CHAPTER - 9

PRACTICAL APPLICATIONS

9.1 A VERTICAL OR A HORIZONTAL PUMP ?

In the design stage itself the question, "Should a horizontal or a vertical pump be used?" must be asked. Generally the type of pump is dictated by various factors and there is simply no choice between them. A good example of this is the vertical turbine or the submersible pump used for pumping water from a deep well. However, there are many cases where we can either go for a horizontal or a vertical pump. In such cases we should consider the advantages of one type over the other so that an optimal choice can be made. It is a mistake to make any inflexible rules about the selection of horizontal and vertical pumps. Each application must be studied thoroughly before a decision is made.

Different areas that should be given consideration are discussed below:

9.1.2 SPACE REQUIREMENT

A vertical pump requires less area, and if space is limited a vertical pump would be more suitable. On the other hand a horizontal pump requires less room head than a vertical pump. Therefore in general we should consider the vertical pump when available area is critical and the horizontal pump when room head is critical.

9.1.3 PRIMING

When the level of the water to be pumped is below the floor level, no special priming equipment is required for vertical turbine pumps, but for horizontal pumps some priming arrangement is required. The possibility of using horizontal pumps with positive suction conditions should also be looked into as it eliminates priming problems.

9.1.4 NET POSITIVE SUCTION HEAD

In order to avoid cavitation $NPSH_A \geq NPSH_R$. For a given set of conditions the $NPSH_A$ increase as the water level over the impeller increases or if there is a suction lift the $NPSH_A$ increases as the lift is decreased. With vertical pumps as noted earlier, the suction lift is eliminated and sufficient submergence can be provided by lowering the depth of pump installation. In contrast, a horizontal pump has its suction lift or submergence fixed by the plan layout. When $NPSH_A$ is extremely low, a vertical pump is usually preferable.

9.1.5 CORROSION AND ABRASION

The high costs of down time and repairs on pumps due to corrosive and abrasion applications are well known. A good example are the vertical turbine pumps at Kurunegala intake. Generally in vertical turbine pumps bearings are lubricated by the liquid being pump. This is a disadvantage when compared with horizontal pumps where bearings are completely isolated from the liquid being pumped and are grease or oil lubricated. However materials are available that resist corrosion and abrasion but generally vertical turbine pumps are more expensive than a horizontal pump made out of the same materials.

9.1.6 FLEXIBILITY

When changes in pumping systems are anticipated because of plant expansion or transfer of the pump to a different application, it is relatively easy and inexpensive to add or remove stages from a vertical turbine pump in order to meet new system conditions.

The horizontal pump is limited in this respect and a new pump would be required if the minimum and maximum diameter impellers are not suitable for the new application.

9.1.7 INSPECTION AND REPAIR

Horizontal pump is far more simple and accessible for inspection, maintenance and repair than a vertical pump. To inspect a bowl in a turbine pump, the motor, the discharge base, column pipe, drive shafts should be removed. In contrast in a horizontally split casing pump, the rotating element can be inspected and removed if necessary very easily. Neither the motor nor the piping need be disturbed. The case is the same for vertically split centrifugal pumps.

9.2 PERFORMANCE OF SUBMERSIBLE MOTORS, PUMPS AND BORE HOLES

9.2.1 SUBMERSIBLE MOTORS

Submersible motors are designed to do the job under water, once regarded as impossible for any motor. Therefore they are extraordinary. However, according to the authors experience there had been several submersible motor failures though we (NWS&DB) do not have proper statistics. One example is the Ruwanwella Water Supply Scheme, where several submersible motors including newly installed ones have failed. Malwana Water Supply Scheme is another example. These failures are due to various reasons like lightening, insufficient cooling, lack of protection, voltage drops etc.

The manufacturers of submersible motors say that the reliability of a submersible motor performance is directly related to its installation.

Following key points are highlighted as indicated by leading submersible motor manufacturers to get the maximum performance from submersible motors and prevent failures.

* **Power Supply**

  Like other motors submersible motors require correct input voltage and frequency. Voltage variations upto 10% is normally allowed.

* **Over load Protection**

  Characteristics of submersible motors differ from standard motors and special overload protection is required. If the motor is stalled, the overload protection must trip within approximately 10 seconds to protect the motor windings. When using 3 phase submersible motors it must be provided with extra quick trip protectors which are of ambient compensated type. Ambient compensation is necessary to provide adequate locked rotor protection at low temperatures and avoid nuisance tripping at high temperatures.

* **Surge Protection**

Submersible motors are vulnerable to surges if not properly protected. A damage can occur when on surge creates a momentary high voltage spike from one or more of the supply lines to the ground. This can happen due to nearby lightning stroke. If the voltage spike is higher than the systems insulation can withstand it will arc to ground at the weakest point. If the point of arcing is in the motor the motor may fail immediately or be weakened. Therefore it is very important that all submersible pumps should be provided with surge arrestors. Proper grounding of the arrestor is a must, without it, the arrestor may give the motor no protection at all.

* **Supply Cable**

Cables for submersible motors must be suitable for underwater operation, and properly sized to operate within rated temperature and maintain adequate voltage at the motor. Connections to the motor must be clean dry and properly tightened. Cable joints (if any) should be water proof. A leaky or high resistance joint will eventually fail. Cable should be properly fasten to the pipes to avoid damage during installation or from rubbing during operation.

* **Frequency of Starts**

The number of starts per day over a long period influences the life of the motor and even more the life of control components such as starters. Therefore when sizing pumps, tanks etc. care should be taken to minimise the number of starts per day.

* **Cooling**

Submersible motors need circulation of the surrounding water to prevent overheating. When the pump is installed below the main fractures in the well. conditions can exist which reduces the rate of cooling water flow past the motor.

If the flow rate is less than the required flow inducer sleeve or an alternate method of increasing the water velocity past the motor must be used.

* **Non-return valve**

If the pump is not fitted with an in-built non-return valve, a non-return valve should be fitted to the discharge line within 7 metres of the pump. Immediate motor or pump failure or premature failure of either can be due to the following;

1. Back spin - When there is no non return valve or if the non return valve is defective, the water in the line will flow back when the pump stops. This can cause excessive wear in the thrust bearing.

2. Up Thrust - Under the same non return valve conditions the pump starts each time against no head, this creates an up thrust and lifts the rotor of the motor until the designed head in developed. Repeated up thrust at each start can cause wear and damage to pump and motor.

3. Hydraulic shock - If the lowest non return valve is more than 9m above the water level, when the pump stops the weight of the falling water column creates void below the non return valve. When the pump starts the next time, water moves at a high velocity and fills the void and strikes the non return valve causing a hydraulic shock. This can damage pump, motor and pipe joints.

(Source : Franklyn Motors 1988).

9.2.2 SUBMERSIBLE PUMP AND BORE HOLE

Reliability of the performance of the installation depends not only on the motor but also on well conditions and pump.

A submersible pump can handle only about 25 to 50 ppm of sand depending on the materials of construction. Therefore the well should provide sand free water to prevent damages to pump components.

The pump should be properly sized according to the diameter of the well. In other words the proper diametrical clearance should be maintained. Generally 25 to 50 mm is sufficient. Low clearances can cause installation problems and inflow of sand into the well. Proper yield tests should be carried out and only the possible amount should be specified to extract.

Before the installation of the permanent pump, the constructed well should be developed using another pump to ensure that the water is free of sand.

If pumps are operated at lower heads than the designed head, an upthrust is created due to the excessive flow of water. This can cause damage to the pump or motor.

If the pump is operated below the minimum submergence required by the pump, sucking of air and cavitation will result in causing damages to the pump. Therefore water level guards should be installed to protect the pump.

All submersible pumps and motors should be pulled out and serviced according to instructions given by the manufacturer annually.

9.3 REDUCING ENERGY COSTS

Energy conservation in a pumping station begins with the accurate information on system requirement and pump operating characteristics. It is a common practice in engineering to apply safety factors when determining flow and system head.

Consequently, to assure adequate flow and to overcome the safety factors systems are over designed. This leads to higher energy costs.

It is necessary to apply all available engineering skills, experience and available tools to minimise and improve the overall effectiveness of pumping stations. Due consideration should be given to the unit energy cost (kWh/m^3) and following areas should be studied.

* **Design stage**

In the design stage, accurate system flow and head requirements should be determined. Excessive safety factors should be eliminated. Care should be taken in selecting the type of pump and the pumping arrangement, such as primary, secondary parallel pumping or variable speed pumping. Also due consideration should be given to the total capital cost, operational cost, reliability, maintenance costs and operator confidence when specifying the equipment.

* **Selection of Pumps**

Pump efficiency varies with capacity and the type of pump. Higher the capacity, higher the efficiency. Pumping will not be efficient unless we operate the pumps at their best efficiency point.

It is necessary to check the effect of operating costs with different levels of pump efficiencies, by defining the relation between water demand and operating time.

Pump types can be ranked in terms of efficiency as follows;

1. **Centrifugal**
2. **Volute casing type mixed flow**
3. **Diffuser type mixed flow**

Therefore to make the pumping station efficient it is necessary to select the pump type and determine the pumping arrangement after studying the different levels of efficiency and the respective operating costs.

*	**Pump Characteristics and maximum Efficiency**

If the pumps are to be run at across a range of flow rates to meet the required varying demand then not only the planned duty point but also the range of high operating frequencies should be indicated in the specification.

In a system which experience substantial periodic demand changes, variable speed drives will reduce pumping costs. There are various choices of variable speed drives; Mechanical. Electrical and Fluid types. However variable speed drives are still new to the National Water Supply & Drainage Board.

*	**Valves and Fittings**

Valves and Fittings are directly related to the pumping efficiency of the pumping station. Therefore in selecting valves and fittings, care should be taken to select the proper size, type and with low losses.

*	**Electrical Facilities**

Energy efficient Motors, Transformers, and other electrical facilities should be used with appropriate power factor correction.

*	**Operation Control**

The overall energy saving in the pumping station can be checked by monitoring the variations in the quantity pumped and the power consumption. That is the variation in kWh/m^3 and corrective action should be taken if the power consumption rises above the acceptable level.

9.4 REPAIR OR REPLACE THE PUMP

First of all the author would like to mention that there must be a clear cut policy in the replacement of Electrical and Mechanical Equipment in the water supply schemes and a priority ranking should be done.

The factors that should be taken into consideration in priority ranking are;

* **Critical factors.**

  Hours of operation required per day.

  Amount of standby

  Availability of spares.

  Hours of operation available from machine

* **Condition factor**

  General condition

Then the equipment could be grouped into different priority levels for replacement.

However if you have an old pump and if you wish to find out whether you should repair it or replace. The answer will depend on the electricity cost.

Let us see the following example.

Assume the water power of the pump be P kW

Originally the pump efficiency 75%

At present the pump efficiency 70%

Therefore, present power requirement of the pump P/0.70 kW.

If the pump can be restored to its original condition by repairing then

Power saving would be (P/0.70 - P/0.75) kW

$$= 0.05 \times P/(0.70 \times 0.75) \text{ kW}$$

If the new pump to be purchased is more efficient and its efficiency is 80%.

Then power saving in buying a new pump would be

$$(P/0.70 - P/0.80) \quad kW$$

$$0.1P/(0.70 \times 0.80) \quad kW$$

If the motor efficiency is the same in both cases and is equal to 90% and the electrical charge is Rs.4.00 per kWh and the number of hours of operation per annum is 5000 hrs, then the annual cost saving would be as follows:

By Repair $0.05 \times P \times 50000 \times 4/(0.70 \times 0.75 \times 0.90)$ Rs.

$= 2116 \times P$ Rs.

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By purchasing a new pump $0.1 \times 5000 \times 4/(0.70 \times 0.80 \times .90)$ Rs.

$= 3968 \times P$ Rs.

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Where P is the Water Power in kW.

Hence in this case purchasing a new pump can save more money.

9.5 WEAR CAUSED BY SAND IN INTAKE WELLS

In some of our intake wells where vertical turbine pumps have been installed, pump wear caused by sand has become a problem. Two examples would be Kurunegala intake and Horana intake. Each year pumps at Kurunegala Water intake well have to overhauled twice or thrice causing unnecessary costs. At these in takes prevention of sand entering the well has become impossible due to the location of the well specially during floods. Therefore this problem should be anticipated at the design stage and lay down specifications to minimize this effect.

The following features should be noted to avoid wear in vertical turbine pumps.

* **Particle Size**

Rates of wear and the reduction in pump efficiency are affected by particle size. Particles that can not get into clearance between the rotating and stationary parts are not too serious but they cause wear to the pump fluid passage.

Particles of the same size as the clearance affects the initial wear on bearings and shafts. These particles get wedged between the mating parts and cause wear due to the grinding action.

Smaller particles pass through the clearances and cause wear due to erosion.

In practice particles of range sizes enter the pump and cause rapid wear if the pump is not designed to handle different particle sizes.

Wear causes deterioration of the pump hydraulic performance. The immediate effect is the reduction of total head developed causing loss of capacity with the resultant loss in pumping efficiency.

This loss is due to the wear in wear-ring. The deterioration of performance is compounded by the wear of bearings and shafting. As bearings wear rotating assembly move off-centre. This creates a condition causing further wear of the wear rings and causing premature failure.

* **Velocity**

Wear rates have been estimated to vary as cube of the velocity. Therefore consideration must be given to pump size and rotational speed to avoid excessive wear. A more costly but slower speed pump is a far more economical choice. However minimum flow velocities must be maintained to prevent solids from settling. The optimum velocity will depend on the characteristics of solids present in the pumped liquid.

* **Materials**

Selection of materials is of great importance. In one extreme when particles are large and hard very hard materials such as manganese steel must be used to provide maximum resistance to high erosion. The other extreme, generally preferred when solids are quite fine, as in the case of river sand, is to use pumps having their principal parts either moulded or coated with natural rubber or neoprene.

* **Sealing**

The most sensitive part of the vertical turbine pump is the area around the shafting where the discharge pressure is sealed off from the atmosphere. The sealing is done either by a series of labyrinth rigs, gland packing or mechanical seals. Gland packing type is the most common type used. If the sealing is not proper due to wear, water at discharge pressure will leak. To extend the life of shaft sleeves materials such as Chromium oxide, Tungsten carbide can now be sprayed onto the shafts and shaft sleeves. Although this is not inexpensive the higher initial investment can often pay off in reducing downtime and longer life between repairs.

* **Bearings**

Another vulnerable part in the vertical turbine pump is the bearing. Pump bearings are lubricated by the liquid being pumped. If there are abrasive in water, wear will increase. line shaft bearings are made of hard rubber and shaft sleeved are sprayed with hard oxide coatings as mentioned above lubrication can be either by self water or by external forced lubrication with clean water.

9.6 CHOICE OF PUMPS TO SUIT SYSTEM HEAD

We know that the power consumed over a period t hours is given by the formula,

$P = Q \times H \times t / 376 \times \eta_o$ kWh

Then power consumed $P \propto Q \times H \times t$

Now we will see how the shape of the system head curve affects the power consumption when different capacity pumps are used.

9.6.1 FLAT SYSTEM HEAD CURVE

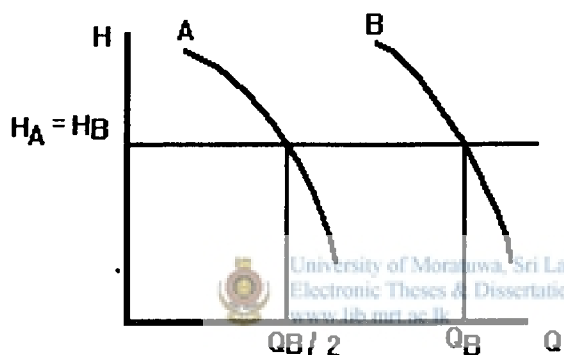

Fig 9.1

Assume that we have the choice of using pump 'A' or Pump 'B'. Pump B has a capacity equal to twice the capacity of Pump A at the same Head. Therefore Pump 'B' will take a time t/2 Hrs. to pump a certain quantity of water, if the time taken by the Pump "A" is t Hrs. to pump the same amount of water.

The relationship between the power consumption is

$$P_A/P_B = (Q_B \times 1/2 \times H_B \times t)/(Q_B \times H_B \times t \times 1/2) = 1$$

Therefore if the system head is flat the capacity of the pump does not change the running cost.

However we should note that higher the capacity of the pump, higher the efficiency. More pumps mean more standby capacity. Generally one running one standby is frequently used giving 100% standby.

9.6.2 NORMAL SYSTEM HEAD CURVE

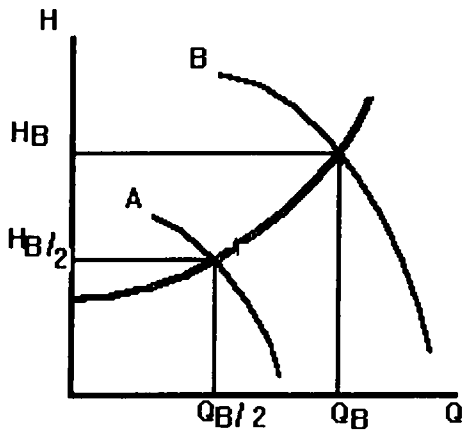

Fig 9.2

The power consumption relationship in this case becomes;

$$P_A/P_B = (Q_B \times 1/2 \times H_B \times 1/2 \times t)/(Q_B \times H_B \times t \times 1/2) = 1/2$$

Higher capacity pump consumes twice the power consumed by smaller capacity pump. This should be noted in deciding the pumping rates.

In the case of wastewater treatment plants, one of the pumps can have a capacity around the average inflow. Higher inflows can be handled by automatic setting on the second and third pumps according to variation of the liquid level in the sump.

9.6.3 STEEP SYSTEM HEAD CURVE

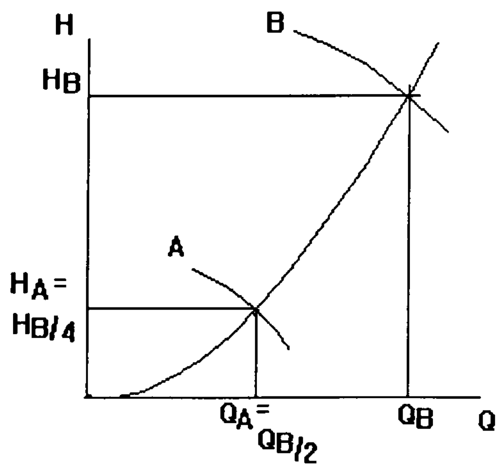

Fig 9.3

The power consumption relationship in this case becomes

$P_A/P_B = (Q_B \times 1/2 \times H_B \times 1/4 \times t)/(Q_B \times H_B \times t \times 1/2) = 1/4$

In this case it is inappropriate to select over capacity pumps as higher capacity pumps consume four times the power consumed by lower capacity pump.

It has been assumed that the pump efficiencies are the same under each case considered.

(Source : Flygt Pumps Undated).

9.7. GLAND PACKING OR MECHANICAL SEAL

When the pump shaft passes through the casing a device to prevent leakage of the water to out side or entrance of air is required. For this purpose both Gland packing and Mechanical seals are used. Since both are subject to wear or failure, neither stuffing boxes packed with gland packing nor mechanical seals are prefect. For some applications the former is better, but for other applications the reverse is true. In some fields both give good results. Therefore the decision as to which is to be used becomes a matter of personal preference. Now we will see the details of the two types.

9.7.1 GLAND PACKING

In this method packings are inserted into the stuffing box round the shaft and are tightened by a gland. This method is widely used. Water under pressure is provided to the stuffing box to prevent air entering from outside when the pressure in the casing is lower than the atmosphere. A shaft sleeve is provided to prevent the shaft wear. Gland must be tightened to a level when a few (40 to 60) drops of water leaks out every minute. Too much of tightening will cause heat and wear. Gland packing needs regular adjustment. Water can be allowed to leak out but not corrosive liquids. As the packing, cotton braid, cotton hemp or asbestos impregnated with oil, grease or graphitic is used. This is relatively cheaper than mechanical seals.

9.7.2 MECHANICAL SEALS

Mechanical seals have excellent properties. It can prevent leakage completely, wear at the pump shaft will not arise and it is simple to use. However when leakage begins, it has to be replaced. This requires the dismantling of the pump. Mechanical seals are expensive and if not installed properly it can malfunction and fail prematurely. Abrasive particles can make the life of the seal short. Mechanical seals are widely used in domestic type small pumps, in submersible type sewage pumps and for special purposes where leakage cannot be permitted. It is not so popular among industrial type water pumps.