

# Irrigation Water Pumps

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## Introduction

The heart of most irrigation systems is a pump. To make an irrigation system as efficient as possible, the pump must be selected to match the requirements of the water source, the water piping system and the irrigation equipment.

Pumps used for irrigation include centrifugal, deep well turbine, submersible and propeller pumps. Actually, turbine, submersible and propeller pumps are special forms of a centrifugal pump. However, their names are common in the industry. In this circular the term centrifugal pump will refer to any pump located above the water surface and using a suction pipe.

Before selecting an irrigation pump, a careful and complete inventory of the conditions under which the pump will operate must take place. The inventory must include:

1. The source of water (well, river, pond, etc.)
2. The required pumping flow rate
3. The total suction head
4. The total dynamic head

There usually is no choice when it comes to the source of the water; it is either surface water or well water and availability will be determined by the local geology and hydrologic conditions. However, the flow rate and total dynamic head will be determined by the type of irrigation system, the distance from the water source and the size of the piping system.

# Basic Pump Operating Characteristics

"Head" is a term commonly used with pumps. Head refers to the height of a vertical column of water. Pressure and head are interchangeable concepts in irrigation, because a column of water 2.31 feet high is equivalent to 1 pound per square inch (PSI) of pressure. The total head of a pump is composed of several types of head that help define the pump's operating characteristics.

## Total Dynamic Head

The total dynamic head of a pump is the sum of the total static head, the pressure head, the friction head, and the velocity head. An explanation of these terms is given below and graphically shown in Figure 1.

**Figure 1.** The Total Dynamic Head (TDH) is the sum of the total static head, the total friction head and the pressure head. The components of the total static head for a surface water and well water pumping system are shown. (16KB b&w diagram)

## Total Static Head

The total static head is the total vertical distance the pump must lift the water. When pumping from a well, it would be the distance from the pumping water level in the well to the ground surface plus the vertical distance the water is lifted from the ground surface to the discharge point. When pumping from an open water surface it would be the total vertical distance from the water surface to the discharge point.

## Pressure Head

Sprinkler and drip irrigation systems require pressure to operate. Center pivot systems require a certain pressure at the pivot point to distribute the water properly. The pressure head at any point where a pressure gage is located can be converted from pounds per square inch (PSI) to feet of head by multiplying by 2.31. For example, 20 PSI is equal to 20 times 2.31 or 46.2 feet of head. Most city water systems operate at 50 to 60 PSI, which, as illustrated in Table 1, explains why the centers of most city water towers are about 130 feet above the ground.

**Table 1. Pounds per square inch (PSI) and equivalent head in feet of water.**

PSI	Head (feet)
0	0
5	11.5
10	23.1
15	34.6

20	46.2
25	57.7
30	69.3
35	80.8
40	92.4
45	104
50	115
55	127
60	138
65	150
70	162
75	173
80	185
85	196
90	208
95	219
100	231

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### **Friction Head**

Friction head is the energy loss or pressure decrease due to friction when water flows through pipe networks. The velocity of the water has a significant effect on friction loss. Loss of head due to friction occurs when water flows through straight pipe sections, fittings, valves, around corners, and where pipes increase or decrease in size. Values for these losses can be calculated or obtained from friction loss tables. The friction head for a piping system is the sum of all the friction losses.

### **Velocity Head**

Velocity head is the energy of the water due to its velocity. This is a very small amount of energy and is usually negligible when computing losses in an irrigation system.

### **Suction Head**

A pump operating above a water surface is working with a suction head. The suction head includes not only the vertical suction lift, but also the friction losses through the pipe, elbows, foot valves and other fittings on the suction side of the pump. There is an allowable limit to the suction head on a pump and the net positive suction head (NPSH) of a pump sets that limit.

The theoretical maximum height that water can be lifted using suction is 33 feet. Through controlled laboratory tests, manufacturers determine the NPSH curve for their pumps. The NPSH curve will increase with increasing flow rate through the pump. At a certain flow rate, the NPSH is subtracted from 33 feet to determine the maximum suction head at which that pump will operate. For example, if a pump requires a minimum NPSH of 20 feet the pump would have a maximum suction head of 13 feet. Due to suction pipeline friction losses, a pump rated for a maximum suction head of 13 feet may effectively lift water only 10 feet. **To minimize the suction pipeline friction losses, the suction pipe should have a larger diameter than the discharge pipe.**

Operating a pump with suction lift greater than it was designed for, or under conditions with excessive vacuum at some point in the impeller, may cause cavitation. Cavitation is the implosion of bubbles of air and water vapor and makes a very distinct noise like gravel in the pump. The implosion of numerous bubbles will eat away at an impeller and it eventually will be filled with holes.

## Pump Power Requirements

The power added to water as it moves through a pump can be calculated with the following formula:

$$\text{WHP} = \frac{Q \times \text{TDH}}{3960} \quad (1)$$

where:

WHP = Water Horse Power  
 Q = Flow rate in gallons per minute (GPM)  
 TDH = Total Dynamic Head (feet)

However, the actual power required to run a pump will be higher than this because pumps and drives are not 100 percent efficient. The horsepower required at the pump shaft to pump a specified flow rate against a specified TDH is the **Brake Horsepower** (BHP) which is calculated with the following formula:

$$\text{BHP} = \frac{\text{WHP}}{\text{Pump Eff.} \times \text{Drive Eff.}} \quad (2)$$

**BHP** -- Brake Horsepower (continuous horsepower rating of the power unit).

**Pump Eff.** -- Efficiency of the pump usually read from a pump curve and having a value between 0 and 1.

**Drive Eff.** -- Efficiency of the drive unit between the power source and the pump. For direct connection this value is 1, for right angle drives the value is 0.95 and for belt drives it can vary from 0.7 to 0.85.

## Effect of Speed Change on Pump Performance

The performance of a pump varies with the speed at which the impeller rotates.

**Theoretically**, varying the pump speed will result in changes in flow rate, TDH and BHP according to the following formulas:

$$\left(\frac{\text{RPM}_2}{\text{RPM}_1}\right) \times \text{GPM}_1 = \text{GPM}_2 \quad (3)$$

$$\left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^2 \times \text{TDH}_1 = \text{TDH}_2 \quad (4)$$

$$\left(\frac{\text{RPM}_2}{\text{RPM}_1}\right)^3 \times \text{BPH}_1 = \text{BPH}_2 \quad (5)$$

where:

RPM<sub>1</sub> = Initial revolutions per minute setting

RPM<sub>2</sub> = New revolutions per minute setting

GPM = Gallons per Minute  
(subscripts same as for RPM)

TDH = Total Dynamic Head  
(subscripts same as for RPM)

BHP = Brake Horsepower  
(subscripts same as for RPM)

As an example, if the RPM are increased by 50 percent, the flow rate will increase by 50 percent, the TDH will increase  $(1.5 \blacklozenge 1)^2$  or 2.25 times, and the required BHP will increase  $(1.5 \blacklozenge 1)^3$  or 3.38 times that required at the lower speed. It is easy to see that with a speed increase the BHP requirements of a pump will increase at a **faster rate** than the head and flow rate changes.

## Pump Efficiency

Manufacturers determine by tests the operating characteristics of their pumps and publish the results in pump performance charts commonly called "pump curves." A typical pump curve is shown in Figure 2.

**Figure 2. A typical pump curve for a horizontal centrifugal pump. NPSH is the Net Positive Suction Head required by the pump and TDSL is the Total Dynamic Suction Lift available (both at sea level).**

(40KB b&w graph)

All pump curves are plotted with the flow rate on the horizontal axis and the TDH on the vertical axis. The curves in Figure 2 are for a centrifugal pump tested at different RPM.

Each curve indicates the GPM versus TDH relationship at the tested RPM. In addition, pump efficiency lines have been added and wherever the efficiency line crosses the

pump curve lines **that** number is what the efficiency is at that point. Brake horsepower (BHP) curves have also been added; they slant down from left to right. The BHP curves are calculated using the values from the efficiency lines. At the top of the chart is an NPSH curve with its scale on the right side of the chart.

## Reading a Pump Curve

When the desired flow rate and TDH are known, these curves are used to select a pump. The pump curve shows that a pump will operate over a wide range of conditions. However, it will operate at peak efficiency only in a narrow range of flow rate and TDH.

As an example of how a pump characteristic curve is used, let's use the pump curve in Figure 2 to determine the horsepower and efficiency of this pump at a discharge of 900 gallons per minute (GPM) and 120 feet of TDH.

**Solution:** Follow the dashed vertical line from 900 GPM until it crosses the dashed horizontal line from the 120 feet of TDH. At this point the pump is running at a peak efficiency just below 72 percent, at a speed of 1600 RPM. If you look at the BHP curves, this pump requires just less than 40 BHP on the input shaft. A more accurate estimate of BHP can be calculated with equations 1 and 2. Using equation 1, the WHP would be  $[900 \times 120] / 3960$  or 27.3, and from equation 2 the BHP would be  $27.3 / 0.72$  or 37.9, assuming the drive efficiency is 100 percent. The NPSH curve was used to calculate the Total Dynamic Suction Lift (TDSL) markers at the bottom of the chart. Notice that the TDSL at 1400 GPM is 10 feet, but at 900 GPM the TDSL is over 25 feet.

## Changing Pump Speed

In addition, suppose this pump is connected to a diesel engine. By varying the RPM of the engine we can vary the flow rate, the TDH and the BHP requirements of this pump. As an example, let's change the speed of the engine from 1600 RPM to 1700 RPM. What effect does this have on the GPM, TDH and BHP of the pump?

**Solution:** We will use equations 3, 4 and 5 to calculate the change. Using equation 3, the change in GPM would be  $(1700/1600) \times 900$ , which equals 956 GPM. Using equation 4, the change in TDH would be  $(1700/1600)^2 \times 120$ , which equals 135.5 feet of TDH. Using equation 5, the change in BHP would be  $(1700/1600)^3 \times 37.9$ , which equals 45.5 BHP. This point is plotted on Figure 2 as the circle with the dot in the middle. Note that the new operating point is up and to the right of the old point and that the efficiency of the pump has remained the same.

When a pump has been selected for an irrigation installation, a copy of the pump curve should be provided by the installer. In addition, if the impeller(s) was trimmed, this information should also be provided. This information will be valuable in the future, especially if repairs have to be made.

## Centrifugal Pumps

Centrifugal pumps are used to pump from reservoirs, lakes, streams and shallow wells. They are also used as booster pumps in irrigation pipelines. All centrifugal pumps must be completely filled with water or "primed" before they can operate. The suction line as well as the pump have to be filled with water and free of air. Air tight joints and connections are extremely important on the suction pipe. Priming a pump can be done by hand operated vacuum pumps, internal combustion engine vacuum, motor powered vacuum pumps or small water pumps that fill the pump and suction pipe with water.

Centrifugal pumps are designed for either horizontal or vertical operation. The horizontal centrifugal has a vertical impeller connected to a horizontal drive shaft as shown in Figure 3. Horizontal centrifugal pumps are the most common in irrigation systems. They are generally less costly, require less maintenance, easier to install and more accessible for inspection and maintenance than a vertical centrifugal. There are self-priming horizontal centrifugal pumps, but they are special purpose pumps and not normally used with irrigation systems.

**Figure 3. A horizontal centrifugal pump.**  
(5KB b&w diagram)

Vertical centrifugal pumps may be mounted so the impeller is under water at all times. This makes priming unnecessary, which makes the vertical centrifugal desirable for floating applications. Also, a self priming feature is very desirable in areas where there are frequent electrical power outages or off-peak electrical price reductions are available. Self priming also lends itself to the new control panels for center pivots where automatic restart is a programmable function. A note of caution: because the bearings are constantly under water, a higher level of maintenance may be required.

## Deep Well Turbine Pumps

Deep well turbine pumps are adapted for use in cased wells or where the water surface is below the practical limits of a centrifugal pump. Turbine pumps are also used with surface water systems. Since the intake for the turbine pump is continuously under water, priming is not a concern. Turbine pump efficiencies are comparable to or greater than most centrifugal pumps. They are usually more expensive than centrifugal pumps and more difficult to inspect and repair.

The turbine pump has three main parts: (1) the head assembly, (2) the shaft and column assembly and (3) the pump bowl assembly as shown in Figure 4. The head is normally cast iron and designed to be installed on a foundation. It supports the column, shaft and bowl assemblies and provides a discharge for the water. It also will support either an electric motor, a right angle gear drive or a belt drive.

**Figure 4. A deep well turbine pump.**  
(7KB b&w diagram)

The shaft and column assembly provides a connection between the head and pump bowls. The line shaft transfers the power from the motor to the impellers and the column carries the water to the surface. The line shaft on a turbine pump may be either water lubricated or oil lubricated.

The oil-lubricated pump has an enclosed shaft into which oil drips, lubricating the bearings. The water-lubricated pump has an open shaft. The bearings are lubricated by the pumped water. If there is a possibility of fine sand being pumped, select the oil lubricated pump because it will keep the sand out of the bearings. If the water is for domestic or livestock use, it must be free of oil and a water-lubricated pump must be used. In some states, such as Minnesota, there is no choice; water-lubricated pumps are required in all **new** irrigation wells.

Line shaft bearings are commonly placed on 10-foot centers for water-lubricated pumps operating at speeds under 2,200 RPM and at 5-foot centers for pumps operating at higher speeds. Oil-lubricated bearings are commonly placed on 5-foot centers.

A pump bowl encloses the impeller. Due to its limited diameter, each impeller develops a relatively low head. In most deep well turbine installations several bowls are stacked in series one above the other. This is called staging. A four-stage bowl assembly contains four impellers all attached to a common shaft and will operate at four times the discharge head of a single-stage pump.

Impellers used in turbine pumps may be either semi-open or enclosed as shown in Figure 5. The vanes on semi-open impellers are open on the bottom and they rotate with a close tolerance to the bottom of the pump bowl. The tolerance is critical and must be adjusted when the pump is new. During the initial break-in period the line shaft couplings will tighten, therefore, after about 100 hours of operation, the impeller adjustments should be checked. After break-in, the tolerance must be checked and adjusted every three to five years or more often if pumping sand.

**Figure 5. Both enclosed and semi-open impellers are used in vertical turbine and centrifugal pumps. Only enclosed impellers are used in submersible pumps.**  
(8KB b&w diagram)

Both types of impellers may cause inefficient pump operation if they are not properly adjusted. Mechanical damage will result if the semi-open impellers are set too low and



the vanes rub against the bottom of the bowls. The adjustment of enclosed impellers is not as critical; however, they must still be checked and adjusted.

Impeller adjustments are made by tightening or loosening a nut on the top of the head assembly. Impeller adjustments are normally made by lowering the impellers to the bottom of the bowls and adjusting them upward. The amount of upward adjustment is determined by how much the line shaft will stretch during pumping. The adjustment must be made based on the lowest possible pumping level in the well. The proper adjustment procedure is often provided by the pump manufacturer. The adjustment procedure for many of the common deep well turbine brands is outlined in Nebraska Cooperative Extension Service bulletin EC 81-760, entitled "How to adjust vertical turbine pumps for maximum efficiency."

## Operating Characteristics

The operating characteristics of deep well turbine pumps are determined by test and depend largely on the bowl design, impeller type and the speed of the impeller shaft. Flow rate, TDH, BHP, efficiency, and RPM are similar to those given for centrifugal pumps. Vertical turbine pumps are generally designed for a specific RPM setting.

A vertical turbine pump curve is shown in Figure 6. This pump curve is similar to the centrifugal pump curve except instead of curves for various RPM's, the curves are for different diameter impellers. Decreasing the diameter of impellers is called "trimming." Manufacturers will trim impellers to the proper size to match the TDH and flow rate requirements of a specific irrigation installation. Pump curves for turbine pumps are normally shown for a single stage so the TDH obtained will be determined by multiplying the indicated head on the pump curve by the number of stages. The brake horsepower requirements must also be multiplied by the number of stages. Note that the flow rate will not change no matter how many stages are added.

**Figure 6.** Deep well turbine pump curve. The brake horsepower and total head are for one stage. If the pump had five stages, multiply the brake horsepower and the total head values by five. The gallons per minute will stay the same no matter how many stages are added.

(27KB b&w diagram)

## Using the Pump Curve

As an example, suppose the pump curve in Figure 6 is for a 5-stage pump, with a 7.13 inch impeller supplying 800 GPM. What would be the TDH and BHP values?

**Solution:** Follow the dashed vertical line from 800 GPM up to where it meets the 7.13-inch impeller curve on the upper portion of the chart. Follow the dashed horizontal line left to where it shows 26 feet of TDH. Multiplying 26 by 5 gives 130 feet of TDH. Next, follow the dashed vertical line from 800 GPM up to the 7.13-inch impeller BHP curve on the lower portion of the chart and then follow the horizontal dashed line left to where it

shows 6.5 BHP. Multiplying 6.5 BHP by 5 stages produces a 32.5 BHP requirement for this pump. Also note that the pump is operating at its peak efficiency of 80 percent. At this efficiency the calculated BHP (equations 1 and 2) is 32.8.

## **Installation of Vertical Turbine Pumps**

Deep well turbine pumps must have correct alignment between the pump and the power unit. Correct alignment is made easy by using a head assembly that matches the motor and column/pump assembly. It is very important that the well is straight and plumb. The pump column assembly must be vertically aligned so that no part touches the well casing. Spacers are usually attached to the pump column to prevent the pump assembly from touching the well casing. If the pump column does touch the well casing, vibration will wear holes in the casing. A pump column out of vertical alignment may also cause excessive bearing wear.

The head assembly must be mounted on a good foundation at least 12 inches above the ground surface. A foundation of concrete (Figure 7) provides a permanent and trouble-free installation. The foundation must be large enough to allow the head assembly to be securely fastened. The foundation should have at least 12 inches of bearing surface on all sides of the well. **In the case of a gravel-packed well, the 12-inch clearance is measured from the outside edge of the gravel packing.**

### **Figure 7. Recommended concrete base with access pipe for water level measurement and chlorination.**

(15KB b&w diagram)

A well access pipe at least 1.5 inches in diameter must extend through the foundation into the well casing. The access pipe serves two purposes. The first is to measure both static and pumping water levels in the well and the second is to allow chlorination of the well. A 3/4-inch diameter polyethylene tubing with the bottom end closed inserted into the access pipe and extending to the pump level will make measuring water levels much easier. Small holes must be drilled into the tubing to allow water to move in and out of the tubing easily. More information on well maintenance can be found in NDSU circular AE-97, "Operation and Maintenance of Irrigation Wells."

## **Submersible Pumps**

A submersible pump is a turbine pump close-coupled to a submersible electric motor as shown in Figure 8. Both pump and motor are suspended in the water, thereby eliminating the long drive shaft and bearing retainers required for a deep well turbine pump. Because the pump is located above the motor, water enters the pump through a screen located between the pump and motor.

**Figure 8. A submersible pump installed in a well.**

(10KB b&w diagram)

The submersible pump uses enclosed impellers because the shaft from the electric motor expands when it becomes hot and pushes up on the impellers. If semi-open impellers were used, the pump would lose efficiency. The pump curve for a submersible pump is very similar to a deep well turbine pump.

Submersible motors are smaller in diameter and much longer than ordinary motors. Because of their smaller diameter, they are lower efficiency motors than those used for centrifugal or deep well turbine pumps. Submersible motors are generally referred to as dry or wet motors. Dry motors are hermetically sealed with a high dielectric oil to exclude water from the motor. Wet motors are open to the well water with the rotor and bearings actually operating in the water.

**If there is restricted or inadequate circulation of water past the motor, it may overheat and burn out. Therefore, the length of riser pipe must be sufficient to keep the bowl assembly and motor completely submerged at all times. In addition, the well casing must be large enough to allow water to easily flow past the motor.**

Small submersible pumps (under 5 horsepower) use single phase power. However, most submersible pumps used for irrigation need three phase electrical power. Electrical wiring from the pump to the surface must be watertight and all connections sealed. The electrical line should be attached to the column pipe every 20 feet to prevent it from wrapping around the column pipe. Voltage at the motor leads must be within plus or minus 10 percent of the motor nameplate voltage. If there is a 5 percent voltage drop in the submersible pump cable, voltage at the surface must not be less than 95 percent of rated voltage. Because the pump is located in the well, lightning protection should be wired into the control box. Lightning hits on wells with submersible pumps is a leading cause of pump failures.

Submersible pumps can be selected to provide a wide range of flow rate and TDH combinations. Submersible pumps more than 10 inches in diameter generally cost more than comparably sized deep well turbines because the motors are more expensive.

Many manufacturers make submersible booster pumps. These pumps are usually mounted horizontally in a pipeline. An advantage to using a submersible as a booster pump instead of a centrifugal is noise reduction. This is a desirable attribute in residential settings and near golf courses. Submersibles have also been used as booster pumps in the suction lines of centrifugal pumps. This application is used in situations where the water level will fluctuate a considerable amount over the season. Having a submersible in the suction line will change the head at the inlet of the centrifugal pump from a suction head to a positive head.

## Propeller Pumps

Propeller pumps are used for low lift, high flow rate conditions. They come in two types, axial flow and mixed flow. The difference between the two is the type of impeller. The axial flow pump uses an impeller that looks like a common boat motor screw and is essentially a very low head pump. A single-stage propeller pump typically will lift water no more than 20 feet. By adding another stage, heads from 30 to 40 feet are obtainable. The mixed-flow pump uses either semi-open or closed impellers similar to turbine pumps.

In permanent installations, propeller pumps are mounted vertically as shown in Figure 9. For portable pumping platforms, they are mounted on trailers or they are mounted on pontoons for use as floating intakes. Portable propeller pumps are commonly mounted in almost horizontal positions (low angles) to allow them to pump into pipelines easily as well as to be backed into a water source. Portable propeller pumps are commonly powered by the power-take-off (PTO) on tractors. On many farms, propeller pumps are used to pump out waste storage lagoons.

**[Figure 9. A propeller pump.](#)**  
(8KB b&w diagram)

Power requirements of the propeller pump increase directly with the TDH so adequate power must be provided to drive the pump at maximum lift. Propeller pumps are not suitable under conditions where it is necessary to throttle the discharge to reduce the flow rate. It is important to accurately determine the maximum TDH against which this type of pump will operate.

Propeller pumps are not suitable for suction lift. The impeller must be submerged and the pump operated at the proper submergence depth. The depth of submergence will vary according to various manufacturers recommendations, but generally, the greater the diameter of pump, the deeper the submergence. Following recommended submergence depths will ensure that the flow rate is not reduced due to vortices. Also, failure to observe required submergence depth may cause severe mechanical vibrations and rapid deterioration of the propeller blades.

## Pump Selection Criteria

The selection of an irrigation water pump is based almost entirely on the relationship between pump efficiency and the TDH the pump will provide at a specific flow rate. As

shown before, these parameters are also the basis of the pump characteristic curve. Table 2 can be used to narrow the selection of a pump type for a broad range of flow rates and total dynamic heads. One item not included in the TDH values in Table 2 is the suction lift. If your application needs to lift the water to the pump then a centrifugal pump will have to be used.

**Table 2. A chart showing the most desirable pump types to use for a given range of flow rates and total dynamic heads.**

Gallons per Minute	TDH (feet)		
	50 or less	50 to 500	500 or more
0 to 300	Propeller Centrifugal	Centrifugal Vertical Turbine Submersible	Centrifugal Vertical Turbine Submersible
300 to 5000	Propeller	Centrifugal Vertical Turbine Submersible	Centrifugal Vertical Turbine Submersible
5000 or more	Propeller	Centrifugal Vertical Turbine Propeller Submersible	Centrifugal Vertical Turbine

## Factors to Consider in Selecting an Irrigation Pump

Pump Type	Advantages	Disadvantages
Centrifugal	<ol style="list-style-type: none"> <li>1. High efficiency over a range of operating conditions.</li> <li>2. Easy to install.</li> <li>3. Simple, economical and adaptable to many situations.</li> <li>4. Electric, internal combustion engines or tractor power can be used.</li> <li>5. Does not overload with increased TDH.</li> <li>6. Vertical centrifugal may be submerged and not need priming.</li> </ol>	<ol style="list-style-type: none"> <li>1. Suction lift is limited. It needs to be within 20 vertical feet of the water surface.</li> <li>2. Priming required.</li> <li>3. Loss of prime can damage pump.</li> <li>4. If the TDH is much lower than design value, the motor may overload.</li> </ol>

Vertical Turbine	<ol style="list-style-type: none"> <li>1. Adapted for use in wells.</li> <li>2. Provides high TDH and flow rates with high efficiency.</li> <li>3. Electric or internal combustion power can be used.</li> <li>4. Priming not needed.</li> <li>5. Can be used where water surface fluctuates.</li> </ol>	<ol style="list-style-type: none"> <li>1. Difficult to install, inspect, and repair.</li> <li>2. Higher initial cost than a centrifugal pump.</li> <li>3. To maintain high efficiency, the impellers must be adjusted periodically.</li> <li>4. Repair and maintenance is more expensive than centrifugals.</li> </ol>
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Submersible	<ol style="list-style-type: none"> <li>1. Can be used in deep wells.</li> <li>2. Priming not needed</li> <li>3. Can be used in crooked wells.</li> <li>4. Easy to install.</li> <li>5. Smaller diameters are less expensive than comparable sized vertical turbines.</li> </ol>	<ol style="list-style-type: none"> <li>1. More expensive in larger sizes than deep well vertical turbines.               <ol style="list-style-type: none"> <li>2. Only electric power can be used.</li> </ol> </li> <li>3. More susceptible to lightning.</li> <li>4. Water movement past motor is required.</li> </ol>
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Propeller	<ol style="list-style-type: none"> <li>1. Simple construction.</li> <li>2. Can pump some sand.</li> <li>3. Priming not needed.</li> <li>4. Efficient at pumping very large flow rates at low TDH.</li> <li>5. Electric, internal combustion engine and tractor power can be used.</li> <li>6. Suitable for portable operation.</li> </ol>	<ol style="list-style-type: none"> <li>1. Not suitable for suction lift.</li> <li>2. Cannot be valved back to reduce flow rate.</li> <li>3. Intake submergence depth is very critical.</li> <li>4. Limited to low (less than 75 feet) TDH.</li> </ol>
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