Chapter 3.6: Pumps & Pumping System

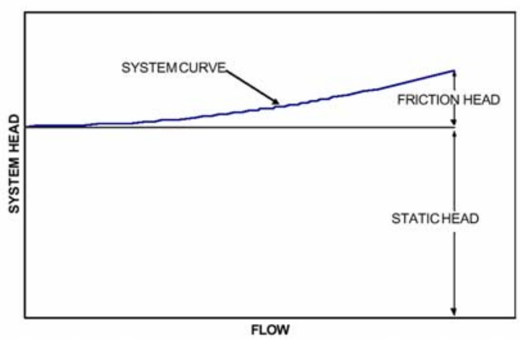
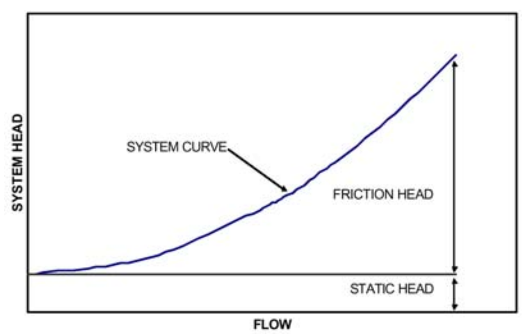
Part I: Objective type questions and answers

1.	Positive displacement pumps are generally less efficient than centrifugal pumps. State whether the statement is true or false
2.	Installing larger diameter pipe in pumping system results in reduction in-------- a) static head b) frictional head c) both a and b d) neither a nor b
3.	Generally water pipe lines are designed with water velocity of a) < 1 m/s b) up to 2.0 m/s c) > 2 m/s d) None of the above
4.	What is the impact on flow and pressure when the impeller of a pump is trimmed? a) Flow decreases with increased pressure b) Both flow and pressure increases c) Both pressure and flow decreases d) None of the above
5.	For high flow requirement, pumps are generally operated in a) parallel b) series c) any of the above d) none of the above
6.	"In case of throttling operation, the pump has to overcome additional pressure in order to deliver the reduced flow". Please indicate whether this statement is (a) True or (b) False?
7.	Friction losses in a pumping system is------ a) proportional to 1/Q b) proportional to Q^2 c) proportional to $1/Q^3$ d) proportional to $1/Q^4$
8.	For large capacity centrifugal pumps, design efficiencies are in the range of a) around 70% b) around 85% c) around 95% d) any of above
9.	The moving part in centrifugal pump is ----- a) impeller b) diffuser c) both a & b d) neither a nor b
10.	The most efficient method of flow control in a pumping system is------- a) Throttling the flow b) Speed control c) Impeller trimming d) None
11.	In case of increased suction lift from open wells, the delivery flow rate-------- a) increases b) decreases c) remains same d) none of the above
12.	Pump efficiency generally increases with specific speed. State whether the statement is True or False.

13.	Throttling the delivery valve of a pump results in increased ____. a) head b) power c) both (a) and (b) d) either (a) or (b)
14.	The operating point in a pumping system is identified by a) Point of intersection of system curve and efficiency curve b) Point of intersection of pump curve and theoretical power curve c) Point of intersection of pump curve and system curve d) Cannot be decided by pump characteristic curves
15.	The intersection point of the pump curve and the system curve is called-------- a) Pump efficiency b) Operating point c) System efficiency d) None of the above
16.	If the speed of a centrifugal pump is doubled, its power consumption increases by------- times. a) two b) four c) eight d) no change
17.	Installation of Variable frequency drives (VFD) allows the motor to be operated with ____. a) lower start-up current b) higher start-up current c) constant current d) none of the above
18.	In case of centrifugal pumps, impeller diameter changes are generally limited to reducing the diameter to about ____ of maximum size. a) 75% b)50% c) 25% d) None of the above
19.	If the delivery valve of the pump is throttled such that it delivers 30% of the rated flow, one of the best options for improved energy efficiency would be a) Trimming of the impeller b) Replacing the motor c) Replacing the impeller with a smaller size impeller d) None of the above
20.	Small by-pass lines are installed some times to _____. a) control flow rate b) control pump delivery head c) prevent pump running at zero flow d) reduce pump power consumption

Part II: Short type questions and answers

1.	What are the different types of pumps? Pumps can be classified according to their basic operating principle as dynamic or displacement

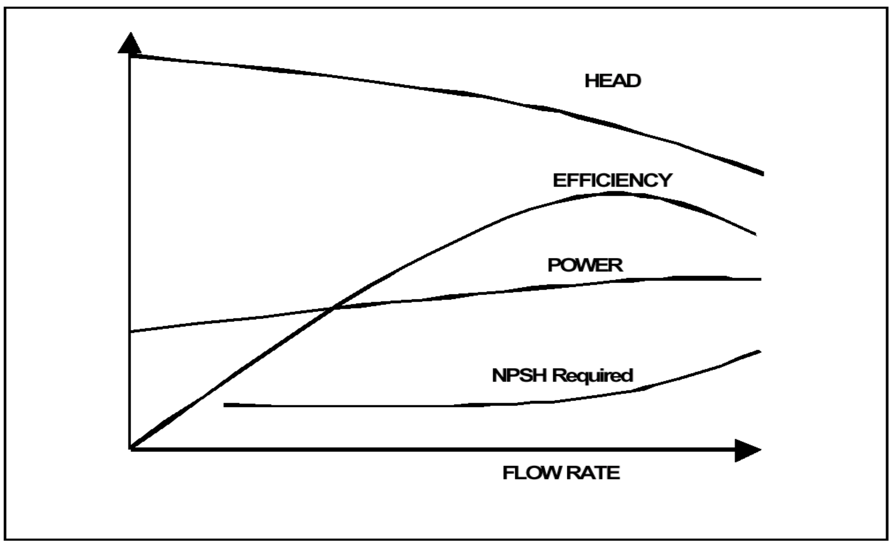
	pumps. Dynamic pumps can be sub-classified as centrifugal and special effect pumps. Displacement pumps can be sub-classified as rotary or reciprocating pumps.
2.	List out the parameters affecting pump system curves. The system curve is basically a plot of system resistance i.e. head to be overcome by the pump versus various flow rates. The system curves change with the physical configuration of the system; for example, the system curves depends upon height or elevation, diameter and length of piping, number and type of fittings and pressure drops across various equipment - say a heat exchanger.
3.	What is the formula for evaluating theoretical power drawn by a pump if the flow rate and head developed are known? Theoretical power, kW = [Flow in lps] × [Head in meters W.C.] × 9.81 / 1000
4.	Draw a centrifugal pump system curve with representation of static and friction head.  **System with High Static Head**  **System with Low Static Head**
5.	Which are the three methods normally followed if the flow from a centrifugal pump is to be reduced? a) Throttling of the delivery valve b) Changing impellers (or) trimming impellers c) Changing of speed
6.	How pumps operating point will be identified? The pump operating point is identified as the point, where the system curve crosses the pump curve when they are superimposed on each other.
7.	What do mean by the term 'cavitation'? If the incoming liquid is at a pressure with insufficient margin above its vapour pressure, then vapour cavities or bubbles appear along the impeller vanes just behind the inlet edges. This phenomenon is known as cavitation.
8.	What are the undesirable effects of cavitation in a pumping system? • Formation of cavitational bubbles leading to erosion of the vane surface • Noise and vibration

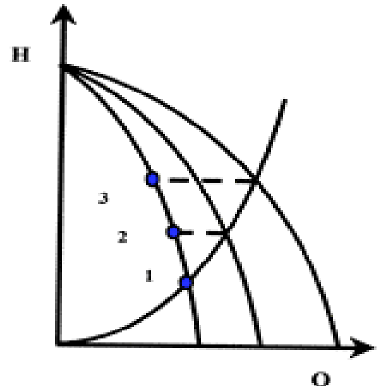
	• Partially choking of impeller passage and thereby reduction of pump performance
9.	For a system, where static head is high proportion of the total head, which is most energy efficient method of flow control? Installation of two or more pump is the best system. Here a variation of flow rate is achieved by switching 'on' and 'off' additional pumps to meet the demand. The combined pump curve is obtained by adding the flow rates at a specific head and the system curve in this case is usually not affected by the number of running pumps.
10.	Highlight the issues relating to impeller diameter trimming for a pump in terms of basic parameters of Q, H and P. Trimming of impeller refers to the process of matching the diameter of an impeller to reduce the energy added to the system fluid and offers useful correction to pump that is over sized for the application. The three major relations Q, H and P after impeller trimming would be as follows: $Q_{new} = \left(\frac{D_{new}}{D_{old}}\right)(Q_{old})$ $H_{new} = \left(\frac{D_{new}}{D_{old}}\right)^2 (H_{old})$ $BHP_{new} = \left(\frac{D_{new}}{D_{old}}\right)^3 (BHP_{old})$
11.	Explain briefly about static head and friction head? There are two types of losses the pump has to encounter. One is to meet the pressure requirement to make the liquid flow at the rate required and must overcome these two types head 'losses' in the system. The static head is simply the difference in height of supply & destination reservoirs and frictional head is the friction loss while moving thro' pipes, valves etc. in the system.
12.	Change in impeller diameter of a pump affects the performance of the pump. Explain? The basic affinity laws which govern the performance are Q x D, pump H x D^2 and P x D^3. Efficiency varies when the diameter is changed within a particular casing. Diameter changes are generally limited to reducing the diameter to about 75% of the maximum, i.e. head reduction to about 50%. Beyond this, efficiency and NPSH are badly affected.
13.	What do you mean by NPSH? Explain briefly. The value, by which the pressure in the pump suction exceeds the liquid vapour pressure, is expressed as a head of liquid and referred to as Net Positive Suction Head Available (NPSHA). This is a characteristic of the system design. The value of NPSH needed at the pump suction to prevent the pump from cavitation is known as NPSH required (NPSHR). This is a characteristic of the pump design.

14.	Plant has two travel grade boilers of rated capacity 38 TPH each and pressure 45 kg/cm². The design steam temperature from the boilers is 420 ± 5 °C. Installed turbo feed water pump to boiler is Q = 135 m³/h, H = 650 m, input pump power = 292 kW with0.93 efficiency of motor, feed water temperature at pump inlet is 105 °C. What will be the design efficiency of pump? (Assume suitable specific weight correction) Design efficiency of pump $$\eta_P = \frac{Q(m^3/h)xH(m)x9.81xW}{\eta\, x 3600}$$ Q = 135 m³/h; H = 650 m; P = 315 kW W = Specific weight of water at 105 °C = 0.95 η_m = Motor efficiency 0.93 η_P = $$\frac{135 x 650\ x 9.81\ 0.95}{0.93 x 3600 x 314}$$ = 77.7%
15.	A cooling water pump connected to pillar furnace, the specifications of the pump are as follows: Q = 12.5 lps H = 60 M p = 13.4 kW As per the pillar furnace manufacture, required quality is 12.5 lps at 3.0 kg/cm². What type of energy conservation measure can be proposed and estimate the reduction in power consumption. It can be recommended to replace the pump with new pump of same quantity (12.5 lps) and low head (30 m). New pump power consumption Q (lps) = 12.5 H (m) = 30 Considering operating efficiency of pump as 65%, power consumption of new pump (motor efficiency as 90%) $$p = \frac{12.5x30x9.81}{1000x0.65x0.9}$$ = 6.3 kW Reduction in power consumption = Present pump power – new proposed pump = 13.4 – 6.3 = 7.1 kW

16.	What is the significance of parallel operation in case of centrifugal pumps? In pumping systems where static head is a high proportion of the total, the appropriate solution is to install two or more pumps to operate in parallel. Variation of flow rate is achieved by switching on and off additional pumps to meet demand. The combined pump curve is obtained by adding the flow rates at a specific head.
17.	Discuss the advantages of stop/start controller in case of pumps. In stop/start control method, the flow is controlled by switching pumps on or off. It is necessary to have a storage capacity in the system e.g. a wet well, an elevated tank or an accumulator type pressure vessel. The storage can provide a steady flow to the system with an intermittent operating pump. When the pump runs, it does so at the chosen (presumably optimum) duty point and when it is off, there is no energy consumption. If intermittent flow, stop/start operation and the storage facility are acceptable, this is an effective approach to minimize energy consumption. The stop/start operation causes additional loads on the power transmission components and increased heating in the motor. The frequency of the stop/start cycle should be within the motor design criteria and checked with the pump manufacturer. It may also be used to benefit from “off peak” energy tariffs by arranging the run times during the low tariff periods.
18.	What is the significance of by-pass control in pumping systems? By-pass control is used when; the pump runs continuously at the maximum process demand duty, with a permanent by-pass line attached to the outlet. When a lower flow is required the surplus liquid is bypassed and returned to the supply source.
19.	What are the merits of VSD application in case of pumps? The flow control by speed regulation is always more efficient than by control valve. In addition to energy savings there could be other benefits of lower speed. The hydraulic forces on the impeller, created by the pressure profile inside the pump casing, reduce approximately with the square of speed. These forces are carried by the pump bearings and so reducing speed increases bearing life. It can be shown that for a centrifugal pump, bearing life is inversely proportional to the 7^{th} power of speed. In addition, vibration and noise are reduced and seal life is increased providing the duty point remains within the allowable operating range.
20.	List any four important energy conservation opportunities in a pumping system. a) Throttled valve system b) Mismatch of head and flow c) Leakage in the piping system d) Over designed sizing of pumps to actual requirement

Part III: Long type questions and answers

1.	Write a note on pump performance curve with sketch. The pressure (head) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. The head and capacity are the main factors, which affect the horsepower size of the motor to be used. The more the quantity of water to be pumped, the more energy is required. A centrifugal pump is not positive acting; it will not pump the same volume always. The greater the depth of the water, the lesser is the flow from the pump. Also, when it pumps against increasing pressure, the less it will pump. For these reasons it is important to select a centrifugal pump that is designed to do a particular job. Since the pump is a dynamic device, it is convenient to consider the pressure in terms of head i.e. meters of liquid column. The pump generates the same head of liquid whatever the density of the liquid being pumped. The actual contours of the hydraulic passages of the impeller and the casing are extremely important, in order to attain the highest efficiency possible. The standard convention for centrifugal pump is to draw the pump performance curves showing Flow on the horizontal axis and Head generated on the vertical axis. Efficiency, Power & NPSH Required (described later), are also all conventionally shown on the vertical axis, plotted against Flow, as illustrated in Figure.  **Pump Performance Curve**
2.	Explain parallel operation of pumps with necessary pump curves. Pumps operating in parallel discharging into a common header exhibit a phenomenon that is completely independent of any static head that might be present. The first pump discharging to the header pressurizes the header. The second and subsequent pumps that come on line must then pump into a pressurized header. The net effect is the same as pumping against a static head. More the pumps running, the higher will be the pressure in the header, affecting system resistance as shown in Figure below:

	 *Fig: Parallel Pumps* *Three curves indicate effect of pumps, in parallel. Innermost curve is for one pump; middle curve for 2 pumps, outer curve for 3 pumps in parallel. Addition of system resistance (1 to 2 or 1 to 3) by parallel operation can be seen.* With three pumps running, each pump operates at point 3 in Figure. Thus, a fourth pump must deliver at least this pressure before it produces any tangible flow. This situation is, therefore, identical to pumping against a static head.
3.	From the parameters given below, calculate the size of the impeller which is geometrically similar size. The existing impeller diameter is of 380 mm

Parameter	Unit	Rated	Required
Flow	M^3/h	310	280
Head	M	45	43.5
Power	kW	55	46

Existing impeller size = 380 mm

Rated pump parameters

Q1 = 310 m^3/h

H1 = 45 m

P1 = 55 kW

Required pump parameters after impeller change

Q2 = 285 m^3/h

H2 = 43.5

P2 = 46 kW

	i) Q2 = $Q1\,x\left(\frac{D2}{D1}\right)^3$ = $\frac{D2}{D1}=\left(\frac{Q2}{Q1}\right)^{1/3}$ = $\left(\frac{280}{310}\right)$ = 0.96 D2 = 0.96 x 380 = 367 mm ii) D2 = $D1\,x\left(\frac{H2}{H1}\right)$ = 380 x $\left(\frac{43.5}{45}\right)$ = 367 mm iii) P2 = P x $\left(\frac{D2}{D1}\right)^5$ $\frac{D2}{D1}$ = $\left(\frac{P2}{P1}\right)^{1/5}$ D2 = 380 x $\left(\frac{46}{55}\right)^{1/5}$ = 380 x 0.96 = 367 mm
4.	Estimate the reduction in power consumption of condensate transfer pump by reducing speed of the pump by 20% to the rated speed. Q= 38 m3/h H = 65m P = 12.5 kW Running pump operating parameters at full speed (N) Q1 = 38 m^3/h H1 = 65 m P1 = 12.5 kW Power consumption at reduced speed (80% of full speed)

	P2 = P1 x $\left(\frac{N2}{N1}\right)^3$ P2 = 12.5 x $\left(\frac{0.8N1}{N1}\right)^3$ $[\Theta\ N2 = 0.8N1]$ = 12.5 x 0.512 = 6.4 kW
5.	In an energy audit study of a cement plants following measurement were noted.

Pump ID	Measured flow, m³/h	Measured , kW	Operating head, m	Rated flow, m³/h	Rated head, m
P1	12.31	42	357.o	15	380
P2	13.14	35	357.0	15	380
P3	21.60	55	362.25	25	380

Note: Motor efficiency is considered as 85%

Evaluate the operating efficiency of the pumps and suitably replace the pumps with new pumps of efficiency 75%. What would be the annual reduction in energy consumption after implementation of the above measure?

Pump efficiency: $\frac{QWHx0.746}{75\,x\,motor\ kW\ \ x\,motor\ efficiency}$

Q: m³/s

W: 1000

H: in meters of fluid column

Typically for pump no. 1

Efficiency η_p : $\frac{12.31\,x\,1000\,x\,357\,x\,0.746}{3600\,x\,75\,x\,42\,x\,0.85}$

34%

P2 and P3 are calculated and tabulated below:

Pump ID	Measured flow, m³/h	Measured kW	Operating head, m	Pump η, %	Remarks
1	12.31	42	357	34	Poor efficiency
2	13.14	35	377	46	Low efficiency
3	21.60	55	362	46	Low efficiency

Considering the operating efficiency, it is recommended to opt for new pumps of same capacity which has an efficiency of 75%.The resulting energy savings of new pumps are:

New pump efficiency: 75%

Considering the existing flow and head, the power requirement is tabulated below:

Pump ID	Present power consumption, kW	Expected power consumption, kW	Energy savings, kW	Annual energy savings, kWh
P1	42	19	23	184000
P2	35	21.4	13.6	108800
P3	55	33.8	21.2	169600