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DP/EGY/81/028

EGYPT

Technical Report: Manufacture of Wind Turbines *

Prepared for the Government of Egypt
by the United nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Helge Petersen
Consultant in Manufacturing
Wind Energy Conversion Systems

Backstopping Office: J. Fürkus, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

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INTRODUCTION

The subject of the mission is to investigate the concept of manufacturing wind turbines in Egypt, and to identify the favourable size or sizes and type of the wind turbines to be produced taking into account the wind energy resources in Egypt and the demand for different forms of energy.
The task is executed by having talks with relevant authorities and persons, by visits to factories and by collecting documentation.
The visits to the factories and the talks with the managements showed great interest and ability to produce wind turbines or parts of the machines.

A number of questions have been evaluated, such as:

- Are the wind energy resources in Egypt rich enough, in other words, does the wind contain sufficient energy to be economically utilized?
- Are the wind turbines of to-day matured, are they sufficiently developed to be reliable and durable without excessive maintenance, and can they stand the environmental conditions?
- Are the wind turbines developed to an extent that allows licence production without further development work?
- For comparison with eventual Egyptian manufacture, what are the prices normally for wind turbines?
- Which applications should the wind turbines be adapted to, should they be grid-connected to feed energy into an existing electric grid, or should they be part of small stand-alone systems?
- Is there a need for testing facilities?
- Is there a need for special training of personnel?
- Based on the findings, can a proposed programme of activities be worked out and recommended?

The last question can readily be answered: The wind resources in parts of Egypt are extremely good and there is a great demand for energy. There are qualified factories in Egypt that can and will manufacture wind turbines by cooperative efforts of Egyptian and foreign partners. For these reasons a proposal for a programme of activities is worked out and presented, based on which a Project Document can be established.

As will be discussed at length later on in the report two different wind turbines are considered, named "Large wind turbine" and "Small wind turbine":

Large Wind Turbine

A wind turbine optimized for the wind climate at sites on the coasts of the Gulf of Suez and the R d Sea. The wind turbine shall be suitable for applications in windfarms as well as in single unit systems for large hotels, factories or similar, in connection with a local diesel generator. The wind turbine is supposed to be of rated power 90 or 110 kW and of diameter 19 to 21 metres.

Small Wind Turbine

A wind turbine optimized for the wind climate in the north part of Egypt, the coastal area of the Mediterranean Sea, as well as the coast of the Red Sea, to operate in stand-alone systems for pumping of water, for desalination or for small-scale electricity supply. The wind turbine shall utilize as a generator the three-phase electric motor produced in Egypt, optional of ratings 18.5 kW at 3,000 rpm, 15 kW at 1,500 rpm or 11 kW at 1,000 rpm. The wind turbine is supposed to be of approximately 12m diameter.

It is proposed that the facilities and related technologies for the fabrication, pilot production and testing of the two types of wind turbines be established through:

- the transfer of technology, i.e. the acquisition of designs with technical documentation for the local production of wind turbines including all relevant information on technical and engineering data, drawings, quality standards, layout of workshops, specifications on machinery, materials, engineering and manufacturing skills etc.,
- the supply of specialized equipment required for pilot manufacturing and testing;
- training of technical counterpart staff and international expertize;

under a technical assistance project of the UNDP following the approach of subcontracting. In this connection it is suggested that the following subcontracts be arranged:

- Subcontract A for the production of large wind turbines.
- Subcontract B for the fabrication of small wind turbines.
- Subcontract C for the production of blades for wind turbines.
- Subcontract D for the establishment of an operational testing facility.
- Subcontract E for wind farm siting and monitoring.

The involved Egyptian and foreign companies, sub-contract A and B, are supposed to establish supplementary contracts on the production of components such as electrical control systems and gear boxes. The next pages present

- the outputs of the programme of activities;
- a skeleton diagramme of organization;
- remarks to the skeleton diagramme.

Outputs of Programme Activities

Output 1:

1.a.

An established manufacturing facility at an Egyptian company for pilot and batch production of wind turbines of 90 - 110 kW generator rating for grid-connection equipped with automatic control system.

1.b.

One pilot manufactured and tested prototype of the 90 - 110 kW wind turbine and 100 machines including siting programmes/plans for the establishment of wind turbine groups (wind farms).

Output 2:

2.a.

An established manufacturing facility at an Egyptian company for the production of wind turbines of 15 kW generator rating primarily for stand-alone, autonomous applications, such as small scale electricity supply, pumping of water and desalination, but also for grid-connection, utilizing a simple, partly manually operated control system;

2.b.

One pilot manufactured and tested prototype of the 15 kW wind tubine.

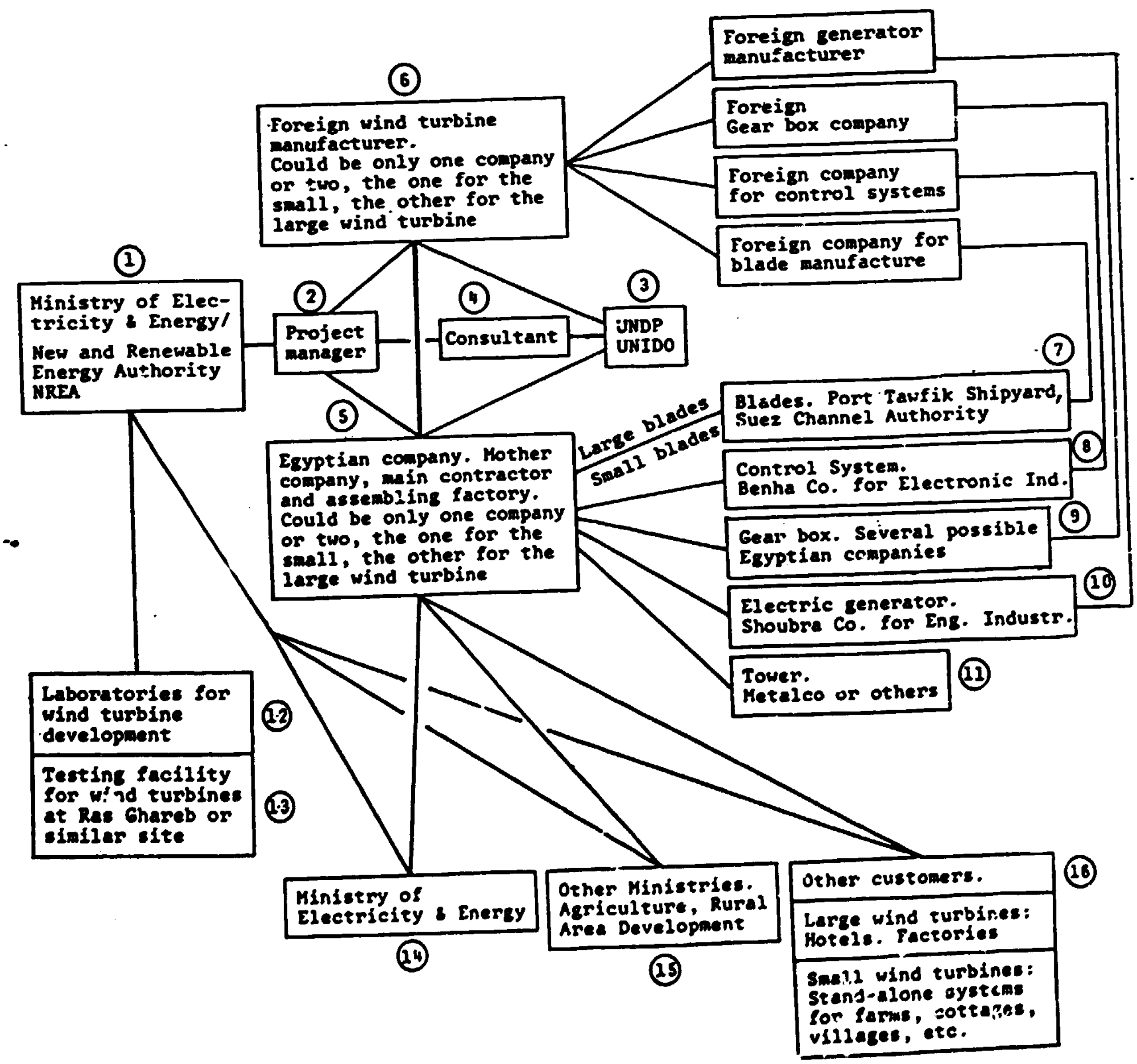
Output 3:

Established manufacturing facilities at the company Port Tawfik Shipyard for the production of blades for the wind turbines manufactured under Output 1 and 2.

Output 4:

An extablished operational testing facility for wind turbines properly equipped and staffed with trained personnel.

A SKELETON DIAGRAMME OF ORGANIZATION



Remarks to the skeleton diagram

THE CONSULTANTS IMMEDIATE PROPOSAL FOR ORGANIZING THE PROJECT

NREA, New and Renewable Energy Authority, (1), appoints a project manager, (2), to conduct the programme UNDP/UNIDO, (3), contracts a consultant, (4), to advise on the start of the programme.
An Egyptian company or alternatively, two, one for the small wind turbines another for the large, (5), undertakes acting as parent company, the main contractor(s). Among the companies visited the following are interested: Egyptian Iron and Steel Co., Helwan Works, (small and large wind turbines), Abu Zaabal Engineering Industries, MF 100, (large), Helwan Company for Engineering Industries, MF 99, (small wind turbines), EL NASR Transformers and Electrical Products Co. - ELMACO (small and large wind turbines), Erection and Industrial Services Co. - ERISCOM (small and large wind turbines).
A foreign company, (6), is contracted for the transfer of technology of wind turbine design(s), alternatively two companies, the one for small wind turbines the other for the large.
A contract on the transfer of know-how for the production of blades for the wind turbines is entered, (7), between Port Tawfik Shipyard, Suez Canal Authority, and a foreign blade manufacturer.
The control systems, (8), could be made on the basis of a subcontract by Benha Co. for Electronic Industry, MF 144.
For the production of gear boxes, (9), several Egyptian companies could co-operate; gear wheels/gear boxes can be made by: Egyptian Iron and Steel Co., Helwan Company for Machine Tools, MF 999, Abu Zaabal Engineering Industries, MF 100, and Aircraft Engine Factory, A.O.I.
Electric generators (induction motors) are made under licence, (10), by Shoubra Co. for Engineering Industries, MF 27, who would also import larger generators aiming at future licence production.
Towers, (11), can be made by several companies, lattice towers as well as tubular towers: METALCO, Iron and Steel Co. Company MF 100 (large lattice towers) and Company MF 99 (small towers). For tubular masts (small towers and ANEMOMETER MASTS) the pipes from Steel Pipe Factory is a possibility.
NREA establish test facilities, (12) and (13), where the wind turbines can be tested, based on which certificates are issued. The users of wind turbines are (14), (15) and (16).

1. Terms of Reference and Briefings

The terms of reference for the mission are given by the Job Description of UNIDO, 14 October 1987, shown in Annex 1.

The first day of the travel, Monday 30.11.87, was spend at UNIDO, Vienna, for briefings. In the briefing by Mr. Fuerkus he emphasized that a Project Document should be prepared on the subject following UNDP/UNIDO guidlines on project formulation for the consideration of all parties concerned, and that the consultant should elaborate on the contents of a Pro. Doc. which might also include for acquisition of drawings and specifications for a wind turbine or for parts of wind turbines to be manufactured locally. Such an agreement could result in a simple licence or it could, besides the licence, cover a cooperative effort by an Egyptian and a foreign company in adapting a wind turbine design through the transfer of technology to be especially adopted for manufacture in Egypt and for the climatic conditions in Egypt.

- In the case of an ordinary licence, which requests the licence holder to manufacture the product precisely to the excisting drawings and specifications two problems may come up: a. that the production methods may not immediately fit Egyptian production facilities; and, b, that the imported parts would have to be procured exactly as prescribed in the licence, which may not be economically from a merchant point of view.
- Alternatively in the case of a cooperative agreement the two problems above, a and b, may be eased. Not the least important is furthermore that the cooperation will train the Egyptian engineers in the design problems of wind turbines, which is also the basis for the operation, maintenance, testing and trouble-shooting.

The comments above - by the consultant - should not be mistaken meaning that the Egyptian company should enter the design work as such, the design should still be relying on the foreign, experienced company, but it is important that the Egyptian company takes part and later on can influence the design.

Besides the subject described above the Pro. Doc. should cover two other main subjects, establishment of an operational testing facility for wind turbines and training of technicians. The anticipated outputs are listed in the Introduction.

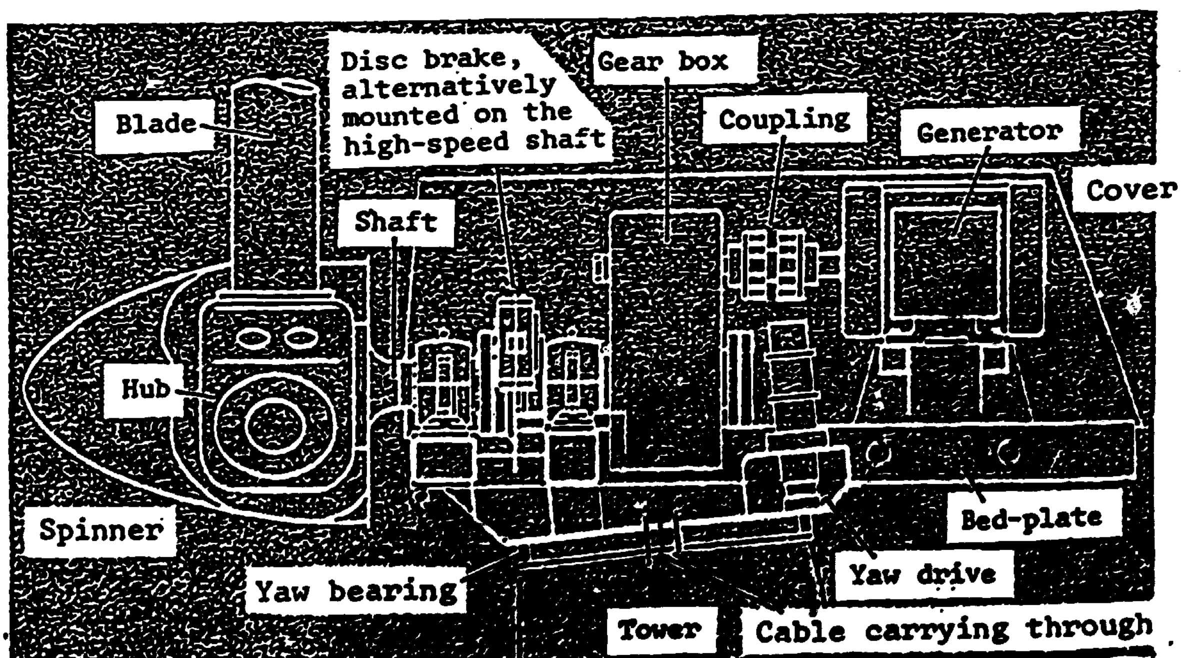
Lists of meetings in Egypt are enclosed, Annex 2 and 3.

2. General

Wind turbines, often called windmills, are used for various applications. For centuries they were - and are still used -for pumping of water with simple mechanical pumps (simple, but not easy to maintain). Wind turbines for generating electricity are on the market at all sizes from 50 Watts to several Megawatts. The small ones are used to charge batteries for lightning a room or to power radio recievers. The large machines of 100 kW to 2 MW, are grid-connected, feading the electric power directly into a public grid. Medium sized windmills of 5 to 50 kW are normally used in stand-alone systems, either for pumping of water by means of electrical pumps, for desalination or in wind/diesel systems for small-scale electricity supply.

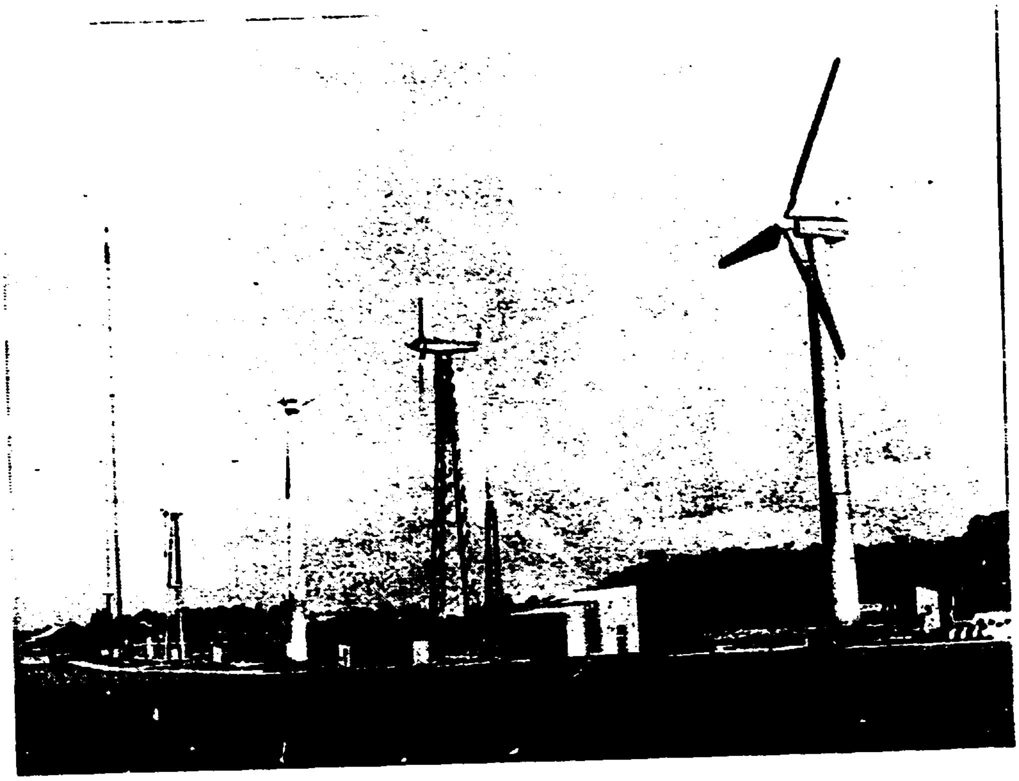
The photographs next page show examples of windmills.

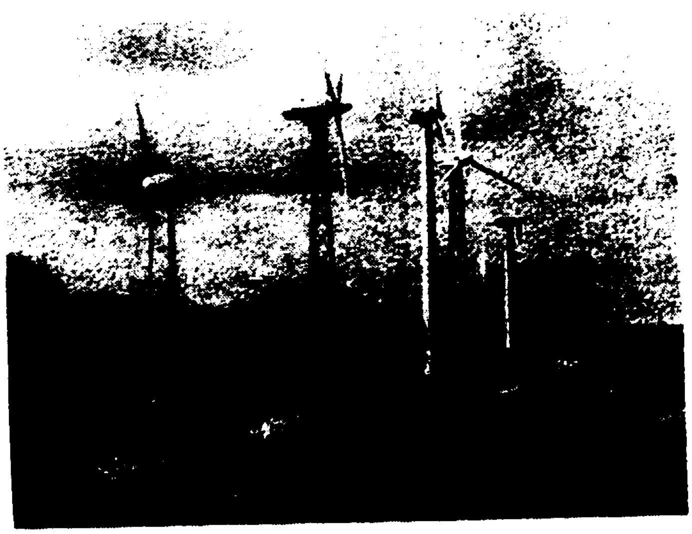
The sketch below examplifies the nacelle of a wind turbine indicating the main components.



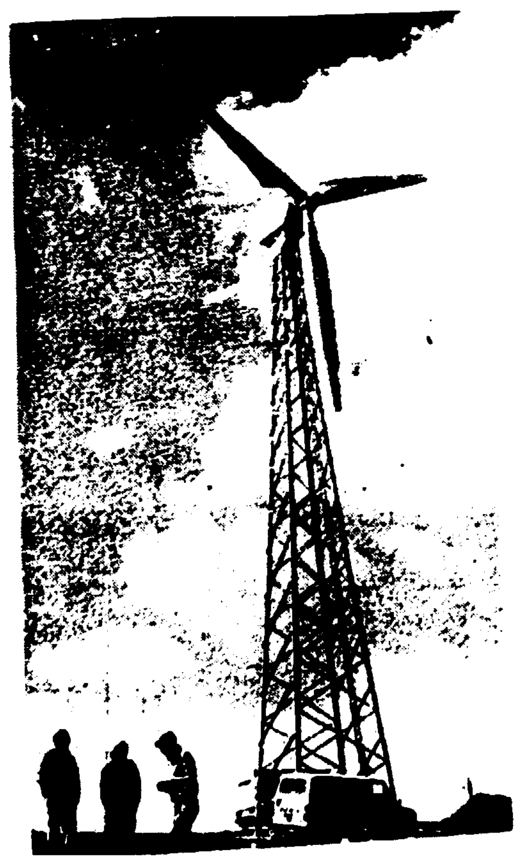
Normally the windmill rotor has three blades, and
normally the machine is stall-controlled, i.e. the blades are fixed pitched, rigidly bolted to the hub, and
normally the generator is asynchronous, an ordinary induction motor used as a generator.

Examples of grid-connected wind turbines





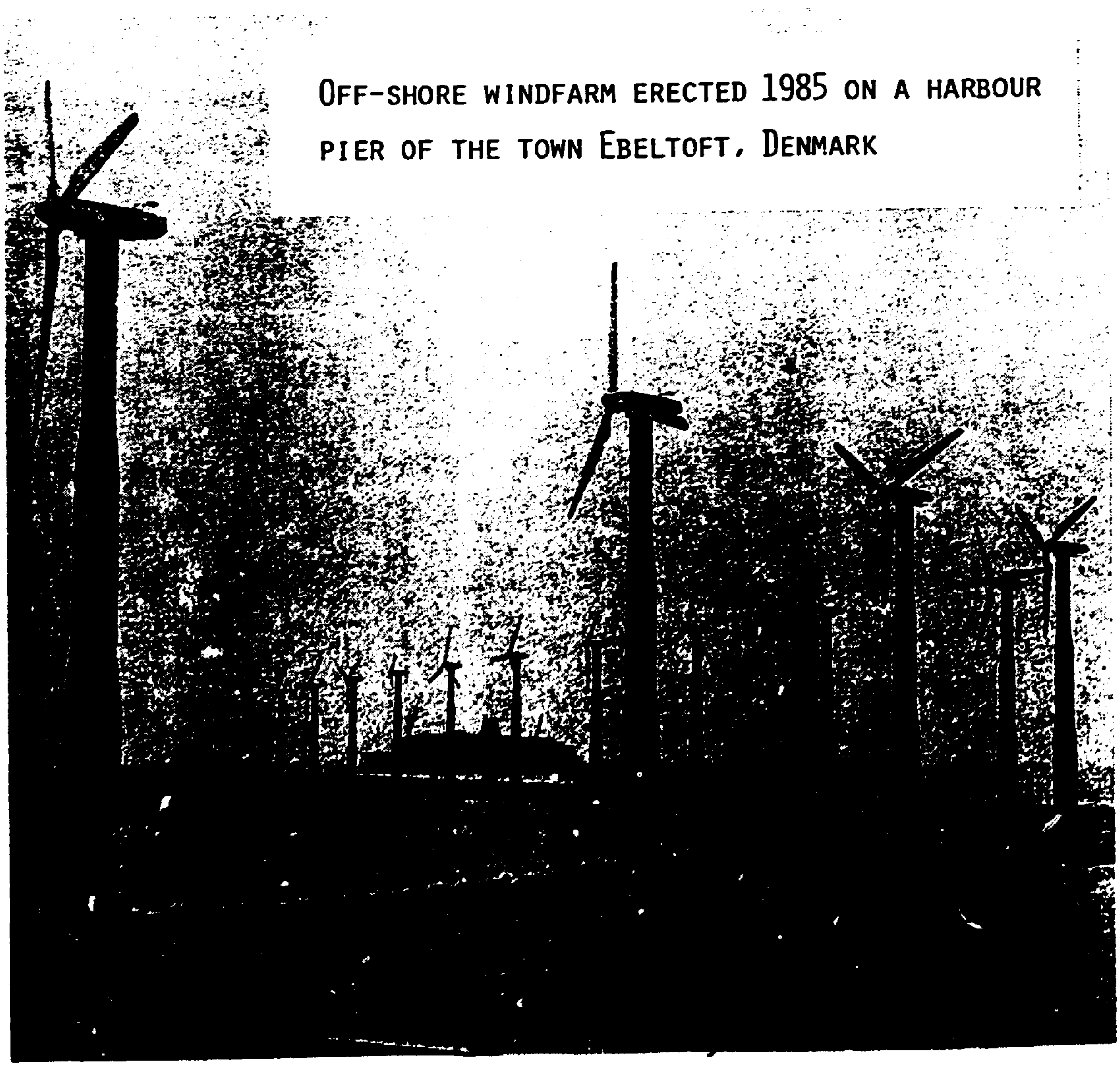
Windmills at the Test Station for Windmills at RISØ, Denmark. Sizes from 20 to 200 kW.



A modern wind turbine of 23-m diameter and of 180 kW.

Examples of Windfarms

Aerial photo of a small windfarm



OFF-SHORE WINDFARM ERECTED 1985 ON A HARBOUR PIER OF THE TOWN EBELTOFT, DENMARK

Examples of wind turbines for battery charging or water pumping

A modern windpump
with mechanical pump.
China, thousands of
these are erected.

A windmill of 50 Watts for charging
of batteries. Used by the nomades
in the Gobi Desert, produced in
China in numbers of hundredthousands.

Small windpumps, electrical and mechanical, at the Test Station

3. Wind Resources in Egypt

3.1. General Considerations

In the report on measurements of wind speeds in Egypt: "Analysis of One Year of Wind Measurement Activities In Egypt , April 1985 - March 1986", prepared for U.S.A.I.D. and E.E.A., Egypt, by Battelle Pacific Northwest Laboratories, U.S.A., information is given on wind speed measurements at a number of locations in Egypt.

In the following the information on wind speed distributions are treated more detailed for the locations: Ras El Hekmah at the coastal area of the Mediterranean Sea and Ras Ghareb at the coast of the Gulf of Suez and Hurghada at the coast of the Red Sea.

For two reasons it is most convenient to convert the measured wind speed distributions to mathematical expressions using the Weibull probability density function or frequency distribution:

- it facilitates the calculations of estimations of energy generation,
- it facilitates the calculations by which the wind turbines can be optimized.

The Weibull function operates with two parameters, the scale parameter and the shape or form parameter. In the Battelle report they are denoted C and K, respectively, and this is used in the following, but it should be noted that the parameters, especially in Europe, often are denoted A and C, respectively. The Weibull probability function is a mathematical function without specific physical relevance, however, it is most often a good fit for wind speed data.

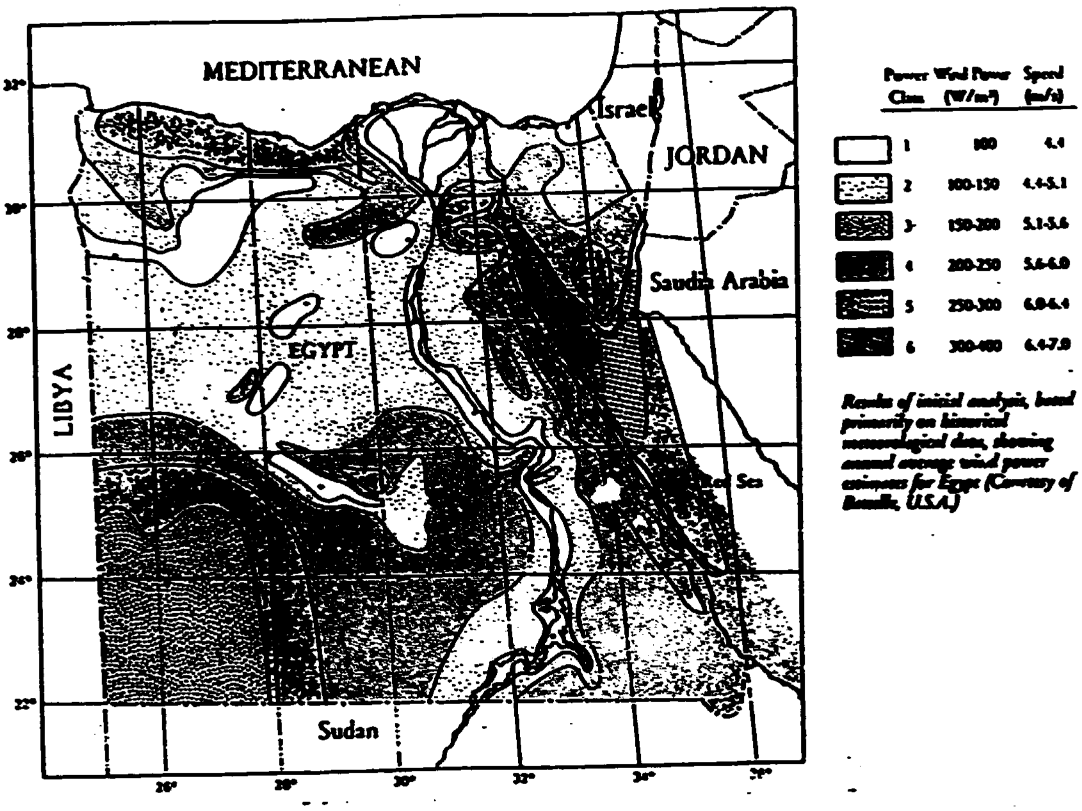
The mathematical expression is

$$f(V) = \left(\frac{K}{C}\right) \left(\frac{V}{C}\right)^{K-1} \exp\left(-\left(\frac{V}{C}\right)^{K}\right) \qquad \text{(Weibull distribution)}$$

where C is the scale parameter and K the shape parameter. The scale parameter, C, has unit of speed, while the shape parameter, K, is dimensionless. In case K= 2 the distribution is identical with the Rayleigh distribution, which is

$$f(V) = \frac{2V}{C^2} \exp\left(-\left(\frac{V}{C}\right)^{2}\right) \qquad \text{(Rayleigh distribution)}$$

The Rayleigh distribution is seldom sufficient to represent an actual wind speed distribution.



Results of initial analysis, based primarily on historical meteorological data, showing annual average wind power estimates for Egypt (Courtesy of Battelle, U.S.A.)

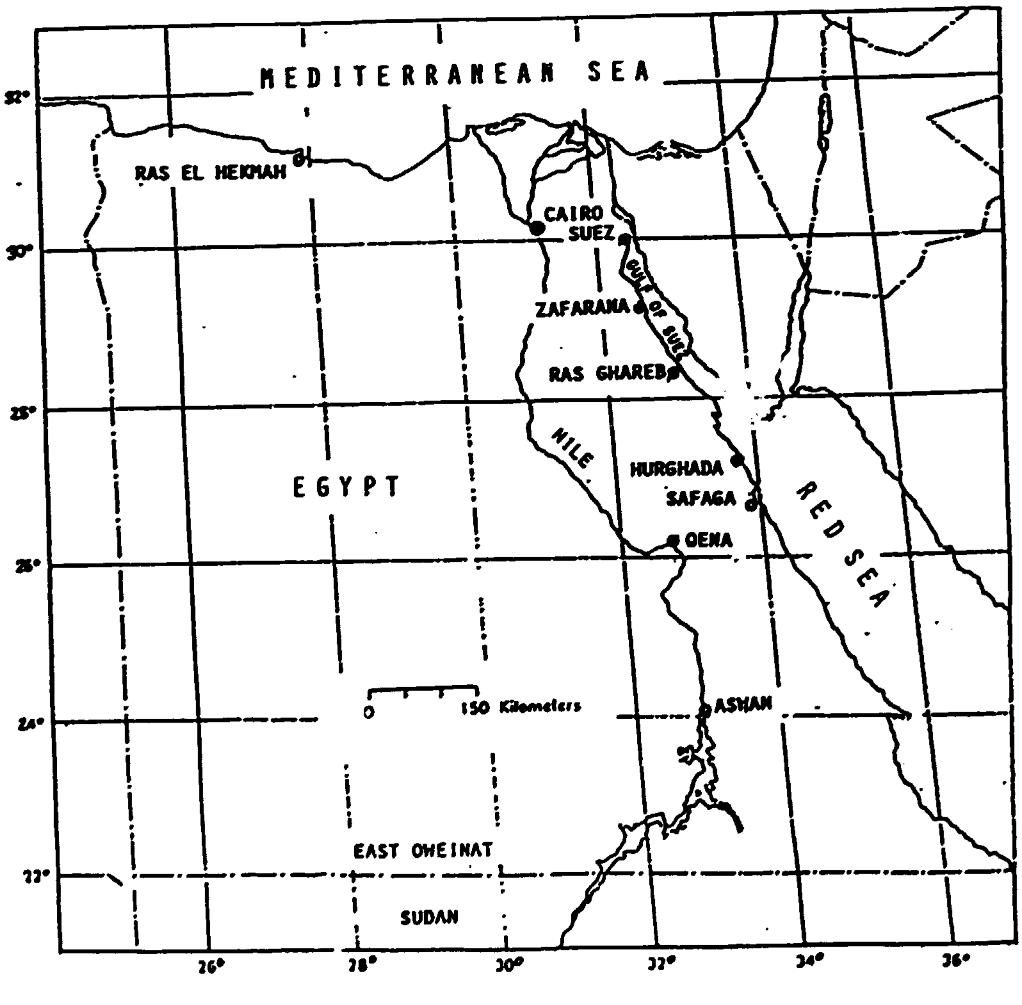


Figure 1 shows two examples of Weibull distributions in order to demonstrate the importance of the shape factor K. In both cases the scale parameter is C= 7.00 m/sec. For K= 1.6 the total power density is considerably larger than for K= 2.2 due to the larger contents of high wind speeds, while the difference in mean wind speed is small.

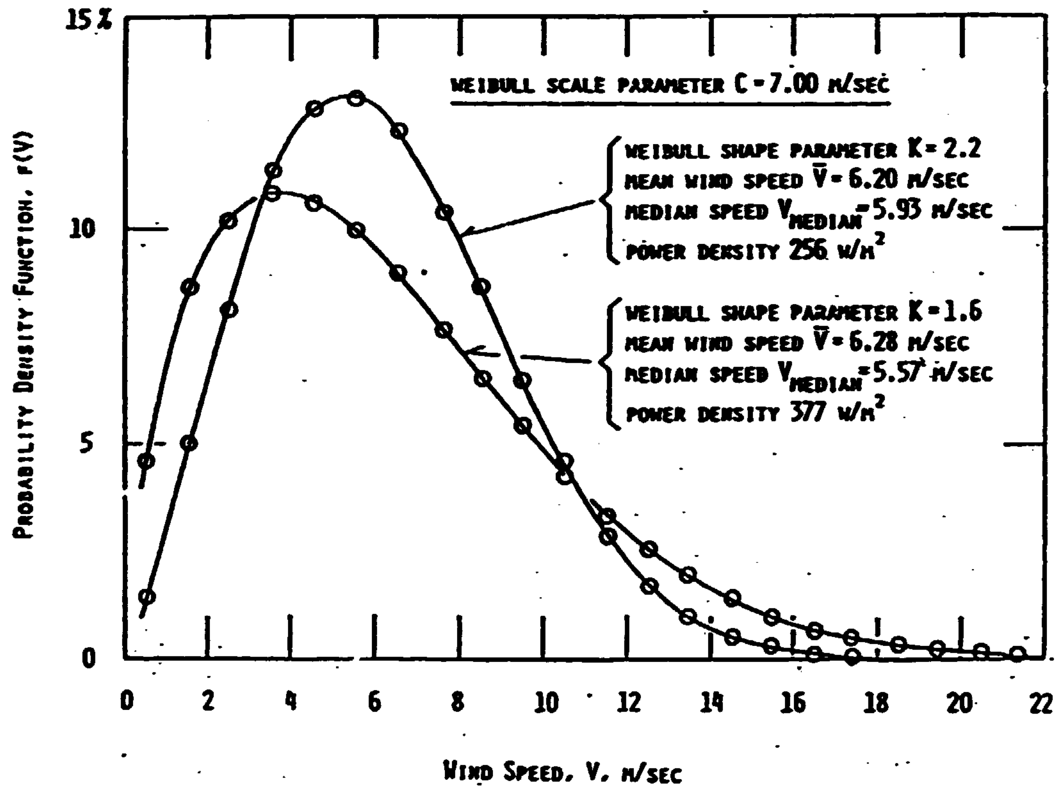


Figure 1. Examples of Weibull wind speed distributions, (wind speed intervals 1 m/sec)

The scale parameter, C, (dimension m/s), varies only slightly with the shape parameter, K, (nondimensional), the ratio $\bar{V}/C$ ($\bar{V}$ is the mean wind speed) varies from 0.885 to 0.900 as shown in Fig. 2.

The energy contents of the wind, here expressed by the power flux, W/m^2, is in proportion to the air density, ρ, and to the cube of the scale parameter, C, and varies strongly with the shape parameter, K, as shown in Fig. 3, the variation with K of the ratio

$$\frac{\text{Flux}}{\frac{1}{2} \cdot \rho \cdot C^3}$$

There are different approaches to approximate the Weibull function to a measured wind speed distribution, this shall not be discussed here. The important issue is to find a Weibull function that will best possible give the same power output as found by using the measured wind speed distribution.

Once the Weibull parameters, C and K, are settled the mean wind speed, $\overline{V}$, and the power flux are found by calculation or by using Figs. 2 and 3.

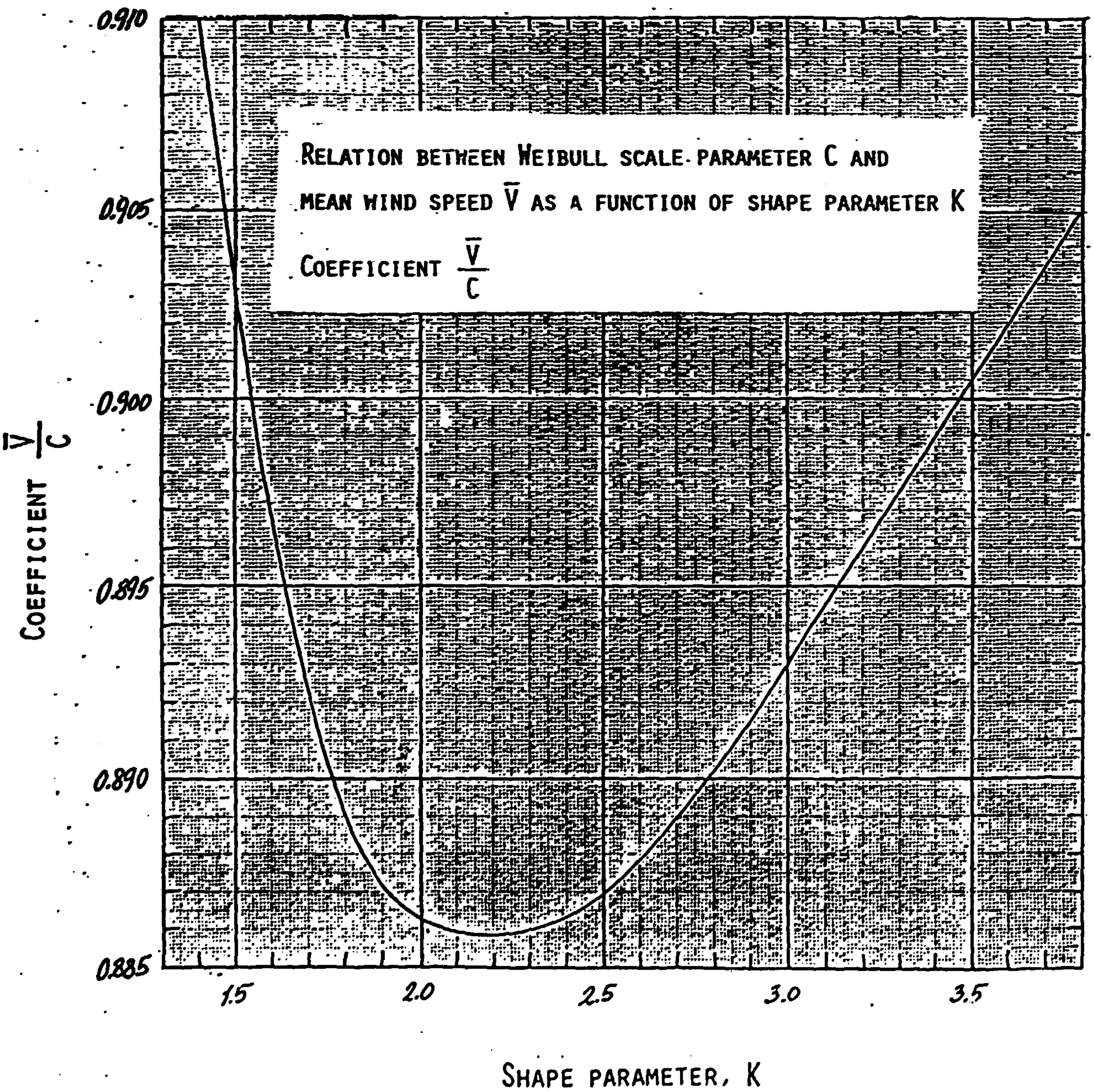


Figure 2

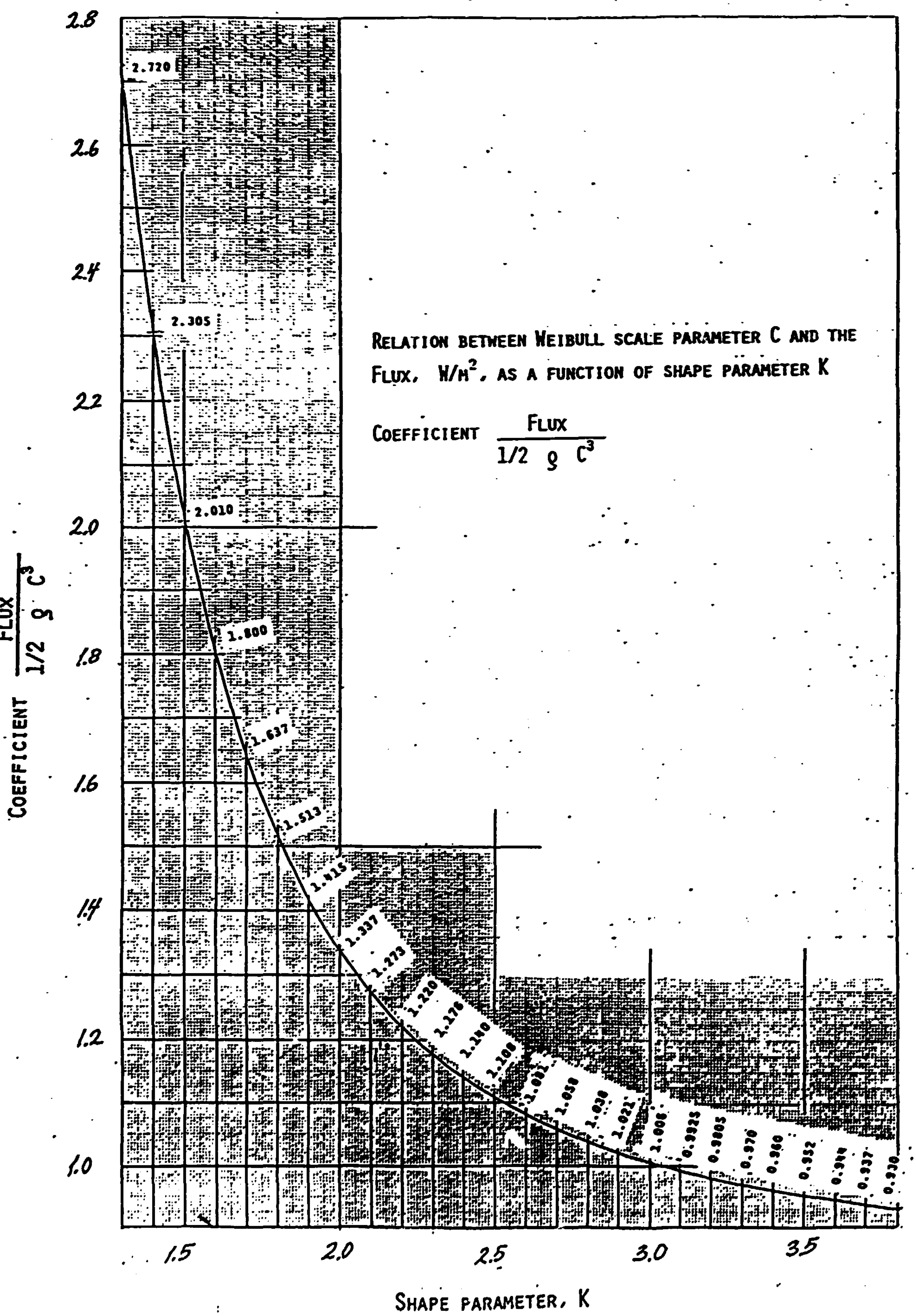
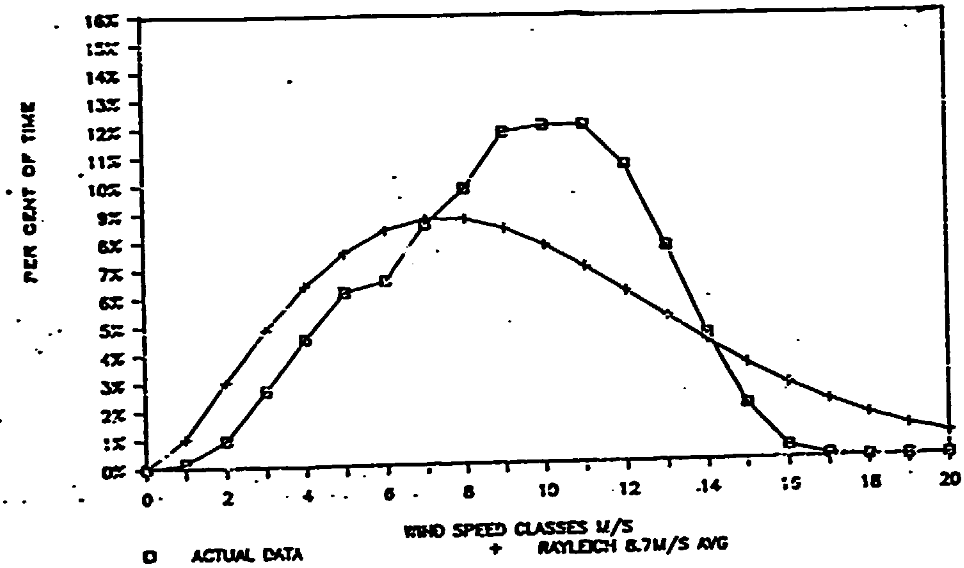

RELATION BETWEEN WEIBULL SCALE PARAMETER C AND THE FLUX, W/M², AS A FUNCTION OF SHAPE PARAMETER K
COEFFICIENT FLUX / 1/2 ϱ C³
COEFFICIENT FLUX / 1/2 ϱ C³
SHAPE PARAMETER, K
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
1.5
2.0
2.5
3.0
3.5
2.720
2.305
2.010
1.800
1.637
1.513
1.415
1.337
1.273
1.220
1.176
1.140
1.108
1.081
1.058
1.038
1.021
1.006
0.9925
0.9805
0.970
0.960
0.952
0.944
0.937
0.930

Figure 3

In the following section the Weibull parameters are fitted to the measured wind speed distributions. An example is shown below for comparison with the Rayleigh distribution having K= 2.0. The figure, FIGURE 5.2. is from the Battelle report, and the flux would for the Rayleigh distribution (V= 8.7 m/s, K= 2, C= 9.8) be: Flux= $0.819 \cdot 9.8^3 = 770\ W/m^2$

while the measured flux is 548 W/m^2.

In contradiction to this the Weibull distribution with K= 3.6 gives the correct flux.



b)

FIGURE 5.2. Frequency Distribution for Wind Speed by Percentage of Time April 1985 - March 1986, Contrasting Actual and Rayleigh Distributions. ~~a) Ras Ghareb (10 m AGL)~~, b) Ras Ghareb (20 m AGL)

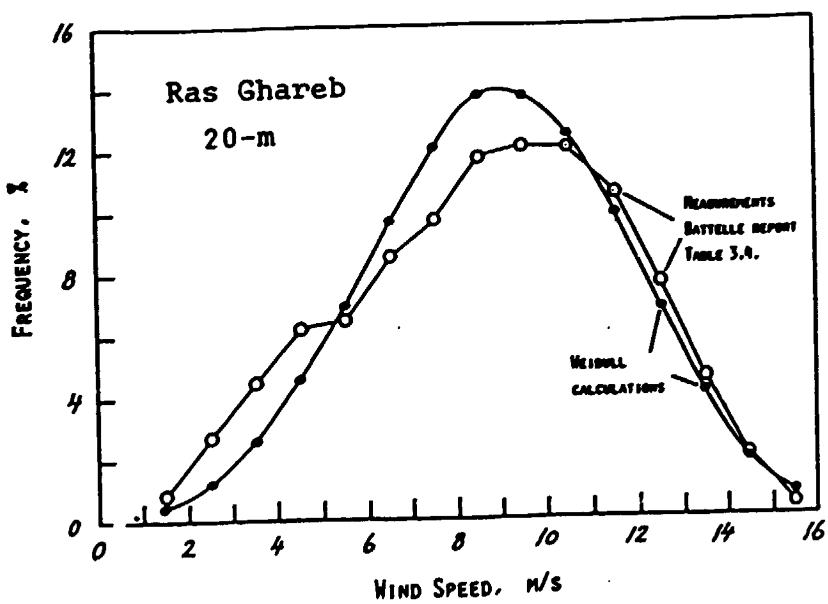


FIGURE 4

3.2. Results of Wind Speed Distribution Analysis

The tables below and Figs. 6 - 10 show the measured and the fitted wind speed distributions. In addition to the locations mentioned in the foregoing values for the site East Oweinat are incorporated based on information from NREA.

ANNUAL MEAN WIND SPEED VERSUS HEIGHT ABOVE GROUND AT FOUR LOCATIONS

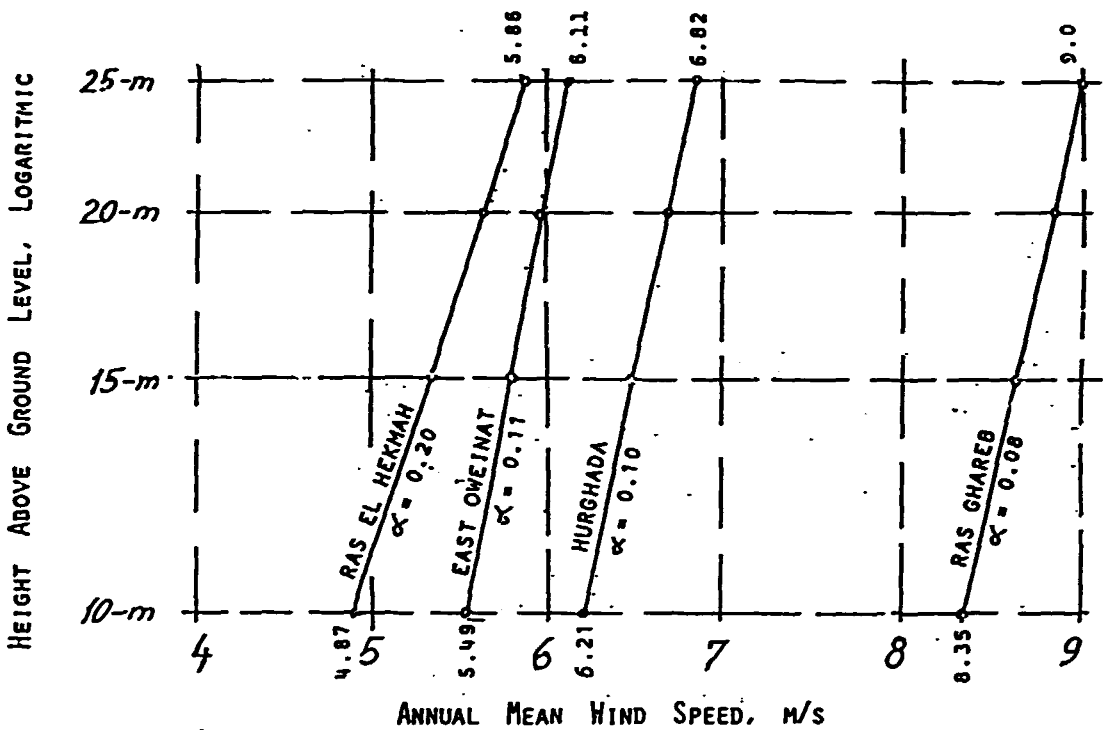


Figure 5

Ras El Hekmah at the costal area of the Mediterranean Sea

The table is based on measurements at 10-m and 20-m level. From this the Power Law Exponent is approx. 0.20. From the measured values of the Power Flux the K-values are derived as tabulated.

RAS EL HEKMAH

Height above ground m	Measurements $\overline{V}$ m/s	Flux W/m^2	$\left(\frac{C_h}{C_{10}}\right)^{0,20}$	C m/s	K	$\frac{\overline{V}}{C}$	$\overline{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m^2
10	4.8-4.9	123	1.000	5.50	2.2	0.886	4.87	1.220	0.747	124
15			1.085	5.96	2.3	0.886	5.28	1.176	0.721	153
20	5.6-5.7	174	1.149	6.32	2.4	0.886	5.60	1.140	0.699	176
25			1.201	6.60	2.5	0.886	5.86	1.108	0.678	195

Ras Ghareb.

Based on measurements at 10-m and 20-m level from which the Power Law exponent 0.08 is found. K-values assumed as tabulated.

RAS GHAREB

Height above ground m	Measurements $\bar{V}$ m/s	Flux W/m^2	$\left(\frac{C_h}{C_{10}}\right)^{0.08}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m^2
10	8.2	481	1.000	9.30	3.30	0.898	8.35	0.970	0.594	478
15			1.033	9.61	3.45	0.900	8.65	0.956	0.586	520
20	8.7	548	1.057	9.83	3.60	0.902	8.86	0.944	0.578	549
25			1.076	10.00	3.70	0.904	9.04	0.937	0.574	574

Hurghada.

Based on measurements at 10-m level. Power Law exponent assumed to be 0.10 and K-values as tabulated.

HURGHADA

Height above ground m	Measurements $\bar{V}$ m/s	Flux W/m^2	$\left(\frac{C_h}{C_{10}}\right)^{0.10}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m^2
10	6.2	231	1.000	7.00	2.50	0.887	6.21	1.108	0.679	233
15			1.041	7.29	2.55	0.888	6.47	1.095	0.671	260
20			1.072	7.50	2.60	0.888	6.66	1.081	0.662	280
25			1.096	7.67	2.65	0.889	6.82	1.069	0.655	296

East Oweinat.

Based on measurements at 10-m level. Power Law exponent assumed to be 0.11 and K-values as tabulated.

EAST OWEINAT

Height above ground m	Measurements $\bar{V}$ m/s	Flux W/m^2	$\left(\frac{C_h}{C_{10}}\right)^{0.11}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m^2
10	5.5	155	1.000	6.18	2.7	0.889	5.49	1.058	0.648	154
15			1.046	6.46	2.8	0.890	5.75	1.038	0.636	172
20			1.079	6.67	2.9	0.892	5.95	1.021	0.625	185
25			1.106	6.84	3.0	0.893	6.11	1.006	0.616	197

Height above ground m	Measurements V m/s	Flux W/m²	$\left(\frac{C_h}{C_{10}}\right)^{0.20}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m²
10	4.8-4.9	123	1.000	5.50	2.2	0.886	4.87	1.220	0.747	124

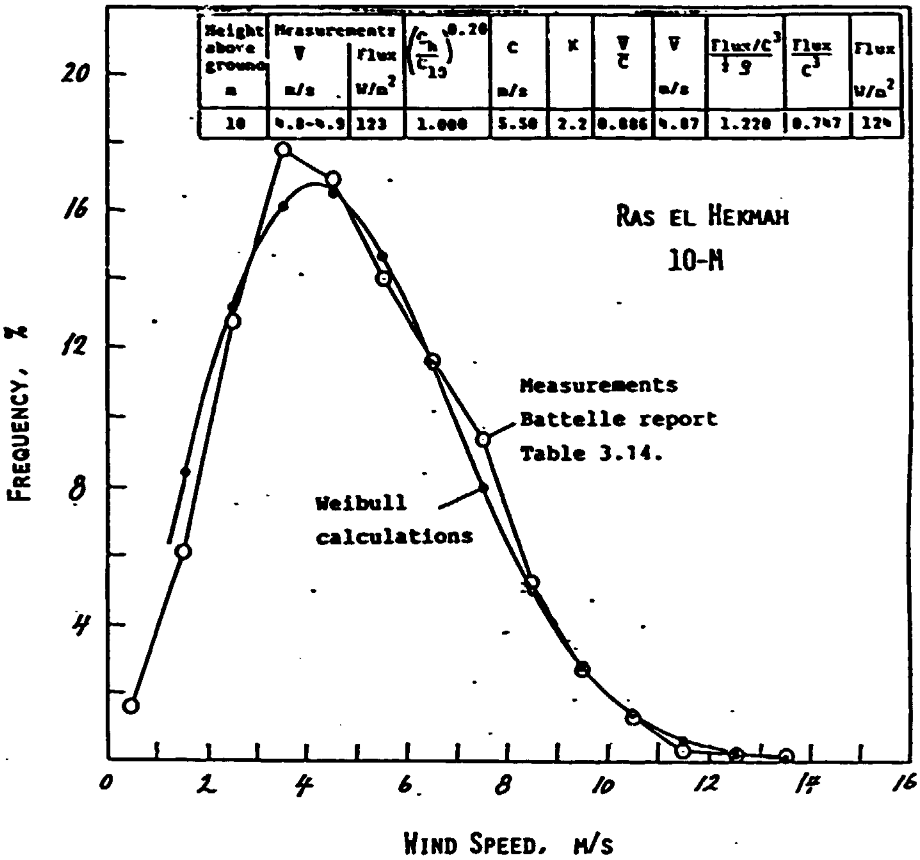


Figure 6

Height above ground m	Measurements V m/s	Flux W/m²	$\left(\frac{C_h}{C_{10}}\right)^{0.20}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m²
20	5.6-5.7	174	1.149	6.32	2.4	0.886	5.60	1.140	0.699	176

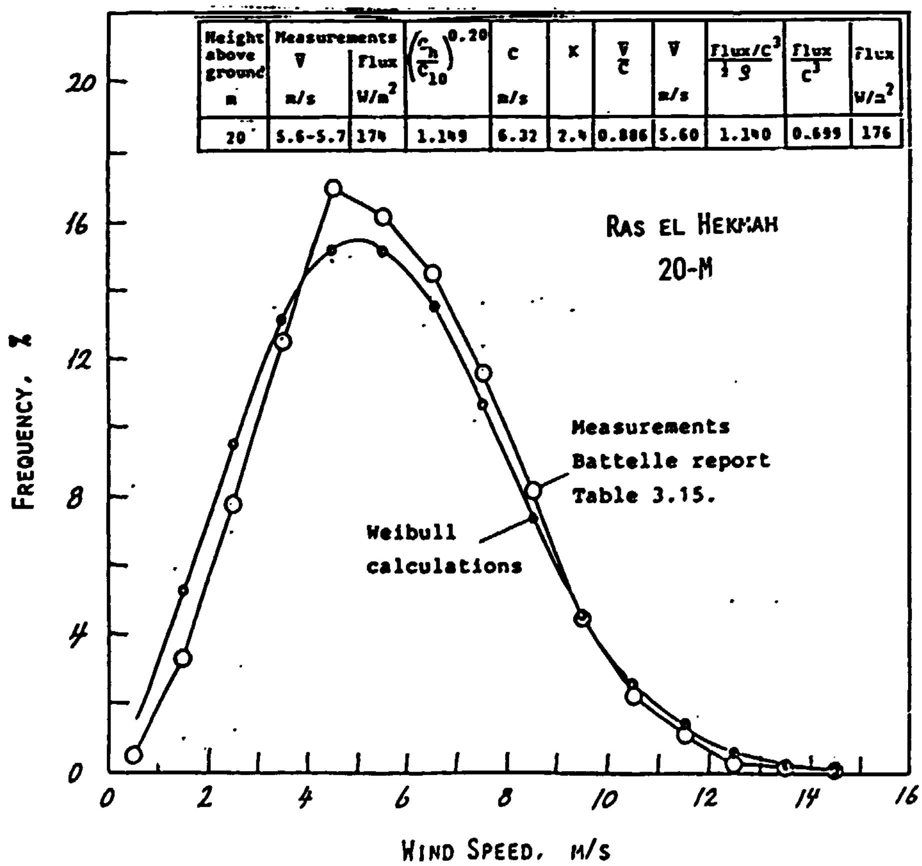
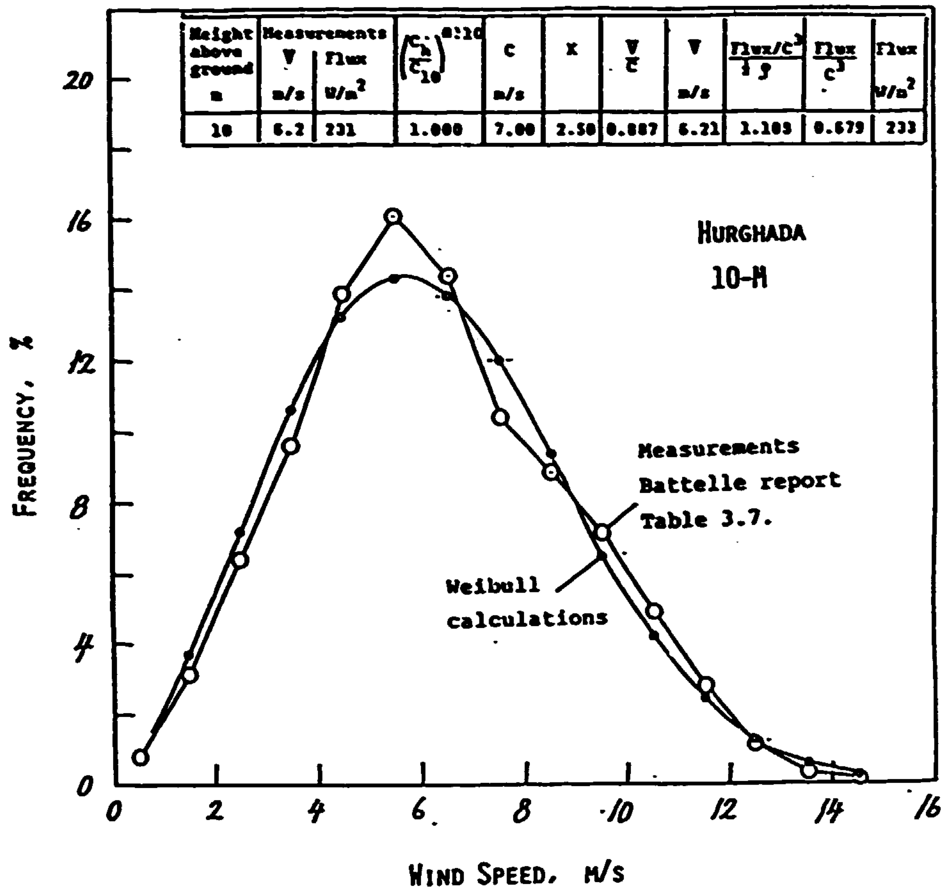


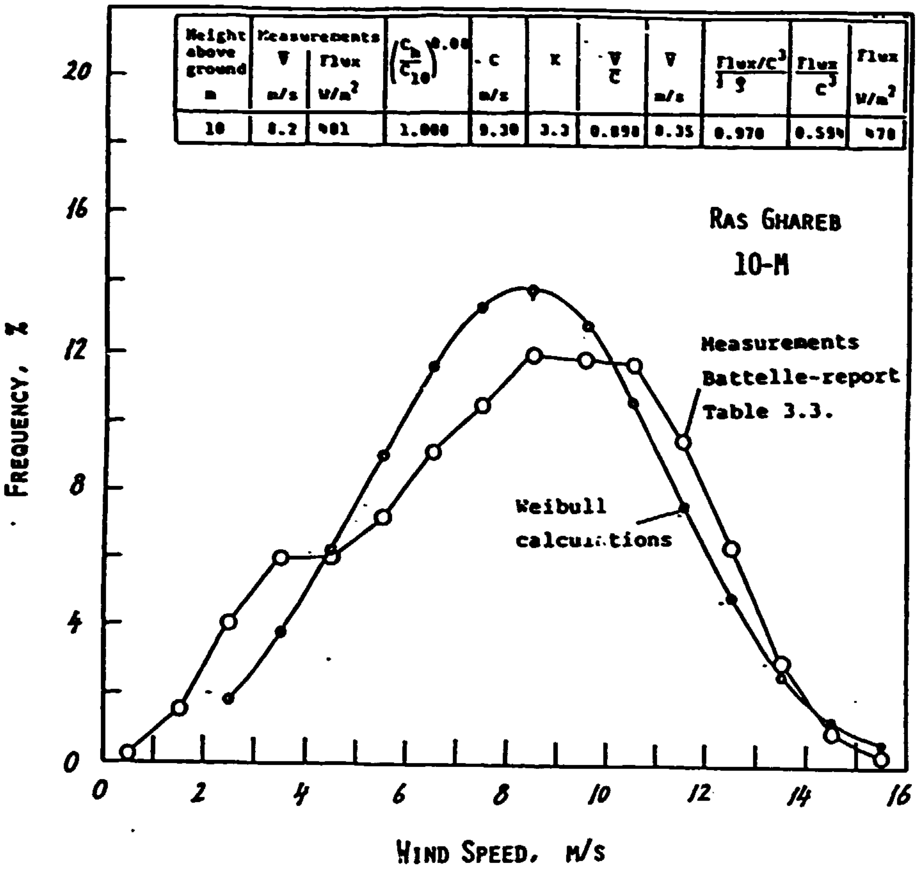
Figure 7



Height above ground (m)	Measurements $\bar{V}$ (m/s)	Measurements Flux (W/m^2)	$\left(\frac{c_h}{c_{10}}\right)^{0.10}$	c (m/s)	k	$\frac{\bar{V}}{c}$	$\bar{V}$ (m/s)	$\frac{Flux/c^3}{\frac{1}{2}\rho}$	$\frac{Flux}{c^3}$	Flux (W/m^2)
10	6.2	231	1.000	7.00	2.50	0.887	6.21	1.103	0.679	233

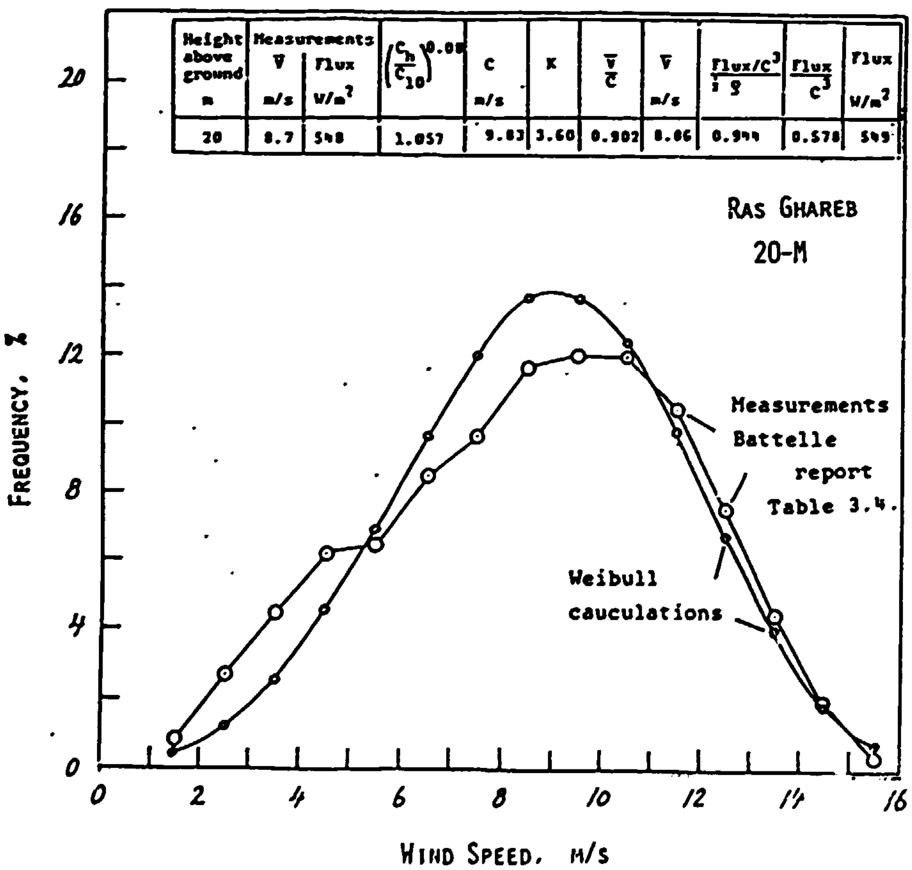
Figure 8

In the foregoing figures, Figs. 6, 7 and 8, there is a good fit of the Weibull function to the measured distributions. In the following figures, Figs. 9 and 10, the fit is less good. It may be possible to obtain better correlations by dividing the measuments seasonaly or diurnally, in that way combining several Weibull distributions.



Height above ground m	Measurements $\bar{V}$ m/s	Measurements Flux W/m²	$\left(\frac{C_h}{C_{10}}\right)^{0.08}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m²
10	8.2	401	1.000	9.30	3.3	0.898	8.35	0.970	0.594	470

Figure 9



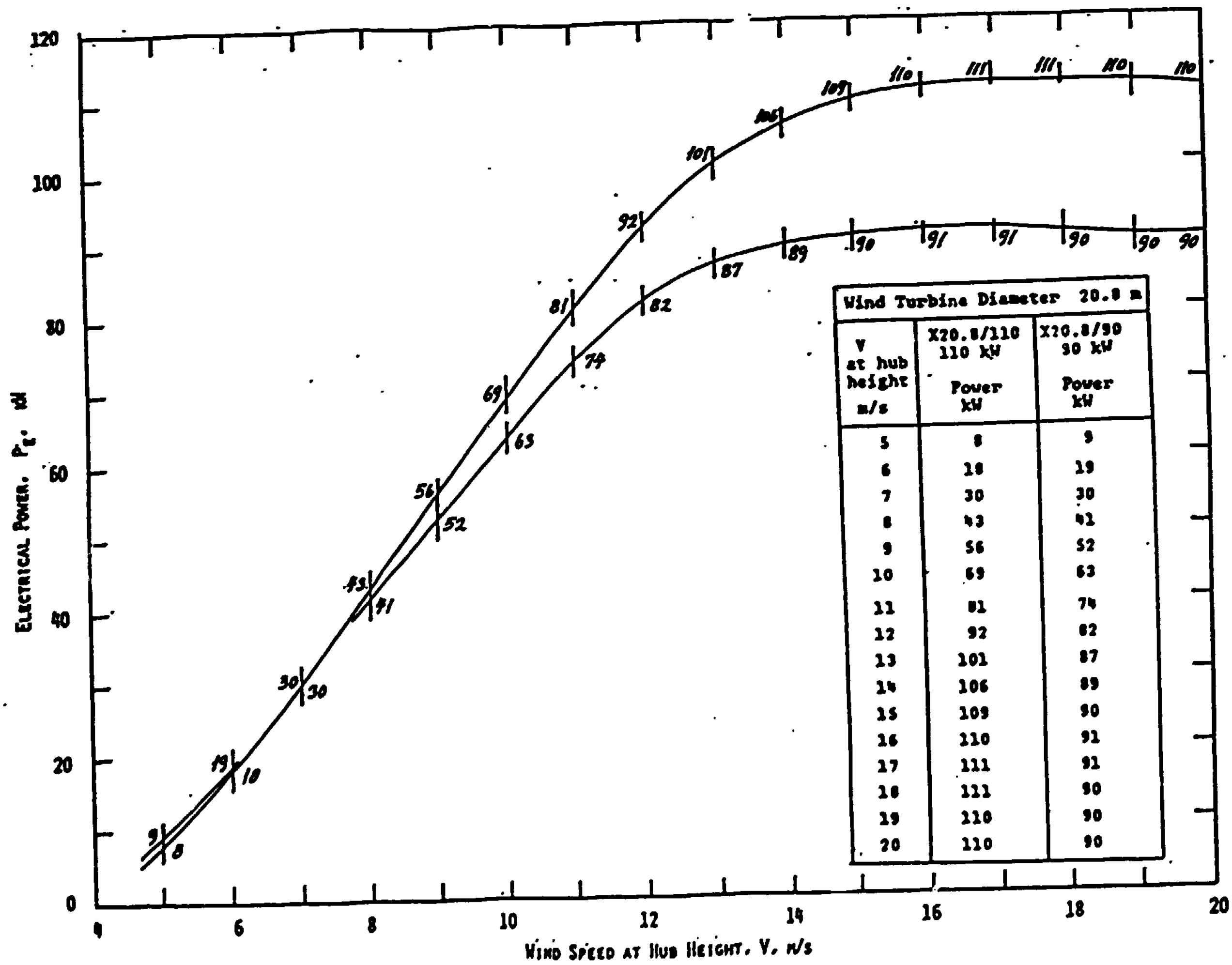
Height above ground m	Measurements $\bar{V}$ m/s	Measurements Flux W/m²	$\left(\frac{C_h}{C_{10}}\right)^{0.08}$	C m/s	K	$\frac{\bar{V}}{C}$	$\bar{V}$ m/s	$\frac{Flux/C^3}{\frac{1}{2}\rho}$	$\frac{Flux}{C^3}$	Flux W/m²
20	8.7	548	1.057	9.83	3.60	0.902	8.86	0.944	0.578	549

Figure 10

3.3. Wind Turbine Generation of Electricity at Ras Ghareb

The table on the next page shows calculations of the generation of electricity at Ras Ghareb, 20-m height, for two wind turbines described in Chapter 5, Performance Analysis of Typical Wind Turbines. The two wind turbines are so to say hypotetical, based on the mentioned analysis. They are named X20.8/110 (20.8 m diameter, 110 kW generator) and X20.8/90 (20.8 m diameter, 90 kW generator). Figure 11 shows the electric power out-put, P_E. The reason for the choise of generator sizes, 110 kW and 90 kW, in stead of say 100 kW, is that 90 and 110 kW are the standard cataloque ratings of the motors, however, it would be legal to uprate a 90 kW motor to 100 kW as a generator.

The calculation of energy generation is based on the measured wind speed distribution.



Wind Turbine Diameter 20.8 m		
V at hub height m/s	X20.8/110 110 kW Power kW	X20.8/90 90 kW Power kW
5	8	9
6	18	19
7	30	30
8	43	41
9	56	52
10	69	63
11	81	74
12	92	82
13	101	87
14	106	89
15	109	90
16	110	91
17	111	91
18	111	90
19	110	90
20	110	90

Figure 11

WIND TURBINE GENERATION OF ELECTRICITY AT RAS GHAREB, 20-M.

RAS GHAREB, 20-METER HEIGHT MEASURED WIND SPEED DISTRIBUTION				$\frac{1}{2}\rho\,(V_n, V_{n+1})^3 A$, kW; $\rho=1.225$, $A=340\ m^2$		W.T. X20.8/110 110 kW		W.T. X20.8/90 90 kW	
V m/s	f %	V m/s	f %		V m/s	Power curve P kW	f·P kW	Power curve P kW	f·P kW
3 - 4	4.5	2.5 - 3.5	2.30						
4 - 5	6.2	3.5 - 4.5	5.35						
5 - 6	6.5	4.5 - 5.5	6.35	27.5	5	8	0.51	9	0.57
6 - 7	8.5	5.5 - 6.5	7.50	46.5	6	18	1.35	19	1.43
7 - 8	9.7	6.5 - 7.5	9.10	73	7	30	2.73	30	2.73
8 - 9	11.7	7.5 - 8.5	10.70	108	8	43	4.60	41	4.39
9 - 10	12.0	8.5 - 9.5	11.85	153	9	56	6.64	52	6.16
10 - 11	12.0	9.5 - 10.5	12.00	210	10	69	8.28	63	7.56
11 - 12	10.5	10.5 - 11.5	11.25	280	11	81	9.11	74	8.33
12 - 13	7.6	11.5 - 12.5	9.05	363	12	92	8.34	82	7.42
13 - 14	4.5	12.5 - 13.5	6.05	461	13	101	6.11	87	5.26
14 - 15	2.0	13.5 - 14.5	3.25	575	14	106	3.45	89	2.89
15 - 16	0.4	14.5 - 15.5	1.20	706	15	110	1.32	90	1.09
16 - 17	0.1	15.5 - 16.5	0.25	856	16	110	0.28	91	0.23

		W.T. X20.8/110	W.T. X20.8/90
FOR A SINGLE WIND TURBINE	ANNUAL AVERAGE POWER OUTPUT, kW	52.72	48.06
	CAPACITY FACTOR	$\frac{52.72}{110} = 0.479$	$\frac{48.06}{90} = 0.534$
	FLUX, W/m^2	155	142
	$\frac{\text{ANNUAL AVERAGE ENERGY}}{\text{ENERGY IN WIND}} = \frac{\text{FLUX}}{550} =$	0.282	0.258
AT WINDFARM CONDITIONS			
GENERATION OF ELECTRICITY AT AVAILABILITY FACTOR 0.95 AND WINDFARM INTERFERENCE FACTOR 0.90 WH PER YEAR		395 000	360 000
UTILIZATION FACTOR, $\frac{\text{ANNUAL AVERAGE GENERATION}}{\text{ENERGY IN WIND}}$		0.240	0.220

COMPARISON OF THE TWO WIND TURBINES

RATIO OF POWER GENERATION	$\frac{X20.8/110}{X20.8/90}$ =>	$\frac{52.72}{48.06} = 1.10$
RATIO OF GENERATOR SIZE	$\frac{X20.8/110}{X20.8/90}$ =>	$\frac{110}{90} = 1.22$

The figure below shows comparison of the power generation at Ras Ghareb and in Denmark at a good site with 5.5 m/s mean wind speed. for wind turbines of the same diameter. As will be seen the production at Ras Ghareb is more than 50% higher.

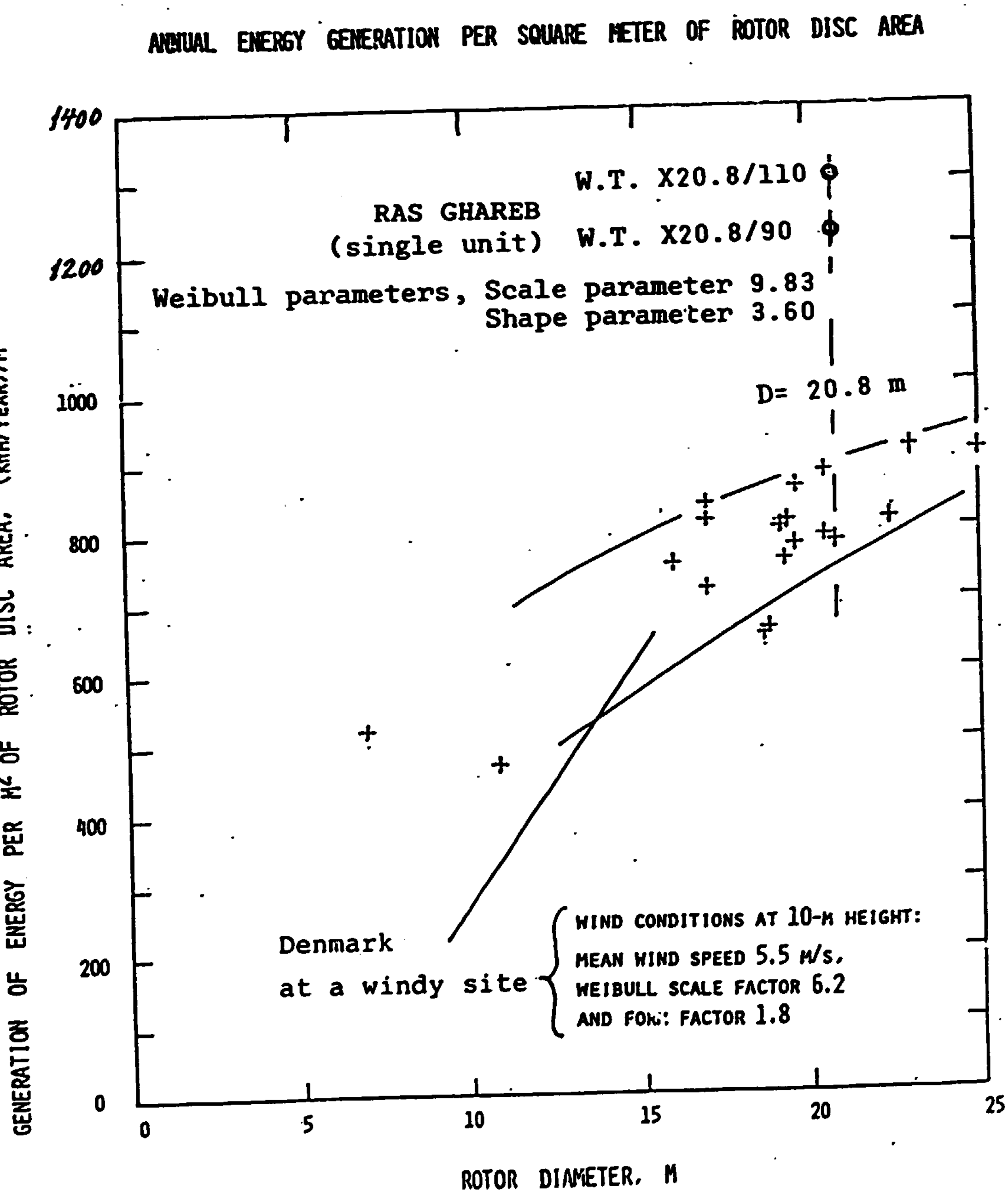


Figure 12

3.4. Wind Turbine Generation of Electricity at Hurghada

Correspondingly to the calculations of electricity generation at Ras Ghareb an estimation of the generation at Hurghada can be made.

The 90 kW wind turbine will at Hurghada generate averagely 29 kW. This is only 60% of the 48 kW generated at Ras Ghareb.

Applying the reduction factors at wind farm conditions: availability factor 0.95 and interference factor 0.9, the annual generation will be

8750 0.95 0.9 29 = 217,000 kWh per year.

Although much lower than at Ras Ghareb it is still reasonable for economical production of electricity.

4. Prospects of Wind Energy Applications in Egypt

4.1. The coasts of the Gulf of Suez and the Red Sea

The most windy places in Egypt are along the coasts of the Gulf of Suez and the Red Sea. The coastal area under consideration is not much populated therefore windfarms can be established here without many environmental problems. One could imagine that windfarms were established on a strip along the coast from Zafarana 100 km north of Ras Ghareb to Hurgada, a strip 250 km long. At Ras Gnareb the wind speed averagely over the year is 8.2 m/s and at Hurghada 6.2 m/s, in both cases at 10-m height. It is told that at Zafarana the wind speed is even higher, 10 m/s. For comparison it can be mentioned that in Denmark, where now 2000 wind turbines are operating, the maximum average wind speed is 6 m/s, most places only 5.5 m/s, from which it will be seen that the sites along the coasts of the Suez Gulf and the Red Sea have very rich wind resources. Let us further suppose that the windfarm occupies a strip along the coast 3 km wide.

The windfarm so is 250 times 3 km. The wind turbines are supposed to of rated power 90 kW and of 20.8 m diameter, an example of wind turbines described elsewhere in the report. In the most frequent wind direction, North-West, the distance between the wind turbines is 9-10 times the diameter, cross-wise they are separated by 3 times the diameter.

At a strip of 250 by 3 km there will be a number of rows of 1250 each row of 50 wind turbines giving a total of 62,500 machines. To account for the residential areas let us suppose that 80% of the number can be established, the result then is 50,000.

50,000 wind turbines each 90 kW means an installed capacity of 4,500 MW. One wind turbine at Ras Ghareb generates as shown in Chapter 3, 360,000 kWh per year, at Hurghada 217,000 kWh per year. Estimating that the wind turbines in the windfarm averagely will generate 280,000 kWh per year the mean power then is 32 kW which is 35,5% of the 90 kW installed.

Totally the 50,000 wind turbines then generates 1,600 MW.

This very large capacity of power of the windfarm can only be absorbed by a very large grid, the Cairo area, and it will be necessary to built a correspondingly strong transmission line across the land, 250 km, connecting to the 500 kV line along the Nile.

Imagining that the windfarm would be fully established by the year 2005 by erecting 3000 machines per year, and supposing that Egypts consumption at that time is 11,000 MW, the windfarm would then cover 15%. These very roughly made estimates show the large potentials, but realization is of course a future perspective.

However, talking short time perspectives, analysing the present plans for the growth in energy demand and supply in the towns Hurghada and safaga, south of Hurghada, it is most possible that windfarms of considerable sizes advantageously could be established in the area. A table of the predictions is shown below.

SAFAGA AND HURGHADA, EXPECTED DEVELOPMENT IN ELECTRICAL ENERGY DEMAND AND SUPPLY

SAFAGA									
Kind of load / Year	1987	88	89	90	91	92	93	94	95
City	2.5	3.2	4	4.5	5.5	6	7.5	8.5	9.5
Grain handling, unloading, storage	8	8	8	8	8	8	8	8	8
Tourist	1.4	1.8	2.5	3	5	7	9	11	13
Industry	2.3	3.5	4	5	7	9	11	13	15
Total	14.4	16.5	18.5	20.5	25.5	30.0	35.5	40.5	45.0
Total minus grain handling multiplied by diversing factor 0.8	5	6.8	8.4	10	14	17.6	22	26	29.6
Available power	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Needed power	-1.4	0.4	2	3.6	7.6	11.2	15.6	19.6	23.2
Available power when a gasturbine of 25 MW is installed: + 0.8·25 = 20 MW	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
Available power for transit to Hurghada: 20 MW minus needed power	21.4	19.6	18	16.4	12.4	8.8	4.4	-	-

HURGHADA									
Kind of load / Year	1987	88	89	90	91	92	93	94	95
City	5	5.5	6	6.5	7.5	8.5	9.5	10.5	12
Tourist	2	3	4	5	7	9	12	14	15
Industry	1.5	2	2.5	3	4	5	6	7	8
Total	8.5	10.5	12.5	14.5	18.5	22.5	27.5	31.5	35
Total, diversing factor 0.8	6.8	8.4	10	11.6	14.8	18	22	25.2	28
Available	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Needed expansion	-	-	0.4	2	5.2	8.4	12.4	15.6	18.6

Supposing that a transmission line is built between the two towns it is likely that the grid of the two towns together would be strong enough to absorbe the power of quite big windfarms even in the near future.

Even more limited applications than the windfarms mentioned above can be envisaged in the area, large tourist hotels, factories and similar consumers could take advantage of wind turbines in connection with their diesel generators.

4.2. The Mediterranean Coast

The annual average wind speeds at the Mediterranean Coast are approximately 5 m/s, but decreasing in-land. These wind speeds are about the minimum speeds for large scale electricity generation in connection with the public grid, but quite satisfactory for water pumping and small scale electricity supply.

Water pumping can be done with so-called windpumps, small windmills with mechanical pumps, however, windpumps are not dealt with in this report. Pumping water by means of electrical pumps powered by electricity generating windmills, which is a method of high reliability and low demand for maintenance, could be feasible. Although large windmills are generally more economical they may be too large ; it may be favourable to spread the windmills over the area using windmills of 10-20 kW. The windmills could as well be used for desalination. Another application is to supply power to small isolated villages, here the wind/diesel systems come into the picture and again small windmills of 10-20 kW could be applicable.

4.3. The Oweinat Area

The Oweinat Area has a quite rich wind climate, 5.6 m/s. This report cannot go into details with the applications of wind turbines in this area, but undoubtly wind turbines could be used with success.

5. Performance Analysis of Typical Wind Turbines

In this chapter performance analysis is carried out for typical wind turbines. The reason for doing this is to establish a firm basis for precalculations of the aerodynamics of wind turbines suitable for applications in the wind climate of Egypt. By means of the analysis of excisting wind turbines one can derive at emperical values of the data which are used in the calculations of the power curves of wind turbines. The importance of this is that wind turbines in this way can be optimized to the actual wind climate.

Five wind turbines are analysed. They are named by their diameters D= 16.6 m, 17.0 m, 19.1 m, 19.6 m 20.8 m, respectively.

The wind turbines have blades of three types, here named: Blade A, Blade B and Blade C.

The combination are as follows:

D= 16.6 m, Blade A, Figure 13
D= 17.0 m, Blade B, Figure 14
D= 19.1 m, Blade B,
D= 19.6 m, Blade C, Figure 15
D= 20.8 m, Blade C. Figure 16

The analysis is used to derive at two hypotetical wind turbies named X20.8/110 (diameter 20.8 m and generator 110 kW) and X20.8/90 (diameter 20.8 m and generator 90 kW) and these are used in Chapter 3 to calculate the energy production at Ras Ghareb and Hurghada.

The figures, Fig. 13 -16, show the analysis of the five wind turbines and Fig. 17 shows a comparison of the results.

Based in this calculations are performed for a 20.8-m diameter wind turbine shown in Fig. 18 and 19, and from these the power curves in Fig. 11, Chapter 3, Sub-chapter 3.3. are derived.

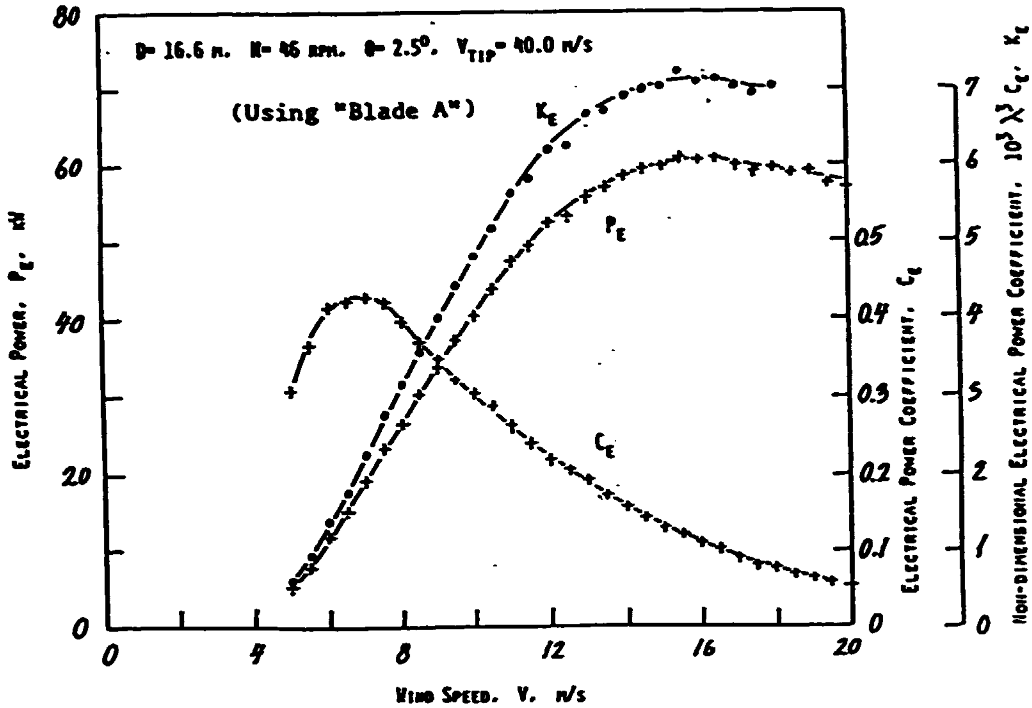


Figure 13

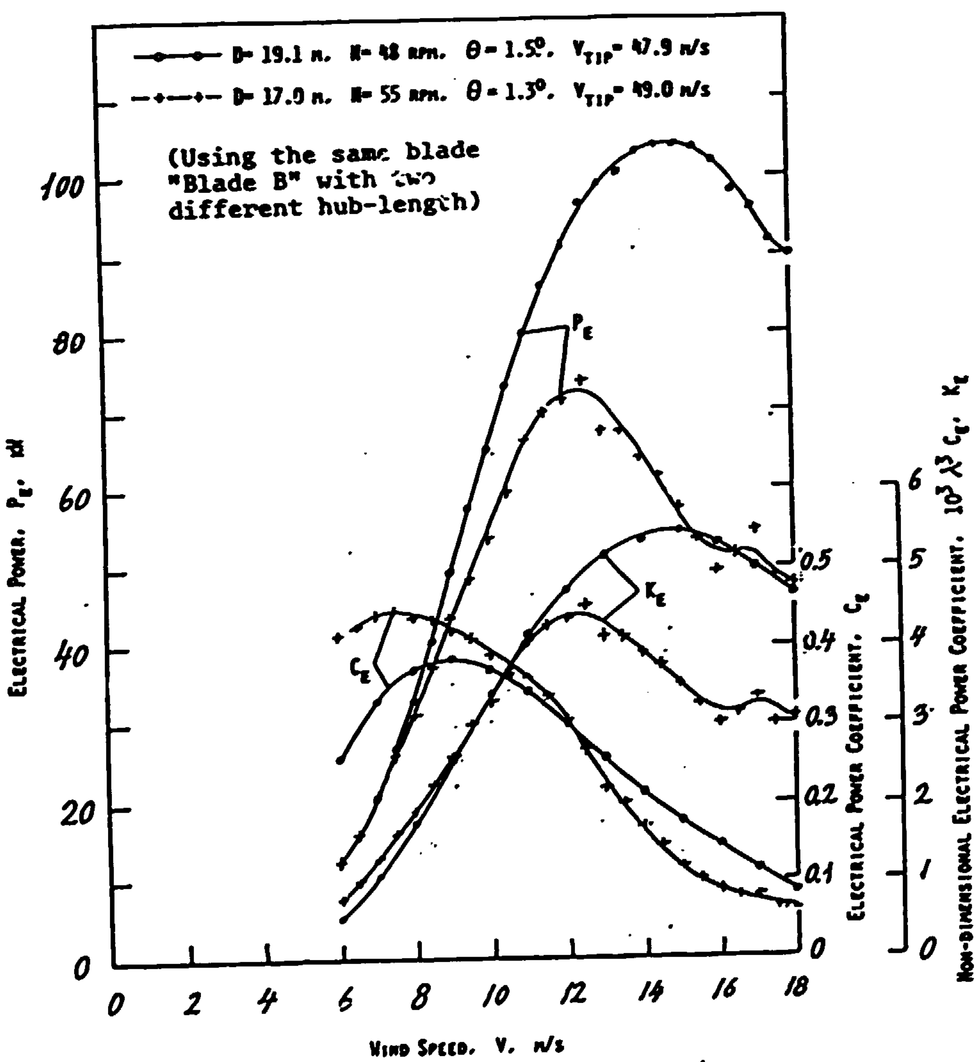


Figure 14

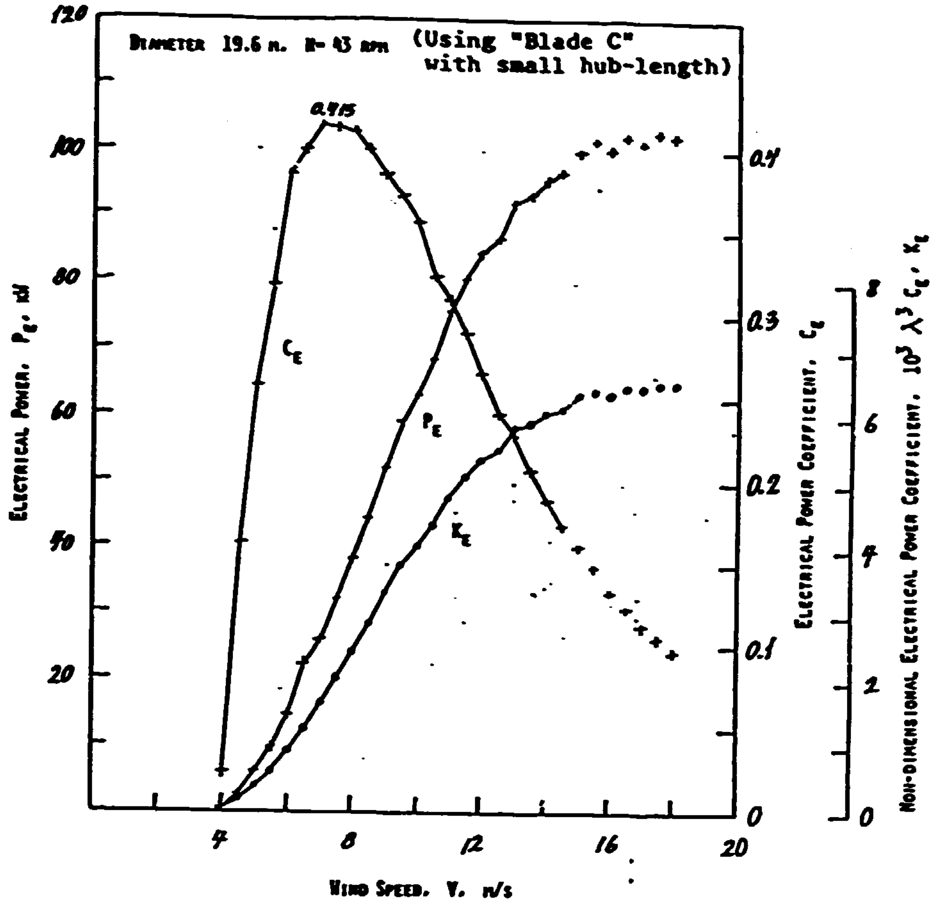


Figure 15

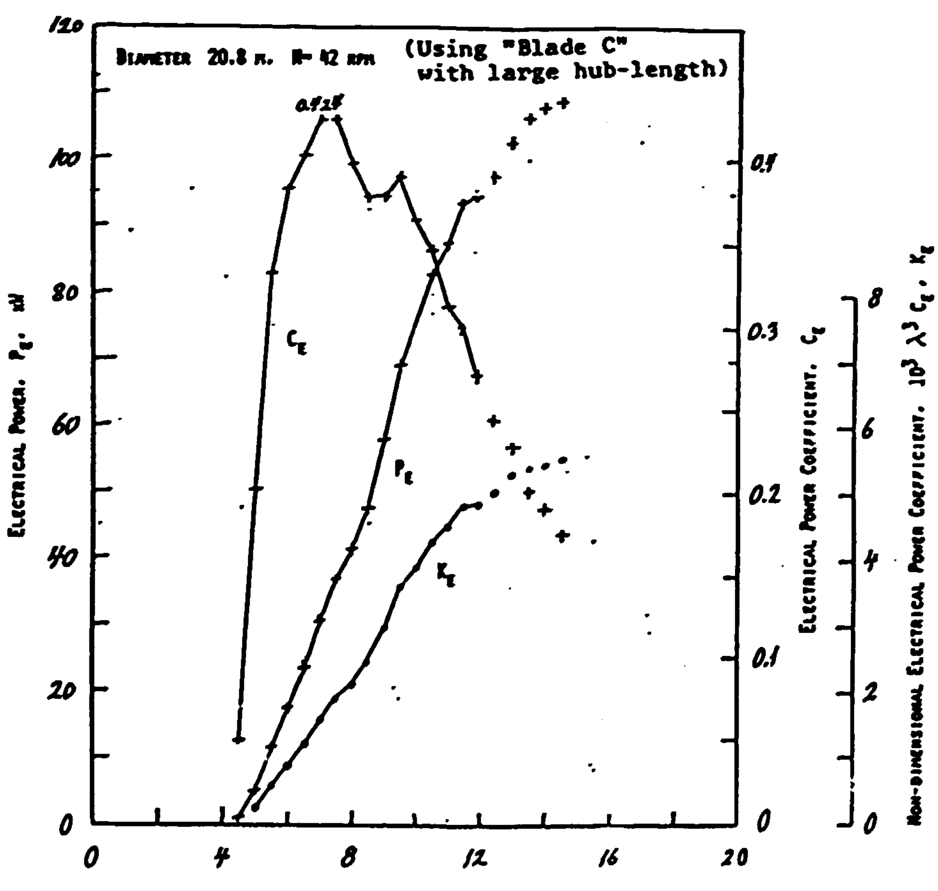


Figure 16

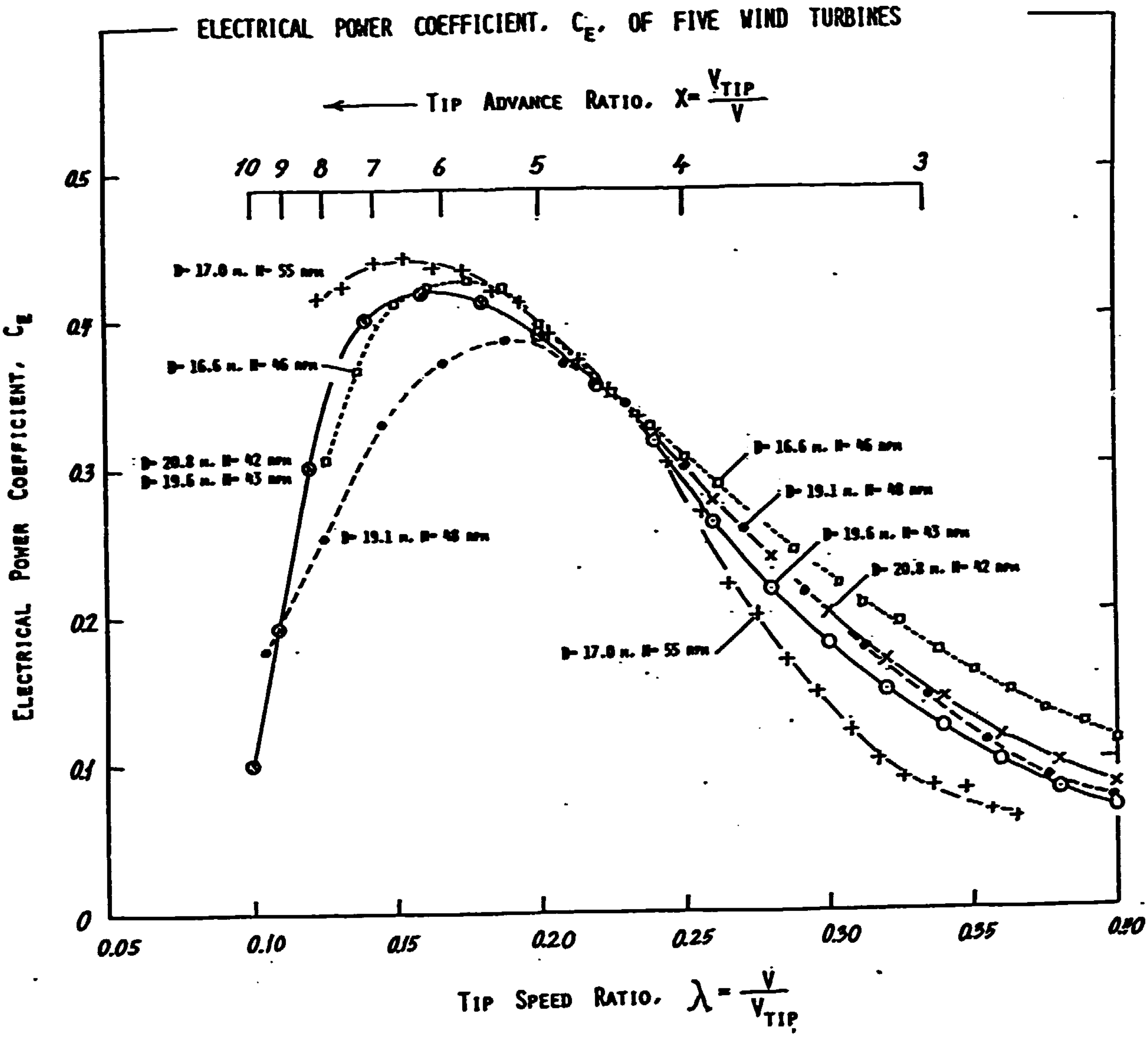


Figure 17

The curves above show a remarkable constancy of the designs, the peak value of the electrical power coefficient, C_E, being 0.42, which is very high, indicating the high level of technology reached.

The divergencies at high values of lambda is due to different tip chord angles for adaption to the selected sizes of the generators.

One of the curves, D= 19.1 m, has a low efficiency which indicates an unfavourable combination of speed of revolution and tip chord angle.

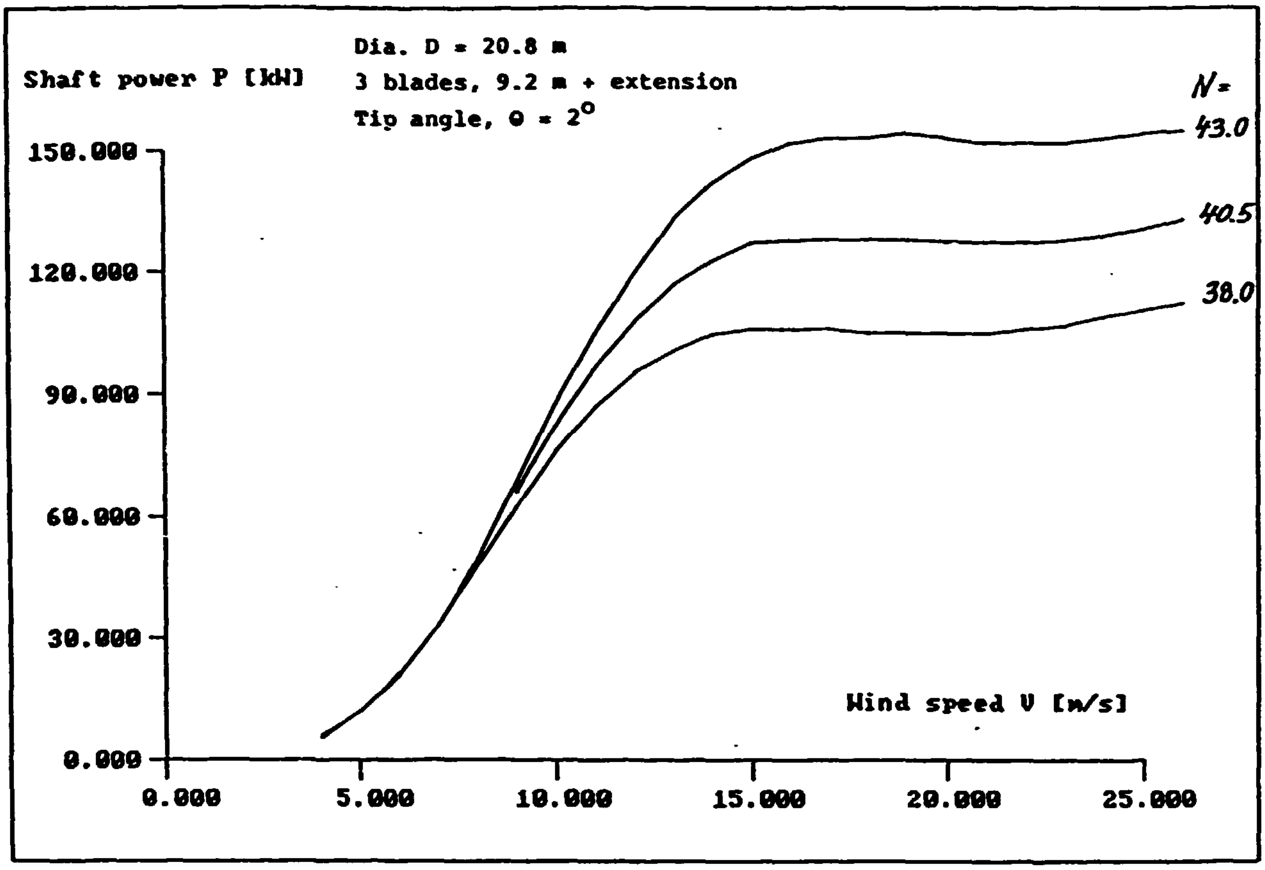


Figure 18

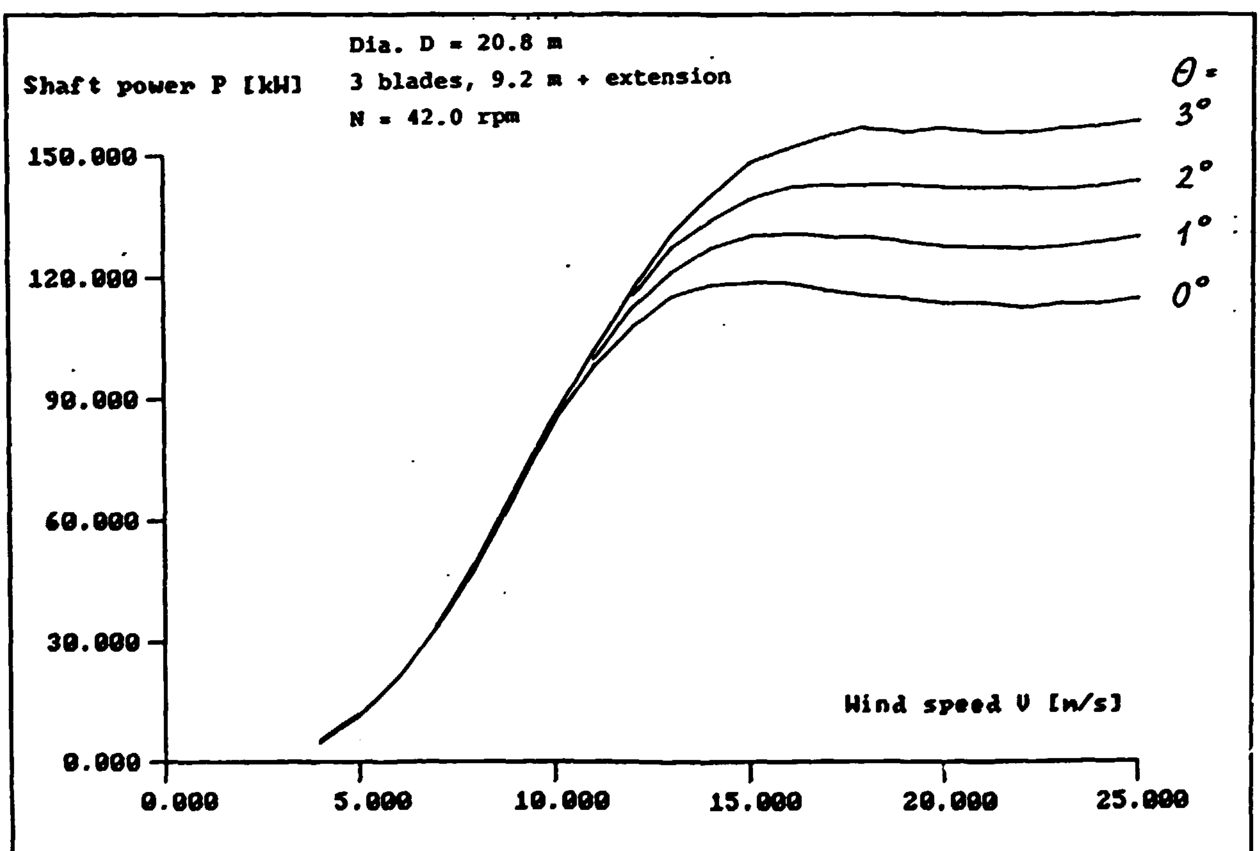


Figure 19

6. Prices of Wind Turbines Related to Size

The figures shown in the following are from the report:

DEVELOPMENT OF COMMERCIAL DANISH WIND TURBINES, RISØ-M-2661
by
Helge Petersen

The paper presents an examination of the development of commercial Danish wind turbines. The wind turbines surveyed are from 7 to 25 meters in diameter. Based on the catalogue prices of the machines and their dimensions graphs are presented indicating on the price relative to both the rotor area and the rated generator power. Based on performance data, the prices are shown relative to both the generation of energy per square meter of rotor disc area in a given wind climate together with graphs showing the wind power utilization ratio and capacity factor. The conclusion arrived at is that within the range of sizes considered from an economic point of view the windmills should be chosen to be as large as feasible for the application in question. In addition technical features of the windmills are surveyed such as the specific power disc loading, rotor solidity and blade tip-speed.

As mentioned in the abstract the learning from the study is that large wind turbines - up to 25-m diameter as examined here - are relatively cheaper than small wind turbines, therefore wind turbines should be chosen to be as large as feasible for the application in question.

There are several reasons for the small wind turbine being relatively more expensive. One reason is that small wind turbines are less effective in power generation, another that they consist of nearly as many parts as the large ones, relatively more expensive. A very costly part of the grid-connected wind turbine may be the control system.

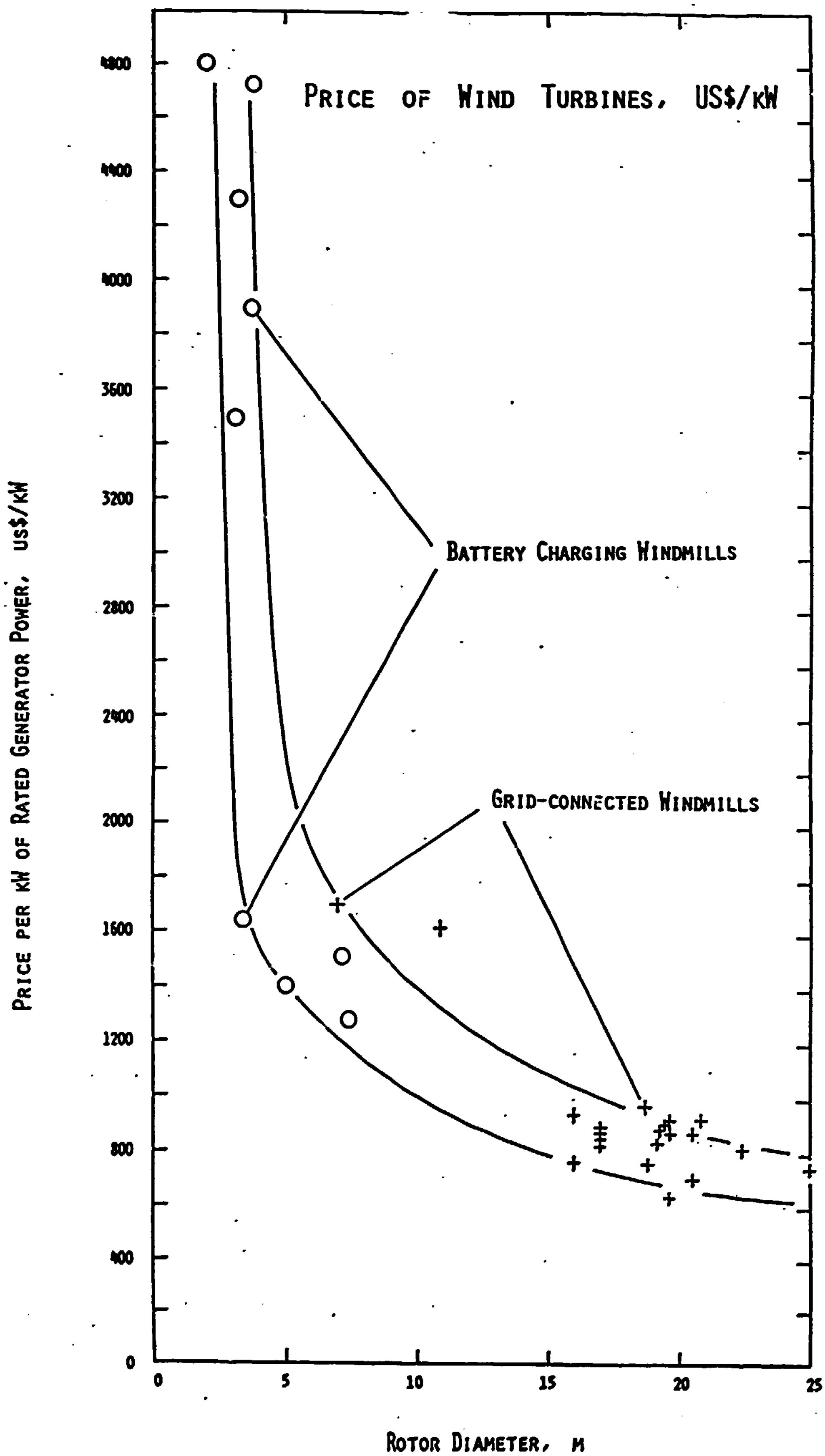

PRICE OF WIND TURBINES, US$/KW
BATTERY CHARGING WINDMILLS
GRID-CONNECTED WINDMILLS
PRICE PER KW OF RATED GENERATOR POWER, US$/KW
ROTOR DIAMETER, M
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
0
5
10
15
20
25

Figure 20

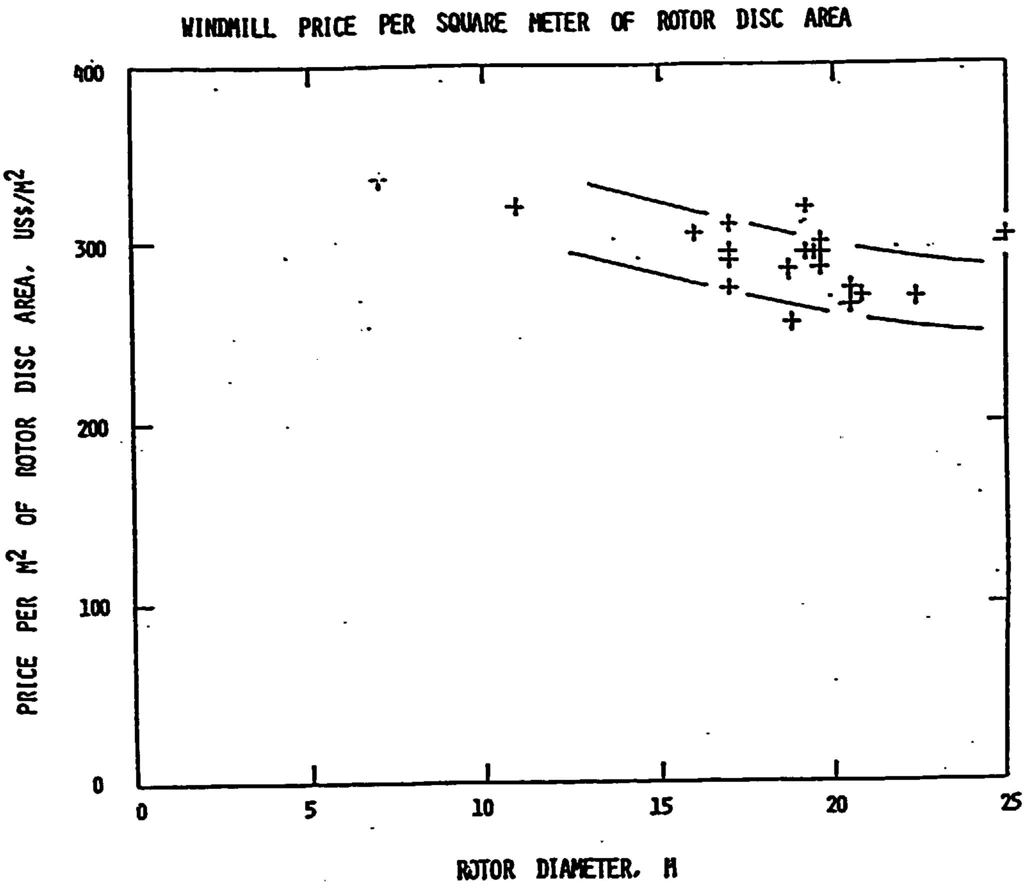


Figure 21

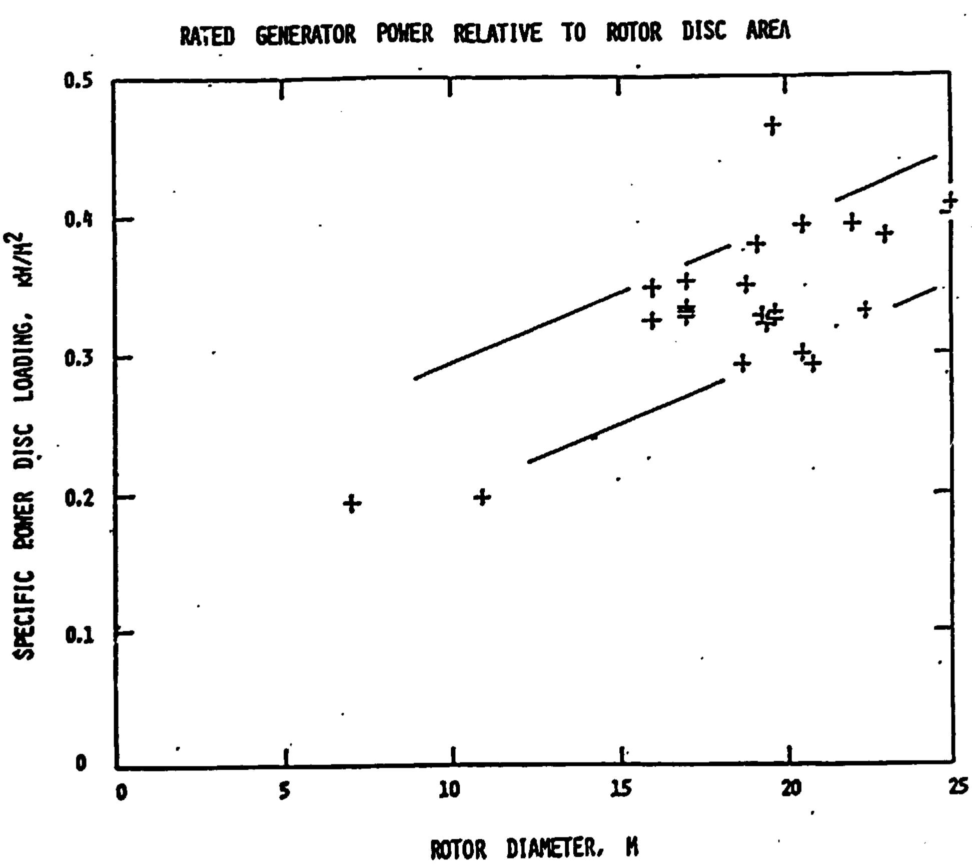


Figure 22

In the following figures the wind turbines are compared as far as the energy generation is concerned. To do this the energy generation is calculated in one wind climate, the same for all the wind turbines. The wind climate is defined by the wind speed distribution given by the Weibull parameters: scale factor 6.2 and shape factor 1.8, the mean wind then is 5.5 m/s.

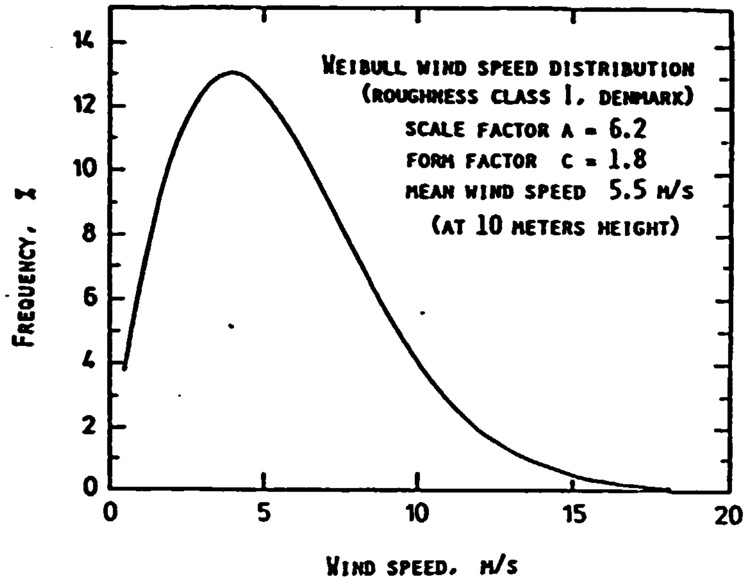


Figure 23

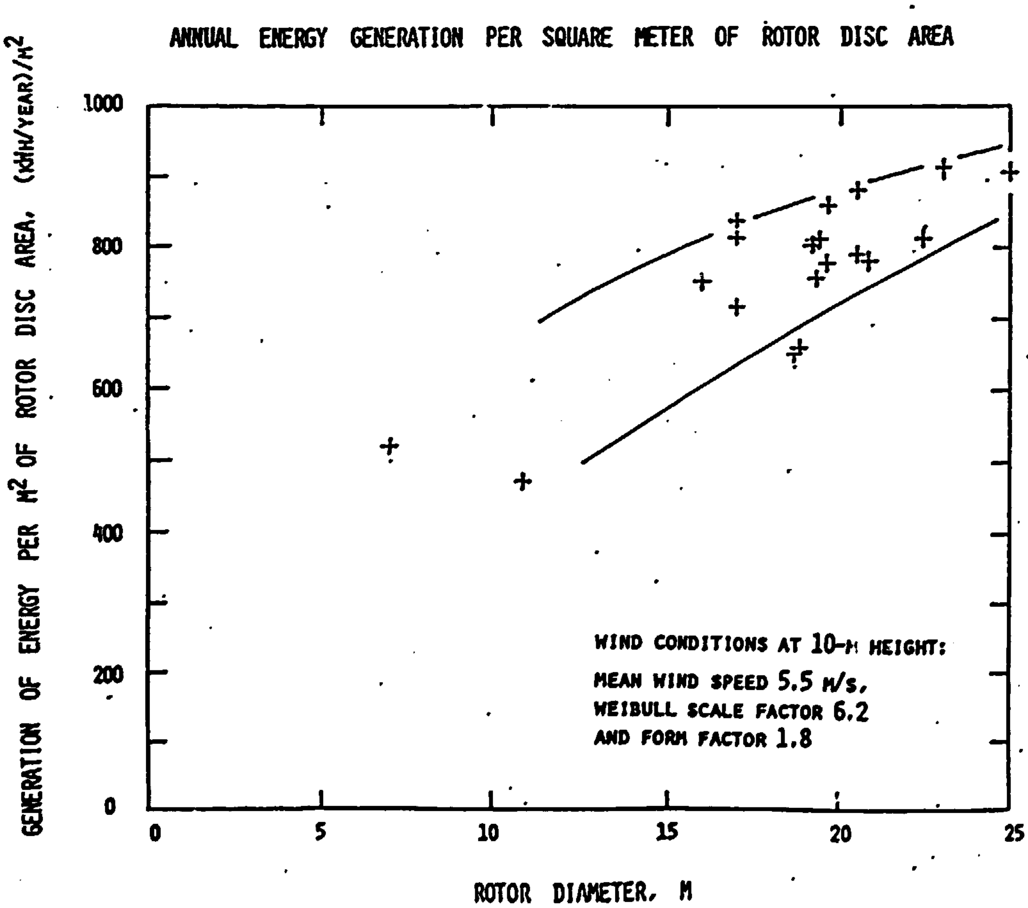


Figure 24

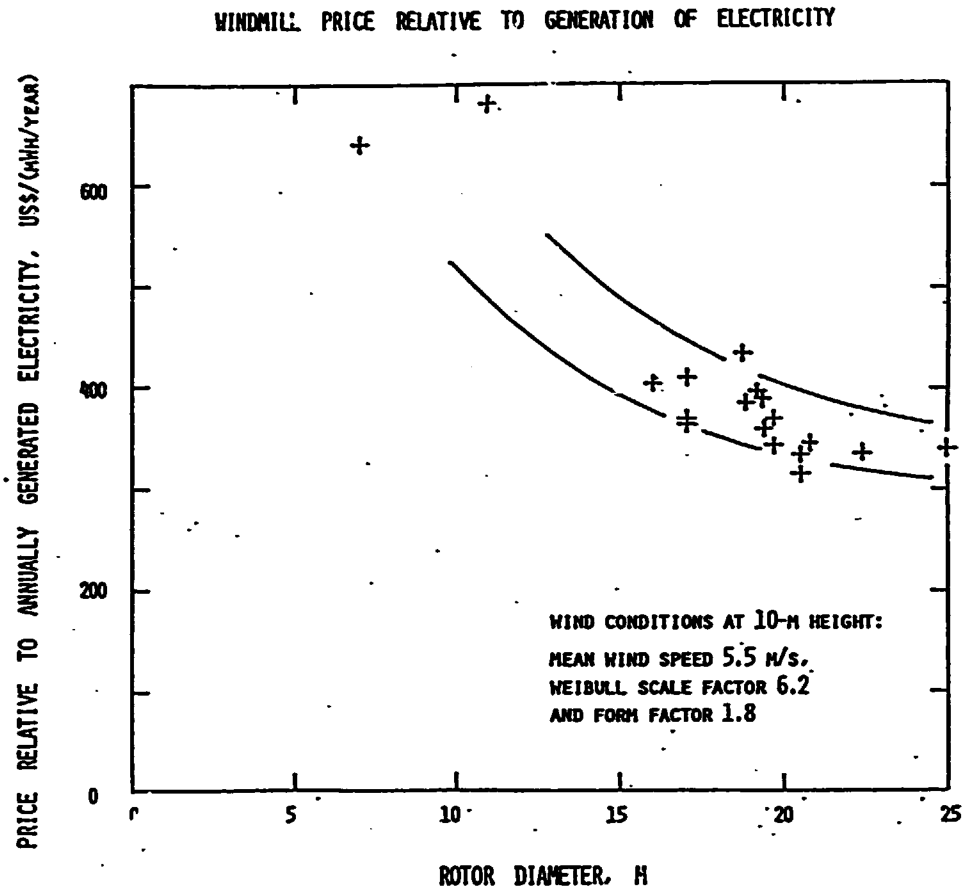


Figure 25

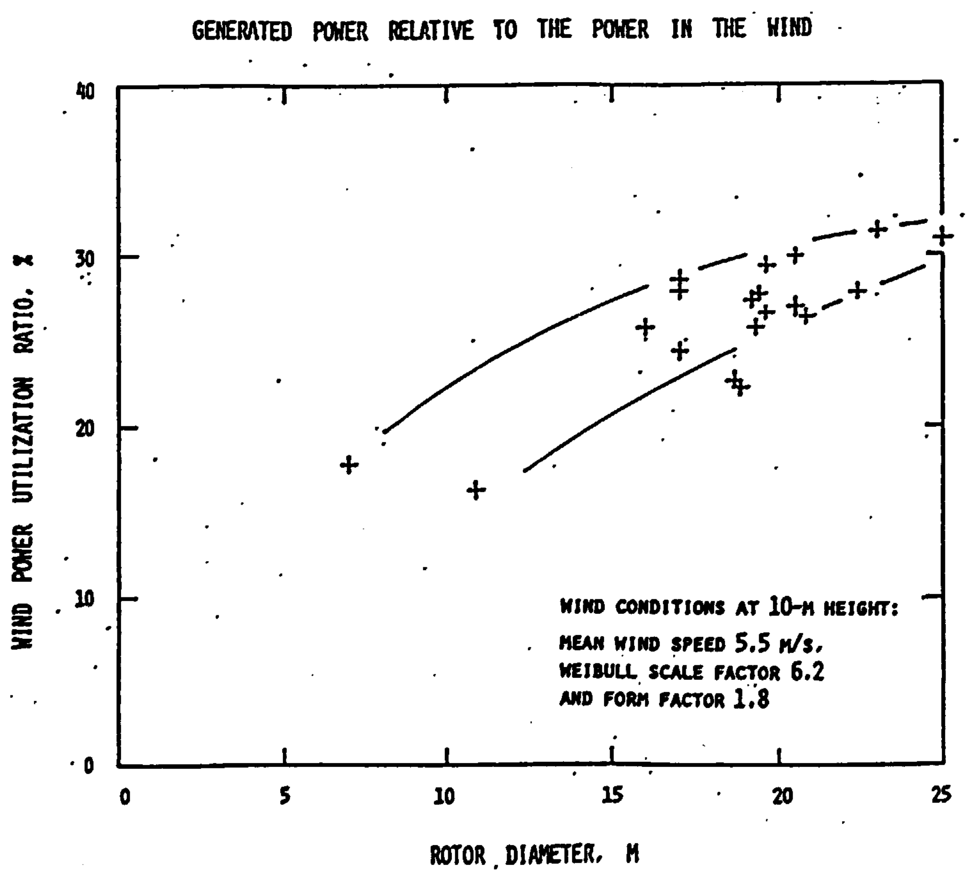


Figure 26

7. Manufacture of Wind Turbines in Egypt

The conclusions of the investigations presented in the foregoing chapters is that there are great perspectives in the use of wind energy in Egypt.

The visits to Egyptian factories and the discussions with the factory managements clearly showed fully qualified capabilities of the factories and great interest of the managements to enter manufacture of wind turbines in Egypt, by making the wind turbines under licence in order to avoid the time-lag involved in development work, and to assure that the products are readily operational.

In Annex 8 a proposal is presented of a contract on licence between an Egyptian and a foreign company.

The nature of technical assistance to be provided by UNDP/UNIDO and technological reasons call, however, for a co-operative approach through the transfer of technology based on sub-contracts.

7.1. Large Wind Turbines

It has been discussed in the foregoing chapters how large a wind turbine should be to be cost-efficient for connection to an ordinary grid. Although more studies should be performed to answer this question, the immidiate result is that wind turbines should be of approx. 100 kW, at least to start with, later on still more economic machines of 200 kW could be considered.

It is therefore recommended to base the manufacture on a wind turbine of this size, it could be the machine discussed earlier, nominal rating 90 kW, diameter 20.8 m. The generator could be the 90 kW motor described in 7.4, Asynchronous Generators, which could be imported by Shoubra Co. aiming at later licence production.

It should be mentioned that the wind turbine described above, the 90 kW, 20.8-m diameter machine, does not refer to any specific wind turbine manufacturer.

In the INTRODUCTION suggestions for the organization of the manufacture is given.

It is recommended that the first machine produced, the pilot manufactured prototype, is thoroughly tested before series production is started.

7.2. Small Wind Turbines

The possibility of producing a small wind turbine based on using as a generator the three-phase motor made by Shoubra Co. in Egypt has been mentioned before. A list of the motors they make is given in Annex 5, Eleven Companies Visited. The motor in question is the same as specified in the Siemens Catalogue, pages of which are shown in Subchapter 7.4., Asynchronous Generators. The largest of the motors produced is rated 18.5 kW at 3000 RPM, 15 kW at 1500 or 11 kW at 1000 RPM. Furthermore other Egyptian companies can produce the gear box. A gear box to speed up the rotation of the rotor of the wind turbine to 3000 RPM is very expensive, so a compromize could be to use the 15 kW, 1500 RPM motor as the generator.

In the INTRODUCTION suggestion for the organization of the manufacture is given.

The wind turbine is to small to be cost-effective compared with the large wind turbine when used in connection with an ordinary public grid. This does not imply that small wind turbines are not economic, it only means that small wind turbines shall be applied where the energy cost from a local engine powered generator is high enough to justify the use or at places far from the main grid where the cost of transmission lines would be too high.

The small wind turbine, estimated to be of 15 kW and 12-m diameter, should be optimized primarily to serve purposes of,

- water pumping for livestock watering, irrigation and drainage,
- desalination, and
- small-scale electricity supply.

Being an electricity generating wind turbine the water pump must be an electric pump. This has also advantages, reliability and low maintenance. An example on a suitable type of pump is given in Annex 7, "Water Pumps".

Brief notes on the use of induction motors as generators can be read in subchapter 7.4. Asynchronous Generators, the second page of the Siemens catalogue reference.

On optimizing the wind turbine a few remarks are given in Annex 6, "Note on Blades for Wind Turbines".

At many places all over the World, in laboratories and companies, development on control systems for stand-alone operation of wind turbines is going on and it is a large subject which cannot be analysed here. It should only be stated that great care should be devoted to the problem.

It is recommended that the first machine produced, the pilot manufactured prototype is tested in the grid-connected configuration, using a simple, partly manually operated control system imported for the purpose.

There are several reasons for the small wind turbine being relatively more expensive than large machines. One reason is that small wind turbines are less effective in power generation. An example is shown in the figure below , however, this generalization may be too pessimistic because the small machines are not developed to the same degree as the 100-kW machines.

The figure below shows the efficiency of Danish wind turbines (in 1986). The figure is based on published data. The wind data, given by a Weibull distribution with scale parameter 6.2 and form parameter 1.8, mean wind speed 5.5 m/s, a typical, good, site in Denmark. The increase in efficiency with size is clearly seen.

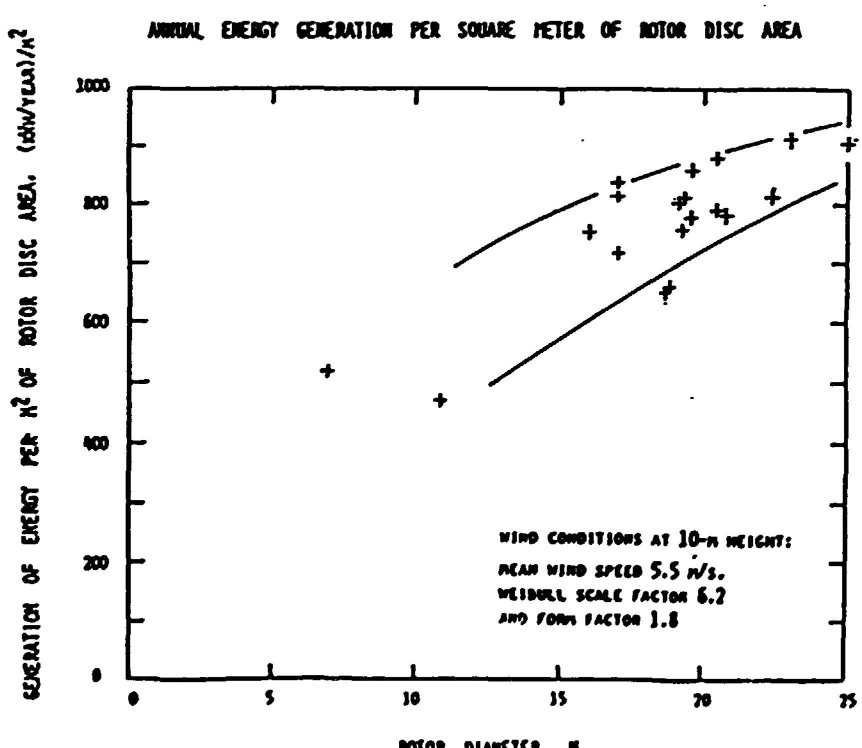


Figure 27

By the way the wind distribution used above corresponds nearly to a good, windy site at the Mediterranean coast.

Another reason for the relatively higher cost of the small machine is that it consists of nearly as many parts as the large one, the parts being relatively more expensive. A very costly part of the grid-connected wind turbine is the control system. The table below gives an example on a control system principle. The system is very comprehensive and the price difference of the system for a large and small wind turbine is not much for the automatic system, only the main relays are cheaper, however, the control system can be made simple (analog system) and cheap if it is acceptable that some of the functions, starting and stopping, are manually done by the owner, which could be the case for single machines for detached houses.

Automatic Control System for a Grid-Connected Wind Turbine

Function: Ensures automatic engagement of generator.
Push-buttons with text for simple operation and checking of the turbine.
Display with indication of faults ensure quick trouble-shooting in the event of stoppage or breakdown.
Automatic start-up after grid failure.
. Wind-turbines are equipped as standard with capacitors, improving cos. ø to 0.96.
Excess voltage protection by means of lightning arresters.
Electronic engaging equipment to restrict current impulses on engagement to 2.6 x top loading of generator.

Safety systems:

1. Centrifugally activated aerodynamic brakes.
2. Electro-mechanical "fail-safe" disc brake.
3. Grid control of:
   a) Voltage 380 V 480 V (US). ± 10%
   b) Frequency 50 Hz 60 Hz (US). ± 0,1 Hz.
   c) Phase equality control.
4. Over-speed control on rotor that activates disc brake.
5. Thermo-detector in generator.
6. Vibration control switch.
7. Automatic un-twisting of cables.
8. Thermo relay for yaw-gear motor.
9. 90° yaw of nacelle, in case of malfunction.
10. Automatic stop for worn brake pads.
11. Automatic start-up in the event of grid failure.
12. Self diagnostic in case of failure. Display indicates failure code.
13. Ready to be linked via modem with computer management system.
14. Built-in data-processor.

7.3. Blades for Wind Turbines

Manufacture in Egypt of wind turbine blades made from glassfibre-reinforced-polyether under licence from a reputed foreign blade manufacturer should present no problem.

During the mission Suez Tawfik Shipyard, Suez Channel Authority, was visited and the company is highly qualified in this kind of work and has excellent facilities such as airconditioned workshop and temperature controlled storage and even a laboratory for test of materials, facilities seldom seen in such factories. There is no significant difference in materials or work between boats and blades.

In Annex 6, "Note on Blades for Wind Turbines", more technical information on manufacture of blades is presented.

7.4 Asynchronous Generators

For simplicity asynchronous generators can be used for wind turbines the table below shows examples of motors suitable as generators.

The motors numbered 1, 2 and 3 are similar to the motors manufactured in Egypt by Shoubra Co.. The motors numbered 4 to 9 are motors which could be used for the approx. 100 kW wind turbine.

Three-Phase Motors

Käfigläufermotoren 1LA5 und 1LA6 oberflächengekühlt

List prices are fictive, even a small number of motors will reduce the price by 50%.

Auswahl- und Bestelldaten

No.	List price Danish Kroner	Nennleistung kW	Baugröße	Momentenklasse KL	Trägheitsmoment J kg m²	Nenndrehzahl min⁻¹	Wirkungsgrad η %	Leistungsfaktor cos φ	Nennstrom bei 380 V A	Nenndrehmoment Nm	Anzugsmoment (als Vielfaches des Nenndrehmomentes)	Anzugsstrom (als Vielfaches des Nennstromes)	Kippmoment (als Vielfaches des Nenndrehmomentes)	Bestell-Nr.	Gewicht etwa kg
3000 min⁻¹ · 2polig · Grundausführung · Schutzart IP 54 · 50 Hz															
1		18,5	160 L	16	0,050	2945	91	0,86	36	60	2,5	7,6	2,9	1LA5 166 - 2AA..	90
		22	180 M	16	0,077	2940	91,5	0,89	41*)	71	2,5	6,9	3,0	1LA6 183 - 2AA..	165
		30	200 L	16	0,14	2940	92	0,89	56	97	2,4	6,9	2,8	1LA6 206 - 2AA..	230
		37	200 L	16	0,16	2945	92,5	0,9	69*)	120	2,4	6,9	2,8	1LA6 207 - 2AA..	250
		45	225 M	13	0,24	2955	93	0,9	82*)	145	2,3	6,9	2,7	1LA6 223 - 2AB..	310
		55	250 M	13	0,45	2965	93,2	0,91	99	177	2,1	6,9	2,7	1LA6 253 - 2AB..	415
		75	280 S	10	0,79	2970	94	0,9	134	241	1,9	7,0	2,7	1LA6 280 - 2AC..	570
4		90	280 M	10	0,92	2970	94,5	0,91	160*)	289	2,0	7,0	2,7	1LA6 283 - 2AC..	610
5		110	315 S	10	1,3	2980	94,3	0,9	196	353	1,8	7,0	2,8	1LA6 310 - 2AC..	780
1500 min⁻¹ · 4polig · Grundausführung · Schutzart IP 54 · 50 Hz															
2	10,800	15	160 L	16	0,07	1460	89	0,85	30	98	2,2	7,7	2,9	1LA5 166 - 4AA..	90
		18,5	180 M	16	0,13	1455	90,5	0,84	37*)	121	2,6	6,2	2,5	1LA6 183 - 4AA..	165
		22	180 L	16	0,15	1455	91,2	0,85	43*)	144	2,6	6,4	2,5	1LA6 186 - 4AA..	180
		30	200 L	16	0,24	1465	91,8	0,86	58	196	2,7	6,4	2,5	1LA6 207 - 4AA..	240
		37	225 S	16	0,44	1470	92,3	0,86	71*)	240	2,7	6,7	2,5	1LA6 220 - 4AA..	300
		45	225 M	16	0,52	1470	93	0,87	85*)	292	2,7	6,7	2,5	1LA6 223 - 4AA..	330
		55	250 M	16	0,79	1475	93,5	0,87	102	356	2,7	6,7	2,5	1LA6 253 - 4AA..	435
6	59,600	75	280 S	16	1,4	1480	94,3	0,86	140*)	484	2,5	5,7	2,5	1LA6 280 - 4AA..	610
		90	280 M	16	1,6	1480	94,6	0,86	169*)	581	2,5	6,8	2,5	1LA6 283 - 4AA..	680
7	71,700	110	315 S	16	2,2	1485	94,7	0,86	205	707	2,5	6,7	2,5	1LA6 310 - 4AA..	830
1000 min⁻¹ · 6polig · Grundausführung · Schutzart IP 54 · 50 Hz															
3	12,000	11	160 L	16	0,080	965	88	0,76	25	108	2,6	7,0	3,0	1LA5 166 - 6AA..	90
		15	180 L	16	0,2	970	89	0,83	31	148	2,6	5,7	2,4	1LA6 186 - 6AA..	170
		18,5	200 L	16	0,29	975	90	0,83	37,5	181	2,6	5,7	2,3	1LA6 206 - 6AA..	220
		22	200 L	16	0,33	975	90,5	0,83	44,5	215	2,5	5,7	2,3	1LA6 207 - 6AA..	236
		30	225 M	16	0,57	978	91,5	0,86	59*)	293	2,6	5,7	2,2	1LA6 223 - 6AA..	306
		37	250 M	16	0,80	980	92	0,85	72	361	2,6	6,0	2,2	1LA6 253 - 6AA..	410
		45	280 S	16	1,3	982	92,6	0,86	86	438	2,5	6,0	2,3	1LA6 280 - 6AA..	540
		55	280 M	16	1,6	982	93	0,86	104	535	2,6	6,2	2,4	1LA6 283 - 6AA..	580
8	88,600	75	315 S	16	2,4	986	93,7	0,86	142	727	2,5	6,0	2,5	1LA6 310 - 6AA..	770
		90	315 M	16	2,9	986	94,2	0,86	169	873	2,5	6,0	2,5	1LA6 313 - 6AA..	820
9	114,200	110	315 L	16	3,5	986	94,5	0,86	206	1070	2,6	6,6	2,5	1LA6 316 - 6AA..	970

Bestell-Nr.-Ergänzungen für Spannung, Bauform siehe Tabelle unten. Momentenkennlinie nach Seite 12 und 13.

Increased temperatures
The torque motors are mainly used as switching compounds and remain permanently connected to the supply. They are therefore built without a fan. Class F insulation is used for achieving a better power/size ratio.

Good heat dissipation should be ensured when incorporating the torque motors into machine tools. When installed free-standing, a guard preventing accidental contact should be provided.

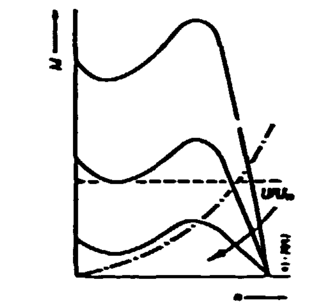
The high temperatures developed necessitate the use of heat-resistant cables, e.g. a SINOTHERM cable, for connecting the terminal box to a junction box.

Phase angle controlled and speed-controlled three-phase squirrel-cage motors
If the motor terminal voltage is reduced to below the rated system voltage, characteristics reflecting heavily reduced speeds under load are obtained. Apart from variable transformers, phase-angle-controlled thyristors and triacs inserted in the motor supply circuit are used for reducing the voltage. To obtain clearly defined intersection points between the load-torque curve (e.g. $M_L \sim n^2$ in the case of fans) and the motor torque, and to reduce the stator losses, special high-resistance rotors (silumin rotors) are used for such motors.

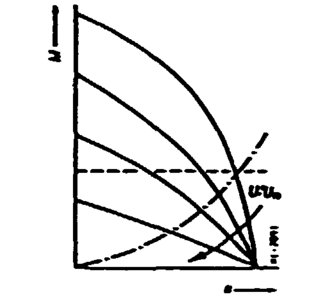
The comparatively high slip losses resulting with this method of speed control require the use of an overdimensioned motor, depending on the desired speed range and the load-torque characteristic.

In the case of drives with varying load torque, adjustment of a definite speed by phase-angle control is not possible. Such applications necessitate an additional closed-loop control circuit with setpoint potentiometer and a tacho-generator, which is coupled with the motor and supplies the actual value of speed. Complete drives of this kind are available – marketed under the name of SIMOTRAS – comprising a three-phase motor with tacho-generator and a three-phase controller.

Details on request.



Characteristics for phase angle control with standard rotor



Characteristics for phase angle control with a high-resistance R_2' squirrel-cage rotor

—— Motor torque with differing U/U_n
- - - Constant and square load characteristic curves

Asynchronous generators

If an induction motor is operated in the direction of rotation of the rotating field at a speed above synchronous, the slip becomes negative. The active-power flow in the motor is thus reversed, i.e. active power becomes available from the stator circuit, and the motor functions as a generator. However, the reactive current required for magnetizing must be made available from an external source as is the case when it operates as a motor. There are two possibilities of achieving this:

1. Operation in parallel with an existing system from which the magnetizing reactive power is drawn and to which the active power generated is supplied.

In parallel operation with an existing system, the power factor is determined by the reactive power of the machine and by its leakage reactance, as is the case with an induction motor, and cannot be varied when the machine operates at a certain load.

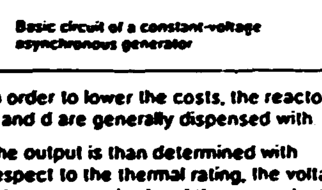
The power output of an induction motor operating as a generator is about equal to the power rating of the same machine as a motor.

An asynchronous generator operating in conjunction with a frequency-determining system has the following advantages:

The machine doesn't need a DC excitation as is the case with synchronous machines. The comparatively expensive voltage regulating equipment can be dispensed with. As a machine with a squirrel-cage rotor the synchronous generator is robust and maintenance-free. Starting up is also quite simple: The asynchronous machine is run up to speed and connected to the system once it has reached synchronous speed. The current surge produced on connection to the system attains approximately the value of the short-circuit current and subsides to the value of the rated current within a fraction of a second.

2. Independent operation of the asynchronous motor as a capacitor-excited asynchronous generator

The capacitor-excited asynchronous generator, driven by an internal-combustion engine, has gained some significance



AG Asynchronous generator with squirrel-cage rotor
b Excitation capacitor
c Saturation reactor
d Harmonics reactor

Basic circuit of a constant-voltage asynchronous generator

In order to lower the costs, the reactors c and d are generally dispensed with.

The output is than determined with respect to the thermal rating, the voltage tolerance required and the power factor.

In any case, the rated output indicated in the motor catalog is to be reduced when an induction motor is used as generator.

8. WIND TURBINE TESTING

The testing of wind turbines is an important part of the work of a national authority for wind turbines. Briefly spoken the main subjects or aims are,

- approval of wind turbines, issuing certificates for the machines,
- testing of a wind turbine basically as documentation for issuing the certificate,
- testing of wind turbines with the purpose of advicing customers on which machines to buy, and advicing local manufacturers on design problems.

Annex 10 is a copy of the law by which NREA is established. It is interesting to note that NREA is authorized to approve wind turbines, since in most countries the organization, institute or laboratory that tests the wind turbine can only issue a certificat which is a guidance for some other authority, it could be the building authority, that takes the final decision on approval.

8.1. Testing by Laboratory Experiments

In a report: "EREDO Feasibility Study and Conceptual Design", ING/2017/127, 1982, Qattara Hydro and Renewable Energy Projects Authority (CESEN), a description is given of test facilities in a laboratory and testing of small wind turbines. During the mission the consultant was asked to look through the report and comment briefly on the proposals for the testing.

In this report a detailed treatment cannot be presented, however, some comments are given in Annex 11.

8.2. Testing of Small Wind Turbines

The report mentioned above: "EREDO......", also deals with testing of small windmills. Again a detailed treatment cannot be given here, some comments are presented in Annex 12.

8.3. Testing of Grid-connected Wind Turbines

Testing of grid-connected wind turbines is a very important subject. It is insufficient just to erect the wind turbine and see how it works, perhaps also measuring its energy generation. The wind turbine must be thoroughly tested along the lines in Annex 9.

The content of this program is described as follows:

- Function tests
- Safety tests of mechanical and air brakes
- Power curve measurements
- Energy production evaluation
- Rotor and transmission efficiency
- Yaw trackability
- Loads at cut-in
- Loads on rotor and tower at stand still and high wind

It is therefore recommended that a test facility for grid-connected wind turbines is established at a windy location like Ras Ghareb.

It is recommended that the testing facility is designed in cooperation with an experienced foreign wind turbine testing institute by establishing a contract on design and delivery of an operational testing facility. The contract should include teaching of personnel in testing and approval of wind turbines.

The main components of the measurement system are

- the computorized data acquisition equipment, and
- the signal sensing instruments mounted on the wind turbine.

The data acquisition equipment

The equipment is supposed to be installed in a van in order to make the system mobile. The software for data acquisition will as a minimum have the following features

- Menue driven programs with easy access
- 16 channel data acquisition
- Scanning with minimum 10 Hz on all channels
- Block averaging of all channels
- On line screen display of signal values
- Method of bins data analysis
- Graphics for data representation

The computer will be supported by a tape streamer for mass-storage, a matrixprinter to print characters and graphics. As an option a fast strip chart recorder could be included.

The signal sensing instrumentation

The following parameters will be supported by sensors that are put on the wind turbine.

- Active electric power (three phases)
- Current on one phase
- Rotor shaft torque
- Rotor rotational speed
- Yaw position
- Tower bending moment

The following meteorological parameters will complete the list.

- Wind speed
- Wind direction
- Air temperature
- Air pressure

The sensors with eventually signal converters will appear in the following list. They are described in the above order.

- Three current transformers and one power converter
- One current converter
- A strain gauge bridge on the main shaft with a one channel FM-transmission system
- Inductive sensor with rpm-signal converter
- Yaw sensor with signal converter
- Strain gauge bridges at the bottom of the tower with a strain gauge signal amplifier
- Two anemometers with signal converters
- Wind direction sensor with signal converter
- Air temperature sensor
- Barometer

Signal transmission will on a main basis be by voltage representaion, which can either be digitized for data analysis or put directly to the strip chart recorder for immediate display.

The meteorology sensors will be mounted on a stationary meteorology tower

The education of personnel

One engineer and one technician at the foreign institute:

- Introduction to the test equipment
- Introduction to the measurement program
- Instrumenting the wind turbine
- Running measurements on the actual computer

The education program at the local test site will consist of the following:

- Installation of hardware and software
- Connection of test equipment
- Running in the test equipment
- Running measurements

Planning of the testing facility

In the described programme for manufacturing wind turbines in Egypt it is planned to make two prototyps by pilot manufacturing, one of the large and one of the small wind turbines, and to carry out testing of them.

From the foregoing description of the testing equipment it will be noted that testing of wind turbines is a big task, which calls upon preparation and education.

It is therefore recommended to establish the testing facility in the following steps:

Step 1. Acquisition of the mobile measurement system and training of personnel abroad.

Step 2. One of the excisting, or at that time excisting wind turbines, is equipped with a set of sensors by personnel from the contracted foreign institute. This wind turbine is then used a training facility for the local personnel.

Step 3. The large wind turbine prototype is erected and equipped with a set of sensors similar to the first set.

Step 4. The small wind turbine prototype is erected and equipped with a set of sensors.

9. TRAINING OF PERSONNEL

Education and training of the technical personnel of NREA at some foreign training establishment is much recommended. Technicians should be trained in operation, maintenance, trouble-shooting and practical testing of wind turbines.

One way to do this is to let them attend courses at Tønder Tekniske Skole in Denmark, it is a public school that runs special courses for wind turbine technicians, also for foreigners. The school has nine different wind turbines equipped for the training courses.

Annex 13 is a brochure from the school.

10. CONCLUSIONS

Through-out the report conclusions are drawn in each of the chapters, and the result is that the recommended activities can be described as presented in the INTRODUCTION.

The conclusions can be summarized as follows,

- The wind resources in Egypt varies from one part of the country to another. Along the coast of the Gulf of Suez it is extremely rich, not only is the mean wind speed high, also is the maximum wind speeds low which is very favourably. The coast of the Red Sea is also a windy region, mostly in the north part of the Sea. At the Mediterranean coast and the Oweinat area the mean wind speeds are moderate, meaning that wind energy can hardly compete with electricity from a public large fossile fired power plant, nevertheless well competable with diesel power plants, and therefore feasible for utilization where the public grid does not reach out or is inconvenient or unreliable.
- Manufacture in Egypt of wind turbines can be established producing the machines on the basis of sub-contracts. The factories visited during the mission gave a picture of well equipped and managed companies and it is most probable that the cost price for Egyptian made wind turbines can compete with foreign markets.
- The demand for energy in Egypt is rapidly increasing and also the energy prices are believed to increase,

- A very simple calculation can give an indication of the economy. From the price examples in the report is derived that a normal price for a wind turbine ab factory would be 700 US$ per kW. Accepting this a 90 kW wind turbine should cost 63,000 US$. According to Chapter 3, a wind turbine in a wind farm at Ras Ghareb would generate 360,000 kWh per year and at Hurghada 217,000 kWh.

Initial costs per wind turbine:	
One wind turbine	US$ 63,000
Transport 2%	1,260
Foundation 12%	7,560
Erection 3%	1,880
Sum	73,700

At the site the transformer stations, control system and connection to the grid are estimated to cover $75,000 per wind turbine. From this follows that the investment per wind turbine is $73,700 + $75,000 = $148,700.

The investment is written off in 12 years at an interest rate of 6%. On an average this is: ($148,700 + $55,000)/12 = $17,000 per year.

The operational costs are 2% of $148,700 = $3,000.

Total cost per year = $17,000 + $3,000 = $20,000.

The kWh price then is:

At Ras Ghareb	=	20,000/360,000	=	0.056 $/kWh
At Hurghada	=	20,000/217,000	=	0.092 $/kWh

- The wind turbines of today are technically matured and developed to an extent that allows licence production without excessive development work,
- two types of wind turbines are recommended for manufacture, the one a 90 or 110 kW wind turbine for wind farm applications, the other a 15 kW machine primarily for stand-alone systems.
- Testing of wind turbines is very important, especially testing of the prototypes of the wind turbines made by pilot manufacturing. Therefore, establishing of an operational testing facility is recommended
- Training of personnel in testing, maintenance and trouble-shooting is essential and a training programme is scheduled.

The final conclusion is that a Project Document should be prepared on the subject for the consideration of the parties concerned.

11. Project Formulation Framework (PFF) and Draft Project Document

As a result of the mission and with assistance of the UNIDO Backstopping Officer, Mr. J. Fürkus, the respective PFF and a draft project document have been elaborated following UNDP's new guidelines on project formulation.

The PFF has been agreed, signed and delivered to the Resident Representative of the UNDP for further action. The project document has been drafted on the basis of the PFF. The draft project document is in quite a mature state. It covers a rather complex subject and will be finalized as agreed.

The project aims at establishing manufacturing and testing facilities for the local production of wind turbines with a capacity of 15 and 90 kW respectively for the generation of electricity through the transfer of technology, provision of expertise, training and supply of related equipment. It is expected that at the end of project implementation, one prototype of each wind machine will be produced and successfully tested for applications on stand-alone systems for small-scale electricity supply, water pumping and desalination as well as for wind farms. In addition, a batch of 100 wind turbines will be manufactured and sited in groups for grid connection and a fully operational testing facility for electricity generating wind turbines will be established in order to enable the New and Renewable Energy Authority (NREA) to carry out a wide range of tests relevant to the introduction of wind energy technologies.

Main data of the project developed:
Estimated UNDP contribution: US$ 1,535,000
Estimated Government cost sharing: US$ 1,500,000
Estimated Government input (local currency): E.L. 6,000,000

Duration: 4 years

The PFF and the Project Document will be issued as separate documents.

UNIDO

ANNEX 1

14 October 1987

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT OF THE GOVERNMENT OF EGYPT

JOB DESCRIPTION

DP/EGY/81/028/11-81

Post title	Consultant in manufacturing WECS (Wind Energy Conversion Systems)
Duration	2 months
Date required	As soon as possible
Duty station	Cairo with travel within the country
Purpose of project	To assist the country in establishing local capacities for manufacturing Wind Energy Conversion Systems through the transfer of appropriate technologies.

Duties

(1) Assess the local potential for utilizing Wind Energy Conversion Systems both in the short and long term.

(2) Visit candidate manufacturing facilities to assess their capabilities for the production of WECS components and assemblies.

(3) Identify possible modification on the production equipment at these facilities to achieve maximum percentage of locally produced components.

(4) Conduct an economic study to estimate the cost of locally produced units in terms of volume of production and make comparison with appropriate international prices.

(5) Propose a plan for efficient implementation of the local production program of WECS and give the following details:

(a) Identify the most suitable sizes for local production and specify the number of units to be manufactured annually from each size, the anticipated capital investment and the production cost of each unit.

....

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division
UNIDO, VIENNA INTERNATIONAL CENTRE, P.O. Box 300, Vienna, Austria

(b) Identification of the local manufacturing facilities for the production of each component or sub-assembly and the system for co-ordination of their assembly together and their overall management.

(c) Proposed modifications on the existing production equipment and needed investment.

(d) Specify advantages and disadvantages of each of Joint Venture and Purchase of Know-how co-operation agreements with reputable international manufacturers in this respect and make own recommendations.

(e) Elaborate a suitable training program.

(f) Recommended program and time implementation schedule.

(6) Prepare a document with terms of reference for the solicitation of the co-operation of reputable international companies in the implementation of the recommended program.

(7) Preparation of a final report on the mission with findings/conclusions/recommendations for the follow-up.

Qualifications: Wind energy expert with practical experience in the design/manufacture of wind energy conversion systems for mechanical and electrical applications and the transfer of related technologies.

Language: English

Background information: The National Strategy for the Development and Utilization of New and REnewable Sources of Energy (NRSE) which was elaborated in 1982 has defined the framework for the development and utilization of NRSE. According to the targets of this national strategy it is, inter alia, envisaged that by the year 2000, 5% of the national energy needs be supplied through the application of Renewable Sources of Energy including wind power.

Available data indicate the presence of windy regions along the Red Sea, the mediterranean Sea coast andEast Oweinat region suitable for the application of wind technologies for both mechanical purposes (water pumping, irrigation) and electricity generation.

The Government of Egypt is embarking on a program for local production of Wind Energy Conversion Systems (WECS) to be used primarily for the utilization of wind energy at suitable sites in Egypt and perhaps for export to suitable markets in Africa and the Middle East.

ANNEX 2

List of Meetings, 30.11.87 - 22.12.87

Monday. 30.11.87
Briefing at UNIDO, Vienna.

Tuesday. 1.12.87.
Briefing at UNDP, Cairo, Mr. Tharwat Sabry.
Meeting, Chairman of NREA, H. Sharaf El-Din, T.El-Tablawi, K. El-Bassyouni et.al.

Wednesday. 2.12.87.
Office meetings, NREA.

Thursday, 3.12.87.
Chairman H.S. El-Din and prof. Amin Mobarak et.al.

Monday, 7.12.87.
Visits to companies: Helwan Company for Machine Tools, MF 999, and Helwan Company for Engineering Industries, MF 99.

Tuesday, 8.12.87.
Visits to companies: Shoubra Company for Engineering Industries, MF 27, and Benha Company for Electronic Industries, MF 144.

Wednesday, 9.12.87,
Visits to companies: Steel Pipe Factory and Egyptian Iron & Steel Factory.

Thursday, 10.12.87,
Visits to companies: Aircraft Factory and Aircraft Engine Factory

Sunday, 13.12.87,
Visit to Abu Zaabal Engineering Industries, MF 100.

Monday, 14.12.87,
Visit to factory, Metalco.

Tuesday, 15.12.87,
Visit to Danish Embassy and to U.S.A.I.D.

Wednesday, 16.12.87,
Meeting, UNDP, Mr. L. Cappelletti and T. Sabry.
Meeting, NREA, H. Sharaf El-Din.

Thursday, 17.12.87,
Visit, Port Tawfik Shipyard, Suez Channel Authority.

Sunday, 20.12.87,
Meeting, Minister of Electricity & Energy, Mohamed Maher Abaza, Minister of National Production, Gamal El-Sayed, Representative of UNDP, L. Cappelletti, Chairman of NREA, H. Sharaf El-Din.

Monday, 21.12.87,
Meeting, U.S.A.I.D.,David Cowles.
Meeting, H. Sharaf El-Din and representatives of National factories.
Lunch at residence of L. Cappelletti with UNDP staff members and ambassador Ibrahim Allam, Director-General of International Economic Cooperation, Ministry of Foreign Affairs.

Tuesday, 22.12.87.
Meeting NREA and meeting UNDP. Wednesday, travel home.

ANNEX 3

List of Meetings, 29.02.88 - 13.03.88

Monday, 29.02.88 and Tuesday, 01.03.88.
Briefings at UNIDO, Vienna.

Wednesday, 02.03.88.
Travel to Cairo.

Thursday, 03.03.88.
Meetings at UNDP, Cairo, Mr. L. Cappelletti, Mr. Tharwat Sabry, and NREA, Mr. H. Sharaf El-Din, Mr. T. El-Tablawi, K. El-Bassyouni.

Sunday, 06.03.88.
Meetings, UNDP and NREA.

Monday, 07.03.88 - Wednesday, 09.03.88.
Meetings, NREA.

Thursday, 10.03.88.
Meeting with the Commitee of Wind Energy Utilization.

Sunday, 13.03.88.
Meeting, Ministry of Electricity and Energy, Minister Eng. Mohamed Maher Abaza, Deputy Director-General, Department of Industrial Operations, UNIDO, Mr. A. Vassiliev, Mr. H. Sharaf El-Din et al.

Monday, 14.03.88
Travel from Cairo.

Meetings, 27.04.88 - 17.05.88

During this split mission, meetings were arranged with:
- the Minister of Electricity and Energy, Eng. Mohammed Maher Abaza;
- Ambassador Herahin Allam, Director-General of International Economic Co-operation, Ministry of Foreign Affairs;
- the Resident Representative of the UNDP in Egypt, Mr. L. Cappelletti;
- the First Under-Secretary of the Ministry of Industry, Dr. Eng. Yusef K. Mazhar;
- the Chairman of the New and Renewable Energy Authority (NREA);
- the Chairman of ERISCOM Eng. Ahmed R. Al Khouly, i.e. the Erection and Industrial Services Co. which is supposed to be appointed as the main contractor for the project and
- other partners engaged in the project concerned.

ANNEX 4

Sheets from the Battelle report on Wind Measurements

At the following pages a number of tables and figures from the Battelle report is shown.

The Weibull approximations described and found in the foregoing are annual averages and they may give valid information on the annual generation of energy.

The information in the Battelle report contains data for the variation over the seasons of the year and over day and night. These information can be utilized to predict variation of the electricity generation.

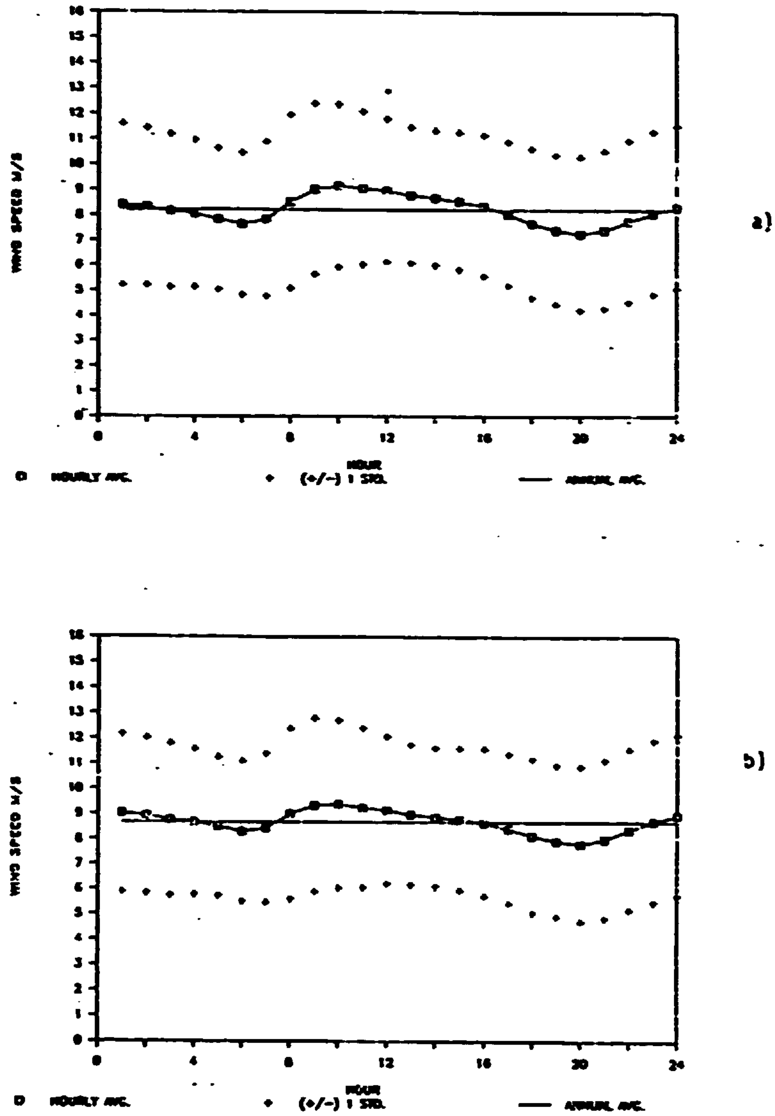


FIGURE 3.1. Hourly Average Wind Speed at Ras Ghareb, April 1985 - March 1986
a) 10 m AGL, b) 20 m AGL.

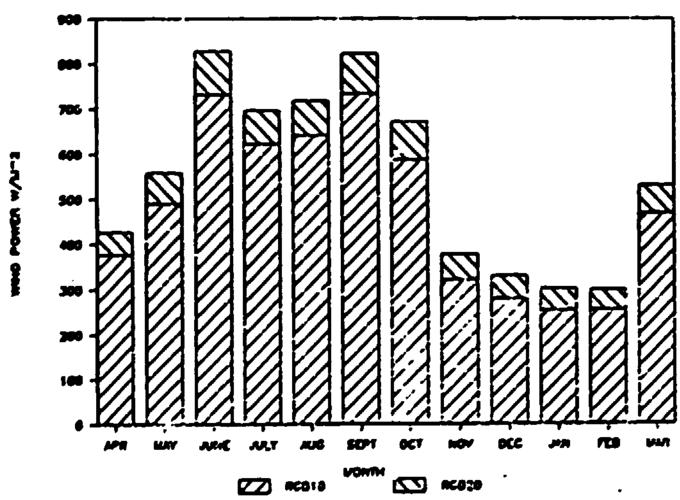


FIGURE 3.2. Monthly Power Flux, in W/m^2, at Ras Ghareb

TABLE 3.3. Monthly Wind Speed Frequency Distribution by Hours and Annual Wind Speed Frequency Distribution by Hours and Percentage of Time: Ras Ghareb 10 m

Wind Speed (m/s)	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Annual Summary: Number of Hours	Percent of Time	Cumulative Percent
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-1	0	2	1	0	0	0	0	1	2	0	4	0	10	0.1	0.1
1-2	18	25	6	2	0	0	3	4	14	12	24	18	126	1.5	1.6
2-3	42	30	7	5	0	5	15	33	56	68	49	35	345	4.0	5.6
3-4	42	38	5	9	0	3	14	55	109	111	91	35	512	5.9	11.5
4-5	65	41	12	8	9	7	16	54	95	71	92	36	516	6.0	17.5
5-6	77	39	14	22	23	13	32	69	108	81	75	47	620	7.2	24.7
6-7	76	48	22	43	35	52	73	95	93	96	85	69	787	9.1	33.8
7-8	84	55	51	71	62	89	72	83	80	78	72	91	908	10.5	44.3
8-9	84	68	70	95	121	90	78	111	55	62	66	111	1031	11.9	56.2
9-10	71	109	108	122	132	80	92	81	22	55	47	104	1023	11.8	68.0
10-11	69	128	125	146	122	106	112	51	23	25	30	72	1009	11.7	79.7
11-12	49	78	142	145	82	93	85	26	32	21	13	58	824	9.5	89.2
12-13	[illegible]	49	111	61	43	99	75	14	35	12	6	29	556	6.4	95.6
13-14	14	8	37	15	33	52	28	12	15	13	8	19	259	3.0	98.6
14-15	7	[illegible]	7	0	19	26	3	0	5	2	6	9	89	1.0	99.6
15-16	0	0	0	0	0	5	0	0	0	0	2	9	16	0.2	99.8
16-17	0	0	0	0	0	0	0	0	0	0	2	1	3	0	100.0
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
18-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
19-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
Total	720	743	718	744	706	720	693	719	744	707	672	743	8634	100%	

TABLE 3.4. Monthly Wind Speed Frequency Distribution by Hours and Annual Wind Speed Frequency Distribution by Hours and Percentage of Time: Ras Ghareb 20 m

Wind Speed (m/s)	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Annual Summary: Number of Hours	Percent of Time	Cumulative Percent
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-1	0	3	1	0	0	0	0	0	3	0	7	1	15	0.2	0.2
1-2	12	20	6	1	0	0	1	2	8	8	15	9	82	0.9	1.1
2-3	30	26	3	4	0	1	9	18	43	37	33	27	233	2.7	3.8
3-4	40	37	5	8	0	7	12	48	62	77	61	33	390	4.5	8.3
4-5	56	32	11	7	4	5	16	58	107	104	89	43	532	6.2	14.5
5-6	75	38	13	15	18	10	21	70	99	82	91	32	564	6.5	21.0
6-7	77	45	19	32	29	24	57	101	114	77	94	65	734	8.5	29.5
7-8	78	45	37	63	59	82	73	85	84	85	70	80	841	9.7	39.2
8-9	89	74	58	85	113	91	79	97	52	86	69	104	1013	11.7	50.9
9-10	78	99	93	120	124	79	62	100	39	56	56	105	1032	12.0	62.9
10-11	73	127	125	135	129	93	101	68	18	36	34	94	1033	12.0	74.9
11-12	51	102	125	147	97	114	100	36	28	21	27	62	910	10.5	85.4
12-13	27	64	122	85	63	91	91	19	35	18	7	36	658	7.6	93.0
13-14	23	22	81	38	36	71	40	11	23	9	4	27	385	4.5	97.5
14-15	10	4	18	4	30	40	16	6	10	11	9	10	168	2.0	99.5
15-16	1	3	1	0	4	12	0	0	3	0	3	9	36	0.4	99.9
16-17	0	0	0	0	0	0	0	0	0	0	2	5	7	0.1	100.0
17-18	0	0	0	0	0	0	0	0	0	0	1	0	1	0	100.0
18-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
19-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
Total	720	743	718	744	706	720	698	719	744	707	672	743	8634	100%	

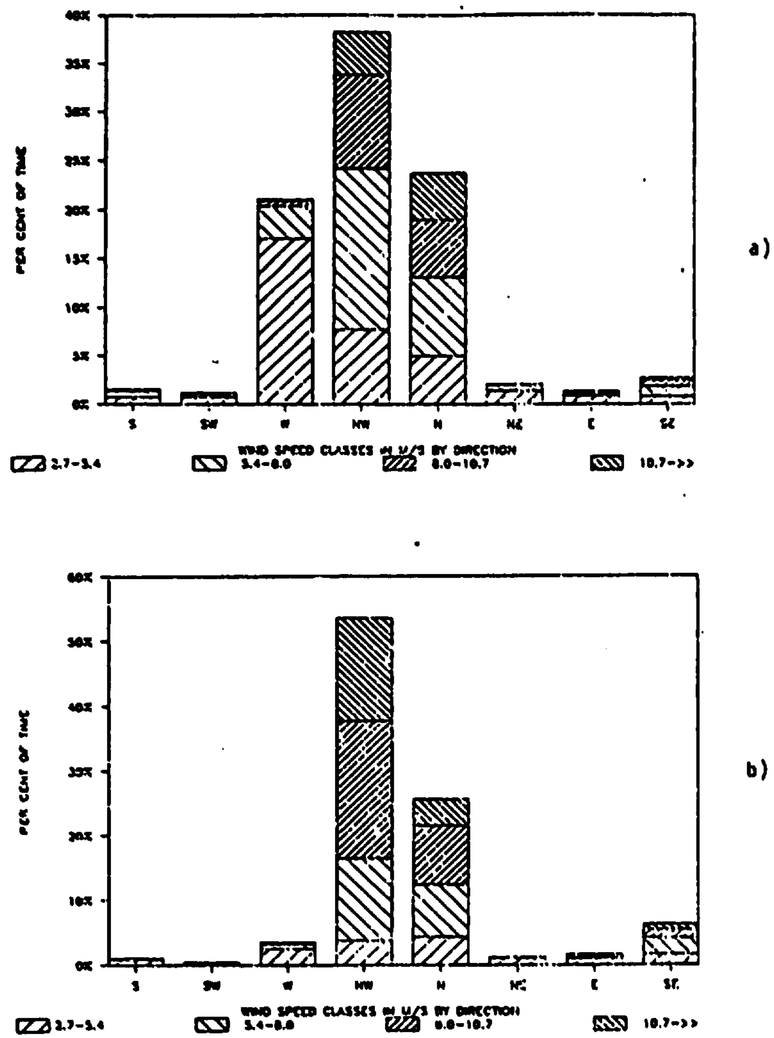


FIGURE 3.6. Joint Frequency Distribution for Wind Speed and Direction by Percentage of Time at Ras Ghareb 10 m AGL, a) December 1985 - February 1986, b) March 1986 and April-May 1985

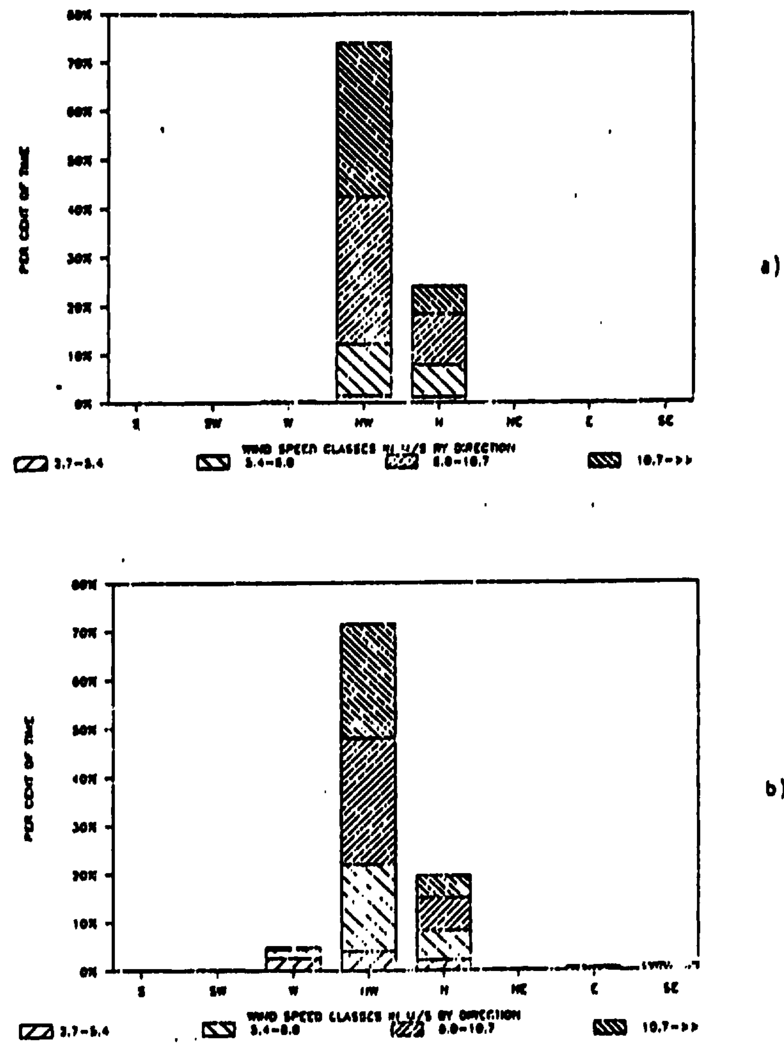


FIGURE 3.7. Joint Frequency Distribution for Wind Speed and Direction by Percentage of Time at Ras Ghareb, 10 m AGL, a) June - August 1985, b) September - November 1985

TABLE 3.7. Monthly Wind Speed Frequency Distribution by hours and Annual Wind Speed Frequency Distribution by Hours and Percentage of Time: Hurghada

Wind Speed (m/s)	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Annual Summary: Number of Hours	Percent of Time	Cumulative Percent
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-1	8	16	4	1	6	2	2	9	8	1	5	5	67	0.8	0.8
1-2	30	60	7	15	14	11	5	31	40	17	21	22	273	3.1	3.9
2-3	67	87	37	35	40	26	11	55	43	50	50	62	563	6.4	10.3
3-4	86	90	69	77	48	59	30	75	65	61	103	76	839	9.6	19.9
4-5	111	80	79	105	103	92	93	167	94	91	107	96	1218	13.9	33.8
5-6	104	70	95	130	112	90	118	149	135	151	129	122	1406	16.1	49.9
6-7	69	67	88	134	97	76	129	79	167	175	101	80	1262	14.4	64.3
7-8	60	91	99	89	65	78	98	52	87	75	54	61	909	10.4	74.7
8-9	63	67	77	67	87	78	97	46	40	46	36	79	783	8.9	83.6
9-10	37	59	67	56	72	100	75	32	22	26	26	54	626	7.2	90.8
10-11	33	25	53	31	63	51	55	6	18	27	13	41	426	4.9	95.7
11-12	35	22	28	4	23	32	21	9	16	13	17	20	242	2.8	98.5
12-13	12	7	5	0	10	17	7	7	5	3	8	15	96	1.1	99.6
13-14	2	2	0	0	3	5	1	1	2	5	0	7	28	0.3	99.9
14-15	2	0	0	0	0	3	0	0	0	2	1	3	11	0.1	100.0
15-16	1	0	0	0	0	0	0	0	0	0	1	0	2	0	100.0
16-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
17-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
18-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
19-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
Total	720	743	719	744	743	720	742	718	744	743	672	743	8751	100%	

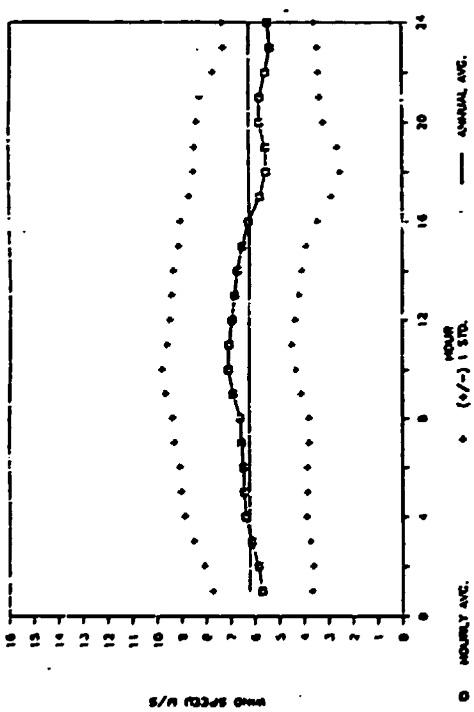


FIGURE 3.8. Hourly Average Wind Speed at Hurghada, April 1985 - March 1986

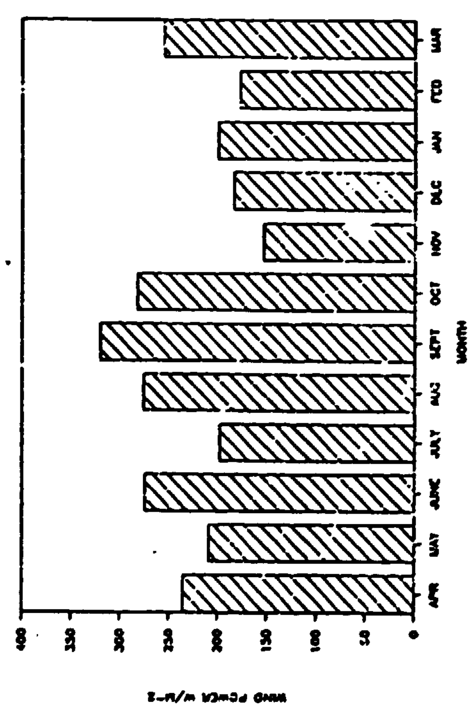


FIGURE 3.9. Monthly Power Flux, in W/m^2, at Hurghada

TABLE 3.14. Monthly Wind Speed Frequency Distribution by Hours and Annual Wind Speed Frequency Distribution by Hours and Percentage of Time: Ras el Hekma 10 m

Wind Speed (m/s)	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Annual Summary: Number of Hours	Percent of Time	Cumulative Percent
0	1	0	0	0	0	0	--	0	0	0	2	2	5	0.1	0.1
0-1	14	22	8	2	9	0	--	16	11	0	8	16	106	1.6	1.7
1-2	45	57	43	11	17	18	--	32	82	29	27	43	404	6.1	7.8
2-3	96	98	73	47	94	35	--	47	119	46	69	112	836	12.7	20.5
3-4	132	123	125	125	103	41	--	91	146	49	102	140	1177	17.8	38.3
4-5	114	99	110	135	122	42	--	63	137	90	73	129	1114	16.9	55.2
5-6	79	83	103	123	116	45	--	34	105	76	38	122	927	14.0	69.2
6-7	61	90	92	140	100	45	--	28	57	48	35	64	763	11.6	80.8
7-8	62	67	61	85	100	36	--	29	55	43	38	49	625	9.5	90.3
8-9	40	35	61	42	45	9	--	18	22	17	15	42	345	5.2	95.5
9-10	16	28	28	23	27	0	--	7	8	7	14	18	176	2.7	98.2
10-11	5	26	11	9	9	0	--	5	1	9	7	7	80	1.2	99.4
11-12	4	9	1	1	0	0	--	0	0	0	7	0	22	0.3	99.7
12-13	3	3	2	0	0	0	--	0	0	0	3	0	11	0.2	99.9
13-14	3	3	1	0	0	0	--	0	0	0	1	0	8	0.1	100.0
14-15	2	0	0	0	0	0	--	0	0	0	0	0	2	0	100.0
15-16	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
16-17	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
17-18	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
18-19	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
19-20	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
Total	677	743	719	743	744	271	--	370	744	405	442	744	6602	100%	

TABLE 3.15. Monthly Wind Speed Frequency Distribution by Hours and Annual Wind Speed Frequency Distribution by Hours and Percentage of Time: Ras el Hekma 20 m

Wind Speed (m/s)	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Annual Summary: Number of Hours	Percent of Time	Cumulative Percent
0	0	0	0	0	0	0	--	0	0	0	0	0	0	0	0
0-1	4	7	1	0	4	0	--	3	5	0	4	4	32	0.5	0.5
1-2	24	40	23	6	10	5	--	22	33	8	18	26	215	3.3	3.8
2-3	64	71	48	13	36	18	--	41	95	35	37	56	514	7.8	11.6
3-4	93	106	79	51	87	32	--	49	111	35	62	121	826	12.5	24.1
4-5	142	105	121	119	125	49	--	72	116	30	80	161	1121	17.0	41.1
5-6	98	95	128	159	126	51	--	57	99	47	74	134	1068	16.2	57.3
6-7	56	83	94	153	123	42	--	41	133	97	45	84	961	14.5	71.8
7-8	61	92	85	124	91	47	--	23	72	75	40	54	764	11.6	83.4
8-9	67	50	59	53	79	25	--	28	45	49	33	55	544	8.2	91.6
9-10	35	29	43	30	39	2	--	22	25	16	24	30	297	4.5	96.1
10-11	15	26	27	17	14	0	--	7	9	9	7	13	144	2.2	98.3
11-12	6	21	7	7	10	0	--	3	0	4	9	5	72	1.1	99.4
12-13	3	10	1	1	0	0	--	2	0	0	5	0	22	0.3	99.7
13-14	3	3	3	0	0	0	--	0	0	0	3	0	12	0.2	99.9
14-15	3	3	0	0	0	0	--	0	0	0	1	0	7	0.1	100.0
15-16	2	1	0	0	0	0	--	0	0	0	0	0	3	0	100.0
16-17	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
17-18	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
18-19	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
19-20	0	0	0	0	0	0	--	0	0	0	0	0	0	0	100.0
Total	677	743	719	743	744	271	--	370	744	405	442	744	6602	100%	

Eleven Companies Visited

The following pages show copies of the front page of brochures for some of the factories.

The role the factories could have in the programme is described at the fold-out sheet in the INTRODUTION, and reference is therefore made to this.

Monday, 7.12.87.
Visits to companies: Helwan Company for Machine Tools, MF 999, and Helwan Company for Engineering Industries, MF 99.

Tuesday, 8.12.87.
Visits to companies: Shoubra Company for Engineering Industries, MF 27, and Benha Company for Electronic Industries, MF 144.

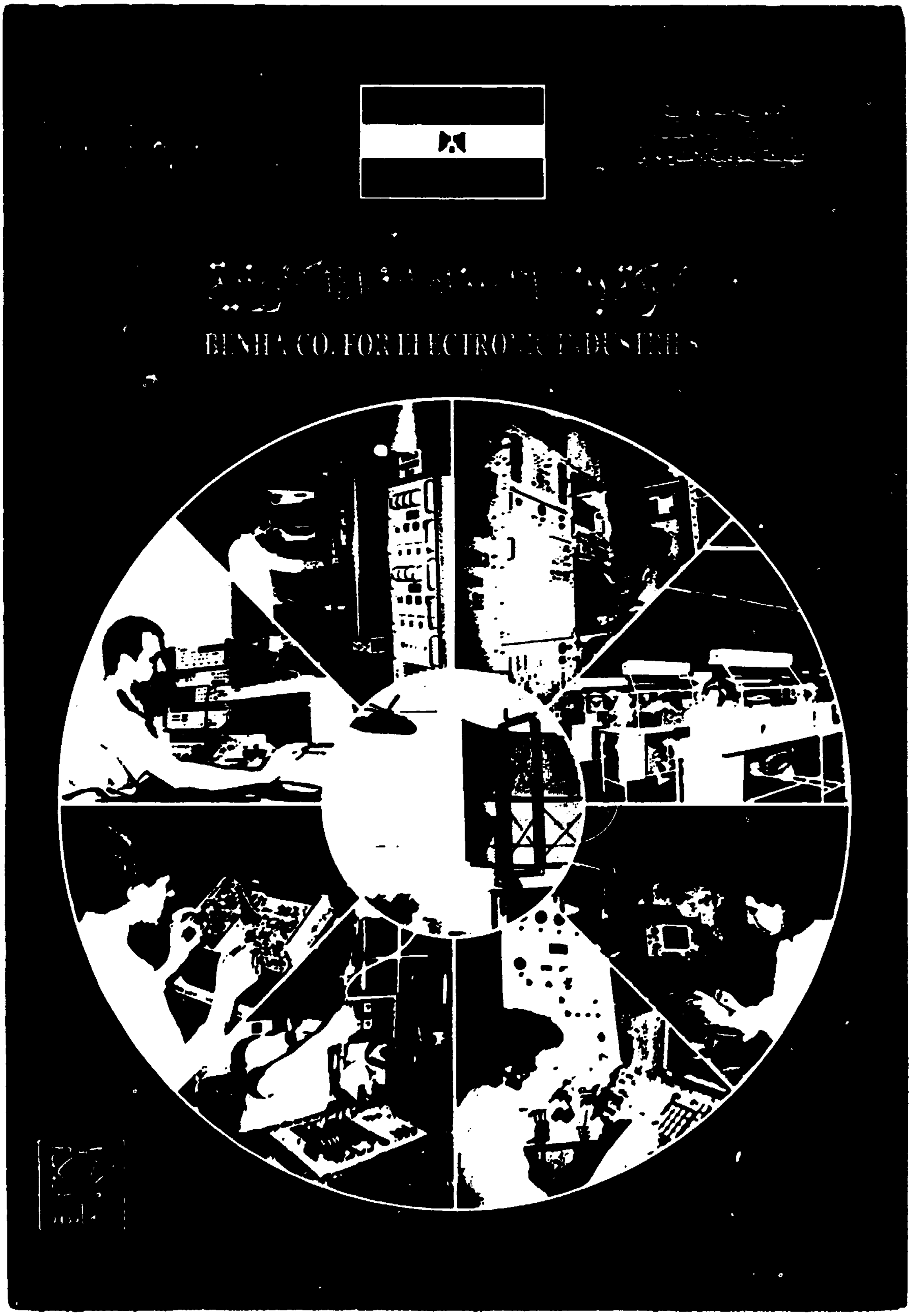
Wednesday, 9.12.87,
Visits to companies: Steel Pipe Factory and Egyptian Iron & Steel Factory.

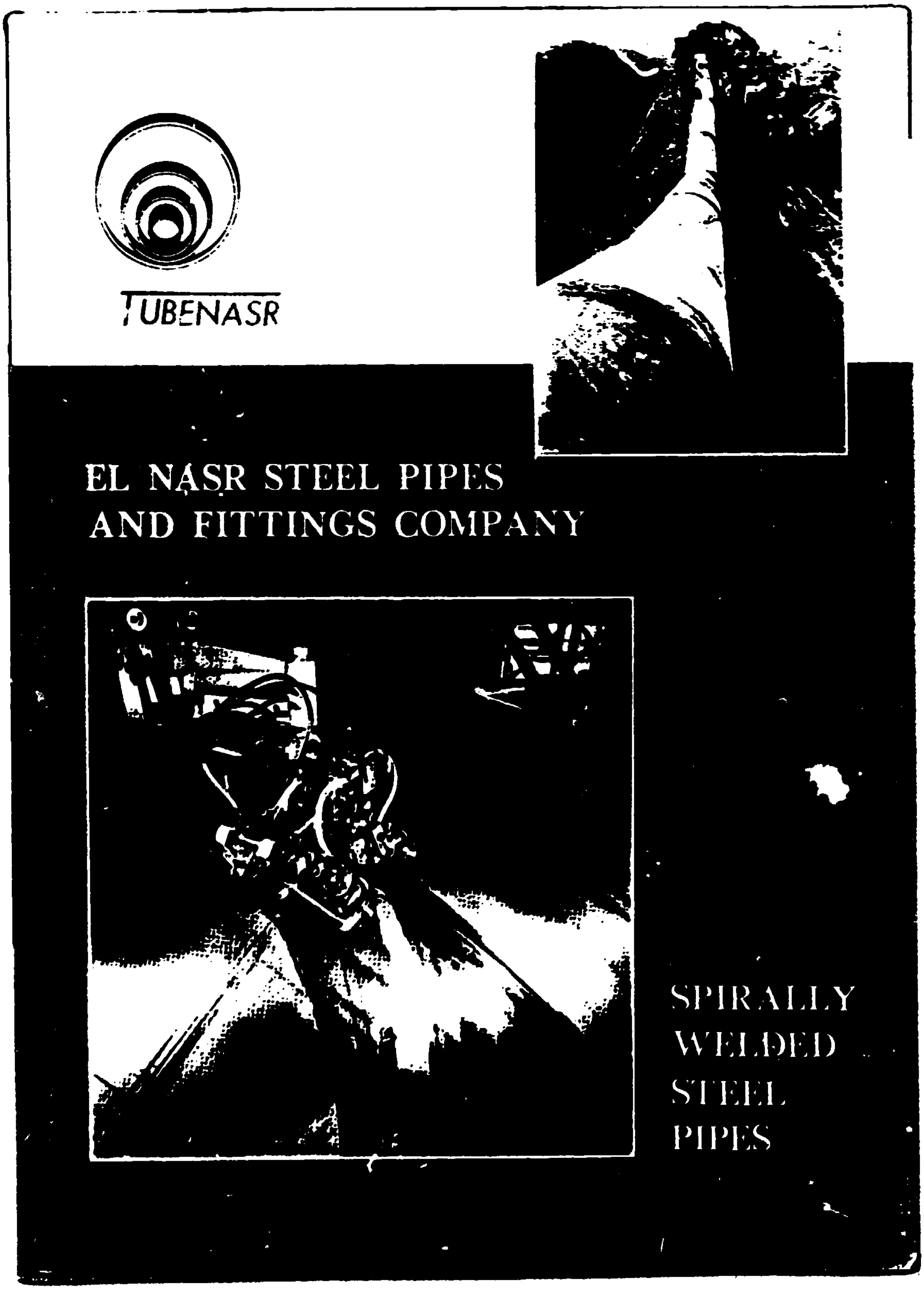
Thursday, 10.12.87,
Visits to companies: Aircraft Factory and Aircraft Engine Factory

Sunday, 13.12.87,
Visit to Abu Zaabal Engineering Industries, MF 100.

Monday, 14.12.87,
Visit to factory, Metalco.

Thursday, 17.12.87,
Visit, Port Tawfik Shipyard, Suez Channel Authority.


BENHA CO. FOR ELECTRO


TUBENASR
EL NASR STEEL PIPES
AND FITTINGS COMPANY
SPIRALLY
WELDED
STEEL
PIPES

ELECTRIC MOTORS

THREE PHASE SQUIRREL CAGE
INDUCTION MOTORS
TOTALLY ENCLOSED FAN COOLED

SIEMENS LICENCE - 1LA3

Factory. 27

Rated output acc. to IEC KW	Rated output acc. to IEC HP	Frame number acc. to I E C	Type 27	Net weight Kg.	Rotor weight Kg.	Moment of GD² Kg. m²	Rated full load values: Rated Speed R.P.M.	Efficiency %	Power factor –	Rated current by 380V	Rated torque m.kg.	By direct starting: Starting torque / Rated torque	Starting current / Rated current	Stalling torque / Rated torque	
0.75	1	80	80-2	8.2	2	[illegible]	2850	74	0.84	1.83	0.255	2.4	6	—	3000 R.P.M.
1.1	[illegible]	80	83-2	9.9	2.5	0.0011	2850	77	0.85	2.55	0.377	2.4	6.1	—	
1.5	2	90 S	90-2	12.6	3	0.0015	2850	78	0.85	3.4	0.51	2.5	6.2	2.5	
2.2	3	90 L	96-2	15.7	4	0.002	2860	82	0.85	4.8	0.754	2.8	6.8	2.8	
[illegible]	4	100 L	105-2	21	6.5	0.0038	2895	83	0.86	6.4	0.999	2.4	7.2	2.6	
4	5.5	112 M	113-2	38	8	0.0055	2895	85	0.88	8.1	1.33	2.4	7.6	2.5	
5.5	7.5	132 S	130-2	[illegible]	[illegible]	[illegible]	2925	85	0.88	11.2	1.83	2.4	7.6	2.8	
7.5	10	132 S	131-2	[illegible]	13.5	0.019	2930	87	0.88	14.9	2.55	2.5	7.7	3	
11	15	160 M	163-2	89	20	0.033	2935	88	0.86	22.5	3.67	2.1	6.5	2.6	
11	15	160 M	163-2	89	20	0.033	2935	88	0.86	22.5	3.67	2.1	6.5	2.6	
15	20	160 M	164-2	100	24.5	0.040	2940	90	0.86	30	4.995	2.3	7.1	2.8	
18.5	25	160 L	166-2	119	29	0.050	2940	91	0.88	36	6.12	[illegible]	7.6	2.9	
.55	0.75	80	80-4	8	2.5	0.0015	1400	71	0.80	1.47	.377	2.3	4.7	—	1500 R.P.M.
.75	1.0	80	83-4	9.4	3	0.0018	1400	74	0.79	1.95	0.520	2.5	5	—	
1.1	1.5	90 S	90-4	12	4	0.0028	1410	75	0.81	2.8	0.765	2.1	5	2.5	
1.5	2	90 L	96-4	15.6	5	0.0035	1405	75	0.81	3.7	1.02	2.2	4.9	2.6	
2.2	3	100 L	106-4	22	6.5	0.0048	1410	78	0.83	5.2	1.53	2.3	5.9	2.6	
3	4	100 L	107-4	24	7.5	0.0058	1410	79	0.83	7	2.04	2.6	6	2.7	
4	5.5	112 M	113-4	42	10	0.011	1435	83	0.82	8.8	2.75	[illegible]	7	3	
5.5	7.5	132 S	130-4	50	14.5	0.023	1450	84	0.85	11.7	3.67	[illegible]	7	[illegible]	
7.5	10	132 M	133-4	66	18	0.028	[illegible]	86	0.85	[illegible]	4.995	2.4	7.6	3.3	
11	15	160 M	163-4	92	24.5	0.05	1440	88	0.86	22	7.34	2.4	7.6	3	
15	20	160 L	166-4	110	30	[illegible]	1460	89	0.88	29	9.996	2.2	7.7	2.9	

MINISTRY OF MILITARY PRODUCTION
SHOUBRA CO.
FOR ENGINEERING INDUSTRIES

1000 R.P.M.

Rated output acc. to IEC KW	Rated output acc. to IEC HP	Frame number acc. to IEC	Type 27	Net weight Kg.	Rotor weight Kg.	Moment of G D² Kg. m²	Rated full load values: Rated Speed R.P.M.	Efficiency %	Power factor Cos	Rated current A at 380V	Rated torque m.kg.	By direct starting: Starting torque / Rated torque	Starting current / Rated current	Stalling torque / Rated torque
0.37	0.5	80	80-6	7.5	2.5	0.0015	900	66	0.74	1.15	0.398	2.2	3.6	—
0.55	0.75	80	83-6	9.4	3	0.0018	905	70	0.73	1.63	0.59	2.3	3.8	—
0.75	1	90 S	90-6	12.2	4	0.0028	905	71	0.75	2.15	0.815	2.2	3.9	2.3
1.1	1.5	90 L	96-6	15.7	5	0.0038	900	72	0.75	3	1.223	2.4	4.1	2.4
1.5	2	100 L	106-6	22	7	0.0063	925	76	0.76	4	1.53	2	4.5	2.1
2.2	3	112 M	113-6	35	9	0.011	945	78	0.74	5.8	2.243	2	5.1	2.4
3	4	132 S	130-6	49	13.5	0.020	955	80	0.75	7.6	3.06	2	5.5	2.4
4	5.5	132 M	133-6	56	17	0.028	960	83	0.76	9.5	4.08	2.4	6.2	2.8
5.5	7.5	132 M	134-6	64	20.5	0.035	960	84	0.76	13.1	5.61	2.6	6.4	3
7.5	10	160 M	163-6	91	27	0.055	965	84	0.75	18.1	7.54	2.3	6.4	3
11	15	160 L	166-6	119	34	0.080	965	88	0.78	24.3	11.009	2.7	7.2	3

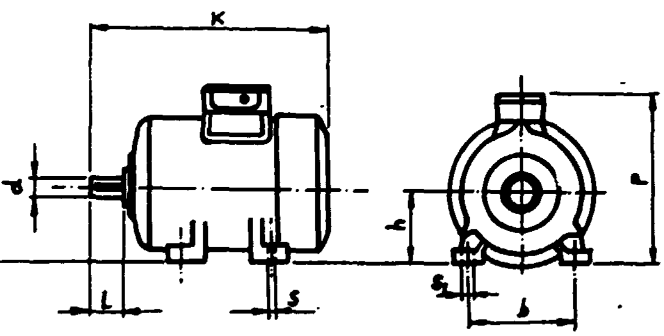
Technical specifications

- Voltage 220 Δ/380 Y (other voltage available). 50 Hz. voltage and frequency deviation ± 5%.
- The motors are suitable for service in dusty and damp surroundings.
- The motors have tropicalized insulation (class B) 130°C.

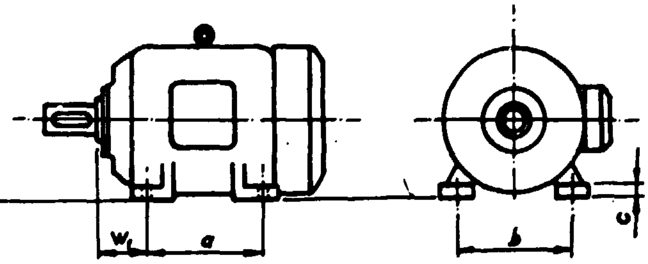
DIMENSIONS

Foot mounted motor — frame B3

TYPE 27	a	b	W_1	c	s	d	K	h	p	S_1	L
080 / 083	100	125	50	8	9.5	19	274	80	204	13.5	40
090	100	140	56	13	10	24	307	90	181	14	50
096	125						332				
106 / 107	140	160	63	14	12	28	372	100	235	16	60
113	140	190	70	15	13	28	395	112	260	16	60
130	140	216	89	17	13	38	455	132	299	17	80
131											
133	178						493				
134											
163	210	254	108	20	16	42	591	160	357	20	110
164											
166	254						635				

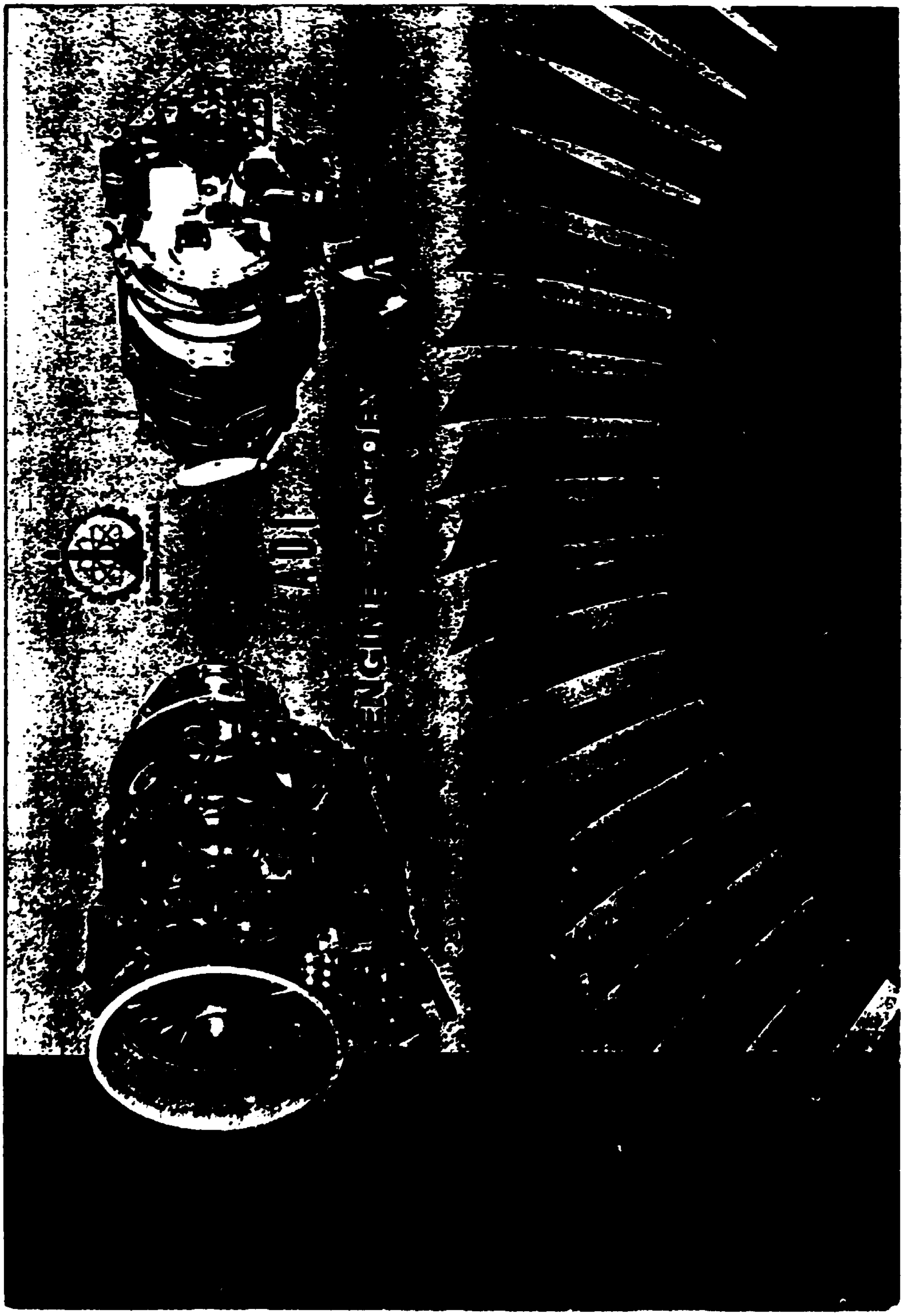


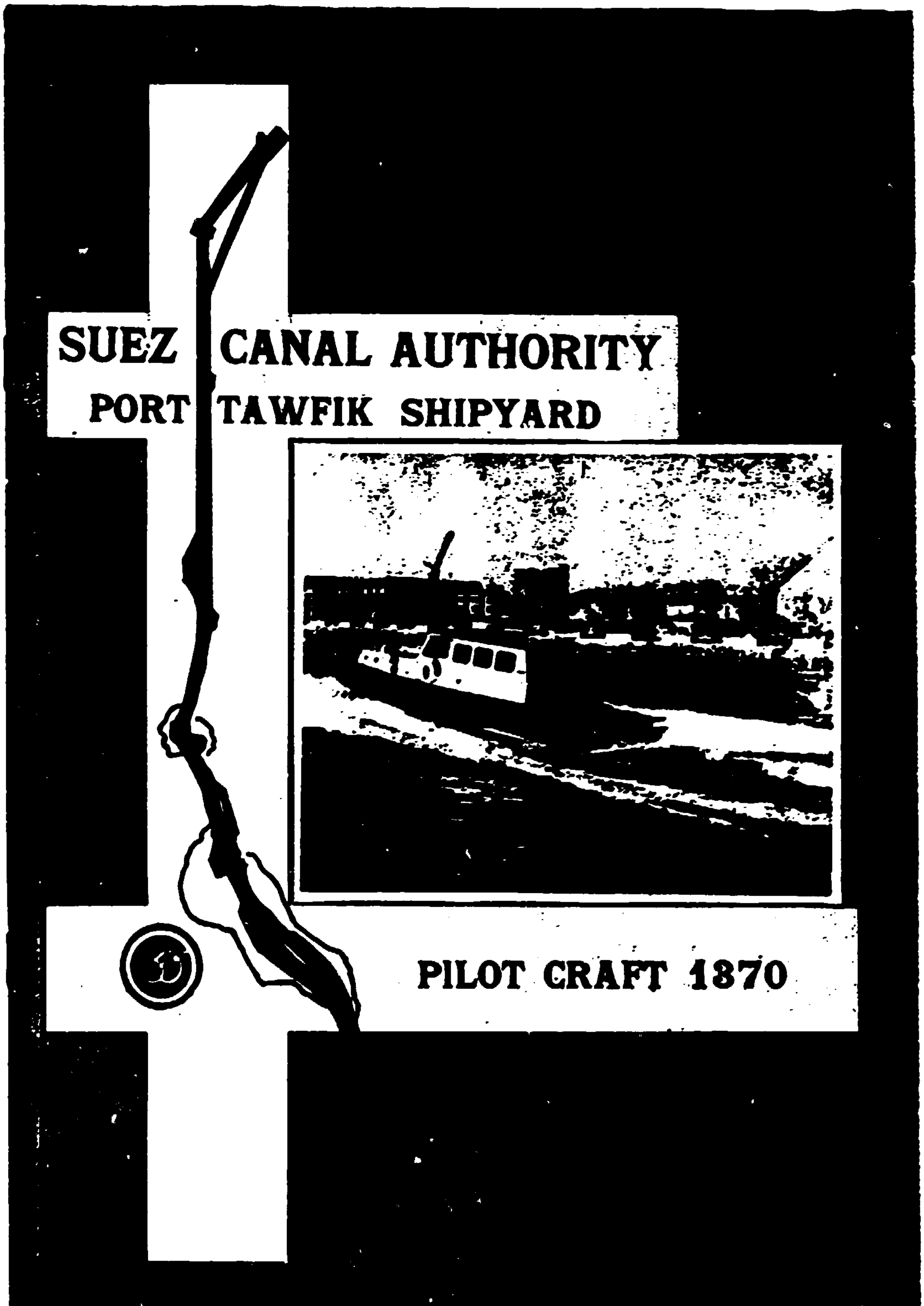
Frame Size - 80



Frame Size 90 - 160

The Egyptian Company for Metallic Construction




SUEZ CANAL AUTHORITY
PORT TAWFIK SHIPYARD
PILOT CRAFT 1870

NOTE ON BLADES FOR WIND TURBINES

Blades for wind turbines can be of different principles of design and construction. The description given here is for a design of which the load carrying spar is a conical tube of glassfibre made by winding a tape of rowings on a rotating mandrel. The technique was originally developed by the company Kaman in USA, transferred to Denmark (by the consultant) in 1978 to be used to produce the blades for the Nibe-windmills. Since then the company OL-Boats have applied the technology to blades of different sizes up to 30 m. (the 30-m blade is designed by the Technical University of Denmark, the others by the consultant). An example, the smallest blade made this way, 7.7 m, is shown below. Blades made by this principle have proved to be of remarkable strength with no tendency to fail.

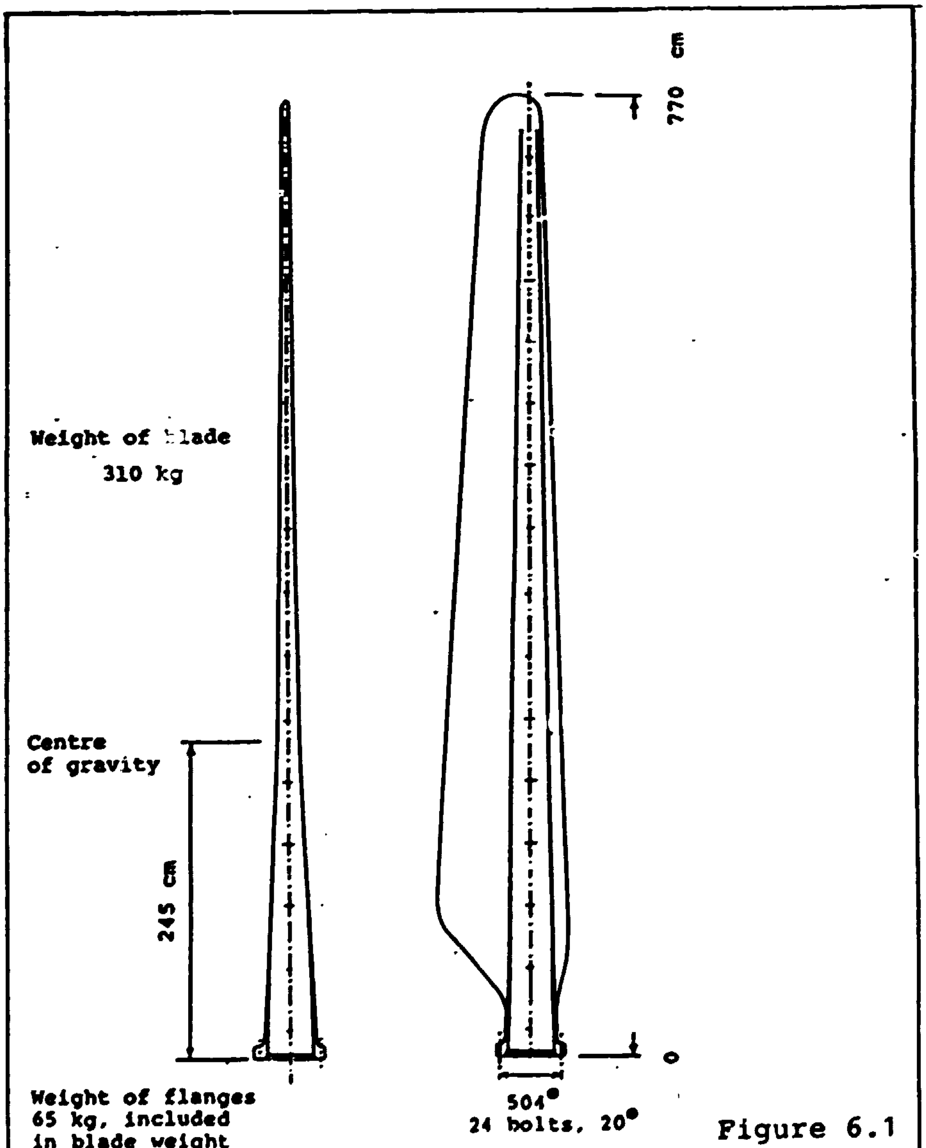
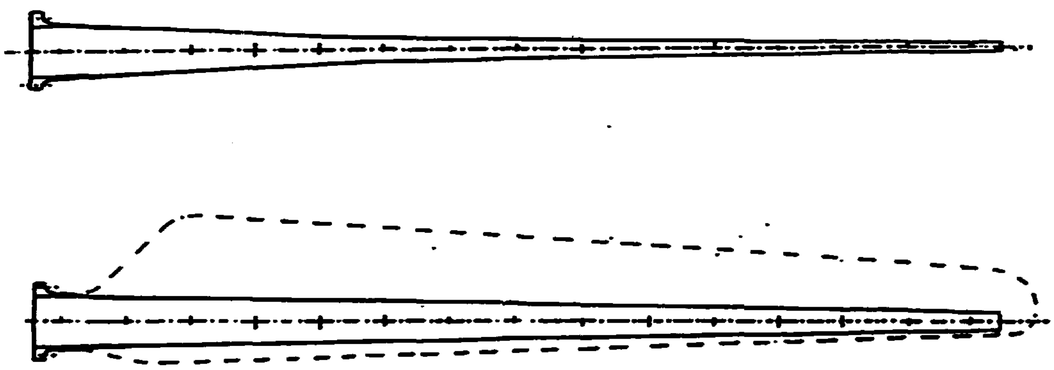


Figure 6.1

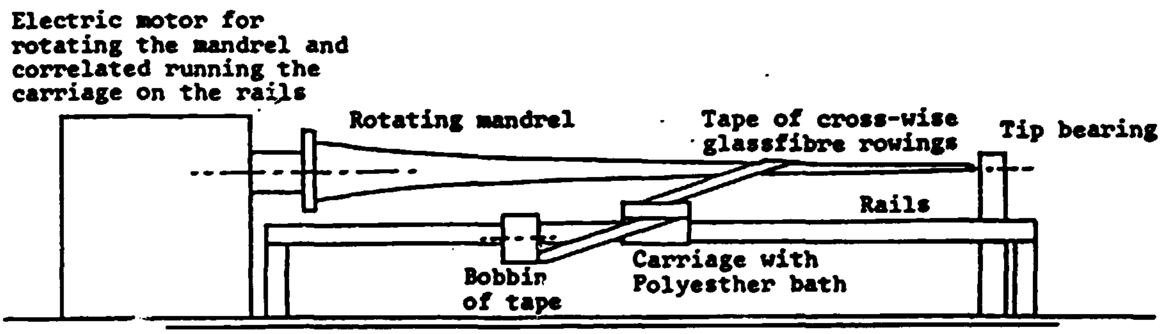
The figures below show in principle a wound spar for a wind turbine and the winding machine.

It should be noted that winding is not the only way to manufacture a spar, it can be made in hand-lay-up. An advantage of the wound spar is that it is made by means of a machine which gives a uniform product, a disadvantage could be higher weight. On the other hand can the higher weight and stiffness of the blade with a wound spar limit the deflections of the blade keeping the strains low.



A WOUND SPAR FOR A WIND TURBINE BLADE

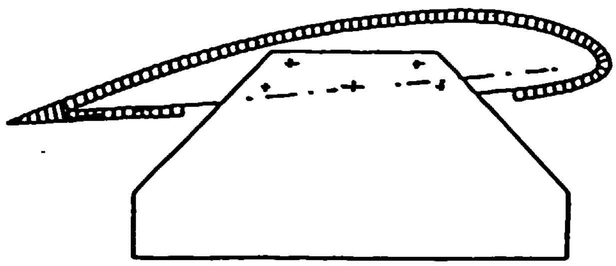
Figure 6.2



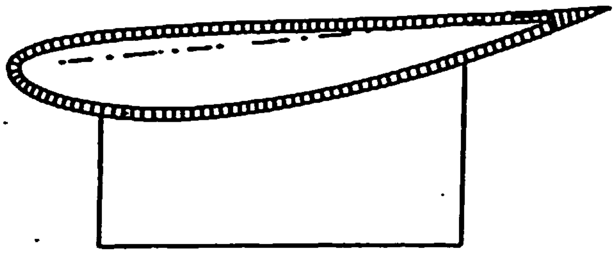
MACHINERY FOR WINDING THE SPAR FOR A WIND TURBINE BLADE

Figure 6.3

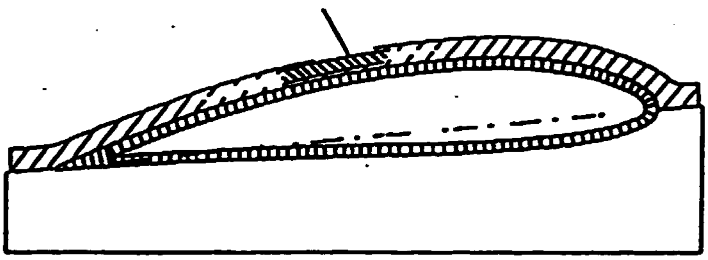
The sketches, Figs. 6.4 and 6.5, show the principle of blade manufacture.



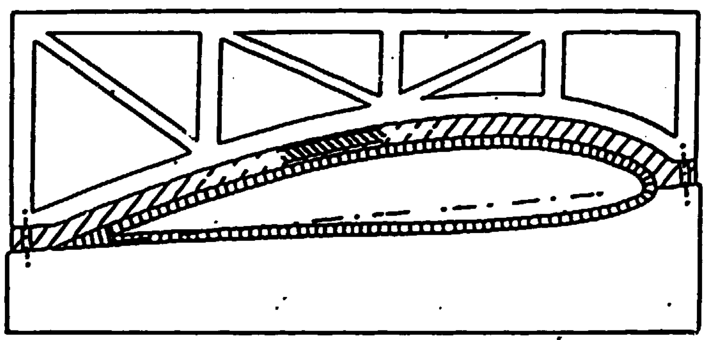
Manufacture of the master blade, the plug, from wood



The material should be solid and heat conducting



Manufacture of the mould

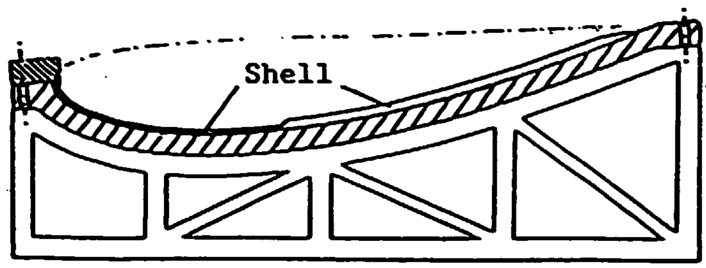


A steel structure is bonded to the mould

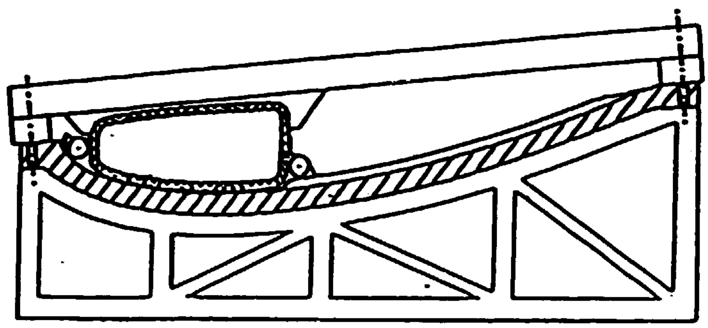
In a similar way the other half-mould is made

MANUFACTURE OF THE MOULDS FOR THE BLADE

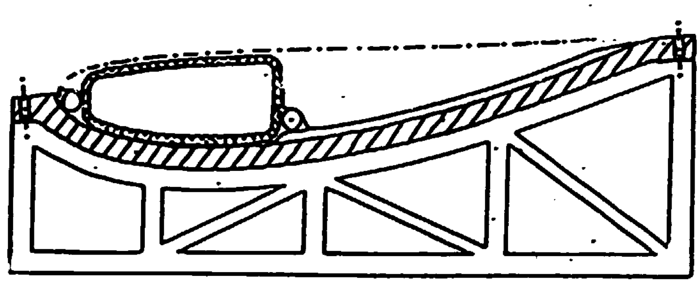
Figure 6.4



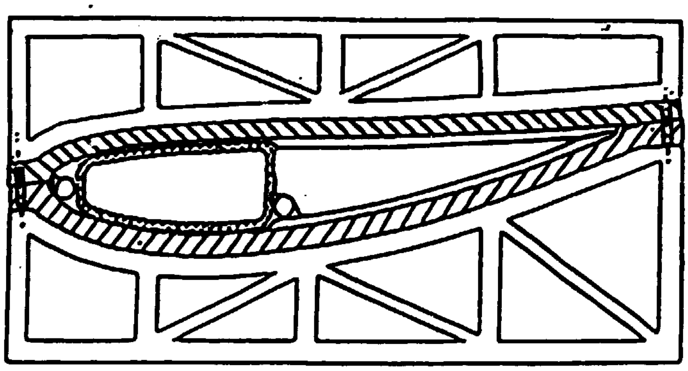
The shell is manufactured by hand-lay-up in the mould



The spar is bonded in position to the shell. Plastic tubes for weight balancing are fixed, normally in tips



Preparing for bonding of the other shell



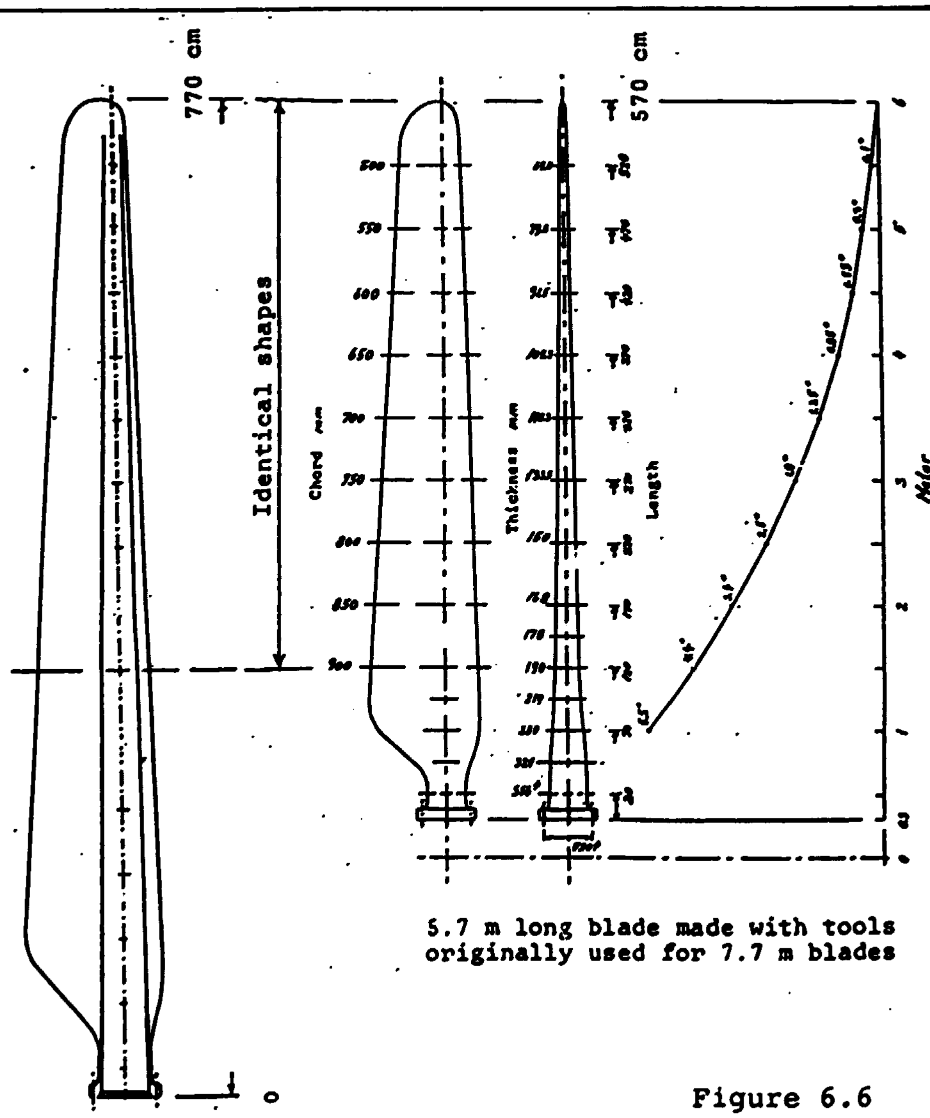
The other shell is bonded, final bonding

MANUFACTURE OF THE BLADE IN THE MOULDS

Figure 6.5

Blades for large windturbines of 100 kW or larger are readily available of different makes, and presents therefore no problem, it will be possible to select a high quality blade for production under licence in Egypt.

The situation concerning a small wind turbine of 12-m diameter is more difficult. Compared with the large wind turbines there are only few of this size on the market and in operation, whatfore the experience on reliability and efficiency is limited. This requires further studies. If suitable blades are not available a blade could be made by modifying an existing blade. An example is shown below in Fig. 5. One reason for doing it this way could be that the blades of the small wind turbine should be relatively broader to make it start at lower wind speeds. However, it must be underlined that it is only per intuition, the problem must be studied.

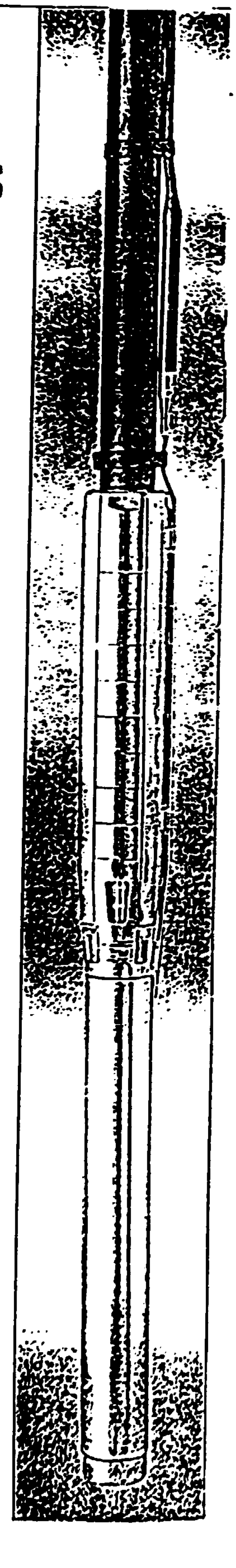


5.7 m long blade made with tools originally used for 7.7 m blades

Figure 6.6

WATER PUMPS. DATA FOR SUBMERSIBLE PUMPS

submersible pumps



Water is required everywhere. The problem is to obtain it. Modern drilling technology solves part of the problem, namely to make the water available. GRUNDFOS solves the next problem: to bring the water out of the ground and into a supply system.

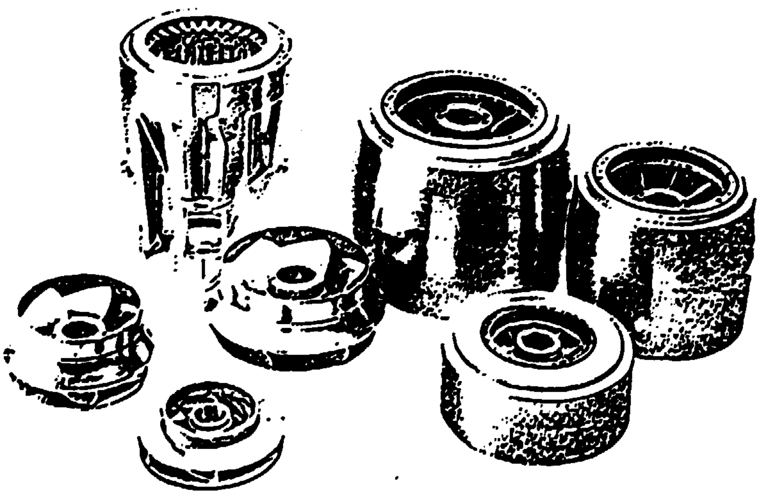
Reliable water supply for years at minimum cost – these are the demands made on water supply pumps. GRUNDFOS submersible pumps comply with these demands. Throughout the world, GRUNDFOS submersible pumps have a reputation for maximum reliability as well as minimum maintenance and power consumption.

Complicated individual parts are made from stainless steel plate (AISI 304, DIN 1.4301) correctly shaped and welded together to form complete impellers and intermediate chambers with guide vanes – the basic components in GRUNDFOS submersible pumps.

Stage by stage, the components are assembled into a complete pump with suction interconnector and discharge chamber. The submersible motor is direct-coupled underneath the pump. The whole unit – the submersible pump – is suspended from the riser main and after connection to the electricity supply, it will deliver water! The advanced, but simple pump entirely of stainless steel offers the following range of advantages:

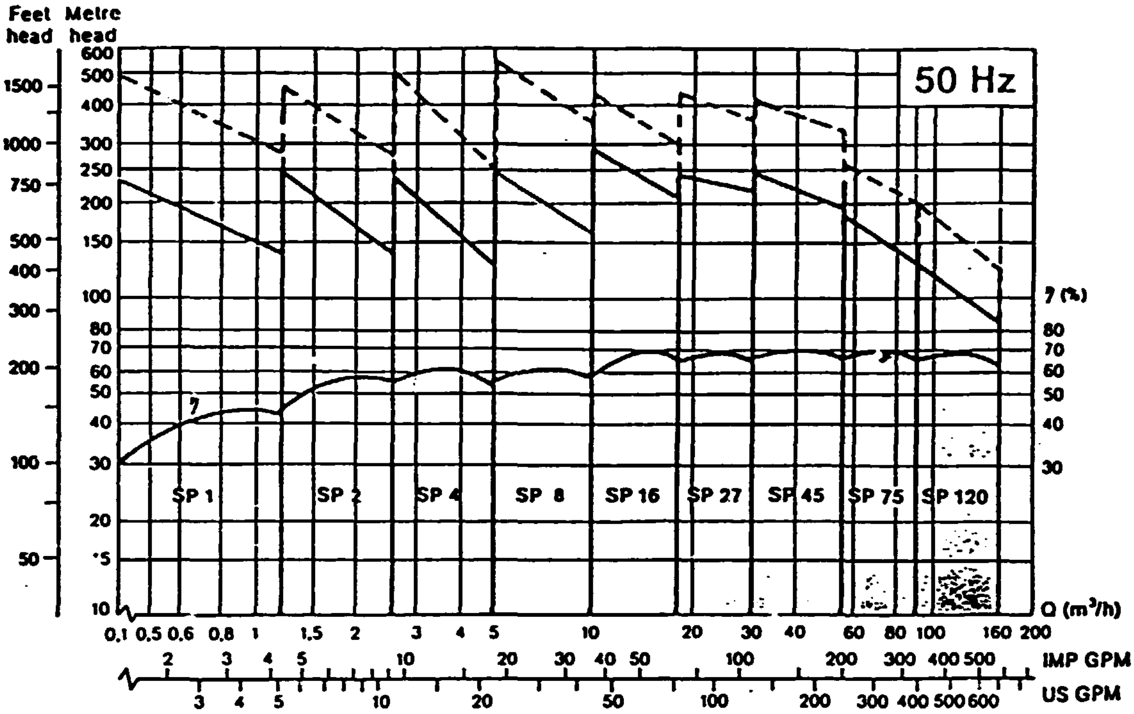
- The widest range of applications for varying water qualities.
- High reliability and long life.
- High efficiency and consequently low power consumption.
- High pump performance for a given bore hole diameter.
- Low weight. Simple and easy to install.
- Highest quality at competitive prices from one of the world's leading pump manufacturers.

A range of advantages which can be offered only by GRUNDFOS!

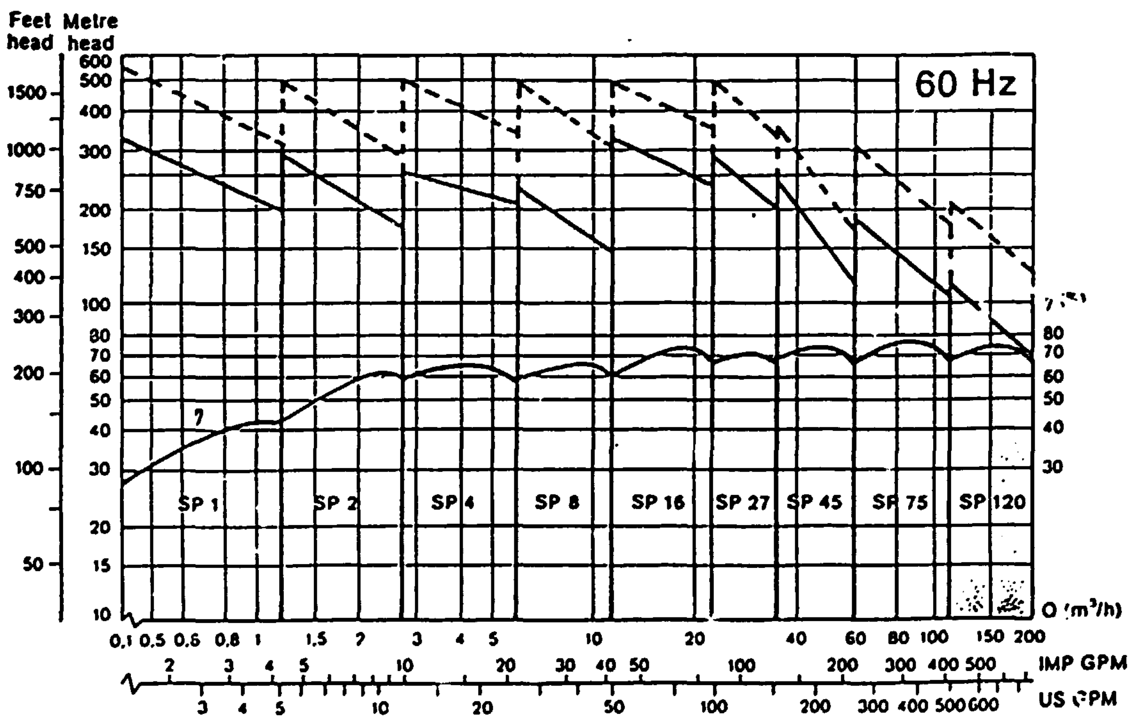


All basic components in the GRUNDFOS submersible pumps are manufactured from stainless steel. Pump design and material specification are approved by experts throughout the world.

Performance Curves



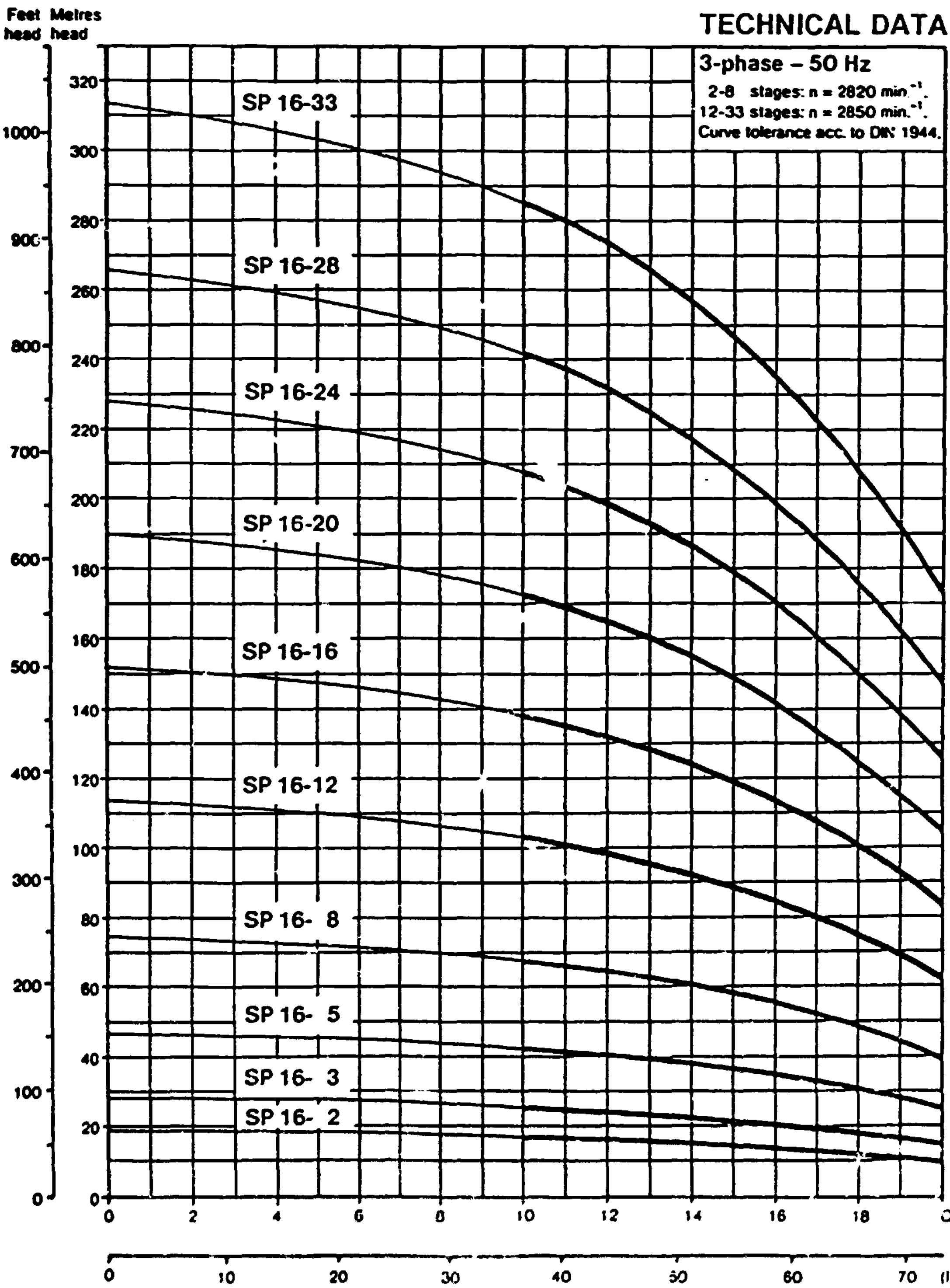
Performance Curves



The curves show the flow range, the maximum heads, and the efficiency of the pumps.
A wide range of standard models makes it possible to select a pump with the correct performance.
The pumps in the shaded area are special high-head versions.
Note: The upper diagram applies to 50 Hz electrical supplies and the lower diagram to 60 Hz electrical supplies.
Ask for GRUNDFOS' technical data sheets on the individual types.

	SP 16
GB **SUBMERSIBLE PUMP**	**50 Hz**

TECHNICAL DATA



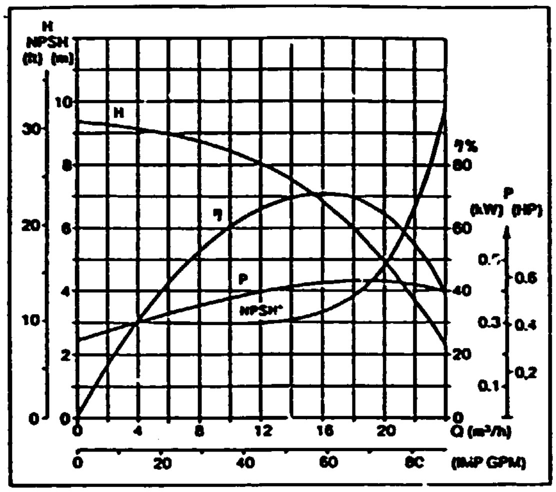
SP 16 flow range: 10-20 m^3/h (37-74 IMP GPM).

The GRUNDFOS submersible pump range covers flows from 0.1-160 m^3/h (0.4-587 IMP GPM).

SP 16

50 Hz

PERFORMANCES PER STAGE



* NPSH is determined at 1 percent head loss.

MATERIALS

SP 16 – Standard version:
All main components in stainless steel: DIN W.-nr. 1.4301. Max. water temperature: Pumps with 4" motors, 40°C. Pumps with 6" motors, 35°C.

SP 16-N – Sea water version:
All main components in stainless steel: DIN W.-nr. 1.4401. Max. water temperature: Pumps with 4" motors, 40°C. Pumps with 6" motors, 35°C.

A hot water version is available on request.

MINIMUM INTERNAL DIAMETER OF BOREHOLE: 6" (152 mm).

Connection to riser main: 2¹/₂" BSP, length of thread 27 mm.

Pumps with larger numbers of stages are available on request: SP 16-40 and SP 16-50.
These pumps are delivered in special stainless steel sleeves (pump section only).

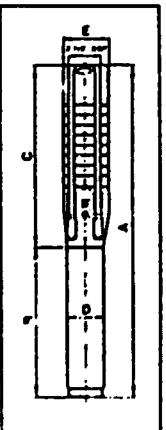
ELECTRICAL DATA

	PUMP TYPE	MOTOR kW	MOTOR HP	MAX. OPERATING CURRENT (amps) 3x220 V	3x380 V	3x415 V	FULL LOAD CURRENT $I_{1/1}$ (amps) 3x220 V	3x380 V	3x415 V	POWER FACTOR (full load) 3x220 V	3x380 V	3x415 V	$I_{start}/I_{1/1}$ 3x220 V	3x380 V	3x415 V
4" MOTOR	SP 16- 2	1.1	1.5	4.5	2.7	2.5	4.6	3.3	3.0	0.84	0.84	0.84	3.8	3.7	3.7
	SP 16- 3	1.5	2.0	5.9	3.4	3.1	6.7	3.9	3.6	0.88	0.88	0.88	4.7	4.7	4.7
	SP 16- 5	2.2	3.0	9.9	5.7	5.3	10.1	5.8	5.4	0.88	0.87	0.87	4.1	4.1	4.1
	SP 16- 8	3.7	5.0	15.2	8.9	8.1	16.1	9.4	8.6	0.88	0.87	0.88	4.3	4.3	4.3
6" MOTOR	SP 16-12	5.5	7.5	20.5	12.4	12.8	21.5	12.8	13.0	0.85	0.85	0.76	5.4	5.2	5.6
	SP 16-16	7.5	10.0	27.5	15.9	16.6	28.5	16.7	17.1	0.86	0.85	0.77	5.5	5.4	5.7
	SP 16-20	11.0	15.0	35.0	21.0	22.0	41	24.5	25.0	0.87	0.86	0.78	6.3	6.0	6.4
	SP 16-24	11.0	15.0	39.5	23.5	24.5	41	24.5	25.0	0.87	0.86	0.78	6.3	6.0	6.4
	SP 16-28	15.0	20.0	50	28.5	31.0	56	32.5	34.0	0.85	0.85	0.76	5.9	5.8	6.1
	SP 16-33	15.0	20.0	55	32.0	33.5	56	32.5	34.0	0.85	0.85	0.76	5.9	5.8	6.1

The electrical data are for SP submersible pumps fitted with GRUNDFOS motors. When using other motor makes, the data can be used as a guide only. Always check the motor name plate. Other voltages are available on request.

DIMENSIONS AND WEIGHTS

	PUMP TYPE	DIMENSIONS mm A	B	C	D	E*	WEIGHT kgs. Net	Gross	SHIPP. VOL. m³
4" MOTOR	SP 16- 2	670	326	344	95	131	20	24	0.04
	SP 16- 3	755	366	389	95	131	22	26	0.04
	SP 16- 5	980	501	479	95	131	24	28	0.04
	SP 16- 8	1259	645	614	95	131	39	44	0.05
6" MOTOR	SP 16-12	1440	630	810	140	140	75	90	0.12
	SP 16-16	1675	685	990	140	140	79	95	0.14
	SP 16-20	1930	760	1170	140	140	90	110	0.16
	SP 16-24	2110	760	1350	140	140	100	122	0.17
	SP 16-28	2380	850	1530	140	140	110	134	0.19
	SP 16-33	2605	850	1755	140	140	116	142	0.20



* E = Max. diameter of pump incl. cable guard + motor.

BY INQUIRY

Please supply the following information with each inquiry:

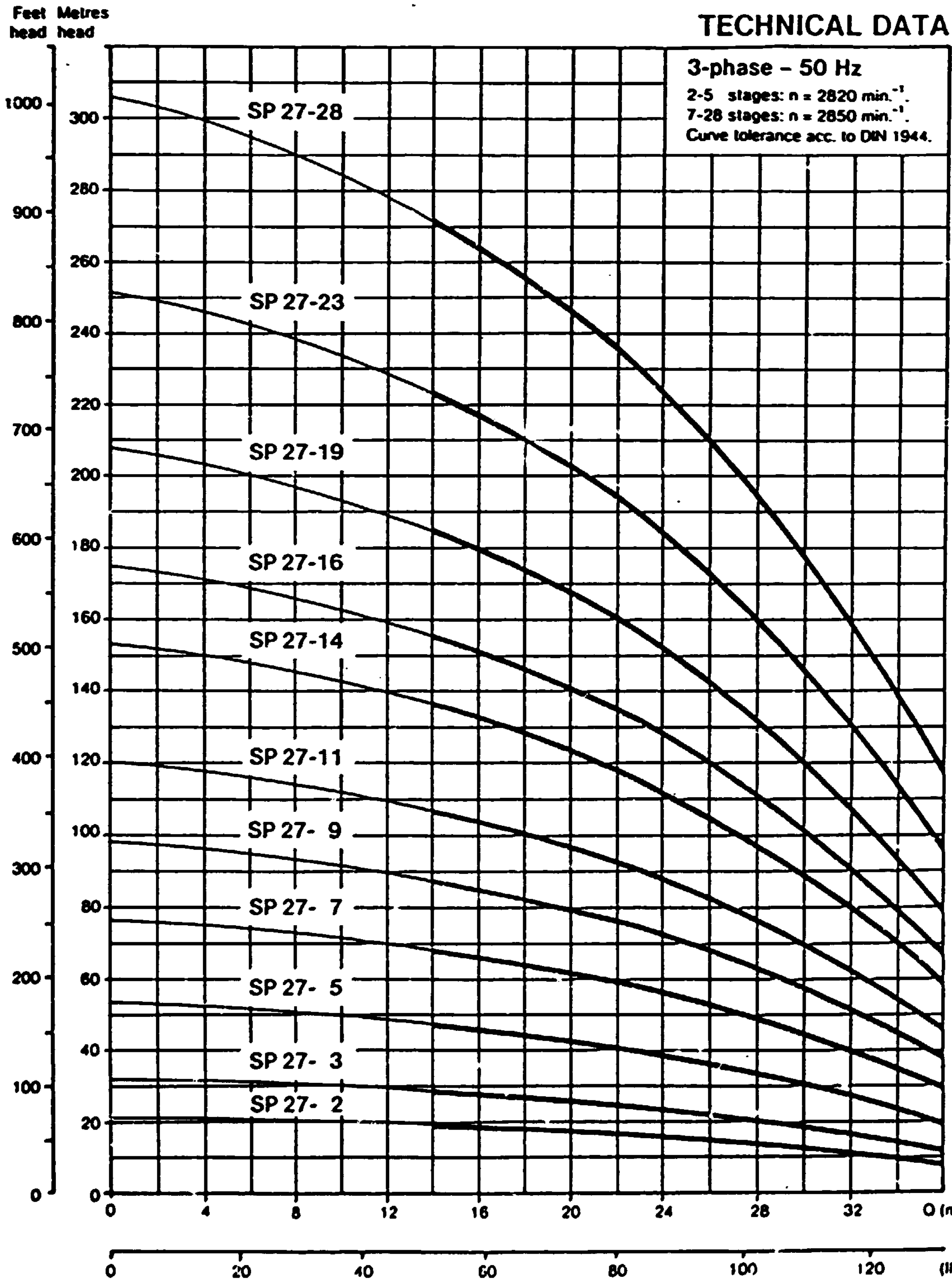
1. Q – the quantity of water required.
2. H – the total manometric head required including frictional losses and tank pressure, if any.
3. The diameter of the borehole (the smallest inside dimension).
4. The distance from ground level to water level at rest.
5. The lowering of the water level, when a certain quantity is pumped.
6. The total length of the borehole, less the length of a borehole filter, if any.
7. The type of electric supply, voltage and frequency.
8. Supplementary information concerning the installation, if any.

Subject to alterations

SP 27

(GB) SUBMERSIBLE PUMP	50 Hz

TECHNICAL DATA



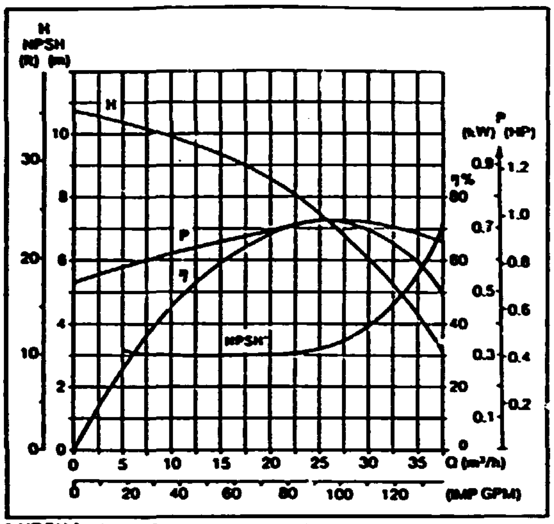
SP 27 flow range: 14-36 m^3/h (52-132 IMP GPM).

The GRUNDFOS submersible pump range covers flows from 0.1-160 m^3/h (0.4-587 IMP GPM).

SP 27

50 Hz

PERFORMANCES PER STAGE



* NPSH is determined at 1 percent head loss.

MATERIALS

SP 27 – Standard version:
All main components in stainless steel: DIN W.-nr. 1.4301. Max. water temperature: Pumps with 4" motors, 40°C. Pumps with 6" motors, 35°C.

SP 27-N – Sea water version:
All main components in stainless steel: DIN W.-nr. 1.4401. Max. water temperature: Pumps with 4" motors, 40°C. Pumps with 6" motors, 35°C.

A hot water version is available on request.

MINIMUM INTERNAL DIAMETER OF BOREHOLE: 6" (152 mm).

Connection to riser main: 3" BSP, length of thread 30 mm.

Pumps with larger numbers of stages are available on request: SP 27-36 and SP 27-45.
These pumps are delivered in special stainless steel sleeves (pump section only).

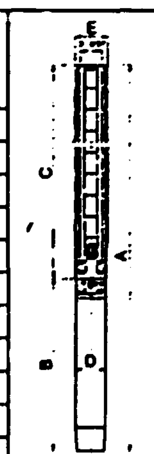
ELECTRICAL DATA

	PUMP TYPE	MOTOR		MAX. OPERATING CURRENT (amps)			FULL LOAD CURRENT $I_{1/1}$ (amps)			POWER FACTOR (full load)			$I_{start}/I_{1/1}$		
		kW	HP	3x220 V	3x380 V	3x415 V	3x220 V	3x380 V	3x415 V	3x220 V	3x380 V	3x415 V	3x220 V	3x380 V	3x415 V
4" MOTOR	SP 27- 2	1.5	2.0	6.3	3.6	3.3	6.7	3.9	3.6	0.88	0.88	0.88	4.7	4.7	4.7
	SP 27- 3	2.2	3.0	9.4	5.5	5.0	10.1	5.8	5.4	0.88	0.87	0.87	4.1	4.1	4.1
	SP 27- 5	3.7	5.0	15.7	9.1	8.3	16.1	9.4	8.6	0.88	0.87	0.88	4.3	4.3	4.2
6" MOTOR	SP 27- 7	5.5	7.5	20.5	12.2	12.6	21.5	12.8	13.0	0.85	0.85	0.76	5.4	5.2	5.6
	SP 27- 9	7.5	10.0	26.5	15.3	15.1	28.5	16.7	17.1	0.86	0.85	0.77	5.5	5.4	5.7
	SP 27-11	11.0	15.0	33.0	19.5	21.0	41	24.5	25.0	0.87	0.86	0.78	6.3	[illegible]	6.4
	SP 27-14	11.0	15.0	39.0	23.5	24.0	41	24.5	25.0	0.87	0.86	0.78	6.3	6.0	6.4
	SP 27-16	15.0	20.0	48	27.5	30.0	56	32.5	34.0	0.85	0.85	0.76	5.9	5.8	6.1
	SP 27-19	15.0	20.0	54	31.5	33.0	56	32.5	34.0	0.85	0.85	0.76	5.9	5.8	6.1
	SP 27-23	18.5	25.0	63	37.0	38.5	67	39.5	40	0.87	0.67	0.80	5.9	5.7	6.1
	SP 27-28	22.0	30.0	75	45	46	80	48	47	0.88	0.87	0.81	5.7	5.4	6.0

The electrical data are for SP submersible pumps fitted with GRUNDFOS motors. When using other motor makes, the data can be used as a guide only. Always check the motor name plate. Other voltages are available on request.

DIMENSIONS AND WEIGHTS

	PUMP TYPE	DIMENSIONS mm					WEIGHT kgs.		SHIPP. VOL.
		A	B	C	D	E*	Net	Gross	m^3
4" MOTOR	SP 27- 2	796	363	433	95	139	20	24	0.036
	SP 27- 3	1024	501	523	95	139	29	33	0.036
	SP 27- 5	1348	645	703	95	139	40	45	0.049
6" MOTOR	SP 27- 7	1529	630	899	140	142	68	84	0.135
	SP 27- 9	1764	685	1079	140	142	80	98	0.153
	SP 27-11	2019	760	1259	140	142	92	112	0.171
	SP 27-14	2289	760	1529	140	142	98	121	0.193
	SP 27-16	2559	850	1709	140	142	113	138	0.208
	SP 27-19	2829	850	1979	140	142	119	148	0.233
	SP 27-23	3229	970	2339	140	142	136	170	0.266
	SP 27-28	3759	970	2789	140	142	147	187	0.299



* E = Max. diameter of pump incl. cable guard + motor

BY INQUIRY

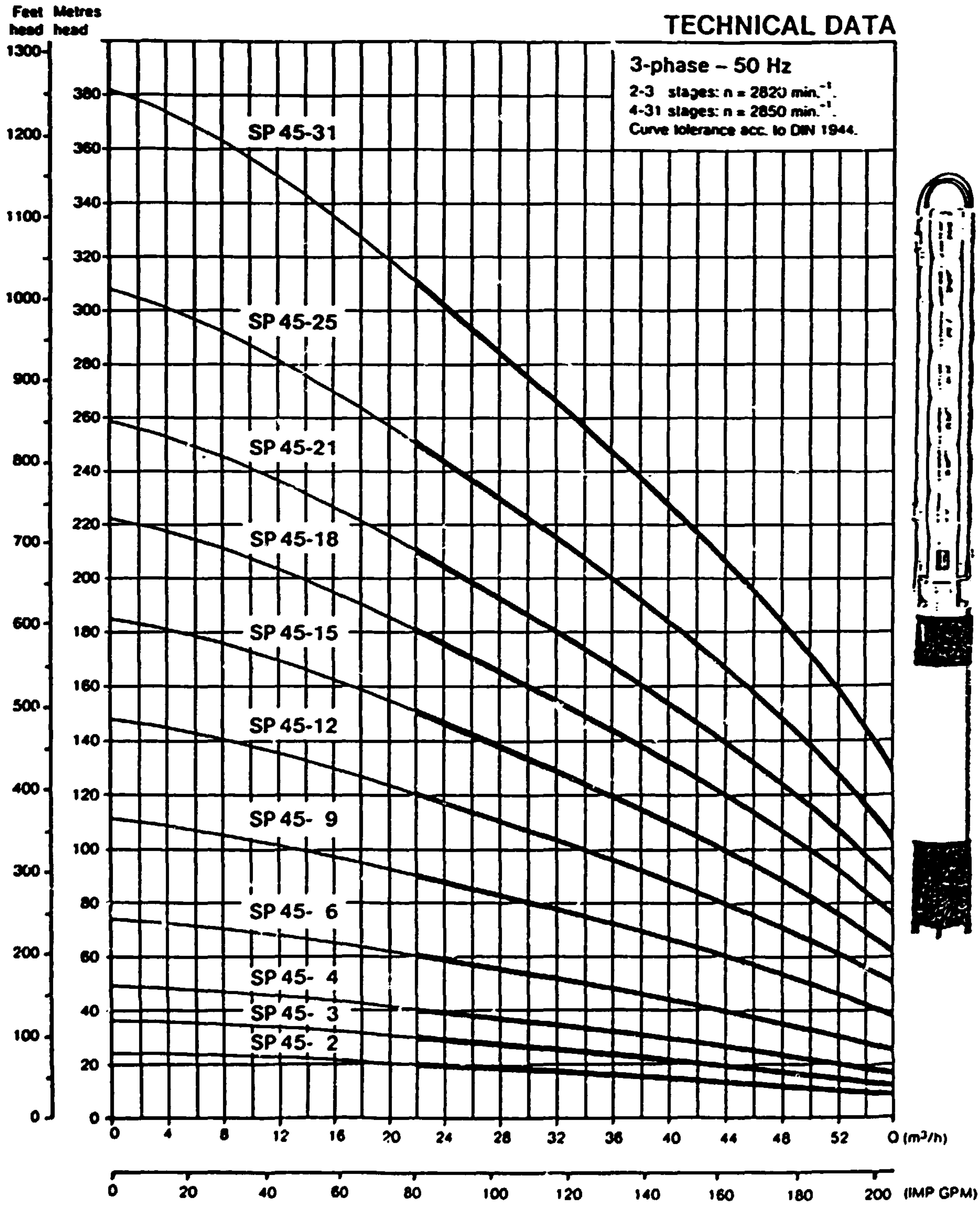
Please supply the following information with each inquiry:

1. Q – the quantity of water required.
2. H – the total manometric head required including frictional losses and tank pressure, if any.
3. The diameter of the borehole (the smallest inside dimension).
4. The distance from ground level to water level at rest.
5. The lowering of the water level, when a certain quantity is pumped.
6. The total length of the borehole, less the length of a borehole filter, if any.
7. The type of electric supply, voltage and frequency.
8. Supplementary information concerning the installation, if any.

Subject to alterations

		SP 45
GB	**SUBMERSIBLE PUMP**	50 Hz

TECHNICAL DATA



SP 45 flow range: 22-56 m^3/h (80-205 IMP GPM).

The GRUNDFOS submersible pump range covers flows from 0.1-160 m^3/h (0.4-587 IMP GPM).

ANNEX 8

CONTRACTS ON TECHNOLOGY TRANSFER, LICENCE

Contracts on licence of manufacture are supposed to be established for:

a. Large wind turbines,
b. small wind turbines,
c. wind turbine blades,
d. electronic control systems, and
e. gear-boxes.

The contract below is an example:
Proposal for a contract on technology transfer between an Egyptian company and a foreign company on manufacture of wind turbines.
It can be noted that in connection with the estimated budget for the programme, the report page 52-54, the expenses in the contract paragraphs 2.3-2.4 and 4. are included in the budget.

COLLABORATION AGREEMENT

This Memorandum of Agreement is made on
.... day of ....
between ....
an Egyptian company having its registered office at
....
which expression shall include its successors and assigns (hereinafter referred to as "A"), and
....
having its registered office at
....
which expression shall include its successors and assigns (hereinafter referred to as "B").

Company "B" is engaged in the manufacturing and marketing of wind turbines and has considerable engineering know-how and technical information regarding wind turbines and are in a position to offer their technical know-how for the design and manufacture of wind turbines, and
Company "A" is desirous of manufacturing in Egypt and marketing in Egypt and the Middel East the items which are set out here and in the schedule hereto annexed (hereinafter referred to as the PRODUCTS) on the terms and conditions herein contained.

TERMS AND CONDITIONS AGREED ON BETWEEN THE PARTIES

1. Definition of Products

1. Said products means wind turbines and the equipment for the operation, drawings of foundations, etc.

   Two different wind turbines are considered:

1.a A wind turbine optimized for the wind climate at sites at the coasts of the Gulf of Suez and the Red Sea. The wind turbine shall be suited for applications in windfarms as well as in single unit systems for large hotels, factories or similar, in connection with a local diesel generator. The wind turbine is supposed to be of rated generator power 90 or 110 kW and of diameter 19 to 21 meters.

1.b A wind turbine optimized for the wind climate in the north part of Egypt, the coastal area of the Mediterranean Sea, to operate in stand-alone systems for pumping of water or for desalination as well as small-scale electricity supply. The wind turbine shall utilize as a generator the three-phase electric motor produced in Egypt, optional of ratings 18.5 kW at 3000 rpm, 15 kW at 1500 rpm or 11 kW at 1000 rpm. The wind turbine is supposed to be of approx. 12 m diameter.

Details of technical conditions and procedures of cooperation between the parties are given in the Annex (to be worked out)

2. Transfer of "Know-how"

2.1 "Know-how" means and includes all inventions, processes, patents, engineering and manufacturing skills and other technical information, whether patented or patentable or not which are presently owned by "B" or which may be so owned, during the terms of this Agreement including, without limitation for the Products defined;

- Technical and Engineering data, calculations, information,
- Design data, calculations and information,
- Specifications, drawings, sketches, photographs,
- Details of technical and quality standards,
- Quality Assurance Plans
- Details of layout of workshops, specifications of machinery,
- Sample parts, sample materials,
- All other forms of recorded information, techniques and design in making of jigs & fixtures, tools & dies, pattern & moulds.

2.2 The term "know-how" shall also mean any and all technical and other knowledge, information and data (including but not limited to patents, rights and patent applications) and experience currently possessed, under control of, or available to or which may hereafter be developed, accrue or come in the possession and control of or available to "B" during the terms of this agreement which "B" is, from time to time, free to disclose relating to the manufacture of the Products.

2.3 "B" shall fully and promptly furnish "A" with such "know-how" as "A" may require from time to time during the terms of this agreement in connection with the manufacture of the products equal in all respects to the products manufactured bu "B". The supply of recorded information (documents, drawings etc.) shall not be limited to what is already available by "B".

2.4 "B" will depute .... engineers at the request of "A" for a period of .... months at the expense of "B" to cooperate with "A" for the production programme and in overcoming any initial technical or production difficulties at "A"s works in Egypt and "B" will for cooperation on the design and for training have .... Egyptian engineers at their works at .... for a period of ...... months at the expense of "B". The deputation of technicians either way shall be subject to the approval of the Government of Egypt.

2.5 "B" shall maintain and will use its best efforts to protect its patents and trademarks in Egypt, and "A" shall not undertake responsibility for protecting "B"s patents and trademarks in Egypt in respect of the products. "B" shall keep "A" protected and harmless against any infringements of "B"s patents and trademarks by others in Egypt as well as the alleged infringement of patents and trademarks of others by "A" in the manufacture and sale of the products by "A" strictly in accordance with the know-how and other information made available to "A" by "B" under the provision of this agreement.

2.6 "A" at their expense, shall procure and maintain patents in Egypt and outside Egypt on such inventions and improvements made by "A" as "A" in their sole discretion shall choose. "B" shall have the right to use the inventions and improvements made by "A" outside Egypt on such terms as may be mutually agreed. If "A" does not wish to maintain such patents in any country, "B" may at its sole discretion and its own expense, procure and maintain patents covering such inventions and improvements in such countries and shall take full title to such patents as procured by "B" in those countries. However, "B" shall not, without the consent of "A" licence any third party the said patents exept its subsidiaries, its parent company, or other subsidiaries of the parent company.

2.7 "A" shall manufacture the products in strict accordance with the said know-how, the standard of quality embodied therein or as may be set from time to time by "B". To ensure the performance of this provision, "B" shall have the right to inspect at reasonable intervals and during business hours the facilities of "A" devoted to the manufacture of the said products.

3. Licence for Manufacturing and Marketing

3.1 Subject to other provision of this agreement, "B" hereby grants to "A", an exclusive licence to make in Egypt the products by use of any or all of "B"s know-how relating to the products, and to use and sell the said products in countries agreed on. If any of these products are covered by "B"s patent, "B" grants the right to "A" to use of these patents without any consideration whatsoever.

3.2 "B" undertakes to provide know-how concerning other products not included in this agreement subject to new, separate contracts. Furthermore "B" undertakes not to licence any of its other products to Egyptian parties not being associated with "A" without having first proposed a licence agreement to "A" on equally favourable terms.

3.3 "A" is entitled to use the trademark................ for the said product to be exported from Egypt. Furthermore, "A" is entitled to use the trademark .... for the products to be marketed in Egypt, subject to the approval of the Government of Egypt.

3.4 "A" agrees to grant "sole importer" contracts to "B" its subsidiaries and associates covering those countries where "B" or its subsidiaries or associates are implanted or will be implanted within the period of this Collaboration Agreement with Annex, subject to mutually acceptable terms.

3.5 "B" agrees to appoint "A", its subsidiaries, associates or nominate distributors as its representative on a number of markets not yet assigned to a company or "B"s associates. This agency will also cover products not included in this Collaboration Agreement but produced by "B".

3.6 Provisions 3.3, 3.4 and 3.5 expires with the Agreement unless otherwise agreed between the two parties.

4. Payment for "Know-How" and Design Transfer

4. In accordance and consideration of "B" having agreed to disclose to "A" the latest design and method of manufacture of the products and other processes developed by "B" in its own country and by its own associates and subsidiaries any where in the World and having further agreed to supply technical advice and data, "A" agrees to pay "B" a sum of .... after deduction of all taxes dues payable to Egypt. This sum shall be due and payable in instalments as follows:

(i) 1/3 after the Agreement has been taken on record by the Government,

(ii) 1/3 at the time of transfer of technical documents and other "know-how",

(iii) 1/3 after the commencement of commercial production, or within 48 months of being taken on record by the Government whichever is the earlier.

5. Royalties

5.1 "A" further agrees to pay to "B" a royalty of ..... percent subject to Egypt taxes on the net selling price of products produced for a period of ..... years. The royalty will be calculated on the basis of net ex-factory sale price of the products exclusive of Excise Duty, minus the cost of standard bought-out components and the landed cost of the imported components, irrespective of the source of procurement including Ocean freight, insurance, customs duties.

5.2 The royalty due shall be payable from the beginning of commercial production provided production is not delayed beyond ...... years of signing this Agreement and the date of commercial production is defined as the first day of the month in which the first customer order is executed and the product passed by Quality Control as corresponding to the desired quality requirements as per "know-how". If the commercial production and sale has not begun before the stated time the parties will negotiate revision of the royalty in order to compensate for the income "B" may loose.

5.3 Payment of Royalty by "A" to "B" under this Agreement shall also constitute compensation for the use of patent rights of "B" by "A" till the expiry of the life of the patent and that "A" shall have the freedom to use the patent and continue to manufacture the product even after expiry of the Agreement without any additional payment.

5.4 "A" shall render to"B" annual records within three months of the last day of December following each calendar year with respect to which royalties are payable under this Agreement, stating the amount of royalty due and payable with respect thereto.

5.5 "A" agrees to keep complete records of the account concerning to products which are the subject matter of this Agreement, which record shall be open to the inspection of "B" or its duly appointed representative agreeable to both parties, during regular business hours for verifying the payments due to "B" under this Agreement.

6. Payments

6. All payments due by "A" to "B" under this Agreement are to be made in .... to "B"s account in any Bank it designates. Conversion shall be made at the rate of exchange prevailing at the date of payment.

7. Certificate

7. Any fee or expense to obtain a certificate of approval for the wind turbine type issued by NREA, Cairo, or an approval issued by EEA, Cairo, for connecting it to the grid, are to be at the expense of "A".

8. Secretness and Sub-licence

8.1 "A" shall maintaine secret at all times during this Agreement all the know-how, drawings and the like disclosed by "B" to "A" or learn during the performance of this Agreement. Likewise "B" shall maintaine secret at all times the information provided by "A" to "B" under this Agreement. This clause, however, will not apply to information which is of public knowledge.

8.2 "A" will, however, be free to sub-licence the technical know-how or product design or engineering design under the Agreement to another Egyptian party/parties, should it become necessary, the terms of such sub-licence will, however, be as mutually agreed to by all the parties concerned including "B" and will be subject to the approval of the Government of Egypt.

9. Agreement Validation and Renewal

9.1 This Agreement shall become effective after it has been duely approved and signed by "A" and "B" and the approval of Government of Egypt has been obtained thereto, including the approval, if any required of the Exchange Control Authorities of Egypt.

9.2 This Agreement shall remain effective for a period of ... months from the date of commencement of commercial production as defined.

9.3 Subject to the approval of Government of Egypt, this Agreement may be renewed in whole or in part for further period by mutual agreement.

9.4 This Agreement shall bebinding upon and insure to the benefit of the successors and assigns of the respective parties hereto, and the obligations hereunder shall not be assignable by either party without written consent being first obtained from the other.

9.5 This Agreement embodies entire understanding of the parties as to its subject matter, shall not be amended, except in writing executed by both parties which shall also be subject to approval of Government of Egypt.

10. Agreement Termination

10. Either party may by notice in writing to the other terminate this Agreement in the event of:

10.1 Any default by such other party in the performance or observation of any of its obligations under this Agreement which is not remedied to the satisfaction of the party giving such notice within ninety (90) days following delivery of such notice, such notice to contain resonable particulars af such default and to state the intension to terminate the Agreement under this Section unless such default is made good or remedied.

10.2 Judicial proceedings for bankruptcy, composition with creditors, sequestration of assets for creditors, or receivership, instituted by or against such other party of its failure to meet its obligations as they mature for any material period of time.

10.3 Liquidation, compuolsry or voluntary, of such other party except in connection with an amalgation, reconstruction, merger, consolidation, reorganization or disposition of assets as a going concern voluntarily undertaken, and with a view to the continuance of the business by the transferee thereof, provided, however, that upon such event the business entity continuing the business formerly carried on by such other party shall in an appropriate instrument delivered to the other party to this Agreement, undertake to perform all of the obligations of such other party hereunder.

11. Failure of Obligations, Disputes on Agreement

11.1 Neither party shall be in default under this Agreement by reason of its failure in the performance of its obligations if such failur or delay is caused by acts of God, Government laws and regulations, strikes,lockouts, war or any other cause beyond its control and without its fault or negligence.

11.2 All disputes, questions or differences etc. arising in connection with this Agreement shall be referred to arbitration by the Egyptian .... Chamber of Commerce according to Egyptian law. The parties commit to pose the case before the Chamber within 3 months from the date of which one of the parties informs the other in writing that differences have arisen.

11.3 Notice and other communications under the Agreement shall be in writing or by established cable, radio or facsimile service, addressed as indicated in the description of parties above or as either party may request in writing, and the effective date of each is the date of its prepaid deposit in the mail for despatch by air or such service properly addressed.

11.4 The Agreement shall be constructed in accordance with and be governed by the laws of Egypt.

IN WITNESS WHEREOF, THE PARTIES HERETO HAVE EXECUTED THIS AGREEMENT AS OF THE DATE FIRST ABOVE WRITTEN.

For and on behalf of "B"	Witnessed
Signed	Signed
For and on behalf of "A"	Witnessed
Signed	Signed

ANNEX 9

TESTING OF GRID-CONNECTED WIND TURBINES

Troels Friis Pedersen,

Risø National Laboratory, Denmark

STANDARD MEASUREMENTS ON WINDMILLS AT THE TEST STATION FOR SMALL WINDMILLS AT RISOE

ABSTRACT

The testing of windmills at the Test Station for Small Windmills at Risoe has been developed to a standard test procedure, which is described in this paper. The test facilities are briefly mentioned and the instrumentation is outlined in detail. The measurements are described, beginning with function testing through structural measurements to performance testing.

INTRODUCTION

The rising sale of windmills in Denmark 1980 and 1981 brought with it a demand for intensified authorized measurements on windmills. From the official side there was a need for securing high quality to justify the subsidy, and from the manufacturers' and consumers' sides there was a need to secure good construction, and to provide a basis for a standard of reference for the individual windmill types.

The measurements for a given windmill should be accomplished in a relatively short time to yield a sufficiently large test capacity, but the content of the measurements should be comprehensive for an adequate description of the fundamental characteristics of the windmill. Practical experience at the Test Station for Small Windmills has also shown that it is very common for the construction to be changed toward an optimized design after the measurements have been carried out. Even small adjustments can change the characteristics of a windmill fundamentally, so it is necessary to repeat the measurements after the adjustments are made.

These considerations led to the philosophy that the first measurements on a windmill should be carried out with limited but highly reliable instrumentation, able to measure fundamental characteristics, such as power regulation, and thereby demonstrate if any fundamental changes are necessary. These measurements give a qualitative picture of the fundamental characteristics of the windmill. At the Test Station for Small Windmills at Risoe they are designated as "standard measurements", and are described in the chapters that follow.

Apart from the standard measurement program, the Test Station carries out more intensified measurements on windmills, and the content of these measurements is established from case to case. Typically, these contain load measurements on the rotor blades under different operating conditions, for instance at high yaw angles.

TEST FACILITIES

The Test Station for Small Windmills was established in 1978 with the main purpose of testing smaller windmills. In this connection a measurement system was developed in close cooperation with the electronics department at Risoe, and seven foundations were built to carry the first generation of windmills. The Test Station was descrited by Helge Petersen at this stage

The foundations have since been extended with four very flexible ones that are able to take static tower bending moments up to 240 kNm. The standard foundations, which they are called, are placed next to four of the original ones at stand Nos. 2, 3, 5 and 6, shown in Fig. 9.1. , so that one can choose between two foundations at four of the seven stands.

The data collection system is based on a PDP-11 computer connected to a 48-channel A/D converter. The data from the stands are transmitted as DC-signals and the maximum available number of channels from one stand is 22. Three channels from each stand are always connected, and these are used for the standard measurements. Time-traces are taken before the A/D-converter and four channels can be traced simultaneously. Frequency spectra are also taken before the converter, and two channels can be analysed simultaneously including their mutual coherence or transfer functions.

The standard data collection is carried out with a computer program that can run measurements on four windmills at the same time. The program samples data on all channels each second and between each sampling some calculations are made. Each channel is corrected with its calibration values and some of the data are corrected to standard air density. All the data are averaged with two averaging times, normally 10 minutes and 30 seconds, and finally the method of bins is used for data reduction.

The test site is rather flat, and the most frequent wind direction sectors, west and south west, provide a free airstream from Roskilde Fjord. The remaining wind direction sectors have some influence from houses and trees, though not enough to disturb measurements carried out with the wind direction in these sectors. The annual mean wind speed at the site at a height of 20 m is 6.0 m/s.

A photograph of the row of windmills is shown in Fig. 9.2, the meteorological tower in the center.

DESCRIPTION AND INSTRUMENTATION OF A WINDMILL

The windmills that are erected at the Test Station for Small Windmills are normally defined through detailed drawings of the construction. On receipt, each windmill is checked to insure that it fits its specifications in the drawings.

The main dimensions of the windmill are measured to give a precise figure of hub height and swept area. The principles for the construction of the nacelle are sketched as shown in Fig. 9.3. The main data for the windmill are outlined in a table.

The attachment of the instrumentation to the windmill takes place at the Test Station's octagonal hall which is situated close to the row of test stands. The instrumentation that is used for the standard measurements takes readings of the following parameters:

- electrical power
- rotor shaft torque
- rotor rotational speed
- wind speed
- wind direction
- air pressure
- air temperature

The three first-mentioned parameters describe the windmill, and the last four describe the meteorological environment (see Fig. 9.4). Besides the instrumentation, which is always mounted on the windmill, accelerometers and strain-gauges are used for eigenfrequency measurements, and current transformers are used for current measurements.

Electrical power data from a windmill is obtained by means of a measurement transformer and a power converter fixed to the foot of the windmill. All three phases of the electrical grid are measured, and the output from the power converter shows total active power.

The rotor torque on the main shaft of the windmill is measured with strain-gauges. The signals are transmitted from the rotating shaft to the nacelle by one-channel, frequency-modulated transmission equipment, which is powered from batteries or accumulators (see Fig. 9.5) The strain-gauge signal is transmitted and received through two induction coils which are mounted on the rotor shaft. At the nacelle, the AC-signal is converted to DC for further transmission.

The rotational speed is measured with an inductive sensor fixed at a row of knots which rotates with the shaft. Sometimes a row of bolts on the braking disc can be used. Usually the sensor is mounted at the fast running shaft with few knots as a matter of sensitivity. The sensor is powered from a box at the nacelle, which also converts the AC-signal to DC.

The wind speed is measured with an anemometer, and the wind direction with a wind vane both of which have been developed at Risoe (Fig. 9.6)
The anemometer is mounted on a movable mast so that it is positioned at hub height for propeller-type windmills, and in the center of the rotor for vertical-axis types. The distance from the windmill to the anemometer is two rotor diameters. The wind direction is measured on the stationary meteorological tower at a height of 30 meters, and during standard measurements the data obtained is considered representative for the wind direction for all

the windmills. During the measurements it is necessary that the wind direction, based on 10 minutes averaging time, be kept within a sector of 45° relative to a line from the windmill to the anemometer.

The air pressure is measured in the room in which the computer is placed, and the air temperature is measured on the stationary meteorological tower at two meters height. These two measurements are used for calculating the actual air density, so that the collected data from the windmills can be corrected to a standard air density of 1.225 kg/m^3. It is our experience that within a period of 48 hours the air density can vary by at least 5%.

FUNCTION TESTING

After the erection of the windmill it passes through some introductory tests, where different functions connected with normal operation and emergency conditions are examined. These tests give one an impression of the functioning of the windmill and a degree of confidence to be gained with it.

The windmill is started up at low wind velocities; its functions of properly cutting in and out of the electrical grid and stopping when switched off are recorded. At somewhat higher wind speeds the safety systems are tested. The mechanical brake is tested by switching off the electrical grid and also by allowing overspeed. The airbrakes are also tested at overspeed. If there are other relevant safety functions these are also tested.

When the windmill has been shown to complete these tests satisfactorily it is put into 24-hour operation, and then proceeds to the next testing stage.

VIBRATION MEASUREMENTS

To insure that no resonance appears in vital parts of the construction, eigenfrequencies are measured separately with the machine in a stopped condition or by frequency spectra measured during operation. First of all, eigenfrequencies of first-order vibration modes are measured, the most important ones being: blade bending, flapwise and chordwise, tower bending, torsion of both the tower and drive train. The vibrations are measured by utilization of accelerometers on the blades and the tower and by strain-gauges mounted on the rotor shaft.

If the construction shows a strong response for other vibrational modes these frequencies are also measured.

POWER MEASUREMENTS

In the standard measurement program the power measurements concentrate on four different subjects which show different characteristics of the windmill. These are: energy production, power regulation, transmission efficiencies, and power fluctuations.

Energy production

In relation to energy production a power curve is measured according to the recommendations of IEA: "Recommended practices for wind turbine testing and evaluation 1. Power Performance Testing"

The measured data are averaged over 10-minute periods, and are corrected to a standard air density of 1.225 kg/m^3. The method of bins is used and wind speed intervals of 1/2 m/s are applied. The recommendation says 1 m/s intervals up to maximum power and 2 m/s intervals above this point. Our reason for using 1/2 m/s intervals is that the resolution is better; also, these intervals are used for the measurements that run simultaneously with an averaging time of 30 seconds. The wind direction is allowed to vary only within a sector of 90°, where the recommendation states 270°. This limitation is due to interference from the row of windmills which can be high at certain wind directions.

The annual mean power output is calculated as a function of the annual mean wind speed. With four different form-parameters the Weibul-distribution is used for the wind speed distribution. One of these form-parameters is chosen to be equal to two giving the Rayleigh distribution recommended by the IEA as a basis of reference. An example of a measured power curve is shown in Fig. 9.7. In Fig. 9.8 the corresponding annual mean power output is shown.

For Danish applications, the annual energy production is best indicated by using the "Windatlas for Denmark" This is a calculational tool for determining annual energy production based exclusively on estimates of the surrounding terrain. The "Windatlas" divides landscapes into four different roughness classes, and the wind direction into eight wind direction sectors. Now if the site for a windmill is given by a roughness class for each sector, it is possible to estimate the annual energy production to a rather high accuracy. In this way the "Windatlas" has shown a broad application in Denmark in practice. Therefore the energy production from a windmill is normally also referenced to the four different roughness classes, which can also be interpreted as four typical Danish landscapes.

Power regulation

For all purposes other than energy production, averaging times of 30 seconds are used. In this way, a better estimate is obtained at parts of the power curve where variations are pronounced, and the variation in the measured wind speed is broader. This is important for measurements of the characteristics of power regulation, where wind speeds as high as possible are needed. However, within test periods of four months, you have no guarantee of wind speeds that are high enough for measurements of power regulation. Other methods will therefore have to be used to show the characteristics of power regulation.

For stall-regulated windmills two methods are used, both aiming at measuring the characteristics of power regulation at a reduced rotational speed, where power regulation commences at a lower wind speed. One method is to operate the windmill solely with a smaller generator connected with a gearing. This method is particularly relevant to windmills designed for dual generator operation, where the smaller generator is already present. Another method is to couple the windmill to a diesel aggregate with a synchronous generator, which produces an artificial electrical grid. The rotational speed of the windmill can then be regulated with the rotational speed of the diesel engine. Both methods have shown good application in practice.

When the characteristics of power regulation have been measured at a reduced rotational speed, it is possible to convert these characteristics to a higher rotational speed. In Fig. 9.9 measured power curves are shown for two different rotational speeds together with a power curve at the high rotational speed but calculated from the data at the low speed. The difference that normally appears between the two power curves at the high rotational speed is due to a Reynolds-number effect.

Efficiencies

Since both the rotor shaft torque and rotational speed of the shaft are measured, it is easy to calculate the transmission losses. Examples of measured transmission losses are shown in Fig. 9.10. From the power curves, measured at an averaging time of 30 seconds, the power coefficients are calculated for the rotor itself and for the total windmill.

Power fluctuations

Time traces of the electrical power from the windmill are recorded for, among other things, an investigation of power fluctuations due to the construction itself. These time traces can eventually be supported by frequency spectra.

STARTING CAPABILITY

Before a windmill begins to produce energy, it will have to be started up, and if this is done without the use of a motor, the rotor shaft torque must overcome the static frictional losses in the drive train. It is therefore useful to know the magnitude of the rotor shaft torque at the stopped condition for the windmill. During the standard measurement program, the rotor shaft torque is measured at the stopped condition as a function of wind speed, and an example of this kind of measurement is shown in Fig. 9.11.

LOADS AT CUT-IN

Windmills that produce power to the electrical grid couple to the grid only when the wind is sufficiently high to raise the rotational speed to the synchronous rotational speed of the generator. During this cut-in, strong torque impulses can appear on the generator shaft and disturbances can be transmitted back to the electrical grid. The rotor shaft torque, rotational speed and electrical current during cut-in is measured.

LOADS AT STOPPING

One of the critical situations that can have a strong influence on the lifetime of a windmill is the braking sequence. In the standard measurement program the rotor shaft torque is measured during a braking sequence. The activation time and static brake torque are important parameters for determining the capability of the brake, but the transients present at the cut-in of the brake are also important factors.

EFFICIENCY OF AIR BRAKES

The air brakes make up the most important safety system of a windmill and by their release the windmill could avoid fatal accidents, even under conditions of high wind speeds and without any other interference. Their efficiency is important and in the standard measurement program it is determined at simulated loose-running where the rotational speed relative to the wind speed is recorded.

TEST REPORT

After the windmill has succesfully completed the measurement program the data are reported. The report is published formally after it has been sent to the manufacturer. The report contains the description of and the measurements on the windmill, which have been outlined here.

In addition, the report contains a log book that describes the events to which the windmill has been exposed during its stay at the Test Station. Among other things, the log book lists dates for its reception, erection, start of operation, and removal, and abnormal operating situations are described, such as safety stops, loose runnings, and damages.

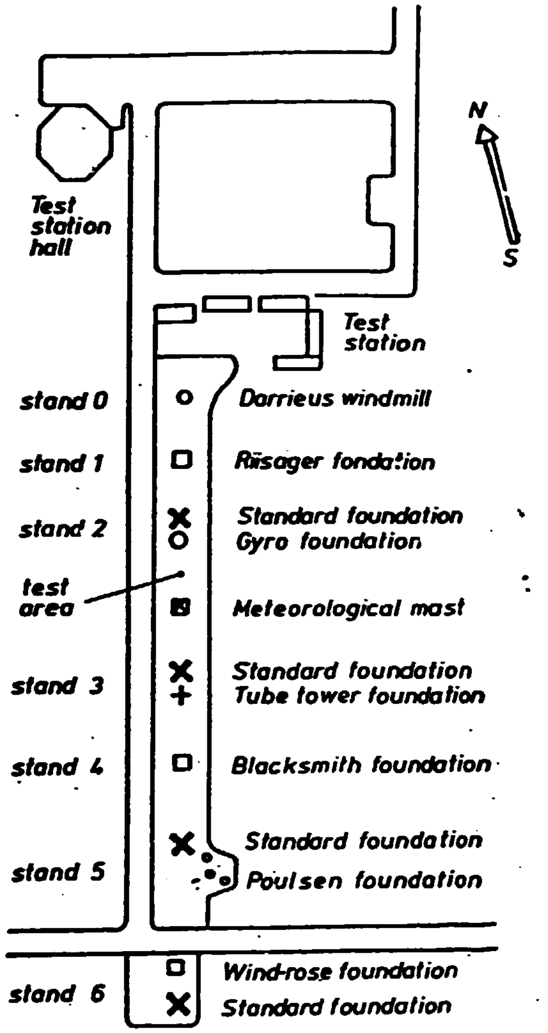


Fig. 9.1. The row of stands.

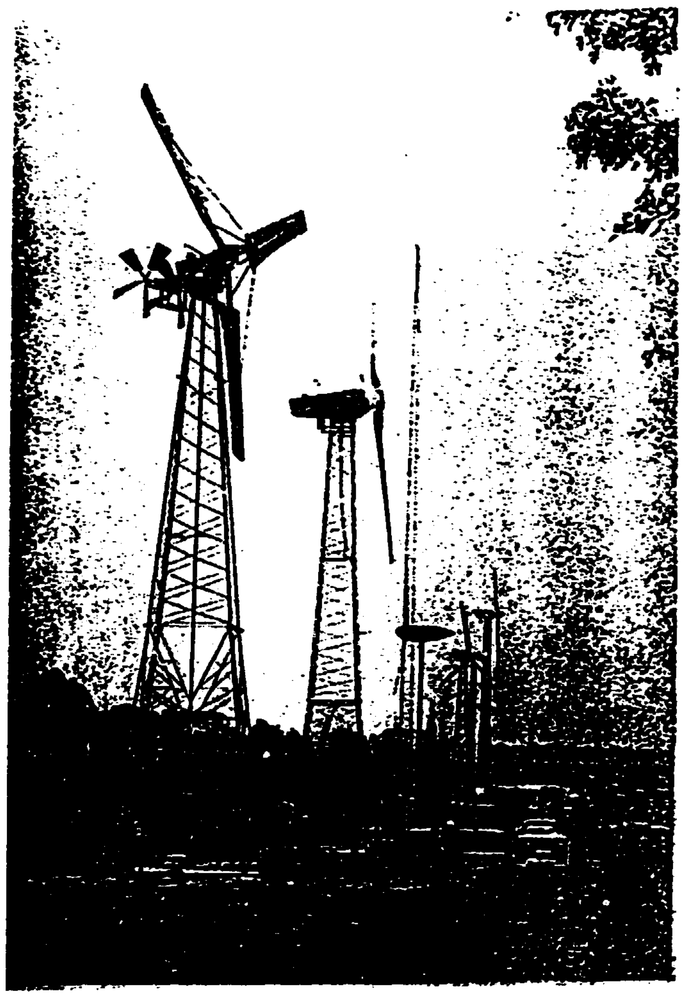
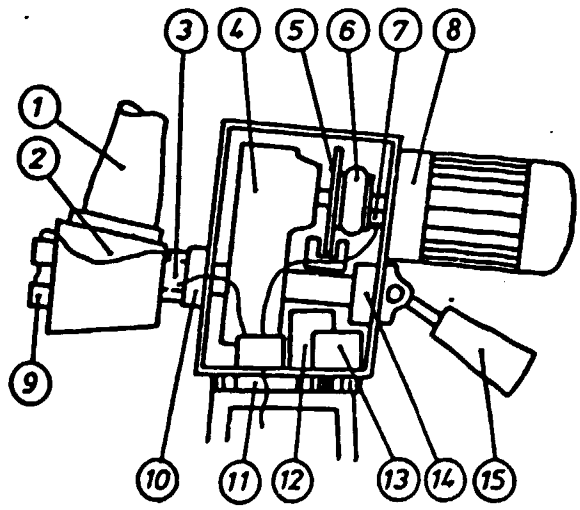


Fig. 9.2. The row of windmills



1. blade
2. hub
3. strain-gauges on main shaft and transmission coils
4. gear box
5. disc brake
6. clutch
7. sensor for rotational speed
8. generator
9. transmission equipment
10. rotor bearing
11. yaw bearing
12. hydraulic brake system
13. gearbox for yaw system
14. rotor bearing
15. yaw rotor

Fig. 9.3. Principal construction of the nacelle with instrumentation.

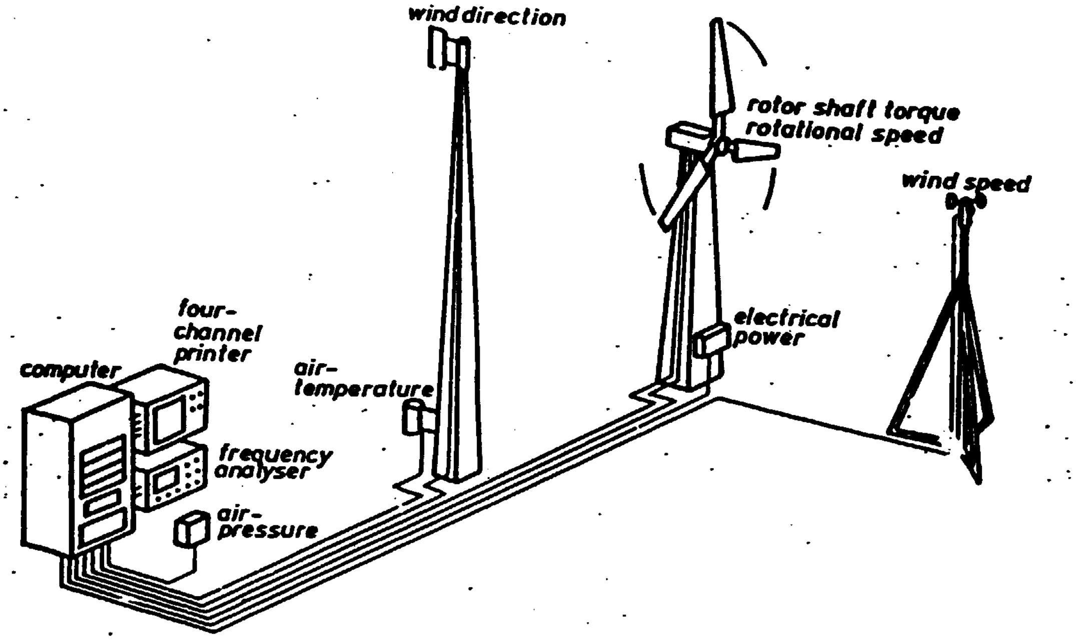


Fig. 9.4. Standard instrumentation used for the standard measurements.

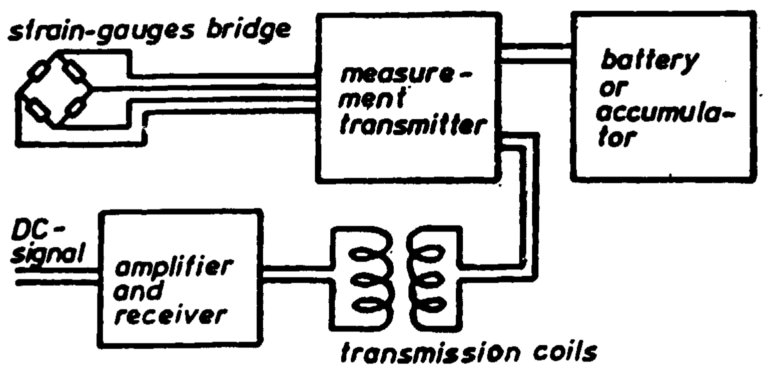


Fig. 9.5. Signal transmission for measurement of rotor shaft torque.

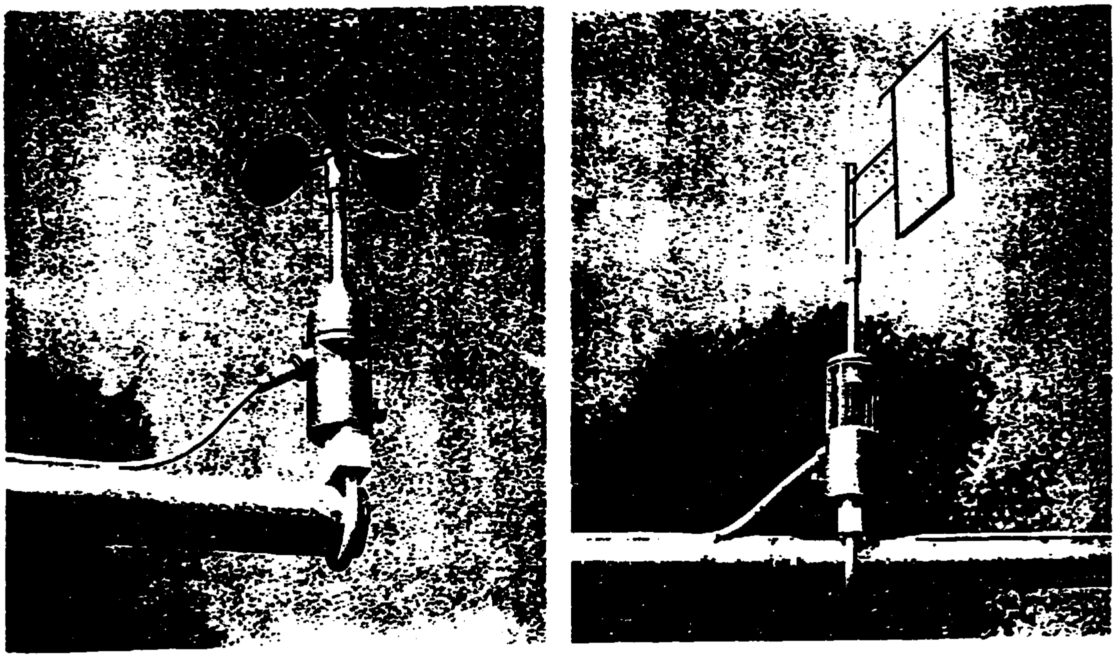


Fig. 9.6. Anemometer and wind vane developed at Risoe.

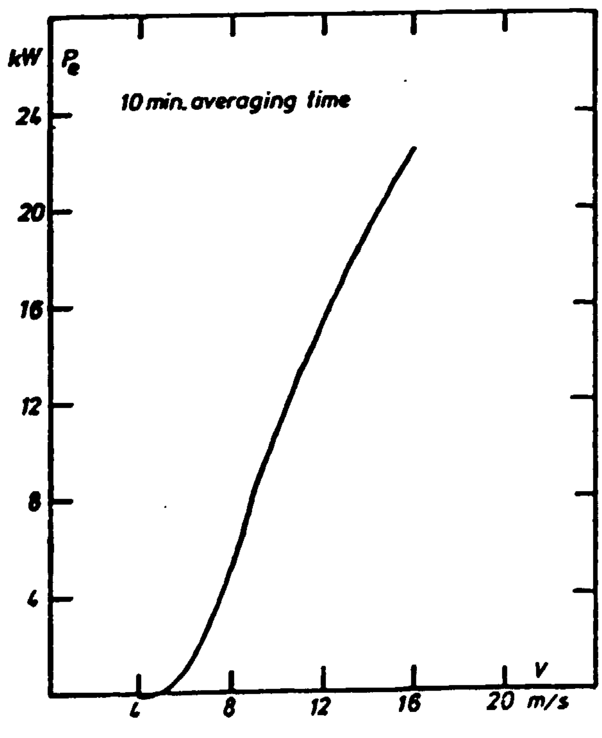


Fig. 9.7. Power curve for a
a 22-kW Blacksmith windmill.

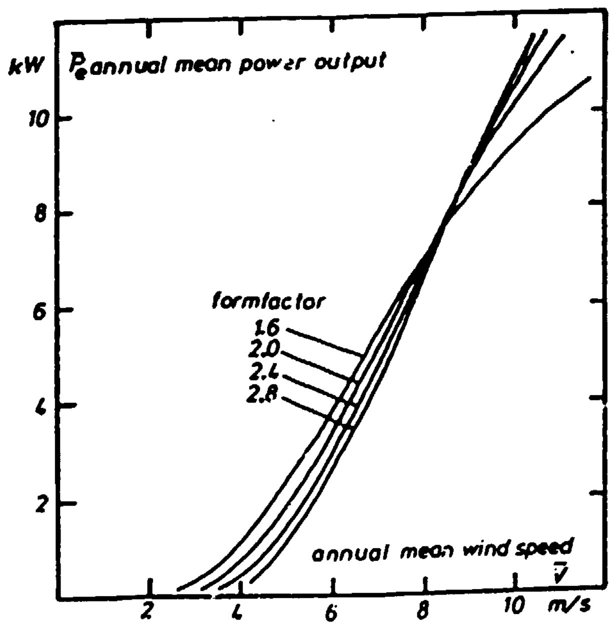


Fig. 9.8. Annual mean power output
for a 22-kW Blacksmith windmill.

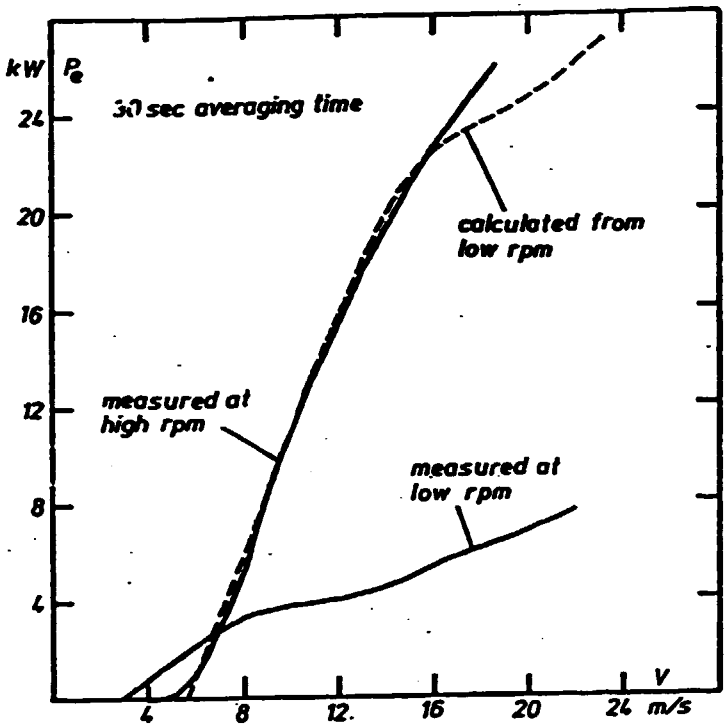


Fig. 9.9. Measurement of power of high- and low-rotational speeds of a Blacksmith windmill.

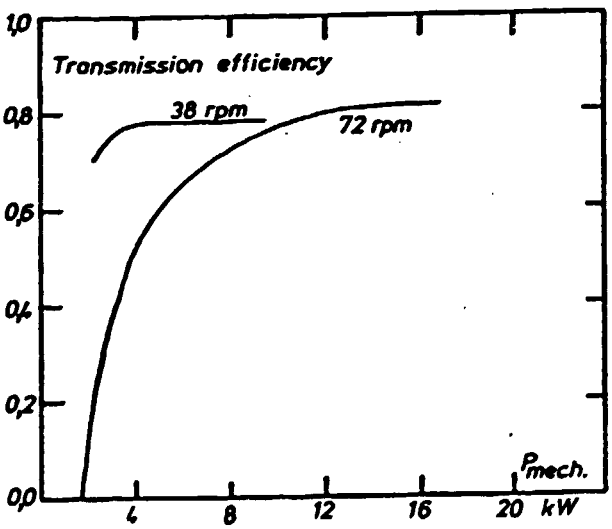


Fig. 9.10. Transmission efficiencies of a Blacksmith windmill measured at high and low rotational speeds.

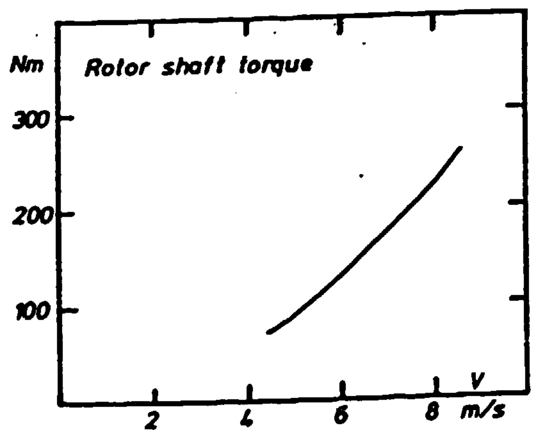


Fig. 9.11. Static rotor shaft torque measured on a Blacksmith windmill at stopped condition

ANNEX 10

LAW NO. 102 , 1986
FOR THE ESTABLISHMENT OF THE NEW AND RENEWABLE ENERGY DEVELOPMENT AND UTILIZATION AUTHORITY

The people assembly has established the following:

Article 1 :

A new authority is established called " New and Renewable Energy Development and Utilization Authority " belonging to the Minister of Electricity and Energy based at Cairo City .

Article 2 :

The Authority , in coordination with the concerned government bodies which are related to the New and Renewable Energy , will assume its responsibilities as follows :

1- Identify and evaluate new and renewable energy resources and plan for its development and use within the frame of the overall energy policies in Egypt .

2- Carry out technical , economical and environmental studies and researches needed for the development of the renewable energy resources either by its own means or in cooperation with other technical institutions inside and outside Egypt.

3- To identify , in coordination with national concerned authorities , field where renewable energy resources can effectively replace conventional energy resources .

The authority is the only authorized organization to issue necessary licenses in order to ensure technical guarantees .

4- To implement " NRSE " projects either through its own means or in cooperation with others .

5- Suggest to the Egyptian standard specifications for renewable energy systems and equipments. Perform standard tests for the performance of the local and foreign produced systems and equipments under the Egyptian conditions and then issue certificates for their validity .

6- Carry on applied field testing for renewable energy technologies .

7- Develop and implement the necessary training programs to disseminate renewable energy applications .

8- Provide consultancy needed in the field of renewable energy as well as the technical expertise for the development of the national industry of renewable energy equipments and its related programs .

9- Implement all agreements held between the government and the general authorities on one side , and the foreign governments and authorities on the other side in the field of renewable energy .

ANNEX 11

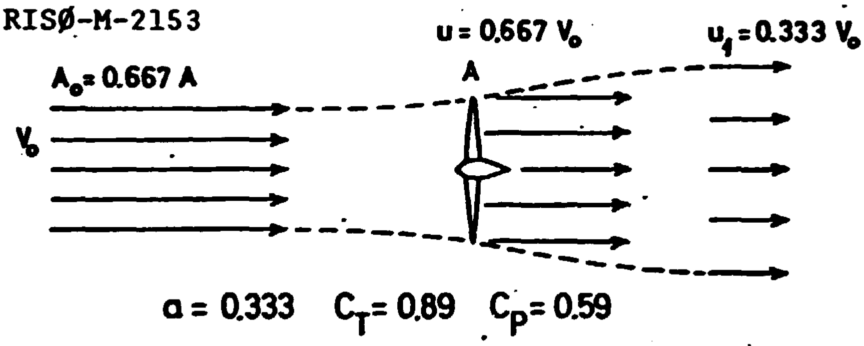
Comments on Wind Tunnel Experiments with Wind Turbines

In the report: "EREDO Feasibility Study and Conceptual Design", ING/2017/127, 1982, Qattara Hydro and Renewable Energy Projects Authority (CESEN), one of the experimental facilities described is a wind tunnel for wind turbine testing.

This subject is commented on in the following.

If a wind tunnel is to be used for measurements of wind turbine performance, the generation of power versus wind speed, the so called power curve, it must be stressed that a high accuracy of a few per cent is needed. This calls upon very careful scaling of the wind turbine, not only in making the model but still more in scaling of the parameters of the similarity laws and avoidance of the tunnel boundary interference. One of the questions is: How large a model is acceptable in a given wind tunnel?
To illustrate this the sketch below shows the stream-lines of the wind upstream and downstream of a wind turbine.

From report RISØ-M-2153



In the rotor-plane of the wind turbine the wind speed decreases to 2/3 of the incomming wind and behind the rotor furthermore to 1/3 of the wind speed. This pattern must not be significantly destroied by the limited jet of air in the wind tunnel.

Therefore the diameter of the wind turbine model should not be more than half of the diameter of the air jet in the wind tunnel, preferably smaller.

The highest speed of the blade speed should not be more than half of the speed of sound, so the maximum blade tip speed would be 160 m/s.

A sketch of the wind tunnel proposed in the EREDO-report is shown next page.

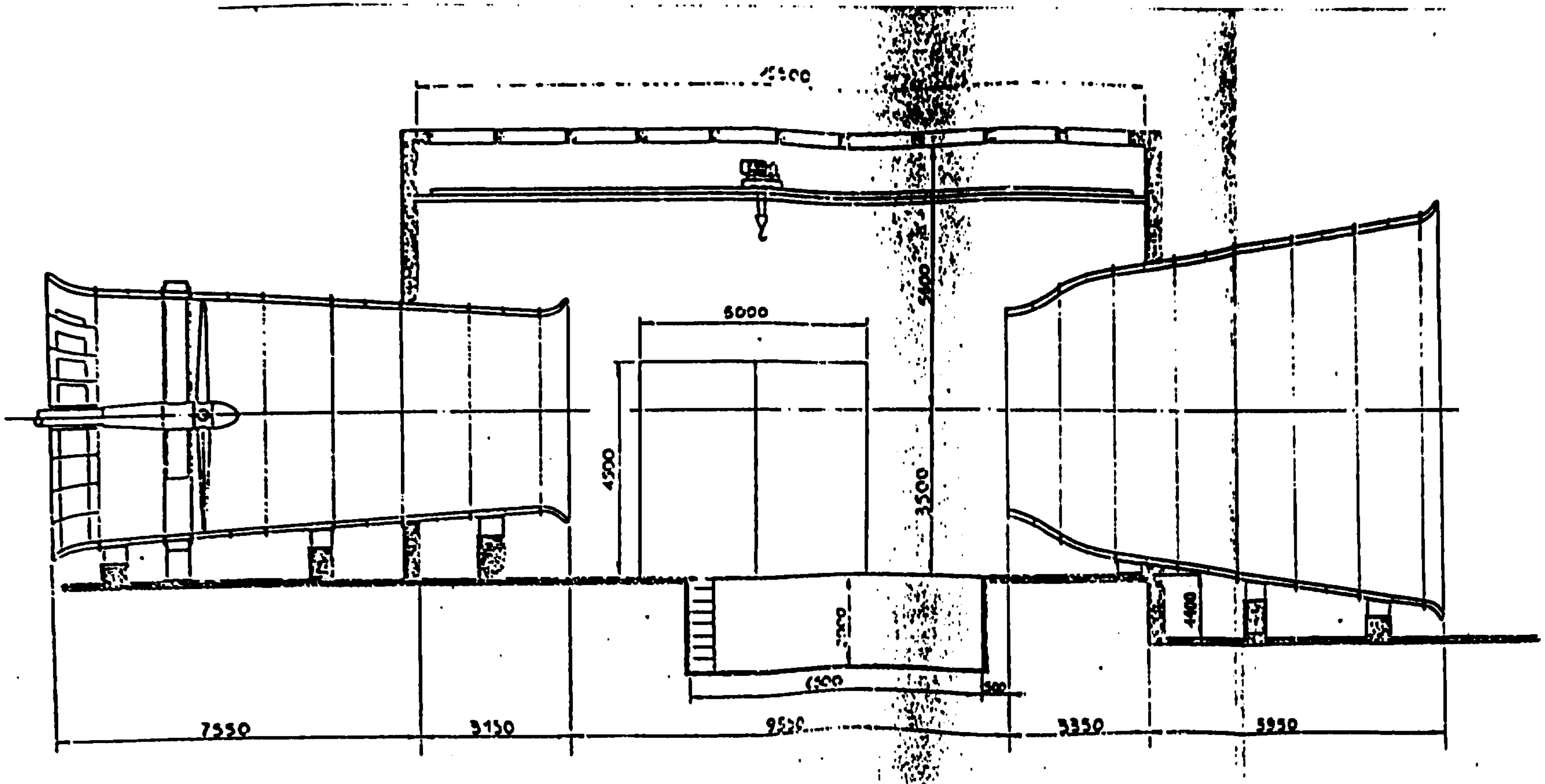


FIG. 3.48

From report "EREDO Feasibility Study and Conceptual Design", ING/2017/127,1982

CESEN CENTRO STUDI ENERGIA RENZO TASSELLI
VIA SERRA, 6 GENOVA (ITALIA)

DIS. N°/DRAWING NO	NOTES/PREPARED BY		
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COMMESSA/JOB NO	SCALA/SCALE	FORM./SIZE	DATA/DATE
2017	-	A3	DEC 82
TITOLO/TITLE: GENERAL LAY-OUT OF THE WIND TUNNEL		DIS.	APPR.

The Diameter of the air jet in the proposed wind tunnel is 4 m, so the model wind turbine could be of 2-m diameter. Tip speed 160 m/s gives angular velocity ω=160 sec^{-1} and so rotational speed N= 1530 rpm. Let us suppose that it is a model of a wind turbine which is designed for maximum C_P = 0.45 at tip advance ratio X= 6, which is normal. At these conditions the air speed in the wind tunnel is 160/6 = 26.7 m/s and the power of the model is

$P = \frac{1}{2} \rho V^3 A C_P$ = 16500 Watt = 16.5 kW.

For a stall-controlled wind turbine the maximum power is of the order of three times higher than the power at maximum C_P, for the model then the maximum power is 50 kW, and this will be attained at 2 to 3 times the wind speed for maximum Cp. Let us say at 2.5 · 26.7= 67 m/s. Therefore the wind tunnel must be able to run the model at least at that speed.

But are the similarity laws fulfilled? To examine this the Reynolds Number must be found. Reynolds Number is in proportion to the product of speed and length, in this case the air speed seen by the blade, the tangential speed, and the length is the chord. So the Reynolds number will be the same for model and actual wind turbine if

$$(V_{tip} \cdot c)_{model} = (V_{tip} \cdot c)_{full\text{-}scale}$$

Typically the tip-chord of a blade is c_{tip} = 0.075 R, where R is the radius. For the model, of R= 1 m, the tip chord is 0.075 m, so therefore $(V_{tip} \cdot c)_{model}$ = 160·0.075 = 12.0

Wind turbines of the type considered often runs at tip speed 45 m/s. This gives $c_{full\text{-}scale}$ = 12/45 = 0.266, and thereby $R_{full\text{-}scale}$=3.5 m or diameter 7 m.

As will be seen the wind tunnel can only simulate wind turbines of 7 m, perhaps 10 m giving some allowance for reduced Reynols Number.

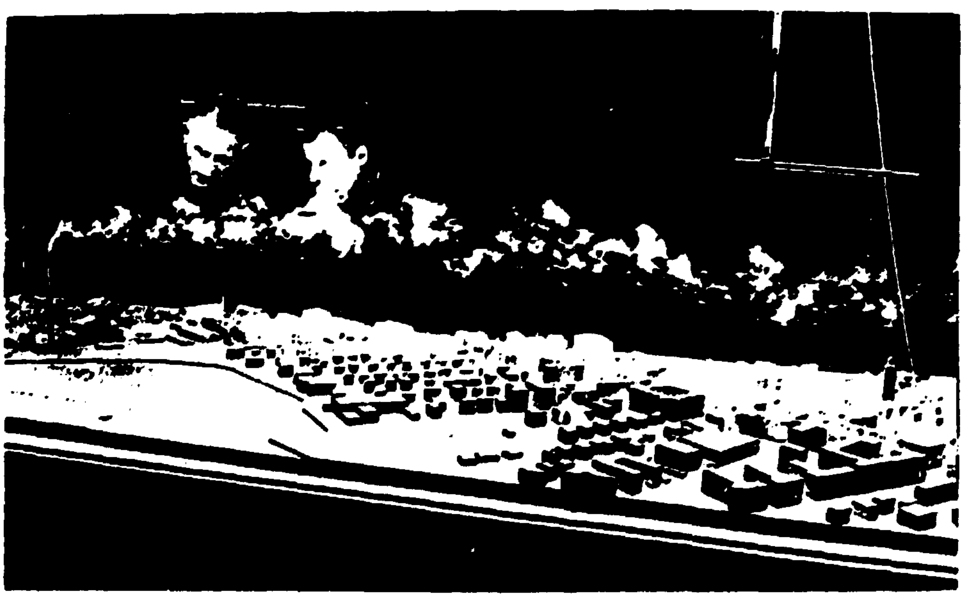
It should also be noted that the specific power of the model is very high; it is 50/3.14 = 16 kW per square meter. Normally a wind turbine has the specific power 0.35 kW/m^2. Because of the very high loads on the blades of the model this would be extreemely expensive the blades being carved out in solid steel.

The learning from this analysis is that performance measurements by means of model experiments in a wind tunnel of the proposed size is not feasible for large, fast running wind turbines, only for small wind turbines for batteri charging and for wind turbines for pumping water, windpumps.

Although a wind tunnel is not suited for performance testing of large wind turbines it can be used for experiments requiring less accuracy, experiments supporting research and development. Even then the wind tunnel should be larger than proposed, and example is shown overleaf, a wind tunnel in Stuttgart made for testing small wind turbines.

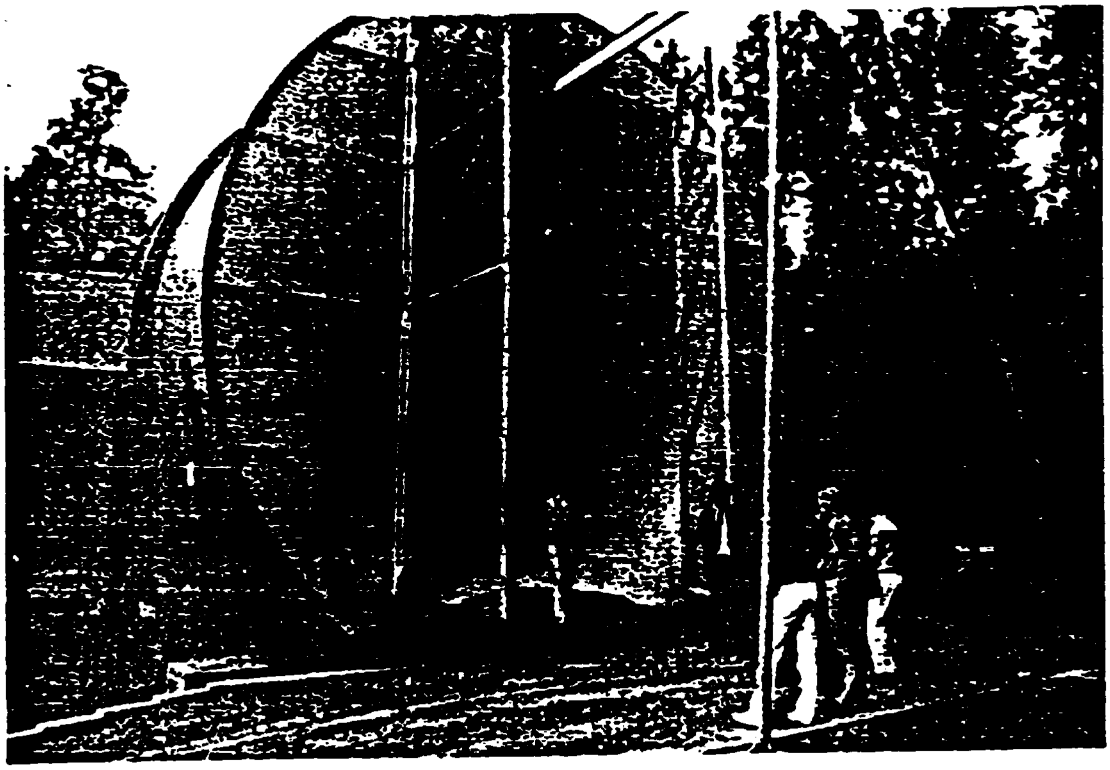
For the reasons mentioned above it is daubtful that the proposed wind tunnel should have high priority, however, a smaller wind tunnel should be built for calibration of anemometers, but a wind tunnel for calibration is of an other type having a closed working section and preferable closed cirquit because of the high precission needed. (Working section preferable 1 x 1 meter)

In the EREDO report it is also mentioned that the wind tunnel could be used for studies of the wind over town or landscapes for environmental purposes. This is not possible in such a wind tunnel, it must be of a very different design, having a very long working section in which the boundary layer can built up. The picture below shows such a wind tunnel which the author built in 1960. The young man to the right in the picture is the consultant 27 years ago!!!

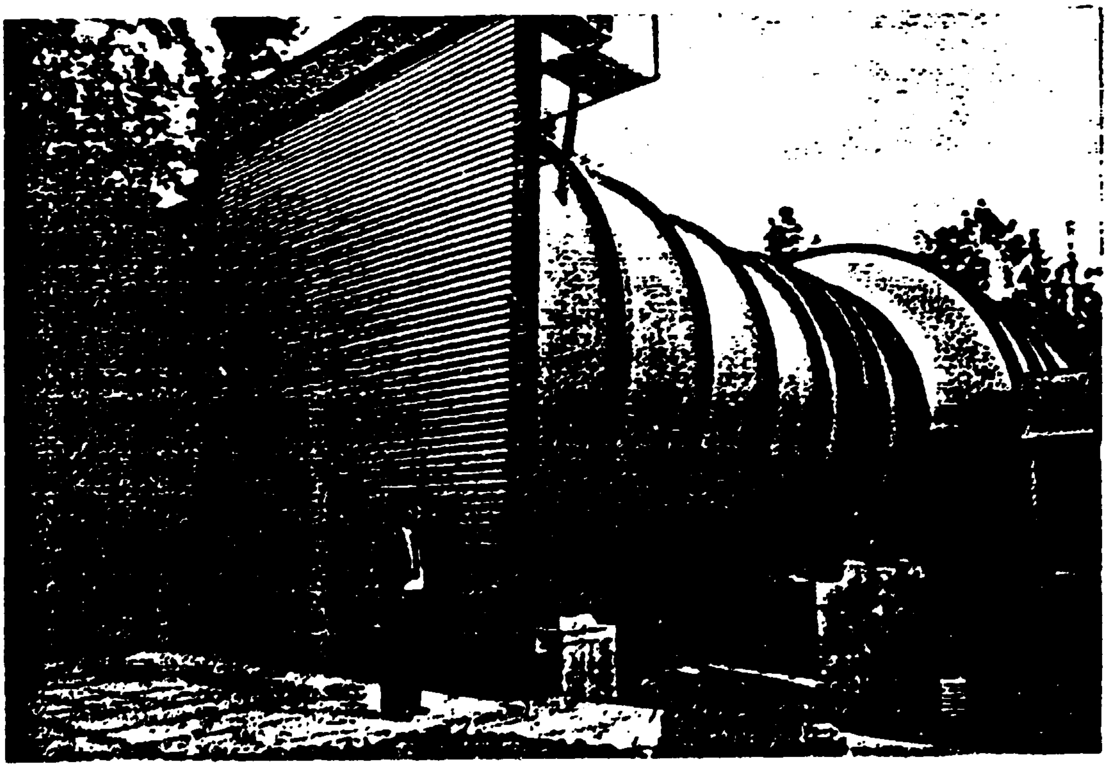


Working section of larger tunnel with 115 cm x 115 cm cross-section; model of Tuborg brewery, scale 1:500

From report RISØ-M-2449



The working section of the wind tunnel has a diameter of 6 m.



A wind tunnel designed for experiments with small wind turbines, University of Stuttgart, Institute for Aerodynamics and Gasdynam.

ANNEX 12

Comments on Laboratory Testing and Small Wind Turbine Testing

In the report: "EREDO Feasibility Study and Conceptual Design", ING/2017/127, 1982, Qattara Hydro and Renewable Energy Projects Authority (CESEN) description is given of test facilities in a laboratory and testing of small wind turbines.

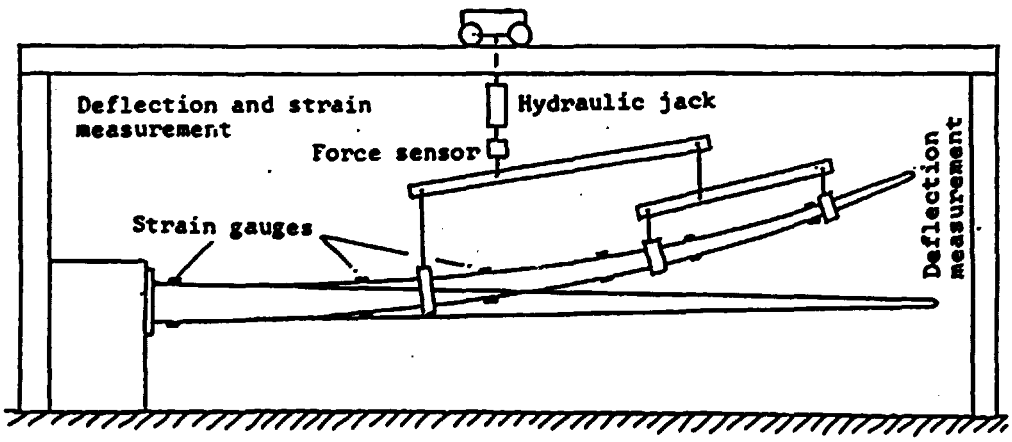
A lot could be commented on these subjects, but the time for writing this report do not allow this. Only a few things should be pointed out.

Two small wind turbines are described and proposed. However, the impression is that they are not bought as complete wind turbines, but in parts from which they can be constructed. A clear warning should here be stated: The wind turbines should be fully completed wind turbines. But for that I cannot recommend Darrieus machines they will never become economical.

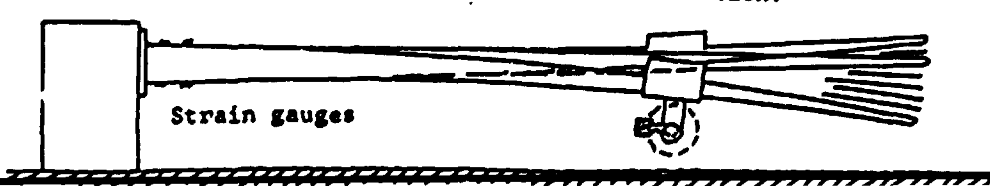
Alternatively one of the wind turbines could be the one dealt with in the programme, the 12-m diameter wind turbine with the 15 kW generator. Nevertheless even this must be delivered to the test site complete from the factory.

On the laboratory facilities: do not forget facilities for testing of wind turbine blades, sketched below.

WIND TURBINE BLADE MEASUREMENTS



Fatigue lifetime testing. Large amplitudes, eigenfrequency, using rotating mass for excitation.



"THE BEATING OF POWERFUL WINGS ALONG" WITH EDUCAITON AND FUTURE

On a piece of virgin nature in the flat marshes just outside the town of Tonder, where the fresh breeze constantly comes from the west, there we find the most exiting windmillpark in Denmark. It has been there since the 6th of September 1984.

The park contains nine different windmills, there are six different products, six different heights and four different sizes.

The windmillpark or rather the windmill-training-park belong to Tonder vacational college, and is a section of the energy- technical department representing the value of both demonstration and education.
This is connected to the fact that the new windmill-training-park is the basis for a completely new training, which Tonder vocational college has developed and carried through namely the training of windmill-electricians.

The erection of the mills was made possible by donations from the Energyboard, the county of Soenderjutland, the city of Tonder and EEC-subsidies.

It is the individual manufacturers, who have erected their mills in the marshes of Tonder and as they stand humming in the breeze, they represent a broad section of the Danish windmills.

The manufacturers have committed themselves to keep their own mills up-to-date, so that the windmill-trainingpark in Tonder will always be offering the latest and most modern design within windmill-technology.

All the mills havde a power that are less than a hundred kw, but as time goes by, it is our intension to havde larger mills situated in the park at Tonder.
Steps have been taken to extend the windmillpark in order to meet future demands.

The output of each windmill can be seen on a display unit in the control centre, which is situated in the area of the windmillpark. The centre holds the latest technics for running and decoding of measurable data.
And furthermore it is the first windmillpark throughout the entire world that is run by computers.

Within the grounds of our vocational college, we have a corresponding centre, which is connected to the centre in the park through the telephone-network. The signals are transmitted per modem.
So whereever you are, you have a possibility to check-up on possible errors and correct them.

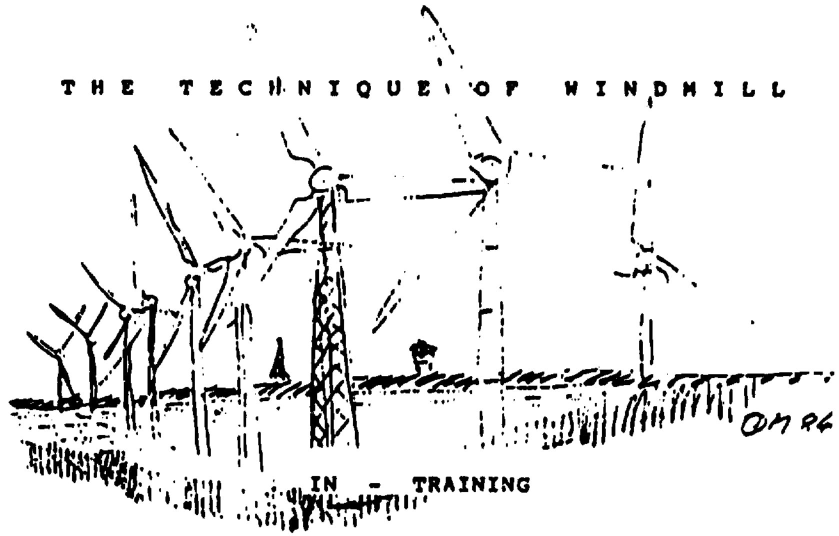
With this new grounds have been broken for the training in windmill technique.
It is Tonder vocational college "the energy college", which has developed and started this brand new training. The training should be seen in connection with the fact that we are leading the way within the field of energy-technics, in training courses, heat pump technics, natural gas, heat technics, continuous energy and now windmill-technique too.

Of course the vocational college constantly develops courses within the energy-section.

TØNDER TEKNISKE SKOLE

PLANTAGEVEJ 35 . DK-6270 TØNDER . TLF. (04) 72 48 11

THE TECHNIQUE OF WINDMILL



IN - TRAINING

DEN ERHVERVSRETTEDE SKOLE MED SKOLEHJEM OG KOLLEGIER
SKOLEN MED ENERGI OG MILJØ I MARSKBYEN TØNDER VED GRÆNSEN

Tønder Tekniske Skole for Training of Technicians

ANNEX 13

AN ALLROUND TECHNIQUE OF WINDMILLS IS ONLY POSSIBLE IN TONDER

AT TONDER VOCATIONAL COLLEGE

With growing development windmills are now being installed around the Danish countryside both as a single windmill and in groups. This creates a need for efficient windmill-electricians. Approximately one electrician to every 100 mills.

According to the official Energyplan and experts in the field of wind power electricity, we have here in Denmark today about 1600 windmills. In twenty years from now there might be between fifty - and sixty thousands of them.
So the amount of windmills will increase with 3000 new ones every year. A training in the technique of windmills has up to now only taken place inside the windmill-factories if you were employed by them. Here the training was aimed solely towards the factorie's own mills.

An allround training in the technique of windmills hasn't been offered before, but now the energy technical department at Tonder vocational college has become involved in the windmill-business and is offering training on a many-sided basis.

The in-training-offer adresses itself to the skilled workers within the blacksmith- and engineering trade as well as the electricity trade. This will give them a broad theoretical knowledge as well as the technology of windmills as far as the electrical and the mechanics are concerned.

The two courses are described below.

Further information can be obtained from the school's energy-technical department telph. 04724211

THE TECHNIQUE OF WINDMILL I:

The aim of the course is - through a theoretical education with practical demonstration and training - to give the participants the basic knowledge of electronics which is used in the wind power electricity.

The education takes place both in the college's special workshops as well as in the classrooms.

There are lessons in e.g. basic electrotechnics, electric measuring units, electric measuring instruments, electrotechnical engineering, operating- and adjustment technique, the electric transmission system and the high voltage manual.

39 Lessons

LEVEL I

LEVEL II

78 Lessons

THE TECHNIQUE OF WINDMILL II:

The aim of the course is - through a theoretical education with practical demonstrations and training - to give the participants the knowledge of construction and function of system approved windmills.

The education takes place partly in the college's special workshops and classrooms and partly in our windmill-training-park.

The curriculum includes construction and function, weather and landscape-configuration, the knowledge of materials, the system of hydraulics, componenttraining, security,

steering, electrical operation, measuring technique, check-ups, maintenance and error-detecting.