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PRINCIPAL INVESTIGATOR'S REPORT

OF AD-HOC SCHEME ON

Design and Development of Wind Turbines and its Feasibility Studies in Kerala.

All India Co-ordinated ICAR Scheme on ' Renewable Sources Of Energy for Agriculture and Agro-based Industries

For Presentation at the Fourth Annual Workshop

To be held at

Central Arid Zone Research Institute,

Jodhpur

February 2-4, 1987

DEPARTMENT OF FARM POWER, MACHINERY & ENERGY

FACULTY OF AGRICULTURAL ENGINEERING & TECHNOLOGY, KCAET

KERALA AGRICULTURAL UNIVERSITY

TAVANUR - 679 573.

ACKNOWLEDGEMENT

Sincere thanks are due to the Indian Council of Agricultural Research for Sanctioning an Ad-hoc. Scheme on "Design and Development of Wind Turbines and its feasibility studies in Kerala" in the Department of Farm Power, Machinery & Energy at Agricultural Engineering College, KAU, Tavanur, under All India Co-ordinated scheme on Renewable sources of Energy for Agriculture and Agro-based Industries. The encouragement, guidance and Co-operation received from Director of Research, KAU to carry out related research work is gratefully acknowledged. Thanks are also due to all the Scientists, Teachers, Technical and Administrative Staff who have helped in preparation of this report.

GENERAL INFORMATION

1.	Project Title	: Design and Development of Wind Turbines and its feasibility Studies in Kerala.
2.	Sanction No.	: 1-1/84-AE dt. 8-7-1985
3.	Date of Start	: 1 - 1 - 1986
4.	Report Period	: 1 - 1 - 1986 to 31 - 12 - 1986
5.	Time for complition of project	: 3 years
6.	Name of the Institution	: Kerala Agricultural University
7.	Department	: Farm Power, Machinery & Energy
8.	Location	: Kelappaji College of Agricultural Engineering & Technology, TAVANUR - 679573.

9. Technical Personnel employed:

a) Principal Investigator : Prof. C.P. Muhammad.

b) Staff Position.

Sl No.	Name and Designation	Date of joining	Total No. of Months spent during report period.
1.	Hamza Mollakadavath Research Associate.	7-4-1986	9 Months
2.	M. Sivadasan Technician	19-5-1986	7 Months

Total amount sanctioned by ICAR = Rs. 2,46,200/-

Allotment for the 1st year = Rs. 1,59,900/-

Expenditure upto 31 - 12 - 1986

Salary	=	15,335.50
Non - Recurring	=	5,965.30
Total		21,300.80

DETAILS OF POSTS SANCTIONED

Sl. No.	Category	Pay Scale	No. of Post	Remarks
1.	Research Associate (Degree in Mech/Agrl. Engineering)	Rs. 1000/- pm (Consolidated)	1	
2.	Research Associate (Agrl. Meteorology)	Rs. 900/- pm (Consolidated)	1	Vacant
3.	Technician	Rs. 800/- pm (Consolidated)	1	

1. KAU Wind Turbine Research

1.1 Introduction

The Scientists and Engineers all over the world are trying their best to utilise the available external sources of non-conventional energy as the rate of depletion of conventional fossil fuels is alarmingly high. Wind energy is one of them. Different types of Wind Mills and turbines are developed to produce energy from wind power and still research is going on ICAR has sanctioned an Ad-Hoc Scheme entitled "Design and Development of Wind turbines and it's feasibility studies in Kerala" for a period of 3 years to K.A.U & the work being carried out in the department of Farm Power, Machinery & Energy.

1.2 OBJECTIVES

The ultimate objective of the project is to substitute a major part of the energy required for pumping water in Kerala State with the wind energy. In specific, the chief objectives of the project are

a) To conduct analytical studies to work out the possibilities and potential of using wind power for Agricultural uses.

b) To conduct comparative studies of various existing wind turbine prototypes.

1.3 Practical Utility:

Potential for wind energy utilization in many parts of Kerala is very high and varied. If wind energy can be utilized effectively and economically for pumping water for irrigation, that leads to considerable saving of electrical energy. If a low costwind turbine can meet the irrigation needs of a small farmer, that is a significant outcome of this research scheme.

1.4 Wind Data

One of the objectives of the scheme is to bring out the feasibilities of wind turbines for water pumping and other Agricultural operations for which wind data are being collected It is true that wind speed is not in the economical range in ma parts of Kerala while it is very much possible in certain parts of the state to use wind turbines.

The data collected from Tavanur, the centre of investifati and the near by places are shown in table 1.1, to 1.3.

The wind data for other stations in Kerala are also reviewed and reproduced in table 2.1 to 2.7.

TABLE NO. 1.1 WIND VELOCITY DATA FROM Ist AUGUST 1986 to DECEMBER 1986 AT TAVANUR (Kms/Hr)

DATE	AUG	SEP	OCT	NOV	DEC
1	3.9	5.8	3.7	4.5	5.7
2	4.0	4.4	6.4	4.2	8.3
3	4.2	6.1	6.7	3.0	6.7
4	8.8	4.4	2.8	2.8	8.3
5	7.0	5.0	5.6	4.3	7.5
6	6.7	5.2	1.6	4.8	5.7
7	8.7	3.8	3.0	5.5	6.9
8	5.1	5.5	4.0	5.5	4.3
9	7.9	6.8	3.3	6.1	3.0
10	6.4	6.5	4.0	3.5	2.3
11	2.7	6.3	4.8	3.3	3.7
12	2.7	5.5	4.6	3.3	4.7
13	2.3	7.6	5.0	3.4	3.6
14	4.0	1.9	3.1	3.1	3.8
15	3.9	4.3	3.0	2.9	3.2
16	5.4	4.7	4.1	3.8	4.0
17	4.8	4.6	4.1	2.5	4.5
18	8.8	3.9	4.7	2.9	5.4
19	8.8	4.0	2.7	3.1	3.4
20	10.6	5.7	5.0	2.9	4.7
21	10.8	4.6	2.2	5.3	4.4
22	7.1	3.9	2.6	1.5	3.9
23	15.8	3.5	3.7	4.9	7.6
24	5.6	3.3	4.3	4.7	2.3
25	4.8	4.2	2.8	4.4	1.9
26	3.2	1.8	4.1	4.6	11.4
27	4.2	4.0	3.3	4.1	5.1
28	7.1	7.3	4.1	6.1	5.2
29	4.2	4.0	3.0	4.3	5.0
30	2.5	3.4	3.4	9.4	6.3
31	4.5	3.5	3.6	9.1	6.0

TABLE NO. 1.2. WIND VELOCITY DATA FROM 1st JANUARY 1986 to DECEMBER 1986 AT VELLANIKKARA (Kms/Hr)

DATE	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC
1	13.32	4.67	7.42	5.79	5.38	7.29	3.54	7.41	5.33	5.04	5.13	21.67
2	14.92	5.71	9.46	6.17	4.67	5.79	5.5	6.67	5.04	4.5	1.63	19.79
3	12.54	8.46	10.38	6.17	5.25	5.13	4.33	7.29	5.21	4.83	3.5	19.5
4	10.71	10.83	12.21	5.46	6.13	5.58	4.75	5.83	5.83	3.88	3.46	17.63
5	11.38	11.21	9.75	5.67	5.13	7.0	5.25	4.75	6.17	4.13	4.33	15.13
6	18.42	9.42	10.71	6.21	7.79	5.17	6.38	9.38	5.13	3.46	4.0	14.21
7	16.66	10.95	10.38	5.21	4.71	5.17	6.42	5.79	5.63	4.25	4.46	9.54
8	11.46	7.75	7.83	6.33	6.25	6.42	5.88	8.42	5.96	3.79	7.92	8.88
9	10.17	8.92	13.83	6.17	6.29	6.41	5.87	7.04	6.92	3.54	4.0	6.71
10	12.83	9.17	22.00	5.96	7.38	4.83	5.5	4.54	6.17	4.04	4.83	12.33
11	10.58	7.92	14.21	5.88	7.63	7.13	7.25	6.13	4.58	3.88	3.29	6.88
12	15.71	6.67	6.89	5.75	8.0	8.58	5.42	5.92	4.79	4.75	3.25	8.46
13	12.92	4.79	6.46	5.04	7.29	5.54	6.17	6.25	4.83	3.45	2.58	7.63
14	7.96	5.17	5.54	6.75	4.71	9.42	5.58	5.92	4.67	3.0	3.88	8.08
15	4.88	5.29	5.89	6.63	7.25	4.29	5.29	6.04	4.79	3.33	8.08	11.04
16	6.17	5.92	4.96	6.29	6.5	3.83	6.42	7.21	4.42	3.79	4.04	14.04
17	6.38	5.92	5.92	5.63	6.0	4.88	6.79	9.42	5.0	3.79	3.92	15.08
18	6.17	5.29	4.63	6.63	6.25	4.5	7.25	7.67	4.79	4.42	4.54	10.42
19	6.08	5.46	5.5	5.75	6.33	4.42	7.29	7.79	7.08	2.5	8.58	18.92
20	8.33	7.00	4.42	5.67	6.86	6.25	4.63	7.17	4.88	3.29	9.42	15.92
21	19.79	10.33	5.13	6.29	6.88	7.75	5.46	8.42	3.5	4.55	9.0	17.08
22	21.04	10.75	4.58	6.5	6.21	6.75	6.96	7.92	3.58	5.0	8.29	17.25
23	16.13	9.17	5.63	5.25	5.38	8.0	5.25	7.5	4.71	3.83	6.42	16.29
24	13.21	9.38	5.5	5.75	5.83	3.5	5.88	5.08	5.42	2.79	14.25	14.79
25	18.13	15.71	5.04	6.42	6.25	4.88	4.71	4.42	3.92	3.92	11.38	12.04
26	15.04	14.45	5.25	5-0	5.42	4.83	4.96	5.29	3.79	2.92	10.88	13.08
27	18.21	16.96	7.0	6.88	5.78	6.17	3.88	6.08	4.58	3.83	14.79	18.29
28	15.71	10.21	6.21	4.46	4.8	3.71	4.33	5.54	3.88	3.33	17.96	19.75
29	11.54	9.48	6.46	5.79	2.79	4.17	5.13	5.0	3.71	3.83	19.95	14.79
30	6.83	12.65	6.67	6.79	7.58	3.75	6.71	6.75	4.71	2.42	14.58	11.08
31	5.05	11.60	6.5	6.50	4.38	4.0	6.83	4.58	4.50	3.88	13.90	10.8

TABLE NO. 1.3. WIND VELOCITY DATA FROM 1st JANUARY 1986 to DECEMBER 1986 AT PATTAMBI (Kms/Hr)

DATE	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV	DEC
1	4.0	2.1	3.7	4.5	3.1	3.4	2.3	3.7	4.5	4.0	1.8	7.7
2	3.4	1.4	2.4	3.7	2.3	3.2	1.9	5.3	3.7	3.1	3.1	7.2
3	3.2	2.4	3.1	3.9	3.4	3.7	3.5	5.5	3.7	2.4	1.3	6.4
4	3.4	2.4	4.3	4.0	1.8	3.7	2.1	5.8	3.1	3.4	2.1	7.1
5	2.7	1.8	4.3	3.5	2.3	3.9	4.2	4.3	3.7	2.9	2.3	4.7
6	2.6	2.4	4.2	3.9	3.5	3.2	4.0	4.5	3.5	3.2	2.4	4.0
7	5.6	3.9	4.0	3.9	4.0	2.7	5.3	6.1	3.1	2.1	2.4	6.6
8	4.0	3.2	4.2	3.7	3.5	2.7	4.0	5.0	4.5	2.6	1.8	3.1
9	3.5	1.9	2.7	3.9	3.7	2.8	3.7	6.9	4.5	2.6	2.9	2.7
10	3.5	4.2	5.6	4.0	5.0	2.7	3.4	4.2	4.3	2.9	1.8	1.6
11	2.3	3.5	7.9	4.2	5.3	2.7	4.2	3.7	4.3	2.9	2.1	2.7
12	1.9	3.4	4.7	4.0	5.8	3.7	3.7	3.4	4.0	2.3	1.8	2.9
13	3.4	2.7	3.4	3.7	5.0	4.8	1.8	3.9	4.2	2.9	1.8	2.4
14	2.9	0.5	2.6	3.2	2.4	2.7	2.7	4.8	3.7	2.1	2.1	2.4
15	2.7	2.4	3.1	4.0	2.9	1.3	2.3	4.0	3.2	2.3	1.0	1.9
16	2.3	2.6	3.2	3.5	3.9	0.6	2.9	4.7	2.9	2.6	1.3	2.3
17	2.7	3.1	3.7	4.0	3.5	1.1	3.7	5.6	3.4	3.2	1.0	3.5
18	3.4	3.2	3.7	4.3	4.2	2.4	4.8	6.1	3.4	2.9	1.0	5.5
19	3.2	2.6	3.1	4.8	4.0	1.6	4.7	6.3	2.9	2.3	2.1	2.4
20	2.7	2.9	3.1	3.1	5.3	2.1	6.0	5.8	4.2	1.4	2.4	6.0
21	2.1	2.6	2.7	3.9	4.5	1.8	2.4	7.2	3.2	0.6	2.6	3.5
22	5.3	3.4	3.4	3.4	3.3	3.1	3.4	5.6	1.1	1.3	2.3	6.1
23	7.9	3.5	2.9	4.3	3.9	2.6	4.3	4.8	2.6	1.8	1.8	7.7
24	5.1	4.3	3.5	3.1	3.7	4.7	3.9	5.5	2.1	2.6	2.4	6.0
25	3.4	4.0	3.4	2.9	4.7	1.4	3.9	3.7	2.7	1.4	2.1	4.3
26	5.0	5.8	3.4	3.5	3.1	2.9	2.9	3.7	2.1	1.3	3.9	4.7
27	5.0	5.8	3.1	1.9	4.2	2.3	3.9	5.3	2.3	2.1	3.4	5.1
28	5.3	6.1	3.5	2.6	3.7	1.1	3.5	4.5	2.3	1.9	3.8	6.0
29	6.4	6.1	3.4	2.7	2.4	0.5	3.7	3.7	2.1	1.1	3.5	6.1
30	4.0	6.2	4.5	2.4	5.6	2.4	4.2	3.4	3.1	2.6	8.5	6.8
31	2.4	5.8	3.9	2.5	2.7	2.5	5.5	4.2	3.2	1.4	8.4	3.7

800568

TABLE NO. 2.1 MEAN WIND SPEED (kmph) AT ALLEPPEY BASED ON DATA FROM 1958 TO 1967

Hours (1ST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0830	5.7	4.9	5.2	4.8	7.7	9.1	9.2	7.8	6.9	6.1	5.6	5.7
1730	17.7	19.4	21.5	19.9	19.9	17.1	17.5	18.2	17.4	16.1	15.5	15.3
W	9.9	10.8	12.3	11.7	13.4	12.2	11.7	11.2	11.1	9.6	9.4	8.6
W_1	13.9	16.1	17.8	15.9	16.3	13.5	13.3	14.1	14.4	13.4	12.7	12.0

TABLE NO. 2.2 MEAN WIND SPEED (kmph) AT CALICUT BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0530	7.3	5.4	4.9	4.5	5.8	7.0	7.9	5.1	4.7	5.2	5.8	6.5
0830	6.8	5.2	4.3	3.5	5.5	5.6	5.3	4.3	4.5	4.3	5.1	5.9
1130	7.3	7.5	8.7	8.0	9.7	8.9	8.3	7.0	8.7	8.1	7.3	6.5
1730	11.1	12.3	13.5	11.8	11.8	10.1	9.7	9.5	10.0	8.8	9.0	9.6
2330	5.7	5.1	8.3	7.9	10.0	7.4	8.5	5.7	5.8	5.7	4.5	4.3
W	9.4	10.9	12.1	11.8	12.8	9.3	9.2	8.3	8.9	8.3	7.8	7.9
W_1	11.5	12.3	14.6	14.3	15.0	10.8	10.1	9.7	11.1	10.4	9.6	9.5

TABLE NO. 2.3 MEAN WIND SPEED (kmph) AT COCHIN AIRPORT BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DE
0230	1.7	1.4	2.1	2.7	4.1	4.8	4.5	3.8	2.7	2.5	2.3	2.
0530	2.6	2.1	2.1	2.3	3.4	4.5	4.4	3.3	2.5	2.2	2.1	2.
0830	5.1	4.5	4.4	4.3	5.1	4.7	4.7	4.0	3.7	3.2	3.9	4.
1130	7.2	8.4	11.3	10.9	11.9	8.6	9.2	11.6	11.8	8.9	7.5	6.
1730	13.6	16.3	18.0	16.2	14.3	10.2	11.1	12.7	11.8	10.5	9.7	10.
2330	2.5	1.8	3.5	5.4	5.3	4.8	4.8	4.1	4.2	2.7	3.0	2
W	7.7	7.8	9.4	9.3	9.7	7.5	7.2	8.0	7.7	7.6	7.4	7
W_1	10.8	12.0	13.9	12.7	12.0	9.3	9.3	10.7	10.5	10.0	9.6	9

TABLE NO. 2.4 MEAN WIND SPEED (kmph) AT FORT COCHIN BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	D
0830	5.6	5.9	5.2	5.0	5.8	4.8	6.2	5.7	5.7	4.4	4.9	5
1730	8.7	9.9	10.3	9.8	9.7	8.1	8.1	8.9	8.5	7.3	6.3	6
W	8.3	9.2	10.2	9.4	10.0	8.5	9.1	9.5	9.4	8.1	7.4	7
W_1	11.8	13.3	14.7	13.2	13.0	10.7	11.8	12.9	12.4	10.6	10.0	10

TABLE NO. 2.5 MEAN WIND SPEED (kmph) AT PALGHAT BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0830	12.0	9.9	7.8	6.4	9.1	10.4	10.4	10.4	9.9	7.7	8.9	10.8
1730	8.9	9.6	11.3	12.6	12.3	12.6	12.1	12.6	12.9	9.7	7.1	7.4
W	10.0	9.2	8.3	8.5	11.2	12.3	12.6	12.3	11.2	8.1	7.5	9.5
W_1	12.9	12.4	10.5	10.1	14.3	15.3	14.6	15.1	14.4	10.3	9.8	12.7

TABLE NO. 2.6 MEAN WIND SPEED (kmph) AT PUNALUR BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0830	1.2	1.4	0.5	0.9	0.5	1.1	0.8	1.6	0.3	0.6	0.8	1.5
1730	4.9	5.4	5.7	4.7	4.1	4.6	4.7	6.0	5.3	3.6	3.1	4.1
W	4.4	5.4	4.6	3.5	3.1	3.5	3.9	4.5	4.0	3.7	3.0	3.7
W_1	6.2	6.9	6.4	5.2	4.7	5.0	5.9	6.5	6.1	4.7	4.4	5.7

TABLE NO. 2.7 MEAN WIND SPEED (kmph) AT TRIVANDRUM AIR-PORT BASED ON DATA FROM 1958 TO 1967

Hours (IST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0830	4.7	4.3	6.5	7.7	12.8	10.2	12.6	14.4	12.8	8.5	5.3	4.3
1730	-	-	-	-	-	-	-	-	-	-	-	-
W	5.8	6.2	7.3	6.8	9.3	8.7	9.2	10.8	9.0	6.8	5.2	5.1
W_1	-	-	-	-	-	-	-	-	-	-	-	-

W Mean daily wind speed

W_1 Mean wind speed for the period 0830 - 1730 IST.

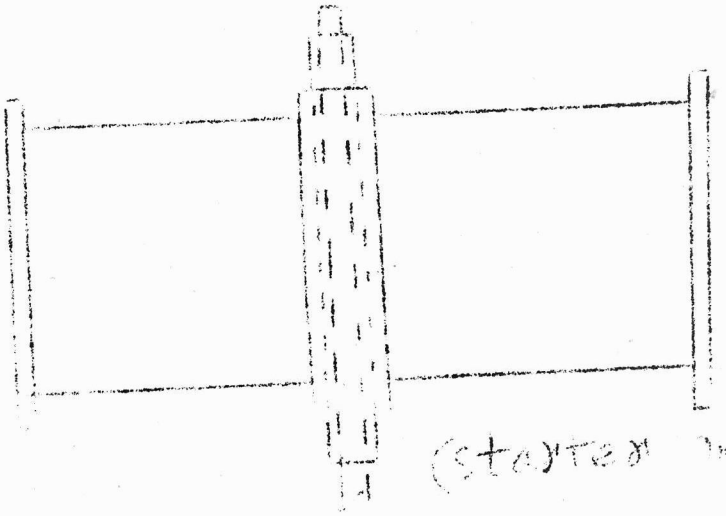
Note: Table 2.1 to 2.7 is reproduced from the Book Wind Energy Data For India by Anna Mani and D.A. Mooley.

2. Investigations:

Literature shows that a wide variety of wind mill designs have been tried all over the world. The power coefficients for the stright bladed cyclogyro, Savonius, 3 bladed horizontal axis and multibladed horizontal axis wind turbine are in the order of 0.4, 0.2, 0.35 and 0.25 respectively. Out of the various models the following models were tried.

2.1 Vertical axis, stright bladed, fixed pitch Cyclogyro:

Although the torque coefficient of this variety of turbines is not attractive, temnted by the higher power coefficient a model having the details shown in fig. 2.1 was fabricated. The primary objective was to use a simple mechanism for starting the turbine and to impart the tip speed for continuous operation. The sail type semi-cylindrical hinged starters provided at $\frac{1}{4}$th arm length from the axis were tried. It was observed that these starters are not big enough to impart the optimum tip speed to the main turbine under load conditions. However if a clutch arrangement for starting the turbine in no load condition till it acquires the required tip speed and then put the load on is provided, these starters show a scope for adoption. Work in this direction is in progress.



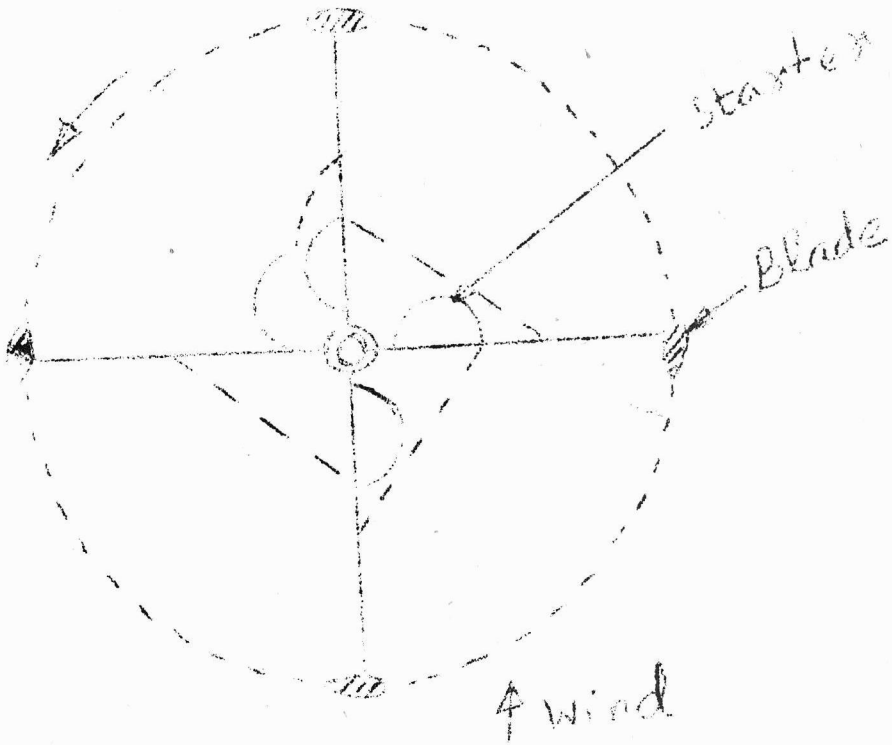
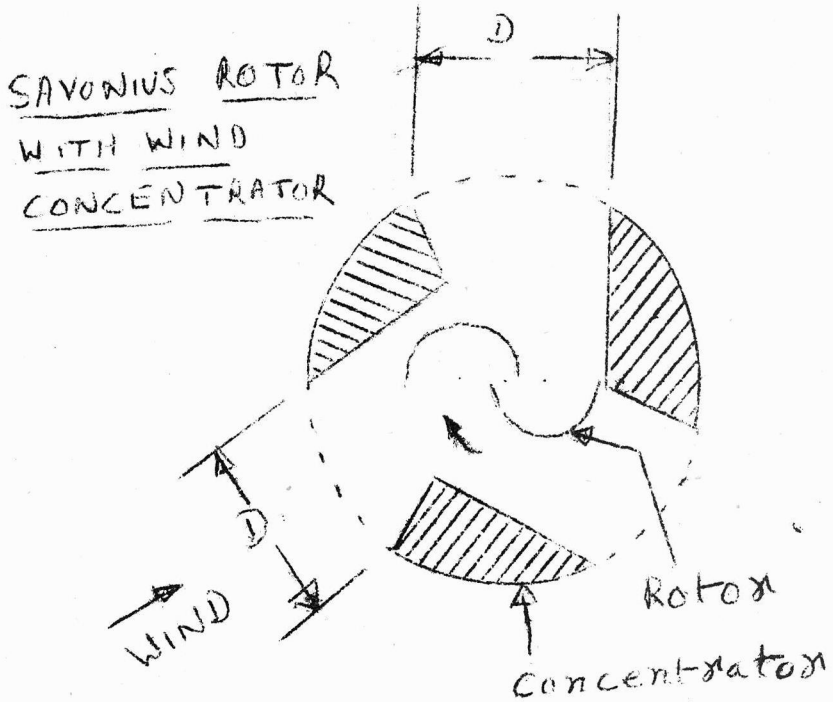


Fig - 21 - Vertical axis straight blad
Fixed pitch, cyclo gyro

2.2 Savonius rotor with deflector Augmentor:

Owing to the simplicity in construction of both rotor and the supporting structure high torque coefficient Savonius rotors are more attractive than many other designs particularly for water pumping. One possible way of improving the existing savonius rotor is by increasing the energy contend in the wind incident on it. A concentrator inside which the rotor is installed, has been tried. This has shown an increased power coefficient as high as 0.5 at a tip speed ratio of the order of 1.5. This value is indeed comparable with the most sophisticated wind turbines of the world. Fig. 2.2 shows the arrangement in schematic. However the construction of the concentrator as depicted is very costly with a view to reduce the cost of constr ction and to achieve a high coefficient of power, a self orienti deflector Augmentor is tried. Fig. 2.3 shows the details of thi improved scaled down version. The initial observational trials shows encouraging results and the investigation is in progress.


SAVONIUS ROTOR
WITH WIND
CONCENTRATOR
D
D
WIND
Rotor
Concentrator

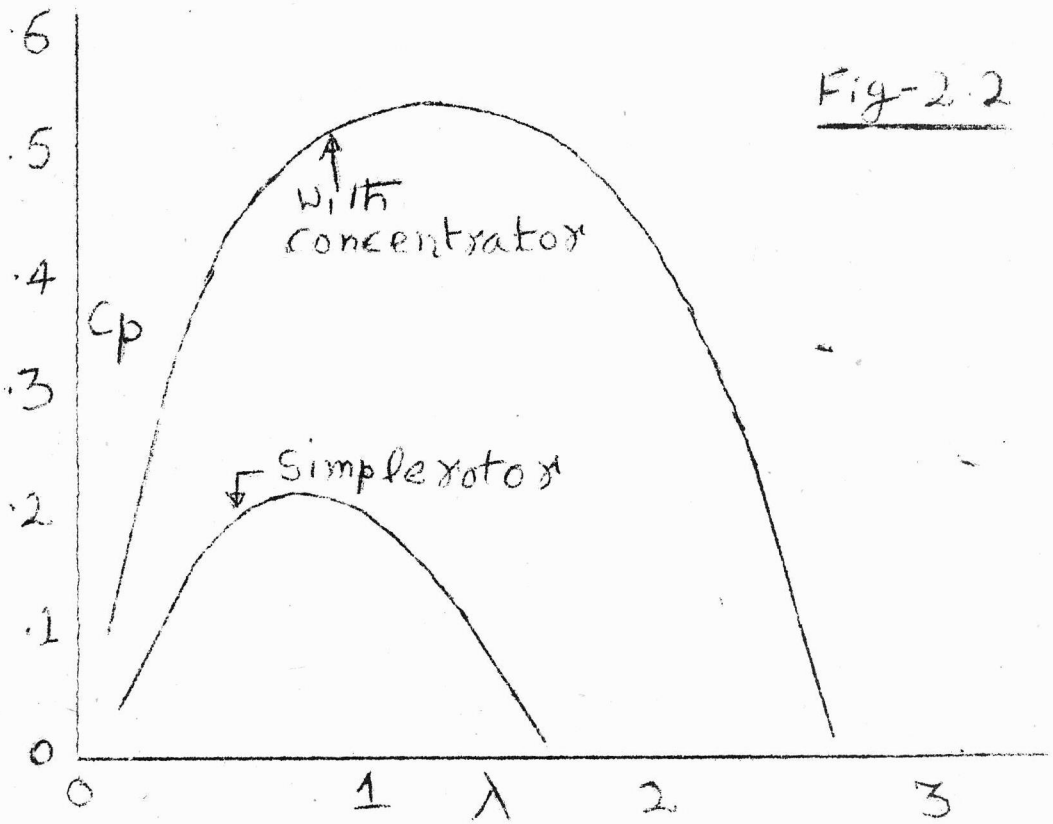
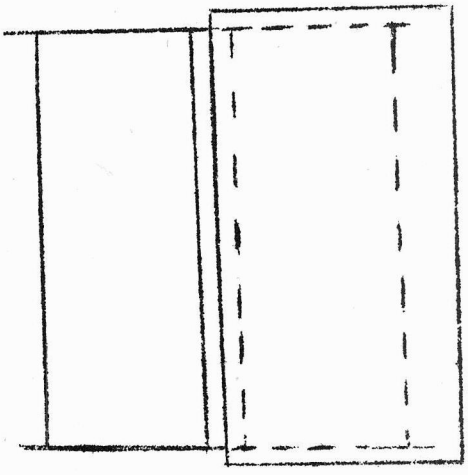

·6
·5
·4
·3
·2
·1
0
Cp
With concentrator
Simple rotor
0
1
λ
2
3

Fig-2.2



Savonius Rotor with Deflector Augmentor

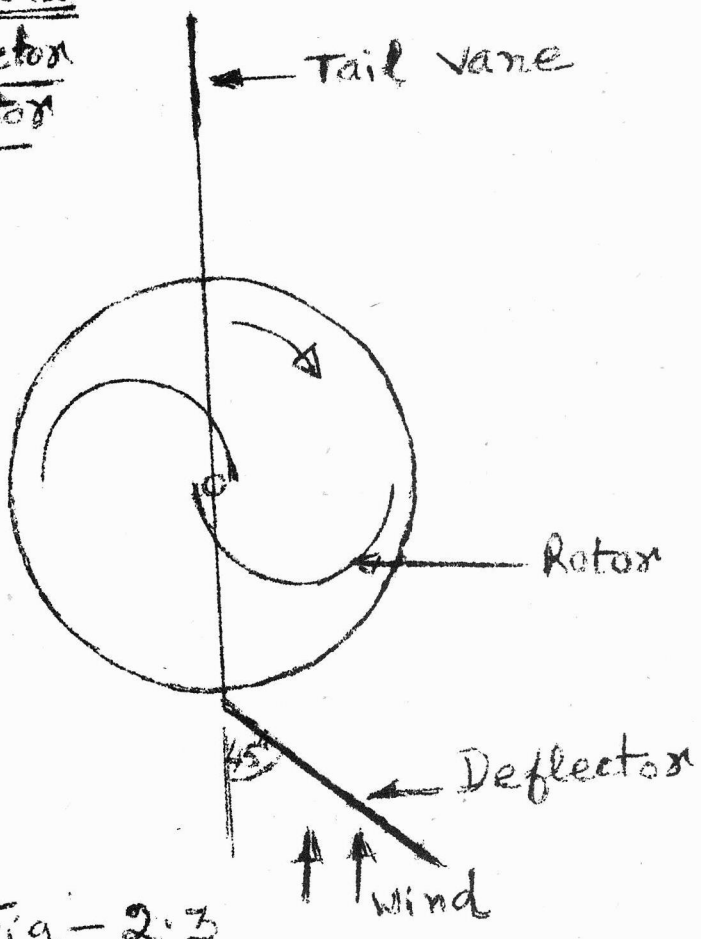


Fig – 2.3

2.3 Horizontal axis - 3 bladed rotor

Multibladed wind turbines, both with metalic blades (APOLY, Murugappa, BHEL) and sail winds (Six bladed NAL) are the present choice for water pumping, primarily because of the local technology and high starting torque. However, of late it is seen that work for the development of a 3 bladed version for water pumping is worthwhile. Use of localy available materials and less sophisticated technology for manufacture are the out standing features in this investigation.

A 3 bladed model having a rotor diameter of 2.5 meters using metalic blades each of 1 meter length, 30cm and 24cm chords at root and tip with 10% camber was fabricated. Bearings of the rotor use steel balls and bicycle components. Investigation is in progress.

2.4 Performance evoluation of existing Multibladed wind pump

It is understood that multibladed wind pump are available readily in the market and correspondence is in progress for procuring them. M/S. Murugappa Polytechnic has agreed to supply one set for trial. It is expected to be received soon.

3.0 Future programme of work

3.1 Work on Rotors

The on going improvements and modifications on the wind rotors will be continued. Introduction of components for higher power coefficients using all un-conventional wind rotors also will be tried.

3.2 Work on supporting structures

The cost of the supporting structures for wind mills usin usual materials such as iron or wood is becoming extremely high. In many cases a cost of support becomes more than that of the rotor. Keeping this in view it is decided to try pre-fabricated R.C.C. Poles for supporting structures.