PUMPS AND BEHAVIOURS

UNDERSTANDING PUMPS

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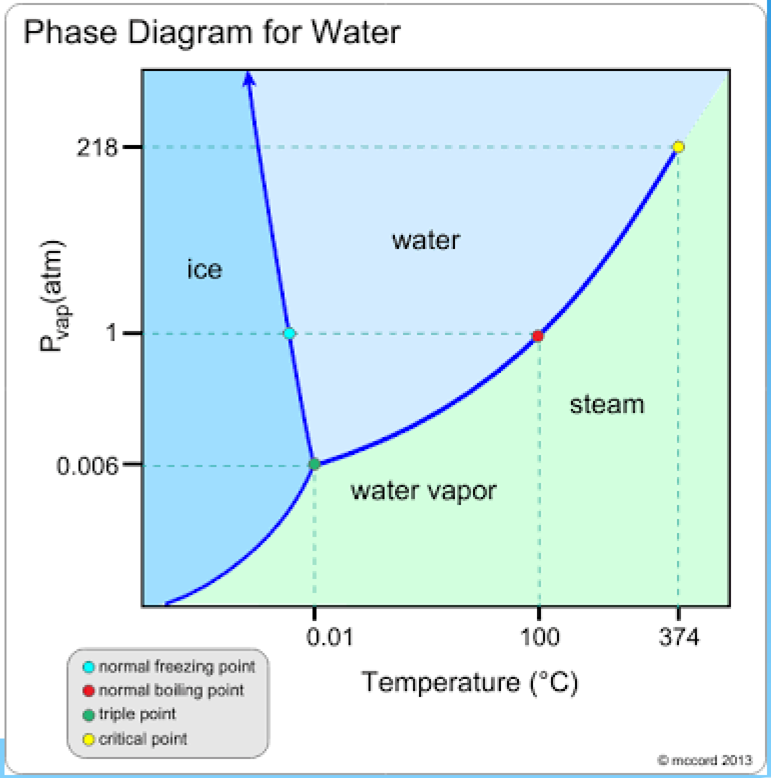
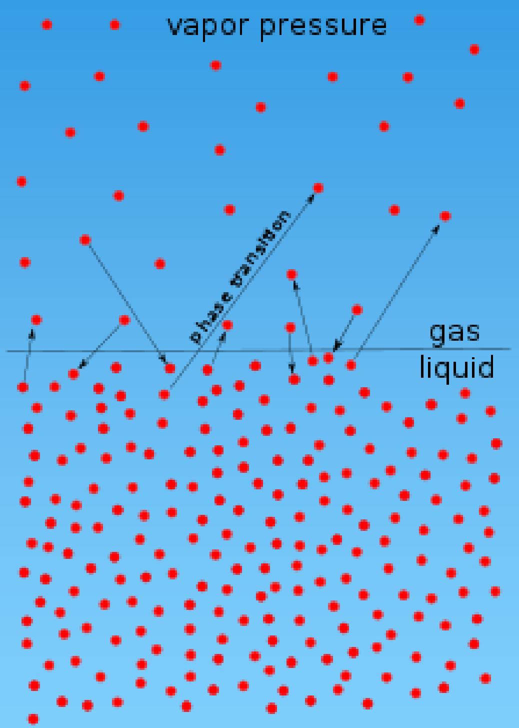
DIVIDED TO 3 SECTIONS:-

- **PUMP CAVITATION**
- **PUMP SPEED MODULATION**
- **PUMP SELECTION**



PUMPS AND BEHAVIOURS **CAVITATION**

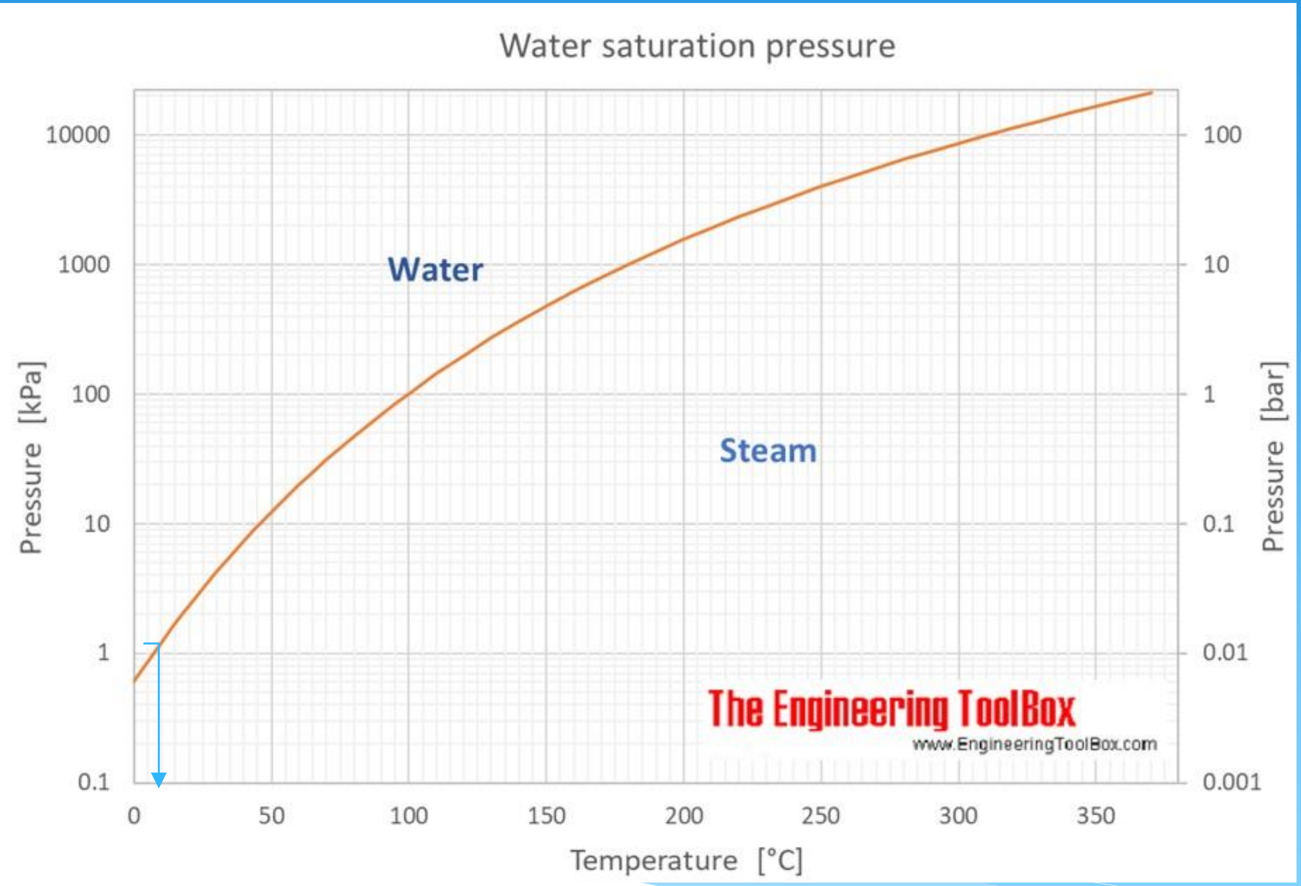


Wikipedia Explanation

Vapor pressure or **equilibrium vapor pressure** is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate. It relates to the tendency of particles to escape from the liquid (or a solid).

Layman's definition:
Vapor pressure is the pressure at which liquid starts boiling in a closed system.

PUMPS AND BEHAVIOURS CAVITATION



At 100kPa, water boils at 100 deg C. At 33.7kPa, ie summit of mount everest, water boils at 70 deg C At 1kPa, water boils at 10 deg C approximately.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

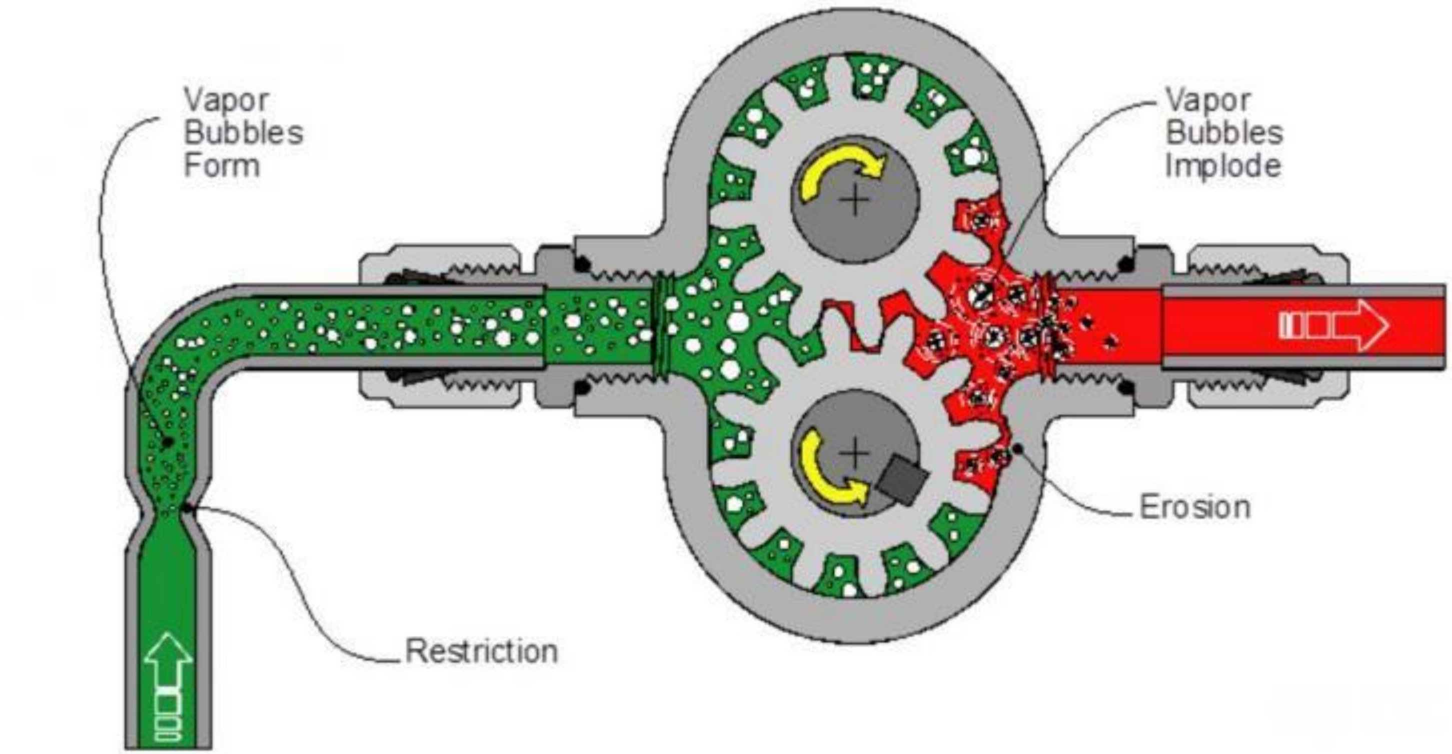
Definition:

Cavitation, formation of vapour bubbles within a liquid at low-pressure regions that occur in places where the liquid has been accelerated to high velocities, as in the operation of centrifugal pumps, water turbines, and marine propellers.

Cause of Cavitation:

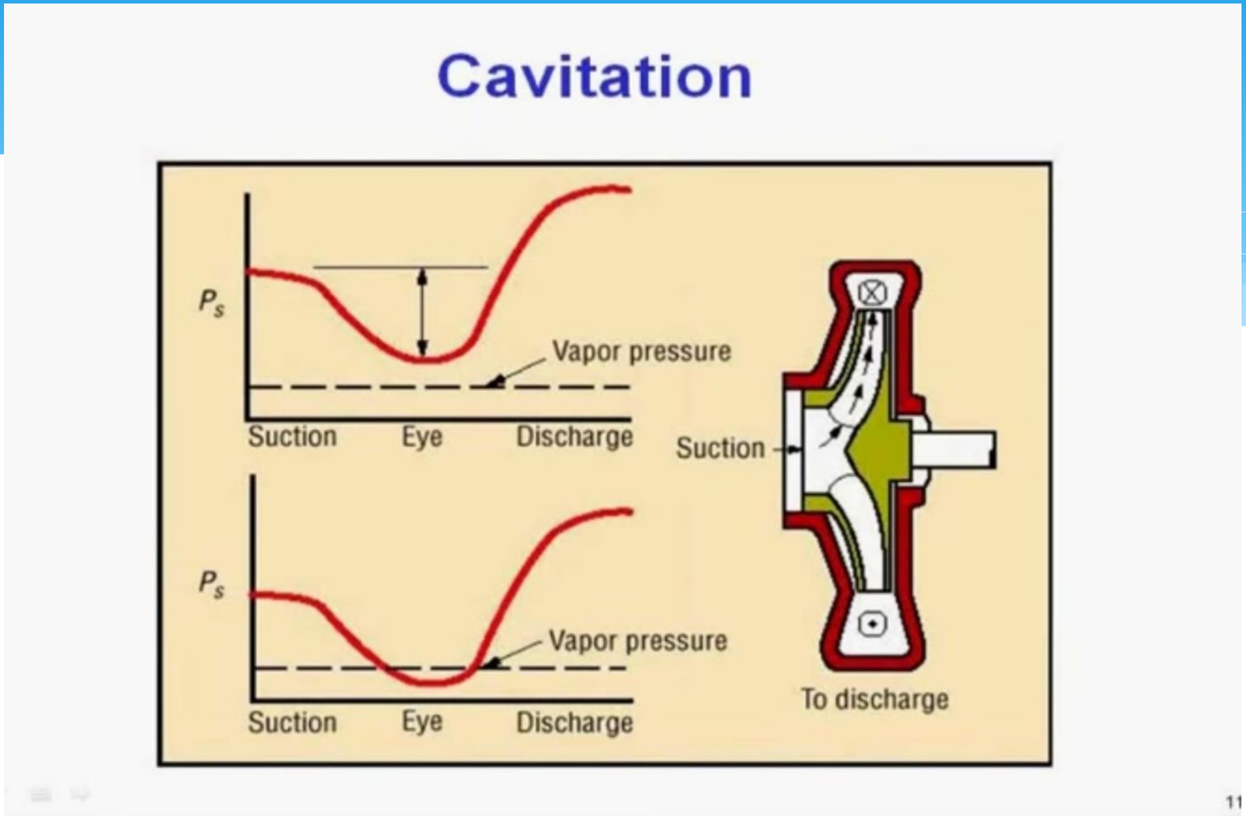
The cavities form when the pressure of the liquid has been reduced to its vapour pressure; they expand as the pressure is further reduced along with the flow and suddenly collapse when they reach regions of higher pressure. The sudden growth and collapse of these vapour cavities cause the extreme pressures that pit the metal surfaces exposed to the cavitating liquid.

PUMPS AND BEHAVIOURS CAVITATION



* Low pressure on suction side, bubble develops, high pressure on discharge side bubble collapses

PUMPS AND BEHAVIOURS CAVITATION



* Pressure drops as water velocity is increased and approaches the impeller. When pressure at eye of impeller is less than vapour pressure, the pump will start to cavitate.

PUMPS AND BEHAVIOURS CAVITATION

* Low pressure on suction side, bubble develops, high pressure on discharge side bubble collapses

PUMPS AND BEHAVIOURS CAVITATION

* Pump Cavitation [Cavitation in a Water Pump and Valve - Excellent Visual and Audible Demostration (youtubemp4.to).webm]

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

Effect Of Cavitation:

- Incurs extensive erosion of the rotating blades. Thus shorter life span of impeller. Eroded impeller also causes decrease in efficiency as aerodynamic of the pump is lost.
- Produces additional noise from the resultant knocking and vibrations
- Results in a significant reduction of efficiency because it distorts the flow pattern.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

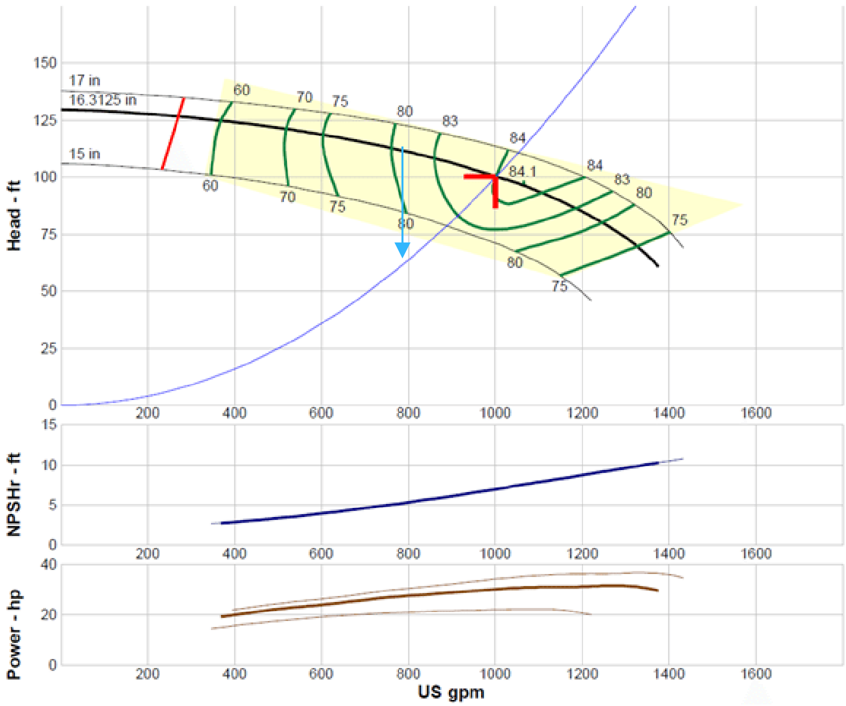
How does pump cavitation occur in a system?

* In order to avoid cavitation, a minimum pressure referred to as the net positive suction head (NPSHr) must be maintained at the suction port so that the liquid does not boil or evaporate. This NPSHr ensures that the pressure applied at the suction port is always greater than the vapour pressure of the liquid at a given temperature of the medium.
* The actual available pressure at the suction port must be greater than the required minimum pressure. The available pressure can be calculated as
  * NPSHa= 10m (atmospheric pressure) – vapour pressure + (the height of low level water level minus the pump level) - friction loss of suction pipe
* **A typical safety margin between Net Positive Suction Head Available (NPSHa) and required (NPSHr) is 5 ft, some publication recommends only 0.5m.**
  * **Thus NPSHr of pump chosen should be NPSHa + 5feet head or lower.**

PUMPS AND BEHAVIOURS CAVITATION

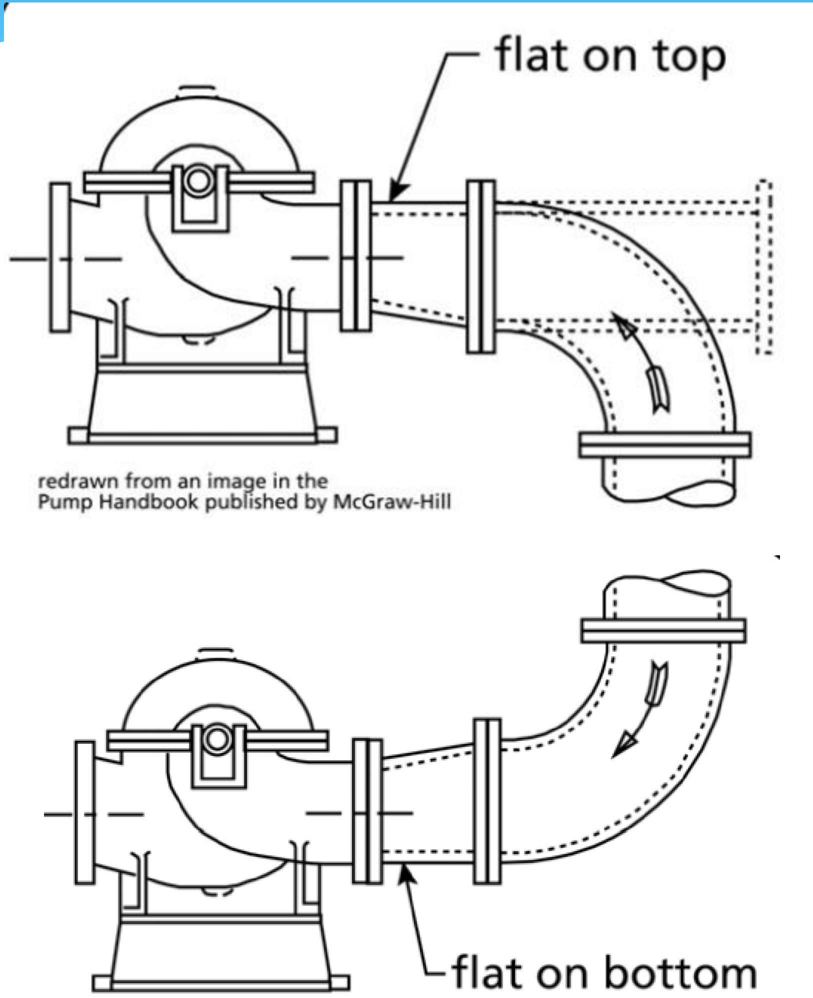
Pump Cavitation Mitigation

* Note: If a pump cavitates, the control valve on the **pressure side (ie discharge side)** should be throttled in order to reduce the flow rate and thus the NPSH value required by the pump. However, it must be ensured that the flow rate remaining is large enough to sufficiently cool and lubricate the pump.



PUMPS AND BEHAVIOURS CAVITATION

PUMP INSTALLATION TIPS TO MITIGATE CAVITATION

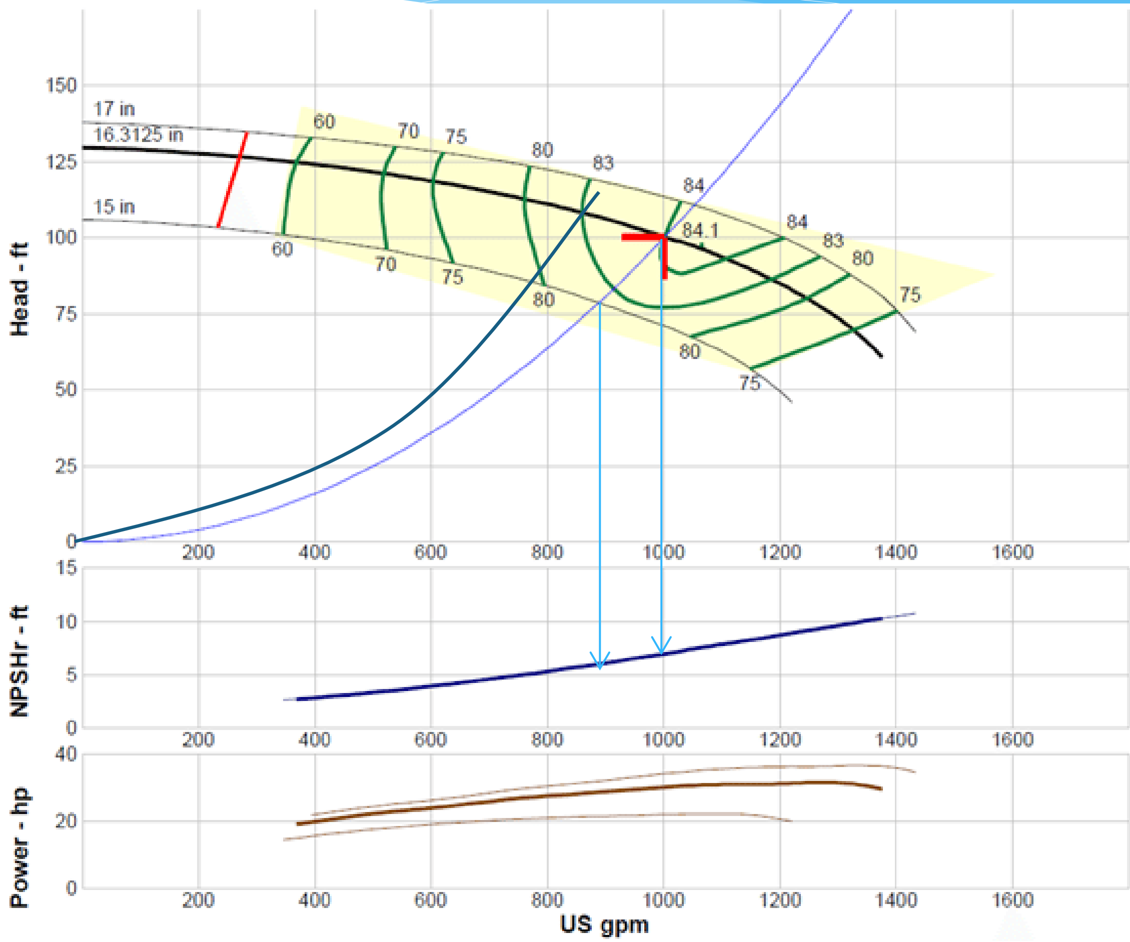


Installation of eccentric reducer helps to reduce cavitation by

1. Installing a bigger suction pipe
2. Avoid air pocket and allow air to be evacuated.
3. Install straight section of 5 pipe diameter before pump inlet where possible.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation Temporary Mitigation



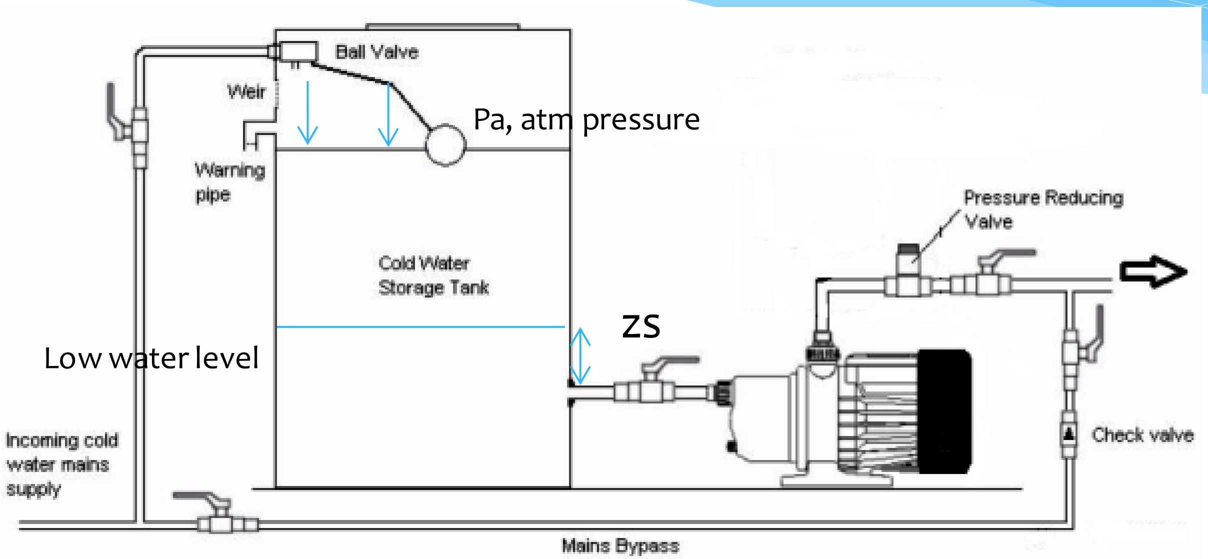
As flow rate increases, net positive suction head requirement increases.

Thus temporary solution is to run the pump at lower speed or to throttle the flow.

It is important that pump minimum flow rate be maintained.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation Mitigation



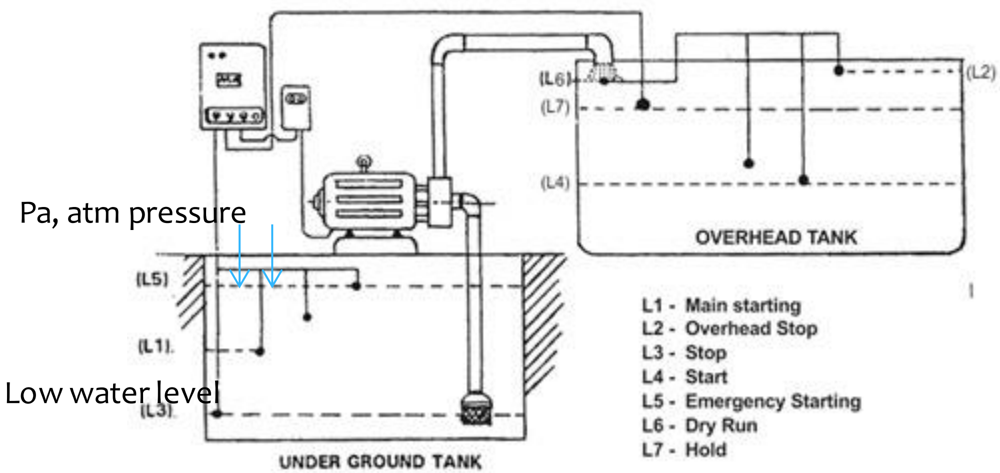
a) Inlet suction pipe must be at least one size bigger than pump, inlet velocity to keep to below 1.5m/sec ie 5 feet per second.

b) Keep suction pipe as short as possible
c) Install at least straight pipe of length 5 to 10 times diameter between any fittings/ obstruction and the pump.
d) Keep strainer clean, dirty strainer will reduce the net positve suction head available.
e) Avoid high pockets in suction pipe to eliminate air entrapment.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

How does pump cavitation occur in a system?



a) This situation is called suction lift and there is danger of cavitation.
b) Foot valve need to be installed to prevent suction pipe from being emptied.
c) Each suction pipe should be linked to one pump, ie no common suction pipe allowed.
d) Net positive suction head available should be 0.5m or 5ft more than net positive suction head required by pump.

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

Calculation of NSPH available

- Net positive suction head available (NPSHA)

= (Patm- Pv)*10.2/(specific gravity of liquid transferred) + Z1 – Hfs

Where Patm= absolute pressure on liquid surface in bar

Pv= vapour pressure of liquid in bar at pump temperature

Z1= height of liquid surface above pump suction in meter, if surface below pump use minus sign

Hfs= friction loss of liquid in suction pipe including entrance loss, etc.

NPSHA >= NPSHr + 0.5m where 0.5m is safety margin

PUMPS AND BEHAVIOURS CAVITATION

Pump Cavitation

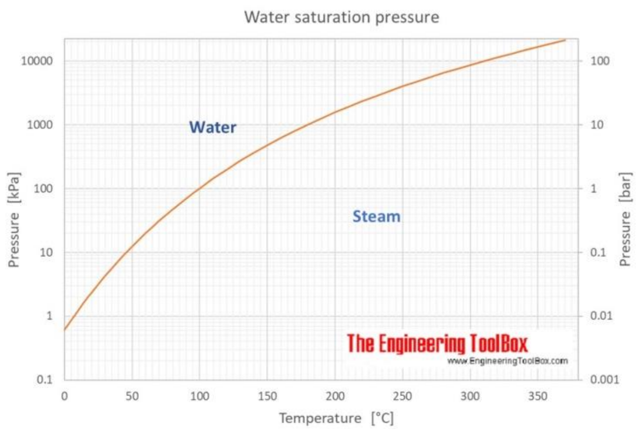
Calculation of NSPH available

* Net positive suction head available (NPSHA)

Pv= vapour pressure of liquid in bar at pump temperature

Temp (deg C)	Vapour Pressure (bar)
15	0.01704
30	0.04241
50	0.1
100	1.0133

Table for water

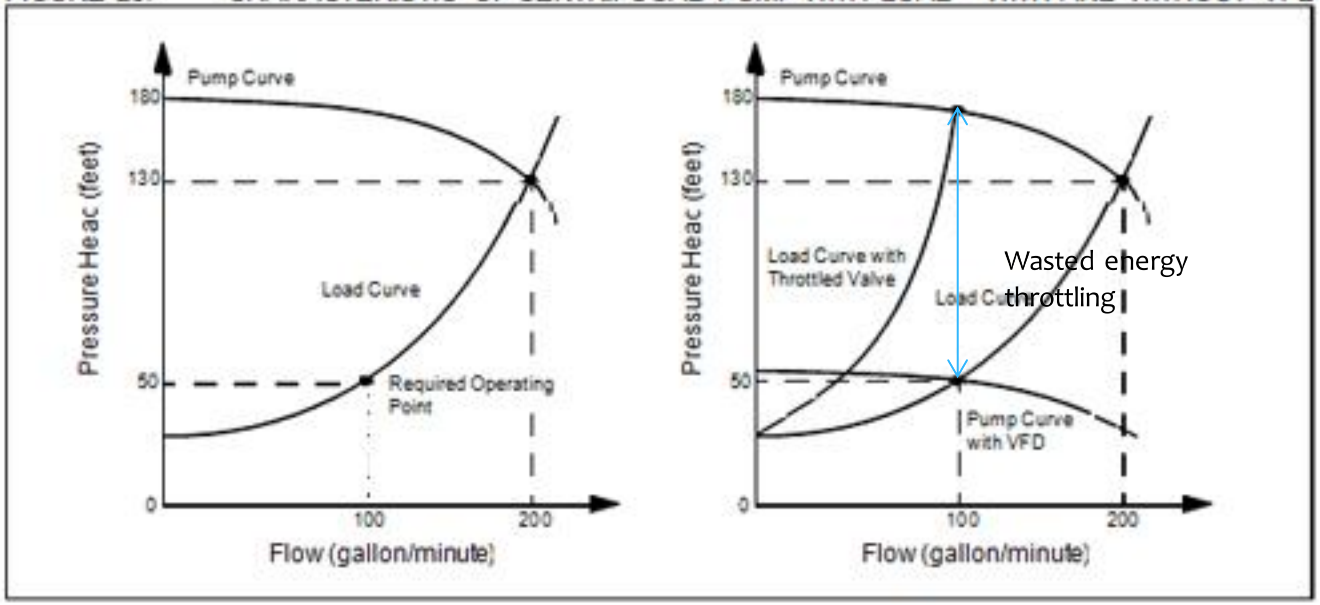


It can be seen that as temperature of pumped liquid increases, the vapour pressure increases and thus the NPSHa is reduced. Thus care must be taken when pumping hot liquid.

PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation

FIGURE 23: CHARACTERISTIC OF CENTRIFUGAL PUMP WITH LOAD – WITH AND WITHOUT VFD



Reasons to go for VSD application:-

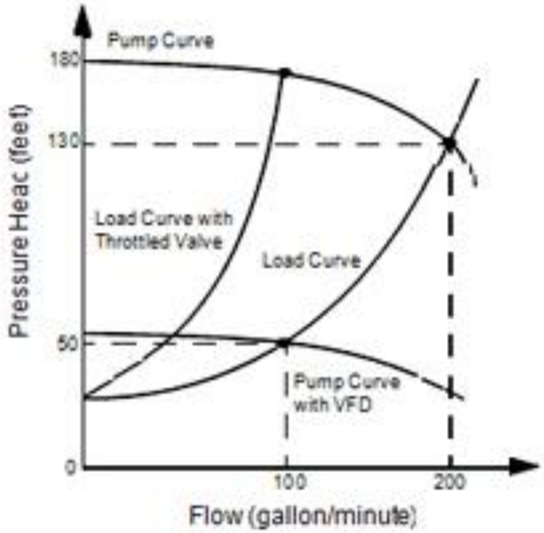
- Pump are normally oversized to cater for maximum demand. For eg, demand for domestic cold water application may not be constant.
- Throttling the pump will get back to required flow rate (such as a circulation system) but will waste energy.
- One way to go about is to vary speed of pump.

PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation

Reasons that the system curve can change are as follows:-

- Maintenance factor, ie friction of pipe increases, this means system curve shifts to the left, thus less flow is obtained at site
- We may also have oversized our pump head, ie design system curve is very steep but actual system curve is on the right hand side. However overheading pump too much and using vsd to bring back the pump operation point can sometimes lead to pump operating in the unstable zone as discussed later.

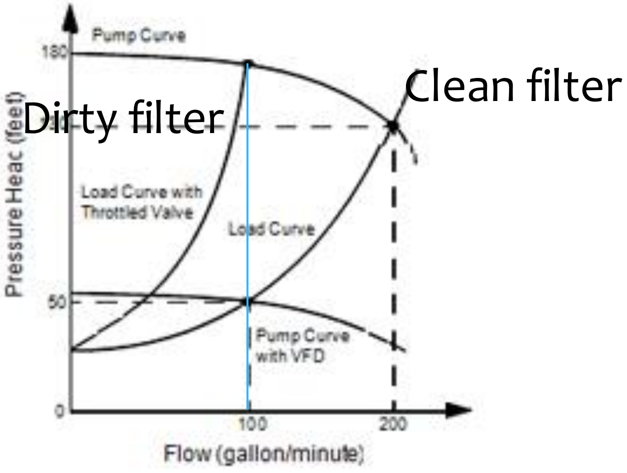


PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation

OTHER REASONS TO GO FOR VSD:-

1. Booster pump application when the demand flow rate is not constant.
2. In air condition application for chill and condensor water. This is because air condition runs at part load most of the time. (In part for IPLV calculation, 100% load is only running at 1%, 50% load is running at 42%, 75% load is running at 45% and 25% load is running at 12%) In fact in overseas, it is mandatory requirement for chill water pump to be variable speed to cater for changing chill water flow demand.
3. Swimming pool application if we want to maintain constant filtration rate as actual pump curve is lower than design pump curve in beginning when filter is clean.

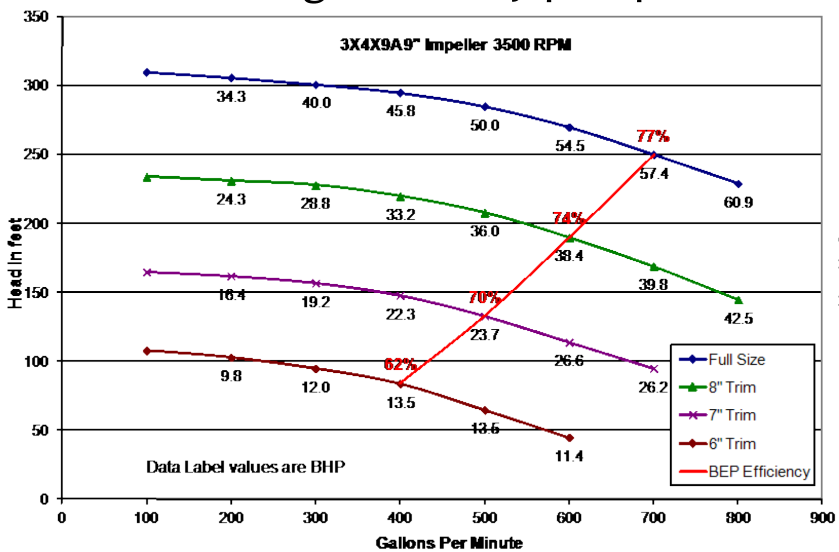


PUMPS AND BEHAVIOURS SPEED MODULATION

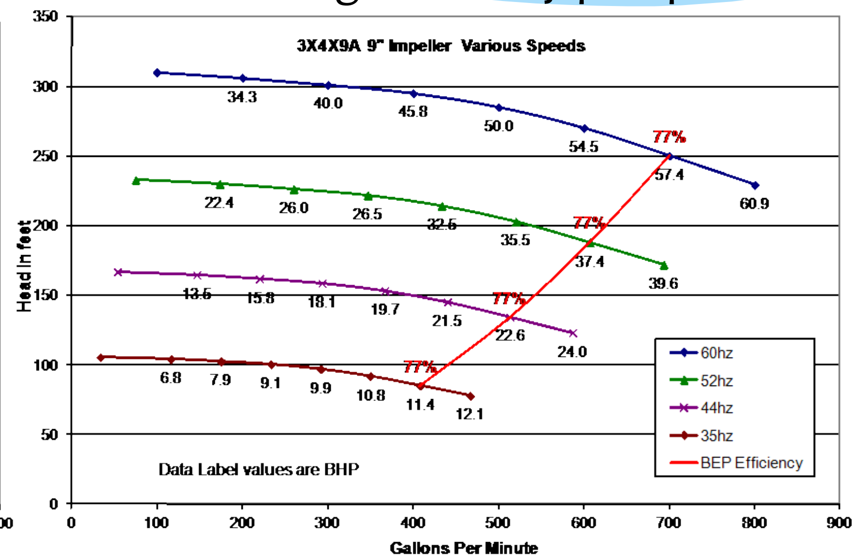
Pump Speed Modulation

Pump impeller trimming versus speed modulation

Decreasing efficiency pump trim



Maintaining efficiency pump vsd

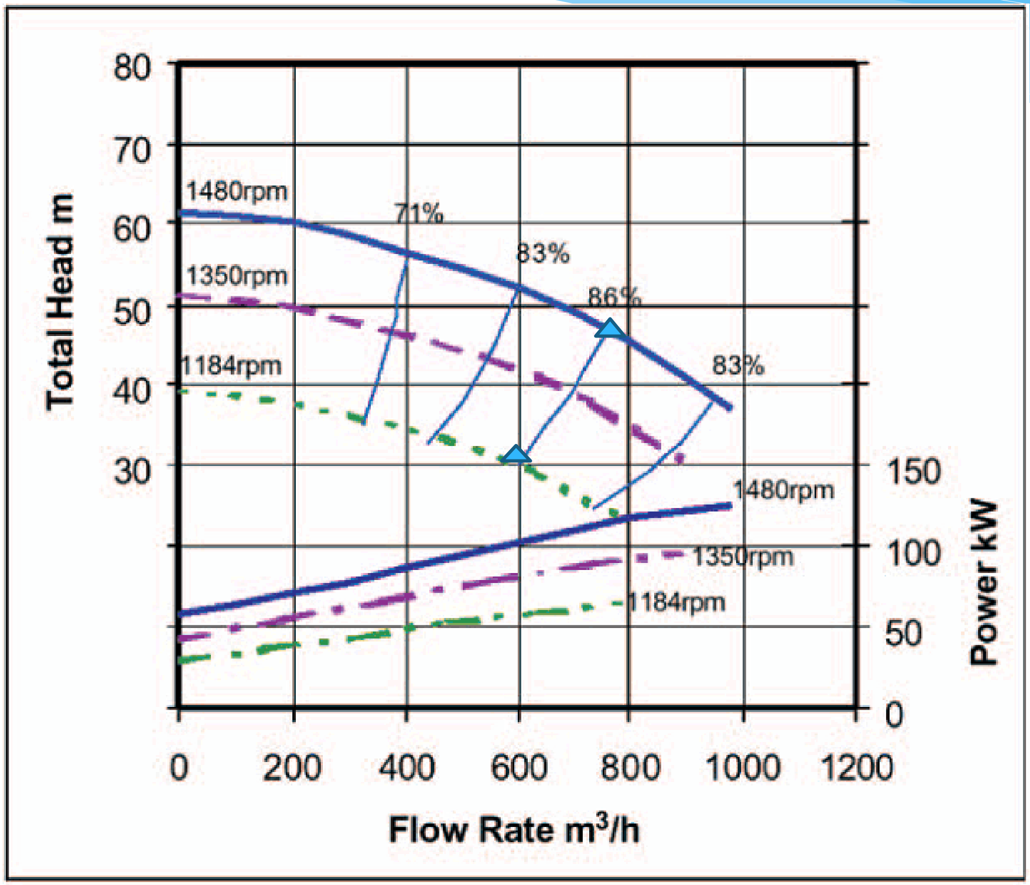


As can be seen, speed modulation is better than impeller trimming. The efficiency remains at optimum if pump is selected to operate at max efficiency and the system curve follows that of the iso efficiency curve. **(ideal case of fricion loss only in system curve). So use vsd when friction loss is high component of pump head.**

PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation IDEAL CASE

VSD APPLICATION



System with minimum static to friction ratio.

Pump chosen to operate at close to maximum efficiency at 86% efficiency.

As demand changes, the efficiency remains since the system curve is almost parallel to iso efficiency curve.

Affinity law:

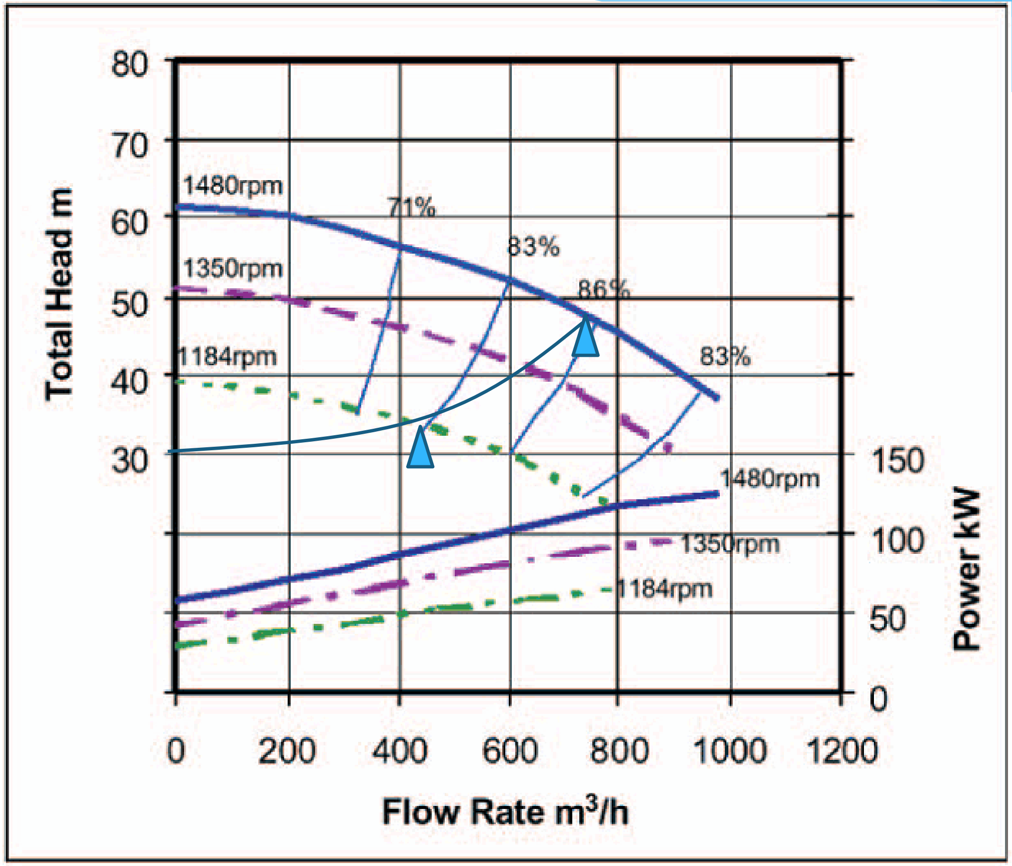
a) Flow is directly proportional to speed.

b) Head is directly proportional to speed ^2.

c) Power is directly proportional to speed ^3.

PUMPS AND BEHAVIOURS SPEED MODULATION

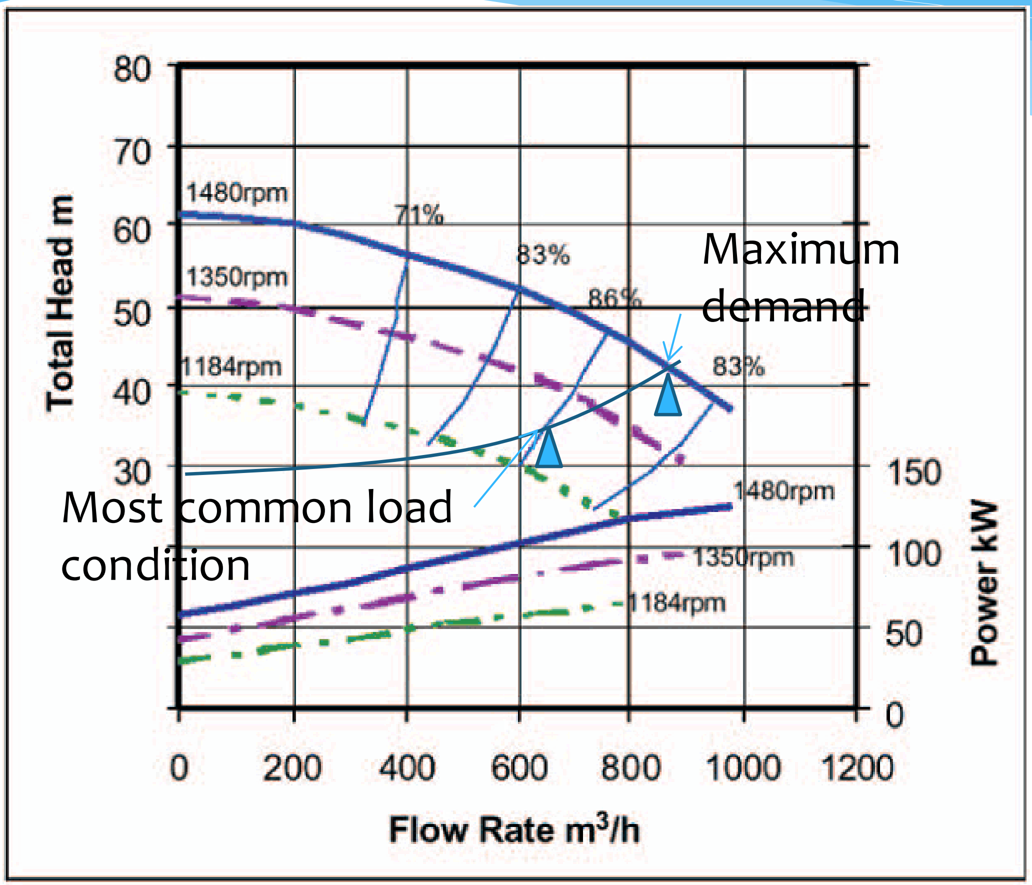
Pump Speed Modulation- ACTUAL ENERGY SAVING IS LESS THAN CLAIMED BY PUMP SUPPLIER



System with high static to friction loss.
The system curve remains flat.
The efficiency changes as the demand changes.
Flow is not proportional to speed.
Affinity law does not apply.
Energy saving is less than with the previous diagram where efficiency remains almost constant

PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation

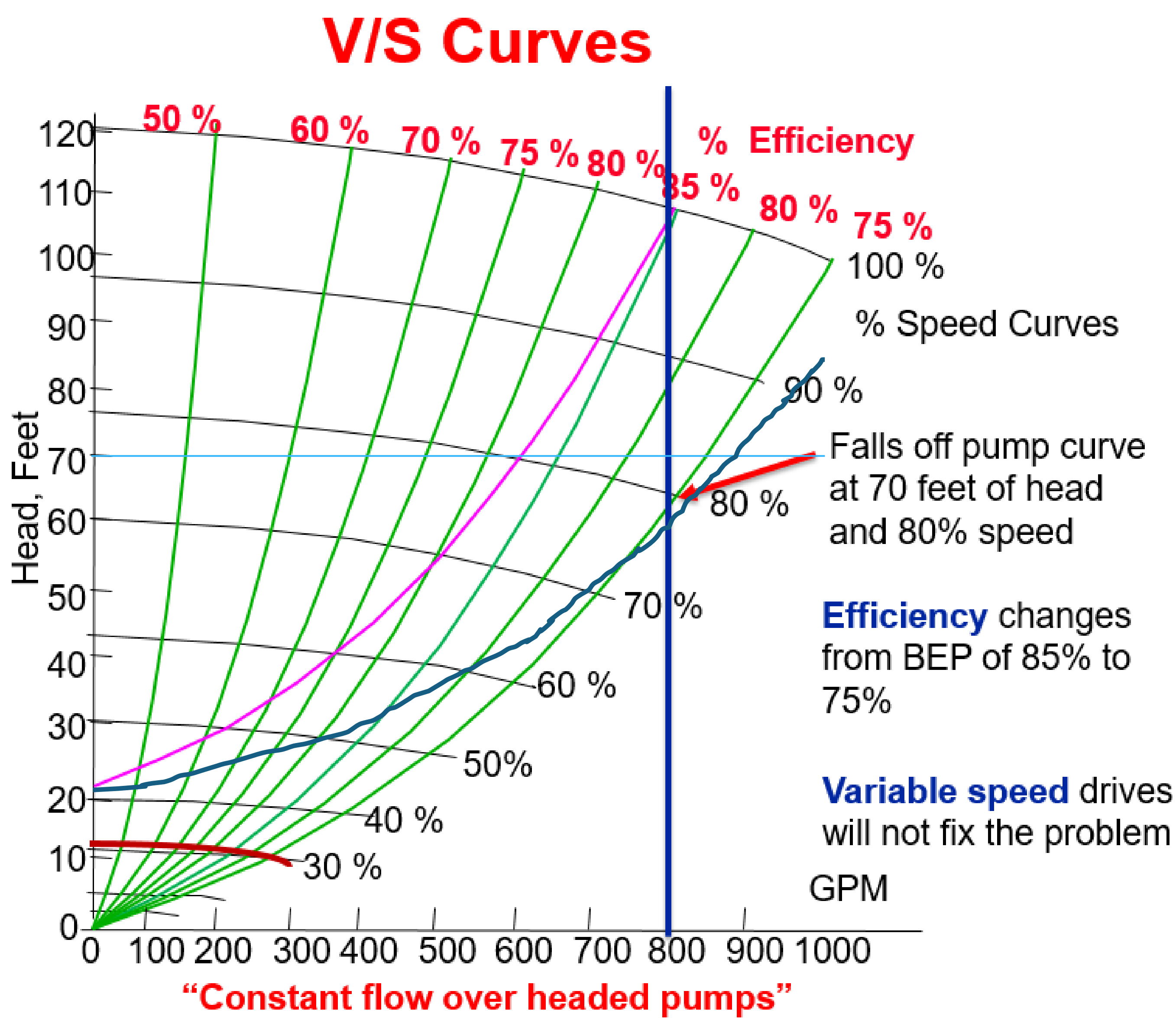


System with high static to friction loss.

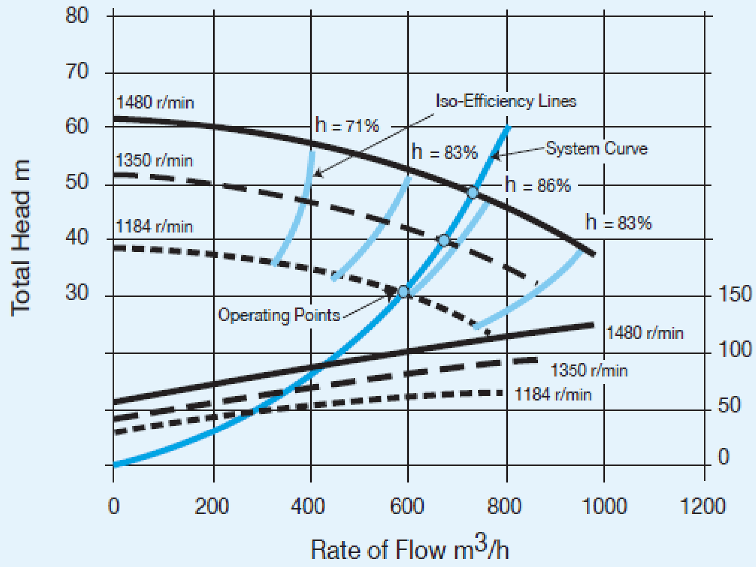
It is advantageous to select the maximum demand to operate at the right of maximum efficiency so that when speed is reduced, the efficiency increases at most common load.

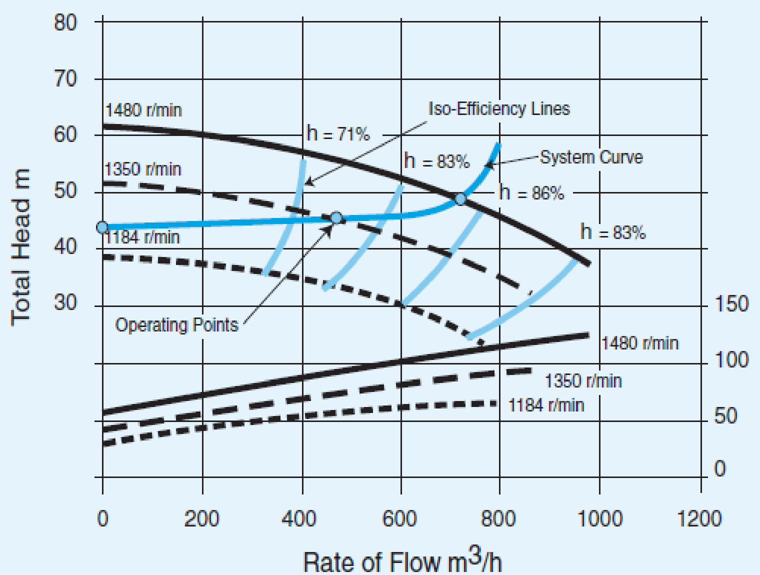
However if unsure of the system head and the pump is slightly overheaded, it is better to put pumps to operate at 80 to 100% of BEP in order to avoid pump cavitation when running at maximum demand as shown next.

PUMPS AND BEHAVIOURS SPEED MODULATION



PUMPS AND BEHAVIOURS SPEED MODULATION



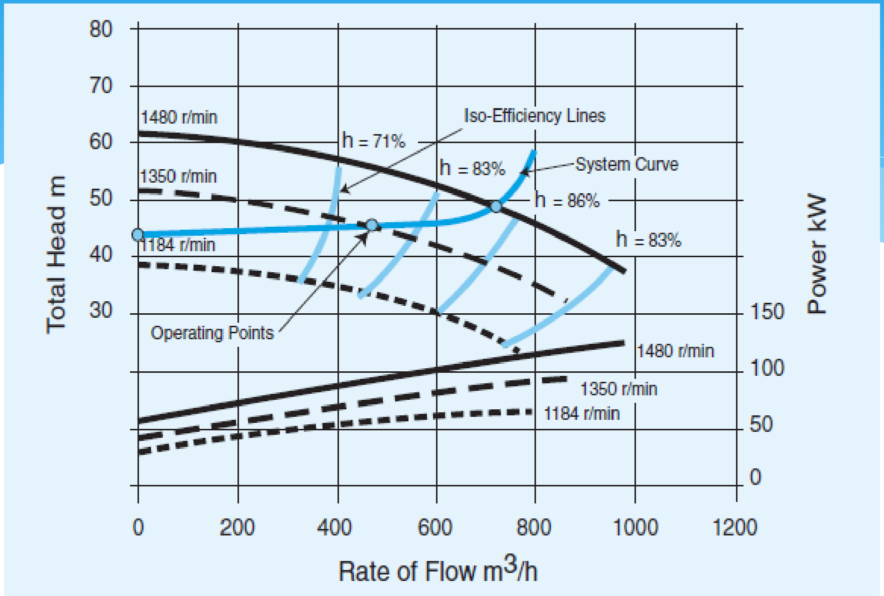


As can be seen speed reduction from 1480r/min to 1350r/min

a) Zero fixed pressure, only friction loss in system curve, flow rate reduction is from 750 to 700m3/hr.
b) Fixed pressure of 42m from total pressure of 50m, flow rate reduction is from 750 to 500m3/hr, WHICH IS VERY BIG DECREASE.
c) When fixed pressure head is very high compared to friction, energy saving from minor speed reduction to reduce flow rate will need to be more than energy consumed by vsd drive.

Thus less energy saving with high constant head.

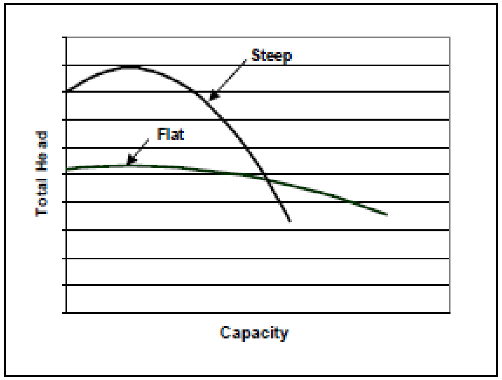
PUMPS AND BEHAVIOURS SPEED MODULATION



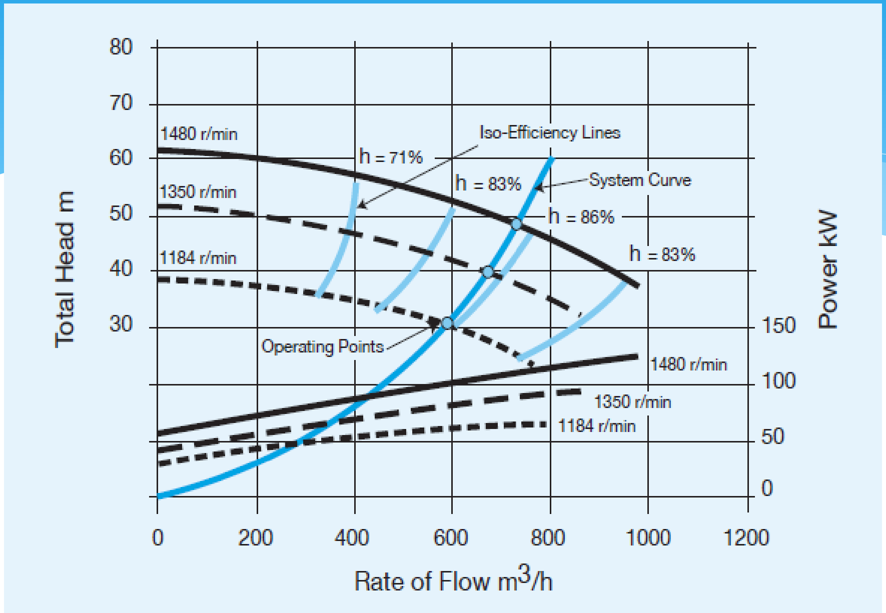
Thus for high static head compared to friction loss, it is better off to choose a flat pump curve and throttle the application.

Flat curves pump recommended for variable flow rate of system but high fix pressure head requirement , ie very little friction loss.

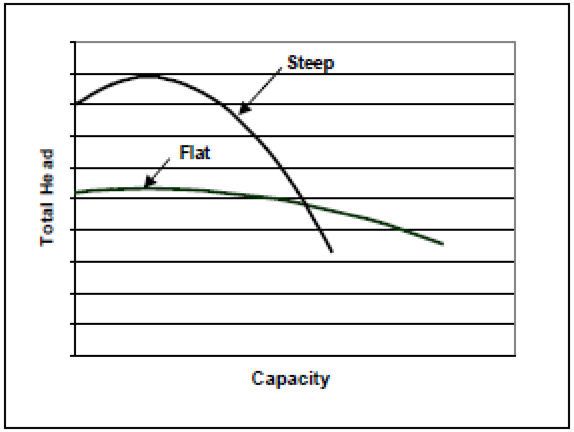
Throttling steep pump curve is not recommended as a lot of energy is wasted.



PUMPS AND BEHAVIOURS SPEED MODULATION



Thus for high friction head compared to static head such as long pipe recirculation and low loss across control valves such as hvac application, it is better off to choose a steep pump curve and apply vsd.



PUMPS AND BEHAVIOURS SPEED MODULATION

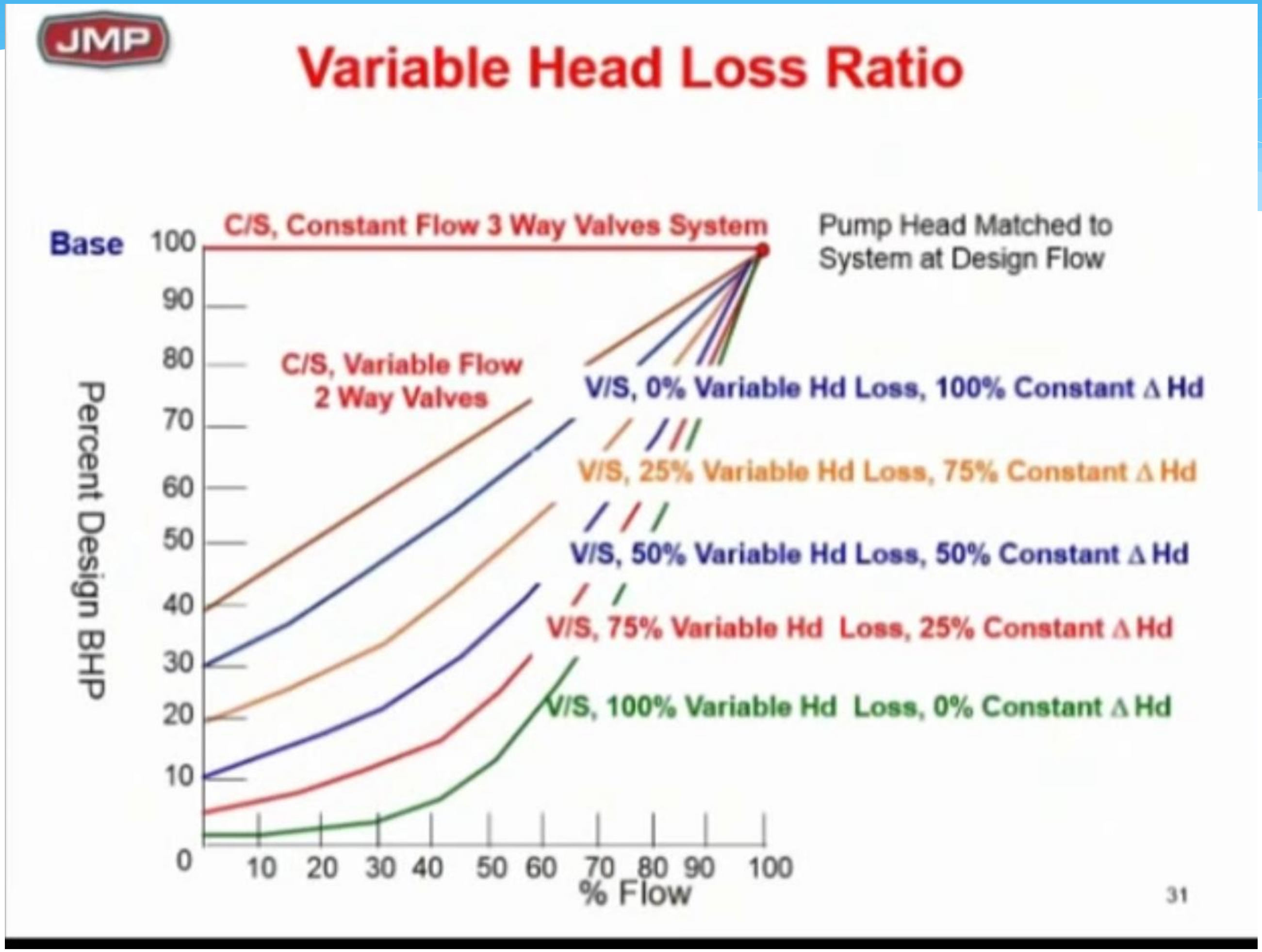
Pump Speed Modulation

Benefits of speed modulation in pump application:-

a) Energy saving for changing flow rate when the friction (dynamic) head is much greater than fixed head.
b) Easier to tune for system curve that is different from design when static head is low compared to friction loss.
c) Longer bearing life as impeller operating on lower speed.
d) Longer impeller life as lower speed means lower forces exerted on impeller.
e) Less vibration and noise due to a more balanced system.
f) Gentle pump stop and also less current consumption for pump start.

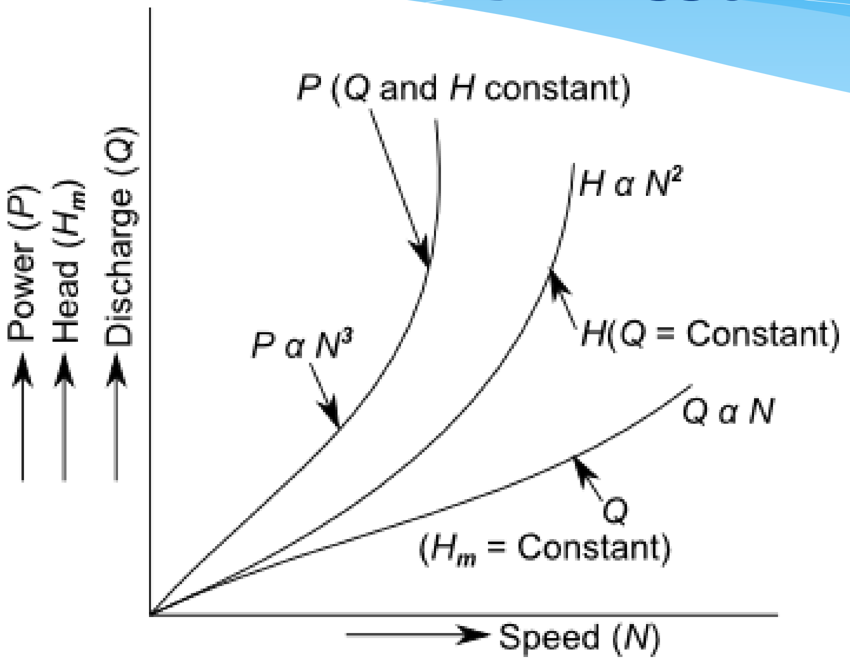
PUMPS AND BEHAVIOURS SPEED MODULATION

Pump Speed Modulation



PUMPS AND BEHAVIOURS- PUMPS SELECTION

Affinity Law APPLICABLE FOR VARIABLE HEAD WITH VERY LITTLE FIXED PRESSURE HEAD.



Main characteristics curves of a pump.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

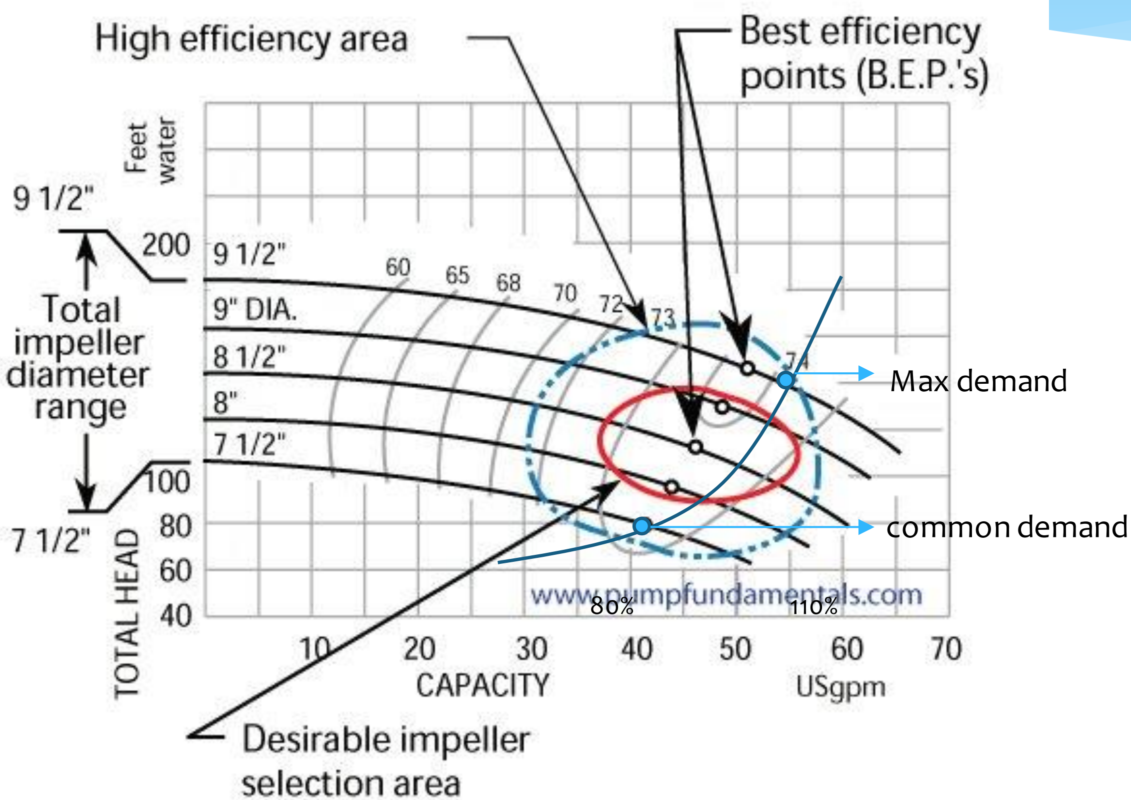
PUMPS SELECTION AND CONFIGURATION

A) PUMP CURVES (ALREADY DESCRIBED ABOVE)
B) PUMPS IN SERIES
C) PUMPS IN PARALLEL
D) NPHS CRITERIA
E) POSITVE DISPLACEMENT PUMP

PUMPS AND BEHAVIOURS- PUMPS SELECTION

ONE PUMP APPLICATION-

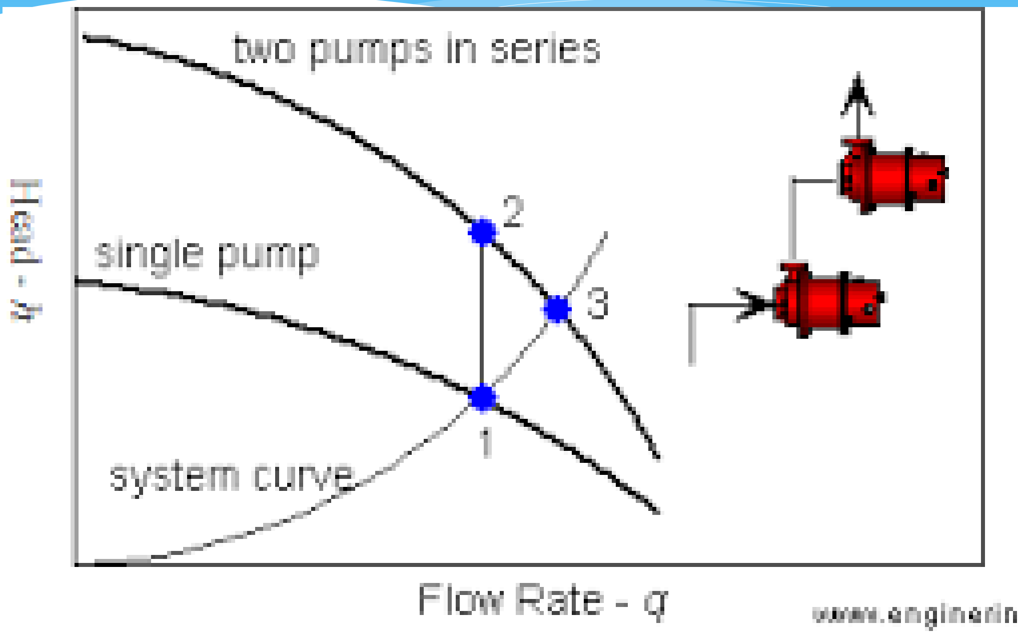
Choosing Pump at best efficiency point for most common (and not highest) demand say for cold water application booster pump where pressure at outlet is allowed to be changed slightly.



This means choosing a pump such that the BEP point of the pump curve falls on the most common load, sacrificing the performance at the peak demand.
Also if possible ensure that pump chosen works at zone that lies between 80 to 110% of BEP in order to avoid cavitation.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

Pumps Connection Series

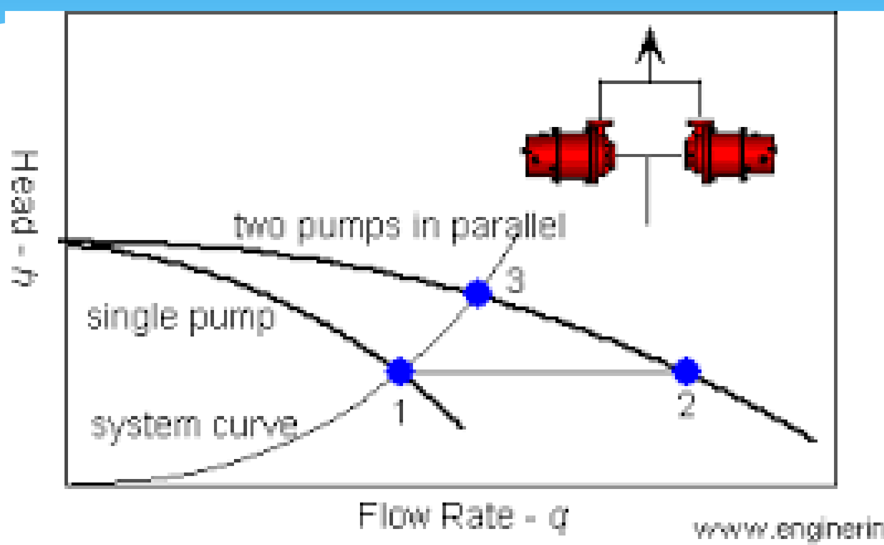


When 2 pumps are connected in series, the pump curve is the summation of 2 indvidual pump curves, with the total head of h2= h pump 1 + h pump 2 for a fixed flow rate q1 where h pump are head for individual pump at flow rate of q1. However due to system curve, the new flow rate is now higher with a lower head achieved with 2 pumps running in series.

This system is used when the pump head requirement is very high and cannot be met using one pump or when 2 pumps selection are more efficient than one pump selection at the specified flow rate and head. Energy efficiency and cost comparison is carried out for selection of most cost effective and efficient system with acceptable breakeven time period.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

Pumps Connection Parallel



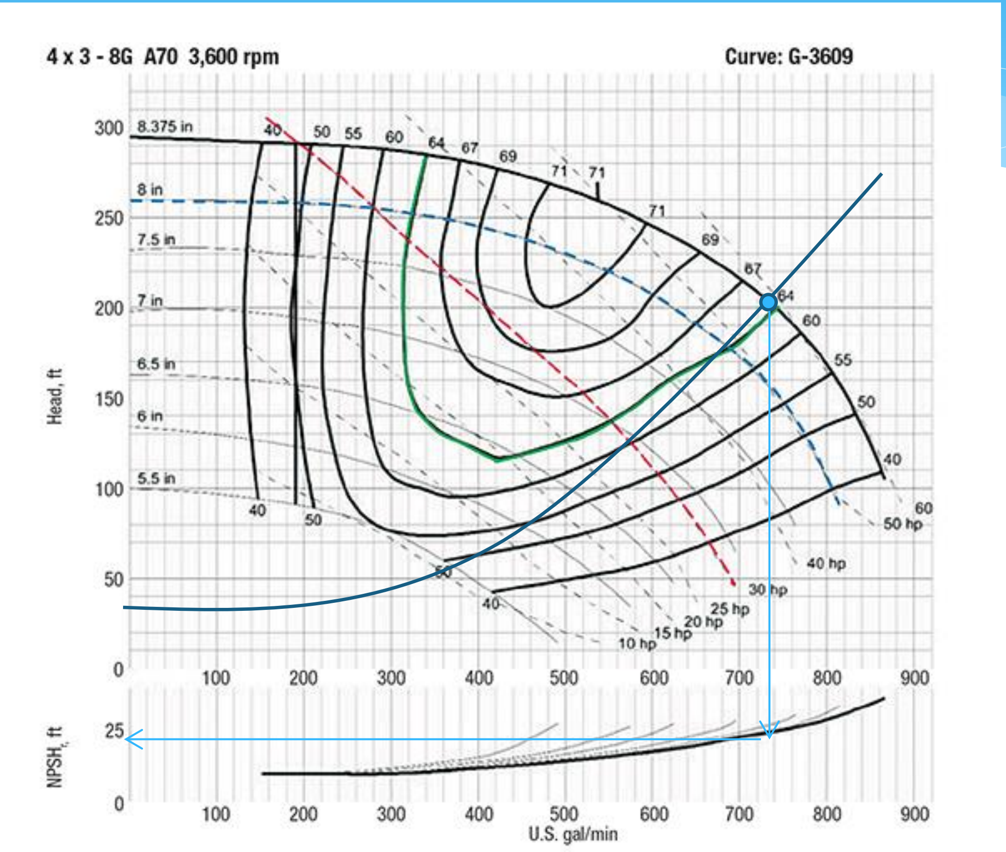
When pumps are connected in parallel, at the fixed head of h1, the flow rate q2 = q pump 1 + q pump 2, where q pump is the flow rate of individual pump at head of h1.

However due to system curve effect, the new operation point is at lower flow rate and higher head.

This configuration is quite commonly used when the pump flow rate is very high. A comparison in terms of energy efficiency is carried to out to evaluate whether a single pump or 2 pumps or even 3 pumps in parallel are most efficient versus the capital cost investment. Works best for flat system curves.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

Net positive suction head requirement



At operation point, net positive suction head requirement can be read off the graph.
Calculation of net positive suction head available is done.
Net positive suction head available > net positive suction head required + 0.5m head to avoid cavitation problem.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

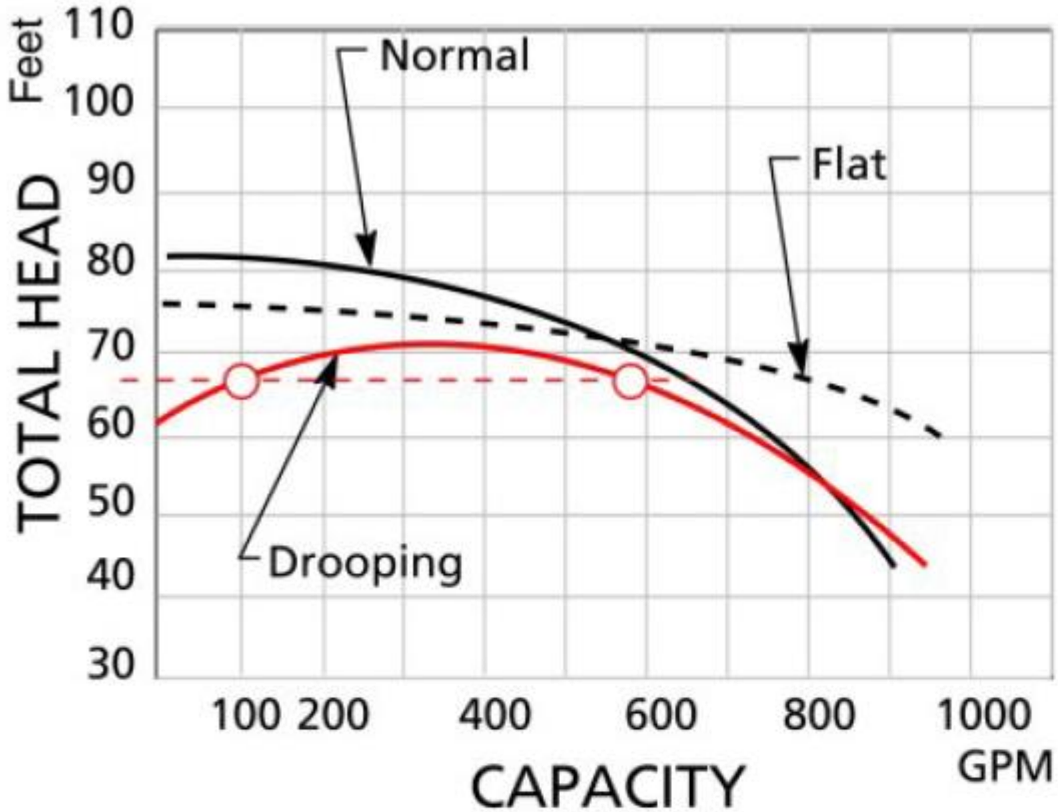


Figure 12 Different types of radial pump characteristic curve profiles.

- Flat pump curve is desirable when the flow can vary but pressure remains almost constant such as sprinkler application

PUMPS AND BEHAVIOURS- PUMPS SELECTION

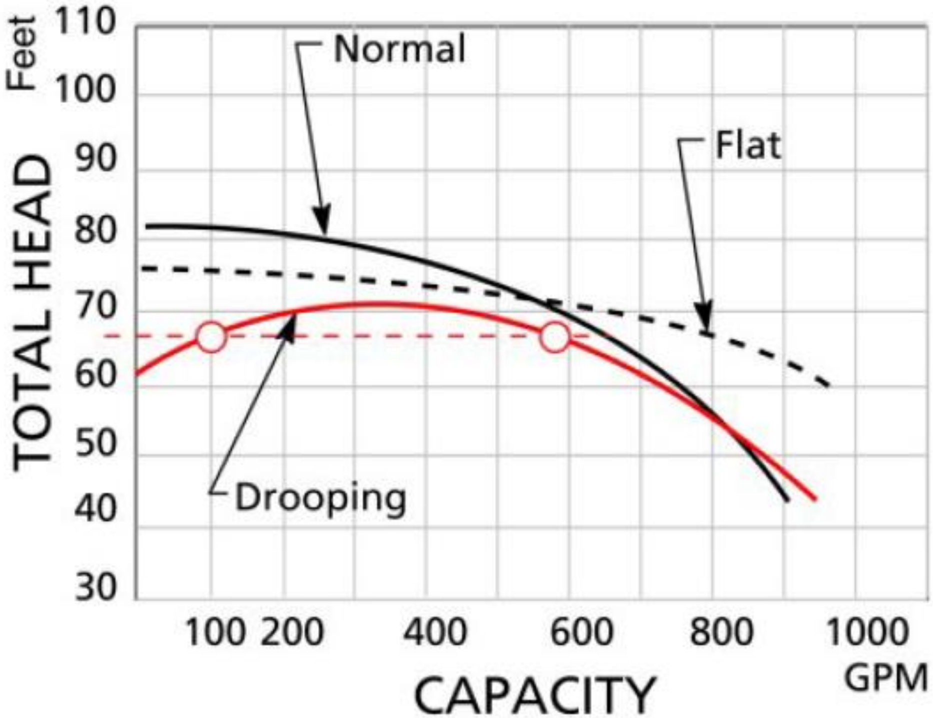


Figure 12 Different types of radial pump characteristic curve profiles.

- If pressure is maintained by prv and pump is running continuously, a flat pump curve would be more efficient than normal pump curve.
- If **pressure switch** control need to be used to sequence the pump, normal curve would be better, ie need higher pressure differential for different flow rate.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

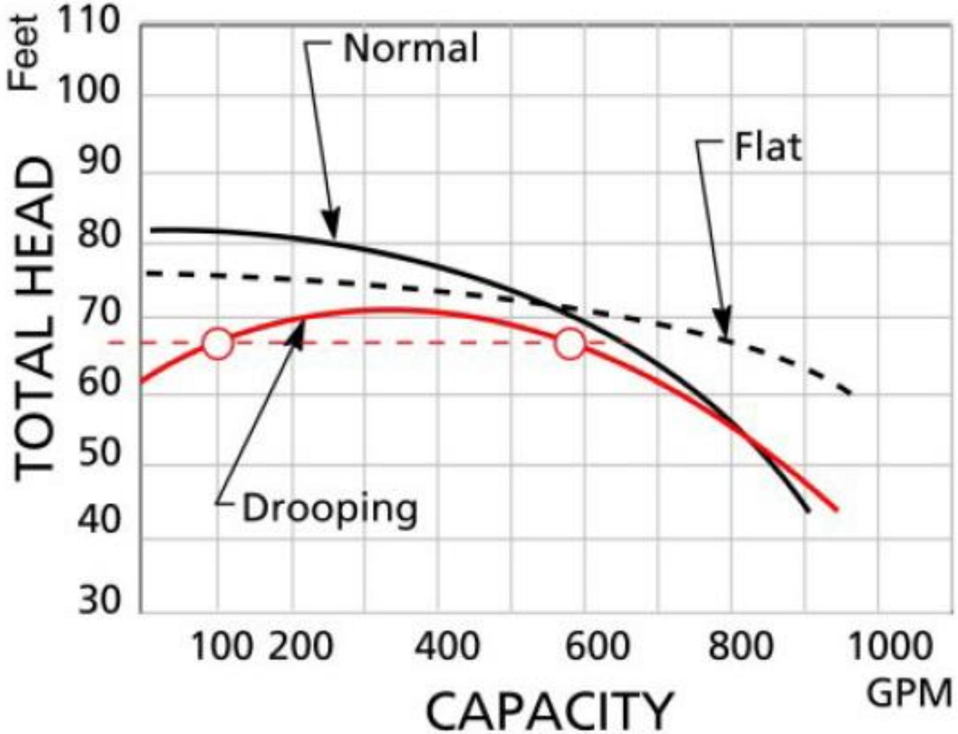


Figure 12 Different types of radial pump characteristic curve profiles.

- For flat pump curves in prv pressure booster system with hydropneumatic tank, pressure switch need to be replaced by **flow switch for pump sequence control as the pressure changes is minimal.**

PUMPS AND BEHAVIOURS- PUMPS SELECTION

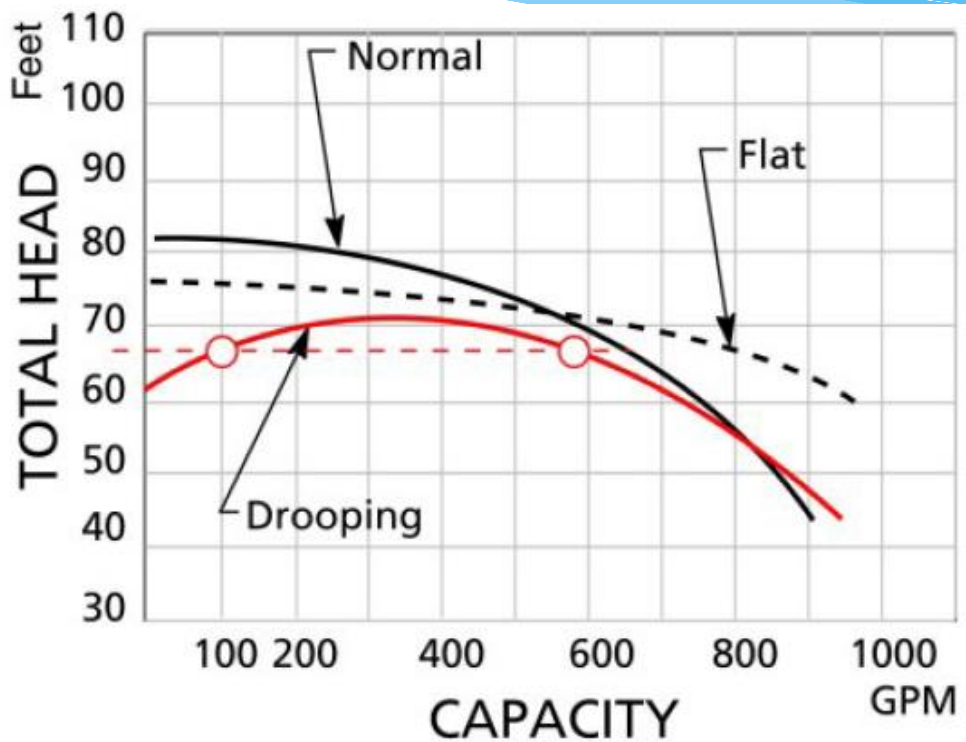


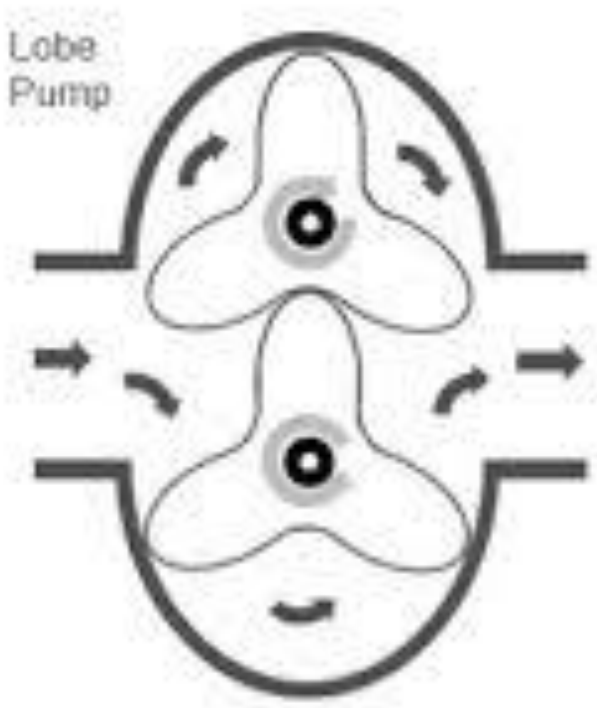
Figure 12 Different types of radial pump characteristic curve profiles.

- For VSD control, always choose a normal or steep pump curve to max the power saving.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

PUMPS SELECTION AND CONFIGURATION

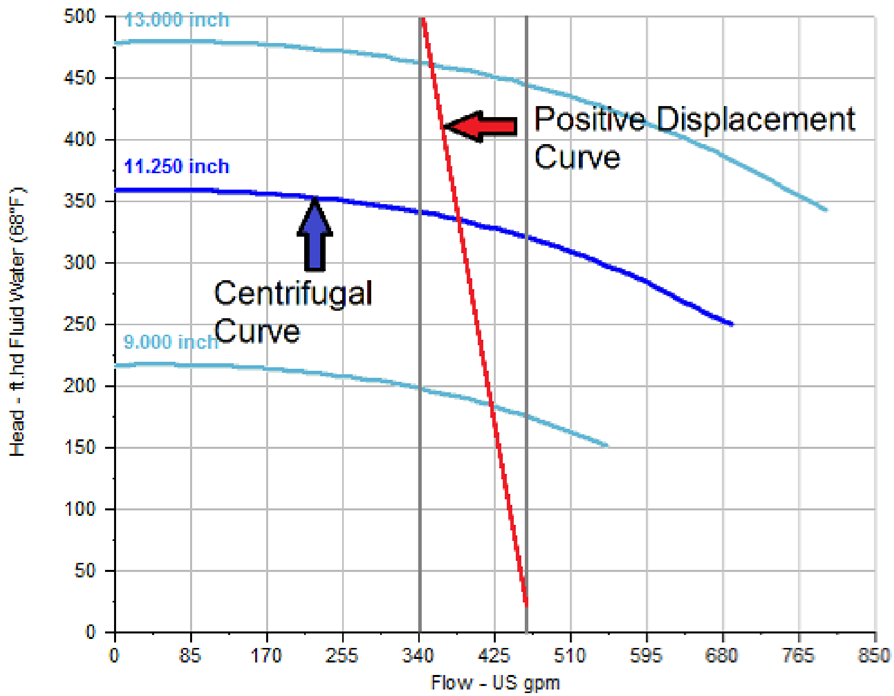
Positive displacement pumps Centrifugal Pump Versus



PUMPS AND BEHAVIOURS- PUMPS SELECTION

PUMPS SELECTION AND CONFIGURATION

POSITIVE DISPLACEMENT CURVE VERSUS CENTRIFUGAL PUMP

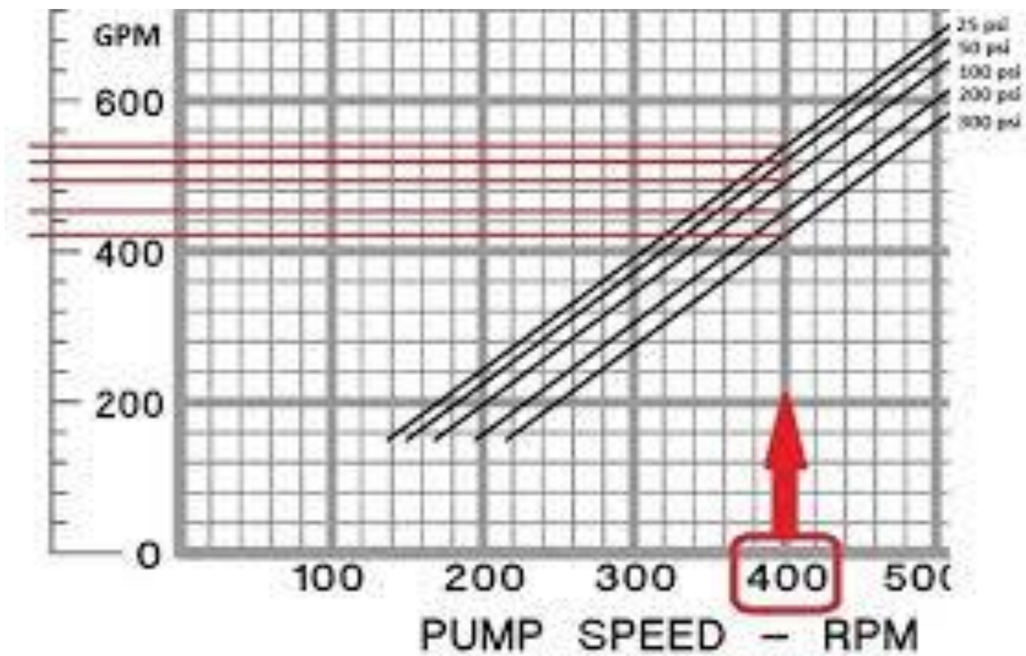


Positive displacement pump curve is very steep compared to the flat centrifugal pump curve.
Flow rate is directly proportional to speed.
Flow rate does not change much with lift/ pump head.
POSITIVE DISPLACEMENT PUMP DOES NOT FOLLOW AFFINITY LAW.

PUMPS AND BEHAVIOURS- PUMPS SELECTION

PUMPS SELECTION AND CONFIGURATION

Positive displacement pump curve

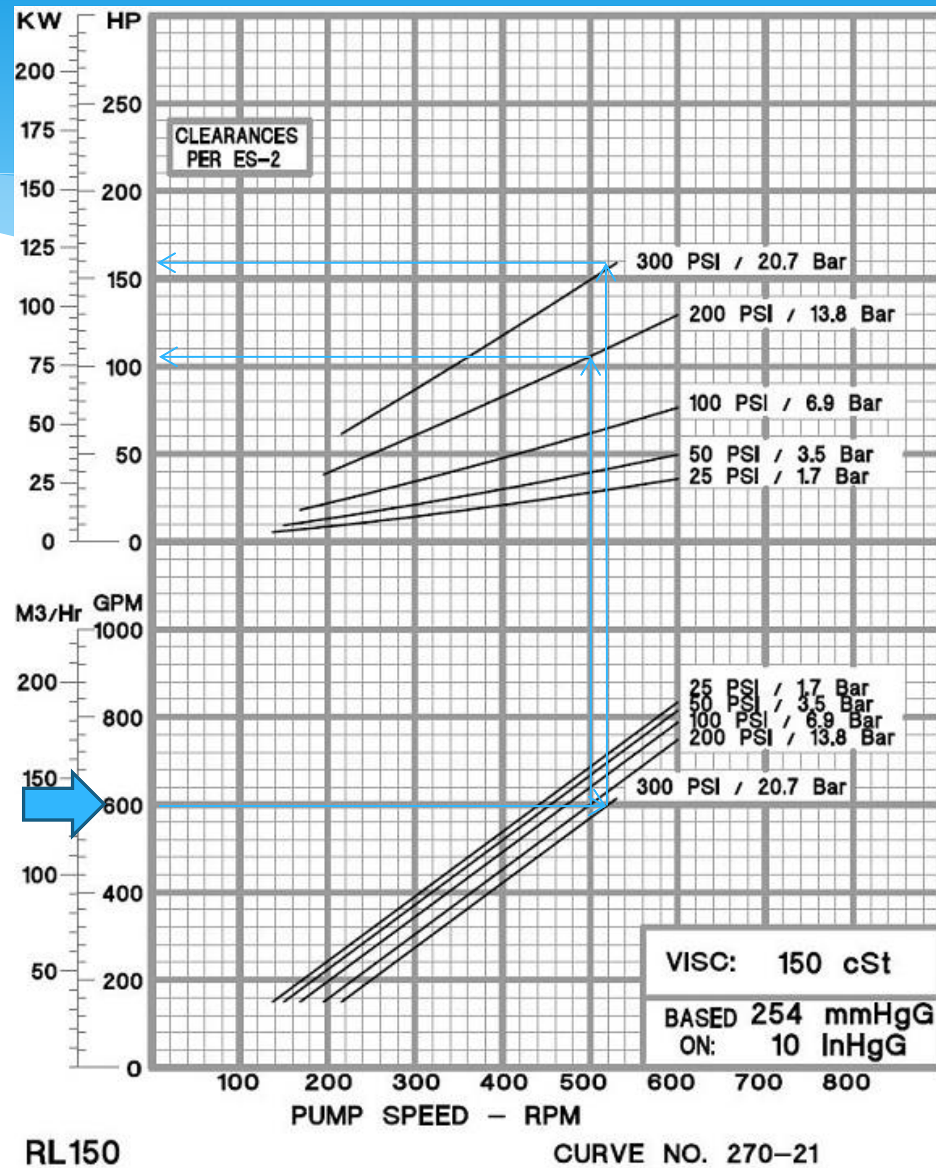


Flow rate is directly proportional to speed. Normally flow rate is plotted against speed. For a certain flow rate and pressure, the speed of pump can be selected. Affinity law is not applicable

PUMPS AND BEHAVIOURS- PUMPS SELECTION

When to choose positive displacement pump?

a) When pressure head is very high
b) When flow rate is constant but pressure can vary substantially due to changes in system such as clogged nozzle, etc
c) When pumping high viscosity fluid
d) When viscosity of fluid changes due to temperature change
e) When high suction head is required of the pump
f) PD pump generally more efficient than Centrifugal pump for varying pressure



Note: →
Flow rate is constant, pressure is increased, pump rpm does not change much but the power input increases.

PUMPS AND BEHAVIOURS- SUMMARY

* Summary:-
* There are 2 types of pumps, centrifugal and positive displacement pump.
* Cavitation occurs when NPSH available is less than requirement of the selected pumps.
* When cavitation is encountered at site, it can be fixed by ensuring no air pocket in suction pipe (by using eccentric reducer), having a larger and shorter suction pipe, cleaning the incoming strainers, avoiding having bends and fittings too close to pump suction, adjusting/lowering the flow rate by using the throttle valves or limiting the maximum speed of vsd drive.

PUMPS AND BEHAVIOURS- SUMMARY

- Summary:-
- Pump head consists of friction loss and static requirement for lifting purpose and across control valve.
- For variable flow rate, when system head consist mostly frictional loss, VSD with steep pump curve would be most ideal, ie system curve starts close to zero pressure head at zero flow.
- For variable flow rate, when system head consists mostly static head, ie system curve starts at high head at zero flow, VSD is not suitable. It would be better to choose pumps with flat pump curve and install constant pressure valve which more commonly known as cycle stop valve with small bladder tank.

PUMPS AND BEHAVIOURS- SUMMARY

* Summary:-
* Where exact flow rate is not important like water transfer pumps between suction and elevated tank located in vicinity of each other and most of the system head is static, constant speed pump is preferable with pump start stop sequence from tank level switches. If static head from water column above pump and flow rate is very high, preferably a soft starter (with adjustable ramp for starting and stopping) should be installed to avoid sudden back pressure during pump stopping, slamming the check valve.

PUMPS AND BEHAVIOURS- SUMMARY

* Summary:-
* Where exact flow rate is not important like water transfer pumps (pumping water from suction tank co-located with the pumps to elevated tanks some distances away) and friction is substantial apart from static, it is still better to have the system operates on the original pump curve rather than speed modulation, such that pump operates at BEP point most of the time. Pump control should be start stop via flow switch or pressure switch as level switch cables would be too long to be pulled. Altitude valve can installed near the end for elevated tank.

PUMPS AND BEHAVIOURS- SUMMARY

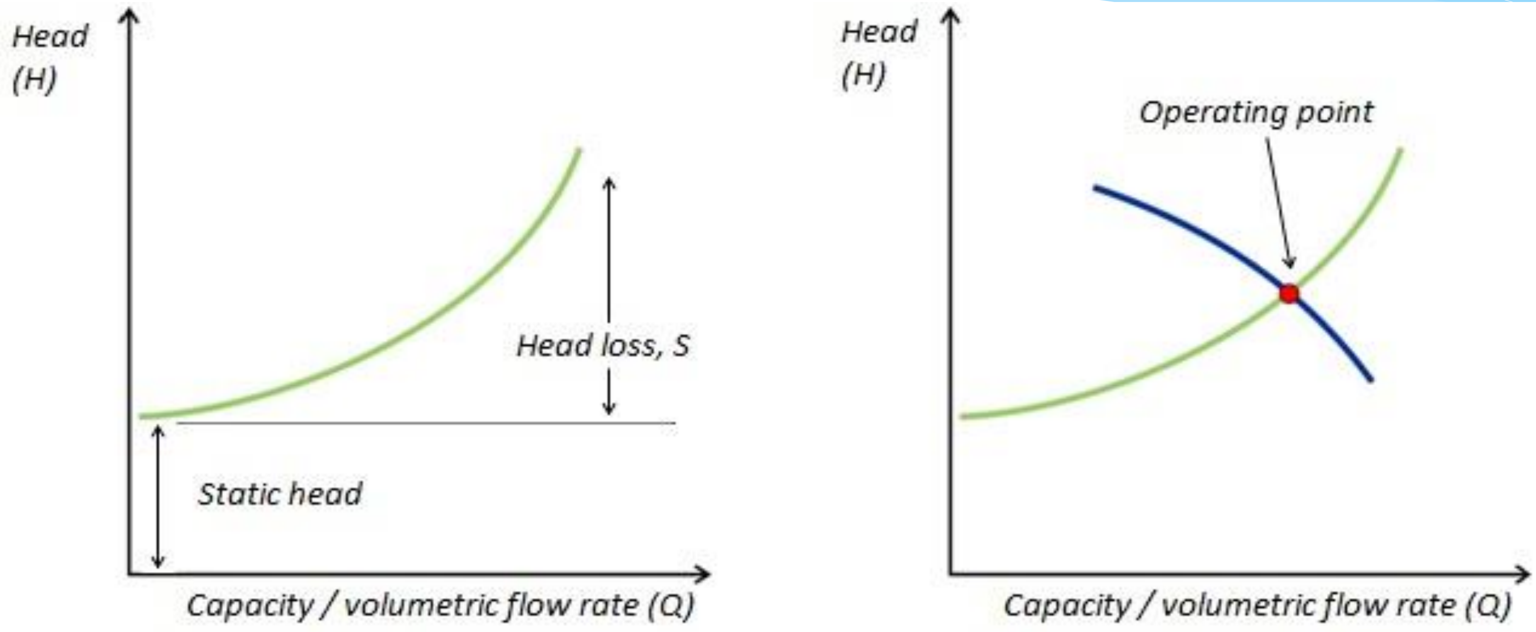
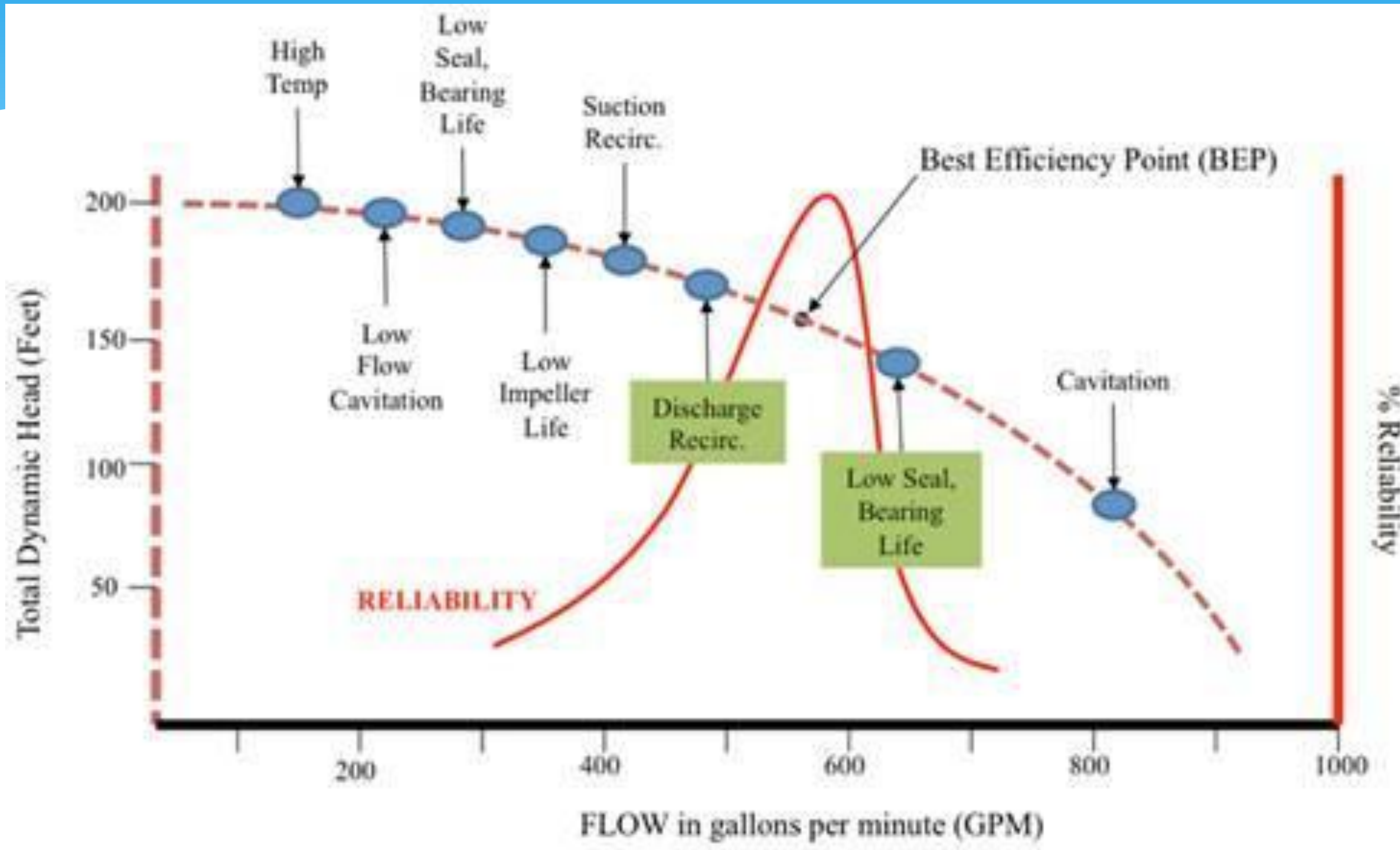


Figure 2. (a) System curve; (b) combining system and pump curves

PUMPS AND BEHAVIOURS- SUMMARY



RECOMMENDED PUMP OPERATING ZONE CORRESPONDS TO 80-110% BEP (BEST EFFICIENCY POINT)

PUMPS AND BEHAVIOURS

THANK YOU

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