ports. The maximum output force available is slightly less than that obtainable from a single acting cylinder due to backpressure generated in the return line. Further in the reverse direction piston rod seals may offer frictional resistance. The following designs of double cylinder exist fulfilling varying requirements.



HYDRAULIC MOTORS

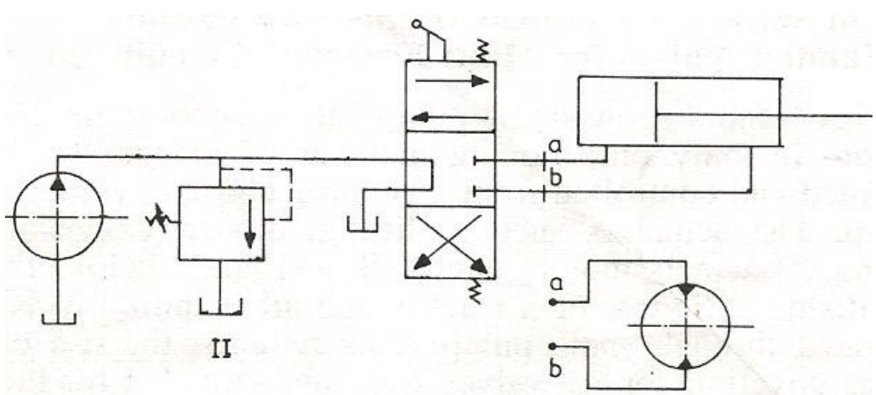
Hydraulic pumps and motors are essentially similar in construction and most of the pumps can act as motors certain valves are not in built with the component. Hydraulic motor can act as a direct alternative to the electric motor with built in infinitely gearbox. Even clutch is unnecessary with the transmission driven by hydraulic motor. Thus no clutch gear changing is involved and the hydraulic motor can remain stalled indefinitely without harm. Even frequent reversing do not cause damage and it can be used for dynamic braking.

Like hydraulic pump, motors can also be classified as fixed type and variable delivery type. According to the constructional feature hydraulic motors are termed as gear type, vane type, piston type etc.

SYSTMS AND CIRCUITS

Hydraulic systems have found versatile application in almost all types of industries. A standard of graphical symbols for hydraulic elements and apparatus was proposed by the Joint Industry Conference of USA. These so called JIC symbols have received international recognition for drawing hydraulic circuits for various hydraulic systems used in industrial equipment. Graphical symbols, showing only the functions of each hydraulic element and apparatus are used for circuit diagrams. Hydraulic graphical symbols are not restricted by any stipulated scales. The size of the symbols is selected to suit the size of the general diagram of the equipment. Hydraulic circuits can be thought of as consisting four basic sections.

Energy transfer is the basic objective of using hydraulic elements in the machine tools and other equipment. The two control factors which affect energy transfer are pressure and flow. Pressure control affects the potential energy level of the fluid in the system. Flow control regulates the quantity of fluid passing through a hydraulic element per unit time. The product of pressure and flow rate is the power transferred by the fluid in the circuit. Force and torque is proportional to the pressure while speed is proportional to the flow rate.



Simple complete circuit with either a cylinder or motor

Hydraulic circuit for each of the cylinder and hydraulic motor is shown in the figure In this circuit a direction control valve unload the pump, bypassing oil to the tank when the lever of the direction control valve is in neutral (central) position. Energy transfer starts from this low level position and builds up as the valve is shifted The shifting of valve causes the oil to move into actuator and therefore to exert itself against the load resistance. The relief valve limits the maximum energy level of the system by limiting the maximum pressure

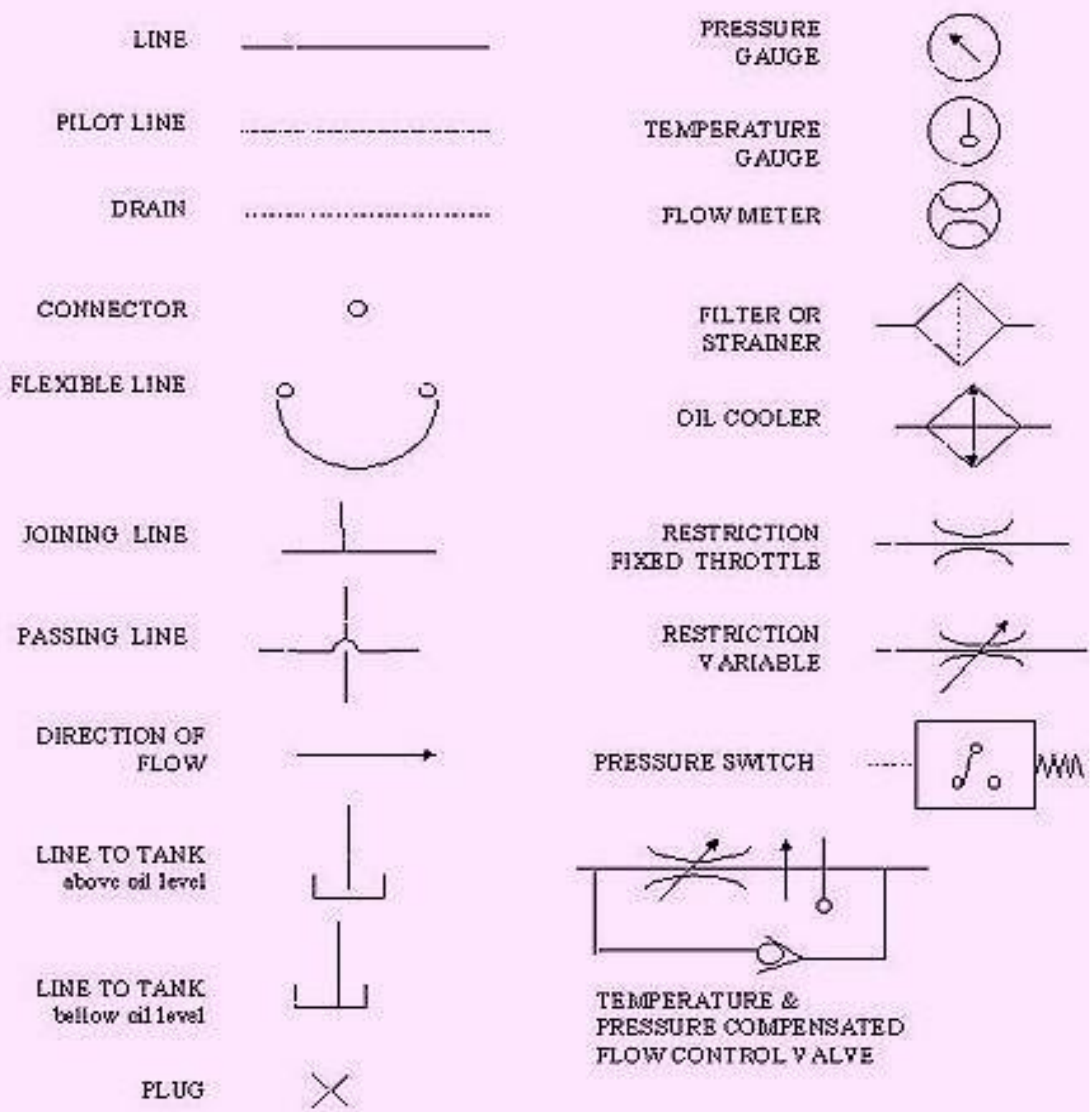
APPPLICATION OF HYDRAULIC CIRCUITS

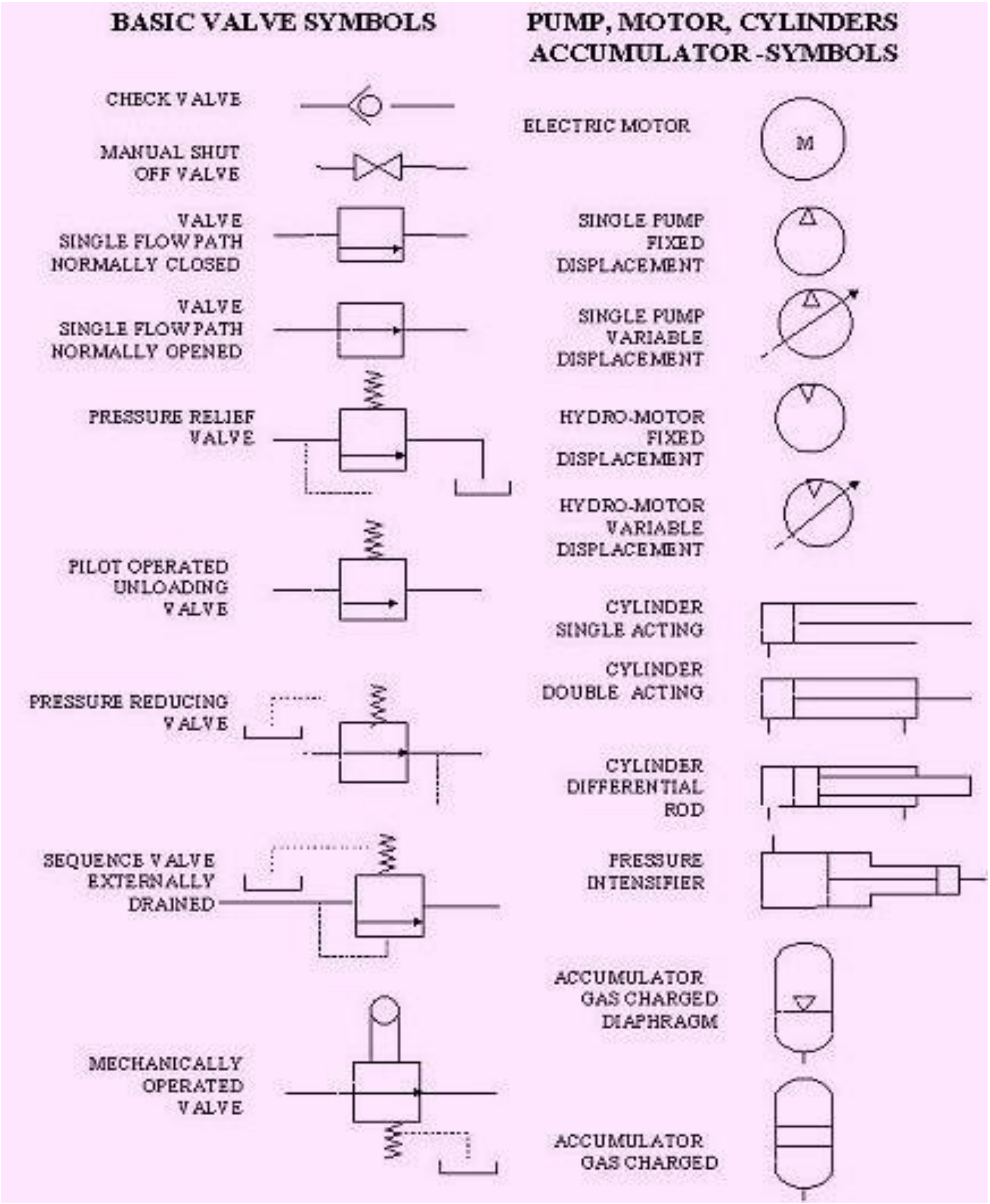
Hydraulic systems are being used on a wide variety of machines. Application of hydraulic circuit form subsystems of many machines deployed in agriculture, construction, mining, earthmoving, material handling, etc. In machine tool engineering, hydraulic elements have found versatile application. They are employed, for instance, in unit built machine tools, transfer machines and programme-controlled machines. In broaching machines, grinders, shapers, copying milling machines, etc. hydraulic-drive have almost superseded other drives.

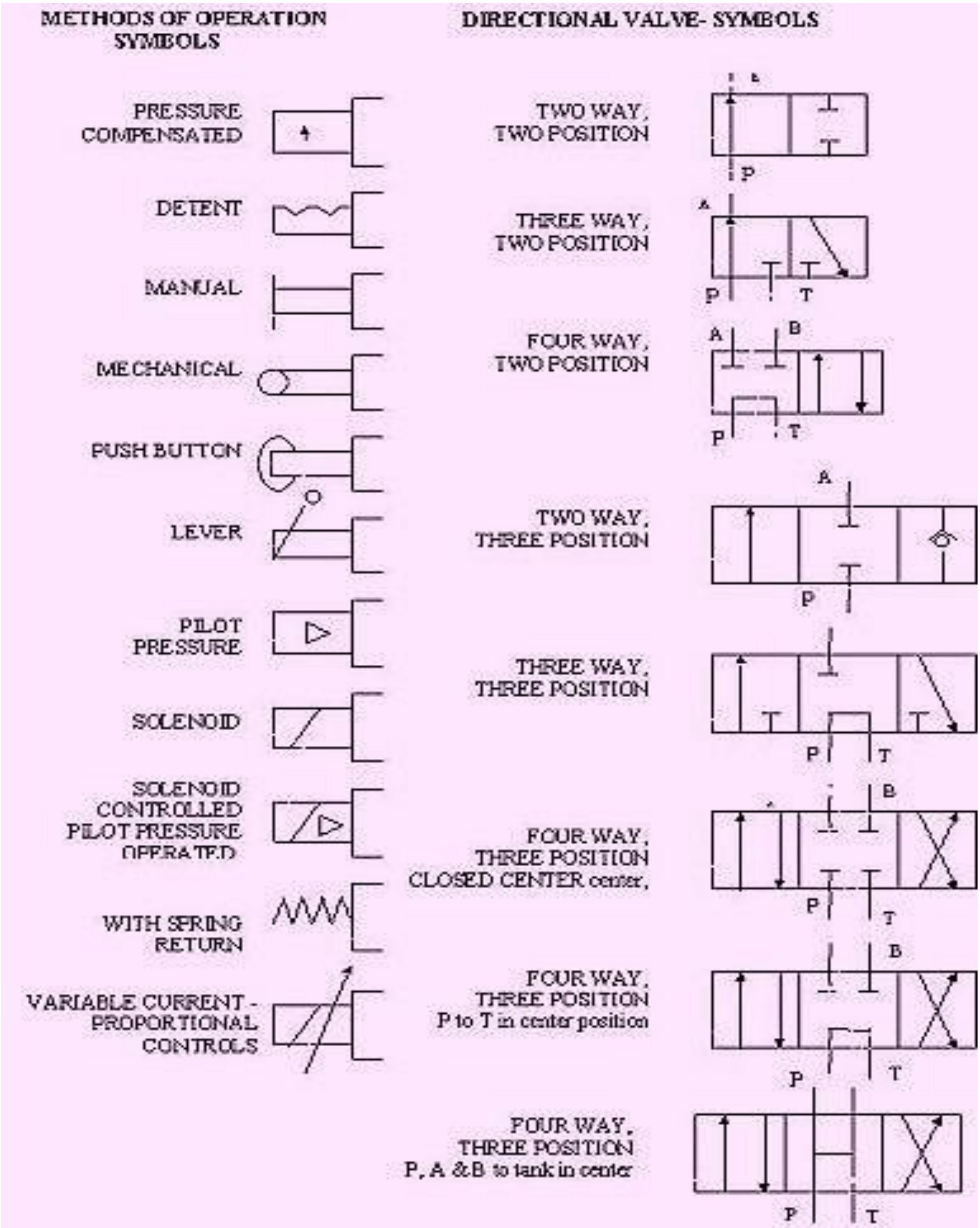
This extensive application of hydraulic system is due to their capability of providing infinitely variable speed over a wide range, smooth reversal of moving machine members, automatic overload protection, easy lubrication etc. Following superior features are achieved by the use of hydraulic elements in various mechanisms and systems of the machine tools and equipment.

- High power stepless variable drives for providing reliable motion with high torque application,
- Automated gear shifting to improve shift point accuracy.
- Incorporation of operating interlocks, self diagnostics and safety features
- Automated torque converter operation between lock up and free running phases
- Frictionless bearings for spindle and slide-ways with the incorporation of hydrostatic system

HYDRAULIC STANDARD GRAPHICAL SYMBOLS




BASIC VALVE SYMBOLS
PUMP, MOTOR, CYLINDERS ACCUMULATOR -SYMBOLS
CHECK VALVE
MANUAL SHUT OFF VALVE
VALVE SINGLE FLOW PATH NORMALLY CLOSED
VALVE SINGLE FLOW PATH NORMALLY OPENED
PRESSURE RELIEF VALVE
PILOT OPERATED UNLOADING VALVE
PRESSURE REDUCING VALVE
SEQUENCE VALVE EXTERNALLY DRAINED
MECHANICALLY OPERATED VALVE
ELECTRIC MOTOR
M
SINGLE PUMP FIXED DISPLACEMENT
SINGLE PUMP VARIABLE DISPLACEMENT
HYDRO-MOTOR FIXED DISPLACEMENT
HYDRO-MOTOR VARIABLE DISPLACEMENT
CYLINDER SINGLE ACTING
CYLINDER DOUBLE ACTING
CYLINDER DIFFERENTIAL ROD
PRESSURE INTENSIFIER
ACCUMULATOR GAS CHARGED DIAPHRAGM
ACCUMULATOR GAS CHARGED


METHODS OF OPERATION SYMBOLS
DIRECTIONAL VALVE- SYMBOLS
PRESSURE COMPENSATED
DETENT
MANUAL
MECHANICAL
PUSH BUTTON
LEVER
PILOT PRESSURE
SOLENOID
SOLENOID CONTROLLED PILOT PRESSURE OPFRATED
WITH SPRING RETURN
VARIABLE CURRENT - PROPORTIONAL CONTROLS
TWO WAY, TWO POSITION
THREE WAY, TWO POSITION
FOUR WAY, TWO POSITION
TWO WAY, THREE POSITION
THREE WAY, THREE POSITION
FOUR WAY, THREE POSITION CLOSED CENTER center,
FOUR WAY, THREE POSITION P to T in center position
FOUR WAY, THREE POSITION P, A &B to tank in center