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Rural Water Supply in Developing Countries

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held in Zomba, Malawi,
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Rural Water Supply in Developing Countries

Proceedings of a workshop on training held in Zomba, Malawi, 5–12 August 1980

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Contents

Water Pumping by Wind Energy in Kenya

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A survey was carried out from 15–30 May 1980 in Kenya to collect information on the present use of wind energy for pumping water. The findings from the survey indicate that wind energy has been used for over 100 years in Kenya to power well-designed and durable windmills manufactured by Southern Cross, Australia; Aeromotor and Dempster, U.S.A.; and Climax, England. Today, only a few of these windmills remain (Fig. 1), having been replaced by diesel engines. With the demand for oil and other fossil fuels continuing to increase, however, it has become necessary to look for alternative sources of energy. Thus, wind-energy technology has been revived.

Since 1973, industrialized countries have concentrated on the development of windmills with rotors of up to 100 m in diameter for generating electricity in the megawatt range, which can be fed into national electricity supply grids. In developing countries, on the other hand, windmill technology was new to many scientists, research facilities were inadequate, and manpower was limited. Because this is still the case, the feasible application of this technology is confined to the use of windmills for pumping water and generating electricity in the 1–10 kW range.

The main objective in these countries is to reduce the need to purchase foreign materials to supply energy by developing methods of producing energy that utilize local resources. Thus, windmills would be produced from locally available materials. This led to the construction of several types of windmill rotors, e.g., in Kenya, a

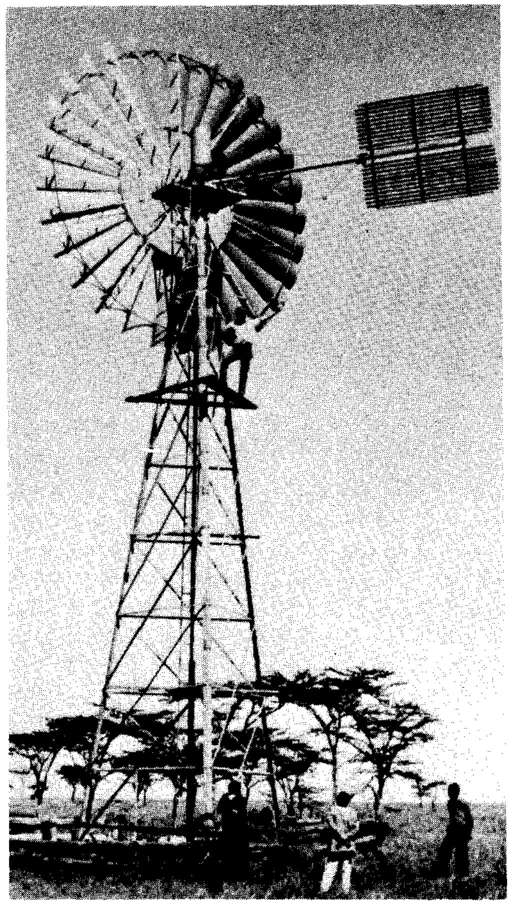

Fig. 1. Southern Cross windmill with a rotor diameter of 21 ft (6.4 m), installed more than 30 years ago.

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windmill was produced in 1976 with bamboo arms and sheet-metal blades (Fig. 2); another, the Cretan sail windmill, had a cloth sail and bamboo arms (Fig. 3). The VITA windmill was produced by the volunteer in technology assistance program based in Maryland, U.S.A., for use in developing countries. These windmills, however, were generally less efficient than the imported models.

As a result, a second stage of windmill development followed, leading to improved machines, e.g., the Kijito windmill, manufactured by Bobs Harris Engineering Ltd. (Fig. 4); the Mbita windmill (Fig. 5), an improved version of the Cretan sail windmill; the KIE (Kenya Industrial Estate) windmill, manufactured by Plough and Allied Products in Kisumu; and Carl Jensen's design, installed in Kisumu through the KIE (Fig. 6). There is, therefore, a wide variety of windmills, and it is difficult to accommodate them all in large-scale installations. Because all of these products are at the research and development stage, careful technical scrutiny is required before any one of them can qualify for large-scale use.

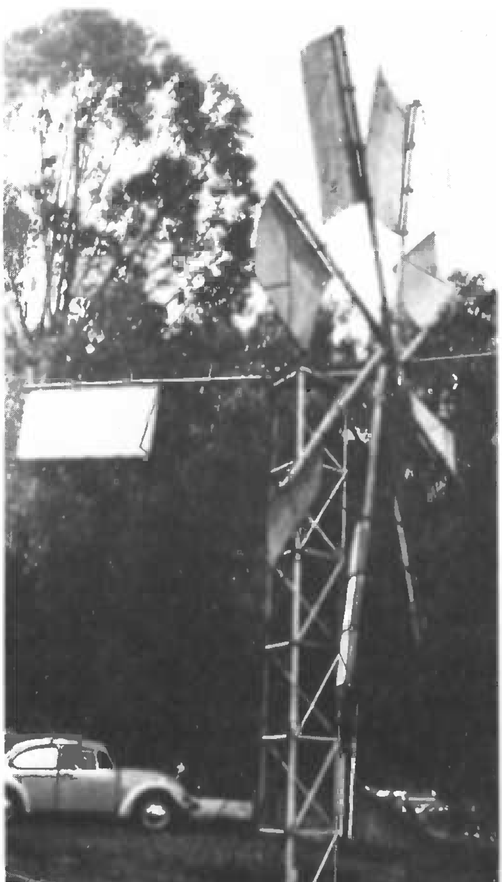

Fig. 2. A rotor with sheet-metal blades and bamboo poles made in 1976.

Fig. 3. A Cretan sail windmill with bamboo poles made in 1976–1977.

Wind-Power Devices

The criteria for identifying a good windmill are: (1) it should have at least 30 percent conversion efficiency; (2) it should be durable, with a lifetime of at least 20 years; (3) it should be affordable by low-income communities; and (4) it should be effective in conserving foreign exchange.

A windmill can only convert a portion of the kinetic energy available in the wind blowing through the area swept by its rotor into mechanical or electrical energy. Kinetic energy (E) is given by the formula

$$E = 0.5\,\rho A V^3$$

where ρ =density of air; A = area swept by the rotor; and V = mean wind velocity.

Fig. 4. The Kijito windmill.

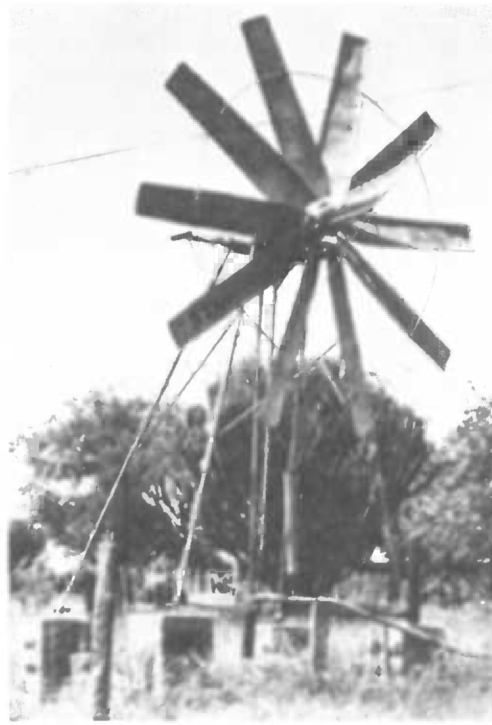

Fig. 5. Front view of a Mbita windmill with twisted blades.

Theoretically, a windmill of ideal aerodynamic efficiency can convert approximately 59 percent of the kinetic energy into useable energy. It is difficult to design a windmill approaching 50 percent efficiency. The best windmills presently known can only reach 30–40 percent efficiency. The efficiency of conversion is known as the coefficient of performance (*C*p). The power available from a windmill, therefore, is given by the formula

$$P = 0.5\,\rho\,C_pA\,V^3$$

Kijito Windmills

The Kijito windmill has evolved from the Intermediate Technology Development Group (ITDG), London, prototype design. Its *C*p can reach 30 percent. The Kijito windmill has a swivel-head rotor that always turns into the wind, thereby preventing damage from high-speed winds, and its blades are moulded from fiberglass, which gives them a good aerodynamic profile and makes them efficient.

The maintenance requirements of these windmills are minimal. They require only monthly lubrication inspections. The manufacturer, therefore, feels that there is no need to train servicemen to look after them, because the chances of failure are minimal. It is recommended that in case of major problems, repairs are best carried out by experts from the production unit. The largest rotor available with the Kijito windmill is 7.3 m in diameter. It has 24 blades and its rated pumping capacity is 220 m^3/day from a depth of 250 m in a wind with an average speed of 5 m/s.

Despite their good performance, Kenyan wind-energy technical experts feel that Kijito windmills have not yet satisfied the standards required of windmills destined for widespread use in the rural sector of a developing country, i.e., the price of these windmills is higher than the price of some of the alternative windmill designs; a large

Fig. 6. The Carl Jensen design.

proportion of the materials used to construct the windmill is imported; and the design itself has not been successful in all cases (e.g., the fiberglass blades have been known to break off after only 4 years of use, due to the effects of weathering). Because the Kijito windmill is still a new product, there is room, through continued research and development, to modify the design to meet the standards of windmills used in developing countries.

Mbita Windmills

The windmills at Mbita, on the shores of Lake Victoria in South Nyanza, are of excellent design, produced by a Dutch engineer (Herman M. Carlsen, Mbita Catholic Mission). The blades are made of galvanized sheet metal and have good aerodynamic efficiency. Very little material is imported for making these windmills. A 6 m diameter rotor, used for deep-well pumping, would cost U.S.$2300. In the production unit, where the windmills are made, trainees are engaged in all aspects of the fabrication and construction of the machines. Training in the use of these machines is readily available to all interested persons.

These windmills have operated successfully under the stormy conditions of the lake region for about 2 years, and further improvements are being made in their design as more ideas develop from field tests. A subsidy program is being considered to encourage and enable prospective users to install them. The Mbita windmills have, therefore, made remarkable advances towards realizing success in rural water supply.

The CITC Cretan Sail Windmill

The production of the CITC Cretan sail rotor has been abandoned because of its poor aerodynamic properties. The only achievement has been the construction of a tower which costs U.S.$370. It is envisaged that a Mbita wind rotor and a CITC windmill tower could be assembled together to achieve a very cheap water-pumping device, and collaborative work between the respective organizations is highly encouraged.

The KIE (Kisumu) Windmill

Plough and Allied Products have produced a machine comparable to the Mbita windmill costing approximately U.S. $2300. The organization is also willing to participate in training prospective users. In collaboration with academic institutions, Plough and Allied Products is attempting to develop methods to reduce the cost of producing its product. It is also anxious to have the government, particularly the

Ministry of Energy, participate in their wind-energy development work.

Water Pumps

Water pumps have followed the same trend as windmills. For many years metal pumps were produced cheaply in commercial sectors. Today, commercial pumps are quite expensive, and scientists have produced a wide variety of alternative designs. The choice of a hand pump is often not critical, because even an inefficient pump can deliver adequate water for consumers' demands. The power requirement for a water pump is given by

$$P = \xi \gamma Q H$$

where ξ = the efficiency of the pump
γ = specific weight of water
Q = flow discharge rate
H = height to which the water is raised

The difficult task usually arises when a windmill is to be properly matched to a pump.

Windmill Size

When deciding on the most appropriate size of windmill for a particular use, it is necessary to carefully match the windmill to the water pump and to ensure that the wind-power potential matches groundwater potential.

To match the windmill to the pump, such factors as average wind speed, rotor diameter, performance efficiency, water demand (pump capacity), and well depth must be considered. These factors can be accounted for by using mathematical equations to calculate the best pump and windmill combination to meet the needs of the consumer.

Consumer needs and windmill size, however, must also match the groundwater potential of the area. The collection and analysis of meteorological data on wind regimes are used to calculate the amount of power that can be harnessed and, therefore, the size of windmill and pump needed to meet the water demand. If this demand is found to be higher than the groundwater potential calculated from geological data, then supplementary sources, such as rainwater storage, must also be considered.

Operating Characteristics and Design Details

The requirements and design parameters of a good windmill have been highlighted in the foregoing discussion. Scientists, however, are not yet satisfied with the performance of even the best windmills currently available. Many attempts are in progress aimed at increasing performance but the problem that arises is that as performance is increased so is the level of sophistication. An example is shown in Fig. 6, where the windmill has a starter rotor containing shorter blades and a larger drive rotor consisting of three blades with flaps on the tips to prevent the blades from rotating too quickly. In developing countries, although the achievement of high efficiency is also of paramount importance, greater priority is given to the designing of machines which are durable and not dependent on imported materials for their construction.

Construction, Production, and Installation

Because research and development work is time consuming, it will be necessary to continue using the windmills that are currently available until improved designs can be developed. Collaborative work among organizations involved in manufacturing wind-powered devices is, therefore, desirable and should continue. In Kenya, prototypes of new designs can be constructed at the KIE (Kisumu) and CITC, Nairobi. Manpower training takes place at Mbita, KIE, and CITC. Trainees are instructed in the construction of windmills and how to repair them in the field.

Financing

The production and installation of commercial windmills is self-financing because there are organizations that finance enterprising industries. The financing of users, on the other hand, is a major limitation to large-scale windmill use, because very few people can afford windmills individually. On a communal basis, convincing all of the people in a community to purchase a windmill jointly is not easily accomplished. Although the use of windmills in rural areas should be promoted, the problem of a shortage of financing must first be solved. Training of farm technicians to install and maintain these machines will also require substantial funding, carefully planned to produce fruitful results. It should be noted that research and development are an essential part of these programs and that funding of well-planned research programs should be encouraged.

Conclusions

The use of wind energy for pumping water has reached the stage where it can be exploited on a large scale in Kenya, and the four manufacturing organizations mentioned earlier, which have brought this technology to a useable stage, are appreciated. Methods of assisting the manufacturers in the installation of windmills on a large scale should be outlined and put into practice. Because all of the present manufacturers need to modify their products to suit local requirements, they should receive research and development support. Prospective manufacturers should also be given technical and advisory support to enable them to enter the industry. In order to make the water supply program successful, manpower training in the construction and maintenance of windmills will be necessary.

The survey team is grateful to the Ministry of Energy for sponsoring the survey trips and making the early stages of wind-energy research in Kenya a success. It is hoped that this support will continue, thereby enabling the team to achieve its ultimate goal. Gratitude is also extended to Miss Elizabeth Efiketi for preparing the text for reproduction and presentation.