Proceedings of the Fourth Symposium on Antarctic Logistics and Operations

Sao Paulo, Brazil
16 to 18 July 1990

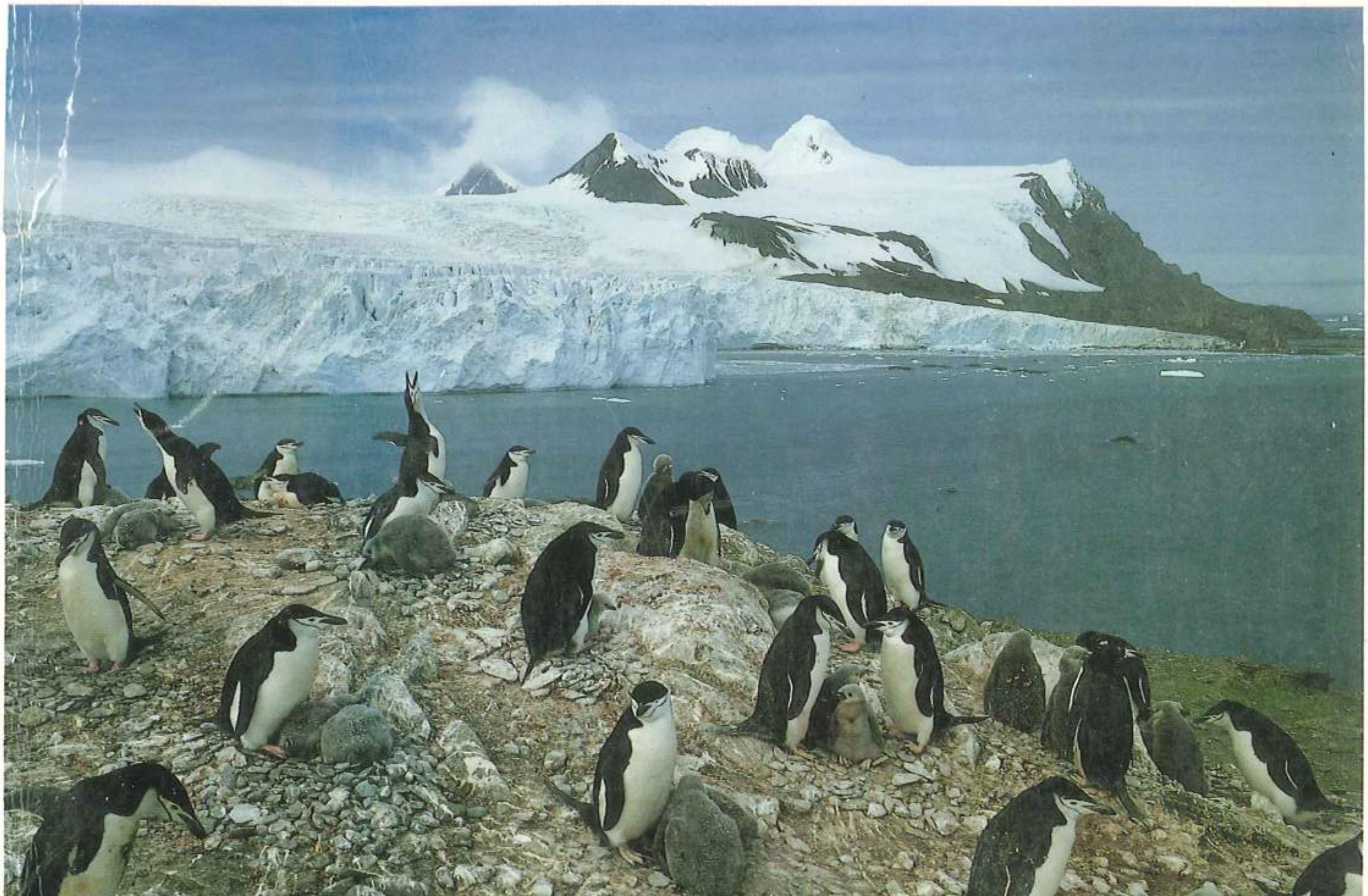


Photo by Haroldo Palo Jr

Proceedings of the Fourth Symposium on Antarctic Logistics and Operations

Sao Paulo, Brazil
16 to 18 July 1990

conducted by
Standing Committee on Antarctic Logistics and Operations (SCALOP)
of the
Council of Managers of National Antarctic Programs (CoMNAP)
in conjunction with

The Scientific Committee on Antarctic Research
at
XXI SCAR

Sao Paulo, Brazil
16 to 27 July 1990

edited by
H. Kohnen/A. J. Teixeira/A. N. Fowler

printed in Brasília, Brazil, by "Gráfica e Editora Ideal Ltda"
with financial support from
"Secretaria da Comissão Interministerial para os Recursos do Mar."

S986p Symposium on Antarctic Logistics and Operations (4.: 1990: Sao Paulo, Brazil) Proceedings of the Fourth Symposium on Antarctic Logistics and Operations / edited by H. Kohner, A. J. Teixeira, A. N. Fowler. — Sao Paulo: SCALOP / CoMNAP, 1990.

CDU 99:6

FOREWORD

In 1960, very soon after the International Geophysical Year, the logisticians involved with national programs of scientific research in Antarctica recognized the need to conduct a symposium on the logistical and operational support aspects of the ongoing investigations of that continent. The Working Group on Logistics of the Scientific Committee on Antarctic Research at the fourth meeting of SCAR in 1960 initially proposed a meeting to exchange experience and knowledge of operations in Antarctica and to discuss problems with construction, transport, life support, and hazardous field operations. The Antarctic Logistics Symposium was held in Boulder, Colorado, USA, August 13 to 17, 1962 in connection with the sixth meeting of SCAR.

The Antarctic Treaty Consultative Meetings in 1962, 1964, and 1966 recognized the value of the 1962 symposium and determined that a similar "meeting or symposium of experts" be conducted in order to discuss problems, exchange views, and consider proposed solutions relating to logistics and operational areas including buildings, waste disposal, transport and safety. Subsequently, in accordance with ATCM Recommendations IV-24 and IV-25, the Antarctic Treaty Meeting of Experts on Logistics was held in Tokyo, 3 to 8 June 1968.

Then, in 1980, the SCAR Working Group on Logistics once again noted the very limited group contact among Antarctic logisticians and the need to more adequately exchange information on the growing complexity involved in the support of science in Antarctica and the successes and failures of new technology. The Third Symposium on Antarctic Logistics was held at Leningrad from 28 June to 3 July 1982, in conjunction with SCAR XVII.

The Council of Managers of National Antarctic Programs and its Standing Committee on Antarctic Logistics and Operations were inaugurated in 1988. With the disbanding of the former Working Group on Logistics, the SCALOP terms of reference include: to serve SCAR by providing advice on Antarctic operations and logistics; and to hold symposia and expositions to inform and review technological advances. The planning to conduct a symposium was set in motion at the first meeting of SCALOP in 1988. This, then, is the background for the occurrance, in 1990, of the Fourth Symposium on Antarctic Logistics and Operations.

I I

INTRODUCTION

The Fourth Symposium on Antarctic Logistics and Operations was held from 16 to 18 July 1990 in Sao Paulo, Brazil in conjunction with the XXIst meeting of SCAR, the Scientific Committee on Antarctic Research. The symposium was conducted by the Standing Committee on Antarctic Logistics and Operations (SCALOP) of the Council of Managers of National Antarctic Programs. During the interval since the last logistics symposium, that was held in Lenigrad in 1982, there have been significant increases in levels of activity, in new national programs, and in emphasis on environmental protection. As one of its first orders of business, SCALOP, at its first meeting in 1988, commenced planning the symposium as a forum in which to present and discuss problems and solutions along with recent logistical and operational developments and technologies.

The symposium, held at the time and place of XXI SCAR was successful in attracting engineers and logisticians, and also in sharing the presented information to and interacting with SCAR scientists. Since the task of Antarctic logistics is primarily to support scientific activities, it is also vital that scientists know what technological and logistical developments are or may be available.

The scope of Antarctic logistics and operations involves providing the correct materials, supplies and provisions at the correct time and place they are needed in Antarctica. Certainly this means meticulous planning and the proper use of all kinds of highly specialized sea, air and land transportation, including the development of transport technologies, appropriate for use in the vigorous Antarctic environment.

It also means facilities design, construction and maintenance; communications including the use of space technologies; field operations under extreme conditions; innovative provisions for health care and safety; and the extraordinary extension of both new and proven methods and technologies for the protection of the environment in Antarctica. In short, Antarctic logistics comprises everything that is required to work efficiently when time is of the essence, to be transported to and from and to live and survive in safety and reasonable comfort in one of the harshest and most remote areas of the world.

Logistics in Antarctica is more expensive than almost anywhere else. Consequently, it uses up major portions of national program resources. Logistics and operations managers must use funds wisely in order to optimize their efforts in relation to required support and to achieve cost effectiveness. They must also be aware of measures adopted by the Antarctic Treaty consultative Meetings, and the proper interpretation and implementation of such measures.

Comparing these proceedings with those of the 1982 symposium it can be recognized that topics like ship and station construction and land and air transportation are of continuing interest. However, topics like environmental protection, space technologies, and the use of alternate energy sources have emerged and are of more concern than a decade ago. Because of the quickening pace of such trends, the members of SCALOP foresee the more frequent and regular scheduling of these logistics symposia in future years.

The support of all, authors as well as organizers, who contributed to the success of the symposium is highly appreciated.
The editors are indebted to Mrs. B. Chiaventone for the technical preparations of the proceedings.

Heinz Kohnen
Chairman of SCALOP

The Steering Committee
John Bawden, UK
Erik Chiang, USA
Michael Engler, France
Valery Klokov, USSR
Heinz Kohnen, FRG
Riita Manukoski, Finland
Antonio Teixeira, Brazil
Maciej Zalewski, Poland

Contents | Page

Environment

Alternative Energy Resources

Communication and Satellite Technologies

Contents

Land, Air, Sea Transportation

Stations

Contents **Page**

CURRENT DEVELOPMENTS IN ENVIRONMENTAL PROTECTION AT TERRA NOVA BAY STATION

by
Cervellati, R.(*), Metalli, P.(*), Testa, L.(*)
Italian Antarctic National Program. PNRA

Abstract

Environmental safeguard procedures of the Italian Antarctic Program at Terra Nova Bay are reviewed.

Members of the expedition are trained and bound to follow a code of conduct.

Local waste production is kept to a minimum. Figures are given for the last expeditions. Wastes are sorted according to type, only partly disposed of after treatment in the Antarctic Treaty Area by means of an incinerator and a water treatment plant and, mostly, retrograded to Italy.

The Station environmental impact is evaluated by monitoring the airborne particulate (tables on elemental composition are given) and the effluents of the plants above.

Introduction

Since the beginning of the Italian Antarctic Program (P.N.R.A.,Programma Nazionale di Ricerche in Antartide), in 1985, safeguard of the unique environment has been taken into great consideration.

It was relatively easy for Italy to build a Station and, at the same time, to cope with environmental problems as much as possible (Figg. 1,2). In fact, great help was received from the experience of other countries like USA, New Zealand, Australia and Argentina which have been operating in Antarctica for many years. Suggestions came as well from the Antarctic Treaty Recommendations on environmental protection, which, with the passing time, has been increasingly considered. The development of new technologies has played an important role too.

Despite the great respect of the environment, an Environmental Impact Assessment (EIA) was not prepared before the construction of the summer Base, during the 1986/87 Expedition. This was prevailingly due to the fact that ENEA, the organization carrying out the Italian Antarctic program, was not involved in advance, before the law was put into force. Problems have been solved on a case-by-case basis.

On the other hand an EIA was not believed necessary before a small excavation was dug to house seismic instruments and before the construction of a bulk fuel tank.

(*) ENEA, C.R.E. Casaccia, P.O. Box 2400, Rome, Italy

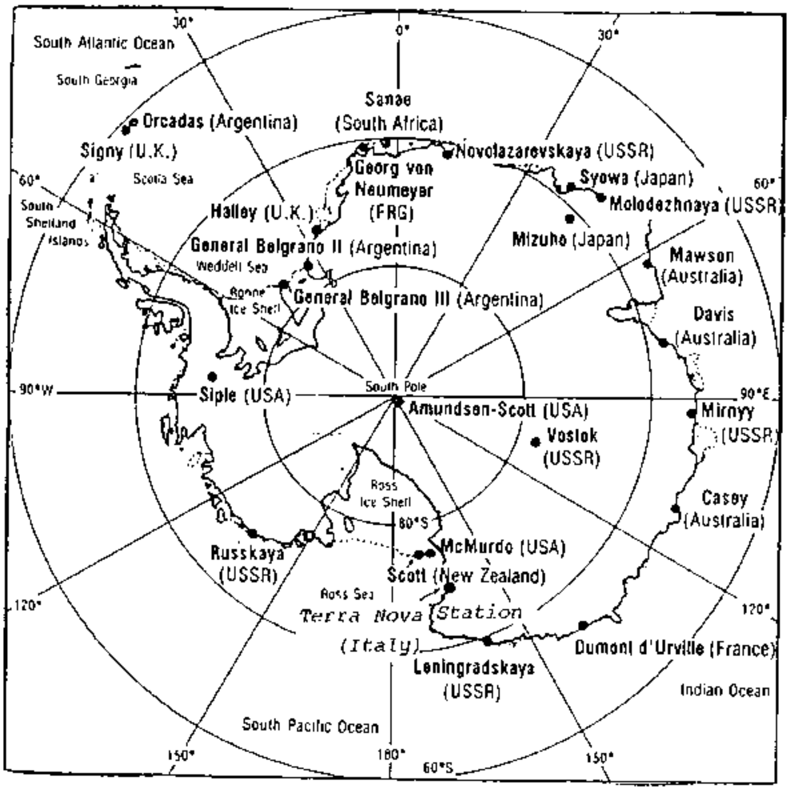


Fig. 1 Antarctica

Fig. 2 View of Terra Nova Bay Station

At present time a long term plan for a winter station is under study; it will be implemented after having drafted the EIA.

From the experience gained until now, fixing an upper limit to the number of the expedition members would be very effective in order to take the environmental problems under control and to avoid a heavy impact. Efforts have to be made in this direction.

Procedures for environmental safeguard at Terra Nova Bay Station

The Antarctic Treaty Recommendations have been the guidelines to write down a man's code of conduct for Italian Antarctic expeditions. This code was circulated since the first expedition and has been updated in the following years. That has been made bearing in mind that we have to minimize the man's impact on the environment without limiting scientific research.

The code and related documents are very often both in italian and in english, to take care of the foreign members of the expedition, guests, visitors and crew.

People are informed by means of:

- training courses;
- pamphlets, handed over before departure;
- circulation of papers, where some topics are stressed as convenient, during the campaign.

In the code of conduct some stress is put on sorting of wastes, respect of living resources and access to SSSI and SPA.

Because since the third Expedition we had field camps, procedures were laid down to prevent environment damages there. The adopted solutions to some practical problems, e.g. the human wastes, did not always succeed. At the beginning chemical toilets were thought to be a good choice, but difficulties were met both with the hard working conditions and with their maintenance. The problem is still open and we are trying to cope with it.

A record is taken of the sites of past and current scientific activities as well as of fuel caches.

Waste management

Waste management policy consists mainly in:

a) waste reduction and sorting
b) waste disposal

a) Waste reduction and sorting

Steps have been taken to reduce as much as practicable the amount of wastes produced by both logistic and scientific activities. In addition, in order to deal with small volumes, wastes are compacted.

Packaging materials are a major source of wastes. To limit their dispersion in the environment the policy has been adopted to store logistic and scientific equipments into standard shipping containers. In this way two advantages are obtained: faster loading and unloading procedures and tidier unpackaging.

Suppliers of goods and Institutions are requested not to use polystirene beads, chips and similar for packing.

Wastes produced during the 1988/89 season were about 30 m^3, equivalent to 4 liter/ (person x day), having taken into account that an average of 130 people worked at the Base from December 12th, 1988, to February 20th, 1989.

Wastes were sorted and collected according to the type both at the Base and field camps. Because some of them were retrograded to Italy, they were classified also according to the italian regulations on this matter.Types and quantities at the end of the 1988/1989 expedition were as in Table 1:

Table 1 - Wastes produced during the 1988/1989 Expedition

Type	Quantities (liter)	Approx. average (liter/person)
- plastics	12000	92
- metal	8400	65
- glass	2400	18
- cans	2200	17
- ashes from incinerator	600	4.5
- mineral oils from machinery	1000	-
- sludges from water treatment plant	1000	8
- organic grease from the kitchen	300	2.5
- rock wool	400	3
- flat batteries	25	0.2
- flat batteries for car	2 pieces	-
- expired drugs	40	0.3
- photographic chemicals	40	0.3
- toxic wastes from laboratories	1200	20

As to the wastes from laboratories the average in Table 1 was made on 60 people.

Plastics, metal and cans were disposed of in New Zealand; the remaining wastes were retrograded to Italy.

During the last Expedition 1989/1990 the same policy was adopted. Complete data are not yet available at the moment the present paper is being written. For this reason provisional quantities are reported here, Table 2, as they were declared in the forms to be filled in when retrograding to Italy.

Table 2 - Estimated quantities of wastes produced during the 1989/1990 Expedition

Type	Quantities (liter)	Approx. average (liter/person)
- plastics	9000	100
- metal	2500	30
- glass	2000	23
- cans	1500	17
- ashes from incinerator	1000	12
- mineral oils from machinery	1000	-
- sludges from water treatment plant	4000	45
- organic grease from the kitchen	300	3.5
- flat batteries	25	0.3
- flat batteries for car	40 pieces	-
- expired drugs	25	0.3
- toxic wastes from laboratories	550	6.5

The relatively small quantity of plastics (9 m^3) is partly due to the fact that in the last season washable dishes and glasses were prevailingly used at the Base instead of the disposable ones.

To reduce the volume of some of the items above, last year a press and a grinding mill for small communities were put into operation. Glasses were ground, cans squeezed and all compressible wastes compacted so that significantly smaller volumes were collected for transportation.

The amount of wastes produced in 1989/1990 is not directly comparable with the previous season because the presences in Antarctica were not the same. The Expedition began on November 1st, 1989 and ended on February 18th, 1990. Until December 22nd, about 30 people inhabited the Base; after December 22nd there was an average presence of 130 people with a peak, for a short time, of 158 people. The average presence over about four months was 87 people.

b) Waste disposal

Since the fourth Expedition (1988/1989) the decision has been taken to retrograde wastes, to the maximum possible extent. The procedure is expensive but worthdoing, because it allows to minimize the impact of human activities.

Terra Nova Bay Station is fitted with an incinerator and an effluent water treatment plant, which were designed to cope with the needs of a community of 60 people (nominal) and for a two month stay. These facilities are fitted into containers placed in the vicinity of the Base. The discrepancy between the quoted average occupation of the Station and the nominal plant capacity can be explained by the fact that about half of the personnel is berthed on board the support ship and they use the Base facilities only during the working day.

What is not harmful to the environment is flushed from the plants above into the sea, (i.e. the purified waters from the water treatment plant) or dispersed into the air. Emissions and effluents from the plants are monitored in order to guarantee the efficiency of the systems.

Incinerator and water treatment plant are discussed below.

<u>Incinerator</u>

The incinerator was specifically designed for the antarctic Station by SIEN, a firm from Legnano, Italy. It mainly consists of: a 1.5 m^3 combustion chamber, where wastes are burnt at a temperature of 650 °C; a post-combustion chamber working at a temperature of 950 °C; fans and burners for a controlled and optimized operation of the combustion process. Then a multistage abatement system follows: the fumes are first passed through a Venturi scrubber, where minor particles are abated; usually particles greater than 5 μm in diameter are abated by means of washing towers. In the first stage of the Venturi system water droplets come in touch with the particulate matter and the efficiency of the process is improved by an optimal choice of the ratio between the droplet diameter and the particle diameter as well as by an optimal choice of the relative velocity. In the second stage gas slows down progressively, promoting clustering of the water droplets and inertial abatement. The abatement process continues in the subsequent final stage, a washing tower, where the finest particles escaped from the Venturi scrubber are captured and a possible small amount of hydrochloric acid is further reduced. This is the result of a rotating movement of the gas stream together with the washing action of a purifier liquid injected from nozzles. Eventually, the liquid phase is separated from the gaseous one and the phases are discharged separately. The exhaust fumes go out through the chimney at a temperature of 120 °C, where part of the liquid reenter into cycle, and the remainder is flushed into the sea.

The incinerator can burn up to 50 kg of wastes per hour with a limit of 200 kg/day.

According to our policy only carton, paper , wood (not chemically treated) and food scraps are incinerated; plastics are not burnt.

The system is fed by diesel oil. During the 1989/1990 Expedition the consumption was 2000 liter.

Water treatment plant

The plant was specifically designed for the Antarctic Station by the firm G. Diefenbach from Monza, Italy.

It is fitted into two rooms obtained from two standard ISO20 modified transport containers; it collects waters both from the toilets and lavatories and from the kitchen. The pathway is the following.

Waters from the kitchen go into a tank (grease separator), where the heavier part of the liquid settles on the bottom, the grease stays on the surface. Then waters flow, together with the other waters into a drain trunk line towards a buffer tank. This tank and two maceration pumps, which work one at a time, are assembled on a skid and are located in a box under the main building of the Base. The liquid from the macerator is cloudy and has suspended particles of minimum size in it. This final product goes into a feeder tank (in the first room - container), through biorolls where the biological digestion takes place, into an Imhoff settler (in the second room - container),and is eventually flushed into the sea. Muds from this plant are pumped into 200-liter drums to be retrograded and disposed of in Italy. Once in a month sludges are discharged into the drums for a better operation of the system. The system has been designed for an input of 10 m^3 of water per day and for a total equivalent BOD_5 of 3 kg/day. The parameter BOD_5 indicates the biological oxygen demand in a 5 day term.

The biorolls are rotating devices which promote an aerobic process. The biological digestion is obtained by inseminating bacteria at the beginning and during the season. The optimum working temperature is of 15 °C. The start up takes seven days. The bacteria used are sold under the trade name of "Biosana". They cause a series of oxidation - reduction processes associated to microbic symbioses in the fluid to be biodegraded. The Biosana inorganic component mainly consists of iron(II) sulfate which hydrolizes giving way to iron(II) - iron(III) hydrate and sulphuric acid. The biorolls have to be fed continuously and regularly. For this reason the working time of the plant ranges from 14 to 24 hr/day with an average of 18 hr/day.

Environmental monitoring

Many research projects supported by the Expedition are devoted to the study of environment in order to understand the long range transport of pollutants from more industrialized areas and to know their effects on the antarctic ecosystems. Scientists from Universities, C.N.R. and E.N.E.A. are involved in this matter. Sea - water, freshwater, as well particulate matter, soils, sediments, air, meteoric depositions are subjects of interest. Analyses are focussed on the determination of inorganic and organic elements and compounds relevant from a biological, geochemical and toxicological point of view.

The results will be helpful for the evaluation of the environmental impact on a global scale but, of course, they will add information on the impact of the Station on a local scale.

Early results generally do not show pollution from industrialized areas, even though a light anthropogenic contamination has been detected for some organic compounds (e.g. PCB's, pp'DDT, Aldrin).

The airborne particulate

Since the 1986/87 Expedition airborne particulate matter was sampled with the aim of characterizing the local atmosphere and of getting background values to compare with further data.

During the following expeditions samplings were carried out in different sites in order to get information on the load due to human activities. One monitoring site, a small pond known as "Skua Lake ", was about 600 m away from the Base, upwind, and around 120 m above the sea level; another one was at the Base itself, downwind.

Tables 3, 4 report the results of the sampling from 1986/87 up to 1988/89 campaign. Analyses of the samples from the last expedition are still in progress.

During the 1986/87 campaign (Table 3) most of the elements had concentration values under the instrumental sensitivity. That was essentially due to the short sampling time. Antarctic atmosphere turned out to be poorer in particulate matter than expected and the sampling time, although longer than the one usually needed in polluted areas, was not enough to obtain good results. For this reason the time was increased in the years after.

The 1987/88 data, compared with those from the 1988/89 expedition, show higher concentration values. This could be attributed to the kind of works in progress at the building yard; during the 1987/88 expedition, in fact, there was a relevant ground handling. This is underlined by the increase, not only in the rare earth contents (La, Ce), in Th (characteristic of the intrusives rocks) and Sc, but also in elements like Fe, Al, Cr, Zn. From this consideration such an increase seems to have a crustal more than anthropic origin.

From a comparison of the filters collected at the Base during the same summer, a noticeable increase in the content of some elements has been observed with time. This is particularly true for V, Fe, Al, Mn and can be attributed to a major particulate matter resuspension because of the human activities. It is not possible to correlate these results with meteorological data because the sampling times are too long, 5 days. The choice of these values has been conditioned by the instruments performance and the need to get meaningful samples.

Table 3 - Airborne particulate matter. Elemental composition measured at "Skua Lake"

	concentration (ng/m^3)		
Element	1986/87	1987/88	1988/89
Na	217±46	230±30	230±40
Rb	<10	<10	N.D.
Sc	<.1	.008±.001	.006±.001
V	<.2	<.2	N.D.
Cr	<.5	4.0±.4	2.5±.3
Mn	<2.0	1.4±.4	N.D.
Fe	<100	70±10	42±5
Co	<.1	.08±.01	.06±.01
Al	61±30	110±20	32±9
Sb	<.1	1.7±.4	<3.0
La	<.1	<.1	.15±.02
Ce	.1±.05	.3±.1	.21±.004
Th	<.1	<.02	.02±.01

Table 4 - Airborne particulate matter. Elemental composition measured at the Base

	concentration (ng/m^3)					
	1987/88			1988/89		
El.	Min.	Max.	Ave.	Min.	Max.	Ave.
Na	280±30	660±70	438±45	<100	250±30	127±30
Rb	<.1	.7±.1	.6±.3	N.D.	N.D.	N.D.
Sc	.01±.003	.1±.05	.04±.01	.002±.001	.1±.05	.03±.01
V	<.2	3.6±.5	.7±.3	<2	<2	<2
Cr	1.0±.1	10.5±1.0	6.9±.7	<1.0	2.7±.3	1.0±.1
Mn	<2	43±9	12±4	N.D.	N.D.	N.D.
Fe	60±10	1050±90	315±30	21±2	220±20	77±10
Co	.10±.02	.42±.06	.3±.05	.1±.02	.5±.06	.2±.02
Zn	3.4±.4	110±10	23±2	2.9±.3	13±1	8.1±.9
Al	100±10	1400±140	460±50	18±10	210±15	70±10
Sb	2.0±.2	6.5±.5	3.4±.5	<.2	6.2±.5	3.0±.5
La	.2±.1	1.1±.2	.4±.1	.008±.001	.3±.1	.10±.01
Ce	<.5	1.8±.2	.7±.2	.2±.02	.7±.1	.4±.1
Th	<.02	.1+.05	.05+.01	<.04	<.04	<.04

Monitoring the incinerator

Particular attention has been paid to the incinerator. Tables 5 report the results of seven isokinetic samplings at the incinerator, taken at different times.

Table 5.1 - Data from the isokinetic sampling at the incinerator (Na, K, Mg, V)

Sample	Na	K	Mg	V
	concentration (mg/m^3) 1988/1989			
1	<1.0	4.73±0.95	<0.05	<0.002
2	3.90±0.80	4.83±0.90	0.07±0.01	<0.002
3	1.94±0.40	1.83±0.36	0.17±0.02	0.002±0.001
4	0.60±0.10	3.35±0.70	0.07±0.02	<0.002
5	12.30±2.40	13.60±2.70	0.26±0.03	<0.002
6	5.40±1.10	<1.0	0.20±0.02	<0.002
7	7.60±1.50	8.98±1.80	0.15±0.02	<0.002

Table 5.2 - Data from the isokinetic sampling at the incinerator (Br, Sb, As)

Sample	Br	Sb	As
	concentration (mg/m^3) 1988/1989		
1	0.04±0.01	0.065±0.007	0.060±0.006
2	0.04±0.01	0.020±0.002	0.080±0.008
3	0.04±0.01	0.010±0.001	0.040±0.004
4	0.04±0.01	N.D.	N.D.
5	0.13±0.02	0.920±0.090	N.D.
6	0.10±0.02	0.311±0.030	N.D.
7	0.80±0.10	0.480±0.040	N.D.

The data are merely indicative of the time at which the sampling was carried out. This is because of some difficulties to obtain isokinetic conditions, partly due to the fact that the incinerator is a model especially designed for a community of about 60 people. Besides, the management of the plant should be reviewed. In fact, wastes are burnt discontinuously and not homogeneously.

To collect greater quantities of particulate from the incinerator samplings will be carried out starting from the next expedition on ceramic thimbles instead of on fiber - glass filters as in the past. Measurements of organic compounds in bottom ashes, fly ashes and condense have been planned since the last expedition.

Monitoring the water treatment plant

Regular BOD_5 and COD (Chemical Oxigen Demand) measurements are made on the effluent waters from the water treatment plant in order to check the operation of the system. Microbiological analyses on the samples were also performed.

Samplings were carried out at the outlet of the water treatment plant. COD measurements, when possible, were performed daily in the morning (9 a.m.), in the afternoon (2:30 - 3 p.m.), in the evening (9 p.m.). Once a week COD, BOD_5, pH, temperature, turbidity and microbiological analyses were carried out on samples taken also from other points which are: the outlet of the desalting plant and two points at the sea that can be affected by the effluent.

BOD_5 and COD data from samplings carried out in the afternoon at the outlet of the system, are thought to be the most representative.

BOD_5 values range from 150 mg/liter up to 470 mg/liter. They are however purely indicative, coming from a single measurement.

On the other hand it was possible to control continuously CO. Samplings were performed during the last campaign when about 130 people worked at the Base. The average value of COD is around 400 mg/liter.

Although the average is consistent with the standard value determined by the Italian law, it is desirable that countries active in Antarctica establish standards applicable to this continent. (The same can be affirmed for air quality standards). All the countries should have the same reference values.

Recent developments

Also the last building activities at Terra Nova Bay, in the season 1989/1990, took into account the environmental impact.

Among them the most important are the new infrared astronomical observatory OASI, the bulk fuel tank and the addition to the electrical generators of a facility for the recovery of waste heat.

OASI is a small and clean laboratory, the activity of which does not increase the scientific population at Terra Nova Bay. Accordingly, it will not be discussed here

Fuel Tanks

To cope with the increasing energy demand of the Base and to provide the future expeditions with a suitable amount of stored fuel, a special fuel reservoir was erected during the last expedition.

The reservoir was studied to prevent oil spillages. It consists of a double tank, one inside the other, with a capacity of 600 m^3.

The outer tank is fitted with a roof. The material used is carbon steel, 8 mm thick, with a proof resilience at -50°C. There are manholes in the inner and outer mantles and on the roof. Extensive X ray tests were performed before filling up.

Another tank is under construction and will be completed next season.

Cogeneration System

During the 1989/1990 Expedition an energy conservation system (cogeneration) was set up at the Base. It was devised for the retrieval and distribution of the heat from the cooling water of the diesel power plant, which consists of two 350 kVA Isotta Fraschini generators. The full power to be obtained by means of cogeneration should reach about 120 kW. At present it is limited to 40 kW which are used only to pre-warm the sea water for the desalting plant at an average temperature of 23 °C.

The system is made up of two units, one for each generator. Each unit consists mainly of an heat exchanger and manifold connecting pipes and valves. The cooling water from the generator goes through the heat exchanger, that works as the radiator and is connected in series with it. Heat is transferred to the desalting plant by means of an intermediate closed circuit with an antifreeze fluid (water and glycol) inside. A bypass valve and heat sensors control the temperature. A pressurized expansion vessel is connected to the closed circuit upstream the circulation pumps. There are two pumps and they work one at a time.

Future Developments and Conclusions

All the plants and activities processes of the Base are unceasingly improved to reduce the pollutants load on the environment.

Plans for the future activity at Terra Nova Bay foresee improvements in wastes management and a better running of the incinerator and the water treatment plant.

Efforts will be made to further minimize the quantities of plastics brought to Antarctica. A reduction is expected to come when the winter station will be operating. At that time materials and scientific instruments will be left at the Base with a cut off of packing stuff.

The figures for the wastes produced in the last two expeditions show that we have been able to reduce the quantity of plastics used.

The inventory of the wastes produced during the last two campaigns gives the typical composition and quantities. However it is understood that actual figures depend both on the number of people and the kind of work in progress at the Base. Presently yard activities are not over at Terra Nova Bay.

The use of the cogeneration system will be increased, including the heating of the ventilation air of the Base; 80 kW, of a total 120 kW, could be devoted to this purpose. Besides, the retrieval of heat from the diesel exhausts was taken into account already when the generator plant was designed. The exhaust heat should be retrieved by assembling fluid - bed exchangers. Heat can also be retrieved from the discharge brine of the desalting plant.

What is made at the Italian Antarctic Base is not the optimum yet, but with the help of new technologies and the exchange of information with countries having more Antarctic operational experience and open to environmental problems better results will be obtained.

- This work was developed in the frame of the Italian National Antarctic Program (P.N.R.A.)

New Zealand Antarctic Research Programme Waste Management Procedures

by
David Geddes
DSIR Antarctic
Department of Scientific & Industrial Research
Christchurch
New Zealand

Abstract

One of the less desirable legacies of human activity is the production of waste materials. Increased environmental awareness in recent years has brought about many changes in the way the world's population treats this problem. Nowhere is this more evident than in the Antarctic, where specific guidelines have been developed to ensure that the impact of human presence is kept to an absolute minimum.

Since the modern era of Antarctic operations commenced in the mid-1950's all human activity has been subject to controls set by the Antarctic Treaty. This has included a Code of Conduct which details recommended procedures for disposal of waste products. This Code of Conduct has recently been revised and forms the basis for the waste management procedures adopted by the New Zealand Antarctic Research Programme.

A key factor in the success of these procedures is the development of the correct attitude amongst all personnel involved in the programme. Their individual responsibilities to the protection of the Antarctic environment are first highlighted during a pre-Antarctic training course and this is further emphasised by the issue of a written directive to all programme personnel prior to departure for Antarctica.

The main elements of the waste management procedures are the separation of waste into three categories - burnable, non-burnable, and hazardous - and the subsequent disposal of each category of waste. Burnable waste is burnt in a high-temperature, double-burning incinerator at Scott Base, while all other dry waste is returned to New Zealand by either aircraft or ship for disposal. Where possible, material which is suitable for recycling (e.g. aluminium cans) is handled separately. With only minor exceptions, waste generated in field camps is returned to Scott Base for disposal through the above system.

In all aspects of waste disposal the New Zealand Antarctic Research Programme is able to equal or better the minimum standards required by the Code of Conduct. This will be further improved with the installation of a sewage treatment plant during the 1990/91 Antarctic summer season. While the costs of keeping the Antarctic in pristine condition are high in terms of money and manpower, it is a cost which all

Antarctic operators must accept. In doing so we, as National Antarctic Operators, are able to set an example to the rest of the world on how our environment can be preserved for future generations.

Introduction

One of the less desirable legacies of human activity is the production of waste materials. Increased environmental awareness in recent years has brought about many changes in the way the world's population treats this problem. Nowhere is this more evident than in the Antarctic, where specific guidelines have been developed to ensure that the impact of human presence is kept to an absolute minimum.

Since the modern era of Antarctic operations commenced in the mid-1950s all human activity has been subject to controls set by the Antarctic Treaty. This has included a Code of Conduct which details recommended procedures for management of waste products. This Code of Conduct forms the basis for the waste management procedures adopted by the New Zealand Antarctic Research Programme (NZARP).

Waste Management Planning

In any form of activity, the success or degree of success is often determined by the planning which precedes the activity. This is particularly relevant to Antarctic operations where detailed planning of the operational programme can significantly reduce the overall impact of human presence. In developing the annual New Zealand Antarctic Research Programme considerable attention is given to limiting or reducing the amount of waste or environmental impact produced by human activity. Accurate and detailed planning of base and field support activities can ensure that excessive use of supply and fuel dumps is avoided and that transportation of personnel and equipment is carried out as efficiently as is possible.

An appointed Waste Management Officer is responsible for the annual updating of a Waste Management Plan. This plan not only includes details of current or planned activities and procedures but also past activities which may impact on the environment or future activities. One of the problems encountered in this respect has been the difficulty in identifying all areas of past operations and whether these activities have resulted in either short or long term environmental disturbance.

A new innovation which will assist in overall waste management is the standard format for Waste Management Plans which will be exchanged annually between Treaty members. As a permanent and on-going record of Antarctic operations it will be a timely reminder of the need to exercise restraint and responsibility in all of our Antarctic activities. It will also serve as a useful planning and information document of other countries activities and plans.

A key element in the development of the NZARP Waste Management Plan is the consideration of national environmental standards. In every respect the NZARP plan betters these standards and those of the Code of Conduct.

Personnel Training and Indoctrination

There is a natural reluctance for most people to want to get involved in anything to do with waste products. It is essential therefore that this psychological barrier is broken if any waste management programme is to be successful. This can be achieved through appropriate training and psychological conditioning.

All members of NZARP are required to attend a week-long pre-Antarctic training course where, along with the usual safety awareness development and training, participants are introduced to the NZARP waste management procedures. Here their individual responsibilities to the protection of the Antarctic environment are identified and the procedures they are obliged to follow are highlighted. This training is reinforced by the issue of a written directive (copy at Annex A) to all NZARP personnel prior to departure for Antarctica.

The development of correct attitudes has proved to be one of the most significant factors in the success of the NZARP waste management procedures. It has been our experience that without the right attitude to waste management the chances of success in implementing any programme are seriously constricted. And it is not a case of simply directing personnel what they are to do - that method seldom works - but rather developing within them an empathy with and a desire to protect and care for the fragile Antarctic environment.

Implementation

There can be little doubt that smaller programmes, operations and bases have an easier task in managing waste products than do larger operations. Not only is the physical amount of waste less but there are also fewer people to train. The chances of successful implementation are therefore greater right from the start.

With the right attitude developed in the pre-Antarctic training the actual implementation of the waste programme in the Antarctic is relatively simple. The main elements of the programme are the separation of wastes into appropriate categories and the subsequent disposal of each category of waste.

Waste Categories

Experience has shown that the initial separation of waste into categories is more successful if it is kept as simple as possible. For this reason and with the exception of sewage, only two primary categories of waste are used, for both base and field operations. These are simply BURNABLES and NON BURNABLES.

After the initial separation of waste is carried out the NON BURNABLE items are subject to further separation before disposal action. This is to separate items which are identified in the Code of Conduct as requiring special handling or treatment. This separation is carried out by specified base personnel to ensure that any errors in identification are kept to an absolute minimum.

The items comprising each category of waste are as follows:

BURNABLE	-	food scraps
	-	paper wastes and products
	-	untreated timber
	-	hydroponic plant remains
	-	low density plastic rubbish bags (containing burnable wastes)
NON BURNABLE	-	glass
	-	rubber products
	-	plastic products
	-	metals
	-	treated timber
	-	building materials
	-	incinerator ash
	-	dry cell batteries
NON BURNABLE (exclusive treatment)	-	lead acid batteries
	-	photographic chemicals
	-	waste kerosene, thinners, gasoline etc
	-	waste lube oil
	-	chemicals (dry)
	-	chemicals (wet)
	-	radioactive materials

Clearly labelled waste bins for each category are sited throughout Scott Base for the convenience of all personnel.

Waste Disposal

A distinction is made in the disposal of waste depending on whether it is generated at base level or as the result of field operations. This distinction is necessary because of the logistics limitations of returning all items to base for disposal, and in some cases because of the geographic location of some field activities.

All BURNABLE waste is disposed of in the high temperature, double burning incinerator at Scott Base. The only exception to this is for parties travelling in extended deep field operations where burnable items may be burnt on site and the ashes buried in the snow.

NON BURNABLE waste, whether originating from base or field operations, is stored separately at Scott Base before being packed into containers (sea transport) or special pallets (air transport) for return to New Zealand and subsequent disposal.

The secondary treatment of NON BURNABLE waste at Scott Base includes separation of those items which are suitable for recycling once returned to New Zealand. This includes aluminium cans and glass as well as some waste petroleum products.

Fuel and Fuel Containers

Careful planning has ensured that fuel required for field operations is not over-estimated and every endeavour is made to ensure that any remaining fuel is returned to base or established fuel dumps by the field parties. A record is maintained of all fuel stored away from base, for future use or return to base when no longer required.

Empty fuel drums are returned to base for re-use or, if unsuitable for further use, to store and transport waste to New Zealand.

Sewage

The handling of sewage is determined whether it is produced at base or in the field.

All base-sourced sewage (including grey water) is macerated and stored in a holding tank and then released into the sea. There is no provision to introduce field-generated sewage into the base system.

Human waste produced in field camps is stored in plastic bags or drums and returned to base where it is emptied from the container into the sea. Limited quantities are disposed of in the incinerator. Some exceptions to this rule are permitted - deep field parties may bury human waste in the snow, and parties operating on or adjacent to sea ice may dispose of their sewage directly into the sea through suitable cracks in the ice.

The disposal of sewage (or ash remains of burnable wastes) in the field is only permitted in areas of extensive cover of snow or ice. Under no circumstances is waste of any type allowed to be disposed of in snow or ice free areas - it must be returned to base for disposal.

Prohibited and Restricted Materials

In keeping with the requirements of the Code of Conduct the introduction of some materials into Antarctica by NZARP personnel is prohibited unless a permit for its introduction has been granted. Those items include:

- polystyrene beads, chips or similar forms of packaging
- all soils
- PCBs

- seeds for hydroponics and human consumption
- living plants

The use of PVC products in packaging is discouraged.

Cleanup Activities

In addition to the routine day-to-day waste monitoring activities undertaken within NZARP, programmes have been initiated over recent years to clean-up areas of earlier NZARP activity. The most significant task has been conducted jointly with the United States Antarctic Program (USAP) to remove all buildings and facilities of the abandoned Hallett Station. This site has now been returned to its natural state and the work included the construction of man-made penguin mounds for the local Adelie population.

Other old camp sites have been visited annually to remove any remaining signs of human activity. During the summer season volunteer groups cover the area adjacent to Scott Base collecting and removing any items of rubbish which may have accumulated during storms or simply through normal human activity.

Problem Encountered in Implementation

In implementing the NZARP waste management procedures some physical as well as psychological problems have had to be overcome.

As the New Zealand economy is largely based on the export of primary produce strict regulations are enforced to ensure that no potentially harmful organisms are introduced to New Zealand from outside the country. In order to import waste products to New Zealand from the Antarctic considerable negotiation was necessary with the relevant authorities to determine the specific requirements under which this waste could be imported safely. This has mainly concerned the importation of any food or animal products and containers used in their transportation. This has resulted in additional training and personal discipline to ensure these standards are met.

Careful planning has been necessary to ensure that sufficient space and suitable containers have been available to transport all waste from Antarctica to New Zealand. This has meant utilising space on both air and sea transport throughout the summer season.

The prohibition of import into Antarctica of some items has required an on-going education programme for all personnel involved in the NZARP programme each year. The banning of some packaging materials commonly used in areas outside of Antarctica has resulted in the need to repack some cargo in order to meet these requirements.

The major penalties in implementing the waste management procedures have been an increase in unproductive time and additional costs. Both of these factors however are considered to be a legitimate cost to the overall running of NZARP.

Future Developments

The annual review of the Waste Management Plan ensures that the procedures are implemented as efficiently as is possible. Plans are underway to introduce a secondary treatment sewage treatment system which will enable all sewage and domestic waste, from both field and base operations, to be treated before disposal. Programmes to monitor incinerator emissions and the overall impact of the waste management procedures will require attention in the future to ensure the highest possible standards are attained.

Summary

In all aspects of waste disposal the New Zealand Antarctic Research Programme is able to equal or better the standards required by the Code of Conduct. Regular education and training programmes to develop the attitudes necessary for the successful implementation of waste management procedures, as well as continual review of these procedures and upgrading of facilities will ensure the standards are maintained in the future. Although the costs of keeping the Antarctic in pristine condition are considerable, it is a cost which all Antarctic operators must accept. In doing so National Antarctic Operators are able to set an example to the rest of the world on how our environment can be preserved for future generations.

Annex

NZARP WASTE MANAGEMENT PROCEDURES

Introduction

The Antarctic Treaty specifically provides safeguards for the protection of the Antarctic environment.

In order to implement these safeguards all NZARP personnel are required to respect the Antarctic environment and keep human impact to a minimum.

This has been achieved by implementing the waste management policy recommended by the SCAR Panel of Experts on Waste Disposal.

For the 1989/90 season the following guidelines are to be adhered to when carrying out the disposal and management of waste products and movement of materials to and from Antarctica.

Waste Categories

The following items comprise each waste category:

a. Burnables

- food scraps
- paper wastes and products
- untreated timber
- hydroponic plant remains
- low density plastic rubbish bags (containing burnable wastes)

These are burnt in the Scott Base High Temperature Incinerator.

b. Non-Burnables

- glass
- rubber products
- plastic products
- metals
- treated timber
- building materials
- incinerator ash
- dry cell batteries

These are to be packed for airfreighting (early season) or in containers (late season) for RTNZ.

c. Non-Burnables (exclusive treatment)

- lead acid batteries - acid drained in carboys provided and batteries placed upside down on pallets for RTNZ
- photographic chemicals - stored in provided 44 gal. drum for RTNZ. Final rinse water can be flushed down the sink.
- waste kerosene, thinners, motor gasolene etc - stored in provided 44 gal. drums for RTNZ
- waste lube oil - stored in 44 gal. drums for RTNZ
- chemicals (dry) - to be repacked by event persons under supervision of stores staff and RTNZ
- special provision to be made to return active wet chemicals to NZ in plastic containers
- radio-active materials - stored separately for RTNZ

Waste Disposal

1. Field Waste

All waste generated in field camps will be returned to Scott Base for disposal. Field parties should separate burnable, non-burnable and human waste into bags provided. Upon return to Scott Base, field personnel should take burnables to the incinerator. For field parties operating at Cape Bird, human wastes may be emptied into the sea. Parties operating on the sea ice may empty human wastes into a suitable tide crack.

Non-burnables should be taken to the storage area, ready for packing into the retro containers.

Human wastes should be emptied from their plastic bags and disposed of in a suitable tide crack, flagged by the Field Storeman.

When travelling on extended deep field operations where transport limitations prevent the practical implementation of this policy, in such cases paper products and rubbish bags may be burnt on site and the ashes buried along with solid human waste, and non-burnable products returned to base at the final pullout.

2. Base Wastes

All waste products at Scott Base are to be separated into two categories - burnable and non-burnable.

Waste bins for each category are clearly labelled.

All aluminium beer cans are to be crushed using the can crusher in the bar and placed in the bin provided. Cans containing food residue must be thoroughly washed out before RTNZ due to MAF Health Regulations.

Fruit juice cans (steel) are to be placed in the rubbish tin provided and must not be mixed with aluminium beer cans.

A receptacle for glass e.g. wine bottles, is available outside near the bar area. Please <u>break</u> them into it.

3. <u>Prohibited Items and Materials</u>

The following are not permitted to be introduced into Antarctica unless permitted by permit.

- polystyrene beads, chips or similar forms of packaging
- all soils
- PCB's
- seeds for hydroponics and human consumption
- living plants

The use of PVC products in packaging is discouraged.

The Experience of Waste Removal and Treatment at the Soviet Antarctic Expedition

V.P. Klopov [1]
V. Y. Shirshov [2]
A.V. Dmitriev [3]

Abstract

The problem of removal and recycling of liquid and solid wastes as a result of economical activity is of paramount importance in the process of interaction between humans and natural environment. Liquid waste in general consists of sewage and black waters, at large antarctic stations sewage from kitchens presents the major part of liquid waste.

Sanitary bacteriological studies of the stations' territory revealed the considerable bacterial contamination of soil, snow and ice at the sites of pumping-over, transportation and discharge of waste water which is of certain ecological danger. To prevent the ingress of untreated sewage into the natural environment of Antarctica the sewage water treatment plant EOS-15 was mounted and started up in 1988 at the AMC Molodezhnaya. EOS-15 conducts the electrochemical treatment of sewage water by means of electrolysis of liquid masses running through the special electrodes after mechanical treatment. As a result of commissioning the optimal operational regime EOS-15 was chosen to provide for the maintenance of treated sewage parameters in accordance with the International Convention for the Prevention of Marine Pollution from Ships MARPOL 1973/78. The content of suspended matter remained at a level of 77 mg/l in comparison with the normal value equal to 100 mg/l. Coli index did not exceed 900 bodies of colibacillus in 1 ml against the normal value 1000 bodies/ml.

In the near future the construction of ecological complexes is planned at the Soviet Antarctic stations including both liquid waste treatment plant and stoves SP-50 for the combustion of solid waste, used fuel and lubricants and solid residual (sludge) forming after sewage treatment. There is a principal opportunity to arrange the close-circuited work of ecological complexes with the utilization of treated sewage and ash remainders after solid waste combustion. The realization of this principle will provide for the safe sanitary epidemiological state of the Soviet Antarctic stations.

---

1) The Arctic and Antarctic Research Institute
2) dito
3) dito

ENVIRONMENTAL MANAGEMENT OF AUSTRALIA'S ANTARCTIC PROGRAM

by

J C A Sayers
Australian Antarctic Division

Abstract

During the last ten years Australia has placed increasing emphasis on the environmental management of its activities in Antarctica. This period has also seen the number of personnel visiting Australia's three permanent stations, and participating in field programs, increase markedly. Building construction, maintenance tasks, and expanding scientific work programs have highlighted the need to develop and implement measures to protect the Antarctic environment to the maximum practicable extent.

Operational guidelines and environmental impact assessment procedures have been developed to implement and supplement existing Australian environmental legislation, Antarctic Treaty Recommendations and obligations under other international agreements. Management plans for stations are being developed.

Environmental awareness is encouraged and developed in expeditioners starting at the recruitment stage. The expeditioner induction program involves progressively more detailed instruction on environmental management. A more intensive training program on environmental responsibilities is given to Station Leaders, Station Environment Officers and Inspectors appointed under Australian Antarctic environmental protection legislation.

Vessels under charter are required to comply with strict requirements for the handling and disposal of shipboard wastes. Waste management plans for stations require the segregation of materials for either local incineration in high temperature incinerators or retrograding to Australia. All waste tips were closed in 1985 and a program of returning waste materials, to the maximum practicable extent, and rehabilitating the landscape is underway. The Australian Antarctic Division is also paying particular attention to improving procedures for the transport, handling and storage of fuels.

Introduction

Background

Australia has been actively pursuing scientific studies and the exploration of Antarctica for the past ninety years. The contemporary Australian Antarctic Program, however, commenced in 1947 with the establishment of the Australian National Antarctic Research Expeditions (ANARE). In the following year the Antarctic Division was created to provide the logistic and administrative support to ANARE and implement the government's policy with respect to Antarctica. In addition to providing the infrastructure for the Antarctic Division's own scientific programs, ANARE also supports the Antarctic activities of the broader scientific community, in universities, research institutions and other Australian agencies, including the Bureau of Meteorology (BOMET), the Ionospheric Prediction Service (IPS), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Mineral Resources (BMR).

Stations and Bases

Australia has three permanent "wintering" stations in Antarctica and a fourth on the subantarctic **Macquarie Island. Mawson Station** was established in 1954, followed by **Davis Station** in 1957 and **Casey Station** in 1969. Casey was built to replace Wilkes Station which had been constructed by the United States expedition in 1957 for the International Geophysical Year. Australia took over administration of Wilkes in 1958, however, the station was subsequently abandoned because of inundation by snow.

Australia also operates a number of small summer field bases which are activated according to the needs of scientific programs. The principal field bases are:

- **Commonwealth Bay Base**
  Located approximately one kilometre from Sir Douglas Mawson's hut and associated structures which were constructed in 1912 for the Australasian Antarctic Expedition.

- **Dovers Base**
  Located approximately 310 km south-east of Mawson in the Prince Charles Mountains.

- **Edgeworth David Base**
  Located in the Bunger Hills approximately 420 km west of Casey.

- **Law Base**
  Located in the Larsemann Hills approximately 120 km west of Davis.

- **Law Dome**
  Established in 1988 on the ice sheet approximately 120 km inland from Casey.

- **Heard Island Base**
  Heard Island was the site of the first ANARE station established in 1947. A number of field huts are currently located at Spit Bay adjacent to the original station.

Station and Base Populations

The wintering population of each of the three permanent Australian Antarctic stations typically varies from between 25-40 persons whereas in summer the populations can rise to 90 or more expeditioners. The population of summer bases can vary from a handful of expeditioners to the current summer peak of 25-30 personnel operating from Dovers in the Prince Charles Mountains.

In addition to station and general scientific field activities, Australia has been active in operating glaciological traverses during the past 30 or more years. Current traverse activity is centred on the Lambert Glacier basin.

Rebuilding Program

During the early 1970s a number of studies were undertaken to evaluate various designs for station buildings in Antarctica. The original station buildings were of a load-bearing "sandwich-panel" construction and had a design life of only 10 to 15 years. Furthermore the earlier buildings were designed and sited with little definitive knowledge of the harsh Antarctic environment.

A new design concept was agreed in 1976 and a major program to rebuild all three stations commenced in the following year. The Rebuilding Program is now approximately 75 percent complete across all three stations and is planned to conclude in the 1994/1995 summer. The estimated total cost of the program at completion, excluding logistics support, is A$150M (1990 prices).

The rebuilding activities have imposed considerable pressures on Australia's Antarctic Program during the last ten years. In addition to the large volume of building materials and equipment to be delivered to stations, it has been necessary to provide temporary accommodation for teams of construction personnel over summer. The need to return to Australia (RTA) or burn significant volumes of packaging materials and other waste generated from the Rebuilding Program has also posed logistics and environmental management problems.

Shipping Operations

During recent years the Antarctic Division has chartered from overseas sources two ice-strengthened vessels to undertake its summer logistics operations. In 1984 the newly constructed *MV Icebird* (built and registered in the Federal Republic of Germany) was chartered to provide much needed additional cargo and passenger capacity to support the Rebuilding Program. The *Icebird* has been used for the last six seasons and has again been chartered for the 1990/91 season.

In 1987, the Australian Government decided that a new research and resupply vessel would be built in Australia to support the Australian Antarctic Program. On 30 March 1990 the Antarctic Division accepted delivery of the newly constructed *RMS Aurora Australis*, the first icebreaker to be registered under the Australian flag. The vessel combines "state of the art" design and technology for ice-class ships, with comprehensive scientific facilities, and will greatly enhance Australia's marine science capability. Forecast cargo and passenger numbers will mean a continuing requirement for a second cargo/passenger vessel in the foreseeable future.

Air Operations

Australia makes extensive use of single-engined, turbine helicopters to support its shipping and scientific programs. The aircraft are used on early season voyages to aid navigation through heavy pack ice and to transfer expeditioners and cargo from the ice edge up to 80 nm offshore. Typically two groups of 2 or 3 aircraft are deployed at stations or field locations to support local scientific activities. In recent years the aircraft have been based at Davis (covering the Vestfold and Larsemann Hills region) and in Prince Charles Mountains south of Mawson.

During the last two years work has been undertaken to examine the feasibility of introducing an inter-continental air transport system between Hobart and Casey using Hercules C130 wheeled aircraft, combined with the possible use of twin-engined helicopters or light fixed wing aircraft to transfer expeditioners between Casey, Davis and Mawson. A compressed snow and ice runway was in preparation at Casey during the 1989/90 summer with the objective of conducting two trial flights, however, heavy snowfalls during the final stages of construction caused the trial flights to be abandoned. The future development of the air transport system is currently being evaluated, following receipt of technical reports on the 1989/90 project.

Growth of Program Activity

The last decade has seen a number of major developments and growth of activity in Australia's Antarctic Program. These include:

- The introduction of improved, "state of the art" vessels giving a substantial increase in cargo and passenger capacity and marine science capability.

- The number of passenger movements between Australia and Antarctica has increased from 440 in 1980/81 to a projected 800 in 1990/91.

- A substantial increase in the number of scientists carrying out summer research programs has occurred with field activities in 1990/91 taking place at Law Dome (south of Casey), the Vestfold Hills, the Larsemann Hills, the Prince Charles Mountains, Commonwealth Bay and Heard Island.

- The installation of shipboard satellite communications and imaging facilities which have improved safety and operational efficiency.

- All three continental stations have been largely rebuilt to provide modern accommodation and support facilities.

- A private satellite network has been established at all stations to facilitate the transfer of data and provide a telephone service connected to the domestic and international networks.

- Operational and scientific forward planning has been enhanced and integrated.

- There have been major improvements to the selection, recruitment, training, development and on-going management of expeditioner personnel.

  This background of increasing scope and diversity of Australia's Antarctic operations during the last decade, has presented particular challenges in terms of ensuring that the highest standard of environmental management is applied to our operations and the impact of previous practices (when less demanding environmental standards applied) are rectified to the maximum practicable extent.

Environmental Policy and Legislative Context

Australia's approach to environmental management in Antarctica has been developed in the context of national and international obligations under the Antarctic Treaty Recommendations, other international conventions, and domestic legislation. Relevant Treaty System environment protection obligations which in Australia, as in other countries, have been embodied into national law include:

- the *Agreed Measures for the Conservation of Antarctic Fauna and Flora, 1963* (known as the Agreed Measures);

- the *Convention for the Conservation of Antarctic Seals, 1972* (known as the Seals Convention); and

- the *Convention for the Conservation of Antarctic Marine Living Resources, 1980* (CCAMLR).

In addition to the above, Australia observes obligations under other relevant international agreements including:

- the *London Dumping Convention, 1972;*

- the *International Convention for the Prevention of Pollution from Ships, 1973* (the MARPOL Convention);

- the *Vienna Convention on Protection of the Ozone Layer and the Montreal Protocol of 1987;* and

- the *Washington Convention on the International Trade in Endangered Species, 1973.*

Legislation and Documentation

Legislation

A range of Australian legislation has been introduced to give effect to the various international environmental agreements relevant to Antarctica. These include:

- the *Antarctic Treaty (Environment Protection) Act 1980* which implements the Agreed Measures and provides:
  - for proclamation of Specially Protected Areas (SPAs), and Sites of Special Scientific Interest (SSSIs);
  - for entry to, and management of, protected areas;
  - for proclamation of specially protected species;
  - a permit system for scientific research on animals and collection of animals and plants for other legitimate purposes;
  - measures against harmful interference with Antarctic animals; and
  - measures to regulate the introduction of non-indigenous species.
- the *Antarctic Seals Conservation Regulations 1986* under the above Act which implements the Convention for the Conservation of Antarctic Seals and also bans sealing by Australians.
- the *Antarctic Marine Living Resources Conservation Act 1981* which implements CCAMLR, and sets heavy penalties for fishing and other activities in breach of the Act, and permits issued under it.
- the *Environment Protection (Sea Dumping) Act 1981* which makes it an offence for Australians and Australian vessels (including those under charter to Australia) to dump waste at sea except under specific circumstances. The Act also applies to the loading of waste for the dumping at sea and the incineration of waste at sea.

In addition to the above legislation the *Australian Antarctic Territory Act 1954* specifies that the laws of the Australian Capital Territory, insofar as they are applicable, should apply to the Australian Antarctic Territory (AAT), as well as other laws which specifically include the AAT in their scope. *(Note: The Australian Capital Territory [ACT] is the location of Australia's national capital, Canberra.)* The laws of the ACT have been used to govern matters such as the use of radioactive isotopes by Australians in Antarctica and the use of mobile plant and equipment on our stations. Those acts applying to all Australian territories but which have particular relevance to the AAT include:

- the *Wildlife Protection (Regulation of Exports and Imports) Act 1975;*
- the *Whale Protection Act 1980;*
- the *Quarantine Act 1908;*
- the *National Parks and Wildlife Conservation Act 1975;* and
- the *Environment Protection (Impact of Proposals) Act 1974.*

The Environment Protection (Impact of Proposals) Act 1974 is particularly relevant in that its provisions are similar to the requirements of ATCM Recommendation XIV-2, but in some respects are more stringent. The Act provides that a comprehensive environmental impact assessment must be undertaken when a proposal is likely to have significant environmental impacts, but there is also provision for a less comprehensive assessment process for proposals which have lesser environmental significance.

Environmental Impact Assessment Procedures

The Antarctic Division has introduced specific procedures for identifying and assessing the potential environmental impact of our activities in Antarctica and drawing a distinction between projects with potential for major and minor impacts. Major Antarctic projects are referred for consideration under the *Environment Protection (Impact of Proposals) Act 1974*. Proposed minor projects within existing station boundaries (such as the construction of helicopter pads) are assessed according to the Antarctic Division's defined procedures. A matrix of guidelines is used as an aid to decision making to identify the potential impact of proposed projects. Decisions on projects with minor impact potential are taken at the Branch or Divisional level, and reviewed by the Antarctic Environment Committee, depending on the scale of the proposal and the potential extent of the environmental impact.

The *Environment Protection (Impact of Proposals) Act 1974* does not lay down an assessment process for established activities which are unlikely to increase the impact on the environment to any significant degree. The Division nevertheless applies its own procedures to such activities which include:

- transport operations and cargo handling within the 1988/89 infrastructure level;
- the following works within the station boundaries, provided they are in compliance with station environmental management plans:
  - construction and maintenance of logistics facilities, and
  - maintenance, upgrading, dismantling or replacement of existing or individual buildings;
- conduct of field and laboratory investigations and research programs (including logistics support and field accommodation); and
- recreational activities using existing facilities.

Preliminary and comprehensive environmental impact assessments prepared under the 1974 Act would also satisfy the requirements of Recommendation XIV-2. There have been no major activities which have been undertaken since Recommendation XIV-2 was adopted which have called for the preparation of a comprehensive assessment.

Internal Documentation

The various international and national legal requirements, and other guidelines relevant to environmental protection in Antarctica, have been embodied in various documents published by the Antarctic Division.

The Division's "Operations Manual" contains standing orders, instructions and guidelines on operational activities including waste and environmental management.

Specific environmental guidelines and instructions have been drawn together in a booklet entitled "Environmental Management of Australia's Antarctic Stations". This publication is frequently updated to reflect developments in policy and changing Treaty and legal requirements. Particular guidance is provided on:

- relevant legal, permit and quarantine requirements;

- procedures for waste management on ships, vessels and in the field;

- specific measures for avoidance of harmful interference with wildlife; and

- precautions against the introduction of non-indigenous species.

A document entitled "Environmental Guidelines for Antarctic Helicopter Operations" has been published to provide a field guide specifically for helicopter pilots to prevent harmful interference with wildlife during helicopter operations. The booklet includes maps outlining SSSIs and SPAs and providing guidance on approaches to antarctic islands and field locations including approved landing areas.

Every expeditioner is provided with a copy of a pocket book entitled "ANARE Antarctic Field Manual" which includes a chapter on environment protection and details of station boundaries and environmentally sensitive areas close by.

Written comprehensive voyage leaders' and field leaders' briefings are provided which include instructions on environmental practices. Other domestic codes of practice governing, for instance, animal experimentation and the use of radio isotopes have also been adapted for use in Antarctica.

Management Plans

The Australian Antarctic Division has thus far focussed on developing a standard protocol for environmental management common to all three Australian Antarctic stations. An environmental brief is also developed for each major field program, such as the Prince Charles Mountains' summer field program.

Individual management plans for each station are currently being developed which take into account regional peculiarities. An outline for a management plan for the Vestfold Hills has been drafted and this was presented as an example in the context of ATCM XV discussion of Multiple-use Planning Areas.

Environmental Administration

Organisational Infrastructure

The Antarctic Division is organised under five Branches. The Branches and their principal functions are as follows:

- **Science Branch**: To undertake scientific research in the field of glaciology, terrestrial and marine biology, upper atmospheric physics and cosmic ray physics.

- **Expedition Operations Branch**: To provide the expedition infrastructure, including station management, ship and aircraft support, and engineering services, needed to support Australia's Antarctic Program.

- **Policy and Planning Branch**: To develop and administer government policy with respect to Antarctica, facilitate forward planning and coordination, and provide information services.

- **Medical Branch**: To provide health care services to all wintering stations, ships and field bases, and undertake research on the interaction of expeditioners with the polar environment.

- **Resources Management Branch:** To provide financial, purchasing, personnel and computing support services.

Matters related to environmental management and policy are considered by an Antarctic Environment Committee which is chaired by the Director. The Committee, which includes representatives from the operational, policy and science areas of the Division, has a role to:

- advise on the environmental impact of ANARE operations and activities:

- recommend ways in which impact on the environment can be minimised whilst achieving the Division's goals;

- advise on ways of increasing awareness of the possible impacts of activities on the antarctic environment; and

- consider reports of the Station Environment Committees and reports by Station Managers, Field Leaders and Voyage Leaders on environment related matters.

Responsibility for environmental management in Antarctica lies primarily with Station Leaders, Field Leaders and Voyage Leaders. Each are responsible for the environmental management of the regions or vessels under their control and for ensuring that procedures and standing orders in the "Operations Manual" and other relevant documents are complied with. Considerable effort is made to educate and encourage expeditioners and visitors to care for the antarctic environment and to make them aware of their legal and other responsibilities.

Station Leaders (and one or more members of the voyage support staff on vessels) are appointed inspectors under the *Antarctic Treaty (Environment Protection) Act 1980* and are required to ensure that the provisions of the Act are met. At the "wintering" stations a Station Environment Officer is appointed to assist the Station Manager in overseeing environment related matters. Each station has an Environment Committee which meets on a regular basis and provides:

- information on monitoring of the local environment;

- advice on proposals for developments within the station environs; and

- early warnings on emerging environmental issues for consideration by Head Office.

Because of the increasing environmental awareness in expeditioners, environmental management is now being driven to a greater extent than ever before from the stations. This is a particularly satisfying development and one which is being actively encouraged through the prompt consideration and feedback on matters raised through the Station Environment Committees.

Expeditioner Training

With a complete changeover of personnel on stations on a yearly cycle, there is clearly a need to ensure expedition personnel are well aware of established environmental procedures and relevant documents.

There is an emphasis on recruiting personnel with responsible environmental attitudes and this is assessed at the selection interview. The environmental awareness-raising process starts at the time of recruitment with the dissemination of a range of pamphlets and printed material to all incoming personnel. The SCAR Visitors' Guide is issued, and the ANARE Field Manual and other handbooks giving guidance on environmental protection in Antarctica.

Station Leaders and Station Environment Officers receive specialised and lengthy briefings on environmental management in relation to station and field activities. Inspectors, appointed under the provisions of the *Antarctic Treaty (Environment Protection) Act 1980*, receive a briefing on the provisions of that law.

All summer and winter expeditioners attend, prior to departure, general briefings on appropriate standards of behaviour, and additional specific sessions on local environmental issues relevant to their own stations. Voyage leaders provide a briefing on the local environment to ingoing expeditioners and round-trip passengers before disembarking at stations or field bases.

Meetings of the Station Environment Committees throughout the year ensure that the importance of environmental protection in Antarctica is a central theme in expeditioners' thinking.

Permit Administration

Permit systems are required under the provisions of the *Antarctic Treaty (Environment Protection) Act 1980*, the *Antarctic Seals Conservation Regulations 1986* and the *Antarctic Marine Living Resources Conservation Act 1981*.

Administration of the permit systems under these laws is conducted by the Policy and Planning Branch of the Division, which ensures a degree of independence in assessment of applications and a separate line of accountability. It involves close scrutiny of the details of operational proposals and applications to conduct antarctic research, from both Divisional and external researchers. The issue of permits is usually conditional upon meeting stringent environmental protection requirements.

A permit is required for the collection of biological specimens of all kinds and items such as lichen on rocks, whether for ANARE or for outside research workers, museums and other institutions. Collection of biological material for personal use is prohibited. Programs requiring the collection of geological samples do not require a permit other than for quarantine purposes providing the collection is approved by the Antarctic Science Advisory Committee (ASAC).

Quarantine permits are required for import into Australia of all collections of biological specimens as well as water, ice, sediments, waste materials and so on.

Environmental Management of Operations

Waste Minimisation

The disposal of waste generated on stations has become a significant issue for the Antarctic Division during the 1980s. Apart from the special focus on antarctic activities, the need for responsible waste management policies has emerged on the environmental agenda of most developed countries during the last 10 or more years.

In recent years our major focus has been towards developing sound waste disposal practices in Antarctica and on vessels, and ensuring that all waste materials and residues are returned to Australia (RTA) or disposed of locally in accordance with Antarctic Treaty Recommendations or the requirements of domestic legislation, whichever is the more stringent.

While some attention has been devoted to waste minimisation there is still much to be done in this area. Quite clearly the prevention of waste by changes to the specification or procurement of products or packaging offers considerable scope for savings in downstream waste management activities.

For example, a study[1] undertaken at Casey Station during the 1989/90 summer found that weekly per capita generation of packaging waste (3.75kg) was almost twice the corresponding figure for the city of Melbourne (1.97kg). The various proportions of packaging waste generated at Casey in comparison with Melbourne is shown in Figure 3.

Packaging Material	Casey Station %	Melbourne City %
Glass	25.3	30.5
Metal (Ferrous)	19.7	9.1
Metal (Aluminium)	3.7	1.5
Wood	16.6	0.5
Plastic	3.5	18.8
Paper	6.9	39.6 (1)
Cardboard	24.3	
TOTAL	100.0	100.0

Figure 3: ***Generation of Packaging Waste at Casey Station and Melbourne***

(1) Includes cardboard component

The distortions between the proportions of packaging wastes generated in Antarctica compared with a major Australian city can probably be explained by:

- the major rebuilding activity taking place which generates a substantial amount of timber packaging materials;
- steel cans used as food and beverage containers whereas in Australia a higher proportion of fresh food products is used; and
- a high proportion of aluminium cans used for beverages which reflects the dominant form of packaging used by suppliers currently under contract.

Current Antarctic Division policy is directed towards the "general obligation" under ATCM Recommendation XV-3 which requires that "the amount of wastes produced, or disposed of, in Antarctica shall be reduced to the maximum extent possible." The use of packaging materials is minimised as far as practical, plastic strapping is not used, and PVC in packaging is banned (as reflected in suppliers' contracts). Used packaging materials, such as drums, crates, cartons, etc are used for transporting RTA cargo and disposed of in Australia.

Waste Management on Stations

Landfill rubbish sites at all stations were closed in 1985 and virtually all solid wastes are now returned to Australia or disposed of in accordance with ATCM Recommendation XV-3. All waste products are sorted at the point of origin on station, and deposited, according to type, into 20 litre bins. The bins are then emptied into 200 litre (ex fuel) drums, which are also identified according to the category of waste, and disposal action takes place as follows:

---

1) Canale, G.; Fulford, B. and Quilligan, H. (1990). Waste Minimisation at Casey Station. *(Monash University, Graduate School of Environmental Science)*

- Kitchen wastes are burned in a high temperature incinerator and the residue is stored in 200 litre drums for RTA.

- Small amounts of non-PVC plastics are incinerated, for example rubbish bags, food wrappers, etc, and other plastics are RTA.

- Glass and aluminium containers are segregated and crushed for RTA. (In 1990 approximately $3500 revenue was earned from the disposal of crushed glass and aluminium for recycling. In 1991 it is expected to at least double this figure through more stringent recovery practices on stations.)

- Waste oils are collected and used as fuel in the incinerators or, if not suitable for this purpose, are RTA.

- Wooden crates previously used to carry building materials, are re-used to stow non-combustible wastes, and combustible wastes not suitable for incineration. These are disposed of in Australia in accordance with state or national regulations.

The 200 litre drums of waste materials are stored on the station in wind (and bird) proof containers pending incineration or RTA. The drums are transported to the incinerator or RTA storage depot by a 4 wheel drive utility, or flat-tray Hagglunds, or in the bucket of a wheel-loader. Some stations keep the drums in a small freight container (ISO Type "E") which is located close to the kitchen or living quarters, and transport the container direct to the incinerator or RTA depot point using a wheel-loader vehicle fitted with fork tines. This arrangement saves handling many loose drums. As RTA freight containers are filled, they are depoted at the loading area ready for shipment.

The Antarctic Division uses two basic types of International Standard Organisation (ISO) freight containers as follows:

- Type "C"& "CC" — 2.44 x 2.59 (&2.44) x 6.1 metres long — 20,000 kg Gross Mass

- Type "E"&"EE"* — 2.44 x 2.59 (&2.44) x 2.0 metres long — 7,000 kg Gross Mass

  * It should be noted that Type "E" & "EE" containers are no longer recognised as ISO standard sizes although they continue to be used in certain maritime trades.

The Type "EE" containers, being smaller and easier to handle on barges and on stations, are ideally suited to our cargo handling operations. The type "C" & "CC" containers, although larger and more difficult to handle, will continue to prove essential for the next 5 -7 years to assist in the removal of old dismantled buildings which have been superseded under the Rebuilding Program. In addition to using freight containers, the Antarctic Division also has a large number of steel box pallets which are designed to be modular to the internal dimensions of the type "E" container. The steel box pallets (which have either mesh or sheet steel sides and base) are used to stow an assortment of small packaged items and hence avoid the need to provide disposable protective packaging such as heavy cardboard or wooden crates.

Waste Management in the Field

Before a field party sets out, the Station or Field Leader is required to brief expeditioners on applicable local rules and restrictions such as the location of protected areas.

Excess packaging is removed from all goods taken into the field in order to save space and weight as well as for environmental considerations. Small field parties of up to 6 persons for two weeks generate minimal amounts of waste. Faeces, packaging materials and food wastes are collected in plastic bags and returned to the station and dealt with according to the established procedures described in Section 6.2. Urine and waste water are deposited in crevasses or tide cracks.

Larger or longer duration field parties practise the same waste segregation practices applied on stations with the various categories of waste being sorted and collected in 200 litre drums. The drums of material are returned to the stations and dealt with according to the established procedures described in Section 6.2. Faeces are returned to the station, and urine and waste water are deposited in crevasses or tide cracks as previously described. Waste oils from machinery, non-combustible rubbish and plastics are returned to the stations for disposal.

The incineration of paper and cardboard at remote field locations is carried out using basic incinerators. This activity is only undertaken during calm weather conditions so as to minimise the dispersal of ash and partially burnt wastes. The burned residues are returned to the station for disposal.

Waste Management on Vessels

Vessels under charter to the Antarctic Division are required to comply with the *International Convention for the Prevention of Pollution from Ships 1973* (the MARPOL Convention) and the Australian *Environment Protection (Sea Dumping) Act 1981*. The vessel's Master is also required to sign a brief prior to the departure of each voyage which outlines the voyage objectives and legal and environmental requirements.

In practice this means that glass and non-biodegradable wastes (plastics, metal, dunnage, etc) generated on board the vessel are stored for RTA. Where vessels are equipped with an onboard incinerator, food waste and other combustible wastes are incinerated; where an incinerator is not carried, food waste, along with sewage and domestic liquid waste, is disposed at sea at least 12 nautical miles from the nearest land. It is also preferred that food wastes be stored for RTA whilst vessels are south of the Antarctic Convergence, however this is not always practical on longer voyages. The Voyage Leader is also required to ensure that no material is loaded for later dumping at sea and that passengers and crew do not dump prohibited rubbish, or other contaminates, overboard during voyages.

Voyage Leaders are required to ensure that all personnel are fully briefed on environmental and safety matters before going ashore in Antarctica. Special environmental requirements are also placed on Voyage Leaders for particular voyages; for instance, special measures were introduced to ensure a strict quarantine barrier during a voyage which visited both of Australia's subantarctic islands, Macquarie Island and Heard Island, so that the accidental transfer of non-indigenous species could be prevented.

Incineration of Waste

High temperature, two chamber, incinerators have been installed at all "wintering" stations. The first chamber burns at between 500° and 900°C and the second between 760° and 1050°C. The incinerators, which have a capacity of about 1 cubic metre, are similar to those used for the disposal of pathological waste at major Australian hospitals.

The incinerators are used for the disposal of kitchen wastes and a limited amount of other suitable combustible wastes. Previously, open pit burning was used for large volumes of combustible materials however this practice is now being discontinued. Chemicals, including photographic and meteorological wastes, glycols, some plastics and other non-combustible wastes are RTA.

In view of the high demand being placed on the incinerators and the wide variety of rubbish being burned, revised instructions have recently been issued to stations detailing the types of material which may be burnt and providing greater emphasis on RTA of waste materials in future.

The emission levels for the incinerators were checked upon installation and commissioning. Nominated station tradesmen undergo a course of instruction on the operation and maintenance of the equipment prior to their departure for Antarctica. The incinerators are regularly serviced and checked by the tradesmen to ensure that efficient combustion is maintained.

Sewage Disposal

Rotating Biological Contactor (RBC) sewage treatment plants have been installed and commissioned at both Casey and Mawson stations. A similar plant is to be installed at Davis Station during the 1990/91 summer and will replace the system of gas fired toilets. The estimated cost of the Davis plant, fully installed and commissioned, is A$0.4M.

The design flow capacity of the RBC systems is 5,000 litres per day with a maximum flow rate of 6,000 litres per day. The equipment is installed in a building or enclosure (in the case of Davis Station) in order to maintain an ambient operating temperature of 15°C.

The sewage is first collected in a storage tank where it is retained for a period of approximately 24 hours to allow settlement and digestion to take place. The settled waste then flows through a Bio-rotor unit comprising polypropylene disc banks which are partially immersed in the effluent. The discs are slowly rotated through the air and waste water alternately, causing a biomass to gradually form on the disc surfaces which assimilate nutrients from the waste water and oxygen from the air. This process results in a staged reduction of the organic impurities in the waste water as it travels past each disc.

The treated waste water undergoes settlement in a clarifier before passing to a final retention tank for discharge to the sea. The effluent is monitored on a regular basis by the station doctor to ensure that it is within the standards set by Australian authorities.

Sediment from the waste treatment plants is removed during regular maintenance and stored in 200 litre drums for RTA. Consideration is currently being given to disposing of the sediment into the sea rather than RTA.

Environmental Management of Fuel

The fuel used for power generation at stations is a Special Antarctic Blend (known locally as SAB) which is a light, clean and volatile fraction of petroleum. Each "wintering" station uses approximately 600,000 litres of fuel per annum. It is current policy to have approximately two years supply of fuel stored on station by the end of the summer supply period. This is to guard against any unforeseen circumstances which may prevent a station being refuelled on schedule or because of the depletion of fuel stocks as a result of emergency demands or accidental loss.

All anchorages for vessels at Australian stations are offshore. The normal anchorages at Casey and Davis are about 1.5km from the shoreline, but at Mawson vessels are able to moor within 150 metres of the shore. Fuel is delivered ashore by either a dedicated fuel barge (having a capacity of 45,000 litres) or by 50/75 mm bore polypropylene pipe. During the 1990/91 summer it is intended to undertake trials using a urethane/polyester reinforced "lay-flat" hose which it is hoped will prove to be more durable.

Fuel delivery operations are attended at all times by ships' officers and station personnel so that the flow rate, pipeline integrity and tank capacities can be continually monitored. During delivery the ice conditions in the anchorage are constantly watched and the pipeline patrolled using a barge or workboat to guard against accidental damage. The supply vessels carry supplies of oil absorbent material in the event that a minor fuel leak should occur. Once the operation has been completed, the pipeline is purged of residual fuel using compressed air before being rewound onto reels located on either the ship or shore.

Fuel is stored on station in cylindrical steel tanks of either 36,000 or 90,000 litre capacity. The tanks are mounted on concrete foundations and, in the case of the latest models, incorporate internal stop valves which can be operated from a platform on top of the tank.

The tanks have, until recently, proved reliable. However, in June 1990, 90,000 litres of fuel was accidently lost from a storage tank at Casey Station when an outlet pipe at the base of a tank was damaged. The tank was awaiting permanent installation but was being used as temporary storage (and levelled on baulks of timber) to accept additional fuel delivered on the last voyage of the season. It would appear that the outlet pipe may have been encased in ice and the tank subsequently moved on its temporary foundations resulting in damage to the pipe. Fortunately the leaking fuel collected in a natural depression a short distance away from the tank from where is was pumped back into empty containers and hence the environmental impact appears to have been minimal.

Various options have been considered to reduce or minimise the risk of environmental damage as a result of fuel escaping from a tank or the associated plumbing. The use of bunding (or a retaining wall) has so far been rejected because the sump formed by the bunding would be likely to fill with snow and ice during winter thereby rendering it ineffective. It may be that the only solution is to enclose the tanks and bunding with a protective cover to prevent inundation by snow and ice.

Energy Management

Considerable savings in energy are already achieved on stations by the use of heat exchangers to recover "waste" heat from the jacket cooling water and exhaust gases of the diesel generator sets. This arrangement now supplies virtually the full heating requirements of stations, but as a back-up there are auxiliary boilers in the power houses and major buildings.

Expeditioners are encouraged to conserve energy by turning off excess lighting and appliances. External lights are fitted with timers or light sensitive switches wherever practicable. As new buildings are completed the older buildings are being closed down and isolated from reticulated power and heating services.

Water production can also absorb a significant amount of power. Fresh water is maintained above freezing temperature in melt lakes at Casey or caverns at Mawson by circulating hot water obtained from waste heat. At Davis, the melting of snow is the primary source, with some supply from a low-salinity tarn. Water production and fuel usage is monitored on a monthly basis by station personnel, engineering staff at Head Office and the Antarctic Environment Committee.

A recent study of energy consumption at Casey Station noted that there was little difference in energy consumption between summer and winter. The station electrical load was generally 12% less in summer although the population was four times that of winter. It was concluded that the overall per capita increase in winter was probably the result of higher variable demand loads (such as heat trace for reticulated pipework, engine block heaters in vehicles and increased use of portable electric heaters) which more than offset the savings yielded by a substantially smaller population.

Clean-up of Waste Tips

The policy of using land fill tips and sea ice dumping for the disposal of waste materials at all three "wintering" stations ceased in 1985. Since that time considerable effort has been devoted to cleaning-up the existing tips although progress was slow at first because of resource constraints and, in particular, a lack of suitable freight containers.

Initially it was intended to remove all dumped materials from stations and return it to Australia for disposal. In the event this has proved to be impractical in some cases because of the difficulty of removing wastes which are permanently frozen into the ground, or because the environmental impact of removing the wastes are worse than leaving them where they lie. Where removal has proven impractical at this stage, the land surface is being cleared to the maximum possible extent and top-dressed to minimise visual pollution. The sites will continue to be monitored and materials which emerge as a result of erosion or melt will be progressively cleared.

Some work has also been undertaken to identify old field dumps and abandoned work sites in eastern Antarctica resulting from the activities of Australia and other national operators. A number of these sites have already been cleared although much work remains to be done. It is considered that, because of the enormity of the logistics task, the work would best be undertaken on a coordinated basis with other national operators in the region.

Environmental Science

Australia's concern for the environmental aspects of its operations is reflected in the current priorities for antarctic research. One of the priority areas identified by the Antarctic Science Advisory Committee (ASAC) comprises "research into the environmental effects of human activity and possible resource activities in the Antarctic and associated environmental protection". Recent and current projects have focussed on questions of global change, but have also included projects relating directly to operational activities such as:

- biodegradation of petroleum in soils and beach sands;
- waste minimisation at stations;
- protected area management;
- input of anthropogenic hydrocarbons to the Antarctic environment; and
- water supply management.

Such programs can facilitate more informed decision making and policy development with regard to environmental management issues.

Conclusion

The last decade has seen considerable growth in the Australian Antarctic Program and ever increasing demands to improve environmental management of operational activities. Much has been achieved during this time through implementing improved procedures, clearing waste materials from stations and field sites, and ensuring that the highest practicable standard of environmental management is applied to current and planned operations.

RECYCLING AND OPTIMIZED UTILIZATION OF MATERIALS AT ANTARCTIC RESEARCH STATIONS

by
Stephan, B.

0. Abstract

Antarctic research stations have a great demand for materials for different purposes as for technical, scientific, maintenance or construction work and for the daily need of the people living there.

The lecture summarizes the consumption and treatment of materials and the waste production by antarctic research stations and will present feasible techniques to reduce, reuse, recicle and treat the needed materials. Stress is put on proposals to improve the operation of essential technical components of an antarctic research station as power generation stations, water supply and waste water treatment systems under the aspects of recycling and minimization of local pollution. Problems of the treatment of solid and chemical wastes under the conditions in Antartica will be discussed.

The main suggestions are:

emissions of polluting materials by fuel combustion can be reduced by applying a bundle of methods improving the operation conditions of the engine; filtering systems for the hold back of solid carbon are available;

washing processes for the flue gases from waste incineration cannot be recommended - all open and "controlled" burning of solid and chemical wastes must be avoided. Containers for the waste removal must be integrated into the logistic planning;

domestic waste waters can be treated by biological processes, systems for this purpose are available; the treatment of the produced sewage sludge (anaerobic stabilization, mechanical and/or thermal treatment or storage below freezing point until removal) must be checked for each specific situation; to facilitate the biological decomposition of organic waste the application of reactive chemicals like chlorine or non degradable chemicals must be avoided.

1. Framework

Research activities in the Antarctica are performed under specific conditions. The main points relevant to ecological impacts are:

- low microbial activity for bioconversion
- low contamination compared to other regions
- high specific use of materials for human activities because of the climatic and logistic conditions
- high costs for the removal of old (dumped) wastes and materials from the Antarctic.

The research activities in Antarctica will increase; the problems of old dumping places - many research stations were estab-

Hochschule Bremerhaven, An der Karlstadt 8, 2850 Bremerhaven
Federal Republic of Germany

lished over thirty years ago - become more and more obvious. During the Antarctic summer about 3000 people are living in that region. In 1988 ...there were 43 continuously occupied stations, 32 permanent summer bases and a number of camps...(*). Based on enquiries, measurements and computed data the following general framework of emission and waste production in the Antarctic can be given:

1.1 Atmospheric Emissions by Fuel Combustion

The report (*) gives a computation based on the fuel consumption and on the burning and incineration of solid wastes. The summarized results are given in table 1.

	tons per year
particalute emissions by fuel consumption	300
particulate emissions by waste burning and incineration	20

Table 1: Atmospheric emissions of particulate materials

The emitted solid material is a mixture of many components with high concentrations of dangerous substances as heavy metals, organohalides, polycyclic aromatic hydrocarbons, dioxins, furans. According to the legislation on the protection of the environment in many countries those materials must be disposed under controlled safe conditions to prevent their escape into the environment.

Table 2 represents figures of energy consumption and calculated emission of materials into the atmosphere, based on the given state of art and average operation times at the German Georg-von-Neumayer Station.

emitted material	emissions kg/a	fuel consumption m^3/a
CO	1200	130
hydrocarbons	800	
NO_x	2100	
solid carbon	200	
SO_2	700	

Table 2: Atmospheric emissions of the Georg-von Neumayer Antartic Research Station from energy generation by diesel generators

(The SO_2-emissions are the result of the utilization "arctic-diesel" with a sulfur content of 0,3%)

Research stations make use of different kinds of vehicles, table 3 gives the calculated emissions for typical devices with their calculated emissions for the Georg-von-Neumayer Station.

typ of vehicle	snow truck (diesel)	Ski-doo (2-stroke)
fuel consumption kg/a	6500	1500
emissions kg/a		
CO	60	100
hydrocarbons	70	70
NO_x	400	5
SO_2	35	0.75
Pb	-	0.217
solids with about 20 % carbon	40	

Table 3: Atmospheric emissions by operation of vehicles

1.2 Liquid Wastes

The liquid wastes can be classified into three groups: domestic waste water, used fuels and lubricants, and liquids contaminated by chemicals. Radioactive mixtures are not subject of this report;it is an absolute must to bring them back without losses.

It is difficult to give precise figures about the overall quantities. Details will be reported later in connection with the description of measures for improvement. The present situation according to (*) can be summarized as follows: The liquid domestic wastes from 43.5 % of all stations and camps are disposed untreated, at 12.5 % a kind of biological treatment is performed, 15 % remove the waste from the Antarctica and 29 % burn the residues. This situation is not satisfying - feasible technical solutions for most cases are available.

The treatment of fuels and other organic liquids and solvents will be discussed later.

1.3 Solid Wastes

The situation is quite complex here, because a lot of Antarctic research stations are more than 30 years old and have accumulated great quantities of solid wastes of different origins. To solve those problems including abandoned stations great efforts are necessary.

According to the SCAR recommendations the solid waste must be collected and treated separately - normally the quantities are too small to install treatment facilities like incinerators of high efficiency including a sufficient keep back of emmisions.

The following figures based on (*) may illustrate the existing situation: 14 % (58%) of all stations and camps remove the combustible (non combustible) waste, 3.5 % (17 %) use landfills, 17 % (12.2 %) dispose to ice pits; 65.5 % of the combustible solid waste are burnt and 12.2 % of the non combustible wastes are disposed to sea or sea-ice.

1.4 Chemical Wastes

The quantity and composition of the chemical wastes is differing due to the specific field of research being conducted at the stations. In general the quantities are comparatively small and a collection and removal from Antarctica is possible and should be done in every case. The proven standards of laboratory practice, including the storage systems for chemicals, are a good basis to perform this task. The chemical wastes are handled in practice in the following way: 28 % of the stations and camps have no treatment facilities, they give the chemicals untreated to land, sea/sea-ice or ice pits; 41 % perform burning, 5 % dispose them treated to sea/sea-ice, and 26 % remove the materials.

To avoid pollution problems by chemicals the best way is to collect all used materials carefully and remove them from Antarctica. Especially burning procedures are not safe, because they can create hazardous substances under uncontrolled conditions.

2. Methods and Systems for Reduction of Pollution

2.1 Fuel Combustion

The previous chapter summarized the immissions produced by the combustion of fuels for generating electrical and thermal energy and to run vehicles. To demonstrate the potential for reducing those emmisions by applying techniques that are available and proven, the situation at the Georg-von-Neumayer-Station is reported,based on a detailed study (**).

The data given in table 2 and 3 are based on the information provided by the relevant manufacturers of the engines. To reduce the emissions there are -besides measures like saving energy by e.g. reduction of fresh water consumtion- basically two possibilities: optimization of the operation conditions of the engines and methods to extract pollutants from the exhaust gases.

The first option is based on a bundle of methods:

- reduction of the energy output
- control and optimization of the air/fuel-ratio
- delay of ignition point
- exhaust gas recycling.

Those methods result in reducing the emissions of NO_x, CO, hydrocarbons and solid carbon. In addition the exhaust gas can be treated by more or less sophisticated procedures as:

- mechanical processes (e.g. separation by filtration)
- chemical and catalytic processes

- thermal processes
- physical processes.

Table 4 summarizes the feasible results, if the mentioned methods are applied. A reduction of the NO_x concentration in the exhaust gases by catalytic reduction with ammonia is possible but cannot be recommended for isolated stations, because the process is very complex and needs considerable efforts on the side of safety and logistic.

substance	emissions per year (kg/a) present situation	optimization of engine performance	exhaust gas purification
solid carbon	200	40	40 -60
NO_x	2100	1300	not recommended
CO	1200	500	20 - 30
hydro-carbons	800	130	320

Table 4: Possible reductions of emissions of diesel generators at the Georg-von-Neumayer Station; calculated values

If both bundles of methods are applied in combination, reductions of the emissions in the range of 93.5 to 99 % excluding NO_x can be reached. The SO_2 emissions can be decreased by a washing process with addition of lime and subsequent oxidation to gypsum. The produced suspension cannot be diposed untreated - a separation process must be added, which makes this treatment process too complicated for smaller units. The situation can be improved by applying fuels with a lower sulphur content: the tendencies are towards 0.2 ... 0.1 % of total sulphur.

2.2 Liquid Wastes

The main fraction of liquid wastes at research stations is formed by the domestic waste waters. Liquid chemical residues as organic solvents, used lubricants, hydraulic liquids and fuels form an other important group with a high pollution potentential.

More than 40 % of the domestic waste water are piped into the Antarctic environment untreated. It may be said that in most cases the (organic) residues will create no environmental or health problems - on the other hand the microbial decomposition of organic materials does not occur or proceeds at very slow rates under the existing natural conditions. The Antarctic region must be kept as free as possible from man-generated pollutants, to enable unimpaired research work; so it is justified to use methods that sometimes may appear to be exaggerated.

Table 5 represents the possible reduction of dissolved and suspended organic and inorganic matter by mechanical and biological waste water treatment.

treatment process	efficiency (%)				
	suspended matter	BOD_5	COD	Phosphorus	Nitrogen
mechan.	40-70	25-40	15	15	7
biolog.	85-95	85-95	80	80	40

Table 5: Efficiencies of material removal by mechanical and biological waste water treatment

The technical possibilities shall be demonstrated by the waste water situation at the Georg-von-Neumayer-Station. The permanent crew at the station is 11 people, for 60 days per year another 10 persons are present. The waste water effluent is now about 550 m^3 (equivalent to 120 l per person and day) with a peak period during the Antarctic summer. The content of solid material in the effluent comes to 880 kg (= 0.16 %). By biological aerobic treatment (sludge formation and sludge sedimentation) sewage sludge can be separated. Subsequent anaerobic treatment can reduce the sludge volume; mechanical dewatering (e.g. by a filter press) can result in further volume reduction. The development of volumes and concentrations of solid materials in the sewage sludge is shown in figure 1.

WASTE WATER	550 m^3	880 kg TS
BIOLOGICAL AEROBIC TREATMENT WITH SEDIMENTATION		
SEWAGE SLUDGE	8.2 m^3	330 kg TS
BIOLOGICAL ANAEROBIC TREATMENT WITH SEDIMENTATION		
STABILIZED SEWAGE SLUDGE	2.5 m^3	250 kg TS
MECHANICAL DEWATERING		
CONCENTRATED STABILIZED SLUDGE	0.8 m^3	250 kg TS

Fig. 1: Volumes and contents of total solids (TS) at different steps of sewage sludge treatment (based on the fresh water consumption of the Georg-von-Neumayer Station)

The compiled data show that a great reduction of the sludge volume can be achieved by combined biological and sedimentation processes. The last step of mechanical dewatering cannot be recommended in general as the volumes are small in relation to the complicated systems that must be installed with the need of additional energy and manpower for operation and maintenance.

Sewage sludge separated from the activated sludge process cannot be stored at temperatures, which enable microbial decomposition of organic matter; the sludge can run very fast into uncontrolled anaerobic conditions producing bad odours. Thus the treatment must include stabilization under well defined conditions which can be performed in systems as described in figure 3 (waste water treatment with integrated anaerobic sludge stabilization), or the untreated sludge must be stored until removal at temperatures below the freezing point. It should be checked whether a thermal (drying) or a combined mechanical-thermal sewage sludge treatment can be operated with advantage.

Figures 2 and 3 demonstrate the relevant process principles and available technical solutions with the needed volumes to ensure sufficient retention times for the processes of microbial decomposition and separation. The integrated system with primary treatment, aeration, secondary treatment and anaerobic stabilization for 30 persons requires a total volume of about 13.5 m^3.

Waste water treatment plants for ships normally have facilities for the chlorination of the treated waters to sterilize them. This procedure is not recommended for Antarctic research stations as the chlorine will transform organic materials into products that can be harmful for the environment and resistant to microbial decomposition. Experiences with the outlet pipes of waste water systems did not create problems of clogging by the growth of biological material from unsterilized waste waters.

An other aspect may be helpful: if a vacuum system for flushing the toilets is chosen (see fig 3) a great amount of water can be saved. According to (** and ***) 160 m^3 out of 550 m^3 (= 29%) of the fresh water, which must be produced by melting snow, are used for the toilets. If a vacuum flushing system is implemented this fraction can be reduced by 85 % resulting in savings of 135 m^3 of water per year. In addition, labour can be saved for melting snow ,and energy - about 3000 kg of diesel fuel are calculated.

Used and unused lubricants and liquids for hydraulically driven machinery must be collected and removed from the Antarctic region for appropiate treatment. The burning of those materials will create pollutions by formation of toxic substances as dioxins, furans and PAH's for example. Unused fuels can be burnt in diesel generators. This purpose should be taken into account during the logistic planning of the fuel supply.

2.3 Solid Wastes

According to SCAR-recommendations solid waste may be burnt in Antarctica, if incineration devices with flue gas cleaning systems are used. It must be stated that it is not possible by the present state of the art to clean the gases completely, even if a complex multi-stage filtering and washing process is installed. E. g. the problem of the formation of hazardous substances like dibenzo-dioxines and -furans will still exist. Recognizing that the scientific importance of the Antarctica is based a great deal on its uncontaminated condition, the burning of wastes must completely be stopped. The materials must be collected separately in containers proven for safe transportation, and be removed.

Measurements at the Georg-von-Neumayer station of the solid waste quantity are shown in figure 4 a/b. Each person produces 1.8 kg of solid waste per day resulting in a total waste production of 10.5 tons per year, if besides 11 permanent present persons up to 30 persons for two month a year are supplied by the station. The volume comes to 52.5 m^3 and can be compacted into 1/3 to 1/5 by a simple compactor (required volume about 2.5 m^3). Thus a 20 feet container is sufficient to store the compacted solid wastes. The weight of the wastes plus container comes up to 16 tons, which can still be transported by a sledge.

2.4. Chemical Wastes

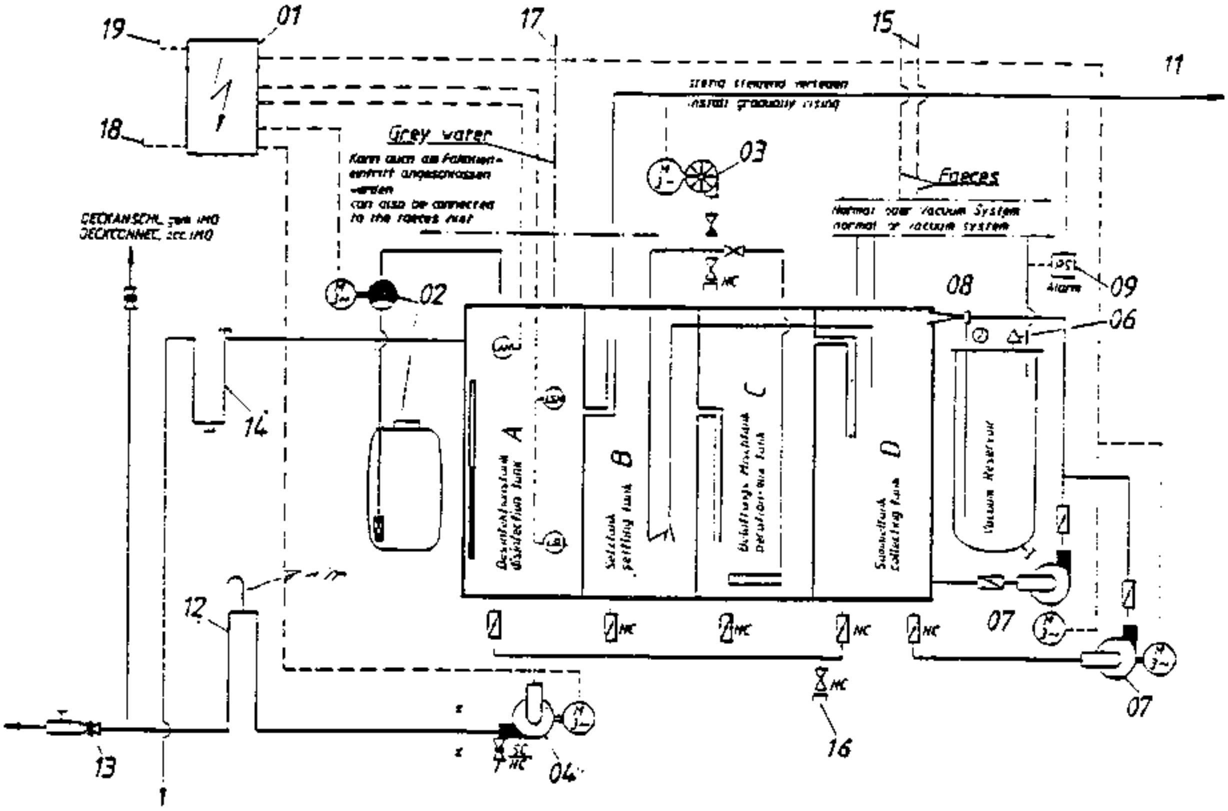
In most cases it cannot be recommended to treat chemical wastes at the research stations. The methods applied until now (see chapter 1.4), with a not longer acceptable high percentage of burning and untreated disposal, must be replaced by specific collecting systems and complete removal. If the chemical processes are mainly water based without polluting substances, e.g. like heavy metals, then the effluents can be treated by an automatically working neutralizing unit with sedimentation/ collection of formed precipitations. The neutralized effluents can be added to the grey water of the station for further treatment.

3. Literature

* : Waste Disposal in the Antarctic; Report of the SCAR Panel of Experts on Waste Disposal, 1989

** : Konzeptionierung der Entsorgung von Forschungsstationen in der Antarktis; Fastenau, A., Krause, L.; Hochschule Bremerhaven 1988

***: Stand und Entwicklungstendenzen dezentraler Abwasserbehandlungsanlagen; Heinrich, F., Nehlsen, O.; Hochschule Bremerhaven 1988



01	Schaltanlage unit control panel
02	Dosierpumpe und Behälter mit Desinfektionsmittel Metering pump and container with disinfectant
03	Belüftungsgebläse Aeration blower
04	Abwasserpumpe Sewage pump
06	Belüftungsventil Air release valve
07	Treibwasserpumpen Flush-water pumps
08	Ejektor Ejector
09	Druckschalter Pressure switch

10	Liefergrenze FORMAT FORMAT supply
11	Entlüftung stetig steigend ohne Querschnittverengung zum Schornstein Ventilation gradual gradient no necking of cross-sectional area up to funnel
12	Förderschleife = Anlagenhöhe + 200 mm mit Be- und Entlüftung h»4 m Delivery coil = installation height + 8" with ventilation h»13'
13	Außenbordarmatur gem. Klassifikation Outboard fitting as per classification
14	Syphon (200 mm) zur Bilge Syphon (8") to bilge
15	Fäkalieneintritt Inlet faeces
16	Spülanschluss Flush connection
17	Grauwassereintritt Inlet grey water
18	Stromeinspeisung 380 V 50 Hz oder 440 V 60 Hz Power supply 380 v 50 c/s or 440 v 60 c/s
19	Störung von 02, 03, 04, LAH und 07,09 z. Kontrollraum Fault from 02.03,04, LAH and 07.09 to control room

Fig. 2: Scheme of a compact biological waste water treatment unit with a vacuum system

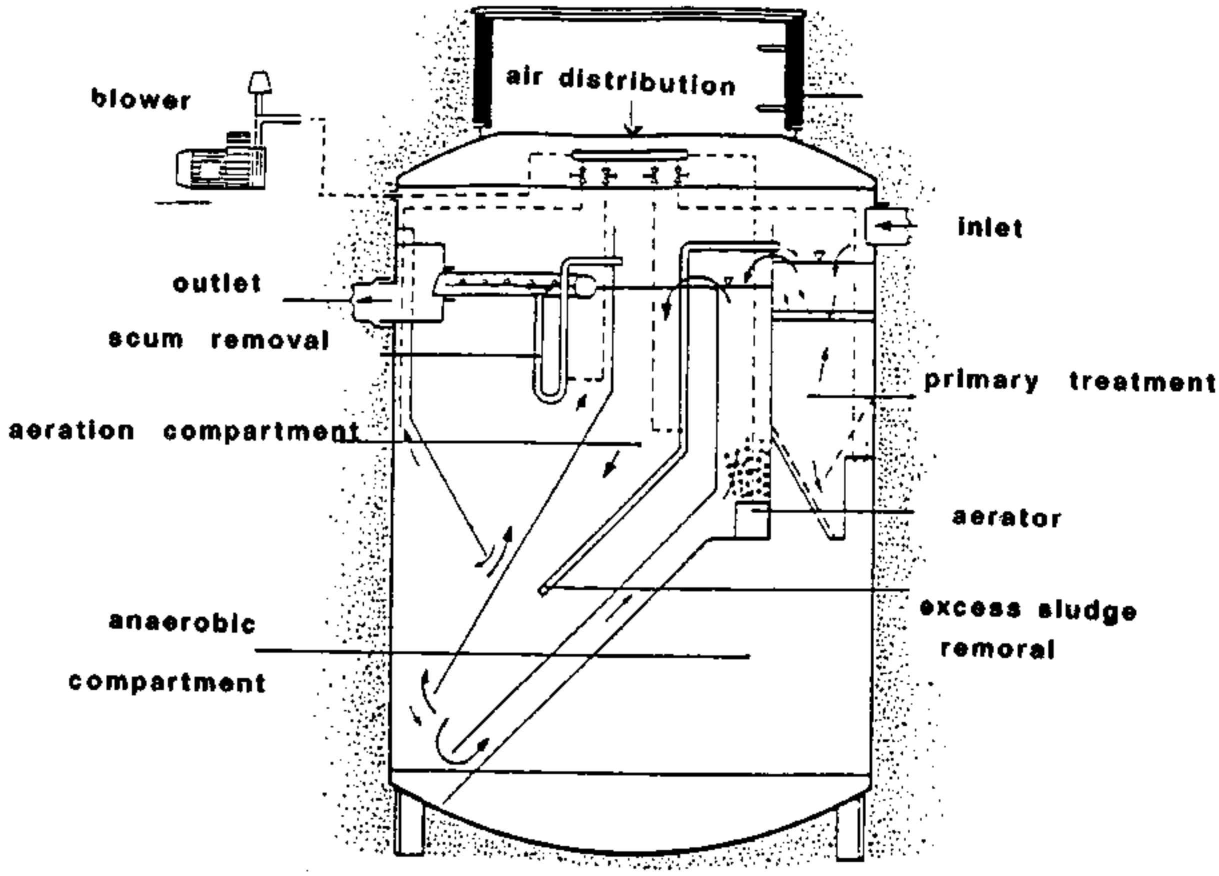


Fig. 3: Scheme of a biological waste water treatment unit with anaerobic sludge stabilization

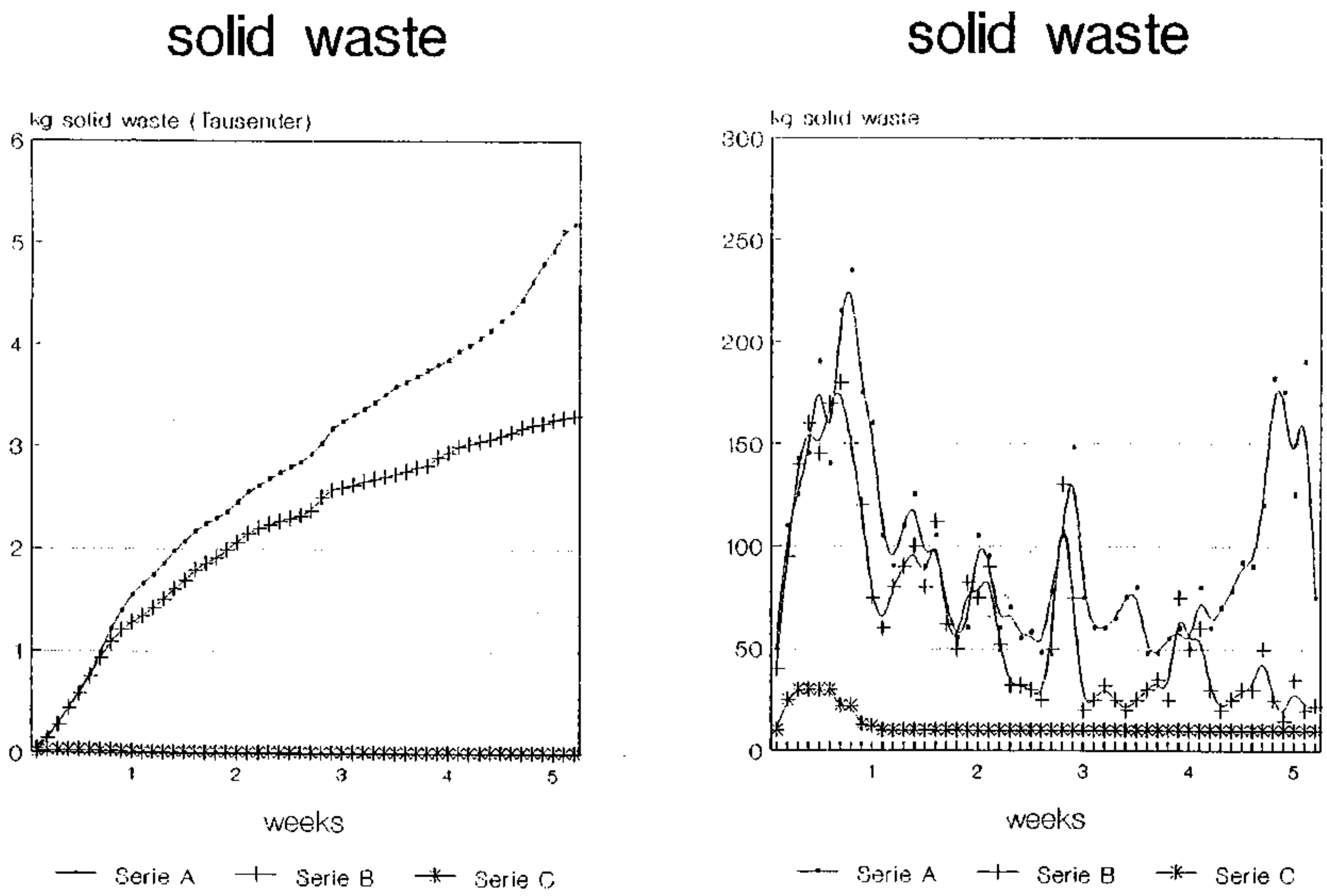


Fig. 4: Waste quantity per year of the Georg-von-Neumayer Station

Fuel Spill Clean-Up in the Antarctic

Peter E. Wilkniss and Erick Chiang

U.S. Antarctic Program

National Science Foundation

Abstract

For the foreseeable future, petroleum products--particularly diesel fuel arctic (DFA), jet fuel, gasoline, and lubricating oils--will be the life blood of antarctic operations because ships, aircraft, stations, vehicles, field camps, and related operations depend on these substances. Although each national antarctic program has strictly tailored existing systems for fuel transportation, storage, distribution, and use to the program's needs, safety and environmental problems continue to be associated with the use of fossil fuels for offshore and onshore operations.

Worldwide attention is increasingly focused on the Antarctic, especially on the potential environmental impact of fuel spills. Although costly and technically difficult, the U.S. Antarctic Program (USAP) has given highest priority to improving the handling of fuels in a safe and environmentally sound manner. Considering the difficulties associated with the clean-up of spills in the Antarctic and the potential impact on the fragile ecosystems, we recognize that prevention is the best approach, but in the severe antarctic environment, accidents have a certain probability, even with the best preparation.

In this paper we describe our experience with several fuel spills and the lessons learned during our attempts to clean up their aftermath. To illustrate the unique aspects of response and clean-up, we have selected examples of spills that occurred in three distinct antarctic environments--marine, coastal; ice shelf, coastal; and antarctic ice sheet, polar plateau. All of these accidents have been publicized and described in television, radio, newspapers, scientific articles, and other publications. This paper focuses on the "inside story"--namely the experiences from the viewpoint of national antarctic program management and related aspects.

Fuel Spill Clean-Up in the Antarctic

Peter E. Wilkniss and Erick Chiang

U.S. Antarctic Program

National Science Foundation

Introduction

Petroleum products--particularly diesel fuel arctic (DFA), jet fuel, gasoline, and lubricating oils--will be the life blood of antarctic operations for the foreseeable future. Because ships, aircraft, stations, vehicles, field camps, and related operations depend on these substances, each national antarctic program has strictly tailored existing systems for fuel transportation, storage, distribution, and use to the program's needs. Considerable safety and environmental problems have been and will continue to be associated with the use of fossil fuels for offshore and onshore operations.

Worldwide attention is increasingly focused on the Antarctic, especially on accidents involving fuel spills and the subsequent environmental impact. Although costly and technically difficult, the U.S. Antarctic Program (USAP) has given highest priority to improving the handling of fuels in a safe and environmentally sound manner. Considering the difficulties associated with the clean-up of spills in the Antarctic and the potential impact on the fragile ecosystems, we recognize that prevention is the best approach, but in the severe antarctic environment, accidents have a certain probability, even with the best preparation. Consequently, in this paper we would like to describe our experience with several fuel spills and the lessons learned during our attempts to clean up their aftermath.

Accidental fuel spills

The examples we will discuss include three separate antarctic environments and illustrate the unique aspects of response and clean-up. These incidents and the relevant environments are:

- Marine, coastal: Sinking of the Bahia Paraiso near Palmer Station, Antarctic Peninsula;
- Ice shelf, coastal: Williams Field skiway on the Ross Ice Shelf near McMurdo Station, Ross Island;
- Antarctic ice sheet, polar plateau: Amundsen-Scott South Pole Station.

All three of these accidents have been publicized and described in television, radio, newspapers, and other publications. Additionally, the impact of the Bahia Paraiso on the ecosystems near Palmer Station is being monitored and reported in scientific articles. The cause, impact, and approach to clean-up operations on the deep snow/firn environments of Williams Field and Amundsen-Scott South Pole Station are being investigated and techniques for disposal of contaminated snow being attempted. This paper focuses on the "inside story"--namely the experiences from the viewpoint of national antarctic program management and related aspects.

Palmer Station, Bahia Paraiso Sinking

This incident, more than any other, tested the limits of our capabilities to effectively deal with a significant accident that resulted in a major fuel spill. The lack of jurisdiction by a national program and the lack of a spill contingency plan was exacerbated by

1) the remote location of the spill relative to available clean-up resources,

2) the need to rescue more than 300 passengers and crew from the damaged ship,

3) and the problems associated with command, control and coordination of the multiple organizations needed to respond to the demands of the situation.

The grounding and subsequent sinking of the Bahia Paraiso by itself required immediate response that would have severely taxed the support capabilities of virtually any antarctic station. Assistance was required from other program resources that could only be coordinated from USAP headquarters in Washington, D.C. Additionally, because the accident occurred on the morning of Saturday, January 28, 1989, USAP managers faced the difficult task of organizing the necessary response on a weekend when everything except emergency services was shut down.

Managerial Challenges

First, an emergency team, under the cognizance of the USAP Senior NSF Representative at Palmer Station, was set up. At the same time, the Palmer Station radio room became the command and control center and access to it was restricted. All routine station operations were halted, and communications were secured. Tasks for the emergency team members were assigned, and a 24-hour watch was put in effect. Second, in Washington, D.C., the National Science Foundation organized an emergency team in the Division of Polar Programs to support and respond to the Palmer Station emergency team as necessary and to coordinate the resources available through other Federal agencies or contractors to the U.S. government.

As this structure was being developed, the Washington and Palmer emergency team leaders agreed on the following priorities:

- protect the lives of all people involved

- protect the environment
- protect U.S. research activities.

To effectively coordinate USAP's response to the emergency, the Palmer State manager was given full control of local activities responding to the accident, while the Washington office advised and assisted in the clean-up response effort.

We then jointly developed a three-phase plan of action:

I. Rescue, problem assessment, damage-control assessment.
II. Damage-control response and ecological impact assessment.
III. Damage-control implementation and full impact assessment.

The response to this emergency was successful because USAP management in Washington, D.C., and at Palmer Station was committed to full and open communications between the emergency field teams and headquarters staff. Only this way could managers make difficult decisions based on factual information provided by the field manager at the station.

Managerial task

Once the plan of action was decided upon, the task of implementing the plan began. In Washington, the main task was to marshall all needed U.S. government resources. This effort included identifying and mobilizing a spill response team with its oil-spill-containment equipment and specially trained personnel, coordinating the delivery of 52 tons of equipment to Punta Arenas, Chile, and diverting the R/V Polar Duke from its planned research cruise so that it could go to Punta Arenas and pick up the spill-containment equipment and personnel for transport to Palmer Station.

On the policy level, NSF had to obtain a commitment for the necessary resources from other U.S. government agencies and had to reprogram financial resources to reimburse these agencies for the incurred expenses. A task critical to the success of the emergency response teams was establishing international lines of communications so that agreement could be obtained on joint actions in the field. While planning its response to the accident, NSF also took this opportunity to organize the necessary technical and scientific experts to initiate a long-term assessment of the ecological impact.

Accomplishments

Ten days elapsed between the time that the Palmer Station manager notified USAP headquarters in Washington, D.C. (January 28, 1989) and the day that the response team arrived at Palmer Station (February 7, 1989). Despite the lack of a spill contingency plan, during this short time USAP managers contacted and organized experts from three other U.S. government agencies and associated Federal contractors, arranged with the U.S. Air Force for the use of a C-5B air transport to carry the equipment and personnel to

Punta Arenas, Chile, and coordinated the delivery of 52-tons of containment equipment and expert personnel to Palmer Station.

Through the efforts of the Palmer Station crew, the more than 300 passengers and crew were recused from the damaged ship and transported to Palmer Station. In response to a call for assistance from USAP, tour ships operating in the area quickly made their way to Palmer Station. Because of their excellent response, the majority of the Bahia Paraiso's contingent were evacuated within days of the accident.

To effectively move people and equipment to the spill site, international cooperation with the Argentine and Chilean governments was paramount. The U.S. government provided full technical assistance, salvage assessment, and scientific/ environmental assessment to ensure the quick response required to minimize the impact of the spilled fuel on the ecosystem.

It will be some time before the full impact from the fuel spilled from the Bahia Paraiso can be assessed. In the mean time, the Standing Committee for Antarctic Logistics and Operations (SCALOP) of MNAP is investigating contingency planning for future spills, and the U.S. and Argentine governments continue to discuss overall assessment and contingency planning.

Williams Field fuel spill

Williams Field is located on the Ross Ice Shelf about 8 miles from McMurdo Station. The field is the skiway for USAP's LC-130 ski-equipped Hercules airplane during the summer season (from October through February) and for approximately 1 week in August each year during our "winter fly-in" operation. The field has its own "fuel pits," positioned on snowberms, consisting of rubberized bladders that each contain about 25,000 gallons of jet fuel and other smaller amounts of DFA and "Mogas"--for a total storage capacity of 250,000 gallons of petroleum products.

On October 11, 1989, personnel working at Williams Field discovered that several of these bladders had leaked. Since August 1989, when the bladders were used for "winfly", several feet of snow had drifted over the fuel pits. As we discovered later, the additional weight of the drifted snow caused about 52,000 gallons of fuel to escape through the top vents pipes of the bladders. The escaping fuel remained on top of nine bladders and was incorporated into the overlying snow.

Managerial challenges and tasks

The approach to the clean-up following the Bahia Paraiso accident emphasized international coordination and the need to mobilize resources to contain the fuel released into a marine environment. The clean-up of the spill at Williams Field emphasized programmatic coordination and the use of available resources. Because the fuel was completely contained either within the containment berms or in the snow pack, this enabled a measured clean-up response.

In the McMurdo Sound area, the U.S. Antarctic Program, which is under the overall management of the National Science Foundation, combines the operational and logistics resources of the U.S. Department of Defense through the U.S. Navy and the construction/facilities maintenance capabilities of a private contractor--ITT/Antarctic Services, Inc. (now Antarctic Support Associates). To conduct an investigation and its subsequent clean-up, separate responsibilities for program functions and resources had to be combined.

The Naval Support Force, Antarctica (NSFA) is responsible for the fuel systems at McMurdo Station and at Williams Field. As the responsible entity, NSFA immediately set-up an official investigation. To effect the clean-up, a response team, combining the capabilities of all USAP organizations, was established. The NSF Representative, Antarctica, assumed overall direction of the clean-up operation because different program resources had to be assigned, and a coordinated plan, using innovative approaches to the clean-up had to be devised.

To develop the clean-up plan, USAP managers had to establish priorities for use of the available resources. Planned program schedules had to be altered, personnel had to be re-assigned to clean-up tasks that were often unforseen, and heavy equipment and mechanical shop resources had to be diverted to meet this emergency. International liaison was established with our neighbors at New Zealand's Scott Base to keep them informed of the situation and to insure proper dissemination of information.

Outside advice and expertise were requested from the Washington, D.C., headquarters to coordinate services not available at McMurdo Station. Key among the many clean-up issues was the technical problem of removing the contaminated snow and fuel. Although much of the fuel could be pumped out of the containment pits, the fuel-contaminated snow remained, and ways to dispose of it had to be developed.

Deciding when to stop clean-up operations proved to be the most difficult decision. The problematic technical requirements and the need for human resources conflicted with the need to carry out the planned field program with finite personnel and material resources.

Accomplishments

Of the estimated 52,000 gallons spilled, 28,000 gallons were recovered by direct pumping. The collapsed fuel bladders formed containers supported by ice bowls that had formed as the sun warmed the bladders and fuel during the previous austral summer.

An additional 3,000 gallons is estimated to be contained in the overlying snowpack. Disposal will be accomplished by melting the contaminated snow in a melter, skimming the fuel from the surface of the melt water via pumping or use of commercially available absorbents, and discharging the melted snow into the snowpack. The meltwater will be analyzed to determine how the effected portion of the ice shelf may impact on the environment when the ice shelf finally calves and melts in the ocean.

Despite the fuel spill emergency, Williams Field operations were started as planned and carried out successfully.

Major improvements in the USAP fuel systems for Williams Field are being implemented. Among these are the use of steel tanks versus rubberized bladders, longer lengths of larger diameter hose to reduce hose-wall pressure for delivery of fuel to Williams Field, use of a single type of fuel versus two types of fuel to simplify fuel handling and storage, and the use of a hose reel system to minimize the man-power needed to deploy and recover up to 8 miles of fuel line.

Finally, fuel-spill contingency plans, including personnel training, spill countermeasures, and the staging of clean-up materials, are being initiated to meet the variety of fuel system components used by USAP in the Ross Island area.

South Pole Fuel Spill

This fuel spill occurred at the U.S. Amundsen-Scott South Pole Station during the austral winter of 1989, when the winter-over contingent was isolated for about 9 months. The fuel leak occurred in the main station fuel arch where nine 25,000-gallon fuel bladders, containing DFA, are located. These are interconnected by 2-inch-diameter pipeline to the power plant.

Although about 40,000 gallons of the total of 200,000-gallon fuel reserve at South Pole were lost over approximately 4 month, station personnel did not detect an obvious loss of fuel. How can that be!?

An investigation, begun after station-opening in November 1989 (the first flight to the station since February 1989), identified two key problems:

- The methods used to determine total fuel quantity on hand produced uncertain results.
- The efforts of the winter-over crew to find an intermittent leak were complicated by the dark and cold and constricted space. This prevented the discovery of the leaking fuel-line joint.

The team determined that fuel disappeared because of the porosity of snow at extremely low temperatures. During the winter, the fuel arch, the fuel and the snow all acquire an ambient temperature of about -60 to -70°C. Under these conditions at the South Pole, spilled fuel--in this case a pencil-thin stream--flows directly through the cold porous "firn" without leaving a trace, analogous to water poured on a dry, uncompacted sandy beach.

Once the leak was discovered, repairing it was difficult because the pipeline was less than 4 inches from the snow surface. A rubber gasket that had failed had to be replaced and the line soldered in place.

Managerial challenges and tasks

Communications with any wintering crew is at best a difficult task. In this example, USAP management in Washington, D.C., had to ascertain the extent of the problem in order to assess the impact on the station's operation through the remainder of the winter, as well as the impact on the resources required to continue operation into the austral summer. Further, in their communications with South Pole Station, management had to avoid anything that could be construed by station personnel as critical of their efforts to cope with a potentially station-threatening problem. Every effort had to be made to allow station personnel to trouble-shot the problem, as management stood by to provide engineering-system consultation to assist the station with isolating the suspected leak.

Locating the source of the leak and repairing it were only one part of the problem. Concurrently, management needed to fully understand the causal problems and from that devise plans to minimize a re-occurrence of such incidents. The expert task force, appointed to conduct the fact-finding mission immediately after the station opened, was charged with

- documenting the chronological events of the spill
- determining the cause of the spill
- assessing the psychological make-up of the station personnel during a potentially station-threatening incident
- recommending future actions to prevent re-occurrence.

The intent was to determine the cause and to develop an approach for future renovation of the fuel system--not to affix fault.

Accomplishments

In the case of the South Pole fuel spill, no attempt was made to recover the lost fuel. The futility of such an attempt was demonstrated by a simple experiment. A gallon of DFA at ambient temperature (-55°C) was allowed to flow onto the firn. The fuel immediately "burrowed" into the firn, leaving essentially no surface trace. Its disposition remains to be analyzed. Clearly, our understanding of the fate of fuel in very cold firn is incomplete and, therefore, techniques to recover fuel in the high polar plateau environment need to be developed.

Theoretical engineering calculations presume that the fuel would pool in a lens centered at a depth of 50 meters (plus or minus a

30-meter vertical extent) with a diameter of about 60 meters (U.S. Army Cold Regions Research and Engineering Laboratory, personal communication, 1989). No danger to South Pole inhabitants--such as weakening the snow foundation under the fuel arch, or contaminating future sources of drinking water--is envisioned.

The cost of the spill was a significant impact on operations for the 1989-1990 season. To complete the 1989-1990 austral summer program and to safely undertake the planned 1990 austral winter program, the fuel had to be replaced. Restoring the amount of fuel to safe operational levels required the re-allocation of 15 LC-130 Hercules flights (90 flight hours).

For the long-term, the task force recommended upgrading the station's fuel system with steel tanks and simplifying the fuel-distribution grid. These system changes, which USAP is planning to put into effect, will be supplemented with major procedural changes for handling and accounting for fuel on and off the station.

Conclusions

Clearly, preventing fuel spills should be the goal for managing any fuel system. Cleaning up a fuel spill significantly affects the resources of any tightly planned seasonal program. The monetary costs along with the cost of reassigning personnel and the effect of disruptions to a field program outweigh the capital investments and design costs to install and implement proper equipment and procedures to prevent spills.

If a spill occurs, despite the best programmatic efforts, antarctic programs will still face great managerial and technical challenges to safe and environmentally responsible operation of their "life blood" fuel systems. Such problems can best be solved by the concerted effort of all technical managers of existing national antarctic programs. Therefore, the USAP feels strongly that this issue should be one of the highest priorities for fuel-spill prevention and contingency planning for each antarctic program as well as for joint COMNAP/SCALOP action.

PUBLICATIONS LISTING

Reports, press releases, articles, and scientific papers concerning fuel spills in Antarctica during 1989

Bahia Paraiso, Palmer Station, January 1989

NSF PRESS RELEASES

- "Supply ship, grounded in Antarctic, may sink"; Jeffrey Norris, 30 January 1989, National Science Foundation, Office of Legislative and Public Affairs (NSF press release 89-7)

- "To protect antarctic wildlife and U.S. research, NSF launches effort to contain fuel spill from Argentine supply ship"; Jeffrey Norris, 1 February 1989, National Science Foundation, Office of Legislative and Public Affairs (NSF press release 89-9)

- "NSF sends team of experts to assess environmental impact of antarctic fuel oil spill"; Jeffrey Norris, 11 March 1989, National Science Foundation, Office of Legislative and Public Affairs (NSF press release 89-16)

NSF PUBLICATIONS

- Articles by Ted Delaca and Polly Penhale in _Directions_, editor Patrick Olmert, Office of Legislative and Public Affairs, National Science Foundation; Spring 1989.

- "Argentine ship sinks near Palmer Station;" _Antarctic Journal of the United States_, Volume 24, number 2, June 1989.

- "Palmer Station and vicinity"; _Antarctic Journal of the United States_, Volume 24, number 2, June 1989.

- "NSF launches oil-spill containment team"; _Antarctic Journal of the United States_, Volume 24, number 2, June 1989.

- "Research team focuses on environmental impact of oil spill", Polly Penhale; _Antarctic Journal of the United States_, Volume 24, number 2, 1989.

- _Antarctic News Clips_, 1989, compiled by the Polar Information Program, Polar Coordination and Information Section, Division of Polar Programs; August 1989. (See attachment for listing of articles included. The clips book provides a sampling of newspaper articles published about the accident.)

- "Petroleum degradation by microorganisms: Initial results from the Bahia Paraiso oil spill, David Karl; Antarctic Journal of the United States, Volume 24, numper 5, 1990 (in press).

- "The intertidal zone at Palmer Station, Anvers Island, Antarctic Peninsula--In the was of the Bahia Paraiso spill, William Stockton; Antarctic Journal of the United States, Volume 25, number 5, 1991 (accepted for publication).

- "The evolution of oxygen in microalgal intertidal communities in the vicinity of Palmer Station, Gustavo A. Ferreyra and Viviana A. Alder; Antarctic Journal of the United States, Volume 25, number 5, 1991 (accepted for publication).

- "Tininnid cytoplasmic volume and biomass", Viviana A. Alder; Antarctic Journal of the United States, Volume 25, number 5, 1991 (accepted for publication).

SCIENTIFIC AND OTHER PUBLICATIONS

- "Spill threatens research"; Science News, 11 February 1989, 135 (6), 85.

- "Oil Slick could scar Antarctica 'for a century'"; New Scientist, 11 February 1989, 1651, 31.

- "National Science Foundation's Rapid Oil Spill Response to the Grounding of the Bahia Paraiso, Mahlon C. Kennicutt II and William Fraser; Biomass (newsletter), Volume 11, number 1; July 1989.

- "Indirect effects of an oil spill", Z.A. Eppley and M.A. Rubega; Nature, 340, 513, 1989.

- "Oil spillage in Antarctica", Mahlon C. Kennicutt II, et.al., Environmental Science & Technology (American Chemical Society), Volume 24, 1990.

- "Skua survival," (Scientific Correspondence), W.Z. Trivelpiece, D.G. Ainley, W.R. Fraser, and S.G. Trivelpiece; Nature, 345, 211, 1990.

- Response by Z.A. Eppley and M.Am Rubega to scientific correspondence by W.Z. Trivelpiece, D.G. Ainley, W.R. Fraser, and S.G. Trivelpiece; Nature, 345, 211-212, 1990.

- "Eco-Quandary: What killed the Skuas?", Marcia Barinaga; News & Comment, Science, 249, 243, 20 July 1990.

- "Indirect effects of an oil spill: Reproductive failure in a population of south polar skuas following the Bahia Paraiso oil spill in Antarctica", Z.A. Eppley and M.A. Rubega; Marine Ecology-Progress Series, In press.

- "The Grounding of the Bahia Paraiso, Arthur Harbor, Antarctica--I. Distribution and Fate of Oil Spill Related Hydrocarbons, M.C. Kennicutt II, S. Sweet, W. Fraser, W. Stockton, and M. Culver; submitted to Environmental Science & Technology (American Chemical Society, 1990.

SELECTED NEWSPAPER ARTICLES FROM 1989

- "Sunken ship's oil spill held a peril to antarctic wildlife", New York Times.
- "Sunken Argentine ship called unsafe", St. Louis Post-Dispatch.
- "U.S. to help clean up oil spill", St. Louis Post-Dispatch.
- "Oil drum recovery is disputed", Philadelphia Inquirer.
- "Mission proves to be test for Dover Air Force Base", News Journal.
- "Antarctica: 250,000 gallons of prevention", U.S. News & World Report.
- "Scientist says antarctic oil spill does significant harm to wildlife", New York Times.
- "Oil spill threatens wildlife research in Antarctica", St. Louis Post-Dispatch.
- "Antarctic oil spill takes heavy toll on animal life", Miami Herald.
- "New shipwreck causes oil slick in Antarctic", New York Times.
- "UC scientists to join study of damage from antarctic oil spill", San Francisco Chronicle.
- "A&M team to study fuel spill", Houston Chronicle.
- "UCSB researchers join emergency expedition to study antarctic oil spill", Daily Nexus.

SELECTED NEWSPAPER ARTICLES FROM 1989 (continued)

- "Scientist flies at chance to study antarctic birds", Davis Enterprise.
- "Scientists fear rise in visitors to Antarctica will hurt

ecology", Detroit News.

- "Scientists fear ecology at risk in Antarctica", Associated Press.
- "Cold halts Argentine oil cleanup", Times-Picayune.
- "Diesel fuel cleanup ending in Antarctica", Plain Dealer.
- "Not-so-isolated Antarctica suffers growing pollution", The Oregonian.
- "Oil spill taints Antarctic", News Journal (Wilmington, Delaware).
- "Marine biologist discusses effects of antarctic oil spill", Fairbanks Daily News-Miner.
- "UCSB scientists return from a one-month study", Santa Barbara News-Press.
- "Oil spills: Some animals benefit", Washington Post.

Fuel Spills at Amundsen-Scott South Pole and McMurdo Stations, 1989

NSF PRESS RELEASES

- "Discovery and repair of diesel fuel leak at Amundsen-Scott South Pole Station"; Jeffrey Norris, 28 September 1989, Office of Legislative and Public Affairs, National Science Foundation (NSF press release 89-72)
- "Fuel loss at Amundsen-Scott South Pole Station"; U.S. Antarctic Program fact sheet prepared by Guy Guthridge, Division of Polar Programs, National Science Foundation (27 September 1989).
- "Fuel leaks discovered near McMurdo Station, Antarctica"; Jack Renirie, 12 October 1989, Office of Legislative and Public Affairs, National Science Foundation (89-81).

NEWSPAPER ARTICLES (Note--this a sample listing of articles that appeared in U.S. newspapers.)

- "Diesel Fuel Spilled"; Montgomery Advertiser (Montgomery, Alabama), 29 September 1989. (This article deals only with the South Pole fuel spill.)
- "Oil disaster--100,000 years later"; Christchurch Press

(Christchurch, New Zealand), 29 September 1989. (This covers only the spill at South Pole.)

- "Fuel spill combated at U.S. Antarctic station"; Associated Press, Dallas Times Herald, 13 October 1989. (The article mentions the fuel spills at both stations.)
- "Fuel and Heating Oil Spilled in Antarctica"; New York Times, 13 October 1989. (This article talks specifically about the McMurdo Station fuel spill and quotes Paul Bogard of Greenpeace.)

TECHNOLOGY LIMITED TO THE MESURES FOR ENVIRONMENTAL PROTECTION IN ADELIE LAND.

BY

ENGLER. ,M.[1)]

EXPEDITIONS POLAIRES FRANCAISES.

ABSTRACT

As part of the French engineering programm in Adelie Land, every possible measures are used to get the environment protected : especially measures of compensation and processing requiring very important studies and means.

Compensatory measures are generally associated with works which alter the morphology and the assignment of natural zones, as for example, the building of an airstrip.

This measures means :

1- Monitoring works and environmental protection.

2- The setting of compensatory zones for artificial nesting for Adelie penguin, snow petrel and cape pigeons.

3- The fitting up of access means for emperor penguins.

Processing measures deal essentially with technology and waste management, being harmful for the ecosystems of the archipelago and for the environmental protection.

In this same spirit, the french administration proposed a new scientific base on the Antarctic Plateau at Dôme "C".
The management of this new base used an original equipment which will permit handling of the waste : recycling of the waste water, global treatment of waste and ventilation.

1). EXPEDITIONS POLAIRES FRANCAISES, 47 Avenue du Maréchal-Fayolle
75116 PARIS.

INTRODUCTION

When the French Polar Expeditions installed themselves in Terre-Adélie in 1950 and constructed the first buildings of the future Dumont d'Urville base for the International Geophysical Year, ecological problems were probably not of an imperative nature. The secureness of the expeditions and the realisation of scientific programmes were exclusive priorities.

The regularity of the operations and the planning of the expeditions have provoked a suden awareness of the ecological problems and a better management of the human activities in the "Pointe Géologie Archipelago" ecosystem.

The French Polar Expeditions have therefore applied themselves to improve the conditions of the treatment of waste as well as the harmful effects brought about by the presence of the base.
A manual has thus been established in order to regulate the following forms of human activity :

- helicopter flight
- unloading of gargo
- construction
- circulation of men
- management of waste.

It is therefore in this spirit that the French administration proposed an impact study linked to the construction of an airstrip in the "Pointe Geologie Archipelago". Athough controversial, this study was the first to be realised by a national operator in Antarctica.

The ecological approach minimizing impact of the airstrip construction on the ecosystem was carried out by a French team led by Doctor JOUVENTIN. A strategy was drawn up on the following points :

1°) The establishment of the very strict planning of the works in order to anticipate means permitting isolation of the work zones before the arrival of the breeding animals.

2°) The arrangement of new nesting zones in order to partly compensate for those destroyed by the works.

3°) The arrangement of accesses on to the causeway to facilitate the crossing of the Emperor penguins.

These operations were submitted to the "Committee of the Environment" and taken to the field by a biologist representing the minister of the Environement in collaboration with the project chief.

During the first summer campaign of 87/88, after the government's decision to construct the Terre-Adélie aerodrome, some co-ordination difficulties apparead which were quickly smoothed out. Since then, both summer and winter operations alike, take place satisfactorily with a high chance of success.

First of all, at the beginning of spring , before the penguins arrive, a team of technicians from the worksite in association with biologists, surround the future summer worksite with several meters of wire netting to prevent the penguins from using the site. The technicians used a similar method with the other nests. This solution forces the birds to settle the new areas prepared during the winter time.
Because during this season, a technical team is drilling holes for blasting in order to provide a mass of stones for the birds to build their nests in . This method permit to transform flat area into a rocky area for the birds. The biologists after blasting set the rocks in order to give an attractive aspect for the new nesting area. The last summer 20% of potential nests have been visited by snow petrels and wilson petrels. For the cape pigeon we used decoys around artifical nests.

At least different dispositions show that the Emperor penguins can freely cross the causeway and are totaly unhindered by the works.

The Terre-Adélie aerodrome was programmed to serve as a means of penetration of the continental shelf. In particular, this airstrip is indispensable for the construction and functioning of a scientific base at Dome "C"

This objective was decided in Ministerial Council on 23rd February, 1990. A project and an associated impact study are presently being discussed.

The government's concern on this subject has been to minimize and even to abolish all hamful effects on the surroundings.

The fragile zone is obviously the coastal zone, where materials and fuel are unloaded. This is also the departure point of the convoys towards the Dôme "C" construction site. A period without the presence of fauna was chosen to carry out these transfers of material. Our transport vehicles are being replaced in order to abolish, on the one hand, those using leaded fuel and, on the other hand to reduce the risk of accidents in the crevassed zone.

The construction procedures of the base will not use any prohibited materials as recommended by S.C.A.R. and the Treaty. The original equipement will permit handling of the waste.

* Recycling of the waste water
* Global treatment of waste without effluent
* Treatment of ventilation

Only the expulsion of exhaust fumes from the electric generators will not be treated. The chosen fuel will be kerosene JET AI.

The principle of the base is that of two geodesic domes constructed on 5 integrated piles fitted with jacks. The two domes are connected by an aerial tunnel. The construction procedure is drawn up from a French patent - it should be started in 1993 and finished in 1995. This base for 15 personns will possess a Summer camp which be abble to accommodate about 25 persons.

About the conception of the construction, the covering (or "skin") of each dome will be made of wood (wood was chosen because it is well adapted to low temperatures, for example, it is used successfully for transporting methane tankers at -170°C). The frame will be a glue laminated timber frame, the external skin will be made of plywood covered with a special material (bitume-polymer), a rock-wool insulation and an internal water tight skin.

The timber frame will be supported by an internal steel structure. The support device allows dilatation between the timber frame and the steel structure. The main internal steel structure has two levels.

The piles will be held in the correct position by centring devices fixed to the lower floor.

At the top of each pile, there is a jack attached to the pile and the upper floor and it keeps the floor in the horizontal position (consequently the lower floor is suspended from the upper floor).

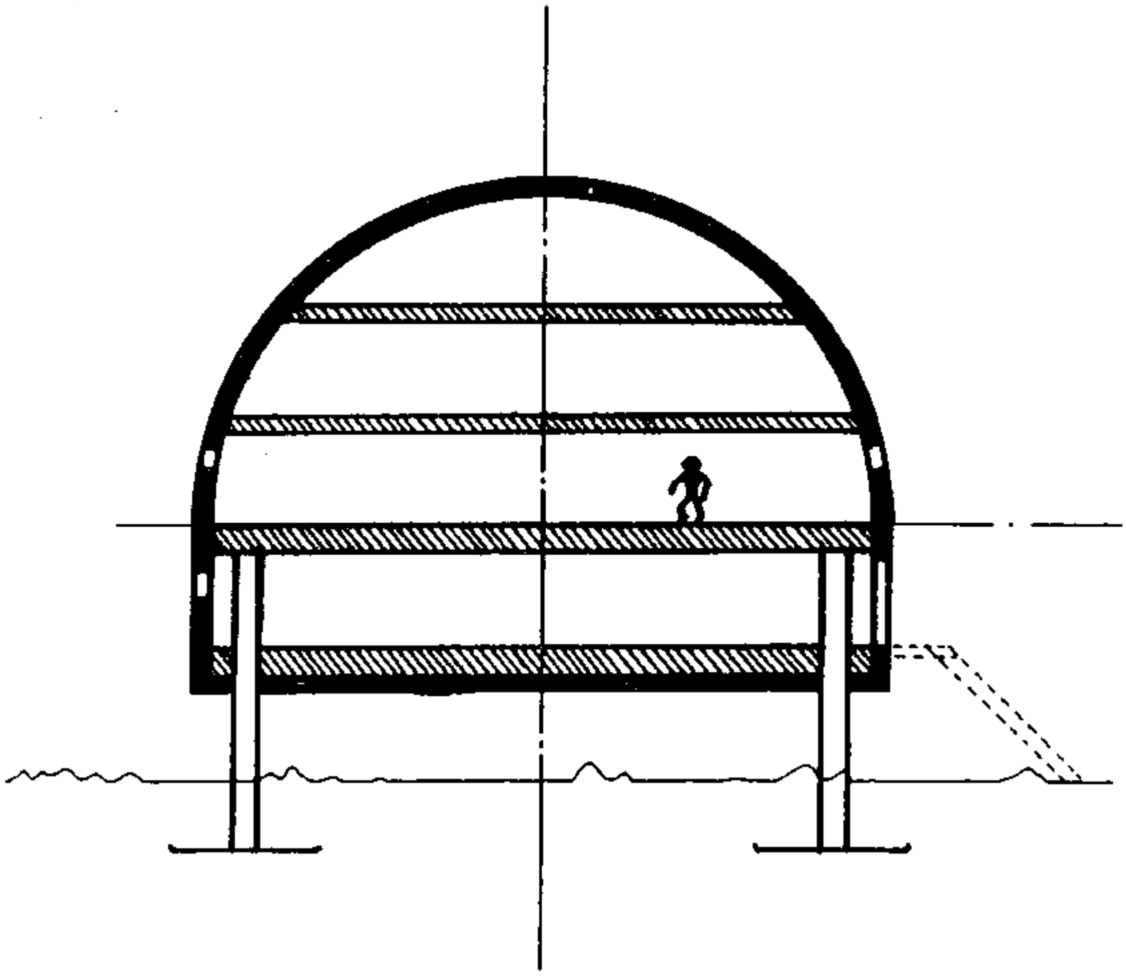
At the present time several solutions for the piles are studying. One of these allows the pile to rise up if there any horizontal movement of the ground and thus prevent damage to the structure.

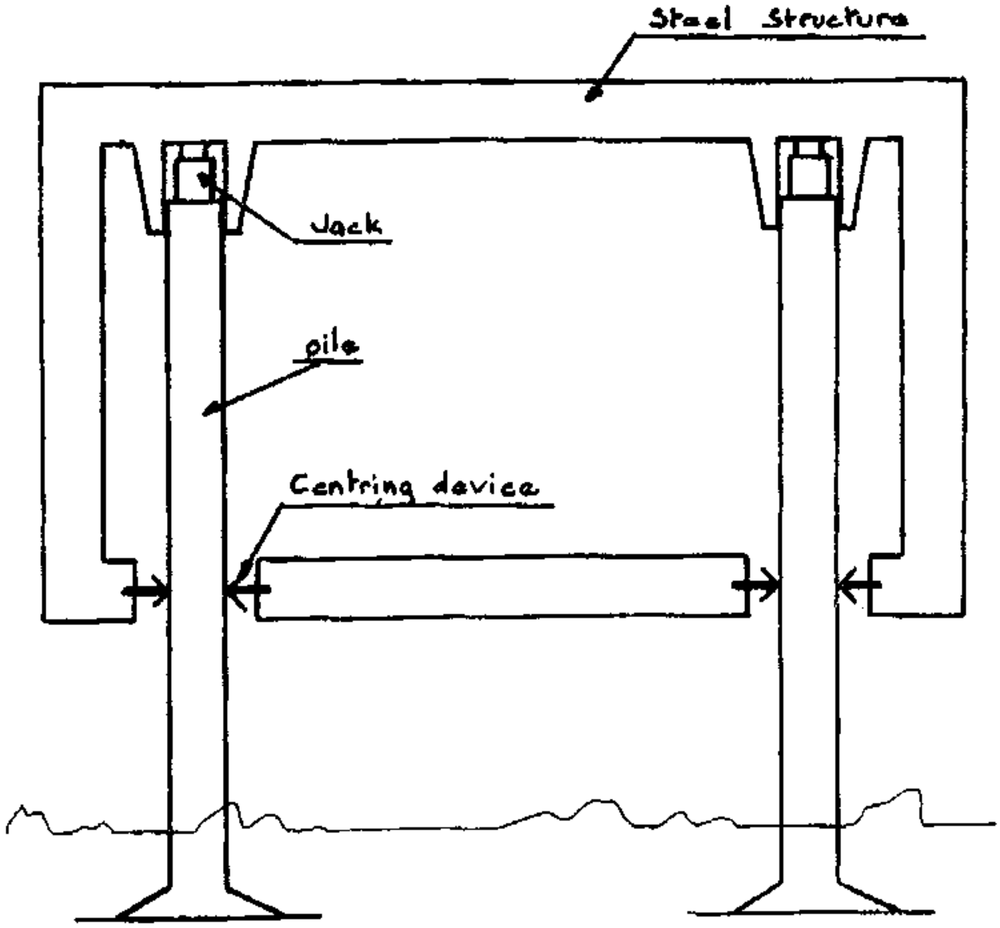
Each dome will be equiped with an external foot-bridge for maintenance operations.

Although the conception of this base is French, the French government proposes that it welcomes the great programms of Antarctic International Co-operation such as the study of ozone - paleoclimatology - astrophysic .

This particularly attractive site, together with a modern, non-polluting base should favour an International scientific activity of the first order in the Antarctica vocation "Land of Science".

SECTION OF A STRUCTURE





PILES & STEEL STRUCTURE
PRINCIPLE

Vertical Axis Wind Turbine
with Integrated Magnetic Generator

by

Heidelberg, G.[1)]
Kohnen, H.[2)]
Krömer, I.[1)]
Lehmann, D.[3)] and
Zastrow, F.[4)]

Abstract

Favourable annual wind conditions at the German winter station "Neumayer" imply the use of wind turbines as alternative energy resources. This is to reduce the fuel consumption and consequently the emission of the station. A smaller amount of fuel being stored would simultaneously minimize the potential hazards of fuel spills.

As first step towards this goal a prototype of a Vertical Wind Turbine (VAWT) with a maximum power output of 20 KW has been developed as a joint project between the Alfred-Wegener-Institute, Germanischer Lloyd, Hochschule Bremerhaven and Heidelberg Motor.

The rigid rotor consists of three straight steel rotor blades; the diameter of the rotor is 10 m with a swept area of 56 m^2.The rotor is mounted on a telescopic tower. The permanent magnetic ring of the running field generator is integrated into the support structure of the tower whereas stator is mounted to the tower. Pitch control and yawing system are not required. The whole system has only one rotating part.

The wind turbine which has been tested 1990 on a special test site of Kaiser-Wilhelm-Koog of the Germanischer Lloyd at the German North Sea coast, will be integrated into the diesel electrical system of Neumayer Station 1991 for further testing.

Introduction

The use of wind/solar energy as support and as an alternative to the diesel electrical power supply of the German winter station "Neumayer" has thoroughly been discussed and investigated. The use of solar radiation as major energy source had to be discarded because the average annual solar radiation input is not sufficient to provide a significant contribution. On the other hand the longterm climatic observations show that the wind energy potential might be favourable for the application of wind turbine systems. Intensive relevant investigations have

1) Heidelberg Motor, Starnberg
2) Alfred-Wegener-Institut, Bremerhaven
3) Germanischer Lloyd, Hamburg
4) Hochschule Bremerhaven

confirmed that the wind potential at Neumayer station might even be ideal for the use of wind turbines. A technical project, in which three institutions and an engineering company are involved, was initiated in 1988 to develop an appropriate system. After initial draw backs due to technical problems arising from the climatic boundary conditions at "Neumayer" a system with a vertical rotor axis was chosen which is considered sufficiently simple and rugged to cope with the rugged Antarctic climate. The system was developed 1989 and tested 1990 at the German North Sea coast. During this test phase some vigorous spring storms were encountered during which the system performed in accordance with the given specifications. The wind turbine will be installed at Neumayer station 1991 for further testing and connected to the station's diesel plant.

The Present State of Wind Energy Technology

After suffering initial setbacks technologies for the use of wind energy have gained considerable economic importance in the last five years. The system used almost exclusively in the past was the traditional wind generator with a horizontal axis operating like a windmill.

The special problems involved in the development of horizontal-axis wind turbines were the very complex loads excessively straining the components on the one hand and on the other hand the necessity to use extensive machinery.

A view of a nacelle illustrates the similarity with an electric power plant (Fig. 1).

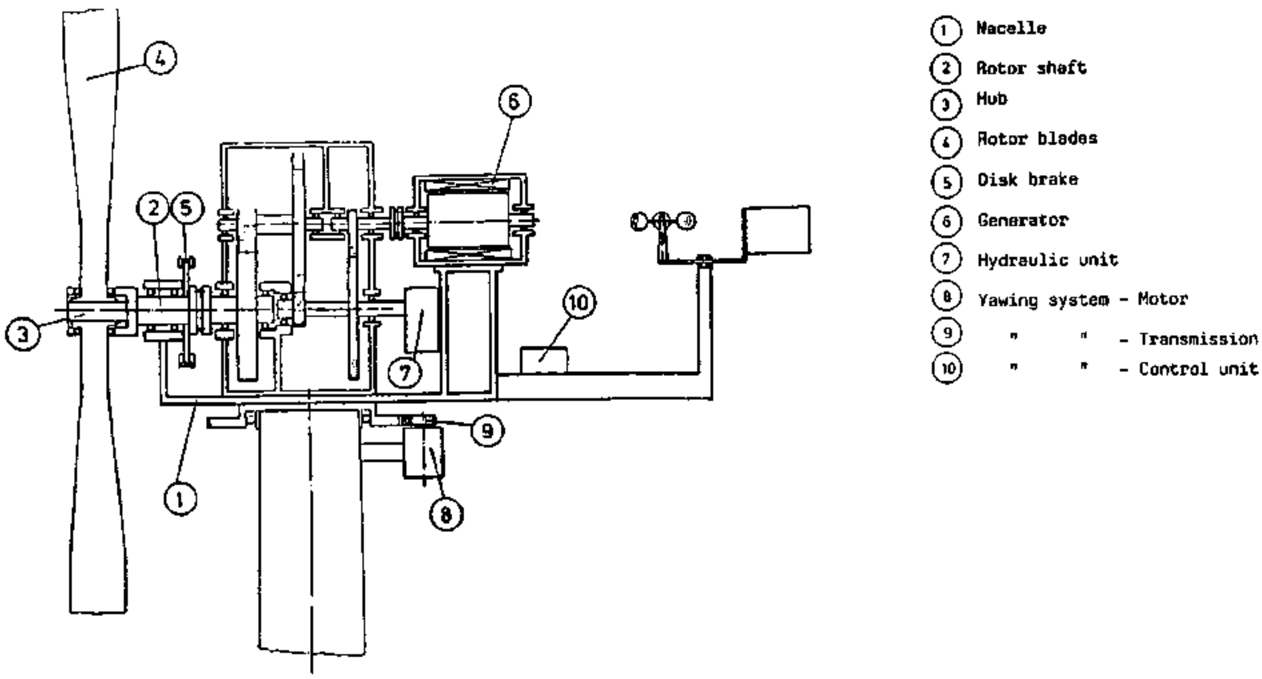


Figure 1: Nacelle of a modern horizontal-axis wind turbine - schematic sketch

The power is transmitted from the rotor blades to the hub and, in larger turbines, through a multiple-stage gearbox with clutch elements to the generator.

The yawing system and the pitch control of the rotor blades being used in many modern systems are additional subsystems requiring a high standard.

These components generally determine the reliabitity, service and maintenance requirements and the durability of the turbine. In spite of the above problems and due to the experience acquired over the years and research conducted in wind turbine technology, it has become possible to achieve a standard which allows the production stage turbines with capacities up to 300 KW approximately.

Although the construction of considerably larger units capable to significantly contribute to the national energy production would be very desirable, larger models developed so far, however, are strictly prototypes. The main reason for the extreme expenditure involved in an increase of size of horizontal-axis turbines are the scaling laws governing this type of system.

A larger size of the radius of the rotor, for instance, will diminish speed of rotation proportionally , as the maximum speed of the blade tip is limited. This will then increase the torque more than the power, thus explaining the high degree of expenditure necessary for the modifications of the transmission.

The unfavourable scaling laws are also applied to other elements, for example to the rotor blades, therefore limiting the general use of large plants, since the expenses lie beyond economic benefits.

Extreme climate conditions (wind velocities, temperatures) also limit the use of large conventional wind generators.

Vertical-axis systems

Vertical-axis turbines have been long considered to be an alternative to the horizontal-axis systems. Vertical-axis systems, in fact, could very well be the oldest windmill construction. Today this type of system has less importance though, than the horizontal-axis type (1,2).

Basically the vertical-axis systems can be classified into three groups:

a) Savonius Rotors
b) Darrieus Rotors
c) H-Rotors

In all three groups of turbines the vertical rotation of the shaft eliminates the need for a yawing system.

confirmed that the wind potential at Neumayer station might even be ideal for the use of wind turbines. A technical project, in which three institutions and an engineering company are involved, was initiated in 1988 to develop an appropriate system. After initial draw backs due to technical problems arising from the climatic boundary conditions at "Neumayer" a system with a vertical rotor axis was chosen which is considered sufficiently simple and rugged to cope with the rugged Antarctic climate. The system was developed 1989 and tested 1990 at the German North Sea coast. During this test phase some vigorous spring storms were encountered during which the system performed in accordance with the given specifications. The wind turbine will be installed at Neumayer station 1991 for further testing and connected to the station's diesel plant.

The Present State of Wind Energy Technology

After suffering initial setbacks technologies for the use of wind energy have gained considerable economic importance in the last five years. The system used almost exclusively in the past was the traditional wind generator with a horizontal axis operating like a windmill.

The special problems involved in the development of horizontal-axis wind turbines were the very complex loads excessively straining the components on the one hand and on the other hand the necessity to use extensive machinery.

A view of a nacelle illustrates the similarity with an electric power plant (Fig. 1).

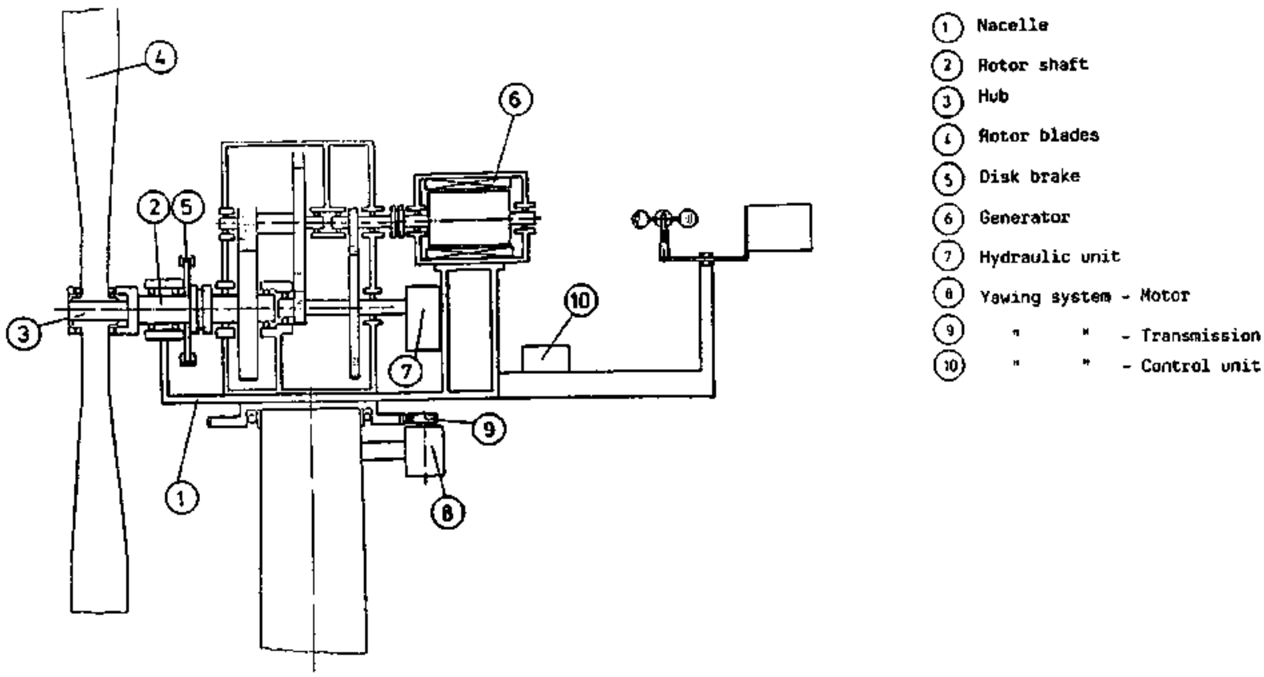


Figure 1: Nacelle of a modern horizontal-axis wind turbine - schematic sketch

The power is transmitted from the rotor blades to the hub and, in larger turbines, through a multiple-stage gearbox with clutch elements to the generator.

The yawing system and the pitch control of the rotor blades being used in many modern systems are additional subsystems requiring a high standard.

These components generally determine the reliabitity, service and maintenance requirements and the durability of the turbine. In spite of the above problems and due to the experience acquired over the years and research conducted in wind turbine technology, it has become possible to achieve a standard which allows the production stage turbines with capacities up to 300 KW approximately.

Although the construction of considerably larger units capable to significantly contribute to the national energy production would be very desirable, larger models developed so far, however, are strictly prototypes. The main reason for the extreme expenditure involved in an increase of size of horizontal-axis turbines are the scaling laws governing this type of system.

A larger size of the radius of the rotor, for instance, will diminish speed of rotation proportionally , as the maximum speed of the blade tip is limited. This will then increase the torque more than the power, thus explaining the high degree of expenditure necessary for the modifications of the transmission.

The unfavourable scaling laws are also applied to other elements, for example to the rotor blades, therefore limiting the general use of large plants, since the expenses lie beyond economic benefits.

Extreme climate conditions (wind velocities, temperatures) also limit the use of large conventional wind generators.

Vertical-axis systems

Vertical-axis turbines have been long considered to be an alternative to the horizontal-axis systems. Vertical-axis systems, in fact, could very well be the oldest windmill construction. Today this type of system has less importance though, than the horizontal-axis type (1,2).

Basically the vertical-axis systems can be classified into three groups:

a) Savonius Rotors
b) Darrieus Rotors
c) H-Rotors

In all three groups of turbines the vertical rotation of the shaft eliminates the need for a yawing system.

a) Savonius Rotors

Of the three groups the Savonius Rotors are the simplest type of construction, only taking advantage of wind drag force and therefore not requiring any aerodynamic profiles. As a consequence the performance coefficient, i.e. the relation between mechanical power at the rotor shaft and the available kinetic wind power, cannot total more than approx. 0.2 compared to a maximum theoretic value of 0.59 for systems using lift-driven rotors (1).

Correspondingly Savonius Rotors are used almost exclusively only for small and simple applications (ventilation of waggons, containers etc.).

b) Darrieus Rotors

The Darrieus Rotor group on the other hand is generally equipped with two semi-circular blades as rotors, thus enabling it to take advantage of lift forces which results in considerably better performance coefficients.
Darrieus rotors are generally not self-starting and therefore are started by means of an electric starter facility or a Savonius Rotor.

Darrieus Rotors with capacities up to the megawatt-range have been constructed. Yet, for use on a large scale this system is too expensive, particularly because of its complicated rotor blades.

c) H-Rotors

Compared to the Darrieus Rotor there is a clear separation of support and aerodynamic function in the H-Rotor, hence giving the option to have entirely different configurations.

H-Rotors have been built as prototypes, primarily in Great Britain. Some of them have been equipped with bladegeometry adjustment systems for efficiency control as well as for limiting the forces at high wind velocities.

Also H-Rotors generally have their transmisssion and generator installed in their tower base.

Both the H-Rotor and the Darrieus Rotor achieve somewhat lower performance coefficients than the propeller driven systems due to the attack angles varying over a greater range.

The HM-Rotor

The present state of development as outlined above reflects the following objectives to be further evaluated:

reduction of the mechanical complexity

- construction of large units carried out without any more extensive specific modifications/expenditure than needed for building small and medium-sized units.

Based on these requirements a new wind-energy converter has been developed (Heidelberg Motor, Starnberg) that can result in considerable progress towards meeting those objectives.

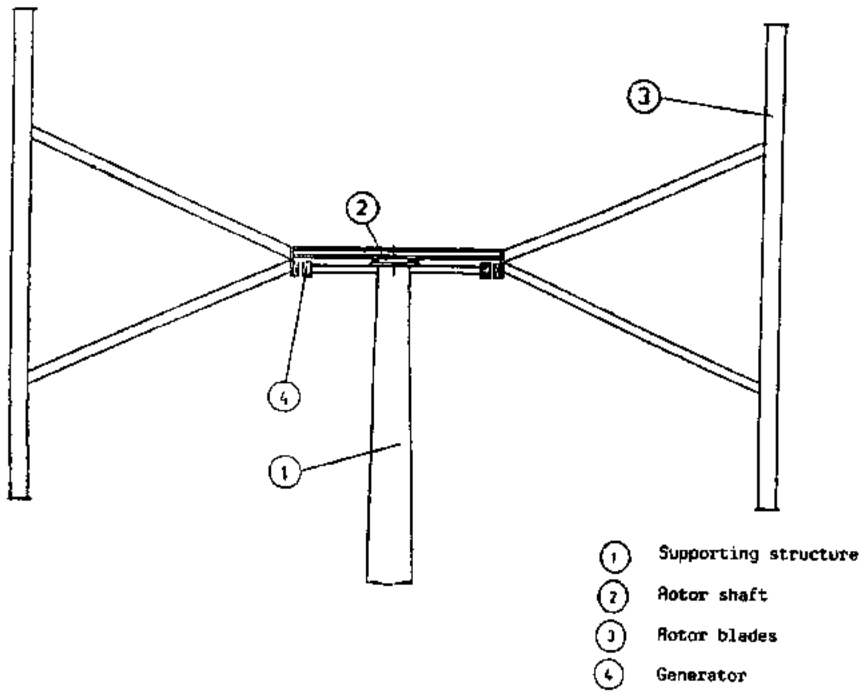


Figure 2: HM-Motor schematic sketch

This turbine is similar to the H-Rotors being equipped with a vertical-axis rotor with straight rotor blades. However, unlike conventional wind turbines, the complexity of the mechanical components in the new "HM-Rotor" has been drastically reduced as follows:

- The HM-Rotor has only one rotating part: the rotor itself is rigid.
- The permanent-magnet travelling field generator is integrated in the steel structure.
- The system does not require a mechanical transmission.
- The rotor blades do not require pitch control devices and yawing systems (e.g. hydraulic systems).

- The speed of rotation is electrically controlled; by using a converter the power output frequency is independent from the frequency of rotation.

With these preconditions a maximum reliability, ruggedness and longevity combined with a minimum of servicing and maintenance may be achieved.

A vital component of the HM-Rotor is the travelling field generator (Heidelberg Motor GmbH and Magnet-Motor GmbH). This design permits high torque density even with a large air gap between stator and rotor.

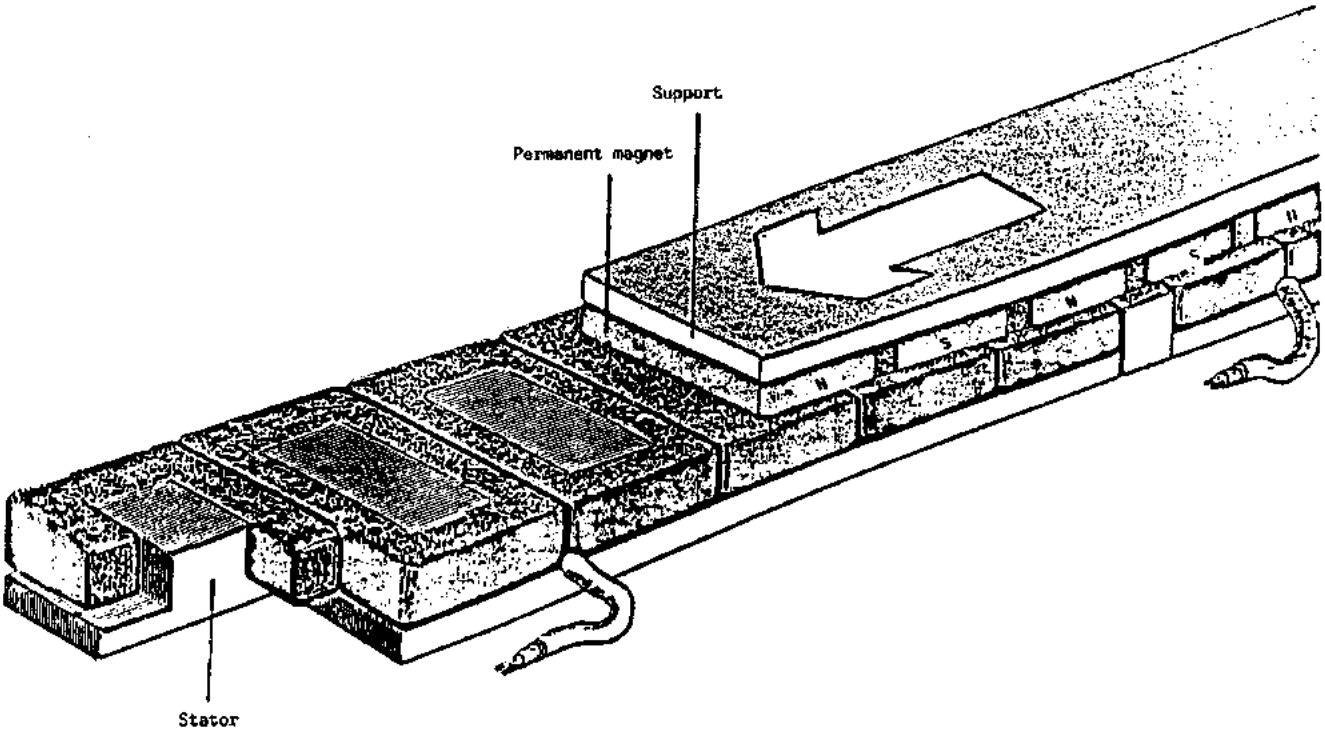


Figure 3: HM-Travelling field generator (schematic drawing)

The permanent magnet ring of the generator is integrated in the support structure of the rotor. The stator is mounted on the tower.

The alternating current produced in the generator is rectified and adapted to the power grid by use of a converter.

In large units the radius of the generator ring is enlarged proportionally to the radius of the rotor. Thus, the specific expenditure nearly remains constant in relation to the increase in rated power.

This also applies to the rotor blades, their specific expenditure remaining almost constant when enlarged. It's only the specific expenditure for structure supports and tower which is affected by the size of construction.

The HM-Rotor does not require a transmission, which tends to make large horizontal-axis wind turbines prohibitively expensive.

Thus, the HM-Rotor enables large wind turbines to be built particularly suitable for:

Application in regions with

- extreme wind velocities
- extreme temperatures
- rugged conditions for maintenance

Wind Generators for the Antarctic

Two diesel generators of 75 kW each provide electrical power for the German Antarctic research station. To reduce the fuel consumption and the emission for the diesel engines, the Alfred-Wegener-Institut in Bremerhaven is planning to install wind generators as alternative power supply. The institute intends to initially set up one HM unit of approx. 20 kW capacity for test purposes, which then can be expanded later by adding other units. The most important requirements are:

- survival wind velocity: 68 m/sec.
- minimum operating temperature: - 55°C

Initial plans to develop and use a conventional system with horizontal rotor axis had to be discarded, because of too great technical problems as consequence of those requirements.

The project is carried out by the Alfred-Wegener-Institut, Hochschule Bremerhaven, Germanischer Lloyd, Hamburg and Heidelberg Motor as constructor.

a) Climatic Conditions at Neumayer-Station

The climatic, particularly the wind conditions at Neumayer Station invite to use windgenerators as an alternative energy source. The average annual wind velocity here is about 9 m/sec which corresponds with an energy potential of about 11200 kW h/m^3. It is interesting to note that many medium wind generators have their maximum efficiency at 9 m/sec.

Thus, a wind generator at "Neumayer" has to cope with a wind spectrum which ranges from zero to about 40 m/sec with an average of 9 m/sec.

The mean annual temperature is 19° C ranging from about 0° C to -50° C as minimum. All components of the wind mill have to be developed and adjusted to these conditions wherein icing, besides heavy storms, might be the most adverse situation.

b) Specifications of the wind turbine

The HM-Rotor Type HMW 56 designed for use in polar regions has the following specifications:

Rotor diameter:	10.0 m
Swept area:	56 m^2
Number of rotor blades:	3
Rated output:	20 kW
Hub height:	10 m above snow surface
R.P.M. range:	30 - 60 min^{-1}

The turbine starts to rotate at a wind velocity of 6 m/sec.
The brake velocity is chosen at 30 m/sec.
Rated output will be obtained from 9 m/sec onwards.

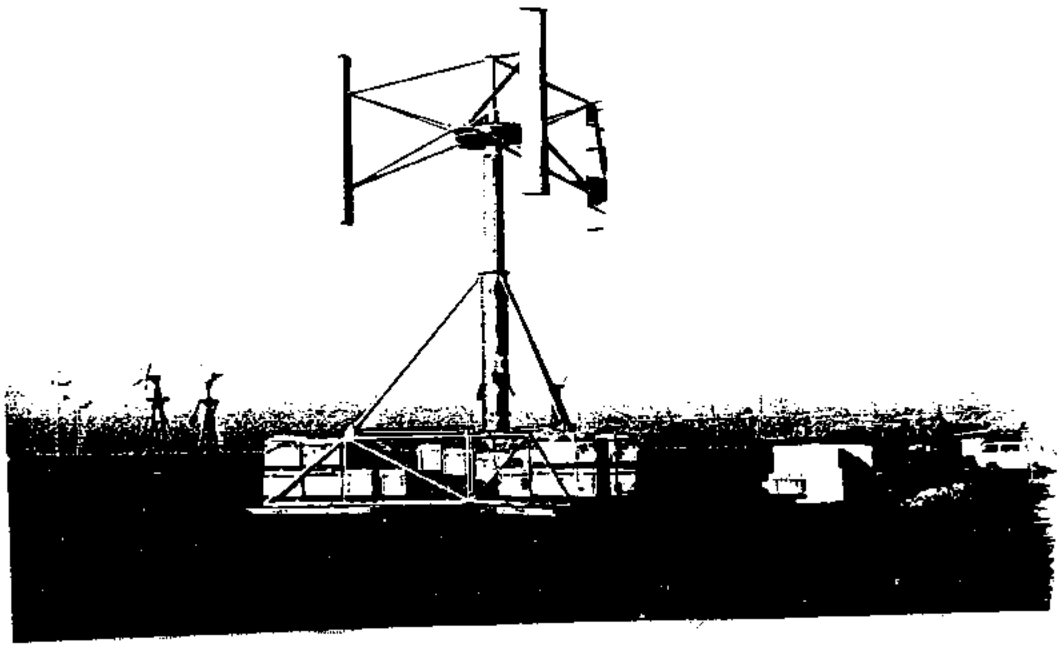


Figure 4: The HMW 56 at the Kaiser-Wilhelm-Koog Test Side

Some special aspects for the setting up and the operation of the unit at the Antarctic research station are:

- The tower is of telescope type which makes it possible to install the unit with a mobile crane.

- The foundation consists of three base frames. These are founded in the snow.

- The annual snow accumulation is approx. 70 cm at the Georg-von-Neumayer Station. In order to operate the HM-Rotor for a long time period (approx. 10 years) the base frames can be raised by adding additional frames (1.40 m each) every second year.

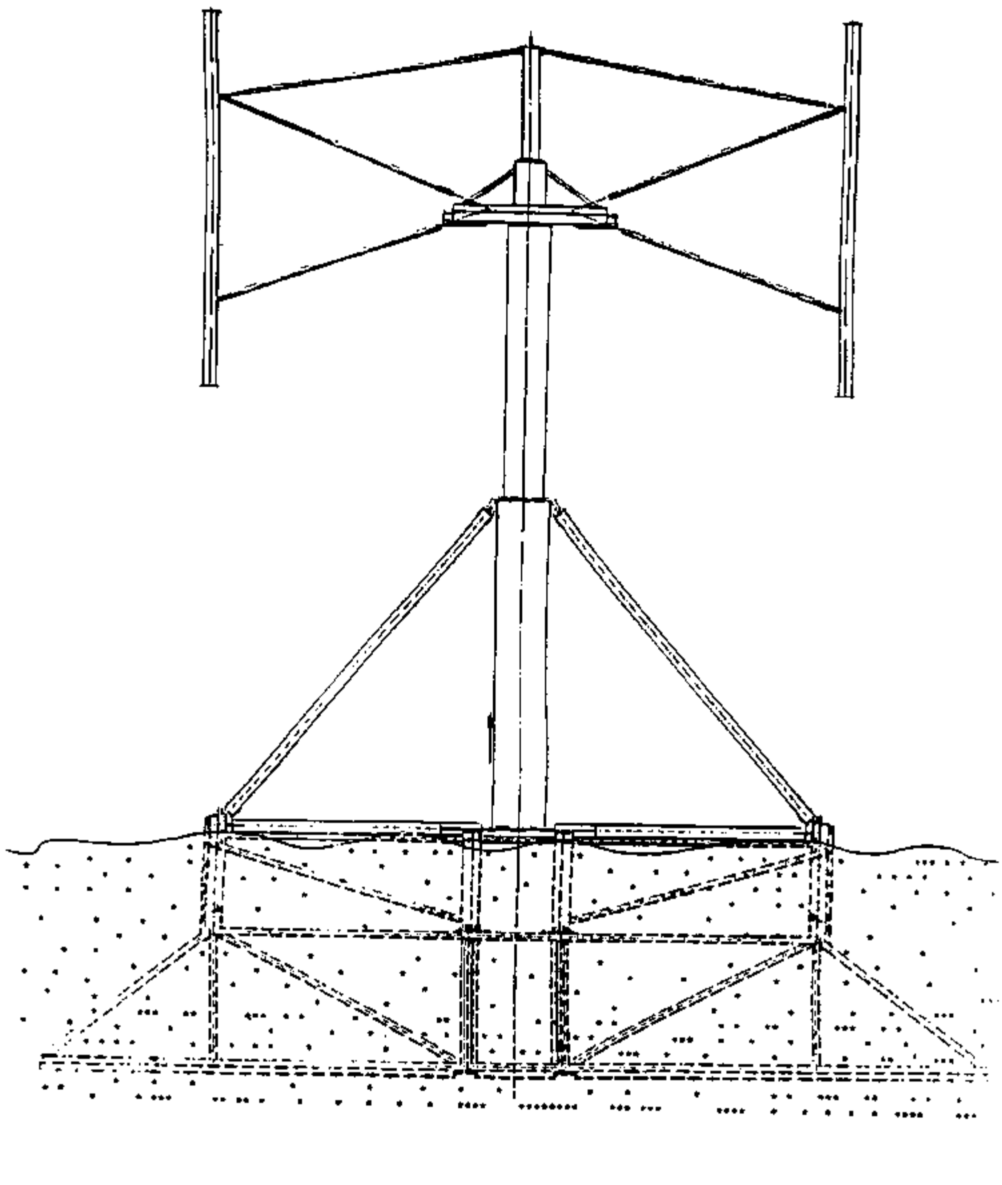


Figure 5: HMW 56 - foundation, additional frames to raise the structure

- The brake system works without any physical contact by using eddy currents. Six redundant and independent circuits guarantee the necessary safety functions.
- The design of the electrical control and steering system takes into account that the diesel generators must always produce a minimum of power to avoid soiling.

The electrical system is illustrated in Fig. 6 as a block diagram.

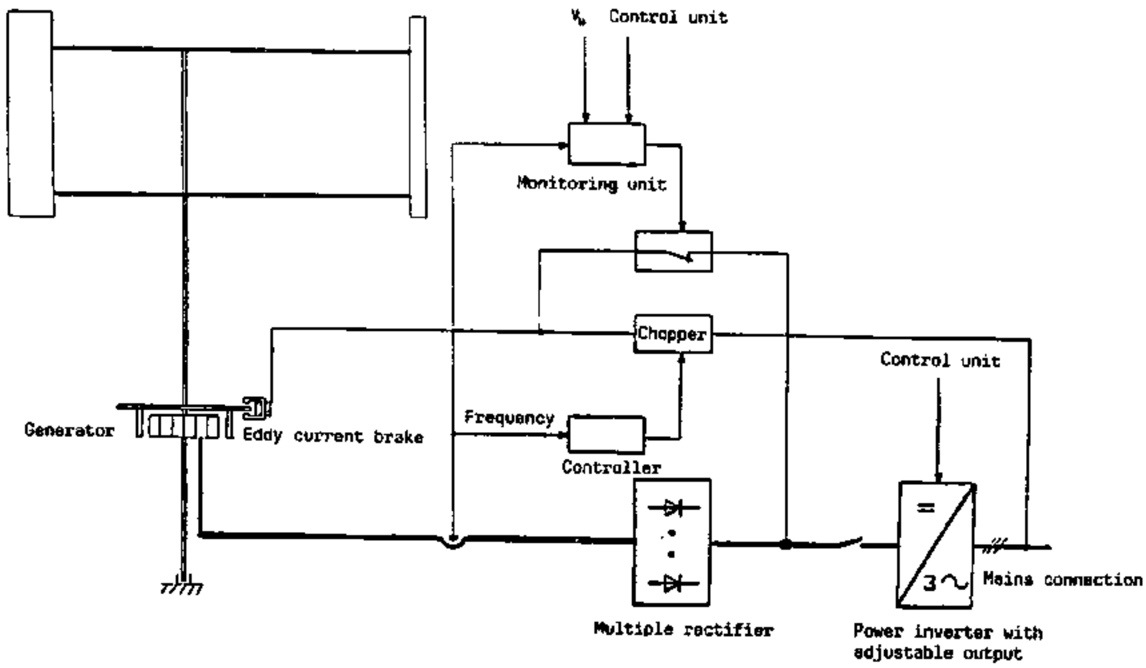


Figure 6: HMW 56 schematic electrical circuit

The AC generated by the HM-Rotor is rectified and fed into the station's network via a frequency converter. To control the rotor direct current is fed via a chopper to the eddy current brake. The chopper is computer-controlled. When a malfunction occurs, the direct current is fed via a contactor directly from the generator to the rectifier and on to the eddy current brake, bypassing the electronic systems.

The system has been tested during the first half of 1990 on a special test field at the German North Sea Coast; it will be shipped to the Antarctic in October 1990 and installed near Neumayer Station for further testing.

Acknowledgement:

The project is financed by the Ministry of Science and Technology of the Federal Republic of Germany and by the Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven.

References:

1. E. Hau: "*Windkraftanlagen*", Springer-Verlag (Berlin, 1988)
2. J. Schmid/W. Palz: "*European Wind Energy Technology*", Reidel Publication Co. (Dordrecht, 1986)

A NEW DESIGNED WIND GENERATOR FOR ANTARCTICA.

ISHIZAWA Kenji(1), KIMURA Shigeo(2) and TAKANAGA Toshiyuki(3)

(1)National Institute of Polar Research

(2)Kanagawa Institute of Technology

(3)Kandenko Co. Ltd.

ABSTRACT: A new wind generator for Antarctica was designed taking the past troubles into consideration. Main improvements are as follows.

1. fixed pitch and fixed yawing control
2. permanent magnet exciter for AC generator
3. mono-pole type tower for minimize snow drift in the leeward

The output power will be about 1 kW at 20 m/s of wind speed. The generator is planed to be installed and operated at Asuka Station(71° 31.5'S, 24° 08.3'E) in 1991.

1. INTRODUCTION

Many wind generators have been used and tested by the Japanese Antarctic Research Expedition(JARE), in order to supply power for unmanned observartories and for domestic power source at inland station. But many troubles have been found in rotors, generators and towers and storage battery system (Ishizawa K., 1988). A reliable system have been required for a long time but it was not completed yet. In order to complete the system, a new wind generator system have been designed.The wind generator is erected on the snow surface at Asuka Station and it is tested from January in 1991 to January in 1992.

2. Necessity of wind generator

2.1 Power source for unmanned observatories

Many unmanned obvservatories are required to install in Antarctica to obtain data related to meteorology, upper atmospheric physics and glaciology. In order to carry out the measurements at an unmanned observatory, two big problems have to be settled. First, measuring instruments such as sensor and data logger must stand up t⌃ low temperature and they need to have low consumption of power. Second, a compact power source which takes out certain output even in the severe cold circumstances is essential. As for instrument, some data loggers stand up to about -35°C with low power consumption are beginning to appear recently. The lithium battery is very successful for the data logger in cold temperature down to about -35°C.

The unmanned observatories with the wind generators JARE operated since 1977 are shown in Fig.1. The solid lines are annual mean air temperature represented by 10-m deep snow temperature. Unmanned observation area becomes to spread into colder region in which the annual mean air temperature is below -35°C. In such a place the instrument does not operate without any heater. The rechargeable lead battery is an easiest power for heating the instrument because of its big capacity of power and reasonable price . But the discharge of the battery is extremely inefficient in the cold air temperature below -30°C as shown in Fig. 2. The relative capacity of the battery at -30°C is 30 % of that at 30 °C. The charging efficiency is also bad in cold condition. Therefore it is essential to product a power at the unmanned observatory located at cold region in which the annual mean air temperature is lower than about -35°C.

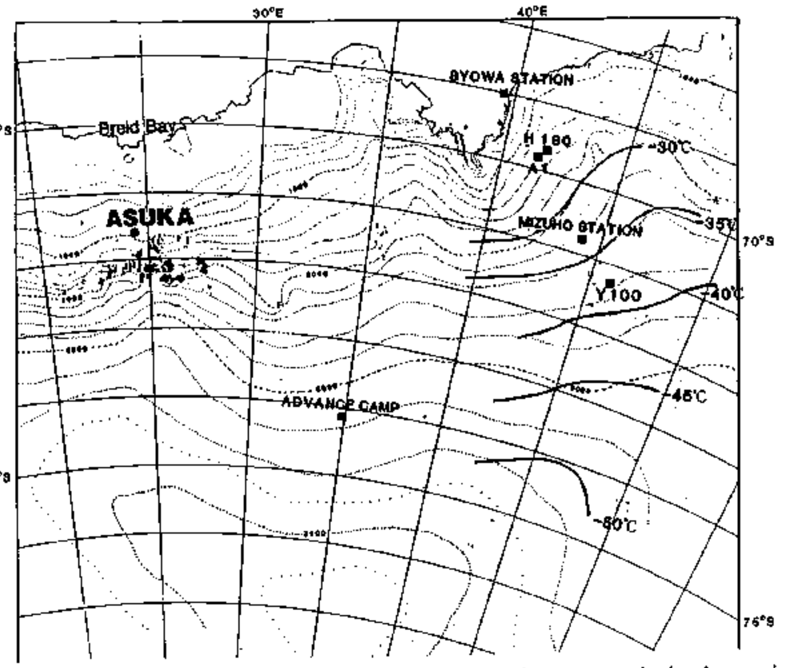


Figure 1. Location of unmanned observatories operated by wind generators(black squares) and the annual mean air temperature represented by 10-m deep snow temperature.

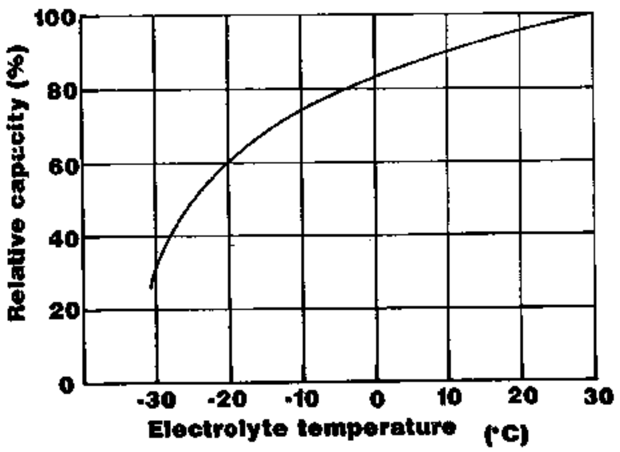


Figure 2. Relative capacity of lead battery on discharging depends on electrolyte temperature. The value is plotted supposing that the capacity of 30°C is 100 %.

It is expected to utilize solar and wind energies to supply a power to the observatory. Fig.3 shows the expected power of solar cells with module area of 1 and 2 m^2 at Mizuho Station The data were calculated by measurement of solar radiation . The solar cell is not useful in the period between April and August. In this period the lead battery is not also available because the air temperature is lower than -30°C. Wind energy is a constant power over the year even in austral winter(see Fig.4) therefore wind energy is expected to be a promising power for an unmanned observatory.

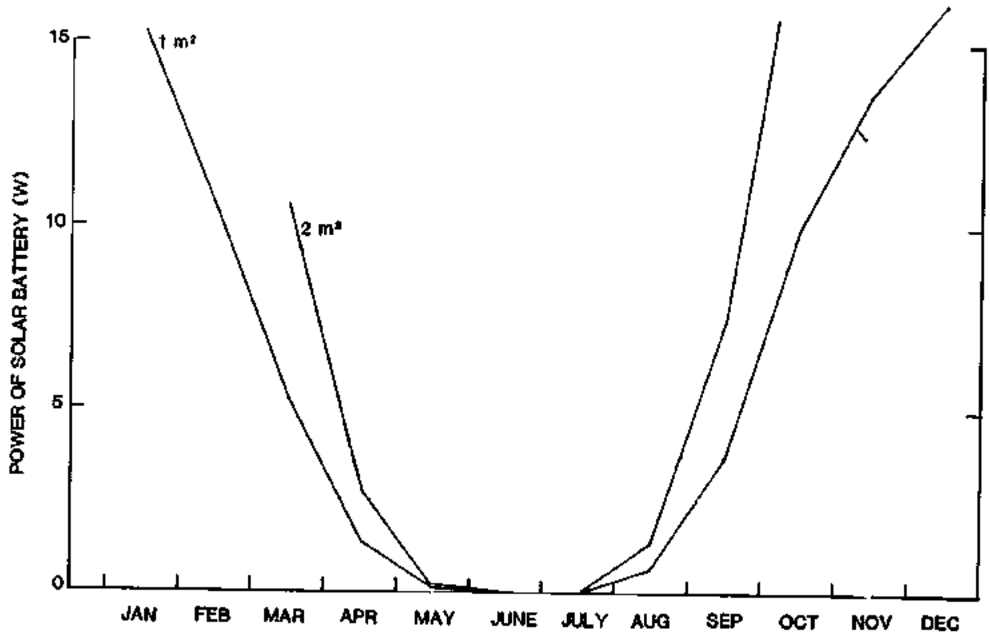


Figure 3. Power of solar cell with module area of 1 and 2 m^2 at Mizuho Station.

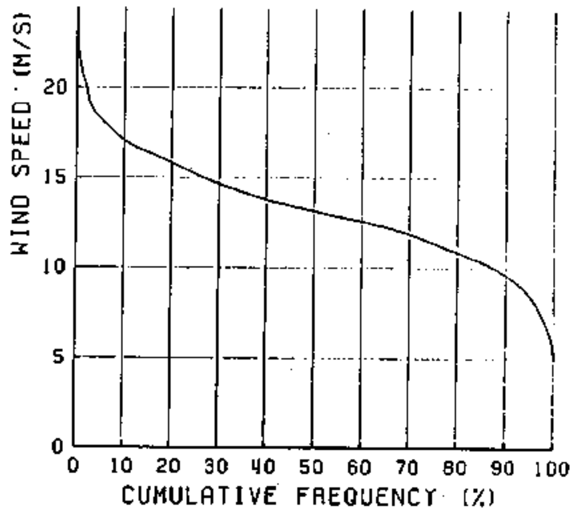


Figure 4. Cumulative frequency of wind velocity in May at Mizuho Station.

2.2 Power source at inland station

Large amount of fuel is required to generate electric power at an inland station, so the transportation of fuel is the biggest problem to maintain an inland station. Most of electric power is used to heaters to keep the facilities at moderate temperature. The use of a wind generator will reduce amount of fuel to be transported to the station over a long distance.

For example, at Asuka Station, The fuel consumption of the diesel engine used for electric generator(30 kVA) is 0.2379 g /Wh. If a wind generator of 5kW is operated at a inland station 500 km away from a supply ship or a main station, amount of fuel of 10.42 tons for electric generation and 1.3 tons for transportation of the fuel by a oversnow vehicle (SM50, Ohara Iron Company) per a year.

3. Problems of wind generators in Antarctica

Table 1 shows the wind generators operated by JARE in the Antarctic. Most of the generators were used for power source of ummanned observartories erected on the ice sheet. But most generators were damaged due to many kinds of troubles such as vibration of blade, freeze of grease, miscotrol of charging batteries system and so on. A lot of troubles result from mechanical defects and vibration of blades was most serious cause for the generators as shown in Table 2.

Table 1 Wind generators operated by the Japanese Anterctic Research Expedition

JARE	1	12A	12B	14	18A	18B	19A	19B	20, 21, 22	21	23	24	25	26
type				NU-101	WY-15G	WINCHERGER	WY-15G	NU-102	WINCHERGER	WINCHERGER	NIPR NO. 1	NIPR NO. 2	0-20-TM- 12V-900R	0-200-TM1- 24V
manufacturer	Honda	Yamada windmill	Yamada windmill	Nihon Univ.	Electro GmbH	Dyna Technology	Electro GmbH	Nihon Univ.	Dyna Technology	Dyna Technology	NIPR	NIPR	Yuasa	Yuasa
tower	5.5m steel pipe	mono-pole (mast)	mono-pole (mast)		4m steel truss	3m steel trus	4m steel trus	steel trus	3m steel trus	3m steel trus	3.5m steel trus	5m steel trus		3m steel trus
windmill	propeller dia. 4.4m 3 pieces	propeller dia. 1.8m 2 pieces wood	propeller dia. 2.75m 3 pieces wood	turbine dia. 1.2m	propeller dia. 3m 2 pieces wood	propeller dia. 1.8m 2 pieces wood	propeller dia. 3m 2 pieces wood	turbine dia. 1.2m	propeller dia. 1.8m 2 pieces wood	propeller dia. 1.8m 2 pieces wood	propeller dia. 2.8m 2 pieces FRP	propeller dia. 2.8m 2 pieces FRP	propeller dia. 1.0m 2 pieces wood	propeller dia. 2.1m 2 pieces steel
yawing contro.	down wind	fixed	upwind	down wind	upwind	upwind	upwind	down wind	upwind	upwind	fixed	down wind	upwind	upwind
prevention of overrevolution	pitch controll	upward deviation	pitch controll	load controll	pitch (11-33m/s, side deviat.	air brake (270-900 rpm)	pitch (11-33m/s) side devi.	brake	air brake (270-900 rpm)	air brake (270-900 rpm)	non	electro-magnetic brake	non	air brake
blade revolu. (rpm)	168	400	220	190 17m/s	220	900	220	303 20m/s	900	900	900 10m/s	900 10m/s	900	900
transmitter	12.6 times			6 times	direct	direct	direct	6 times			direct	direct	direct	direct
generator	DC24V 40A	brush DC	brush DC	1-phase AC 100V	parmanent magnet AC	4 poles self excited DC	parmanent magnet AC	sepalately excited AC	4 poles self excited DC	4 poles self excited DC	sepalately excited brushless AC	sepalately excited brushless AC	DC	DC
actual output (kW)		0.1 7m/s	0.1 7m/s	0.3 15m/s				2.38 26-30m/s					0.007 10m/s	
rated power(kW)	1.0	0.1	0.3		1.2	0.2	1.2		0.2	0.2	1.0	1.0	0.02	0.2
rated speed(m/s)				17	10	10.3	10				10	10		
operating period	0 (This system sunk in the sea)	1971.5.30-6.26 1971.9.28-1972.1.18	1971.8.1-10.15		1977.1.18-2.20 1977.5.30-8.23?	1977.5.28-5.29	1978.1.25-2.5? 1978.9.5-1980.1.23?		1979.10.17-10.27? 1980.1.15-2.? 1981.9.30-11.9?	1980.11.4-1981.1.10?	1982.6.7-7.17 1982.7.17-10.3	1983.4.17-4.25	1984.11.25 1985.5.5?	1985.2-27 5?
place of installation		Mizuho	Syowa	Syowa	A1	A1	A1	Syowa	Y100	H180	Mizuho	Mizuho	advance C.	advance C.
aim	emergency	experiment	experiment	experiment	unmanned observat.	unmanned observat.	unmanned observat.	experiment	unmanned observat.	unmanned observat.	experiment	experiment	unmanned observat.	unmanned observat.
trouble		12m/s, 22m/s vibration noise by brash	refreezing of snow in generator	snow penetration on to the timming belt	explosion of hydrogen gas by overcharging breaking of wire under low temp. Bolts were dropped out by vibration	Mast fell down by strong wind.	overrotation system was operated but not returned.	Overdischarging by	slip ring was destroyed. destruction of blade breaking wire under low temp.	slip ring was destroyed.	destruction of blade by viblat. wear of blade by browing snow. Stiffness of grease	destruction of blade by overro. ele.-mag. brake was burned by overwork. viblation of blade	destruction of blade by overro.	Bolts were dropped out by vibration destruction of tail vane. Stiffness of grease

TABLE-2 Causes of wind generators' troubles

trouble point	vibration of blades	structural defect
tower	1	
blade	5	
tail vane	2	1
transmitter		
brake		1
electric wire	2	
slipring		3
charging control for battery		3
total	10	8

4. Wind condition of Asuka Station

In view of the past failure, a new system of wind generator was designed in order to built up a reliable system. It was planed to erect on the ice sheet at Asuka Station(71° 31'S,24° 08'E, 930m a.s.l.) which is about 170 km apart from the Breid Bay in Princess Ragnhild Coast(see Fig.1). Annual mean air temperature of the Station is -18.0°C and annual mean wind speed is 12.6 m/s .

The mean , the maximum mean and instantaneous maximum wind velocities observed in 1988 are shown in Figure 5. Fig.6 shows a wind velocity appearance frequency. The wind velocity frequency has two distinct peaks near 8 and 16 m/s. Wind energy appearance frequency is also drawn in the Figure. The frequency gives the peak value of wind energy at which energy could be most extracted from the wind. The frequency is calculated by multiplying the power of a wind velocity by the wind velocity appearance frequency. The wind direction appearance frequency is shown in

Figure 7 .   The figure has a sharp peak at SES direction, and the appearance coverages in narrow region of +/- 30 degrees centered at the direction with the highest frequency. That is a typical phenomenon in the Katabatic wind area. Yaw control system is not necessary because the wind have the prevailing direction.

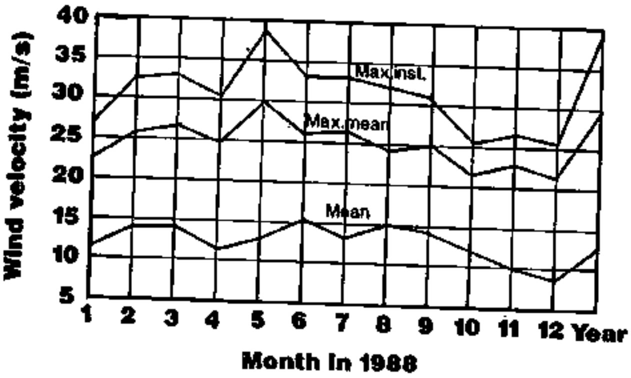


Figure 5. Monthly change of wind speed at Asuka Station in 1988.

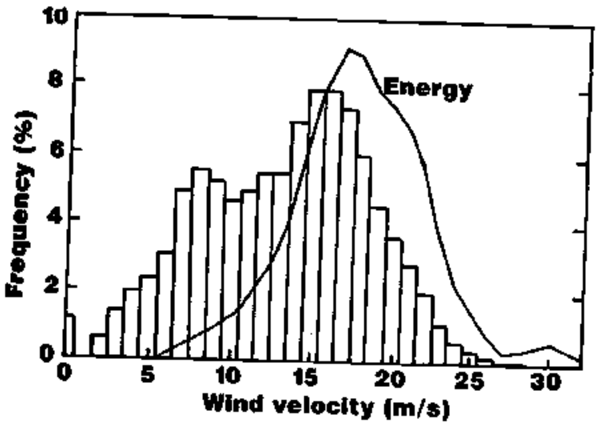


Figure 6. Wind speed appearance frequency and the energy frequency at Asuka Station.

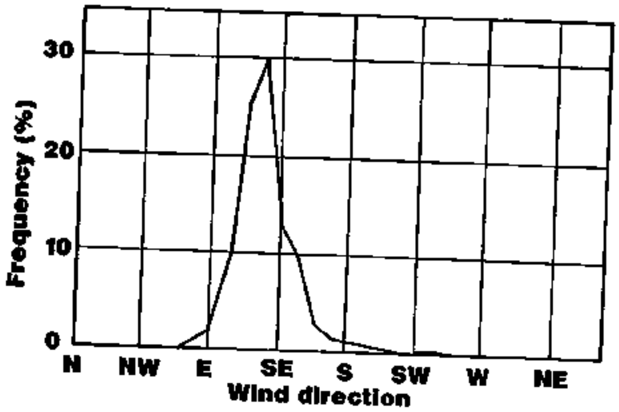


Figure 7. Wind direction appearance frequency at Asuka Staion.

5. Basic concept of the system design

5.1 Use

The power is used as a heater which does not give serious damage to the heated object even if any trouble happens in the generator system.

5.2 Power output

The peak of the energy appearance frequency was obtained at 17 m/s of wind velocity, so the rated power output was set 1kw near the wind velocity. The relation between power output and rotor revolution is shown in Fig.8. The generator was newly designed to prevent the high power output at the strong wind because the rotor was not controlled by pitch control.

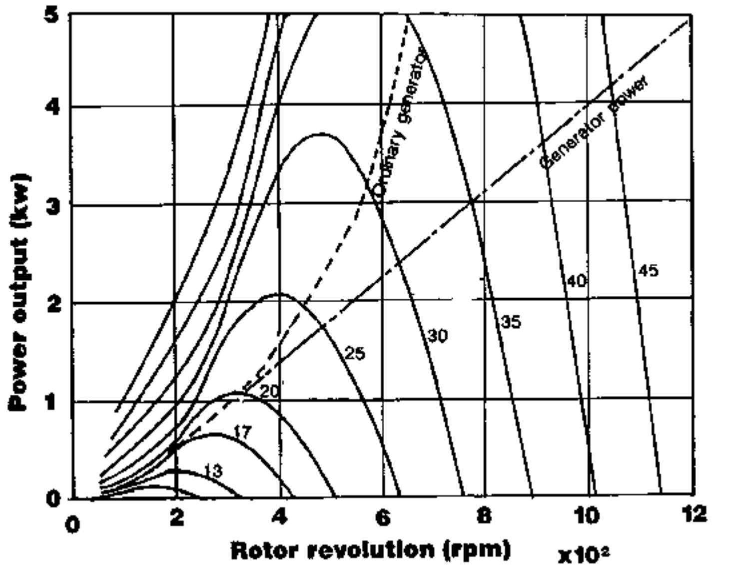


Figure 8. Relation between power output of wind and rotor revolution. Power by an ordinary generator is plotted with dashed line and power by the newly designed one are drawn with doted line.

5.3 Control of rotor's rotation

In order to minimize the number of movable components, pitch control was not adopted. The rotor revolution is roughly controlled by changing the amount of load.

5.4 Yaw control

Fixed yawing control system was introduced because the wind has a prevailing direction at Asuka Station. That was also adopted for making the system simple. The rotor is faced to the windward using a yawing gear with handle as shown in Fig.9.

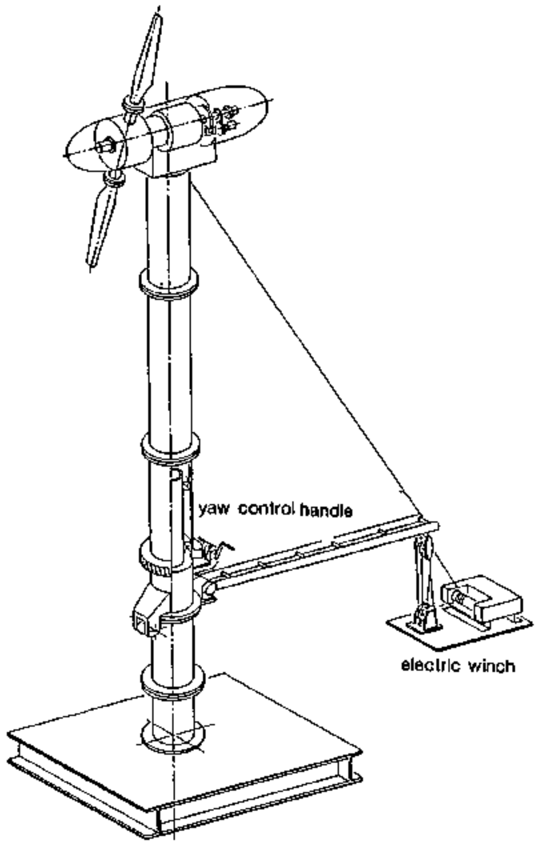


Figure 9. Schematic view of blade, nacelle and tower.

5.5 Tower

The mono-pole type was planned to minimize the snow drift in the leeward, and the tower is easily able to rise up and fell down by electric winch when the maintenance is necessary. The schematic view is shown in Fig. 9.

5.6 Generator

The output power is easily controlled by changing the exciting current, but JARE experienced the trouble of exciting current in the past experiment. The battery was overdischarged due to supplying exciting current when wind was not enough to generate power. A generator with permanent magnet exciter was adopted to prevent such an accident. The output rises in proportion to the rotor's revolution. The output voltage is regulated by changing nput taps of transformers depending on the output of the enerator.

.7 Load

Rechargeable lead acid batteries are set between output of the enerator and load in order to supply power to the load ontinuously even when the wind is weak(see Fig.10). The battery tops supplying power when the battery voltage decreases to the imit. Another load is installed to absorve the power which emains when the strong wind blows.

The conceptual specifications of the system are summarized in ABLE 3.

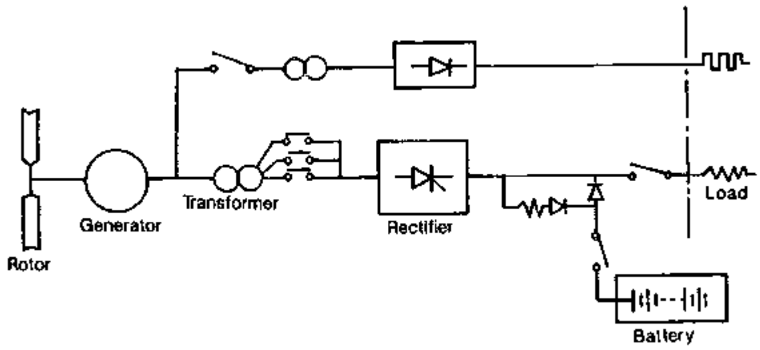


Figure 10. Schematic diagram of the wind energy system.

TABLE 3 Conceptual specification of wind generator system

component	item	specification
system	rated power	1kW
	rated wind speed	20m/s
	rated revolution	300rpm
	cut-in wind speed	10m/s
	cut-out wind speed	nil
	yaw control	fixed(adjustable by hand)
rotor	up/down wind	up-wind
	diameter	2m
	maximum revolution	1000 rpm at 40 m/s of wind speed
	number of blades	2
	pitch control	fixed(adjustable by hand)
blade	material	FRP
	wing section	NACA44 series
generator	type	3-phase AC generator with permanent magnet exciter
	rated output /revolution	1 kw/350 rpm
	rated voltage	AC
transmitter		direct
nacelle	material	aluminum
tower	type	mono-pole
foundation	type	buried in the snow
load	type	lead acid battery and heater

REFERENCES

ISHIZAWA Kenji (1988): The significance and the problems of wind generator development in Antarctica experimented by the Japanese Antarctic Research Expedition., Antarctic Record, Vol.32,No.2, pp.140-162

Potential For Renewable Energy Sources in the Antarctic

by

Sheinstein, A.S.[1)]
Shpilrain, E.E. [2)]

Abstract

Potential for the use of solar and wind energy systems in the Antarctic was analyzed. Based on a specially designed procedure annual solar radiation intake on inclined solar collectors was obtained and their optimal orientation was defined. Advantage of the use of solar heating systems was shown. Economical performances of solar and wind power systems were given. Potential for low temperature sources was discussed.

Introduction

At present there are no indigenous energy sources in the Antarctic. The polar stations use costly diesel fuel, which is transported by ships, aircrafts and vehicles to these stations. A ton of diesel franco station fuel costs $50 - 2500 (1). Fuel transportation difficulties cause social and economic problems even today when fuel consumption is relatively small. Furthermore diesel generators cause pollution on the fragile Antarctic environment. Energy problems will be more complex in the future with increasing fuel consumption.

It is obvious that alternative energy options are needed for the polar stations. From our point of view alternatives to diesel generators could be:

- energy-efficient buildings
- renewable energy sources
- Stirling engines.

This paper discusses the potential for renewable energy sources in the Antarctic.

It seems to be paradox, but in Antarctica potential for renewable energy sources is better than at the equatorial regions.

In terms of solar radiation intake the inland Antarctic regions surpass southern regions of the northern hemisphere. For example, the annual Hp sums are 1.6 times larger at 78°S (i.e. Vostok station) than at 41°N (i.e. Tashkent), Fig. 1. The Antarctic Continent is situated at about 2000 m above sea level altitude, where the air mass (3) is smaller than at the sea level. The clean polar air with low moisture content absorbs less of the sun's energy than at the lower latitudes. The monthly average clearness index (3) is 0.8 - 0.85 there (4). At

1) Institute for High Temperatures USSR Academy of Sciences
2) Institute for High Temperatures USSR Academy of Sciences

the inland regions potential for solar energy is the most favourable, because of the long Australian summers and insignificant cloudiness. The value of n/N ranges from 70 t0 97 % there (4). At the coastal regions solar radiation intake is obscured by clouds. For these regions n/N does not exceed 52 % (4). However, potential for solar energy is quite favourable there as wekk. Exception is the Antarctic Peninsula, where n/N is only 10-20 % (4).

To evaluate potential for solar energy, it is needed to have solar radiation on inclined surface data. For this purpose special design procedure was developed (5). The results of calculation are shown in Fig. 2. At the inland regions the annual solar radiation intake on the optimal oriented collector reaches 8.0 GJ/m^2. At the coastal ones it is more than 4.0 GJ/m^2. At the snow-covered areas solar collectors that face towards the equator should be oriented vertically. At the South Pole vicinity the vertically oriented collectors will receive only 30 % less radiation intake than two-axis tracking collectors continuously oriented to face the sun (table 1). At the coastal regions with snow surface vertical and tracking collectors will receive annually approximately the same solar radiation intake. For Antarctic´s "oasises" (2) the optimal slope of collector is 45°, Fig. 2. Ht variation does not exceed 5 % in the range of ±20°. At the rock-covered "oasises" the amount of reflected solar radiation on inclined collectors is smaller than in snow-covered areas.

It is necessary to point out some pecularities of solar radiation intake in Antarctica. Solar radiation is characterized by extreme seasonal changes and can be only used there during the six months' summer season. At the inland regions there is continuous sunlight for a few months. Through the Australian summer the sun travels parallel to the horizon, completing one circle each day. During this period average monthly sums of Hp are 2.0 - 2.5 times higher at the inland regions than at the southern regions of the northern hemisphere, Fig. 5. The highly reflected surface (estimates of albedo of the surfaces is 0.8 - 0.85 (4) and can add 30 - 40 % to the energy available on inclined solar collectors (1), (5). Approximately half of the total reflected energy is forwarded scattered to the collectors (1). It is noteworthy that "energy" potential of solar radiation is high in Antarctica. Total solar radiation on the horizontal surface consists of 50 - 70 % beam radiation (4). The solar radiation intensity is 500 - 1000 W/m^2 even by small sun elevation (4). Irradiance on inclined surface can reach 1200 W/m^2 (5). Some additional factors should also to be pointed out. In summer at the polar stations the amount of personnel and energy requirements are higher than in winter (1), (6). There is a strong tendency of an increase in the number of summer seasonal polar stations (6). It is known (3) that energy consumption for space heating is directly proportional to heating degree/days in a region. Our calculation shows that in Antarctica daily heating degree/days is always a positive value. Even during summer months (six months) total heating degree/days reaches 10.000. The annual value varies from 6000 at the Antarctic Peninsula to 25000 at the South Pole vicinity, Fig. 4. Thus there is a favourable potential for the use of solar heating systems especially at the inland regions.

In the Antarctic the use of solar energy has economical advantages even today when the cost of solar power systems is high. At the South Pole even the most costly PV systems ($ 4 - 8 per WP (1)) could provide about 30 % of annual energy requirements of the polar station at less than $ 0.16 per KWH (1). This is 5 times less than a diesel generator. Solar heating systems could provide about 80 % of summer seasonal requirements (1).

In Antarctica solar energy could be used for space heating, snow melting, water heating, electricity production, buildings technology, greenhouses. It is obvious that use of solar energy problem in Antarctica requires further investigation and design.

Potential for Wind Energy

There is also a favourable potential for wind energy in the Antarctic.
At the majority of the Antarctic regions value of V is more than 5 m/s (4). At the coastal regions V is 7-11 m/s, Fig. 5. At the inland regions there is a stable wind speed distribution which ranges from 1 to 8 m/s (4). This wind speed occurres more than 300 days per year (4). According to simulation results (1) annually average utilization of various (1-500 KW) wind machines vary from 3.3 to 28.6 % at the South Pole. However use of wind machines has an economical advantage there today because of high fuel cost. One KWH of electricity produced by wind machine will cost 3 - 4 times less compared to diesel generator production (1). There are more favourable potentials for wind energy at the coastal regions, where V is higher than at the inland ones. However, stormy wind can damage wind turbines there. Specially designed wind machines are needed for use in harsh climate.

Potential for Low-Temperature Energy Sources Utilization

In the coastal regions there are some low-temperature energy sources which are interesting regarding the energy problem. These sources are located in "oasises" and shelf ices (2) for prospective future exploration and exploitation .
One of such sources is the South ocean. Inspite of low water temperatures (-1°C, - 2°C) (2), there is a potential for the use of the ocean heat . It could be realized in a thermodinamic cycle based on existing temperature difference (between ocean water and ambient air). The air temperature is -10, - 20°C (4). In Antarctica OTEC installations could be based on a closed cycle scheme using an air condenser (8), Fig. 6. OTEC efficiency could be enhanced by the use of solar energy and wind and diesel exhaust heat systems.

It is well known (2), (9), that in "oasises" there are many various lakes, Fig. 7. which also are low-temperature sources of heat. Temperatures of these lakes range from +0.5 to +25°C (9). It must be noted that the future use of Antarctic lakes as an energy source will need ecological expertise, yet it is worthwhile, however, to discuss the potential for their application.

There are many fresh water lakes with an average temperature of +4°C (9). These are permanent ice covered lakes with large surface areas (a few square kilometers) and depths ranging from 50 to 100 m (2). Another type of large lakes that has relatively high thermal capacity is the saline lakes with stratified water structure. Their water temperature reaches 8°C, 25°C (10), Fig. 10. Besides there are shallow lakes and ponds with temperatures of +15°C, saline lakes with +0.5°C and hypersaline lakes with 13 times more salt than sea water (10).

It can be interesting to analyse the lakes for use of heat supply for large polar stations, especially in winter when energy heating requirements increase compared with the summer season. There is a potential for the use of the lakes'heat by heat pumps, Fig. 8. It can be also interesting to use the lakes as a heat store. Solar heating system with a lake as interseasonal heat store is shown in Fig. 9. Another well-known heat storing option is a "solar pond" (11). In Antarctica there are some natural "solar ponds", such as lake Vanda, Fryxell, Bonney (9). Stratified salt water structure, permanent ice cover allow to store heat at relatively high (positive) temperatures even at low air temperature and wind conditions. Some simulating study of artificial "solar ponds" performances in cold climate shows potential of their use at high latitudes (12), (13). In the "oasises" there is also a potential for "solar ponds" constructing. Rock catchments, sea water, hypersaline lakes could also be used for this purpose.

Conclusion

Thus Antarctica is one of the most attractive regions for the use of renewable energy sources. Solar radiation and wind energy intake are quite substantial there. At the same time the cost of diesel fuel as well as transportation and ecological problems cause alternative energy options for the use of polar stations.The most favourable potential for solar energy is to be found at the inland regions, where the annual amount of beam radiation are larger than at the southern regions of the northern hemisphere. The cost of the fuel reaches $2.500 per ton there. The annual heating degree/days reaches 25000.For these regions vertical oriented collectors (it is the optimal fixed collectors orientation) will receive annually about 8 GJ/m^2 solar radiation intake. The highly reflecting snow can add 30-40% to the energy available on inclined collectors. Solar space and water heating, snow melting, PV, solar energy conversion (based on Bryton, Stirling cycles) power systems are prospective there. At the South Pole PV power systems could allow to save

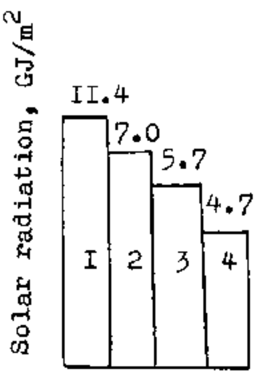
30-40 % of the fuel. 1 KWH of electricity, produced by PV systems there could cost 5 times less as compared with diesel generators production. Wind energy use is also of economical advantage there. Solar wind-solar power systems are prospective for using in Antarctica. At the coastal regions there is potential for solar and wind energy too. The optimally oriented fixed collectors will receive there about 4-6 GJ/m^2 solar radiation intake annually. Passive solar heating, snow melting, water heating, solar-wind power systems are favourable there. In the coastal regions and "oasises" there is potential for low-temperature heat sources using.

Nomenclature

HP	solar radiation intake on two-axis tracking collector continuously oriented to face the sun, GJ/m^2
N	maximum possible hours of bright sunshine per year, h
n	average value of bright sunshine hours per year, h
PV	photovoltaic
V	wind speed, m/s
OTEC	ocean thermal conversion
Ht	solar radiation intake on inclined collector, GJ/m^2

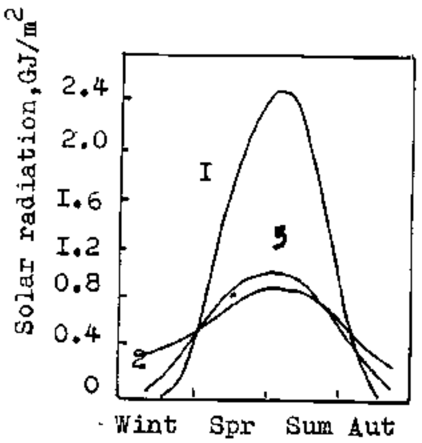
References

1. Wills, R.H. (1988) Using Solar Energy at the South Pole. Report of Skyline Engineering/Fairlee/USA
2. Korotkevich, E.S. (ed.) (1966). Atlas of the Antarctic Region. Gidrometeoizdat/Leningrad/(Russian)
3. Duffie, J.A. & Beckman, W.A. (1980). Solar Engineering of Thermal Processes. A Willey-Interscience Publication/New York.
4. Dolgin, I.M. (ed.) (1977). The Climatic Observation Data for the Antarctic Continent. Gidrometeoizdat / Leningrad
5. Shpilrain, E.E., Sheinstein A.S. (1988). Potential for Solar Energy in the Antarctic. Proc. of "North Sun'88 Int. Conf./Borlange/Sweden.
6. Slevich, S.B. (1985). Antarctica in the Modern World/Muysl Publication/Moscow/(Russian).
7. Wills, R.H. (1988). Generating electricity from wind at the South Pole. Report of Skyline Engineering/Fairlee/USA.
8. Wershinskiy, N.V. (1986). The Ocean Energy. Nauka/Moscow
9. Heywood, R.B. (1972). Antarctic Limnolgy: A Review. Br. Antarctic Surv.Bull.29: 1972, p.55-65
10. Pridlle, J. Heywood R.B. (1980). Evolution of Antarctic Lake Ecosystems. Biological Journal of the Linnean Society. 14: 1980, p. 51-66.
11. Abdel-Salam, H.E. Probert, S.D. (1986). Solar Ponds: Design and Prospects. Applied Energy. 24:1986, p. 91-126.
12. Lund, P.D. Routti, J.T. (1984). Feasability of Solar Pond heating for Northern Cold Climates. Solar Energy. 33.1984, p. 209-215.
13. Rabl, A. Nielsen, C.E. (1975). Solar Ponds for Space Heating. Solar Energy. 17:1975, p.1-12.



I – Vostok station, 78°S
2 – Tashkent, 41° N
3 – Novolazarevskaya station, 71°S
4 – Molodyozhnaya station, 67°S

Fig.I. Annual sums of Hp in the Antarctic.



I – Vostok station, 78°S
2 – Tashkent, 41°N
3 – Novolazarevskaya ststion 71°S

Fig.3. Monthly sums of Hp in the Antarctic

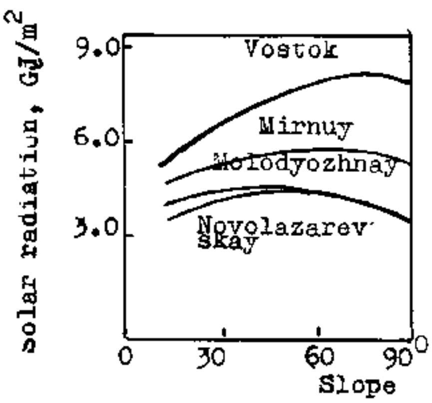


Fig.2. Calculating data of annual solar radiation intake on inclined collectors in the Antarctic

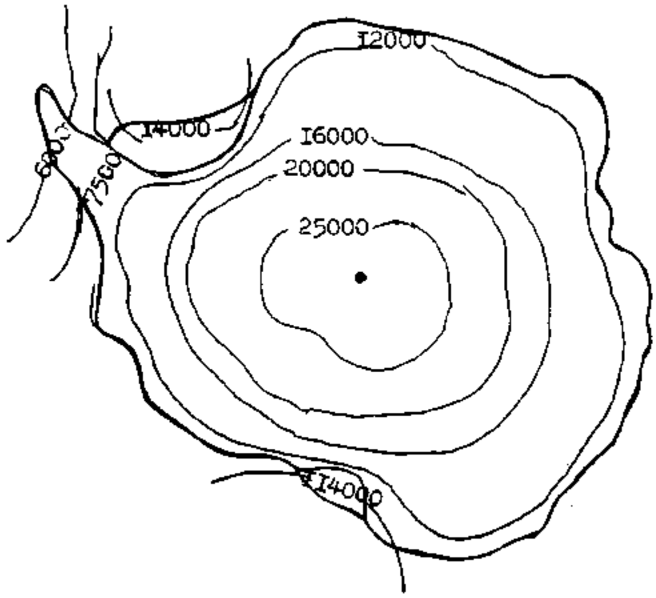


Fig.4. Map of annual heating degree-days distribution in the Antarctic

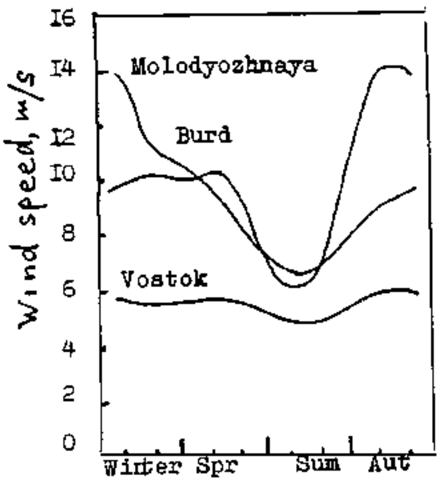


Fig.5. Annual wind speed distribution in the Antarctic

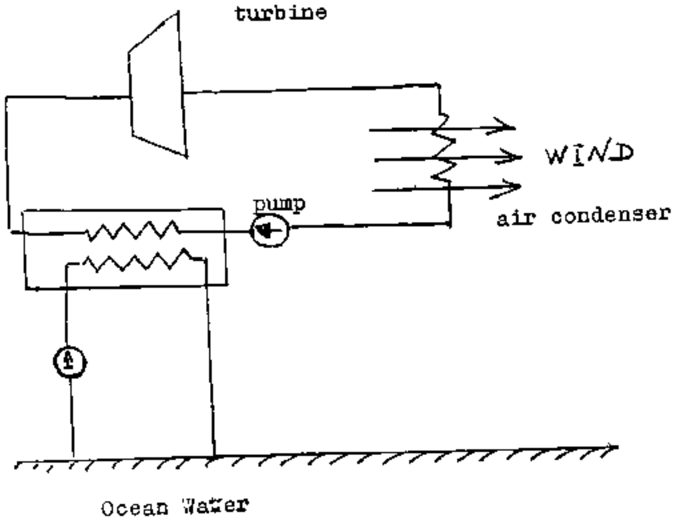


Fig.6 .OTEC closed cycle installation scheme

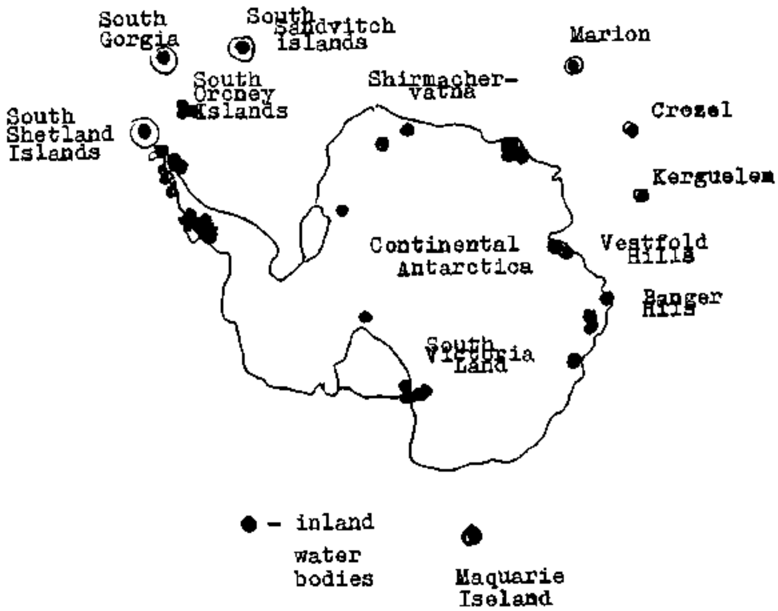


Fig.7 Map of Antarctica showing the locations of water - bodies(IO)

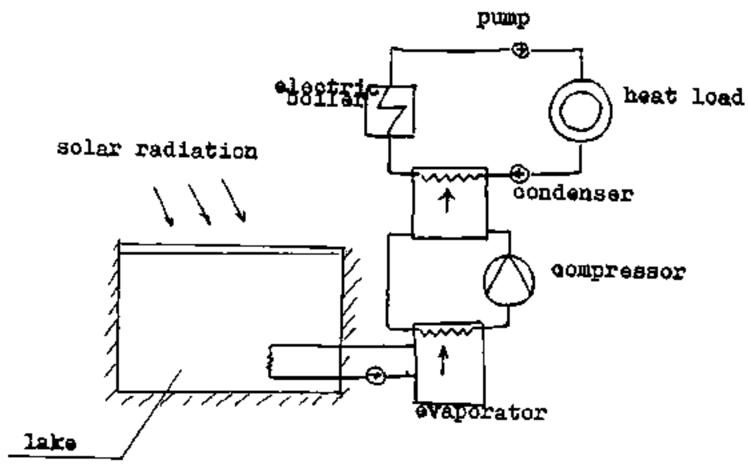


Fig. 8 Principle of lake heat utilization

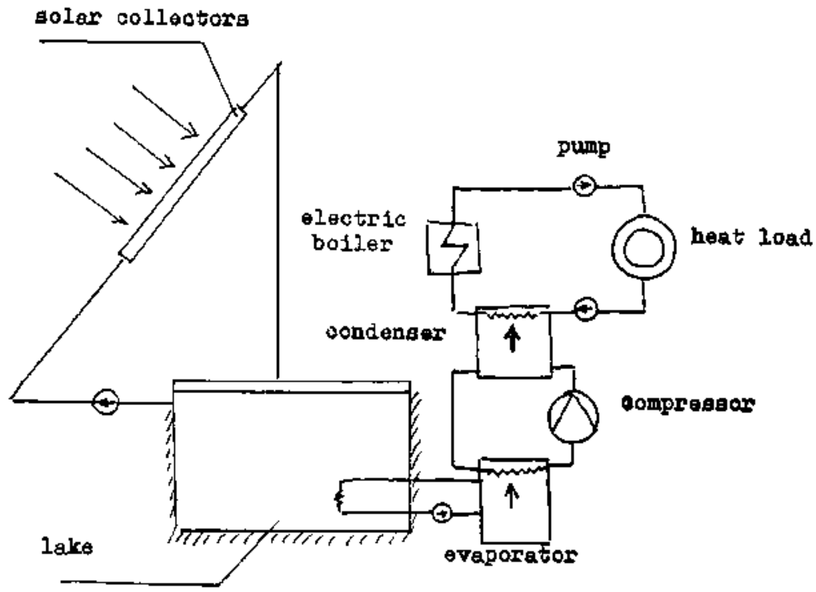


Fig. 9 Principle of lake using for
solar energy storing

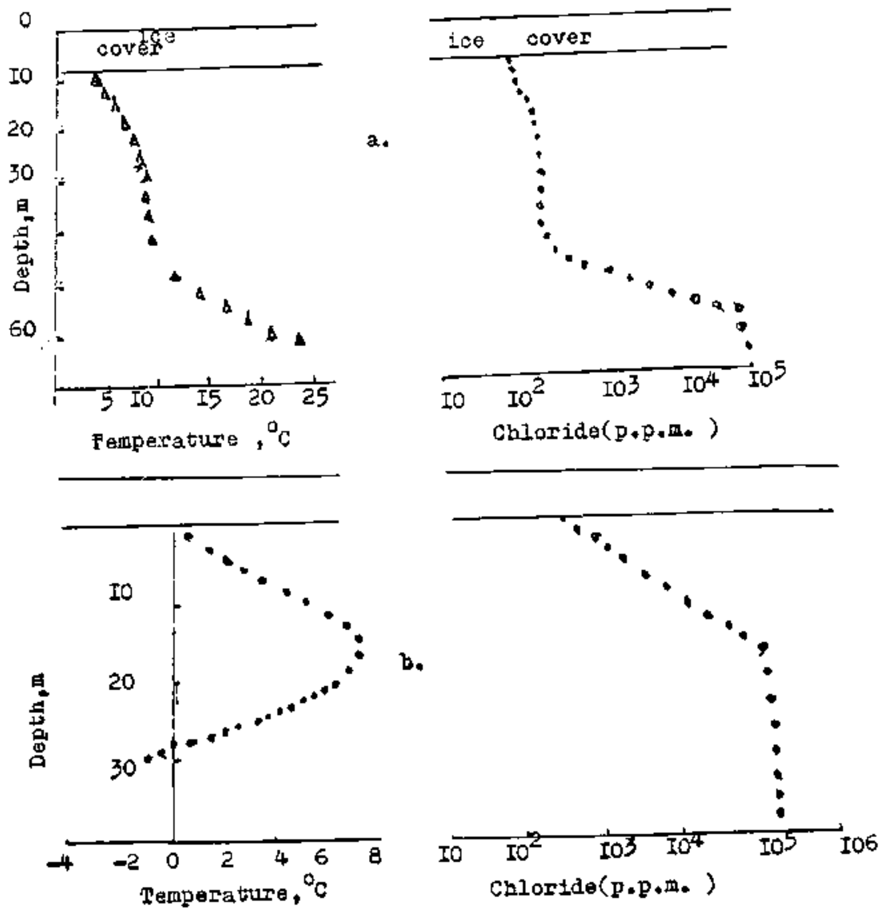


Fig.IO . Temperature & chloride concentration profiles for: a. Lake Vanda; b. – Lake Bonney (IO).

Polar station	Recieving surface orientation			
	Horizontal	Optimal	Vertical	Ray-perpendicular
Vostok, 78°S	4.6	8.0	7.8	II.4
Mirnuy, 66°S	4.4	5.6	5.I	5.0
Molodyozhnaya, 68°S	4.I	4.4	3.5	4.7
Novolazarevskaya, 7I°S	3.8	4.4	3.5	5.7

Table I. Annual solar radiation intake on differently oriented solar collectors in the antarctic, GJ/m²

Project and management criteria and scientific support to integrated communication system of Italian Antarctic Research Program

Blasi L.[1] , de Simone M.[2] , Testa M.[3]
Italian National Program of Antarctic Research
(Telecommunications working group)

Abstract

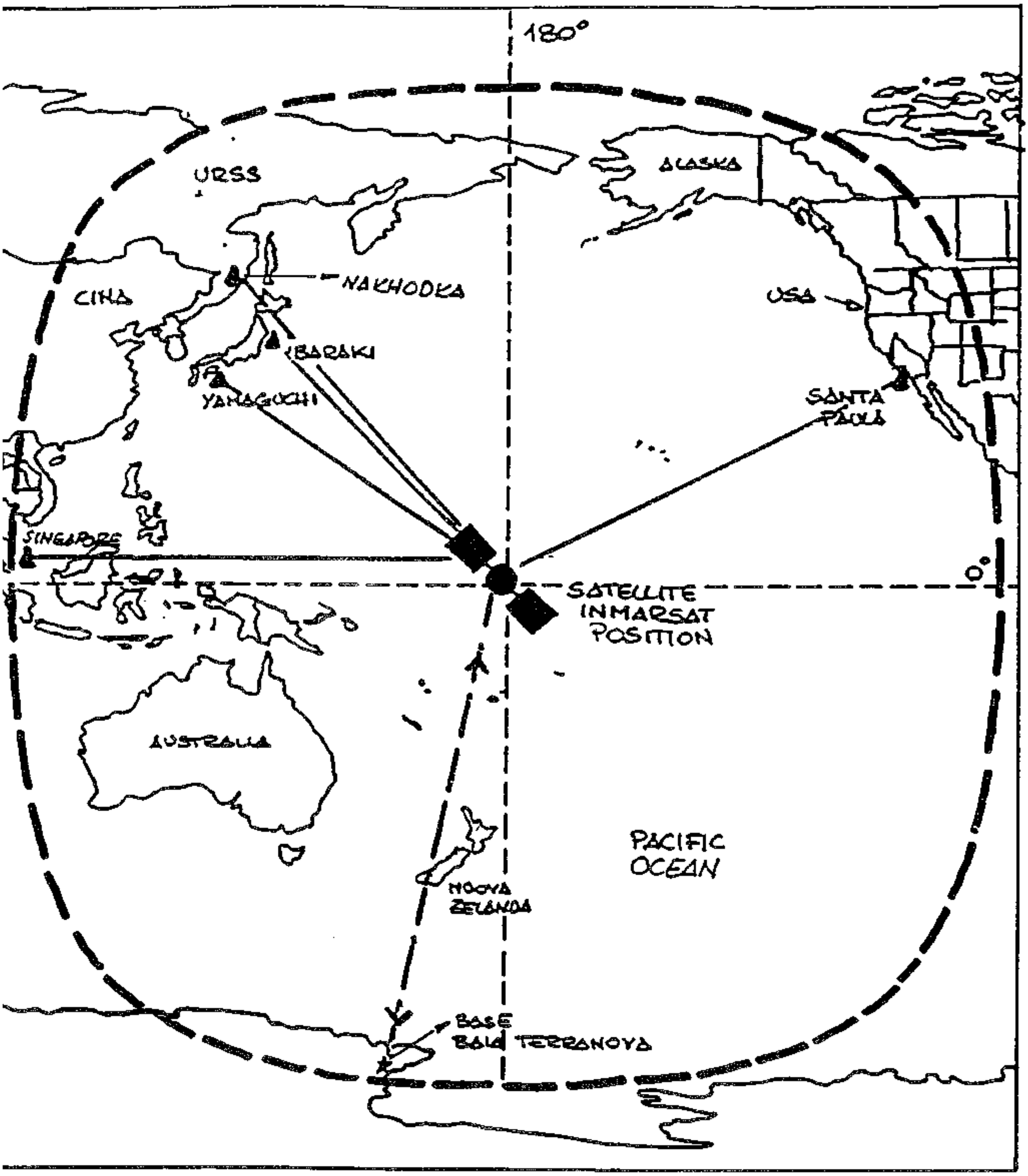
The project criteria of the integrated communication systems of the Italian Antarctic Research Program are presented.
These systems include different kinds of realization and installation so that transmission can be carried out on HF, VHF, UHF and Satellites bands.
There are also presented the integration problems of various systems and the realization made according to different needs due to very extreme enviromental and climatic operation conditions.
Particular care has been devoted to solve engeneering problems due to the installations of large dimension antennas.
It is also described the future development lines of telecommunication activity with particular attention to the digital transmission in HF and Satellite bands.
All the above in view of the building and management of the planned winter permanent Italian Base.
It is also described the research activity which support the communication systems in Italy and in Antarctica, with particular care to propagation prevision computing and the research about the physics of ionosphere.
This activity will enable us to reach the final goal that is the realization of a reliable telematic remote control system for the Italian Base in Antarctica.

Introduction

With law 184 of 1985 the Italian government decided to allocate funds to conduct a campaign of research and study in the Antarctic.
Various research bodies including ENEA and universities, grouped under the name of National Program of Antarctic Research (P.N.R.A.), was set up to conduct the scientific activities in Antarctica.

In this program ENEA provides the logistic support for all research and exploration activities, and thus, it is also responsible for the telecommunications system.

1) Progetto Antartide (ENEA)
2) Progetto Antartide (ENEA)
3) Progetto Antartide (ENEA)



★ BTN BASE POSITION

▲ GROUND STATION FOR SATELLITE TRAFFIC AND CONTROL FOR PACIFIC AREA

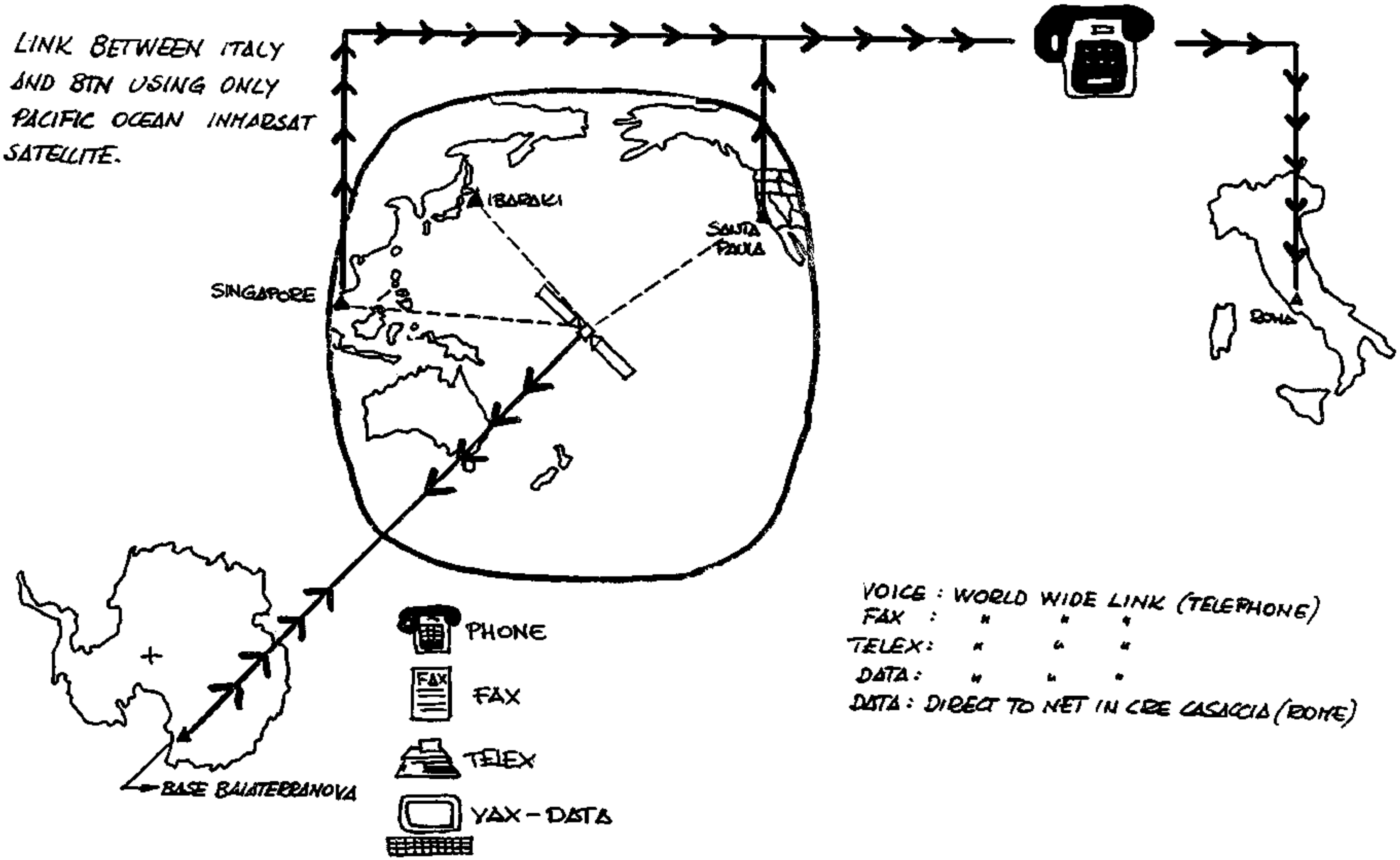
— — — PACIFIC OCEAN SATELLITE COVERAGE AREA.

The P.N.R.A. has provided to build a summer station on Terranova Bay. Exact co-ordinates are 74° 41' 42" Latitude South and 164° 07' 23" Longitude East.

ENEA had to start from scratch to design, install and run the support system for the initial exploration of the area and the building of the base.
All of this was done while trying to keep the equipment as modular as possible, not only to facilitate maintenance, but also to permit future expansions of the system.

ACCOMPLISHMENTS DURING THE I, II, III, IV CAMPAIGNS

The strategic importance of the telecommunications system was evident right at the beginning of the planning stage of the expedition. However, at that time we had only limited know-how about how to prepare such a system correctly so that it could satisfy the many needs that gradually became apparent to us. Furthermore, it was necessary to become familiar with the morphology of the terrain where we were going to work and also to think carefully about where the base was to be located. For these reasons we initially developed only very general outlines about the systems to be used and their siting in the area to ensure the widest possible coverage for the system.
The first problem to be tackled was that of establishing a continuous and reliable link to the other continents and to the other bases in the Antarctic and so we provided the mission with one satcom linked to the INMARSAT satellite network. The satellite terminal allowed us to become operational immediately by using a conventional telephone line even though the operating costs were very high.
Another immediate objective was to provide the mission with a communications system that would connect the base with the most remote operating areas, the ship and support aircraft. Like other countries before us, we decided to standardize the use of VHF Marine band. Thus, the problem became a question of carrying out an analysis of the team's needs and a careful study of the area's morphology in order to plan all the measures required to guarantee the system's maximum reliability.
To maximise the operational area, we also decided to install a semiduplex repeater on Mount Melbourne, which is located 50 kilometers from the base at a height of 2,720 meters. The repeater system that we installed could be coupled with lower frequency transponders to create a network of repeaters with a wider coverage. In this way, maximum operational back-up could be guaranteed to the

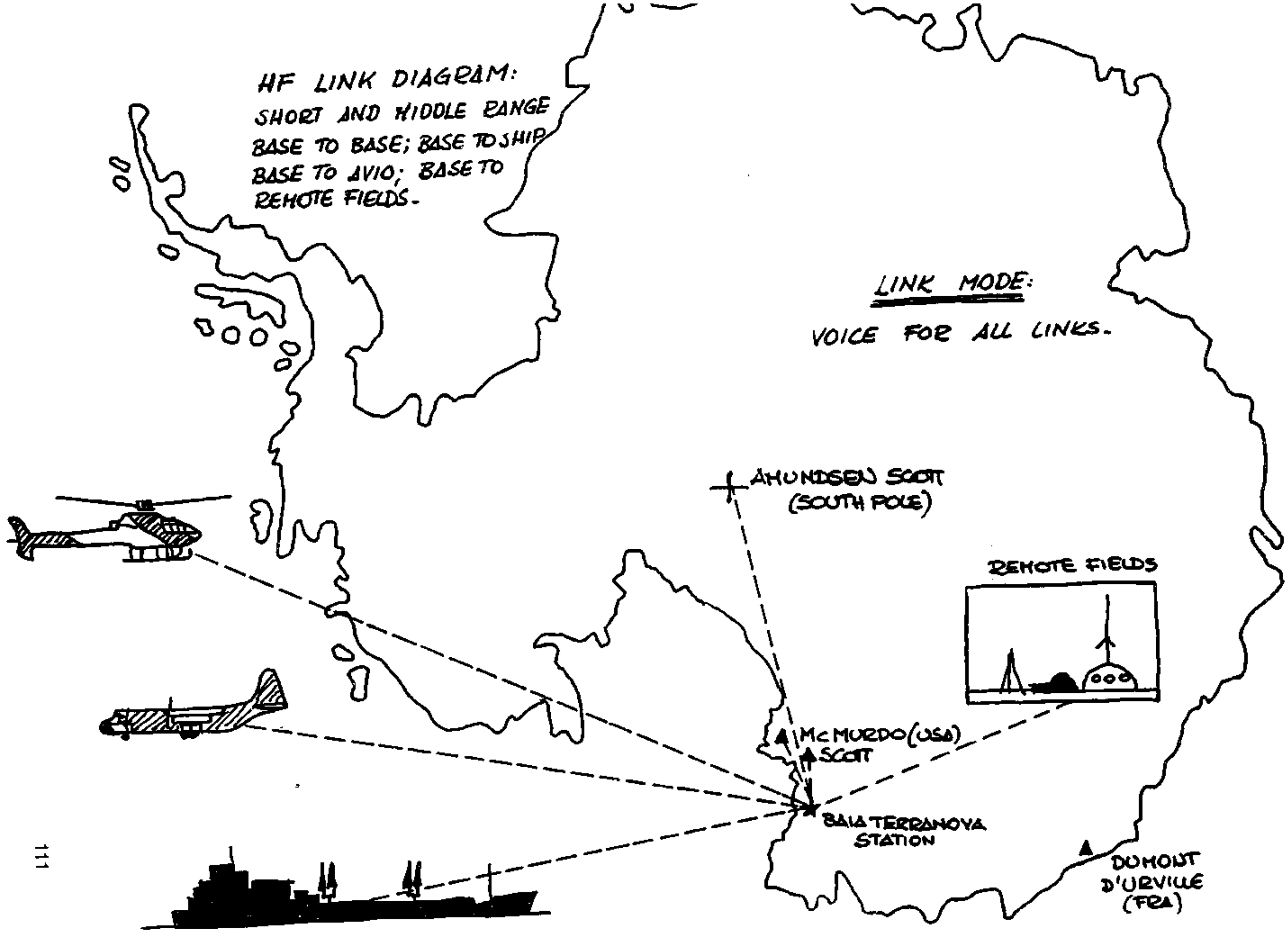


LINK BETWEEN ITALY
AND BTN USING ONLY
PACIFIC OCEAN INMARSAT
SATELLITE.
IBARAKI
SANTA PAULA
SINGAPORE
ROMA
BASE BAIATERRANOVA
PHONE
FAX
TELEX
YAX - DATA
VOICE : WORLD WIDE LINK (TELEPHONE)
FAX : " " "
TELEX: " " "
DATA: " " "
DATA: DIRECT TO NET IN CRE CASACCIA (ROME)

geological expeditions, which for various reasons would travel over 200 kilometres away from the base.
Although being quite effective, our VHF system did not provide an adequate coverage over all our area and it was unable to guarantee a link with the other bases operating in the Ross Sea area. In fact, the system installed on Mount Melbourne can cover the range between 150 and 200 kilometres for land stations, and 300-350 kilometres for helicopters.
Thus, we have also had to tackle the problems relating to the choice and dimensions of an HF system that could provide a link to our remote fields and to other bases (this system was vitally important for those bases which could not use the satellite link). Moreover, not being able to make a precise estimate of the VHF system's effective coverage area, we decided to install also HF transceiver systems in the heavy vehicles which would travel far from the base.
In this phase the HF system also served as a back-up to the satellite system, for example, in matters relating to the telex system, thereby allowing link-ups with the coastal stations in Australia and New Zealand.
The systems used at this stage had 200 watt power with wire antennas. Portable army-type 25-watt transceivers powered by batteries or solar cells together with a hand-powered system were used for the remote fields HF systems.
The results obtained in all these sectors in the initial phase were satisfactory and helpful in determining later implementations.

ACCOMPLISHMENTS IN THE V CAMPAIGN (1989/90)

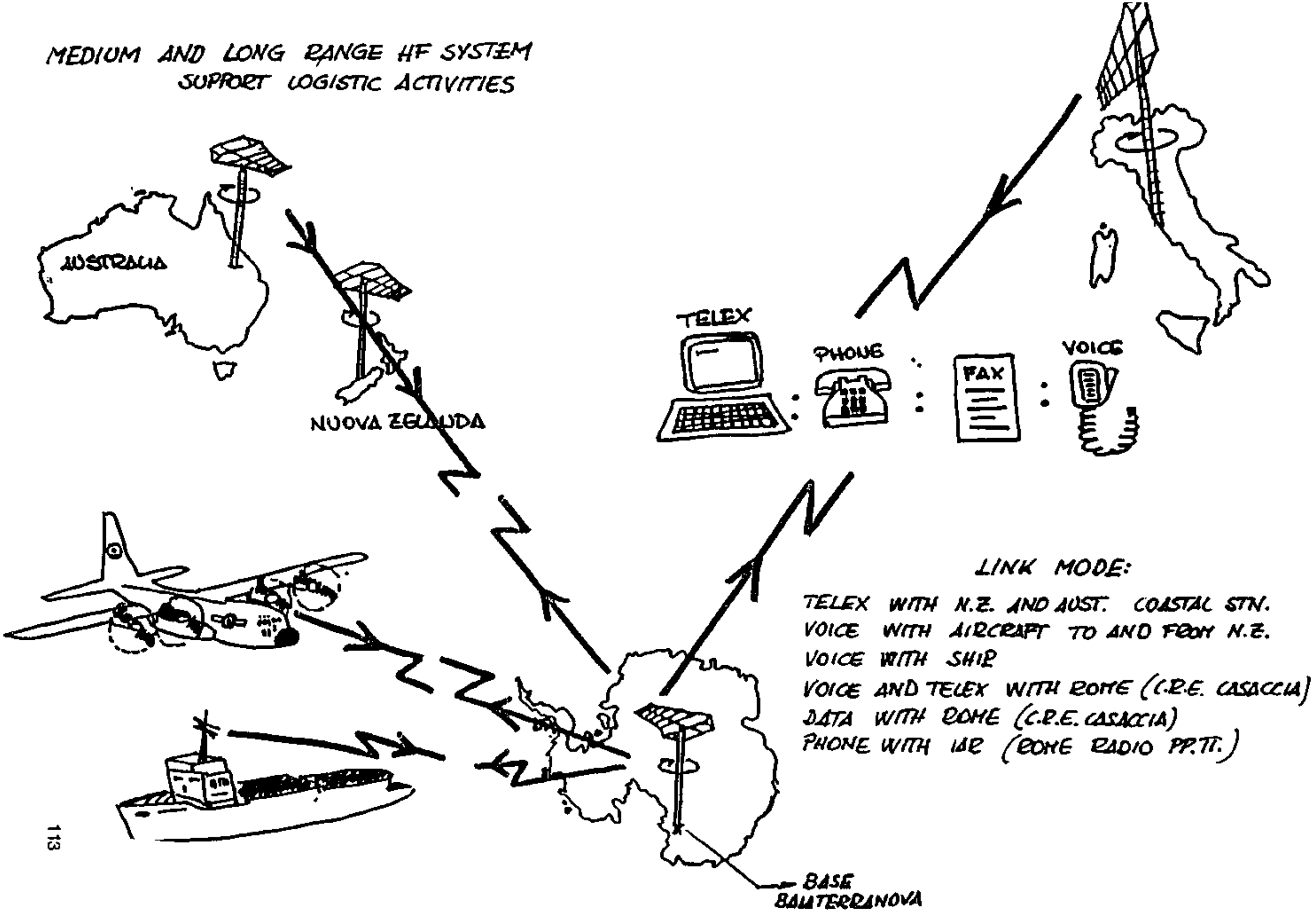
Having from the outset related the planning of the project to its possible future applications, we can say that the system as a whole has undergone few substantial modifications. Some parts of the system have been strengthened and developed to make it more flexible and reliable.
Keeping in mind the funds available, work has been carried out to rationalize the service by improving its quality.
Starting from financial considerations of the heavy burden that the satellite carrier fee represents for the P.N.R.A.'s telecommunications budget, we decided to use this carrier only for important communications and telematic activities.
Experience gained in these first few years has shown us that it is possible to, for example, have a stable short wave link between Italy and the Antarctic for communications between the Base personnel and their families, and for some of the data and telex traffic. Naturally, all of this can take place during certain quite large time windows linked to ionospheric propagation. However, aside from this albeit important application, it has been necessary to invest more resources in the HF sector, which was initially undersized, in order to make it a really effective back-



HF LINK DIAGRAM:
SHORT AND MIDDLE RANGE
BASE TO BASE; BASE TO SHIP
BASE TO AVIO; BASE TO
REMOTE FIELDS.
LINK MODE:
VOICE FOR ALL LINKS.
AMUNDSEN SCOTT
(SOUTH POLE)
REMOTE FIELDS
McMURDO (USA)
SCOTT
BAIA TERRANOVA
STATION
DUMONT
D'URVILLE
(FRA)

up to the satellite system. In this field we have also been able to lay the foundations for profitable co-operation with the Italian National Geophysics Institute. During the 1989-90 season this institute provided support with forecasts of radioionospheric propagation starting with its own calculation tables. As we shall see later, this scientific co-operation will to increase and become real applied research.
As already mentioned, the installation of the HF system has required huge resources in terms of both men and means; the antenna system installation was particularly difficult and required the support of helicopters for lifting the towers.
To cover such a large distance as that between Italy and the Antarctic (16,500 kilometres), it was decided to use a rhombic antenna and, for medium and short dinstances, a rotable log periodic antenna.
The rhombic bidirectional antenna was designed to cover a range of frequencies between 10 and 22 MHz (usable for shorth and long path) and is composed of four thirty-meter stayed towers located at the corner of a 110- by 200- mt. diamond. Particular care was taken over the selection of the materials for the radiating part of the antenna in order to ensure maximum resistance without compromising the conductor's electrical characteristics. Much attention was also paid to the design of the radiating system in order to guarantee its resistance and also its ability to withstand wind pressure.
For the log periodic antenna we turned to companies with particular experience design and installations of antenna in very extreme climatic conditions.
The transmitter system's power has been raised to 1 kW by using a commercial transceiver with its specifications in accordance to harsh climatic conditions.
Furthermore, in order to minimize interference from radiating systems (interference which gave a lot of trouble in the past) and to find an area where such an antenna system could work without being a hazard to helicopters, we decided to move the whole radiating and transceiver system about two kilometres away to a hill overlooking the base. The transceiver system is housed in a military-style shelter that has been equipped to contain, not only this system, but also the radiobeacon for air support. Moreover, in this shelter there is the DC emergency power supply system with batteries as back-up units that can provide about 100 hours, with ratio 1/10, of operating time at 100 watts. It also houses all the antenna-transceiver selection system (antenna matrix) and the terminal system for the remote control of all the functions , including the alarms and rotation controller. The shelter is connected to the base via two cables: one for the power supply and the other for remote control. The remote control is obtained by interfacing everything required with two modems that are connected via a 30-pairs telephone cable.
Bearing in mind future developments to the system and the possibility of setting up another base for winter work, as from the next expedition remote control will be

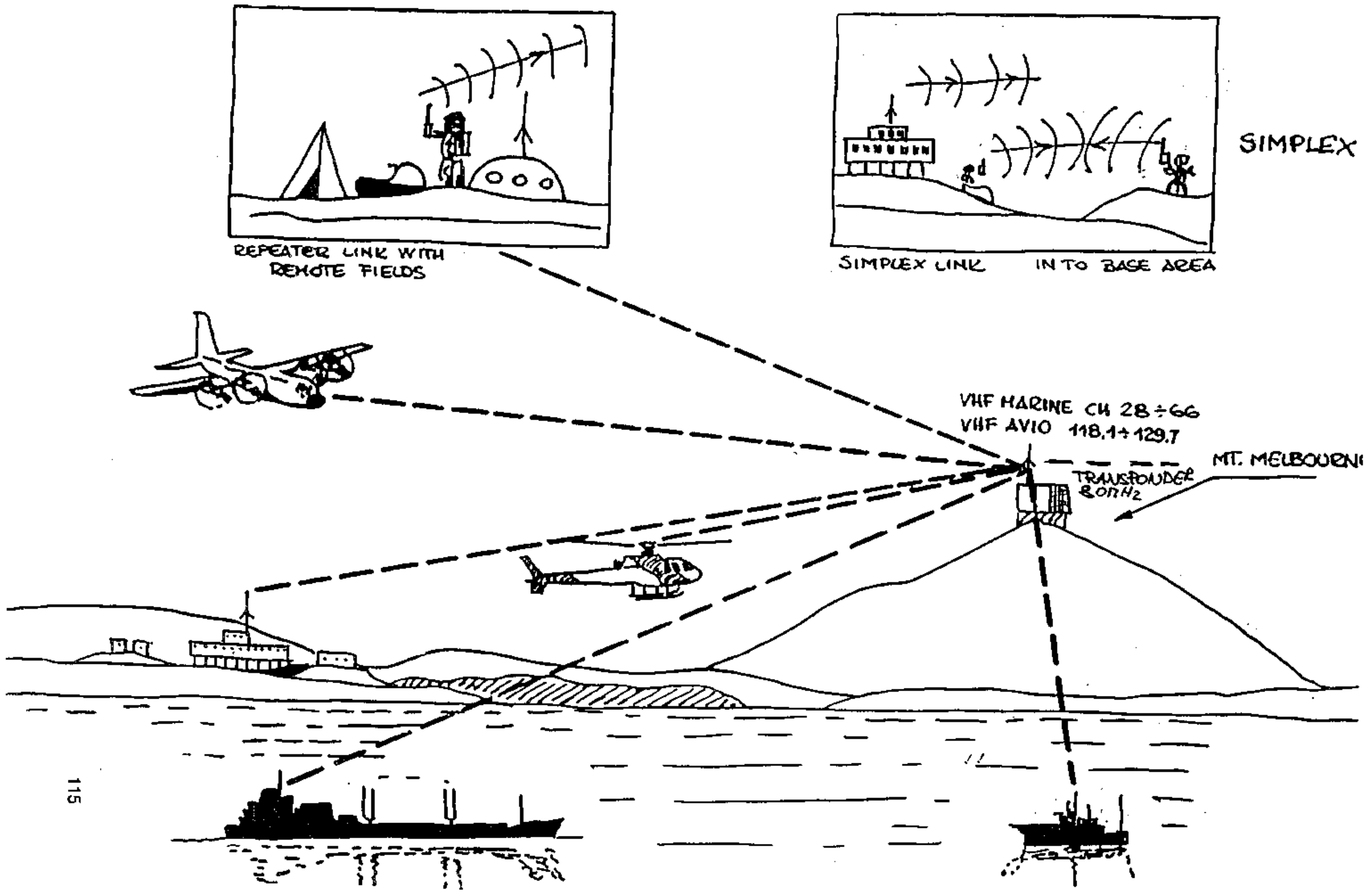
MEDIUM AND LONG RANGE HF SYSTEM
SUPPORT LOGISTIC ACTIVITIES



conducted via a radio bridge with a 200 MHz multiplexer, thus eliminating the telephone cable link.
This HF installation and the traffic passing through this carrier have been achieved according to current international regulations; for the Antarctic-Rome point-to-point link we asked the Italian Ministry for Post and Telecommunications to allocate some frequencies that were then registered to the Bureau Internationale.
The goals achieved during this season were: the regular daily link between Terranova Bay and P.N.R.A. headquarters in Rome; the link between the Terranova Bay and the station of the Italian Ministry for Post and Telecommunications IAR (Roma Radio) for communications between Base personnel and their families; the daily link between the Terranova Bay and ships approaching the Base; the link with coastal stations in Australia and New Zealand for telex traffic; and lastly, improved quality and reliability of the link with remote fields.
The proliferation of scientific and logistic services that have decided to use VHF and UHF transceiver equipment has caused us a little trouble because of the adjacent setting of the two services and the interference that they produce. Thus we had to begin to rationalize the assigning of frequencies, to improve communications .
We decided to provide the Base with a repeater (installed on Mount Melbourne) operating on the VHF Aviation band (in our case, as it is a repeater, it operates on 118.1-129.7 MHz) to provide adequate support to the helicopters and also because it is planned to provide a direct link to Terranova Bay from the aircraft made available by the Italian Air Force.
Our aim was to increase the safety level for avionic support and guarantee greater reliability for the whole network of local communications. But this operation was not crowned with succes due to operational difficulties, but it is our intention to reach this goal and we hope that from the next season we shall be fully operational with the VHF Aviation repeater.
Another repeater was installed to supply a direct VHF link between Terranova Bay and Scott Base to minimize the black-outs caused by geomagnetic activity, which destroys HF communications for days some times.
On line with this strategy we have also decided to gradually move to the UHF band all data transmissions from the automatic recording stations, in order to minimize reciprocal interference.
For reasons of environmental impact we have decided to concentrate all the operating equipment on Mount Melbourne in a small specially-prepared shelter.

FUTURE TASKS

Work in the telecommunications sector is by no means finished and important developments and new challenges lie ahead as we work to make the telecommunications ever more flexible and reliable.
The most ambitious objective of the 1990-91 season is to install an automatic station at Terranova Bay that can


SIMPLEX
REPEATER LINK WITH
REMOTE FIELDS
SIMPLEX LINK
INTO BASE AREA
VHF MARINE CH 28 ÷ 66
VHF AVIO 118.1 ÷ 129.7
TRANSPONDER
MT. MELBOURNE

collect and transmit data during the 1991 southern winter without the need for personnel being present. The link controlled by a VAX 3800, installed in BTN, will be via satellite or via short wave system; for the HF link we are developing a short wave high-speed transmission system specifically for a range of 16,000-25,000 kilometres and also developing the software for the control of the communications and of the self error-correcting codes for transmission packets.Moreover, these systems are programmed to transmit data and also information about the selection of the best frequencies available. This means that the frequencies can be managed so as to maximise link-up possibilities and the time windows when they can take place.

All of these systems will be housed in a specially built shelter while keeping remote the HF transmitter system . Power will be supplied by a sophisticated system of generators that will have to guarantee 9 months operation without maintenance. All of the system will be remote controlled from Italy via the link we will set up and this will provide us with valuable experience for one of our remaining objectives, which is the remote telematic control of the base.

During this campaign the HF sector will be able to make use of further support provided by the Italian National Geophysics Institute which intends to install a Barry radioionosonde at Terranova Bay to study the ionosphere. This radioionosonde will be used in order to study and observe the ionospheric characteristic and the electron density at different levels by means of vertical reading at a sampling rate of up to one every five minutes.

These studies will give an important tribute not only to the knowledge of the Antarctic Region high atmosphere but they can be correlated to the other studies on the possible interaction between medium, low and high atmosphere.

For our purpose these studies have effects in real time on the propagation forecast for short distance links with the remote fields and with the others bases in the Ross sea area.

The scientific view of this activity is aimed to improve the knowledge on the fine dynamic of the ionosphere and on the atmospheric waves caused by the tropospheric perturbations.

Particularly interesting is the study of the interaction between ionosphere and neutral atmosphere. At the same time slant readings between BaiaTerranova (BTN) and Rome (CRE Casaccia) will be performed in order to verify and improve the long range propagation forecast mathematics models.

This is a help for the base operators to choose the best working conditions.

Such slant readings, with continuos emission between 1 to 30 MHz, will be effectuated using the trasmitter part of the radioionosonde installed at BTN and the receiving part installed at CRE Casaccia (Rome) seat of P.N.R.A.

With regard to this latter possibility of slant readings, we are planning to conduct this experiment for a period

of five to six weeks from the first few days of January until the end of February 1991. As the Barry system is an open one, anybody who is interested in this type of observation can get in touch with the Italian National Geophysics Institute or with us to decide a schedule of transmission times so the systems can be synchronized.
It is important to bring into evidence the fact that it is the first official Barry ionosonde system installed in Antarctica.

Another task that we want to entrust the HF system with is keeping in contact with the C130 of the Italian Air Force as it flies between New Zealand and the Antarctic. Moreover, bearing in mind the geomagnetic problems already mentioned, in order to ensure greater reliability of the aircraft to Base communication system, a technical/economic feasibility study has begun to provide the C130 with an INMARSAT satellite terminal.
It is foreseen the use of portable satellite terminal for the remote fields; this satellite terminal will be also used in emergency conditions. In order to reach this goal we started a study on the technical and economical feasibility; we are particularly concerned of extreme enviromental conditions.
Another future task is the upgrading of HF power trasmitter to 10 KW in order to have better system performances; regarding the antennas systems, will be installed a multimode spiracone antenna with which will be possible to broadcast simultaneously with two system (at different frequencies) with different take off angle.
The telecommunications working group is supporting also scientific activity such as the trasmission of medical data; for this activity we plan to use the INMARSAT satellite for slow scan television.
The weather forecast activity is performed by using HF trasmission or ARGOS polar satellite system; the ice maps acquisition is achieved by AVHRR satellite system. These activities are managed by the scientific branches withy the technical support of the telecommunications working group.
A large part of our effort is now dedicated to the feseability study on receiving and trasmitting fast scan television between Italy and Antarctica.

SARSAT Beacon Use in Antarctica

by

Dougherty, T. [1)]
Nitschke, R. .[2)]

Abstract

The United States Antarctic Program (USAP) began equipping selected remote scientific field parties with Search and Rescue Satellite (SARSAT) beacons during the 1989-90 austral summer season. These beacons offer a tremendous potential for mobile, remote teams to transmit their precise location and an emergency notification to their home base without use of VHF, UHF or HF communications. This capability is particularly valuable to increase the safety net for scientific investigators during the coming years of increasing solar flare activity with its negative impact on HF propagation.

Two years of investigation, research and trials, with lessons learned along the way, led to the decision to acquire the beacons and deploy them in the field. There have been some growing pains. We continue to learn more about their use and have run across a number of problem areas, including hazardous cargo designation, closing the communication loop back to the home station and necessary international coordination for testing.

This season's experience (1989/91) has brought some answers about SARSAT beacon use in the field and its viability as a useful tool for the scientist and operations/logistics manager in Antarctica.

We are exploring means for further applications that will make it an even more useful safety/operations tool, enabling nearly immediate notification back to the home station. As new technologies overcome system/equipment limitations, SARSAT beacons will probably be the norm for safe antarctic operations.

The Use of SARSAT Beacon

The SARSAT beacons used by the USAP utilize the resources of the international COSPAS-SARSAT systems. COSPAS (Space System for Search and Rescue of Vessels in Distress) and SARSAT (Search and Rescue Satellite Aided Tracking) were

---

1) Commander, U.S. Naval Support Force, Antarctica, US Navy
2) Lieutenant Commander, U.S. Naval Support Force, Antarctica, US Navy

designed to provide for rapid detection and location determination by satellite of aircraft and ships in distress. Rescue results since system became operational in 1982 have proven that this enhanced speed and accuracy of detection increases the chance of survival and reduces the length and cost of SAR operations.

COSPAS-SARSAT is sponsored by the United States, Canada, France and the Soviet Union. SARSAT equipment is carried aboard National Oceanic and Atmospheric Administration (NOAA) satellites. Canada provides transponders. France provides on-board receiver/processors. COSPAS equipment is carried on Soviet COSMOS satellites. The Soviet Union provides its own equipment and launching. These four countries, as well as Australia, Brazil, Chile, Hong Kong, India, Norway, and the United Kingdom provide the ground receiving facilities. Several other nations are currently developing ground stations.

The three COSPAS and the three SARSAT satellites are in low-altitude (850 - 1000 km), near-polar orbits. Signals are relayed in real-time or stored aboard the spacecraft for later retransmission to the ground station known as a Local User Terminal (LUT). Currently 19 LUTs are in operation and provide real-time coverage of most of the Northern, and parts of the Southern Hemispheres. The LUTs are generally unmanned and fully automated. At the LUT the signal is processed and the location of the emergency beacon is determined.

This location data is then relayed to a Mission Control Center (MCC) which is manned 24 hours per day and relays the alert to the appropriate rescue coordination center. Currently there are ten MCCs, their areas of responsibility are shown on the "MCC Service Area" diagram. Note that the Antarctic continent does not fall within the area of responsibility of any of the existing MCCs.

Detection and location are provided on three frequencies: 121.5, 243.0 and 406 Megahertz (MHZ). The system has regional and global coverage modes. In the regional mode all three signals are relayed in real-time to the LUT. Mutual beacon-satellite-LUT visibility is required. Beacons within 4000 km of the LUT will be detected. The global mode is available for 406 MHZ only. Since the 406 MHZ signal is more stable, and contains the coded beacon identification, the signal can be processed on-board the satellite and then stored in memory for later retransmission to all LUTs. This mode allows world-wide coverage, but again it must be stressed, only for the 406 MHZ beacon signal.

In light of the COSPAS-SARSAT capabilities, USAP decided several years ago to investigate if this new technology could benefit Antarctic operations. The location of many USAP science projects makes it imperative that a reliable communcations path exists for reporting emergency situations and requesting assistance from base stations. As the diagram "On-Continent Science Support" shows, a typical season will have numerous remote field camps located away from McMurdo station, or any other base camp, to distances in excess of 2,000 km. Much of the work done in these remote locations involves glaciological or geological work, thus the potential for a climbing, crevasse or cold injury accident is significant.

USAP Search and Rescue policy requires remote field parties to check in with a base station every 24 hours, normally by High Frequency (HF) communications. If a camp has not checked in within 72 hours, SAR resources are activated including the launch of LC-130 aircraft to the last known location of the science party. Given the normal vagrancies of HF communications, especially in the polar regions, it is always difficult to maintain communications within our SAR parameters. As the solar maximum approaches the incidence of solar events is expected to increase. The 10 day polar cap absorption episode experienced in October 1989 certainly demonstrated the disruption to communications and operations that can occur due to solar activity.

Potential benefits to antarctic programs from use of a system such as COSPAS-SARSAT appear to be significant. The ability to report a legitimate emergency quickly and reliably may provide the margin between life and death or serious injury, and is an important safety net for deep field personnel regardless of the status of conventional communications systems. For the Antarctic Operations Manager, knowing that a reliable means of emergency communications is in place will prevent the use of scarce aviation assets to find out the condition of field personnel who have not been able to give a status report due to degraded communications.

Since initial investigation showed that utilization of satellite location beacons in Antarctica could aid the USAP, the next step was to demonstrate that suitable equipment was available for field party use and that the systems would actually work reliably in the antarctic environment.

In January 1987 the National Aeronautics and Space Administration (NASA) conducted tests in field locations near McMurdo Station, utilizing two 406 MHZ locator beacons. One beacon was used as a control on the surface while the other was placed in various orientations and depths in snow trenches, crevasses, snow bridges, etc. Collected data indicated that over 70 % of responses were received by the USMCC in less than 2.5 hours. NASA concluded that the SARSAT system is viable for Antarctic operations and recommended implementation for future field operations. It was noted during this testing, that although the system response to beacon activation was rapid, notification of USAP operations on the continent was not as timely due to the normal delays in inter-continental communications. This negative feature continued to plague us into actual operational use in the 1989-1990 season and will be addressed later.

Based on the successful tests, the USAP purchased six Kannad 406F beacons in 1989. This beacon, illustrated in the "USAP Emergency Position Indicating Radio Beacon" diagram, weighs 1.75 kg and measures 150 x 270 mm. It is powered by lithium manganese batteries, with a shelf life of 4 years. The specified operating temperature range of the batteries is -20 to +70 degrees C, with a life span of 50 hours minimum at -20 degrees.

During November 1989 four of the beacons were deployed with scientific field parties in various remote locations. No problems were noted in the field, the size of the beacon being small enough not to impair the group. As solar activity degraded HF communications periodically throughout the austral summer, there were several instances during which SAR operations were not launched to locate a party overdue in reporting. This step could be safely taken because a beacon was in the field. Although fortunately no beacon had to be activated, battery test done upon return to McMurdo station indicated no adverse effects on power or life span occurred in the extreme cold of the remote areas.

Throughout our experience with this new technology various limitations and problem area have been encountered. The first of these is the use of lithium batteries in the beacons. Although an excellent power source in cold conditions, they are considered hazardous cargo by United States regulations. Lithium batteries may not be carried on aircraft with passengers, and a waiver had to be procured just to transport them at all. The waiver allows us to transport the beacons to the field, however, there are still unanswered questions regarding lithium battery safety.

Secondly, as indicated previously, there was no reliable method for the MCC to quickly pass SARSAT beacon activation information to Antarctica. We experimented with a variety of multiple path notification schemes including HF voice, HF radio teletype, INMARSAT voice, and INMARSAT telex. At the end of the austral summer season a procedure utilizing single call INMARSAT telex appeared to provide the necessary speed of notification even when INMARSAT telephone lines are in use.

Arranging an operational test of a beacon is very difficult due to the amount of international coordination required by the host country MCC. To prove the system with the actual beacons USAP wished to activate a beacon on pre-arranged schedule. Permission for such a test was never granted. This problem can be partially overcome by use of a test beacon, available from the MCC. Use of a test beacon is planned by the United States during the next season.

Several other operational limitations or lack of enhanced features have been identified including:

- Beacons must be physically activated by a person. No automatic alerting feature exists for land applications.

- No capability is incorporated for transmitting non-emergency but possibly urgent messages.

- System is activated only by a 406 MHZ beacon until a LUT is installed on the continent.

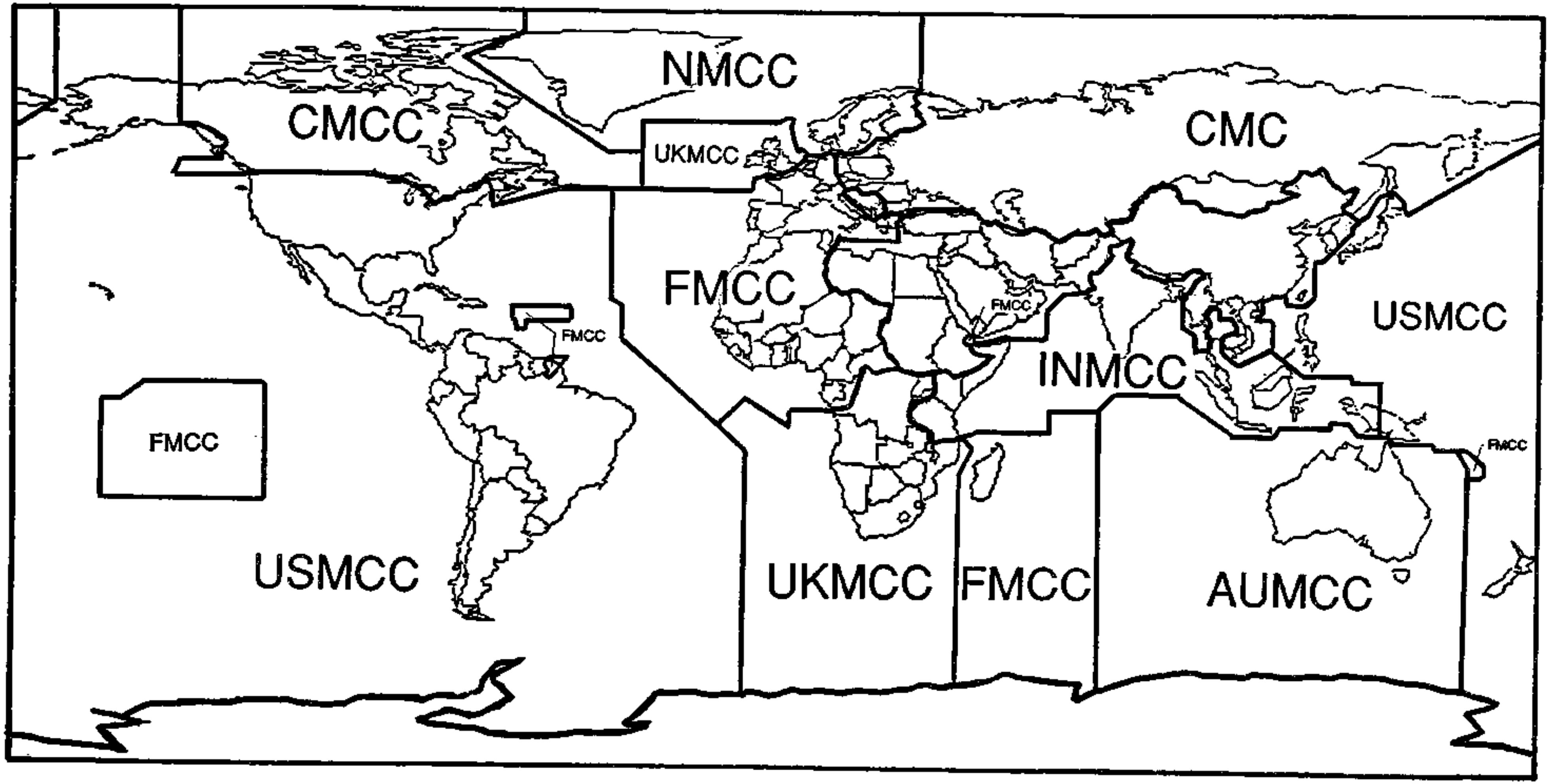
- Specifying the nature of the emergency and what help is needed is not possible with the beacon model USAP uses.

In spite of the weaknesses noted, we feel that use of the COSPAS-SARSAT system in Antarctica is advantageous. Some strong points of this system include relatively low cost (beacon purchase is the only required equipment), ease of use and transport in the field, and excellent durability of the equipment. This is a proven SAR system with a world wide infrastructure in place. It provided rapid response to beacon activation and furnishes positioning information accurate to within 5 km.

Other systems do exist or are under development which could also be utilized in a SAR coordination role. The Argos system for example has a unit that may be used for "distress alarm monitoring". This system normally charges a lease fee and a daily fee for this service. Argos also is developing a microprocessor based, small sized terminal that may be used to automatically collect meteorological data independent of observer activity. Location determination is performed by the Argos processing system. Manual entry of other data is possible by keyboard. Systems like this one may be useful in some areas of operations where more information than COSPAS-SARSAT provides is required.

Summary

Use of a satellite based system for aiding search and rescue coordination will certainly benefit the antarctic programs of all nations, especially if inter-program cooperation exists. Appropriate international agreements should be initiated, defining responsibilities, standard procedures and a protocol for inter-program notification during an antarctic SAR. Such agreements will make it even more likely that international efforts of the kind that have occurred during the last several years will continue to lead to successful SAR and medical evacuation operations. These actions, followed by placement of required ground station equipment on the continent, will allow all programs to fully utilize this valuable safety/operations tool.

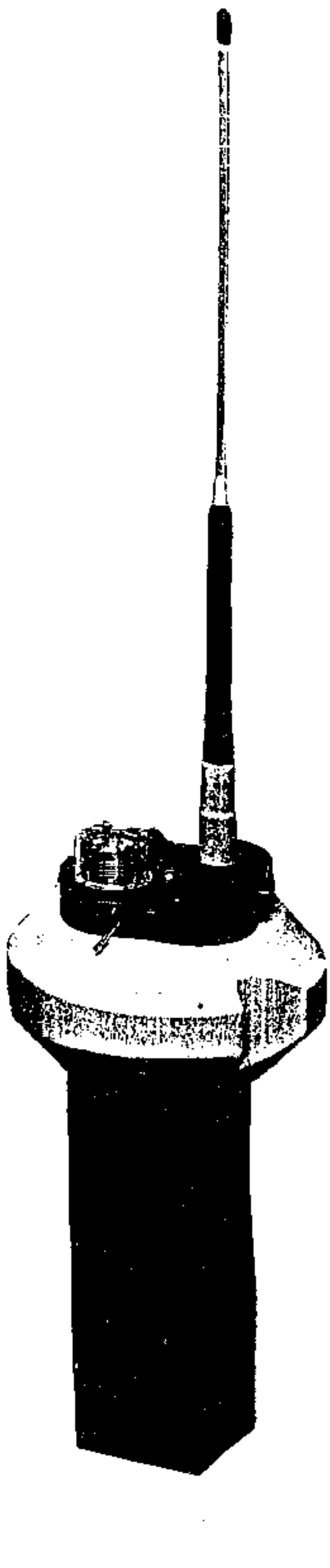


MCC SERVICE AREAS

ON-CONTINENT SCIENCE SUPPORT

U.S. Antarctic Program 1989-90 Season

LC-130 Supported Science Operations



USAP EMERGENCY POSITION INDICATING RADIO BEACON

Multipurpose Satellite Data Receiving System Constructed at Syowa Station

by

Masaki Ejiri, Sadao Takeuchi and Natsuo Sato
National Institute of Polar Research

Abstract : Multipurpose Satellite Data Receiving (MSDR) system with a large dish antenna of 11 m in diameter was built at Syowa Station in Antarctica. In austral summer season 1988, the foundation for the antenna structure was constructed, together with a building of 120 m^2 and a cable duct of about 80 m. In 1989 all the system was completed installing the parabolic antenna and radome (17 m in diameter) on the foundation, and has been operating by receiving and processing S-and X-bands data from satellites since February 1989. This system has also a capability to receive a signal from radio sources and used as a very long baseline interferometer to determine a precise position of Syowa Station.

This antenna system was designed to be satisfied with following conditions.

(1) The radome can stand a blizzard of a maximum wind speed of 60 m/s.
(2) The antenna structures including azimuth and elevation driving mechanisms can operate under the air temperature of -45°C.
(3) All structures are divided into a piece which can be transported by the ice breaker Shirase and easily recondtructed, giving the guarantee of designed performances.

1. Introduction

Japanese Antarctic research has been conducted many scientific activities, having now the main station of Syowa (69°00'22"S, 39°35'24"E) since 1957. Scientific interests have been expanding, including space and upper atmosphere physics, meteorology, glaciology, oceanography, geology, geomorphology, solid geophysics, biology, and so on.

Since it is not adequate to make observations from the ground, even by using sounding rockets and balloons, for fully understandings of the vast Antarctic, the Working Group (WG) on Upper Atmosphere Physics (UAP), Scientific Committee on Antarctic Research (SCAR), issued in 1982, REC XVII-UAP-1 that SCAR invite COSPAR (Committee on Space Research) and SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) to assist in encouraging space agencies to consider the possibility of

---

National Institute of Polar Research, Kaga 1-9-10, Itabashi-ku, Tokyo 173, Japan

launching one or more satellites dedicated to the interests of polar research. It has been also recognized that it is essential to have a ground-based satellite data receiving stration in Antarctica to obtain a large amount of data sets around the observed regions.

National Institute of Polar Research (NIPR), the Ministry of Education, Science and Culture decided to develop the multipurpose satellite data receiving system at Syowa Station to receive and process the data from EXOS-D (auroral observation satellite of the Institute of Space and Astronautical Science (ISAS)), MOS-1 (Marine Observation Satellite of the National Space Development Agency (NASDA)), ERS-1 (European Space Agency (ESA) Remote-sensing Satellite) and other satellites to be launched in future. This system is also designed to have a capability for VLBI (Very Long Baseline Interferometer) and radio astronomy.

In order to construct a large facility in Antarctica, very far from the civilized country and under severe weather conditions, there are several conditions imposed upon the system, e.g. limitations of weight and size due to the means of transportation. Also very short periods for outdoor works are allowed there i.e. one month a year. Prior to the loading into the ship, all the system, both constructual hardwares and electrical equipments, were assembled in Japan and tested by receiving the satellite's data, which gave confirmations of the constructual procedure as well as system performances. Members who took charge of this system participated in this operation as their trainings.

In 1988 JARE (Japan Antarctic Research Expedition) 29th party constructed the foundations for the antenna structure, the building for electrical equipments, and the cable duct. All the system was completed by JARE 30th party and has been operating for MOS-1 since February 12 1989 and for EXOS-D since February 22 1989. On August 31 1989 the signals from the radio source (Quasar 3C273) were detected for the first time in Antarctica; this means the system can be used as a radio astronomical telescope. In January 1990 the VLBI test experiments between Syowa Station, Kashima space station in Japan and Tidbinbilla NASA deep space station in Australia were successfully carried out, which gave a baseline distance between Syowa and Kashima.

System specifications and constructual procedures are described. Anticipated scientific gains are also delineated in Appendix.

2. System design and characteristics

The MSDR system consists of (1) an antenna structure with its AZ-EL (azimuth and elevation) drive and control equipments, (2) a radome, (3) an S-band preamplifier, (4) an X-band preamplifier, (5) an S-band main reciever and demodulators, (6) an S-band data recording system, (7) an X-band main receiver and demodulators, (8) a high-density data recorder, (9) computer quick-look systems, and (10) station control equipments. In addition to the above main system, there are a collimation system which was constructed at West Ongul island, about 4 km away from the antenna, a standard time generator using GPS (global positioning satellite) system, and a satellite data link system through which a part of received and processed data obtained at Syowa Station is transmitted to the computer at NIPR Japan using the Inmarsat satellite.

2.1 Antenna structure with drive and control equipments

For full tracking of a satellite at zenith, it is desired to install an antenna dish on X-Y mount or 3-axis mount system which requires a total weight of about 80 tons. But due to weight limitation and other conditions, the AZ-EL mount system was adopted. Total weight of antenna was 22 tons and divided into a piece whose weight was less than 1.4 tons; a helicopter we used can bring a cargo of about 1.8 tons.

Main characteristics of the antenna are:

(1) The antenna structure is covered by the radome. Therefore the weather conditions during the construction in summer time was only considered when designed its structual strength. This reduces the weight tremendously.
(2) The weight was reduced by optimum structure analysis by the large computer and by adopting an aluminum compound metals.
(3) A large housing box for front-end equipments such as low noise amplifiers (LNA) was installed, which makes easy maintenance.
(4) A two-frequency colligate horn and a frequency selective sub-reflector realized a high efficiency for both S- and X-bands and suppressed their side-lobes.
(5) Tracking sequences including a preceding drive mode can be automatically changed

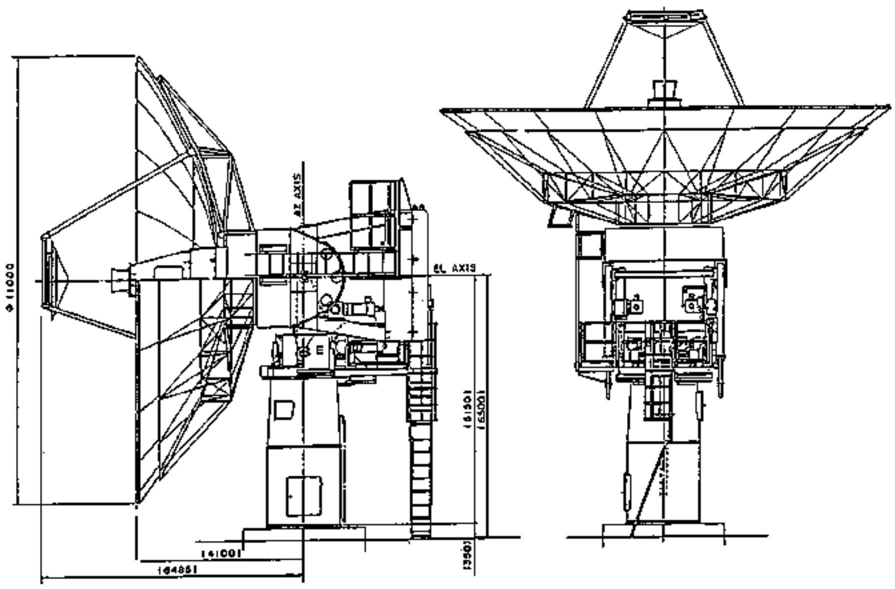


Fig.1 Drawing of the antenna structure: figures in mm.

Photo.1 External view of the antenna structure constracted at Syowa Station, East Ongul island in Antarctica.

The antenna structure without a radome is illustrated in Fig.1, and its external view constructed at Syowa Station in Photograph 1.

Following specifications are applied to the antenna system:

(1) A diameter of the main parabolic dish is 11 m.
(2) A range of EL is from 0° to 90°, and that of AZ from -360° to +360°
(3) A variety of antenna controls are selective such as S- and X-bands monopulse auto-trackings, program tracking, digital slave mode, slew mode, preset mode, manual position mode and search mode. The tracking errors for S- and X-bands are within 0.01° rms and 0.005° rms, respectively. The driving speeds for AZ and EL are 10°/sec and 6°/sec, respectively, while their accelerations are both $8°/sec^2$.
(4) The AZ axis relative to the vertical is set to be 90 ± 0.004°. The AZ and EL axes were crossed within 1.3 mm.

2.2. A radome

A radome of 17 m in diameter covers the antenna structure in order to protect it against a strong blizzard. This also results in keeping the structure a good shape and ease to maintenance. Most effectiveness of a radome is that the antenna system can be always operative under any weather conditions.

The radome consists of 570 pieces of trianglar panels made of fiber reinforced rubbers (membrane) with anticorrosion alumimum alloy frames. This membrane has excellent characteristics of antiweathering (temperature down to -45°C), anti-ozone, anti-ultraviolet radiation, and good transparency of high-frequency radio waves. The losses through this radome are 0.7 dB and 1.1 dB for S- and X-bands, respectively.

In order to endure the strong blizzard with a wind speed up to 60 m/s, 39 anchor bolts of 1200 mm in length and 25 mm in

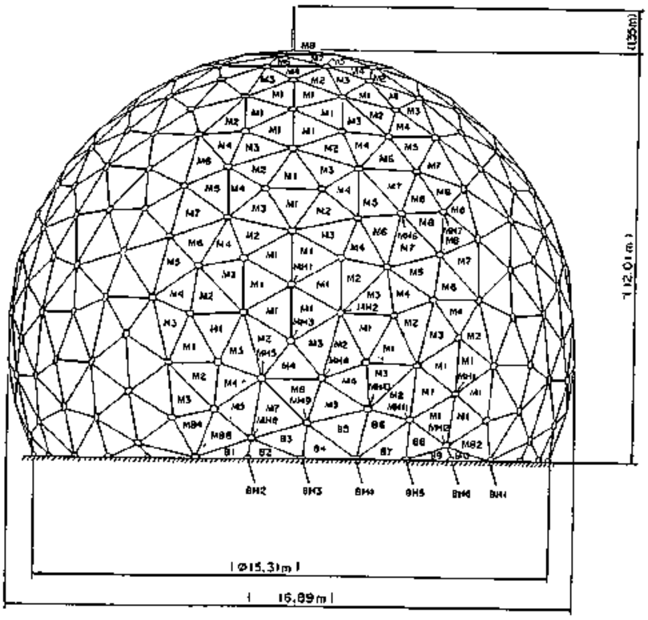


Fig.2 Panel structure of the radome. (M stands for main membrane, B base and H hub piece.)

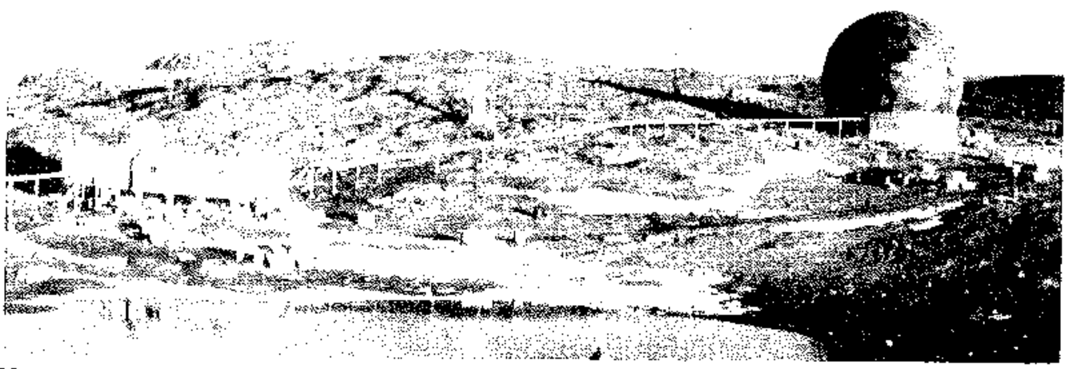


Photo.2 External view of the complete antenna system. The building of the satellite center is lower left side in the photo.

diameter were fixed into boreholes of the concrete base. This stands also snow and ice accumulations of 80 cm thick and 25 cm thick, respectively. Through the wintering in 1989, however, no snow and ice accumulations have been observed except a part of the redome covered with snow of a few cm in thickness. Also there is no snow drift formed around the radome. These may come from the circular shape of the structure, and dry snow with winds in the Antarctic region. The panel structure is illustrated in Fig.2 and the external view is shown in Photograph 2.

2.3 S- and X-bands receiving subsystems

The frequency converages for S- and X-bands are from 2200 to 2300 MHz with an antenna gain more than 46 dB and from 8025 to 8400 MHz with 57.5 dB. A lower frequency limit of X-bands is set to be 7860 MHz with 57.3 dB for the radio astronomical use. The down-converted IF (intermediate frequency) signals of 70 MHz (S-band) and 140 MHz (X-band) are fed to the several demodulators corresponding to the satellite telemetry modulation systems. This IF signal is also used to detect a tracking angular error whose level drives an auto-tracking controller. Five kinds of demodulators are equipped, i.e., PCM (CONV)-PSK-PM, PCM-PM and VSB-PM for S-band, and PCM-MSK and PCM-QPSK for X-band (PCM: pulse code modulation, CONV: convolution, PM: phase modulation, VSB: vestigial side band, MSK: minimum shift keying, QPSK: quad phase shift keying).

2.4 Data recording systems

Adding a time code signal, the demodulated telemetry signals of S-band are directly processed by the computer, while two sets of HDDR (high density data recorder) are used for recording X-band telemetry signals. The MOS-1 signals of 8.78 Mbps for 1.8 hours are stored in one volume of 9200 feets, and the ERS-1 signals of 105 Mbps are only for about 10 minutes recording in one volume. A part of the X-band data is also processed by the computer for quick-look purposes.

2.5 A station control equipment

In JARE members a limited man power is available for operation of this system. Automatic control system is introduced in order to manage this system normally by one operator. Major functions of this equipment are:

(1) Based upon the satellite orbital elements the estimated values of azimuth and elevation angles of the antenna are computed.
(2) Plannings of the satellite tracking schedule are performed.
(3) All sub-systems are setting up, initialized and automatically controlled according to the tracking schedule.
(4) After LOS (loss of signal) a logging of the operation is automatically done.

If the orbital element is so precise that the predicted satellite position at AOS (acquisition of signal) is within a main beam of the antenna, this automatic system is well-functional. If not such as the case of the EXOS-D, the initial manual tracking is required.

3. Construction works

JARE 29th party was in charge of construction of the foundation and the building of satellite center. It took 31 days (total 319 man × days) for the foundation with 55.7 m^3 concrete. As for the building it took 29 days (323 man × days).

JARE 30th party arrived at Syowa Station on December 29 1988, and most of the cargo of 167 tons were transported by the snow vehicles with sleighs from the ice breaker Shirase to the East Ongul island; it took only 3 days. The construction of the antenna pedestal, AZ and EL driving mechanisms, main dish frames and sub-rellector subsystem including their adjustments required 5 days (total 130 man × days). It took 9 days (153 man × days) for the radome, in which we had to interrupt the works for 2 days due to strong winds of the maximum speed of 26.8 m/s. Another 4 days (31 man × days) were required to make coatings to fill up their gaps between panels and their hub pieces. To set up and to disintegrate a scaffolding for above works it took 7 days (57 man × days). Total working days including preperations done by JARE 30th were 30 days (380 man × days).

Just after completion of all works, the strong wind with the maximum speed of 50.8 m/s tested our structure for 2 days. Fortunately and as designed there were no damages at all.

4. Conclusion

The Multipurpose Satellite Data Receiving system with 11 m dish covered by the radome was constructed at Syowa Station in Antarctica. It has been operating since February 1989 to receive data from MOS-1 and EXOS-D. Also it was confirmed this system can be used as a radio astronomical telescope and the VLBI test experiment was carried out. This is only one system of satellite receiving facility with a large dish antenna in Antarctica.

Acknowledgements

This Multipurpose Satellite Data Receiving system has been designed and built in cooperation with many scientists and engineers and members of administration under the leadership of the National Institute of Polar Research, the Ministry of Education, Science and Culuture, Japan. The 29th JARE constructed an antenna foundation and a building of satellite center. The 30th JARE completes the whole system. Thanks are due to all members of both JARE parties as well as the supports of ice breaker Shirase's crew. Especially we would like to express our gratitudes to Messrs. H. Ariyoshi, N. Kurihara, M. Masuda, I. Hiruta, M. Ozaki, M. Kawakubo, and T. Ugeta.

Appendix

Following scientific objectives are investigated though satellite's data received by this MSDR system.

Auroral Physics: Both in-situ and remote observations by scientific satellites give a unique opportunity to reveal physical processes in the source and accelaration mechanisms of auroral particles and their relevant phenomena though a variety of auroral observations have been carried out from the ground. Japanese polar-orbiting EXOS-D satellite is dedicated to study physical mechanisms of aurora, in conjunction with the ground-based electromagnetic and optical observations. This MSDR system is only one station in Southern hemisphere to receive data from the EXOS-D.

Glaciology: A variety of measurements, including the high resolution observations by Microwave Scanning Radiometer (MSR) of MOS-1 and Synthetic Aperture Radar (SAR) of ERS reveal the variations of ice sheet and ice masses for a whole year in the polar region. Thus the earth observation satellite is of particular usefulness and interest to understand the spatial distribution of snow and ice, ice dynamics, and ice snow geophysical properties.

Earth Sciences: Multi-spectral observations of MOS-1 and ERS-1 provide surface conditions on snow convered and outcropped areas of Antarctica from visible, near infrared to infrared bands. SAR from ERS-1 gives detailed topography and geological lineaments. The monitoring of satellite remote sensing data thus tell seasonal and annual changes of surface conditions of wide converage which can never be observed from land surveys. Comprehensive analysis of remote sensing data is also important for prospecting of mineral resouces.

Meteorology: MSR data of MOS-1 gives an estimation of water vapour content in the atmosphere and liquid water content of cloud. VTIR (Visible and Thermal Infrared Radiometer) data provide albedo and surface temperature, which give horizontal distribution budget. Covering large area in the polar region, the satellite data contribute much to clarify the mechanism of maintaining the polar climate system.

Marine Biology: VTIR data of MOS-1 provide information on surface ocean color which is used to estimate near-surface phytoplankton chlorophyll standing stocks. Though the primary producer within marine ecosystem has been observed on board at limited points along cruise tracks, the satellite imagery is to expand scales of temporal and spatial variability of primary production.

Scientific Goals and Technical Design of the Combined German ERS-VLBI Antarctic Ground Station

K. Nottarp

Institut für Angewandte Geodäsie (IfAG)
6000 Frankfurt a.M., Federal Republic of Germany

K.-D. Reiniger

Deutsche Forschungsanstalt für Luft Raumfahrt (DLR) - WT-DA/SN
8031 Oberpfaffenhofen, Federal Republic of Germany

November 28th, 1990

Abstract

The Federal Republic of Germany will install during the Antarctic summer 1990/91 a combined system for ERS satellite data reception and VLBI measurements at the chilenian Antarctic base 'Bernardo O'Higgins' in a cooperative project. The paper describes scientific goals and the chosen technical design for this complex installation.

1. Introduction

Since 1983, the Federal Republic of Germany has been persuing plans to design and implement a transportable station for the acquisition of data from remote sensing satellites. A phase-A study performed by Dornier System in 1984 [1] under DLR contract and a follow-on phase-B study, performed by DLR on 1986 [2], had shown the feasibility of such a concept. In parallel, the scenario of potential users has been investigated [3] to identify applications. As a result, the only group finally justifying the need for the station was the Germanm Antarctic research community. A modified version of the station, including a VLBI capability but not transportable anymore, was proposed for funding to the German Ministry for Research and Technology (BMFT). At the end of 1988, the BMFT asked the Alfred Wegener Institute for Polar and Marine Research (AWI), the Institut für Angewandte Geodäsie (IFAG) and DLR to design, procure and operate a station for the acquisition, recording, and quick-look processing of Synthetic Aperture Radar (SAR) data from the first European Remote Sensing Satellite ERS-1 as well as to make VLBI-observations on the Antarctic plate. This station shall be deployed on the Antarctic Peninsula, to monitor the Weddell Sea, a region of prime interest in the German Antarctic research program.

According to Figure 1, all SAR data acquired with the German Antarctic Receiving Station will be recorded on tapes and transported later to the German Processing and Archiving Facility (PAF) for further processing. The German PAF, a facility of DLR's Remote Sensing Data Center, is one of four Processing and Archiving Facilities forming the European ground segment for the off-line processing of ERS-1 payload data, which is coordinated by ESA's Eartnet ERS-1 Central Facility (EECF). The German PAF will generate ***standard products*** according to ESA specifications under ESA contract, and ***special products*** in close cooperation with national users.

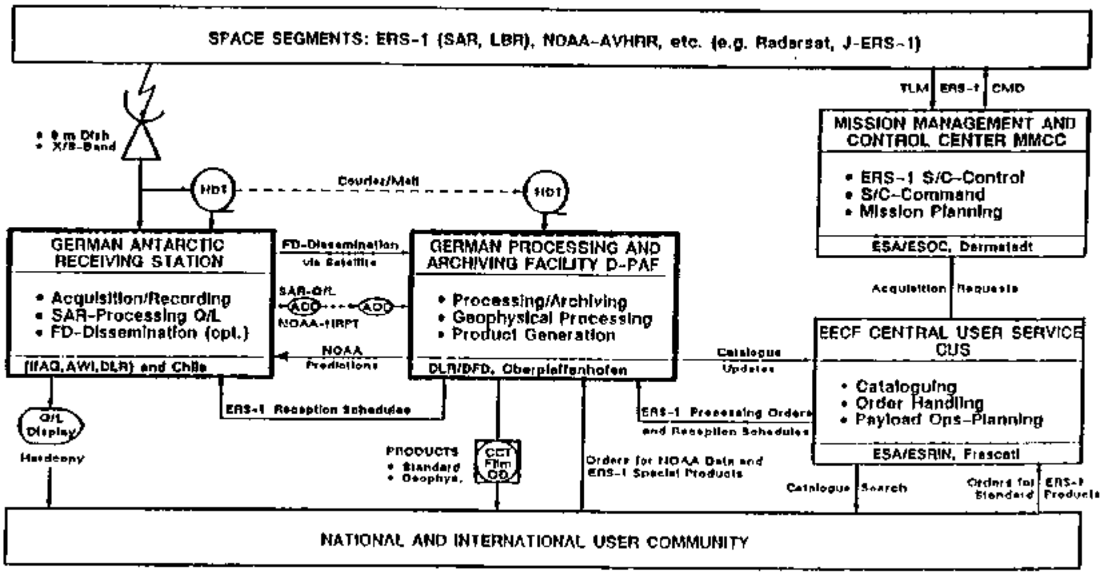


Figure 1. Acquisition and Processing of Remote Sensing Data from Antarctica

2. The German Antarctic Receiving Station

2.1 Station Concept, Implementation Planning, Location and Visibility

The goal for the design and implementation of the German Antarctic Receiving Station is to provide to the scientific community a dedicated facility, to support the research of the Antarctic continent and its surrounding water bodies, by means of satellite remote sensing technology and Very Long Basline Interferometry (VLBI). Due to the long term aspects of the research programs and the demand of continuous data support for at least 10 years, the station could no longer be designed to be transportable. The concept now assumes a fixed ground station, located on the Antarctic Peninsula, with a combines capability for satellite data acquisition and interferometry on quasars.
The station has to be built onto tectonically stable bedrock and its visibility circle has to cover the research relevant areas of the Weddell and Bellingshausen sea. Therefore, the Antarctic Peninsula is the only possible place for location. Furthermore, only there the high operational requirements (all-the-year access, short term availability of received data) can be satisfyingly fulfilled. To avoid establishing a complete new base with all logistic implications and also to minimize additional environmental import it was decided to run the ERS/VLBI- Observation station in close connection and cooperation with an already existing winterover station. In this region two existing bases with sufficient infrastructure could be identified, suitable for

an installation. These are 'Esperanza base' (63° 24'South, 57° 59'West) operated by Argentina and O'Higgins base (63° 19'South, 57° 54'West) operated by Chile.
In the final selection 'O'Higgins' was preferred due to its direct connection with the main gate way to the Antarctic 'Teniente March'. Furthermore, Chile has shown its great interest in the project and in a future cooperation in this field of research.

It should be mentioned that Japan has installed a similar station at its Syowa base. These two stations and a U.S. station, under discussion for McMurdo, could then cover the Antarctic continent north of 82° S and most of the ice covered southern oceans.

The station is financed by the German ministry for research and technology BMFT and will be produced by German industry with DORNIER as main contractor. Presently the design phase was completed, full production is under way. The infrastructural work at O'Higgins has been completed in March 89. Integration and tests will take place at DLR during June to October 1990. Then it will be shipped to the Antarctic immediately to start operation in parallel with ERS-1.

The circle of visibility and the SAR illuminated swath for the 3-day orbit is shown in fig. 2. There it is clearly shown that the Weddell and Bellinghausen Sea are well covered by the satellite and the station, the Drake passage and the southern part of South America are only partly covered. This changes rapidly with the alternative 35-day orbit. Other remote sensing-and weather satellites completely cover this area, however, are limited in observation due to the optical sensors, used.

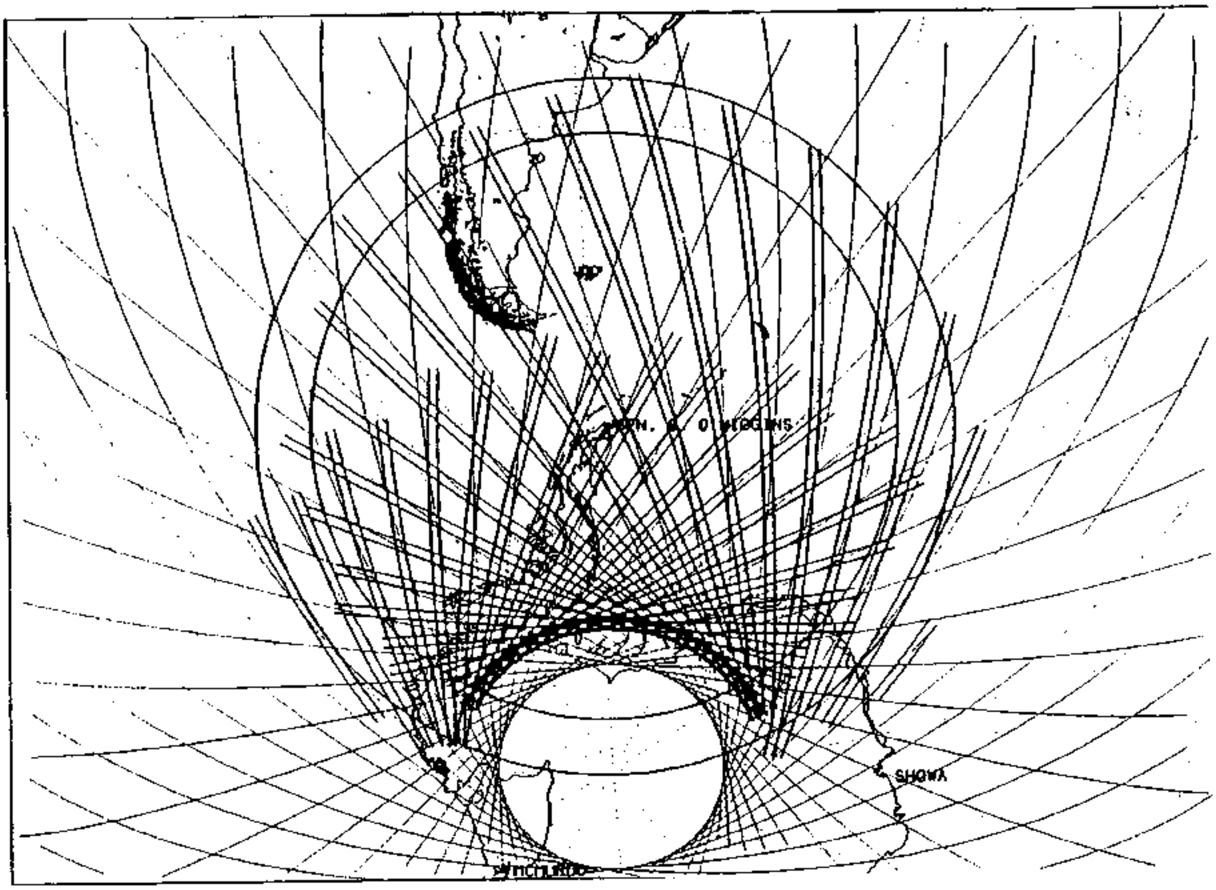


Figure 2. ERS-1 Visibility of the German Antarctic Receiving Station for 0° and 5° Antenna Elevation

2.2 Acquisition, Recording and Quick-look Processing of Remote Sensing Data and Star Signatures

The station, as outlined in Figure 3, shall acquire image data transmitted by remote sensing satellites, especially weather independant, high resolution ERS-1 SAR data of the Antarctic continent and its shelfice. In addition to that, it shall support measurements of the three-dimensional drift rate of the Antarctic continent, and thus close a long existing gap in the worldwide observation net for continental drift measurements and for earth ressources due to the reception. As a highly desirable derivative of these VLBI measurements, a change of the mean ocean sea level can be determined and may be applied in this context to research of the worldwide climatic change.

Furthermore, the station is designed to acquire as well Low Bit Rate (LBR) data from ERS-1 in an emergency back-up situation, in case the onboard recorders would fail and lead to a complete loss of LBR data over Antarctica. An upgrade to NOAA can be performed easily and at low cost. The raw data recording at the station is generally on magnetic tape. The processing of all data has to be performed at the relevant processing centers in Europe for ERS-1 and NOAA data and in the USA and Germany for VLBI measure-

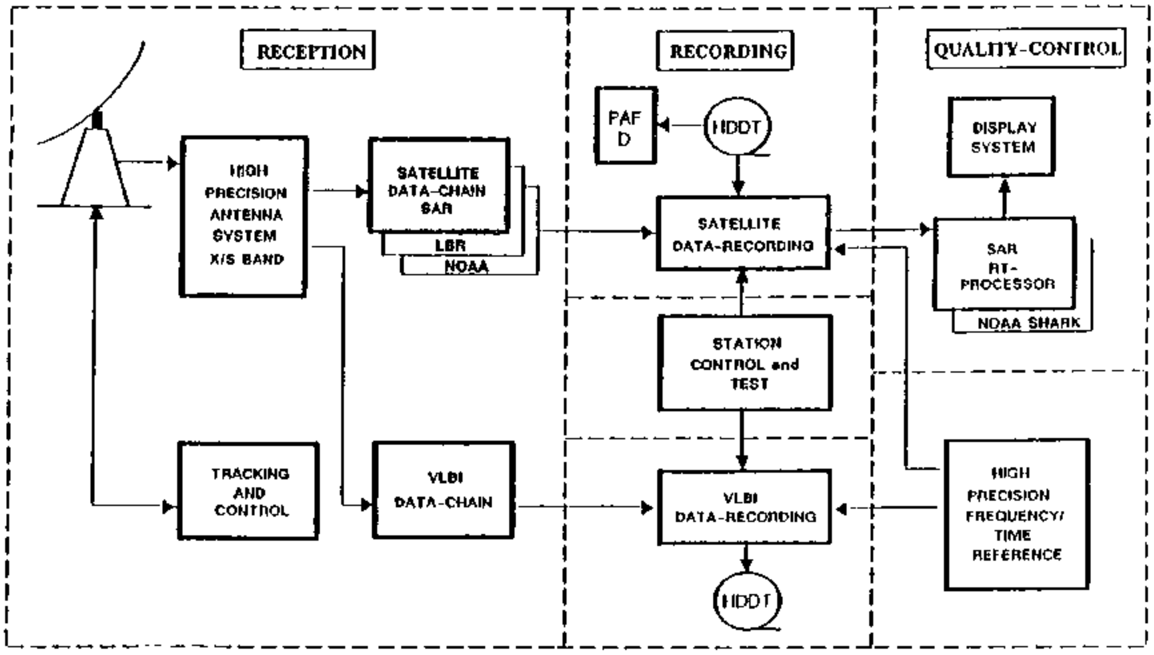


Figure 3. Functional Block Diagram of the German Antarctic Receiving Station

ments. However, quick-look products to be used for quality control and as fast delivery products are generated at the station. For the purpose of data acquisition a high-precision 9m, tiltable antenna system of the cassegrain type (fig.4) will be installed, covering the contradictional requirements of its application remote sensing data reception and star signature measurements in pointing (high angular movement for satellites, and very low movement at high precision for extra-galactic stars), and identical requirements for reception at X- and S-Band.

Due to the required accuracy of less than 1 millimeter phase delay of the incoming wave-front propagating to the feed, valid for the complete antenna aperture and for any pointing angle and windload the shaping must be very precise and stiff and the installation of a protective radome is prohibited. This requires unconventional methods of mechanical engineering, applying latest state-of-the-art technology, to operate and survive in the rough Antarctic climate, with wind speeds up to 70 m/s. To avoid ice accretition on the antenna structure, the back structure of the antenna dish is completely covered, the mount has a smooth surface without any sharp edges and the whole antenna has a special surface coating.

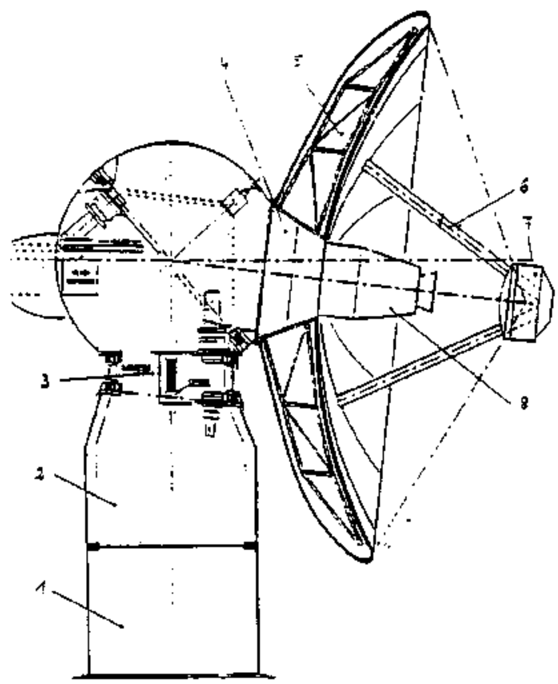


Figure 4. ERS-1/VLBI Antenna System

2.2.1 ERS-1 SAR and Low Bit Rate (LBR) Data

The reception of ERS-1 SAR and LBR data utilizes the X-Band channel. After down conversion, the raw SAR data will be recorded as serial bit steam on one of the two HDDT recorders. In parallel, the SAR data will be processed in real time by a dedicated Quick-Look SAR processor, providing images in reduced resolution on a display monitor and storing it as digital quick-look data on a WORM optical disk. In delayed time, images of higher resolution can be produced for immediate analysis, or for retransmission to DLR via a standard communication satellite channel. This option could provide to user community Fast Delivery Products, if required and still have to be investigated.

Low bit rate data can be simultaneously received and stored on a separate track of the HDDT recorder.

2.2.2 NOAA Advanced Very High Resolution Radiometer (AVHRR) Data

Data acquisition from the polar orbiting NOAA satellites is also planned. For L-Band data reception, the antenna system can be used with reduced efficiency, but still providing sufficient margin for errors less acquisition. Tracking, however, is only possible in program track (ephemeridic data) mode. No operational constraints are expected. The standard tracking receivers will be used for reception and for recording the ERS-1 LBR HDT recorder will be utilized, thus causing no additional costs for NOAA data acquisition.

NOAA data will be processed on the stations' control processor applying the existing ESA SHARK software [4], which includes DLR's acquisition software. For archiving, the above mentioned optical disk can be used. NOAA data processing and archival then becomes fully compatible with ESA and DLR standards.

2.2.3 VLBI Measurements

The reception of radio signatures from extra-galactic stars will be performed by the same reception channel. However, data processing requires completely separate equipment. The noise signatures will be split into 28 different channels of 2 MHz bandwidth each, and then recorded on a specialized tape recorder. The required high precision time correlation is performed by an H-Maser for exact relative time reference (10^{-14}/sec), a high performance Cesium clock for absolute time reference and GPS reception for the time transfer.

2.3 Future Upgrade Capabilities

The German ERS/VLBI Antarctic Station will be fully compatible with existing and future earth resources satellite system, in order to give a continuity in the system operation for the planned life time. Therefore, upgrades for future systems can easily be implemented. Basic upgrades are limited to reception frequency channels, dedicated signal demodulators, recording of higher bit rates, and dedicated SAR processing. In the station concept, upgrade possibilities for J-ERS, RadarSat, SPOT, LANDSAT and the future Polar Platforms are already envisaged. However, such upgrades will only be implemented if required by users.

AIR CUSHION VEHICLE TRANSPORT IN ANTARCTICA:

FROM CONCEPT TO REALITY

Presented on:
17 July 1990
SYMPOSIUM ON ANTARCTIC LOGISTICS AND OPERATIONS
SAN PAULO, BRAZIL

Prepared by:
Bruce W. Winter
United States Antarctic Program

AIR CUSHION VEHICLE TRANSPORT IN ANTARCTICA: FROM CONCEPT TO REALITY

Bruce W. Winter
United States Antarctic Program

ABSTRACT

This paper involves the search for an improved means of ground transportation in the Antarctic environment. It starts with a concept to improve the mobility of science researchers utilizing a surface vehicle as opposed to the more expensive aircraft. A review of reports on air cushion vehicle studies, along with the site inspection reports, will be made. The outcome of these studies, which was the solution to our search, will be presented.

The paper will also consider the design criteria that went into selecting an air cushion vehicle and its delivery at McMurdo Station, Antarctica. The arrival of the air cushion vehicle was only the beginning. An evaluation and operational plan to use this unique vehicle had to be developed. A summary of the operational statistics and review of some of the missions accomplished by the vehicle will be made in conjunction with a slide presentation of actual missions in the McMurdo area.

The travel location capability in regards to surface conditions encountered will be covered in the paper. A review of modifications made to the existing vehicle and changes recommended for future air cushion vehicles procured for Antarctic research to expand its operational capabilities will be included in the presentation.

The conclusion will show that the air cushion vehicle is a means by which science researchers and logistical support can have increased mobility over the Antarctic terrain. This is accomplished with improved safety for its users and with little or no operating cost increase.

THE CONCEPT

Transportation in Antarctica has always been a major consideration when exploration of the Continent has been undertaken. The need for dependable and swift transport over the long distances from base facilities to scientific work sites have taken many forms over the years. The progression from dog sledges to mechanized vehicles increased travel speeds. However, the terrain and surface conditions become a factor as speed increases.

Todays tracked vehicles are capable of traveling on unprepared surfaces in relative comfort due to improved suspension systems. However, the realistic traverse speeds are still in the 8 to 15 miles/hour (13 to 25 kilometer hour range).

The need for a means of transport that could increase mobility had been sought after for many years. The introduction of the helicopter answered many of these problems. The helicopter proved a means of rapid transport to locations that were previously thought impossible to reach. The helicopter became the preferred mode of transport for the science community. As exploration of the Continent continued, the demands placed on the helicopter support increased to a point where severe restrictions had to be placed on helicopter use. Scheduling of time became a major task and advance approval of time allocation became a major factor in planning a science groups season. The answer to this dilemma could not be the procurement of additional helicopters due to their high initial cost and the continued extensive maintenance programs.

The need for an alternative transportation system became critical in the mid-1980's. All participating organizations in the United States Antarctic Program (USAP) began researching vehicles and transport equipment. The criteria was rapid movement of personnel and cargo over long distances in safe and relative comfort. After reviewing the product lines of conventional vehicle manufacturers the outlook did not look promising. Then, reports were found from the mid-1970's that the U.S. Army Corps of Engineer at the Cold Regions Research and Engineering Laboratory (CRREL) had performed ACV evaluations in the Arctic. Conclusions of these reports were not all that optimistic for the craft tested but the concept was ideal for the transport being researched. The advantage of not having contact between the vehicle and the terrain surface was ideal as long as maneuverability could be kept within reasonable control. Investigation showed that improvements had been made in the aerodynamic means (ducted propeller, rudder, elevators, and skirt shift mechanisms) of providing directional controls since the CRREL reports were prepared.

Discussions between the National Science Foundation (NSF) and ITT Antarctic Services, Inc. (ANS) began for the investigation and evaluation of ACV's currently being produced. After examining the various ACV configurations being produced by manufacturers around the world, the Hover Systems, Inc., (HSI) of Eddystone, Pennsylvania was awarded a contract to build a Husky Model 1500 TD Hovercraft for evaluation and operation in Antarctica.

AIR-CUSHION VEHICLE PROGRAM

Construction and Delivery: Construction of the ACV began in July of 1987 and was completed four months later in November. The craft required extensive modifications from the original design to meet the challenges of operating in Antarctica. The United States Coast Guard is the governing organization for ACV's in the United States. The craft was built to meet or exceed all Coast Guard requirements and was required to pass operational certification tests.

Performance evaluations and certification began in late November. HSI's test site on the Delaware River provided water, mud and land evaluation sites to test the maneuverability and stability of the craft. The craft exceeded the design parameters in all categories and testing was completed in the middle of December. Disassembly, packaging in a 40-foot mil-van, and shipping was completed in time for vessel delivery to McMurdo Station, Antarctica in late January.

Operator Training: Extensive operator training is required to operate the ACV. HSI provided a three week U.S. Coast Guard certified "Hovercraft Operators Training Course" on the Delaware River and a supplemental trip to Antarctica for the initial "start-up" of the program to meet this requirement. In 1989, a one week repair and maintenance class was added to the course requirements for personnel who had already completed a one week course on the engine by its manufacturer. Also added was a navigation and radar operation course to familiarize the operators with the on-board specialty instrumentation. To-date, there have been 13 individuals trained as operators. However, only two operators are selected each year as designated operators.

All operators undergo further training sessions and familiarity training in Antarctica. Several days of training are completed prior to the operational season "start-up" and continues through the season as scheduling permits. Since the "back-up" hovercraft operators have other primary job responsibilities, training on their normal day-off in the work week is performed.

Hazardous Cargo Transport: Concern for the transportation of hazardous cargo required for scientific work was addressed with the assistance of the Marine Technical and Hazardous Material Division of the U.S. Coast Guard in Washington, D.C. The craft was licensed as a "Research Vessel" by the U.S. Coast Guard. This permits carrying most hazardous cargo above deck or in the open cargo bay. Special containers were fabricated to safely package hazardous cargo for transport. A "Hovercraft Operations and Safety Guide" was written to provide hazardous cargo handling procedures as well as other necessary information to users of the ACV.

Mission Tasking: The planning season starts early in May with initial requests for time allocations for the ACV from the science community. Time allotments are given for the science groups planning purposes. When science groups arrive to begin work at McMurdo Station, "Hovercraft Support Request" forms are completed by science group personnel which state time requirements, locations, number of passengers and cargo. These are then reviewed by the NSF for approval and given to the support contractor to implement.

On the designated day of the mission, the group assists the ACV operators in loading cargo. A briefing is then given by the operators to the passengers on conduct and features of the craft. Once underway, the ACV operators have the final say involving mission operations or the abortion of a mission.

Facilities: The ACV is housed in a warehouse on a tractor–trailer flat bed for the winter season. In early October, the craft is moved to a parking pad along the McMurdo Sound shore line. There is no protective structure for the ACV during the operational season. The craft sits outdoors on the prepared pad with tie–down straps attached to dead–man anchors frozen into the soil to ensure craft safety during high winds. Electrical service for craft preheaters and maintenance are available at the pad. A fuel storage tank and a small storage container are also at the pad site. At the beginning of each season and after major snow storms, the transition ramp between land and the sea ice is prepared by mechanized equipment.

Tidal cracks along the shore line has made continuation of ACV operation impossible after late December for the last two years. The parking location has had to be moved to Williams Field. This area is on the Ross Ice Shelf about eight miles (13 kilometers) from McMurdo Station. Vehicle transportation is frequent to this location since it is the air operations base. The facilities are essentially the same as those found at the McMurdo site.

Operations from the McMurdo site are on the sea ice mostly in the early part of the season. Late season work seems to be mostly on the Ross Ice Shelf. A transition is prepared or a natural ramp is found for access between the two sites during the entire operational season.

Maintenance and Repair: The first season the operators were not trained as mechanics. The maintenance work was the responsibility of the Vehicle Maintenance Facility (VMF) staff. This added responsibility, along with the diversification of repairs to other vehicles and equipment, did not provide the response time required to keep the ACV always on schedule.

The second year, the operators selected could also perform all mechanical maintenance and repairs with the exception of major engine failure. The maintenance and repairs are performed at the parking pad. Only in the event of a major component failure would the craft be taken into the VMF.

The designated operators and the VMF personnel are cross–trained in operation and repair techniques. This has proven beneficial to the program in maintaining a reliable transportation system.

TERMINOLOGY

The ACV is considered an amphibious craft, therefore, it uses many nautical terms. However, the operation of an ACV brings with it an additional new set of terms for describing its components and how it operates. To assist in understanding this terminology, listed below are a few definitions for the terms used in this paper.

Skirt – The rubberized material at the base of the craft which contains the air required to lift the craft.

Loop and Segment Type Skirt – Around the hem of the skirt are attached a number of individual segments to seal the lower part of the skirt system and provide flexibility in the horizontal plane. The segments form a loop that traps the air pressure under the craft. The geometry of this system contributes to the lateral and longitudinal stability allowing the craft to negotiate uneven surfaces.

Skirt Shaft: – To move the skirt from side–to–side off its central position. The shifting of the skirt allows the center of pressure of the air cushion to be moved horizontally to trim the craft laterally and allow it to bank.

Skirt Shift Mechanism: A large number of short links between the hull and the flexible segments connected by cables and bell crank levers on each side of the craft. A cable between the bell crank and the bow passes over an electric winch drum. An electric switch at the operators steering yoke controls the directional rotation of the winch pulling the skirt from side–to–side.

Hover: – To have the craft suspended above the air pressure being forced below.

Hover Height/On Hover: – To have the craft lifted off the surface at any height up to its maximum hover height.

Getting Over the Hump: – The speed at which the craft is on full hover and has minimal frictional contact with the surface.

Hump Speed: – Any speed at which the craft gets over the hump.

ACV DESCRIPTION

The ACV, in current operation at McMurdo Station, Antarctica, is a Hover Systems Husky Model 1500 TD hovercraft. The design is a well refined but simplified ACV. The design combines recent developments in diesel technology with a fully amphibious hull utilizing the latest in skirt designs. This combination produced a craft that is fuel efficient, economical to maintain, and easily operated after proper training. The general characteristics of the Husky 1500 TD are as follows:

Length (off hover)	32 ft. 10 in. (10 meters)
Width (off hover)	12 ft. 5 in. (3.8 meters)
Height (off hover)	8 ft. 8 in. (2.7 meters)
Hover Height	15 inches (5.9 centimeter)
Maximum Gross Weight	10,660 pounds (4,835 kilogram)
Rated Payload (Standard 2 crew with 16 passengers or cargo)	3,307 pounds (1,500 kilogram)
Antarctic Payload (10 passengers or cargo, balance of rated payload used for craft modifications and survival gear)	2,000 pounds (907 kilogram)

The propulsion comes from an air cooled turbo-charged Deutz diesel type BF6L913C engine. The direct injection diesel has a rating of 180 hp (141 KW) at 2500 RPM. The engine is coupled to a simple transmission at the rear.

A commercial vehicle type clutch permits the drive to the propeller to be disengaged for hovering. The output shaft from the clutch is fitted with a sprocket and toothed drive belt, transmitting power to the upper propeller shaft. The fixed pitch, four bladed propeller is mounted in an aerodynamically shaped duct. Three rudders mounted in the slipstream of the propeller duct provide directional control and four elevators provide pitch control. The entire propulsion unit can be removed easily on a unitized machinery frame which is supported by the longitudinal members of the primary structure. Individual components may also be removed independently for minor maintenance and repair.

The centrifugal lift fan is driven from the forward end of the engine crankshaft through sprockets and a toothed belt. This permits the lift air flow to be controlled by the engine RPM. The high volume, low pressure air is contained under the craft by the flexible skirt of the loop and segment type attached around the periphery of the crafts hull. A simple mechanism is attached to the skirt system (**SKIRT SHIFT MECHANISM**) which assists lateral trim and maneuverability by changing the geometry of the skirt. This permits the craft to bank into its turns.

The primary hull structure is fabricated of welded, marinized aluminum, with bonded and riveted aluminum top sides and gunwale. The hull has four main bulkheads in addition to two longitudinal members enclosing watertight compartments. The forward and aft bulkheads carry watertight, bolt on, bow and stern extensions. The secondary structures along each side of the primary hull (wings) may be hinged upward for transport.

Fuel for the 10 hour operational range of the craft is contained in bow and stern mounted tanks equipped with fuel cell bladders for added safety. The movement of fuel between these tanks is accomplished by two electrically driven pumps which can also be used to trim the craft longitudinally as needed.

ACV MODIFICATION

The USAP has learned over the years that extensive cold weather modifications are required to standard production vehicles and equipment when they are to be used in Antarctica. The ACV was no exception. Considerable investigation went into the preparation of specification changes for the craft. A few of the modifications and additions follow:

a. Installation of aluminum skids on the underside of the hull.

b. Increased thickness to the aluminum sheeting on the underside, a sort of "armored" hull.

c. Heaters for the engine oil, battery boxes, fuel lines, windshields, and two very large capacity personnel heaters.

d. Natural rubber used for both the skirt system and the drive belts.

e. A 600 lb. capacity Davit (crane) was designed to allow the lifting of typical payloads such as a 55 gallon fuel drum or a snowmobile.

f. A removable roof over the rear third of the cargo and passenger compartment for carriage of large cargo.

g. Installation of a small marine surface navigation RADAR.

h. A spray skirt was added over the skirt system to reduce blowing snow.

Since delivery of the craft additional modification and equipment have been added. They include:

a. Installation of two aircraft type gyrocompasses.

b. Installation of a VHF and an HF radio.

c. Installation of a single-channel radio telephone link. **(This permits direct dialing into the McMurdo Station telephone system.)**

d. Installation of a radio directional finder.

e. Installation of a satellite navigational system.

f. Stiffening reinforcement of the machinery frame supporting propulsion components and adding adjustable belt tensioners.

g. Procurement of a fully reversible variable pitch propeller. This will allow control of propulsion thrust independent from lift height pressure. Plans are to install this system during the 1990/1991 summer season.

PERFORMANCE EVALUATIONS

The ACV's operational performance was evaluated by conducting tests for several standard performance test as well as some special tests. The results of these tests were obtained over two seasons of operation, under varying weather conditions, varying loads, and by different operators. However, each test was completed within the same day and with the same operator so the results within a test were comparable. The procedure, conditions and results of each test follow.

Craft Speed – The speed of the craft was tested by operating it through a designated course and speed was measured with a radar gun aimed at the craft from a fixed position alongside the course. On the day of the test, a wind speed of eight knots was present. To compensate, the craft was operated directly into the wind and running with the wind. Surface conditions were hard packed snow. The results were as follows:

ENGINE RPM'S	SPEED AGAINST THE WIND	SPEED WITH THE WIND	AVERAGE SPEED
1800	Stalled	12 MPH (19.3 K/H)	6 MPH (9.7 K/H)
2000	14 MPH (22.5 K/H)	22 MPH (35.4 K/H)	18 MPH (29.0 K/H)
2200	18 MPH (29.0 K/H)	37 MPH (59.5 K/H)	27.5 MPH (44.3 K/H)
2400	28 MPH (45.1 K/H)	44 MPH (70.8 K/H)	36 MPH (57.9 K/H)

STOPPING DISTANCE: – Stopping distances were evaluated by both the spin–out and propeller clutch disengagement methods. An evaluation using the spin–out method for stopping was conducted by operating down a designated course and spun 180 degrees to reverse the propeller thrust. The winds were calm and light snow was falling. Surface conditions were smooth ice covered with light powdered snow. The results were as follows:

ENGINE RPM'S	SPEED OF CRAFT	STOPPING DISTANCE
1900	12.5 MPH (20.1 K/H)	180 Feet (54.9 Meters)
2000	17.5 MPH (28.2 K/H)	234 Feet (71.3 Meters)
2100	20.0 MPH (32.2 K/H)	300 Feet (91.4 Meters)
2200	23.75 MPH (38.2 K/H)	350 Feet (106.7 Meters)
2300	26.25 MPH (42.2 K/H)	450 Feet (137.2 Meters)

The second evaluation for determining stopping distances used the propeller clutch disengagement method. This method allows the craft to coast until it comes to a stop. The evaluation was performed in conjunction with the speed trials. An eight knot wind was present with surface conditions of hard packed snow. The same course was used running an up wind/down wind comparison test to provide an average stopping distance. The results are as follows:

ENGINE RPM'S	SPEED AND STOPPING DISTANCE AGAINST THE WIND	SPEED AND STOPPING DISTANCE WITH THE WIND	SPEED AND STOPPING AVERAGE
1800	Stalled	12 MPH/30 Ft. (19.3K/H-9.1M)	6 MPH/15 Ft. (9.7K/H-4.6 M)
2000	14 MPH/75 Ft. (22.5K/H-22.9M)	22 MPH/500 Ft. (35.4K/H-152.4M)	18 MPH/257.5 Ft. (29.0K/H-78.5M)
2200	18 MPH/400 Ft. (30.0K/H-121.9M)	37 MPH/1100 Ft. (59.5K/H-335.3M)	27.5 MPH/750 Ft. (44.2K/H-228.6M)
2400	28 MPH/550 Ft. (45.0K/H-167.6M)	44 MPH/2000 Ft. (70.8K/H-609.6M)	36 MPH/1275 Ft. (57.9K/H-388.6M)

SAR ADOPTABILITY: – A Search and Rescue (SAR) evaluation was staged from Williams Field to the Windless Bight area. Three SAR team members, two hovercraft operators and one medical representative conducted the evaluation. The wind speed was five knots and the travel route was over hard packed snow.

The ACV was configured in its "pick up truck" mode. This means that the aft half of the passenger cabin was removed exposing the cargo bay area. A piece of 3/4 inch (19MM) plywood was layed across the top of the cargo bay and a Bombardier Elan snowmobile was placed on it. Although one Elan snowmobile would fit in the cargo bay, the plywood eased the loading of the snowmobile, provide additional rescue gear storage and also provided a second litter location under the plywood.

The three major concerns in using the ACV for this SAR exercise; the skirt could be damaged when loading a snowmobile, the adverse effect of a higher center of gravity due to carrying the snowmobile on maneuverability, and difficulty in loading a litter into the craft proved of little concern. The light weight Elan snowmobile (285 pounds) can be picked up by several fit individuals and loaded onto the plywood. This meant the snowmobile did not have to be along side the skirt for davit loading. There was little effect felt in maneuverability keeping it well within safe operating limits. The loading of patients onto litters was performed into the forward cabin and into the cargo bay. With the rear cabin hatch open, heat from the forward cabin kept passengers in the cargo bay under the plywood at a comfortable temperature.

<u>SEA TRIAL EVALUATION TEST</u>: – A sea trial of the ACV over open water in the Ross Sea was completed on 29 January 1990. **(The ACV underwent Coast Guard Certification Tests over water before shipment by the manufacturer.)** As part of a complete evaluation of the design and concept of use for this craft, the sea trial showed us the practicability to operate over open water and also the working limitations.

There was bright sunshine and a temperature of 35°F on the day of the test. The wind was 5–7 knots with a calm sea. The sea temperature was 29.5°F. One concern was that the craft would experience icing either under the craft fouling the control cables or on the wings and propeller duct causing ice chucks to be pulled through the propeller. No icing was experienced on this day even though it's been found that the critical icing condition is normally just above freezing when our vehicles are moving. The spray skirt installed on the craft functioned extremely well allowing very little water spray onto the top surface of the craft. The air temperature increased only 3°F passing through the propeller duct as measured by thermometers placed at the entrance and exit of the duct. Three certified operators were on board the craft along with a full compliment of survival gear and full Coast Guard Regulation equipment for water operations. This gave the craft a load of approximately 600 lbs. for initial tests. It should also be noted that a light fuel load was on board.

The initial transition from ice to water was performed at 18 knots, well over "hump speed". This presented no problem to the craft. Several ice to water and water to ice transitions were performed during the sea trial. There was never any difficulty in transitions. The maximum ice lip found in McMurdo Bay was 10 inches (254 MM). Ice chunks blown back onto the ice edge in many locations did not present a problem because a clear area could always be found to transition.

The speed of the ACV in water was hampered by its ability to stay over hump speed. The craft was able to get over hump with relative ease going with the wind, but it was difficult to maintain hump speeds in a cross wind and virtually impossible when heading into the wind. Near full throttle of 2400 RPM was required to maintain hump speed. The fastest forward speed obtained was 18 knots.

The ACV was tested for its ability to achieve break away hump speed after sitting still in the water. A thorough draining of the skirt was performed by disengaging the propeller clutch and increasing engine RPM's so the lift fan could raise the craft out of the water. After draining was completed the clutch was engaged and full throttle was applied in an attempt to achieve immediate breakaway hump speed. This proved to be difficult and not often successful. It was found that the easiest way to obtain a breakaway was to cross an ice sheet (frequently found floating free after it broke away from the ice edge) and to transition across it for added lift off the ice surface.

The weight of the load was increased during the evaluation to determine its effect. It was found that 800 lbs. (362.9Kg) was the maximum weight for which the craft could maintain "hover" even after running with the wind. Increases in the load up to 1600 lbs. (725.7Kg) resulted in the craft being capable of operating in the displacement mode only. However, even with the full load, the craft was capable of making transitions at the ice edge when full throttle was applied.

ICE BREAKING CAPABILITIES: – The ACV was evaluated for its ice breaking capabilities. It efficiently broke ice 4 in. (10.2 CM) thick when on hover by hovering over the ice. Cutting the throttle to allow the weight of the craft to drop onto the ice would break 8 in. (203 CM) of ice.

FUEL CONSUMPTION: – An accurate fuel consumption evaluation has not been possible as yet due to lack of fuel metering equipment. However, operational records indicate that the fuel consumption averages approximately four gallons per hour (15.1 liters per hour). This is an improvement over the original anticipated fuel consumption of six gallons per hour (22.7 liters per hour).

NOISE LEVELS: – The noise level readings were taken using a decibel meter while the ACV was operating on a smooth snow surface at 2,000 engine RPM's. A reading of 78 dB's was recorded at the operators seat location in the craft. Only a slightly higher reading of 84 dB's was against the rear cabin firewell adjacent to the lift fan and engine bay. This upper level reading just approaches the industry standards for protective hearing devices. For comparison, all of the tracked vehicles tested that are used by our science groups operate in the 82 to 96 dB's range. Prolonged exposure for eight hours or more at these levels cause permanent hearing lost.

FUTURE EVALUATIONS: – Future testing and evaluations are planned for the ACV. A high lift fan and a high altitude compensated injection pump were designed and procured for evaluation of the craft at the South Pole Station. High altitude operations, if found feasible, would open the Antarctic plateau for research by ACV travel.

Additional maneuverability studies on both hard surface and over water would benefit future designs being considered. Turning radius, stopping distance and speed data needs to be collected in open water operations.

Lastly, the practical application of a ACV on the Antarctic Peninsula at Palmer Station needs to be studied. With open water around the station for the majority of the year, an ACV could give a sturdy work platform for science research on that part of the Continent.

OPERATIONAL HIGHLIGHTS

The ACV has performed many diversified missions since becoming operational. The missions could be summarized into three categories: **Close Support, Familiarization and Resupply.**

Close Support: – The hovercraft was used in many different ways as a close support vehicle. Compared to any other overland vehicle available in McMurdo, in most cases the hovercraft provided a faster and more direct route to the designated field site. Examples of close support operations follow.

1. Travel to a fish hut site approximately eight miles (13 kilometer) from McMurdo Station took over one hour to reach by tracked vehicle. The ACV could make a round trip in the same amount of time. The reduction in travel time reduced the amount of time specimens were on artificial life support systems.

2. A slow traverse of a nine mile (14.7 kilometer) stretch of ice edge to take a seal census and obtain age data on seal pups. This work was completed in one afternoon. The normal practice used snowmobiles and took two days to complete.

3. Field parties frequently take snow samples from the Ross Ice Shelf. The majority of travel to these sites is by helicopter. The helicopter scheduling does not provide ample close support time to recover samples. This means science groups are dropped off for later pickup. Difficulty in relocating field parties or weather conditions have frequently delayed pickups. The use of the ACV minimizes field party exposure to severe weather conditions. On one occasion in January of 1989, a science group traveling by ACV spent an overnight in the field collecting samples. The next day, surface definition on the return route became poor to nil. The ACV was able to return to McMurdo. If helicopter pickup had been required the science group would have spent four more days in the field.

4. Many biologist groups have used the ACV as a dive platform. The speed and comfort of the craft makes it possible to visit several sites in the same day. Divers change into their diving suits in the warmth of the cabin and frequently go off the side of the craft straight into dive holes. The former procedure used helicopters or tracked vehicles and required "suiting-up" in a tent.

Familiarization Trips: – The ACV was a new means of transportation to the McMurdo community. It was found that the best way to promote and encourage the use of the ACV was by demonstrating the capabilities to potential users.

The science community requested several familiarization trips to evaluate the craft's potential for biology, oceanography, and glaciology work. Advanced requests for the craft, in following years, show a favorable acceptance of the craft.

All science groups were favorably impressed by the smooth ride and speed of travel in comparison to other surface traverse vehicles.

<u>Resupply</u>: – The hovercraft proved to be a fuel efficient and expedient means to resupply field parties. Examples of this capability follow.

1. During the month of December, 1988, four trips were made to the Southeast side of Minna Bluff (in the vicinity of 78 45'S – 169E). At the completion of these trips, a 220 KM flagged route had been established and a double fuel cache set up for a field parties return trip to McMurdo. This 440 KM round trip distance took eight hours by ACV. The one–way return by the science group took 2–1/2 days by snowmobile.

2. During the first week of January, 1989, the ACV was the sole–support vehicle for a joint seismic project. Four trips were made to the seismic line over a seven day period delivering fuel, mail, radios, snow machine parts, and one day, a mechanic. Because the route used by the field party to reach their site was radioed back as being "unsafe", a new route was flagged by the ACV during the first resupply trip. By the end of one week, a safe route had been established for the return of the field party, fourteen 55 gallon drums of fuel had been delivered and 17 empty drums were retrograded.

OPERATIONAL TERRAIN AND SURFACE CONDITIONS

The first season, 1988/1989 of operation for the ACV, exceeded the proposed initial planned evaluation guideline. The craft soon proved its capability to negotiate the sea ice surfaces and started to range out on the ice shelf.

The second season, 1989/1990, saw a continuation of the expansion of job tasks placed on the ACV. Many of these tasks have taken the craft to new locations, some of which have proven the craft's capability to maneuver in areas thought impossible originally.

Surface conditions in which the ACV have operated include the following:

1. Smooth ice and hard pack snow surfaces are ideal for ACV operations. Fortunately, the majority of the annual sea ice and the Ross Ice Shelf present these operating conditions. Travel time is greatly reduced by being able to operate at near maximum speed.

2. Crevasses and tidal cracks require operational judgment to negotiate safely. The original operational theory was that the ACV would be capable of crossing open cracks up to a third the length of the craft. This has not proven out at slow maneuvering speeds. An incident near the landing pad for the craft found it losing sufficient lift over an 18 inch (70 centimeters) tidal crack. We then had to wait for high tide to move the craft. The speed of the craft over an opening determines the width capable of crossing. At cruising speed, openings of 4 feet (1.2 M) can be crossed with only a dip being noticed in the ride of the craft. The concern for passenger safety in the event of bottoming out or plough–in warrants an operators constant awareness and good visibility to perform operations in known crack areas.

3. Dry powdery snow increases the drag of the skirt. Experience during an 8 inch (20.3 centimeters) snow fall showed it required an additional 400 engine RPM's to maintain 18 knots of forward speed. The trim of the craft is also an important factor. A low angle acts like a plow pushing a berm of snow and eventually stopped the craft from forward movement. The spray skirt installed on the craft keeps almost all blowing snow created by the craft from causing visibility problems for the operators. Overall performance of the craft exceeded that felt possible in these conditions.

4. Ice surface melting occurs in late December through the remainder of the summer season. Dirt blown onto the ice is sufficient in many areas on the annual sea ice and in the areas of blue ice found on the ice shelf to create large melt pits.

   Two conditions can occur. The first is that the pits remain open and present the same problems as tidal cracks and crevasses. Some pits were 4 feet (1.2 meters) deep and up to 6 feet (1.8 meters) in diameter. Having to slow speed for maneuverability decreased the capability to cross this surface due to the loss of lift.

   The second condition found was when the pits became melt pools. The speed of the craft would increase with the water acting as a lubricant on the already slick ice surface. When the speed was reduced, the loss of lift caused the craft to bottom out.

   These conditions presented a real challenge in which to operate. The original design of the craft, with lift dependent on the engine speed and having a direct relation to forward speed, makes it almost impossible to safely navigate in these conditions. With the planned retro-fit of a fully reversing variable pitch propeller, it will become possible to travel into these areas late in the summer season.

5. Pressure bubbles in the ice and hummocks caused by the wind were encountered in the blue ice area of the Ross Ice Shelf. Some bubbles had heights exceeding 3 feet (.9 meters). The requirement for good visibility and slow maneuvering speed made these areas difficult in which to operate.

6. Undulating sea ice and wind blown rollers resembling frozen waves are frequently encountered. The height and wave length vary in different locations. The speed of the craft needs to be checked closely to keep the harmonics of the craft in control. In areas of large rollers, a directional heading at an angle over the roller was found to provide the safest ride.

7. Wind blown sastrugi and tidal crack ridges come in many different shapes and sizes on the sea ice. Small irregular drifting under the 15 inches (38 centimeters) of hover height present no problem, with virtually a smooth ride. Areas over 15 inches can be in the form of ridges or wind rows and be several feet high. Operator caution when navigating in these areas is required. Normally, a gentle sloped side can be found to cross or an angled approach will allow the craft to negotiate higher ridges.

8. Ice edge accumulations of trash ice and pressure ridges around land masses are frequent. Areas around Marble Point have for the past years, been heavily cluttered with trash ice which has made it virtually impossible to reach Marble Point. The maneuvering required is so slow that lift cannot be maintained. On one vehicle recovery mission this past season, the craft became high centered twice, requiring the assistance of additional manpower to move it off of a four feet (1.2/meter) high pressure ridge. Operations in this area is not practical with the present design of the craft. Even with the change over to the new propeller, travel speed and endangerment to passenger and craft can hardly be justified.

The few limiting ice and snow conditions can always be avoided given enough room for maneuverability. Surface conditions will change annually on the sea ice. The first season, the ice edge was only 5 miles (8 kilometer) from McMurdo Station. The second year, it was 40 miles (64 kilometers) and littered with trash ice for the last five miles to the edge.

Changes also occur throughout the season. At the beginning of the season, the sea ice is ideal for operating with exposed ice or slight snow packed conditions. Later in the season, melt pools, snow pits, and wet snow reduce the travel capabilities of the craft.

The surface changes have a great effect on location travel capabilities. Under ideal conditions frequent travel to the locations of New Harbor, Marble Point, Granite Harbor, Cape Evans and Cape Royds are well within the crafts capability. The first season, we could not reach Cape Evans or Cape Royds and we have as yet not been able to travel to Marble Point or Granite Harbor.

Even with all these factors in mind, the ACV is capable of coping with the constant changes in surface conditions. This was also accomplished at speeds not possible before by any surface traverse vehicle and at a much lower operating cost than a helicopter.

CONCLUSION

The acceptance of the ACV has been very good. It has provided a rapid means of surface transportation in comfort and safety no other vehicle can come close to. The craft design and construction has been proven sound and adaptable to the Antarctic environment.

Performance evaluations have exceeded the design criteria in almost all areas. The speed has exceeded the design speeds by 60% over smooth ice. The fuel consumption is 66% better than anticipated. The only area where additional investigations into craft design is required is in over water operations. The added weight to the craft for Antarctic modifications and equipment causes difficulty in effective use over the water.

The retrofit of the fully reversible variable pitch propeller will greatly increase the craft's capabilities. The present configuration of the engine RPM directly applied to the lift fan and propeller presented many drawbacks. Speed increases rapidly on an ice surface. To check the speed of the craft engine, RPM is reduced to reduce propulsion and increase skirt drag. The result is that you lower the hover clearance of the craft increasing surface contacts. The new propeller will allow a constant engine RPM to maintain full hover height while controlling speed with the pitch of the propeller.

The improved navigational and communication systems now installed on the craft gives a greatly enhanced support capability. The craft can operate in "white out" conditions when aircraft are grounded. The only operational limitations are high winds, but even the design parameters of 25 knots have been exceeded by operating safely in 40 knot winds.

Cooperation of all organizations in the USAP has been excellent. Special recognition to the five designated operators; Lou Czarniecki, Sarah Krall, Aaron Walters, Ray Miller and Dale Woolet is required for their efforts in making this transportation system a success.

The ACV answers the concept design challenge and is a reality in current operation. Already, lessons have been learned which have allowed upgrades of the craft. Future crafts could be built to new design specifications which would further improve operational capabilities. The future looks bright for continued ACV operations in Antarctica.

REFERENCE AND SOURCE MATERIALS

Reports

Ronald A. Lister, Observations of Surface Effect Vehicle Performance, April 1973 Corps of Engineers, U.S. Army,Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, 03755.

Ronald A. Lister, Operational Evaluation of the SK-5 Air Cushion Vehicle in Alaska, September 1973, CRREL.

K.F. Sterrett, The Arctic Environment and the Arctic Surface Effect Vehicle, January 1976, CRREL.

Gunars, Abele and Ronald A. Lister, Air Cushion Vehicle Ground Contact Directional Control Devices, December 1976, CRREL.

J. Stephen Dibbern, The Introduction of Air Cushion Vehicle Operations at McMurdo Station, Antarctica, December 1988, U.S. Army Foreign Science and Technology Center, 220 7th St., N.E., Charlottesville, Va., 22901.

Harvey C. Cook, Hovercraft Experiences in Antarctica, September 1988 and 1989 Update, Hover Systems, Inc., Eddystone, Pa., 19013.

Lou Czarniecki, Hovercraft Operations End of Season Report, 1988/1989, ITT Antarctic Services, Inc., Paramus, N.J., 07652.

Aaron Walters, Hovercraft Operations End of Season Report, 1989/1990, ITT Antarctic Services, Inc., Paramus, N.J., 07652.

E. "Mickey" Finn, Personal Log and Remembrance of Antarctic Experiences, 1980 to 1990, ITT Antarctic Services, Inc., Paramus, N.J., 07652.

Bruce W. Winter, Personal Log on Antarctic Experiences, 1986 to 1990, ITT Antarctic Services, Inc., Paramus, N.J., 07652.

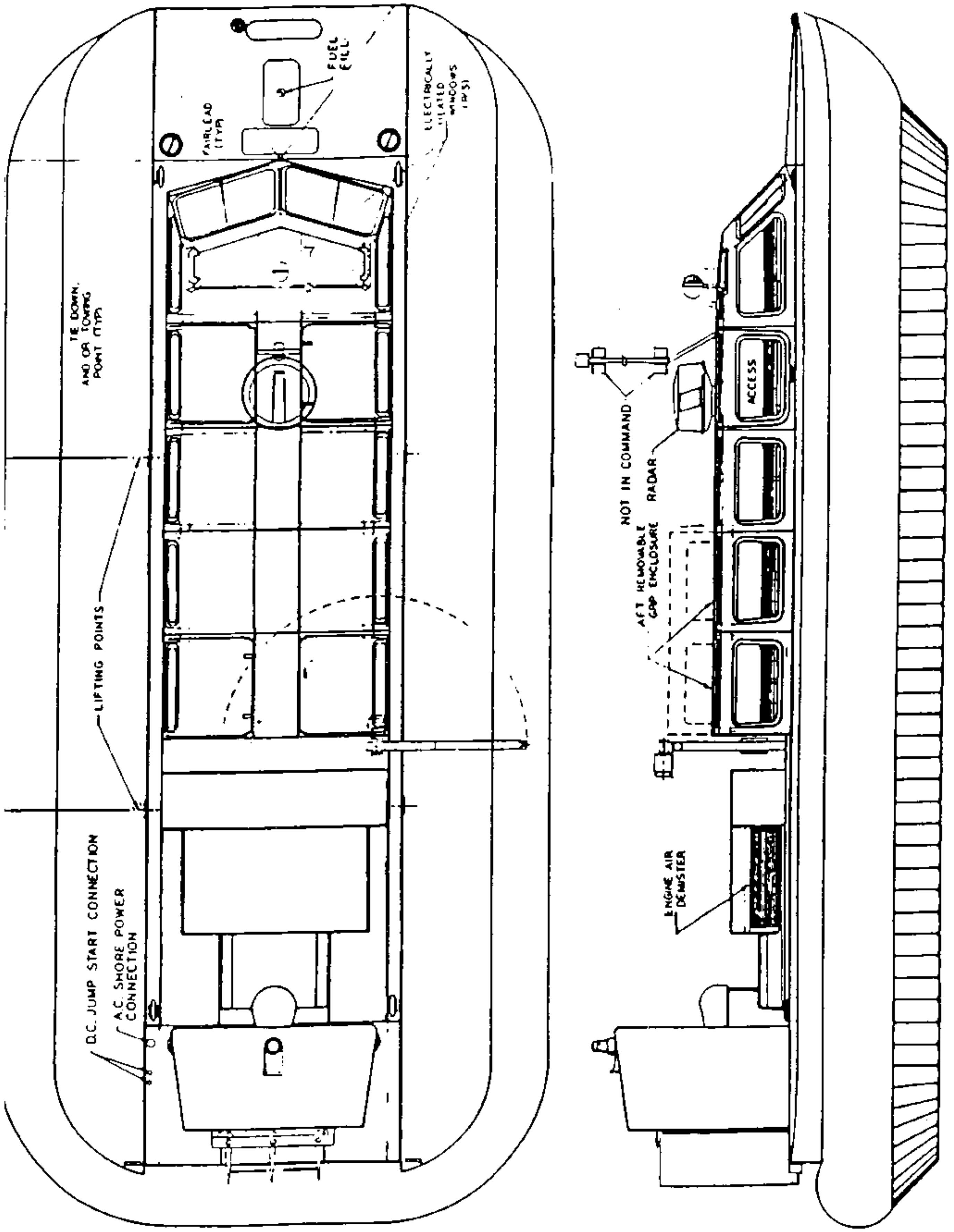
Photo Credits

Aaron Walters, Major contributor from personal collection.

Lou Czarniecki, Selected photos from personal collection.

Bruce Winter, Selected photos from personal collection.

0466d/dc


FUEL FILL
FAIRLEAD (TYP)
ELECTRICALLY HEATED WINDOWS (P/S)
TIE DOWN AND OR TOWING POINT (TYP)
LIFTING POINTS
D.C. JUMP START CONNECTION
A.C. SHORE POWER CONNECTION
NOT IN COMMAND
RADAR
AFT REMOVABLE GRP ENCLOSURE
ACCESS
ENGINE AIR DEMISTER

Antarctic Fields

by

Mellor, M. [1)]

Abstract

Following a summary of recent U.S. air activities in Antarctica, aircraft runways are considered. Various airfield options, from open-field landings to conventional paved runways are dealt with, the relevant factors being given in tables that cover (a) construction and maintenance and b) operations. Bearing capacity, rutting resistance, surface roughness and runway dimensions are discussed. It is concluded that a system of hard-surface runways for conventional aircraft is technically feasible.

Recent U.S. Activity

The USAP enjoys a high level of air support, with frequent flights to and from Antarctica, air access to virtually all parts of the continent, and intensive helicopter operations. In October, November and early December, large conventional transports (C-130, C-141, C-5) use a hard-surface runway on annual sea ice at McMurdo Station (Barthelemy, 1990). Thereafter, all flights to and from Antarctica are by ski-wheel LC-130 aircraft, which use a skiway airport near McMurdo. Internal flights that involve landings are mainly by LC-130 ski-wheel aircraft, with occasional operations by smaller chartered DHC-6 ski-wheel aircraft.

In anticipation of extended seasons and expanded operations, compacted snow runways for large wheeled aircraft were considered by the USAP in 1987 and CRREL was asked to make feasibility studies near McMurdo and at South Pole (Mellor, 1988). Given the types of aircraft that were to be used, the equipment and logistic facilities that were available, the prevailing site conditions, and the desire for all-season access, compacted snow runways were not deemed to be feasible over the short term. Alternatives were then investigated.

As an alternative to freight deliveries to South Pole by the expensive, highly-specialized, and heavily-committed LC-130, natural "blue ice" airfields were sought in southerly parts of the Transantarctic Mountains (Swithinbank, 1989; Mellor and Swithinbank, 1989), the idea being to complete the freight and fuel deliveries by overland sled trains into Pole. In 1988/89 a large expanse of blue ice was found 160 n.m. from the Pole (at Mount Howe), and an excellent blue ice "alternate" was found on a direct line between McMurdo and Pole (on Mill Glacier, near Plunket Point). Another possibility considered for Pole was air-

1) Cold Regions Research and Engineering Laboratory, Hanover/USA

drop by wheeled transports, the method used when the first Pole station was built.

At McMurdo, the first need is for extension of the wheel-aircraft season from mid-December to early March, with an ultimate goal of all-season access by conventional aircraft. From a technical standpoint, the needs could best be met by a conventional rock-fill runway, 10,000 ft (3 km) long, built at Marble Point, about 45 n.m. from McMurdo Station (Mellor, 1988). In 1988/89, previous engineering and environmental studies of this site were reviewed, additional site studies were made, and a construction plan was outlined. Since an airfield at Marble Point is not an ideal practical solution for the short term, alternatives were sought. In 1989/90, an experimental runway was built on the Ross Ice Shelf, at the westward extremity of the snow accumulation area, some 7 n.m. from the base. At this location, a thin layer of snow can be compacted against the underlying hard ice. The snow pavement (~0.1 m thick) is easy to grade and it protects the underlying ice against radiation melting (which led to the demise of an earlier blue-ice runway in the nearby area of net ablation). Full-scale tests are planned for October/November 1990, with a view to possible limited operation in February 1991.

During an engineering survey of Palmer Station in December 1988, possible sites for a hard-surface runway were reconnoitered. Although there is no intention of building a runway for Palmer, a rock-fill runway, up to 6,750 ft (2 km) long, could be built in the Joubin Islands, about 9 n.m. from the station. Small low-lying islands could be leveled and linked by filling the shallow water gaps that separate them.

For safe, effective and economical operation of conventional aircraft in Antarctica, multiple hard-surface airfields are needed. Ideally, these should be at strategic locations throughout the continent, distributed so as to provide emergency alternates and a basic transport network using wheel aircraft. Information on the airfield resources of other Antarctic nations was sought, and possibilities for new airfield sites were explored (Budd and Russel-Head, 1990).

Details for most of these technical studies are recorded in recent CRREL reports (see references). General notes on Antarctic aviation (Mellor, 1990) have been distributed at this meeting in the hope of gaining additional information. After correction and amplification, these notes will also be recorded in a CRREL report.

Airfield Options

In principle, a specially modified aircraft such as the LC-130 can land almost anywhere in Antarctica at almost any time, making open-field ski landings on unprepared snow, or using groomed skiways. For unmodified aircraft with standard wheels, various types of runways can be prepared on snow and ice. Annual sea ice is usually flat and smooth; it can be used after snow-removal, provided that the thickness is adequate and high-temperature deterioration has not set in. Multi-year ice tends to be thicker and more stable; the relatively rough surface is likely to need planing, and large permanent snowdrifts can build up. Compacted snow runways can be built in some locations, but bearing strength and rutting resistance are likely to be inadequate for most types of aircraft, especially in summer. Snow-free "blue ice" can provide natural hard-surace airfields, with all-season availability if there is no significant summer melt. The blue ice of coastal ablation areas is likely to be unsuitable for summer use. However, accumulation/ablation transition zones may permit a thin snow cover to be compacted over hard ice, giving the potential for all-season wheel operations. Gravel and rock fill can be spread on glacier ice to form a runway, but the method is only advantageous under very special circumstances. Conventional rock-fill runways, with or without paving, can be built at suitable sites; initial cost is high but long-term value is great. Expedient runways built with manufactured landing may seem unattractive in terms of cost, logistic effort and durability.

Table I gives a summary of the factors that have to be considered in assessing the various airfield options. More detailed information, together with examples of the various types of airfields, are given elsewhere (Mellor, 1990).

Bearing Capacity, Rutting Resistance and Surface Roughness

Any runway, whether on ice, snow or rock, has to be: 1) strong enough to support the aircraft that use it, 2) hard enough to avoid the formation of wheel ruts, 3) smooth enough to avoid damage to the aircraft and distress to the pilot.

Bearing capacity

The bearing capacity of a runway is determined by the flexural strength of the pavement slab and by the penetration resistance of the underlying subgrade material. The most critical factor in the design and operation of a runway is the weight of the aircraft and the way that weight is transferred to the surface of the runway. In general the upper limit for an aircraft would be characterized by its maximum ramp weight, which can exceed the maximum gross takeoff weight, but in typical Antarctic operations it might be rare for an aircraft to be loaded to that upper limit. Most of the weight is carried by the main landing gear (MLG); the nosewheels typically carry no more than 5 % to 8 % of the total load.If the main wheels are close together (relative to the pavement thickness), the patterns of deflection that they produce overlap, and in the limit the MLG approximates the behaviour of a "point load". If the main wheels, or mainwheel clusters, are far apart (again relative to pavement thickness) then they tend to produce independent patterns of deflection, thus easing the tendency to break through.

Table I. Airfield options for Antarctica.
Part A: Construction and maintenance.

Type of airfield	*Site characteristics*	*Construction method*	*Maintenance*	*Examples*	*Environmental impact of construction and maintenance*
Unprepared open field.	Any deep and level snowfield or snow cover, provided roughness is not extreme.	None required.	None.	Throughout Antarctica.	None.
Groomed skiways.	Any deep and level snowfield or snow cover.	Grading, dragging, chaining to smooth the surface. Compaction in soft-snow areas. Runway markers.	Periodic repeats of of initial procedures—at least annually.	Full-time summer operation, regular maintenance: Williams Field (10,000 ft), South Pole (14,000 ft). Irregular operation, occasional maintenance: Palmer (5,000 ft), Byrd (10,000), Neumayer (3,300 ft), Rothera, Fossil Bluff, Arturo Prat, Carvajal.	Insignificant at temporary skiways if all markers and materials removed. Potential for irretrievable liquid spills at permanent skiways. All visible evidence soon disappears.
Compacted snow runways (deep snow).	Deep perennial snowfield that is level and has low accumulation rate. Summer temperature approaching 0 C desirable.	Summer compaction at sites where snow becomes cohesive without suffering excessive ablation. No fully acceptable methods for construction on cold, dry snow.	Conversion of annual accumulation to hard pavement.	Molodezhnaya, Novolazarevskaya, Vostok, Progress.	Compaction process per se is innocuous. Potential for irretrievable liquid spills. All visible evidence soon disappears.
Compacted snow on hard ice.	Transition zone between accumulation and ablation areas (crevasse-free). Snow cover on sea ice.	Depending on site conditions: (a) Bulldozing to plane ice surface and mix snow. (b) Spreading snow uniformly. (c) Compacting and grading. (d) Surface grooming.	Annual re-grading. Periodic surface grooming.	Pegasus Site, McMurdo (12,000 ft) (experimental). Casey (8,000 ft) under construction).	Solids remain at, or near, surface. Liquids mix with surface snow layer. Melt pits can form. Cleanup relatively easy. Accumulation or ablation restores cleaned site to original condition.
Snow-free glacier ice (blue ice).	Smooth, level areas of net ablation, usually kept free of snow by cold local winds.	None required at the best sites. Minor planing to remove scattered bumps at some sites.	None required at ideal sites. Annual removal of scattered snow patches at some sites.	Patriot Hills (11,200 ft), Mill Glacier (24,000 ft), Mt. Howe (22,600 ft) (to be developed). Mt. Lechner (9,800 ft), Rosser Ridge (7,900 ft). Potential sites near Mawson (16,000 ft), near Mt. Cresswell, and in the Fimbulheimen and Sør-Rondane Mts. (10,000 ft).	All solids remain on surface. Non-volatile liquid contaminants disperse but remain on surface. Melt pits can be formed. All disturbance and contamination easy to clean-up. Evaporation then restores site to pristine condition.
First-year sea ice.	Undisturbed, land-fast annual sea ice.	Snow plowing. Grading and grooming of thin snow cover desirable.	Periodic snow removal. Frequent ice thickness measurements for safety checks.	McMurdo (10,000)—early Oct to mid -Dec. Syowa (3,300 ft)—operated Jan. only.	All evidence of site occupation removed by ice breakup. Solid materials and wastes left on the ice undergo uncontrolled "dumping at sea". Cleanup inhibited by hasty evacuation at end of season. Site usually evacuated before seals appear.

Table I (cont'd).

Type of airfield	*Site characteristics*	*Construction method*	*Maintenance*	*Examples*	*Environmental impact of construction and maintenance*
Multi-year sea ice.	Land-fast sea ice that is more than one year old (thick, low salinity, relatively rough surface).	Planing to smooth the surface. Snow plowing.	Snow plowing. Annual planing.	None in current use. Past use at McMurdo. Potential site at Bunger Hills.	Soilds and non-volatile liquids remain on surface. Efficient cleanup is feasible. Possible disturbance of seal activity.
Conventional rock-fill runway (paved or unpaved).	Level or gently-rolling ice-free terrain with unobstructed approaches. <u>or</u> Closely-spaced coastal skerries.	Ripping, scraping, drill-and-blast, rock crushing, screening, dumping, grading, paving, drainage.	Minor snow plowing. Maintenance of drainage ditches.	Marsh (4,240 ft). Marambio (4,000 ft). Under construction at Dumont d'Urville (3,600 ft) and Rothera (3,000 ft). Site available for 10,000 ft runway at Marble Point. Potential sites near Palmer (Joubin Islands, 7,350 ft), at Vestfold Hills (10,000 ft) and Bunger Hills (10,000 ft).	Permanent alteration of local landscape and minor alteration of surface drainage. Waste removal necessary but easy. Possible minor effect on bird habitats. Coastal construction unlikely to have adverse long-term effects on seals or penguins.
Rock fill over glacier ice.	Almost stagnant glacier ice with low ablation rate, level surface, and nearby source of rock fill. Alternatively, flat-lying moraine on glacier ice.	Scraping, hauling, dumping, grading. Lateral drainage.	Pothole filling, regrading, restoration of shoulders. Recutting of lateral drainage channels.	None in use or proposed.	Alteration of local landscape —could last for decades after abandonment. Waste removal necessary. Liquid spills could be irretrievable
Manufactured landing mats.	Flat, level site with low inherent bearing strength (deep snow).	Grading to close tolerances. Hand assembly of panels.	Recovery and re-installation to accommodate snow accumulation.	None in use or proposed.	Runway has no significant permanent impact if all imported materials are eventually removed. Potential for irretrievable liquid spills.

Part B. Operational considerations.

Type of airfield	*Operational limitations*	*Merits*	*Disadvantages*	*Appropriate aircraft*
Unprepared open field.	Special aircraft required. Landings should not be made on very rough snow.	Zero site costs. Widespread availability.	Special aircraft needed—very high cost for large aircraft. Can be hazardous.	Robust and relatively slow aircraft with skis. STOL aircraft. Tactical transports.
Groomed skiways.	Special aircraft required. Reduction of takeoff weight when snow is "draggy".	Low site costs. Widespread availability of sites.	Special aircraft needed—very high cost for large aircraft. Takeoff performance reduced.	Ski planes.
Compacted snow runways (deep snow).	Probably limited to aircraft with fairly low tire pressures and low ACN/LCN. At "warm" sites, may not be useable in mid-summer.	Reasonable availability of suitable terrain. Moderate cost at favorable sites.	Borderline technology with little safety factor for bearing strength. Probably not available for all-season operation.	Aircraft with soft, large-diameter tires on wide-spaced multi-wheel assemblies.

Table I (cont'd).

Type of airfield	*Operational limitations*	*Merits*	*Disadvantages*	*Appropriate aircraft*
Compacted snow on hard ice.	At "warm" sites, may have to close for wheel traffic in mid-summer.	Low initial cost, low maintenance cost. Very high bearing strength.	Strict discipline needed to avoid dirtying the surface.	Most types of aircraft with tire pressures less than about 200 lbf/in.2 (< 14 bar).
Snow-free glacier ice (blue ice).	Crosswinds and/or turbulence at some sites.	Negligible cost for development and maintenance of runways.	Windy locations. Dirt or stains on surface cannot be tolerated.	Most types of transport aircraft.
First-year sea ice.	Weight limits set by ice thickness and temperature. Short operating season-late winter to early summer. Long-term parking not available for very heavy aircraft.	Low cost for preparation and maintenance. Widespread availability. Very smooth.	Limited season—cannot be used in mid-summer and autumn. Investment is lost every year. All facilities must be portable.	Any aircraft, provided ice thickness is sufficient. Limit of max. wt. proportional to ice thickness squared. For extremely heavy aircraft (C-5, An-124), no first-year ice thick enough for long-term parking.
Multi-year sea ice.	Shutdown during ablation season. (Might be possible to alleviate or eliminate this problem.)	Stronger, more stable and longer lasting than first-year sea ice. Moderate cost.	Special equipment required for planing. Snowplow berms can accumulate to unacceptable size. Summer shutdown likely.	Any aircraft, provided surface is smoothed and ice thickness is sufficient. Max. allowable wt. proportional to ice thickness squared.
Conventional rock-fill runway (paved or unpaved).	No special limitations for a runway of adequate length and width.	Permanent investment. Safety, familiarity. All-season availability. Permanent facilities and landing aids.	High initial cost. Strong justification needed. Not many sites near existing bases.	Any aircraft if runway is paved and of sufficient length and width. Loose gravel disqualifies some aircraft or necessitates gravel deflectors.
Rock fill over glacier ice.	No special limitations for a runway of adequate length and width.	Similar to conventional runway.	High initial cost. Ill-suited for siting facilities. Not many suitable sites in useful locations.	Any aircraft suitable for operation from gravel.
Manufactured landing mats.	Not known.		Very expensive. Not permanent.	Depends on subgrade strength and shear connection between mat and subgrade (flexure, flexural waves, and "carpet rippling").

Environmental impact on operations:

All occupied sites contribute minor air pollution. Air operations give intermittent minor air pollution. Airborne pollutants put trace contaminants into deposited snow, permanently in areas of net accumulation. Possibility of liquid spills from aircraft, ground equipment and fuel storage. Containment and cleanup straightforward on impermeable surfaces but almost impossible after seepage into deep snow or deep, unsaturated gravels/tills/rock fills. Possibility of disturbing birds and mammals at some sites.

The severity of pavement loading for any aircraft can be characterized by the ACN, the Aircraft Classification Number. Taking into account the aircraft weight and the geometry of the gear, the ACN is calculated for rigid pavements and flexible pavements using, in each case, four different values of subgrade strength. For any given aircraft, the ACN increases with weight raised to a power slightly greater than unity. For any given weight, the ACN tends to decrease as the size of the aircraft increases. In short, the required bearing strength increases with the weight of the aircraft using the runway, but things can be made easier by using aircraft that distribute the weight over a large area.

Rutting Resistance

On conventional runways the surface is usually hard enough to resist rutting, even by tires that have very high inflation pressure. The same can be said for well-built conventional runways in Antarctica, and also for runways where the surface is hard ice at sub-freezing temperatures. However, if the runway is surfaced with snow, then low tire pressures are needed to avoid rutting. There is no systematic guidance on allowable pressures, but one would probably expect trouble on snow with pressures above about 100 lb/in^2, or 7 bar.

Inflation pressure alone does not give the complete story, especially for a thin snow layer on a hard substrate, or for snow in which density (i.e. strength) increases rapidly with depth. Under such conditions, the bigger the footprint of the tire, the better the performance. Where the footprint width is much larger than the thickness of a finite snow layer, the snow is under triaxial compression; the tire tends to compact the snow instead of punching through it. In "deep" snow, the depth of the stress bulb is proportional to the footprint width; bigger tyres mobilize the strength of deeper layers.

The footprint area is estimated by dividing the wheel load by the tire pressure. It is assumed to be elliptical in shape with the minor axis (perpendicular to the travel direction) 60 % of the length of the major axis. Footprint width is estimated as $0.874 \times (\text{contract area})^{1/2}$.

Surface Roughness

On unprepared runways and sub-standard runways, surface roughness may be a problem. An isolated bump can induce a shock load. Continuous and irregular uneveness can excite vibrations. At risk are the gear and airframe, sensitive avionics or instruments, the pilot's peace-of-mind and (of less consequence) passenger comfort.

There are no agreed standards for assessing roughness and setting safe limits. Roughness has been characterized in terms of: 1) the vertical accelerations imposed on a given aircraft (or major components of the airframe), 2) subjective judgments by pilots, 3) measurements of surface profiles on runways.

For Antarctic runways, CRREL has measured sample profiles by conventional surveying and analyzed the measurements so as to obtain plots of bump height versus wavelength. Having amplitude and wavelength, it is easy to obtain vertical accelerations for given horizontal speeds. Two types of analysis have been tried so far. One uses Fourier analysis to characterize recurring bumps; by averaging, it tends to underestimate the severity of a single bad bump in the profile. The alternative is a "two-point maximum bump height" analysis, which identifies the bad bumps and tends to exaggerate the roughness problem (the worst bump may be non-recurring). The difficulty is to establish safe limits for roughness described this way.

Roughness or vibration limits for specific aircraft do not seem to be readily available, either from manuals or from manufacturers, although there has been research into operation from bomb-damaged runways and the FAA is apparently developing criteria for specific aircraft. The U.S. has a military specifiation, MIL-A-8863B, which gives limiting envelopes of "cosine" bump height versus wavelength for paved fields (Fig. 1). This has been adopted by CRREL for assessing Antarctic runways. On the surfaces studied so far, the main problem seems to be with wavelengths ranging from the footprint length to about 30 m (100 ft). Wavelengths greater than 60 m (200 ft) do not seem to be very troublesome.

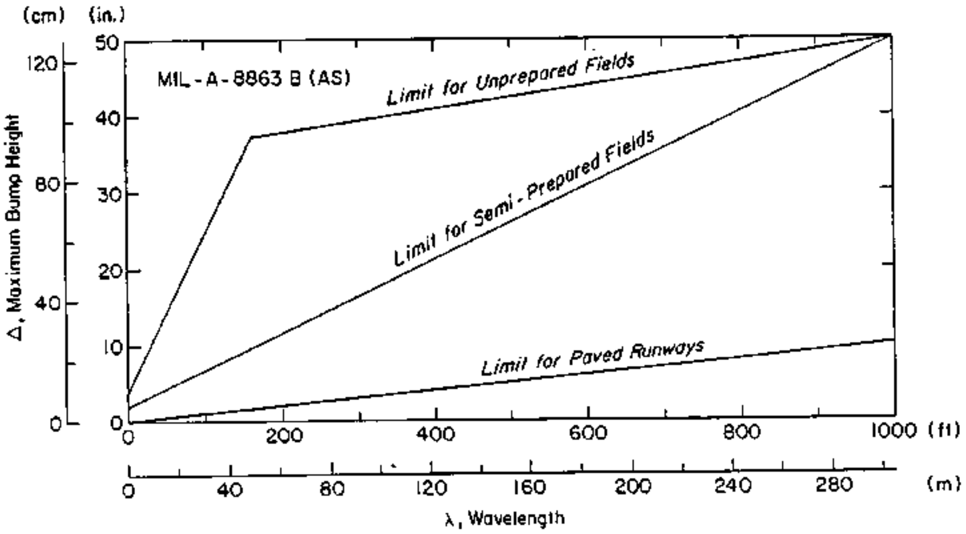


Figure 1. Military specifications for the roughness limits of runways (MIL-A-8863B(AS), 6 May 1987).

Runway Dimensions

Runway length

Up to now, Antarctic runways have been expedient runways, with length often restricted by natural site limitations and/or by local capabilities for construction and maintenance. For the future, the aim should probably be to develop some major airfields that meet or exceed the length criteria for conventional airfields handling heavy aircraft.

In temperate regions, runway length is determined b: 1) the performance characteristics of the aircraft that will use the field regularly, 2) the aircraft operating weights, or haul distances, 3) the field elevation, 4) maximum expected temperatures, 5) surface condition on the runway, 6) surface gradient on the runway. Appropriate design manuals exist in both civil and military agencies (see, for example, FAA Advisory Circular 150/5325-4A, 1990).

For aircraft that have a maximum takeoff weight exceeding 60,000 lb (27,200 kg), general guidance for temperate regions is provided by Figure 2, which gives required runway length as a function of haul distance, with field elevation as parameter. In Antarctica, the requirements can be reduced somewhat in accordance with the low prevailing air temperatures.

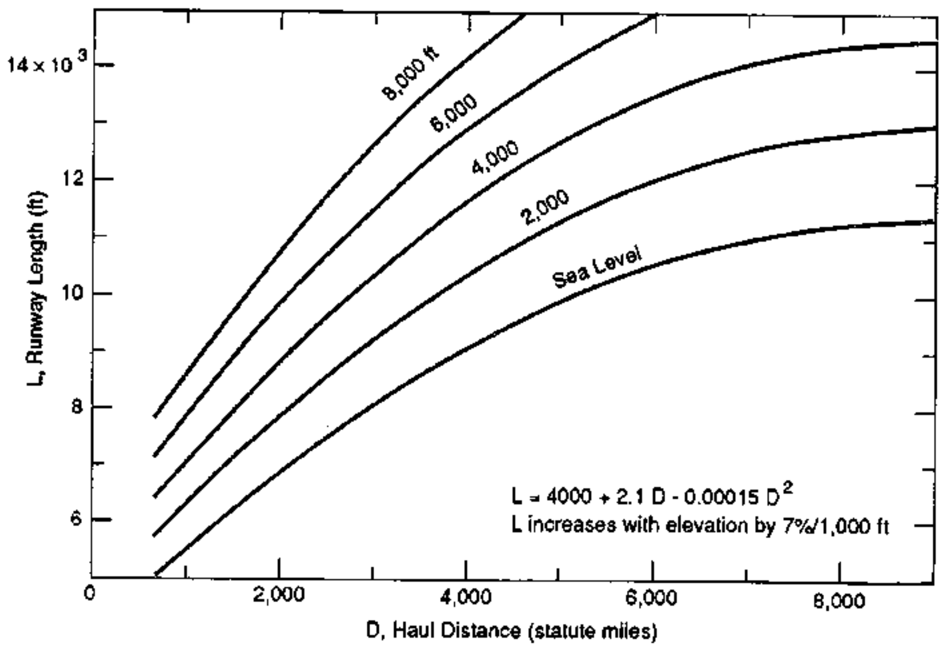


Figure 2. General planning guide for runway length at airports used by aircraft having maximum takeoff weight exceeding 60,000 lb (27,200 kg) (from FAA, AC 150/5325-4A, 1990).

The runway should have safety area extensions at both ends to accommodate undershoot. For aircraft in approach categories C and D (approach speed 121-141 and 141-155 knot respectively), the safety area extensions beyond the runway ends are, by FAA standards, 1,000 ft (300 m) long. Figure 3 indicates the probability of undershoot and overrun for large transport aircraft.

Unconventional runways in Antarctica can meet or exceed the length requirements for large transport aircraft. The existing, and projected, conventional runways are substandard in terms of length.

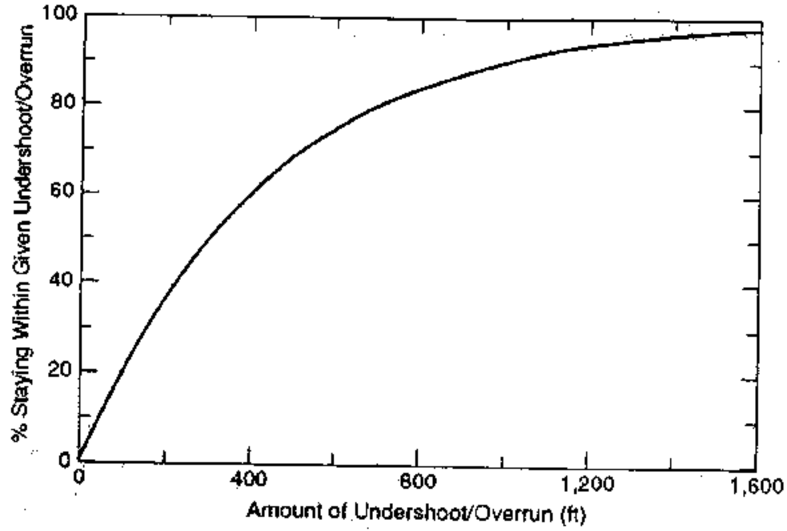


Figure 3. Approximate probability of undershoot or overrun for large aircraft (after FAA, AC 150/5300-13, Appendix 8).

Runway width

On a conventional airfield, the structural pavement is flanked by runway shoulders that have less bearing capacity. The shoulders provide insurance against veering, but they also serve to retain and support the subsoil along the edges of the runway. Beyond the shoulders are clear strips designated as runway safety area. These strips are free from obstacles, flat and level, drained, firm enough to support emergency vehicles and, in emergency, aircraft.

The requirements for runway width depend on the design group and the approach category for the largest and fastest aircraft that are intended to use the runway. Design group is determined by wing span. The largest aircraft, such as the C-5 Galaxy, are in group VI (214-262 ft, or 65 - 80 m). Aircraft such as the C-130 Hercules, the C-141 Starlifter, or the Ilyushin IL-76 are in Group IV (118-171 ft, or 36 - 52 m). Approach category is defined on the basis of landing-configuration stall speed multiplied by 1.3 i.e. approach speed. Most of the large transports that are of interest for Antarctic use would fall into Category C (121-141 knot), or possibly Category B (91 - 121 knot).

For design group IV and approach C/D, the required runway width is 150 ft or 45 m, and the required shoulder width is 25 ft or 7.5 m, giving a total width of 200 ft or 60 m. For any design group in approach category C/D, the required total width for the runway safety area (enclosing the runway) is 500 ft or 150 m.

In Antarctica, unconventional runways are not likely to have different construction methods for the runway and the shoulders, and the safety area may also have a surface quite similar to the runway itself. The U.S. Navy maintains a plowed width of 300 ft (91 m) on the McMurdo sea ice runway. At the Williams Field skiway, both "runways" are 300 ft (91 m) wide. At South Pole, the width of the skiway is 250 ft (76 m).

The conventional runways in Antarctica are much narrower, about 100 ft, or 30 m, at Marsh, Marambio and Dumont d'Urville, and 150 ft, or 45 m, at Rothera.

Conclusion

In future Antarctic research, air transport is likely to become a necessity rather than a luxury. Although ski aircraft may always be needed for field support, the key to efficient and affordable air transport is an ability to utilize conventional aircraft. This, in turn, requires that there be hard-surface runways which remain serviceable for long periods each year. There are a number of viable technical options for providing hard-surface runways.

Clearly the most desirable option is the conventional runway, built on rock or solid and preferably paved. While there are many sites for runways 2 km or more long, few are in close proximity to existing stations. Initial cost for a conventional runway is relatively high, but modest in relation to the cost of LC-130 aircraft. The investment provides a permanent asset that has low maintenance cost.

Blue ice airfields in cold, icy ablation zones are attractive, since the cost of initial development is very small and, with careful operation, maintenance costs are negligible. However, few of these sites are close to existing stations.

The best way to utilize glacier ice at low-elevation coastal locations is to compact a thin pavement of snow on top of the hard ice so as to protect it from summer melting. Given a suitable site, the construction cost is low.

Land-fast annual sea ice in protected locations can provide excellent early-season runways at low cost. Ice thickness sets a limit to the size of aircraft that can land, taxi and park. Airport facilities have to be set up and evacuated on an annual basis.

Land-fast multi-year sea ice gives higher bearing capacity and longer life for a runway. The surface usually has to be smoothed by planing or flooding. If snow plowing is needed at the site, there may be progressive built-up of permanent snow berms, which can eventually crack the ice.

Compacted snow runways on deep perennial snow-fields can be built at suitable locations but, with present technology, they lack the bearing capacity and rutting resistance to handle most large transports, especially in summer.

In planning for the future, one of the difficult decisions facing managers of national programs is whether to relocate major stations to sites that are favorable to airfield construction, whether to settle for substandard airfields near existing facilities, or whether to do without air transport. Another potential problem is how to respond to the possibility of growth in the air operations of non-government entities, something which is certainly feasible from a technical standpoint.

References

Barthelemy, J.L. (1990) Thirty-five years of sea-ice runway operation - McMurdo station, Antarctica. *Proceedings IAHR Ice Symposium, Espoo, Finland.*

Budd, W.F. and D.S. Russell-Head (1990) Runway sites for heavy wheeled aircraft in East Antarctica. Meteorology Dept. University of Melbourne, *for* USA Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, 95 p and maps.

Mellor, M. (1988) Hard-surface runways in Antarctica. USA Cold Regions Research and Engineering Laboratory, Special Report 88-13, 87 p.

Mellor, M. (1990) Notes on Antarctic aviation. USA Cold Regions Research and Engineering Laboratory, (unpublished).

Mellor, M. And C. Swithinbank (1989) Airfields on Antarctic glacier ice. USA Cold Regions Research and Engineering Laboratory, CRREL Report 89-21, 97 p.

Russell-Head, D.S. and W.F. Budd (1989) Compacted-snow runways: Guidelines for their design and construction in Antarctica. USA Cold Regions Research and Engineering Laboratory, Special Report 89-10, 68 p.

Swithinbank, C. (1989) Ice Runways Near the South Pole. USA Cold Regions Research and Engineering Laboratory, Special Report 89-19, 42 p.

Improvement of Methods for Construction of High-Strength Aerodromes in Antarctica

G.Y.Klyuchnikov [1)]
V.P. Klopov [2)]
V.G. Averyanov [3)]
V.N. Petrov [4)]

Abstract

High-strength snow aerodromes were constructed and have been successfully operated in the vicinity of the Molodezhnaya Antarctic Meteorological Center (AMC) and the Novolazarevskaya station since 1980 to provide for the air communications with Antarctica by means of long-range trunk-route AEROFLOT aircraft. In compliance with requirements worked out for those aerodromes considerations in respect to the sites included climatic and glaciological features of the area, such as the direction of predominent gravity and cyclonic winds in particular, relief and slope angle of the snow/ice surface, necessary dimensions of airstrips to provide for the safety of continued or rejected take-off in case of one of the engines' failure during operations.

The provision of high strength (bearing capacity) of the aerodrom's snow/ice surface capable to endure take-offs and landings of heavy wheeled aircraft is a very important requirement. The methods of calculation and design of such surfaces were developed.

The example of the structure of snow and snow/ice surfaces created for the first time at the Molodezhnaya AMC for IL-18D aircraft with take-off mass of 64 t is shown in Fig. 1. The structure consists of the following layers:
1 - protective layer of fresh snow with any strength;
2 - surface made of strengthened firn and snow;
3a - artificial foundation made of firn and snow;
3b - artificial foundation made of strengthened firn;
4 - natural foundation of firn with tested guaranteed strength.

Strength of layers decreases from the upper layer downwards in accordance with the regularities of reduction of stresses with the change of snow/firn cover depth. Stresses were determined by means of equipment consisting of membrane gauges (gauges converting mechanical stresses into electric ones) and different amplifiers of electric signals. The total thickness of strengthened snow layers was 70 cm and was equal to the active depth of aircraft wheel impact.

The snow aerodrome with such a surface was constructed by means of an ecologically clean and resource-saving

1) The Arctic and Antarctic Research Institute, Leningrad/USSR
2) dito
3) dito
4) dito

method, the essence of which is in the pulverization of the natural snow/firn cover and then repeated mechanical compaction in layers the snow cover by pneumorollers (1, 7, 9). The sequence of operations is presented in the following table.

Technology of snow surface construction

Operation Number	Operation	Device
1	Levelling of snow/firn surface	Leveller
2	Cover pulverization with destruction of weak structural links and snow stirring	Disk ripper
3	Preliminary compaction of the surface by initial pressure	Pneumoroller w. mass 10-15t
4	Final compaction of the surface by hightened pressure	Pneumoroller w. mass 25 t
5	Smoothing of the compacted surface	Smoother

This technology was developed for pneumorollers used for ground compaction by layers when embankments are filled. Due to the little depth of the active zone of impact produced by pneumatic wheels of these rollers on snow/firn cover (15 - 20 cm) the required structure (Fig. 1) was created by means of the repeated compaction by layers. At first the upper layer of snow cover was compacted - layer 3 b; then as soon as new snow falls - layer 3 a; and at last layer 2 - fresh snow, heated by solar radiation. When the temperature drops this layer freezes forming strong snow/ice. Such technology for construction of snow aerodromes in Antarctica proved to be reliable.

Taking into account the advantages of the above method (ecological cleanliness, reliability, use of unlimited resources of natural snow instead of traditional materials for construction of aerodromes, such as concrete and asphalt concrete) different ways of its improvement were developed for its higher effectiveness in different conditions.

The first way of improving the method is designed for the Antarctic areas with deep snow/firn cover. The higher effectiveness in this case is achieved by more intensive mechanical influence upon the cover, namely by increasing the depth and degree of compaction as a result of the increase of parameters of rollers' pneumatic wheels or special compacting plants and by use of broad aircraft wheels with high internal pressure.

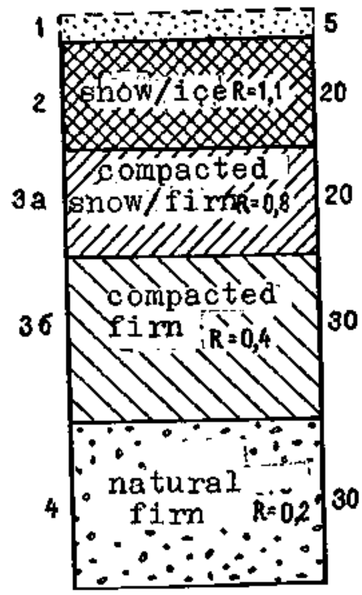


Fig. 1. High-strength structure of snow aerodrome at the Molodezhnaya AMC for wheeled aircraft IL-18D. Left-hand side - number of layer; in the middle - material and required strength R, mPa; right-hand side - layer thickness, cm.

The method of calculation of such a cover compaction was developed based on the profile of the stressed state of snow by depth depending on the pressure at the surface and size of pneumatic wheels. The profile was calculated on the basis of the regularity determined earlier and the definition of the depth of compaction was made at the point where this profile crosses the elastic limit profile of the compacted snow as shown in Fig. 2. This figure illustrates the results of the evaluation of the increase of the cover compaction depth when the breadth of pneumatic wheels of the compacting machine changes from 30 cm (pneumorollers) to 50 cm (aircraft wheel) with the same specific pressure in the wheels equal to 0.5 mPa. The profile of elastic limit of the compacted snow was taken constant by depth because in this case the design depth of cover compaction by the roller is equal to the real depth of 25 cm.

As can be seen from the above data when the breadth of wheels increases from 30 to 50 cm the depth of compaction grows from 23 to 38 cm. This allows one to create the cover structure with the thickness of 70 cm as in Fig. 1 using only two cycles of the snow/firn cover treatment.

At the aerodrome in the area of the Molodezhnaya AMC the experimental studies were carried out, the results of which are shown in Fig. 3. The snow cover at the aerodrome was compacted at first by applying traditional methods by the pneumoroller with the mass of 25 t and specific pressure 0.4 - 0.6 mPa in the pneumatic wheels. The compaction was estimated by the resistance of the cover to the dynamic sounding N. The maximal value of N was equal to 4 (curve 1). Then at the same aerodrome the method of intensive compaction by means of special machine - dummy undercarriage with the mass of 55 t with aircraft wheels in which the specific pressure was equal to 0.9 mPa (curve 2) was applied. The comparison of the curves 1 and 2 in Fig. 3 shows that the considerable rise of effectiveness of the cover compaction both achieved by the degree and depth of compaction. To apply this way of improvement of the cover strengthening method the layouts of special compacting machines were worked out which can also be used for testing the constructed aerodromes as they have aircraft wheels.

The second way to improve the method of snow aerodrome construction is aimed at the creation of the frame layered cover using snow/ice layers and interlayers with high-strength properties. Several types of such structures are invented (4,6).

Snow/ice strenthening layers and interlayers can be created in any climatic conditions of Antarctica by means of the thermal and mechanical influence upon the snow cover. Different methods of this influence may be applied depending on the local climatic conditions.

In the coastal areas of Antarctica with high summer temperatures and intensive solar radiation a radiation mechanical method can

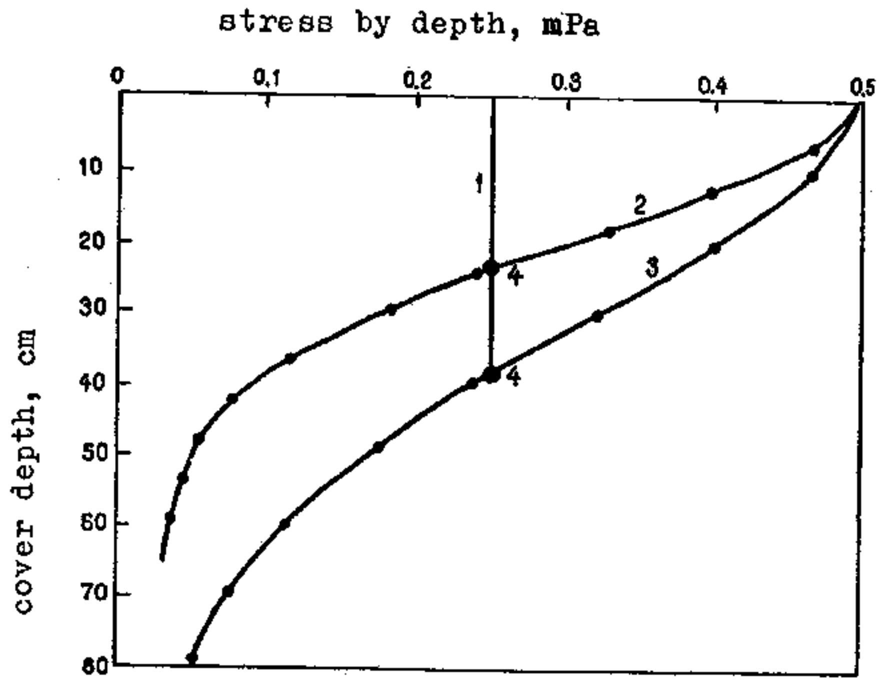


Fig.2. Design increase of compaction depth of snow/firn cover:

1 - profile (line) of elastic limit of compacted snow

2 - profile of stresses in cover after impact of wheel 30 cm broad

3 - profile of stresses in cover after impact of wheel 50 cm broad

4 - depth of cover compaction

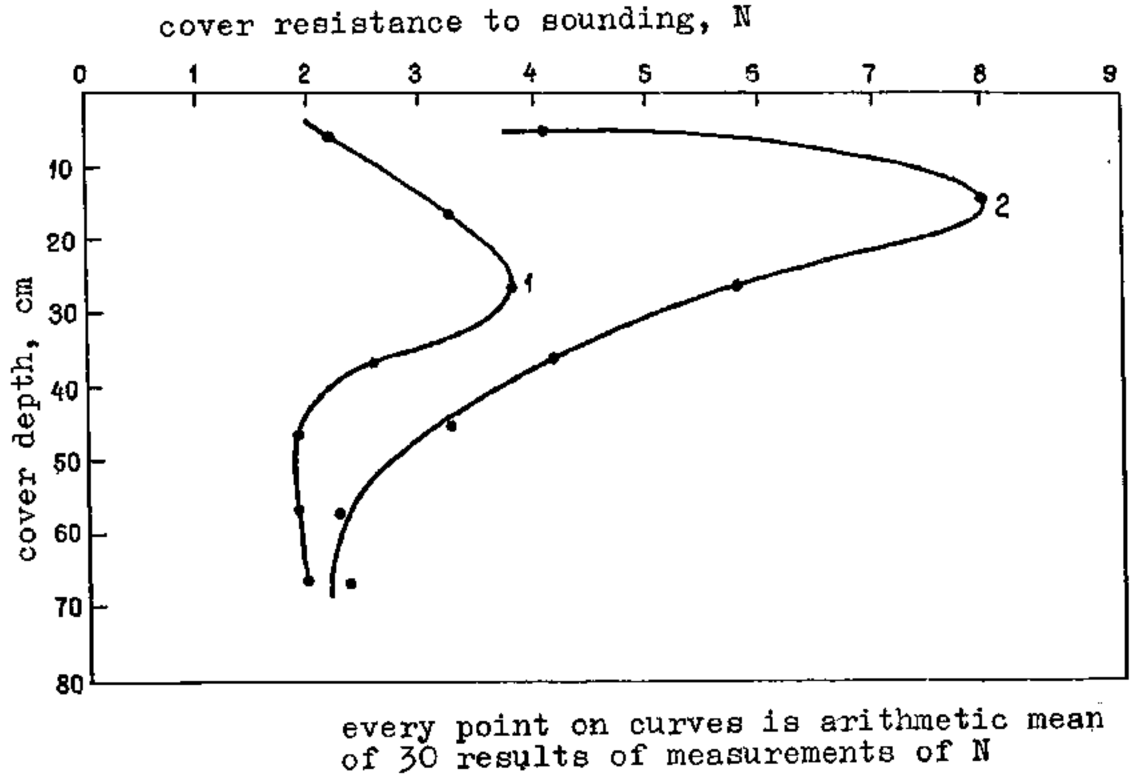


Fig.3. Experimental increase of effectiveness of snow/firn cover compaction

1 - compaction by pneumoroller with mass of 25 t and specific pressure in pneumatic wheels 0,4-0,6 mPa

2 - additional compaction by machine - dummy undercarriage with mass of 55 t and aircraft wheels, specific pressure - 0,9 mPa.

be implemented. Its essence is in the total influence of solar radiation upon the snow cover to heat the snow and mechanical compaction of the heated snow by pneumorollers (3, 7). To intensify the snow heating by solar radiation one should preliminarily change the reflecting capacity of the cover forming a thin ice crust on its surface. Due to this ice crust the reflecting capacity of the surface decreases and as a result of this the quantity of short-wave solar radiation absorbed by the cover and respectively snow heating grow. The ice crust on the surface creates the greenhouse effect within the cover, thus preserving heat and reducing heat losses due to evaporation. The higher snow temperatures increase the effectiveness of its compaction and are conductive to the creation of snow/ice layers and interlayers. A special device for the efficient and ecologically clean formation of the ice crust on the surface by means of preliminary fusion was worked out.

To create snow/ice aerodromes in any region of Antarctica irrespectively to the air temperature and presence of solar radiation a thermovibration method was developed (2, 4). It focusses on the atomization of snow mass, fusion of the surface of every snow particle by hot gas and compaction by pneumatic wheels after vibroplate is necessary to prevent cracking of the smooth snow surface when it is cooled quickly and also to make rough cover surface. After the snow mass, which is compacted in that way, freezes,the corrugated snow/ice cover is made being strong and suitable for air operations.

To construct permanent aerodromes on rocks the methods are developed utilizing the products of erosional rock distribution (stone chippings and sand) as intitial material for the formation of the levelling layer and strong aerodrom cover without concrete and asphalt concrete. Building mixes for the covers are made from local materials indicated above, cement and different chemical additions according to several recipes.

In accordance with one of them (5) the complex addition consists of epoxy resin, aminophenol hardener and surface active substance. The percentage of the addition is not high but the strength of the material obtained is 70 - 250 % higher than without it. The limiting extensibility also grows. This results in the increase of the crack resistance under low temperatures. According to the other method (8) the complex polymer addition includes epoxy resin, amine hardener and copolymer of vinylacetate with ethylene also in small quantities. After the compaction and hardening of such mixes the covers are suitable for different types of aircraft. The main problem of aerodrome operation on Antarctic rocks will only consist in their protection from snow drifts.

The implementation of the methods described in this paper will allow you to construct aerodromes of any types at any point of Antarctica in the future .

Development, Design and Construction of an Antarctic Research and Supply Vessel

by

Jones, D., British Antarctic Survey

__Abstract__

British Antarctic Survey needed to replace the 1956-built "John Biscoe" in order to meet expanding needs for the relief of the five Antarctic stations and to enhance its limited marine research capability in line with objectives identified by the UK Government.

In the mid-1980's a successful bid was made for the necessary funds for such a dual-role vessel with improved ice capability and enhanced cargo-carrying capacity, including the ability to transport aviation turbine fuel in bulk. To address the research objectives, a representative group of users of the existing UK research vessel fleet was assembled. They were asked to define a scientific specification covering current requirements and anticipated developments in marine science through the expected life-span of the vessel.

The most significant, and ultimately most expensive aspect of the resultan specification was the demand for limitation of underwater radiated noise during research cruises.

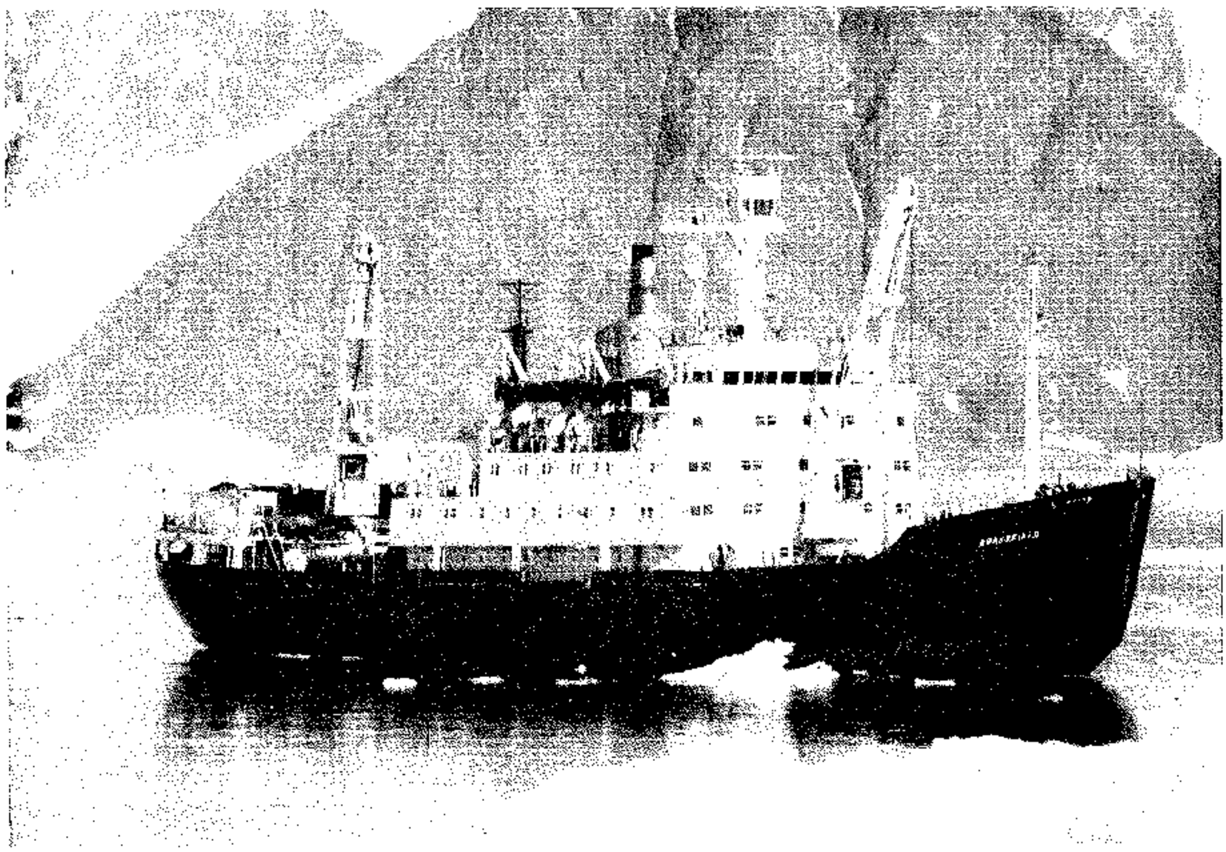
Initial world-wide tendering in 1988 resulted in bids substantially above estimates; re-tendering on a reduced specification with modified contractual requirements resulted in a contract being placed on Swan Hunter Shipbuilders in the UK.

The vessel is being constructed with large working deck and laboratory areas, sophisticated and comprehensive data acquisition and processing facilities and largely single-berth scientific accommodation.

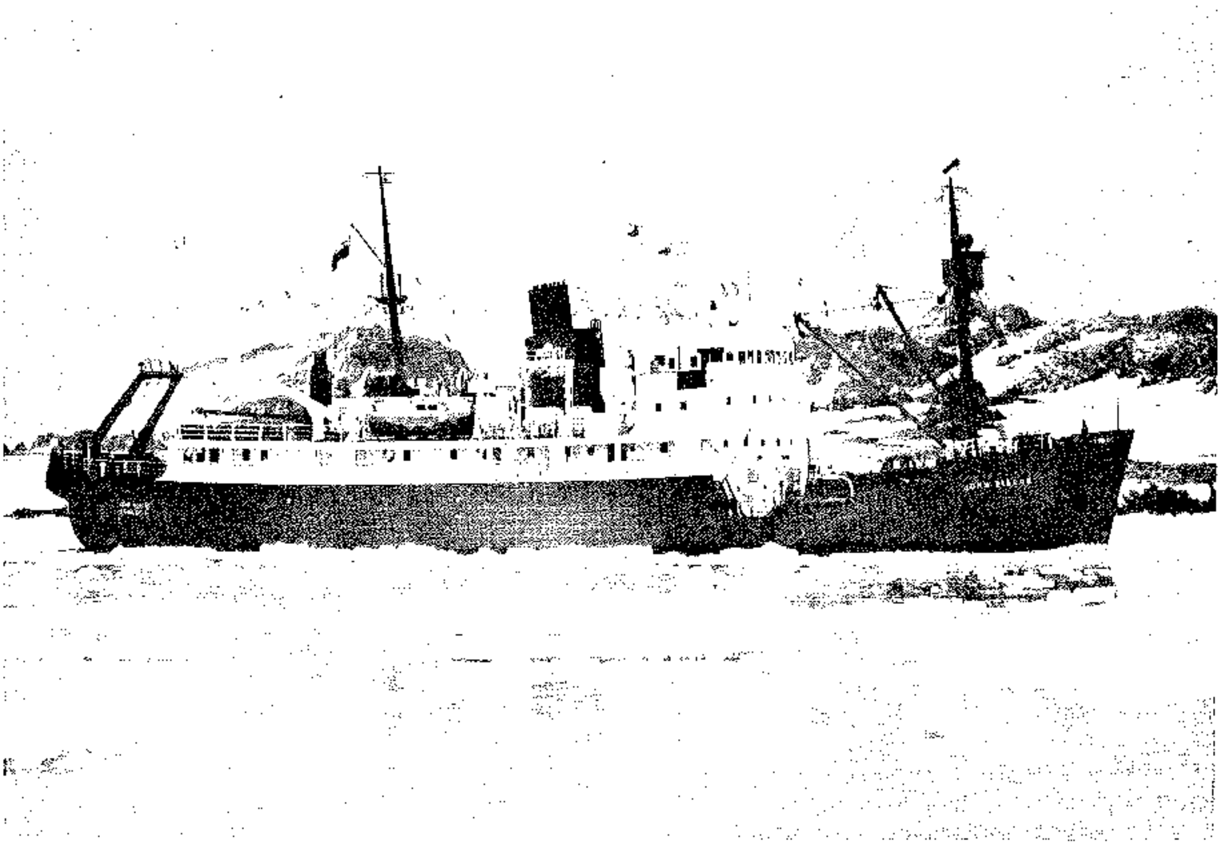
The Need For a New Ship

British Antarctic Survey maintains five permanent stations, four in the Antarctic Peninsula - Weddell Sea sector of the Antarctic and one in South Georgia.

The shipping of personnel, materials and equipment is carried out at present by the Survey's two ships, RRS "Bransfield" and the smaller RRS "John Biscoe".



RRS "BRANSFIELD"



RRS "JOHN BISCOE

RRS "John Biscoe", was constructed in 1956 and re-engined and modified in 1979 to provide a platform for biological oceanography and some marine geophysics. A consequence of this conversion was a substantial reduction in her cargo-carrying capacity through the loss of the after hold.

The Growth of Antarctic science in the 1980's has served to increase cargo and personnel movement requirements and forced a review of BAS' shipping capability. This resulted in a clear need for increased cargo capacity and improvements to the marine science capability (particularly in the area of marine geoscience). The review identified various alternative developments. Two options considered were:-

a. Two new ships, one a simple ice-strengthened cargo vessel with passenger capability, the second a dedicated research vessel which could also be operated outside the Antarctic.

b. A single multi-role scientific research and logistics vessel. The latter was the option selected.

3. The Type of Vessel

The parameters, of the proposal vessel in terms of power, volumes and berths required are determined largely by its logistics role. Restrictions were, however, imposed in terms of vessel length and draught due to the need to access two stations with confined and comparatively shallow approaches.

An analysis of cargo volumes showed that, despite the increase in activity and recognising the capabilities of "Bransfield", a return to former cargo capacity of the John Biscoe would be adequate. It would fulfil the requirement of carriage of basic relief supplies and transfer of personnel for all stations in the event of "Bransfield" not being able to carry out her role in any one season. This, together with container-carrying capability to cope with expansion, new construction projects and pending improvements in handling facilities at the Antarctic stations, met the foreseeable increase in requirements.

It was also important to provide capacity for the transportation of bulk aviation turbine fuel to improve the efficiency of existing air operations and so reduce the stowage and handling problems created by the carriage of large numbers of barrels.

Personnel transportation requirements tuned on the need to deploy field staff, early in the Antarctic operational season, at the BAS station at Rothera. This bone is the centre for deep field air-supported programmes. At the present time on Weinke Island "John Biscoe" makes two cruises each with around 25 passengers from the South American mainland or Stanley in the Falkland Islands to the facility at Damoy. An obvious advantage would be gained if this could be undertaken in one rotation.

Calculation of the power required by the new ship was based on the lack of power of her predecessor. The "John Biscoe" had encountered difficulty when working the type of broken pack ice found off the Antarctic Peninsula in the Summer, particularly pressurised brash ice commonly termed "porridge". Such conditions have potentially endangered the ship in the past. As a consequence of this experience it was concluded that a pure ice-breaking hull form was not a first priority. A more important consideration was the need to have an adequate power margin combined with a hull form conducive to the science role of the new vessel (in terms of underwater quietness). In addition an ability to work several ice types (pack, level ice, multi-year floes) was considered essential.

A combination of three ship roles was sought:

A long distance economical cargo personnel carrier;
A quiet research vessel, providing a stable and efficient working platform for science operations;
An powerful ice-capable vessel.

To some extent these roles are incompatible and inevitably led to significant compromises, especially in the area of economy.

The science role of the proposed vessel has been considered to be of great importance.

A considerable body of expertise existed within BAS and Natural Environment Research Council to enable the initial scientific requirements to be defined and an outline specification written. It was necessary, however, to maximise the efficiency and adaptability of the vessel to cater for potential roles outside the current requirement for work in Antarctica, and to recognise trends in marine science technology. In order to gain the maximum breadth of input a group of experienced marine scientists was drawn together representing all the users of the existing U.K. fleet of research vessels.

This group was to specify ideal requirements and to anticipate developments in marine science as practical.

The group defined the general parameters which included the following aspects:-

i. A 25-metre long clear after deck for handling and operation of large equipment packages, remotely operated vehicles etc;

ii. A large articulated stern gantry of A-frame type with 20 tonne capacity and good horizontal and vertical clearances;

iii. A 30 tonne capacity articulated side gantry, located as close as possible to the vessel's centre of pitch, for vertical wire work, including envisaged heavy coring operations for core lengths up to 40 metres.

The articulation of the outboard sections of the two gantries was regarded as important in reducing the pendulum effects associated with equipment deployment and recovery operations.

iv. Traction winch systems designed for minimum rope wear and maximum flexibility covering a wide variety of warp types including conducting and non-conducting superaramids, high capacity electro-mechanical cables and conventional coring, trawling and conducting wires.

v. A commercial-style twin warp trawling system for midwater and bottom-trawling operations

vi. A variety of specialist and general working laboratories

vii. Accommodation for up to 30 scientific and support personnel

Interesting omissions from the requirement included a moonpool; this was discussed within the group and rejected eventually on the following grounds:-

i) effect on underwater radiated noise signature
ii) difficulty of installation and maintenance of closure devices (to combat i) above) in an ice-working environment
iii) potential contamination of an enclosed water system on programmes requiring clean instrumentation

viii. The choice of a propulsion system was heavily influenced by past experience and by advice from ice ship consultants. The two current vessels were both originally diesel electric, single shaft, one with a fixed pitch propeller and one with controllable pitch (CP). "John Biscoe" was converted to direct diesel drive with CP propeller in 1979, so broadening the BAS experience.

A single propeller offers higher protection in ice conditions since it is protected by the hull. Fixed pitch is sturdier, cheaper and more easily maintained. It is also more easily optimised for the required role of the vessel although with the three non-compatible requirements this issue would remain a problem. Removable blades were recommended for ease of repair in the case of ice damage; this could be important in the case of damage being sustained immediately prior to a science cruise (when propeller noise could be a serious disadvantage).

Diesel electric drive gives maximum manoeuvring flexibility, withstands more readily shock loads inherent in ice operations and is potentially the quietest system for science programmes sensitive to underwater radiated noise.

The widely varying requirements for the vessel range from high power whilst working a heavy "hotel" load during transit trips with passengers, (particularly, during some marine science cruises) to low power needs for quiet research steaming and economical single engine passage speeds. These different activities pointed to a "power-house" system with different engine sizes suited to individual parts of the vessel's roles.

The selection of hull form was based on the advice of a Finnish constructor who had built the majority of the world's ice-breakers and also had experience from more than fifty research vessels constructed mainly for Soviet owners. The hull form is a hybrid giving good ice-working potential (tests have indicated a capability of breaking 0.8 metres of level first year ice at a constant speed of 2 knots), reduced resistance for economical cruising and quietness for science operations.

The installed power is from four diesel-powered alternators, two of 3.1MW and two of 1.0MW capacity, with a maximum output at the propeller of 8,500 SHP, (the power level calculated as necessary for ice-working requirements). One of the larger sets will power the ship and provide hotel loads during normal transit passages at the selected economical cruise speed of 12 knots.

Given the importance of the scientific research role of the vessel, reduction of underwater radiated noise has been a high priority. The group of experts specified standards using an existing vessel, the "Charles Darwin", as an analogue. The Charles Darwin is the UK's most recent general purpose research platform, and had given good data for several years. That vessel's noise signature had been measured upon delivery and a filtered version taken as a requirement for the construction contract.

Acquisition

Specialist contractors with proven expertise in the field of ice and science ships were required. Initially, a competition was held to obtain professional naval architect services. Competing companies were required to show their experience or how they proposed to acquire it. A combined team of the naval architects who had been responsible for the "Charles Darwin" and the South African Antarctic ship "Aghulas", together with the consulting arm of a Finnish shipbuilder, was engaged.

A Steering Committee was tasked to draw up the detailed specification. The membership incorporated the consultants, advisers from the relevant science fields, in-house experts experienced in specifying and fitting scientific equipment to the current research vessel fleet and ships officers seconded from the current BAS operations. The latter inclusion was of prime importance given the unique nature of Antarctic operations. No matter how experienced a consultant or shipbuilder might be, the direct practical experience of professional mariners who have spent many seasons working with the BAS Antarctic operation will always be essential.

Following a short but essential period of six months in compiling the specification requirements and preparing outline designs, expressions of interest were invited from shipbuilders, on a world-wide basis. Responses were received from 31 yards on three continents, no doubt influenced by the potential market then being created through a number of Antarctic Treaty nations being in, or about to embark upon, the same process.

Given the requirement for a demonstration of expertise in the fields of ice operations and platforms for marine research, invitations to tender were issued to 16 yards in Europe, North America and the Far East. Five valid tenders were received, with the lowest bid substantially higher than the budget believed to be adequate by our Consultants. The worldwide escalation in shipbuilding prices played a significant part in this. Requirements were re-examined and the five yards invited to re-tender on the basis of a less stringent contract with a reduced specification. The main casualty at this stage was the proposed Swath Bathymetry system for fast, efficient sea-bed mapping. The high cost of this facility made it an appropriate candidate for savings without the need for cost-effectiveness judgements.

The second round of tenders showed that between tender dates, world prices had continued to escalate and, despite the reductions in specification the lowest offers were very little changed from the first round. The necessary additional funding was, therefore sought and was fortunately forthcoming. The competition was narrowed to two bids, the final selection being wholly price-related in favour of a UK yard, Swan Hunter Shipbuilders on the River Tyne, a specialist warship builder with high technology civil ship experience. The competition was represented by Wartsila Marine of Finland, who had previous involvement in the design and specification process. The Swan Hunter bid, however, also involved Wartsila as ice-ship consultants, so their expertise was retained. The choice of a naval shipbuilder, with its background of high technology military vessels and, in the civil market, cable ships, gave BAS a strong advantage in achieving the underwater radiated noise requirements. The yard was, in fact, the only tenderer to have unreservedly accepted these needs as achievable!

The outline design, on which the shipyard had tendered was eventually considered to be too small in size to contain all the BAS requirements. The original concept had been to progress the outline design to a detailed stage before tender in order to shorten build time. Due to the redesign work required of the shipbuilder this objective was frustrated and there will continue to be debate over which approach is better; to use Consultants to closely specify (at a cost), or to give an outline design to a shipyard and trust them to produce the ship you require.

The Problems Encountered

Construction of the vessel commenced in November 1989, eight months after contract signature, with the cutting of the first steel. A number of problems have arisen in the intervening period, some of which are worthy of examination.

1. **Underwater Radiated Noise**
   Earlier reference has been made to the prime importance during science cruises of minimal underwater noise. Although it is impossible to analyse realistically the cost of individual design components, it would appear that the URN requirement has proved

expensive. The evidence for this is available in the size and cost of all machinery being delivered for the ship. The propulsion motor is much increased in size compared to "Bransfield"; machinery must be rafted and resiliently mounted. Water and air flows must be at reduced velocity which increases pipe dimensions and space requirements. In addition pumps have to be slower and, therefore, larger. The net effect is to increase cost and weight.

2. <u>Classification</u>
The two existing BAS vessels are classified as Class VII cargo ships despite their carriage of expedition personnel. This is because the "passengers" are BAS employees. The new vessel was originally destined for the same classification, although the higher subdivision and fire-fighting requirements of the Passengership category were specified. The new IMO classification of "Special Purpose Ship" was also reviewed, and construction to this standard was required. Since this classification had not yet been introduced into UK legislation; the Department of Transport felt it necessary to classify the ship as a Passenger Vessel Class I. This has been due to expedition personnel not being employed on board the vessel. A number of exemptions from the more stringent requirements of PVC-1 have been allowed. There will, however, be significant operational implications resulting from the classification in terms of fire and safety drills.

3. <u>Accommodation</u>
Single berth cabin accommodation for all personnel was required, but the high numbers involved in the short period transit role for expedition personnel have resulted in scientists cabins being designed with a convertible bed-settee and a "Pullman"-type stowable berth above, to double accommodation numbers. Most science cruises will have single berth facilities. Every cabin has its own private toilet and shower facility. To maximise space on the ship, officers' and crew cabins also have a convertible bed/settee; the arrangement gives an impression of spaciousness and comfort within the minimum space.

<u>The Final Ship and its Facilities</u>

Scientific Specification detail

The three Vessels in the Research Vessel Services fleet of the NERC utilise an on-board (and shore-reflected) computing system developed in-house. A development of this system is being installed on "James Clark Ross". It is essentially a three-level (equipment interface, data collection, data processing) system. BAS stations in Antarctica and the Cambridge Headquarters, use a different system based on VAX architecture which is also being installed on board. Both systems will be linked by satellite with the UK, allowing real-time bi-directional data transfer and, potentially, remote control of experiments.

All cabins on the ship (except crew cabins) will be wired to have potential access to the scientific or ships computing systems.

The laboratory area comprises some 370 square metres of wet, dry, environmentally-controlled and small task-dedicated laboratories, together with workshops, cool and cold rooms, computer suite and data preparation areas. An underway instrumentation and control room contains all the controls for winches and gantries in a location with clear oversight of the main operational areas. Working laboratories have easy access to the main working decks.

A series of in-house developed Automatic Weather Stations feeding into Darmstadt facility , will be extended by installation of a marinised version on the new ship.

Provision is being made for the carriage of project-specific and specialist containerised laboratories for work such as ultra-clean chemistry or atmospheric research.

Accommodation comprises 20 cabins for scientific personnel plus single-berth accommodation for 27 Officers and ratings. The Chief Scientist's suite is located at Bridge Deck level overlooking the main science working areas.

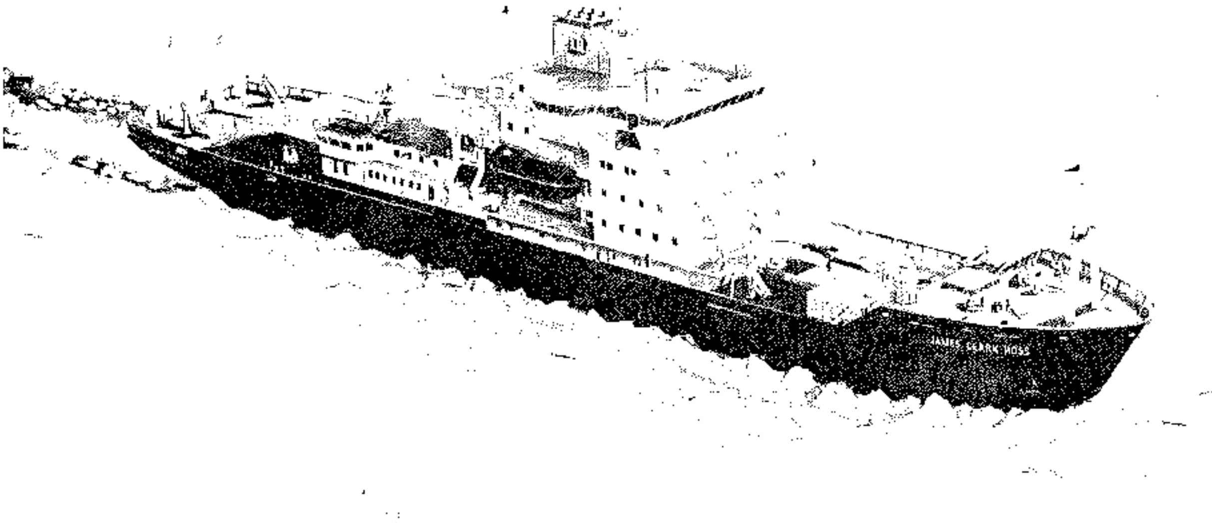
There is no helicopter facility but the 25-metre clear after deck, will allow the ship to be readily adapted for helicopter operation.

The cargo facilities comprise two holds, together capable of carrying 1500 cubic metres of general cargo, and tankage for 250 tonnes of aviation turbine fuel and 300 tonnes of cargo diesel fuel for the Antarctic stations. The cargo areas are served by a 20-tonne capacity articulated crane with a 20-metre working radius.

Provision is being made for the carriage of 15 standard 20-foot containers in the holds and on the hatches. For intensive operations such as base construction projects additional containers can be carried on the large clear after deck.

Cargo will be discharged in the Antarctic with the aid of a tender designed to carry a loaded 20-foot container. It will have a bow ramp for simple discharge of vehicles onto the beach.

A large scientific equipment hold below the main working deck aft contains air-conditioned delicate equipment stores as well as general stowage areas. Permanent and portable magazines allow the carriage of up to 30 tonnes of seismic explosives. The science working areas are served by a main crane of 10-tonne capacity with a 22-metre working radius, together with a number of small articulated service cranes for assistance in scientific equipment handling and deployment.



ARTIST'S IMPRESSION OF RRS "JAMES CLARK ROSS"

Conclusion

The vessel is scheduled for delivery in mid-1991 and BAS has great confidence in the ability of the shipbuilder to produce, on time, a first-class platform for marine science into the 21st century combined with a capable and flexible logistic tool. This will permit the continuance of the high level of support which the Antarctic operations require.

DESIGN OF AN OCEAN-RESEARCH AND LOGISTICS SUPPORT VESSEL FOR THE ITALIAN SCIENTIFIC BASE IN ANTARCTICA

by
F. Orlandini [1], A. Cordano [2]
Italian Antarctic National Program, PNRA

Abstract

The development of the Italian Scientific Base and relevant research activities requires the exploitation of a purposely designed Vessel.

The ship's design was defined taking into account the experience gained in the previous expeditions, the development programs of the Italian Base in Antarctica and the research activities to be carried out.

Consequently, the Vessel's design criteria were developed and defined on the basis of the mission profile.

Introduction

The construction and management of permanent scientific bases in Antarctica involves the availability of vessels purposely designed and studied to carry out ocean-research and logistic support operations.

The present study development is the result of a cooperation between ENEA and FINCANTIERI and originated from the need of integrating the environment knowledge and the operational requirements with the proven design capabilities of the modern research ships, in order to attain a high degree of operational efficiency in consideration of the high technology involved.

Moreover, as far as ice problems are concerned, FINCANTIERI availed itself of the collaboration of well-known international experts as the MASA YARD.

The design was developed through the following phases:

A) Analysis of the following items:
   . Experience gained in the Previous Expeditions,
   . Planning of the Permanent Base Development and Maintenance Activities,
   . Planning of the Ocean-Research Activities.

B) Definition of the Mission Profile.

C) Definition of the Vessel's Design Criteria.

In general, the operational tasks the Vessel is to fulfil can be summarized as follows:

---

[1] ENEA, C.R.E. Casaccia, P.O. Box 2400, Rome, Italy
[2] FINCANTIERI - Cantieri Navali Italiani, Via Cipro, 11, Genoa, Italy

1. <u>As a Logistic Support Ship for the Scientific Base</u>:

- transport of scientific and logistics support personnel,
- transport of scientific facilities and logistics support material to the scientific base (fuel, provisions, and so on),
- transport of the vehicles necessary for carrying out the base activities (e.g.: transfers, maintenance operations, etc.),
- transport and recovery of helicopters,
- transport of containers and/or other material in bulk.

2. <u>As an Ocean-Research Ship</u>:

The scientific activities concern the following fields:

- physical oceanography,
- chemical oceanography,
- biological oceanography,
- hydrology,
- taking samples with ROV,
- geological oceanography,
- acoustic research of sea bottom,
- seismological research (fitted for, but without equipment),
- meteorology.

The following design criteria were taken into account:

- optimization of the ship dimensions,
- operational efficiency as ocean-research vessel (wide laboratories, suitable working areas, low radiatd noise at sea),
- operational efficiency as logistics support vessel (wide spaces for the different cargoes and suitable handling facilities),
- protection and safeguard of the environment,
- flexibility of operation (interior spaces to be used for different purposes),
- high comfort in the living quarters and laboratories,
- helicopter operation facilities.

Before illustrating in detail the above-mentioned design criteria and the solutions adopted, we would state hereafter the main characteristics of the Vessel:

. Length, overall		abt.	98	m
. Breadth		abt.	22	m
. Depth to upper-deck		abt.	14.5	m
. Max. speed		abt.	16	Kts
. Range		abt.	14,000	N.M.
. Endurance	provisions for 100 days		for 108	persons
. Deadweight		abt.	3,500	t
. Accommodation for			108	persons
. 2 C.P. Propellers				
. 2 Side thrusters forward, each of			500	kW
. 1 Propulsion thruster afterward			380	kW
. 4 Diesel Engines, each of			2,200	kW

- 2 Propulsion D.C. Electric Motors on Shafts for silent operational states
- 2 Auxiliary Diesel-generators

- Silent Diesel-generators
- Towing resistance of scientific equipment of 6 t at 6-Kt speeds in silent mode
- Fuel-oil tank capacity abt. 1,700 m^3
- Hold volume abt. 1,050 m^3
- RO/RO deck surface 500 m^2
- Helideck fitted for deck-landing of SIKORSKY SH 3D size helicopters
- Hangar fitted for two AB 212 size helicopters
- 8 Laboratories + available spaces for additional modular laboratories
- 2 Working areas, one of which fitted with a moon-pool. A third area could be arranged forward.

The Vessel is designed in accordance with the REGISTRO ITALIANO NAVALE's (R.I.Na.) Class. The ice strengthening of hull and propulsion system is in compliance with 1A Super-class Finnish-Swedish Rules with special consideration to ice conditions in the Antarctic areas.

VESSEL'S DESIGN CRITERIA

I) Hull Dimensions

Considering the area where the Vessel is to operate, studies were made in order to maintain the ship's length below 100 m, in order to guarantee a good manoeuverability, even in narrow places, both in case of Vessel operating as a research-ship and in case of Vessel operating as a logistics support-ship, very close to the Scientific Base.
As far as sea-keeping, manoeuverability and low radiated noise at sea are concerned, the hull shapes were designed basing on shapes of proven ice-breaking and research-ships.

II) Capability as Logistics Support Vessel for the Antarctic Scientific Base

In order to ensure the best possible operational efficiency, as first step, the type and quantity of the materials required for the development and maintenance of the Italian Scientific Base were identified.
The following types of cargoes were considered as necessary to be carried:

- arctic Diesel-oil,
- aviation fuel,
- crafts and vehicles for the transfer of people and/or materials such as motor-sledges, flex-mobiles, snow trucks,
- work means such as excavators, fork-lifts, air-compressors, cranes, to be used for maintenance and/or development operations of the Permanent Base,
- containers and other building material in bulk,
- scientific equipment for the Base activities.

The transport arrangements for these types of cargoes are:

- fuel tanks (arctic Diesel-oil and aviation fuel) for a total of 1000 m^3,
- a fore hold for containers and/or other material in bulk,
- a garage for crafts and vehicles, on the RO/RO deck, for an aggregate surface of abt. 500 m^2, one third of which with a free-deck height of 6 m. The remaining area has a free-deck height of abt.3.5 m.

The material handling systems have been designed and arranged in order to comply with the following criteria:

- ready and easy loading/unloading operations,
- reliability and security,
- flexibility of operation, i.e. possibility to use the ship interior spaces for different purposes.

Let us see now how each cargo space can be used as loading/unloading system:
The fore hold is fitted with a crane having a lifting capacity of abt. 30 t, suitable for container loading/unloading operations.
Another crane, with the dual-duty of gangway and light cargo crane, is arranged forward, on the forecastle.

The garage is connected to the hold through a sliding door, at the main-deck level, and is provided with a vehicle-landing ramp, on the starboard side. The ramp, 10 m long, is fitted to carry the above-mentioned vehicles and work means.
A third crane, located in proximity of the hangar, is capable of operating on the flight-deck and through hatchways in the aft working area, which is in communication with the garage through a door.
In short, every ship area (aft, amidships, forward) was provided with a loading/unloading system, with possibility of communication between the different areas.

III) <u>Capability as Ocean-Research Ship</u>

As already said, the Ocean-Research Ship general design criteria consider the adoption of:
. wide and properly located laboratories,
. suitable working areas,
. low radiated noise (underwater radiated noise) and low airborne noise.

In detail, the arrangement of laboratories and working areas is as follows:
* Aft there is a weather-deck working area, fitted with A-frame for lowering the scientific equipment into the water.
  The scientific equipment winches are fitted in an adjacent winch-room, in consideration of the environmental conditions in which the Vessel is to operate,
* Another shelter working area, with associated ocean winches, is arranged amidships, on the main-deck.
  Research activities, in this area, can be performed either through a door on the ship's starboardside or through the midship moon-pool.
  The Vessel is fitted with a moon-pool considering that, sometimes, she may have to operate with ice all around herself.
  This working area is properly located as far as pitch and rolling are concerned (amidships and not far from water-line).
* The laboratories for scientific research activities are situated on the main-deck in order not to jeopardize people and materials.
  They are concentrated in one only area which is baryncetric with respect to the two working areas.
  In the proximity of laboratories and working areas there are the scientific equipment workshops and stores.
* A weather station with associated laboratory is also provided on the upper-deck.
* In addition, a third weather-deck working area can be equipped on the upper-deck, forward superstructures. For this purpose, the hold hatchway is flush with deck.

The Vessel is capable of carrying, lowering at sea, and recovering the following work boats:
. 1 hydrographic boat,
. 1 oceanographic boat of 20 t of displacement.

As, during the research activities, the Vessel is to be capable of a good platform stability and station-keeping, a suitable passive stabilizing system is fitted.

IV) Low Radiated Noise at Sea

To maintain the ship's own radiated noise at the lowest level is a compulsory feature in order not to interfere with the scientific instrument signals and ensure the best efficiency in the performance of the research and survey work.
Thus, an ANTI-NOISE DESIGN PHILOSOPHY was developed, basing on the previously gained experience, as well as on the intensified measurements and results obtained in the recent construction of a very quiet Ocean-Research Vessel.
The development phases of this ANTI-NOISE PHILOSOPHY are:

. Definition of the operational requirements of the Vessel in the research mode (for instance: speed, towing capacity, duration of the research activities, etc.);
. List of the necessary running machinery in this operational state;
. Identification of noisy machinery and/or critical sources;
. Selection of the most suitable types of machinery;
. Concentration of the noisy sources;
. Location of noisy sources at the highest possible levels;
. Separation of quiet from noisy spaces.

The following solutions were identified:

. Type of Diesel-electric propulsion, for the research activities up to 6-Knot speeds, with a towing capacity of 6 t.
  In this configuration, the propellers are driven by two d.c. electric motors fitted on the shafts and actuated by the silent generators.
  The reduction-gears and Diesel propulsion engines, used in the transfer mode, are disconnected by means of a coupling fitted downstream the reduction-gears.
. Special design and special manufacture of propellers.
. Silent generators fitted in the upper part of the Engine Room.
. Adoption of acoustic measurements for critical machinery (single/double resilient-mounting system, special silencers, suitable flexible hoses).
. Special design of machinery seating and rafting.
. Definition of an "Acoustic Budget" as noise controlling instrument during the Vessel's detail design and construction, similarly to what done for weights, through the Light-Weight Ship.

V) Protection and Safeguard of the Environment

The protection and safeguard of the environment was one of the primary factors which were taken into account in the study and design of this project, as some solutions can be adopted only at an early stage in order not to cause an impact on the general architecture of the ship.

After an analysis in this respect, it appeared that oily pollution, as a consequence of accidents/casualties at sea, is one of the major hazards for the environment.
Unfortunately, that was the case of the disasters happened last years, even in the Antarctic areas.

Then, considering:
. the risks for Ship's damages due to navigation through ice,
. the particular ambient conditions,
. the distance of ports that can guarantee the immediate availability of rescue means,

it was decided to fit the fuel tanks not in direct contact with the ship's side (as you can see from the projected schematic), in order to prevent from oil pollution.
There were installed cofferdams for non-polluting liquids such as ballast water. As regards oily waters, solid garbage and sewage, treatment systems (incinerators, separators, and so on) were provided in order to comply with 73/78 MARPOL Rules.
Moreover, for removal of solid garbage from the Antarctic area, the Vessel is fitted with suitable stowing spaces.

VI) Flexibility of Operation

Planning of annual expeditions requires flexibility of operation.
For instance, during some expeditions, it is necessary to carry out planned maintenance or development works in the Base, thus the Vessel, to meet such requirements, is to be capable of carrying a larger amount of materials and facilities; in other expeditions, instead, transport of materials may be limited whilst the scientific research activities extended.
This flexibility in the expedition planning needs, consequently, a flexibility of operation of the Vessel.
The Ship's area, allowing this flexibility, is the garage, which, for its characteristics, can be used either as space for the transport of vehicles and materials or as an area for additional laboratories.

* In fact, its free-deck height allows the arrangement of modular laboratories.
* Such arrangements are made easier by the access ramp.
* These additional laboratories are fitted close to the other laboratories and close to the two working areas.

Then, it is possible to extend the scientific area, in full compliance with the requirement to have the laboratories situated above the bulkhead-deck, in proximity of the working areas and in a barycentric position with respect to these.

VII) Safety and High Comfort in the Accommodation and Scientific Areas

Location of the accommodation spaces and laboratories above the bulkhead-deck ensures a very high safety degree.
Moreover, steps taken to reduce the ship's noise level have a positive impact on the airborne noise of this space, too.
A high living comfort is also guaranteed by the arrangement of these spaces far from noisy sources and by the adoption of high

habitability standards (every cabin is fitted with private sanitary room).
Accommodation rooms are provided for 28 crew-members and 80 scientists.
Wide spaces are also destined for recreational and public areas (gymnasium, two hobby rooms, bar, library).

VIII) Helo Operation Facilities

The considered helo operation facilities are as follows:

- flight-deck fitted to deck-landing of a SIKORSKY SH3 size helicopter, and provided with lashings system;
- helo refuelling system;
- night operation system;
- fixed hangar, suitable for recovery of two AGUSTA-BELL 212 size helicopters;
- fire-fighting system.

The hangar was installed in consideration of the quite severe environmental conditions (low temperatures, strong winds) in which the Vessel is to operate or navigate, and also for transport of helicopters from ITALY to ANTARCTICA.

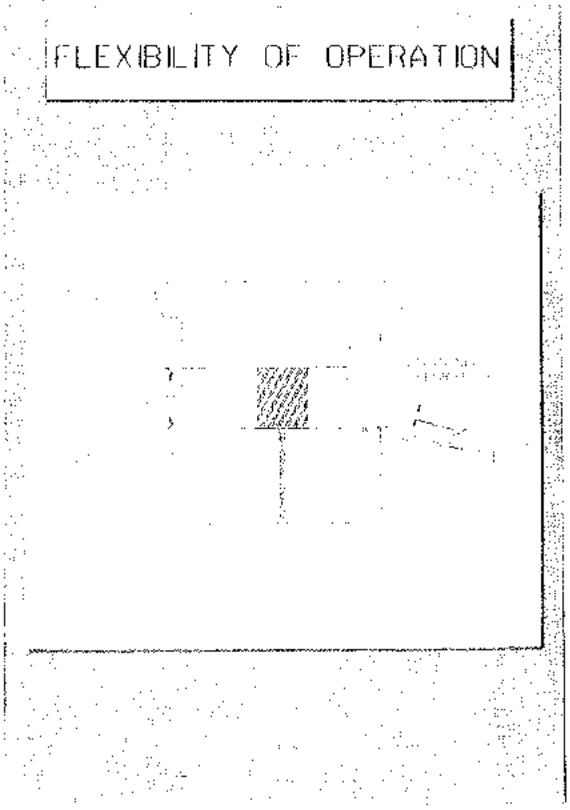
IX) Navigation and Communication Equipment

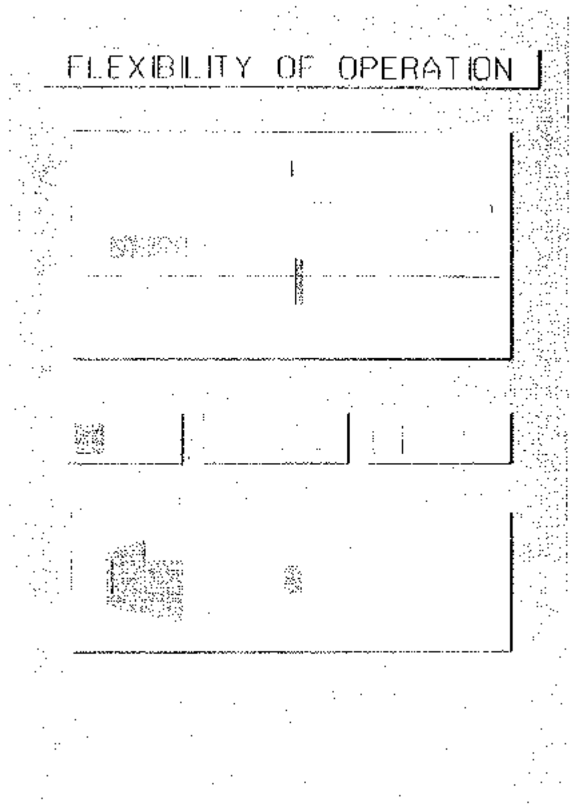
The navigation and communication aids consist of the following equipment:

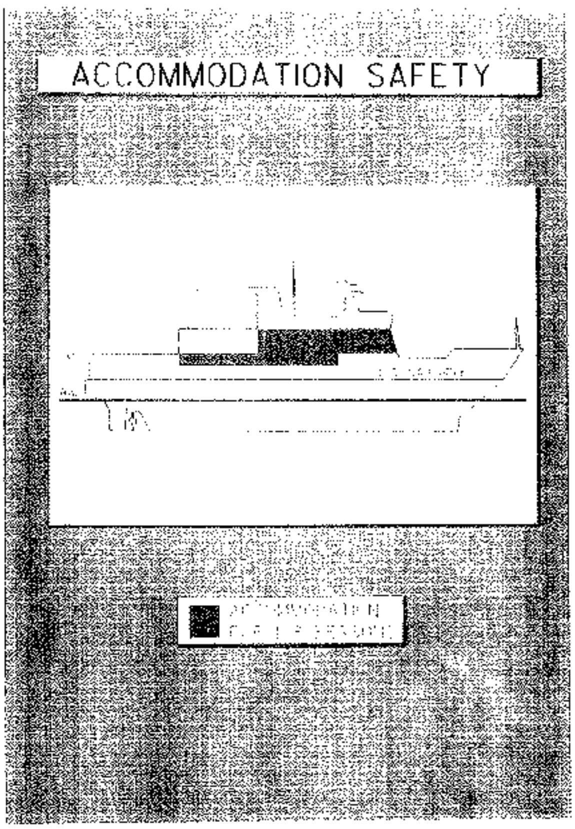
- Gyro-compass,
- Radio-direction finder,
- 2 Radars (ARPA type),
- Radio beacon,
- Weather fac-simile and satellite receiver,
- Satellite navigator (Transit, GPS),
- Fishing sonar to locate icerbergs,
- Telex,
- Telefax and telephone via Inmarsat,
- Doppler log,
- Doppler log for ice conditions,
- 2 echo-sounders,
- Auto-pilot,
- NOAA/Meteor APT satellite for ice conditions,

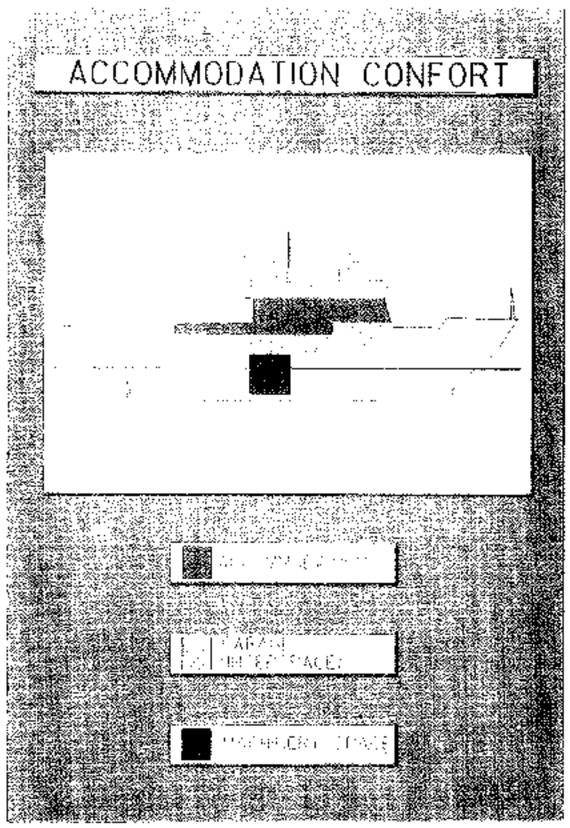
X) Acknowledgements

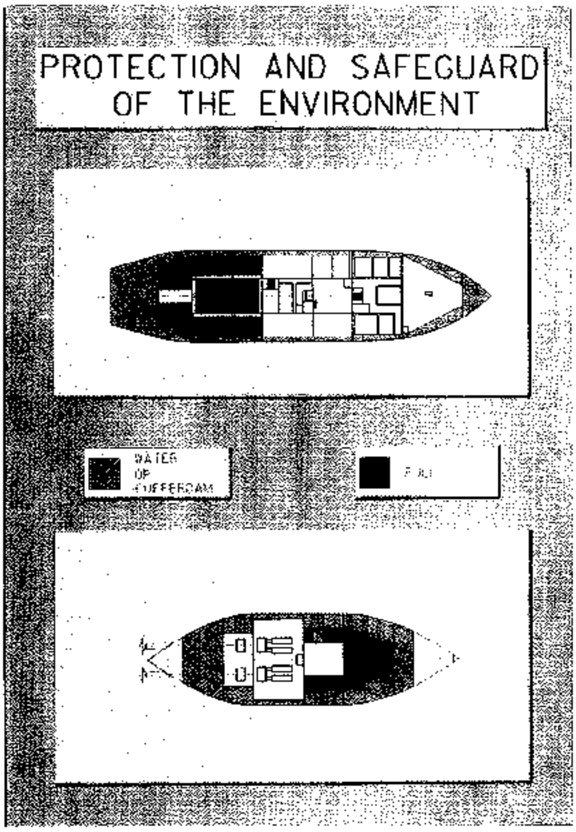
The Authors wish to thank Mr. Eero MAKINEN of MASA YARD for his kind co-operation.

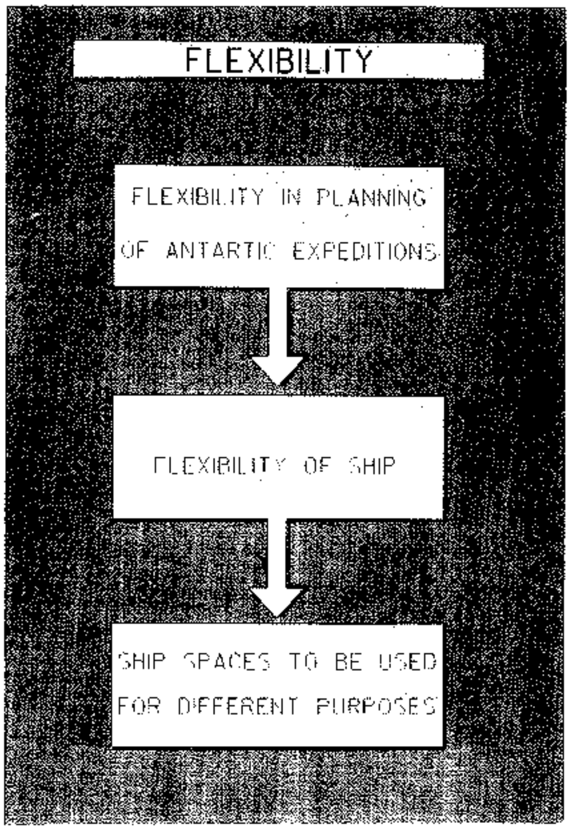

FLEXIBILITY OF OPERATION

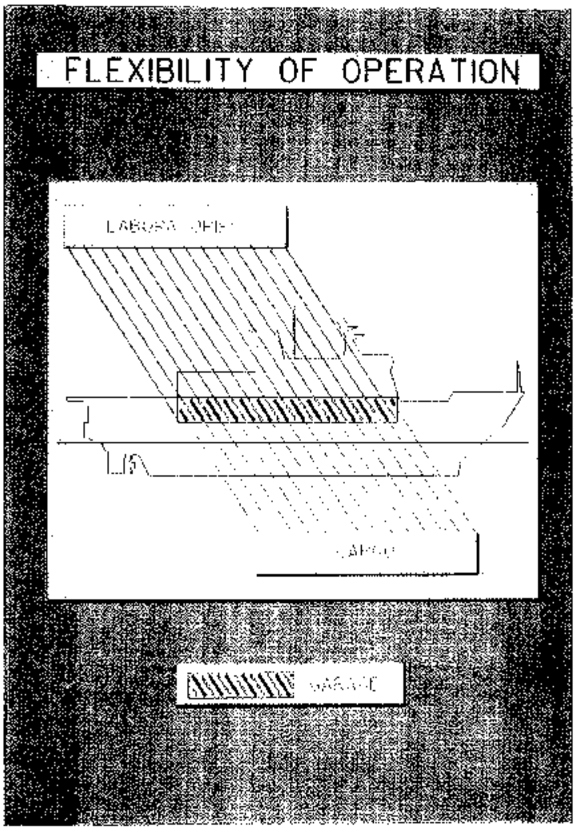

FLEXIBILITY OF OPERATION

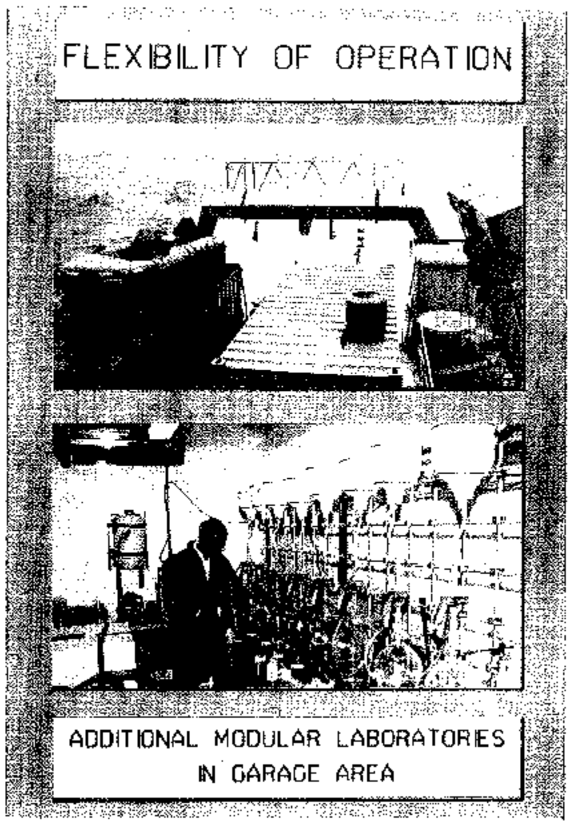

ACCOMMODATION SAFETY

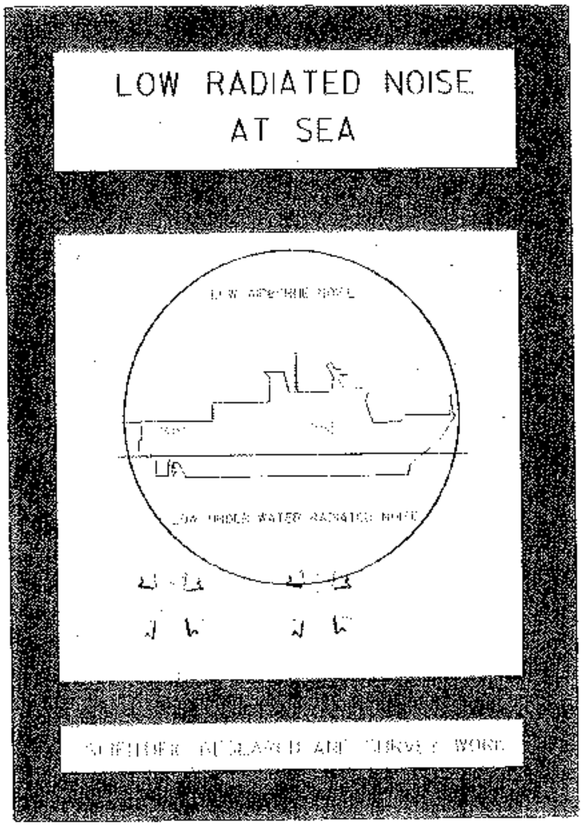

ACCOMMODATION CONFORT

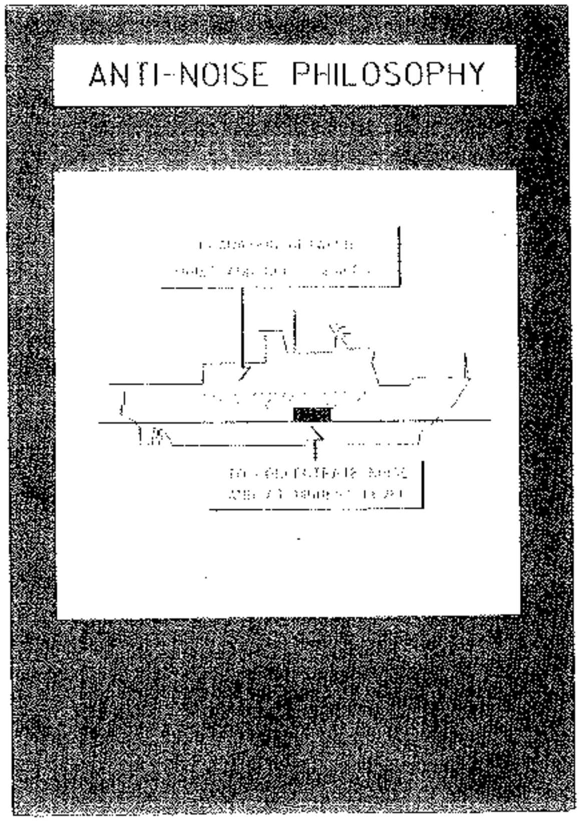

PROTECTION AND SAFEGUARD
OF THE ENVIRONMENT

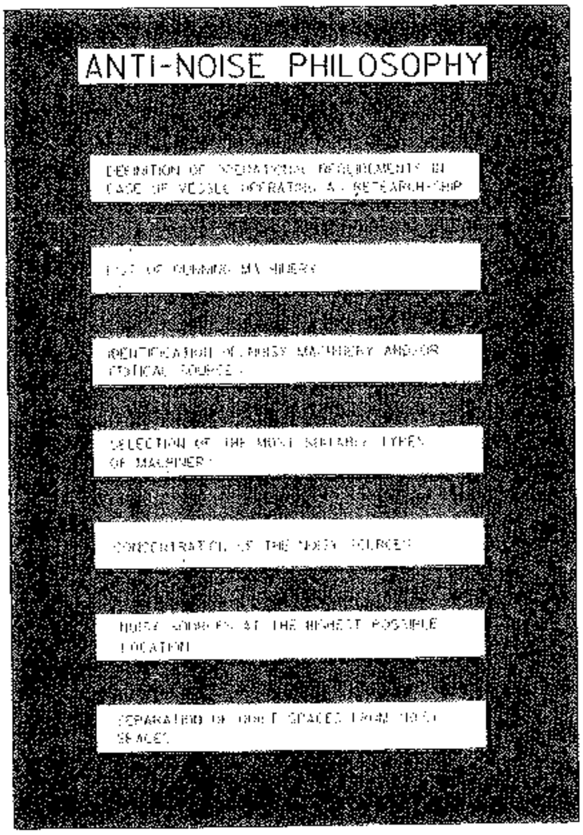

FLEXIBILITY
FLEXIBILITY IN PLANNING
OF ANTARTIC EXPEDITIONS
FLEXIBILITY OF SHIP
SHIP SPACES TO BE USED
FOR DIFFERENT PURPOSES

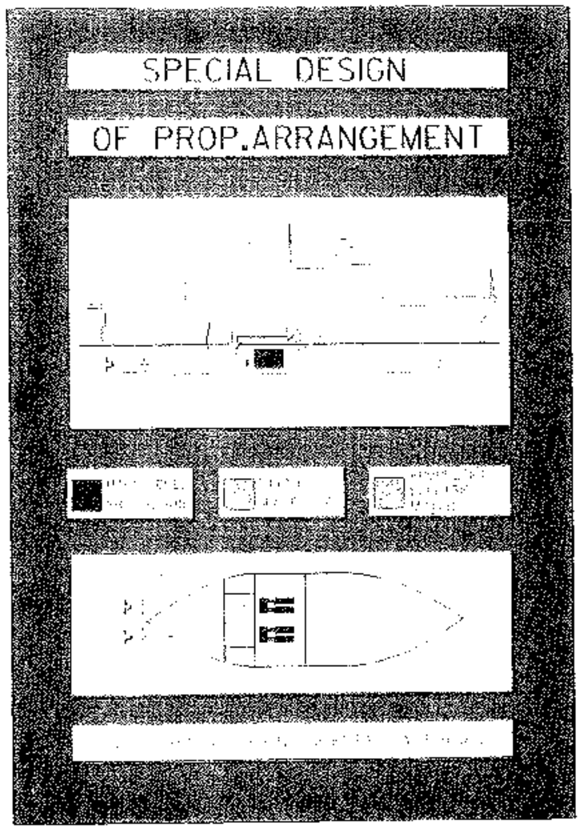

FLEXIBILITY OF OPERATION

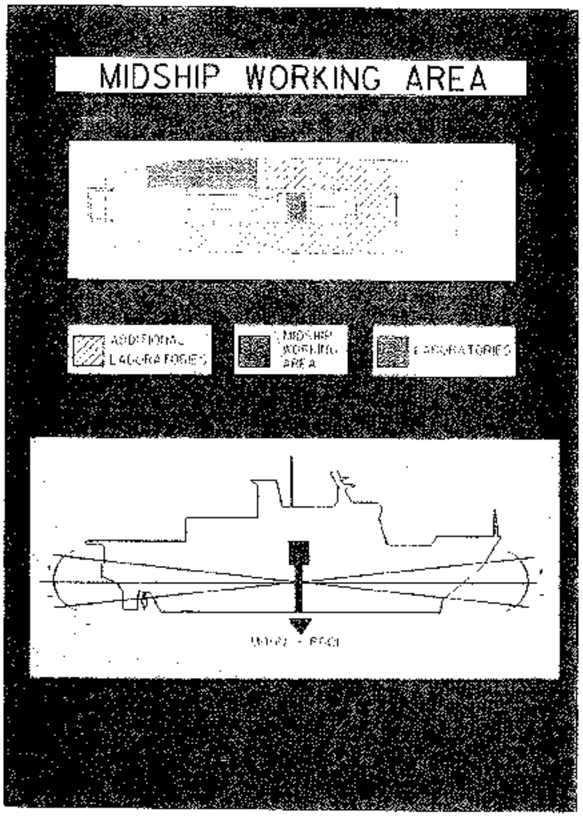

FLEXIBILITY OF OPERATION
ADDITIONAL MODULAR LABORATORIES
IN GARAGE AREA

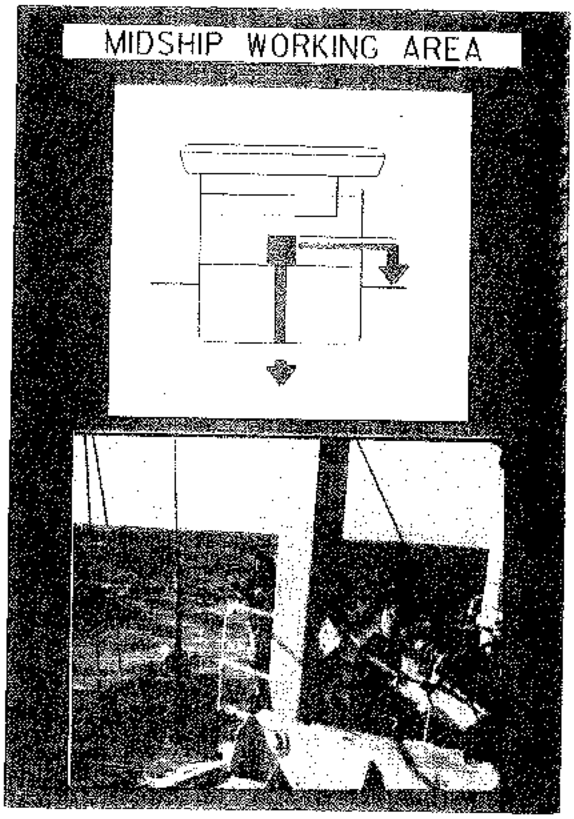

LOW RADIATED NOISE
AT SEA

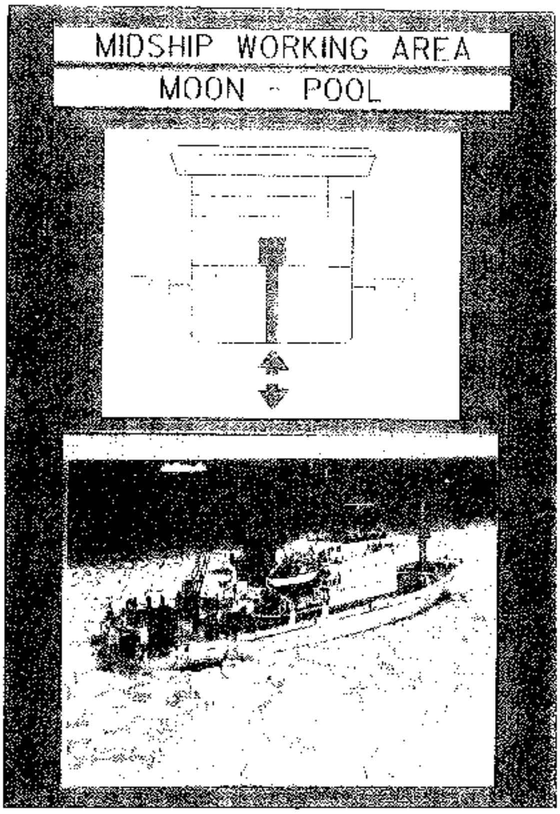

ANTI-NOISE PHILOSOPHY

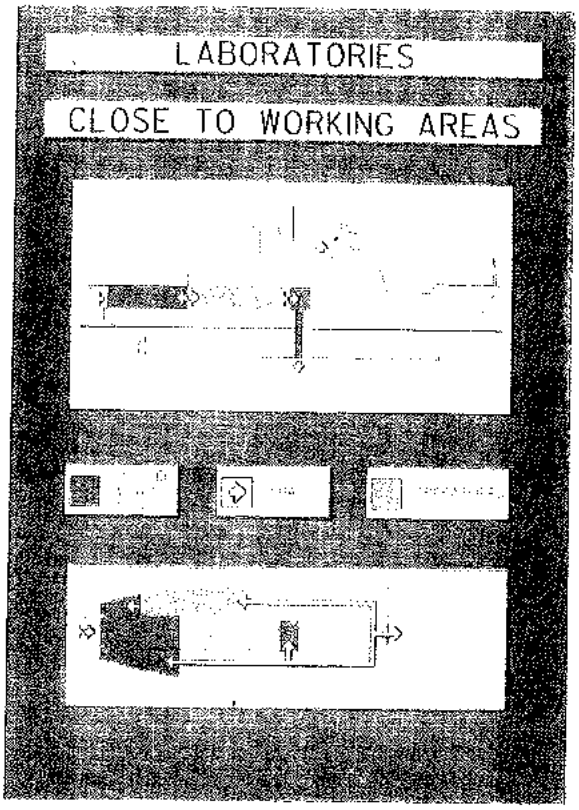

ANTI-NOISE PHILOSOPHY

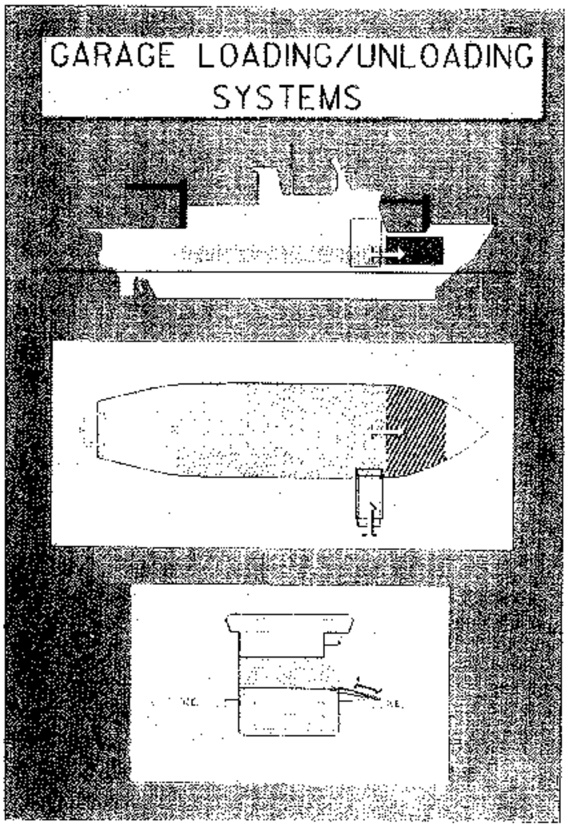

SPECIAL DESIGN
OF PROP.ARRANGEMENT

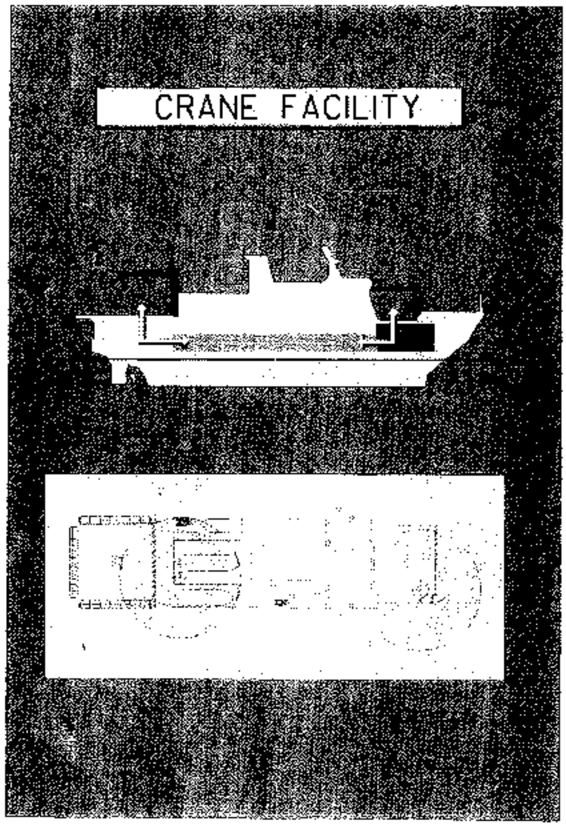

MIDSHIP WORKING AREA
ADDITIONAL LABORATORIES
MIDSHIP WORKING AREA
LABORATORIES

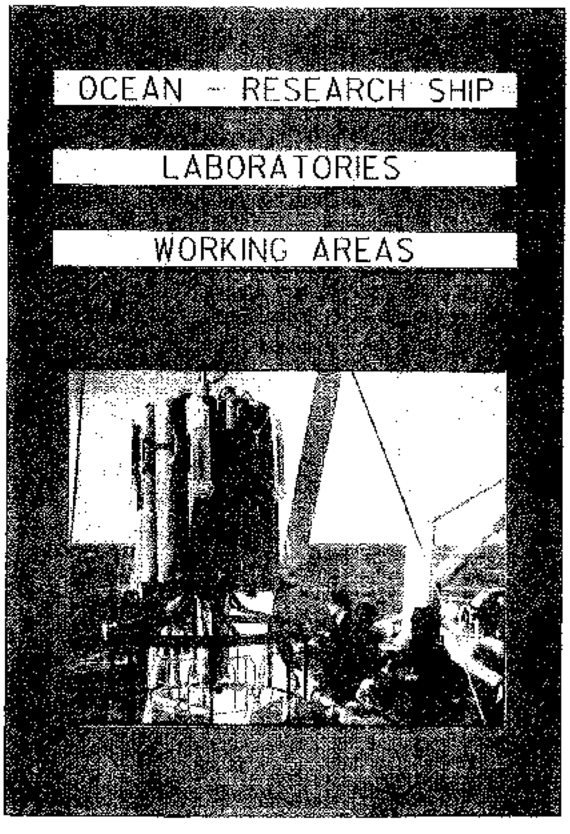

MIDSHIP WORKING AREA

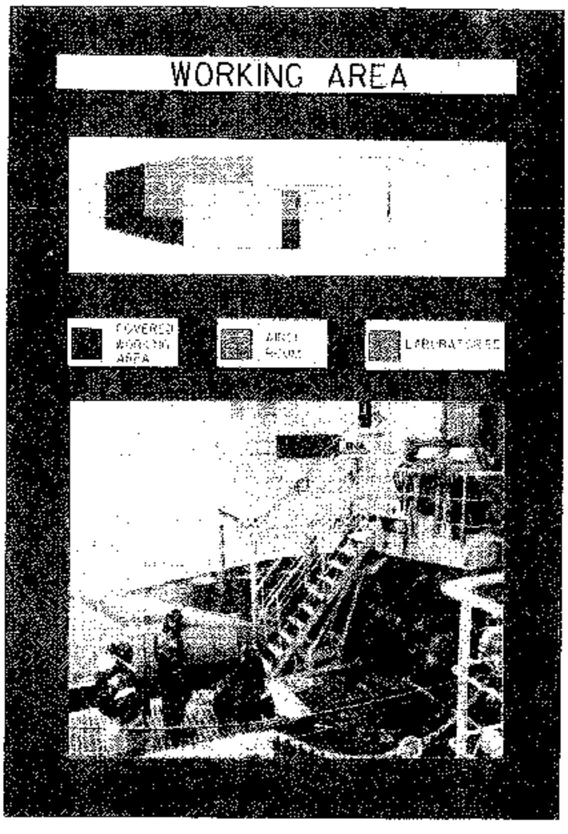

MIDSHIP WORKING AREA
MOON - POOL

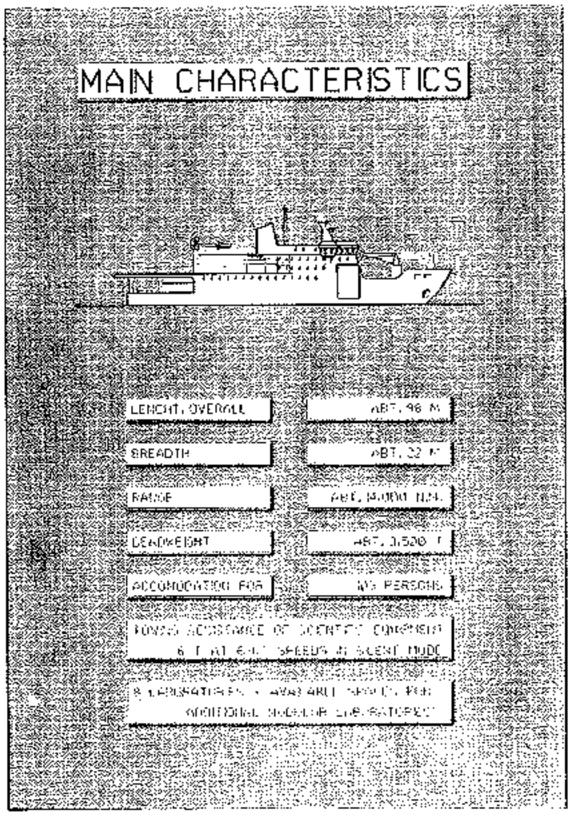

LABORATORIES
CLOSE TO WORKING AREAS

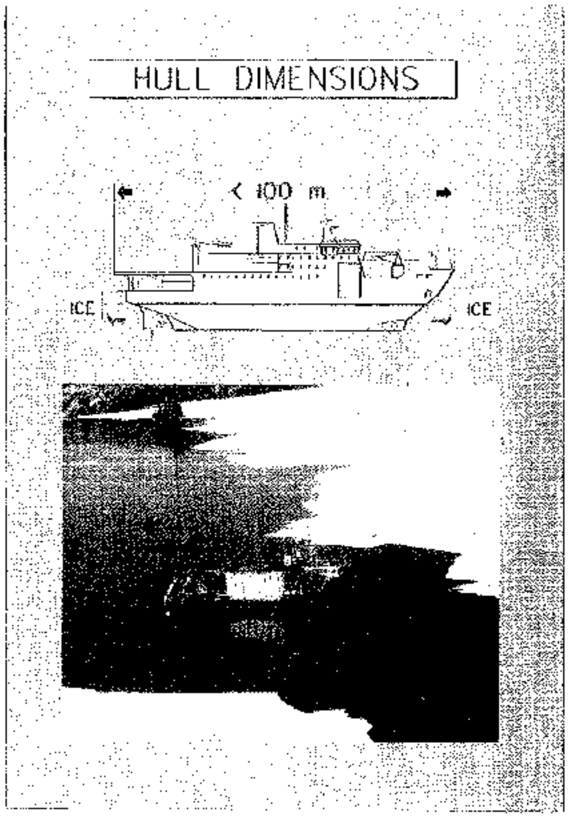

GARAGE LOADING/UNLOADING SYSTEMS

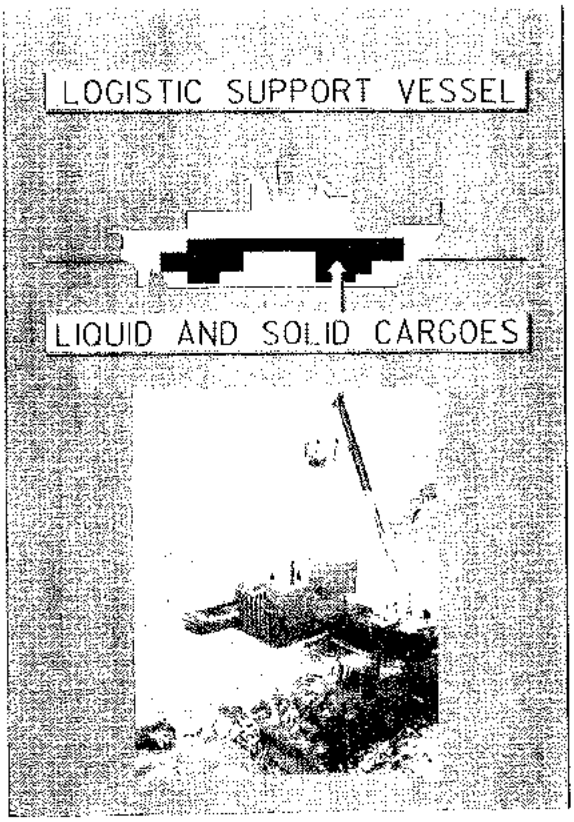

CRANE FACILITY

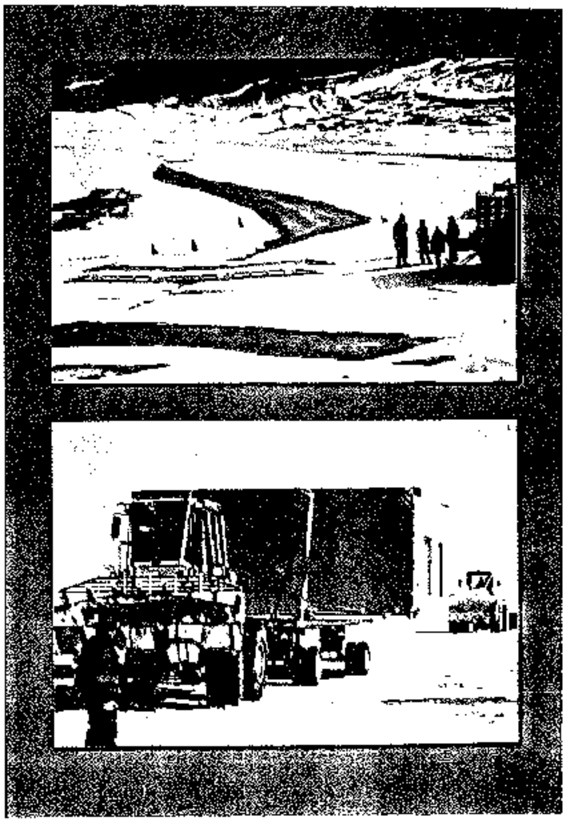

OCEAN - RESEARCH SHIP
LABORATORIES
WORKING AREAS

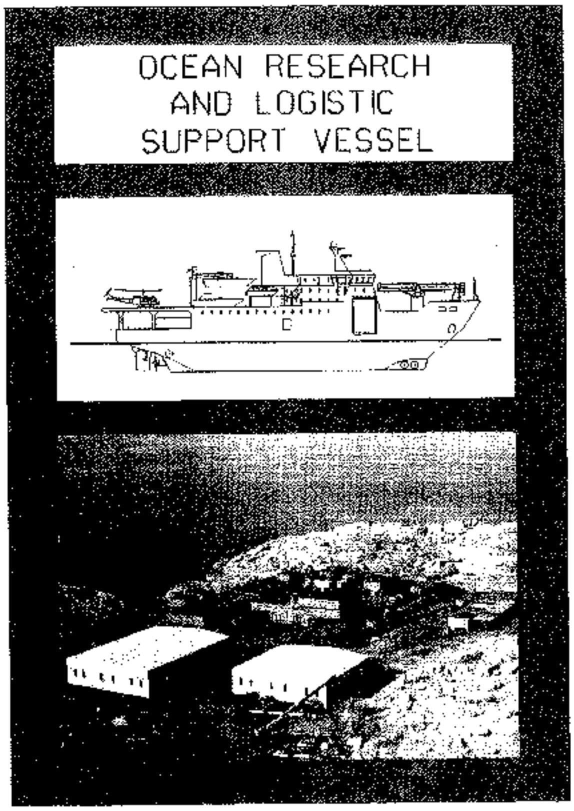

WORKING AREA
COVERED WORKING AREA

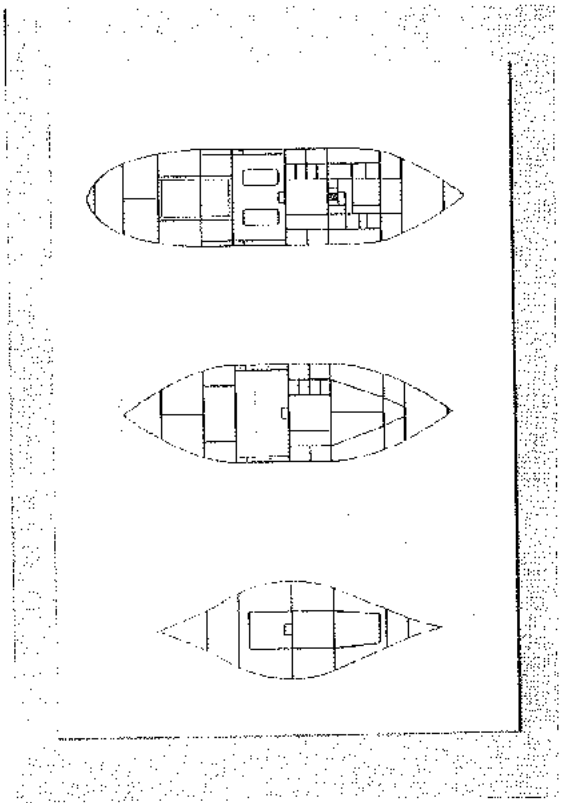

MAIN CHARACTERISTICS
ABT. 96 M
BREADTH
ABT. 22 M
RANGE
DEADWEIGHT

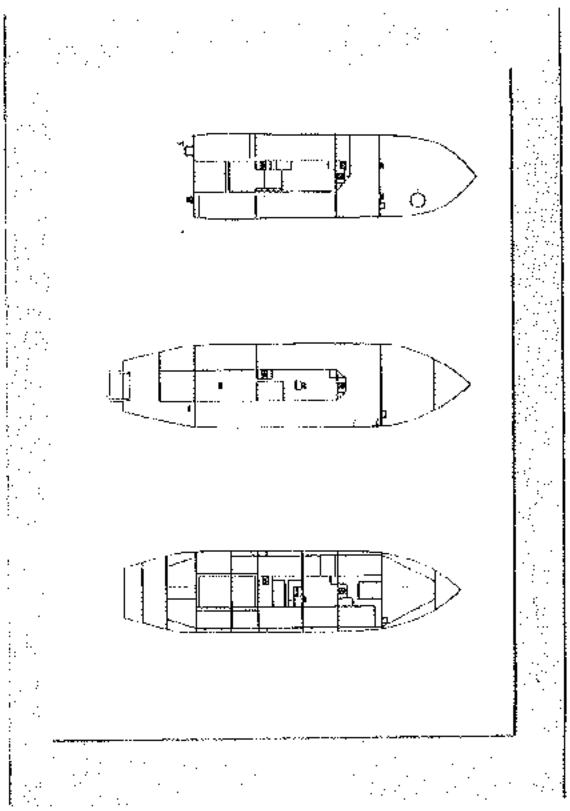

HULL DIMENSIONS
< 100 m
ICE
ICE

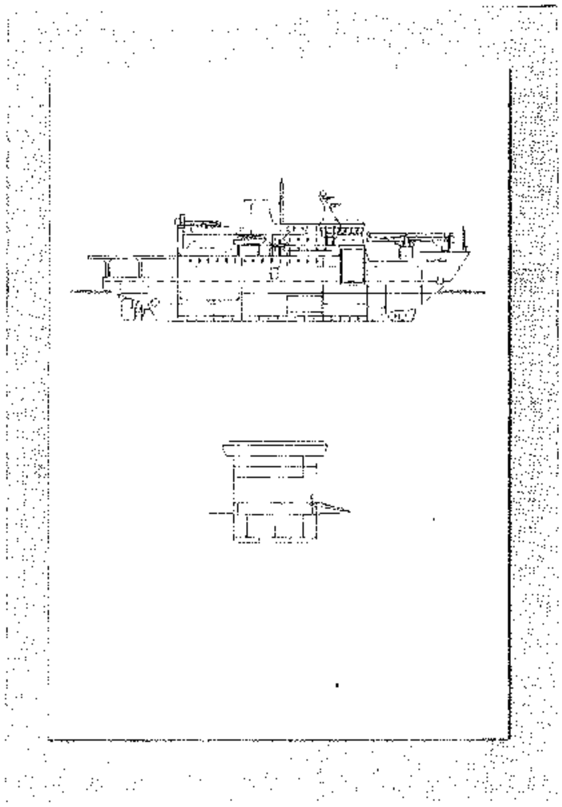

LOGISTIC SUPPORT VESSEL
LIQUID AND SOLID CARGOES




OCEAN RESEARCH
AND LOGISTIC
SUPPORT VESSEL







Symposium on Antarctic
Logistics and Operations

Sao Paulo , Brazil
16-18 July ,1990

R/V ARANDA ON THE WEDDELL SEA ON SEASON 1989-90

by

Mälkki, P.1), Niemistö, L.1) and Aro, E.2)

ABSTRACT

The expedition FINNARP-89 consisted of two sections: research carried out at Aboa research station and the marine research program based on a new research vessel. The marine research program was carried out on the Weddell Sea on the season 1989-90.There were seven marine research programs. The expedition as a whole was successful. In all about 80 % of the programs and samplings planned were carried out. The new research vessel especially taylored to marine research was compromise between a large and a small vessel in many respect. During the expedition, however, shortcuts, restrictions and limitation in equipments and instruments were observed. The total time period for expedition was 150 days and for execution of scientific programs 56 days. It was observed, that at this time, too many scientific programs were included. Time table was too tight and some of the projects were running out of time. In the future expeditions like this should not be devided in two parts and cooperation between various projects could be made more effective. The projects in operation could also be more flexible. Some parts of the communication system were not satisfactory and should be renewed.

1. INTRODUCTION

The expedition FINNARP-89 consisted of two sections: research carried out with the Aboa station as a base, and the marine program based on a new research vessel. The marine program was carried out at the Weddell Sea on the season 1989-90. A number of scientists from other countries participated the expedition. A total of 54 persons at maximum partcipated the first part of the

1) Finnish Institute of Marine Research, P.O. Box 33, SF-00931 Helsinki, FINLAND

2) Finnish Game and Fisheries Research Institute, Fisheries Division, P.O. Box 202, SF-00151 Helsinki, FINLAND

survey. 25 scientists took part to marine research projects, 16 scientists was on their way to research stations ABOA and WASA and 13 belong to vessel's crew. During the second part of the expedition the total number of participants was at maximum 47 persons: In all 18 scientists for marine research projects, 2 Norwegians on their way to K/V ANDENES, 16 scientists from research stations ABOA and WASA on their way home and 13 persons belong to vessel's crew.

2. GENERAL OUTLINE AND TIMETABLE OF THE PROGRAMS

2.1. Timetable for research vessel as planned

The marine research programs was planned to carry out by the new research vessel, R/V ARANDA, especially fitted for the requirements of scientific programs concerned (Appendix 1). Because of the unknown ice conditions, three separate detailed plans were prepared. Marine studies were planned to be made both along the continental shelf (mainly geology) and in the abyssal sea close to the ice edge. A substantial part of the ice and physical oceanography studies were planned to be carried out by helicopters over the open pack ice. The ship was not planned to operate in closed pack ice.

The operational area of the marine programs was planned to be the eastern Weddell Sea, roughly between 68°00' S and 74°00' S ; 10°00' W and 30°00' W (Figure 1). The expedition was planned to leave Helsinki on November 3, 1989 and departure from Montevideo for the first leg of the expedition on December 8, 1989 (Table 1). The marine program was divided into two legs, each of some 5 weeks in duration. The first leg was planned to consist of programmes in marine biology, ice, meteorology, physical oceanography and ship technology. The first leg of the expedition was planned to make its way to the Western Queen Maud Land, where the participants in the land-based research are to be transferred to the Aboa station (73°03' S ;13°25' W,) by two helicopters. After that the program was planned to continue with the oceanographic and marine biology research as well as marine technology and ice studies. The change of some expedition members and vessel's crew was planned to take place between 24.-26. January 1990 at Ushuaia. During the second leg the program consisted of physical and chemical oceanography, meteorology, marine geology and ship technology. The second leg was planned to start from Ushuaia on 26th January 1990. The land party was planned to be picked up at the end of the second leg, according to preliminary plans on about 15th of February 1990. The vessel was planned then to return via Montevideo to Finland. Arrival to home port was expected to take place at 30th March 1990 (Table 1).

3. THE MARINE RESEARCH PROGRAMS AS PLANNED

The topics of seven marine research programs were:

1. Structure and controlling factors in the Weddell Sea pelagic community

2. Sedimentation of trace elements and nutrients in the Weddell Sea

3. Evolution of the surface layer of the Weddell Sea in summer

4. Sea ice research

5. Air-sea interaction and marine meteorology

6. Detailed marine geological study from ice front to shelf break, north of the Kraul MTS, western Queen Maud Land

7. Ship ice loads and mechanical properties of Antarctic Sea ice

3.1 CONTENTS OF MARINE RESEARCH PROGRAMS

3.1.1. Structure and controlling factors in the Weddell Sea pelagic community

Main aim of the study

The main aim of the study was to monitor the distribution of primary production between the principal consumer groups. The other area of investigation was the factors regulating the function of the pelagic ecosystem, i.e. predation and competition.

Operating plan

Studies was planned to be made during both legs, but the emphasis was on leg 1. Sampling was to be made along the route of the research vessel, while concentrating on areas that probably have a high primary production (two possible areas was chosen): the marginal ice zone and the site/area where the sedimentation studies was to be made both for laboratory studies and for preservation of samples. Sampling was planned to consist of water samples as well as of vertical and horizontal tows with various plankton nets. On-track, quasi-continuous sampling was to be carried out for particle counting. The time needed for sampling at one station was expected to be dependent on local conditions, but was estimated to normally require 1 to 6 hours. Some sampling was planned to be made during night time.

Support

The plankton studies needed information about CTD-measurements, weather data (solar irradiance, reflection), ice conditions and reconnaissance, ship position and especially nutrient analyses. Support for sampling was also necessary.

3.1.2. Sedimentation of trace elements and nutrients in the Weddell Sea

Main aims of the study

The general aim was to study mass balances and long-term changes in nutrients and trace elements in the Weddell Sea. Answers to following questions were sought:

1. The distribution of biologically and chemically important nutrients and trace elements in the Weddell Sea.

2. The heterogeneous equilibrium of these compounds and elements between sea water and the sedimenting particulate material.

3. Long-term changes in trace element concentrations in the Weddell Sea.

4. Estimation of inputs and mass balances of nutrients and trace elements.

Operating plan

Both periods were used for the observations, the main emphasis was on the second leg. Sea water sampling was carried out daily (CTD, nutrients, O_2, alkalinity, trace elements). Sedimentation traps equipped with automatic sample bottle changers was to be installed at the beginning of the first leg and they were recovered at the end of the second leg. Sediment sampling was to be carried out at approximately ten locations with depths down to 1000 m, mainly during the second leg.

Support

Support from personnel in other projects was needed each day for the CTD runs. Sampling was planned to be carried out in connection with the CTD runs needed for the physical projects. Assistance from ship crew was needed in the lowering and recovery of the sedimentation traps.

3.1.3. Evolution of the surface layer of the Weddell Sea in summer

The main aims of the study

The aims of the physical oceanography programme were to describe the hydrographical conditions along a transect running NW from Kap Norwegica to the Weddell Gyre region. The chosen section lies close to the one observed during the Winter Weddell Sea program 89 by R/V Polarstern. The profile was to be extended towards the pack ice by a helicopter-borne portable CTD, used simultaneously with the sea ice measurement programme. The section was to be repeated during the expedition, according to possibilities. Observations of turbulent characteristics will be made during 2 to 3 intense observing periods in order to evaluate the components of the turbulent energy equation in different layers, in particular close to the pycnoclines. Air-sea interaction measurements was to be made in connection with the project number 5.

Operating plan

The estimated observation time required for hydrography was 30 stations á 2 hours, for intensive observations two periods á 2 days during the second leg, and during the first leg observations at the ice edge simultaneously with ice observations and sampling program.

Support

Air-sea interaction observations are needed from the meteorology program plan and the sea ice observations from the respective research program.

3.1.4. Sea ice research

The main aims of the study

The main aims of the sea ice research were:

1. To obtain ice cores for examining the crystal structure and impurities (in particular salinity) of sea ice.

2. To obtain information about the detailed structure of ice ridges and the statistical distribution of the occurrence and size of ice ridges.

3. To obtain observations for validating mathematical ice-ocean models for the Antarctic.

Operating plan

Sea ice observations were made on both legs. The number of scientists on leg 1 was planned to be three and on leg 2 two. The basic sea ice data was collected during the second leg. The ice conditions in the vicinity of British Metocean buoys at the Weddell Sea launched in January 1989 was to be studied and ice thickness, topography and concentration observations from helicopter and ice floes was also to be studied.

Support

The studies were coordinated with the mechanical ice properties research (Program no. 7), so that the ice strength can be related to the structure and salinity of the ice. The ice observation programme of the first leg was also to be coordinated with the FRAM project.

3.1.5. Air-sea interaction and marine meteorology

The main aims of the study

The main aims of the study were to collect data on:

1. Air-sea momentum exchange and fluxes of sensible heat and latent heat

2. Information about meteorological conditions and surface layer stratification

3. By the automatic (ARGOS) stations, (one or two drifting buoys) drift data information about the general circulation pattern in the sea

Operating plan

During the marine expedition (both legs) the calibration and monitoring of the proper functioning of the stations was to be done using a local user terminal and the stations was to be left functioning in the area when the Finnish marine expedition ends. Theoretically, the stations are capable of functioning for one year. In practice they are expected to work for a shorter period and, hopefully, for at least a few months during the austral autumn. The position tracking function, for drift data and recovery, should work for at least 15 months. After a successful recovery and service, the ARGOS station programme is to be continued e.g. by participating in internationally coordinated field work during the next few years.

Support

The project was closely connected with the projects numbers 3 and 4 and is also cooperating with the University of Bergen (Norway) and the University of Hannover (FRG). Supplementary meteorological data was planned to be collected for other projects.

3.1.6. Detailed marine geological study from ice front to shelf break, north of the Kraul MTS, western Queen Maud Land

The main aims of the study

The main goal was to acquire a broad spectrum of data on the glaciomarine processes that have been active in the formation of the present shelf. The data was expected to allow preparation of a comprehensive description and analysis of the glaciomarine conditions that have been active in the area. The acoustic profiles and the coring will provide vertical (cross-sectional) data, while the side scan sonar, video imaging (ROV) and sea floor photographs will provide the lateral data.

Operating plan

Choice of study area was based on earlier international work conducted in the region and the preliminary results of the geological work conducted from the Aboa, FINNARP land base. The final delineation of the work area was dependent on the local ice conditions. Seismoacoustic profiling was planned to be conducted only in open water, while sea floor sampling, coring and visual observation will be possible in ice infested conditions.

Support

The land based (Aboa) studies was expected to complement the marine geological observations and the sea floor core samples in particular, by providing local lithological input.

3.1.7. Ship ice loads and mechanical properties of Antarctic Sea ice

The main aims of the study

The research program related to ship technology was planned to concentrating on the ice loads of the research vessel and the mechanical properties of Antarctic sea ice. The aim of these measurements was to improve knowledge of sea ice characteristics, and to gather ice load data for ship design and marine transport.

Operating plan

The ship ice load research was planned to be carried out during both legs. On the first leg the measuring system will be turned for the existing load signals. Special attention was to be paid to observation and documentation of the ice conditions. The personnel required for the ice load investigation was two persons during the first leg, and one person during the second leg. Their tasks was to operate and maintain the measuring system, data recording and ice condition observations.Testing of the mechanical properties of the ice was planned to be performed by the same personnel as in the ice load investigation.

4. THE MARINE RESEARCH PROGRAMS AS EXECUTED AND CRITICISM

The total number days for the expedition was about 150. Transitions between operation areas (Helsinki->Montevideo->Weddell Sea->Queen Maud Land->Weddell Sea->Ushuaia->Weddell Sea->Queen Maud Land->Montevideo->Helsinki) took in all 94 days. The total time used for scientific projects was thus 56 days (Table 1). During short expedition time several shortcuts, limitations and critical points were observed:

4.1. R/V ARANDA

Using a small vessel for expedition in Antarctic, there are advantages and disadvantages. A comparison between a large cargo vessel converted to Antarctic logistic transportation and oceanographic research and a small vessel taylored for oceanographic research may result as follows:

Large vessel	Small vessel
Advantages	**Disadvantages**
Large capacity taking cargo, helicopters, fuel, food, people etc.	Small capacity
Longer duration of cruises	Limited duration of cruises
Deep draught enables operations in ice conditions	Shallow draught makes propeller vulnerable
High cruising speed	Low cruising speed
Disadvantages	**Advantages**
Sampling takes place high above sea surface	Working near sea surface makes mooring installation and recovery easy
Maneuverability restricted	Maneuverability at station easy
Usually temporary arrangements	Specialized to certain objectives and marine research tasks
High costs	Low costs

One important point in designing of R/V ARANDA was to locate the research facilities as near the sampling areas as possible in order to ensure speed and flexibility in operations. That is why most of the research facilities have been concentrated on a special research deck: e.g. the sampling court, laboratories (270 m^2) and the instrument workshop (Annex 1). The sampling court is a covered space, centrally situated between the CTD-laboratory and bottling laboratory. The design of the sampling system proved to be very effective during the expedition.

Maneuverability of R/V ARANDA at sampling stations proved to be easy because of her dual engine system, new designed azimuth thruster and combined dynamic positioning and location systems (Decca, Loran C, Omega, Syledis supplemented by GPS and NNSS Satellite Navigator) and taut-wire system. The whole system is computerized. The new azimuth thruster of 400 kW is mounted in a tunnel, which can be lowered and turned through 360° enabling it to be used as a pushing propeller as well as a bow thruster. On the boat deck at the stern there is a large universal winch and a towing winch.The traction of the universal winch is 15 kN and that of towing winch 50 kN. These winches can be operated from mobile control panels. For winches there is a large 100 kN double tilted A-frame in the stern. A-frame together with boat deck winches make mooring very easy.

The research vessel has a ice classification of "Det Norske Veritas 1A1 Ice 1A". However, the operation of R/V ARANDA in close Antarctic pack ice is not possible, and was thus not planned either. Transportation of scientists from R/V ARANDA on ice was difficult. A new transportation basket (type Valdivia) as in icebreakers should be installed.

4.2. Scientific projects

During the expedition it was observed that probably too many scientific programs were this time included. This was however, intensional in order to involve a wide range of Finnish scientists to Antarctic studies. Unfortunately during the expedition many projects were running out of time. Number of projects should thus be reduced in the future with the same kind of planning. Projects could be more concentrated to certain hypothesis and because of the distances only one leg during expedition is recommended. Time table was also too tight and reserve planning for projects could be made more carefully, although three separate plans were made already in advance. Cooperation between various projects could be made more effective and projects could be made more flexible in operations.

4.3. Helicopter operations (Agusta Bell Jet Ranger 206 B)

Unloading and loading of helicopters from and to vessel's hangar was critical. It needs a "too" nice weather. However with minor changes this can easily improved. Time table for transportations was made too tight for helicopter pilots especially during transports to and from ABOA and WASA research stations. Communication system between helicopters, research stations and vessel was not optimal and should be renewed and integrated more carefully. D Despite these difficulties trans-portations were carried out with success. GPS worked very well with helicopters.

4.4. CTD-sonde

The CTD used during the expedition was EG&G MK V, obtained in final modification during the way to Montevideo and tested for performance in the Atlantic during the voyage. The sonde contains a number of extra sensors, assembled for the first time in the same configuration:

- two component acoustic Doppler current meter,
- transmittance unit,
- fluorescence meter
- altimeter for bottom approach,
- oxygen sensor

For temperature measurements, two separate sensors were available, one with slow response and one with fast response. The sonde was basic unit for all oceanographic work and, therefore, any technical difficulties were found very problematic. For the case of malfunction, one ordinary MK V and one ordinary MK III sonde of the same manufacturer were available. The special MK V was used on all 76 deep stations, ranging from 500 db fast soundings (biological stations) to deep stations down to 3900 db (chemical stations). The final analysis of the performance of the recordings is under way, it is thus premature to present their results in detail. During the operation, the following problems were found:

The adjustment of pressure in the surface was very slow causing unnecessary time delay.

The two temperature sensors and/or pressure sensor gave results which caused false salinity values until a final calibration curve was obtained during the second half of January at the end of the first leg.

The big amount of sensors implied unestimated power consumption, which obviously had an impact on calibration results as well.

The transmittance sensor broke at a very early stage.

Calibration samples were taken by Rosette multi bottle system and temperature calibration by reverse thermometers, but not all of them are reliable because of the unpredictable firing depth of the bottles (the voltage problem presented above). For work on pack ice using helicopters a portable CTD-sonde (SIS, Kiel) was used. Its operational range is 500 m, and operation proved to be reliable. In temperatures below 0° C attention was paid on the operation of the portable PC. Only in one occasion the istrument failed because of freezing of some components.

4.5. Rosette

The Rosette multi bottle sampling system contained 12 bottles of 1.7 liters each. Due to the very short response time to answer the firing command, the indication very often gave "misfire" altough bottles had fired properly. The firing mechanics also caused some trouble in the cold sea water.

4.6. Echo sounders

The vessel is equipped with three Krupp Atlas Deso 25 echosounders. The frequencies are 210, 100, 33 and 15 kHz and separately one 12 kHz pinger receiver. Only 15 kHz was used during the survey due to the depth. It might be notable that the 12 kHz pinger system could not be used in connection with acoustic release command.

4.7. Microcomputers and VAX

R/V Aranda has a computer system consisting of MicroVAX 2, VAX-station 3200, Ethernet and 16 PC:s (AT). The main frame is used for data bases and collecting information from navigational computer system, VAX station for number crunching, and the PC:s for laboratory automation and basic processing of analysis data. The VAX system in use did not yet have full software available, thus part of the database functions were not available and substantial part of data analysis was done on PC:s, and the main frame was mainly used for final backup storage. To secure the ope-rations, all PC:s were from the same manufacturer, and the VAX system was duplicated. During the operations, no system failure occurred due to accelerations (waves, shocks on inpact with ice). As a deck unit of CTD, the 286 processor proved to be too slow, in particular for the post processing of data when dynamic ocean-ography sections were taken. For such work, a more powerful 386 processor would be more flexible.

4.8. Container laboratories

The ship is equipped with two container laboratories. The ice research container is equipped with a diesel driven electrical power plant. It can be left for autonomous work for two weeks. The temperature inside can be regulated between +20^o - 20^{o}C. The clean laboratory container is dependent on the ships logistics. It is devided in three different compartments with a gradual increase of cleaness, and space for changing clothes. The air cleaning system consists of a two phase filter equipment and the laboratory has a laminar chamber. According to USFS-standard 209 B the class is 100 particles (0.5 μ)/ m^3.

4.9. Weather station

The weather station of R/V ARANDA is Vaisala MILOS 200 tested in many occasions previous to the expedition. The station functioned properly, but some problems were found in sensor mountings. Prior to installation, wind tunnel model experiments were made in order to eliminate the vessel's dynamic effects. Because of technical reasons, it was not possible to mount wind speed sensors exactly in proper places and, there-fore, the meter underestimated winds, depending on relative wind direction. Calibration of the meter en route gave errors up to 30 % , and even more when the wind direction was unfavorable. It will be necesssary to modify the system for use of two separate anemometers, depending on wind direction. The humidity sensors did have problems with sea spray, and are not always reliable. In one single occasion the connecting tube for pressure gauge became filled with water, despite of its location in sheltered place some 15 m above the sea level.

4.10. Living quarters and internal communication system onboard

It was an original idea to have equal cabins for all crew and scientific persons onboard. However, this could not be followed up and there is a great variety in size and shape, but every cabin is equipped equally. They contain a wc-shower compartment, are equipped with an ice box and a TV-monitor. Scientific single cabins can be temporarily used by two scientists. The crew cabins are single. There are 13 crew cabins and 13 scientists cabins, 12 of which are double. The total capacity to accomondate is thus 38. On the FINNARP-89 cruise 54 people were accomondated using libraries, messrooms and the ping-pong cabin as temporary sleeping rooms for 16 scientists heading for the land base.

4.11. Scientific meetings onboard

During all the expedition, scientists' meetings were arranged daily at fixed times for three purposes:

- to orientate participants to the problems studied by other teams,

- to distribute up to date weather and operational information

- to discuss and decide work plans for the next few days.

These meetings, being combinations of scientific seminars and operative planning sessions proved to be of great value for the successful accomplishment of the expeditions. Potential problems due to diverting requests of different teams could be solved at an initial stage. Similarily, teams were able to assist each other within the limits of spare time available. Of particular interest for everybody were the expectations presented in the beginning of the voyage, when compared with the results gained during the work. The meetings did not replace the information available on internal TV-channels, i.e. navigational and schedule data and other relevant announcements, such as news and daily information bulletins.

4.12. Operational ice information and cooperation with Bellingshausen (USSR) research station

For the expedition, a special arrangement was made with the Arctic and Antarctic Institute of the USSR for obtaining ice charts and ice and weather forecasts during the expedition. According the agreement, the Bellingshausen Antarctic station processed ice information from satellite data and sent them by Inmarsat facsimile daily to the expedition. This agreement was a successful one, it improved both the operation safety and the fulfilment of research plans greatly. During the whole expedition we had reliable data on ice conditions and thus we were able to avoid difficulties. We were also able to plan and carry out our ice and physical oceanography program in places where the conditions were most favorable during the season.On the basis of this experience it may be stated that it will be worth while to consider this kind of cooperative ice service as a standard for Antarctic sea operations in future. The expences involved are well paid by the minimizing of risks, especially when operating with small to moderate scale vessels.

TABLE 1. THE TIMETABLE OF FINNARP-89 EXPEDITION

AS PLANNED	AS EXECUTED
Departure from Helsinki 03.11.1989	Departure from Helsinki 03.11.1989
Arriving to Montevideo 04.12. 1989	Arriving to Montevideo 04.12. 1989
Departure from Montevideo 08.12.1989	Departure from Montevideo 08.12.1989
Arrival to Queen Maud Land Unloading and transports to ABOA and WASA research stations 22.12-29.12.1989	Arrival to Queen Maud Land 23.12.1989. Unloading and transports to ABOA and WASA research stations 23.12. 24.12.1989.
Scientific programs on Weddell Sea 29.12.1989-20.01.1990.	Scientific programs on Weddell Sea 25.12.1898-18.01.1990
Arrival to Ushuaia 24.01-26.01.1990.	Arrival to Ushuaia 23.01.1990

Table 1 (cont.)

AS PLANNED	AS EXECUTED
Departure from Ushuaia 26.01.-28.01.1990	Departure from Ushuaia 28.01.1990
Scientific programs on Weddell Sea 30.01.-15.02.1990	Scientific programs on Weddell Sea 03.02.-12.02.1990
Arrival to Queen Maud Land; Transports scientists and equipments from research from stations ABOA and WASA 15.02-18.02.1990	Arrival to Queen Maud Land 12.02.1990. Transports of scientists and equipments research stations ABOA and WASA 12.02-13.02.1990
Scientific programs on Weddell Sea 18.02.-20.02.1990	Scientific programs on Weddell Sea 14.02-19.02.1990
Scientific programs completed on Weddell Sea 20.02.1990.	Scientific programs completed on Weddell Sea 20.02.1990.
Sailing to Montevideo 20.02-27.02.1990. Arrival to Montevideo 28.02.1990.	Sailing to Montevideo 20.02.-27.02.1990. Arrival to Montevideo 28.02.1990.
Departure from Montevideo 01.03.1990.	Departure from Montevideo 02.03.1990.
Arrival to Helsinki 30.03.1990	Arrival to Helsinki 30.03.1990.

ON DEVELOPMENT OF A PREVENTIVE MAINTENANCE PROGRAM FOR MCMURDO STATION ANTARCTICA

by
Martin, A. G.
U.S. Antarctic Research Program

Abstract

This presentation covers the evolution involved in development of a preventive maintenance program at McMurdo Station. The presentation outlines the objectives of a preventive maintenance program and provides an overview of the department for which the preventive maintenance program was developed.

The presentation then provides a brief chronological sequence of events that took place during the development process. Next it reviews the six computer modules that are the nucleus of the preventive maintenance program. The presentation concludes by identifying some of the benefits the preventive maintenance program has provided, offers several practical suggestions and identifies problems to be aware of.

Introduction

The objective of any good maintenance program is to optimize the use of an organization's resources by keeping existing facilities and equipment operating efficiently thereby prolonging its useful life. Parallel objectives include:

- -To increase productivity within the maintenance shop.
- -To improve inventory management.
- -To control costs.
- -To provide factual information for decision making.

A maintenance program should ensure that mechanics are allowed to concentrate on efficient job performance and job quality. The mechanics should be permitted to complete their assigned tasks without interruption. Whenever a mechanic is constantly interrupted from completing his assigned job, in order to work on more urgent jobs, then productivity, quality, and morale suffer.

It is also important that a maintenance program capture 100% of all maintenance work performed, even if it is after the fact. This information is essential for maintaining record accuracy, which in turn provides factual information to base decisions on. Accurate labor and material costs are required by management in order to effectively control costs. Complete and accurate information is required to predict future costs, plan and manage budgets, and measure performance.

In 1984 there was very little evidence of a formal preventive maintenance system for the vehicles, buildings and equipment at McMurdo Station. The first objective established for the Operations and Maintenance Department was to develop a preventive maintenance program that would accomplish the objectives identified in the first three paragraphs. This preventive maintenance program had to cover all of the vehicles, buildings and equipment, maintained by the civilian contractor, in and around McMurdo Station. Our second objective was to identify all of the responsibilities and taskings of the department and document them in an Operations and Maintenance Manual. This manual would identify the annual chronological sequence of events required by the department to successfully support the U.S. Antarctic Program.

To better explain the magnitude of these two objectives I would like to provide some background information about McMurdo Station and the Operations and Maintenance Department. McMurdo Station is the largest of the U.S. stations in Antarctica and consists of three distinct work sites. The first site is McMurdo Station which supports between 750 and 1000 people from early October until late February. The second site is Williams Airfield which is located approximately 8 miles (13 kilometers) from McMurdo and supports between 150 and 175 people. The third work site is the annual temporary flight operations at the Ice Runway located about 3 miles (5 kilometers) from McMurdo and which supports approximately 50 to 75 people. Between all three work sites there are approximately 195 buildings, 600 pieces of equipment with internal combustion engines, and over 3000 pieces of stationary equipment ranging from boilers to galley equipment to scientific equipment. In addition to the maintenance responsibilities the department is responsible for operating the boiler rooms, water and power plants, and for providing many other support services such as 24 hour a day shuttle bus service, fuel delivery, and transportation operations. These responsibilities and tasks are accomplished by the 180 people employed within the Operations and Maintenance Department. Each year approximately half of the people hired are new employees who have never been to Antarctica before.

Due to the high percentage of employee turnover each year and the diversity of equipment to be maintained, the preventive maintenance program had to be flexible and easy to use. Several commercially available preventive maintenance programs were looked at but did not meet our requirements for various reasons. The person hired to oversee the development of the preventive maintenance program recommended that we develop our own system.

The first year of actual development was spent understanding how the various work centers functioned and interacted. We began with identifying all the equipment, both mobile and stationary, that would require maintenance. It was at the end of this first year of effort that we began to realize that no preventive maintenance system would work without sufficient parts support.

An accurate inventory of the parts available to support the system was necessary in order for us to implement any preventive maintenance program.

During the second year of development, continued effort was devoted to writing programs, debugging programs, and systems planning. At the same time we utilized every available person within the department to inventory both mobile and stationary assets as well as all repair parts. The people conducting the inventories and collecting the necessary name plate data had no previous experience in this area, so the best we could hope for was about a 50 to 60% accuracy rate. It is important to realize that the collecting of this information was accomplished on a "not to interfere basis" with the person's normal job that he or she was hired for. The collecting of all necessary information was extremely tedious and very time consuming. We also began developing standard processes for each type of equipment. A standard process is a brief description of the maintenance tasks to be accomplished on any given work order.
It was during the third year of development that several people were actually hired as terminal operators to input the data that was being collected. It was also during this year that the Vehicle Maintenance Repair Facility was relocated across town into a new building. This work center had the largest inventory, over 15,000 line items, and was the furthest along in the implementation of the preventive maintenance program. The relocation effort set our preventive maintenance program development back by six or seven months within this work center. It was also during this third year that we realized how important it was to secure the inventories so that accurate record keeping could be accomplished. It does not require many people to destroy inventory accuracy by their failure to record parts being taken from, returned to, or relocated within the stockrooms. For this reason all stockrooms were secured and access was restricted to as few people as possible so that we could hold people accountable for inventory accuracy.

During this third year many changes were also taking place in the programs that were being written. It was decided to expand the preventive maintenance system to include a computer controlled Resupply System and Information Management System (IMS). This change in direction made for an improved system but also caused delays in completing the preventive maintenance project. Computers with expanded capabilities had to be obtained to run the larger programs and to perform search functions faster. The procurement and installation of these new computers again delayed program development.

By the fourth year of development most of the stationary and mobile assets had been identified and the name plate data had been loaded into the computers. A major effort was then undertaken to identify and obtain copies of all repair and parts manuals. From this information additional standard processes were written or updated for each type of equipment.

We also began loading cost information for each part. This information allowed us to track material costs, as well as labor costs, for each work order completed.

In order to assist in teaching people how the whole IMS system worked we began developing a detailed instruction manual which explained what the system was and how it worked. Step by step instructions were provided for each program/module within the system.

During the fifth year of development another major hurtle had to be dealt with when all of the Public Works functions were transferred over from the Navy to the civilian contractor. This doubled the amount of equipment we were responsible for maintaining. It also greatly expanded the inventory of spare parts we were required to consolidate within our current inventories. A major effort was likewise required to obtain all of the name plate data from this newly assigned equipment and to load the information into the computers. Additionally, over 50% of the existing parts inventories, which were already organized in various stockrooms and loaded into the computer, required relocation and consolidation into stockrooms in other buildings. During this transition, work continued on developing and debugging programs, writing the IMS instruction manual, and completing preventive maintenance work orders. Even with all of the turmoil, results of the previous years of effort were beginning to become evident in the various programs and reports that were available to plan for the next season. We now had detailed reports of all equipment located in McMurdo and Williams Air Field. We had fairly accurate inventories of all available repair parts. We knew what parts were on order and where in the logistical system they were. We could simulate various project requirements to determine if the equipment and/or parts were available to complete the project. Management reports were becoming available which identified how much money was being spent in materials and labor to maintain every building, vehicle and piece of equipment at all three work sites. Each passing year continued to add to the historical information that was available for making decisions on whether to repair or replace equipment. Now that we knew what we had in terms of equipment to maintain and we knew what parts were required to maintain the equipment, we began a major effort of identifying what equipment and parts could be retrograded back out of Antarctica to the United States. Approximately 1.75 million pounds of unnecessary material and scrap was shipped out of Antarctica when the resupply ship departed in February of 1989.

During the sixth year of development, which was this past season, considerable effort was made at continuing the pricing of all parts in our inventory. This was necessary to more accurately capture the material cost of repairs and for budgeting purposes. Also during this past year continued effort was put into reorganizing material storage areas and consolidating the inventory of parts acquired in the transfer of Public Works functions from the Navy.

In addition to writing an instructional manual on how to use the programs within the Information Management System (IMS), we began writing a detailed manual which identified, in chronological order, all of the tasks and responsibilities assigned to each work center within the Operations and Maintenance Department. The plan was to have an operational manual which would provide an overview of the department's responsibilities, list each work center within the department and identify work center responsibilities and taskings. Next, every position within each work center would be listed and the responsibilities and tasks assigned to the position would be identified. Each and every position requires support from the IMS system and the Operations and Maintenance Manual would refer people to the IMS manual for information on the IMS system. With these two manuals someone who had never been to Antarctica could read about what their department, work center and position responsibilities were and then obtain detailed information on their individual responsibilities from the IMS manual and work order system. Basically the Operations and Maintenance Manual tells you what you are to do and when you are to do it in broad terms. The IMS manual explains the system that will tell you how to do the specific tasks by providing detailed instructions and time frames.

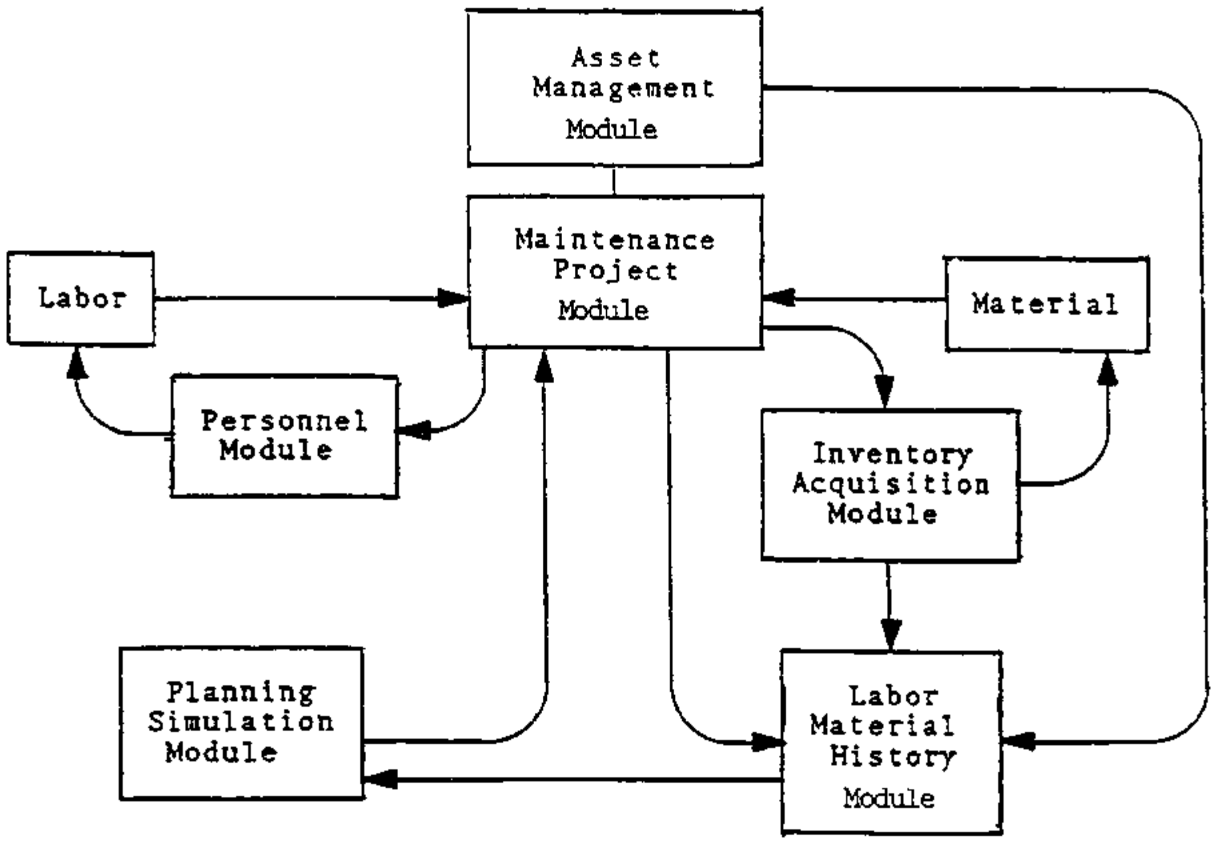
Also during this past year we were able to retrograde over 2 million pounds of excess equipment, obsolete parts and scrap. This action freed up valuable space in our parts storage rooms for us to continue organizing and consolidating these areas.

This past year we were able to complete an increased number of preventive maintenance work orders. As the amount of completed preventive maintenance work orders increases, the amount of unscheduled/emergency work orders decreases. The computer system allows us to identify problem areas by printing out reports that show what equipment has had the most unscheduled/emergency work orders assigned to it. Once a piece of equipment has been identified as having an excessive amount of repairs then the problem can be addressed. Once a month the supervisor can receive a report that identifies the pieces of equipment or systems requiring the most time and material in unscheduled/emergency work during the past month. Then he or she can begin planning on how to correct the problem. After a year or two of eliminating these problems the amount of time spent on unscheduled/emergency repair should be minimal. This will allow more time to accomplish preventive maintenance and planned repairs.

To this point we have discussed some of the efforts and problems encountered in setting up a preventive maintenance program at McMurdo Station. I would like to now explain in a little more detail how the actual maintenance system is set up and how it functions.

The maintenance system was designed with six individual but interdependent modules. All work centers, regardless of the function they perform, are able to use the same basic programs within each module. The six modules within the maintenance system are shown below. The arrows represent the flow of information between modules and indicate interaction between the module programs. If a change is made to a program within one module the change will impact programs within the other modules it interacts or shares information with.

THE MAINTENANCE SYSTEM



Next we will take a look at each of the six modules and discuss the elements that make up each module and how the information is used.

To start with, the Asset Management Module is made up of both mobile and stationary asset files. Mobile assets include anything that is portable in its use. Examples are: vehicles, construction equipment (such as dozers, dump trucks, front end loaders, etc...), portable ice drills, generators, chain saws, etc... Stationary assets include anything that is not portable in its use. Examples include: buildings or structures and all network systems such as water, sewer and electrical distribution systems. The mobile and stationary assets are further broken down into features which describe the major assemblies or systems within the higher level unit. For example, within a vehicle a feature would be the type of engine, transmission or differential it has. Within a structure a feature would be the type of boiler or air handler installed in the structure. A feature is then further broken down into components. A component is a part or assembly used within a given feature. A component of an engine within a vehicle could be its crankshaft or piston. A component of a boiler within a structure could be a burner nozzle or a tube assembly.

Basically, anything that requires maintenance must be listed within the Asset Management Module. An example of a printout listing the mobile assets within this module is at attachment #1.

Next is the Maintenance/Project Module. Within this module are the call-in (emergency/unscheduled) work order files; the standard process files; the project work order files; and the preventive maintenance work order files. This module controls any and all work performed on the assets listed in the Asset Management Module. A brief description of each file within this module is:

1) The call-in work order file allows anyone within the community to call, 24 hours a day, and talk to a person at a computer who will record the pertinent information into the computer and print out a work order. We have assigned three levels of urgency to the call-in work orders and depending upon the urgency code assigned to the work order a maintenance person will be dispatched within a certain time frame to perform the work identified on the work order.

2) The standard process file is a standardized list of task descriptions and material requirements used to complete the work orders. The standard process list acts like a pick-off chart and simplifies the identification of work to be done on a given work order. By using numbers to identify tasks, accuracy is improved and time is saved. An example of a standard process is at attachment #2.

3) Preventive maintenance work orders identify routine repetitive tasks required to keep the asset in proper operating order.

4) Project work orders identify planned repairs, such as engine overhauls; and projects, such as adding a wall to an existing office.

The Inventory Acquisition Module is a rather complex module but basically it tracks the movement and cost of all material into and out of the maintenance system. This module tracks from the minute the part is placed on order through the purchasing function, through shipment, through receipt of the part on station, through the use of the part and back to the reorder point at which time the cycle repeats. As it pertains to the maintenance system, any part required to complete a work order on any asset is controlled through this module.

The Personnel Module contains pertinent information on all employees hired by the civilian contractor to support the U.S. Antarctic Program. From this module the maintenance system obtains the wage rate and job classification of every employee who performs work on a work order.

The Labor and Material History Module tracks every work order performed on every asset since the initial start-up of the maintenance system. This module stores the historical information and provides management reports containing facts that can be used to make informed decisions concerning the program assets. These reports also provide valuable information for planning budgets and manning levels.

The Planning/Simulation Module allows management to simulate various scenarios to find out what material and labor requirements and/or shortfalls there are. For example, if you were reviewing information from the historical files and you noticed that on an average 250 oil changes were completed on a specific type engine. You could plug this information into the simulation program to find out what labor will be required and what material shortfalls there may be. The simulation program searches the other modules to obtain the necessary information and can identify if there are sufficient filters on hand, or on order, to complete the 250 anticipated oil changes. The planning portion of this module provides management with programs that can be used for budget planning purposes based on historical information.

Let's take a quick review of the six modules that make up the maintenance system and their functions:

1) The Asset Management Module identifies every item that

requires maintenance.

2) The Maintenance/Project Module identifies all work to be performed on the items listed in the Asset Management Module.

3) The Inventory Acquisition Module provides the status on all material required to complete the work orders in the Maintenance/Project Module.

4) The Personnel Module provides the necessary information concerning all labor required to complete the work orders in the Maintenance/Project Module.

5) The Labor/Material History Module maintains files concerning all completed work performed on the buildings and equipment listed in the Asset Management Module.

6) The Planning/Simulation Module utilizes information from the other modules to allow management to project into future the outcome of various planning scenarios. This module also supplies information useful in preparing budgets.

The Preventive Maintenance Program developed for the U.S. Antarctic Program at McMurdo Station accomplishes all of the objectives identified at the beginning of this presentation and includes:

A. Improved equipment reliability
B. Improved productivity and quality
C. Improved inventory management
D. Ability to control costs
E. Ability to capture labor and material costs
F. Ability to capture historical information
G. Ability to obtain factual information for decision making

The development of our Preventive Maintenance Program has taken six years and there are still two or three years of effort remaining to fine tune the system. Many of the delays in developing our system were caused by changes in the U.S. Antarctic program requirements. According to several articles in professional maintenance trade journals, the average U.S. company requires nine months to investigate and select a commercially available computerized maintenance system. Once a selection has been made it requires anywhere from 18 to 48 months to install and become operational on the system. The amount of time required to become operational on a system is dependent on the complexity of the system and the size of the maintenance operation.

In closing, I would like to make a few suggestions to consider and identify a few problems to be aware of. These are mostly common sense items but if they are not considered they can negatively impact your program.

I Management Support:

A. Make sure you have top management support and that they understand the effort and resources required as well as the benefits from the system.

B. Top management must provide the direction and communicate the goals to all people. If people do not understand the objective they will not support the effort which can slow down or halt progress.

C. People must be held accountable for the accuracy of the information they are responsible for. If you can not maintain inventory and record accuracy then your program will suffer and lose its effectiveness.

D. Management must maintain strict control over both the computer hardware and software.
   1. Who is authorized to move computers?
   2. Who is authorized to use them? Do not allow individuals to load games on the computers as they can blow up your programs.
   3. Who is authorized to write or change programs?
   4. Standardize on the hardware and software. It is a real inconvenience to discover that programs have been written using different software packages and no way to convert them.

II Unique Problems with Computers in Antarctica:

A. Use caution on transporting computer hardware and software as they are damaged if frozen. We discovered that no matter how hard we tried, some items still ended up damaged due to freezing.

B. If your computers will be exposed to dirt and/or volcanic ash then consideration should be given to purchasing severe environment cabinets to keep the computers in. As a minimum the computers should be kept in a pressurized clean room.

C. Static electricity is another problem in Antarctica. Make sure that you have sufficient anti-static mats to protect the computer.

D. It is a good idea to back up the information on the computer at least every couple of hours in case of a power outage or power spikes. Automate the back up process if possible. Electrical surge protectors and/or uninterrupted power sources are highly recommended.

E. When transporting information via floppy disks it is advisable to send at least two copies via different people to prevent loss of information due to accidental freezing or damage to the disks.

III <u>Potential Input Problems:</u>

A. Standardize noun names/descriptions of inventory items to prevent duplication of entries under different descriptions. Is it a washer or an "O" ring? Is it a seal or a gasket?

B. Make sure the information is spelled correctly. At one time we had the word Caterpillar spelled 12 different ways.

C. According to one publication the average experienced terminal operator makes one error for every 300 characters entered. Any programming that can be done to reduce the amount of input that is required will improve the level of accuracy. If possible you may want to consider integrating a bar code system into the process.

IV <u>Equipment Standardization:</u>

A. Equipment standardization should be the goal of any maintenance program and especially in an isolated area such as Antarctica.

B. Management should require that any new structures be designed utilizing standardized equipment, fixtures and systems such as:

1. Bathroom fixtures
2. Lighting systems
3. HVAC systems
4. Windows and doors
5. Plumbing and electrical systems

By standardizing these items this will allow you to keep spare parts inventories at a minimum and requires less training for the mechanics.

C. Recommend staying clear of unique or specialized pieces of equipment which require special skills or training to operate or maintain.

D. Purchasing of equipment that requires maintenance should be controlled or reviewed by the department that must maintain it.

E. All new pieces of equipment should be procured with sufficient repair parts to maintain the equipment for two years.

What I have discussed is a brief and incomplete overview of the preventive maintenance program at McMurdo Station. If you would like additional or more detailed information I would suggest that you contact Mr. Pete Mitchell who was the Systems Analyst that designed the Information Management System and the Maintenance System for the civilian contractor at McMurdo.

Mr. Mitchell may be contacted at the following address:

Sector Computer Systems
P.O. Box 457
1340 Sierra Street, Suite 100
Kingsburg, California 93631

Telephone Number: (209) 897-7957
Telefax Number: (209) 897-5463

<u>Presented By:</u>

Mr. Al Martin
Operations and Maintenance Manager (1984-1990)
McMurdo Station
U.S. Antarctic Program

Contact Address:

ITT/Base Services
P.O. Box 619
Fort Leonard Wood, Missouri 65473

Telephone Number: (314) 596-7216
Telefax Number: (314) 329-2988

VEHICLES AND/OR EQUIPMENT TYPE REPORT - GARAGE GGECC03
** VEH/EQP FEATURE FILE - MOBILE ASSETS **

USN NUMBER	NSF NUMBER	MODEL NUMBER	YEAR	MANUFACTURER	NAME	DESCRIPTION	SERIAL NUMBER	STATION	POOL CODE	WHERE ASSIGNED	EVALUATION INITIALS	EVAL DATE
97-29422		TR-572	1968	FABCC		20 TON	TR-572-57	MCMURDO	B	NAVY	T. LAIRD	12/05/89
97-29423		TR-572	1968	FABCO		20 TON	TR-572-58	MCMURDO	B	TRANSPORTATION	T. LAIRD	12/05/89
97-35224		M131A4C	1966	HEIL		5000 GAL FUEL TANKER TRAILER	556	MCMURDO	B	TRANSPORTATION	T. LAIRD	11/27/89
** VEH/EQP TYPE: TRENCHER												
43-00859	0001-2671	TF 1000	1974	VERMEER-DAVIS			0165253	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/05/89
43-00969		T 600 D	1986	VERMEER			1VRE1780261002464	WILLIAMS FIELD	B	PWD	T. LAIRD	12/08/89
** VEH/EQP TYPE: TRUCK AMBULANCE												
95-27497		CD-30903	1987	CHEVROLET	CUCV	AMBULANCE	1GCHD34J7HF397280	MCMURDO	C	NAVY MEDICAL	T. LAIRD	12/13/89
** VEH/EQP TYPE: TRUCK DUMP												
25-01579		M910	1974	AM GENERAL		TANK TRUCK 6X6 W/OUT WINCH	01579	MCMURDO	B	CONSTRUCTION	T. LAIRD	11/28/89
96-31877		M51A2	1969	KAISER-JEEP	PUMPKIN PIE	5 TON 6 X 6	L723-10911	MCMURDO	B	TRANSPORTATION	T. LAIRD	12/07/89
96-32735		M51A2	1969	KAISER-JEEP		5 TON 6 X 6 W/OUT WINCH	L723-10764	MCMURDO	B	CONSTRUCTION	T. LAIRD	11/27/89
96-32737	0001-2631	M51A2	1969	KAISER-JEEP	WENDY	5 TON 6 X 6	L723-10786	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/04/89
96-33433	0001-2572	M51A2	1969	KAISER-JEEP	GREEN PIECE	5 TON 6 X 6	L723-11025	MCMURDO	B	CONSTRUCTION	T. LAIRD	11/28/89
96-33441		M51A2	1969	KAISER-JEEP	FOXY KATE	5 TON 6 X 6 W/OUT WINCH	L723-11033	MCMURDO	C	CONSTRUCTION	T. LAIRD	11/27/89
96-33446		M51A2	1969	KAISER-JEEP	WILD THANG	5 TON 6 X 6 W/OUT WINCH	L723-11068	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/05/89
96-33835		M817	1972	AM GENERAL	SHIRLEY MARIE	5 TON 6 X 6 W/OUT WINCH	C123-11658	MCMURDO	B	TRANSPORTATION	T. LAIRD	11/27/89
96-33836		M817	1972	AM GENERAL	ROMULUS	5 TON 6 X 6 W/OUT WINCH	C123-11659	MCMURDO	B	TRANSPORTATION	T. LAIRD	12/13/89
** VEH/EQP TYPE: TRUCK FIRE												
00-19866		5300	1974	AMERICAN AIR FILTER	ENGINE #1	PUMPER	19866	MCMURDO		NAVY		/ /
03-28401		M45A2WLF	1968	KAISER JEEP		PUMPER	45-067	MCMURDO	B	NAVY	CJN	02/17/89
73-02397		M45A2	1979	KAISER-JEEP	KILLER BEE	FULLY LOADED W/OUT WINCH	0334-10297	MCMURDO		RETRO YARD	T. LAIRD	12/06/89
73-02821		26116-85	1985	WARD DUPLEX		PUMPER	1D91M44L7F1008567	MCMURDO	B	NAVY	T. LAIRD	11/28/89
92-63446		R-200	1975	WARNER SWASEY		PUMPER	13603	MCMURDO	B	NAVY	C. J. NEIL	02/10/89
73-02165		M45A2WLF	1968	KAISER JEEP		PUMPER	45-184	MCMURDO	C	NAVY	T. LAIRD	11/27/89
** VEH/EQP TYPE: TRUCK FLAT BED												
37-00401		M54A2	1971	KAISER		6X6	9525-10457	MCMURDO	B	NAVY	T. LAIRD	12/04/89
94-05365		F250	1977	FORD		TOW TRUCK	F26BRAJ4701	MCMURDO	B	RETRO	C. J. NEIL	02/01/89
94-08128	1586	F350	1978	FORD		3/4 TON 4X4	F28BRDE3858	MCMURDO	B	RETRO	C. J. NEIL	02/01/89
94-08129	0001-1588	F250	1978	FORD		3/4 TON 4X4 TOOL BODY	F28BRDE3860	MCMURDO	B	COMMUNICATIONS	T. LAIRD	11/28/89
94-08130		F250	1978	FORD	BIRTHA	3/4 TON 4 X 4	F28BRDE3859	MCMURDO	B	RETRO	C. J. NEIL	02/01/89
94-13512		F350	1982	FORD		1 TON 4 X 4	1FDJF3826CPA03628	MCMURDO	B	RETRO	C. J. NEIL	02/01/89
94-13513	0001-2944	F350	1982	FORD		1 TON 4 X 4	1FDJF3828CPA04036	WILLIAMS FIELD	C	PWD	T. LAIRD	12/08/89
94-13514	0001-2665	F350	1982	FORD		1 TON 4 X 4	1FDJF3824CPA03627	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/11/89
94-13515	515	F350	1982	FORD		1 TON 4 X 4	1FDJF3728CPA03625	MCMURDO		RETRO		/ /
94-13571		F350	1982	FORD		1 TON 4 X 4	1FDJF3822CPA03626	MCMURDO	B	NAVY		/ /
94-15089	0001-2578	F350	1983	FORD	TONKA	SERVICE TRUCK	1FDHF386ADRA04201	MCMURDO	B	GARAGE	T. LAIRD	12/05/89
94-20107		F250	1985	FORD		3/4 TON 4 X 4 W/LIFTGATE	1FTEF26YXFKA22663	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/01/89
94-20108		F250	1985	FORD		3/4 TON 4 X 4 W/LIFTGATE	1FTEF26Y1FKA22664	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/20/89
94-23315		F250	1986	FORD		3/4 TON 4 X 4	1FTEF26Y3GKA27809	MCMURDO	B	CONSTRUCTION	T. LAIRD	12/07/89
94-23316		F250	1986	FORD		3/4 TON 4 X 4	1FTEF26YXGKA27810	MCMURDO	B	NAVY	T. LAIRD	12/14/89
94-23317		F250	1986	FORD		3/4 TON 4 X 4	1FTEF26Y1GKA27811	MCMURDO	B	CONSTRUCTION	T. LAIRD	11/27/89
94-28712		F250	1986	FORD		3/4 TON 4 X 4	1FTEF26Y4GKB33873	MCMURDO	B	NAVY	T. LAIRD	12/09/89

OSAQB1*STANDARD PROCESSES
TASK DESCRIPTIONS

LINE	DESCRIPTION
** JOB CODE: 1800	
*	TITLE: TRANSMISSION REPAIRS
1	FILL WITH TRANSMISSION OIL
2	TEST TRANSMISSION PRESSURES
3	CHECK TRANSMISSION OIL LEVEL
4	CHECK TRANSMISSION
5	CHANGE TRANSMISSION FLUID AND FILTER
6	REMOVE/REINSTALL TRANSMISSION OIL PAN
7	REMOVE/REINSTALL TRANSMISSION
8	INSTALL NEW TRANSMISSION MODULATOR
9	INSTALL NEW TRANSMISSION OIL SEAL
10	REBUILD TRANSMISSION
11	INSTALL NEW TRANSMISSION OIL HEATER
12	ADJUST TRANSMISSION LINKAGE
13	CHECK/REPAIR TRANSMISSION LEAK
14	CHANGE GEAR LUBE
15	REPAIR LINKAGE
** JOB CODE: 2000	
*	TITLE: ENGINE CHECKS AND REPAIRS
1	CHECK CRANKCASE FOR FUEL DILUTION
2	CHECK ENGINE OIL LEVEL
3	FILL WITH ENGINE OIL
4	CHANGE OIL
5	REMOVE/REINSTALL CYLINDER HEAD
6	INSTALL NEW VALVE TRAIN PARTS
7	INSTALL NEW ENGINE OIL SEAL
8	INSTALL NEW BELT
9	REPAIR FUEL OIL/ENGINE OIL LEAK
10	REBUILD ENGINE
11	REPLACE BELT(S)
12	INSTALL NEW OIL PUMP
13	CHECK FOR EXCESSIVE OIL COMSUMPTION
14	CHECK FOR OIL LEAK
15	REPLACE HOSE(S)
16	CHECK COMPRESSION
17	CHECK OIL PRESSURE
18	ADJUST VALVES
19	REPLACE CAMSHAFT
20	REMOVE AND REINSTALL ENGINE
21	GRIND VALVES
22	INSTALL NEW PISTONS
23	INSTALL NEW OIL PUMP
24	INSTALL NEW SHORT BLOCK ASSEMBLY

ATTACHMENT #2

DESIGN GEUIDELINES OF ANTARCTIC BUILDINGS FOR WIND LOADS AND SNOWDRIFTING

D.H. KIM (1)
K.C.S. KWOK (2)
H.F. ROHDE (3)

SYNOPSIS

This paper describes a wind tunnel study to evaluate the wind induced loads and snowdrifting formation around a number of different shapes of elevated buildings for Antarctic use. A 1/50 scale boundary layer wind model was generated in a closed-circuit boundary layer wind tunnel at the School of Civil and Mining Engineering, Sydney University, Australia. A force balance was used to measure the aerodynamic forces on the elevated models. Coefficients of mean drag, lift and standard deviations of drag and lift are presented. Snowdrifting simulations were performed by using sodium bicarbonate as a model snow. A Moiré fringe camera, image-grabbing system and contour analysing software were used to analyse the data. The result showed that elevated Antarctic buildings are recommended to have chamfered or radiused corners. The chamfer or radius should be as large as is practicable, given the restriction on the internal layout of the building. It was also evident that the buildings should be raised above ground to avoid the attachment of the snowdrift against the building at the leeward side.

1. ANTARCTIC BUILDINGS - STATEMENT OF PROBLEMS

The snowdrift problems of Australian Antarctic buildings typify those encountered by Antarctic buildings generally. Australian original Antarctic buildings were relatively small and structures made from load-bearing insulated timber panels. They were built directly on the ground and held down by external wires. This design had numerous shortcomings including noise and vibration problems and inadequate vapor barriers in the floors. Furthermore, guy wires made it difficult for snowdrift clearing equipment to get close to the building, and if one of the insulated planels was damaged it was difficult to unscrew and replace. The site planning was congested and failed to account sufficiently for the prevailing wind direction. This lead significant snowdrift innundation of the building.

To solve these problems, the Australian government developed a new system of building construction programme (the Australian Antarctic Building System, AANBUS), of existing Australian Stations - Casey, Mawson and Davis, in 1981. A$ 70 million was allocated for a 10 year to replace the dilapidated huts of the 1950s and 1960s with bigger buildings better able to withstand the harsh conditions of Antarctica and to provide modern standards

---

(1),(2) Research Associate and Senior Lecturer, respectively, School of Civil and Mining Engineering, The University of Sydney, Australia
(3) Managing Partner, Helmut Rohde and Partners, Sydney, Australia

of comfort, efficiency and durability. As part of the above extensive and expensive rebuilding programme, a modular building system (the AANBUS Modular System) had been proposed as part of the AANBUS.

Modular construction was proposed in order to to enable prefabrication, assembly, installation of services and internal fitting of modular units to be carried out under factory conditions in Australia. This substantially reduces the installation time and requirement for on-site labour in Antarctica. Preparation of the site requires no more than the installment of concrete footings with suitable locking pins for the modules to be lowered into. Stacking a series of container modules would also permit multi-storey construction. The module size was the standard 6 m shipping container length, 3.6 m wide (half as wide again as a shipping container) and up to 4 m in height. The plan dimensions thus allowed two modules to fit into the hold space normally allocated to three shipping containers.

However, design wind loadings and snowdrifting effects of the above new building systems had not been assessed in the design stage even though the buildings have suffered from perennial problems including inconvenience around access ways (see Plate 1), and blocked windows (see Plate 2).

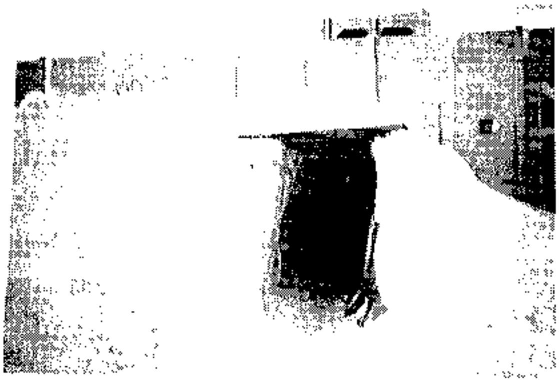


PLATE 1. BLOCKED ENTRANCE

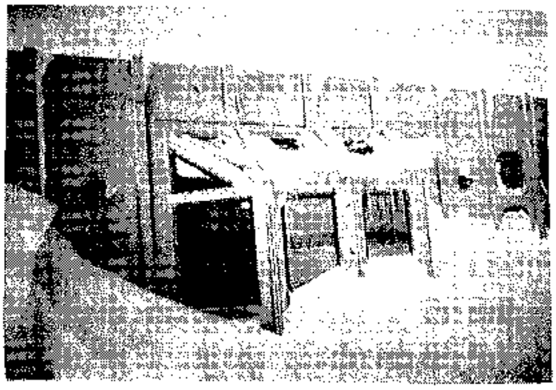


PLATE 2. BLOCKED WINDOW

2. REVIEW OF PREVIOUS RESEARCH

The development of buildings and structures in the Arctic and Antarctica should include extensive studies on snowdrifting. However field tests and observations of prototype are not only time consuming and expensive but also the desired control of the environment can not be attained. Consequently model testing turns out to be the most practicable method for investigating and predicting snowdrift problems around Antarctic buildings. Although a perfect simulation of the various aspects of snowdrifting has been regarded as an extremely difficult task, model tests have been performed to achieve economic problem solving.

Style and Melbourne (1968) performed wind tunnel tests and developed a theory to control the location and the drift accumulation of the proposed Australian Wilkes Station. Iversen (1982) showed realistic model results for snow accumulation near a highway facility. Isyumov (1971), Calkin (1975), and Irwin and Williams (1981) investigated snowdrifting problems on building roofs by using fine silica sands in a water tunnel. Feasey (1980) performed wind tunnel tests to investigate snowdrifting around and under the building complex of Scott base in Antarctica by using tuft and sand scour flow visualization around model buildings. Da Matha Sant'Anna (1985) used a wind tunnel to study the snowdrifting accumulation pattern on a flat building roof by using sawdust. Isyumov and Mikitiuk (1989) also examined drift formation on the lower level of a large-area two level roof at different wind speeds and in two different approach terrains. They used 'bran' which is a flake-like material sieved to remove both its coarse and fine flour-like fractions. The modelling of snowdrifting around elevated buildings in Antarctica was expanded by the research of Anno (1984). He performed the simulation of Antarctic snowdrifting by using activated clay particles in a closed-circuit wind tunnel. His result showed a good match with the full-scale measurements of snowdrift around the Observation Hut of the Japanese Shyowa Station in Antarctica conducted by Mitsuhashi (1982).

3. EXPERIMENTAL ARRANGEMENTS

Since the process of snowdrifting around buildings is a complex phenomenon which is still ambiguous, there exist some doubts about the use a theoretical method to investigate snowdrifting problems around Antarctic buildings at this stage. While a perfect simulation of all aspects of snowdrifting is not practically possible, this investigation shows how the use of the wind tunnel experiment, with the aid of comparisons with field observations, can provide valuable information for the design and planning of Antarctic buildings.

Simulation of scaled turbulent boundary layer flow in a wind tunnel is one of the important similitude parameters in deciding the scale of a building model. Hence, a careful experimental approach is needed to simulate the flow which represents the flow over the prototype topography. The sites of Australian Antarctic stations Mawson, Casey and Davis are located at coastal sites comprised of relatively open, flat, ice-free rock during summer, which becomes snow-covered for approximately 8 months during winter. This topography fits closely that of an open terrain described in the Australian standard wind code (AS 1170.2-1989) as terrain category type 2 and this has been adopted as the prototype condition for this investigation. For more detailed descriptions of turbulent boundary simulation with and without the model snow and a model snow particle selection, refer to Kim et al (1989).

Using the selected model snow particle (sodium bicarbonate), the snowdrift accumulation around a scale model of the Shyowa station (1/50) was simulated. The results were compared with the field data of Mitsuhashi (1982) and a good agreement between simulated and prototype snowdrift formation around the Station was observed, as shown in Figure 1. The reverse riming formation at the leeward end of the roof, which is commonly found in Antarctica, was realistically simulated as shown in Plate 3.

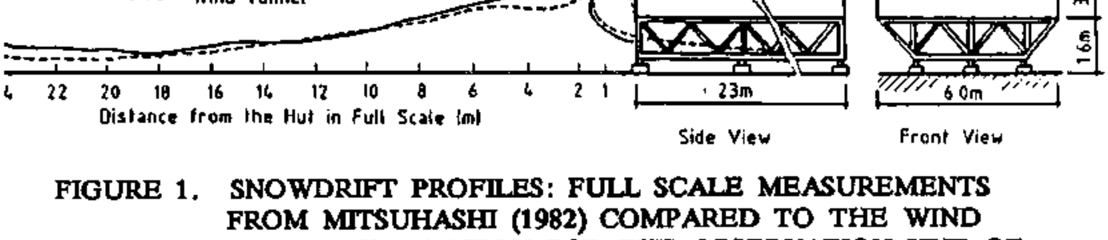


FIGURE 1. SNOWDRIFT PROFILES: FULL SCALE MEASUREMENTS FROM MITSUHASHI (1982) COMPARED TO THE WIND TUNNEL SIMULATION FOR THE OBSERVATION HUT OF JAPANESE SHYOWA STATION IN ANTARCTICA

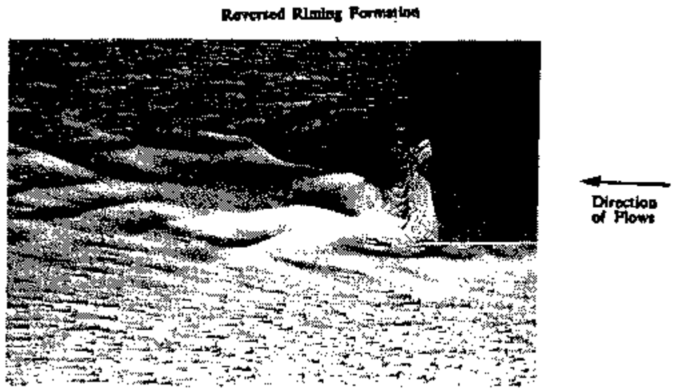
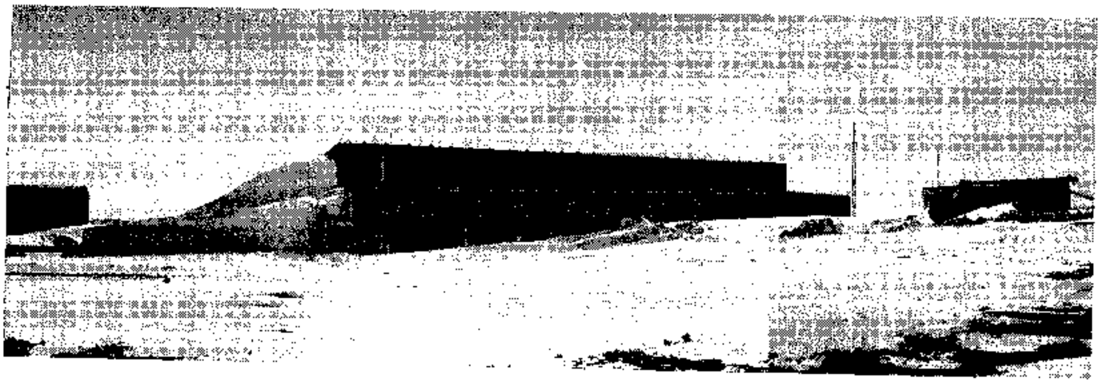
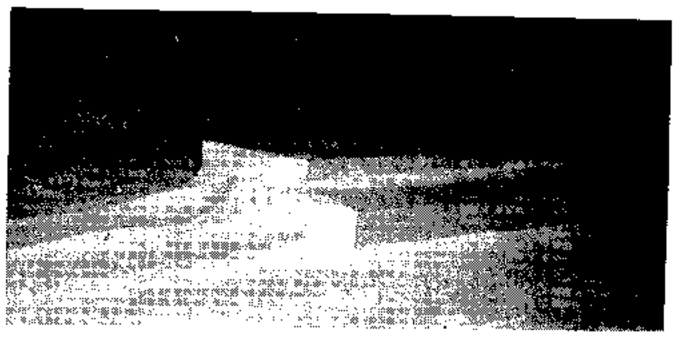


PLATE 3. SIMULATED SNOWDRIFTING AROUND THE MODEL BUILDING AND THE REVERSED RIMING FORMATION

For furhter confirmation of the experimental reliability for the Australian Antarctic Territory, another experiment was performed around a 1/100 scale model of the storage building at Australian Davis Station in Antarctica. The result of the simulated snowdrift shape around the 1/100 scale model was compared with photographic observations from around the building and shows a good agreement as shown in Plates 4 and 5.





PLATES 4 AND 5. FULL SCALE SNOWDRIFT ACCUMULATION AT THE LEEWARD SIDE OF THE STORAGE BUILDING AT AUSTRALIAN DAVIS STATION IN ANTARCTICA COMPARED WITH THE SIMULATED SNOWDRIFT ACCUMULATION AROUND THE 1/100 SCALE MODEL

5. THE BUILDING MODEL

In order to achieve a high natural frequency which was required for the reasonable force emasurement, light-weight rigid models were considered. Extruded polystyrene provided suitable rigidity and density. The models used were based on dimensions of 120 mm x 56 mm x 72 mm (1/50 scale) which represents a module similar to a standard shipping container. 7 different shapes were made and given a smooth surface finish. Details of their dimensions and shapes are shown in Table 1.

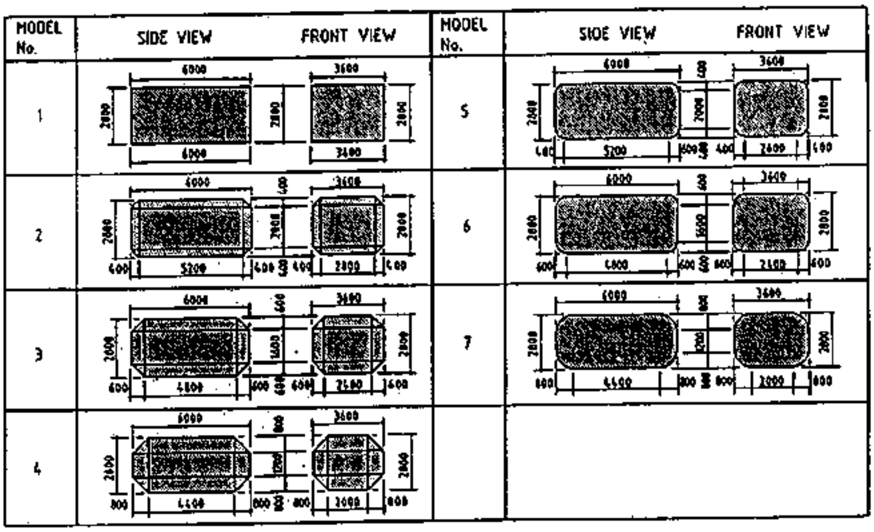


TABLE 1. DIMENSIONS OF THE WIND TUNNEL MODELS

Model 1 is a reference model, without chamfered edges. Models 2, 3, and 4 are 45 degree chamfered by 400 mm, 600 mm, and 800 mm, respectively in full scale. Models 5, 6, and 7 have all edges radiused by 400 mm, 600 mm, and 800 mm, respectively.

6. WIND FORCE MEASUREMENTS

The force balance was installed under the centre of the test section of the wind tunnel. Models were mounted on a copper shaft (5 mm diameter) which was connected to the force balance. The model and balance responded with a resonant frequency of around 67 Hz. The signal output from the force transducer was low-pass filtered at 30 Hz to attenuate instrumentation noise of a greater frequency. The resulting signal was digitized by means of an analogue to digital converter, and sampled by a micro-computer. Sample times of approximately 30 seconds were used and four samples were averaged in three different wind angles (0°, 45° and 90°). The total forces, which include the forces on the shaft which connects the models to the force balance, as a sum of the mean and standard deviation of drag and lift forces were measured.

The force coefficients were non-dimensionalised in the following form:

Mean drag coefficient

$$C_{Fx} = \frac{F_x}{\frac{1}{2} \rho u_h^2 A_x} \qquad (1)$$

Mean lift coefficient

$$C_{Fy} = \frac{F_y}{\frac{1}{2} \rho u_h^2 A_y} \qquad (2)$$

Standard deviation of drag coefficient

$$C_{Fx}' = \frac{F_x'}{\frac{1}{2} \rho u_h^2 A_x} \qquad (3)$$

Standard deviation of lift coefficient

$$C_{Fy}' = \frac{F_y'}{\frac{1}{2} \rho u_h^2 A_y} \qquad (4)$$

where F_x = mean drag force
F_y = mean lift force
F_x' = standard deviation of drag
F_y' = standard deviation of lift
A_x = projected building area on x-axis
A_y = projected building area on y-axis
ρ = air density (1.2 kg/m³)
u_h = mean wind speed at building roof height

Results of the wind force measurement are shown in Figures 2 - 5. It was observed that each radiused model had lower drag than its respective

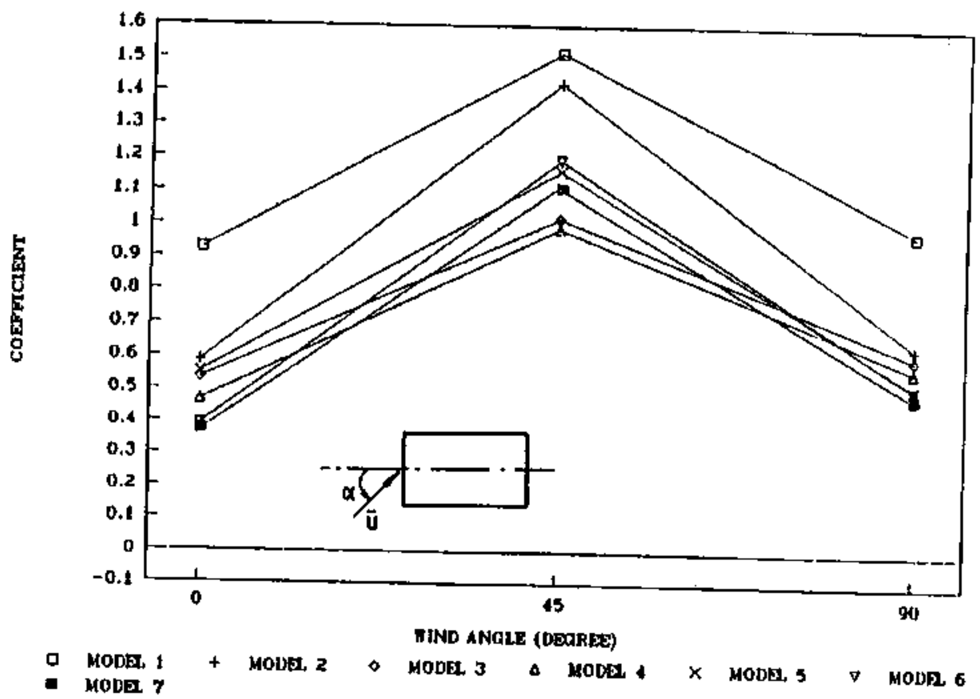


FIGURE 2. COEFFICIENTS OF MEAN DRAG

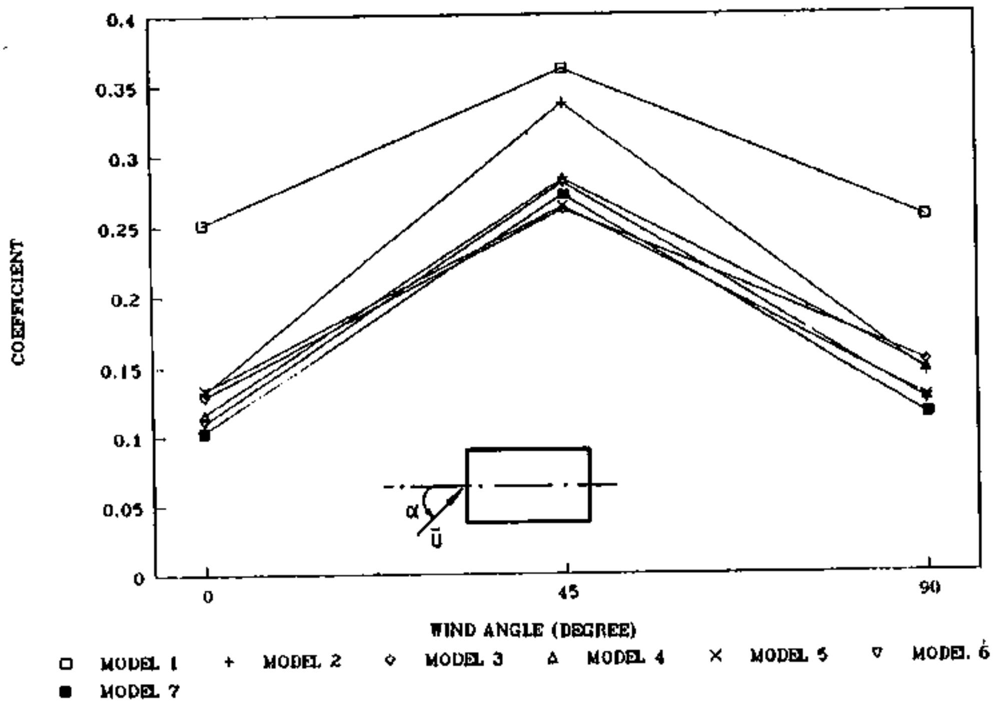


FIGURE 3. COEFFICIENTS OF STANDARD DEVIATION OF DRAG

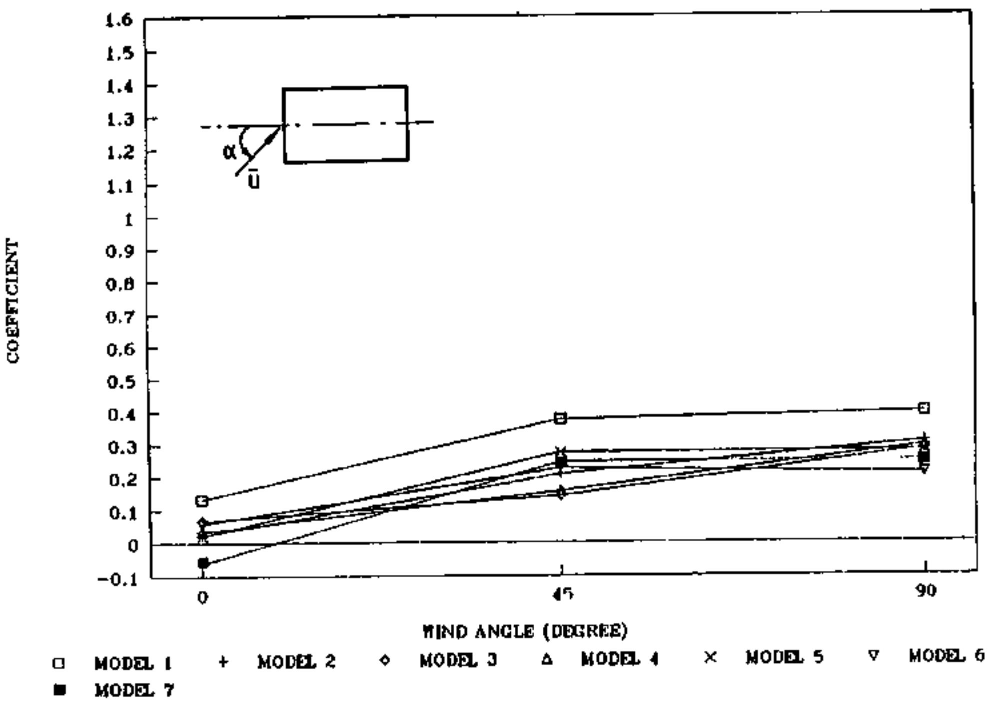


FIGURE 4. COEFFICIENTS OF MEAN LIFT

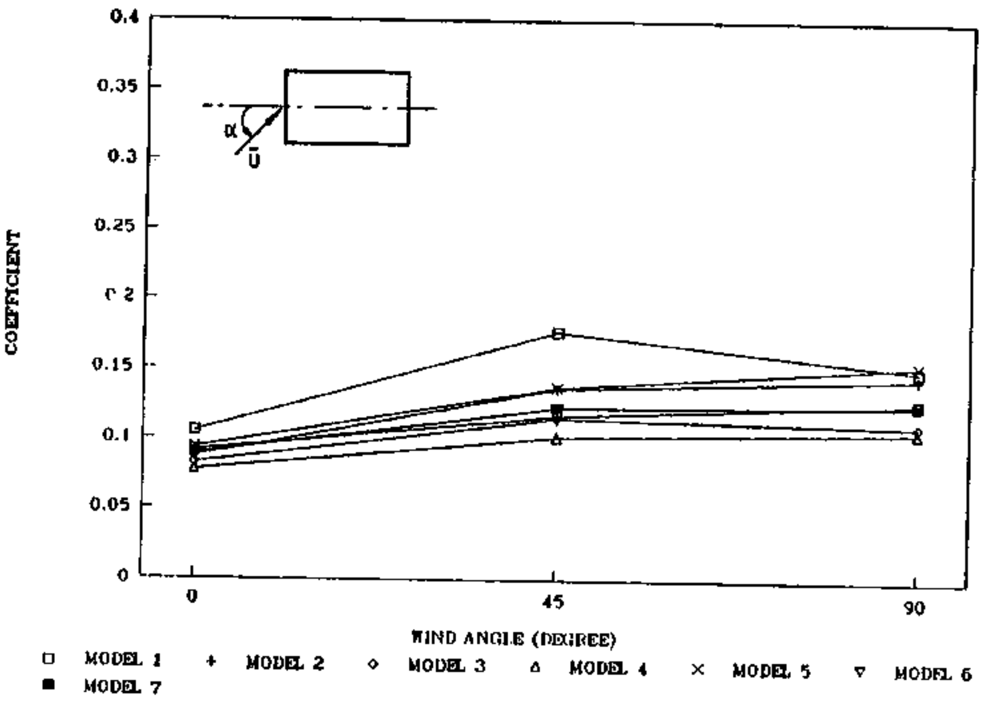


FIGURE 5. COEFFICIENT OF STANDARD DEVIATION OF LIFT

chamfered model for 0° and 90°. However, at 45° wind angle, the models with radiused corners of more than 600 mm gave higher values of mean drag force than the models with chamfered corners . Also it was observed that the models with radiused corners had lower lift forces in all except 45°. Neverthelsss, test results indicated that the models with chamfered and radiused corners gave an average 38% and 40% reduction in mean drag and standard deviation of drag, respectively from the values of Model No.1 which is a reference model. Also these buildings gave an average 53% and 21% reduction in mean lift and standard deviation of lift, respectively.

7. SNOWDRIFTS AROUND VARIOUS SHAPES OF ELEVATED BUILDINGS

Seven different shapes of elevated models (0.9 m height above ground in full-scale) were tested in three different wind angles (0°, 45° and 90°) to investigate the relationships between snowdrift shape, snowdrift volume, wind angles and the shape of building. Wind tunnel running times were 4 hours. For each model, the contour image of the snowdrift formation was captured and stored in the computer.

Contour images of the snowdrift shapes (see Plate 6) were generated by a grid projection type Moire fringe camera. The measuring sensitivity was 5 mm height (black to black stripe). The contour images were captured by a CCD camera equipped with 2/3 inch zoom lens. The captured contour image was then sent to an image-processing system and processed with the contour analysing software which is an interactive, menu-driven graphics program that produces three-dimensional surface representations for output to the screen, printer, or plotter. The program also gives the volume of snowdrift. The resulting form can be displayed in either perspective or isometric views.

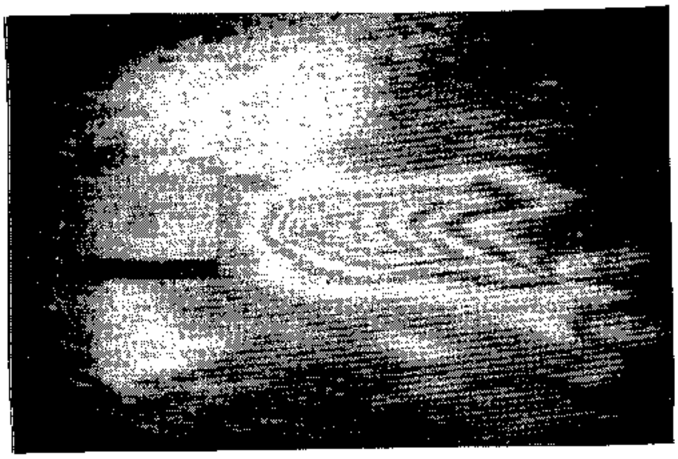


PLATE 5. A CONTOUR IMAGE OF THE SIMULATED SNOWDRIFT AT THE LEEWARD SIDE OF MODEL 1

Tables 3 and 4 and Figure 4 show the snowdrift shapes and the snowdrift volume ratio of the seven different shapes of the models at 0° wind angle as a representative example. It can be seen that the models with radiused corners created less snowdrift than the models with chamfered corners at other wind angles. The larger the chamfer or radius, the less the snowdrift volume.

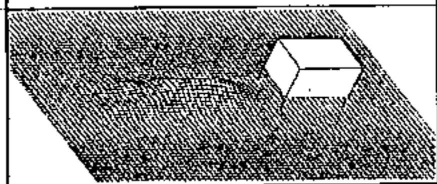
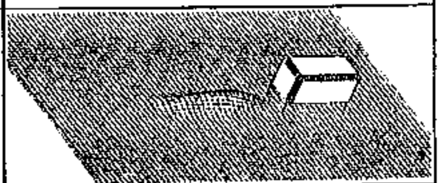
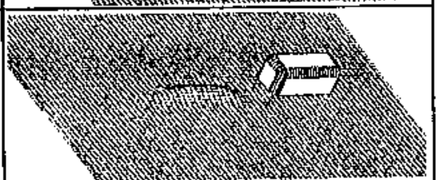
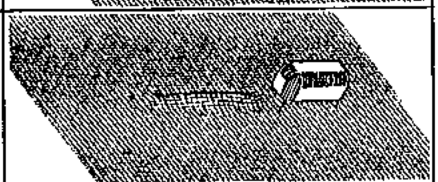
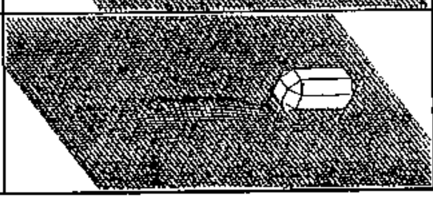
MODEL	SNOWDRIFT SHAPES	MODEL	SNOWDRIFT SHAPES
1		5	
2		6	
3		7	
4			

TABLE 2. ISOMETRIC VIEWS OF THE SNOWDRIFT FORMATIONS AROUND THE MODELS

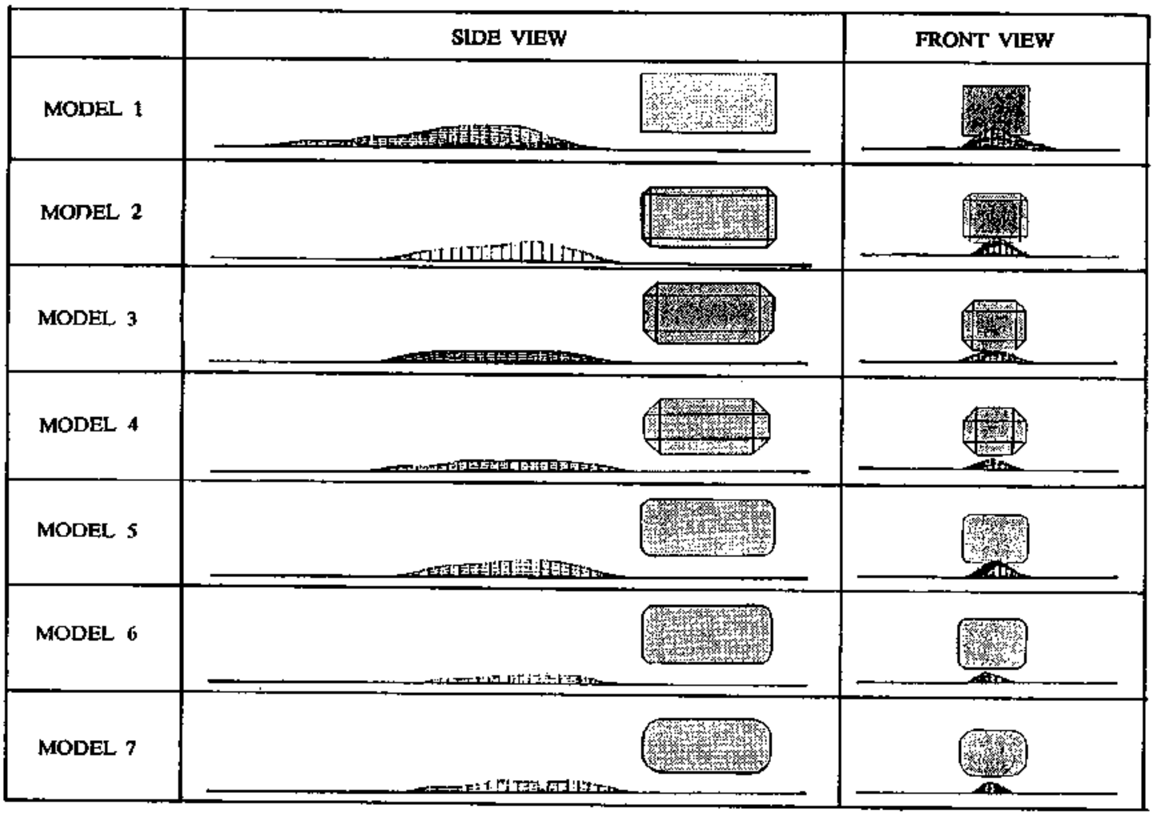


TABLE 3. SIDE AND FRONT VIEWS OF THE SNOWDRIFT FORMATIONS AROUND THE MODELS

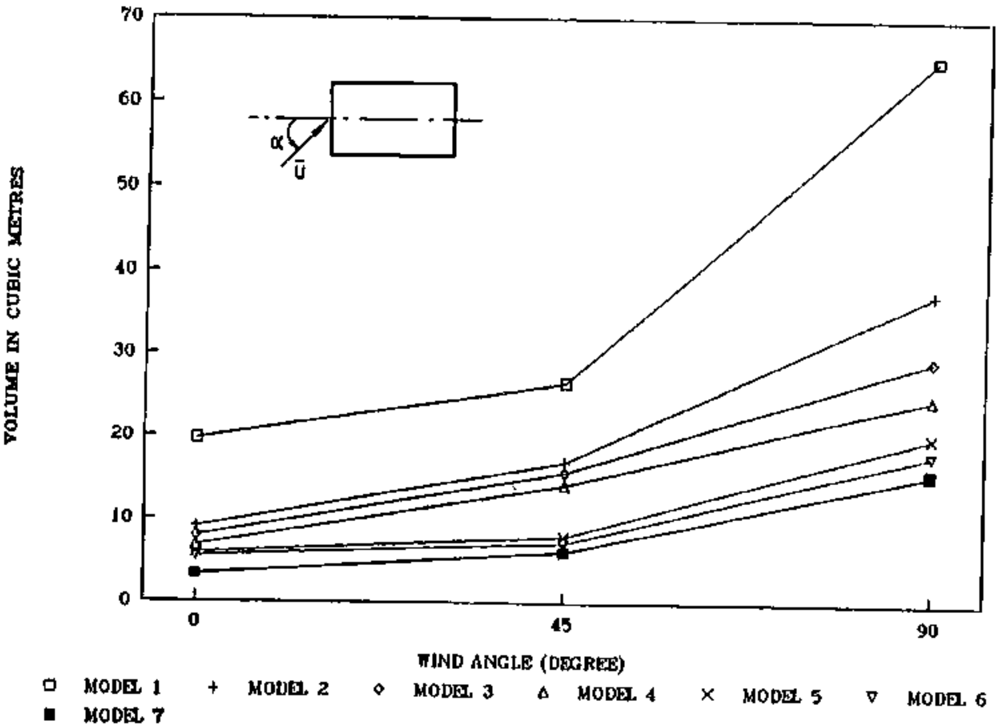


FIGURE 6. SNOWDRIFT VOLUME OF THE MODELS

8. CONCLUSIONS

It is suggested that elevated Antarctic buildings have chamfered or radiused corners. The chamfer or radius should be as large as is practicable, given the restriction on the internal layout of the building. It is also recommended that the building should be raised above ground to avoid the attachment of the snowdrift against the building at the leeward side. However careful architectural and structural consideration should be made to achieve optimal building performance. It is also recommended that entrances and windows should not be located at the leeward side of on-ground and above-ground buildings since the building surface on the leeward side will be subject to the snowdrifting accumulation and the riming of snow particles to the building surface.

Further research is being carried out to expand Antarctic building design guidelines. There is also a continuing need for further research into the model simulation technique in order to improve the accuracy of the model results. It is hoped that the application of the design guidelines to Antarctic building will reduce the negative impacts of human inhabitation in Antarctica.

ACKNOWLEDGEMENTS

This study was supported by Australian Research Council awards to K.C.S. Kwok and H.F. Rohde. The efforts of Ms. D. Smedley in performing experiments are acknowledged. The help of Ms. K. Pham in tracing graphs and tables is also acknowledged.

REFERENCES

Anno, Y. (1984). Requirements for modelling of a snowdrift. Cold Regions Sci. and Tech. 8:241-252

Calkin, D.J. (1975). Simulated snowdrift patterns - evaluation of geometric modelling for a three dimensional structure. Special report 219, U.S.Army Cold Regions Science and Engineering Laboratory, Hanover, NH, Spec. Rep. 219

Da Matha Sant'Anna, F. and D.A. Taylor. (1986). Snowdrifts on flat roofs, part II - Wind tunnel and field measurements, unpublished, Institute for Research in National Research Council of Canada

Feasey, R. (1980). Wind tunnel studies of snow deposition at Scott base. Central Research Report No. 9-80/1 , Gracefield, Lower Hutt, Ministry of Works, New Zealand

Irwin, P.A. and Williams, C.J.(1981). Prevention of excess snow accumulation due to roof mounted solar collectors. Rept. for Ministry of Municipal Affairs and Housing of Ontario, Toronto, Dec.1981 ISBN 0-7743-7068-8

Isyumov, N.(1971). An approach to the prediction of snow loads, Ph.D. Thesis, University of Western Ontario, Canada.

Isyumov, N. and Mikitiuk, M. (1989). Wind tunnel model tests of snow drifting on a two-level flat roof, Proceedings of the 6th U.S. National Conference on Wind Engineering, Vol.II, Mar., 1989, University of Houston, Texas

Iversen, J.D. (1982). Small scale modelling of snowdrift phenomena. Proc. Int. Conf. on Wind tunnel Modelling Criteria in Civ. Eng. Applications, Gaitherburg, April, 1982, Cambridge Univ. Press, pp.522-545

Kim, D.H., Kwok, K.C.S. and Rohde, H.F. (1989). Wind tunnel model studies of Antarctic snowdrifting, Proceedings of 10th Australasian Fluid Mechanics Conference, University of Melbourne, Australia, Dec., 11-15, 1989, Vol.2, pp. 9.35-9.38

Kind, R.J. and Irwin, P.A. (1979). Study of snow accumulation on the removable roof of the Montreal Olympic Stadium. National Building Research Council of Canada. TTR-LA-239

Mitsuhashi, H. (1982). Measurements of snowdrifts and wind profiles around the huts of Shyowa station in Antarctica. Antarctic Record 75. pp. 37-56

Strom, G., Kelly, G.R., Keitz, E.L. and Weiss, R.F. (1962). Scale model studies on snow drifting, Research Report 73, U.S. Army Snow, Ice and Permafrost Establishment.

Style, D.F. and Melbourne, W.H. (1968). Outline design of an Antarctic station to minimise drift accumulation. Records of a Antrarctic Treaty Meeting of Experts on Logistics, Tokyo, Ministry of Educ., Part 2. pp. 90-112

SETTLEMENT AND DEFORMATION OF BUILDINGS AT ASUKA STATION

ISHIZAWA Kenji(1), HANNUKI Toshio(2), SANO Masashi(1) and KUSUNOKI Kou(1)

(1) National Institute of Polar Research, Tokyo, Japan

(2) Collage of Science and Technology , Nihon University, Tokyo, Japan

ABSTRACT: The buildings at Asuka Station (71° 31.5'S, 24° 08.3'E; 930.45m a.s.l.) were erected on the ice sheet between December 1984 and February 1987. Those buildings of living hut , power plant , observation hut , workshop and passage are now almost buried in the snow. Measurements on the movement and settlement of buildings in relation with the ice sheet flow and snow accumlation have been carried out every year since 1985. Horizontal northward movement of living hut was about 1.0 m/a. The settlement of buildings was remarkable in the first year but it decreased gradually. Uneven settlement within a hut was observed , which was due to the differance in the snow accumlation on the windward and leerward of the hut; snow drift in the leeward sometimes reached 5m high above the undisturbed surface.

1. Introduction

Asuka Station was designed to serve as a logistics support base for field research work in the Sør Rondane Mountains in Queen Maud Land and to carry out staion research programs in various scientific displines. The station is located at 71° 31'34"S and 24°08' 17"E with an elevation of 930.45m above sea level, which is about 150 km south of Breid Bay in Princess Ragnhild Coast(see Fig.1). It was planned to accomodate about 10 men at first and 15 in later years.

Preliminary enviromental surveys of station area indicated a high rate of snow build-up, so that floor-elevated buildings were designed and a research program on the effects of snow cover uopn buildings was planned. In the 1984/1985 season the first building, the living hut , was erected on the ice sheet; a prefabricated building with a floor area of 5m x 20m was constructed on truss structures about 1m high. The power plant (5m x 19m in floor size) was erected in the 1985/1986 season. In the next season, after erecting an observation hut (5m x 20m) and constructing hut-connecting passage and other facilities, the station was officially opened on February 20 1987 by 8 men and has been occupied continuously. Staion observation programs are on meteorology, glaciology upper atmosphere phisics, geomagnetism and medical reserch. Desposition of buildings at Asuka Station is shown in Fig.2.

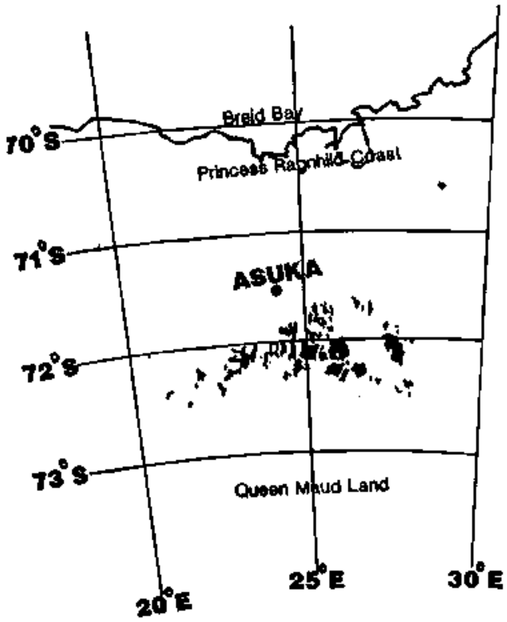


Figure 1. Location of Asuka Station.

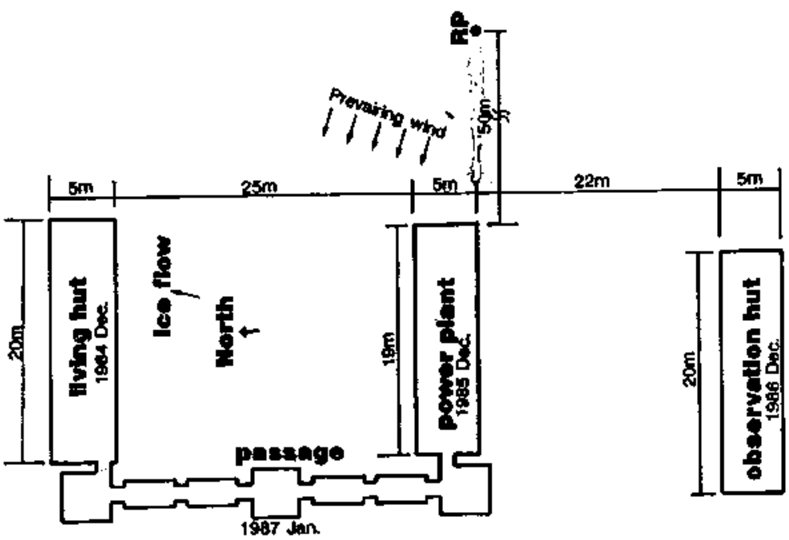


Figure 2. Desposition of buildings at Asuka Station. The dates of construction are written in the huts. RP is the reference point(standard point) for measuring settlement of the huts.

2. Movement of buildings

Movement of buildings erected on the ice sheet was measured with reference two outcrops; "Seal" rock(about 2km west of the station) and Romnoesfjellet(about 7km NW) form about a 6 km long base line and the change in the position of station hut was measured with reference to the Seal. The reference point at the station was established on the roof of living hut. When the roof was covered with snow a reflector-attached pole was installed on the hut. An automatic theodolite and a laser distancemeter were used to measure the movement of the living hut. Change in the position of living hut gave an average horizontal movement of 1.0m/a for 4 years(Fig.3). On January 4 1985 the elevation of the living hut was 14.412m lower than that of Seal. On account of downstream ice sheet flow to the north and the settlement of the hut, the elevation difference increased year by year, giving 550mm/a for the first 2 years and 407mm/a for the later 2 years(Fig.4).

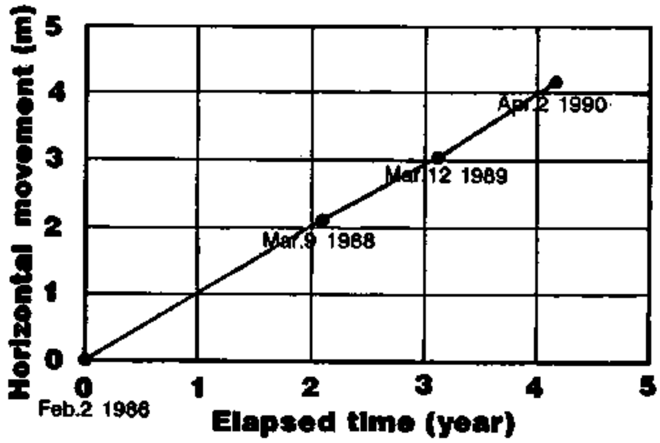


Figure 3. Horizontal movement of the living hut by ice sheet flow. Elapsed time is the time from the first measurement.

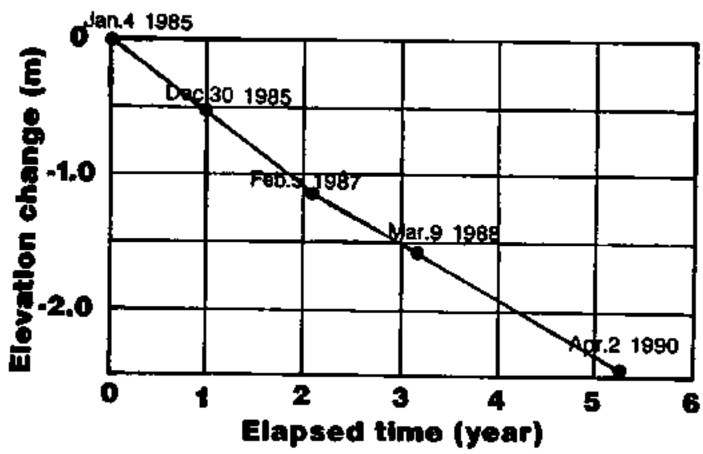


Figure 4. Elevation change of the living hut due to downstream ice sheet flow and the settlement of the hut.

3. Settlement of huts

As was shown in Fig.2, the construction of buildings was performed in consecutive three austral summer seasons. As an example of floor-elevated prefabricated hut, elevation view of power plant are shown in Fig.5. On leveled off snow surface 24 pieces of 1m plywood plates were set under steel trusses.

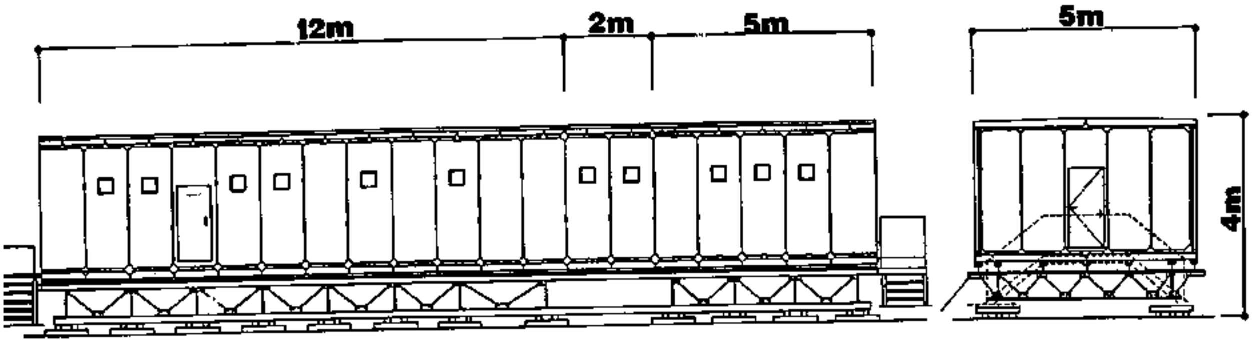


Figure 5. Elevation view of the power plant.

As a reference point for settlement measurement, a pole with a square plate at one end was set in the snow about 50m apart from the power plant(Fig.2). With reference to this standard pole, the change in the height of living hut, power plant and observation hut were measured at points marked on the western edge of the roof. The decrease of relative height of living hut is shown in Fig.6a, as well as Fig.6b for power plant and Fig.6c for observation hut. The schematic change of snow drift around the living hut and the power plant are illustrated in Fig. 7a and 7b respectively. The settlement is apparently due to snow compaction and snow loading around buildings. In Fig.6a the highest change getween A and B is 175mm for 414 days, whereas the absolute change in almost the same period(402 days in Fig.4) was

623mm. This will give an altitude decrease of 448mm/414 days which was due to downward ice sheet flow, assuming that the standard pole at the station did not sink by snow compaction. The standard pole was buried rather shallow in the snow and the snow accumulation took place thereafter, which will make the interpretation of settlement mechanism more complex. With regard to the power plant, the settlement was 375mm for the first 414 days and it gradually decreased. The large value of settlement may result from a heavy weight of the hut in which generators, oil strage tank and so on were installed. The initial settlement of observation hut was not so large in comparison with that of power plant.

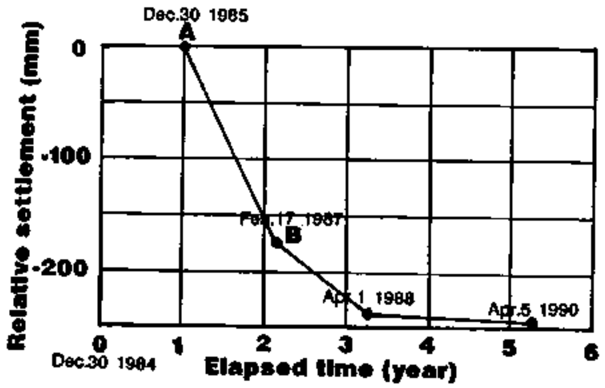


Figure 6-a. Relative settlement of living hut. Elapsed time is the time from construction of the hut.

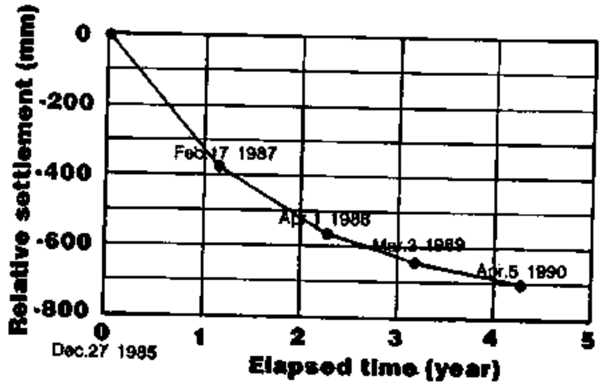


Figure 6-b. Relative settlement of power plant.

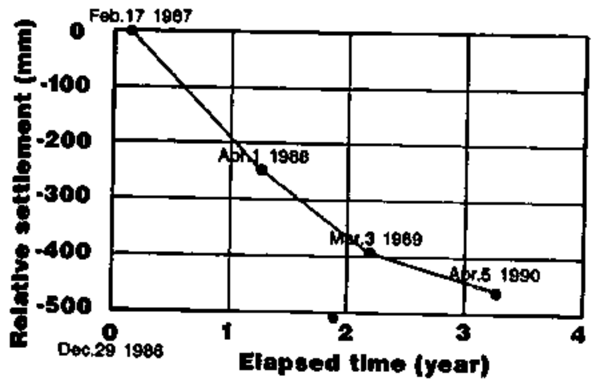


Figure 6-c. Relative settlement of observation hut.

Figure 7-a. Change of snow drift around living hut.
A(7a) is almost the same time indicated in Fig.6a.

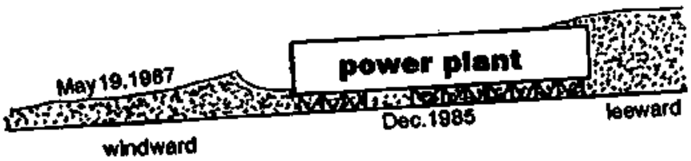


Figure 7-b. Change of snow drift around power plant.

4. Uneven settlement of buildings

The buildings at Asuka Station were disposed roughly in parallel with the privailing wind direction ESE. Effect of snow drifts in the leeward area are evident in the settlement of buildings. Inequality of settlement within one building was measured ; relative heights along the northern edge and the southern edge of building roof were given with reference to the highest point. The results are shown in Fig. 8a for living hut, Fig. 8b for power plant and Fig. 8c for observation hut. Uneven settlement within a hut is clearly shown and its temporal changes. The settlement measurement in January 1990 was carried out only for the power plant, because other huts were complately coverd with the snow. Remarkably large amount of settlement of power plant may be explained by warm snow temperature which accelerated snow compaction. The sewage was discharged into a hole about 50m apart from the power plant and the latent heat of sewage affected snow temperature. A total of 594kl sewage was discharged during about 3.5 years.

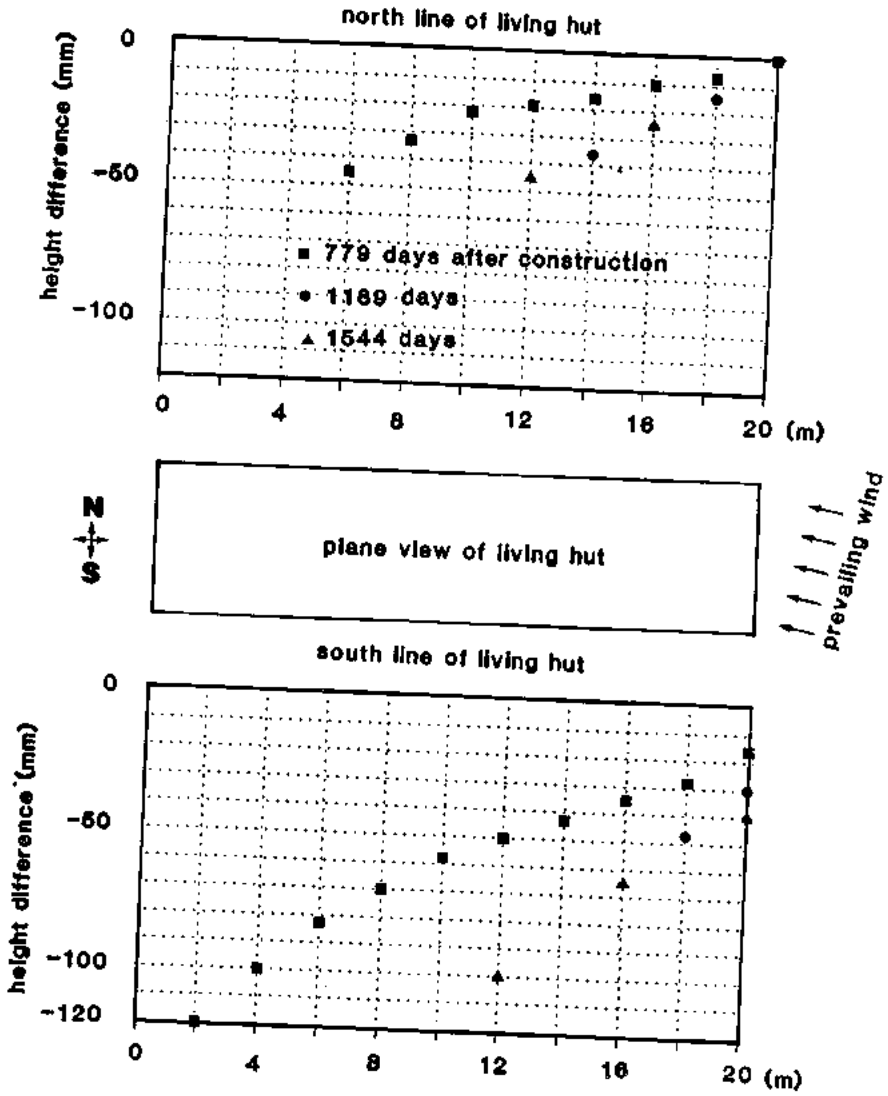


Figure 8-a. Relative heights along the northern edge and the southern edge of building roof with reference to the heighest point (living hut).

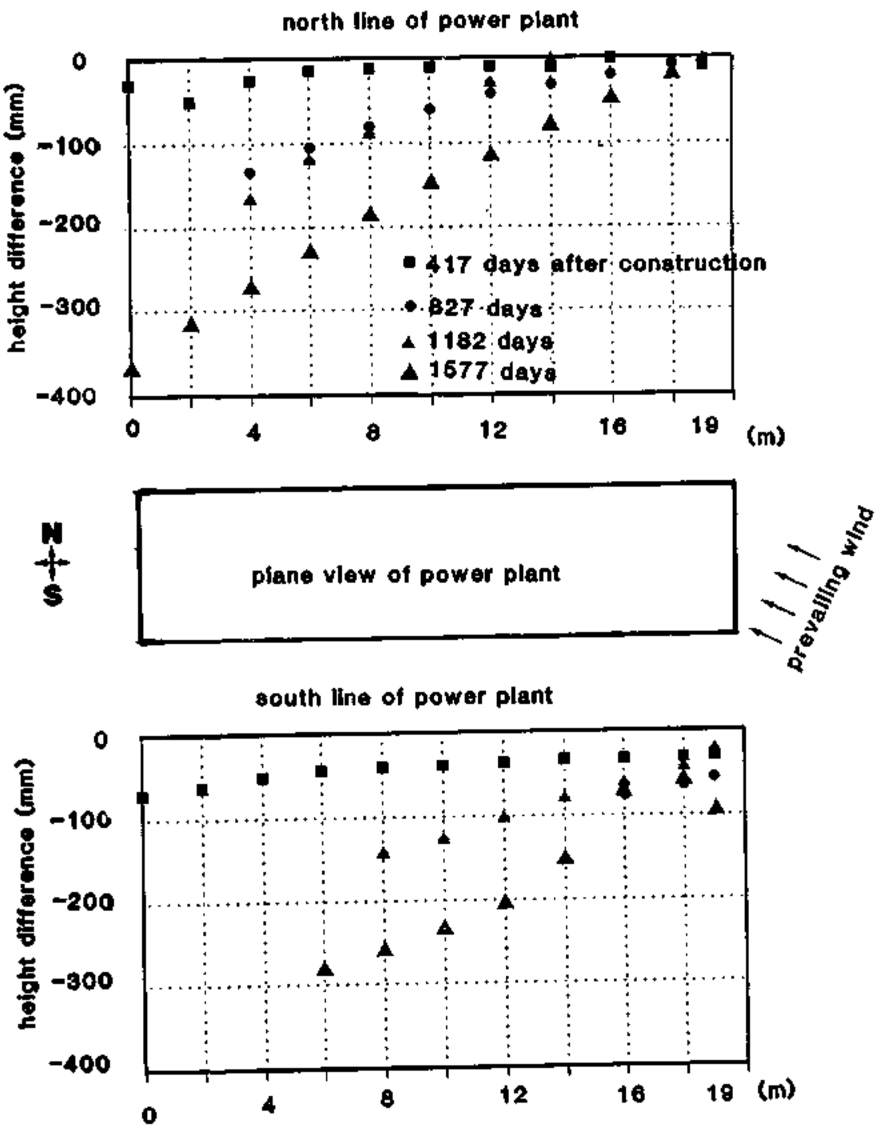


Figure 8-b. Relative height of power plant.-

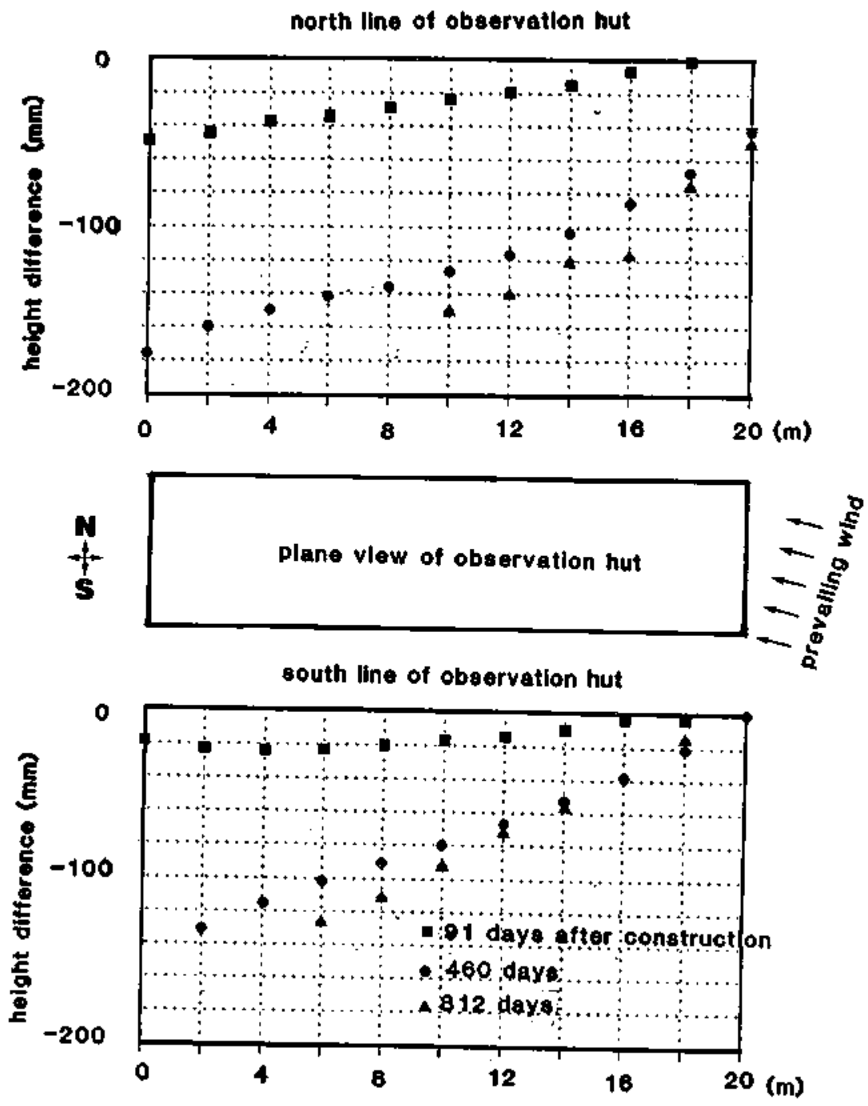


Figure 8-c. Relative height of observation hut.

The passage shown in Fig. 2 was constructed in January 1987. It is also used for storage of materials. Since the power plant was erected one year later of living hut , there is a difference of 1.43m in passage floor elevation. On accout of differential snow compaction rate within the passage, pronounced settlement in the power plant site resulted in the damage of roof and deformation of door there(Fig.9).

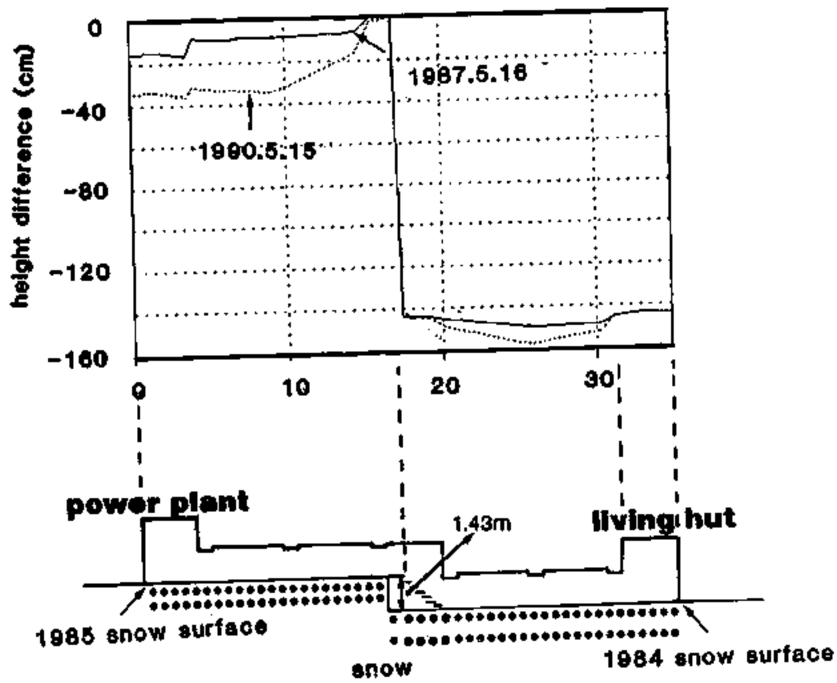


Figure 9. Change of height on the passage floor.
There was a difference of 1.43m in passage floor on construction of the hut.

5. Snow drift around the station

Remarkable development of snow drift in the leeward of the buildings has been noticed. Figure 10 shows surface topography of snow observed on April 2-6 1988, clearly indicating high accumulation area more than 5m high. At present the snow surface is level with the roof hight , so it is unlikely that further increase in the drift height will take place in the leeward.

The present engineering glaciological observation will be continued for the maintenance of the station, in paticular, the watch of deformation of buildings and relevant facilities.

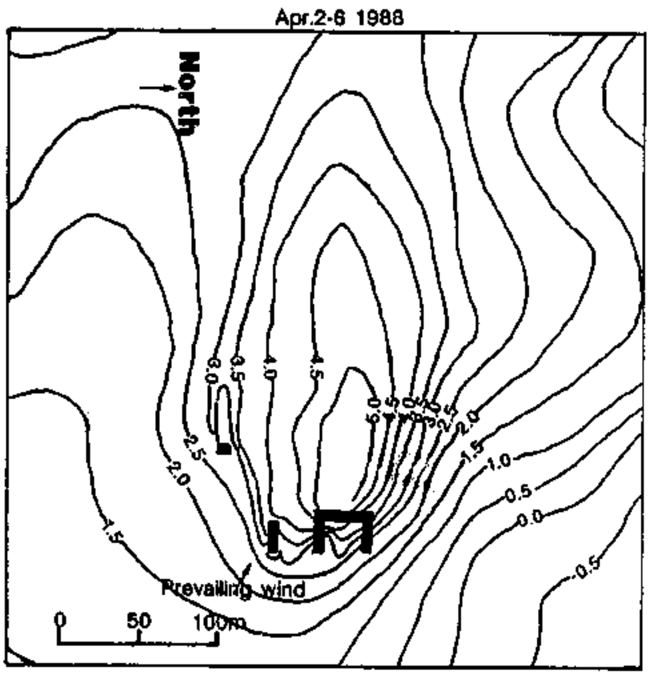


Figure 10. Snow drift around the station measured on April 2-6 1988.

DESCRIPTION AND DESIGN CRITERIA OF THE ITALIAN BASE IN ANTARCTICA

A.I.M.
Automatic integrated module

A. LORI, D. VOLI, M. ZUCCHELLI

Abstract

Italian scientific teams have been working now in Antarctica for six years. The summer base has grown during these years and all building plans are practically finished. Design criteria and development plans have been strongly affected by the extreme environmental conditions.

During the summer there is little time available for operations. This has not only heavily influenced the development of the buildings but also limited the duration of scientific activities. Even those activities which do not require personnel, such as the recording of environmental data, have been discontinued when all personnel leave Antartica for the winter.

The Antarctic Project has decided, after request from the Italian scientific world, to develop an automatic system capable of generating electrical energy for nine months of the year to permit the collection of data and its transmission to Italy.

TABLE OF CONTENTS

The Italian Station "Terra Nova Bay"

The Italian station Terra Nova Bay was established in 1986/87 in the Northern Foothills on the coast of Victoria Land, Ross Sea (74 41 42 S, 164 07 23 E). The station was developed in the following year and completed as a permanent summer station during the last 88/89 expedition.

Base Covered Areas:

- 400 m2 accommodation for 60 people;
- 350 m2 cafeteria and recreation room;
- 750 m2 chemistry and geology laboratories, instrumentation and radio rooms, offices;
- 300 m2 aquarium and technical plant for routine maintenance;
- 180 m2 OASI (submilimetrical infra-red astronomical observatory, consisting of 10 ISO 20 modules and a telescope dome;
- 180 m2 workshops;
- 1200 m2 storage area for equipment and transport vehicles.

Base Equipment

- infirmary;
- incinerator capable of burning all the daily waste from the base;
- water treatment plant capable of treating up to ten cubic metres of sewage per day;
- heliport;
- heat generation plant;
- two 60 cubic metre fuel tanks (one to be completed);
- salt water plant capable of producing up to 28 cubic metres per day;
- rhombic antenna for long distance HF communication.

Main Scientific Activities

Scientific research has been carried out in the following fields:

- Oceanography (Physics, Chemistry, Geology and Biology);
- Atmosphere Physics;
- Cosmology and cosmogeophysics;
- Earth and raw materials sciences;
- Biology and Medicine;
- Environmental impact

Present Observatories and Program For Future Installations

Some of the scientific activities previously mentioned make use of automatic observatories for data collection.

A list of numbers and types of operational observatories follows:

TYPE	NUMBER
Geomagnetism	1
Geosismic (VBB, very broad band)	1
Tilt and temperature (recorded locally)	5
Seismic network	4
Meteorology:	
Automatic Weather Stations satellite data transmission	8
Meteorological Network	5

There are plans to install other scientific stations such as a tide gauge and an oceanographic station consisting of instruments located on a buoy (a block diagram of the stations is in Appendix 1).

With remote measurement stations and radio transmitters good results were obtained by using specially designed low temperature battery systems supplemented by solar panels and wind generators. AWS (Automatic Weather Station) meteorological data are stored locally and transmitted via satellite (ARGOS) all year round. Seismic data are transmitted (via VHF radio) to the base.

Meteorological data and tilt data are stored locally in 124 Kbyte memory but not transmitted via satellite. Since the memory can only be substituted in the summer, and the power supply does not support a larger memory, the amount of data which can be recorded by permanent remote observatories is considerably limited.

At the moment the VBB seismic station operates only in the summer. The enormous amount of data produced requires memories compatible with large computers. These absorb quantities of electrical energy not presently available during the winter.

The proposed automatic system will allow all stations to operate in the winter. In future the remote stations will use the electricity available to provisionally store the data locally and periodically send it (via VHF radio) to the base, where a computer will identify, prelaborate and compact the information. Other stations, such as the VBB seismic station will be supplied directly by the automatic system, and connected to the same main computer. The computer completes its tasks by transmitting the information via HF radio or satellite (INMARSAT) to laboratories in Italy. However, the meteorological data from the AWS network will not be part of this experimental unit next year.

Scientific Institutions Interested In Year Round Collection of Data

Some scientific institutions have requested an extension of electrical supply during the winter months for scientific activities involving huge quantities of data and necessitating powerful mass storage.

The requests have come from:

- The National Institute of Geophysics (ING);
- The University of Catania Institute of Volcanology;

- The Genoa Institute for Naval Automation (CNR);

The ING utilizes a computer based on 68000 microprocessor and on the VME modular system in the VBB station in Antarctica. To extend the mass storage of the VME, from one month (which is its capacity) to nine months, it was branched to a Mvax 3800 provided with a one Gb capacity optical disk. The VME and the Mvax are linked by a high velocity data transmission interface produced by BIT3 COMPUTER. The user in Italy will be able to analyze the data stored in the VME by using the Mvax 3800 in Antarctica as a terminal and establishing a link between this and the Digital Inc. system in Italy (via satellite or HF radio). (Appendix 2 shows a block diagram of the VBB seismic station). ING also intends to use the geomagnetic station year round. Last year the station worked just during the summer. The electrical energy was supplyed from the main base, and the data were memorised in a local 768 Kbyte mass storage. Next year electrical power will be supplied all year round, and data will be memorised in the main computer Mvax 3800 .

The University of Catania Institute of Volcanology has installed a network of five local recording tiltmeters on Mount Melbourne. This instrumentation has low power requirements and so is supplied by lithium batteries (which can operate at low temperatures). Each station consists of the following:

- a sensor;
- a local mass storage;
- a VHF transceiver (radio link with the base).

A computer housed in the instrumentation container controls operations: another VHF memorised data to the central station where they are stored on magnetic disks.

The Institute of Volcanology will be able to check the data using the Mvax as a terminal of the PC. The link can be made either via HF radio or INMARSAT satellite.

The Genoa Institute for Naval automation plans to install a tide gouge in Antarctica.

The IDROMAR s.r.l. tide gouge uses 220 A.V.C. and needs ten watts.

Total Electricity Needed During the Winter Months

It was decided to use the computer (Mvax 3800), already installed in Antarctica, as the main computer in the automatic system module, since its mass storage capacity met our requirements. Greater reliability was achieved with two Mvax 3800 in CLUSTER configuration (peripherally linked by Ethernet) and provided with the MIRA system (one computer is back-up to the other). The realibility figures given by the supplier is five minutes of stoppage per year.

The need for high realibility in all the components making up the automatic system has determined the installation of a second no-break unit power system (acting as a reserve to the first) and a second satellite station.

In the light of what has been said the overall power required has been calculated at about six Kw.

(AIM) Automatic Integrated Module

The AIM is entirely autonomous. On the one end it is responsible for generating energy, and on the other for collecting, elaborating, and transmitting data.

Energy Production

Most energy systems on the market are not able to supply 6-7 Kw continuously for long periods of time. In our studies the following systems have been analysed:

1) Systems using SEEBECK effect
2) Sterling engines
3) ORMAT generators
4) Wind generators
5) Modified diesel engines
6) Production model diesel engines

Number six system has been choosen because its good reliability, good efficiency, end low cost.

PRODUCTION DIESEL ENGINES

The Antarctica Project has decided to use slightly modified production model diesel engines, to meet its energy requirements. Reliability has been improved by doubling the number of engines (six instead of the three modified engines previously modified) used in the Automatic integrated module.

The engines will be even more reliable because they will be working at 50% power.

Modifications of the engines, were assessed and made by Ruggerini S.P.A.

Test runs were carried out in a cold chamber.

ANTARCTIC PROJECT "ENERGY PRODUCTION SYSTEM"

Six autonomous electrical diesel generator units, each having a supplementary oil tank, starting battery charger and electric panel, make up the system.

A central electronic device makes sure that one of the six generators is working all the time, activating another if one stops for any reason.

Main engine characteristics:

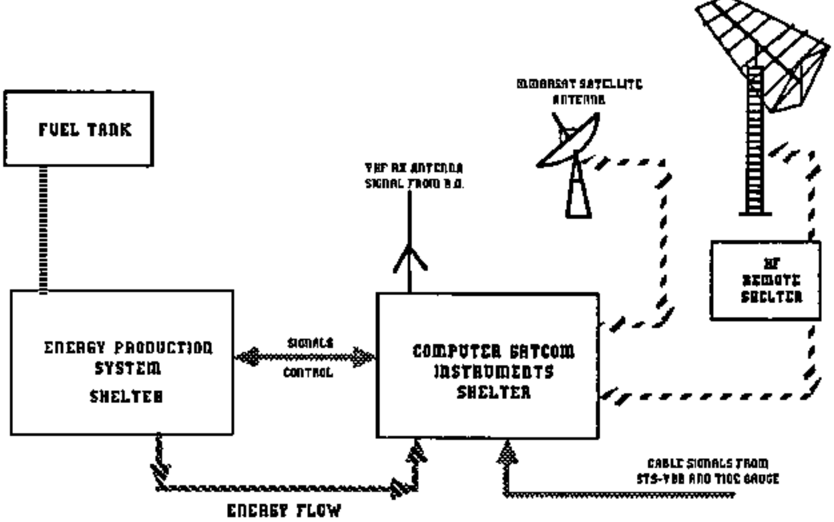
- Cycle - 4 stroke diesel engine
- Number of Cylinders - 2
- Compression rated 19:1
- Fuel - diesel, yet - A1
- Cooling system - forced air

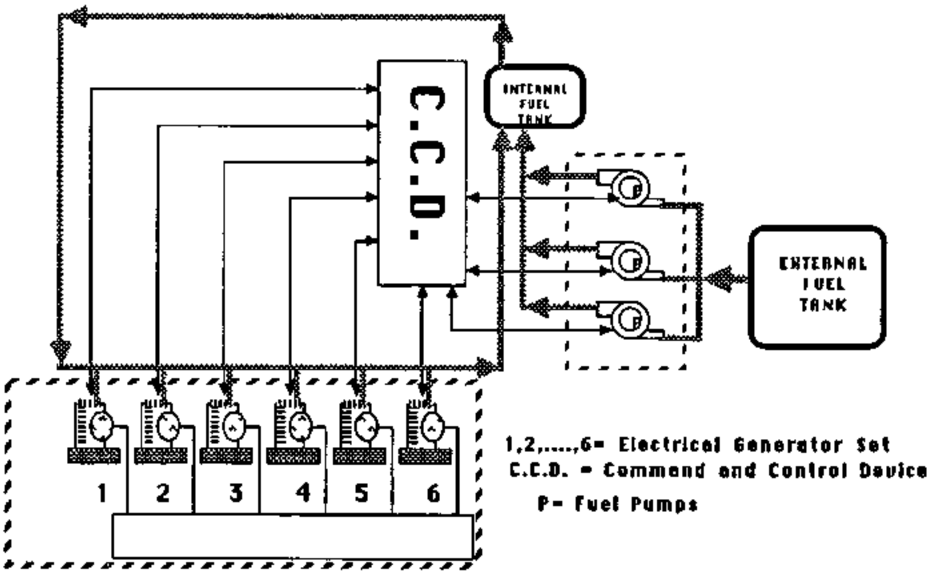
Results:

- maximum power a 3000 rpm: 13,5 Kw;
- maximum couple is at 2600 rpm;
- specific fuel consumption is equal to 0.232 Kg/Kwh;
- engine efficiency: 35%.
- exhaust fumes at fixed rpm are well within EC antipollution limits.

Block Diagram of:

A.I.M. Automatic Integrated Module





1,2,.....,6= Electrical Generator Set
C.C.D. = Command and Control Device
P= Fuel Pumps

Block Diagram of Energy Production System
A.I.M. Automatic Integrated Module

The following modifications have been made:

1) glow plug at engine head;
2) suction system in oil pump;
3) injection pump adapted to jet-A1 fuel.

The glow plug was installed to improve the engine's starting. Problems in fact could arise if the temperature inside the shelter dropped below a certain limit. A burner (webasto) controlled by a thermostat was installed in the container to overcome this drawback.

Problems regarding oil level, topping up and changing the oil every hundred hours, were solved by simply adding a supplementary 50 litre capacity tank. It is located below the normal engine oil sump. A tube between the two tanks keeps the oil level constant in the upper tank as well as allowing oil to drop into the lower tank (figure 1).

The oil pump, which takes oil from the larger tank, keeps all 50 litres of lubricant in circulation. The size of the supplementary oil tank was mainly designed to preserve the lubrifying qualities of the oil. Oil consumption[1] was also taken into account.

The engines were adapted to jet-A1[2] fuel by modifying the injection pumps.

Main alternator characteristics:

Make - Gen set;

Type - asynchronous, condenser excitation without brashes;

Power - KVA (7,2 Kw).

Command and Control Device (CCD)

The CCD controls three operations:

1 - activation of engine in sequence;
2 - performing test runs once a week;
3 - diesel supply.

1) The CCD controls the system simply by checking generator output voltage-level. Once this level falls, the CCD transfers operations to another engine.

Time delay relays have been used to transfer command from one engine to another. The relay on the first starter motor has a delay of zero second, the relay on the first starter motor has a delay of sixty seconds and so on up to 300 seconds for the last relay.

Once the AIM is in operation, the first starter motor to be activated will be that of the first generator G1.

Two possibilities may follow:

- the engine starts and so all other engines are excluded;
- the engine doesn't start.

---

[1] Diesel engines under small loads, as opposed to maximum loads, tend to consume oil. In our case consumption could be in the order of 1 g/Kwh.

[2] iet-A1 was chosen for its low temperature properties and because of the ANTARCTIC PROJECT's policy to supply in future only one type of fuel, and jet-A1 (JP8) is the most suitable.

If the engine starts, it runs first at 1500 rps for 40 seconds, after which speed is increased to 3000 rpm.

As soon as the generator output voltage is acceptable, the RTV 1 device connects the generator to the network and excludes the other engines.

In the second case the starter motor continues to turn for 30 seconds until disconnected by a time-delay relay.

After another 30 seconds (which means 60 seconds from beginning) the relay controlling the G2 starter motor is excited and there is an attempt to start up G2.

Again the same two possibilities may follow.

However, since the only control parameter is the output voltage level, the change over from one engine to another occurs only after failure has taken place. To overcome this potentially serious drawback, the computers installed in the instrumentation container are used to detect damaged engines and exclude them from starting-up procedures.

The following indications are memorised and utilized by the computers:

- oil pressure;
- fuel consumption;
- generator output voltage level;
- temperature in the engine and instrumentation housing;
- humidity in instrumentation housing.

The computer takes into account all warning signals to reduce breakdown risks. Low pressure, for instance, could indicate that shut-down is necessary and that the engine must be excluded from the CCD.

Computer decisions are not of course definitive. They can be overruled from Italy if analysis of control parameters do not confirm the decision.

Humidity and temperature indications, if above or below danger thresholds, can lead to AIM shut-down.

In this case the computer would not make the final decision, but the alarm would be given in Italy.

2) The CCD switches the engines in line for a 15 minute test run every week. This is to prevent damage arising from prolonged inactivity.

3) The three diesel pumps (one + two in reserve) are also activated by the CCD. If the first breaks down, the second, and then the third come into operation. The pumps supply a single daily tank (150 litres) from which the diesel oil is supplied to the generators (See Appendix 3, flow diagram showing CCD operations).

Collection, Elaboration and Transmission of Data

List of Equipment

The following equipment is housed in a purpose-built container.

1. Two Digital Mvax 3800 computers (760W x 2)
2. A cabinet containing two optical disks (400W x 2)

3. Two no-break power (7.5 KVA each)
4. Two satellite-stations (500 W x 2)
5. Two VHF radio relay systems
6. A rubidium - vapour clock
7. A VME bus station processor
8. Two personal computers.

Total power consumption is about 4 KW/h.
(Appendix 4 - block diagram of the equipment).

Description of the equipment.

The Mvax 3800 stores "VBB seismic station" data on an optical disk, manages communication with Italy, gives access to data stored in the VME bus processor (one-month-old recordings), and data stored in the PC of the Institute of Volcanology of Catania; finally it memorizes the control parameters regarding the generators, and the temperature and humidity inside the AIM housing.

Mvax 3800 is provided with DEC-NET protocol for communication lines management. The computer selects either satellite or radio communication after taking certain parameters into consideration such as cost of utilizing the telephone lines and the possibilities of establishing HF links. Satellite station links are very expensive while radio links cost practically nothing (if we exclude investment expenses). However, satellite links are always possible whereas radio links are available for only brief periods of time.

The same criteria are used when establishing radio links from Italy.

Two no-break power units are used in parallel because most of the equipments need a continuous electrical supply of electricity. It is especially important that there be no power cuts to the Mvax 3800, which.manages.the AIM. Continuity in power supply is also very important for the Rubidium Vapour clock, which provides absolute time to the seismometric data files(reference times are of fundamental importance for this type of data and it is for this reason that the clock is accurate up to 1/1000 of a second per year). The satellite station also needs a continuous electrical supply. In fact, if there were a power cut the parabolic antenna would stop pointing at the satellite and might not be able to re-establish contact when the power returns.

There are two satellite stations. The old Magnavox station will work in conjunction with another station also using INMARSAT but which has a higher performance.

Generator and Instrumentation Containers

Two container are used to protect the AIM. One houses the generator and the CCD, command and control device, the other the instrumentation used for data acquisition, elaboration and memorization, telephone line management and HF radio.

Generator Set Container

(Appendix 5 - plan of the container)

Engine operation takes place at around a temperature of 10°C. Specific consumption is 0.232 Kg/Kwh amounting to a global figure of about 1.7 Kg/h equal to 20.000w. Since the following heat balance may be reasonably assumed:

- 30% of total energy is transformed into electricity;
- 30% " " " is lost in exhaust emissions;
- 30% " " " is used by the cooling system;
- 10% " " is transfered through irradiation.

There would still be about 6000 Kcal available to keep the temperature constant inside the container.

Container insulation is in line with current Italian energy saving standards, where cd (volume coefficient of heat loss) is put at 0.7 Kcal/h mc°C[4] plus Cv[5] (loss due to air replacement) - good engine operation needs 60 m3 fresh air every hour.

At the same time air is used to heat the Magnavox antenna (50-60 mc/h). Heat loss due to irradiation accounts for 600-800 Kcal/h where the outside temperature is -40°C. The remaining 1.500 kcal/h guarantee the inside temperature above 10°C. Anyway if the inside temperature becomes too high an air impeller, which normally provides 70 m3 of air, increases this air flow. The container is provided with a Webasto (activated if the temperature falls too low). The arrangement of the generators in the container are shown in figure (2)

Weights:

- Containers ISO 20		4.500 Kg.
- Generator dead weight	290x6=	1.740 Kg.
- Batteries	40x6=	240 Kg.
- Central Electrical Device		250 Kg.
- Fire extinguisher		200 Kg.
	Total	6.930 Kg.

Instrumentation Container

(Appendix 6 - plan of the container)

Operating temperature for the computers in the container is between 10°C and 35°C. The insulation used for this container has the same characteristics as above, namely Cg = 0.7 Kcal/h°C mc equivalent to an over thermal load of about 2000 Kcal/h when there is a temperature difference of 50°C.

The energy which is dissipated by the instrumentation inside the container is about 4 Kw (3400 Kcal/h).

This is more than enough to meet temperature requirements and a disposed system is needed to get rid of excess heat.

Outside air is used for this purpose. When inside temperature rises above 35°C, outside air is aspirated and forced inside a radiator located in the upper part of the container.

---

[4] Cd Thermal load is about 2 Kcal/h in the worst conditions (50°C difference)

[5] Thermal load due to air replacement is about 2 Kcal/h in the worst conditions.

The system can transfer up to 2000 Kcal/h.

A humidifier will keep relative humidity inside the container between 15% and 40%.

A fire extinguisher system is provided to prevent serious incidents.

In the Appendices:

- a block diagram of all the instrumentation;
- a plan of the container showing equipment arrangement.

Work Schedule

The AIM is now almost complete with regard to the generator set:

- engines have been modified as described and tested for about 40 hours;
- engine and alternator assembly was completed as scheduled;
- the CCD has been designed and built;
- generators have been assembled in the containers.

Test runs took place on 12/7/90 and involved the following:

- positioning of system in test hall;
- visual inspection of electrical and mechanical connections;
- resistive load applied in relation to power required;
- generator start-up and verifications under load.
  * with engine at idling speed check for oil and diesel tube connections and engine leakages.
- engine at normal operating speed for a few minutes without load.
  * step by step loading up to full power;
  * operation at full power for ten hours;
  * performance with a two Kw overload.
- verification of CCD operations;
- verification of measurement instrumentation during operation;
- simulation of malfunctions to verify CCD operativeness;
- instantaneous load variations to verify reaction times;
- unloading, two minutes running and shut off.

The system delivery is scheduled for 20/7/90.

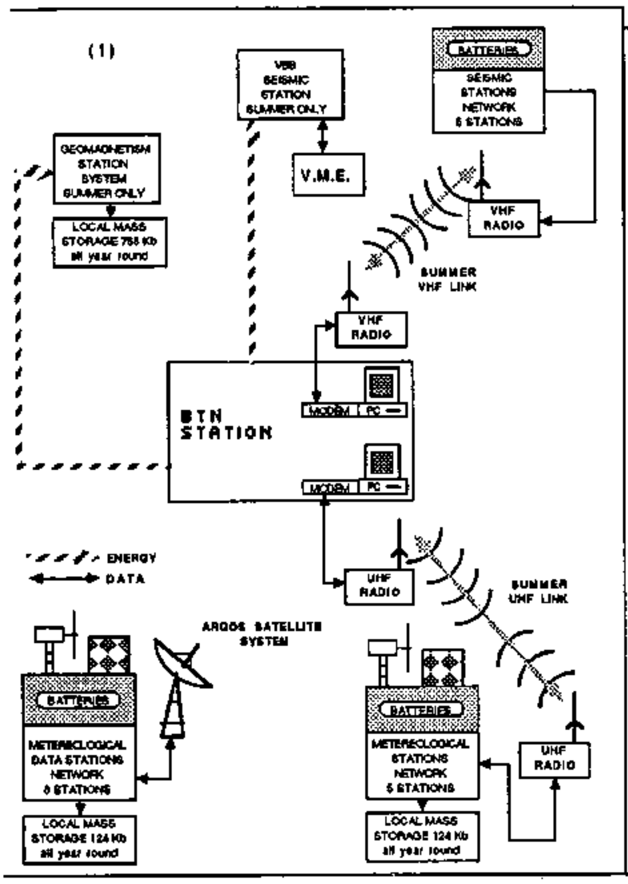
The instrumentation containers still have to be prepared.

Plans are ready except for a few bureaucratic details.

The instrumentation described in sections 7-2 is all available and has only to be assembled.

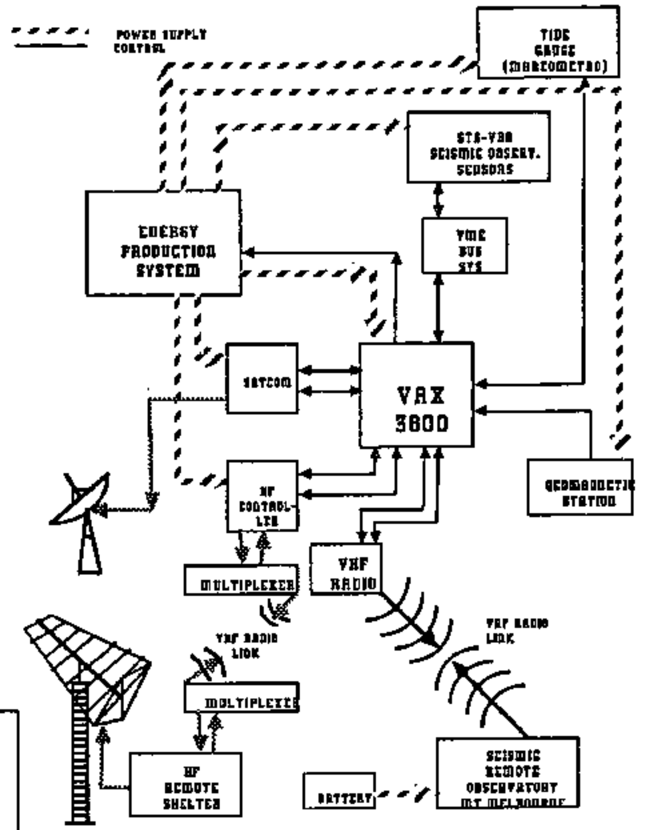
Digital Inc.has provided invaluable help in preparing the acquisition and transmission control software.

(1)

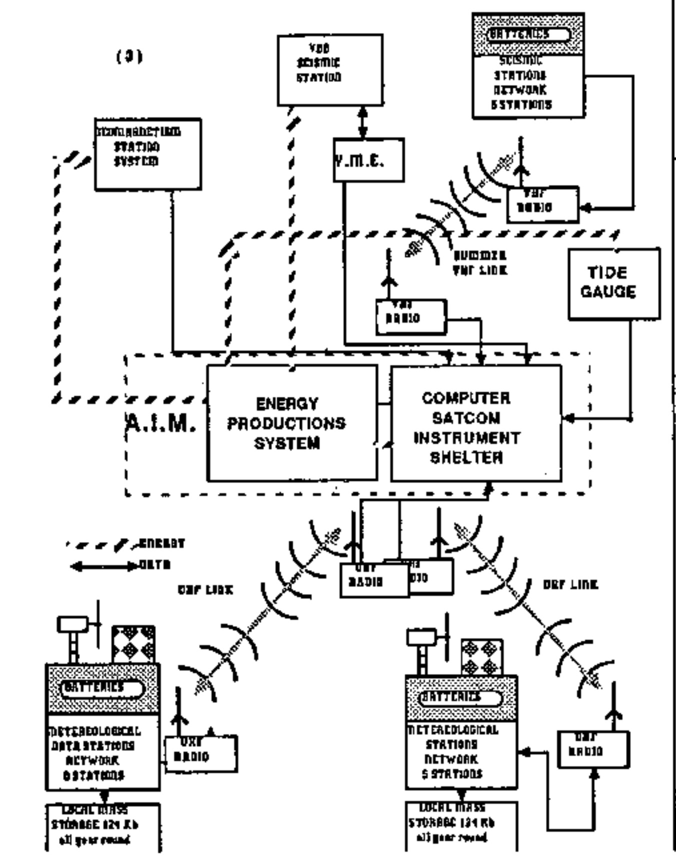


(2)

BLOCK DIAGRAM - Power Supply and Control of:
A.I.M. Automatic Integrated Module



(3)



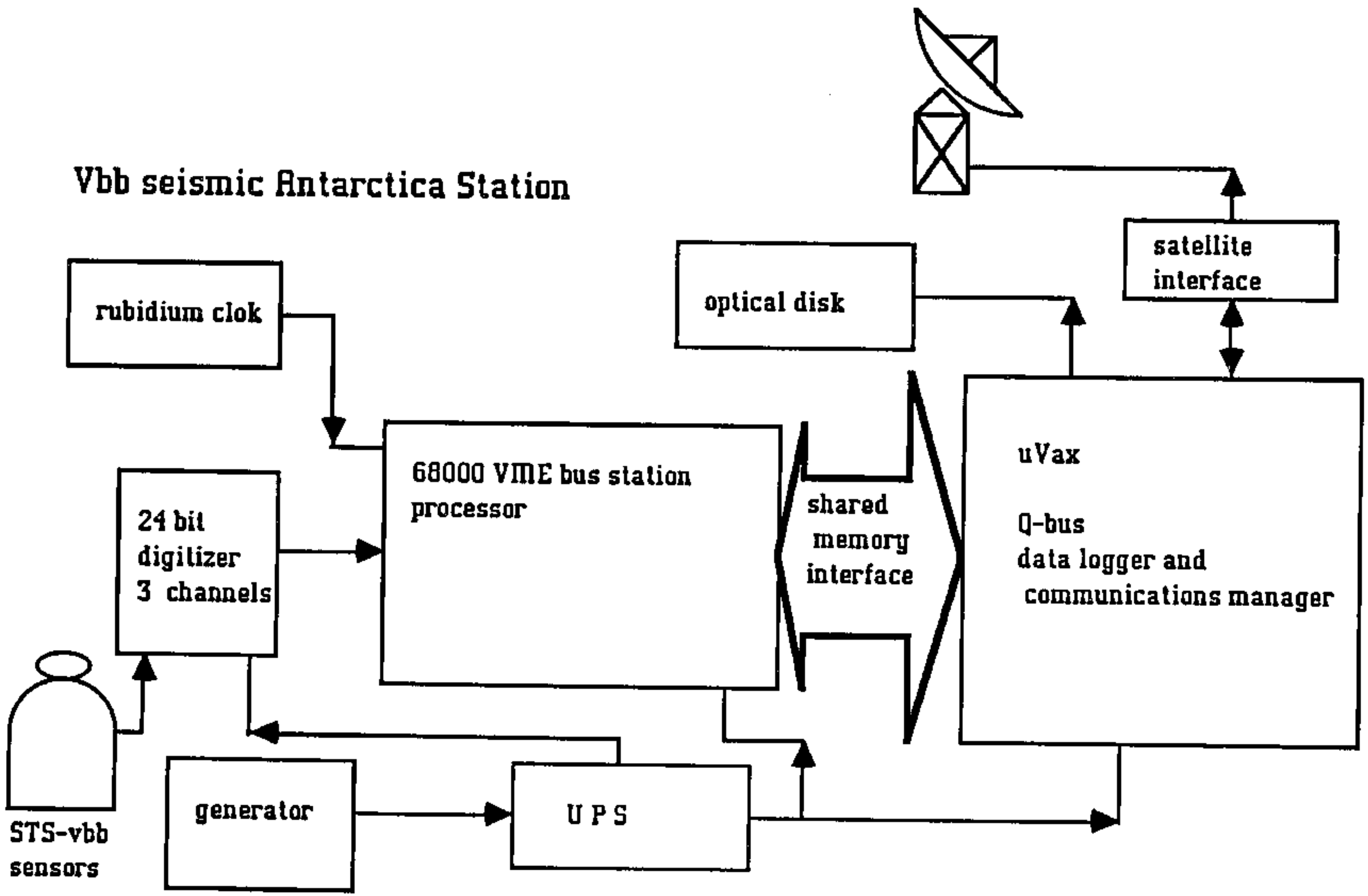
1) block diagram showing situation before A.I.M.

2) Block diagram showing situation next year

3) Block diagram showing future situation.

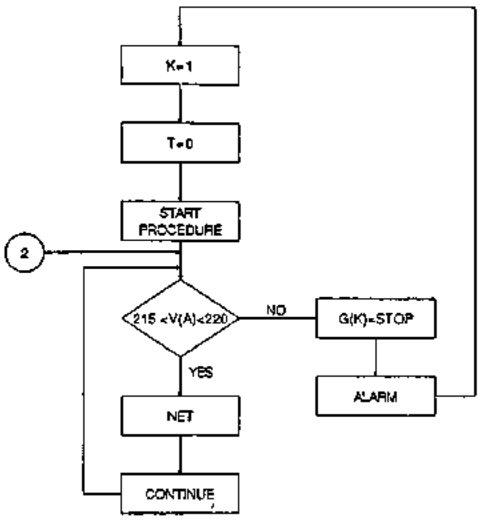
Appendix 2

Vbb seismic Antarctica Station

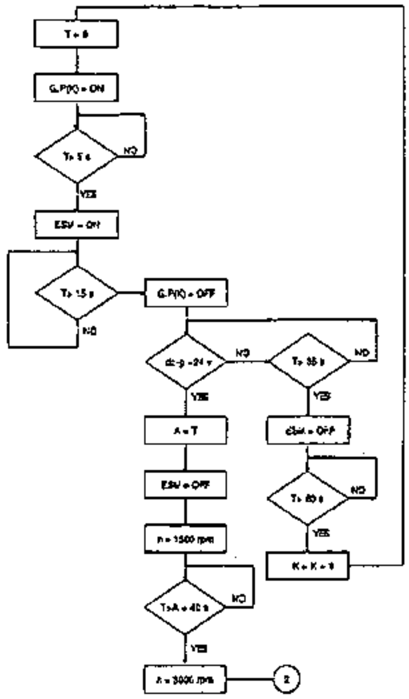


CCD LOGIC

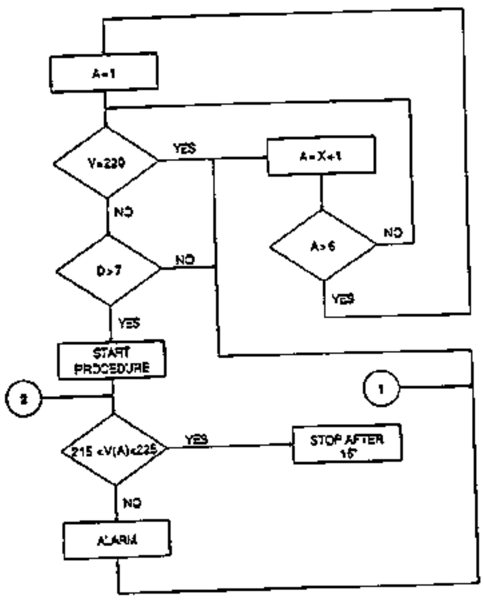
Command and control device



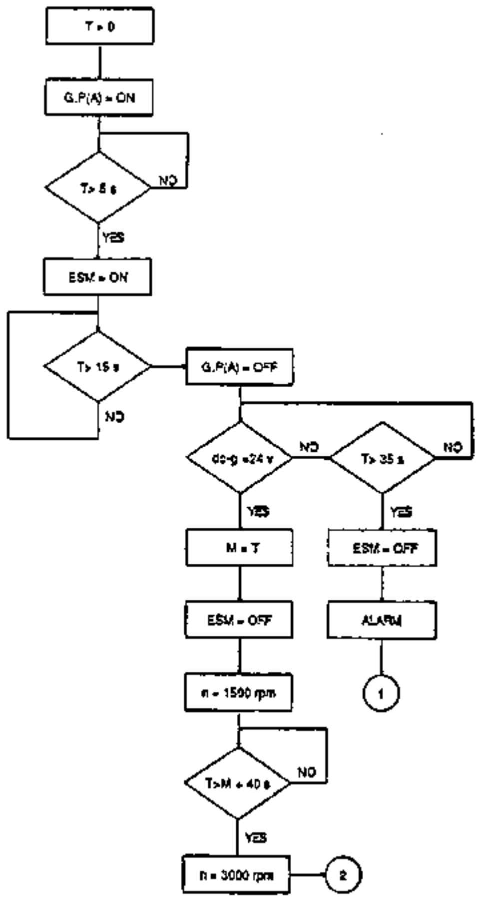
START PROCEDURE



TEST RUN PROCEDURE LOGIC

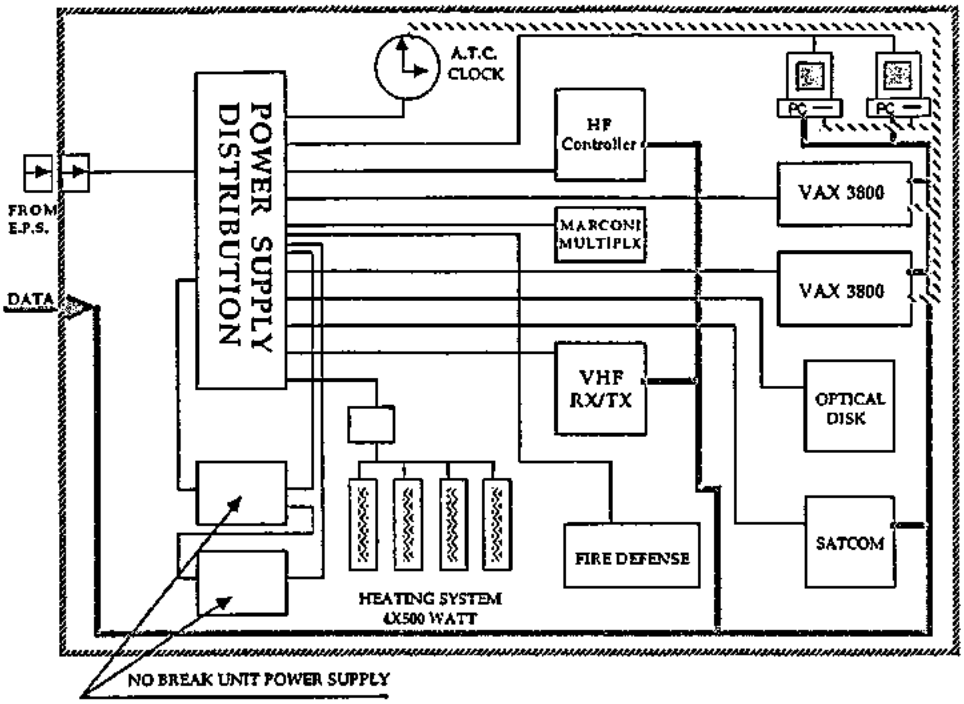


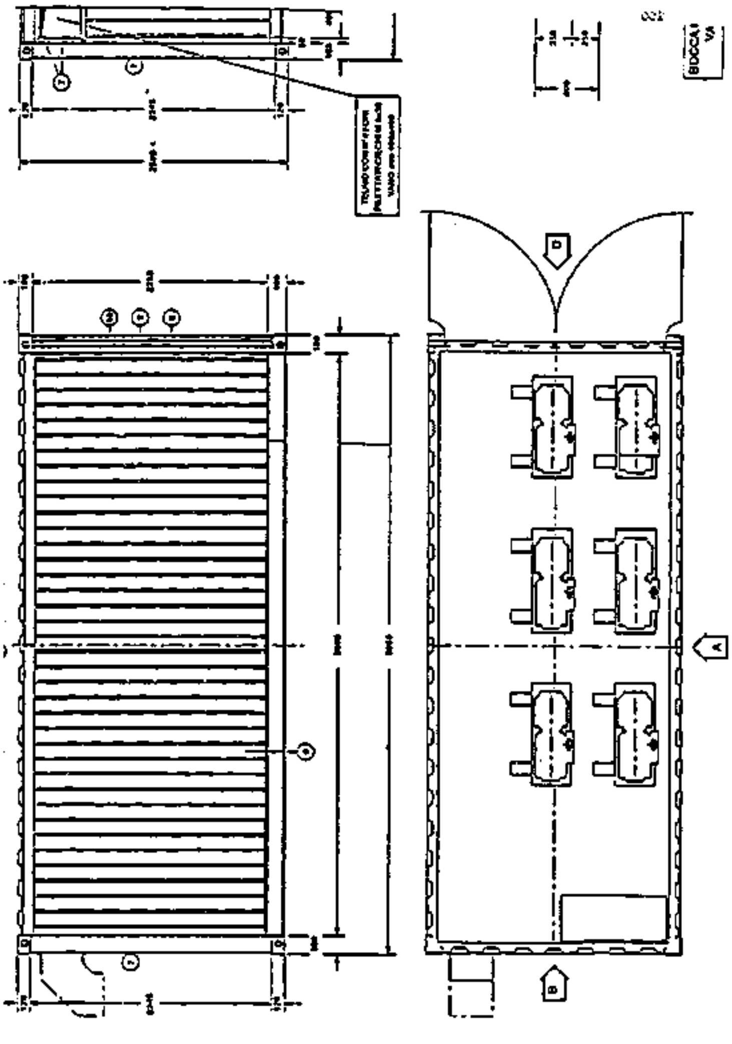
START PROCEDURE "TEST RUN"



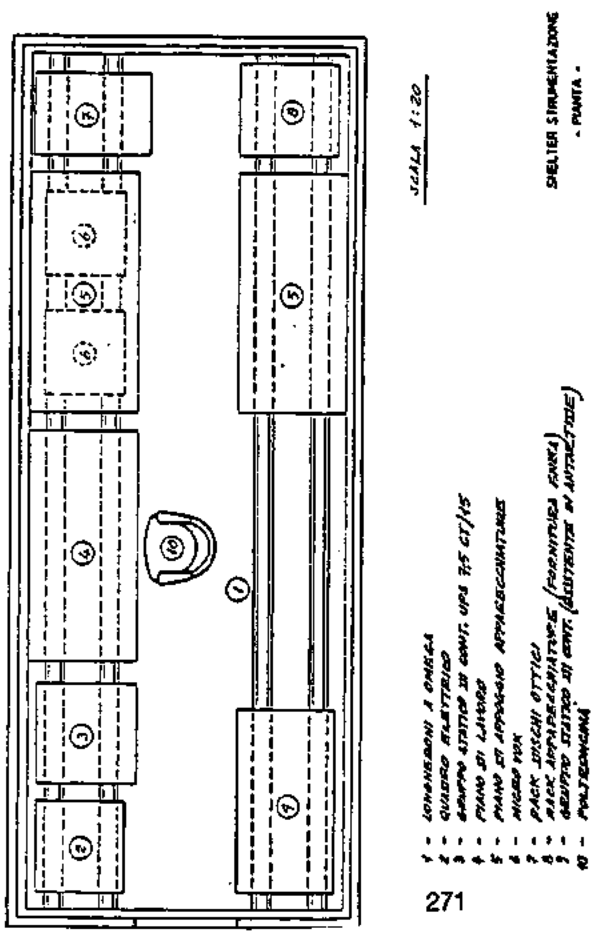
Appendix 4

Block Diagram of Computer, Satcom Instrument Shelter





APPENDIX 5



APPENDIX 6

FINNARP 88 Construction Activities

by
O.P. Nordlund, M.Sc. (Eng.)
Technology Development Centre of Finland

Abstract

The Finnish Antarctic Station Aboa comprises the other half of the Nordenskiöld base locating on the mountain Base (about S 73 dec, W 13 dec), the other half being the Swedish station Wasa. The stations were built during the austral summer of 1988-89 to serve the national research programmes of both countries independently.

The design principles and the equipment for the station are described. The construction work on the site was carried out by four persons only, and it will be described how the building work of the station was organized in 30 days with an engineering, a mechanic, an electronic technician and a medical doctor.

The transportation effort to haul 7 living containers, 4 ISO containers, a communication tower, a steel arch garage tent, fuel, food and equipments for two coming seasons (the total of more than 100 metric tons) 150 km inland in close collaboration with the Swedes is described.

The heat and electricity generation on the station and satellite communication and radio equipments is discussed.

Introduction

During the austral summer 1988-89 Sweden and Finland established a common research camp called **Nordenskiöld base** on the mountain Basen (S 73^0, W 14^0). There are two completely independent national research stations which are able to support each other in case of crisis. Despite of that it gives a unique opportunity to shear the transportation expenses.

Both station, Finnish **Aboa** and Swedish **Wasa**, are located about 200 meters from each other on the plateau of Basen at elevation of 450 m. The Finnish station consists of a central building (80 m^2, Figure 1), a generator house (generator room and workshop),

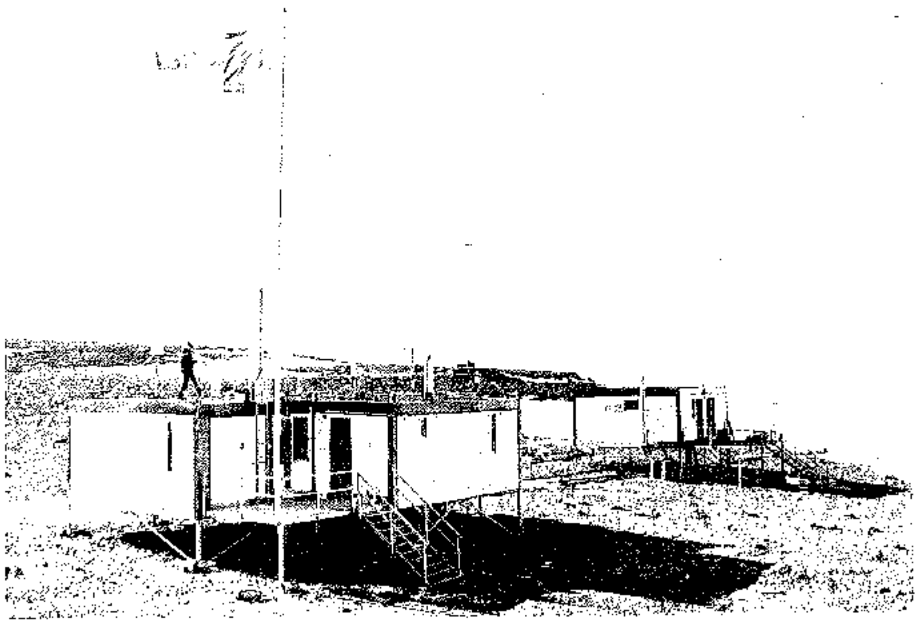


Figure 1. Aboa is located at an elevation of about 270 m above the surrounding ice plateau. The Swedish station, Wasa, consist the other part of Nordenskiöld base. The distant between the two independent stations is about 200 m.

storage facilities (4 pieces ISO 20 lightweight containers), a garage tent (erected 1989-90) and a communication tower for Inmarsat antenna.

The station was planned to give the basic facilities (accommodation, local vehicles, energy, fuel and food for two coming seasons) for 6-10 people. It was designed to create a "home like" atmosphere. The station is equipped with central heating, electricity, and water supply.

Resources

The biggest limitation to plan the construction work was the lack of time and human resources. Only 30 days and four people were available to build the station. The construction team was composed of a structural engineer, an electronic engineer, a mechanical technician, and a medical doctor. The shortage of building resources at the construction site necessitated the use of well prefabricated volume modules. The decision to select volume

Figure 2. All the equipment were hauled 170 km over the ice to the first costal mountain, Basen. The transportation was done in a close collaboration with the Swedes. Five Bv 206 tracked snow vehicles pulled 40 sleigh loads to the base.

containers was a calculated risk, too. The lifting capacity of the helicopters was max. 500 kg. This meant that the expedition was forced to find a suitable surface road from the ship to Basen with the total length of 170 km.

The transportation of 110 metric tons of equipment and fuel was done in close collaboration with the Swedes. The Finns had two Bv 206 -snowcat with 8 sleighs good for containers and single items. The maximum container weight was 7 tons in contrast with the preferred 4-5 tons. The transportation (Figure 2) was three times as big an effort as assumed. The Bv-train contented of five vehicles. The drivers were supposed to be changed by helicopters every the tenth hour. However, the white out forced the drives often to continue up to 30 hours.

Description of the station

The ground at the station is frozen moraine with a high water content, and special consideration was given to establishing a station that would withstand the Antarctic weather with only seasonal crews in attendance.

The central building was built from five modules (Figure 3) and the generator house was built from two modules. All modules were 6 x 3 m^2. In each corner of the modules was a telescoping steel

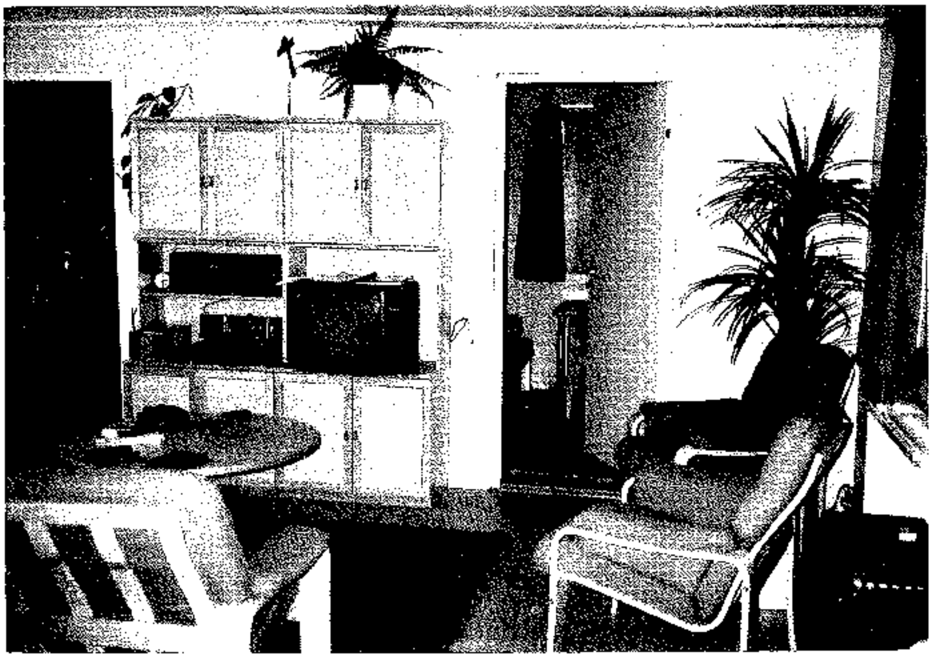


Figure 3. Interior view of the living room at Aboa. The station is equipped with a circulating antifreeze heating system. On the right is one of the oilstoves used to thaw the station after the winter.

leg. The modules were welded together and anchored by drilling expanding anchors into the permafrost and affixing the legs of the modules to the anchors. Diagonal supports were welded between the legs. The modules themselves had a frame built of tubular steel beams with sandwich type lightweight panel walls, floor, and roof. The sandwich type panel was made from 0.5 mm thick plastic coated steel sheet, 200 mm polystyrene, and another steel sheet. Except for the edges, each panel was a hermetic package.

All technical devices in the central building were concentrated in one module. These consisted of the communication equipment, the kitchen equipment, sauna and shower, electrical panel and water system (storage tank, pump, and boiler). Two modules formed the living room (Figure 3). One module contained the bedrooms for researchers and one module the office/bedroom for the station chief and technician plus the vestibule and the toilet (Figure 4).

The entire electrical system (220 V/50 Hz) can operate on one 20 kVA diesel generator. However, there are two identical generators in the generator house to ensure continuous operation and also to give the option of parallel drive. The integrated power system can deliver electricity, heat, and water as well regulate the balance between heat and electricity. The cooling heat of the engines is recovered with a heat exchanger and is used to heat the central

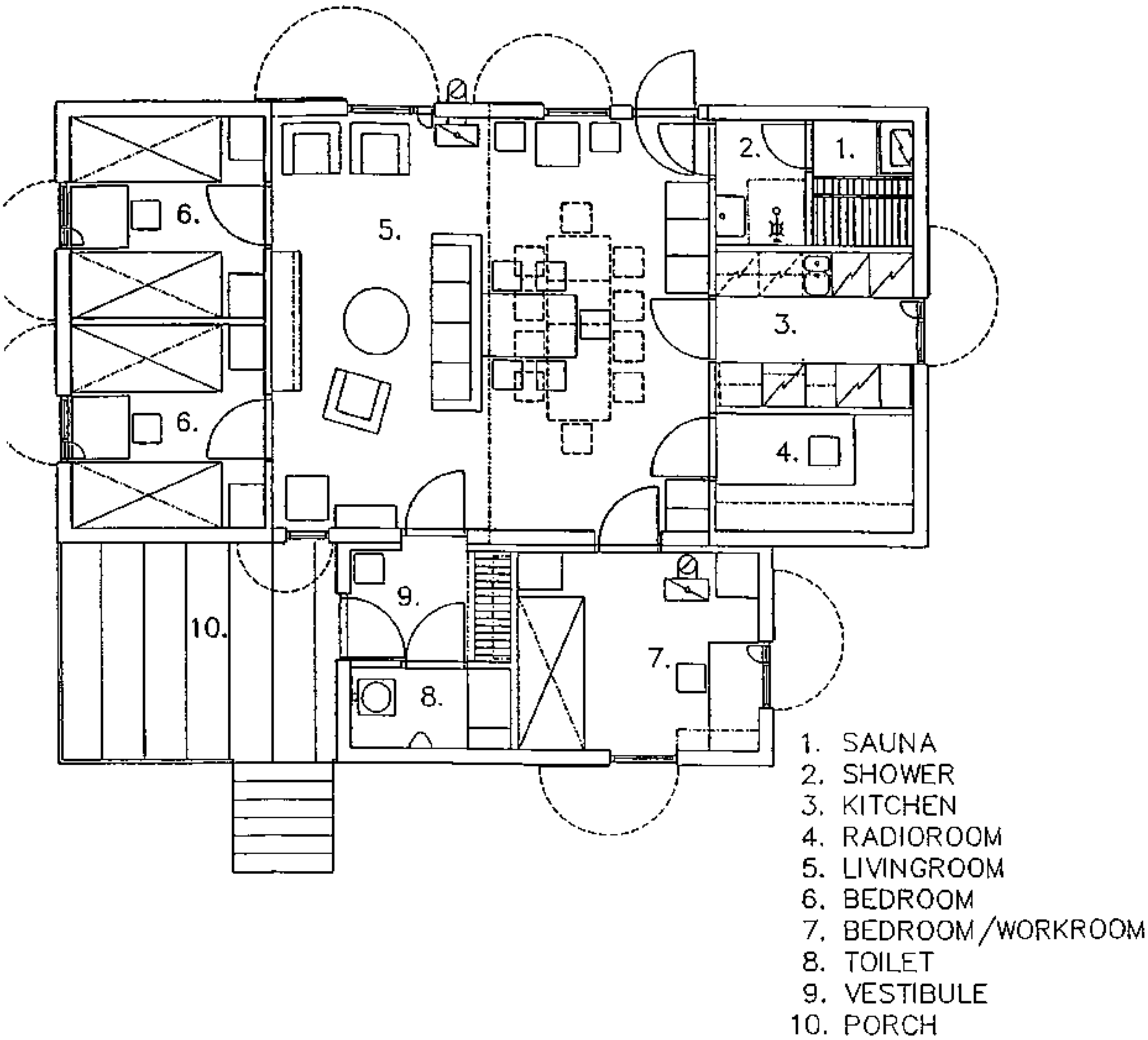


Figure 4. The layout of the central building at Aboa. All the technical devices are concentrated in the kitchen module on the right. The station is equipped with 10 pullman type beds.

building. In case there is a need to get more heat the system has two thermostatically controlled 4.5 kW electrical pipe type boilers. The spare heat of the system is used to melt snow in the water making pool outside the building. The spare heat for water making is automatically activated when reserve heat is available. There is also an option to lead manually more heat into the melting pool. In case of emergency the Swedish and Finnish stations can deliver electricity to both directions trough a connecting cable.

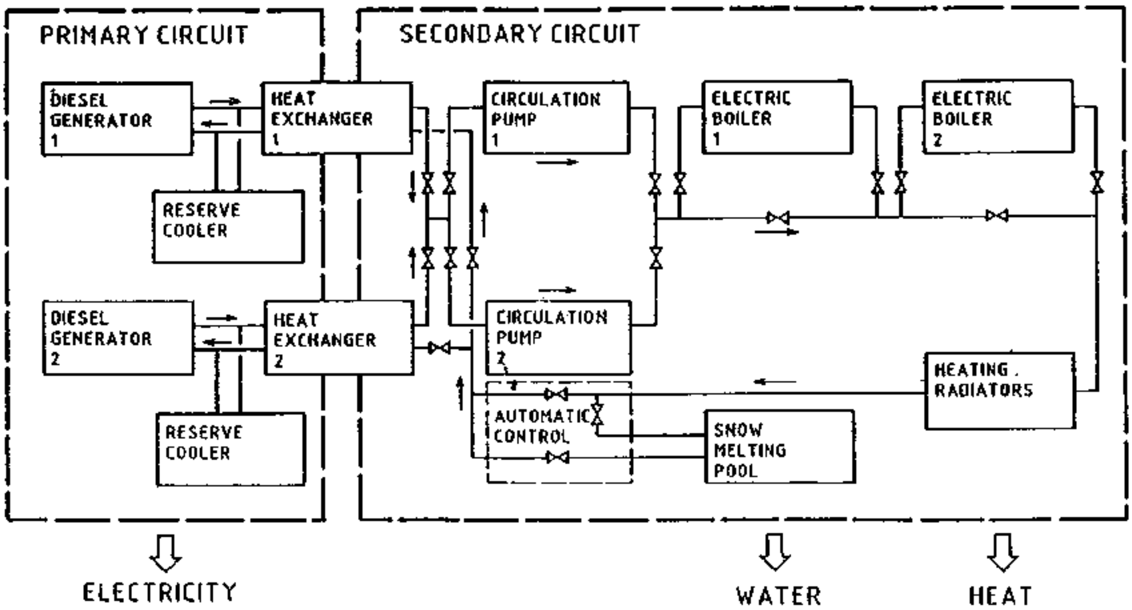


Figure 5. The principle circulating diagram of the energy system at Aboa. The system can operate with one diesel generator providing about 20 kW electricity maximum, and 20 kW for heating and water melting.

The waste management has been organized to collect all the solid garbage in one of the storage containers. The toilet is of the plastic pack type. In connection of the next coming resupply all the waste will be transported back. Only the grey (wash) water is allowed to run onto the ice.

Communication

To communicate with the rest of the world, the station has an Inmarsat satellite communication facility. There is a two number telephone with telefax capability as well as a telex. The system can transmit data, if needed. The ability to relay messages between Wasa and Aboa through a communications cable ensures external transmissions.

For local purposes there is a VHF radio network with relaying station on the top of the mountain and with ADF (automatic direction finder) and HF (SSB) radio to communicate with field parties and other stations and vehicles in the vicinity. There is also a NDB working on 395 kHz during the presence of the crew.

The automatic weather station is functioning year around to provide data for local use and to transmit them through the Arcos-system for the WMO network. The transmitted data (air temperature, humidity and pressure, wind speed and direction, and global radiation) are updated every three hours.

An Autonomous Antarctic Observing Station

by

H. Tüg

Abstract

This paper describes the development of an automatic, unattended platform for multi-purpose applications in polar regions. The platform consists of a 10' measuring container and two symmetrically mounted fuel tanks in 10' standard frames. The main unit contains the complete power generation, air temperature regulation, a central µ-VAX computer and additional electronic racks. Five kilowatts of electrical power (220 V AC, 50 Hz) are available for about one year of continuous operation. End of 1990 the station will be placed close to the German "Georg-von-Neumayer" base to collect meteorological, oceanographic and glaciological data. These data are stored internally but also telemetered via the polar orbiting bidirectional satellite "TUBSAT" to Bremerhaven.

Introduction

The presence of attended stations under the severe Antarctic conditions is very expensive and therefore limiting the number of permanent observing sites. About 2,000 tons of logistical material are needed to keep a typical station in operation all around the year. Considering that most of the scientific data collection is routine work automatic observing platforms are becoming increasingly important in future. Apart from high reliability and redundancy basic requirements for such a station are real-time control and a bidirectional data link between the platform and the home institute for a continuous observing run of at least one year.

In support of meteorological research numerous automatic weather stations (AWS) have been developed and deployed at various Antarctic locations (Stearns and Weidner, 1990; Allison and Morrissy, 1983). While previously on-site recording on tape was used modern systems utilize the ARGOS satellite network. Examples for applications in oceanography and sea-ice research are the Arctic Ice Monitoring System (AIMS, Fowler and Knox, 1988), the Autonomous Ocean Profiler, (AOP, Douglas et al., 1988) or the Arctic Remote Autonomous Measurement Platform (ARAMP, Prada and Baggeroer, 1988). Data are telemetered either by NOAA/TIROS-N polar orbiting satellites or GOES and METEOSAT satellite networks. A more capable automatic geophysical observatory (AGO) was announced by the Division of Polar Programs of the National Science Foundation (Lynch, 1989). Major features are the high data storage capacity of 1.5 gigabyte, 40 watts of permanent electrical power and the capability of data transmission via satellite.

Alfred-Wegener-Institut für Polar- und Meeresforschung, Columbusstraße D-2850 Bremerhaven
Federal Republic of Germany

In 1988 the Alfred-Wegener-Institute (AWI) started the development of a more powerful and compact autonomous observing station. The main objective was to have an automatic, unattended platform in such areas where seasonable research camps can only get temporary limited data sets. In the present paper special emphasis will be placed on the power supply, container construction and telemetry.

Power Supply

A reliable electrical power source is the precondition for any autonomous observing station. Ideally there should be enough power to use indoor electronics like in a laborabory while outdoor sensors and instrumentation packages can be heated. Looking for such type of multi-purpose Antarctic "plug-box" a feasibility study was made by Erding and Thiele (1988). Five kilowatts of stable permanent electrical power over one year were found to be a good compromise between scientific demands and logistic expense.

Photovoltaic arrays, wind generators or a combination of both are momentarily applicable for either small automatic platforms or as supporting power sources for attended stations. Sufficient electrical storage capacity is needed as well as an extended control system. While an adequate Stirling motor is still not commercially available and a turbine engine becomes efficient only in the range above 60 kW a Diesel generator was finally considered to be the best solution at least for the first year of operation. We chose a slightly modified two- cylinder Deutz engine in combination with a Leroy Somer three-phase generator. The motor is of heavy-duty type normally used in various vehicles for road construction. As lifetime mainly depends on lubrication there is a permanent double-cycle reduced oil exchange from a 150 l tank through an extended filter system. To assure a long lifetime the generator is oversized by a factor of five and from high quantity series. For redundancy reasons the power station contains two independent motor and generator units. They are running alternately in time intervals of two weeks. Longer periods of inoperation reduces the lifetime and can lead to starting problems. In case of a sudden total failure of one unit the second motor starts automatically independent of the programmed time interval and keeps running, if necessary, even for the rest of the year. Our initial plan using a 220 V generator with phase synchronization for the turn-over was abandoned because of lower reliability. The now installed repeater and control unit is rather simple but needs a battery buffer for a few seconds. During the warming-up of the second engine both aggregates are running with an overlap of several minutes. The three-phase generator current is fed via a UPS unit consisting of rectifier, battery buffer and inverse rectifier. The final output is a 220 V AC current of 50 Hz up to a total power of 5 kilowatts. Advantages are high stability and a galvanic seperation between generator and elecronic equipment. Characteristics of the power unit are summarized in Table 1.

Container Set-up

The automatic station consists of three standard 10' units, a basic measuring container and two symmetrically mounted tank containers as shown in Fig. 1. The central unit contains the complete power supply (Diesel engines, generators, control board, UPS), a 19" electronic rack and the air conditioning system. While the outside temperature ranges from -50°C to +5°C the inside temperature varies only between +5°C to +25°C i.e. that electronic equipment can operate almost like in a laboratory. It seems strange that even under severe Antarctic conditions the cooling of the container is a more serious problem than the heating. The reason is that approx. 2/3 of the total combustion energy is directly converted to heat, from which about 50% remain inside the container while the other 50% are exhausted by the motors. Corresponding to the efficiency of the generator system only one third of the energy is transformed to electrical power from which most of it will finally also heat up the container, depending on inside electronics. The container has a 5 cm insulating layer of ceramic wool.

Two independent radial fans regulated by the inside temperature blow the warm air out. Cold air from outside comes in through a 3 m high pipe on top of the container. It is warmed up in a mixing chamber with warm inside air. The exchanging air volume depends on the outsite temperature and is computed to range from 0.16 to 0.83 m^3/s. This relative high air mass keeps it unnecessary to protect the electronics from oil vapour. Both fans are directly driven by the three-phase current from the generator and are operating alternately in similar time intervals as the generator system.

The electronic rack contains a central μ-VAX computer with TK 50 tape drive, RX 33 floppy drive with 1.2 Mbyte, 2 hard discs of 169 Mbyte each and a 8 Mbyte ram. For data acquisition the basic configuration offers 16 A/D and D/A channels with 12 bit resolution, 1 parallel port and 20 serial ports. The storage capacity can be extended up to 2.5 Gbyte. If necessary a second 19" electronic rack can be installed.

Container bottom and walls are completely closed and waterproof in case that the station might be covered by drifting snow or placed on sea-ice for longer periods. The only access to the interior is from the top by several openings. Each of the cylindrical fuel tanks (mountred in 10' standard frames) has a volume of 10.5 m^3 and a net weicht of 2.6 tons. About 16 tons of Arctic Diesel oil are necessary to keep the station running for 9,000 hours. The basic technical concept of the whole station was developed in cooperation with Secon Ingenieurbüro, Bremen. The station needs to be served annually with the possibility to remove instruments and to install new ones according to the scientific program.

Telemetry

Geostationary satellites like METEOSAT/GOES, INMARSAT or INTELSAT have almost on-line capability, but unfortunately they can only be reached by some Antarctic coastal regions. Polar orbiting satellites like NOAA/TIROS-N are well-suited for polar research because they have about 14 useful passes per day. But data transmission is not bidirectional and limited to 256 bits in one-minute intervals.

To overcome these problems a polar orbiting "mail-box" satellite was considered to be an acceptable compromise. Such a satellite was built at the Technische Universität (TU) Berlin under the name "TUBSAT" and scheduled to be launched together with the ERS-1 in spring 1991 from Kourou Center, French Guayana. The basic characteristics of TUBSAT are summarized in Table 2. In cooperation with the TU Berlin (Institut für Luft- und Raumfahrt, Prof. U. Renner) the AWI will use the satellite in a pilot project for data transfer between the polar automatic platform and Bremerhaven. It will allow to telemeter in both directions but with a time delay which varies between 1 to 7 hours corresponding to orbit characteristics and the difference in latitude between the platform and Bremerhaven. At an altitude of 800 km the satellite has about 10 communication windows in the polar region but only 6 at 50° N. The baud rate of 1200 bits/s allows to transfer a data package of about 32 kbyte during one pass. The satellite will be programmable either from Berlin or Bremerhaven to pick-up the data from the polar station. Read out will then be possible at the following transit. The TU Berlin is always operating as a master, while the satellite has master capability only for communication purposes with the platform. The satellite will also be supplied with a digitizer to mail voices and spoken messages up to two minutes duration in the same manner as data.

As another option a singe-channel transponder is planned to support intra-Antarctic communication. During a transit lasting up to 10 minutes direct communication will be possible in a range of several thousands of kilometers simply by using slightly modified walkie-talkies.

Operation

After the testing phase the platform will be shipped to Antarctica in autumn 1990 by the German Research Vessel "Polarstern". The three containers can be mounted together on a special sled construction to be moved by a "Pistenbully" to the observing site. During the first year of operation the platform will be placed in a distance of 2 km from the Georg-von-Neumayer station; i.e. that independent of all automatic functions the platform is under control of an attended station. A computer link between both sites allows to ask for the actual status of the platform as well as for scientific data and to intervene in case of malfunction. As TUBSAT will not be available before spring 1991, during the first months the actual data are telemetered to Bremerhaven using the INMARSAT system via Georg-von-Neumayer. At the beginning high priority is given to numerous housekeeping data of the platform.The first scientific equipment will consist of a meteorological mast to measure air temperature, wind speed, wind direction and solar radiation, an array of new sensors for the detection of drifting snow and a sonde which will be placed below the shelf-ice for the measurement of water current and to observe freezing and melting processes.

Conclusions

The development of an autonomous station for use in polar regions reveals a strange paradox. On one hand the components must be of high reliability, preferably coming from high series production. On the other hand one needs sophisticated equipment being designed or adapted to perform under severe conditions. Therefore the final outcoming concept is a mixture of modern technology with plain but well proved elements.

Autonomous platforms together with remote sensing satellites will be of increasing importance for future polar work. A powerful platform like the one described in this paper, needs only about 1% of the logistical material compared with a typical attended station but can do most of the scientific routine work. Our future activities will concentrate on the instrumenting of the platform and the data transfer. In case of a successful outcome of TUBSAT pilot project more efficient satellite capability is desired.

Acknowledgement

The author wishes to thank all colleagues, in particular J. Blanke and E.R. Krabel who donated figures and information on the various instruments.

References

Allison, I., J.V. Morrissy: Automatic Weather Stations in the Antarctic, Austr. Met. Mag. 31 (1983) 71-76.

Douglas, C.E., J.H. Morison, E.W. Geller: The Autonomous Ocean Profiler, a Tool to Obtain Profiles of Arctic Ocean Properties, Instruments & Measurements in Polar Regions. Proceedings of a workshop, Monterey 1988.

Erding, A., K. Thiele: Energieversorgung eines unbemannten Meßcontainers in der Antarktis, Diplomarbeit, Hochschule Bremen, 1988.

Fowler, G.A., D.F. Knox: Systems Employed by Bedford Institute of Oceanography for Sea Ice Data Collection, Instrumentation and Measurements in Polar Regions, Proceedings of a workshop, Monterey,1988.

Lynch, J.: Automatic Geophysical Observatories, EOS - News from Jan. 31, 1989.

Prada, K.E., A.B.Baggeroe, An Arctic Remote Autonomous Measurement Platform, Instruments & Measurements in Polar Regions. Proceedings of a Workshop, Monterey 1988

Stearns, C.R., G.A. Weidner: Polar Automatic Weather Stations, preprint 1990.

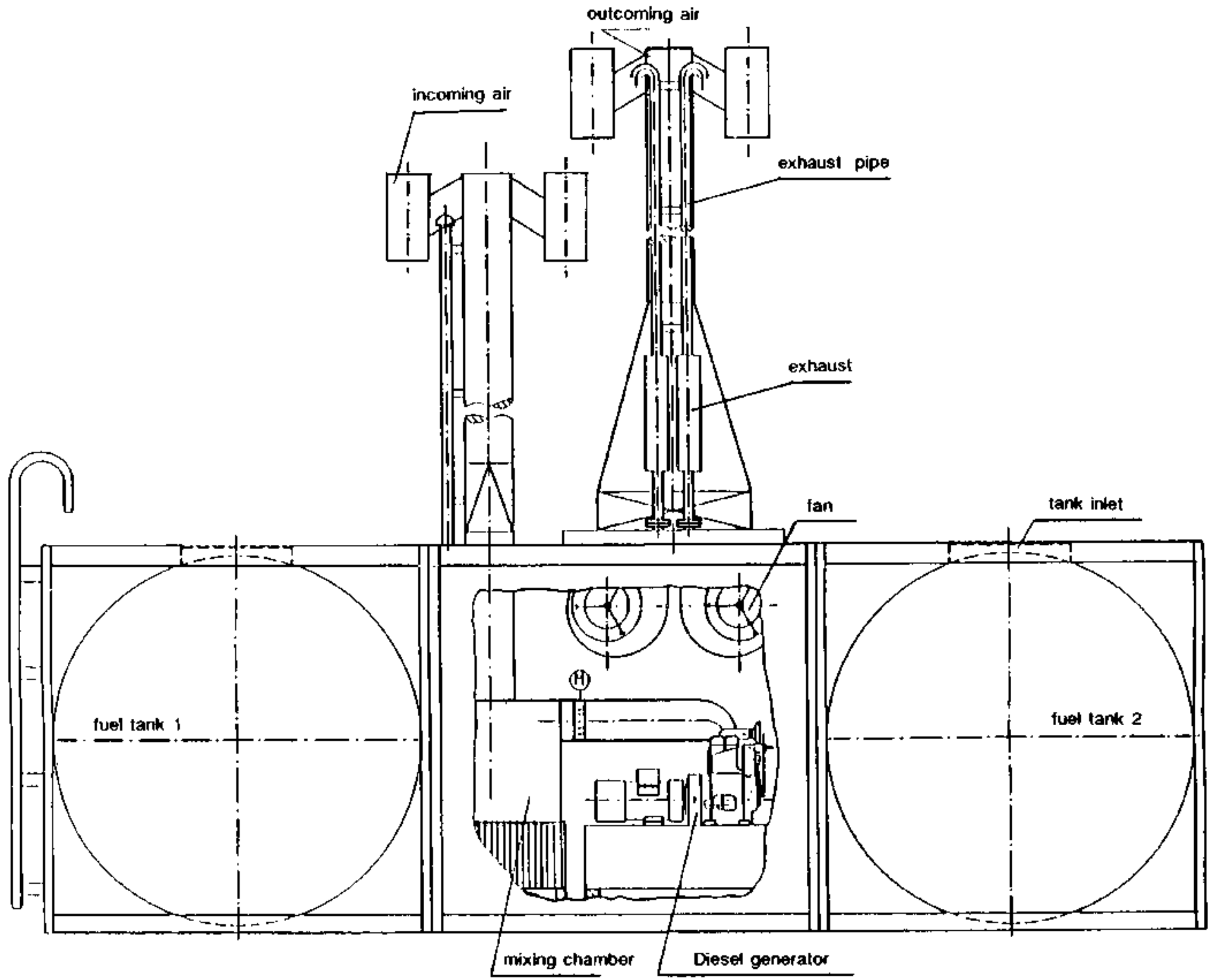


Fig. 1: Container set-up of AWI autonomous platform

Table 1: Power Supply Characteristics

Diesel engine (2 x):	Klöckner-Humbold-Deutz F2L511D 2 cylindres, air-cooling 1,500 cycles/min.
Mechanical power:	10.8 kW (Arctic Diesel Oil)
Fuel consumption:	289 g/kWh (Arctic Diesel Oil)
Motor oil supply:	150 l, extended filters, two oil cycles
Generator (2 x):	Leroy Somer, LSA 410 L 4A 3 x 380 V AC, 50 Hz
Nominal power:	25 kW
UPS system (1 x):	Siemens 4105, 5 kW
Input:	3 x 380 V AC, 50 Hz
Output:	220 V AC, 50 Hz
Total available power:	220 V AC, 50 Hz, 5 kW, stabilized from UPS 3 x 380 V AC, 50 Hz, 5 kW, from generator

Table 2: TUBSAT Characteristics

Orbit:	Polar
Altitude:	800 km
Period:	94 min.
Dimensions:	38 x 38 x 20 cm^3
Mass:	30 kg
Transmitting power:	5 W
Frequency:	2 m band
Data rate:	1200 baud
Data memory:	32 kbyte
Options:	digitizer, transponder

THE INFLUENCE OF ARCHITECTURAL THEORY ON THE DESIGN OF AUSTRALIAN ANTARCTIC STATIONS

by
Incoll, P.G.[1]
Australian Construction Services

ABSTRACT

''Habitability'' theories of architectural design are used as the basis of a thesis which states that the correct architectural design of a building can create a positive effect on the morale of its occupants. This effect is of more value to buildings in Antarctica than in any other place on Earth.

Applications of these theories to the design of Australia's Antarctic buildings in the 1980's are described and a project to assess their effect on the morale of the occupants is suggested.

INTRODUCTION

''Social Influence'' theories, or ''Habitability'' theories of Architecture recognise that the built environment has an effect on the people who occupy this environment. This effect can be positive, neutral , or negative. It may effect people consciously or unconsciously and in physical or mental ways.

This type of theory is one which, if soundly based and effectively applied, can be seen to be obviously useful in the design of Antarctic stations. Fortunately the parallel field of the Arctic environment has produced research which is relevant to the Antarctic situation, most notably by C. Burgess Ledbetter, an architect with the United States Army Cold Regions Research Laboratory.

(1) Senior Architect, Antarctic Design Group, Australian Construction Services, 239 Bourke St., Melbourne, Vic. 3000, Australia

At the time when site planning and design of Australia's Antarctic station re-building program was being formulated - between 1976 and 1980 - some of these theories (References 3, 4 and 6) were drawn to my attention by the Australian Antarctic Division's Project Officer for the Re-building Program at that time, Ian Holmes. Ian had a large part in the implementation of the concepts that will be described in this paper and contributed many ideas to the work.

Also in the later part of that time the University of Melbourne was conducting the Melbourne University Program of Antarctic Studies (MUPAS) and this program produced a number of papers from the School of Architecture under the supervision of Ross Clark which related to the interaction between people and the built environment in Antarctica (References 8, 9, 10, 11).

I have only recently realised that a lack of written description of the inclusion of such ideas into our buildings has meant that those currently active in Australia's rebuilding programme are unaware of these design factors and of their influence on the design of the new buildings. This realisation is one of the reasons for writing this paper.

The other reason is that now that a number of the buildings which include these applications of theory are completed and occupied it is possible to take the process a stage further and test the ideas.

In addition to this the international Antarctic Treaty community may be interested in these applications and may wish to take them up in their own projects.

It is interesting to note that in this age when the effects of what is built in Antarctica on the flora and fauna are of great interest and importance, there has been little attention drawn to the equally interesting and important effects of what is built on the human 'fauna' who occupy these structures!

At this point then, I will propose a thesis relating the built environment to the experience of life on an Antarctic station, from the point of view of its occupants.

Thesis

1. It is possible for a positive effect on the state of ''well being'' of a person, living in (or passing by) a ''built environment'' to be produced by inclusion in the design of this environment of features, forms and arrangements which have been found to have such an effect in previous environments. This effect will also be promoted by excluding from the built environment any features and arrangements which have previously been found to have an adverse effect.

2. The provision of such positive architectural properties of the built environment is more important in Antarctica than in any other environment on this planet because of the extreme nature of the Antarctic situation, and particularly during the extreme isolation and deprivation of the Antarctic winter.

3. This effect is valuable enough to the successful operation of the station and the attaining of its purposes to be worth increasing expenditure beyond the basic minimum required for reasons of physical

necessity. However, some measure of this effect can be provided without such increased expenditure if time and effort is provided during the design of the built environment to consider these 'architectural' properties.

While 'architectural' design features were consciously included in the designs of Australian stations this was done without the benefit of any specific formulation of intent and further was done on an 'opportunity' basis which means that the features were included when designer and/or client were aware of a relevant idea and when their awareness happened to coincide with a design opportunity.

Obviously if a conscious search for all factors which had been shown to have such an effect had been carried out at an early stage in the project and these factors had then been applied uniformly over the whole design period a greater effect could have been obtained.

Another factor which becomes evident is that much of the research in architectural theory has little support in terms of physical or statistical data. There are exceptions to this general state of affairs such as the work of CRREL in Cold Regions Habitability (Reference 4, 5, 6).

This does not mean that the conclusions of work without 'measurement' data are invalid but it does mean that there will be personal and subjective interpretations of data and that it will be difficult to reliably apply general theories to some specialised situations.

APPLICATIONS OF ARCHITECTURAL THEORY IN THE DESIGN OF AUSTRALIAN ANTARCTIC STATIONS

Overall Form of the Stations:

'Old' Casey station was designed in the 1960's following Australia's occupation of the Wilkes Station, constructed by the United States for the International Geophysical Year in a bowl shaped recess. This station over a period of years became almost completely buried in snow due to its location.

Similar, but not as extensive problems with drift snow had been experienced at Mawson and Davis and with the Wilkes experience to top it off resulted in a determination to learn from experience. Thus Casey station was

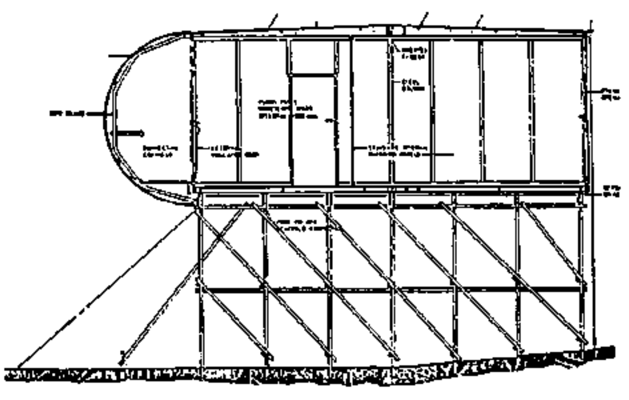


Figure 1. Section through Casey Station, 1969.

designed following wind tunnel tests to determine the drift free nature of this design, as a line of buildings to be elevated some 3 metres above ground. Orientation was North - South with its long dimension across the direction of the drift-bearing winds from the East.

Individual buildings were connected by a sheltered walkway along the eastern edge of the structure formed by corrugated galvanised steel sheets (as used in Australia to make rain-water tanks). This walkway was not heated and was open at the west between buildings. It was partly obstructed by icicles during winter but was still a part of the structure and was quite separate from the normal external environment. Power generation and workshop buildings were not part of the main station structure but were located on the ground to the south of it. (Refer **Figure 1.**)

Some years after Casey was occupied the Antarctic Division believed that the occupants of work areas included in the main elevated and walkway connected structure were less productive than similar expeditioners at the other stations. Tasks which required to be performed outside the structure by these people were often not done and the conclusion was reached that a form of 'cabin fever' (see Eb Rice, Reference 2) was being encountered.

So the requirement was laid down that an expeditioner's normal day would include a walk to work across the snow - providing him with daily evidence that he could cope with the outdoor environment, and that the Abominable Snowman did not lurk behind the next snowdrift!

Australia's redesigned stations were thus formed by this requirement and by considerations of fire safety, construction convenience and noise control, into a group of separate buildings. The degree of separation was ultimately determined by the shape of the landscape, in addition to the above factors and became greater than was originally intended. It may indeed, as many have stated, have become too great. Experience in operation will have to give the answer to this.

The buildings were aligned with their long direction parallel with the drift bearing winds, providing a simple solution to the snow drift accumulation problem in that doors and windows in these sides were swept clear by the wind itself. Rock and gravel foundations free of ice in their structure enabled the buildings to be placed directly on the ground, and thus avoid the vibration experienced in the Casey structure.

The size and content of each separate building was a result of the combination of groups of closely related activities, for example: the radio office, the Officer - in - Charge's office, and the meteorological office (the latter two activities generating the bulk of the radio traffic). This group was gathered together to form a building known at first as the Office Building, and later as the Administration Building. Other buildings were formed in a similar way.

'Architectural' Aspects of Individual Building Designs:

The second building to be constructed in the rebuilding program was **Davis Living Quarters**, comprising kitchen, mess, lounge and recreation spaces.

At the suggestion of Ian Holmes, inspired by photographs of the view through the windows of Palmer station, a large glazed observation bay was placed on the front of this building. This was done deliberately to provide a connection between the interior and the exterior worlds - in contrast to the old buildings whose small square windows were often obscured by condensation and were small light 'spots' in a dark wall.

When I visited Mawson and Davis in the summer of 1967-77 I was rather appalled at the poor condition of most of the buildings and at the drabness of the stations. A note of contrast (in colour, not condition) was struck by the plywood clad huts which the expeditioners were allowed to paint in any way they chose, whereas painting of the zincilate sheeted main buildings was not permitted.

The expeditioners close the brightest colours they could lay their hands on and these colours relieved the dreariness of the stations both from the distance and at close quarters.

It was therefore decided to have the new buildings finished in bright primary colours for the particular purpose of producing an overall effect of cheerful contrast to the drab brown summer rock or to the white of the winter snow. The bright colours of the buildings also have another vital function in making them easier to see in blizzard conditions.

At Davis there was a need for building finishes to withstand sand blasting from grit picked up by summer winds across the exposed ice-free rock areas upwind. This required use of special abrasive resistant materials and thus made selection of colours difficult, which resulted in Davis Living Quarters being more of a pastel shade than was desired. Still, any colour was an improvement on rust - streaked grey!

Inside the building the entry lobby was provided with a northerly facing high level clerestory window to give penetration of sun and light to the lobby when available. This area was fitted with planter boxes to house green indoor plants and it was intended to install an aquarium - these features were planned to give positive boosts to morale.

The observation bay gave the main lounge a view out across the sea and islands to the spectacular groups of grounded ice bergs which are a feature of the approaches to Davis. The penetration of sunlight into the lounge made it very attractive.

The previous building accommodation had no provision for separation of different recreational activities. On film show nights the projector was set up in the main lounge and all other activity had to cease. In the new Davis L.Q. a separate theatrette was provided and this could be used by hi-fi enthusiasts when films were not being shown or just as an alternative space to be in.

This building was the first Australian Antarctic building to be fitted with carpet - as a positive psychological measure.

A fireplace was planned into this and successive living quarters as a source of positive 'psychological' warmth and interest and not for its heat output, but these have not been installed as it is felt they constitute a safety hazard and an operational problem.

Casey Office Building was the next building to include some intentional morale building features.

The clerestory windows, planter boxes, etc, in the lobby were repeated. Windows of all areas were larger than before being 1200 mm high and 800 mm wide

Those spaces which were occupied the most were placed on the north side of the building providing maximum sun and a view out to sea. Stores and service areas were placed on the south side of the building.

The O.I.C.'s office which is also used for staff meetings was given even larger 1500 high and 800 wide windows facing north.

The communications arrangements at that time between expeditioners and Australia were by radio - telephone. ''Rad-phone schedules'' were provided at particular times of the day when calls were booked between expeditioners and their families or friends. This meant a group of people gathered twice a day around the rad-phone booth.

This routine was seen as being an occasion to provide a positive environment for those gathered and waiting for their turn at the phone - often with some anxiety in their minds. A small lounge area was created adjacent to the radio office and the sound isolated phone booth, with comfortable seating and a view to the north through large windows. Facilities for making tea or coffee were provided.

The **Mawson Sleeping/Medical Quarters** was the next major building. Mawson is a solid granite rock outcrop projecting out from the ice cap and had few level areas on which to build, many of them already occupied by such things as radio aerials. The site for this building was deliberately selected as being clear of the lower more drift prone areas and thus provided excellent views. Attempts to plan a single storey building large enough to accommodate 50 people in summer reduced to 25 in winter, together with bathrooms, toilets, laundry and a medical facility showed that a complicated structure with floors stepped down the hillside would be required. Therefore a two storey building was designed which was revolutionary at the time but much more efficient economically and thermally.

To keep it compact and still ensure that every bedroom has a window, a double-corridor layout was devised with service rooms in the centre artificially lit and ventilated.

The old building's sleeping cubicles were 1.8 metres square and had packed in to them a desk and a wardrobe by means of placing them beneath an elevated bunk and had only a curtain to close them off and thus possessed no privacy from a noise point of view. These were replaced by more normal bedrooms, fitted with a solid core timber door, with space on the floor for a bed, a desk, a wardrobe and even a visitor's chair!

Winter expeditioners had a room to themselves while summer expeditioners were either two to a room or in larger rooms with 3 or 4 beds. These larger rooms were planned to provide additional living space during the winter for those who remained there throughout the year. It was also thought that these rooms could provide for a married couple.

At the end of the building on the upper floor overlooking Horseshoe Harbour a small full time lounge was provided. A Hobby workshop was provided for hammering and banging activities not suited to bedrooms and this was also the location of the home brewery.

The fire isolated stair wells were part of the centre core of the building but were provided with northerly clerestory windows to give them some natural light and a patch of bright sun when available.

Bathrooms and toilet facilities were designed as complete units containing shower, basin and W.C. to avoid frustrations often experienced in barrack like plans where you emerge from the W.C. only to find all the showers, which were empty when you went in, are now occupied and you have to wait! They were also considered to be better suited to a building intended for both male and female expeditioners. At Mawson there are 'barrack style' facilities as well and here the partitions are full height to give privacy for use by both sexes. There was deliberately no segregation of the building into areas for males and females as this was felt unnecessary and would create an administrative nightmare in dealing with varying numbers of each sex and in taking up a stance of needing to police their relationships from above.

These toilet facilities provide a privacy level in total contrast to the almost partionless incinerator latrine at Mawson - even if a social opportunity is missed in the process!

The Medical Suite is grouped with the bedrooms for reasons of convenience for night-time calls from ward patients to doctors or any other person on duty and also with the thought that if more people were confined to bed than could be accommodated in the ward they would be close to the medical centre even in their own rooms.

Fire safety measures are provided in more than adequate sufficiency to give a sense of assurance to those aware of the high danger from fire in Antarctic conditions. The building is split into separate zones by fire barriers, provided with two completely fire isolated internal escape stairs, and every space is also actively protected by sprinklers and by electric thermal fire detectors. Smoking is prohibited in bedrooms which are equipped with smoke detectors rather than thermal detectors based on the fact that death could occur to an occupant by suffocation before a smouldering fire created enough heat to set off a thermal alarm.

The colour of the exterior was chosen to be a warm red colour based on the image of a red barn nestling in the snow of American farm land - probably gained from Walt Disney! - providing an impetus.

The **Stores** buildings were next to be constructed and their relevance to this paper is that they offer the great psychological and physical advantage of providing access to supplies without needing the aid of a shovel to dig for them. They are of sufficient size to permit a vehicle to drive inside and be loaded under cover when drawing stores in the winter.

A point of interest arises from the decision not to fit out the Mawson Store with its mobile pallet racks. This left the interior open forming a space 25 metres by 20 metres, 10 metres high, and this was reported to be highly prized by Mawson expeditioners for indoor ball games. This supports the validity of the Recreation Buildings intended for this usage which were part of the rebuilding plans but are now unlikely to be built. Recreation Buildings also provided for emergency or over flow sleeping accommodation.

At about this time **the layout of the new Casey site** was determined. The old site was restricted and uneven and subject to salt spray from upwind sea water so the new station was to be constructed inland. This was originally to be placed with buildings in a relatively close arrangement

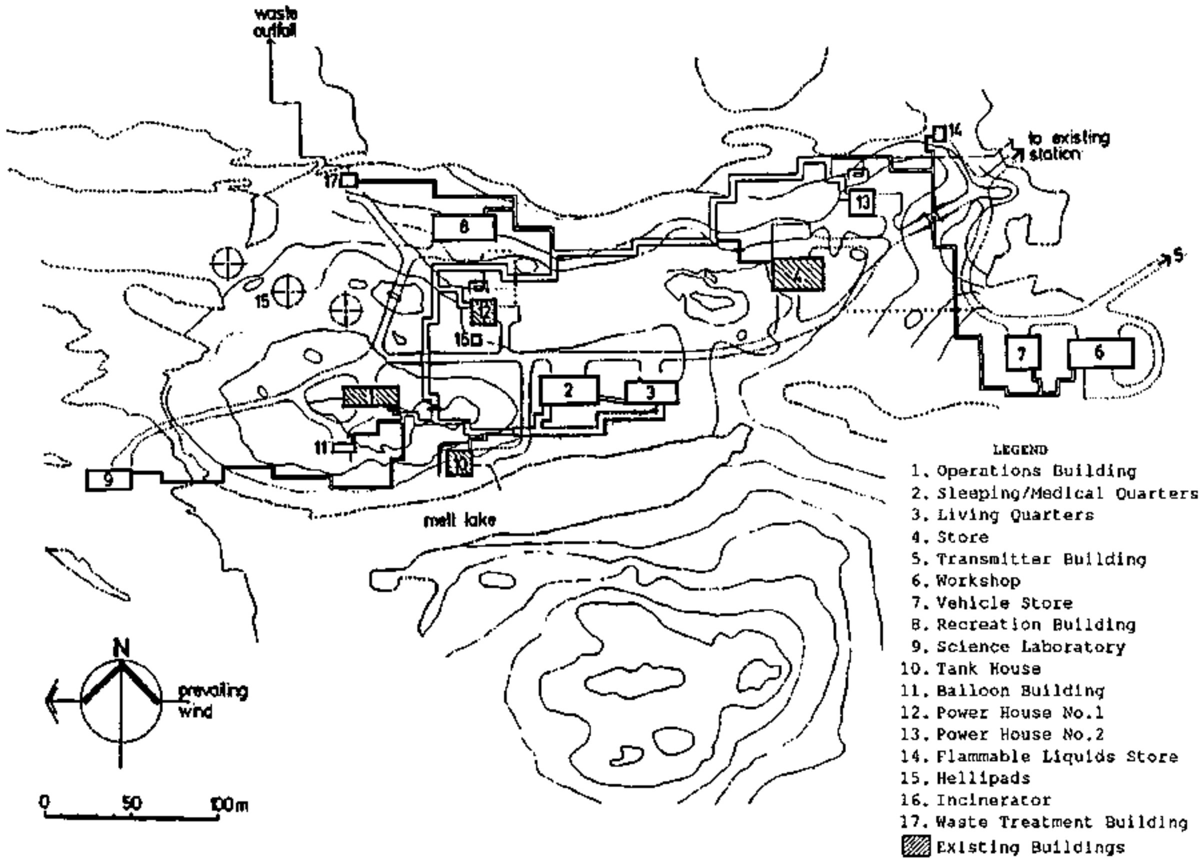


Figure 2. New Casey Site Layout, 1980

but using two adjacent hilltops. It was then discovered that the valley between was occupied by beds of moss. To avoid damage to the moss the station was confined to a single hill-top. As a result the layout is less efficient and more spread out than intended. (The extra distance between buildings also affected services reducing the viability of re-use of waste heat from power generation and requiring high voltage electricity reticulation). (Refer Figure 2.)

Living Quarters Buildings for Casey and Mawson are the place where the most conscious application of Architectural Theory was made. They were first planned in 1979.

''Undermanning and Architectural Accessibility'' by C. Burgess Ledbetter (Reference 4.), ''Post Occupancy Evaluation of a Remote Australian Community: Shay Gap, Australia'' by Bechtel, Ledbetter and Cummings (Reference 6.) and ''Cold Regions Habitability - A Selected Bibliography'' (Reference 3.) were supplied to me by Ian Holmes and from these the idea of the lounge being at the ''focal point of activity'' and of providing a ''graded hierarchy'' of privacy of spaces was obtained and used in the design of the later Living Quarters Buildings.

These theories as I remember my conception of them at that time are:

A concentrated focal point of activity provides a needed and known place which all of the population will be in, or pass through a number of times daily. This point is provided with 'services' or facilities which make it

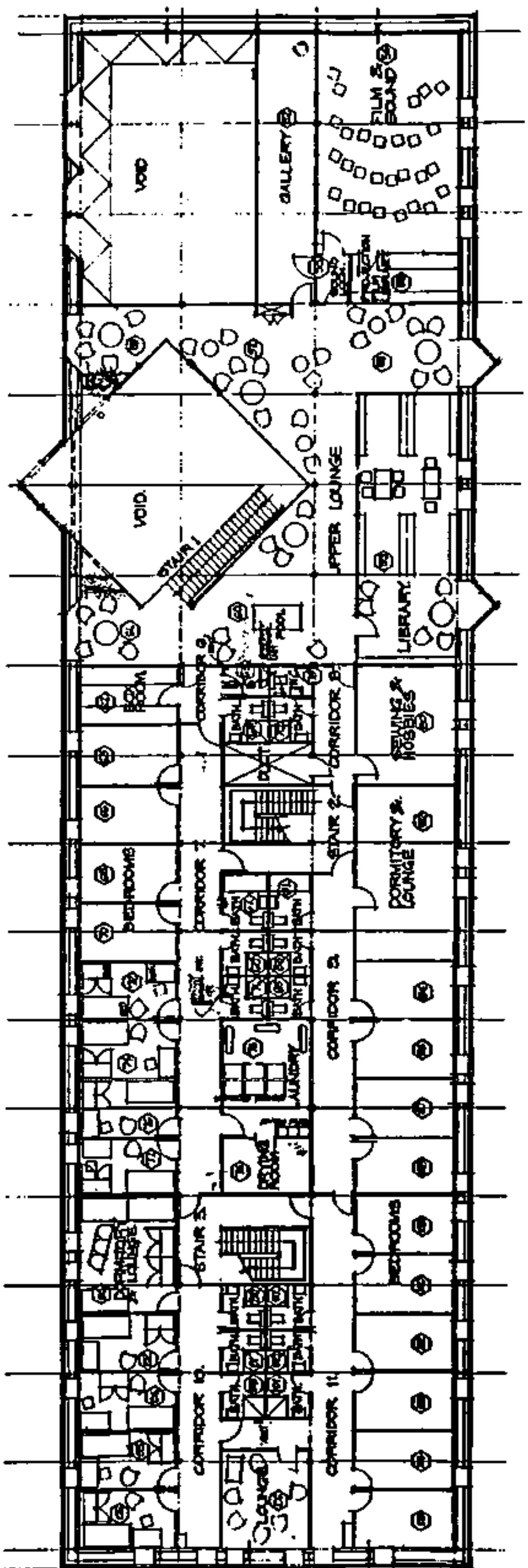
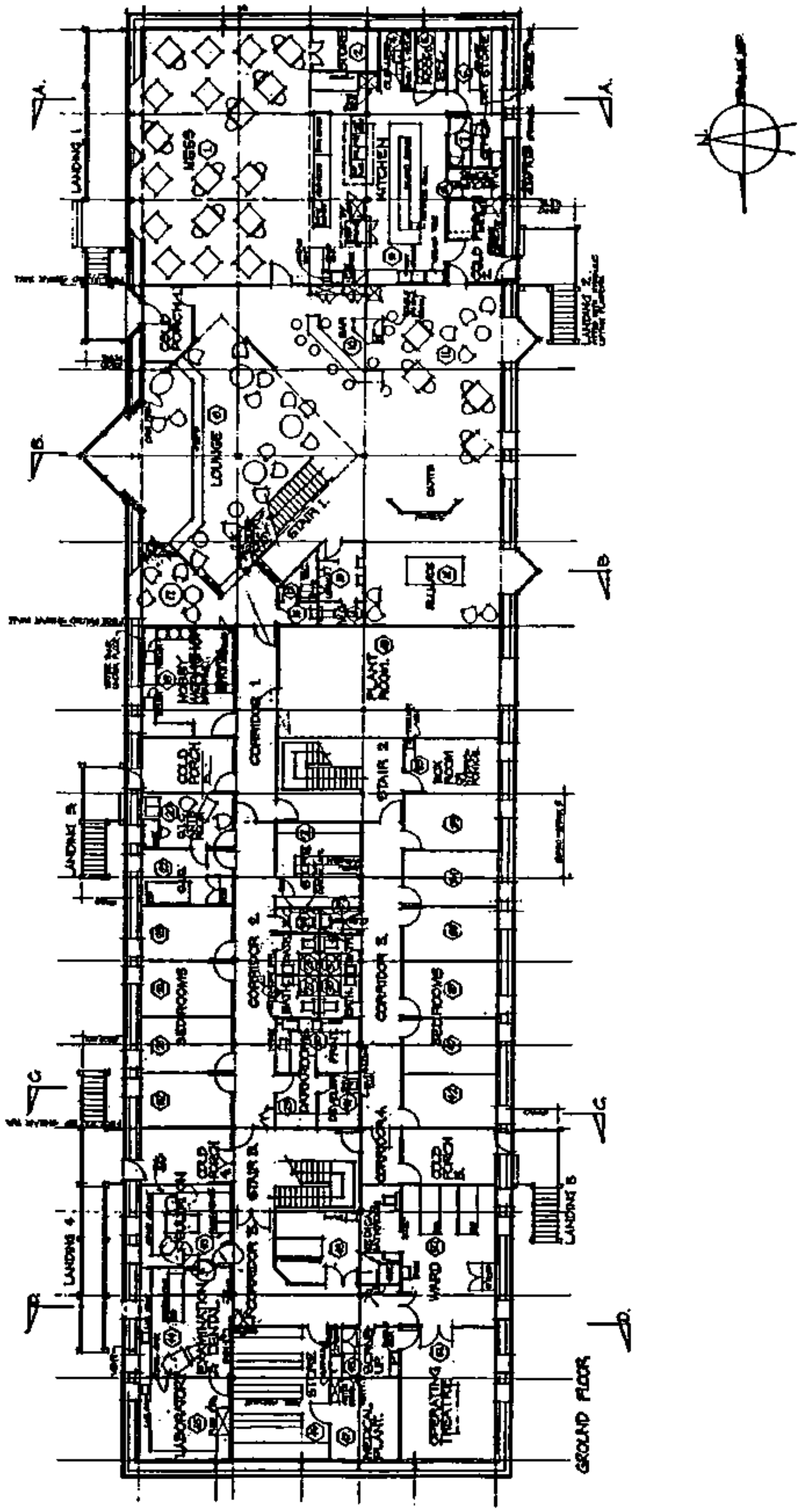


Figure 3. Casey Domestic Building. First Floor Plan



gure 4. Casey Domestic Building. Ground Floor Plan

socially attractive and thus normally occupied, and is designed to be on a main thoroughfare both to increase its utilisation and to provide those with anti-social tendencies with some automatic social contact with others, a particularly important point in Antarctica and other isolated areas. This concept also provides administrative benefits in producing a place where an O.I.C. will be able to make contact with most of the population without searching for them, either in person or, less effectively perhaps, by means of a notice board.

The graded hierarchy of privacy allows individuals a choice of the extent of socialisation that they desire rather than being forced to be either a hermit or a barfly! The range of privacy extends from fully private (bedrooms) through partly secluded (small lounge areas and rooms) to fully public (the centre of the main lounge area).

The combination of Sleeping/Medical and Living Quarters Buildings to form **Casey Domestic Building** provided our best opportunity to utilise these architectural behaviour theses. (Refer Figures 3 and 4 for plans).

At Casey all who wish to eat must pass through the door of the Mess which opens to the ground floor of the Lounge. All expeditioners must pass through the lounge on the ground floor or down the central stairs into the lounge to reach this point. Close by was to be the bar, a centre of great popular interest, and lounge areas designed for a leisurely chat.

This concentration of traffic and facilities creates the strong central focal point and the compulsory socialisation discussed above.

The design of the Casey Lounge provides a central 2 storey high space lit by full height windows. These provide the maximum amount of sun and a view out to the north, which is beautiful in itself and also in the fact that it overlooks the anchorage of the relief ship - the return of which provides physical reconnection to home, family and the wider world.

Around this completely open and unprivate space are the smaller scale spaces where small groups or individuals may choose to be, with a sense of separation from each other and the main space, yet still sharing in and conscious of whatever activity is taking place there. Off this again are necessarily enclosed spaces for noisy activities - the theatrette, and for relatively quiet activity - the library. Elsewhere in the building there are spaces providing less public and more private meeting opportunities and of course the full privacy of bedrooms and bathrooms.

The large physical dimensions of the spaces in the centre of the lounge and of the mess were deliberately provided to offset the confinement of days spent indoors under blizzard conditions, when the window connection to outdoor space is negated by winter darkness, and to be a positive contrast to the small low ceiling spaces in the Sleeping Quarters.

One concept that we were advised of between the design of Mawson Sleeping Quarters and of Casey Domestic was the idea of increasing an expeditioner's sense of control over his environment by not fixing the furniture in place and thus allowing him to express himself by moving it about. This idea has been implemented in Casey Domestic. The application is probably limited because the size and shape of the room does not give much scope for different arrangements. However Antarctic expeditioners are noted for their ingenuity - one occupant of Mawson Sleeping Quarters was found to have constructed a timber frame to elevate his bed back up into the air as in the old 'dongas' and thus provide a large extra space in his room for storage.

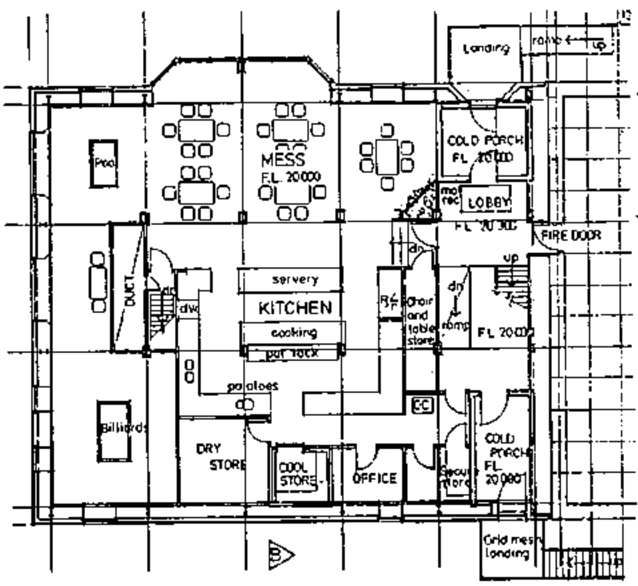


Fig. 5. Mawson Living Quarters Ground Floor

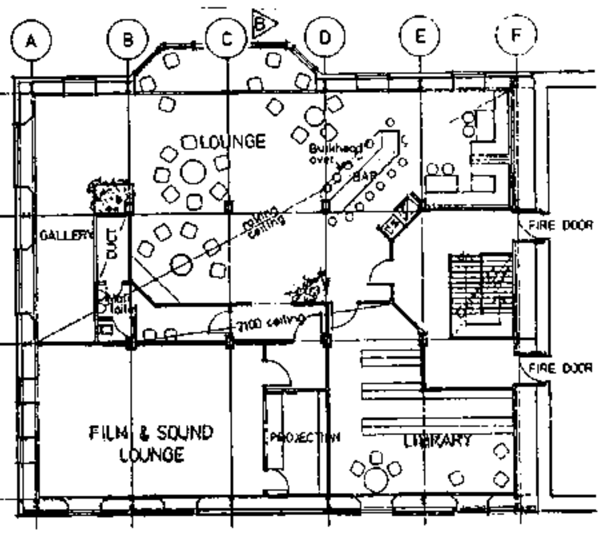


Fig. 6. Mawson Living Quarters First Floor

This does express a desire for extra storage which was planned to be provided in the form of personal secure space in the Store Building. The Mawson expeditioners are still waiting for this because the planned store racking was returned to Australia and a new store layout has not yet been provided.

When **Mawson Living Quarters** was required to be re-designed as an extension of the Mawson Sleeping-Medical Quarters rather than being a separate and parallel building it was unfortunately found to be impossible to provide all of these design features. (Refer Figures 5 and 6).

The Lounge area and the Mess had to be placed one on top of the other because of the restrictions of the site and available finance.

This meant that no large interior volume of space could be provided and also that the lounge was much less of a focal point because there was no way to contrive a compulsory passage through it to the mess. Thus it can be predicted from evidence accumulated by Burgess Ledbetter that the Mawson lounge will be less fully used than the Casey one and that there will be some individuals who will rarely enter it.

It was therefore all the more important to provide what could still be achieved, a variety of different spaces with varying degrees of connection to the main spaces.

That is why the ground floor billiard room was accessed through the mess and via a constricted ''gallery'' area which overlooks the harbour and the relief ship anchorage. Again on the first floor a `dead end' gallery provides magnificent views over Horseshoe Bay and also a secluded space where some may choose to gather, to contemplate the outlook, or to chat as they survey the scene.

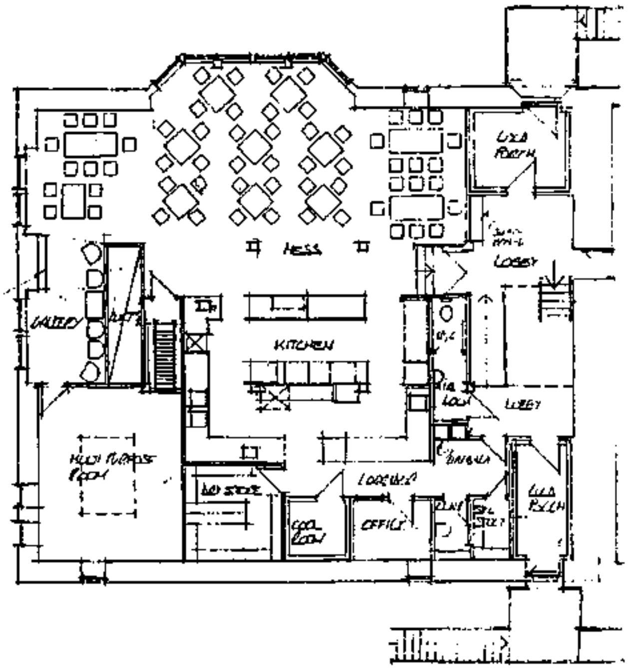


Fig. 7. Mawson LQ Revised
Ground Floor

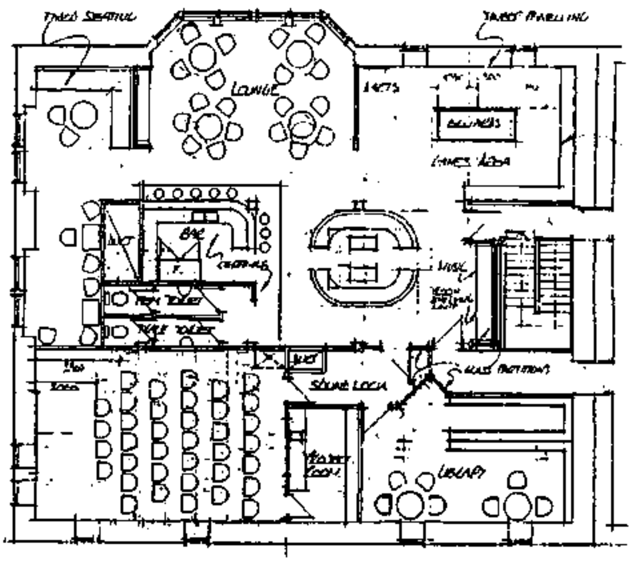


Fig. 8. Mawson LQ Revised
First Floor

The central lounge area was shaped as well as could be managed with the restricted headroom available, to provide an open central area lit by the main windows of the building, with more confined areas around it which are intended to be subsidiary spaces just as described at Casey. The main windows face north-east across East Bay to a great view of islands, icebergs, and the sun. The gallery windows and others in the end of the building receive sun from the north-west.

One of the main dividers necessary to create the semi-separate space adjacent to the centre lounge space was the ''Bar'' provided as an alternative social setting rather than for the function of serving drinks.

Off to the side beyond the bar, built-in 'booth' style padded benches were to be provided as a total change of atmosphere from the open area and moveable furniture of the main lounge.

The angled walls of the fireplace and planter box are shaped that way to complete the polygonal formation of the central lounge.

Again, as for Casey, the separated noisy and quiet areas, the theatrette and the library, are provided - deliberately entered by a path providing some contact with the main lounge room.

Some amendments to the design are now proposed. An increase in the capacity of the mess from 40 to 60 persons is required to cope with the summer peak. An adjustment in the concept of the bar facility is seen to be needed. In 1980 it was considered that the bar designs in use which needed an (unpaid amateur) barman on one side and his ''customers'' on the other were not appropriate to the real situation and the new designs produced thus gave open access to the bar sink and refrigerated drink storage and provided adjacent to this a bar-like seating arrangement to reproduce the furniture style and `feel' of a commercial bar. The feeling is now that there is normally one person in most groups who desires to take up the role of barman' or `host' and thus a more conventional counter like layout is better.

When installation of the fittings was carried out at Casey Domestic Building the personnel on site re-arranged the bar in this way. They also moved it away from its place at the central focus of interest which seems unfortunate, as circulation patterns at Mawson do not really allow the same type of placement and we will thus be unable to determine the value of this particular detail.

Another problem with the implementation of the designs is that importation of exotic plant species (let alone goldfish!) is now prohibited and a substitute needs to be found to provide the positive effect of growing green plants. I am willing to accept modern artificial substitutes but no-one else seems to like the idea!

The proposed re-arrangement of Mawson Living Quarters is shown at Figures 7 and 8 but has not yet been completely redeveloped. The opportunity has been taken to route any traffic from the southern door from the Sleeping Quarters wing through the lounge area, rather than passing it by in the stair well.

Photographs of the completed Casey Domestic lounge show fairly sparse furnishing and a rather empty look and I believe that these spaces need attention from an interior design point of view to co-ordinate furnishings and spaces to fulfil the design intentions.

It may be noted that most of the discussion above refers to buildings for living in rather than working in. This emphasis is due to two factors. First that the source documents related to these aspects of life - which are more subtle than the practical needs of the work place. Secondly it has always been my design practice to tailor the design of a work area around the functions required to be performed in it, including the sort of Habitability needs discussed for Casey Office above.

ASSESSMENT OF THE EFFECTIVENESS OF THE APPLICATIONS

No real effort has been made to assess the effectiveness or otherwise of the designs. In fact, until Casey Domestic Building was occupied there was not a great deal of information to be obtained.

''A Psycho-Environmental Evaluation of Australia's Antarctic Rebuilding Programme'' by Clarke, Wellington, and Kong (Reference 11.) suffers from being written before many new buildings were in use but made a beginning to the process.

Even though the authors had discussions with me as part of their assessment they have in my opinion made criticisms that show a lack of understanding of the facts of the situation - such as drift snow accumulation. I say this not to defend the designs in question but to point out that future assessments should include continued inter-action between designer and critic to permit the assessment to retain contact with design intentions and practical reality and thus increase its usefulness.

The first occupants of Davis Living Quarters who moved in there in 1979 were perhaps naturally, given the total contrast in size and standard of accommodation, very favourably impressed.

Many visitors to Casey Domestic have, on the contrary, seen the provision of the large internal spaces as waste and extravagance - not having any idea of why they were provided. Would they still feel the same after living in the building through the winter darkness, and being shut up in it through days of blizzard conditions?

We can obtain 'ad hoc' and often conflicting impressions from many sources but it seems that a proper assessment of the success of these ideas needs a more extensive investigation along the lines of the CRREL post-occupancy evaluation of Shay Gap (Reference 6.). I would like to recommend that such an evaluation should be done and have made initial suggestions on this matter to the Australian Antarctic Division, the Tasmanian University IASOS group, and to CRREL. Australian Construction Services would of course be interested in participating in this work.

CONCLUSION

A number of authors have described Antarctica as the greatest available laboratory for experimentation into human behaviour. (eg. Goldmsith and Lewis: ''Polar studies may be looked upon as human laboratories'', Strange and Klein (1973): ''Antarctic stations .... social microcosms offering immense opportunity for study of human phenomena which have significance far beyond the Antarctic continent). (References 18 and 19)

The extreme conditions of Antarctic life for human beings certainly favour this claim. They also provide the situation in which architectural theories relating the built environment and human well-being can be implemented with the greatest benefit.

I would therefore urge the international Antarctic community to include assessment and utilisation of these theories in the list of valuable areas for immediate research action, believing that there will be a reward for this to be found not only in Antarctica, but perhaps also in the even more extreme situations humanity will meet in orbiting space stations, on the lunar surface, and in buildings on other planets.

THE INFLUENCE OF ARCHITECTURAL THEORY ON THE DESIGN OF AUSTRALIAN STATIONS

Base References

1. "Personality Problems in Antarctica"
Phillip Law
"Medical Journal of Australia", February 20 1960

2. "Building in the North"
Eb Rice
Geophysical Institute of the University of Alaska,
Fairbanks, Alaska, December 1975

3. "Cold Regions Habitability - A Selected Bibliography"
C.R.R.E.L. Special Report 211 1974

4. "Undermanning and Architectural Accessibility"
C. Burgess Ledbetter
C.R.R.E.L. Special Report 213, October 1974

5. "Collaboration of Architect and Behavioural Scientist in Research"
C. Burgess Ledbetter
C.R.R.E.L. Report 77-23, August 1977

6. "Post Occupancy Evaluation of a Remote Australian Community: Shay Gap, Australia"
R. Bechtel, C.B. Ledbetter and N. Cummings
C.R.R.E.L. Special Report 80-29, July 1980

7. "Habitability Guidelines for Design of Cold Regions Buildings"
C. Burgess Ledbetter and Steve Flanders, US Army C.R.R.E.L.

(Abstract published in ''Proceedings of the Second International Symposium on Cold Regions Engineering'' University of Alaska, Fairbanks, August 1976)

8. "Habitability Expectations of Antarctic Expeditioners"
Ross Clark
M.U.P.A.S. Report No 8, Melbourne University Programme in Antarctic Studies, December 1979

9. "Patterns for the Antarctic Habitat"
Peter Jensen
M.U.P.A.S. Report No 9, Melbourne University Programme in Antarctic Studies, March 1980

10. "Some Aspects of Antarctic Habitat"
Ross Clark
Unpublished lecture notes, University of Melbourne Public Lectures 1980.

11. "A Psycho - Environmental Evaluation of Australia's Antarctic Rebuilding Programme"
Ross Clark, Paul Wellington, Allen Kong
M.U.P.A.S. Report, Melbourne University Programme in Antarctic Studies, June 1981.

12. "AANBUS - The Creation of a Building System for Antarctica"
Phil Incoll
Department of Housing and Construction, Commonwealth of Australia, June 1980

13. "A Comparative Study of Antarctic Stations"
Phil Incoll
Department of Housing and Construction, Commonwealth of Australia, February 1981

14. "Design Brief for the Rebuilding of Australian Antarctic Stations"
Antarctic Division, Department of Science and Environment, Commonwealth of Australia, 1980/81

15. "Rebuilding Australia's Antarctic Stations - Statement of Evidence to the Parliamentary Standing Committee on Public Works"
Department of Housing and Construction, February 1981

16. "Rebuilding Australia's Antarctic Stations - Supplementary Evidence, Casey Domestic Building"
Department of Housing and Construction, May 1981

17. "Enclosing Behaviour"
Robert B. Bechtel
Downden, Hutchinson & Ross, 1977

18. "Medicine and Public Health in the Arctic and Antarctic, Selected Papers from a Conference"
World Health Organisation, Geneva, 1963
"Psychological Aspects of Transient Populations in Antarctica".
G. Palmai, Australian Antarctic Division

19. "Polar Human Biology"
O.G. Edholm and E.K.E. Gunderson
William Heinemann Medical Books, 1973
"United States Winter over Parties". Strange and Klein

Use of Individual Protective Means for Breathing Organs in Conditions of Central Antarctica

by

Klopov, V.P. [1)]
Smurov, S.V. [2)]
Moiseenko, S.I. [3)]

Abstract

The high mountains plateau of Central Antarctica is one of the earth's regions with the most extreme natural conditions. Superlow temperatures together with very low humidity and the factor of hypoxic hypoxia make very high demands on the functional state of external breathing organs.

In normal conditions heat losses from human breathing-passages at rest are less than 1 % of general heat losses of human organism, but in conditions of Central Antarctica they may almost be equal to the half of general heat losses. Therefore the problem of the protection of breathing organs from overcooling during the stay in central Antarctica is undoubtedly actual. The authors developed a device for the protection of breathing organs providing hot air to the breathing zone and thus the normal functioning of external breathing organs. The device consists of a helmet-mask, air-heating unit and valve box. The helmet-mask is a hemisphere of two acrylic plastic layers, fastened on a hat. This allows the helmet-mask to be protected from sweating due to the formation of condensate in the under-mask space. The heating chamber, fan and device for automatic control of the air temperature are located in the heating unit. The air temperature gauge connected with the automatic controller of air-heating degree is built in the valve box. The resource of the heat-transfer agent allows one to conduct operations under superlow temperatures for one hour. In this case the air temperature in the breathing zone is maintained within the limits of 20-22°. If there is a necessity to operate in the open air for longer periods one should replenish the heat-transfer agent's resource.

The trials carried out at the Soviet intracontinental station "Vostok" revealed the effectiveness of the proposed device which provides for the stable fitness of specialists operating under low and superlow temperatures. This device can also be used at coastal antarctic stations as means of protection for the face and breathing organs from the impact of heavy wind loads.

---

1) The Arctic and Antarctic Research Institute
2) dito
3) dito

New Concepts For Antarctica

by

Bardin, V.I.[1)]
Sheinstein, A.S.[2)]

Abstract

New research programs and design concepts for Antarctica were suggested at the Soviet-American seminar for Architecture in Extreme Environments, which was held in Moscow in April 1990. This paper discusses Antarctic Planetary Testbed (USA) and Design of the Antarctic Polar Station Based on Energy Saving Options (USSR) concepts.

Introduction

The joint seminar was initiated by Sasakawa International Centre for Space Architecture (SICSA) & by the USSR Union of Architects to discuss the problems dealing with building design, conservation-minded technologies for beneficial applications in space and polar environments. Some papers deal with Antarctica. It is interesting to discuss the new concepts.

Antarctic Planetary Testbed (APT)

APT concept, developed by SICSA (I), was presented by Professor Bell. The concept includes research developments and technologies demonstration. It is proposed that a new international research facility be established in Antarctica to support and advance important science programs on earth and in space. Costs for creating and operating the facility will be shared by participating nations. The exact location and research activities will be determined by participating organizations. The APT will serve to demonstrate and evaluate advanced technologies in Antarctica. These technologies can enhance living conditions and operational economies in harsh space and earth setting. Lessons learned can be applied to Antarctic research facilities at other sites. Examples of key technologies to be demonstrated include:

- Habitat construction and crew accommodation
- Power systems to reduce fuel transportation costs
- Waste treatment systems to avoid environmental pollution
- Satellite communication systems to support operations
- Automated/teleoperated research processes
- Improved safety and rescue strategies and systems

---

1) Soviet Committee on Antarctic Research
2) Institute for High Temperatures USSR, Academy of Sciences

At the same time APT will serve as a model for manned space planetary programs development. Antarctica contains areas where the environments and terrain are more similar to regions on Moon and Mars than other place on earth. These features offer opportunities for simulations to determine performance capabilities of people and machines in harsh, isolated localiti. Besides, APT will serve as a model for demonstrating benefits and opportunities of international cooperation. APT objectives are to:

- Advance science programs of global importance
- Support planning of manned space exploration programs
- Demonstrate useful technologies for extreme environments
- Serve as a model for future international initiatives

The proposed APT initative will combine goals and resources of space and antarctic programs of participating nations. Cooperation between nations, common to polar and space policies can be realized by APT initiative. Successful implementation of the given program requires close cooperation between all participants of the program at the stages of planning and coordination.

Design of the polar station based on energy saving options was suggested by Soviet scientists and architects. Objectives are to:

- Reduce consumption of costly diesel fuel
- Avoid environmental pollution
- Reduce transportation costs
- Enhance living conditions

Power supplying of the polar stations is a key problem in harsh environments. Today it is very difficult to transport large amounts of costly diesel fuel to polar stations that are situated in the isolated localities. Besides, it is needed to reduce pollution of fragile environments. Thus, energy saving is a key option for Antarctica and for other isolated harsh localities. The proposed concept will demonstrate and evaluate various energy saving technologies such as renewable energy sources, energy-efficient buildings, alternative power installations. There is a favourable potential for solar and wind energy in Antarctica (2). Besides, there is a potential for using low-temperature energy sources. Examples of key technologies to be demonstrated include:

- Photovoltaic
- Solar space and water heating
- Heat pumps
- Storage facilities
- Wind machines
- Energy-efficient buildings

Solar heated "superinsulated" and "adaptable" buildings for harsh environments were designed by scientists and architects from Institute for High Temperatures of the USSR Academy of Sciences and from the USSR Union of Architects.

References

1. Bell, L. (ed.) (1988): The Antarctic Planetary Testbed (APT): A Planned International Initiative SICSA Outreach I:8:1988

2. Shpilrain, E.E. and Sheinstein A.S. (1988): Potential for Solar Energy in Antarctica. Proc. of the "North Sun '88" Int. Conf./Sweden

A Pilot Solar Water Heater Testing in Antarctica

by

Sheinstein, A.S.[1)]

Abstract

For harsh environment conditions solar water heater has been designed. The results of testing a pilot water heater at Molodyozhnay station have been discussed. The outcome of it indicated that in Antarctica a flat plate solar collectors could be used for water heating at a temperature level of 50 - 60°C. It was shown that at the polar regions an inclined collector discretely moving to "track" the sun would receive higher available solar radiation than fixed collectors.

Introduction

There is a potential for the application of solar space and water heating systems in Antarctica (1). It is important to design and to test such systems under the field conditions of Antarctica. A pilot solar water heater was designed and tested at Molodyozhnay station during summer months. Design of the facility, solar radiation measurements, solar facility thermal performances are discussed below.

Design of the Facility

A pilot solar water heater facility is shown in Fig. 1. Two flat plate collectors (1.4 m^2) and water tank (50 l) are fixed to a telescopic tower and can be rotated around it. The tower can be fixed to the ground with gue lines to improve the facility's reliability. The collectors are installed on a frame which can be fixed to the ground or can be rotated around the tower to track the sun. To use the facility on snow surface additional support should be installed in a drill hole. The facility is equipped with pyranometers installed on the plane of the collectors, thermocouples installed in the tank and control and recording potentiometers.

Solar radiation measurements data

The results of the measurements are shown in Fig. 2 and 3. At the snow covered areas irradiance that falling on the optimally oriented collectors (1) reaches 1.2 KW/m^2. At the southern region of the northern hemisphere (Mahachkala, 43°N) irradiances are lesser than at the Antarctic "oasis". It is interesting that in polar regions solar radiation intensity is large even when the sun elevation is small. At the same time the daily changes of the the sun's intensity and elevation are not so obvious as compared with lower latitudes. It causes a potential for available solar radiation enhanced by the collector's turning twice a day (in the evening and in the morning, Fig. 3). Thus, a

1) Institute for High Temperatures USSR Academy of Sciences

discrete tracking mode is available for solar collectors in Antarctica.

Thermal Performances

Thermal measurements have been taken at Ta= -5, -15°C and V=5-15 m/s. Data of solar heating at a clear day are shown in Fig. 4. A review on the daily increasing advantage of the facility can be determined by the "input-output" diagramm, Fig. 5.

Conclusion

1. The designed solar water heater can be used in harsh environments.
2. At the polar regions discretely moving collectors mode is available.
3. Flat plate collectors can be used for water heating at 50 - 60°C.
4. Solar water heater "input-output" diagramm for antarctic conditions is obtained.

References

E.E. Shpilrain, A.S. Sheinstein (1988) Potential for Solar energy in Antarctica. Proc. of the "North Sun '88", Int. Conf. Sweden

Nomenclature

Ta-ambient temperature
V-wind speed

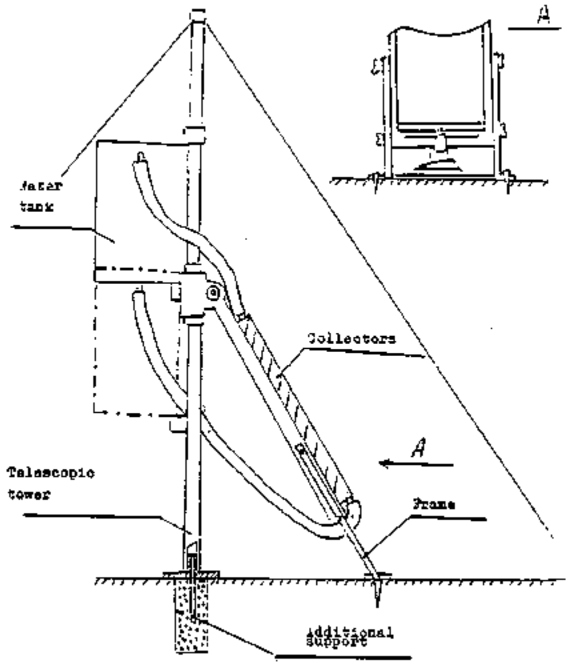
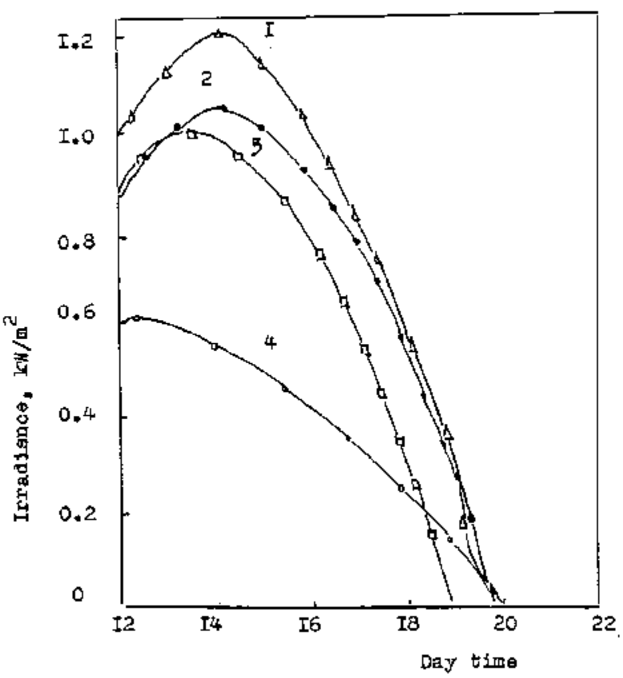
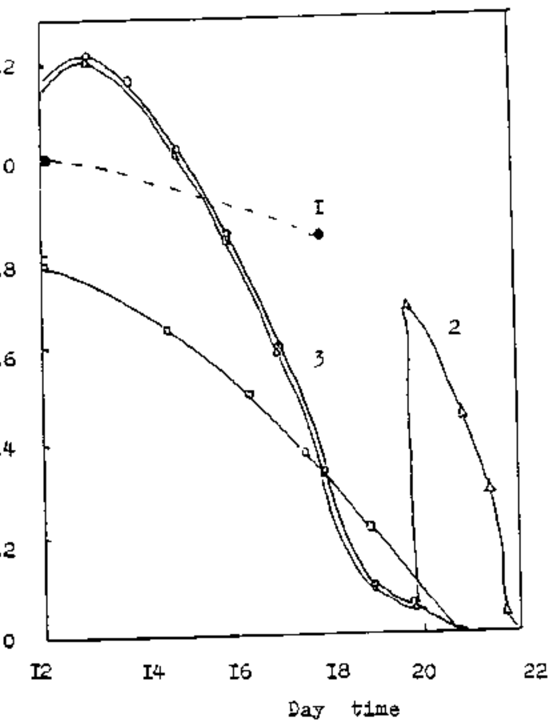


Fig.I. Design of the facility



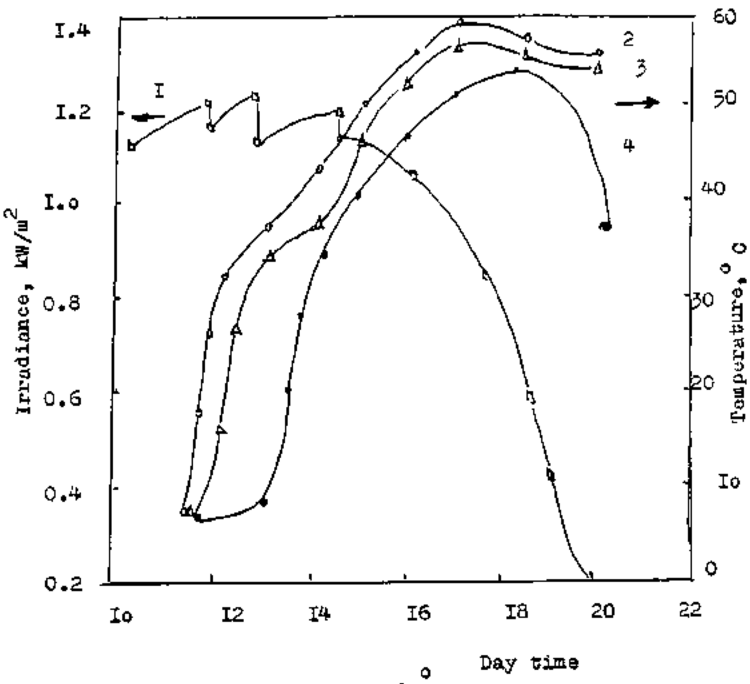
I-sloped at 60°
2-vertical
3-optimally oriented for Mahachkala, 43°N
4-horizontal

Fig. 2. Irradiances at snow covered area of Molodyozhn station and at the southern region of the Northern Hemisphere



I-intensity
2- descretely moving , slope 60°
3- fixed , slope 60°

Fig.3.Intensity and irradiances for fixed and descretely moving collectors



I- irradiances,slope 60°, descretely moving
2,3,4- temperature of water in tank

Fig. 4. Irradiances and water temperature measurements , cleăr day

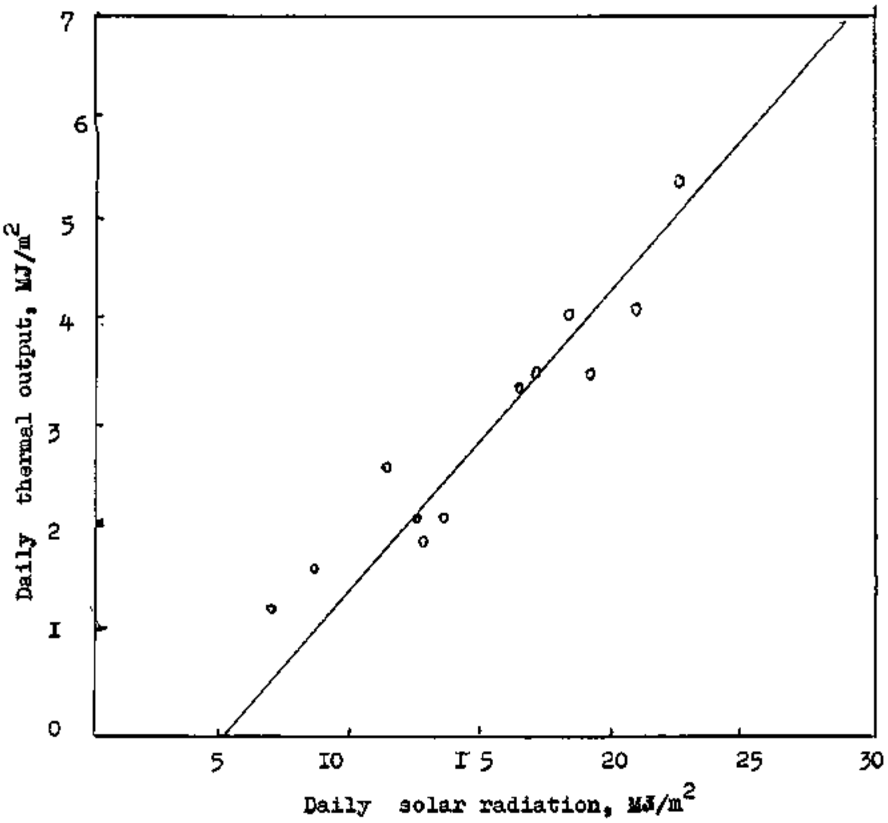


Fig. 5 Daily usefull collection gain of the pilot solar water heater in antarctic "oasis "