# Fluid Mechanics - Course 223.0

## ANSWER SECTION

---

### Page 1, Paragraph 3

1. $$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Thus Mass} = \text{Density} \times \text{Volume}$$

$$= 1100 \times 2.6$$

$$\text{Mass of } D_2O = \underline{\underline{2860 \text{ kg}}}$$

### Page 1, Paragraph 4

2. $$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Thus volume} = \frac{\text{Mass}}{\text{Density}}$$

$$= \frac{37924}{998}$$

$$\text{Volume of the Line} = \underline{\underline{38 \text{ m}^3}}$$

### Page 2, Paragraph 3

3. Relative Density x 1000 = density of substance

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Thus Mass} = \text{relative density} \times 1000 \times \text{volume}$$

$$= 0.85 \times 1000 \times 5000$$

$$\text{Mass of oil} = 4.25 \times 10^6 \text{ kg}$$

Page 2, Paragraph 4

4. Sectional area of line $= \frac{\pi D^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.0707\ m^2$

$$\text{Volume of line} = \text{Area} \times \text{length}$$

$$= 0.0707 \times 120 = \underline{\underline{8.48\ m^3}}$$

$$\text{Mass} = \text{Volume} \times \text{Density}$$

$$= 8.48 \times 0.78 \times 1000$$

$$\text{Mass of Kerosene} = \underline{\underline{6616.2\ kg}}$$

Page 3, Paragraph 1

5. $Qv = \text{Area} \times \text{vel}$ $\quad Qv = 0.22\ m^3/s$

$\therefore$ Velocity $= \frac{Qv}{\text{Area}}$ $\quad$ Area $= \frac{.25^2}{4} = 0.049\ m^2$

$$= \frac{0.22}{0.049} = \underline{\underline{4.48\ m/s}}$$

Page 4, Paragraph 1

6. Area of line $= \frac{\pi D^2}{4} = \frac{\pi \times 0.35^3 s}{4} = \underline{\underline{0.096\ m^2}}$

$$Q_v = \text{Area} \times \text{Velocity}$$

$$= 0.096 \times 5.6 = \underline{\underline{0.539\ m^3 s}}$$

$$Q_m = \rho \times Q_v$$
$$= 0.915 \times 1000 \times 0.539 = \underline{\underline{493\ kg/s}}$$

Page 4, Paragraph 2

7. Area of line $= \frac{\pi D^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.0707\ m^2$

$$Q_m = \rho \times \text{Area} \times \text{Vel}$$

$$\therefore \text{Vel} = \frac{Q_m}{\rho \times \text{area}} = \frac{400}{1100 \times 0.0707} = 5.14\ m/s$$

Page 5, Paragraph 3

8. (a) 84 kPa(a) → 84 - 101.3 = -17.3 kPa(g)

(b) 22 kPa Vacuum → = -22 kPa(g)

(c) Atmospheric pressure = 101.3 kPa(a) = 0 kPa(g)

(d) 143 kPa(a) 143 - 101.3 = 41.7 kPa(g)

Page 6, Paragraph 1

9. (a) -46 kPa(g) → 101.3 - 46 = 55.3 kPa(a)

(b) Atmospheric pressure = 101.3 kPa(a)

(c) 247 kPa(g) → 247 + 101.3 = 348.3 kPa(a)

(d) 90 kPa vacuum → 101.3 - 89 = 12.3 kPa(a)

Page 7, Paragraph 1

10. The height of the tank is unimportant!

The height of the oil is the one that really counts.

Pressure due to oil = $\rho$ x g x h

= 0.85 x 1000 x 9.81 x 9.4

= 78381.9 Pa

= 78.38 kPa

Page 7, Paragraph 2

11. Pressure due to the liquid = Pressure due water + Pressure due to Kerosene

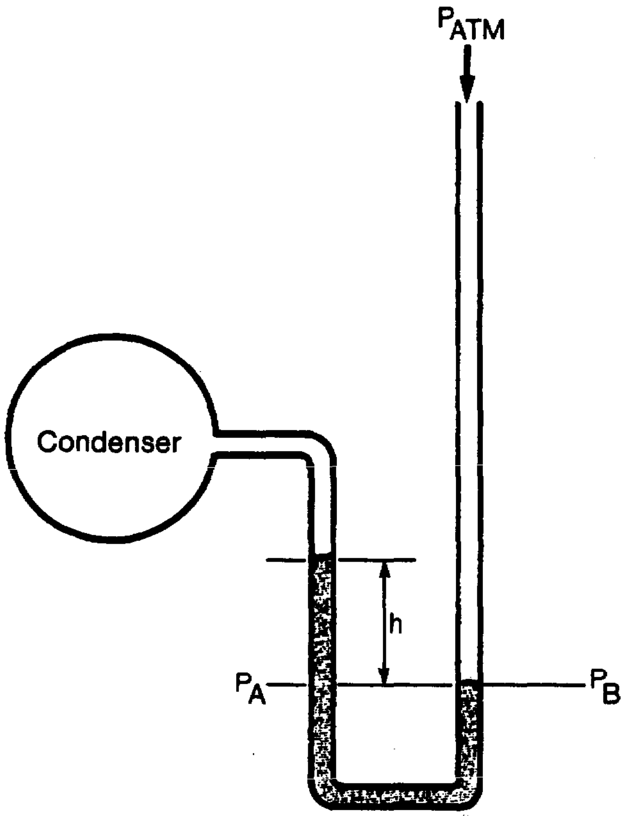
$P = (\rho \times g \times h)_{water} + (\rho \times g \times h)_{kerosene}$

= (1000 x 9.81 x 0.6) = (0.78 x 1000 x 9.81 x 5.8)

= 5886 + 44380.44 = 50.27 kPa

Page 10, Paragraph 1

12.




$P_{SYST}$ = 6 kPa(a)

$P_{ATM}$ = 101.3 kPa(a)

$P_A$ = $P_B$

$P_A$ = $P_B$

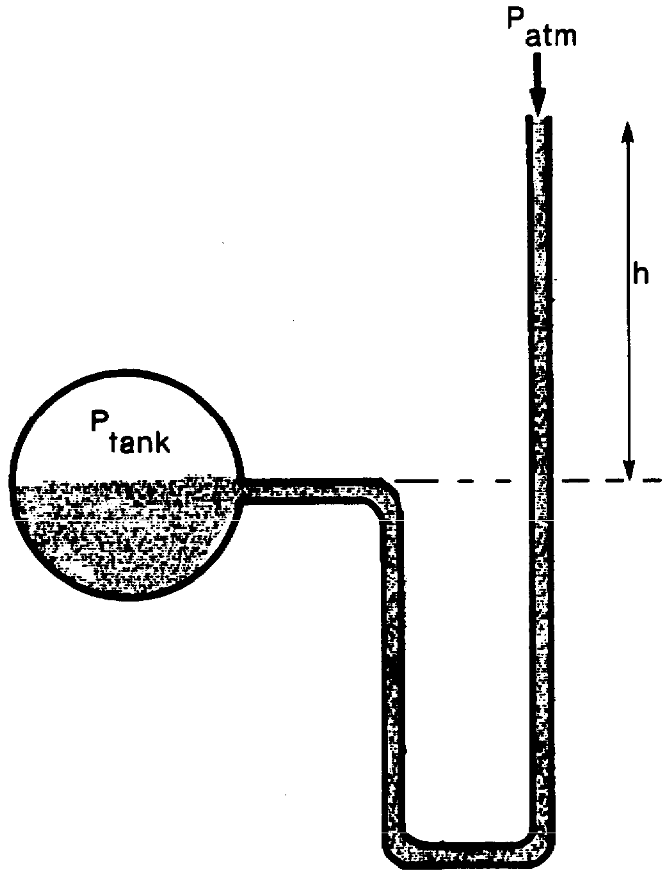
Thus $P_{SYST} = \rho \times g \times h = P_{ATM}$

$6000 + 13546 \times 9.81 \times h = 101\ 300$

Thus $h = \dfrac{95\ 300}{13546 \times 9.81}$ = 0.717 m of mercury

Page 10, Paragraph 2

13.

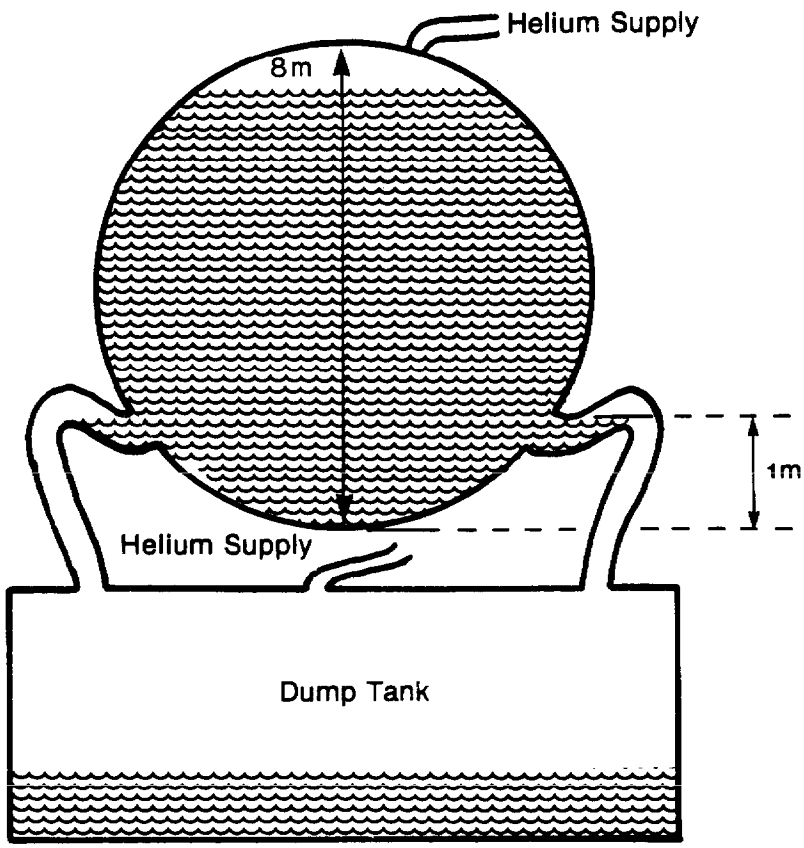



$$P_{TANK} = P_{ATM} + \rho \times g \times h$$

$$\therefore 300 \times 1000 = 13.546 \times 1000 \times 9.81 \times h$$

$$\therefore h = \frac{300 \times 1000}{13.546 \times 1000 \times 9.81} = \underline{\underline{2.258 \text{ m of mercury}}}$$

14. Page 10, Paragraph 3




The pressure in the goose neck is the pressure of helium in the dump tank. The pressure at this point is also equal to the pressure due to the weight of heavy water plus the cover gas pressure.

$$\text{The } P_{\substack{\text{dump}\\\text{tank}}} = \rho \times g \times h + P_{\substack{\text{cover}\\\text{gas}}}$$

$$\text{Thus } P_{\text{helium}} = p \times g \times h$$

$$= 1.1 \times 1000 \times 9.81 \times 7$$

$$= 75537 \text{ pA}$$

$$= 75.54 \text{ kPa}$$

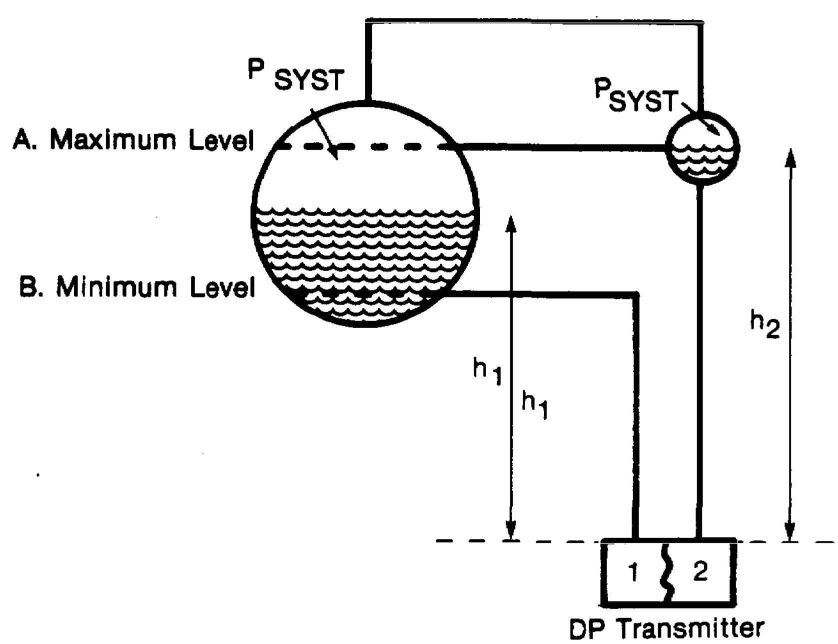
Page 11, Paragraph 2

Apart from NPD, the cover gas pressure is kept just above atmospheric pressure. The major problem is increased corrosion in the moderator circuit. If air is allowed to enter the cover gas system the nitrogen combining with oxygen and water forms nitric acid, assisted by the gamma radiation. The nitric acid would result in accelerated corrosion plus heavy expenditure of IX columns used to remove the nitrates.

Page 13, Paragraph 1

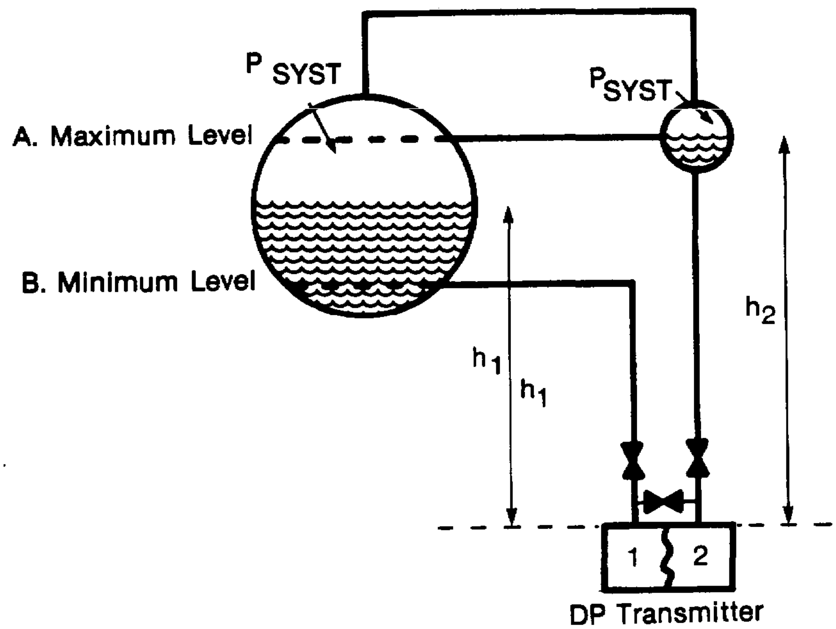
15. If the level in the drum falls below that of the minimum position the leg to side 1 of the transmitter will not see this effect, because the liquid will not drain out. Consequently the transmitter will steadily record low level B.

Similarly if the level rises above the high level A the liquid levels on both sides of the transmitter will increase by the same amount and the pressure differential would remain constant so the transmitter would only indicate the maximum level irrespective of how far above A the actual level rose.



Page 13, Paragraph 2

16.

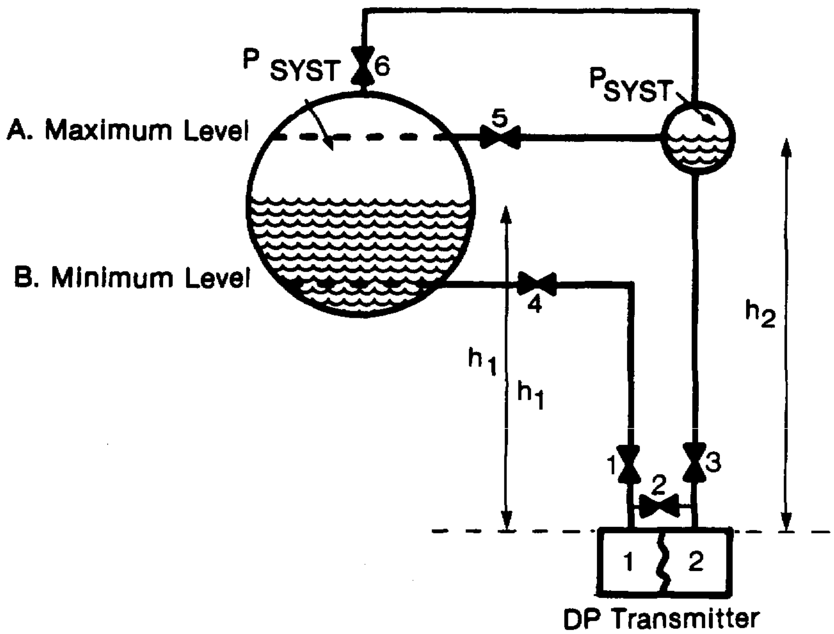



To provide a test reading corresponding to the maximum level in the tank we must provide a zero differential pressure at the transmitter.

This is easily achieved by partially isolating the transmitter from the process by the following valving procedure; close valve to side 2 of transmitter and then opening the equalizing valve which will produce a zero differential pressure. The transmitter output should be at its maximum value.

A return to service is achieved by reclosing the equalizing valve (3) and re-opening valve 2.

17.




Before considering valve positions etc, an important point to note is that the DP cell is only designed to measure a differential pressure representative of the liquid height in the drum, (ie, a few metres, say 100 kPa). No operation should allow one side of the cell to be depressurized while the other side remains under full system pressure, (ie, liquid pressure and steam pressure $\simeq$ 4 MPa) which would over pressurize the pressure sensing element.

## Response Test for Maximum Level

In this case the ΔP must be zero. This may be done by isolating either the working side or the reference side of the DP cell. (The reference side is preferred since there is then no danger of losing the wet leg).

(i) Close valve 2 and open equalizer valve 3 (the same pressure is now applied to both sides of the cell and the DP is zero).

Return to service by closing the equalizing valve 3 and opening valve 2.

## Response Test for Maximum ΔP Corresponding to Low Drum Level

Before performing this test there are three important points to be considered:

(1) Extra Valves

Valves must be provided to isolate the process from the measuring circuit. This function is performed by valves 4, 5 and 6. Provision must also be made to depressurize, and if necessary recharge with liquid, the measuring circuit. This can be achieved by valves 7 and 8.

(2) Protection

It is important that protection procedures be carried out to ensure that hazards due to live steam are avoided and also that the pressure capsule in the ΔP cell is protected.

(3) Isolation Procedures for ΔP cells

To remove a cell from service

(1) Isolate low side (2)
(2) Open equalize valve
(3) Isolate high side (1)

At this stage the cell is still at the process pressure although isolated - bleeding of the transmitter is required to lower the pressure to zero is required. The transmitter is usually fitted with bleed valves or this purpose.

To put a cell into service

(1) Ensure equalizer valve is open.
(2) Open high side valve (1).
(3) Close equalizer valve.
(4) Open low side valve (2).

There may be trapped air or vapour present in the ΔP cell which will require bleeding.

Response Test Procedure

(a) Isolate process from measuring circuit by closing valves 4, 5 and 6.

(b) Isolate the ΔP cell using the standard isolating procedure.

(c) The measuring circuit is still at full system pressure. Relieve this pressure by carefully opening valves 7 and 8.

(d) Return ΔP cell to service using standard procedure. The ΔP cell will now see a differential pressure corresponding to a minimum level in the drum, ie, maximum differential pressure. The transmitter output should be at its minimum value.

To Return System to Service

Normal working conditions must be re-established, ie, transmitter and measuring circuit must be subjected to full system pressure.

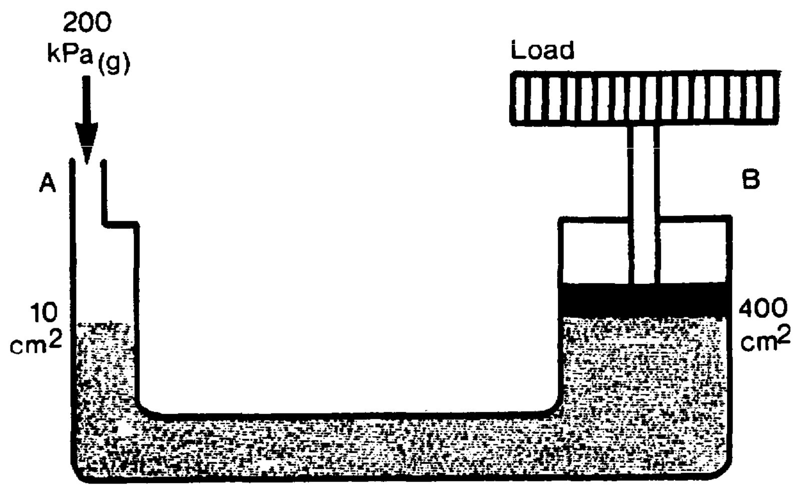
(a) Isolate the ΔP cell.

(b) Close valves 7 and 8.

(c) Open valves 4, 5 and 6.

(d) Return ΔP cell to service.

18. Page 15, Paragraph 1




The pressure on the surface of the fluid is the same in the left cylinder as in the right hand cylinder.

Thus the pressure under the load piston is 200 kPa(g).

Thus the force which is acting under the load cylinder may be found from the basic definition of pressure.

$$P = F/A$$

Thus $F = P \times A$

$$= 200 \times 1000 \times \frac{400}{10000}$$

$$= \underline{\underline{8000 \text{ N}}}$$

Work Done = 8000 N x 2 m = 16000 Joules

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{16000}{2 \times 60} \text{ J/S} = \underline{\underline{133.3 \text{ Watts}}}$$

The volume increase of fluid in the power cylinder would be 2 x 0.04 $m^3$. This would also be the decrease in volume in the control cylinder

Thus if h is the loss of height of fluid in the control cylinder

Change in Volume = Loss of Height x Sectional Area

$$0.08 = h \times 0.01$$

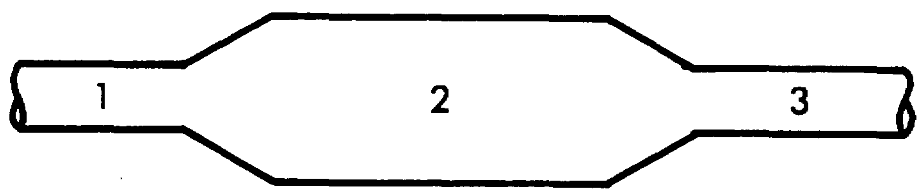
$$\therefore h = 8 \text{ m}$$

Page 16, Paragraph 2

19. (b) More than 360 kPa(a)

because pressure has been gained as velocity has been reduced due to the larger cross sectional area. Flowrate remains constant. As the velocity reduces so the effects of friction are reduced and pressure is further increased.

20. Consider the section of line shown with the flow left to right. First of all we must remember that in all these section the flowrate remains constant. We cannot have more fluid flowing in one section than another.




In section 1 the velocity will be relatively high because the section is small. Consequently the pressure will be low because of the high kinetic energy and the loss due to friction. As we progress to the larger section, the flowrate remaining constant, the velocity decreases with increasing section and the pressure rises by an appropriate amount. Thus a pressure gauge in section 2 would read higher than one in section 1. In section 3 the pressure will not be the same as section 1 even though the section area, velocity and flowrate are the same. Why not? The loss of pressure due to frictional effects is irrecoverable unlike kinetic energy.

By the time we examine section 3 although all other conditions are the same the total pressure energy available has decreased by the pressure which has been converted into heat due to friction in sections 1 and 2.

Thus $P_3 < P_1$

$P_2 > P_1$

$P_2$ may still be greater than $P_3$ depending on the system.

Page 16, Paragraph 6

21. The motor efficiency is surplus information!

The motor output is the pump input which is 5 MW. The pump is 60% efficient so the energy loss across the pump is 40% and this appears as heat 40% of 5 MW = 2 MW

Page 17, Paragraph 2

22. The pressure drop of 2.5 mPa is entirely due to frictional effects in the circuit. These effects appear as heating. Run the PHT pumps with the reactor shutdown, result, the circuit warms up due to friction heating.

Page 17, Paragraph 3

23. $$\text{Power} = \frac{\text{Joules}}{\text{Sec}} = \frac{3.6 \times 10^8}{60} = 6\text{ MW}$$

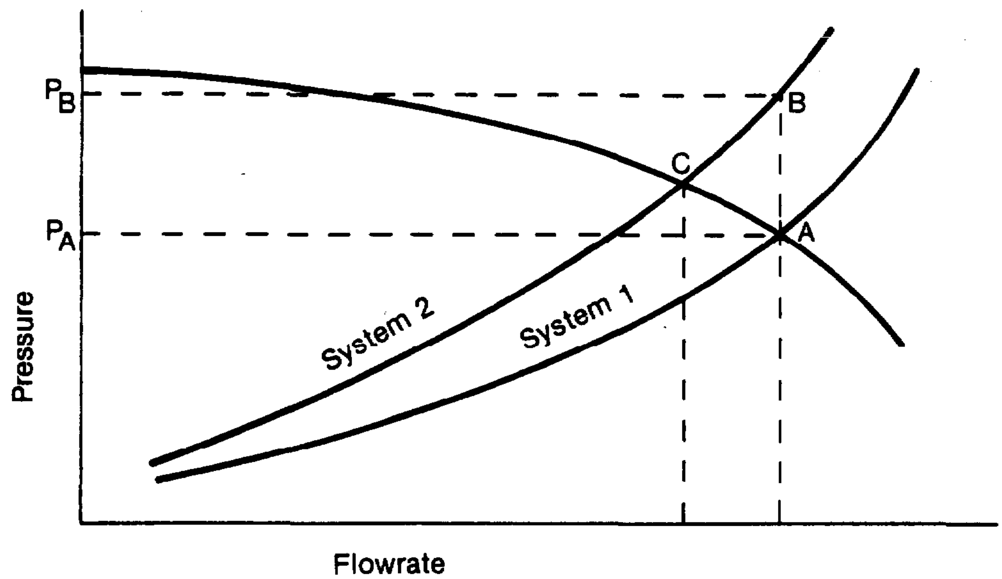
All this energy is input to the pump and appears throughout the system. This energy is distributed in two distinct ways:

(a) Heat being generated across the pump due to churning and slippage. Energy appearing in this manner is equal to the pump losses = 32% of 6 MW = 1.92 MW.

(b) The rest of the power input, ie, 4.08 MW appears as pressure energy to be lost in the circuit as frictional heating.

Page 21, Paragraph 1

24.




The effect of partially closing the valve in the system is to increase the friction losses in the circuit for the same flow, consequently a higher pressure is required to maintain the same flow. If we look at the system head curve we can see how the curve changes with increased frictional effect. The curve changes from system 1 to system 2 and you can clearly see that the pressure required for the same flow in system 2 has increased from $P_A$ to $P_B$. The increased pressure is not available from the pump at this flowrate and so the flowrate starts to fall. As the flowrate falls two simultaneous effects are produced:

(a) the discharge pressure available from the pump rises due to lower kinetic energy, lower friction and the pump characteristic.

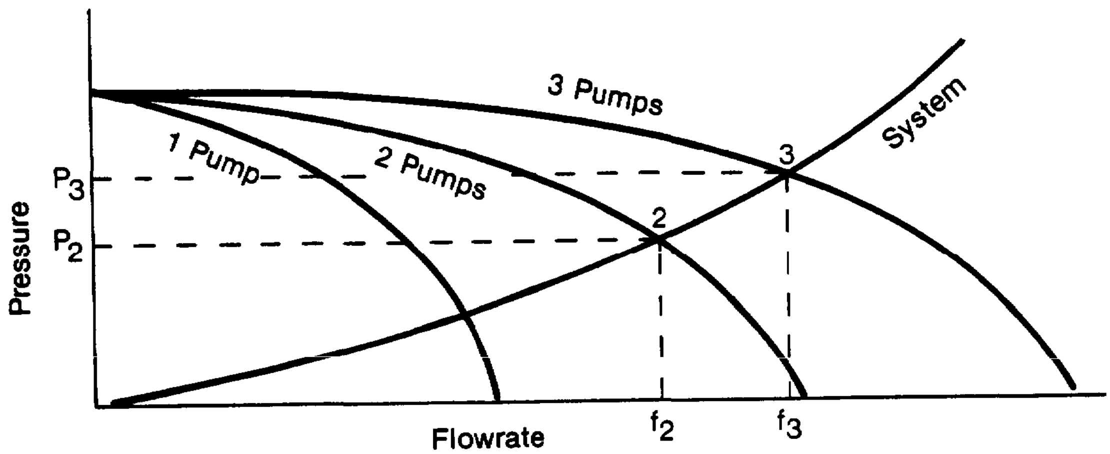
(b) the pressure required by the system falls as the pressure energy needed for kinetic energy and friction falls with reducing flowrate.

This process continues until the discharge pressure which is rising coincides with the required system pressure which is falling and this occurs at point C.

Thus we have a lower flowrate at a higher pump discharge pressure because of the added frictional effects produced by the valve. In practice this is the function that a control valve performs. It effectively changes the position of the system curve by adding or removing frictional effects and in so doing varies the pressure required by the system and produces a change of flowrate.

Page 21, Paragraph 3

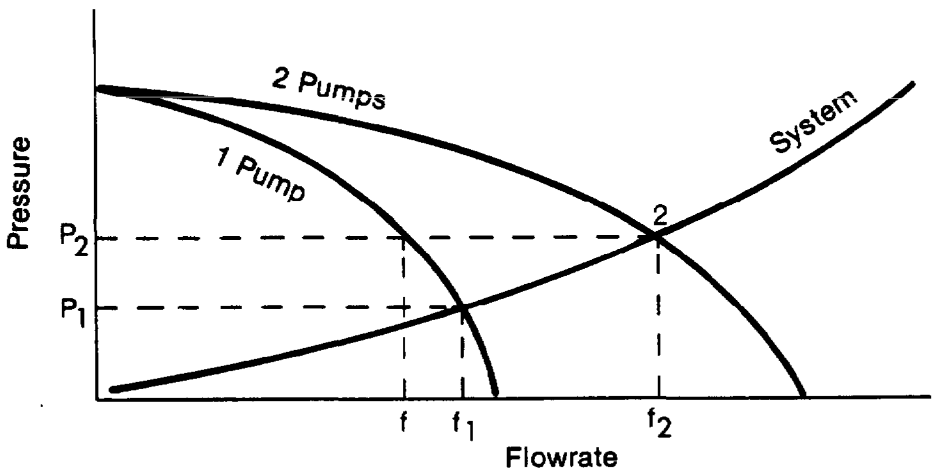
25.




With two pumps operating in parallel the flowrate would be $f_2$ at a pump discharge pressure of $P_2$. The addition of a third pump in parallel would raise the discharge pressure from the pumps and the flowrate through the system would increase until the required system pressure and the pump discharge pressure were equal at point 3. At this pressure $P_3$ the system flowrate has increased fo $f_3$, but not by 50%, the pump discharge pressure is higher and the individual pump flowrates have fallen.

Page 21, Paragraph 4

26.




Under the original conditions we have two pumps producing a system flowrate of $f_2$ which is equally shared by the pumps with a discharge pressure of $P_2$. The operating point is 2 on the head curves.

Under the original conditions we have two pumps producing a system flowrate of $f_2$ which is equally shared by the pumps with a discharge pressure of $P_2$. The operating point is 2 on the head curves.

If one pump trips, the flowrate through the second pump starts to increase due to the hydraulic inertia of the system. As the flowrate through the pump increases the pump discharge pressure falls below that needed to maintain the original system flowrate. The reason for the pump discharge pressure falling is increased kinetic energy and increased friction within the pump at the higher flowrate, together with the falling characteristic.

The reduced pump discharge pressure that is applied to the system will not maintain the original flowrate and the flowrate starts to fall. As the system flowrate falls, the pressure energy needed to overcome friction and establish kinetic energy also falls.

The result of this change is that the system flowrate is reduced from $f_2$ to $f_1$ because of a lower applied discharge pressure, $P_2$ to $P_1$, but the individual pump flowrate has increased from f to $f_1$.

J. Irwin-Childs