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A Primer on Pumps on HVAC

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Pumps are used to produce water flow in pipe lines. The prime mover is either an electric motor or an air motor (run by compressed air) or an oil/diesel engine, most common being the electric motor. Pressure energy added by the pump is used to:

- Raise the water to a higher elevation. The height is known as "Static Head" and it does not depend on the rate of flow.
- Overcome the friction caused by the flow through the piping, fittings and valves. Frictional losses are variable losses and are proportional to the length of pipe and the square of the water velocity. This is known as "Dynamic Head". This head is related to flow and so, when specified, is valid for a particular flow rate. If flow is increased in a particular pipe diameter, the water velocity increases (directly proportional to the flow) and the frictional losses increase as the square of the velocity. The reverse happens when pipe diameter is increased.

Types of Pumps

Pumps are classified either by their construction like Monobloc, Coupled, Split casing, Back Pull-out or by the axis like Horizontal or Vertical or by their motion like Reciprocating or Rotary or by the number of stages like Single Stage or Multistage. In addition there can be classifications on the basis of liquids to be handled like clear water or slurry or chemicals.

- Monobloc pumps are the most optimised pumps in the form of material content and compactness. The pump casing is mounted directly on to the motor end shield, the motor shaft is extended and accommodates the impeller. As these are mainly used in agricultural applications even the tax structure helps in keeping the cost down. The only disadvantage being the noise level due to high speed and the difficulty in servicing. As most of the models in this type run at 2900 RPM, (since higher speed motors are compact and economical) the noise and vibration level is high. Motors of these pumps cannot be removed for servicing without disturbing the piping.

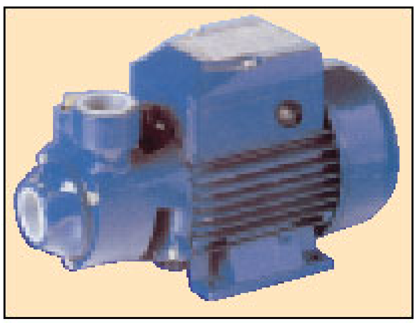

Figure 1 : Monobloc Pump

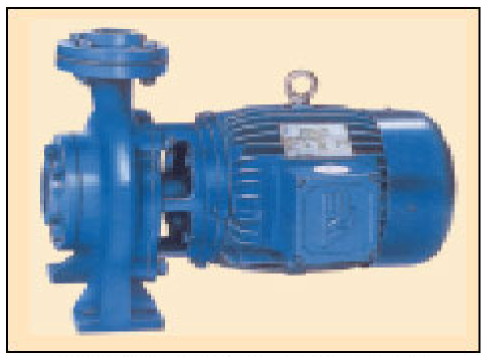

Figure 2 : Back Pull-out Pump

- The difficulty of service is taken care off by modifying the design to Close Coupled or Back Pull-out type pumps. In these pumps the motor can be removed for servicing without disturbing the piping. In these types of pumps it is possible to obtain models with 1450 RPM motors.
- In the case of Split Casing pumps, the pump casing is split and then bolted together. It not only facilitates servicing but also allows the easy removal and refitting of the impeller. These pumps are coupled with motors and are mounted on a common base frame.
- In Horizontal pumps of Monobloc or Back Pull-out type the impeller weight is overhanging and even microscopic bending causes vibration which increases the bending further. This has a cumulative effect and thus deteriorates the performance over a period of time. Some manufacturers opt for stainless steel shaft to take care of this deficiency. Consultants and users on the other hand tend to specify 1450 RPM instead of 2900 RPM for the same purpose. Use of Vertical pumps do away with this disadvantage and the pump can be run at 2900 RPM for a long time without any

fear of bending of the shaft. Vertical pumps also save space and the cost of a foundation. With a higher speed the motor becomes more compact and economical.

- Reciprocating pumps are positive displacement pumps which are not used for circulation purposes. These pumps are mainly used for transporting liquids or slurries or for generating very high discharge pressures.
- Multi-stage pumps use multiple impellers to produce high head and are used in hydro-pnuematic systems and fire fighting applications. In HVAC these pumps are very rarely used as the heads encountered are very easily possible with single stage pumps.

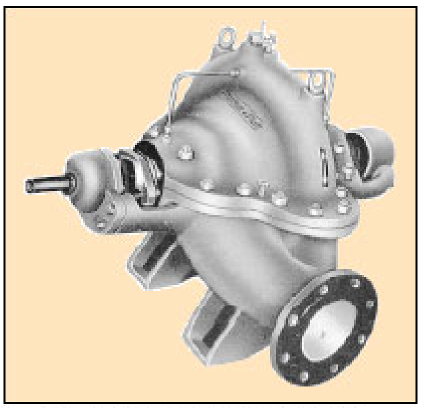

Figure 3 : Split Casing Pump

Figure 4 : Vertical Pump

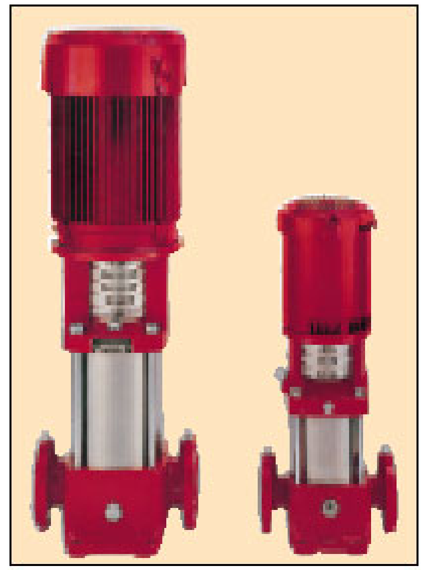

Figure 5 : Vertical Multi-stage Pumps

Materials of Construction

In most of the pumps the casing is made of Cast Iron. This material gives the designer flexibility with adequate strength and hardness. For special applications like chemicals, the material can be Stainless Steel or even Polymeric. For very small circulators, die-cast Aluminium is used for the casing. Impeller material can be Cast Iron, Bronze, Stainless Steel or Polymer. Bronze is the most common material for the impeller for a long, trouble free life. The shaft is another member where material plays an important part. Popular choices are EN-8(standard Shaft Steel) or Stainless Steel 410, the second being obviously better.

Sealing (to prevent water flowing towards the motor) is done either by a Gland Packing or by a Mechanical Seal. A gland packing requires some water leakage to cool the glands. Mechanical seal pumps are expensive but they do not allow water to drip. In HVAC application, the use of mechanical seal pumps is recommended for chilled water lines because dripping of chilled water means loss of energy. Also use of pressurised expansion tank necessitates the use of mechanical seal pumps because leakage will mean loss of pressure. The seal should be thermally stable up to at least 0°C so that the lapped surfaces of the seal do not warp at the chilled water temperature and allow water to drip. For cooling tower water circulation gland packing can be used.

Pump Laws

Pump laws relating to flow rate, head and energy are as follows :

- Flow is proportional to Speed as well as Impeller Diameter
- Flow is proportional to square of the Head
- Flow is proportional to cube of Energy

Thus if a pump is selected for 25% excess flow, it would be encountering 56% excess head (square of 1.25) and consume 95% excess energy(cube of 1.25).

Pump Curve and System

Curve Head v/s Discharge flow curve for the pump and the system curve is as shown in **Figure 6**. The intersection point is the operating point.

Pumps for HVAC

In HVAC applications, pumps are used for circulation of chilled water and condenser water and hence the pumps have to take care of only frictional losses of the pipes, valves and coils. However in the case of cooling tower water circulation, the cooling tower height is the static head, in addition to the frictional losses. So for a cooling tower, the system curve will start at about 3m (height of cooling tower) on the Y axis.

Generally, frictional losses of terminal units/ chiller/condenser are around 3 m (of water column) at the rated flow. Frictional losses in the pipes depend on water velocity and are controllable (by choosing a lower velocity these can be reduced). Normally these are around 5% of the pipe length. Thus the total head which the pumps have to encounter is fairly low, requiring low head/high discharge pumps.

For large installations, Horizontal Split Casing pumps running at 1450 RPM and for medium and small installations Circulators (Vertical Inline pumps) are an ideal choice.

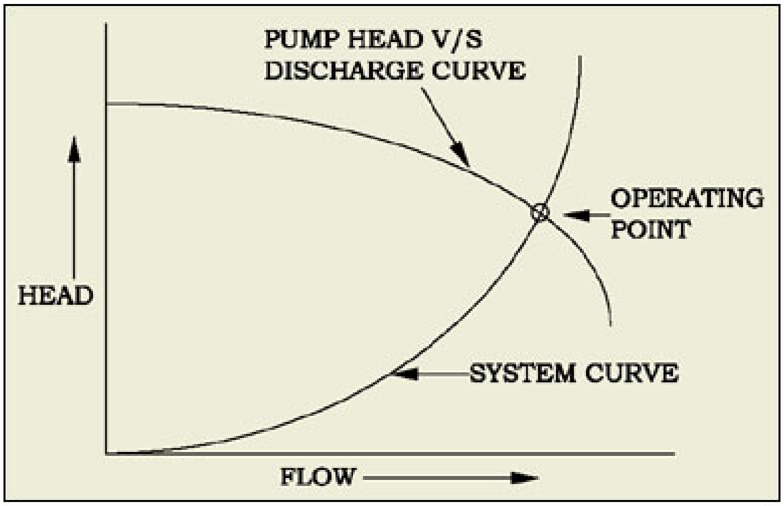

Figure 6 : A typical Head v/s Flow curve for a pump

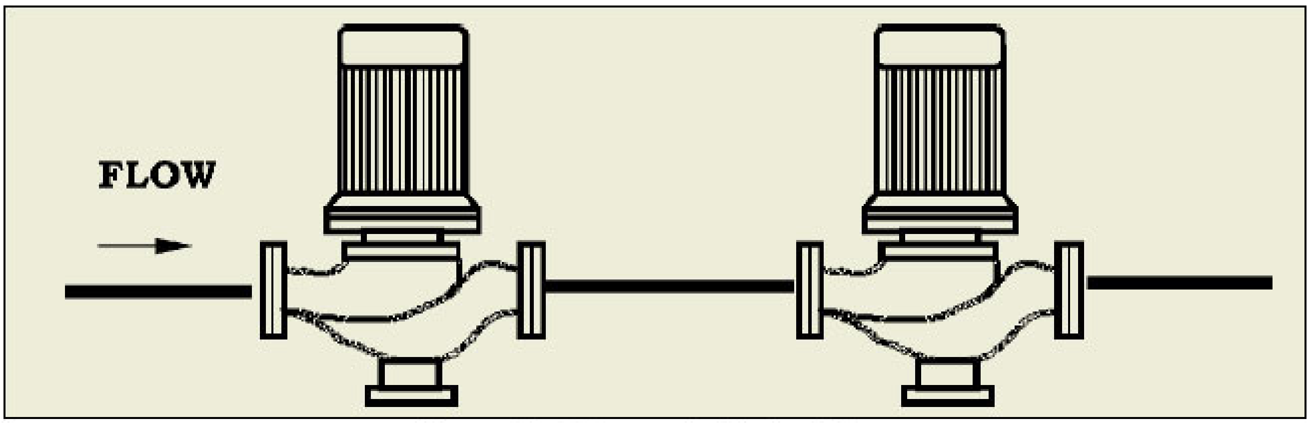

Figure 7 : Pumps in Series Flow

Pumping Systems

Pumps can be used in :

- Series : Where the flow through the pumps is the same but the head generated gets added.
- Parallel : Where the head generated is the same but the flow gets added.
- Primary/ Secondary : Where the flow through a chiller is by primary pumps and distribution by secondary pumps. This system allows variable flow through the distribution network keeping the flow through a chiller constant.

Flows/Heads in HVAC

In a chilled water system, water is circulated through a chiller, pipes, valves and terminal units (FCU or AHU) by pumps. The flow rate for chilled water is derived by considering a fixed temperature differential across the coil/chiller. The design figure for this differential is normally 5°C (9°F) to 5.5° C (10°F). Corresponding to this differential, the flow through the coil/ chiller comes to 10 lit/min/TR (2.6 USgpm/TR) to 9 lit/min/TR (2.4USgpm/TR). For cooling tower water circulation, the flow is about 25% more as the energy (motor power) spent in cooling also gets rejected in the cooling tower. So flow for a cooling tower would come to 12.5 lit/min/TR (3.3 US gpm/TR) to 11.25 lit/min/TR (3 US gpm/TR).

The head encountered in chilled water lines ranges from 20 m to 30 m and for cooling towers 16m to 20 m depending on piping lengths and water velocities.

Pump Selection

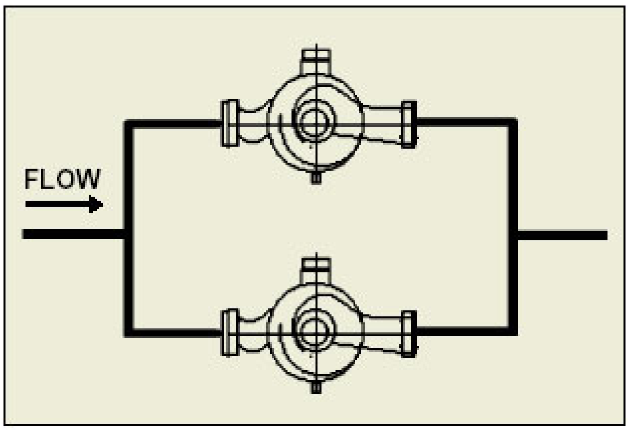

Figure 8 : Pumps in Parallel Flow

The following steps are recommended for selection of pumps for HVAC application :

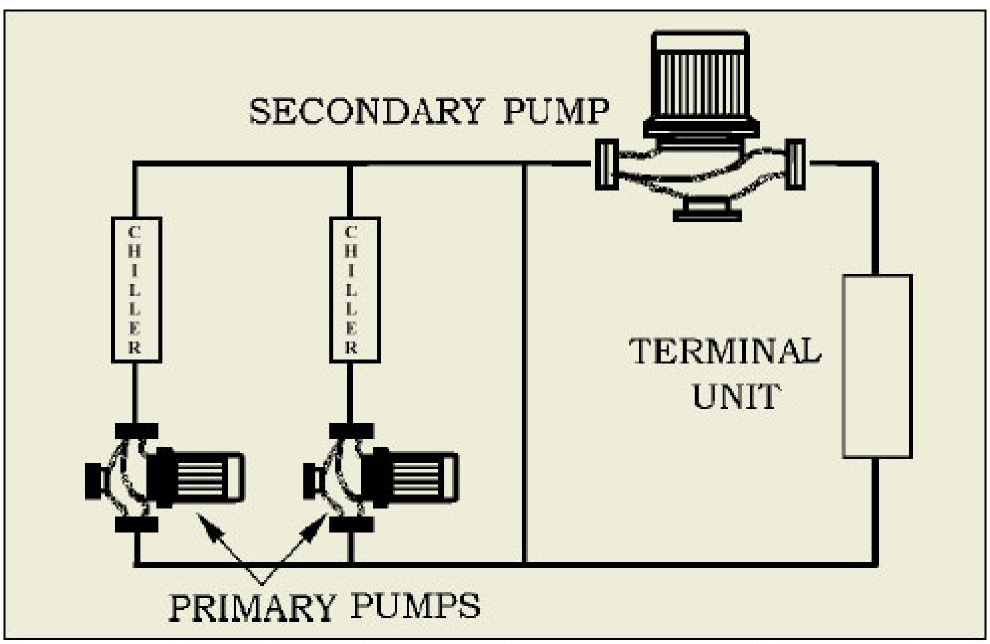

Figure 9 : A Primary and Secondary Pumping System

- Select type of pump i.e. Horizontal or Vertical.
- Finalise the system (Primary and Secondary or otherwise).
- Calculate the required flow and head.
- Select the pump from the manufacturers head/discharge table or curve.

- In case of multiple pumps, check an alternative selection by reducing or increasing the number of pumps. Compare the two alternatives and choose the better one.

Example

Cooling tower water circulation.

Option1– 15 hp

(1 Working +1 Standby).

Option 2 – 5 hp

(2 Working +1 Standby).

The second option gives the benefit of lower connected hp, lower power consumption, use of DOL starters (because of lower hp) and possibility of running one pump at the time of low wet bulb temperature or partial load.

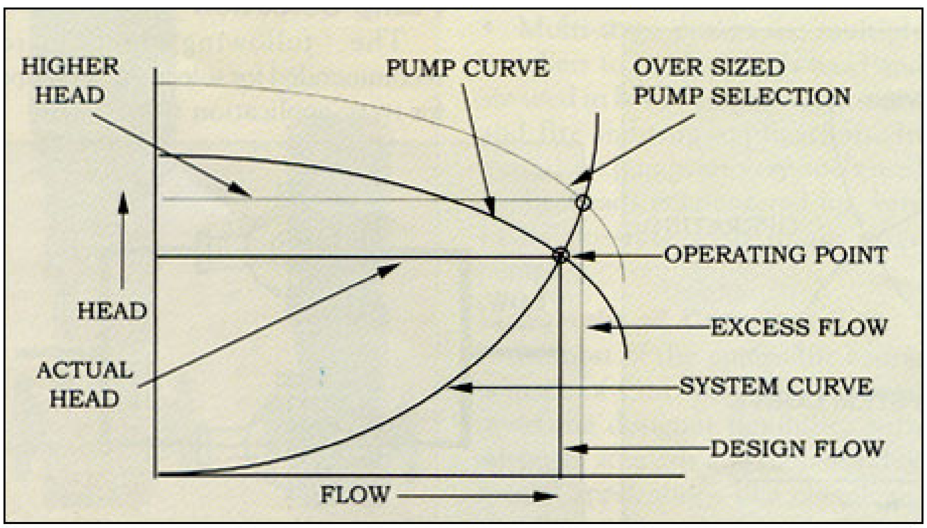

Figure 10 : Head v/s Flow curves for optimised pump selection

Energy Conservation

It has been observed that many of the old installations have oversized pumps. There are many possible reasons for this, such as :

- Low electric tarriff at the time of installation.
- Higher factor of safety considered.
- Expansion plans which did not materialise.
- Higher velocities assumed for calculation of head.
- Pipe sizes rounded of to higher sizes and effect on head not taken into account.

With high electricity tariffs prevailing today, it is worthwhile undertaking this activity of optimisation of pumps for energy conservation. This has been successfully carried out at :

- Nicholas Piramal where 10hp pump (2 nos) have been replaced by 3 hp (2 nos) Vertical Inline pumps.
- BSES, Marol where cooling tower pumps of 15 hp (1W + 1S) were replaced by 5 hp (2W + 1S) Vertical Inline pumps.
- Fariyas Hotel where 10 hp (6 nos) have been replaced by 5 hp (6 nos) Vertical Inline pumps.

In all cases the payback period was very attractive. For optimisation or reselection the following steps are recommended :

- Check the suction/discharge pressure of the pumps and find out the actual head.
- From the pump curve find out the actual flow corresponding to this head. In most of the cases this flow is in excess of design figures mentioned above.
- For design flow as mentioned above, calculate head from pump laws.
- Select the pump for design flow and calculated head.