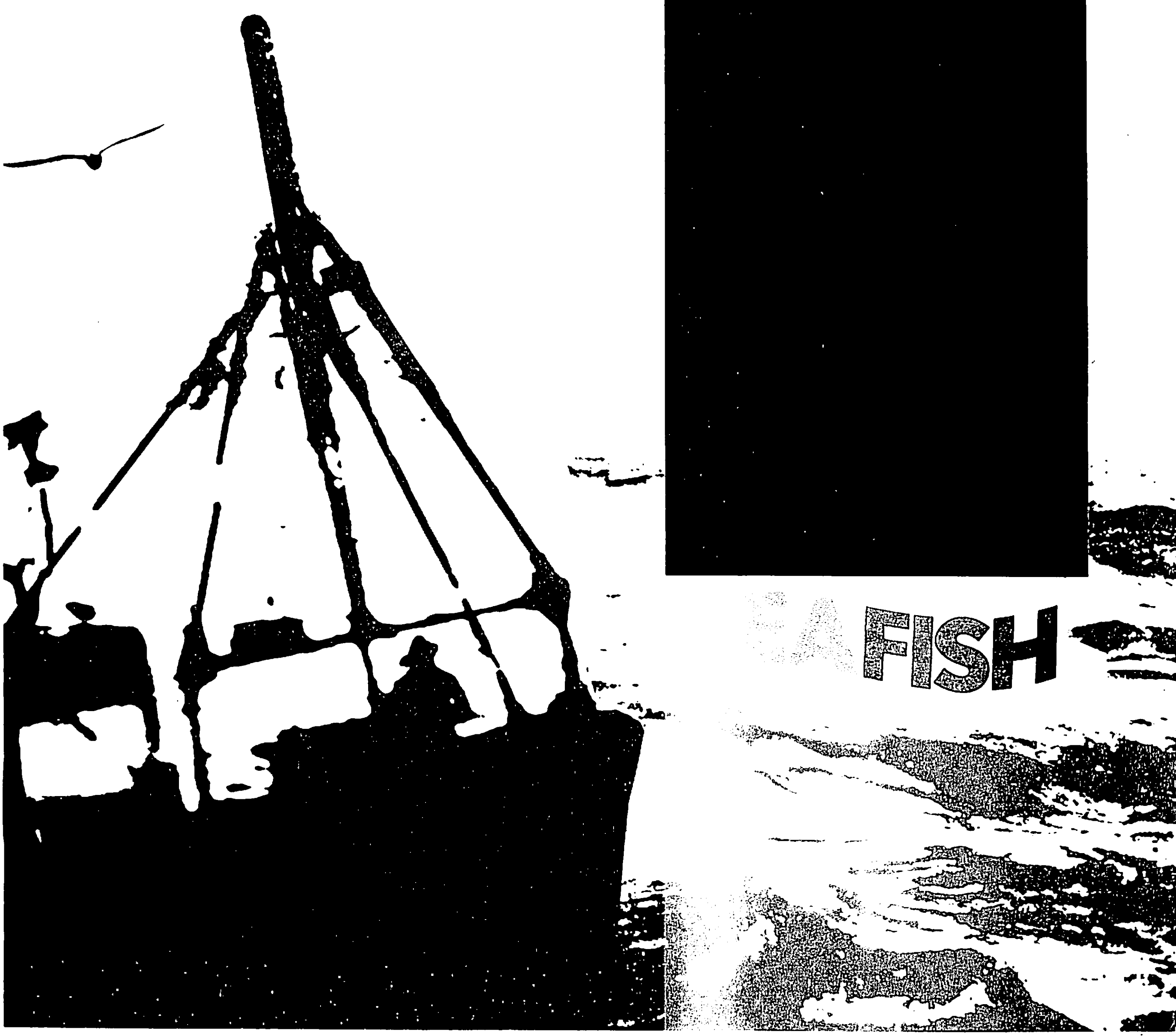
SEA FISH INDUSTRY AUTHORITY

Hydraulics in Fishing Vessels

by J.R. Gifford

OPEN LEARNING



Hydraulics in Fishing Vessels

Hydraulics in Fishing Vessels
An Open Learning Module for the
Seafish Open Learning Project.

This work was produced under an Open Tech contract with the Manpower Services Commission. The views expressed are those of the author and do not necessarily reflect those of the MSC or any Government Department

ISBN 1 85280 013 5

Contents

The Author

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A Guide for Open Learners

This will help to explain what open learning is all about. It will help you to make the best use of your open learning module.

WHAT'S SO GOOD ABOUT OPEN LEARNING?

Open learning gives you freedom to choose.
You study:–

- What you like
- Where you like
- When you like
- At a pace to suit you.

You can pick the subjects you want. You don't have to be in a certain classroom at a certain time. You won't be bored because the teaching is too slow, or lost because it's too fast.

You seldom need any qualifications before you are allowed to study.

All this freedom lets you fit your studying into your daily routine.

The best thing about it for most people is that they can study without taking valuable time off work.

Modules are written in a way that allows you to study without help. However, it is expected that you will need assistance from time to time, this can normally be provided.

THINGS YOU SHOULD KNOW ABOUT YOUR MODULES

What is a module?
A module is the name we have given to a study package. It will have a printed text. In a few of them there will be audio or video tapes as well.

Each module will be divided into segments. You could think of each segment as a lesson.

Before you begin

Each module will have a short introduction. You will be given a list of things you will need. For some modules, special equipment will be needed. We can supply most of this. This section will also tell you if you need any knowledge or experience before you begin. Check that you have everything you need.

Objectives

Modules are based on objectives which tell you what you will be able to do when you have finished. These are clearly stated. You should check that the module objectives match your own reasons for studying. You will be told when you have achieved each one of the objectives. In this way you can easily keep track of your own progress.

S.A.Q.'s

This is short for **self assessment questions**. These questions are carefully designed to help you. They let you know how you are getting on. They help you to find out any problems that you may be having with the material and help you to put them right.

Don't be tempted to skip these questions. Don't look at the answers before you try them! You will only be cheating yourself.

Where you are expected to write an answer, a space will be left in the text. Remember the module is your learning tool, not a textbook, so go ahead and write on it. **Don't** try to keep an answer in your head until you have checked it. **Always write down your answer first**. Writing the full answer down is very important, it makes you really think about what you are doing. The wide margins are also there for you to make notes in.

You will notice that the numbers given to the S.A.Q.'s are out of order. We did this on purpose. This is to stop you from accidentally seeing the answer to the second S.A.Q. when you are looking at the response to the first. The responses to the S.A.Q.'s are at the back printed on yellow paper. They are in the correct number order. I have called them responses because they are usually more than just answers. It is a good idea to read the whole response every time. It usually helps to know about common mistakes even though you got the right answer.

S.A.Q.'s are shown by a box with a question mark and the number of the question.

? **SAQ1**

Important information
Other boxes are used to show different types of information. This box with the ⓘ in the top left corner contains important information.

ⓘ

Warnings
This box with the warning sign gives information about possible dangers, health hazards, etc.

⚠

Definitions
A box with smaller print is used for definitions and extracts from documents.

smaller print

Other emphasis
Shading like this is used to pick out important sentences and paragraphs.

Bold type is used to make **important words** or **numbers** stand out.

HELP IF YOU GET STUCK

At the time of obtaining your module you will be told of any support which can be arranged.

This might be through one of the following:

- Telephone
- Face to face meeting
- Letter
- Tutor marked assignment

Questionnaire
Some modules will be accompanied by questionnaires. The questionnaire is your chance to help us. Your answers are our way of finding out if any changes are needed. If there is one, please remember to fill it in and return it.

HINTS ON STUDYING

When?
Try to get into a regular study routine. Set aside times for study but be ready to give and take a bit. Miss one of your planned sessions if you must, but try to make it up later.

Set yourself realistic targets such as 'I will finish segments one and two by this weekend' and **stick to them!**

Grab the chance to study at odd moments. You'll be amazed how much you can learn in fifteen minutes. It's difficult for the average person to really concentrate for more than 20 minutes at a time anyway. A word of warning – don't think you can learn anywhere. You need to be able to concentrate, there are often distractions which prevent this.

- Time spent just **reading** a module is not the same as time spent **learning**.

- You must become involved, the best learning happens when you're active, e.g. answering questions and making notes.

- Don't study too long without a break.

This module will remind you of suitable places to stop for a while, but if you need a break earlier, take one. It's entirely up to you.

Where?
Try to find somewhere where you will not be distracted. Almost anywhere will do. It all depends on how you are placed at home and at work. Don't forget your local library. Fishermen might find their local mission is able to help, especially with video equipment.

The secret is, **be flexible**. If the kids are having a party, go to Auntie's. If she's not in, go to the library. All you need is somewhere where you can get on with it and not be disturbed.

Carry your module with you when you can. Try to find gaps in your normal routine when you could do some useful work.

Now that you've decided to have a go, **stick with it!** Don't give up. Most people find studying hard at times, this is quite natural. It is also quite natural to need help with parts that you find especially difficult. I'm sure you'll find it worthwhile.

Introduction

Welcome to this study module on the hydraulic systems used in fishing vessels. These systems are now an important feature of nearly all fishing vessels. They allow the fisherman to have very fine control over the machinery used in fishing operations such as power blocks and winches and also allows this control to be from the bridge and other suitable positions.

Some fishing methods are not possible without the help of hydraulics and it is important that you understand how these systems work and the attention they may require. This module will help you to achieve this and give you guidance on fault-finding and maintenance.

PRE-ENTRY REQUIREMENTS

Study of this module does not require any previous academic knowledge apart from simple arithmetic.

EQUIPMENT REQUIRED

The only equipment required is a pencil, paper and two (red and green) crayons or water-based felt tip pens.

Objectives

After completing this module, you should be able to:

1. Explain the function of hydraulic systems fitted in fishing vessels.
2. Identify the components used in hydraulic systems.
3. Describe the action of hydraulic pumps and motors and explain how they are controlled.
4. Interpret circuit diagrams of hydraulic systems.
5. State the maintenance which is required by hydraulic systems on fishing vessels.
6. Describe procedures for fault-finding on hydraulic systems.

Segment One

Basic Hydraulic Systems

Segment One – Basic Hydraulic Systems

Welcome to the first segment in this Module in which we will see what a hydraulic system is composed of.

AIMS OF THE SEGMENT

The main aim of this segment is to help you to achieve Objectives No. 1 and No. 2 given on page xiii.

For this you should be able to:

- State the principal components of a hydraulic system.
- State the purpose of each component.
- Describe the basic actions of pumps, valves and actuators.

HYDRAULIC SYSTEMS

A hydraulic system is a system which uses hydraulic fluid (usually oil) to produce motion or power at some distance from the source of power and the person controlling it. For example, it can produce motion or power on deck from a pump in the engine room.

All hydraulic systems have the same general layout. There are 4 basic components:

- A **tank** (reservoir) to hold the fluid.
- A **pump** to force the fluid through the system.
- **Valves** to control the pressure, direction and flow of the fluid.
- An **actuator** (a cylinder or motor) to convert the energy of the fluid into mechanical force and produce power.

Two simple hydraulic systems are shown in Figures 1 and 2.

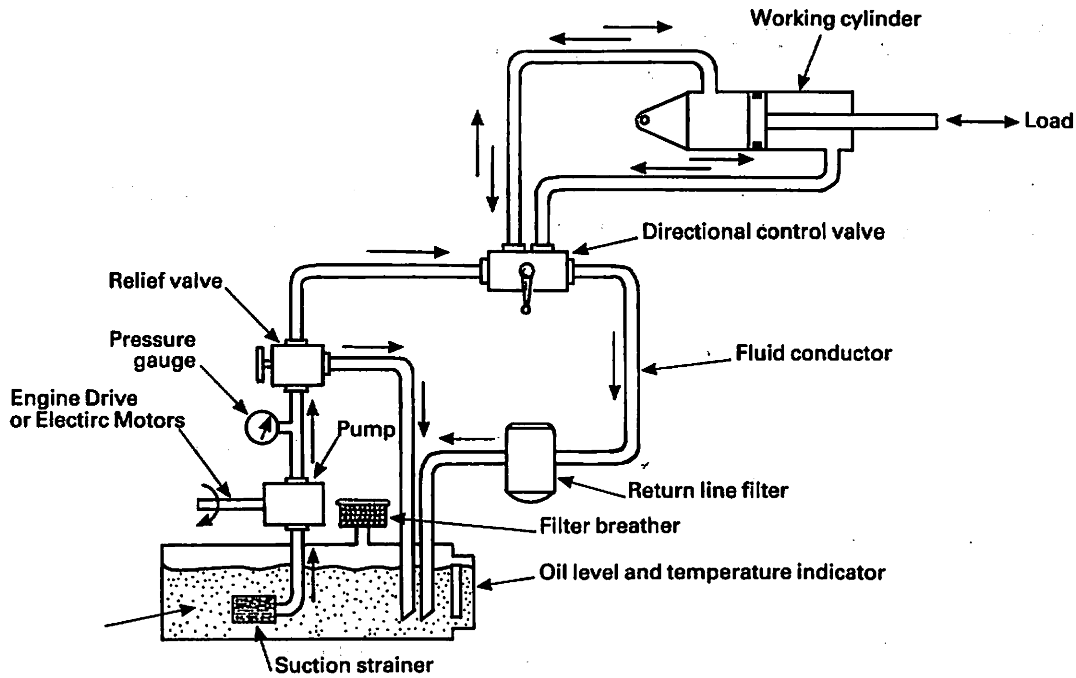

Figure 1.

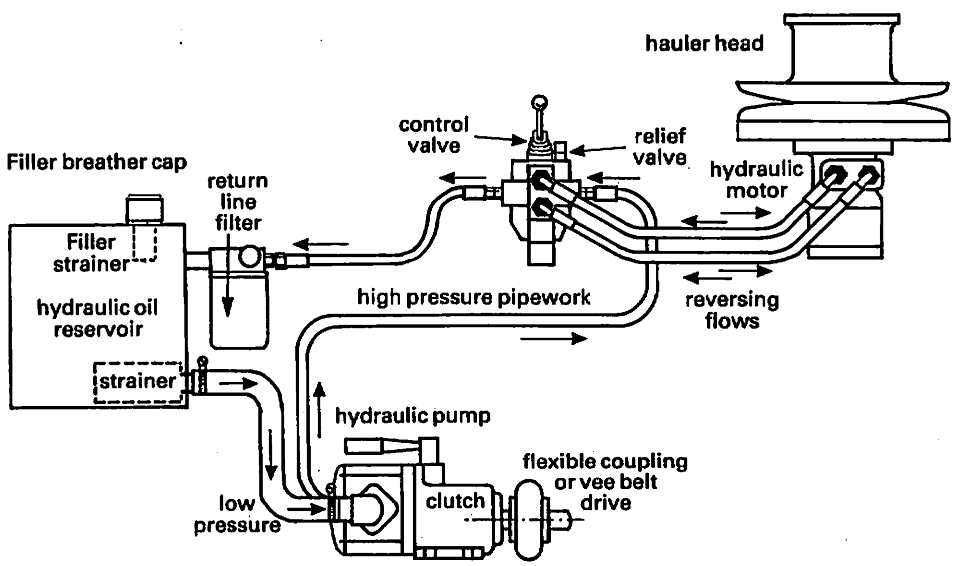

Figure 2.

Figure 1 shows a system using a cylinder to give linear motion. An example of this on a fishing vessel is raising the power block head.

Figure 2 shows a system using a motor to give rotary motion and an example of this is using a hydraulic motor to turn the power block drum.

Now look at Figures 1 and 2 in turn and follow the system round. Start at the pump and using the arrows, trace the path of the hydraulic oil. Make a note of each item as you come to it.

On most fishing vessels there will be at least one of each of the systems shown in Figure 1 and 2. As soon as you have the opportunity and when the weather is suitable, go out on deck and have a look at the power block and its hydraulic system on your vessel.

Try to identify the reservoir, the pump, the valves and the actuator(s). Most of these are usually quite easy to identify but the reservoir and the pump may be difficult to find. This is because they are often in the engine room, the pump being driven off the engine shaft.

⚠

Remember always to ask permission before entering **any** engine room or before looking around the deck of a fishing vessel of which you are not a member of the crew. Never attempt to move any of the controls you are looking at.

Now try your first SAQ.

SAQ1
Write down a list of the main components in a hydraulic system.

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COMPONENTS OF HYDRAULIC SYSTEMS

We will now consider the principal components of a basic hydraulic system in detail.

The Tank or Reservoir

The tank must be large enough to hold all the oil required to fill the system and some in reserve. As a general guide the tank should be able to hold 2 to 3 times the capacity in litres per minute of all the pumps in the system.

The return pipes to the tank are located at the opposite end from the suction pipes because the returning oil is usually hot. Arranging the pipes in this way prevents the hot oil from being immediately pumped through the system again. In some cases the tank may be fitted with an oil cooler through which either sea water or fresh water passes.

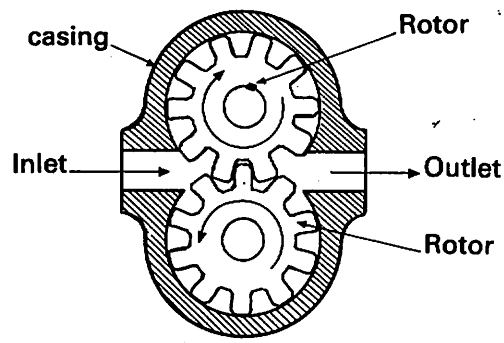
A baffle plate fitted between the return pipes and the suction pipes helps to take heat away from the oil and release any air which is contained in the return oil. It will also help to separate out any dirt in the oil before it is recirculated.

The tank should be fitted with an oil level indicator and in many cases will also have a temperature indicator.

The Pump

All pumps used in hydraulic power systems are of the **positive displacement type,** that is, they deliver a fixed (positive) amount of fluid during each revolution. The most common types of pump used are:

- Gear Pumps

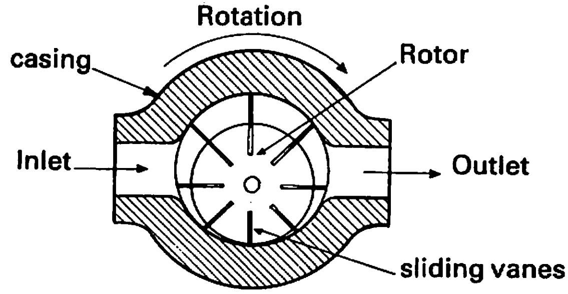


External Gear Pump

Figure 3

In this type the rotors are like gear wheels. One rotor is driven by the power shaft and the second rotor is driven by the first rotor. The teeth on the rotors form pockets with the casing and as the rotors turn, oil is carried round from the inlet to the outlet of the pump. As the teeth mesh together on the outlet side the oil is forced out. For this pump to be efficient the rotors must be a neat fit in the casing.

- Vane Pumps

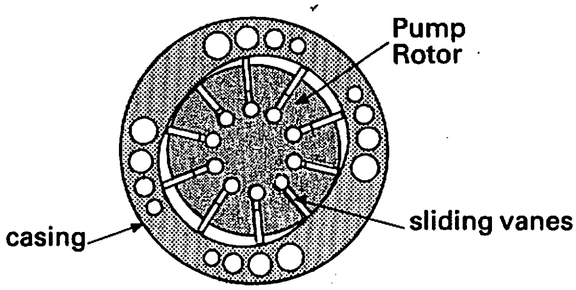


Unbalanced Vane Pump

Figure 4.

In this type the rotor shaft is off-centre and the vanes slide out and in as the shaft rotates. The vanes form pockets with the casing and as the shaft rotates these pockets first get larger and oil is drawn in. As the shaft continues to rotate, the pockets get smaller and the oil is forced out.

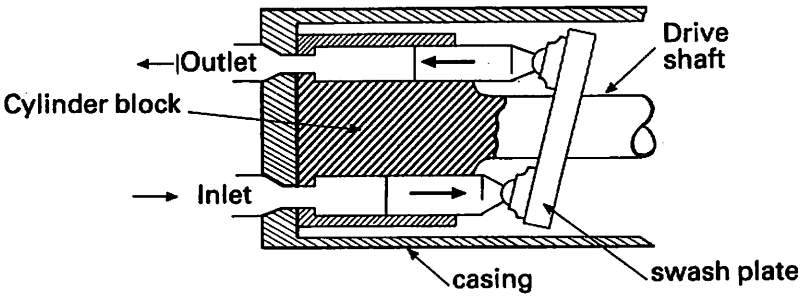
Since the rotor is off-set from the centre line, a side thrust is created in this pump and this force is carried by the shaft bearings. To eliminate this side thrust a balanced rotor is used and oil drawn in and compressed on opposite sides of the rotor. This form of the pump is shown in Figure 5.



Balanced Vane Pump

Figure 5.

- Piston Pumps



Axial Pump

Figure 6.

In these pumps the mechanism causes the pistons to move in and out in their cylinders as the driving shaft turns. The pistons slide on the face of the swash plate and move out during the first half of each revolution. They then move in during the second half of each revolution and force the oil out. The oil ports are arranged so that the inlet port is open as the piston moves in and the outlet port is open as the piston moves out. Each piston acts in turn and this gives the pump a smooth delivery.

In fishing vessels pumps are driven from either the main engine or an auxiliary engine by a power take-off shaft or a belt drive. A clutch is usually included to allow the pump to be disconnected.

There are many variations of the pumps shown in Figures 3-6 and these will be dealt with in a later segment.

Now try these two SAQ's.

> ⓘ **SAQ22**
> Name the 3 types of pump used in hydraulic systems.

....

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....

Valves

Valves are designed to control the pressure, flow and direction of the hydraulic oil in the system. There will be several of these valves in every hydraulic system, and we will now look at some of these.

Pressure Control Valves

Positive displacement pumps can generate very high pressures. The pressure in the system will increase if the actuator stalls due to an excessive load, or if the actuator (a hydraulic cylinder) is to hold a load in place.

Excess pressure is reduced by a **relief valve.** Every hydraulic system is fitted with at least one relief valve on the pump outlet line and this valve discharges back into the tank.

A simple relief valve is shown in Figure 7.

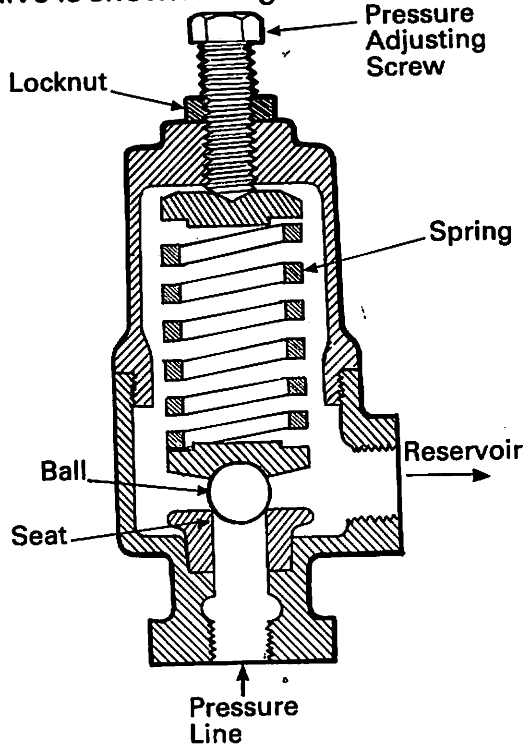


Figure 7.

The spring holds the ball on its seat until the pressure in the line lifts it off and allows oil to return to the tank. When the pressure drops the ball is re-seated. The lifting pressure can be altered by turning the pressure adjusting screw above the spring.

A direct operated relief valve as shown in Figure 7 is only suitable for systems with small flow variations. For systems with large flow variations, relief valves are operated by a pilot valve as shown in Figure 8.

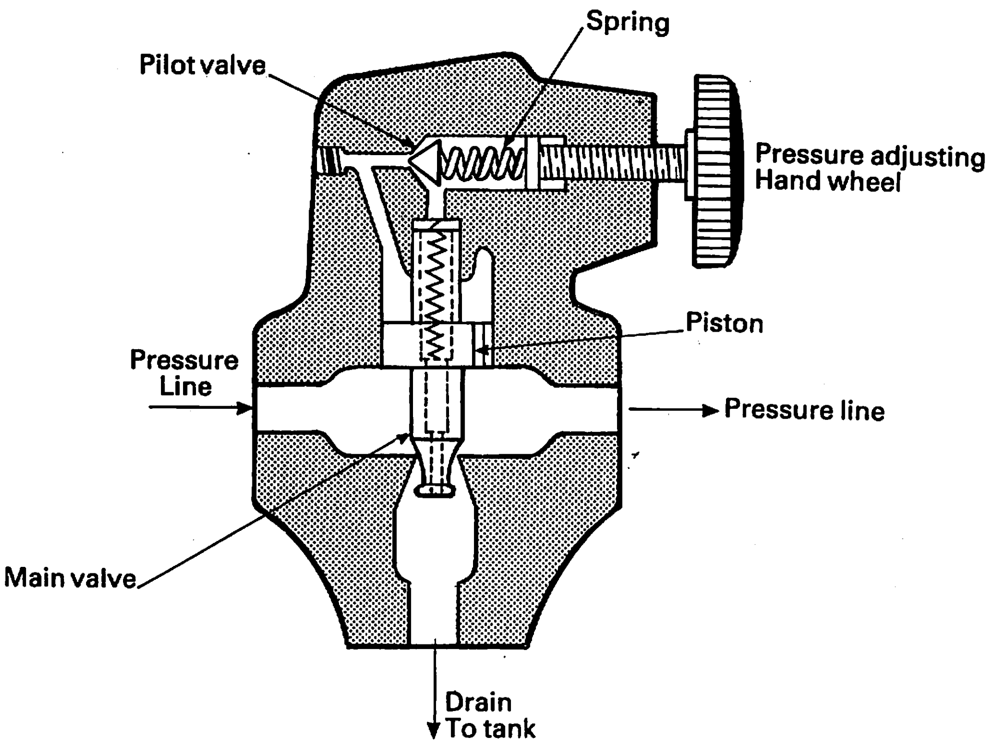


Figure 8.

The small hole in the main valve piston allows high pressure oil into the space above the piston. When the pressure in the line is too high, this pressure opens the pilot valve which allows the oil to pass down through the central hole in the main valve piston and into the passage below the main valve. Since this passage is open to the tank, the pressure **above** the main piston will be **less** than the pressure **below**, the main valve piston will lift and the main valve will allow full flow from the pressure line into the tank.

When the pressure in the pressure line falls to the normal value the pilot valve closes and pressure increases in the space above the main valve piston. This will then cause the main valve to close the drain passage. Turning the handwheel will adjust the pressure in the line at which the relief valve opens.

⚠

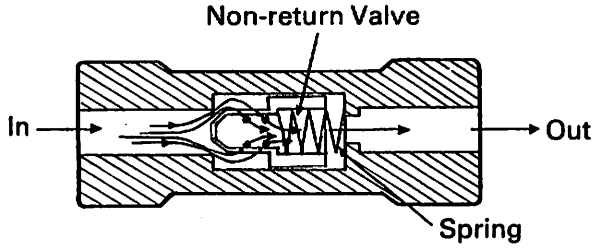
Relief valves are either pre-set by the manufacturer or set when the system is installed or after repairs and/or servicing. They are then **locked** and should not be continually adjusted or tampered with.

Check Valves

These valves are similar to relief valves except that they do not discharge to the tank.

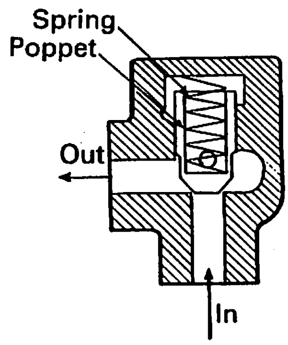
They are used to limit pressure in a line and also prevent any back flow.

They are often referred to simply as non-return valves. Figures 9 and 10 show two types of check valve.



In line

Figure 9.



Right angled

Figure 10

Directional Valves

These are valves which direct the flow of oil to one side or the other of an actuator.

The commonest type of directional valve is the spool type shown in Figure 11. Ports A and B on the body are connected to the actuator.

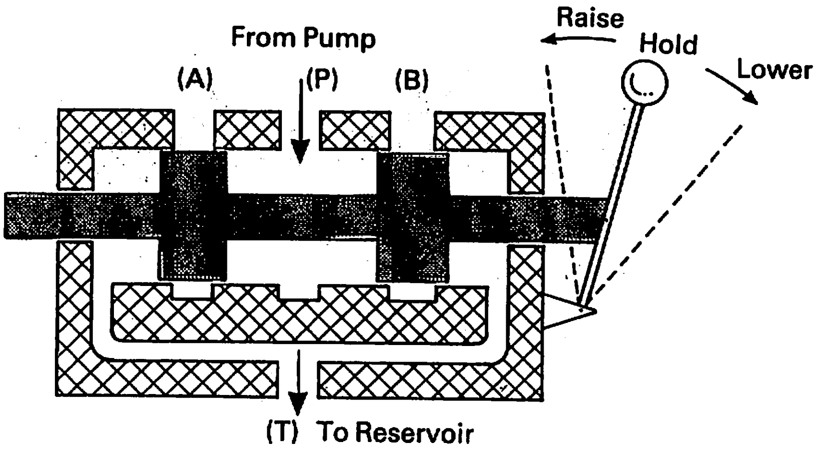


Figure 11.

In Figure 11 the valve is shown in the **'hold'** position. In this position the actuator (cylinder or motor) is held stationary because the oil cannot flow from P to A or from P to B.

In the **'raise'** position, shown in Figure 12 the oil flows from P to A and drains from B to T.

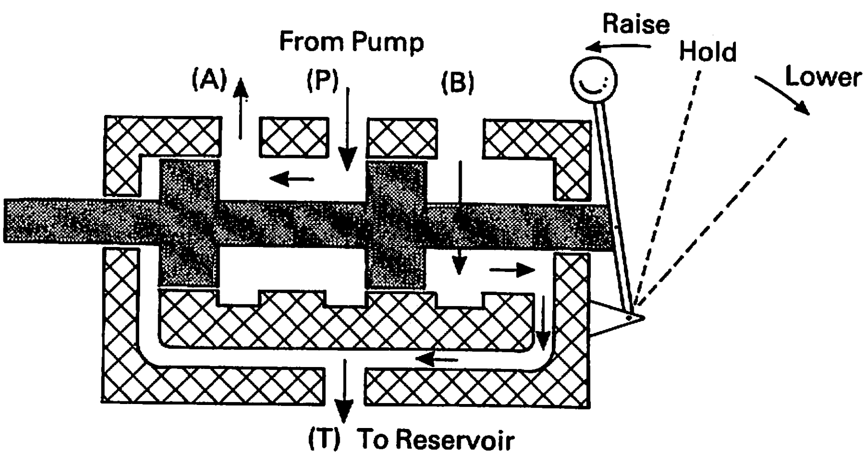


Figure 12.

In the **'lower'** position, shown in Figure 13 the oil flows from P to B and drains from A to T.

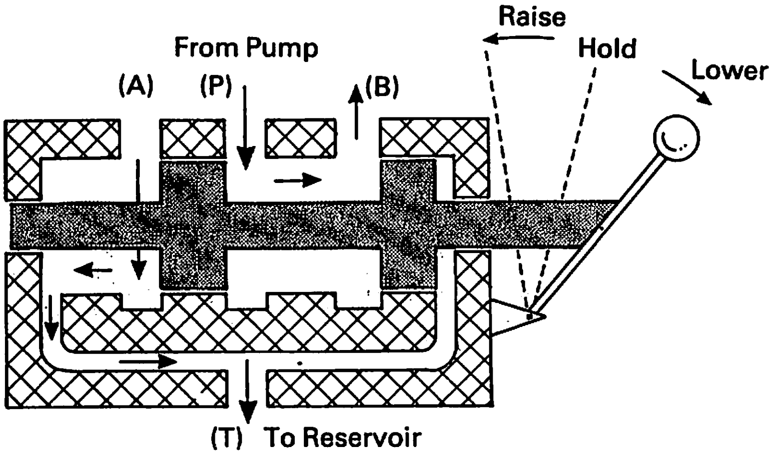
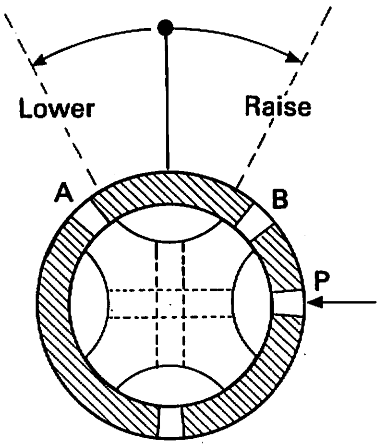


Figure 13.

These valves can be operated by hand (as shown), by a pilot valve, or by a solenoid (electro-magnet). Carefully follow through the paths of the oil in Figures 12 and 13 before considering the next type of valve.

Another type of directional valve which can be used on low pressure systems, is the **rotary valve** shown in Figure 14.



No flow position

Figure 14.

In this type the centre shaft is machined with grooves as shown and has two separate oil passages drilled across at different positions along the shaft.

The **'raise'** and **'lower'** positions are shown in Figures 15 and 16 together with the corresponding oil flows, as the centre shaft is turned by the operating lever.

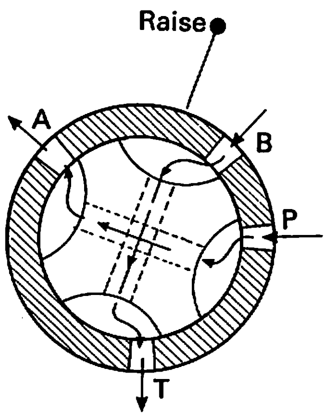


Figure 15.

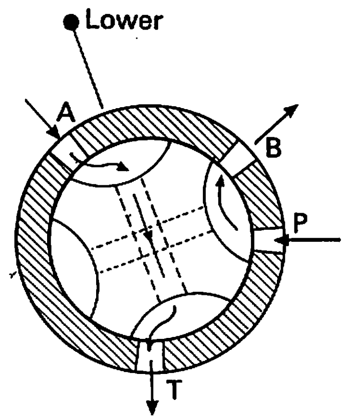


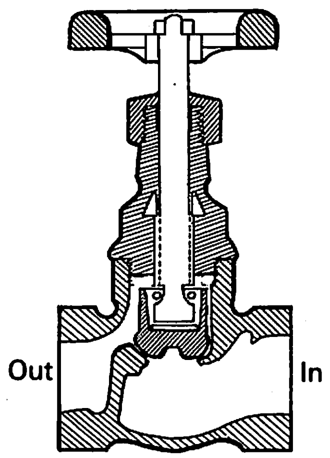
Figure 16.

Look back to Figures 12 and 13 and you will see that the oil flows correspond to those shown in Figures 12 and 13.

Each type of directional valve has its particular uses depending on the type of hydraulic system.

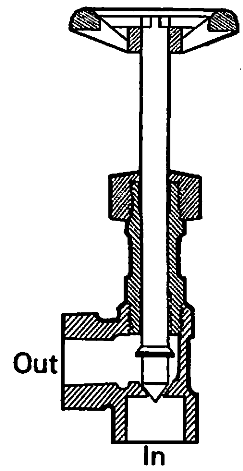
⚠
Take particular note that the ports A and B can be connected in reverse in each of the above directional valves. This is important to remember when hydraulic hoses are being connected to them.

Flow Valves
The simplest flow control valves are either a globe valve or a needle valve as shown in Figures 17 and 18. They regulate the flow of oil to the actuator and also shut the oil flow off more positively when necessary.



Globe valve

Figure 17.



Needle valve

Figure 18.

The flow of oil to an actuator determines the speed at which the actuator moves.

Sometimes the flow of oil is controlled by an orifice. This is a small bore restriction in the pipe line as shown in Figure 19.

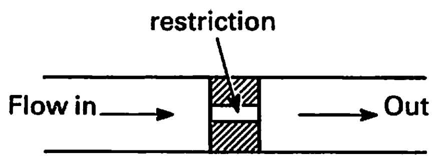


Figure 19.

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The reduction in flow caused by a restriction orifice also causes a drop in pressure in the line after the restriction.

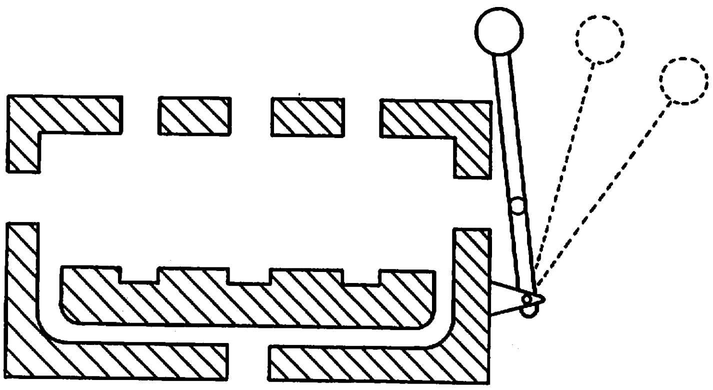
Directional control valves can also regulate the flow of oil if they are only partially opened. This causes a restriction and the flow of oil is reduced.

Now for two SAQ's about valves.

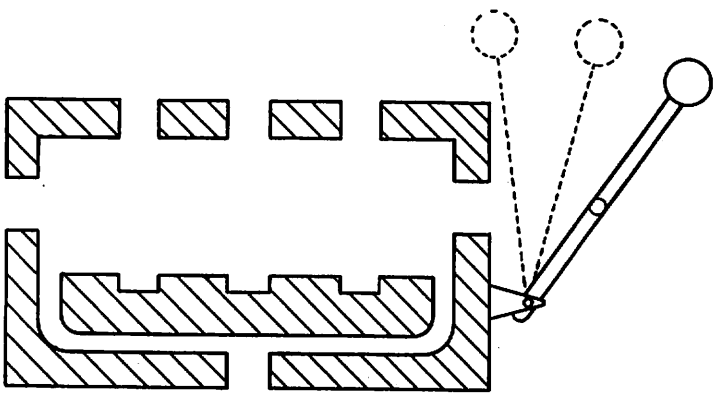
Ⓘ **SAQ14**

Sketch in the spool valve on this diagram and show how the spool valve directs the flow of oil to:
(use a soft pencil)

a) Port A



b) Port B



SAQ25
Explain how a relief valve controls high pressure in a pipe line.

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Take a short break at this point before studying the next part.

Actuators
This is the 'business end' of the hydraulic system, namely, where the work is done! An actuator can take a number of different forms but in general:

An actuator is any device that converts hydraulic pressure into mechanical work.

Cylinders (Linear Actuators)
The cylinder on your power block probably looks like Figure 20.

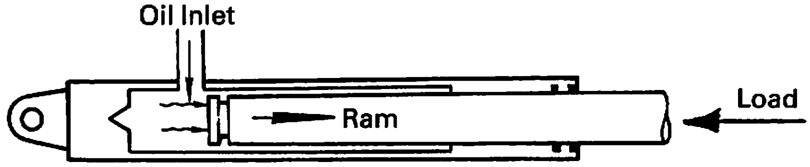


Figure 20.

The oil pressure acts on the face of the ram against the load (the power block head). When the pressure is released the weight of the load returns the ram and the oil is returned to the tank. The ram has a large diameter so that it resists bending.

This type of cylinder is called **single acting** because it can only push in one direction. Another type of single acting cylinder is shown in Figure 21.

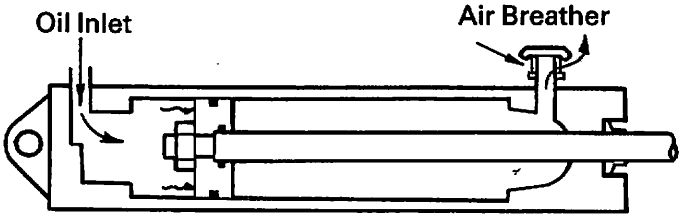


Figure 21.

The breather is fitted with a filter. Air is vented from behind the piston when the piston moves to the right and incoming air is filtered when the piston returns to the left.

For applications where the load does not return the piston, a double acting cylinder is used as shown in Figure 22.

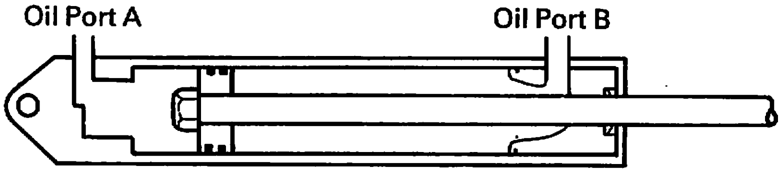


Figure 22.

A directional valve diverts the flow of oil to one oil port or the other, and oil from the opposite end is returned to the tank, as shown in Figures 23 and 24.

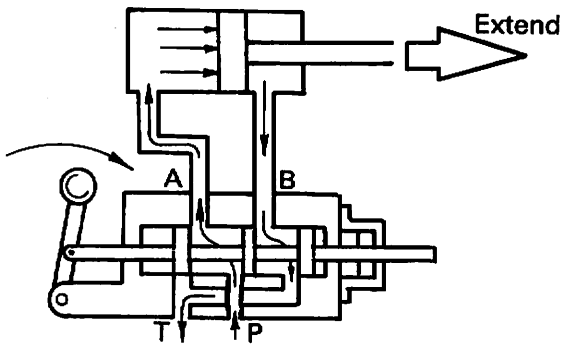


Figure 23.

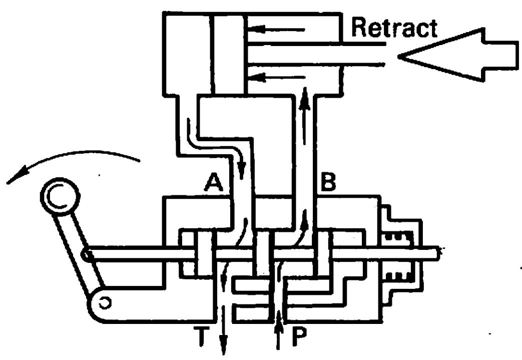
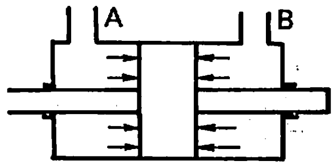


Figure 24.

The cylinders shown in Figures 23 and 24 are referred to as **'unbalanced'**. This is because in this type of cylinder the force on the face of the piston (Port A) is greater than the force on the back of the piston (Port B). This is due to the difference in areas of the two faces. This also causes a different speed of operation in each direction. When the **same** force is required in each direction a **balanced piston** is used as shown in Figure 25.



Balanced Actuator

Figure 25.

This type of cylinder also allows two loads to be moved at the same time, that is, one on each end of the piston shaft.

> The balanced piston actuator also gives the same speed of operation in each direction.

Hydraulic Motors (Rotary Actuators)

Any hydraulic pump of the **vane** or **piston** type can be used in reverse as a motor. When it is used as a pump, the mechanical work used to drive it, generates high pressure fluid. When it is used as a motor, the high pressure fluid generates mechanical work.

You may recognise the following external views of some hydraulic motors on your vessel.

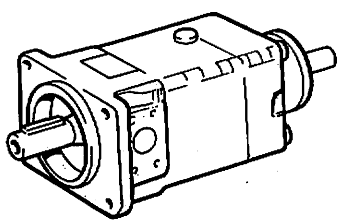

In-line piston pump

Figure 26.

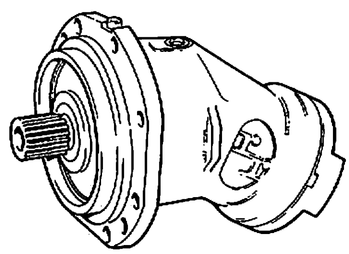
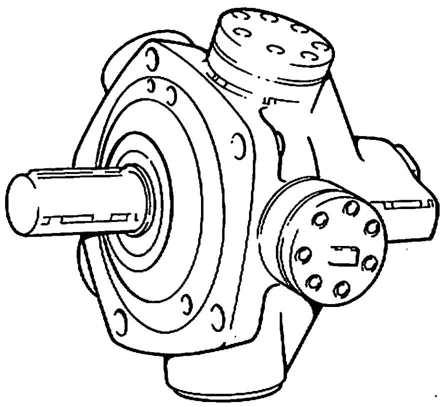
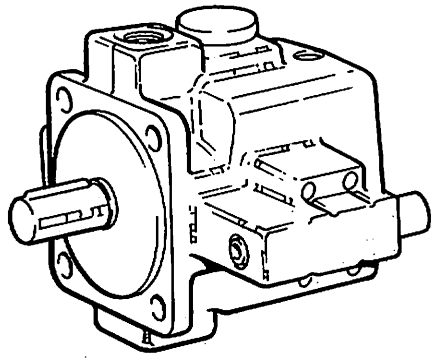

Angled piston pump

Figure 27.



Radial piston pump

Figure 28.



Vane pump

Figure 29.

The motor on your power block is probably concealed inside the drum. This is quite normal. All that can usually be seen is the pipe connections at the centre. In this case the centre shaft remains stationary and the casing of the pump rotates with the drum.

Steering Motors (Semi-Rotary Actuators)

A steering gear can be operated by a single cylinder as in Figure 30 or double cylinders as in Figure 31 (outside view). It can also be operated by a semi-rotary vane motor as in Figures 32 and 33(a & b). Figure 32 is the outside view but Figure 33a shows the internal parts. The tiller arm is attached to the rudder stock and is moved by the rotary piston. Oil is directed to either side of the piston through port A or port B. Semi-rotary just means that the rudder stock is turned through an angle but not by a complete revolution. Figure 33b uses the same principle and has three moving vanes attached to the rotor on the rudder stock.

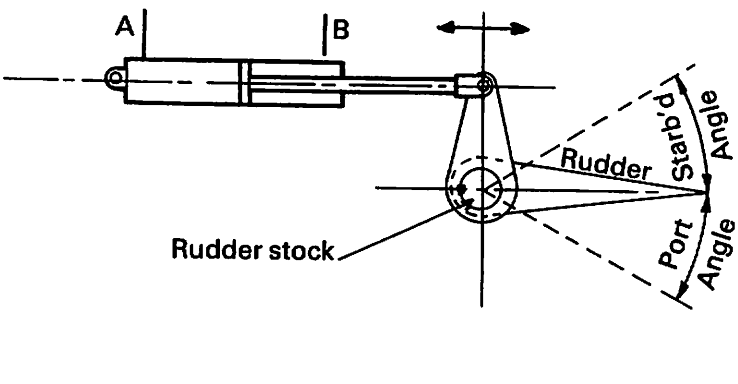


Figure 30.

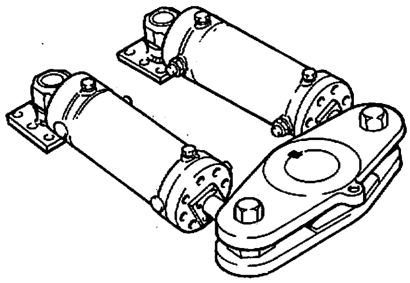


Figure. 31.

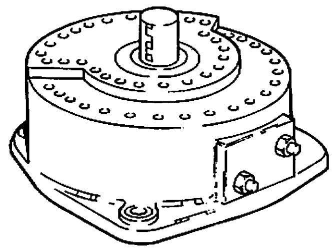


Figure 32.

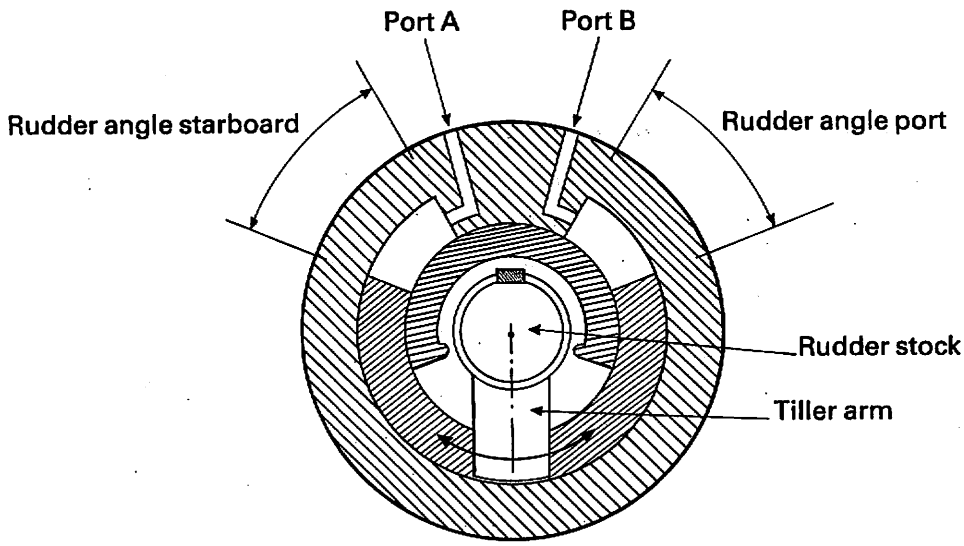


Figure 33(a). Rotary Piston Actuator (Low Pressure)

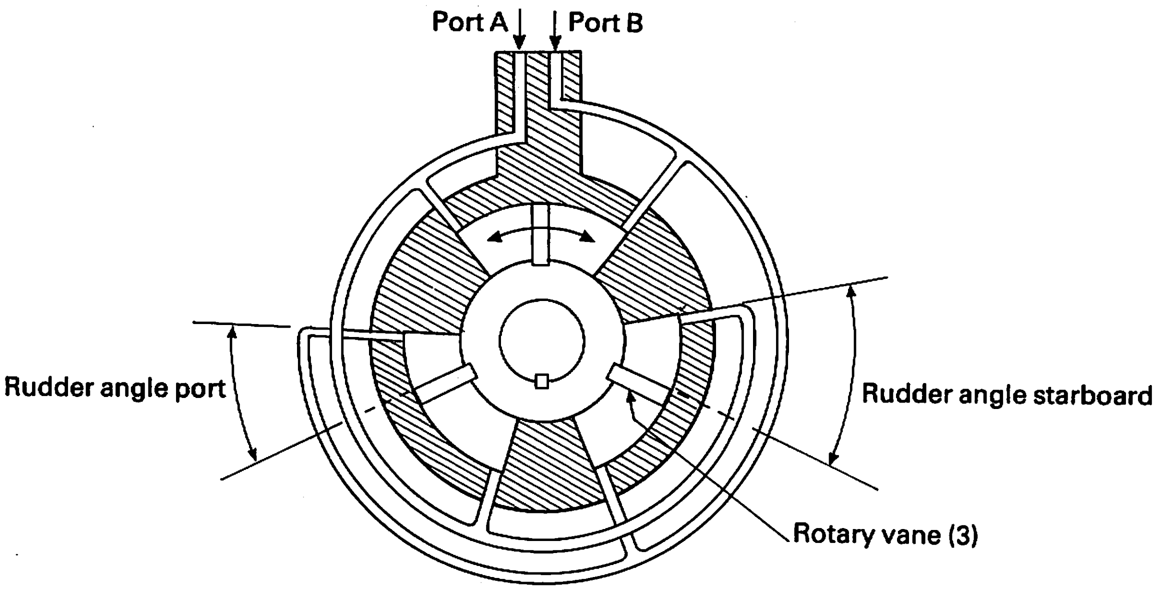


Figure 33(b) Rotary Vane Actuator (High Pressure)

In each case the flow of oil is determined by a directional control valve which directs oil to either port A or port B.

To complete this segment try these SAQ's.

SAQ16

State the differences in action of a linear actuator, a rotary actuator and a semi-rotary actuator.

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ⓘ **SAQ32**
Which types of pumps can be used as a hydraulic motor?

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SUMMARY

You have now completed Segment One in which the aims were that you should now be able to:

- State the principal components of a hydraulic system;
- State the purposes of the components;
- Describe the basic actions of pumps, valves and actuators.

If you have completed and checked the responses to all the SAQ's you will have also achieved Objectives No. 1 and No. 2 given on page xiii. Well done!

This has been a long segment and may be a new form of study for you. Take a well earned break before starting Segment Two.

In the meantime remember to look at the hydraulic systems on your vessel if an opportunity presents itself.

Segment Two

Basic Hydraulics

Segment Two – Basic Hydraulics

Welcome to Segment Two.

In this Segment we will carry out some simple calculations regarding the pressure and the action in a hydraulic system.

AIMS OF THE SEGMENT

The main aim of the Segment is to assist in achieving Objective No. 3 on page xiii.

On completion of this Segment you should be able to:

- Calculate forces produced by the application of hydraulic pressure.
- Calculate the speed of response of an actuator.
- Explain how the speed of response is controlled.

BASIC CALCULATIONS FOR HYDRAULIC SYSTEMS

Hydraulic systems depend on a supply of **high pressure** oil, the pressure being measured in bars or pounds per square inch (p.s.i.) and the **flow rate** measured in litres per minute (l/min) or gallons per minute (g.p.m.).

Hydraulic pressure is generated by applying a mechanical force to a fluid and having some kind of load to resist the flow of fluid.

The force can be applied by a weight, a hand pump, a piston in a cylinder or the mechanical action of a pump.

The flow rate depends on the physical size of the pump and its speed of operation.

Hydraulic Pressure

The pressure of the fluid acts equally in all directions. Figure 34 shows an arrangement similar to a hydraulic jack. The small piston A would be operated by the handle of the jack and the larger piston B would lift the load e.g. a motor car.

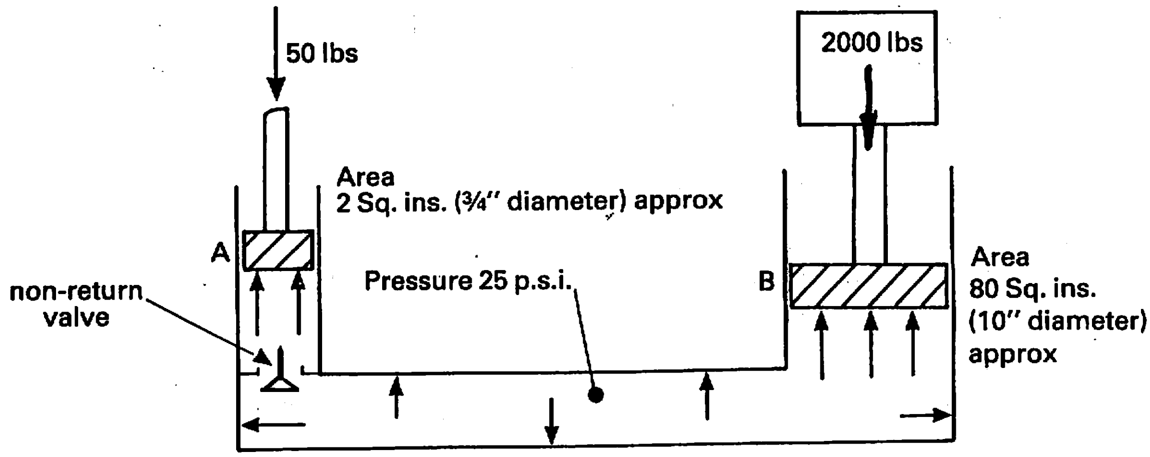


Figure 34.

Units

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

This can also be written Force = Pressure x Area

$$\text{In Figure 34, Pressure (psi)} = \frac{\text{Force (lbs)}}{\text{Area (in}^2\text{)}} = \frac{50}{2}$$

$$= \text{25lb per square inch}$$

If this pressure acts on piston B then:

$$\text{Force produced} = 25 \times 80 = 2000 \text{ lbs}$$

The units used in the above calculation are Imperial Units which are gradually being superseded by SI Units. You will begin to find these on new equipment.

When using S.I. Units 'Force' is given in Newtons (N)
'Area' is given in Square Metres (m^2)

Therefore, Pressure is given by:

$$\frac{\text{Force in Newtons}}{\text{Area in } m^2} = \text{Newtons per } m^2$$

A pressure gauge usually indicates pressure in 'Bars'. A pressure of 1 Bar = 100,000 N/m^2

For convenience this is divided by 1000 to give
1 Bar = 100 kilo Newtons/square metre (kN/m^2)

We will now use these units and repeat the calculations for Figure 35.

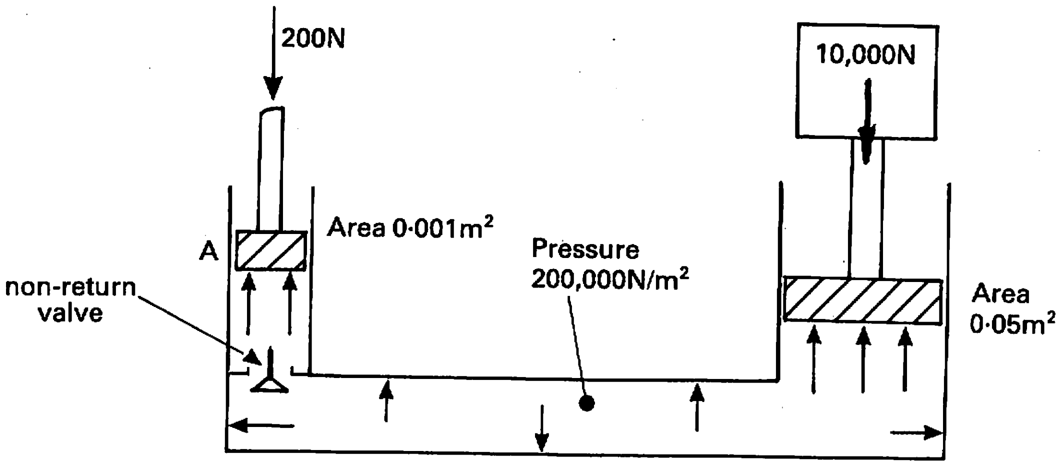


Figure 35.

A force of 200N acting on the area of 0.001m^2 (Piston A) generates a pressure of:

$$\text{Pressure} = \frac{200}{0.001} = 200{,}000 \text{ N/m}^2 \text{ or } \frac{200{,}000}{100{,}000} = 2 \text{ bar}$$

This pressure acting on the larger area of 0.05 m^2 produces a force of:

Force (F) = 200,000 x 0.05 = 10,000 Newtons

In order to help you to compare these figures in the different units, the following conversions can be used.

1 bar = 14.5 p.s.i.

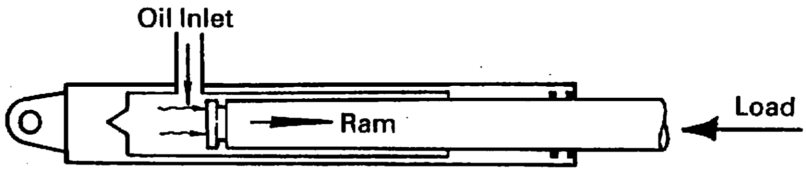
1 pound = 4.45 Newtons

So, 2 bar = 2 x 14.5 = 29 p.s.i. and

10,000 Newtons = $\frac{10,000}{4.45}$ = 2242 lbs force

SAQ27

Calculate the force created by an actuator:



a) which has an area of 7 square inches (3" diameter) when it is subjected to a pressure of 3000 p.s.i.

b) which has an area of 0.005m^2 (80 mm diameter) when it is subjected to a pressure of 200 bar.
(Note: 1 bar = 100 kN/m^2)

a) ....
....
....
....

b) ....
....
....
....

If you found those calculations difficult, do not worry too much. It is not often that you will have to make such calculations but they are important for you in your understanding of the operating conditions in a hydraulic system.

When you examine a hydraulic system you will see that many of the actuator cylinder rods are small in diameter. The pistons in hydraulic pumps and motors are also quite small.

Small diameters are used because the pistons and rods are then **easier to seal** and so prevent leakage.

> ℹ
>
> Hydraulic systems in fishing vessels operate at pressures of about 200 bar (about 3000 p.s.i.) so that even small diameter cylinders can exert very large forces.

The **pressure** in the system determines the force that can be produced but the **flow of oil** determines the distance moved by an actuator.

Using Figure 34 on page 24, if piston A moves down 4 inches it will displace 2 x 4 = 8 cubic inches of oil (Volume displaced = area of piston x distance moved).

This volume of oil then moves piston B up a distance of

$$\frac{8}{80} = \frac{1}{10} \text{ inch. (distance moved} = \frac{\text{Volume displaced)}}{\text{area of piston}}$$

The principle of a hydraulic jack shown in Figure 34 is that after each movement of Piston A, Piston B moves up a small amount and a non-return valve or check valve prevents the oil flowing back from under Piston B. It therefore requires a number of strokes of Piston A to lift the load on Piston B the required amount. To lower the load, a release valve would have to be opened (not shown on this diagram).

Now try another SAQ.

> ⓘ **SAQ18**
> Using Figure 35 on page 25 determine the movement of piston B when piston A moves down 10 cm (0.1 m).

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Rate of Flow

The output of hydraulic pumps is stated in either litres per minute (l/min) or gallons per minute (g.p.m.). The **rate** of flow of the oil will determine the speed of operation of an actuator, whether it is of the cylinder or a motor type.

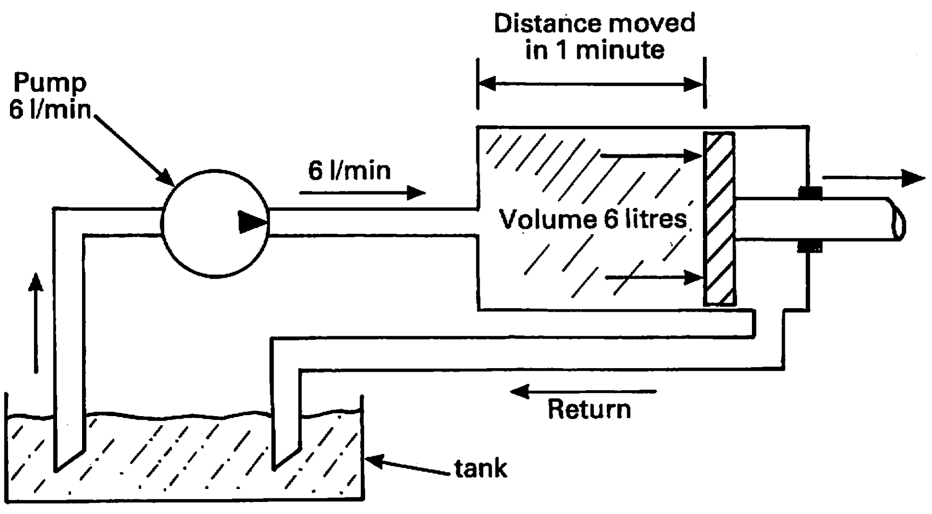

Figure 36.

In Figure 36 you will see that the piston has moved a distance such that the volume of the actuator is now 6 litres. The output of the pump is 6 litres/minute and so the actuator will take one minute to move this distance.

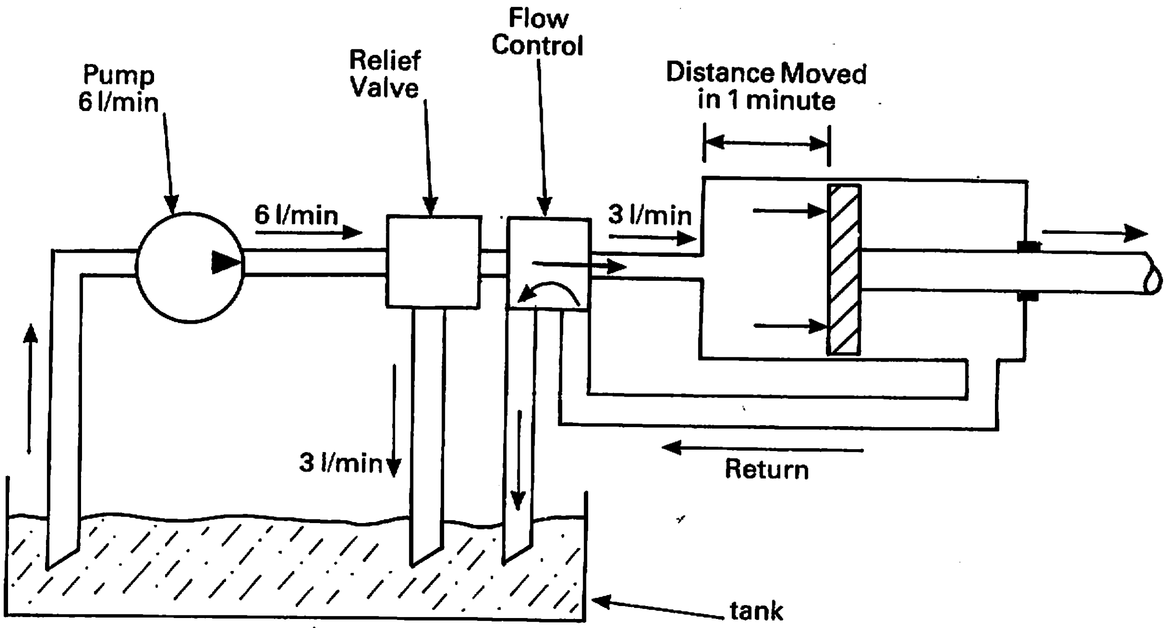

Figure 37.

In Figure 37 a relief valve and a flow control valve are now included. The flow control valve is reducing the flow to 3 litres/minute and the actuator has moved a shorter distance in one minute. So, the actuator moves more slowly. If a motor was used instead of the cylinder then it would turn more slowly. Also in Figure 37 you will see that the relief valve is now allowing 3 litres/minute to pass into the tank.

> **i**
>
> Notice that on the piston rod side of the cylinder the volume is reduced by the volume of the piston rod, therefore the return stroke will be faster than the forward stroke.

Now try this SAQ about a hydraulic motor.

(?) **SAQ29**

When a hydraulic motor is supplied with oil at a rate of 2 litres/minute it rotates at 60 rpm. If the pump has a maximum output of 6 litres per minute what will be the maximum speed of the motor?

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SUMMARY

You have now completed Segment Two and are making good progress. Before you take a break I will remind you of the aims of this Segment.

These were that you should now be able to:

- Calculate forces produced by the application of hydraulic pressure.
- Calculate the speed of response of an actuator.
- Explain how the speed of response is controlled.

In completing these aims you have also partly achieved Objective No. 3 on page xiii. This will be completed in Segment Three where we will look at hydraulic pumps and motors in detail.

This has been a shorter segment but still an important one and a break at this point is well earned.

Segment Three

Hydraulic Pumps and Motors

Segment Three – Hydraulic Pumps and Motors

Welcome to Segment Three which is about the types of hydraulic pumps and motors which are used in hydraulic systems.

AIMS OF THE SEGMENT

The main aim of the Segment is to complete Objective No. 3 on page xiii.

For this you should be able to:

- Describe the various types of pumps and motors which are used in hydraulic systems.
- Explain how the output of pumps is controlled.

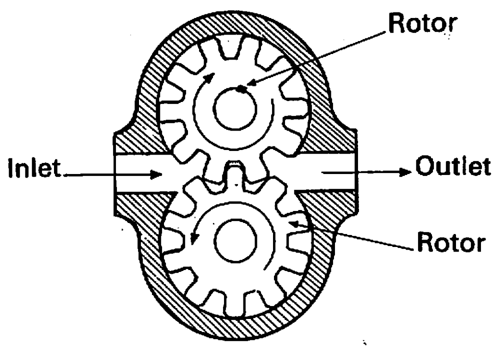
HYDRAULIC PUMPS

Gear Pumps

There are two basic types of gear pump in common use in the hydraulic systems on fishing vessels. The **external gear** type which we have already seen in Segment One and the **internal gear** type.

In each type the basic principle is the same. The teeth coming out of mesh on the inlet side create a vacuum which draws oil in from the inlet port. The oil is then carried round by the rotor in the spaces between the teeth and when the teeth mesh the oil is forced out of the spaces and into the outlet port.

This is shown again in Figure 38.



External Gear Pump

Figure 38.

Another type of external gear pump is shown in Figure 39. This uses the same principle of meshing teeth but in this case both gears rotate in the same direction, the outer gear being driven by the inner gear. In order to maintain a seal, part of the body forms a crescent shaped seal between the teeth on the 'open' side of the gears.

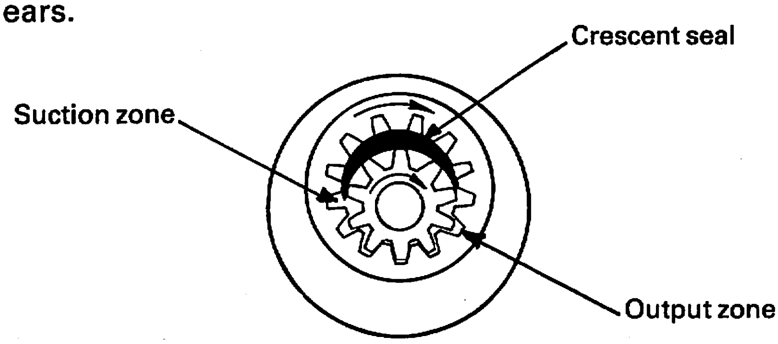


Figure 39.

You may come across a further type of gear pump which uses a **'gerotor'** element as shown in Figure 40.

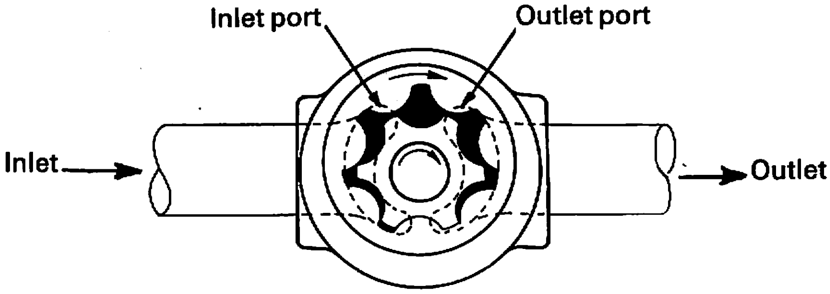


Figure 40.

In this pump both gears rotate in the same direction but, instead of a crescent shaped seal, the gears are so designed that the tips of the teeth of the internal gear are always in contact with the profile of the external gear and so form a seal.

> **i**
> The inner gear has one tooth less than the external gear.

In each of the gear pumps shown in Figures 38, 39 and 40 the tips of the teeth form the seal. Since all moving parts must have some form of clearance in order to allow them to operate, this seal is not perfect and there is always a little leakage, and therefore, a small loss in pressure and flow.

To reduce this leakage, end plates are fitted to the sides of the gears and the clearance kept as small as practicable. In the pump casing the ports are arranged so that the inlet port is at the point where the teeth come out of mesh, and the delivery port at the point where the teeth mesh together.

To obtain high pressure these pumps may be mounted in a common body and the outlet from one pump led to the inlet of the next, the pressure being built up stage by stage.

> ⚠
> Wear on the teeth or casing will increase leakage and after long service, the pump will require replacing.

Vane Pumps
In Segment One the two basic forms of vane pump were also shown. In a vane pump, a rotor with longitudinal slots is driven by a driveshaft between closely fitting side plates inside a circular or elliptical ring. The vanes, which are hardened and polished, slide in and out of the slots to maintain contact with the surface of the casing and make a seal.

The vanes are pushed out by centrifugal force, but also assisted by springs or pressurised oil from the system in some types of this pump.

The pockets formed by the vanes, the side plates and the ring increase in volume from the inlet, which causes oil to be drawn in.

As the rotor moves round, the pockets reduce in volume towards the outlet and the oil is forced out.

Figure 41 shows an **unbalanced** vane type pump. It is called unbalanced because the high pressure on one side of the rotor causes a side thrust on the bearings in the opposite direction.

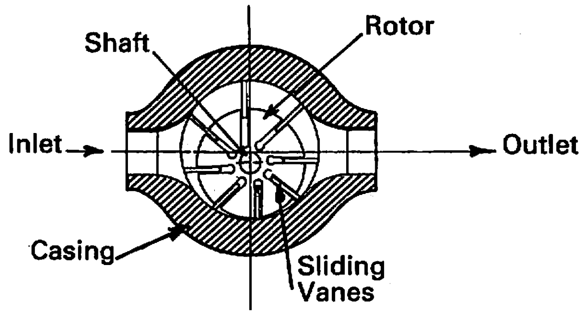


Figure 41.

The output of the pumps shown so far cannot be varied except by altering the speed of the pump.

The outlet of a pump of the vane type can be made variable by fitting a moveable circular ring as shown in Figure 42.

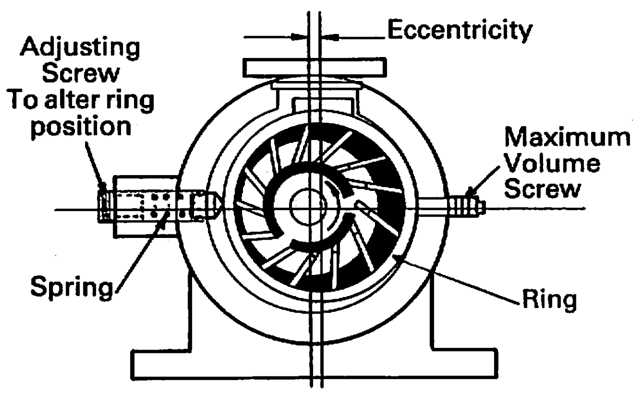


Figure 42.

The unbalanced side thrust acts against the spring loaded adjusting screw. Any change in position of the ring alters the volume of the pockets between the vanes and changes the output of the pump. The setting of the maximum volume stop screw sets the maximum output of the pump.

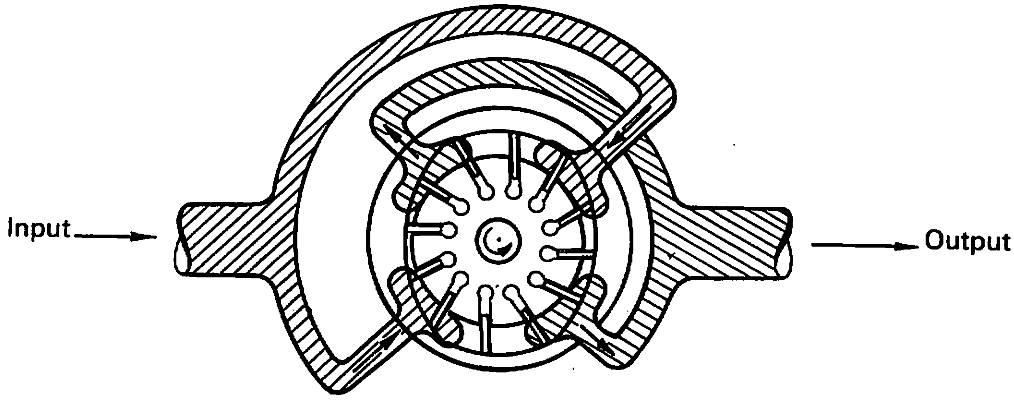


Figure 43.

To eliminate the side thrust balanced vane pumps are used. In this case the 'ring' becomes elliptical in shape and the pump then has two inlets and two outlets which are placed opposite each other as shown in Figure 43. The side thrusts will then balance each other.

Try this SAQ about vane pumps before considering the next type.

? SAQ3

Explain how the vanes are kept in contact with the outer casing in a vane pump.

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Piston Pumps

All piston pumps depend on the reciprocating action of a piston in a cylinder. There are several designs in use at the present time. The two basic forms are **'axial'** and **'radial'** piston pumps. Both types can be fixed output or variable output.

Axial Piston Pumps

Figure 44 shows an axial piston pump drawn in simple line form.

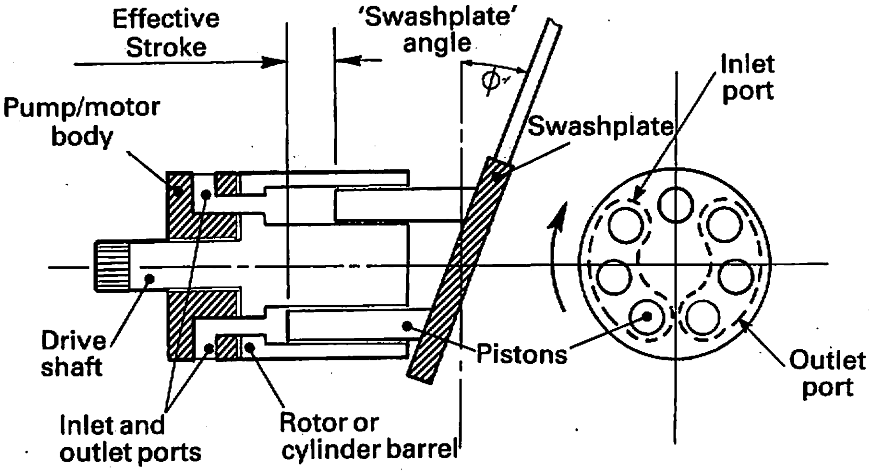

Figure 44.

The drive shaft turns the cylinder body containing the pistons. As the pistons move round the swash plate they move out and draw in oil at the top and then move in and discharge oil at the bottom, as shown. The **effective stroke** is the difference between the outermost position and the innermost position of the pistons. This is the volume of oil which is delivered by each piston each revolution of the pump.

The kidney shaped inlet and outlet ports are cast into the pump body and the pistons either draw from them or deliver oil into them.

In an axial piston pump with a **variable output,** the angle of the swash plate can be altered and this will vary the effective stroke of the pistons.

If the swash plate is moved to 0° the pistons do not move in and out and no oil is delivered. If the swash plate is moved further over to the other side then the flow of oil from the pump is reversed. The swash plate can be moved either by hand or by a control piston.

A second form of this pump is the **'bent axis'** piston pump as shown in Figure 45. This type is often used as a pump/motor unit.

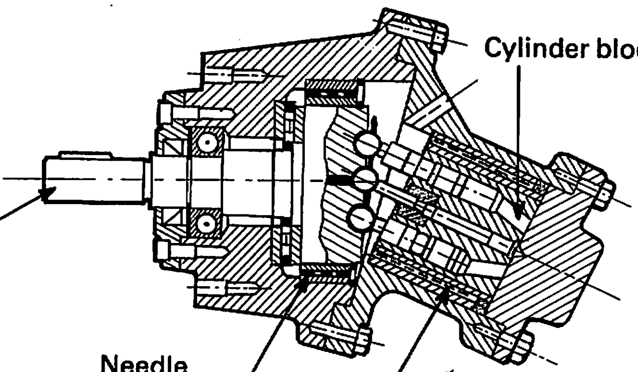

Figure 45.

In this form the angle of the swash plate is fixed by the shape of the casing. The drive shaft rotates the swash plate which, in turn, rotates the pistons and the cylinder block. The swash plate and cylinder block are mounted in needle roller bearings so that they rotate easily.

Now an SAQ about axial piston pumps.

> ⑦ **SAQ11**
> Describe how an increase in the swash plate angle of an axial pump would alter the volume delivered by the pump.

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Another form of **'bent axis'** pump is shown in Figure 46.

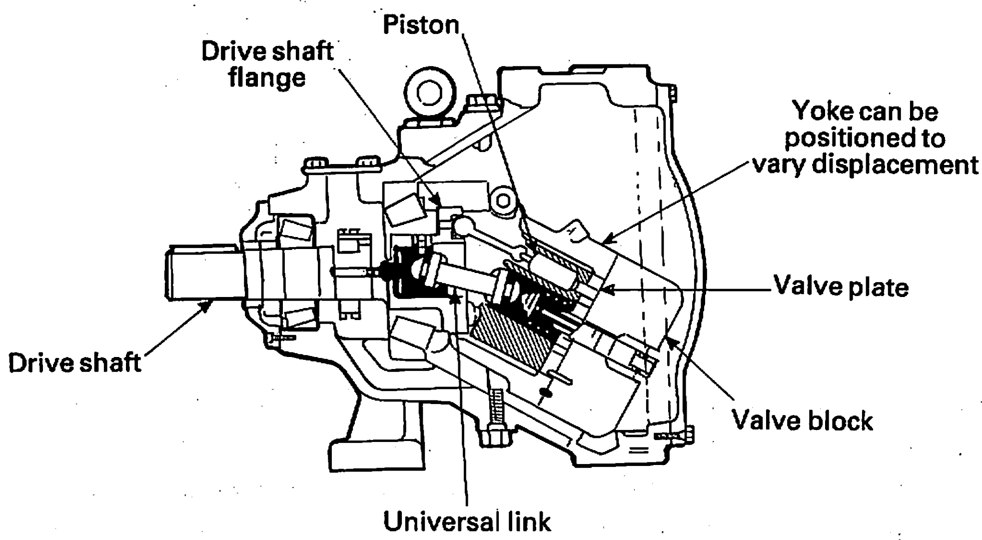

Figure 46.

In this type, the position of the yoke and the angle of the 'bent axis' (Ø) can be altered to give a different flow rate. The principle of this is shown in simple form in Figure 47.

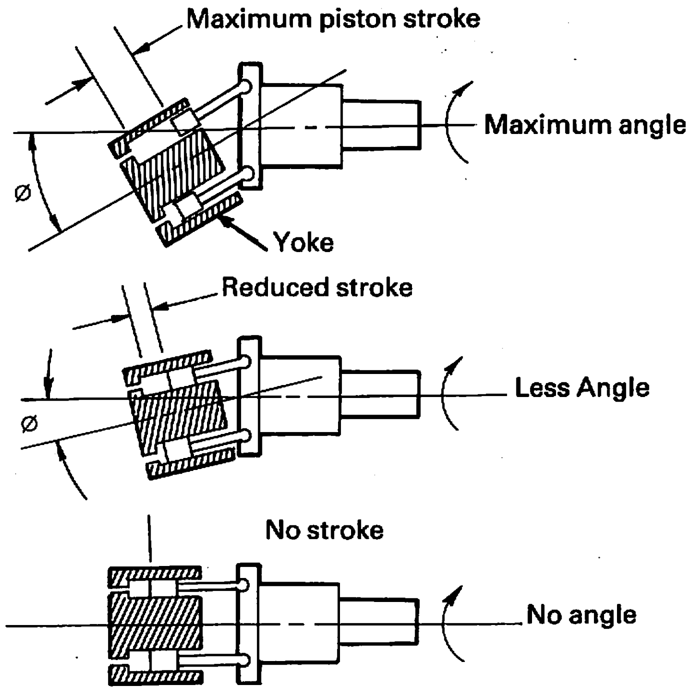

Figure 47.

Radial Piston Pumps

Radial piston pumps have their pistons arranged in a cylinder block in star formation and there are two main forms of this type of pump.

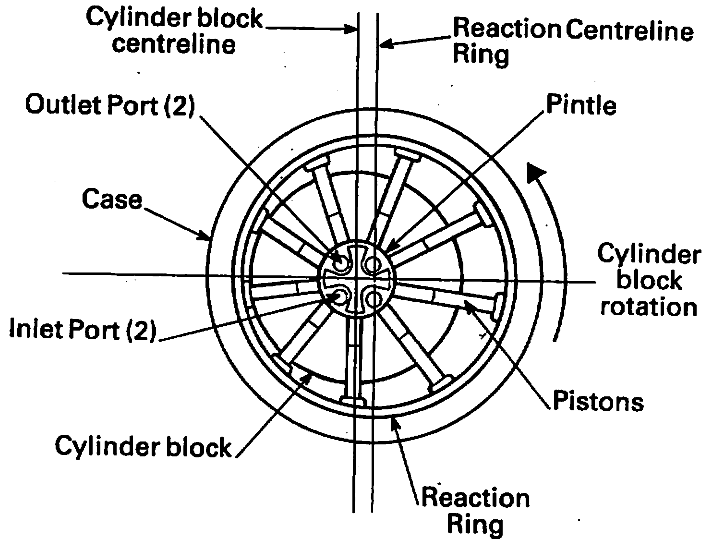

Figure 48.

The first form which is shown in Figure 48 has its pistons mounted in a cylinder block which rotates round a central shaft. The centreline for the cylinder block is arranged slightly 'off-centre' or eccentric to the reaction ring and casing.

As the cylinder block rotates the outer ends of the pistons keep in contact with the reaction ring and this causes them to move in and out in their cylinders.

As each piston moves out, oil is drawn in from the inlet ports and as the ring pushes each piston in, oil is delivered to the outlet ports. The pressure line is coupled to the outlet ports and the return line to the inlet ports. The capacity of the pump is determined by the number of pistons, their diameter and the speed at which the pump is rotated.

Figure 48 shows a pump with a fixed reaction ring. In some types the reaction ring can be moved sideways and this will alter the output of the pump.

The second form of radial piston pump is shown in Figure 49. In this form the cylinder block is stationary and the pistons are operated by a central eccentric on the shaft.

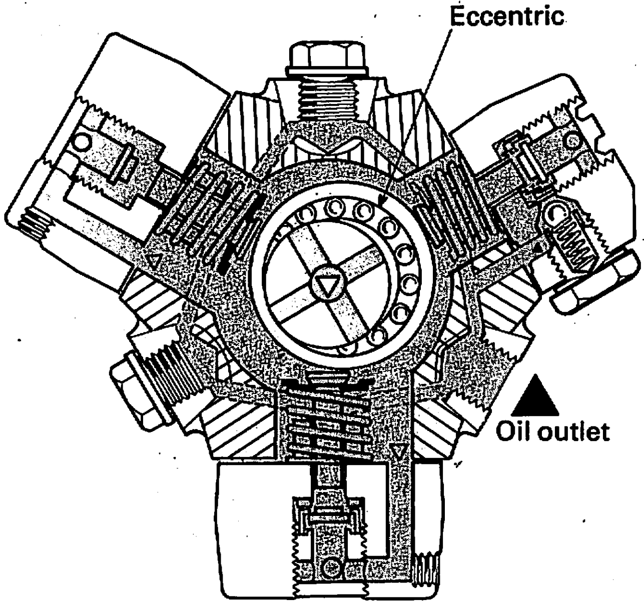

Figure 49.

SAQ21

Explain how a reduction in volume flow can be achieved in a radial pump of the type shown in Figure 48.

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These pumps can have 3, 5 or 7 pistons and for additional power or flow can be doubled up to give 2 banks of 3, 2 banks of 5, or 2 banks of 7 pistons.

Pumps with five cylinders of the type shown in Figure 49 are common on fishing vessels.

Pumps with five cylinders of the type shown in Figure 49 are common on fishing vessels.

HYDRAULIC MOTORS

All the pumps shown in Figures 41, 43, 45, 46, 48 and 49 can be operated in reverse and used as motors. All that is required is that the pressurised oil is let to the 'outlet' port and the return oil taken from the 'inlet' port.

You should recall that external views of some of these pumps and motors were given in Segment One.

> ⚠
>
> Hydraulic pumps and motors are complicated and have very fine working clearances. This means that they should not be dismantled by unskilled personnel and contamination of the hydraulic oil must be prevented.

SUMMARY

You have now completed Segment Three and it is a suitable point for me to remind you of the aims of this Segment.

They were that you should be able to:

- Describe the various types of pumps and motors which are used in hydraulic systems.
- Explain how the output of pumps is controlled.

This also means that you have now fully achieved Objective No. 3 on page xiii.

In the Segments up to this point there have been a number of diagrams showing a lot of detail. In Segment Four you will see how a hydraulic system can be represented by simple symbols and diagrams.

Segment Four

Hydraulic System Diagrams

Segment Four – Hydraulic System Diagrams

Welcome to Segment Four.

In this Segment we will see how a hydraulic system and its components are represented in the form of a circuit diagram and how these diagrams can be used.

AIMS OF THE SEGMENT

The main aim of this Segment is to achieve Objective No. 4 given on page xiii.

For this you must be able to:

- Explain the symbols used to represent the components of a hydraulic system on a circuit diagram.
- Trace the oil flow through each component and through each part of the circuit diagrams.

CIRCUIT DIAGRAMS AND SYMBOLS

A circuit diagram is the way in which the whole or part of a hydraulic system is represented on paper. It enables a large hydraulic system to be shown in a compact way or a small complicated system to be enlarged and more easily interpreted.

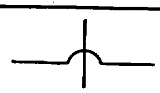
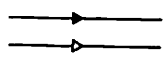
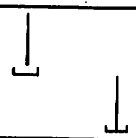
The circuit diagram shows the arrangement of the components and together with fault finding tables is most useful when tracing and explaining faults in a hydraulic system.

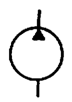
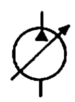
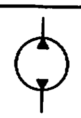
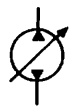
Figure 55 on page 56 is an example of a circuit diagram. We will be using this diagram later in this segment but first we must see what each of the symbols mean.

Symbols
Symbols are just a shorthand way of describing what each unit or component does in the system.

Tables 1 and 2 on pages 45 and 46 show a selection of the symbols used in circuit diagrams. You will find that many of these symbols are easy to understand but some will be more difficult. So I will explain some of the more important ones and those which you may have difficulty with.

THE SYMBOLS SHOWN HERE CONFORM TO THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) SPECIFICATION. THE BASIC SYMBOLS CAN BE COMBINED IN ANY COMBINATION.

LINES AND LINE FUNCTIONS	
LINE, WORKING	
LINE, PILOT (L>20W)	
LINE, DRAIN (L<5W)	
CONNECTOR	
LINE, FLEXIBLE	
LINE, JOINING	
LINE, PASSING	
DIRECTION OF FLOW, HYDRAULIC (OIL) PNEUMATIC (COMPRESSED AIR)	
LINE TO RESERVOIR ABOVE FLUID LEVEL BELOW FLUID LEVEL	
RESTRICTION, FIXED	
RESTRICTION, VARIABLE	

PUMPS	
PUMP, ONE WAY, FIXED DISPLACEMENT	
PUMP, ONE WAY, VARIABLE DISPLACEMENT	
PUMP, REVERSIBLE, FIXED DISPLACEMENT	
PUMP, REVERSIBLE, VARIABLE DISPLACEMENT	

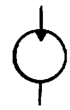
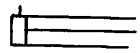
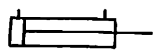
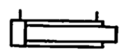
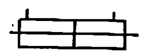
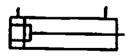
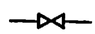
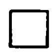
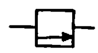
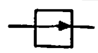
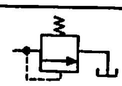
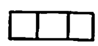
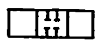
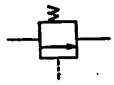
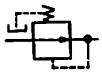
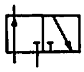
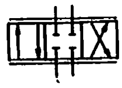
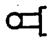
MOTORS AND CYLINDERS	
MOTOR, ROTARY, FIXED DISPLACEMENT	
MOTOR, ROTARY, VARIABLE DISPLACEMENT	
MOTOR, OSCILLATING	
CYLINDER, SINGLE ACTING	
CYLINDER, DOUBLE ACTING	
CYLINDER, DIFFERENTIAL ROD	
CYLINDER, DOUBLE END ROD	
CYLINDER WITH CUSHIONS (□) BOTH ENDS	
BASIC VALVE SYMBOLS	
CHECK VALVE	
MANUAL SHUT OFF VALVE	
BASIC VALVE ENVELOPE (OR BODY)	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN	
VALVE, MAXIMUM PRESSURE (RELIEF)	
BASIC VALVE SYMBOL, MULTIPLE FLOW PATHS	
FLOW PATHS BLOCKED IN CENTRE POSITION	
MULTIPLE FLOW PATHS (ARROW SHOWS FLOW DIRECTION)	

Table 1

BASIC VALVE SYMBOLS (CONT.)	
UNLOADING VALVE, INTERNAL DRAIN, REMOTELY OPERATED	
PRESSURE REDUCING VALVE	
DIRECTIONAL VALVE, TWO POSITION, THREE CONNECTION	
DIRECTIONAL VALVE, THREE POSITION, FOUR CONNECTION	
VALVE, INFINITE POSITIONING (INDICATED BY HORIZONTAL BARS)	
METHODS OF OPERATION	
PRESSURE COMPENSATOR	
DETENT	
MANUAL	
MECHANICAL	
PEDAL OR TREADLE	
PUSH BUTTON	
LEVER	
PILOT PRESSURE	
SOLENOID	
SOLENOID CONTROLLED, PILOT PRESSURE OPERATED	
SPRING	
SERVO	

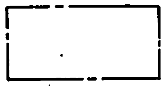
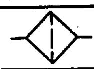
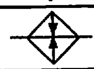
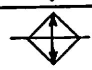
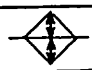
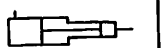
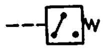
MISCELLANEOUS UNITS	
DIRECTION OF ROTATION (ARROW IN FRONT OF SHAFT)	
COMPONENT ENCLOSURE	
RESERVOIR, VENTED	
RESERVOIR, PRESSURIZED	
PRESSURE GAUGE	
TEMPERATURE GAUGE	
FLOW METER (FLOW RATE)	
ELECTRIC MOTOR	
ACCUMULATOR, SPRING LOADED	
ACCUMULATOR, GAS CHARGED	
FILTER OR STRAINER	
HEATER	
COOLER	
TEMPERATURE CONTROLLER	
INTENSIFIER	
PRESSURE SWITCH	

Table 2

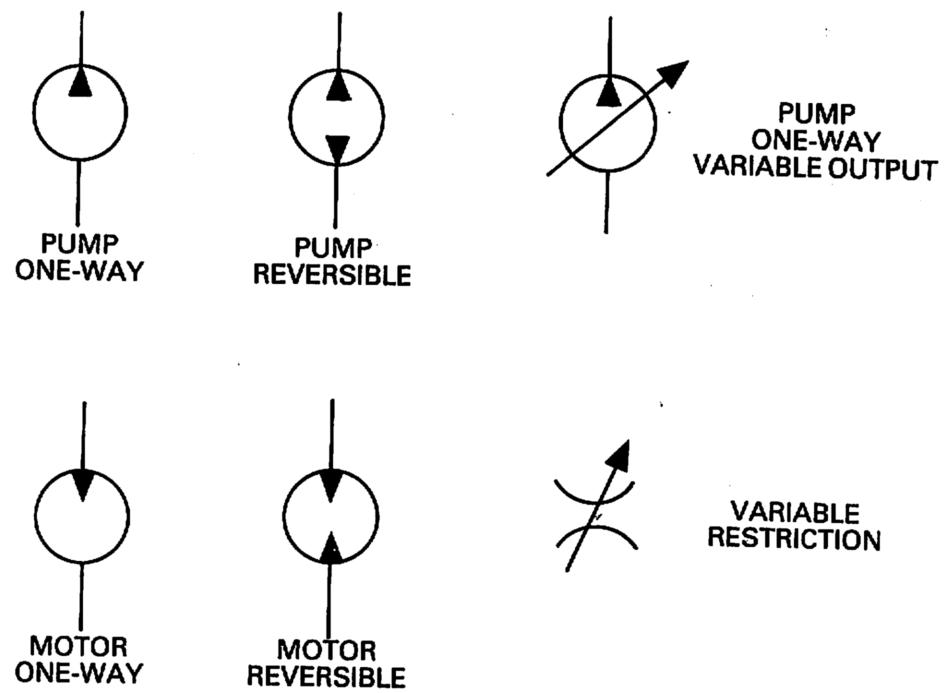


Figure 50.

- **Pumps and Motors** are represented in a very simple way (see Figure 50). The triangle (▲) inside the circle indicates the direction of oil flow. If they are reversible, then pumps can deliver to either line and motors can receive pressure oil from either line.
- An **arrow** through any symbol indicates that its output of either speed, flow or pressure is variable.
- An oscillating motor (**semi-rotary actuator**) provides a circular motion but only backwards and forwards – not a complete revolution.
- A cylinder (**linear actuator**) with a differential rod has a cylinder rod of larger diameter than normal. This gives the actuator a faster return stroke but a smaller return force.

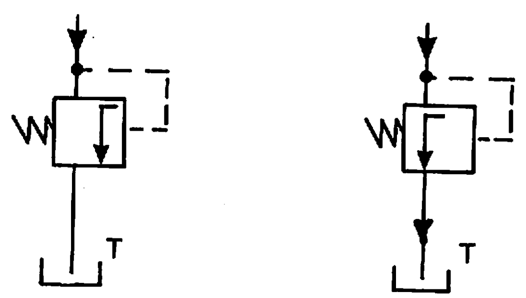


Figure 51.

- In a **relief valve,** Figure 51, you should imagine that the excess pressure acting through the loop line moves the 'arrow' across and oil pressure passes to the tank (T).

  In order to simplify circuit diagrams many outlets are shown returning to the tank (see Figure 53). This avoids running lines from all over the circuit diagram back to the tank and makes the diagram simpler.

- In a **pressure reducing valve** you will see that the loop connection is from the **outlet side** of the valve and acts on the 'arrow'. This valve automatically keeps the outlet line pressure at a pre-set lower value.

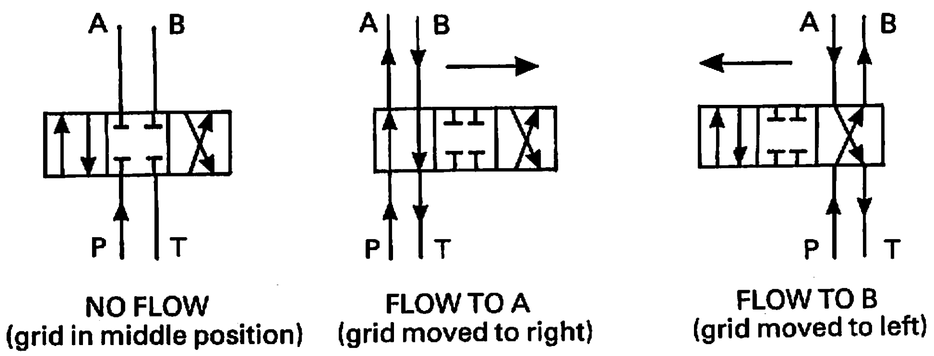


Figure 52.

- The action of **directional control valves** is best understood by imagining that the 'grid' moves across into different positions as shown in Figure 52. This particular figure shows a 'three position valve' which means that the valve can be moved into any **one** of the three positions. If two bars (lines) are added to the valve it means that the valve can take up **any** position between the two limits of movement.

- The term **compensated** means that the design of the component allows for variations in temperature and/or pressure.

Valve Operation
Valves can be operated in many different ways as Table 2 shows. Many are easy to understand but some require further explanation.

- **Pilot pressure** means that oil pressure acts on a small pilot piston to open or close a valve.

- **A Solenoid** is an electric coil with a metal core. When an electric signal is sent to the coil, the core moves and opens or closes the valve.

- **Servo** operated means that a small motor moves the valve.

Now look through the list of miscellaneous items. Again some are clear but note the following points.

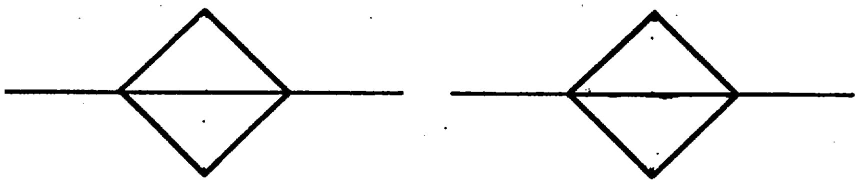
- An **Accumulator** stores a quantity of oil in it but also contains a spring or gas cushion. The cushion absorbs hydraulic shocks in the system and helps the system to have a smooth action.

- In a **heater, cooler** or **heat exchanger** the arrows show the direction of the heat flow. In a temperature controller heat is either added or taken away from the oil as it passes through. This keeps its temperature at a chosen value. Therefore, the symbol has double-arrows.

- An **intensifier** is sometimes used to increase the pressure in part of a circuit. It uses the principle shown in Figure 34. Oil pressure acting on the large piston drives a small piston which then creates the higher pressure.

- In a **pressure switch** oil pressure acts inside to alter the switch to the 'on' or 'off' position.

Now before we look at the circuit diagrams try this SAQ.

> ? **SAQ2**
>
> In the diagrams of a heater and a cooler shown below, add the 'arrows' which indicate the path of the heat flow.
>
> 
>
> (a) heater (b) cooler

HYDRAULIC SYSTEM DIAGRAMS (EXAMPLES)

Now look at Figure 53. It shows part of a hydraulic system diagram with a pressure supply line P and return lines to the Tank T.

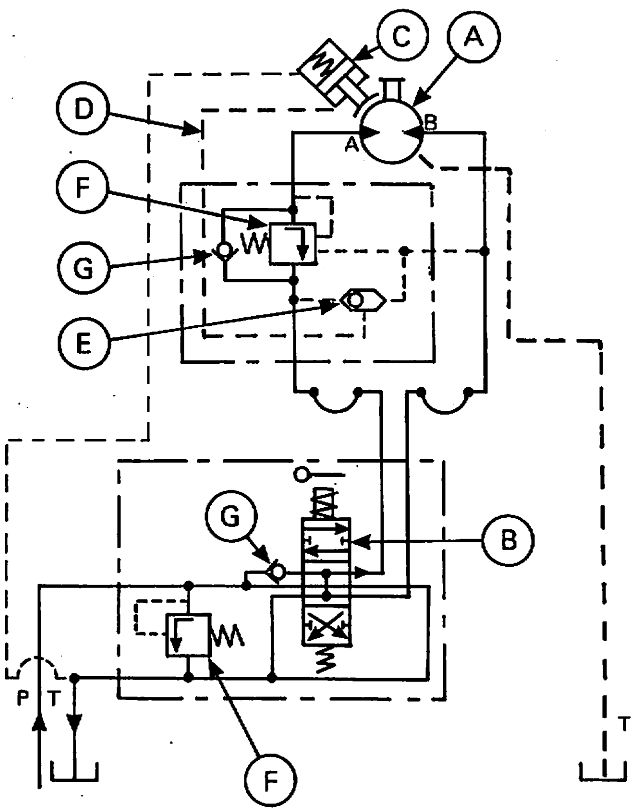


Figure 53.

Ⓐ A reversible motor with a brake Ⓒ

Ⓑ A directional control valve which is hand operated and is fitted with a spring at either end to centralise the spool when hand pressure is released. This cuts off the pressure supply and holds the motor stationary.

Ⓒ A brake cylinder which releases the brake as long as line D is pressurised.

Ⓓ The pressure line to C which is fed from either Port 'A' or Port 'B' through a two way non-return valve E.

Ⓔ A two way non-return valve.

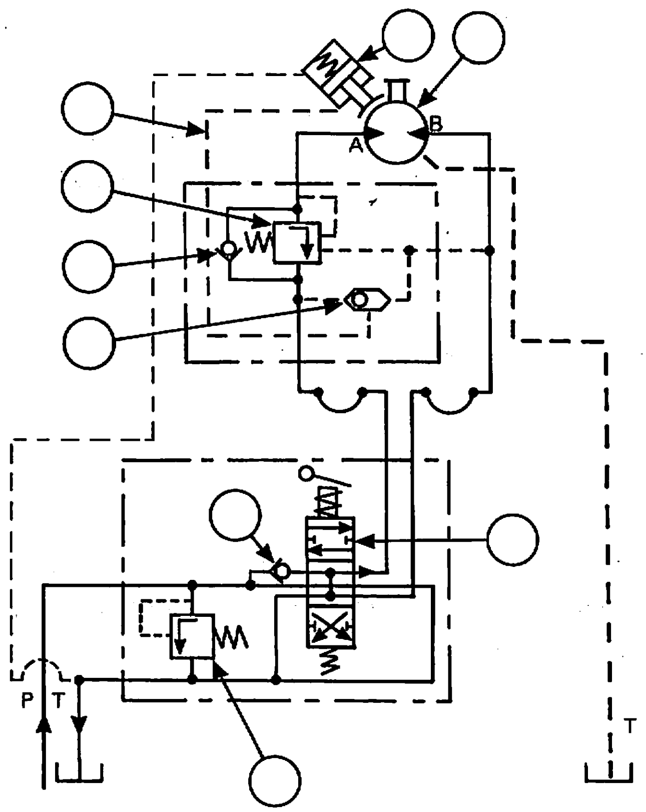
Ⓕ **Two** pressure relief valves, one for each direction of flow of oil under pressure.

Ⓖ Non-return valves.

When you have identified all the items, try the following SAQ's. **Use a soft pencil until after you have checked your response.** Then colour the flow path in.

ⓘ **SAQ24**

Using the information given in Figure 53 trace the flow line from P through to Port A and back to T.



ⓘ SAQ15

Using the information given in Figure 53 trace the flow line from P through to Port B and back to T.

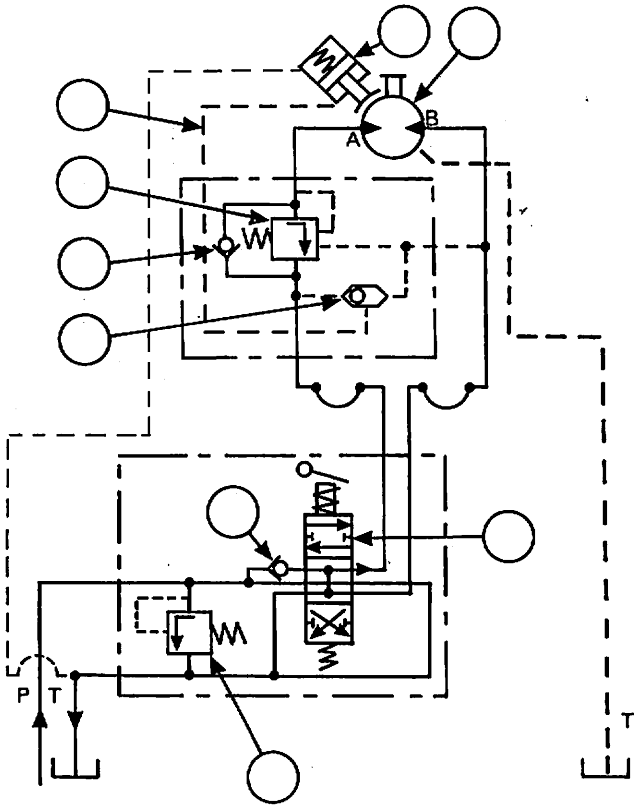


Figure 54 shows another part of a hydraulic system diagram with two pumps driven by an auxiliary engine.

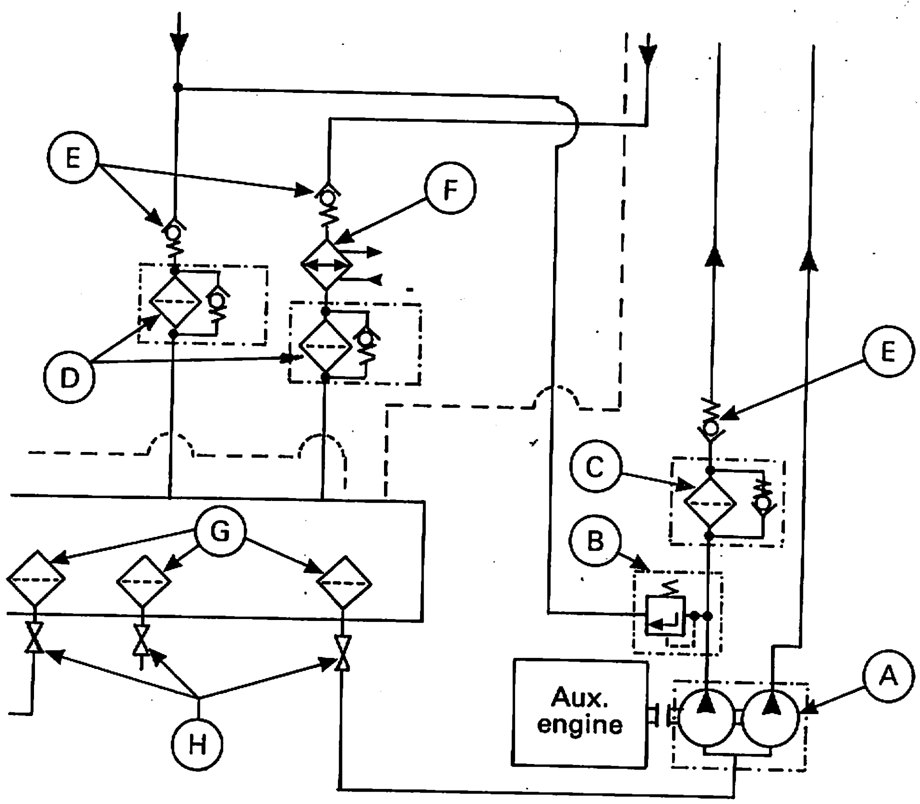


Figure 54.

This part system consists of the following items:

Ⓐ Two pumps with a common drive.

Ⓑ Spring loaded pressure relief valve.

Ⓒ Pressure line filter with a by-pass non-return valve.

Ⓓ Return line filters with by-pass non-return valves.

Ⓔ Non-return valves in line.

Ⓕ Water cooled heat exchanger.

Ⓖ Tank filters.

Ⓗ Shut-off valves.

First, identify each of the items in Figure 54 and then attempt the following SAQ. (Remember to first use a soft pencil and after you have checked your answer go over it with colour).

SAQ6

Using the information given in Figure 54 trace the oil flow when excessive pressure occurs in the supply line (P) and the return line filters are choked.

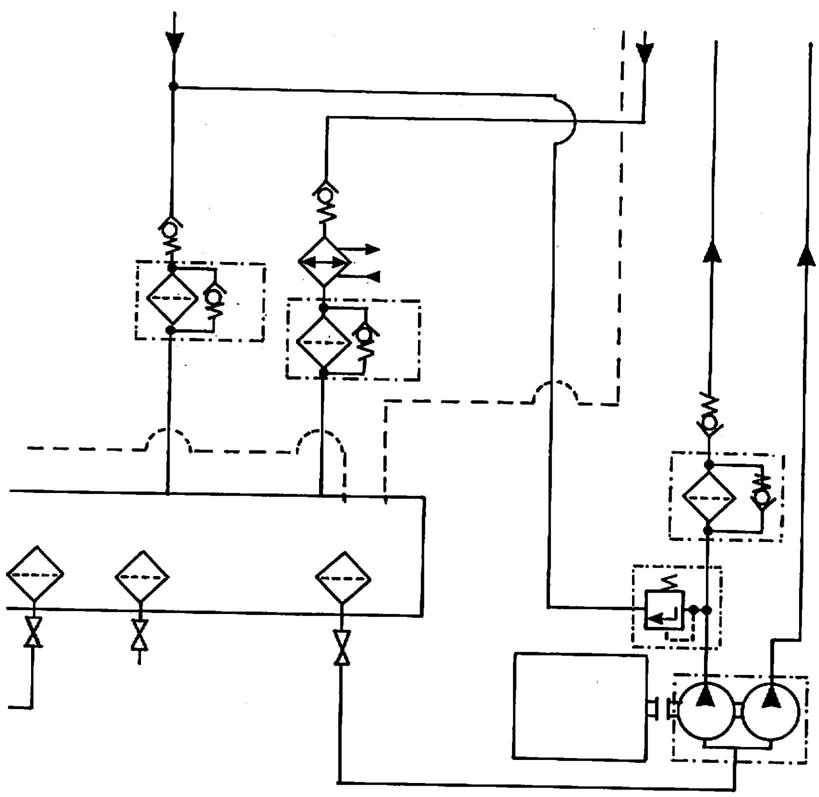


Figure 55 shows a complete hydraulic system of an engine-driven, unidirectional pump operating a reversible motor with a pressure operated brake release.

The dotted lines "_ _ _ _ _ _" indicate 'Drain' lines. The chain dotted lines "____ . ____ . ____" indicate that all the components inside the lines are contained in a single unit.

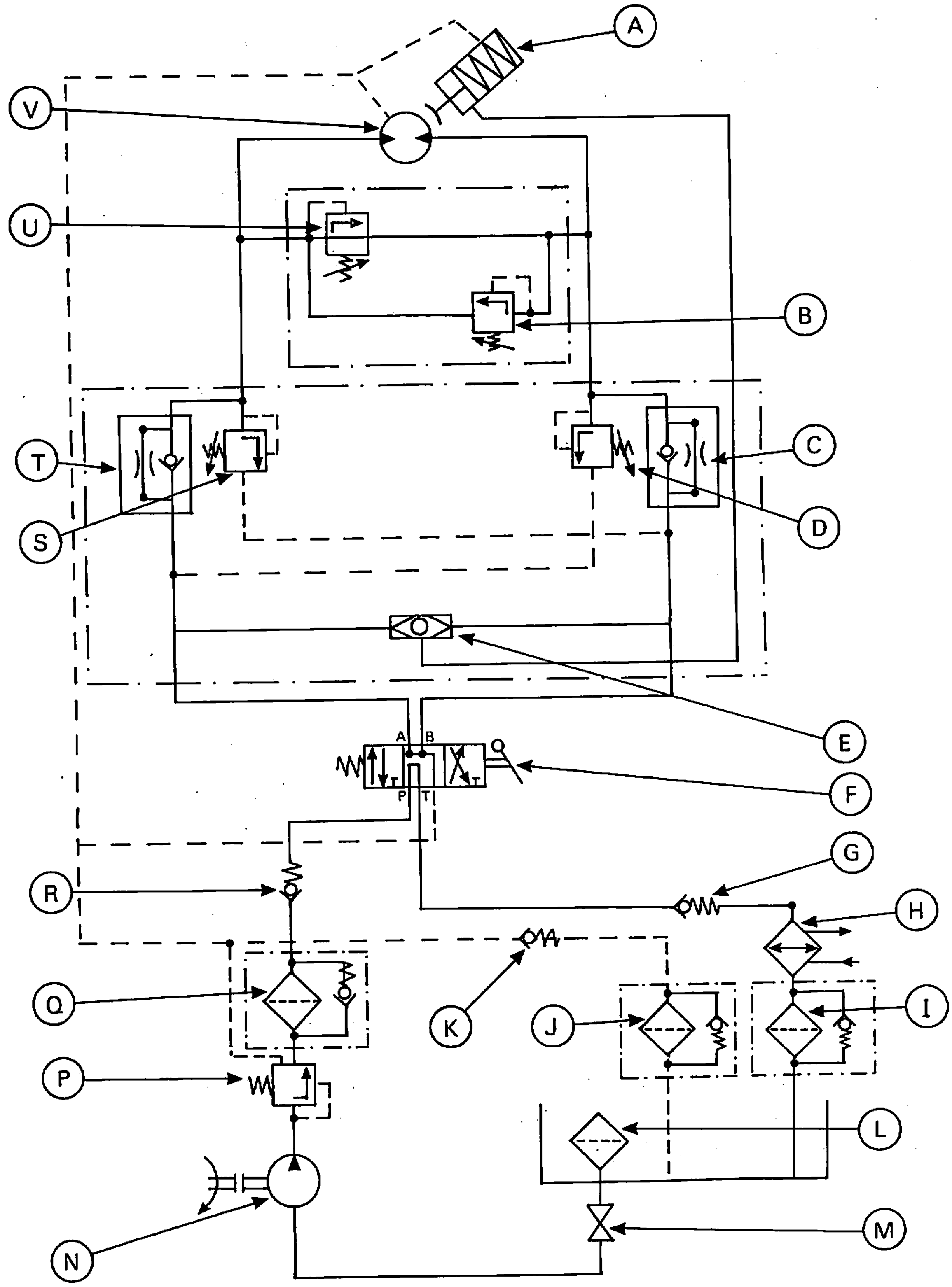


Figure 55.

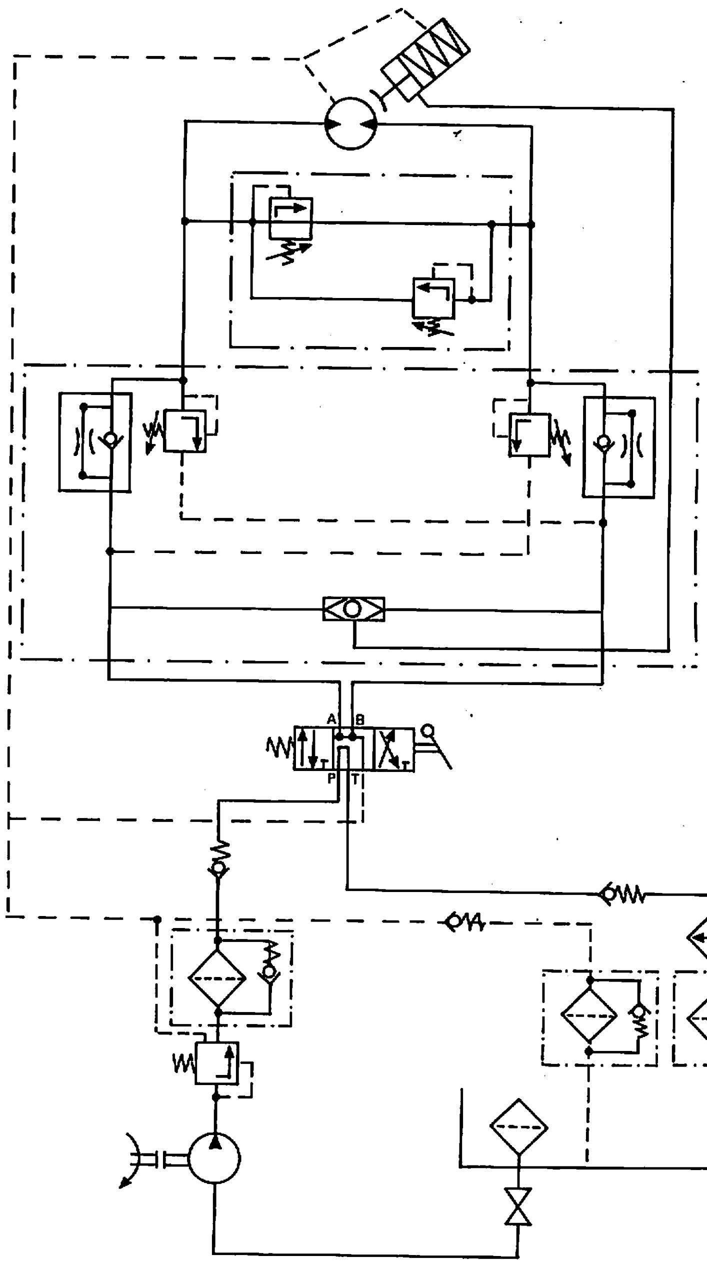
ⓘ SAQ28

Using the diagram of Figure 55 identify the following components using the letters in the circles:

1. Pump ______
2. Motor ______
3. Suction Filter ______
4. Two-Way non-return valve ______
5. Non-return valve with restrictor ______
6. Spring loaded non-return valve ______
7. Relief Valve ______
8. Variable pressure relief valve ______
9. Stop valve ______
10. Directional spool valve ______
11. Delivery line filter with by-pass ______
12. Return line filter with by-pass ______
13. Motor brake cylinder ______
14. Water cooled heat exchanger ______

ⓘ SAQ8

Using the information given in Figure 55 trace the pressure line and the return line when the spool valve delivers oil to Port A.



SUMMARY

You have now completed Segment Four and have worked well. Before taking a break I will remind you of the aims for this Segment. These were that you should now be able to:

- Explain the symbols used to represent the components of a hydraulic system on a circuit diagram.
- Trace the oil flow through each component and through each part of a circuit diagram.

You have also achieved Objective No. 4 on page xiii.

In Segment Five we will consider the various properties which a hydraulic oil should have, the contamination which can occur and the ways in which the contamination is dealt with.

But before that take a good break!

Segment Five

Hydraulic Oils and Filters

Segment Five – Hydraulic Oils and Filters

Welcome to Segment Five in which we will consider the important properties which a hydraulic oil must have and how the oil can become contaminated.

> ⚠
>
> Contamination of the oil causes the greatest number of problems which occur in hydraulic systems.

AIMS OF THE SEGMENT

The main aim of this Segment is to assist in achieving Objective No. 5 given on page xiii.

For this you should be able to:

- State the important properties required by a hydraulic oil;
- State the various forms of contamination which can occur in a hydraulic system;
- Explain the purpose of oil filters;
- Identify the faults caused by oil contamination and the inadequate maintenance of filters.

PROPERTIES OF HYDRAULIC OILS

The use of clean, high quality fluid is the first step in achieving efficient and reliable operation of hydraulic systems.

The most common fluid used in hydraulic systems is oil. This is not just any oil that happens to be available, but an oil which has particular properties.

Oil is a lubricant, which means that all moving components are being lubricated as they work and this keeps them moving freely. It also reduces wear on the parts to a minimum and prolongs the working life of the components.

As well as being a lubricant the oil must:

- transmit power,
- seal the working clearances,
- act as a cooling agent and remove heat from the working parts.

Oil is virtually incompressible which means that action is almost instantaneous when a pump is started, or when a valve operates.

But this is only true if there is no air entrained in the oil or air pockets trapped in the system.

You will no doubt be aware that it is necessary to bleed the air from the braking system of a car if the brakes are to be properly effective.

Also to give good action and to provide proper lubrication and sealing of clearances and glands, the oil must have the correct range of **viscosity**.

Viscosity of Oils

The viscosity of an oil is a measure of its resistance to flow and varies with its temperature.

When temperatures are low the oil must be able to flow freely in order to lubricate all the rubbing surfaces.

At the working temperature the oil must still be "thick" enough to form a seal, but not so "thin" that lubrication of the parts is reduced.

A high viscosity indicates a 'thick' oil and a low viscosity indicates a 'thin' oil.

Too high a viscosity will result in:

- High resistance to flow through the system.
- Increased power consumption due to frictional losses.
- High oil temperature caused by friction.
- Increased pressure drop in the system because of the higher resistance to flow.
- Sluggish operation of pumps, motors and cylinders.
- Difficulty in separating air from the oil in the reservoir.

Too low a viscosity will cause:

- An increase in internal leakage past pistons and control valves.
- Excessive wear or seizure of working parts due to an insufficient oil film between the moving parts.

ⓘ **SAQ31**
State the four main functions of hydraulic oil.

....
....
....
....

ⓘ **SAQ20**
How is the viscosity of an oil affected by:

a) low temperatures
b) heat

a) ....

....

b) ....

....

Relative Viscosity
For most practical purposes the viscosity referred to is the **relative viscosity**.

Relative viscosity is determined in the laboratory by measuring the time it takes for a measured quantity of the oil to pass through a small hole of standard size. The instrument used is called **a viscometer.**

For hydraulic oils, the method used in Britain is the **Saybolt Viscometer** and the time taken is given in seconds. The viscosity is quoted in **Saybolt Universal Seconds (SUS).** As we have seen previously that the viscosity of an oil varies with temperature and to allow for different working conditions, the viscosity is measured at two different temperatures.

Oils for use at low temperatures are measured at 0°F. Oils for use at high temperatures are measured at 210°F.

In the low temperature range the SUS value ranges from 6000 seconds to 48000 seconds.

In the high temperature range the SUS value ranges fromn 45 seconds to 110 seconds.

SAE Numbers

The system of SAE numbers was developed by the Society of Automotive Engineers and represent ranges of SUS viscosities which the oil will have at low temperature and at high temperature.

You will often see these numbers quoted in a car manual and on tins of lubricating oil.

The Table 3 gives a guide to the ratings of SAE numbers.

SAE No.	SUS at 0°F Min.	SUS at 0°F Max.	SUS at 210°F Min.	SUS at 210°F Max.
5W	–	6000		
10W	6000	12000		
20W	12000	48000		
20			45	58
30			58	70
40			70	85
50			85	110

Table 3

As an example, an oil quoted as 10W/40 will have a minimum viscosity of 6000 SUS at low temperatures and a minimum viscosity of 70 SUS at high temperature.

The following SAQ's will help you understand the use of SAE numbers. Try them now.

> ? **SAQ12**
> Using Table 3 determine the viscosity range of an oil designated SAE 5W/20

....

....

....

ⓠ **SAQ26**
Using Table 3 determine the viscosity range of an oil designated SAE 20W/30

....

....

....

Viscosity Index
The viscosity of all hydraulic oils reduces as the temperature rises, and increases as the temperature falls.

Some oils show a large change in viscosity when the temperature changes, whilst the viscosity of other oils changes very little.

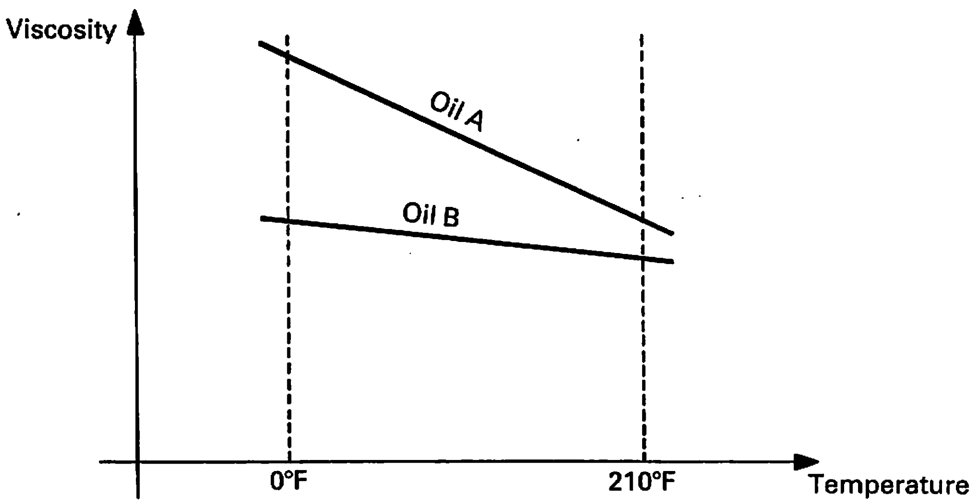


Figure 56.

In Figure 56 you can see that the viscosity of oil B increases only by a small amount at low temperatures and this means that this oil would be suitable for hydraulic systems which have to operate in cold weather conditions. If oil A was to be used the hydraulic system would have a sluggish action at low temperatures due to the increase in viscosity.

Oil A is said to have a **low viscosity index** and could have a typical value of 20. Oil B is said to have a **high viscosity index** and could have a typical value of 100.

For most hydraulic systems, a viscosity index of at least 90 is recommended.

> **i**
>
> The terms **viscosity** and **viscosity index** have different meanings and each value must be considered when checking if an oil is suitable for a hydraulic system.

The necessary information for checking a hydraulic oil is usually found in the operator's manual provided by the manufacturers of the hydraulic system.

Pour point

The pour point of an oil is the lowest temperature at which the oil will flow satisfactorily.

The pour point of any oil used in a system should be at least 10°C below the lowest temperature which the hydraulic system is expected to operate in.

Other Properties

As well as having a suitable viscosity range, viscosity index and pour point, a hydraulic oil must:

- Prevent rusting.
- Resist the formation of sludge, gums and varnish.
- Resist foaming if air is mixed into it.
- Allow any water contamination to separate from it easily.
- Not attack or dissolve the material of seals and gaskets.

Additives in Hydraulic Oils

Many parts of a hydraulic system are made of steel and **rust** can form on steel surfaces if oxygen and water are present in the oil.

It is not possible to keep all air out of the system and air contains both oxygen and water vapour.

Corrosion is a reaction between different metals when water and acid is present. An unprotected metal surface will be 'eaten away' by corrosion and the surface becomes pitted.

Acid can be formed in the oil when oxygen is mixed in it and particularly when the oil is allowed to become overheated. This will also cause sludge, gums and varnish to form in the oil.

Particles of rust and particles resulting from the corrosion can cause wear on surfaces which rub together and also damage the seals on pumps and actuators.

Additives in the oil are used to put a protective film on the metal surfaces so that they resist rusting and corrosive attack.

Additives also help to prevent the formation of gums, sludge and varnish in the oil which can cause valves to stick and also block small, restriction orifices which may be in the system.

⚠

Additives are blended into the oil by the oil manufacturer and cannot be added to the oil by the operator of a hydraulic system.

ℹ

Not all the hydraulic oils which are available contain these additives in sufficient quantities and only oils recommended by the manufacturers of the system should be used.

So, you should now realise that a hydraulic oil has a number of special properties.

Try these SAQ's before we look more closely at the contamination of the oil.

SAQ9

State the various properties which an oil should have so that it is suitable for use in a hydraulic system.

....
....
....
....
....
....
....

SAQ17

a) State three values which you should check before using an oil in a hydraulic system.

b) Where could you find out what these values should be?

a) ....
....
....

b) ....
....

When you have checked your responses to these SAQ's I suggest a short break before starting the subject of 'contamination'.

CONTAMINATION

Dirt and other forms of contamination can enter a hydraulic system in a variety of ways.

- From new oil:
  New oil in a drum may contain contaminants due to long storage periods or if it has been previously opened and not re-sealed properly.

- From the atmosphere:
  Cylinder rods in the extended position can pick up contamination in the form of fine dust and water. The rod must have a clearance to allow movement, and the clearance can become large enough to allow dirt to be dragged through the seal and into the system.
  The air breather on the reservoir may also allow contaminants to enter the system if it is damaged or faulty.

- From the components and seals:
  All moving parts wear. As the surfaces rub together, tiny particles of metal and seal material get rubbed off and then circulate with the oil.

Dirt and other solid contaminants in a hydraulic system consist of large particles which can be seen but also many fine particles which cannot be seen.

The coarse dirt is easily removed by a coarse filter in the reservoir but the fine dirt requires a special fine filter to remove it. Dirt particles are measured in **microns.** A micron is a millionth part of a metre, or a thousandth of a millimetre (0.001 mm). The symbol for **microns** is μm.

To give you some idea of the size, a human hair has a diameter of 50 μm and the human eye can see a particle of 40 μm in diameter but with difficulty.

A common type of filter used in the hydraulic systems of fishing vessels removes particles down to 10 μm.

The only way to see dirt of this size is with a microscope, but that does not mean it is unimportant!

Although the dirt particles are very small, they are of sufficient size to block fine orifices and clearances and they can act like a grinding paste on the working parts of the system.

Contaminants drawn in to the system may also form acids with other elements in the oil and cause corrosion of the working parts.

> ⓘ **SAQ5**
> State **three** sources of contamination of a hydraulic fluid.

....

....

....

FILTERS

Experience in the field of hydraulics shows that **70%** of the faults which occur in hydraulic systems can be traced to the condition of the hydraulic oil. So,

> ⚠
> To avoid trouble with hydraulic systems use the correct oil and keep it clean!

The kind of faults which make up the 70% include:

- **Dirt and dust**
- **Grease** – from dirty cleaning rags
- **Metal chips** – these may have been left in when the part was manufactured

- **Metal wear particles**

- **Packing and gasket fragments** – due to wear in the seals and wrong assembly of the seals

- **Paint flakes** – these occur if protecting paints have not been applied properly

- **Pipe scale** – due to the pipes not being cleaned internally when the system was made or repaired

- **Pipe thread compound** – excessive amounts of sealing paste used when making joints

- **Rust particles** – from corrosion or poor internal cleaning of pipes

- **Weld spatter** – small droplets of weld metal in the region of a welded joint can become loose.

- **Water** – taken in through seals and breathers

- **Wrong oil** – the wrong type of oil used when re-filling or making up the oil level

The remaining 30% of faults are divided into:

10% – Mechanical failures such as bearing failure and seal failures.
10% – Improper diagnosis of trouble or faulty repair.
5% – Overloading of equipment
5% – Miscellaneous causes

The oil being added to the system should be carefully filtered, even from a new unopened drum. The area around the filling plug should be cleaned **before** the filling plug is removed and only clean containers used for filling.

Since all contamination cannot be prevented, the system must be constantly filtered in such a way that the dirt entering the system is removed by the filters at the same rate.

Coarse filters, often referred to as strainers, are made of fine wire mesh or a series of discs separated by fine spacers. The space between the wire mesh or the discs determines the size of particle which will be trapped in the filter. The disc type can usually be cleaned by turning a handle at the top, causing the dirt to fall to the bottom where it can be drained out of the system.

Although strainers do not provide fine filtering, they offer less resistance to flow and are used where the pressure drop must be kept to a minimum.

Strainers are fitted in the tank or close to the pump inlet to prevent large particles from going through the pump causing damage and possibly causing it to seize up. In earlier segments we saw that the working clearances in pumps are very fine.

Fine filters contain screening elements made of paper, wood cellulose or plastic and remove the very small dirt particles I mentioned earlier. Normally these filter elements cannot be cleaned but must be replaced.

Filters are classed as either **full-flow** or **proportional flow.**

In a **full flow filter,** all the fluid entering the filter unit passes through the filter element. The filter unit is fitted with an indicator which shows when the filter element needs changing. The indicator is either a coloured button which moves out as the filter element gradually blocks, or a coloured disc which moves round as the filter blocks.

A common type of filter shows:

- green – clear flow
- yellow – partially blocked
- red – almost completely blocked and requires changing.

Full flow filters are all fitted with a by-pass valve which opens as the pressure builds up in the inlet line to a blocked filter element. When the by-pass valve is open, **the oil is not filtered** as it passes through the filter unit.

Sometimes pressure gauges are fitted before and after a filter. As the filter blocks a difference in the pressures they show will gradually develop.

In a **proportional filter**, part of the fluid flow is directed through the filter element and part of it passes straight through and is not filtered. This type of filter is not normally fitted in the high pressure systems which are used on fishing vessels.

Filters should be cleaned or changed at regular intervals. The number of **working hours** is a good guide. The makers of the equipment will probably have stated a recommended time between cleaning or changing, but this time will be reduced if your equipment is worked severely.

⚠
A choked filter increases the resistance to flow in the oil circuit. This increases the friction in the circuit and can cause the temperature of the oil to rise. This is a waste of energy and means that the engine driving the pump will use more fuel.

To complete this segment try these two SAQ's.

? **SAQ13**
State the two basic types of filter elements used in hydraulic systems.

....

....

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🛈

A filter which blocks after 10 hours and doesn't get changed until 30 hours will by-pass unfiltered oil for 20 hours!

⑦ **SAQ7**

If no indicator is fitted to a filter, how could you tell if the filter element was blocked?

....

....

....

SUMMARY

You have now completed Segment Five and are making good progress. Before taking a well earned break I will remind you of the aims for this Segment. These were that you should now be able to:

- State the important properties required by a hydraulic oil;
- State the various forms of contamination which can occur in a hydraulic system;
- Explain the purpose of oil filters;
- Identify the faults caused by oil contamination and the inadequate maintenance of filters.

In completing these aims you have also achieved part of Objective No. 5 on page xiii. This will be completed in Segment Six where we will see more of the maintenance which a system requires and some simple fault finding procedures.

Now take a good break.

Segment Six

Maintenance and Fault-Finding

Segment Six – Maintenance and Fault-Finding

Welcome to the final segment in this Module in which we will look at the maintenance which a hydraulic system requires and how you can carry out some simple fault-finding.

AIMS OF THE SEGMENT

The main aim of this Segment is to achieve Objectives No. 5 and 6 on page xiii.

For this you should be able to:

- State the key maintenance problems which can arise in a hydraulic system.
- State the items of maintenance which should be carried out regularly.
- Describe simple maintenance procedures.
- Use fault finding tables to identify and locate faults in a hydraulic system.

MAINTENANCE OF HYDRAULIC SYSTEMS

A hydraulic system is normally easy to maintain. The oil provides an effective lubricating medium and the relief valves in the system protect the equipment from mechanical overloading.

The system can be damaged by excessive working pressures, high operating temperatures and by contamination of the oil.

⚠

By carrying out a regular maintenance programme you will eliminate the more common problems and become aware of special problems which are developing.

These problems can then be corrected before a breakdown occurs.

The key maintenance problems are:

- Contaminated oil
- Poor filtration
- Incorrect oil
- Low oil level
- High oil temperature
- Leaks in pipe lines and at joints
- Faulty seals

Contaminated Oil

As I stated in Segment Five, 70% of the faults which occur in hydraulic systems are a result of contamination of the oil of one kind or another.

Some contamination will always occur but you should not add to it by lack of care when adding oil to the system. Attention to the following points is then important:

- Keep oil clean from the minute it is delivered to you.
- Store it in a clean, dry place.
- Always keep the lid on the container.
- Use a clean funnel fitted with a fine-mesh screen when pouring oil from the container into the reservoir.
- Use lint-free cloth to wipe around the filler and breather.
- Use the correct oil as recommended by the manufacturer.
- Always plug disconnected hoses and the openings in any component with clean plastic plugs when maintenance is being carried out.

⚠
Cleanliness has top priority.

- Keep the oil clean
- Keep the system clean
- Add only clean oil

Poor Filtration
Filters are included in the system to remove the particles of contamination which are carried around the system by the oil. Filters should have **regular** attention, so:

- Clean or replace filters at regular intervals.
- Clean the area around the filters before changing the element.
- Oil which has leaked out or been spilled should be dumped and **not** returned to the system.
- Make sure that all drains, filler caps and breathers are properly secured.

⚠
Never run the system unless all filter elements are in place.

Oil Level in the Reservoir
A low oil level in the reservoir may cause cavitation in the pump. This means that the pump may draw in air with the oil. This causes a loss in efficiency of the pump and makes the pump noisy in operation.

The circulating oil carries away the heat generated in the system. If the oil level is too low there will be less oil in the system and the same oil is circulated more often. The oil will then become overheated.

So, check the oil level regularly and remember that a drop in oil level is a tell tale sign of leakage.

Now try these SAQ's.

> ⓘ **SAQ19**
> State the precautions you would take when adding oil to a hydraulic system.

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....

> ⓘ **SAQ10**
> Why should disconnected hoses and holes in components be plugged during maintenance operations.

....
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....
....

Oil Temperature Too High
High oil temperature causes the oil to break down faster and lose its effectiveness as a lubricant and a sealer of working clearances. It can also damage the seals and coat the working parts with varnish deposits. The reduction in viscosity caused by the higher temperature also causes extra leakage past pistons, vanes and spool valves and thus reduces the output of the system.

Hot Oil is a relative term. Most systems are designed to operate at about 50°C (120°F) and can go up to about 70°C for short periods. As a rough guide, if you can hold your hand on a pipe or component for 10 seconds then its temperature is below 50°C (120°F).

⚠
Do not 'grip' a hot pipe. Try a fingertip first.

The system temperature should be measured at the tank because local heating up at pumps, motors and valves is quite normal.

Oil that has been overheated has a distinct 'burnt' smell. It is darker than new oil and is thinner to the touch.

⚠
Oil that has been overheated should be replaced by new oil at the first opportunity and the cause of overheating identified and corrected, otherwise the overheating will be repeated.

Leaks
Some **internal leakage** is necessary to lubricate the mating parts of pumps, motors, cylinders and valves, but if wear occurs on any of the parts then this leakage can become excessive. The amount of internal leakage can be checked by keeping a watch on the drain returns to the tank.

Internal leakage does not cause any loss of oil from the system but it does reduce performance and efficiency. It may allow movement of cylinders and motors from the 'hold' position but this movement could also be caused by internal leakage at a spool valve, or through a relief valve.

External leaks can be expensive and dangerous as well as causing a loss of power. A leak of one drop per second amounts to 8 gallons in a week! If the reservoir has to be topped up often it is a sure sign of external leakage.

Every joint and flexible hose is a possible point of leakage and if it is near a hot surface there can also be a danger of fire.

The rubber cover on flexible hoses may crack or split without actually leaking. Any oil dampness is a sign that a crack may be there and the hoses should be replaced.

If a connection is leaking, tighten the joint only until the leak stops.

> ℹ
> Do not over-tighten – you may strip the threads and/or distort the parts.

If the joint still leaks the connector must be replaced or re-sealed.

When replacing a coupling or a flexible hose use thread tape wrapped around the male threads leaving the first two threads clear.

Also use two spanners, one to hold the coupling or hose, and the other to tighten the nut. This will prevent the hose from being twisted.

> ℹ
> A twisted or kinked hose may cause a restriction in the flow of oil.

After correcting any leaks run the system until it is warm and check that no further leaks have developed. You should then re-check the system oil level and top up if necessary.

Air Leaks into the suction lines can also occur. These can be detected by pouring a small quantity of oil over the suspect area. If the noise or bubbling in the lines stops then you have located the leak.

Faulty Seals

Faulty Seals on pumps, motors and actuators are not only a source of external leakage but also can allow contamination to pass into the system. When a leaking seal is replaced, close attention should be paid to the following points:

- Always use a **new** seal which is an approved spare part. Do not be tempted to use a worn seal however good its condition may appear.
- Clean the seal pocket and the area around it very thoroughly. Any dirt which is left there could damage the new seal.
- Examine the pump or motor shaft or the actuator cylinder rod very carefully. If it is marked or scored then the new seal will only have a short life and replacement or repairs to some of the parts will be necessary.

Before starting the fault-finding section of this Segment try this SAQ.

? SAQ30

Why should two spanners be used when replacing or re-connecting hoses and care taken not to over-tighten the connections?

....

....

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....

....

FAULT FINDING

Even the best designed and maintained system will develop faults eventually but good maintenance will reduce the number of problems to a minimum.

The following tables list common faults in order of their likelihood of happening and are similar to those in 'Operators Manuals' produced by manufacturers of hydraulic systems.

Depending on the equipment you have available, for example, pressure gauges, and your own expertise and experience, some of the remedies may not be practical and in these cases the manufacturer or his agent should be called in.

> ⚠
> Prolonged delays in correcting faults can result in large repair bills at a later date.

Many of the suggested remedies are common to several faults.

For simplicity they have been listed alphabetically on a fold out page, namely, page 91. Open this page out and then consider each fault together with the possible causes and the suggested remedies given on the fold out page.

Excessive Noise

Unit	Possible Cause	Remedy
		See page 91
Pump	Cavitation	(a)
	Air in the oil	(b)
	Coupling mis-aligned	(c)
	Pump worn or damaged	(e)
Motor	Coupling mis-aligned	(c)
	Coupling worn or damaged	(c)
	Motor worn or damaged	(e)
Relief Valve	Setting too low	(d)
	Worn valve or seat	(e)

Table 4

Excessive Heat

Unit	Possible Cause	Remedy
		See Page 91
Pump	Cavitation	(a)
	Air in the oil	(b)
	Relief valve set too high	(d)
	Excessive load	(c)
	Worn or damaged pump	(e)
	Overheated oil (see 'oil')	
Motor	Relief valve set too high	(d)
	Excessive load	(c)
	Worn or damaged motor	(e)
	Overheated oil (see 'oil')	
Relief Valve	Setting incorrect	(d)
	Worn or damaged valve	(e)
	Overheated oil (see 'oil')	
Oil	System pressure too high	(d)
	Relief valve set too high	(d)
	Dirty oil	(f)
	Low level in tank	(g)
	Incorrect oil viscosity	(h)
	Faulty cooler	(i)
	Worn component in system	(e)

Table 5

Incorrect Flow

Unit	Possible Cause	Remedy
		See page 91
No Flow	Pump not receiving oil	(a)
	Pump drive not operating	(e)
	Pump drive turning in wrong direction	(j)
	Directional control in wrong position	(k)
	Entire flow passing over relief valve	(d)
	Damaged pump	(c)
	Improperly assembled pump	(c)
Low Flow	Flow control set too low	(d)
	Relief valve set too low	(d)
	Flow by-passing through a partially open valve	(k) or (e)
	External leak in the system	(l)
	Actuating device on a variable dis-placement pump not working	(e)
	Worn component	(e)
	Incorrect drive speed for the pump	(m)
	Smaller size pump fitted as a replacement	(n)
Excessive Flow	Flow control set too high	(d)
	Actuating device on a variable dis-placement pump not working	(e)
	Incorrect drive speed for the pump	(m)
	Larger size pump fitted as a replacement	(n)

Table 6

Incorrect Pressure

Unit	Possible Cause	Remedy
		See Page 91
No Pressure	As for 'no flow' page 87	
Low Pressure	As for 'low flow' page 87	
	or	
	Pressure reducing valve set too low	(d)
	Pressure reducing valve worn or damaged	(e)
	Worn component	(e)
Erratic Pressure	Air in the oil	(b)
	Worn relief valve	(e)
	Contamination in the oil	(a)
	Accumulator (if fitted) defective or lost pressure	(o)
	Worn component	(e)
Excessive Pressure	Pressure relief valve, reducing valve or unloading valve wrongly adjusted	(d)
	Actuating device on a variable displacement pump not working	(e)
	Pressure relief valve, reducing valve or unloading valve worn or damaged	(e)

Table 7

Faulty Operation

Unit	Possible Cause	Remedy
		See page 91
No Movement	As for 'no flow' page 87	
	Limit or sequence control not working or wrongly adjusted	(e)
	Mechanical binding	(p)
	No signal to servo mechanism	(q)
	Inoperative servo valve	(e)
	Worn component	(e)
Slow Movement	As for 'low flow' page 87	
	Oil viscosity too high	(r) or (h)
	Insufficient lubrication	(s)
	Sticking servo valve	(e) & (f)
	Worn component	(e)
Erratic Movement	As for 'erratic pressure' Page 88	
	Air in the oil	(b)
	Insufficient lubrication	(s)
	Erratic command signal	(q)
	Sticking servo valve	(e) & (f)
	Worn component	(e)
Excessive Speed or Movement	As for 'excessive flow' page 87	
	Feedback not working properly	(e)

Table 8

So you can see that there are many faults, each with a number of possible causes which can occur in a hydraulic system. In practice you will get clues to the cause of the fault if you know that some of the parts have been changed or repairs and alterations carried out.

Faults often result from the lack of attention to items of regular maintenance, so always:

- Change and clean filters regularly.
- Keep the oil level in the reservoir topped up.
- Keep an ample supply of clean filters in a clean dry place.
- Check for leaks in the system and correct as soon as possible.
- Check the system temperature regularly.
- Check pumps, motors and valves for overheating.
- Listen for excessive noise.
- Check tension in V-belts (if fitted).

Now before completing this Segment, try the following SAQ's.

? SAQ23
A hydraulic motor is making excessive noise and is overheated. Using the fault finding tables suggest what the cause could be.

....

....

⓪ **SAQ4**

A linear actuator will only move slowly when the control lever is operated.

Using the fault finding tables make a list of the possible causes.

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SUMMARY

You have now completed Segment Six but a reminder of the aims for this segment would not be out of place.

- State the key maintenance problems which can arise in a hydraulic system.
- State the items of maintenance which should be carried out regularly.
- Describe simple maintenance procedures.
- Use fault finding tables to identify and locate faults in a hydraulic system.

You have also achieved Objectives No. 5 and 6 on page xiii and have worked well. If you have checked your responses to the SAQ's you have also completed the module and I hope you have found it both useful and interesting. It does not cover all that is to be known about hydraulic systems in fishing vessels but should help you to keep the systems on your vessel in working order and trouble free.

Responses to the Self Assessment Questions

Responses to the Self Assessment Questions

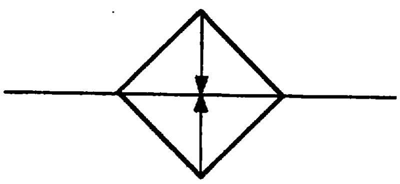
SAQ 1

Your list should include, tank, pump, control valve, filters, relief valve and cylinder or motor.

You may also have included breathers, pipelines and pressure gauges.

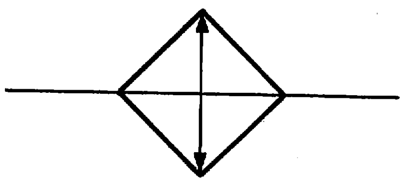
SAQ 2

a)



(a) in a heater, heat passes into the fluid.

b)



b) in a cooler, heat is removed from the fluid.

SAQ 3

The vanes are kept in contact with the casing by one of the following methods:

- Centrifugal force throwing the vanes outwards.
- Springs on the underside of the vanes.
- Oil at system pressure being fed to the underside of the vanes.
- Curved push rods. (Vickers Pumps). As one vane is pushed in by the shape of the casing, another is pushed out by the curved rod.

SAQ 4

There are quite a number of things you can list in this answer, but you should first have looked for **'slow movement** in Table 8 on page 89. It gives you four possible causes:

- Oil viscosity too high
- Insufficient lubrication
- Sticking servo valve
- Worn component

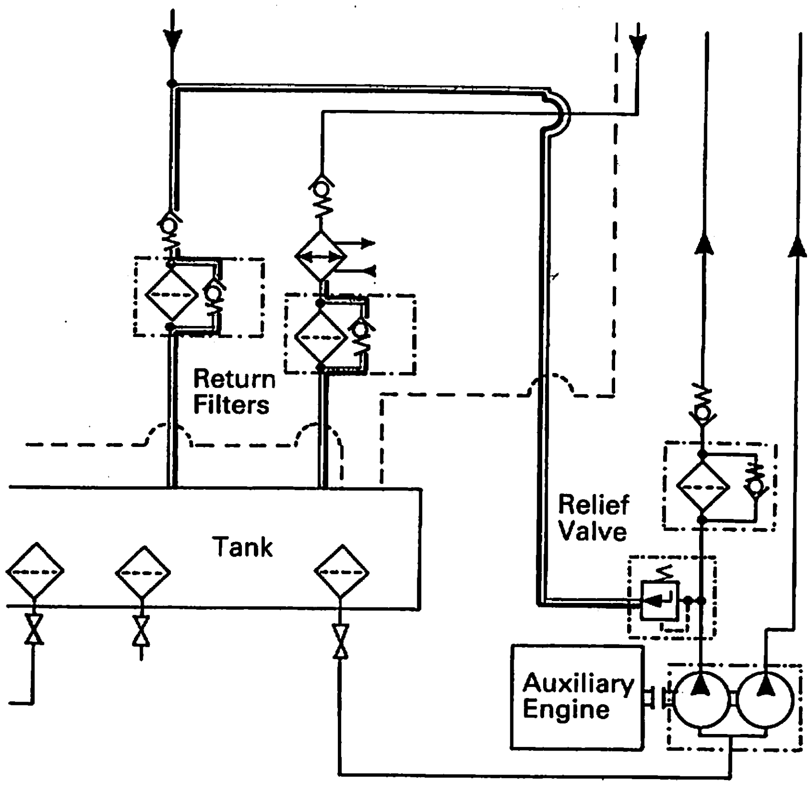
But it also tells you to look under 'low flow' on page 87 where you are given another eight possible causes, one of which, namely, 'worn component', has already been listed. So, there are **eleven** possible causes which you should have listed.

SAQ 5

The **3** main sources of contamination are:

(a) Contaminants in the replacement oil.
(b) From the atmosphere through seals and from the surfaces of cylinder rods, and through the breather on the tank.
(c) From the wearing of components in the system.

SAQ 6



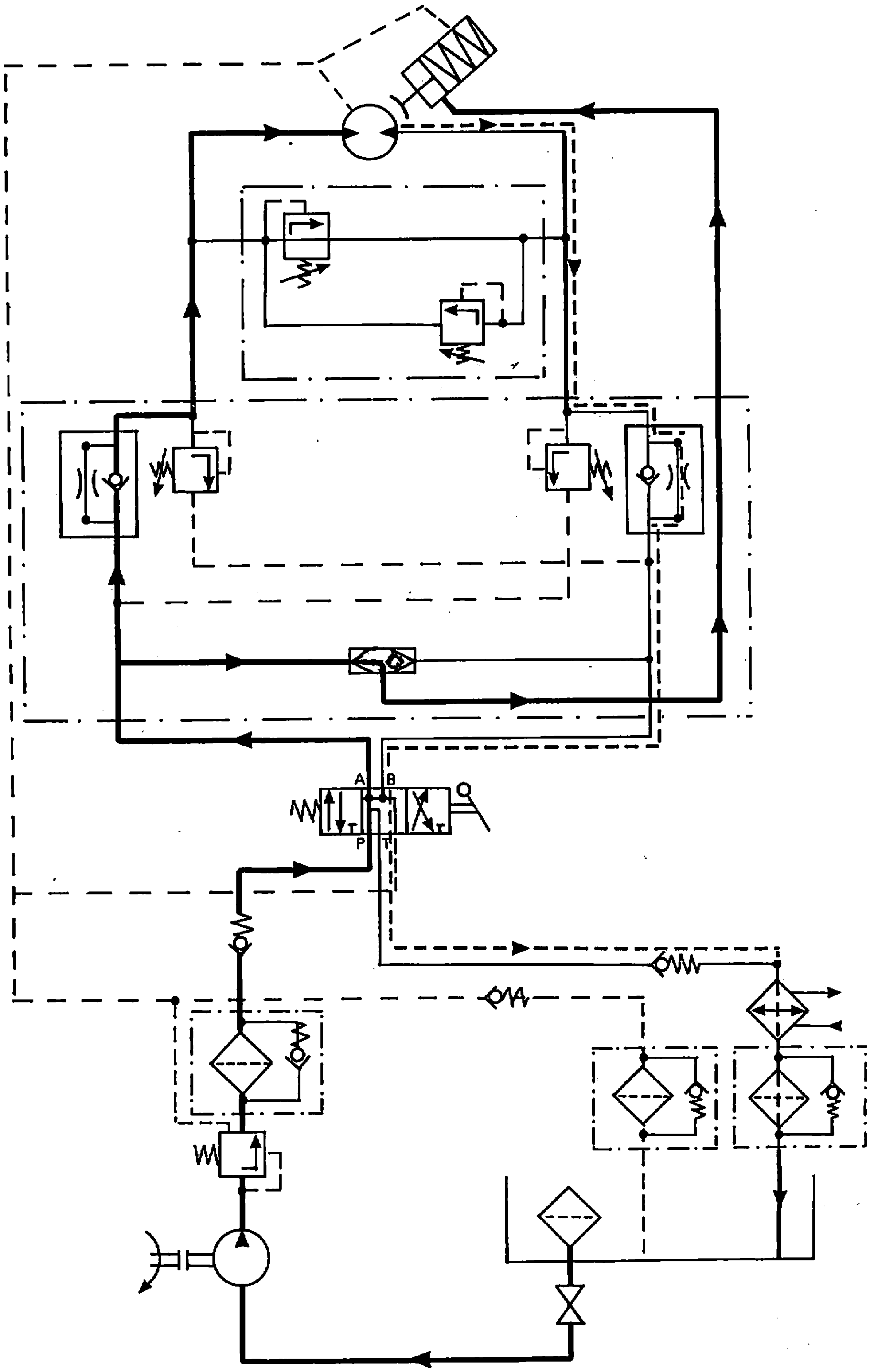
Did you show the change in position of the 'arrow' in the relief valve Ⓑ ? Also the SAQ indicated that both the return line filters were choked. You should have shown oil flowing through the bypass loop on each filter.

SAQ 7

If no indicator is fitted there should be pressure gauges in the line. There will be a large pressure difference between the gauge on the inlet line and the gauge on the outlet line.

As the filter blocks the flow through the element is restricted and the pressure before the filter builds up and the pressure after the filter will be lower than normal.

SAQ 8



Did you show that the valve in the two-way non-return valve Ⓔ has moved to the right and prevents the escape of pressure oil to the return line?

SAQ 9

The various properties which a hydraulic oil should have are:

- Correct viscosity or as an alternative, the correct viscosity range (SAE number)
- Correct Viscosity Index – not thicken excessively at low temperature
- A suitable Pour Point – remain fluid at low temperatures
- Prevent rusting and corrosion
- Resist the formation of sludge, gums and varnish
- Resist foaming with air
- Suitable for use with the materials of seals and gaskets

Perhaps you did not get all the properties listed above. Look back in the segment and find the ones you missed and why they are included in the oil.

SAQ 10

Whilst hoses are disconnected and components dismantled, water and dirt could easily get into them and you may not be aware of it! This is particularly the case on the deck of a fishing vessel – it can be a busy place!

SAQ 11

(See Figure 44). As the angle of the swash plate is increased, each piston is moved further out at the top and pushed further in at the bottom. This increases the length of the **effective** stroke and so increases the volume of the flow.

SAQ 12

SAE 5W/20 oil will have a maximum viscosity of 6000 SUS when cold and a minimum viscosity of 45 SUS when hot.

SAQ 13

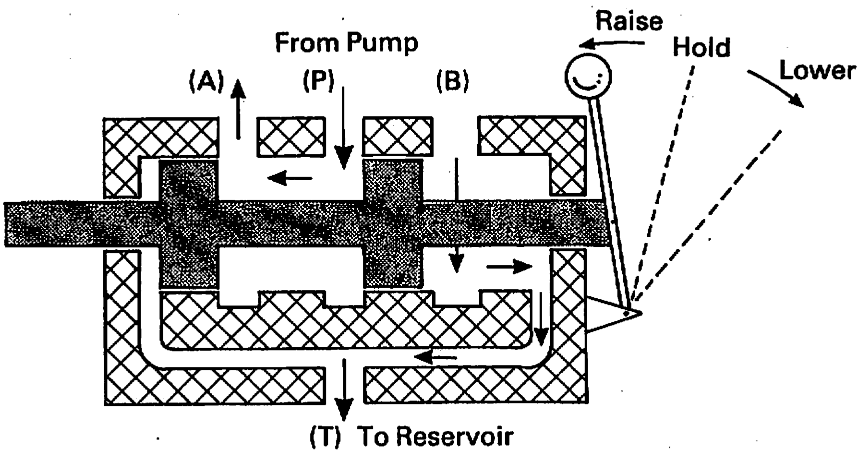
The **2** basic types of filter elements are:

(a) Wire mesh or disc type for coarse filtering. This type is re-usable.

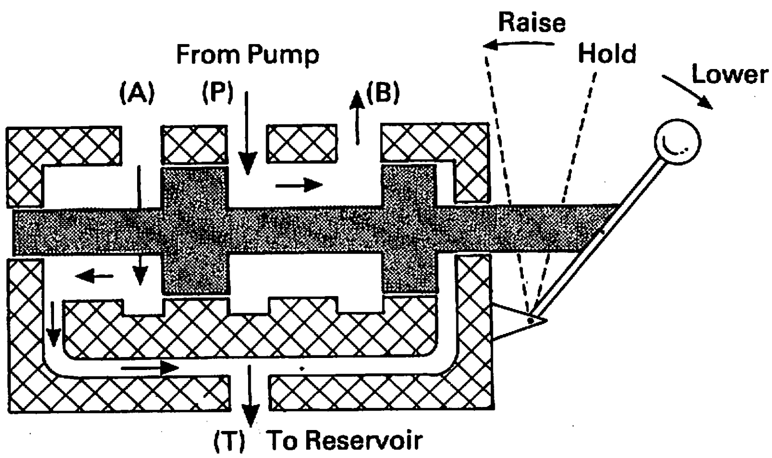
(b) Paper, or other material, cartridge type which cannot be cleaned but must be replaced.

SAQ 14

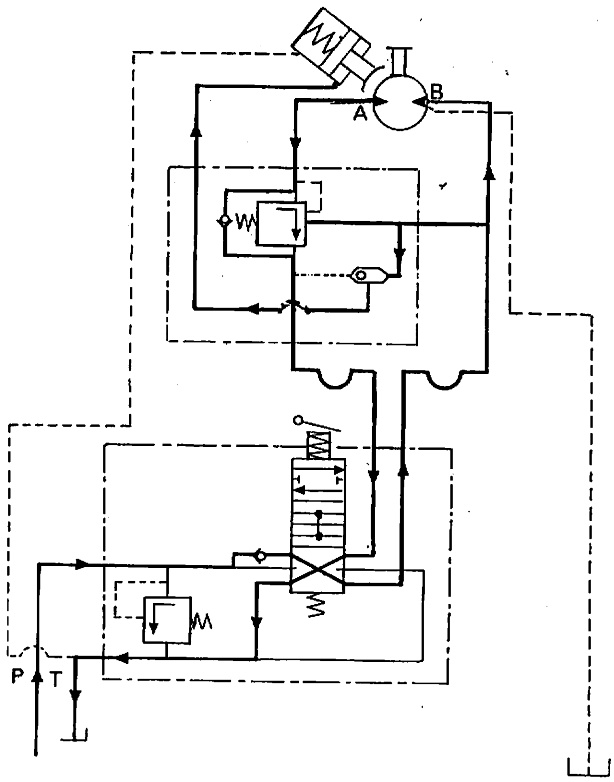
a) Flow to Port A



b) Flow to Port B



SAQ 15



SAQ 16

A linear actuator provides straight line motion. A rotary actuator provides circular motion. A semi-rotary actuator provides an oscillating motion, that is, circular motion but only backwards and forwards – not a complete revolution. A good example is the actuator for a steering gear, Figure 33(a) on page 20.

SAQ 17

(a) The three important values you would check are:

- **The Viscosity** – remember to check the units because sometimes units other than "SUS seconds" are given. As an alternative the SAE number may be used.
- **The Viscosity Index** – usually more than 90.
- **The Pour Point** – this is particularly important if your vessel is to operate in very cold conditions.

(b) The operator's manual produced by the makers of the hydraulic system should give you the values you want. If the manual is not on board you could contact the agents or the makers of the system.

SAQ 18

$$\text{Volume displaced at A} = 0.001 \times 0.1 = 0.0001\ \text{m}^3$$

$$\text{Movement of B} = \frac{0.0001}{0.05} = 0.002\ \text{m} = 2\ \text{mm}$$

SAQ 19

The thing to avoid when adding oil to the system is allowing dirt and other forms of contamination to enter the system. So the precautions should include:

- Cleaning the area around the filter plug thoroughly **before** removing the filter plug. Also clean the top of the oil container.
- Use a **clean** funnel filter with a fine mesh filter screen.
- Don't add oil to the system if there is water splashing and repairs being carried out nearby.

Remember to use the correct oil and remember to replace the filling plug correctly.

SAQ 20

(a) Viscosity **increases** as the temperature falls. This makes the oil "thicker" and tends to cause sluggish operation of components.

(b) Viscosity **decreases** as the temperature rises. This makes the oil "thinner" which reduces the lubrication film between any rubbing surfaces. It may also cause increased leakage past a seal or a spool valve.

SAQ 21

A reduction in volume flow in a radial pump is obtained by moving the centre lines of the reaction ring and the cylinder block closer together. In the type of pump shown in Figure 48 this would be done by moving the reaction ring to the left, and this would reduce the length of the effective stroke of each piston.

SAQ 22

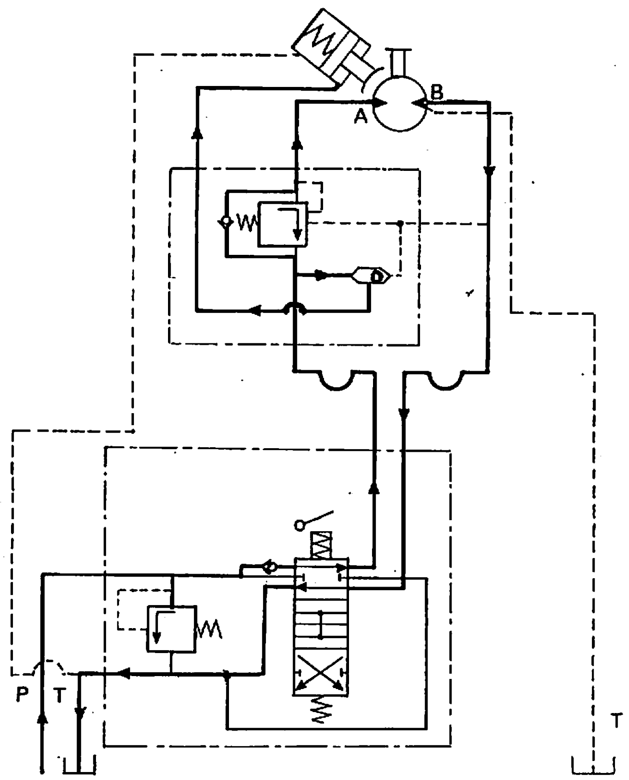
Gear pump, Vane pump, Piston pump

SAQ 23

You should first have looked in Table 4 on page 85 and you will see that **excessive noise** from the motor means that it is worn or damaged. If you then look in Table 5 you will see that **excessive heat** can also indicate a worn or damaged motor.

So your answer should be: 'probably a worn or a damaged motor'.

SAQ 24



SAQ 25

When the pressure in the pipeline exceeds the spring setting of the valve, the pressure of the oil lifts the ball off its seat and allows some of the oil to exhaust to the tank.

When the pressure in the line reduces, the ball re-seats to close the valve and maintain the desired pressure in the line.

I don't expect you to have said exactly the same words as I have. As long as you have written something with the same meaning that will be in order.

SAQ 26

SAE 20W/30 oil will have a maximum viscosity of 48000 SUS when cold and a minimum viscosity of 58 SUS when hot.

SAQ 27

(a) Force = Pressure x Area
= 3000 x 7
= 21 000 lbs force

You should already know that 2240 lbs = 1 ton.

Therefore this actuator is producing a force of:

$$\frac{21\,000}{2\,240} = 8.9 \text{ tons!}$$

(b) 200 bar = 200 x 100 = 20 000 kN/m^2
Force = Pressure x Area
= 20 000 x 0.005
= 100 kN

SAQ 28

1. N
2. V
3. L
4. E
5. C, T
6. G, K, R
7. P
8. B, D, S, U
9. M
10. F
11. Q
12. I, J
13. A
14. H

SAQ 29

An oil rate of 2 litres/minute produced 60 rpm.
An oil rate of 1 litre/minute produces $\frac{60}{2}$ = 30 rpm.

$\therefore$ An oil rate of 6 litres/minute produces 30 x 6 = 180 rpm.
The maximum speed of the motor will be 180 rpm.

SAQ 30

If only one spanner is used, the hose could be twisted and kinked as you tighten the connection. If you over-tighten the connection, the threads could be stripped and the connection distorted and it will continue to leak. A full replacement of the connectors will then be the only answer.

SAQ 31

The four main functions of a hydraulic oil are:

- to transmit power from the pump to the actuator.
- to lubricate all moving parts so that they move easily and do not wear.
- to form a seal at mating parts and reduce leakage past pistons and valves etc.
- to act as a cooling agent in the circulation system and remove heat from the working parts.

SAQ 32

Vane pumps and piston pumps can both be reversed and used as hydraulic motors.

Gear pumps are not normally run as motors.

Other modules in this series which should be of interest to seafarers include:

Using the International Code of Signals

Stability of Fishing Vessels 1

Stability of Fishing Vessels 2

Meteorology for Seafarers 1

Meteorology for Seafarers 2

Morse Code by Light

Introduction to Chartwork

Chartwork 2

Chartwork 3

Rule of the Road and Buoyage 1

Rule of the Road and Buoyage 2

Introduction to the Decca Navigator

Compass and Associated Equipment

The Use of Tide Tables

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