Chapter 4

PUMPS

In rural areas some villages may be so situated as to obtain their water supplies entirely by gravity from springs or infiltration galleries originating in nearby hills. Other villages and individual farms may depend on pumps to raise water from wells, lakes, or reservoirs, or to boost water into distribution pipes. The choice of the right pump for any particular situation is of the utmost importance. Experience shows that pumping problems are most often responsible for the breakdown or poor operation of small water-supply systems. It is therefore appropriate to include in this monograph a brief discussion of various types of pumps, their principles of operation, and their efficiency and maintenance. It is important to remember that each pump has been developed by its manufacturer for a specific purpose, and has a definite range of application. It is the responsibility of the water-supply designer to choose the pump that will do the best job at the least cost.

The most common types of pumps for small-community water systems, individual houses, or public wells are:

1. hand- or power-operated reciprocating pumps, where the cylinder is above ground as part of the pump's body;
2. power-operated centrifugal pumps with the pump mechanism above ground;
3. hand-, power- or wind-operated reciprocating deep-well pumps, where the cylinder is in the well;
4. deep-well turbine pumps driven either from the surface or from a submersible electric motor;
5. jet pumps, power-driven at the surface; and
6. hydraulic rams.

A further type, rarely used for water production but very useful for testing purposes, is the air-lift pump, operated by a power-driven compressor on the surface.

Under ideal conditions the pressure of the air at sea level is enough to raise a column of water 10.3 m (34 ft) in a vertical pipe in which a perfect vacuum has been made. Conditions under which pumping usually takes place are far from ideal (because of pump imperfections, air leaks, the
# TABLE VI. RELATIVE MERITS OF PUMPS FOR USE IN SMALL WATER-SUPPLY SYSTEMS

<table>
<thead>
<tr>
<th>Types of pumps</th>
<th>Positive displacement</th>
<th>Velocity</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hand pumps, plunger type</td>
<td>motor, wind driven, plunger type</td>
<td>chain or continuous bucket</td>
<td>centrifugal</td>
<td>deep-well turbine</td>
<td>jet</td>
</tr>
<tr>
<td>Efficiency range (%)</td>
<td>Low; can be improved with double-acting cylinders: 25%-60%</td>
<td>Low; can be improved with double-acting cylinders: 25%-60%</td>
<td>Low</td>
<td>Good: 50%-85%</td>
<td>Good: 65%-80%</td>
<td>Low: 40%-60%</td>
</tr>
<tr>
<td>Operation</td>
<td>Very simple</td>
<td>Simple</td>
<td>Very simple</td>
<td>Simple</td>
<td>More difficult; needs attention</td>
<td>Simple; air locks can cause trouble</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Simple, but valves and plunger require attention; more difficult when pump cylinder is in the well</td>
<td>Same as hand pump; maintenance of motors sometimes difficult in rural areas</td>
<td>Simple</td>
<td>Simple, but attention is necessary</td>
<td>More difficult and constant; skilled attention is necessary</td>
<td>Simple, but attention is necessary</td>
</tr>
<tr>
<td>Capacity (litres/minute)</td>
<td>10-50</td>
<td>40-100</td>
<td>15-70</td>
<td>Very wide range: 5 to unlimited</td>
<td>Very wide range: 100-20 000</td>
<td>25-500</td>
</tr>
<tr>
<td>Head (metres)</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>5-500</td>
<td>20-500</td>
<td>Low</td>
</tr>
<tr>
<td>--------------</td>
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<td>-----</td>
<td>-------</td>
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<td>-----</td>
</tr>
<tr>
<td>Cost</td>
<td>Low, but higher when cylinder is in the well</td>
<td>Low, but higher when cylinder is in the well</td>
<td>Reasonable</td>
<td>Reasonable</td>
<td>Higher, especially in deep wells</td>
<td>Reasonable</td>
</tr>
<tr>
<td>Advantages</td>
<td>Low speed; easily understood by unskilled people; low cost</td>
<td>Low cost; simple; low speed</td>
<td>Simple; easy to operate and maintain</td>
<td>Efficient; wide range of capacity and head</td>
<td>Good for small-diameter boreholes; ease of operation</td>
<td>Moving parts on surface; ease of operation</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Low efficiency; limited use; maintenance more difficult when cylinder is in the well</td>
<td>Low efficiency; limited use; maintenance more difficult when cylinder is in the well</td>
<td>Low efficiency; limited use</td>
<td>Moving parts and packing require attention</td>
<td>Moving parts in well; rather expensive; requires good maintenance and operation</td>
<td>Limited application; low efficiency; moving parts require attention</td>
</tr>
<tr>
<td>Power</td>
<td>Hand or animal</td>
<td>Wind, motor</td>
<td>Hand, animal, wind, motor</td>
<td>Motor</td>
<td>Motor</td>
<td>Motor</td>
</tr>
</tbody>
</table>
presence of air in water, etc.). In practice, the suction lift, i.e., the vertical distance from the pump cylinder to the water surface, should never be more than 5-6 m (16-20 ft). Pumps installed in this way need to be primed before they can operate; that is, the suction pipe must be filled with water from an outside source in order to eliminate air; and this priming water can in itself carry severe risk of pollution unless strict precautions are observed.

When the suction lift would be greater than 5-6 m (16-20 ft), the pump cylinder should be lowered into the well, or some other type of pump must be used—for instance, one in which the pumping action takes place within 5-6 m (16-20 ft) of the surface of the water (i.e., within the distance of possible suction lift). Another method consists of immersing the pump cylinder, jet, or turbines in the well water. This method has the further advantage of avoiding the need for priming the pump.

Classification

There seems to be an infinite number of classifications for pumps. The one chosen here is based on the mechanical principles involved.

(1) Displacement
   (a) reciprocating
   (b) rotary
   (c) chain

(2) Velocity
   (a) centrifugal (standard centrifugal and deep-well turbine)
   (b) jet

(3) Buoyancy: i.e., airlift

(4) Impulse: i.e., hydraulic ram

Table VI shows some of the relative merits of these various types of pumps. In the following paragraphs the practical characteristics of those pumps most commonly used under rural conditions are discussed.

Types of Pumps

Displacement pumps

By far the largest category of pumps under this heading is the reciprocating plunger pump in which water is moved by the direct push of a plunger, piston, or bucket which reciprocates in a closed horizontal or vertical cylinder. By an arrangement of valves this reciprocating motion of the plunger produces a more or less steady stream of water flowing in one direction: in the simplest type, the plunger on the forward stroke pushes the water from the cylinder up a discharge pipe, while at the same time the space behind the plunger is filling from the suction pipe; the reverse stroke
In addition to the foot and bucket valves of the lift pump, a head valve is provided. In operation, during the up-stroke, atmospheric pressure forces water into the cylinder; during the down-stroke, this water is transferred from the lower to the upper side of the piston.

Other minor categories under this heading include the semi-rotary hand pump, chain and bucket pumps, and any other device of bucket and windlass or bucket and counterweight where water is moved by the direct push of a moving container or impeller.

The reciprocating plunger pump is probably the most widely used throughout the world since it ranges from small, hand-operated plungers of a centimetre or two in diameter to huge, steam-driven pistons whose diameters may equal a metre or more. Very large pumps of this class are rarely installed today, since the centrifugal type has many advantages in the larger ranges; but for rural water-supplies in sizes up to, say, 15 cm (6 in.) in diameter, the reciprocating pump is extensively used in power-driven installations, and almost exclusively so in wind-, animal-, or hand-operated units.
Some of the main advantages of this type of pump in power-operated schemes are as follows:

(1) **Flexibility**: The delivery from a plunger pump is the volume of water displaced in the cylinder times the number of strokes of the plunger in a given time. Within wide limits the speed of the plunger can be varied, and the delivery varies in exact proportion. Only when too rapid a motion of the piston causes “slip”, or movement of water backwards between the plunger and cylinder walls, is the limit of capacity reached. In addition, in most types performance can be adjusted by varying the length of stroke. Consequently, a pump of this type has a wide range of duty with little decrease in efficiency—i.e., the efficiency curve is a very flat one (see below)—and it is possible to standardize on a particular type of pump to meet varying conditions, thus reducing the number and type of spares and replacements to be carried. Another advantage accruing from this flexibility is the ability of an individual pump to perform varying duties without loss of efficiency. An instance of this is in a scheme where the reservoir is designed as a balancing tank “floating” over the distribution system. At peak hours when large draw-offs take place on the rising main, the head on the pump may be low; at other times, when the whole of the water is being delivered to the reservoir, the pump will work against a high head. A reciprocating pump is better able to carry out these different duties than other types.

(2) **Speed of operation**: This type of pump normally needs a slower prime mover than a centrifugal type; consequently, wear is reduced and the life of both the pump and the engine is prolonged. Small variations in speed cause only small variations in output, so that less accuracy is required in adjustment.

(3) **Ease of maintenance**: With slow-moving bucket pumps little maintenance is required other than replacement of the leather bucket or plunger washers, and these are relatively easy to fix. The wear on these leathers is dependent on the purity of the water pumped: if it is free from silt or abrasive matter they may last for years without replacement. Properly used, these pumps rarely require any expensive replacements; and any work done on them can be carried out by relatively unskilled staff.

(4) **Robustness**: There are few, if any, delicate parts in this type of pump; and it will stand mishandling better than centrifugal pumps, where dimensions may be critical. Should the water fail, for instance, and the plunger continue to operate without actually pumping, little damage will be done; a similar situation in a high-speed turbine pump would quickly ruin the whole mechanism.

(5) **Initial cost**: Because of their simplicity, the cost of reciprocating pumps is usually lower than that of centrifugal pumps of similar capacity.

The hand-operated pump (Fig. 39, 40, and 41A) can be used in wells of any depth. In those which have a draw-down level of less than 5 m (16 ft), the cylinder is usually placed above ground. When the static water
INSTALLATION OF WATER-SUPPLY SYSTEMS

Fig. 39. DISPLACEMENT PUMP OPERATION

When the cylinder is above ground, a foot valve is necessary to avoid pumping.

level is more than 5 m (16 ft) the cylinder is attached to a drop-pipe and placed in the well as shown in Fig. 13-15 (see pages 77-79).

This type of pump is quite reasonable in cost, especially the reciprocating pump of which the cylinder is above ground. It can give good service provided the plunger leathers and cylinder valves (Fig. 41) are maintained. The maintenance process is simple but must be carried out repeatedly. Where a closed cylinder (Fig. 41) is placed in the well, some complication is introduced because, in order to maintain the installation, the cylinder and
With this arrangement, water can be taken out at the pump or pumped up to a point at a higher elevation by closing valve A.

A = Hand-operated valve  
B = Check valve  
C = Air chamber  
D = Stuffing box

Drop-pipe must be removed. Open-end cylinders are available which are built in such a way that the bucket and foot valves, together with the pump rods, can be removed to the surface without taking out the drop-pipe. In any case, under rural conditions such pumps are much more difficult to maintain than other pumps whose cylinders are above ground.

Priming is usually necessary for pumps with cylinders above ground where suction is required in order to get the water up to the plunger, since the cylinders, leathers and valves wear with time, causing a leakage of air.
Fig. 41. PUMP CYLINDERS AND PUMP CYLINDER VALVES

A = Closed-type cylinder
B = Open-type cylinder with ball valve. Plunger may be removed without taking cylinder from the well.
C = Poppet valve
D = Spool valve
E = Spring-activated poppet valve

Leathers and valves wear on all types of cylinders and need replacement from time to time.
into the suction line. As a result, the vacuum beneath the plunger is broken and, in order to pump again after a short interval of time, water must be put into the cylinder from above. When the pump is delivering into a rising main, this priming can be effected by allowing the water in this rising main to flow back into the cylinder through a simple bypass; but, when the pump discharges directly into the open air (as in Fig. 39, 40), a quantity of priming water must be introduced from an external source. This process obviously offers a good chance for the introduction of contamination into the well; in fact, this is almost inevitable. Therefore, from the sanitary point of view, pumps whose cylinders are immersed in the well water below the point of maximum draw-down have definite advantages.

Hand-operated reciprocating pumps have a capacity limited by the power which can be exerted by one or two men. Consequently, the lower the level from which the water must be drawn, the less the amount delivered. Some typical figures are as follows:

- Shallow pump, operated by one man, lift 6 m (20 ft), 35 litres (9 US gal.) per minute
- Deep-well pump, operated by one man, lift 30 m (100 ft), 6 litres (1 1/2 US gal.) per minute
- Deep-well pump with rotary head, operated by two men, lift 30 m (100 ft), 15 litres (4 US gal.) per minute.

With hand-operated pumps, an air chamber is sometimes incorporated (as in Fig. 40) to give a smooth flow and increase efficiency when pumping through a rising main; with power-operated pumps, such air vessels are invariably installed, and occasionally differential plungers are also used for this purpose.

Reciprocating pumps on the surface operated by electric, diesel, or petrol motors (Fig. 41A) can have a total capacity limited only by the size of the power unit; but the length of the suction is limited as described on page 124. They can also be designed to pump to considerable heads above pump level. When they are operated below ground, however, a limiting factor is the diameter of the cylinder which can enter the bore-hole casing. For single-acting pumps, the following are some typical delivery capacities, using a 12 h.p. prime mover:

- 9.5-cm (3 1/4-in.) barrel, for 10-cm (4-in.) rising main to go into a 15-cm-(6-in.-) diameter bore-hole gives 100 litres (26 US gal.) per minute against 131 m (430 in.) total head
- 14.6-cm (5 3/4-in.) barrel, for 15-cm (6-in.) rising main to go into a 20-cm-(8-in.-) diameter bore-hole gives 250 litres (66 US gal.) per minute against 56 m (185 in.) total head

In order to increase the efficiency of a single-acting barrel (i.e., one in which water is lifted on the upward stroke only), counterweights are usually
fitted to keep the engine running with even power; but double-acting cylinders can also be fitted (Fig. 42). The latter obviate the use of counterweights and give increased output; but they are more susceptible to maintenance troubles, particularly when there is any sand in the water pumped.

Fig. 42. DOUBLE-ACTING DISPLACEMENT PUMP

When piston is in position A, intake is at lower left and discharge at upper right. In position B, intake is at lower right and discharge at upper left.

Fig. 43. TYPICAL SEMI-ROTARY HAND PUMP

Reproduced by kind permission of Lee, Howl & Co, Ltd. (Catalog A, 1955, pp. 34, 37). Tipton, Staffs., England
They are also more expensive and more difficult to repair. Typical delivery capacities of double-acting cylinders are:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Barrel Size</th>
<th>Rising Main Diameter</th>
<th>Bore-Hole Diameter</th>
<th>Delivery Capacity</th>
<th>Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.3-cm (3½-in.)</td>
<td>10-cm (4-in.)</td>
<td>15-cm (6-in.)</td>
<td>8.3-cm (3½-in.)</td>
<td>8.3 m (27 ft)</td>
<td>185 litres (49 US gal.) per minute against 198 m (650 ft) total head</td>
</tr>
<tr>
<td>13.3-cm (5½-in.)</td>
<td>15-cm (6-in.)</td>
<td>20-cm (8-in.)</td>
<td>13.3-cm (5½-in.)</td>
<td>370 litres (98 US gal.) per minute against 91 m (300 ft) total head.</td>
<td></td>
</tr>
</tbody>
</table>

Hand-operated plunger pumps of varying types are popular in most areas where small outputs are required. In some places attempts have been made, with varying degrees of success, to build such pumps out of
standard iron pipes and fittings and other materials put together by village craftsmen. Since the handles on hand-operated reciprocating pumps are most susceptible to breakage from rough usage, wooden handle assemblies have sometimes been successfully built out of materials available in rural areas.a,b

The semi-rotary pump, double-acting or quadruple-acting type, is often used in individual water-systems in rural areas for low lifts of water from wells, cisterns, and underground reservoirs to overhead tanks. Fig. 43 illustrates the operation of a double-acting, semi-rotary pump. Without a

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a American Friends Service Committee (1956) Social and technical assistance in India; an interim report, Philadelphia (Unpublished document)
foot valve, these pumps are satisfactory for only very small suction lifts. When a foot valve and a strainer are fitted to the bottom of the suction pipe, the pumps will operate with a suction lift of up to 6 m (20 ft). Their capacity depends upon the number of strokes of the handle per minute.

Other types of displacement pumps are in most instances powered by hand or animals, and are used for low lifts of water from cisterns and dug wells for irrigation or domestic purposes. They include:

1. the rope and bucket systems, sometimes operated by means of a windlass (Fig. 44, 45);

Fig. 46. CONTINUOUS-BELT BUCKET PUMP

Water is elevated in small buckets attached to a belt which continuously carries it to the surface. This is a fairly foolproof system, with little maintenance required. The original cost is considerable, but the pump could be made locally from local materials. Note the location of openings (A) of buckets.

Fig. 47. MULTICELLULAR BAND PUMP

The band pump works on the principle of elevating water which is fixed to the folds in the band by surface tension. This pump is rather high in initial cost but gives long service with few maintenance problems.
(2) the chain bucket pump, which consists of a series of metal buckets attached to an endless vertical chain extending below the water level; as the chain is revolved, the buckets pick up water and are carried upward over a toothed wheel or a trough into which they empty themselves (Fig. 46);

(3) the chain-and-plug pump, which consists of a series of rubber, hemp, or wooden plugs or pistons fitted to an endless chain moving inside a metal or wooden pipe immersed in the water; the plugs form a close fit with the pipe's interior surface and push the entrained water upward to a discharge-spout situated at the top of the well;

(4) various types of water elevators, which consist of an endless metal band folded in such a manner as to create a large number of small, open-end, horizontal cells (multicellular band) which retain the entrained water and discharge it into a trough when they pass over a pulley at the top of the well (Fig. 47).

With the chain pumps mentioned under (2), (3), and (4) above, it is necessary that the water level in the well should remain fairly constant and should not be subject to wide seasonal extremes.

**Velocity pumps**

In velocity pumps, water is moved through the continuous application of power by some mechanical means. In the centrifugal pump, energy

![Centrifugal pumps: Turbine-type (I) and Volute-type (II)](image)

The rapidly rotating impeller (A) supplies energy to the water, causing it to flow out through the opening (B).
This is the best and simplest arrangement for centrifugal pumps. Power unit may be electric motor or internal combustion engine.

Belt-driven centrifugal pumps are common but introduce belt maintenance. Necessary in order to get the correct engine-pump speed ratio.

The manufacturers’ recommendations for operation and maintenance should be followed.

is applied by a rapidly rotating impeller in which kinetic energy is transformed into water pressure (see Fig. 48, 49); as a result, water is propelled out of the discharge opening. In the jet pump, the kinetic energy of the
Fig. 50. JET PUMP

Fig. 51. TYPICAL INSTALLATION OF JET PUMP

A = Water being returned from pump above
B = Water from well being sucked up into throat (D) by high-velocity discharge (C)

A = Jet assembly
B = Water line from pump to nozzle
C = Rising water
D = Centrifugal pump
E = Pressure-regulating valve
F = Discharge pipe
G = Height of water pushed by jet
H = Suction by centrifugal pump (about 4.5-6 m, or 15-20 ft)

high-velocity jet of water or steam is converted into water pressure in the portion of the suction pipe immediately following a restricted opening or throat similar to the discharge half of a venturi meter (Fig. 50, 51).

Velocity or rotary pumps, while all working on the centrifugal principle, are usually known as either centrifugal or turbine pumps. In the centrifugal type the water enters at the centre of the impeller and leaves at the periphery—in other words, the flow is radial—while in the turbine type the water flows in the general direction of the axis of the pump through a number of stages. Fig. 48 and 52 illustrate this difference.
In the turbine pump, water is lifted from one stage (B) to next by small impellers (A) being rotated by shaft (C), which is attached to power unit. The number of stages and the design of the impeller vary with the pumping requirements. This pump is highly efficient and, when properly operated and maintained, gives long service.
Both centrifugal and turbine pumps (particularly the latter) can be of very high efficiency, but this efficiency is usually dependent on a carefully calculated, narrow range of duties. In other words, each pump must be designed for the exact duty it has to perform; and the more it varies from that duty the less efficient it is. Centrifugal pumps may, of course, be designed with a wider range of duties—i.e., with a flatter performance curve—but very high efficiencies are not obtainable with such designs.

An advantage possessed by turbine pumps, particularly, is their compactness. Very powerful pumps can be built into small-diameter boreholes; and, when large quantities of water are required from a bore-hole, this type is usually chosen in preference to a displacement pump. In addition they work at much higher speeds, and the transmission mechanism is lighter and more compact, though the increased delicacy of this mechanism renders it more liable to breakdown and more difficult to repair. Speed of operation, too, is more critical; and, with rural electricity supplies, or with inadequately maintained petrol or diesel engines, pumps may run at greatly reduced efficiency because the rate of rotation falls below that for which they were designed.

As a general rule, single-stage centrifugal pumps are used for situations where a low suction lift, medium pumping-head, and large quantities of water are required, such as river intakes, shallow wells, or low-pressure boosting; and turbine or multi-stage pumps are used where compactness is essential or high pumping-heads are required, such as bore-hole intakes or high-pressure boosting.

Jet pumps, sometimes referred to as ejector pumps, are less efficient than any of the types mentioned so far but have certain advantages which make them suitable for very small water-supplies where conditions favour their installation. Essentially a jet pump consists of a small, centrifugal pump which forces water down a well at high pressure. This high-pressure water, issuing from a jet into the throat of a venturi tube (see Fig. 50), causes a larger volume of water at lower pressure to be delivered from the rising main. Of this delivery, a quantity equal to the high pressure operating water is recirculated through the pump, the useful delivery being the difference between the two quantities. Priming is necessary since, until the whole system is filled, operation will not start; and, unless this can be done by means of a return feed from the storage tank, there is danger of pollution.

There is little advantage in fitting a jet pump where the depth to water level is less than 6 m (20 ft), as a simple centrifugal pump will perform the same duties more efficiently. The normal limits of duties of the small jet pump are a lift below ground of 6-30 m (20-100 ft) and a discharge of up to 75 litres (20 US gal.) per minute against a delivery head above ground of 15 m (50 ft) or thereabouts. At all times the jet must be covered by at least 1.5 m (5 ft) of water, so that the well cannot be completely emptied.
A jet pump is light and compact and has all moving parts on the surface. When polythene or other flexible delivery and operating pipes are used, it is very quickly installed; and the unit can operate in a narrow bore-hole. The pump and motor are mounted to one side of the hole, thus leaving the well top clear. For this reason a portable jet pump may often be used for emergency supplies and can be quickly transferred from one source to another. A further advantage is its ability to pump water containing sand or silt, provided, of course, that it is possible to separate such abrasive material from the portion of the water which is recirculated to the pump for operating the jet.

Some typical figures for small jet-pump performance, using a diesel prime mover of 1 1/2 h.p. or electric motor of 1 h.p. are as follows:

- Water level, 12 m (40 ft) below ground; delivery head, 15 m (50 ft) above ground; capacity, 55 litres (15 US gal.) per minute
- Water level, 24 m (80 ft) below ground; delivery head, 30 m (100 ft) above ground; capacity, 20 litres (5 US gal.) per minute.

**Characteristic curves**

Usually a centrifugal pump is designed to give a specified discharge against a specified head at maximum efficiency for a given pump speed. However, there is a moderate range over which, at or near maximum efficiency, a greater discharge may be obtained against a reduced head or a lower discharge against a greater head, and a much larger range over which varying discharges can be obtained at lower efficiencies. A curve can be prepared showing the relationship between the quantity pumped and the total pumping-head for any given pump speed. This curve, and curves showing the relationship between the quantity pumped and horsepower absorbed and between the quantity pumped and the percentage efficiency, are known as the pump characteristic curves.

Fig. 53 shows the characteristics of two different 8-cm (3-in.), two-stage pumps (A and B) running at 1450 r.p.m. and of a five-stage, submersible pump (C), running at 2900 r.p.m., suitable for installation in a 20-cm (8-in.) internal diameter bore-hole. Fig. 53 D is a chart from which it is possible to choose suitable deep-well turbine pumps.

1. **Quantity head-curve:** This curve shows that, as the pumping head decreases, the quantity pumped increases. The head shown for zero quantity is known as the "shut-off" or "closed-valve" head, and is the head generated when the pump is running with the delivery valve closed. With some pumps the head decreases progressively as the discharge increases from zero, (e.g., pump A), whereas with others the head begins to rise and then falls, as with pump B. This is not important in the case of pumps working singly; but, where two pumps may run in parallel, it is essential that the closed-valve head be greater than the total pumping head when the two pumps are discharging together.
In most cases the curve has a flat slope at the low discharge end, and a small increase in pumping head can result in a large decrease in the quantity pumped. It is undesirable to work on this portion of the curve.

(2) **Quantity efficiency-curve:** This curve increases from zero at zero discharge to a maximum at the discharge for which the pump is designed, and then falls off more rapidly, and often much more rapidly, than the rising portion. This curve indicates over which portion of the pump’s range it can satisfactorily operate. In the case of pump A, there is a range of from 852 litres (225 US gal.) per minute against 56 m (184 ft) to 1230 litres (325 US gal.) per minute against 42 m (139 ft) over which efficiency is a little below the maximum; and, at from 568 litres to 1420 litres (150 US gal. to 375 US gal.) per minute, the efficiency is not unduly low. Outside this range, the efficiency is too low to permit satisfactory operation. Generally, the efficiency of centrifugal pumps available on the market ranges between 40% and 85%, the larger pumps being more efficient than smaller ones.

(3) **Quantity horsepower-curve:** In some cases, e.g., pump B, this curve is more or less a straight line, rising as the quantity increases, and the slope may even steepen as the quantity increases beyond that for optimum efficiency. In other cases, e.g., pumps B and C, the curve flattens or even falls off beyond this point. The latter type of curve is “non-overloading.”

It is necessary to provide a motor of adequate power to cope with the worst pumping conditions that may be encountered. In certain circumstances, as for example in the case of a pumping main to a storage reservoir which is also used as a distribution main, there may be a very considerable fluctuation in the pumping head at different times of the day, the maximum being when there is no draw-off and all the discharge is going to the reservoir, and the minimum being when all the supply is going to the distribution system. A pump must be selected which will have a satisfactory efficiency over the whole operating range; and, if it has a quantity—horsepower characteristic as in pump A or pump C, a smaller motor will suffice than would be necessary for a pump with a characteristic similar to pump B.

In the case of the submersible pump, C, the horsepower curve is nearly flat over the working range of the pump, giving flexibility of performance without the risk of overloading the motor. This is valuable for boreholes in which the water level may vary considerably.

The curves for deep-well turbine pumps are similar to those for submersible pumps except that for a given capacity and speed the efficiency is somewhat lower due to the horsepower absorbed by the long shaft and bevel gear or twisted belt drive.

Fig. 53 shows the characteristics of a submersible pump for five stages (pump C). The addition of stages to a turbine pump increases the head capacity in direct proportion to the number of stages without affecting the
Fig. 53. TYPICAL CHARACTERISTICS OF DEEP-WELL TURBINE PUMPS

A, B = 3" two-stage centrifugal pump, 1450 r.p.m.
C = 7 \frac{1}{8} " five-stage submersible pump, 2900 r.p.m.

D = 6" deep-well turbine pump
quantity. The horsepower absorbed also increases directly with the number of stages. For about three or more stages the efficiency remains unchanged, but there is a slight reduction when there are only one or two stages.

The speed of a centrifugal pump has a considerable effect on its performance, the quantity varying directly as the speed, and the head varying as the square of the speed. The horsepower absorbed is therefore proportional to the cube of the speed. The efficiency tends to improve as the speed increases, but this depends on the design of the pump. A high-speed pump is therefore lighter and cheaper than a low-speed pump of similar capacity. However, increase in speed tends to lead to increased maintenance costs, and a suitable balance between original costs and maintenance costs has to be adopted.

Usually the characteristic curves of a pump are plotted separately for each particular speed; but they may be shown for a number of speeds, as in Fig. 53 D, which gives the characteristics of a deep-well turbine pump per stage for speeds varying from 1450 r.p.m. to 2900 r.p.m. Characteristics for intermediate speeds may be interpolated.

These curves, which are applicable to a particular pump operating at a specific speed, change with the width and design of the pump’s impeller. An impeller with more vanes (see Fig. 54) produces flatter performance curves; so does an impeller with more radial or wider vanes. An impeller with a large suction eye produces more water.

Suction lift is also of great importance when dealing with centrifugal pumps. When it is close to the theoretical maximum (approximately 10 m, or 33 ft), a very inefficient operation will result; and wear and tear on the pump’s moving parts will be speeded up. This is show graphically in Fig. 55. Here the total lift or head is assumed to be 10 m (33 ft). A pump installed 3 m (10 ft) above water surface will lift the water 7 m (23 ft) above its centre, while the same pump installed with a suction lift of 8 m, or 26½ ft (i.e., 80% of the theoretical maximum of 10 m), will raise the water only 2 m (6½ ft) above its centre. Such a situation may arise in a well in which the draw-down due to pumping is excessive; this is illustrated by the typical capacity curves shown in Fig. 55. It is important, therefore, to test a newly constructed well for draw-down and yield and to install the centrifugal pump in such a manner that its centre will never be more than about 5 m (16 ft) above the lowest water-level obtained in the well when pumping.

It is normally only in the case of pumps of large capacity that such pumps are designed specially for the duty to be performed. Manufacturers produce a large range of standard pumps to cover varying arrangements of quantity and head; and, by modifications of impeller sizes, and sometimes of speeds, one of these standard pumps can be adapted to suit, more or less closely, any pumping duty over a wide range. For any given duty, a pump made by one manufacturer may be more closely adapted than those of other
Fig. 54. EFFECTS OF VANES AND SIZE OF INTAKES ON PERFORMANCE CURVE AND CAPACITY OF CENTRIFUGAL PUMPS

Larger intake—greater capacity

Wider impeller—flatter performance curve

More tangential vanes—flatter performance curve

More vanes—flatter performance curve
Fig. 55. **TWO PUMPING SITUATIONS, SHOWING CENTRIFUGAL PUMP CAPACITY CURVES**

A = Performance curve when pumping with low suction lift
B = Performance curve when pumping with high suction lift
manufacturers; and it is by the study of the characteristics of the various pumps offered that a decision can be made as to which is the most suitable for a particular duty. 

*How to choose a suitable deep-well turbine pump*

A deep-well turbine pump (see Fig. 52, 56, 57) is required to go into a 15-cm- (6-in.-) diameter bore-hole, and to give 662 litres (175 US gal.) per minute against a 30-m (100-ft) head. From the upper part of the chart in Fig. 53 it will be seen that at 1450 r.p.m. this type of pump will give 1.2 m (4 ft) head per stage at 662 litres (175 US gal.) per minute; in other words, a 25-stage pump will be needed to give a 30-m (100-ft) head with an efficiency of 50%. Similarly, at 1760 r.p.m., 11 stages will be required (efficiency, 65%); at 2250 r.p.m., 6 stages (efficiency, about 64%); at 2500 r.p.m., 4 stages (efficiency, about 61%); and at 2900 r.p.m., 3 stages (efficiency, 55%).

*Fig. 56. DEEP-WELL TURBINE PUMP: ELECTRIC MOTOR (I) AND DIRECT DRIVE AND ANGLE-GEAR HEAD (II)*

This is the best and simplest drive arrangement for deep-well turbine pumps. A reliable source of electricity must be available.

If angle-gear drives are used, a direct connexion is best, for belt maintenance is eliminated. Various gear ratios are available to get the correct engine-pump speed ratio. Angle-gear drives require careful lubrication and maintenance.

The manufacturers' recommendations for operation and maintenance should be followed.
From this it appears probable that the pump chosen will be an 11- or 6-stage pump at 1760 r.p.m. or 2250 r.p.m., but a check on the bottom part of the curve will give the power required. At 1450 r.p.m., 0.4 brake horsepower b.h.p. per stage will be needed; hence a 25-stage pump will require 10 b.h.p. to drive it. Similarly, at 1760 r.p.m., $11 \times 0.65 = 7.15$ (b.h.p.) will be necessary; at 2250 r.p.m., 8 b.h.p.; at 2500 r.p.m., 7.28 b.h.p.; and at 2900 r.p.m., 8.4 b.h.p. The most suitable pump, therefore, is an 11-stage pump which will absorb 7.15 b.h.p. for the duty envisaged.

This is the horsepower absorbed. If a direct-coupled electric motor is to be used, approximately 10% should be added for transmission losses, and an 8-h.p. motor would be chosen. If a diesel engine is used to drive the pump, either direct-coupled through a bevel head and gearbox or by a twisted belt drive, then about 33$\frac{1}{2}$% will be necessary to allow for the extra losses, and a 10-h.p. engine would be chosen.

**Buoyancy pumps**

In the air-lift pump, water is raised from its static level in a well by mixing it with air, thus changing the specific gravity of the mixture. The main parts of such a pump are shown in Fig. 58. By means of a compressor, air is forced down the well through a small pipe placed inside the eduction-pipe. The air-water mixture, being lighter than the water outside the eduction-pipe, rises to the top of the well.
This pump has the great advantage that there are no moving parts within the well, all power and moving equipment being located above ground. It is often used for drawing water from drilled wells in which the water level is at a considerable depth below the ground. It is also well adapted to pumping dirty or sandy water and for drawing water from crooked wells, i.e., wells which are not straight and vertical.

For proper operation, it is necessary that the eduction pipe be from 50% to 70% submerged in the ground water for pumping against heads up to 61 m (200 ft). This, of course, means that existing wells, if they are to be fitted with air-lift pumps, may need to be deepened in order to secure adequate submergence of eduction-pipes. In areas where the ground-water level fluctuates greatly or where the drawdown during pumping is considerable, this type of pump may not be used. Another disadvantage is that water cannot be pumped any appreciable distance horizontally. The efficiency of the air-lift pump is usually low, around 20%-50%. For this reason, and also because of the high cost of air compressors, this system should be carefully investigated before being employed in small and rural water-supply systems.

**Impulse pumps**

In the hydraulic ram, power is derived from the water hammer that is intentionally produced (Fig. 59). The force of the water is captured in a chamber where air is compressed and released when the compressed air expands, pushing a small amount of the water to a higher elevation than that from which it originally came. The water not raised up to a higher level is wasted. At each compression and decompression of the air in the chamber, a definite quantity of water is pushed up to the tank or reservoir.
A = Supply—litres/minute
B = Difference in elevation between ram and supply-power head
C = Length of drive pipe
D = Difference in elevation between ram and highest point to which water is to be elevated—pumping head
E = Total length of supply pipe
F = Stand-pipe, necessary in case of exceedingly long drive pipe

Under the proper circumstances—a situation similar to that shown, in which the supply of water is considerably in excess of the needs, and is situated so that the ram can be located well below the supply—the hydraulic ram can be an excellent solution to a pumping problem.

When writing to manufacturers about ram sizes, the information in items A, B, C, D, and E is necessary. With this the factory will be able to recommend the correct size, feasibility, etc.

Where a continuous supply is available—from a spring, for example—this process can go on continuously; and a great deal of water is pumped over a 24-hour period.

The following tabulation gives an idea of the amount of water that can be pumped with various heads and amounts of power water:

<table>
<thead>
<tr>
<th>Ratio of pumping head to power head</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery in gal. per day for each gal. per min. of power water</td>
<td>540</td>
<td>345</td>
<td>240</td>
<td>192</td>
<td>160</td>
<td>137</td>
<td>120</td>
<td>107</td>
<td>96</td>
<td>80</td>
<td>64</td>
<td>43</td>
</tr>
</tbody>
</table>
It is rather uncommon to find suitable topographical conditions for the installation of hydraulic rams; but, when they exist, this apparatus is one of the most useful pumps to be considered, especially for individual water-supply installations. It is durable and inexpensive in initial cost. It requires practically no maintenance, and will work 24 hours per day with neither attention nor operating costs. However, only a small portion of the available water will be pumped. Unless the remainder of the operating water can be used in other ways (for crop irrigation, for example), it is wasted. When a supply is desired from a spring, or other supply source which has a good fall and a flow several times greater than is required for the water-supply system, then a hydraulic ram should always be considered as a possibility.

Other pumps similar to the hydraulic ram but employing differential cylinders as motive power may be found on the market. They have the advantage of being able to pump clean water from a well while using some other water, such as that from a contaminated stream, as motive power.

Selection of Pumps

It is not possible to establish strict rules for selecting pumps since there are so many factors capable of influencing a decision. The most important considerations are:

1. the extent and reliability of the service which will be available for maintenance;
2. the initial cost of the pump and its driving equipment;
3. the cost of operation;
4. the capacity and lift required;
5. the sanitary features of the pumps available commercially;
6. the desirability of standardization and reduction of the number and diversity of spare parts when smaller pumps are in operation.

Other factors include the type and size of wells, fluctuations of drawdown levels, location of pumps and engines, variations in load, etc.

As a general guide, the following advice may be given with regard to the selection of pumps for rural water-supply systems:

1. Pumps in which all moving parts are above ground and easily accessible are preferable and will, in most instances, give the best service simply because they are easier to maintain with means available in rural areas. However, if, qualified maintenance can be assured, pumps with submerged cylinders should receive first consideration.
2. Where motor power is used, efficiency is a very important factor; and the more expensive the power, the more important becomes the efficiency. In many places a new pump installed to replace an old, inefficient one would pay for itself within a very short time simply by reducing the cost of motor operation.
(3) Centrifugal and deep-well turbine pumps must operate under the conditions for which they were designed, or a great loss in efficiency will result. Pumps with flat efficiency curves are to be preferred for rural water-systems since they allow for greater flexibility in design, i.e., they eliminate the necessity of designing to precise limits. Consequently, such pumps will do varying duties under a substantial range of conditions; and, when adopted as standard equipment on several water-supply systems within the same rural area, they will facilitate maintenance and reduce the need for a multiplicity of spare parts.

(4) The pump selected should be one for which repair and replacement parts can be obtained easily and promptly.

(5) The pump equipment should be so constructed and installed as to prevent the entrance of contaminating water or material either into the well or into the water that is pumped. Special attention should be paid to the following sanitation specifications:

(a) The pump head should be designed to prevent contamination by hands, dust, rain, birds, flies, and similar sources from reaching the water-chamber of the pump. Ordinary lift pumps with slatted pump-head tops should not be used for domestic water-supply systems.

(b) The pump base should be so designed as to facilitate a waterproof seal with the well cover or casing.

(c) The pump selected should be so designed and installed that priming will not be necessary.

When ordering or inquiring about a pump, the following information should be specified:

(1) the inside diameter of the smallest part of the casing or hole in which the pump is to be installed;

(2) the static water level in the well or reservoir, measured in metres (or feet) below land surface or other reference point;

(3) the desired yield, in litres per minute (or in gallons per minute);

(4) the draw-down in metres (or feet) or the lowest water level expected when pumping at the desired yield (in the case of a well, this should either be measured during a test of the well, or carefully estimated from the best available information on similar wells nearby);

(5) the desired water pressure at ground level, i.e., the operating pressure of any pressure tank (if any), the height of any elevated tank or standpipe, plus the friction in the delivery pipe;

(6) the type of power available (if electricity, full specifications—for example, 220 volts, 3-phase, 60 cycles, alternating current—should be given);

(7) the total depth of the well or reservoir.

It should also be stated whether the well is straight, at least down to the level at which the pump is to be set.
For all reciprocating deep-well pumps, whether operated by hand or by one or another source of power, the important feature is the extractable cylinder. By specifying a cylinder size smaller than the riser pipe, it is possible to use a submerged cylinder with operating parts that can be drawn up through the riser pipe for inspection, repair, or replacement. The alternative is to use a riser pipe of the same diameter as the suction or tail pipe and to draw the whole system when repairs are needed. Another important point is to require that the handle, fulcrum, and bracket on such a pump be made of malleable iron, and not of cast iron, which is brittle and breaks under repeated shock or impact, as it often does in operation or transport. A typical specification for a deep-well, hand-lift pump is given in Annex 6, page 296.

**Power for Pumps**

The cost of pumping is mainly the cost of power to operate the pump, so that in areas of limited economic means the use of power is of the utmost importance. Anything that Nature has provided should be used to full advantage. As a matter of fact, the type of power available will be in many instances the determining factor in the design of the rural water-system. This, of course, is often a function of available economic resources, but it is not always so.

The types of power that are available are as follows.

1. Man power and animal power are the oldest, and in many places the only, kind available. Animal power can be completely adequate and should not be overlooked nor underestimated.
2. Gravity is the cheapest source of power when it is possible to use it. Extensive effort should be made to find a solution in which water will flow to the consumer by gravity. Considerable extra initial cost is justified for such a solution. Usually an economic formula can be worked out based on the life and cost of pumping and equipment as compared to the cost of a pipeline to bring in water by gravity. In hilly, rough country there are ample opportunities for gravity supplies. Experience in Latin America would indicate that for small communities this is by far the preferred solution from the point of view of maintaining continued service. Almost without exception small towns with gravity systems are satisfactorily supplied with water at all times. Local materials can often be used to build gravity pipelines, thus further reducing the project cost.
3. Wind (see page 155) is another very cheap source of power which should be given careful consideration in either individual or community supplies.
4. Steam is usually not practical; but in areas with dense vegetation and lacking in other resources, it may be a good possibility. Small wood-burning boilers are not unreasonably expensive; and in jungle areas where wood is being produced prolifically, this source of power may be a good
solution. Once installed, a wood-burning boiler is a cheap and simple installation to maintain. Small steam-systems have been in operation in the Amazon Valley of Brazil for as long as 30 years with little or no maintenance, and they are still working.

(5) Electricity is to be preferred if it is available at reasonable cost, i.e., from some central supply. Electric motors are reasonably low in original cost and are cheap to operate. They require very little attention and give long service. Electricity has a very wide range of application, from the smallest fractional horsepower motors to "giants" far beyond the scope of this monograph. Small water-supplies in towns and homes require small units whose needs are perfectly met by the use of electric motors. On the other hand, it is unwise, in most rural areas, to attempt to generate electricity for the specific purpose of driving electrical equipment. Small electric generating units give so much trouble, especially in the tropics, and need so much specialized maintenance, that their installation should not be contemplated except in extremely rare cases.

(6) Internal combustion engines (gasoline or petrol, diesel, kerosene), in spite of being expensive and, in some instances, difficult as well as costly to maintain, are the types of motor power which are often required for most small community supplies in rural areas. Experience in such areas would indicate that diesel engines are generally the best from all points of view, even though they are the most expensive in original cost. Heavy, low rotary-speed, diesel engines can give long service with a minimum of maintenance and low operating cost. Natural gas engines are also low in operating cost and are of long life, but they are not generally practical. Gasoline and kerosene engines are high-speed motors with short life and high operating cost and are useful only in certain places—Venezuela, for example, where gasoline is cheap. Besides the cost of power, the following items must be considered when the actual cost of pumping water is calculated: interest on, and depreciation of, the equipment, the wages of operators, the efficiency of the pumps, and the depreciation of the building cover. In the USA, the cost of pumping one million US gallons (3.785 m³) through a height of one foot (30 cm) varies from 2-3 cents to 30-40 cents, 10 cents being considered a reasonable figure.\(^{\text{21}}\)

The b.h.p. required to drive a pump is calculated by the following formula:

\[
\text{b.h.p.} = \frac{Q \times H}{3960 \times e}
\]

where

\(Q\) is the pump discharge in US gallons per minute,

\(H\) is the total head in feet pumped against, and

\(e\) is the pump efficiency expressed as a decimal.

The total head \((H)\) includes the feet difference in elevation between the low-water level during pumping and the point of discharge, the loss of head
in the suction and delivery pipes, and minor losses of head due to strainer, valves, entrance and exit of pump, etc.

Windmills

Energy which Nature has provided, such as the wind, should be taken advantage of whenever possible. In many Northern European and Western Hemisphere countries, wind energy is used for pumping water for farms, homes, and small communities. This method (see Fig. 60) is excellent for obtaining a steady flow of water from a well at a very low cost.

For proper operation, the following conditions must be met:

1. winds of more than 8 km per hour during at least 60% of the time;
2. available windmill equipment;
3. wells that can be pumped for many hours' duration each day;
4. storage capacity of three days' supply (or more) to take advantage of long pumping periods and to provide for calm periods when there is no wind;
5. clear sweep of wind to the windmill. This can be obtained by the use of a tower to raise the windmill 4.5-6 m (15-20 ft) or more above the surrounding obstacles.

The pump used in connexion with windmills is usually of the reciprocating type and has an extension of the piston rod above the upper guide with a hole for connexion with the pump rod from the windmill (see Fig. 61, 62). Provision may also be made for pumping by hand or for using animal power when extremely long periods of calm are likely to occur. The gearing on windmills varies with manufacturers and wind conditions: some pump one stroke with each revolution of the mill, while others pump one stroke with three or four revolutions. The former requires more and higher-velocity winds; the latter is advantageous in areas where there are winds of low velocity much of the time.
All modern mills are designed in such a manner as to ensure that the windwheels will pivot freely and answer quickly to changes in the direction of the wind. They are also equipped with a "pull-out" system which will automatically turn the windwheel off to one side when the velocity of the wind is excessive—i.e., 48-56 km (30-35 miles) per hour. Provision may be made for lubrication of the mechanism by an oil-pump system operated from the ground.

The size of windmills is usually expressed in terms of the diameters of their windwheels. Sizes of 1.5 m to 9 m (5 ft to 30 ft) may be obtained from manufacturers. An idea of the capacities of windmills may be
Fig. 62. TYPICAL ARRANGEMENT OF WINDMILL TOWER, PUMP, AND WELL

A = Well casing
B = Pump
C = Pump rod extending to above windmill
D = Pump cylinder
E = Windmill tower

Gained from the following examples. A 3-m (10-ft) mill in combination with a reciprocating pump cylinder 7.5 cm (3 in.) in diameter will produce about 760 litres (200 US gal.) of water per hour with a wind velocity of 16 km (10 miles) per hour. The same mill could pump up to 11 350 litres (3000 US gal.) per day, against a total lift of 24 m (80 ft). Similarly, a 7.5-m (25-ft) mill in combination with a 15-cm- (6-in.-) diameter pump cylinder could raise up to 60 560 litres (16 000 US gal.) per day against a head of 37 m (120 ft).

When ordering a windmill, it is important to state the average velocity of the wind, in addition to the data mentioned under “Selection of pumps” (page 151). Windmills will operate with wind velocities as low as 6.4 km (4 miles) per hour. In places where this equipment must be imported from distant manufacturing countries, it is well to plan for the construction of a strong tower, at least, from local materials and to import the rest.
Sanitary Safeguards for Hand- and Power-pump Installations

Besides the selection of pumping equipment possessing the desirable sanitary safeguards, it is important in water-supply systems for domestic use that the installation of this equipment be made in such a manner as to prevent contamination of the water being pumped. This point is often overlooked in small water-systems; and it is not uncommon, in such installations, to observe that drainage water and waste oil from the pump-room floor find an easy way into the well or reservoir water below. Protective measures should be provided for right at the planning stage and should be incorporated into the engineering plans and specifications to be followed by the construction engineer or contractor.

Among the measures recommended by the US Joint Committee on Rural Sanitation, the following may be cited:

"Hand-pump installations"

"... The pump cylinder should be installed near or below the static water level in the well so that priming will not be necessary..."

"The design (of the installation) should provide for frost protection pump drainage within the well..."

"The installation should be designed to facilitate necessary maintenance and repair, including overhead clearance for removing rods and pipe..."

"The pump base should be designed to serve a twofold purpose: first, to provide a means of supporting the pump on the well cover or casing top; and second, to protect the well opening or casing top from the entrance of contaminating water or other material. The base should be of the solid, one-piece, recessed type, cast integrally with or threaded to the pump column or stand. It should be of sufficient diameter and depth to permit a 6-inch [150-mm] well casing to extend at least 1 inch [25 mm] above the surface upon which the pump base is to rest. Provision should be made for fastening the pump base rigidly to the well cover or casing top to prevent movement. The use of a flanged sleeve imbedded in the concrete well cover or a flange threaded on the top of the casing to form a support for the pump base is recommended. Suitable gaskets should be used to insure tight closure. To insure rigidity and the stability of the pump-base closure, the pump should be suitably braced against movement..."

"The protective closing of the pump head, together with the pollution hazard incident to pump priming, makes it essential that the pump cylinders be so installed that priming will be unnecessary.

"Power-pump installations"

"... The sanitation specifications pertaining to hand-operated pumps are in general equally applicable to power-driven installations."

"The base plate of a power-operated pump placed immediately over the well should preferably be designed to form a watertight seal with the well cover or casing. As in the hand-operated pump, the base should be recessed to permit the casing or pipe sleeve to extend into it at least 1 inch [25 mm] above the foundation upon which the pump base rests. All well casings for power-pump installations should extend at least 6 inches [15 cm] above the pump-room floor or platform slab. In installations where the pump is not installed directly over the well or where an open-type pump base is used, the well casing or pipe sleeve should extend at least 6 inches [15 cm] above the floor of the pump room..."
Fig. 63. TYPICAL PUMP INSTALLATION USING STANDARD TEE AND UNDERGROUND ARRANGEMENT TO DISCHARGE WATER BELOW FROST LINE

Reproduced from US Public Health Service. Joint Committee on Rural Sanitation (1950) Individual water supply systems, Washington, p. 47
house, and the annular space between the casing and the suction pipe should be closed with an acceptable watertight packing or seal.

"Power-pump installations usually require enclosure in some form of protective housing. The pump-room floor should be of watertight construction, preferably concrete, and should slope away in all directions from the well or suction pipe. Due to the protective housing, it should not be necessary to use an underground discharge connection with a power pump. The necessary protection from freezing temperatures can be provided for a motor-operated pump through the installation of a thermostatically controlled electric heater. Automatic frost protection drain-back devices can be designed to drain exposed piping where heating is not practical. For individual installations in rural areas, a 100-watt light bulb may give the needed protection if the pump house is properly constructed and the light wired for continuous burning.

"Where an underground discharge is provided, it can be installed without the use of a pit below the ground surface. Fig. [63] illustrates a method of providing an underground discharge below the frost line. This type of installation is particularly applicable to wells in which the pump cylinder is of larger diameter than the drop pipe.

"Experience with installations of this type indicates that when a pressure tank is provided in the distribution system there is no difficulty with water hammer. Sometimes it may be necessary to provide an air chamber on the discharge line from the well located near the pump.

"If the pumping rate makes the use of an air-relief vent necessary, the open end of the vent should be at least 18 inches [45 cm] above the pump-room floor. The end of the vent pipe should open downward and be protected by proper screening.

"Certain types of power pumps require the filling of the pump system with water for priming or water-lubrication purposes before being started. Water thus returned to the pump should be taken from the original source for which the pump is used through bypass piping in the connected discharge line from the pump to avoid contamination.

"It is desirable to provide a water-sampling cock on the discharge line from power pumps which also may be used for releasing any trapped air in the system."

For additional notes regarding sanitary specifications for pumping stations, the reader is referred to Annex 9, page 313.