

## **A CASE STUDY ON FIELD TESTING OF WINDPUMPS IN INDIA**

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### **ABSTRACT**

This paper describes a simple approach to the testing of appropriate technology design windpumps and some early experience in operation of a relatively simple field test. This field test includes comparative assessment under identical conditions, an impartial record of maintenance requirements, and generates performance data to predict the quantity of water likely to be lifted on gross monthly basis at different places.

### **INTRODUCTION**

There is considerable interest in designing low cost wind pumps for the irrigation of small farms. In 1976-77 a project was initiated to design a sail-type windmill of 10m diameter (later reduced to 7.5m) coupled with a rotary pump. Two prototypes were monitored in an open field at the National Aeronautical Laboratory (NAL). Performance was monitored by hourly and daily aggregate output measuring average with hub-height wind speeds.

Multivane windmills of appropriate technology type have also been developed by other institutions. Field performance data in respect of these designs were not available and extrapolated claims, calculated apparently on the basis of short term tests, seemed optimistic.

If decision makers are to make the best choice between the available technology, it is essential to substantiate claims of cost-effectiveness through appropriate and comparable tests of performance. It was therefore decided to simultaneously operate several different windpumps in the same field under identical conditions.

A number of sophisticated field tests are used in several industrialised countries for testing wind electric generators. Meel and Oldenkamp (1984) report a single example at Eindhoven in the Netherlands.

This paper describes a relatively simple approach to measuring performance which would be suitable for any developing country without external assistance.

### **A TENTATIVE METHODOLOGY FOR WINDPUMP TESTING**

1. **Emphasis on shallow wells:** As stated earlier, the field testing discussed in this paper is primarily for the use of windpumps for irrigation in small farms from shallow open wells. Therefore, this activity reflects performance measurement in the range of total head not exceeding 8 metres.
2. **Emphasis on gross performance data:** One aspect of this programme has been to put more stress on comparative gross performance of windpumps under identical conditions. It is also envisaged to generate performance data on 10 minute averages as well as analysis of wind distribution at the site recorded by means of an anemograph.

Therefore, performance at sites of different wind distribution can be extended later.

However, wind velocity distribution data are available only in 37 locations in India. Monthly mean wind speed data are available for 317 locations. Therefore, as a first approximation, gross performance over 24 hours and aggregated performance over a period of a month and longer have been used.

3. Emphasis on extended testing: Endurance testing of the prototypes is carried out in the field to determine the fall in performance, if any, over time and obtain an idea of maintenance requirements. This is essential in respect of appropriate technology designs due to lack of standardisation.
4. Measurement of rotor power coefficient: As a side study, power coefficient of the rotor was determined treating a rotodynamic pump as a calibrated load. The pump was tested in the laboratory to determine its input power requirement at different rotational speeds for selected static heads. By measuring pump speed and hub-height wind speeds under steady wind conditions of 5-10 second duration, it was possible to estimate power drawn by the pump and thereby the power coefficient of the rotor inclusive of gear trains. This was possible only in respect of the NAL sail windmill which has a rotary drive train coupled to a rotodynamic pump.

### EARLY EXPERIENCE WITH SAIL WINDMILL TESTING

#### NAL sail windmill

While the development of this windmill is not the subject of this paper, aspects which have a bearing on its field testing will be described. This windmill consists of a low-cost sail rotor of 7.5m diameter. Initially, sails were triangular in shape typical of Greek designs. After development of a novel spoiler type regulation, the plan form of blades were changed to trapezoidal since manual furling for which triangular shape is more convenient, was no longer required. This windmill is intended to operate rotary and rotodynamic pumps kept at the ground level. There is a vertical drive shaft supported at the top and the bottom of the tower (Figures 1 and 2). The housings at the top and lower end consist of mass produced bevel and hypoid gears which also provide the necessary rotor speed step-up required for the pump.

Since 1978 prototype testing of the NAL sail windmill has been carried out on a well exposed field situated in the campus. However, since prototypes have also been undergoing developmental changes, the testing has not always been continuous. A flow meter was placed in the return delivery line for taking advantage of the fact that discharge from rotary and rotodynamic pumps was not of intermittent nature. In the absence of a good source of water supply, the testing was carried out by devising a recirculatory arrangement simulating a total static head of 6-8 metres.

Almost uninterrupted flow meter data are available from at least one of the two prototypes during the last two years. Measurements were carried out once a day on water meter and cup counter anemometer. A plot of 24-hourly discharge against wind speed indicated fairly good correlation. This was confirmed in more recent tests in which the rotary vane pump was replaced by regenerative turbine

pump and prototypes had either triangular sails or rectangular sails (Figure 3). Correlation of performance with Weibull parameters is planned for the future.

#### Determination of rotor power coefficients

Wind speed was measured by means of an electrical cup anemometer. The speed of rotation of the pump shaft was continuously recorded by a tachogenerator. In this manner, pump speed and wind speed correlation were established by selecting only steady records of 5-10 second duration. Observations which represented conditions under which the rotor appeared to be in the process of orienting with the direction of the wind were rejected. Also peaks representing instantaneous gusts were not considered.

The measured rotational speed of the pump was interpreted in terms of power absorbed by the pump. This was possible from variable speed pump characteristics determined on a test bench in the laboratory. Care was taken to match the total static head in both laboratory and field conditions.

Figure 4 give the power coefficient of the rotor (which includes losses in gear trains and shafts). The details of the test are provided Ramesh (1985).

#### Extended testing of components

Four additional wind pumps were field tested using three types of sail material, namely, medium and heavy quality canvas ( $500 \text{ gm/m}^2$  and  $750 \text{ gm/m}^2$ ) and woven polypropylene. The pumps were operated for 2-3 years period. Synthetic material was only 18-24 months.

Initially the windmill was designed around a commercially available swinging-vane rotary pump (Figure 5). This pump appeared scientifically matched with a medium solidity windmill rotor since it does not load the latter until it has picked up some speed (Tewari et al 1978).

During field operations this pump showed significant amounts of wear on the tips of the vanes. This was primarily attributed to the high coefficient of friction between brass and aluminium in the presence of water. In addition, earlier prototypes did not have rotor speed regulation which resulted in increased contact pressure due to centrifugal forces.

Experiments were made with bonded rubber tips on brass vanes but these needed replacing every month. These findings suggest that this pump requires significant development for use with windmills and it was experimentally replaced by a rotodynamic pump.

Due to the absence of automatic regulation, the design wind speed and rotor speed depended largely on how timely manual furling could be effected in the event of a sudden storm. Therefore, choice of gear strength and fatigue life was somewhat arbitrary. While rotary vane pump power characteristics did not create problems for gears, the occasional high loads at pump speed beyond its rated value which is typical of centrifugal pumps results in premature gear failures. This problem was resolved by using stronger gears and the development of an automatic technique for rotor speed regulation (Tewari and Ramesh 1983).

In early gear box designs the arrangement for lubrication was not adequate in field testing. Subsequently, greater care was taken to ensure flow and retention of lubricant in bearings and at gear contacts.

### **TESTING OF OTHER WINDPUMPS**

Two multivane windpumps are being tested in identical conditions at NAL campus as shown in Figure 6.

At present water is being lifted by windpumps from shallow sumps of about 3m depth. The pump lifts water by an additional 2 to 5m depending on the design. Figure 7 shows the recirculatory arrangement through a watermeter.

While extended testing is necessary, preliminary findings suggest a significant decline in performance of these low cost appropriate technology design windpumps (Figure 8). The pump being used is not constructed from non-corrosive metal. There was no rigorous attempt to match its parts and it was a very cheap model for its size (15cm diameter, 25cm stroke, two air chambers costing 1500 Indian rupees).

### **CONCLUSIONS**

From the studies conducted it is possible to recommend that simple and inexpensive field testing of windpumps can provide very useful information for the development and evaluation of low-cost appropriate technology designs primarily intended for irrigation in small farms from shallow wells.

### **ACKNOWLEDGEMENT**

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**FIGURE 1: NAL sail windmill with triangular sails**

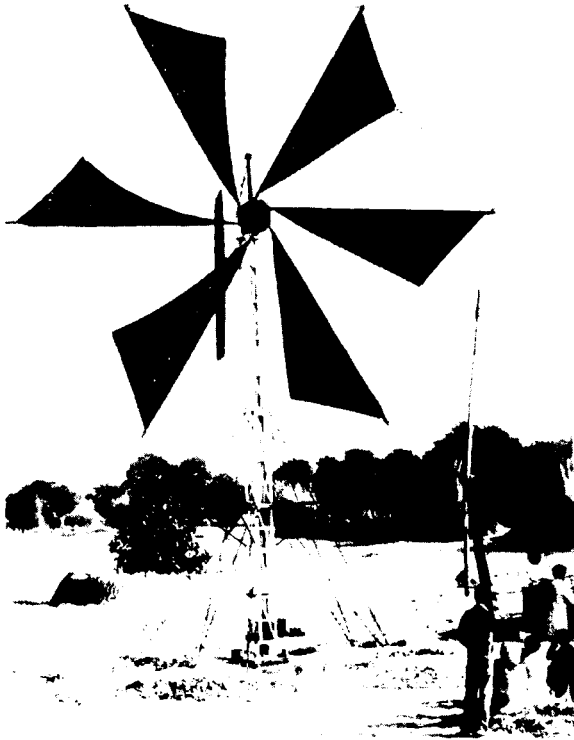


FIGURE 2: Schematic arrangement of NAL sail windmill

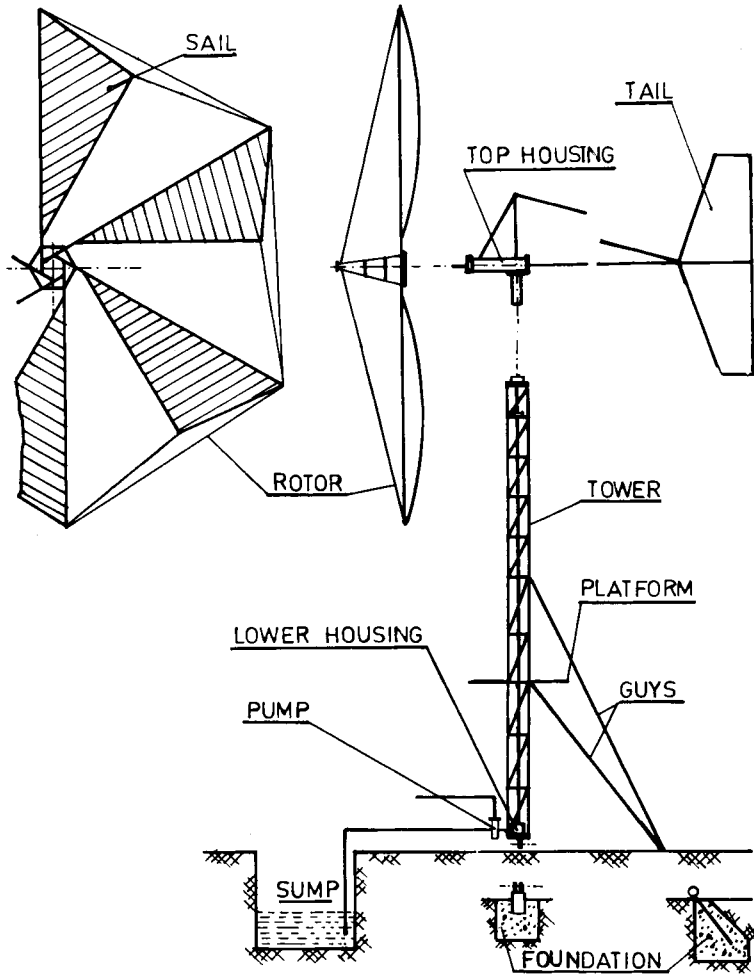


FIGURE 3: 24-hourly discharge and average wind speed correlation

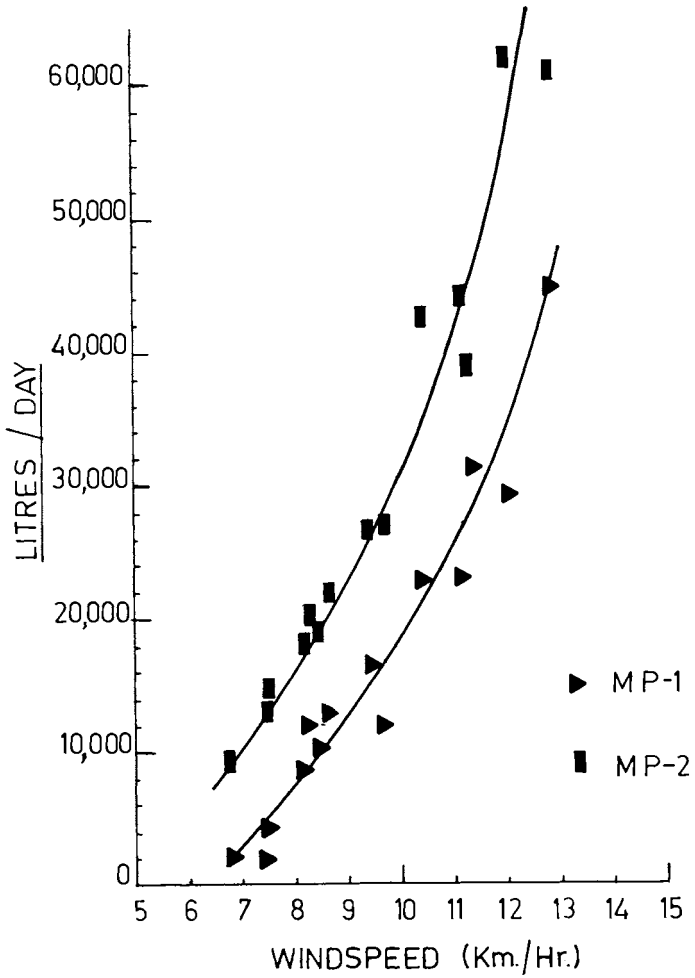


FIGURE 4: Rotor power coefficient shown against tip speed ratio

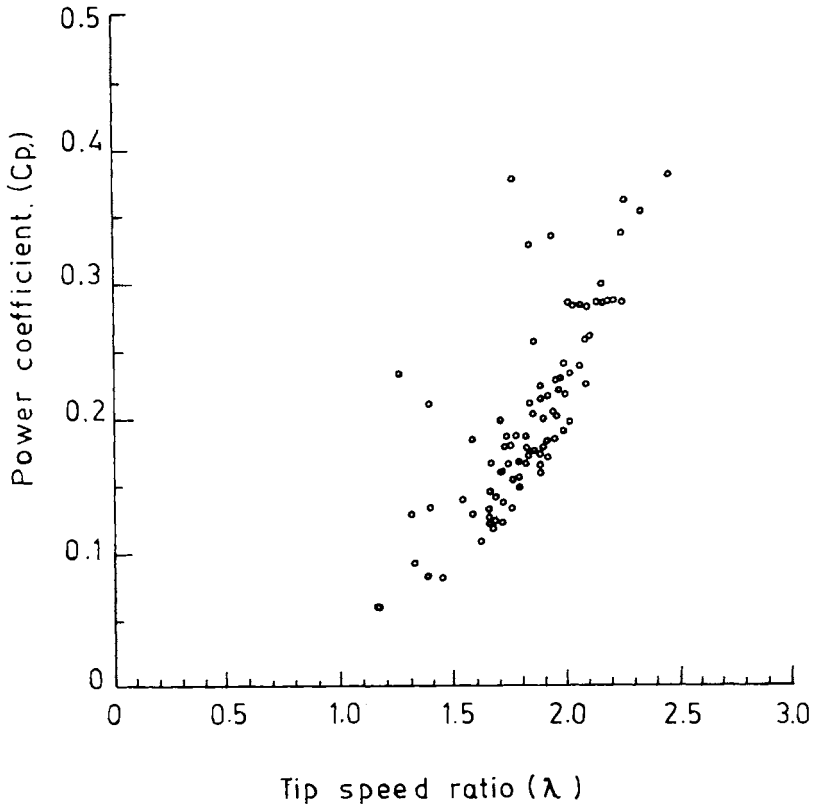
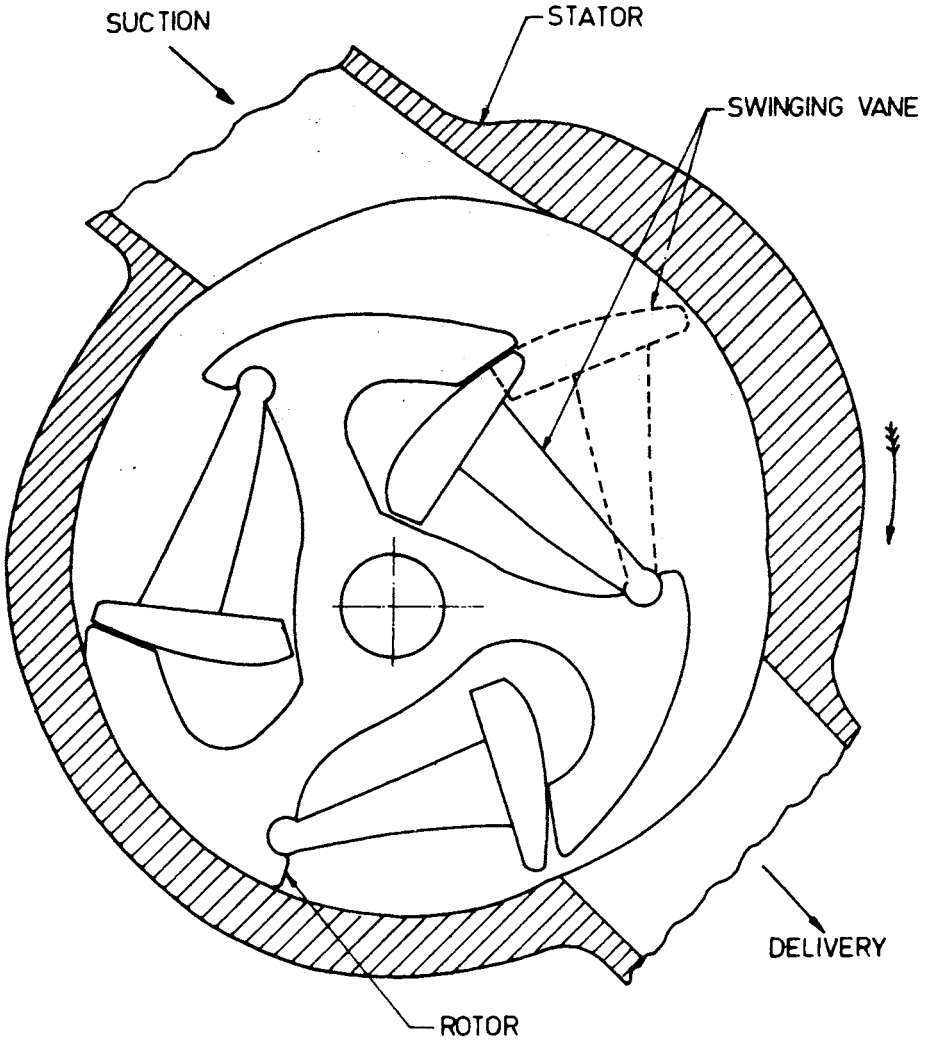


FIGURE 5: Schematic diagram of swinging vane rotary pump



**FIGURE 6: A view of the windpump test field in the campus of NAL.**

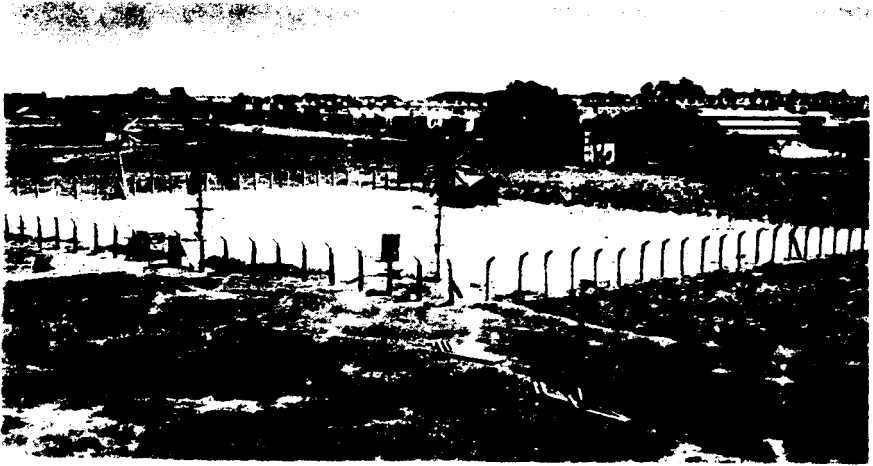
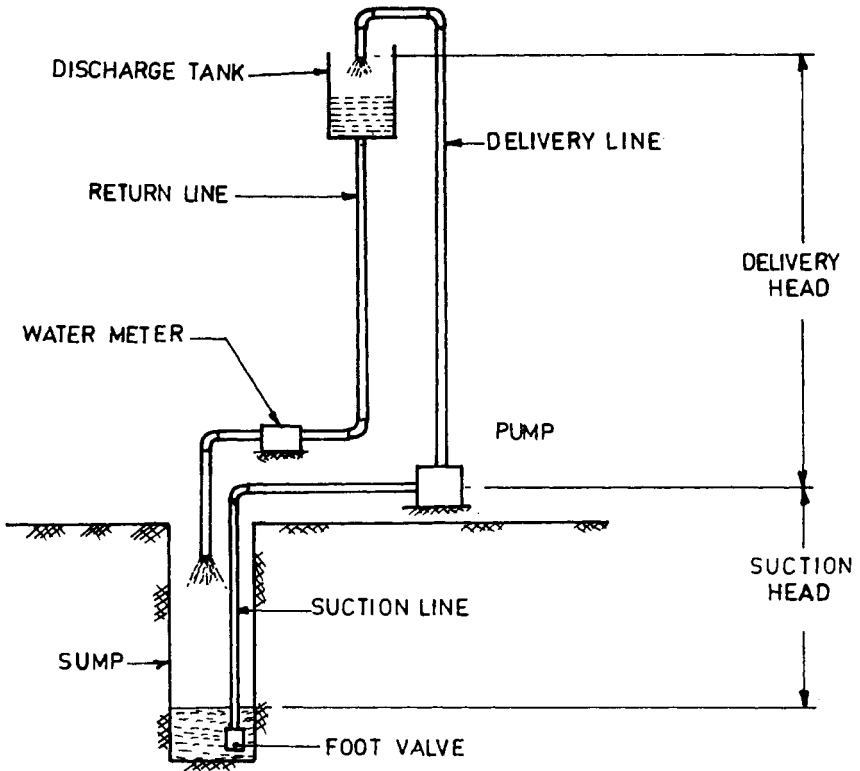


FIGURE 7: Schematic arrangement of water lifting in the test field



**FIGURE 8: Plot of daily system efficiency against daily mean wind speed**

The data are categorised on a weekly basis and identified by the number of the particular week ranging from 1 to 10 shown on 1 m/s intervals (1.5-2.5, 2.5-3.5, etc). A clear trend regarding fall in performance is observed. The information is in respect of a low cost piston pump (Venkatanarayana and Samaraj 1985).

