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# Bilateral Project between Cape Verde and the Netherlands "Renewable Energies"

## Final Report Phase 2
## 1981-1984

Report XXV

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July 1984

Consultancy Services
Wind Energy
Developing Countries

Divisao de Energias Renováveis
Ministério do Desenvolvimento
Rural

CONTENTS PAGE


| | | |
|---|---|---|
| | PREFACE | 5 |
| | SUMMARY | 7 |
| 1. | INTRODUCTION | 12 |
| 2. | SCOPE OF WORK | 15 |
| 2.1. | Objective of the project | 15 |
| 2.2. | Project description | 15 |
| 2.3. | Collaboration with USAID | 16 |
| 2.4. | State of activities at start of phase 2 | 16 |
| PART ONE - WORK ACCOMPLISHED | | 19 |
| 3. | ACCOMPLISHMENTS | 21 |
| 3.1. | Windmills with mechanical transmission | 21 |
| 3.2. | Electric windmills | 31 |
| 3.3. | Workshop | 34 |
| 3.4. | Prototype for local production | 36 |
| 3.5. | Anemometry | 38 |
| 3.6. | Performance measurements | 41 |
| 3.7. | Site selection | 42 |
| 3.8. | Non-wind activities | 46 |
| 4. | PERSONNEL AND ORGANIZATION | 48 |
| 4.1. | Personnel | 48 |
| 4.2. | Transfer of knowledge and training | 50 |
| 4.3. | Organization | 51 |
| 5. | END USE AND ECONOMICS | 53 |
| 6. | REVISION OF THE WATER PUMPING POTENTIAL BY WINDPOWER | 59 |

CONTENTS (continued)


| | | PAGE |
|---|---|---|
| 7. | PROJECT SUPPORT | 62 |
| 7.1. | Project management | 62 |
| 7.2. | Technical support | 62 |
| 7.3. | Logistics | 63 |
| 7.4. | Short missions | 63 |
| 8. | REPORTS | 64 |
| PART TWO - SOME IMPORTANT ASPECTS HIGHLIGHTED | | 69 |
| 9. | TECHNICAL ASPECTS OF OPERATION AND MAINTENANCE | 71 |
| 9.1. | Description of the mechanism of a windpump | 71 |
| 9.2. | The weak points | 76 |
| 9.3. | Actions taken to improve the weak points | 77 |
| 10. | SITE SELECTION | 82 |
| 10.1. | Site selection procedure | 82 |
| 10.2. | Water pumping strategies | 84 |
| 10.3. | Technical note E.R., 13 July 1982 | 88 |
| 10.4. | Technical note E.R. August 1984 | 90 |
| 11. | TWO CASE STUDIES | 92 |
| 11.1. | Achada de São Filipe | 92 |
| 11.2. | Achada Baleia | 95 |
| 12. | ELABORATION OF WIND DATA | 98 |
| 12.1. | Equipment | 98 |
| 12.2. | Praia airport | 99 |
| 12.3. | Achada de São Filipe | 102 |
| 12.4. | Ribeira Saltos, Flamengos and São Miguel | 105 |
| 12.5. | Ribeirão Chiqueiro | 105 |

CONTENTS (continued) PAGE


| | | |
|---|---|---|
| 13. | PERFORMANCE MEASUREMENTS | 107 |
| 13.1. | Ten minute measurements | 107 |
| 13.2. | Long term measurements | 112 |
| 13.3. | Measurements on Aerowatt | 117 |
| PART THREE - CONCLUSIONS AND RECOMMENDATIONS | | 118 |
| 14. | CONCLUSIONS AND RECOMMENDATIONS | 119 |
| 14.1. | General | 119 |
| 14.2. | Comparison with project proposal | 119 |
| 14.3. | Conclusions and recommendations per subject | 122 |
| REFERENCES | | 126 |

## PREFACE

This report deals with the second phase of the bilateral project between Cape Verde and The Netherlands "Renewable Energies", which started on 1 July, 1981 and lasted 3 years.

The project has been executed by DER, the Renewable Energy Division of MDR, the Ministry of Rural Development of the Republic of Cape Verde. The Netherlands' contribution to the project was carried out by DHV Consulting Engineers, on behalf of and as partner of CWD, Consultancy Services Wind Energy Devloping Countries.
The US Agency for International Development (USAID) delivered material, equipment and tools to the new workshop of DER, which was constructed during Phase 2.

The Netherlands Ministry of Development Coopération (DGIS) financed the Dutch technical assistance, the construction of the new workshop and the procurement of windmills and additional materials.

Women waiting for water

the electric axed windmill erected

The new workshop under construction

Water used for irrigation

## SUMMARY


### Introduction

The Republic of Cape Verde has been afflicted by a drought period of almost two decades. Half of the water supply (drinking water and irrigation) has to be done by pumping. The use of wind energy for water pumping is an economic necessity, as the country has no fossil resources. Since 1977 within the Ministry of Rural Development (MDR), the Division of Renewable Energies (DER) has been carrying out an installation and maintenance programme of mechanical wind pumpers. Various donor organizations like UNDP, UNICEF, Church World Service, FAC and USAID have helped DER with material and equipment. The imported mills are Dempsters from the USA and Southern Crosses from Australia.
The Netherlands Ministry for Development Cooperation (DGIS) has been involved in DER activities since 1979, in the form of technical assistance (Phase 1). In July 1981 DGIS' involvement became a project of, for the time being, three years (Phase 2). This report deals with the results of this DGIS project and with the contribution of other donors during this phase.
In the meantime, the project has been extended by three years until June 1987 (Phase 3).
The parties involved in the implementation of the project have been DER and CWD (Consultancy Services Wind Energy Developing Countries, The Netherlands). The project aims at:

- supplying technical assistance to DER (two resident consultants)
- importing some 30 windmills
- starting up local production of windmills
- financing the construction of DER's new workshop; equipment and material for the new workshop have been supplied through the USAID project

### Achievements

During Phase 2, 21 wells were equipped with water pumping windmills.
A team of 20 persons at DER, consisting of mechanics, trainee mechanics and painters, as well as six mechanics from islands other than Santiago, were trained in installation, maintenance and repair of water pumping windmills. Installation and maintenance were standardized; of each windmill a file is kept; monthly maintenance sheets are filled in by mechanics on all islands equipped with windmills.

Installation manuals for Dempsters and Southern Cross windmills were composed by the project.
The first experiment of water pumping with wind generators (make: Aerowatt) was a failure.
The construction of a new workshop was financed with project funds. The workshop was well equipped through the USAID project and personnel was trained in workshop and machine operation. The first prototype (of 5 diameter) for local production was constructed, installed and monitored by DER.
Wind measurements were taken at 25 sites, to analyse the wind regime at a certain spot chosen for future installation. Some performance measurements were carried out; these measurements, together with theoretical analyses, have resulted in output prediction curves of windmills in use by DER, for the Achada and Ribeira wind regimes.
36 site studies (i.e. to investigate if and what kind of windmill can be installed at a site) were carried out in Phase 2. The wind powered water pumping potential was estimated and an instruction on how to carry out a site study was written. The transfer of knowledge to the mechanics in the form of on-the-job training, has been quite a success. Transfer of knowledge at staff and medium level has commenced only very recently for want of Cape Verdean technicians.
The project recieved technical and management support from CWD in the Netherlands.

## Problems encountered

During the greater part of Phase 2, DER suffered from want of Cape Verdean staff. Especially the lack of a mechanical engineer (not appointed until May 1984) has seriously hampered the development of local production. Since the end of phase 2, the situation of DER staff has improved considerably; only an electrotechnical engineer is still lacking.
Training in installation and maintenance had to start almost from zero, as two qualified mechanics, trained in Phase 1, left shortly after the beginning of Phase 2.
The windmills are subject to rapid corrosion in the Cape Verdean climate, a problem not easy to solve.
The start of the construction of the new workshop was delayed for almost a year due to administrative procedures; this has delayed all DER activities.
Procurement of commodities, from both the USAID and CWD projects, has caused various problems:

- lack of good catalogues to make the specifications
- no procurement officer USAID in Praia
- the procuring organization AAPC (for the AID project) made various errors and had to be checked meticulously
- sometimes commodities were insufficiently packed, causing damage and loss
- misunderstandings between the various parties involved
- customs clearance in Cape Verde is very time-consuming and troublesome

In-country transport is far from optimal: sometimes one has to wait for months for a boat to one of the islands. Almost all installation equipment still had to be constructed by DER.
Recurrent problems with the truck and the jeep have delayed progress too.
As the precipitation has been decreasing for 2 decades, pumping test data cannot easily be extrapolated and are not as reliable as they should be.
In some cases the quantity of water has decreased to such an extent that the mill cannot operate for 24 hours. In two cases mills had to be dismantled because of seawater intrusion.

State of project at end of Phase 2

37 Water pumping windmills are in operation, pumping some 1700 $m^3/d$; the water is used as drinking water for approximately 10,000 people in rural areas (5% of the rural population) and as irrigation water from some 20 ha.
The cost of drinking water by means of windmills varies from 10 to 20 $esc/m^3$, which is substantially lower than that by means of motor pumps.
The installation rate at the end of Phase 2 was one per month, with good prospects to increase to two per month during Phase 3, which is the necessary rate for production and replacement of all windmills in the future.

Logistical and procurement problems are under control, but will continue as they are inherent to the introduction of new technologies.
The workshop is now in operation; some minor improvements can be made; personnel should be trained further.
The main problem of maintenance is corrosion; experiments with all kinds of pre-treatments and paints are being carried out. Water pumping with electric wind generators has to start anew; the first Lagerwey - Van de Loenhorst wind generator will be installed at Achada Baleia in September 1984. The first 5000 LW prototype will be installed in the second half of 1984 too. Everything is ready for the second one to be constructed by DER itself.
8 Automatic wind speed recorders and 15 wind run meters constitute the wind measuring equipment of DER. A measuring programme for the first year of Phase 3 has been made. Data processing is done by DER itself with the help of a microprocessor.
Output prediction curves and a site selection methodology are the instruments used for the preparation of new installations.
At the moment DER has five staff members (of which two are expatriates), three employees on medium level and some 20 persons on execution level.
A well documented library has been set up.

Conclusions

The application of water pumping windmills in the Republic of Cape Verde has passed its introductory and experimental phase and has proved to be a reliable means to pump water. Careful installation and regular maintenance have been the key factors in achieving this.

The objectives of the project proposal (1980) for Phase 2, could not all be achieved; main reasons are:
- want of Cape Verdean staff
- delay in the construction of the new workshop
- all kinds of logistical problems
- project proposal was too optimistic

Furtunately, both Cape Verde and the Netherlands have taken a flexible attitude towards adaptating the project policy to reality. All project money has been spent in a useful way.
The main problems which still exist are:
- logistics and procurement
  their effects can be minimized by proper planning and control of stock, but the problems will continue to exist
- corrosion
  the effects can be diminished by adequate pre-treatment and a satisfactory type of paint; the problem will remain as the cause is climatological
- uncertainties in the groundwater data
  this problem will diminish gradually with the on-going ground water resources studies, but will remain as long as the drought continues

## Recommendations

It is recommended to adopt a flexible attitude towards the project policy and project aims during Phase 3, as there are still many problems and uncertainties.
It is proposed to organize courses for windmill guards, so that part of the maintenance and the cleaning can be done by the guard. In case of excess water (drinking water supply on Achada's) he can use this water for (very) small-scale irrigation around the tank. The technical infrastructure should be completed; i.e. installation and maintenance equipment on all islands. It is not advisable to continue with the Aerowatt wind generator for water pumping. The first Lagerwey - Van de Loenhorst wind generator, for the same purpose, should be monitored thoroughly.
The existing output prediction curves, methodology of site selection and water pumping strategies should be evaluated and improved in practice.
A training programme for the first year of Phase 3 has been composed; it is recommended for implementation.
The end use and economic analyses, should be worked out in detail and improved.
Technical support in Phase 3 will comprise: local production, tank size studies, tackling of corrosion problem, irrigation by windmills and electric windmills.

DER's long-term objectives are to achieve the entire water pumping potential by windpower: 300 mechanical wind pumpers and 66 wind generators for water pumping. Two-thirds of all installations will be on Santiago. 75% of the potential of pumped water can be pumped with wind energy; this means 47,700 $m^3$/day.

# 1. INTRODUCTION

The interest of the Republic of Cape Verde in the utilization of renewable energy is essentially an economic interest: the country is very poor and all energy costs weigh heavily on its national economy as there are no "traditional" energy resources.

The use of renewable energy for water pumping is of major importance because it diminishes the import of fossil fuels. Both wind and solar energy offer high potentials in Cape Verde.
The country is being afflicted by the worst and longest period of drought ever experienced in its history. One can imagine the problems encountered in supplying water for people and cattle and in irrigating the relatively few soils suited for cultivation.
Drinking water supply is extremely important in this country to guarantee, literally, a survival minimum to its mostly rural population (190 000 out of 300 000 inhabitants), being already deprived of large parts of their sources of income as the crop yields of rainfed agriculture and the numbers of cattle have decreased dramatically during the last 15 years.
In irrigated agriculture, at the moment totalling a mere 2000 ha, relatively large amounts of fuels are used as 50% consists of pumped irrigation.
The Government of Cape Verde therefore strongly promotes the use of renewable energies. Priority has been given to applications of wind energy, as the islands have a very favourable wind regime and technology for these applications has been available for quite some time.

Activities in this field started in 1977 with the installation of the Renewable Energy Division (DER) within the Ministry of Rural Development (MDR). Funds became available from the Government of Cape Verde and the UNDP: Non-Conventional Energy Demonstration Project PNUD CVI/76/X05.
This project provided three wind generators and a volunteer, Mr. Van Meel, who had formerly worked at the Eindhoven Wind Energy Group, partners of the Netherlands Consultancy Services Wind Energy for Developing Countries (CWD).
From its very beginning, the division focussed its attention on water pumping for the drinking water supply, which was and is an urgent need on the Cape Verdean Islands.
Church World Services offered 25 Dempster windmills of 8' rotor diameter and later on UNICEF delivered 10 Dempsters of 14'.
Gradually, more donor organizations became involved in the DER activities, like CIMADE, FAC, USA embassy, Canadian embassy, ICCO etc.
In 1979 the Netherlands Ministry of Development Cooperation (DGIS) took over the assignment of the UNDP-volunteer. Also in 1979, USAID became involved. A renewable energy project was identified and implemented (Ref. 1). This project started in August 1980. The main part of the project consisted of the procurement of materials and equipment for a new workshop of DER. One of the principles of the project was that DGIS would supply the technical assistance to the Division.

At the request of DGIS, a feasibility study on the application of water pumping windmills was carried out by CWD in the first half of 1980 (Ref. 2). The study revealed that 75% of Cape Verde's water pumping needs could be fulfilled with windmills. The proposed project concerned not only technical assistance but also the financing of the new workshop and the procurement of some 30 windmills. After approval of Cape Verde and DGIS this "Bilateral project between Cape Verde and the Netherlands - Renewable Energies" came to a start on 1 July, 1981 and would run for three years.
The period 1977 to July 1981 is now referred to as Phase 1 of the project. During this period, CWD already provided occasional technical backstopping. The period July 1981 - July 1984 is referred to as Phase 2 and is dealt with in this report.
The project has been carried out by DER. Since February 1983 director of DER has been Mr. D. Livramento, Doctor in physics (Brasil 1982). Other staff members are Mr. D. Cardoso (since November 1983) and very recently, since May 1984, Mr. F. Ferreira. The Netherlands contribution to the project has been carried out by DHV Consulting Engineers, on behalf of and as a partner of CWD.
Mr. K. Versteegh, CWD consultant, started working at the project on 1 July, 1981 and Mr. N. Pieterse, CWD consultant, on 15 September, 1981. Mr. Van Meel left the project on 1 November, 1981.
The project was evaluated in November 1983 by a tripartite (Cape Verde, USAID, DGIS) evaluation mission (Ref. 3). The findings of this mission were, in general, positive and extension of the project was strongly recommended, with emphasis on local production of windmills.
In the meantime, DER and CWD had prepared a proposal for extension of the project by another three years (Ref. 4). This extension has been approved of by Cape Verde and DGIS. In July 1984, Mr. Versteegh was, and in September 1984 Mr. Pieterse will be replaced by Mr. J. Diepens and Mr. H. van der Spek respectively.

This report deals with the following subjects:
In Chapter 2 the scope of work is given, which includes a survey of the activities carried out in Phase 1.
In the remainder of the report, the activities during Phase 2 are reported; it is divided into three parts:

Part One - (Chapters 3 through 8) describes the work accomplished:
- installation, operation and maintenance of water pumping windmills
- services and hardware delivered
- personnel and organization
- end use and economics
- revision of water pumping potential
- project support
- reports

Part Two - highlights some important aspects of the project:
- operation and maintenance of windmills (Ch. 19)
- site selection methodology (Ch. 10)
- some case studies of operating systems (Ch. 11)
- elaboration of wind data (Ch. 12)
- performance of windmills used by DER (Ch. 13)

Part Three - presents conclusions and recommendations (Ch. 14)

## 2. SCOPE OF WORK

### 2.1. Objective of the project

The aim of the project is to promote the use of wind energy in the rural areas of Cape Verde with emphasis on water pumping. This aim was to be achieved by the realization of the proposals specified in the study "Wind energy for water pumping in Cape Verde" by H.J.M. Beurskens, CWD 81-1 (Ref. 2), which are described below.
The proposals were made for a period of five years, starting 1 July, 1981. Three of them have been covered by Phase 2.

### 2.2. Project description

During Phase 2:
- 33 commercially available windmills were to be imported, with rotor diameters ranging from 8' to 25'
- 8 were to be purchased locally (the São Vicente mills of 8' diameter)
- the first 5 of a 5 m prototype, developed by CWD, were to be constructed locally, and
- the first 3 of a 3 m prototype were to be constructed by DER

All these windmills had to be installed and maintained.

The project would finance the construction of the workshop to supplement the USAID project, which would supply equipment, tools and materials to the workshop.

Technical assistance would be provided in the form of two expatriate experts on a permanent basis, technical support from the Netherlands by written communication and short-term missions if necessary
The two experts had to divide the following tasks between them:
- consultancy on the feasibility of windmill systems for application on specific sites
- consultancy on local production of windmills
- consultancy on the design of windmills
- training in administration and operation of the renewable energy workshop
- consultancy and assistance in the following on-going activities:
  - windmill installation programme
  - setting up of a library
  - experiments with solar energy and biomass systems
  - consultancy to various ministries on the applications of renewable energies
  - consultancy on the coordination with other institutions
- Project management and project support (e.g. procurement) from the Netherlands, including seven management visits.
- The procurement of six motorbikes and miscellaneous small equipment not readily available in Cape Verde.
- The progress was to be reported every three months; a final report would become available at the end of Phase 2.

The total budget of the project amounted to Dfl. 3,117,000.-.

## 2.3. Collaboration with USAID

Although not explicitly mentioned in the bilateral project documents, the project was supposed to be carried out in close collaboration with USAID, which, from 1980 to December 1983, has a project with DER (Ref. 1). Its main input was the procurement of equipment and materials for the new workshop. Furthermore, some technical assistance and training of Cape Verdeans had to be included.
The budget of this project amounted to US$ 500,000.

## 2.4. Status of activities at the start of Phase 2

The state of DER activities at the beginning of Phase 2, has been reported in Report I. +). Here, a short survey will be given:

a. The Bicycle Wheel Wind Turbine of the initial UNDP-project, started by Mr. J. van Meel and Mr. D. Livramento, was completely out of order. The Elektro and Darrieus were electrically operational, but had not pumped any water as mills and pumps were not matched to each other (Ref. 5).
b. The Sofretes solar pump, furnished by CIMADE, had worked only for a very short time as the pump broke down. The Aerowatt for Achada Baleia had still to be installed.
c. 16 of the 25 Dempsters 8' delivered by Churld World Service had been installed: 6 on Santiago, 3 on Maio, 4 on Sal and 3 on São Nicolau.
d. 4 of the 10 Dempsters 14', delivered by UNICEF, had been installed: 2 on Santiago, 2 on São Nicolau.
e. Materials to construct the first prototype, which was developed by CWD, had arrived.
f. The construction of the workshop (financed by CWD) had been planned (site chosen and preliminary drawing available).
g. Some of the equipment and materials of the USAID project had been ordered, but the majority still had to be specified and ordered.
h. The 3 Southern Crosses of 25', delivered by the bilateral project Santo Antão - Holanda, had arrived on Santo Antão.
i. The 3 Dempsters (one of 8' and 2 of 12') delivered by the Canadian Embassy to be installed on Maio, had arrived at the Customs.
j. Two Southern Crosses of 25', delivered by the ICCO-project on Achada Baleia, had arrived.
k. One of the two water pumping Aerowatts of the projects of the FAC had been installed on São Nicolau, and one of the three Aerowatt wind measuring units had been installed on Achada de S. Filipe.
l. At the guard's house on Achada de S. Filipe, a 2 $m^2$ solar still and a solar cooker were in operation.
m. The 3 projects financed by the USA Embassy, the biogas installation, the "siphon" water lifting device and the solar still for Maio, still had to be started.
n. a 3 kW wind generator "Aeropower", delivered by USAID food crop protection project, had been installed and was in operation.

+) Reports with Roman numerals refer to reports written by the project staff. These will be treated in Chapter 8.

DER personnel consisted of 2 technicians, 2 mechanics, one foreman, one painter, three labourers, two apprentices and a workshop caretaker. DER had a small workshop in Praia, where only simple facilities like for drilling, grinding and welding were available. DER had an old lorry and an old jeep at its disposition, which were frequently not available for reasons of maintenance and repair.
The wind measuring equipment consisted of 2 Stewart's wind run meters, 2 Casella counter cup anemometers and 1 Lambrecht registrating unit.
Two units of a 1 m diameter wind generator (WESP) for battery charging had been installed.
Table 2.1. gives a survey of windmills installed by DER as of 1 July, 1981.

Table 2.1. - Windmills installed by DER, on 1 July, 1981

A. Water pumping windmills

| Island | Mill | Site | Obs(ervation ) |
|---|---|---|---|
| Santiago | Dempster 8' | Achada S. Filipe, FT 170 | |
| Santiago | Dempster 8' | Pensamento | |
| Santiago | Dempster 8' | Lem Duque | |
| Santiago | Dempster 8' | Granja S. Filipe | |
| Santiago | Dempster 8' | Portete | |
| Santiago | Dempster 8' | Santa Cruz | |
| Santiago | Dempster 14' | Trindade | |
| Santiago | Dempster 14' | Granja S. Filipe | |
| Maio | Dempster 8' | Centro | |
| Maio | Dempster 8' | Brigadinho | |
| Maio | Dempster 8' | Cascabulho | |
| Sal | Dempster 8' | Alto Solarino | |
| Sal | Dempster 8' | Tapadona | Not operating |
| Sal | Dempster 8' | Palmeira | |
| Sal | Dempster 8' | Palmeira | Not operating |
| São Nicolau | Dempster 8' | Châ de Norte | Not operating |
| São Nicolau | Dempster 8' | Belém | Not operating |
| São Nicolau | Dempster 8' | Belém | Not operating |
| São Nicolau | Dempster 14' | Châ dos Penedos | Not operating |
| São Nicolau | Dempster 14' | Châ dos Penedos | Not operating |
| Sao Nicolau | Aerowatt | Campo de Preguiça, FN10 | |

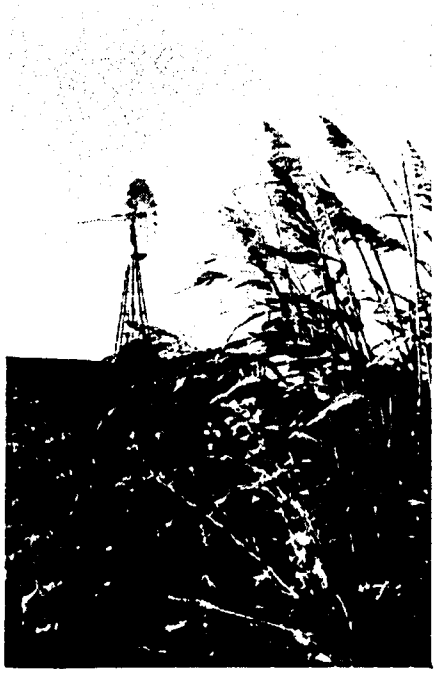
Note:
The mills on S. Nicolau were actually installed from July to September 1981, but as all preparations were made in Phase 1, they are included in this list. The reason why they were not yet in operation wat that the tanks still had to be constructed.

B. Windmills with other end uses

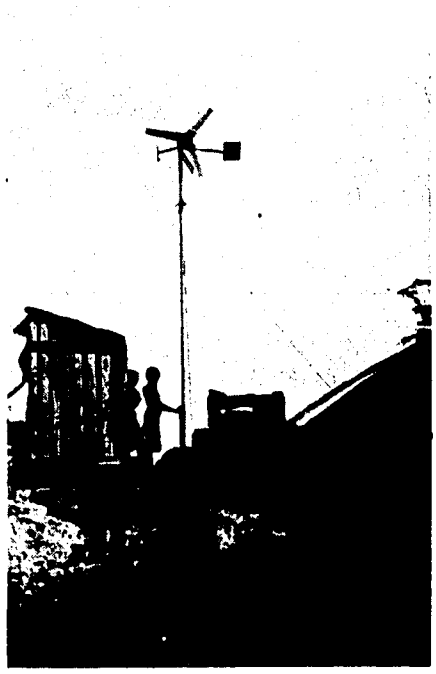
| Island | Mill | Site | Obs(ervation ) |
|---|---|---|---|
| Santiago | Bycicle wheel | João Varela | Out of order |
| Santiago | Elektro | Achada S. Filipe | Not functioning |
| Santiago | Darrieus | Achada S. Filipe | Not functioning |
| Santiago | Aeropower | Achada S. Filipe | |
| Santiago | Wesp | Achada S. Filipe | |
| Santiago | Wesp | San Pedro | |

# PART ONE

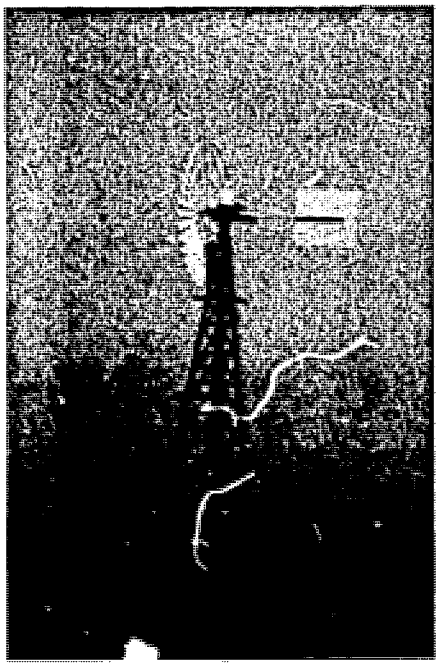
## WORK ACCOMPLISHED



A Dempster for irrigation



A 1 m diameter electric generator



A Southern Cı . , 25 ft in operation

Women carrying water, where there is no windmill

# 3. ACCOMPLISHMENTS

## 3.1. Windmills with mechanical transmission

### 3.1.1. New installations in Phase 2

During Phase 2, 21 wells were equipped with mechanical wind water pumpers and (in one case) with a handpump. Three pumpers had to be dismantled; two because of salt water intrusion, one for lack of water and recurrent breakdowns (the handpump). A brief description of the installation follows below:

- October-December 1981:
  A Southern Cross 25' at Achada Baleia (tubewell FT 177). This mill was purchased by the integrated project of Achada Baleia which is financed by ICCO (Dutch non-governmental aid organization). A tank and a taphouse had already been completed at the time of installation. The water was meant partly for drinking water, partly for irrigation. The mill was in operation from December 1981 to May 1982 (only for drinking water supply). Then a rise in the conductivity of the water was observed. After consultation with the MDR-Groundwater department and BURGEAP, the mill was shut down, pending water analyses to show whether the rise was due to seawater intrusion or to salt particles in the aquifer, liberated because of the water flow.
  As far as DER knows, this chemical analysis was never carried out and DER dismantled the mill early 1984, because it was badly needed at another site. Total amount of pumped water by this Southern Cross at Achada Beleia was less than 1000 $m^3$.

- December 1981:
  Dempster 14' at Monte Vaca, Achada de São Filipe, tubewell FT 173. This mill belongs to the water supply system of Achada de São Filipe, which is described in detail in Part Two, Chapter 11. The mill is a replacement of the SOFRETES solar pump, which worked only a few days. Daily amount of pumped water by this mill is about 35 $m^3$/day.

- February 1982:
  Dempster 14' at Ponta Furna (SSP 12). In the northern area of Santiago this mill is one of the few water taps; it provides drinking water for people and cattle. A tank and a small set of taps complete the installation. The water quality is rather poor (high salinity), but people have to use it as there is no better. The installation serves approx. a thousand people; the number of cattle is unknown.

- April/May 1982:
  Southern Cross 25' at Mont Vaca (FT171). This mill also belongs to the water supply system of Achada de Sao Filipe, which is described in Part Two, Chapter 11. The mill is a replacement of the Darrieus system which has never pumped any water. The mill pumps on an average 100 $m^3$/d.

- June/September 1982:
  Three Southern Cross 25' on Santo Antão:
  At Châ de Arroz, Picoteiro and Corulinha. These three mills were financed by the bilateral project Santo Antão - Holanda.
  At Châ de Arroz and Picoteiro, they pump water for irrigation, while the one at Corulinha provides the drinking water supply of Porto Novo (partly). Although installed in 1982, the mills did not become operational until mid 1983, because it took such a long time to acquire the rising mains (ordered by DGIS) on Santo Antão. At the moment the mill at Châ de Arroz is out of operation due to a lack of water (it has not rained at all on Santo Antão in 1983).

- July 1982:
  Dempster 14' at Ribeira Flamengos, FT 5. This mill provides the water supply of several small villages in Ribeira de Flamengos; there is a tank and a taphouse including toilets and laundry facilities.

- October 1982:
  Dempster handpump at Mendes F. Rendeiro, FT 133; drinking water supply.
  This installation has suffered from two kinds of problems: rapid depletion of the well and frequent breakdowns. The latter were due to excessive overspeeds, as people tried to fill their buckets as quickly as possible, even causing rupture of the pump lever.
  As in addition the water level kept falling, the pump was finally dismantled.
  Other experiences in Cape Verde and other African countries also show that troublefree operation of handpumps is far from easy to achieve.

- February/April 1983:
  Installations on the island of Maio: a Dempster 8 in (MSP 2), a Dempster 8' in Figueira Seca (MSP 13) and a Dempster 12' in Morro (MF 22), all for drinking water supply.
  The Dempster 8' at Brigadinha (for cattle water) was dismantled in this period: the water had become too brackish.

- May/June 1983:
  The mechanics participating in DER's course on installation and maintenance of windmills installed two Dempsters 14', one in Saltos (for irrigation), the other in Ribeirão Manual (doemstic water supply).

- June 1983:
  The first design of the prototype constructed by DER mechanics, was installed on Achada de Sao Filipe. The water is used for irrigation. The mill has been thoroughly monitored.

- September/October 1983:
  A Southern Cross 25' was installed on Ribeira de Flamengos at a newly dug well. This installation was carried out with the help of the Watershed Management Project of the MDR Department of Conservation of Soils and Water.

- April/May 1984:
  Installations on the Island of Maio, of a Dempster 12' at Pedro Vaz and a Dempster 8' at Alcatraz, both for drinking water supply.

- May/June 1984:
  Installation of a Southern Cross 21' at Salineiro, tube well FBE-2. The mill provides the drinking water supply of this village.

- June/July 1984:
  Installation of a Southern Cross 25' at Ribeirão Chiqueiro, to provide the drinking water and some water for irrigation.

To sum up, during Phase 2 the following installations were carried out:
- 3 Dempsters of 8'
- 2 Dempsters of 12'
- 5 Dempsters of 14'
- 1 Southern Cross of 21'
- 7 Southern Crosses of 25' (of which one was dismantled again)
- 1 Prototype for the local production of windmills
- 1 Handpump (and dismantled)

Table 3.1. presents a survey of all water pumping windmills with mechanical transmission, as of 30 June, 1984.

Table 3.1. - 'Mechanical' water pumping windmills - June 1984

| Install. year | Site | Equipment | Observation |
|---|---|---|---|
| 1978 | São Filipe, T. | Dempster 8' | |
| 1978 | Portete, T. | Dempster 8' | |
| 1978 | Lem Duque, T. | Dempster 8' | No guard |
| 1978 | Pensamento, T. | Dempster 8' | |
| 1978 | Granja S. Filipe, T. | Dempster 8' | Lack of water |
| 1979 | Calheta, M. | Dempster 8' | |
| 1979 | Cascabulho, M. | Dempster 8' | No guard |
| 1980 | Santa Cruz, T. | Dempster 8' | No guard |
| 1980 | Trindade, T. | Dempster 14' | Little water |
| 1980 | Granja S. Filipe, T. | Dempster 14' | Lack of water |
| 1980 | Poço Verde, S. | Dempster 8' | No guard |
| 1980 | Tapadona, S. | Dempster 8' | No guard, no pump |
| 1980 | Palmeira, S. | Dempster 8' | No guard |
| 1980 | Palmeira, S. | Dempster 8' | No guard, out of operation |
| 1981 | Châ do Norte, N. | Dempster 8' | |
| 1981 | Belém, N. | Dempster 8' | |
| 1981 | Belém, N. | Dempster 8' | No guard |
| 1981 | Châ dos Penedos, N. | Dempster 14' | No guard |

| Install. year | Site | Equipment | Observation |
|---|---|---|---|
| 1981 | Châ dos Penedos, N. | Dempster 14' | No guard |
| 1981 | Sao Filipe, T. | Dempster 14' | |
| 1982 | Ponta Furna, T. | Dempster 14' | |
| 1982 | Sao Filipe, T. | Socross 25' | |
| 1982 | Châ de Arroz, A. | Socross 25' | Lack of water |
| 1982 | Picoteiro, A. | Socross 25' | |
| 1982 | R. Corunjinha, A. | Socross 25' | |
| 1982 | R. Flamengos, T. | Dempster 14' | |
| 1983 | Calheta, M. | Dempster 8' | |
| 1983 | Morro, M. | Dempster 12' | No guard |
| 1983 | Figueira Seca, M. | Dempster 8' | No guard |
| 1983 | Rib. Manuel, T. | Dempster 14' | Little water |
| 1983 | R. Saltos, T. | Dempster 14' | No guard |
| 1983 | Sao Filipe, T. | Prototype 5 m | |
| 1983 | R. Flamengos, T. | Socross 25' | |
| 1984 | Pedro Vaz, M. | Dempster 12' | |
| 1984 | Alcatraz, M. | Dempster 8' | |
| 1984 | Salineiro, T. | Socross 21' | |
| 1984 | Rib. Chiqueiro, T. | Socross 25' | |

T. = Santiago
M. = Maio
S. = Sal
N. = Sao Nicolau
A. = Santo Antao

### 3.1.2. Operation, maintenance and repair

After a windmill has been installed, a person normally is appointed to guard the mill, operate it and to report any breakdown or malfuntioning to DER. In general the guard is selected and paid by the local MDR authorities, except for the island of Sal, where the municipality exploits the windmills.
13 of the 37 windmills installed do not have a guard (see Table 3.1.). These mills are operated by one or more persons, who are not appointed and do not recieve payment. This situation has to be improved, also because a guard can take care of part of the maintenance (see subsection 3.1.5.). The problem can be solved by DER in conjunction with local MDR departments.
30 of the 37 windmills installed are pumping water. Three mills are out of operation because of a lack of water.

The other four do not pump water, because the mill has not yet been connected to a tank (2), the pump has never been installed because the owner preferred the existing motor pump (1: this mill will be dismantled) or the tube well is not deep enough (1: this mill will be moved to another site). These last four mills are on Sal and São Nicolau.

In the beginning of 1981 regular maintenance has been introduced on Santiago and since April 1983 on the other islands too. To achieve this, DER has given a course on installation, repair and maintenance of windmills for mechanics from the local MDR departments of Tarrafal, Maio, Boa Vista, Sal, São Nicolau and Santo Antão. (Report XVIII).*
Maintenance is done monthly and once a year a more thorough inspection is made whereby the transmission oil is changed. The monthly maintenance is done by a team of two persons, whose main tasks are:

- Measurements:
  The conductivity and the level of the water are measured as well as the output during five minutes, simply to gain an idea about the performance. In the future all the mills will have a water meter, to obtain long-term performance measurements and to control the amount of water taken from a certain well to avoid over-exploitation. Water meters also facilitate easy control of the water distribution.

- Inspection:
  Checking of the functioning of the mill.

- Lubrication:
  The maintenance is done by means of a checklist on which measurements and observations also have to be written. The most important data are transferred (in the office) to an annual data sheet to facilitate rapid checking of the satte of the mill. Maintenance sheets of mills on other islands than Santiago have to be sent monthly to DER; this is not yet done meticulously in all cases.
  Figure 3.1. presents an example of a filled in maintenance sheet.
  One of the main problems of maintenance of the mill is corrosion. Painting the mill once a year takes 75% of the annual maintenance costs (Report X). It is at present investigated what paint and what painting system are to be preferred for use in Cape Verde (Report XVIII). An experiment to clean the mill monthly with a cloth to remove the dust, seems to be successful (the dust contains saline elements). This could lengthen the lifetime of a paint coat. The cleaning can be done by the guard or by voluntary work of the people who use the mill-water.
  Table 3.2. presents the number of breakdowns on Santiago.

* This course was financed by Church World Service.

Table 3.2. - Windmill breakdowns on Santiago 1981-1983

| Year | No. of mills in operation | No. of break-downs | % of break-downs caused by normal wear and tear | annual frequency |
|---|---|---|---|---|
| 1981 | 9 | 9 | 30% | 1 |
| 1982 | 12 | 17 | 24% | 1.42 |
| 1983 | 13 | 10 | 70% | 0.77 |

Note:
Breakdowns on other islands are not included as DER has not received regular information until April 1983.

The table shows that the actual breakdown frequency is 0.77 per year, which is considered low, but should be further improved, as each breakdown means being without water for some days.
During Phase 2, the most frequent breakdown causes have been analysed and resolved, like the water losses at the pump rod sealing and the turning loose of pump rod connections. Chapter 19 of Part Two gives more details. It should be noted here, that the breakdown rate of mills might increase with with the age of the mills. This can partly be prevented by very accurate inspection of the most vital components, or rather, the components that are most subject to wear and tear and their replacement before they break down.

Figure 3.1. Maintenance sheet

Site : _____ No. and Name of Windmill : _____

Date : _____ Mechanic : _____

Arrived at : ____ hrs. Left at : _____ hrs.

REMARKS :

1. Was mill pumping water ? Yes. If not, specify reason : _____
2. Was packing leaking water ? No. If yes, specify reason : _____
3. Did windmill start and stop normally ? Yes. If not, specify reason : _____
4. Was there any noise in mill ? No. If yes, specify in which part : _____
5. Were there any vibrations in the pumping rod or tube ? No. If yes, specify reason : _____
6. Were there any missing or loose screws ? No. If yes, specify where : _____
7. Was there any other fault with the windmills ? No. If yes, specify: _____
8. Are there any parts requiring painting ? No. If yes, specify : ____

READINGS :

1. Water level _____ m
2. Conductivity _____ s/cm
3. No. of strokes over period of 5 minutes _____ $m^3$
4. Meter before same period of 5 minutes _____ $m^3$
5. Meter after same period of 5 minutes _____

WORK REQUIRED : ( check and/or lubricate )

Main vane and shock absorber springs O

Wire, chain and brake pulleys O

Lubricating cups and nipples O

Furling tube assembly O

Asbestos coat in packing or control of leather cup O

Drain air chamber. Was it full ? Yes. No.

Note : If lubrication was required, place check mark against the "O"

REPAIRS AND MODIFICATIONS :

Type of work : _____

Fault : _____

Parts replaced : _____

Other remarks :

In this respect the introduction of a course for mechanics on other islands, has been very useful.
Two installation manuals have been produced by the project, one for Dempsters (Report XI), the ohter for Southern Crosses (Report XX), which have proved to be valuable tools in increasing the level of the mechanics, not only in their tasks of installation and repair, but also in the preparation of component lists that have to be sent to other islands in case of windmill repair.

### 3.1.3. Technical infrastructure

The most important technical infrastructure that DER has at its disposal is, of course, the new workshop, which will be treated in subsection 3.3.
In the beginning of Phase 2, the only auxiliary equipment was a derrick for the installation of Dempsters.
It was soon realized that more equipment for installation was needed:

- three winches were imported by the project, of which one was sent and sold to the bilateral project Santo Antão - Holanda
- two plastic reservoirs of 2 $m^3$ each were imported through the USAID project; these reservoirs can be used at a recently installed site where the concrete reservoir is not yet ready (an other department within DER is responsible for the construction of brickwork reservoirs)
- DER constructed two metallic tanks of 1 $m^3$ each, which are used to transport water to new installations for the preparation of concrete for the foundations
- DER constructed 9 derricks for the installation of Dempsters and Southern Crosses, which have been distributed over the islands as indicated in Table 3.3.:

Table 3.3. - Distribution of installation derricks

| Island | Derrick for: | | |
|---|---|---|---|
| | Dempster 8' | Dempster 12'-14' | Southern Cross 17'-21/25 |
| Santiago | 1 | 1 | 1 |
| Maio | 1 | 1 | - |
| Boa Vista | 1 | 1 | - |
| Sal | 1 | - | - |
| Santo Antão | - | - | 1 |

- DER constructed workshop benches
- DER constructed a small bench vice (mobile) for work in the field
- DER constructed a large tripod for lifting of electrical pumps (for mechanical pumps the windmill tower is used as such)

On islands other than Santiago, where the means at the disposition of the local MDR department are often limited, the windmill mechanics have been supplied with a tool box, pulleys, steel cables and a motorbike to solve transport problems.

### 3.1.4. Logistics and commodity procurement

The local market lacks most of the materials that DER needs to function normally an in addition supplies are irregular, i.e. certain items may not be available for months. So, for many of its materials, DER has to rely on its own importation.
All parts, components and materials are neatly stocked in DER storehouses, where each article has its own card describing the article, stating the place where it is stored and the remaining number of articles. This way a future lack of a certain article can easily be prevented.

For the installation and maintenance of windpumps, materials have been obtained from the local market (paid by MDR) and from abroad (paid by the project or other donors).
From the local market:

- (galvanized) gas pipes
- reinforcement bars
- cement
- bolts and nuts
- angle profiles, strips and other construction material. However, these articles are not always available; one may go for months without. It is important to keep a fair stock of these materials and to remain alert when materials appear on the market. One DER employee is charged with this task. However, the variety of construction material on the local market is very limited and DER itself has to import them too. During Phase 2 this has been done twice. The CWD project ordered materials for the construction of the CWD 5000 HW prototype and 10 tons of various construction materials have been procured through the USAID project. At the time when this report was written (June 1984) 66 commercially available windmills had been purchased by various organizations:

Table 3.4. - Windmills purchased by various organizations

| Year | Organization | Type | Number | Pump size |
|---|---|---|---|---|
| 1976 | Church World Service | Dempster 8' | 25 | 2½" |
| 1977 | UNICEF | Dempster 14' | 10 | 3" |
| 1979 | Embassy of Canada | Dempster 8'/12' | 3 | 3", 4" |
| 1980 | ICCO | Southern Cross 25' | 2 | 4" |
| 1980 | S. Antão-Holanda project | Southern Cross 25' | 3 | 5",8",10" |
| 1981 | CWD-DGIS | Dempster 8' | 8 | 2"-4" |
| - | | Southern Cross 14' | 4 | 3"-4" |
| 1983 | | Southern Cross 17' | 2 | 3"-4" |
| | | Southern Cross 21' | 1 | 4" |
| | | Southern Cross 25' | 8 | 3"-8" |

37 of these 66 have been installed, 29 are in stock and 8 are on their way. It is absolutely necessary to have such a large stock because:

- practice has shown that the period between order specification and arrival at DER is at least one year
- DER always prepares various installations at the same time, because almost all are postponed and some even cancelled; this depends on the availability on inter-island transport, the priorities of local MDR-departments, the rapid change in ground water potential at some sites, the availability of money to pay the mechanics, the availability of cement, etc.
- the size of the windmill depends largely on wind and ground water data; these are often still lacking at the time when windmill orders have to be placed.

However, in view of the relatively small total number of windmills (around 300) it has been decided (Ref. 4) to reduce the number of sizes to 3:

- one of 3 m rotor diameter (about 10')
- one of 5 m (about 17')
- one of 8 m (about 25')

During Phase 2, the windmill orders have been placed by DER in cooperation with CWD in Holland, i.e. CWD contacted the manufacturer. This has led to various misunderstandings and serious delays. In the case of S. Antão - Holanda project, procurement was done directly by DGIS; the mills have stood idle for more than a year, as the rising mains had not yet arrived. It was decided (Ref. 4) that in the future procurement should be done direct by DER. The procedure consists of the following steps:

- DER makes a specification based on the manufacturer's catalogue
- DER asks for pro forma invoice
- the manufacturer sends a pro forma invoice and conditions of payment
- DER confirms the order and informs the manufacturer about the way of payment; the financing organization opens a letter of credit
- the company confirms the purchase

The reason why procurement takes so long is the period needed for fabrication, (3-4 months), transport (2-3 months) and customs clearance. Windmill components often remain at the port for six months, where they are subject to corrosion by the salty air (after the sea voyage often on deck!) The project has complained to RCV about this problem on various occasions.

### 3.1.5. Some remarks

Up to now emphasis has been laid on improvement of the quality of work. Attempts have been made to standardize the method of installing and of constructing parts, as well as that of maintenance and repair. As corrosion is the largest maintenance problem, attempts should be made to have the windmill guards play a more active role in maintenance. Cleaning of the mill and lubrication should also belong to their tasks in the future. This way the maintenance costs can be reduced as the field supervisor on his motorbike can be responsible for monthly control and taking measurements. Expenses due to corrosion will be lower as it has already been proved that by regular cleaning the lifetime of the coat is increased.
A course for the guards has to be arranged, probably one on each island. The guards should be selected with the help of the local MDR department. Little is known about the breakdown of maintenance costs. A tentative analysis was presented in Report X, but a more detailed one is necessary, including use of workshop, costs of spare parts, etc.

## 3.2. Electric windmills

### 3.2.1. Electric windmills for water pumping

The first option for water pumping with windmills in RCV is undoubtedly pumping by means of the mechanical wind water pumpers driving a piston pump. These mills are cheap, easy to maintain and can be locally produced.
In two situations wind generators driving electric pumps can however be more suitable:
If the site of a well does not have a good wind regime and another nearby site does, one can install the wind generator at the latter and, via an electric transmission, drive an electric submersible pump into the well.
If the yield of a tube well is higher than the yield pumped by a piston pump with the maximum diameter than can still enter the tube well, electric submersible pumps can deliver these high yields and still have a relatively small diameter. According to a recent survey (Report XXII), the total number of these applications would amount to approximately 70.
The UNDP project, which started in 1976, delivered 3 wind generators: the Bicycle Wheel Wind Turbine, the Elektro WVG 50 G and a DAF Darrieus. All three were meant for water pumping, but as reported in Ref. 5, pumps and generators did not match well and/or had failures.
The Bicycle Wheel Wind Turbine was already out of order on 1 July, 1981 (bent and broken rotor blades) and was dismantled by DER in September 1981.

The idea to pump water with the Elektro and the Darrieus was abandoned and other end uses were found for these wind generators. See following subsections.

The first Aerowatt 4100 FP 7 was installed at Campo de Preguiça (São Nicolau) in 1980. The rotor blades of this machine came down. It was repaired in August 1981, together with the installation of the second Aerowatt, also at Campo de Preguiça.

These Aerowatts each drive a submersible Grundfos pump via a control box. In September 1981 a third Aerowatt 4100 FP 7 was installed at Achada Baleia, Santiago. This machine drove a Guinard vertical shaft DC pump via a rectifier and a control box.

Operation of these three Aerowatts has been a real problem to DER.
All machines encountered various breakdowns, of which the most frequent were:
- burnt out alternator
- broken alternator bearings
- malfunctioning of switches in the control box

DER has repeatedly insisted that Aerowatt should analyse the causes of the breakdowns. As far as DER knows, this has never happened. Instead, the damaged components were each time replaced by the factory and would break down again after some months of operation. It is not known whether these replacements were done on the basis of the warranty or were paid for by the French Cooperation.
Since April 1983, Aerowatt does not respond any more to requests from DER, neither directly, nor through the French Cooperation. Since that month, the wind generator at Achada Baleia has (again) been out of operation. One of the two machines on Sao Nicolau, which are taken care of by the French Cooperation, is, on the average, in operation. Aerowatt seems to have promised them to send (again) two new alternators (of higher power this time). DER is of the opinion that the experience of the past three years has clearly shown that neither the machine, not the factory is reliable and that consequently, no water supply system in RCV can be based on Aerowatt. Any activity to keep the machines going is a waste of time and money, which had better be spent on reliable equipment.
A technical note (IX, no. 12) was written on the experience with the Aerowatt on Achada Baleia; when in operation, the average total efficiency factor (nett power of lifted water divided by power in the wind) never exceeded 0.03. For mechanical windmills, where mill and pump match well, this factor can be 0.1).

During the past two years, CWD in Holland has been developing an electric wind water pumping system, consisting of a 10.6 m diameter Lagerwey - Van de Loenhorst wind generator, directly coupled to one (or more) electric submersible Grundfos pumps. Mr. Livramento, director of DER, visited the field test installation in November 1983 and approved of the purchase of such a system by the CWD project.
This system has been transported to RCV and will be installed at Achada Baleia, at the old site of the Aerowatt. Probably this wind generator can serve two tube wells at a time, FT25 and FT26, which are close to each other.

In the extension of the project (Phase 3), four more of these systems are expected to be delivered by the project.

### 3.2.2. Autonomous system

An autonomous system produces electricity of constant voltage and frequency, independently of any grid. It consists of one or more wind generators, a diesel plant and a control system. Depending on the available wind speed, it may operate in three ways:

- power supply by wind generator alone
- power supply by wind generator and diesel plant
- power supply by diesel plant alone

A system like this is meant to save on fossil fuels. Since autonomous systems seem to be attractive for application in rural areas of Cape Verde and since the technology has become available, DER and CWD agreed to have a feasibility study, carried out by CWD and DHV Consulting Engineers. This study was done in September 1983 (Ref. 6).
The result of the study is that under the present conditions the application of autonomous systems is not economically feasible, as the existing load patterns are not favourable. However, these systems will become feasible, once additional electric loads will have been installed, like cooling, ice production, water desalination, telecommunication and water pumping.
The study team elaborated case studies for DER workshops at Porto Novo and Sal Rei. The study team proposed to move the wind generator Elektro from Monte Vacas to DER's new workshop at Achada de São Filipe, where together with the diesel plant, it can in the future serve as a demonstration project of an autonomous system.
Since January 1984, electricity to the workshop has been delivered to the workshop either by the diesel plant (when three phase power is needed) or by the Elektrovia a battery bank and a voltage source inventor (during idle hours of the high power machines and during the night for illumination purposes).
In the extension of the project, the installation of one autonomous system is expected.

### 3.2.3. Wind generators for other end uses

At the start of Phase 2, DER had the Darrieus from the UNDP project and the Aeropower from the USAID food crop protection project for stand-alone electricity production. The end use of the Darrieus had been changed into power supply to a potato storage (cooling) experiment, while the Aeropower supplied electricity to the food crop protection storehouse, via a battery bank and a voltage source invertor.
Recurrent problems with the control box and starting motor of the Darrieus have made DER decide to discontinue using the machine. As this machine was a provisional prototype when delivered to RCV, problems of this kind can be expected, especially when any kind of electric component has to be imported.
This has led to the potato storage experiment being cancelled for the time being.

The Aeropower system first suffered from malfunctioning of the voltage source invertor; the factory sent a replacement. In November 1981, the blades of the wind generator hit the tower. The factory supplied replacements, without, however, the requested instructions how to regulate the safety system. Moreover, it became known in August 1982 that the wind generator manufacturer had discontinued its production. In spite of this, the mill was re-installed in December 1982. The mill was in operation until April 1983, when the tail vane broke and the main shaft appeared to be bended. The Aeropower was then dismantled.

Three so-called WESP's are in operation now and maintained by DER. The WESP is a 1 m diameter wind generator developed by CWD. The alternator used in this design is a Sturmey-Archer hubdynamo. The electric output of the wind generator is only 5 Watts, but this is sufficient for illumination of a house during a few hours at night. The system further consists of a rectifier bridge and a car battery for storage and to stabilize the voltage.
Three more WESP's are under construction.
The INC (National Institute for Cooperatives) has shown interest too; DER has requested INC to start a marketing-survey first.

Table 3.5. - Electric windmills of DER; June 30, 1984

| Island | Mill | Site | Observation |
|---|---|---|---|
| Santiago | Aerowatt | Achada Baleia | Out of order |
| São Nicolau | Aerowatt | Campo de Preguiça | Not reliable |
| São Nicolau | Aerowatt | Campo de Preguiça | Not reliable |
| Santiago | Elektro | A. São Filipe | In operation |
| Santiago | Darrieus | A. São Filipe | Out of order |
| Santiago | Wesp | A. São Filipe | In operation |
| Santiago | Wesp | Pensamento | In operation |
| Santiago | Wesp | Tira Chapeu | In operation |

## 3.3. The workshop

At the start of Phase 2, DER was housed in a small courtyard with office and storage, in Paria, next to the Customs. There were facilities for welding, drilling and grinding only. Already in Phase 1, DER had commenced a bilateral project with USAID; this project was to deliver material, equipment and tools for a new workshop; the workshop was meant for maintenance and repair (of windmills) in the first place and secondly for the development of prototypes for local production.
The funds for the workshop construction were included in those for Phase 2 of the Dutch CWD project. Unfortunately the start of the construction was delayed considerably because of various procedures required: the contract between Cape Verde and the Netherlands was not signed until February 1982 and concluding the contract between MDR and the contractor, the Cooperativa de Construçao Civil, took some months, too.

Finally, civil works started in July 1982 on Achada de São Filipe, close to the buildings of some other MDR departments (Reafforestation, Rural Improvements, Soil and Water Conservation). The Director of Rural Improvements was appointed as controlling engineer; the daily inspection was done by DER staff members.
In accordance with the contract, the construction had to be completed within one year. The completion date was, however, 19 November, 1983. This delay was accepted by MDR, as DER had requested some modifications and extensions during the construction.
Inauguration of the new workshop took place on 19 November, 1983, by the Prime Minister of the Republic of Cape Verde, in the presence of the Minister of MDR, Secretary of State for Cooperation and Planning, Ambassador of the United States and other officials.
The construction of the workshop costed 15,000 contos or Dfl. 600,000.
"The architecture of the building is beautiful, which creates an environment where it is nice to work (quotation from Ref. 22).

The workshop consists of:
- a courtyard of 800 $m^2$ with a grease pit
- a storehouse for equipment and material of 92 $m^2$
- a storehouse without a 100 $m^2$ front wall
- a storehouse for tools of 46 $m^2$
- a machinery room of 92 $m^2$
- a bench-work room of 92 $m^2$
- space for forgery and casting of iron
- a designing room of 25 $m^2$
- a room for anemometry and sophisticated equipment of 19 $m^2$
- a room for director and technicians of 19 $m^2$
- a room for secretary and library of 20 $m^2$
- a guard's room, canteen, dressing room, toilets and showers

As mentioned before, material, equipment and tools were obtained mainly from the USAID project.
The main equipment comprises:
- a lathe
- a drill press
- a grinding machine
- a vertical mill
- a hydraulic press
- an electric welding machine
- a mobile electric welding machine (diesel powered)
- autogenous welding equipment
- a sheet cutting machine
- a sheet bender
- a sheet roller
- a compressor with compressed air grid in the whole workshop
- a forge

- casting equipment
- a large amount of manual tools
- battery-control equipment
- carshop tools
- a diesel generator of 50 kVA

The electricity of the DER workshop is supplied:
- either by the 50 kVA diesel generator, when the workshop is in operation
- or by the Elektro-battery-invertor system of 3 kVA (in the future 10 kVA) when only the office is in use and for illumination at night.

The procurement of these commodities has demanded much time and energy from the project staff. Not only had all the specifications to be drafted, but the procurement process itself led to various problems which were often beyond DER's control:
- USAID has no procurement officer in Praia
- based on DER's specifications, actual procurement was done by AAPC in New York; this implied communication problems
- differences in US and European standards; this concerned metric-inch sizes and the electric grid specification
- according to AID regulations, shipping had to be done with US flag carriers; this implied transshipment in Lisbon, with no communication on re-embarkment
- many commodities had been insufficiently packed (while "seaworthy packing" was charged) leading to damage and loss
- the last problem is the customs procedures which is common to all shipment

Technical report XXIV no. 10 is the final receipt report of the USAID commodities.

## 3.4. Prototype for local production

Since the very start of DER activities, it was considered to replace the expensive imported windpumps by locally constructed ones. Ref 2 gives some advantages:
- saving of foreign currency
- creation of employment
- no problems in obtaining spare parts

In cooperation with DER CWD has designed a 5 m diameter windpump for performance in high wind regimes. This mill, the CWD 5000 HW of EMIDERI-1, was first built in the Netherlands and later in Cape Verde, by DER mechanics. The Cape Verdean prototype was installed on Achada de São Filipe in June 1983.
Both in Cape Verde and in the Netherlands, performance measurements have been executed.
Figure 3.2. presents some of the results.

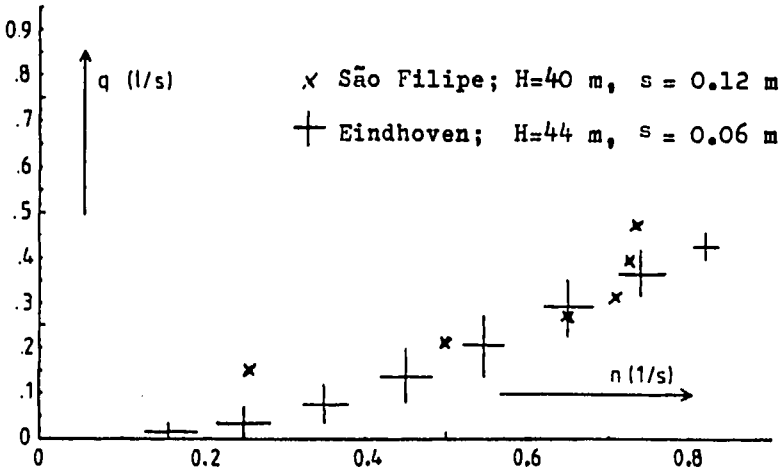



Figure 3.2 Rotor speed bin sort. Measurement of CWD 5000 HW
The Eindhoven measurements derive from Ref. 27

In Technical note XVI, no. 12, the experiments with the first prototype were described. The production cost were calculated to be 168,000 Escudos RCV, which is at least 3.5 times cheaper than a commercial windpump of the same size.
Recently CWD has developed the CWD 5000 LW, designed for medium wind regimes. Based on the experiments with both mills and the results of a short mission carried out by a CWD-consultant (Refs 7 and 8), it has been decided to change to the 5000 LW.

Arguments were:
- the LW is the new CWD 5 m diameter prototype and all the improvements resulting from application in other developing countries can also be used on Cape Verde
- the mill can be furled from ground level, the HW cannot
- the tower height of the LW is 12 m, while the HW tower is only 6 m and the LW has a bolted version of the tower
- the maximum stroke of the LW is larger (200 mm versus 120 mm)

The existing HW prototype on Achada de Sao Filipe will be dismantled and at the same site a 5000 LW, manufactured in Holland, will be installed in the second half of 1984. Meanwhile a second 5000 LW will be constructed at the DER workshop, possibly in collaboration with a workshop on São Vicente.

## 3.5. Anemometry

### 3.5.1. Introduction

In order to select the right windmill for the right site, it is, amongst others, necessary to execute wind measurements. Cape Verde has a wide variety of wind situations: Achadas and Ribeiras, where every valley is somewhat different from another, blocking and shadowing effects of hills and mountain ridges may occur, etc.
The anemometry section of DER has gradually obtained the necessary equipment to collect and elaborate wind data; at the end of Phase 2, the anemometry equipment consists of:

- 2 anemometers Casella (wind run meters)
- 1 anemograph Lambrecht
- 8 automatic registrating units MS 778 of Aeolian Kinetics
- 15 wind run meters WP 4000 of Aeolian Kinetics
- about 30 Maximum WPA-10 anemometer cups, to be used with MS 778 as well as WP 4000 systems
- 1 microprocessor AIM 65 of Rockwell, adapted by Aeolian Kinetics

The anemograph has been lent to the AGRHYMET-project. The 3 Aerowatt measurement stations never produced reliable data; the data are recorded on a cassette, which has to be treated in France. Aerowatt has reported that the cassettes contained no data. The problem could not be solved by a visiting Aerowatt technician. As in the meantime the wind meters had suffered from various mechanical breakdowns, and Aerowatt did not respond any more to DER's requests, DER decided not to use them any longer and to replace them by reliable anemometers. The WP 4000 and MS 778 systems have been in operation since the middle of 1982. Problems encountered during the introduction of this equipment, have caused some loss of data.

### 3.5.2. Anemometer sites

#### Praia airport

As the meteo-station at Praia airport has a relatively fair amount of recorded years (9) and is well exposed to the prevailing winds, this station of the National Meteorological Service has been used by DER as a reference station. Copies of the hourly wind speed records are transferred each month to DER, which is gratefully acknowledged here.
The station is situated on an Achada; measuring height is 6 m. If sites happen to have a good correlation with Praia, relatively short periods of measurements are sufficient to predict the wind regime on those spots.

DER measuring stations

In Phase 2, DER has executed wind measurements at the following sites:

Table 3.6. - Wind measurements by DER in 1981-1984

| Site | Anemometer | Period |
|---|---|---|
| 1. Achada S. Filipe, T. | MS 778 | May '82 - July '84 |
| 2. Achada Lém, T. | MS 778 | Sept. '82 - July '83 |
| 3. Salineiro, T. | MS 778 | Dec. '82 - April '83 |
| 4. Ribeirao Manuel, T. | Stewart | Sept. '82 - Jan. '83 |
| 5. Achada Baleia, T. | Casella | March '82 - July '84 |
| 6. Tower Aeropower, S. Filipe | WP 4000 | July '82 - Oct. '82 |
| 7. On top of Darrieus, S.F. | WP 4000 | Nov. '82 - Dec. '82 |
| 8. Tower Southern Cross, S.F. | WP 4000 | July '82 - Aug. '82 |
| 9. Next to Dempster 8', S.F. | WP 4000 | Dec. '82 - Jan. '83 |
| 10. Tarrafal, Chao Bom | Casella | Sept. '82 - Dec. '83 |
| 11. R. Saltos, Achada Laje | WP 4000 | March '83 - April '83 |
| 12. Flamengos (poço) | WP 4000 | May '83 - Aug. '83 |
| 13. R. Sao Miguel (poço) | MS 778 | Dec. '83 - May '84 |
| 14. R. Saltos, Margosa | MS 778 | Dec. '83 - July '84 |
| 15. Tarrafal, Vila | Aerowatt | March '82 - March '83 |
| 16. Tarrafal, Achada Grande | Aerowatt | March '82 - March '83 |
| 17. Tarrafal, Ribeira Grande | WP 4000 | Sept. '83 - Dec.'83 |
| 18. Tarrafal, Rib. Grande, SST 28 | WP 4000 | May '84 - July '84 |
| 19. Tarrafal, A. Grande | WP 4000 | May '84 - |
| 20. Sao Miguel, FT 35 | WP 4000 | May '84 - July '84 |
| 21. Saltos, FT47 | WP 4000 | April '84 - July '84 |
| 22. Flamengos, next to Dempster | WP 4000 | April '84 - July '84 |
| 23. Flamengos, next to Socross | WP 4000 | April '84 - July '84 |
| 24. Ribeirao Chiqueiro, FBE 53 | WP 4000 | Dec. '83 - March '84 |
| 25. Santo Antao, Ribeira Grande | WP 4000 | |

Obs.:
Measuring heights are 12 m
The anemometers in Ribeiras are removed before the rainy season.

### 3.5.3. Elaboration of data

Praia airport

The hourly wind speeds are "manually" (by typing) entered into the microprocessor AIM 65 and saved on cassette. DER's PRAIA programme calculates the monthly frequency distribution, mean wind speed and energy pattern factor $k_E$. More details are given in Part Two, Chapter 12 of this report.

MS 778

Data first have to be transferred from MS 778 memories to the microprocessor AIM 65. This is done by an internal micro processor program. This programme also takes care that data are recorded on cassette. When data are needed for elaboration, another internal programme transfers the data from cassette to the memories of AIM 65.
Data are then elaborated with DER's CLASE programme to obtain the monthly frequency distribution; the programme also calculates the mean monthly wind speed and the energy pattern factor $k_E$. There is an instruction manual (Report XVI, no. 3). Programmes are also saved on cassettes for further use.

WP 4000

This type of equipment records the wind run. In general, two readings per day are done by guards, at 6 and 18 hrs; this way nocturnal and diurnal mean wind speeds are obtained. Calculations are done in the office by hand. In order to compare these 12-hour means rapidly with Praia or MS 778 data, DER developed the PNODI programme which calculates the 6-18 hrs and 18-6 hrs mean wind speeds from Praia or MS 778 data.

Weibull paper

This paper (developed by CWD) makes it possible to obtain quickly the factors k and c from the best fitting Weibull estimation of the cumulative frequency distribution and allows easy comparison of the two stations (see Chapter 12 of this report).

Statistical correlation

The data of two wind measuring stations can be compared by calculating the relation and correlation factor, by linear regression. This can be done for the mean wind speeds, the energy pattern factor as well as for the Weibull factors.

### 3.5.4. Some remarks

The anemometry equipment which DER has at its disposition, in general complies with our objectives. With the WP 4000 some problems with poor electric connections have occurred, but they can probably be solved.
The anemometers Maximum WPA-10 appear to read systematically 0.5 m/s too low (Ref. 9). Therefore, all data obtained with these anemometers should be increased by 0.5 m/s. It also seems necessary to calibrate the anemometers every six months; dust is very abundant in Cape Verde.
Wind measurement activities have been reported twice by DER, in Reports VI and XVII.

Analysis of the Praia station has shown that one can distinguish three periods during the year:

- period 1: January through May : $P > 300$ Watts/m$^2$
  (P = power in the wind)
- period 2: July through September : $P < 200$ Watts/m$^2$
- period 3: June, October through December : $200 < P < 300$ Watts/m$^2$

The periods can also be characterized with Weibull factors:

- period 1: $K \geqq 3$ and $c \geqq 30$ km/hr
- period 2: $K < 3$ and $c \leqq 30$ km/hr
- period 3: $k \geqq 3$ and $c \leqq 30$ km/hr

The correlation factors between two stations appear to be different for different periods.

## 3.6. Performance measurements

In order to be able to select the right windmill for the right site, it is necessary to make more or less reliable predictions on the outputs of the windmills. Performance measurements are a necessary tool in doing so. Activities concerning the performance of windmills, as undertaken by DER, can be divided into three parts:

- theory
- power vs wind speed measurements
- long-term output measurements

In this section a survey of these activities is presented; the measurements and their analysis will be treated in Chapter 13 of Part Two.

### 3.6.1. Theory

At the start of Phase 2, theoretical output predictions of Dempsters 8' and 14' windmills were available. This work had been done by Van Meel (Ref. 10). The predictions are based on aerodynamic calculations of the rotor, yearly wind speed distribution of Praia airport of 1978 and an output calculation model. These predictions have been refined in Phase 2 (Report VI), using 1975 to 1981 wind data of Praia and presenting monthly output predictions for both Achada and Ribeira wind regimes.
Furthermore, based on field experiments, manufacturer's data and the two above mentioned predictions, the performance of all windmills used by DER has been presented in two graphs, which are in use at site selections. These graphs will be presented in Part Two, Chapter 13 Justification of these graphs can be found in the site selection document Report XXI.

Besides this theory on mechanical water pumpers, an analysis was made of the Aerowatt-Guinard electric water pumping windmill combination on Achada Baleia (Report IX, no. 12).

### 3.6.2. Power vs wind speed measurements

In accordance with the recommendations of the IEA, the power vs wind speed curve of a windmill should be measured with ten-minute intervals. Firstly, a technical note was written on how to perform these measurements (VI, Annex 6.3.). By way of illustration, some measurements were presented of the Dempsters 14' at Achada São Filipe (pumping head = 40 m). Total efficiency did not exceed 0.04 (total efficiency is defined in this final report as nett power of water pumped divided by power in the wind).
Secondly, a considerable number of this kind of measurements have been performed on the Dempster 8' on Achada de São Filipe; measurements have been reported and analysed in a technical note (XXIV, no. 3). Conclusions are, that:

- actual performance is 25% lower than predicted by Van Meel (Ref. 10)
- maximum total efficiency with this load (i.e. design wind speed $V_d$ = 5.5 m/s) is 0.10
- total efficiency on a yearly basis (calculated with the power-wind speed curve and the wind speed distribution of Praia airport) is 0.045 for Achada wind regimes ($\bar{V}_{annual}$ = 6.5 m/s) and 0.07 for Ribeira wind regimes ($\bar{V}_{annual}$ = 4 m/s).

Obviously, these total efficiencies can be improved by increasing $V_d$ for Achada wind regimes and decreasing $V_d$ for Ribeira wind regimes. Strength calculations (Ref. 11) have however, shown, that the maximum allowable design wind speed for a Dempster 8' is 5.8 m/s and for a Dempster 14' only 3.8 m/s. Thirdly, some measurements have been carried out on the prototype installed at Achada de São Filipe. These measurements seem to confirm similar measurements carried out by CWD on the prototype in Eindhoven, but their number is not sufficient to draw any firm conclusion.

### 3.6.3. Long-term measurements

These measurements were carried out in the simplest way (and are therefore not very accurate) by reading the water meter every month and taking the monthly wind speed from a nearby anemometer (if any). As water meters were not installed until the end of 1983 (and not at windmills without guards and some meters got out of order after a short time), only very few of these measurements are available. The readings of the water meters are taken from the monthly maintenance sheets.
All available measurements are in accordance with the performance graphs developed by DER (see Part Two, Chapter 13).
The long term output measurements of the Aerowatt at Achada Baleia revealed that the total efficiency factor never exceeded 0.03.

## 3.7. Site selection

The term "site selection" means all preparatory activities needed to select the most suitable pumping equipment for a particular site. This process of site selection is often complicated due to the Cape Verdean conditions. The following aspects are involved:

- Wind regime:
  Cape Verde has in general a very favourable wind regime; it is governed during 9 months per year by the north-eastern trade winds. The annual mean wind speed in Praia is 6,7 m/s at H = 8 m; March has the highest monthly mean (7.8 m/s); August has the lowest (4.8 m/s). The Weibull shape factor k varies between 3.9 in March and 2.1 in September. However, for site selection it is necessary to carry out short-term spot measurements and obtain correlations with the very few meteorological stations.

- Water availability:
  Due to the wide variety of and abrupt changes in geologic layers, quantity and quality of subsoil water are difficult to predict. Moreover, some areas suffer from the danger of seawater intrusion.

- Well characteristics:
  Pumping tests are often difficult to interpret and extrapolate as the precipitation has been less than normal for 15 years

- Analysis and prediction of water needs for domestic use and/or irrigation:
  The Government of Cape Verde intends to supply 30 l per day per person, as a short term goal.

- Field measurements of the performance of windmills used by DER:
  At the moment (pending local production) these mills are Dempsters of 8' and 14' and Southern Crosses of 21' and 25'. Measurements have shown that the nett power delivered by these mills does not exceed 0,075 x the rotor area x the cubed annual mean wind speed ($0,075 \times A \times V^3$).

- Choice of equipment to be installed:
  This concerns the diameter of the rotor and diameter and stroke of the pump. This choice is based on the results of the analysis mentioned above.

During Phase 2, a more or less consistent procedure has gradually been developed. This procedure has been described only very recently (Report XXI). Besides the aspects mentioned above, it turned out to be necessary to develop a strategy, or rather strategies, in order to make sensible use of the pumped water. This strategy will be treated briefly in Chapter 5 (end use) and more in detail in Part Two, Chapter 14 (on site selection). The more general part of this procedure (i.e. that leads to the choice of type and size of equipment) has been used in the revision of the potential of water pumping by wind power (Report XXII), which was done during the last months of Phase 2. This revision will be treated in Chapter 4.
It is thought that with these two reports (XXI and XXII) the project has produced a guideline for future installations; of course, its details can and should still be refined.

In the next table the site selections during Phase 2 are presented.

Tabel 3.7 - Site selections during Phase 2

| Island | Site | Equipment chosen |
|---|---|---|
| Santiago | Achada de S. Filipe, FT 173 | Dempster 14' |
| Sal | Horta | Dempster 8' |
| Santiago | Ribeira de Flamengos, FT 5 | Dempster 14' |
| Boa Vista | Poço de Rabil | Dempster 14' |
| Boa Vista | Bala, Ribeira de Rabil, BSP 3 | Dempster 8' |
| Boa Vista | Fogao, Rib. de Rabil, BSP 4 | Dempster 8' |
| Boa Vista | Ribeira Preta, BF 7 | Dempster 8' |
| Boa Vista | Ribeira Larga, BF 8 | Dempster 8' |
| Boa Vista | Fundo das Figueiras, BF 18 | Dempster 14' |
| Santiago | Salineiro, FBE 2 | Southern Cross 21' |
| Maio | Figueira Horta, MF 2 | Southern Cross 25' |
| | Rib. Saltos | Identified some 10 |
| Santiago | Rib. Flamengos | shallow wells which |
| | Sao Miguel | can be equipped with windmills |
| Santiago | Various sites | Pilot project for irrigation with windmills |
| Santiago | Rib. Saltos, Achada Laje | Dempster 14' |
| Santiago | Ribeirao Manuel, FT 223 | Dempster 14' |
| Santiago | Achada de Sao Filipe, FT 176 | Prototype CWD 5000HW |
| Santiago | Flamengos, shallow well | Southern Cross 25' |
| Santo Antao-Mamanha, Ribeira Figueiral | | Southern Cross 25' |
| Santo Antao-Boca Ribeirinha Jorge, Rib.Torre | | Southern Cross 25' |
| Santo Antao-Boca de L. de Gueme, Rib. Torre | | Southern Cross 25' |
| Santo Antao-Porto Novo, FA 2 | | Southern Cross 25' |
| Santo Antao-Porto Novo, FA 11 | | Southern Cross 25' |
| Santo Antao-Ribeira Torta, FA 15 | | Southern Cross 25' |
| Maio | Pedro Vaz, MF 11 | Dempster 12' |
| Maio | Barreiro, MSP 14 | Dempster 8' |
| Maio | Alcatraz, MF 9 | Dempster 8' |
| Santiago | Ribeirao Chiqueiro, FBE 53 | Southern Cross 25' |

Note that not all selected sites have been equipped yet:

- The proposed installations on Boa Vista have been postponed because the ground water has dropped and become saline. It has not rained there since 1980. In Sal Rei, the main population centre of Boa Vista, it has become necessary to install a desalination unit.
- The pilot project for irrigation has not yet started.. It is proposed to utilize the Southern Cross 25' in Ribeira de Flamengos to this aim.
- The windmills for Santo Antão (to be financed by the bilateral project Santo Antão-Holanda) have not yet been ordered.

- In Figueira Horta, Maio, preference was given to a motorpump, as the largest windmill DER has at the moment, does not have sufficient power to pump the yield of the well.
- When the concrete cover of the tube well in Barreiro, Maio, was removed to start the installation, it appeared that the well had completely dried up.

In the following table, a survey is given of the sites ready, or almost ready, to be installed.

Table 3.8. - Possible sites to be installed from July 1984 to June 1985

| Site | Preliminary choice of equipment | Site study done? |
|---|---|---|
| Rib. Torta, FA 2, A. | Southern Cross 25' | Yes |
| Praia Baixo, FT99, T. | Dempster 14' | Not yet |
| Joao Varela, FT200, T. | Dempster 14' | Not yet |
| Palmareio, FT117, T. | Southern Cross 17' | Not yet |
| Rib. d[illegible]arco, FT217, T. | Dempster 8' | Not yet |
| Rib. b[illegible]nde, SST28, T. | Dempster 14' | Not yet |
| Chico Vaz. MF16, M. | Southern Cross 25' | Not yet |
| Lagoa, SPM15, M. | Southern Cross 17' | Not yet |
| Rib. Corujinha, FA2, A. | Southern Cross 25' | Yes |
| Rib. Corujinha, FA 11, A. | Southern cross 25' | Yes |
| Rib. Rabil, BSP3, B.V. | Dempster 8' | Yes |
| Rib. Rabil, BSP4, B.V. | Dempster 8' | Yes |
| Rib. Larga, BSP8, B.V. | Dempster 8' | Yes |
| Rib. Preta, BF7, B.V. | Dempster 8' | Yes |
| Campo de Serra BF11, B.V. | Dempster 14' | Yes |
| Campo de Serra, BF12, B.V. | Dempster 14' | Yes |
| Horta, poço, S. | Dempster 8' | Yes |
| Flamengos, poço(s), T. | Southern Cross(es) 25' | Not yet |
| Amargosa, poço, N. | Dempster 8' | Yes |
| Recanto, FN50, N. | Dempster 8' | Not yet |
| Campo de Preguiça, FN9, N. | Southern Cross 25' | Not yet |
| Campo de Preguiça, FN10, N. | Southern Cross 25' | Not yet |
| Maria Palinha, FN35, N. | Dempster 8' | Not yet |
| Maiama, FN16, N. | Dempster 8' | Not yet |
| Vila Rib.Brava, FN13, N. | Dempster 8' | Not yet |
| Lameirão, FV4, V. | Dempster 14' | Not yet |
| Madeiral, FV17, V. | Dempster 14' | Not yet |
| Madeiral, FV21, V. | Southern Cross 17' | Not yet |
| Ribeira Juliao, FV22, V. | Southern Cross 25' | Not yet |

## 3.8. Non-wind activities

At the start of Phase 2, the following renewable energy activities, not concerned with wind, had commenced:

- The SOFRETES solar pump had been installed but already been given up.
- A small solar still (2 $m^2$) was in production at Achada de Sao Filipe. The distilled water was used for batteries.
- A mirror-type solar cooker was irregularly in use at the guard's house at A. Sao Filipe.
- Sketches for a woodstove and a solar water heater had been made.
- A design had been made for a small Indian type biogas-plant at the cattle center at Sao Jorge, Santiago.
- Drawings were ready for a 67 $m^2$ solar still in Ponta Cais, Maio.

The accomplishments in this field during Phase 2 are the following:

- The 2 $m^2$ solar still at A. Sao Filipe has been maintained and is still in operation. The distilled water is used by DER and Variante. The still was equipped with a provision to facilitate the run-off of residues.
- The solar cooker was destroyed by severe wind gusts.
- One woodstove was made but is not in use any more, as the guard at A. Sao Filipe was not content with it.
- The biogas-plant in Sao Jorge was installed, but has up to now not been started up; one of the reasons is that, according to a biogas-expert, the design is not good.
- Attempst were made to have the construction of the solar still at Ponta Cais started, but they were not successful because no one was able and willing to supervise.

At the end of 1982, DER decided to skip the non-wind activities. Priority had always been on wind energy applications, and lack of time and manpower had caused DER to regard these activities as gap-filling. Consequently, the solar equipment furnished to DER by the USAID project has been transferred to INIT (National Institute for Technological Investigation). It is hoped that this institute can devote more time to these applications, some of which might become very important to RCV (e.g. wood stoves).

In mid 1983, at the request of the Minister of MDR, DER made a project proposal for a small (60 $m^3$/day) desalination unit for the water supply of Sal Rei, Boa Vista (Report XVI, no. 11). After approval by the Council of Ministers of RCV, it was decided that execution shall be done under the responsibility of the Secretary of State for Energy and Industry. DER will give assistance if necessary. Especially the opportunity to use an autonomous system (subsection 3.2.2.) there in the future is very interesting.

As part of the technical assistance paid by the USAID-project, Mr. C.F. Kooi carried out a mission (April to August 1983) to investigate solar energy applications on RCV (Ref. 12). Although his work was done under the responsibility of INIT, DER staff has given him much assistance. His main conclusion was that - apart from wind energy applications, which should have priority - the use of salt gradient solar ponds, improved cooking stoves and methods, photovoltaic electricity generators and desalinated water/electrical power production systems powered by combinations of petroleum source, wind machines and solar ponds might be possible and should be further investigated.

# 4. PERSONNEL AND ORGANIZATION

## 4.1. Personnel

### 4.1.1. Staff

On 1 July, 1981, DER staff consisted of:
- Mr. Fonseca, director, electrotechnical engineer
- Mr. Monteiro, agronomist
- Mr. Teixeira, electrotechnical technician

The mere fact that none of these persons were still working with DER on 30 June, 1984, illustrates one of DER's basic problems during Phase 2: insufficient Cape Verdean staff due to general lack of qualified technicians in Cape Verde; a situation which is improving, but cannot be solved quickly.
The following changes in staff have taken place during Phase 2:
- Mr. Fonseca left in August 1981 for another Ministry.
- Mr. Monteiro became acting director.
- Mr. Monteiro left Cape Verde in May 1982 to start working for the Portuguese government in Setubal; Mr. Teixeira became acting director.
- In February 1983 Mr. Livramento was appointed director of DER; he finished his studies in physics in December 1982 (Brasil) and had been one of the founders of DER in 1977.
- In May 1983 Mr. Teixeira left for INIT.
- In November 1983 Mr. Cardoso (technical engineer, agronomist) started working for DER; his tasks are office management and data elaboration.
- In May 1984 Mr. Ferreira (mechanical engineer) started working for DER.
- Mr. Versteegh (mechanical engineer, expatriate CWD-consultant) worked for DER during the entire period of Phase 2.
- Mr. Van Meel (applied physics, expatriate DGIS-expert), who was with DER during the entire Phase 1, left on 1 November, 1981.
- Mr. Pieterse (electrotechnical engineer, expatriate CWD-consultant) started on 15 September, 1981 and will stay with DER until 1 October 1984.

The lack and discontinuity of Cape Verdean staff has seriously hampered not only the progress of the project, but also its implementation: foreign technical assistance will have to continue longer than the five years expected in 1981.
Especially the lack of a mechanical engineer has delayed all transfer of knowledge on windmill design and local production technology and consequently delayed the introduction and development of a prototype for local production.
A national electrotechnical engineer is still lacking, but is to be appointed before the end of 1984.
The shortage of staff has been discussed by the project management with MDR and Secretary of State of Cooperation and Planning on various occasions.
The prospects at the end of Phase 2 (3 qualified national staff members working for DER and 1 promised) are good.

### 4.1.2. Medium level

During the first two years of Phase 2, no need was felt to have people at medium level positions. The group of personnel was relatively small (15 persons) and all on-the-job training facilities had to be used for the execution level personnel, as mechanics with windmill experience are, of course, very scarce.
Gradually, with more personnel and trained mechanics available, with the new workshop in operation, the need and the opportunity came to create the following medium level positions:

- workshop supervisor: this position is in the hands of Mr. C. Costa since November 1983; he has already worked with DER since 1978
- field supervisor: to be selected from DER's qualified mechanics; this selection has been postponed because:
  - some of the mechanics will attend a course in September 1984
  - maintenance work will probably be different from that in the past (see 3.1.5.) and therefore the job specification cannot yet be made
  - the decision whether or not the motor pumps will be integrated in DER has not yet been taken
- field and logistics surveyor who is responsible for:
  - the collection of all data to prepare new installations
  - all logistics at DER
  - anemometer park and readings
  - inspection of equipment installed but not maintained direct by DER

Maria de Lourdes Moreira, former trainee mechanic but with three years of secondary school is a candidate for this position and has been receiving on-the-job training since May 1984.

- draughtsman (vacancy)

It is felt that these medium level positions may become key positions within DER, which would guarantee the progress of daily work. These persons might form the basis for DER's continuity.

### 4.1.3. Execution level

On 1 July, 1981, the personnel at execution level consisted of:

- foreman
- 2 mechanics
- painter
- bricklayer
- storekeeper
- labourers (3)
- apprentices (2)

Shortly after the start of Phase 2, the two qualified mechanics left (one for INIT, the other for his home island, S. Vicente). Gradually, personnel has been increased; they received on-the-job training which has been quite successful. Regarding personnel, DER could install new windmills at three different sites at the same time, but logistic and transport limitations prevent this.

In June 1984, the personnel at execution level consisted of:
- 5 qualified mechanics of which 2 are machinists
- 4 apprentice mechanics
- 3 painters
- 2 electricians
- 1 storekeeper
- 3 drivers
- 1 administrator
- 1 typist
- 1 librarian
- 3 cleaning women
- guards

## 4.2. Transfer of knowledge and training

The loss of three technicians and two qualified mechanics during Phase 2 has been a serious blow to the project, but not so for Cape Verde: with the exception of one, all work within the national economy and apply their abilities there.
The present director , Mr. Daniel Livramento has first made himself acquainted with the activities of DER and its donor organizations; he paid visits to Holland (CWD), Denmark, Italy and the United States. In the first six months he has spent much time in making himself acquainted with the organizational and administrative matters of the Division, since the activities of the consultants have been gradually diminished and at the moment are restricted to giving occasional advice.
Mr. Livramento attended also a 4-weeks language course in England.
The site feasibility studies are of main importance to him at the moment. Together with Mr. Pieterse, he has executed the revision of water pumping potentials in Cape Verde (see Chapter 6). Mr. Cardoso has very rapidly made himself acquainted with DER's administrative and personnel matters; the task of office manager is carried out efficiently by him.
With the help of Mr. Pieterse, he made himself acquainted with the anemometry equipment, especially with the microprocessor. The calculation of monthly frequency distributions from the MS 778 data and Praia airport data is done by Mr. Cardoso. He and Mr. Pieterse have written the instruction manuals for the operation of the programmes and the microprocessor 6 (Reports XVI, no. 3 and XXIV, no. 1). Together they have also analysed the wind data gathered in 1982 and 1983 (Report XVII), treating such oddities as energy pattern factors, Weibull parameters, energy density, correlation factors, etc.
The national mechanical engineer, Mr. Ferreira, counterpart of Mr. Versteegh, was appointed as late as May 1984. As far as transfer of knowledge in the field of technical design and modifications were concerned, Mr. Versteegh could not do more than carry out documentation and reports (technical notes and yearly maintenance reports). Such a short time has passed since the start of Mr. Ferreira, that at the end of Phase 2 he was still making himself acquainted with matters, with the help of Mr. Versteegh.
The workshop supervisor still needs much assistance from the mechanical engineers.

The training of the field and logistics surveyor has only started very recently; all that can be said is that the expectations have been more than fulfilled up to now.

On execution level, nearly all training has been done on-the-job (installation, maintenance, repair). Some classroom sessions on the reading of drawings have been given by Mr. Versteegh. In early 1983 a course in maintenance and installation of windmills was given by DER for mechanics from the islands, which has proved to be effective.
In general it can be stated that the training at execution level has been quite successful, although the equipment does not function well without guidance and quality control by the mechanical engineers.

Three mechanics have attended courses at the technical school of Cabnave shipyard in São Vicente (Mr. C. Costa for workshop supervisor, two others for machinists).

During the last months of Phase 2, training courses for the first year of Phase 3, have been planned. Four 9-months courses have been planned in Lisbon:
- one metal worker
- one machonist
- draughtsman
- one electrician

Furthermore, training of the field surveyor at the Wind Energy Group in Eindhoven (CWD-partner) has been asked for.

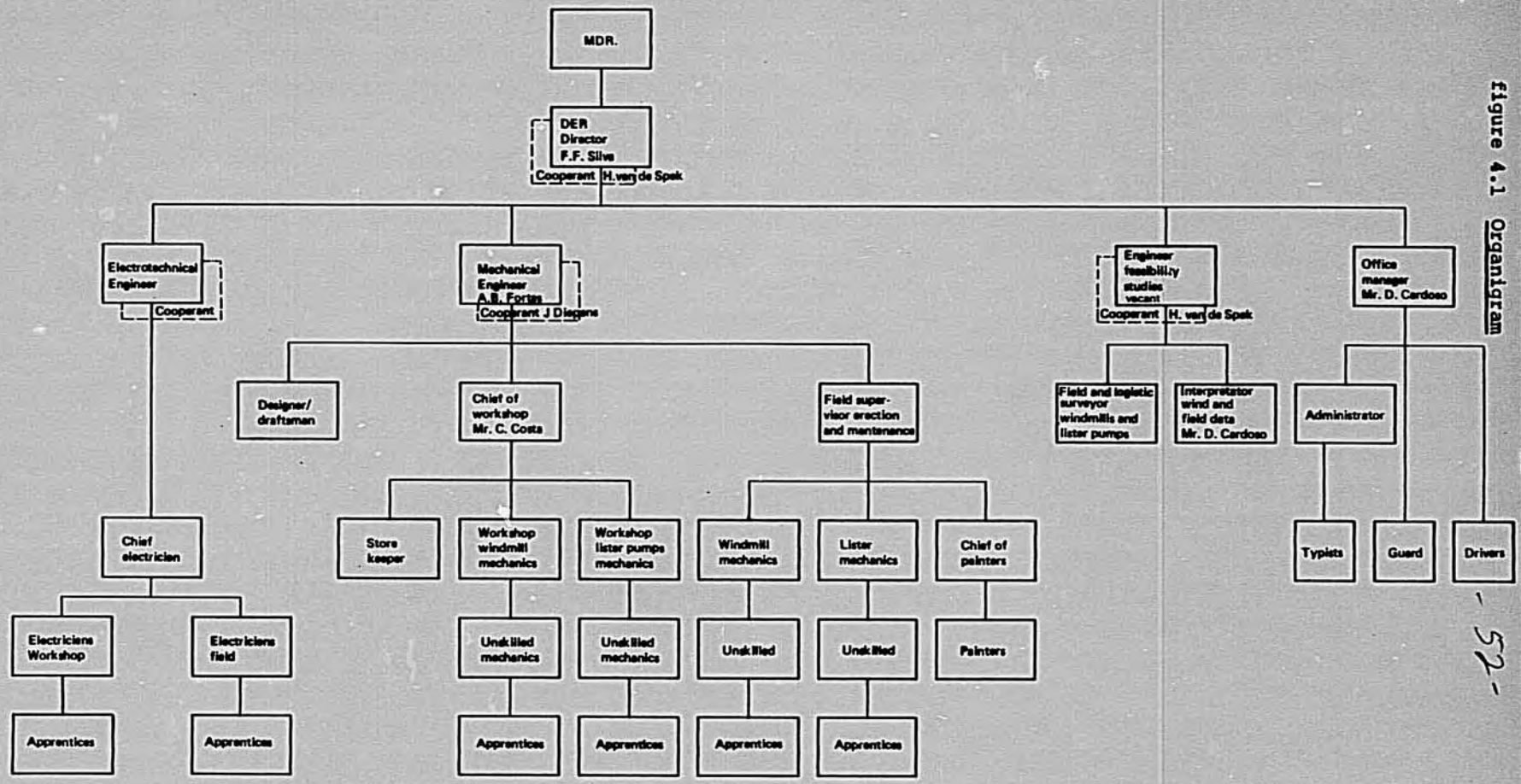
## 4.3. Organization

The organizational set-up of DER is outlined in an organigram (see below). This was made last February with the assistance of the project manager Mr. J. Costa (Ref. 22)*.
Within MDR, DER belongs to the Directorate General of National Resources. An important change in MDR's organization is being prepared; it is hoped that coordination problems which have occurred with other MDR-departments (Ground water department, Rural Improvement department) can then more easily be solved.

Weekly staff meetings, which include planning of next week's activities, have proved to be a valuable instruments for the progress of work.

* This organigram is not yet fully in operation.

figure 4.1 Organigram




ORGANIGRAM OF DER ON OCTOBER 1, 1984

## 5. END USE AND ECONOMICS

End use and economics are issues which should not be lacking in a final project report. It should be admitted that rather few data on these subjects have been gathered by DER's staff. It is however, felt, that this lack can be justified as follows:

- In an urgent situation like that in Cape Verde, the first concern is simply to pump water and leave it to the common sense of the consumers how the water is used, without worrying about the costs.
- A more or less experimental application (water pumping with windmills) should, in DER's opinion, first run technically smoothly before reliable data about end use and economics can be gathered and be compared with those of "conservative" technologies (i.e. motorpumps in our case).

The present ideas of DER of how water should be used, will be presented in Chapter 14 (Part II; site selection strategies). These strategies can be summarized as follows:

a. Water pumped from the Achada subsoil should be used for drinking water. If there is an excess of water (which in case of windmills will occur in 9 of the 12 months if sufficient water is available) this water can be used for (very) small-scale irrigation close to the water tank; preferably carried out by the windmill guard.
b. Water pumped from Ribeira subsoil should be used for irrigation and, where necessary, for drinking water. It has been shown that it is very advantageous (in the case of windmills) to pump the irrigation and drinking water requirements of a certain Ribeira area with the same machine.
c. In areas where there is a danger of seawater intrusion, drinking water for the Achada's should be pumped from the Ribeira's.
d. Shallow wells in the Ribeira's can be equipped with both a windmill and a motorpump at the same time, in case the power of the windmill is not enough to pump all water available. The economic viability of this system still has to be studied.

The end use of a few windmill applications is treated in detail in Part Two, Chapter 11 (case studies). The next table presents the end use of all DER's windmills. It should be noted that the figures given are rough estimates.

Table 5.1. - End use of water pumping windmills (as of June 1984)

| Site | Type of mill | Strategy | Drinking water (persons) | Irrigation (ha) |
|---|---|---|---|---|
| São Filipe, T. | Dempster 8' | A | 500 | 0.25 |
| Portete, T. | Dempster 8' | B | 25 | 0.25 |
| Lem Duque, T. | Dempster 8' | B | 240 | 0.10 |
| Pensamento, T. | Dempster 8' | B | 400 | - |
| Granja, T. | Dempster 8' | B | - | - |
| Calheta, M. | Dempster 8' | A | 100 | 0.40 |
| Cascabulho, M. | Dempster 8' | A | 400 | 0.10 |
| Santa Cruz, T. | Dempster 8' | B | 400 | - |
| Trinidade, T. | Dempster 14' | A | 250 | 0.50 |
| Granja, T. | Dempster 14' | B | - | - |
| Poço Verde, S. | Dempster 8' | A | 500 | - |
| Palmeira, S. | Dempster 8' | A | 500 | - |
| Chã do Norte, N. | Dempster 8' | A | 20 | 0.50 |
| Belém, N. | Dempster 8' | A | 50 | 0.30 |
| Belém, N. | Dempster 8' | A | 50 | 0.30 |
| Chã dos Penedos, N. | Dempster 14' | A | - | - |
| Chã dos Penedos, N. | Dempster 14' | A | - | 1 |
| São Filipe, T. | Dempster 14' | A | 250 | 0.75 |
| Ponta Furna, T. | Dempster 14' | A | 600 | - |
| São Filipe, T. | Socross 25' | A | - | 2.5 |
| Chã de Arroz, A. | Socross 25' | B | - | - |
| Bicoteiro, A. | Socross 25' | D | - | 7.5 |
| Corujinha, A. | Socross 25' | C | 2,000 | - |
| Flamengos, T. | Dempster 14' | B | 500 | 0.25 |
| Calheta, M. | Dempster 8' | A | 100 | 0.40 |
| Morro, M. | Dempster 12' | C | 400 | 0.40 |
| Figeira Seca, M. | Dempster 8' | C | 250 | - |
| Ribeirão Manuel, T. | Dempster 14' | A | 400 | - |
| Achada Laje, T. | Dempster 14' | D | 300 | - |
| São Filipe, T. | Prototype | A | - | 0.50 |
| Flamengos | Socross 25' | B | - | 3.5 |
| Pedro Vaz, M. | Dempster 12' | B | 400 | - |
| Alcatraz, M. | Dempster 8' | A | 250 | - |
| Salineiro, T. | Socross 21' | A | 800 | - |
| Ribeirão Chiqueiro, T. | T. Socross 25' | A | 300 | 2 |
| Achada Baleia, T. | Aerowatt | C | - | - |
| Total | | | 9,985 | 21.5 |

So, approx. 10,000 persons receive their daily water supply through DER windmills. This is 5% of the rural population (Ref. 13 states that 190,000 people belong to the rural area, i.e. in villages with less than 1000 inhabitants). This figure is still relatively small; one should realize that in the past these people had no easy access to water at all, because in general motorpumps are only in use for concentrations with more than 1000 persons. A great deal of work still has to be done in this field by DER, especially as windmills are economically far more attractive for low capacities than motorpumps (see blow).
21.5 ha are irrigated by DER windmills; the total irrigated area in Cape Verde is at present around 2000 ha, of which 50 % is pumped irrigation.

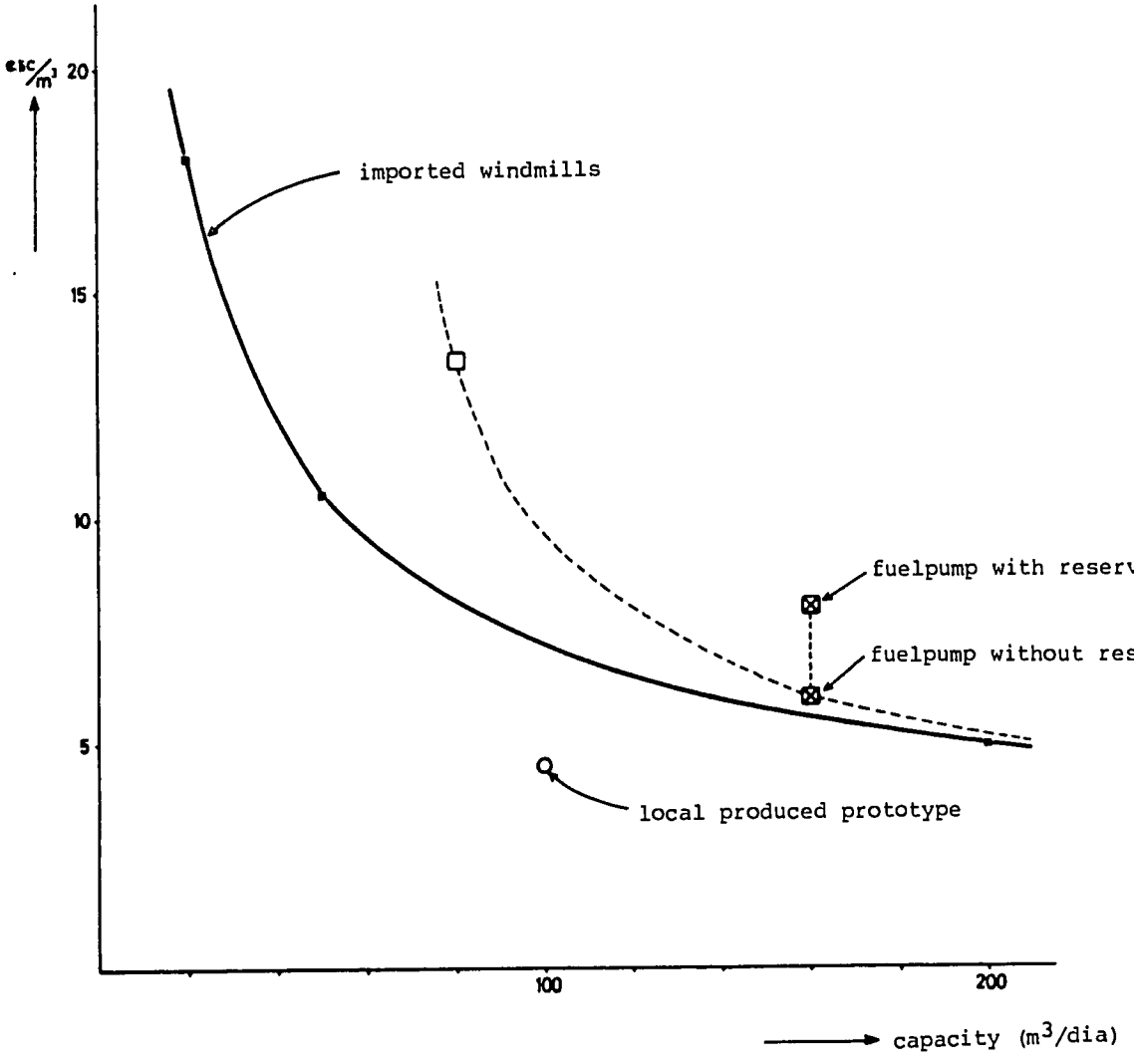



Figure 5.1. - Water pumping costs versus capacity

Table 5.2. - Percentage cost breakdown pricelevel December 1983 (Ref. 3)

| | total yearly costs (CVE) | wind-mill/ diesel pump % | in-stal-lation % | tank % | well and tap house % | plumb-ing % | operation and tenance % | guard-well operator % |
|---|---|---|---|---|---|---|---|---|
| Dempster 8' | 117,140 | 11 | 2 | 15 | 23 | 7 | 11 | 31 |
| Dempster 14 | 156,542 | 21 | 2 | 23 | 17 | 6 | 8 | 23 |
| Southern Cross 25' | 266,322 | 29 | 2 | 37 | 10 | 3 | 6 | 13 |
| Prototype 5 m | 154,935 | 6 | 1 | 40 | 17 | 6 | 7 | 23 |
| Motor pump without tank | 287,311 | 11 | 2 | - | 10 | 3 | 61 | 13 |
| Motor pump with tank | 384,887 | 8 | 1 | 25 | 7 | 2 | 47 | 10 |

Note: In case of a loan with an interest rate of 5%.

Irrigation has come second up to now. It should be reminded that part of the DER area is land that otherwise would not be irrigated and is just a spin-off, though very valuable, of the drinking water supply (strategy A!).
According to the Agricultural Department of MDR, in the ideal situation (availability of water throughout the year, good seeds, good technical assistance, rapid transport to the market) horticulture can give a nett profit as high as 1500 contos/ha/year. The average, however, is as low as 80 (on Santiago) to 110 (on Santo Antonio) contos/ha/year (Ref. 13). The reason why the average is so low, is because of the cultivation of labour saving and drought resistant crops, like sugar cane and bananas. The existing water division quota are based on these crops: water gifts to the individual farmer (often tenant) only every 2 or 3 weeks. Moreover, the infrastructure for rapid transport to the market, often does not exist (Santo Antão).
For irrigationwith windmills, very tentatively a profit of 1000 centres/ha/year is taken, because it concerns very small areas, probably difficult to optimize. It should also be noted, that another source (CWD/ILRI) mentions 500 contos/ha/year as the maximum possible on Cape Verde.
This leads us to the economics of water pumping windmills. In November 1983, the evaluation team and DER staff worked together to obtain and analyse the cost of water pumping equipment. The results are summarized in Figure 5.1 and Table 5.2. It should be noted that the analysis is based on sometimes very rough estimates and interpretation should be subject to the various restrictions made (see the evaluation report, Ref. 3). A striking result of the cost breakdown is that both the guard and the water tank constitute a substantial part of the annual costs.

Combining these data on end use and economics, one can observe the following:

- Water pumping windmills with capacities lower than 100 $m^3/d$, are much cheaper than motorpumps. Capacities in the range of 10 to 30 $m^3$/day are requirements typical of villages in rural areas; costs are in the range of 15 to 20 esc./$m^3$. Comparing these costs with those for urban areas: Praia: 35 esc/$m^3$ to Mindelo: 330 esc/$m^3$ (desalination). Data from Refs. 12 and 14.
- Irrigation in strategy A is done with excess water from the windmill. As far as the national economy is concerned, this water is pumped at no cost. The profit per ha can be as high as 1000 contos. A Dempster 8' with 0.25 irrigated ha from excess water, produces 250 contos/year, which is more than two times the annual costs of the windmill. National benefits are even higher, as the agricultural production has increased (allegedly very little, but there where it is needed).
- The price of water supply in case of strategy B (if water supply is combined with irrigation) is only about 10 esc/$m^3$, as the bulk of the investment costs are those for the irrigation component; extra investments for water supply are the small tank and the taphouse.

## 6. REVISION OF THE POTENTIAL OF WATER PUMPING BY WINDPOWER

In the beginning of 1980, DER and CWD carried out a feasibility study on water pumping with windmills in Cape Verde (Ref. 2). The result of this study was that 75% of water to be pumped in Cape Verde can be pumped with wind energy. A quantity of some 400 windmills and 50 wind generators was estimated to be sufficient for this purpose.
Since that time, more data have become available on:

- the ground water potential, as well as on the risk of seawater intrusion in certain areas (studies done by DSEGAS, PNUD, SCETAGRI (Ref. 13), BURGEAP (Ref. 14 and 15), Bosscher (Ref. 16)
- the tube well characteristics; study by DSEGAS (the Ground water department of MDR)
- the wind regime; by DER (Reports VI and XVII)
- the performance of windmills in use by DER; study done by DER (see, for example, Report XXI)

With these data available, it was deemed convenient to re-assess the water pumping potential by windpower. To this aim, all exploitation tube wells of Cape Verde were visited by DER staff in April and May 1984 to gather current data.
For all tube wells it was estimated which pumping equipment would be the most suitable; for shallow wells a more general survey was made. Instruments used in doing so, were the performance graphs and the site selection strategy, which both have been described in the report on site selection.(Report XXII); both will be presented briefly, in Chapters 13 and 14 respectively.

The revision of water pumping potentials was dealt with in Report XXII. Some important tables are reproduced here: the first table gives a survey of the present equipment used for the operation of tube wells of Cape Verde; the second gives a similar survey of the possible future equipment:

Legenda:

MEV - Diesel motor with vertical shaft pump
GE - Diesel generator with electric submersible pump
MS - Diesel motor with suction pump
MAN - Handpump
AB - Mechanical wind pumper
AG - Wind generator driving an electric submersible pump
PE - To be equipped

Table 6.1. - Present distribution of pumping equipment for tube wells in number and yield ($m^3$/day)

| Equipment<br>Island | MEV | GE | MS | MAN | AB | AG | PE | Total |
|---|---|---|---|---|---|---|---|---|
| Santiago | 50<br>(10183) | 12<br>(1969) | 15<br>(3065) | 1<br>(--) | 15<br>(478) | 1<br>(150) | 20<br>(3786) | 114<br>(19622) |
| São Nicolau | 11<br>( 870) | 3<br>( 360) | | 5<br>(30) | 5<br>(122) | 2<br>(150) | 1<br>( 200) | 27<br>( 1732) |
| Santo Antão | | | | | | | 3<br>( 300) | 3<br>( 300) |
| São Vicente | 3<br>( 650) | | | | | | 4<br>( 400) | 7<br>( 1050) |
| Maio | 3<br>( 1460) | | 1<br>( 150) | | 7<br>(120) | | 5<br>(2388) | 16<br>( 4118) |
| Boa Vista | 6<br>( 210) | | | | | | 7<br>( 210) | 13<br>( 420) |
| Sal | | | | | 2<br>( 40) | | | 2<br>( 40) |
| Total | 73<br>(13373) | 15<br>(2320) | 16<br>(3215) | 6<br>(30) | 29<br>(760) | 3<br>(300) | 40<br>(7284) | 182<br>(27282) |

Table 6.2. - Possible future distribution of pumping equipment for tube wells in number and yield ($m^3$/day)

| Equipment<br>Island | MEV | GE | MS | MAN | AB | AG | PE | Total |
|---|---|---|---|---|---|---|---|---|
| Santiago | 16<br>( 1221) | 5<br>( 502) | | | 31<br>(1766) | 62<br>(16133) | | 144<br>(19622) |
| | 8<br>( 830) | 2<br>( 160) | | 1<br>( 5) | 15<br>( 357) | 1<br>( 380 ) | | 27<br>( 1732) |
| Santo Antão | | | | | 3<br>( 300) | | | 3<br>( 300) |
| São Vicente | | | | | 7<br>(1050) | | | 7<br>(1050) |
| Maio | 2<br>( 1180) | | | | 10<br>(1044) | ( 1894) | | 16<br>(4118) |
| | | | | | 11<br>( 380) | | 2<br>(40) | 13<br>( 420) |
| Sal | | | | | 2<br>( 40) | | | 2<br>( 40) |
| | 26<br>(3231) | 7<br>( 662) | | 1<br>( 5) | 79<br>(4937) | 67*<br>(18407) | 2<br>(40) | 182<br>(27282) |

* Number of tube wells receiving power from wind generators. The number of wind generators needed is 46.

It should be noted that pumping by wind power from tube wells can be increased from 1060 $m^3$/d to 23344 $m^3$/day or from 4% to 85% of the total potential.
The data of shallow wells are not nearly as accurate as those of tube wells. The Revision report (XXII) mentions a total water potential of 25,000 $m^3$/day, of which 13,000 $m^3$/d can be pumped with windmills.
Supposing that:

a) the yield from tube wells will increase in the future to 40,500 $m^3$/day (Ref. 13 and XXII)
b) the same division between wind pumps and motor pumps is applicable to the amount in a)
c) the yield from shallow wells remains the same (so 25,000 $m^3$/d)

Windmills and wind generators would be able to pump 20,400 and 27,300 $m^3$/day respectively, which together means 75% of the total potential of all wells (65,500 $m^3$/day).
Table 6.3. presents the type and number of windmills that would be needed in that case.

Table 6.3. - Distribution of type and number of wind pumps in the maximal future situation

| Type of mill | Santiago | Other islands | Total |
|---|---|---|---|
| Mechanical wind pump Ø 3 m | 26 (+8) | 28 (+12) | 54 (+20) |
| Mechanical wind pump Ø 5 m | 76 (+2) | 24 (+ 3) | 100 (+ 5) |
| Mechanical wind pump Ø 8 m | 70 (+4) | 44 (+ 3) | 114 (+ 7) |
| Wind generator | 60 (+1) | 5 (+ 0) | 65 (+ 1) |
| Total | 232 (+15) | 101 (+18) | 366 |

(+ ...): already installed

Table 6.3. shows a large difference with Beurskens' study (Ref. 2): more large-size mechanical wind pumps and wind generators are needed than predicted by Beurskens. The project policy has already been adapted for this purpose (see extension proposal, Ref. 4).

Teh table shows that 67% of all installations will take place on Santiago.

# 7. PROJECT SUPPORT

The project received support from CWD, the Netherlands. This support has been various:
- project management
- technical support
- logistics
- short missions

## 7.1. Project management

In principle the project manager visits the project every six months to discuss the progress, analyse and solve problems and outline the policy of the project and to have official contact with the Government of Cape Verde.
During Phase 2, the following six management visits were carried out:

| | | |
|---|---|---|
| - May 1981 (preparation) | by G.A. Van de Rhoer | (Ref. 17) |
| - February 1982 | by G.A. Van de Rhoer | (Ref. 18) |
| - November 1982 | by G.A. Van de Rhoer | (Ref. 19) |
| | and H. Schoenmakers | (Ref. 20) |
| - September 1983 | by J. Van Meel | (Ref. 21) |
| - February 1984 | by J. Costa | (Ref. 22) |

In November 1982 an intermediate internal evaluation was made by G.A. Van de Rhoer (Ref. 23) half-way the project.
In September 1983 a proposal for extension of the project was written by J. Van Meel (Ref. 4).
Moreover, holidays and medical visits of the two resident consultants have been used for discussions with the project manager. On one occasion, one of the consultants made a special trip to Holland for this purpose.
The project manager is also responsible for the contacts with the Dutch government (DGIS) and for the coordination of the project support activities of CWD.

## 7.2. Technical support

Technical support was given by the four partners of CWD for various problems. The following list gives the main items, but is far from complete:
- pumprid sealing
- corrosion
- allowable load on Dempsters (Ref. 11)
- comments on reports by DER
- supply of technical literature
- tank size calculations (Ref. 24)
- calculations for potato storage experiment
- consultancy for desalination plant in Sal Rei (Report XVI, nr. 11)
- preparation of wind generators for Achada Baleia (Ref. 25 and 28).

In general, the technical support has been adequate, although sometimes there were long delays. Furthermore, the problems of written communication occurred here too.

## 7.3. Logistics

CWD took care of the supply of a large variety of equipment and material; not only those defined in the project proposal, but also many small items which appeared not to be available locally.
By way of illustration an incomplete list follows:

- 24 windmills and spare parts (Dempster and Southern Crosses)
- 1 Landrover with trailer
- 1 Renault 4 TL
- 6 motorbikes
- 50 water meters
- waterlevel meters
- 1 concrete test hammer
- paint
- switches and diodes
- etc.

## 7.4. Short missions

During Phase 2, two short missions were executed:

- one to study the feasibility of autonomous systems on Cape Verde by Mr. J.A.N. de Bonte (CWD) and Mr. M. Dieleman (DHV Consulting Engineers); Ref. 6
- one to analyse the local production, by Mr. A. Kragten (CWD); Ref. 7

Both short missions have already been treated in subsection 1.2.2. and subsection 1.4. respectively.

## 8. REPORTS

The project has been rather extensively reported on. Not only the project staff wrote various reports (which will be treated below), but also the project managers, technical supporters and people on short missions presented reports.
The reports other than by the project staff have been mentioned in the foregoing chapter. They are also included in the list of references at the end of this report.
In accordance with the bilateral contract, progress reports had to be written every three months. This has been carried out meticulously, with the exception of the first one, which was a status rather than a progress report. So, 12 progress reports have been produced in Phase 2.
Besides, important technical developments have been reported in separate reports:

- state and progress of operation and maintenance of water pumping windmills have been reported three times (Reports IV, X and XVIII)
- installation manuals of Dempsters and Southern Cross windmills have been produced and are being used (Reports XI and XX)
- the elaboration of wind data has been reported twice (Reports VI and XVII); Report VI also deals with the output prediction of Dempster windmills
- a revision of the potential of water pumping with windmills has been carried out and reported on (Report XXII)
- a report on the methodology of site selection has been produced (Report XXI)
- several technical notes on various subjects (e.g. visits to islands, performance measurements, site selection, development of prototype) have been written; these were gathered in three reports: IX, XVI and XXIV

Finally, this final project report has been composed.
Table 8.1. presents all reports; Tables 8.2. through 8.4. give the titles of the technical notes.

Table 8.1. - Reports written by project staff

| Number | Title | English | Portuguese |
|---|---|---|---|
| I | Status October 1981 | x | - |
| II | Progress July - December 1981 | x | - |
| III | Progress January - March 1982 | x | - |
| IV | State of mechanical windmills - 1981 | - | x |
| V | Progress April - June 1982 | x | x |
| VI | Estimated yields of Dempster windmills using wind speed data of Praia of '75 through '81 | - | x |
| VII | Progress July - September 1982 | x | x |
| VIII | Progress October - December 1982 | x | x |
| IX | Technical notes of 1982 | - | x |
| X | Maintenance of windmills in 1982 | - | x |
| XI | Installation manual of Dempsters 12' and 14' | x | x |
| XII | Progress January - March 1983 | x | x |
| XIII | Progress April - June 1983 | x | x |
| XIV | Progress July - September 1983 | x | x |
| XV | Progress October - December 1983 | x | x |
| XVI | Technical notes of 1983 | - | x |
| XVII | Anemometric study of stations under responsibility of DER during 1982 and 1983 | - | x |
| XVIII | Maintenance of windmills in 1983 | - | x |
| XIX | Progress January - March 1984 | x | x |
| XX | Installation manual of Southern Cross 25' | - | x |
| XXI | Methodology of site selection | - | x |
| XXII | Revision of water potential by wind-power | x | x |
| XXIII | Progress April - June 1984 | x | x |
| XXIV | Technical notes first semester 1984 | - | x |
| XXV | Final project report Phase 2 | x | x |

Table 8.2. - Technical notes of 1982 (Report IX)

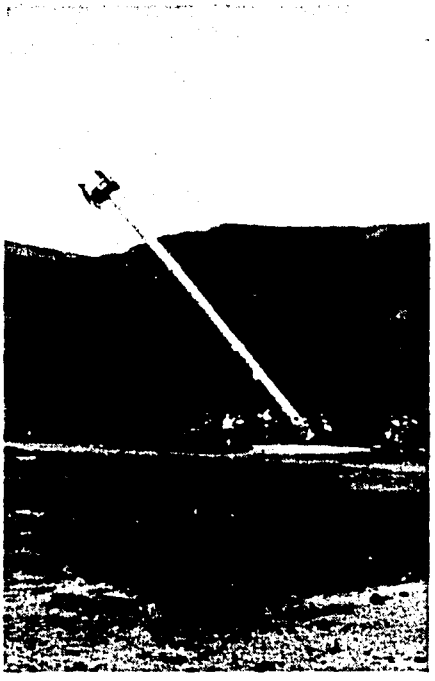
| Number | Title |
|---|---|
| 1. | Proposta de um projecto para electrificação do aeroporto de Sào Nicolau |
| 2. | Relatório da visita à ilha do Sal, dias 16 e 17 de Fevereiro de 1982 |
| 3. | Rapport des travaux effectués ces derniers mois |
| 4. | Relatório da visita técnica da Divisão de Energias Renováveis à ilha da Boa Vista de 12 a 16 de Abril de 1982 |
| 5. | Mission à l'île de S. Nicolau du 16/6 au 22/6/82 |
| 6. | Equipamento di furo FBE-2, Salineiro, Santiago |
| 7. | Equipamento do furo FT-5, Flamengos, Santiago |
| 8. | Rapport et chronologie des travaux de maintenance, Achada Baleia, AW 4100 FP7 |
| 9. | Equipamento do furo MF-2 em Figueira da Horta, Maio, para o abastecimento de água à Vila Porto Inglês |
| 10. | Progresso de trabalho na ilha de Santo Antão |
| 11. | Projecto integrado do Maio - Equipamento dos furos FM-23, MSP-13, MSP-2, e poço no. 63 - Discussão técnica |
| 12. | Funcionamento do sistema Aerowatt/Guinard na Achada Baleia, Santiago |
| 13. | Bomabgem eólica nas Ribeiras de Saltos, S. Miguel e Flamengos; Visita de avaliaçao de 15 a 17 de Setembro de 1982 |
| 14. | Visita à conferência internacional sobre energia eólica, em Stockholm, de 21 a 28 de Setembro de 1982 |
| 15. | Visites sur le tas au sujet de l'irrigation utilisant des éoliennes |
| 16. | Etat actuel des stations de pompage électrique |
| 17 | Bilan des projets financés par la Coopération française dans le domaine éolien et solaire 1980-1982 |

Table 8.3. - Technical notes of 1983 (Report XVI)

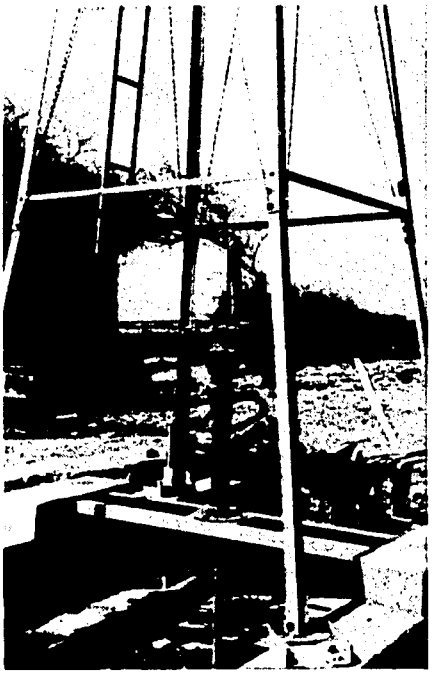
| Number | Title |
|---|---|
| 1. | Compra de aerobombas fabricadas em Cabo Verde |
| 2. | Visita técnica à ilha do Maio de 22 a 25 de Fevereiro de 1983 |
| 3. | Como obter a distribuição de frequências dos dados de MS778 utilizando o microprocessador AIM 65 |
| 4. | Equipamento do furo FT 223, Ribeirão Manuel |
| 5. | Equipamento de poço Ribeira de Saltos |
| 6. | Proposta para a instalação do protótipe |
| 7. | Estrutura de futura oficina da DER |
| 8. | As aerobombas na ilha de Santo Antão |
| 9. | Proposta e orçamento estimado para as instalações de novas aerobombas em Santo Antão |
| 10. | Relatório da visita de trabalho à Holanda, Dinamarca e Italia |
| 11. | Projecto de transformação da água do mar en água potável na ilha da Boa Vista |
| 12. | EMIDERI-I, the first locally constructed windmill by MDR-DER |

Table 8.4. - Technical notes of first semester of 1984 (Report XXIV)

| | |
|---|---|
| 1. | Tratamento dos dados da Estação Meteorológica do aeroporto da Praia com o AIM 65 para obtenção da distribuição de frequências |
| 2. | Visita à ilha do Maio |
| 3. | Mediçoes de rendimento de Dempster 8', São Filipe |
| 4. | Visita técnica para ilha do Sal |
| 5. | Visita téchnica par ilha de São Nicolau |
| 6. | Visita à ilha do Maio |
| 7. | Aerobomba para Salineiro |
| 8. | Aerobomba para Ribeirão Chiqueiro |
| 9. | Funcionamento de sistema "Elektro" |
| 10. | Final receipt report of equipment and material procured under project USAID 625-0937.03 |

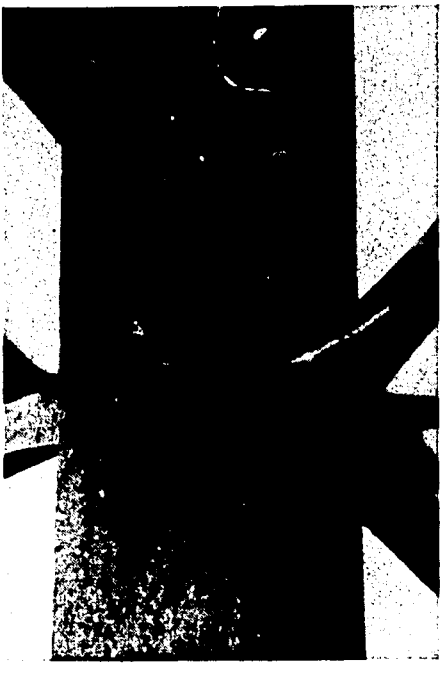


The erection of the Lagerwey and V.d. Loenhorst windmill



The pump of a Dempster windmill

Centering the windmill above the well



Severe corrosion problems

# PART TWO

## SOME IMPORTANT ASPECTS HIGHLIGHTED

In this Part Two some aspects of DER's work will be highlighted.
The aspects to be treated are:

| | |
|---|---|
| Chapter 9: | Technical aspects of operation and maintenance |
| Chapter 10: | Methodology of site selection |
| Chapter 11: | Some case studies |
| Chapter 12: | Elaboration of wind data |
| Chapter 13: | Performance measurements |

The technical background and analyses which form the basis of these chapters, should have been, ideally speaking, common knowledge to the national staff members by now. This is, however, only partly so, for the obvious reasons mentioned earlier.
It should be noted also, that during the last year remarkable progress has been achieved in this transfer of knowledge and that there is good prospect in continuing so in Phase 3.

The aspects are treated in a more or less illustrative way; i.e. more to show the reader what is the matter about, rather than completely justified presentations.

# 9. TECHNICAL ASPECTS OF OPERATION AND MAINTENANCE

## 9.1. Descrtiption of the mechanism of a windpump

The commercially available windpumps which DER installs can be divided into two types: the direct acting mills and the double geared mills, both driving a single-acting piston pump. In case of the former, the pump is directly coupled to the crank of the wind rotor. See Figure 9.1. This implies that one revolution of the rotor corresponds with one stroke of the pump.

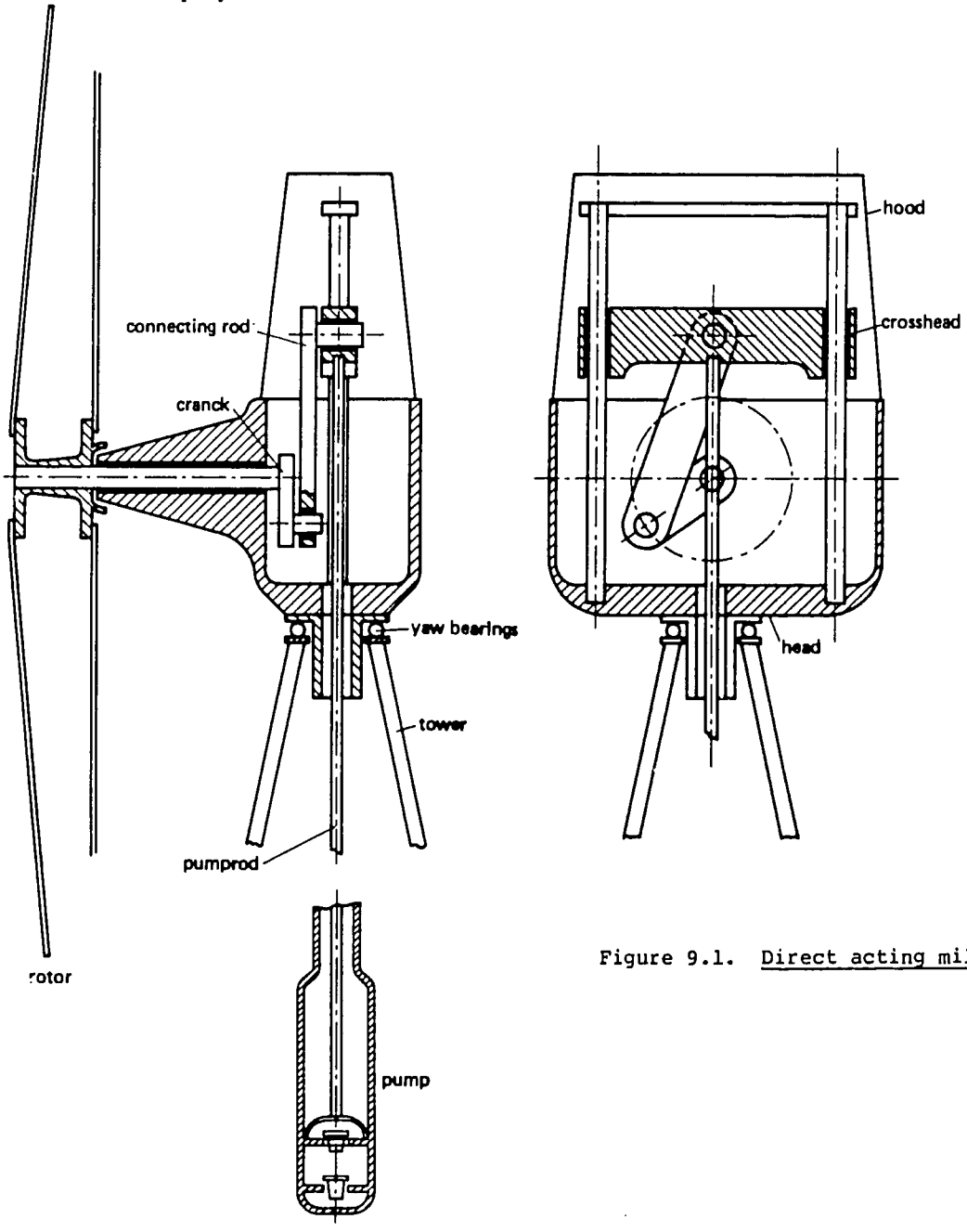
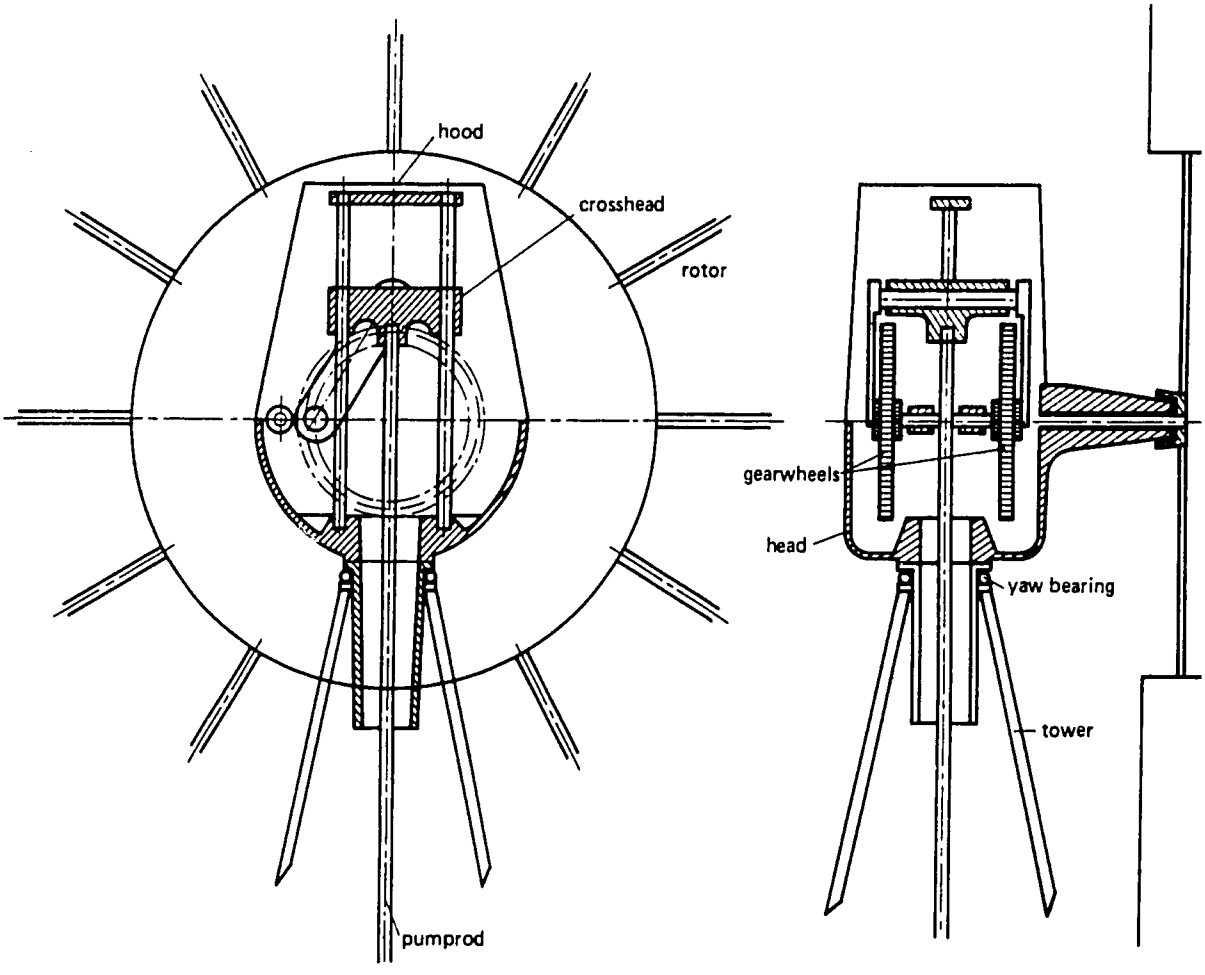



Figure 9.1. Direct acting mill

In case of the latter, the rotational speed is reduced with a ratio 3:1 by means of gear wheels. See Figure 9.2.



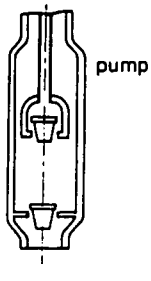




**Figure 9.2 Double geared mill**

The tip speed ratio of the windpumps is approximately equal to unity; this means that the optimal speed of the blade tips is the same as the wind speed independent of the rotor diameter. Mills with a smaller rotor diameter make more revolutions per minute; a reduction by means of gears is generally used for mills with a rotor diameter smaller than 17'.
As the piston pumps are mounted without airchamber, it is necessary to limit the pumprod forces. For all windpumps, the number of strokes per minute does not exceed 45 and in this way the forces remain limited. To achieve this maximum of 45 strokes per minute and to limit the axial forces acting on the rotor with high windspeeds, the rotor speed is regulated and limited by turning the rotor sideways. This is done either by means of an inclined hinged vane or an ecliptic control.
In the inclined hinged vane system, the excentrically (in relation with the tower centre) placed rotor balances the weight of the wind vane. See Figure 9.3. As the vane remains more or less parallel to the wind, by increasing wind speed the head is turned away and the vane has to turn around its inclined hinge and is thereby lifted. The weight of the vane provides the torque that balances the torque of the excentric rotor.

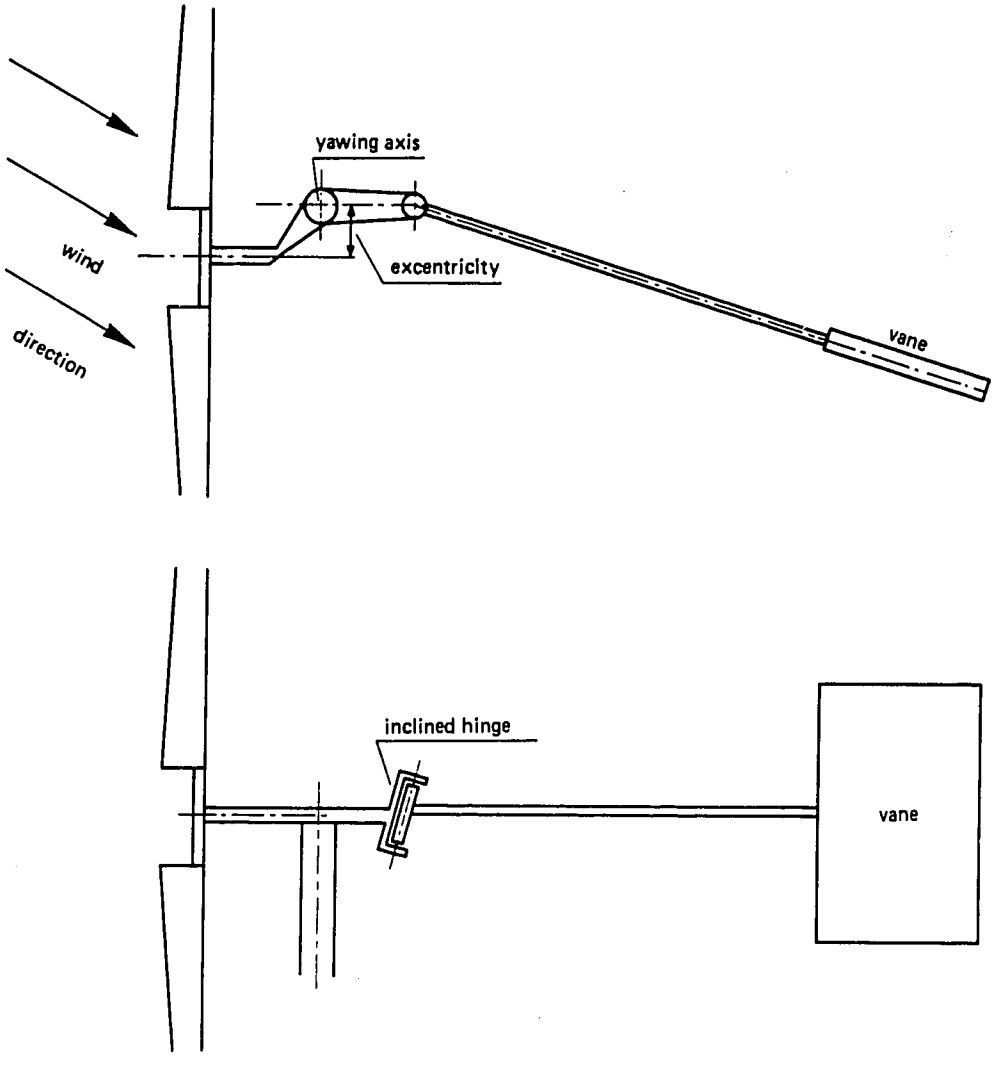



Figure 9.3 The inclined hinged vane system

The eccliptic control means that the excentric rotor balances a spring-loaded vane. In this case turning of the head, due to increasing wind speed, implies that the vane, staying parallel to the wind, is turned around its vertical hinge loading a spring and this causing the balancing torque. See Figure 9.4.

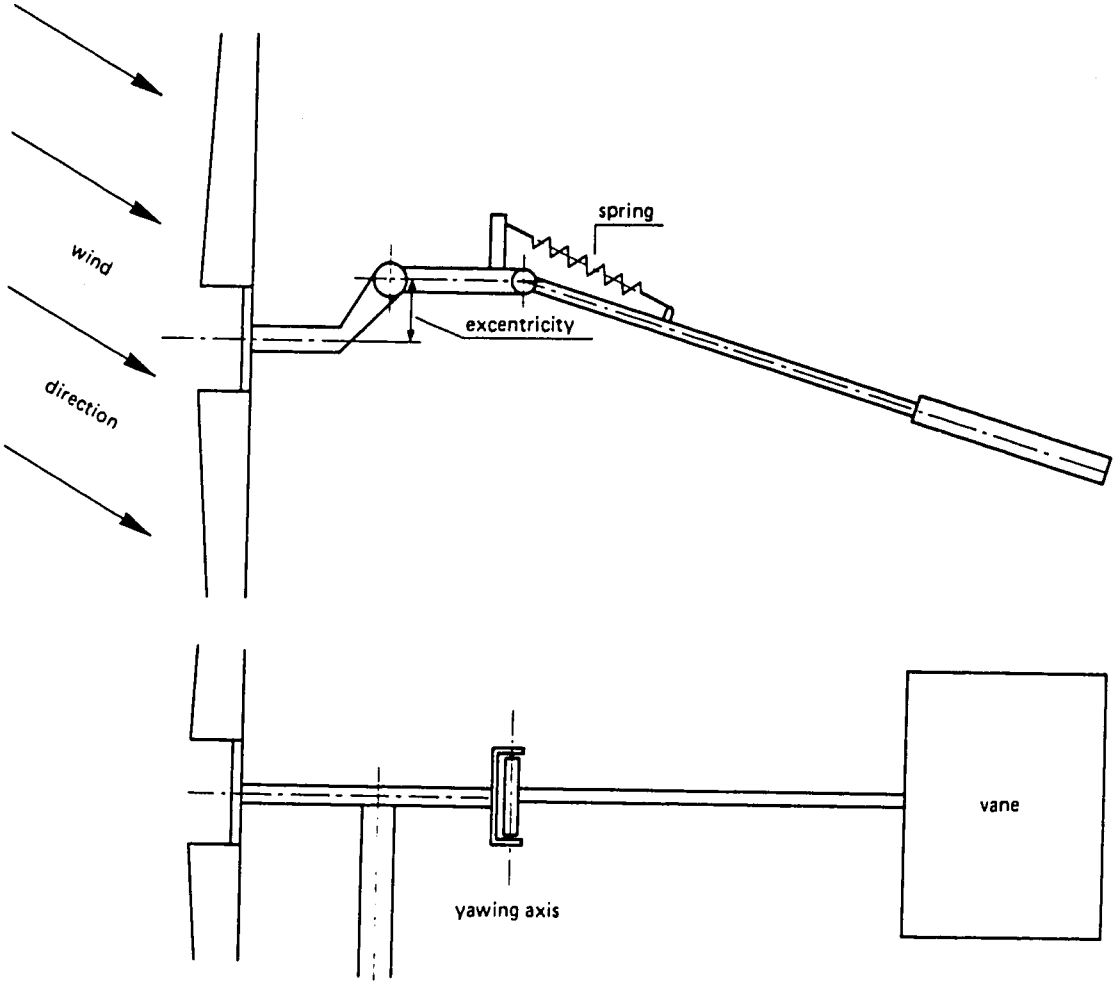



Figure 9.4. - Eccliptic control

## 9.2. The weak points

If well installed and regularly greased and lubricated, the windpumps have only one weak point: the leather pump cups have to be substituted when worn out. In case the reservoir is situated at a higher site than a mill, a pumprod sealing is necessary. This pumprod sealing wears out too and needs regular inspection.
Most problems occurred with the transmission, especially in the case of a pumprod sealing.
The following table presents causes and consequences.

Table 9.1. - Causes and consequences of problems in the moving parts

| | | |
|---|---|---|
| 1. | Bad alignment of windmill and borehole | Leather cups wear out rapidly at one side of the cup; the pumprod can unscrew itself; the pumprod connections wear out faster due to continuous beating to the rising main, especially during the upward stroke; the rising main wears out the pumprod connections; this can finally result in a split pipe or rupture if it concerns the threaded pipe end. |
| 2. | Poor construction of the pumprod causing bending and vibrations. In fact, a misalignment is created | The asbestos stuffing wears out too fast causing leakage through the sealing; bolts unscrew or loosen; in addition the same consequences as sub 1, but less. |
| 3. | A bad pumprod guidance | The asbestos stiffing wears out too fast causing leakage. |
| 4. | Corrosion due to atmospheric conditions<br>Corrosion due to brackish water | Rusting of rotor and tower, resulting in a shorter lifetime.<br>In case of a stuffing box the sealing rod corrodes, damaging the stuffing; corrosion of pumprods and rising mains. |

## 9.3. Actions taken to improve the weak points

The figures below show some of the solutions; however, bad alignment cannot be resolved. Only some measures can be taken to prevent the consequences partially.

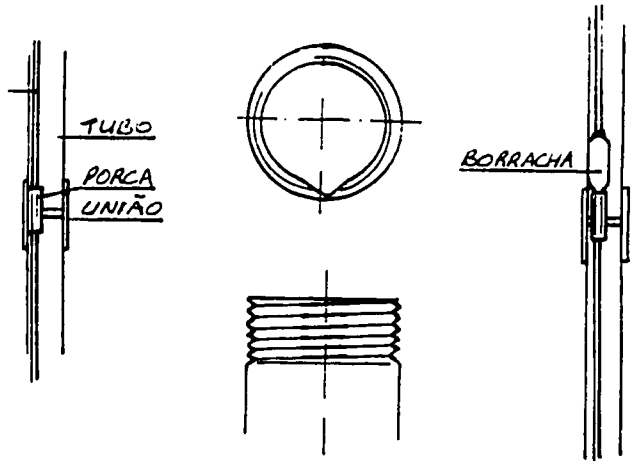



Figure 9.5. - Consequences and "solution" of bad alignment of windmill and borehole (Report XVIII)

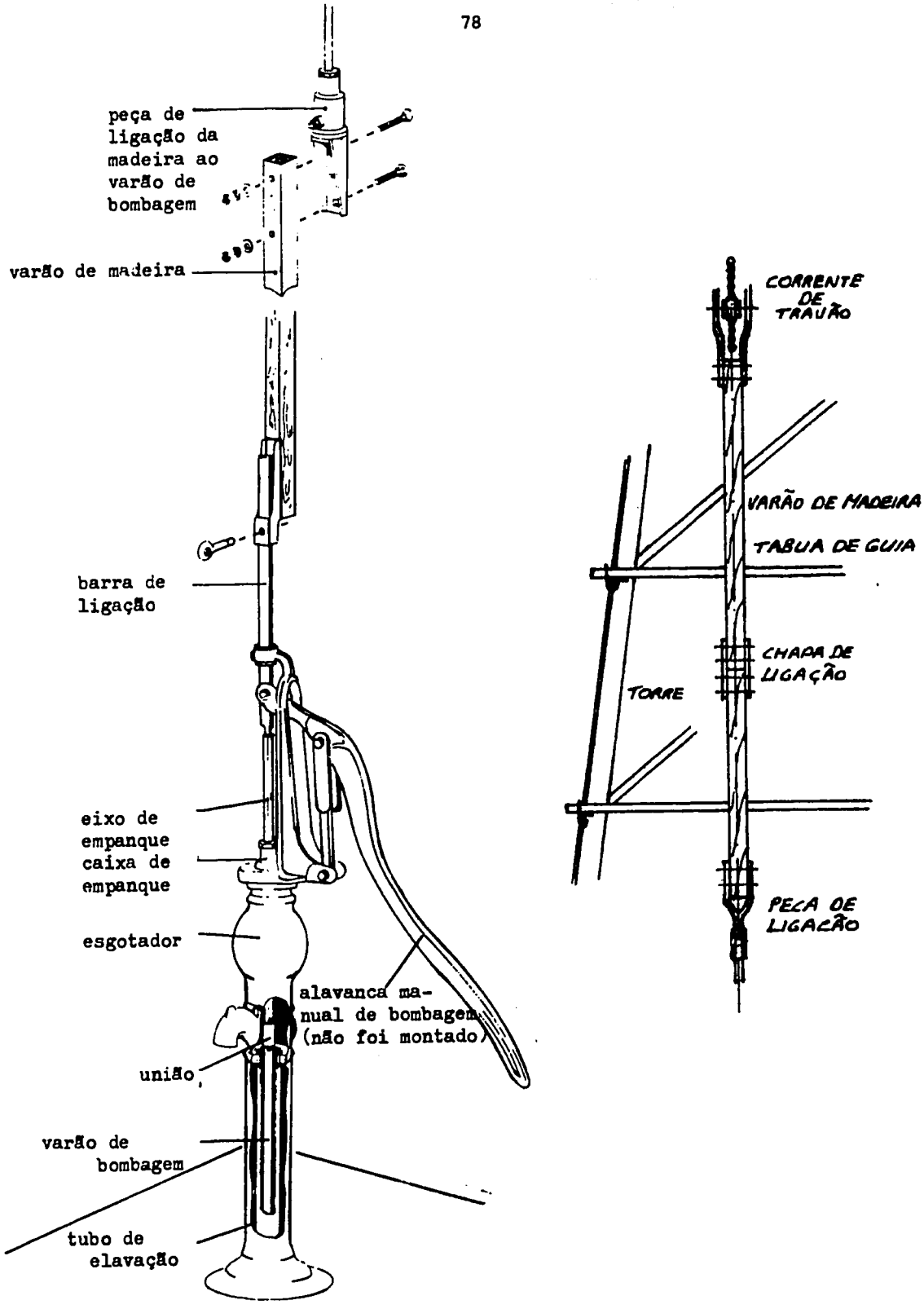



Figure 9.6. Pumprod connections of Dempster (left) and Southern Cross (right) (report IV and XX)

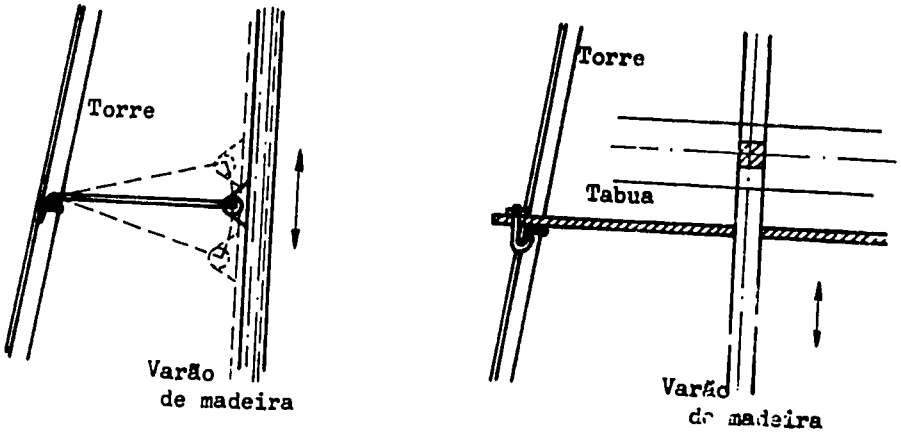



Figure 9.7. - Original pumprod guidance of Dempster and improvement Report IV)

When for some reason the pump has to be lifted, all components have to be inspected and replaced if necessary.
The original stuffing boxes of Dempster proved to be sensitive to slight displacements and corrosion; they require daily inspection as the stuffing can wear out very rapidly causing loss of water. It can be fully prevented by using bornze counterpistons

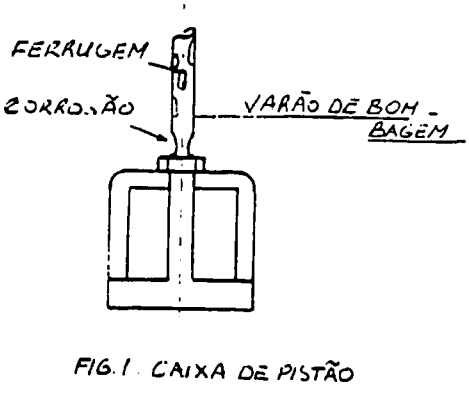
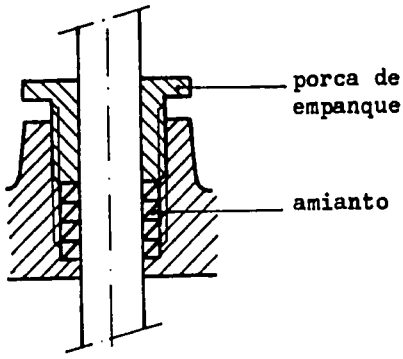



Figure 9.8. - Effects of corrosion on rising main (Report XVIII)




Pormenor de
empanque

Figure 9.9. - Dempster stuffing box

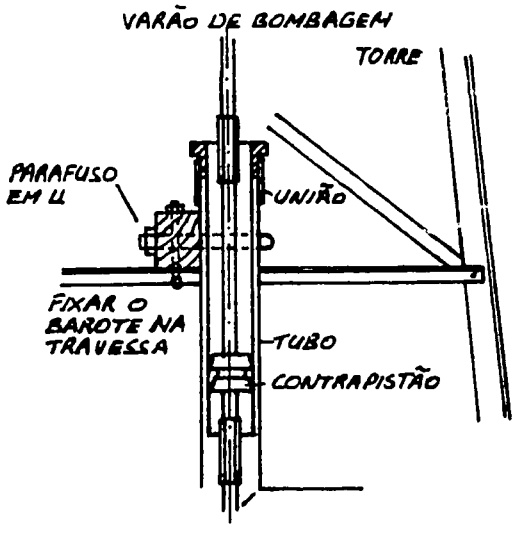
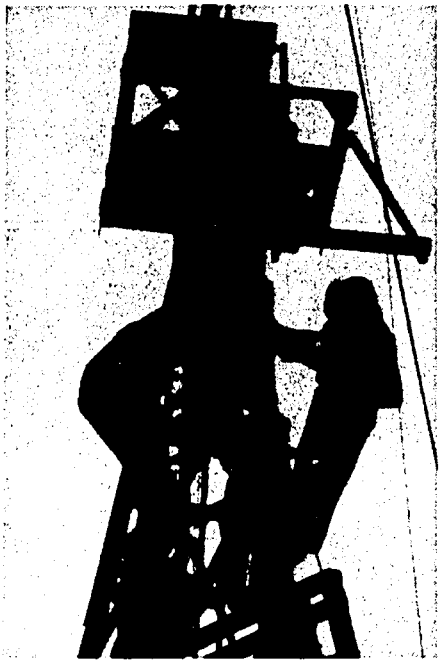


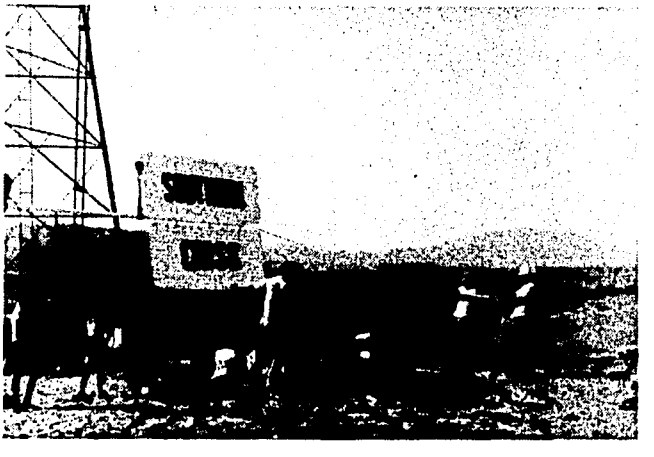

Figure 9.10. - Counterpiston used by Southern Cross



A windmill under construction

The mounting of a Dempster vane

The installation of a pump



The vane of a Socross hoisted

# 10. SITE SELECTION

Note:
This chapter is a summary of Report XXI, without the technical details.

## 10.1. Site selection process

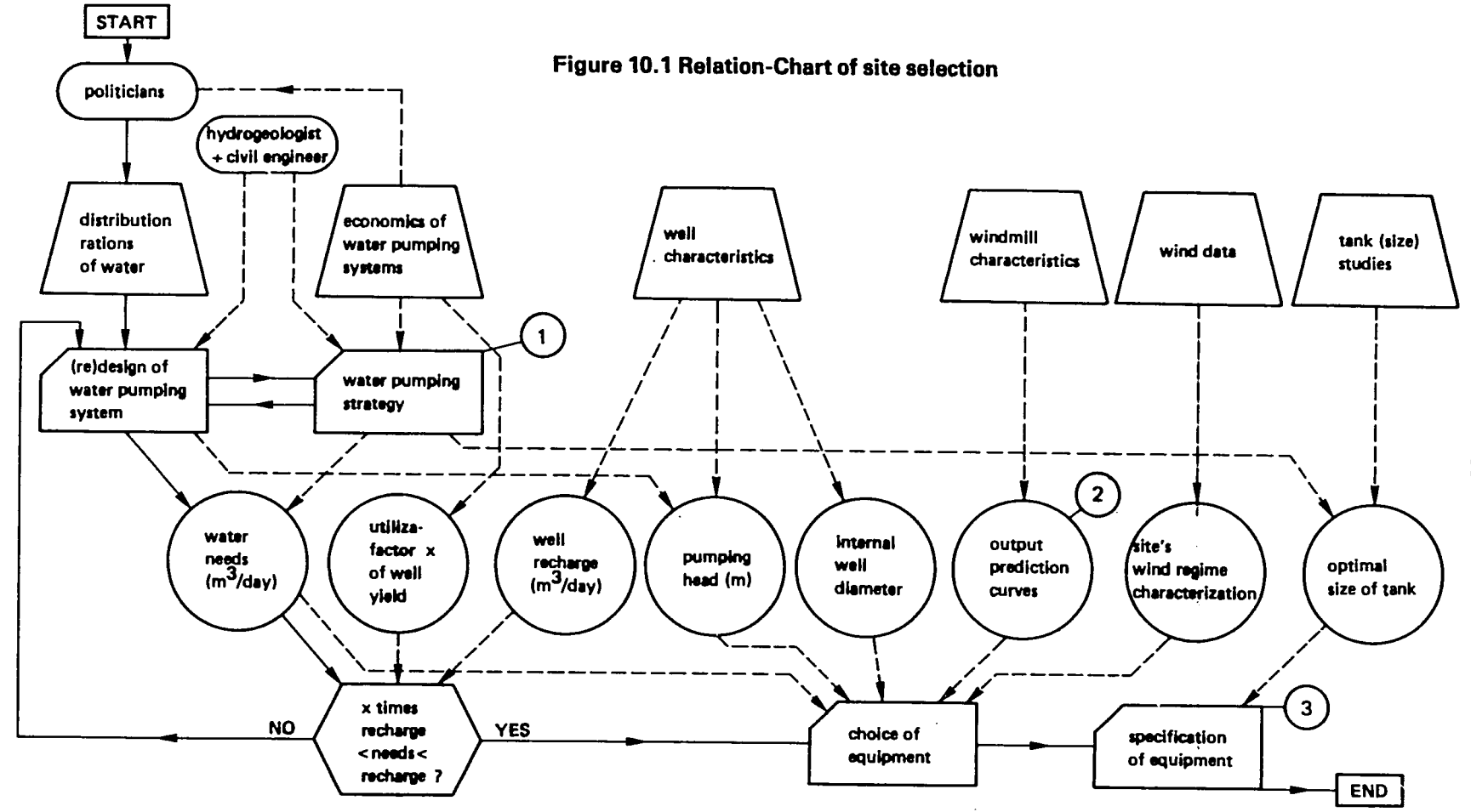
The following aspects play a role when one investigates which equipment should be used at a certain site:
- water distribution rations determined by the competent authorities
- economics of water pumping systems
- (tube)well characteristics
- windmill characteristics
- wind data
- tank (size) studies

The first step is to design the water pumping system and determine the water pumping strategy; this is to be done by the hydrogeologist, the civil engineer and the pumping equipment specialist together.
Then the following factors are obtained:
- water requirements
- utilization factor of maximum well yield
- well recharge
- pumping head
- internal well diameter
- windmill output prediction
- wind regime characteristics of the site
- optimal size of tank

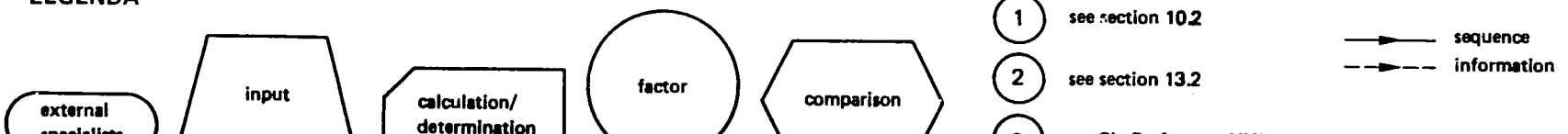
The process finally leads to the choice of equipment (windmill, wind generator or motorpump and size) and the equipment specification (pump diameter, stroke volume, size of canalization, tank size, etc.).

Figure 10.1. presents the relation chart of the site selection process.

**Figure 10.1 Relation-Chart of site selection**




LEGENDA



## 10.2. Water pumping strategies

The relation shows that another important element in the site selection process is the determination of the water pumping strategy; or in other words: what is the most sensible way to use the water from a certain well? On Cape Verde, practically every situation has its own pecularities; nevertheless, a distinction can be made between four:

a. Water pumped from Achada subsoil should primarily be used for the drinking water supply. Figure 10.2. gives the outline.

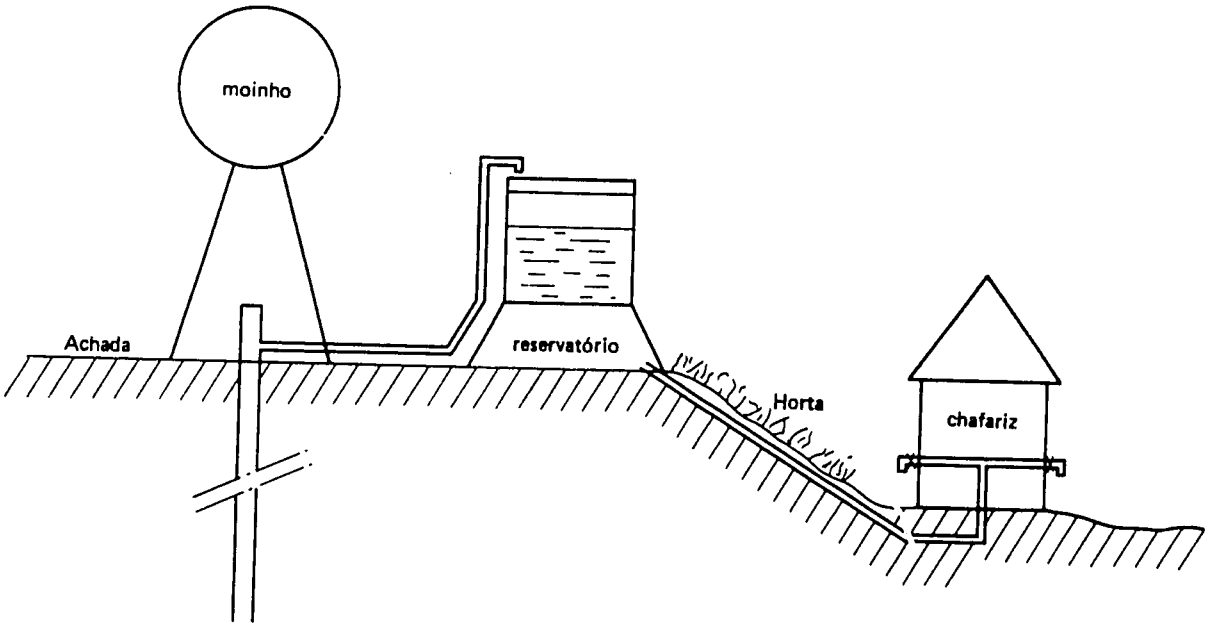



Figure 10.2. - Strategy A

As the output of a windmill in the Achada wind regime varies to a large extent during the year (see Figure 10.3.), more water will be pumped than consumed during the (9) windy months of the year. This water can be used for very small-scale irrigation.
The design windspeed choice lies preferably around 4.5 m/s to ensure availability during the less windy months. If the stroke of the mill can be varied, this can be utilized in the following way: small stroke in the light wind season (July through September), large stroke during the rest of the year.

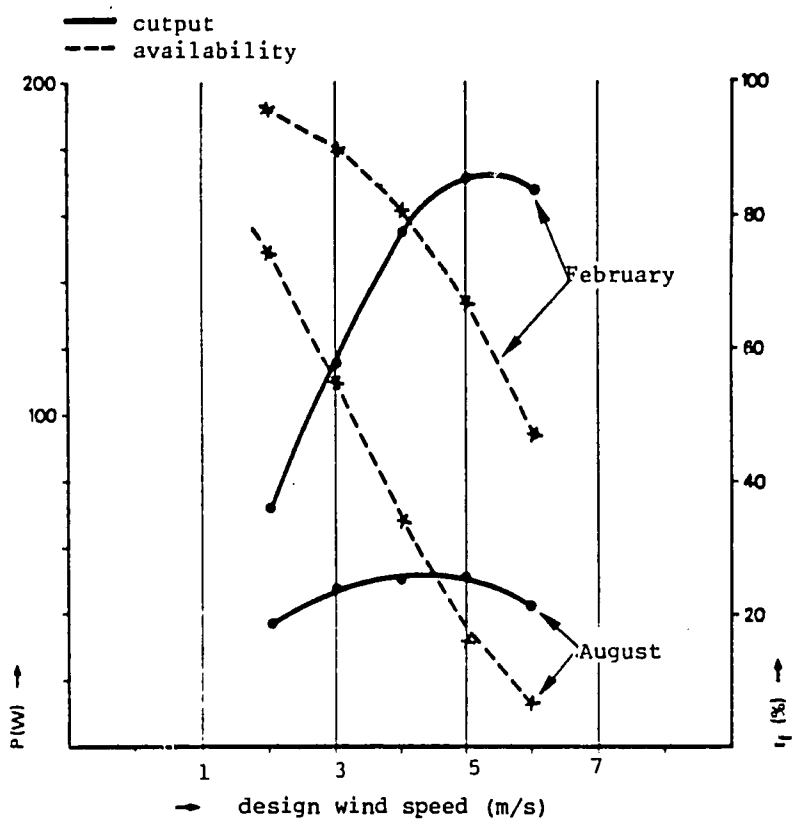



Figure 10.3. - Typical relations between output and availability for the different wind seasons of the Achada wind regime and the influence of the design windspeed. (Figure from Report VI)

b. Water pumped from Ribeira subsoil will in most cases also be used in the Ribeira.

In the Ribeira's it is very advantageous to combine irrigation and drinking water supply, i.e. use the same pumping equipment for both end uses. The reasons are:

- In the rainy season with less wind, there is no need for irrigation; all the water pumped can be used for the drinking water supply.
- The quantity of drinking water is, in general, only a few percent of the irrigation needs; with relatively few extra costs (drinking water tank, tap house) one can solve the drinking water needs in that area.

  The design wind speed is generally chosen around 4 m/s, as this will be in most cases the mean annual wind speed.

  Figure 10.4. presents the basic outline.

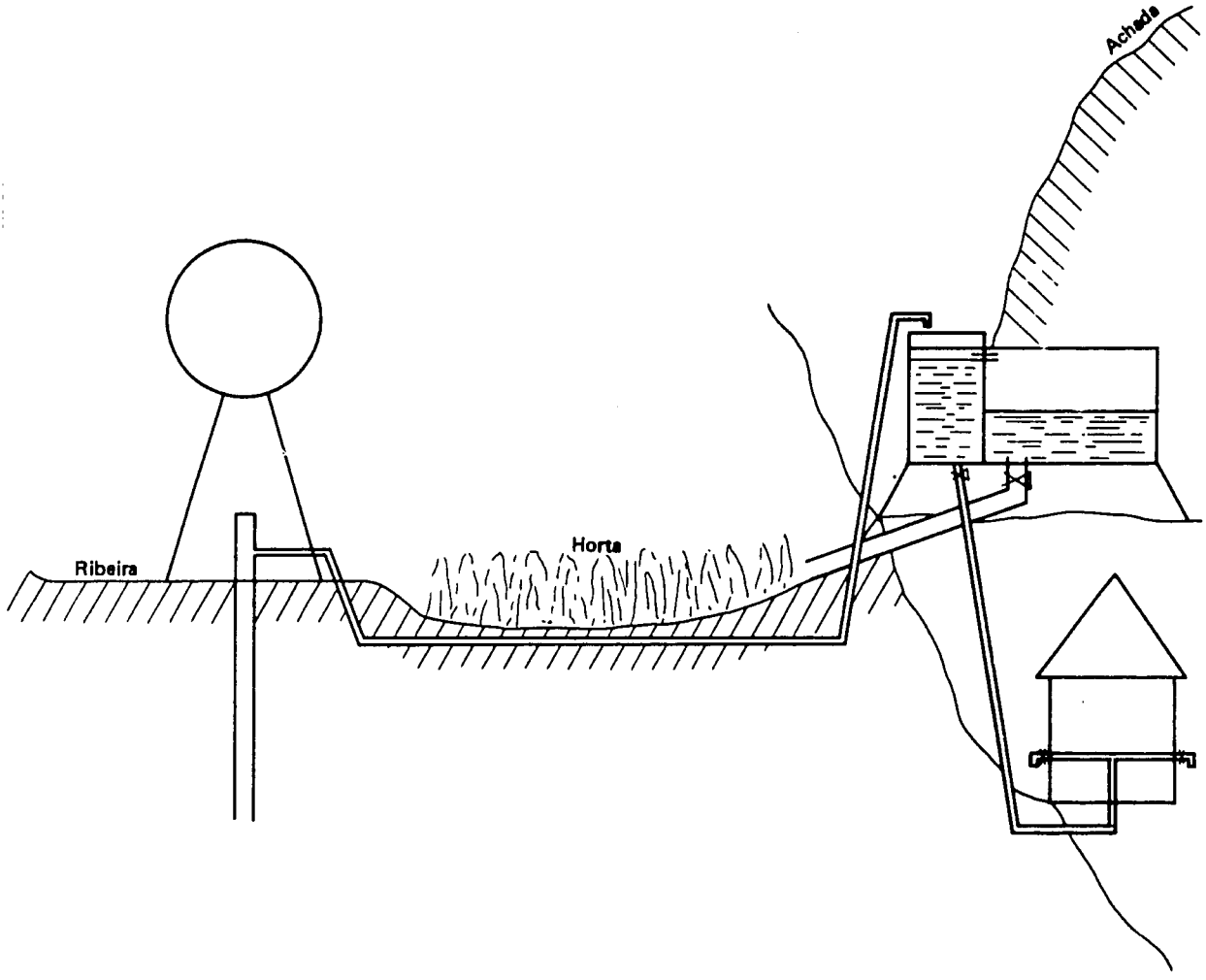



Figure 10.4. - Strategy B

c. In some situations it will be necessary to pump water from Ribeira's to Achada's for drinking water supply. It is (again) advantageous to combine this with irrigation pumping in the Ribeira's. See figure 10.5.

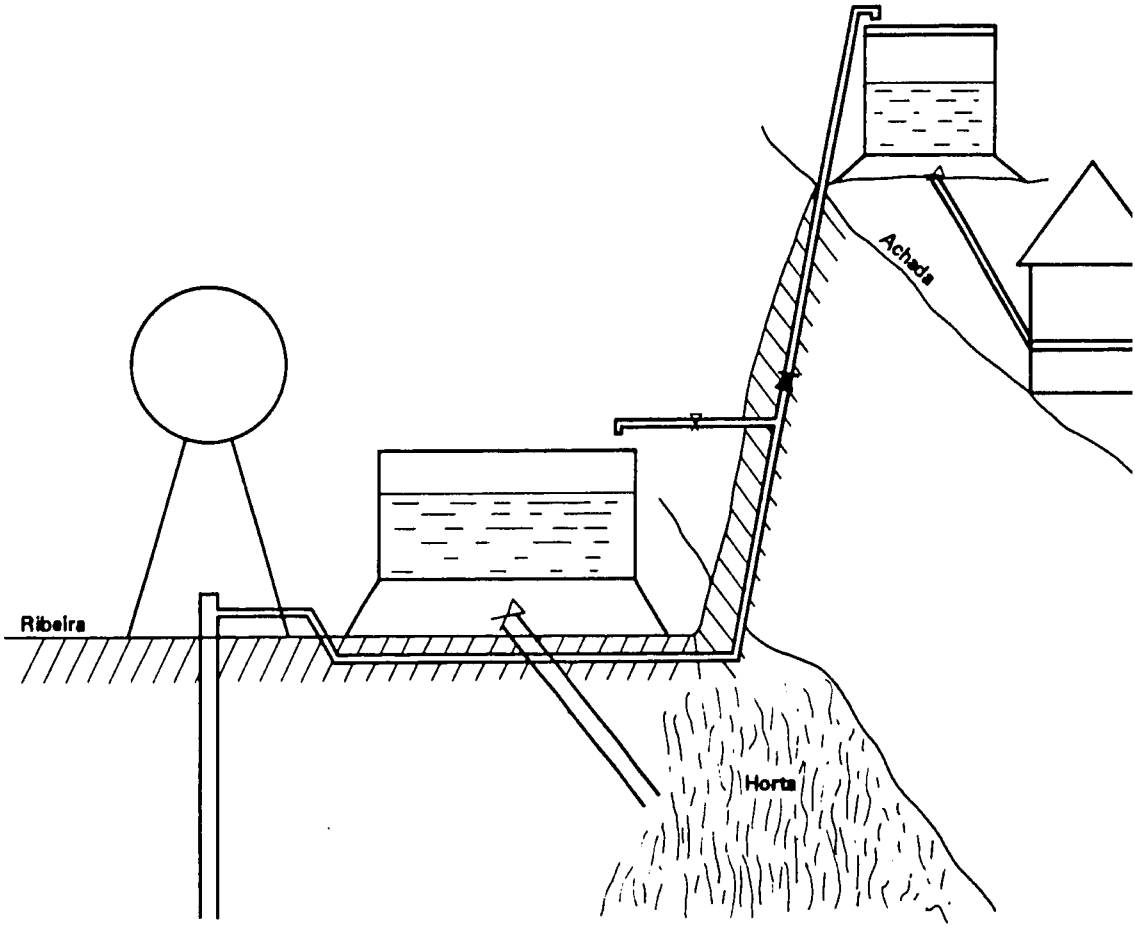



Figure 10.5. - Strategy C

The only difference with strategy B is that the pumping head for drinking water supply is different from that for irrigation. To be on the safe side, one could choose the stroke volume which belongs to the highest pumping head. Another, probably more efficient way, is to choose the stroke volume larger (than the one belonging to the Achada pumping head) and have the guard make use of the hours with more than average wind speed, by pumping water to the Achada. It should be noted here that the Ribeira's almost certainly have lower k-values than the Achada's.

d. The same as strategy B of C, but now the equipment is a combination of windmill and motorpump. This is only possible in case of shallow wells and only necessary when the well yield is larger than the amount that can be pumped with the largest windmill. (If this occurs with tube wells, a wind generator should be used).

The choice of equipment is done with DER output prediction curves: Figures 13.8. and 13.9. of this report.
Two examples of site study reports are presented below; the first was written in July 1982, the second in May 1984.

## 10.3. Technical Note E.R., 13 July 1982

Equipamento do Furo FT 5, Flamengos - Santiago
Niko Pieterse - DER/MDR - July 1982

### 1. Introduction

The equipment of tube well FT 5, in the Ribeira of Flamengos, with a windmill Dempster 8', has been scheduled for more that a year now. The civil works (tank, tap house) have been completed recently. In July 1982 the windmill installation will take place.
This note presents the technical justifications.

### 2. Well data and water needs

Tube well FT 5:
Drilled in 1973
Depth: 70 m
Drain from 8 to 36 m
Internal diameter of casing is 150 mm
Static water level: 7 m (1973)
The pumping test of 24 hours with a yield of 4.33 $m^3$/hour provoked a drawdown of 6 m; the recuperation was very good (1973)

The water needs (drinking water supply) are approximately 15 $m^3$/day.
The pumping head is about 22 m, of which 12 above groundlevel.

### 3. Aeolic evaluation of the site

Tube well FT 5 is situated some 10 metres from shallow well no. 8, in the Ribeira of Flamengos.
The site is very well exposed to the north-east, the prevailing wind direction and also the direction of the Ribeira. The only obstacles are the crops, with heights lower than 2 m. So, the site is suitable for a windmill installation.

## 4. The wind regime

Situated in a Ribeira which runs to the north-east, approximately 4 km from the sea, the wind regime at the site is the typical Ribeira regime, as described in the report by Jos Beurskens, "Wind energy for water pumping in Cape Verde", pages 4-10.
So, the mean wind speeds are 0.7 times those of the meteorological station of Praia airport and the wind speed distribution is identical to the one at Praia (estimates by Beurskens).

## 5. The equipment

By using the results of Ref. 10 and Report VI, it is possible to estimate the mean daily yield for every month. One has to admit that the daily yield of a Dempster 8' is rather low in August: only 6 $m^3$/day. (Note: August has the least favourable wind speed distribution - see Report VI).
Together with the Director of Rural Improvements, it was then decided to use a 14' Dempster.
Below a table is presented with the results of the calculations carried out in accordance with the method of Report VI; the pumping head is 22 m.

Table - The monthly yields of a 14' Dempster in Flamengos

| Month | Yield s/$m^3$/day) | | |
|---|---|---|---|
| | Stroke vol. 1.26 I ($V_{start}$ = 3 m/s) | Stroke vol. 1.39 I $V_{start}$ = 3.16 m/s) | Stroke vol. 2.23 ($V_{start}$ = 4 m/s) |
| January | 23.0 | 25.5 | 37.1 |
| February | 25.1 | 27.7 | 41.0 |
| March | 25.7 | 28.4 | 42.6 |
| April | 24.5 | 27.0 | 39.8 |
| May | 27.0 | 29.8 | 44.1 |
| June | 21.4 | 23.6 | 32.8 |
| July | 13.8 | 15.2 | 18.7 |
| August | 12.9 | 14.2 | 17.5 |
| September | 12.9 | 14.2 | 18.4 |
| October | 20.2 | 22.3 | 30.9 |
| November | 19.9 | 22.0 | 30.3 |
| December | 21.1 | 23.3 | 33.1 |

A stroke volume of 1.39 l has been chosen, so a pump with an internal diameter of 3" and a stroke of 12". If in the future it should be necessary to increase the yield, this can be done with a pump of 4". It is clear, that also the tank size should then be increased. As the tank entry lies 12 m above ground level, it is necessary to use a southern Cross counterpiston as pump rod sealing (see Report IV).

6. Conclusion

Tube well FT 5, Flamengos, Santiago, can be equipped with a 14'Dempster, driving a pump of 3" diameter and a stroke of 12".
The mean daily yield is estimated at 23 $m^3$/day, with a maximum of 30 $m^3$/day in the month of May and a minimum of 14 $m^3$/day in August.

## 10.4. Technical Note E.R. August 1984

Windmill for Ribeirão Chiqueiro

Niko Pieterse
David António Cardoso DER/MDR May 1984

1. Introduction

In this note the justification of the equipment choice for Ribeirão Chiqueiro is presented. In May 1984 the Ground-water Department carried out a pumping test on the tube well, no. FBE 53; this test was analysed in "Interpretation of the pumping test on tube well FBE 53", DSEGAS, Emanuel Monteiro.

2. Well data

Tube well FBE 53:
Drilled in October 1983
Depth: 136 m (114 m)
Static level: 99.96 m
Dynamic level: 100.00 m with 5 $m^3$/hour after 24 hours
The vertical difference between tank and top of tube well will be less than 1 metre (tank to be constructed).
The pumping head will consequently, be, about 105 m.

3. Water needs

As this tube well is relatively good, it is convenient to pump as much as possible out of it.
The drinking water needs for the population do not exceed 10 $m^3$/day. We suppose that also Variante will use this water; their needs are also 10 $m^3$/day at the most.
The rest of the pumped water can be used for irrigation.

4. The wind regime

The site is known for its favourable wind regime.
DER measured the wind speed at the site on a 12 m high pole during January through March 1984, with a WP 4000 wind run metre.

Table - The relation between wind speeds at Ribeirão Chiqueiro and Praia

| Month | $V_{Praia}$ (m/s) | $V_{Rib.Chiq.}$ (m/s) | $\frac{V_{praia}}{V_{Rib.Chiq.}}$ | Correlation factor r |
|---|---|---|---|---|
| 1. During the night (18 pm - 6 am) | | | | |
| January | 9.39 | 9.23 | 0.98 | 0.70 |
| February | 6.64 | 6.87 | 1.03 | 0.72 |
| March | 6.46 | 6.90 | 1.07 | 0.82 |
| 2. During the day (6 am - 18 pm) | | | | |
| January | 10.50 | 8.26 | 0.79 | 0.81 |
| February | 8.82 | 6.78 | 0.77 | 0.61 |
| March | 8.21 | 7.60 | 0.93 | 0.76 |
| | | Mean: | 0.93 | |

The analysis of this table makes us conclude that wind speeds during the night seem to be slightly higher at Ribeirão Chiqeiro, while the opposite seems to be true for the daytime. The average of the relation between Praia and Ribeirão Chiqueiro being 0.93, the conclusion that we can use the output graph for the Achada wind regime is justified.

## 5. Equipment choice

We have chosen the most powerful windmill DER has at the moment: a Southern Cross 25'. The pumping head being 105 m, the average daily output will be about 70 $m^3$/day with a pump of 3" diameter (see Report XXI). In the piston a starting hole of 1.5 mm will be made to facilitate starting.

# 11. TWO CASE STUDIES

## 11.1. Achada de São Filipe

In 1977, Achada de São Filipe, at 6 km from Praia, was a complete desert where only sand and stones could be seen.
Now, in 1984, thanks to the reafforestation programme and the water pumping activities of DER, the Achada de São Filipe has a totally different outlook now. See photos.
The water pumping system on São Filipe is outlined in Figures 11.1. and 11.2.

### Description

The prototype CWD 5000 and Southern Cross 25' normally pump into the large reservoir (300 $m^3$), which is an open tank for pressure irrigation, an experiment of the Centre of Agraric Studies of MDR. The experiment has, however, not yet begun. Possible irrigation area is about 2.5 ha.
The Dempster 14' pumps into a drinking water tank of 50 $m^3$. From there, water goes by gravity to:

- the food crop protection storehouse
- MDR offices and DER workshop
- tree nursery of FAO-reafforestation project
- the second drinking water tank of 40 $m^3$

The Dempster 8' pumps into the drinking water tank of 40 $m^3$, from where water flows by gravity to the village of São Filipe (two tap houses) and to a cattle drench.
The Southern Cross and the prototype can also be connected to the drinking water tank of 50 $m^3$.

### Water needs

- 2.5 ha of irrigation (100 $m^3$/day)
- about 100 persons in offices and workshop
- water for civil works (DER windmill foundations, dams (rural improvements) or other (FAO)
- tree nursery of FAO (about 5 $m^3$/day during 5 months of the year)
- 500 persons in São Filipe (12.5 $m^3$/day)
- unknown and very variable number of cattle

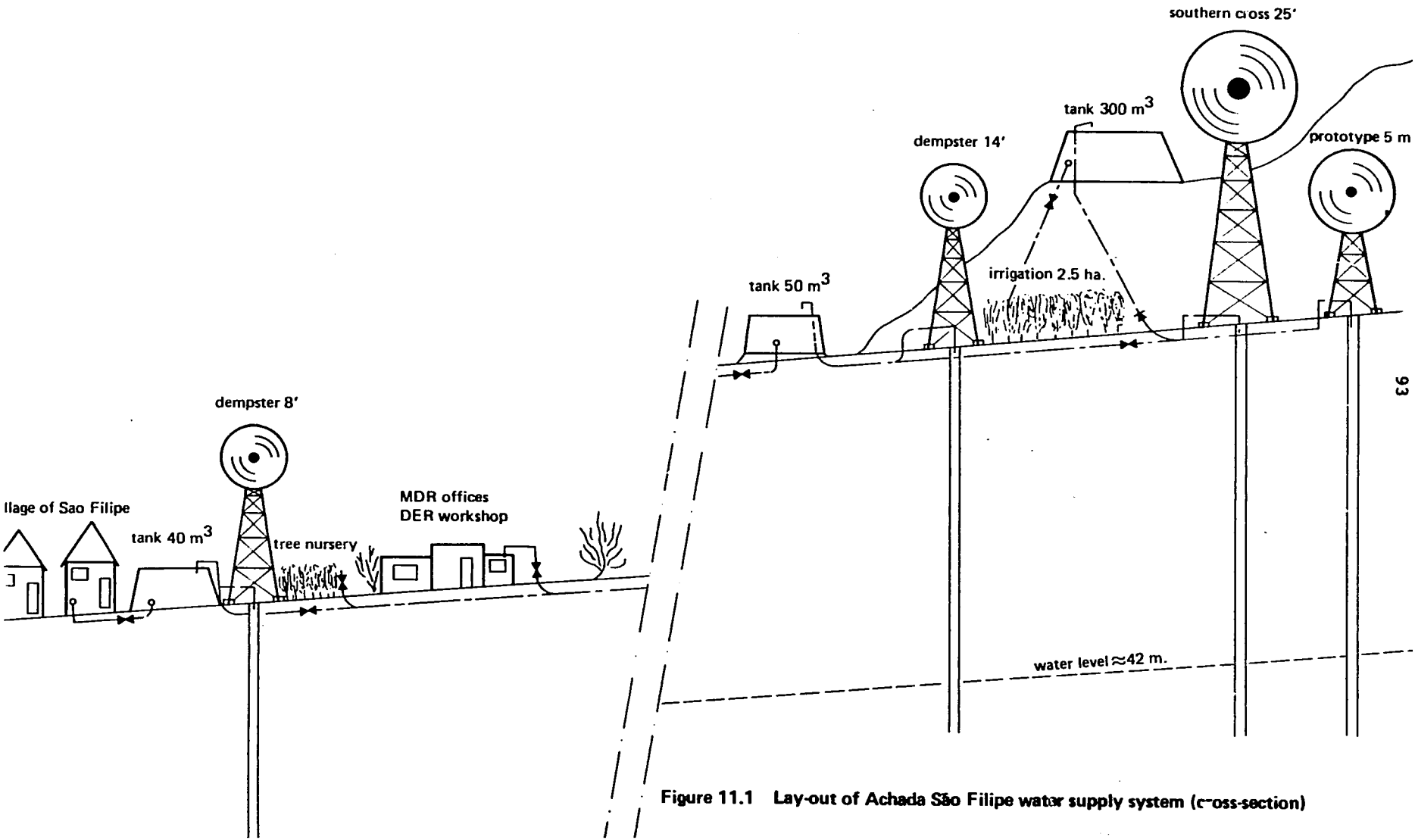



Figure 11.1 Lay-out of Achada São Filipe water supply system (cross-section)

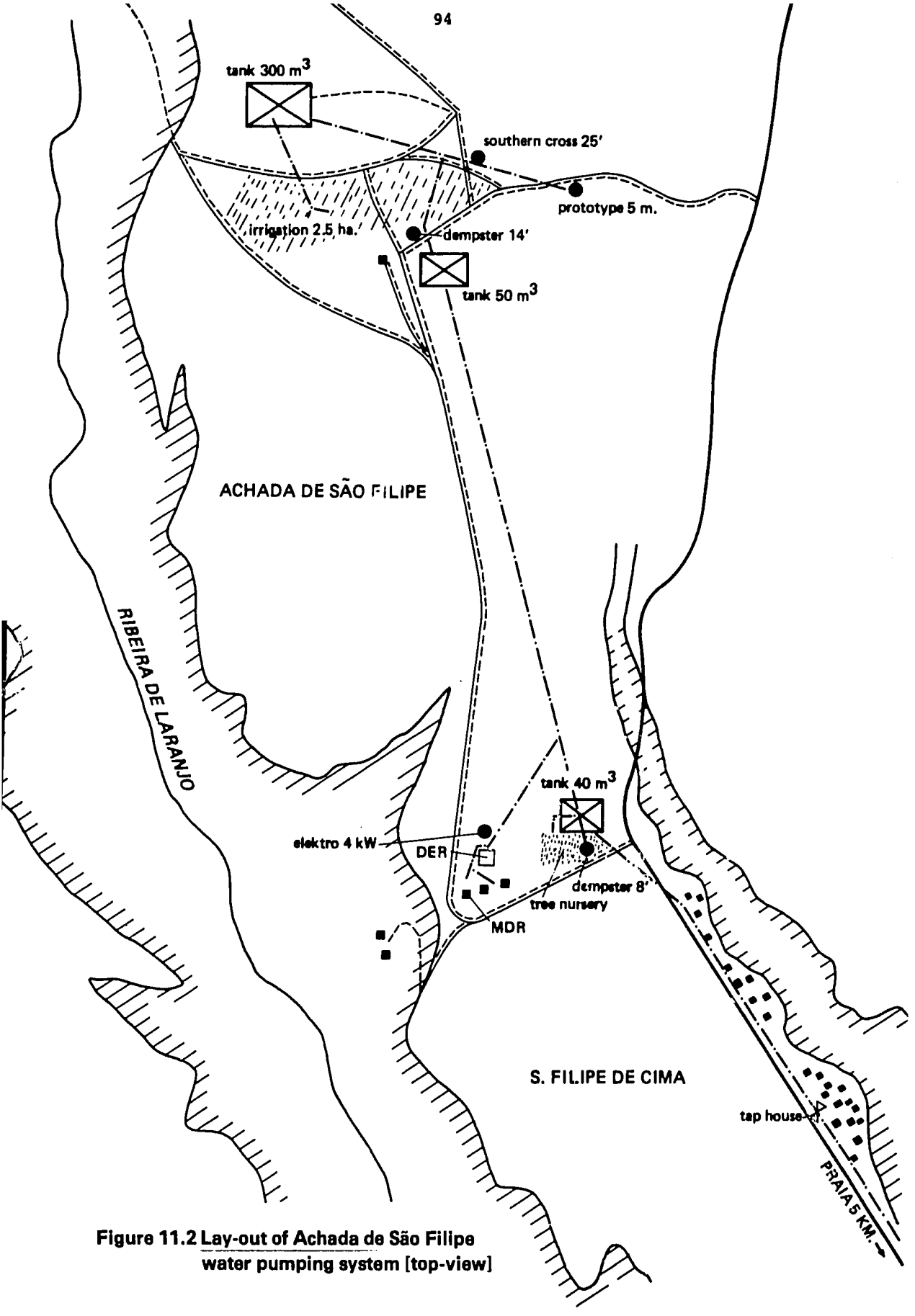



**Figure 11.2** Lay-out of Achada de São Filipe water pumping system [top-view]

Pump capacities (see Figure 13.8.)

| | | |
|---|---|---|
| Southern Cross 25' | : | 95 $m^3$/day with 75 m pumping head (to the large tank)<br>105 $m^3$/day with 50 m pumping head (to the 50 $m^3$ tank) |
| Prototype 5 m | : | in theory 75 $m^3$/day, but as the mill is experimental, it is not always operational (modifications) |
| Dempster 14' | : | 36 $m^3$/day (50 m pumping head) |
| Dempster 8' | : | 14 $m^3$/day (40 m pumping head) |

Water pumping strategy

The Southern Cross and prototype have been designed for a pumping head of 75 m; so when they are connected to the 50 $m^3$ tank (50 m pumping head), they operate with a low design wind speed and will start pumping even with low wind speeds. This happens especially in the rainy season when no irrigation water is needed. They can then help the two Dempsters with the drinking water supply. Consequently, the Dempsters have been designed with relatively high design wind speeds, to profit the most from the favourable Achada wind regime during nine months of the year.
As there is a connection between the tank of 40 $m^3$ and the one of 50 $m^3$, the Dempster 8' can receive support from the three other mills.
This system has been in operation (in this configuration) for more than a year now; water has only be lacking for two days in the entire period, when two mishaps were encountered: almost no wind and the Southern Cross under repair.

## 11.2. Achada Baleia

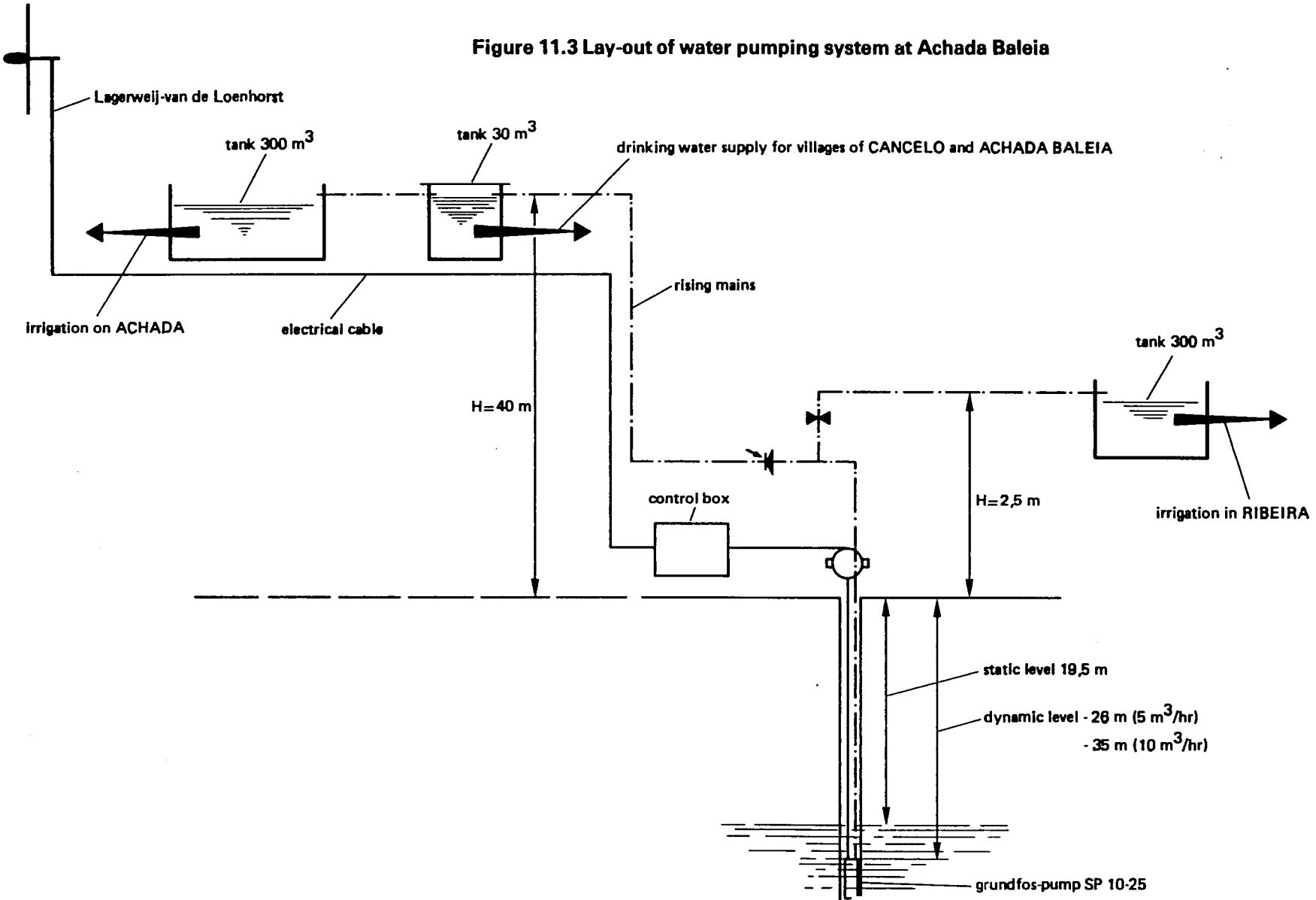
In September 1981, a wind generator AEROWATT 4100 FP7 was installed on Achada Baleia; it drove by means of an electric transmission and a control box, a submersible pump into tube well FT 25 (in Ribeira de S. Domingos). See system layout in Figure 11.3.
Due to various technical problems (described in 3.2.) the system has only been in operation intermittently, in total for not more that a year. The wind generator is out of order now and will be replaced in September 1984 by a Lagerweij-Van de Loenhorst wind generator, financed by the CWD project.

Description

Water is pumped either to the Ribeira or to the Achada; this is controlled by a single valve.
On the Achada, the end use of water is two-fold (from two tanks):
- drinking water supply to the village Cancelo (approximately 400 persons
- water for irrigation not yet commenced due to the various breakdowns

In the Ribeira the water is pumped to a tank for irrigation purposes. The amounts of water lifted should have been 125 $m^3$/d when pumping to the Achada and 225 $m^3$/d when pumping to the Ribeira, but this was never achieved.

**Figure 11.3 Lay-out of water pumping system at Achada Baleia**



Mr. Cardoso explains to a reporter on the television the functioning of an anemometer

The computer to elaborate the winddata

The first water from a new installed windmill

The site selection team

# 12. ELABORATION OF WIND DATA

Note:
All data mentioned in this chapter come from Report XVII or VI.

## 12.1. Equipment

DER uses maximum WPA-10 anemometer cups, to be used either with the Aeolian Kinetics WP 4000 wind run meter, or with the MS 778 automatic data registering unit of the same make.
The anemometer is installed on top of a 10 m pole; this pole consists of one 6 m long, galvanized gas pipe of 1¼" and another of 1". The pipe of 1" enters into the one of 1¼" for a length of 2 m; the pipes are bolted to each other. The pole is guyed with twice 3 nylon ropes, at 6 and 10 m height. Three (mobile) concrete blocks serve as attachment points for the ropes and one as base of the pole. See figure 12.1.
The equipment can be (re)installed by a team of 6 persons.

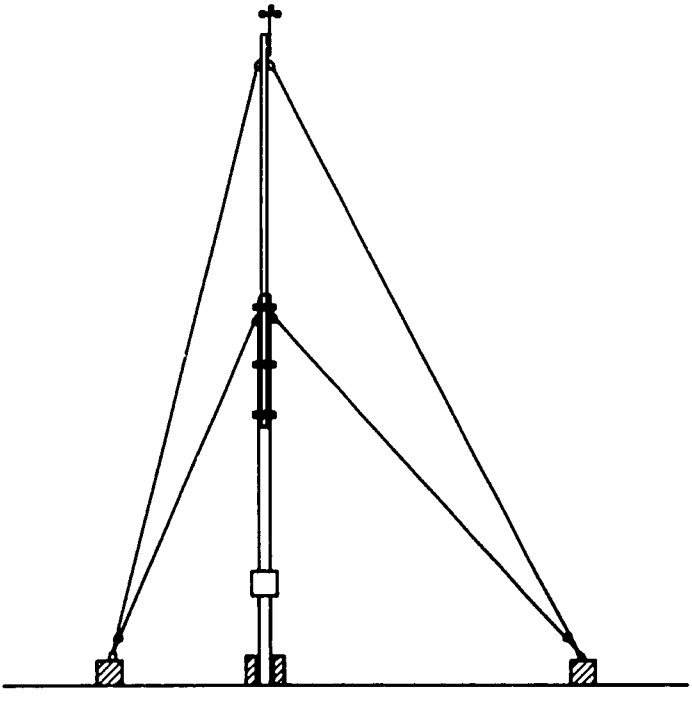


Figure 12.1. - Mobile wind measuring station of DER

Readings of the WP 4000 are taken twice a day by a guard; normally at 6 am and 6 pm. In the office the diurnal and nocturnal wind speeds are calculated and tabulated. The MS 778 is used by DER to measure hourly wind speeds.

It has 2048 memories, so enough for 85 days. Every 85 days the data are taken from the MS 778 by the Rockwell ATM 65 microprocessor (adapted by Aeolian Kinetics) and saved on cassette. The AIM 65 has so-called user's programmes to do so. Elaboration of data, again, takes place at the DER office; the monthly frequence distribution (including mean wind speed and energy pattern factor) and diurnal and nocturnal wind speeds are calculated. Results are printed on paper by the AIM 65. The elaboration programmes have been developed by DER. In the following sections some examples and results are presented.

## 12.2. Praia airport

The hourly wind speeds are introduced to the AIM 65 by hand via the keyboard. The data are saved on cassette, month by month.
The monthly frequency distribution is calculated with the AIM 65, using a programme developed by DER. The text of the programme is presented below:

Identification: PRAIA
Saved on cassette no. 3, side A, revs. 195-201
Language: BASIC

```
10 DIMKL(40)
50 VG=0:VCUB=0
60 INPUTN
70 FOR I=0 TO Nx24-1
80 V=PEEK(2048+I)
90 Q=INT(V/16)x10 + (V-INT(V/16)x16)
100 V=Q
110 VG=VG+V
120 VCUB=VCUB+V^3
130 A=INT(V/2)
140 KL(A)=KL(A)+1
150 NEXT
155 NTT=Nx24
160 B=0
170 VG=VG/(NTTx3.6)
180 VCUB=VCUB/(NTTx3.6^3)
190 KE=VCUB/VG^3)
200 FOR J=0 TO 40
210 B=B+KL(J)
220 PRINT!2xJ;KL(J),INT((B/NTT)x1000+.5)/1000
230 NEXT
240 PRINT!"     V-MES=";INT(VGx100+.5)/100
250 PRINT!"     KE=";INT(KEx100+.5)/100
260 PRINT!"     NTOT=";NTT
270 END
```

DITRIBUICAO DE
FREQUENCIAS
PRAIA AEROPORTO
MES DE MAIO
DE 1984

| CLASSE | HORAS | F(V) |
|---|---|---|
| 0 | 1 | 1E-03 |
| 2 | 0 | 1E-03 |
| 4 | 0 | 1E-03 |
| 6 | 0 | 1E-03 |
| 8 | 4 | 7E-03 |
| 10 | 2 | 9E-03 |
| 12 | 7 | .019 |
| 14 | 5 | .026 |
| 16 | 17 | .048 |
| 18 | 17 | .071 |
| 20 | 46 | .133 |
| 22 | 47 | .196 |
| 24 | 59 | .276 |
| 26 | 62 | .359 |
| 28 | 50 | .426 |
| 30 | 63 | .511 |
| 32 | 71 | .606 |
| 34 | 58 | .684 |
| 36 | 73 | .782 |
| 38 | 46 | .844 |
| 40 | 47 | .907 |
| 42 | 29 | .946 |
| 44 | 16 | .968 |
| 46 | 12 | .984 |
| 48 | 8 | .995 |
| 50 | 4 | 1 |
| 52 | 0 | 1 |
| 54 | 0 | 1 |
| 56 | 0 | 1 |
| 58 | 0 | 1 |
| 60 | 0 | 1 |
| 62 | 0 | 1 |
| 64 | 0 | 1 |
| 66 | 0 | 1 |
| 68 | 0 | 1 |
| 70 | 0 | 1 |
| 72 | 0 | 1 |
| 74 | 0 | 1 |
| 76 | 0 | 1 |
| 78 | 0 | 1 |
| 80 | 0 | 1 |

V-MES= 8.57
KE = 1.21
NTOT = 744

Obs.:
The calsses are in km/h, so classe "0" consists of wind speeds 0 and 1 km/h, etc.
The second column gives the number of hours of the class and the third column the cumulative frequency distribution.
V-MES ($V_{month}$) is in m/s.

NTOT are the number of hours in that month

Reports VI and XVII contain all the frequency distributions of Praia, from 1975 through 1983 (8 years). Based on these eight years, probability intervals (95%) of the monthly and annual mean wind speeds have been determined:

Table 12.1. - Probability intervals of monthly mean wind speeds of Praia Airport 95%)

| Month | Lower limit (m/s) | Upper limit (m/s) |
|---|---|---|
| January | 6.52 | 7.82 |
| February | 7.31 | 8.51 |
| March | 7.34 | 8.20 |
| April | 6.74 | 8.12 |
| May | 7.76 | 8.32 |
| June | 6.35 | 7.03 |
| July | 4.80 | 5.50 |
| August | 4.36 | 5.16 |
| September | 4.52 | 5.60 |
| October | 5.87 | 6.95 |
| November | 6.16 | 6.70 |
| December | 6.29 | 7.81 |
| Year | 6.52 | 6.80 |

The power density of the wind P (in Watts/m$^2$) can be calculated from the mean wind speed and the energy pattern factor $k_E$: $P = \frac{1}{2} k_E \rho \bar{V}^3$. When calculating P for every month, it turns out that the "wind year" can be divided into 3 periods:

- period 1: January-March with P>300
- period 2: July-September with P<200
- period 3: June+October-December with 200<P<300

So even with optimally designed windmills, their output will vary widely over the year in the Paria wind regime.
The Weibull factors k and c have been obtained by using the graphical method with the Weibull-paper. This method was developed by the Wind Energy Group in Eindhoven (partner of CWD).

The results are given in the next table. An example of the use of the Weibull paper is presented in Section 12.3.

Table 12.2. - Weibull factors k and c for Praia Airport

| Month | '75 - '81 | | 1982 | | 1983 | |
|---|---|---|---|---|---|---|
| | k | c(km/h) | k | c(km/h) | k | c(km/h) |
| January | 3.3 | 30 | 3.1 | 29 | 3.7 | 31 |
| February | 3.6 | 32 | 5.2 | 35 | 3.8 | 29 |
| March | 3.9 | 33 | 2.8 | 30 | 3.0 | 33 |
| April | 3.3 | 32 | 3.5 | 30 | 3.6 | 31 |
| May | 3.7 | 33 | 3.9 | 31 | 3.6 | 35 |
| June | 3.0 | 28 | 3.5 | 27 | 3.2 | 26 |
| July | 2.6 | 21 | 2.9 | 23 | 3.1 | 23 |
| August | 2.7 | 19 | 3.0 | 22 | 2.6 | 21 |
| September | 2.1 | 21 | 3.7 | 26 | 2.1 | 21 |
| October | 3.0 | 27 | 3.3 | 29 | 1.8 | 23 |
| November | 3.4 | 28 | 3.3 | 27 | 3.0 | 26 |
| December | 3.6 | 28 | 5.0 | 35 | 5.0 | 32 |

Comparison of these data with division into three periods, shows that the periods can also be classified with the Weibull factors:
- period 1: July-May $k \geq 3$ and $c \geq 30$ km/h
- period 2: July-September $k < 3$ and $c < 30$ km/h
- period 3: June+Oct.-Dec. $k \geq 3$ and $c < 30$ km/h

## 12.3. Achada de São Filipe

Since May 1982 the wind measurements have been carried out here with a MS 778 (formerly with a Stewart wind run meter). Achada de São Filipe serves as a test site for DER; all types of windmills that DER possesses are installed here.
The wind measurements are particularly important for the long term output measurements, which are being carried out (see Chapter 13).
With the aid of the AIM 65, the monthly frequency distributions and diurnal and nocturnal wind speeds are calculated with programmes similar to those for Praia airport.
Relation factors between the wind measuring site and the windmill sites have been obtained for wind speeds averaged over 12 hours:
- between the Aeropower and MS 778: relation (between mean wind speeds) 1.06, correlation factor 0.96
- between the Southern Cross and MS 778: relation 1.02, correlation 0.75 (this relatively low correlation is probably due to the wake effects of Monte Vaca)
- between the Dempster 8' and MS 778: relation 1.06, correlation factor 0.98.

A comparison with Praia airport has been made too. The mean monthly wind speeds and the Weibull factors k and c have been compared. The average wind speed relation between Praia and São Filipe is 0.92, with a correlation factor of 0.85. It is interesting to note that the correlation factors for each of the three wind periods differ widely from each other. In the case of São Filipe

- period 1: r=0.95
- period 2: r=0.995
- period 3: r=0.06

This has also been observed at other stations (Achada Baleia, Achada Lem), although the pattern is not always the same. The number of measurements and sites is not yet sufficient to determine the causes of this phenomenon. Once it can be determined, it may indicate where and when a good correlation implies that the frequency distributions are similar, measuring of the average wind speed will be enough to obtain the wind regime of a site. A comparison of Weibull factors k and c is easily made with Weibull paper: see Figure 12.2, where the cumulative frequency distributions (April 1983) of São Filipe and Praia are compared.

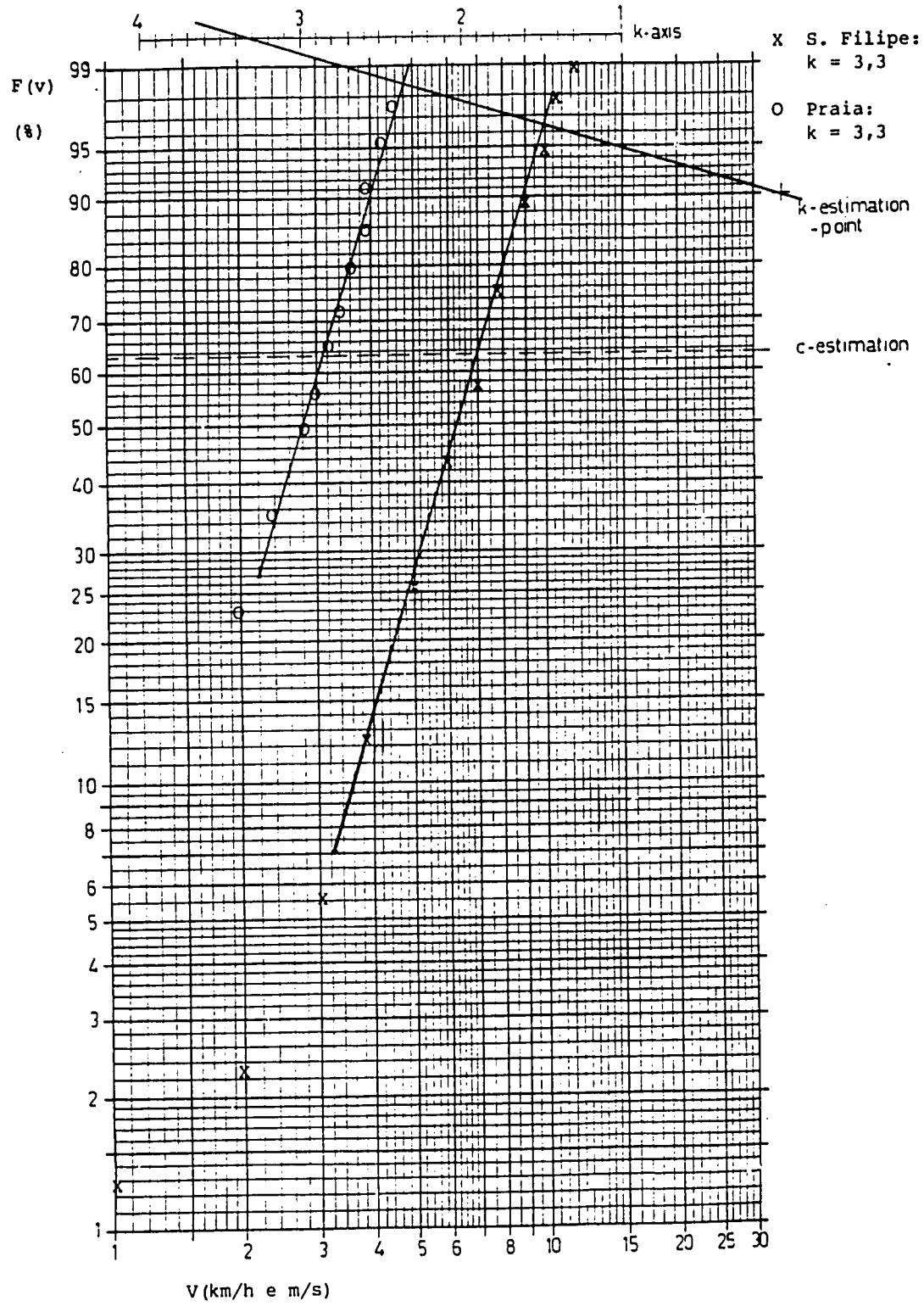



Figure 12.2. - Determination of the Weibull factors k and c from the cumulative frequency distribution

## 12.4. Ribeira Saltos, Flamengos and São Miguel

Up to now DER has carried out relatively few measurements in Ribeira's. Those that have been made (Report XVII) indicate that the estimate by Beurskens (Ref. 2) that the annual mean wind speed in Ribeira's would in general be 0.7 times that of Praia, is too high.
DER's hypothesis is now:

- in periods 1 and 3: 0.55 times Praia
- in period 2 : 0.75 times Praia

This hypothesis has to be confirmed.
To this aim a campaign was started in some Ribeira's early 1984. The measurement stations are given in Figure 12.3.

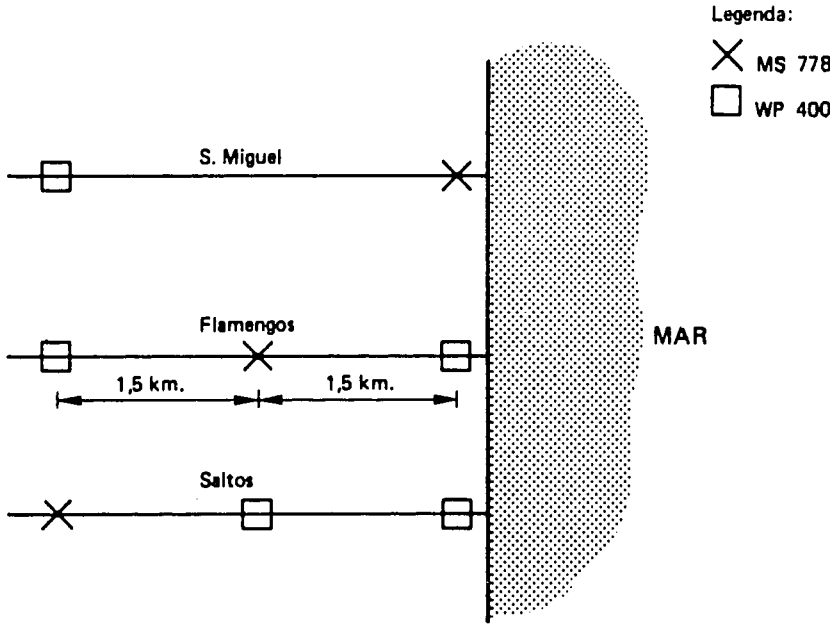



Figure 12.3. - Configuration of anemometer sites in Ribeira Saltos, Flamengos and Sao Miguel

These measurements are now in progress; results cannot yet be given. During the rainy season the anemometers have to be taken away, as the risk of equipment loss by river floods is too high.

## 12.5. Ribeirão Chiqueiro

Here a new tube well was drilled in November 1983.
Wind speeds at the site were measured during three months with a WP 4000, which was read twice a day. The results are presented in Table 12.3.
It was concluded that the output prediction for the Achada wind regime (see Figure 13.8.) could be used here.
DER chose a Southern Cross 25' with a 3" pump, which should deliver 70 $m^3/d$; pumping head is 105 m.

Table 12.3. - Relation Riberão Chigueiro - Praia

| Month | $V_{Praia}$ (m/s | $V_{R.Chiq.}$ (m/s) | $V_{Praia}/V_{R.Chiq.}$ | correlation factor r |
|---|---|---|---|---|
| 1. During the night (6 pm - 6 am) | | | | |
| January | 9.39 | 9.23 | 0.98 | 0.70 |
| February | 6.64 | 6.87 | 1.03 | 0.72 |
| March | 6.46 | 6.90 | 1.07 | 0.82 |
| 2. During the day (6 am - 6 pm) | | | | |
| January | 10.50 | 8.26 | 0.79 | 0.81 |
| February | 8.82 | 6.78 | 0.77 | 0.61 |
| March | 8.21 | 7.60 | 0.93 | 0.76 |

# 13. PERFORMANCE MEASUREMENTS

## 13.1. Ten minute measurements

Ten minute performance (power vs wind speed) measurements have been executed on the Dempster 8' at Achada de São Filipe. The wind speed was measured with a maximum WPA-10 anemometer and an Aeolian Kinetics WP 4000 wind run recorder.
The water yield was measured by counting the number of strokes in ten minutes and multiplying it by the stroke volume multiplied by volumetric efficiency. The stroke volume was .44 litre. The volumetric efficiency was obtained by filling an empty oil drum of 200 l and dividing the 200 l by the number of strokes it took to fill the drum; it was supposed that the volumetric efficiency remained constant for all rotational speed. The volumetric efficiency was .95.
The pumping head was obtained by measuring the water level and adding 5 m for the vertical distance tube well tank and 2 m for the pipe losses. The water level remained practically constant; pumping head was 40 m.
The next two pages give the results of the measurements (reproduced from XXIV, no. 3): in accordance with the IEA standard the presentation is done with the "method of bins".
In Figure 13.5 "Cp.$\eta$ overall" means: nett power of lifted water divided by mean wind speed cubed multiplied by swept rotor area.

In addition two pages are presented with wind tunnel measurements on a model of the Dempster 8', as executed by the Wind Energy Group in Eindhoven (partner of CWD). Unfortunately it is not possible to give a reference, as the measuring report has not yet been published.

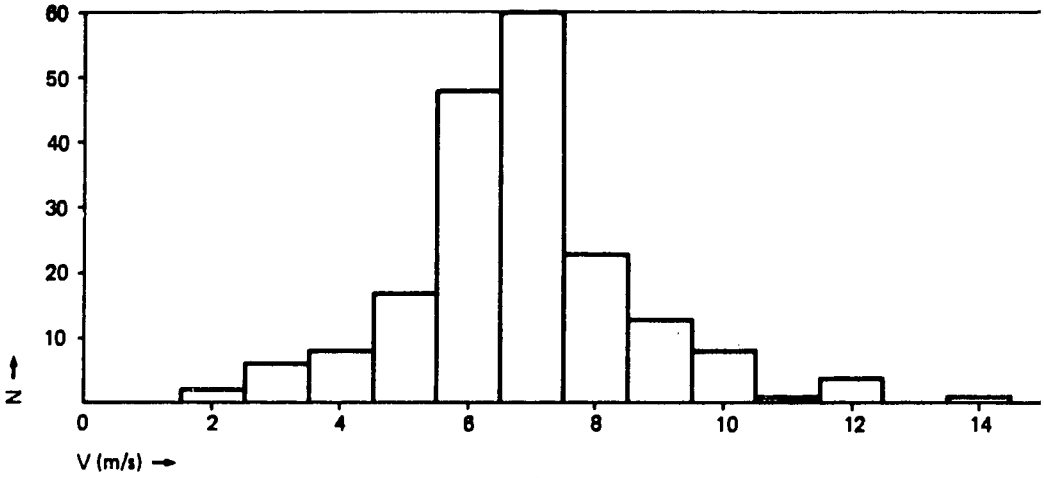



Figure 13.1 Bin frequency versus windspeed

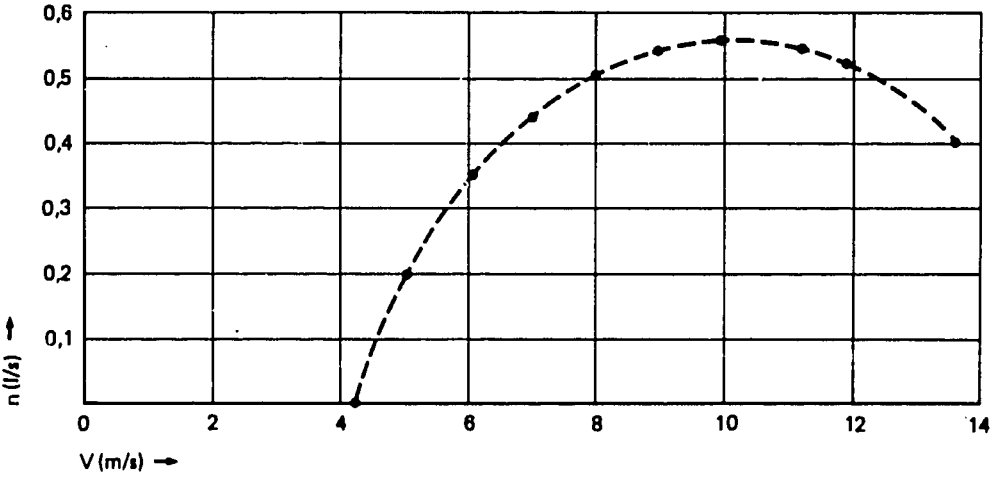



Figure 13.2 Rotational speed versus windspeed

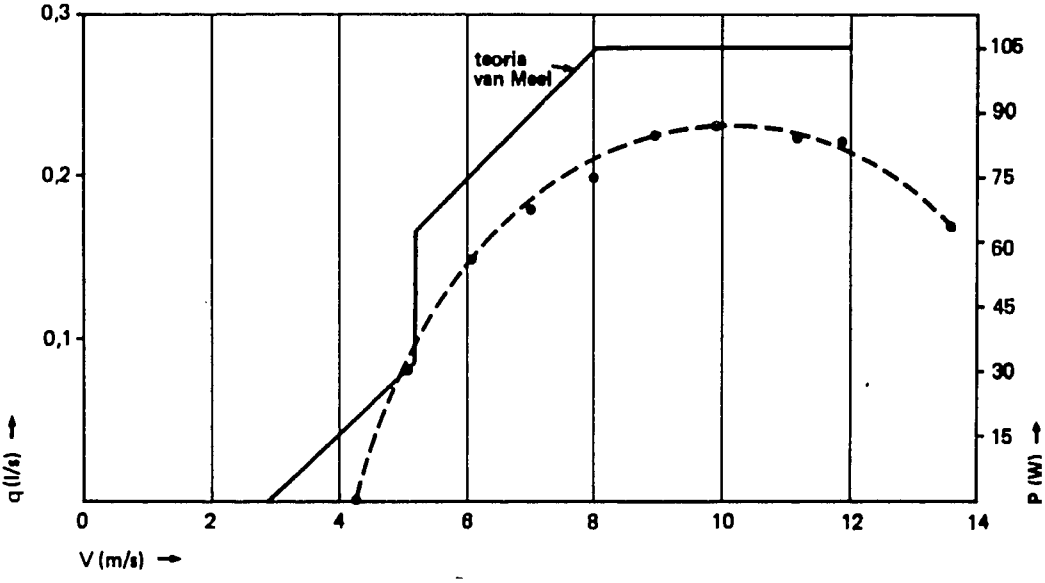



Figure 13.3 Water output versus windspeed

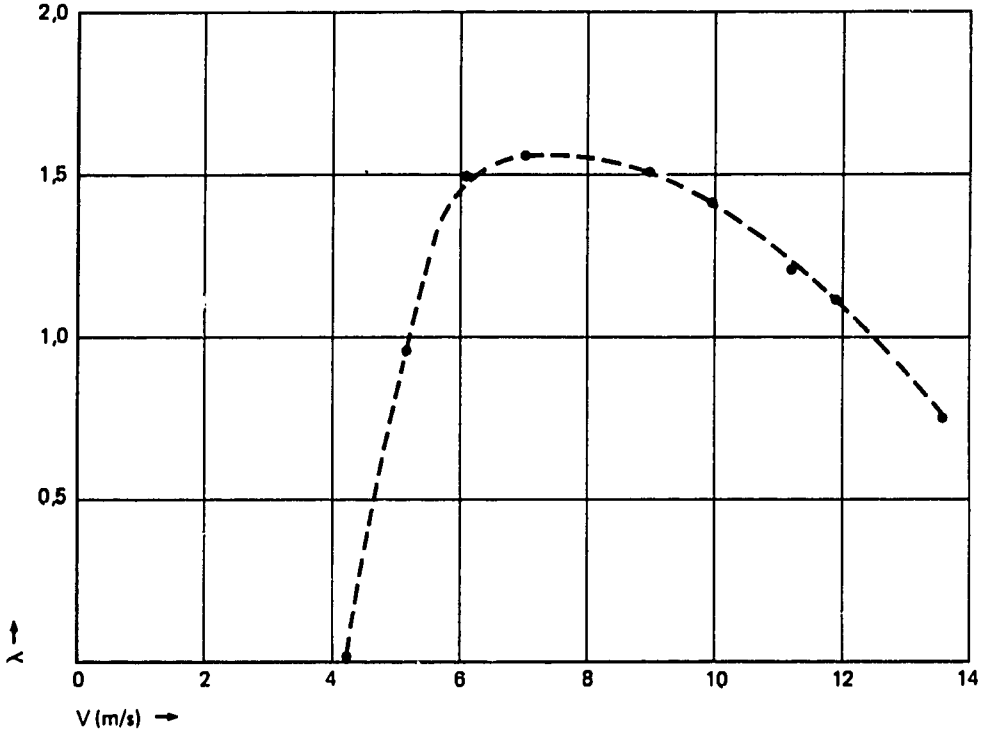



**Figure 13.4 Tip speed ratio versus windspeed**

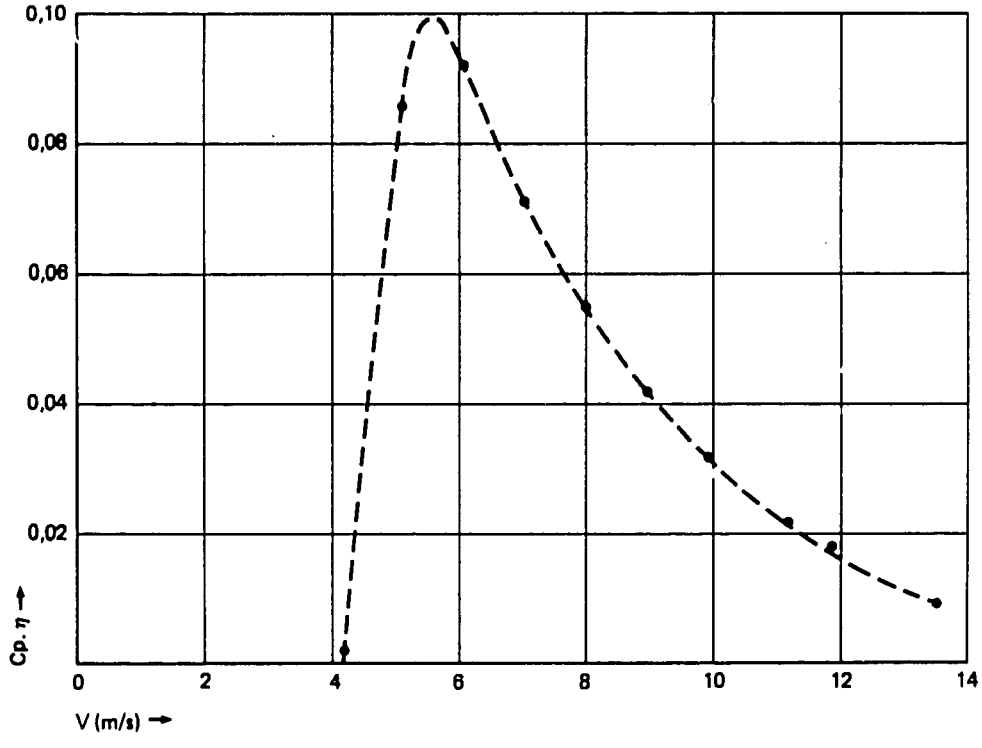



**Figure 13.5 Overall efficiency versus windspeed**

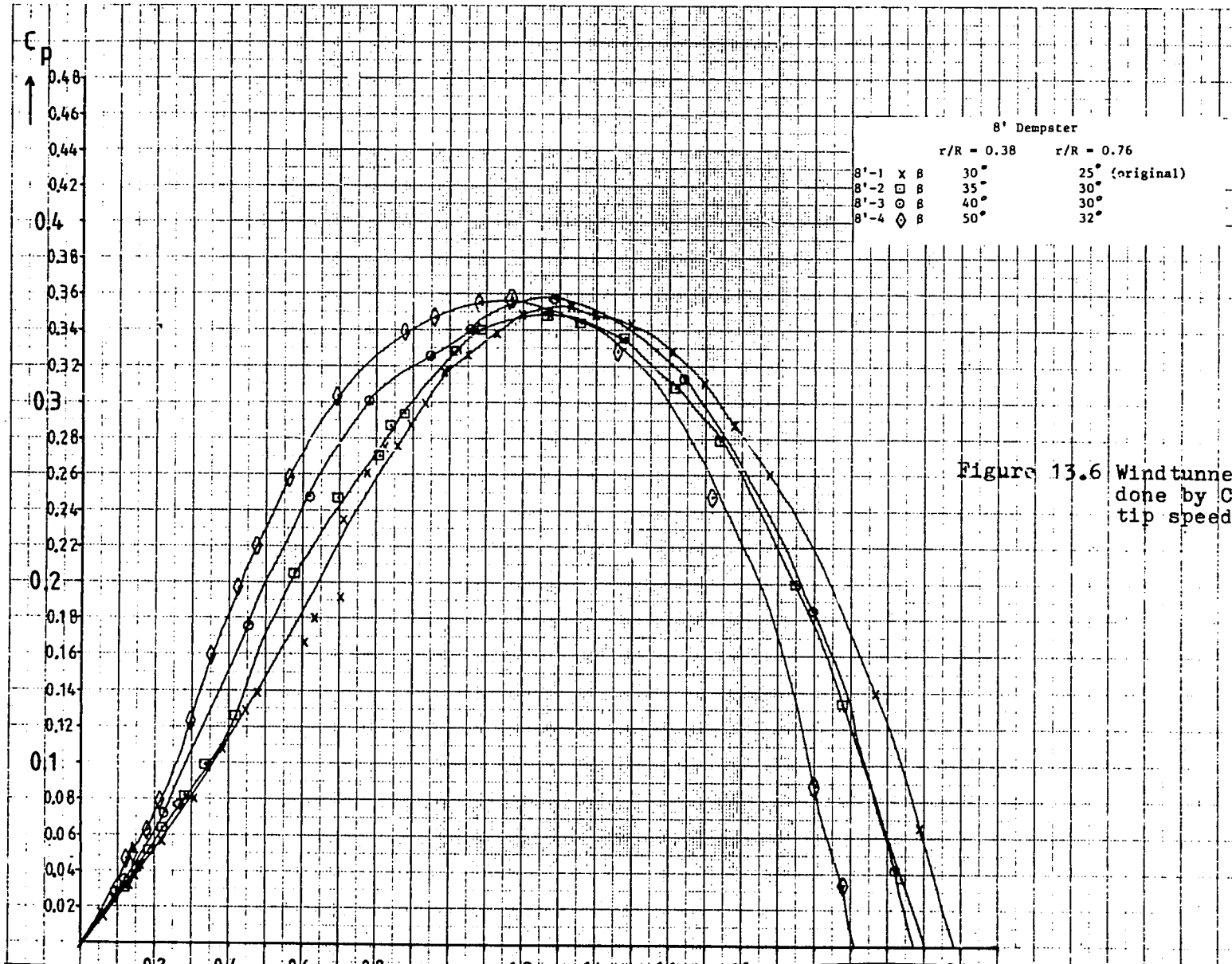



Figure 13.6 Windtunnel measurements done by CWD (power vs tip speed ratio curve)

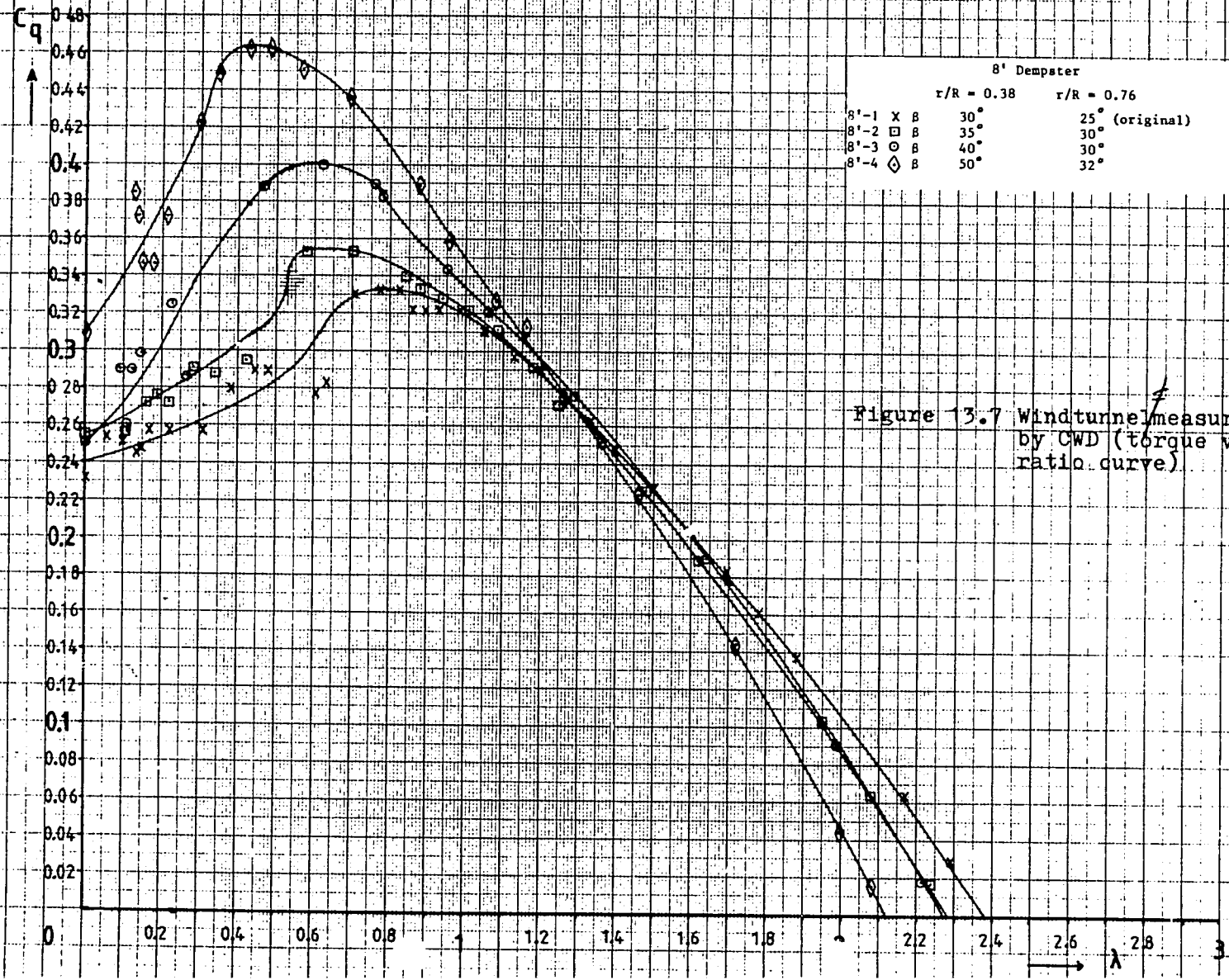



Figure 13.7 Windtunnel measurements done by CWD (torque vs tip speed ratio curve)

The conclusions from these ten-minute measurements on the Dempster 8' are:

- Comparison with Van Meel's theory (Ref. 10, indicated in Figure 13.3.) shows that the water yields are in practice 25% lower and that the starting wind speed is considerably higher.
- Comparison with the wind tunnel measurements shows that the optimal tip speed ratio values correspond (tip speed ratio is 1.2 for design wind speed 5.5 m/s, Figures 13.4., 13.5. and 13.6.); the starting torque seems to be higher in the field than measured in the tunnel.
- It is advisable to install a larger diameter pump (higher design wind speed) which is more appropriate to the Achada wind regime and will thus pump more water. (To overcome starting problems, a small starting hole can be made in the piston; for the starting hole theory, see, for example, "Introduction to Wind Energy", publication by CWD; Ref. 26). However, in accordance with the strength calculations (Ref. 11) the maximum allowable design wind speed for a Dempster 8' is 5.8 m/s.
- By multiplying the measured power to wind speed curve by the annual frequency distribution of Praia (for $V_{annual}$ = 6.3 m/s, the annual mean wind speed of the site), one obtains a yearly water yield of 4100 $m^3$ or 11.25 $m^3$/d or 52 Watt nett average efficiency factor (nett average power divided by annual mean wind speed cubed multiplied by swept rotor area) of .045.
  The value of 11.25 $m^3$/d corresponds rather well with the actual long term measurement (12.1 $m^3$/d; see Section 13.2.).
- In Ribeira wind regime with $V_{annual}$ = 4 m/s the production would be 1654 $m^3$/year or 21 Watt nett average power*. It is clear that now the design wind speed should be lowered to obtain better results; this can be done by installing a smaller diameter pump.

## 13.2. Long-term measurements

Based on field experiments (adapted) manufacturer's data and theoretical predictions (Ref. 10 and Report VI), two yield vs pumping head graphs have been determined by DER for the Dempster 8', Dempster 14', Southern Cross 17', Southern Cross 25' and an (ideal) prototype of 8 m; one for an Achada wind regime with $V_{annual}$=6.5 m/s, the other for a Ribeira wind regime with $V_{annual}$=4 m/s. See Figures 13.8. and 13.9. The justifications of these graphs can be found in Report XXI.

Table 13.1. presents the (few) long term measurements (output) that DER has the disposal of (data taken from the monthly maintenance sheets):

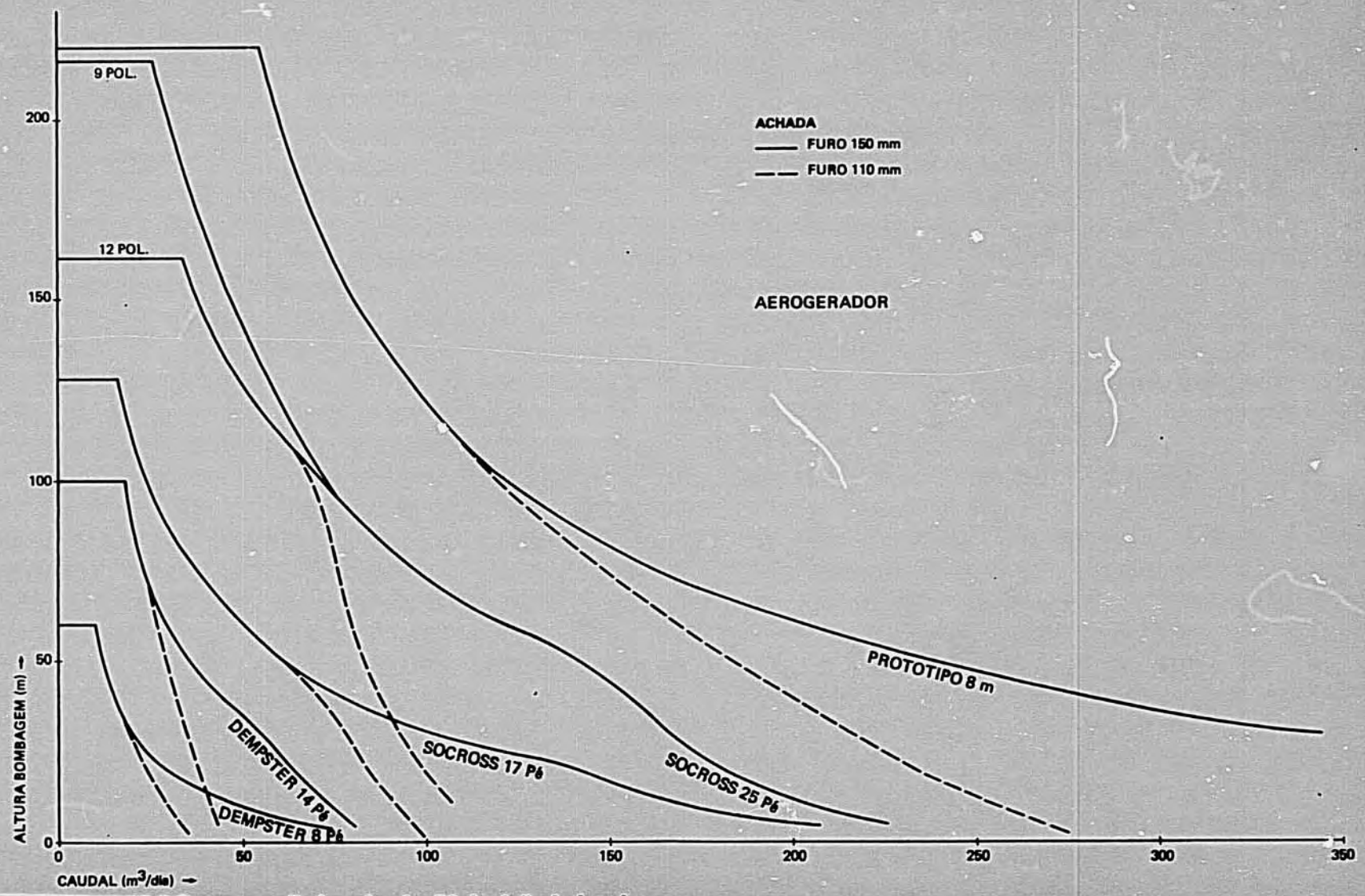
*This corresponds with an average total efficiency of .07.

Table 13.1. - Long-term output measurements

| Site | Mill | Regime period | Pumping head (m) | $m^3$/day measured | $m^3$/day Fig. 13.8/9 |
|---|---|---|---|---|---|
| S. Filipe | Dempster 8' A | 6/'81-2/'83[1]) | 40 | 12.1 | 14 |
| S. Filipe | Dempster 8' A | 2/'83-5/'84[2]) | 40 | 15.4 | 14 |
| Portete | Dempster 8' R | 12/'83-5/'84 | 35 | 4.1 | 5.5 |
| Lem Duque | Dempster 8' R | 1/'84-5/'84 | 26 | 6.6 | 7 |
| S. Filipe | Dempster 14'A | 1/'84-5/'84 | 50 | 30 | 36 |
| S. Filipe | Socross 25'A | 8/'83-3/'84 | 50 | 25[3]) | 105[4]) |

[1]) with stroke volume .44 l
[2]) with stroke volume .64 l
[3]) the mill is underused (irrigation net yet started)
[4]) the size of pump is chosen in accordance with 75 m pumping head

An operation record is kept of the last two mills in Table 13.1. (Dempster 14' and Southern Cross 25' on Achada de São Filipe), the nearby wind speeds are also measured.
Figure 13.10. presents the results; the monthly yields have been corrected for out-of-operation time.




[illegible] for the "Achada" wind regime

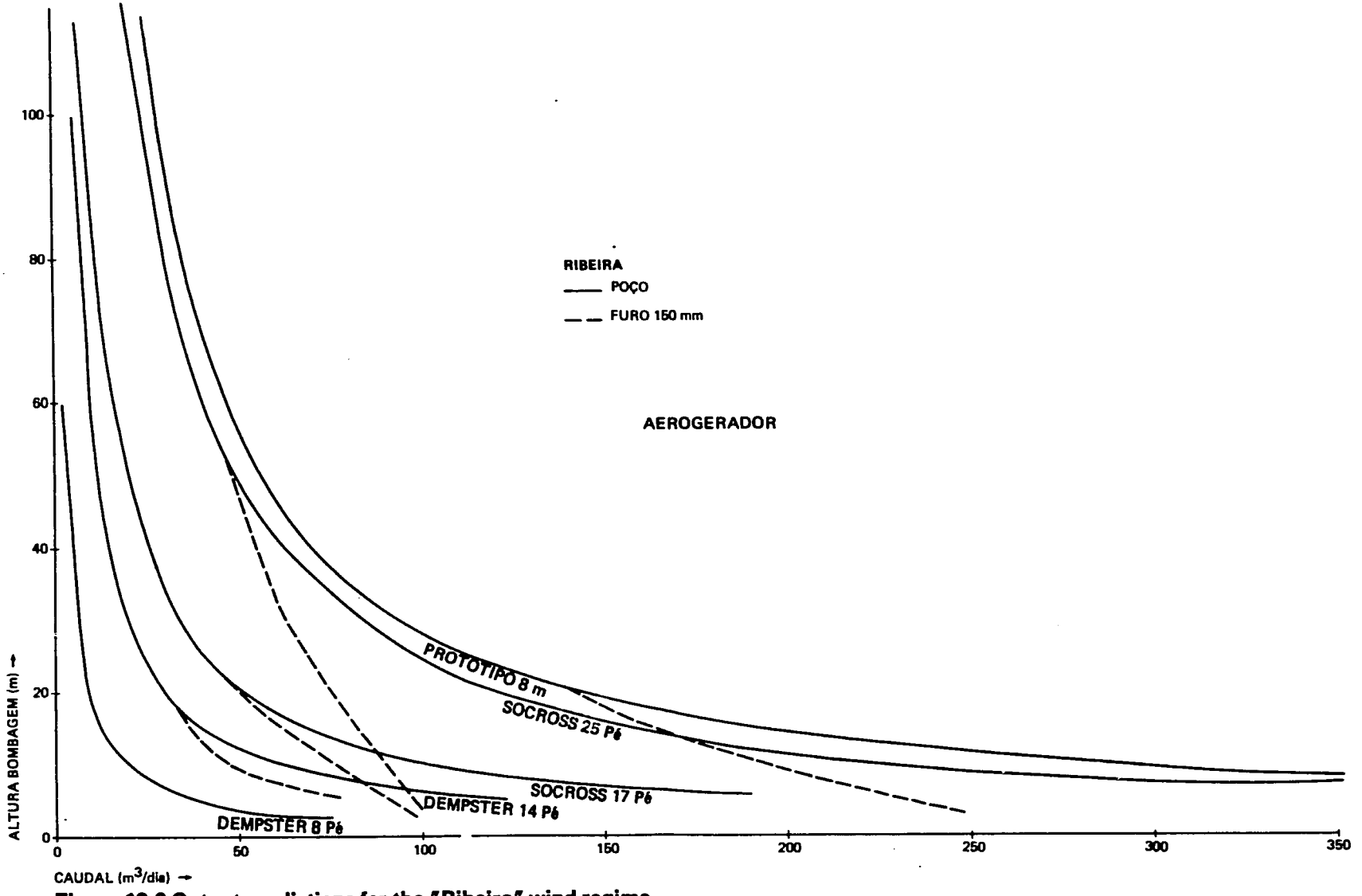



**Figure 13.9 Output predictions for the "Ribeira" wind regime**

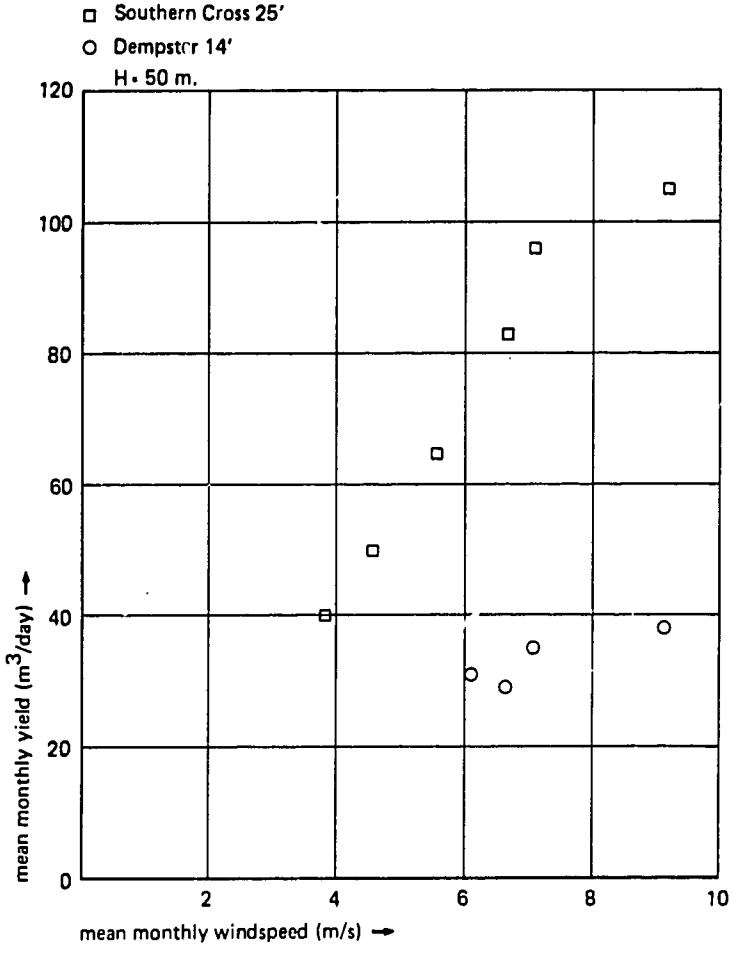



**Figure 13.10** Monthly yields versus winspeeds for the Southern Cross 25' and Dempster 14' at Achada de São Filipe

## 13.3. Measurements on Aerowatt

Figure 13.11. presents the theoretical output (instanteneous values) of the Aerowatt water pumping system on Achada Baleia. The graph was calculated from wind rotor, generator, control and pump characteristics.

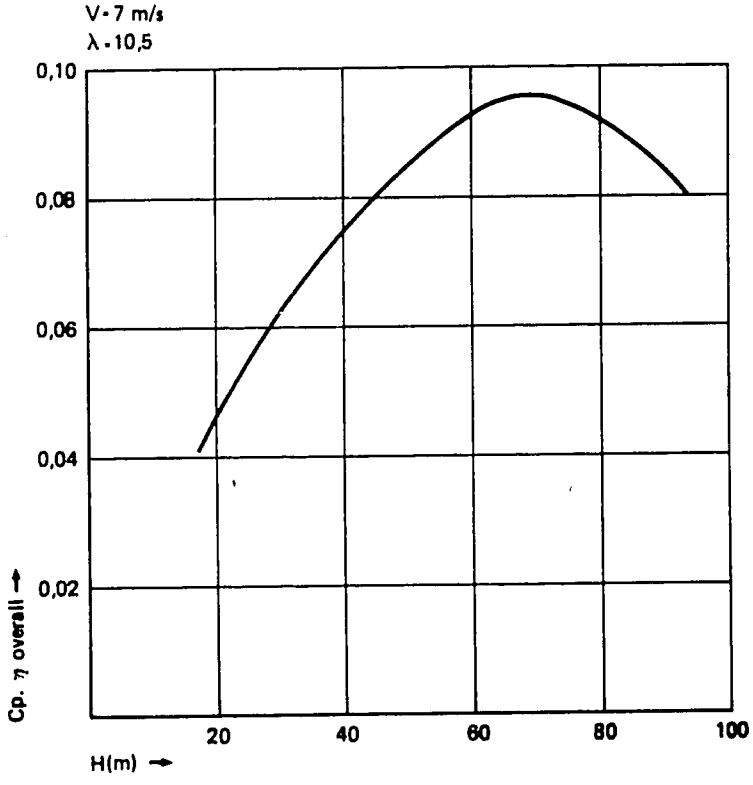



Figure 13.11. - "Instanteneous" efficiency of Aerowattmotor water pumping system at Achada Baleia (theoretically)

The measured long term output efficiencies (measuring period March through June 1982) never exceeded .03. for the time the system was in operation.

# PART THREE

# CONCLUSIONS AND RECOMMENDATIONS

# 14. CONCLUSIONS AND RECOMMENDATIONS

## 14.1. General

The application of water pumping windmills in the Republic of Cape Verde has passed its introductory and experimental phase and has proved to be a reliable means to pump water. Careful installation and regular maintenance have been and will remain the key factors in achieving reliability. 37 Water pumping windmills are in operation now; they serve the dinking water requirements of 10,000 persons, which is 5% of the rural population. DER's long term objectives are to realize the entire water pumping potential by windpower: 300 mechanical wind water pumpers and 66 wind generators for water pumping. Two-thirds of all installations will be on Santiago. 75% of the total potential of pumped water can be realized with wind energy; this means 47,700 $m^3$/day. The objectives of the project proposal (1980) for Phase 2 could not all be achieved; main reasons are:

- want of Cape Verdean staff
- delay in the construction of the workshop
- all kinds of logistical problems
- project proposal was too optimistic

Fortunately, both Cape Verde and the Netherlands have taken a flexible attitude towards adapting the project policy to reality. All project money has been spent in a useful way.

## 14.2. Comparison with project proposal

In Table 14.1. the project proposal (Ref. 2) has been compared with the achievements.

Table 14.1. - Comparison between project proposal and accomplishments

| Nr. | Proposal | Accomplishment |
|---|---|---|
| 1. | 33 Windmills imported | 24 windmills imported (of which 9 on their way) |
| | 8 windmills bought locally | 5 bought locally |
| | 5 prototypes of 5 m constructed | 1 prototype of 5 m constructed |
| | 3 prototypes of 3 m constructed | 0 prototype of 3 m constructed |
| | installed rate: 2/months | installation rate was 1/month |
| 2. | Finance of workshop | funds available but workshop only in operation since Novemner 1983 |
| 3. | Technical assistance: | |
| | - consultancy on site feasibility | 36 sites were studied; a priority list of 28 future site studies has been prepared; the water pumping potential by wind power was reviewed (Report XXVII); a report on site selection methodology was produced (Report XXI) |
| | - consultancy on local production | 1 prototype was constructed with the aid of a CWD engineer; short mission on local production |
| | - training in operation and administration of workshop | training has been provided, but only fully effective since November '83 |
| | - consultancy on windmill installations | 21 windmill installations have taken place; at the same time on-the-job training of mechanics; installation manuals for Dempster and Southern Cross mills were produced; a 3-months training for mechanics from the islands was given |
| | - consultancy on set-up of library | consultancy was carried out; the library has .. books and .. reports; a catalogue is available |
| | - consultancy on solar activities | these activities were abandoned or transferred to INIT |
| | - consultancy to various ministries | only very sporadically |
| | - consultancy on coordination between ministries | not carried out |
| 4. | Project management and support | Was carried out (e.g. 6 management visits and very frequent correspondence |

| Nr. | Proposal | Accomplishment |
|---|---|---|
| 5. | Training | One reconnaissance visit of DER Director to Europe and a 4-weeks language course<br>More could not be done for want of staff |
| 6. | Procurement of 6 motorbikes and other miscellaneous material and equipment | Equipment and material was ordered conform to actual needs |

The following observations can be made:

With reference to 1.:

Local production had a very slow start during Phase 2 due to:
- lack of a national mechanical engineer
- delay in the construction of the workshop
- other activities, like training of mechanics in installation and maintenance, took more time than planned

The installation rate could not be achieved, because:
- the installation teams still had to be trained
- all kinds of logistical problems (underestimated in the project proposal), like:
  - procurement problems
  - customs clearance
  - transport between the islands
  - want of installation equipment
  - sometimes financial problems due to RCV (payment of living allowance of mechanics)

At the end of Phase 2, part of the problems have been solved, others are better known and controlled. It is estimated that much more time can be devoted to local production in Phase 3 and that the installation rate can increase; however, it may not be until the end of Phase 3 before this rate will be two per month.

With reference to 2.:

The workshop is in operation, so this aim was achieved. The delays were due to procedural barriers.

With reference to 3.:

DER had no time to continue the solar and other non-wind activities; in November 1982 it was decided to transfer those activities to INIT.
The last two consultancy activities were not carried out because they now belong to the tasks of INIT, which did not yet exist at the time the project proposal was written.

With reference to 4. through 6.:

No observations needed.

The facts being as they are , it is not easy to see what else could have been done to improve the project's progress.

The one important recommendation which should be given here is to adopt a flexible attitude towards project aims and not hesitate to change them.

## 14.3. Conclusions and recommendations per subject

### 14.3.1. Mechanical windmills

Up to now emphasis has been laid on improvement of the quality of work. Attempts have been made to standardize the method of installing and of constructing parts and components, as well as that of maintenance and repair. A team of mechanics has been created.
It is proposed to organize courses for windmill guards; probably a large part of the maintenance can be done by the guard and the monthly work by DER is then reduced to inspection and measurements. The number of break-downs can probably be reduced by regular inspection of the components most liable to wear and tear; those should be replaced before their possible rupture. The main present problem is that of corrosion. Various types of paints are being tested at the moment. It has been shown that the paint coat remains longer intact if the dust is taken away regularly. It is recommended to have this done with all windmills, preferably by the guard.
Experiments can be made to increase the maximum possible design wind speed of Dempsters and Southern Crosses by installing pressure air chambers right at the pump (Ref. 11), to reduce shock forces due to acceleration and closing of valves. The technical infrastructure for installations (derricks etc.) should be completed; i.e. each island should have its own equipment.

### 14.3.2. Electric windmills

The first experiment with water pumping by wind generators has been a failure. It is no use to spend more efforts on the three Aerowatt machines.
As the potential of water pumping with wind generators is substantial (around 70 wind generators pumping in total 27,300 $m^3$/day) efforts should be spent on other machines, preferably of the same make.
At the moment the first Lagerwey-Van de Loenhorst wind generator is under installation on Achada Baleia; this machine should be thoroughly monitored for six months. Then a decision, on the purchase of four more wind generators expected in Phase 3 should be taken.

The economic viability of autonomous systems has not yet been proved. A first experiment will be carried out in Phase 3. It is proposed to have this done on Santiago, at a site where the end use will be water pumping. Such possible sites are Santa Cruz, Joao Varela and Tarrafal.

### 14.3.3. Workshop, procurement and logistics

A new workshop was constructed and equipped during Phase 2 and is in full operation now. Personnel has been trained, so that in principle all services possible in the workshop can in fact be rendered.
Careful administration of the stock of materials and good maintenance of the machines is and will be very important. Methods of finding easy acquisition of spare parts of USA-orogin machinery should be found as the AID project has finished. Problems in the field of procurement and logistics are under control, but will remain as they are inherent to the working conditions on Cape Verde. By sound planning and strict control of stocks, the effects of this kind of problems can be minimized.
In-country logistics should become one of the tasks of the field surveyor. DER should gradually take over all procurement activities that are now carried out by CWD in the Netherlands, as the project will end some time.

### 14.3.4. Local production

One prototype of 5 m (the CWD 5000 HW or EMIDERI-I) was constructed, installed and monitored; it was concluded that another design (the CWD 5000 LW) will be preferable for Cape Verde. This is being installed now. It is recommended to give priority (especially by the consultants) to the development of local production in Phase 3, as this will be one of DER's key-stones in the future.

### 14.3.5. Anemometry

The equipment in use by DER has functioned satisfactorily up to now. It has been shown that the division of the wind year into three periods is useful for the comparison of DER measuring stations with the reference station in Praia.
The programme of measurements in Ribeira's should be extended as not enough is known yet about their wind regimes.
Data of Sal airport should be obtained to have a second reference station.

### 14.3.6. Performance measurements

Ten-minute performance measurements show that American-type fanmills are more suited to low and medium wind regimes that to high ones; total efficiencies of these mills do not exceed 0.075. Most important result of Phase 2 is the formulation of output predictions of DER windmills for Achada and Ribeira wind regimes. In Phase 3, these predictions should be verified and, if necessary, adapted by means of long-term (monthly) output measurements on as many as windmills as possible.

### 14.3.7. Site selection

The project has developed a methodology of site selection, described in a separate report. This report supplies instructions to the field surveyor as well as a flow chart of the selection progress, describes the water pumping strategies and gives graphs and tables for equipment choice.
The methodology should be closely evaluated during Phase 3 and adapted if necessary. Especially the water pumping strategies can be further elaborated.
A list of possible future (on short-term) installations is available.
Full attention should be given to tank size studies; if reductions in size are possible, important savings on the cost of water pumping systems can be made. Cheaper tank construction methods should also be devised (in collaboration with Rural Improvements).
It is proposed to try and improve the coordination with other MDR departments as far as the site selection process is concerned; this can be done especially with the design of the water pumping system.
Analysis of the water pumping strategies has shown that there is no need to operate windmills with design wind speeds higher than 5 m/s. This should be incorporated into the design of future prototypes for local production on Cape Verde.

### 14.3.8. Personnel and organization

During the greater part of Phase 2, DER was understaffed; transfer of knowledge at staff and medium level could not commence until quite recently.
There are at present vacancies for an electrotechnical engineer and a draughtsman.
Important progress has been achieved by the project with on-the-job training of mechanics in windmill installation and maintenance, as well as workshop operation.
However, much training is still needed; the following courses are proposed for the first year of Phase 3:

- English course for all staff members
- a course in windmill production at CWD for the mechanical engineer
- one-year courses for three mechanics and one electrician in Lisbon (already being prepared)
- one two-weeks course in metal painting in Lisbon (being prepared); if the course suits DER's purposes, all painters should attend it
- a six-month course for the field surveyor at CWD (has already been requested by DER)

Of course, normal on-the-job training should be continued as well.
It is recommended to organize DER conform to the organigram (in as far as it is not yet done) and evaluate this after a year.

### 14.3.9. End use and economics

A preliminary analysis of the end use and economics has been made.
Windmills are attractive especially for the drinking water supply where relatively small quantities are needed and in Ribeira's if irrigation and water supply are combined.

It is proposed to start with two pilot projects on irrigation in the first year of Phase 3; one on a Ribeira (proposed site: shallow well, in Ribeira Flamengos, equipped with a Southern Cross 25') the other on an Achada with excess water (proposed site: Achada de Sao Filipe with a Dempster 14'), in collaboration with the agricultural department of MDR.
A detailed economic analysis should be made of the operation and maintenance costs of water pumping windmills, in comparison with motor pumps, as well as of the water costs and benefits.

### 14.3.10. Water pumping potential by wind power

The project revised the estimates of the water pumping potential made by Beurskens in 1980. For one part the results confirm those by Beurskens (75% of the total pumped potential can be pumped by wind power; number of all installations approx. 400), but for another part they are different: larger diameter windmills and more wind generators.
It is recommended to follow all water resource studies closely, especially BURGEAP's study on Santiago, in order to be able to adapt the DER programme as soon as new data become available.
It is recommended to make an inventory of all shallow wells in the two Ribeira's, one with a great deal of soil and water conservation works (e.g. Ribeira Flamengos), the other with relatively few (e.g. Ribeira de Sao Francisco); this should be done to improve the estimates of the shallow well potentials.

### 14.3.11. Project support

The project support from the Netherlands has proved to be indispensable; major improvements can still be made in reaction time and clarity in communication (from both sides). The most important items for support during Phase 3 will be:
- local production
- tank size studies
- corrosion problem
- irrigation by windmills
- electric windmills

### 14.3.12. Reports

Reports during Phase 2, both on progress and technical subjects, have been adequate, which has facilitated the transfer of knowledge, control of the quality of work and project support.
It is therefore recommended to continue the reports in Phase 3 in the same way.

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