Windpump Manufacturing & Application – The Indian Experience **

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Wayback in 1980, the Institute of Engineering & Rural Technology, Allahabad, India, identified the potential of low windspeed windpumps for micro-irrigation in the Gangetic plains and later in other regions. Followed by this, through the cooperation of the Department of Non-Conventional Energy Sources, Govt. of India, an ambitious local production of Windpumps was initiated through which nearly 1000 Windpumps were installed throughout the country. Applications as diverse as micro-irrigation to brine pumping for salt-production were adopted, and varied experience gained, which constituted a sound basis for future proliferation of this technology.

1.0 THE BACKGROUND :

The Centre for Development of Rural Technology, in the Institute of Engineering & Rural Technology, at Allahabad (India), is a set up devoted to the development of technologies appropriate for rural areas and their extension for the betterment of socio-economic conditions of village communities. This centre has been working actively for the last 10 years in the field of Renewable Sources of Energy, besides other major areas like housing, transport, sanitation, agricultural implements etc. The Indian economy being basically agrarian the outstanding need is to increase and sustain food production matching steep increase in the population. The primary energy input for agriculture is for supply of irrigation water. An attempt was therefore, made to explore the feasibility of extraction of wind power for water pumping. Based upon very rudimentary data and simple design approach a small group of rural skilled hands, technicians and technical teachers made the first multibladed horizontal axis wind mill connected to an existing manually operated low-lift pump. This device was installed in a nearby agricultural field in Aug. 1979 and irrigated a 1/2 hectare vegetable plot almost flawlessly for 3 months. A chance meeting with the visiting team of TOOL Foundation of Holland, their appreciation of the potential of the work group and the infrastructure available at IERT, culminated into a joint endeavour which lasted for 2 years. During this period design of 12 bladed horizontal axis windmill, with a matching reciprocating pump, was developed. The prototype was designated as 12 PU 500 (where 12 is the number of blades, PU stands for pumping unit and 500 mm is the rotor diameter). The design of 12 PU 500 was specifically done for low wind regime. On the basis of scanty wind data an operating range of 2.5 to 10

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meters per second was taken to design a windmill to produce high torque at low wind speeds and energise a single action reciprocating pump. Towards the end of 1980 the Department of Science & Technology, Govt. of India, assessed the potential of this technology and asked I. E. R. T. to take up a 30 Windmill Demonstration Project. After the successful completion of this Project the newly constituted Commission for Additional Sources of Energy, Govt. of India (which later became the Deptt. of Non-Conventional Energy Sources), established a Wind Energy R&D Centre in I. E. R. T. in Sept. '81. The Windmill Demonstration Project was further expanded by the end of 1985, 530 Windpumps were installed, in different parts of the country, through this project and about 500 through other projects.

The Wind Energy Centre continued till March '87 and was reconstituted as Regional Wind Energy Test Station (R. W. E. T. S.) in July '87. In late seventies a number of windmill prototypes, ranging from an all bamboo/wooden to all metal structures, were adapted or developed for water pumping over shallow to moderate depths. Most of the variants were either horizontal axis machines or Savonnious Rotors, like those of Sherman's Madurai (adapted from Cretan design), C. S. M. C. R. I. Bhavnagar, CAZRI Jodhpur, AMM Chettiar Madras etc. However, the prototype 12 PU 500 survived the test of time in respect of performance, cost effectiveness and most importantly the capability of local production on decentralised basis.

Meanwhile the data available from various central organisations like the Central Electricity Authority, Indian Metereological Department, Central Groundwater Board etc. confirmed our assessment about the wind energy potential and prospects of its utilization for water lifting for micro-irrigation in rainfed areas and drinking water supply in water scarcity areas. As Annexure-I indicates the wind energy potential surveyed in 1980 by the Central Electricity Authority is of the order of 180 Giga Watt-hours or equal to 20,000 Megawatt installed capacity. It is estimated that some 10,000 villages in India, situated in far flung and disadvantageous locations, are beyond techno-economic feasibility of getting electricity from the utility grids or fuel-oil by road transport. Further, as illustrated in Annexure-II a fairly large chunk of India's geographical area appears suitable for wind power extraction, even if the above stated low wind regime is taken as the basis. Besides, this, in terms of water sources available for installation of wind pumps, as per 1981 estimates, there are at least 2 million open wells without any mechanised water lifting device. On a random basis even if 25% of these fall in suitable wind regime the scope of wind pumps is more than substantiated. Further, more open wells/borewells can be constructed to harness ground water for irrigation and drinking water supply. According to the Central Groundwater Board, the permanent annual draft in 1981 was over 90 Million Acre-feet and that available for further development is 175 Million Acre-feet, though only a small part of this resource will be amenable to low-lifts. In addition to this, an important situation which the author identified through his extensive field work in the Northern Region, is numerous canals flowing much below their adjoining command areas. It is an irony of the situation to see nearby farmers lifting water from such canals using most primitive water-basket system (worked upon by 4 to 8 adults) to irrigate their fields. Windpumps could be an excellent answer to such situations. This will lead to reduction of human drudgery, increase in agricultural production on small and marginal farms, thus betterment of living conditions of the rural poor and release of draught animals for productive functions like tillage, transport etc. The potential of wind energy for other farm applications like winnowing, shelling, chopping, grinding etc. is yet to be achieved even on a demonstratable scale but an area worth exploring. Needless to state that the gravity of the foregoing appraisal is heightened in the backdrop of critical commercial energy shortage prevailing in India. The adverse impact of this shortage was most felt in post-1973 period wherein the galloping outgo of hard earned foreign exchange (about Rs. 60 Billion or 90% of our foreign exchange earning in 1981) has resulted into severe inflationary pressure on the economy. It still continues, albeit at a reduced level, but the rising demand of the oil again presents a very unfavourable scenario for years to come.

2.0 THE DEVICE

2.1 Design considerations :

As stated earlier on the basis of I.M.D. Wind data, though not basically for harnessing wind energy, an appropriate assessment led to development of low wind speed water pumping windmills. These are basically multibladed horizontal axis machines with matching reciprocating pump and automatic furling/unfurling attachment.

The maximum power extractable by a horizontal axis windmill is given by :

$Pm = 0.593\, P.A.\, (U_o^3/2)$ m = maximum power extracted (watt)

P = density of air (Kg/m^3)

A = area of rotor (m^2)

Uo = Wind velocity (m/s)

Since the power varies as cube of the wind speed, it is imperative to obtain dependable wind speed data. For an ideal evaluation of extractable wind power it is necessary to have hourly average wind speeds for a period of 10 to 20 years near the proposed windmill site. Generally the height of wind measuring instrument may not necessarily be same as that of the windmill rotor. Since windspeed varies with the height, corrections have to be made empirically as follows :

$$\frac{V_h}{V_H} = \frac{h}{H} \cdot a$$

Where, h = height of windmill rotor (m)

H = height of wind speed measuring instrument (m)

Vh = Average wind velocity at height h (m/s)

V_H = average wind velocity at height H (m/s)

a = coefficient of surface roughness.

'a' depends upon roughness of the ground surface which in turn is influenced by topographical features. In open areas on land value of 'a' will generally lie between 0.2 and 0.25. Fig. 2.1 depicts three typical surface roughness and corresponding 'a' values.

Another important consideration, in windmill design, is the windspeed frequency distribution. The total amount of energy convertible as shaft power from the wind can be worked out from the frequency distribution and the expression for power extraction.

Mostly monthly intervals are chosen as indicated in Fig. 2.2. For detailed analysis it is better to use irrigation interval. In general, the wind pattern does not change very much within a month (except during weather changes like onset or end of monsoon etc.) Windspeed-frequency distribution is used between the values of cut-in or starting windspeed and the cut-out or maximum permissible windspeed (due to safety reason). These are respectively 2.5 and 10 m/sec. for the prototype 12 PU 500 windpump. It is obvious that the power-windspeed frequency distribution figures between these two limits should be used for the performance calculation. The power obtainable from the windmill should match the power required for water lifting which is determined in the following way

$$P_1 = \frac{P_w.\ g\, H\, Q}{n_p} \text{ (W)}$$

Where P_1 = Power for water lifting (watts)

n_p = efficiency of the pump

P_W = density of water (kg/m^3)

g = acceleration due to gravity (m/sec^2)

H = total pumping head (m)

Q = discharge (m^3/sec)

The last major consideration is the available command area from a certain windpump. The command area per windpump can be worked out on the basis of water balance in the irrigated field. Fig. 2.3 illustrates water balance :

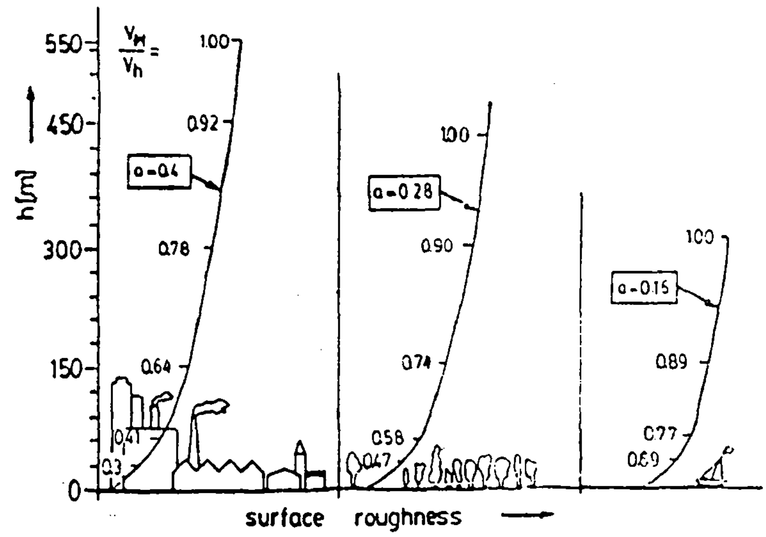


Fig. 2.1 Effect of surface roughness on coefficient 'a'

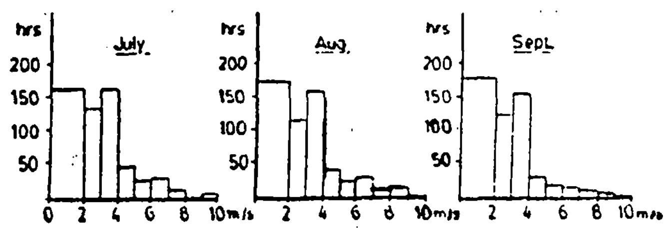


Fig. 2.2 Wind speed frequency distribution at a typical met station (AV. of 1975-78)

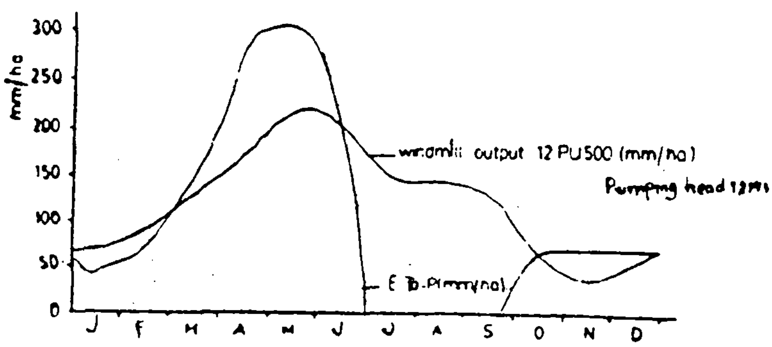


Fig. 2.3 Water Balance in a typical irrigated crop field (1mm/ho = 10m³)

From the Fig. 3 it is clear that for the period July to September, there is no need for artificial irrigation. For the periods March to July and October to December, the windpump output falls short of the requirement. Yet it is possible, as confirmed by action research, to supply sufficient water for upto 1.25 ha by crop plan adjustment and selection of proper crop varieties.

The command area is given by the following expression :

$$A = \frac{E-P}{I}$$

A = Command area (ha)

E = Evapo-transportation (mm/month)

P = Precipitation (mm/month)

I = Effective irrigation (mm/month/ha)

2.2 **The salient Features of the Windpump.**

1.	TOTAL HEIGHT OF THE TOWER	: 7.0 m (from the centre of the rotor shaft to the ground level)
2.	NUMBER OF BLADES	: 12
3.	ROTOR DIAMETER	: 5.0 m
4	ROTOR EFFICIENCY	: 38%
5.	OPERATIONAL LIMITS :	
	(i) CUT-IN WIND SPEED	: 2.5 m/sec.
	(ii) CUT-OUT WIND SPEED	: 10.0 m/sec.
	(iii) STROKE LENGTHS	: 120mm/180 mm/240 mm
	(iv) OUTPUT PER STROKE	: 4 5 1/sec. (16,208 l.p.h.) at 240 mm stroke length, 8 m/sec wind speed and 5m elevation head.
	(v) MAXIMUM PUMPING HEAD	: 20.0 m.
6.	VOLUMETRIC EFFICIENCY	: 82% at 8.5 m/sec. wind speed
7.	PUMP DIAMETER (STD. PUMP)	: 160 mm (Smaller ones for deeper water table).
8.	TOTAL WEIGHT OF THE WIND PUMP	: 450 kg.
9.	BASE AREA REQUIREMENT FOR THE TOWER	: 2.5 m × 2.5 m.
10.	COMMAND AREA (In case of irrigation)	: 1.25 to 1.5 ha.
11	TIP-SPEED RATIO	: 2

For micro-irrigation, a storage tank of average 150 cum. capacity has to be built near the windpump to equalise demand and supply (Provide water during windless periods).

2.3 **Constructional Details :**

Following is the brief description of main component of the windpump structure :

(i) TOWER CONSTRUCTION :

The standard tower is made of 40 × 40 × 5 mm and 30 × 30 × 3 mm m. s. angles, 30 × 6 mm m. s. flats and 100 mm m. s. pipe. The base dimension is 2.25 m × 2.25 mm. In case of long distance transportation tower is made knock-down and packed in a 2.75 × 1.0 × 0.5 m box. Tower height is suitably increased or the tower mounted on reinforced concrete pillers at sites having obstructions around.

(ii) HEAD CONSTRUCTION, TAILVANE AND SECURITY DEVICE :

The head provides a rigid frame for the rotor and its shaft. An extended tail (4.0 m long) and vane steer the rotor in wind direction automatically. Basic materials for these are 40 × 40 × 4 mm m. s. angles, some flat iron and 1 mm C. R. sheet etc.

A simple automatic security device-a spring actuated ratchet mechanism-unlocks the rotor from the main tail in case of high winds exerting pressure on the help-vane. The rotor turns 75° out of the wind direction and will be protected. With the fall in the wind speed the automatic security device will, in steps, gradually give proper orientation to the rotor for its normal functioning.

(iii) TRANSMISSION SYSTEM :

Wind's kinetic energy is converted into rotary motion with the help of a fabricated crank on the rear end of the main shaft, wooden crosshead, connecting rod, and pumprod which is directly coupled to single acting reciprocating pump. This system provides 3 working positions for different windspeed ranges. These position correspond to 60 mm, 90 mm, 120 mm crank radius. Basic materials used are m. s. shaft of 50 mm diameter, 30 × 6 mm m. s. flat, 38 × 10 mm m. s. flat, 25 × 5 mm m. s. flat 3/4" B. S. P. G. I. Pipe pillow blocks etc.

(iv) ROTOR

The rotor frame consists of 6-spokes (40 × 40 × 4 mm m. s. angles), inner and outer rings (30 × 6 mm m. s. flats) and a hub (40 × 40 × 4 mm m. s. angle) which clamps around 500 mm diameter shaft. Its accuracy is within 3 mm in radial and axial directions both. Each of the twelve blades of the rotor are fixed on-to the blade supports, which provide right curvature and twist. The blades are made out of 1.5 mm C. R. Sheet rolled out on pipe rolling machine.

(v) PUMP

A teak wood piston slides in a steel cylinder actuating leather suction and pressure valves. Big suction and air chambers are integrated with the pump design, to eliminate hammering effect and provide smooth flow of water. 2 mm C. R. sheet is used for fabrication of pump.

2.31 WATER STORAGE TANK :

Water storage tank is an important adjunct with windpumps used for micro-irrigation as it facilitates storage of water during surplus period and use during deficit period. Depending upon several factors like water depth, soil conditions, crops, area to be irrigated etc. The capacity of the tank should be about 150 cubic meters. For this capacity the tank dimensions are 10 × 10 × 1.75 m. Of the total depth 0.5 m is below ground and the rest above with a free board of 0.25 m. The overflow outlet is at 1.5 from the bottom. The lining of the tank, to withhold water, will depend upon the soil characteristics and will greatly influence the total investment and economics of windpump irrigation. The side embankments are generally 2 m wide at the base and 1 m wide at the top. A 50 mm diameter flexible hose syphon is used to deliver water to adjoining field channel. It gives a flow of 4 litres/sec.

2.4 OUTPUT OF THE WIND PUMP

The standard 12 PU 500 Windpump water output is merely governed by average hourly windspeed and the depth over which the water has to be lifted. As stated earlier the crank radius has to be adjusted according to the wind speed range in order to get the best performance. The table below provides the water output data for different values of windspeed at a pumping head of 10 metres :

Wind speed (m/sec.)	Flow rate for different crank radius (litres/sec.)		
	R1 160 mm	R2 190 mm	R3 120 mm
2 5	0.6	—	—
3.0	0.8	1.2	1.4
3.5	1.0	1.6	2.1
4 0	1.3	2.0	2.5
5.0	1.5	2 5	3.0
6 0	1.6	2.9	3.5
7.0	1.8	3.3	4.1
8.0	2.1	3.7	4 6
9.0	2.3	4.0	5.2
10.0	2 6	4 5	5.7

R1. R2, R3, the different crank radii, correspond to stroke lengths whose respective values are 120 mm, 180 mm, and 240 mm Windspeed discharge curves for four different elevation heads and different crank radii given vide Annexe-III. The shaft power generated at different wind speeds is given below :

Wind speed (m/sec)	Rotor velocity (r. p. m.)	Shaft power (Watts)
2.	15	20
3.	24	120
4.	31	280
5.	40	560
6.	46	9700
7.	53	1520
8.	60	2250

3.0 THE MANUFACTURING PLAN

The wind pump design is far from conventional in order to avoid undue sophistication in the manufacturing process and limit the variety of fabrication materials. Practically an all steel structure. It can be made using following general fabrication equipment :

1. Electric are welding set (30 welding transformers etc.)
2. Power hacksaw.
3. Drill machine.
4. Pedestal grinder.
5. Plate rolling machine.
6. Turning lathe.
7. Common hand-tools.

Depending upon experience and skill of production the fabrication of a standard 12 PU 500 windmill requires 200 to 300 man-hours. Help-devices or manipulators have been developed for rotor and head construction. These devices not only help in reducing the fabrication time but also ensure precision and standardisation in the fabrication work (refer Annexure IV). Further a test-rig has also been developed for quality control and checking of pump assemblies. It mainly consists of a standard tower mounted over a 3-4 m deep and 1.5 m diameter masonry sump, an auxiliary air chamber and a 5 H. P. synchronous electrical motor feeding power to a standard head and crank mechanism. Each pump is attached to the air chamber and tested continuously for three different values each of the elevation, head, stroke and rotational speed.

A workshop shed of 10 m × 20 m size is needed to turn out 50 to 70 wind pumps every month and provide some storage space for raw-materials and hardwares.

Under the technology transfer programme, IERT helped over half a dozen public institutions to start windpump manufacturing activity. Manpower development was also taken up to sustain newly coming up manufacturing units and through them the regional production programme. Private groups also joined the efforts. It is redeeming to observe that a number of manufacturing units are operating successfully and meeting the regional windpump demand.

4.0 THE APPLICATIONS :

4.1 General.

Windpumps hold prospects for application for diverse end uses like :

1. Drinking water supply.
2. *Irrigation.*
3. Fish-rearing.
4. Brine-pumping in salt-pans.
5. Sewage-pumping.

Of the above the experience of windpumps in Micro-irrigation is fairly extensive. However, the methodology of site selection, installation and maintenance is common to a great extent for other end uses as well. Before selecting a windpump site following data is required :

(i) Meteorological : Mean hourly wind-speeds for as many years as possible (but at least one full year), location and height of the measuring station, evaporation, precipitation and temperature data.

(ii) Geo-Hydrological : Water sources in the area and their capacities, in case of ground water average monthly depths of water-table, for at least one full year, water quality and soil characteristics in respect of engineering and agricultural uses both.

(iii) Socio-Economic : Land-holding pattern, cost of irrigation water from other devices in the area, draught-animal and their deployment.

(iv) Infrastructural : Financing institutions, technical backup services, transport and communication etc.

4.2 **Site Considerations :**

Water pumping windmills can be installed on open wells, bore-wells, near canals, ponds, streams, creeks etc. The windpump site should be free of obstructions of not more than 4 m height in a radius of 100 m. If the obstructions cannot be removed the height of the windmill tower has to be suitably increased or the site abandoned. In case of installation over open well, the well diameter should be less than 2.25 m i.e. the pitch of the tower legs. If the well diameter is more then bridge-supports have to be made for supporting the tower legs. Refilling capacity of the well should not be less than 25 cubic meter per hour, otherwise suitable augmentation measures have to be taken. In case of a bore well a masonry pit of 1.5 m diameter and of suitable depth has to be constructed. The suction and delivery heads, together, should be under 20 m and the pump should be installed as close to the water-table as possible to minimise leakage losses.

4.3 **Maintenance Schedule:**

The preventive maintenance of the windpump 12 PU 500 is neither complicated nor expensive Routine check-up lubrication and replacement of certain worn-out parts can assure good service over years. A detailed maintenance schedule has been prepared to provide guidence in this regard.

4.4 **Economic viability :**

The economic viability of windpump, as an irrigation device, is a complex issue due to a number of variables upon which it depends, for instance :

— Wind regime
— Geo-hydrological and climatic conditions.
— Farmers adaptibility in respect of crop adjustment and other innovative measures (like fish rearing and blue-green algae cultivation in the storage tank)
— Techno-socio-economic conditions of other irrigation devices in the area and their reliability.

The low reliabiilty of the windpumps, in terms of assured supply of irrigation water, is more than compensated by several uncertainties prevailing with other irrigation devices, the cost of unit quantity of water and the policy support (if available). A comparative cost structure of three alternative devices of irrigation viz. wind pumps diesel-pumps and Electric-Pumps is given vide Annexe-V for sets of 4 different conditions, which are : without subsidy, with 25% subsidy, with 33% subsidy and with 50% subsidy. It would appear from this comparison that wind pump and electrical pumps, only on the basis of unit water cost consideration, are at par. But a detailed consideration of hidden factors like long gaestation periods in setting up power plants and laying transmission-distribution lines, supportive infrastructure and its cost, requirement of technical back-up, erratic power supply, employment generation and a host of other unquantified factors will easily tilt the scale in favour of windpumps. Besides these the biggest question is the availability of electricity itself. Further shallow depths leading to higher windpump output, lower evapo-transpiration by better crop and water management, will not only reduce the windpump water cost but also enhance the command area In this limited presentation a detailed discussion of these aspects is not possible. It should be clearly understood that the wind ump irrigation management is founded upon realisation of a chain of related factors and its economics should be worked out by detailed study and evaluation of these factors in an integrated manner.

5.0 **THE FOLLOW-UP**

5.1 **General**

As mentioned in the foregoing nearly 1000 windpumps were installed by IERT upto 1985. On one hand this alternate energy technology came to stay and received good encouragement from all quarters, but on the other hand a number of problems came up which seriously threteaned the survival of this technology.

As information on growing number of inoperative or malfunctioning windpumps came, it became imperative to device a plan for detailed study of the status of the installed windpumps, exact nature of problems, identification of causes and possible remedial measures. Accordingly at the instance of the Department of Non-Conventional Energy Sources, Government of India, the Regional Wind Energy Test Station at IERT, Allahabad took-up shortly after its inception in July, 1987, a statistical survey of 12 PU 500 windpumps for evaluation of their performance, breakdown, component failures, their causes etc. The survey covered about 20% of the windpumps installed under various demonstration projects in different agro-climatic regions of the country. Besides collecting data through site inspection series of group discussions were held with the designers engineers, technicians, field-staff beneficiaries etc. to elicit as much information as possible. The summary of the finding of this survey was that most of the failures were due to factors like improper site selection, bad fabrication, design defects grossly inadequate preventive maintenance, repairs and replacements. The exercise elucidated a number of remedial measures minimise unsuccessful cases. It is heartening to note to that some of these measures have already been implemented or are underway. To quote the important ones :

(i) Preparation of detailed design document.
(ii) Preparation of User's guide-book.
(iii) Manpower development programme.
(iv) Establishment of windspeed monitoring stations.
(v) Development of a new prototype to overcome design defects and to improve the performance.

5.2 **The New Prototype** :

As a result of step number (v), quoted above, a new prototype named AEROPUMP has been developed. It is a vastly improved and sturdy machine. The salient features of the AEROPUMP are as follows :

TOWER

Completely knock-down, 3 legged, tubular, self-supporting tower simplifies erection alignment, providing inter-changeability of components and stability of the structure, suitable to withstand wind velocity upto 160 kilometers per hour.

TRANSMISSION SYSTEM

Improved mechanical power transmission system incorporates reinforced connecting rod, self lubricating and durable polypropelene crosshead, self adjusting polypropelene guides for pump extension rod and ball and socket joint to take case of misalignment to a certain degree.

ANTICORROSION MEASURES

90 percent zinc rich primer and subsequent coating of synthetic enamel paint, comparable to galvanic treatment, makes the blades and the blade supports suitable to withstand corrosion even in saline atmosphere

SECURITY MECHANISM

Special material has been used for security mechanism, ratchet and knife-edge to reduce wear and tear and also simple arrangement to replace them.

ROTOR

Newly designed Rotor, incorporating three rings (as against two presently) to avoid blade bendings, the rings are in two pieces only to check instability.

PUMP

New Windmill pump with C.I. Cylinder has following specialities :

* Light in weight
* Accurately machined and honed cylinder gives uniform bore eliminating the ovality which is almost impractible in the cases of cylinders made the out of M. S. pipe.
* Clearance between the bore and the piston has also been reduced to 0.5 mm uniformly.

- The cylinder being made of cast iron, ensures longer operational life and makes it rust resistant.
- Spherical suction valve makes it leakage free.
- Totally metallic suction valve assembly offers long life and trouble free service.
- Completely knock down design simplifies maintenance.
- Detachable suction valve of the pump makes the inspection of the suction valve and piston of the pump easier and simplifies the replacement, if necessary, unlike the old system where complete heavy pump is to be taken out of well for even petty repairs.
- Can be installed above the well (provided in any condition water level below pump is not more than 7 meters), integrated with tower structure so that pump axis combines with the axis of tower pipe thus eliminating misalignment problems.

5.3 Bullock-drive attachment :

Another aspect, which has been given consideration from viewpoint of augmenting deficit of windpump output during low windperiod of winter seasons, and maintaining the irrigated area, is supplementing wind energy by draught-animal power using a pair of bullocks. A bullock drive attachment has been developed, by the R W. E. T. S , by means of which the wind pump is driven by a pair of bullocks moving on a circular path harnessed to a gear-train, a crank mechanism and other suitable linkages of an alternative transmission system. Preliminary trials have indicated the soundness of the new supplementary device. Detailed study is in progress for data analysis and extension of the technology to the field.

6.0 STRATEGIES FOR THE FUTURE :

The foregoing account of the feedback, broadly speaking, indicates an exercise in upgradation of the technology for greater reliability and some documentation as a part of the system package. No doubt a sound technology is the starting point, but on the application side there are still some imponderables which merit serious efforts on the part of technologists, planners and implementors.

Arising out of author's own involvement and experience, in the early stages of the wind energy programme, it will be pertinent to add, that one crucial factor which unfortunately received little attention, is the aspect of use of windpump as an irrigation device and its all associated factors influencing agricultural production. Early trials of windpumps had given clear signals on the need of thorough evaluation of the interplay of four factors viz crop, soil, water, and wind regime. The peculiarity of the dynamics of these factors is the main determinant for the success of windpump for which this programme was initiated. It would therefore, be of paramount importance in the author's opinion, to formulate strategies incorporating, alongwith the above, the following issues :

(1) To start windpump irrigation action research projects in as many typical agro-climatic and wind regime zones as possible, covering the inter-relationship of the aforementioned four factors, within which the focus should be on :

(a) agronomic extension like manipulation in cultural practices, inter-croping, mixed-croping, use of early sowing and/or drought-restraint varieties, their marketibility, subsistance needs of farmers etc.

(b) optimisation of economic benefits of the windpump irrigation system through use of innovative measures like algae-production and fish rearing in the storage tank, reduction in field losses etc.

(ii) To prepare a well chalked out awareness programme spacifically for farmers and financing institutions.

(iii) To prepare technical and users' literature, both in regional languages.

(iv) To develop deepwell pumps without execessive power requirement.

(v) To develop alternative windpump designs optimising agro-climatic and wind-regime requirements of different regions.

(vi) To install substantial number of wind monitoring stations.

I earnestly hope that those at the helm of the decision making apparatus will catch the spirit of these suggestions before the wind is out of the sails or the high winds of traumatic changes overtake us.

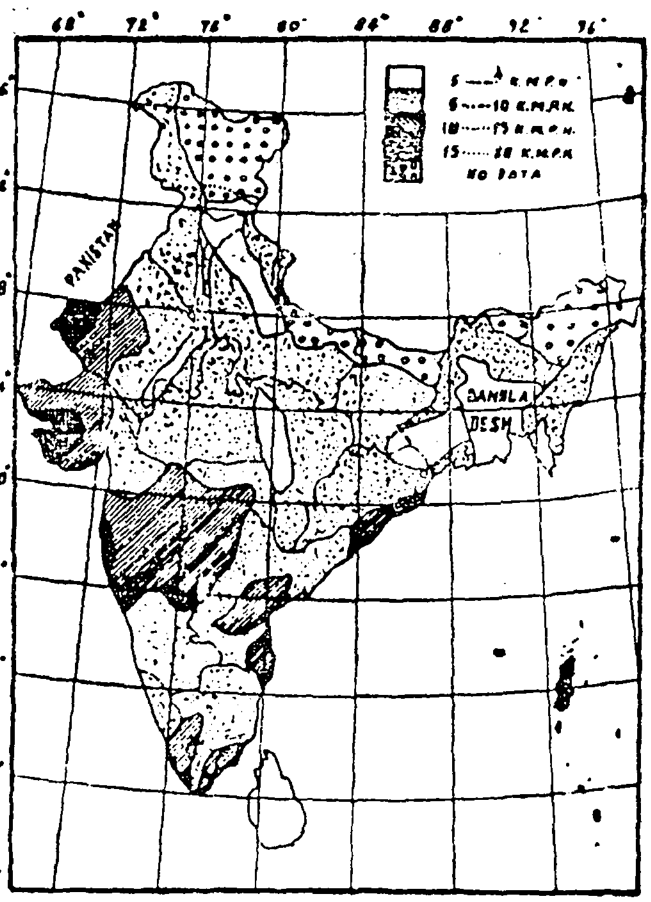
ANNEXURE—I

ESTIMATES OF WIND ENERGY POTENTIAL

Sl. No.	State	Estimated wind energy 10^9Kwh	Electricity consumption during 1978-79* 10^9Kwh
1.	Andhra Pradesh	30.93	4.20
2.	Bihar	7.38	4.34
3.	Gujarat	27.02	6.85
4.	Haryana	2.80	2.41
5.	Kerala	3.24	2.42
6.	Madhya Pradesh	21.04	4.28
7.	Maharashtra	21.25	12.85
8.	Meghalaya	1.26	0.04
9.	Orissa	8.49	2.42
10.	Punjab	2.77	4.73
11.	Rajasthan	23.97	2.60
12.	Tamilnadu	15.23	8.18
13.	Uttar Pradesh	13.13	7.69
14.	West Bengal	2.04	5.97
	TOTAL	180.55	68.98

* Central Electricity Authority, Commercial Directorate, 1980.

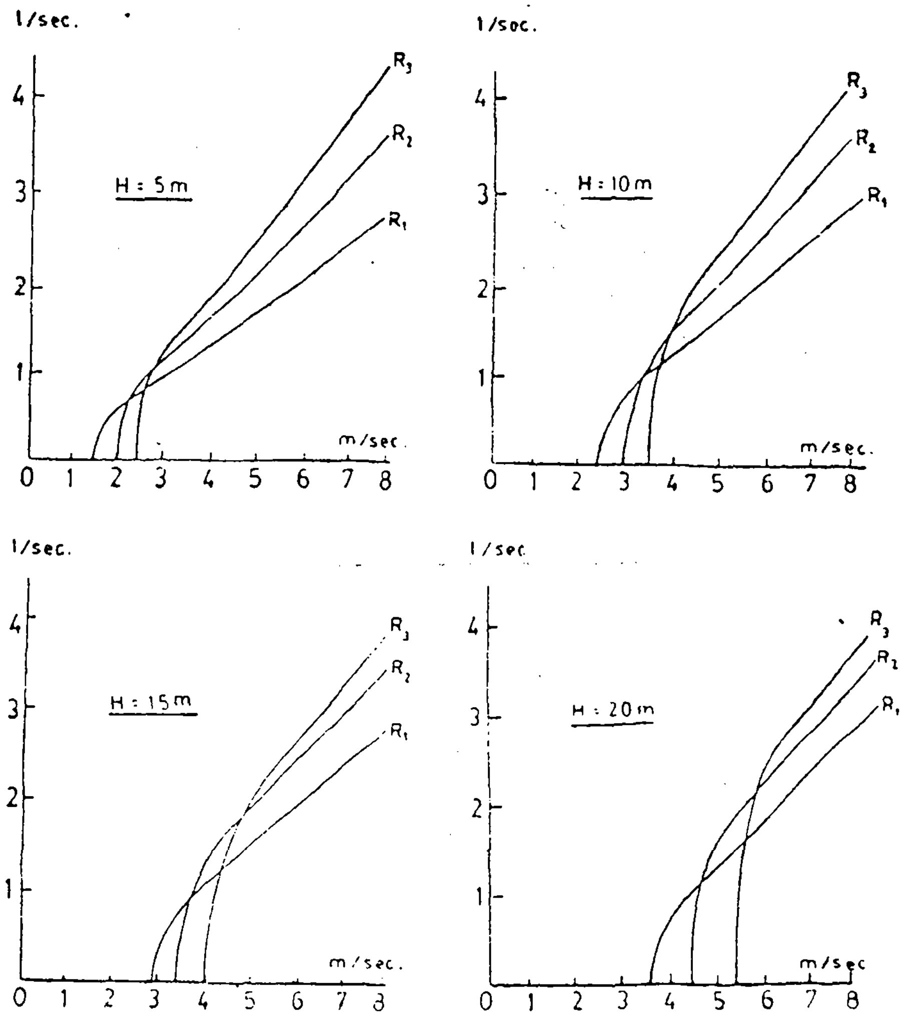
ANNEXURE—II



ANNUAL MEAN WIND SPEED IN INDIA

ANNEXURE—III

Discharge in litres per second (corresponding to crank radii R_1 R_2 and R_3) versus prevailing wind velocity (V) in metres per second at different elevation heads.

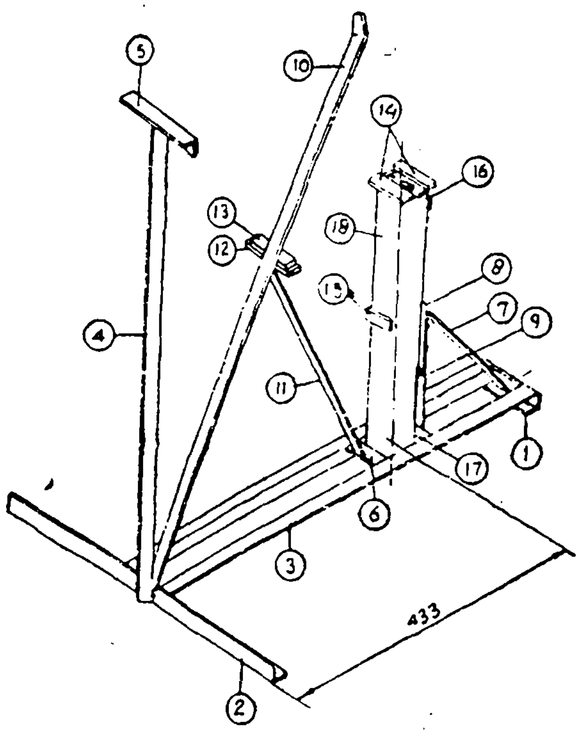


H = ELEVATION HEAD

R_1 = 60 mm
R_2 = 90 mm
R_3 = 120 mm
} CRANK RADII

ANNEXEURE—IV (a)

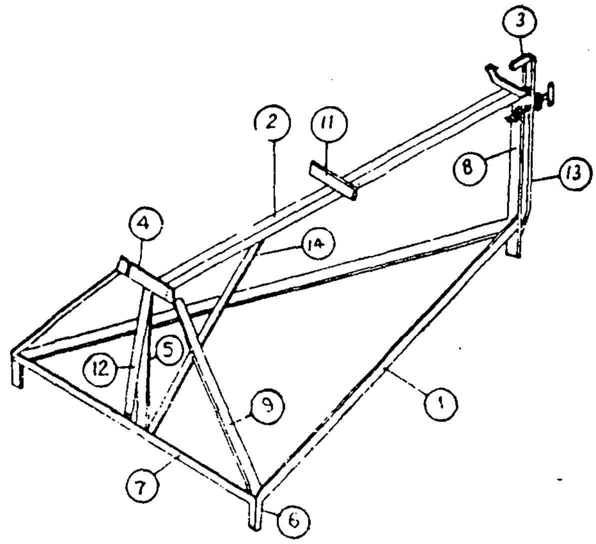
WELDING FIXTURE FOR HEAD CONSTRUCTION
12 PU 500



S. No.	No.	MATERIAL	LENGTH
1	1	ANGLE 40×40×4	220
2	1	,, ,,	608
3	2	,, ,,	645
4	1	,, ,,	1855
5	1	,, ,,	259
6	2	,, ,,	112
7	1	FLAT 30×6	2 5
8	1	,, ,,	270
9	1	,, ,,	300
10	1	,, ,,	1168
11	1	,, ,,	335
12	1	,, ,,	118
13	1	,, ,,	110
14	2	,, ,,	112
15	1	,, ,,	180
16	2	,, ,,	100
17	4	FLAT 25×3	30
18	1	4″ PIPE	

ANNEXURE—IV (b)

HELP DEVICE FOR ROTOR ASSEMBLY 12 PU 500



S. No.	No.	MATERIAL	LENGTH
1	2	ANGLE IRON 30×30×2	1940
2	2	,, ,, ,,	1940
3	1	,, ,, ,,	57
4	1	,, ,, 45×45×5	250
5	1	,, ,, ,,	508
6	3	,, 30×30×2	110
7	1	,, 45×45×5	1000
8	1	FLAT IRON 30×6	658
9	2	,, ,, 30×6	625
10	1	ANGLE IRON 30×30×2	70
11	2	FLAT IRON 25×3	300
12	1	,, ,, 25×3	418
13	1	,, ,, 25×3	640
14	1	,, ,, 30×6	660

ANNEXE—V

Table : **Comparative cost structure of three alternative devices of irrigation.**

S. No.	PARTICULARS	WINDPUMP	DIESEL PUMP	ELECTRIC PUMP
1.	Size of irrigation device.	12 PU500	5 H. P.	5 H.P.
2.	Working Life of the device (years)	15	15	15
3.	Init. investment (Rs) released by the farmer.			
	(a) without subsidy.	15,000.00	14,000.00	11,550.00
	(b) with 25% subsidy.	11,250.00	10,650.00	8,662.50
	(c) with 33% subsidy.	9,900.00	9,372.00	7,623.00
	(d) with 50% subsidy.	7,500.00	7,100 40	5,775.00
4.	Annual Maintenance cost.	300.00	350.00	350.00
5.	Annual Operational cost.	Nil	1 312.00	780.00
6.	Annuity factor @12% interest for 15 years.	0.1468	0.1468	0.1468
7.	Annual cost due to investment (Rs.)			
	(a) without subsidy	2,202.00	2,084.56	1,695.54
	(b) with 25% subsidy	1,651.50	1,563.42	1,271.65
	(c) with 33% subsidy	1,453.32	1,375.81	1,119.05
	(d) with 50% subsidy	1,101.00	1,042.28	897.77
8.	Total annual cost (Rs.) (4+5+6)			
	(e) without subsidy	2,502.00	3,745.56	2,825.54
	(b) with 33% subsidy	1,753.32	3,037 81	2,249.05
	(c) with 25% subsidy	1,951.50	3,225.42	2,401.65
	(d) with 50% subsidy	1,401.00	2,704.28	1,977.77
9.	Cost percubic meters water (Rs.)			
	(a) without subsidv	0.14	0 37	0.13
	(b) with 25% subsidv	0.11	0.32	0.11
	(c) with 33% subsidy	0.10	0.30	0.10
	(d) with 50% subsidy	0.08	0.27	0.09

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