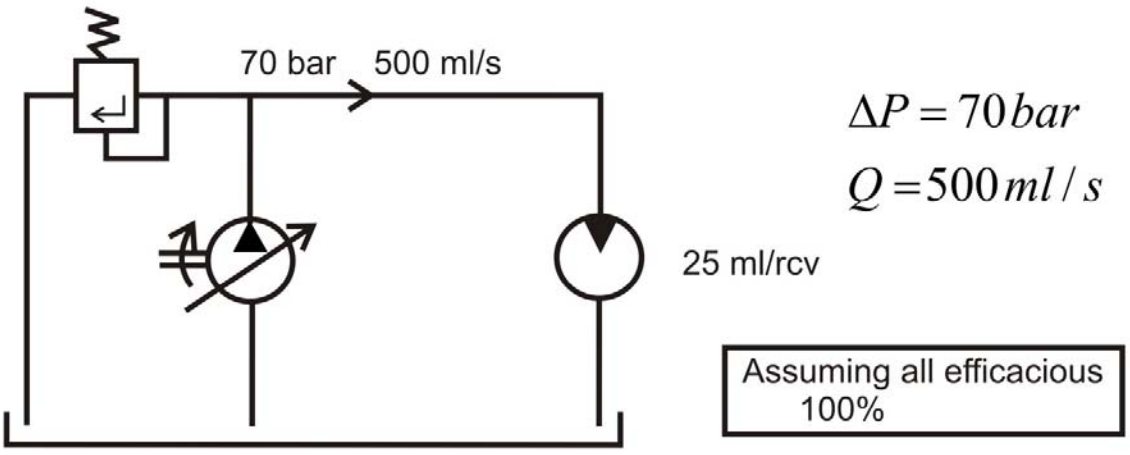
MODULE-11: Appendices
LECTURE- 42: TUTORIAL-II ON MODULE 1 & 2

Q_1.(a) A hydrostatic transmission system consists of a fixed displacement motor of capacity 25 ml/ rev and a variable displacement pump. Between the pump and motor the maximum flow is 500 milliliters/second and the maximum circuit pressure is 70 bar. Determine (i) the maximum power in kW (ii) maximum speed of motor in r.p.m and (iii) maximum torque available at the motor output shaft in Nm assuming all efficiencies as 100%.

(b) If a constant power output of 2 kW is to be developed determine (i) the minimum speed at which this power can be developed and (ii) the torque in Nm available when the motor is running at maximum speed.

(c) If below the minimum speed obtained from above (b) the max torque is maintained constant, determine the speed at which 20% of the systems maximum power output is being developed.

A_1. (a)



We know that the power N_w is given by:

$$N_w = \frac{Q(ml/s)\Delta P(bar)}{10}\ (Watt) \qquad \ldots (-1)$$

$$or, \quad N_w\,(Watt) = Q(m^3/s)\Delta P(Pas)$$

Where, ΔP is pressure drop and Q is flow rate.

Therefore, substituting the values of ΔP and Q the power through put:

$$N_w = \frac{500\,(ml/s)\times 70\,(bar)}{10} = \underbrace{500\times10^{-6}(m^3/s)\times 7\times10^{6}(Pas)}_{\text{SI Unit}}$$

$$\therefore N_w = 3500\,W = 3.5\,kW \qquad \ldots \quad (-2)$$

The speed of the motor n_m is given by:

$$n_m(rps) = \frac{Q(ml/s)}{S_v(ml/rev)} = \frac{Q(m^3/s)}{S_v(m^3/rev)} \qquad \ldots(-3)$$

Where, S_v is the displacement per revolution i.e., 'Swept Volume' of the motor.

Putting the value.

$$n_m = \frac{500(ml/s)}{20(ml/rev)} = \frac{500\times10^{-6}(m^3/s)}{20\times10^{-6}(m^3/rev)} = 20\,(rps)$$

$$N_m = n_m \times 60 = 1200\,rpm. \qquad \ldots \quad (-4)$$

Where, N_m is the output motor speed in revolution per minute (rpm). This result is for no loss (leakage) consideration.

The torque T_m is given by:

$$T_m\,(Nm) = \frac{\Delta p\,(bar)\times S_v\,(ml/rev)}{20\times\pi} = \frac{\Delta p\,(Pas)\times S_v\,(m^3/rev)}{2\pi} \qquad \ldots \quad (-5)$$

Putting the value.

$$T_m\,(Nm) = \frac{70\,(bar)\times 25\,(ml/rev)}{20\times\pi} = \frac{7\times10^{6}\,(Pas)\times 25\times10^{-6}\,(m^3/rev)}{2\pi}$$

$$T_m = 27.852\,Nm \qquad \ldots \quad (-6)$$

(b) Assuming maximum pressure as 70 bar the minimum flow at which 2 kW is developed is given by:

$$2000\,W = \frac{Q_{\min}\times 70(ml/s)}{10} \qquad \ldots \quad (-7)$$

$$or,\ Q_{\min} = \frac{2000}{7} = 285.7\ ml/s = 2.857 \times 10^{-4}\ m^3\ /\ \mathrm{s}$$

The speed of the motor at this flow :

$$(n_m)_{\min} = \frac{285.7}{25} = 11.43\ rps.$$

$$(N_m)_{\min} = 11.43 \times 60 = 685.68\ rpm. \qquad \ldots \quad (-8)$$

Assuming that the flow to be $500\ ml/s$ at maximum speed pressure drop at 2 kW output given by :

$$\Delta p_2 = \frac{2000 \times 10}{500} = 40\ bar \cong 4\ MPa. \qquad \ldots \quad (-9)$$

The torque output at that situation:

$$T_{m2} = \frac{40 \times 25}{20\pi}\ Nm = \frac{4 \times 25}{2\pi}\ Nm = 15.92\ Nm. \qquad \ldots \quad (-10)$$

$$\left((Torque)\ Nm = \frac{MPa \times ml/\mathrm{sec}}{2\pi} = \frac{Pa\ \times m^3/\mathrm{sec}}{2\pi} \right) \qquad \ldots \quad (-11)$$

(c) 20% of the systems maximum power is

$$0.2 \times 3.8 = 0.7kw = 700w \qquad \ldots \quad (-12)$$

If torque is maintained constant at 2 kW / 685.68 rpm the pressure would be 70 bar.

Then, the flow:

$$Q_{0.7} = \frac{700 \times 10}{70} = 100\ ml/s \qquad \ldots \quad (-13)$$

$$(n_m)_{0.7} = \frac{100}{25} = 4\ rps = 240\ rpm. \qquad \ldots \quad (-14)$$

Q_2.

(a) What are the various functions of valves in a hydrostatic transmission circuit? How are the valves represented symbolically?

(b) Explain the functions of a flow control value. Why is pressure compensation required? What are series and parallel pressure compensation? Which is more efficient and Why?

A_2. (a) The valves in a hydrostatic transmission circuit can be classified into the flowing functional groups.

1. Direction control (or, dc) valves,
2. Flow control valves,
3. Pressure control valves.

The groups are illustrated below with graphical symbols.

(i) <u>Direction control values.</u>

These are used to switch or drive the flow of fluids in the desired paths. Therefore, these are provide with a number of ports, varying from 2 to 6 or more, called way and a number of positions, each position resulting in certain combination of ports. The combinations are shown by drawing the connections in separate boxes (the icons). The complete valve symbol is the juxtaposition of the boxes. For example a group of 2 way, 3 way and 4 way valves are drawn below. The mode of position shifting, viz. manual, hydraulic, pneumatic or solenoid is also shown by symbols.

<u>Two way values</u>



Manual, spring return,
2 position (2/2 dc)

Solenoid operated, spring return
2 position (2/2 dc)

Fig. A-2_(i) 1.

<u>Three way Valves</u>

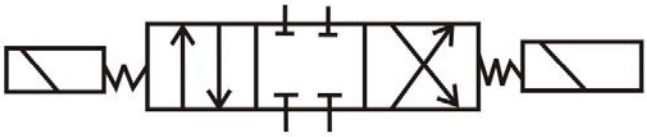


Manual, spring return,
2 position (3/2 dc)

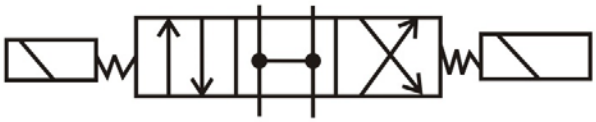
Solenoid operated, spring centered,
3 position (3/3 dc)

Fig. A-2_(i) 2.

Four way values



Sol. op. spring centered, Close center
3 position (4/3 dc)



Sol. op. spring cantered, Open center
3 position (4/3 dc)

Fig. A-2_(i) 3.

(ii) Flow control values

a) A common value used in hydraulic circuit is the check valve or non-return valve which allows no flow in the backward direction.
These are illustrated as:

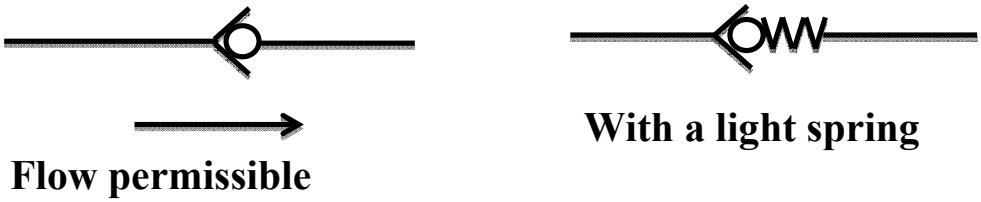


Fig. A-2_(ii) a_1.

This valve is self operated. However, it may also be pilot (solenoid, hydraulic etc) operated or manual operated.



Pilot operated. *Manual operated.*

Fig. A-2_(ii) a_2.

Throttle valve

b) The throttle valve which offer takes the form of a needle valve or a variable orifice. It is used to create resistance in the circuit then by controlling the flow.

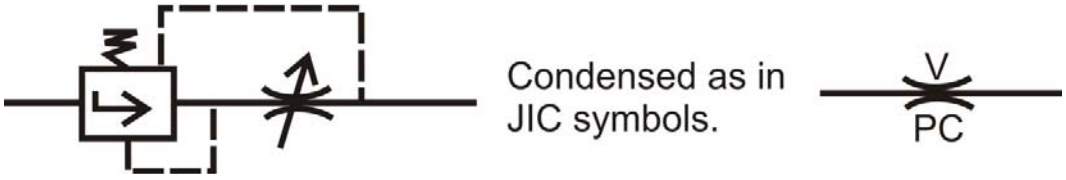


A fixed orifice **An adjustable orifice**

Fig. A-2_(ii) b_1.

These are often provided with a pressure compensating device which keeps the pressure across the orifice constant by au additional balanced spool, (often called a 'pressurestat') either in series or in parallel.

Series



Parallel

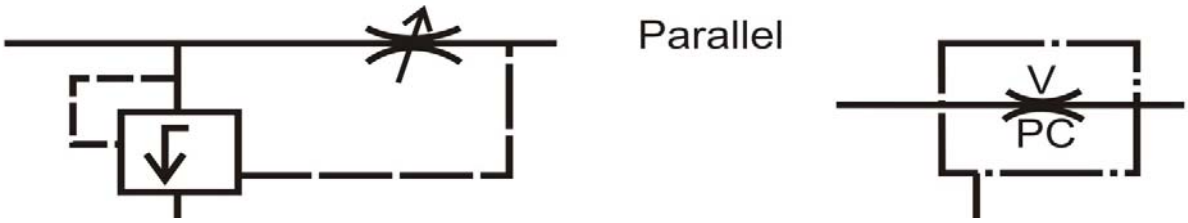


Fig. A-2_(ii) b_2.

(iii) Pressure Control Values

(a) The essential function of a pressure control valve is to operator when the pressure reaches a certain value.

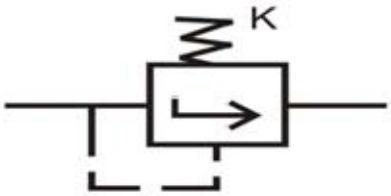


Fig. A-2_(iii) a_1.

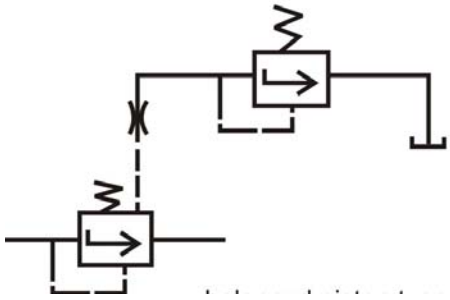
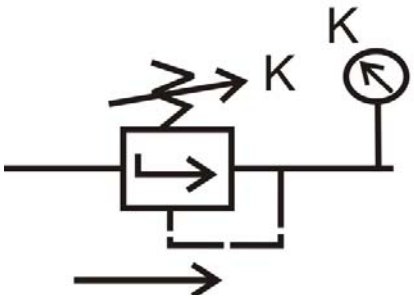
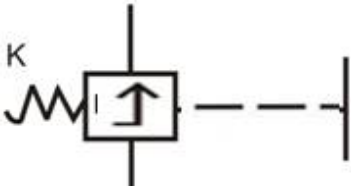


Fig. A-2_(iii) a_2.



Two relief valves are combined to give pressure relief at very low pressure override. This is called balanced piston type relief valve(Fig. A-2_(iii) 2).

Fig. A-2_(iii) a_3.



A pressure reducing valve (Fig. A-2_(iii) 3) can hold the pressure of a part of a circuit to a constant value.

Fig. A-2_(iii) a_4.

The simplest example is a relief valve or a pressure limiting valve (Fig. A-2_(iii) 1). This valve permits flow when the pressure reaches spring setting K.

A sequence valve (Fig. A-2_(iii) 4)opens when pressure in a different circuit reaches the setting.

(b) *Pressure compensation* is required to keep the flow constant irrespective of presser variations in the circuit,

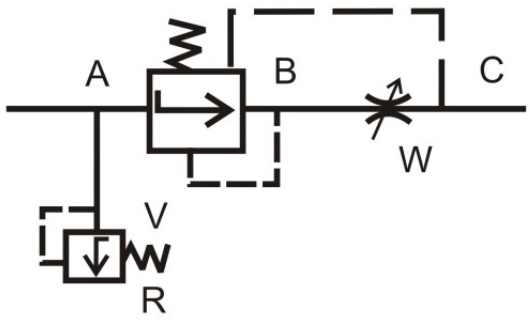


Fig. A-2_(iii) b_1.

A *series type* flow control valve with pressure compensation devise is shown. The pressure difference between points B and C is maintained constant by the valve V. This valve is a balanced spool type which is fed by the two pressures at BandC. If the difference of pressure increases, it shifts slightly, thereby increasing the resistance and dropping the pressure at B, which maintains the reqd. pressure difference constant.

As the pressure drop across w is constant, the flow which is given by a formula:

$Q_w = K_w a_o \sqrt{\Delta p}$ is also held constant to adjustment of a_o.

Where, K_w is the valve characteristics constant, a_o is the orifice area at W and Δp is the pressure difference across A and B.

The excess oil has to be passed through relief valve, marked R.

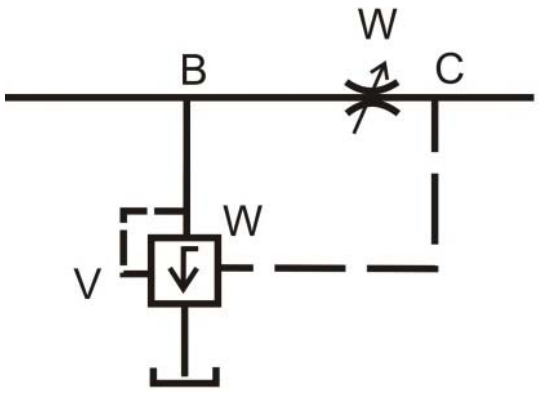


Fig. A-2_(iii) b_1.

A parallel type of flow control valve has the valve V in a parallel circuit, going back to the tank. The excess oil, therefore, goes back to the tank at a pressure developed B.

The series type flow control is less efficient. The parallel type pressure compensation saves energy specially, where the speed and torque are low.

If the pressure at C is fixed at p_c, the pressure at B is $p_c + \Delta p$ where Δp is given by:

$$\Delta p = \left(\frac{Q_w}{K_w a_o} \right)^2$$

It the relief valve setting is R (pressure) and pump flow $Q_{p,}$ then excess oil, $Q_p - Q_w$ is going back to tank at pressure R in series type and at $(p_c + \Delta p)$ in parallel type.

If R is always higher than $(p_c + \Delta p)$, the parallel type pressure compensated flow control is <u>always</u> more efficient.

Q_3.

What essential properties a hydraulic fluid in hydrostatic transmission system should posses? What are the factors to decide its viscosity? (iii) What is viscosity index and what is its relevance in this field? (iv)What properties are taken care of by additives? (v)What are fire resistant fluids? (vi) What are their limitations?

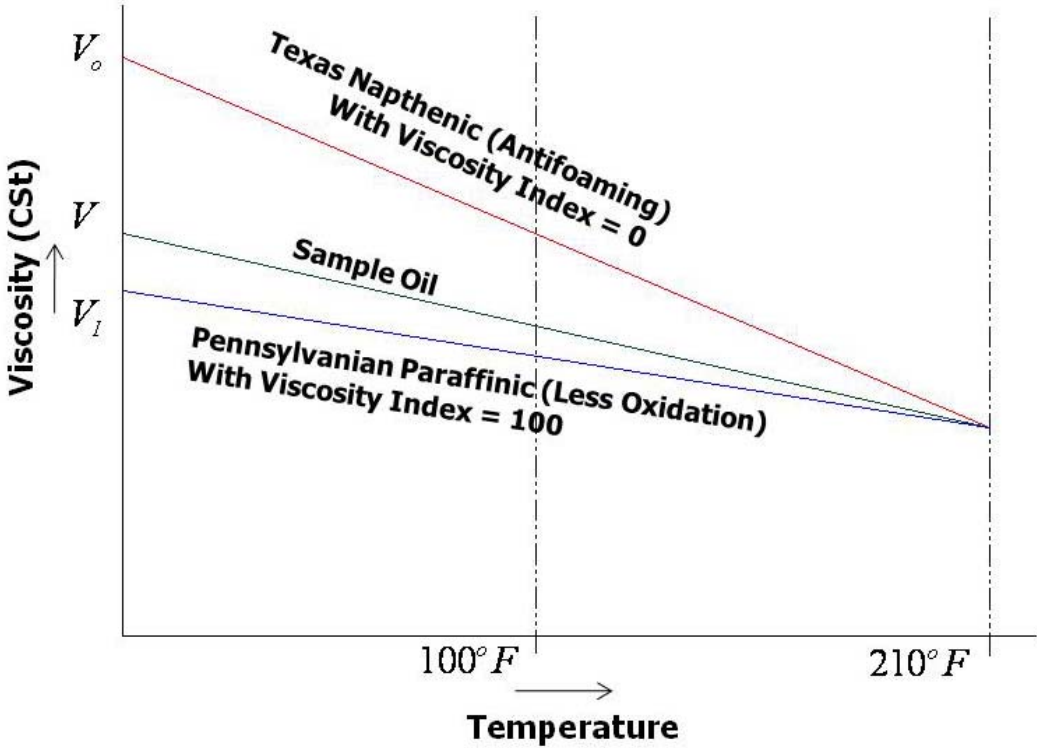
A_3.

(i) The essential; properties of hydraulic fluid are:

a) Viscosity – All hydraulic systems have viscosity limitations in the form of maximum and maximum values. An optimum value may be recommended for highest efficiency. Typical hydraulic fluids have viscosity equivalent to 150 to 225 Saybolt Universal Seconds (SUS) at 100^0 F.

(b) Viscosity index $(VI)_s$ – This is a sale which denotes the variation of viscosity with different temperature. The scale is from 0 to 100. A certain grade of oil is given $(VI)_s$ ="0" and another is given $(VI)_s$ ="100".

These are Texas Naphthenic oil and Pennsylvanian paraffinic oil respectively.



The viscosity index is expressed as : $(VI)_s = \left(\frac{V_o - V}{V_o - V_I}\right) 100$

Where, V_o - Viscosity of Texas Napthenic at a temperature T

V_I - Viscosity of Pennsylvanian paraffinic at temp. T

V - Viscosity of the oil in use at temp. T

A Good hydraulic oil should have $(VI)_s$ around 90.

(c) Stiffness - Though oil is considered incompressible, it has a definite compressibility. Normally, hydraulic oils have a 'bulk modulus' of 17.5×10^3 bar. Gases and air entrapped in oil essentially reduce the bulk modulus which reduces system rigidly.
(d) Antifoaming characteristics – As oil is vigorously circulated it tends to form foams which affects system operation.
(e) Antioxidant- Over a long period of time the oil gets oxidized, giving rise to sludge and change in properties. A good oil must have long life.
(f) Anticorrosion - The oil is to protect all metallic parts coming in contact with it by forming a suitable coating. Thus samples of oil which cannot protect metals are considered unsuitable.
(g) Anti wear - Oil is expected to form stable films between metallic bodies in contact, carrying load and effectively reduce wear. This property of oil is very important.
(h) Five resistance - If oil is highly inflammable, it is dangerous to use and therefore, not suitable as a hydraulic fluid.
(i) Non-Toxicity and absence of odour.
The oil must be nontoxic for the safely of personnel and also free unpleasant odour.
(j) Lubricity - Ability to lubricate moving parts.

(ii) The factors to decide the viscosity are-

(a) Type of pumps and motors-

Some pumps are all two operate only with a close range of viscosity. Vane pumps are unable to operate with a viscous fluid. Gear pumps and piston pumps are on the other hand able to handle a wider range.

Screw pumps are able to pump thickest hydraulic oils.

(b) Speed of pumps and motors

It is easily seen that high speed machines are best operated with a thin oil as otherwise loss due to viscous drag may be high, reducing system efficiency.

(c) Pressure –

It difficult to operate a very high-pressure system with a thin oil, as leakage and consequently power loss will increase.

(iii) Viscosity index as explained in 3i(b) is a measure of stability of viscosity over a wide range of temperature. In all hydraulic systems, there is invariably a temperature rise owing to power loss.
If viscosity falls rapidly with the temperature rise, the system may become inefficient as the viscosity may more away from the optimum value.

(iv) In modern hydraulic oils additives are added to improve properties viz,

(a) <u>VI improvers</u>

Certain polymers and similar additives are added to improve the Viscosity Index (VI) . Viscosity Indexes in excess of 100 are not uncommon.

(b) <u>Antifoaming properties.</u>

These acts on the surface tension and prevent formation of bubbles.

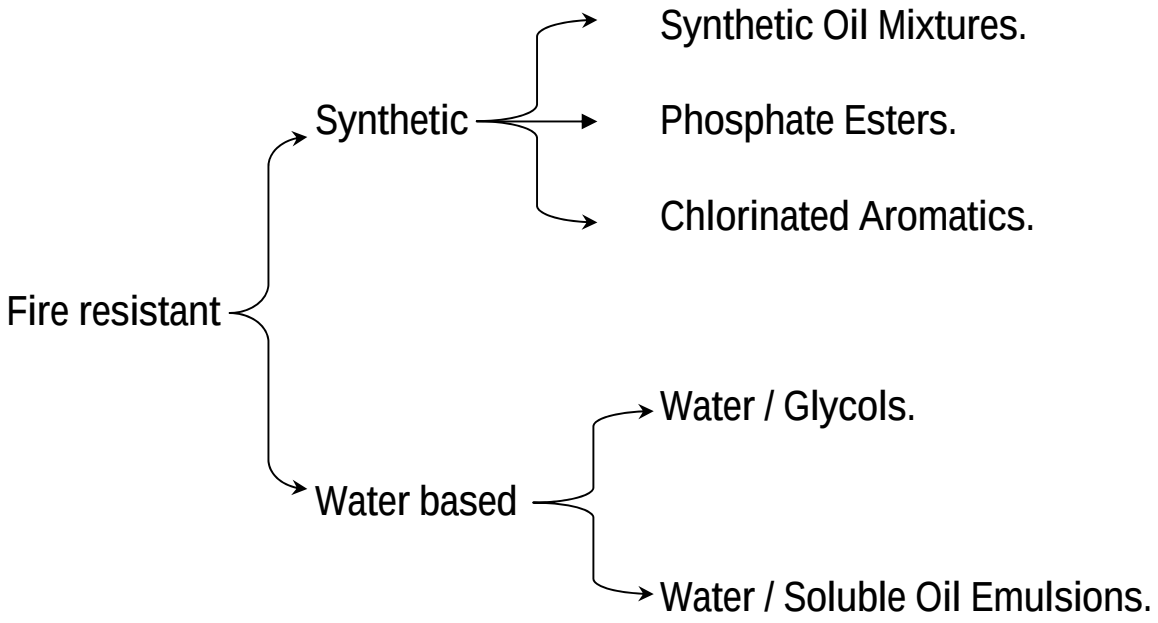
(c) <u>Anti-oxidants</u>

Increase oxidation stability of oils.

(d) <u>Anti-wear</u>

Helps in the formation of stable oil films.

(v) Mineral oil is normally not considered fire resistant as these have definite flash points.
For hazardous locations, fire resistant fluids are often employed. These are clarified as:



(vi) The fire resistance of chlorinated aromatics is very good, whereas that of water based oils is fair.

Some of these oils viz, phosphate esters and aromatics are costly.
Some of these oils have severe effects on seals.