Checklist for selection of type of pump and important units/components in layout of huge pumping stations

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1.0 Introduction :

Careful selection of the right type of pump for a particular application is important, because plant efficiency is directly affected by the pump efficiency. Probably the biggest problem faced by an engineer designing an pumping system is the choice of class, type, capacity, head and details of pumps to be used in the system, because large variety of pumps of different configuration and of different ratings are available in the market. Moreover, so many applications are possible for each type. As such, it is often difficult to narrow down the choice of specific pump. Lack of proper attention to various important steps involved in pump selection many times leads to improper pump selection, which finally results in poor performance of the entire pumping system. This situation underlines the necessity of proper selection guidelines, procedure and development of a checklist for selection of type of pump, which will be suitable for given application.

For pump selection, the pump user has to initially undertake complete hydraulic calculations of head and estimation of flow requirements for the pumping system and then choose a suitable unit from current catalogues of pump manufacturers and rating charts. The selection includes selection of type of pump, material of components, constructional features, etc. There are two approaches for pump selection viz. :

(i) Selection left to pump manufacturer by giving him end requirements
(ii) Selection by the user.

2.0 Checklist for pump selection :

In both the cases, the pump user is acquainted with the pump selection procedure vis-a-vis a list of various essential information of the planned pumping system which needs to be highlighted in the pump specification, so as to enable the bidder to select type of pump which will be the most suitable for a given application. Many of the points governing pump selection are covered in the manufacturer's typical data sheet (Table 1).

The following checklist (which is furnished in the form of questions) can be used as a guideline to complete the data/ requirement and to precisely define the end requirements of pump for a given application and will enable appropriate pump selection.

2.1 Liquid characteristics :

What is the nature of the liquid to be pumped ?

Information pertaining to liquid being handled needs to be furnished :

(a) Fresh or salt water; acid or alkali; oil, gasoline, or slurry.
(b) Cold or hot. If hot, its temperature.
(c) Specific gravity of the liquid
(d) Vapour pressure of the liquid
(e) Viscous or non-viscous liquid
(f) Clear and free from suspended foreign matter or dirty and gritty. If the latter, the size and nature of the solids, and whether they are abrasive? If the liquid is of a plupy nature, the consistency expressed in percentage or in kg per cubic metre Nature of the suspended material.
(g) Chemical analysis of liquid, its pH value, variations expected in this analysis and liquid characteristics.

Remarks :

Liquid characteristics, furnish first a clue to decide the pump type and material of construction. Exceptionally severe conditions may rule out one or another class right at the start, because if fluids are contaminated, they need special provision against corrosion, erosion, choking, etc.

2.2 Capacity :

What is the required capacity as well as minimum and maximum amounts of liquid the pump will be called upon to deliver ?

Remarks :

The rating of the pump (in terms of head and capacity) can be decided after a study of layout of the pumping system. This furnishes the first clue as to what class of pump is suitable e.g., where high head (up to 13,000 mwc) with small capacity service is required (flows as less as 1 lpm), a reciprocating pump would be suitable, however, for larger capacity and smaller head, centrifugal pump is suitable.

Selection on the basis of capacity may help in deciding the pump type likely to be the most suitable for a particular application. However, there are overlaps of capacities of different types of pumps. In that case, out of those possible alternatives, further selection can be made using criteria of better efficiency, head, cost criteria and other criteria mentioned in subsequent paras.

The approximate operating flow ranges of different types of pumps' impeller are as follows:

Radial .. 0.1 to 0.32 cum/ sec
Double suction .. 0.1 to 2 cum/ sec
Mixed flow .. 0.2 to 6 cum/ sec
Axial flow .. 0.3 to 6 cum/ sec

2.3 Variation in flow rate:

Is there a likelihood of variation in flow rate demand?

Remarks :

When plant load/production rate or other factors are likely to cause change in liquid demand, extreme care is necessary in specifying pump capacity. Variation in amount of liquid delivered by a pump generally influences the efficiency of the pump, which is maximum at its duty point. Hence, usual practice is to choose a pump so that during busy operating seasons, it will be operating at desired total head (duty head) and will deliver required/desired capacity.

However, when large variation in flow demand is expected, such situations need to be taken care of by using two or more pumps operating in parallel instead of one, which permit each to operate over its best efficiency range for most of the time. While initial cost of using more pumps may be higher, the operating cost is lower.

2.4 Requirements of suction lift :

What are the suction conditions? Is there a suction lift or suction head ? What variations are expected in these conditions?

Remarks:

As indicated earlier, suction lift in case of a rotor dynamic pump is very much limited. This gets further limited as the altitude and ambient temperature of the pump house increases. The maximum theoretical suction lift possible for rotodynamic pump is 8.1 m when the pump is very low and is installed near sea level, whereas the mixed flow type pump has got very limited suction lift – lower than 4.5 m and for axial flow perhaps the lift is further lower. As such, the suction conditions prevailing at site, form an important factor in pump selection.

To avoid occurrence of cavitation in pump and the associated problems, the NPSH available at the site of pump installation (site specific) should always be greater or at least equal to the NPSH required (the characteristic of the pump specified by manufacturer).

If requirement of suction lift is excessive and is exceeding the value allowable for that type of pump (the maximum theoretical lift), it becomes essential to select a submersible/ vertical turbine type pump or wet pit type pump.

2.5 Head on pump :

What is the static head? Is it constant or variable? What is friction head? What is the maximum pressure on delivery side against which the pump must deliver the liquid?

Remarks :

In order to estimate the above data, a single line diagram of the pumping system showing all piping (suction and delivery) fittings, valves, equipment, etc. needs to be prepared. The length of pipe runs, vertical lifts, number of bends, tapers and diameters of each need to be shown on the sketch.

The total head against which the pump has to deliver water is computed with the help of dimensioned layout of piping system. For estimation of head loss in the piping system, the rated flow rate, decided from system requirements, is taken for computation of velocities in the pipe. The total head, along with these head losses thus estimated, is finally taken as the parameter for selection of pump.

The ranges of head developed by various types of impellers are as follows:

Radial .. 3 to 35 mwc
Double suction .. 1.9 to 100 mwc
Mixed flow .. 6 to 38 mwc
Axial flow .. 1.5 to 10 mwc

On the basis of these head ranges, vis-a-vis requirement for given application, the selection of the pump from amongst the alternatives can be further narrowed down.

2.6 Type of service :

Is the service continuous or intermittent ?

Remarks :

If a pump is to be used only intermittently, it may not be necessary to have the most efficient unit. The selection can be made on the basis of lower initial cost. In case of a pump intended for a continuous service, it must have reliability, high efficiency and long life.

2.7 Pump position :

Is the pump to be installed in a horizontal or vertical position ? If the latter, whether to be installed in a wet pit or in a dry pit?

Remarks :

Where space is not the limitation and if the water level is within the permissible suction level of the pump, possibility of installing horizontal type of pump could be explored. On the other hand, vertical pumps are easily adopted within a limited space, since the pump and its driver i.e., the motor may be assembled on the same vertical axis.

2.8 Pump prime mover-type :

What type of power is available to drive the pump and what are the characteristics of this power?

Remarks :

In remote areas, where electricity is not available, pumps driven by I.C. engines (especially diesel ones) have to be selected. Steam / gas and hydraulic turbines as well as steam engines are also used in some cases to drive the pumps. In order to accelerate the rotor and impeller while starting the pump, the torque developed by the prime mover should be greater than the resisting torque of the pump. The power of the driver should be so chosen that it runs near its maximum efficiency and at the same time, it ensures that the pump operates at optimum efficiency.

2.9 Location of installation :

Whether the pump installation is indoors or outdoors ?

Remarks :

Selection of a pump should also consider whether the installation is outdoors or indoors. Electric motors require special enclosure and special treatment for outdoor installations, particularly when they are required to be operated in hazardous field conditions. For indoor installations, ordinary drip-proof motors are sufficient. As far as pumps are concerned, they would need special treatment, if they are require to be installed and operated in corrosive atmosphere.

2.10 Type of source :

What is the type of source for pumping ?

Remarks :

Method of pumping and suitability of pump also depend upon the type of source i.e., place from where liquid to be pumped is obtained e.g., it can be river, canal, well, pool, etc. Depending upon the type of source and level of water in it, the type of pump will vary.

2.11 Special requirements :

Are there any special requirements or market preferences with respect to the design, construction or performance of the pump ?

Remarks :

Special requirements of pump design, construction and performance of pump specific to that individual site need to be taken care of in pump selection for which it needs to be understood :

- Whether the requirement is in respect of constant capacity/ flow rate at fixed head. In such a case, the pump is supposed to work almost on the stipulated duty point on head capacity curve and hence high value of efficiency at that point would be appreciated.
- Variation in capacity or flow rate with head / pressure remaining nearly cosntant : this is encountered in actual practice e.g., when a pump has to discharge into water supply mains of a colony/plant, under a nearly constant pressure. For such an operation, flathead capacity curve would be desirable.
- Variable head with slight capacity variations: this is a common situation, involving a variation in static head, due to variation in water levels in different seasons, which should not be followed by considerable capacity variation. For such an operation, steep-head capacity curve would be desirable.
- The pump may also be required to be operated under severe adverse conditions of voltage and frequency. If so, a motor should be selected which will function satisfactorily in such conditions also.

2.12 Configuration requirements :

What is the requirement of piping layout ?

Remarks :

Depending upon the requirement of piping layout for the application under consideration, the pump casing type can be selected in terms of :

- nozzle configuration (end-suction top delivery / in-line type, etc.)
- method of splitting (horizontally/ vertically).

2.13 Location of installation :

What are the environmental conditions ?

This should include reference to elevation above sea level, geographical location and site atmospheric environmental conditions.

Remarks :

Site conditions like temperature, humidity, altitude, working environment (i.e., presence of dust, fumes, smoke, fog, etc) influence the selection of pump material whereas operating conditions decide the selection of the type of pump; as such, environmental conditions need to be specified/ considered during selection.

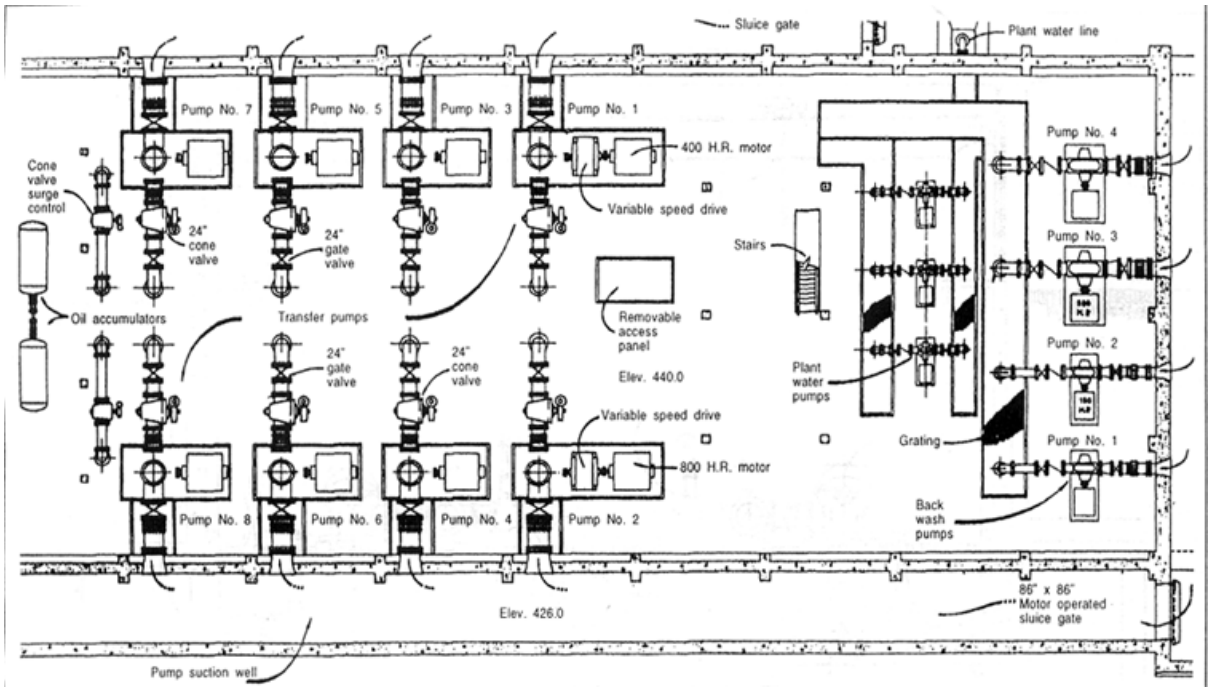
Thus, through the above mentioned steps, the selection of type of pump can be concluded. Family of curves prepared by various pump manufacturers furnish the optimum operating ranges for different pumps manufactured by them. With the help of these curves and catalogues, further selection of pump can be made.

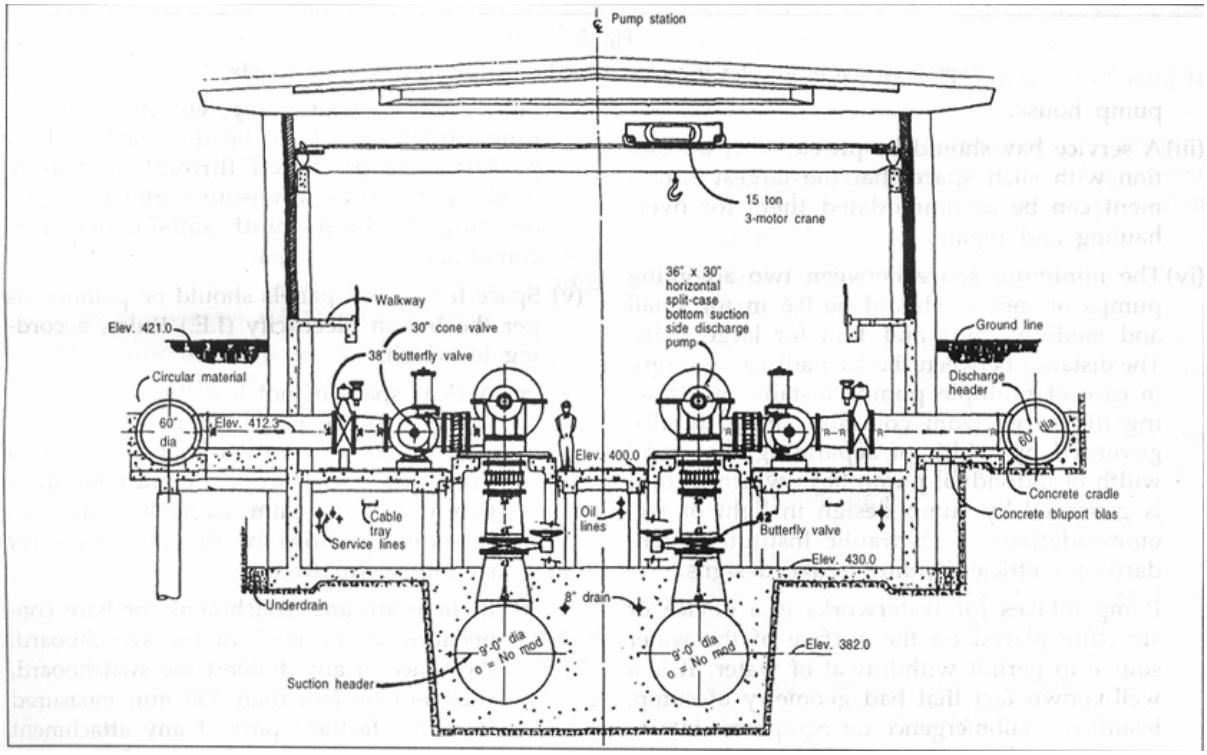
3.0 Pumping station general consideration :

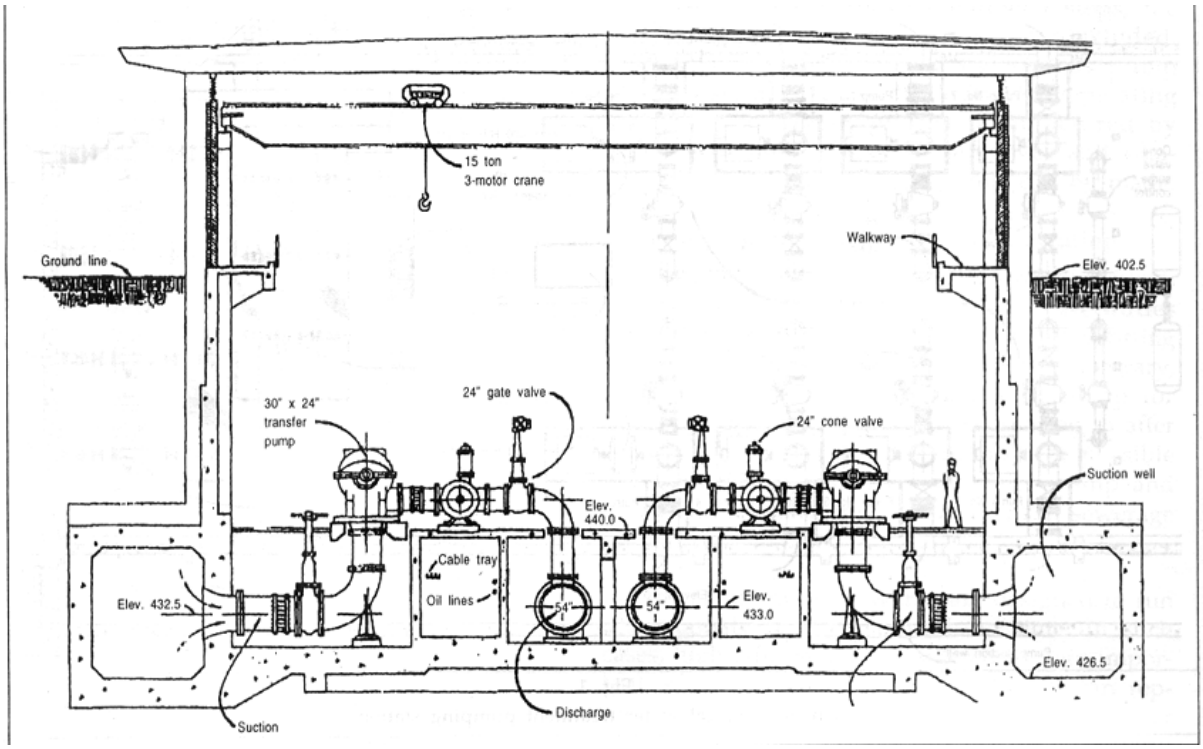
Pumps form a basic part of waterworks engineering/ water supply system, where their duties range from abstraction of raw water to boosting of flow or pressure in pipeline. On the contrary, contrast in sewerage design, use of pump for sewerage pumping may only be resorted to after detailed investigation of a number of possible alternatives with gravity flow, since pump and allied equipment form a weak point in sewerage system.

Pumps for many waterworks are designed to run continuously for long periods of time. In such cases, high efficiency is considered as very important, since increase in efficiency by 1% can represent considerable saving in running costs over a long period. Such pumps which have continuous operation, must be reliable in use. Pumps installed for land drainage are usually required to lift huge quantities of comparatively dirty water through quite low heads. These pumps are only required to operate at times with high run-off and may therefore stand idle for long periods, as such, their capital cost should be as low as possible.

Depending upon the type and purpose of pumping plant, pumps and different essential auxiliaries are appropriately designed, selected and installed in a pump house. (Figs. 1, 2 and 3), which are as follows.







3.1 Space requirement planning for various auxiliaries :

(i) Sufficient space needs to be provided in the pump house to locate the pump, motor, valves, piping, control panels and cable trays in a rational manner with easy access and with sufficient space around each equipment for maintenance and repairs.

(ii) Provision of space for installation of an additional pump in future shall be made in the pump house.

(iii) A service bay should be provided in the station with such space that the largest equipment can be accommodated there for overhauling and repairs.

(iv) The minimum space between two adjoining pumps or motors should be 0.6 m for small and medium units and 1 m for large units. The distance between the two adjacent pumps, in case of multiple pumps installation drawing discharge from common sump, is also governed by width of separating piers and width of individual pump bays which in turn is governed by sump design in light of recommendations of Hydraulic Institute's Standards for efficient pump-intake designs.

Pump intakes for waterworks is a device or structure placed on the surface of the water source to permit withdrawal of water. It is a well-known fact that bad geometry of sump, insufficient submergence for equipment intake, etc. can lead to occurrence of swirl, air-entraining vortices leading to noise, vibrations, fall in efficiency of pump, etc. As such, the pump intake needs to be designed and its performance predicted through hydraulic model tests, so as to ensure vortex-free flow entering the intake with satisfactory flow conditions.

(v) Space for control panels should be planned as per the Indian Electricity (I.E.) Rules, according to which,

- A clear space of not less than 915 mm in width shall be provided in front of the switchboard. In case of large panels, a draw-out space for the circuit breakers may exceed 915 mm. In such a case, the recommendations of the manufacturer should be followed.
- If there are any attachments or bare connections at the back of the switchboard; the space, if any, behind the switchboard, shall not be less than 230 mm measured from the farthest part of any attachment or conductor for boards up to 760 mm in width.
- If the switchboard exceeds 760 mm in width, these shall be a passageway from either end of the switchboard, clear to a height of 1830 mm.

3.2 Requirements of civil works for pumping station :

(i) Entrance of large objects into the pump intake structure and gravity flow pipes shall be prevented by course screens which can be travelling type. Screen wash pumps shall also be provided to washout the floating matter adhered to screens.

(ii) The total effective sump capacity of all the chambers together including the distribution chamber of pump house shall be minimum five times of the ultimate capacity. Cast iron/ mild steel sluice gates shall be provided for isolation of the compartments. Necessary travelling type screens shall be provided at the inlet.

(iii) The pump house sump shall be provided with low-level alarm and the pumps shall be provided with dry running protection.

(iv) The layout of various equipments inside the pump house shall be designed keeping in view the safety of the personnel and accessibility of the equipment. The pump house shall be provided with necessary store, toilet, repair and maintenance room, operators and guardroom along with supervisor/ shift-in-charge's room.

(v) The suction chamber/ sump shall be provided with drain and overflow connections leading to the nearest storm-water drain.

(vi) In large installations, the floors should be so planned that the piping and valves can be laid on the lower floor and the upper floor should permit free movement.

(vii) Structural platform shall be provided with handrailings, so that the valves shall be accessible for operation and maintenance.

(viii) The pump house shall be provided with adequate drainage facilities with necessary side slope, channels, etc. leading drained water to drainage sump of suitable capacity. The pumps should have adequate head and rated for adequate flow rate and be provided with automatic operation using level probes.

(ix) The pump house is a civil construction, closed on all sides. The pump house shall have RCC roofing and staircases. It shall be provided with minimum two entries. One of the entries shall

be provided with rolling shutters having sufficient width for truck entry. A ramp or a loading and unloading bay should be provided.

(x) The pump house shall be provided with office room, toiler facilities and drinking water supply.

(xi) The pump house shall be provided with proper ventilation, electrics, welding sockets, instrumentation, etc.

3.3 Piping :

The various components / accessories in a pumping station which are associated with pumps are piping, supports, valves, surge protection devices, etc. The various criteria for their layout are briefly mentioned below:

3.3.1 Suction piping layout :

(i) Each pump shall have independent suction.
(ii) Suction piping should be as short and straight as possible
(iii) Any bends or elbows should be of long radius.
(iv) Where suction lift is encountered, no point on the suction pipe should be higher than the highest point on the suction part of the pump.
(v) When a reducer is used, it should be of the eccentric type.
(vi) When working on suction lift, the taper side of the reducer should be below the centre line of the pump.
(vii) Suction strainer should have net open area, minimum equal to three times the are of the suction pipe.

3.3.2 Discharge piping :

(i) The size of the discharge piping may be selected of one size higher than the nominal delivery size of the pump. Alternatively, the delivery pipe should be of such size that the velocity shall be about 2.5 m/s.
(ii) A dismantling joint must be provided on suction and delivery sides of the pump as well as between the pump and the valves.
(iii) Discharge piping connecting to a common manifold or header shall be connected by a radial tee or by 30^{o}C or 45^{o}C bend.
(iv) Delivery line of each pump shall be connected to the main header.
(v) Each header shall be provided with suitable number of valves for isolating and maintenance purpose. For slurry/ scale water, dual headers each of 100% capacity shall be provided.
(vi) Each header shall be provided with local indication of pressure as well as indication, recording and signalling of flow and pressure which shall be depicted on the panel of the control room. In case of dual headers, each of the header shall be provided with the same facilities.
(vii) The pipe network and valves within the pump house shall be adequately supported so as to avoid undue stress on the pumps.

3.4 Valves :

Each pump shall be provided with a gate valve/ butterfly valve on the suction side and a on return valve and butterfly valve combination on the delivery side. Valves of diameter 450 mm and above and valves requiring remote control operation shall be electrically operated and provided with limit switches as safety measure besides provision for manual operation also. All manual valves of size 250 mm and above shall be gear operated.

3.4.1 Suction valves :

When suction lift is encountered, a foot valve is provided to facilitate priming. The pump can be primed also by a vacuum pump if the pump is of large size, usually with suction pipe larger than 300 mm NB. Foot valves are normally available with strainers. The net area of the openings of the strainer of the foot valve should be minimum equal to three times the area of the suction pipe.

When there is positive suction head, a sluice or a butterfly valve be provided on the pump suction, for isolation. The sluice valves should be installed with their axes horizontal to avoid formation of air pockets in the dome of the sluice valve.

3.4.2 Delivery valves :

A non-return (reflux) valve and a delivery valve (sluice of butterfly valve) near the pump should be provided. The non-return valves should be in between the pump and the delivery valve.

3.4.3 Air valves:

Whenever there are distinct high points in the gradient of the pipeline, an air valve should be installed to permit expulsion of air from the pipeline during initial filling with water. If air is not expelled, it is likely to be compressed by the moving column of water. Compressed air develops high pressures which can even cause bursting of the pipeline. Air valves also permit air to enter into the pipeline when the pipeline is being emptied during shoutdown. If air would not enter during emptying, the pipeline will have vacuum inside and the atmospheric pressure would act externally, owing to which, the pipe line may get subjected to undue stresses.

3.5 Surge protection devices :

When starting or stopping a pump (or by operating the regulating valves rapidly), certain pressure fluctuations are caused, which travel up and down in the pipeline during the transient conditions. This can cause zones of alternating low and high pressures, particularly at apex points on the pumping main and subsequently cause hammering noise. If such pressure-surges exceed the pressure permissible in the pipeline, the pipeline may even burst. Suitable surge protection devices / anti-water hammer devices e.g., air vessel, etc. be provided in such cases.

3.6 Electrics :

The electric of a pump house shall be designed as per the technical specifications for electricals. The starters for the pump motors be rated as per their proposed duty. Huge pumping plants are usually built up into a composite floor mounting panel to include cubicles for switchgear and recorders together with units to house fuses and circuit breakers of subsidiary circuits. Meters and recorders installed in pump house should be provided with transmitters, so that the information can be repeated at a distance from the event i.e., a central point for these instruments. Cut-outs for starters, alarm lights/ bells be fitted to give warning of low water in suction pump. A provision for emergency lighting be made by providing auto-start diesel-driven generator or at least providing low-voltage (24 V) power supply so as to actuate alarm light /bells and hand lamps.

All the controls for the raw water system and auxiliaries shall be provided and the control pane shall depict the operating conditions of various units.

3.7 Auxiliary pumps :

Minimum two drainage pumps shall be provided to drain out the leakage/ seepage water. The drainage pump shall operate automatically based on water levels in the sump.

One adequate capacity portable type submersible, vertical, non-clog, centrifugal pump shall be provided for dewatering of isolated suction chambers and for any emergency dewatering.

3.8 Auxiliary equipment / services :

(i) Material handling equipment of sufficient rating be provided all along the length of the pumping station. Thus related requirements in terms of head room, tackle, etc. should be fulfilled.

(ii) The capacity of the hoisting and handling equipment shall be selected in such manner that it is able to handle the single heaviest load. Cranes/ monorails with hoists shall be provided.

(iii) Portable-type fire extinguishers (of carbon dioxide as well as dry chemical powder type) be provided with initial fill and necessary accessories need to be also provided at various premises of raw water pump house.

3.9 Conclusion :

Lack of proper attention to various aspects involved in the process of pump selection many times leads to improper pump selection which finally results in poor performance of the entire pumping system and thereby causes wastage of power and money. The checklist elaborated in this presentation will furnish useful information to the user regarding various parameters involved in pump selection, provide guidelines to exactly define the end requirements of the pump, compile the required data of the system in which the pump has to operate, and will enable appropriate pump selection. The presentation will also enable the user to know the important units/ components to be incorporated in the pumping station and the criteria generally adopted in designing its layout.

Reference Book:

Indian Pumps
Newsletter of the Indian Pump Manufacturers Association,
June 2005