Centrifugal pump

Getting basic right!

At first sight, a centrifugal pump seems to be one of the simplest machines. In practice, however, it is capable of posing an enormous spectrum of different problems. Occasionally, one comes across problems that seem to defy everything, we know about centrifugal pumps. This article details the various problems and solutions faced by the engineers.

The selection of the right pump for the right job is very important and results in minimum maintenance of pumps. But this calls for knowledge of not only what happens within the pump but also what happens behind and beyond the pump. Therefore, it has to be a joint effort between the hydraulic expert and the process specialist. Selection of the right pump itself rewards - start up, operating problems, maintenance cost, etc, are minimised.

The performance of the pump is very much dependent on the performance of the overall system. Head, pressure, over sizing, pump running away from BEP, etc, have to be clearly understood and properly synchronised, to get proper and better result from centrifugal pumps.

The word Head is frequently spoken in the field of water works, pumping, etc. A column of water or any liquid in a vertical pipe exerts a certain pressure (force per unit area) on a horizontal surface at the bottom; this pressure is expressed in kg / cm^2 or metre of liquid column (mlc). The height of a liquid column is known as Head.

A square container with 1 metre sides is filled with water to the height of 1 metre, ie, it contains one cubic metre of water weighing 1,000 kg. Hence, at the bottom it exerts a pressure of 1,000 kg / 10,000 cm^2 or 0.1 kg / cm^2.

In other words a water column of 1 metre will exert a pressure of 0.1 kg / cm^2 at the base. (Specific gravity (sp gr) of water is 1) To make for tanks with different cross sections but the same liquid column heights, the pressure gauges at the bottom of the tanks read the same pressure.

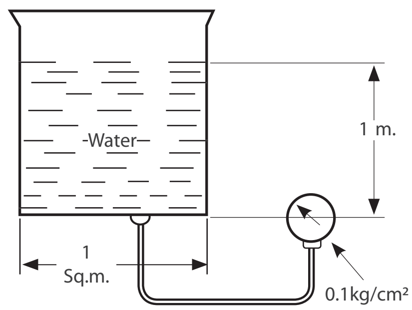
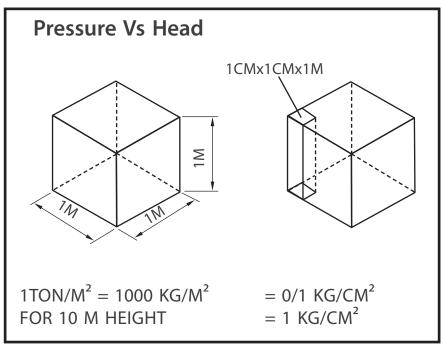


Fig. 1: Concept of Head



Head and pressure

The relation between Head in metre of liquid column and pressure in kg / cm^2 can be expressed as under:

$$\text{H in mlc} = \frac{\text{P x 10}}{r}$$

Where, P = Pressure in kg / cm^2, r = sp gr of liquid. (1 kg / cm^2 = 10 m of water column).

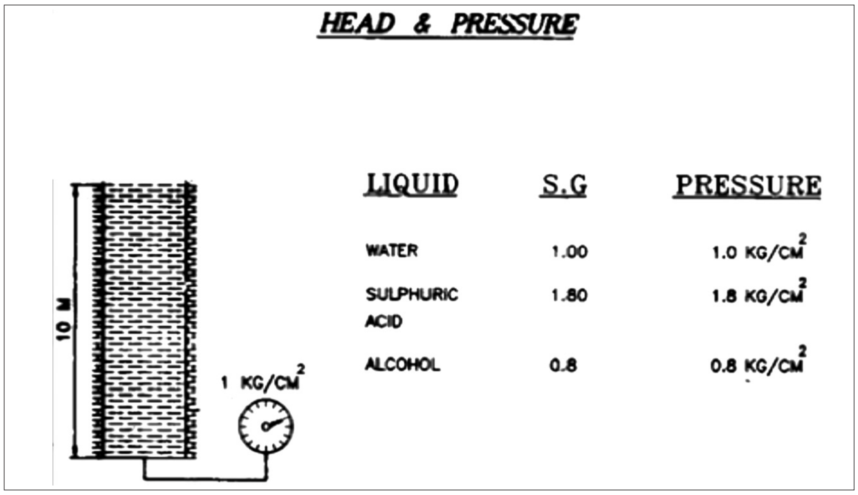
A centrifugal pump with a given speed in rpm and impeller diameter will deliver any liquid to the same height (Head) irrespective of its sp gr though pressure gauge readings will vary according to sp gr.

Suppose water, acid and alcohol are pumped to the same height of 30.5 metre by three similar pumps, then pressure gauges attached to each discharge pipe will read pressures differently. These shows the pressures are directly proportional to the sp gr of liquids. That is why, it is always wise to think in terms of metre of liquid column (mlc) rather than pressure when dealing with pumps.

Develop an approximate system – step-by-step Head curves

A pump operating in a system must develop a total Head which is made up of several components:

- The static head between the source of supply and the point of delivery
- The difference in pressures (if any) existing on the liquid at the source of supply and at the point of delivery
- The frictional losses in the piping, valves, etc, in the system
- Entrance and exit losses at the source of supply and at the point of delivery respectively
- The difference in velocity heads at the pump discharge and at the pump suction



Because the first two components generally do not vary with flow, they can be lumped together into a single term and become the total static head. On the other hand, the remaining three components vary as a function (roughly as the square) of the flow through the system. They are frequently lumped together into a single term and considered as friction losses.

If the sum of the total static head and of the friction losses for a series of assumed flows is plotted against flow (or pump capacity), the resulting curve is called the system-head curve. Such a curve is illustrated in Fig 1.44. If either the static head or the pressure difference varies under certain conditions, it is necessary to plot two or more such curves. At least one of these curves should correspond to the minimum total static head and one curve to the maximum total static head.

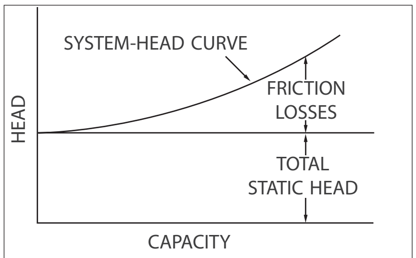


Fig. 2 Construction of system-head curve.

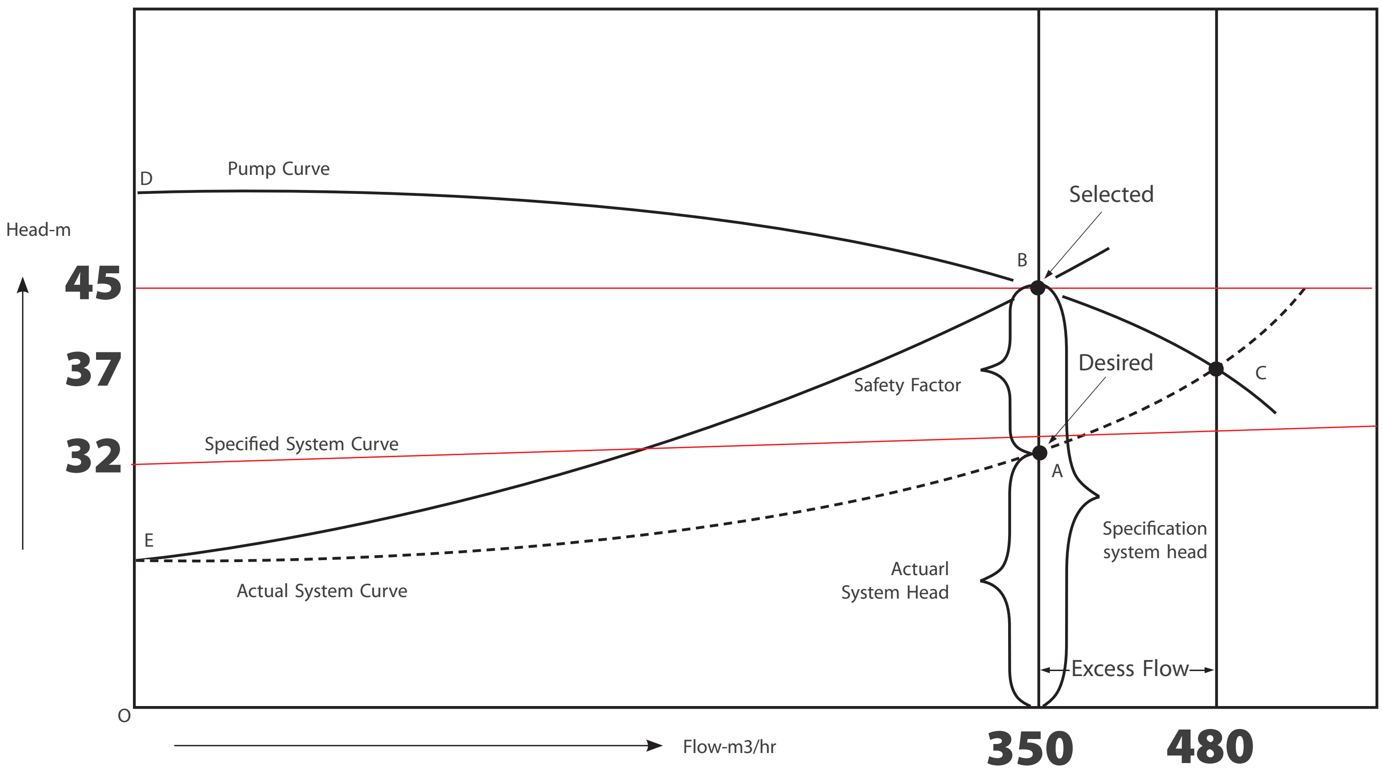
To determine the capacity that a given pump or a group of pumps will deliver into the system, it is merely necessary to superimpose the head-capacity curve of the pump or pumps on the system-head curve. The intersection of the head-capacity and system-head curves will indicate the flow that will take place through the system (Fig 1.45).

Effects of over sizing pumps

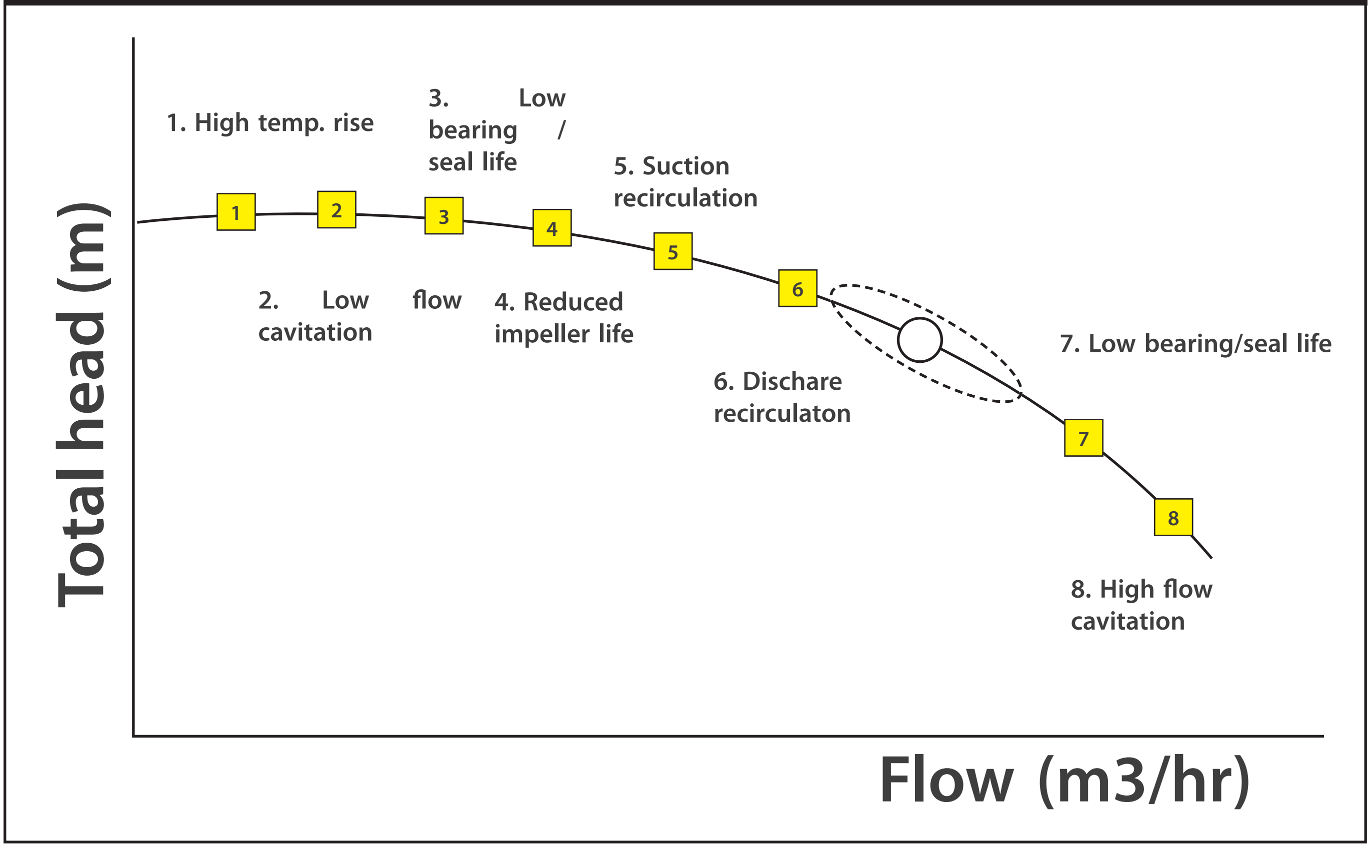
The system head curve is developed by plotting total system head (static and friction loss) as the flow varies from zero to maximum. System head curve analysis helps define the operating relationship between the pump head and the system head. Efficient and trouble-free operation depends on a close match of pump curve and system curve. Otherwise pumps may be picked that are improperly sized and do not run at the conditions for which they are selected/purchased.

At design flow 350 cum/hr, the engineer calculates the head as 32 metre, Erroneously believing that using a safety factor will ensure his reaching B, he adds 12 metre, to obtain total head of 45 metre. Assuming the user needs a pump to operate 350 cum/hr, and 45 metre, pump manufacturer selects a pump with curve D, B, C. The pump curve intersects the system head curve at BEP- Best Efficient Point.-B.

However, the actual system curve is E, A, C and the pump will run at C rather than B. Because with discharge valve fully open, pump seeks equilibrium with the system and operate at the intersection of pump curve and system head curve. At point C the pump will produce a flow of 480 cum/hr. Not only the user is getting different conditions than he wants, he is also operating at a less efficient



Centrifugal pumps seldom run at their bes efficiency point (BEP). Let's look at what happens when we go off the BEP:



point on the pump curve and spending more on energy.

To get 350 cum/hr, the valve is gradually closed, steepening the system head curve. The pump produces 350 cum/hr and 45 m. But head at 350 cum/hr is 32 m. The pump thus produces 45 metre and 350 cum/hr but delivers only 32 metre and 350 cum/hr to the system. The additional head 12 metre is thus wasted across the valve as heat and noise.

The effects of over sizing the pumps are

1. Operation at excess capacity requires greater NPSH®
2. High pressure drop through foot valve
3. Cavitation leading to efficiency drop and premature failure of rotor
4. Greater power consumption
5. High initial purchase cost
6. Internal loading and hydraulic radial thrust and
7. Vibration and dehydration.

The solutions are

1. Reduce impeller diameter
2.Reduce speed and
3.Go for new correct sized pump

Effects of pump running away from best efficieny point (BEP)

One can compare man as a machine with a man-made machine say pump. The performance of man can be measured by his consistent output. To have consistent output, one has to see that the man is working at or near his expected capacity, that is, he is neither overloaded nor otherwise. Overloading may lead to fatigue and under expectation develops frustration. This condition is monitored by his behaviour, mistakes in work and losing temper. So is the case of pump. The pump has to be selected and operated at or near its best efficiency point. Over expectation may lead to overloading of the motor, cavitations, increased vibrations, etc. Operating the pump at part capacity may lead to increased loading on the bearings thereby increasing bearing temperatures, increased vibrations and noise. That is, the performance of the pump can be monitored by its behaviour, mistakes and temperature.

It is always prudent to include a safety margin to ensure the pump can accommodate unforeseen system changes. The safety margin has to be considered as pump insurance. So, it has a premium that must be paid. The more the pump is oversized, the higher is the premium. Our job is to decide the right amount of insurance and know what we are paying for.

Getting it right

Getting the head right is the first step to efficient and satisfactory operation. Good pipe work is real energy saver, although for the untrained observer, it is doing nothing. Selecting the BEP in curve comes easily after that. Follow these steps and energy efficiency, with all its attendant benefits could be yours. WPI

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