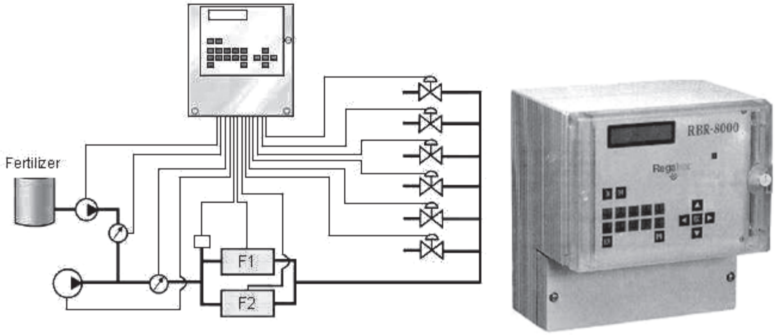
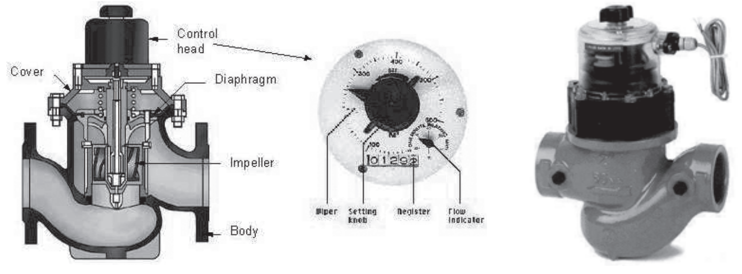
FIGURE 3.38 - Operational scheme and photograph of an irrigation controller device.



Automatic volumetric metering valves. These valves consist of a water meter, a pilot assembly and a shut-off mechanism. Once the pre-set volume of water has been delivered, they shut off automatically (Figure 3.39). Small sizes are operated mechanically and larger ones hydraulically by means of a diaphragm or a piston. Small sizes are available with screw-type joints while larger sizes, made of cast iron, come in flanged connections. They have a relatively limited application, mainly due to their high cost.

FIGURE 3.39 - Operational scheme and photograph of an automatic volumetric metering valve.



OPERATION EQUIPMENT

For the proper management of the irrigation systems, frequent simple water and soil checks and other measurements must be carried out on site. For this purpose, there are several instruments that give direct readouts of the results.

Soil moisture sensors. Soil moisture measurement is difficult mainly because of the variability in soil types, calibration of the sensor, area of influence of the sensor, and the extrapolation of that measurement to crop management. Basically, two parameters are of interest: (i) the volumetric soil moisture because it provides information on the ratio of soil water to solid phase plus air (it is a useful measurement for irrigation control informing about how much water is needed in order to “fill the sponge”) and (ii) the soil moisture tension because it informs about the effort the plant has to make to extract moisture from the soil. At present, there are various technologies for soil moisture measurement. Two of them, because of their relevance, are briefly explained below:

- Tensiometers: The force by which the water is held in the soil is called soil water tension and it is directly related with the moisture content in the soil. It is measured in centi-Bars by the use of tensiometers. Nearly all types of tensiometers consist of three parts, a closed plastic tube, a ceramic porous cap at the bottom and a vacuum measuring gauge at the top. They are available for various depths in several lengths from 30 to 150 cm. They are filled with de-aired water and inserted permanently into cored holes in the soil near the plants, always in pairs, at two different depths, one at 30 percent the effective root-depth and one at 60 percent. Good contact of the surrounding soil must be arranged. The water availability is easily controlled and high osmotic pressure values in the root environment can be secured. At the state of field capacity the soil moisture tension is normally 10 cBars in sandy soils, 20 cBars in medium and 30 cBars in clays. Readings below 10 centibars indicate saturated soil, 20–40 excellent soil water availability and higher than 55 danger for severe water stress. In cash crops irrigation starts when the reading of the shallow depth tensiometer is in the range of 18–25 cBars depending on the type of soil and the stage of growth (Figure 3.40).
- Time Domain Reflectometry (or TDR). The method is based on the principle that velocity of an electromagnetic wave depends on the conducting medium. The larger the soil water content is, the slower the wave will travel. Thus, the wave travelling time along a probe of known length can be related to the soil water content. The main advantages of the method are that it is accurate, continuous, and it does not require calibration. The main disadvantage is that it has complex electronics and expensive equipment.

Conductivity meters. These portable instruments are battery powered and enable rapid and accurate determination of the concentration of soluble salts in the soil solution and the irrigation water. They are temperature compensated but they need frequent calibration (Figure 3.41).

Soil solution extractors. These instruments consist of a plastic tube with a porous ceramic cap at the bottom, like the tensiometers, and a syringe. They are inserted in pairs into the soil at the root plant area (in microirrigation

FIGURE 3.40 - Scheme and photographs of tensiometers and a TDR.

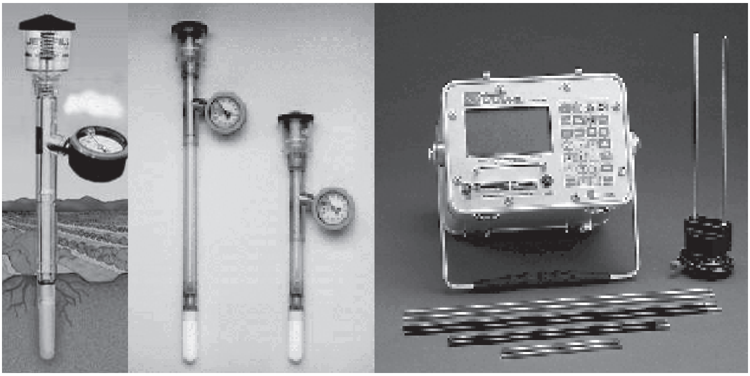


FIGURE 3.41 - Direct measurement of soil solution with a conductivity meter and extractors in the field.

one near the emitter and one between the emitter's lines). A vacuum is created within the empty tube and forces the moisture to move from the soil into the extractor through the ceramic cap. The solution collected is then withdrawn by the syringe for evaluation. These instruments enable the continuous follow up of the change in the soil total salinity, the chlorides and the nitrates content and the pH, as a result of intensive irrigation and fertigation. They are available in various lengths from 15 to 150 cm.

Class A evaporation pan. This is an open circular pan which is widely used to measure evaporation. It is made of 22-gauge galvanized steel plate, all surfaces painted aluminium, or of 0.8 mm Monel metal. The pan has a standard size: 121 cm in diameter and 25.5 cm deep. It is placed level on a wooden beamed base support 15 cm above ground (Figure 3.42). It is filled with water to 5 cm below the rim. It has a simple or advanced reading mechanism to indicate the decrease in water level due to evaporation. Measurements are recorded every morning at the same time. The water is topped up when its level drops to about 7.5 cm below the rim.

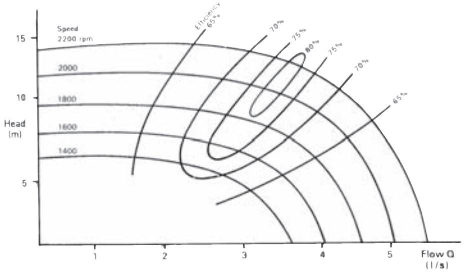
FIGURE 3.42 - A class A evaporation pan in the field.

WATER-LIFTING DEVICES

Pumps and lifting/propelling devices are often classified on the basis of the mechanical principle used to lift the water: direct lift, displacement, creating a velocity head, using the buoyancy of a gas or gravity. Most categories sub-divide into further classifications “reciprocating/cyclic” and “rotary”. The first of these relates to devices that are cycled through a water-lifting operation (for example, a bucket on a rope is lowered into the water, dipped to fill it up, lifted, emptied and then the cycle is repeated); in such cases the water output is usually intermittent, or at best pulsating rather than continuous. Rotary devices were generally developed to allow a greater throughput of water, and they also are easier to couple to engines or other mechanical drive.

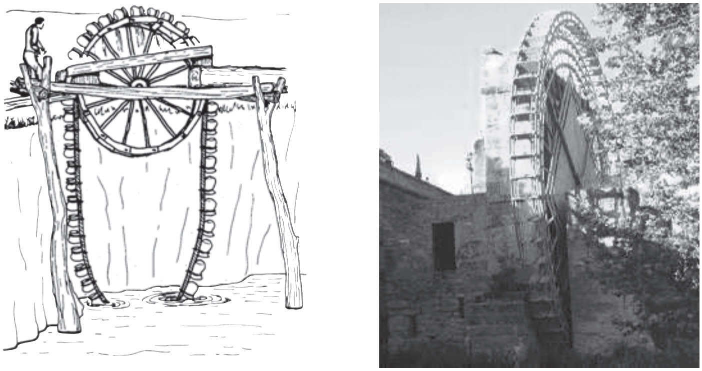
Virtually all water lifting devices can best be characterized for practical purposes by measuring their output at different heads and speeds. Normally the performance of a pump is presented on a graph of head versus flow (an H-Q graph, as in Figure 3.43) and in most cases curves can be defined for the relationship between **H** and **Q** at different speeds of operation. Invariably there is a certain head, flow and speed of operation that represents the optimum efficiency of the device, i.e. where the output is maximized in relation to the power input. Some devices and pumps are more sensitive to variations in these factors than others; i.e. some only function well close to a certain design condition of speed, flow and head, while others can tolerate a wide range of operating conditions with little loss of efficiency. For example, the centrifugal pump characteristic given in Figure 3.42 shows an optimum efficiency exceeding 80 percent is only possible for speeds of about 2000 rpm.

FIGURE 3.43 - Typical curves showing relationship between head, flow, speed, and efficiency (example for a centrifugal pump).



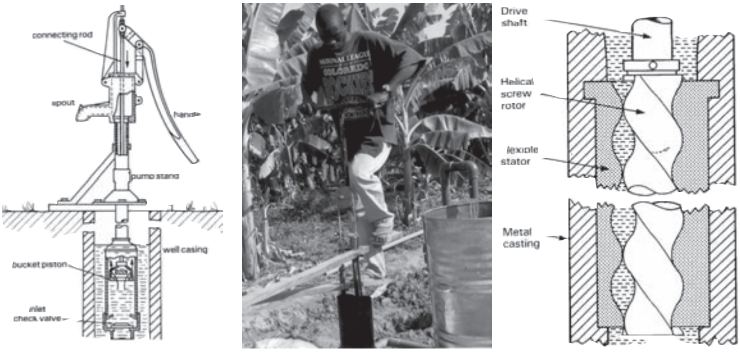
Direct-lift devices. These are all variations on the theme of the bucket and are the earliest artificial method for lifting and carrying water. It generally improves both efficiency and hence productivity if the water lifting element can move on a steady circular path. An obvious improvement to the simple rope and bucket is to fit numerous small buckets around the periphery of an endless belt to form a continuos bucket elevator. The original version of this, which is ancient in origin but still widely used, was known as a “Persian wheel”. The water powered Noria, a water wheel with pots, is similar in principle (Figure 3.44).

FIGURE 3.44 - Scheme of a Persian wheel and photograph of a Noria.



Displacement pumps. The most common and well-known form of reciprocating/cyclic are the piston-type pumps and of rotary/continuous are the Archimedean screw-types. In the piston pump, water is sucked into the cylinder through a check valve on the up-stroke, and the piston valve is held closed by the weight of water above it; simultaneously, the water above the piston is propelled out of the pump. On the down-stroke, the lower check valve is held closed by both its weight and water pressure, while the similar valve in the piston is forced open as the traped water is displaced through the piston ready for the next up-stroke. The rotary positive displacement pumps have their origins among the Archimedean screw. Modern concepts have appeared such as the progressive cavity pump (also called “mono” pump), yet they all have a number of similarities. The principle is that water is picked up by the submerged end of the helix each time it dips below the surface and, as it rotates, a pool of water gets trapped in the enclosed space between the casing and the lower part of each turn. The progressive cavity (mono) pump is ready to fit in down boreholes and it is of great advantage because positive displacement pumps can cope much more effectively than centrifugal pumps with variations in pumping head. Therefore, any situation where the water level may change significantly with the seasons makes the progressive cavity pump an attractive option (Figure 3.45).

FIGURE 3.45 - Left: Scheme of a hand pump with single acting bucket piston (piston valve shown open as on the down-stroke, and inlet valve is closed). Center: A peadle piston-type pump. Right: Scheme of a progressive cavity or "mono" pump.



Velocity pumps. Their mechanism is based on the principle that when water is propelled to a high speed, the momentum can be used either to create a flow or to create a pressure. The reciprocating/cyclic ones are rarely used while the rotary/continuous ones are highly widespread. The latter are called rotodynamic pumps and their mechanism is based on propelling water using a spinning impeller or rotor.

Since any single rotodynamic pump is quite limited in its operating conditions, manufacturers produce a range of pumps, usually incorporating many components, to cover a wider range of heads and lows. Where high flows at low heads are required (which is common in irrigation pumps), the most efficient impeller is an axial-flow one (this is similar to a propeller in a pipe). Conversely, for high heads and low flows a centrifugal (radial-flow) impeller is needed (Figure 3.46).

Where a higher head is needed than can be achieved with a single pump, two pumps can be connected in series. Similarly, if a greater discharge is needed, two centrifugal pumps may be connected in parallel (Figure 3.47).

FIGURE 3.46 - Rotodynamic pumps: (a) radial or centrifugal pump and (b) axial pump.

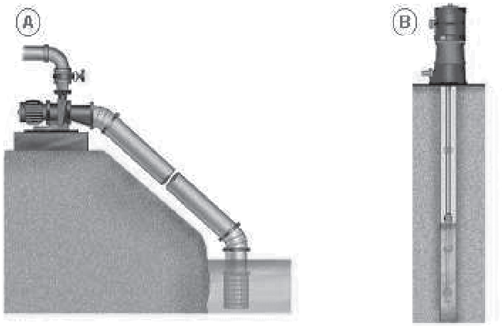
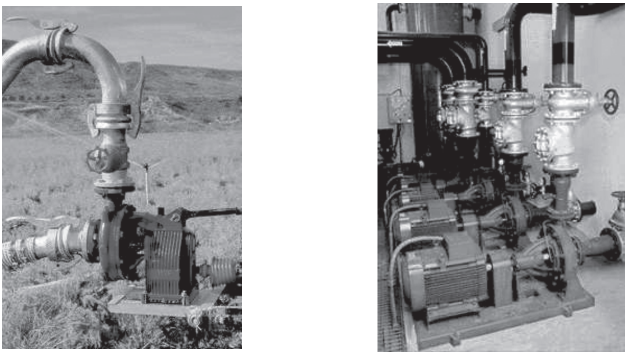
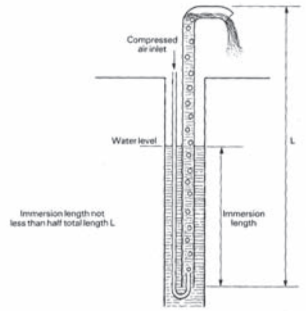


FIGURE 3.47 - Left: a rotodynamic pump powered by a tractor. Right: a pumping unit with rotodynamic pumps in parallel.



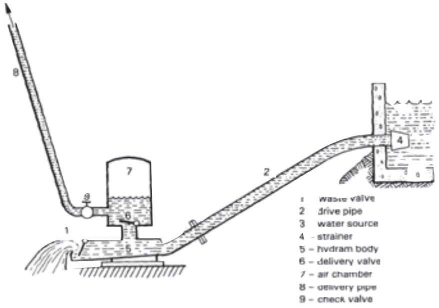
Air-lift pumps. A rising main, which is submerged in a well so that more of it is below the water level than above it, has compressed air blown into it at its lowest point. The compressed air produces a froth of air and water, which has a lower density than water and consequently rises to the surface. The compressed air is usually produced by an engine driven air compressor (Figure 3.48). The main advantage of the air-lift pump is that there are no mechanical below-ground components to wear out, so it is essentially simple, reliable, virtually maintenance-free and can easily handle sandy or gritty water. The disadvantages are rather severe: first it is inefficient as a pump, probably no better than 20-30 percent in terms of compressed air energy to hydraulic output energy and this is this is compounded by the fact that air compressors are also general inefficient. Second, it usually requires a borehole to be drilled considerably deeper (more than twice the depth of the static water level) than otherwise would be necessary.

FIGURE 3.48 - Scheme of an air-lift pump.



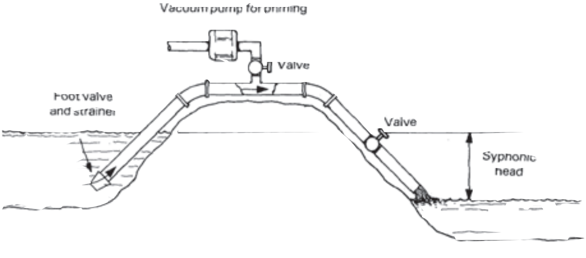
Impulse (water hammer) pumps. These devices apply the energy of falling water to lift a fraction of the flow to a higher level than the source. The principle they work by is to let the water from the source flow down a pipe and then to create sudden pressure rises by intermittently letting a valve in the pipe slam shut. This causes a “water hammer” effect which results in a sudden sharp rise in water pressure sufficient to carry a small proportion of the supply to a considerably higher level. They therefore are applicable mainly in hilly regions in situations where there is a stream or river flowing quite steeply down a valley floor, and areas that could be irrigated which are above that level that can be commanded by small channels contoured to provide a gravity supply. A practical example of this pump is the hydraulic ram pump or “hydram” (Figure 3.49). The main virtue of the hydram is that it has no substantial moving parts, and is therefore mechanically extremely simple, which results in very high reliability, minimal maintenance requirements and a long operational life. However, in most cases the output is rather small (in the region of 1–3 litre/sec) and they are therefore best suited for irrigating small-holdings.

FIGURE 3.49 - Schematic diagram of hydram installation.



Gravity devices. Syphons are the most common device of this type, though strictly speaking they they are not water-lifting devices, since, after flowing through a syphon, water finishes at a lower level than it started. However syphons can lift water over obstructions at a higher level than the source and they are therefore potentially useful in irrigation (Figure 3.50). Syphons are limited to lifts about 5 m at sea level for exactly the same reasons related to suction lifts for pumps. The main problem with syphons is that due to the low pressure at the uppermost point, air can come out of solution and form a bubble, which initially causes an obstruction and reduces the flow of water, and which can grow sufficiently to form an airlock which stops the flow. Therefore, the syphon pipe, which is entirely at a subatmospheric pressure, must be completely air-tight.

FIGURE 3.50 - A syphon arrangement.



Calculation of the power requirements (P)?

The power requirements are calculated as:

$$P(HP) = \frac{Q(l/s) \times Ht(m)}{75 \times e1 \times e2}$$

and

$$P(kw) = \frac{Q(l/s) \times Ht(m)}{102 \times e1 \times e2}$$

where:
Ht is the total head;
e1 is the pump efficiency (fraction in the order of 0.5–0.8); and
e2 is the driving efficiency (fraction of 0.7–0.9 for electric motors and 0.5–0.75 for diesel engines).

The total head (Ht) required for the normal operation of the system is the sum of the following pressures (Figure 3.51):

FIGURE 3.51 - Ht is the total head, Ha is the elevation head, Hi is the emitter operation head and Hp is the friction losses head (sum of friction losses in the main line, submains, manifolds, laterals, valves, pipe fittings and minor losses).