



Working Group on Development Techniques
University of Twente

The WOT-field

*A test-site for small scale
sustainable energy applications*



Working Group On Development Techniques
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The WOT-field

The WOT-field: A test-site for small scale sustainable energy applications
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Table of contents

1. INTRODUCTION.....	5
MAP OF THE WOT-FIELD.....	6
2. SOLAR ENERGY APPLICATIONS.....	8
2.1 COOKING WITH SOLAR ENERGY	9
2.1.1 <i>The cooking box</i>	10
2.1.2 <i>The parabolic cooker</i>	11
2.1.3 <i>The haybox</i>	12
2.2 SOLAR WATER HEATING.....	13
2.2.1 <i>The solar shower</i>	16
2.2.2 <i>The Deuss-system</i>	17
2.3 OTHER APPLICATIONS OF SOLAR ENERGY	18
2.3.1 <i>The Kiwanda</i>	18
2.3.2 <i>PV cells for electricity generation</i>	19
2.3.3 <i>The solar dryer</i>	20
3. HAND-PUMPS.....	22
3.1 THE WOODEN HAND PUMP.....	24
3.2 THE STEEL HAND-PUMP, TANZANIA MODEL.....	24
3.3 THE FARM PUMP.....	25
3.4 THE ROPEPUMP	25
3.5 THE INJECTION MOULDING MACHINE	27
4. HYDRAULIC RAMS	29
4.1 THE BILLABONG	30
4.2 THE BREURRAM.....	31
5. WINDMILLS.....	32
5.1 WATER PUMPING WINDMILLS	33
5.1.1 <i>The Diever</i>	34
5.1.2 <i>The Cretan windmill</i>	35
5.1.3 <i>The Oasis</i>	36
5.1.4 <i>The 4-wing</i>	36
5.1.5 <i>The Kijito</i>	37
5.1.6 <i>The ferrocement watertank</i>	37
5.2 ELECTRICITY GENERATING WINDMILLS	38
5.2.1 <i>The Virya</i>	39
6. THE TEST TOWER FOR WATER PUMPS.....	40
7. THE WOT.....	41
8. USED LITERATURE.....	43

1. Introduction

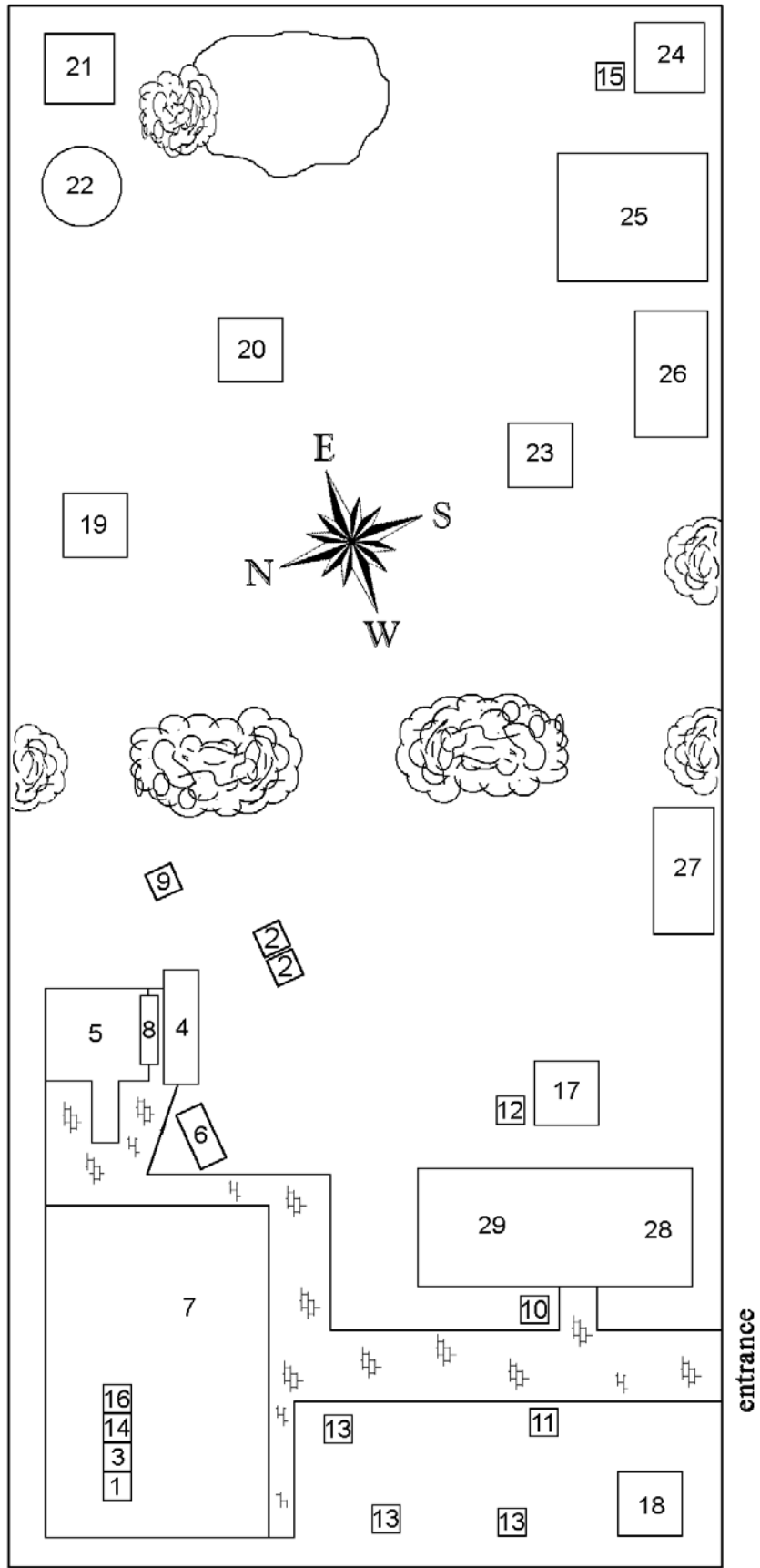
The WOT has a test and demonstration field, located at the Achterhorst on the campus of the University of Twente in the Netherlands. This booklet guides you along all the demonstration objects on the WOT-field. The objects are divided in different categories; solar energy applications, hand pumps, hydraulic rams and windmills. About every category some general information will be given before the actual objects are described. Also, something about the testing tower for waterpumps and about the WOT itself will be described at the end of the tour. A visit to the WOT-field isn't necessary to read this booklet, lots of pictures and figures are present to visualise the tour.

First of all, a map of the WOT-field is given. As you can see there, a wood gasifier is also present on the WOT-field. However, this gasifier belongs to the Biomass Technology Group and will not be discussed in this tour.

I hope this tour gives you a good impression of the WOT and its activities. For more information, you can always contact the WOT. The address is in the chapter about the WOT. Have a nice tour!

Map of the WOT-field

1. Cooking box (in workshop)
2. Parabolic cooker
3. Haybox (in workshop)
4. Collectors of the solar shower
5. Solar shower
6. Deuss-system
7. Kiwanda (workshop)
8. PV-cells
9. Solar dryer
10. Wooden handpump
11. Steel handpump
12. Farmpump
13. Hand-ropepump
14. Injection moulding machine (in workshop)
15. Billabong
16. Breurram (in workshop)
17. Cretan windmill
18. Diever
19. Oasis
20. 4-wing
21. Kijito
22. Ferrocement watertank
23. Virya
24. Test tower for water pumps
25. Wood gasifier
26. Storage container
27. Storage space
28. Library
29. Office



2. Solar energy applications

Solar energy is a form of sustainable energy, which in principle is available in large quantities. The amount of solar energy that reaches the earth annually is 20.000 times the energy used in the entire world. Techniques to use this energy are quite advanced by now, but they are used only on a small scale. This is, among other reasons, because of the high installation costs (especially for photo-voltaic systems) and the low efficiencies that can be reached.

Of course, the amount of solar energy that is available isn't constant or continuous. If there are no good energy storage facilities, solar energy can only be used as an extra energy source, and not as the main one. It is clear that solar energy can be a very useful and interesting energy source, but that there are many social-economical and technical barriers that have to be overcome first.

The WOT builds and tests different devices that use solar energy. Roughly, the WOT studies solar water heating and solar cooking. The WOT also has a limited experience in the fields of solar drying and generating electricity with the sun. On the next pages some general principles about cooking and water heating with the use of solar energy will be explained. You will also find a description of the different devices, which can be seen on the WOT-field.

2.1 Cooking with solar energy

In many developing countries, for example in the Sahel, forests are cut down rapidly, which causes desertification. The majority of the people use wood to cook. The problems that result have been researched for many years. Many people sought different kinds of solutions. Wood-saving ovens were introduced and forests planted. Some people considered solar cooking as a promising alternative. So several solar cookers were developed.

The introduction of the solar cooker met many problems, because people had paid little attention to social and cultural circumstances. The devices were hard to fit into local habits. People complained that the food tasted differently and that they were forced to cook on different times of the day than they were used to. Also, some of the first devices were dangerous to people, there was a risk of burning or blinding.

But science advances. Currently far more advanced equipment is available and in development. More attention is paid to social and cultural factors that regarding solar cooking. Especially in refugee camps, where there is a great shortage of wood and people are forced to be more willing to change their habits, solar cooking is a suitable option. Solar cookers can also be successfully used as a complementary way of cooking. For example, rice is prepared in the solar cooker, while meat is prepared on a traditional wood fire. Of course, good instruction and education is important when solar cookers are introduced. This didn't always happen in the past.

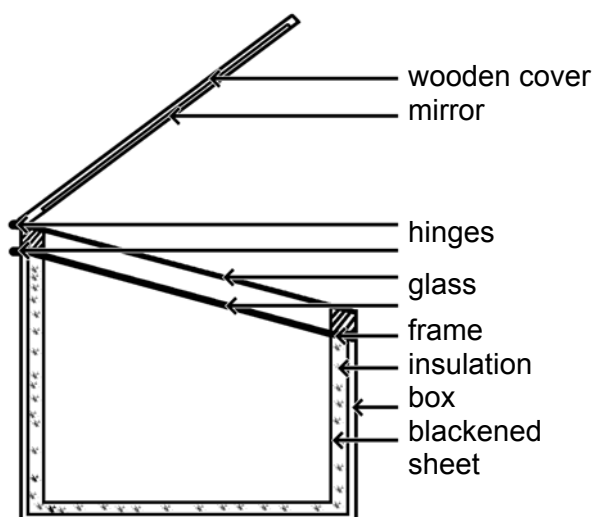
In past years WOT experimented a lot with cooking boxes. Several prototypes are displayed. The WOT also has two parabolic cookers.

2.1.1 The cooking box

The cooking box is a well-insulated box with a top of double glass. Through the glass the sunlight falls in the box, which is black on the inside and contains a pan. The sunlight heats the inside of the box and the pan. High temperatures (over 100° C) can be reached if mirrors, which catch extra sunlight, are placed at the side of the box.



Figure 1
Cooking box



A great advantage of the cooking box is that it is simple to make out of materials that usually are available locally. No wood is used during cooking. The cooking box also has many disadvantages, which makes it difficult to introduce in some societies. The glass and mirrors are sometimes not easily available and rather expensive compared to the rest of the materials that are used to build the cooking box.

Cooking with a cooking box often involves changing cooking and living habits. For example, it is impossible to stir while cooking in a cooking box. Solar cookers only work if there is a lot of sun. That means that people have to cook in the afternoon. In many societies it is common to take it easy this time of the day. Also it is not comfortable to cook in the burning sun. People cannot eat hot food during the evening and the morning anymore. The cooking box cannot be used to fry food. Moreover the cooking box can never replace some of the other functions of a wood fire, like supplying heat and comfort and chasing off insects with smoke.

2.1.2 The parabolic cooker

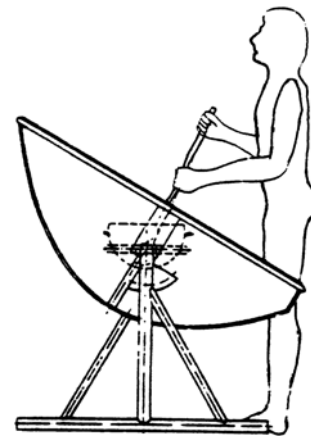


Figure 2
Parabolic
cooker

The parabolic cooker is a so-called reflector cooker. Reflector cookers concentrate the sunlight directly on the pan, so this type of cooker is very efficient compared to the cooking box. High temperatures can be reached quickly with this type of cooker.

On the WOT-field there are two SK-14's, a reflector cooker developed by Dr. Ing. D. Seifert. He is connected to the non-profit development organisation EG-solar in Germany. The SK-14 consists of a parabolic mirror (reflector) that concentrates the light on a black pan. The pan absorbs the sunlight, and cooks what is in it. Two litres of water will boil in 18 minutes. The parabolic cooker can be used for example to cook or fry. Besides the preparation of meals, it can also be used to sterilise or distillate water. In the design of the SK-14 disadvantages of earlier reflector cookers have been taken into account. The focus point distance is chosen to be small so there is practically no risk of burning or blinding.

The cooker itself is robust and simple. The frame can be made out of different kind of materials. So the design can be adapted to locally available materials and techniques. The reflector consists of specially coated, very durable (at least 15 years), high shine aluminium. In combination with a haybox, the SK-14 can be used to prepare food for about 15 people. The cooker can be used from one hour after dawn to one hour before sunset. Due to the work of development groups, the SK-14 has been spread in about 50 countries. In quite a number of countries the SK-14 is produced in local workshops (e.g. Ecuador, Colombia, Peru, Bolivia, Argentina, Uganda, Nepal en India).

2.1.3 The haybox

It is only possible to use solar energy to cook during a limited time of the day. To allow people to have a hot meal in the evening that is cooked during the afternoon, a so-called haybox can be used. The principle is simple. You make a box or basket out of wood, reed or any other material. The box should be a bit bigger than the pan that is meant to be kept warm in it. Inside the box you make a bed out of insulating material, e.g. blankets, wool, hay or another locally available material. After cooking, the food can be kept warm for hours inside the box. An extra advantage is that the food can get ready inside the box. For example it is possible to cook rice in the parabolic cooker. After five minutes you place the rice inside the haybox and half an hour later it will be done. In the mean-time the solar cooker can then be used to prepare another dish.



2.2 Solar water heating

The radiation from the sun can be transformed into two useful kinds of energy; heat and electricity. Photo-voltaic systems are used to generate electricity. This will be described later on.

Solar radiation can be transformed into heat with a so-called collector. Roughly there are two types of collectors: concentrating and non-concentrating collectors. The first type concentrates light on a small surface, this makes it possible to reach high temperatures, that can be used to create steam. The second type collector has a simpler design, but doesn't reach temperatures as high as the concentrating collectors. There are several examples of this type on the WOT test field. They are used to heat water.

The general principle of the system is simple. Water is heated in the collector and is stored for later use. A solar water heater consists of a solar collector and a storage tank that are connected with pipes or tubes. If the storage tank is placed at least 40 cm above the top of the collectors the water can circulate naturally. The picture below illustrates the principle.

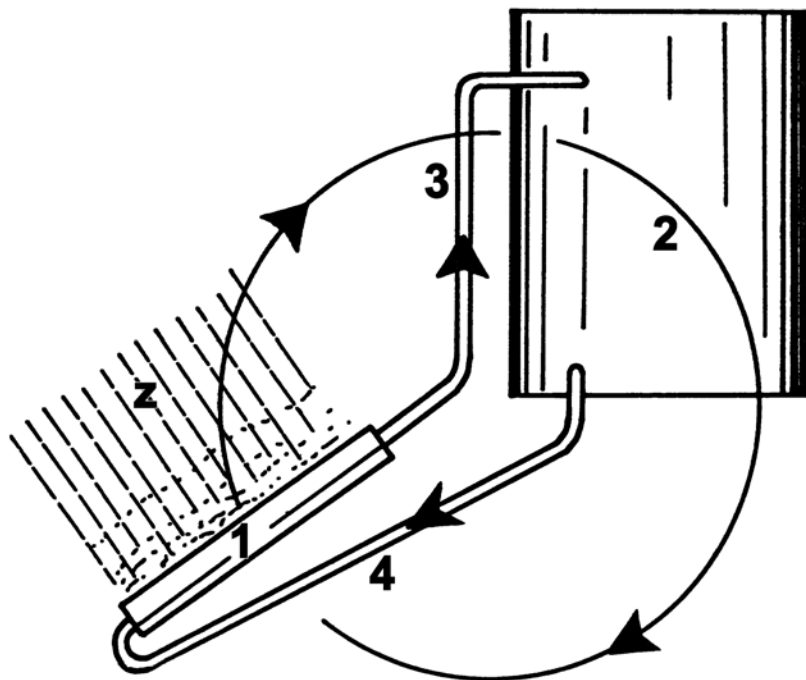


Figure 3
Principle of
the solar
water heater

Solar Radiation (Z) heats the collector (1) and the water that is in it. The hot water starts to flow upwards through a pipe (3), to the storage tank (2), because hot water always flows to the highest point in a closed system. The hot water is replaced by cold water from the bottom of the tank (4). This starts a circulation, which allows all the water to be heated. This circulation is called “natural convection”, because only solar energy is needed to start it. If an external pump is used to circulate the water this is called “forced convection”. A pump is necessary when the system has a storage tank that is placed beneath the collectors. The solar shower on the WOT test field is an example.

Depending on the ambient temperature and the insulation of the system temperatures of 40°C to 70°C can be reached. The several collectors on the WOT test field will be described below.

On the WOT test field there are several types of solar collectors. The WOT collectors consist of a wooden box with metal pipes inside, through which the water flows. The collectors are painted black. The top of the wooden box is single or double glass. Everything is well insulated. Before the several types of collectors are described, several aspects that are important will be discussed.

1. absorption

A collector must absorb the solar radiation well, and it should radiate as little energy in the form of heat as possible. Black is a logical choice, because black absorbs a large part of the spectrum. Blackboard paint is often used in simple collectors.

2. reflection

Reflection plays a role in two different ways. Of course, the absorbing layer should reflect as little light as possible. The glass plate should reflect the infrared light that the absorbing layer is emitting. This creates a greenhouse effect inside the collector.

3. insulation and the surroundings

The heat leaking to the surroundings of the collector should be minimal. This means a well made box, good insulation material and double glass.

There are several ways to make the collector. The first is the so-called flat plate collector. This is made out of two steel plates that are connected with a little space between them. This allows the water to flow between the two plates. In theory this method is the most efficient, but experience shows that it is hard to make the two plates waterproof and that they start to leak after a while. A collector made out of several parallel pipes that are connected to a black metal plate is called a pipe collector. A combined type, which is called zigzag collector, consists of a metal plate onto which a pipe is placed in a zigzag form. A special bending tool is needed to bend the pipes.

The pipe can be connected to the metal plate in several ways. First the pipe can be soldered onto the metal plate. If it is not possible to solder, the metal plate can be cut in the length and be woven around the pipe. This version is less efficient than the soldered one. A third option, which is a good compromise between easy manufacture and high efficiency, is to connect the pipe to the plate with small bent plates, which are riveted to the metal plate.

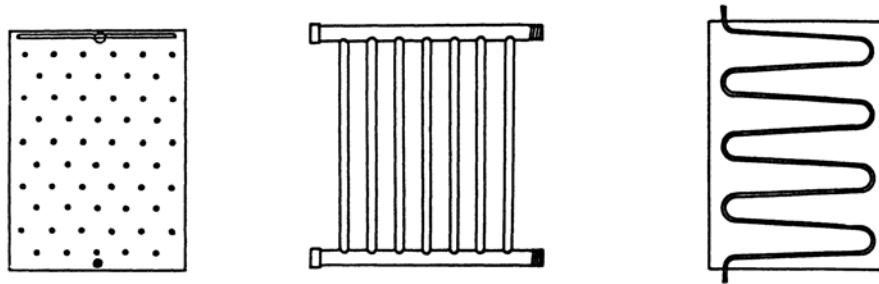


Figure 4
*Flat plate,
pipe- and
zigzag collector*

2.2.1 *The solar shower*



Once a year the WOT organises a Technical Week (T-Week) for development workers. The course-members sleep in tents on the test field. To enable our guests to take a shower a solar shower was built in 1994.

The shower has three zigzag collectors. For the left collector, the metal plate was “woven” around the pipe. For the middle collector, the pipe was soldered on the metal plated. The pipe of the collector on the right is riveted onto the plate using small bent plates. The shower has a large 1200 litre storage tank in the basement. It is not possible for the water to circulate naturally, because the tank is placed below the collectors. A small electrical pump is used to circulate the water.

The solar shower works well. At least thirty people can shower each day, when the sun shines a few days. If the water is heated to about 50°C or 60°C and the sun stops shining, it is still possible to enjoy warm water for days because the storage tank is well insulated.

2.2.2 The Deuss-system



Since 1981 the BACIBO Foundation is actively involved in installing hot water systems powered by solar energy. On the WOT test field there is an example of such a system. The hot water systems are built for distant hospitals, clinics, revalidation and training centres in developing countries. They replace existing wood burning hot water systems. The construction is simple but proper and locally available materials are used. Local craftsmen are trained in producing the solar collectors and building and maintaining the systems. With BACIBO's help at least 60 solar heaters were placed in at least 25 different locations in developing countries between 1981 and today.

The picture below shows the Deuss-system schematically.

Cold water flows through a pipe (1) into the bottom of the storage tank (2). Then the water flows to the bottom of the solar collectors (3). The water is heated and returns through natural circulation to the storage tank (4). The hot water can be taken out of the storage tank through a tap (5). To prevent pressure from building in the tank a ventilation opening (6) is present. The collectors in the Deuss-system are zigzag collectors.

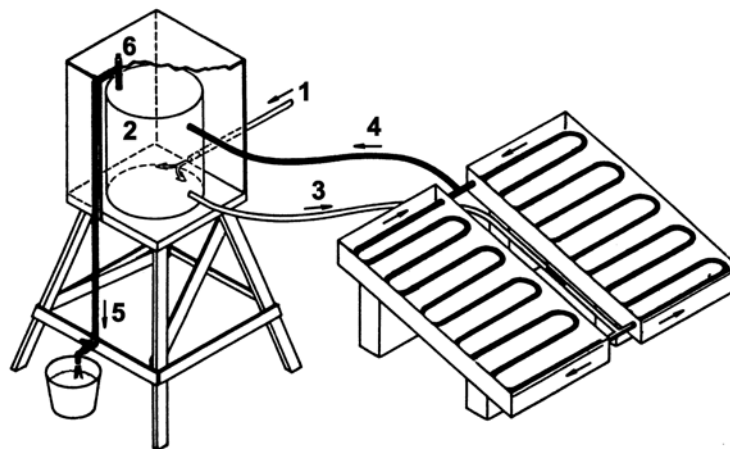


Figure 5
Principle
of the
Deuss-system

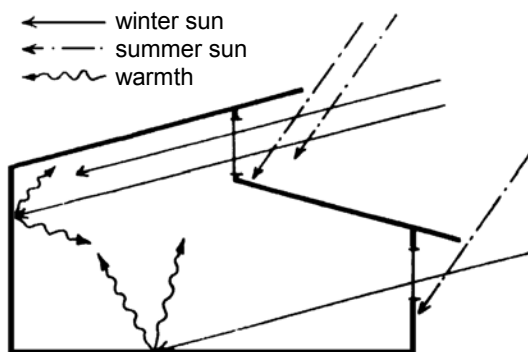
2.3 Other applications of solar energy

2.3.1 The Kiwanda



“Kiwanda” is the Swahili word for workshop. The WOT-members work in this building to maintain the objects on display. New techniques are also tested here. The building is designed with the principle of passive solar energy. This means that the building stays warm in winter and cool in summer, due to the way the building reacts to the sun and ambient temperature. The picture below shows how this is done.

Figure 6
Workshop



1. The building has many double glass windows at the south-side and hardly any windows in the other walls. This allows the solar warmth to enter the building.
2. Barrels filled with water are placed at the north wall side. Solar warmth falls on this wall of water and the concrete floor and is stored there.
3. The building is well-insulated (20 cm), this keeps the warmth inside.
4. The roof is extended above the windows. At summer when the sun is high, the light doesn't enter the building. The low winter sun shines in underneath the extended roof parts.

Passive solar energy is also used in hospitals in high altitude regions in developing countries. During the day, there is a lot of sun, but at night the temperature drops. Thanks to the use of passive solar energy it is not necessary to burn the limited supply of wood.

2.3.2 PV cells for electricity generation.



To generate electricity so called photo voltaic cells (PV-cells) are used. The way a PV-cell works is rather complicated and the production is highly technical. This means that the cells cannot be made by WOT. Nor is it interesting to do this in developing countries, because it is an expensive process and not much of the costs are labour (which is cheap in developing countries), only about 10 to 20 %. The rest is an investment in equipment, energy and materials. The separate cells (10 x 10 cm) can be assembled into complete panels (50 x 100 cm) in developing countries. The necessary side-equipment like the control, wiring and frame can also be made in developing countries.

The WOT has placed a small PV-system on the building of the solar shower. It provides the energy for the lighting in the shower. The WOT doesn't research PV-systems, however we do give advice about them, using handbooks and the research from other parties.

2.3.3 The solar dryer

Unlike water heating and electricity generation, drying crops is a direct use of solar energy. The use of solar energy to dry crops is nothing new in the tropics. Many edible products, but also cash crops like cacao and coffee, have been placed on drying racks in the sun. The sun heats the products and the air around them, which allows the water to evaporate.

Next to drying on racks, special installations can be used, the so-called solar dryers. Solar dryers can work both direct and indirect. Both principles are explained in the pictures below. A prototype of an indirect solar dryer is on display on the WOT test field.

Figure 7
Direct
solar dryer

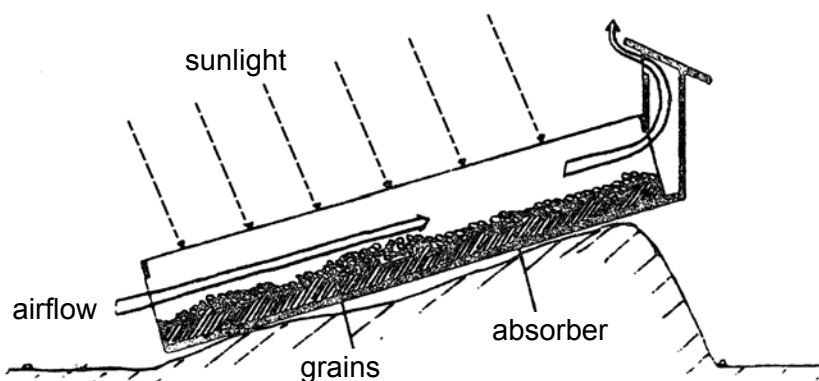
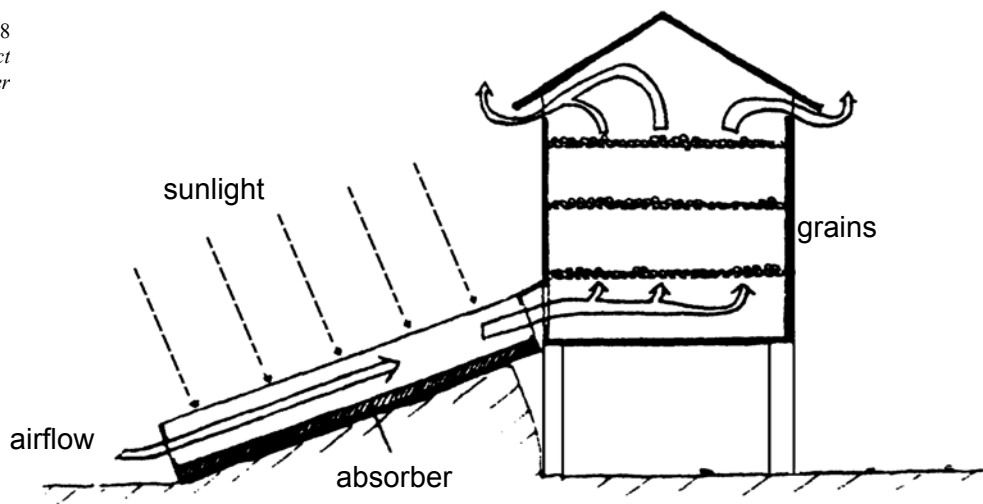


Figure 8
Indirect
solar dryer



Direct solar dryers are cheap to make and easy to use, but allow almost no control over the temperature. It is hard to protect the product that is drying from external factors. Also, many vegetables and fruits change colour if they are exposed to sunlight for too long. This has undesired effects. Many vitamins are lost and the product looks less appetising, and will therefore fetch a lower price on the market, if the product is to be sold.

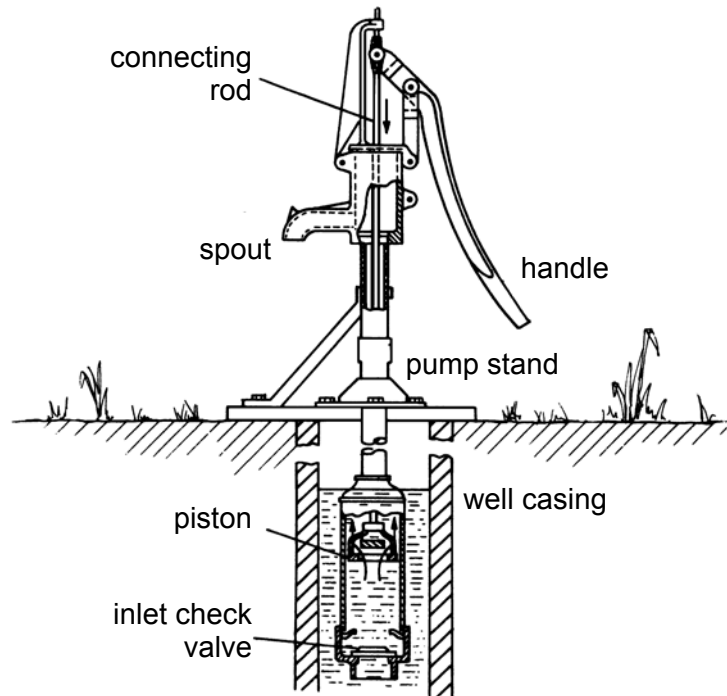
With indirect drying it is possible to control the temperature better. The product isn't exposed to ultraviolet radiation, and therefore won't change colour. However, indirect dryers are more expensive to make and harder to use.



3. Hand-pumps

One of the primary needs of people in developing countries is a safe and good water supply. Wells are easily contaminated with diseases if they are in direct contact with the open air. Possible solutions are the use of a closed well and/or ground water. A hand-pump can be used to get the water up. Hand-pumps are used a lot in developing countries because they are easy to make and because they are cheap. Below you see a drawing of a hand-pump that uses a piston-pump. The piston pump will be described further on.

Figure 9
Hand pump



A hand-ropepump doesn't make use of a piston pump. It uses little pistons to suck the water out of the well. You can read about the ropepump later on.

The past has shown that there are several disadvantages and problems to the use of hand-pumps. Often they are badly maintained, so in a short term they can't be used anymore. Sometimes they are badly built, or the wrong kind of technology is used. Hand-pumps can be placed on the wrong spot, at a place where there is little water or only very deep in the ground. Often the communities are hardly involved in the preparation and implementation of hand-pump projects.

There are three working handpumps with a piston pump on display on the WOT-field. There are also some ropepumps.

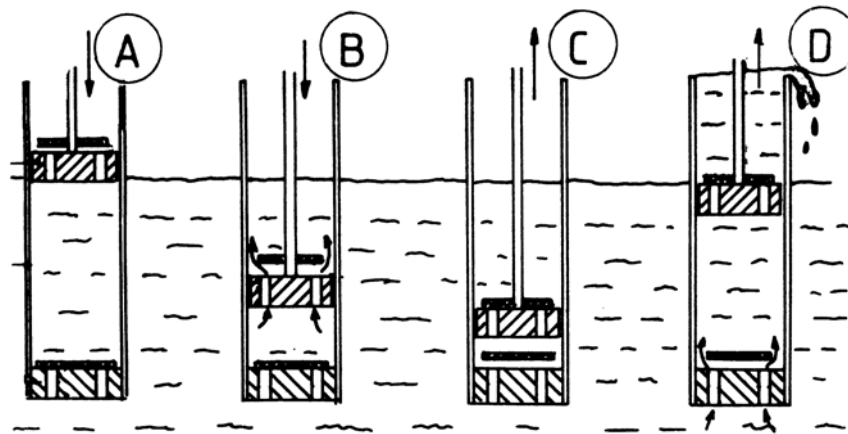


Figure 10
Principle
of the
piston pump

The type most often used is the single-operating piston pump. This type of pump consists of a piston, a cylinder and two valves. In picture A the piston is in the highest position and moving downward. The piston valve opens and the base-valve is pushed closed. In B the piston is moving downward and the water flows through the piston. In C the piston is in the lowest position and starts moving upward. The piston valve is pushed closed and the base valve is opened. In D the piston pushes the water upward while new water enters the pump through the base valve. The cycle starts all over again.

There also are double operating piston pumps. These pumps deliver water when the piston moves in either direction. These pumps have a far more complicated set of valves than the single-operating piston pump. Double operating piston pumps are used far less.

3.1 The wooden hand pump

The wooden hand-pump is partly made out of wood. Wood is a cheap and simple construction material. A disadvantage is that insects (termites) can effect it and that it rots when it stays moist.

The part above the ground of the simple wooden hand-pump on display on the WOT test field is made of wood. The pump itself and the delivery pipe for the water are made of steel and PVC (plastic). The piston that is used in the pump is made out of wood.



3.2 The steel hand-pump, Tanzania model



The steel hand-pump is very similar to the wooden one and it works the same way. Some wood is used as bearing material in the centres of rotation of the handle. The life span of these bearings is reasonable and if they wear they can easily and cheaply be made to fit again.

3.3 The farm pump



The farm pump was given its name because in the past it was used a lot on farms. The main difference between this type of pump and the normal hand-pump is that the piston is placed above the ground, a little below the handle. A bucket of water is therefore needed to start the pump, because the piston is not entirely waterproof.

3.4 The rope pump

The rope pump is no new invention. The principle has existed for thousands of years. In recent years, interest in the technique has been increasing, because it is simple and cheap and can tremendously improve the living conditions of people in developing countries.

The working principle of the rope pump is simple. One end of a plastic pipe is placed in a well and the other end just above the ground. Through the pipe goes a rope with small pistons that fit exactly into the pipe. The rope goes over a wheel that can be turned with a handle. As the rope moves through the pipe, the pistons pull the water up. The water leaves the pump through an outlet pipe.

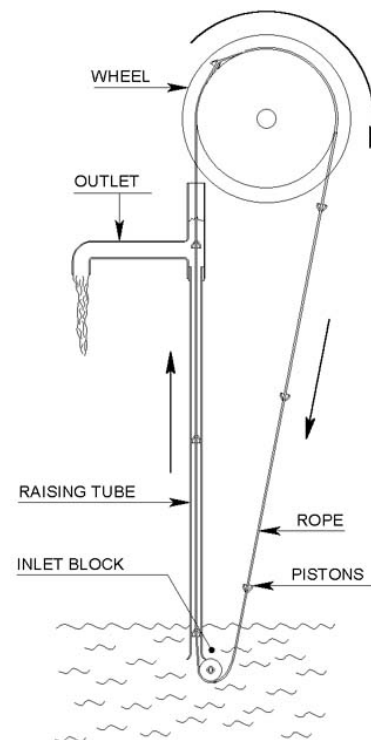


Figure 11
principle
of the
rope pump

The pump can be used to pump a lot of water with little effort. If the water is at a depth of 12 meters, an adult can get approximately 25 litre of water up each minute. If the water is less deep, it is possible to pump up 60 litres each minute. The maximum depth that can be reached is about 70 metres. The price is between 50 and 100 euro, which is 4 to 12 times as cheap as a similar piston pump. This makes the pump especially interesting for poor groups of people.



The pump has proven to be not only cheap but also reliable. Since the technique is simple, the people who use the pump can maintain and repair it themselves, which is done on a large scale. To repair the pump locally available material can be used, for example rope, plastic pipe and rubber for the pistons.

An extra advantage of the pump is for health reasons. In many places in developing countries people use a bucket on a rope to get up water. Such an open well, which is easily accessible for insects is often a source of worm-infection and diarrhoea. If the well is closed with a concrete lid, with a rope pump on it, then the risk of infection is greatly decreased.

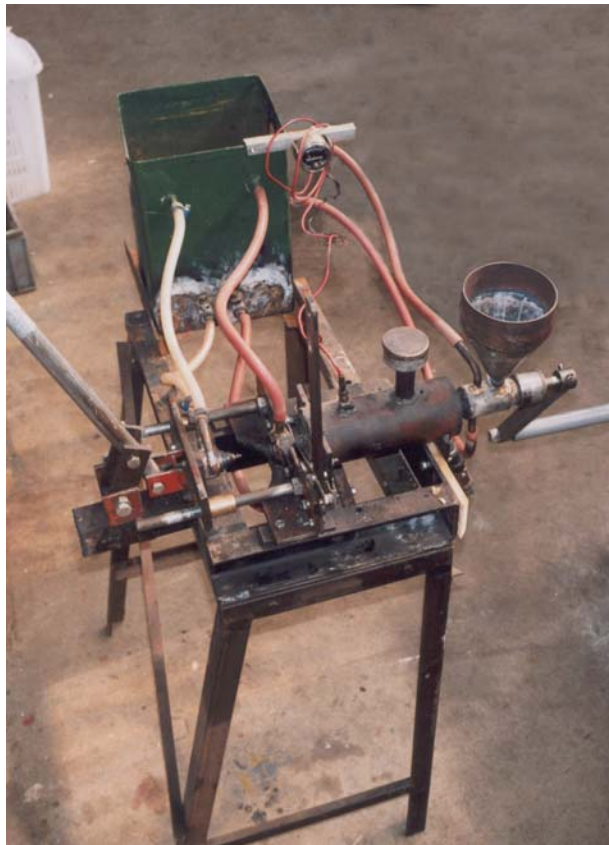
3.5 The injection moulding machine

In recent years the rope pump has been introduced in several places in developing countries. The success in Nicaragua, where more than 40.000 hand rope pumps have been placed, is becoming better known. Of course the developments on the rope pump have not yet stopped. New variations are developed, like driving the rope pump with a windmill. Also the pistons aren't perfected yet. They wear quickly.

Plastic pistons might be a good alternative for rubber pistons. The WOT has designed an injection moulding machine to produce plastic pistons efficiently. With the injection moulding machine, waste plastic can be used to make pistons.

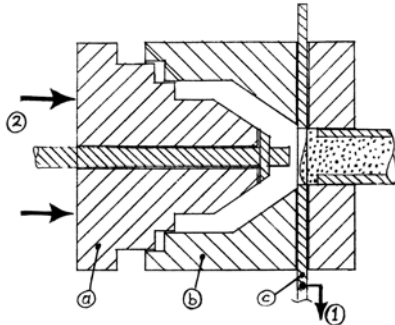
An advantage of this injection moulding machine is that no electricity is used to make the piston. The plastic is heated using gas or another fuel. The cooling water circulates naturally. If no proper waste plastic is available, polyethylene grains can be used.

The moulds of the injection moulding machine can be replaced if necessary. Then, other product can be produced.



The injection moulding machine works as follows (see figure 12 a to 12d). An extruder is placed in a mantle with deep fat. The deep fat is heated with a gas flame to about 130°C. The extruder is filled with HD-polyethylene grains. The grains melt and become a viscous-fluid mass. The injection moulding can begin.

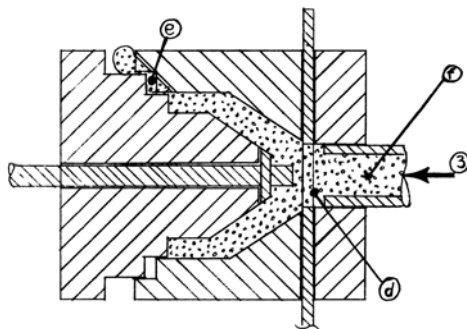
Figure 12a
principle of
the injection
moulding
machine



1. The closing device (c) is opened.

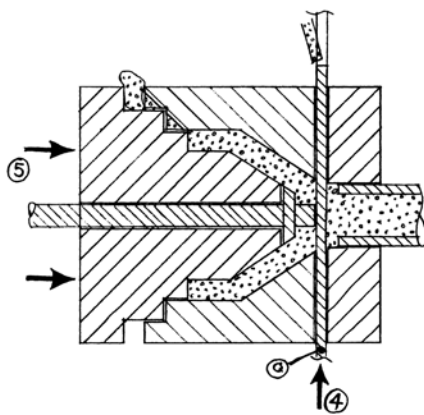
2. The two moulds, a male (a) and female (b), are closed almost completely.

Figure 12b
principle of
the injection
moulding
machine



3. The moulds are filled through the filling opening (d) with the viscous-liquid mass (f) until the mass flows out through the vent hole (e).

Figure 12c
principle of
the injection
moulding
machine

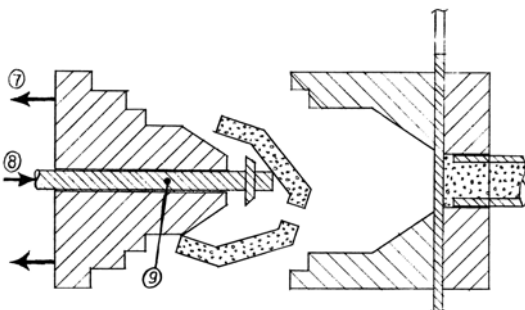


4. The closing device is closed.

5. The moulds are closed completely.

6. The cooling water circulating around the moulds, keeping the moulds on a temperature of approximately 60°C. The mass solidifies.

Figure 12d
principle of
the injection
moulding
machine



7. The moulds are opened.

8. The ejection pin pushes the product out of the moulds. The cycle is ended and the next piston can be made.

4. Hydraulic rams

The hydraulic ram is a kind of pump that uses water power to pump. A ram could be used in a river with a small height difference to pump the water to greater heights where it can be used for irrigation or domestic use.

The basic principle of the hydraulic ram is simple. In the figures the main part of the ram is shown schematically. On the right side the water flows into the hydraulic ram. Water flows into this opening continuously. This water is delivered through a plastic pressure pipe, which comes from at least 1 metre above the ram. The necessary height difference can be created by making a small dam or by digging a small extra canal next to the river.

First the water flows out of the ram through the top part (see figure 13a). This water flows back to the river. The water gains more speed, until at a certain point the water pushes the waste valve in a closed position. The water closes off its own way out.

But the water in the pressure pipe is still flowing, this causes an excess pressure (see figure 13b). This pressure-rise also happens when you suddenly close the tap at home. Then the exit is “suddenly” closed, but the water is still flowing. A loud “toink” can be heard in the water pipe. This effect is known as a “water ram”, and has named the ram pump.

In the hydraulic ram, this water ram is used to pump water: The excess-pressure opens the delivery valve on the left side (see figure 13c), and the water flows through it. This side of the pump leads to the delivery pipe. After a short period of time the excess-pressure disappears, this closes the delivery valve. At this moment the water is almost at a standstill. Gravity makes the waste valve fall into an opened position. Now the cycle restarts. This whole process happens about 2-3 times each second. Every time a little bit of water is pumped into the delivery pipe, and is pumped up.

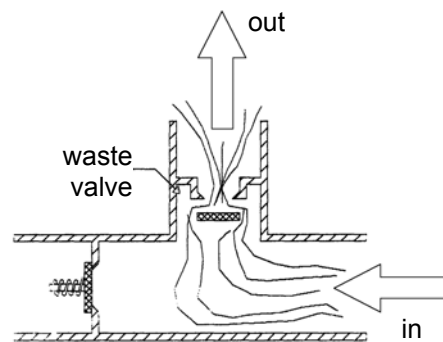


Figure 13a
Principle of
hydraulic ram

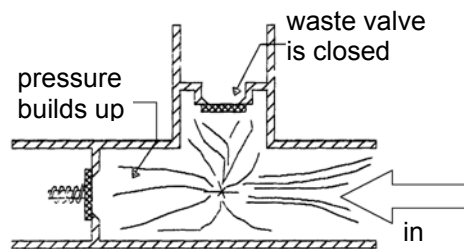


Figure 13b
Principle of
hydraulic ram

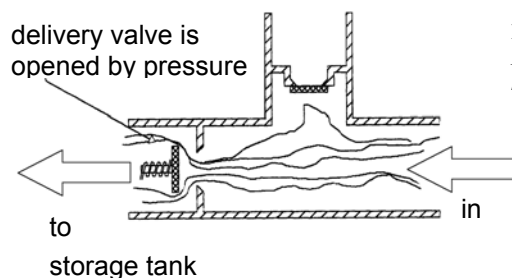


Figure 13c
Principle of
hydraulic ram

An important advantage of the ram pump is that it works completely on its own, as long as the water is flowing into the pump. In many cases water rams have worked, non-stop for years without malfunctioning. Hardly any wear is found in the hydraulic ram. The ram doesn't cost anything while it is being used.

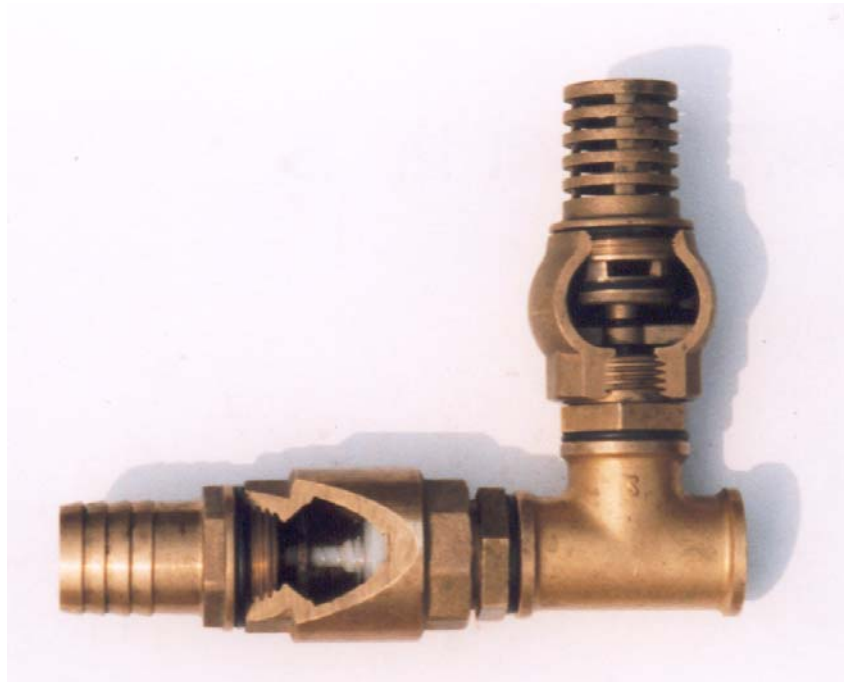
4.1 The Billabong

On the test field, two different types of hydraulic rams are installed. The oldest ram is almost a collector's item, because the manufacturer from Australia doesn't produce this "Billabong" anymore. It has a characteristic blue colour. It is cast and made for heavier duty. The cost of a similar ready to use hydraulic ram range between 500 to 1500 euro. The WOT has tested the device. If 1000 litres of water from 2.25 m high flows through the pump in 20 minutes, 60 litres of this water can be pumped to 12 meters high. For this test WOT installed a galvanised pressure pipe from the ferrocement tank to the Billabong. From the Billabong the water can be pumped up to 12 meter high to the top of the testing tower. The water that isn't pumped up, flows into the reservoir underneath the testing tower.



4.2 The Breurram

Cast hydraulic rams, like the Billabong, are often expensive and only interesting for larger scale use. Furthermore a lot of knowledge is needed to install, and if necessary, to repair the ram. To make the hydraulic ram more interesting and because the principle of the ram is rather simple, several organisations have successfully developed rams that can be build by yourself. In 1996 WOT also designed a hydraulic ram: the Breur ram. This ram is unique because it was designed especially for very small scale applications. It is possible to install the Breur ram yourself using cheap and widely available parts. The costs for the parts are about 50 euro in the Netherlands. The Breur ram has a remarkably high efficiency. Comparing with the Billabong: If 600 litres of water, with an initial height difference of one metre is supplied to the Breur ram, the same 60 litres can be pumped up 7 metres. Because the Breur ram is so small this does take longer, about 130 minutes. But as said before, the ram can run for 24 hours a day, without costs, wear or supervision. So the water should be pumped into a storage tank of some kind.



5. Windmills

Windmills can be used for many different purposes. Roughly there are two important purposes: electricity generation and water pumping. Several examples of water pumping windmills can be seen on the WOT test field. There is also one electricity generating windmill. In the next part of the tour around the WOT-test field, several general principles will be discussed. Followed by the water pumping windmills. Finally the electricity generating windmill will be described.

5.1 Water pumping windmills

A windmill is made of a tower with a head on top. Parts of the head are the rotor, something to turn the head to the wind and safety systems. The rotor (the set of wings) catches the wind, and transfers the energy of the wind into mechanical energy. A main vane points the rotor to the wind in small windmills. This allows the windmills to function if the wind blows from different directions. The safety system is made of a small side vane, which turns the rotor out of the wind during storms.

A water pumping windmill usually uses a piston pump (the principle of this type of pump was described in the chapter on hand-pumps). A crankshaft is used to transform the rotating movement into an up and down movement to drive the piston pump. A windmill with this type of pump can be recognised by the high number of wings on the rotor (8 to 24). This number of wings is needed, because it takes a lot of force to start the windmill. This type of rotor turns slowly compared to other types. Sometimes a transmission is used to further increase the moment of force.

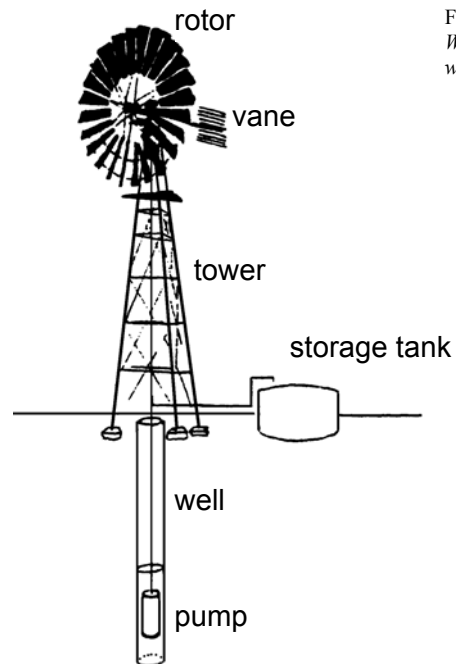


Figure 14
Water pumping
windmill

A water pumping windmill is often placed above a well or near a river. Next to the mill a storage tank can be placed, to have a buffer supply of water for the times that the mill doesn't work. The ferrocement tank on the test field is an example of such a storage tank. This tank will be described further on. The water from the storage tank can be used domestically, as drinking water for cattle or for irrigation. The water can also be used to breed fish. If the water is to be used as drinking water, the storage tank should be covered to prevent that the water becomes contaminated.

First and second generation windmills

Around the year 1900 a lot of windmill manufacturers existed. Only few of them exist today. Their products are sound, because the designs were developed during years of experience and mistakes. A lot of material is used in these windmills, some parts are made of cast iron (heavy). A lot of iron makes these mills expensive in their material costs. These so called first generation windmills are still sold on account of their reliability.

A windmill can be made cheaper by using less material. In the 1970's the second generation windmills were designed. Cast pieces were replaced by welded constructions of standard materials. These standard materials, like angled profiles and plate material, are cheap and of high quality. In the beginning of the 20th century plates and profiles were cast especially for their purpose. No agreements had been made about standardisation. The "Oasis" on the WOT test field is an example of a second generation windmill.

5.1.1 The Diever

The Diever-windmill currently on the test field, is the third version of a windmill designed by the WOT. The original thought behind the windmill was to gain experience in designing, building, testing and improving windmills.



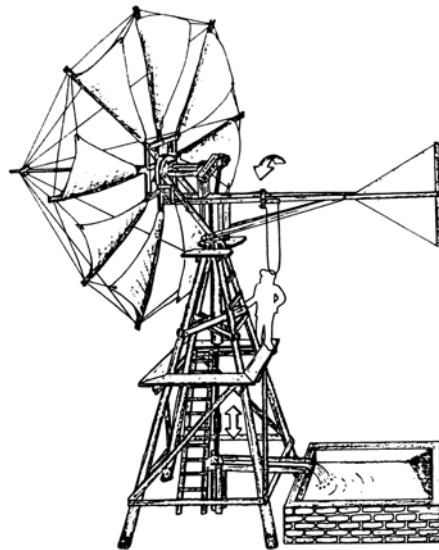
The Diever is a so-called 18 PU 450. This means that the windmill has 18 wings, and a rotor diameter of 4.5 metres. PU means Pump Unit. This allows everyone in the world to know which type of windmill it is. The windmill is made almost entirely out of steel, only the rotor axis has wooden bearings. The maximum power output is about one kilowatt. At low wind speeds the Diever can pump about 2.5 litres of water each second. This is 150 litre per minute. The windmill is named after Appie Diever, who was actively involved in the WOT for several decades.

5.1.2 The Cretan windmill

The WOT tries to find designs that can be made in a simple workshop. This means that only standardised materials are used. No accurate work has to be done, and no expensive machines are necessary. These principles were important in the design of the Cretan windmill.

The Cretan windmill was built in 1976 and has proven to be quite reliable. It is one of the most special and beautiful windmills on the WOT test field, because it is built almost entirely out of wood. The rotor is of a type that is also used on Crete (An island in the Mediterranean Sea), and has a diameter of six metres. The windmill has no brake to stop it if storm is coming. The sails must be rolled in. The rotor drives a piston pump. This allows the windmill to pump up water from a maximum of 15 metres. With a wind speed of 4 metres per second (3 Beaufort) the mill delivers 15 litres per minute if the height difference is 10 metres. If the height difference is less, the mill will deliver more. To build the windmill, tools for woodworking are necessary.

Figure 15
Cretan
windmill



5.1.3 The Oasis

This small windmill is a French product. It is used in Northern Africa (Algeria). This windmill was given to the WOT by the former windmill group “CWD”. The CWD has compared this windmill with their own mills and donated it to us afterwards.

It is interesting to see how industrial windmills are constructed. This type of windmills, can however not be made in a simple workshop and they are far too expensive for the target group of the WOT. The Oasis has a side vane for storm protection. The pump is small, which allows the windmill to turn, even at very low wind speeds. The amount of water that is pumped up is therefore small.



5.1.4 The 4-wing



When the Ghazipur windmill in India was designed, it turned out there was a need for a smaller, cheaper windmill. From leftover material the 4-wing was built. This mill is cheap and can pump water from shallow depths (several metres). It is easy to transport and can be used to pump irrigation water from a canal. The windmill only starts to turn at high wind speeds because it only has 4 wings.

5.1.5 The Kijito

In 1975 the Intermediate Technology Development Group from England started a windmill project in Kenya. The goal was to develop a commercial, modern and reliable windmill. The Kijito was the final result. The former windmill group “CWD” from the Netherlands performed many measurements on the windmill. In the end WOT was given a Kijito windmill to demonstrate it.

5.1.6 The ferrocement watertank

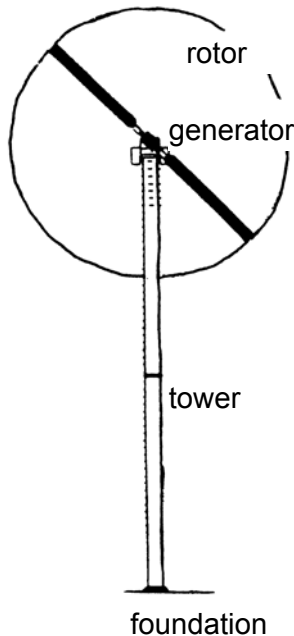
This tank is a storage tank for the windmill next to it (The Kijito). The tank can contain 10 cubic metres of water and is made out of ferrocement. This is a cheap version of reinforced concrete. Ferrocement consists of chicken wire covered with several layers of a mixture of sand and cement. Such a tank is a hygienic storage for drinking water if it is covered. The costs for a tank usually are as high as the costs for the windmill.



5.2 Electricity generating windmills

Electricity generating windmills are also called wind generators. The generator itself is in the head of the windmill. The rotor has many rotations per minute because it has only a few blades, which are placed more perpendicular to the wind and have a wing profile.

Figure 16
Electricity
generating
windmill



The speed of the point of the wings is high compared to the wind speed. This is desirable because then a small generator suffices. Often a transmission is used to have the generator operate at even higher rotational speeds so a smaller generator can be used. The rotors, which are used in wind generators, have a high efficiency, but start only at relatively high wind speeds.

There are electricity generating windmills that are connected to the power grid (Usually the larger ones), but also so called 'stand alone' windmills which are used most in distant areas. These types of windmills are not connected to the power grid, but for example to a battery. Windmills up to 1 MW have proven themselves, windmills generating more power are being designed.

5.2.1 The Virya

The Virya is an electricity generating windmill, which can be used to supply power to lights and refrigerators to cool medicines. Compared to other highly technical electricity generating windmills it is cheap to make. It costs about 2000 euro.

The windmill consists of a 12 metre high tripod tower. This is constructed in such a way that the tower can be held over. It is made out of two parts that are connected and disconnected with flange and bolts. This makes the mill easy to transport.

On the head are the generator and the rotor. To keep the mill simple, no transmission is used. This isn't necessary for the type of generator used. The rotor has three wooden wings with a combined diameter of 3.3 meters. The windmill generates 1 kW if the wind speed is 6 Beaufort (Approximately 12 meters per second)

The WOT has adapted the windmill to our own insights. The original design used a self-made generator, but this is not convenient for our target group, because of the tools needed. Therefore we decided to use a commercially available generator. Also a switch was designed to have the windmill transfer wind power into a current suitable for the battery as efficiently as possible.

The windmill is used by WOT to make coffee in the Kiwanda. For this purpose a cable was laid from the Virya to the Kiwanda.



6. The Test tower for water pumps

The test tower is used to test different pumps. It is 12 metres high and has a water reservoir underneath it. Both piston and rope pumps can be tested. The tests reveal efficiency and wear of the pumps. Also the forces in the pumps can be investigated.



7. The WOT

What is the WOT?

The WOT is active in the field of small scale appropriate technology for developing countries. The WOT provides a free consultancy service, free advice is given to people and organisations in developing countries.

"WOT" is the Dutch abbreviation of "Working Group on Development Techniques". We are a non-profit organisation based at the University of Twente in the Netherlands. WOT members are volunteers. They are supported by a small professional staff.

The WOT supports the improvement of social and economic living conditions in developing countries. We try to achieve this goal by transfer of technology in various ways:

- providing a consultancy service in the field of small scale appropriate technology for developing countries.
- receiving visitors to our testing field.
- writing and distributing publications on appropriate technology.
- conducting research to support our technical advice.
- maintaining a documentation centre, containing approximately 2600 titles.

Consultancy service

The WOT supplies a consultancy service in the field of small scale appropriate technology for developing countries. If you want to pose a question to the WOT please state the following items:

- subject (e.g. wind, water, sun).
- country to which your question concerns.
- local conditions (e.g. climate, available skills).

Topics

The WOT is active in the field of small scale sustainable energy for developing countries, examples of our knowledge are:

Handpumps

Handpumps are frequently used in developing countries. We can give advise on the well-known piston pumps. In the last couple of years the use of the ropepump has been advised more and more. The ropepump is cheaper and easier to maintain than a piston pump. The WOT has also created a ropepump piston machine, which can convert used plastic into pistons for the ropepump.

Solar energy

The WOT can give advice on thermal solar energy and photo-voltaics. Examples are solar water heating, solar drying, solar cooking, cooking boxes, parabolic cookers and small scale photo-voltaics (solar panels to generate electricity).

The advice on photo-voltaics is limited to information on dimensions, prices, names and addresses of suppliers. Photo-voltaic panels have to be bought; it is impossible to build your own panels, but assembling a complete photo-voltaic system is possible.

Wind energy

The WOT can give you information on water pumping and electricity generation by wind energy. If wind energy seems to be a feasible option, reliable windmills can be bought or proven models can be build under license. We can help you with calculations and addresses of local suppliers.

Hydro power

In the field of micro-hydro power we can give advice on electricity generating, hydraulic rams and direct use of the hydro power by sawing, grinding, and other machines. In the last couple of years the Breurram, which is a simple and cheap device which can pump water using the energy of a flowing river.

Address

For more information please visit our homepage, which has a lot of information about the WOT and applications of small scale sustainable energy for developing countries. Of course you can also contact us. For our consultancy service also use this address:

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