



केवल कार्यालयीन उपयोग हेतु
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भारत सरकार GOVERNMENT OF INDIA
रेल मंत्रालय MINISTRY OF RAILWAYS

TROUBLE SHOOTING AND MAINTENANCE OF SUBMERSIBLE PUMPS



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रेल अग्रदूत Transforming Railways



Indian Railways
Centre for Advanced Maintenance Technology

Maharajpur, GWALIOR - 474 005

Trouble Shooting And Maintenance Of Submersible Pumps

QUALITY POLICY

"To develop safe, modern and cost effective Railway Technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs and Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the railways".

PREFACE

Submersible pumps of various capacities have wide applications over Indian Railways in pumping installations and their proper upkeep and maintenance are essential for trouble-free supply of water for day to day operations.

This handbook on "Troubleshooting and Maintenance of Submersible pumps" is prepared with the objective to disseminate knowledge on pumps and their selection, installation. This handbook comprises general description, selection and installation along with troubleshooting for common troubles. This handbook also comprises selection of cables for pumps, minimum submergence etc.

It is clarified that this handbook does not supersede any existing provisions laid down by Railway Board/ Zonal Railways/ RDSO, OEMs. This handbook is for guidance only and it is not a statutory document.

I am sincerely thankful to all field personnel who helped us in preparing this handbook. Technological up-gradation & learning is a continuous process. Please feel free to write us for any addition/ modification in this handbook.

CAMTECH, Gwalior
Date: 22.02.2019

Manoj Kumar
Joint Director /Mech

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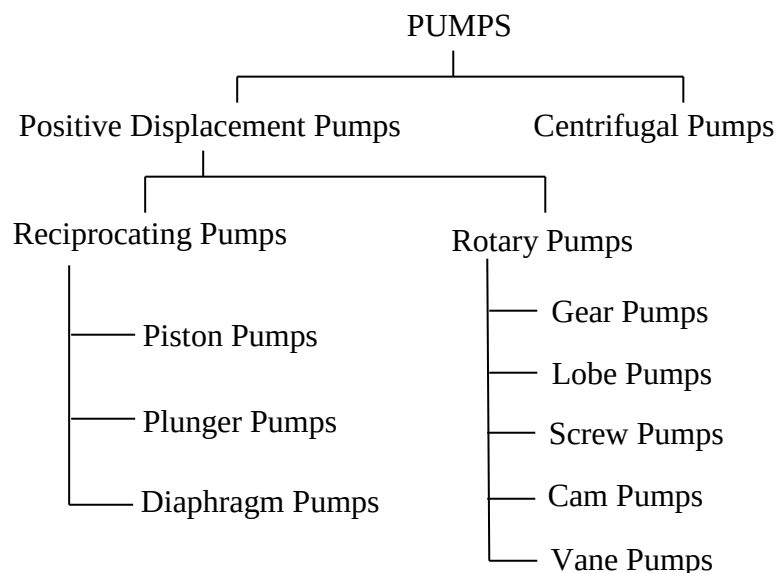
CHAPTER 1

GENERAL DESCRIPTION

1.1 PUMP

- ☞ Pump is a mechanical device which raises the energy levels of various fluids by converting kinetic energy imparted by its prime movers into hydraulic energy.
- ☞ Pump is a machine to transport the liquid from one place to another place usually through a pipe.
- ☞ It imparts energy to a fluid passing through it to enable the fluid to move from one point to another.
- ☞ It converts mechanical energy into kinetic energy.
- ☞ In practice, pumps change both the velocity and the pressure passing through them.
- ☞ A pump may, therefore, be defined as “a mechanical device which converts the mechanical energy imparted to it from an external source (electric motor, diesel engine or even manual energy) into hydraulic energy in the fluid handled by it”.
- ☞ As a consequence, the energy level of fluid handled by the pump or flowing through the pump is augmented, making it possible for the fluid to move from a lower level to a higher level, against gravity and friction.

1.2 CLASSIFICATION OF PUMPS



1.3 SUBMERSIBLE PUMP

- This pump initially found most versatile use in naval applications and gained popularity for deep well applications.
- Both pump and motor are installed deep inside the tube-well/ bore well.
- It makes, suction head minimum which makes it possible to lift water from depths as low as 800 meters.

- These pumps are coupled with wet type squirrel cage induction motor/ PMSM (Permanent Magnet Synchronous Motors)/ IPMSM (Integrated Permanent Magnet Synchronous Motors)/ BLDC (Brush Less D C motors). Both motor and pump operate totally submerged below the surface of water.
- The motor winding is either wet or dry type.

1.4 ADVANTAGES OF SUBMERSIBLE PUMP

- ✓ Lower initial investment.
- ✓ Easy to install, as it requires no foundation.
- ✓ Lower operational and maintenance cost due to near perfect hydroelectric design and perfect workmanship.
- ✓ Oiling or Greasing of bearing is not required, since the bearings are water lubricated.
- ✓ Long life: Sturdy construction protected against corrosion and abrasion.
- ✓ Pump is below water level, as such there is no suction trouble.
- ✓ Reliable: Motor winding designed to withstand normal fluctuation and normal overload.
- ✓ Noise and vibration free operation.
- ✓ Sleek design: More clearance between pump and bore casing pipe.
- ✓ Overall efficiency of pumping is highest in submersible pump.

1.5 DISADVANTAGES OF SUBMERSIBLE PUMP

- ✗ Motor is comparatively costlier than a vertical turbine pump.
- ✗ The water has to be perfectly clear, free from sand, as sand has an abrasive action on the impellers.
- ✗ The supply voltage has to be perfectly good and fairly constant, since considerable voltage drop occurs in the cable as the motor is under great depth.
- ✗ Rewinding and repair of the motor is a specialized job and it has to be absolutely perfect.

1.6 APPLICATION OF SUBMERSIBLE PUMP

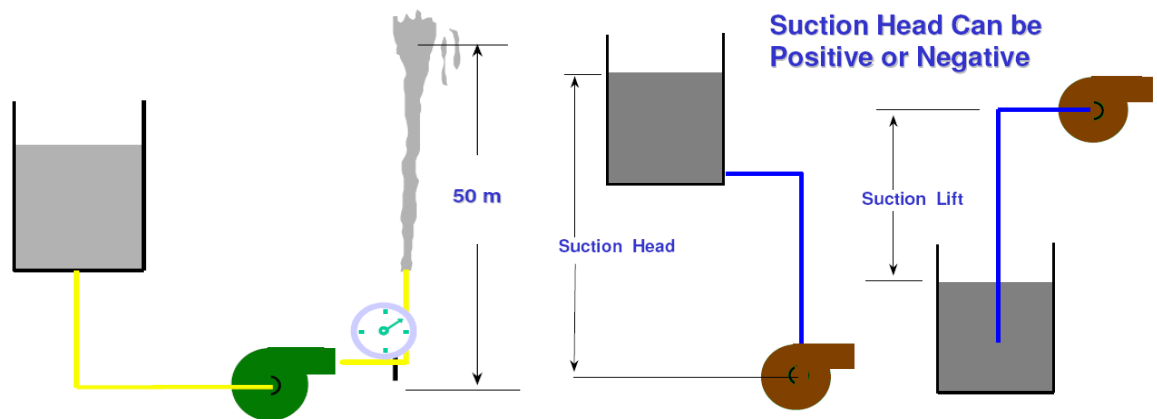
- Domestic
- Fountain
- High Rise Building
- Construction
- Agriculture
- Drip & Sprinkler Irrigation
- Irrigation
- Water Circulation
- Rural Water Supply Schemes
- Industrial Water Supply
- Process House



1.7 BASIC TERMINOLOGY OF PUMP

1.7.1 Head

The head of the pump is an expression of how much height the pump can lift the liquid. This is measured in terms of meter of water column, independent on the liquid density.



1.7.2 Static Head

- ❖ The vertical height difference from surface of water source to centreline of impeller is termed as static suction head or suction lift ('suction lift' can also mean total suction head).
- ❖ The vertical height difference from centreline of impeller to discharge point is termed as discharge static head.
- ❖ The vertical height difference from surface of water source to discharge point is termed as total static head.

1.7.3 Total Head/ Total Dynamic Head

Total height difference (total static head) plus friction losses & 'demand' pressure from nozzles etc. i.e. Total Suction Head + Total Delivery head = Total Dynamic Head.

1.7.4 NPSH (Net positive suction head)

Net positive suction head – related to how much suction lift a pump can achieve by creating a partial vacuum. Atmospheric pressure then pushes liquid into pump. A method of calculating if the pump will work or not.

Net Positive Suction Head or NPSH for pumps can be defined as the difference between liquid pressure at pump suction and liquid vapor pressure, expressed in terms of height of liquid column.

1.7.5 Specific Gravity (S.G.)

Specific gravity, weight of liquid in comparison to water at approximate 20°C (SG = 1)

1.7.5 Specific Speed

A number which is the function of pump flow, head, efficiency etc. Not used in day to day pump selection, but very useful as pumps with similar specific speed will have similar shaped curves, similar efficiency/ NPSH/ solids handling characteristics.

1.7.6 Vapour Pressure

If the vapour pressure of a liquid is greater than the surrounding air pressure, the liquid will boil.

1.7.7 Viscosity

A measure of a liquid's resistance to flow i.e. how thick it is. The viscosity determines the type of pump used, the speed it can run at, and with gear pumps, the internal clearances required.

1.7.8 Flow (Q)

Flow rate with which liquid is moved by the pump. Measured in m^3/hr or GPM, LPD, LPM or LPS.

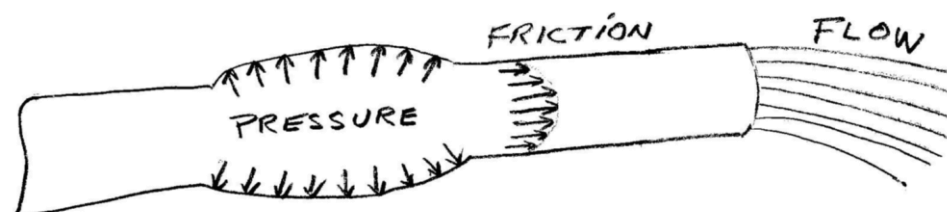
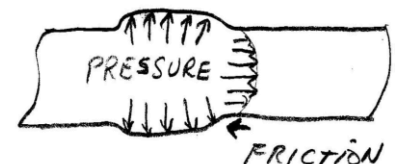
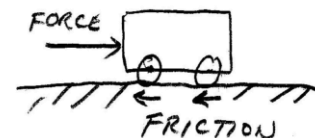
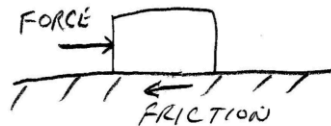
Capacity depends on- liquid characteristics, pump size, inlet & outlet sections, impeller size, impeller rotational speed RPM, size & shape of angles between vanes.

1.7.9 Friction Loss

The amount of pressure/ head required to 'force' liquid through pipe and fittings.

1.7.10 Friction

It is a form of resistance to the movement of flow. This is depending on velocity and the area. This is measured in terms of head in meters.

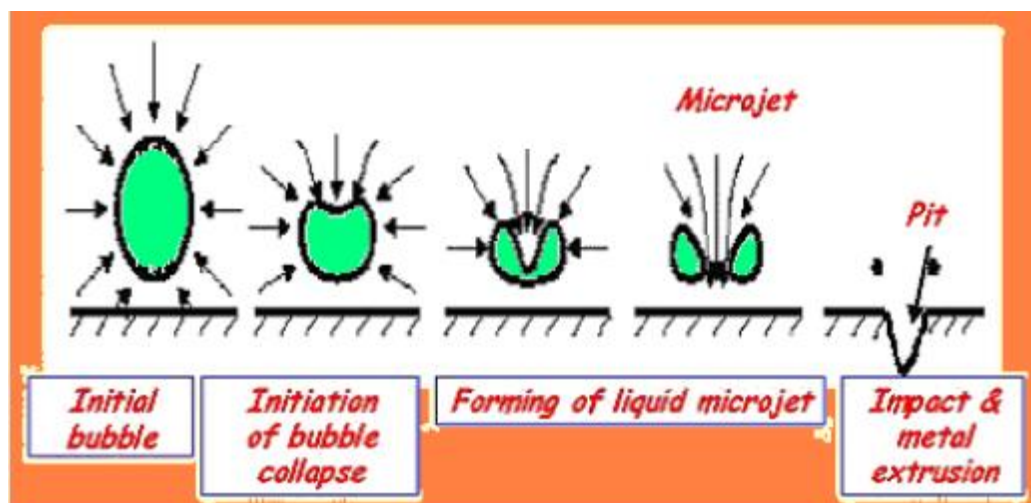
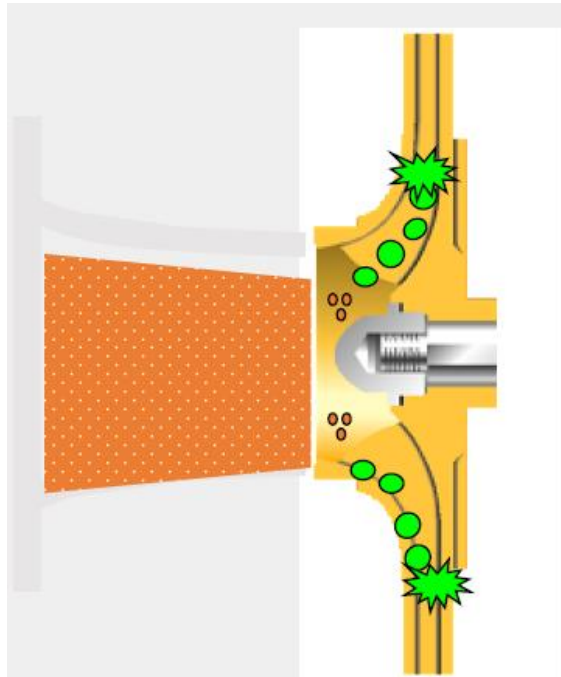


1.7.11 Shaft

Shaft is a component that carries all the rotating pump parts and also provides power to the impeller. The shaft has to withstand the rotating torque, axial and radial thrust.

1.7.12 Cavitation

If the pressure drops below the vapour pressure of the liquid at the operating temperature, the liquid will vaporize.



CHAPTER 2

SELECTION AND INSTALATION OF PUMP

2.1 INSTALLATION:

Before installation, read the installation and operating manual of OEM carefully for right method of installation.

2.1.1 Positional Requirements

- Where it is accessible, the coupling must be suitably isolated from human touch.
- Depending on motor type, the pump can be installed either vertically or horizontally.
- If the pump is installed horizontally, the discharge port should never fall below the horizontal plane.
- If the pump is installed horizontally, e.g. in a tank, it is recommended to fit it in a flow sleeve.

2.1.2 Liquid Temperatures/ Cooling

- It is recommended to install them on or above the well screen in order to achieve proper motor cooling
- In cases where the stated liquid velocity cannot be achieved, a flow sleeve must be installed.
- If there is a risk of sediment deposition, such as sand, around the motor, a flow sleeve should be used in order to ensure proper cooling of the motor.

2.1.3 Maximum Liquid Temperature

- Out of consideration for the rubber parts in pump and motor, the liquid temperature must not exceed 40 °C (~105 °F).
- The pump can operate at liquid temperatures between 40°C and 60°C (~105°F and 140°F) provided that all rubber parts are replaced every third year.

2.2 ELECTRICAL CONNECTIONS

Warning

Before connecting the pump supply, make sure that the electricity supply has been switched 'OFF' so that it cannot be accidentally switched 'ON'.

2.2.1 General Instructions

- The electrical connection should be carried out by an authorized electrician in accordance with local regulations.
- The supply voltage, rated maximum current and power factor ($\cos\phi$) appear from the loose data plate that must be fitted close to the installation site.

- The required voltage quality for submersible motors, measured at the motor terminals, is $-10\%/+6\%$ of the nominal voltage during the supply voltage and losses in cables.
- The pump must be properly earthed.
- The pump must be connected to an external mains switch with a minimum contact gap of 3mm in all poles.
- The motors are wound for direct-on-line starting or star-delta starting and the starting current is between 4 and 6 times the full load current of the motor.
- The run-up time of the pump is only about 0.1 second. Direct-on-line starting is therefore normally approved by the electricity supply authorities.

2.2.2 Motor Protection

2.2.2.1 Single-phase Motors

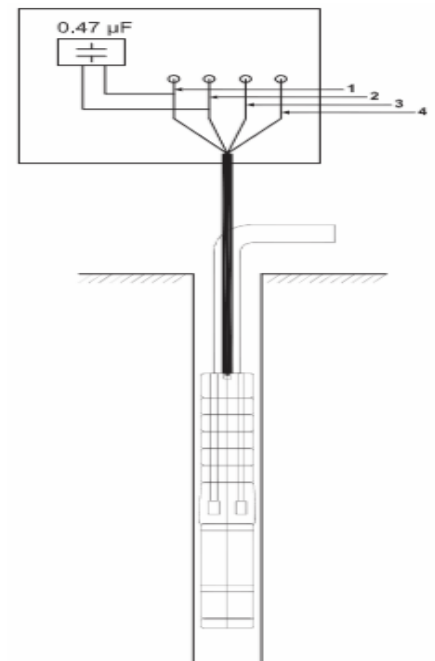
- Single-phase submersible motors type 4" must be protected by a protective device which can either be incorporated in a control box or separate.

2.2.2.2 Three-phase Motors

- Motors have no built in temperature transmitter. A PT-100 sensor is available as an accessory. Motors with PT-100 sensor must be protected by means of:
- Motor starter with relay or connector(s)

2.2.2.3 Required Motor Starter Settings

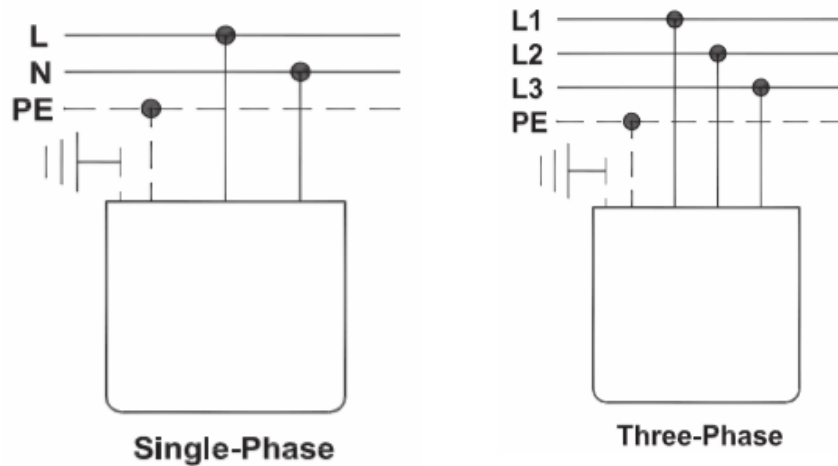
- For cold motors, the tripping time for the motor starter must be less than 10 seconds at 5 times the rated maximum current of the motor.
- In order to ensure the optimum protection of the submersible motor, the starter overload unit should be set in accordance with the following guidelines:
 1. Set the starter overload to the rated maximum current of the motor.
 2. Start the pump and let it run for half an hour at normal performance.
 3. Slowly grade down the scale indicator until the motor trip point is reached.
 4. Increase the overload setting by 5 %.



- The highest permissible setting is the rated maximum current of the motor.
- For motors wound for star-delta starting, the starter overload unit should be set as above, but the maximum setting should be as:

$$\text{Starter overload setting} = \text{Rated maximum} \times 0.58$$

- The highest permissible start-up time for star-delta starting or auto transformer starting is 2 seconds.



2.2.3 Lightning Protection

- The installation can be fitted with a special over voltage protective device to protect the motor from voltage surges in the electricity supply lines when lightning strikes somewhere in the area.
- The overvoltage protective device will not, however, protect the motor against a direct stroke of lightning.
- The overvoltage protective device should be connected to the installation as close as possible to the motor and always in accordance with local regulations.

2.2.4 Cable Sizing

- Make sure that the submersible drop cable can withstand permanent submersion in the actual liquid and at the actual temperature.
- The cross-section (q) of the cable should meet the following requirements:
 - i. The submersible drop cable should be sized to the rated maximum current (I) of the motor.
 - ii. The cross-section should be sufficient to make a voltage drop over the cable acceptable.

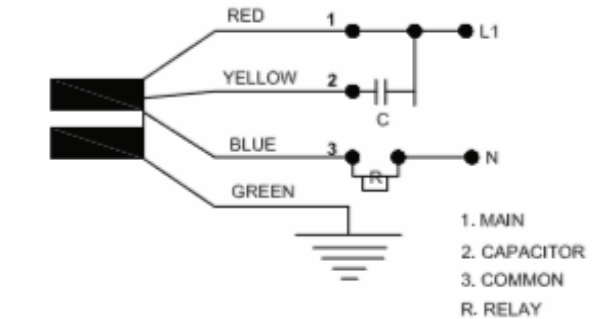
Nominal Area in mm ² (for copper conductor)	Current Rating at 40°C (Amp).
1.5	14
2.5	18
4	26
6	31
10	42
16	57
25	72
35	90
50	115

2.2.5 Control of Single-Phase Motors

The single-phase submersible motor with motor protection(separate)which cuts out the motor in case of excessive winding temperatures while the motor is still supplied with voltage. Allow forth is, when the motor forms part of a control system.

2.2.6 Connection of Single-Phase Motors

The single phase motors are connected to the mains via an operating capacitor which should be sized for continuous operation.



2.2.7 Connection of Three-Phase Motors

- Three-phase submersible motors must be protected.
- When a conventional motor starter is being used, the electrical connection should be carried out as described below:

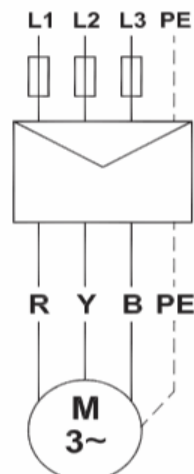
2.2.7.1 Checking of direction of Rotation

When the pump has been connected to the electric supply, determine the correct direction of rotation as follows:

1. Start the pump and check the quantity of water and head developed.
2. In case of head not developed, stop the pump and interchange two of the phase connections. In the case of motors wound for star-delta starting, exchange lead wire.
3. Again start the pump and check the quantity of water and head developed.
4. Stop the pump and compare the results taken under points 1 and 3, the connection which gives the larger quantity of water and the higher head is the correct connection.

2.2.8 Direct-On-Line Starting of Motors

The connection of submersible motors wound for direct-on-line starting appears below:



2.2.9 Star-Delta Starting of Motors

The connection of submersible motors wound for star delta starting appears below:

2.2.10 Connection in case of unidentified cable marking/connection

If it is unknown where the individual leads are to be connected to the mains in order to ensure the correct direction of rotation, proceed as follows:

2.2.10.1 Motors wound for direct-on-line starting

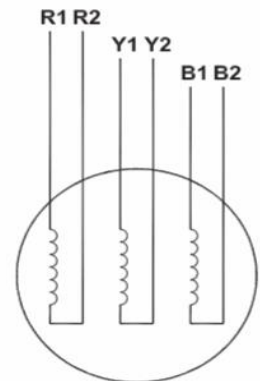
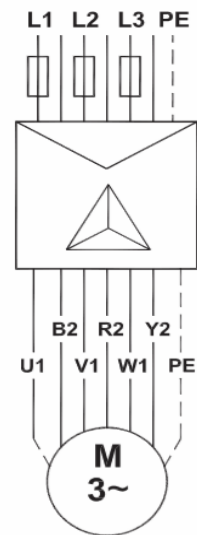
Connect the pump to the mains as is expected to be right. Then check the direction of rotation as described in earlier section of *Checking of direction of rotation*.

2.2.10.2 Motors wound for star-delta starting

The windings of the motor are determined by means of an ohmmeter, and the lead sets for the individual windings are named accordingly.

If star-delta starting is required, the leads should be connected as shown earlier.

If direct-on-line starting is required, the leads should be connected as shown earlier. Then check the direction of rotation.



2.2.11 Soft Starter

The use of soft starters which control the voltage on all three phases and which are provided with a bypass switch is recommended.

2.3 ASSEMBLY OF MOTOR, PUMP AND INSTALLATION

Warning

Before starting any work on the pump/motor, make sure that the electric supply has been switched 'OFF' so that it cannot be accidentally switched 'ON'.

2.3.1 Assembly of Motor and Pump

How to couple motor with pump:

STEP - 1
REMOVE THE SHAFT PROTECTOR,
NUT & WASHER (REF FIG-A)

Surfaces of parts to be
 connected are free from
 dust & dirt.

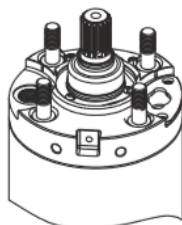


FIG - A

STEP - 2
PUMP FITTED ON MOTOR BY
ADJUSTING SPLINE (REF FIG-B)

Apply water resistant, acid free grease
 to the inner part of coupling

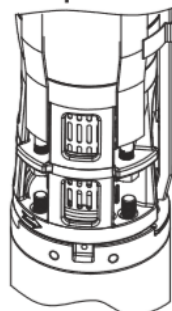


FIG - B

STEP - 3
PLACE SPRING WASHER
INSIDE MOTOR STUD
(REF FIG-C)

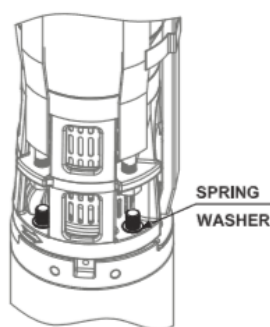


FIG - C

STEP - 4 PUT NUT OVER
SPRING WASHER & TIGHT
CROSSWISE AS PER
TABLE, TORQUE STATED IN
TABLE-1 (REF FIG-D)

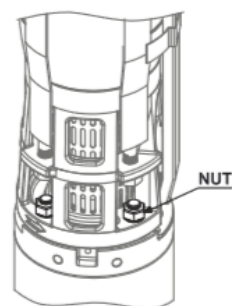


FIG - D

The bolts and nuts securing the straps to the pump must be tightened diagonally to the torques stated in the following table:

Table-1

Straps Bolt/Nut	Torque [Nm]
M8	18
M10	35
M12	45
M16	120

Caution

Make sure that the coupling between the pump and motor engages properly. When assembling the motor and pump, the nuts must be tightened diagonally to the torques stated in the following table:

Pump/Motor Stay Bolt Size	Torque [Nm]
M8	18
M12	150
M16	200
M20	300

Caution

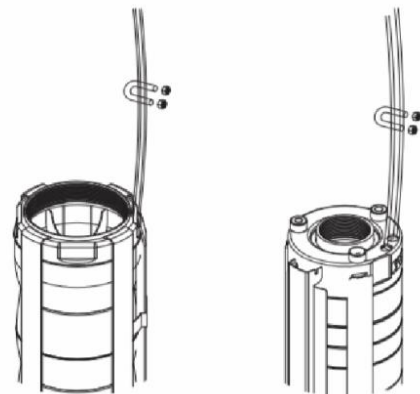
Make sure that the pump chambers are aligned when assembly has been completed.

2.3.2 Fitting of Submersible Drop Cable

- Before fitting the submersible drop cable to the motor, make sure that the cable socket is clean and dry.
- To facilitate the fitting of the cable, lubricate the rubber parts of the cable plug with non-conducting silicone paste.
- Tighten the screws holding the cable to the torques stated:
Motor 4": 1.5 Nm
Motor 6": 4.0-5.0 Nm
Motor 8": 15.0 Nm

2.3.3 Riser pipe

- If a tool, e.g. a chain pipe wrench, is used when the riser pipe is fitted to the pump, the pump must only be gripped by the pump discharge chamber.
- The threaded joints on the riser pipe must all be well cut and fit together to ensure that they do not work loose when subjected to torque reaction caused by the starting and stopping of the pump.
- The thread on the first section of the riser pipe which is to be screwed into the pump should not be longer than the threads in the pump.



NOTE:

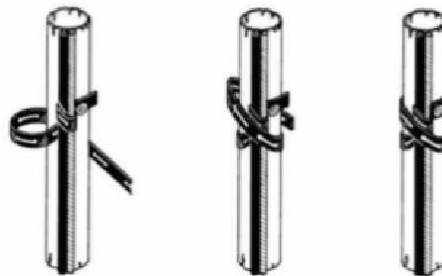
- Plastic pipes are recommended for 4" pumps only.
- When plastic pipes are used, an unloaded straining wire to be fastened to the discharge chamber of the pump, should secure the pump. See figure.
- When connecting plastic pipes, a compression coupling should be used between the pump and the first pipe section.
- Where flanged pipes are used, the flanges should be slotted to take the submersible drop cable and a water indicator hose, if fitted.

2.3.4 Cable fitting

Cable clips must be fitted every 3 meters to fix the submersible drop cable and the straining wire, if fitted, to the riser pipe of the pump.

- Cable clip set consists of a 1.5 mm thick rubber band and buttons.

- Cable fitting: Cut off the rubber band so that the piece with no slit becomes as long as possible.
- Insert a button in the first slit.
- Position the wire alongside the submersible drop cable,
- Wind the band once around the wire and the cable.
- Then wind it tightly at least twice around the pipe, wire and the cable.
- Push the slit over the button and then cut off the band.
- Where large cable cross-sections are used, it will be necessary to wind the band several times.
- Where plastic pipes are used, some slackness must be left between each cable clip as plastic pipes expand when loaded.
- When flanged pipes are used, the cable clips should be fitted above and below each joint.



2.3.5 Lowering the Pump

- It is recommended to check the borehole by means of an inside caliper before lowering the pump to ensure unobstructed passage.
- Lower the pump carefully into the borehole, taking care not to damage the motor cable and the submersible drop cable.

Note:

Do not lower or lift the pump by means of the motor cable.

2.3.6 Installation depth

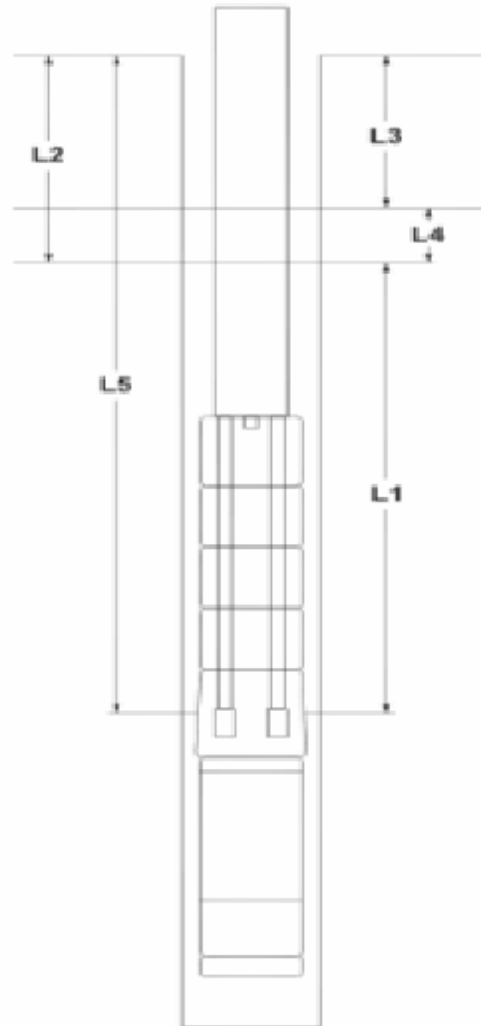
- The dynamic water level should always be above the suction interconnector of the pump.
- Minimum inlet pressure is indicated in the NPSH curve for the pump.
- The minimum safety margin should be 1metre head.
- It is recommended to install the pump so that the motor part is above the well screen in order to ensure optimum cooling.
- When the pump has been installed to the required depth, the installation should be finished by means of a borehole seal.
- Slacken the straining wire so that it becomes unloaded and lock it to the borehole seal by means of wire locks.

NOTE:

For pumps fitted with plastic pipes, the expansion of the pipes when loaded should be taken into consideration, when deciding on the installation depth of the pump.

2.4 START-UP AND OPERATION

- When the pump has been connected correctly and it is submerged in the water to be pumped, it should be started with the discharge valve closed off to approximate 1/3 of its maximum volume of water.
- Check the direction of rotation as described earlier under “Checking of direction of rotation”.
- If there are impurities in the water, the valve should be opened gradually as the water becomes clearer. The pump should not be stopped until the water is completely clean, as otherwise, the pump parts and the non-return valve may choke up.
- As the valve is being opened, the drawdown of the water level should be checked to ensure that the pump always remains submerged.
- The dynamic water level should always be above the suction interconnector of the pump.



Where:

L1: Minimum installation depth below dynamic water level. Minimum 1 meter is recommended.

L2 : Depth to dynamic water level.

L3 : Depth to static water level.

L4: Drawdown. This is the difference between the dynamic and the static water levels.

L5: Installation depth.

- If the pump can pump more than yielded by the well, it is recommended to fit the motor protector, or some other type of dry-running protection.
- If no water level electrodes or level switches are installed, the water level may be drawn down to the suction interconnector of the pump and the pump will then draw in air.

Caution

Long time operation without water or containing air may damage the pump and cause insufficient cooling of the motor.

CHAPTER 3

TROUBLE SHOOTING

S. No.	Fault	Probable Causes	Suggested Remedial Measures
1.	The pump does not run.	a) The fuses are blown.	Replace the blown fuses. If the new ones blow again, the electric installation and the submersible drop cable should be checked.
		b) The ELCB or the voltage- operated ELCB has tripped out.	Cut in the circuit breaker.
		c) No electric supply.	Contact the electricity supply authorities.
		d) The motor starter overload has tripped out.	Reset the motor starter overload (automatically or possibly manually). If it trips out again, check the voltage. Is the voltage OK, see items e) to h) below.
		e) Motor starter/contactors is defective.	Replace the motor starter/contactors.
		f) Starter device is defective.	Repair/replace the starter device.
		g) The control circuit has been interrupted or is defective.	Check the electric installation.
		h) The dry-running protection has cut off the electric supply to the pump, due to low water level.	Check the water level. If it is OK, check the water level electrodes/level switch.
		I) The pump/submersible drop cable is defective.	Repair/replace the pump/cable.
2.	The pump runs but gives no water.	a) The discharge valve is closed.	Open the valve.
		b) No water or too low water level in borehole.	See item 3 a) below.
		c) The non-return valve is stuck in its shut position.	Pull out the pump and clean or replace the valve.
		d) The inlet strainer is choked up.	Pull out the pump and clean the strainer.
		e) The pump is defective.	Repair/replace the pump.

3.	The pump runs at reduced capacity.	a) The drawdown is larger than anticipated.	Increase the installation depth of the pump, throttle the pump or replace it by a smaller model to obtain a smaller capacity.
		b) Wrong direction of rotation.	See earlier section “Checking of direction of rotation”.
		c) The valves in the discharge pipe are partly closed/blocked	Check and clean/replace the valves, if necessary.
		d) The discharge pipe is partly choked by impurities (ochre).	Clean/replace the discharge pipe.
		e) The non-return valve of the pump is partly blocked.	Pull out the pump and check/replace the valve.
		f) The pump and the riser pipe are partly choked by impurities (ochre).	Pull out the pump. Check and clean or replace the pump, if necessary. Clean the pipes.
		g) The pump is defective.	Repair/replace the pump.
		h) Leakage in the pipe work.	Check and repair the pipe work.
		i) The riser pipe is defective.	Replace the riser pipe.
4.	Pump gives less than the rated discharge	a) The differential of the pressure switch between the start and stop pressures is too small.	Increase the differential. However, the stop pressure must not exceed the operating pressure of the pressure tank, and the start pressure should be high enough to ensure sufficient water supply.
		b) The water level electrodes or level switches in the reservoir have not been installed correctly.	Adjust the intervals of the electrodes/level switches to ensure suitable time between the cutting-in and cutting-out of the pump. If the intervals between stop/start cannot be changed via the automatics, the pump capacity may be reduced by throttling the discharge valve.
		c) The non-return valve is leaking or stuck half-open.	Pull out the pump and clean/replace the non-return valve.

		d) The volume of air in the pressure/diaphragm tank is too small.	Adjust the volume of air in the pressure/diaphragm tank in accordance with its installation and operating instructions.
		e) The pressure/diaphragm tank is too small.	Increase the capacity of the pressure/diaphragm tank by replacing or supplementing with another tank.
		f) The diaphragm of the diaphragm tank is defective.	Check the diaphragm tank.

CHAPTER 4

MISCELLANEOUS

4.1 SELECTION OF CABLE SIZE

4.1.1 How to choose correct cable size according pump?

- Cable selection is a very important factor while selecting a pump and motor. If we did not select a proper size cable so whether it can damage motor or gave a heavy electricity bill.
- All cables are not appropriate to use in submersible motor because all the cables are not able to stop water to enter in it periphery, submersible motor needs water proof cables.
- If waterproof cable will not be used, this condition can result in premature failure or damage of cable, motor and control panel.

4.1.2 Points to take into consideration when selecting cables

- Selected cable shall be suitable for the field condition where it is to be used in.
- It shall be adequate in size to operate within the rated temperature of the cable and to ensure the voltage drop within 3% from the point of supply to the motor terminals.
- Cable manufacturer rating is specifically specified for continuous use within a submerged state.
- If simply someone took the same cable type to cover the distance from splice to electrical panel, the cable would most likely to burn and so would submersible motor. This is because the cable will get overheated in open air due to its small cross-section area & also due to length of cable, it will generate a large voltage drop so the motor will be under-supplied.
- For these reasons, borehole professionals will splice the motor short lead to a larger cross-size “drop cable” that will safely carry the required current and supply the motor with the desired voltage.
- Some important data needed for sizing the cable:
 - ✓ Chemical properties of the water.
 - ✓ Temperature of water inside bore hole.
 - ✓ Temperature of air in the borehole and along the entire field where cable installed
 - ✓ Max. submergence (or max pressure in booster applications)
 - ✓ Agency approvals: water condition drinking water or non-drinking water
 - ✓ Nominal operating voltage of load
 - ✓ Nominal motor current
 - ✓ Cos Φ (power factor) of motor
 - ✓ Total length (from submersible motor to electrical panel)

4.2 PUMP SELECTION

General pump selection criteria based on following points:

1. Pump application
2. Head discharge
3. Efficiency
4. NPSH
5. Power
6. Material
7. Fluid

4.2.1 Application of Pump

It contains two major points field of usage whether industrial, agriculture or domestic purpose and select a pump according to the nature of fluid used whether it is oil, water or any other type of fluid.

Two major types of pumps are used

- a. Surface pumps (pumps used on surface)
- b. Submersible pumps (pumps used under water)

a. Surface Pumps

Surface pumps are designed to pump water from surface source like spring, ponds, tanks or wells. Basically if we have water in reservoir then we use surface pump. One more reason to use surface pump, if we have long suction head another reason for selecting surface pump is cheap cost. Most of our surface pumps are either diaphragm pump or rotary vane pump.

b. Submersible pump

Pump which is merged in water with their motor are known as submersible pump. They are made up of steel which have high corrosion resistance properties below and that is why it is costly than surface pump and one more thing this pump is mostly used where there is low suction head.

4.2.2 Head Discharge

Total Suction Head (TSH)

$$\text{Total suction head} = (\text{static head} + \text{static discharge head} + \text{friction loss})$$

Static head: static head means height from water taken.

Static discharge head: head between the pump and the storage reservoir where water has to pump or discharge.

Friction loss: it is loss which happens due to friction present in pipe and system.

Head discharge

Head discharge basically a term which shows total fluid discharge from the pump. It generally measures in meters.

Head and discharge curve

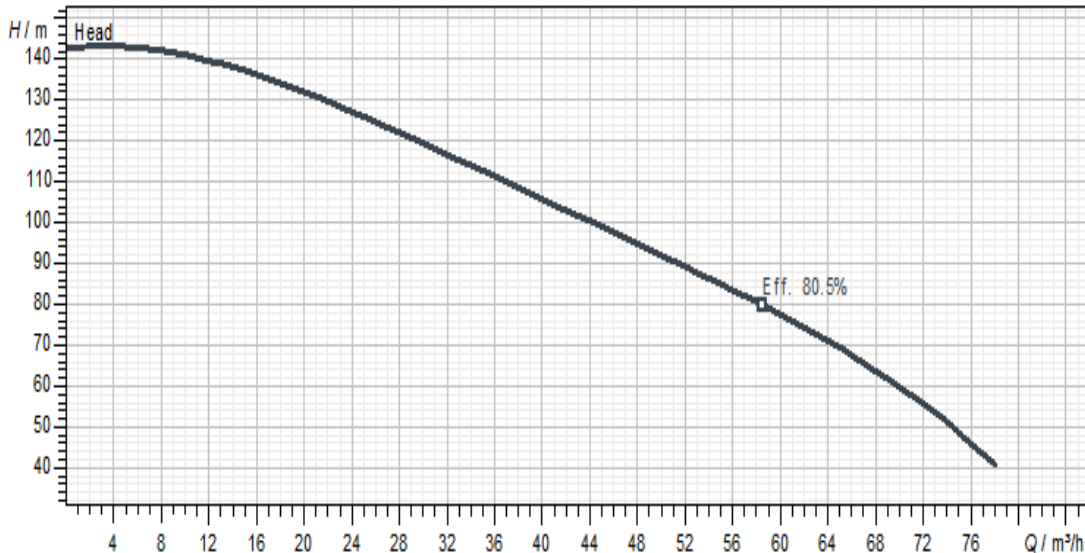


Fig: Head and discharge curve

The above curve shows relation between head and volume (discharge).

- Start at a point called the closed value head where the pump is not doing any work just generating pressure.
- It is a point where we don't want pump to work at all because it is simply churning at the point.
- The flow rate then increases and the available head drops off.

The head of centrifugal pump is determined by impeller diameter and rpm.

- To select the point for operating point of the pump. It should be selected at duty point because at duty point pump provides maximum efficiency.

4.2.3 Power

Pump power is nothing but basically it is a power of motor which is used by pump to transfer water from one place to other and it plays a very important role in pump selection. Power curve is provided below for better understanding.

Power curve

The power curve shows the power used by the pump at particular flow rate. The selection of power for particular pump should be at the point of maximum flow rate because if the operator runs the pump at greater than duty point then pump will not give maximum overall efficiency. If the power is selected at duty point, pump life and efficiency both will be good.

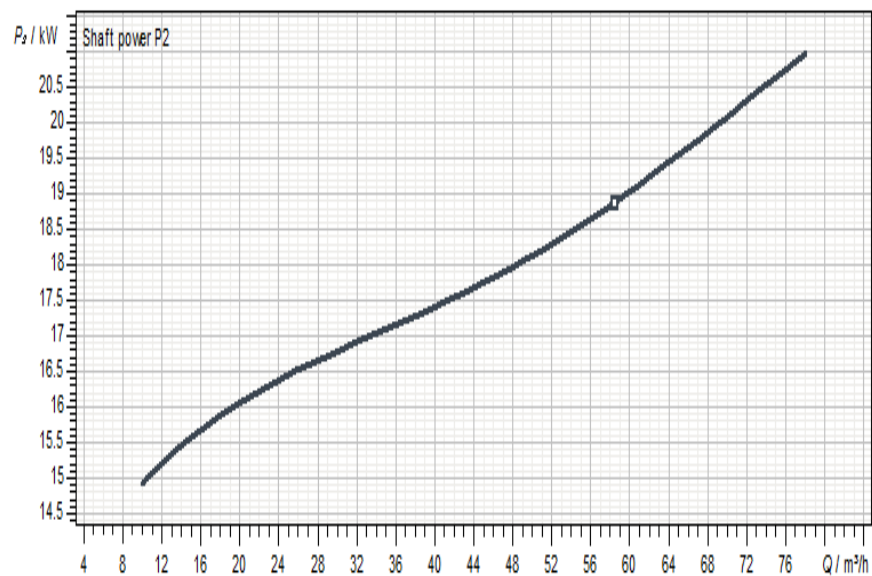


Fig: Power Curve

4.2.4 NPSH (Net Positive Suction Head)

NPSH means “Net Positive Suction Head” and it is further divided in two categories.

- i. **NPSH_R (net positive suction head required):** It means the minimum pressure required at the suction port of the pump to keep the pump away from cavitation.
- ii. **NPSH_A (net positive suction head available):** NPSH_A is a function of installed system and must be calculated, whereas NPSH_R is function of pump and provided by pump manufacturer.

NPSH Curve

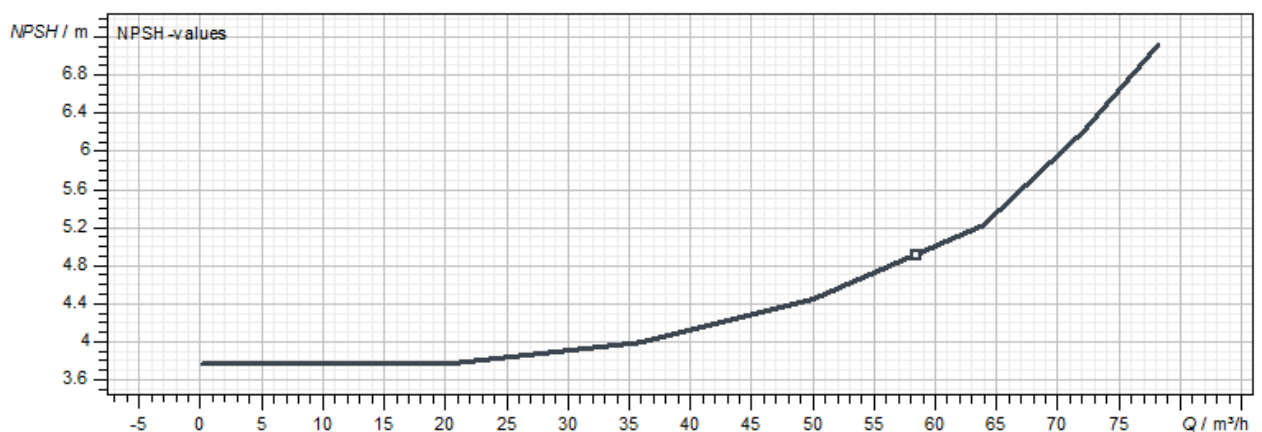


Fig: NPSH Curve

The curve that is shown on this set is the NPSH (net positive suction head). It shows the immersion that the pump impeller needs to avoid it get cavity and becoming damaged.

For cavitation free operation of the pump $NPSH_A$ should be greater than $NPSH_R$ to calculate $NPSH_A$ following formula is used.

$$NPSH_A = H_a - H_v + H_s - H_f$$

Where,

- H_a = atmospheric pressure at sea level
- H_v = vapor pressure of fluid at operating temperature
- $+H_s$ = suction head
- $-H_f$ = suction lift

4.2.5 Efficiency

In most of the cases, user neglects the efficiency of pump compared to price. But in the simple way to understand effectively, “more efficiency more profit”.

Efficiency curve

The curve is shown below; it is an efficiency curve.

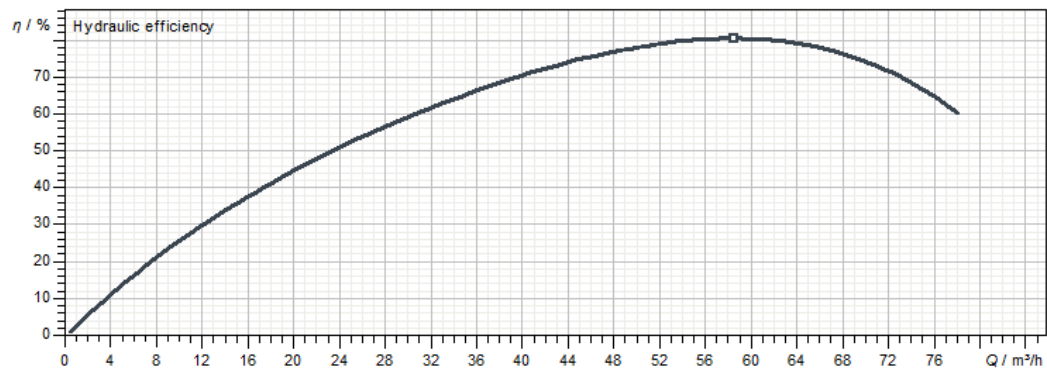


Fig: Efficiency Curve

The point on curve is a best efficiency point that is where one really want the pump to run to achieve the best overall solution for our particular system.

4.2.6 Pump selection curve

This curve contains all the curves of related parameter of pump and help to selecting a good pump.

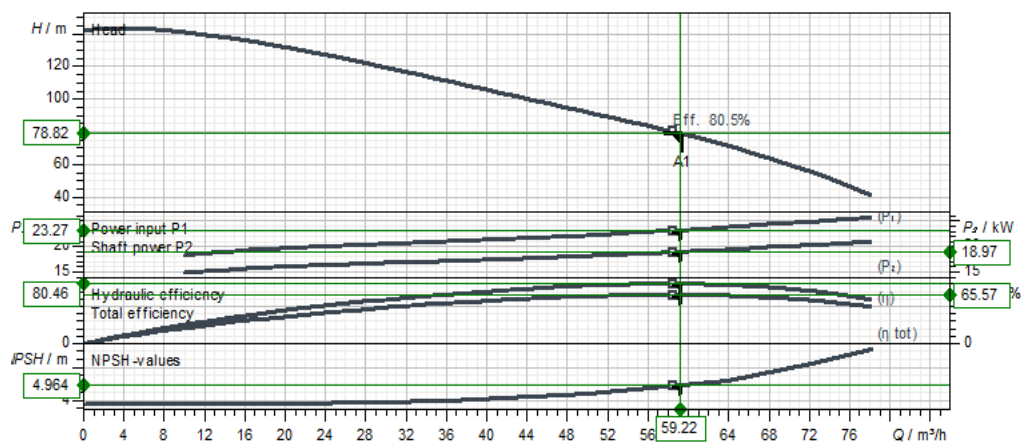


Fig: Pump selection Curve

Now, for selecting a pump, first we see **best efficiency point** on curve. Compare that point with the duty point. If the best efficiency point close to our pump duty point which is on head discharge curve. Then our system is ideal for selection and gives better result to add better performance.

BEP (Best Efficiency Point)

It is a point which lies on efficiency curve and it is a maximum efficiency point where pump give maximum efficiency and profit.

Duty Point

It is a point on which we select our pump, we compare our pump's duty point with BEP which present on efficiency curve.

According to that duty point we select the power used to run the pump.

4.2.7 Head Flow Curve

This curve shows, if your duty point lies in between point A1 and point A2 on the following place then your pump will get maximum performance, shows this type of characteristic which shows on plotted curve.

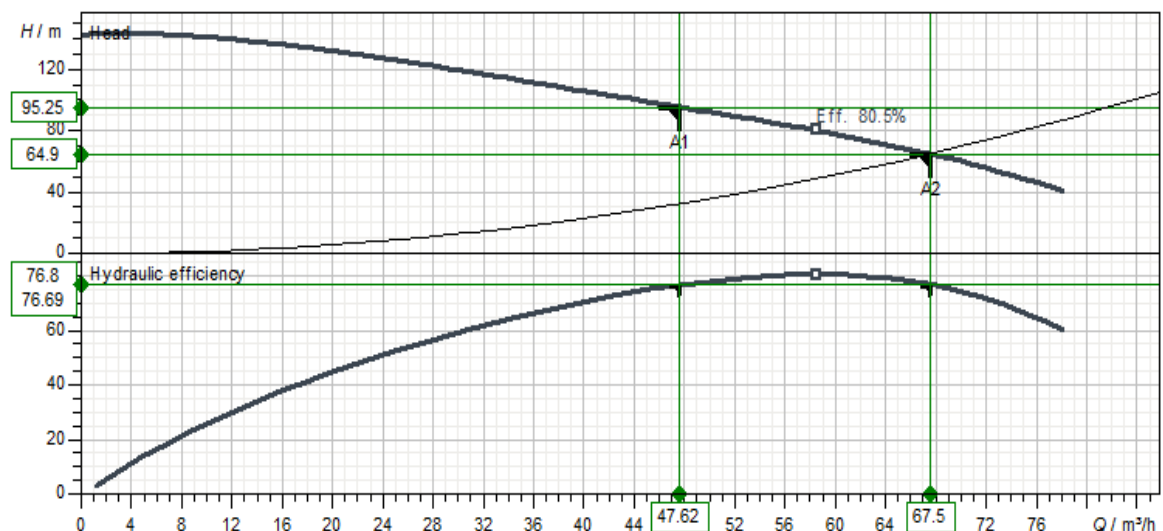


Fig: Head Flow Curve

4.2.8 Material

Material plays a vital role in pump selection and it clearly affects the application and life of pump. So following basic properties of material should be considered for material selection

- Corrosion resistance
- Abrasive-wear resistance
- Cavitation resistance
- Strength
- Casting and machining properties
- Cost

Material preference according cost and properties rank wise order from high material properties to low material properties in both surface & submersible pump.

- Nickel aluminum bronze alloy
- Titanium
- Bronze
- Stainless steel 304
- Stainless steel 316
- Cast iron
- Brass
- Mild steel

4.2.9 Fluid

Fluid is another important parameter in pump selection because you might need to specify a pump that delivers 10 bars of pressure. But if you do not consider the pumped liquid properties, it is highly unlikely you will make the right choice.

If you don't account differing viscosity and density of liquid, you may end up with too big a pump, which is overly expensive to buy and run. If the pump is too small you simply burn out the motor of pump. The denser liquid needs more power to transfer liquid and at different temperature the liquid changes its density so keep this in mind while selecting pump.

CONCLUSION

It is concluded that if we consider given points in above discussion that we can select an appropriate pump for our application. The most important point of pump selection is duty point where we measure all the parameters related to pump.

4.3 INSULATION CLASS

Critical factor in the life of electrical equipment is heat. The type of insulation used in a motor depends on the operating temperature that the motor will experience. Average insulation life decreases rapidly with increase in motor internal operating temperatures. NEMA (National Electrical Manufacturers Association) has established safe maximum operating temperatures for motors based on an average 20000 hour lifetime.

These maximum temperatures are the sum of the ambient and maximum temperature rise ratings of the motor. There are four NEMA insulation classes based on thermal endurance of the system for maximum temperature rating purposes. These are listed on the Motor's name-plate and are either A, B, F, or H. These codes indicate the maximum temperature the motor insulation can withstand without failure.

4.3.1 Insulation Class A

In class 'A' maximum permissible winding temperature is 105°C. Insulation class 'A' consists of insulating materials such as cotton, silk, and paper suitably impregnated or coated or immersed in dielectric liquid.

4.3.2 Insulation Class B

In class 'B' maximum permissible winding temperature is 130°C. Insulation class 'B' consists of insulating materials or combinations of materials such as mica, fiber, asbestos, etc. bonded together with varnishes or oil-modified synthetic resins, bitumen, shellac and Bakelite.

4.3.3 Insulation Class F

In class 'F' maximum permissible winding temperature is 155°C. Insulation class 'F' consists of insulating materials or combinations of materials such as mica, fiber, asbestos, etc. bonded together with epoxy, poly-esterimide (polyamide or polyimide), polyurethane or other resins having superior thermal stability.

4.3.4 Insulation class H

In class 'H' maximum permissible winding temperature is 180°C. Insulation consists of materials or combinations of materials such as mica, fiber, asbestos, etc. with suitable bonding, impregnation or coating substance such as appropriate silicone resins or silicone elastomers.

4.3.5 Important Factors Selecting Insulation Class for Motor

Operating temperature

When considering suitable operating temperature for motor, the temperature at the hottest point is important, this temperature is referred to as "Hot spot" temperature. In Motor winding hot spot is somewhere near the center of winding.

Temperature rise

In operation of a continuous duty motor occurs a condition when motor temperature become steady while generating heat from windings, magnetic cores and friction losses and dissipating heat to surrounding at same time. The difference between this steady temperature and cooling medium temperature is the temperature rise. This rise is always the same regardless the temperature of cooling medium temperature.

High value temperature rise limit the value of ambient temperature (installation site temperature).

For each 10°C rise in operating temperature of motor above the rated temperature of insulation class motor life will reduce by one-half.

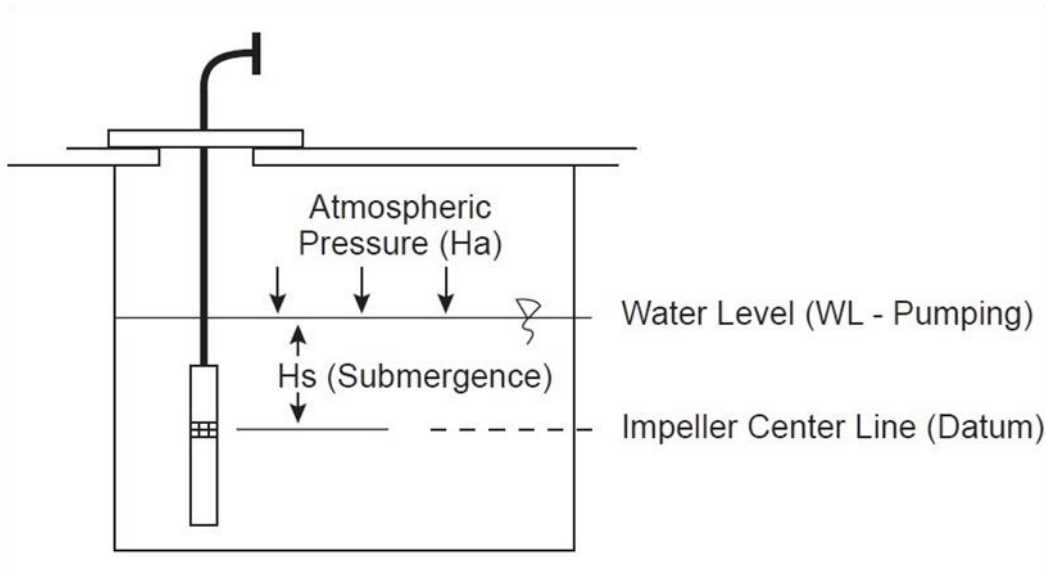
Insulation class 'A' only used for fractional power motors. Insulation class 'B' used for small integral power motor. Insulation Class 'F' used in most of the motors but by using higher insulation class such as class 'H' motor can be made in compact size.

CHAPTER 5

MINIMUM SUBMERGENCE

5.1 INTRODUCTION

Minimum submerge is the condition of water level above the inlet of pump to satisfy pump operating conditions. Submergence is the distance between liquid levels and submerges setting. In order to insure proper hydraulic performance, the pump manufactures minimum submerge should be followed. Submergence is necessary to maintain prime, prevent vortexing and may be provided to the pump NPSH requirement.



Submergence should not be confused with NPSH, as it is a term used to relate liquid level to the intake setting level. In the case of a conventional submersible pumps some submergence, in addition to the $NPSH_R$, is necessary to maintain prime and prevent vortex formation on the liquid supply surface.

5.2 MINIMUM SUBMERGENCE

Minimum submergence requirements are commonly provided by the pump manufacture and should be used for design purposes when required. In the absence of this information, submergence requirement can be approximated using one of the following rules of thumb which fits the application:

1. Can / De-watering application. 1.5 feet above the pump intake plus 1 feet additional submergence for each 500 gpm of flow. (i.e. min. submergence at 1000 gpm should be not less than 3.5 feet.
2. Sump application 3 feet above the pump intake plus 1 feet additional submergence for each 1 liter per second (lps) in approach piping inlet velocity.

Following situations arise due to insufficient submergence of the pump which are:

- i. Cavitation
- ii. Vortexing
- iii. Entrained Gas

5.3 CAVITATION

Cavitation is the condition at which the suction pressure at inlet of pump is below the vapour pressure of the liquid. Cavitation can be generally avoided by providing the $NPSH_R$ of the pump at the maximum flow requirement and water temperature anticipated. The following analysis should be performed during the pump selection process.

- Determine the maximum flow requirement under all possible operating condition and select the pump which handles the maximum flow requirement within the published performance curves.
- Calculate $NPSH_A$ for the application and compare with maximum $NPSH_R$ of the selected pump at maximum flow point established in point 1 above. $NPSH_A$ must be greater than $NPSH_R$ to prevent cavitation.
- The submersible pump intake must always be submerged for proper operation. In some cases, the minimum submergence requirement is dictated by the $NPSH_R$ needs of the pump. The minimum submergence should be not less than 3 feet (or as specified by the manufacture) at the lowest possible pumping level at maximum flow.

Favorable factors for cavitation

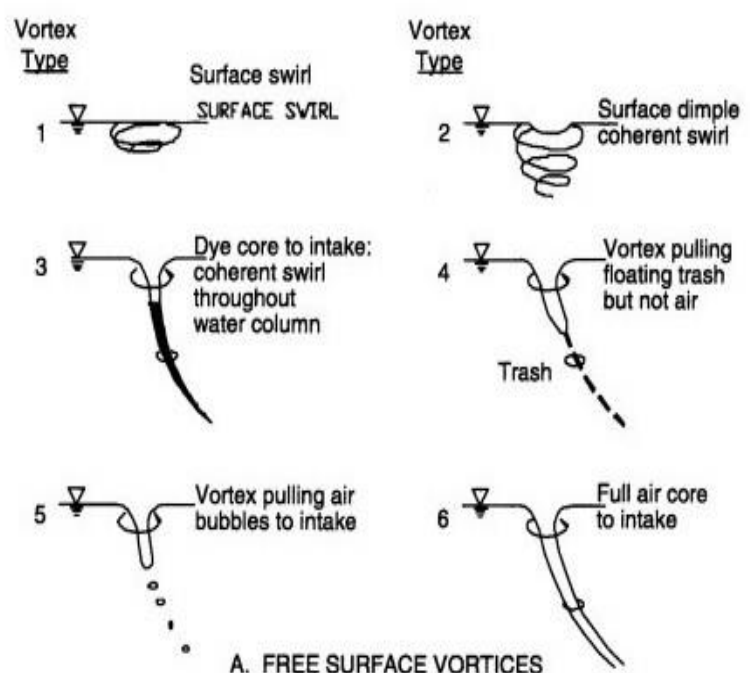
Factors which may create/ contribute to conditions favourable for cavitation, which are often overlooked at the design stage, are:

- Entrained (free) gas.
- Sudden drop in discharge head that significantly increase pumps flow.
- Insufficient submergence (dewatering/improper low level shut-off point).

5.4 VORTEXING

Vortexing is a term frequently used to describe flow patterns which result in formation of vortices, causing loud rumbling noise. A vortex is a whirlpool caused by a combination of factors such as sump design, inlet velocity, and direction of flow, submergence and position of intake. Air entering the pump through these vortices is responsible for noise and vibration, but not cavitation.

Vortexing is rare in submersible pump application; however, when it does occur, it is generally a result of improper submergence.



5.5 ENTRAINED GAS

Most liquid carry small amounts of air or other gases completely dissolved in the liquid. Entrained gas is typically not a problem until it exceeds approximately 1-2% of the total pumped volume of the fluid.

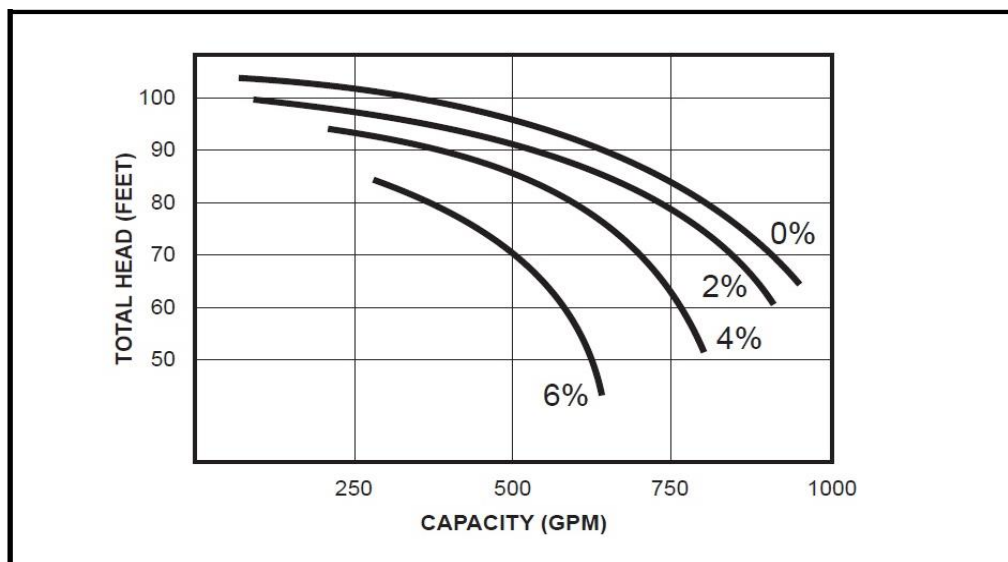
The presence of entrained gas is usually noted by:

- 1) Noise
- 2) Deterioration of H-Q (Head-Discharge) performance and efficiency.

The two most common entrained gas problems encountered in water well applications involving submersible pumps are cascading water (falling water) and formation of gases.

Effect of Entrained Air

The build-up of entrained air specifically affects the performance of centrifugal pumps as shown in below figure. Centrifugal force throws heavier liquid outward from the impeller eye. The lighter air remains behind and will gradually build into a bubble as big as the impeller inlet (“eye”) area, which chokes off the intake flow. This is called “air locking”.



Air Entrainment and H-Q Performance

Increase submergence to reduce potential vortices and/ or to increase the submergence pressure on entrained gas in order to keep it in solution.

REFERENCE

1. Data and literature collected from M/s Shakti Pumps (I) Limited, Pithampur – 454774 Distt. Dhar, (M. P.).
2. Data and literature collected from M/s Texmo Pumps, Mettupalayam Road, Coimbatore (TN).
3. Data collected from Railway units and field study.
4. Comments and suggestions received during the seminar held on 14.12.2018 at CAMTECH, Gwalior.

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