Unit 5 Hydraulics Circuits

Marks Distribution for this Unit

Unit No	Unit Title	Teaching Hours	R Level	U Level	A Level	Total Marks
V	Hydraulic circuits	08	00	04	08	**12**

R-Remember, U-Understand,A-Apply
* Refer syllabus for details about Bloom's taxonomy

Syllabus content

5.1 Simple hydraulic circuits
Single and double acting hydraulic cylinder and motors

5.2 Speed Control circuits
Speed control by Meter-In circuit, Meter-out circuit and Bleed off circuit

5.3 Other Hydraulic circuits
Regenerative circuit, counterbalance circuit, sequencing circuit, Synchronizing circuit, two pump unloading

5.4 Hydraulic circuits applications
Hydraulic circuits for Milling machine, Grinding machine, Shaper machine and slotting machine

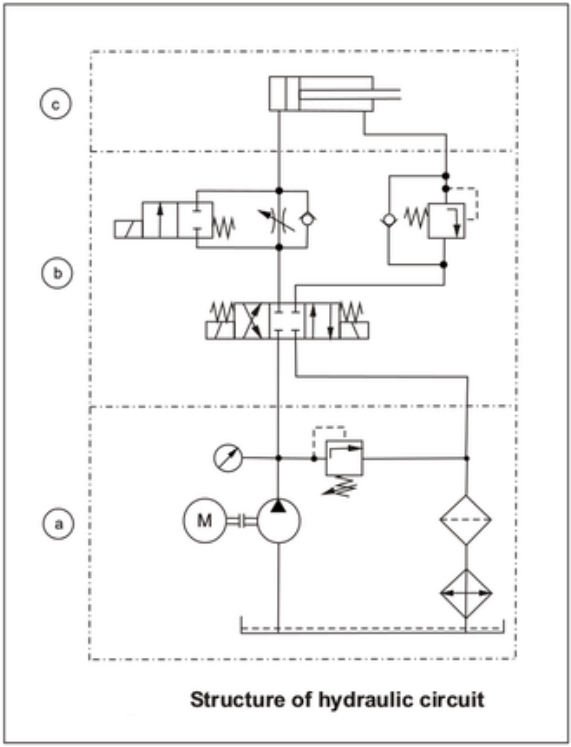
5.5 Hydraulic circuits Faults and remedies
Remedies and fault detecting in pneumatic circuits.

5.1 Simple Hydraulic circuits

Q.1. What is a Hydraulic circuit ?

Ans : A hydraulic circuit is systematic arrangement (with interconnection) of various hydraulic components to perform a specific task. Obviously every hydraulic application will have a different circuit, but basically there are certain circuits, which are meant to perform certain tasks in the complete circuitry e.g. sequencing circuit, speed (flow) control circuits etc.

Q.2. Explain with sketch Basic structure of Hydraulic circuit .



Structure of hydraulic circuit

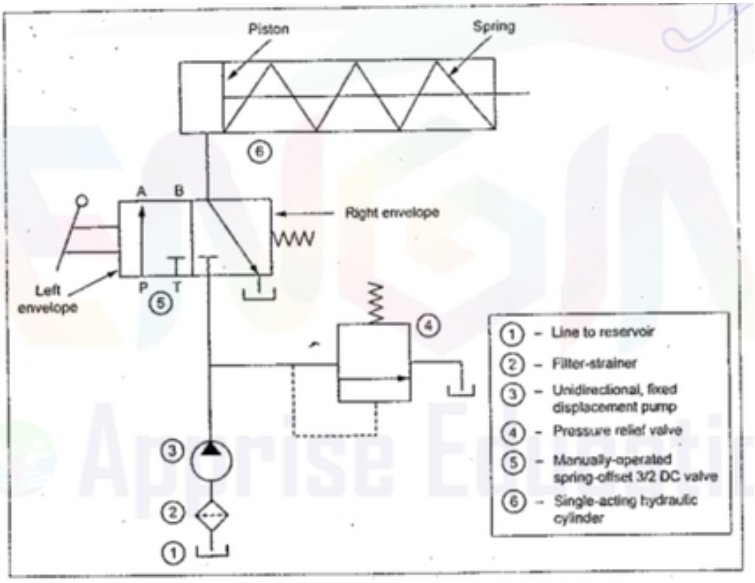
Ans : A hydraulic circuit comprises of main three groups of elements.

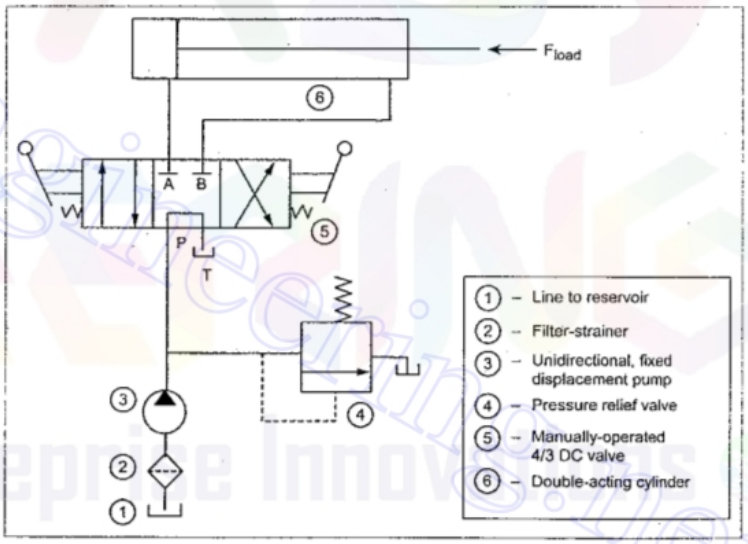
1) Drive assembly : This accomplishes the transformation of energy. A drive assembly consists of a pump, actuating motor (or prime mover) and tank. It also includes a safety valve, filter, cooler etc.

2) Control system : They modulate and control the fluid power. Essential components are the various valves and connections between them.

3) Loads and consumers These are usually hydraulic cylinders or hydraulic motors, which transform hydraulic energy into mechanical energy.

Q.3. Draw the circuit of control of single acting and double acting(DA) hydraulic cylinder with manually operated valve.





5.2 Speed Control circuits

Q.4. Explain with sketch Meter in Circuit and explain its working?

Ans : The fig.below illustrates the circuit connections of a meter-in circuit, in which the flow control valve is placed in the primary line, directly before the load. Following pressure measures are taken at three different points.

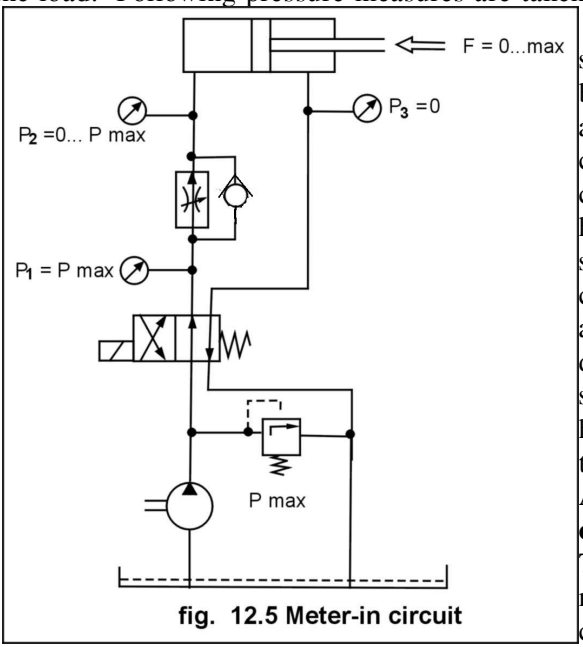


fig. 12.5 Meter-in circuit

In meter-in-circuit speed control is achieved by changing the flow adjustment of the flow control valve, which controls the oil going to the head end of cylinder. It should be noted that flow control in given circuit is achieved in forward direction only i.e. in return stroke the return flow from head of cylinder bypasses through check valve.

Advantages of Meter-in-circuit :

The chief advantage of meter-in circuit is that the cylinder undertakes one-sided pressure with a value corresponding to the real load.

The relatively small friction (due to pressure on one side, decided by load) of the piston sealing ensures its long life.

Uniform motion of the piston rod even at very slow speed.

Flow rate estimation is made based on the large piston area, which is significant advantage when very small piston rod speeds are to be achieved.

Disadvantage of meter-in circuit :

The major disadvantage of this circuit lies in the fact that there is no pressure on the piston rod side of cylinder, due to this the load actuated by the piston rod is not held firmly in position. This means that in case of

" Pulling" type loads if the load suddenly collapses, the piston rod shoots forward causing an uncontrolled shift. Special counter balance measures are to be taken if above circuit is to be used for such applications.

Applications of meter-in circuit :

Meters in circuits are generally used when the load characteristics are constant and positive. If the load is erratic or negative, the actuator will have jerky motion. Hence, meter-in circuits are ideally applied on surface grinder, milling machines etc.

Q.5. Explain with sketch Meter Out Circuit and explain its working?

Ans : The Circuit diagram below illustrates the circuit connections of a meter-out circuit, in which the flow control valve is connected in the secondary line, directly after the load. The following measures of pressure are taken at various pressure gauges.

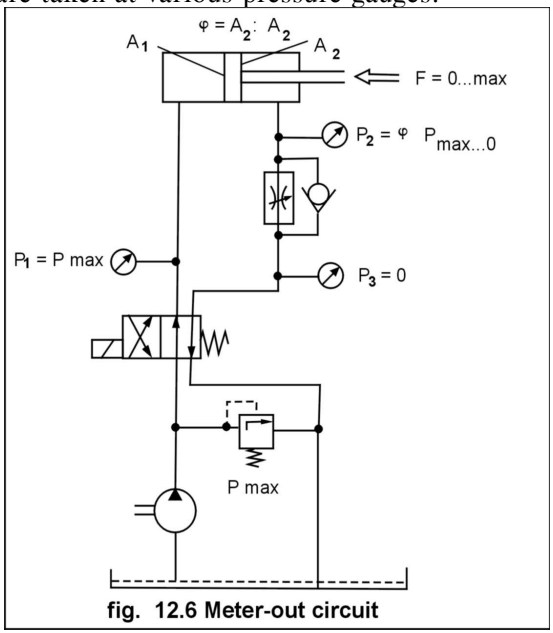


fig. 12.6 Meter-out circuit

Pressure gauge P_1 : Indicates the Pmax as set by the pressure relief valve. This pressure is formed on the left side volume of the cylinder, irrespective of the load; hence sealing in this side is always subjected to maximum pressure.

Pressure gauge P_2 : Indicates the pressure P_2, which is determined by the difference between pressure Pmax and the load pressure. This difference depends on the ratio of the two-piston areas.

Pressure gauge P_3 :Pressure in the return stroke is always equal to 0 .

In a meter-out-circuit speed control is achieved by changing the flow adjustment of the flow control valve, which controls the flow coming out

from the piston rod end of cylinder. Here also it should be noted that in a given circuit, flow control is in forward direction only i.e. in return stroke the flow of pump to the piston rod end of cylinder is bypassed through check valve.

Advantage of meter-out circuit :

The load is always under pressure from both sides i.e. it is counter balanced.Even when the load changes direction (e.g. starts pulling). No uncontrolled jerk motion occurs.

Disadvantages of meter-out circuit :

The left side of the cylinder is always under maximum pressure even with a minimum load. Due to continued pressure on both sides, there is more friction and less seal life.

Applications :

Meter-out type circuits are found successful in operations like drilling, boring, reaming etc, where the drills and mills passing through the work piece often tend to drag the entire tool unit foreword, in such situation meter-out circuit is the best solution.

Meter in and meter out circuit comparison
https://www.youtube.com/watch?v=4eCuPVxezzY

Q.6. Explain with sketch Bleed-Off Circuit and explain its working?

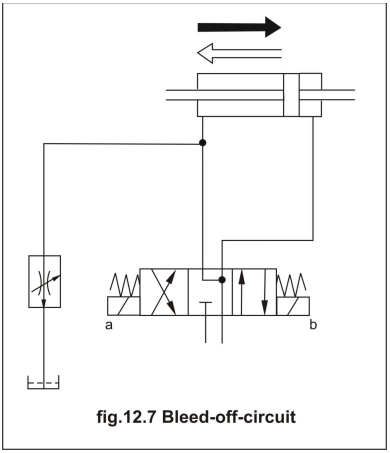


fig.12.7 Bleed-off-circuit

Ans : This is the third basic circuit, which controls neither the flow going to the actuator not flow returning from the actuator but controls the diverted part of fluid to control the flow. In this type of circuit flow control valves are placed in the by-pass line. The cylinder speed in this case is determined by the difference between the pump deliver flow and the flow being directed to the tank through the flow control valve.

The bleed-off valve may be in the

pressure line or in the cylinder line.

Advantage of bleed-off circuit : Unlike in the meter-in and meter-out circuit there is no excess flow going through the pressure relief valve, hence the system is more efficient and energy saving as well the hydraulic fluid is not heated due to flow through relief valve.

Disadvantages of bleed-off circuit :

Bleeds off circuits provide less accuracy in speed control because in these circuits metered flow goes to tank rather than to cylinder. In such type of circuits an individual pump should power each cylinder. A bleed-off circuit is not sensitive enough to compensate for very small flow such as those encountered in precise boring operation

Applications :

Bleeds off circuits are applied where pressure is reasonably constant and precise speed control is not the prime requirement. These circuits are widely used in broaching machines, shapers, planers etc., where a large quantity of fluid is to be used, and small percentage is by passed.

5.3 Other Hydraulic circuits

Q.7. Explain with sketch Regenerative circuit.

Ans : A circuit is said to be operating on re-generative principle when the fluid returning from other end of cylinder is forced into the head end of cylinder. Obviously, some energy is consumed to force out the fluid from piston-rod end when cylinder is extending. The re-generative circuit enables to utilize this part of energy, which would have otherwise wasted. The net result of re-generation is increase in cylinder speed, with same discharge of pump. The circuit in fig. depicts a typical re-generative circuit with solenoid operated 4/3 directional control valve. The circuit is similar to the previous linear circuit except the change in center position of direction control valve.

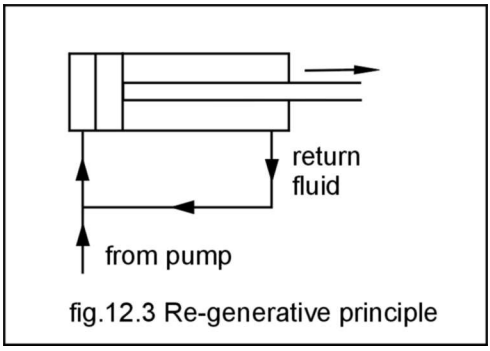


fig.12.3 Re-generative principle

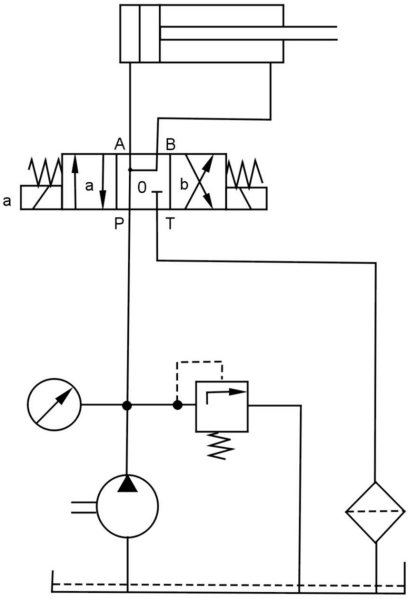


fig. 12.4 Re-generative circuit

When the valve is in central position the cylinder extends, with about twice the normal speed, thus effecting the re-generative function. When the valve shifts to right position, the regenerative effect is nullified and cylinder moves with normal speed (as decided by pump flow).
When the valve shifts to left, the cylinder retracts. The regenerative principle can be applied to any motion i.e. extending or retracting.

Q.8. Explain with sketch Counter balance Hydraulic circuit .

Ans : Counterbalance valves are commonly used to counterbalance a weight or external force or counteract a weight such as a platen or a press and keep it from freefalling.Figure1.16 illustrates the use of a counterbalance or back-pressure valve to keep a vertically mounted cylinder in the upward position while the pump idles, that is, when the DCV is in its center position. During the downward movement of the cylinder, the counterbalance valve is set to open at slightly above the pressure required to hold the piston up (a check valve does not permit flow in this direction). The control signal for the counterbalance valve can be obtained from the blank end or rod end of the cylinder. If derived from the rod end, the pressure setting of the counterbalance valve equals the ratio of the load to the annulus area of the piston. If derived from the blank end, the pressure

setting equals the ratio of load to the area of piston. This pressure is less and hence usually it has to be derived from the blank end. This permits the cylinder to be forced downward when pressure is applied on the top. The check valve is used to lift the cylinder up as the counterbalance valve is closed in this direction. The directional control valve unloads the pump.

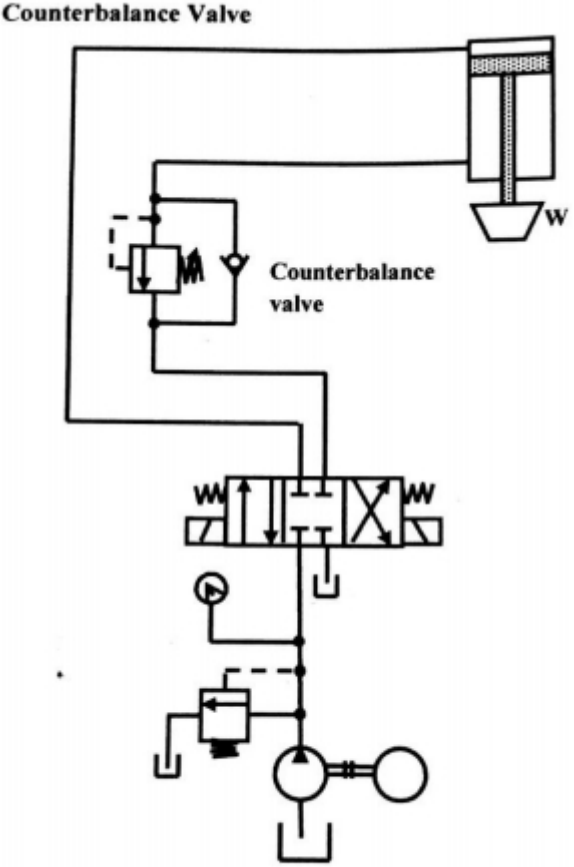


Fig. **counterbalance hydraulic circuit**

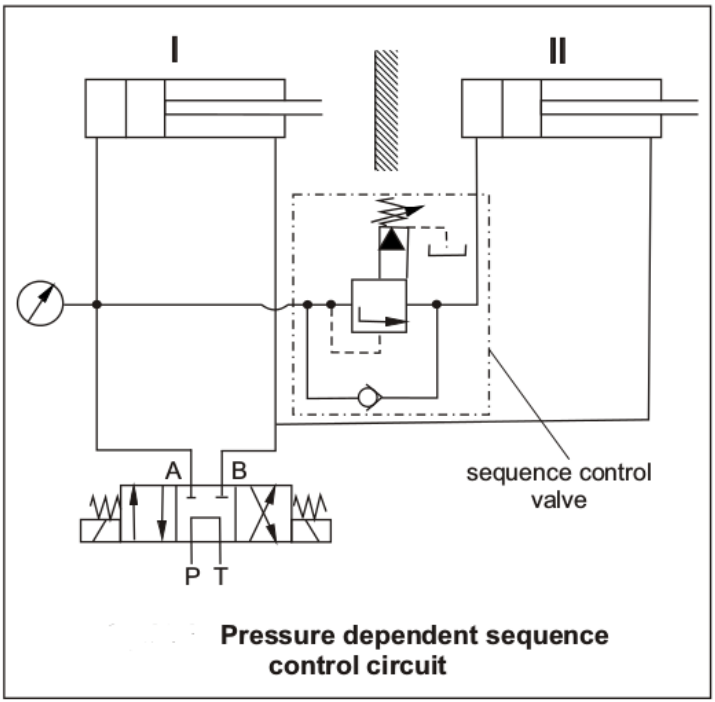
Counterbalance video: https://www.youtube.com/watch?v=4GC6OV5gwyo

Q.9. Explain with sketch Sequencing circuit .

As the name suggests the sequencing ciruit is used when two or more operations are to be sequenced one after another, means the second operation should not start until the first operation is not completed. This is needed in lot of applications like automation and processing.

The sequencing circuits can be travel dependent or pressure dependent, means the next circuit gets oil when either the first circuit completes the travel or the pressure builds above certain level.

Following circuit is Pressure dependent sequencing circuit.



Pressure dependent sequence control circuit

As shown in th diagram the first cylinder is operated first, when the piston of first cylinder reaches its end point, the pressure starts building, when the pressure builds to the set point of sequence control valve, the valve opens and the oil is supplied to the next cylinder.

Sequencing circuit: https://www.youtube.com/watch?v=brM7odcIhIA

Q.10. Explain with sketch Synchronizing circuit .

A synchronizing circuit is used when we need the synchronized movement of two or more cylinders(or motors). Means we need that the both cylinders move exactly at same time and at same speed. This is required in several applications. Synchronization can be achieved by mechanical means of coupling also. The following diagram depicts the synchronizing circuit

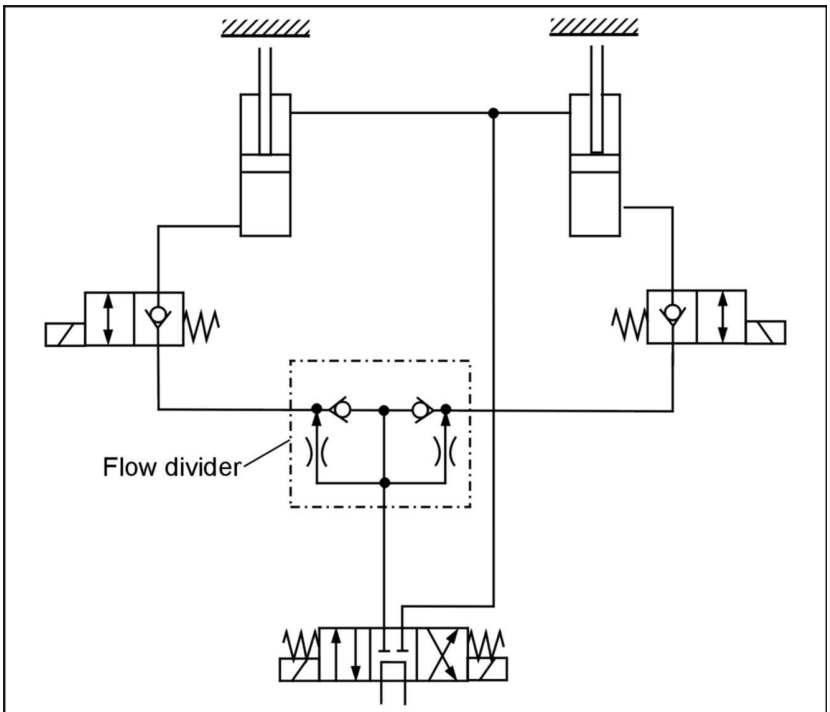


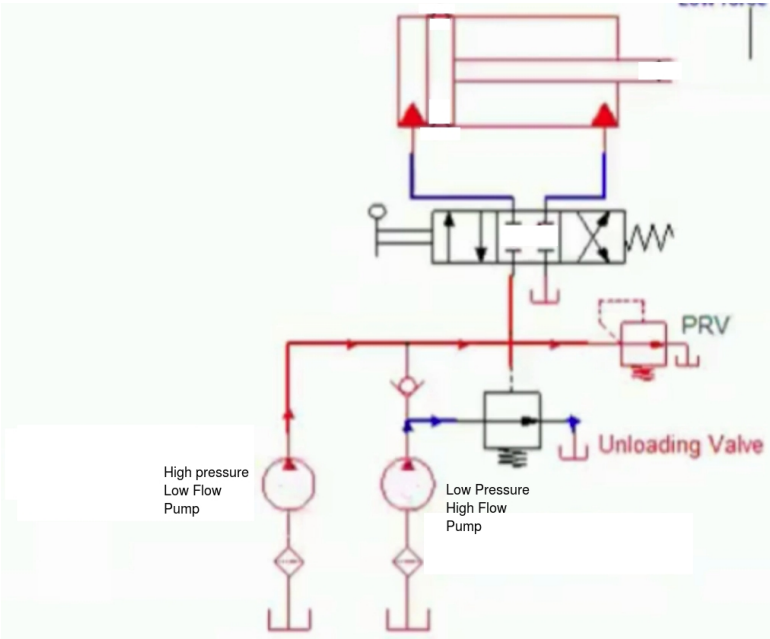
fig. 12.12 Synchronization with flow dividing valves

with the use of flow dividers.

Flow dividing valves can be used effectively to obtain the synchronized motion. As shown in fig below flow dividing valves divide the flow into two equal parts irrespective of load. One point should noted that flow dividing valve synchronize extension stroke only (in case of circuit diagram shown),if synchronization is required in the return stroke also, then additional flow divider in top line must be installed.

Q.11. Explain with sketch two pump unloading circuit .

A two pump unloading circuit is used in situation where some part of the piston travel is required at high speed and low pressure and some small part is required at High pressure and low speed. For such purpose it is uneconomical to use a very high pressure and high volume pump. Instead the unloading circuit is used which uses two pumps for two purposes. When the motion is required with less force(pressure) both of the pumps discharge in the cylinder, and when the motion is required with high force(pressure) only the high pressure pump discharges to the cylinder and low pressure pump returns back oil to tank through unloading valve.



Application: This circuit finds application in machine tools like punching machine and other cutting machines.

Two pump unloading circuit videos
https://www.youtube.com/watch?v=Od9B8LDA-ME
https://www.youtube.com/watch?v=SsJHfdbsHgE
https://www.youtube.com/watch?v=Fw5F7Q4uaoE

5.4 Hydraulic circuits Applications

Q.12. Explain with sketch hydraulic circuit for the Milling machine.

Ans : Hydraulic circuit for a milling machine is comparatively different from the former two circuits, because the table movement in milling operation is comparatively slower. As well, different feeds (adjustable) are required for milling different type of work. Hence, in the hydraulic circuit for milling machine in addition to other elements a flow control valve (graduated in terms of feeds) is incorporated in the circuit.

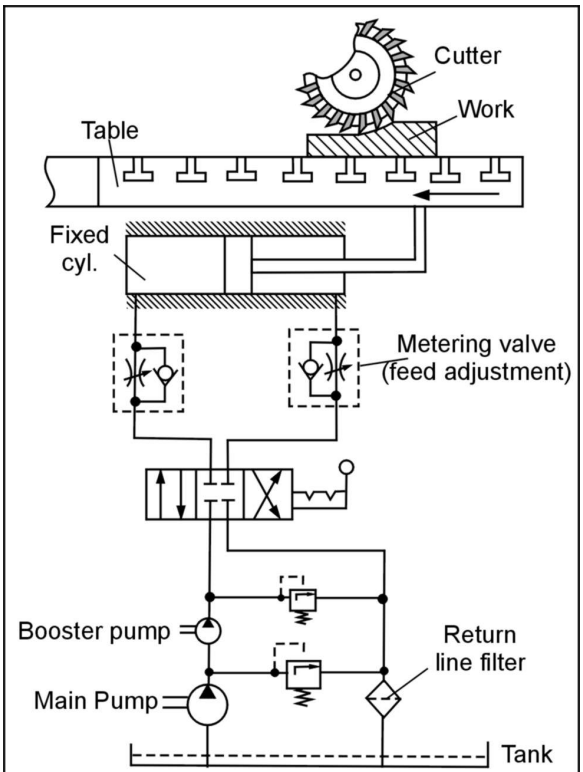


fig.12.18 Hydraulic circuit for milling machine

Figure depicts the hydraulic circuit for milling machine. It has a main pump, which is a low pressure, and high discharge pump, and one booster pump, which is a low discharge high pressure pump. The function of the booster pump is to boost the hydraulic pressure to a level above that of provided by main pump (this combination saves the power as well as use of a high flow and high discharge pump is avoided).There are two sets of flow control valve and check valve, fitted in both supply and return line to cylinder, to achieve speed control in both directions. A manually operated spool valve decides the direction of flow to the cylinder.

Q.13. Explain with sketch hydraulic circuit for the GRINDING machine.

Ans : Hydraulic circuit for a surface grinding machine is depicted in sketch below. It consists of a power pack to supply pressurised oil, one pilot operated direction control valve which decides the direction of flow of pressurized oil.

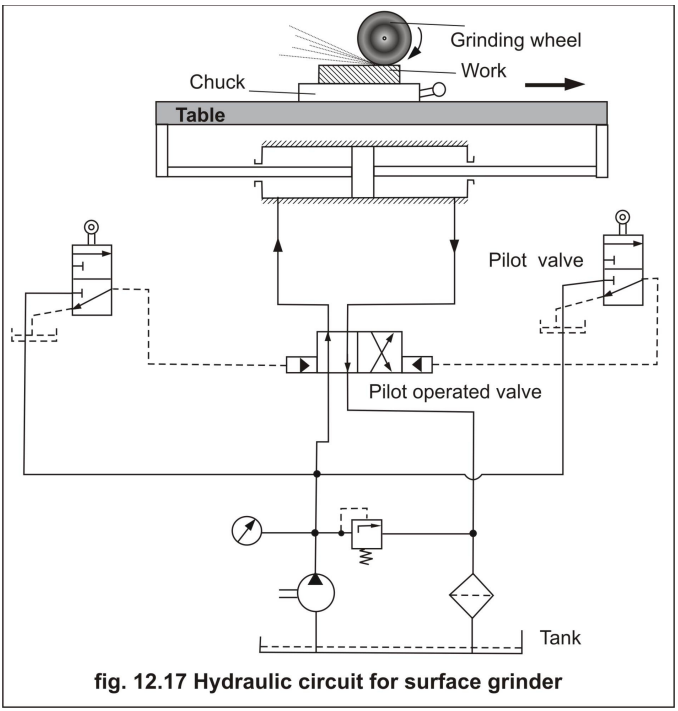
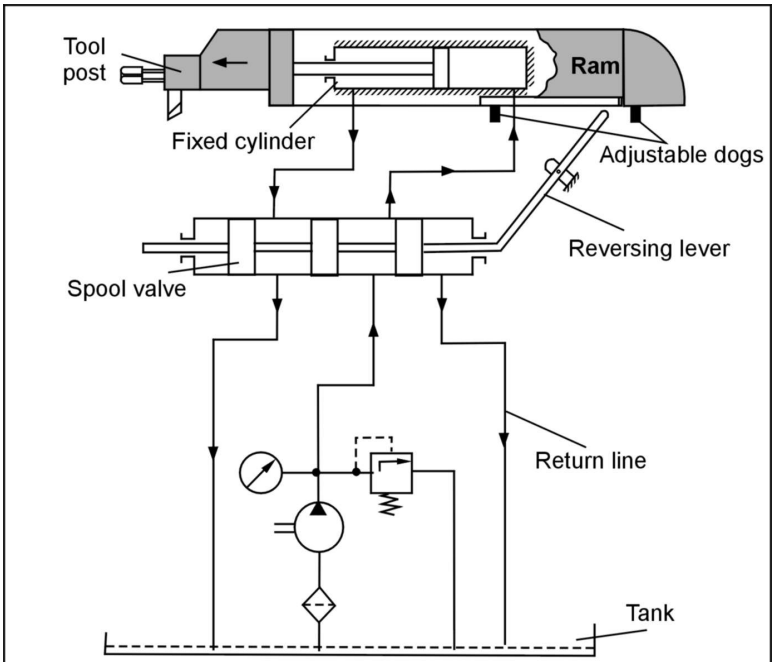


fig. 12.17 Hydraulic circuit for surface grinder

The piston rods on both sides are mechanically coupled with the table of the machine. There are two roller actuated pilot valves, which are actuated by cams fitted to the table (cams not shown in diagram). These valves provide pilot impulse to the main valve, thus deciding the position of main valve and hence the direction of motion of the cylinder (and consequently the table). Every time either of the pilot valves is pressed by the cam. The cam positions are adjustable, which decides the stroke length movement of the table. Whenever the work-piece to be ground is changed the operator is required to change the position of the cams to suit the length of work-piece.

Q.14. Explain with sketch hydraulic circuit for the SHAPING machine.

Ans : Figure below depicts the hydraulic circuit for shaping machine. The circuit utilizes a double acting cylinder with single piston rod and spool type directional control valve, which is shifted by a reversing lever.



Hydraulic power-pack supplies the pressurised oil to the spool valve. The position of spool valve decides whether the pressurised oil should go the head end or the piston rod end of the cylinder. The cylinder is mounted in such a manner that the forward stroke occurs when the oil is supplied to the head end of the cylinder and reverse stroke occurs when oil is supplied to piston rod end of the cylinder. Due to the difference in annular areas of head end and piston rod end, the return stroke is faster than the forward stroke. The stroke length of the ram can be adjusted by changing the positions of the adjustable dogs, i.e. closer the adjustable dogs shorter the stroke length and vice-versa. Several additional controls may be added to this basic circuit to enhance its performance and to have precise control over operation.

5.5 Hydraulic/Pneumatic circuits Faults and remedies

Q.15.Enlist the common Faults and causes in the Hydraulic system

Ans : **Following are the common faults in Hydraulic systems**

1. Reduced speed of travel of machine tool elements
2. Slow response to controls
3. Excessive loss of system pressure
4. Excessive leakage in the systematic
5. Rise in the oil temperature
6. Non-uniform or jerky movement of actuators
7. Increased noise in the systematic
8. No supply or less supply from pump
9. Cavitation due seal failure
10. High rate of seal failure
11. Poor oil life
12. High degree of contamination level of system medium.

Following are the common causes of hydraulic system breakdown

1.Inadequate supply of oil in the reservoir

2. Clogged or dirty oil filters

3. Leaked seals

4.Loose inlet lines that cause the pump to take in air

5.Incorrect type of oil

6. Excessive oil temperature

7. Excessive oil pressure

Troubleshooting chart for hydraulic circuits/systems

Sr. No.	Sources of trouble	Possible Causes
A	**Excessive noise**	
1	Mechanical drive.	Coupling wrongly aligned. Coupling loose. Coupling defective. Loose mounting on pumps. Other transmission elements loose (V-belts, tooting belts etc.) Pump or motor defective.
2	Suction line.	Suction line resistance excessive because, ▪ Tap or cock in the suction line closed or only partially open. ▪ Suction filter clogged or too small. ▪ Suction line blocked or leaking. ▪ Suction line has wrong dimensions or too many bends. ▪ Fluid level too low.

3	Pump	Pump is turning too fast. Max. Pump pressure exceeded. Charge pumps defective. Shaft seals or seals on suction side are defective. Pump defective.
4	Pressure line.	Line mounting missing or loose. Lines have been wrongly laid. ID of line too small.
5	Return line.	Line mountings missing or loose. Lines have been wrongly laid. ID of line too small. Return terminates above fluid level. Return filter blocked.
6	Pressure valves.	Valve chatter due to dirt on valve seat, valve worn. Insufficient damping. Flow noise when operating. Unsuitable characteristic curve. Wrong design.
7	Flow control valve.	The valve oscillates and excites other elements to oscillate. Flow noises. Control system oscillating.
8	Direction control valves.	Valve chatter due to defects in solenoid or the voltage is too low. Valve defective due to dirt or wear. Through flow excessive. Pilot pressure variation. Check the electrical controls.
9	Fluid	Cavitation problem because, ♦ Fluid level too low. ♦ Viscosity too high.

		3 Fluid is contaminated and dirty this leads to damage and breakage of equipment. 4 Fluid foams.
10	Drive (Motor, cylinder etc.)	Wear of turning surfaces. Control system oscillating.
B	**Insufficient power and Torque at the power takeoffs (Pressure too low)**	
1.	Mechanical drive.	Power transmission defective V-belt or toothed belt slipping. Direction of rotation wrong. Motor defective. Key sheared off at pump or motor.
2	Suction Line.	Suction line resistance excessive because, 6 Tap or cock in the suction line closed or only partially open. 7 Suction filter clogged or too small. 8 Suction line blocked or leaking. 9 Suction line has wrong dimensions or too many bends. 10 Fluid level too low.
3	Pump	Internal leakage due to wears. Unsuitable type. Pump defective. End of control pressure set too low, or control element defective.
4	Pressure line.	Leakage in pressure line. Excessive line resistance. Pressure filter blocked.
5	Return line.	Excessive line resistance. Filter blocked.

6	Pressure valves.	Operating pressure set too low. Internal leakage due to wears. Dirty or damaged valve seat. Broken spring. Unsuitable type.
7	Flow control valves.	Pressure losses excessive. False setting. Valve defective. Unsuitable type.
8	Direction control valve.	Wrong switched position. Solenoid defective. Internal leakage due to wears. Excessive flow speeds. Spool jams.
9	Fluid.	Viscosity too low and therefore leakage excessive. Viscosity too high excessive flow resistance. Fluid foams.
10	Drive.	Internal leakage (e.g.cylinder packing is worn). Wear of running surfaces. Excessive internal friction.
11	Others.	In the case of pressure controls there may be a defect in the open loop / or closed loop control circuit. Display instruments defective.
C	**Jerky cylinder and Motor movements (variation in pressure and delivery flow)**	
1.	Mechanical Drive.	Coupling wrongly aligned. Coupling loose. Coupling defective. Loose mounting on pumps and or motor defective. Other transmission elements loose (V-belts, tooting belts etc.) Pump or motor defective.

2	Suction Line.	Suction line resistance excessive because, ▪ Tap or cock in the suction line closed or only partially open. ▪ Suction filter clogged or too small. ▪ Suction line blocked or leaking. ▪ Suction line has wrong dimensions or too many bends. ▪ Fluid level too low.
3	Pump	With variable pumps control system is defective. Pump defective. System conditions affecting the pump control system. Unsuitable pilot valve.
4	Pressure line.	Installation not bled completely.
5	Return line.	Excessive line resistance. Filter blocked.
6	Pressure valves.	Valve chatter due to dirt on valve seat,valve worn. Insufficient damping. Excessive length of un-damped remote control line. Unsuitable remote control valve.
7	Flow control valve	Coupling wrongly aligned. Coupling loose. Coupling defective. Loose mounting on pumps and or motor defective. Other transmission elements loose (V-belts, tooting belts etc.). Pump or motor defective.

8	Direction control valve.	Valve chatter due to defecting solenoid or the voltage is too low . Valve defective due to dirt or wear. Through flow excessive. Pilot pressure variation. Check the electrical controls.
9	Fluid	Hydraulic fluid contaminated. Hydraulic fluid foams.
10	Drive.	Stick slip effect due to the friction of cylinder packing being too high. Operating below lower limit of motor speed.
11	Others.	Insufficient load counter balance.
D	**Power take off either does not turn at all or too slowly**	
1.	Mechanical drive.	Coupling wrongly aligned. Coupling loose. Coupling defective. Loose mounting on pumps and or motor defective. Other transmission elements loose (V-belts, tooting belts etc.). Pump or motor defective.
2	Suction line.	Suction line resistance excessive because, ▪ Tap or cock in the suction line closed or only partially open. ▪ Suction filter clogged or too small. ▪ Suction line blocked or leaking. ▪ Suction line has wrong dimensions or too many bends. ▪ Fluid level too low.
3	Pump.	Internal leakages due to wear. Pump defective. Inlet and outlet lines connected wrongly.

4	Pressure line.	Leakage in pressure line. Excessive line resistance. Pressure filter blocked.
5	Return line.	Excessive line resistance. Filter blocked.
6	Pressure valves.	Operating pressure set too low. Internal leakage due to wears. Dirty or damaged valve seat. Broken spring. Unsuitable type. with sequential control, the sequence valve setting is too high or the valve is defective.
7	Flow control valves.	Through flow set too low Unsuitable type (Setting range too low) Valve blocked (Dirt)
8	Directional control valve.	Wrong switched position. Solenoid defective. Internal leakage due to wears. Excessive flow speeds. Spool sticking. Manually operated valves not in through flow position.
9	Fluid	Viscosity too low and therefore leakages are excessive. Viscosity too high excessive flow resistance. Fluid foams.
10	Drive.	Internal leakage (e.g.cylinder packing is worn). Wear of running surfaces. Excessive internal friction. Power take off blocked (e.g. piston seizure).

11	Others	Conditions for standing not fulfilled (pump control system defective). Electrical line -open circuit. Signaling elements (e.g. press switch wrongly set or defective, limit switch not contacted.).
E	**Excessive operating temperature**	
1	Pump.	Reduction in efficiency due to wears. With variable pumps, the pump control system is defective. Rotational speed and delivery excessive.
2	Pressure line.	Internal diameter too low, causes frictional resistance. Pressure filter blocked.
3	Return line.	Internal diameter too low, causes frictional resistance. Pressure filter blocked.
4	Pressure valves.	Constant delivery flow too high. Unsuitable valve type (ID too small). Pressure setting too high. Response time too long.
5	Flow control valve.	Through flow set too low (excessive pump delivery through pressure relief valve).
6	Directional control valve.	Leakage losses too high. Pressure circulation fails to switch On. Spool sticking.
7	Fluid.	Viscosity too low and therefore leakages are excessive. Viscosity too high excessive flow resistance. Fluid foams.

8	Drive.	Losses in efficiency due to wear. Internal friction too high. Internal leakage losses.
9	Others.	Cooling performance of the assembly insufficient in to the installed power on the operating time. Insufficient hydraulic fluid in the installation.
F	**Foaming of Hydraulic Fluid**	
1.	Mechanical drive.	--
2	Suction line.	Suction line leakages. Fluid level too low. Wrongly designed reservoir.
3	Pump	Shaft packing or seals on the suction side defective. Return oil line terminates above fluid level.
4	Pressure line.	--
5	Return line.	Return terminates above fluid level. Vortex effect due to wrongly laid lines.
6	Pressure valves.	--
7	Flow control valves.	
8	Directional control valves.	--
9	Fluid	Unsuitable make.
10	Drive	--
11	Others.	--