

Algorithm for pump selection

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(A) Should centrifugal pumps be default selection?

One would often select a centrifugal pump by default, because most thinking of pumps focuses on centrifugal pumps. This is so, because centrifugal pumps are made in such majority over other types of pumps. However an algorithm should rather ensure that there is no default section. This algorithm hence provides for checking whether the application would warrant a pump other than a centrifugal pump. In short, it takes into account the limitations of centrifugal pumps. From the algorithm, one would realise that centrifugal pumps do have many limitations.

An algorithm is better readable as a flowchart. An algorithm has been attempted and is at Annex 1. Notes below explain the logic of the algorithm.

(B) Most common parameters of pumping duty:

Pump selection should start with data on hand about some most common parameters of pumping duty, viz. head and/or pressure, flow-rate required, preferred speed, number of pumps.

(C) Factors governing flow-rate per pump:

There are statutory codes to be followed, especially when selecting pumps for fire fighting. Fire-fighting pumps (IS-12469) have nominal discharge ratings specified in the code itself. Depending upon the degree of hazard, one has to select a discharge rating from the nominal ratings given in the code.

For pumping water to the overhead reservoir in a multistorey residential building, number of hours of inflow of municipal supply, capacity of Ground Level Reservoir (GLR) and total daily requirement of the residents will together decide the flow-rate. E.g., if there are 50 families in a building, i.e. a population of 250 people at an average of 5 persons per family, then at 200 litres per capita per day, daily requirement becomes 50 m^3 . If number of hours of inflow of municipal supply is 3 hours and the capacity of GLR is only 20 m^3 , balance of the total requirement i.e. 30 m^3 will have to be pumped to OHR in the 3 hours of inflow. So required flow-rate of pumping becomes $10 \text{ m}^3/\text{h}$.

In a sewage pumping station, flow-rate for pumps has to vary at different times of the day, depending upon the rate of inflow of sewage, size of sump, and time within which sewage should be pumped so that it does not become septic, also taking care that the pump should not suffer too many starts and stops at too short intervals. Traditionally this is managed by running different number of pumps in parallel. One may as well have pumps of different flow rates to run in parallel. Variable Speed Drives (VSD) make a good, energy-saving alternative for such regulation of flow-rate.

(D) Factors influencing the total head:

Total head primarily comprises the level difference and/ or pressure difference and the hydraulic friction. Hydraulic friction depends upon the selection of types and sizes of pipes and fittings.

All these data on the most common parameters of pumping duty may often prompt the default selection of a centrifugal pump. However, there are many other parameters to be considered to decide the type of pump.

(E) Factors influencing operating speed:

Wear life, bearing life, preference for a compact design and variety reduction influence selection of operating speed of the pump. Abrasive and corrosive wear will be more pronounced at high operating speed. Bearing life will also be less at high operating speed. But pumps designed to run at high

operating speed are compact and space-saving and are better portable. If pumps have to operate even optional drive from internal combustion engines, or if standby pumps for emergency operation have to be with internal combustion engines, variety of pumps and carrying of inventory of spares can be less if both electrically-driven and I. C. engine-driven pumps are of common design.

(F) Initial procedure of the algorithm:

1. Is viscosity > 350 cSt?

1.1 If yes, select a positive displacement pump Check if viscosity is shear sensitive?

1.1.1 If yes, select positive displacement pump, where liquid will not suffer shear at the pumping element. A helical rotor, progressive cavity pump or a diaphragm pump may be considered.

1.2 If not i.e. if viscosity <350 cSt, proceed to 2

2. Is distortion or damage to entrained solids acceptable?

2.1 If not, select a helical rotor, progressive cavity pump

2.2 If yes, i.e. if distortion or damage to entrained solids is acceptable, proceed to 3

3. Does duty need metering or dosing?

3.1 If yes, select a positive displacement pump

3.2 If not, proceed to 4

4. Is multi-phase medium to be handled e.g. oil, gas and mud in oil exploration? If yes, consider piston rod or plunger pumps. Pumps called as sucker rod pumps in the oil Industry are basically plunger pumps.

5. Are solid-contents > 10%?

5.1 If yes, select a positive displacement pump, but get back to step 2.

5.1.1 Is distortion or damage to entrained solids acceptable?

5.1.2 If yes, consider a positive displacement pump.

5.1.3 Is flow-rate of micro scale? If yes, consider a peristaltic pump.

5.2 If solid-contents < 10%, consider a non-clog centrifugal pump.

6. Is specific speed < 6?

Calculate the specific speed from the pumping duty, viz. Q, H and rpm. If pressure is dominant factor of the duty, convert pressure to equivalent head to find the specific speed.

6.1 Check if running at higher speed acceptable, so that higher speed will make higher specific speed and will make a centrifugal pump feasible. Then go to 5.6.

6.2 Check if liquid is clear, i.e. if turbidity is <500 ppm, if yes, check whether multistage construction is acceptable, so that specific speed per stage will again be higher.

6.3 If checks (5.1) and (5.2) are negative, and liquid is clear, check if pulsating flow is acceptable.

6.3.1 If pulsating flow is acceptable, a positive displacement pump can be more energy-efficient than any impeller pump. But with thin liquids, there will be slip flow, which will cause the efficiency of pumps to be less than normal.

6.3.2 If pulsating flow is not acceptable, one may consider a regenerative turbine type pump. But these pumps are not energy-efficient. But the advantage is that they can run at high running speed and are in turn compact, have non-pulsating flow, and also have a fair degree of self-priming capability. Check whether this capability has cost-benefit advantage in the application.

6.4 Further option for selecting centrifugal pumps is to select the pump for higher discharge and bypass the excess flow back to suction. This again will not be energy-efficient.

6.5 Selecting from feasible options should be by Life Cycle Cost (LCC) analysis.

(G) Selecting among positive displacement pumps:

6.6 Specific applications where helical rotor, progressive cavity pumps, metering or dosing pumps, peristaltic pumps, diaphragm pumps would become selection options as have been mentioned above. Where the algorithm lends selecting positive displacement pump as a general option, various types of positive displacement pumps can be considered, viz. piston or plunger pumps, internal gear pumps, external gear pumps, lobe pumps, vane pumps, flexible vane pumps, multiple screw pumps, etc. Again, selecting from feasible options should be by Life Cycle Cost (LCC) analysis.

(H) Selecting the type of mounting:

Most common arrangement of a pump is with its working axis horizontal. Centrifugal pumps with horizontal working axis often operate with a suction lift, unless the pump is to draw the liquid from a suction vessel above the pump.

Vertical mounting becomes an option for following reasons:

- (a) NPSH available may not be adequate. If so, mounting the pump to be submerged in the liquid will improve NPSH available. Vertical turbine pumps become an option to large mixed flow or axial flow end suction pumps or axially split casing horizontal pumps. But dismantling vertical turbine pumps for overhauling becomes quite an exercise. Also it becomes important to ensure structural stability, non-resonant frequency and limited and controlled vibration in case of vertical turbine pumps.
- (b) Mounting more than one pump in a pit would warrant proper design of sump.
- (c) Volatile or high temperature liquids with high vapour pressure would warrant pump to be mounted in a vertical can with enough depth, to take care of NPSH required by the pump in the depth of the can itself.
- (d) Vertical mounting often makes a compact, space-saving installation. Vertical in-line pumps are an eminent example.
- (e) Submersible pumps in tube wells are vertical pumps. Most pumps for drainage and dewatering are also vertical, since they then are compact and hence portable.

- (f) Submerging pumps in the liquid, often called as 'wet pit' mounting has become feasible with the development of submersible motors.

TABLE 1

Various options in shaft sealing with degree of sealing

| Type of sealing | Degree of sealing |
|--|--|
| Gland with soft packing and lantern ring | Zero leak sealing not desirable, since leakage would flush the wear-out away and also cool and lubricate the packing, carrying the heat away |
| Labyrinth sealing | If over-designed, may draw in air into the pump |
| Oil Seals or U buckets | Susceptible to work hardening and wear of sleeve. Common in reciprocating pumps for degree of sealing better than rope packing |
| Mechanical Seal | Commonplace seal is seemingly zero leak, though there are invisible fugitive emissions. |
| Injectable Sealant | Competes with mechanical seals, substantially reducing the cost of repairs and replacements as compared with mechanical seals |
| Hydrodynamic seal | Designed integrally with each pump. Cannot be interchanged across pumps, unless pumping duty, viz. head discharge, speed are all identical. |
| Canned Motor Pumps | Are truly zero leak. Detailed consideration needed, if liquid does not have lubricity or pumping temperature is high. Part of discharge is circulated through the motor. This reduces efficiency. |
| Magnetically coupled pumps | Are truly zero leak. Detailed consideration needed, if liquid does not have lubricity or pumping temperature is high. Magnetic induction itself generates heat, causing transmission losses and reducing overall efficiency. |

TABLE 2

Which Sealing Plan to use when

| Plan No. | Features | Solids in liquid | | | Temperature | | | Pressure | |
|----------|---|------------------|---------------|-----------|-------------|------|-----------|----------|------|
| | | Absent (clear) | Present | | Normal | High | Cryogenic | Normal | High |
| | | | Not offensive | Offensive | | | | | |
| 1 | Internal circulation from pump discharge to seal | . | | | . | | | . | |
| 2 | Dead end seal chamber with no circulation. Stuffing box cooling and neck bush are necessary | | | | | | | | |
| 11 | Circulation from pump case through an orifice | . | | | . | | | | . |
| 12 | Circulation from pump case through a strainer and an orifice | | . | | . | | | | . |
| 13 | Circulation from seal chamber through an orifice and back to suction | . | | | | | | | . |
| 21 | Circulation from pump case to seal through an orifice and a cooler | . | | | | . | | | . |
| 22 | Circulation from pump case through a strainer, an orifice and a cooler | | . | | | . | | | . |
| 23 | Circulation from the seal by means of a pumping ring, through a cooler and back to seal | | | | | | | | |
| 31 | Circulation from pump case through a cyclone separator | | | . | | | | | |
| 32 | Injection of a clean fluid from an external source. | | | . | | | | | |
| 41 | Circulation from pump case through a cyclone separator and through a cooler | | | . | | . | | | |
| 51 | Dead end quench, (usually methanol) | | | | | | | | |
| 52 | External fluid reservoir, pressureless, thermo siphon or forced circulation or as required | | | . | | | | | |
| 53 | External fluid reservoir pressurised, thermo siphon or forced circulation as required | | | . | | | | | |
| 54 | Circulation of clean fluid from an external system | | | . | | | | | |
| 61 | Tapped connection for use of customer | | | | | | | | |
| 62 | External fluid quench (steam, gas, water, etc.) | | | | | | . | . | |

Various types of submersible motors are in vogue, mechanically sealed dry motors, water-filled motors, oil-filled motors and encapsulated motors.

(I) **Selecting other features:**

7. **Shaft-sealing:**

See Table 1.

7.1 Traditionally seal – manufacturers supply seals to be assembled by the user. Now seals are also available as ready, assembled seals, assembled in a cartridge. Seals are also available as split seals for in situ installation or replacement without the need to dismantle the pump. API-682 details various plans for using seals. When to use which plan, is detailed in Table 2.

8. **Heating Jacket:**

If the liquid has high melting point and in turn, a tendency to solidify at ambient, the pump will not restart after shut down. A heating jacket will help to liquefy the solidified mass blocking the suction.

9. **Cooling jacket:**

9.1 When pumping temperatures are high, to prevent the shaft seal from malfunctioning and bearings having short life, cooling will be needed around stuffing box and bearing housing.

9.2 If pumping duty is less than safe minimum flow, pump will experience rise in temperature, vapour pressure will be higher and pump may suffer cavitation. To control the rise in temperature, cooling jacket will be necessary for the pump casing also.

(J) **Selecting Materials of Construction (MOC):**

The main considerations behind selecting material of construction for different components are to have

- ◇ Wear-life, especially against wear due to corrosion and /or abrasion
- ◇ Creep –strength to withstand the temperature of liquid to be pumped.
- ◇ Wear-life against cavitation erosion

Corrosion, abrasion, cavitation-erosion and liquid temperature will primarily affect the ‘wetted’ components of the pump. In case of centrifugal pumps, ‘wetted’ components include the casing impeller, impeller nut, casing cover and seal housing, shaft sleeve, gaskets, shaft seal material for whichever shaft sealing arrangement is selected

Corrosive effect of a liquid is mainly due to alkalinity or acidity. Liquids with pH value between 6.5 and 7 are neutral and hence are most comfortable to handle with commonplace material like Cast Iron. Until the development of stainless steels, for alkaline corrosion, especially for alkalinity as of sea water copper-based alloys like Naval Bronze were much in vogue. Many stainless steel materials however have good corrosion resistance both against alkaline and acidic corrosion.

Many commonly used materials are better known by acronyms or codes. For the sake of accuracy, one should be conscious of finer distinctions in the codes. For example, 18-8 Cr-Ni stainless steel is commonly known as SS-304. However, since components like casing and impeller are made by casting process, the code name is CF8, derived from grade CF8 in specification A-351 of American society of Testing and materials (ASTM). American Iron and Steel Institute (AISI) designated same material in wrought form as Grade 304.

Corrosion-resistance and abrasion-resistance do not go together. Abrasion-resistance would require high degree of hardness. Alternatively if the abrasive particles would impinge on the boundary surfaces at some angle of impedance, resilient materials would cause the abrasive particles to bounce off and not cause wear. Abrasion with low or zero angle of impedance becomes erosion. So, for abrasion-resistance, one should choose hard materials for erosive wear and resilient materials for bouncing particles, e.g. particles of sand. For components like pump casing resilient materials like rubber are better provided as linings in a cast casing.

Often components running close to each other, even when made of appropriate corrosion-resistant materials will suffer galling and electrolytic corrosion because of their chemistry being identical. A differential hardness or difference in chemistry of the close running surfaces can reduce or eliminate this galling and corrosion. Simple example to note this is by realising that a piece of glass moves harder over another surface of glass, than how hard a piece of steel would move on a glass surface.

(K) Selecting pumps for parallel operation:

When flow to be pumped needs regulation, one can get increased flow by running more pumps to run together in parallel. Switching off some of the pumps can reduce the flow. The flow is however not directly proportional to the number of pumps running. Study of system characteristics along with pumps' characteristics is necessary to devise a trouble-free system for pumps running in parallel. It is also necessary that HQ characteristics of individual pumps to run in parallel should be continuously rising towards shut-off. Also shut-off head of pumps should be identical as far as possible.

(L) Life Cycle Cost analysis:

Most situations of pump selection can provide opportunity to explore options. Most economic selection would emerge by Life Cycle Cost analysis.

$$LCC = PSC + ICC + OC + MIDC$$

Where

PSC = Pumping System Cost as the sum total of costs of Pump, Driver, Controller, Coupling, Piping, Valves, etc. Options in sizes of pipes and fittings should be considered as independent options of the Pumping System.

ICC = Installation and Commissioning Cost inclusive of costs of excavations and building of sump and pump room and material handling tackle, on-site assembly and testing

OC = Operating Cost over the life. Period for all options should be life of that option, which has longest life.

MIDC = Maintenance, Inventory and Downtime Cost over the same period as for Operating Cost.

Reference:

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