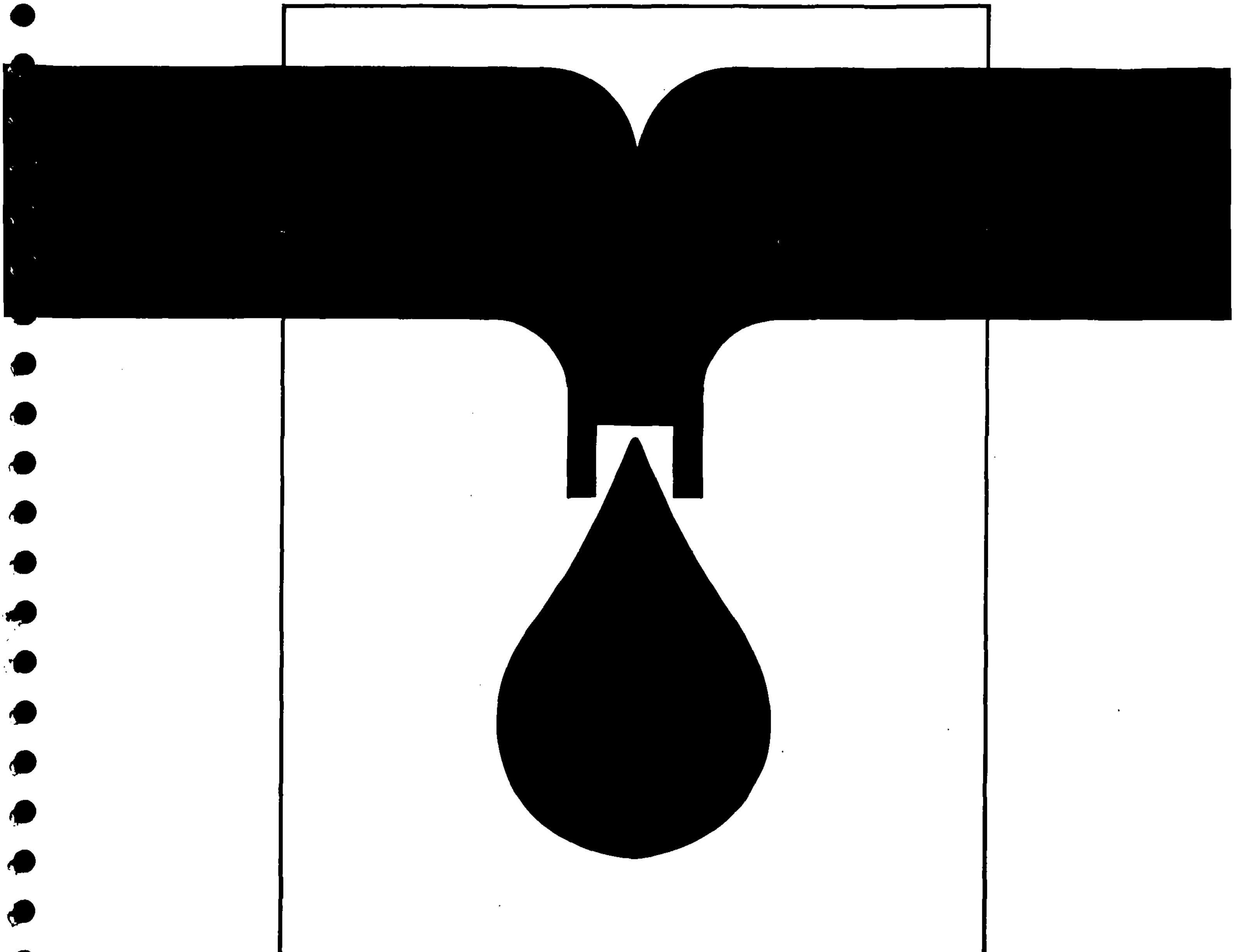
TRAINING MODULES FOR WATERWORKS PERSONNEL



Special Knowledge

2.3 c

Maintenance and repair of simple driven systems

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

Our grateful thanks are due to

Prof. Dr.-Ing. H.P. Haug
and
Ing.-Grad. H. Hack

for their committed coordination work and also to the following co-authors for preparing the modules:

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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

Dr. Ing. Klaus Erbel
Head of Division
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Eschborn, May 1987

Title: Simple drive systems

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0. Introduction

The term "simple drive systems" is used in this module to refer to drive systems which can be operated and maintained without excessive technical outlay. The following forms of energy are suitable for simple drive systems which can be used for lifting water:

- Muscle power
- Water power
- Wind power

1. Water-raising apparatus and pumps operated by muscle power

One of the oldest methods of drawing water from wells is to lift the water by means of human muscle power, using a vessel or bucket on a rope.
The addition of a block and tackle can facilitate the drawing of water for domestic purposes to a considerable extent.

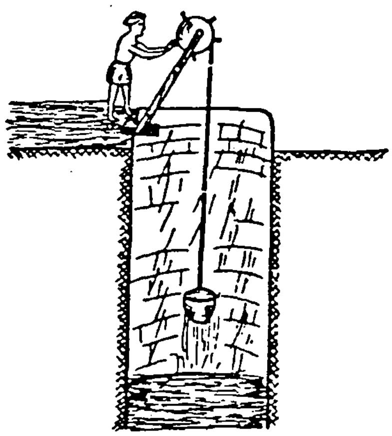


Fig. 1: Lifting water with the aid of a block and tackle

The shaduf, a simple lever device with a vessel suspended so that it can move and a counterweight, has been facilitating the raising of water by hand for many thousands of years. River water can be raised to the required level in stages via intermediate basins.

Fig. 2: Shaduf

Human muscle power is likewise used for raising water in the case of the treadwheel. The rotary motion of the wooden wheel, produced by a man walking inside the wheel, is transmitted to a roller, likewise made of wood.
Over this roller runs a belt with attached buckets, which fill with water (Fig. 3).

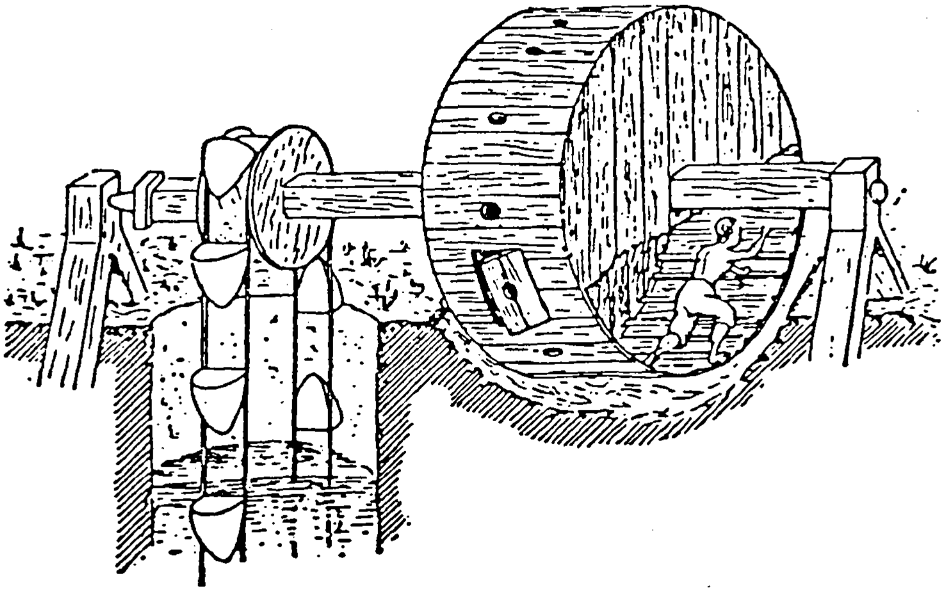


Fig. 3: Raising of water through the use of human muscle power with the aid of a wooden treadwheel.

The Archimedean screw is used to lift river water. The simplest wooden type is still used today for irrigating fields.

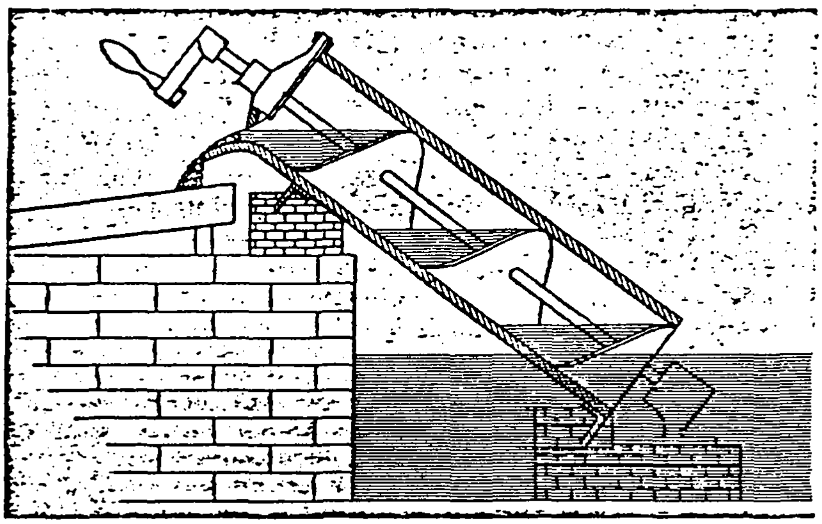


Fig. 4: Archimedean screw

A further development in the area of water-drawing devices is represented by elevators. Special mention should be made of the following three types:

a. Chain-type bucket elevator

The chain-type bucket elevator operates as follows:

Buckets are attached one after the other to an endless vertical chain (or belt). This chain passes over a toothed drum, which is generally driven by means of human muscle power and which moves the chain. The chain, with its buckets, extends below the level of the water in the well, where the buckets are filled. The full buckets are transported upwards on the chain and are then emptied into a trough or some other container.

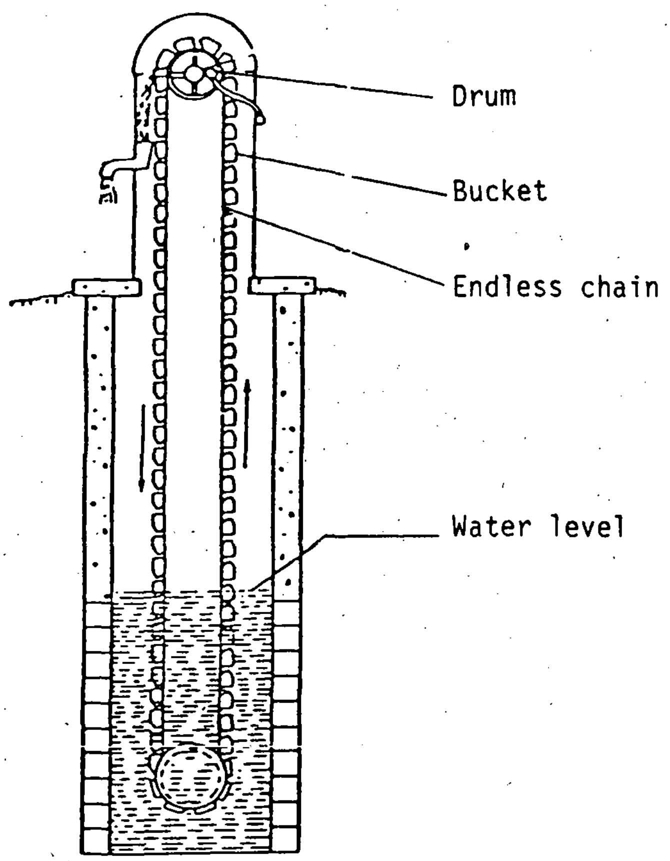


Fig. 5: Chain-type bucket elevator

b. Chain-type plug elevator

A number of rubber, hemp or wooden plugs are secured to an endless chain. This chain is moved upwards through a metal or wooden tube (in a similar manner to the chain-type bucket elevator). The lower end of the tube extends into the water.

As the plugs precisely fit in the tube, water is retained between them and transported to the top, where it is emptied into a trough or similar container.

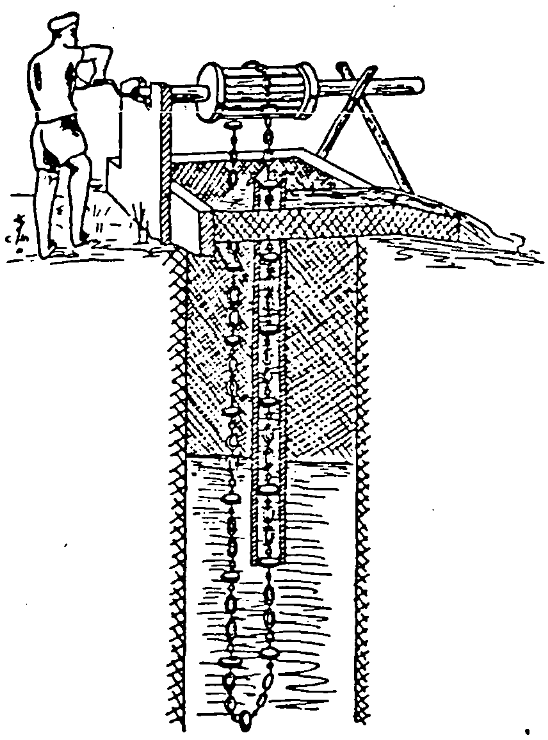


Fig. 6: Chain-type plug elevator

c. Water lift

Water lifts may be constructed in various ways. In principle, they consist of an endlessly folded metal strip. The strip is folded such that it forms a large number of horizontal containers or cells, all of which are open on one side. The water is retained in these cells while the strip is moved upwards by means of a drum. As soon as the strip is guided around the drum, the water drains out of the cells and flows into a collecting vessel.

The water lift is likewise generally operated by human muscle power.

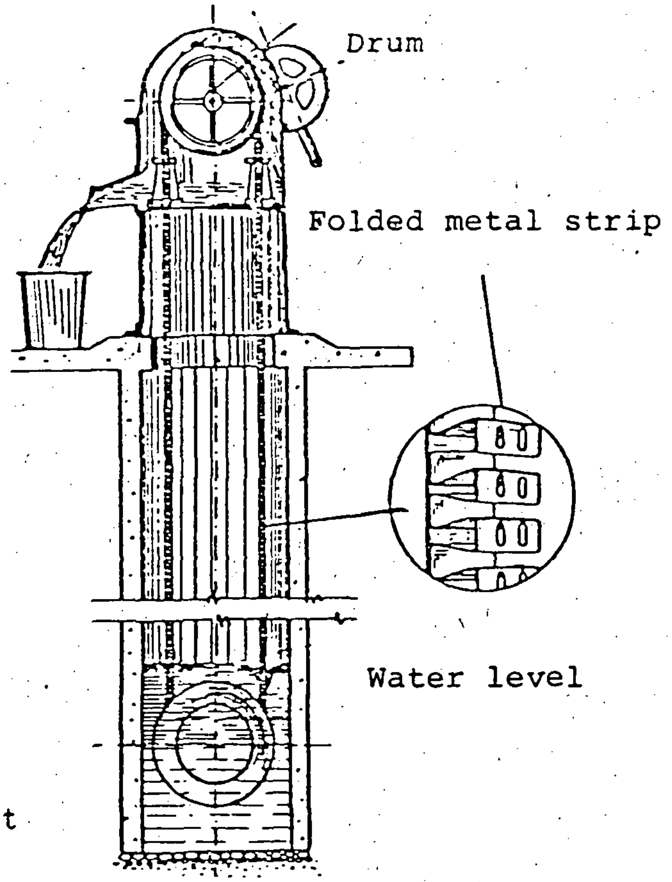


Fig. 7: Water lift

Animal muscle power can likewise be used for water-raising apparatus (capstan). This is done by means of transmission, i.e. the rotation in the horizontal plane is transmitted to the vertical one. The animals (donkeys, cattle etc.) are tied to a horizontal wheel, which they then turn. Power transmission is effected by a simple gear mechanism made of metal or possibly wood. Use of a crossed belt drive is also possible. If animal muscle power is used, care must be taken to ensure that the drinking water is not contaminated by faecal matter.

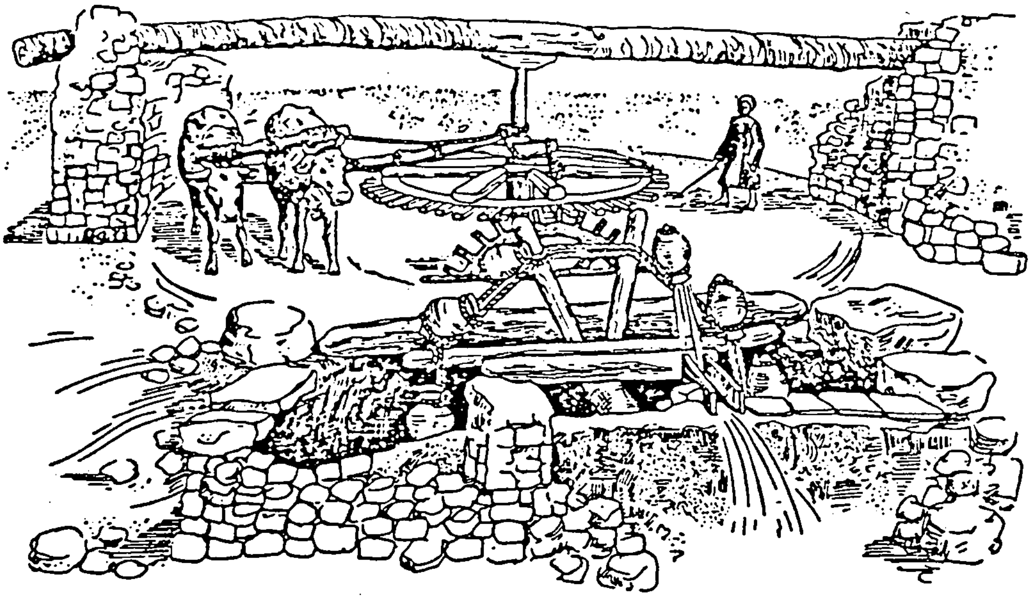


Fig. 8: Wheel-type water-raising apparatus

In addition to the systems described above, ordinary hand pumps and foot pumps should also be mentioned. They are likewise operated by muscle power (see Module 1.1).

2. Water power as a means of driving water-raising apparatus and pumps

Where water power is used to operate water-raising apparatus or a pump, a distinction can be made between two types of use:

a) Direct, i.e. water power is utilized directly as mechanical energy.

b) Indirect, i.e. the water power is converted by a generator into electrical energy, which then drives an electric motor.

2.1 Direct utilization of water power

The flow-operated noria is probably the oldest type of waterwheel. Before it was invented, there were only wheels operated by muscle power, to which pitchers were attached. The waterwheel is made of wood and the vessels of clay or metal.

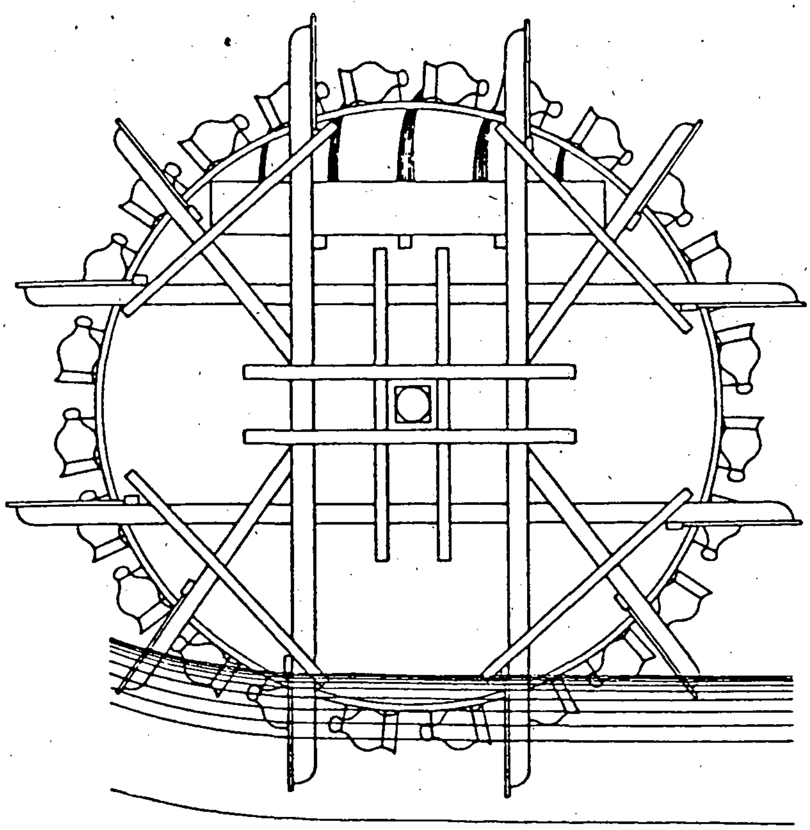


Fig. 9: Flow-operated noria

The bucket chain with undershot paddle wheel represents a further development of the noria. The torque of the paddle wheel (a) is transmitted via a chain (b) to a shaft (c) with a triangular drum (d). When the drum revolves, the water-filled containers are transported upwards and empty their contents into the pipe (e).

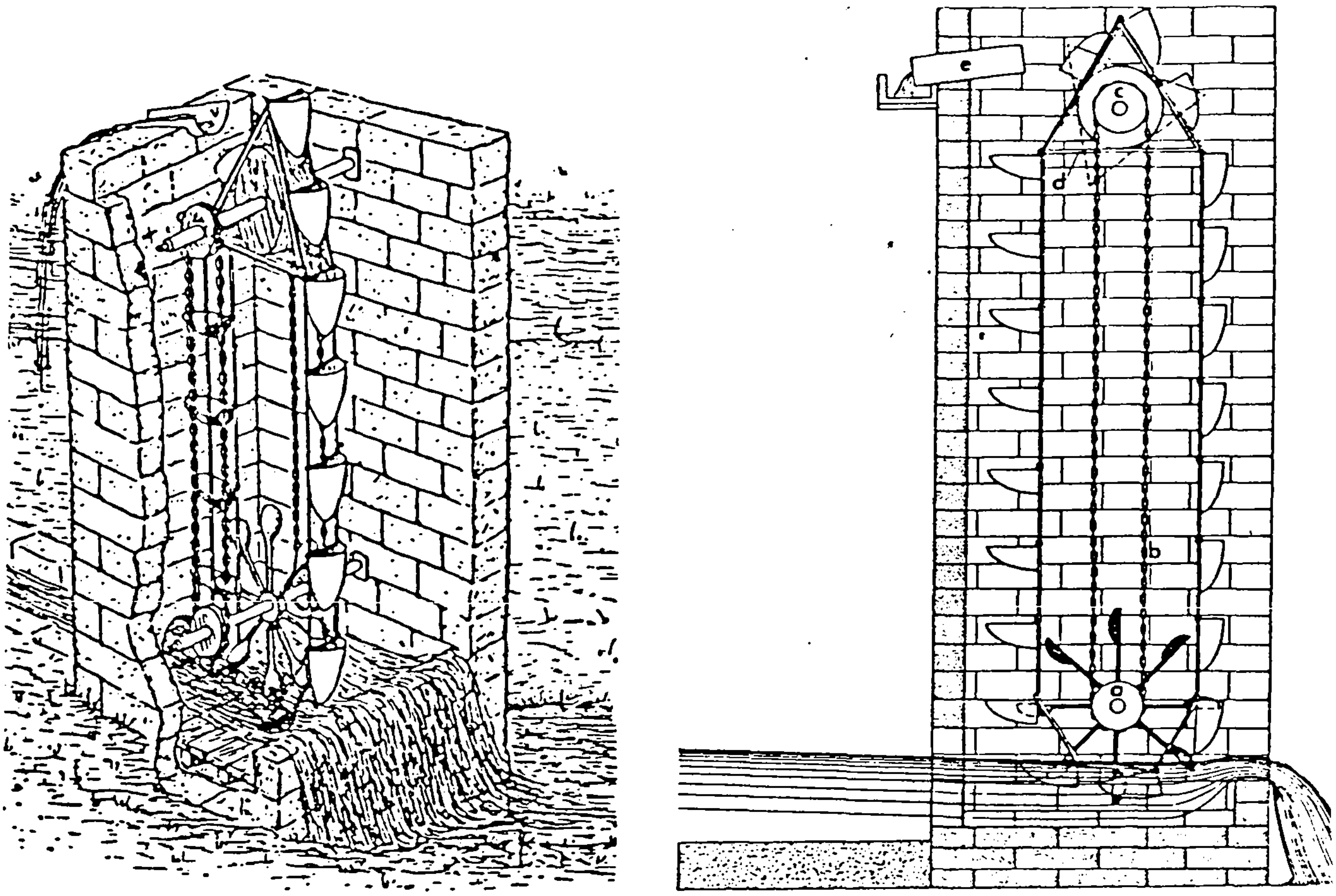


Fig. 10: Bucket chain driven by undershot paddle wheel

The waterwheel is the oldest form of water power machine; its formerly varied and often individual use is reflected in a large number of types of waterwheel and modes of operation.

The waterwheel can be subdivided into two basic types - paddle wheel and bucket wheel - depending on the shape of the blades. The bucket wheel has regularly arranged water-holding buckets designed as cells. The paddle wheel generally has straight, or at most slightly curved, blades without sides. Depending on the way in which the water flow is regulated, waterwheels are subdivided into undershot, breastshot and overshot types. Fig. 11 illustrates various types of waterwheels.

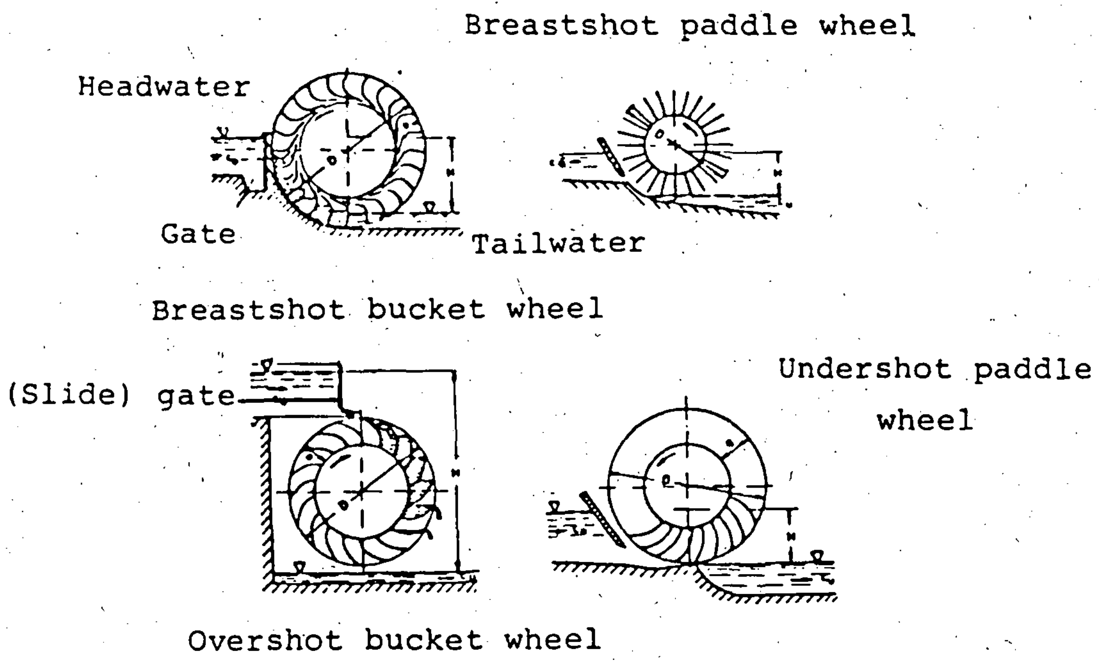


Fig. 11: Types of waterwheels

The energy generated by the waterwheel can be transmitted to a machine via an angular gear unit. The principle of such units has already been indicated in Fig. 8. The angular gear mechanism consists of a cog wheel and a lantern. If the rotary motion is transmitted only once, the system is a single-step gear mechanism, while if it is transmitted several times the unit is a multi-step-gear mechanism.

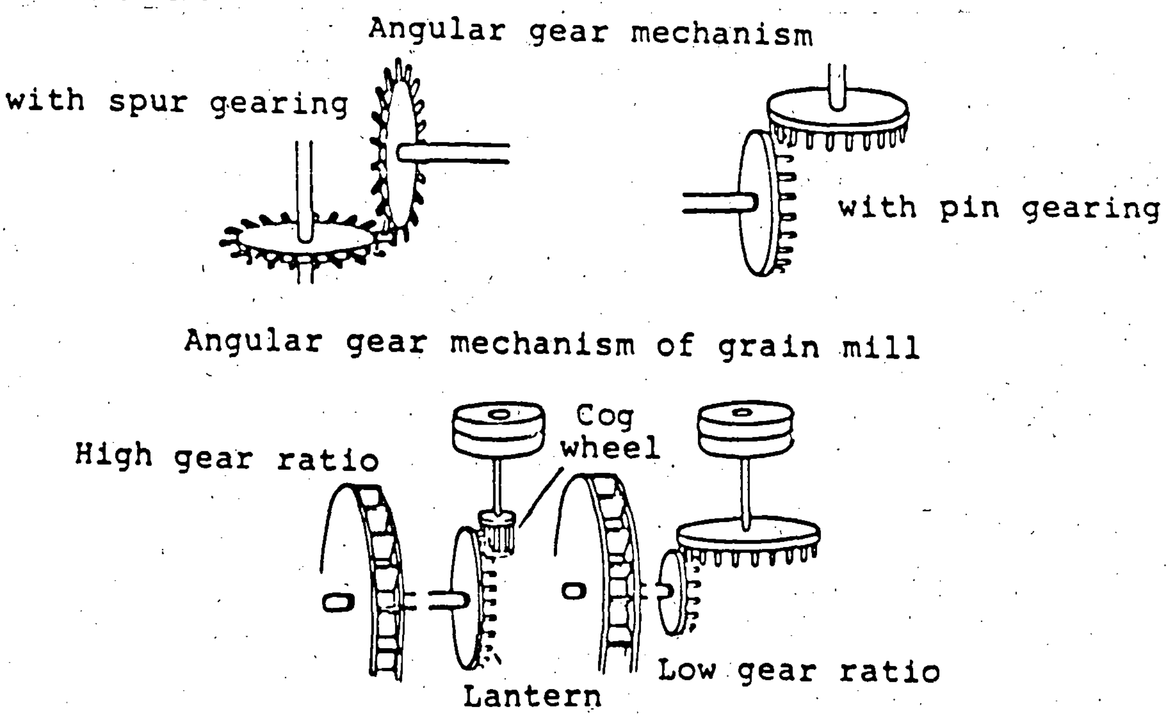


Fig. 12: Arrangement of angular gear mechanisms.

The waterwheel offers two possibilities for raising water: direct emptying of the water from the blades or buckets of the waterwheel into a channel or driving of a water-raising device for a well near the river bank by means of a waterwheel and an angular gear unit.

Another means of directly utilizing water is the hydraulic ram. This is a pump which is driven by water power.

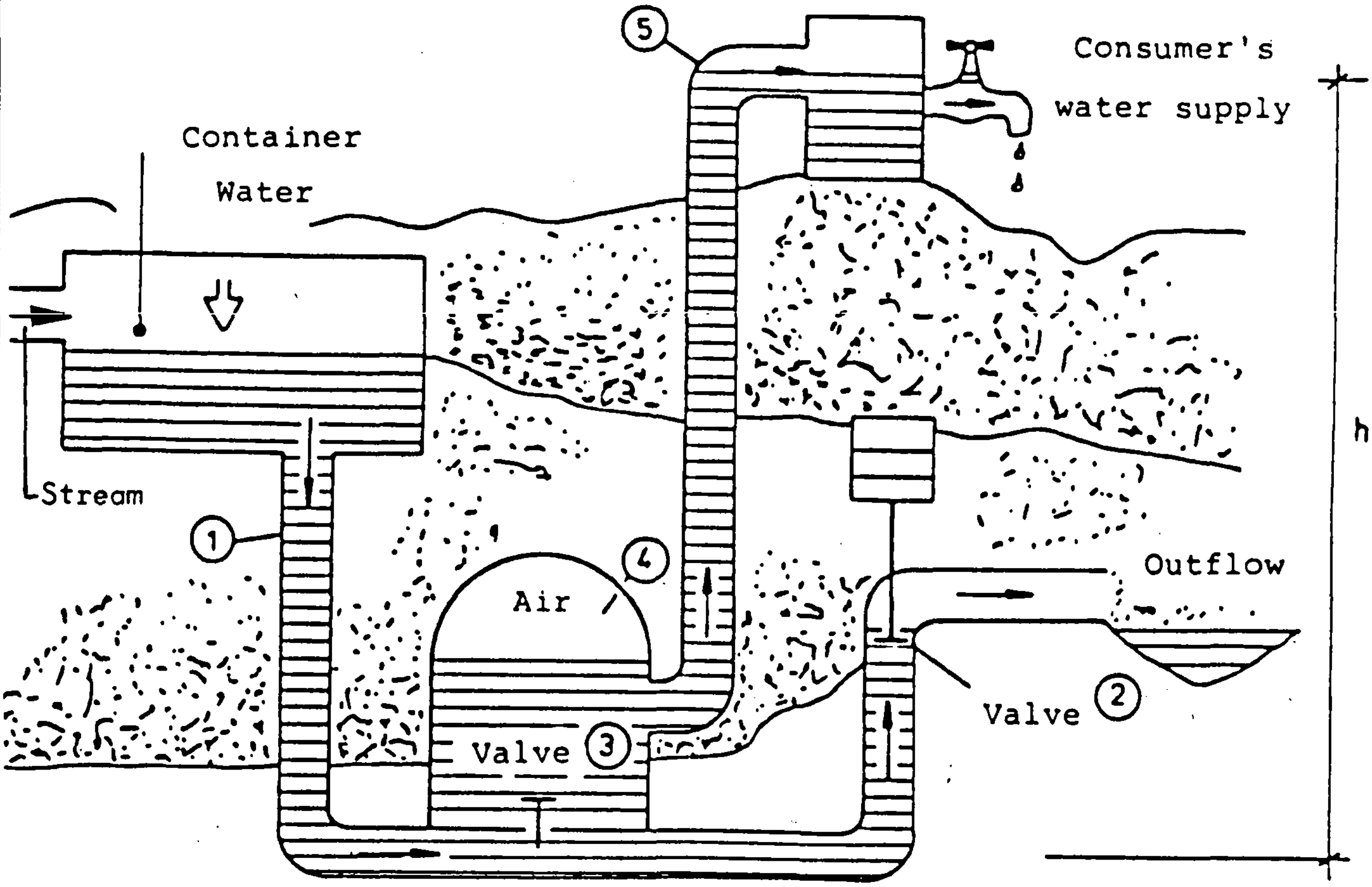


Fig. 13: Hydraulic ram

In order for a hydraulic ram to be operated, the available quantity of water must be far greater than the amount required and the terrain must be suitable.

The water flows from its container into a pipe (1) where, as the flow velocity increases, it
closes a relief valve (2). This creates a backflow, which opens another valve (3) in the supply line.

The water flows through this line into an air-filled pressure vessel (4) and compresses the air. The pressure on the relief valve is simultaneously reduced; the valve opens again on account of its own weight and allows water to pass through. The pressure in the supply pipe (1) is now equal to that in the pressure vessel (4). The valve (3) between them closes. The compressed air forces the water which has accumulated in the pressure vessel upwards through a second pipe (5).

At the same time, the pressure on the relief valve increases again and the valve closes. The whole process starts again from the beginning.

The head (h) should not be greater than 15 - 20 metres, otherwise several rams must be arranged in stages.

Provided that the conditions for its operation are fulfilled, the hydraulic ram is particularly suitable for small water-supply facilities on account of its low purchase and operating costs and its ease of maintenance.

2.2 Indirect utilization of water power by waterwheels

Instead of utilizing the drive power directly as mechanical energy, the waterwheel is connected to a generator and the drive energy converted into electrical energy. Waterwheels are a viable proposition only in the case of power outputs up to 20 kW; turbines are used for higher outputs.

DC generators are generally used with waterwheels, since within a specific range they deliver a constant voltage even if the speed fluctuates.

3. Wind power as a means of driving scoop wheels and pumps

The kinetic energy of the wind can be used in water supply systems to raise water. The wide range of variation in the available wind power, however, can cause problems. Systems which can still be operated at high wind velocities and are so strongly built that they can withstand even violent storms without damage generally have a fairly high starting velocity. Systems which are to have a low starting velocity, however, must be of a light-weight design and are therefore usually susceptible to high wind velocities.

An upper limit for the utilizable wind velocities is not easy to specify. The design of the system (storm security, pitch changing) plays a decisive role in this respect.

Wind velocities as low as 2 m/s can be used for pumping water, and velocities from 4 m/s upwards for generating electricity.

3.1 Wind power as a means of driving scoop wheels

Fig. 14 shows a schematic diagram of a wind-powered water scoop wheel. The rotary motion generated by the blades of the wind wheel is transmitted to the scoop wheel by means of an angular gear mechanism.

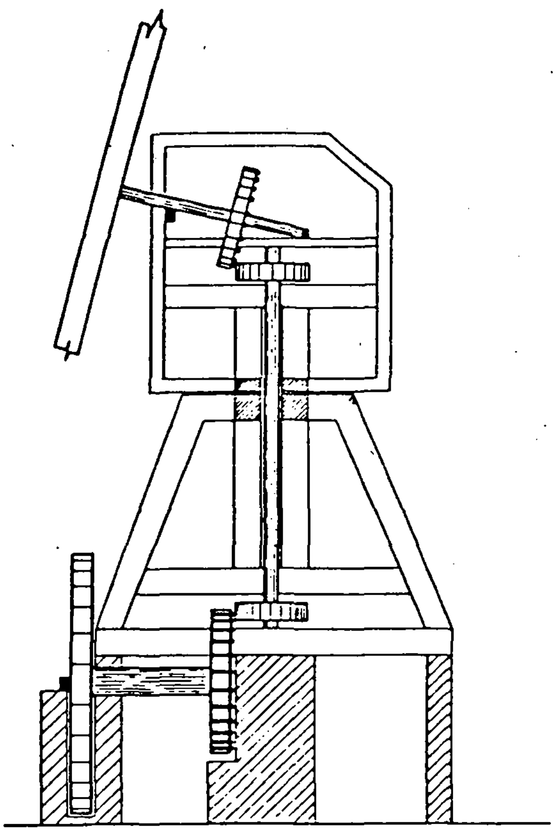


Fig. 14: Wind-powered water scoop wheel

A slow-running wind wheel can also drive an Archimedean screw (see Fig. 4).
This configuration is suitable for raising surface water (it does not adjust automatically to the wind direction, but must be directed according to the prevailing wind).

3.2 Wind power as a means of driving pumps

Wind wheels can be used in conjunction with reciprocating pumps, diaphragm pumps and centrifugal pumps for raising water.

The advantages and disadvantages of the individual types of pump are as follows:

Type of pump	Advantages	Disadvantages
Reciprocating pump	Low speeds sufficient, highly suitable for slow-running wind wheels with considerable torque, large delivery heads possible, principle of reciprocating pump simple and easy to understand.	Difficult to ensure optimum matching of reciprocating pump to wind energy converter, service life of pump dependent on water quality.
Diaphragm pump	Large discharge volume per stroke, self-priming given air-filled suction line, easy for users to manufacture.	As for reciprocating pump.
Centrifugal pump	Direct drive possible given adequate speed, little space required, little outlay on operation and maintenance, even flow delivered, highly suitable for large discharge volumes, inexpensive.	Manufacture by users impossible, drop in speed involves major efficiency losses, suction line must be filled with water if system located above water level, since partial vacuum too small for air suction.

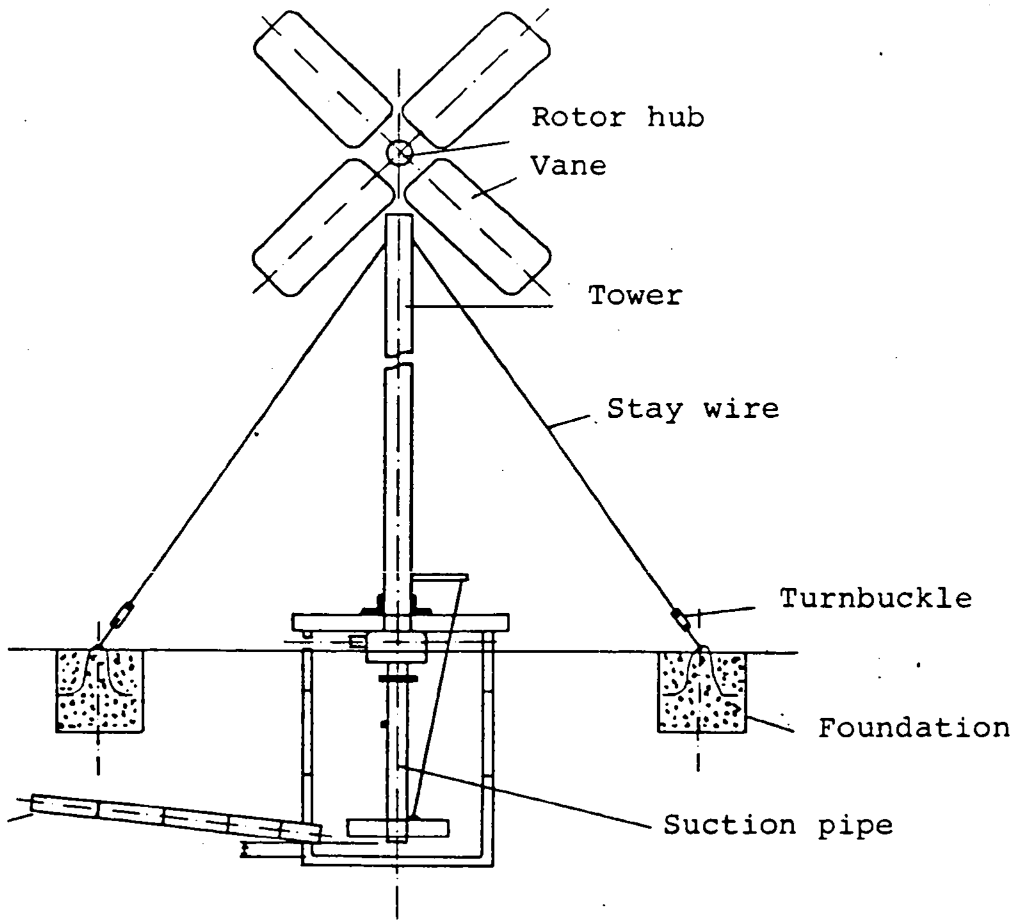


Fig. 15: Wind pump, front view

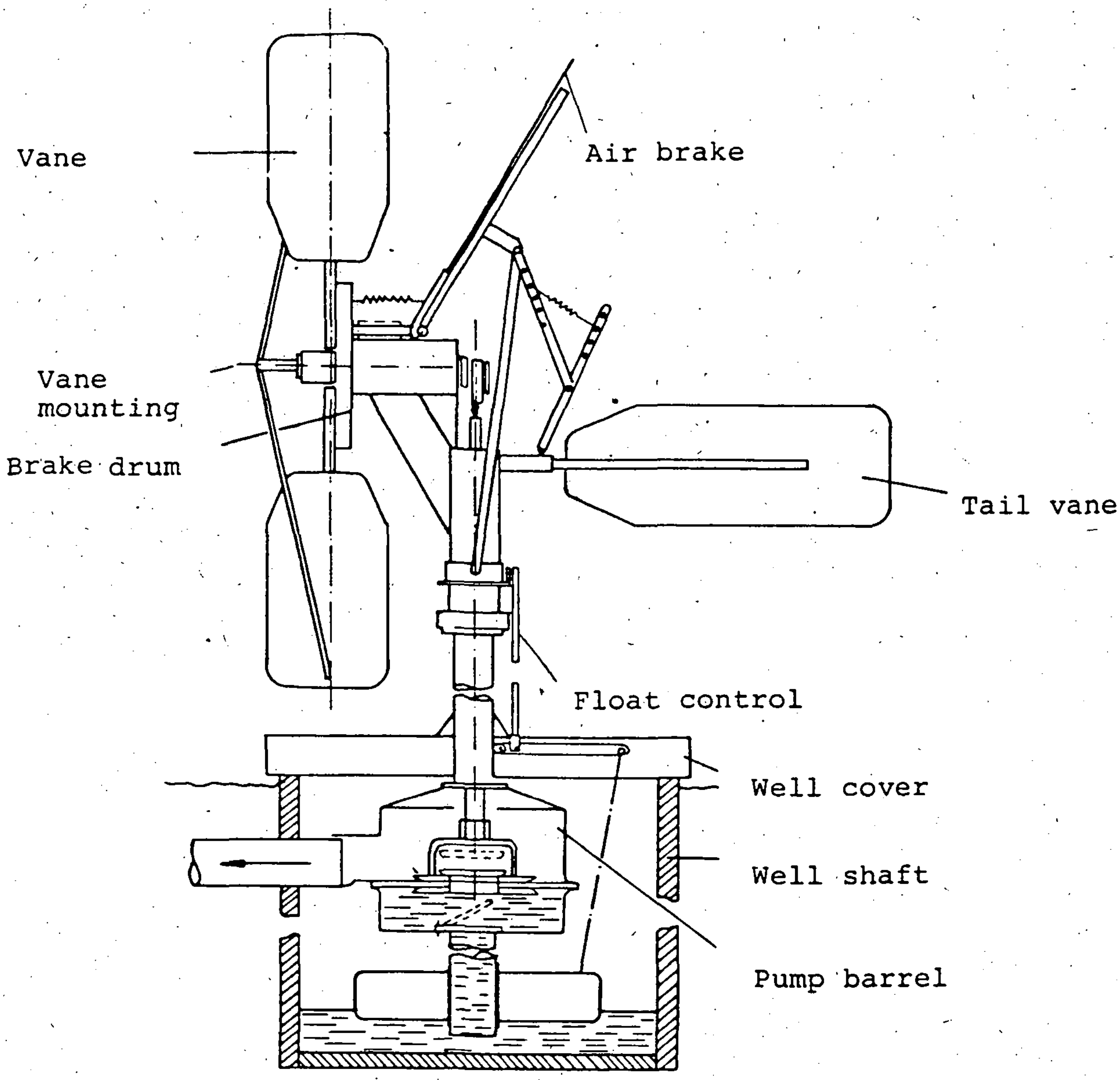


Fig. 16: Sectional view of wind pump

Fig. 15 and 16 show an example of a wind pump. The water is lifted by means of a diaphragm pump. The way in which this wind pump operates can be described as follows:

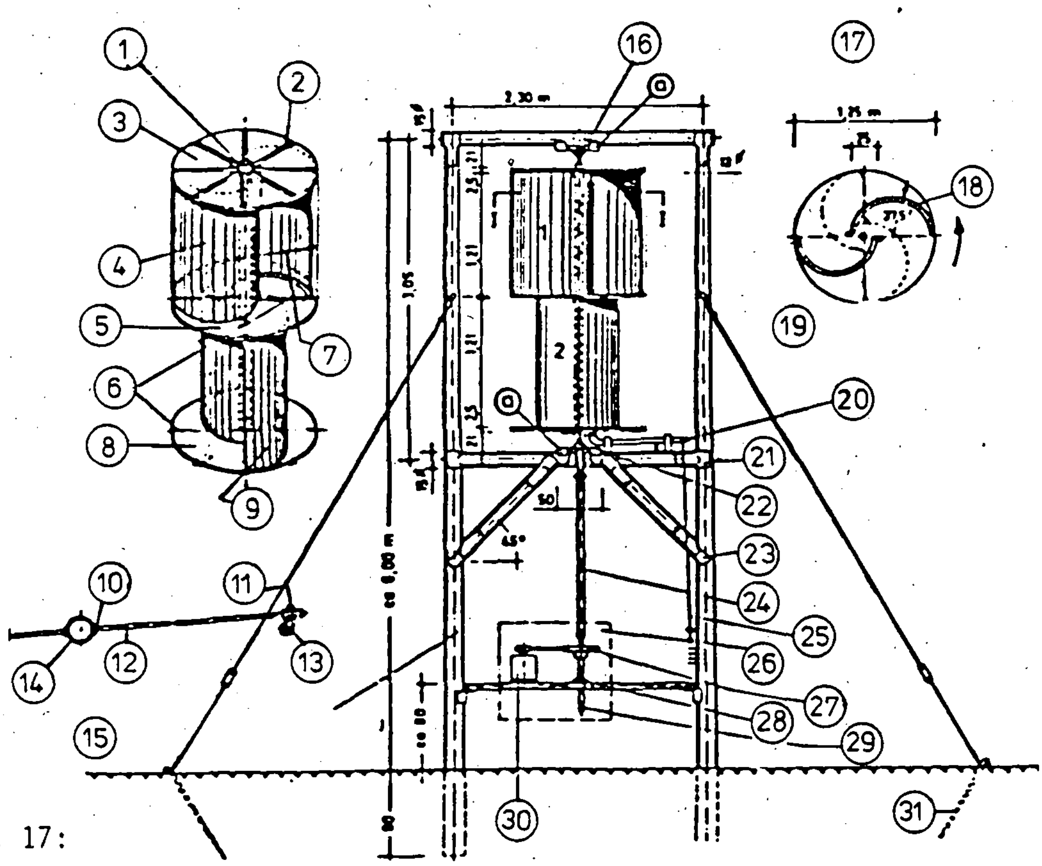
Four fixed vanes drive the pump rod via a crankshaft; the pump rod actuates the diaphragm and two large flap valves through the pump standpipe at the bottom of the pump barrel. This lifting motion causes the water to be drawn in by the suction pipe and delivered via the discharge port in the pump barrel. The delivery is determined by the wind velocities in the locality in question. Once a specific wind velocity is attained, the air brake (storm security) actuates a disc brake by means of the wind pressure via a linkage and thus automatically brakes the vanes.

3.3 Conversion of wind energy into mechanical or electrical energy

With the aid of rotors, wind energy can either be utilized directly as mechanical energy via a gear mechanism or a transmission-type wind energy converter, or converted into electrical energy by a generator.

Fig. 17

Windmill



Legend Fig. 17:

1 = Continuous shaft, pipe 51 dia. x 3.2 DIN 2458
2 = Spokes for reinforcement (roller blind U-sections, sharp-edged, 24x15x2 mm)
3 = Upper disc Plywood AW 100, 10 mm thick (1 mm galvanized steel sheet/ 2 mm polyester sheet)
4 = Stage 1
5 = Centre disc
6 = Spokes
7 = Clampbar to prevent buckling
8 = Lower disc
9 = Stage 21, Offset 90° with respect to stage 1
10 = Welded
11 = Vane
12 = Clamp 8 dia.
13 = Shackle
14 = Continuous shaft
15 = Round timber poles, impregnated by roller printing, mean dia. 15 cm
16 = Upper bearing, shaft dia. 30 mm
17 = Section I-I
18 = Vanes (blades), galvanized steel sheet 0.8 mm
19 = Rotor, counterclockwise rotation
20 = Lever for locking brake
21 = Round timber connector, T-piece, 90°, 13 - 17 dia.
22 = Centre bearing, shaft dia. 30 mm
23 = Round timber connector, T-piece, 45°, 13 - 17 dia.
24 = Main shaft, pipe 38 dia. x 3.6 DIN 2458
25 = Brake cable, can be locked in position
26 = Safety grille
27 = V-belt pulley
28 = Lower bearing, shaft dia. 30 mm
29 = Free shaft end for equipment connection
30 = Generator, pump or compressor
31 = Ground anchor 80 cm long, T-section 50 x 50 x 5
32 = (Drawing: Weihenstephan Agricultural Engineering)

Revised:

4. Bibliography

The literature used in Module 2.3c is listed below.

a. Flemming	Weltmacht Wasser Musterschmidt Verlag Göttingen
b. Franckh'sche Verlags- handlung, Stuttgart	Fachwörterbuch für Be- und Ent- wässerung
c. Gate	Special Energy Programme: Wind Energy
d. Giesecke, J.; Neumayer, H; Ruppert, J.	Untersuchung des hydraulischen An- triebs einer Mühle, Wasserwirtschaft 72 (1982) 7/8
e. Pahl, W.	Hobby-Magazin der Technik No. 23, 1982
f. Saunders, R.J.; Warford, J.H.	Village Water Supply, World Bank Publication
g. Schoeder	Reiseführer Sudan
h. Smith, N.	Mensch und Wasser Udo Pfriemer Verlag, Munich
i. Sölter, W.	Die Essener Wasserhämmer Rheinland Verlag GmbH, Cologne
j. Strandh, S.	Die Maschine Herder Verlag, Freiburg
k. Thomas Rotarius-Verlag, Cölbe	Dauerhafte Energiequellen
l. Wagner-Lanoix	Water Supply for Rural Areas
m. WHO International Reference Centre for Community Water Supply	Hand Pump for use in drinking water supplies in developing countries Technical paper 10, July 1977

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TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

0.1 Basic and applied arithmetic
0.2 Basic concepts of physics
0.3 Basic concepts of water chemistry
0.4 Basic principles of water transport
1.1 The function and technical composition of a watersupply system
1.2 Organisation and administration of waterworks

Special Knowledge

2.1 Engineering, building and auxiliary materials
2.2 Hygienic standards of drinking water
2.3a Maintenance and repair of diesel engines and petrol engines
2.3b Maintenance and repair of electric motors
2.3c Maintenance and repair of simple driven systems
2.3d Design, functioning, operation, maintenance and repair of power transmission mechanisms
2.3e Maintenance and repair of pumps
2.3f Maintenance and repair of blowers and compressors
2.3g Design, functioning, operation, maintenance and repair of pipe fittings
2.3h Design, functioning, operation, maintenance and repair of hoisting gear
2.3i Maintenance and repair of electrical motor controls and protective equipment
2.4 Process control and instrumentation
2.5 Principal components of water-treatment systems (definition and description)
2.6 Pipe laying procedures and testing of water mains
2.7 General operation of water main systems
2.8 Construction of water supply units
2.9 Maintenance of water supply units Principles and general procedures
2.10 Industrial safety and accident prevention
2.11 Simple surveying and technical drawing

Special Skills

3.1 Basic skills in workshop technology
3.2 Performance of simple water analysis
3.3a Design and working principles of diesel engines and petrol engines
3.3b Design and working principles of electric motors
3.3c –
3.3d Design and working principle of power transmission mechanisms
3.3e Installation, operation, maintenance and repair of pumps
3.3f Handling, maintenance and repair of blowers and compressors
3.3g Handling, maintenance and repair of pipe fittings
3.3h Handling, maintenance and repair of hoisting gear
3.3i Servicing and maintaining electrical equipment
3.4 Servicing and maintaining process controls and instrumentation
3.5 Water-treatment systems: construction and operation of principal components: Part I - Part II
3.6 Pipe-laying procedures and testing of water mains
3.7 Inspection, maintenance and repair of water mains
3.8a Construction in concrete and masonry
3.8b Installation of appurtenances
3.9 Maintenance of water supply units Inspection and action guide
3.10 –
3.11 Simple surveying and drawing work

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