# Wind and water: The Poldaw windpump

***The age-old technology of windpumping has benefited enormously from modern design over the last twenty years. Sandy Polak and Paul Dawson outline the process and improvements of the Poldaw windpump***

PEOPLE HAVE FOR centuries used the power of the wind for lifting water. In the last century many thousands of windpumps were used in countries such as Australia and the United States to provide water for farming purposes, and these contributed in no small way to the development and prosperity of these countries.

Many of the windpump designs developed about a hundred years ago have proved to be very robust and reliable, and it is believed that as many as a million windpumps are today still providing water in many of the world's remote areas. The problems which have been encountered, particularly in developing countries, are those of high initial cost, difficulty of local manufacture, and the need for regular maintenance. These characteristics are inherent in the designs, which have not evolved substantially during this century — until recently that is.

This article is about the development of a modern windpump design, tailored to the needs of developing countries, which has gone through the design and testing stages, and is now entering production in small factories in different parts of the world.

## Design criteria

The major advance which this machine represents is the low capital cost for its size, while maintaining high strength and reliability. In these days of high interest rates, a very low capital cost is essential if the windpump is ever to be affordable by individual farmers and small communities without aid from governments or foreign donors.

The Poldaw windpump designers have had considerable involvement with windpumps and other machinery for use in developing countries, and from their experience know the importance of various design criteria.

Robustness and reliability are paramount, and ideally the machine should require zero or very little maintenance. The machine should cope with all forces thrown at it by the elements, and also have sufficient safety margins to cope with abuse resulting from imperfect installation or unskilled maintenance. A 20-year lifetime should be the minimum aim for all bearings and all structural components.

The design should use readily available low-cost materials, and should require the minimum of labour and equipment to manufacture. Although the cost of labour is low in developing countries, the rate of work is also often slow because of poor or worn out equipment and generally low productivity, so the labour content of the manufacturing cost can be significant. The use of expensive machinery such as milling machines and gear cutters must be avoided if possible.

Installation and maintenance should be simple, quick, and safe. The hazard of carrying out assembly and fitting work while perched on the top of a tower can be avoided by assembling the entire machine with the tower lying horizontal, then winching the whole assembly upright.

The size of the machine must be sufficient to give a useful output of water. As a minimum this should be at least three or four times the output of a handpump, as anything smaller would have very limited market appeal. As our target was a small, affordable windpump, the minimum size criteria meant that a rotor diameter of at least three metres.

The designers had already been involved with the development of the IT Windpump, and had produced the final engineering design and production manuals for that machine. This experience enabled them to bypass much of the normal development process and produce an initial design which would be very close to the final production version.

A few technical features of the design may be of interest to those with some knowledge of windpumps.

*The windpump transmission is assembled in the workshop in Harare.*

## Special features

First, the rotor has a 'direct' drive to the reciprocating pump, via a crank, connecting the rod and rocker arm. This is unusual for a machine of this size, which would usually have a speed-reducing gearbox, because a small rotor revolves relatively fast for best aerodynamic efficiency, and a direct drive would result in unacceptable dynamic forces in the reciprocating pump drive system. But gearboxes are expensive, difficult to manufacture, and require good lubrication. The approach taken therefore was to design a rotor to give very high torque but with very low speed (design tip-speed ratio approximately 0.7), which gives reduced aerodynamic efficiency, but a vastly cheaper mechanism. The loss in efficiency is simply and cheaply offset by making the rotor blades a bit longer.

For some of the continuously moving joints, self-aligning ball-bearing units are used. These are universally available, very reliable, and only require greasing about once a year. Some joints, however, only oscillate through an angle of about 20 degrees, and for these joints low-cost automotive rubber bushes are used. Provided these are mounted correctly, all the movement occurs by flexure of the rubber. No wear takes place, and these joints last indefinitely, while being only 10 to 20 per cent of the cost of an equivalent capacity ball-bearing.

Bearings which only move intermittently, such as the main head swivel and the tail bearings, are made from plastics or hardwood as appropriate.

As mentioned earlier, all parts of the machine were designed for minimum cost both in terms of materials and labour. The projected materials costs of the final design are between £250 and £450 (depending on the country), with labour costs and overheads adding approximately £200 (again very variable).

Construction and testing of the first machine was carried out in the UK, using small workshop production facilities not unlike those found in developing countries. Previous experience (and common sense) had confirmed that to build and test the first machine overseas has major disadvantages. Communication is difficult and slow, unless a member of the team can be present the whole time. Secondly, if a failure occurs in the field, it can be very difficult to discover if it is a result of faulty design, faulty construction, or faulty materials. Thirdly, the collaborating company in the developing country could be very tempted to go into production prematurely.

The first machine for trials was produced by GB Windpumps, a small company which up till then had been refurbishing and restoring older designs of windpump on farms all over the UK. This machine was installed at a test site in Somerset in early 1993, and monitored carefully over the following 18 months. On two occasions the machine was completely dismantled to inspect it for wear of bearings and for any fatigue cracks or weld failures. No significant defects were found, and the only design changes required were an increase in thickness for one small component in the tower, and a lengthening of the tail boom to improve the steering performance.

During this initial testing period the machine was subjected to strong winds estimated to be in excess of 50 knots (the anemometer was not functioning at the time), and suffered no ill effects. This was as expected, since the design is such that there should be no damage in a wind of 100 knots or more.

In parallel with the testing, detailed engineering drawings were produced for every component, using Autocad. For developing country workshops, large drawings are inconvenient, and making copies of large drawings is not always possible locally. Therefore each drawing was produced in A4 size, ensuring that all the necessary details and dimensions were clearly visible on this scale. This approach means that the drawings can be easily filed in a ring binder, and that copies for use in the workshop can be made using a small photocopier.

A manufacturing and installation manual was also produced, giving fabrication and assembly sequences and drawing attention to any critical areas. As people rarely read the instructions, this manual was regarded as a supplement, with the drawings being mostly self-explanatory.

Various manufacturers showed considerable interest in the development, and by the time the testing was completed satisfactorily, one manufacturer in Zimbabwe had signed up for a manufacturing licence, and another in Pakistan had requested a unit for trials.

## Technical specifications

Most of the material is steel angle sections, steel tubing and steel plate and sheet. Little machining is required, only turning and drilling, and the only critical dimensions are the seatings for the ball-bearings. Use of a few simple jigs and fixtures ensures accurate manufacture and interchangeability of parts.

Only three standard flanged ball-bearings are used, and the remainder of the moving parts are supported by various wood, plastic, and rubber bearings and bushes. This minimizes the cost of bought-in components.

The total weight of the machine including a 6-metre high tower is 400kg, and easy, safe installation is ensured by assembling the machine with the tower lying down, and then winching the whole assembly upright.

Maintenance is limited to greasing the three ball-bearings at least once a year, and touching up or repainting every few years. With attention to the paintwork (or the optional galvanized finish) the lifetime of the machine will be at least 20 years.

Any reciprocating (piston) pump can be used, with size appropriate to the depth of well. A range of low-cost shallow well pumps has been designed to complement the windpump. The aerodynamics of the wind rotor have been optimized to provide high torque at low speeds. This low speed operation permits the use of a simple low-cost direct drive transmission (no gears) without any risk of dynamic problems.

With appropriate pumps, the machine will start working in winds as low as 6mph (3m/second) and the automatic storm protection mechanism furls the windpump at speeds of 30mph or more. The mechanism acts by allowing the rotor to turn edge on to the wind, thus presenting the minimum area and minimizing the wind forces. When the wind drops, the machine automatically returns to normal operation.

Optional extras include a galvanized finish for extra corrosion resistance, and tower extensions for sheltered sites where more height is needed to expose the rotor fully to the wind. The tower extensions also provide a wider base which can be useful for straddling open wells.

## Materials list and manufacturing times

| *Materials* | |
|---|---|
| Mild steel angle section | 152kg |
| Mild steel strip | 12kg |
| Mild steel bright bar | 33kg |
| Mild steel black bar | 27kg |
| Mild steel plate | 51kg |
| Galvanized sheet (1mm thick) | 56kg |
| Mild steel tubing | 58kg |
| Flanged ball bearing units (one each of 30, 40, and 50mm) | 3 off |
| Fasteners (galvanized bolts, various lengths, sizes M6, M10, M12, M16, with nuts and washers) | 140 off |
| Pipe couplings: 1.5 inch | 4 off |
| 3 inch | 2 off |
| Rubber bushes (truck torsion bar bushes) | 4 off |
| Miscellaneous: Tufnol or hardwood for bearings, PVC pipe, chain, leaf spring | |

| *Manufacturing times* | *Hours* |
|---|---|
| Turning and drilling | 20 |
| Cutting, welding, and assembly | 50 |
| Painting | 10 |
| Total | 80 |

These times are per machine. Batches of at least five machines are recommended, and the times above are based on this. The time required to lay foundations and install the pump is not included.

## Setting up production

The intention with any new manufacturer is to provide training and supervision of initial manufacture. The first manufacturer in Zimbabwe was Hubert Davies Ltd., a competent engineering company who already make a number of products similar in construction techniques to the windpump. Therefore the approach taken was to supply the drawings and manuals and to have them produce the jigs and individual components before the initial two-week consultancy visit. Once this was done, one of the designers went out to Zimbabwe to supervise manufacture and installation of the first machines, in December 1994.

*Fitting the rotor blades during installation at the ART farm.*

On arrival the consultant inspected all the jigs (making a few necessary corrections), checked all the piece parts which had been made, and then supervised the welding of the main sub-assemblies. A trial assembly was then carried out before painting. This process took about a week, and left sufficient time for training the installation team and preparing the site, including the concrete foundations.

The first installation was at the ART (Agricultural Research Trust) Farm, not far from the factory, and the opportunity was taken to have factory production staff on site to gain first-hand experience of the site assembly and erection techniques. This provides a strong reinforcement of the need for quality control in the factory! The total time required on site to assemble and install the windpump is only about five hours, assuming the foundations, well, and pump are already prepared.

Also during the visit a presentation was given to all managers and sales staff to explain and affirm various aspects of windpumping. This includes marketing, site surveys, ongoing customer support, and maintenance requirements.

At the end of a hectic two weeks, the manufacturer was ready and enthusiastic to start making and selling windpumps in earnest in early 1995.

## The future

The intention is to license the design to manufacturers in any country which has a significant home market. In general only one licence will be let per country, giving the licensee exclusive sales rights in that territory, though some very large countries it may be appropriate to divide the territory and have more than one manufacturer.

The design of a larger machine, with a rotor diameter of 5 metres and twice the water output, is under way. When this has been similarly tested it will be made available, initially to licensees of the current 3.5 metre design.

A demonstration machine is in operation and on general display at the Centre for Alternative Technology, Macynlleth, Wales. ●

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