9 Pumping

Reviewed and adjusted by Patrick Okuni

9 Pumping

9.1 Introduction

Water pumping technology developed in parallel with the sources of power available at the time. Indeed one can say that our first ancestors who cupped their hands and lifted water from a stream chose the 'pumping' technique appropriate to them. Modern devices such as centrifugal pumps have reached a high state of development and are widely used, particularly in developed countries, only because suitable power sources such as diesel engines and electric motors became available.

For small communities in developing countries, human and animal power is often the most readily available power for pumping water, particularly in rural areas. Under suitable conditions wind power is of relevance. Solar energy can also have potential. Diesel engines and electric motors should only be used if the necessary fuel or electricity supplies are reliably available, together with adequate maintenance and spare parts.

A wide range of pump types is available on the market. Prevailing local conditions and management capacities determine the type that is most suitable and sustainable. While it may seem obvious that effective involvement of users, the private sector and support organisations is important in the choice of pumping technology, the fact remains that it is frequently disregarded. Too often technical capacities of users and local support are over-estimated, resulting in pumps not being properly operated and maintained, and eventually to their breakdown.

Participation by representatives of the different user groups, including women and children of different ages, in selecting and trying out the pumps, helps to ensure that a type is chosen that is suitable and acceptable to them. Productive use of the pumped water generally has a very positive effect on the upkeep and lifetime of the pump. It also helps when users learn about the proper way of operating a specific type of pump and the underlying reasons, and set up and implement a system for proper operation as part of local participatory planning and management of the service. When local interest is not generated, lack of local funds or incentives to invest in O&M and replacement of pumps means that their condition degenerates quickly.

9.2 Power sources for pumping

Human power

The simplest pumps of all are those operated by human power. In this category come a range of handpumps and footpumps. They are capable of lifting relatively small amounts of water. Using human power for pumping water has important benefits for small communities in developing countries:

- The power requirements can be met from within the users' group.
- The capital cost is generally low.
- The discharge capacity of one or more manual pumping devices is usually adequate to meet the domestic water requirements of a small community, including, if needed, for small-scale productive uses within households.
- Design developments during the last 20 years mean that pumps can be repaired and maintained by appropriately trained local caretakers (men or women).

The power available from human muscle depends on the individual, the environment and the duration of the task. For work of long duration, for example eight hours per day, a healthy man is estimated to produce 60-75 watts (0.08-0.10 horsepower). This value must be reduced for women, children and the aged. It also must be reduced for high temperature, and work environments with high humidity. Where the pump user and the pump are poorly matched, much of the power input is wasted, for example, when a person operates a pump from a stooped position. Tests and user evaluations help to bring out problems, such as rejection of footpumps because pregnant women and young children could not easily operate them or the movement was not culturally acceptable.

Animal power

Draught animals are a common and vital source of power in many developing countries. Animals may be used for pumping water for irrigation as well as for human consumption. The most efficient use of animals is at fixed sites where they pull rotating circular sweeps or push treadmills to drive slow moving, large displacement pumps with gears. However, with the increased access to other sources of energy, the use of animal power for water pumping is declining.

Wind power

The use of wind power for pumping water should be feasible if

- winds of at least 2.5-3 m/s are present 60% or more of the time;
- the water source can be pumped continuously without excessive drawdown;
- storage is provided, typically for at least 3 days' demand, to provide for calm periods without wind;
- a clear sweep of wind to the windmill is secured, i.e. the windmill is placed above surrounding obstructions, such as trees or buildings within 125 m; preferably the windmill should be set on a tower 4.5-6 m high;
- windmill equipment is available that can operate relatively unattended for long periods of time, e.g. six months or more. The driving mechanism should be covered and provided with an adequate lubrication system. Vanes, and sail assemblies should be protected against weathering.

By far the most common type of wind-powered pump is the slow-running wind wheel driving a piston pump. The pump is generally equipped with a pump rod that is connected to the drive axis of the windmill. Provision can be made for pumping by hand during calm periods.

The wind wheels range in diameter from about 2-6 m. Even though the windmills themselves may have to be imported, strong towers can usually be con-structed from local materials.

Modern windmills are designed to ensure that they automatically turn into the wind when pumping. They are also equipped with a *pull-out* system to turn the wheel auto-matically out of excessive wind that might damage the windmill, i.e. stronger than 13-15 m/s. The *sails* or fan blades can be de-signed in such a way that they furl automatically to prevent the wheel from rotating too fast in high winds. The windmill will normally not begin pumping until the wind velocity is about 2.5-3 m/s. Fig. 9.1 shows several typical arrangements for windmill-pumped water supply systems.

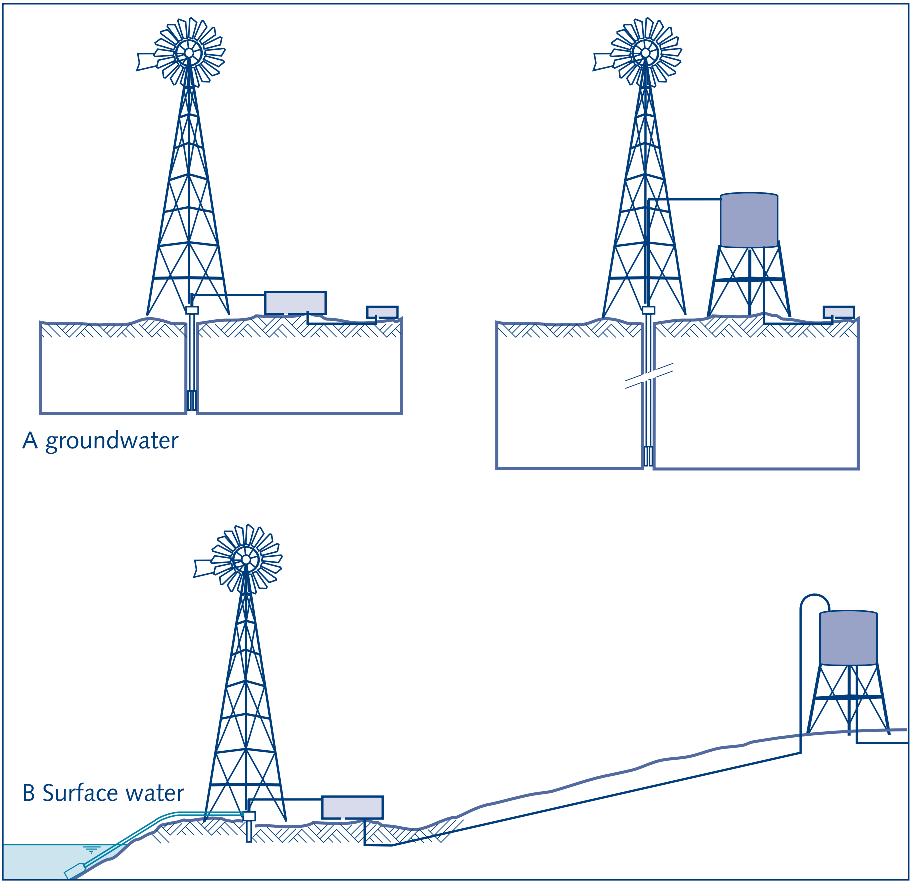

Fig. 9.1. Windmill-pumped water supply systems

Electric motors

Electric motors generally need less maintenance and are more reliable than diesel engines. They are therefore preferable as a source of power for pumping, provided a reliable supply of electric power is available. The electric motor should be capable of carrying the workload that will be imposed, taking into consideration the various adverse operating conditions under which the pump has to work. If the power requirement of a pump exceeds the safe operating load of the electric motor, the motor may be damaged or burnt out. Attention must also be paid to the characteristics of the motor and the supply voltage.

There is sometimes a tendency to use general-purpose motors offered by the manufacturers without giving due consideration to the characteristics of the partic-ular pump used. This results in frequent failure or burning out of the motor. The squirrel-cage motor is mostly selected for driving a centrifugal pump as it is the simplest electric motor manufactured.

Diesel engines

Diesel engines have the important advantage that they can operate independently at remote sites. The prin-cipal requirement is a supply of fuel and lubri-cants and these, once obtained, can be easily trans-ported to almost any location. Diesel engines, because of their ability to run independently of electrical power supplies, are especially suitable for driving isolated pumping units such as raw water intake pumps.

Diesel engines may be used to drive reciprocating plunger pumps as well as centrifugal pumps. Gearing or another suitable transmission connects the engine with the pump. For any diesel-driven pump installa-tion, it is generally prudent to select an engine with 25-30% surplus power to allow for a possible heavier duty than under normal conditions.

Extensive use of electric and/or diesel pumps for drinking water supply and irrigation may cause shallower dug wells to fall dry. This may cause great problems for poor people - especially poor women – who depend on the wells as their domestic water source.

Solar power

Solar panels made of photovoltaic cells arranged into an array convert sunlight into a direct current (DC). This current is used to drive a submersible pump of the DC type. Another option is that the DC is first converted to alternating current (AC) as most submersible pumps on the market are of the AC type. On the other hand, converting DC means a substantial loss of energy (about 25%). In photovoltaic pumping systems, the pump works whenever there is adequate sunshine, and this is independent of the ambient temperature.

The water is pumped into a storage tank to cater for water demands during the periods that there is no sunlight and therefore no pumping. Solar powered pumps can lift water up to 100-200 m, but the system is most economical up to a pumping head of 50 m.

The solar powered pumping system is an attractive option for remote areas where power and fuel supply is difficult and expensive. The only requirement is sufficient sunlight. The investment cost is high due to the (still) high price of solar panels, but operation and maintenance costs are low. The solar system is vulnerable to vandalism and theft because solar panels have many applications.

When solar, electrical or diesel pumps are installed, it is important to assess who will decide on their installation and use, and who will manage and benefit from them. Often, different groups are involved, such as cattle owners, women from better-off families who use the water also productively, and women from poor families who use the water only for domestic uses. The interests of the more powerful groups then often prevail, unless each group is equitably involved in decisions and management.

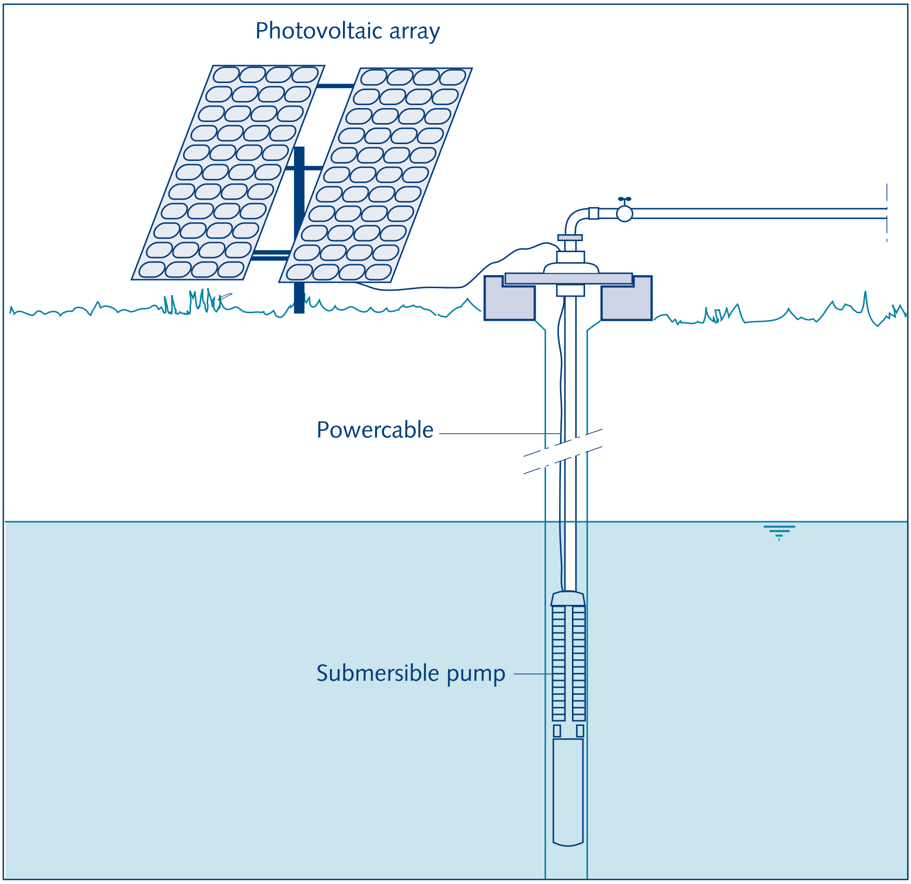

Fig. 9.2. Solar powered pump system

9.3 Types of pumps

The main applications of pumps in small community water supply systems are:

- Pumping water from wells
- Pumping water from surface water intakes
- Pumping water into storage reservoirs and the distribution system, if any

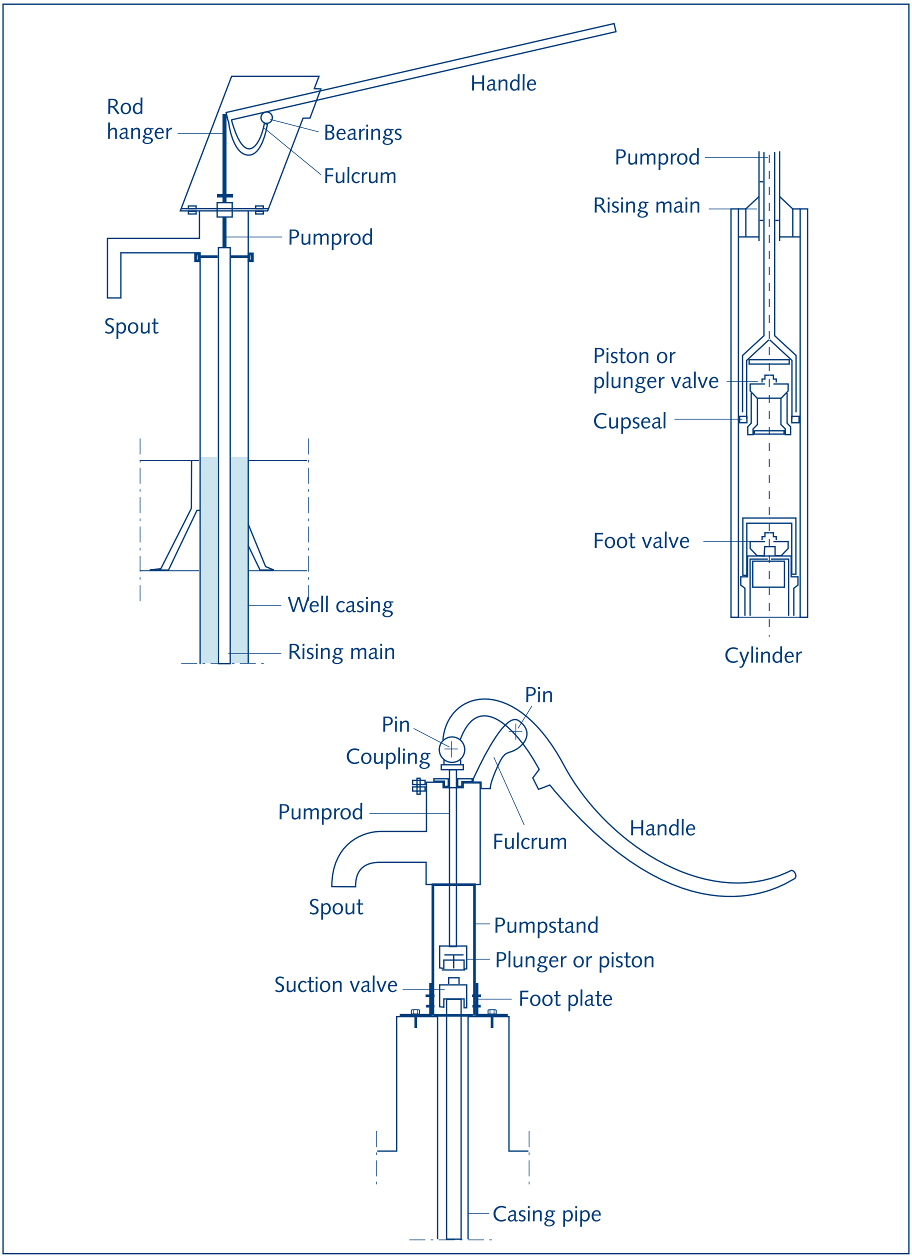

Fig. 9.3. Types of pumps

Based on the mechanical principles involved, these pumps may be classified as follows:

- Reciprocating[2]
- Rotary (positive displacement)
- Diaphragm
- Axial-flow (propeller)
- Centrifugal
- Air lift

Another type of pump with limited application in water supply systems is the hydraulic ram. Table 9.1 gives characteristics of the various types of pumps.

Table 9.1 Information on types of pumps

Type of pump	Depth range	Characteristics and applicability
1. Reciprocating (plunger)		Low speed of operation; hand, wind or motor powered; efficiency range 25–60%
a. Suction	Up to 7 m	Capacity range: 0.5-1 l/s; suitable to pump against variable heads; valves and pump buckets require maintenance attendance
b. Suction: treadle pump	Up to 6 m	capacity range: 0.5-2.5 l/s; mostly used for irrigation but also feasible for water supply if water is treated
c. Lift (direct action)	Up to 15 m	As for suction
d. Low lift: rower pump	Up to 3-6 m	capacity: 0.5-2 l/s mostly used for irrigation but also feasible for water supply if water is treated
e. Lift (high lift)	Up to 180+ m	As for suction
2. Rotary (positive displacement)		Low speed of operation; hand, animal, wind powered
a. Rope pump	Up to 45 m	Capacity range: 0.2-1.0 l/s Discharge constant under variable heads

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2 Reciprocating pumps have a plunger (or piston) that moves up and down (reciprocates) in a closed cylinder for positive displacement of water. On the upward stroke the plunger forces water out through an outlet valve, and at the same time water is drawn into the cylinder through an inlet valve. The downward stroke brings the plunger back to its starting position, and a new operating cycle can begin.

Type of pump	Depth range	Characteristics and Applicability
b. Helical rotor	25-150 m Usually submerged	Using gearing; hand, wind or motor powered; good efficiency; best suited to low capacity – high lift pumping
3. Diaphram (rubber diaphragm in cylinder)	Up to 45 m	Capacity: 0.2-0.3 l/s; hydraulic pressure on diaphragm
4. Axial-flow	5-10 m	High capacity low-lift pumping; can pump water containing sand or silt
5. Centrifugal		High speed of operation - smooth, even discharge; efficiency (range 50-85%) depends on operating speed and pumping head
a. Single-stage	20-35 m	Requires skilled maintenance; not suitable for hand operation; powered by engine or electric motor
b. Multi-stage shaft-driven	25-50 m	As for single stage; motor accessible, above ground; alignment and lubrication of shaft critical; capacity range 25-10,000 l/min
c. Multi-stage submersible	30–120 m	As for multi-stage shaft-driven; smoother operation; maintenance difficult; repair to motor or pump requires pulling unit from well; wide range of capacities and heads; subject to rapid wear when sandy water is pumped
6. Air lift	15-50 m	High capacity at low lift; very low efficiency especially at greater lifts; no moving parts in the well; well casing straightness not critical

9.4 Technology selection

Recent research and development (R&D) has focused on ease of operation and maintenance, and corrosion resistance. Corrosive water seriously affects galvanised iron and mild steel, reducing the life span of components and causing deterioration of water quality. Even stainless steel can show some corrosion (mainly galvanic[3]). Components made from uPVC, polypropylene and engineering plastics are increasingly being adopted. However, plastics may extend over time due to weight. Fibreglass is also being tested for pump rods in deep settings. These materials are light in weight (easing lifting) and corrosion resistant, and are likely to have a greater application in the near future.

Pump selection criteria

In selecting a pump type for a specific purpose the following technical criteria need to be considered:

- Rate of delivery required
- Vertical distance from pumping level to delivery level
- Variations expected in water levels at the source
- Durability of basic components (including corrosion resistance)
- Weight of below ground parts
- Availability and cost of spares
- Ease of maintenance

Apart from these technical criteria, several institutional and community criteria have significant influence on the sustainability of the functioning and use of the pump (see also chapter 2):

- Involvement of both men and women from the different user groups in the choice of the most suitable pump (that can also be used by children and pregnant women); choice of pump location(s); the selection of women and men who will operate, maintain and manage the water supply system and go for training; and the financing system through which the various costs will be met
- Assessment of ability and willingness to pay for the expected cost of operation and maintenance (O&M), repair and management
- Institutional and organisational capacity at community level to manage the water supply service, including technical capacity for O&M
- Representation of the different user groups in management and training for maintenance and management of the water supply
- Institutional and organisational capacity outside the community to support the community in their tasks – governmental agencies, NGOs, water associations and the private sector could provide this support

3 Galvanic corrosion is caused by contact between two materials with different electrochemical potentials in contact with an electrolyte such as water.

9.5 Reciprocating pumps

The type of pump most frequently used for small water supplies is the reciprocating (plunger) pump[4]. Several types may be distinguished:

- Suction and lift pumps
- Free delivery and force pumps

Suction pumps (shallow well)

In the suction pump, the plunger and its cylinder are located above the water level usually within the pump stand itself (Fig. 9.4).

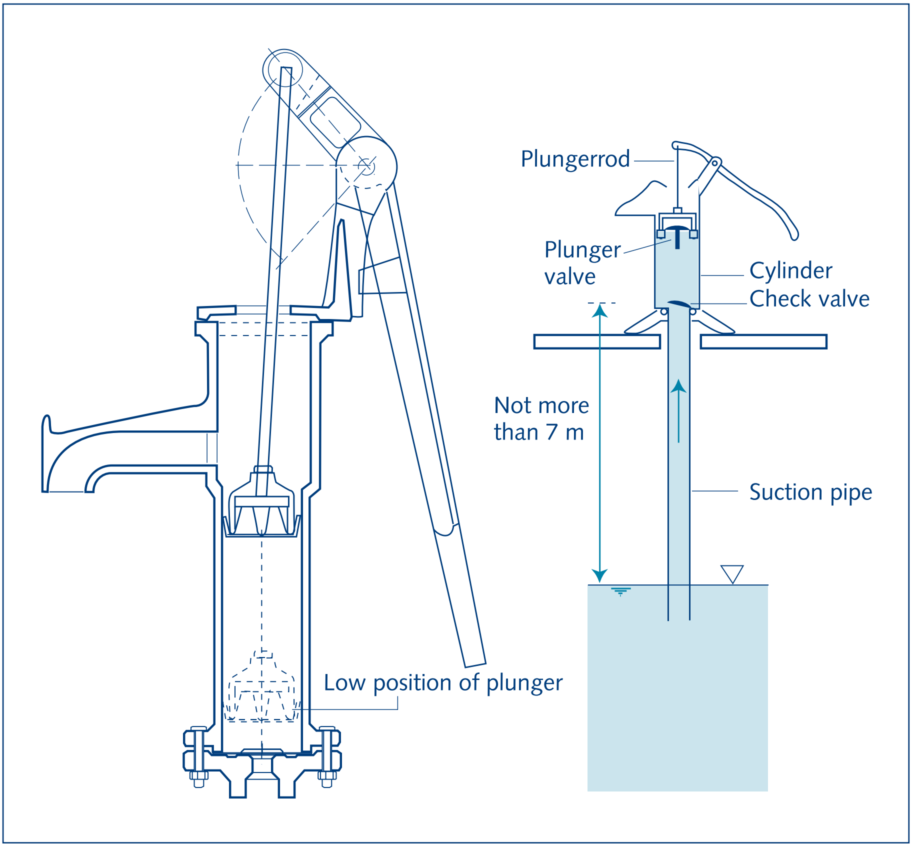


Fig 9.4. Suction pump (for shallow well)

Because of its reliance on atmospheric pressure (about 10 m of water column), the suction pump gives a high discharge up to a lifting height of 7 m (at high altitudes 4 m), beyond which it becomes unstable. In addition it cannot be used when the water table drops. Suction pumps are simple to install and maintain.

4 While this section focuses on the reciprocating plunger pump, the principles outlined also apply to other types of positive displacement pumps.

Treadle pump

In certain Asian countries, the treadle pump is commonly used as a small-scale irrigation pump. It is also suitable for drinking water supply provided the water is treated afterwards at household level. The pump is relatively easy to manufacture locally and therefore suitable for areas with limited technical development.

The pump is operated by the legs, which can produce more power than arms. Therefore, the capacity, about 1 l/s, is higher than other human-powered pumps. The treadle pump is a typical suction pump and therefore the maximum water lift is 7 m.

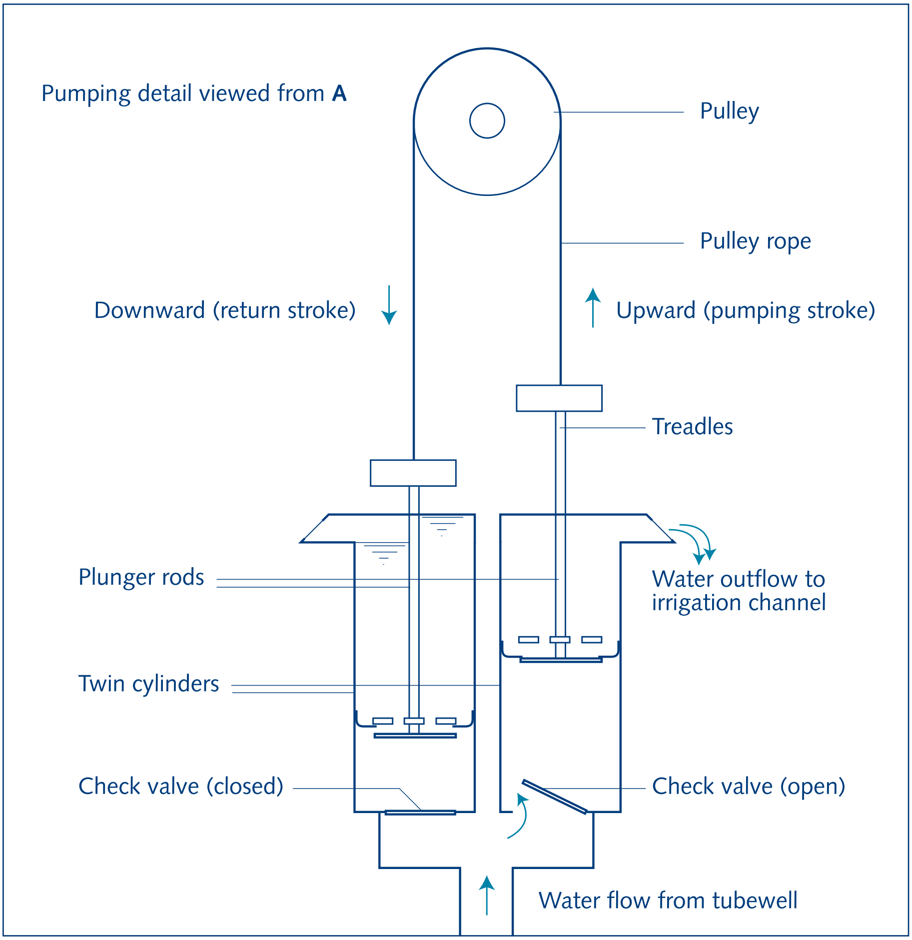


Fig. 9.5. Treadle pump

Rower pump

The rower pump is another commonly used small-scale irrigation pump, which can be used as a drinking water pump provided the water is treated before drinking. It is also a suction pump, so the maximum pumping lift is 7 m. It can be easily constructed with PVC pipes and simple valves and piston. The investment costs are low.

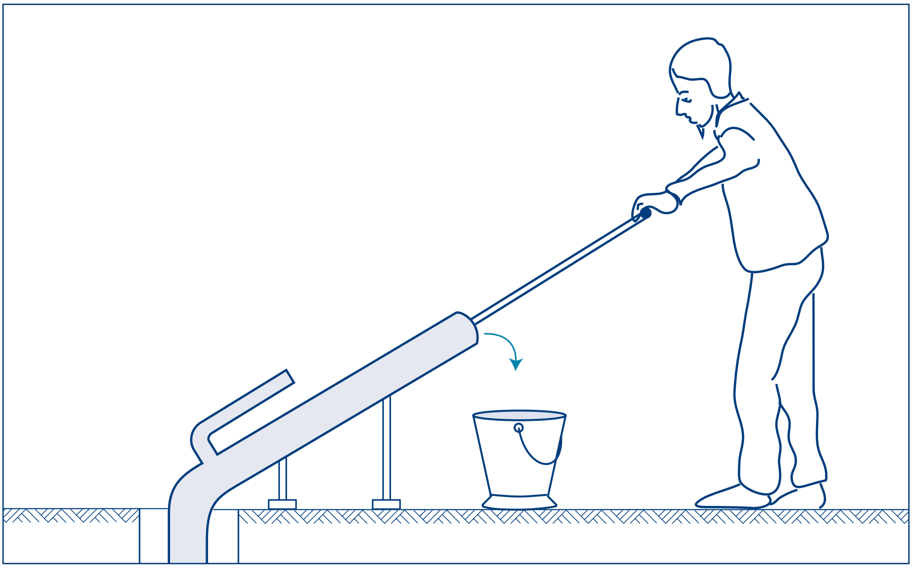


Fig. 9.6. Rower pump

Lift pumps (deep well pump)

In lift pumps, the cylinder and plunger are located below the water level in the well. The cylinder has to be submerged in the water to ensure priming of the pump. In terms of definitions, *deep* or *shallow* well refers to the depth of the water level (usually the chosen setting for the cylinder), not the depth to the bottom of the well (Fig. 9.8).

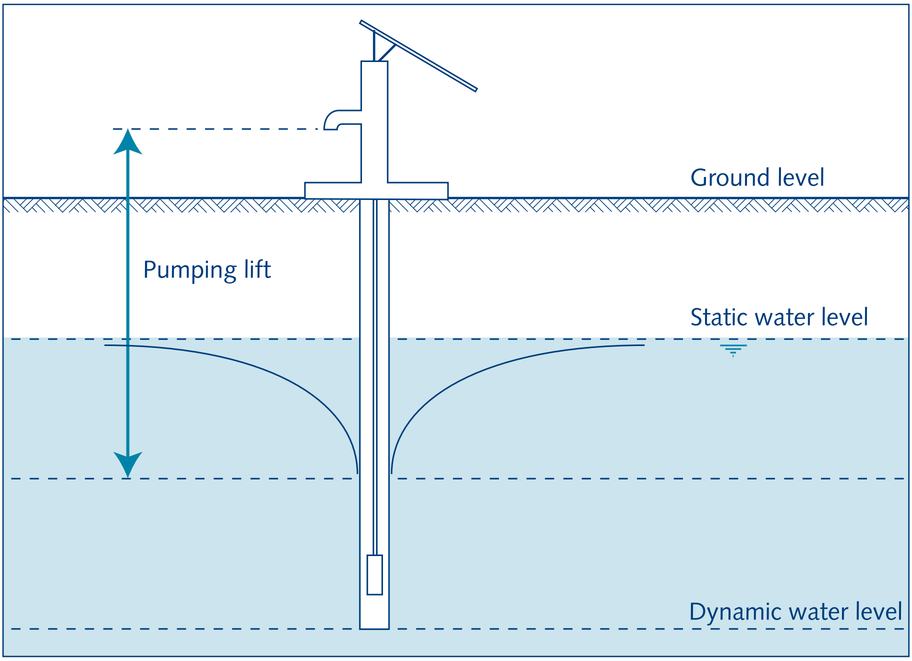


Fig. 9.7. Pumping lift

Because of the fact that the cylinder and plunger are located below the water level, this pump can lift water from wells as deep as 180 m or even more. The forces created by the pumping increase with the depth to the water table. Also the problems associated with reaching the cylinder, deep in the well, for maintenance and repair are much more difficult than in shallow well pumps. Thus the design of pumps for deep well use is more critical and complicated than for suction pumps. An example of a deep well lift pump is shown in figure 9.8.

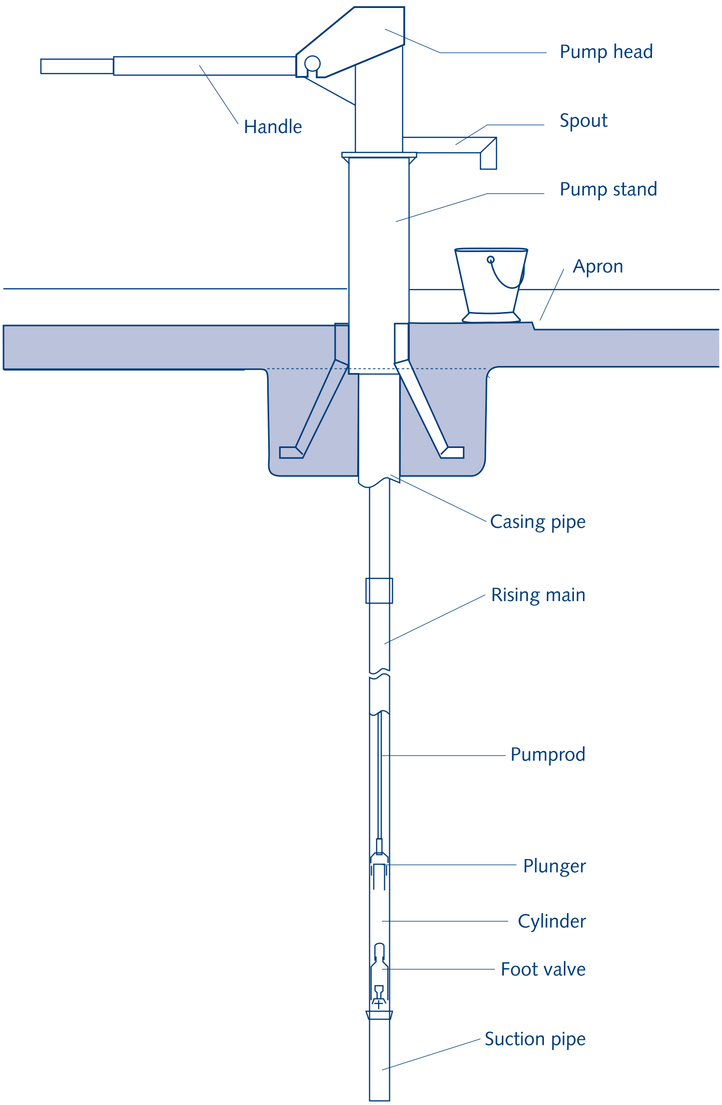


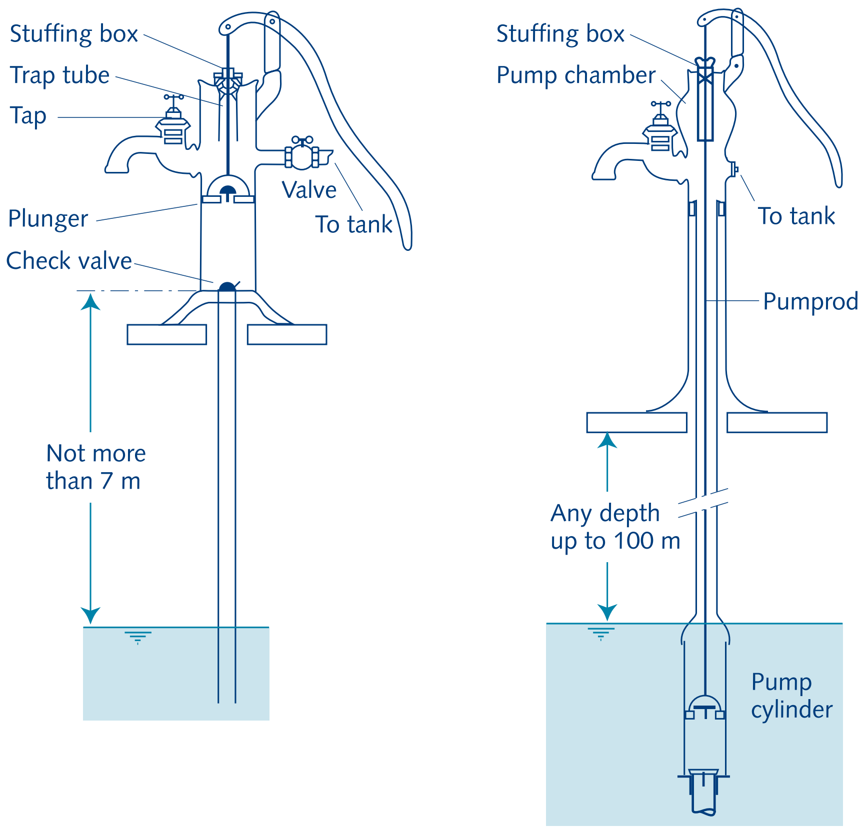
Fig. 9.8. Lift pump (deep well)

Direct action handpumps are effective up to 15 m, and are self priming, which reduces the risk of contamination. They do not rely on lever action and bearings, which eases maintenance. They are simple and light (with semi-buoyant rods), and have a high discharge.

High lift pumps are required beyond 15 m. They are sometimes used at shallower settings for reasons of standardisation.

Force pumps

Force pumps are designed to pump water from a source and to deliver it to a higher elevation or against pressure. All pressure-type water systems use force pumps. They are enclosed so that the water can be forced to flow against pressure. Force pumps are available for use on shallow or deep wells (Fig. 9.10).



A Force pump on shallow well

B Force pump on deep well

Fig. 9.9 . Force pumps

A shallow-well force pump is shown in figure 9.9a. Its operating principle is the same as that of the suction pump discussed earlier, except that it is enclosed at the top and, therefore, can be used to force the water to elevations higher than the pump. For this, either a separate connection or a hose or pipe is fitted to the spout.

Force pumps usually have an air chamber to even out the discharge flow. On the upstroke of the plunger, the air in the air chamber is compressed and on the downstroke the air expands to maintain the flow of water while the plunger goes down. The trap tube serves to trap air in the air chamber, preventing it from leaking around the plunger rod.

The operation of a deep well force pump (Fig. 9.9b) is the same. The principal difference is that, like the lift pump, its cylinder is down in the well. The pump can therefore lift water from depths greater than 7 m.

Diaphragm pump

Diaphragm pumps are positive displacement pumps. There are two entirely different types.

Conventional diaphragm pumps are more commonly used as dewatering pumps than as pumps for drinking water supply. The main part of the pump is its diaphragm, a flexible disc or tube made of rubber or metal. Non-return valves are fitted at the inlet and outlet (Fig. 9.10).

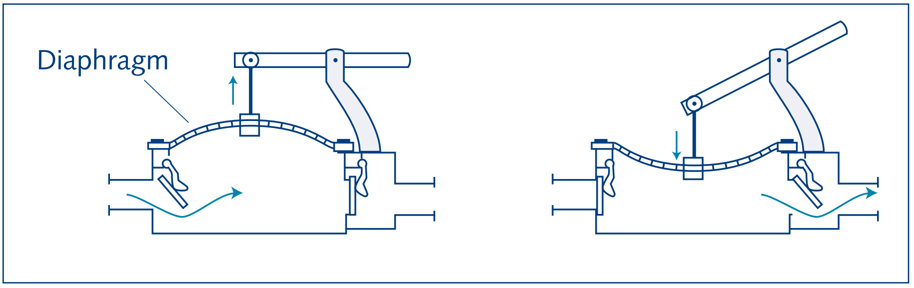


Fig. 9.10. Traditional diaphragm pump

The edge of the diaphragm is fixed to the rim of the water chamber and the centre is flexible. A rod fastened to the centre moves it up and down. As the diaphragm is lifted, water is drawn in through the inlet valve, and when it is pushed down, water is forced out through the outlet valve. These pumps are self priming.

The second type – the hydro-pump – uses the diaphragm pumping principle. The special feature in its design is the use of a small rubber tube in the pumping element that expands when water flows in and is contracted by the hydraulic action created by the pump pedal. This contraction of the diaphragm forces water through the plastic delivery hose to the spout (Fig. 9.11). The pump needs considerable power to operate, and the diaphragm needs regular cleaning. An advantage is that it is not sensitive to sand and other small soil particles. Only the French company Vergnet manufactures this pump.

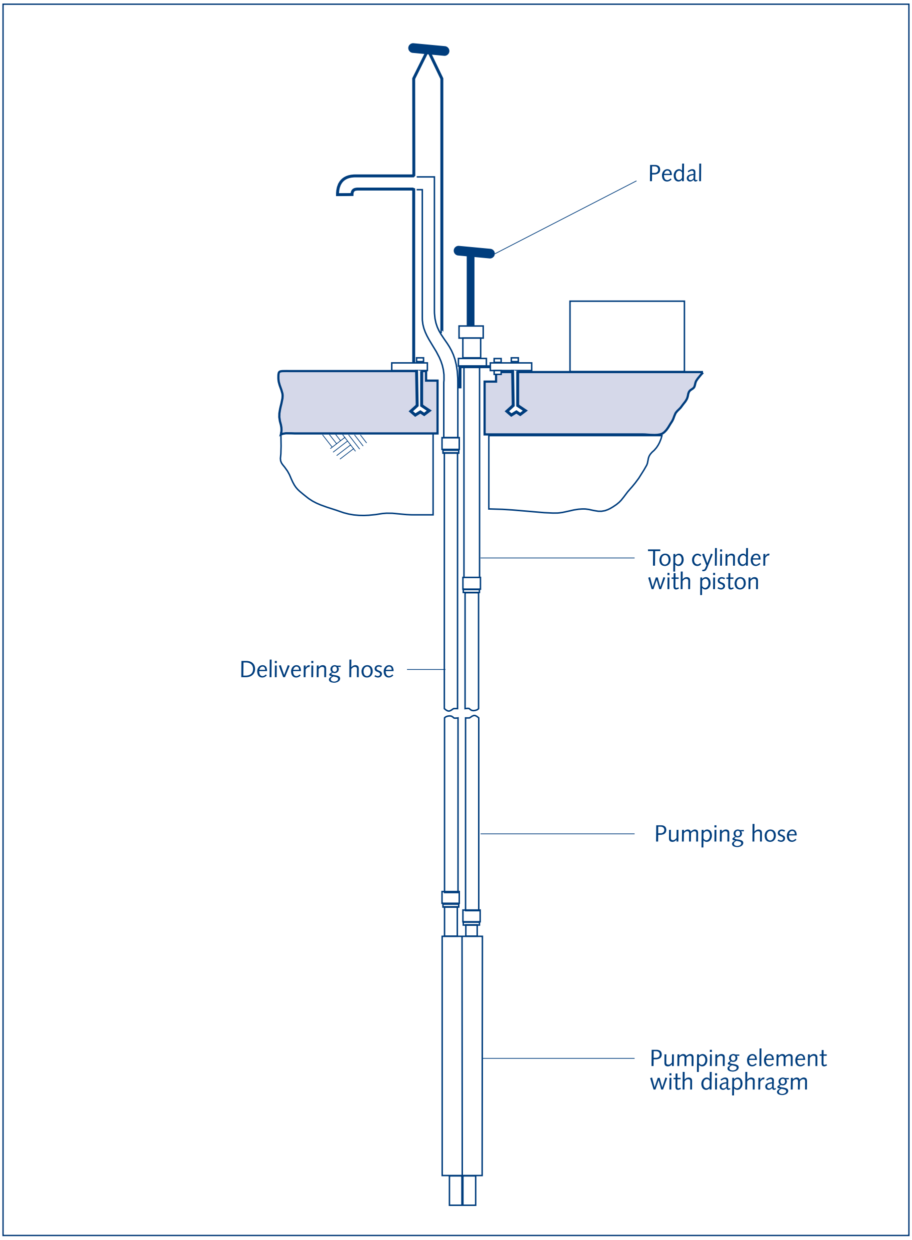
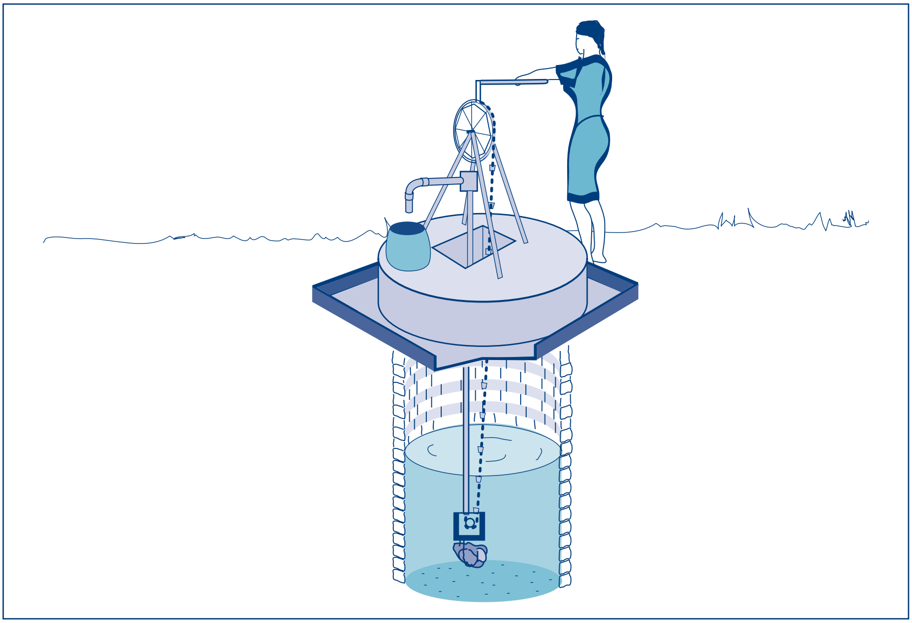


Fig. 9.11. Diaphragm foot-operated pump (hydro-pump)

9.5 Rotary (positive displacement) pumps

Bucket or rope pumps

These pumps use a continuous chain of small buckets, discs or knots on an endless rope moving over a wheel to lift water. Each bucket or disc carries water from the bottom of the well and empties it into a spout at the top. In the rope pump, the rope and discs pass through a tightly fitting riser pipe, and lift the water as they move. Rope pumps can be used for storage tanks, shallow dug wells and also boreholes. Because of their capacity, they are used at single- or multiple-family level or for small communities. They are very suited to local manufacture and maintenance. The investment cost is low and it is therefore attractive as a family pump (and irrigation pump). The rope pump needs frequent maintenance (e.g. the rope) but it can be repaired by the users with easily available material.



Fig, 9.12. Rope pump

Helical rotor pump

The helical rotor pump consists of a single-thread helical rotor that rotates inside a double-thread helical sleeve, the stator (Fig. 9.13). The meshing helical surfaces force the water up, creating a uniform flow. The water output is proportional to the rotating speed, and can be varied simply by changing a pulley. As the rotor and stator provide an ef-fective continuous seal, the helical rotor pump requires no valves. Helical rotor pumps are available for use in 4-inch (100 mm) or larger tube wells. Although relatively expensive, these pumps have given good service on deep wells in parts of Africa and Asia, where they are known as "Mono" pumps after their British manufacturer.

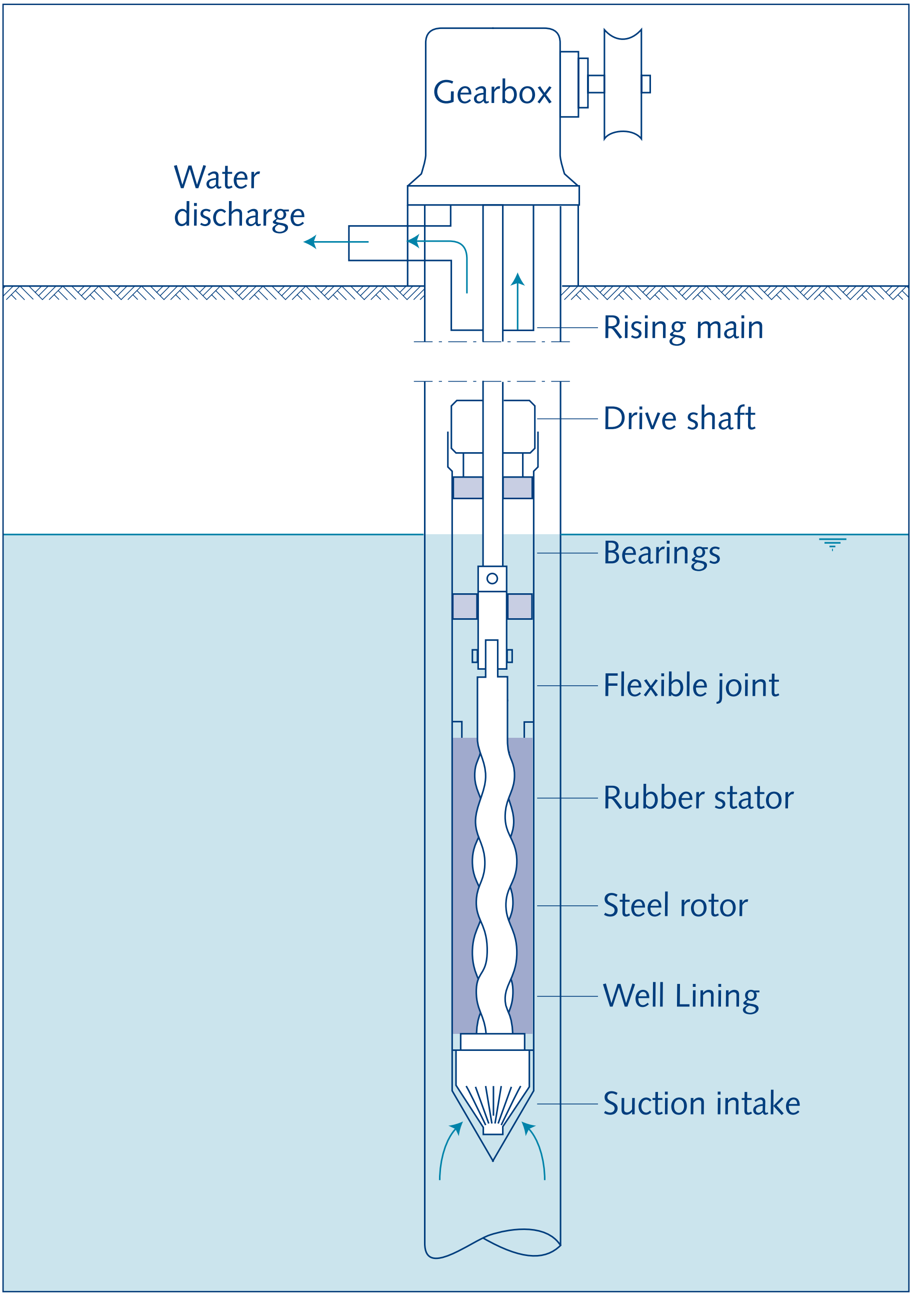


Fig. 9.13. Helical rotor pump

Drive arrangements suitable for helical rotor pumps are manual operation, electric motors, diesel and petrol engines. Different drive heads are available. If there is plenty of space, a standard head with a V-belt drive can be used. Where a compact unit is required, geared heads are installed for diesel engine or electric motor drives.

9.6 Axial-flow pumps

In the axial-flow type of pump, radial fins or blades are mounted on an impeller or wheel, which rotates in a stationary enclosure (called a casing).

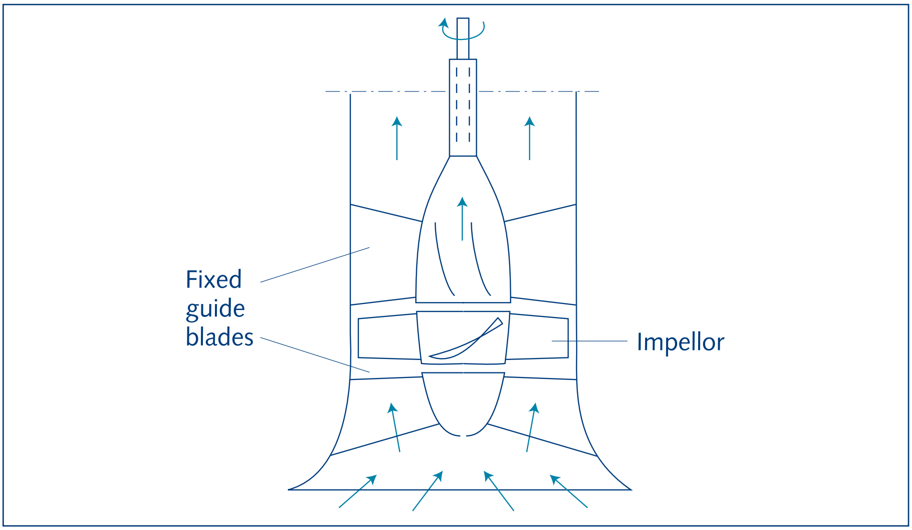


Fig. 9.14. Axial-flow pump

The action of the pump is to lift the water mechanically by the rotating impeller. The fixed guide blades ensure that the water flow has no "whirl" velocity when it enters or leaves the impeller.

9.7 Centrifugal pumps

The essential components of a centrifugal pump are the impeller and the casing (Fig. 9.15).

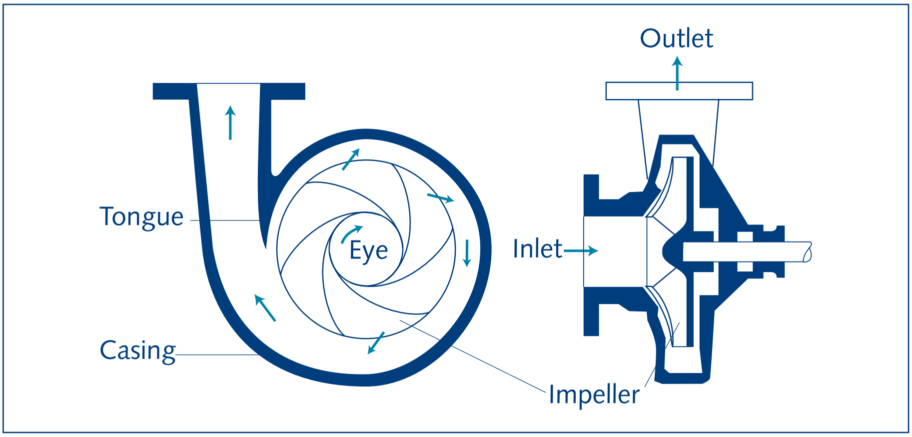


Fig. 9.15. Centrifugal pump (Volute-type casing)

The impeller is a wheel with vanes radiating from the centre to the periphery. When rotated at a suffi-ciently high speed, the impeller imparts kinetic energy to the water and produces an outward flow due to the centrifugal forces. The casing is so shaped that the kinetic energy of the water leaving the impeller is partly converted to useful pressure. This pressure forces the water into the delivery pipe. The water leaving the eye of the impeller creates suction; it will be replaced by water drawn from the source and forced into the casing under static head.

An impeller and the matching section of the casing are called a stage. If the required water pressure (pumping head) is higher than a single stage can practicably produce, a number of stages may be placed in series (multiple-stage pump). The impellers are attached to a common shaft and therefore rotate at the same speed. The water passes through the successive stages, with an in-crease in pressure at each stage. Multiple-stage centrifugal pumps are normally used for high pumping heads.

The rotating speed of a centrifugal pump has a con-siderable effect on its performance. The pumping efficiency tends to improve as the rotating speed increases. Higher speed, however, may lead to more frequent maintenance requirements. A suitable balance has to be aimed at between the initial cost and maintenance cost. A comprehensive study of the pump's character-istics is necessary for final selection.

In centrifugal pumps the angle between the direction of entry and exit of the water flow is 90. In an axial-flow pump the water flow continues through the pump in the same direction with no deviation (0°). The term *mixed-flow pump* is used for those centrifugal pumps where the change in angle lies between 0 and 90°; they can be single or multiple stage.

9.8 Pump drive arrangements

Two different drive arrangements exist for pumping water from deep wells: shaft-driven and close-coupled submersible electric motor.

Shaft-driven

The crankshaft or motor is placed at the ground surface and powers the pump using a vertical drive shaft or spindle (Fig. 9.16). A long drive shaft will need support at regular intervals along its length and flexible couplings to eliminate any stresses due to misalignment. The advantage of a drive shaft is that the drive mechanism may be set above ground or in a dry pit and thus will be readily accessible for main-tenance and repair. An accurate alignment of the shaft is necessary; the shaft-drive arrangement is not possible in crooked tubewells.

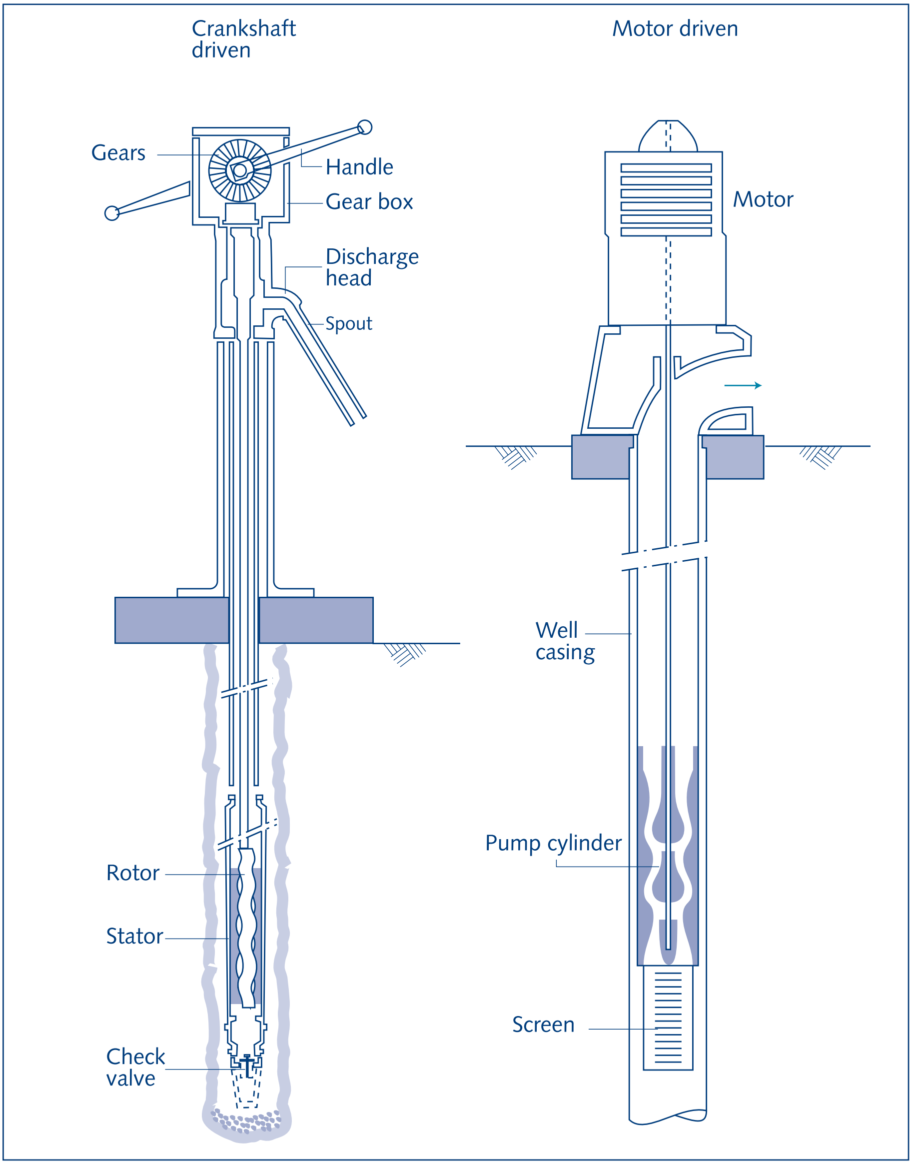


Fig. 9.16. Shaft-driven pumps

Close-coupled submersible electric pump

In this pump drive arrangement, a centrifugal pump is connected directly to an electric motor in a common housing, with the pump and motor as a single unit. This unit is constructed for sub-merged operation in the water to be pumped (Fig.9.17).

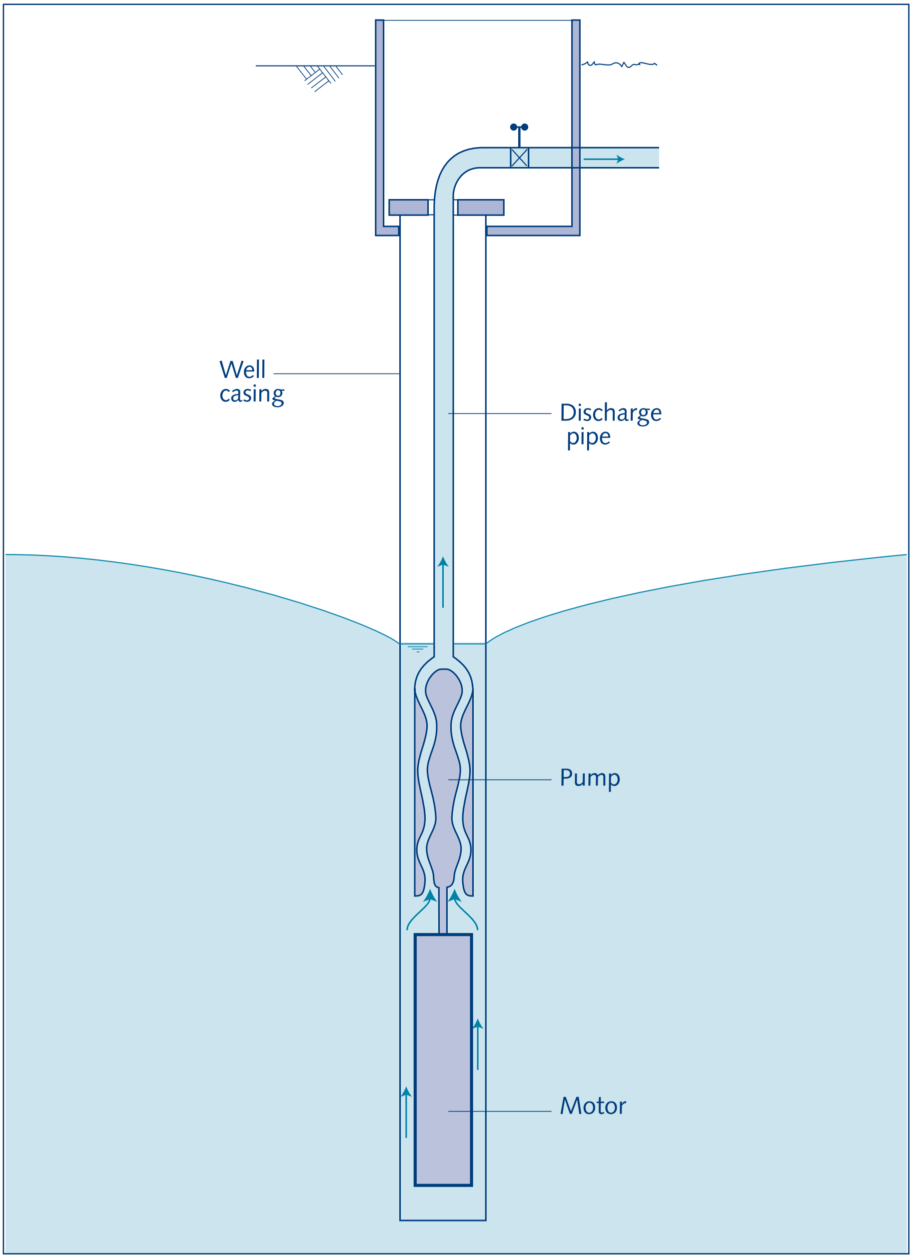


Fig. 9.17. Pump driven by a close-coupled submersible electric motor

The pump-motor unit, usually called the sub-mersible pump, is lowered inside the well casing and set at a suitable depth below the lowest drawdown water level in the well. Submersible pumps are often a tight fit in a tubewell as their outside diameter is usually only 1-2 cm less than the internal bore of the well casing. Consequently, great care is needed during installation or removal of these pumps. A waterproof electric cable connects the motor with the control box housing, the on-off switch and the power connection.

The electrical control should be properly grounded to minimise the risk of shorting and damage to the motor. Figure 9.18 shows a submersible pump in exploded view. The submersible pump-motor unit is usually supported by the discharge pipe, which conveys the pumped water to the connecting pipeline or tank. When sand is found or anticipated in the water source, special precautions should be taken before a submersible pump is used. The abrasive action of sand during pumping would shorten the life of the pump considerably.

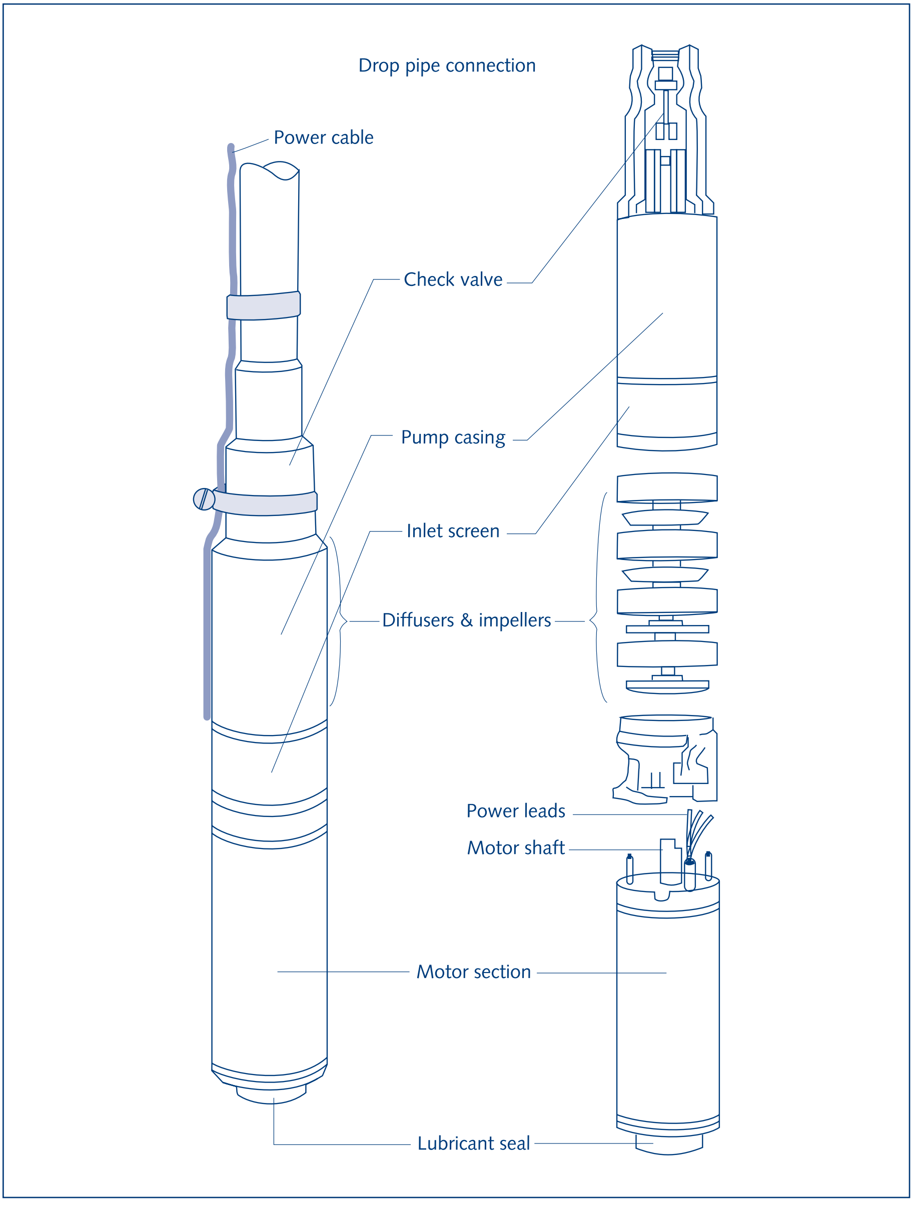


Fig. 9.18. Submersible pump (exploded view)

9.9 Air-lift pumps

An air-lift pump raises water by injecting small, evenly distributed bubbles of compressed air at the foot of a discharge pipe fixed in the well. This requires an air compressor. Because the mixture of air and water is lighter than the water outside the dis-charge pipe, the water/air mixture is forced upward by the hydrostatic head (Fig. 9.19).

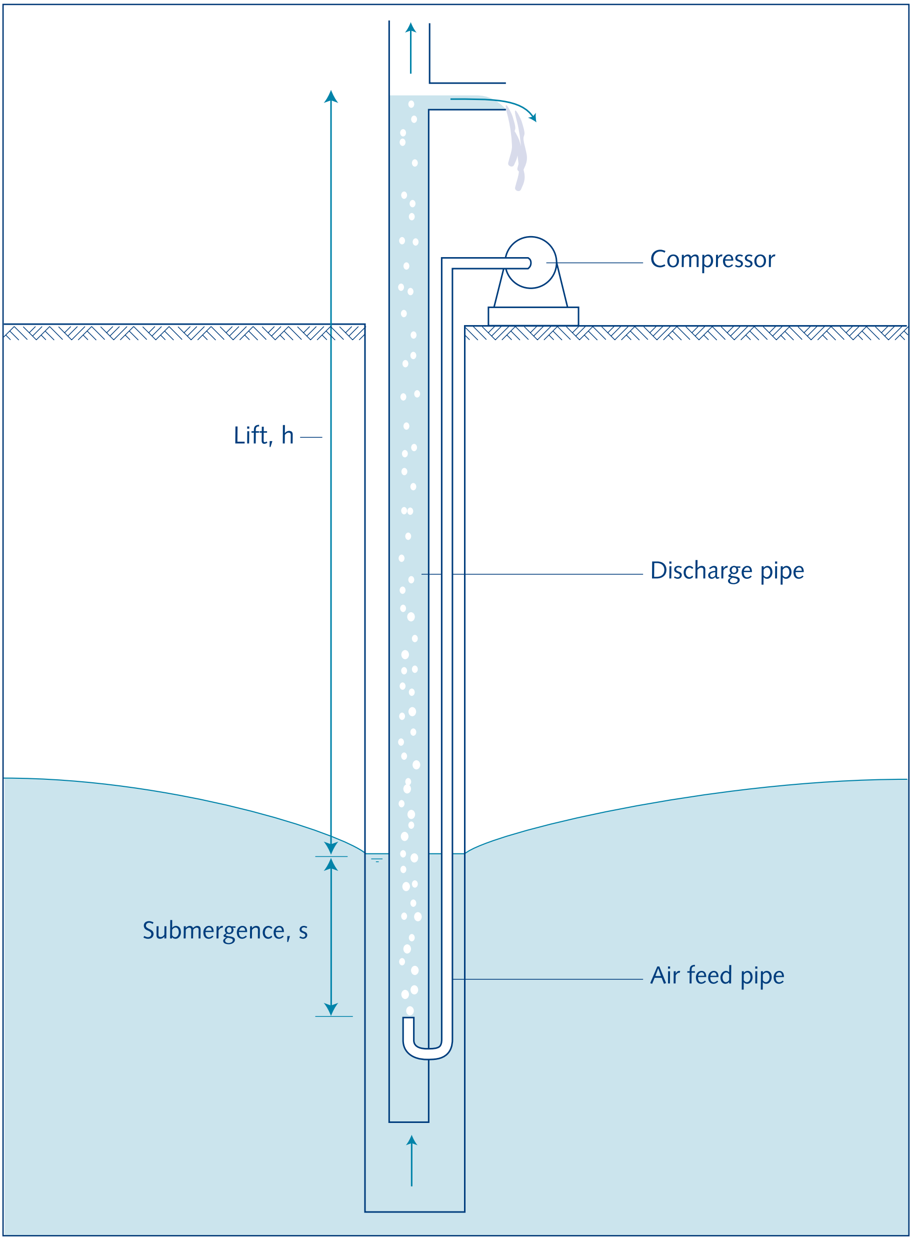


Fig. 9.19. Air lift pump (schematic)

The major drawback of air-lift pumps is their low mechanical efficiency, about 25-40%. The additional energy losses in the compressor give a total efficiency of not more than 15-30%. Air-lift pumps have the important advantages that they are simple to operate and not affected by sand or silt in the pumped water.

9.10 Hydraulic ram

The hydraulic ram needs no external source of power. The ram utilises the energy contained in a flow of water running through it, to lift a small volume of this water to a higher level. The phenomenon involved is that of a pressure surge, which develops when a moving mass of water is suddenly stopped. A steady and reliable supply of water is required with a fall sufficient to operate the hydraulic ram. Favourable conditions are mostly found in hilly and mountainous areas (Fig. 9.20). Hydraulic rams are not suited to pumping water from wells.

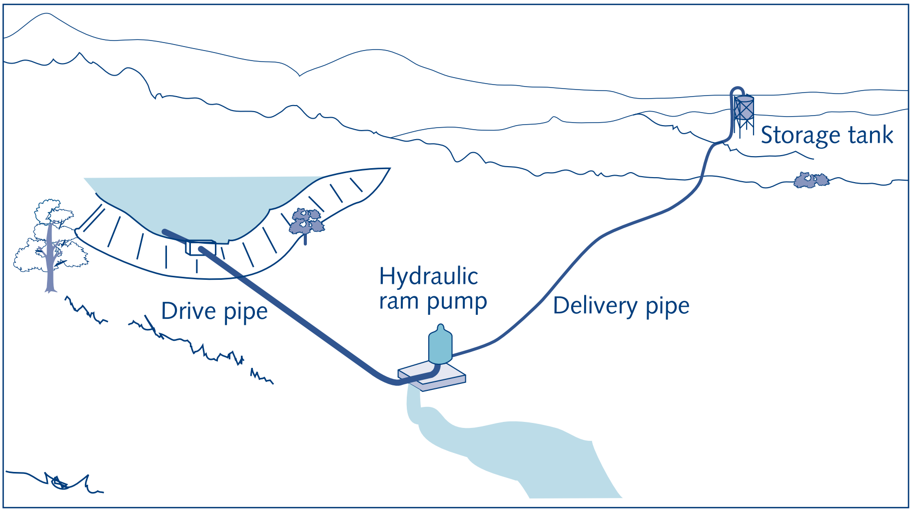


Fig. 9.20. Hydraulic ram installation

The ram operates on a flow of water running from the source down through the drive pipe into the pump chamber. The water escapes through the opened impulse valve (waste valve). When the flow of water through the impulse valve is fast enough, the upward force on the valve will exceed the spring tension of the valve adjustment and the impulse valve is suddenly shut. The moving mass of water is stopped, with its momentum producing a pressure surge along the drive pipe. Due to the pressure surge, water is forced through the non-return (delivery) valve and into the delivery pipe. Water continues to pass the non-return valve until the energy of the pressure surge in the drive pipe is exhausted. The air chamber serves to smooth out the delivery flow of water, as it absorbs part of the pressure surge that is released after the initial pressure wave.

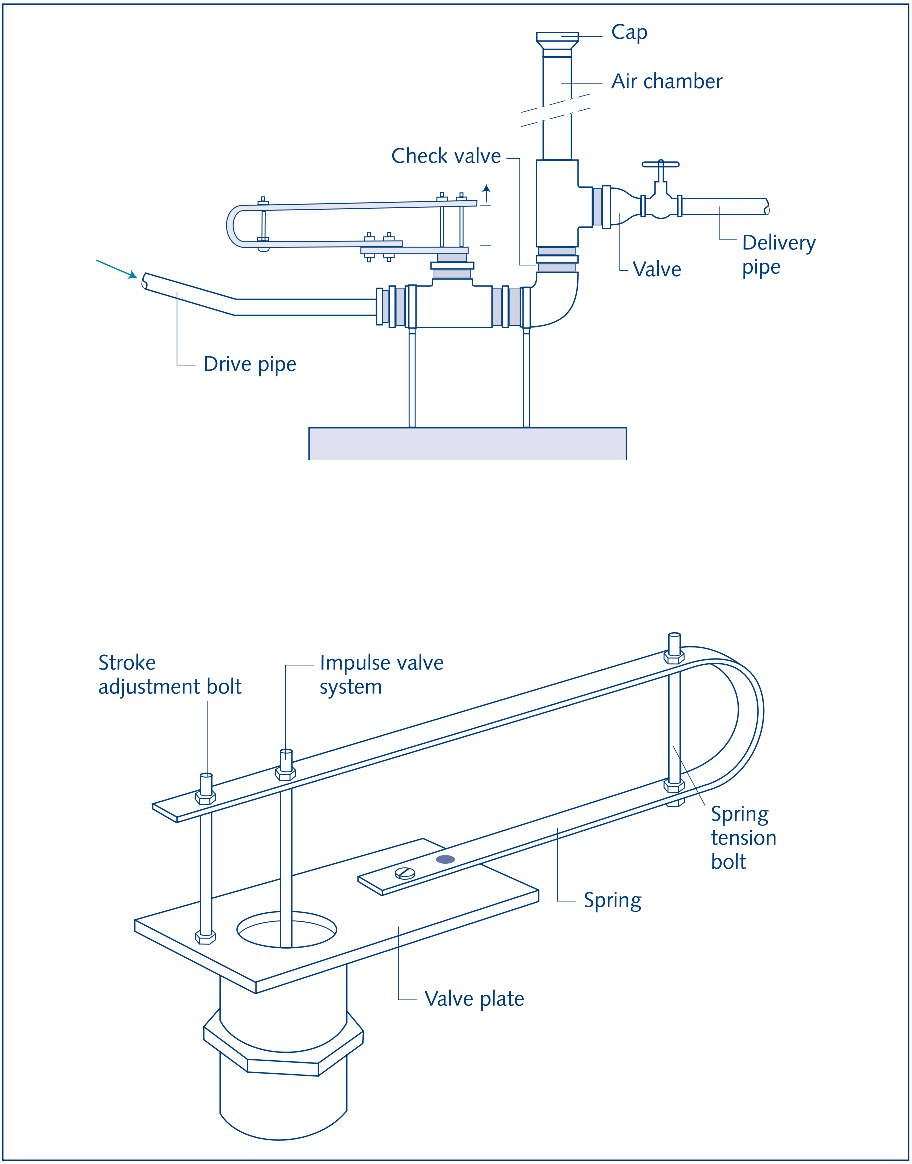


Fig. 9.21.Typical hydraulic ram

When the pressure surge is fully exhausted, a slight suction created by the momentum of the water flow, together with the weight of the water in the delivery pipe, shuts the non-return valve and prevents the water from running back into the pump chamber. The adjustment spring now opens the impulse valve, water begins to escape through it, and a new operating cycle is started.

Once the adjustment of the impulse valve has been set, the hydraulic ram needs no attention provided the water flow from the supply source is continuous at an adequate rate and no foreign matter gets into the pump, blocking the valves.

An air valve is provided to allow a certain amount of air to bleed in and keep the air chamber charged. Water under pressure will absorb air and without a suitable air valve the air chamber would soon be full of water. The hydraulic ram would cease to function.

The advantages of the hydraulic ram are:

- No power sources are needed, and therefore no running costs
- Suitable for local production
- Only two moving parts

Most hydraulic rams will work at their best efficiency if the supply head is about one-third of the delivery head. The higher the pumping head required, the smaller the amount of water delivered. In cases where the required pumping capacity is greater than one hydraulic ram can provide, a battery of several rams may be used, provided the supply source is of sufficient capacity (Fig. 9.22).

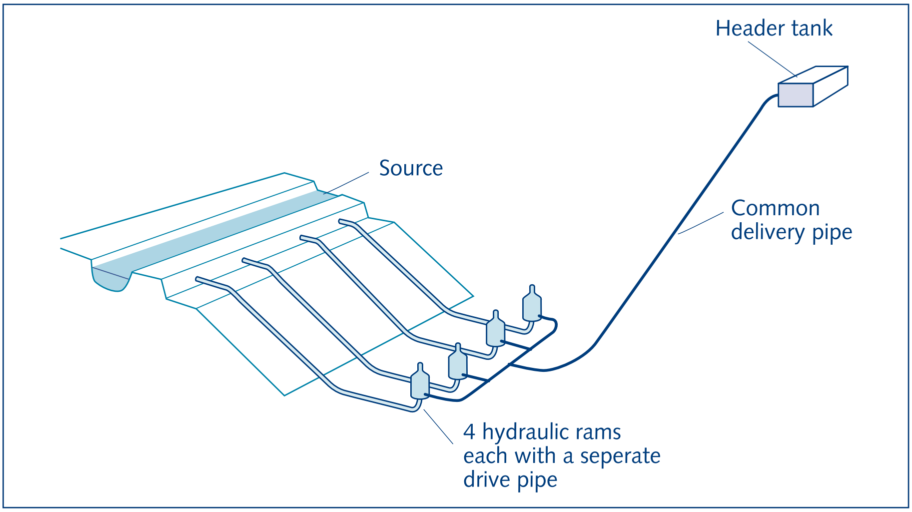


Fig. 9.22. Hydraulic rams placed parallel.
Source: Watt S.B., 1974

The maintenance required for a hydraulic ram is very little and infrequent. It includes activities as replacement of the valve rubbers when they wear out, adjusting the tuning, and tightening bolts if they get loose. Occasionally the hydraulic ram may need dismantling for cleaning. It is essential that as little debris as possible enters the drive pipe. For this reason, it is necessary to provide a grate or strainer to keep back floating leaves and debris.

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Web sites

For technical drawings: http://www.skat.ch

HTN Network for cost-effective technologies: http://www.skat.ch/htn/

Discussion groups

GARNET-HTN see: http://www.lboro.ac.uk/departments/cv/wedc/garnet/tnchandp.html