VOL.5.
STUDY OF HYDRAULIC CIRCUITS

Q. S. Khan
B. E. (Mech.)

Tanveer Publications,
Mumbai - 78

CONTENTS

Hydraulic Circuit **10.1 to 10.62**

10.1 What is circuit?
10.2 Classification of hydraulic circuit.
10.3 Selection of different circuit for some function.
10.4 Selection of working pressure.
10.5 Pressure in hydraulic Ststem.
10.6 Calculation of heat generation in hydraulic Ststem.
10.7 Sequence and cycle diagram.
10.8 Circuit diagram for modular type power pack.
10.9 Use of filter in hydraulic circuit.
10.10 What is pumping unit and power pack unit?
10.11 Pressure control circuit.
10.12 Pressure holding circuit.
10.13 Decompression circuit.
10.14 Hydraulic circuit with back pressure.
10.15 Back Pressure in a hydraulic cylinder.
10.16 Hydraulic circuit using sequence valve.
10.17 Direction control circuit.
10.18 Regeneration circuit.
10.19 Brake circuit.
10.20 Flow control circuit.
10.21 Synchronisation circuit.
10.22 Circuit diagram of drill.

10. Introduction to Hydraulic Circuit

10.1. What is Circuit?

- The Hydraulic power is generated by pumps, and supplied to hydraulic actuators. This hydraulic power must be controlled in order to achieve the desired function. A hydraulic circuit is basically designed to have effective control over this generated power. A hydraulic circuit consists of fluid conductor such as steel pipe, hoses, and manifold block to transfer fluid. It has valves to control pressure, direction, and flow of hydraulic fluid. And hydraulic accessories for better control of various parameter and to have safety and long life of hydraulic system.

In this chapter we will study various types of hydraulic circuit.

Generally three types of controls we do over generated hydraulic power.

a) Direction control.
b) Pressure control.
c) Flow control

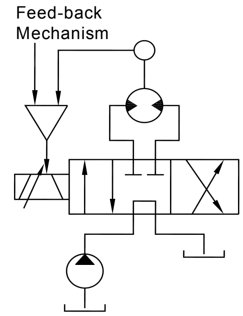
- Direction control feature, and direction control valve is common in almost all the hydraulic circuits.
- Pressure control feature and safety valve is also common in all the hydraulic system. In addition to main system pressure, some circuits are specially designed to reduce pressure, to generate back pressure, to have different pressure at different parts of the circuit.
- Some circuits are exclusively designed to control flow of hydraulic fluid in the system.
- A complex hydraulic circuit may have all the three features in it. That is control of direction of fluid, and control of its pressure and flow.
- To thoroughly understand hydraulic circuit and simplify its study, we will classify various types of hydraulic circuit in to various categories, then study each category in detail.

10.2 Classification of Hydraulic Circuit

Hydraulic power system or hydraulic circuit could be divided in to two broad categories.

a) Closed-loop circuits:-

A close-loop hydraulic circuit has all the basic elements of hydraulic circuit, such as hydraulic pump, hydraulic valves to control direction, flow and pressure, hydraulic accessories etc. In addition to these component it also has a feed back mechanism which continuously monitors system output. It generates a signal which is proportional to output, then it compares it with input or command or reference signal. If the two matches, then there is no adjustment and the system continue to operate as programmed. If there is a difference between the input command signal and the feed back signal, then the system has provision and mechanism to correct and adjust the out- put to match with the command requirement.



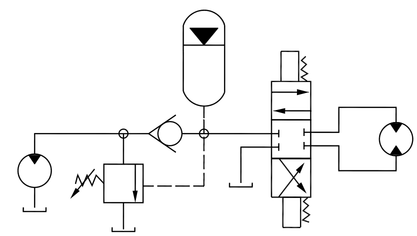
CLOSE-LOOP CIRCUIT

An electro-hydraulic servo system is a feed back system which measures and corrects the output.

b) Open loop circuit:-

In this type of circuit, we do not get feed back.

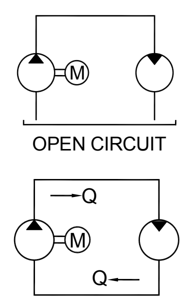
An open-loop hydraulic circuit do have all the basic elements of hydraulic circuit but it does not have feed-back machenism.


OPEN LOOP CIRCUIT

Open loop as well as closed-loop circuit could be further sub-divided into two categories.

1) Open circuit
2) Close circuit

In open circuit the fluid is sucked from reservoir by pump. Fluid passes through hydraulic component and again exhausted to reservoir. Reservoir has excess quality of fluid then what is required by hydraulic circuit. And quantity of fluid in hydraulic circuit could be changed without any restrictions.



COLSE CIRCUIT

In close loop, reservoir is eliminated and suction of pump is connected to exhaust line of circuit. Hence a fixed quality of fluid keeps on circulating in hydraulic system.

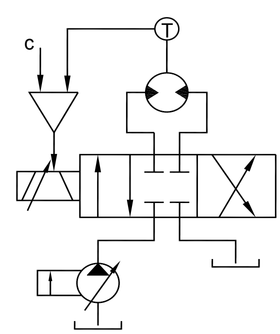
Majority of hydraulic systems are open circuit. Close circuit is used for sophisticated, highly accurate and compact machineries.

Constant flow circuit and demand flow circuit:-

These two terms are also used for hydraulic circuit.

In constant flow circuit, full discharge of pump always flows through the system and returns to reservoir, The volume of flow does not change in minimum as well as in maximum pressure condition.

While in demand flow circuit, the volume of fluid circulating through circuit changes with demand or requirement of circuit. Volume of fluid could be reduced by using variable discharge pump or other type of hydraulic valves.



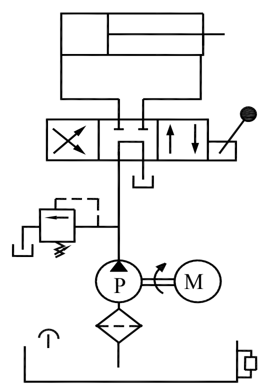
Demand flow circuit
variable with displacement pump

- Most of the hydraulic systems are designed as per open loop and open circuit. Hence first we will study open circuit in detail.

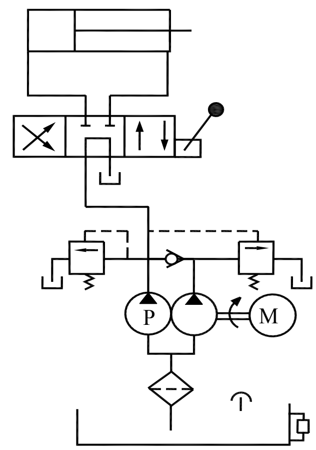
10.3 Selection of different circuit for same function

Suppose a hydraulic cylinder of 35 ton capacity has to move a load for distance of 50 cm. Now said circuit could be made in many ways . Four of them are as follow.

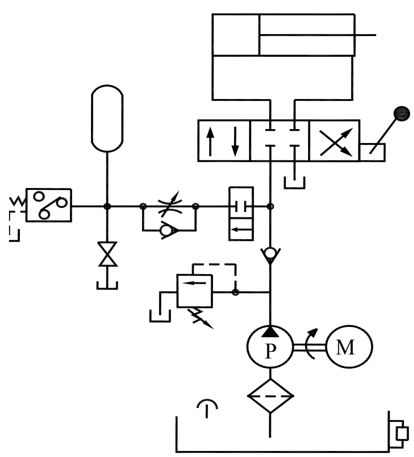
TYPE 1



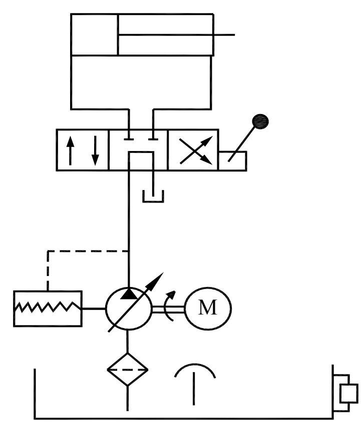
TYPE 2



TYPE 3



TYPE 4



- In first system actuator moves with same speed throughout it's stroke. And maximum working pressure is available from start of stroke, till end of strokes.
- In second and fourth system, actuator could have fast approach and return speed and show pressing speed. And full working pressure will be available in last slow pressing operation.
- In third system, we can have high speed as well as full working pressure throughout stroke. But accumulator takes some time for charging. It cannot give continuous high speed and pressure without charging, and some delay time.

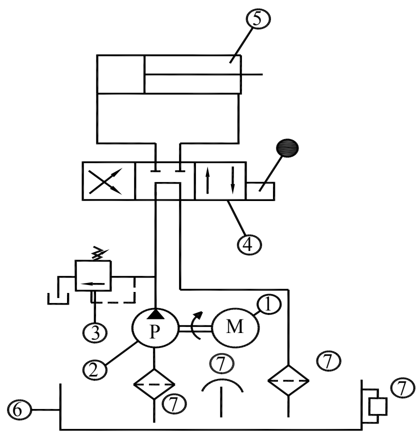
All the four system has their unique advantage and disadvantage; similarly any hydraulic circuit could be designed in many ways, hence knowing different types of vlaves and components, their functions their cost and knowing basic requirement of hydraulic machine is must before designing hydraulic system.

10.4 Selection of working pressure

With the help of following example, we will study the importance of working pressure while designing a hydraulic circuit.

Examples:

- Suppose we want to move a weight of 35 ton at the speed of 160 cm/min., for a distance of 50cm
- We select a simplest hydraulic circuit for said purpose, which consists of a motor, pump, relief valve, direction control valve, hydraulic cylinder and standard hydraulic accessories.



HYDRAULIC CIRCUIT DIAGRAM

Bill of Material

Sr.No.	Name of components	Functions
1	Motor	Prime mover
2	Pump	To deliver oil
3	Relief valve	To regulate pressure
4	Direction control valve	To control direction of cylinder
5	Hydraulic cylinder	Actuator
6	Oil tank	Oil reservoir
7	Standard accesories	To maintain quality of oil and safety of system

- We will select three pressure 70, 200 and 350 kg/cm^2 and find the capacity of pump, valves and standard accessories to have 160 cm/min speed while moving 35 ton load at these pressures.Various parameter at 70kg/cm$_2$ will be as follow
- Load = Cross-sectional area of cylinder X working pressure

$$W = D^2 \times \frac{\pi}{4} \times P$$

$$35000 = D^2 \times 0.785 \times 70$$

$$D = 25.238 \text{ cm}$$

Pump capacity = Cross-sectional area of cylinder X speed

$$Q = D^2 \times \frac{\pi}{4} \times V$$

$$= (25.238)^2 \times \frac{\pi}{4} \times 160$$

$$= 80001.25 \text{ cc per min.}$$

$$\simeq 80 \text{ litre per min.}$$

Where:
W = Load (kg.)
D = Inside diameter (cm)
P = Working pressure (kg/cm^2)
V = Velocity of cylinder (cm/min)
Q = Pump discharge (cm^3/min)
η = System efficiency in percentage

$$\text{Power of electric motor (kw)} = \frac{P X Q X 100}{612 \times \eta}$$

$$= \frac{70 X 80 X 100}{612 \times 80} = 11.4$$

- Hence at 70kg/c$_2$ working pressure ID of cycle will be 25.238cm, pump capacity will be 80 LPM, and power of electric motor will be11.4 kw.

- For 200kg/cm^2 working pressure, inside diameter of cylinder and pump capacity will be

D = 149.308 cm

Q = 28 LPM

Power of electric motor remain same.

- For 350 kg/cm^2 working pressure, inside diameter of cylinder and pump capacity will be:

D = 11.287 cm^2

Q = 16000.98 cm^3/min

or 16 LPM

Power of electric motor remains the same.

- CETOP is an international standard for standardising hydraulic component. It specifies mounting dimension and oil port. For 16 LPM flow we select smallest series of CETOP standard valves, that is CETOP-01 series valves.
- For 28 LPM we select CETOP-03 size of valves and for 80 LPM we select CETOP-6 size of valves.
- As on today that is 26 th May 2008, cost of various components are as follow:

	Working pressure	70 kg/C^2			200 kg/C^2			350 kg/C^2		
Sr. No	Componets	Make	Model	Cost	Make	Model	Cost	Make	Model	Cost
1.	Motor	Hindustan Motors	15 HP Vertical	Rs 21497/-	Hindustan Motors	15 HP Vertical	Rs 21497/-	Hindustan Motors	15 HP Vertical	Rs 21497/-
2.	Pump	Yuken	PVR-150-70	Rs 20070/-	Polyhydron	2RCE-7-DD	Rs 15400/-	Polyhydron	2RCE-7-CC	Rs 15400/-
3.	Relife Valve	Yuken	BG-06	Rs 3365/-	Polyhydron	DPRH-10-3-200	Rs 1220/-	Polyhydron	DPRS-06-S-400	Rs 700/-
4.	Direction Control Valve	Yuken	DMG-o6	Rs 5500/-	Polyhydron	4DL-10-G10.S	Rs 1540/-	Polyhydron	4DC-1D-G-103	Rs 1540/-
5.	HydraulicCylinder (Dimension are in mm)	Hydro Electric Machinery	ID-250 Rod-100 Stroke-500	Rs 70000/-	Hydro Electric Machinery	ID-150 Rod-80 Stroke-500	Rs 25000/-	Hydro Electric Machinery	ID-120 Rod-80 Stroke-500	Rs 15000/-
6.	Oil Tank	Hydroteck	800 ltr	Rs 13000/-		400 ltr	Rs 8000/-		200 ltr	Rs 6000/-
7.	Accessories			Rs 10000/-			Rs 8000/-			Rs 6000/-
8.	Total Cost			Rs 143434/-	Total Cost		Rs 80655/-	Total Cost		Rs 66155/-

From above example we found that system with high pressure are economical and low pressure are costly.

With time the cost of component will change. But the difference of cost between smaller, medium and large size will always be there. Hence in every era the high pressure compact hydraulic system will be always economical than low pressure bulky system.

- With increase of pressure, size of equipment and cost reduces, but maintenance problem increases. While at low pressure, size of equipment and cost increases. Hence pressure is decided carefully considering various factors.
- In case of machine tools, the load on hydraulic cylinders are much less as compared to hydraulic presses. If we select high working pressure for them, and try to calculate the dimension of hydraulic

cylinder, then these dimensions may be less than 1 cm or only few centimeters. Such thin and small cylinder may not give stability and maintenance free operation, hence for machine tool, we generally select low working pressure, that is between 50 to 100 kg/cm^2.

• There is no hard and fast rule for selection of working pressure But in general we have following range of working pressure for various systems in industry.

Sr. No	Filed of application	Range of Working Pressure
1.	Injecton Moulding Machine	210 - 350 Kg/c^2
2.	Pump	210 - 350 Kg/c^2
3.	Relife Valve	30 - 70 Kg/c^2
4.	Direction Control Valve	70 - 300 Kg/c^2
5.	HydraulicCylinder (Dimension are in mm)	40 - 250 Kg/c^2
6.	Oil Tank	140 - 250 Kg/c^2
7.	Accessories	350 - 700 Kg/c^2

Above data based on general study and old trend of industry. Nowadays most of manufactures prefer, and designs high pressure system.

10.5 Pressure Drop in Hydraulic System

The pressure drop in hydraulic system is basically due to resistance to flow. While over coming this resistance energy is lost. This loss of energy gets converted into heat, which increases temperature of working fluid. Pressure drop is an undesirable phenomena, and following are the main causes of pressure drop in a hydraulic circuit.

1) Decrease in pump efficiency:-

Pump efficiency decreases due to wear and tear of it's internal components, or due to rise in temperature. High temperature increases clearance between pump casing and moving element, through which high pressure oil escapes back to low pressure side. This cause pressure drop and further increase in fluid temperature.

2) Throttling in valves:-

Valves are designed as per CETOP standard, and oil hole in them are 6 mm, 11 mm, 22 mm etc. These oil holes work like an orifice. Whenever large flow passes through a small hole, the velocity of fluid increases but pressure drops. Similarly when fluid passes through hydraulic valves, there is some drop in pressure due to throttling.

3) Internal leakage in valve:-

Direction control valve has a sliding spool in valve body. Due to constant use sliding contact area wears out. As clearance increases internal leakage increases. When high pressure fluid leaks through these clearances, it causes drop in pressure, and fluid heating.

What we have described for direction control valves also hold good for all valves with sliding spool and poppet and with metal to metal sealing arrangement. (sealing by fine clearance)

4)Valves with spring loaded poppet:-

Construction of some valves are such that whenever fluid passes through them, then it has to lift a spring loaded spool or poppet or steel ball etc. Whenever fluid pressure acts against such spring force to over-come compression of spring then some energy is lost and pressure drops. Such valves are pressure reducing valves, sequence valves, check valves, pilot operated check valves, relief valves etc.

5) Resistance to flow through pipe line:-

Fluid experiences resistance to flow while passing through pipe line, joints and bends etc. Hence there is pressure drop at every joint and bend in pipe line. While passing through pipe line due to such resistance energy of fluid is lost and pressure drops.

- Pressure drop is studied carefully and calculated to ascertain the heat generation in system, because pressure drop reduces the system efficiency, and heat which get generated damages the system. Hence special steps are taken at design stage to control and keep both of them in safe limit.

At every valve, joint, and bend etc. pressure drop could be calculated with help of technical data available in design book. Once we get total pressure drop, heat generated could be calculated.

10.6 Calculation of Heat Generation In Hydraulic System

Heat generation due to loss of efficiency:-

- The purpose of calculation of heat generation in hydraulic system is to find and use correct size and specification of oil cooling system.
- A low capacity cooling system will get overloaded, and may not be able to maintain temperature within optimum temperature limits. And a higher capacity cooling system will be costly, and cooling system itself will utilise more electric power, and may be under utilised. Hence to have right cooling unit, correct estimation of heat generation is necessary.
- Hydraulic systems are not 100% efficient. As a thumb rule we assume 80% efficiency, and we assume that balance 20% input energy gets converted in to undesirable heat.

So if we use 11.5 kw motor, then we assume that 2.25kw (That is 20% of 11.5KW) will get converted in to heat. So our cooling system should be able to extract 2.25KW of heat from hydraulic system.

For extracting 2.25kw heat, w e require 0.799 TR capacity cooling system as per following calculation.

2.25 (kw) X 860 = 1935 kcal/hr.

$\frac{1935}{3024}$ = .06398 TR (Ton Refrigeration)

If we assume 80% efficiency of cooling system, then 20% more capacity is to be added in cooling capacity

$\frac{0.6398}{0.8}$ = 0.7997 TR

Heat generation due to pressure drop:-

- Second method of finding amount of generated heat in system is by calculating amount of pressure drop in system. The energy lost in form of pressure drop get converted in to heat.
- Example: Considers a hydraulic system with following specification.

1) Motor Hp = 15 Hp or 11.5 kw
2) Capacity low flow and high pressure pump = 20 LPM
3) Capacity of high flow and low pressure pump = 70 LPM
4) System should have following special features.

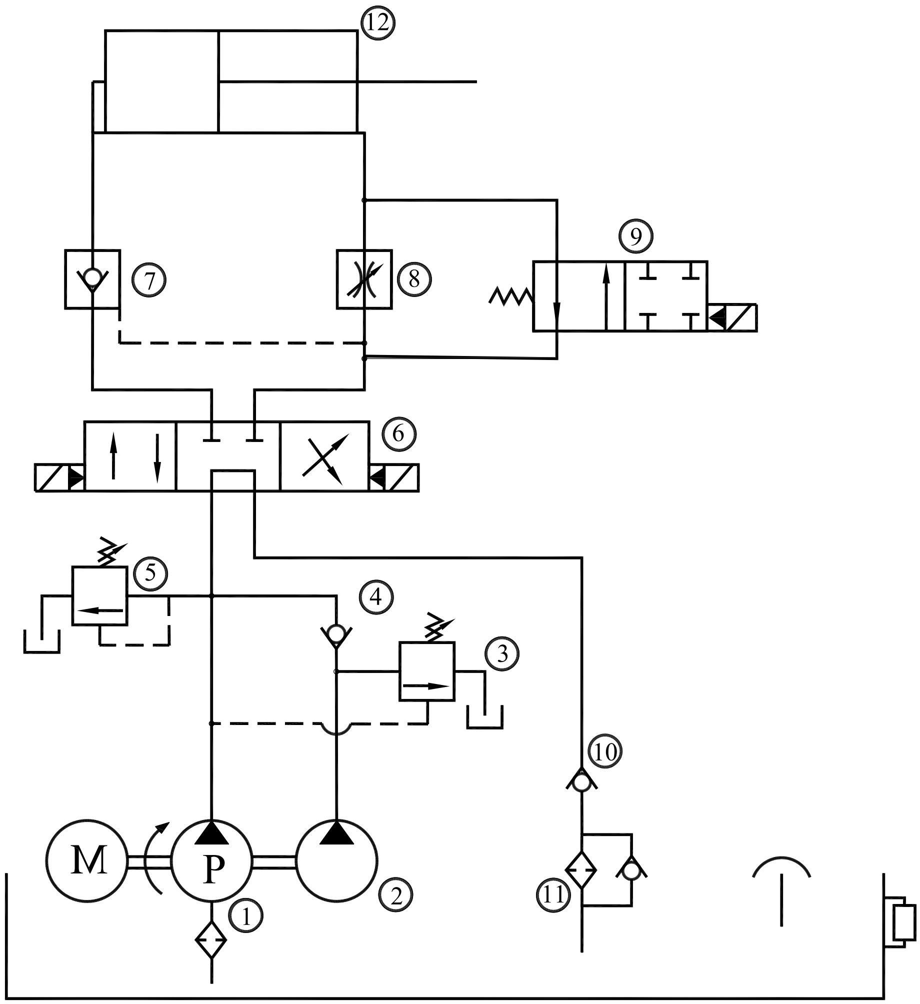
a) Pressure will be held in cylinder by using pilot operated check valve . System will also have flow control to have variable and controlled speed while pressing. System will always have full and maximum approach and return speed.

b) The detail of component used, and hydraulic circuit diagram to fulfill above mentioned requirements are as per sketch No.___

Solution:-

- To calculate total pressure drop, we have to calculate, pressure drop in pipeline, pressure drop in hydraulic valve, and pressure drop in cylinder due to seal friction.
- Pressure drop in pipe line could be calculated by using monogram/graph
- In present example we are using standard pipe with 24mm inside diameter, and 33.4mm outside diameter. Pressure drop in pipe will be 0.1 kg/cm^2 per meter for flow of 100 LPM (As per monogram). We assume that total length of pipe line will be 10 meter. Hence approximately total pressure drop in pipe line will be 1Kg/cm^2
- Manufacture of hydraulic pumps and valves provides complete technical detail in their catalogue, including pressure drop at various pressure and flow. So as per out working pressure and flow we can find pressure drop from catalogue of respective valve and pump

- Pressure drop in hydraulic cylinder is due to seal friction. Loss of energy to overcome seal friction is calculated as follow.



Sr.No.	Components	Make	Make	Detail and Pressure Drop
1	Piston pump	Polyhydron	2RCE7DD	---
2	Vane-pump	Yuken	PVR-150-70	---
3	Unloading valve	Polyhydron	PPRU	---
4	Check valve	Polyhydron	C-30-S-1	Pressure drop 2kg/cm^2 at 100 LPM Flow
5	Relief vlave	Polyhydron	DPRS-10-S-315	---
6	Direction control valve	Yuken	DSHG-06-3C60-A240	Pressure drop 2kg/cm^2 at 100 LPM Flow
7	Pilot operated check valve	Polyhydron	CI-30-S	Pressure drop 2kg/cm^2 at 100 LPM Flow
8	Flow control valve	Polyhydron	2PF-H-10-C-32	Minimum pressure difference.5kg/cm^2
9	Direction control valve	Yuken	DSHG-06-2B2A-A240	Pressure drop 6kg/cm^2 at 100 LPM Cracking pressure-5kg/cm^2
10	Check-valve	Polyhydron	C-30-S-4	Pressure drop 6kg/cm^2 at 100 LPM Cracking pressure-5kg/cm^2
11	Return line filter	Hydax	RLF-10-25	With clean oil not pressure drop.In clogged condition inbuild check valve open at 5kg/cm^2. We assume 2kg/c^2 pressure drop at normal working condition.
12	Hydraulic cylinder	Hydro Electric Machinery	ID =280 mm Rod =170 mm Stroke =500 mm	Pressure drop 5kg/cm^2

- Total pressure drop at fast speed and low pressure will be.

2 kg/cm^2 - cracking pressure of check valve (1)
2 kg/cm^2 - main direction control valve (6)
2 kg/cm^2 - pilot operated check valve (7)
5 kg/cm^2 - hydraulic cylinder (12)
2 kg/cm^2 - direction control valve to control flow (9)
6 kg/cm^2 - check valve to develope back pressure to operated direction control valve (10)
2 kg/cm^2 - pressure drop in return line filter (11)

21 kg/cm^2

- Total pressure drop at low speed and high pressure will be

2 kg/cm^2 - cracking pressure of check valve (4)
2 kg/cm^2 - cracking pressure of pilot operated check valve (7)
5 kg/cm^2 - pressure drop across flow control valve (8)
5 kg/cm^2 - pressure drop due to seal friction in cylinder (12)

14 kg/cm^2

- After calculating total pressure drop heat generation is calculated using following equations.

$$H = \frac{10X60XPXQ}{427}$$

Where H = Heal in Kcal/hr
P = Pressure drop kg/cm2
Q = Flow of pump in lpm

1 Kw/hr = 860 Kcal
1 Kcal = 827 Kgm
3024 Kcal/hr = 1 TR (Ton refrigerator)

- In present example heat generated is = $\frac{10X60X21X90}{427}$ =2655.7kcal/hr
- For removing 2656 kcal/ hr heat we need = $\frac{2656}{3024}$ = 0.878 TR Capacity cooler
- If we assume cooler efficiency as 80%, then we should selected cooler capacity as

$$= \frac{0.878}{80} X100 = 1.097TR$$

This calculation is based on heat generation at high speed and low pressure operation. But system also operates for some time at low speed and high pressure in which case heat generation is low. Hence actual heat generation will be less than 1.097 TR.
1 TR is standard capacity of cooler, hence we will select 1 TR Air-cooled oil cooler (chiller) in our system.

- Another equation which could be used for calculating capacity of water cooler is

$$m \times s \times (t_1-t_2) X\ 60 = H\ (kcal/hr)$$

Where m = mass of fluid (LPM)
S = specific heat of fluid.(it is 1 for water and 0.85 for mineral oil)
t_1-t_2= Temperature difference of fluid before and after cooling.

10.7 Sequence and Cycle Diagram

Very few power packs are operated by hand. Most of the power packs are controlled and actuated by electrical control panel. Press design, hydraulic circuit design, hydraulic power pack manufacturing, assembly and testing, commissioning, and maintenance, all these jobs are done by different engineers. For better communication and understanding among them there should be some blueprint which all should read, understand and interpret without any difference.

Hence for this purpose along with circuit diagram, sequence chart and load cycle diagram is also made. Sequence chart contains, sequence of energisation of various solenoid, and their controlling parameter. While load cycle diagram indicates stroke, load developed and time required.

An example of sequence chart and load cycle diagram for a **deep drawing press** is as follow.

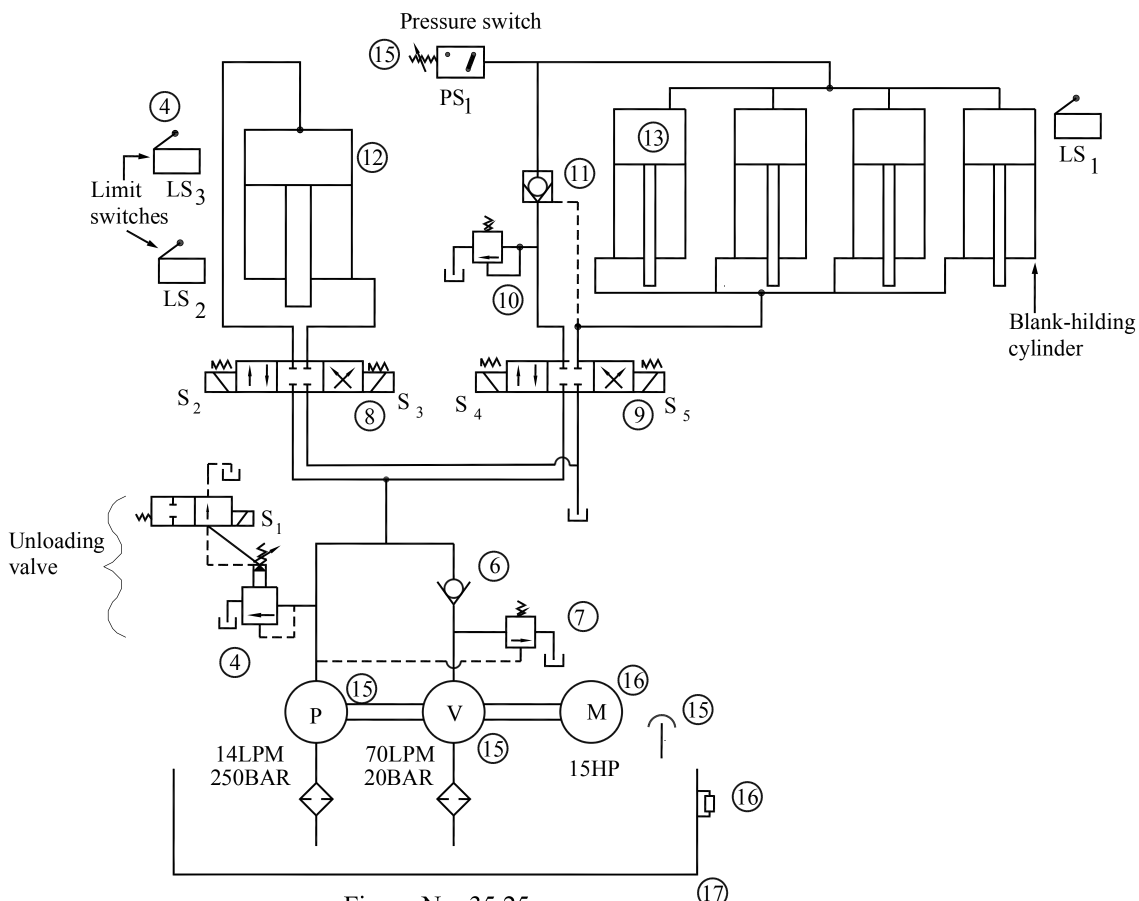


Figure No. 35.25

Hydraulic Circuit Diagram of Deep Drawing Press

Operation of Deep drawing Press: -

1. Press has four blank-holding cylinder[13] and a main pressing cylinder[12]. Four blank-holding cylinder operated by a common solenoid-operated direction control valve[4], while main cylinder operated by another direction control valve[8].

2. Two pumps are used in which low pressure pump[2] is unloaded by unloading valve, which is actuated, and control by a solenoid valve[5]. (S1)
3. For deep drawing operation sheet-metal blank is placed on press-table manually. On pressing push-button blank-holding cylinder moves forward, and presses the sheet-metal blank. Load is sensed by pressure switch (PS1), which gives signal to main cylinder to take its forward stroke.
4. The depth of draw produced by forward stroke of main cylinder is sensed by (Limit switch) LS2, and this stops forward stroke and activate return stroke.
5. Completion of return stroke is sensed by limit switch LS3 and it stops return stroke and activate return stroke of blank-holding cylinder.
6. Return stroke of blank-holding cylinder is sensed by limits switch LS1. It stops the return stroke of blank-holding cylinder.
7. Ejection is automatic and achieved by mechanical means. Linkages are provided by which the returning platen of blank-holder also eject the drawn component. Drawn component removed manually and new blank-loaded manually. This makes press ready for next operation.

Sequence of Operation Chart

SEQUENCE OF OPERATION	S1	S2	S3	S4	S5	CONTROLS/ ACTUATION BY
Start of Cycle Blank-holding Cylinder Forward Stroke	ON	OFF	OFF	ON	OFF	Push-botton (Manual)
Main Cylinder Forward Stroke	ON	ON	OFF	OFF	OFF	PS1 (Presure switch)
Main Cylinder Return Stroke	ON	OFF	ON	OFF	OFF	LS2
Blank-holding Cylinder Return Stroke	ON	OFF	OFF	OFF	ON	LS3
Completion of ReturnStroke and End of Production Cycle	OFF	OFF	OFF	OFF	OFF	LS1

Note : S1, S2,S3, S4, S5 are Solenoid electrical coil of valve No.5, 8, 9

Note: - A simple control panel uses contactor, push-button etc.for actuation of solenoid coil when control instrument such as limit switch, pressure-switch etc. get actuated they give signal in control panel. And because of which as per the wiring and design of panel, one solenoid get switched off and other switch on.

Cycle Diagram: -

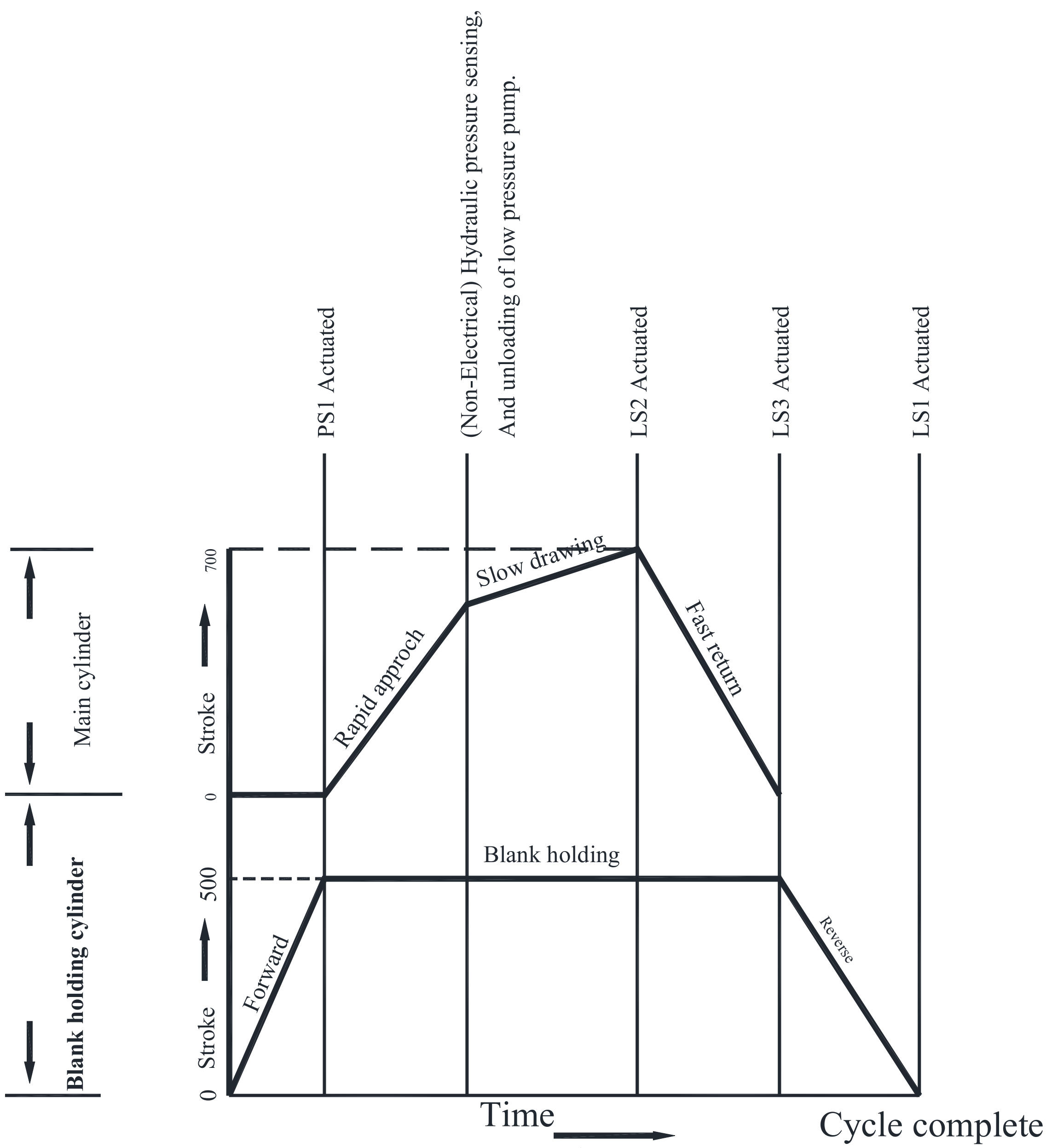


Figure No. 35.26

10.8 Circuit Diagram For Modular Type Power Pack: -

Modular valves are most widely used in industry because of convenience in using them. They do not require complicated manifold block and piping. To represent the way and sequence in which they have been stacked one above the other, while assemblyling a hydraulic system, their circuit diagram is slightly modified. We briefly explain it as follow.

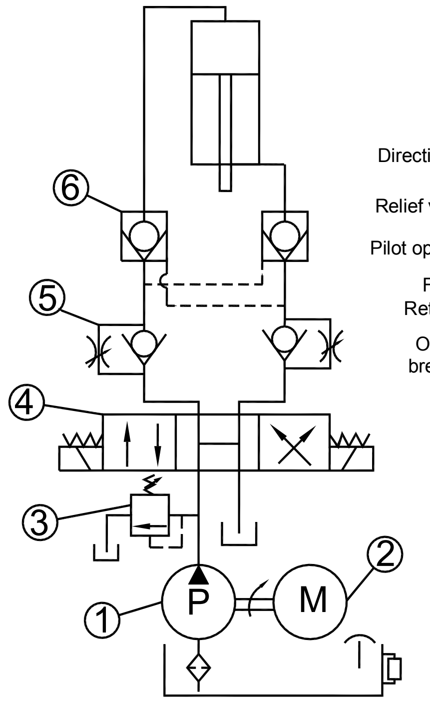
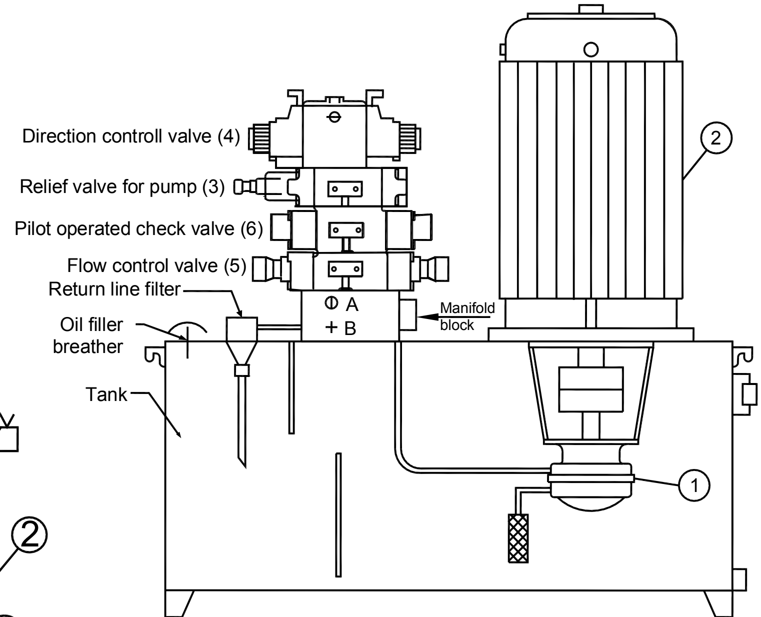


Figure No. 35.21



Example of a Modular Valve stacked

Figure No. 35.22

Above mention circuit is general hydraulic circuit diagram. For modular valve same above circuit can also be drawn in following ways.

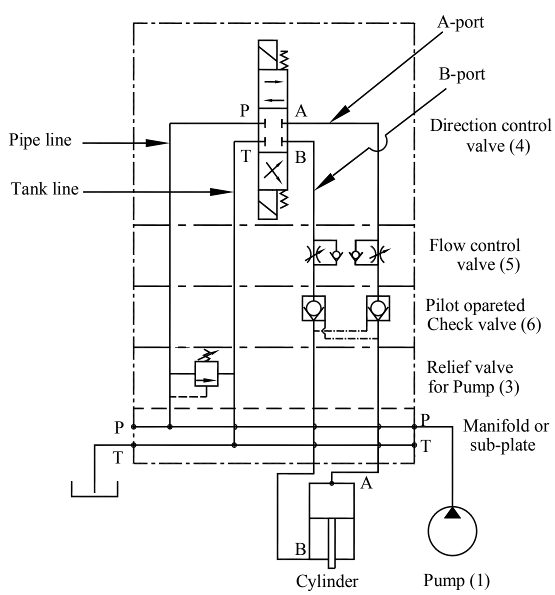
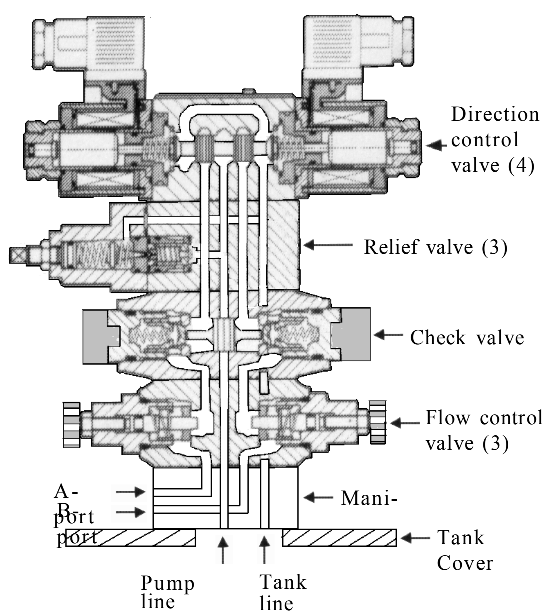


Figure No. 35.23



Some of the logic and feature of making such type of circuit is as follow.

1) As a common pump line and tank line drilled through manifold for number of solenoid valves. Hence a corresponding two straight horizontal lines are drawn as pump & tank line in circuit diagram.
2) In case of modular valve, all the valves have same holes namely, P-(Pump), T-(Tank), A&B (both port of cylinder), As per international standard these holes of all the valves have same dimension, and perfectly match each other when staked one above the other. When valve stacked one above the other, four vertical pipe like passage forms. Oil passes through all the four line of all the valves, irrespective of whether valve requires those line or not. Hence we have drawn four vertical lines.
3) As Pump line (P) and Tank line (T) starts from Pump and Tank and mostly passes through direction control valve and ends at actuator (Cylinder or Motor). Hence out of four vertical lines two starts from Pump, Tank passes through direction control valve and ends at A and B-port of cylinder.
4) Hence two horizontal and four vertical lines are common feature in this type of circuit diagram.
5) As per valve added in circuit, their graphic diagram drawn between corresponding six lines.
6) For better understanding a dotted line is drawn for manifold and valve. Each dotted block indicates one unit of valve or manifold (sub-plate).

7) We have drawn above circuit diagram for one valve bank (set of a valve). More number of valves bank could be added on manifold, using same pump and tank. If a relief valve, pilot operated check valve, flow control valve and direction control valve is further added to operate one more cylinder in same power pack with common pump and motor, then new circuit diagram will be as follow.

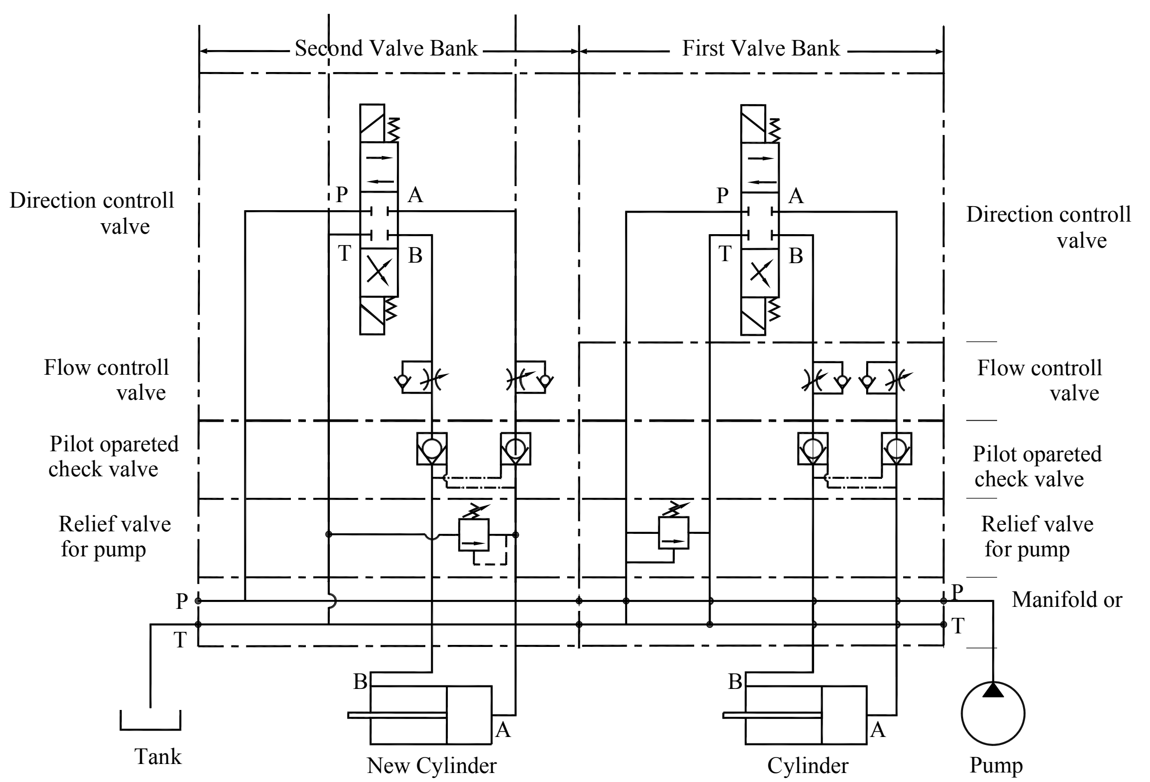
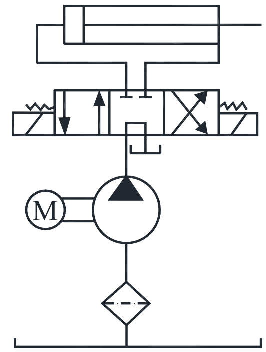


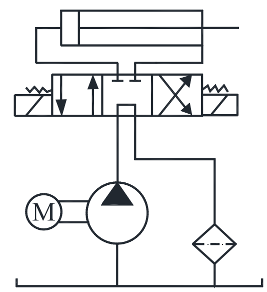
Figure No. 35.24

10.9 Use of filter in Hydraulic Circuit:-

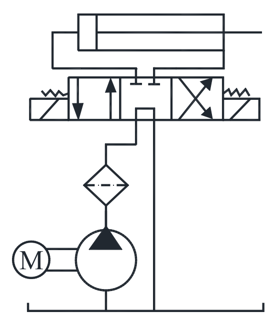
A hydraulic circuit could be designed in five ways to filter oil in system.



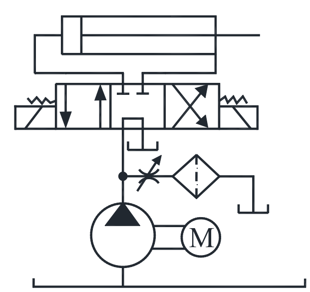
1) Circuit with suction stainer:-
In this design a filter is provided at suction side of pump. Advantage of this design is that it prevents entry of large size contamination in system. Which may cause immediate and severe damage to system. Disadvantage of this design is that fine filter could not be used at suction side as this may result in high pressure drop in suction, which will cause cavitation in pump. Generally 150 mesh size filter which can filter upto 100 micron size particle are used in suction stainer.



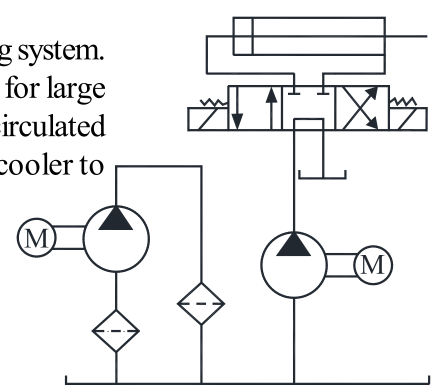
2) Circuit with discharge line or return line filter:-
In this design the oil exhausted to tank are filtered. Advantage of this design is that it can tolerate high pressure drop as compared to suction stainer, so the filter with filtering capacity of 10 micron could be used. Disadvantage of this design is that some valves such as proportional or servo valve require less than 5 micron cleanliness. If we use 5 micron filter at return line then it will cause excessive and constant back-pressure which is undesirable. Hence fine filtering element could not be used in return line filter.
Suction stainer and return line filter do have some disadvantages, but because of protection they provide to the system, they are almost compulsory part of all hydraulic circuit.



3) Circuit with pressure line filter:-
For absolute cleanliness of oil pressure line filter is used. But use of this filter causes excessive pressure drop in system.



4) Pressure line bleed-off filters:-
Suction stainer, return line filter or pressure line filter are selected as per pump capacity of system. For very high capacity pump, vary large capacity of filter is required, which may be vary costly. For simple economical system, and those system, where involvement of contamination is very less, pressure line bleed of type circuit is used. In this system through an orifice a small quantity of oil is discharged to tank through filter. Advantage of this system is that a small size filter be used in the filtering system. Disadvantage of this system is that the oil passing through orifice for filtering is lost from the effective pump output.



5) Independent filtration circuit:-
This type of circuit is also called kidney loop or off line filtering system. In this system a separate pump is used to filter oil. Generally for large and critical hydraulic system this is used. The fluid which is circulated by independent pump for filtration may also pass through cooler to maintaining temperature of fluid.

10.10 What is Pumping Unit and Powerpack Unit?

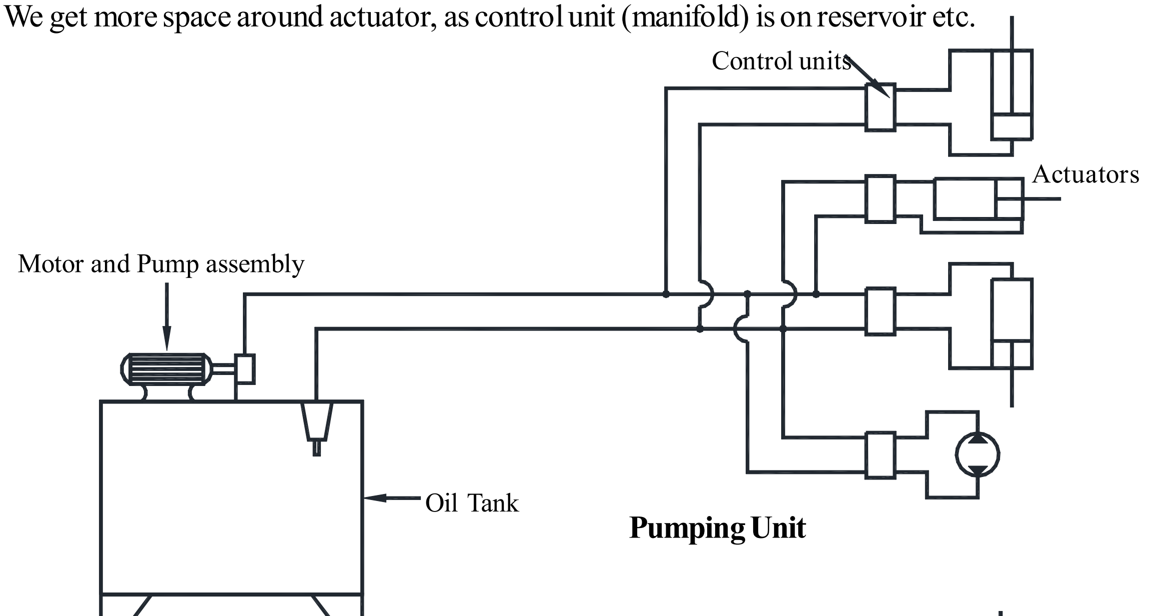
In case of huge machinery like steel rolling plant etc where more number of hydraulic actuator and control of hydraulic actuator are used, system could be designed and made in two ways. In first method the control and manifold block of each actuator could be placed very near to actuator (which may be a cylinder and motor). And pump and motor which are common to all manifold are placed at long distance at some suitable place. As in this case motor, pump, relief valve and reservoir assembly supply only oil to all the manifold block. And do no control each actuator. Hence they are called as pumping unit

In pumping unit we have few advantages such as:

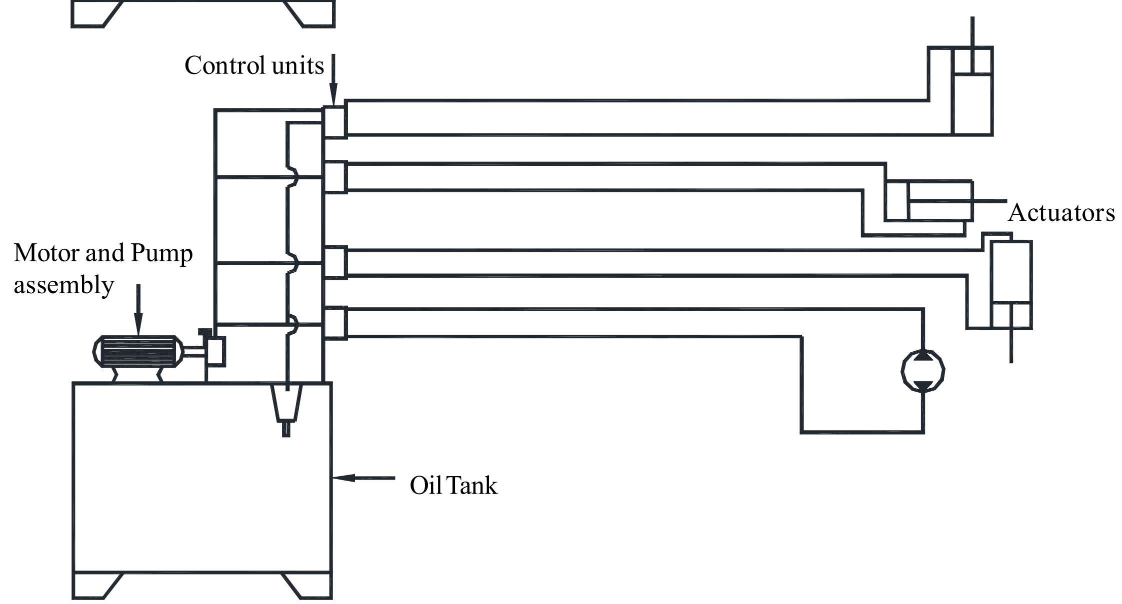
Length of pipe between manifold block and actuator are less and hence less cost of piping, less possibility of leakage, less problem of sponginess and compressibility of oil ete.

While in power pack design, manifold block and valves of all actuators are mounted on single oil reservoir. And from manifold block long piping are laid to all the actuators.

Power pack type of design also have some advantages over pumping unit, such as maintenance of hydraulic equipment is easy. Because of more number of long piping heat of oil get dissipated. We get more space around actuator, as control unit (manifold) is on reservoir etc.



Pumping Unit



Power pack unit

10.11 Pressure Control Circuit

1. There should be always a relief valve to control the maximum pressure of the system. Relief valve should be immediately after pump, so that due to any reason if oil flow generated by pump gets blocked then it can pass through relief valve, without damaging any other parts of the system.

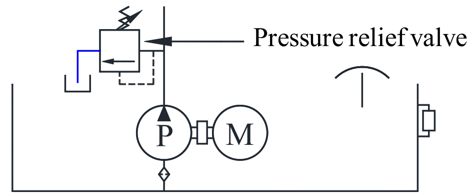
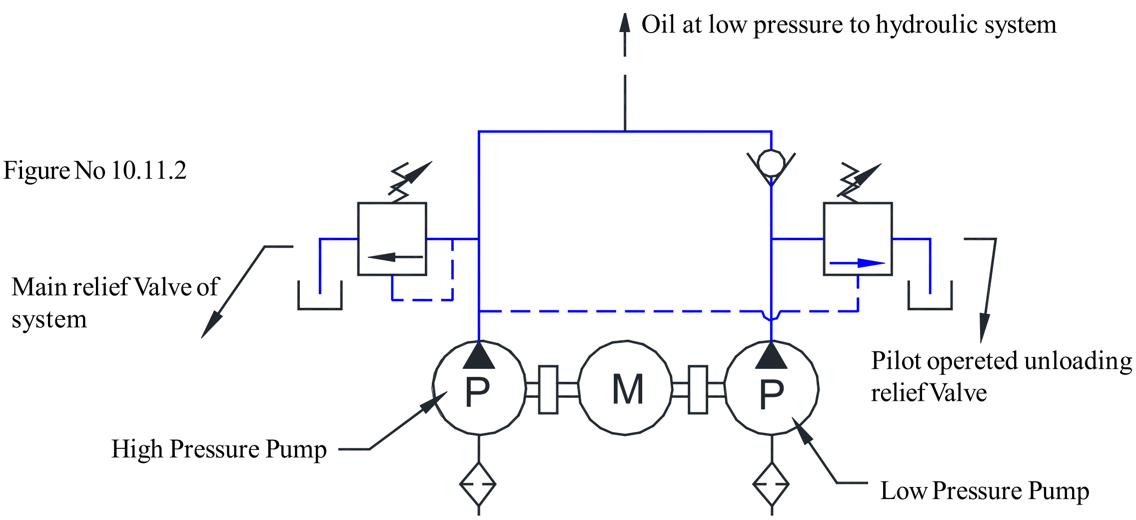


Figure No 10.11.1

2. When two pumps are used in a system in which one pump is with high flow and low working pressure for fast approach and return speed, and second pump is with low flow capacity and high working pressure for actual pressing operation. Then after reaching certain pressure high flow pump is required to be unloaded to tank to avoid excessive load on prime-mover. For such application "Unloading type relief valve" is used as shown in following circuit diagram.

Figure No 10.11.2



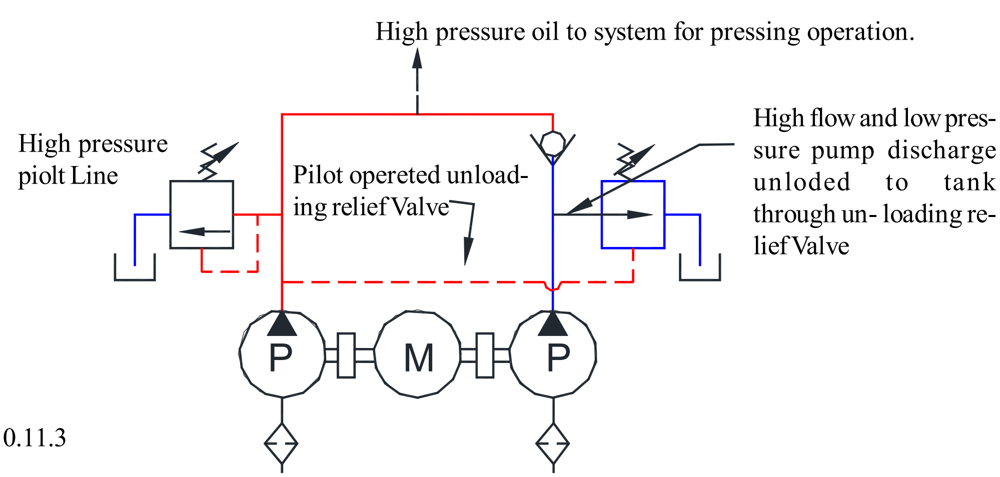


Figure No 10.11.3

Hydroulic circuit diagram when unloading valve got actuated

In a hydraulic circuit when different pressures are required at different stage of operation, then following type of arrangement of direction control valve and pressure relief valve could be used. If pressure setting of 'Pressure Relief Valve-A' and 'Pressure Relief Valve -B' are lower than system pressure, then when solencid-1 is energized, then maxium pressure in system will be as per Pressure Relief Value -A and when solenoid-2 is energized then maximum pressure in system will be as per Pressure Relief Valve-B. And when both the solenoids are switched off then maximum pressure will be as per setting of relief valve-C. Unloading relief valve D in circuit 35.2 will only control pressure of low pressure pump. (Fig 35.2)

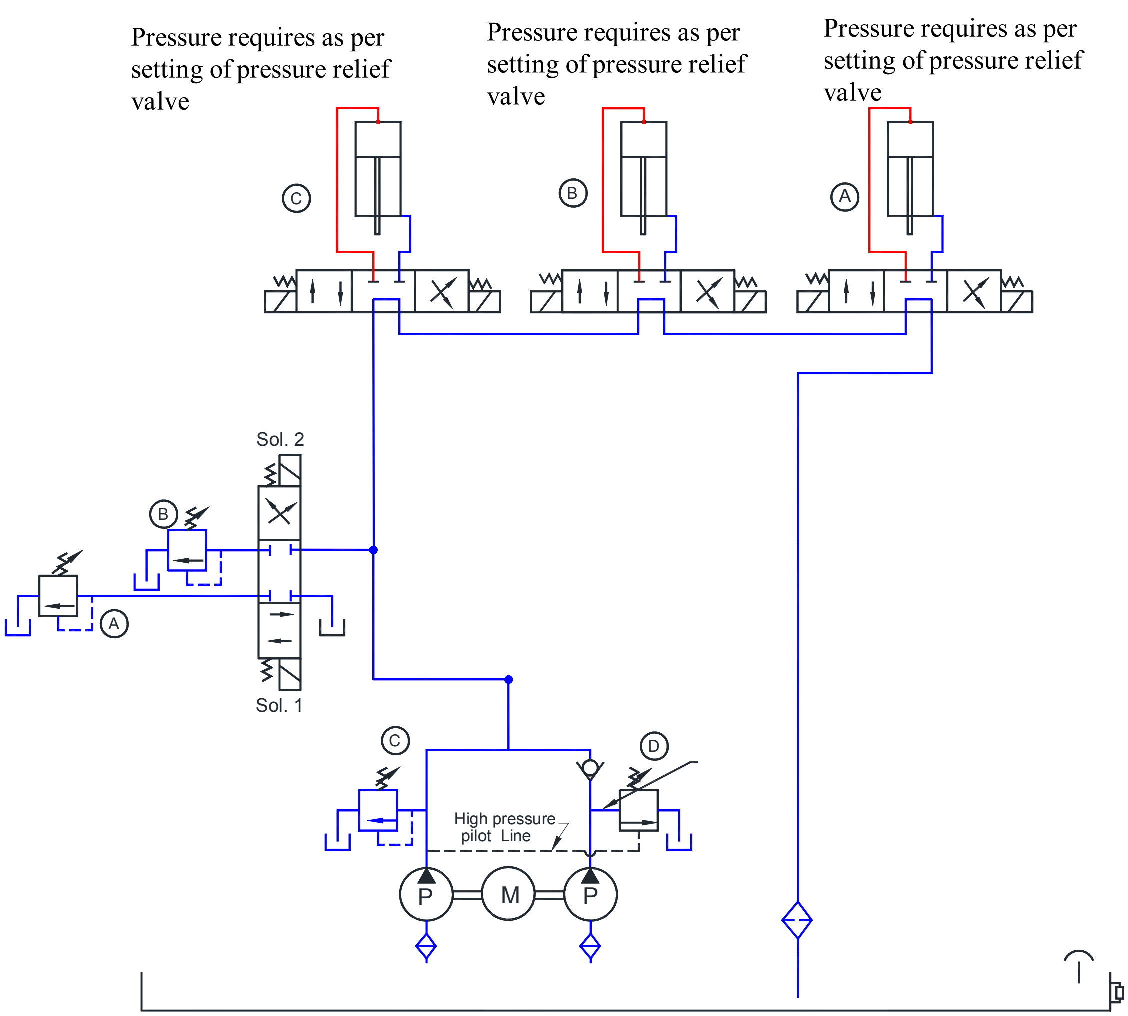


Figure No. 10.11.4
Hydroulic circuit diagram when unloading valve got actuated.

10.12 Pressure Holding Circuit

(By using pilot operated check valve)

Many time hydraulic presses are required to hold the job under compression for very long period of time. For such operation if motor runs continuously to develop pressure for pressing operation then it will be uneconomical, due to excessive electric consumption. Also oil will get heated up, as most of the pump discharge will pass through the relief valve.

For such application pilot operated check valve is used in circuit. Which hold the pressurized oil in cylinder or system for long time. A simple circuit of this type is as follow.

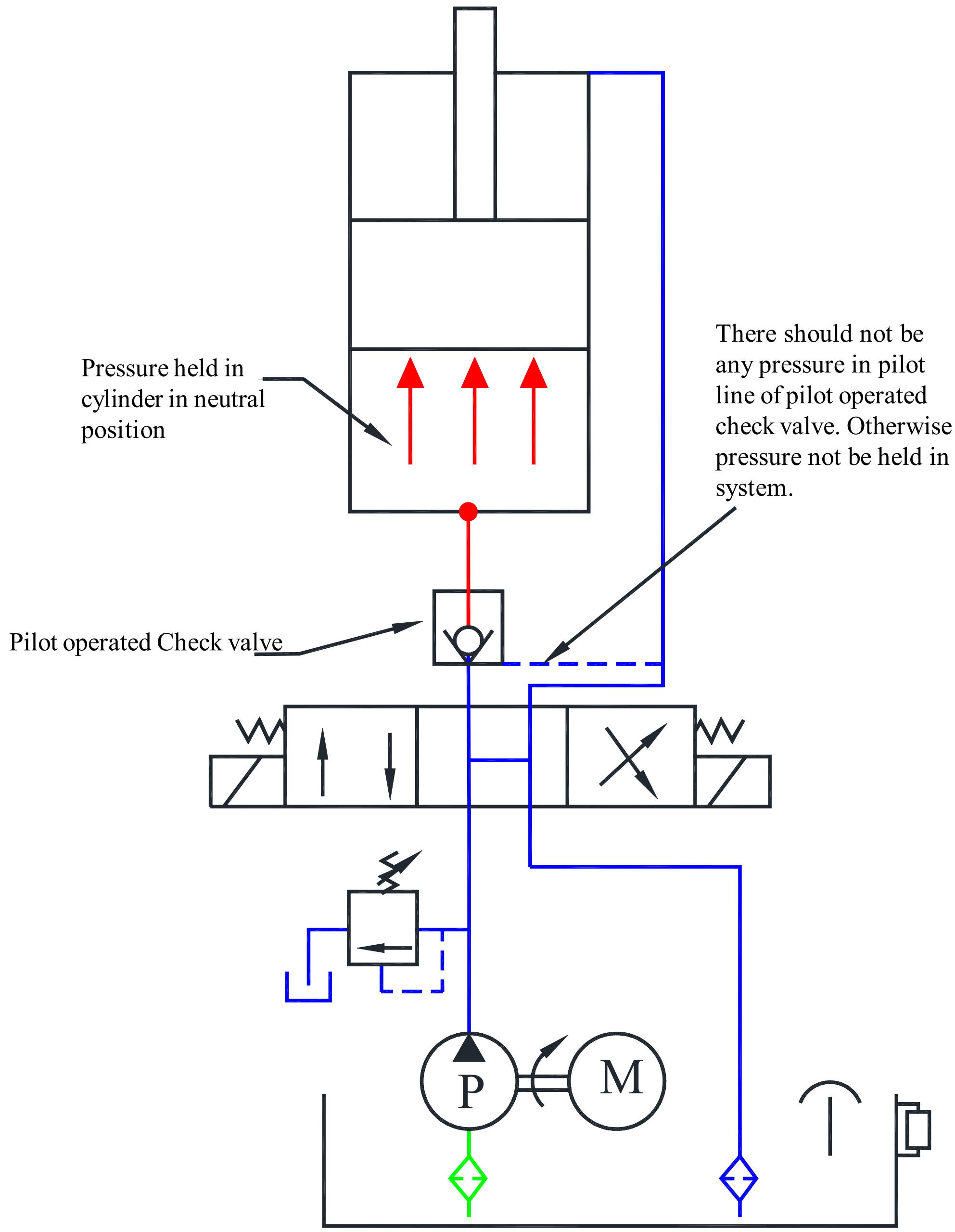
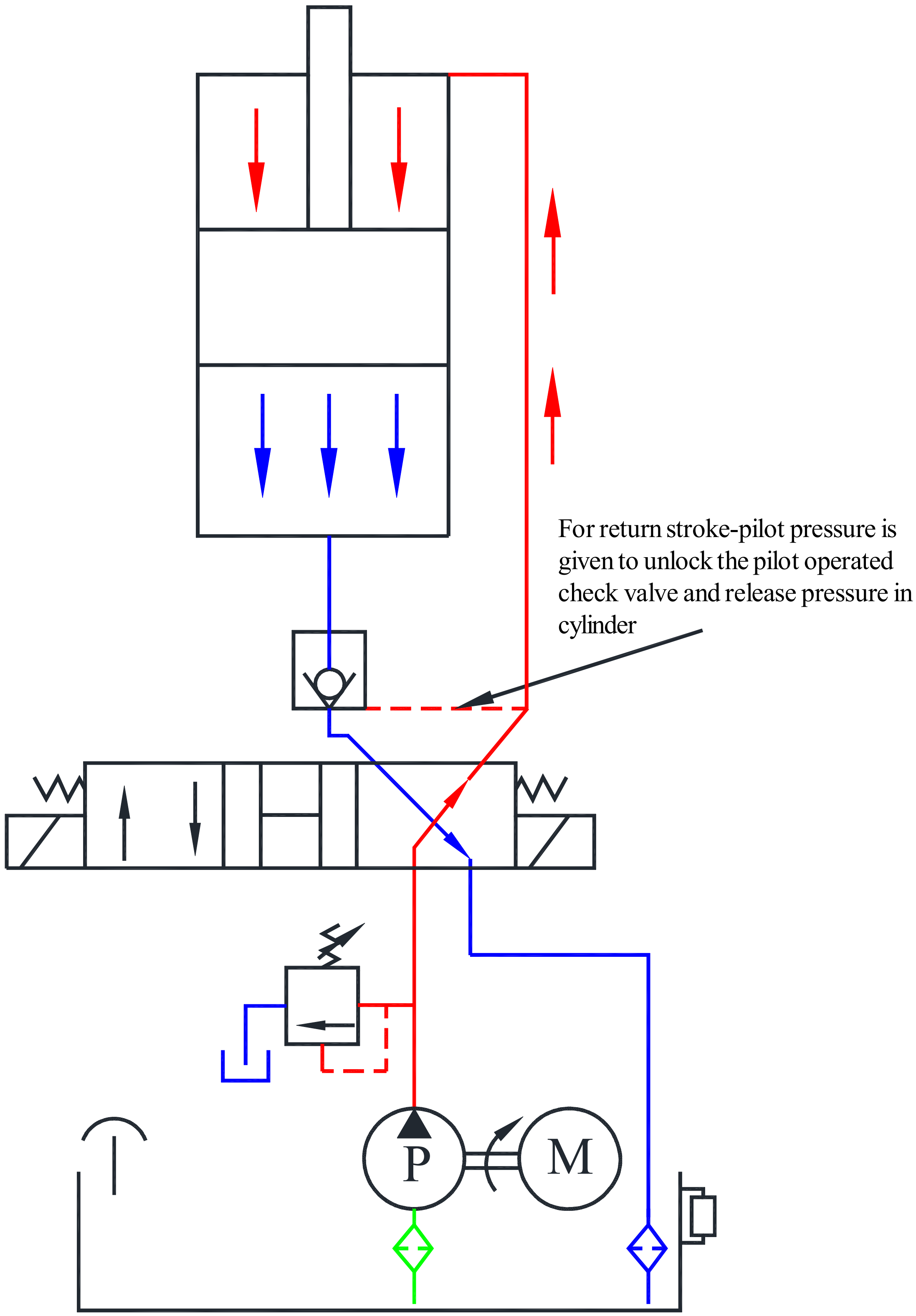


Figure No 10.12.1

Pressure held in cylinder at neutral position.



Pressure released from cylinder for return stroke.

Figure No 10.12.2

10.13 Decompression Circuit

This is a feature of hydraulic circuit. When high pressure fluid is held in cylinder, and when this high pressure is suddenly released, then a surge of large volume of fluid passes through the pipeline and produces a banged sound and vibration. Sudden release of stresses also cause Jerk in press-body. To avoid this, pressure is slowly reduced to minimum possible, then cylinder allowed to retract. This feature of slow release of high pressure in system is called **decompression**.

For Decompression four types of circuits are used.

a. Decompression circuit using an orifice and check valve.
b. Decompression circuit using orifice and solenoid operated direction control valve.
c. Decompression circuit using valve which have in-build feature of decompression.
d. Decompression by direction control valve (slow movement of its spool).

a) Decompression circuit using an orifice and check valve.

In following circuit diagram when pump develops pressure, no oil will flow through check valve. Only in neutral position of solenoid operated direction control valve, pressurized oil of cylinder will slowly press over check valve to tank. Due to orifice the release of pressurized oil will be very slow. This arrangement cannot be used when there is always a pressure in pump line. (Fig. No. 35.4)

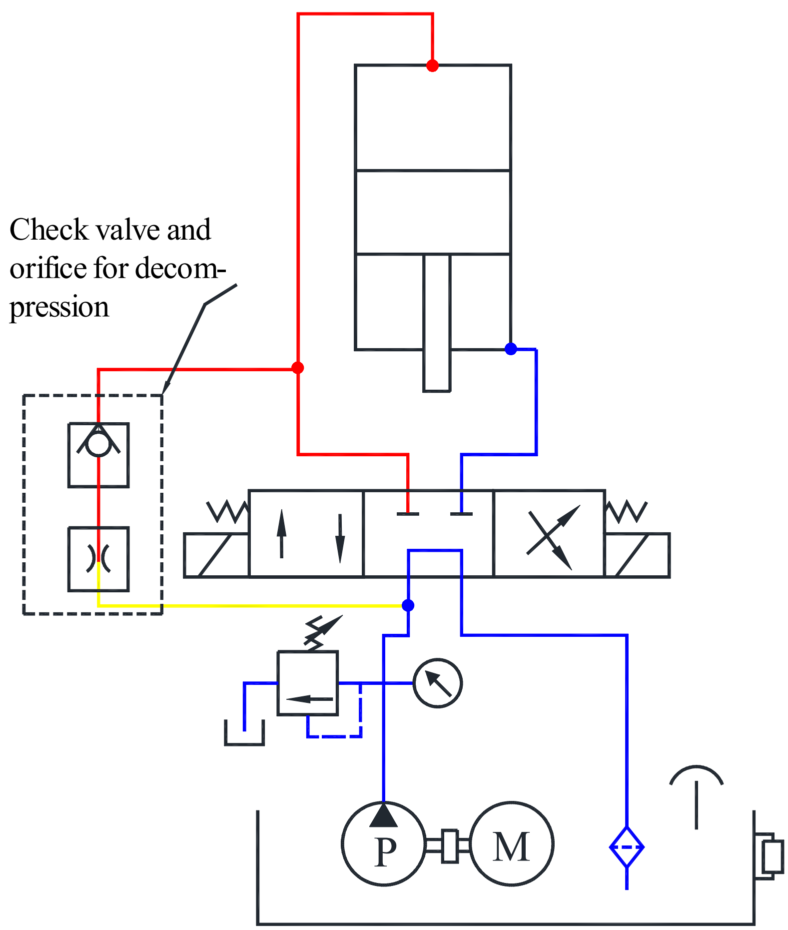


Figure No 13.1

b) Decompression circuit using orifice and solenoid operated direction control valve.

When there is always a pressure in system, then above mentioned arrangement cannot be used. In such case a direction control valve in place of check valve is better alternative.

In following circuit when two-way-two-position solenoid valve is energies, it releases oil to tank. Due to orifice there will be gradual drop in pressure. (Figure No. 13.2)

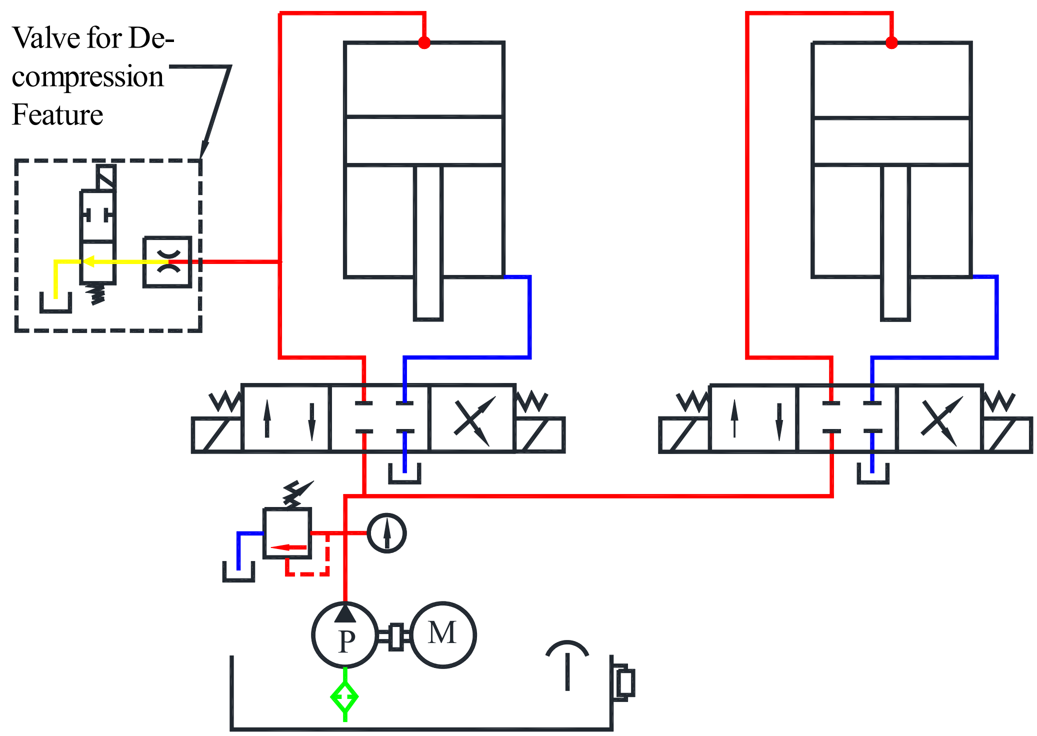


Figure No 13.2

(Pressure held in first cylinder is getting De-compressed)
Status of Pressure in Neutral Position after forward stroke

c. Decompression with in-build feature in valves: -

Pilot operated check vale, pre-fill valves etc. can also have decompression feature in their basic design. When such valves are used, they automatically reduce pressure gradually. Details of such valve have been described in chapter No. 31.

d. Decompression by direction control valve:

Spool of direction control valve changes its position from one finite condition to another in fraction of a second. In transit condition the pressurized port may get connected to tank as explained in following figure. This causes a sudden drop in pressure resulting in large sound and vibration.

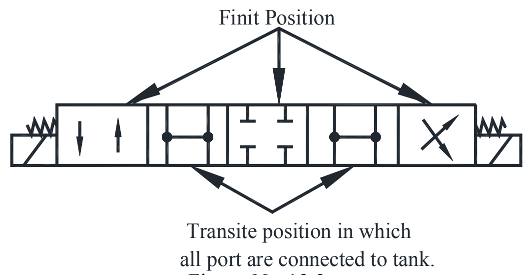


Figure No 13.3

To avoid this situation, a pilot operated check valve could be used to hold pressure in system when solenoid operated valve is changing position, and then decompress the pressure by three methods discussed earlier.

Second method to reduce the sudden fall of pressure is to move spool so slowly that pressure drops slowly. Some type of solenoid valves have in-built features to move spool slowly.

In case of pilot operated solenoid valve without in-built decompression feature, a throttle cum check valve is used between pilot valve and main direction control valves for decompression purpose. Throttle cum check valve controls the flow of oil in pilot line to main direction control valve, which shift the spool. Reduced oil flow in pilot line slows down the movement of spool results in slow fall of pressure in system.

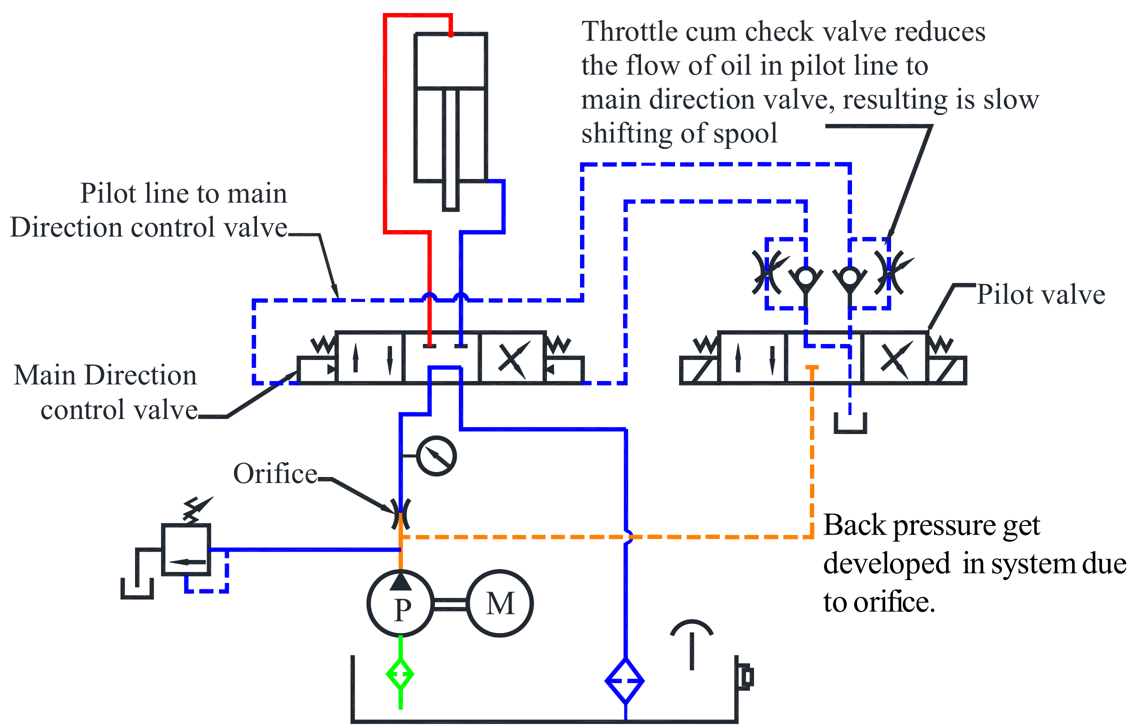


Figure No 13.4

10.14 Hydraulic Circuit with Back Pressure: -

A backpressure may be required in a hydraulic system to operate a pilot operated directional control valve.

For such back pressure an orifice or a check valve is used, as shown in following circuit diagram. Orifice and check valve is used just after high-pressure pump while a check valve could be used in return line of system also. But when orifice and check valve is used, we cannot change or vary the back pressure. For accurately select and vary the backpressure special backpressure valve is used in return line, in place of simple check valve (Fig. No. 35.9)

By using backpressure valve we can exactly vary and select the backpressure. While by using a check valve back pressure will be fixed and as per the cracking pressure of spring of check valve.

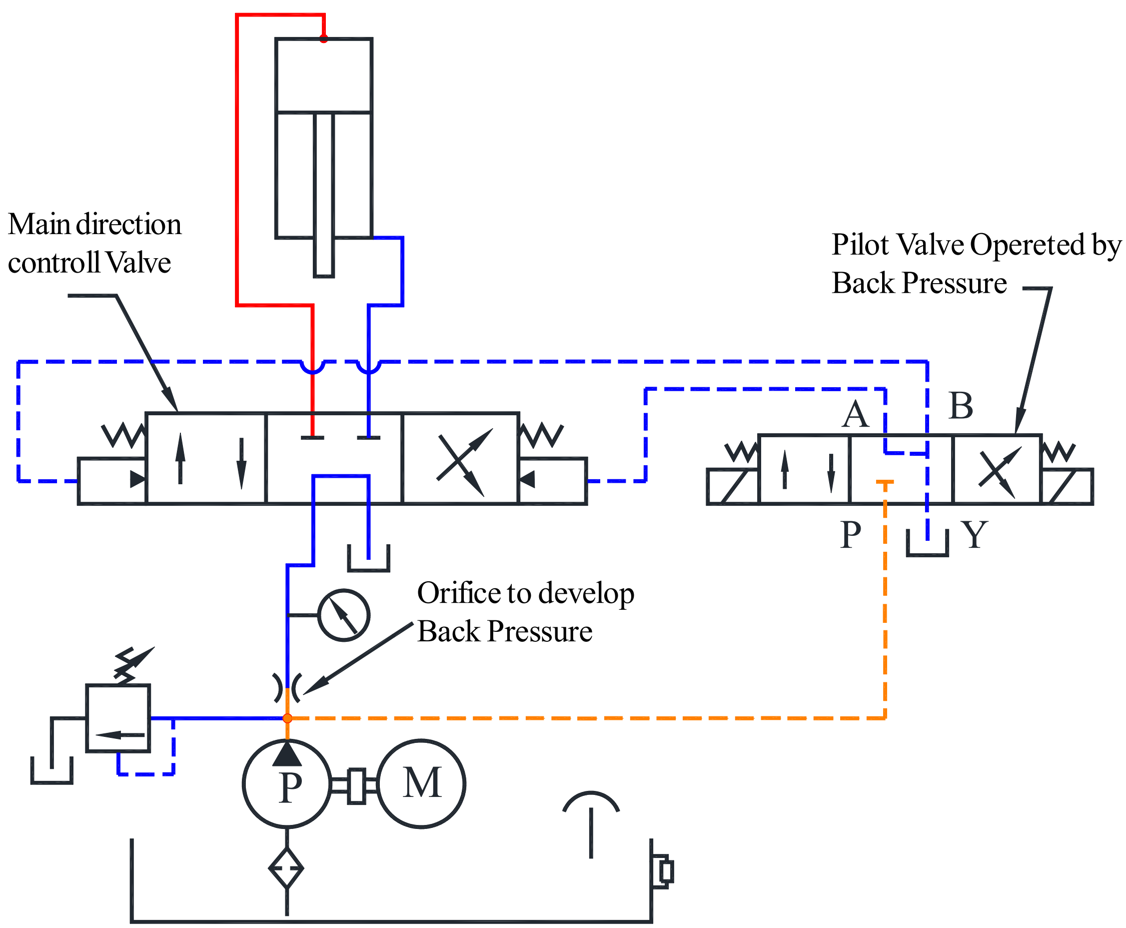


Figure No. 14.1

Back pressure in system by using orifice. In place orifice a check valve also could be used.

An orifice should always be used after a relief valve, so that if any dust particle get strucked in orifice, then build-up pressure will not damage the pump and system.

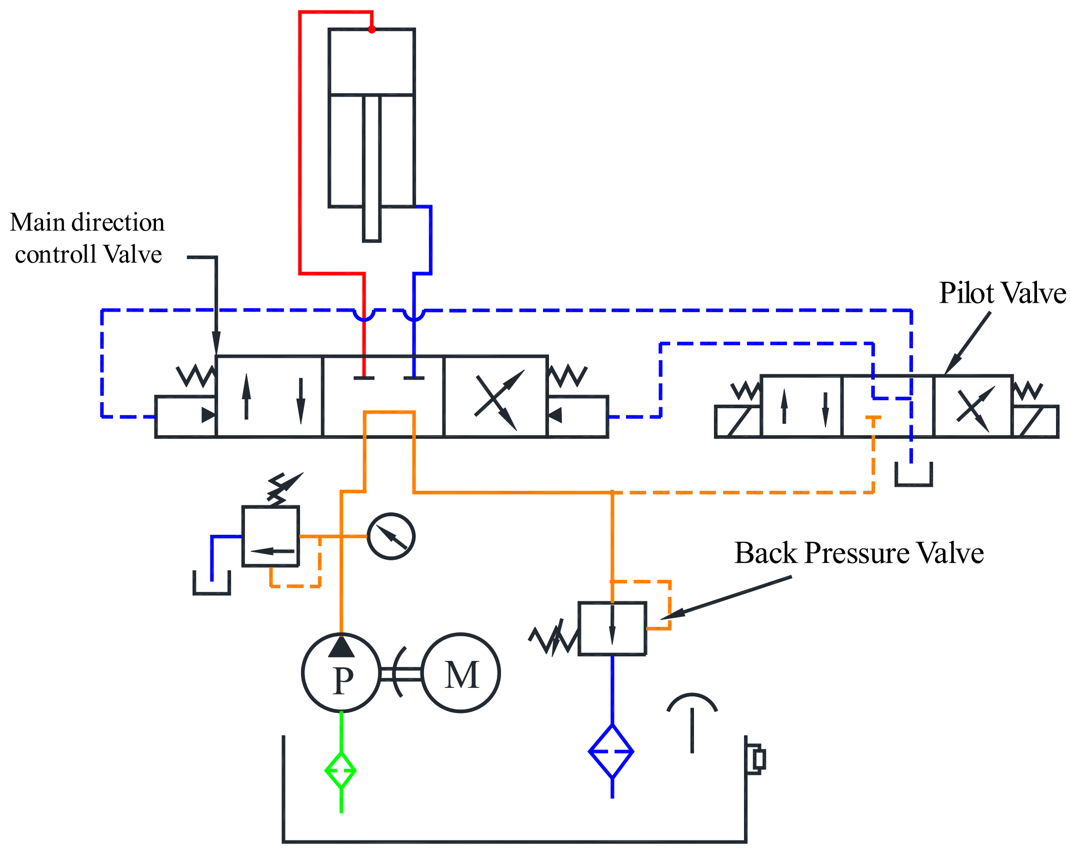


Figure No. 14.2

Back pressure in system by using back pressure relief valve in return line

10.15 Back pressure in a hydraulic cylinder (Counter balance circuit)

Suppose a heavy load is hanging from the piston rod. In such case in forward stroke the cylinder may travel at higher speed than speed possible by pump capacity (discharge volume) of system. In such case vacuum gets created in cylinder, and oil starts evaporating, resulting in spongy action of cylinder.

To avoid over running of piston rod under load, a back pressure is developed in the return port of cylinder using counter balance valve as shown in following circuit diagram.

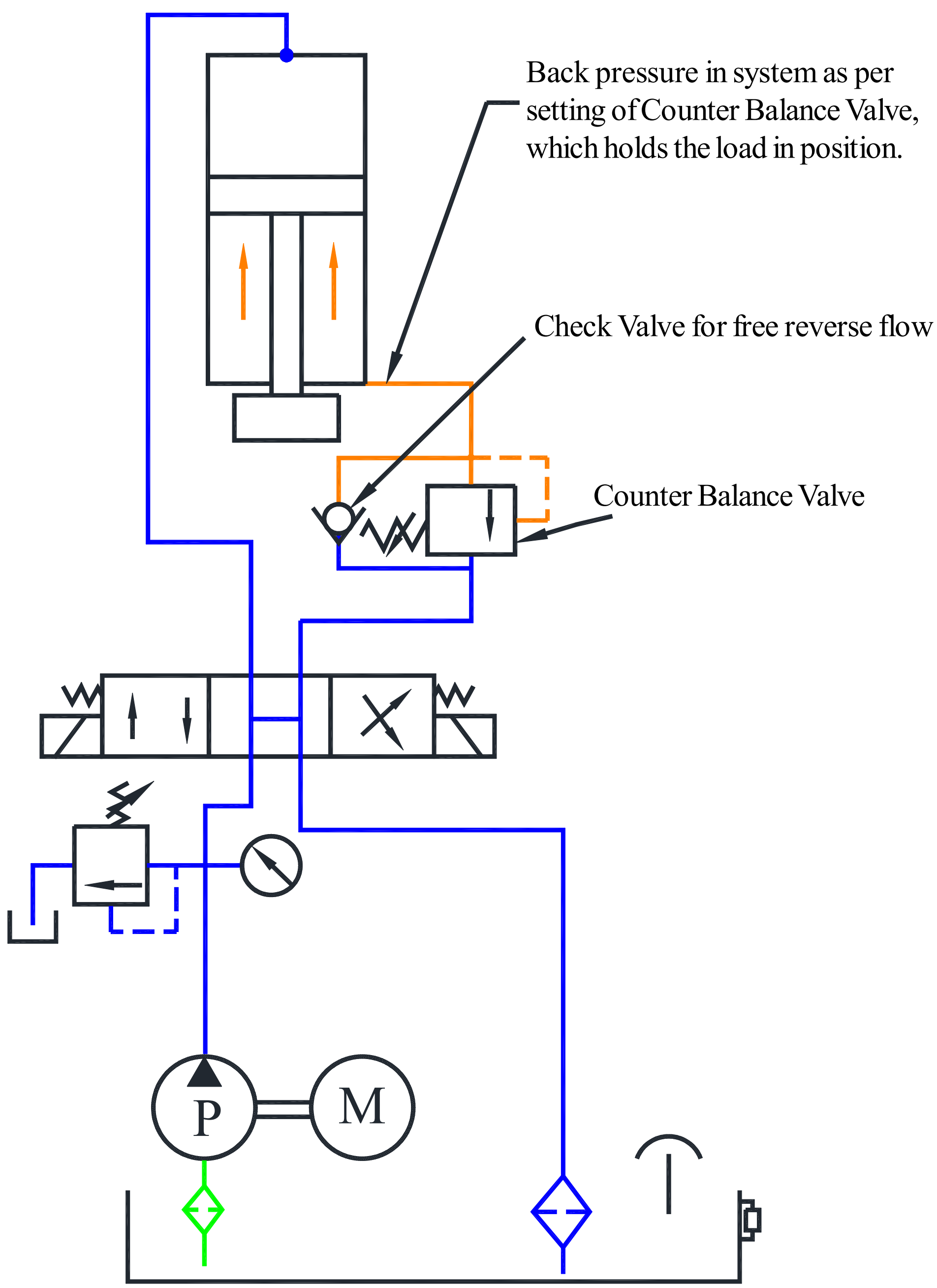
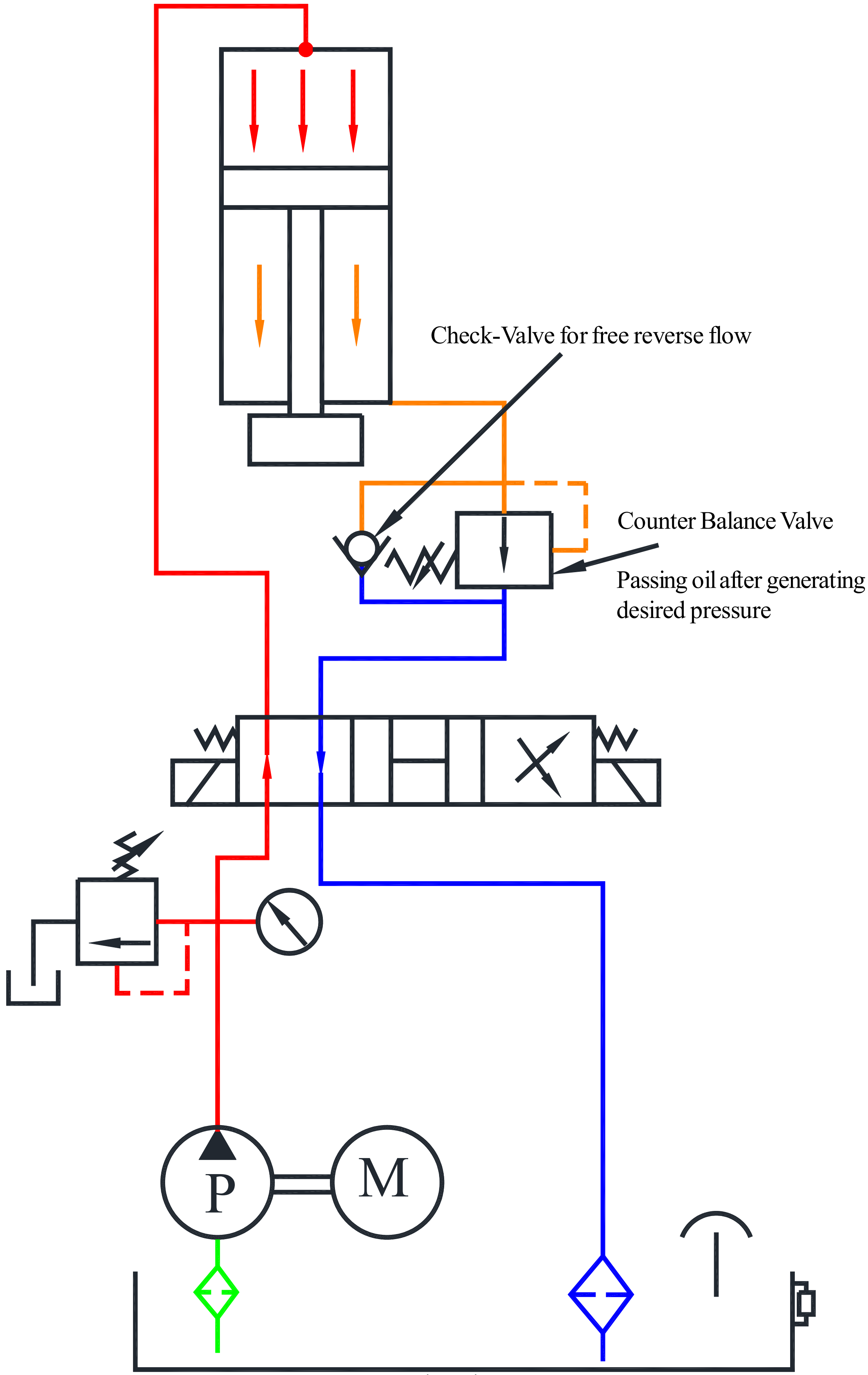


Figure No. 10.15.1

Status of pressure in natural position after forward stroke.



Forward stroke

Figure No. 10.15.2

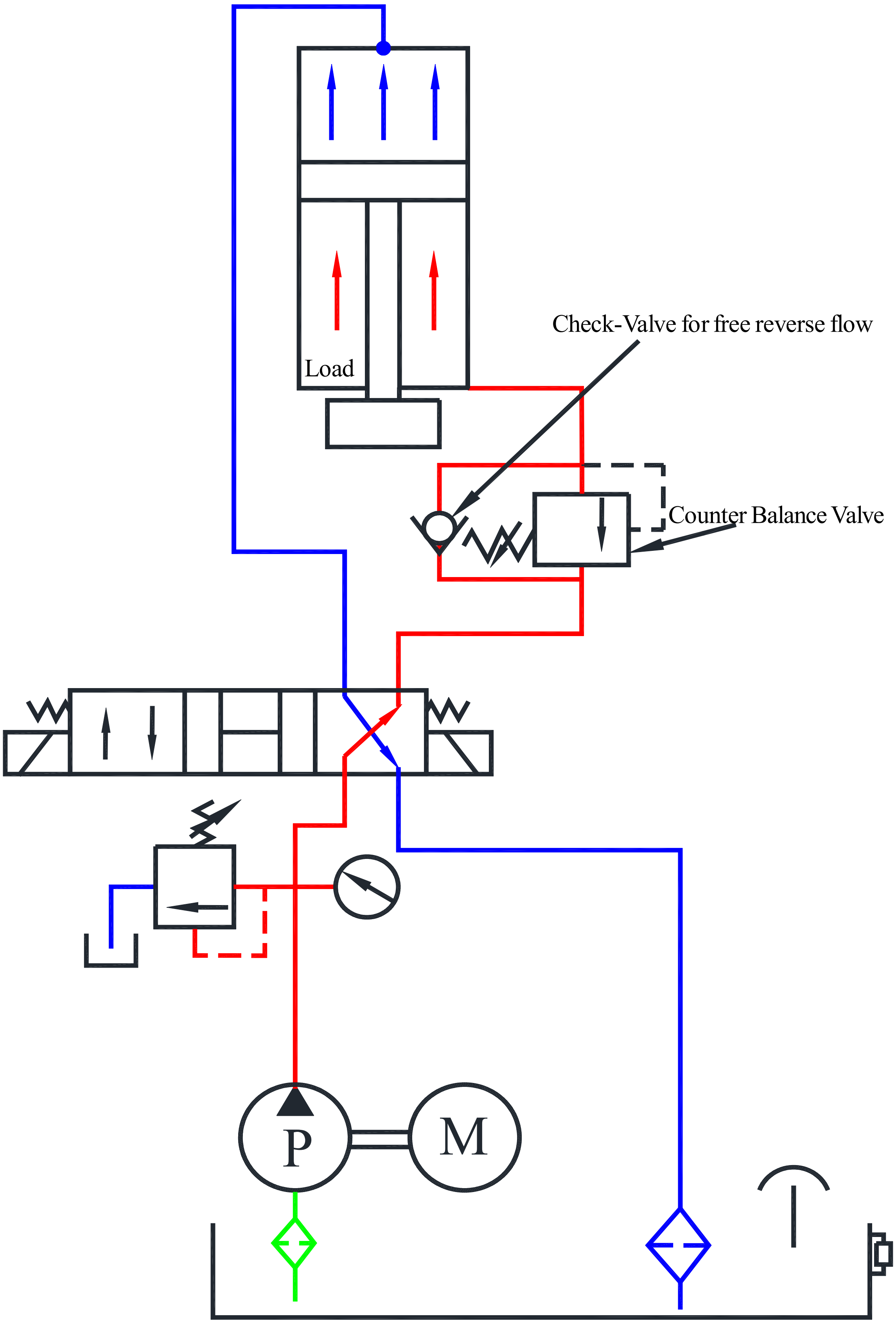


Figure No. 10.15.3

Reverse stroke

10.16 Hydraulic Circuit Using Sequence Valve

Consider a hydraulic press, which has a job-holding or fixing clamp, operated by hydraulic cylinder. When press is operated, first clamp cylinder is required to get actuated and clamp the component. And after clamping component at certain pressure, main cylinder is required to be actuated for pressing operation on the component. By using a sequence valve said requirement could be economically achieved.

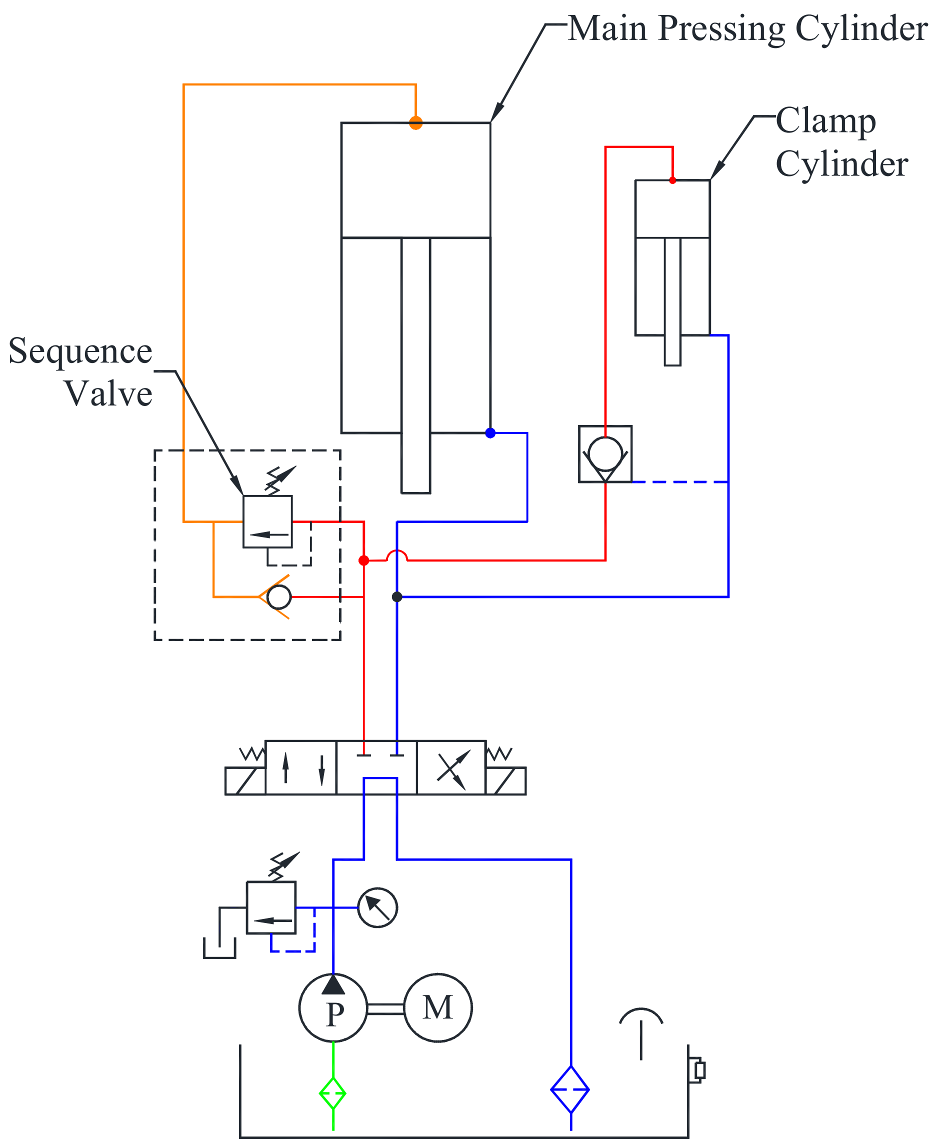


Figure No. 10.16.1

Forward Stroke actuated only for clamping cylinder

In above circuit as soon as solenoid valve actuated. First clamp cylinder will clamp the component, and after developing certain pressure and as per pressure setting of sequence valve, sequence valve will allow main cylinder to be actuated. Hence a performance which was possible by using a costly direction control valve can be achieved by using a economical sequence valve.

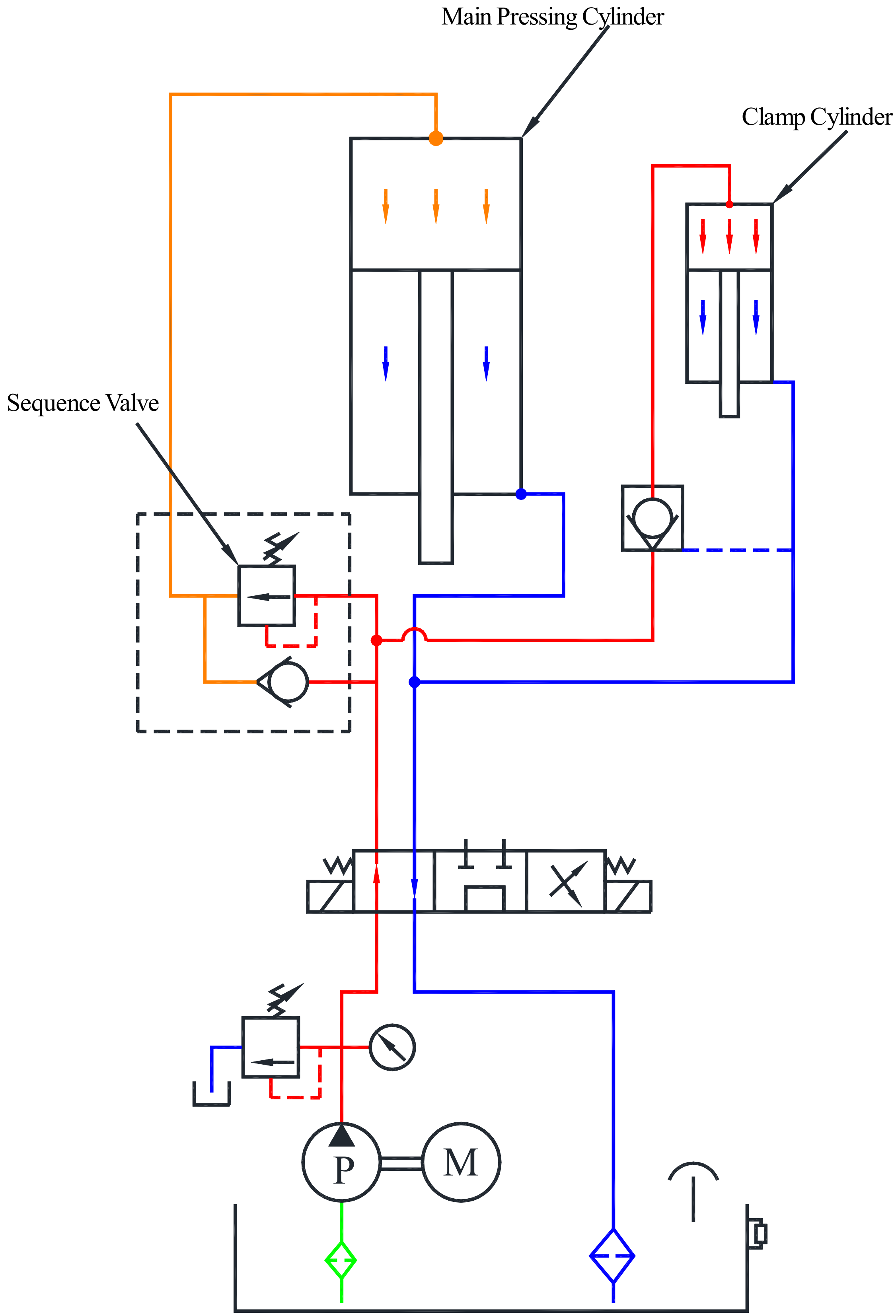


Figure No. 10.16.2

Forward Stroke actuated only for main cylinder

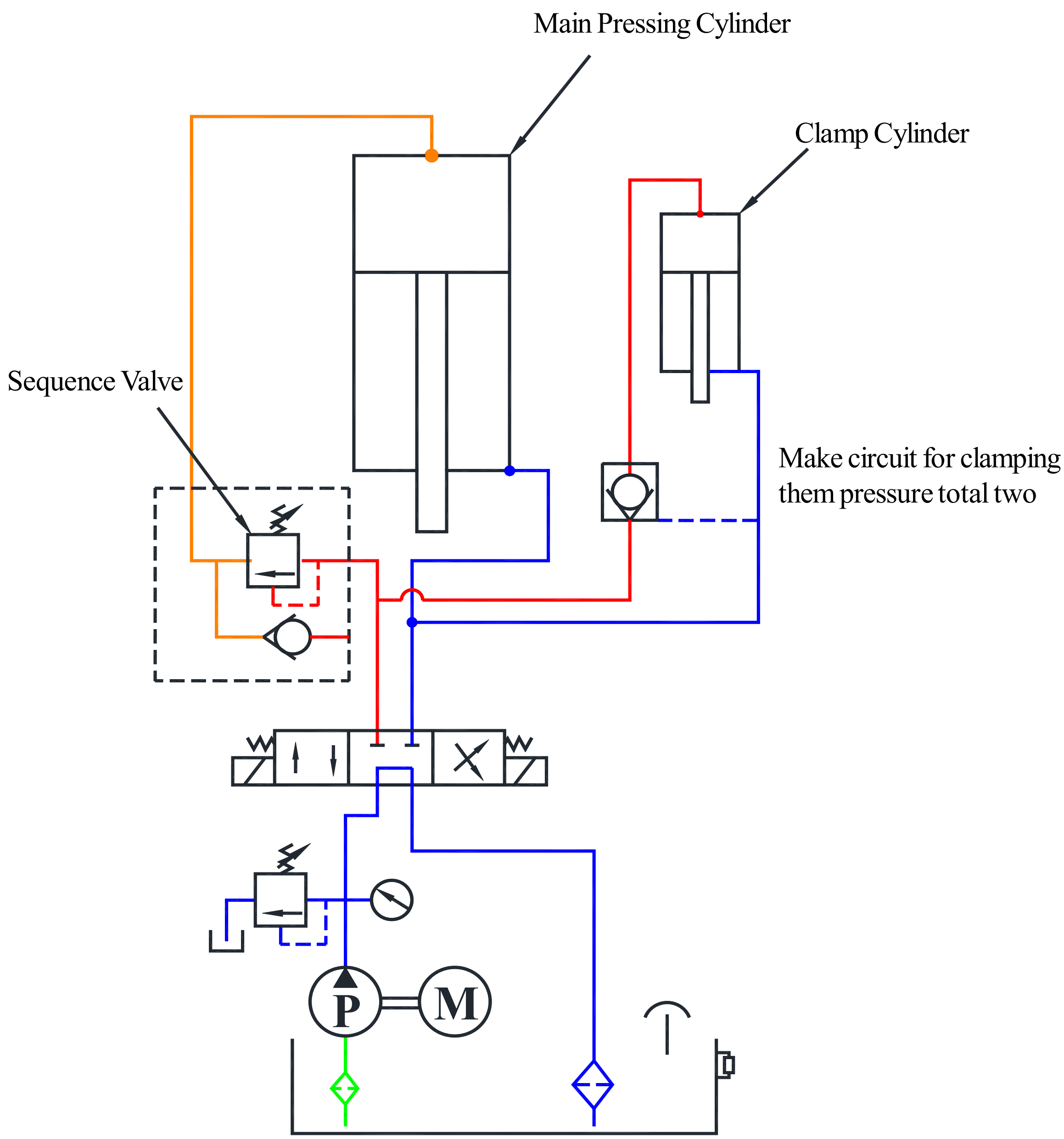


Figure No. 10.16.3

Status of presure in neutral position after forward stroke

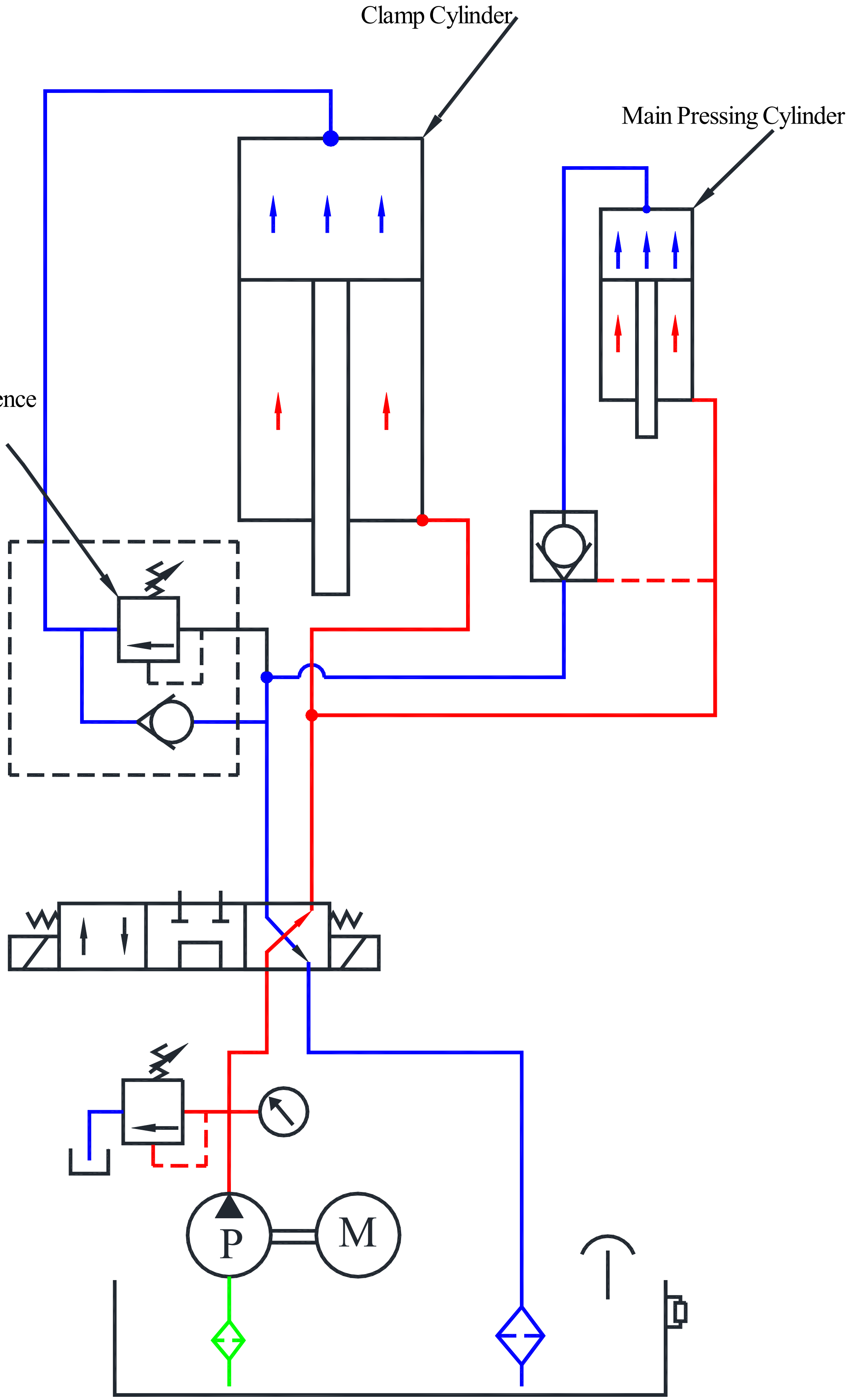


Figure No. 10.16.4
Return Stroke

10.17 Direction Control circuit

Hydraulic Circuit For Actuating Number of cylinder with common Motor and Pump:-

When more than one cylinder is used in a system, and all the cylinders are required to be actuated independently, then more than one direction control valve in circuit is required. If the basic requirement of circuit is that when cylinders are not actuated (in idle condition), pump should be unloaded to tank. And when cylinders are actuated then only pressure gets developed. This could be achieved in number of ways as follow.

a. Using Tendum type direction control valve in series: -

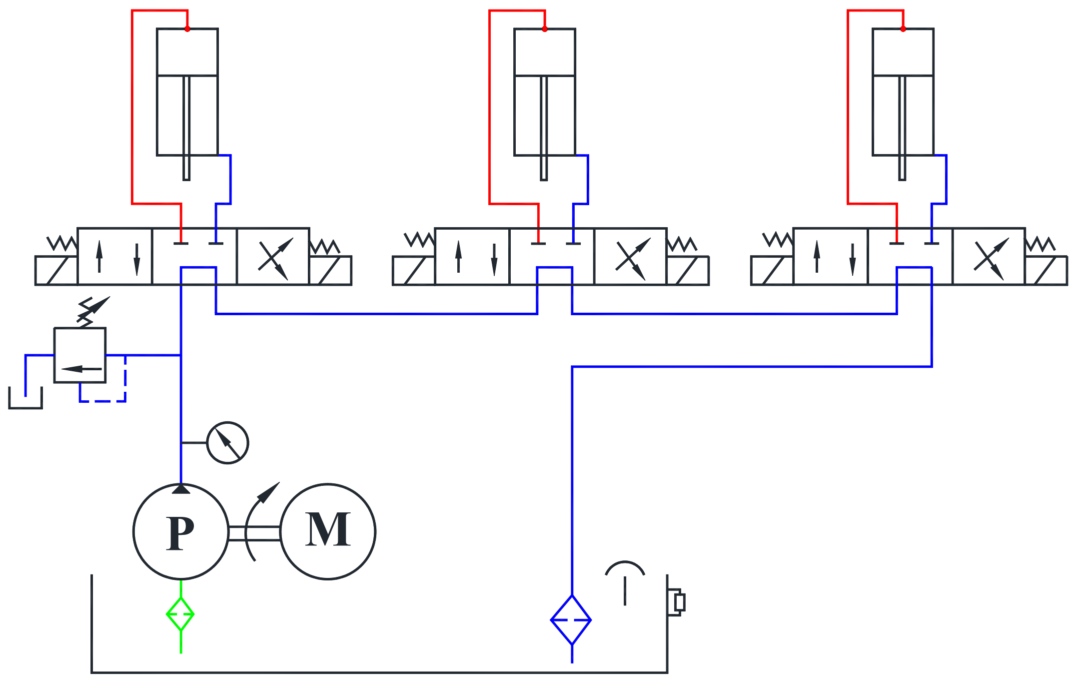


Figure No. 10.17.1
Status of pressure in neutral position after forward stroke.

- This circuit could operate each cylinder independently, but not simultaneously.
- Working pressure of 2nd and 3rd cylinder will depend on the pressure rating of first solenoid valve at its tank port. (It is generally 100 Kg/Cm^2)
- As all the time oil passes from all the direction control valve hence there will be a pressure drop and oil heating, if pump of high discharge is used.

b) Hydraulic circuit to operate more number of cylinders using all-port-block valve and solenoid operated unloading valve.

- In this circuit all the cylinders can have high pressure.
- When none-of the cylinder is actuated, unloading valve will unload pump discharge to tank. When any solenoid operated direction control valve gets activated, solenoid valve of unloading valve should also be actuated to develop pressure in system.
- When lever operated direction control valves are used then addition direction control valve is used in place of unloading valve to unload the pump when not in used, and to develop pressure when required. Pressure developing direction control valve is always operated with all the direction control valves.

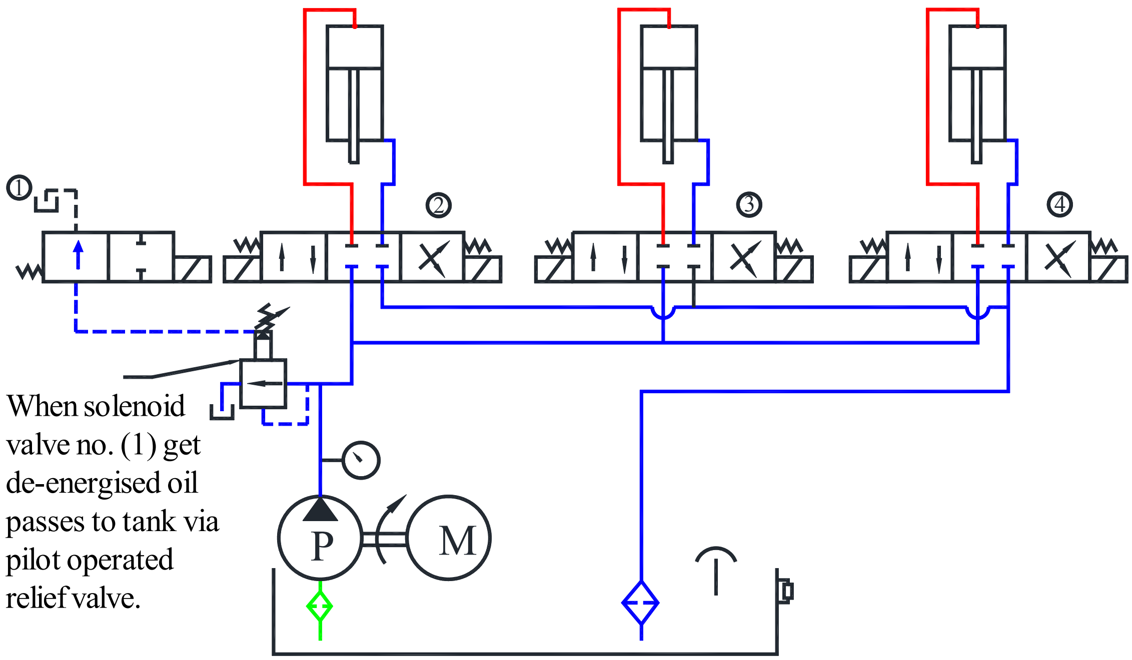


Figure No. 10.17.2
Status of pressure in Neutral Position after forward stroke.

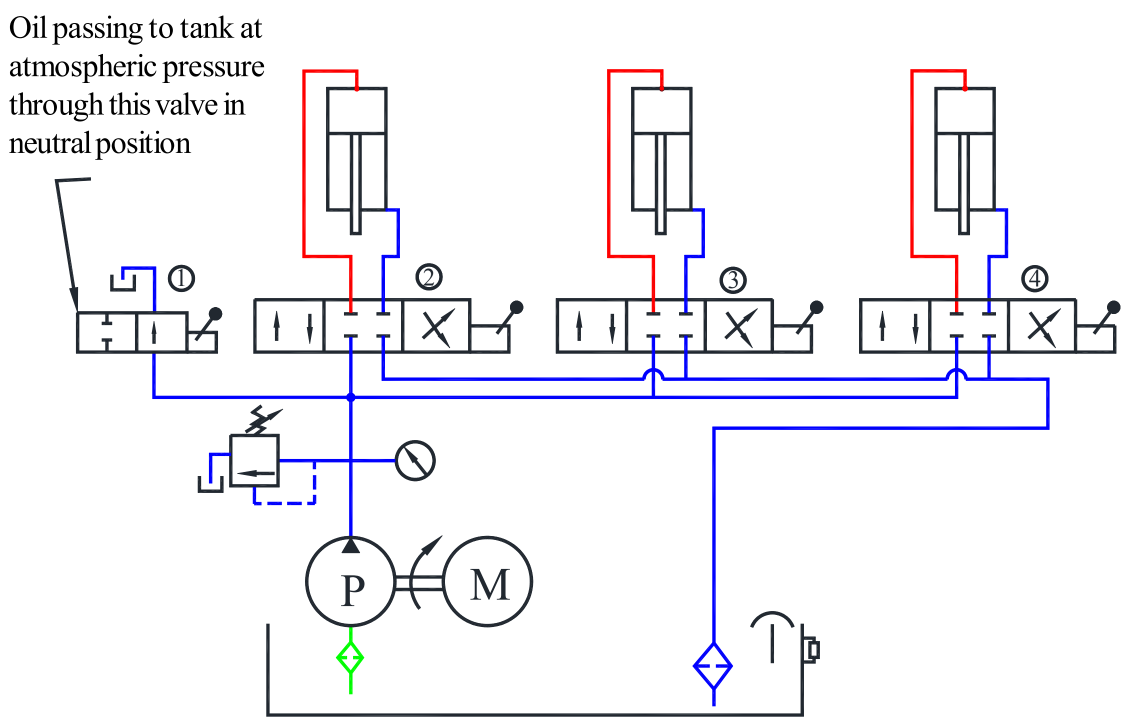


Figure No. 10.17.3
Status of pressure in Neutral Position after forward stroke.

10.18 Regenerative Circuit

This is special type of circuit, and named as regenerative circuit, because we re-use the exhaust oil coming out from return port of cylinder while cylinder is taking forward stroke. And exhaust oil along with pump discharge is supplied again to the cylinder for its forward stroke. Following circuit will explain its principle.

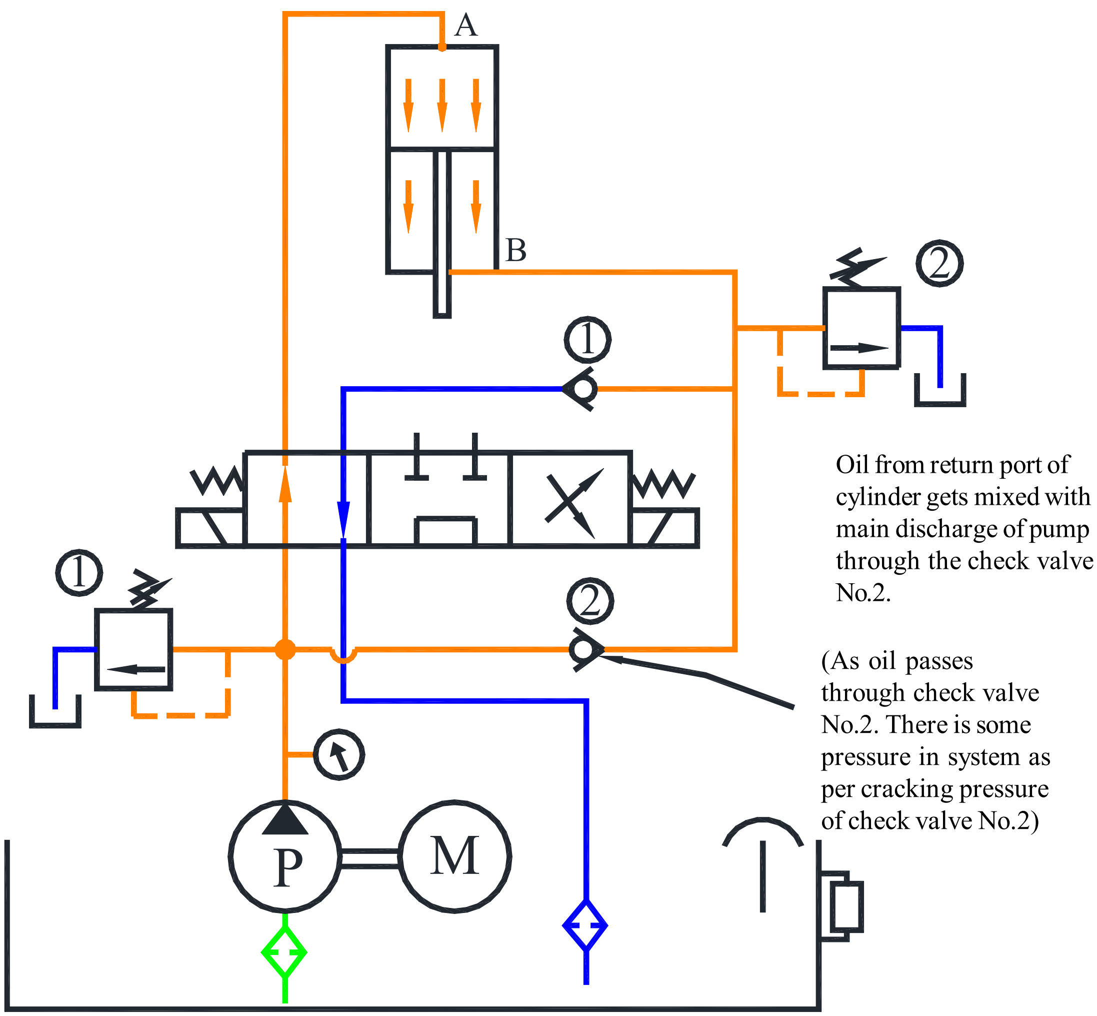


Figure No. 10.18.1

Forward Stroke at low pressure

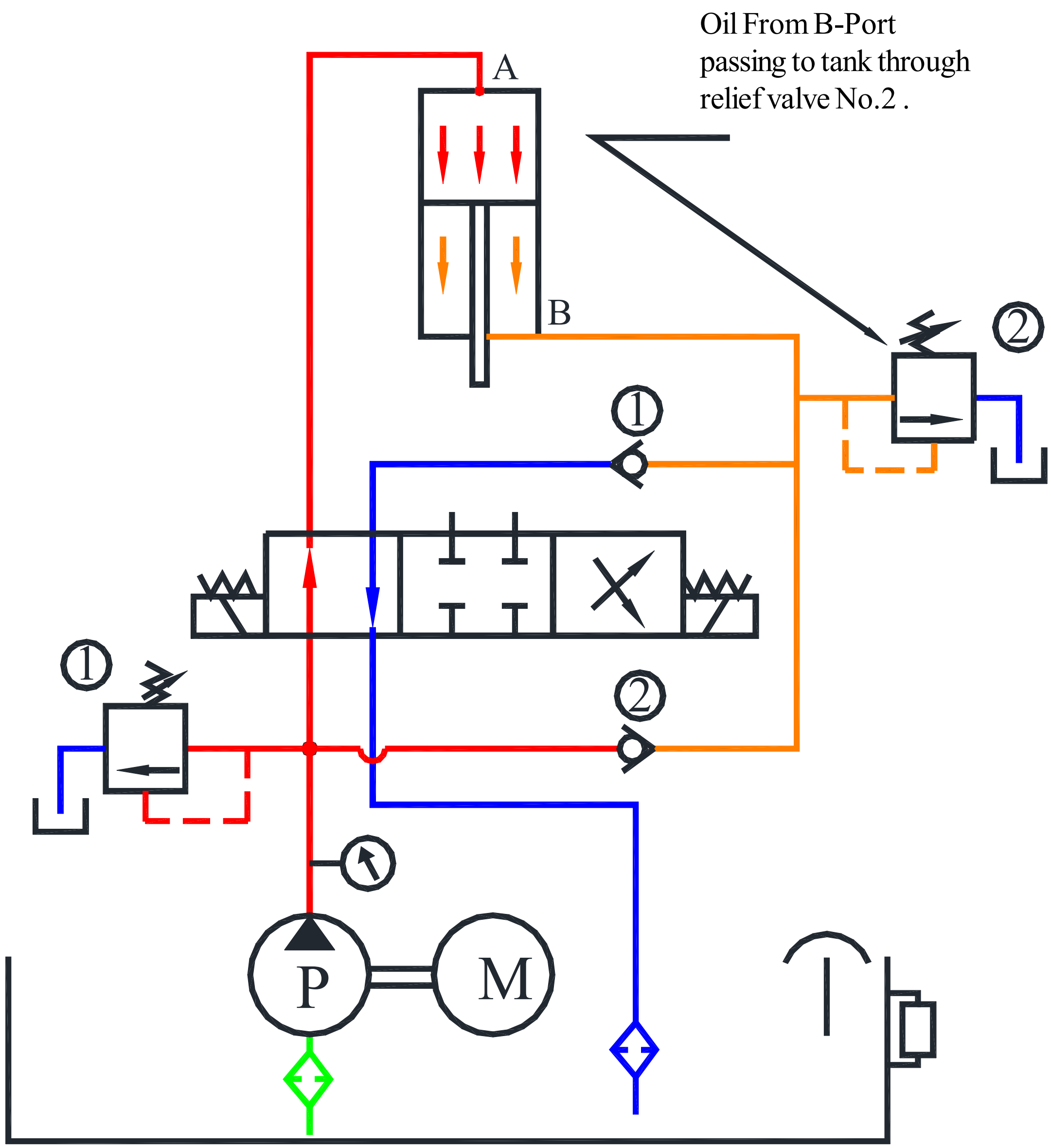


Figure No .10.18-B
Forward stroke under pressure

Oil will not pass through check valve (2), because there is higher pressure on pump side.

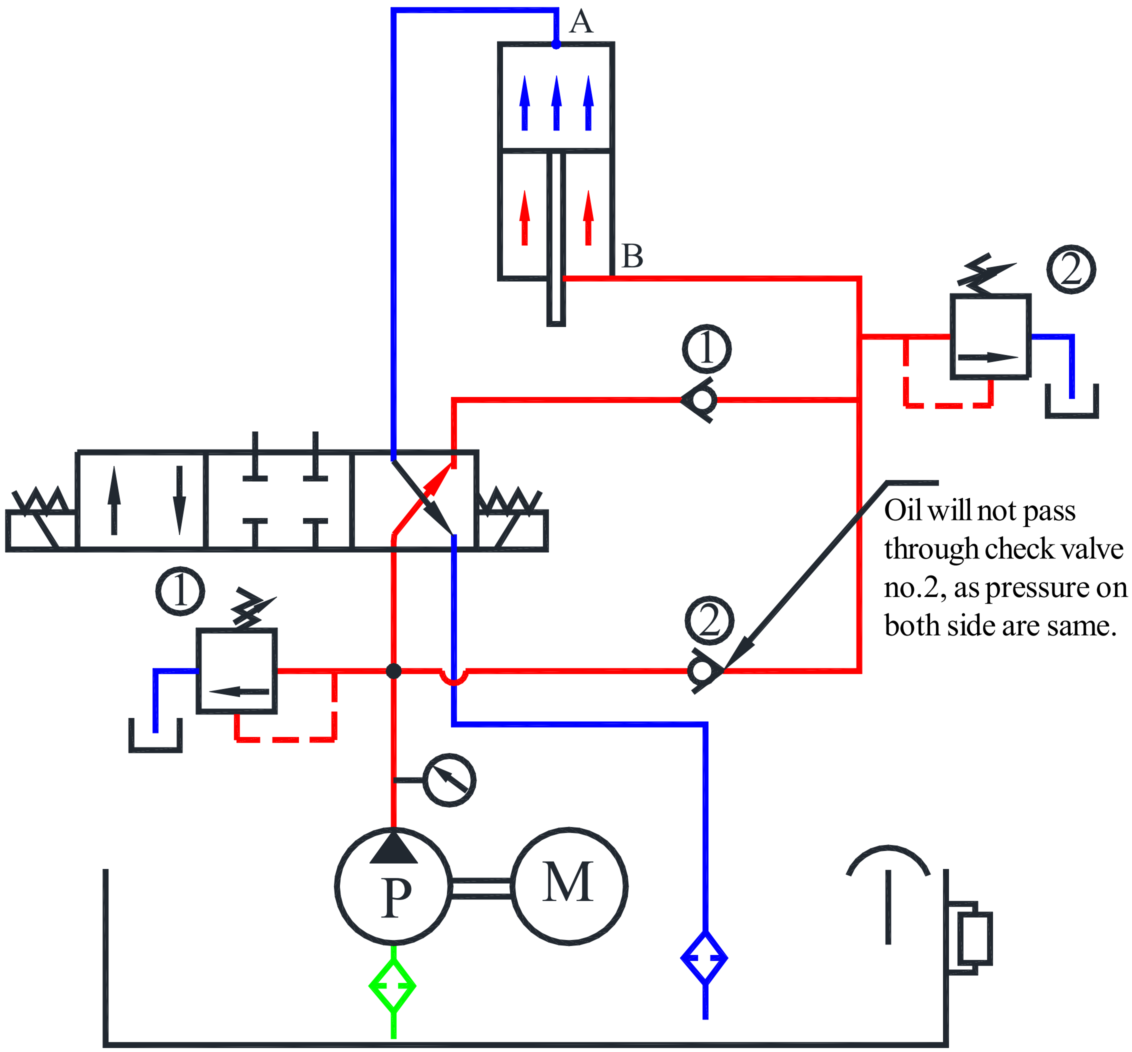
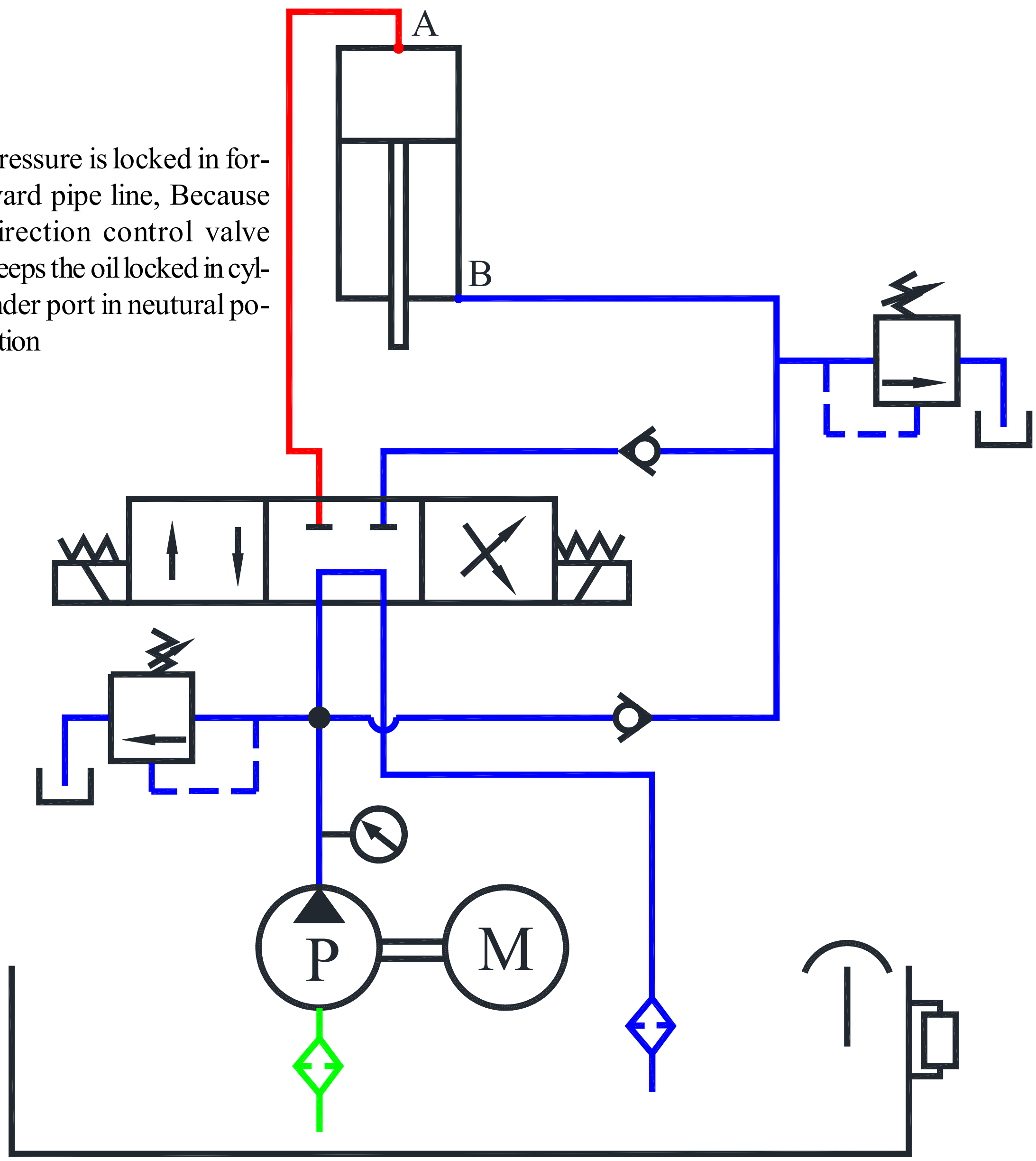


Figure No. 10.18-C
Return stroke

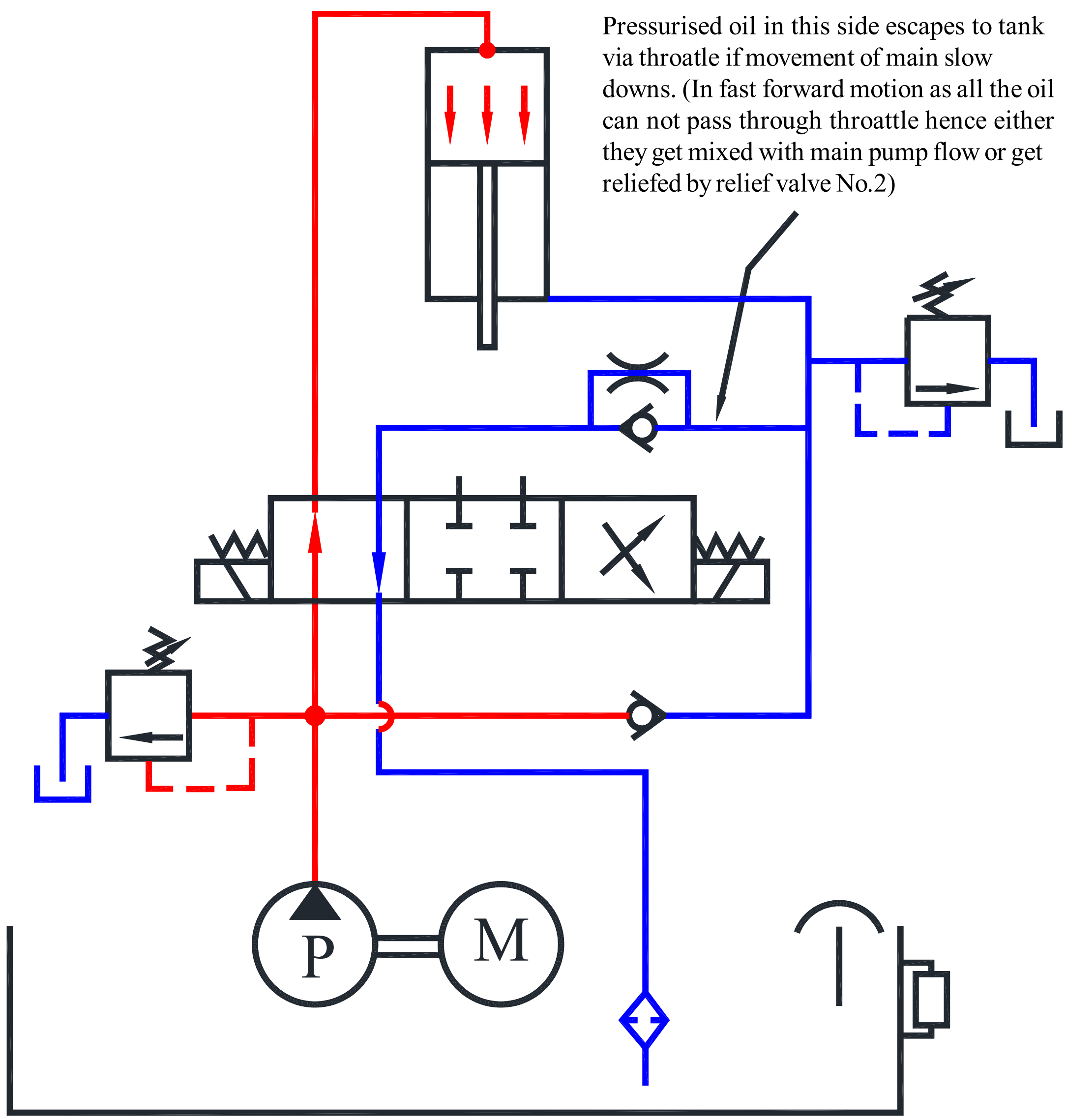


Pressure is locked in forward pipe line, Because direction control valve keeps the oil locked in cylinder port in neutural position

Figure No. 10.18-D
Status of Pressure in Neutral
Position after forward stroke.

- In re-generative circuit as all the oil exhausted from B-port combined with pump discharge, and supplied to port-A. Hence cylinder speed will be more than the speed which could be achieved by using only pump.
- If the cross-section area of ram is exactly half of the cross-section area of cylinder. Then we get same forward and reverse speed.
- As pump pressure increases, back pressure at B-port also increase. Due to higher backpressure the effective compressive load which cylinder can develop get reduced correspondingly.
- To reduce backpressure many arrangements are used. Some of which are as follow.

a) When after developing pressure cylinder does not have to travel any longer, as in case of coining, embossing etc. then an orifice provided parallel to check valve reduces the build-up backpressure. But this also reduces forward speed slightly. Because from return port some oil escapes from orifice and returns to tank (instead of getting mixed with pump discharge).



Forward stroke under pressure by very slow movement (for for coining forming)

Figure No 10.18-E

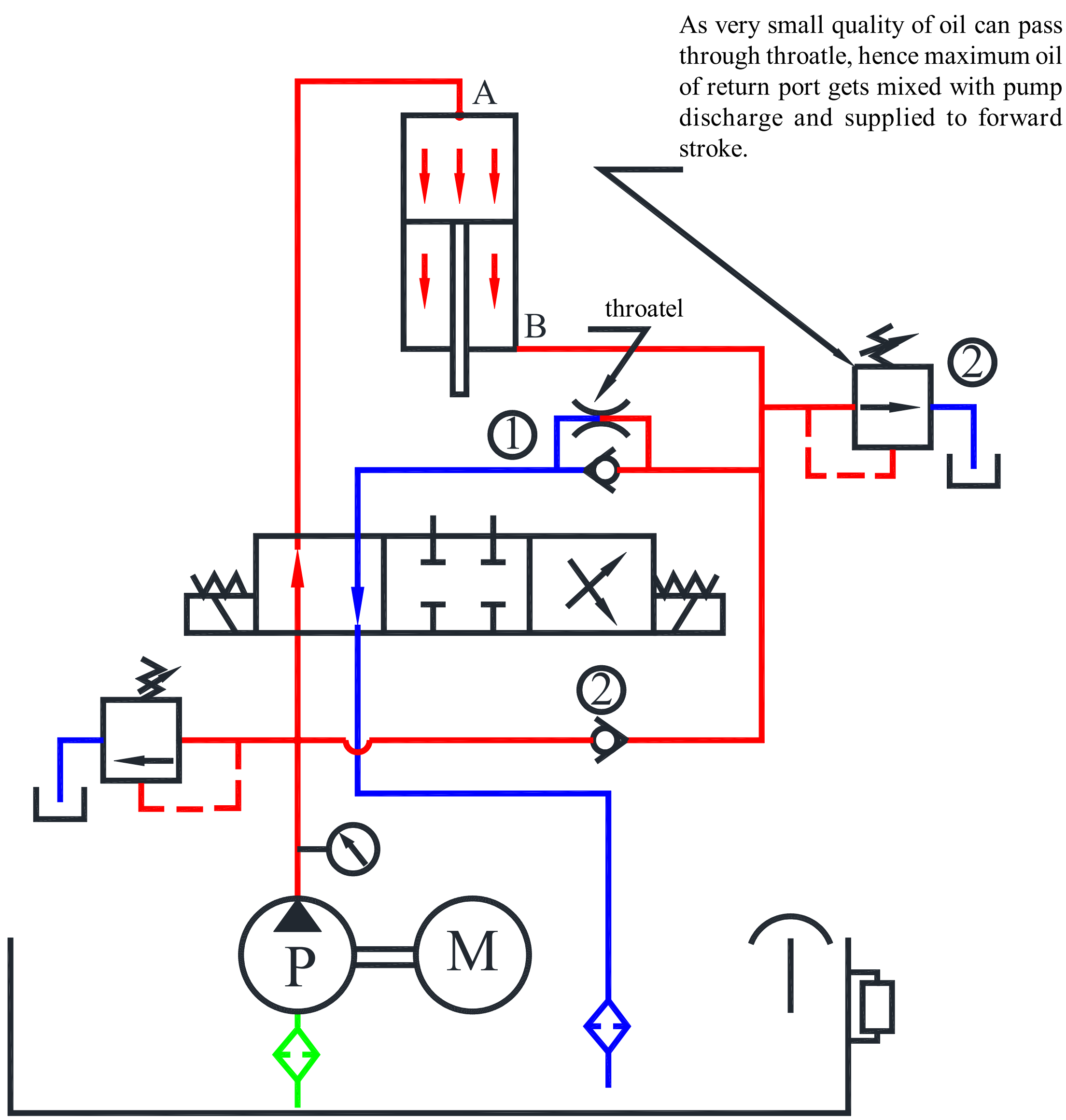


Figure No. 10.18-F
Forward stroke
under pressure and fast movement (before coining and forming operation)

Regenrating circuit with unloading valve in return port of cylinder

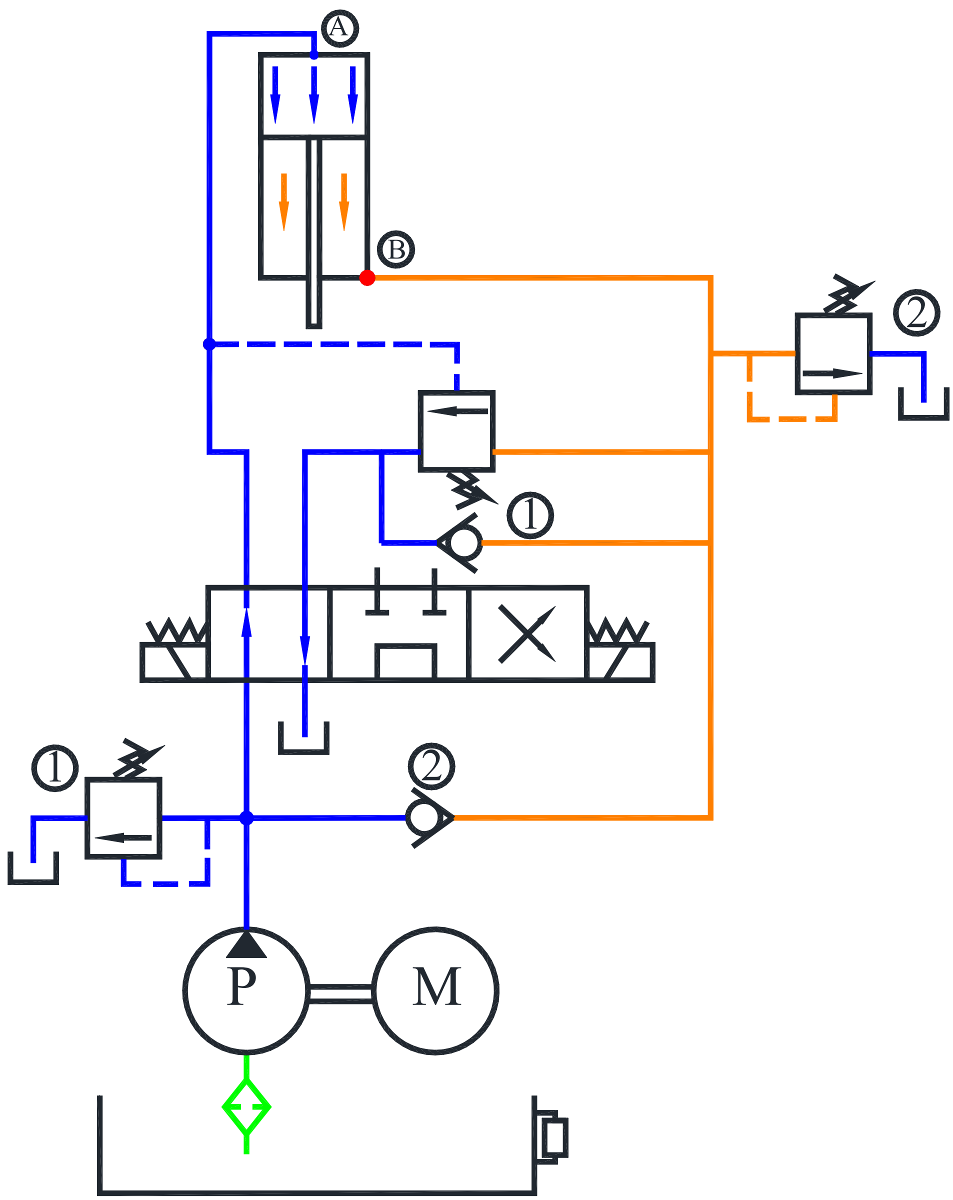


Figure No. 10.18-G

Forward stroke without pressure

(A-Port side of piston area is larger than B-port side of piston area Hence a slight pressure on A side develops high pressure on B side. Oil on high pressure gets mixed with oil on lower pressure through check valve No.2)

b) In following circuit as soon as some pressure gets developed at A-port, oil coming out from B-port gets unloaded to tank through unloading relief valve. Hence backpressure gets mini-

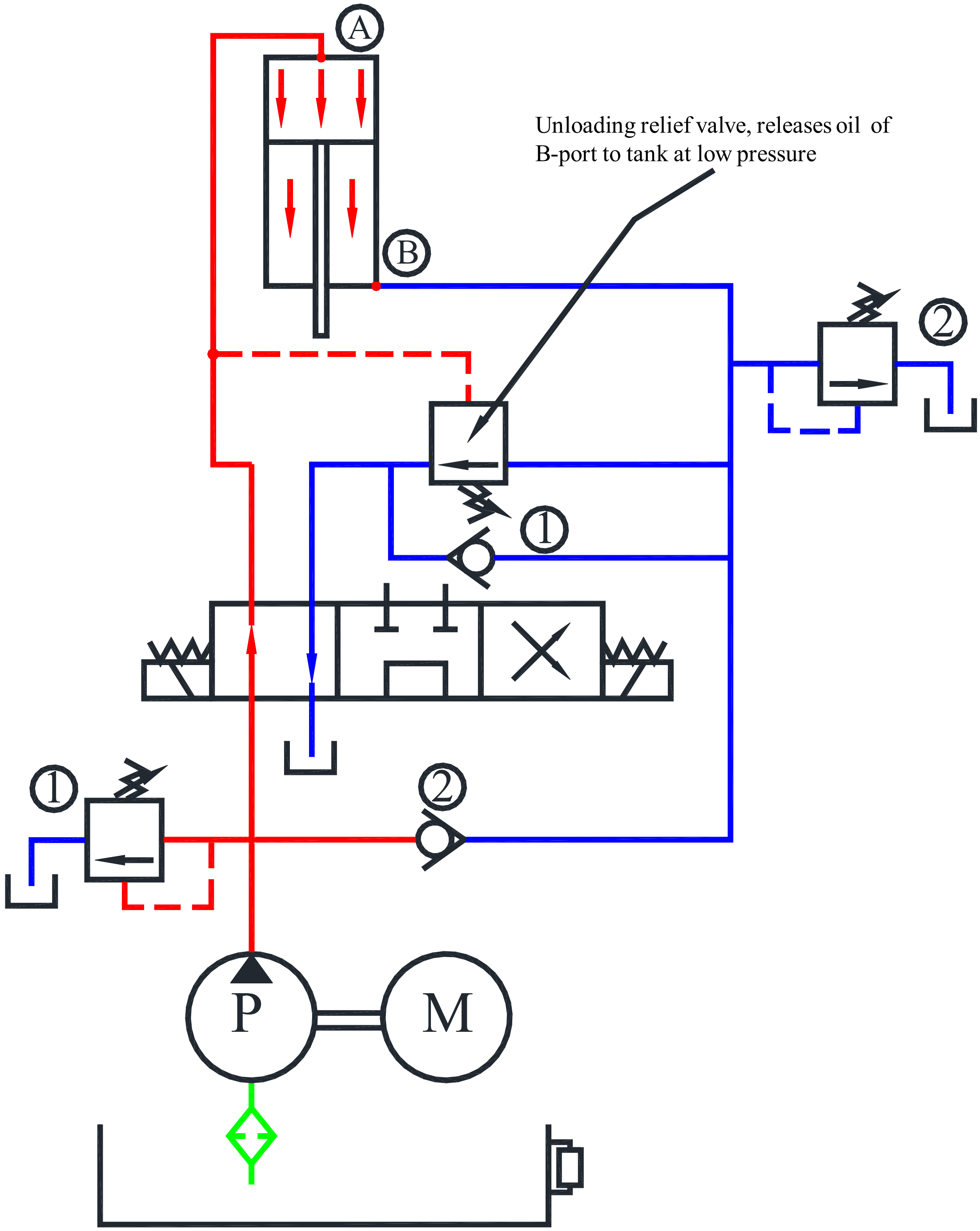


figure No. 10.18-H
Forward stroke under pressure

(After facing resistance when pressure of A-port side increased more than B-port side, oil stops mixing through Check Valve No.2)

mized.

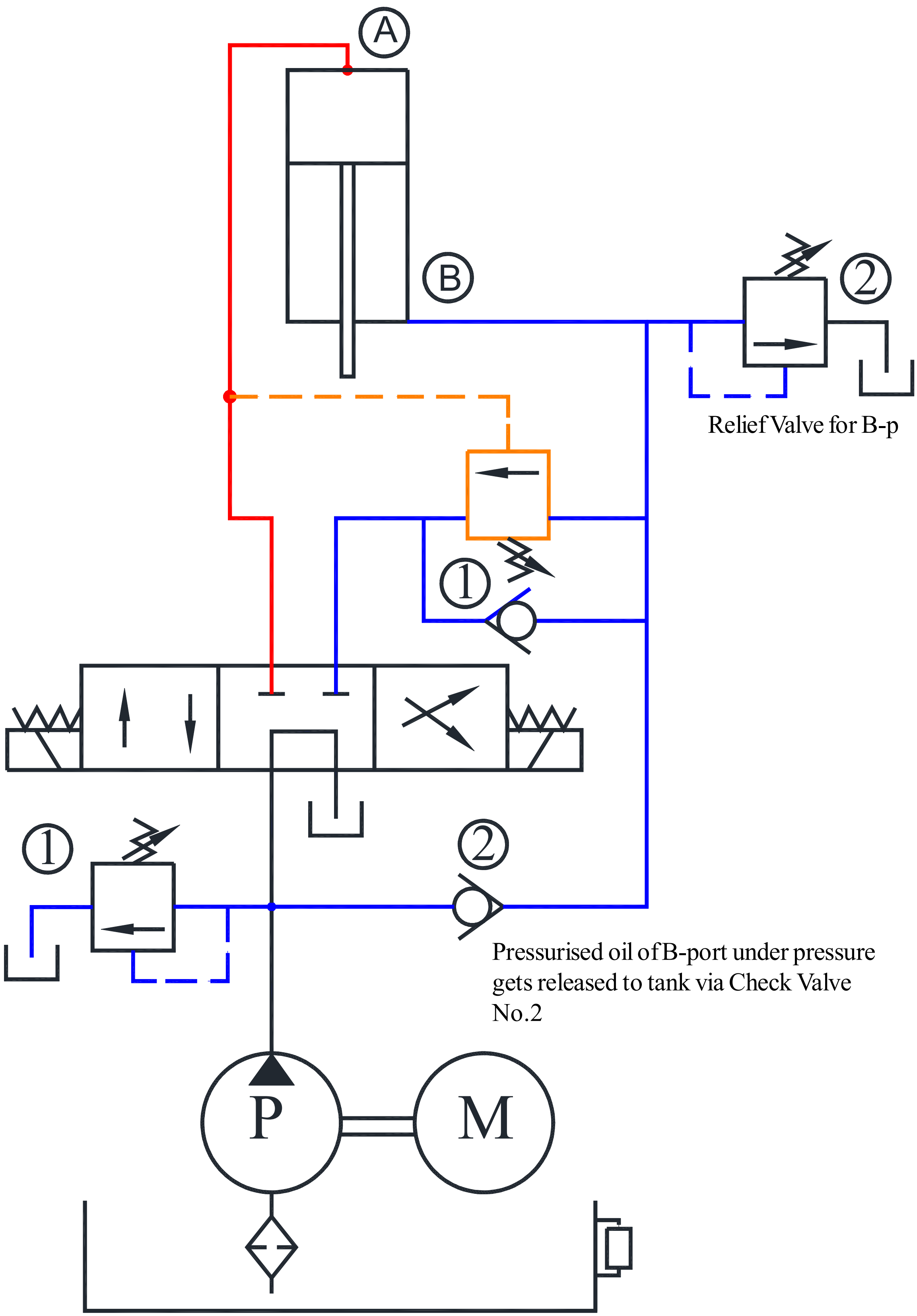


Figure No. 10.18- I
Status of Pressure in Neutral
Position after forward stroke

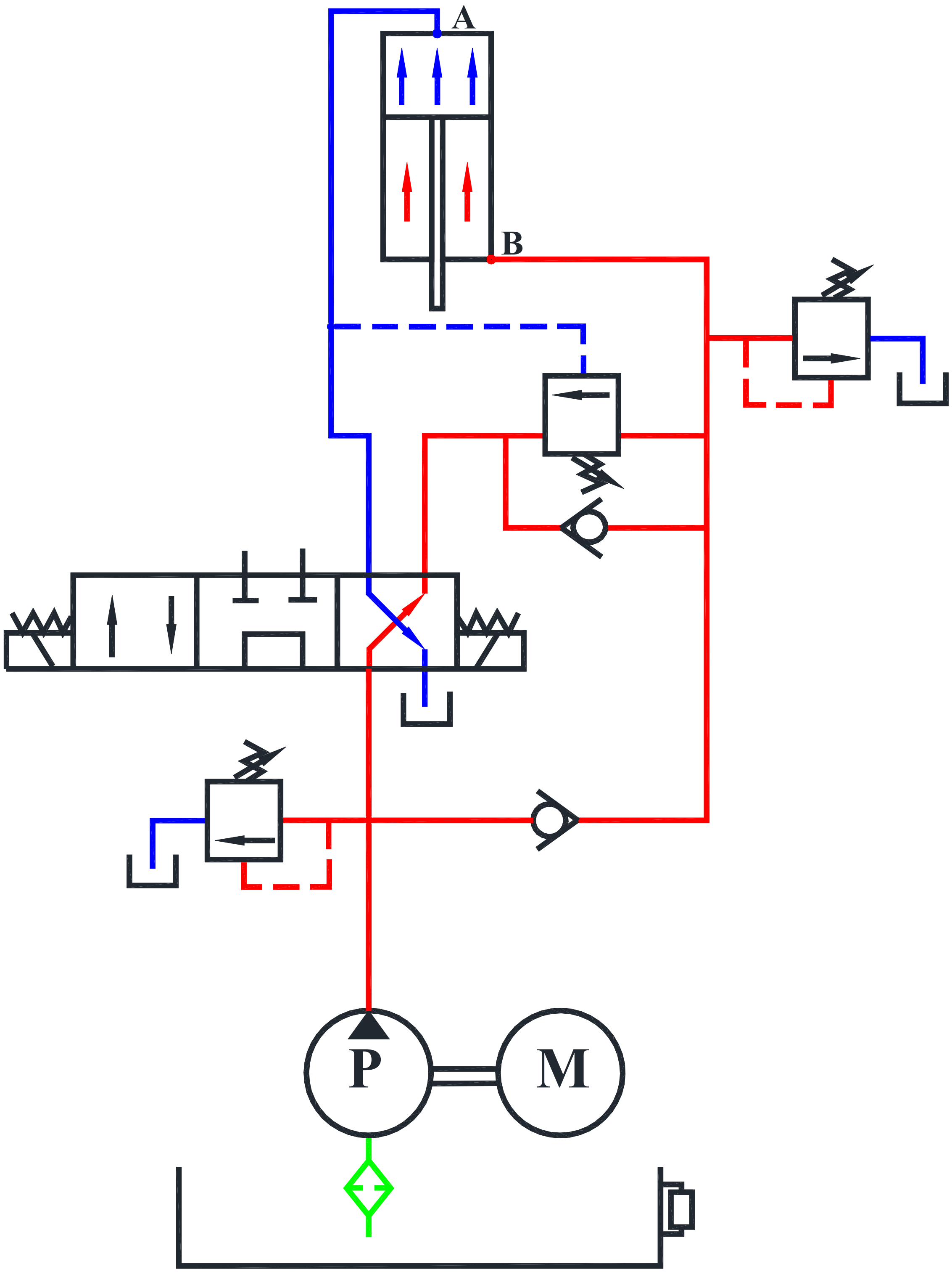


Figure No. 10.18-J
Return stroke

10.19 Brake Circuit

When motor rotates at a load. Even after the supply to motor switched off, due to inertia of load motor keeps on rotating. To stop the motor following circuit may be used.

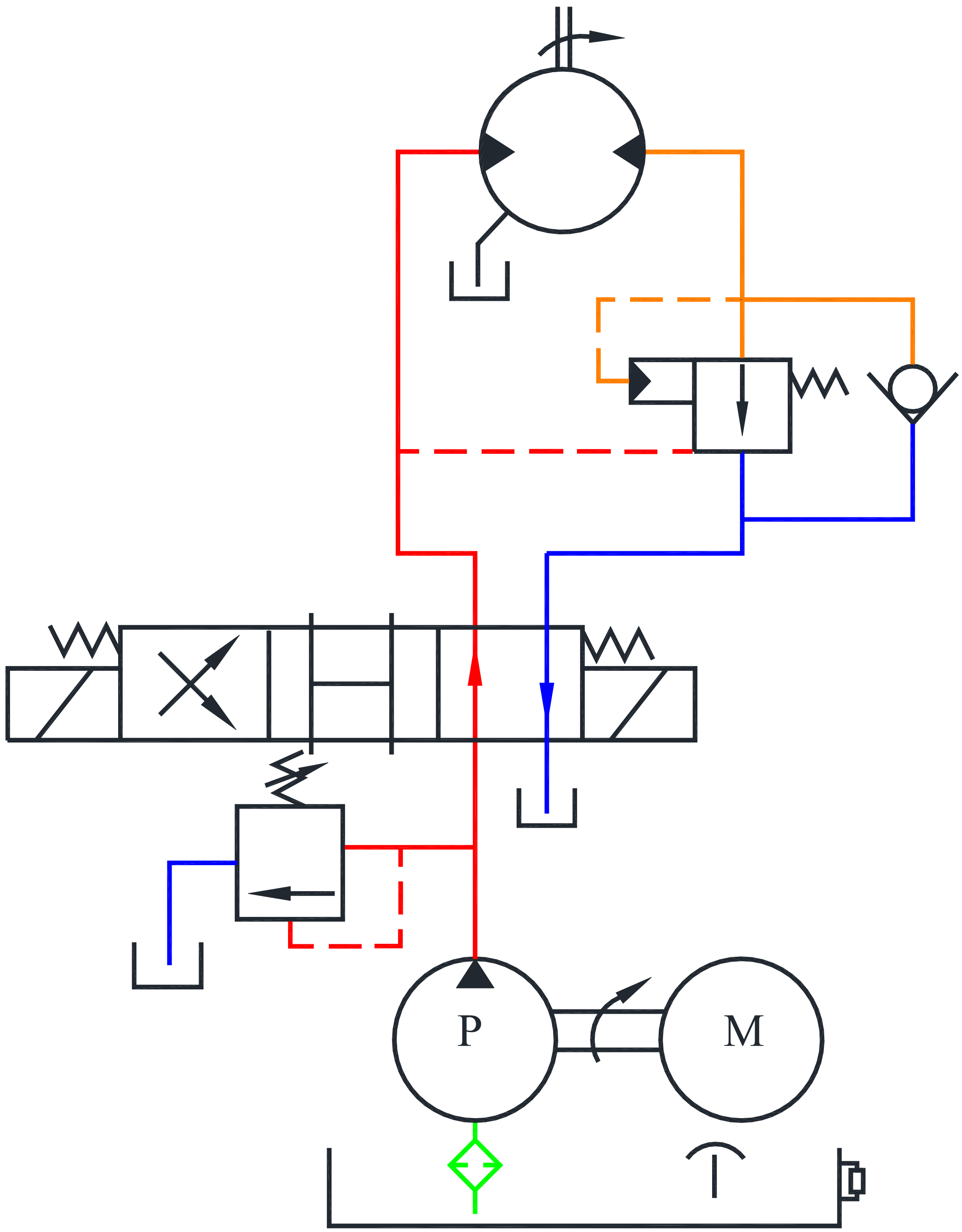


Figure No. 10.19.1

Forward stroke.

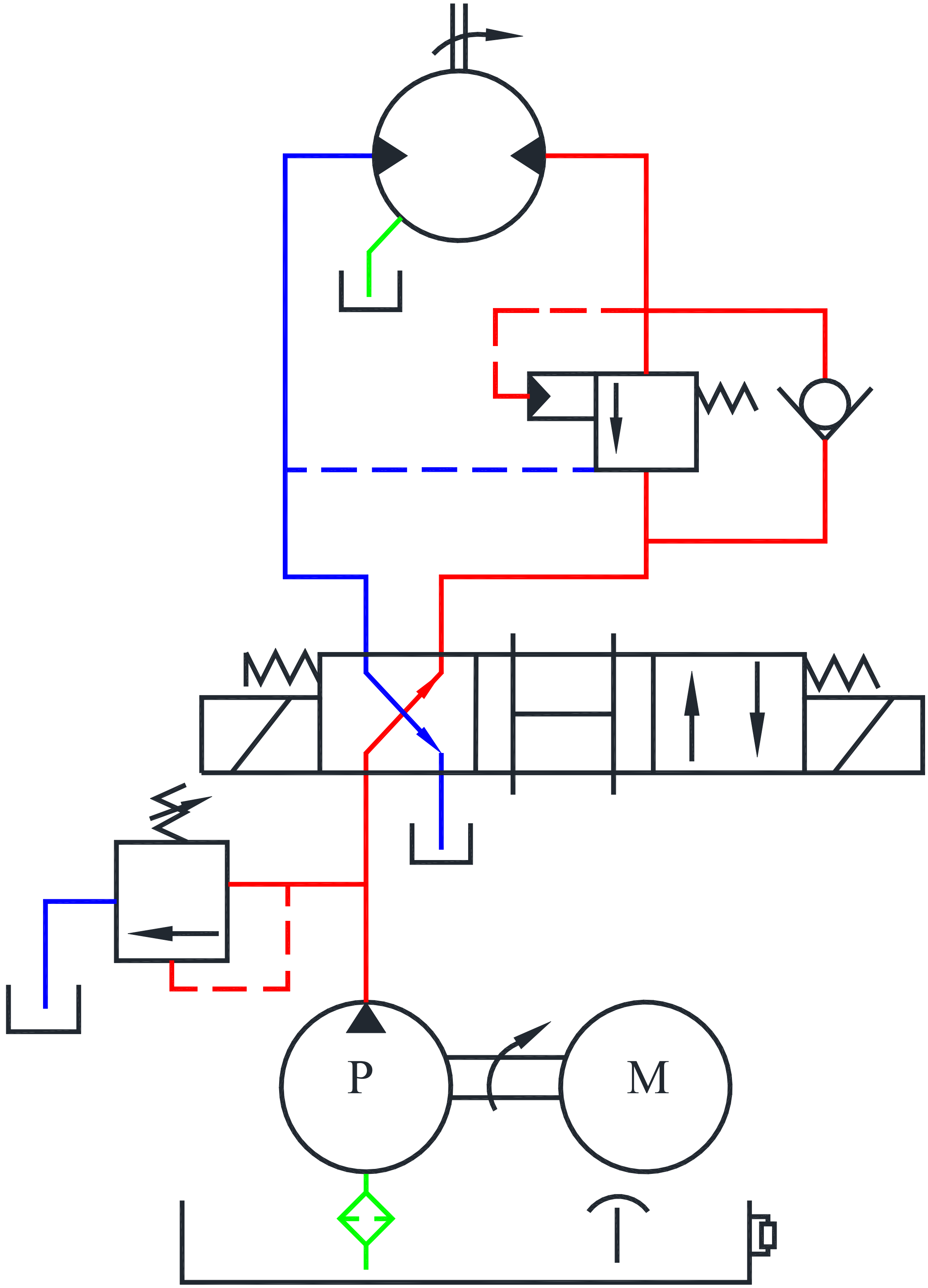


Figure No. 10.19.2

Reverse stroke.

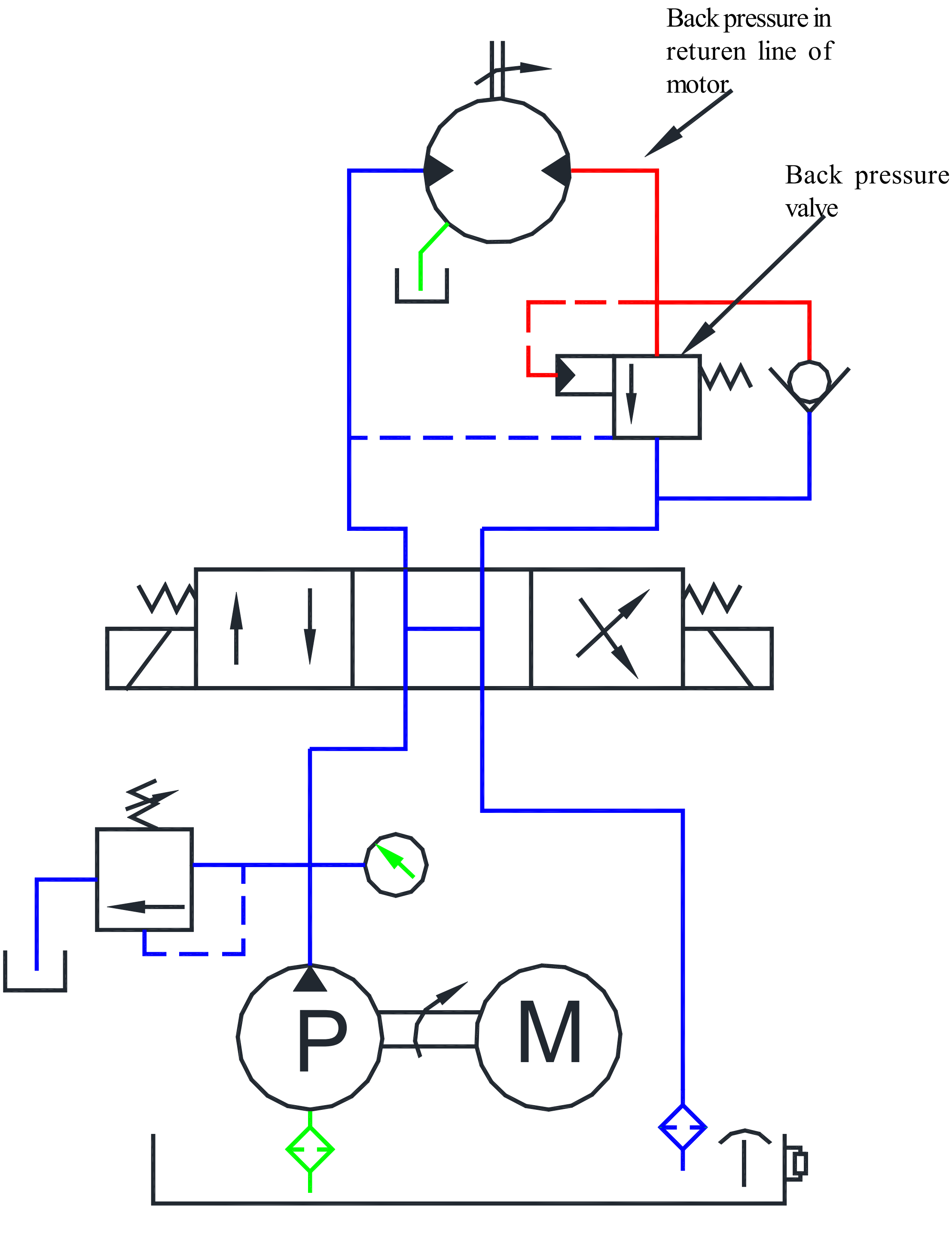


Figure No. 10.19.3
Neutral Position

Due to back-presure valve, motor faces a constant resisting pressure or force. This offers resistence to extra rotation of motor due to inertia of rotating load.

10.20 Flow control circuits

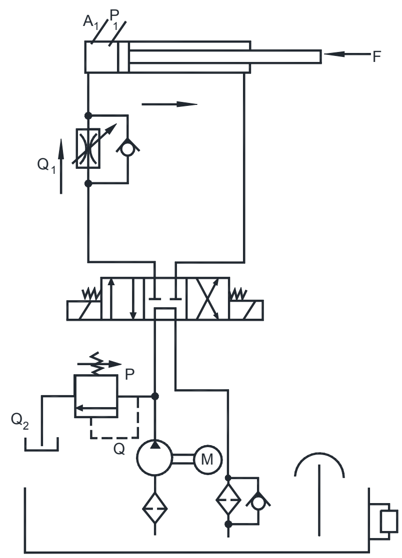


Figure No 10.20.1

Meter-in type circuit:-

In meter-in type of circuit we control flow of oil entering on actuator.

Q = Pump output (LPM)

Q_1 = Fluid volume (supplied to actuator)

Q_2 = Fluid volume returning to tank (through relief valve)

P = Pump pressure (kg/c^2)

P^1 = Back-pressure in actuator due to resistance

A^1 = Area of cylinder (cm^2)

Loss of energy in Meter-in-type will be

$$Le = \frac{PxQ_2}{612} - \frac{(P-P_1)xQ_1}{612} \text{ (Kw)}$$

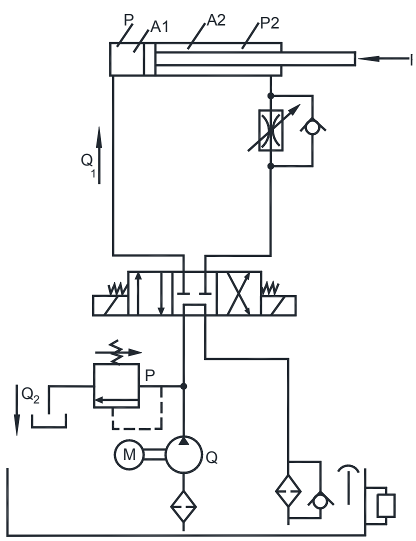


Figure No 10.20.2

Meter out type circuit:-

In meter-out type of circuit we control flow of oil exhasting (comig -out) from actuator.

Q2 = Q-Q1

$$P_2 = \frac{(PxA)-F}{A_2}$$

For same working presure and same setting of flow control valves, the energy loss is same in meter-in and meter-out circuit.

$$Le = \frac{PxQ_2}{612} - \frac{(P-P_2)xQ_1}{612} \text{ (Kw)}$$

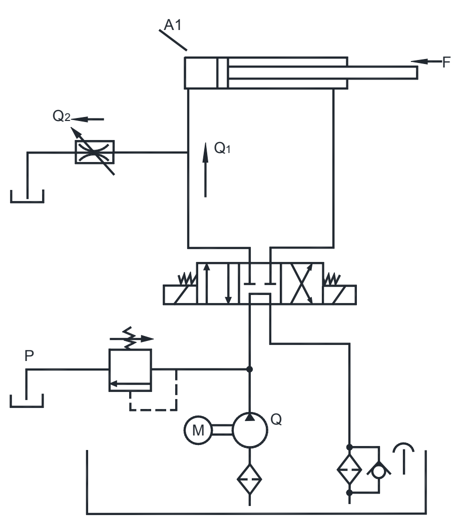


Figure No 10.20.3

Bleed-off type circuit:-

In bleed-off circuit by by-pass extra oil to tank.

$$P = \frac{F}{A_1}$$

$$\text{Loss of energy} = Le = \frac{PxQ_2}{612} \text{ (Kw)}$$

In bleed-off type circuit the loss of energy is less than meter-in or meter-out type of circuit.

Many time different speed of actuator required using single pump. In such situation following circuits are used depending on requirement

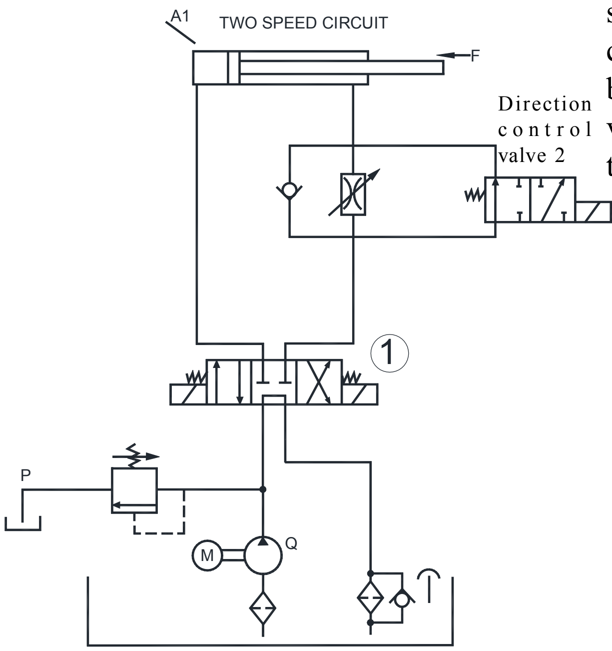


Figure No 10.20.4

4) Two speed circuit:-

In this circuit we have option of having full speed, which we achieve by by-passing flow control valve. Or we can have controlled speed by using flow control valve. Direction control valve No.2 we use for by-passing or blocking the flow

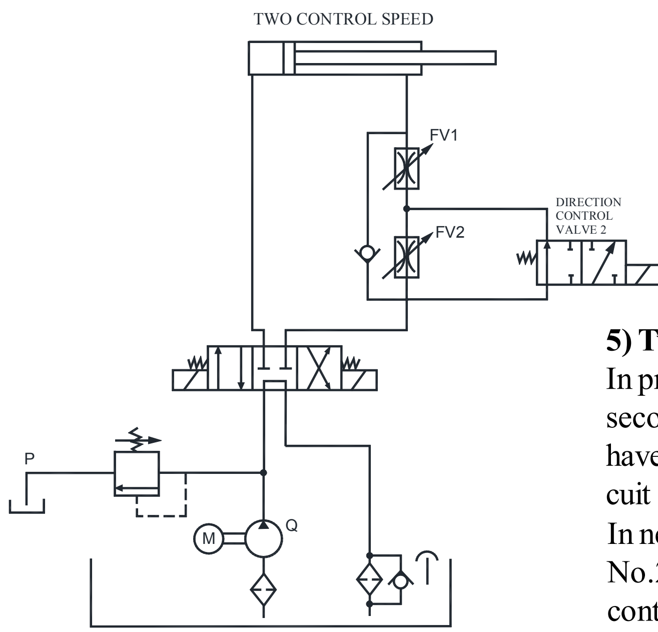


Figure No 10.20.5

5) Two control speed:-

In previous circuit we had one full speed and second controlled speed. But if we want to have two controlled speed then followng circuit is used.

In neutral position of direction control valve No.2. We have speed as per setting of flow control valve number - FV_1 .And when direction control valve No.2 is energised then we have speed as per combined setting of FV_1 & FV_2.

Functioning of two speed circuit (In this circuit both the speed could be adjusted).

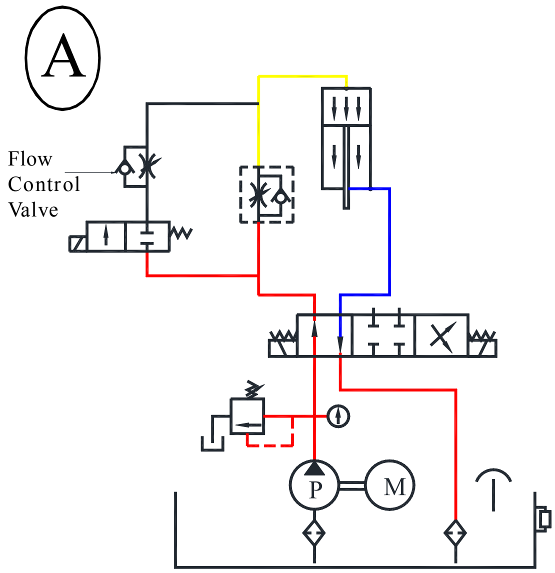


Figure No 10.20.1

Figure No. Forward stroke (First slow speed)

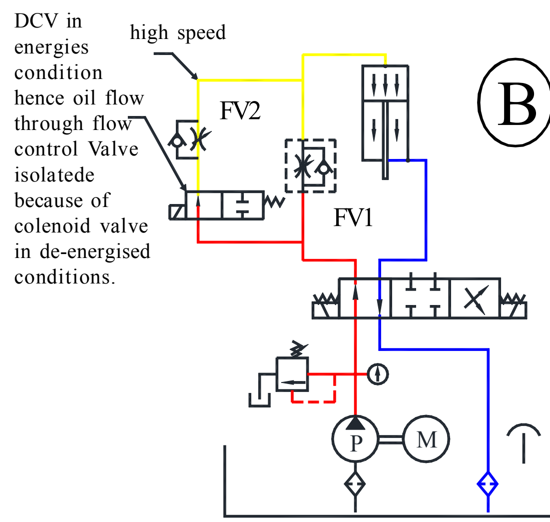


Figure No 10.20.2

Forward stroke.

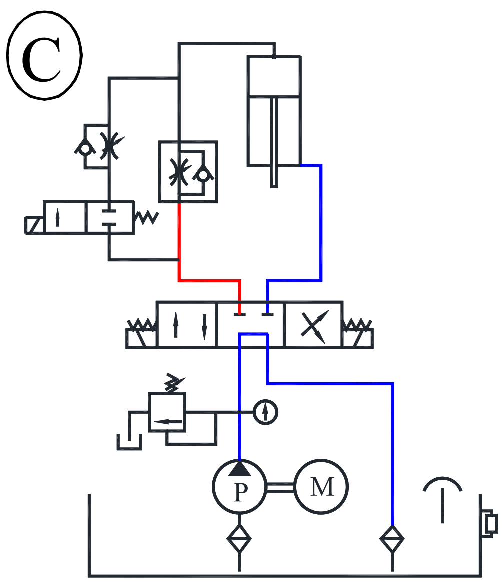


Figure No 10.20.3

Status of Pressure in Neutral Position after forward stroke

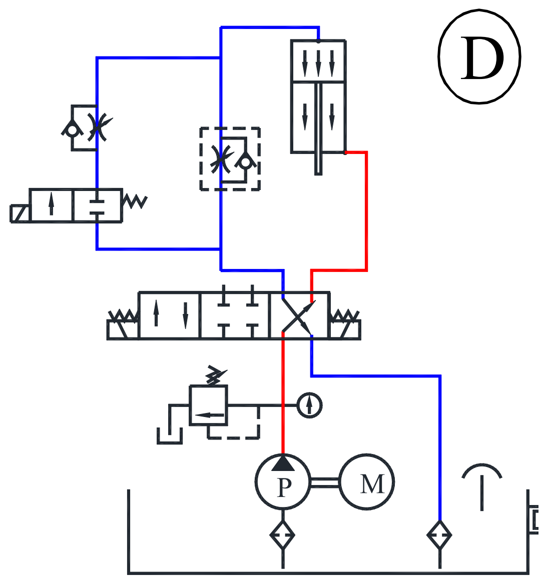


Figure No 10.20.4

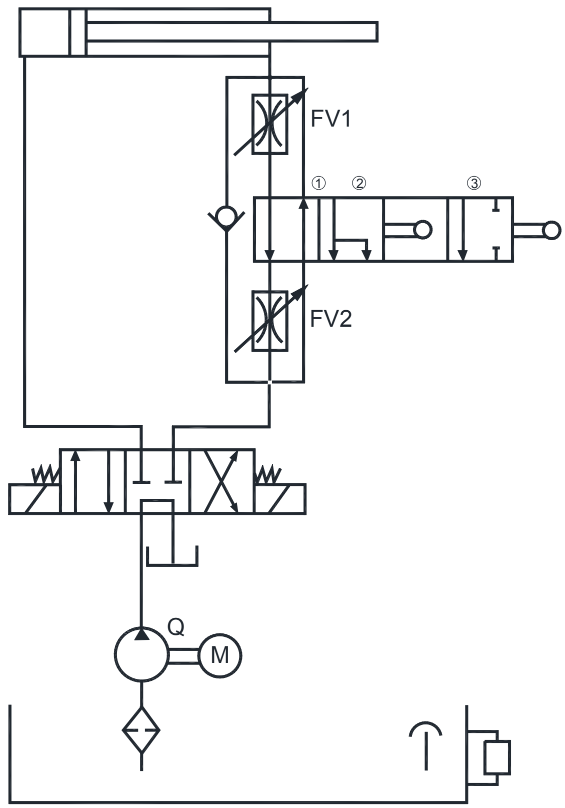
Return stroke.

In this circuit we have used meter-in type flow-control valves. To have two speed of actuator we have used one more flow control valve along with a solenoid valve in parallel with first flow control valve. Same arrangement can be used for meter-out as well as Bleed-off circuit.

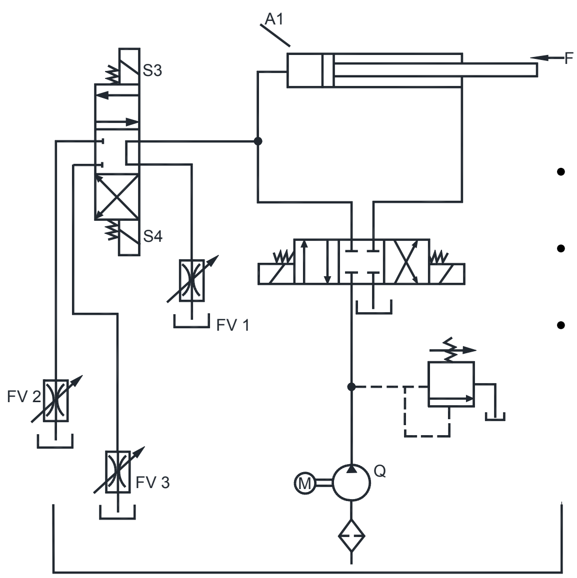
6) Three speed circuit:-

In this circuit first speed is full speed without any control; second speed is as per flow control valve FV_1. and third speed is as per combined setting of FV_1 & FV_2. This manupulation we are able to do by using special valve. (Model No, UCF2-04) made by M/s. Yuken India Ltd.

- In first position we by-pass FV_1 & FV_2. Hence get rapid speed (full speed)
- In position 2 we by-pass FV_2. Hence get medium speed as per setting of FV_1 .
- In 3 rd position, we get speed as per combined setting of FV_1 & FV_2.



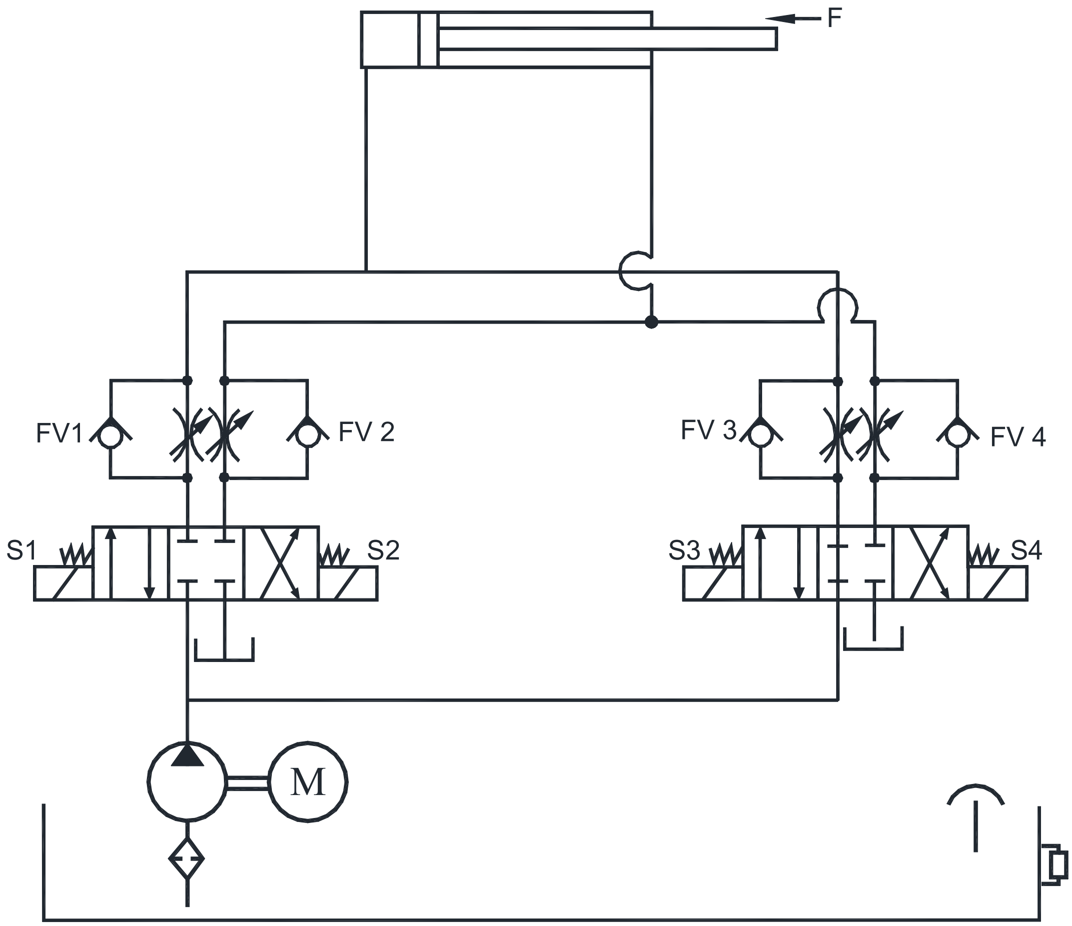
- Three speed also could be achieved by using following circuit diagram.



- When S3 & S4 are in switch off condition , we get speed as per FV1.
- When S3 energised, we get speed as per FV2.
- When S4 energised , we get speed as per FV3.

SLOW START AND STOP, AND FAST MOVEMENT CIRCUIT

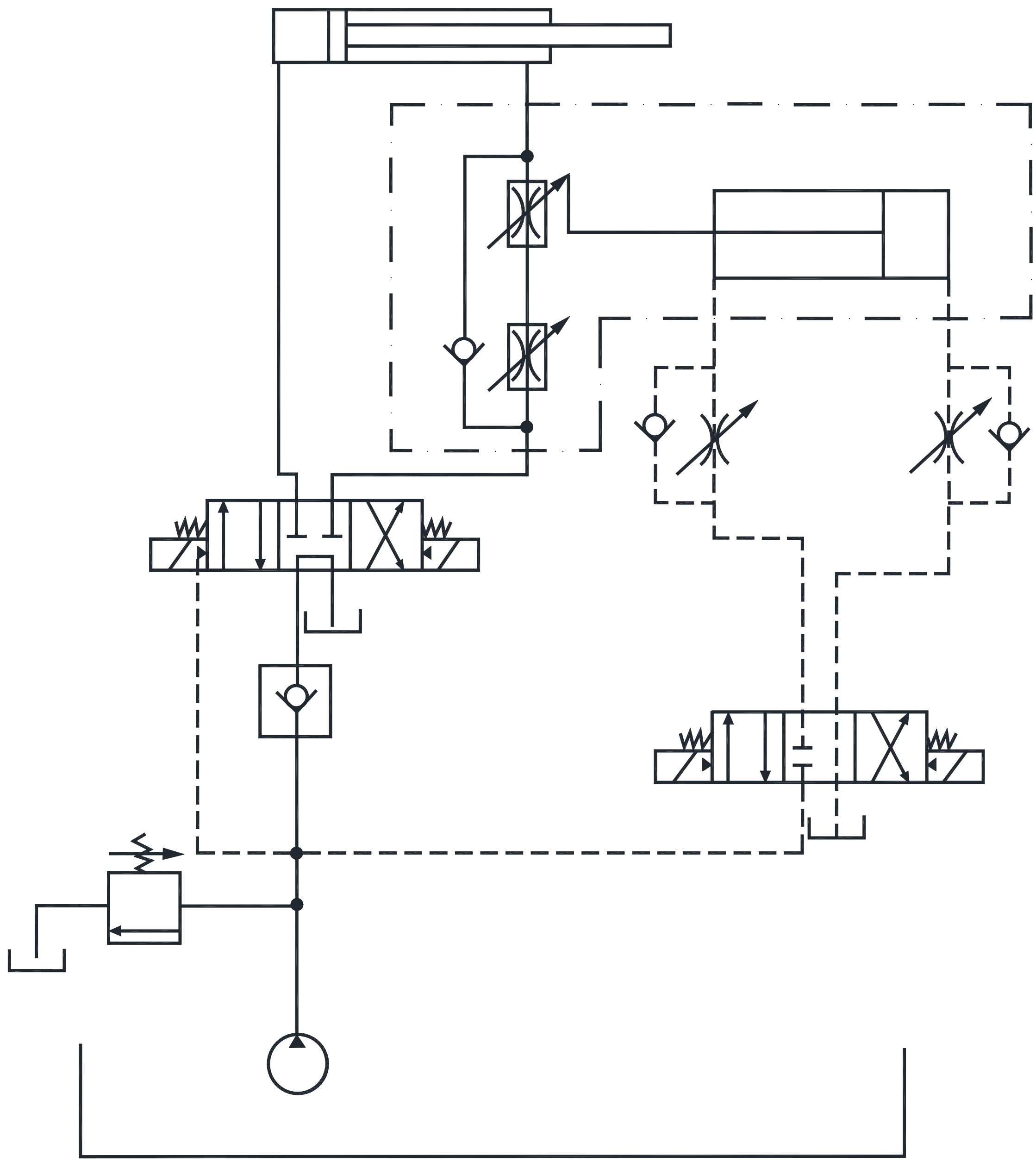
To have slow start and stop and fast movement of actuator, we use folllowing circuit diagram.



S_1	ON	-	Slow start (Flows as per FV_1.)
S_3	ON	-	Full speed (Flows as per FV_1.+ FV_3.)
S_3	OFF	-	Slow stop (Flows as per FV_1.)
S_1	OFF	-	Stop
S_2	ON	-	Slow retraction (Flows as per FV_2.)
S_4	ON	-	Fast retraction (Flows as per FV_2.+ FV_4.)
S_4	OFF	-	Slow completion of retraction (Flows as per FV_2.)
S_2	OFF	-	Completion of retraction (Stop)

8) Continuous speed control (Autometic speed control):-

To have continuous speed control as per the demand of process, we have to use proportional electro-hydraulic flow control valve as per following circuit.



10.21 SYNCHRONISATION CIRCUIT

By using four flow control valve we can synchronize speed of two-cylinder. But this is not a foolproof system. Error may occur and may accumulate with every stroke. Hence error after every stroke must be corrected.

One of the method of correcting error is to provide limit switches for both forward and return stroke of both the cylinder (Total four limit switches). And when both the limit switches at one end are actuated then only cylinder will take the next stroke. Hence on each stroke the error difference in stroke gets corrected. Synchronization could be achieved more accurately by using pressure and temperature compensated flow control valve.

1. Synchronisation by using pressure and temperature compensated flow control valve

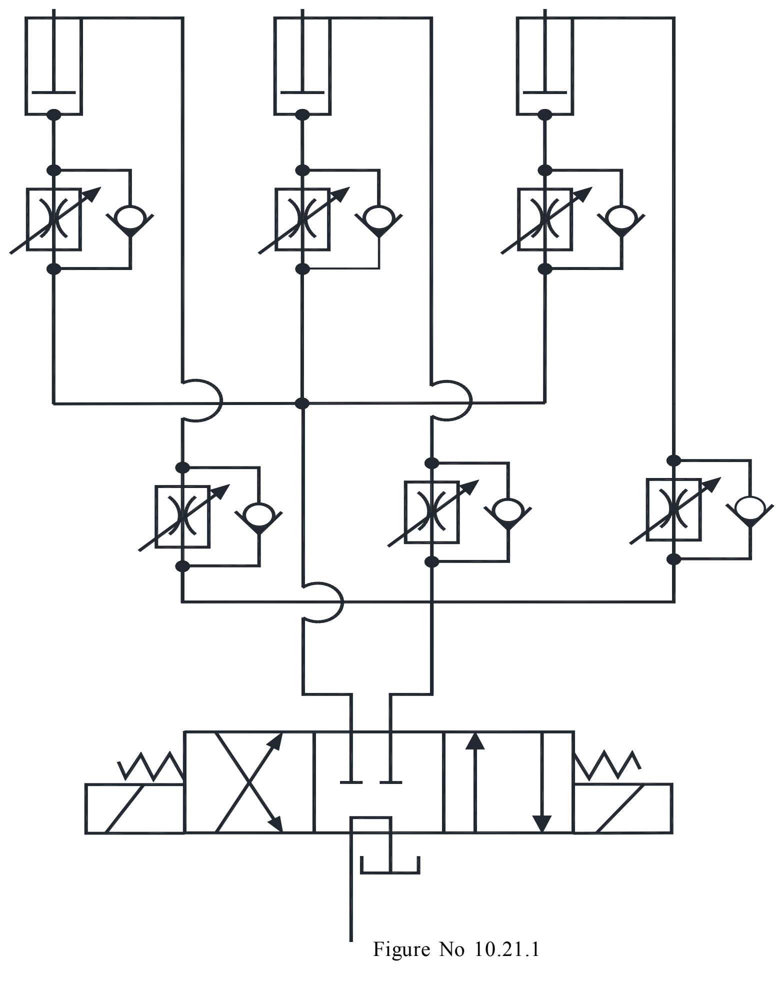


Figure No 10.21.1

By using pressure and temperature compensated flow control valve we can achieve synchronisation in stroke distance up to 95%, but still 5% variation may exist. To avoid cumulation of error in stroke, at the end of each stroke error should be corrected.

2. Synchronisation by using more number of pumps -

If each cylinder is provided with individual pump with perfectly same flow, and individual direction control valve, then synchronisation in stroke could be more accurately achieved. But if load on individual cylinder are different, the pump discharge will again vary, resulting in variation in stroke. In this case also the error should be corrected at end of stroke.

Providing individual pump for individual cylinder is very costly option. Hence Tedium gear pumps type flow dividers are used for synchronisation. In this type of flow devider number of small gear pumps of equal discharge are assembled with single spiddle or shaft. Their suction is also common. Hence when they rotate, they supply equal amount of oil from all the pumps, which are supplied to each actuator.

Visit the website __www.vivolo.com_ who is manufacturer of such valve, to understand them throughly. (Ref. page no. 36-49)

These valves also give good accuracy. But as load on individual cylinder various, variation in stroke is bound to happen. Hence correction of error at the end of stroke is unavoidable.

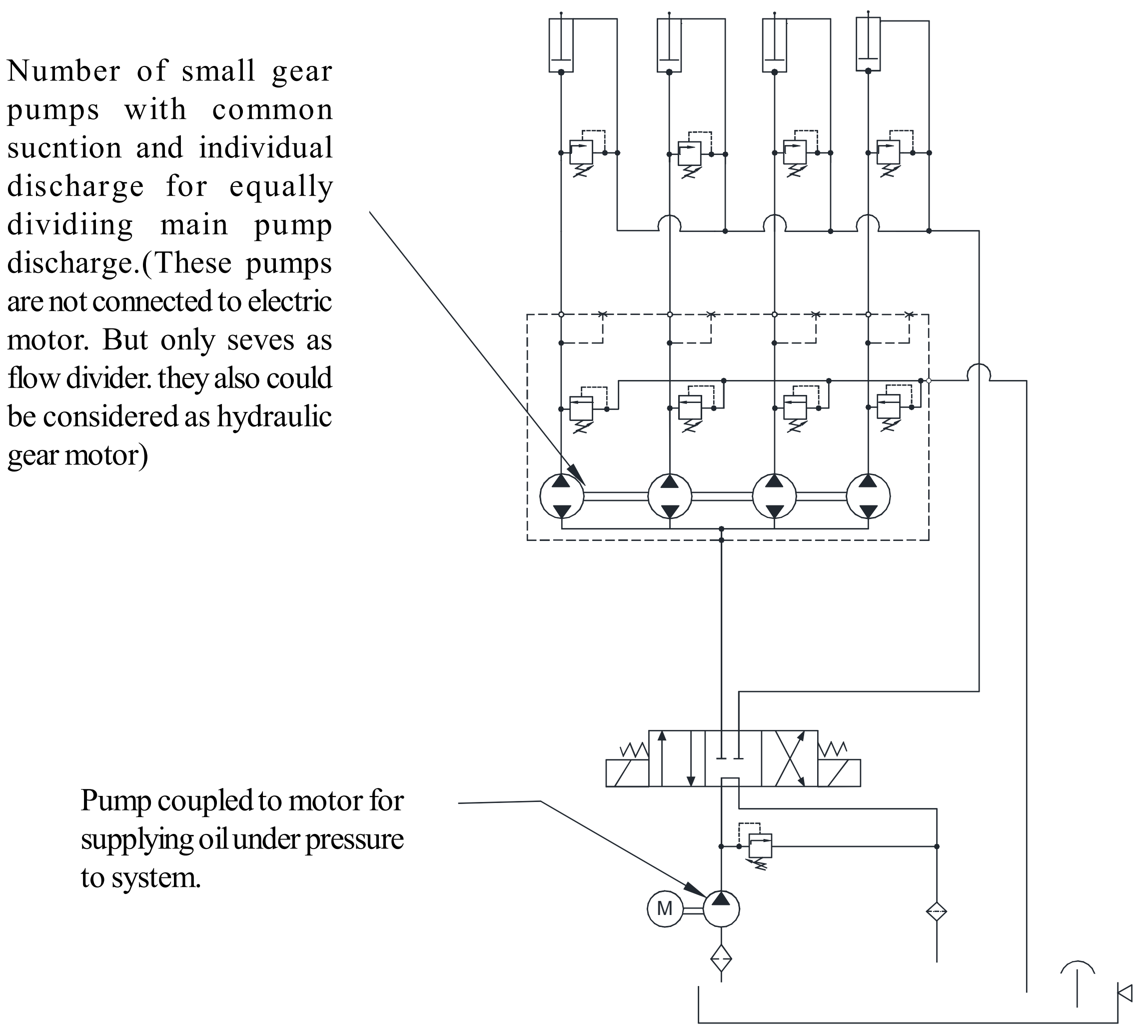


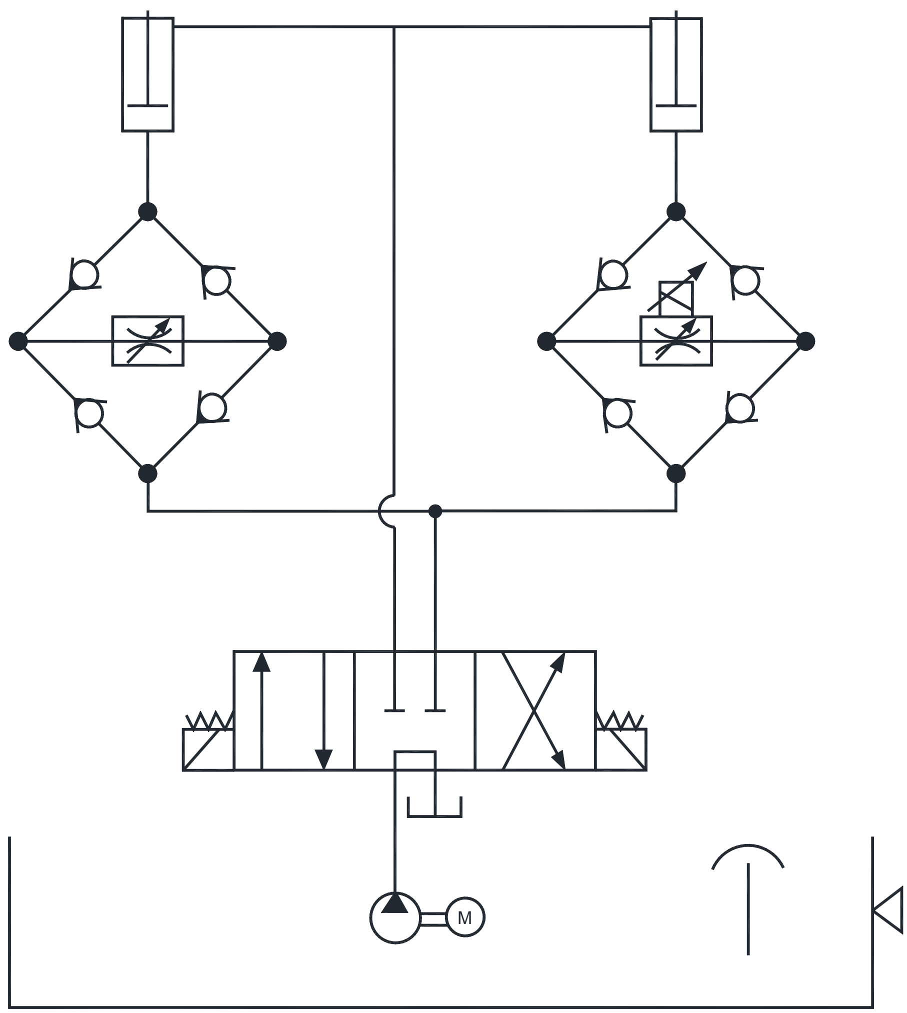
Figure No 10.21.2

Synchronisation circuits for two cylinders.

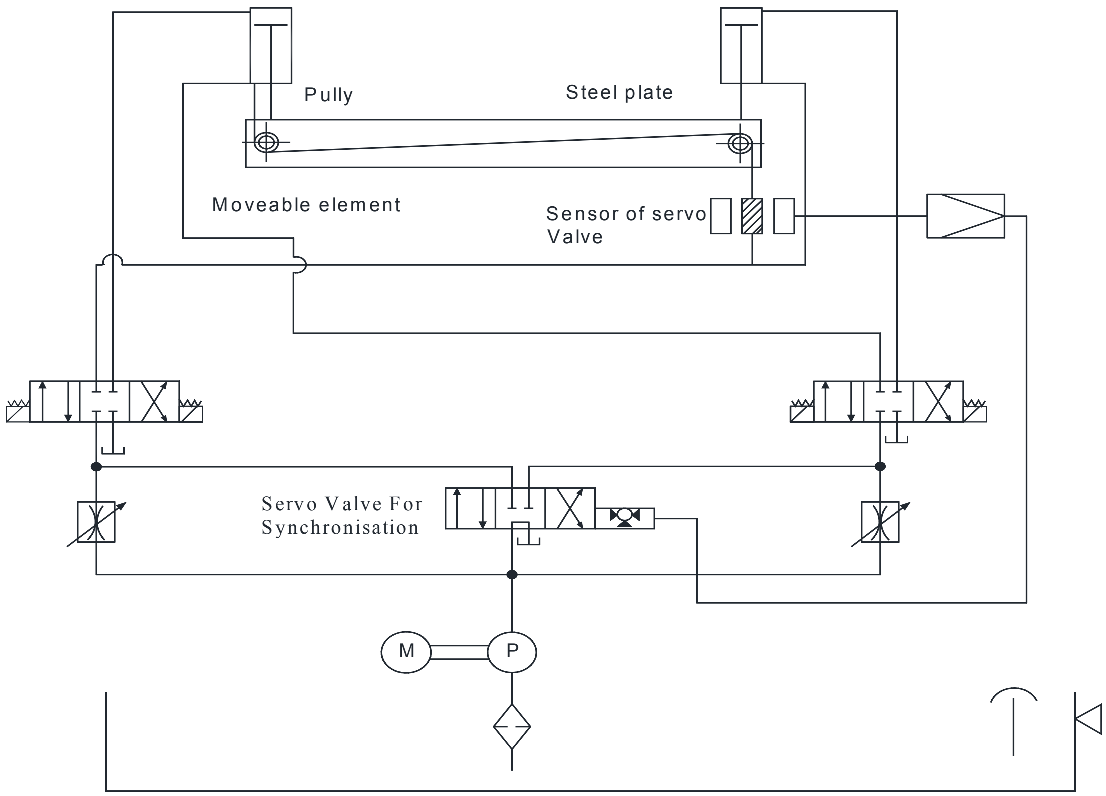
Synchronisation of two cylinders is possible by using flow control valve and tedium pump as discussed earlier. Few special circuits are also possible to achieve synchronisation; some of them are as follows.

Diamond circuit: - In this circuit two flow control valves are used to control speed of two cylinders in both directions. But forward and reverse speed could not be adjusted and selected separately. Also during up stroke the control is meter-in and during down stroke, it is meter-out.

To increase accuracy, one flow control valve could be replaced with proportional electro-hydraulic flow control valve. This valve senses the variation and adjusts the flow to achieve high accuracy.



Doamond Circuit
Figure No 10.21.3



Synchronisation by serro -valve

Figure No 10.21.4

10.22 Circuit Diagram of Drill

Pump①:-

A variable discharge pump is used so that as load increases, speed decreases and when drills get jammed due to any reason it stops rotating. Reduced or no discharge from variable displacement pump at high pressure safe guard against oil heating.

Direction control valve②:-

Advantage of using three positions all port block valves is that at neutral position cylinder remains locked, and it does not drain-out system pressure.

Flow control valve③: -

By using flow control valve we control spindle approach and return speed.

Four-way-two position direction control valve④:-

Because of two positions, cylinder will either clamp or un-clamp. Circuit is designed in such a way that when solenoid valve un-energised it remains in clamp position. These safeguards accidental released of job.

Check valves⑤ safeguards variable displacement pump against sudden over loading and accesses pressure generated in cylinders.

J-type direction control valve⑥ is used for drill head feed cylinder, so that pressure should not be locked in pipe line of cylinder. Locked pressure may actuate the pilot operated check valve which holds spindle in lifted condition.

Counter balance valve⑦ develops a back pressure, because of which drill head does not over travel due to weight of spindle. Because of counter balance valve, flow control valve also works accurately.

Pilot operated check valve⑧ locks drill head feeding cylinder in position, so that when drilling stops, spindle remain stationery and do not slides down due to own weight.

Reducing valve⑨ is used to reduce pressure supplied to up-down cylinder without reducing system pressure.

Meter-out type flow control valve⑩ is used to control spindle speed. Meter-out type valve reduces fluctuation in speed much better than meter-in type circuit, with change in cutting load.

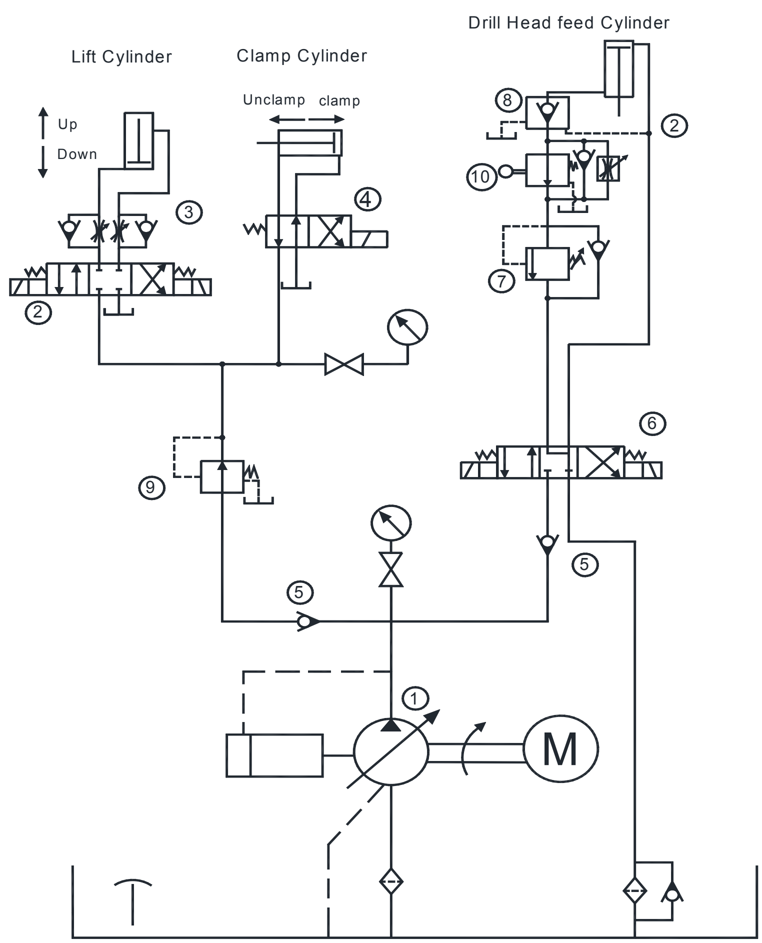


Figure No 10.22.1

10.23 Honning

What is honning?

Honing is similar to internal grinding, but in this process instead of grinding wheel grinding stone sticks are used and grinding stone sticks are rotated as well as reciprocated inside an cylindrical object to remove material of object as per requirement. In honing, ovality as well as taper of inside diameter is corrected. As per the size and grade of honing stone stick used for honing we get surface finish better than grinding process. Honing process is generally used in manufacturing of hydraulic cylinder or cylinder of automobile engine.

High flow high pressure pump①:- To reciprocate honing head at required high speed high flow pump is used as per requirement.

Relief valve② regulates pressure of reciprocating cylinder.

Flow control valve③controls the speed of reciprocating cylinder.

Direction control valve④ controls the direction of reciprocating cylinder.

This **simple counter balance valve**⑤ offers some back pressure when cylinder descends down,

HONNING

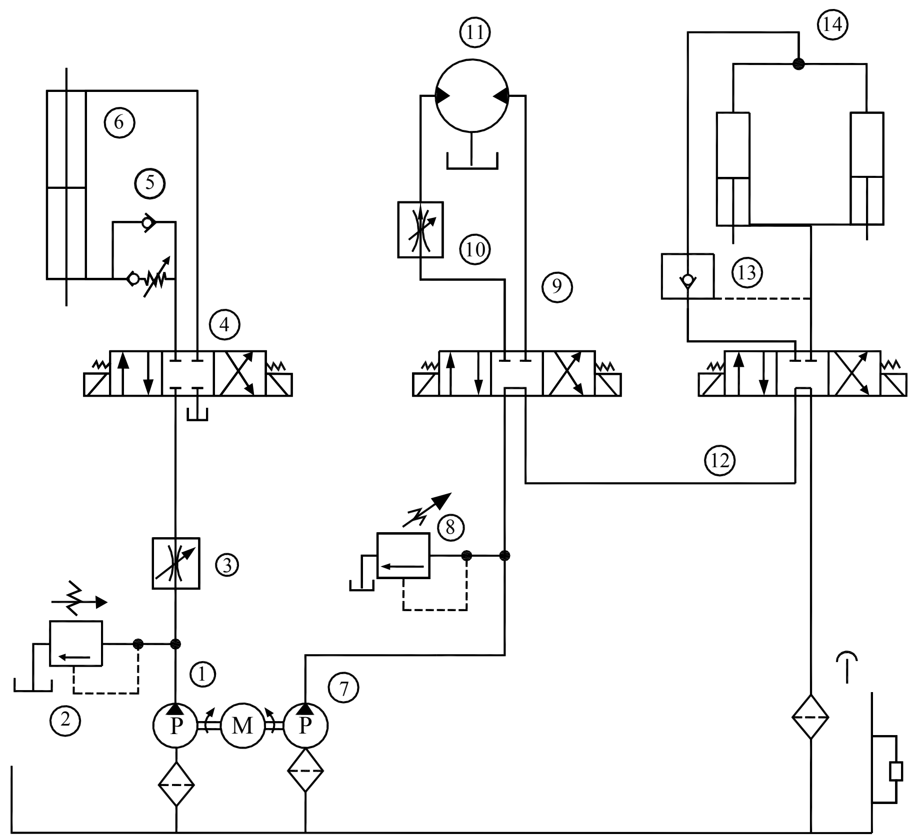


Figure No 10.23.1

because of this speed of cylinder remains under control as per flow control valve setting.

Reciprocating cylinder⑥: - In honing machine up and down speed of honing head should be same, hence either cylinder in mode double ended. Or differential cylinder is used along with regenerative circuit.

Pump⑦ with low discharge is used for hydraulic motor of honing head, as revolving speed of honing head is between 10-70 rpm only, and clamping cylinder is operated only at the beginning and at the of operation. **Relief valve**⑧ controls working pressure of pump No. 7

Direction control valve ⑨ and ⑫ are used in series because of two reasons.
a) Flow is small hence heating will be minimum.
b) Clamping cylinders are rarely used, hence it does not interfere functioning of hydraulic motor.
If we use all port block valve in such situation, then one more valve we have to add to unload pump when both hydraulic motor and clamping cylinder are not in use. Hence by using two direction control valve in series we save one valve.
Flow control valve ⑩, controls and varies the speed of hydraulic motor attached to honing head.
Hydraulic Motor⑪:- rotates the honing head. By using hydraulic motor in place of general geared electric motor, we have full and easy control over speed and torque of honing head.
Pilot operated check valve⑬ locks the clamping cylinder under pressure. **Clamping cylinder**⑭ holds the job firmly, as in honing job is subjected to rotary torque as well as up and down pulling and pushing force.
In this hydraulic circuit we have used meter in type flow control valve. Bleed of type is also used. In bleed-off power loss is comparatively less.

CIRCUIT DIAGRAM OF

SURFACE GRINDING MACHINE

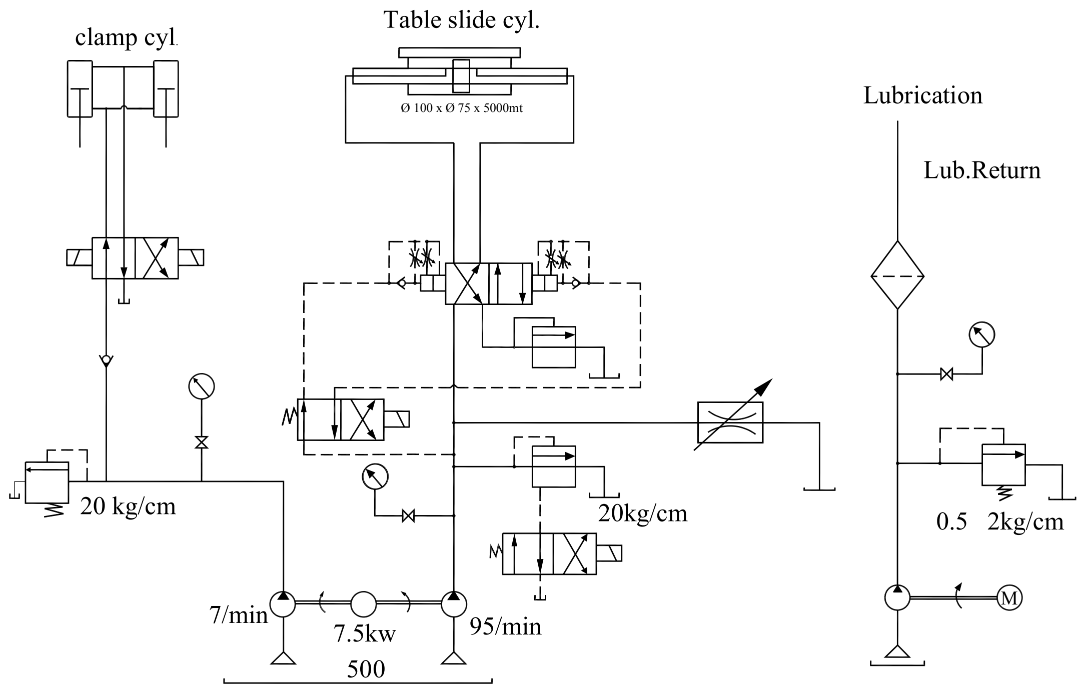


Figure No 10.23.2