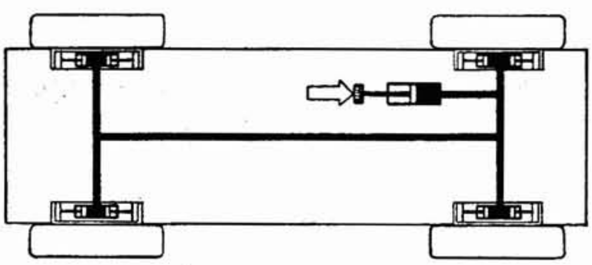
Pressure flow and power

Hydraulic systems transmit and control energy or power through the use of moving and pressurized fluids.
When man first learned how to exploit water power to turn millstones and power pumps, he had taken the first step towards industrialisation.

Nowadays, the use of hydraulics as a power medium is widespread throughout many different industries. In fact, usage has expanded to such an extent, today very few industries would be able to survive without hydraulics.
Many of us drive cars and each time we brake we make use of the vehicle's hydraulic system.

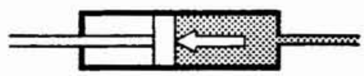


This is what happens when the brake pedal is pressed down, a hydraulic cylinder is influenced which raises the pressure in the braking circuit. This increase in pressure is in turn transmitted to the brake cylinders which activate the brake shoes, forcing the vehicle to a standstill. The fluid in the circuit therefore has the ability to transmit a force.

What is meant by a force? By force we mean that we can either create or change movement of a body. The law of inertia dictates that an immobile object cannot move by itself. If force is applied to an object, it can then move in either of two directions.

Hydraulic pressure

Since we know that a fluid in motion has the ability to transfer power, it is also possible to replace human force with the aid of a fluid and move an object as easily or even more easily than by using physical exertion.



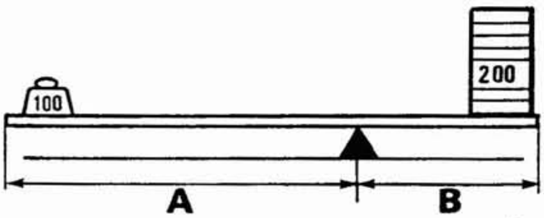
If we replace the human braking force with a fluid, we will achieve the same effect.
How? The answer is to be found in the characteristics of the fluid used. The fluid is non-compressible, in other words it cannot be compacted or decreased in size.

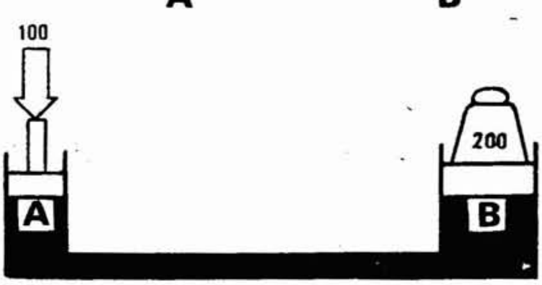
This is a bottle which has been completely filled with a fluid. If the cork is pressed down even further into the fluid using relatively light pressure,

the bottle will ultimately explode. The reason for this is that the pressure inside the bottle spreads in all directions.

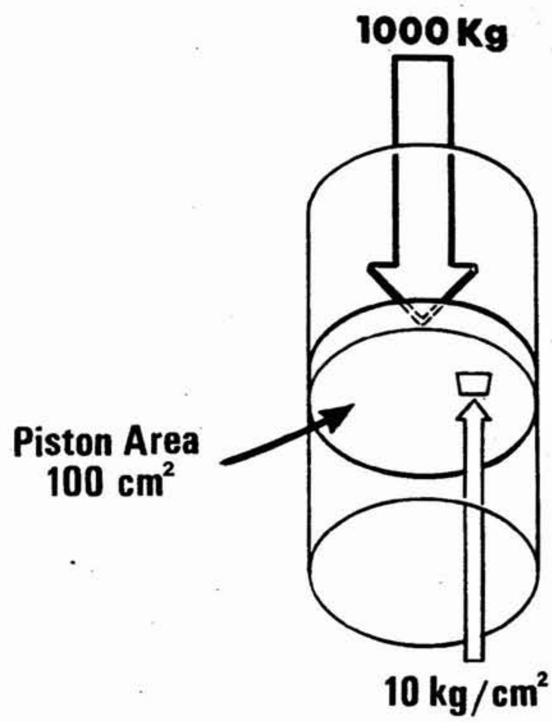
Since this pressure is uniform at all points inside the bottle, a large force will be created over the entire inner surface of the bottle.

A corresponding phenomenon occurs within the technology of hydraulics. In this case it is a fluid which creates a substantial increase in force.





If you compare these two illustrations above you will notice that the lever arm has been replaced with a fluid system, where the different levers are represented by two different surfaces. As you can see the right-hand piston area is twice as large as the one on the left.

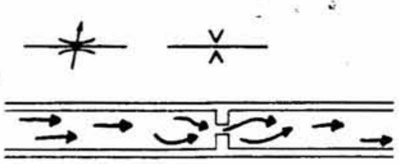


The cylinder shown opposite has been subjected to a load of 1000 kg. This load is evenly distributed over the entire piston area of 100 cm². This means that every cm² is subjected to a load of 10 kg. The force per surface area of hydraulic fluid is what we term pressure.

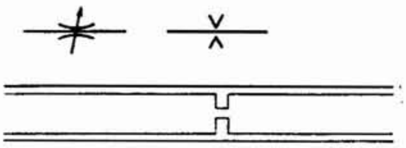
MPa	BAR	Kp/cm²
0,01	0,1	0,1
0,1	1	1
1	10	10
2	20	20
3	30	30
4	40	40
5	50	50
6	60	60
7	70	70
8	80	80
9	90	90
10	100	100
11	110	110
12	120	120

Pressure is usually measured in MPa (MegaPascal). However, older units of measurement such as Bar and kp/cm² are still in common use. The table shows the differences between these units. The figures given on the same line correspond to each other. If we look at the marked line, we will see that 10 MPa corresponds to 100 Bar or 100 kp/cm².

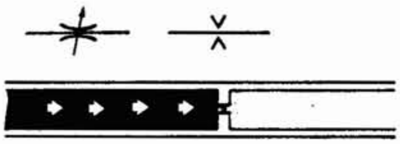
Let's now study the function principle of a construction in a hydraulic system.



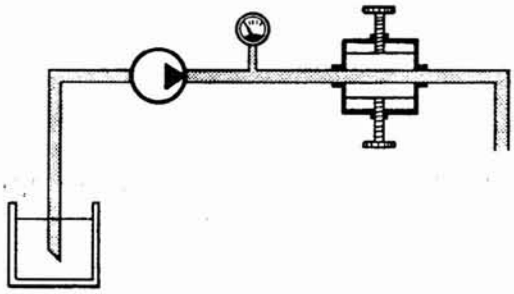
The inward-cambered part or constriction in the pipe serves as a throttle. This causes the entrapped fluid to move in whirls, so-called turbulence. Constriction also generates heat.



This sketch shows that the pressure on both sides of the constriction is equal, consequently there is no movement of the fluid.

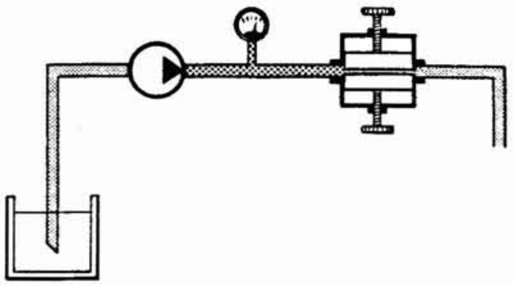


If the pressure on one side is higher than on the other, the fluid will start to flow towards the side with the lower pressure.

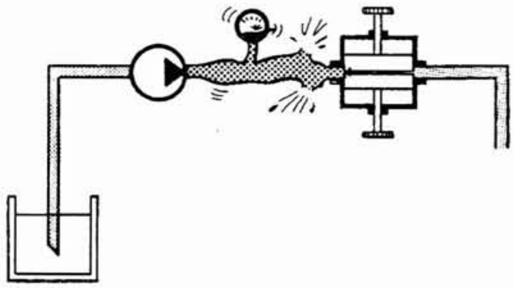


If we continue by mounting a throttle valve in the line, we can alter the size of the passage through which the fluid will flow.

When the valve is fully open, the fluid can then flow from the pump totally unhindered. A pressure gauge mounted on the line shows the pressure reading is zero.

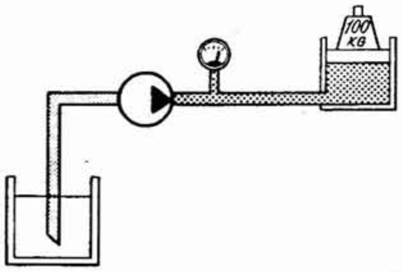


When the throttle valve is threaded down, pressure is required to propel all the fluid delivered by the pump. The passage in the valve narrows and the pressure gauge gives a pressure reading.



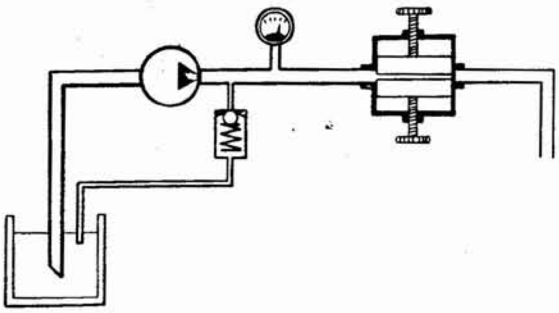
If we continue to thread down the throttle valve and make the passage in the line even narrower, the pressure will increase even more. When it has risen to a specific level something must happen. Either the pump, the pipe or the valve itself will fracture or burst, unless the pressure is reduced once more.

The point here is that unloaded pumps do not provide pressure. They merely supply a volume flow, usually stated in litres per minute. A modern hydraulic pump is capable of supplying a more or less constant volume flow independent of the pressure. Pressure is generated through loading and here it is achieved through constriction.



What happens if the load is in the form of a weight?

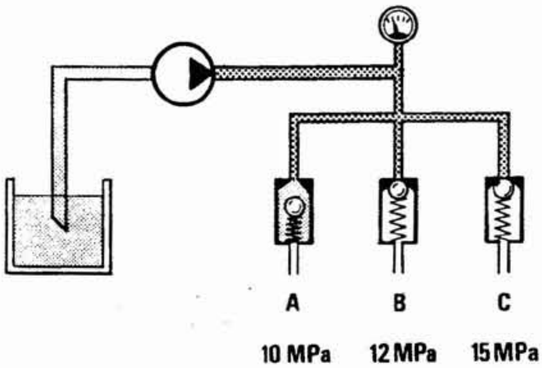
If we remove the weight, the pressure will drop. Consequently, it is not the pump that supplies pressure.



This is the same system shown to you a few moments ago. When we adjusted the throttle valve we increased pressure. We also mentioned that if the pressure is increased too much, then something is bound to happen or break.

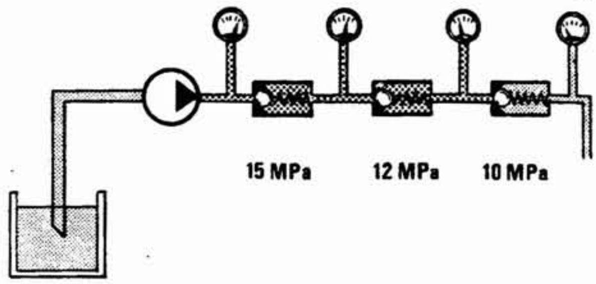
To avoid this, it is common to install a pressure limiting valve into the system. This valve contains a ball or poppet which is spring-loaded against the pressure. It seals against a seat. When the pressure becomes so high that the spring force is no longer able to resist it, the fluid starts to flow through the pressure limiting valve and back to the tank. The pressure will not increase further even if the throttle valve is threaded down even more.

Will the valves function in a similar manner when they are parallel-connected or series connected? The answer is NO and this is why.



When several pressure limiting valves are connected in parallel, in other words next to each other, the valve which has the lowest pressure setting will determine the system pressure. In this case valve (A) is set at 10 MPa, another valve (B) at 12 MPa and a third valve (C) at 15 MPa.

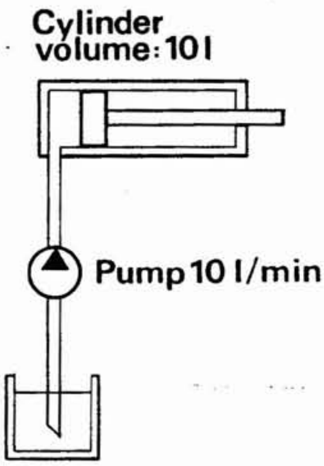
Now let's connect the valves in series or one after the other. In front of and behind each valve we connect a pressure gauge to see what happens at the various stages along the line. The pressure limiting valve nearest the pump is set at a pressure of 15 MPa, followed by the next set at 12 MPa and the last in the line set at 10 MPa.



Now study the pressure gauges from right to left. The gauge furthest to the right shows the atmospheric pressure, in other words the pressure of the air we normally breathe. The next gauge gives a reading of 10 MPa and the third, a reading of 22 MPa. This is easily explained by adding 10 + 12 – 22. At the same time, it's not hard to work out that the gauge nearest the pump will give a reading of 37 MPa, since 10 + 12 + 15 – 37. Consequently, when pressure limiting valves are series-connected, pressure is added together.

A hydraulic fluid .....

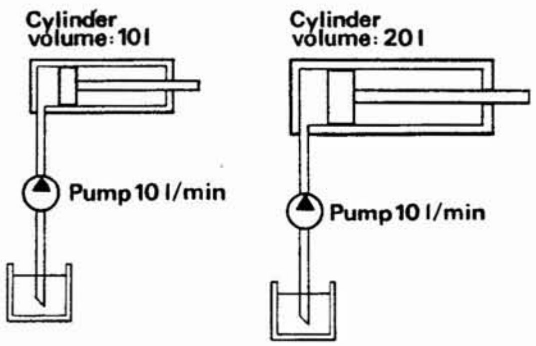
flows in a cylinder that holds 10 l when filled completely.



If the pump delivers a flow of 10 l/min then the cylinder will be filled within 1 minute.

If instead, the pump delivers 20 l/min, then the cylinder will become filled in half the time, in other words within 30 seconds. The speed of the cylinder piston is therefore determined by the volume of fluid flowing to the cylinder per time unit. This is measured in l/min. No matter how far the piston lifts, the velocity remains unaffected. It is therefore the volume flow of fluid that determines the velocity.

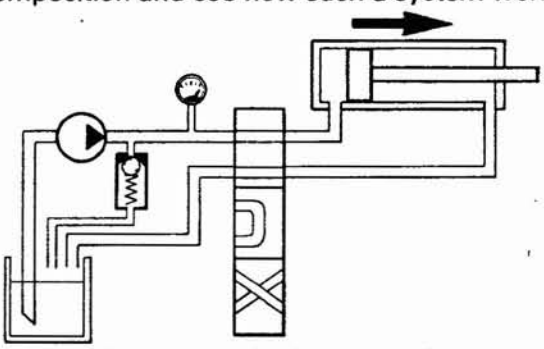
The speed of the piston is also influenced by the diameter of the cylinder. Here are two different-size cylinders. If these are connected to individual pumps that are of identical size and which are started at the same time ...



We will soon notice that after a short while they have moved different distances. The larger cylinder piston has moved only a short distance while the piston in the smaller cylinder has completed its full work cycle.

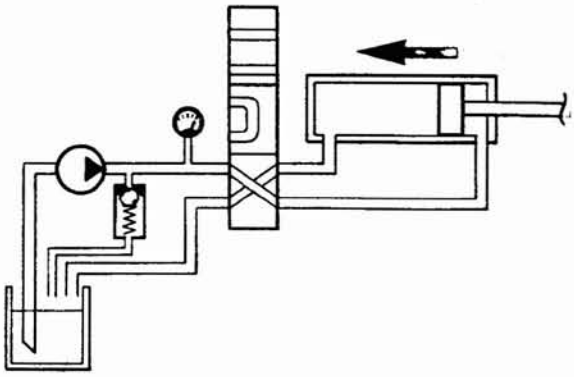
Composition of a simple hydraulic system

We have now advanced to the stage where we can study a simple hydraulic system, note its composition and see how such a system works.

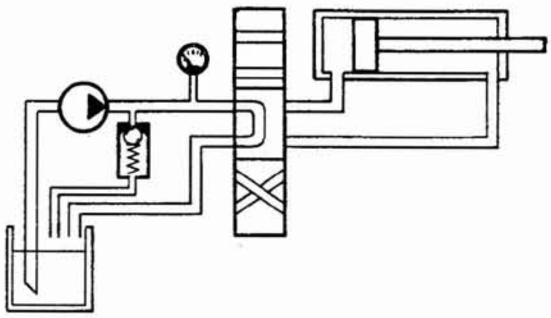


The valve in the cylinder is activated so that the piston in the cylinder moves in the direction of the arrow. The pump supplies fluid to the plus side of the cylinder, the red section, and the piston starts to move in the desired direction. The minus side of the cylinder, the blue section, is also filled with fluid. Due to movement of the piston the fluid is forced out through the blue line to the tank.

When the cylinder reaches its end position, the fluid has nowhere to go. This could then result in something fracturing unless specific measures are taken. A pressure limiting valve has therefore been mounted in the system to prevent this happening. The entire flow of fluid now passes through the valve and back to the tank.



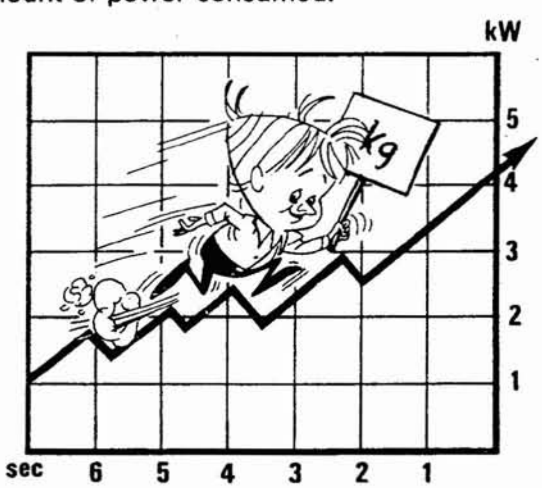
If we now want the piston to return to its original position, then the volume flow from the pump should now move to the minus side of the cylinder. This entails connecting the plus side to the tank so that the fluid can flow back. This is achieved with the valve shown.



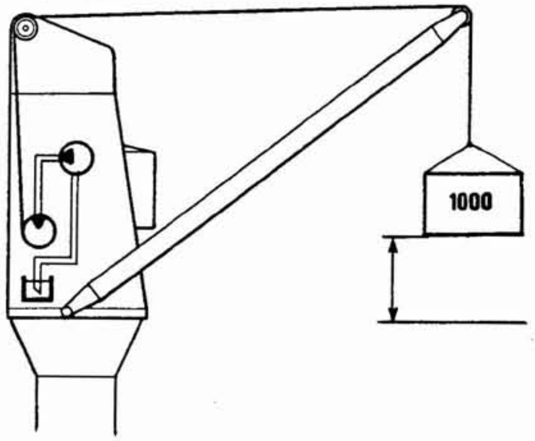
When the piston has reached its end position, further movement can be terminated without switching off the pump. It is now necessary to prevent the flow from passing by way of the pressure limiting valve back to the tank. This is done by moving the valve into the zero position.

Hydraulic power

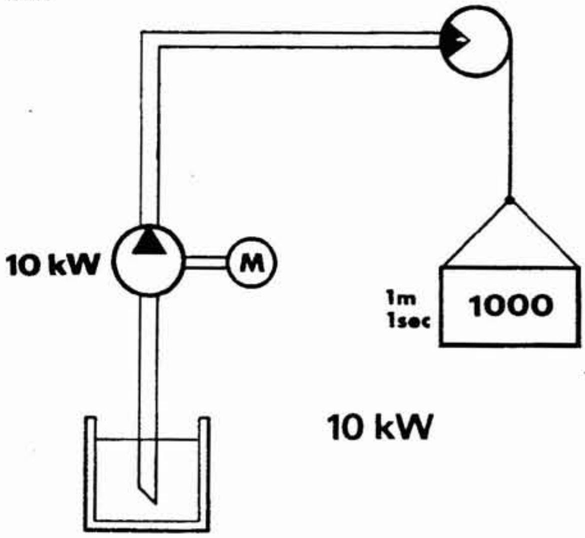
With power we mean the work capability per time unit. The faster a job is completed the greater the amount of power consumed.



If this deck crane is so successfully hoist this crate 1 (one) meter within 1 (one) second, then it needs to generate a power capacity or work capability of 10 (ten) kW.

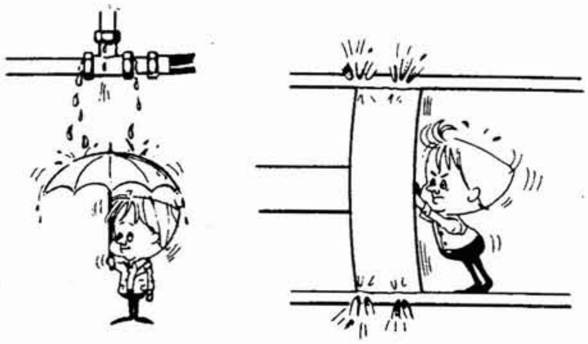


To enable the same crane to generate 10 (ten) kW, the pump must also generate at least 10 (ten) kW.



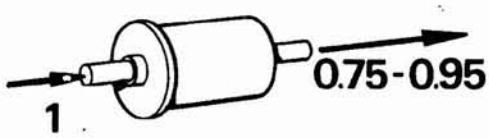
In actual fact, the pump must generate a larger capacity than 10 (ten) kW, since flow losses in the line combined with valve leakage absorb a small proportion of the initial power generated.

By now we are all aware of the fact that a pump cannot operate without energy losses. Some of the pressurized fluid leaks back to the tank and certain flow losses occur inside the pump. Also, some of the capacity is lost through friction between different components inside the pump.

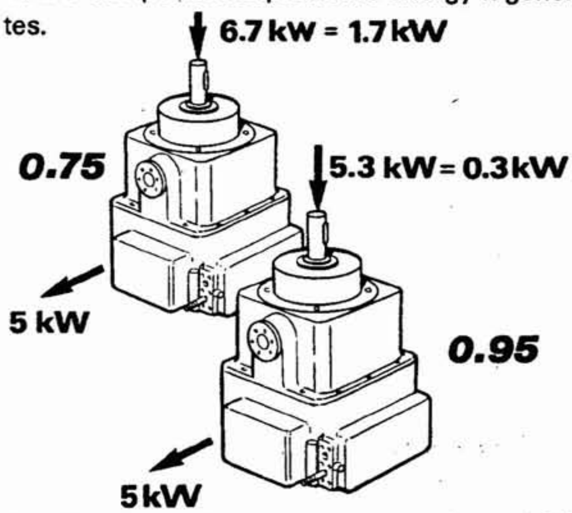


Leakage and flow losses are known under the common name of hydrodynamic losses, because fluids are involved. Losses caused through friction are termed mechanical losses.

Efficiency



The degree or level of efficiency is a measure of how a component exploits the energy it generates.



This illustration demonstrates the substantial differences that can occur between different types of pumps. Let's compare the two shown. They both generate the same capacity, namely 5 kW. The pump at the top has a poor level of efficiency and therefore demands an installed capacity of 6.7 kW in order to generate 5 kW. The energy loss here is therefore 1.7 kW.
In contrast, the pump underneath has an excellent level of efficiency and only needs a capacity of 5.3 kW. The energy loss for this pump is thus no more than 0.3 kW.

The application of hydraulics in deck cranes

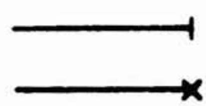
Hydraulic symbols, basic

Working oil line

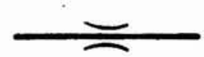
Pilot line

Drain line

Plug, plugged connection (alternative symbols)

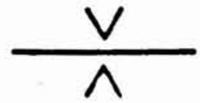


Fixed restriction



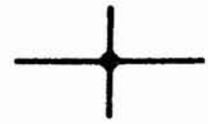
Variable restriction

Restriction unaffected by viscosity



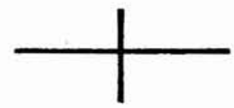
Flexible hose

Pipe junction

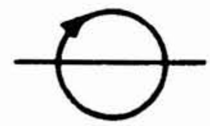


BASIC HYDRAULICS

Crossed pipe, no connection



Rotary connection



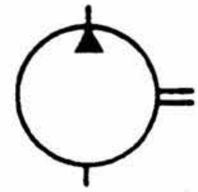
Line to tank

Regulation, or variability

Enclosure of component assembly

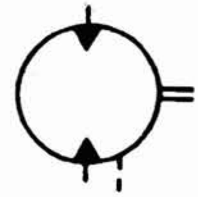
Mechanical connection

Pump, fixed displacement

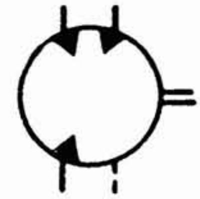


Pump, variable displacement

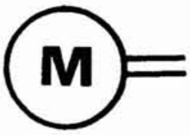
Hydraulic motor, 3 ports shown



Hydraulic motor, 4 ports shown

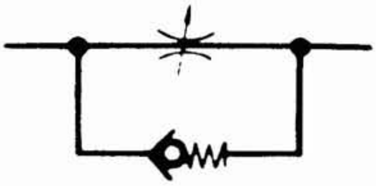


Electric motor



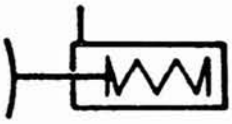
Non-return valve

Non-return valve with variable restriction

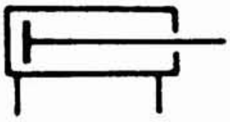


Shut-off valve

Brake cylinder



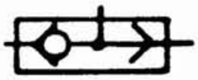
Hydraulic cylinder



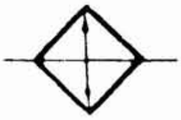
Remote control cylinder

Servo cylinder

Shuttle valve

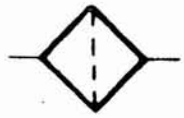


Oil cooler



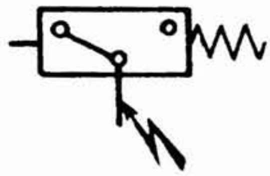
Accumulator

Filter

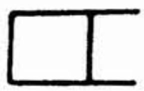


Filter with non-return valve

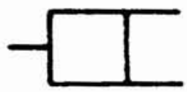
Pressure electric switch



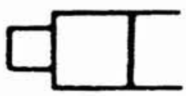
Valve basic symbol



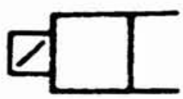
Pilot controlled valve



Mechanically controlled valve



Electrically controlled valve

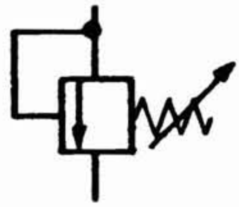


3/2 direction valve
Pilot controlled three-way valve with two positions, spring return to neutral position.

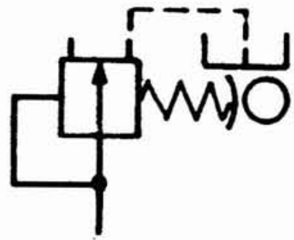
4/2 direction valve
Mechanically controlled four-way valve with two positions, spring return to neutral position

4/3 direction valve
Pilot controlled four-way valve with three positions, spring centred

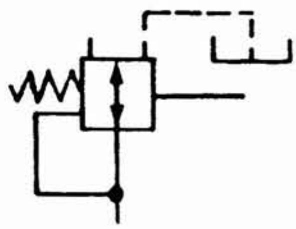
Pressure relief valve



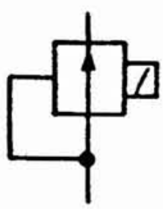
Pressure regulator, lever operated



Pressure regulator, pilot controlled

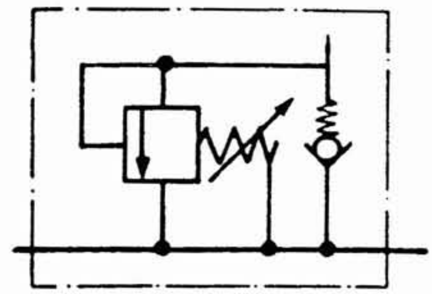


Pressure regulator, electrically controlled

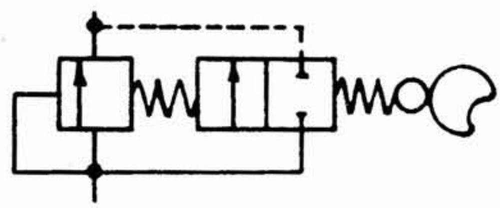


Valve assemblies

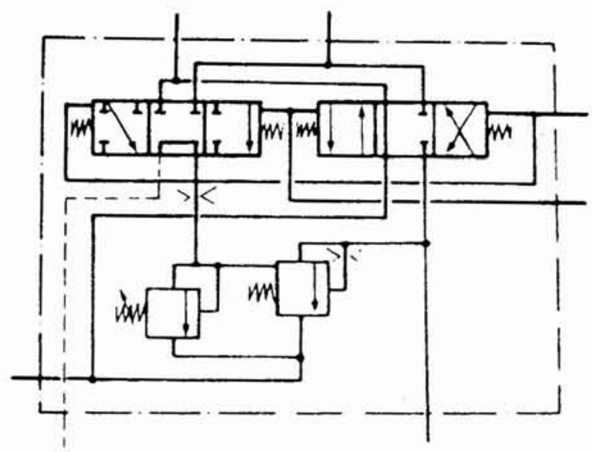
Pressure relief valve and non-return valve
This pilot operated counterbalance valve is used in the stabilising wire winch circuit, when fitted.



Pressure control valve and cam-operated direction valve
Used in slewing limit devices in twin cranes.

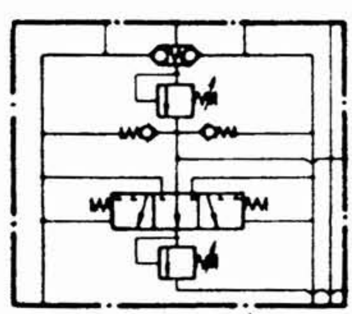


Direction valve and pressure control valve combination
Pilot controlled operation control valve, open-type luffing circuit.

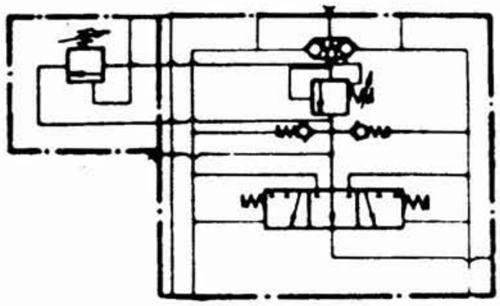


Unit valves, used in closed-type working circuits – three types

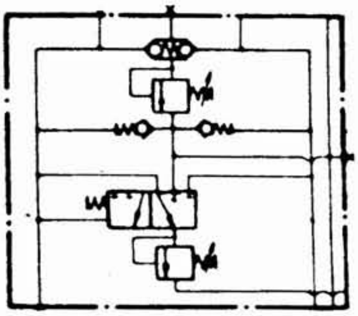
Unit valve, basic type



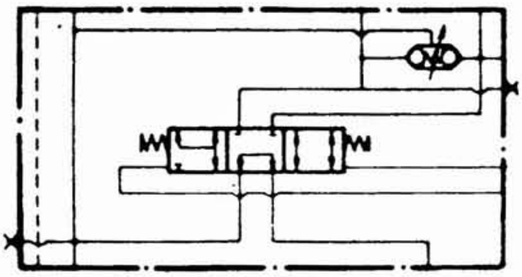
Unit valve, less feed pressure control valve, fitted with external pilot control of high-pressure relief valve.



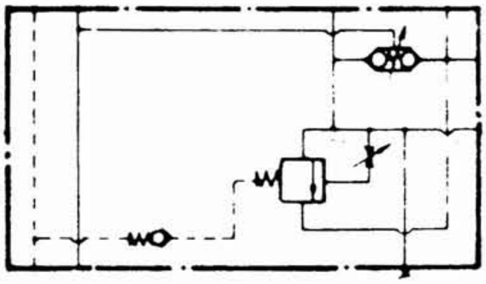
Unit valve, with two-position shuttle valve

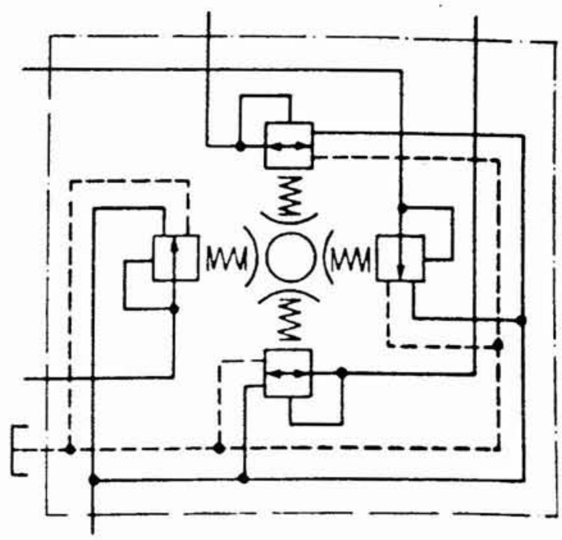


Two-speed valve
Combination direction valve and shock valve, used in hoisting circuit.



Counterbalance valve
Combination pressure relief and shock valve, used in open-type luffing circuits.





Quadruple pressure control valve
Lever operated, used in hoisting, luffing and slewing circuits.

Deck crane hydraulics

Hydraulic systems

The hydraulic system of Hägglunds hydraulic deck cranes comprises three separate work circuits, i.e. the hoisting, luffing and slewing circuits which, together with the feed and control-pressure circuits, make up the complete crane hydraulic system. (Mechanically controlled cranes have no control-pressure system.)

Each work circuit contains a hydraulic pump and a hydraulic motor. The pump types used are variable-displacement axial piston pumps, vane pumps, and screw pumps. The motors are low-speed high-torque radial-piston type motors.

All pumps are driven by a common electric motor through a distributing transfer gearcase. In G-type cranes, the feed pump has a separate drive.
There are two types of hydraulic system – closed circuit and open circuit.

Closed circuit systems use variable-displacement axial piston pumps: open circuit systems, vane pumps. Feed and control-pressure circuits have vane pumps or screw pumps.

In mechanically controlled cranes of earlier manufacture, up to 15 tons, an open hydraulic circuit was used for the luffing winch, closed circuit systems for hoisting and slewing.

In certain types of cranes with hydraulic control, up to 8 tons, open circuit systems are used for luffing, closed circuits for hoisting and slewing. Above 8 tons, closed circuit systems are the rule for all three work circuits.

Identifying hydraulic circuits

Identifying circuits in the hydraulic diagram, Fig. 1, shows the arrangement of the three work circuits and the feed circuit. The circuits appear in the same order in the hydraulic diagram.

Legend

MHO	Motor	Hoisting circuit
MLU	Motor	Luffing circuit
MSL	Motor	Slewing circuit
PHO	Pump	Hoisting circuit
PLU	Pump	Luffing circuit
PSL	Pump	Slewing circuit
PF	Pump	Feed circuit

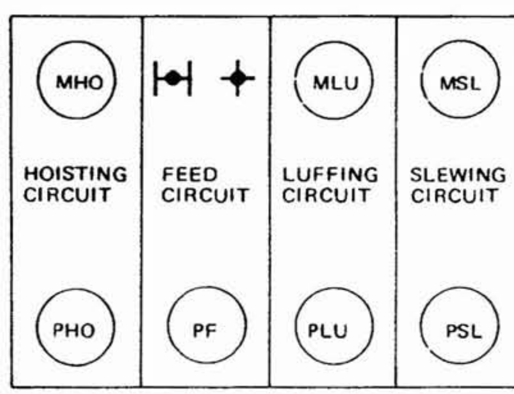


Fig. 1. Identifying hydraulic circuits

Closed circuit

This type of hydraulic system, Fig. 2, comprises a variable displacement piston pump and a hydraulic motor with interconnecting hydraulic lines. The flow rate and the direction of flow are controlled by means of a servo cylinder. The pump has a position where it delivers no flow: this is the starting position, with the electric motor running and the control lever in neutral.

If this system is completely filled with oil and the pump is then started, the oil in the circuit will escape from the system at a rate which is determined by the pump pressure (high pressure/high leakage: low pressure/low leakage). To compensate for the leakage, certain other components must be added to the system: see Fig. 3, page 3.

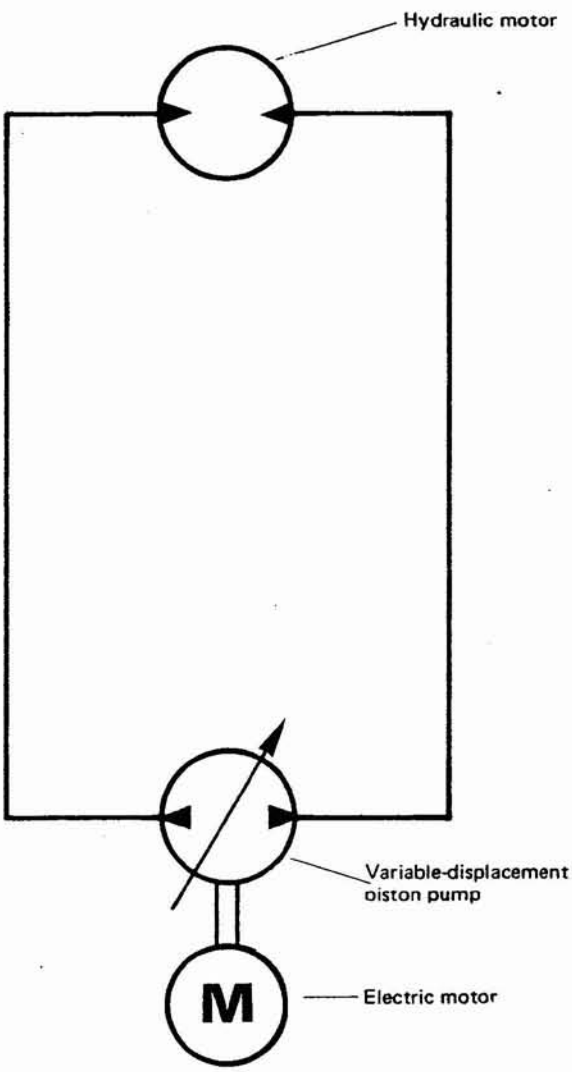


Fig. 2

Feed pump – Fig. 3

The task of the feed pump is to fill the circuit with oil when starting and to make up for the leakage. For filling, the circuit has two check valves: a by-pass valve limits the feed pressure to a value between 17 and 25 bars, which is required for the hydraulic pumps and motors used in hydraulic deck cranes. Setting of exact feed pressure is specified in the instruction book. When the system is put to work, a working pressure which is determined by the magnitude of the load, will build up in one of the hydraulic lines. The working pressure closes one of the check valves: to replenish the circuit during operation, oil enters the circuit through the check valve at the return side which will thus be maintained at feed circuit pressure, i.e. 17-25 bars. Thus, the double task of the check valves is to separate the working pressure side from the return side, and to keep the work circuit filled with oil, regardless of which side of the circuit is at working pressure.

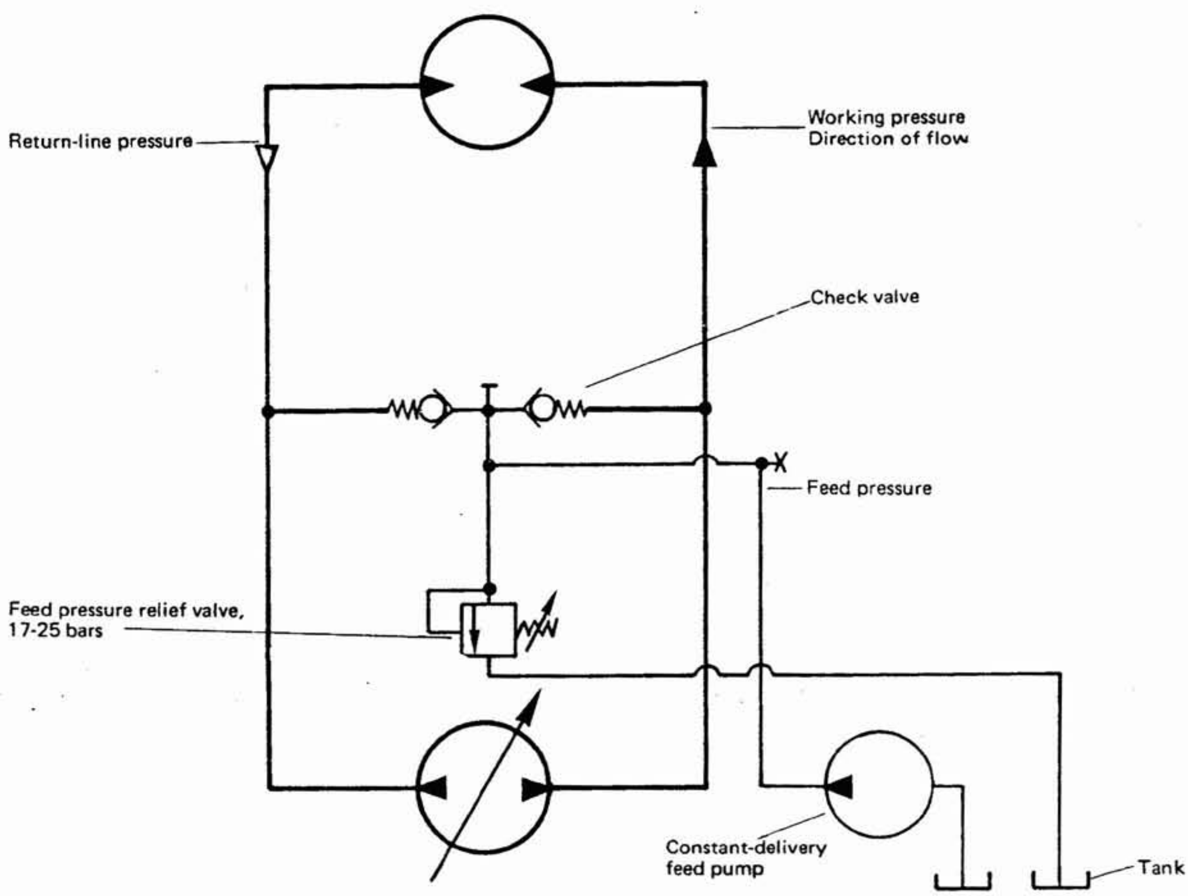


Fig. 3

Safety valve — Fig. 4

The work circuit is designed for a certain maximum pressure: the working pressure must, therefore be restricted to a safe value that does not burst the system open. For this purpose, a main pressure relief valve is used to discharge oil from the working pressure side to the return side when a set maximum pressure is reached. A double check valve with a common spring ensures that the relief valve will always be operative whether the working pressure is on the right-hand or left-hand side of the circuit in the figure.

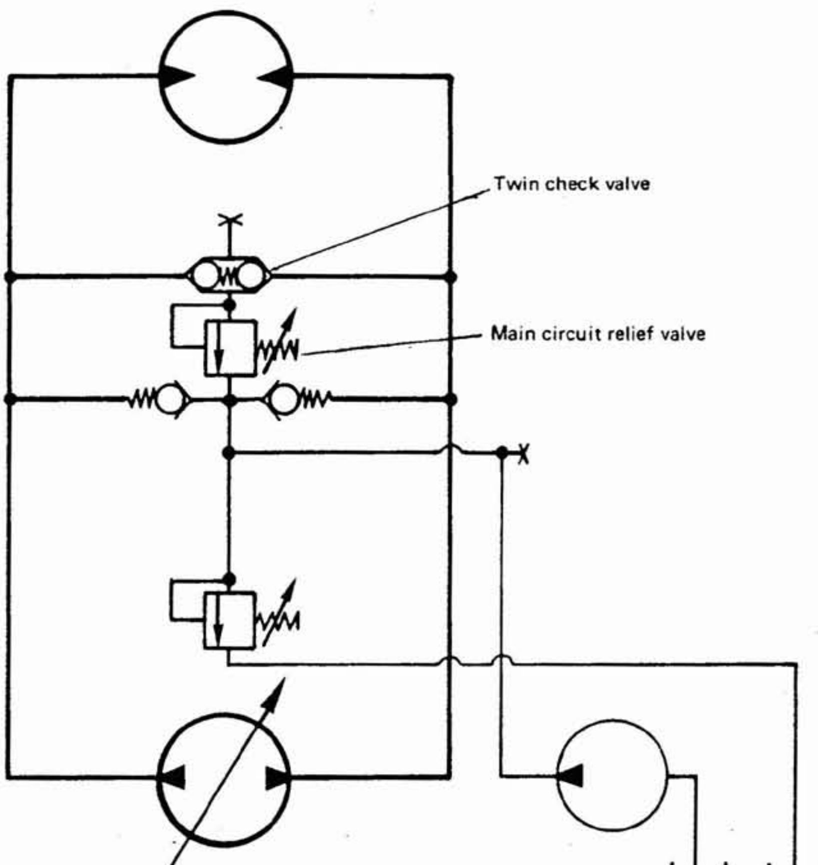


Fig. 4

Cooling – Fig. 5

As the oil is put to work, internal and external friction in a comparatively small volume of oil causes the temperature to rise, the oil becomes more light bodied (less viscous), the leakage increases, and the system cannot build up the pressure required to perform the work for which it has been designed. An oil cooler in the drain line to the tank will cool only the small volume of leakage oil, which is altogether too insignificant to provide effective cooling.

A shuttle valve is installed to direct oil from the return line through the cooler to the tank. This valve is controlled from the working-pressure side. Fig. 5 shows the valve in neutral position; the feed pump delivers its full flow to fill the circuit, the oil then passes through the shuttle valve to the feed pressure relief valve which maintains the pressure at 17-25 bars.

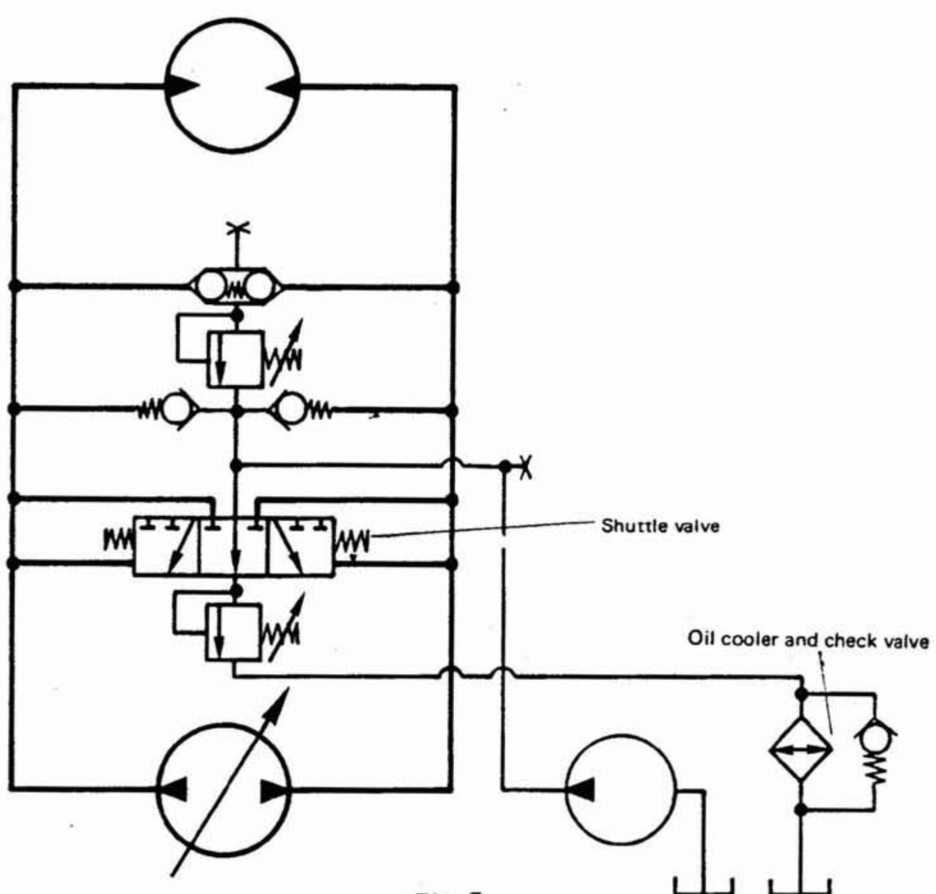


Fig. 5

System at work – Fig. 6

Working pressure has been built up in the right-hand main-circuit line. This pressure acts upon the main relief valve by way of one of the check valves, the other check valve sealing against the return line. The working pressure also closes the right-hand check valve for the feed pressure, and shifts the shuttle valve. The colder feed-circuit oil now enters through the left-hand check valve and forces the hot oil through the shuttle valve, the feed pressure relief valve, and the cooler back to the tank. Thus, an exchange of cold oil is now possible. The return side pressure is maintained at 17-25 bars by the feed pressure relief valve. – The operating principle is identical, if working pressure obtains at the left-hand side. Other equipment parts – brake, control lever, servo and two-speed valve – are discussed later.

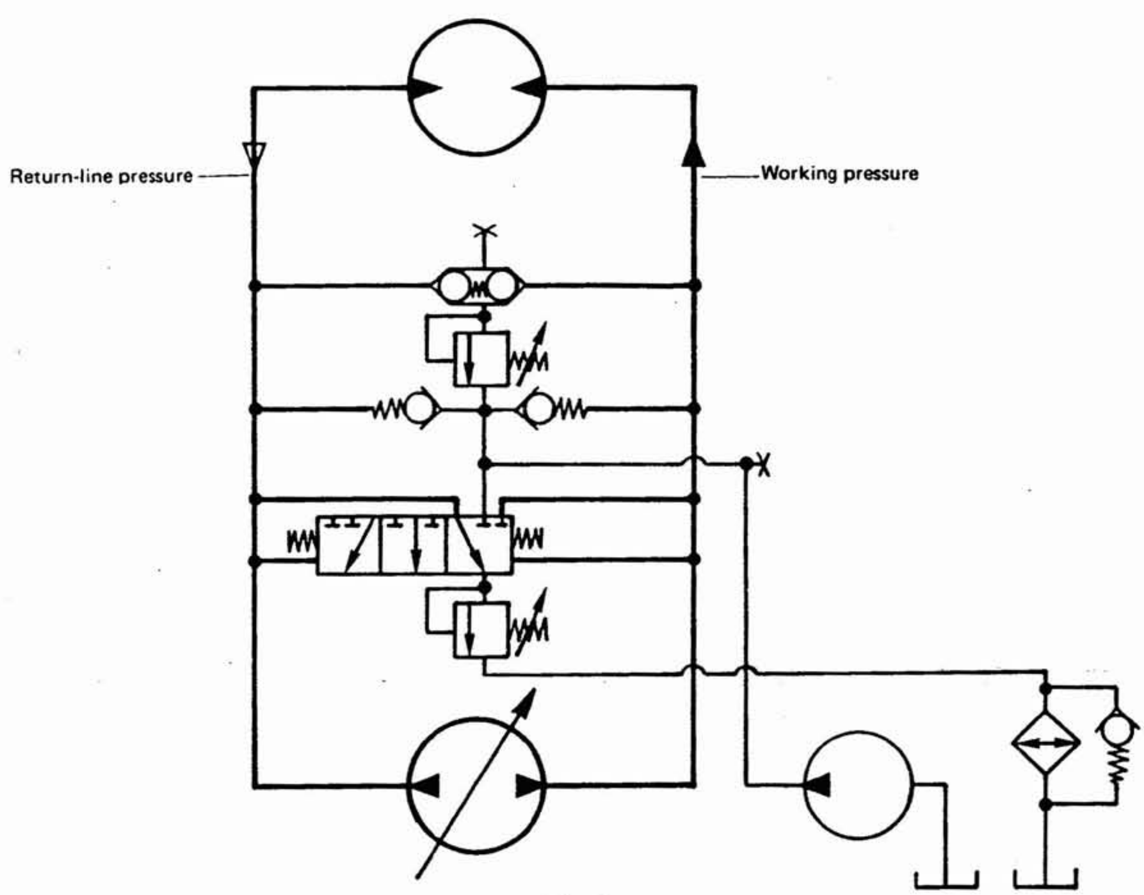


Fig. 6

Unit valve – Fig. 7

The valves described above are all mounted in a common valve block, and are collectively known under the name of »unit valve».
Luffing and slewing closed-circuit systems also possess unit valves, although without feed pressure relief valves.
In new cranes, types DS and G, there is no feed pressure relief valve in the hoisting circuit unit valve either, as the valve is mounted on a separate valve block and designated item 4148 in the hydraulic circuit diagram. The unit valves are called 1122 for the hoisting circuit, 2123 for luffing, and 3121 for slewing.
In earlier cranes, hoisting circuit unit valves are called 102 and 152 for single-motor and double-motor winches, respectively: the luffing circuit unit valve is No. 252, and the slewing circuit unit valve, No. 302.
In newer cranes, only one unit valve is used in the hoisting circuit, also if the winch is equipped with two motors.

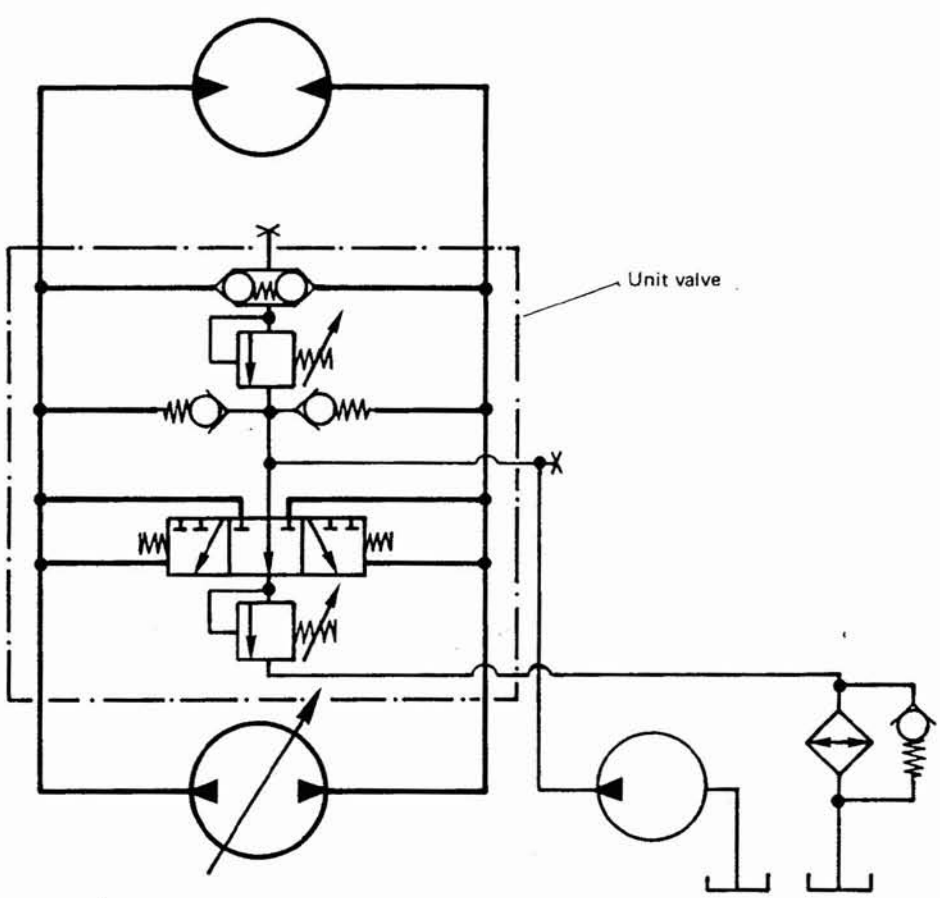


Fig. 7

Unloading the pump circuit when idling

When idling, the variable displacement hydraulic pump will still produce a certain flow of oil, sufficiently large to maintain a hydraulic pressure against the immobilised hydraulic motor. Even if this flow is very small, a corresponding amount of oil will have to be discharged from the circuit by the main relief valve. To avoid unwanted heating of the oil and unnecessary component wear, the pump circuit is short-circuited through the motor valve.

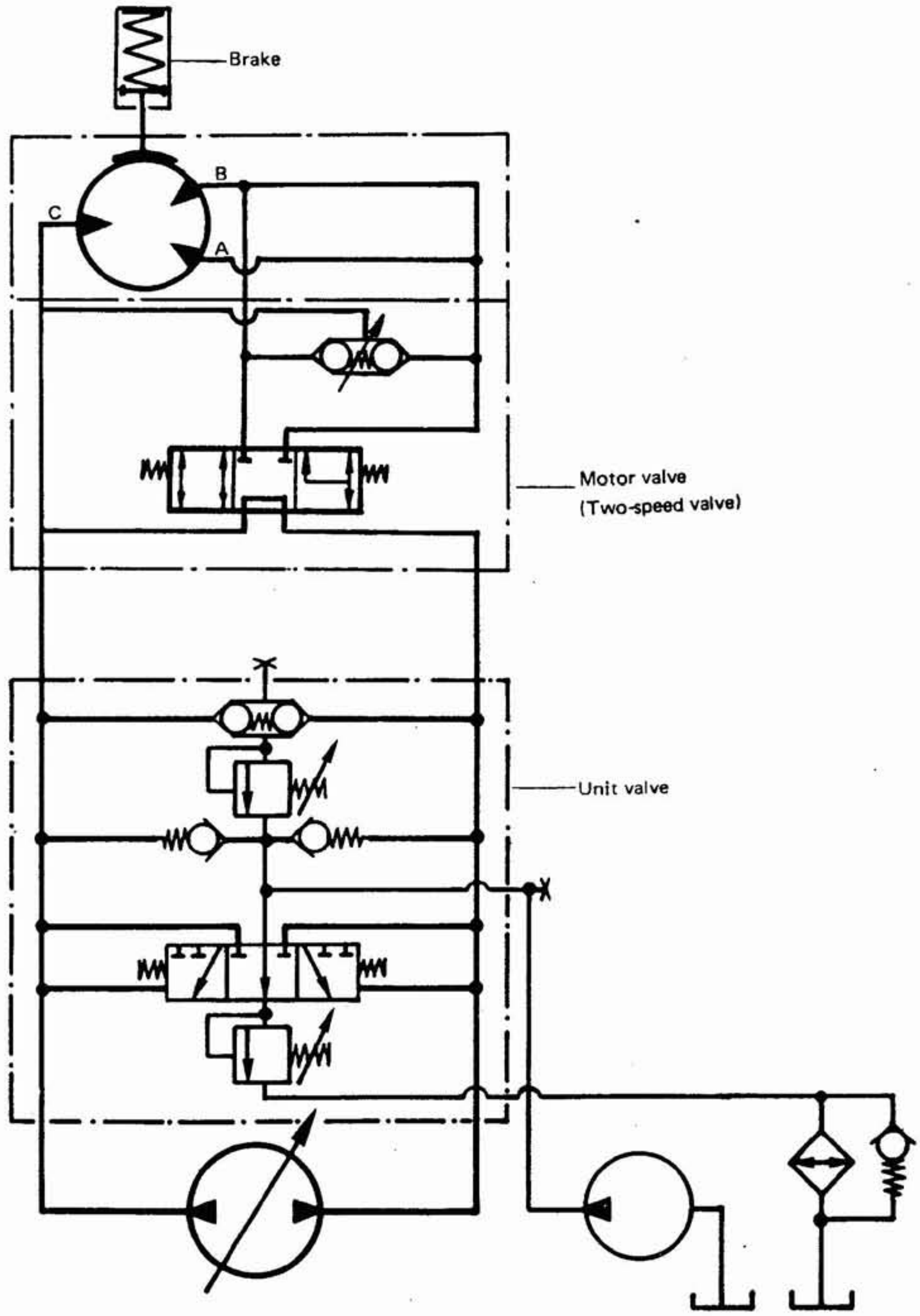


Fig. 8

Motor valve function at low speed

With the hoisting winch operating in the low speed range, the motor-valve spool is shifted to its proper position by pilot pressure at the same time as the motor brake is released. Oil is supplied to both motor connections A and B in parallel.

Shock absorber valve

Pressure peaks in the circuit are taken care of by a shock absorber valve that forms part of the motor valve, and discharges a certain amount of high-pressure oil to the low-pressure side. This valve functions both in the normal (low-speed) range and in the high-speed range.

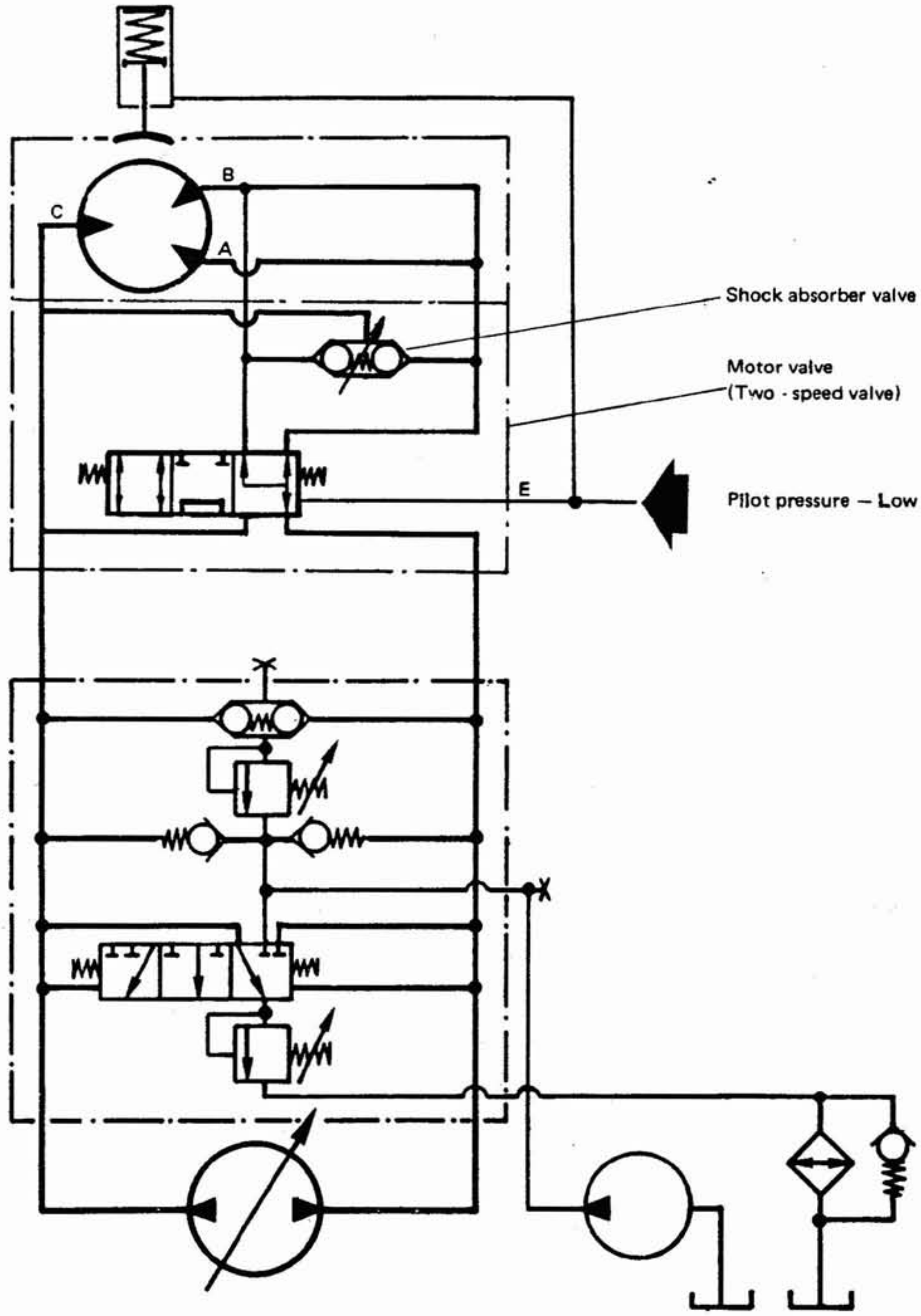


Fig. 9

Motor valve function at high speed

The hydraulic motor may be operated at half its normal displacement by introducing a so-called two-speed plug to separate the A and B connections of the hydraulic motor. The motor will then run at approximately twice its normal speed, and the lifting capacity of the winch will be reduced to some 40 % of the capacity in the standard-speed range.

The normal, low-speed range is obtained by applying pilot pressure at the two-speed valve »E» connection. By applying pilot pressure at the »F» connection, the two-speed valve spool is shifted to a position where hydraulic motor ports B and C are connected to each other.

Hydraulic motor connection A will then recieve the entire oil flow produced by the pump, circuit leakage excepted, and the motor will run at its »double» speed.

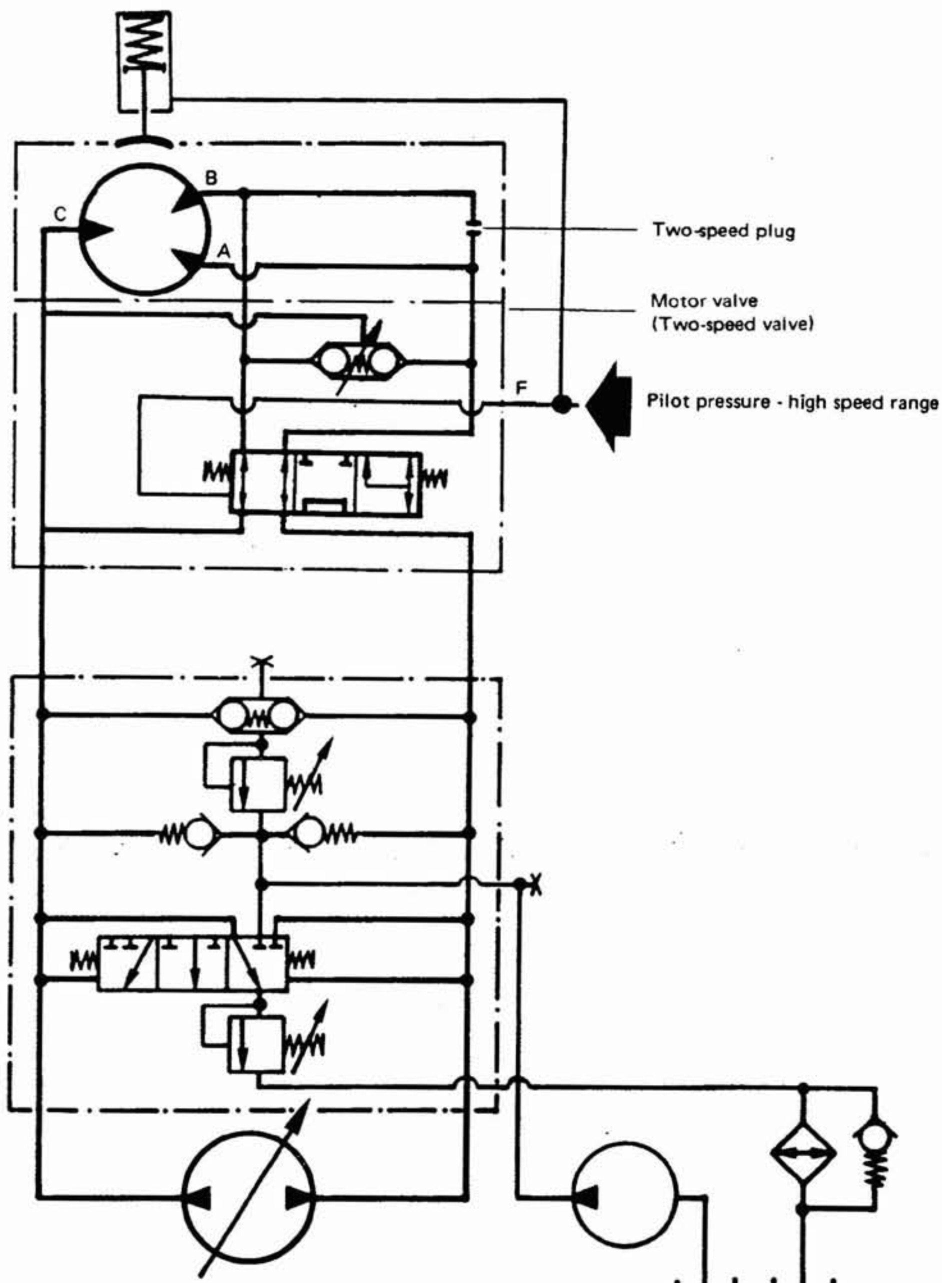


Fig. 10

Open circuit system

An open hydraulic circuit consists of a constant-speed, constant-displacement type vane pump driven by the main electric motor. The pump is self-priming, drawing oil direct from the oil tank. The pressure side of the pump supplies oil to the hydraulic motor whose discharge side is returned direct to the tank, Fig. 11. When the circuit is operating, oil is always fed into the same side of the motor which will, thus, always rotate in the same direction.

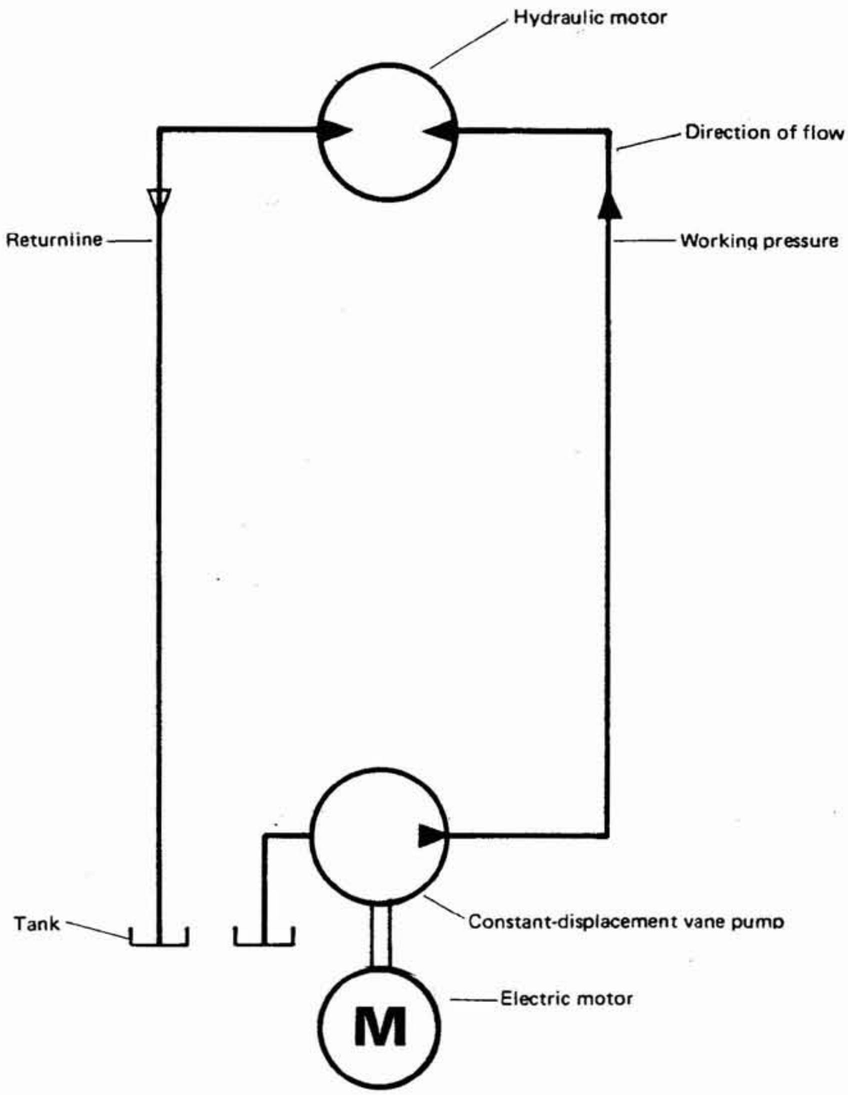


Fig.11

Control valve – Fig. 12

A special flow-control valve must be installed in order to control the speed of the hydraulic motor in both directions of rotation, and to stop it without shutting off the pump which supplies a constant flow of oil when the crane is running. In earlier, mechanically controlled cranes, the three-position flow control valve is connected mechanically to the control lever, Fig. 8. Later crane types, of 5 to 8 tons, are hydraulically controlled as shown in Figs. 19, 20, and 21.

When starting the crane, the control lever is in neutral, and oil flows through the valve in neutral position to the tank, Fig. 12. As the pump discharge side connects directly to the tank, no operating pressure can be built up, and the pump operates against zero load.

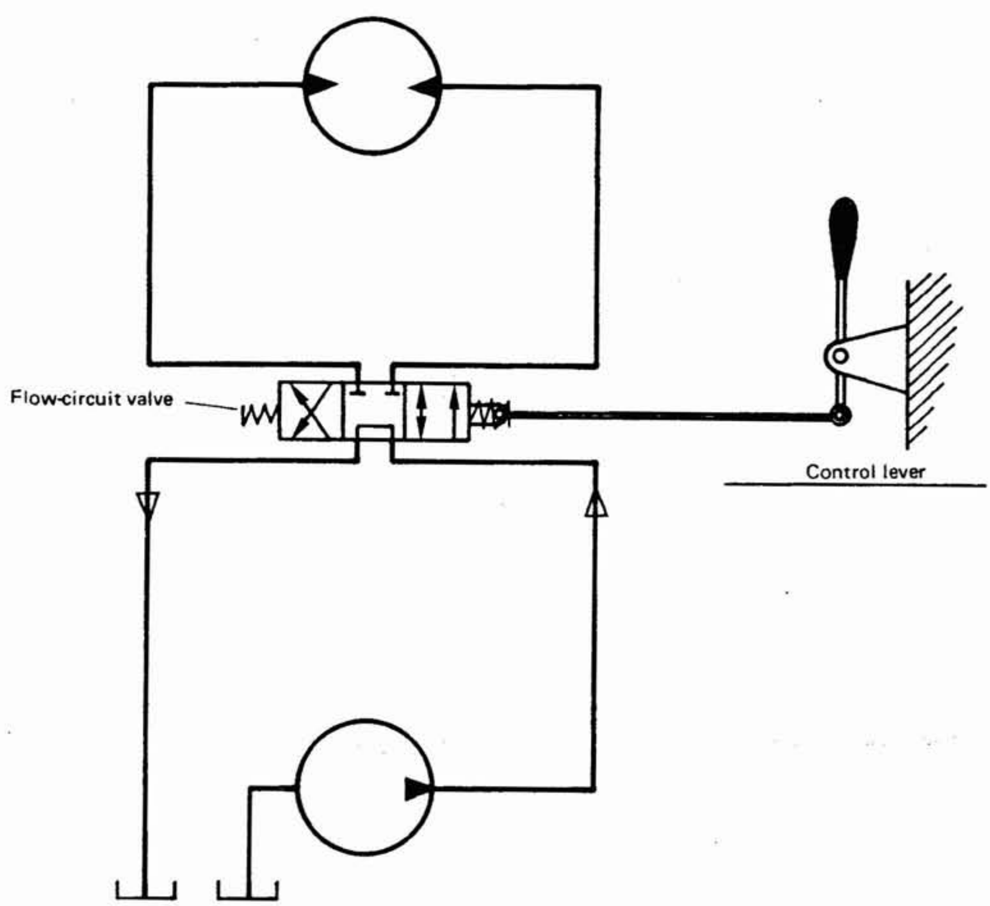


Fig. 12

Direction of rotation — Fig. 13

The two illustrations of Fig. 13 demonstrate how the direction of rotation of the hydraulic motor is reversed by means of the control lever and flow control valve.

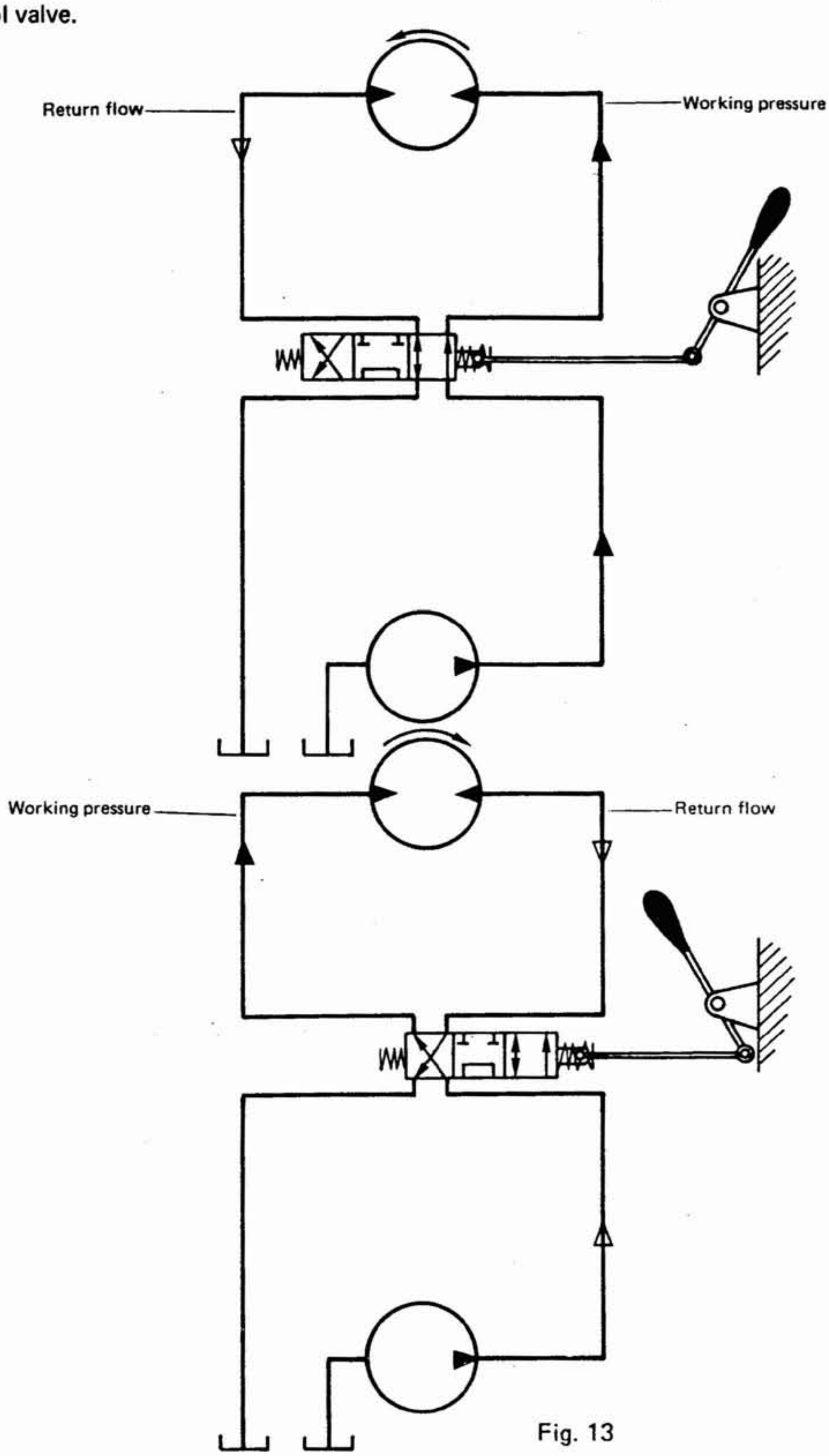


Fig. 13

Safety valve – Fig. 14

Like the closed circuit, an open circuit must be protected against excess pressure by a relief valve, Fig. 14, which opens when the working pressure exceeds a fixed value (approximately 155-175 bars: see Instruction Manual).

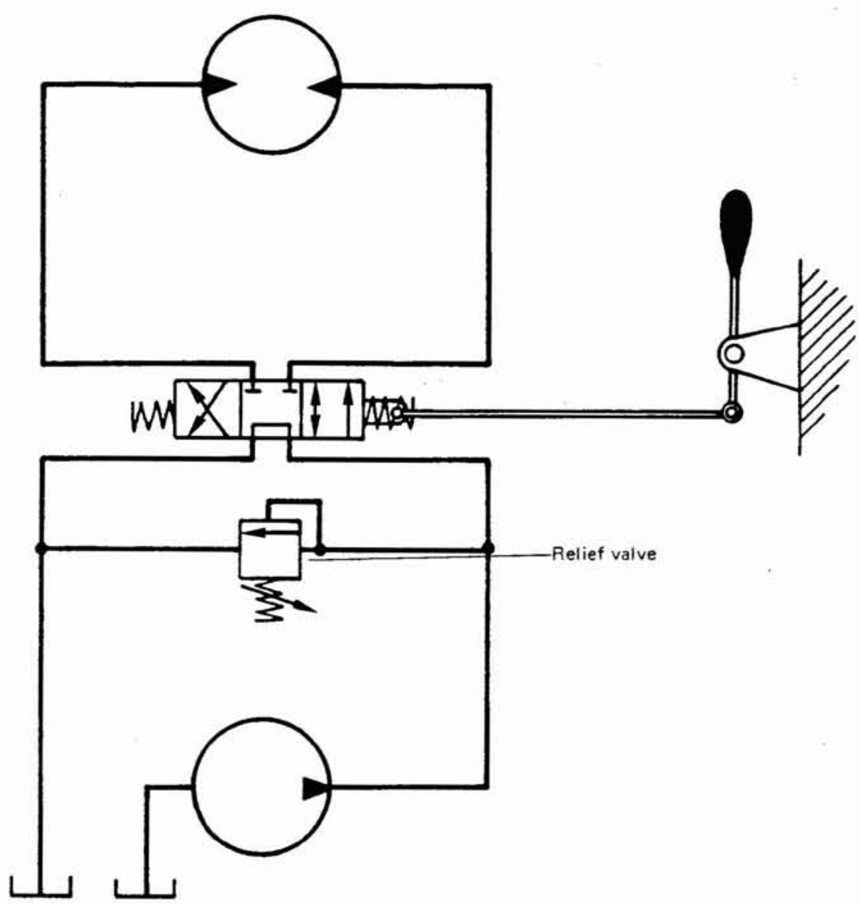


Fig. 14

Luffing winch brake – Fig. 15

A brake is required to stop the hydraulic motor when the control lever is returned to neutral. The brake consists of a cylinder with a spring-loaded piston which pulls a brake band tight around the rotary motor housing.

The brake opens at a pressure of some 20-22 bars. When the control lever and flow control valve are in neutral position, there is no pressure in the brake oil line, and the brake immobilize the motor.

Moving the control lever to an operating position admits oil under pressure to the brake cylinder; the brake opens and releases the motor when the pressure attains approximately 20-22 bars.

In order to control the opening delay of the brake, a combined check and throttle valve is used. (The opening delay is some 1-1.5 seconds when the crane is at operating temperature.)

In order that the motor shall rotate, a working pressure in excess of what is required for brake release, must be built up: the working pressure of the work circuit is determined by the load on the hydraulic motor.

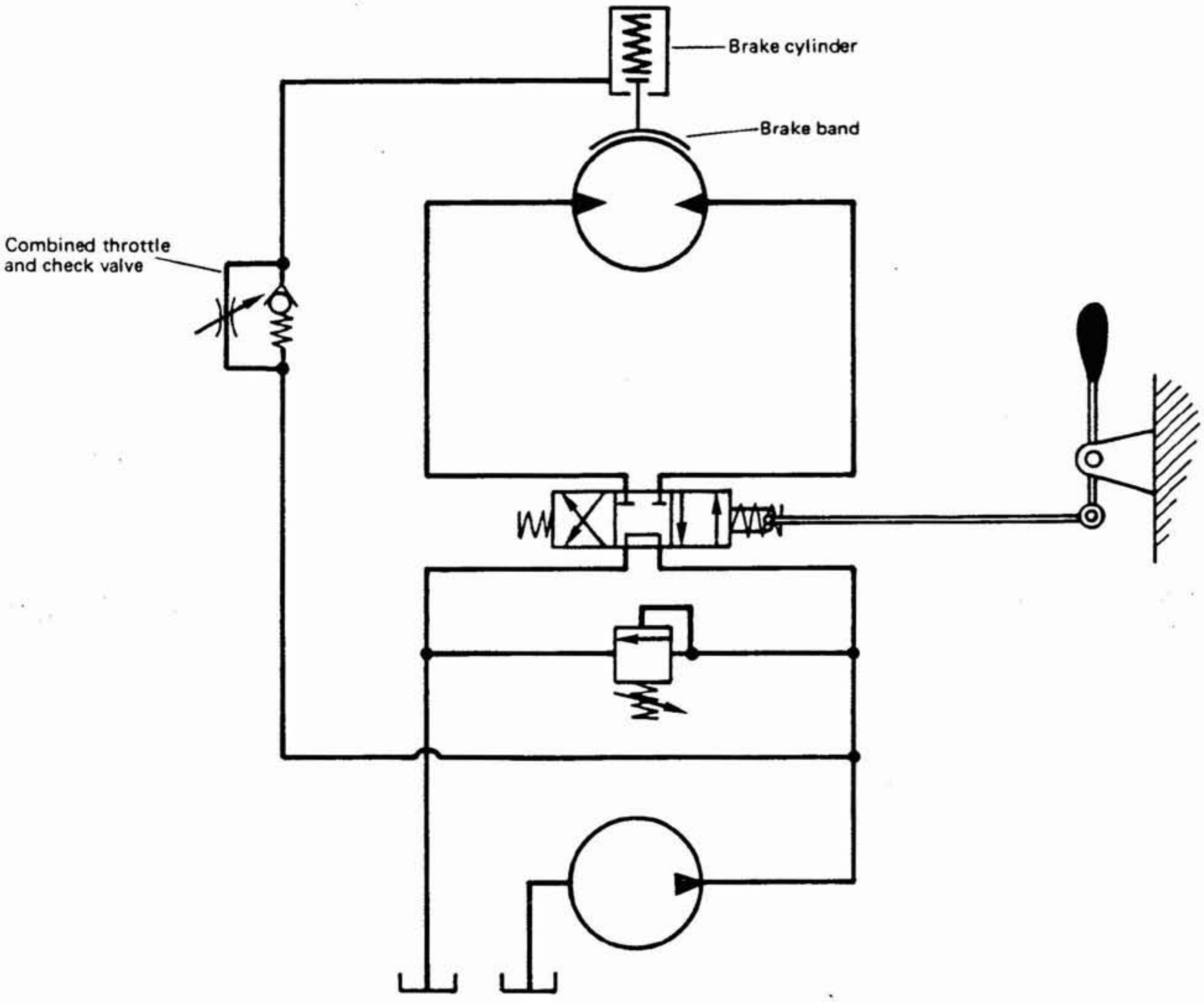


Fig. 15

Filtering the oil – Fig. 16

When the crane is operating, the luffing circuit pump will deliver a constant flow of oil. With the control lever and flow control valve in neutral, the oil is returned to the tank through the flow control valve. When the flow of oil is relatively large, it is advisable to filter the oil by means of a suction filter in the pump suction line from the tank, and a magnetic filter in the return line for the spent oil, Fig. 16.

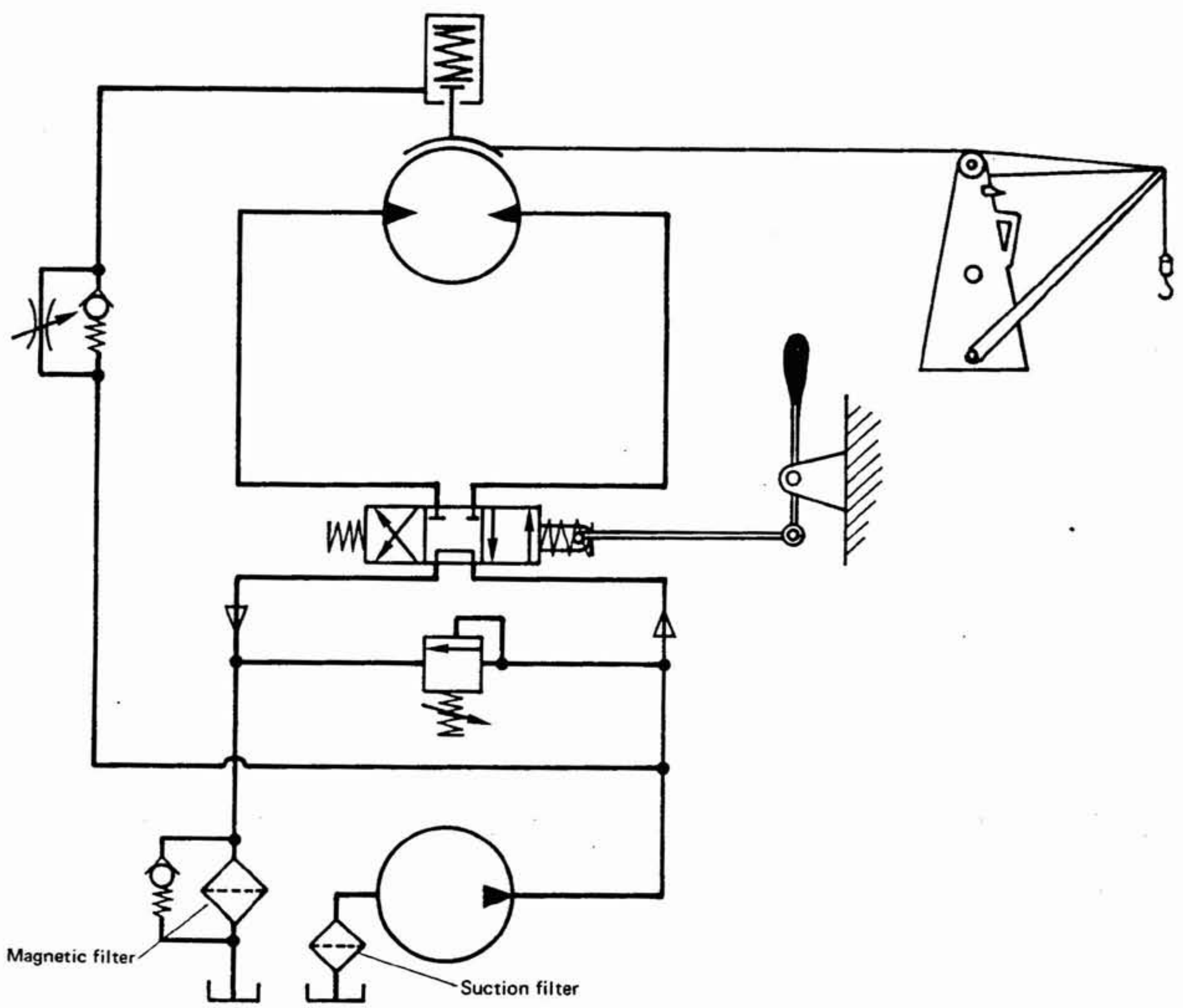


Fig. 16

Raise jib — Fig. 17

To raise the jib - luffing-in - move the control lever to operating position »up», Fig. 17; an oil pressure corresponding to the weight of the load will then be built up. After the brake has opened at about 20-22 bars, the jib is raised at a speed which is determined by the amount of control lever deflection.

If the jib is run against the bumpers at the crane-house top, the oil pressure will reach the opening pressure of the relief valve which opens and drains the working pressure side to the tank.

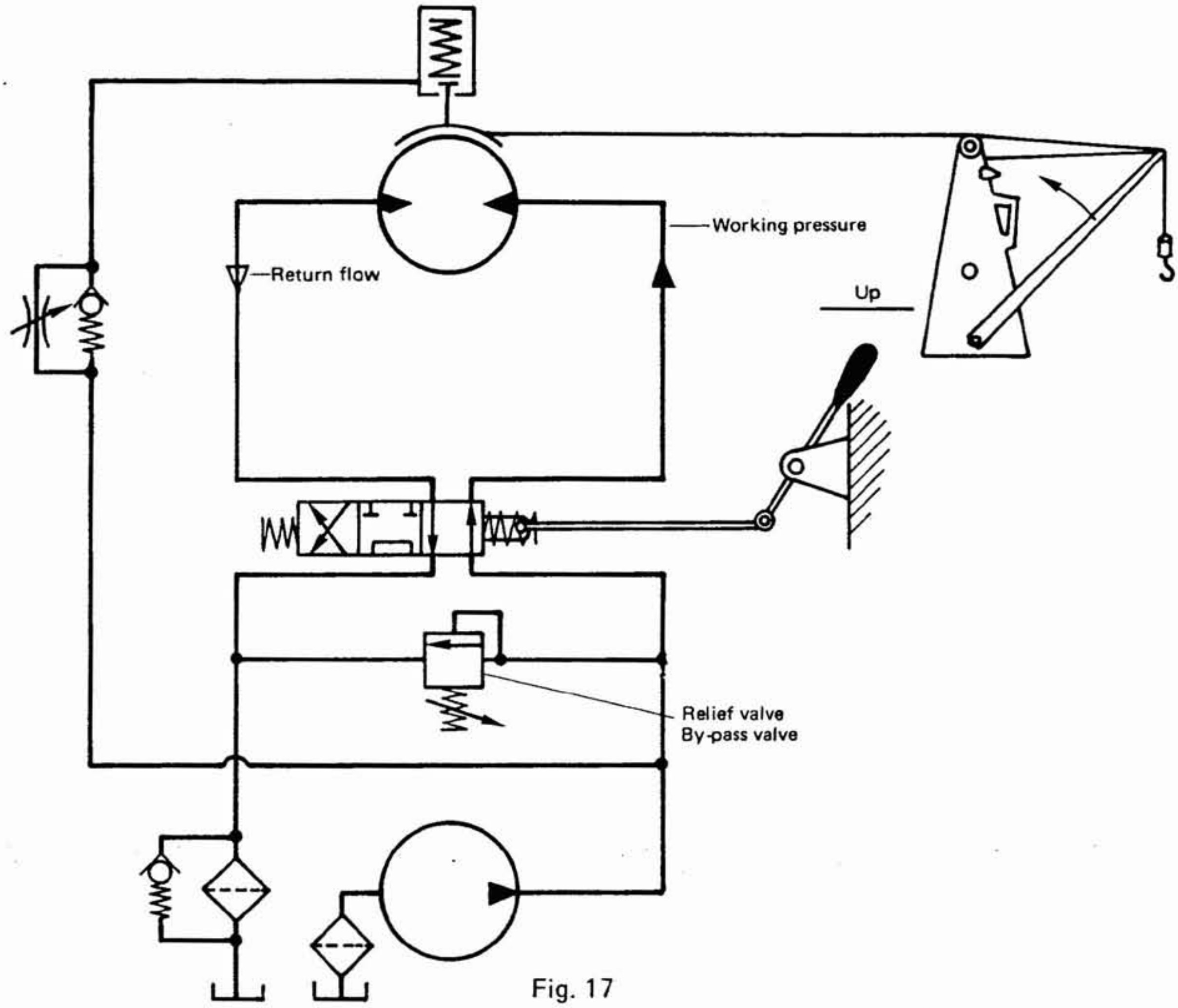


Fig. 17

Lower jib — Fig. 18

To lower the jib - luffing-out - move the control lever to operating position »down», Fig. 18. The oulet side from the pump is connected to the left-hand inlet side of the motor. To build up the required working pressure and to prevent the jib falling down under its own weight when the brake is released, a check valve and a counter balance valve are installed on the other side of the motor. (The counterpressure is approximately 140-160 bars: see Instruction Manual.)

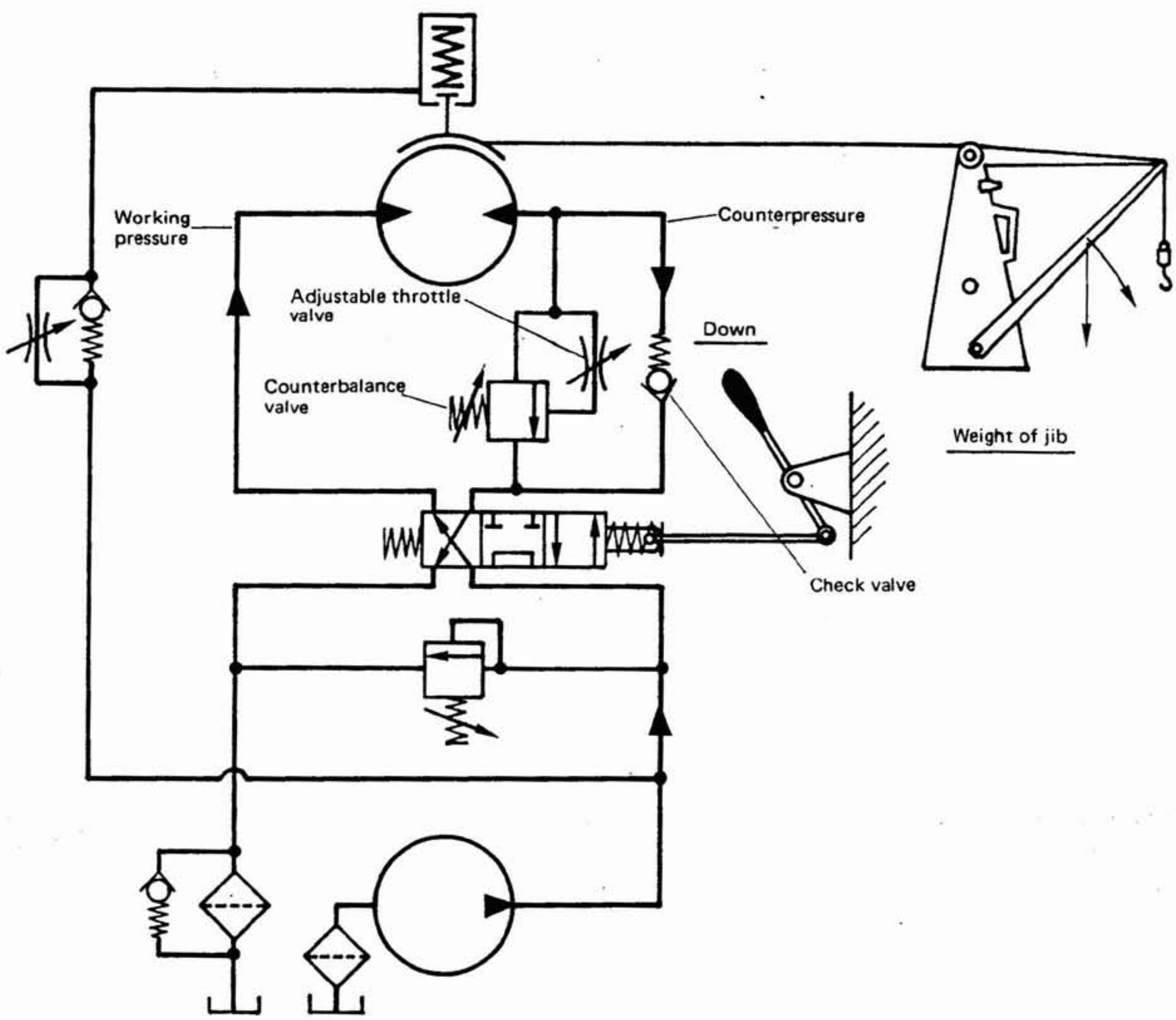


Fig. 18

Open circuit, hydraulic control — Fig. 19

In the open circuit system with hydraulic control installed in 5-8 tons cranes of present production, the control lever operates various hydraulic control valves; a flow control valve, a pressure regulating valve, the control circuit pump, and a pressure relief valve set to 36 bars.

The three-position flow control valve is controlled by the control pressure built up by the control lever movement. The pressure regulating valve item 1 is controlled by pressure adjusting valve item 3.

With the crane switched on, the control-circuit pump and the luffing-circuit pump will both deliver oil at constant flow rates. With the control lever in neutral, a control circuit pressure of 36 bars will be built up against the control circuit relief valve and throttle valves 4 and 5. The lines (C and D) from the throttle valves to the flow control valve connect to tank through the control-lever operated valves. Lines C and D being thus drained to the tank, the flow control valve is in neutral. The luffing circuit pump is unloaded, because pressure regulating, item 1, is open.

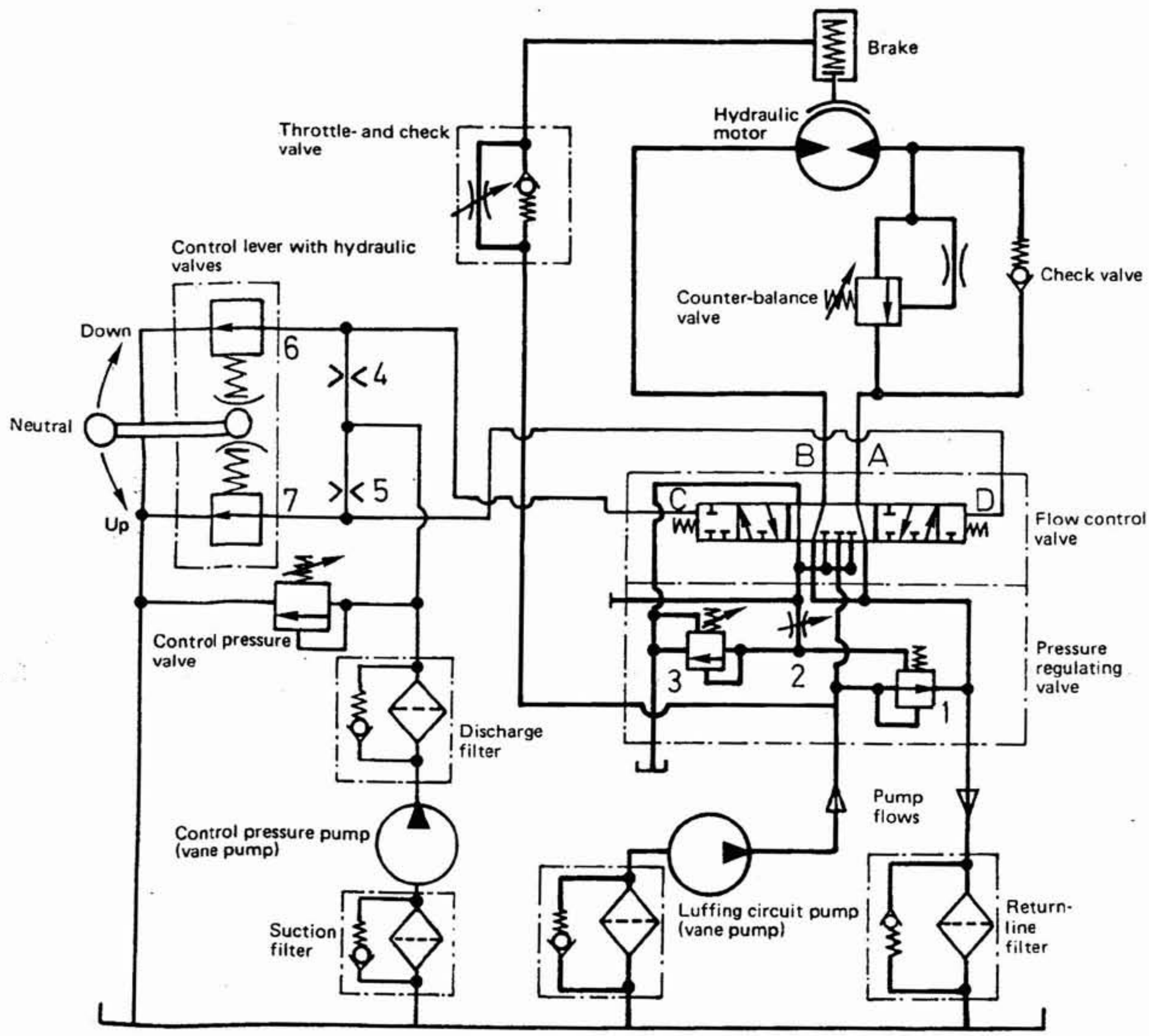


Fig. 19

Raise jib — Fig. 20

To raise the jib, move the control lever to operating position »up», Fig. 20. Control valve, item 7, is part throttled, and control pressure is obtained at the three-position flow control valve, which moves to the position shown in Fig. 20.

The luffing circuit pump discharge side connects to the right-hand inlet of the hydraulic motor. Pressure regulating valve 1 closes, and a working pressure builds up which is determined by the load. The brake opens when the working pressure reaches about 20-22 bars.

If the jib is luffed-in agianst the bumpers at the crane house top, the oil pressure rises to the opening pressure of adjusting valve 3, which opens for the oil at pressure regulating valve 1 which also opens. The working pressure is limited, the brake closes, and luffing-in is discontinued.

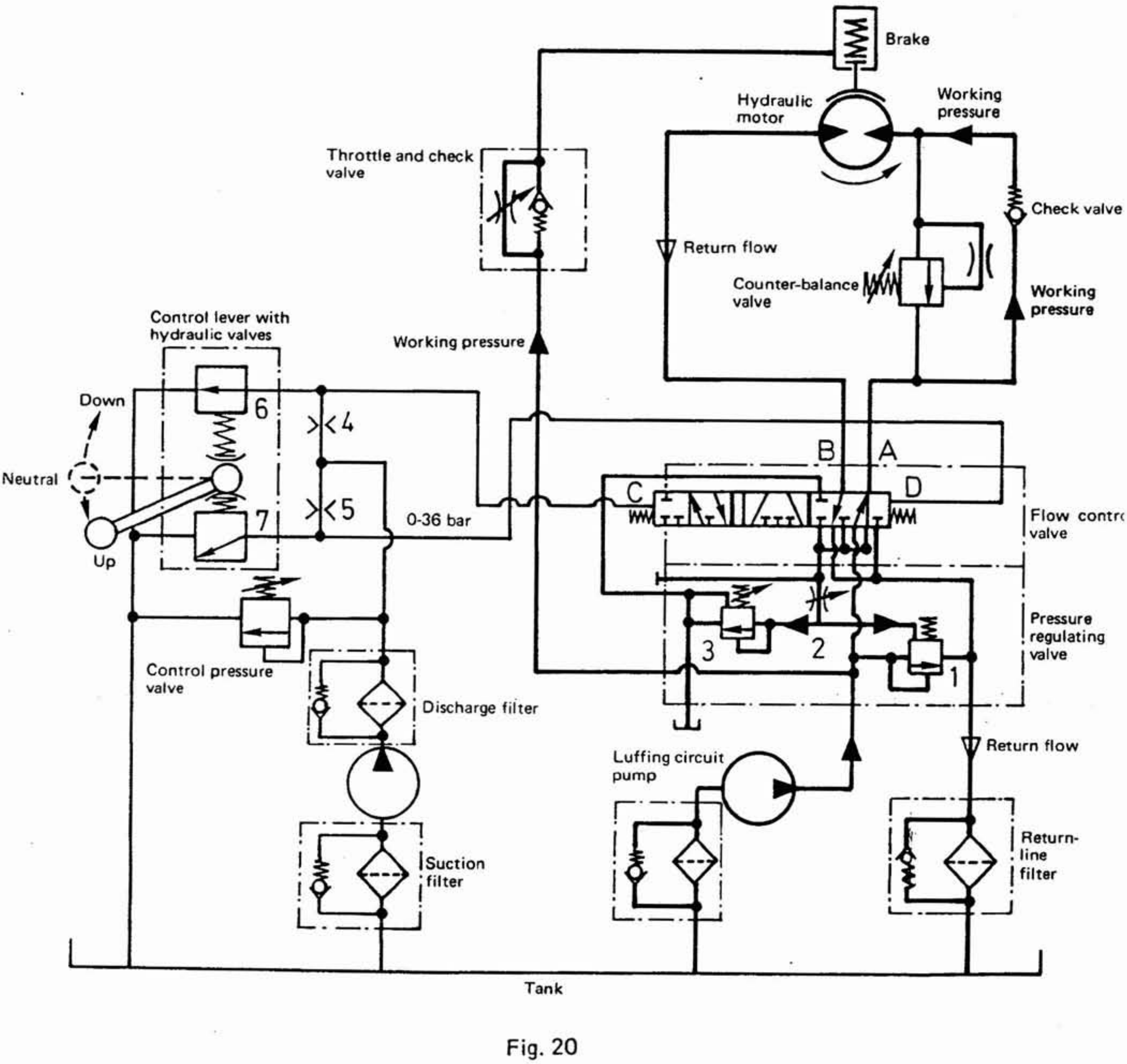


Fig. 20

Lower jib – Fig. 21

To lower the jib, move control lever to operating position »down», Fig. 21. Valve 6 is part throttled, and control pressure is built up at the three-position flow control valve, which moves to the position shown in Fig. 21.

The luffing circuit pump discharge side is connected to the left-hand inlet of the motor. Pressure regulating valve 1 closes, and working pressure is built up on the left-hand side of the motor. To prevent the jib from dropping under the influence of its own weight when the brake opens, a check valve and a counter-balance valve are included in the circuit. The function of the counter-balance valve is to build up a working pressure to the left-hand inlet side of the motor to support the jib.

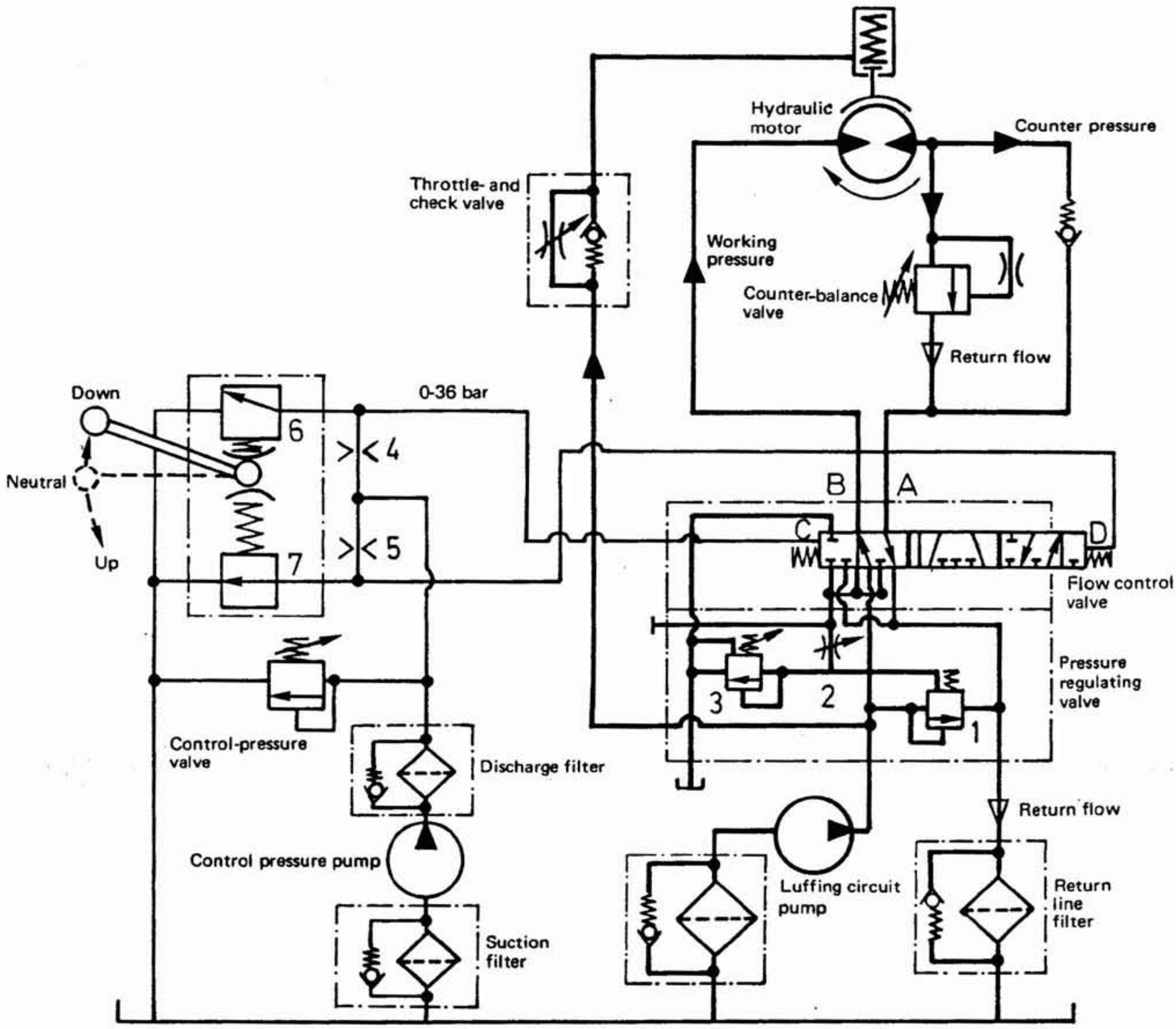


Fig. 21