Technical brief

WaterAid

Handpumps

Part of a series of WaterAid technology briefs.

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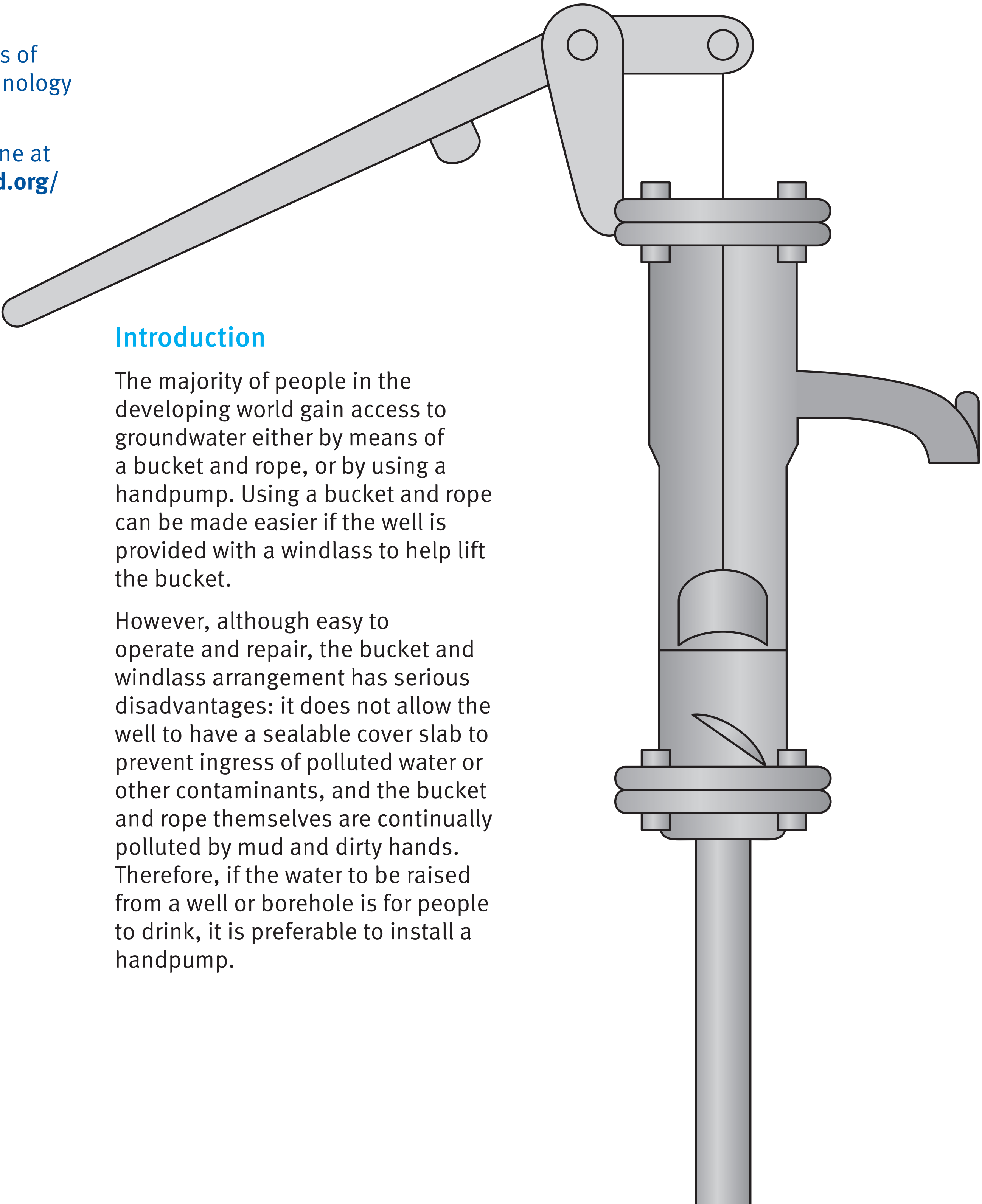


Introduction

The majority of people in the developing world gain access to groundwater either by means of a bucket and rope, or by using a handpump. Using a bucket and rope can be made easier if the well is provided with a windlass to help lift the bucket.

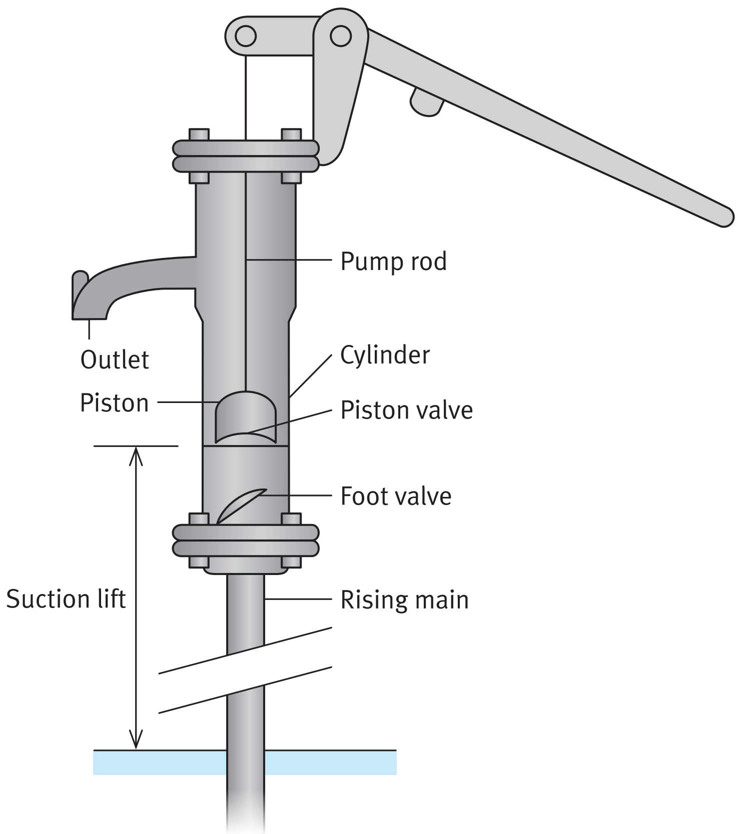
However, although easy to operate and repair, the bucket and windlass arrangement has serious disadvantages: it does not allow the well to have a sealable cover slab to prevent ingress of polluted water or other contaminants, and the bucket and rope themselves are continually polluted by mud and dirty hands. Therefore, if the water to be raised from a well or borehole is for people to drink, it is preferable to install a handpump.

Main principle of handpumps

There are many different types of handpump. However, most of them are positive displacement pumps and have reciprocating pistons or plungers. In a piston pump, the piston is fitted with a non-return valve (the piston valve) and slides vertically up and down within a cylinder that is also fitted with a non-return valve (the foot valve). Raising and lowering the handle of the pump causes vertical movement of pump rods that are connected to the piston. When the piston moves upwards, the piston valve closes and a vacuum is created below it, causing water to be drawn into the cylinder through the foot valve, which opens. Simultaneously, water above the piston, held up by the closed piston valve, is displaced upwards. In a simple suction pump it emerges through the delivery outlet; in a pump with a submerged cylinder it is forced up the rising main.

When the piston moves downwards, the foot valve closes, preventing backflow, and the piston valve opens, allowing the piston to move down through the water in the cylinder.

Fig 1: Typical handpump design



Range of lift

The ranges over which water can be lifted are grouped in the following categories:

Low lift pumps	0-15 metres
Suction pumps	0-7 metres
Direct action pumps	0-15 metres
Intermediate lift pumps	0-25 metres
High lift pumps	0-45 metres or more

Low lift pumps

These operate in the range 0-15 metres. With lifts above seven metres, the cylinder and piston have to be located down the well or borehole, and preferably below water level in order to provide a positive suction head.

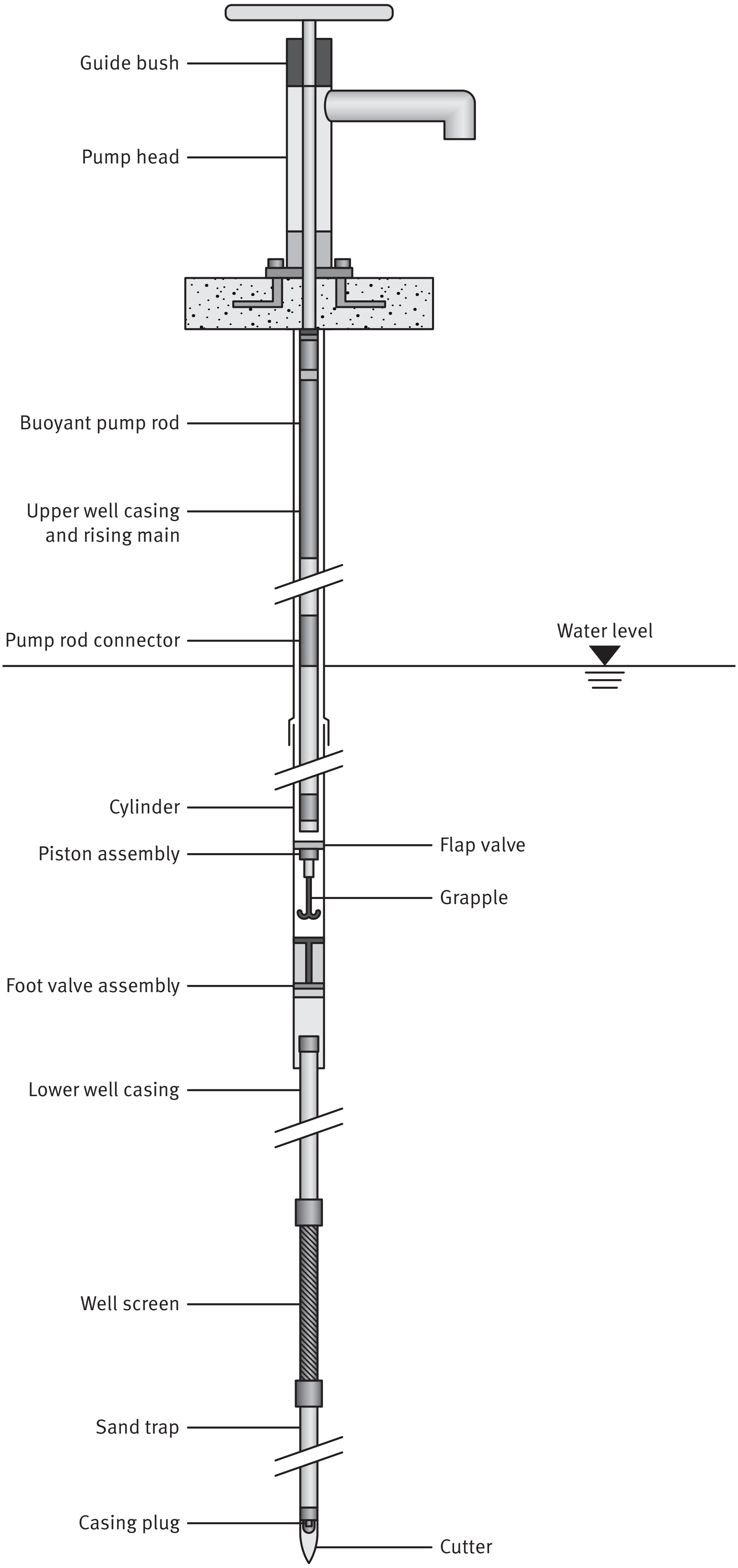
Suction pumps

For a shallow well, the cylinder and piston operate by suction to create a suction lift and can be housed in the pump stand above ground. In practice, the maximum suction lift is about seven metres.

Suction pumps can only operate when the rising main contains water, and therefore it is necessary to pour water down the pump head before using it for the first time (or after repairs). This is called ‘priming’ the pump. It is important that clean water is used for priming, so that it does not contaminate the pump.

Suction pumps have a limited range of application but are the most common type of handpump used in the world, mainly because they are relatively cheap, easy to use and maintain.

Fig 2: Tara handpump model

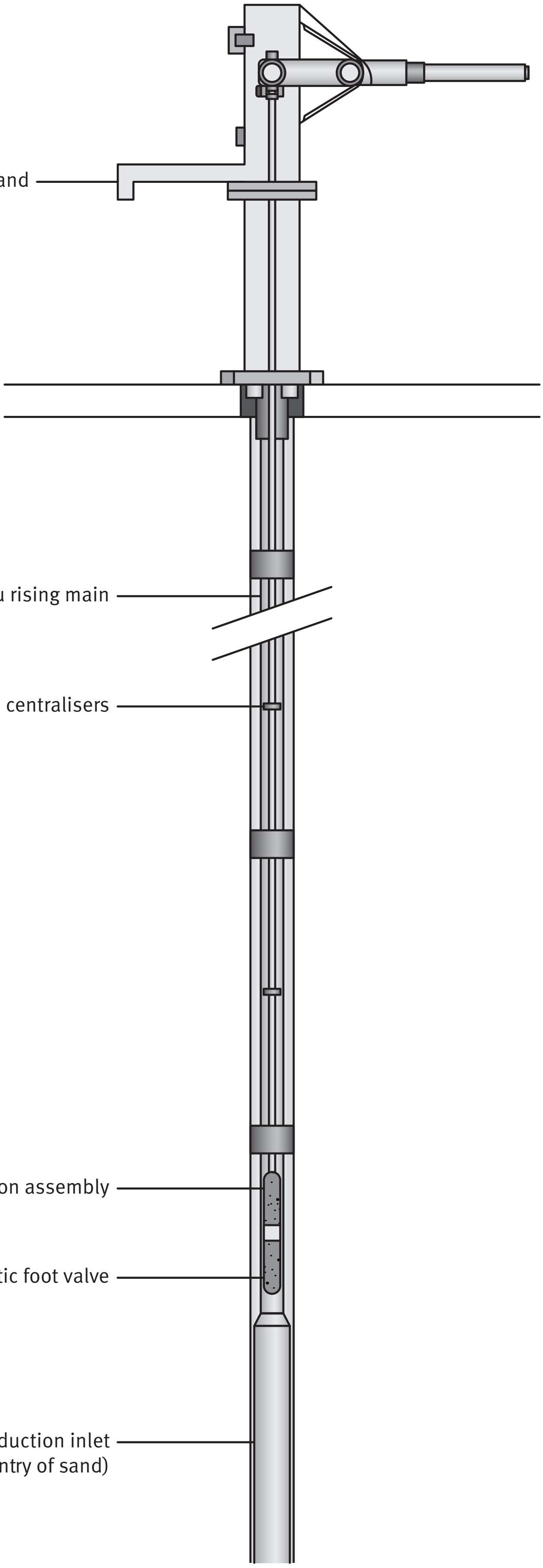


Direct action pumps

Direct action pumps operate without the help of leverage, linkages and bearings, and depend on the strength of the operator pumping to lift the column of water. Some designs, such as the Tara model make this easier by using a plastic pipe filled with air as the pump rod, the buoyancy of which helps the upstroke operation. Other designs use very small diameter cylinders and rising mains to pump smaller quantities from greater depths.

In general, direct action pumps, being simple in action, are cheaper to buy and operate than high lift handpumps.

Fig 3: High lift Afridev handpump



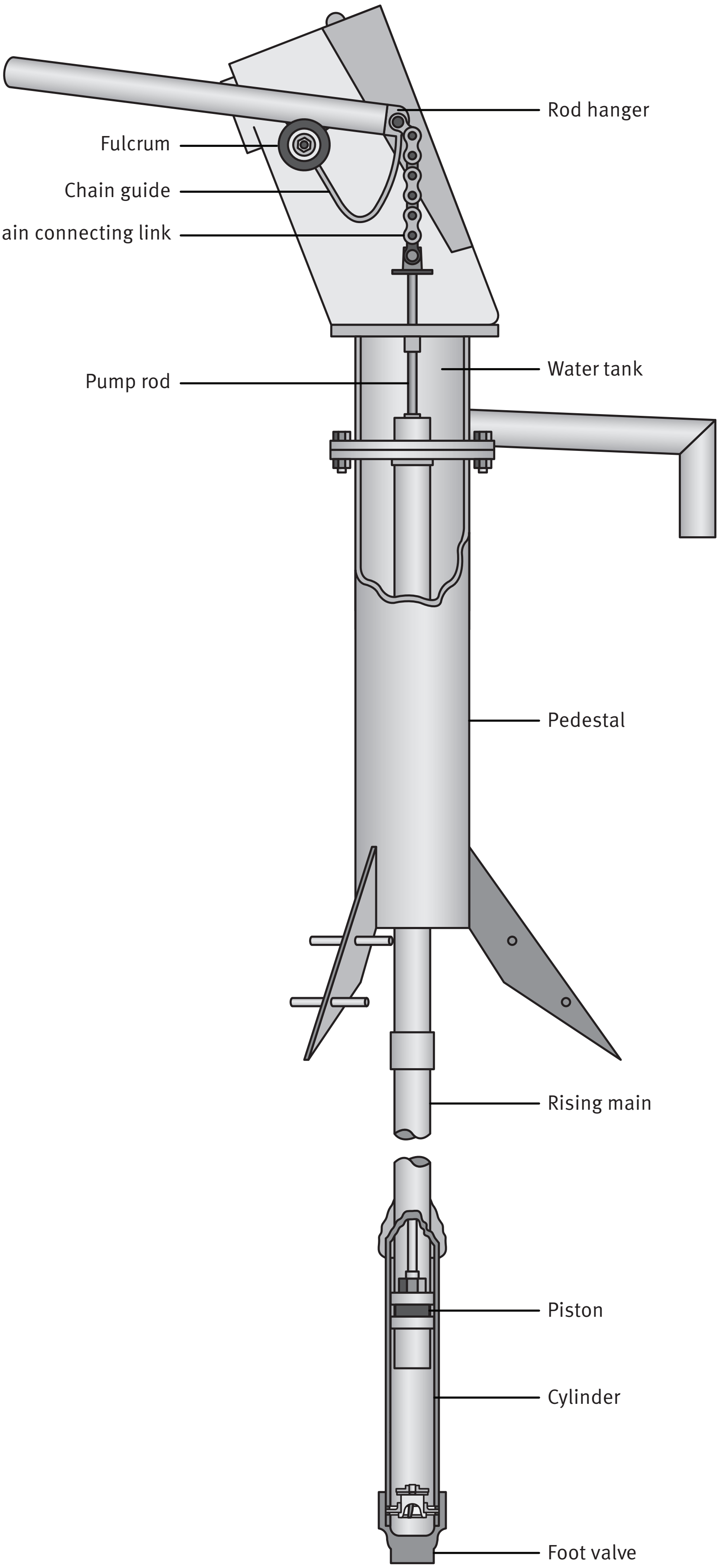
Intermediate and high lift (deep well) handpumps

An intermediate lift pump operates in the range of 0-25 metres and a high lift pump in the range of 0-45 metres. Some of the high lift handpumps can operate at lifts of 60 metres or more, albeit with reduced output of water. Intermediate and high lift piston handpumps are designed so as to reduce, by means of cranks or levers, the physical effort required when pumping. They have to be more robust and are provided with bearings and components capable of handling the larger stresses imparted by the pumping efforts required. The high lift Afridev and India Mark II are good examples of these.

High lift Afridev handpump

The high lift Afridev, shown in Figure 3, is a conventional lever action piston pump, with an 'open top' cylinder design, allowing the pump rods, piston and foot valve to be removed for maintenance without lifting out the riser main pipes. It is designed to lift water from a depth no greater than 45 metres. Thanks to the successful design and the strong international partnership approach, the Afridev pump has become the second most popular community handpump in the world, after the India Mark II.

Fig 4: India MK II handpump



India MK II handpump

The India Mark II development focused on the following key aspects:

- Development of a sturdy and reliable community handpump that could work without failure for a year.
- Large-scale local production in simply-equipped workshops at low cost (less than USD 200).
- Use of materials and components available in the country.
- Reducing pumping effort to minimise the burden on women.
- Demonstrating that a better-designed handpump, standardisation and quality control could facilitate a more effective maintenance system.
- Demonstrating that a more reliable supply of potable water could reduce the incidence of water-borne and water-related diseases.

The India Mark II pump is a robust conventional lever action handpump. It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 50 metres.

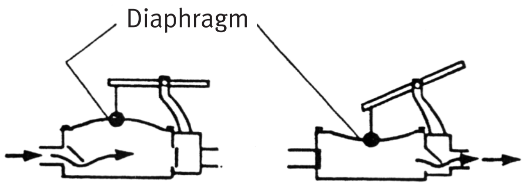
The India Mark II is a public domain pump defined by Indian Standards and RWSN specifications. It is not corrosion resistant.

Non-piston pumps

An example of a high lift pump that is not a piston pump is the Mono Progressing Cavity handpump. This has a rotating pump rod in the rubber stator within the pump cylinder, thereby producing a progressing cavity, which screws the water upwards. The meshing surfaces provide a moving seal. Although a very reliable handpump, any maintenance task that requires removal of the rods and rotor assembly requires special lifting equipment.

Diaphragm pumps

Another type of deep well handpump is the diaphragm pump.



This operates by the expansion and contraction of a flexible diaphragm within a closed system actuated by a secondary piston pump, itself activated by a foot pedal or hand lever. The primary rigid cylinder has a suction valve and a delivery check valve. On the contraction of the diaphragm, the suction valve opens to draw water into the primary cylinder and the discharge valve closes. When the diaphragm is expanded by operating the secondary system, the suction valve closes and the discharge valve opens to pump water up a flexible rising main. Although the pump is easy to maintain, replacement diaphragms are required at relatively short intervals; these are expensive and the cost is often beyond the capacity of village communities to fund repeatedly.

Examples of a diaphragm pump are the Vergnet handpump, originated in France, and the Abi-ASM, a variant made in the Ivory Coast.

Rope pump

A rope pump, shown in Figure 5, can operate in the range of 0-25 metres. They can be adapted to wider diameter hand-dug wells or boreholes. For wells up to 25 metres, they can be cheaper and more sustainable than piston handpumps. They can also produce a greater yield than reciprocating handpumps. Because of their low cost they are popular for domestic use. They were introduced in Nicaragua, though recently have been adopted in Africa, using slightly different models.

The construction of a rope pump starts by attaching the rising main to the guide block. The rising main is constructed by adding together riser pipes – if the well needs to be deepened during the dry season, the rising main can be adjusted in length by adding additional riser pipes and increasing the length of the rope with pistons.

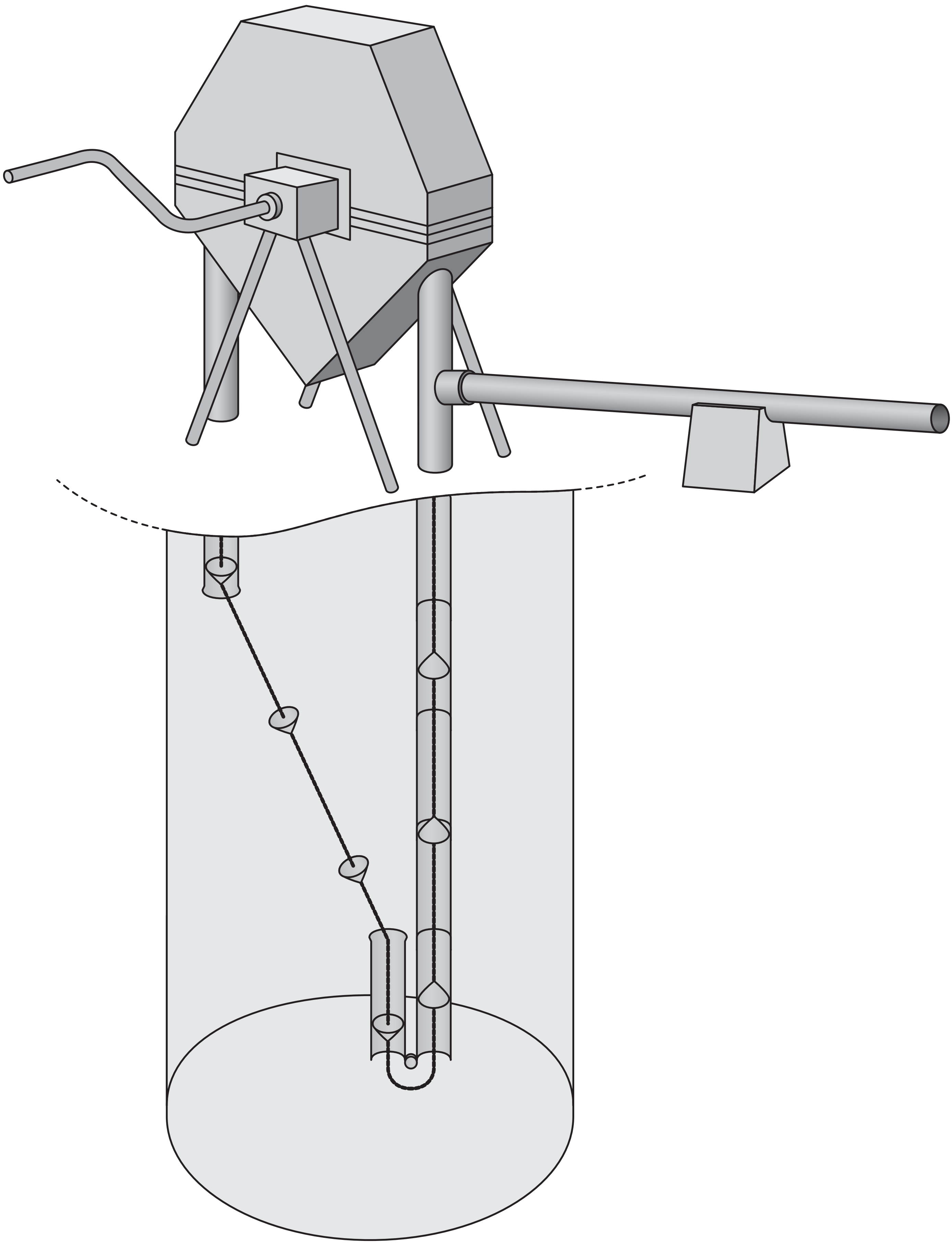
A rope knotted (or woven) with pistons (or washers) is inserted down through the rising main and guide block, looped back around and secured with a knot to create a pulley. The rising main and pulley are then fed down the well or borehole and attached to the wheel of the rope pump.

The pistons act like valves with enough tolerance to trap a column of water, so that when the wheel is turned, the pulley moves up through the rising main, bringing column after column of water to the outlet at ground level.

The VLOM concept

The term VLOM (village level operation and maintenance) was coined during the World Bank/UNDP Rural Water Supply Handpumps Project, which, from 1981-91, looked at the availability of handpump technologies and maintenance systems around

Fig 5: Assembly of rope pump in hand-dug well



the world at that time. A series of performance tests were undertaken: laboratory testing of 40 types of handpump and field performance monitoring of 2,700 handpumps. It was concluded that centralised maintenance systems were the cause of many problems and that village level maintenance was desirable, but only feasible if the design of the pump made it possible. Initially, the VLOM concept was applied to the hardware, with the aim being to develop pumps that were designed to be:

- Easily maintained by a village caretaker, requiring minimal skills and few tools
- Manufactured in-country, primarily to ensure the availability of spare parts
- Robust and reliable under field conditions
- Cost effective

Subsequently, the VLOM concept was extended into software and organisational matters. Thus the 'M' in 'VLOM' has become 'management of maintenance', for the success of a project was generally seen to be dependent on a strong emphasis on village management. Therefore, the following elements were added:

- Choice by the community of when to service pumps
- Choice by the community of who will service pumps
- Direct payment by the community to the caretakers/pump mechanics

The application of the VLOM principles, when considering pump selection, often involves compromising one principle to take advantage of another. A handpump with a low rate of breakdown might be thought preferable to another with a higher rate. However, a handpump that breaks down monthly but can be repaired in a few hours by a local caretaker is preferable to one that breaks down once a year but requires a month for repairs to be completed and needs replacement parts to be imported and skilled technicians to be available.

The Afridev handpump was developed during the course of the World Bank/ UNDP project to embody all of the VLOM design principles.

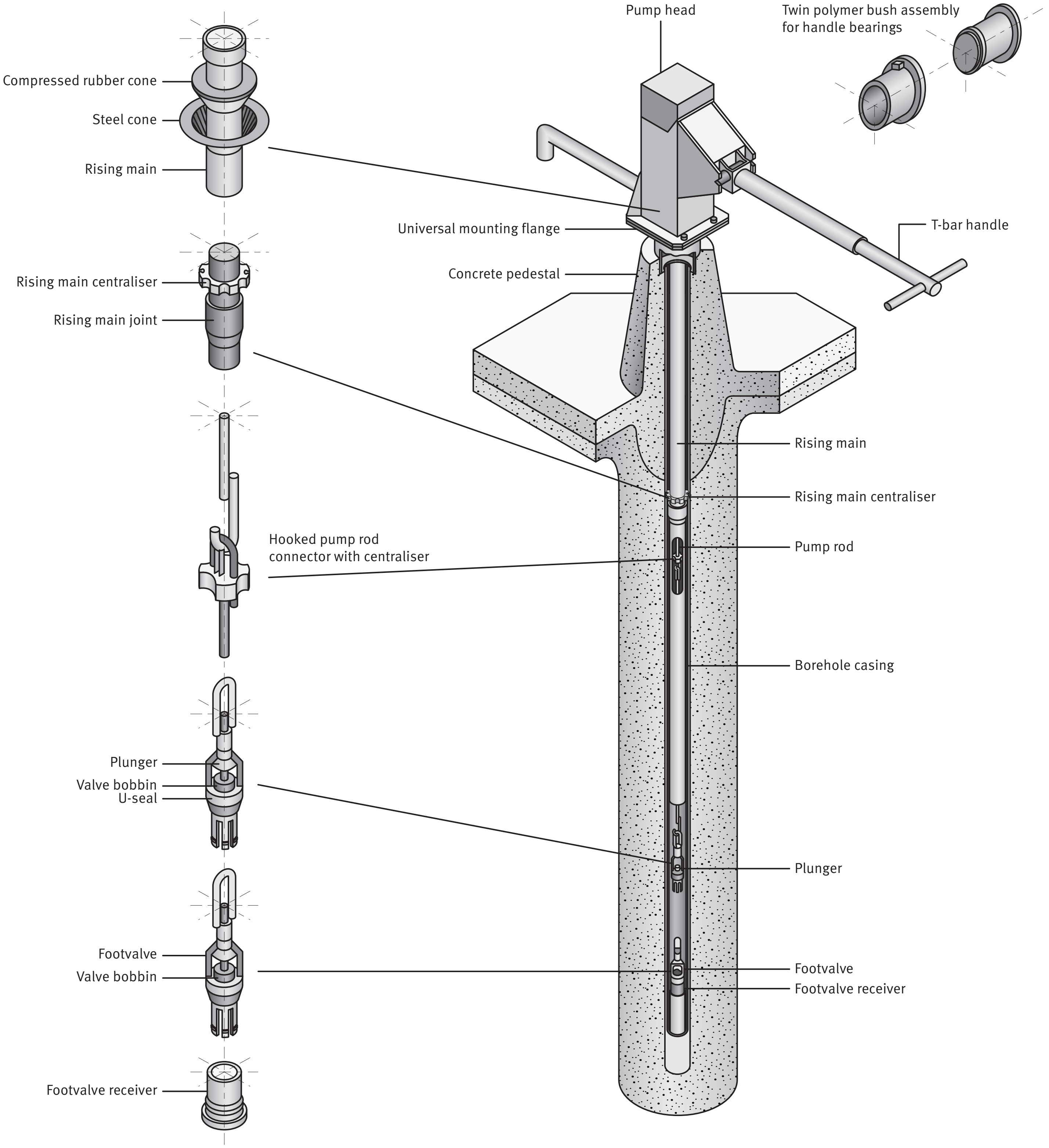
Production began in Kenya in 1985 and modifications were made after field trials in Kwale in southern Kenya. Improvements continue to be made. SKAT (Swiss Centre for Development Cooperation in Technology and Management) acts as a repository for the design drawings and specifications for the benefit of users and manufacturers of the handpumps. An exploded view of the pump is shown in Figure 6.

Choice of handpumps

The recommendations for handpumps that are proposed for use in community-based water supply projects have been set out clearly in the World Bank/UNDP Handpumps Project (see References). As well as the manufacture and performance specifications, the VLOM principles outline many attributes relating to ease of maintenance, local manufacture, robustness, standardisation, low capital cost and operating costs, availability of spares, and community management and maintenance.

When considering the most appropriate pump for a particular project, it is also important to take into account local preferences and government policy. Pumps and their spares should be freely available in local markets as a pre-requisite for ease of maintenance and replacement. Imported or donated pumps that are not available in the local markets are therefore considered inappropriate.

Fig 6: The Afridev handpump



Handpump performances

Typical performances of some common types of handpumps:

Name	Type	Lift range (metres)			Discharge rates (litres/min)			VLOM	Origin
Afridev	Deep well	7	25	45		22	15	Yes	Kenya, etc
Afridev	Direct action	7	15		26	22		Yes	Kenya, etc
Bucket pump	Improved bucket and rope	6	15		5	10		Yes	Zimbabwe
India MK II	Deep well	7	25	45	12	12	12	No	India, etc
India MK III	Deep well	7	25	45	50% of MK I				India, etc
Monolift	Deep well progressing cavity	25	45	60	16	16	9	No	UK, South Africa
Nira AF 76	Deep well	7	25		25	26		No	Finland
Nira AF 84	Deep well	7	25	45	23	22	21	No	Finland
Nira AF 85	Direct action	7	15		26	24		Yes	Finland
New No. 6	Suction pump	7			36				Bangladesh
Tara	Direct action	7	15		24	23		Yes	Bangladesh
Vergnet	Deep well diaphragm	7	45		24	25		No	France
	Windlass and Bucket	0	45		5	15			Universal
Rope pump	Direct lift	0	30		12	23		Yes	Nicaragua

Notes: Deep well handpumps are lever-operated reciprocating action pumps unless otherwise stated.

Case study

WaterAid Uganda and its partner, Wera Development Association (WEDA), have set up a handpump mechanics association, according to VLOM principles. Pump mechanics contribute a membership fee to the association. This income is used to pay for new tools, maintenance manuals and further training. WaterAid Uganda, through its work with district local governments, has also helped prioritise the operation and maintenance of water wells in communities by providing handpump mechanics with better access to complete tool boxes to enable them to carry out effective repairs. Consequently, handpump mechanic records show an improvement in the number of water wells functioning regularly.

Bernard Egangu, Amuria Deputy District Water Officer reports:

"Previously, it would take over a month to report and respond to water source issues. However, with training of more handpump mechanics, responses are swifter. Problems are quickly identified, reported and rectified which ensures regular access to water by the communities."

Handpump mechanics collect data for the District Water Office as they attend callouts. This allows the District Water Office to map the functionality of the pumps on a regular basis and employ the mechanics to carry out routine preventative maintenance of handpumps.

The development of the handpump association provides an appropriate technology option to ensure a sustainable supply of water to beneficiary communities.

Geoffrey Martin Okello – a handpump mechanic for the Katakwi district, Sorimon, Uganda

WaterAid/Caroline Irby

Advantages of handpumps

✓ Different handpumps can adapt to different well depths

✓ Require a cover slab which can be sealed to prevent ingress of polluted water

✓ Water discharge volumes are better than bucket and rope models

✓ Depending on the model, can be relatively cheap

✓ With regular maintenance can have life span of over ten years

✓ Efficient and easy to operate

Disadvantages of handpumps

✗ Require trained mechanics to fix even though designed according to the VLOM principle

✗ May require parts that cannot be sourced locally

✗ Moving parts can break down regularly

✗ Metallic parts can be subject to corrosion, especially in coastal areas

High lift Afridev handpump in Tanzania

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Water source options: See which water sources are used in conjunction with handpumps

	Water source	Capital cost	Running cost	Yield	Bacteriological water quality	Situation in which technology is most applicable
	Spring protection	Low or medium if piped to community	Low	High	Good if spring catchment is adequately protected	Reliable spring flow required throughout the year
	Sand dams	Low – local labour and materials used	Low	Medium/high – depending on method used to abstract water. Water can be abstracted from the sand and gravel upstream of the sand dam via a well or tubewell	Good if area upstream of dam is protected	Can be constructed across seasonal river beds on impermeable bedrock
	Sub surface dams	Low – local labour and materials used	Low	Medium/high – depending on method used to abstract water. Water can be abstracted from the sand, gravel or soil upstream of the sub-surface dam via a well or tubewell	Good if area upstream of dam is protected	Can be constructed in sediments across seasonal river beds on impermeable bedrock
	Infiltration galleries	Low – a basic infiltration gallery can be constructed using local labour and materials	Low	Medium/high – depending on method used to abstract water	Good if filtration medium is well maintained	Should be constructed next to lake or river
	Rainwater harvesting	Low – low cost materials can be used to build storage tanks and catchment surfaces	Low	Medium – dependent on size of collection surface and frequency of rainfall	Good if collection surfaces are kept clean and storage containers are well maintained	In areas where there are one or two wet seasons per year
	Hand-dug well capped with a rope pump	Low	Medium – spare parts required for pump	Medium	Good if rope and pump mechanisms are sealed and protected from dust. Area around well must be protected	Where the water table is not lower than six metres – although certain rope pumps can lift water from depths of up to 40 metres
	Hand-dug well capped with a hand pump	Medium	Medium – spare parts required for pump	Medium	Good if area around well is protected	Where the water table is not lower than six metres
	Tube well or borehole capped with a hand pump	Medium – well drilling equipment needed. Borehole must be lined	Medium – hand pumps need spare parts	Medium	Good if area around borehole/tubewell is protected	Where a deep aquifer must be accessed
	Gravity supply	High – pipelines and storage/flow balance tanks required	Low	High	Good if protected spring used as source	Stream or spring at higher elevation – communities served via tap stands close to the home
	Borehole capped with electrical/diesel/solar pump	High – pump and storage expensive	High – fuel or power required to run pump. Fragile solar cells need to be replaced if damaged	High	Good if source is protected	In a small town with a large enough population to pay for running costs
	Direct river/lake abstraction with treatment	High – intake must be designed and constructed	High – treatment and pumping often required. Power required for operation	High	Good following treatment	Where large urban population must be served
	Reverse osmosis	High – sophisticated plant and membranes required	High – power required for operation. Replacement membranes required	High	Good	Where large urban population must be served
	Household filters	High – certain filters can be expensive to purchase/produce	Filters can be fragile. Replacement filters can be expensive or difficult to source	Low	Good as long as regular maintainance is assured	In situations where inorganic contaminants are present in groundwater sources or protected sources are not available
	SODIS (solar disinfection)	Low – although clear bottles can be difficult to source in remote areas	Low	Low	Good	In areas where there is adequate sunlight – water needs to be filtered to remove particulate matter that may harbour pathogens before SODIS can be carried out effectively. SODIS is not appropriate for use with turbid water

= most preferable

= preferable

= least preferable

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