Proceedings
of the Ninth SCALOP Symposium

Tokyo, Japan
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COMNAP
Standing Committee on Antarctic Logistics and Operation (SCALOP)

Proceedings

of the Ninth SCALOP Symposium

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Cover photograph: Oversnow traverse convoy to Dome Fuji Station by the snow vehicles “OHARA SM100S” with ice radar antennas.

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Foreword

The Ninth Symposium on Antarctic Logistics and Operations was held in Tokyo, Japan on 13 July 2000 in conjunction with the XII COMNAP meeting. This publication contains the 22 papers and 13 abstracts of presentations made at the Symposium.

Prior to the call for papers, the SCALOP Symposium Working Group selected four topics corresponding to the current issues discussed by the COMNAP/SCALOP working groups, that is:

- Best available technology
  - * Alternative energy
  - * Communications
  - * Remote sensing and automated instrumentation and Developments

- Human Resources Management
  - * Education and training of Antarctic staffs
  - * Food and nutrition aspects
  - * Personal management, physiology and psychology

- Transportation Management
  - * Air, ship and field operations
  - * Air networks
  - * Air and ship technologies
  - * Navigation in Antarctic water

- Environmental Issues
  - * Response actions to environmental emergencies
  - * Preventative measures

About 70% of the 35 presentations related to topics under "Best Available Technology" in which alternative energy, environmental matters and station design technologies were most common.

Some new initiatives were introduced at the IX SCALOP Symposium. Firstly, a poster session was held in conjunction with the symposium. The posters were displayed during the first week of the meetings. Secondly, two guest speakers from outside of COMNAP/SCALOP community were invited to give keynote addresses on topics relevant to current operational issues. A subsidiary event comprised a special session (called National Display) in which national Antarctic operators displayed posters on their current logistics activities in the Antarctic. A total number of 18 countries participated in the National Display. Finally, fourteen commercial companies and organizations participated in the Trade Exhibition during the first week of the meeting.

The Symposium Working Group wishes to acknowledge the financial support provided by COMNAP to facilitate the attendance of a keynote speaker. Thanks also go to Mr. John Hall of British Antarctic Survey for his effort to convene a working group meeting in London in conjunction with another event.

Finally I wish to extend sincere thanks to staff of the Japanese National Institute of Polar Research (NIPR) for the efforts that went into planning and preparing for the Symposium. Special thanks are due to Mr. Masashi Sano for helpful advice throughout the process. I am also grateful to Ms Kazuha Hemmi and Ms Kimiko Seno for their efforts to edit abstracts and prepare the proceedings.

Members of the Symposium Working Group comprised Erick Chiang (USA), Luis Fontana (Argentina), Patrice Godon (France), John Hall (UK), Jan-Erling Haugland (Norway), Valery Klokov (Russia), P.C. Pandey (India), Kazuyuki Shiraishi (Japan) and Jan H. Stel (Netherlands).

Kazuyuki Shiraishi
Chairman of the IX SCALOP Symposium

CONTENTS

The historical background and logistics of the Dome Fuji project

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Abstract: In 1996, Japanese glaciologists succeeded in deep drilling to a depth of 2,500m at Dome Fuji, the highest point in East Dronning Maud Land. This deep ice core drilling project, conducted by the Japanese Antarctic Research Expedition (JARE), was started under the Dome Fuji Deep Ice Coring Project, as a 5-year project, from 1992 to 1997. Actual deep drilling started in 1995, and terminated at a depth of 2,503m in December 1996. The aim of this project is not only to study climatic change over the last 300,000 years, but also to reveal the climatic condition of the inland region, especially the relation between troposphere and stratosphere. This success was the culmination of Japanese research efforts in the interior of Antarctica since the I. G .Y.

1 .Introduction

Many expeditions to the interior have been carried out using over-snow vehicles. These expeditions have succeeded in reaching the Yamato Mountains over land, and in penetrating 1,000 km into the interior from the coast.

A major turning point in observations in the interior of Antarctica came in 1968, with the success of the over-land traverse from Syowa Station to the South Pole. For this traverse we were able to obtain large KD60 over-snow vehicles built to withstand very low temperature. The success in reaching the South Pole and acquisition of the large over-snow vehicles acquired for that expedition opened an era of extensive full-scale activity by Japan in the interior of Antarctica.

During the 30 years since then, long-term glaciological research projects have been carried out in the interior of Antarctica (Fig.1). The first such project was the Enderby Land Glaciological Project, carried out on Mizuho Plateau from 1968 to 1975.

In those days, the American group that succeeded in drilling to the bed rock at Camp Century on the Greeland Ice Sheet, then succeeded in full-depth drilling to a depth of 2,163m, at Byrd Station in West Antarctica. This success had a strong effect on Japanese glaciologists, and Japan began preparations to do its own ice drilling work.

Japan's first base in the interior of Antarctica, Mizuho Station, was first built to serve as a base for ice drilling. At Mizuho Station (70° 42′ S,44° 20′ E,2,230ma.s.l.) simple drilling was first started with a thermo-electrical drill. Our technical level at that time was very poor and we were not able to drill deeper than 150m, but this attempt was our first step toward deep drilling.

2. Brief history of Japanese glaciological observations on the Mizuho Plateau

Following the Enderby Land project, the second phase of the glaciology project, the East Dronning Maud Land project, was started from 1979. An organized program of observations was conducted in cooperation with the International Glaciological Project (1969 - 1982) conducted under auspices of the SCAR Glaciology Working Group.

The main purpose of this project was traverse research work along the 2,000m contour line. Observations on ice dynamics, surface mass balance and, ice thickness had been conducted in East Queen Maud Land. Also during this second phase, ice drilling was started at Mizuho Station, eventually reaching a depth of 700m corresponding to 9,700 years of climatic history.

The brief history of Japanese inland activities is summarized in Table 1. The results of Japanese glaciological work over the last 30 years are summarized in N.I.P.R. glaciological Folio Series (N.I.P.R.,1997).

3. Searching for the highest point on East Dronning Maud Land

These results make clear the glaciological conditions in the Shirase Glacier drainage region. This is a closed system of mass balance and ice flow. Observations in the upper part of this drainage region constituted the first step of the Dome Fuji Deep Drilling Project (Table 2).

At the start of the project, we first had to find the highest point in East Dronning Maud Land. As part of the East Queen (Dronning) Maud Land Glaciological Project (1982-1987), topographic and glaciological surveys were carried out on the inland plateau in the summer of 1985 by the JARE-26 over - snow traverse party.

The maximum elevation of the dome was found at 77° ,22′ S, 39° ,37′ E at elevation 3,807m by a GMR satellite positioning system together with barometric altimetry and a theodolite survey of maximum slope direction. In addition, the ice thickness was measured by radio echo sounding. The ice thickness in the vicinity of this summit is more than 3,000m.

This summit is about 50km northwest of the "Fuji Divide" which the traverse party of JARE-9 crossed on the way to the South Pole. The name Dome Fuji originated from this. The summit of the high dome in Dronning Maud Land had previously been named the "Valkyjedomen" on a British map. We do not know its exact location.

4. Determination of the drilling point

The surface topography of the Dome is very smooth and flat. Surface elevations at six radial points 30km from the dome summit are only 7m to 30m lower than the summit, the mean drop being 20m. The mean surface slope in this circle of radius 30km is estimated as about “1 over 1500”.

A topographic map of the bedrock around Dome Fuji was based on radio echo sounding data collected in 1992 - 1993. The location of Dome Fuji Station was decided on the basis of both surface and bedrock topographies. Dome Fuji Station is situated above relatively flat bedrock about 800m in altitude. The bedrock topography around the dome exhibits what appears to be a saddle point.

The summit of Dome Fuji is ideal for ice drilling because there is no horizontal ice movement or melting, and the ice is more than thick enough.

5. The materiel transport plan

One of most difficult operation in the Dome Fuji Project was collecting the materials needed to succeed in 3 years of wintering operations at the site. Since Dome Fuji is located on a high plateau more than 3,800m above sea level, the environment becomes severely cold in all seasons except summer, leaving only a 3 month period, from November to early February, during which transport operations are possible. It was necessary to increase our transport capacity to complete the necessary transport in such a short time. For this purpose, the SM100, which itself weighs 10 tons, was developed, along with a special cold weather vehicle and a new bulldozer that can operate at -60 degrees C.

Nevertheless, the transport plan required 4 years before wintering operations could start. In the year before the first year of drilling, JARE-32 extended the over-snow traverse route from Mizuho Station and established a relay station at 74° S, 43° 00'E, 3,350m elevation, about 650km from the coast. Transportation of fuel to the relay station was started, and a new cold weather tractor was introduced and tested.

The next year, 1993, the route was extended to Dome Fuji by JARE-33.

The SM100 over-snow vehicle was introduced and driven to Dome Fuji Station.

6. Shallow drilling and casing

Rather than build the station first and then start drilling, we first drilled a hole and inserted a casing, and then decided on the layout of the wintering base buildings.
Thus, operations started 2 years before the actual start of the deep drilling. This procedure contributed to the success of the drilling. In 1994, the shallow bore hole was drilled by JARE-34 and the casing was inserted.

Since deep drilling is done in a liquid-filled hole, before deep drilling is done, it is necessary to drill a shallow hole, and then ream it to a larger diameter and insert a reinforced fiberglass casing. This casing prevents the liquid used to fill the hole from seeping out and penetrating into the surrounding firn layer.

In shallow drilling, a 135mm diameter hole was drilled to a depth of 112m, then reamed to a diameter of 250mm and a casing inserted to a depth of 86m. This was Japan's first experience with this reaming and casing technology.

7. The base construction plan

Since the annual average temperature in the vicinity of Dome Fuji Station was expected to be -60 degrees C, it was designed with careful attention to ability to withstand cold. A trench was dug in the snow layer for the actual drilling site, considering the limitation on the amount of materials. Another reason for drilling in a trench was to confine the odor of the liquid used to fill the drilling hole.

The main part of the facility was constructed by JARE-35, following the transportation of 200 tons of building, equipment and fuel by the new SM100 over-snow vehicles , and heavy duty tractors. The area is 298 square meters; and the number of rooms is 9. The living and research area is composed of five above ground prefabricated structures (8.1m x 4.5m): two living huts, mess hut, observation hut, and a somewhat larger generator hut.

Satellite links were used for communication among Dome Fuji Station, Syowa Station and Japan. The height of the satellites in the sky was not what we would have hoped, but in practice this turned out to not be an obstacle to communication. The availability of satellite communication played a very important role in the deep drilling project.

8. The natural environment at the dome summit

During reconnaissance observation in the dome summit area by the JARE 26 traverse team, surface annual accumulation rate estimation and snow temperature from the surface to 10m depth measurement were carried out.

They found a remarkable peak of tritium content which corresponds to the winter layer in 1966 according to the results at the South Pole. From these results, mean annual net accumulation rate in the period from 1966 to 1985 can be calculated as 3.2 cm in water equivalent. The snow temperature at 10m depth is used as the average annual air temperature. In the summit area, the 10 m deep snow temperature was -57.3℃.

Air temperature and pressure, wind speed and direction, and global solar radiation were automatically recorded during wintering operations. An annual mean air temperature of -53.9℃ at 1.5m height was recorded. The lowest temperature for this period, -79.7℃, occurred in May 1995. Annual mean atmospheric pressure was 598.2hPa, and annual mean wind speed at 10m height was 5.8m/sec. Wind direction sometimes rotated counterclockwise; no prevailing wind direction was observed. The most frequent wind direction was north-easterly, but this accounts for only 15% of the total.

The annual surface mass balance from January 25,1995 to January 31, 1996 was net accumulation of 2.5±1.0g cm^{-2} per year. More than 95% of the net accumulation occurred from February to mid-October. The seasonal distribution of $\delta^{18}O$ in the surface snow at Dome Fuji is in the range -50% to -65%, increasing in summer and decreasing in winter.

9. Drilling operation and in situ analysis

The drilling site was a roofed trench, 21m long, 4m wide and 4m deep. Since the drilling system was 10m long and had to be rotated, the top of the drilling hole was 7.5m below the hole surface. Deep ice core drilling was planned to start at Dome F station in 1995 as two -year program. The drilling was be done with a newly developed liquid-full type electro-mechanical drill system. An electro-mechanical ice coring system was developed starting in 1988. Table 3 shows the fundamental specifications. It was designed to be (a) light, (b) easy to operate and (c) safe under the conditions at

Dome Fuji

Ice core drilling started on August 23, 1995 from the bottom of a pilot bore hole at a depth of 112m. The drilling terminated at a depth of 2503.52m on December 8, 1996. Fig. 2 shows the drilling operation which was carried out by two drill operators on a two-shift basis. The temperature of the drilling site was kept in the range -25 to - 35℃. The total numbers of drilling and chip collection runs were 1370 and 836 respectively.

The average length of core obtained per run was 1.75m. The quality of the core was fortunately excellent through the whole depth even in the brittle zone from 500 m to 840 m depth due to the small depth of the cutting, as small as 0.2 mm because of ice hardness at -50 to -60℃.

The borehole was kept almost vertical, deviating not more than 0.5° until 1800 m but increased gradually to 4.6° at 2250 m depth. At deeper depths, the inclination decreased. Liquid temperature increased from -55℃ at shallow depths to -20℃ at 2500 m in depth (Dome-F deep coring group, .1998)

10. In situ analysis

In-situ core analyses consisting of electrical conductivity measurements (ECM), stratigraphical discription including examination of tephra layers, cloudy bands and air bubble/ clathrate hydrate observation, and bulk density measurements, were carried out.

In the processing line, first logging and bulk density measurements were made. Then cores with a diameter of 95 mm were cut by 60 % and 40 % of sectional area along the core axis. The cutting surfaces of the former parts (60 %) were used for both AC- and DC-ECMs and stratigraphical observations. At the end of the core process line, cores were finally cut into three pieces along the core axis: 60 % (A core); 25 % (B core) and 15 % (C core); and cut at every 50 cm for packing.

The cores were brittle at depths between around 500 m and around 840 m. The starting depth of the brittle zone is roughly the same as the depth at which the first cloudy bands and clathrate hydrate crystals appeared. More than 700 distinct cloudy bands were found. Most of them were found in three depth ranges, around 550 m, 1000 m and 2000 m. In contrast, in the other depth ranges they were rare.
Visible air bubbles have not been observed at depths below about 1100 m (Hondoh et al, 1999 and Watanabe et al, 1999).

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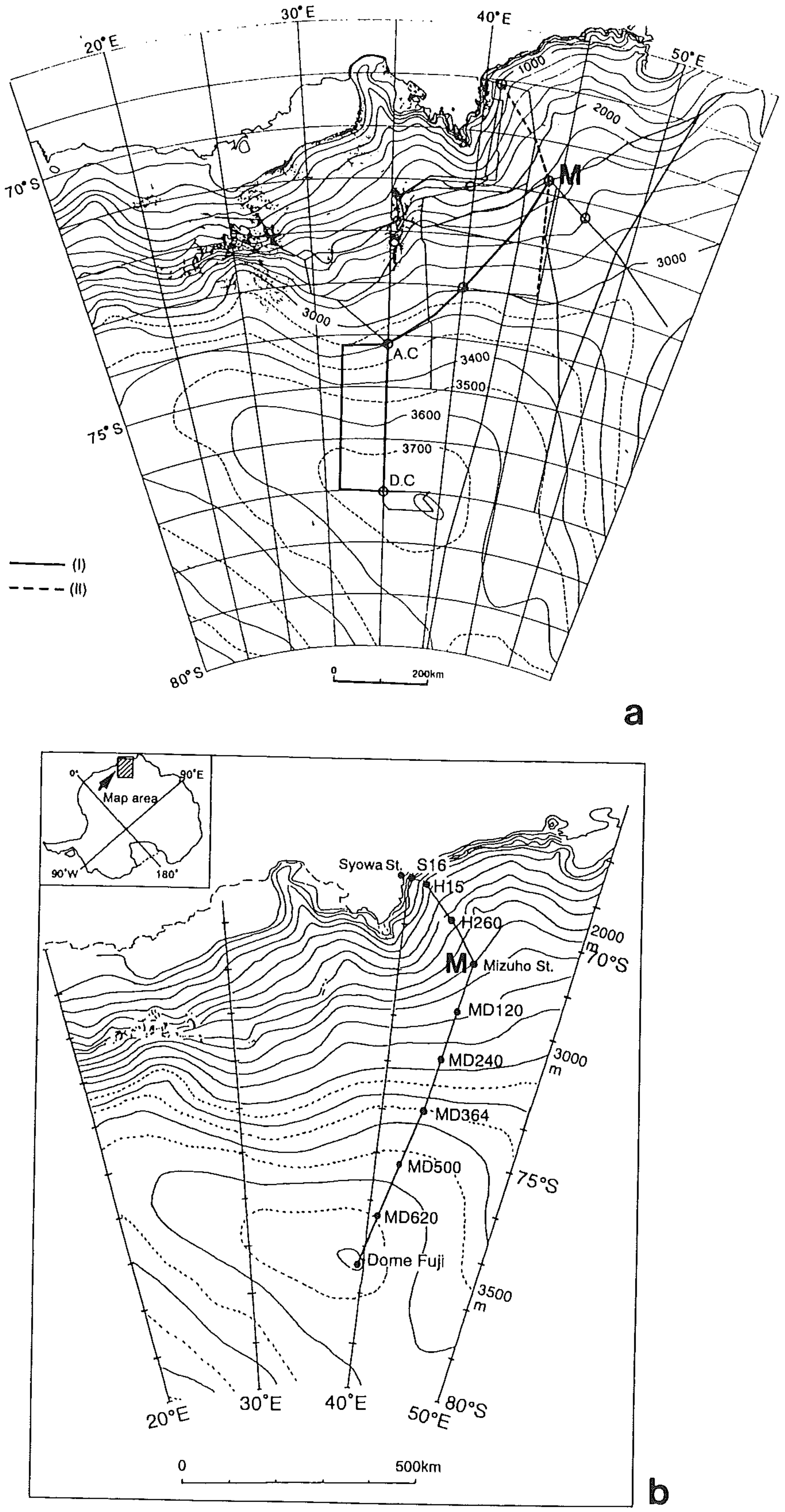

Fig.1 (a) Japanese research traverse routes in the Mizuho Plateau, east Dronning Maud Land

(I): The Enderby Land Glaciological Project,

(II): The East Dronning Maud Land Glaciological Project

Fig.1 (b) Traverse route between Syowa Station and Dome Fuji Station

M: Mizuho Station

Table 1 History of Japanese Inland Traverses

1957 - 58	**IGY Launching wintering in Syowa Station**
1960:	Traverse to the Yamato Mountains
1961:	Traverse to 75° S
1965:	Resume wintering in Syowa Station, New snow vehicle " KD60"
1967:	Traverse to Plateau Station (7915S, 4030E)
1968 - 69:	Success of Syowa Station - South Pole Traverse
1969 - 75	**Enderby Land Glaciological Project**
1969:	Setting of long triangular surveying from Yamato Mountains
1970:	Open the first inland station "Mizuho"
1971:	Ice core drilling in Mizuho Station
1972:	Drilling reached to a depth of 147 m
1975:	Traverse to 75S
1979 - 81	**POLEX South Project**
1980:	Traverse to the divide between Shirase and Lambert Drainages
1982-87	**East Dronning Maud Land Glaciological Project**
1983-84	Medium depth ice core drilling at Mizuho Station
1984:	Drilling reached to a depth of 706 m
	Established advance camp (AC) at 74° S, 35° E
1985:	Topographical survey in the plateau area of Dronning Maud Land
	Shallow drilling at AC (204m) and Dome Camp (77S,35E, 40m)
1988:	Reconnaissance of the route to Dome Fuji from Mizuho Station
1991:	The first fuel transportation to the relay point to Dome Fuji Station

1992 - 1997 Dome Fuji Deep Drilling Project

Table 2 Dome Fuji Deep Drilling Project (1991～1997)

Ⅰ Preparation phase (1984～1990)		**JARE**
	・Reconnaissance field survey to Dome summit location	(25, 26)
	・Traverse route setting	(29, 32, 33)
	・General glaciological observation	(29, 32 - 38)
Ⅱ Logistic operation phase (1991～1994)		
	・Transportation of fuel and logistic survey	(32 - 37)
	・Drilling site selection	
	＊Precise surface topographic survey (1991)	(33)
	＊Ice radar survey on bed rock topography (1991)	(33, 37)
	・Shallow drilling (112m deep)	(34)
	・Reaming (135 - 250 mm diameter) and Casing	(34)
	・Construction of Dome Fuji Station (1994)	(35)
Ⅲ Deep drilling phase (1995～1997)		
	・Drilling to a depth of 605.0 m (Aug.1995 ～ Jan. 1996)	(36)
	・Drilling to a depth of 2503.52 m (Feb. 1996 ～ Dec. 1996)	(37)
	・In situ core analyses	(36 - 38)
	＊Stratigraphic description	
	＊D.C. and A.C. ECM measurements	
	＊Bulk density measurements	

Drilling Site (Dome Fuji Station) Description

Location : 77° 19′ 01″ S, 39° 42′ 12″ E

Altitude : 3810 m a. s. l.

Ice thickness (estimated from radio- echo sounding) : 3028 ± 15 m

10 m depth snow temperature : −57.3 ℃ (−53.6 ℃ : annual mean air temp.)

Mean annual net accumulation :

estimated from 1966 ^{3}H reference horizon : 32 mm water equivalent

surface snow stake measurement : 2.5 ± 1.0 mm)

Table 3 Description of Japanese Deep Drilling System

Drill: Outer diameter; 122mm lengh 8.54m; weight 200kg, core diameter 94mm; core length 2.24m; hole diameter 135mm: drill motor 600W

Winch: motor 11kW; max. load 3.4t, controlled to speeds as slow as 1 cm min -1

Monitoring parameter: Cable length, cable tension, winch speed, power-supply voltage, motor voltage, motor current, motor rotation, cutting load, drill inclination, hole liquid pressure, temperatures at several pointss

・ The drill is of double tube type consisting of an outer tube and an inner barrel (or a core barrel, 2.3 m long) with three cutters.

・ Spirals are attached to the outer side of the inner barrel to transport chips upward while the barrel is rotating to cut ice.

・ Above the core barrel, chips are forced up into a chip chamber (3.3 m long) by a fin like booster.

・ The pressure tight chamber that contains the motor, reduction gears and computer section was designed for 3500 m liquid filled drilling.

・ Because of its low energy consumption, a generator of 28 kW has enough capacity to supply electricity to the total drill system even when the core process line is active.

Mr. Chairman, Ladies and Gentlemen!

Construction in Antarctica and Cost Effects on Research after Implementation of the Environmental Protocol

Dietrich Enss [1]

Construction in Antarctica has so far been governed by the harsh climate, the often unique ground conditions, and by logistic constraints. The Protocol on Environmental Protection to the Antarctic Treaty, which came into force in 1998, in addition requires due consideration of environmental impacts of the construction works, the buildings proper, the maintaining of the installations and of the disassembly and retrogradation after their use. The environmental impact assessment and permit procedures will add considerably to the planning time and effort. New construction and running the facilities in Antarctica will change under these conditions, and compatibility with nature will be of prime concern.

The Environmental Protocol is part of the Antarctic Treaty System which like other international conventions has been signed by a good number of governments, but not by all. However, all national operators presently maintaining bases in Antarctica are members of the Antarctic Treaty, and the Protocol has been incorporated into legislation in their countries or will be incorporated shortly.

REQUIREMENTS UNDER THE PROTOCOL

There are substantial and procedural requirements to be met when carrying out new construction in Antarctica. Beginning with the latter, the operator will have to apply for a permit with the relevant authority to go ahead with his plans in Antarctica. Permits for construction works, which generally will be expected to have more than a minor or a transitory impact, will inevitably be given only after a satisfactory Comprehensive Environmental Evaluation (CEE) of the project. The CEE procedure is a lengthy business which comprises scoping of the relevant details of the environmental evaluation, preparation of the impact study including extensive documentation (to the satisfaction of the authorities), public notice, three months public layout of all documents and subsequent discussion of objections. Before a decision can be made on the application the results of the CEE must be exchanged with the consultative members of the Antarctic Treaty. This includes a four months

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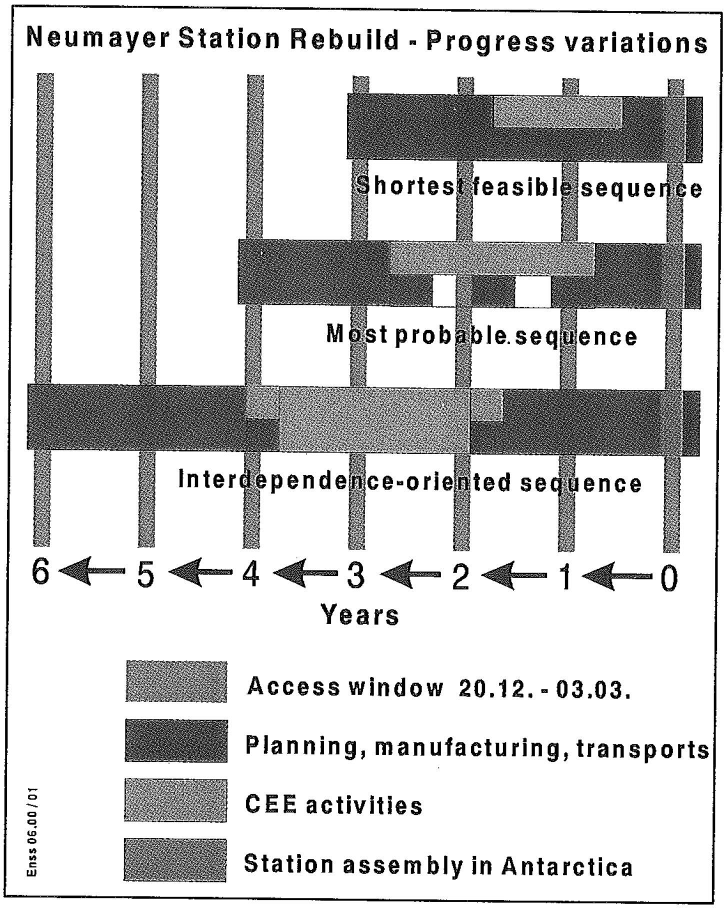
examination period to be given to the Committee for Environmental Protection before the start of the Antarctic Treaty Consultative Meeting (ATCM), waiting for and reacting to the comments of the ATCM which may take several months or even a year, and another two months waiting period before commencing the works in order to give the signatories of the Protocol the opportunity to comment or to intervene. The ATCM takes place once a year, so additional delays are possible even before the ATCM. Even with smooth progress and without changes of plans, the CEE and permit procedure might easily take two years to complete. This does not include the time needed for preparation of the CEE documents and of the permit application.



On the graph you can see the overall results of three possible station building progress sequences aligned to the installation in the end. The question behind the investigation was: when do we have to begin with new planning? The time variation amounts to three years, and that is without major changes expected in consequence of the CEE. The graph should perhaps better show the same starting point for all sequences, and thus highlight the uncertainties in the time schedules.

The substantial requirements can be summed up under the heading "environmental compatibility". Some of them are clearly defined such as the ban on packing materials containing polystyrene and on all materials containing PCBs, as well as the ban on usage of polyvinyl chloride products, the task of removing all wastes from the site, and the liability to dismantle the installations after use and bring them back to the country of their origin. Of possibly greater effect on planning effort and costs are the requirements which are less explicitly stated: the chosen design, the logistics, the installation and the operation of the facility are to be compared with alternative designs and working methods, and the environmental superiority of the chosen solutions are to be shown. As well, environmental monitoring of the impacts of the activities must be devised and implemented. Such monitoring will have to be continued for some years after the facility has been removed from Antarctica, and it needs scientific support to be of value.

THE EFFECTS ON PLANNING

In future it will not be sufficient to design a new station with priorities such as cost effectiveness, safety, state of the art or architectural appeal. Minimising the environmental impact becomes the overriding priority. This holds for all stages of the venture: transport, erection, running and maintaining of the facilities and their eventual removal from Antarctica. Costs do not count in this context. There are no provisions for exceptions from the rules because of high costs. Doing nothing, instead of doing something which is not environmentally sound, is an alternative the Protocol asks to be considered.

The biggest constraints are the number and depth of alternative designs that must be investigated and valued by their environmental impacts, and the unforeseeable delays that may be caused by the environmental evaluation and permit processes. There may also be considerable apprehension that the design will be rejected or questioned so strongly that works must start anew or the project be given up completely. Planning will have to be strictly separated from all other stages of the project because changes or the discontinuation of the project may be required, as is expressed with the third sequence in the graph, were interdependent activities do not overlap. Long preparatory or contractual pre-phase activities, such as chartering a ship for transport or ordering certain special materials, must be delayed until the permit is actually obtained.

It may be argued that extended planning times open the doors to better designs and to save money otherwise being spent on overtime working. I must say that in all the years I have been in the business I have never seen this happen, neither of the two.

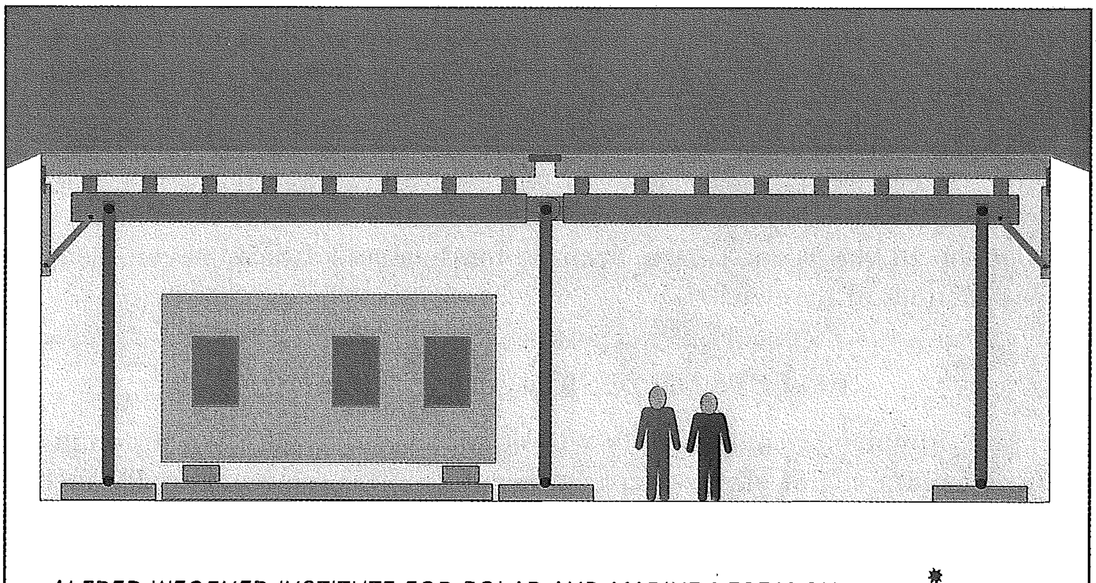
EFFECTS ON DESIGN AND EXECUTION

Environmental compatibility will dominate designs for construction and services in future. But other specifications may suffer too much under such an overriding preference, so that compromises necessarily must be sought. The superiority of the compromise over a more environmental-oriented solution is to be shown, however, and it must be demonstrated that there are no viable solutions having less impact.

Normally it is not the construction proper which poses environmental harm but the erection works, the running and maintenance of the facilities, and their dismantling and removal in the end. Construction assembled from prefabricated parts on site without much waste producing fitting and without voluminous packing materials will prevail. Foundations and ground anchors - as far as they are supposed to remain in the ground after abandonment of the facility - will have to be of materials with no discernible impact on the environment during the many years until they finally rot away. Concrete, plain steel and untreated timber have been regarded as such materials in the past. It is doubtful, however, if steel or wooden construction at sub-surface bases will be allowed to be left in the Antarctic ice under the Protocol, simply because the problem would not arise with above-ground stations. These are usually built on stilts which are extended regularly to compensate for the snow accumulation and thus continually reach farther down into the snow. Such non-retrievable legs - not to speak of any spread foot foundations - may not any longer be acceptable, giving way to the much more expensive platforms on spuds which after predetermined settlement can be lifted individually and set down again after filling up the holes with snow.

The French-Italian Concordia Station at DomeC is a good example of these concepts. The two main buildings are resting on individual retrievable spuds, while the powerhouse is on skies.

What regards sub-surface stations POLARMAR (the company I have been working in during the nineties) has proposed a protective underground hall whose articulated roof sections are kept flush with the snow surface by intermittent jacking. Such building can be completely removed without any



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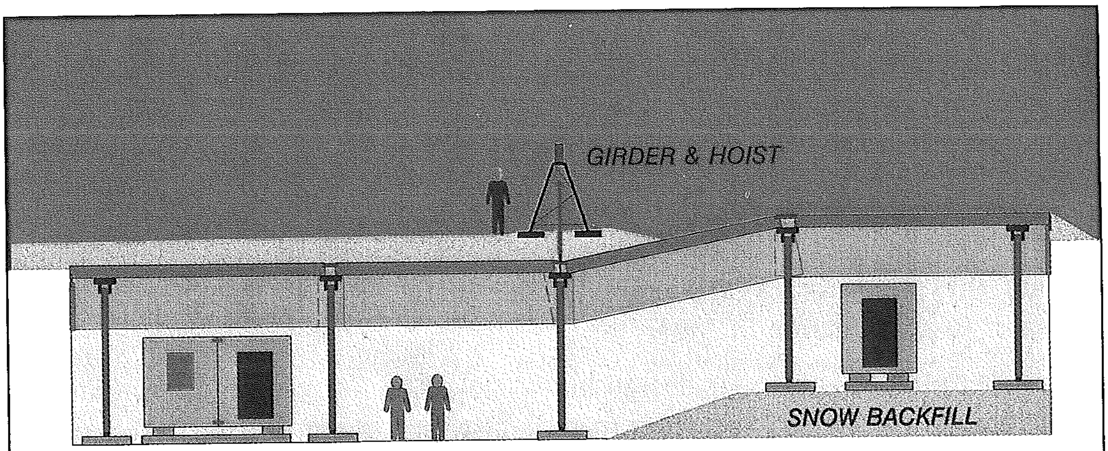
NEUMAYER STATION GARAGE BUILDING - CROSS SECTION
EUROPEAN PATENT 0410550



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NEUMAYER STATION GARAGE BUILDING - LONGITUDINAL SECTION
EUROPEAN PATENT 0410550

digging at the end of the station life time. The hall is designed to accommodate self contained station buildings or stores. A prototype used as garage has been successfully tested at the Neumayer Station since March 1992. Last season the roof has been raised for the third time, while minor height adjustments had been made whenever practical and suitable by help of spindles in the supports.

Construction and equipment materials brought to Antarctica should be environmentally unobjectionable not only in their normal state but also in case of fire. Paints, insulation and plastic materials giving off pollutants or poisonous fumes when heated or burning must be rejected.

When considering impacts from different ways to equip, run and maintain a base, the environmental compatibility of the overall performance will probably tip the scales. Solar and wind power generation for part or all of the station demands, use of low pollutant-containing POL products, exhaust gas cleansing, energy saving equipment, limited use of detergents, sewage treatment and effective waste management will all become standard. Maintenance works and station reliefs may be carried out in different ways, and these different ways may have different effects on the local environment. Not only the impact of one such endeavour is to be regarded here, but the so called cumulative impacts.

Life saving, rescue and emergency activities have priority over the provisions of the Environmental Protocol. It is well known that the biggest environmental hazards are often connected with emergencies. Very thorough contingency planning is therefore required for all activities in connection with the installation, running and dismantling of facilities in Antarctica. The contingency plans will also be subject to scrutiny during the CEE process.

EFFECTS ON COSTS

As we all know construction is more expensive in Antarctica than at home. Besides the extra costs for insulation and structural strengthening against the wind forces and snow loads, there is the big expenditure for transport to and erection in Antarctica.

The planning costs of design and installation are already high, but with the Protocol and its requirements to be considered there will be a substantial increase of costs in this section. For some operators the necessity under the Protocol to submit the documentation also in English may further add to the costs.

Part of the project	At home	Antarctica until 1997	Antarctica since 1998
Design, supervision	6	10	14
Procurement	36	36	37
Prefabrication and tests	2	11	11
Packaging and transports	1	14	15
Erection at the site	6	19	21
Dismantling	1	4	5
Return transport	-	6	6
Monitoring	-	-	1
Total	52	100	110

Breakdown of Relative Costs
for Winter Station Projects in Antarctica

The table gives a breakdown of relative costs averaged for four medium sized winter stations, two on snow ground such as Neumayer or Halley Station and two on dry ground such as the bases at the Peninsula, before and after implementation of the Protocol. For comparison, the costs for the same installation at home (in this case central Europe) are also shown. The costs are about double in Antarctica as compared to home, and the Protocol will be accountable for a further increase of about ten percent.

You can see that for easier comparison we have calibrated the table to total costs of 100 in 1997. Of course the costs vary widely due to different sizes, standards, site conditions and accessibility, and individual estimates must be made to determine exact costs in any new project. The figures in the table are a fair indication, however, of inevitable increases due to the Protocol. Let me remind you that doing the extra work with "in-house personnel" and using "in-house resources" does not do away with the fact that the extra expenditure is there.

Finally and just for clarification: price escalation is of no meaning in these considerations. Inflation is a separate problem.

SUMMARY AND CONCLUSION

Construction in Antarctica in future will largely avoid negative effects on the environmental assets to be protected. Considerably more time will be needed in the planning phase of a project to accommodate the environmental evaluations and the permit procedures. The overall costs for construction in Antarctica will increase by about ten percent due to the Protocol. The international exchange of documents and evaluations may well lead to very similar design solutions for most of the new construction in Antarctica. We will see more prefabrication here, larger self contained units, and less permanent interference with the underground. The running and relief of stations will be conducted with less environmental impact than until recently.

CRITICISM

Practically all permanent installations in Antarctica serve scientific research. Money for research in Antarctica is scarce, although the importance of Antarctic research is growing. In most countries the budgets for Antarctic research also cover the required logistics and installations. Making them more expensive is counterproductive to research. The Antarctic Treaty members have willingly placed this burden upon themselves when negotiating and signing the Environmental Protocol. Let us hope that they will find practical ways to minimise the time consuming and cost producing effects of the Protocol and to maximise the effects for the protection of the Antarctic environment.

This, ladies and gentlemen, has been my contribution to the symposium as initially proposed and accepted. It fitted well the period of 15 to 20 minutes I understood would be given to me including discussion. When I inquired about detailed schedules later I learned that I would have more time to my disposal. What would you like me to talk about then, I asked. Oh, take on whatever you like, was the answer. Now, it's seldom that one gets such an opportunity! Thank you very much, Professor Shiraishi and Mr. Sayers.

I should like to take that opportunity to look a little deeper into the – let me say – more or less unwanted side effects of the Protocol, now that we have the first two years of practical experience behind us.

The possible effects of the Protocol on costs have never been discussed during the times when the Protocol was shaped. I have learned this from someone who took part in the negotiations. But surely the delegations must have made some calculations with regard to their future monetary commitments. We all know that for some Treaty members the foreseeable costs, especially in the region of abandoned site clearing, have been a burden difficult to overcome. Possible and meanwhile in many places real problems connected with environmental evaluation and permit procedures were to my knowledge not so clearly addressed. These problems take working time, cause delays, and in any case cost money, not to speak of annoyances to be endured.

Interestingly, in Germany each new legislation must beforehand be evaluated for its cost implications, and the results be made public. So in the draft legislation of the Act implementing the Protocol it was stated that the Protocol itself will cause no costs, but that costs must be expected with the execution of the Protocol, because new tasks would have to be allocated to administrative authorities. So much to costs on the administration side. The question of fees readily comes in here, and indeed the German Federal Environmental Agency meanwhile asks for fees when issuing permits for tourist visits to Antarctica. Such costs plus costs for additional preparation and equipment of tourist expeditions – though in no way marked with figures - were mentioned in the evaluation. But mind you, no additional expenses were mentioned for Antarctic research activities!

Could it be that in the long discussions before the cost implications for the research groups, especially also for the national operators, had not been perceived? Or had these assumed that additional costs in connection with the Madrid Protocol would be covered, at least when state funding is involved? Finally, could it be that the organisations representing research in the negotiations that led to the Protocol and to the respective national legislation had willingly dispensed with any compensation, and thought to fit all extra costs into the ordinary budgets? If so, had they been aware of solid estimates?

For me as an outsider these questions are difficult to answer. So I tried to approach a few people I know in your ranks to find out how these things were dealt with in their countries. I did not realize the drive and speed within the COMNAP communication net, however, and almost before I had my questions properly assembled the first answers were coming in. Thank you Hartwig Gernandt and Jack Sayers!

The answers to my little survey are not representative. First of all, these were quickly devised questions without any prior consultation with you.

Secondly the time for answering was very short, and only 12 answers were received. Perhaps this initiative and any further interest on your side may lead to deeper investigations by COMNAP respectively SCALOP later. I prefer to leave the answers anonymous, and I shall not pass on individual answers without prior consent of the authors.

The wide spectrum of answers in my opinion reflects the different approaches to management of the Protocol on the administrative side and to deal with it on the operator's side. A markedly different feeling about cost implications is going together with budget allocation in the different countries. Where funding is separate for logistic and for science operations the strain is comparatively small, especially when the largest part of additional costs comes under logistics and when these are managed by a completely different outfit like the military. In some countries as in the UK special tasks under the Protocol, namely the cleaning-up of old sites, have separate funding. Clean-up operations and conversions of ships to comply with the Protocol are extremely cost-intensive, but they will be more or less once for all operations. In my questionnaire I did not distinguish between first and final expenses and others that will be continuous.

Environmental Protocol influence on costs and programs			
1	Are costs induced by the Protocol to be borne by your organisation?	100 % 80 % 75 % 100 % by logistics Partly	7 1 1 1 2
2	Are these costs known, and if yes, what is the percentage of the total budget?	<5 5 6 - 10 >10 10 - 20 8 of logistics	2 1 3 1 1 1
3	Have the budgets been adjusted for these additional costs?	No Yes Yes for clean-up Partly	6 3 1 2
4	Has environmental research / monitoring been initiated / enhanced by the Protocol?	No Yes	2 10
5	Is there extra funding for environmental research / monitoring?	No Yes Mostly not applic.	7 3 1 1

6	Is there a feeling or certainty that Antarctic research is suffering from payments or from the withdrawal of resources used for Protocol procedures or purposes?	No Yes No, but increased work load	9 2 1
7	Is there a feeling or certainty that research program progress is been handicapped or delayed by Environmental Protocol procedures?	No Yes Possibly	9 2 1

In any case - in most organisations having answered there is little or no extra funding for Protocol induced recurring expenses, and these expenses run from less then 5 percent to 20 percent of the total budgets, concentrating at 5 to 10 percent. This is certainly no small amount, and I do admire the operators, the majority of those who answered by the way, who claim that their research work in Antarctica is in no way suffering from cost effects of the Protocol. I suppose that these operators agree with me, however, when I say that – like with all other expenses – the costs induced by the Protocol must be effectively controlled.

I had a very encouraging answer from Dr. Chiang – in this case I have his consent to give names – who wrote that the impacts of he Protocol have been less than anticipated and that the US Antarctic program has benefitted from a thorough overhaul of the logistics infrastructure initiated by the Protocol. Also had some scientific research activities gained from the environmental impact assessment process which had led to the identification of alternatives which were superior to the initially proposed methodology. It is worth while noticing that in some countries the Protocol helped or still helps to make the available money go further.

Some people maintain that in scientific research organisations there is often limited interest in the economics of their activities. Scientific and logistic personnel using a considerable part of their time to fill in application forms and to explain their research work and its environmental effects to the bureaucracy may not require moneys to be paid from one account to the other, but here are definitely costs produced. I hope that the COMNAP members who have sent in answers had considered this.

There are bound to be definite differences in the methods and speeds with which applications are acted upon in the different countries. What had been envisaged early, that with international research projects the permit application could move to a more lenient administration of the participants, has become reality already as far as I know.

In most countries, when the Protocol was incorporated into their national law, some authority was given the task by the legislator to realize the directions of the Protocol. Unfortunately, in some cases these authorities had very limited experience with the Antarctic, even less with Antarctic environments, with Antarctic research and the complex logistics involved. Often, in recognition of this fact, the participation of the very same research organisations in the decision making is required by the law, who have prepared the environmental impact documents and who apply for permits. Not only does this reduce the idea of control and supervision, but also times and moneys are invested to little avail.

What should have been done, may possibly be done still, or should be considered with future regulations to come like the Liability Annex and the Polar Code?

- The preference of scientific research in Antarctica as manifested in the Antarctic Treaty has to be maintained also in all dependent or new legislation regarding the Antarctic.
- In view of the many long-term research programs in Antarctica and the long preparatory phases the transition times until new legislation takes effect (at least on such programs) must be chosen sufficiently long.
- In the ATCM as in all large international bodies information distribution and decision making are lengthy processes. In order to speed up the proceedings and thus save costs more competence should be given to the appropriate committees. The Committee on Environmental Protection in my opinion could decide on environmental effects of new projects quickly and expertly, and it could help avoiding double effort for permission of activities evaluated elsewhere before.
- Cost implications of new Antarctic legislation must be openly addressed. Additional costs cannot always automatically be allocated to research. We all benefit from increased environmental protection, so the general public is also to pay for it leaving the research budgets intact.
- Decisions should be taken and control be left to where the expertise is. Bureaucratic administration, we know that from Parkinson, tends to fill every gap and to grow exponentially. Where administration cannot contribute in substance it should be reduced to strictly administrative tasks. At the same time the institutions of self-control in the Treaty system should be strengthened.

The problems I have mentioned have to my knowledge not been listed or publicly discussed, perhaps also because they were to a great extent self-generated when introducing the Protocol. Please don't get me wrong: there was every justification for creating the Protocol and making it mandatory, and it is like the Antarctic Treaty itself an extraordinary example of peaceful and appropriate international co-operation. But just imagine the same Protocol had been introduced by an outside body or authority. Don't you think you would be loudly protesting against costly and irritating side effects?

Thank you

Overcoming problems of contaminated sites clean-up using engineering solutions

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Introduction

Public awareness of the extent of contaminated sites and abandoned waste in Antarctica will continue to grow as more and more tourists visit the continent each year. Motivation for national programs to clean up their contaminated sites and abandoned waste is increasing as environmental awareness and recognition of the responsibility brought by the Madrid Protocol grows. Annex III of the Protocol establishes the obligation that 'past and present waste disposal sites on land and abandoned work sites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites'. But the Treaty also contains the clause that this is not required 'in circumstances where the removal by any practical option would result in greater adverse environmental impact than leaving the structure or waste material in its existing location'.

Management and rehabilitation of contaminated sites, abandoned facilities and waste dumps in Antarctica will be financially and logistically very demanding. Before we can make informed decisions about risks, potentially 'adverse environmental impacts', and possible site management solutions, we need to understand the physical and chemical processes that govern contaminant interactions in the Antarctic environment (Snape et al., submitted, a). Australia's Antarctic research program is addressing these research needs through a multidisciplinary study at two sites: the abandoned American/Australian Wilkes Station, and the disused and dismantled Australian 'Old' Casey Station.

Key aspects of our research include:

- Identification of the main contaminant sources.
- Definition of dispersal mechanisms and pathways.
- Quantification of dispersal and natural attenuation rates.
- Definition, assessment and quantification of impacts.
- Development of a risk-based cost–benefit approach to environmental decision-making.
- Development and optimisation of site management practices and engineering techniques.

In this contribution we emphasise the need to take a holistic process-oriented approach to contaminated sites investigations, and illustrate how knowledge of contaminant mobility can be used to optimise engineering techniques for site clean-up and remediation in Antarctica.

Problems associated with tip removal and spill clean-up

Contamination at Antarctic research stations such as Wilkes and Casey occurred through the now discontinued practice of disposing of waste, such as batteries and fuel drums, in open tips (Figure 1); through accidental spills, usually of fuel; or by discharge of liquid effluent, which contains human waste, but may also include other contaminants. Although modern management practices no longer allow abandonment of solid waste we are left with a legacy of abandoned tips and fuel drum caches from times when environmental protection was not considered a priority. Similarly, it is impossible to guarantee that fuel spills will not occur in the future (COMNAP, 1999) or that liquid wastes will be adequately treated.

A joint study by the Australian Antarctic Division and the Tasmanian Department of Environment and Land Management established a Contaminated Sites Registry for the Australian Antarctic Territory in 1994 (Deprez et al., 1994; 1999). In their report, they identified that the 'Old' Casey Station tip and the petroleum-contaminated sediments near the Mechanical Workshop/Powerhouse were the highest priority for remedial action. From a grid-based geochemical survey of Thala Valley, Deprez et al. (1994; 1999) found that sediments had concentrations of contaminants, including heavy metals (Cu, Pb and Zn), polycyclic aromatic hydrocarbons (PAH), and petroleum hydrocarbons, that were significantly above background and Environmental Investigation Guideline levels (ANZECC/NHMRC, 1992).

Figure 1. Although most nations currently operate a 'return to origin' policy for waste associated with station operations, past practices have created a large legacy of abandoned hazardous waste, such as this example from the abandoned American/Australian Wilkes Station.

In response to recommendations made by Deprez et al. (1994; 1999), a clean-up of Thala Valley tip was initiated. In 1995–1996, large rubbish material was extracted from the tip by a log grab attached to a Cat 240E Excavator. Over a period of 2 months, 149,200 kg of large rubbish material was removed from the tip and transferred to half-height 'C' containers, before being returned to Australia and consigned to a landfill in Tasmania. The remaining material in Thala Valley, consisting of small fragments of rubbish and fine loose sediment, was pushed into a stockpile on the edge of Brown Bay until further management action could be decided (Snape and Riddle, 1998).

In a post-clean-up assessment of the site, Snape and co-workers (1998; 2000; submitted, a) concluded that the 1995–1996 operation did not remove the bulk of the contaminants from the site. Contaminant concentrations in the active layer (the layer that seasonally melts and refreezes) are believed to be higher now than before the clean-up attempt. Disturbance caused by removing large waste fragments from the surface has effectively redistributed the most chemically reactive particles and concentrated them into the active layer. Snape and co-workers further concluded that the removal of some of the tip without controlling waters that moved through the site had increased the contaminant flux into Brown Bay since the excavation operation.

In addition to the sites identified at Casey by Deprez et al. (1994; 1999), there have been a number of site investigations at the abandoned Wilkes Station, 3 km north of Casey. As with the sites at Casey, two main areas and types of contaminants were identified at Wilkes: A large, approximately 20,000 m^3 tip site, and up to 10 000 m^3 of petroleum-contaminated sediments at the abandoned Fuel Farm site (Snape et al., 1998). An identification and assessment of sites at Wilkes Station also revealed that both heavy-metal- and petroleum-contaminated waters were flowing from the tip and fuel-farm areas into the nearby marine environment (Snape et al., 1998).

In summary, the problems thus far identified stem from the presence of a very large volume of abandoned hazardous tip material that is a primary source of heavy-metal and petroleum pollution. These tips and fuel caches cannot be removed by bulk extraction at present because of the risks associated with disturbance. Petroleum-contaminated sediments are also a problem because spills on land commonly flow into permeable sediments, which then become long-term secondary sources of pollution that can release petroleum for decades after the spill event. Bulk extraction of these sediments is neither practical, technically feasible, nor cost-effective. Managers of national antarctic programs must determine the best management solution for these sites given the very high cost of antarctic operations. To begin to address this need we must first consider how contaminants interact in the antarctic environment.

Dispersal mechanisms (from Snape et al., submitted, a)

It is a common perception among environmental managers that buried station waste (landfill) or chemical spills in Antarctica are frozen and trapped in the ground, and that release rates are therefore negligible. The sites we studied around Casey Station indicate that this is not the case. We found that chemical gradients can develop quickly in sediment profiles and that contaminant dispersal is sometimes extremely rapid. For heavy metals associated with tips, the main contaminant flux is through entrainment of particles, or sorption to particles, and dispersal by surface runoff. For petroleum hydrocarbons that have been spilled into porous sediments, sorption to particles is important but shallow groundwater flow dominates for much of the summer season. Defining contaminant release pathways in the catchment management context is essential to understanding how contaminants migrate in seasonally frozen ground.

Using a Geographical Information System (GIS), it is possible to define watersheds and relate the location of contaminated sites or future potential spill locations to a model of the dominant drainage patterns for the region (Figure 2). By integrating models of catchments with an understanding of the dominant dispersal processes, managers and engineers are better able to prioritise sites for remediation, assess the suitability of removal and remediation techniques, develop site-specific management strategies, or even develop spill contingency plans based on predictive modelling.

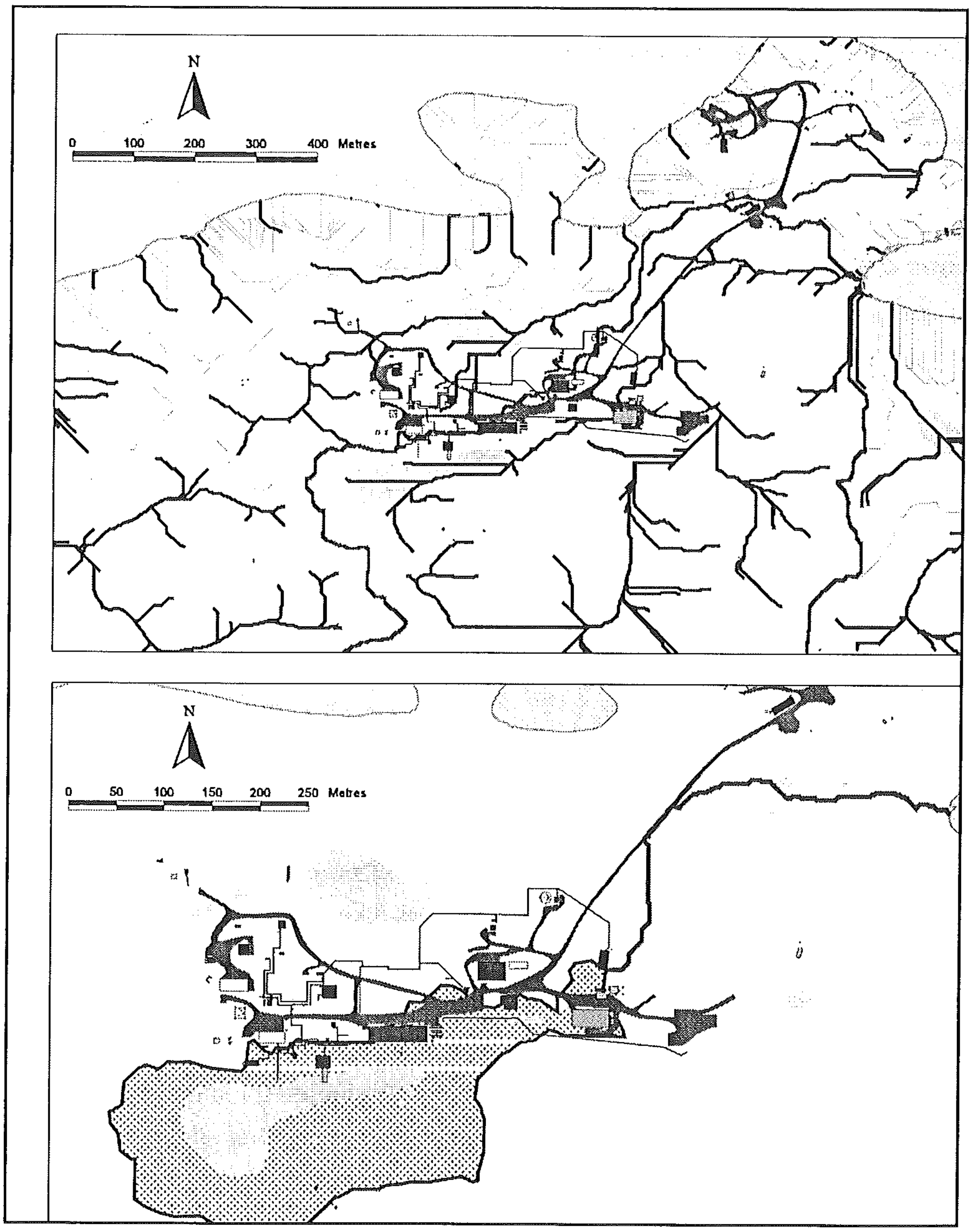

Figure 2. Illustration of the predictive use of GIS as a tool to characterise catchments near antarctic research stations. Using a digital elevation model it is possible to estimate catchment yield, flow volumes and vectors, and predict what the likely outcomes will be if there is a fuel spill at a certain locations. The inset illustrates the predicted flow line that would be followed by a petroleum spill at the fuel storage area at Casey Station. It is also possible to predict how large the up-stream catchment is, and thereby estimate how dynamic (and hence potentially difficult to manage) the through-flow for a site might be. Predictive modelling and spill contingency planning

We can predict meltwater sources, stream locations and time-integrated flows by using a Geographical Information System (GIS) and by incorporating parameters such as snow accumulation, solar flux, temperature and slope. For areas such as the abandoned Wilkes Station, where snow rarely melts sufficiently to see bedrock or sedimentary landforms, this can provide important information for researchers and contaminated sites managers. Such information can be used to manage contaminated sites, for example, by defining where water should be diverted during remediation or removal works. Using the predictive capabilities of GIS in this way, we are now able to define areas that are either favourable or unfavourable for biodegradation (e.g. Guille et al., 1997), locate areas suitable for reactive barrier management of old spills (e.g. Snape et al., submitted, b), or predict likely flow paths (and consequences) of future spills (e.g. Figure 2).

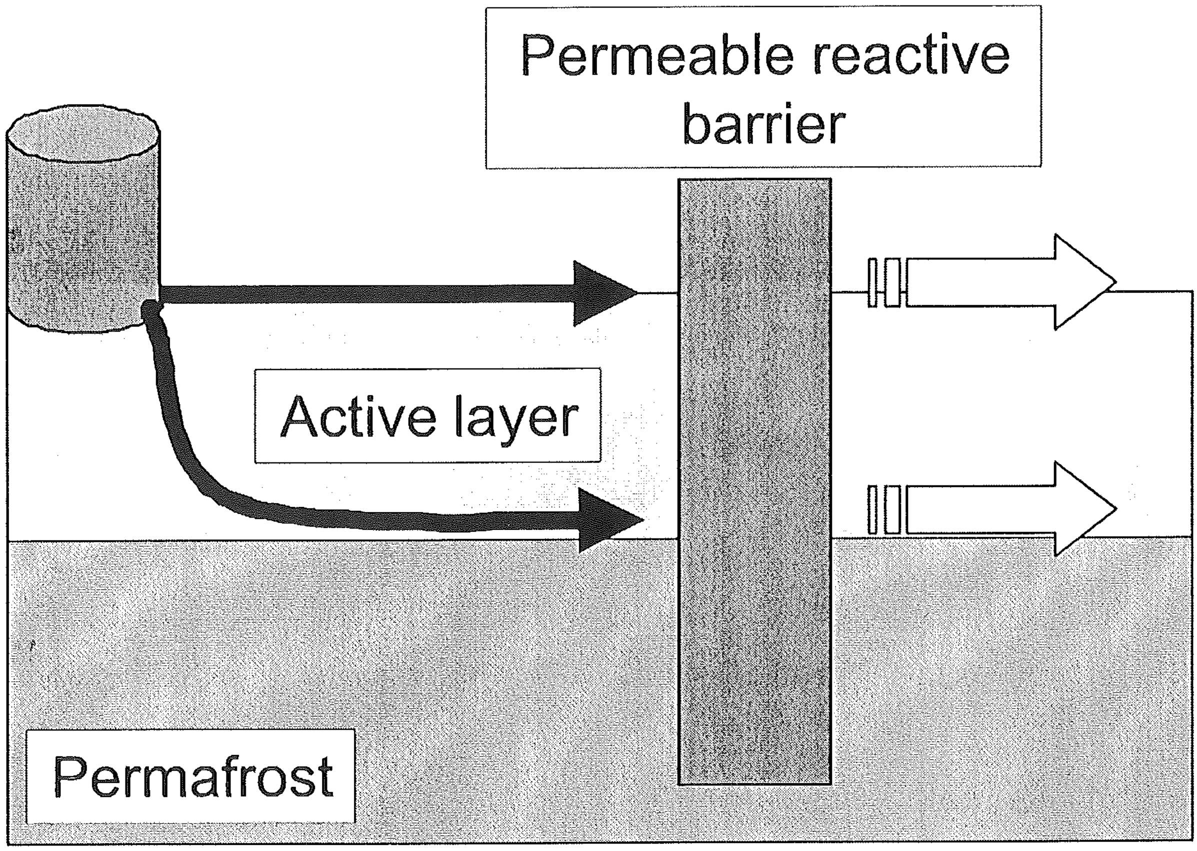

Figure 3. Schematic illustration of a permeable reactive barrier that is being trialled for remediation and management of a fuel spill at Casey Station.

Treatment strategies

The use of permeable reactive barriers during tip removal and spill remediation

We foresee that permeable reactive barriers will be useful during removal of heavy-metal-contaminated solid waste, for the transient management of terrestrial fuel spills where dispersal is via groundwater advection, and during the remediation of long-term contaminated soils.

Permeable reactive barriers (Figure 3) are passive, simple to install, require little to no maintenance and should be able to cope well with the changing flow regimes and weather conditions that occur during the summer months. Preliminary chemical results from barrier trials using granular activated carbon (Figure 4, Snape et al., submitted, b) indicate that excellent adsorption can be obtained for petroleum products commonly used in Antarctic operations (e.g. Special Antarctic Blend light diesel and mineral lubrication oil). Under field conditions, granular activated carbon was also an effective adsorbent for the heavy metals (copper, lead and zinc) commonly associated with abandoned tips in Antarctica (see Snape et al., submitted). Further research will be needed to develop the modular concept for barrier fabrication to enable rapid deployment in remote areas. Such a system is also needed to ensure efficient recovery from frozen ground at the end of the treatment phase.

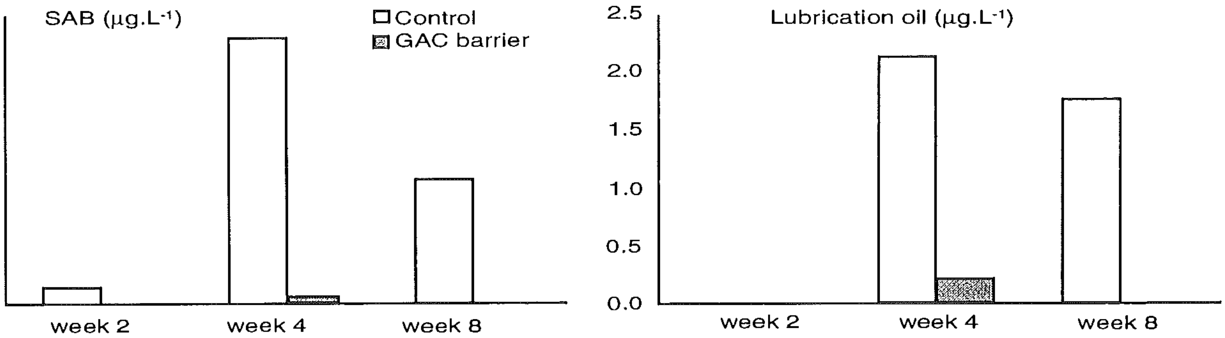

Figure 4. A comparison of groundwater compositions (SAB and lubrication oil) for water that has passed through a granular activated carbon barrier (GAC) and water that has not (control) in the Old Casey Workshop/Powerhouse Site. Graphs illustrate that the GAC-filled permeable barrier removed more than 90% of SAB and almost 90% of lubrication oil from the groundwater (From Snape et al., submitted, b).

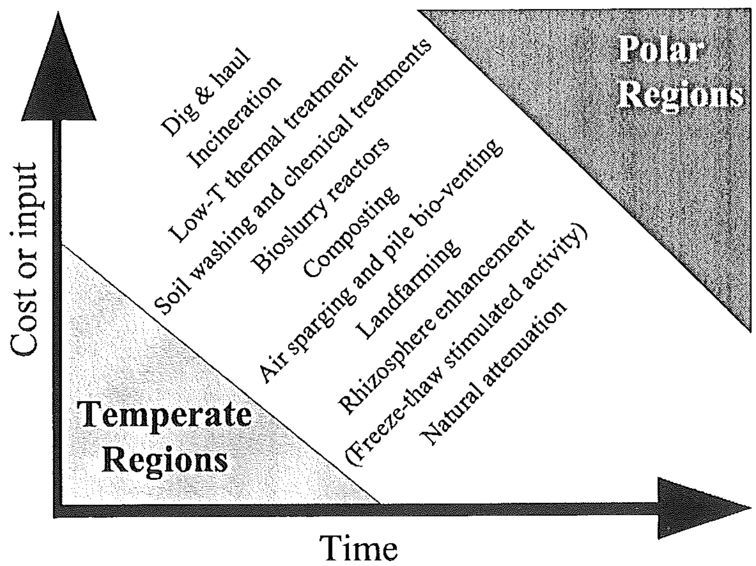

Figure 5. Comparison of cost and time factors associated with remediation technologies in temperate and polar regions. Many remediation strategies that are currently used in temperate regions will potentially work in polar regions – but rates will be slower and costs will be higher (Figure modified after Reynolds et al., 1997).

The use of in situ and/or on-site remediation of petroleum spills

Many remediation strategies have been identified that may be applicable for use in Antarctica, but there is invariably a trade-off between the time over which a strategy will take to degrade petroleum contaminants and the cost involved (Figure 5). For polar regions in general, and Antarctica in particular, operational costs and the length of time required for remediation are typically much higher than in other regions. This is primarily because there are two main limiting factors: the extreme

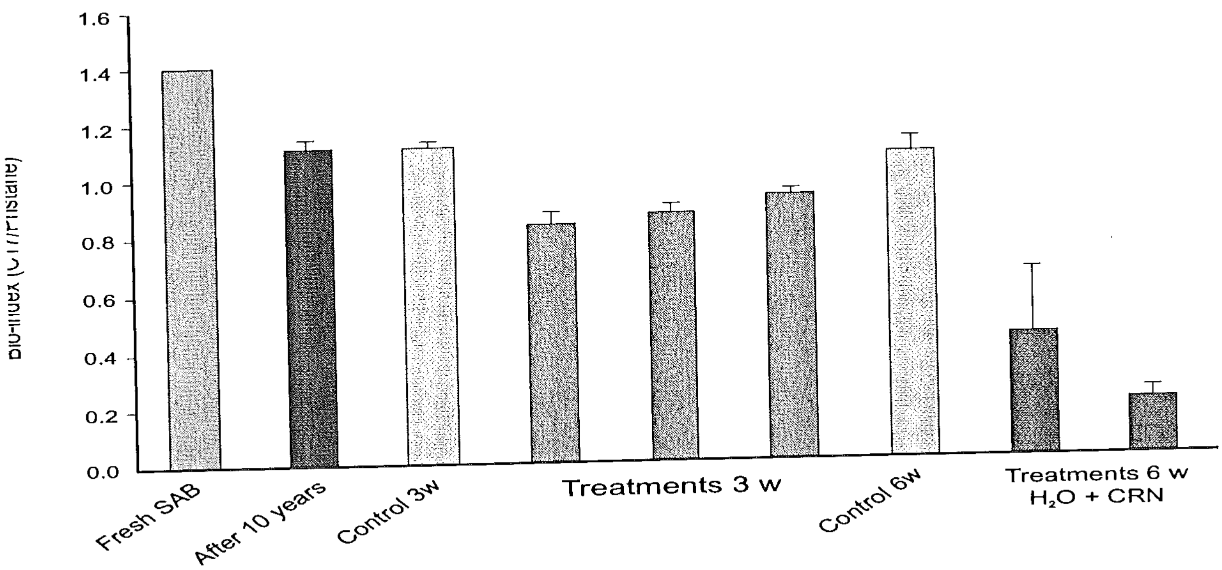

Figure 6. Graph to illustrate the results of in-situ bioremediation trials that are being conducted at Casey Station. Changes in petroleum hydrocarbons are shown for different treatments using a geochemical indicator (or 'biodegradation index') that can be used to monitor or validate biodegradation. The spill is approximately 10 years old, and in that time very little biodegradation has occurred in these cold and nutrient poor sediments. Using appropriate nutrient and water amendments, however, we have been able to stimulate biological mineralisation rates, so that breakdown occurs in weeks rather than decades (Snape, unpublished data).

cold and low nutrient levels that reduce the effectiveness of low-cost bioremediation, and the financial costs of generating energy and supporting high-technology strategies. The main aim of environmental researchers and managers therefore, is to overcome environmental rate-limiting factors, while avoiding the tendency towards spiralling costs (Snape et al., submitted). If managed efficiently, in situ and on-site remediation of contaminated sites in Antarctica has the potential to deliver significant environmental and financial benefits relative to the more traditional practices of excavation and removal, or the 'do nothing' option.

Remediation is commonly accepted as one of the most cost-effective means of reducing environmental risks associated with fuel and oil spills in temperate regions. This is because in situ treatment avoids the economic and technical disadvantages, and the environmental risks, incurred by transport of hazardous wastes to treatment facilities (cf. Riser-Roberts, 1998). This is especially relevant to Antarctica where the costs of excavation and transport are so high that removal of petroleum-contaminated sediments cannot be seriously considered for anything other than the very worst spills. Although remediation technologies for the treatment of petroleum spills under antarctic conditions remain unproven and largely untested, they probably offer the only achievable rehabilitation strategy for contaminated sediments on the antarctic continent (Snape et al., submitted, a).

Fuels and oils that have been in the ground for several years, or even decades, show little apparent natural biodegradation (Guille et al., 1997; Snape et al., 2000; cf. Gore et al., 1999). Relying on natural attenuation as a management strategy for the sites we studied because rates of breakdown are slower than the seasonal transfer of contaminants to environmentally sensitive nearby marine areas. By comparison, preliminary results from remediation field trials in Antarctica are encouraging and indicate that significant remediation is possible in a reasonable timeframe and at an acceptable cost. We have conducted experiments to determine how to best manipulate environmental conditions to derive a cost-effective remediation strategy. These manipulations have involved nutrient addition, chemical oxidation, microbial transfer from locally enriched sources, and water addition. To validate these experiments we have determined natural and experimental rates of degradation using a variety of geochemical, microbiological and isotopic techniques. From these results, we are now able to go someway toward defining a workable remediation strategy for the Casey region. For example, we have found that optimisation of nutrients and water can significantly increase biological mineralisation rates when compared with natural attenuation (Figure 6, Snape and co-workers, in prep.).

Conclusions

The most important finding from our studies is that although contaminants do not behave in the Antarctic as they do in temperate regions, a good understanding of fundamental physical-chemical processes can be used as the basis for remediation tailored to Antarctic conditions. For example, our studies show that chemical profiles develop quickly in the active layer, and that heavy-metal and petroleum-hydrocarbon contaminants are mobile in the summer months. For heavy metals associated with tips, the main contaminant flux is through entrainment of contaminant particles, or sorption to particles, and dispersal by surface runoff. For petroleum hydrocarbons, sorption to particles and groundwater flow is the dominant dispersal mechanism. These observations, when linked to the research of other disciplines such as ecology and chemical engineering, provide important information for site management, and define which of the three possible management options: ‘do nothing and rely on natural attenuation’, ‘dig-and-haul removal’, or ‘in situ rehabilitation’ is most appropriate. We have identified that permeable reactive barriers are an important technical development that can be used to reduce contaminant dispersal caused by removal, and as a quick response for containing fuel spills. Permeable reactive barriers will also be useful as part of the strategy for managing long-term petroleum-contaminated catchments. However, confirmation of the viability of bioremediation for treating petroleum spills awaits final validation from the multi-year trials that are currently underway.

Acknowledgements

This paper is a summary of detailed work that is currently being published elsewhere. Many of the ideas, results and interpretations are the product of multidisciplinary research involving many people. We would like to particularly acknowledge David Smith (GIS Officer, AAD), Ric Morris (Chemical Engineer, University of Wollongong) and Coleen Cole (DPIWE) for their contributions. Thanks also to Cathy Bruce and Doug Thost for help with production of this paper.

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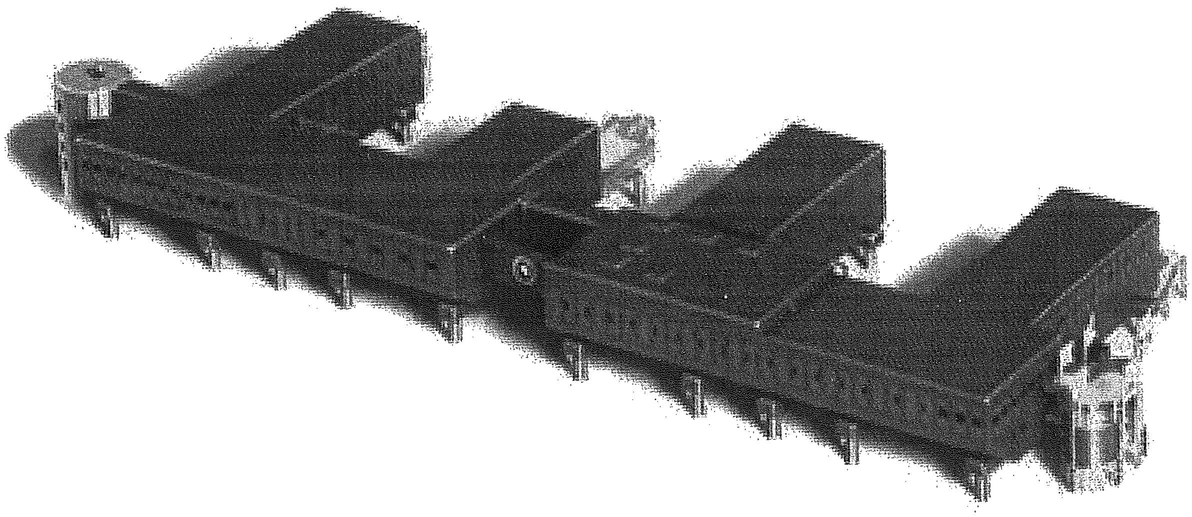
South Pole Station Modernization Project
An Energy Efficient Facility

By Frank Brier[1] and John Rand[2]



The National Science Foundation, Office of Polar Programs (OPP), has completed the design and initiated construction for replacement facilities at Amundsen-Scott South Pole Station. Three years of construction have been completed and five more years are scheduled to complete the South Pole Station Modernization Project. The design by Ferraro-Choi Associates Ltd incorporates industrial functions (fuel storage facility, garage and shops facility, power and water production plants, and warehousing facility) in steel arches below the snow surface, and science and habitable functions (housing, dining, administration, communications, and recreation) in elevated structures. The design meets current U. S. health and safety standards and is environmentally sensitive. One of the primary design perimeters was energy efficiency. The design is based on minimizing electrical/heating requirements and balancing available waste heat against heating requirements. Under normal operating conditions fuel will not be required for space heating or water production. The exception to this condition is short periods of extreme low temperatures during the winter when fuel supplemented heating is required.

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Fuel is only used for electrical power generation, heating of remote building, and vehicle operations

This paper discusses the general design perimeters of the South Pole Station Modernization project and specific information on energy efficient features of the new facilities.

Introduction

The present station (Figure 1), which was completed in 1975, is one of the most remote outposts in Antarctica and is in need of replacement and modernization. The existing station was designed for a 20-year facility life for 33 men. Since 1975 several additions have been completed to accommodate the current summer population of 220 people (including 80 construction staff). During the summer season most of the personnel are housed in inefficient, canvas Jamesway huts. Electrical brownouts of the power plant have been experienced, which damages scientific equipment and reduces the efficiency of scientists and operational personnel. Due to confined working space and the condition of the facility, the original garage was considered the single largest industrial hazard. The fuel storage facility consisted of nine 94,600 liters (25,000-gallons) neoprene bladders with no secondary containment.

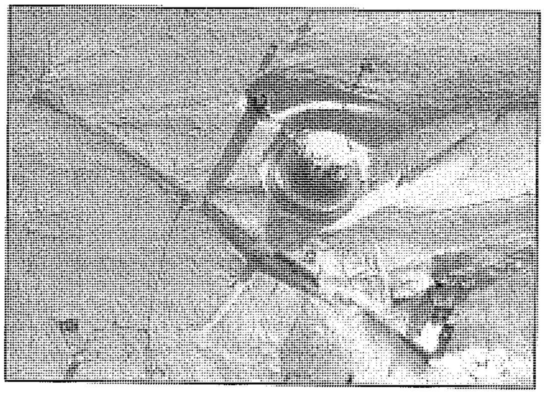

Figure 1. Present Station

Because of urgent safety and environmental issues, NSF identified three projects of the highest priority: Garage/Shop Facility, Fuel Storage Facility, and Power Plant. These projects were funded in 1997, and construction started in 1998. Initial funding for the core facilities followed in 1998, and construction will start in October 2000. The core facilities will be composed of two elevated C-shaped pods (each two stories high), a remote science facility, a cargo/enclosed storage facility, and a remote satellite communication facility. Functional areas within the elevated station include the winter berthing rooms, the kitchen and dining area, the medical facility, summer berthing rooms, computer work stations, a centralized science area, communications and administrative areas, a multipurpose gymnasium, and an emergency facility

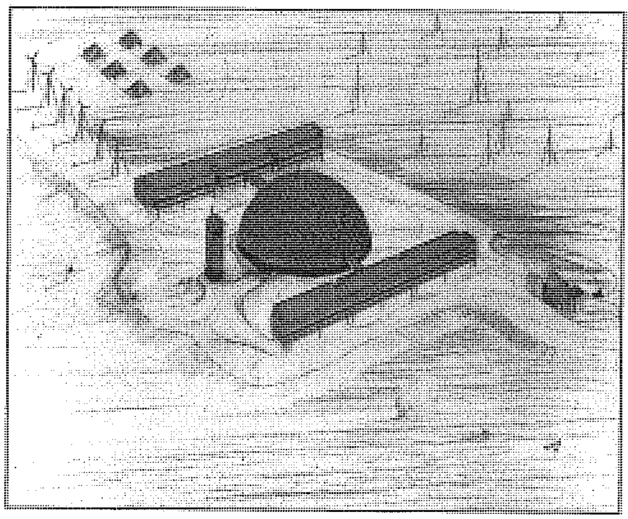

Figure 2. H-Dome Concept.

including emergency power and water production capabilities.

Conceptual Development

In October 1989, the Director of OPP issued the following mission statement to provide guidance to the project's development. His purpose was to "create and implement a design that will serve the most complex frontiers of science, with technologies yet to be developed, while maintaining the essential pristine character of the vast polar plateau on which it will be situated" (NSF, 1989). Realizing the existing station's condition, NSF, through an agreement with the Pacific Division of the Naval Facilities Engineering Command (PACDIV), engaged various architects and engineers to develop concepts and perform preliminary engineering studies. Figure 2 is one of three early Metcalf and Eddy concepts developed that retained the geodesic dome as the center feature of the station (Metcalf & Eddy, 1990).

Following several planning meetings, NSF identified the science and operational requirements for the new Station, as follows:

- Provide a platform for existing and future science
- Minimize operational personnel and maximize science personnel
- Provide a safe working and living environment
- Minimize environmental impact
- Minimize disruption of ongoing science
- Optimize use of the existing facilities
- Achieve a 25-year station life
- Maintain a U.S. presence in accordance with National Policy.

Under a PACDIV contract, Ferraro-Choi Associates Ltd. completed in 1994 a Conceptual Design and Programming Study that was used as the basis for the final design of the new facilities.

Architectural and Engineering Design

The redevelopment process has evolved from engineering and architectural studies of all aspects of the South Pole Station, including projected science requirements, logistics, construction limitations, and operation and maintenance of the completed facility. Over 40 engineering studies and reports were prepared during the design process. The documents ranged in subject matter from snowdrift and detailed analysis of power and heating requirements to the preparation of an Environmental Impact Statement. Options for station size and configuration were considered throughout the process.

The final design (Figure 3) incorporates a combination of below-surface and elevated facilities. It was determined early in the design phase that the existing geodesic dome had been structurally damaged by differential snow loading and was prone to future loading problems inherent to its shape and construction. Reconfiguration and reuse were considered impractical and costly. Therefore, reuse of the dome was not considered a design parameter, and plans were developed for its removal.

The existing steel arches were evaluated in detail and found to be structurally sound and with a minor increase in height will serve as long as the new elevated facilities. The design incorporates reuse of the existing fuel arch and replacement of the neoprene bladders with stacked steel tanks and secondary containment. Fuel storage capacity was increased from 850,000 liters (225,000 gallons) to 1,700,000 liters (450,000 gallons). The existing bio-medical, power plant, and garage arches will be connected to form one arch to house a new cargo and waste management facility. New arches have been erected parallel to the cargo arch for the new garage/maintenance shops facility and power plant. A smaller arch and vertical tower act as a utility, supply, and personnel link to the above surface station and the elevated facilities.

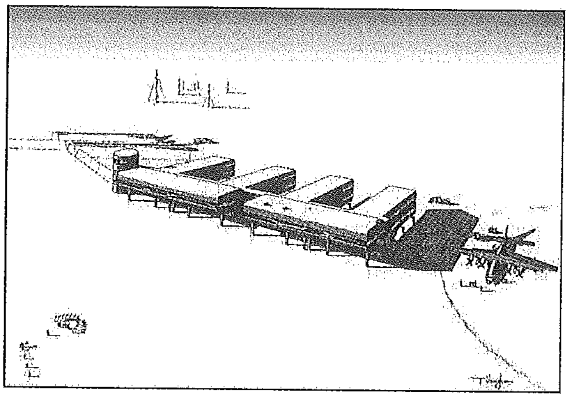

Figure 3. Conceptual View of New Station

The elevated facilities were conceived to be of modular design capable of being periodically raised to extend their useful life and incrementally jacked to adjust for differential settlement (Brooks, 1999). Their size, alignment, shape and height above the surface are based on water flume and computer-based snowdrift studies (Figure 4) conducted by a Canadian-based research firm Rowan Williams Davies & Irwin Inc RWDI, 1999). The drift studies indicated that to meet the 25-year station life requirement the elevated station should be constructed 3 meters above the surface and would need to be raised twice. Each raising is projected to be 4 meters high. These prerequisites combined with the necessity for a phased design and construction approach, resulted in a linear, piano-key-like design plan of two-story buildings connected to a segmented spine.

This approach allowed utilities to be distributed along the spine as new modules were constructed and brought into service and disconnected when building sections were raised. It also allowed for modules to be closed during the winter season to save energy. The spine is a two-story pedestrian and utility corridor that connects the elevated modules. The leading edge of the elevated facility and corridor act as an airfoil to accelerated wind speeds below the building to control snow drifting. The upwind buildings, having the greatest access to the corridor plus views of the South Pole monument and arriving aircraft, will contain public, administrative, and research functions. Downwind buildings will contain the station's personnel berthing, recreational facilities and emergency facilities including a backup power plant, galley, and berthing. The emergency facilities could operate as a first area of refuge during a winter or summer catastrophe. A second level of refuge is provided in remote science facilities.

adversely impacting science or operational perimeters could be incorporated in the facility. They included:

- highly insulated air-tight building shell (up to R-70)
- minimum space allocations
- vestibules and refrigerator doors
- minimum outside air ventilation rates that meet health standard
- reuse of electronic instrumentation and facility equipment waste heat
- localized zone control room exhaust
- minimized water usage
- ambient process cooling systems
- hydronic clothes dryers
- high-speed extractor

The remote science facilities also incorporate several unique energy conservation features. Like the core facilities, they are highly insulated and energy efficient, and ventilation is closely monitored to reduce heating requirements. Since exhaust vapors from oil-fired furnaces and boilers interfere with many scientific experiments the remote facilities are electrical heated. However, the primary heating source for the buildings is waste heat from electronic equipment. Up to 50 % of the heating load for the remote buildings is provide by electronic equipment waste heat.

When the new power plant is commissioned in January 2001, four diesel generators will be available to provide the electrical power for the station: three 750 kW and one 250kW peaking unit. The maximum peak electrical load is projected to be 1,000kW. Based on engineering analysis by the design team, the expected station load at completion of the South Pole Station Modernization Project in 2006 is 498 kW, allowing a 100% growth factor for future science. A summary of electrical loads and fuel consumption is provide below:

	Average Load kW	**Seasonal Demand KWhrs**	**Estimated Fuel Consumption Liters (gallons)**
Summer	467	1,120,800	332,000 (88,000)
Winter	510	3,243,600	956,000 (253,000)
Annual	498	4,364,400	1,289,000 (341,000)

As a result of increased station heated area, 8,950 square meters (96,300 square feet) compared to 5,900 square meters (63,600 square feet), the over all electrical power demand for the new station is greater than that for the existing facilities. However, annual electrical demand per unit area was significant reduced from 51.9 kW/square feet to 45.3 kW/square feet. A 13% increase in electrical efficiency.

As can be seen from the following table, without any use of renewable energy resources, the new station will use 216,000 liters (57,000 gallons) more fuel than the existing facilities. When considered on an area basis the station-wide fuel efficiency increased by 21% from using 163 liters/square meter/year to 128 liters/square meter/year.

	Existing Facilities 6,880 m^2 (63,600 square feet)	**New Facilities** 10,420 m^2 (96,300 square feet)
Electrical Production	976,300 Liters (258,000 gal.)	1,289,000 Liters (341,000 gal)
Heating Load	141,700 Liters (37,000 gal.)	45,000 Liters (12,000 gal.)
Total Fuel Usage	1,118,000 Liters (296,000 gal.)	1,334,000 Liters (353,000 gal.)
Area Based Usage	163 Liters/M2/Year	128 Liter/M2/Year

Although diesel generators are the primary power and heating source for the new station, NSF is actively pursuing use of both photovoltaic and wind turbines to reduce the use of fossil fuel. Currently the South Pole Station Modernization Project design includes a photovoltaic array, and $420,000 has been budgeted for procurement and installation. The installed array will consist of 848 panels mounted to the exterior vertical surfaces of the elevated station and the associated power integration hardware. The summer model for this array indicates a maximum output of 27 to 28 kW tapering to a minimum of 3 kW. No power will be produced during the winter season. The projected energy out-put per day during mid summer is estimated at 400-420 kWh. The projected annual fuel savings are estimated at 8,100 liters (2,300 gallons). At a cost of $4.15/liter ($15.70/gallon), the simple payback period would be 12 years

NSF is also considering the use of wind turbines at South Pole Station. The National Renewable Energy Laboratory (NREL) is currently developing a 100 kW Cold Weather Turbine (CWT) for application in Alaska and Antarctica. The principle features of the CWT are; a 100 kW direct-drive generator, 20-meter fixed-pitch rotor, 3-blade assembly, fail-safe main-shaft brake, an upwind active yaw control, remote monitoring and controls, a self erecting tower and a temperature rating to minus 50°F. A proof-of-concept turbine was commissioned in February 1999 in Barre, Vermont, and two prototype turbines are being constructed for installation at two other sites—NREL's test site in Golden, Colorado, and a site in Kotzebue, Alaska.

Preliminary results from the NREL tests are very promising, but additional field tests at low temperatures are needed to validate the wind turbines performance and durability. Once the field tests are complete and any required modifications are identified, NSF plans to install several units at South Pole. At an average power production of 14kWh and an estimated cost of $250,000 per unit the payback is approximately 1.6 years. The annual fuel saving in reduced generator loading is 9,970 gallons. However, the decrease in generator loading also reduces the available waste heat, resulting in an increase in supplemental boiler operations equivalent to 4,120 gallons of fuel. The annual net fuel saving is estimated to be 5,850 gallons fpr each 100 kW wind turbine.

Project Schedule

As a result of logistical and staffing constraints, a phased construction approach is required. The phasing plan allows for individual components to be placed in service

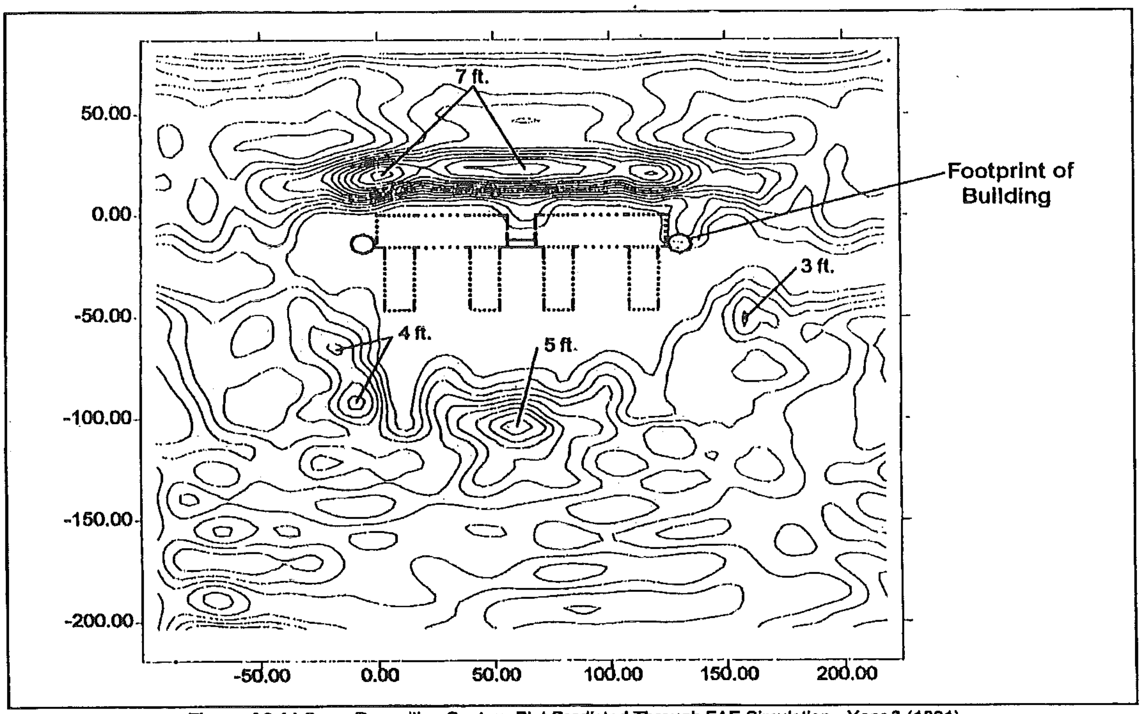

Figure A9.14 Snow Deposition Contour Plot Predicted Through FAF Simulation - Year 3 (1991)

Figure 4. Computer generated drift patterns.

The location of the elevated and remote science facilities was established by a quadrant analysis of the site (Ferraro, 1999). Advantages and disadvantages of each quadrant were analyzed and the recommendations incorporated in the design. The remote science facilities are being developed as two-story elevated structures; these are located away from the main station to minimize technical interference between science and operations.

In recent years, several remote (up to 800 meters away) science facilities have been constructed to accommodate specific science requirements for clean-air sampling, balloon launching, and electromagnetic free environments. The new facilities were retained in the station concept and additional remote facilities will be provided in the Dark Sector. In addition, the existing balloon launch building will be remodeled and cryogen facility constructed.

Energy Efficiency and Fuel Utilization

One of the primary goals of the South Pole Station Modernization Project is to minimize the use of fossil fuels. Early in the design phase of the project, several studies evaluated the use of solar and wind power (SBIR Phase 2 Report, 1995). These studies concluded that neither renewable energy resource could provide year-round, constant, primary electrical or heat energy for the facilities, but either, or both, could supplement the primary power system for a few months each year. Fuel cells were also investigated, but without changing the preferred fuel source, JP-8, to a clean gaseous fuel, fuel-cell technology could not be applied until technology advances are made. Change to a gaseous fuel would also require major changes to the logistical support system. Diesel engine generators were therefore selected as the primary power source.

To minimize fuel usage, the electrical and mechanical designs were developed using state of the art equipment and hardware, and a direct digital control (DDC) system. The specific electrical features used to minimize power requirements included:

- minimize motor size
- variable speed drive motors
- electronic generator controls to optimize performance
- high-voltage distribution system to limit line loss
- motion-controlled lighting
- task lighting
- day lighting

The DDC system controls and monitors operational perimeters in occupied spaces to maintain minimum environmental control and to monitor mechanical and electrical systems to minimize energy usage. Over 1700 points are connected to the DDC system station wide. Specific features of the DDC system include control of:

- outside air intake
- electric motors
- room temperature
- room ventilation
- glycol pump control
- modulated heating and cooling coils
- environmental control of unoccupied spaces
- supply and exhaust fan control

Once the minimum electrical load was calculated for the projected science and operational conditions of the new station, the available waste-heat budget from the diesel engine generators was determined. The waste-heat budget is the amount of heat energy recoverable from the engine cooling system and engine exhaust systems. For the 498 kW average electrical load projected for the new station, the energy value of the waste heat is equal to 556,400 liters (147,000 gallons) of JP-8 fuel. Detailed analysis indicated that distribution of the waste heat to remote buildings was not cost effective, and only the core facilities—the two elevated pods and arch-covered industrial facilities—would be connected to a hot "water" waste-heat distribution system. The project team of Ferraro-Choi, PDC Consulting Engineers, BBFM Engineers, and Dowl Engineers was directed to design the facilities such that the heating requirement for space heating, water production and domestic water heating did not exceed the waste heat budget. This goal was met except for short period of extreme low temperatures during the winter. Total fuel usage for heating the core facilities is projected to be only 45,000 liter (12,000 gallons) annually. To meet the objective of balancing the heating requirement and waste-heat budget it was determined that cost effective methods to minimize heating requirements without

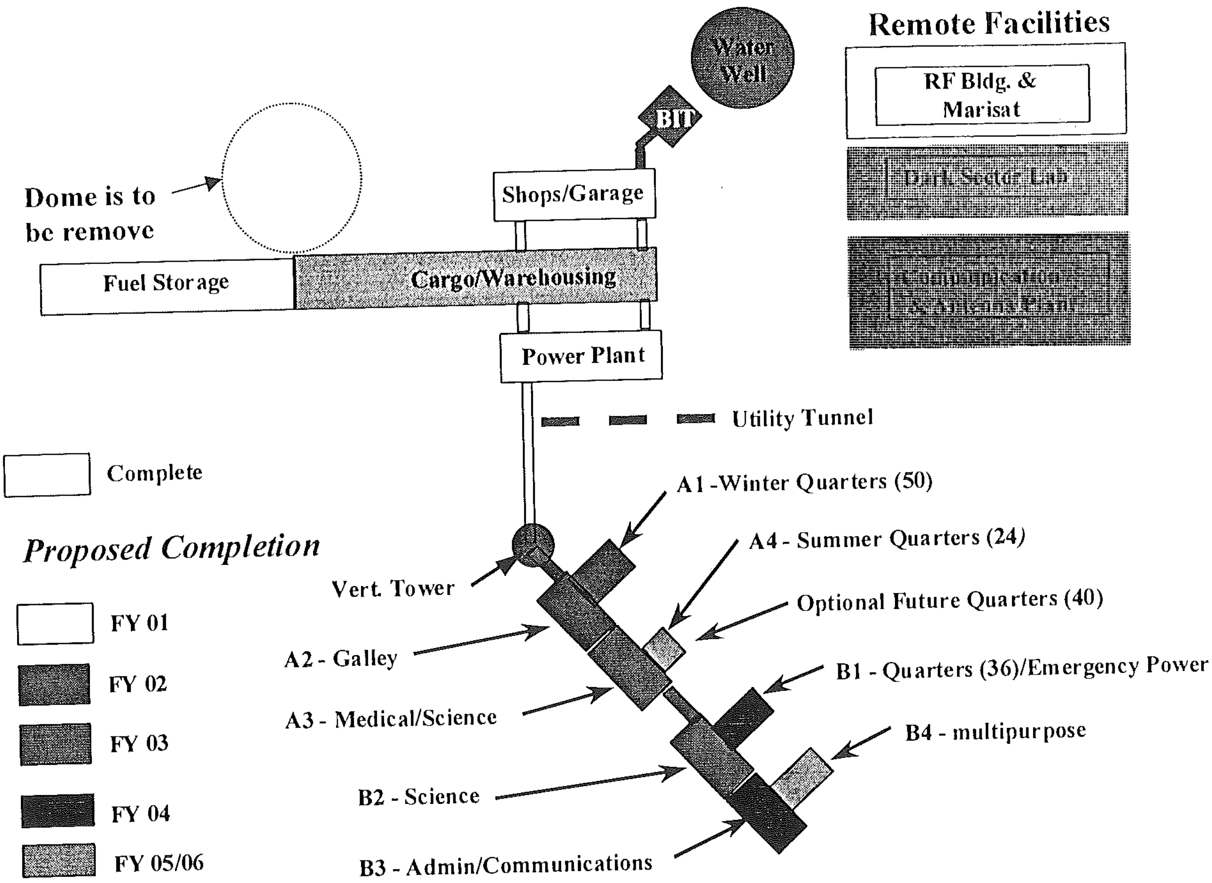

Figure 5. Construction Phasing Plan

prior to final completion of the station. Heavy construction is planned during the summer seasons, with smaller winter-over construction crews completing the interiors. The phasing (or sequencing) of construction is based on priority of needs, construction requirements, functional relationships, and minimization of impacts on science.

The project schedule is an integral part of the design development and project planning. Unlike most projects, this construction effort is constrained by logistics (weight, size, and annual capacity), the size of the construction force, on-site utilities and support, and project phasing. The project schedule includes over 3,000 activities covering all project management, architecture and engineering support, procurement, fabrication, logistics, construction, and inspections. The schedule was developed using project management software. The construction-phasing diagram (Figure 5) best presents the project schedule. The various colors represent the completion of the phased construction.

Conclusions

The process that NSF followed to develop the redevelopment concept and ultimately obtain the support of the National Science Board and Congress to provide funding was a lengthy, yet effective, evolution. With the design completed, the procurements well underway for the elevated station, and the third construction season completed, the project is on track for completion in 2005. The NSF project management structure is continuously interacting with the support contractor and the design team. The identified risks to the project are monitored carefully to assure that the project remains on schedule and within the budget.

The station has been designed to minimize the use of fossil fuel and on an area basis is more than 21% more fuel efficient than the existing facilities. Many unique features are incorporated in the design to obtain this increase in efficiency. In an effort to reduce fuel use, NSF is evaluating the installation of a photovoltaic array and wind turbines farm. One or both of these two renewable energy options will be included in the final station configuration.

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DUMONT D'URVILLE
ENERGY MANAGEMENT SYSTEM

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INTRODUCTION

Global energy management has become a priority in the design and operation of Antarctic stations for both financial and environmental reasons. It usually translates into three different but combined courses of action:

- To minimise needs
- To optimise production and transmission efficiency
- To increase renewable energy input

The French Institute for Polar Research and Technology (IFRTP) and its parent organisation the French Polar Expeditions (EPF), successive operators of Dumont d'Urville Station, have always practised a progressive, long-term energy management strategy for the station. For many years it focused on 'minimising' and 'optimising' using simple yet effective design and operational procedures and decentralised analog control systems.

A few years ago, IFRTP started the progressive introduction of a centralised, computerised energy management system, Énergie Système™, capable of controlling and coordinating the three courses of action. This new system already manages successfully most 'minimising' and 'optimising' functions previously put in place but with a significant increase in flexibility and efficacy.

Énergie Système™ is built around a central processing unit (CPU) communicating via a single Lonworks™ bus with Input/Output (I/O) modules placed around the station. The parameters (temperatures, on/off states, etc...) to take into account are read by sensors connected to the input channels of the modules and queried by the CPU. The CPU sends its control orders are sent through the output channels of the modules. A PC communicating with the CPU via RS232 or modem is only used as a programming or monitoring terminal.

The Lonworks™ bus operates at 78kps over a single shielded twisted pair of 2,000 m maximum length. The CPU identifies unambiguously each I/O module connected to the bus by reading the module's unique serial number.

The CPU can manage a total of 148 inputs and outputs and up to 255 CPUs can be connected together via a RS422 serial link to create a wider system managing up to 37,740 points.

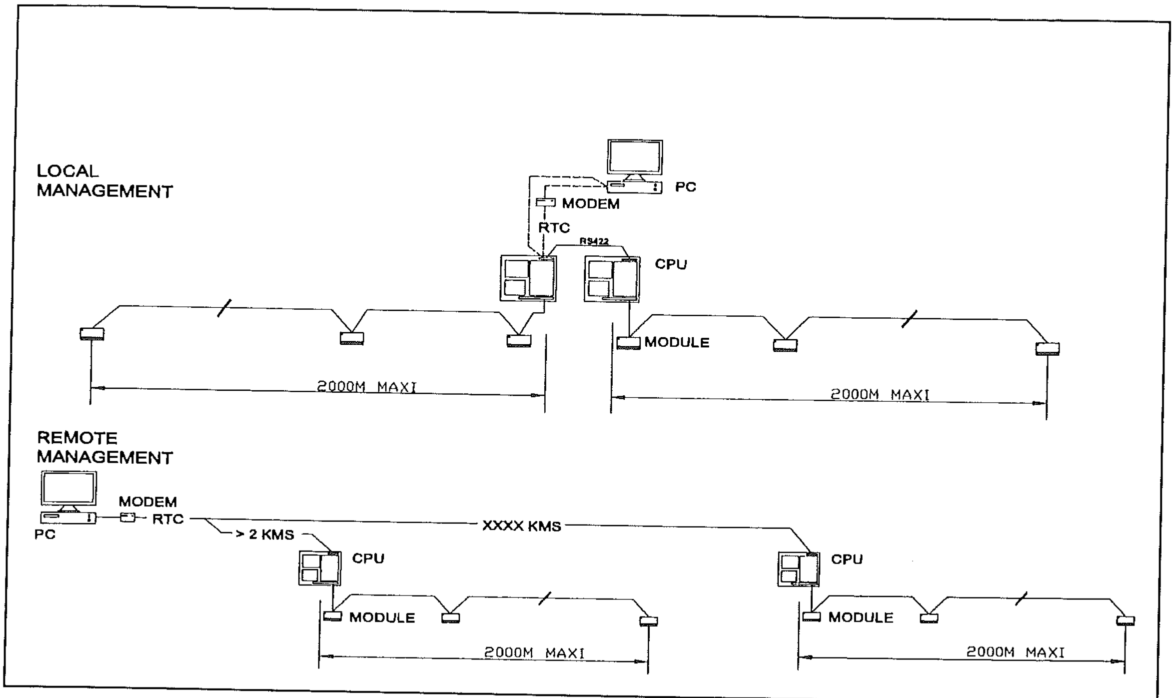

Figure 1 : Énergie Système™ hardware structure

The system sends its orders to adjust valves or to switch loads on or off according to the program loaded in the CPU. The program is written a versatile, simple programming language, can use as variable any parameter input into any module and can send an order to any output channel of any module. It is not restricted to predefined functions, can easily be modified on site and allows recording of all variables for later analysis and fine-tuning of the system.

The system first took over the control of the electrical load shedding, designed to ensure an optimal energy production efficiency. It significantly increased the range and flexibility of the shedding function but also provided a finer control of a large number of electrical appliances and contributed to a much better management of the load. The system is now also controlling some non-electrical thermal loads and provides an efficient, time and weather dependent control of internal building temperatures.

The scope of the system will keep expanding over the next few years. It will notably provide advanced control capabilities of the electrical and thermal load mix, paving the way to the effective management of increasing renewable energy contributions.

1) STATION ENERGY SYSTEM OVERVIEW

1.1 - Structure and Operating Principles

Dumont d'Urville is a fairly compact, efficient station with limited site services infrastructure.

The Main Power House (MPH) accommodates three Diesel generator sets of 144 kW rated electrical output and a fresh water production unit where seawater is desalinated in an evaporator. Most of the waste heat recovered from the generator sets out of both jacket water and exhaust gases is used within the building in the evaporator. Occasional excess heat is injected in a primary heating hot water (HHW) loop sent out of the MPH to heat surrounding buildings. If there is insufficient heat recovery for desalination, additional heat is provided within the building by a boiler and if necessary by electrical heating elements.

The MPH is exporting electrical power to the entire station but is exporting fresh water and brine (the desalination by-product) to only a small number of selected buildings. Freshwater is delivered on demand while brine is constantly delivered as it is produced and rejected through the sewage system.

Only small shelters are heated electrically. All major buildings are heated directly or indirectly with Diesel-fired boilers. Some buildings are equipped with their own standalone boiler. The other buildings are serviced by one of two 'primary' heating hot water (HHW) loops reticulating hot water from building to building. The first primary HHW loop is fed and controlled by a central boilers' room housed in a dedicated building. The second primary HHW loop is fed and controlled by the MPH and uses any potential heat surplus of the MPH.

Each building has an internal, 'secondary' closed HHW loop feeding radiators. The secondary loop receives heat either from a primary loop through an exchanger or directly from a standalone boiler. Each secondary loop is always equipped with an in-line electric heating element. This allows isolation of the loop but will also in the future allow an advanced, optimised management of the electrical / thermal mix of the station load. In buildings where a domestic hot water circuit is needed this circuit operates off the 'secondary' HHW loop.

Relative to the Lower Heating Value (LHV) of the Special Antarctic Blend (SAB) Diesel fuel used at the station (9.8 kWh per litre) the MPH generator sets have an efficiency of about 37% towards electrical production and 42% towards thermal production, that is a combined "cogeneration" efficiency of 79%, providing of course that all the heat generated is used and does not require much electricity (for example in pumps) to reach its point of use. Boilers have a similar efficiency close to 80%, all towards thermal production.

The guiding operating principles used at Dumont d'Urville are:

(a) To limit the electrical load to ensure that the waste heat recovered on the generator sets does not exceed the heat needed within the MPH

(b) To control the electrical load so that only one generator set is ever used at any given time and that this generator set operates within its optimal load range

(a) was achieved through the minimisation of the station's electrical needs and the design of a desalination unit with adequate heat input requirements.

(b) was in the past achieved through the use of an electromechanical load shedding system capable of switching off a limited number of non-priority electrical loads. These loads had to be switched back on manually by the person on watch at the MPH. The load shedding is now entirely controlled by the computerised energy management system and acts on a much larger number and variety of electrical loads.

1.2 - Typical Loads and Fuel Consumption

Over the four years 1996-1999 the average station electrical load was around 75 kW. Using the assumed efficiencies detailed before, the average station thermal load was around 225 kW broken down into 90 kW recovered on the generator sets, 35 kW produced by the MPH boiler for additional heat input into the desalination plant and 100 kW produced by the various boilers heating the buildings. That gives an average total (electrical + thermal) station load of 300 kW.

The corresponding annual Diesel fuel consumption was 342,000 litres broken down into roughly 192,000 litres for the generators, 38,000 litres for the MPH boilers and 112,000 litres for the buildings' boilers. The station overall energy production efficiency is around 79% (energy production relative to LHV energy content of fuel consumed).

This is for a station comprising 2,800 m^2 / 8,400 m^3 of heated building space and producing an average of 4,257 litres of fresh water each day by desalination. The average station occupancy is 39.35 persons or 14,375 person-days a year. This gives an average per occupant of: 1.9 kW electrical load, 5.7 kW thermal load, 7.6 kW total load, 108 litres of fresh water per day and 23.8 litres of Diesel fuel per day.

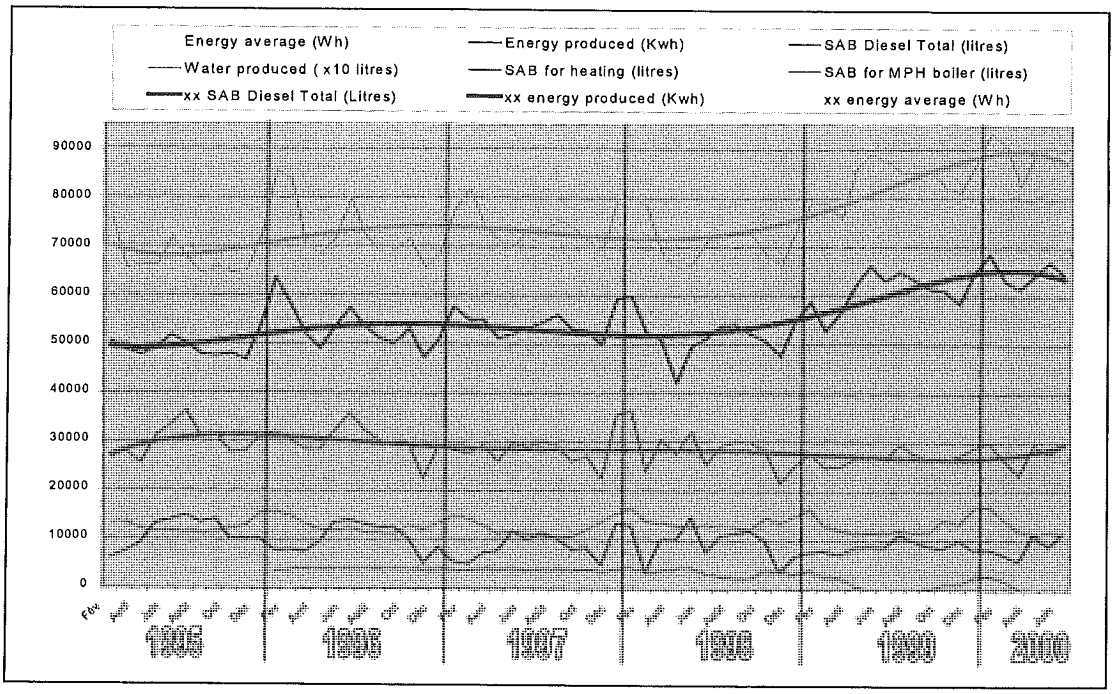

Figure 2 – Energy summary 1996-1999

2) MINIMIZING NEEDS

A large proportion of an Antarctic station's energy needs is for space heating. The minimisation of space heating needs at Dumont d'Urville has focused both on the increase of buildings' thermal properties (good insulation and reasonable size) and on the optimisation of internal temperature control (time dependent optimal temperatures corrected according to meteorological conditions).

Another significant proportion of energy needs is for lighting, especially during the long, dark winter months. At Dumont d'Urville, it accounts for about 25% of the electrical load.

The lighting load is minimised through the use of efficient lighting appliances, timers and motion detectors.

2.1 - Increasing building thermal properties

Dumont d'Urville Station includes six generations of buildings. It started with fairly basic timber constructions and evolved through trial and (hopefully few) errors to a couple of thermally efficient, durable and low ground impact building concepts each adapted to a category of use.

Generation 1 dates back to the early 1950s. The buildings were constructed entirely in timber. There is one such building left on station, "Base Marret". Of heritage value, the building has been restored and is used occasionally.

Generation 2 "AGI" dates back to the late 1950s, the times of the International Geophysics Year (in French Année Géophysique Internationale or AGI). The buildings consisted of a prefabricated steel shell with an internal insulation lining. There is no building of this type left.

Generation 3 is similar to generation 2 but with improved internal insulation lining. There are five of these buildings left. They are currently the subject of a significant renovation and upgrade program (see further).

Generation 4 "SPAIR" appeared in the 1960s and was a real innovation. A steel frame, usually elevated on stilts, was holding from the outside a continuous shell of single-skin composite panels with no thermal bridge. The composite panels were 90mm reinforced sandwich panels made of fibreglass and non-flammable, rigid PVC foam.

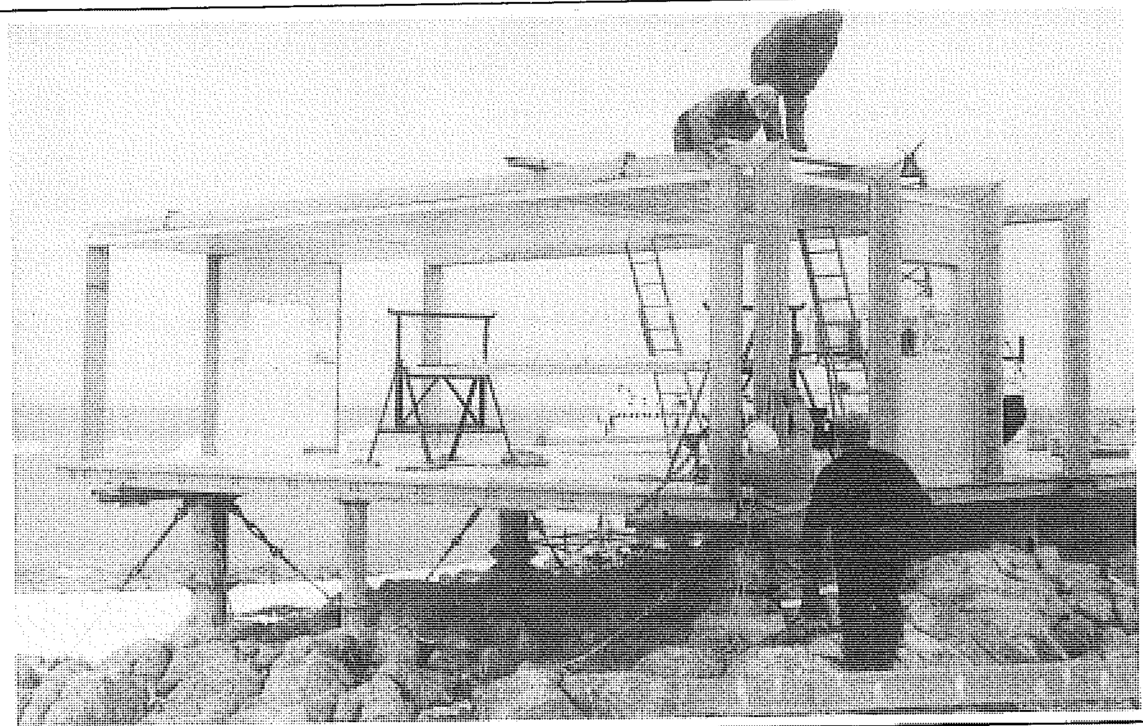

Figure 3: Generation 4 "SPAIR" building under construction

The main advantages of this concept are a high degree of prefabrication, the panels coming all ready with doors and windows openings fitted, a very low volume and weight of materials to be shipped and handled and very easy to handle individual elements which allows a construction process with little impact on the surroundings. The main disadvantages are poor soundproofing and wind induced vibration filtering properties, the high cost of the panels and a durability of the external skin now well superseded by new materials.

Built between 1963 and 1970, the six 'SPAIR' buildings built are now between 30 and 37 years old and have resisted well to many storms including one with winds over 315 km/h. The six buildings are still in operation and represent in terms of floor area about half of the buildings permanently heated.

Generation 5 "Siporex" appeared in the very early 1990s. Buildings are built with light, non-flammable and non-combustible "Siporex™" cellular concrete blocks glued together and protected from the weather by a thin external cladding.

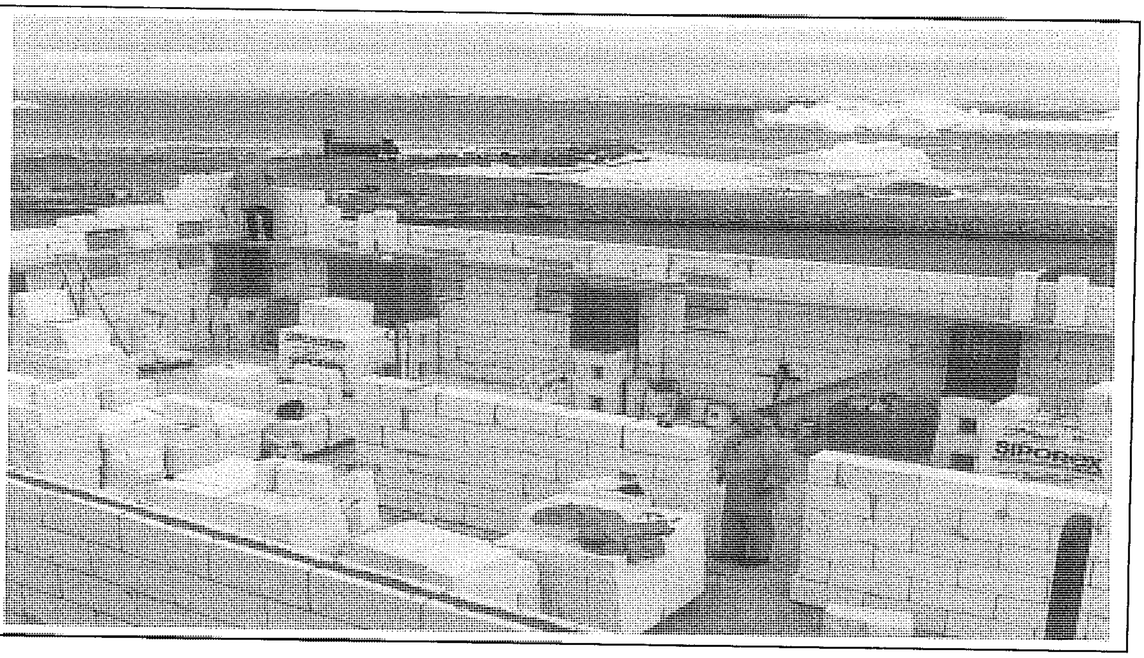

Figure 4: Generation 5 "Siporex" building under construction

The main advantages are a very high proportion of natural, ecological materials (basically sand and limestone), good thermal insulation and soundproofing properties and a very stable structure not prone to wind induced vibrations. This creates very comfortable buildings providing a high quality living environment. It must be noted that the relatively light weight of the cellular concrete still allows construction of the buildings on piles for minimal impact on the ground. The main disadvantages are the requirement for a high volume of building material (200mm walls are needed to give the same insulation than the 90mm composite panels of the 'SPAIR' buildings) and a labour intensive construction process including significant finishing work.

Generation 6, first used in 1998 for storage buildings, combines many advantages of previous generations. A stable, well insulated load-bearing slab base is constructed on piles with 150 to 200mm of cellular concrete blocks sandwiched between two layers of concrete, a lower, reinforced structural slab poured in formwork and an upper, finishing concrete floor. A steel structure is erected on the slab base, clad on the outside by plastic-coated steel sheets and in the inside by sandwich panels. The sandwich panels are either M1 rating (non-flammable) fibreglass-reinforced polyester and polyurethane foam panels or M0 rating (non-flammable and non-combustible) steel and rockwool panels. The space in between the cladding and the internal panels is filled with insulation, either injected M1 foam or M0 rockwool sheets.

The main advantages of this concept are a reasonable volume and weight of materials, a fairly quick and easy construction, little finishing work and a stable, sturdy and well-insulated platform that can be mounted on piles for a minimal impact on the ground. The only slight disadvantages are soundproofing and wind induced vibration filtering properties a bit lower than for generation 5 "Siporex™".

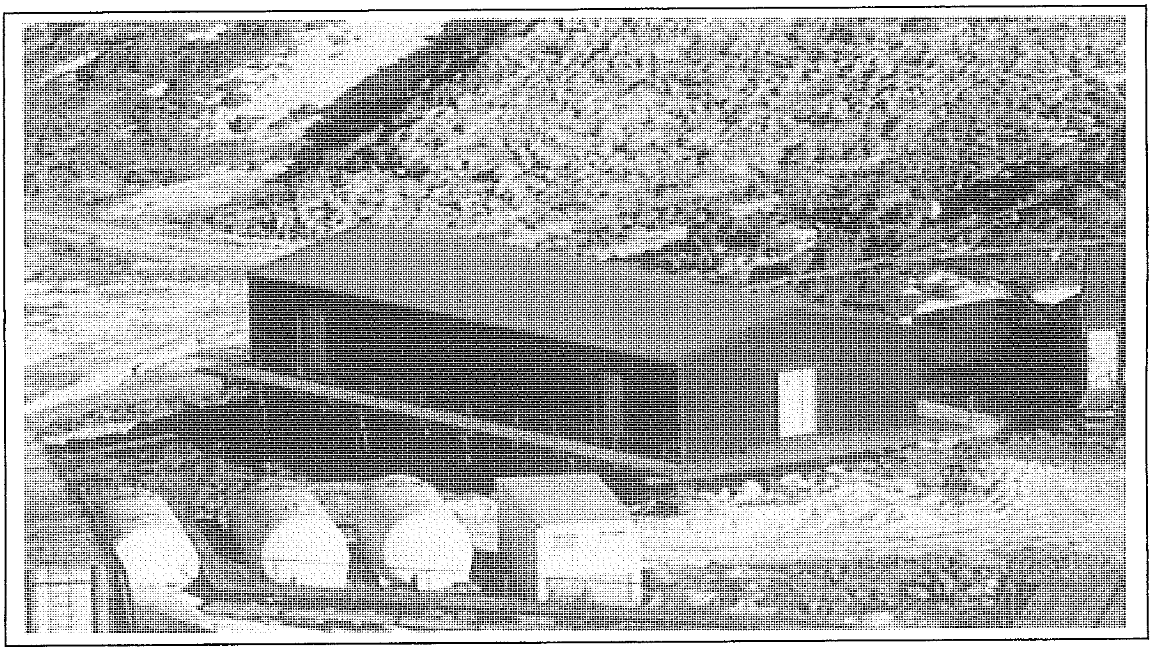

Figure 5: Generation 6 building

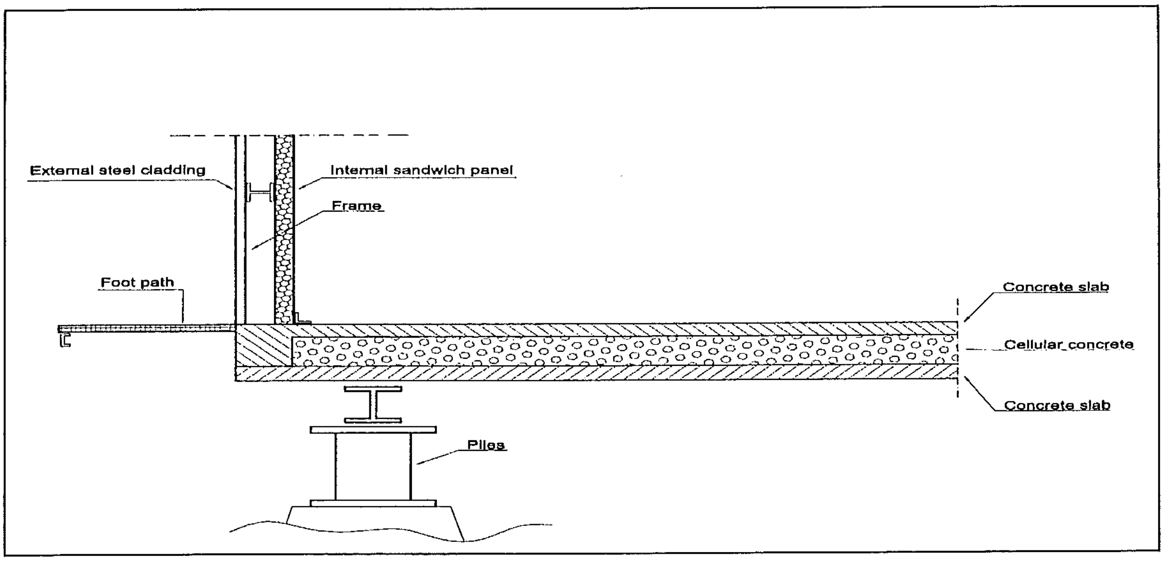

Figure 6: Cross section of a Generation 6 building

The plastic-coated steel sheeting used in the cladding of the last two generations of buildings is a very durable, high quality product offering excellent resistance to the weather. It is galvanised and coated on the external side by a very strong plastic coating applied early in the fabrication process, before any shaping of the panels. It suffers less alteration than both the old steel claddings and the fibreglass panels.

Figure 7: Generation 3 building after renovation

This plastic-coated sheeting is used in a renovation program now under way for buildings of generation 3 and 4 and destined to both extend significantly the buildings life and further increase their thermal properties. The buildings are clad on the outside with the plastic-coated steel sheeting on a simple steel frame and the space created in between the new cladding and the old external skin of the building is filled with insulation, either injected M1 foam or M0 rockwool sheets.

In the near future, Generation 5 should be used for frequently occupied buildings, especially for a future accommodation building, and Generation 6 should be used for storage buildings.

We are also following with interest the apparition of a new expanded-glass material developed by a unit of the French National Centre for Scientific Research (CNRS) and to be manufactured by a French-Belgian company. This material has good insulation properties, is inert and non-combustible. It is also a natural, ecological material made exclusively of silica. It is manufactured by expanding crushed recycled glass.

2.2 - Optimising internal temperature control

There are various reasons for heating a building, such as providing a comfortable temperature for users, a satisfactory operating temperature for equipment or an ideal storage temperature for food or other supplies. It is important to satisfy these requirements and just these requirements. Any small temperature excess might have a cascading effect generating a large increase in heat consumption, for example if a dissatisfied user regulates his room temperature by opening a window. Any significant temperature excess or deficit might be detrimental to the building's functions, for example by indisposing personnel, causing equipment malfunction or degrading supplies.

The system in place at Dumont d'Urville for many years involved regulation at a constant, optimal room temperature using individual, temperature controlled valves. The building heating hot water circuit reticulated water at a fixed temperature and the flow of this water through each radiator was adjusted automatically by a temperature controlled valve. Each valve was set at the desired room temperature then sensed the difference between this desired room temperature and the actual room temperature and adjusted the flow of water through the radiator to reach and maintain the desired temperature.

This system has the inconvenience of maintaining a constant 'normal operating temperature' while lowering room temperature when the building is not occupied can allow significant energy savings. Using an additional, simple time dependent control is often of limited interest due to its incapacity of adjusting to varying thermal inertia in changing weather conditions. Variations of the external weather conditions, mainly temperature and wind speed, induce variations in the thermal losses through the building's skin and hence variations in the speed at which the heating system can respond to and adequately follow a temperature control rule.

The computerised management system Énergie Système™ now provides an additional, versatile layer of control used to optimise time evolution of room temperature.

The first step is to analyse the building usage and establish a time dependent function of the desired room temperature. This typically consists of a plateau with the 'normal operating temperature' during normal times of human presence in the building and lower 'standby temperatures' during other times.

Ensuring close compliance of the actual room temperature with the desired room temperature function in varying weather conditions can then be achieved by the combination of two actions:

(a) Adjusting the temperature control rule according to weather conditions by allowing longer transition times when thermal losses are higher (see Figure 8).

(b) Increasing the temperature of the heating hot water circuit, that is improving the response capability of the heating system, both when thermal losses increase (see Figure 9) and/or when the difference increases between the control temperature to reach and the actual room temperature. The adjustment of the water temperature is done through a three-way mixing valve.

Énergie Système™ manages and coordinates the different rules with input from a wind monitor and outdoor air temperature sensor connected to analog channels of the system. Figure 8 shows an example of time dependent temperature control rule adjusted for various wind speeds. Figure 9 shows an example of heating hot water (HHW) temperature rule as a function of both outdoor air temperature and wind speed.

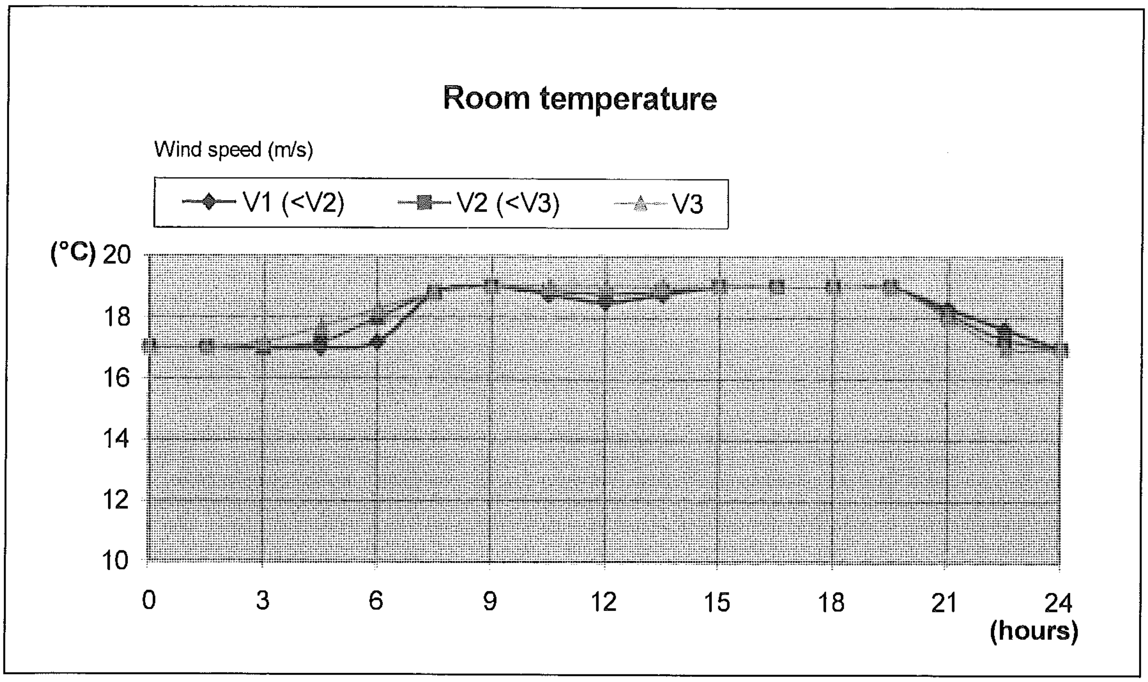

Figure 8: example of time and weather dependent room temperature control rule

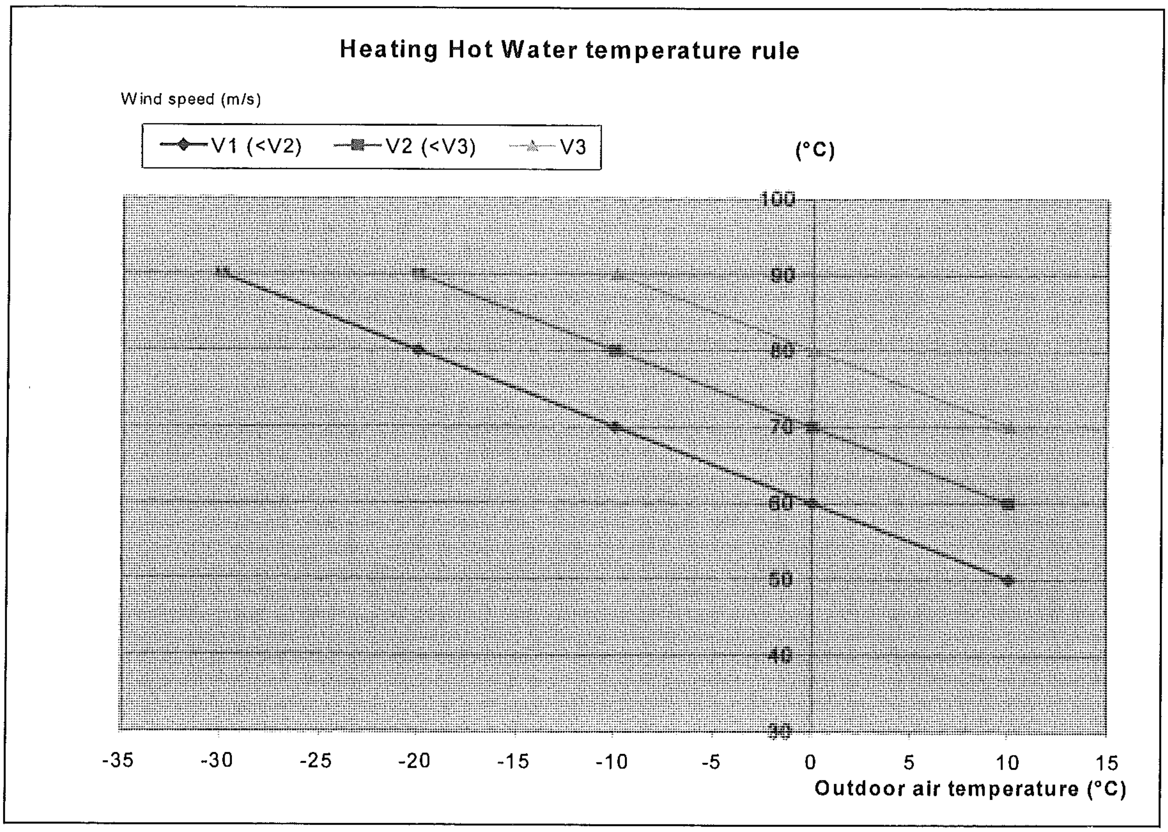

Figure 9: example of weather dependent HHW temperature rule

It must be noted that a traditional, individual temperature controlled valve is still mounted on each radiator where it effectively provides for each local area a fine, independent control of the 'normal operating temperature'. When the system wants a lower room temperature it decreases the temperature of the heating hot water which causes the individual valves to increase the flow through the radiator until it reaches its maximum flow. From then on, Énergie Système™ has the effective control of the room temperature and can adjust it to any temperature lower than the 'normal operating temperature'.

2.3 - Minimising Lighting Loads

Efficient lighting is now used extensively throughout all the buildings occupied regularly. To avoid having lights left on when not needed, the common areas are equipped with a combination of timers and infrared motion sensors which switch the lighting off after a certain time during which no movement has been detected.

3) OPTIMIZING PRODUCTION AND TRANSMISSION EFFICIENCY

3.1 - Cogeneration

The current MPH building built in 1963 included cogeneration right from the start with heat recovered from the engine jacket water used in the evaporator for the desalination process. Close to a third of the fuel's energy content can be recovered relatively easily from the engine jacket water through its cooling system. Significantly less, usually well under a sixth of the fuel's energy content, can be recovered from the exhaust gases and it requires more complicated equipment. This is why it was initially decided in the 1960s to only recover heat from the jacket water.

The amount of heat recovered from the jacket water was under normal circumstances close to the amount needed only a few metres away by the evaporator to assist the desalination process. A standalone boiler was producing any additional heat required by the evaporator.

In recent years the apparition of newer equipment combined with an increased focus on fuel economy and environmental issues triggered the decision to add exhaust heat recovery capabilities to the MPH. This was done during a significant upgrade of the MPH involving the installation of a new generation of generator sets.

Figure 10 shows the principle of the new MPH heating hot water system composed of three independent circuits separated by heat exchangers.

- the jacket water heat recovery and evaporator heating circuit (JW) is in red
- the exhaust heat recovery circuit (EX) is in purple
- the intermediate transfer and primary loop circuit (TR) is in green

This structure allows an optimal use of all the heat recovered from the generators either within the MPH or via the primary loop in nearby buildings. The JW circuit picks up heat from the engines' jacket. If necessary it can pick up additional heat first from the TR circuit then from electric heating elements. It delivers heat to the evaporator. The EX circuit picks up heat from the exhausts and delivers it to the TR circuit. The TR circuit picks up heat from the EX circuit plus if necessary from a the MPH boiler. If necessary it delivers heat to the JW circuit through the heat exchanger. It then delivers heat to nearby buildings via the primary HHW loop plus

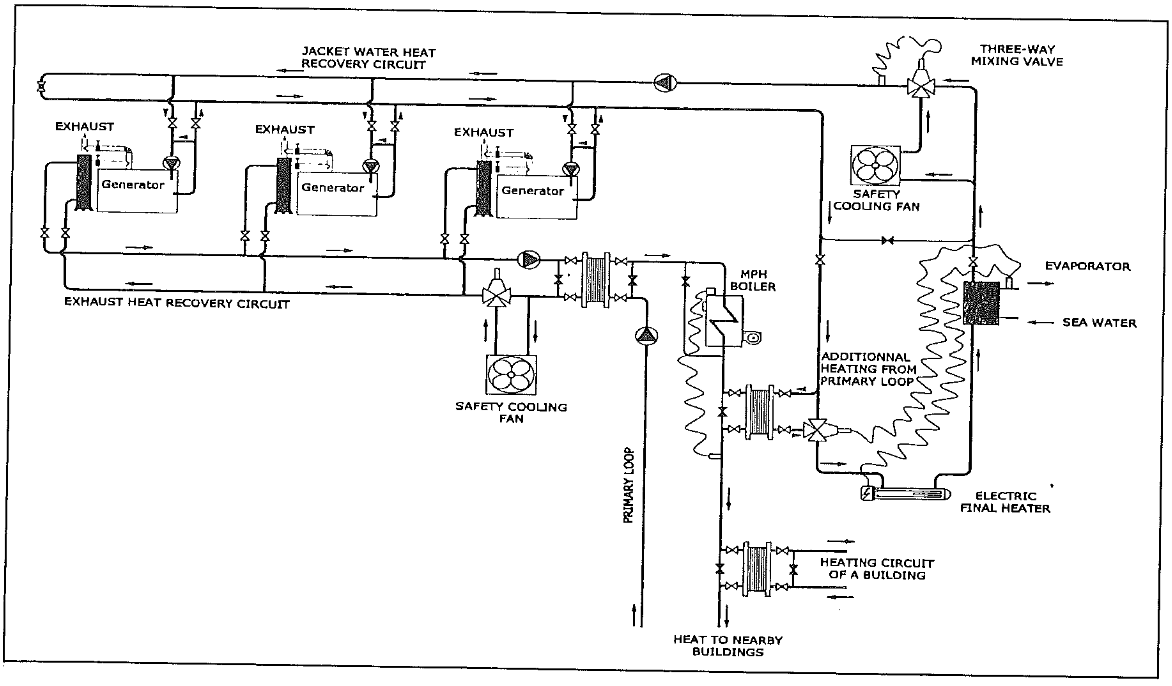

Figure 10: MPH Heat Recovery and Heating Hot Water Circuits

The JW circuit primarily picks up heat from the engines' jacket and delivers it to the evaporator where it is used in the desalination process. If the heating water arrives at the evaporator under a certain temperature threshold (70°C), a three-way mixing valve diverts some of the water to the heat exchanger with the TR circuit where it can pick up additional heat originating from the EX circuit and/or from the boiler. If the seawater in the evaporator is under a certain temperature threshold (69°C) the electric heating elements switch on by 12 kW increments to increase the heating water temperature. It must be noted that when the electric heating elements come on it increases the load on the generators and hence increases the amount of heat recovered on both exhaust and jacket water circuits, quickly reducing the need for the operation of the electric elements. If the heating hot water returns to the engine jackets over a certain temperature threshold (80°C) , that is when there is not sufficient engine cooling, a three-way mixing valve diverts some of the water to a cooling fan. A bypass allows restriction of the circuit to the engine jackets and the cooling fan, providing if necessary a simple cooling system with no heat recovery.

The EX circuit primarily picks up heat from the condensers mounted on the exhausts and delivers it to the TR circuit. If the heating hot water returns to the exhausts over a certain temperature threshold, that is when there is not sufficient exhaust cooling, a three-way mixing valve diverts some of the water to a cooling fan. A bypass allows restriction of the circuit to the condensers and the cooling fan, providing if necessary a simple cooling system with no heat recovery.

The TR circuit is a versatile multifunction circuit. It allows transfer of heat from the EX circuit to the JW circuit if needed, allows the production of additional heat with the MPH boiler if necessary and allows the export of excess exhaust heat out of the MPH to nearby buildings via the primary loop. If the heating hot water about to exit the building is under a certain threshold temperature (80°C) the MPH boiler comes on to provide additional heat. A three-way valve to be installed just before the primary loop exits the MPH will allow the regulation of the loop's HHW temperature to minimise heat losses.

3.2 - Management of the Electrical Load

The ideal situation would be to have a fixed, constant electrical load in the optimal range of the generator set. It would provide the most efficient operation of the generator plus a stable, easily manageable heat recovery and all components and functions could be sized accurately.

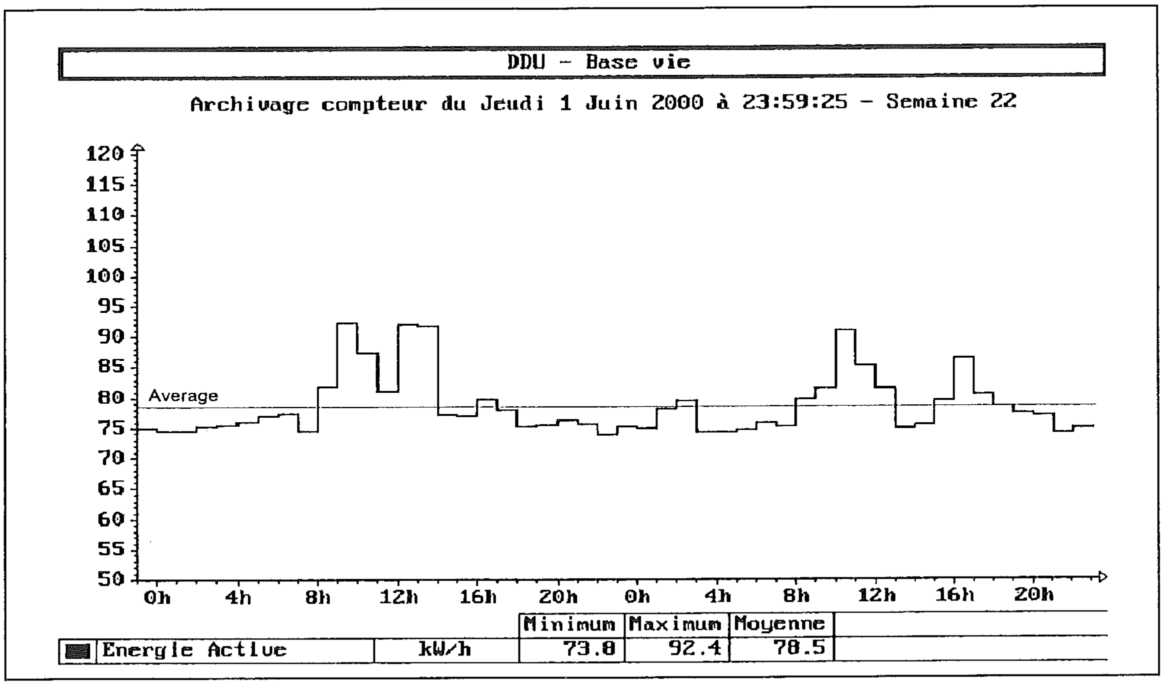

Figure 11: Generator output without load shedding system

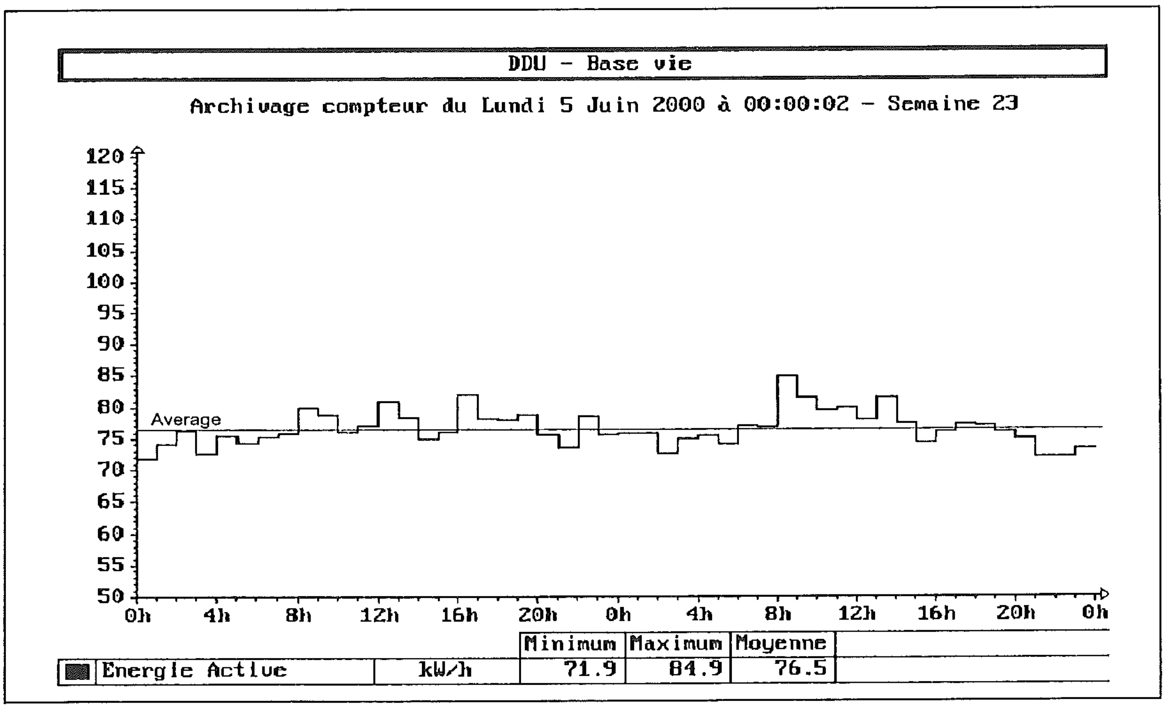

Figure 12: Generator output with load shedding in function

A basic load shedding system only manages the suppression of most load peaks to avoid excessive transitory power surges, protect the generators from overloading and reduce the need for starting up an additional generator. It usually works by switching off a limited number of non-priority appliances in a fixed, predetermined order with the same lowest priority appliance always switched off first. The switching off is triggered when the total load goes over a certain threshold.

The more advanced load shedding function of the Énergie Système™ actually enables a sophisticated, uninterrupted management of the load by sequencing the switching of a large number of electrical appliances. It effectively creates an additional 'load management' function. It operates within a series of individual rules established for each appliance. The rules are designed not to interfere with the satisfactory operation of the end-service it provides and to ensure satisfaction of the end-user.

The appliances involving a thermal process with inherent inertia are the best candidates for management by the system, the more inertia the better. Such appliances include for example electrical heating of small shelters, ovens and autoclaves and heating functions of dishwashers, washing machines and clothes dryers. These appliances have an optimal operating point and an acceptable operating range around the optimal point declared in the system. The optimal point and acceptable operating range can vary in time on a daily, weekly or annual basis but can also vary according to other parameters sensed by the system, such as meteorological conditions or room temperatures.

With control over a wide range of these appliances, the system can finely sequence their operation so that the total load stays as constant as possible and each appliance fluctuates within its acceptable operating range.

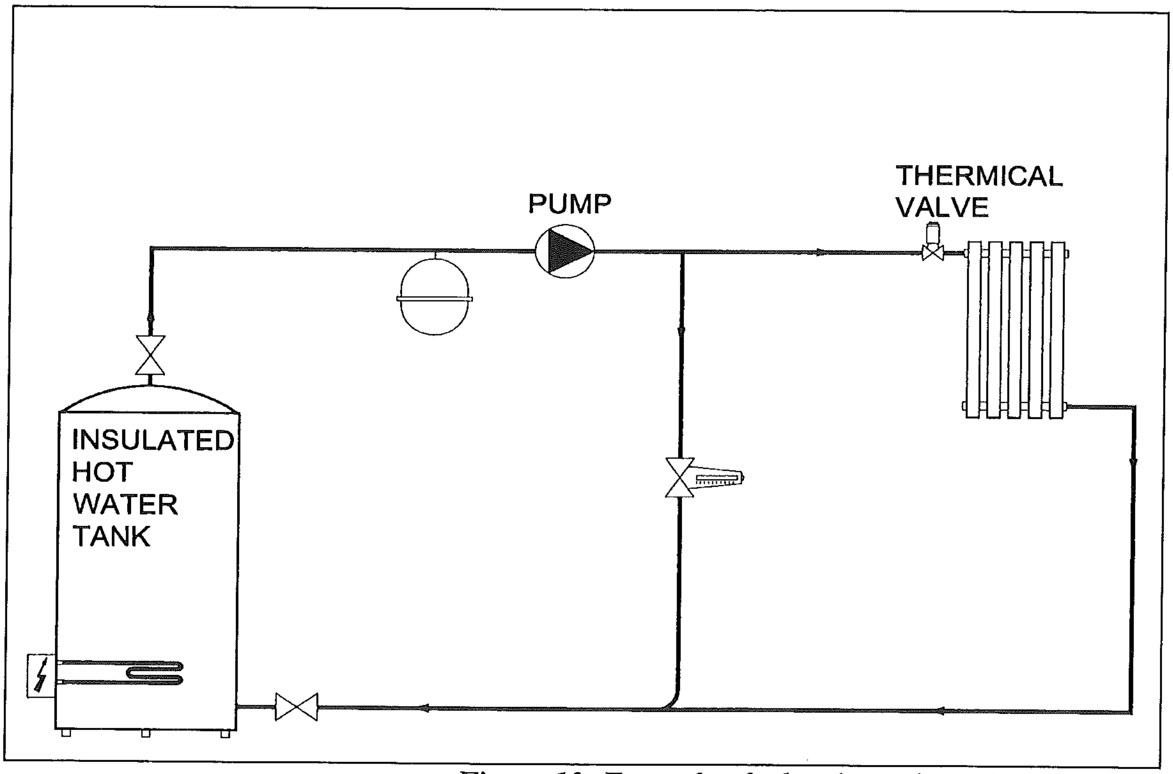

Figure 13: Example of a heating using a hot water tank

To take further advantage of these new capabilities, some appliances and services will where possible be modified to increase their thermal inertia. This can significantly increase the potential of the system. For example, isolated shelters were heated by conventional, dry convector heaters. The thermal inertia of the service is restricted to the limited inertia of the air in the shelter. Many shelters will be progressively equipped with hot water based heating system offering a much higher inertia. The electric heating elements will heat a 500 litre hot water cylinder that will in turn feed hot water into a wall. The room temperature is controlled by a combination of the hot water temperature and a variable flow through the radiator. This offers both a significant thermal inertia and a wide operating range for the water temperature, providing a flexible load highly useable by Énergie Système to manage the station load.

The system can also manage some non-priority on-off type appliances that can be either disconnected for certain predefined time periods where high loads are expected or can if necessary be switched off when operating without significant inconvenience. This includes for example the 11kW garbage compactor. The control of these appliances participates to the basic load shedding function (avoiding power surges and generator overloading) but contributes little to the more advanced load management function.

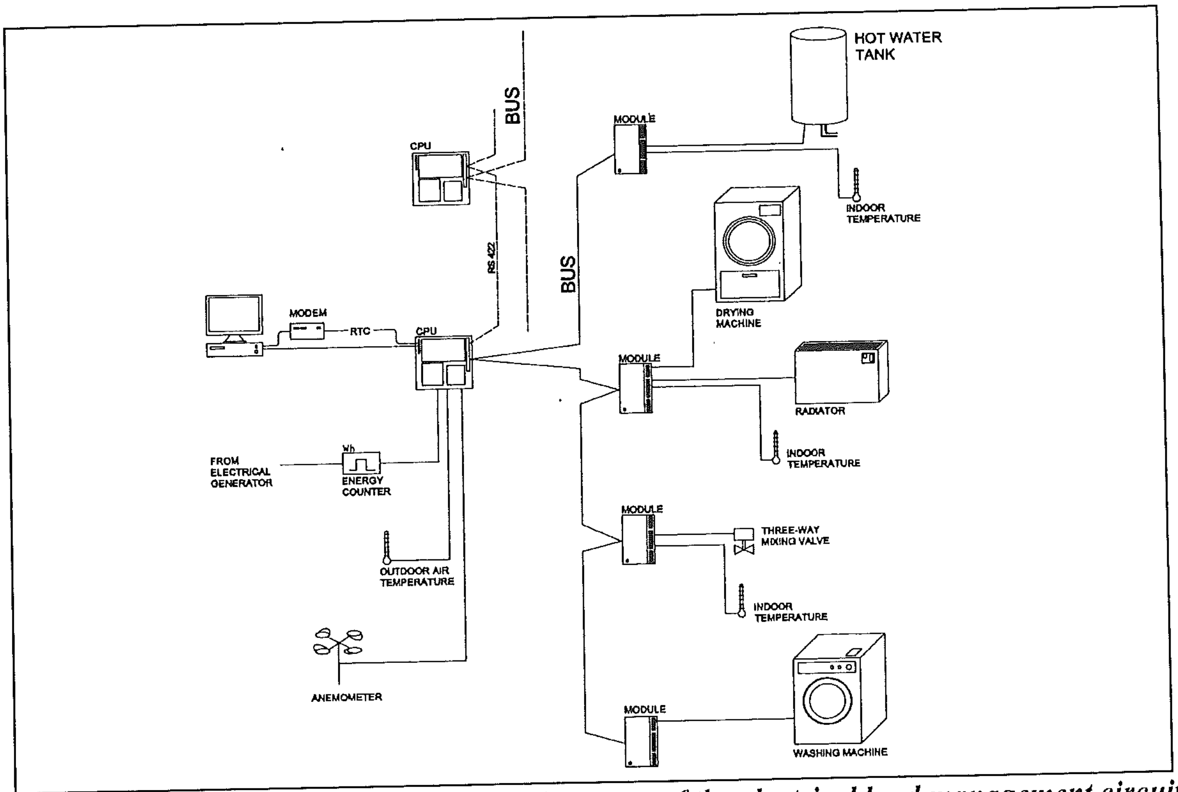

Figure 14 : Structure of the electrical load management circuit

The planned introduction of this load shedding and load management functions of the Énergie Système™ allowed a more precise sizing of the new generator sets and prevented a costly over-sizing of the infrastructure. The effective operation of the system now allows a relatively stable operation of the MPH on one single generator at the lower limit of its optimal range, leaving room for possible future activity increase on station. The past, occasional need for operating two generator sets in parallel has virtually disappeared. It resulted in fuel savings due to an increase in production efficiency. It also resulted in parts, lubricants and man-hours savings due to a decrease in engine hours.

4) INCREASING RENEWABLE ENERGY INPUT

Once station energy needs have been minimised and the power system production and transmission efficiency have been optimised, the obvious way of further reducing fuel consumption and increasing sustainability is to input into the power system as much energy as possible produced locally from renewable sources such as wind or solar radiations.

A solar, photovoltaic array is operational at Dumont d'Urville but restricted to an isolated, standalone set of buildings located at Cape Prud'homme and opened only in summer. The major inconvenient of solar power for year-round Antarctic stations is its marked seasonal variability with negligible output over the long winter. It is not envisaged at this stage to install large solar arrays for the main station.

Dumont d'Urville experiences fairly strong and consistent winds throughout the year with a long term wind speed average over 10m/s. There is a good potential for significant wind generation capacity and some models of wind generators are currently under consideration for use at the station. A new concept of wind generator developed by a French company seems well suited to the station's conditions and a prototype unit should be tested on site in the near future.

As shown in previous sections of the paper, the good, efficient operation of the entire power system relies on preserving an appropriate, stable electrical load and on maintaining an adequate balance between the electrical and thermal loads.

If the traditional fossil fuel based power generation systems used at the station provide power 'when needed', renewable energy sources provide by essence power 'when available' and are characterised by a high level of temporal variations. This means that installing large amounts of renewable energy production capabilities will induce the introduction into a well-balanced system of an uncontrollable and highly variable quantity of power. This will unbalance the station system and jeopardise its efficiency unless the system is capable of a high level of load management including a high level of control of the balance between the electrical and thermal components.

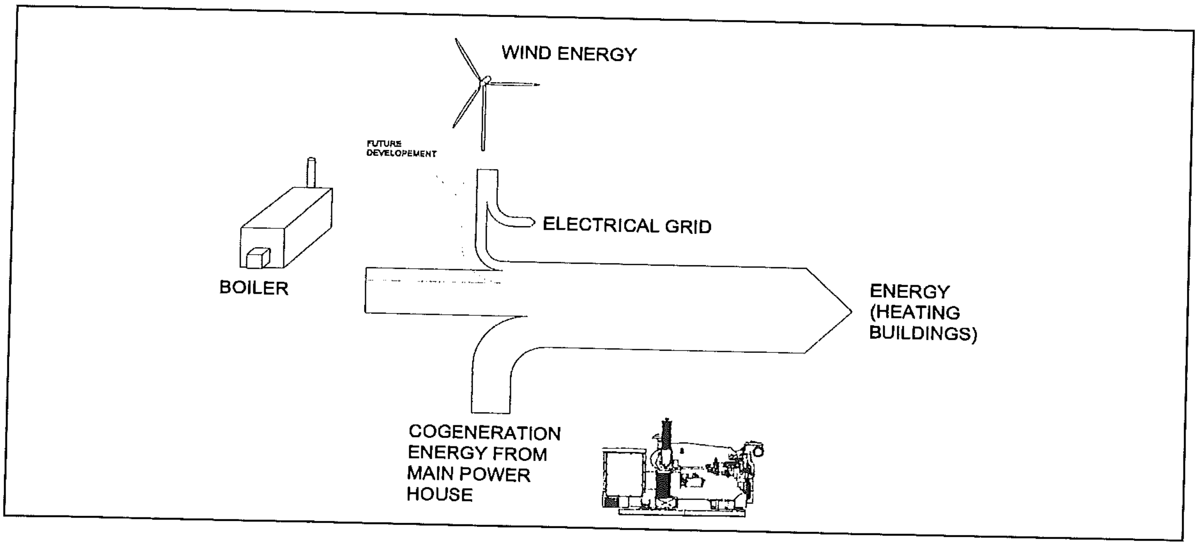

Figure 15 : Renewable energy input

For example, a direct input of electricity from wind generators into the electrical grid of a system where electrical and thermal loads are separated could force the generators to run for long hours well below their normal operating range causing poor generation efficiencies and excessive engine wear.

On the other hand the input of electricity from wind generators into electric heating elements within a similar system at times of low thermal needs, for example in summer, may exceed the low amount of heat needed in complement of the generator heat recovery causing a reduction of the effective cogeneration efficiency.

Of course, such scenarios may still reduce the overall station fuel consumption but they imply a loss of energy and it is important to remember that although renewable sources like wind and solar radiation are free, converting them into power with solar arrays or wind generators is not free. Any loss of energy will correspond to an increase in the unit cost of energy production.

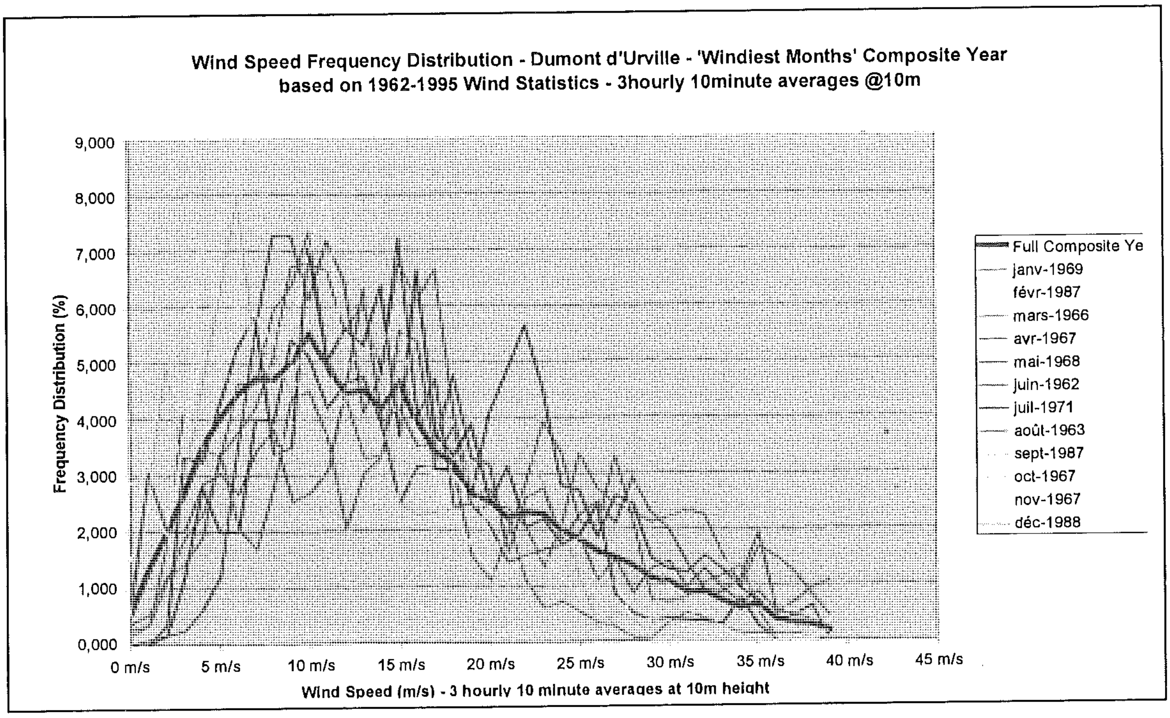

Figure 16: Wind potential

The development of the Énergie Système™ load management function will further allow a dynamic distribution of the load between electrical and thermal components and offer a highly dynamic, flexible power environment where renewable energy input can be used efficiently and smoothly.

CONCLUSION

Dumont d'Urville research station is supported by an efficient, well balanced energy supply system. The recent introduction of a computerised energy management system has contributed to further reductions of the energy requirements and further gains in generation and transmission efficiencies. It also allowed a fine estimate of the needs for infrastructure upgrade, avoiding costly oversizing of new installations. The continuing expansion of the system will provide further improvements and will pave the way for a smooth, efficient increase of renewable energy contributions.

06/07/2000

Power System for the Continuous And Efficient Operation of the new CONCORDIA Station

By

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Background

The French Polar Institute IFRTP and its Italian counterpart ENEA are partners in the installation at Dome C of the permanent research station Concordia. The two organisations have designed a power system that will ensure the continuous, efficient operation of this new station on the Antarctic ice cap. The powerhouse building was entirely mounted in Europe then separated into modules shipped to Antarctica and about to be reassembled on site.

All buildings at Concordia Station are above ground. The two main buildings, Building 1 or "noisy" building and Building 2 or "quiet" building, are two cylindrical structures mounted on piles adjustable in height. Three storey high, these two cylindrical structures contain the research laboratories as well as the living and storage areas. The powerhouse is in a third, modular building mounted on skis. The building is composed of nine modules on a first level and two modules on a second level. Being on skis, the building can be towed away from time to time to level the snow drifts and grade the ground back to its original level.

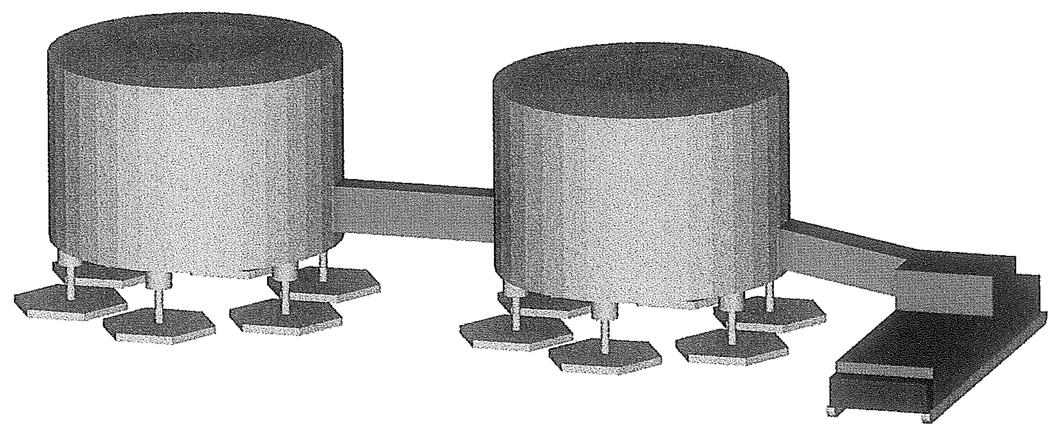

Figure 1 : Concordia station project

Power System Principles

The main design parameter for the station's entire power system was efficiency. The quantity of Diesel fuel consumed at Dome C must be strictly limited both to limit local impacts and limit the quantities of fuel to be transported long distance by tractor trains then stored on site. In normal operations the fuel demand is only driven by the electrical load and by the use of vehicles. All space heating needs are met using Diesel generator set's waste heat recovered from the jacket water cooling system and the exhaust.

The Diesel generator sets can deliver 110 kW electrical at 100% load under Dome C low atmospheric pressure conditions. At this load, manufacturer's specifications indicate that waste heat recovery on the jacket water will provide a similar power of 110kW thermal and recovery on the exhaust will provide a further 45kW thermal.

At full load, 155 kW of waste heat will be successfully recovered in the powerhouse and distributed inside the three station buildings through the heating circuit outlined in this poster. Additional heat will be generated within the buildings by all electrical appliances.

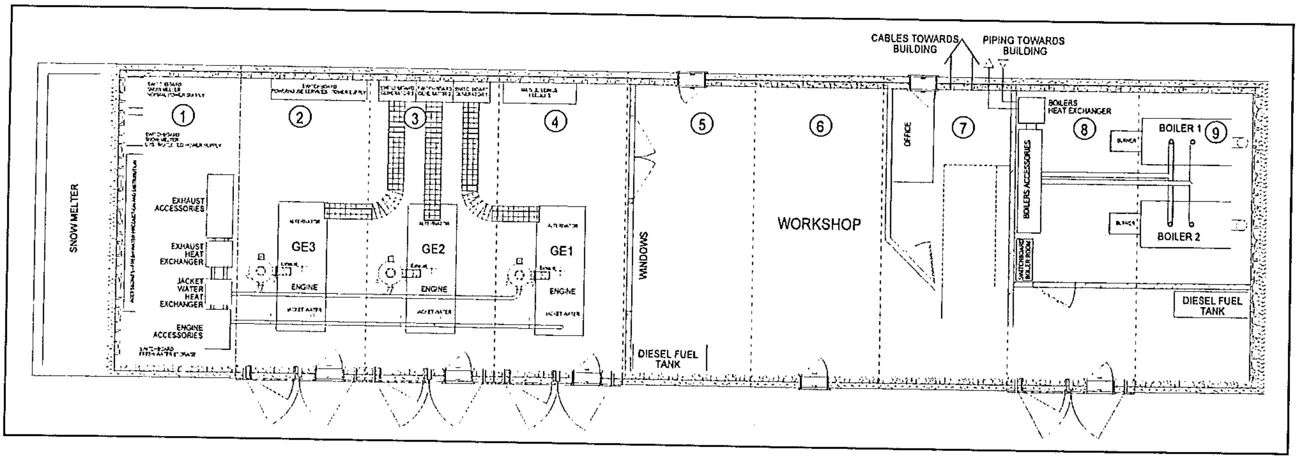

Figure 2: Power house fitting out

Operational simulations of this system indicated that a maximum heat loss of 70 kW for each of the two main buildings would allow the system to run normally without the need for additional heat to be generated in boilers. The external insulation and ventilation system were designed to ensure that heat loss will remain under 70 kW even under the most unfavourable conditions.

Heating Circuit

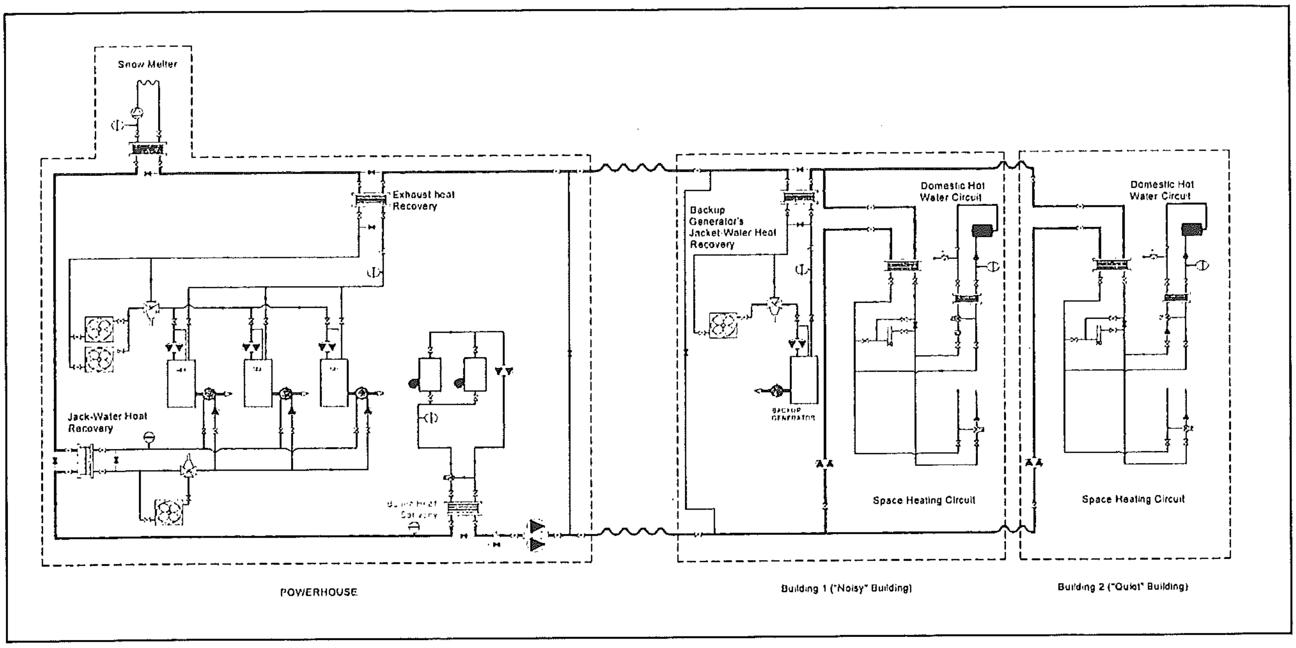

Figure 3: Hydraulic circuits

The heating circuit is separated through heat exchangers in independent circuits. There are three distinct types of circuits: 'production', 'transport' and 'user' circuits. Several independent 'production' circuits provide heat to the 'transport' circuit which then delivers it to several independent 'user' circuits. The domestic hot water 'user' circuits are secondary circuits feeding off the buildings' space heating circuits.

This configuration allows great flexibility and safety in the management of the heating system with extensive isolation capabilities.

- The 'production' circuits are shown in red for the flow from the source of heat to the exchangers feeding the 'transport' circuits then in yellow for the return.
- The 'transport' circuits are shown in orange.
- The domestic hot water 'user' circuits are shown in light blue for the cold water feed to the exchanger then in dark blue for the flow of hot water from the exchanger to the taps.
- The other 'user' circuits are shown in dark green for the flow from the input exchanger to where the heat is used then in light green for the return
- Bypass installations are shown in black.

'Production' Circuits

The jacket-water cooling circuit operates by delivering heat out through an exchanger into the transport circuit. If the cooling is not sufficient, a progressive three-way valve directs some of the jacket-water flow towards a bank of radiators so as to reduce the temperature of the water return to the temperature specified for the engine.

An exhaust cooling circuit delivers heat out through an exchanger into the transport circuit. If the cooling is not sufficient, a progressive three-way valve directs some of the exhaust cooling water flow towards a bank of radiators so as to reduce the temperature of the water return to the specified temperature of 60°C.

A boiler circuit delivers heat out through an exchanger into the transport circuit. The boilers only switch on if there is a deficit of heat; that is if the temperature of the transport circuit flow out of the powerhouse is too low, usually under 85°C.

A backup generator set is installed in Building 1. The jacket-water cooling circuit of this generator operates by delivering heat out through an exchanger into the transport circuit. This generator is not equipped with an exhaust heat recovery system.

'Transport' Circuit

The cooled down water of the transport circuit return enters the powerhouse at the point marked 'E', picks up heat from the jacket water circuit exchanger, goes through the snow melter 'user' exchanger where it delivers heat to melt snow and produce fresh water if necessary, picks up more heat from the exhaust cooling circuit exchanger and from the boiler circuit exchanger then exits the powerhouse at the point marked 'S' towards the two main buildings.

The hot water of the transport circuit flow enters Building 1 where it separates into two lines. One line feeds Building 1's user circuits while the second line goes through to Building 2 where it feeds that building's user circuits. Building 2's return line comes back into Building 1 where it merges with that building's return line. The common return line goes first through the backup generator set's jacket water circuit exchanger where it can pick up heat when the generator is running, then goes out of Building 1 and back into the powerhouse.

The transport circuit can be isolated into two loops, one into the powerhouse and one between the two main buildings. In the powerhouse the excess heat of the jacket-water and the exhaust cooling would then be dissipated into the radiator banks. In the main buildings the backup generator could be used to feed some heat into the transport loop.

Space Heating 'User' Circuits

Each of the two main buildings has one space heating circuit. This circuit includes 24kW of electric heating elements capable of providing significant amounts of heat directly into the circuit if necessary, for example if there is a problem on the transport circuit. Under most normal conditions, the 24kW plus the heat dissipated inside the building by all usual electrical appliances would be sufficient to maintain the building at a reasonable temperature. This means isolating one or both buildings from the transport circuit would not prevent its normal operation. It would only increase the electrical load on the powerhouse and fuel consumption.

Reliability through Simplicity

Dome C is particularly cold and isolated. We considered it dangerous to rely on entirely automated or excessively sophisticated equipment:

- If a fault occurs in the control system, it is better to operate the equipment manually than to spend time investigating the fault then fixing a sophisticated electronic control system.
- The personnel has to be operational quickly upon arrival at the station, which is easier to achieve with a control system requiring little intervention.

At Concordia, the power system does not operate automatically. Generator sets have to be started and stopped by an operator and the frequency and voltage regulators can function manually. There is a high level of redundancy. There are three generator sets in the powerhouse and one in Building 1 while only one is needed at any time. All pumps have one backup unit placed in parallel and switching from one to the other only requires the simple, manual operation of a set of valves.

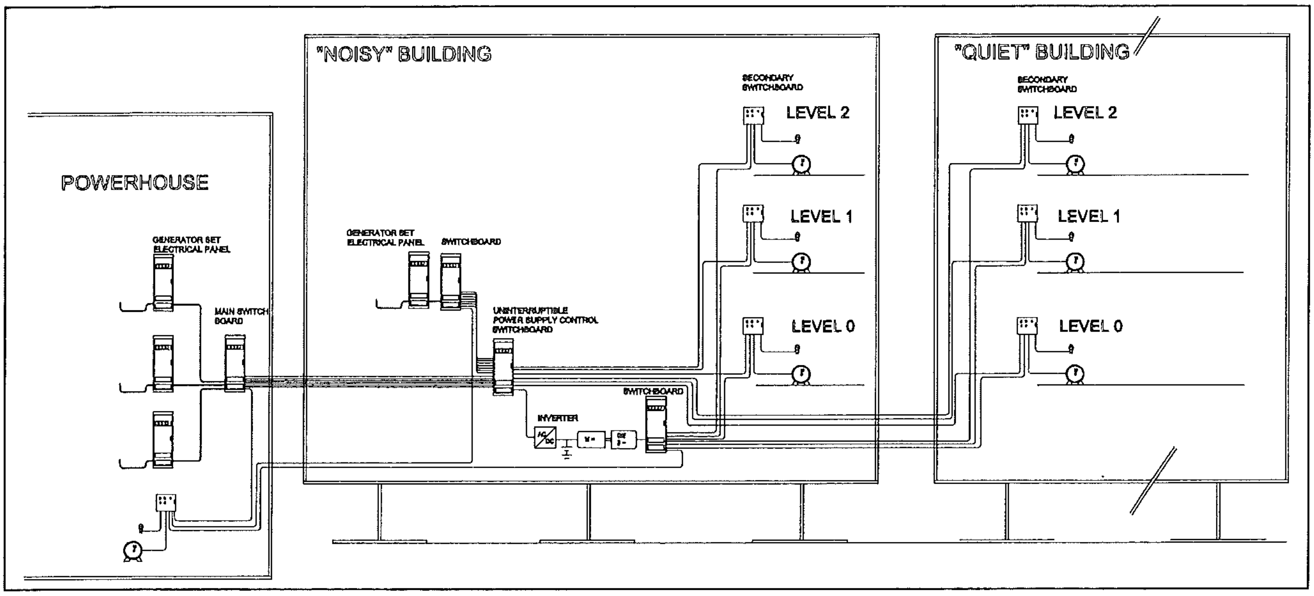

Figure 4 : Electrical grid

Monitoring

An extensive monitoring network constantly sends information to a central alarm panel. The parameters monitored and controlled include:

- Pressure, temperature and flow of the liquid circuits, all pressurised between 50 and 100 kPa.
- Status (starting, on, off, faulty) of all appliances.
- Temperatures in buildings and status of all external doors.

Uninterruptible Electrical Supply

Three dynamic inverters connected to a battery bank provide an uninterruptible electrical supply system. Dynamic inverters were preferred to static inverters. Static inverters are more complicated to maintain and are sensitive to storage in low temperatures. If the normal electrical supply fails, the system can feed the major appliances, including lighting, for about one hour.

Fire Protection

The powerhouse building is made of non-combustible materials: steel-rockwool sandwich panels for the walls, cellular concrete for the floor. Generators and boilers are installed in two separate rooms.

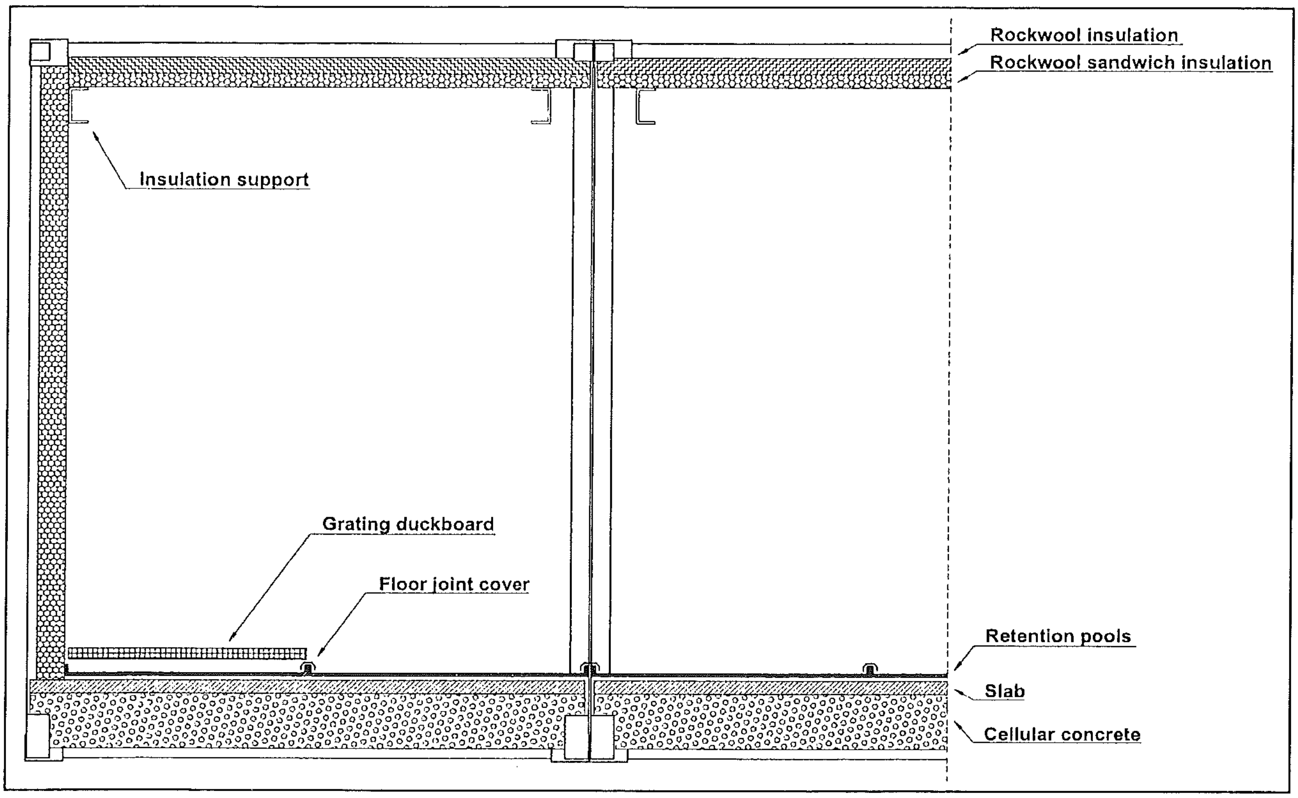

Figure 5: Power house units, tranversal section

Two separate, parallel networks of extinguishers provide a high level of fire fighting capabilities:

- A network of individual extinguishers.
  Each generator set and boiler is fitted with a totally independent fire extinguisher. This extinguisher is equipped with a simple, mechanical automated trigger system backed up by a manual trigger system that can be activated either locally, or remotely from the powerhouse control room.

- Two large extinguishers
  Both the generator and the boiler rooms have a separate, large extinguisher bank for the entire room.

The whole three station buildings have fire detection sensors feeding information constantly into a dedicated fire alarm panel.

Environmental Protection

The exhaust cooling system installed on the Diesel generator sets does not only allow the recovery of waste heat. It also allows the condensation of some of the water vapour produced in the engine combustion process, thus reducing the impact of water vapour on the quality and clarity of the atmosphere surrounding the station.

The latest catalytic converters will be be fitted to clean out exhaust gases.

The floor of each module of the powerhouse building is fitted with a four centimetre deep retention pool to contain possible spills of liquids: heating water, coolant, lubricant or fuel. Where necessary, grids provide a walking path above the retention pool.

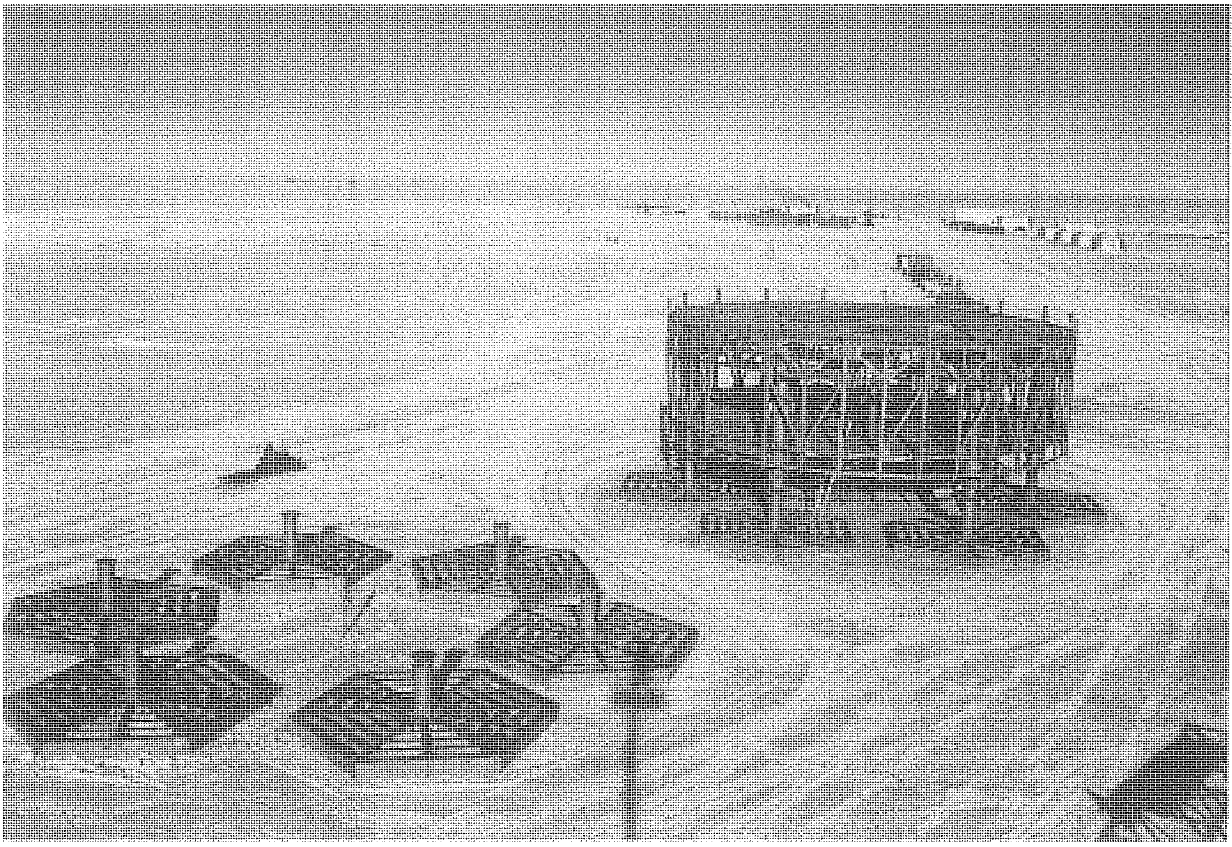

Figure 6: View of the construction site

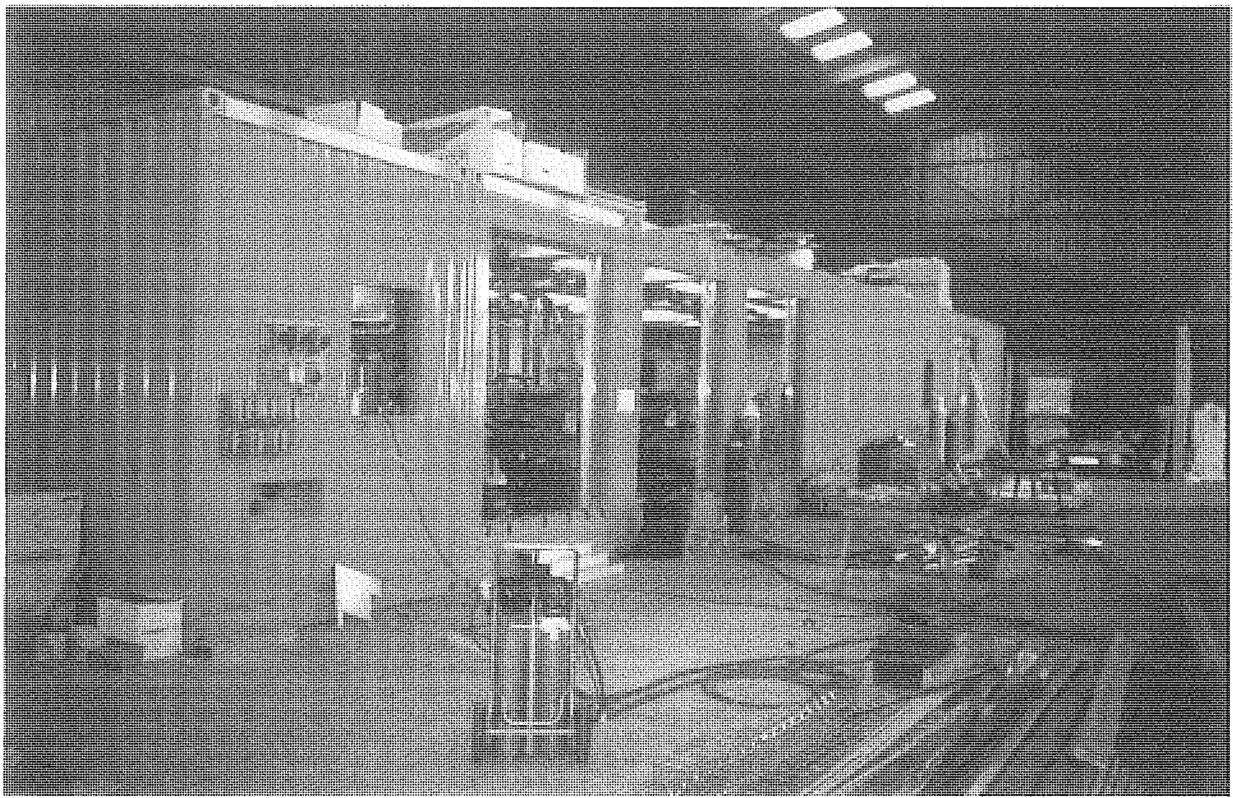

Figure 7: View of the power station during mock mounting

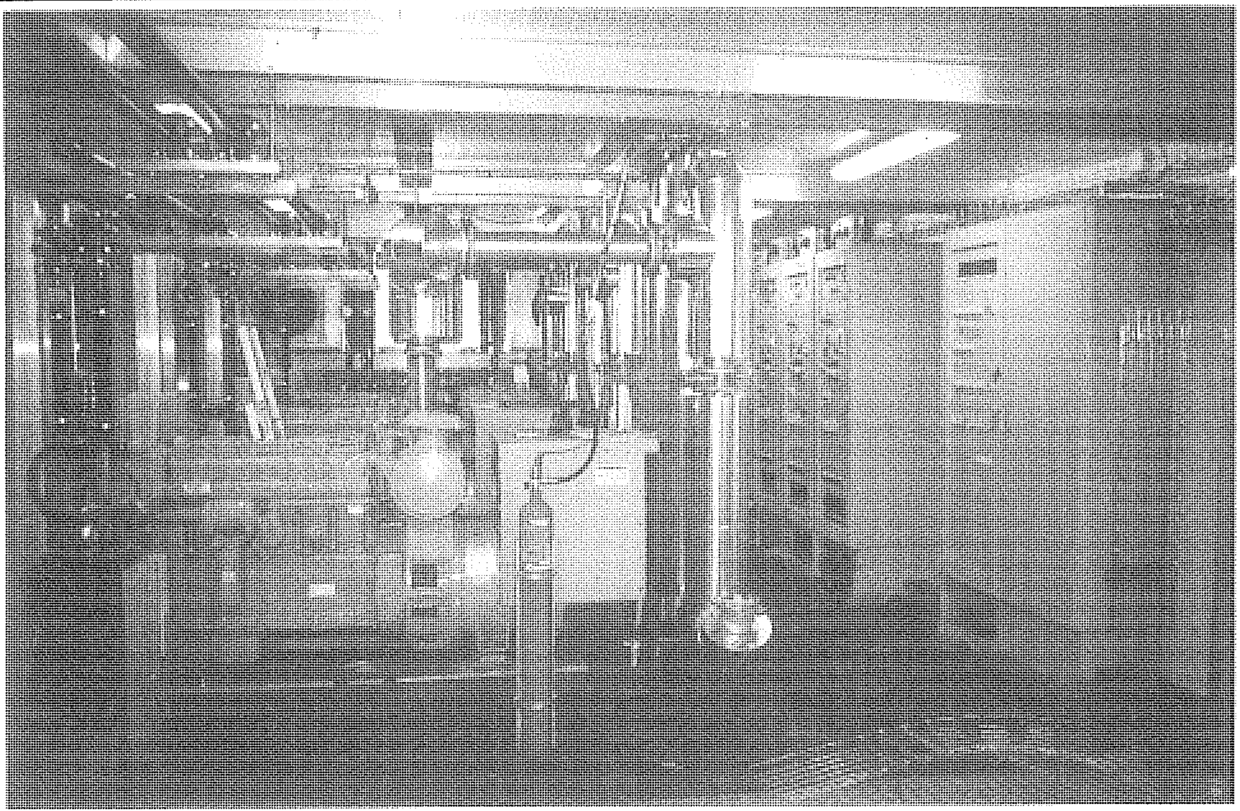

Figure 8: View of the power station during mock mounting

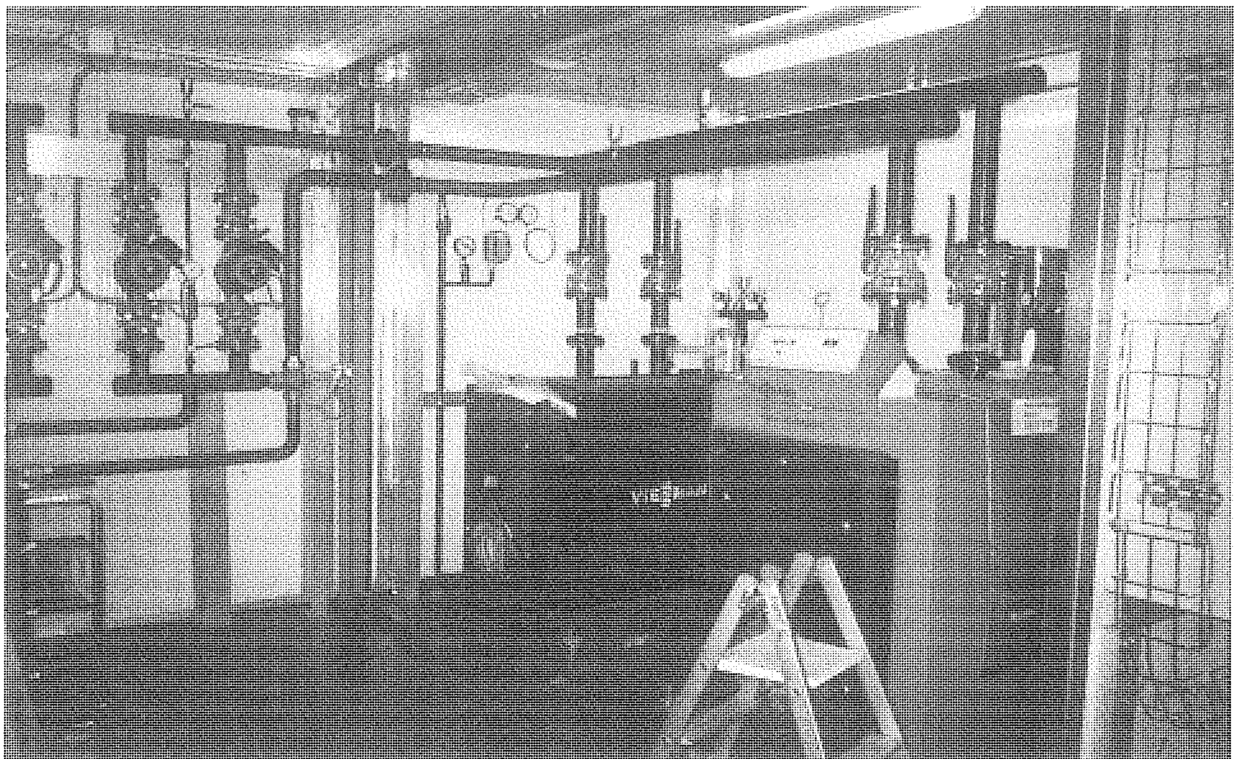

Figure 9: View of the power station during mock mounting

The Use of Building Monitoring and Control Systems to Reduce Energy Consumption in Antarctic Stations.

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Introduction

Australia has three permanent stations on the Antarctic continent – Casey, Davis and Mawson, and a station on subantarctic Macquarie Island. (Figure 1). Their primary role is to serve as a base for the support of Antarctic science. As a result of rising prices, and to allow funding to be redirected to the direct support of science in the Antarctic, opportunities to reduce the operating costs of the stations are continually being sought. Of course, it is also good engineering practice to do so.

This paper discusses the use of a Building Monitoring and Control System (BMCS) as a tool to better understand the various engineering systems in place at Australia's continental stations so that their operation may be monitored and optimised. In this way, station amenity is maintained while a reduction in the station operating costs is expected.

Station Description

In the early 1980's, Australia commenced a program of replacing the old timber station buildings with modern, steel framed energy efficient buildings. This rebuilding program was completed in the mid 1990's leaving Australia with large, modern and comfortable stations.

The present stations consist of a number of discrete buildings that are separated to reduce the impact of any fire. The buildings are thermally efficient and have sophisticated heating and ventilation systems.

Power at the stations is generated using diesel generator sets. Each station has two powerhouses and the main powerhouse at each is fitted with four (4) generator sets of 110 kW rated capacity. As station electrical load varies, either two or three of these engines is requires to meet the electrical needs of the station.

Maximum use is made of the waste heat that is generated in the power houses by using it to heat water. This "heating hot water" is pumped around the stations and provides the primary means of heating the buildings. Fuel fired boilers provide make up heat when required. The site service pipes are insulated and fitted with heat trace to ensure freeze ups don't occur. An end-of-line relay provides an indication of whether that particular heat trace is on or not.

Water production at Mawson and Casey consists of a melt bell that utilises heat from the site services, supplemented by a diesel fired boiler, to melt fresh water in melt lakes adjacent to the stations. At Davis, a reverse osmosis plant produces water over the summer months from a saline tarn. This water is stored in two 600 kl tanks for use over winter.

The Building Monitoring and Control System Basics

A control system is not unlike a standard computer system in that it consists of inputs, outputs, hardware and software:

- The inputs to a control system are in the form of sensors and switches such as temperature sensors or push button switches.

- The hardware in the Australian Antarctic Divisions case is a Single Board Computer (SBC). Other sorts of Control System hardware include Distribution Control Systems (DCS), Programmable Logic Controllers (PLC) or Micro Controllers.

- The outputs for a control system can be either hardware based such as starting a pump, opening a valve or turning on a light, or software based such as raising an alarm, collecting field data or undertaking calculations.

- The software in a control system is usually programmable by the end user. Its main purpose is to let the hardware know how to monitor the inputs and control the outputs. The system software in our system is "inet 2000".

An overview of the system is shown in Figure 2.

The Project Timing

The impetus for the BMCS project came when an audit of the system that was in place in 1988 revealed that the data loggers used were not Y2K compliant. Additional funding became available in mid 1998. A specification was developed and tenders called in late 1998. CSI pacific was selected as the preferred tenderer, and work commenced with a view to delivering equipment to the stations on the last voyage of the 1998/99 season.

The deadline was met, and in February 1999, the system was shipped with recently recruited and trained electricians to the stations of Mawson, Davis and Casey, arriving during March 1999.

Installation of equipment commenced as soon as the equipment arrived. Across the three stations, a total of 63 cabinets containing 115 Process Control Units (PCUs), were installed at the stations. Over the next 5 months, the Project Electricians between them connected up approx. 2800 sensors and switches.

Programming was carried out concurrently with the installation of the sensors and switches and was completed in October 1999. Thus, the initial system was up and running within 8 months after the arrival of the equipment.

The system can be monitored, programmed and configured from the Australian Antarctic Divisions head office at Kingston in Tasmania. This is achieved through the Divisions Satellite based Wide Area Network (WAN). This is particularly useful feature of the system in that it provides a way in which Head Office engineers can assist the on-site trades people in the maintenance and operation of the stations.

Monitoring to Date

It was mentioned earlier that "heating hot water" is pumped around the stations and provides the primary means of heating the buildings. In fact, the station buildings are connected via a system of pipes referred to as "Site Services". These pipes carry the heating hot water, potable and fire sprinkler water as well as the sewage. These pipes are heat traced which is perhaps best described as "Electric Blankets" on the pipes. The Electric Blankets are designed to turn on when the contents inside the pipe gets - too cold and thus prevent the pipe from freezing. . The BMCS monitors the temperatures within these pipes these pipes and the status of the heat trace. (See Figure 3).

The system also monitors the flow and pressure of the potable water system, and will soon be connected to storage tanks to give an indication of water levels and water production rates. The status of water making equipment is currently monitored at Mawson as shown in Figure 4.

Also, typically, the BMCS is monitoring the temperature in a range of building spaces and controlling primary and zone specific air heating coils as shown in figure 5. The system also monitors the status of electrical switch boards, fire panels and power house engines (figure 6).

The items currently being monitored in the main powerhouses include the status of the engine (online or shutdown), engine warnings, fuel flow, fuel consumption, Fuel Consumption, Power Generated, Power Consumed, Heat Produced, and Hours Run as shown by Figure 6.

Other uses to date include using the BMCS to monitor air quality (CO^2, CO, Methane and Hydrogen Sulphide), and monitoring wind speed, wind direction and relative humidity through an interface to the meteorological automatic weather stations.

A recent innovation is to use the text alarms generated by the System to send alarms to pagers which are capable of receiving text messages. This system allows a duty trades person to be in 24hr contact with the equipment they are responsible for.

Energy Monitoring

An ultimate goal of the use of the BMCS is to reduce the operating costs of the stations. A key part of this is to identify where the energy is being used, and to assess the success of any optimisation strategies developed. The stations use both electrical and thermal energy, both of which are logged by the BMCS. Logging of electrical energy is undertaken with electrical energy meters. Logging of thermal energy is undertaken using flow meters and temperature sensors, and a calculation to determine energy in kW.

To date in the project, a total of 111 electrical energy metres are connected and are measuring electrical energy usage. Thermal energy is calculated using data from 24 flow meters and 150 temperature sensors.

Mawson Cold Store Project Case Study

At Mawson station, a new cold store was constructed over the winter of 1999. The cold store uses outside radiators as heat rejection units and has conventional compressors as a backup.

The final result is two energy efficient cold stores used for the long term storage of food, one at 6 deg C and one at 2 deg C. Their operation is shown in figure 7.

The cold stores when completed used on average 20 kWh per day compared to the original refrigerated containers which had an estimated usage of over 100 kW per day. The BMCS was connected to the system to control the number of fans and pumps, and the energy usage dropped to 16 kWh – a saving over the "uncontrolled" system of 20%. (Figures for July indicate a usage of approximately 7 kW per day).

Davis Workshop Lighting Project Case Study

An energy audit was undertaken at Davis Station in 1998. Figure 8 shows the results. An analysis of the results (Figure 8) revealed that the Davis workshop seamed that have an inexplicably high energy usage, especially when compared to other similar sized buildings.

Investigations into the load revealed that the lighting was a major consumer of electrical power. The latest in lighting was researched and a decision taken to replace the existing lighting system.

A total of 327 old fluorescent tubes were replaced with 172 triphosphur tubes mounted in new mirror like reflectors. The new lights were rotated to maximise use of reflection from walls, and lowered. They were also powered through a proprietary "Eco-Box" light voltage control system.

The light switching system was also replaced using Clipsal's C-BUS technology. This allowed the automatic switching of lights on to provide a pathway, it allowed people to choose the amount of light they required, and it provided a means for people to switch off all the lights in the workshop with a single switch located at each exit. The C-BUS system included 15 PIRs, a total of 50 new switches, and the grouping of lights into 44 groups. The whole building was then connected to the BMCS for duplicate control.

The end result was a 40% increase in the light levels available.

Other changes in the building included BMCS control of the air handling system, the workshop air compressor, and the floor heating coils. The total reduction in energy usage as a result has been estimated to be 56%. Based on the then pump price for diesel, this represents a pay back of less than two years.

Conclusions

The BMCS project has allowed the Australian Antarctic Division to gain a better understanding of energy usage at the three Antarctic Stations of Davis, Casey and Mawson. It has also allowed the automation of some of the station engineering systems which have allowed them to be optimised resulting in a reduction in operating costs of the stations. It is expected that a number of other projects will be able to be completed over the coming years which will allow the operating costs to be reduced even further.

Figures

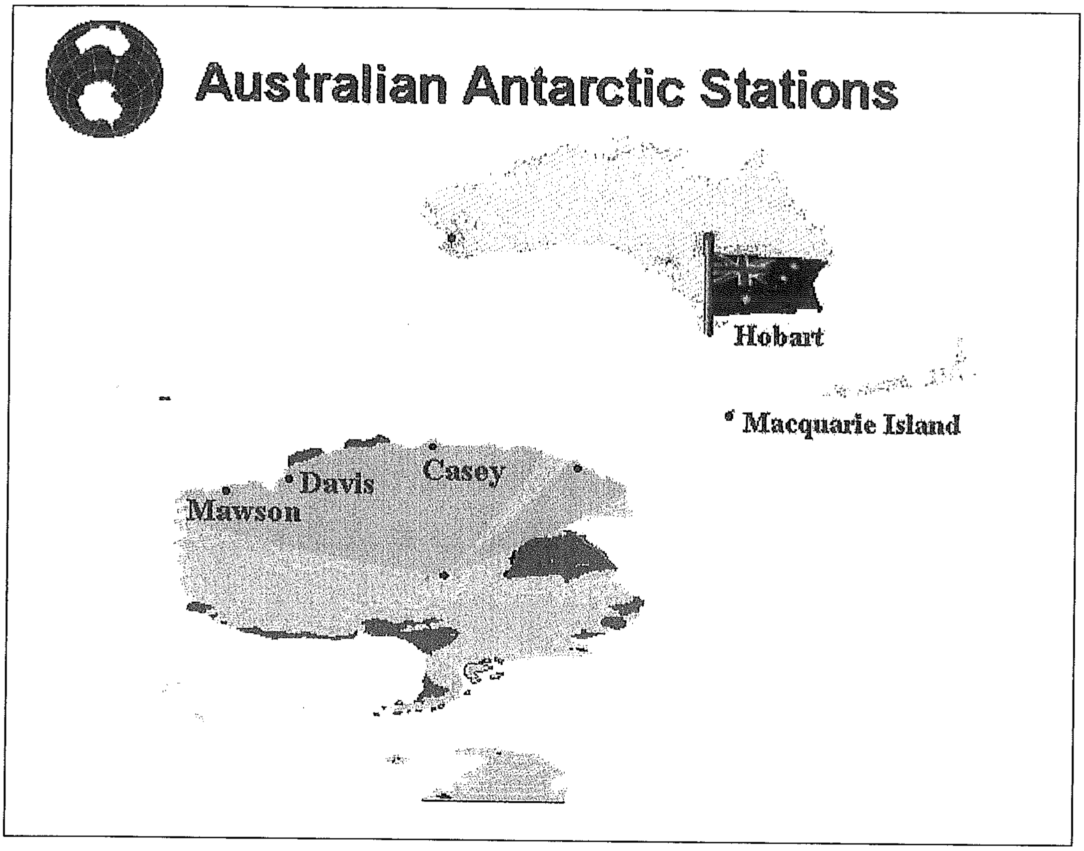

Figure 1 - Location of Casey, Davis and Mawson

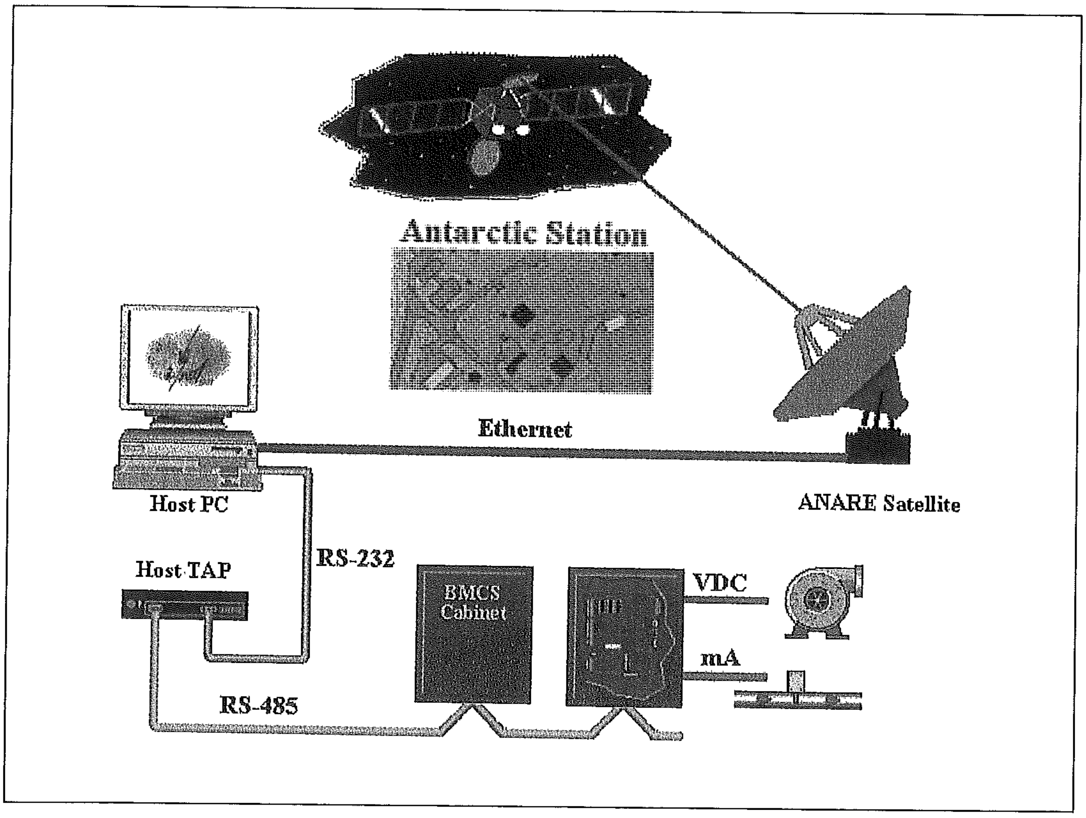

Figure 2 - Schematic of BMCS communications

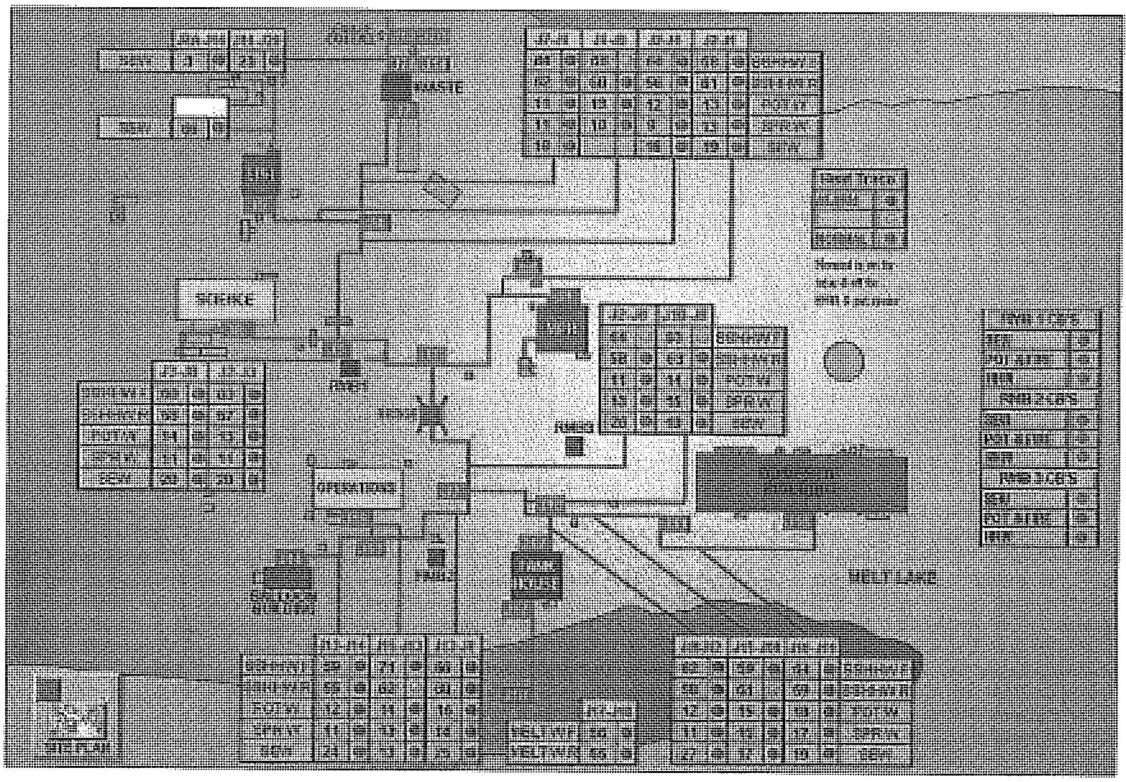

Figure 3 - Site Services monitoring

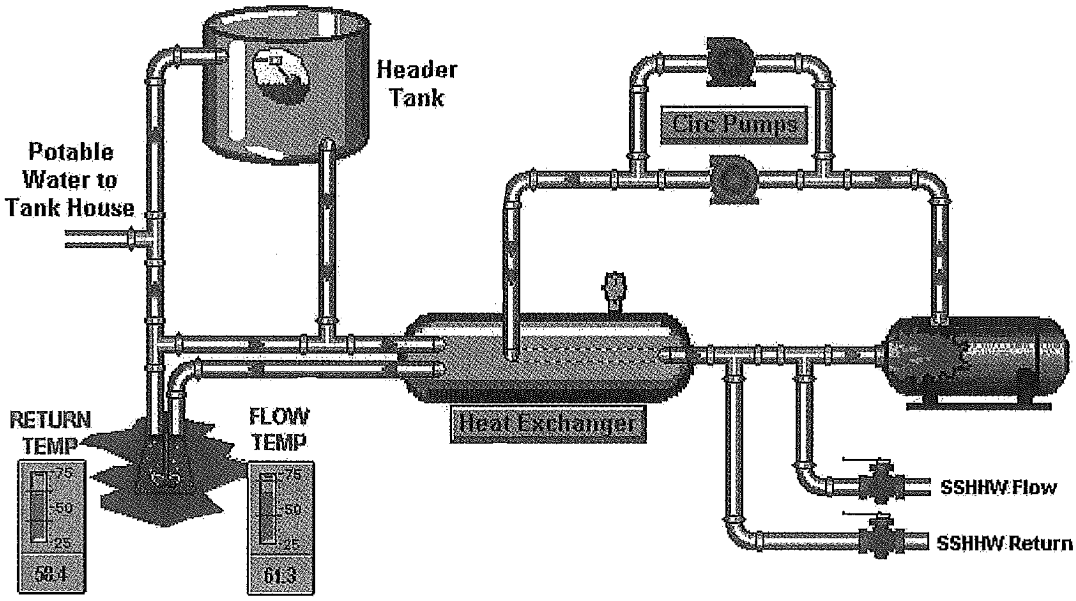

Figure 4 - Water production monitoring

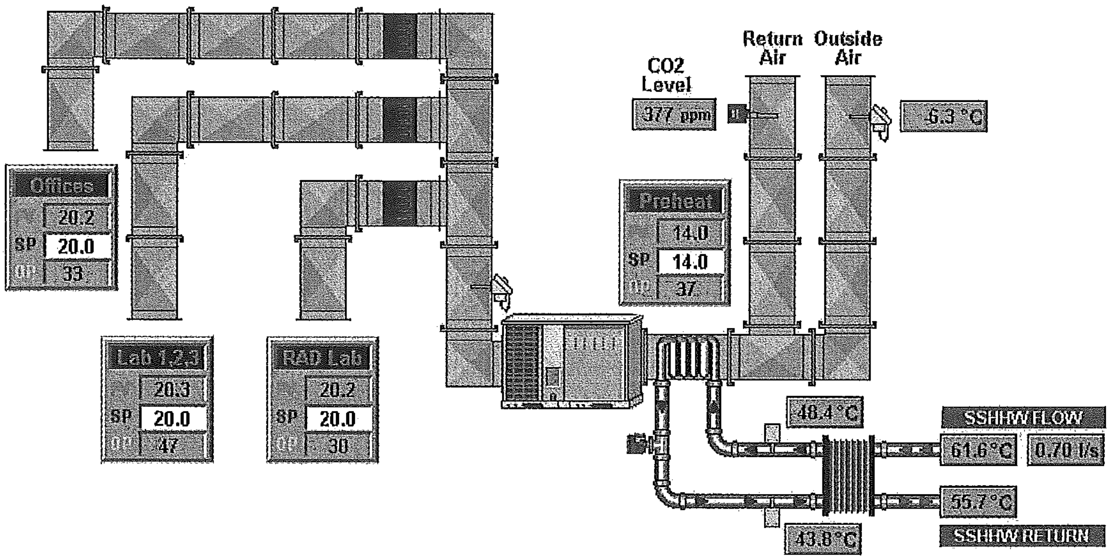

Figure 5 - Heating and Ventilation

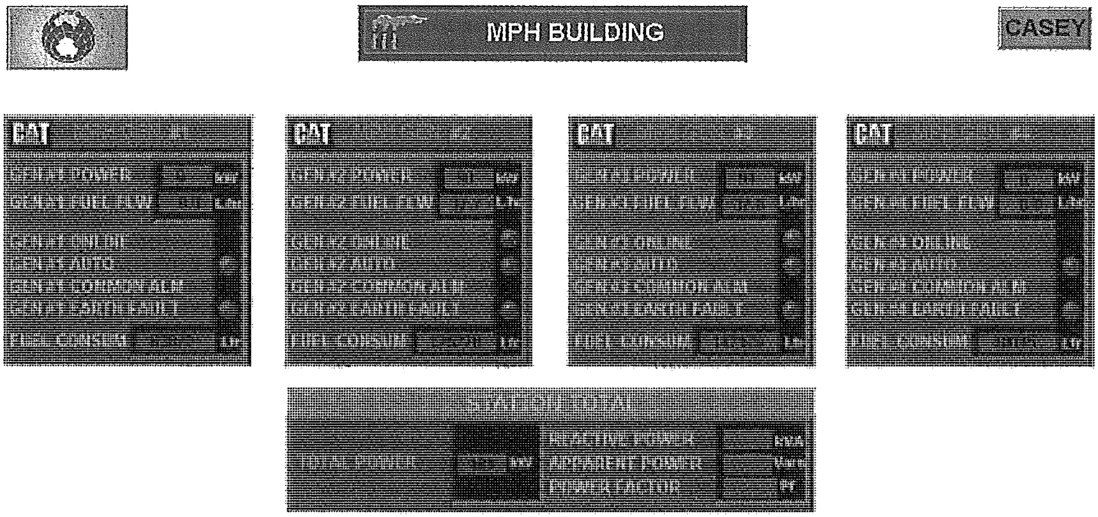

Figure 6 - Power house monitoring

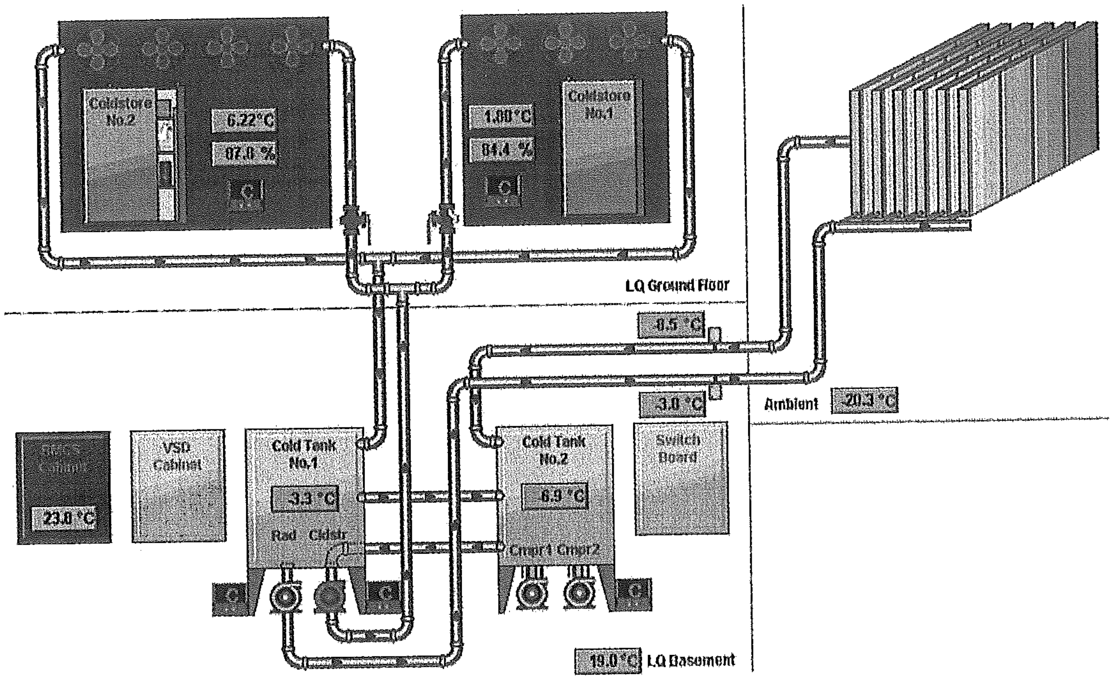

Figure 7 - Mawson cold store monitoring

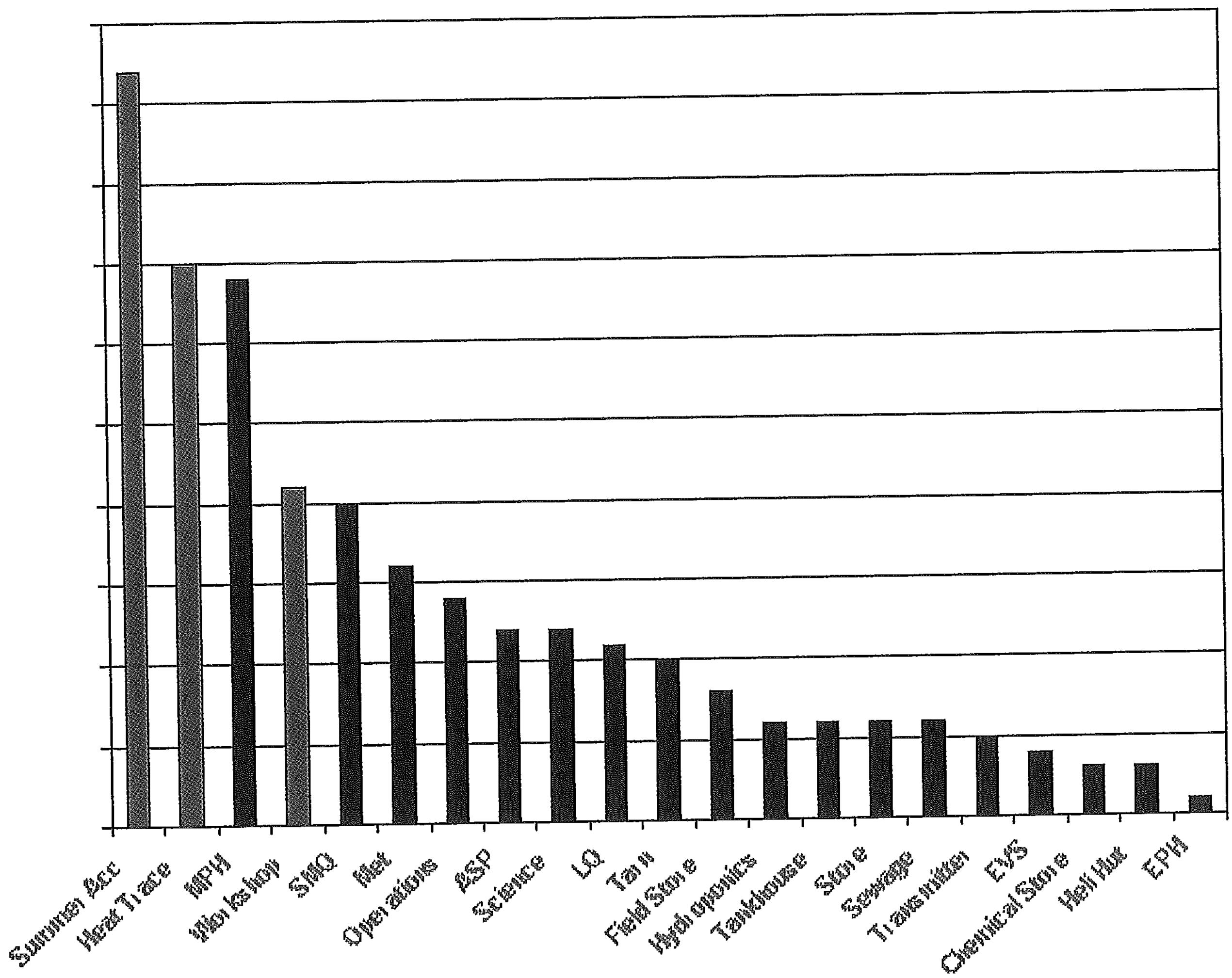

Figure 8 - Results of Davis energy audit

Energy Services: Back to Basics and Up to Hybrids

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ABSTRACT

The provision of energy services has always held a vital, central role in the support of Antarctic research operations. Progressive increases in research activities and in the standard of facilities have combined to expand the scale and importance of the infrastructures dedicated to the provision of energy services. These infrastructures rely almost exclusively on imported fossil fuels.

Over the last decade there has been an increasing emphasis on the reduction of both the quantity of fossil fuels used and the environmental and operational impacts of the infrastructures. As a result, several wide-ranging studies have been conducted, focusing on the characteristics of the current systems and requirements, on the resource potential for renewable energy production, on the technological and operational aspects of renewable production and energy storage and on the potential of advanced energy management systems.

This paper reviews the basic concepts of energy requirements and energy production and distribution. It then outlines how the evolution of the stations' energy networks towards less fossil fuel dependence and decreased impacts is linked to the evolution towards hybrid networks mixing multiple power generation options and interactive electrical-thermal combinations controlled by advanced energy management systems.

The focus is on fixed, hybrid station energy supply networks providing heat and electricity without large, expensive add-on storage capability and hence retaining a minimum amount of fossil-fuel based power production. The aim is to provide a clear, synthetic view of the main guiding principles of the design and operation of the most realistic, reliable options available with current and emerging technologies.

This paper also clarifies the reasons behind the current development of energy management strategies and new equipment installations at the Australian and French Antarctic research stations. It can be read as an introduction or complement to papers and posters presented at the SCALOP 2000 symposium by Bonnice et al, Alain et al, Magill et al and Williams et al.

BASIC NETWORK STRUCTURE

The stations' energy supply networks are established to provide energy services required for the good operation of the stations in support of research activities. The structure of the network is based on the fundamental flow: Energy Production to Energy Carrier to Energy Service.

Figures 1 to 4 outline different configurations of this fundamental structure. Generator sets, boilers and renewable systems produce a mix of heat and electricity. Electricity is used to satisfy the basic electrical demand of non-heating services plus a certain amount of the heating demand. Heat is used to satisfy the rest of the heating demand. The quantity and scheduling of the electricity diverted to heating services is the element that can provide the stability and optimal efficiency of the entire network.

Various primary energy production devices feed a combination of two energy carriers, heat (thermal carrier) and electricity (electrical carrier) which in turn power the energy services divided in two main categories, heating services and non-heating services (see Figures 1 to 4).

ENERGY SERVICES

Energy Services are essentially divided in heating and non-heating services.

Heating services are the services whose primary function is to deliver heat. Examples are space heating, domestic water heating for showers, oven heating, water heating in dishwashers or washing machines. These heating services have two important characteristics:

- an inherent inertia hence an **inherent buffer storage capacity**.
- the capability of being **powered with a combination of heat and electricity**, combination often very flexible.

The operation of heating services usually requires the simultaneous operation of less intensive, accessory non-heating services such as the operation of a pump or a control system.

Non-heating services are all the other services. Examples are the operation of a pump, a computer, communications or lighting. It must be noted that the operation of these services may dissipate heat as a by-product but it is not their prime function and more importantly it is not the amount of heat that will determine the level of operation of the service. These non-heating services have:

- no inherent inertia hence **no inherent buffer storage capacity**.
- to be **powered exclusively by electricity**.

Most of these services tend to operate 'when needed' with little scheduling or variation flexibility. These services control the minimum, 'bare' electrical load demand.

ENERGY CARRIERS

Stations' energy networks usually include both an electrical and a thermal energy carrier. The presence of the thermal carrier is not strictly necessary since all heating services could be powered exclusively by electricity but it is generally well justified by the facts that 1) a large amount of waste heat can be recovered on the electricity generation process and 2) heat-only can be produced much more efficiently than electricity-only.

The electrical carrier takes the form of an electrical cable network or electrical grid reticulating electricity around the station.

The thermal carrier usually takes the form of a pipe network reticulating heating hot water (HHW) around the station. Heat is then delivered to the services through heat exchangers. Operation of the HHW network requires a minimum of electricity for the circulating pumps and controls.

FOSSIL FUEL BASED ENERGY PRODUCTION

Most stations currently generate the bulk of their electricity and heat with diesel or kerosene fuelled generator sets and boilers.

Generator sets are designed to generate electricity in an alternator driven by an engine but a large proportion of the heat dissipated in the engine can be recovered from both the jacket water and the exhaust. When operating within its optimal load range, usually between 80 and 100% of its rated capacity, a good current model generator set will convert 37% of the fuel energy content into electricity and 42% into recoverable heat, giving a combined cogeneration efficiency of 79%. It must be noted that operating the generator outside of its optimal range will not only decrease these efficiencies but also increase the wear and tear of the engine. It will increase the cost of maintenance per unit of electricity produced. It is important also to note that the quantity of heat produced with the generator sets is only function of the electrical demand, not of the heat demand and that the production of any excess heat not required by the station effectively corresponds to a decrease in production efficiency.

A good boiler will convert 80% of the fuel energy content into heat and will only be switched on to respond to heat demand. A boiler can easily be operated in on-off sequences at its optimal load because of the inherent inertia of the heat carrier behind it.

These conversion or production efficiencies are relative to the 'lower heating value' (LHV) energy content of the fuel. The LHV of the special Antarctic blend diesel fuel (SAB) used by the Australian and French Antarctic programs is 9.8 kWh per litre.

This means that burning one litre of SAB Diesel fuel will produce

- 3.6 kWh of electricity and 4.1 kWh of heat in a generator set
- 7.8 kWh of heat in a boiler.

RENEWABLE PRODUCTION

The fossil fuel based 'on demand' production can be supplemented by heat or electricity produced ' when available' by renewable resources conversion system. The most likely conversion systems to be used are wind generators and photovoltaic panels producing electricity and solar thermal systems producing heat.

ENERGY NETWORK PRINCIPLES

The "true efficiency" of the system is directly related to the output-input ratio where the output is the effective service in support of research activities and the input is the quantity input into the system. For fuel efficiency the input is the quantity of fuel and for financial efficiency the input is the financial cost supporting the system, including purchase, installation and maintenance costs. It is not the intention of this paper to discuss what an "effective" service may be or how it may be assessed. It will be assumed here that the services provided are both legitimately needed and fully used.

The main guiding principles are:

- The total electrical load (bare electrical load + load diverted to heating services) must be stable and stay within the optimal operating range of the generator set(s).
- The heat recovered from the generator sets must be inferior to the heat demand (demand of heat on the thermal carrier from the heating services).
- The power produced by renewable systems should be used as much as possible. The resource may be free but the purchase, installation and operation of the conversion system is not free and any wastage corresponds to an increase in the cost of the useful energy produced.

Figures 1 to 4 outline four different configurations of this fundamental structure. Generator sets, boilers and renewable systems produce a mix of heat and electricity. Electricity is used to satisfy the basic electrical demand of non-heating services plus a certain amount of the heating demand. Heat is used to satisfy the rest of the heating demand. The extent and flexibility of the capability to divert electricity to heating services is the element that can, with adequate control, provide the stability and optimal efficiency of the entire network.

The management of the diversion capability requires an advanced, automated management system with control over a large number of energy services. The potential of the management will depend on the number and variety of heating services controlled but also importantly on a significant thermal inertia of the services.

Figure 1 shows the common configuration still widely used. This is essentially a fossil fuel based system with no diversion capability. The thermal carrier feeds a first group of heating services while the electrical carrier feeds a second group of heating services as well as the non-heating services. The two groups of heating services are dissociated and are both calling for power when it is required by their own operating rules without any regard to the operation of the rest of the system. Such a system is characterised by very limited load shedding capabilities, relatively high bare loads and potential heat excess.

A typical, progressive evolution of the configuration shown in Figure 1 involves an increased control of the heating services via a central system capable of some alteration of the heating services' "output" operating rules depending on the state of the entire system. For example when the load on the generators is too high a building usually set for a minimum temperature of 18°C may be allowed to go down to 15°C or the heating may be cut on washing machines.

This can progressively lead to the configuration shown in Figure 2, a fossil fuel based system with extensive diversion capability. In this configuration, about all heating services are primarily fed by the thermal carrier but include electric heating elements that allow the electrical carrier to provide any proportion of their needs. A centralised system controls not only the output operating rules but also the repartition of thermal and electrical power provided to the system. The bare electrical load is restricted to the provision of non-heating services and the heating services can be used for load shedding and scheduling to provide a stable load on the generators as well as for balancing the electrical and thermal productions to reduce potential for excess heat.

Figure 3 shows a hybrid system with no diversion capability. This is the common, basic system with no diversion capability shown in Figure 1 to which renewable production has been added, bringing highly variable and essentially unpredictable (especially for wind) inputs into the electrical and thermal carriers. If the renewable input capacity is high, it does increase the occurrences of unstable operation of the generator, of operation outside of the generators' optimal operating range and of excess heat production. It results in a decrease of the effective efficiency of the fossil fuel system and in the case of very high renewable input capacity can result in significant excess production. It must however be noted that such behaviour if kept within limits can still provide both fuel and financial "true efficiency" improvements over a purely fuel-based system.

Figure 4 shows an advanced hybrid system with extensive diversion capability. This is the system shown in Figure 2 to which renewable production has been added. The extensive diversion capability allows an optimal management of both the fuel-based production and the use of the renewable production. In particular it allows optimisation of the effective utilisation of renewable electricity production without extensive electrical storage capacity. For example when the wind blows a large wind farm capable of producing a little bit more than the overall station load can power the entire station with all heating needs fed through the diversion system with production variations absorbed by the inertia of the heating services. Variations of the production around the level of the bare load can be handled by a limited electrical storage device such as a flywheel which can absorb short term shortfalls and if necessary provide the time necessary to start up a generator. Once generators are started the diversion function is constantly adjusted, as both station load and wind production fluctuate, to provide both a stable operation of the generator within its optimum range and an effective use of the generator's heat recovery.

CONCLUSION

Well designed, advanced centralised energy management systems controlling a large number of heating services

- fed by a flexible combination of heat and electricity and
- including a significant thermal inertia

are the key to

- optimising the efficiency of fossil fuel based production
- allowing a large penetration of renewable energy production with little waste of excess power, a limited need for large electrical storage capacity.

Such energy management systems can be implemented progressively to evolve from common, basic fossil-fuel systems to advanced, effective hybrid systems where fossil-fuel and renewable production can coexist with little conflict and achieve high efficiency. But it is clear that the establishment of well-defined, adequate operating rules is crucial to the creation of a successful management system. This requires a clear understanding of basic energy concepts and a clear view of the operation of hybrid stations' networks.

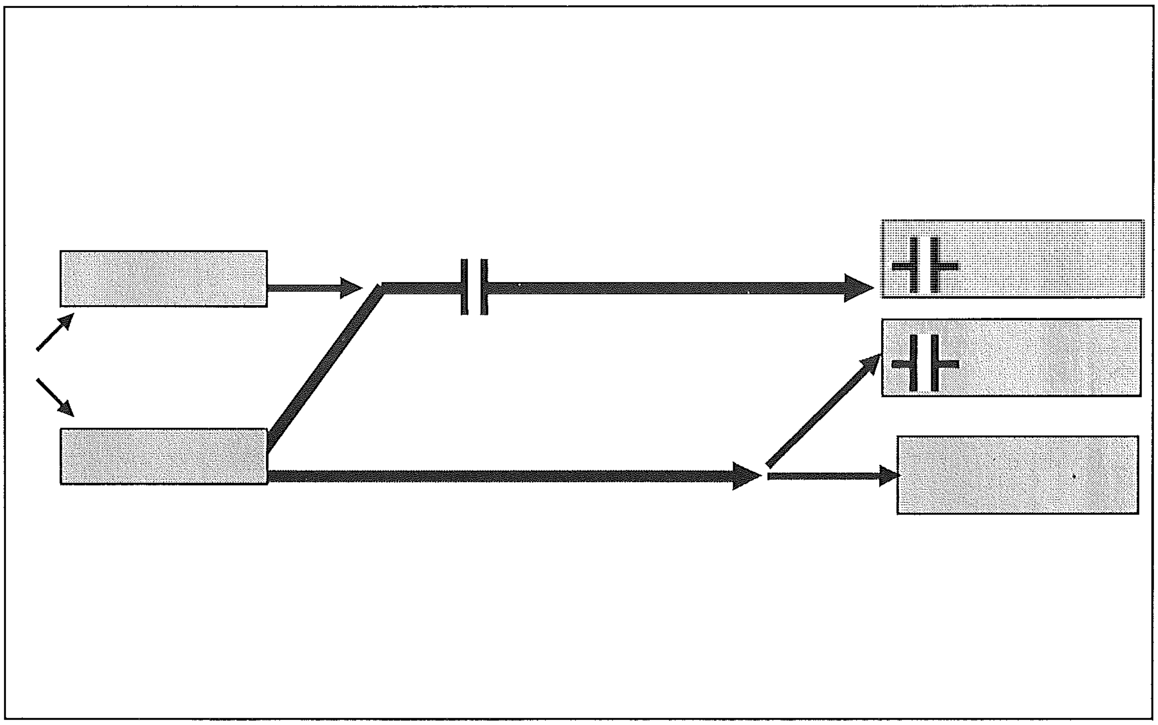

Figure 1: Fossil-fuel based system with no diversion capability

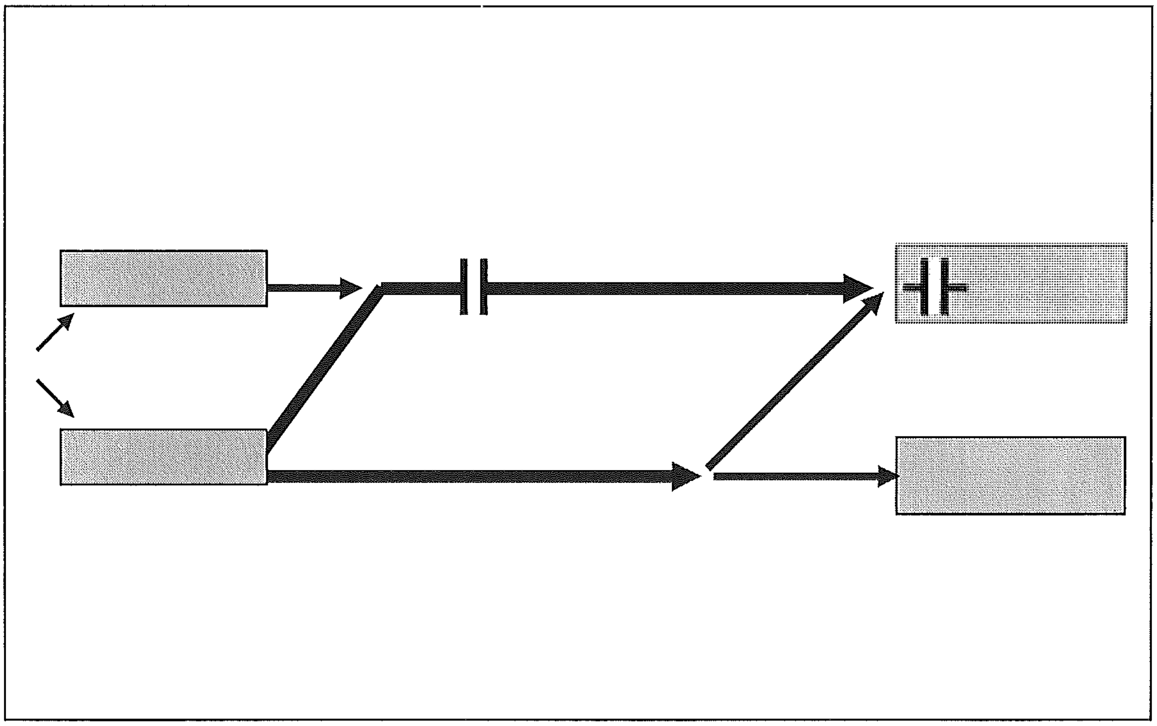

Figure 2: Fossil-fuel based system with diversion capability

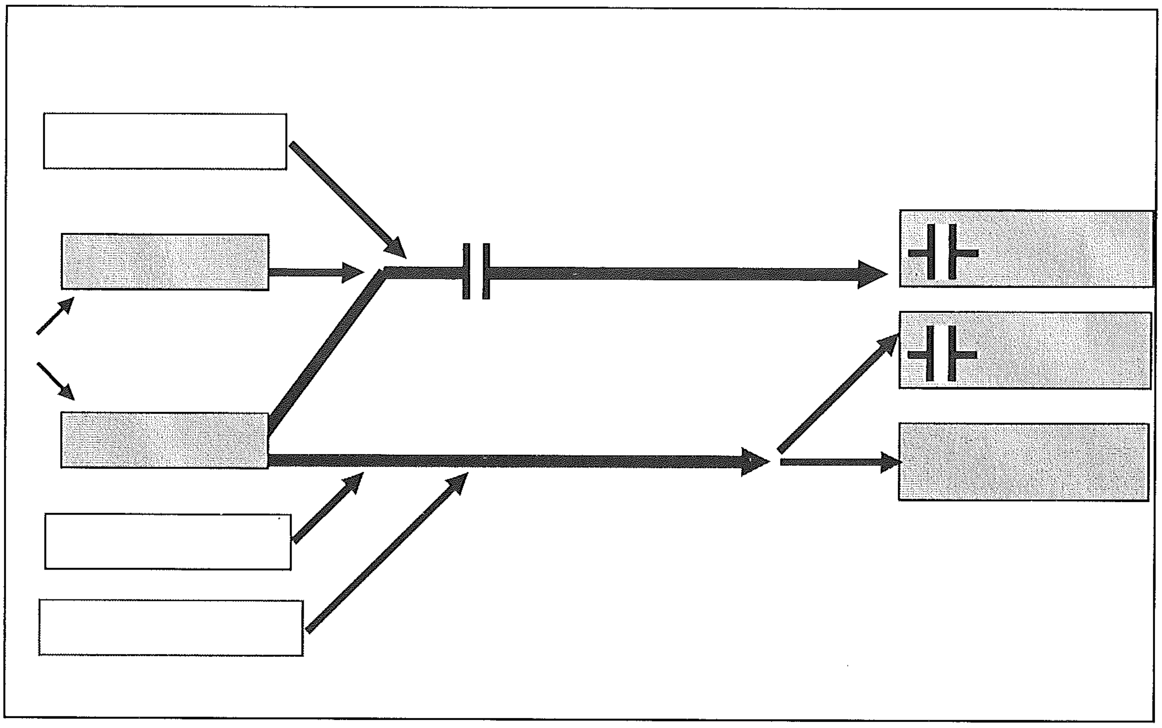

Figure 3: Hybrid system with no diversion capability

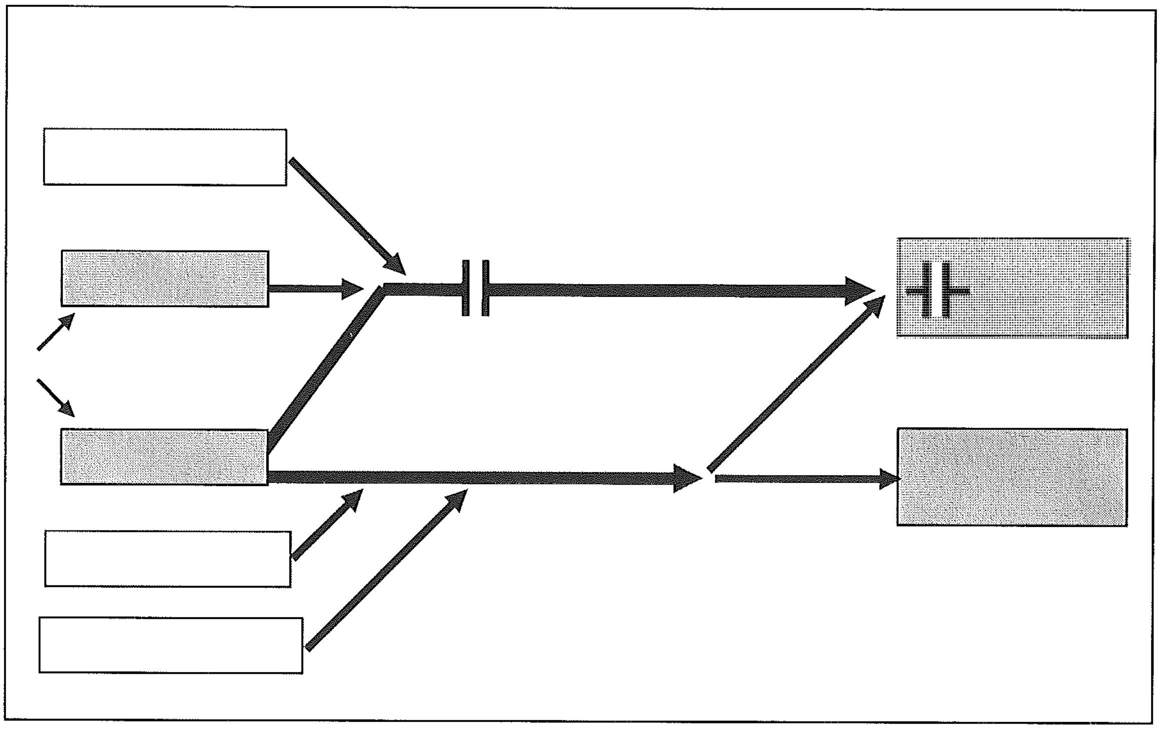

Figure 4: Hybrid system with diversion capability

Operational Experience with Wind Power Technology at Neumayer-Station

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Abstract

A vertical axis windgenerator of 20 KW power was developed and installed in 1991 at the German Antarctic station "Neumayer". Used technology, analysis of available wind energy and operational experience are here presented.

The windgenerator produces in average about 35.000 Kwh/year and so it contributes by about 6% to the total electrical energy consumptions of the station. This saves about 12.000 l/year of diesel fuel.

The yearly mean wind speed was about 10 m/s. Spectral analysis show that 50% of available wind velocities were between 3 and 7 m/s.

Introduction

The energy supply of permanently occupied Antarctic stations is mainly based on diesel engines. In order to reduce fuel consumption and consequently emissions, the application of alternative energies has to be considered for improving an environmentally sound operation. Since 1988 the Alfred-Wegener-Institute (AWI) for Polar and Marine Research, Bremerhaven, has promoted efforts to use windgenerators as an alternative energy source. A prototype of Vertical Axis Wind Turbine (VAW) was designed as a joint project between AWI, Germanischer Lloyd, Hamburg, Hochschule, Bremerhaven and Heidelberg Motor, Starnberg. Operation was interrupted between May 1994 and December 1996 due to the defects on the control unit.

The 20 KW prototype windgenerator (HMW 56) was installed at Georg von Neumayer station in summer 1991 and was used there till 1993, when it was shifted in summer 1993 to the new Neumayer station (70° 39' S; 08° 15' W) and it is still operational there till now.

The operational experience showed that HMW 56 is a very appropriate construction for Antarctic temperature and wind conditions. No mechanical damages or faulty functions occured until now. The foundation is now a proven technology. The plant needs only a little maintenance work.

During the main operation period, the windgenerator provided in average about 10 KW of electrical power (35.000 Kwh/year). It is directly fed into the energy supply system of the station. The mean fuel consumption was in average reduced by about 6 % (12.000 l/ year).

Fig. 1 shows the installed windgenerator at Neumayer-Station.

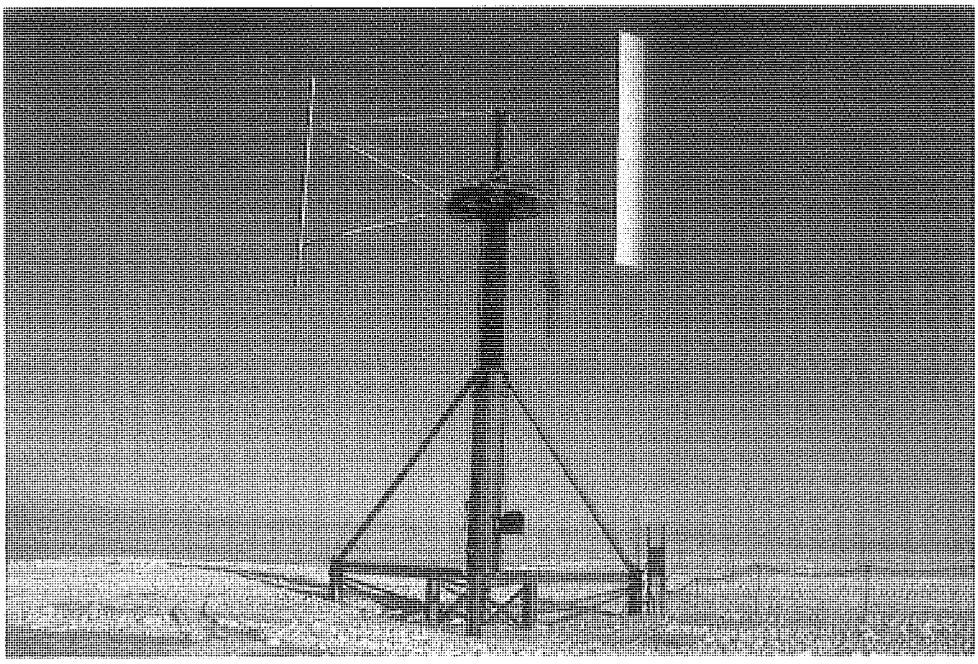

Fig. 1: The windgenerator (HMW 56) at Neumayer Station / Antarctica

After about 10 years of operation we would like to line out the results and the experiences of the used technology.

The used technology

The used generator has a vertical-axis HM- Rotor (Type HMW 56) with straight rotor blades and was specially developed by Heidelberg Motor, Starnberg, to meet the environmental requirements in Antarctica. It was mechanically simplified by follows:

- There is only one rotating part. The rotor itself is rigid. There is no transmission gearbox between rotor and generator.
- The three rotor blades have no pitch control devices and yawing systems.

- The permanent-magnet travelling field generator is integrated in the steel structure.
- A brake system using eddy currents controls the rotor speed.
- A converter ensures that the power output voltage and frequency are independent from rotor speed.
- The foundation consists of three base frames. The base frame can be raised according to the snow accumulation.
- The steel tower is mechanicaly liftable by a small winch

Figure 2 shows a schematic sketch of the HM-Rotor and the complete generator.

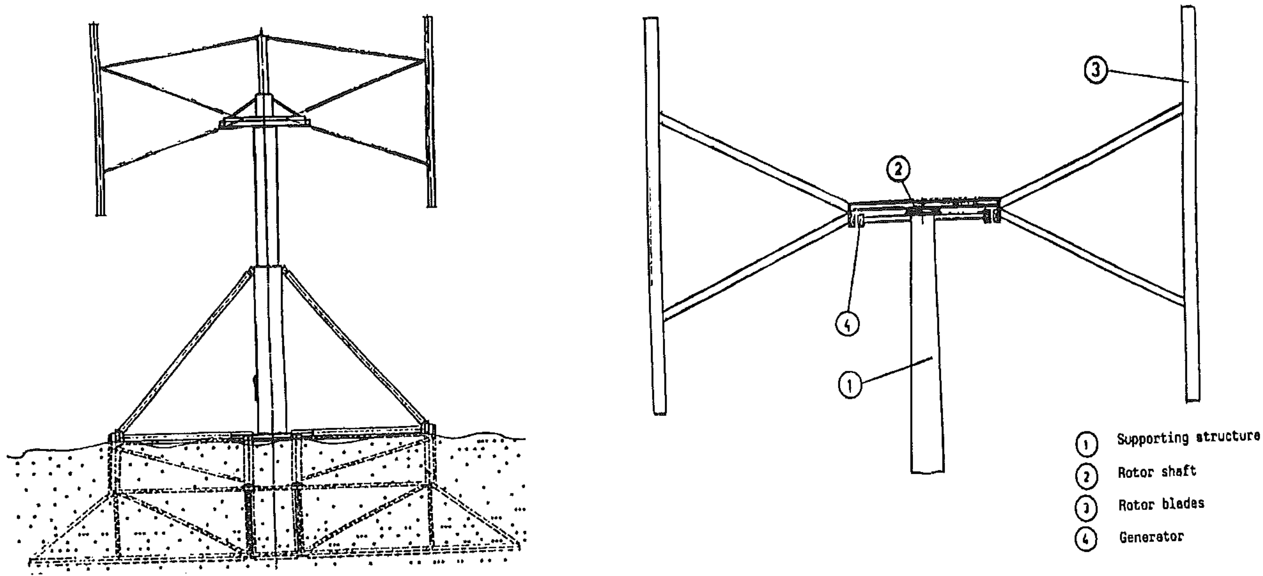

Fig. 2: Schematic sketch of the HM-Rotor and the complete generator

Technical data and specifications

The HMW 56 generator was designed for the following polar climatic conditions :

- Survival wind speed:	68 m/s
- Minimum operating temperature:	- 55° C
- Snow accumulation rate:	70 Cm / year

The technical data of the generator are:

- Rotor diameter:	10.0 m
- Swept area:	56 m2
- Number of rotor blades:	3
- Bladelength:	5.6 m
- Bladewidth:	0.82 m
- Rated electrical power output:	20 Kw

- Hub height: 10 m above snow surface
- R.P.M. range: 30 - 60 /min
- Cut-in wind speed: 7 m/s
- Cut-off wind speed: 23 m/s
- Rated wind speed : 14 m/s
- Generator weight: 2.8 t
- Tower weight: 2.5 t

The travelling field generator permits high torque density even with a large air gap between stator and rotor. The permanent magnet ring is integrated in the support structure of the rotor. The stator is mounted on the tower.
The alternating current produced by the generator is rectified, converted to 220 V AC, 50 Hz, synchronized and fed without intermediate storing to the local mains.

Wind data, state and analysis

Wind data are collected at old and new Neumayer-Station since 1982 by using different data logging systems and different sample rates. Wind speed and direction are measured at 2 and 10 m level above the snow surface. From 1982 - 1986 only 3 hour based data sets were recorded. From 1986 to 1992 a 10 minutes based data set was collected in addition to the 3 hour set. Since 1992 a 5 minutes data set is available. All meteorological data are processed and archived at the AWI, Koenig-Langlo, 2000, 1996.
The 5 minutes based data set was used for all wind analysis presented here.
In Fig. 3 the yearly mean wind speeds are presented for the years 1993 - 1999. In the same graph the measured maximum wind speeds are also presented. The graph shows that the yearly mean wind speed was varying between 8.6 and 9.6 m/s. The maximum wind speed over the years was between 32 and 40 m/s. Spectral analysis of wind speed from 0 - 40 m/s in 1 m/s steps is shown in Fig. 4. Wind speed of 4 and 5 m/s presents the maximum fractional distributions (about 10% each). Higher wind speed categories contribute significantly by more than 60% to the total wind speed and should be considered by planning and construction of windgenerators. Wind gaps are also analysed for the mentioned time period for wind speed between 0 and 7 m/s to calculate the storage capacities needed in the future.

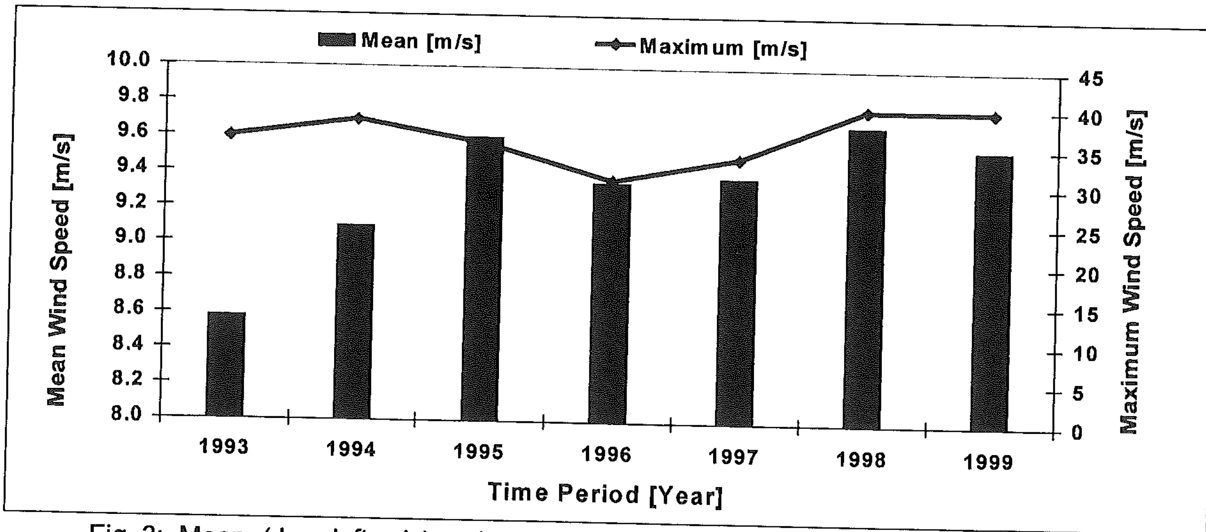

Fig. 3: Mean- (bar, left axis) and maximum wind speed (line, right axis) for the year 1993 - 1999 at Neumayer-Station

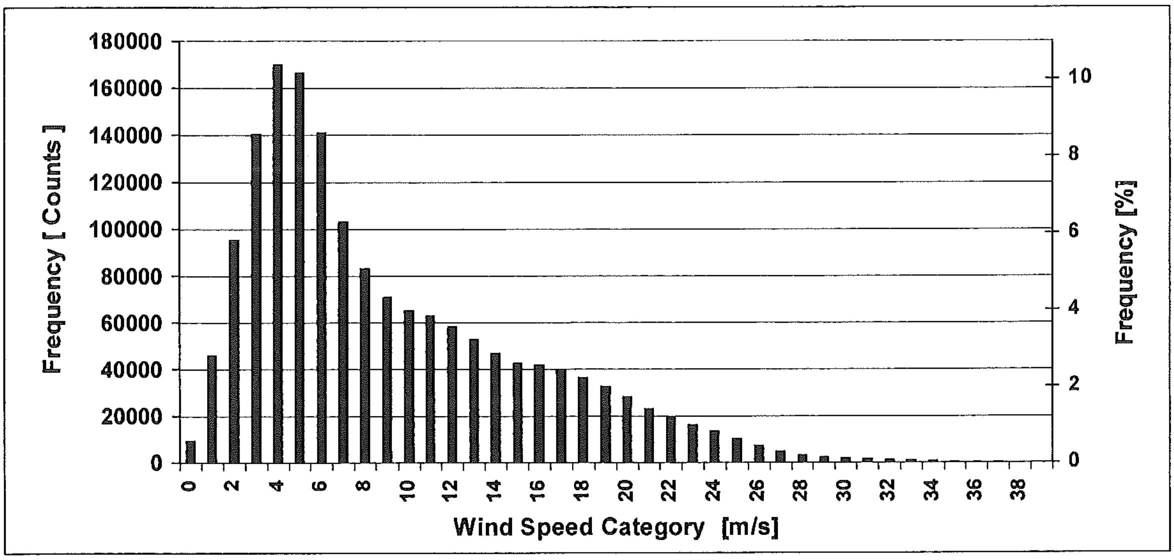

Fig. 4: Spectral analysis of wind speed at Neumayer-Station. Data set from 1993 to 1999, 5 minutes data base and 10 m level above snow.

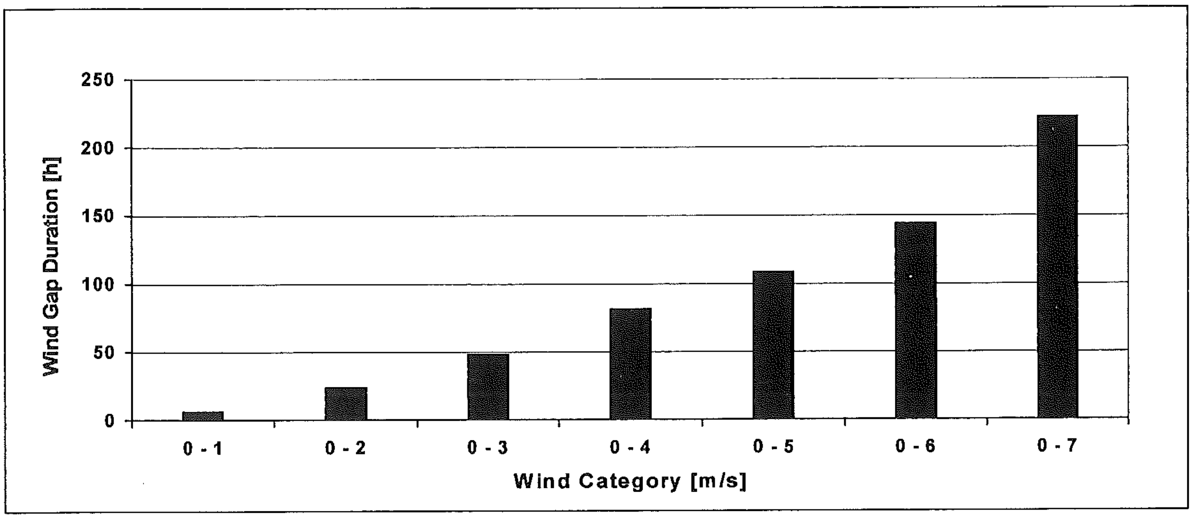

Fig. 5: Wind gaps in the time period 1993 - 1999 at Neumayer-Station.

Fig. 5 presents the maximum time of wind gaps for different wind speed categories for the time period 1993 -1999. The wind gap is here defined as the maximum time period in hours, in which the wind speed remains continuously in the specific wind speed category. Statistically the maximum time gap for wind speed below 7 m/s was about 9 days (222 h). Ignoring wind speed jumps for some hours to higher categories in the above mentioned statistics, a wind gap of more than 15 days was recorded.

Wind energy yield

The conversion of wind energy to mechanical energy (Hau,1988 ; Zastrow et al., 1992) is given by:

$$P_{Wind} = \frac{1}{2} * \rho * A_R * V^3$$

$$Where: \; P_{Wind} = Maximum \; Wind \; Power \; (W)$$
$$\rho = Air \; Density \; (Kg/m^3)$$
$$A_R = Swept \; Area \; (m^2)$$
$$V = Wind \; Velocity \; (m/s)$$

This conversion of wind energy can only be done partial due to imperfect reduction of the wind velocity by the swept rotor area.

The power at the rotor is given as:

$$P_{Rotor} = \tfrac{1}{2} * \rho * A_R * (V - V_{Behind})^3$$

$$V_{Behind} = Wind \; Velocity \; behind \; the \; swept \; area \; (m/s)$$

$$C_P = \frac{P_{Rotor}}{P_{Wind}} \approx 0.25 \; .... \; 0.593$$

$$\boxed{P_{Rotor} = \tfrac{1}{2} * C_P * \rho * A_R * V^3}$$

Considering the real parameter of the used generator and by using the above equation, the theoretical output power is calculated and presented in Fig. 6.
At a mean wind velocity of 10 m/s, the output power is:

$$P_{Rotor} = 9223 \; W$$

This is also in well agreement with the real mean power yield of the generator.

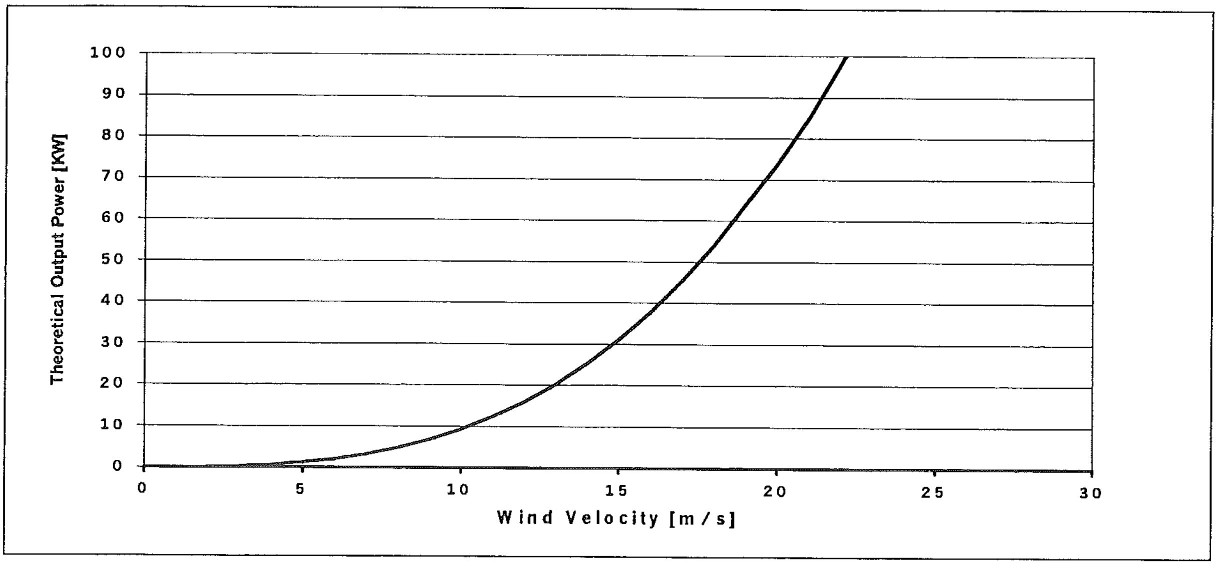

Fig. 6: Theoretical output power of the windgenerator (HMW 56)

Electrical energy and fuel consumption were daily recorded at Neumayer-Station since 1993. Contribution of the windgenerator to the station grid was also daily measured and recorded.
Fig. 7 shows the energy consumption and energy yield of the windgenerator for the time 1993 - 1999. In the years 1995 and 1996 the generator was out of order. Converter and control unit were replaced by a new system after 3 years of prototype operation.

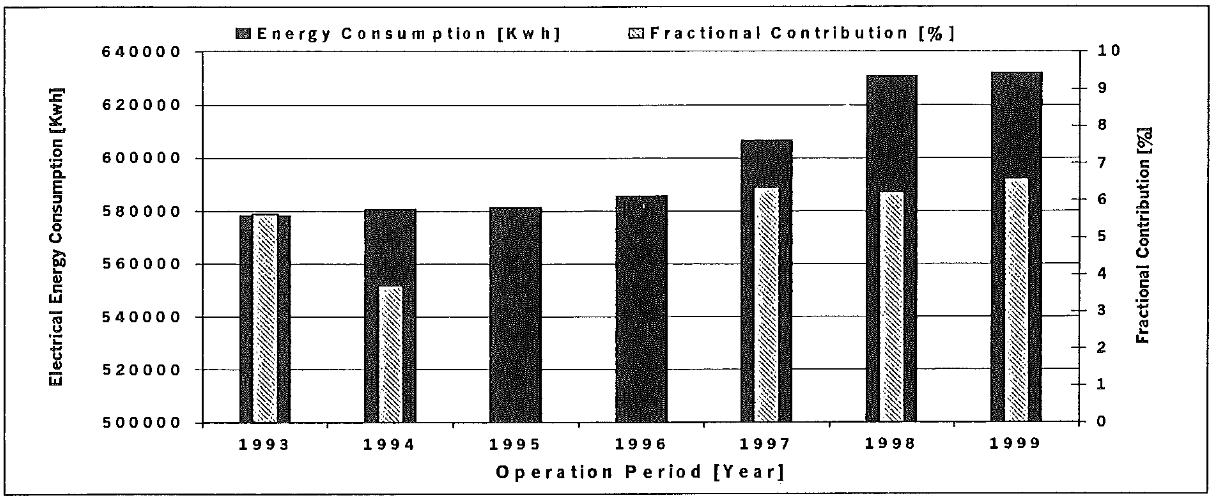

Fig. 7: Electrical energy consumption (solid bar, left axis) and the fractional contribution (dashed bar, right axis) of the windgenerator at Neumayer-Station

The station consumes about 630.000 Kwh per year. The wind generator covers in average only about 6% of the needed energy (about 35.000 Kwh/year). To produce the required electrical energy, about 200.000 l of Arctic diesel are needed. The windgenerator saves in average about 12.000 l diesel/year.
Fig. 8 presents the saved fuel in absolute and in relative units for the considered time period.

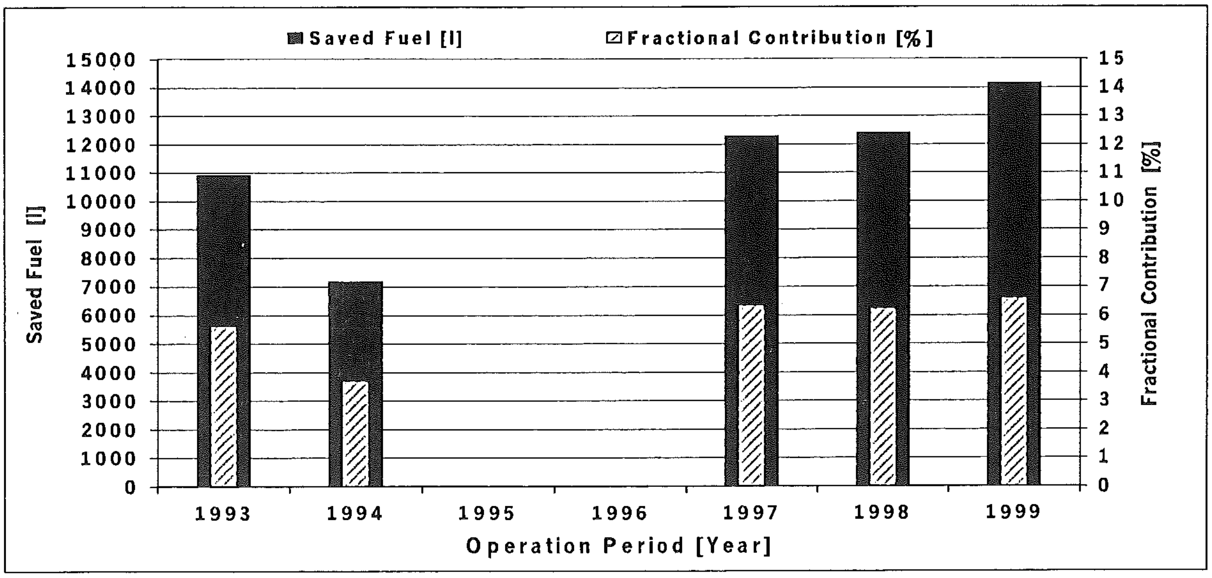

Fig. 8: The saved fuel (solid bar, left axis) and fractional contribution % (dashed bar, right axis) by using the windgenerator at Neumayer-Station.

We have analysed the contribution of the wind generator and the electrical energy consumptions during the year 1999 to monitor the energy yield and its variations during a year. Power consumption was reduced in the winter time by about 13% compared to that at the summer time, due to the increased activities during the summer. The fractional contribution of the wind generator had its maximum in the winter time and was about 10% (Fig. 9).

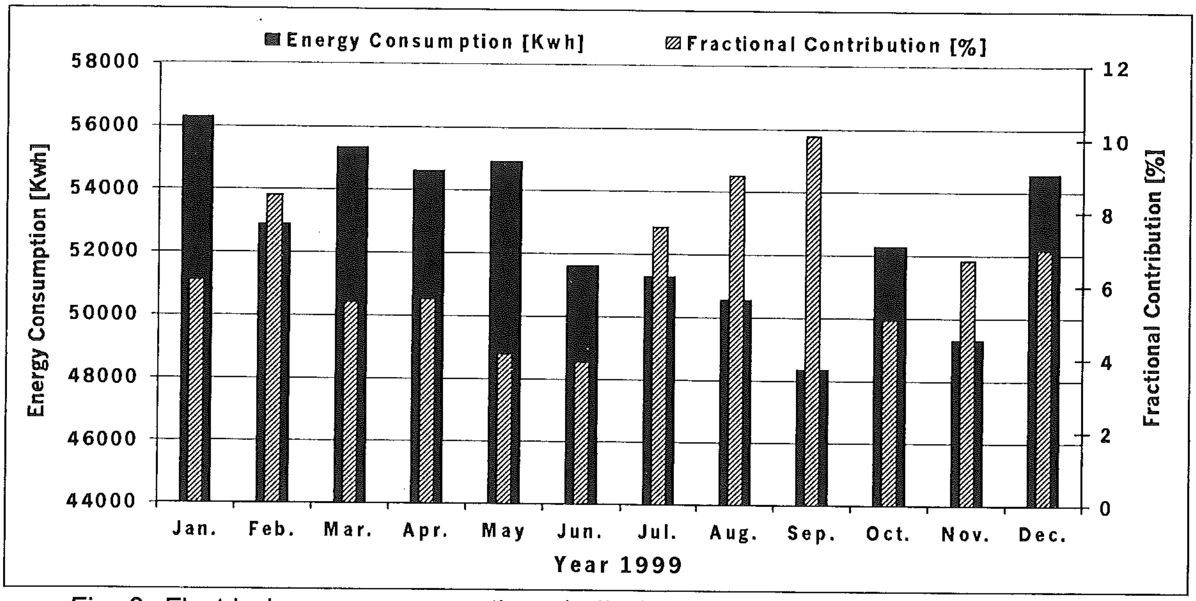

Fig. 9: Electrical energy consumptions (solid bar, left axis) and the fractional contributions (dashed bar, right axis) of the windgenerator for the year 1999 at Neumayer-Station.

Conclusions

The results of the used generator are very encouraging in terms of the principle application of this type of wind turbine. Further development is now being focused to increase the fraction of wind energy supply of the station. Preliminary studies are made to use a wider range of wind velocities and to improve the electrical control and steering system to feed the electrical energy into the station supply system.
The wind energy potential is very high at Neumayer-Station. This is about 165 W/m^2 at mean wind speeds of 10 m/s and could be used more efficiently for supplying the station by providing more than one wind generator.
The used technology is appropriate for operation in Antarctic environment. Larger generators of the same prototype can be built for more efficient utilization of the available wind energy.
The generator contributes in average by 6% to the electrical energy consumption and saves yearly about 12.000 l of arctic diesel.
Storing the produced electrical energy is still not possible and too expensive to realise. Development and research on this field should be forced by an international co-operation to provide a common solution for the Antarctic Treaty System.

Acknowledgement

The autors would like to thank Dr. Gert Koenig-Langlo for providing the processed wind data.

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Wind power utilization at Syowa Station

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1. Introduction

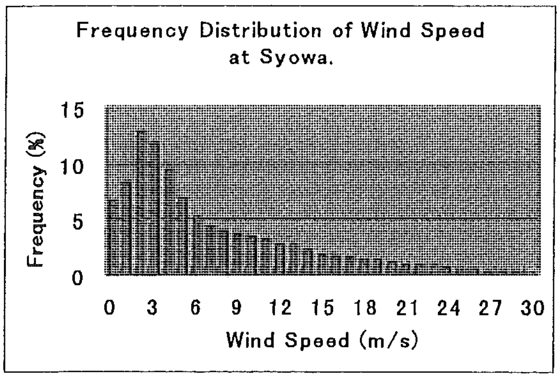
In the light of the protection of the environment in Antarctica, harnessing alternative energy resources such as solar and wind power has to be considered at Syowa Station in order to reduce consumption of fossil fuel. Solar cells have been already utilized to supply electricity since 1997. Based on the test results of the small turbine successfully operated at Asuka Camp in 1991[1], the new wind turbine system was developed and installed at Syowa Station in February 2000.

As the second stage, the connection of turbines to the grid is scheduled in the future. For that purpose, the storage batteries, the resistance and the regulator should be integrated into the exiting system in order to minimize any influence to the grid in terms of the voltage and the frequency.

The NIPR is planning that the electric power produced by wind turbines will sum up to 50 kW at the maximum. At the final stage the generation of electricity from the natural energy sources will come to 100 kW, which covers 12 percent of total electricity required at Syowa Station.

2. Wind condition at Syowa Station

Syowa Station is located at East Ongle Island which is about 4 km apart from the coast of the Antarctic Continent. The average wind speed is lower than that of Katabatic wind area such as Asuka Camp, but strong wind more than 25 m/s frequently blows in blizzard. Fig.1 shows the frequency distribution of wind speed at Syowa Station measured from 1990 to 1994. The figure shows that weak wind lower than 5 m/s is dominant and strong wind more than 20 m/s also exists up to 30 m/s.



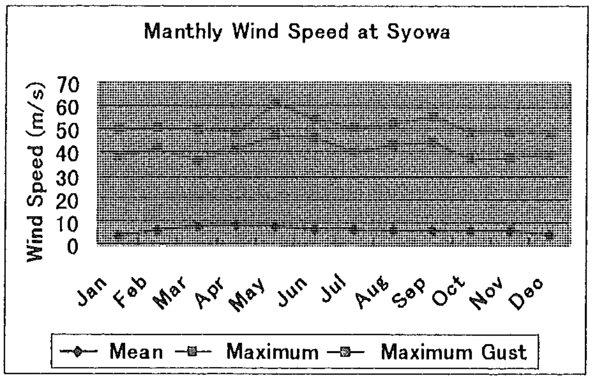


Fig.1 Frequency distribution of wind speed at Syowa Station

Fig.2 Monthly wind speed at Syowa Station

Fig.2 shows monthly wind speed summarized for the period between 1961 and 1990 at Syowa. The maximum of gust has recorded 61.2 m/s. The wind speed is low in summertime and a peak of average wind speed is in April.

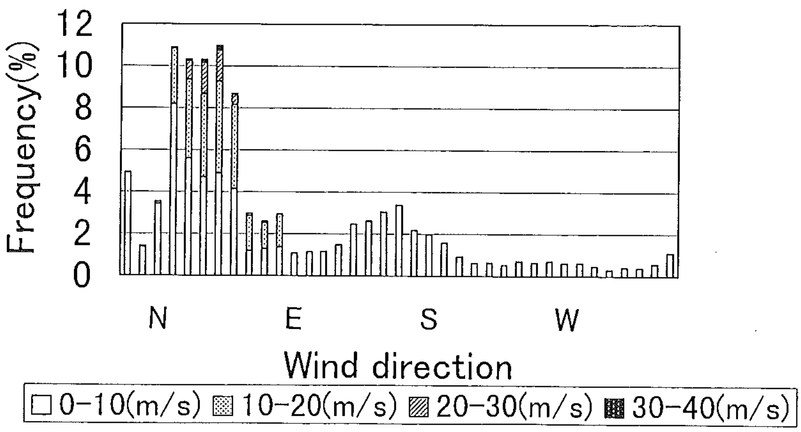


Fig. 3 Frequency of wind direction classified by wind speed.

It is obvious that the wind of NE direction prevails at Syowa Station as shown in Fig. 3. That made the yaw-control of the turbine fix to NE direction when the design was conducted as mentioned in the next chapter.

3. Design of the wind turbine system

3.1 rotor

A rotor with two blades (3.5m radius) was adopted and the aerodynamic performance of the rotor was calculated using strip and momentum theory. The wing section is NACA44-series. Figs. 4

shows rotor power vs. rotor revolution depending on pitch angles (10, 15, 20 and 25 degrees) .The straight line is output of an imaginary generator which is attached to the rotor. The power greatly changes by the pitch angle of the blades.

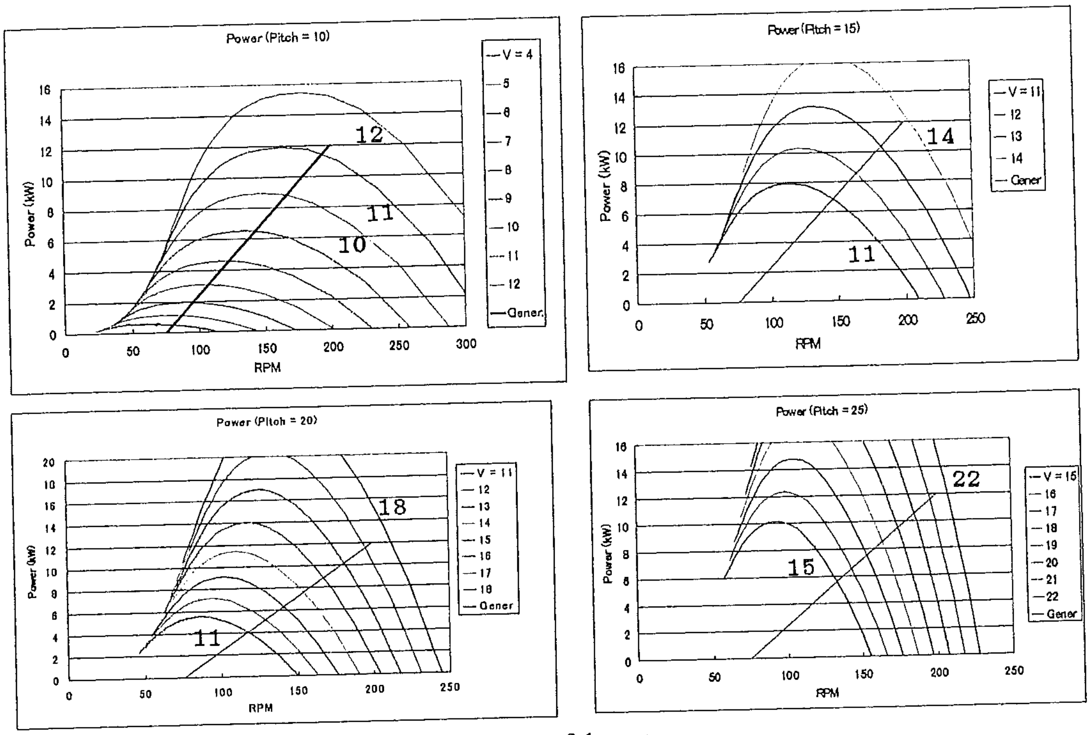


Fig.4 Calculated power of the rotor

If we connected the generator which can change its power as indicated by the straight line in Fig. 4, the revolution of rotor (Fig.6) and the power of the wind turbine (F.ig.7) could be constant by means of the precise pitch control (Fig. 5).

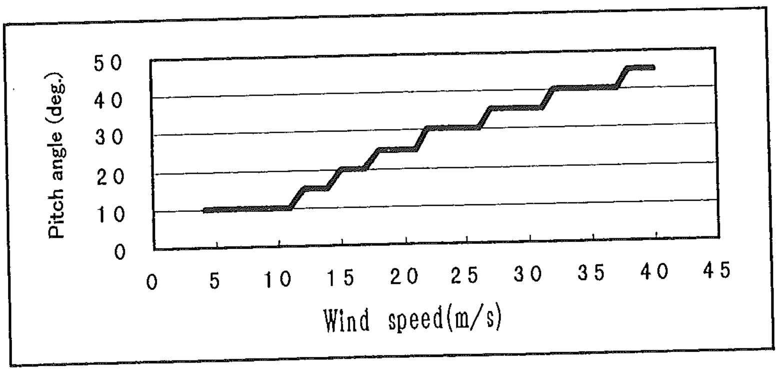


Fig. 5 Setting of pitch angle

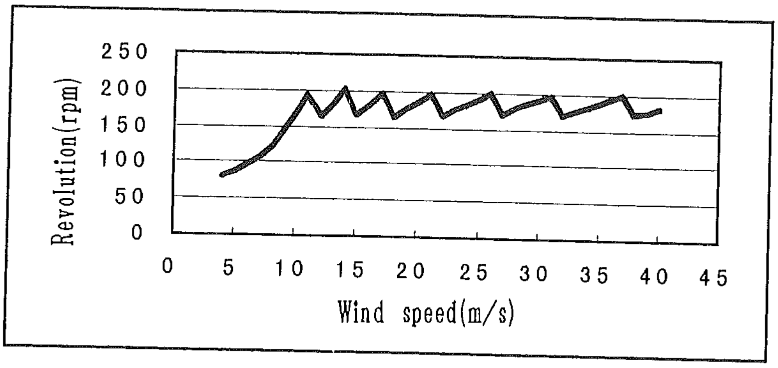


Fig. 6 Controlled revolution of rotor

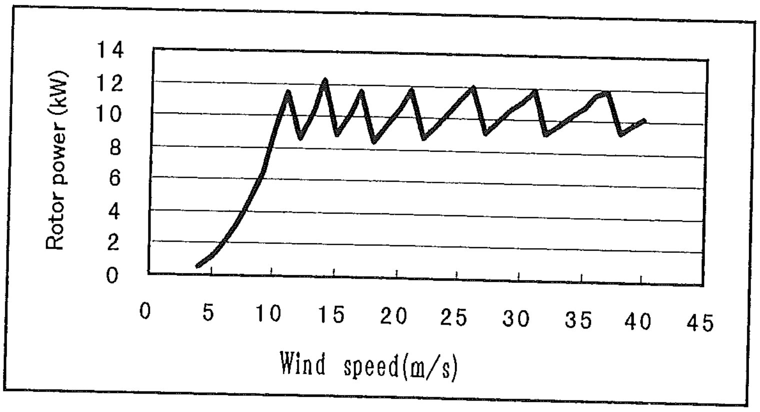


Fig. 7 Controlled power of wind turbine

The pitch angle of the blades is determined by an algorithm using wind speed and rotor revolution. The pitch angle is set to 80 degrees when wind speed exceeds 25 m/s to protect the over-revolution of rotor.

The fixed yawing angle is one of the prominent features of this wind turbine. It was accepted since the wind blows prevailingly from NW at Syowa Station. The yaw sets to the right angle of the prevailing wind direction automatically if the pitch control system failed or emergency stop was necessary.

3.2 Generator and nacelle

A permanent magnet AC generator was employed and the rotor was connected to the generator with a speed-increasing gearbox which has a step-up ratio of three. The output power of the generator changes linearly with its revolution. The output was connected to a resister which can melt snow and/or ice in a pond for drinking water. The rotor hub, gearbox and the generator were completely covered with a GFRP nacelle in order to prevent them from penetration of ice particles.

3.3 Tower

The turbine tower was erected on a reinforced concrete foundation. The height between the center of hub and the ground is 10 m, and the diameter of the cylindrical tower made of steel is 400 mm. The tower was erected using a small electric winch and a 4-m gin-pole. An anemometer to measure wind direction and wind speed was attached to the tower at the height of 6 m from the ground and the data was recorded by PC set in the power house about 500 m apart from the tower. The schematic view and the photograph of turbine system are shown in Fig. 8 and 9 respectively.

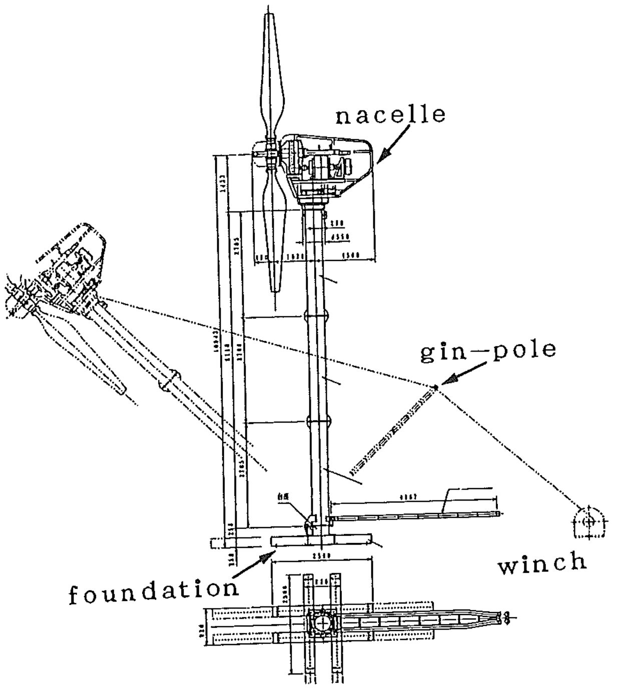


Fig. 8 Schematic view of the wind turbine system.

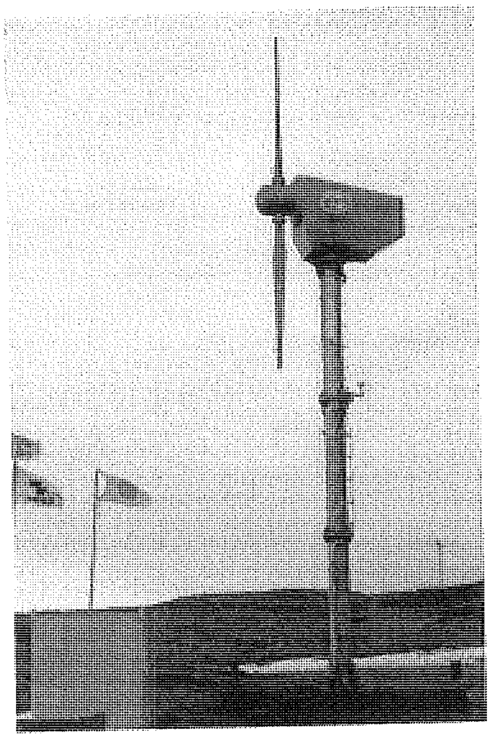


Fig. 9 Wind turbine erected at Syowa Station.

4. Specifications

Specifications of the wind turbine system are summarized in Table 1.

Table 1. Specifications of turbine system

Item		Specifications
Wind velocity	Cut- in	5 m/s
	Rated	11 m/s
	Cut-out	25 m/s
	Maximum	60 m/s
Rotor	Location	Up-wind
	Diameter	7 m
	Rated revolution	200 rpm
	Allowed max. rev.	327 rpm
	Rev. direction	Clockwise
Blade	No. of blades	Two
	Material	GFRP
	Wing section	NACA44-series

Generator	Type	3-phase permanent magnet brushless alternator
	Rated voltage	140 V AC
	Rated output	11 kW
	Max. output	14.3 kW
	Rated revolution	600 rpm
	Max. revolutions	960 rpm
Speed Increaser	Gear drive	1:3 spur gear
Tower	Type	Shell
	Hub height	10 m
	Diameter	400 mm ϕ
	Material	Steel
Control	Pitch control	variable pitch controlled by wind speed, revolution and output
	Yaw control	Fixed(remote manual control)
Weight	Nacelle	1500 kg
	Tower	950 kg

5. System performance

The test operation started in February 2000 and the measurement of the system characteristics has been carried out continuously, and the acquired data have been stored into the MO disk every one second controlled by PC. The acquired data were wind direction, wind speed, pitch angle of the blades, revolution of the blade, output current and voltage of the generator and power.

An example of the data train is shown in Fig.10. In this figure, it is recognized that the power greatly changes by the pitch angle of the blades. The relation between power and wind speed is plotted in Fig. 11. The obtained power is lower than that in the specification of Table 1 because the program of calculating formula determines the pitch angle was set for holding down the revolution in this test operation.

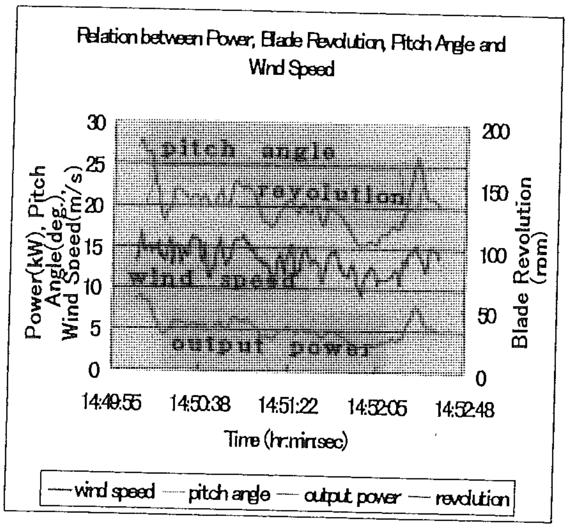


Fig.10 Wind speed, Pitch angle, Revolution and Power

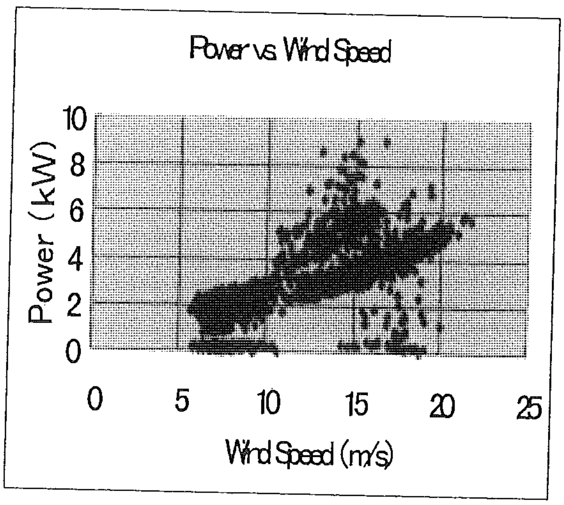


Fig. 11 Power vs. wind speed

6. Concluding remarks

Field test operation of 10- kW wind turbine started at Syowa Station and the operating data of the system was obtained. The data is analyzed in detail and the system will be improved. We are planning to connect the turbine output to the grid in the future.

7. Acknowledgement

The authors are pleased to acknowledge the members of 41th. Japanese Antarctic Research Expedition lead by Ayukawa Masaru for their devoted efforts at Syowa Station. They transported materials, assembled and erected the system, and continued measurement and maintanances.

8. References

(1) S. Kimura, K. Ishizawa, T. Takanaga, Y. Ichikawa and K. Suzuki (1993): Field Test of a Small WECS in Antarctica.. Proceedings of European Community Wind Energy Conference pp.732-736

Utilization of Air-type Solar Collector at Syowa Station

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1. Introduction

Utilization of alternative energy is now developing at Syowa Station in order to decrease the fuel consumption for diesel generators and heating devices. Photovoltaic panels have been installed since 1997 and the grid connection with diesel generator was completed and a 10kW-wind turbine was introduced in 2000. The air-type solar collector for warming the inside of the rooms was set to the wall of living accommodations and tested as a part of the same planning scheme in 1999. The test operation was conducted from February 1999 to the end of January 2000, and the air temperature data of the warmed room was obtained. The efficiency of the solar collector was analyzed.

2. Mechanism of air-type solar collector

The collector panel is a black aluminum plate with many holes of which diameter are 1.5 mm ϕ. The total area of the holes makes up 0.6% of the collector plate. This collector panel can efficiently collect solar heat. The mechanism is explained as follows (see Fig.1); the panel is heated by sunlight at first and the heated panel warms the air in front of the plate. The heated warm air is sucked through tiny holes into the inside of the wall by convection and fan. The air can obtain more heat from the rear wall of the solar collector while it travels along the panel.

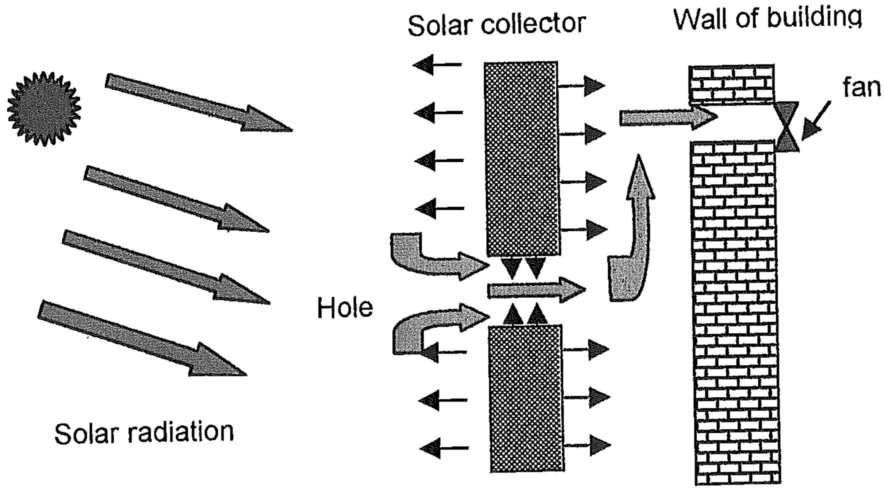

Fig.1 Mechanism of solar collector

3. Solar collectors tested at Syowa Station

Two types of solar collector panel were set in order to compare their performances. One of them is a ventilation-type (A type) which sucks up fresh air from the outside. Another is a circulation-type (B type) which is contained by a transparent panel made of acrylic acid resin, therefore the heated hot air is circulated between the chamber of solar panel and inside of the building. Fig.2 shows the cross section of the circulation-type solar collector (B type) attached to an insulated wall of a building. Two holes are made through the wall for passing the air. A small electric fan installed at the upper hole draws heated hot air into the building and cooled air inside of the room enters into the collector chamber through the lower hole. This air is heated at both sides of the collector panel and returns to the inside again.

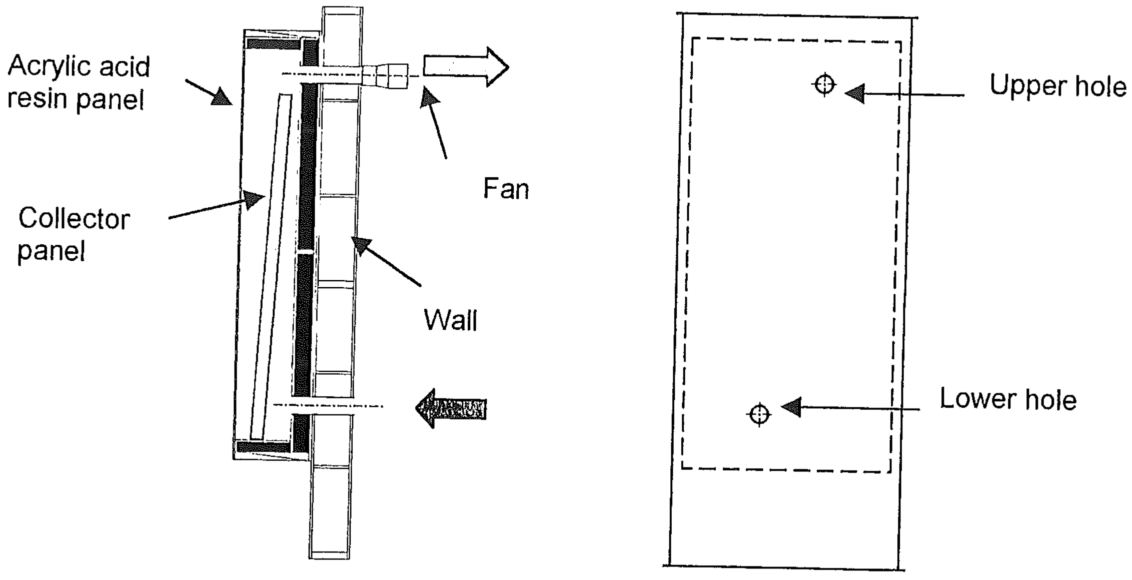

Fig.2 Schematic view of collector panel installed on a wall.

Fig. 3 shows a plane view of living accommodations No.13 and No.9 and the setting points of the solar collectors. The type of the collectors is described as A1, A2, B1, B2, B3 and B4 .The detail of these panels are shown in Table 1. Fig. 4 is a photograph of the solar collectors set on the wall of the living accommodations No.9 and No.13.

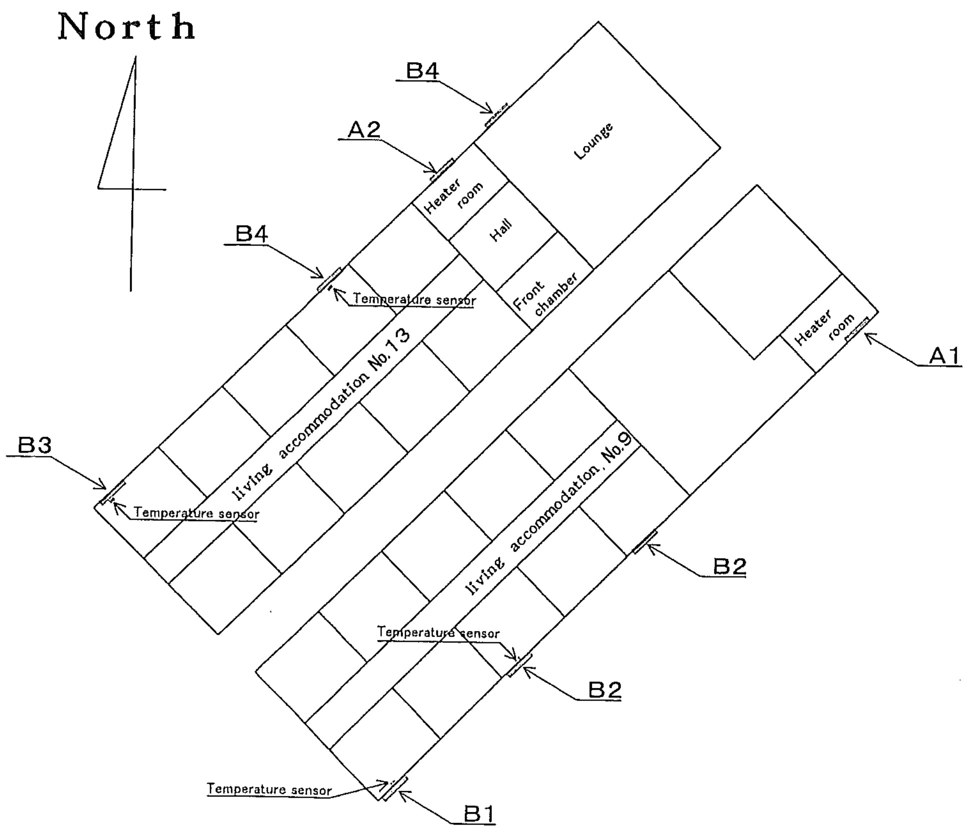

Fig. 3 Installed position of solar collectors on the wall of living accommodations No.9 and No.13

Table 1 Type of solar collector panels

Type	Specifications	Building	Installation azimuth	Power of fan
A1	Ventilation-type	Living accommo. No.9	southeast	12 W
A2	Ventilation-type	Living accommo. No.13	northwest	12 W
B1	Circulation-type / large fan	Living accommo. No.9	southeast	15W
B2	Circulation-type / small fan	Living accommo. No.9	southeast	12 W
B3	Circulation-type / large fan	Living accommo. No.13	northwest	15W
B4	Circulation-type / small fan	Living accommo. No.13	northwest	12 W

Fig.4 Solar collectors set on the wall

4. Data analysis

Two thermometers were set on the inside wall of each room in order to compare the temperature difference between inlet air (Ch.2) and the room (Ch.1) as shown in Fig .5.

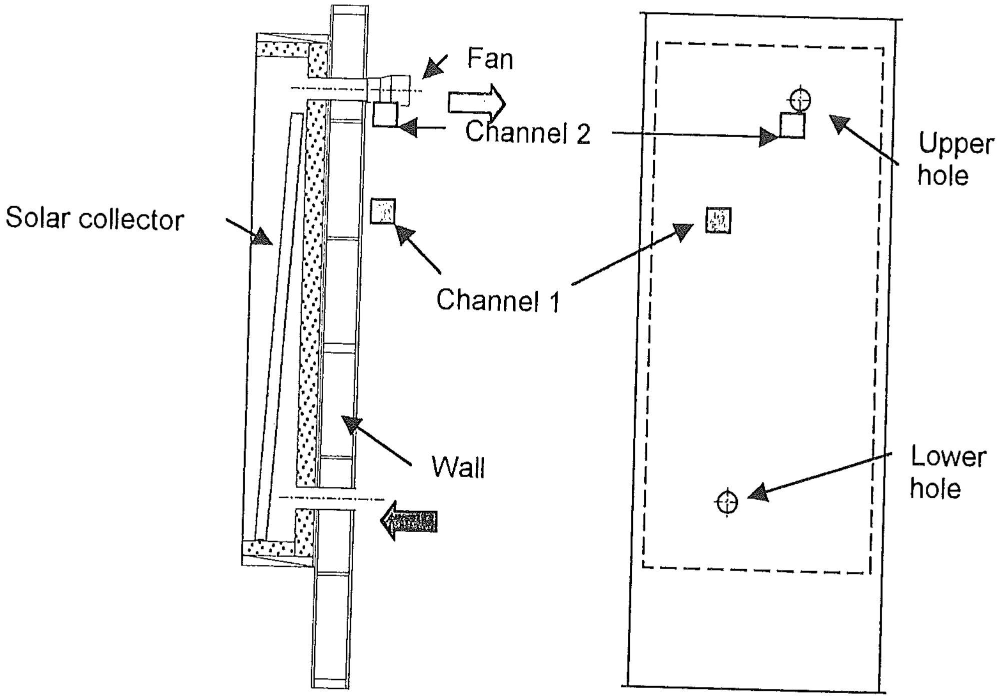

Fig. 5 The position of thermometers (Ch.1, Ch.2) set on the inside wall of the buildings.

The measurement was carried out from May 1999 to January 2000. The analysis was conducted on the data for the period between March and June 1999. The characteristics found through the period are as follows;

1. Daily periodic cycles of the temperatures are found from March till 10th April, and after the cycles are becoming more longer, two/three days to ten days.
2. The temperature difference between Ch.1 and Ch.2 of the panels orientating the NW direction is great for the period before 10th April, while there is little difference about SE direction.

The data on 27th March was analyzed as a representative of fine day. Fig.6 shows a response of the solar collector (B3 and B4) orientating NW direction. The temperature differences between the inlet air (Ch.2) and the room (Ch.1) are shown with solar radiation. on a horizontal surface.

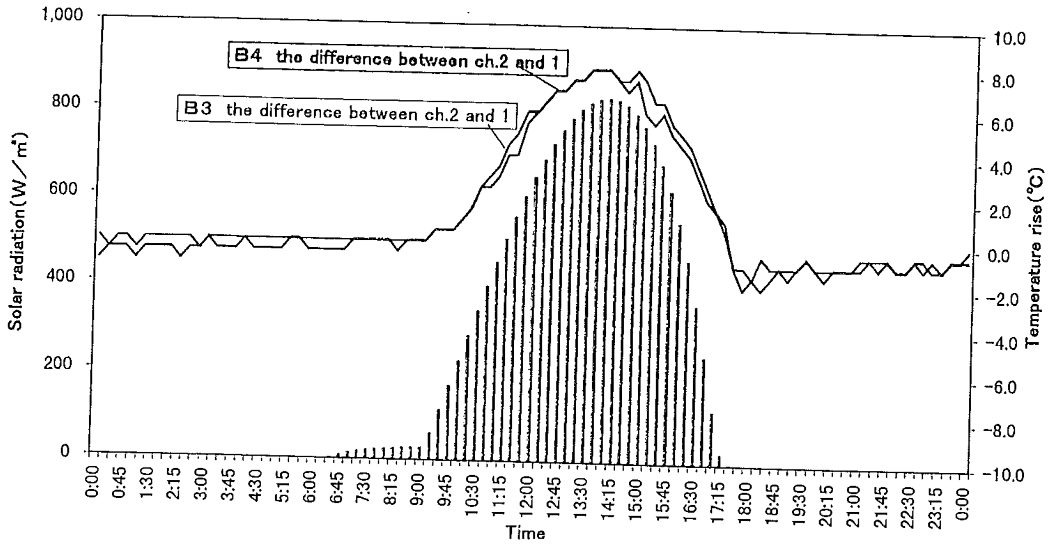

Fig.6 Solar radiation and temperature difference between ch.2 and ch.1 of NW panels on March 27

The temperatures of Ch1 and Ch2 on B-type panels on 27th March are shown in Fig.7. The temperatures of inlet air (Ch.2) and room (Ch.1) on NW direction panels (B3 and B4) rise with solar radiation, while those of SE direction panels (B1 and B2) scarcely rise. The peaks of room temperatures (Ch.1 of B3 and B4) are about two hours behind those of inlet air temperatures (Ch.2 of B3 and B4).

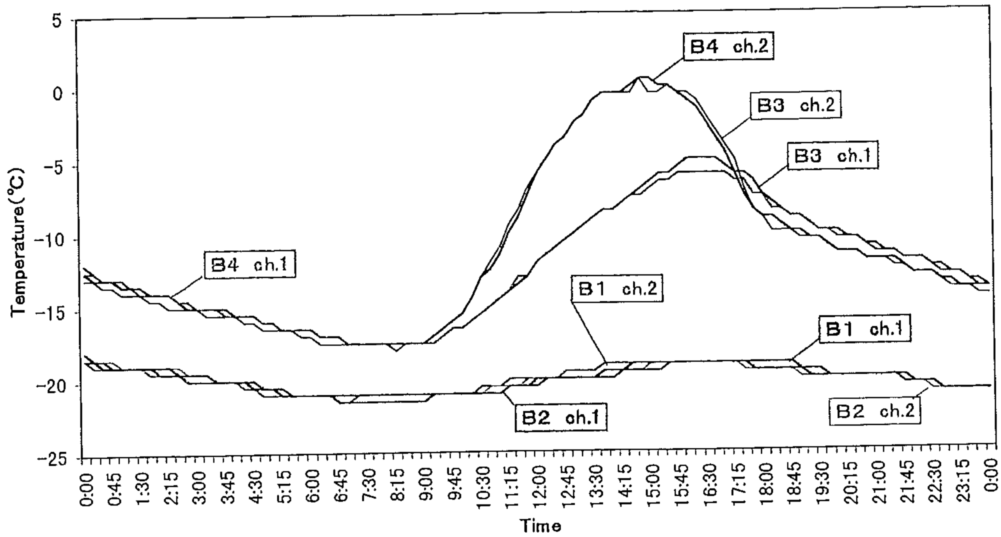

Fig.7 Temperature change of B-type panel on 27th March 1999

4.1 Effect of panel's type

The room temperatures (Ch.1) of A1, B1 and B2 orientating SE direction on 27th May are shown in Fig. 8. The temperature of A1 (ventilation-type) is higher than those of B1 and B2 (circulation-type) for the period between 10:30 and 19:00. On the other hand, the temperatures of A2, B3 and B4 orientating NW direction on same day are shown in Fig.9. The temperatures of B3 and B4 (circular-type) are higher than A2 (ventilation-type).

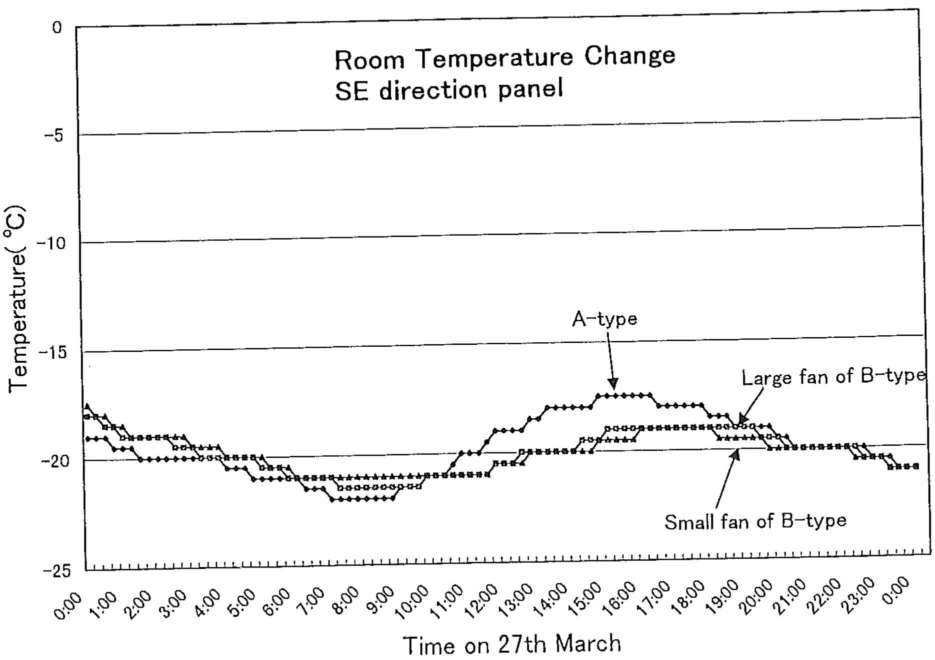

Fig.8 Room temperature change (SE direction panel)

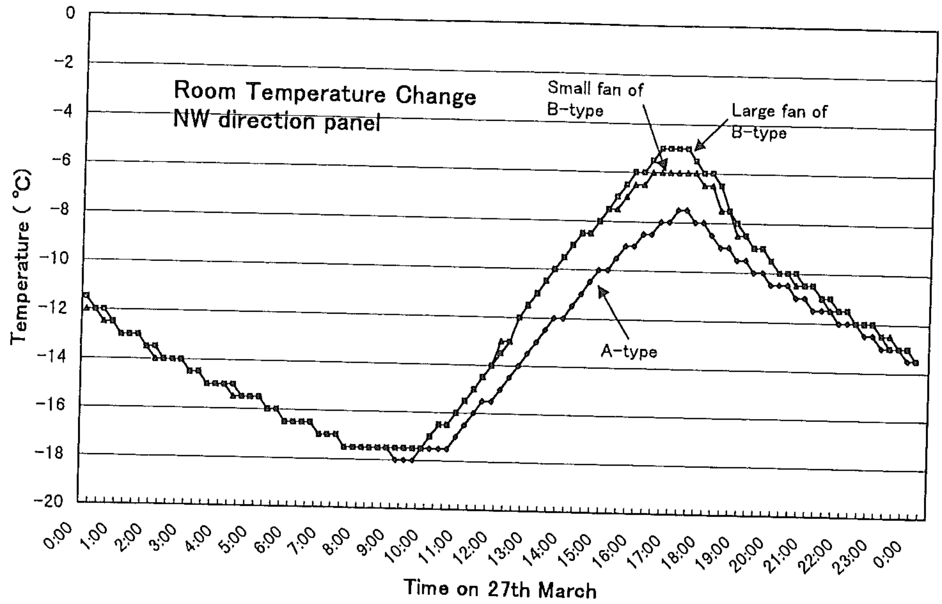

Fig.9 Room temperature change (NW direction)

4.2 Effect of orientating direction

The panels of NW direction are more efficient than those of SE direction. The figures are classified by three types (A-type, small fan B-type and Large B-type) and shown in Figs.10.11 and 12 respectively.

The temperature differences of the rooms (Ch. 1) are between 10 and 14 degrees, while those of the inlet air (Ch.2) are between 12 and 19.5 degrees.

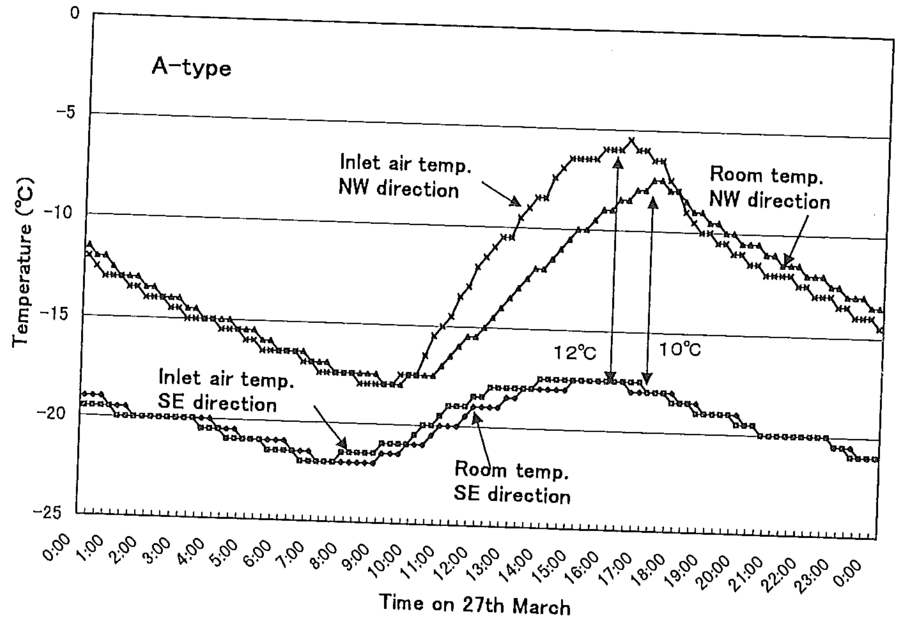

Fig.10 Inlet air and room temperature change (A-type)

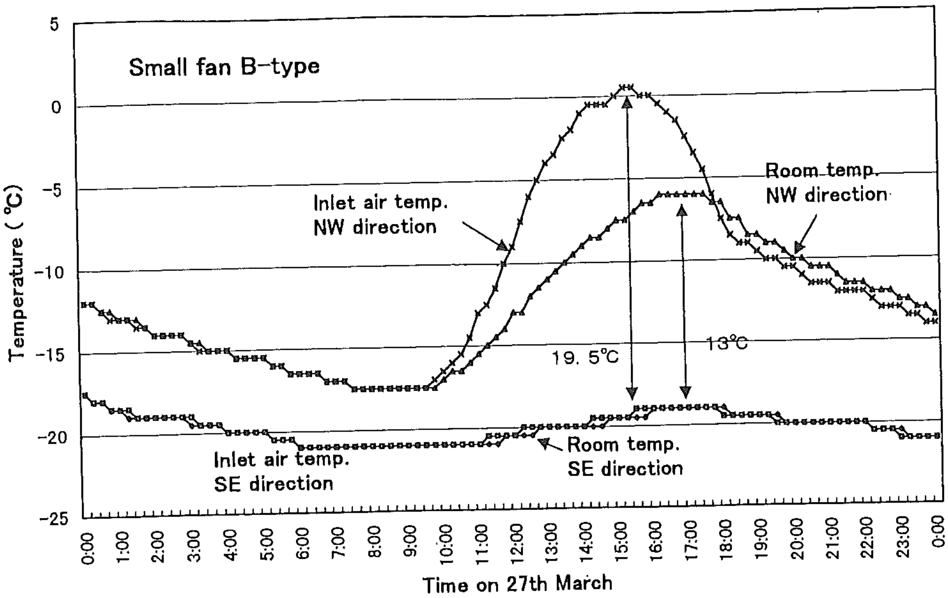

Fig. 11 Inlet air and room temperature change (Small fan B-type)

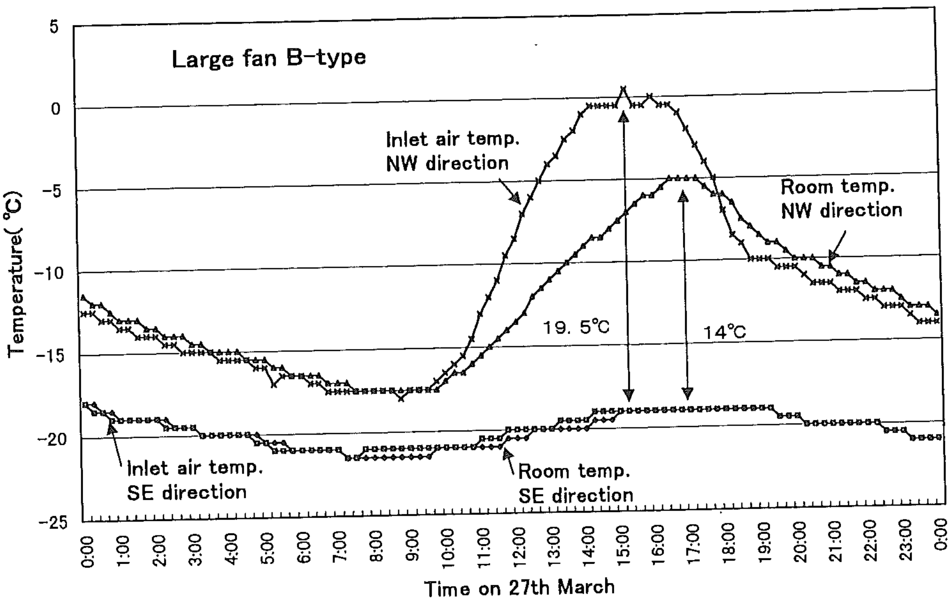

Fig.12 Inlet air and room temperature change (Large fan B-type)

4.3 Effect of fan

The fan, which has larger flow rate, was more effective for warm the room temperature compared with small one of circulating –type. (See Fig. 8 and 9)

5. Concluding remarks

Any type of the solar collectors orientating NW direction is effective while the solar radiation exists.

As for the collectors orientating SE direction the effect is negligible, though the temperature rise can be found in the ventilation-type collector. The temperature of inlet air of NW direction unit is getting lower than that of room after the sun sets because the fan sucks in the cool air from the collector chamber. The problem would resolve if the power of the fan would be stopped when sun set or the power would be supplied by Photovoltaic panel attached to the same wall of the building.

6. Acknowledgement

The authors are pleased to acknowledge the members of 40 th Japanese Antarctic Research Expedition lead by Shiraishi Kazuyuki for their construction work of the panels and data acquisition at Syowa Station.

A NEW TYPE OF SOLAR SNOW MELTING FACILITY BASED ON SPACE TECHNOLOGIES

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ABSTRACT

The paper discusses the results of R&D work aimed at designing and developing of a pilot solar heating facility for potable water production under extreme environmental conditions of High Antarctic Plateau (Vostok station). The concept is based on solar concentrating technologies coupled with the modern space technologies enabling to effectively utilize energy of the Sun for low-potential heat production under extremely low ambient temperatures. Based on these principles the pilot autonomous solar facility serving for portable water production by snow melting has been developed. According to the scientific program of 45th Russian Antarctic Expedition the facility has been tested under conditions of Vostok station during the Austral summer season of 1999-2000. The peculiarities of the facility design and the results of the testing have been discussed. The obtained results of the testing have shown that the autonomous solar snow melting facility and all main parts and mechanisms have been properly designed and manufactured.

The project has been carried out with the support of the Russian Ministry of Science and Technologies and Arctic and Antarctic Research Institute. The engineering and research team consisted of physicist, specialists in mechanics optics, and space technologies. The following subcontracting organizations took part in this R@D work: firm «TAIS», firm «Solto», firm «Kalimp». The laboratory testing of the facility has been done in the Lavochkin Space Association.

I. INTRODUCTION

Ten years ago only few papers presented at the SCALOP Symposium were devoted to the problem of renewable energy sources using for energy supply of the Antarctic scientific stations. Nowadays this problem is in the focus of the IX Symposium and attracts much attention of the Antarctic expeditions [1]. The projects aimed at preserving the Antarctic environment and making the Antarctic logistics at scientific stations less dependable from organic fuel are being carried out in various countries and by international group of specialists.

As concern facilities based on solar energy using, PV modules is a good choice mainly due to its high reliability and because they are directly convert solar energy into electricity. However efficiency of the existing PV modules is low and thus it is preferable to use more effective types of solar facilities for meeting of heating requirements in Austral summer season. Considering the issue related with solar heating systems utilization under low ambient temperatures one should thoroughly take into consideration the question of heat transfer media choosing and how to effectively organize heat transferring from the absorber to heating load. Bearing in mind these questions we have tried to design and develop a new type of solar heating facility for reliable and effective exploitation under low ambient temperatures.

High Antarctic Plateau and South Pole are the unique regions with extreme climatic conditions where research projects of great importance are being conducted. For example, Vostok station is now in the focus of research activity because of growing scientific interest to subglacier lake Vostok. At the same time these two stations are considered as the most complicated from the viewpoint of energy supply, especially Vostok station. According to Peeran [2] at the South Pole diesel fuel, which is transported by airplane costs as much as $12 per gallon. Nowadays Russian Antarctic Expedition has the only way to supply Vostok station with fuel - by means of tow-tractors. As fuel bulks to be transported to High Antarctic Plateau region are restricted it is worth to try harnessing solar and wind energy for meeting of growing energy requirements of the station.

The present stations water potable production system is based on the facilities in which snow is melting by using of electricity and waste heat of diesel. Our evaluation shows that 1 litre of water obtained with the help of electricity costs $0.3-0.4. At Vostok station there are some difficulties dealing with utilisation of the waste heat and maintenance of pipelines under extremely low temperatures. In this connection it is worth to develop another technics of potable water production. Because there is a substantial solar energy intake in High Antarctic Plateau zone (Fig. 1) it is worth to harnessing direct solar energy radiation, which can be used in Austral summer (period of enhanced demands in potable water) around the clock.

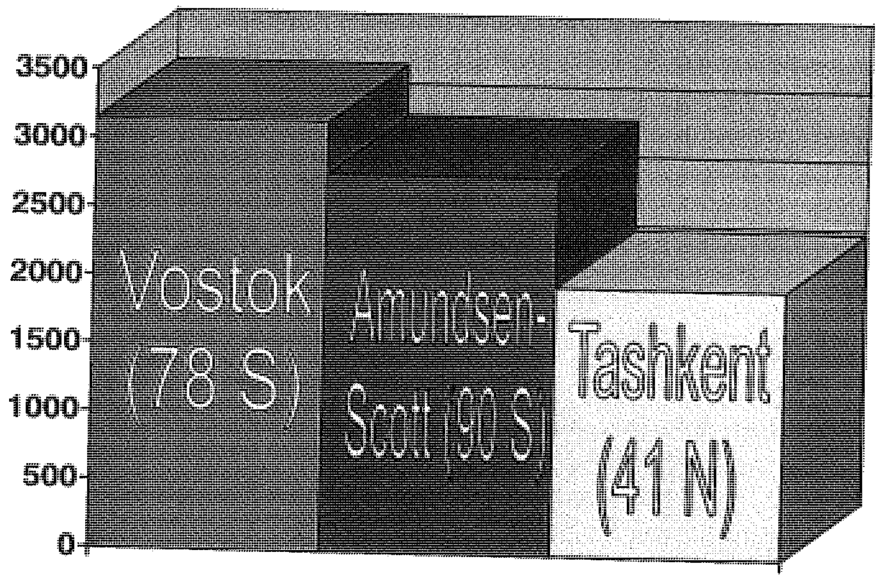

Fig. 1. Solar energy on normal surface (kWh/m^2year) for different regions

II. A PILOT SOLAR SNOW MELTING FACILITY

The project goals were:

1. Studying of «solar» snow melting process (mathematical and numerical simulation, PC software development)
2. Development of design concept of solar snow melting facility for potable water production under conditions of High Antarctic Plateau zone (Vostok station)
3. Design, development and manufacturing of a pilot snow melting facility capable to reliably operate under extreme environmental conditions
4. Experimental study of the solar snow melting facility (laboratory and field testing)
5. Development of recommendations for manufacturing group (Russian private company) to organize production of the solar facility

Solar heating facility concept

Fig.2 shows schematic diagram of autonomous portable solar heating facility serving for potable water production by snow melting. The solar facility consists of concentrating solar collector having lightweight solar concentrator and absorber (equipped with special quartz glass envelope that has been used in the experimental series with glazed solar collector), special heat transferring system, enabling to transport high-density heat fluxes from the absorber to snow bulk without electrical circulating pump, container in which snow is loaded. The main operational mode can be described as follows. Snow is loaded in the container, the concentrator is oriented towards the sun automatically, sunrays are concentrated on the absorber and the obtained solar heat is effectively transported from the absorber to snow through the heat transferring system. The obtained water is automatically discharged and the cycle can be repeated. For convenient using of the solar facility under extreme environmental conditions automatic system enabling to track the concentrator the sun and to discharge the obtained water from the container has been designed and developed. The main part of the tracking system is optoelectronical sensor allowing the concentrator to track the Sun with accuracy of 0.1^0. To provide the drives reliable exploitation under extreme low temperatures a special lubricant (normally used in space industry for exploitation at ambient temperature up to minus 110 ^{0}C) has been chosen. The drives are actuated with the help of energy-efficient solar power supply system consisting of 5 W PV module and 5 Ah Ni-Cd batteries. The facility has been equipped with special cables (used in space industry) allowing to reliably operate under low ambient temperatures.

The multifunction solar facility that was developed can be used for the following several purposes: snow melting, water heating, water boiling, meal cooking, and electricity production (the last one mode is under development). The concentrator can be separately used for solar cooking (water boiling, meat cooking). So this facility has been named as Solar Energy Module («SEM-1»).

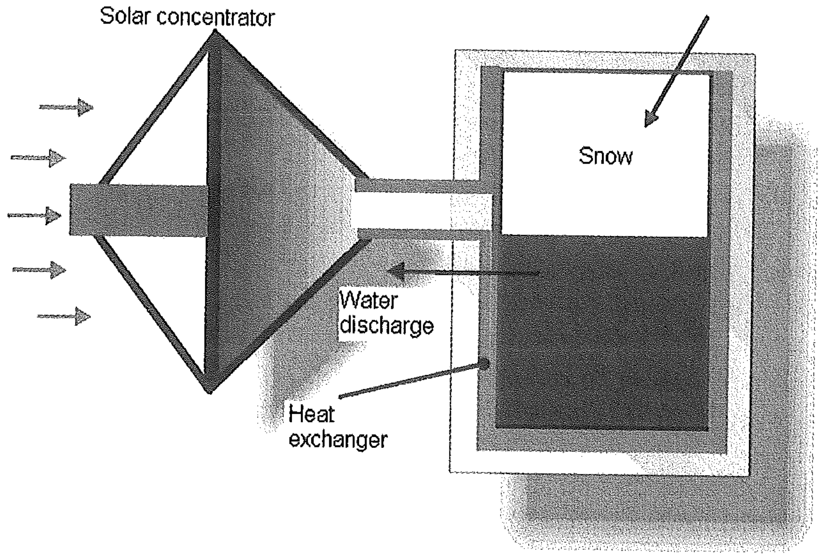

Fig. 2. Schematic diagram of solar snow melting facility

Mathematical and numerical models and software

Theoretical investigation that has been carried out in the project frame dealt with the calculations of thermal characteristics of solar snow melting facility. For this purpose mathematical models and software have been developed (co-author is Dr. I.L. Maikov, IVTAN).

The model describes process of snow melting occurring in bounded volume. It was used for the pilot solar facility designing and water productivity evaluating. Numerical simulation of solar snow melting process with the help of the facility has been done.

The computer program enables to determine thermo physical characteristics of melting snow and the solar facility characteristics under simulated conditions.

To develop mathematical model the following approximations have been made:

1. Snow thawing is one-dimensional non-stationary process
2. Snow is considered as porous media having hard skeleton formed by ice grain having the specific dimension
3. There are water and air in porous
4. Capillary effect is taking into consideration
5. Thawing velocity is determined from the equation describing the grains dimension variation during thawing process
6. Pressure difference between liquid and gaseous phase is considered as steady

It is to be noted that the model and software are modernized for the glaciology topics study (this work is being carried out together with Academician V.M. Kotlyakov under the Russian Foundation for Basic Sciences grant).

III. DISCUSSION OF THE EXPERIMENTAL RESULTS

Experimental investigations have been carried out aimed at obtaining thermal characteristics of the pilot solar facility and testing of the main units of the facility under low ambient temperatures in laboratory and under field conditions of Antarctica.

The laboratory testing has been carried out in the Lavochkin Space Association. The testing goals were to study functionality of the facility units and to obtain thermal characteristics of the heat transferring system under simulated environmental conditions of Vostok station where in Austral summer ambient temperatures may reach -70^{0}C [3]. Special freezing chambers allowing to test samples under ambient temperatures of minus 150^{0}C - plus 150^{0}C have been used.

Fig. 3. shows temperature distribution in the different points of the facility installed in the freezing chamber. This experiment has been done to obtain data on the pilot facility capability to effectively melt ice at low ambient temperatures. To simulate solar heating of the absorber electrical heater with 500 W power has been used. Temperatures in different point of the facility as well as ambient temperature have been recorded. At the first stage of the experiment the freezing chamber have been cooled down during 5 hours. Half and an hour later the plastic bags with water have been placed in the chamber for obtaining ice to be melt in the facility. Then electrical heater has been switched on and the transferring system had started operation within approximately 15 min. On the basis of the obtained experimental data it was determined that the facility water output at T_a = -50 ±10^{C}C was as much as 4 l/h. This experiment has shown that the heat transferring system and thermal insulation had been properly designed enabling the facility to effectively melt ice (snow) under low ambient temperatures. Effectiveness of the transferring system has been proved also as a result of the facility testing in water heating mode. Testing of the tracking system, cables, batteries, drives and special paint coating of all the metallic part of the facility (exception is the metallic parts of the concentrator) has also been made in the freezing chambers. All parts of the facility operated properly.

Temperature distribution in freezing chamber.

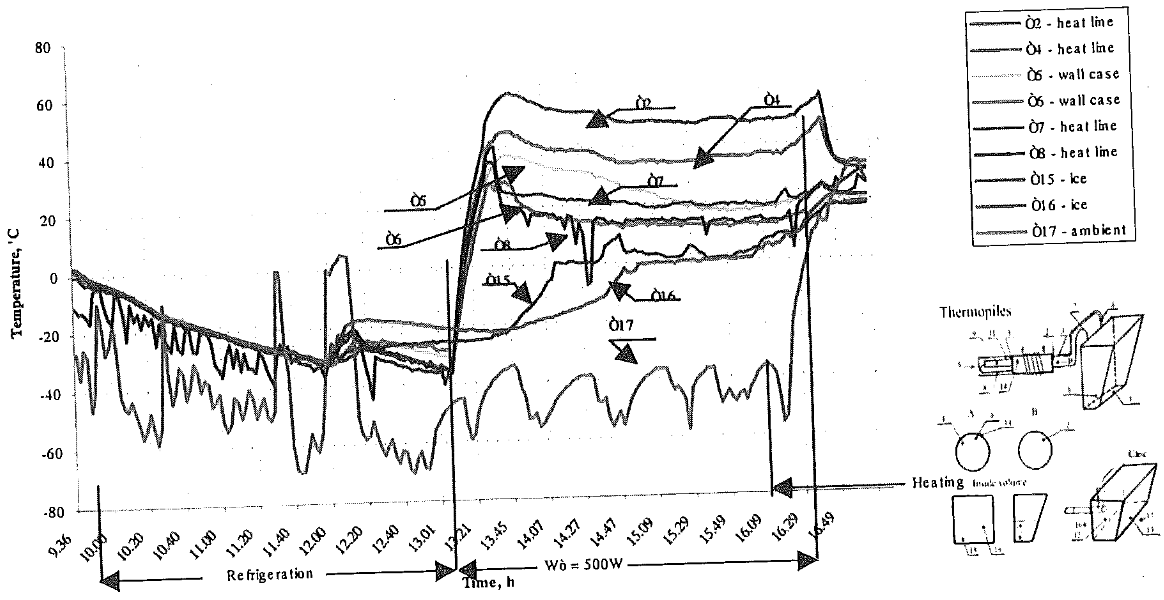

Fig. 3. Temperature distribution in the solar snow melting facility (experiment on ice melting in the freezing chamber)

In December 1999-January 2000 the solar heating facility has been tested under field conditions of Vostok station at ambient temperatures up to minus 45^{0}C and wind speed up to 15 m/s (Fig. 4).

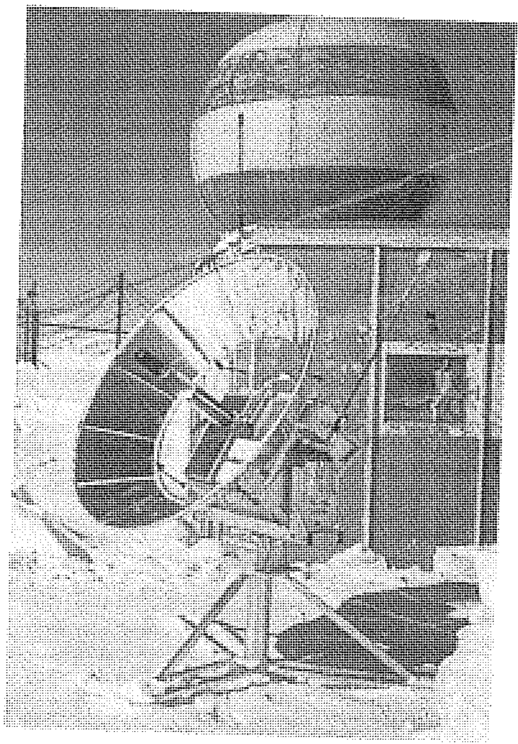

Fig. 4. The pilot solar snow melting facility («SEM-1») testing during the work of 45th Russian Antarctic Expedition at Vostok station, 78^{0}S (This picture is a courtesy of A.Sheynshteyn)

After arriving to Vostok station the inspection of the facility units has been made. The inspection has shown that the units that were transported from Moscow to Antarctica had no any damages.

Only one person has deployed the facility.

The facility was equipped with measurement and registration system. Solar radiation, snow temperature and density have been measured during testing. Snow temperature varies from minus 24^{0}C to minus 37^{0}C, snow density - from 320 to 400 kg/m^2. The facility tested and operated in different modes («solar» snow melting, water heating, cooking).

The experimental results can be presented as plots and diagrams. The diagram in Fig. 5 shows the pilot solar snow melting facility average daily water production under Vostok station conditions. The minimum water production (3 l/h) has been obtained with unglazed concentrating collector (UCC) at ambient temperature -40^{0}C and wind speed 7-9 m/s. The maximum water production (6.4 l/h) has been obtained with glazed (GCC) concentrating solar collector at air temperatures -35^{0}C and wind speed 3-4 m/s. Figs. 6 and 7 show input-output diagrams (experimental daily useful heat versus daily solar radiation on the concentrator aperture). Using the diagrams one can easily determine efficiency and water productivity of the solar facility with UCC and GSS for wide range of solar radiation data.

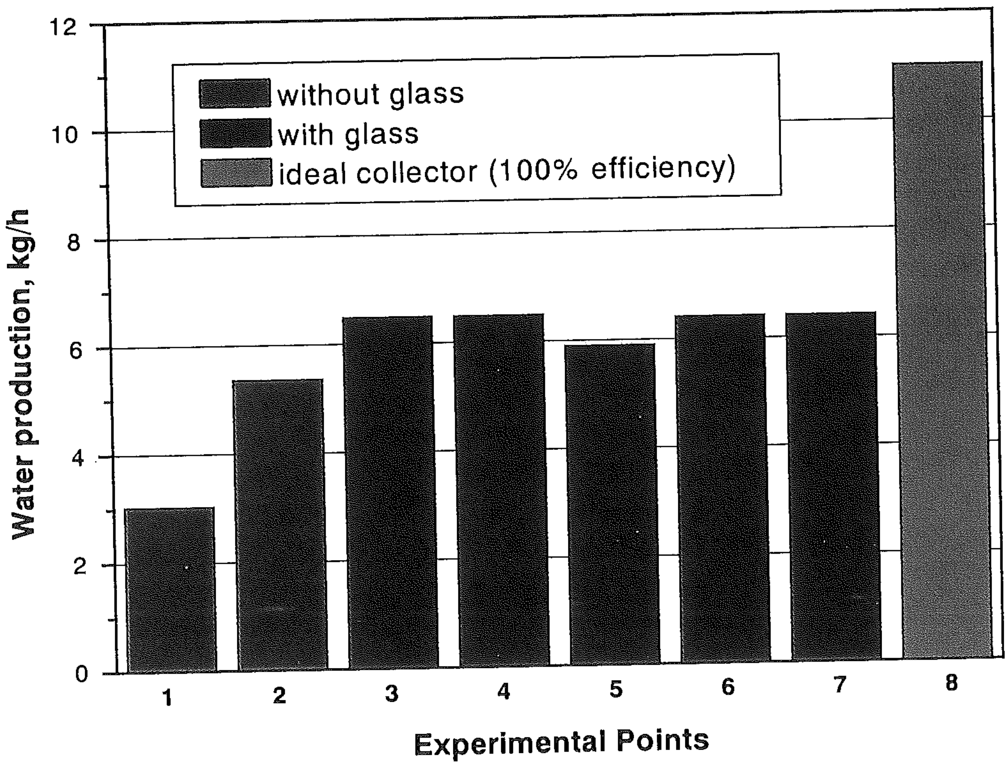

Fig. 5. Average daily water production under conditions of Vostok station

Fig. 5 shows the obtained results of the pilot solar heating facility field testing under conditions of Vostok station. (See also technical data description in the Appendix)

It is to be noted that with the help of the solar snow melting facility pure potable water can be obtained. High quality water obtained during the experimental work has been used for the station needs. This fact has been stated in the Russian report to SCAR and SCALOP on the activity in Antarctica in 1999-2000.

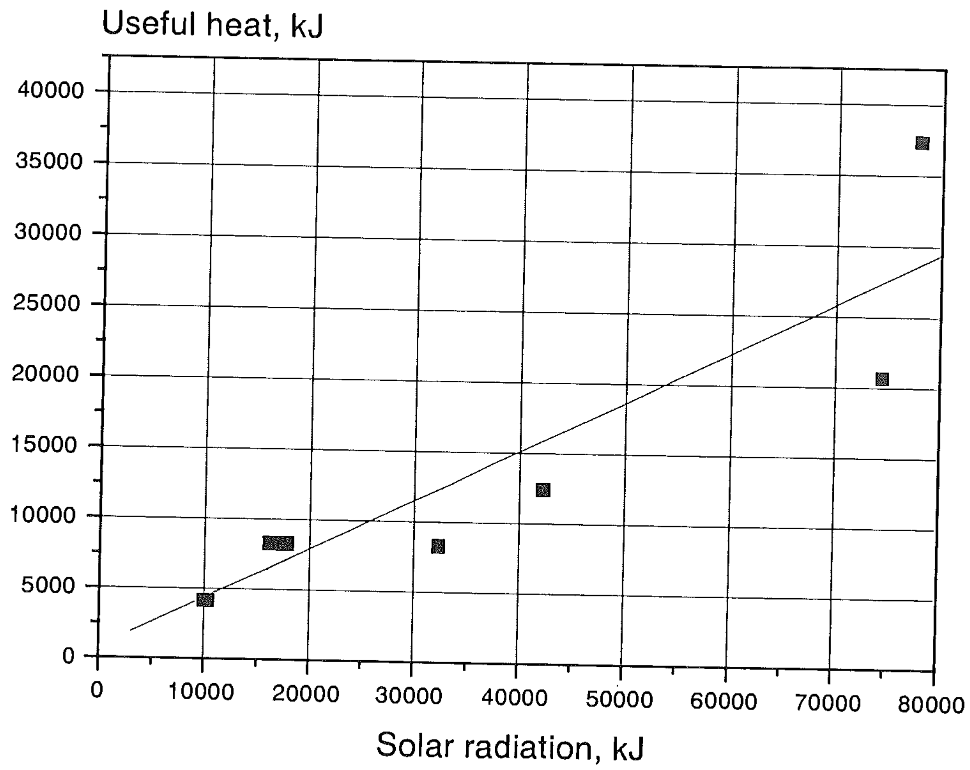

Fig. 6. Input-output (unglazed)

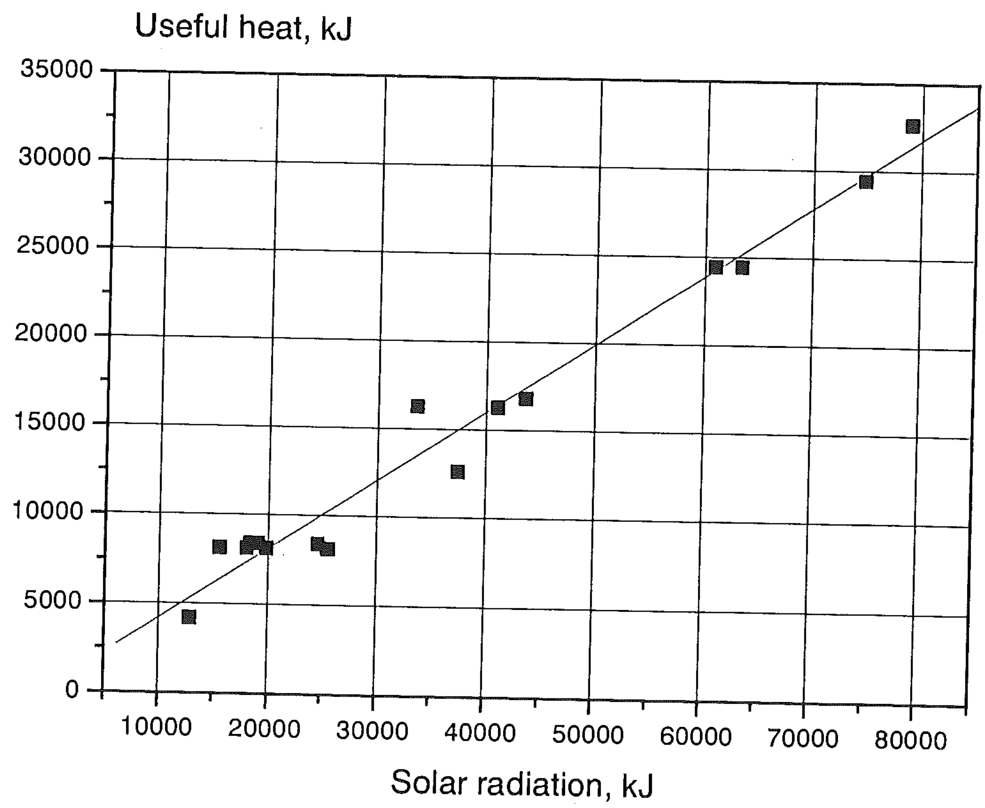

Fig. 7. Input-output (glazed)

IV. CONCLUSIONS AND RECOMMENDATIONS

1. A new type of autonomous portable solar snow melting facility «SEM-1» for water production, water heating, cooking under conditions of polar and high mountain regions has been designed and developed. The facility has been successfully tested in special freezing chambers at Lavochkin Space Association and under field conditions of Antarctica (Vostok station)
2. The experimental results have shown that due to space technologies (special heat transferring system, lubricant, paint coating, cables) the «SEM-1» can be reliably exploited at remote localities under extreme environmental conditions of polar regions
3. The developed heat transferring system enable to effectively transport solar heat to snow without using any electrical circulating pumps. The system is self-regulated (enable to prevent water freezing) and highly reliable
4. The testing have shown that the autonomous pilot solar snow melting facility reliably operate under extremely low ambient temperatures. The average daily water productivity and thermal efficiency of the facility are 5-6 l/h and 40-50% respectively
5. With the use of the facility hot water with temperature of 60^0C can be also obtained under extremely low ambient temperatures
6. The obtained experimental results have also shown that solar concentrator can be also used for cooking (water boiling, meat cooking) under low temperatures
7. The «SEM-1» is considered by the Russian Antarctic Expeditions as a basis for construction of potable water production system for using at Vostok station in Austral summer season
8. Mathematical model of snow thawing process occurring in the bounded volume has been developed. The model has been verified and works proper. Now it is modernized to be used as an instrument in glaciology studies
9. The «SEM-1» solar facility is being produced in small series at the Russian private manufacturing firm

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3. Antarctic climate handbook (1977)// (Ed. Dolgin I. M.). Gidrometeoizdat. Leningrad. (In Russian)
4. Aronovitch A., Gilliaret D. (ed.). Recommendations for performance and durability tests of solar collectors and water heating systems. Luxembourg.1989. 275 p.

ACKNOWLEGEMENT

The author would like to express his deep gratitude to Prof. E.E. Shpilrain (IVTAN) for his advises in carrying out the project and to the IVTAN colleagues: Mr. V.S. Zakharenko, who took participation in the facility concept design, Dr. V.Ya. Mendeleev for fruitful discussions of the tracking system design principles, Dr. S.E. Frid (IVTAN) for his assistance in preparation of the poster. The author also thanks Mr. B.I. Imerekov and Mr. A.S. Studenetskiy from the Russian Ministry of Science and Technologies for their support of R@D works aimed at renewable energy utilization in Antarctica.

APPENDIX

THE «SEM-1» TECHNICAL DATA

PERFORMANCE

Snow melting mode

- Thermal efficiency ~ 50%
- Average daily productivity (if 1 concentrator is in use) – 5 – 6 litres/hour
  The facility can be equipped with several concentrators
- Capacity of the container – 60 (example, can be equipped with large capacity container)
- Hot water with temperature +60^{0}C
- Water boiling – (2 litres per 30 – 40 min)
- Meat grilling – 1 kilogram per 30 – 40 min
- Design life time – 15 – 20 years
- Maintenance Interval – 4 years

ENVIRONMENTAL TOLERANCE

Temperature – up to minus 80^{0}C
Wind steady – 10 m/s
Survivable wind speed 20 – 25 m/s

SHIPPING DIMENTIONS

Solar Concentrator

Total weight – 5 kg
Total volume – 0.01 m^3

Heat transferring system with aluminium container (examples)

Total weight – 35 kg
Total volume – 0.5 m^3

Support with drives (examples)

Total weight – 55 kg
Total volume – 0.375 m^3

Project of 60kW Photovoltaic System at Syowa Station and assessment of the effects

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(1) National Institute of Polar Research (2) Nissin electric Co., Ltd.

ABSTRACT

We have been depending on fossil fuel as an energy source in Antarctic activities since the opening of Syowa Station. But owing to environmental issues, increasing use of energy and a limit of the transportation of fuel, a renewable energy needs to be introduced at Syowa Station urgently.

The test operation was carried out for about two years since1995 and the data of solar radiation and the PV output was obtained. As a result, despite an absence of sunlight for about two months(June and July), it turned that PV is useful enough as a sub power source at Syowa Station. The installation of PV panels has been carried out since 1997 and the total amount of panels is 40kW up to February 2000. The grid connection with the diesel generator started in April 1998.

The panels will be added up to 60 kW by 2002 and total electricity produced by PV is estimated to be 57,486kWh, that is about 6% of annual generation at Syowa Station. As a 10 kW wind turbine was installed in February 2000, hybrid-generating system of diesel generator, PV and wind turbine will be completed in the future and the system can decrease the consumption of fossil fuel.

1. INTRODUCTION

Today , a big problem to affect the continuation of mankind such as environmental issues and the resources problem is actualized . We have a same problem in Antarctica, so the introduction of renewable energy is hurried.

We started this project in1995 for the purpose of using solar energy as regular power source. Now , PV array 40kW and PCS 50kW work as a grid-connected generating system at Showa Station .

I show the outline and effects of PV system in the following.

2. Plan

Matters as follows are regarded as a basic problem to introduce PV system into Showa Station.

① Potential ability of solar energy
・・・Can PV system become an effective power source under a condition at Showa Station?

②Correspondence to the severe weather condition
・・・Can PV modules, support structures, and wiring materials installed outdoors be withstand cryogenic temperature and strong wind in Antarctica?

Therefore , we planned this project by steps as follows.

Step 1 (1995-1996) : The establishment of test devices
…Investigation of solar energy and weather condition.
Confirmation of PV Characteristics and resistance to the surroundings at Showa Station

Step 2 (1996-1997) : The establishment of an ice melting system
…Confirmation of the resistance to the surroundings under practical condition (support structures, PV modules, junction box and cable)

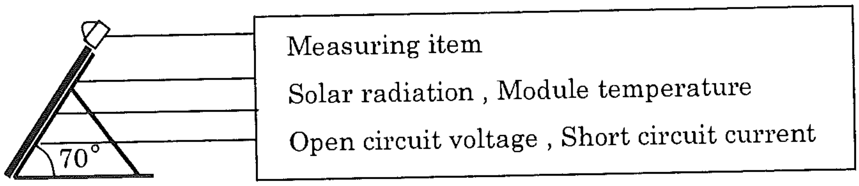
Step 3 (1997-1998) : The establishment of Power Conditioning Subsystem (PCS) for grid-connected operation
…Inspection of grid-connected operation with diesel generator.

Step 4 (1998-2002) : Increase of PV array
…Enlargement of capacity of PV system.

3.Establishment of test devices

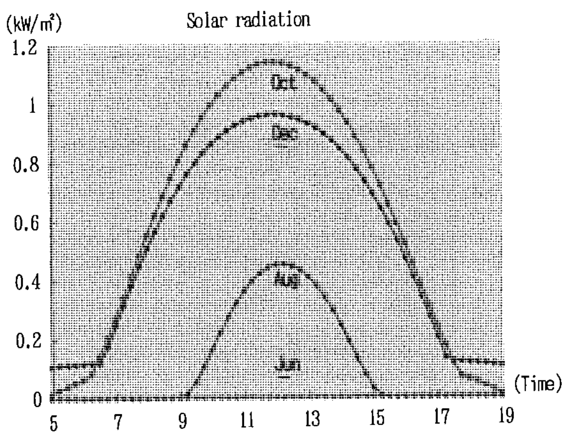
We installed test devices to measure solar energy and PV module characteristics in 1995 in order to investigate the effectiveness and possibility of PV system at Showa Station.

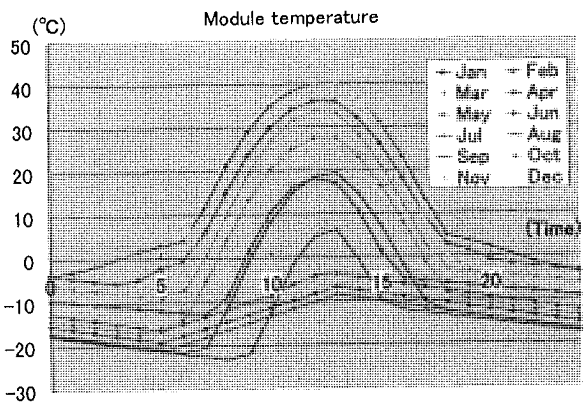
As a chart below, it consists of a measurement device, two pieces of PV modules, a pyrheliometer and a temperature sensor of module.



From the collection data, solar radiation at Showa Station exceeded that in Japan greatly in a peak. Also we could understand PV system is useful enough as sub power source despite an absence of sunlight for about two months.

I show examples of solar radiation data and PV module temperature one provided testing devices with graph below.



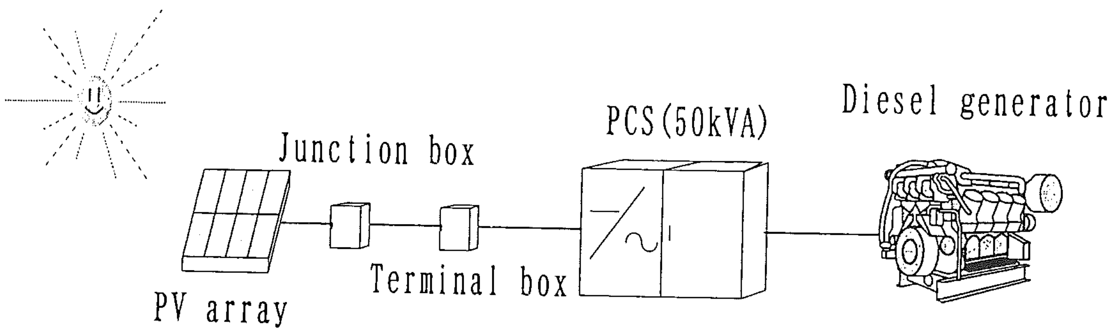


4.Project of 60kW Photovoltaic System

Because the effectiveness and possibility of PV system at Showa Station were identified with test devices, we examined full-scale introduction.

In order to use electricity generated by PV system as power source at Showa Station , we did it grid-connected system with diesel generator . This system is consists of PV array , support structures , junction box , connection box and Power Conditioning Subsystem(PCS : inverter and linkage protection devices).

Block diagram of this system is chart below.



About components, we did various examination in order to consider a special condition of Antarctica.

We show them in the next clauses.

4-1. PV modules

It is resistance to the surroundings that become a problem in the choice of PV module most.

Because being installed under the condition blowing a gale all the year round , We thought wind-resistant is the most important selection point.

In addition, we thought important to install easily with only 2 or 3 people.

Specification of PV module is as follows.

Specification

Output : 85.5W/piece

Dimension : W1200*H530*D35

Weight : 8.5kg/piece

Resistance to the static pressure : Wind speed 62m/s

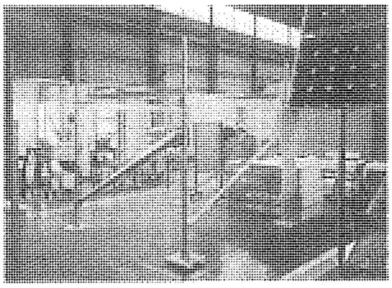
Efficiency : 13.4%

4-2. Support structure

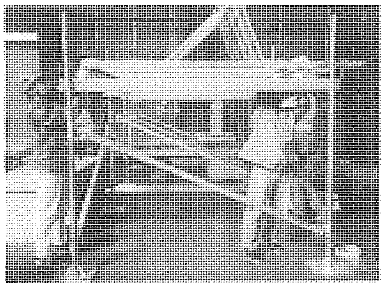
Structures to set up PV modules. Because of weather conditions, geographical conditions and work efficiency, there were various limitations . The limitations and the measures are in a list below.

Strong to salt damage (because of beach Neighborhood)	Adopt fusion galvanized (Z55) steel
Withstand a strong wind	Design with the wind-resistance at wind speed 62m/s
Can regulate height (because installed in the ground with unevenness)	Make possible to regulate with combination of pipes and U-bolt
Can transport without use of heavy Machinery	Design the maximum weight of a component less than 30kg
Can assemble without special tools	Be possible to assemble with a normal tool
Can assemble with only 2 or 3 people.	Design with light weight components
Can work under low temperature Condition	Avoid small works as possible in design

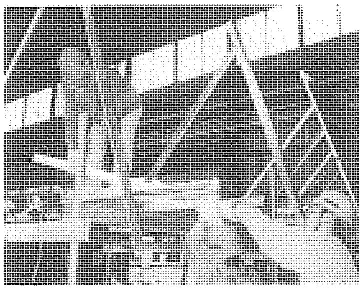
Doing measures as the above, we designed support structures. Photographs below are took in training of assemble.



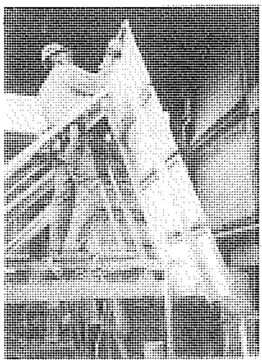
1.Setting up poles



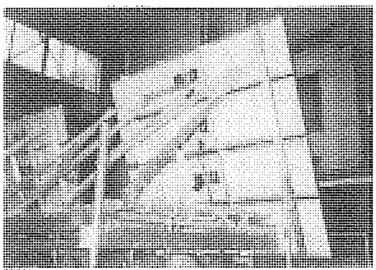
2.Horizontal strut



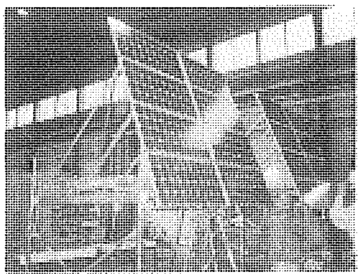
3.Module frames



4.Install modules



5.Wiring behind modules



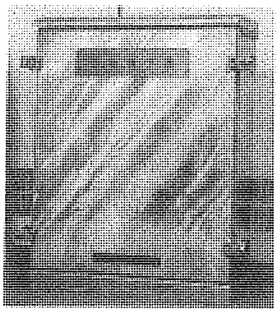
6.Finished

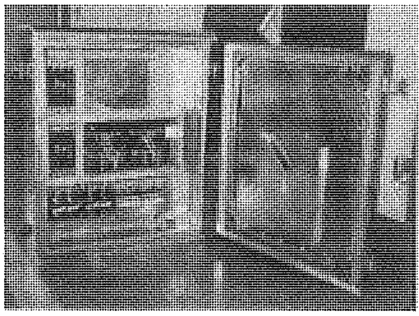
4-3. Junction box, Terminal box

Considering enlargement of every year , We installed junction box every 10kW. And also , for the connection between PCS in the building and PV array , we established a terminal box.

Because being installed outdoors , we paid attention to the points as follows.

Resistance to the salt damage	Adopt fusion galvanized (Z55) steel
Resistance to low temperature	Adopt MCCB and packing of low temperature specification
Sealing up structure	Close door with screws and raised sealing up degree





4-4. Power Conditioning Subsystem(PCS)

Functions of PCS are to convert DC power to AC one and grid-connect with diesel generator with linkage protection devices.

Basically , It is normal grid-connected PCS same in Japan. But we had to pay attention to the points as follows.

①There is fear of reverse flow from PV system to diesel generators when PV generation > load electricity in grid-connected operation.

…Getting information that the average of load electricity 160kW and minimum load 70kW, we were able to confirm that there was no problem in particular.

②So that PCS has a transformer , there is fear to let diesel generators stopped with an exciting current by mistake.

…We established a resistor for exciting current restraint.

③When the condition of PV generation ≒ load electricity in checking of diesel generator , there is fear that PV system continues operation and charge wiring to generators.

…With getting a operation signals of 3 generators , we construct the system which let PV system stop in case of all generators stopped.

5. Operation data

PV system started grid-connected operation in February 1998.
This system continues operation smoothly to date without a big problem.
As one example of operation data, we show the following three kinds of data.

①Data of PV generation from August to December in 1998
(PV module : 20kW, PCS : 50kW)

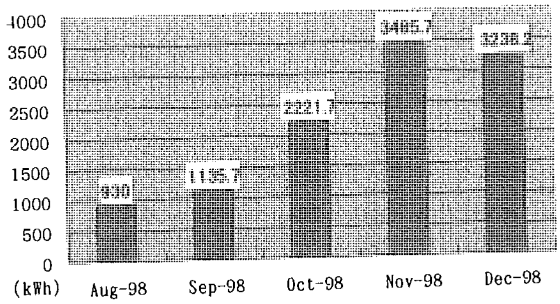
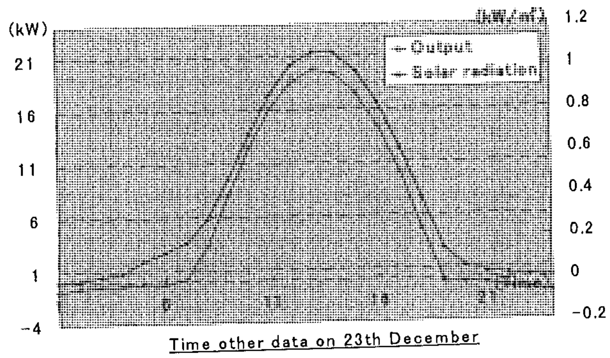


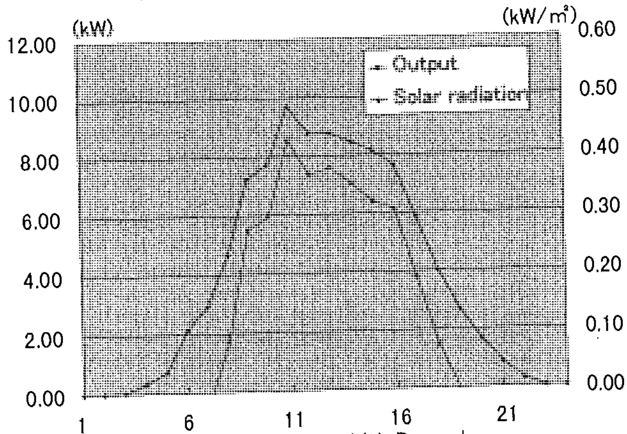
Fig2. Data of output energy

②Time other generation quantity on 23rd December(beautiful weather day)



Time other data on 23th December

③Time other generation quantity on 14th December (cloudy day)



Time other data on 14th December

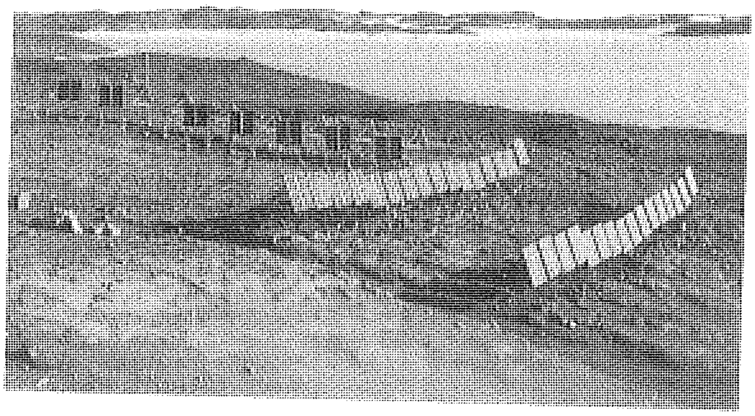
6. Future plan

PV system continues operation smoothly as shown in item 5.

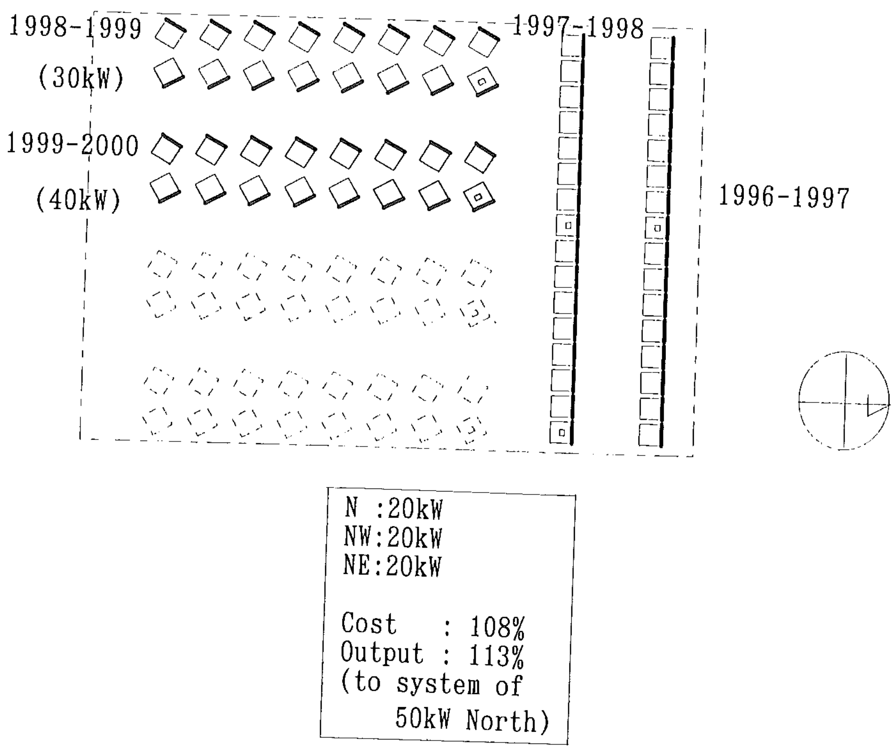
We have a plan to increase PV modules to 60kW finally as the chart below , calculated from the area of the establishment place and the limitation of PCS capacity (50kW) .

PV output can be controlled less than the upper limit of the PCS capacity by installing them in a 3 directions (Due north 20kW , 60 ° east from due north 20kW , 60° west from due north 20kW)

Then the electricity got from PV system is 113% to 50kW(due north) system between years.(Cost up of this case is around 8%.)



PV array : 30kW



7. Test calculation of PV system effects

From conventional weather data and operation data, we try to calculate the effects of the last system.

Prediction method of PV generation

①At first we set an expression to show as a model type of solar radiation beneath.

In=Ir*exp(-m · B)

I(d)=In*cos($\theta+\phi-\pi/2$)*sin(β)

I(r) =In*RE* cos($\theta+\phi-\pi/2$)*sin(β)

I(s)=In*SC

Insolation strength of atmosphere outside(1.354kW/m²)

Ir : Average of insolation strength after the upper air atmosphere passage In each month

In : Average of insolation strength after the lower atmosphere passage in each month

I(d) : Direct insolation

I(r) : Reflection insolation

I(s) : Scattered insolation

m : Air mass

B : Absorption coefficient of the lower atmosphere

θ : Altitude of the sun

ϕ : Inclination of the sun

β : Azimus of the sun

②Based on the observation data, we estimate each fixed number.

We did the data of a beautiful weather day as a model case. Because , even though climate changes are big in Antarctica , there are few change elements in a beautiful weather day .

I show the comparison actual data with that from model case in a figure.

③Calculation of PV generation on a beautiful weather day in each month

Using an above model, we predict PV generation on a beautiful weather day. Because a climate change is intense in Antarctica, setting a model of average for a long term.Therefore, we make a model calculation on a beautiful weather day.

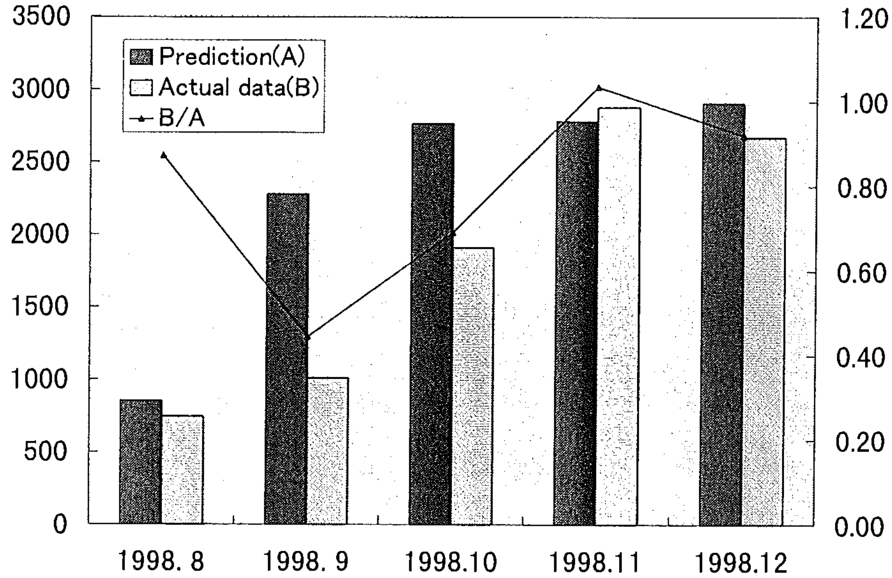
④Investigate the relation between degree of cloud amount and PV generation on beautiful weather days.

Setting a model relation between degree of cloud amount and PV generation on beautiful weather days , we predict PV generation for a day according to degree of cloud amount.

⑤Using the data of an average year of time according to degree of cloud amount in each month , we predict monthly PV generation.

7-2.Precision of our prediction

We show the comparison the results value (data ① of item 5) with prediction from August to December in 1998 in chart below in order to confirm precision of our prediction.



Relation between prediction and actual data

7-3.Prediction of PV generation and fuel reduction effect of final system

Based on prediction method mentioned above, we show PV generation and fuel consumption reduction effect when 60kW PV array is installed finally as follows.

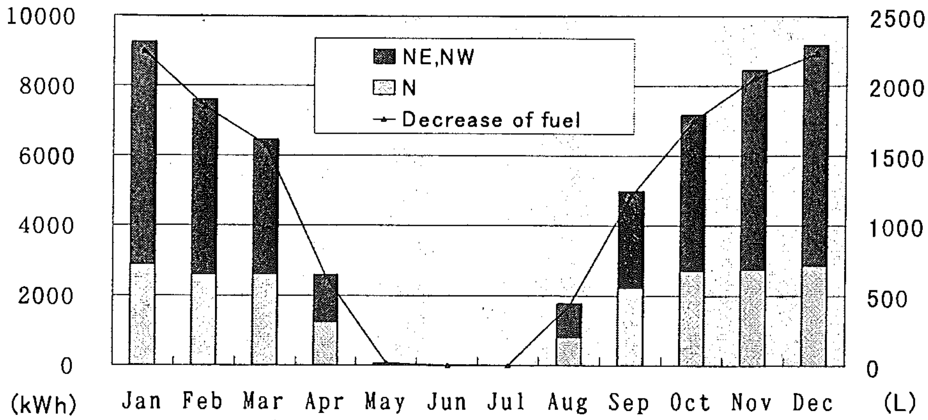


Fig2.Estimate of effects (Final system)

In the last,
This plan progresses smoothly and expects that this PV system can provide about 5% of electricity at Showa Station finally.
We believe this PV system will prove that PV system is an effective power source in Antarctica despite an absence of sun light for about 2 months.
We will inspect whether there is not deterioration of components and also show operation data.
We hope this PV system promotes the introduction of PV system in Antarctica and reduce consumption of fossil fuel as a result.

Using Large Commercial Wind Turbines in Antarctica
(Wind Power for Australian Antarctic Stations)

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INTRODUCTION

Research and data collection over several years has allowed us to determine the best alternative energy option for Australian stations. This is to install a small number of large commercially available, minimally modified wind-turbines. They would be variable-speed, 280kW machines without gearboxes, mounted on 33m or 50m steel towers. Matching an appropriate turbine design to the local climatic conditions has to be coupled with innovative solutions to the logistics and installation issues.

A computerised power-house management system is vital to the efficient operation of such a windfarm This will optimise the instantaneous wind resource and diesel generator outputs to the station load. When the wind resource exceeds around 40% of the station load, short-term energy storage systems such as fly-wheels, batteries or hydrogen powered fuel cells are required to hold the station load while different combinations of wind and diesel are switched onto the grid.

The planned windfarm, initially at Mawson, together with a power-house control and flywheel storage system will provide 100% of the station load for at least 75% of the time. The pay-back period in terms of fuel and infrastructure savings is expected to be between 4 and 5 years.

INSTALLATION ISSUES

Transport

Large (up to 250kW) commercial turbines can have individual components weighing up to 13 tonnes and 15 meters in length. Special cranes and transport equipment may be required to move the components from the re-supply vessel to the site.

Erection
Usually, cranes of 100 tonnes or greater are required to erect large turbines. Alternative erection systems such as tilt-up or self-erecting climbing cranes will need to be considered for remote installations such as those in Antarctica. Also to be considered is the small window of opportunity over summer to undertake an installation.

Foundations
Special consideration should be given to foundation design due to the high winds and cold temperatures. Permafrost ground conditions at some coastal sites is also a critical design factor. In general, concrete mass and cantilever designs are required with high quality control during construction.

Training
Specialised maintenance and servicing of turbines will need to be undertaken by station staff for which specialised training will be required each year. The training would include safety aspects of working at heights.

Siting
Turbine design life and annual output can be greatly decreased by turbulence generated by buildings, other turbines and prominent land formations upwind and in the near vicinity. Depending on wind speeds, "near vicinity" can be many hundreds of meters.

Wildlife
Experience has shown that the chance of bird-strikes is greatly reduced if the turbine is un-guyed, mounted as high as possible and is slow revving. Modern large commercial wind-turbines fit this profile.

RFI
Large variable-speed turbines use complex switching electronics to maintain fixed voltage and frequency output to the load. Care must be taken to ensure that interference from these electronics systems does not impact on sensitive scientific instrumentation which can be located near-by.

Electrostatic
Static build-up on cables, turbine blades etc due to the low humidity and blowing drift snow can be a problem at some sites. Sound earthing practices especially around control electronics need to be considered at the design stage.

Temperature
The constant low temperatures in Antarctica can lead to costly problems with gearbox oils, oil seals etc. Turbine designs which do not use gearboxes are therefore to be recommended.

Icing
Icing of blades, furling mechanisms and monitoring equipment would normally only be a problem at sites where onshore wind-blown wet snow or rain occurs. At most Antarctic stations, cold dry snow from the continental interior prevail and icing would not be an issue. Most large turbines are now available with blade heating.

Wind Abrasion
At sites where the prevailing wind direction is from areas which are substantially ice-free, "sand-blasting" of the blades could be a problem which needs to be considered. A loss of efficiency and a decreased design life could result if precautions are not taken. Wind driven snow can also be a problem, but to a lesser extent.

Fatigue
Compounded by the cold temperatures, metal fatigue due to the cyclic loadings in high winds, is the biggest issue in adapting large commercial turbines for use in Antarctica. Design modifications to the turbine and tower, including the use of specialist steels and castings, could be required.

CONCLUSION

Large wind turbines (greater than say 100kW) which are capable of withstanding the high wind regimes and cold temperatures in Antarctica are now available "off-the-shelf", so cost-effective replacement of diesel-burning power stations is possible. However, total power-house replacement will also rely on the provision of efficient energy storage systems and special computerised "powerhouse" management systems.

WIND SPEED DATA ACQUISTION AT DOME-C USING LOW POWER CONSUMPTION EQUIPMENT

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ABSTRACT: A research activity has been undertaken at Dome-C Concordia station in order to develop wind power exploitation in inner antarctica environment.
As a first step, a one year of wind speed and direction measurement has been performed, using standard instruments modified in order to permit operation a t –80 °C.
The experimental results after one year of operation are quite satisfactory, and in general terms agree with AWS data taken at DOME-C II site, but show a slightly more favorable wind resource.
Further development is anyway required since there are still clear indications that during some periods the speed sensor was blocked or turning not properly due to abnormal friction; the reason of that is not known at the moment.
The experience gained up to now suggests that the reliability of wind speed measurements performed in antarctic environment should be properly assessed with adequate experiments.

Keywords: Wind power, Wind speed measurements, Renewable energy, Zero-emission power sources, Very low temperatures.

1. INTRODUCTION

A research activity has been undertaken at Dome-C Concordia station, managed in the frame of an Italian-French collaboration, in order to develop wind power exploitation in inner Antarctica environment.
Indeed the utilization of wind power is regarded as a key factor in order to develop zero-emission power supply equipment for antarctic unmanned experiments [1], [2].

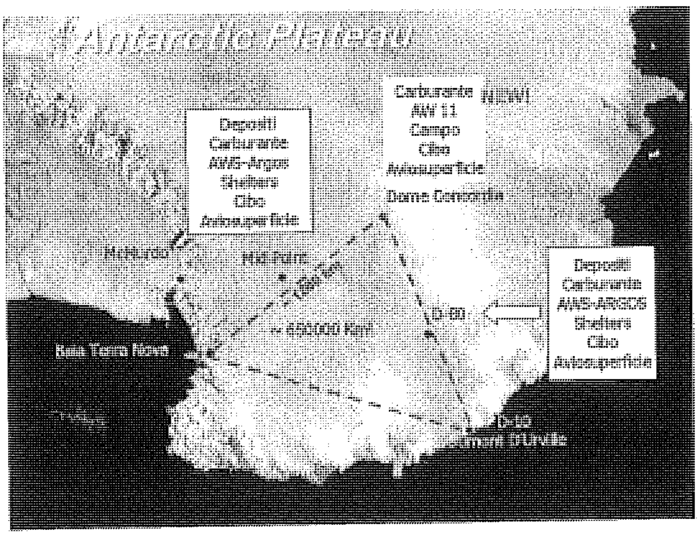


Fig. 1 - Position of Concordia station

As a first step, the issue of the available wind resource at the site was addressed.
Data available from the near Dome-C Automatic Weather Station (AWS) kindly published by the University of Wisconsin were examined at first.
These data, also reported by Guichard [2] showed that a quite low wind-speed regime had to be expected, and were however considered too limited and incomplete to perform a good wind power assessment.
It was therefore decided to install a measurement and data acquisition system able to measure wind speed and direction with a sufficient sampling rate and to store a year of 10 minutes average data, comprising wind speed, temperature and solar radiation.

2. SYSTEM DEVELOPMENT

Indeed the specifications needed for reliable operation of the equipment proved very demanding, principally due to the very low temperature range, that can reach -85 °C in winter, thus requiring special equipment.
The problem is mitigated by the fact that inner Antarctica does not require special provisions for freezing phenomena, normally the most severe problem in wind speed measurements in cold regions.
In our case an important requirement was also a very limited power consumption, since no reliable power supply was at that time available at the site during the 10 months of unattended operation.
A survey on existing equipment offered in the market led to the conclusion that all available models (see table I, taken from [3]) needed too much power to be correctly operated.

Model	Thies Clima 4.3324.21	Vaisala WAA25	Rosemount Aerospace 1774W	Hydro-Tech WS-3
Min. operating Temperature (°C)	-35	-55	-55	n.a.
Power (W)	40	70	Max. 370	Max. 1500

Table I – Minimum temperature and Power consumption of some commercially available heated anemometers

Indeed even if most of the power consumption is evidently needed to de-ice the anemometer, in any case none of them could in principle guarantee operation at –80 °C without additional power.
In addition, preliminary tests on climatic chamber, even in "dry" conditions, showed not proper operation of instruments normally adopted in Antarctica without additional heating
The decision was then taken to modify two standard wind speed and direction sensors (Vector Instruments model) normally used by ENEA for wind energy assessment activities.
The adopted instruments were:

- Wind speed: Vector Instr. Mod. A100R
- Wind direction: Vector Instr. Mod. WP200P

Modifications were introduced in:

- bearing mounting and lubrication, allowing either for differential contraction between bearing and anemometer body
- seals

- pulse generators
- potentiometer

While the original sensors were not able to operate at temperatures lower than minus 40 °C, tests on the climatic chamber showed good performance at temperatures as low as -80 °C, with negligible power consumption (no additional heating nor electronics is installed in the sensors).
The data acquisition system has been designed around a Campbell Scientific CR10X unit specified for -55 °C operation; this temperature is compatible with the range of minimum temperature that can be reached by the container where the equipment is installed, at 6 meters of depth in the snow.
The unit is powered by a series of 4 Lythium Thyonil Clorure batteries (Total rating: 15 V-16.5 Ah), sufficient for one year of operation; indeed the measured average power consumption is of only 30 mW .
In figure 3 a drawing of the data acquisition wiring is shown.

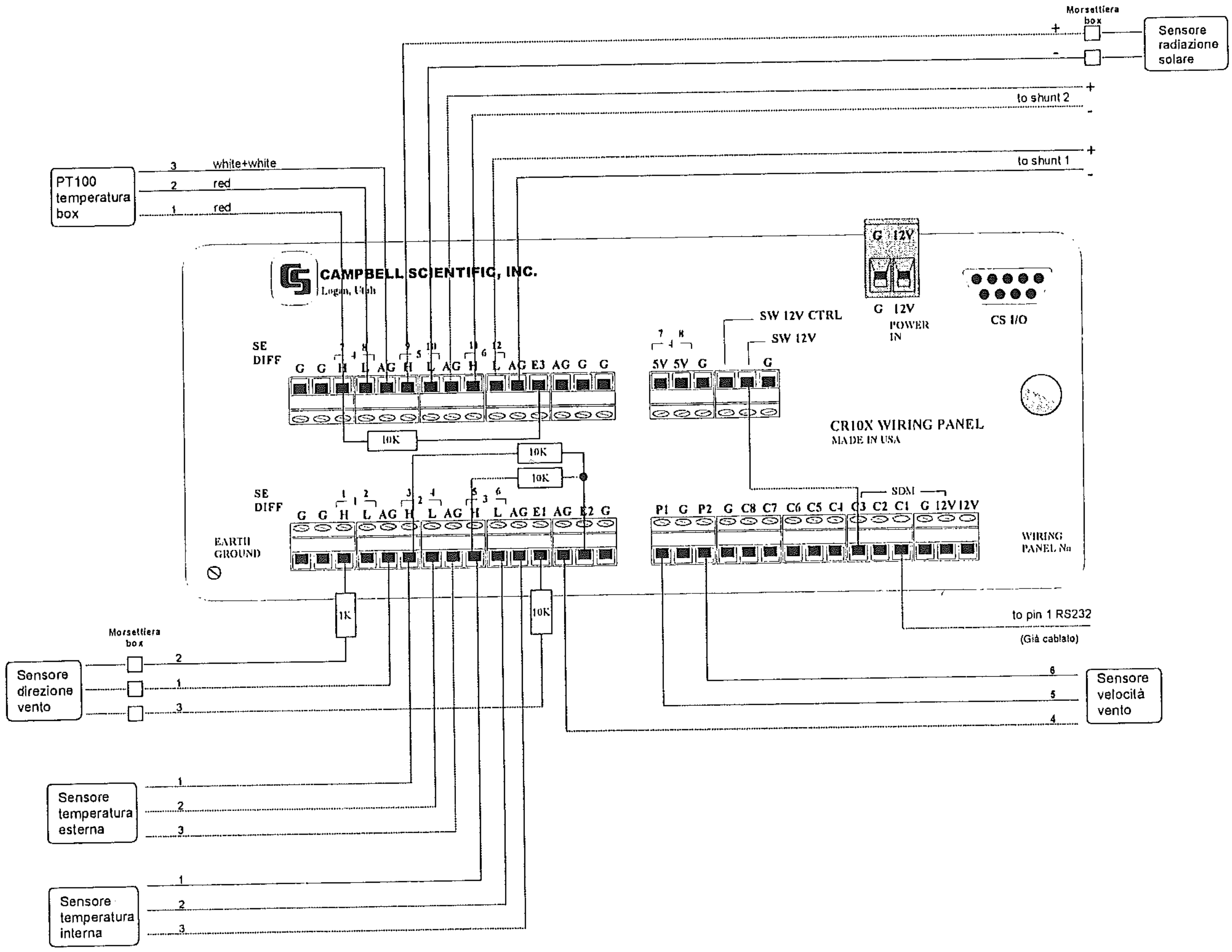


Fig. 2 – data acquisition system wiring

3. INSTALLATION OF THE SYSTEM

The sensors and the data acquisition equipment were installed at Dome-C Concordia during the 1998-99 campaign.

Figure 3 shows the position of the anemometer and of the direction sensors, mounted on a pole at 9 meters a.g.l.

The picture, taken during the 1999-2000 campaign, shows also the new wind-turbine that has been recently installed, described in [4] and in another paper of this symposium [5].

Also shown are two small wind turbine, of the Rutland type, MARLEC make, with a rated power of 70 W.

These two units were added at the end of the 1999-99 campaign and connected to small heaters contained in the same insulated container, buried at 6 meters down the snow, hosting the data acquisition equipment.

These two units were added only for test purposes, since, as expected, their contribution to container heating have been practically negligible.

They proved useful anyway, since their output was monitored by the same data acquisition system, and permitted to get some additional information on wind-speed.

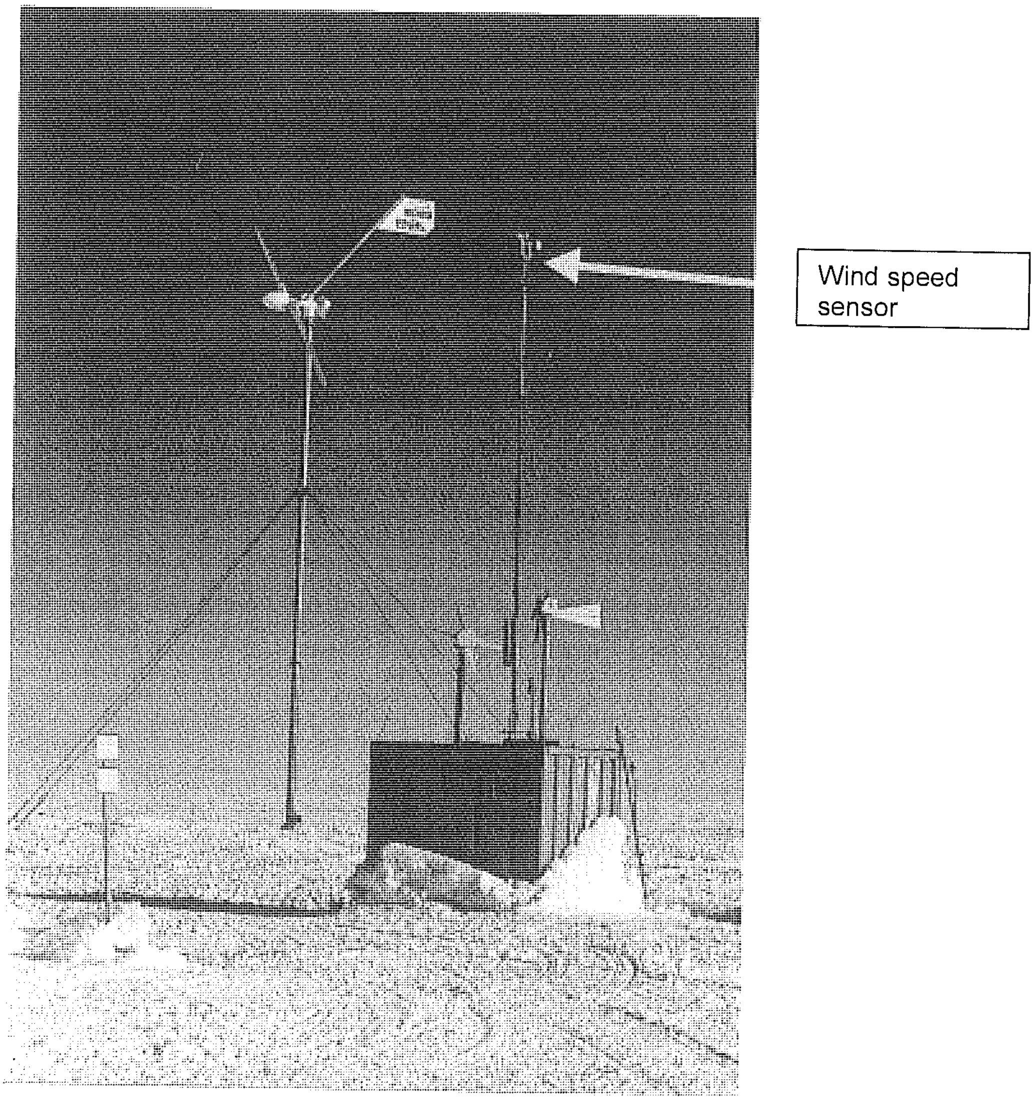


Fig. 3 – Position of the anemometer and wind direction sensors; also the new wind-turbine and two small 70 W Marlec units are shown.

4. EXPERIMENTAL RESULTS

Wind speed has been sampled at 10 sec. rate, while all other parameters (Wind direction, Solar Radiation, External an Internal temperatures, Current from Marlec Turbines) and has been sampled every minute.
10' averages of Wind speed and direction and hourly means of the other parameters have been stored in the memory of the data-acquisition unit; the data have been recovered during the 1999-2000 expedition.
The quality of data, comprising 10 months of measurements, from 1st February 1999 to 2nd December 1999, is quite satisfactory, since no data points are lacking.
The comparison of wind speed and solar radiation measurements, depicted in fig. 4, shows that for during 4 winter months the solar radiation is practically zero, as expected.
In addition, during July and August also available wind power energy appears very limited.
It must be noted that the scale of solar radiation is unreliable, since the radiation sensor was added at the last minute and was not fit for the site conditions.
The very limited wind speed resource found in august lead to the suspect of possible anemometer malfunctions.

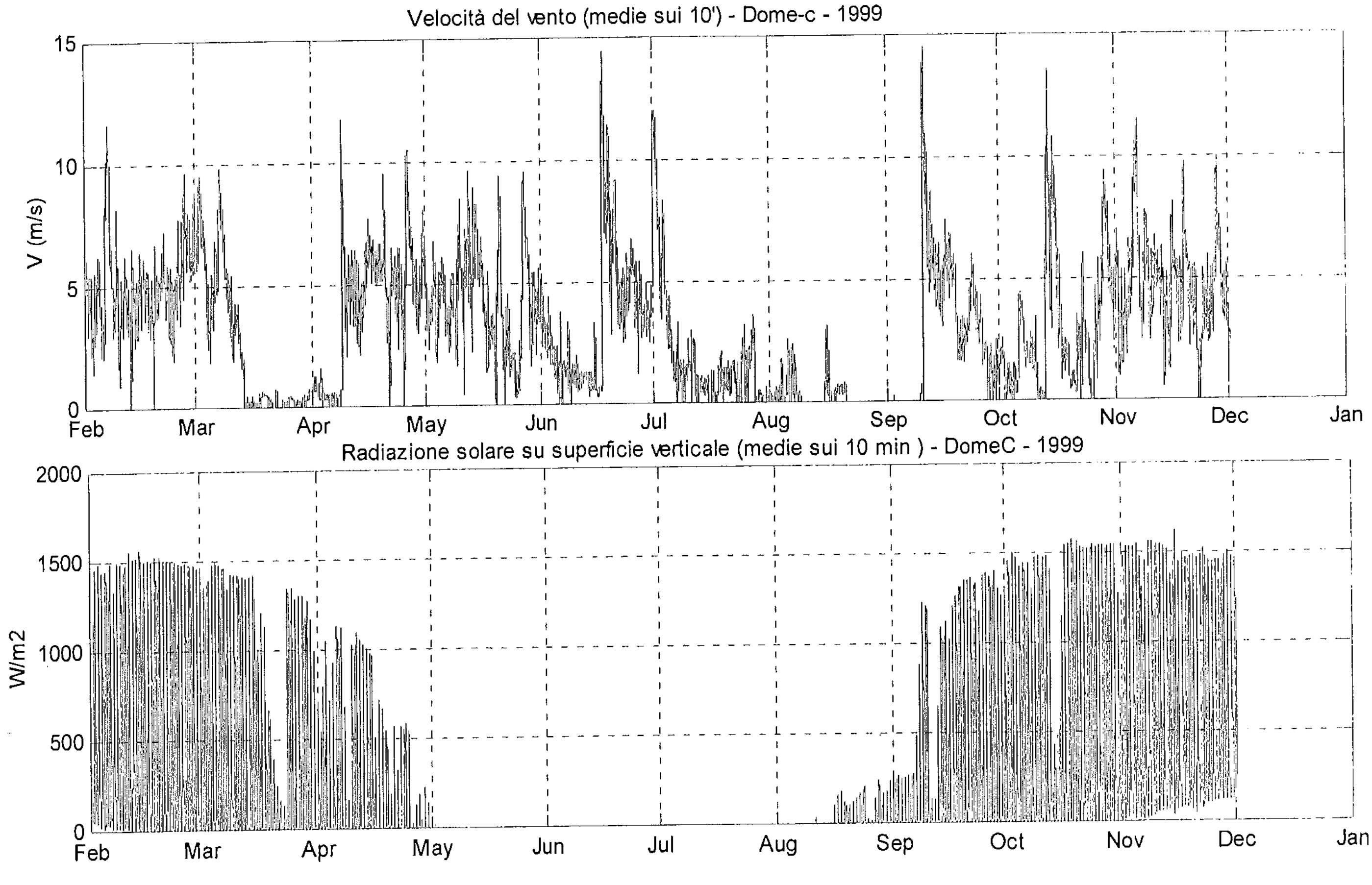
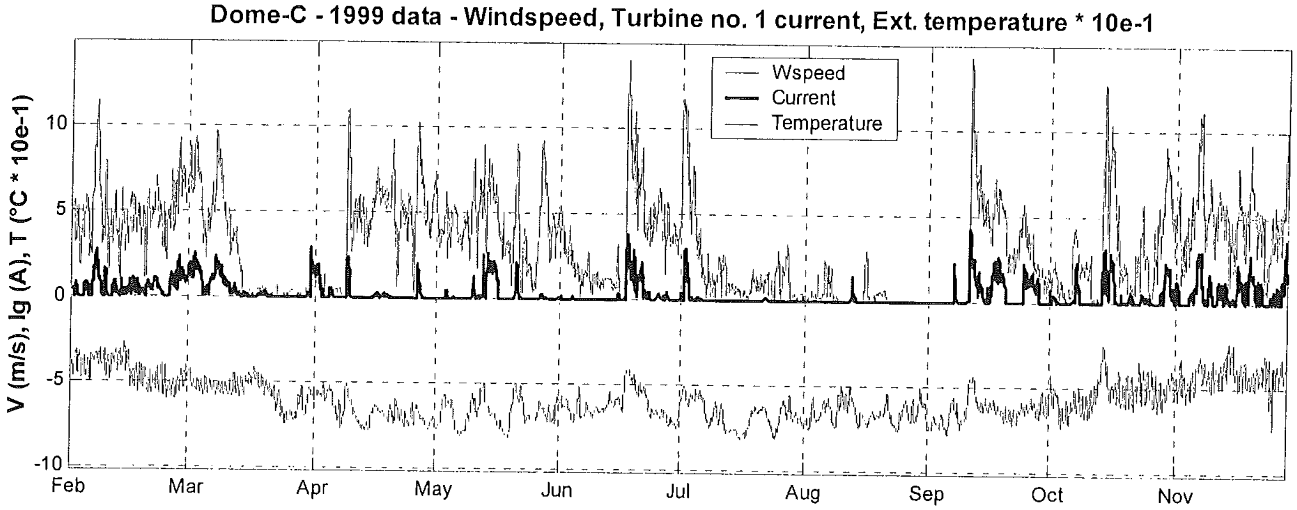


Fig. 4 – Wind speed and solar radiation on a vertical surface (scale unreliable)

Indeed further analysis on data clearly showed that not only in august but even during other periods the anemometer operation was not completely reliable leading to resource under-

estimation.. Comparison with output of the two small Rutland 70 W wind turbines left at the site was then used to detect anemometer malfunctions.
Indeed, while one of the two turbines was almost completely jammed by the cold, the other was running for sufficient time to show clear periods of jammed anemometer while the turbine is operating, and vice-versa. Reasons for this behavior have not been identified yet, since it is not univocally linked to temperature.
Wind-speed data were therefore corrected calculating the correlation wind-speed/turbine output during periods of reliable operation of both units, and then using the turbine power output as wind-speed estimate during periods of jammed anemometer.
Figures 5 to 7 show the comparison of wind speed, temperature, turbine output; in the graph, error flag = -1 indicates periods of unreliable anemometer operation.



5 – Wind speed, turbine current and external temperature (multiplied by 10^{-1})

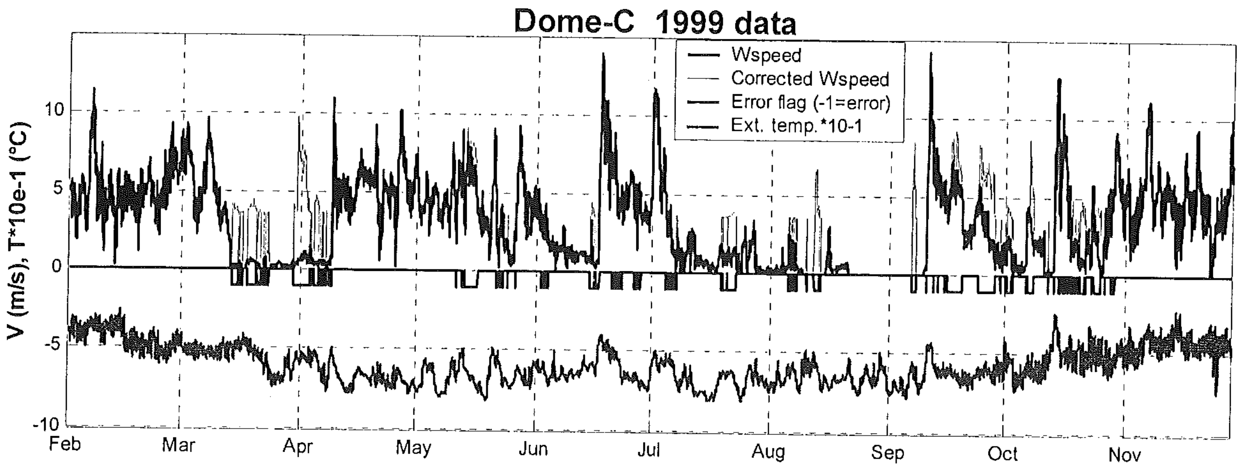


Fig. 6 – Traces of Wind speed (as measured and "corrected"): discrepancy is signaled by error flag = -1; there is not clear correlation with temperature.

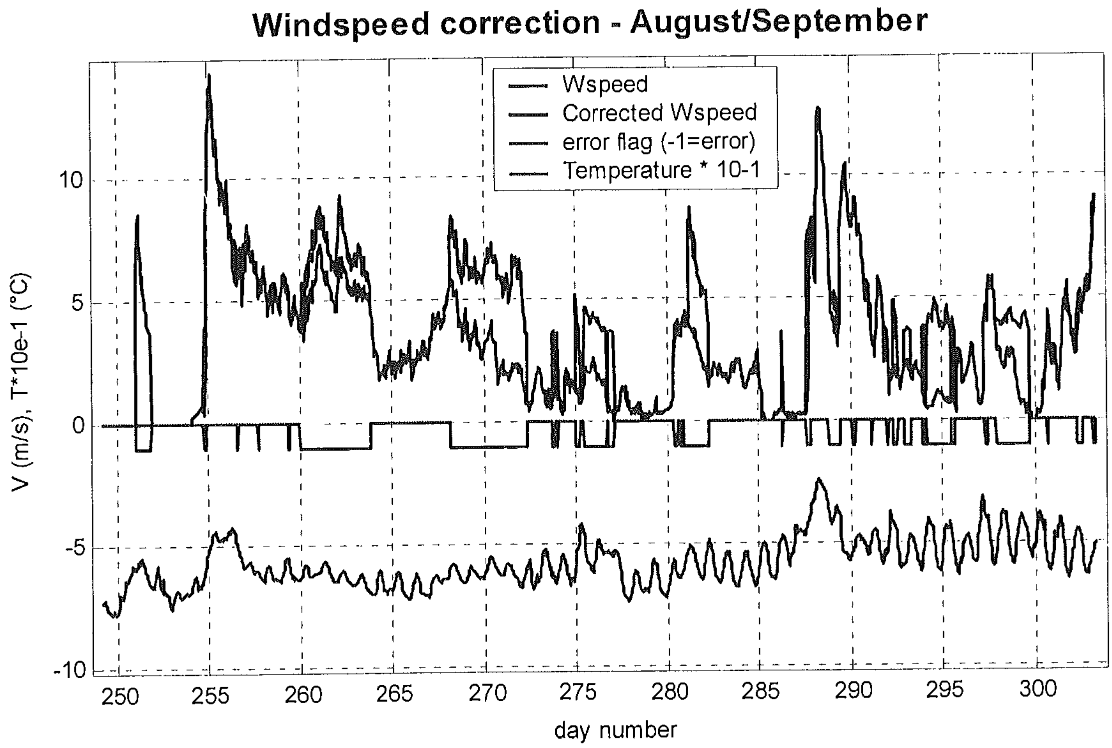


Fig. 7 – Wind speed correction: detail of period August-September

It must be emphasized that, in any case, this type of errors leads to resource underestimation, and is therefore conservative for the analysis, but also is more pronounced in case of very low wind-speed, not significant from the point of view of power production.

5. WIND SPEED STATISTICS

The statistics calculated on the data-set show a limited difference with respect to data taken at Dome-C by AWS stations (DOME-C site, years 1985-1995 [2], and statistics on raw data, Dome-C II site, AWS).

The comparison is shown in fig. 8, where statistics of "original" and "corrected" data of Concordia and AWS data of the period 1985-1995 and of 1999 are superposed.

Even if Dome-C wind energy in year 1999 has been a little more than the average of years 1985-1995, distribution measured at Concordia seems a little more favorable.

In addition, data taken at Concordia during august could be affected by significant underestimation; the only check that is possible is with AWS data of 1999; a comparison of monthly averages is shown in fig. 9; clearly it is possible that during august either the anemometer and the Marlec turbine were jammed.

Regarding wind direction, prevailing winds were found from the southern quadrants, while maximum wind speed of about 15 m/s from SE were more frequent, as shown in figure 10.

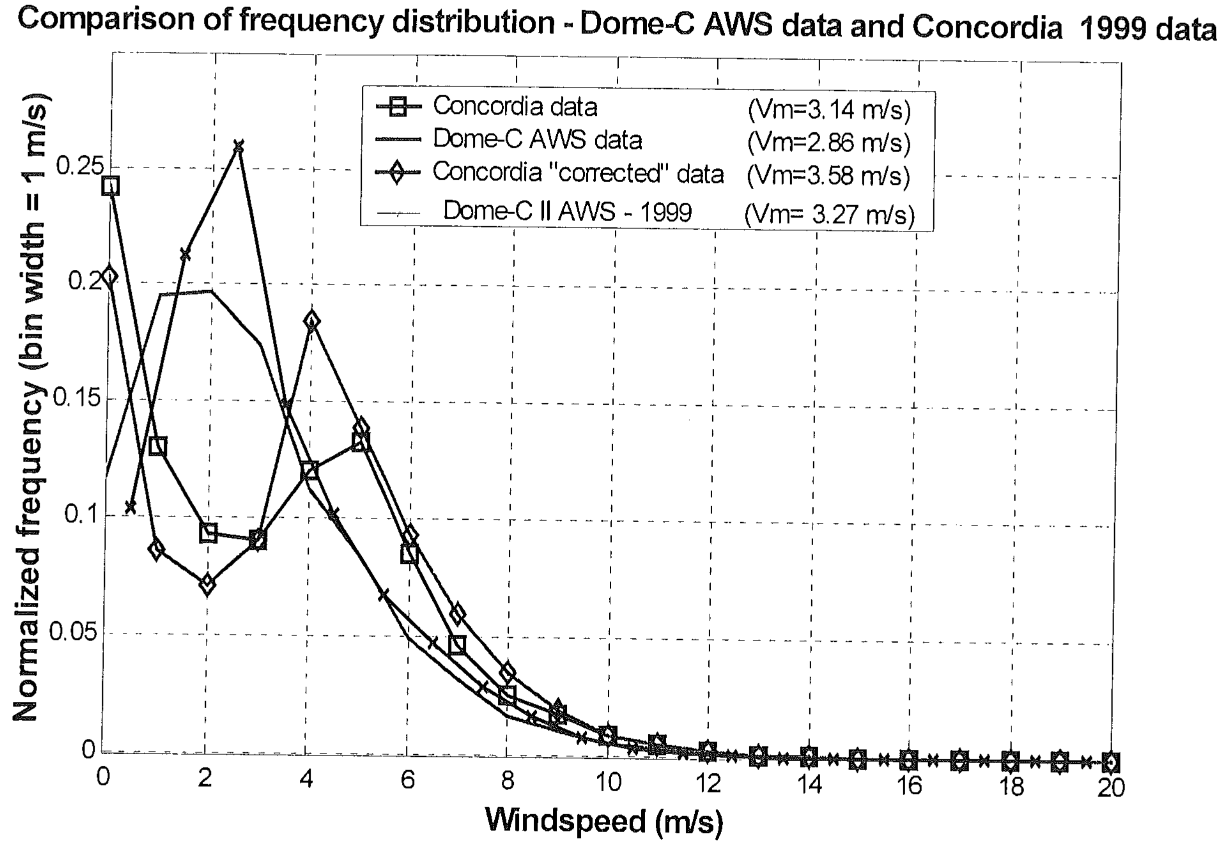


Fig. 8 – Wind speed statistics

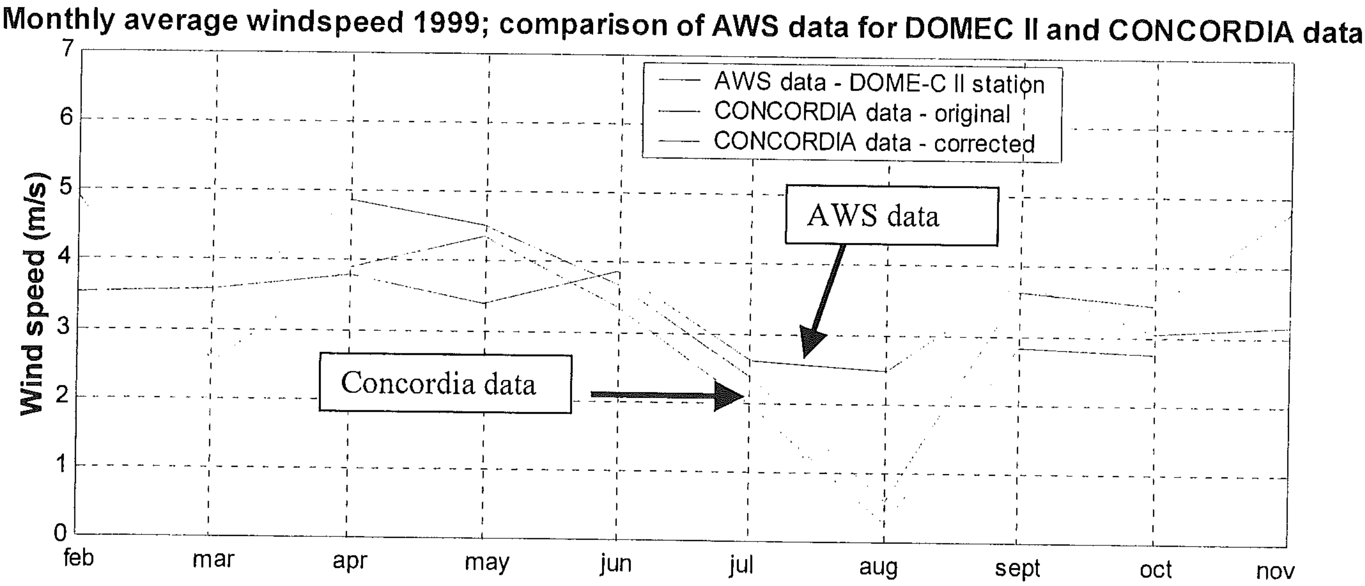


Fig. 9 – Monthly averages at Concordia and at AWS DOME-C site – 1999.

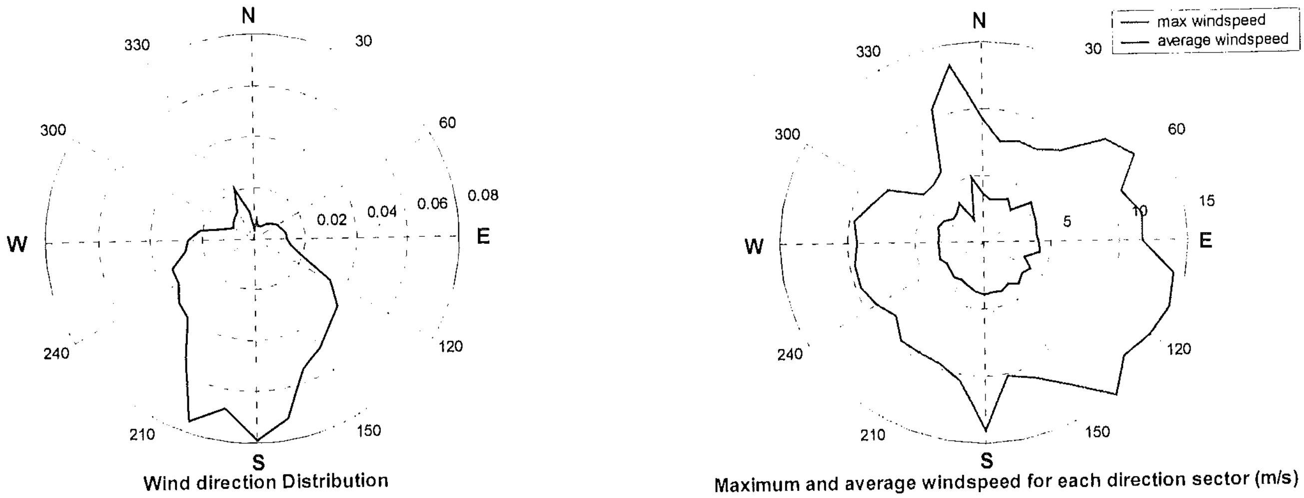


Fig. 10 – Wind direction statistics

6. CONCLUSIONS

Wind speed measurement in antarctic conditions requires special equipment and qualification tests.

The reliability of wind speed measurements performed in antarctic environment should anyway be properly assessed with adequate experiments, and thorough cross-examination of data sources is needed to avoid resource underestimation.

The equipment developed for the measurement campaign behaved satisfactorily, but further tests should be conducted in order to assure complete absence of measurement errors in all conditions; in particular there are still clear indications that during some periods the speed sensor was blocked or turning not properly due to abnormal friction; the reason of that is not known at the moment.

Wind power resource at Concordia, though not very abundant, seems a little more promising than in earlier assumptions, and anyway sufficient for exploitation in zero-emissions power supply of unattended installations.

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[5] M. Falchetta, A. Lori, R. Maso, A. Nunzi, D. Prischich, F. Caricchi, F. Crescimbini, L. Solero – A new wind Turbine for remote installations in Inner Antarctica – IX SCALOP Symposium, 12 July 2000, Tokyo.

A NEW WIND TURBINE FOR REMOTE INSTALLATIONS IN INNER ANTARCTICA

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ABSTRACT: Interest in zero-emission power sources for electricity supply of remote installations and stations in Antarctica is increasing among researchers and bodies involved in Antarctic research.
Since activities are now increasingly focusing on inner antarctica, where the environmental conditions are very peculiar in terms of very low minimum temperatures, low average expected wind speed and no sunlight for 5-6 months/year, a special 5 kW wind turbine has been developed.
Improvements include a directly driven Nd-Fe-B permanent magnet generator and qualification/modification of mechanical components to face the extremely low temperatures expected.
Most of the components have been tested in a climatic chamber at temperatures of -80 °C.
The wind turbine has been tested for one year at the C.R. Casaccia test field of ENEA and has been finally installed at Dome-C during the 1999-2000 antarctic expedition.

Keywords: Wind turbines, renewable energy, zero-emission power sources, Permanent magnets, Very low temperatures

1. INTRODUCTION

PV modules and small wind turbines are currently employed for a number of very small and small size unattended field instrumentation and telecom power supply, either in arctic and antarctic coastal environments [1], [2], [3], [4].
Indeed zero emission renewable power sources offer substantial advantages in view of environmentally friendly, reliable and competitive power supply in many remote applications in Antarctica.
As the area of operations moves towards inner regions, closer to the South pole, far away from the main bases, an increasing need for solutions able to supply substantial amount of energy will arise.
ENEA, responsible for the implementation of the logistic activities of the Italian National Antarctic Research Program (PNRA) is actually evaluating the application of zero-emissions power supply for Concordia station, operated at Dome.-C site in the frame of an Italian-French cooperation.
As part of the activities, some evaluations have been performed on the technical-economic potential of zero-emission power supply using hybrid wind-pv power sources with long-term hydrogen storage by means of electrolyser/fuel cell systems, with promising results [5].
At the same time, other researchers/institutions have performed similar evaluations, both considering only conventional storage systems [6] or advanced hydrogen storage systems [7].
Being wind power a key element of a zero-emission power source, a particular effort has been undertaken to develop and improve its applicability in the specific environmental conditions of inner Antarctica.

2. WIND POWER FOR CONCORDIA

2.1 Wind Power for Inner Antarctica

Antarctica is normally renown for its strong, even destructive winds; indeed this is the situation of many coastal areas of Antarctica, with medium/high or even exceptionally high wind strength connected to frequent icing conditions and relatively "moderate" temperatures. Catabatic winds easily can reach a speed of 250 km/hr., while some coastal sites show record monthly averages as high as 29 m/s (!) (Port Martin, 66°49'S, 141°24'E, with a yearly average of 16.9 m/s) [3].

Therefore in these areas emphasis is on turbine structural strength and ability to survive blade erosion and icing conditions, more than efficiency, since the achievable capacity factor [1] is so high that the only question is if the turbine can survive and safely operate for a reasonable lapse of time.

On the other hand, zero-emissions power supply solutions able to operate on a year-round basis in inner Antarctica must face two problems:

- Unavailability of sun power for 5-6 months a year
- Very cold and dry climate, with substantially low average wind-speed

That means that in inner Antarctica:

1. wind is practically the unique available renewable power source during the long winter
2. on the other hand the average power density that can be reasonably be exploited is quite limited if compared to what is normally achievable on a typical windy site of Europe or U.S.

As a matter of fact, typical wind farm sites in Europe show an yearly average wind speed comprised between 6 and 9 m/s, permitting to achieve a capacity factor in the range of 20 to 50%, while in inner Antarctica, with typical averages in the range of 3-5 m/s it seems hardly possible to reach capacity factors higher than 10%.

Bearing in mind that the capacity factor is directly proportional to the energy yield of a wind turbine, it can be shown that a wind turbine in inner Antarctica will typically produce substantially less energy than what is normally expected from a wind turbine.

Aiming at a year-round power supply, one choice could be to introduce a long term hydrogen storage, sufficient at least for 5-6 months, able to store from pv sources during summer all the energy that will be needed during winter; but economic and reliability considerations lead to show practical convenience of systems where wind has aniway an important role.

This means a very difficult task for a wind turbine, that must be able to operate at high efficiency mostly at partial load at extremely low temperatures. The difficulty is partly mitigated by the absence of icing problems.

2.2 The Concordia project

The first application of the type here considered has been proposed by ENEA staff operating the Concordia station at site DOME-C, in the frame of an Italian-French cooperation.

The station is in the antarctic plateau (lat. 75°06'06", long. 123°23'42") at an altitude of 3233 mts. a..s.l.., quite far (1200 km) from the Italian and French main bases, and is actually operated only during the three "warmest" months (dec. to feb., with temperatures ranging from –10 °C to –50 °C); actual total cost of electricity supply using conventional fuel fired gensets has been evaluated in the order of 3.5 Euro/kWh.

From the meteorological point of view, DOME-C is an extreme example of "continental Antarctica", with an average winter temperature of -70 °C (with a minimum recorded value of - 85 °C) average wind speed in the order of 3-4 m/s, maximum expected wind speed less than 20 m/s.

Indeed, from the wind energy point of view, the real situation found by specific measurements performed in the frame of this project (and described in a different paper in the same symposium [8]) seems now to be a little more favorable than earlier predictions, since data of 1999 show an average value of 3.6 m/s, that in energy terms is worth 66% more than the 2.86 m/s predicted from earlier observations, computed by A. Guichard [6] and based on data of the Automatic Weather Station (AWS) ARGOS 8904, actually some 50 km. away from Concordia.

The comparison of data recorded at the site on 1999 (original and "corrected" from errors leading to underestimation) and data coming from AWS Dome-C observations is shown in fig. 1.

Even if such more optimistic perspective, it is a matter of fact that the wind resource available at the site is quite limited., and this is confirmed by the human experience.

In the near future some of the activities will be performed on an annual basis and will need zero emission power (e.g. astronomical installations) and unmanned winter operation; wind power is therefore regarded as a "very interesting" option.

Recent pre-feasibility studies [5], [6], [7] show that in order to assure zero-emissions at Dome-C or similar antarctic sites a hybrid solution with pv and wind power combined with hydrogen long term storage and battery short term buffer will be needed, the sizing of components depending mainly on the available wind resource.

As a first step, a small Rutland wind turbine and a pv panel were left at the camp during the 1997 antarctic winter and were found still alive and operating by the 1997/98 and 1998/99 expeditions; no record is available on effective energy production during the coldest periods. On the same time, the development of a wind turbine with a size in the range of 5 kW has been undertaken.

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[1] The capacity factor CF is defined as the ratio E/(Pn*8760) between the yearly energy yield "E" and the maximum possible energy that could be produced continuously operating the generator at its nominal power "Pn"; it is a measure of the "energy exploitation" of the machine. For a given Pn, CF basically depends on site energy density and on efficiency and reliability of the turbine.

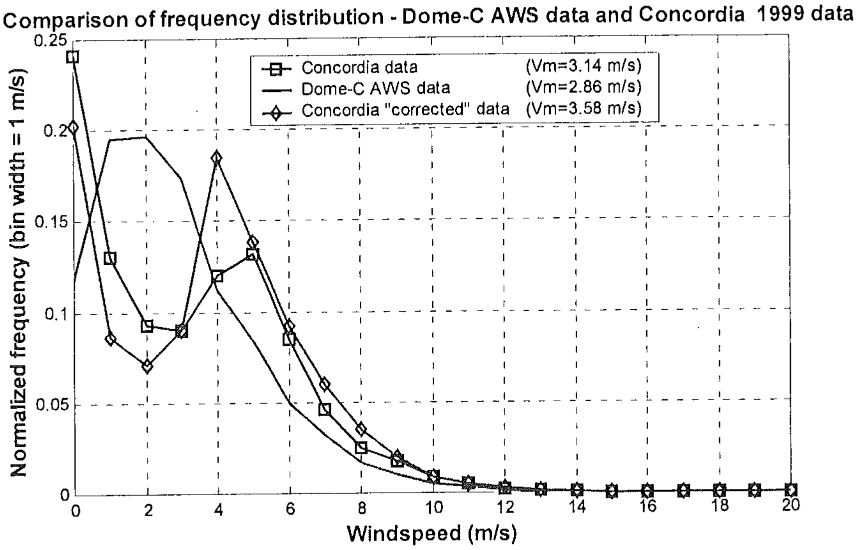

Figure 1: Estimated Wind speed distribution at DOME-C

3. DEVELOPMENT OF THE WINDTURBINE

3.1 Choice of the turbine

It was decided to start as possible from existing models with distinctive records of operation in Antarctica;. the conclusion was drawn that none could be guaranteed from the point of view of minimum temperatures.

The French Vergnet company (formerly Aerowatt) was finally chosen for the development in order to exploit the italian-french collaboration at Dome-C and since it guaranteed survival in the hardest wind conditions that could be present in other antarctic sites; indeed Vergnet machines are reported to have survived wind speeds of 90 m/s.

3.2 Modification of the turbine

The Vergnet GEV 5/5 conventional model is characterized by:

- 5 m. rotor, nominal power 5 kW
- up-wind rotor with 2 blades
- drive train with gearbox and self-excited asynchronous generator, fixed speed
- speed control mechanism based on centrifugal regulation of blade pitch (negative pitching provoking blade stall for speed higher than nominal).
- tail vane for nacelle orientation.
- guyed mast, with height from 12 to 18 meters.

It was decided to maintain as possible the solutions, among others the speed control mechanism, that proved to work ät Casey station [3], but at the same time to increase the energy yield in low wind speed regimes and to assure cold temperature operation, through:

1. adopting a rotor diameter of 6 meters instead of the standard rotor of 5 meters.
2. introducing a directly driven generator instead of the standard gearbox driven one
3. operating the turbine at variable speed.

Points 2 and 3 were achieved through the adoption of a special Axial Flux Permanent Magnet generator connected to a controllable electronic converter with switch-mode dc-dc IGBT step-down stage; both units have been developed and manufactured by the Electrical Engineering Department of the University of Roma "La Sapienza", under ENEA contract.

The generator was designed to operate at a minimum temperature of –80 °C; at this purpose the rotor is mounted directly on the main shaft without any additional bearing, and the Nd-Fe-B magnets are not glued nor bolted to the rotor but they are held in place only by magnetic attraction.

The electronic converter was designed to operate at temperatures as low as –35 °C and its voltage and current output is limited according to battery temperature. Both units are better described in [9] and in [10].

The expected advantages of direct-drive in the specific application are:

- lower maintenance and higher reliability
- higher efficiency, especially at partial load, leading to increased energy yield in low wind speed sites.

The elimination of the gearbox drastically reduces drive-train mechanical losses and maintenance: it must be added that it would have been very difficult to guarantee normal operation of the gearbox in such low temperatures, principally from the point of view of oil viscosity and bearing lubrication.
In addition, the structure of the generator permits to connect it to the main shaft without any additional bearing; generator losses therefore comprise only joule losses in the stator windings and iron losses, yielding efficiencies of 90% from one quarter to full load..
Operation at variable speed in its turn permits to increase aerodynamic efficiency at low wind speed, since maximum cp operation can be achieved in a wide range of wind speeds.
The simplified scheme of connection and two pictures of the generator during assembly and of the electronic converter are shown in fig. 2-4; in fig. 5 the overall efficiency is shown as function of speed; a 94 % maximum efficiency of the IGBT converter has been measured.

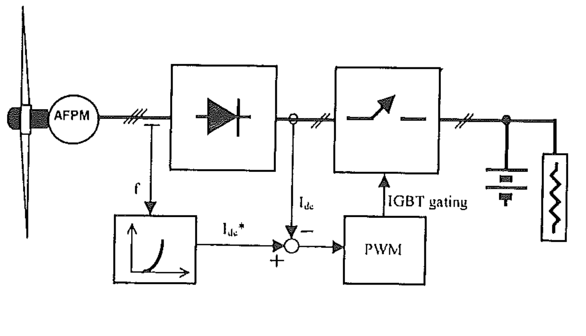

Fig. 2: Generator/converter connection

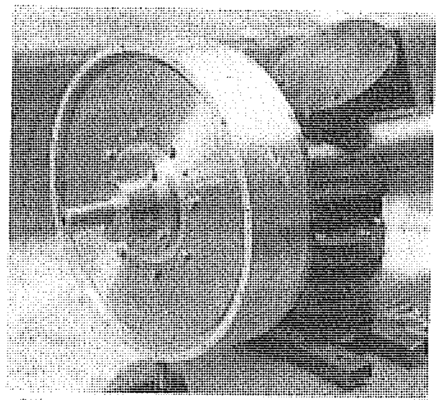

Fig. 3: Generator during assembling

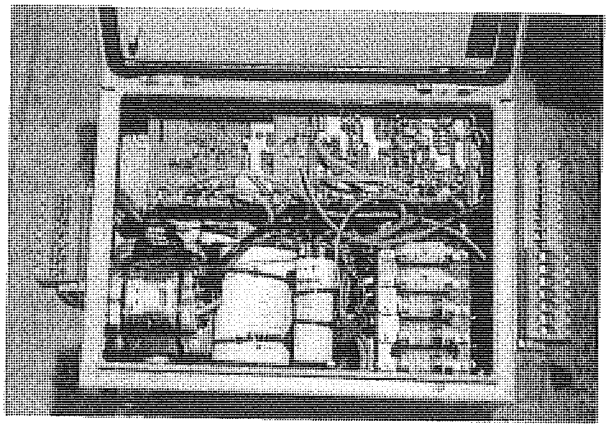

Fig. 4: IGBT converter assembly

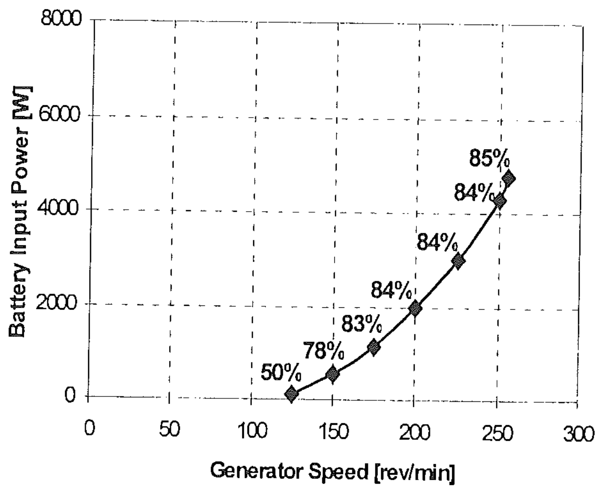

Fig. 5 Overall system efficiency vs. speed

4. QUALIFICATION OF COMPONENTS FOR THE ANTARTIC CLIMATE

The maximum effort has been exerted in the design phase in order to guarantee the ability of the turbine to operate in very cold conditions.
The task proved more difficult than originally considered; most difficulties begin at temperatures lower than –60 °C. Extensive use of a climatic chamber with a capacity of 1070 liters, able to reach and maintain a minimum temperature of –82 °C was found necessary in order to test as possible critical components.
Indeed the first tests on the turbine as built by Vergnet showed a complete jam of all the bearings at temperatures lower than –40 °C.
Key issues analyzed in the following development process have been: differential dilatations, bearing friction due to dilatations and grease viscosity, stiffening and embrittlement of materials.

The following solutions have been adopted:

- **Rotor:** wooden blades have been adopted instead of fiberglass, in spite of their reduced aerodynamic efficiency, since laminated wood promises a better behavior in cold conditions.
- Special Molykote powder has been utilized for the bearings of the pitching system: the spring force has been checked and regulated for proper operation by tests of the rotor assembly in the climatic chamber.
- The bearing mountings have been modified to account for differential contractions.
- **Drive train:** Due to the low starting torque of the rotor and to the low average wind speed of the site it is of capital importance to guarantee very low friction even at the lowest temperatures.
  At this purpose higher clearance have been introduced in the bearings, the bearing mountings have been modified, plastic seals avoided or modified, special aerospace grease able to work properly at –82 °C introduced. The complete nacelle has been successfully tested in the climatic chamber at –82 °C; measured starting friction torque increased from 1.9 Nm at normal room temperature to 2.9 Nm at –82 °C.
- **Generator:** the resins and stator coils have been tested in the climatic chamber; Nd-Fe-B magnets have a satisfactory behavior in cold conditions, and this was confirmed by tests at the lowest temperatures. The complete generator has been finally tested at –82 °C, in order to guarantee coils integrity.
- **Yaw system:** the behavior of the yaw bearing supplied by Vergnet proved unsatisfactory due to increasing friction leading to complete jam at temperatures lower than –30 °C. Dry lubrication and elimination of seals solved the problem The slip ring behavior was instead satisfactory.
- **Cables and elastomeric materials:** Special silicone cables were adopted either for power and for signal transmissions, in order to avoid insulation cracks. Elastomeric materials were substituted by steel plates.
- **Structural materials:** stainless steel and aluminum have been adopted when possible; tower materials were not changed since the structure is highly over-dimensioned and maximum expected wind-speed is only 17 m/s.
- **Controlled converter:** analogic electronics has been utilized for the control sub-sytem, in order to guarantee operation at temperatures as low as –35 °C or less.

Figures 6 and 7 show some details of the tests in the climatic chamber.

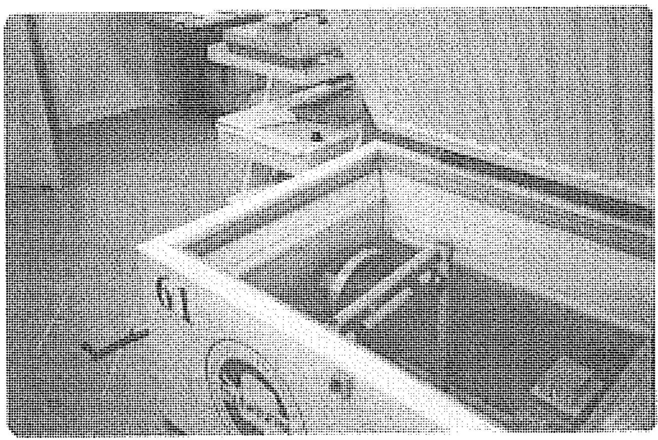

Fig. 6: tests on the yaw bearing

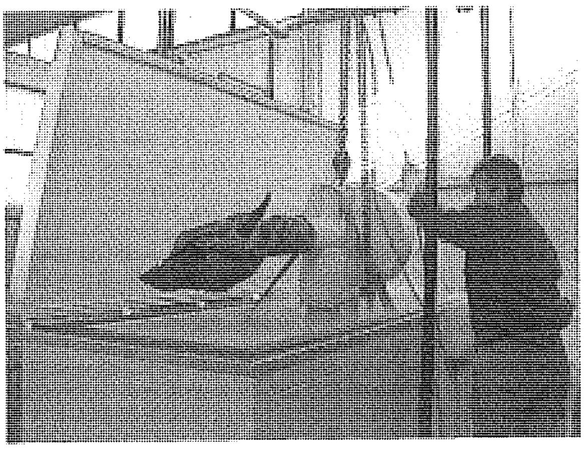

Fig. 7: tests on the complete nacelle

5. FIELD TESTS AND FINAL COMPONENT QUALIFICATION AT ENEA

The Wind turbine has been commissioned and tested at the Vergnet test field on October 1998. During these tests the turbine survived wind-speeds up to 25 m/s, but with nominal power limited to 3 kW due to limitations in test equipment.

Incomplete component qualification for Antarctic temperatures advised to avoid sending the unit to Antarctica with the 1999 expedition, as originally planned, and to continue the development at ENEA, as previously described before in chapter 5.

The turbine was then installed at the ENEA Casaccia test field (fig. 8), where it operated for 9 months.

The tests permitted to tune the control parameters of the converter and choose the best pitch position for optimal performance at low wind speed.

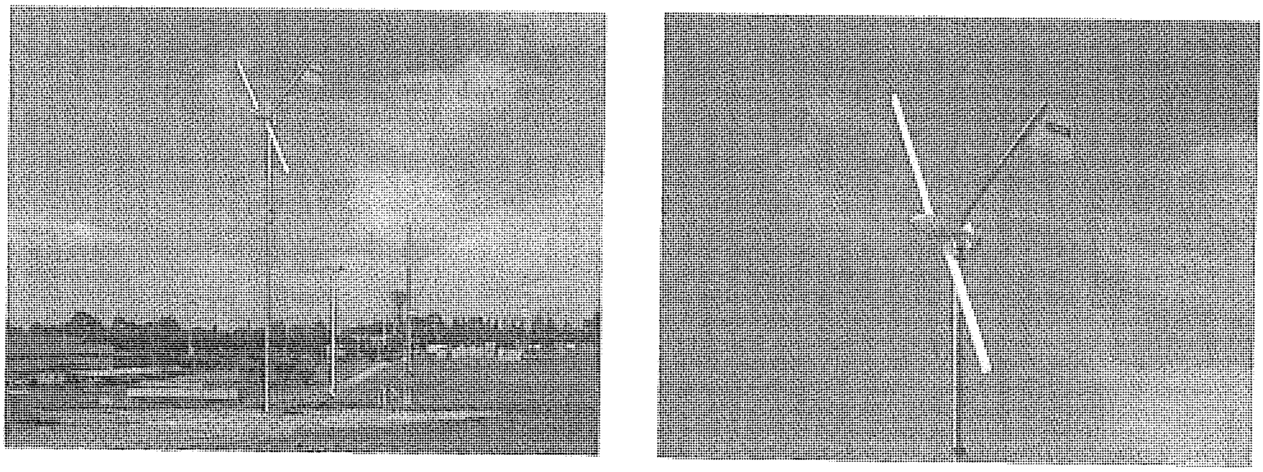

Fig. 8: The modified turbine at ENEA test field

Some of the measured power curves are shown shown in fig. 9 and 10. The first illustrates the power curve and experimental data collected with a nominal pitch position of 7°; the power was limited to less than 4000 W due to a "cautious" setting of the speed limiting device.
The second shows a comparison of two power curves obtained with different pitch settings; the 5° setting resulted more favorable in all range of wind speeds, in spite of first assumptions based on manufacturer data that claimed for better behavior with 7° pitch at low wind speed.
The power here in this case is limited to 4000 W due to the absence of high wind data with 5° setting.
The turbine is anyway able to produce 5 kW at a speed of 256 r.p.m. The overspeed limiting device, actuated by centrifugal force is very precise and permits to limit the maximum speed and power very precisely.

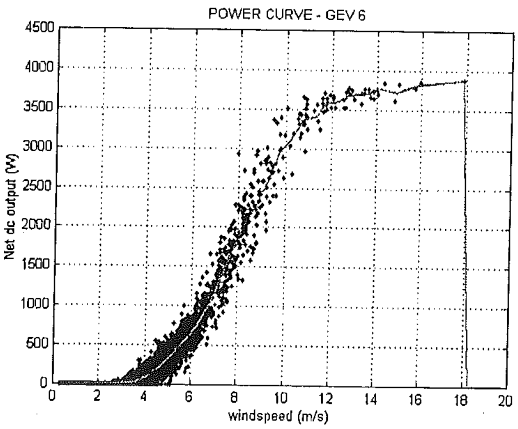

Fig. 9: Measured power curve, nominal pitch 7° Max frequency 48 Hz.

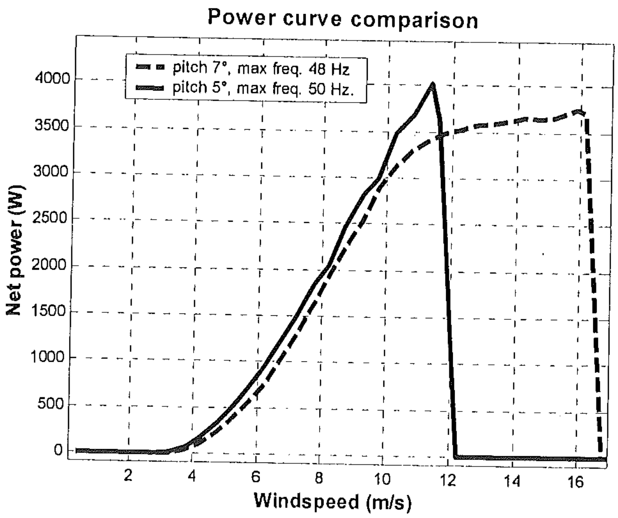

Fig. 10: Comparison of power curves with different pitch settings.

6. INSTALLATION AT CONCORDIA

The turbine has been finally shipped to Concordia following the XV expedition of ENEA.
Some of the components have been transferred by Twin-Otter plane, while others were transferred by one of the land convoys leaving from the French base of Dumond d' Urville. The turbine is anyway designed in order to be contained in one Twin Otter flight.
The foundations have been locally made by means a wooden platform laid on the snow soil; the concrete pillars normally used to hold the guys have been substituted by ice filled fuel tanks buried on the snow soil.
For the erection a crane was used, but the turbine can be erected by means of a 2 ton. winch, provided the foundations be properly designed.
In figures 11 and 12 the turbine during erection and in its final configuration is shown; in order to ease orientation at low wind speeds and to increase visibility for air operations, an increased surface orange painted tail has been introduced by Concordia staff.

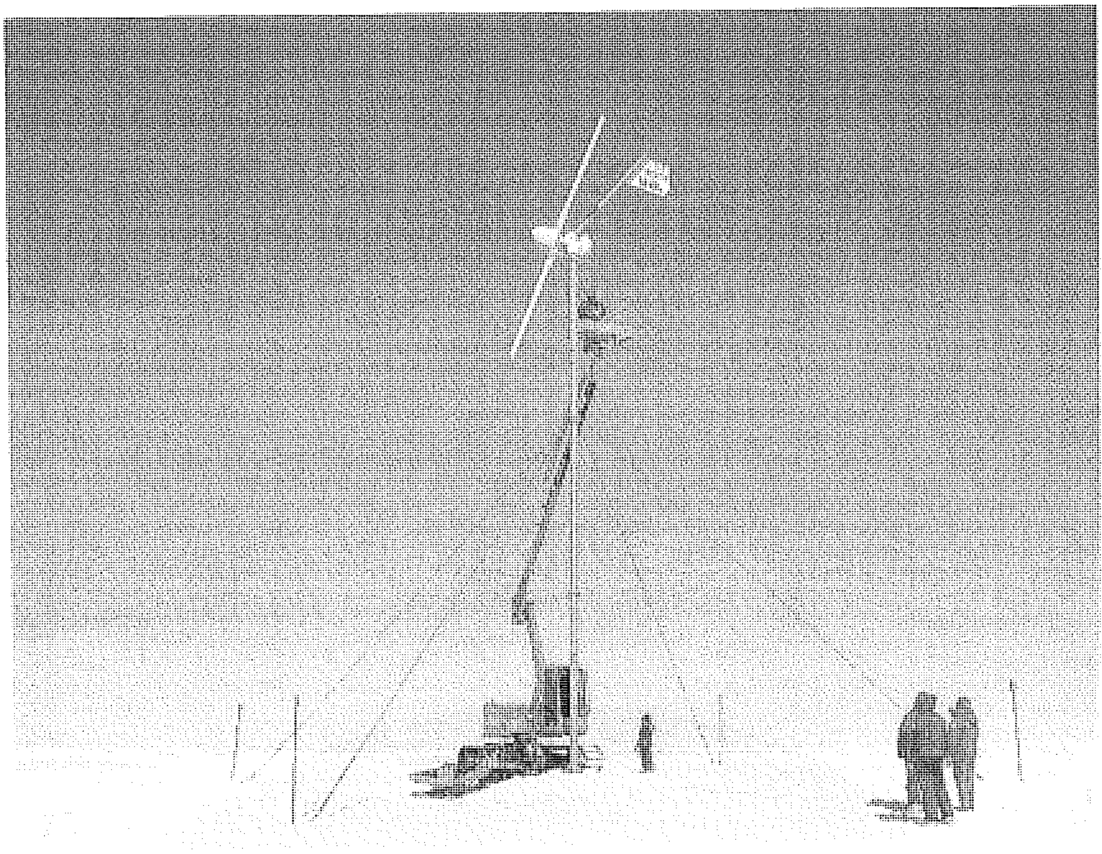

Fig. 11: the turbine during installation

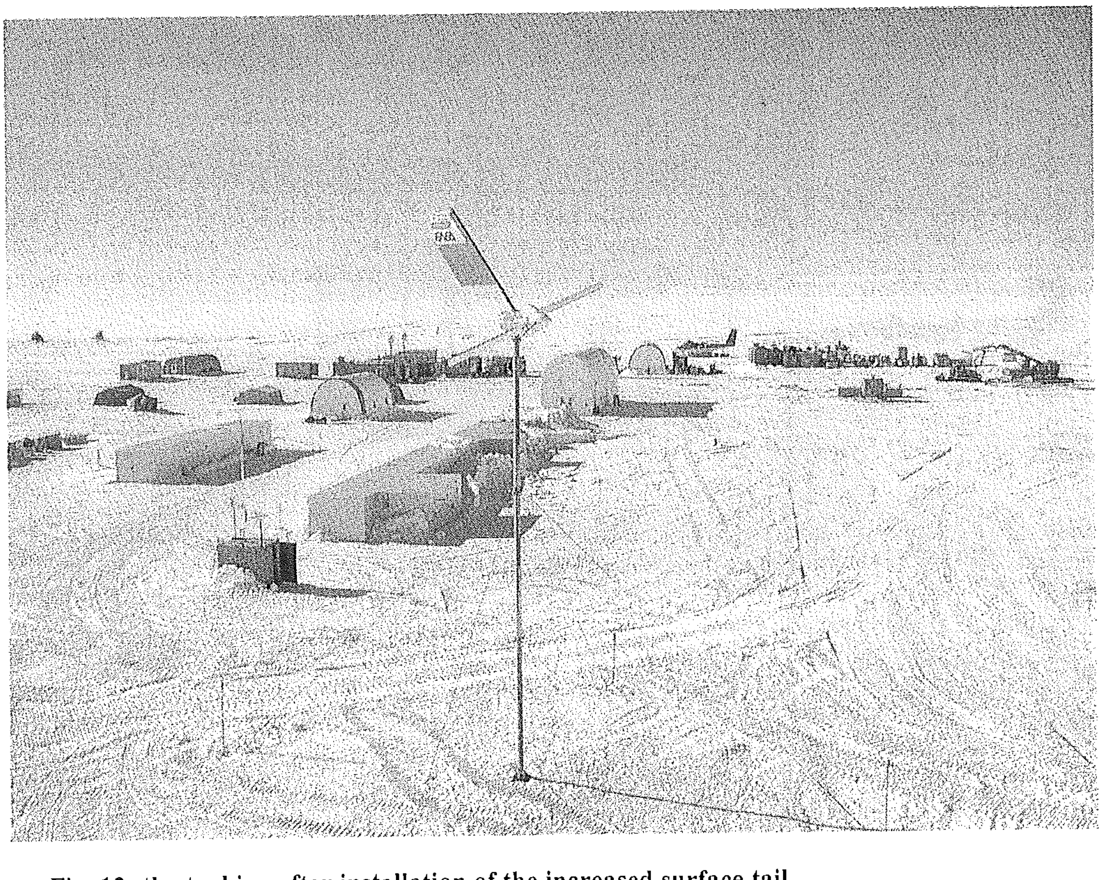

Fig. 12: the turbine after installation of the increased surface tail.

7. TURBINE CONTROL AND DATA ACQUISITION

The main aim of the pilot plant is to evaluate/demonstrate the performance of the wind turbine during a year of unattended operation. At this purpose, the load is practically the data acquisition system installed in order to store data on wind turbine behavior.

On the same time, the turbine will hopefully maintain relatively "warm" during the long winter some electronic equipment and a set of 200 kWh lead-acid batteries for truck engine starting. The capacity of these batteries is relatively limited if compared to what would be needed for a true stand.-alone power supply of this size, but it is anyway sufficient for the experimental purpose of loading the turbine.

A number of dump load resistors will maintain the state of charge of the batteries within limits, providing heat to the equipment and the batteries themselves; in fact all electric energy produced will be finally dissipated to heat, either directly through resistors or indirectly due to equipment losses.

All the control and data acquisition equipment has been be located inside an insulated shelter buried under 6 m. of snow, in order to have a constant external temperature of around –55 °C.

The insulation level has been calculated in order to maintain an internal temperature in the order of 0° C with an average input power of 300 W; two 1500 water/glycol tanks will store sensible heat during high wind speed periods, releasing it during periods of low wind speed

On the base of the recorded 1999 data and of the recorded experimental power curve, the turbine should be able to produce a gross energy yield up to 3769 kWh/year, corresponding to 430 W average and to a CF = 8.6 %, well in excess of design assumptions of minimum thermal energy supply.

An artist' s view of the installation is shown in fig. 13.

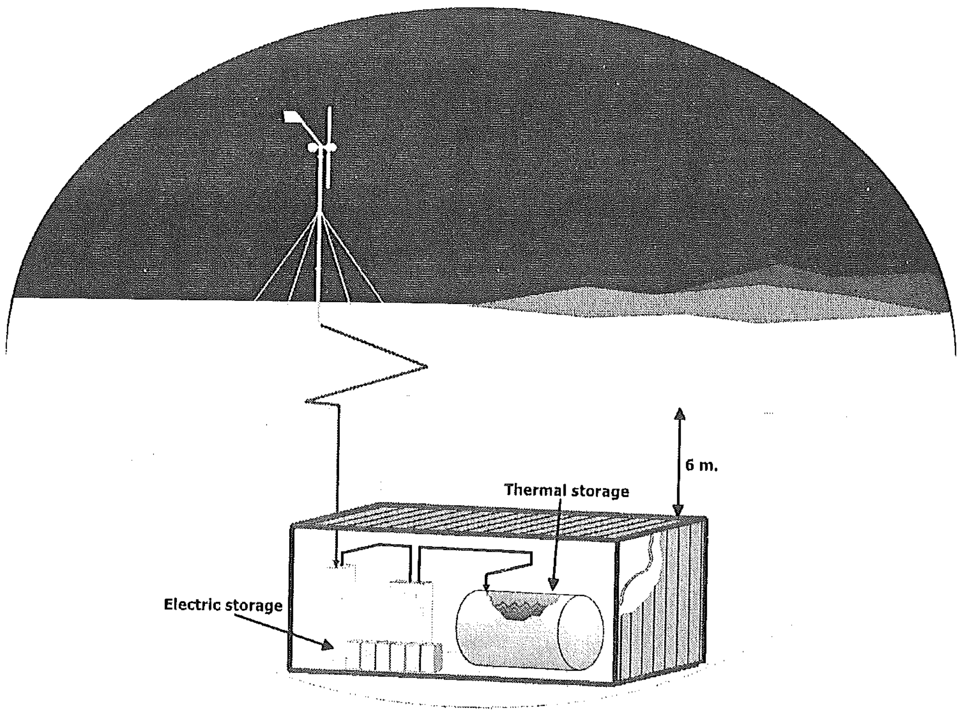

Fig. 13 – Artist' s view of the turbine installation

In order to increase reliability of the power supply a "passive" converter made by a diode bridge rectifier and a series resistance has been introduced: this passive system does not permit optimal control of the current, but it is more reliable than the electronic unit. The system will automatically commutate to the "passive" unit in case of failure of the controlled converter. The electric circuit is shown in fig. 14.

The generator can be connected to a set of resistors, able to safely stop the turbine up to wind speeds of 14 m/s, and keep the rotor at very slow rotation up to 30 m/s.

A thermostatic control will switch the generator to directly connected 3-phase heaters in case of too low battery temperatures, in order to avoid battery damage; indeed at least for this "pilot test system" no guarantee on load supply continuity is required.

The "fault unit" is able to switch from the electronic "active" converter to the "passive" unit in case a fault of the converter be detected.

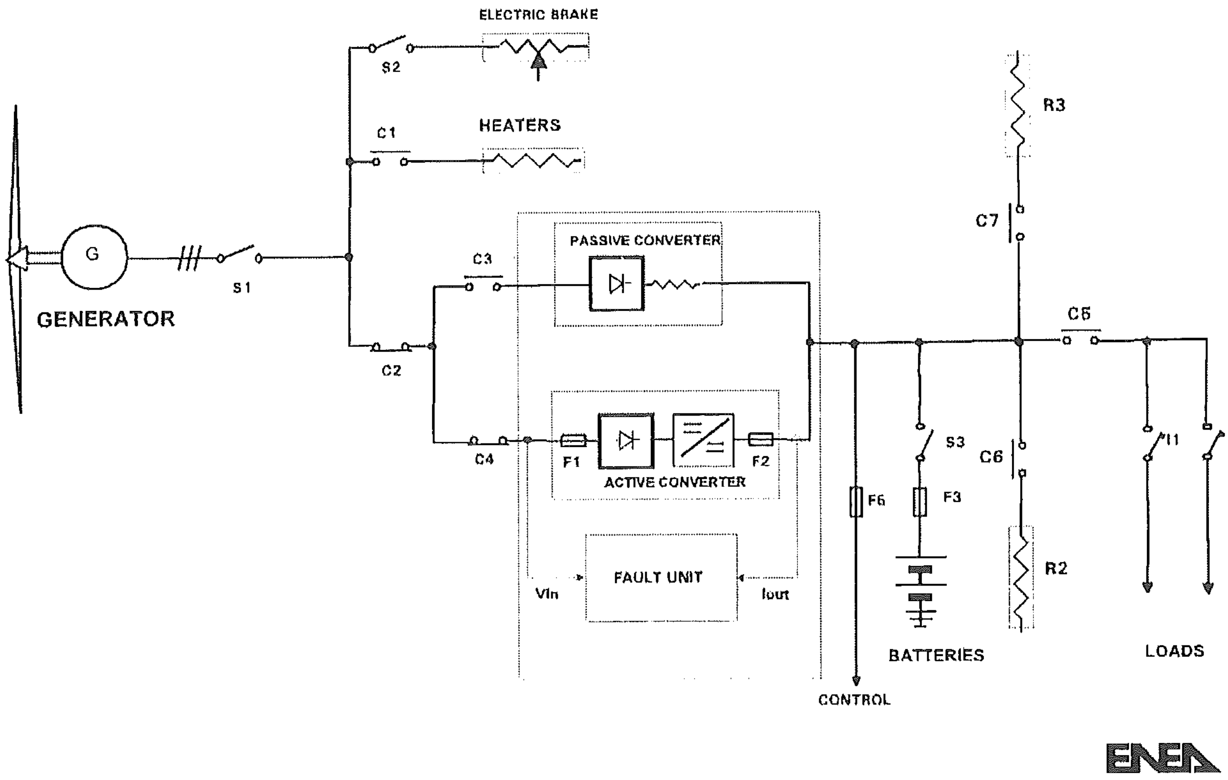

Figure 14: electric connections

Two dump load resistors, R2 and R3 are used to discharge the batteries when battery voltage is sufficient.
R2 is a 3 kW unit inside the heat tanks, while R3 is a small 100 W unit for the electric cabinet, since this is located outside the main insulated container.
Both resistors are also controlled by a thermostat, in order to avoid possible overheating.
All main contactors C1 – C4 are of the self retaining type, with a mechanic retainer, in order to reduce losses.
In this way the self consumption of the electric cabinet when batteries are at the lower voltage level has been reduced to only 5 W, while in normal operation is equal to 50 W.
The data acquisition equipment is based on a dedicated Campbell CR10X data acquisition unit, yet successfully installed during the 1998/99 expedition, with good results [8]; the data logger requires only 30 mW of power on average and can operate at temperatures down to –55 °C. Power supply will come either from the turbine and from a backup set of 16.5 Ah – 15 V Lithium Thyonyl Clorid dry cells able to power the unit for at least one year.
The unit will measure wind peed and direction, temperatures and main parameters of the turbine (voltage, current, battery current, frequency).

8. CONCLUSIONS

Next expedition will confirm if the turbine survived, and what is more important, if it produced enough power during the long antarctic winter at Dome-C.
If successful it will hopefully open new perspectives in zero-emissions power supply of Antarctic installations.

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Wind Energy Utilization at Maitri, The Indian Antarctic Scientific Station

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1.0 Introduction

Indian Antarctic program aims at the conduct of scientific research associated with Earth sciences, Biological, Atmospheric studies in the Antarctic continent leading to a better understanding of various scientific aspects and their impact at a global level. Enormous ground has been covered both at scientific and logistic levels from the first expeditions to Dakshin Gangotri. Today, the full-fledged permanent station at "Maitri" located in Shirmacher hill range is fully operational and is equipped to accommodate twenty five persons in winter and nearly seventy persons during summer.

The scientific and logistic groups together work on various pre-determined scientific studies. Most of the experiments conducted are not energy intensive. High quality electricity is required for data logging equipment, communication equipment and other scientific instruments. The station is dependent on fuel transported from India for all its energy requirements. India is highly conscious of ecological consequences of using fossil fuels in excess and this is even more so in a sensitive environment like Antarctica. Among all renewable energy technologies, Wind Energy has the best promise, particularly in Antarctica. During winter, it is the only renewable energy source available. The Expert Committee (set up by the Department of Ocean Development) while envisaging a ten-year profile of scientific research in Antarctica made a particular reference to renewable energy conversion for use in station[1]. A large portion of the energy demand, particularly from the new summer facilities was to be met through renewable energy sources, of which wind forms a big proportion. In this paper, the approach taken so far has been explained.

2.0 The Approach

In order to provide an effective wind energy program for use at Indian Station, the following steps were envisaged and are being implemented:

1. Quantification of Wind Energy as a Resource.
2. Study of Energy Consumption patterns.
3. Study of infrastructure available at the station.
4. Identification of most suitable location/s.
5. Experiment with available WE hardware.

Based on the above factors optimum system sizing and configuration is to be determined. The system that will be eventually introduced should be reliable, safe, cost effective and should be able to accommodate the "*common sense approach*" that the just trained O & M personnel would adopt.

2.1 Winds in Antarctica

Antarctica was able to maintain a pristine environment for so long with the help of unbearable winds that make living in Antarctic environment an extremely difficult proposition. In fact, it is the most often quoted difficulty by the early explorers as well as present day scientists involved in the out door work at Antarctica. Some estimates of peak winds have crossed 250 km/h in the coastal regions. Inland, on the continental ice and oases, where stations have been in place have not shown very high values when compared to the coastal regions. The phenomenon of very high winds is generally explained by the occurrence of very frequent cyclones and anti-cyclones that are formed around 55° to 60° South around the continent. This happens very frequently and with great intensities. Apart from this, presence of strong and sustained Katabatic winds have also been experienced in the coastal zones and glaciers.

2.2 Meteorological Measurements at Indian Stations:

Wind speed and Directions were measured at Dakshin Gangotri as well as Maitri as part of the meteorological measurements that were undertaken by the India Meteorological Department. The readings were taken at Synoptic hours. Apart from this, wind speeds were kept track of using strip chart recorders. Dakshin Gangotri showed exceptionally high average wind speeds. This is understandable, as Dakshin Gangotri was located on the shelf ice. The averages at Maitri were relatively lower and strongly influenced by the time of the year. This is an important point that should be noted as the successful integration of wind energy conversion devices with existing energy supply system would very largely depend upon a clear understanding of nature of wind energy availability in the given region. Figure 2.1 shows the measured monthly averages at Maitri over a five-year period [2]. The pattern of winds is somewhat different from the monsoon based wind system. Summer months shows relatively light winds and quite consistent over years. Mid-winter shows a relatively high wind season, but inter-annual variation is also somewhat high during this period.

The wind speeds collected at Maitri by IMD are a part of Synoptic weather observations. The data is being collected as per the standards set by World Meteorological Organization. But this could not be employed for quantification of wind energy availability for two reasons. First was that the information between two observations was not directly available . The second point was that the sensors are located on the top of Maitri station. In wind energy work, it is important to measure the free stream velocities at a number of elevations from ground to be able to describe wind energy potential with a good degree of accuracy. There are a number of other installations on the building and the building itself can cause difficult to model type of perturbations in to the flow field. It was therefore decided to set up an independent microprocessor based three level wind monitoring system. Ice-free wind speed and direction sensors rated at 90m/s survival speed were fixed on an already existing 28 m tall mast at three levels. Data loggers were housed in summer huts where experiments related to SODAR, Geomagnetism and other sciences were set up. Data loggers were programmed to store hourly averages of wind speed, direction, and standard deviation . The data collection was initiated by January 1997. Monthly average wind speeds at two levels are shown in Fig 2.2. Mid level wind speed sensor was damaged while being serviced. Although readings were obtained subsequent to repair, the readings could not be taken with much confidence.

There were some breaks in the data for various reasons. From among the data that became available, it was feasible to get continuous records for nearly two years. Survey of India has published a contour map of Maitri environs. Based this map a Digital Terrain Model of the area was prepared (fig 2.3). This, in combination with the wind speed and direction information was used to determine effective wind power availability around Maitri. The calculations were carried out on a 25 m x 25 m grid and possible energy production levels were determined. In order to be able to get a good understanding of how this wind potential gets translated into energy production, the annual energy outputs (normalized) from a typical wind turbine has been calculated for the entire region around Maitri and presented in fig 2.4. Slightly elevated regions can give better outputs than sheltered regions. This will be one of the important factors to be considered while siting wind turbines. Depending upon where the new summer facilities would be set up, location of future wind turbines would be determined. For the existing station a suitable location could be to the South of the station at a distance of about 300 m. The energy that could be expected would be in the range of 4000 to 4500 kWH/year/kW installed. Other locations could be considered as by and large, the area has possible production levels at about 3500 to 4000 kWH/year/kW.

3.0 Energy Consumption Patterns in the Station:

The station plan is shown in figure 3.1. and consists of a specially designed structure with living quarters located at ground floor. There is a mezzanine floor which houses communication room as well as stores. Summer huts are located to the North of the station around the lake. The station is designed to house 25 persons during winter and with a number of "Summer huts" can accommodate up to 50 persons during Antarctic summer. Electrical power is provided using Aviation Turbine Fuel driven engines with three phase alternators. The main station has a provision for space of heating using hot water circulation and hotplates.

3.1 Electrical Power:

Station has ten alternators rated at 62.5 KVA in three independent clusters to cater for electrical power requirements. At any point of time two generators are kept operational. The two generators are not synchronized and cater for independent loads. Summer huts also get the electrical power requirements supplied from the main station. Recently two used 100 kVA alternators were added to station's electrical generation capacity, but no scheduled loads were earmarked for this additional back up capacity. The total energy consumption patterns based on data available at the station has been calculated and is presented in figure 3.2. The hourly records from the generator rooms have been used to determine daily average power requirement [3]. The average power requirement during summer falls slightly. During winter the power consumption gradually increases. Latter part of winter, that is, after September the power consumption falls slightly. Fuel requirements for power generation is estimated using a linear model. The model was established using specific fuel consumptions as indicated by the engine manufacturers. Except for a few perturbations, the fuel consumption patterns and power requirements have been in the range of 30 to 50 kW and an average fuel consumption of 300 to 400 liters per day is to be expected. Over an year, the estimated fuel requirement is in the range of 150,000 litres for power generation. There is a separate automotive workshop with its own 30-kVA alternator. The electrical power requirements of this workshop are separately catered for by this independent generator. Automotive workshop has a few power tools, lathe, drilling machine and welding sets. Automotive Battery charging is another load that needs to be met from this generator. Frequently the alternator would be pressed into service for battery charging purposes.

3.2 Heating System at Maitri:

The station is equipped with four oil-fired furnaces placed in Boiler room. Heating of the living quarters is manually controlled. Normally only one burner will suffice to maintain station temperature above 10° C. The boiler room also houses the water pumping controls to pump water from the lake to the station. Each room and living areas are equipped with heat exchangers with re-circulating hot water systems. All the heat exchangers are connected in parallel. The burners consume about 10 liters of fuel per hour and based on the number of hours the burners are kept operational fuel requirement is estimated on a daily basis[3]. The average daily consumptions on a monthly basis are presented in figure 3.2. In the same graph the monthly mean wind speeds are plotted. In general, higher wind speed months show higher fuel for heating consumption. There are exceptions during the Months of March and latter parts of the year. This could be due to the fact that the wintering team would have just taken over by March and acclimatization to Antarctic Winter would take some time. On an average fuel consumption for station heating is in the range of 100 to 350 liters per day and during winters the monthly consumption can reach 8000 to 9000 liters.

4.0 Infrastructure at Maitri:

The Indian station has most of the installation equipments that are necessary for installation of medium sized wind power equipments. There is one track-mounted crane with a capacity of 18 tons with a boom height of 70 feet. It is feasible to move the crane to any desired location with out any difficulty. Apart from this, the station has welding, machining and other workshop facilities. There are crab winches of 10 to 20 tons pulling and lifting capacity. At the station, during summer there are sixty to sixty five persons available and installation of wind power equipment up to 50 kW capacity range would present no serious problem. For bigger machines, some preparations would be necessary. However, under the present and immediate future load levels, machines of larger capacity may not be required.

5.0 Battery charging requirements:

Maitri serves as a base station for field camps run by Geological , Botanical and Zoological, Geomagnetic scientists and other scientific groups. These groups of researchers, convoy management groups are required to keep in touch with the base station and use of microwave repeater stations and other communications will be very important. The communication equipment, other data logging equipment are powered by batteries. These batteries require charging on a regular basis. A considerable portion of logistic effort would be directed to providing charged batteries, fuel and small generating sets, their O & M. Towards this end it was decided to experiment with available machines and carry out required modifications.

A number of small portable machines, which have worked well elsewhere, were tested. The machines in the capacity range of 100 to 400 watts were quite effective in providing charge to batteries. Particularly at microwave repeater station and at automotive workshop it was very useful to install these machines. The machines were able to cut down the number of times the generator set had to be started for battery charging purposes. The machines worked for about six to eight months without much problem. Subsequent to that some snags developed. Two important points emerged from these studies.

1. The off the shelf machines require considerable re-engineering.

2. Special attention is required towards safety, O & M and other factors. It was found that the furling tail mechanism was under damped and main bearings undersized. Subsequent to the bearing failure, the bearing life was calculated based on the wind speed data, machine characteristics and it was found that for the type of (aerodynamic) loading conditions, the bearing life was no more than an year. This is rather important because this pertains to the design conditions that have been assumed, which are not necessarily meant for a harsh environment like that is faced in Antarctica.

Therefore two corrective measures were under taken. One was to introduce a yaw-bearing damper. The other was to replace the normal bearing grease with an aircraft quality grease that can retain proper lubricating characteristics up to –80° C. With these modifications the machines were re-installed and the performance is being monitored.

6.0 Future Programs:

The efforts on providing battery charging for convoys, automotive workshops, isolated data logging equipment, communications would continue. The savings of fuel in these cases would form a small part of the logistic efforts required to maintain batteries in remote areas. The idea would be that the modified/redesigned machines shall be tested further. Ease of installation, proper O & M follow-up, load matching and safety problems will form part of the projects.

With the data collected and experiences gained so far, it has been proposed that a machine of about 10 kW is to be tested at the station. The machine could be newly developed specifically for Antarctic conditions or after study of the options available, re-engineer and test the best possible machine. The machine would be initially used for station's heating. This would ensure that the existing systems would not be unduly disturbed and in case of any system malfunction, the services required would not be affected. The room heating is controlled by the ambient temperature and the simple scheme shown in fig 6.1 would be able to cut down the duration for which burners are required to be kept working. The heat energy provided by the wind turbine would keep the hot water tank temperature sufficiently high. In the next phase, the machine, which would have established credibility among users would be used for generation of grid quality electricity.

On a parallel, efforts would be made to set up an autonomous wind diesel system for energy supply in the station. The experience so far has been that not withstanding manufacturers claims, wind machines do need considerable re-engineering and design changes to be effectively used in Antarctic conditions. Towards this end discussions are underway with the concerned Scientific and Governmental agencies.

References:

1. *Recommendations of the Expert committee on Antarctic Reseach UR Raos Committee 1996*

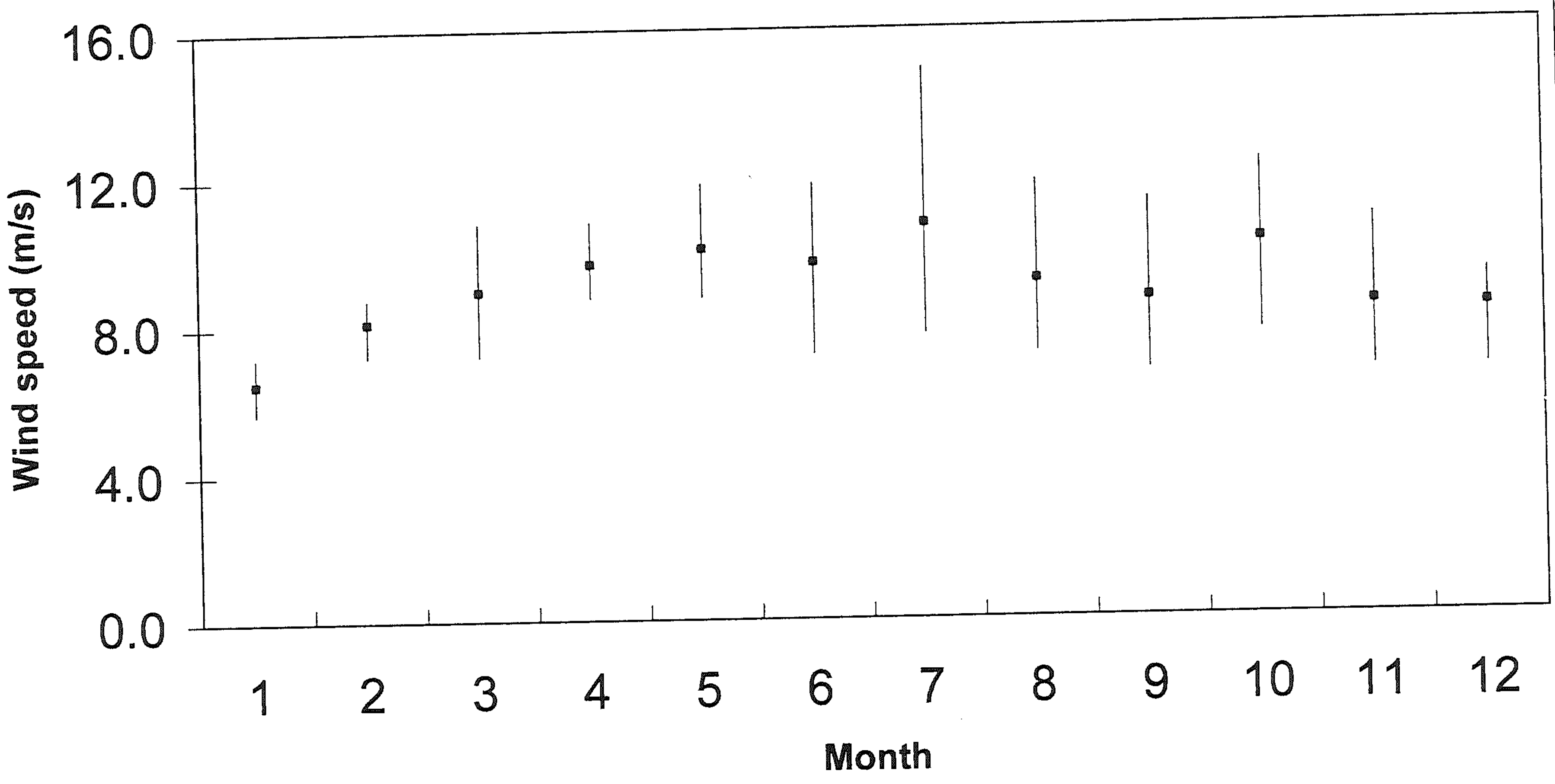
2. *Personal communication from Dr.A.L.Koppar, Director Incharge, IMD, Bangalore,*

3. *Station Records*

Acknowledgements:

The author is grateful to Department of Ocean Development, Council of Scientific & Industrial Research, National Aerospace Laboratories, the organizations that have made this important activity possible. The Secretary, DOD. DG, CSIR, Director, NAL and Director, NCAOR have been very supportive of the program. Chairman, CSIR-SCAR and SCAR-INSA committee has provided invaluable advice and has provided continued support right across the program. The Armed forces have provided very important inputs. User departments have been very cooperative and enthusiastic about application of wind energy. The staff of Wind Energy Division, NAL have spared no effort in executing the assignments. It is gratefully acknowledged.

Fig 2.1 Monthly Mean Windspeeds at Maitri



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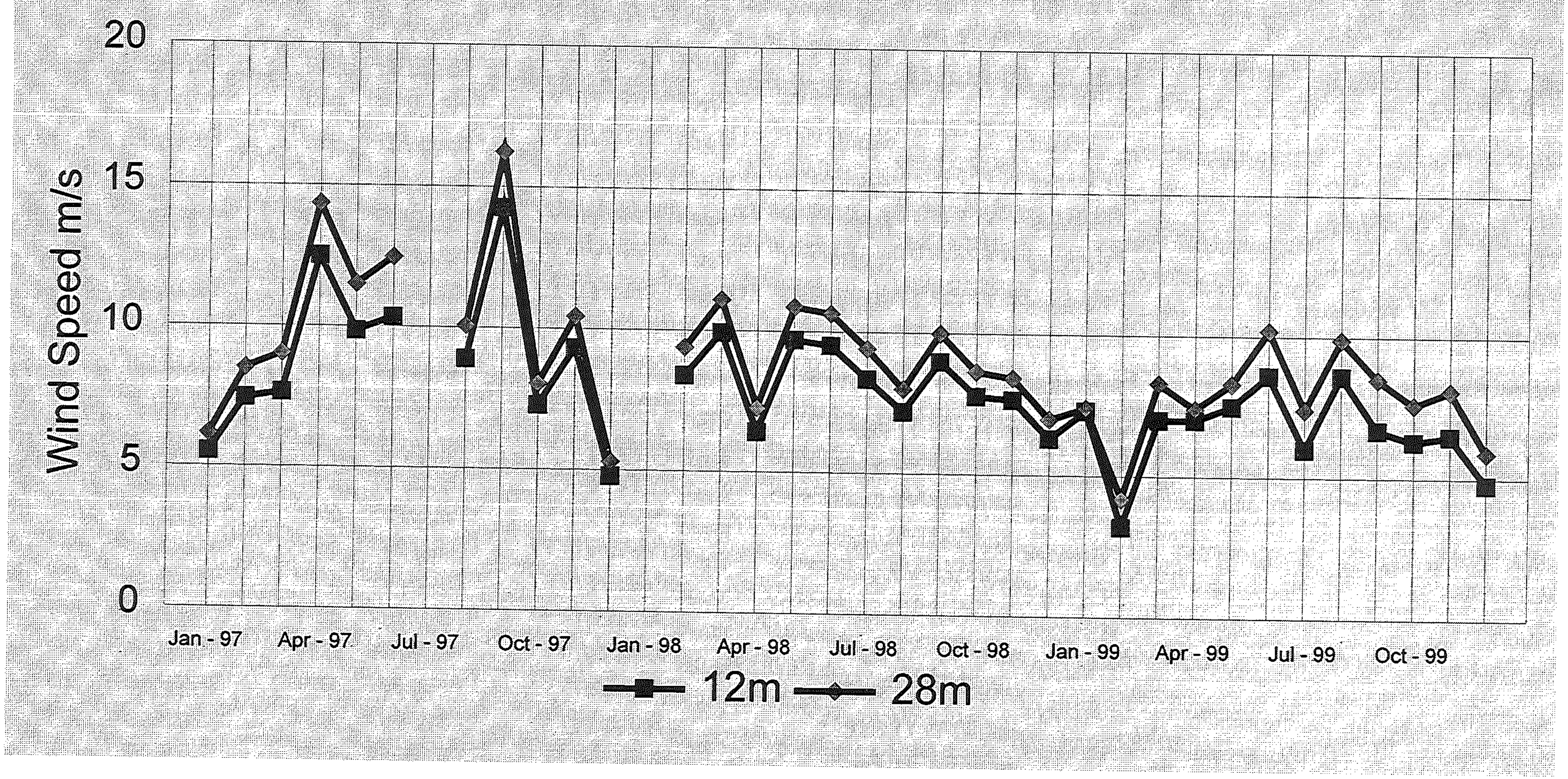
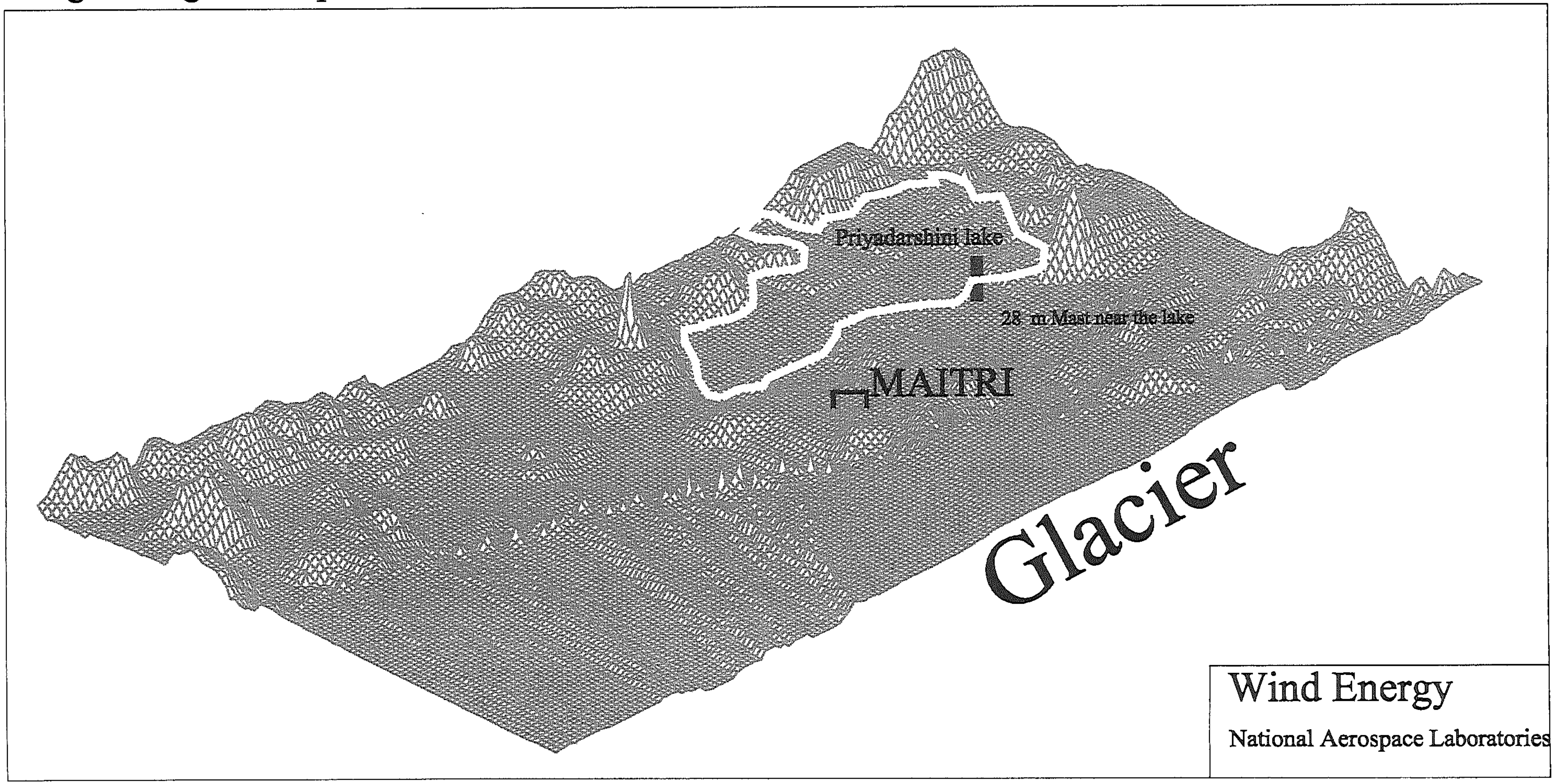


Fig 2.2 Wind Speeds at Maitri, Antarctica

Fig 2.3 Digital Perspective view of Maitri & environs



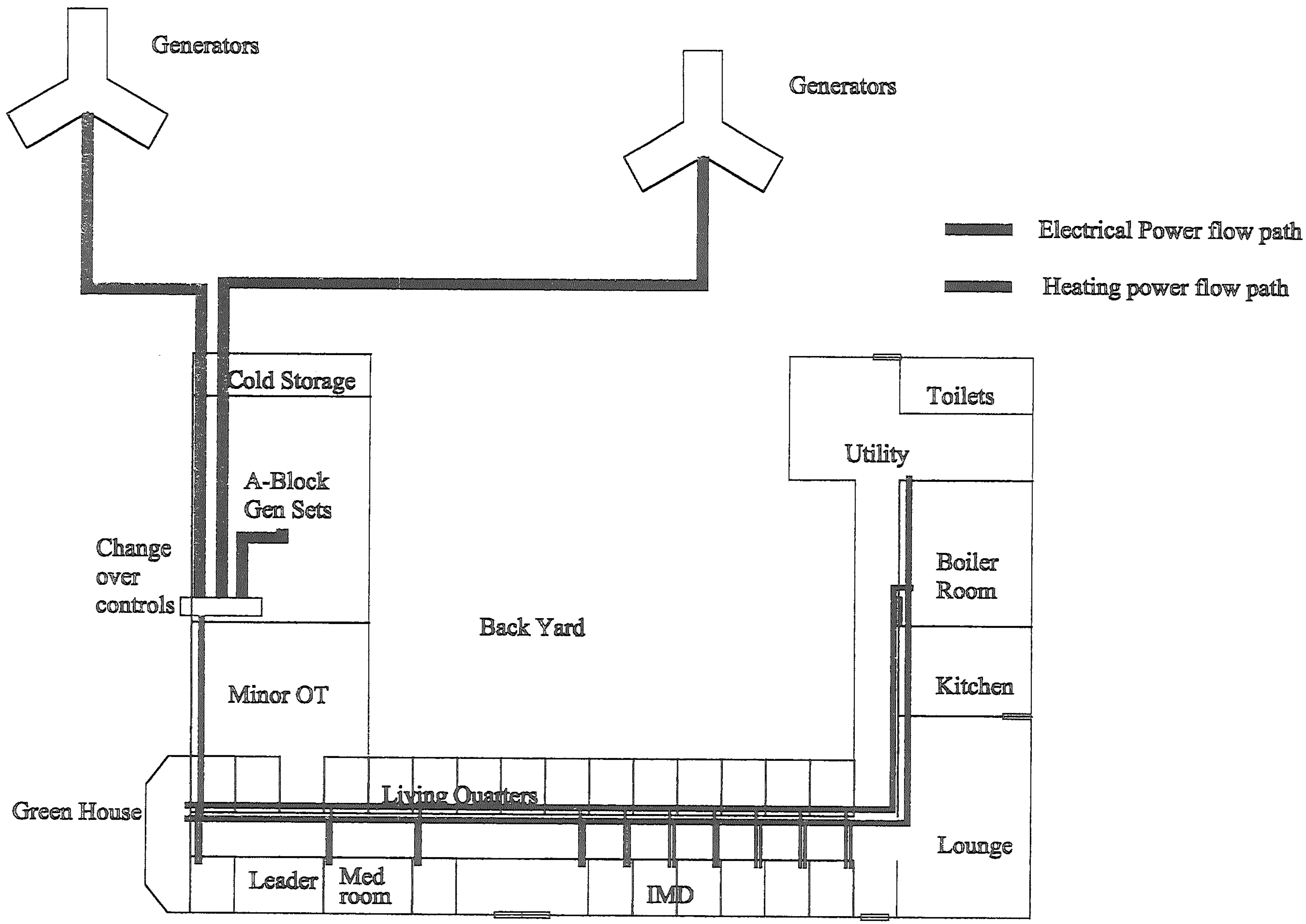
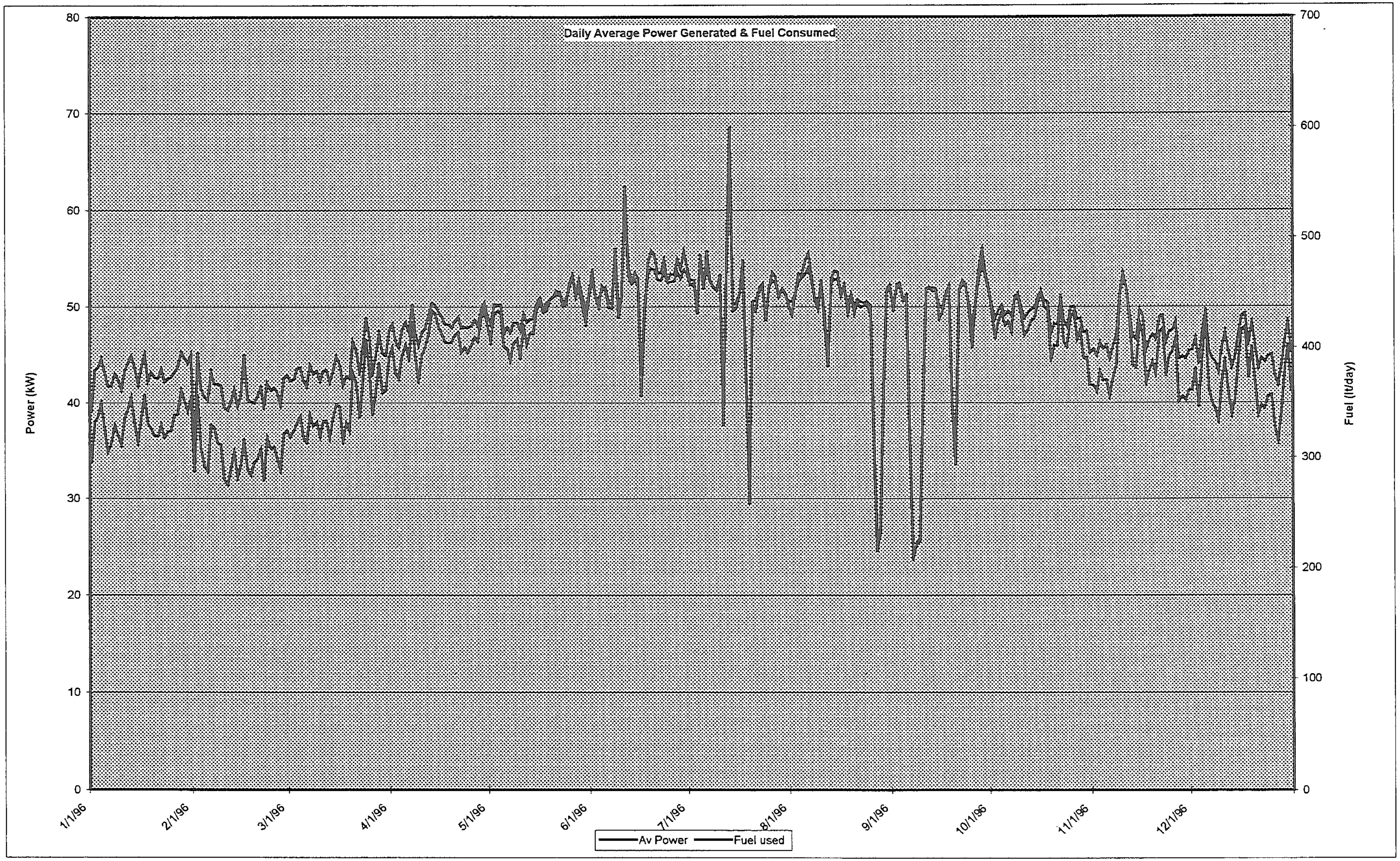


Fig 3.1 Station plan of Maitri


Daily Average Power Generated & Fuel Consumed
Power (kW)
Fuel (lt/day)
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
1/1/96
2/1/96
3/1/96
4/1/96
5/1/96
6/1/96
7/1/96
8/1/96
9/1/96
10/1/96
11/1/96
12/1/96
Av Power
Fuel used

Daily

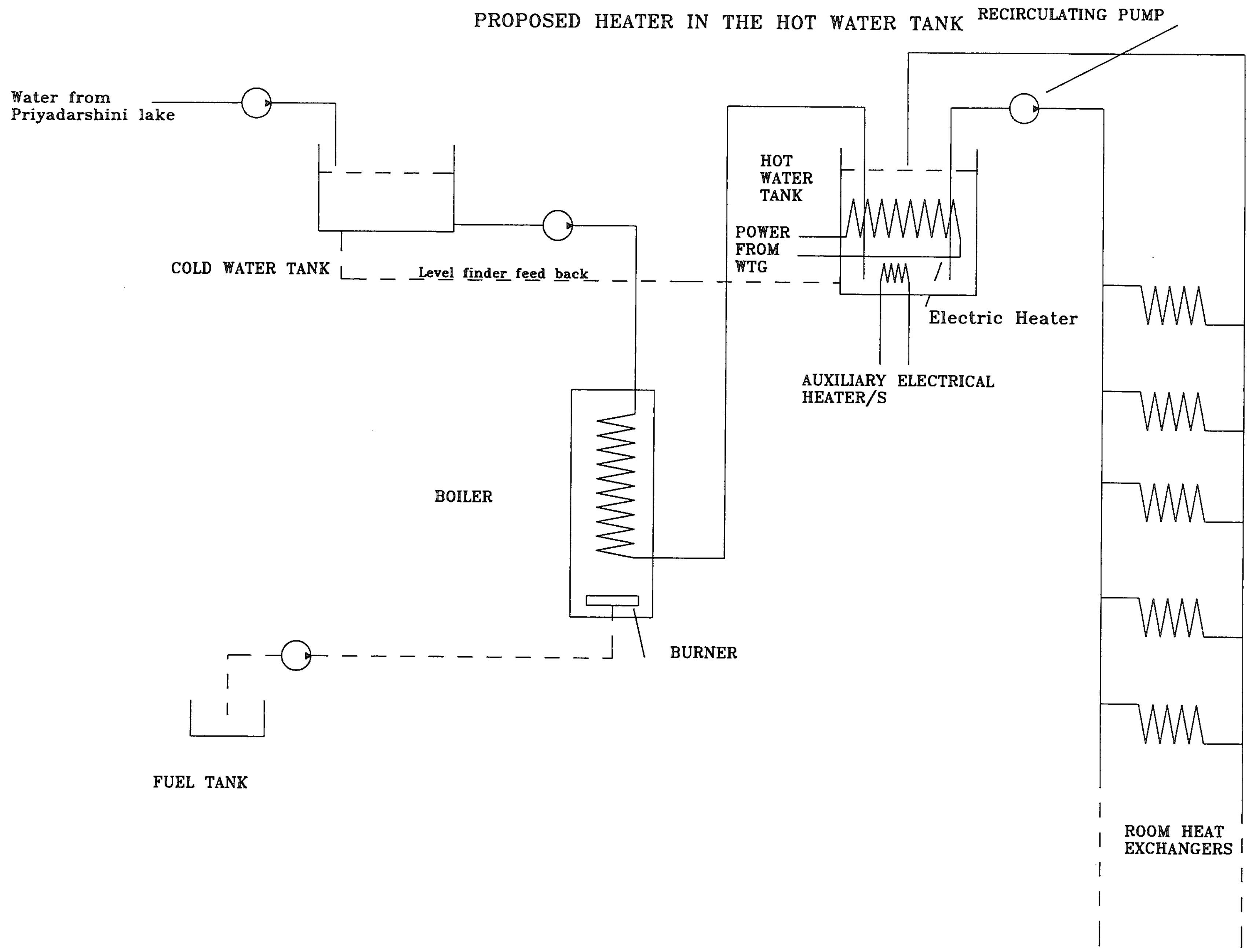


Fig 6.1 SCHEMATIC DIRAGRAM OF CENTRAL HEATING SYSTEM AT MAITRI

In situ Bioremediation of oil spills in the Antarctic

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Abstract :

The Antarctic marine ecosystem, considered one of the last remaining pristine ecosystems, is almost uncontaminated by anthropogenic hydrocarbons. However, accidental contaminations by fuel oil occur frequently and there is an urgent need to understand the fate of hydrocarbon contaminants in this extreme system.

In recent years, there has been an increasing interest in developing cost-effective *in situ* techniques for bioremediation of oil-contaminated environments. Bioremediation may be defined as a field procedure designed to increase the rate of natural degradative processes of contaminants. Biodegradation by naturally occurring populations of micro-organisms is a major mechanism for the removal of petroleum from the environment (Bioattenuation). However, in certain environments, there are conditions limiting the presence or effectiveness of natural degrading consortia. In these cases, the practice of biostimulation or bioaugmentation may be warranted. Biostimulation refers to the addition of chemicals such as nutrients (eg nitrogen, phosphate and/or oxygen) or surfactants to stimulate the natural flora, while bioaugmentation refers to the addition of exogenous organisms (eg those having oil-degradative phenotypes) to the environment to augment the natural microflora. Instead of these *in situ* treatments, similar procedures may be applied on-site after removal and conditioning of contaminated soils or sediments (biopiles).

The present paper describes the bioremediation studies conducted in the vicinity of the Antarctic French stations. The initial studies have evaluated the benefit of fertilisers addition in sub-Antarctic and Antarctic seawater, in Antarctic sea-ice, in sub-Antarctic intertidal sediments and in Antarctic soils. Data obtained in marine environments demonstrated that bioremediation may be a useful tool in more severe environmental conditions than those of Alaska where its effectiveness has now been clearly established. However, in intertidal sediments, the results also revealed a significant toxicity of the remaining fractions of the contaminants. In Antarctic soils, climatic conditions limit the effectiveness of bio-attenuation and biostimulation processes.

Introduction

As a result of industrialization in the 20th century, many toxic substances, including anthropogenically generated hydrocarbons, have been discharged into the environment. Oil pollution of the oceans and coastal environments has been a problem ever since man began to use fossil fuels. However, the Antarctic marine ecosystem exists as one of the last remaining pristine zones on Earth and remains uncontaminated by anthropogenic hydrocarbons [BERKMAN (1992) ; PLATT and MACKIE (1980) ; REINHARDT and VanVLEET (1986)]. The patterns of the hydrocarbons found in Bransfield Strait, Antarctica indicated that their origin was biogenic and there was no strong evidence for anthropogenic hydrocarbons in the Antarctic marine ecosystem [CRIPPS (1990)]. However, the probability of contamination of the Antarctic by anthropogenic hydrocarbons is increasing. Antarctic waters are now crossed regularly in the summer by tourist, supply and fishing vessels. The shipwreck of the supply ships *Nella Dan* and *Bahia Paraiso*, which ran aground and subsequently sank near Macquarie Island and the Antarctic Peninsula [KENNICUTT et al. (1991) ; KARL (1992) ; SMITH and SIMPSON (1995)], highlighted the need for research into hydrocarbon contamination of the Southern Ocean ecosystem.

Biological degradation (Bioattenuation) represents one of the main route through which organic chemicals are removed from contaminated environments. Biodegradation by naturally occurring populations of micro-organisms is a major mechanism for the removal of petroleum from the environment [ATLAS et al. (1981); LEAHY and COLWELL (1990) ; BRAGG et al. (1994)]. However, little is known about hydrocarbon degradation processes in cold environments. While it is recognized that microorganisms play a critical role in the breakdown of hydrocarbons, the impact of petroleum pollutants on the metabolism and abundance of natural microbial communities is poorly understood. Crude oil, for example, has been shown to enhance [DELILLE and DELILLE (2000)], reduce [GRIFFITHS et al. (1981)] or have no effect [BAUER and CAPONE (1985)] on total abundance of sedimentary bacteria. Bacterial communities vary considerably in their metabolic response to hydrocarbons [ALEXANDER and SCHWARZ (1980)].

Bioremediation may be defined as a field procedure designed to increase the rate of natural degradative processes [ATLAS and CERNIGLIA (1995) ; FLOODGATE (1995)]. Treatment technologies for the clean-up of polluted sites use a range of methodologies to enhance the natural biodegradation of contaminents. In certain environments, conditions limit the presence or effectiveness of natural degrading consortia. In these cases, the practice of biostimulation or bioaugmentation may be warranted. The former term refers to the addition of chemicals such as nutrients (eg nitrogen, phosphate and/or oxygen) or surfactants to stimulate the natural flora, while the latter refers to the addition of exogenous organisms (eg those having oil-degradative phenotypes) to the environment to augment the natural microflora. Due to the impossibility of introduction of non-indigenous bacteria, bioaugmention will be extremely hard to use in Antarctica. In place of these *in situ* treatments, similar procedures may be applied on-site after removal and conditioning of contaminated soils or sediments (biopiles).

Biostimulation treatments have been shown to stimulate the biodegradation of oil on a number of contaminated shorelines [SVEUM and LADOUSSE (1989) ; LEE and LEVY (1991) ; BRAGG et al. (1994)]. Following the accidental oil spill of the *Bahia Paraiso* in the Antarctic, questions raised about the rate of oil biodegradation under Antarctic weather conditions and about the applicability of bioremediation in cold regions.

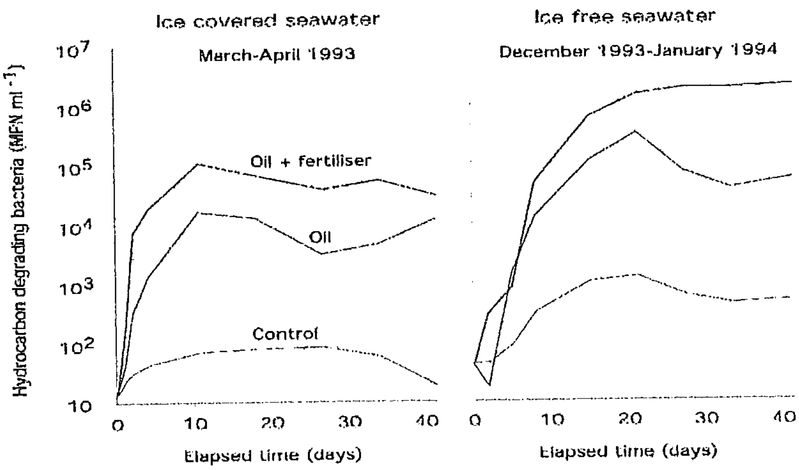
Bioremediation experiments

Seawater

Several observations concerning oil degradation processes have been made in Arctic [ATLAS et al. (1978) ; GRIFFITHS et al. (1981) ; HOROWITZ et al. (1983)] and Antarctic ice-free seawater [CLARKE and LAW (1981) ; PLATT et al. (1981)] but relatively few data are available for ice-covered areas [CRIPPS and PRIDDLE (1991) ; DELILLE and SIRON (1993), SIRON et al. (1993)]. Our first study in this research field was carried out between January 1982 and January 1983 in Morbihan Bay, Kerguelen archipelago (70°E - 49° 30'S). This study had evaluate the benefit of a slow release fertiliser (Inipol EAP 22, Elf Atochem) addition in subAntarctic seawater [DELILLE and VAILLANT (1990)].

Located in the South-East of the archipelago, Morbihan Bay (about 30 x 20 km) opens to the Indian Ocean through "Royal Pass" which is 12 km wide and 40 m deep. Batch experiments (3 m^3 tanks) were carried out on shore near the "Port aux Français" Marine laboratory. *In situ* studies were conducted in a small sheldered bay, using four free-floating open bottom chambers permitting direct contact between crude oil and the underlying seawater column. Similar experiments was conducted each year from January 1991 to December 1995 in the Géologie Archipelago (Adélie Land, 140° 01'E - 66° 40'S) using 220 l tanks [DELILLE et al. (1998 a)]. Periodic sampling allowed a regular survey of total, psychrophilic saprophytic and hydrocarbon-degrading bacteria. The changes in bacterial communities were studied during 40 day periods after contaminant addition. At the end of each experiment the remaining hydrocarbons were carefully collected and stored at -20°C until analysis. After decantation and filtration, they were separated in 4 different fractions (aliphatics, aromatics, resins and asphaltenes) using a silica gel column. Analysis of aliphatic fractions were performed on a gas chromatograph (Hewlett Packard 5980). Some quantitative ratios of alkanes and aromatic hydrocarbons were calculated from chromatographic data to characterise the weathering processes affecting the added oil. A decrease in the ratios C_{17}/pristane and C_{18}/phytane over time has been reported to reveal the bacterial degradation of oil [BLUMER et al. (1973) ; ATLAS et al. (1981)].

Figure Nr 1



All results revealed a clear response of subAntarctic and Antarctic microbial seawater communities to hydrocarbon contamination (Fig. 1). Hydrocarbon-degrading bacteria were always present in prystine samples. The ubiquitous distribution of hydrocarbonoclastic bacteria has already been reported in a wide variety of niches (for reviews see ATLAS (1981) and LEAHY and COLWELL (1990). Hydrocarbon-degrading bacteria ranged from 0,001% of the total community before contamination to more than 80% after two weeks of contamination with crude oil. Thus, biological degradation (bioattenuation) by naturally occurring populations of micro-organisms will be a significant mechanism for the removal of petroleum from the Antarctic environment. However, two orders of magnitude increases of total bacterial abundance could be observed after crude oil contamination with added fertiliser. It is well established that nutrients are one of the major limiting factors of hydrocarbon biodegradation at sea [LEE and LEVY (1989)]. In these surveys the bacterial growth was doubtless improved by the availability of mineral nutrients released by INIPOL EAP 22.

The biodegradation of hazardous substances is often limited by the antimicrobial action of the pollutants [HEIPIEPER et al. (1992)]. The potential toxicity of the water-soluble oil fraction to marine bacteria has been demonstrated [HODSON et al. (1977) ; GRIFFITHS et al. 1981)]. However, such inhibiting effects against bacterial communities seem relatively uncommon in Antarctic seawater. Solar radiation had no measurable effect upon crude oil-contaminated seawater. In contrast, there was a clear toxic effect upon bacterial communities contaminated with diesel fuel [DELILLE et al. (1998 b)]. Data suggest that the initial state of the bacterial communities can play a major role in the potential biodegradation. Some surface bacterial assemblages seem to demonstrate a better resistance to solar radiation than deeper ones.

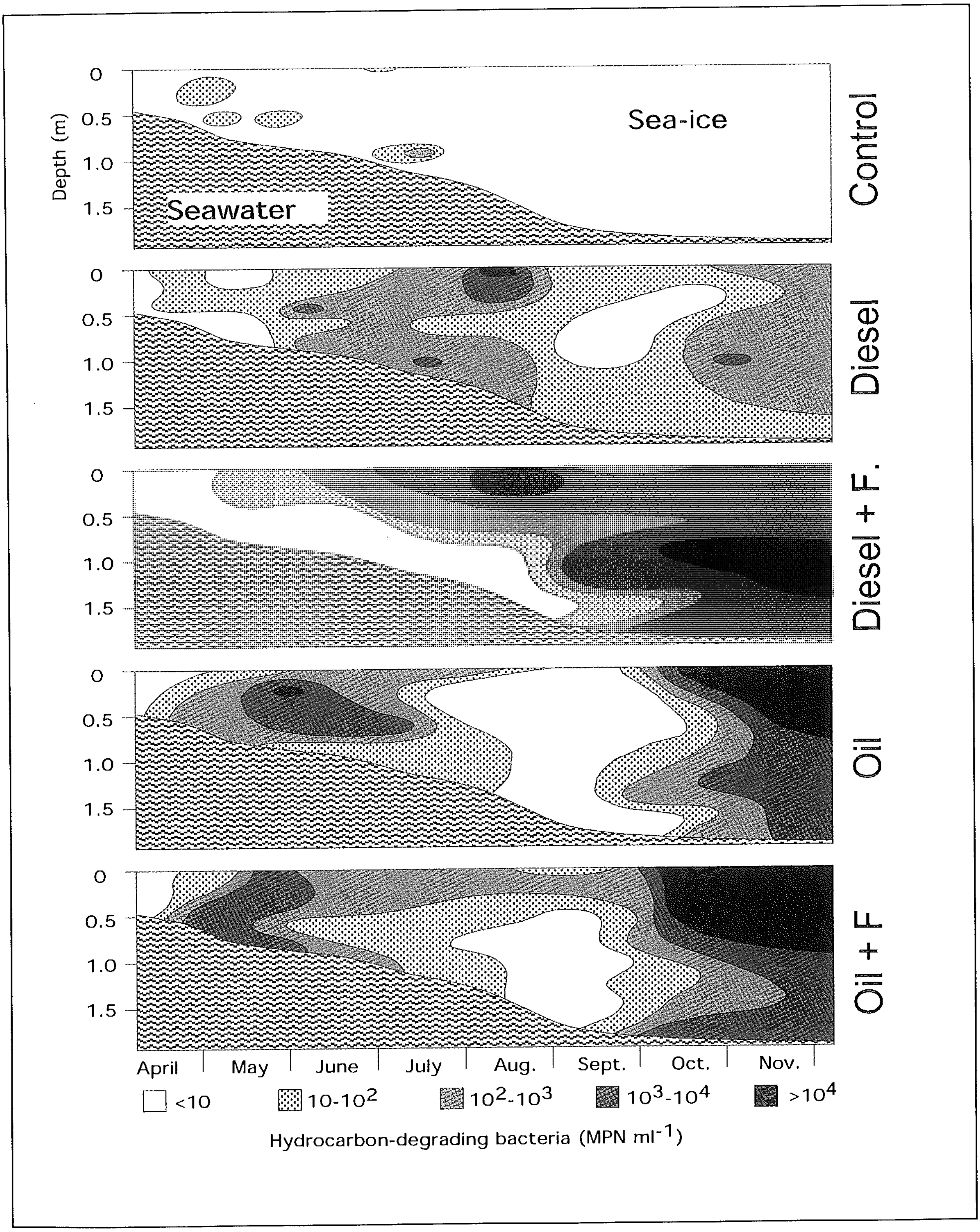
In any case, the considerable enrichment in hydrocarbon degrading bacteria after a few days of crude oil contamination is a clear indication of possible biodegradation. This is consistent with chemical analysis of residual hydrocarbons which demonstrated a decrease of the aliphatic fraction during contamination experiments. All the data collected in seawater demonstrated that bioremediation may be a useful tool in more severe environmental conditions than those of Alaska where its effectiveness has now been clearly established [BRAGG et al. (1994) ; ATLAS and CERNIGLIA (1995)].

Sea-ice

Approximately 23 millions km^2 of the ocean surface freezes to produce sea ice on a seasonal basis [MAYKUT (1985)]. Ice algae are estimated to contribute 20% of total primary production in both Antarctic and Arctic Sea [KIRST and WIENCKE (1995)]. Sea ice microbes succesfully inhabit the surface, interior and the bottom of the ice [GRADINGER (1999)]. Sea-ice bacteria actively grow and assimilate dissolved organic substrates [McCONVILLE and WETHERBEE (1983) ; GROSSI et al. (1984); KOTTMEIER and SULLIVAN (1987) ; GROSSMANN (1994)].

All the studies concerning hydrocarbon contamination in ice-covered environment have been conducted in the Northern hemisphere. A bioremediation study was conducted from May to December 1993 in the land fast-ice of "Géologie Archipelago" [DELILLE et al. (1997)]. The station was located 500 m offshore in the middle of the channel existing between the main islands of the archipelago (20 m depth). The changes in bacterial communities were studied *in situ* after crude or diesel oil addition in 1 m^2 sectors cut out in newly formed sea-ice. Weekly sampling in sea-ice allowed a regular survey of total, psychrophilic saprophytic, psychrotrophic saprophytic, and hydrocarbon-degrading bacteria. Ice cores were collected using 10 cm (internal diameter) ice-coring augers. The cores were cut into segments with a sterile blade. Subsamples were taken in the center of these segments and stored in a sterile glass box before melting in a known quantity of sterile aged seawater.

Figure Nr 2



Three orders of magnitude increases of bacterial microflora can occurred in sea-ice after both diesel fuel and crude oil contamination. A concomitant enrichment in oil degrading bacteria was generally observed : from less to 0.001% of the community in uncontaminated samples to up to 10% after 30 weeks of contamination. Addition of fertilisers (INIPOL EAP 22) induced clear enhancements of both saprophytic and hydrocarbon-utilising microflora (Fig. 2). Bacteria in sea-ice have been reported to be generally larger than those found in seawater [MARRA et al. (1982) ; DELILLE 1992, PALMISANO and GARRISON 1993)], which may be a reflection of generally higher organic nutrient concentrations in the ice environment [MARRA et al. (1982) ; SULLIVAN 1985)], lower temperature [WIEBE et al. (1992)] or lower grazing pressure [TURLEY et al. (1986) ; GONZALES et al. (1990) ; GROSSMANN and DIECKMANN (1994)]. In any case, addition of fertilizer strongly enhanced this phenomena..

Intertidal sediments

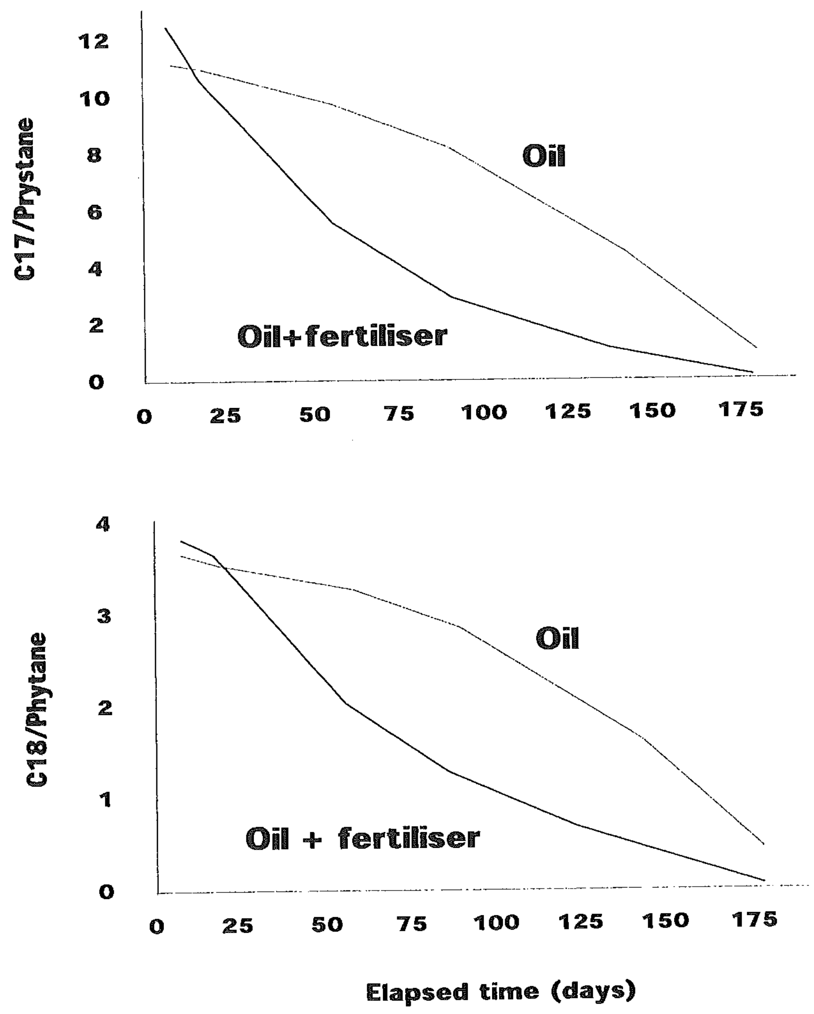
A field study was initiated in February 1996 in a remote sandy beach of The Grande Terre (Kerguelen Archipelago, 69° 42'E - 49° 19'S) with the objective of determining the long-term effects of some bioremediation agents on the biodegradation rate and the toxicity of oil residues under sub-antarctic conditions. A series of 10 experimental plots (1 m^2 each) were settled firmly into sediment and covered with 200 µm plankton net in order to keep oil in place and protect experimental plots from wild animal disturbance. Each plot received 2 l of Arabian light crude oil and some of them with treated with bioremediation agents : slow release fertilizer Inipol EAP-22 or fish composts. Each plot was sampled on a regular basis over a one-year period. Sediment and interstitial waters were collected for bacterial, chemical and toxicological measurements. All samples were analysed for total bacteria, heterotrophic viable assemblage and hydrocarbon utilising microflora. Biodegradation rate in each plot was estimated by the chemical analysis of both aliphatic and aromatic fractions of recovered oil residues. Gas chromatographic separations allowed the determination of biodegradations indexes for alcanes (ALC/ISO, C17/PR, C18/PHY, PR/PHY, C30/Hopane) and aromatics (2MN/1MN). Toxicity of oil residues and interstitial waters was determined using Microtox® test in dissolved and solid phases. The test was calibrated using unweathered crude oil and various aqueous and solvant extractions of weathered crude oil.

Two orders of magnitude increased of hetrotrophic and hydrocarbon utilizing bacteria occurred during the first month of experimentation in all treated spots but the were no clear differences between the different plots. Very high bacterial concentrations remained present during the 311 day experiment. The 52 spectra obtained from hydrocarbon analyses provided numerous informations on oil degradation. C17/PR ,C18/PHY and C30/Hopane ratios exhibited a similar pattern. The ratios followed a constant decrease until day 177 which is representative of a regular oil biodegradation (Fig. 3). Biodegradation within treated spots was faster than within untreated ones. At day 177, every ratio gathered to a same point. It was then possible to observe a nearly complete degradation of haliphatic hydrocarbons within all spots including untreated ones. The high and low molecular weight ratios were more sensitive after day 177.

Analyses of interstitial water presented no toxicity. Correlation graphs even showed that some boiremediation treatments seemed to reflect an increasing stimulation with time. Analyses of sediments samples gave the opposite response. A high toxicity signal appeared for all spots with a slight reduction with time. The signal of high toxicity remained after 311 days of oil exposition. (Fig.4)

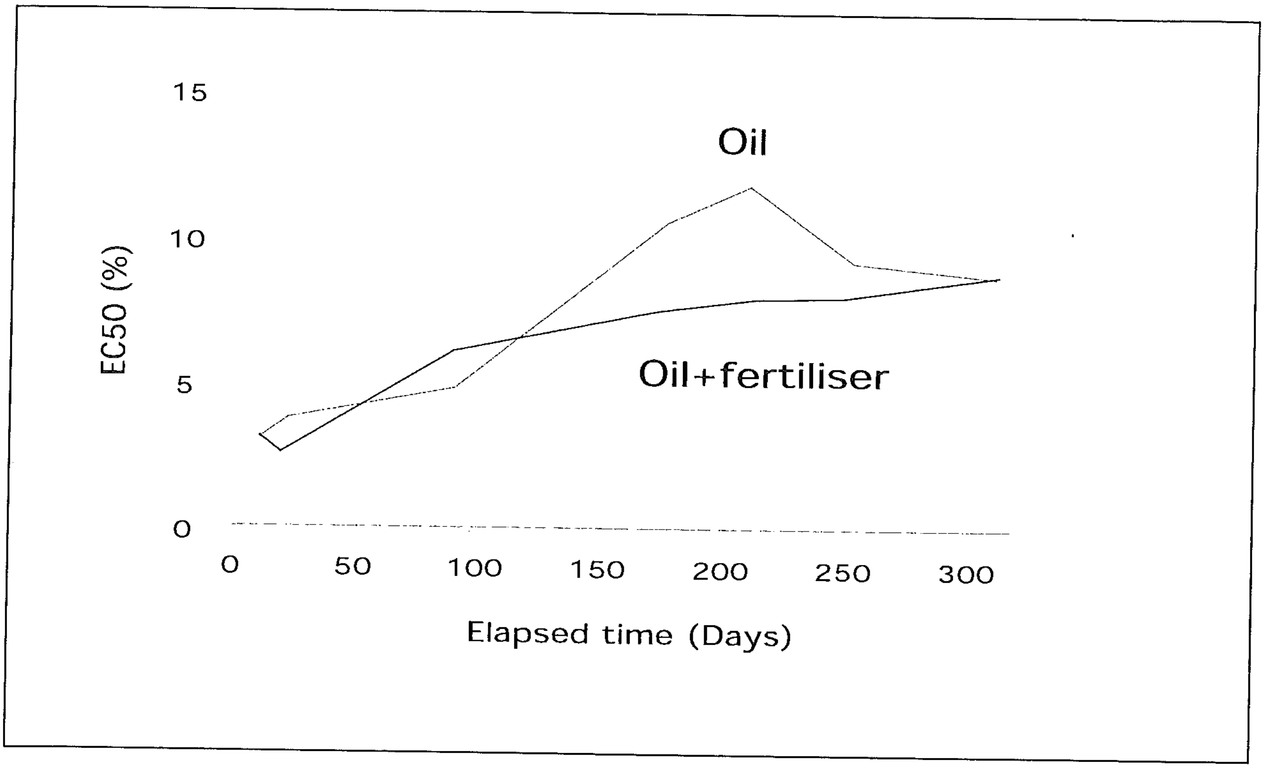
As a conclusion, it is clear that the biodegradation was important. However, bioremediation treatments showed relatively little efficiency. The observed bioremediation remained a short-term phenomenon. The toxicity evaluation of sediments within the different spots did not harmonized

Figure Nr 3:



with the oil degradation response. Non toxic materials were degraded and toxic ones remained. The speed of oil degradation was improved but the final residue giving a high toxic signal was unchanged. A long-term survey conducted in the same sediments will allow to study this residual toxicity.

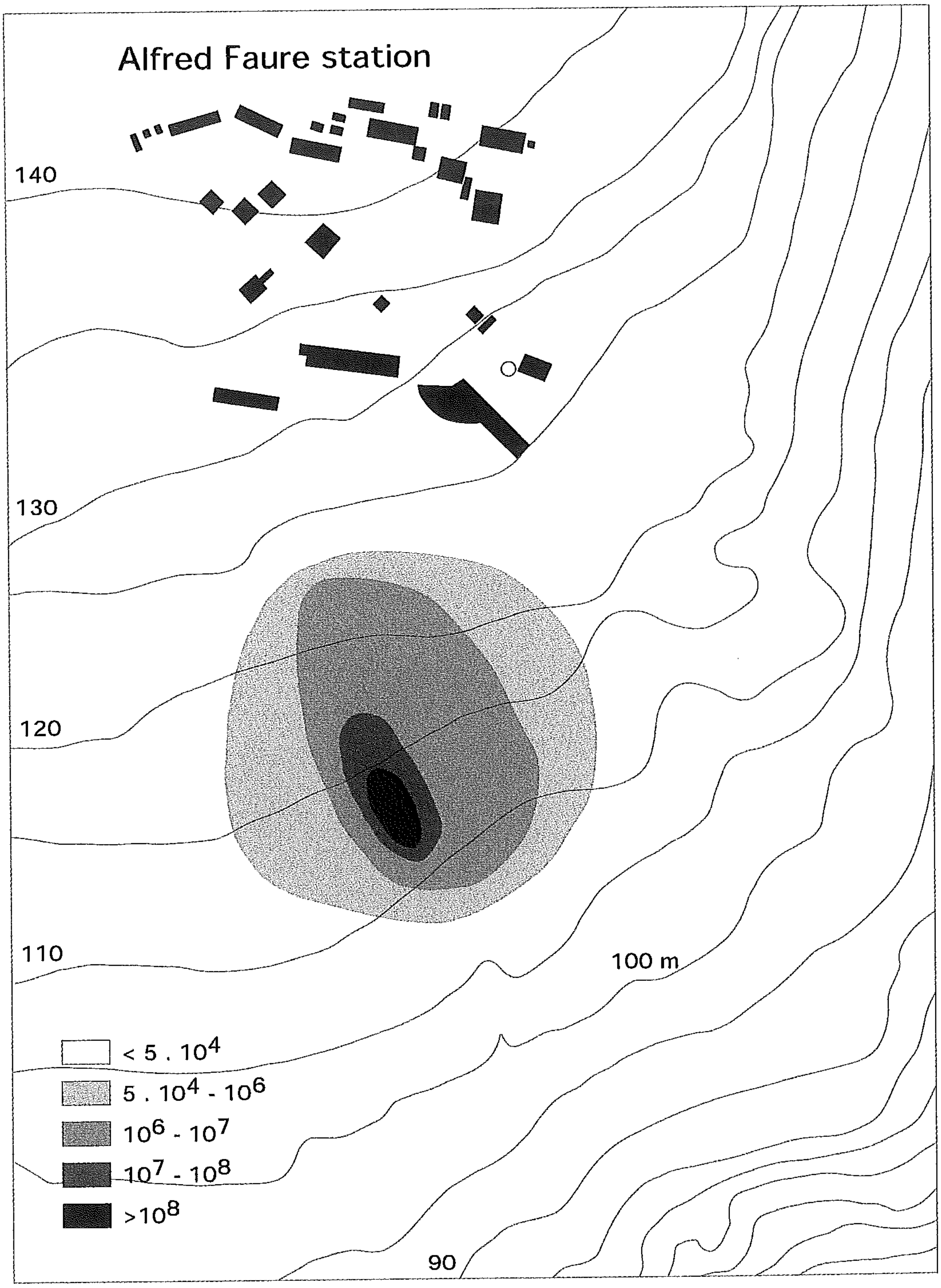
Figure Nr 4:



Soils

In recent years, there has been increasing interest in developing cost-effective *in situ* technique for bioremediation of oil-contaminated soil [JOERGENSEN et al. (1995) ; MØLLER et al. (1996)]. However, relatively few data are available for Antarctic soils [AISLABIE et al. (1998) ; McCORMACK and FRAILE (1997)]. Accidental contamination of Antarctic soils with fuel oil occurs frequently. There is a continuing need to understand the fate of hydrocarbon contaminants in these extreme systems. At the present time, in subAntarctic and Antarctic soils, our studies concerning oil degradation have only taken in account bioattenuation processes.

An accidental contamination occurred in the subAntarctic Crozet Island between July and November 1997 near the "Alfred Faure" scientific station. More than 20.000 l of diesel fuel have been spill in the direct vicinity of the power station. The results of a first analytical survey conducted in December 1999 clearly show a significant response of subAntarctic microbial soil communities to hydrocarbon contamination (Fig.5). The very high numbers of hydrocarbon-degrading bacteria present in the more contaminated zone are probably an indication of bioattenuation activities. However, under the more severe Antarctic conditions bioattenuation processes seem insufficient



Hydrocarbon-degrading bacteria MPN g^{-1}

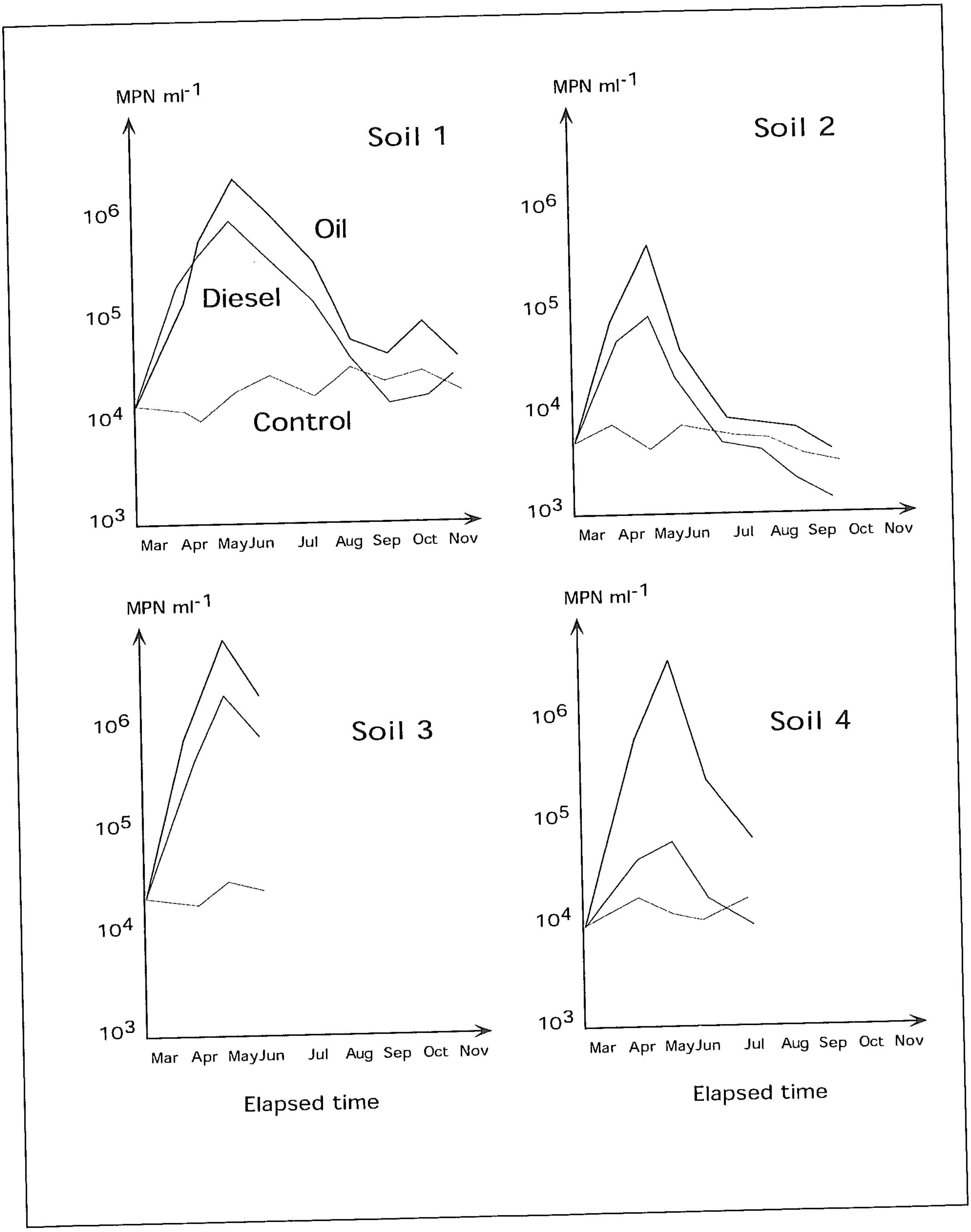
In Antarctica a study was conducted from February to December 1995 in the Géologie Archipelago. The 4 studied stations were located on Petrel Island. Mean monthly temperature in the study area rise above freezing only during the months of December-January and reach -16°C in July-August. Thus, the resulting annual hydrologic cycle can be described in terms of four periods: winter, snowmelt, summer and freeze up. The penguins and other birds transfer nutritive material from a large zone of the relatively rich antarctic ocean to a very restricted area of cold desert land. During summer season the 4 soils were submitted to penguins manuring. However, bird influence was relatively reduced in soil 1 when compared with the 3 other soils. The changes in bacterial communities were studied *in situ* after crude or diesel oil addition in 400 cm^2 square.

An initial increase of total bacterial abundance occurred in all contaminated soils. These stimulating effects could reach one order of magnitude. However, they were always limited in time. The results clearly revealed a concomitant enrichment in oil degrading bacteria (Fig.6). Two orders of magnitude increases in oil degrading bacterial abundance occurred after contamination. With values generally close to 10^4 bacteria ml^{-1} the hydrocarbon degrading bacteria found in prystine soil never represented more than 1 % of the saprophytic assemblage. After 3 month of contamination this proportion can exceed 95%. However these differences between prystine and contaminated soils completely disappeared after July. A very low level of biodegradation of contaminant was suggested by chemical analysis of oil residues collected at the end of the experiment. The rate of microbial degradation of hydrocarbons in soils is affected by several physicochemical and biological parameters including the numbers and species of microorganisms present; the conditions for microbial activity (e.g., concentration of nutrients, pH, oxygen and temperature); the quality, quantity and bioavailability of the contaminants and the soil characteristics [MARGESIN and SCHINNER 1997)]. The present data set provide further evidence of the presence of indigenous hydrocarbon-degrading bacteria in Antarctic soils and their potential for bioremediation. More surprising is the general decrease observed at the end of the experiment. As reported by LONG et al. (1995) petroleum contaminants could exert toxic effects on the active microbial community. Although fuel oil can be toxic for many organisms, it is also an easily available substrate for some groups of organisms. Although it has been demonstrated that microbial communities can affect chemical pollutants, the presence of chemical pollutants can also affect microbial community structure [(DELILLE and SIRON (1993) ; LONG et al. (1995)]. The chemicals can alter the community structure through selection of pollutant degraders or through acute toxicity to microorganisms. Readily biodegradable pollutants can increase population densities by promoting growth through providing carbon and energy to microorganisms in otherwise oligotrophic environments. Contaminants in soil are not solely subject to microbiological degradation, but are also subject to various adsorption and distribution processes [LANGBEHN and STEINHART (1995)]. Furthermore, a measurable amount of contaminants is not completely oxidised to $C0_2$ and H_2O, and other oxidation products accumulate in the soil. This is especially important for toxicologically relevant PAH, for which a strong toxicological potential of its oxidation products is suspected [GIBSON and SUBRAMANIAN (1984)]. At low temperature, toxic short-chain hydrocarbons volatilise more slowly which may result in increased toxicity to microorganisms [ATLAS (1981)]. Further investigations taking account of the contaminants toxicity will be necessary to determine if the observed decrease of all the bacterial parameters will be related to such toxic limitation.

Microbial metabolism increases as temperature increases [LEAHY and COLWELL (1990)], usually doubling for each 10°C increase in temperature from 10 to 40°C [BOSSERT and BARTHA

(1984)]. Oil may also be degraded more slowly at low temperatures because of the increased viscosity of oil that reduces its availability to microorganisms [ATLAS (1981)]. However, the metabolism of psychrophilic and psychrotrophic bacteria is adapted to work and function at low

Figure Nr 6:



temperature [GOUNOD (1991) ; FELLER et al. (1996)]. In the studied area, temperature close to 0°C had been show to allowed oil biodegradation in sea water and sea-ice. In coastal Antarctica 12°C is typical summer surface soil temperature [WILSON et al. (1997)]. Antarctic soils are thermally unstable, experiencing large temperature fluctuations with temperatures dropping well below 0°C at night and reaching much more than 20°C during sunny afternoon [HARRIS and TIBBLES (1997)]. Thus, they suffer frequent summer freeze-thaw cycles. Antarctic maritime soils are also reported to experience other extremes of environmental stress, principally desiccation and freezing [WYNN-WILLIAMS (1990); DAVEY and CLARKE (1991)]. All these extreme fluctuations may seriously affect bacterial activity. Bacteria must acclimate continuously and be able to rapidly switch activity on and off. Stability of temperature (like in sea-ice or seawater) may render a habitat more favourable for bacterial growth than do relatively high but fluctuating temperatures as that existing in antarctic soils.

This first data set showed that severe climatic conditions limit the effectiveness of bioattenuation in Antarctic soils. The main objective of the future studies will be to evaluate the effectiveness of biostimulation and "biopiles" treatments.

Acknowledgements. This research was supported by the "Institut Français pour la Recherche et la Technologie Polaires" .

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Figures captions

Fig. 1. Changes of hydrocarbon degrading bacterial abundance in experimental batches experiments conducted with Antarctic seawater.

Fig. 2. Seasonal variation of vertical distribution of hydrocarbon-degrading bacterial abundance in Antarctic land fast-ice after crude or diesel oil addition (F. = slow release fertilizer Inipol EAP 22)

Fig. 3. Changes of C17/PR and C18/PHY ratios during the *in situ* experiment conducted in subAntarctic intertidal sediments ("Anse sablonneuse", Kerguelen Archipelago).

Fig. 4. Changes in toxivity (Microtox® test) during the *in situ* experiment conducted in subAntarctic intertidal sediments ("Anse sablonneuse", Kerguelen Archipelago).

Fig. 5. Spatial distribution of hydrocarbon-degrading bacterial abundance in the vicinity of the Alfred Faure station (Possession Island, Crozet Archipelago) two years after an accidental contamination by diesel fuel. The maximum visible occurrence of the contaminant corresponds exactly to the maximum occurrence of the hydrocarbon-degrading bacteria.

Fig. 6. Changes of hydrocarbon degrading bacterial abundance in 4 artificially contaminated Antarctic soils (Petrel Island, Adélie land, Antarctica).

Sewage Treatment at Syowa Station

Akihito Umezawa[1],Masaru Sakamoto[1],Kikuo Yanagiya[1],
Jiro Yoshida[2] and Yoshitaka Kato[2]

1. Preview

Syowa Station is located at 69-degree south latitude and 39-degree east longitude, and in the East Ongul Island 4 kilometer away from the ice edge of the Antarctica. Out of other Station, the Syowa Station region is relatively warm, showing that the average temperature is 0 degree centigrade (0℃)in summer season and minus 20-degree centigrade (-20℃)in winter season. The coldest temperature at the period from 1998 to 2000 is minus thirty-seven point seven degree centigrade (-37.7℃). The average wind velocity is seven to eight meter per second (7-8m/s), and the maximum is fifty-four point six meter per second (54.6m/s).

Syowa Station started its operation from January 1957, and about 40 members currently conduct, as the wintering party, the observation and construction operation. Sewage exhausted from Syowa Station, except the sewage from experiment, is mainly the human waste and living waste. To treat those wastes, we have adopted the contact aeration type of water treatment system, and report this system at this time.

2. History to adopt the sewage treatment system

To restrict the activity in Antarctic region to the activity for the purpose of peace, the Antarctic Treaty was executed in 1991 among the countries conducting activity at Antarctic region. This treaty constitutes the basic agreement of 1) freezing insistence of territorial right, 2) freedom of scientific investigation and ensuring international cooperation, 3) prohibition of military usage, 4) preservation of animals and natural environment, at the region higher than 60-degree south latitude. Under the circumstances where environmental preservation at the global scale has recently been required and human activity in Antarctic region has been increased for sightseeing and observation, many recommendations has been adopted. To the end, Protocol of the Antarctic Treaty concerning the environmental protection has been adopted where the treatment and administration of waste disposal was prescribed.

Diagram of the wastewater treatment at Syowa Station is shown in the drawing-1

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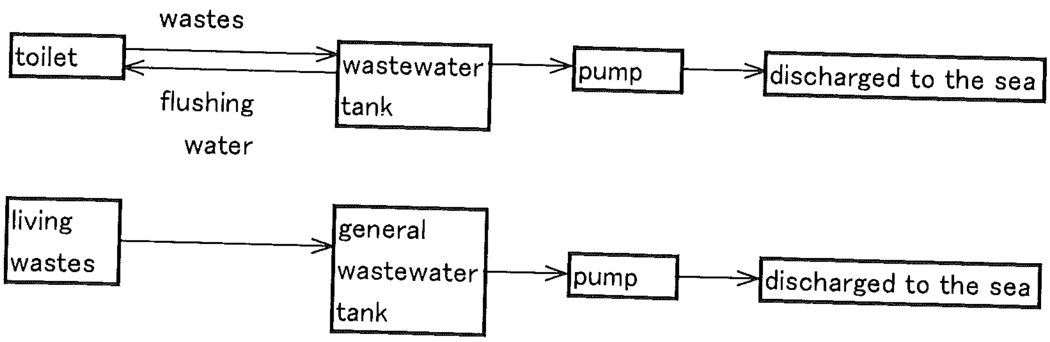
below. The wastewater tank is prepared solely for human waste, and the circulation type toilet is used. Water with chemical is stored in the wastewater tank and is used for flushing. Human waste and flushing water are returned to the wastewater tank and is recycled for use of flushing water after filtration. The wastewater tank is full in fifteen days, and when it is full, the wastewater is discharged by the compression pump to the sea adjacent to the Station. The living wastes (except human waste) is temporarily stored in the general wastewater tank, and discharged to the sea under automatic operation. Every time when water discharge is completed, air blow is conducted for prevention of freezing wastewater-discharging pipe.



drawing-1

Sewage treatment plan at Syowa Station begins in 1991 to conduct the basic investigation on the sewage and disposal within the Station. In March 1999, the contact aeration type of wastewater treatment equipment is partially operated by the 40th wintering party, and in February 2000, all wastewater from main buildings of the Station, such as Administration Building, Power Generation Building, and Residential Building are treated and discharged to the sea.

Following is the history of sewage treatment facility installation:

History of Sewage Treatment Facility Installation

1997	To install the sewage treatment building and main equipment
1998	To implement the piping work and install equipment
1999	To start sludge treatment of administration building
2000	To start sludge treatment of power generation building, and first and second residential buildings

3. Design criteria of sewage treatment system

Most of the sewage at Showa Station is from human waste and living waste, and its volume is about $6m^3$ in total and 150 litter per person, which is about 60% of the average volume in Japan. At the result of actual investigation, we have assumed that BOD is 320mg/L, SS is 320mg/L. We have adopted the advanced treatment in accordance with Advanced Treatment Criteria of Japanese Sewage Law, and established the treatment criteria: BOD to be 20mg/L and SS to be 70mg/L.

4. Selection of treatment method

From the viewpoint of small treatment volume and treatment space limitation at Syowa Station, it is assumed that the treatment with the usage of septic tank is appropriate. In this case, the percolating filter method、 contact aeration method, rotating biological contactor method, activated sludge treatment method are to be studied as the treatment method. The rotating biological contactor method is adopted at Australian Station, while the contact aeration method is mainly used for living wastewater treatment in Japan.

The rotating biological contactor method is the treatment method where the disc is installed in a manner that one part of it is under water through horizontal shaft and is rotated slowly to have microorganism attach to the disc for wastewater treatment.

The contact aeration method is the treatment method where contact media is filled in the aeration tank and air is blown from the bottom for circular contact of the sewage and the contact media. Microorganism grown at the contact media treats the wastewater.

Taken the following limitations into consideration, we have studied both the rotating biological contactor method and the contact aeration method, upon introduction of sewage treatment system.

- Treated water quality: to attain the treated quality to the level higher than the level required by advanced treated standard of Sewage Treatment Law in Japan.
- Maintenance: to be the treatment system of easy maintenance that requires a few daily maintenance checks, since an expert is not stationed.
- Electric power: to be the treatment system that requires less than five-kilo watt.
- Transportation: transportation volume is limited, since yearly observation ship is

only available for transportation. The system shall require the spare parts that can be transported by one ship.

- Installation: to be the treatment system of easy installation that can be completed about one month in the summer.
- Installation space: to be the treatment system that requires small building. Space for the Base is limited because of geographical features.
- Odor control: to study the necessity of odor control system.

We have studied and found that both systems are same in its performance from the viewpoint of treated quality, maintenance, and required power. However, with regard to the transportation and installation, the rotating biological contactor method requires precision at the rotation part of drive unit. Also, it requires the elevated building because of its operational needs, which is not appropriate to Syowa Base requiring the small building. With regard to the odor control, both contact aeration system and rotating biological contactor method have aeration tank and require the odor control system.

From the above, we think that the contact aeration system of many installation experiences in Japan is appropriate for the sewage treatment system at Syowa Station and have adopted it there.

5. Selection of sewage transportation system

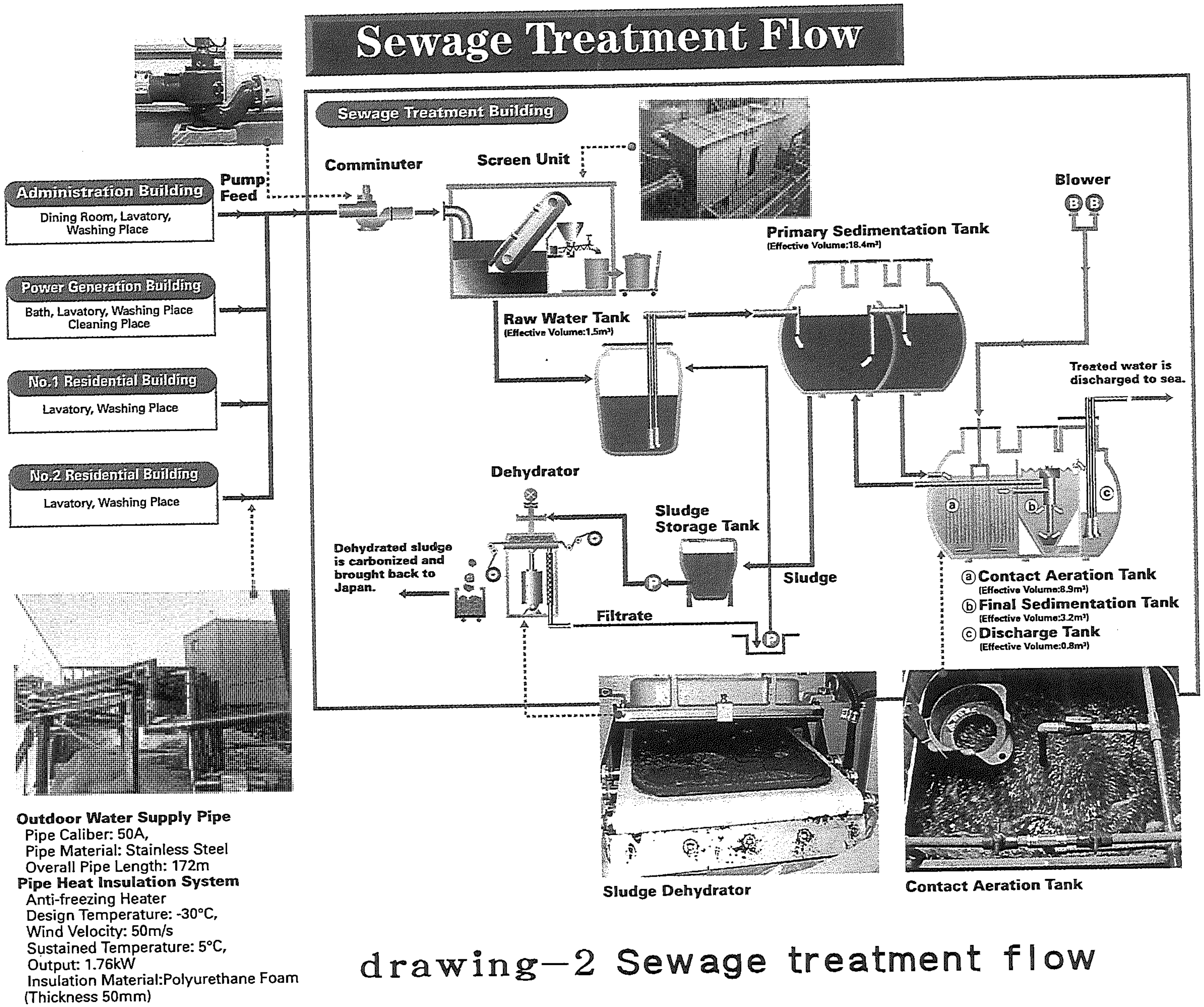
Pressurized type and vacuum type are available for sewage transportation from sewage source place to sewage treatment building. We have adopted the pressurized type at this time because it is the type of relatively easy maintenance, only requiring replacement of the pump for spare in case of the failure of the running pump.

6. Outline of sewage treatment building

Sewage treatment building is steel structured flat building with use of steel panel, with the easy assembly into consideration. The floor area is 109 square meter. Because of biological treatment, temperature of this building keep constant at 18 degree centigrade by the water heating system with the use of the heat energy recovered from power generation.

7. Sewage treatment system flow

Flow chart for the sewage treatment system is shown in the drawing-2.



drawing—2 Sewage treatment flow

Dining, lavatory, and washing place are stationed each at Administration, Power Generation, and Residential Building, and the exhausted sewage is first stored at the pump tank in each building. All those sewage are then transferred to the Sewage Treatment Building and are treated there.

Pump pressurized transfer pipe is 50A in its diameter and stainless steel in material, and its overall length is 170 meter. The pipe is installed at the declination to the degree that enables to implement the gravity transportation. And since the pipe is located outdoor, it is protected by frozen prevention heater and insulation material. In designing the heater, it is assumed that outdoor temperature is minus 30 degree centigrade (-30℃), wind velocity is 50m/s, and maintained temperature at pipe is five degree centigrade (5℃). Overall output for the heater is 1.76-kilo watt. Polyurethane foam of 50mm thickness is used for the insulation material. Heater and insulation for this pipe were pre-assembled to unit in Japan and the piping work conducted at the Base was unit connection only.

The vinyl chloride pipe is used for the piping inside the buildings with easy processing into consideration.

Sewage from each building is fed to the comminuter and screen for the purpose of eliminating large size of sludge and other disposal, and screened sewage is stored in the raw water tank. The sewage in the raw water tank is fed to sedimentation tank by the constant feed pump with adjustable flow speed function. At the sedimentation tank, the solid is separated, and at the contact aeration tank of the following process, biological treatment is conducted for the purpose of treating organic wastes. At the final sedimentation tank, the treated water is discharged to the sea. Upon finishing the discharge, air blow is conducted for the freezing prevention. Since the discharging volume is small, $6m^3$/day, disinfection is not conducted with the adverse environmental effect taken into consideration. The sediment at the final sedimentation tank is returned to the sedimentation tank and is extracted as sludge there together with the sediment of the first flow. Polymer and inorganic coagulation material is added to the sludge, which is then dehydrated by the pressurized filter and treated with raw garbage by the carbonation equipment at the Syowa Station. The carbonated materials are brought back to Japan and are given final treatment.

8. Summary

Treatment work at the sewage treatment system has just begun, and the remaining work that we need to do is to analyze the treatment data. Also, we need to introduce the odor control system. Study at Antarctic region is of the scientific value, and the observations at this region assume to continue. However, this scientific value will be invalidated if these observations deteriorate natural environment. We need to continue the maintenance administration of sewage treatment system, aiming to improve the environmental protection at Antarctic region, solving the issues of reduction of water discharging volume, recycling, and advanced treatment method.

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Biological Sewage Plants at "Neumayer" and the Argentinian Base "Jubany" Antarctica

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Abstract:

Since 1981 the Alfred-Wegener Institute for Polar and Marine Research (AWI) has been operating a permanent station in Antarctica. The Neumayer-Station (70° 39' S; 08°15' W), was rebuilt in 1992 in accordance to the regulations of the protocol on environmental protection to the Antarctic Treaty, to minimise any environmental impacts. Thus a biological sewage treatment plant was developed. Those plants were installed at Neumayer-Station in 1997 and at the Argentinian base "Jubany" in 1998. The Neumayer plant was designed to treat sewage water to an amount of 5.8 m^3/day and at Jubany 7.9 m^3/day to meet the planned capacities required for 40 and 60 persons, respectively.
In principle the sewage water treatment works by deploying a biological reactor which uses the own bacteria of the sewage water without any additives. Only oxygen is pumped into reactor tanks. The treated water is finally sterilized by an UV-lamp and pumped into the ice as clean (recycled) water. Remaining sludge is treated by alcaline material (slaked lime), dried, collected in special bags and disposed of as a normal waste.
After 3 years of operation the experience shows that sewage issues could be solved by the used technology.

Introduction

In the years 1991/92 the new German Antarctic station Neumayer (70°38'S/ 08°15'W) was planned and built. With the objective of guaranteeing an environmental friendly operation of the station, extensive environmental protection measures were considered during planning and construction. In compliance with the provisions of the protocol on environmental protection to the Antarctic Treaty, waste management and sewage treatment were also considered, planned and realised.
The specially developed sewage plant is based on a Marine Sewage Plant series (MSP), Aqua Mer, which was approved by the German maritime employee's liability insurance association. This plant fulfils the relevant requirements of national and international regulations.
Two biological sewage plants of the same type and different capacities were installed at Neumayer-Station (1996/97) and at the Argentinian station "Jubany" (1998) to treat station's waste water (grey and black water from toilets, kitchen, showers, washing facilities and laboratories).

Operational experience of both plants has been collected, analysed and will be presented.

Technical requirements and operational conditions

This type of plant is a prototype for Antarctic stations which are permanently occupied. A special feature of Antarctic stations operating throughout the year is that considerably more people live on the station during summer months than in winter season. The sewage plant for the Neumayer station has been designed for 30 persons in the summer and 9 persons in the winter and can treat about 5.8 m^3/day of sewage water. The plant at Jubany has been planned for 75 persons in the summer and a maximum of 20 persons in winter and is able to treat about 7.9 m^3/day. However, the plants have proved their worth even under short-term high loading conditions, with a far greater number of people than mentioned above.
A further special feature is that plants of this type are constantly subjected to peak loads during daily operation of the station. While in the early morning, and particularly in the evening, there is a high waste water inflow, this is reduced in the mid-morning and afternoon periods and stops completely during the night.
Such extreme fluctuations and peak loads are buffered by upstream-connected collecting tanks, and by means of suitable control devices controlling a continuous inflow.

Construction and technical performance

The plant consists of a multi-step, 4-chamber system, which is built into a steel container. In order to prevent corrosion the containers are constructed of stainless steel (V 4 A). The container has the following sizes: length 2000 mm, width 1.800 mm, height 1.800 mm. The principle operation is shown in Fig. 1.

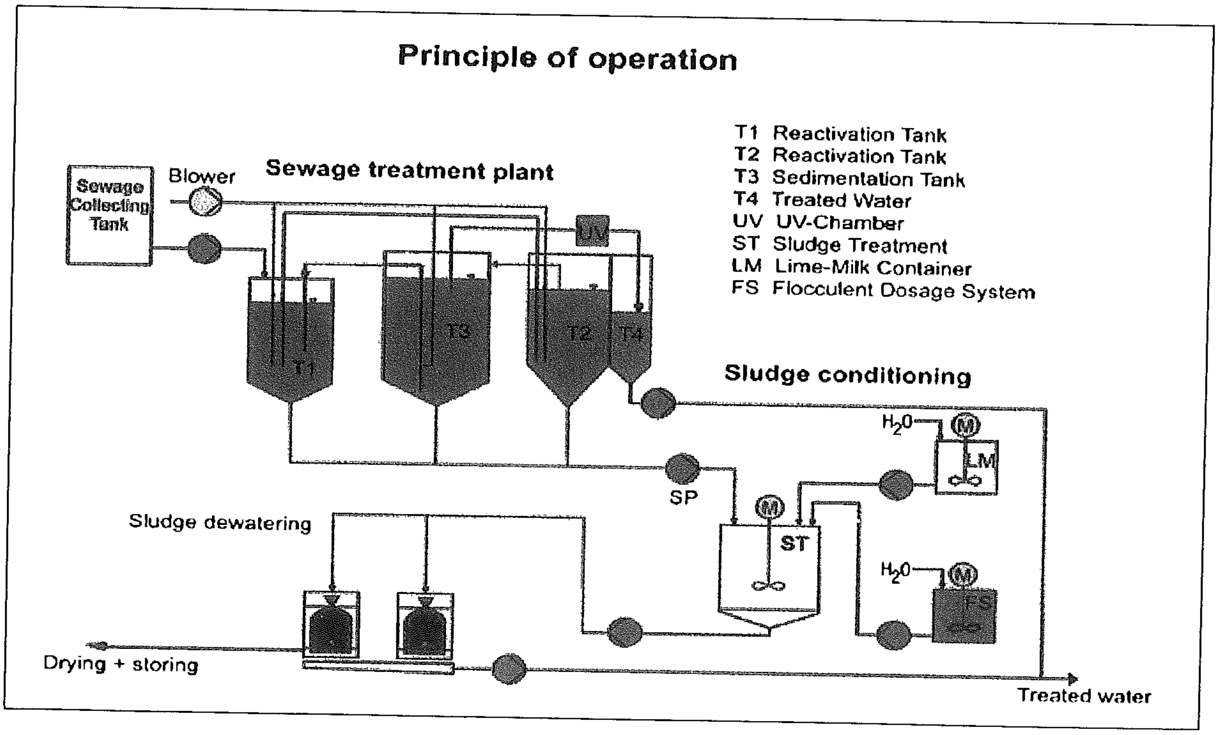

Fig. 1: Principle of operation of the MSP swage plant .

A sludge treatment unit, consisting of sludge reactor and drying oven with the necessary technical equipment, is integrated into the plant.
Waste water from the station is directly pumped to chamber I. Oxygen is supplied in regulable intervals to chambers I and II, and this promotes the formation and stimulation of bacteria in these chambers. The waste water to be clarified flows through an overflow system to chamber III. Chamber III serves as an absolute-rest precipitation tank and settling tank. The lower region is suitably sloped so that the settling biological sludge can be guided towards the opening of an injection pump. During the ventilation phase the settled activated sludge is returned to chamber I in a continuous circulation system by means of this injection pump. This is mixed there with the freshly inflowing waste water and so activates the bacteria in chamber I.
The processed water in chamber III flows at the end of the settling phase to chamber IV as surface water and passes through a UV reactor to destroy any remaining microorganisms. Therefore, no harmful bacteria should survive after the treatment.
The purified waste water is drawn off by a feed pump into an outside drainage pit in the snow at Neumayer, or into the sea at Jubany base.
With this method the following maximum concentrations of suspended material can be obtained for the purified discharged water, which correspond to the German standards for sewage treatment.

Solids (suspended particles)	< 100 mg/litre
Coliform bacteria (Escherichia coli)	< 200 / 100 ml
BOD_5 (Biochemical Oxygen Demand)	< 50 mg / litre

The mineral sludge produced during the purification process is retreated in the sludge unit. This is passed into a sludge tank by means of a pump, and is stabilised and hygienisated there by addition of hydrated lime solution to minimise further organic activities and bacterial growth. This reduces the smell of stored sludge. Residuals of microorganisms are still present but inactive, so that the sludge can be considered as harmless waste.
The sludge is finally dried by a drying oven and filled into special bags. The dried sludge is considerably reduced by volume and weight (about 5% of the original mass), is intermediately stored at the station and properly disposed later as the other waste of the station according to the Antarctic Treaty System.

Operational experience

Both plants have been in continuous operation since 1997, and are working perfectly. They are technically designed to operate automatically, with a minimum of maintenance work. Alarm devices inform the operator in case of faulty function. Furthermore, a three-way valve controlled by float type switches prevents the overflow inside the plant. Safety for machineries and personnel is automatically realised by a logical connection of level indicators, stirrers, dryer and pumps to the control indicators and to the safety circuit.

Important parts , like fans, pumps etc. are installed in duplicate for safety reasons, and can be switched over within seconds.
Daily visual check of the plant, control lamps and valve settings are necessary for proper operation.These procedures take not more than 5 minutes per day.
Scum in tank III should be controlled weekly. Sludge treatment should be done every 4 to 6 weeks. The remaining sewage sludge should be pumped out and treated as described above (stabilisation, hygienisation). This work can be done within 2 hours.
The preduced dry sludge at Neumayer-Station during the winter (9 persons) is about 4.5 Kg within 4 to 6 weeks. This is only about 5% of the original mass.
The operating costs of the plant are approx. US $1500 /year , and mainly include spare parts and consumables as filters, bags and others.

Conclusions

The installation and operation of the biological sewage plants at Neumayer- and Jubany-Station have improved the environmental protection and minimised the impacts to the ice and to the sea . Treated water and sludge reach a high degree of purification. No environmentally harmful bacteria enter the area adjacent to the stations. The yearly dried sewage sludge amount is about 4 kg / person and can be easily transported out of Antarctica. Less than 6 - 8 hours of supervising of the sewage plants per month are needed to keep the system running. There were no major problems in system performance during the past 3 years of operation.
The used technology is proven and can be recommended for application at other stations.

Acknowledgement

The sewage plant was developed under supervision of the Alfred-Wegener-Institute for Polar and Marine Research. Conceptional work and tests were performed at Hochschule Bremerhaven. The safety concept was proved by Germanischer Lloyd Hamburg / Bremerhaven. The experts report was provided by Institut für Siedlungswasserwirtschaft, Aachen.
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Physiological and psychological changes of Chinese Antarctic Expedition Members.

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Systematic researches have been made of the effects of the special Antarctic environment on human health and the ability to work andj in the light of the changes in physiology, psychology and pathophysiology of China's expedition team and their condition of nutrition, labour and health during their work and stay in the Antarctic, the standard of demands of the expedition team for nutrition and heat energy, the preselection options for psychological qualities and the suggestions on the integrated measures of medical and health care have been worked out and they all have value for application.

In 1984 China constructed the Great Wall Station and dispatched her first Antarctic research expedition to conduct scientific investigation in the area of King George Island. Since then a series of human physiological and psychological researches have been carried out.

Our previous studies showed that under the Antarctic circumstance of ice and isolation from the world, the Antarctic expedition member's cardiac function was enhanced in compensatory way in a while followed by decline in the summer at the Great Wall Station(Xue *et al* ., *1989*). The immune function was decreased after residing in Antarctica and recovered when returning back(Yu *et al* ., *1991*). The changes of the personal character and psychological behaviour of some members were also found especially in winter(Xue zhohong *et al* .., *1990*).

In Great Wall station, no important nutrition problem was found except slight low vitamine B_1,A,PP, C , and heat energy intake. Respiratory ventilatory function was almost remained unchanged, while only FEV_1 and FEV_{25} were increased. No significant changes of autonomic nervous system function were found except a decrease of heart rate after deep insperation. An increase of skin microcirculatory perfusion was found in face by using laser doppler flowmeter.

28 male members of Chinese Antarctic Research Expedition were divided into two age-groups: gp.1,n=17,30.8 。 ɫ.1yrs.;gp.2,n=11,48.0。 ɫ.7 yrs. The results indicated that at the Great Wall Station during summer the people of edler age is behind the young in heart ability for adaptation to Antarctica .(Deng *et al* .)

24 hours dynamic electrocardiogram (DECG) was measured in 14 members in summer and winter respectively. The result showed that the total heart beats, mean heart rates and most slow heart beats of the expedition member in winter were significantly decreased than that in summer, but no abnormal changes were found (Yuan, *et al* .., *1988*)

Based on these investigations, the following researches were carried out.

Changes of cardiac function

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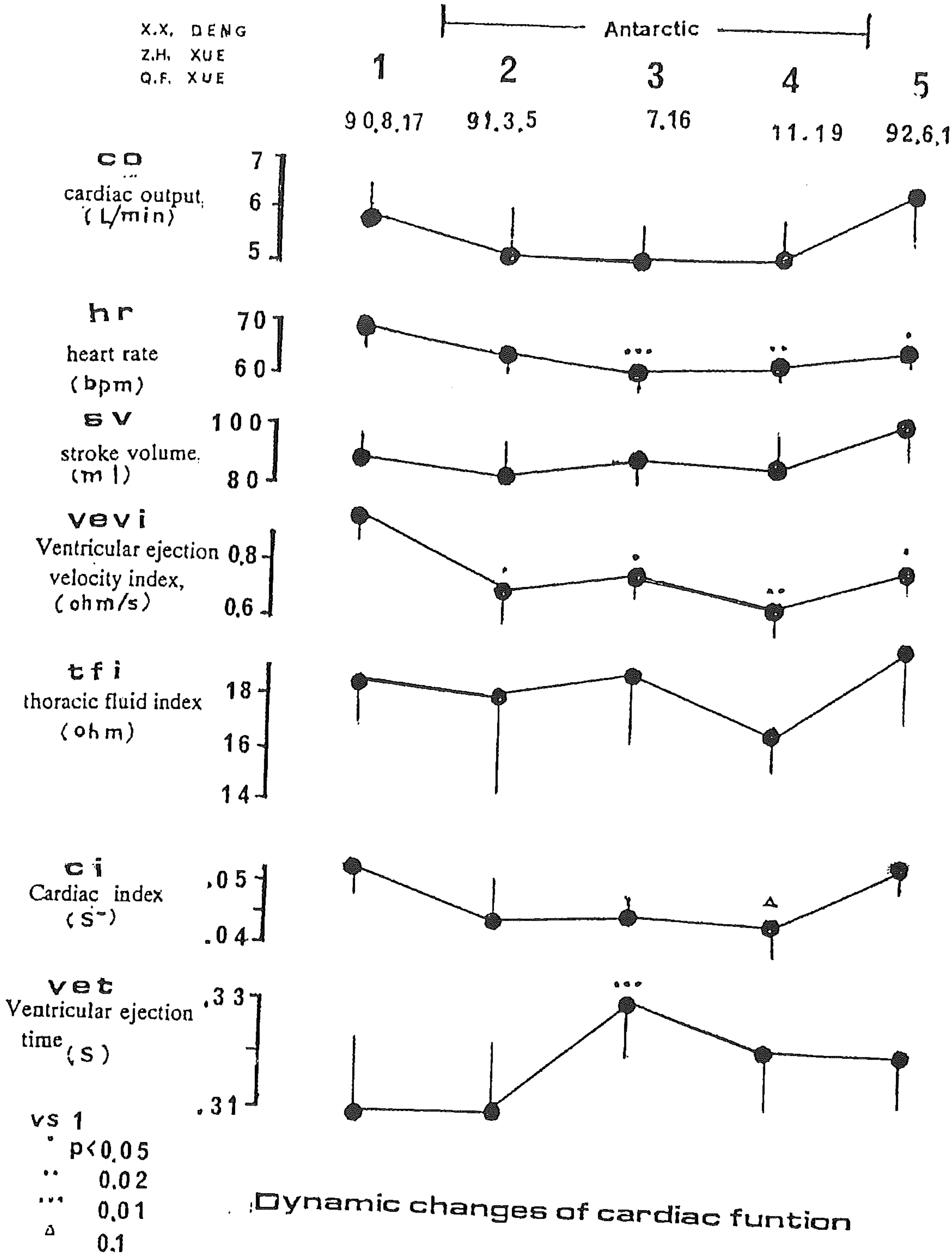
Cardiac function was performed noninvansively by using cardiac function estimating system (Bomed CO,USA)(N=15, male average age 35.6 years old, Zhongshan Station)

It was found that Ventricular Ejection Velocity Index (peak value of cardiac ejected blood velocity) was decreased rapidly after arriving Antarctica which implied that the cardiac constricted force was decreased. The decrease of IC and increase of VET also support this conclusion.



Dynamic changes of cardiac funtion

A survey on changes in multiple humoral factors in Antarctic expedition members

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Since changes of cardiac function, electroencephalogram findings, immune responses as well as the personality of the Antarctic expedition members had been reported by our group, the underlying contribution of behavior and physiological changes would be further studied in this time. Samples were taken, under standardized procedures, on the same individual at different time such as: (1) before leaving to Antarctica; (2)2 weeks after arrival at the Great Wall Station; (3) 12.5 months after arrival; (4) after returning back to Beijing for a break (summer over member); (5)after returning back to long break (winter-over member)

Results showed that a prominent increase of urinary noradrenaline (NE) in Antarctica (2) decreased at (3), and returned to the normal range in comparison with (1) and (4) . The increase of urinary adrenailne was even greater than that of NE at Antarctica (2) . It indicated that a rather early response in activation of sympathetic system, especially the adrenal glands, gradually lowered down as time went on.

Plasma and urinary cortisol also increased significantly at Antarctica (2), but sustained for a long time even after returning back to Beijing. Both parameters are closely related to stress syndrome.

Plasma tryptophan decreased significantly at Antarctica (2). Some even sustined after returning to Beijing (5). Whether or not, such changes might correlated to the change of 5-HT metabolism in brain, in turn to show some effect on psychological or mental disturbances, which should be carefully evaluated.

Serum MDA, the peroxidation product, increasing together with the findings of decreased RBC SOD activity, the scanvenger for 0_2, and increased plasma glucuronidase, the lysozyme released from damage of lysosome membrane, strongly indicated the presence of cellular damage by increasing O_2 production and membrane peroxidation and with damage of lysosome unduly. Severe cold and extensive ultraviolet exposure should be considered carefully.

The significances of the above findings were discussed and the possible preventive of therapeutic measures have been suggested. Since the destruction of the ozonelayer might increase the extent of ultraviolet radiation, it is worth to further investigate the biological damage effect of ultraviolet in Antarctica.

Results

1. Changes of urinary catecholamine content

Results showed that after arrival in Antarctica urinary NE and E increased, and NE resumed normal after winter and after-return. But E kept high level all along(Table 1)

Table 1. Changes of urinary catecholamine ($\bar{X} \pm SD$)

	①Before arriving in Antarctica	②2 weeks after arriving in Antarctica	③12.5 months after arriving in Antarctica	④After return from Antarctica
Noradrenaline	35.82±8.26	52.54±22.70*	22.92±12.06△△	30.80±9.80○
(μg/24h)	(7)	(7)	(7)	(5)
Adrenaline	8.28±4.42	18.11±5.01***	10.76±4.15△	15.56±7.73○**
(μg/24h)	(7)	(7)	(6)	(5)

Compared with ①: * $p<0.05$; ** $p<0.01$; *** $p<0.001$. Compared with ②: △ $p<0.01$; △△ $p<0.001$. Compared with ③: ○: NS. Number in brackets is number of subject.

2. Changes of plasma and urinary cortisol

Both plasma and urinary cortisol increased 2 weeks after arrival in Antarctica and remained high level except the urinary cortisol of the summer-over members when they returned (Table 2)

Table 2. Changes of plasma and urinary cortisol [$\bar{X} \pm SE$ (SE)]

	①Before arriving Antarctica	②2 weeks after arriving in Antarctica	③12.5 months after arriving in Antarctica	④After return (summer over)	⑤After return (winter over)
Plasma	7.82±0.37	19.11±2.18**		17.33±1.76**	20.17±2.86**
(μg%)	(16)	(9)		(6)	(6)
Urine	64.0±5.6	9.82±5.8**	85.3±8.7*	50.5±7.8	147.5±7.5**
(μg%) /24h	(12)	(11)	(7)	(8)	(6)

Compared with ①: * $p<0.05$; ** $p<0.001$. Number in brackets is number of subject.

3. Changes of plasma tryptophan and urinary 5-HIAA

Plasma Trp decreased 2 weeks after arrival in Antarctica and remained low level after return to Beijing (Table 3).

Table 3. Changes of plasma tryptophan [$\bar{X} \pm SD$, ($\mu g/cm^3$)]

	①Before arriving in Antarctica	②2 weeks after arriving in Antarctica	③After return (summer-over member)	④After return (winter-over member)
Winter-over member	11.29±1.73 (7)	9.36±1.91** (7)		7.88±1.48**△ (7)
Summer-over member	12.79±3.08 (5)		9.60±1.70* (5)	

Compared with ① : * $p<0.05$; ** $p<0.01$. Compared with ②: △ $p<0.05$. Number in brackets is number of subject.

Urinary 5-HIAA increased in member only after winter at Antarctica(Table 4).

Table 4. Changes of urinary 5-HIAA [$\bar{X} \pm SD$, (mg/24 h)]

	①Before arriving Antarctica	② 2 weeks after arriving Antarctica	③ 12.5 months after arriving Antarctica	④ After return (summer-over member)	⑤ After return (winter-over member)
Winter-over member	3.91±1.60	4.43±1.49	8.29±4.32*		3.82±1.24△
Summer－over member	4.24±2.89			3.22±0.79	

* Compared with ①: $p<0.05$; △ Compared with ③: $p<0.05$. Number of subject=7. Self-compared.

4. Changes of MDA and SOD

Preliminary result showed that serum MDA increased and RBC SOD activity decreased after arriving in Antarctica(Table 5).

Table 5. Changes of blood MDA and SOD ($\bar{X} \pm SD$)

		RBC-SOD-activity [U/ (g·Hb)]	Serum MDA ($nmol/cm^3$)
Summer-over member	before arriving in Antarctica (6)	6 569.5±304.5	0.93±0.09
	after return (6)	5 401.9±309.9**	1.67±0.24*
Winter-over member	before arriving in Antarctica (6)	6 090.0±220.1	1.13±0.10
	after return (6)	5 707.4±244.5	1.72±0.08*

Compared with before arriving in Antarctica: * $p<0.05$; ** $p<0.01$. Self-compared. (The samples got in Antarctica were not examined because of haemolysis) Number in brackets is number of subject.

5. Changes of plasma β-glucuronidase

Changes of plasma β-glucuronidase increased and remained high level after return to Beijing(Table 6)

Table 6. Changes of Plasma β-glucuronidase [$\bar{X} \pm SE$, $\mu g/(cm^3 \cdot h)$]

Before arriving in Antarctica	2 weeks after arriving in Antarctica	After return (summer-over member)	After return (winter-over member)
4.98±0.55 (16)	9.24±1.34** (7)	8.42±0.67** (8)	8.08±1.60* (6)

Compared with before in arriving in Antarctica: * $p<0.05$; ** $p<0.01$. Number in brackets is number of subject .

Discussion

The psychological isolation with one's own family, friends for a long time, and physiological adaption to such extreme environmental changes might be a realistic problem to face among the Antarctic expedition members.

There is a prominent increase of urinary nonadrenaline and adrenaline at 2 weeks after arriving in Antarctica, some with rather prolonged effect. It is enough to explain the changes observed in cardiovascular system, immune system and electroencephalogram. The more increase of adrenal-content in urine might be also important contribution to behaviour changes (Robert,1984)

Selye recognized that the cortisol is an adaptative hormone in facing the "stress", and it existed for a longer period, so it was with our case.

Emotional unstability with anxiety, depression, sleep disturbances was seen in our members. Cortisol and adrenaline might play some role in it together (Kendall, 1984), with the possible role of 5-HT metabolism changed in brain making us to partially realize such possible linkage. Because Trp is capable of penetrating into brain to synthesize 5-HT. The decrease of plasma Trp may lead to the decline of brain 5-HT, which might play a role in the express of depression syndrome (Hoes, 1982), especially in winter-over member. Urinary 5-HIAA decreased after winter may be explained.

If so, the intervention of L-Trp or supplement of related food might be valuable (milk and banana are rich in Trp) . The suitable blocker on the stress signal transduction pathway might valuable too.

The presence of cellular damage, proved by the results obtained from studies of MDA,SOD, β-glucuronidase (the damage of lysosome membrane led to the release of lysozume and the increase of β -glucuronidase) is convincing enough. Therefore, the protective measure on cold exposure or ultraviolet radiation or other stress should be considered and carefully controlled in order to avoid such events, and the routine intake of some anti-oxidant should be undertaken.

All results, although some are preliminary, even with some speculation, are enough to be utilized in explaining the possible relationship between the physiological and psychological responses of the members and their humoral changes.

Acknowledgments ---- Zhou Chaofeng, Xi Pingxiang, Jin Shuming, Zhang Hong, Duan Yanping were responsible to technique work.

Psychological changes of fifteen expedition members of Chinese Antarctic Research

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Eysenck Personality Questionaire (EPQ), Behavior Patttern Questionaire (BPQ) and Social Responses Questionaire (SRQ) were used to survey the psychological character changes on 20 members at Zhongshan Station in Antarctica in winter. Changes on memory by using visual memory span are also observed, In addition, the changes on their higher nervous activity flexiblilty are indirectly measured by drawing test. The questionaires yield the follow results: (1) No statistical significance was found in the score of three factions of EPQ, but significant changes happened in a few cases. (2) The score of EPQ of Type A had a tendency to drop. (3) Subjects had the tendency to turn to external control on their locus of control.

Being different from the members' subjective feelings, memory test showed no significant change. The flexibility of higher nervous system activity declined temporarily during polar nights, and returned rapidly to normal level after this period. In summary , the results of questionaires and tests prove to be helpful for winter members to be adapted to the Antarctic natural and social environment. It is the first time that mental activities of our winter members were tested. Relevant research is continuing.

Results

Table 1. Subscale scores of EPQ at different time-span*

Subscale	Dec.1990, Qingdao		Nov.1991, Zhongshan Sta.		Jun.1992, Tianjin	
	M	*SD*	*M*	*SD*	*M*	*SD*
P	4.933	1.948	4.266	2.048	3.800	1.948
E	12.733	4.106	12.000	4.016	11.666	3.517
N	8.933	4.711	8.200	5.268	7.800	4.805
L	15.333	3.259	14.400	3.611	16.066	3.714

* L: lie; *M*: mean; *SD*: standard deviation.

Results indicate that there is no significant difference among the subscale scores of P(psychosis), E (extrovert-introvert),N (neurosis) of EPQ (Table 1).

Table 2. Subscale scores of BPQ at different periods*

Subscale	Dec. 1990		Nov. 1991		Jun. 1992	
	M	*SD*	*M*	*SD*	*M*	*SD*
TH	13.066	4.986	12.466	4.133	12.800	4.888
CH	12.400	4.160	12.000	3.864	12.800	3.562
TH+CH	26.800	7.295	23.800	6.881	25.600	6.322
L	4.733	2.515	4.200	1.641	4.733	2.205

* TH: time hurry; CH: competence hostility.

Table 3. Changes on behavir type at different time-spans (number of subjects)

Time-span	Type A	Type B	Mid-type
Dec. 1990	3	2	10
Nov. 1991	0	3	12
June 1992	0	2	13

The result of BPQ (Table 2) showed no significant difference among the subscale scores at different time-spans. As Table 3 showed there were three subjects who changed their initial Type A character to Type B or mid-type after one year life in Antarctica. For Zhongshan Station it is mainly natural environment (polar nights) and harsh climate that lead to psychological pressure. Excessive Type A character was helpless to the research work and harmful to members security.

Table 4. Rating results of locus of control ($N=15$)

Number of subject	Dec. 1990 Qingdao	Nov. 1991 Zhongshan Station	June 1992 Tianjin
1	2	10	7
2	9	4	5
3	13	16	14
4	11	13	15
5	3	9	9
6	5	3	11
7	12	11	12
8	9	15	15
9	7	11	12
10	6	16	14
11	11	13	11
12	8	7	6
13	9	13	16
14	5	4	8
15	11	12	14
$M \pm SD$	8.07±3.214	11.13±3.667*	11.93±3.087**

* $t=-2.4360$, $p<0.05$. ** $t=-3.3609$, $p<0.01$. Comparing with the base value.

Results showed that winter members' LOC became higher than the base value after one year of Antarctic life ($p<0.05$) and the score kept on increasing even when they had been back to China. This suggested that members of the small group in the Antarctic tend to become more extrovert. Therefore they always attributed unfortunate events to the uncontrollable outer factors. This way of thinking may lower their mental stress and be helpful for them to get psychological balance. It was found that changes occurred on 2/3 of the subjects' LOC. It suggested that the extrovert is adapted better to the Antarctic environment to some extend.

Table 5. Number memory span of winter members

Time	Place	Maximum		Error time	
		M	SD	M	SD
Dec. 1990	Qingdao	7.666	1.920	3.133	0.805
March 1991	Zhongshan Station	8.000	1.505	3.600	1.083
July 1991	Zhongshan Station	8.200	1.514	3.666	1.192
Nov. 1991	Zhongshan Station	8.266	1.842	3.733	1.062
June 1992	Tianjin	8.266	2.048	3.400	1.440

According to our result (Table 5), the Antarctic expedition members' memory ability had no significant change ($p>0.05$).

Table 6. Flexibility test of high nervous system activities (number of subjects)

Time	Place	Flexible	Mid-level	Inflexible
Dec.1990	Qingdao	6	0	7
March 1991	Zhongshan Station	8	0	5
July 1991	Zhongshan Station	3	3	7
Nov. 1991	Zhongshan Station	9	1	3
June 1992	Tianjin	5	3	5

From the result (Table 6) we found that correct numbers drawn out decreased during polar nights and returned to orginal level, even increased, during polar days (comparing to that of December 1990).

Effect of the environment in Antarctica on immune function and electroencephalogram

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An observation on the changes of immune function (serum immunoglobulin, lymphocyte transformation) and electroencephalogram were carried out when the explores were residing in Antarctica for a long time.

Serum IgM, IgG decreased by the end of 12 months residing in Antarctica. It was only 40%;38%($p<0.01$) of the previous value before leaving Antarctica. Serum IgA increased first and then returned to its previous value before leaving Antarctica. When they returned back to Beijing for 2 months serum IgA was lower than that before leaving ($p<0.05$). Lymphocyte transformation rate decreased to 45% ($p<0.05$) of its previous level before leaving Antarctica. The low lymphocyte transformation rate lasted for 2 months after return. But the variation of Ig level and lymphocyte transformation rate were small in the control group at different seasons. It is obviously that the significant change of Ig level and lymphocyte transformation rate of explorers residing in Antarctica is the result of special environment.

The desynchronization process on electroencephalogram (EEG) increased. The frequency and index of β-wave band increased during their stay in Antarctica. There is close relationship between the decrease of lymphocyte transformation rate and the increase of the index and amplitude of β-band on EEG. It indicated that the decrease of immunity(especially cell mediated immunity) resulted from living under stress for a long time.

Results

Table 1. Comparison of serum immunoglobulin prior during and post residence in Antarctica between explorers and controls ($\bar{X} \pm SD$)

Immuno-globulin	Group	Before leaving Antarctica	Residing in Antarctica		Two months after return
			6 months	12 months	
IgM	explorers	178.0±86.3	156.0±63.4	106.0±72.9**	154.9±73.7
	controls	125.3±64.4	114.7±44.1		
IgG	explorers	112.7±18.3	142.9±24.1	70.2±27.4	118.6±28.7
	controls	114.2±32.1	99.3±27.3		
IgA	explorers	104.5±29.7	134.9±42.9*	117.8±42.8	89.1±47.6*
	controls	102.7±32.8	104.2±47.7		

* $p<0.05$. ** $p<0.01$. Explorers: $n=21$. Controls: $n=20$.

The results (Table 1) showed that the variation of Ig level and lymphocyte transformation rate was small in the control group at different seasons. It is obviously that the significant change of Ig levels and lymphocyte transformation rate of explorers residing in Antarctica is the result of special environment.

Table 2. T lymphocyte transformation rate (%) ($\bar{X} \pm SD$)

Group	Before leaving Antarctica	Residing in Antarctica		Two months after return
		6 months	12 months	
Explorers	66.95±11.0	47.88±23.4*	36.42±16.0*	34.76±14.7*
Controls	50.30±18.0	65.35±12.7		

* $p<0.05$. Explorers: $n=20$. Controls: $n=20$.

The lymphocyte transformation rate of the explorers residing in Antarctica decreased significantly ($p<0.05$) to 45% of its previous level before leaving Antarctica (Table 2). The low lymphocyte transformation rate lasted until 2 months after return.

The amplitude and index of α-bands on EEG were lower compared with those prior to residing in Antarctica

Table 3. The change of frequency, amplitude and index of α-band in EEG prior, during and post residing in Antarctica ($\bar{X} \pm SE$)

Time	Frequency (Hz)	Amplitude (μV)	Index (%)
Before leaving the Antarctica	10.12±0.8	32.18±11.2	69.60±24.8
Residence in Antarctica			
3 months	10.18±0.8	32.59±11.6	64.95±26.5
6 months	9.88±0.7	29.06±10.4	64.29±25.7
9 months	10.00±0.9	32.55±14.3	62.15±27.3
12 months	10.00±0.9	28.13±11.2	59.25±30.0
Two months after return	9.98±0.7	31.71±13.6	62.75±31.9

$n=23$.

(Table 3).

Table 4. The change of frequency, amplitude and index of β-band in EEG prior, during and post residing in Antarctica ($\bar{X} \pm SE$)

Time	Frequency (Hz)	Amplitude (μV)	Index (%)
Before leaving the antarctic	18.82±2.5	6.62±5.3	18.65±16.3
Residence in Antarctica			
3 months	20.50±2.3*	7.30±3.7	36.04±26.0**
6 months	20.35±2.3*	7.17±3.3	36.29±22.8**
9 months	20.35±2.2*	8.37±4.7	37.30±24.1**
12 months	20.62±1.5*	8.00±3.7	43.80±28.0**
Two months after return	19.80±1.8	7.12±2.9	30.30±23.4

Compared with the value before leaving the Antarctica. * $p<0.05$. ** $p<0.01$. $n=23$.

The frequency, the amplitude and index of β-bands were in a tendency to increase slightly (Table 4). These indicated that the dissimilation of electric activity in higher nervous system, and stress on higher nervous system increased.

The results in Table 5 showed that no microorganism could be found from the samples collected in winter (June) time outside the station when they were incubated under 37℃ in medium. Only a few microorganisms were found in summer (December) from where 100 m away from the station.

Table 5. Microorganisms (37 ℃) found at the Zhongshan Station in Antarctica (CFU/m^3)

Places	Date	Morning	Evening	$\bar{X}$
Bed room	June	648.69	707.67	
	Dec.	629.04	78.63	516.09
Sports room	June	117.95	235.89	
	Dec.	209.94	249.26	203.26
Power station	June	156.26	204.41	
	Dec.	141.53	94.36	149.39
Dining room	June	100.85	283.07	
	Dec.	13.37	249.26	161.63
Television room	June	65.26	293.15	
	Dec.	62.96	172.99	137.34
100 m away from the station	June	0	0	
	Dec.	26.72	40.02	15.68

Table 6. Germs isolated from indoor and outdoor air of Zhongshan Station

Sampling number	Germs		
Indoor 4	staphylococus	xylstalphylococcus	nonpathogen
Indoor 5	staphylococus	xylstaphylococcus	nonpathogen
Indoor 7	staphylococus	xylstaphylococcus	nonpathogen
Indoor 10	streptococcus	Streptococcus	Dubious pathogen
Outdoor 12	·Bacilli		

It is obviously that the microorganisms found in rooms were broughrt from the original living places where they used to live, and the microorganisms found around the residence were contaminated questionable pathogenic microorganisms (Table 6)

Discussion

The immune function of most explorers decreased after residing in Antarctica and recovered when they returned back. It is considered that the decrease of immunity was originated from lacking stimulamtion from exterior antigens. In the winter time, the number of task force members was much less, the extend of activity was more limited (only in house). They suffered polar night. The mental and psychological stress was much heavier. These could be observed and identified from the rusults of EEG. There was a relationship between the increase of index of β-band and the decrease of lymphocyte transformation (see Fig.1)

The effexct of stress lasting for a long period of time on the activity of higher nervous system may lead to increase β-endorphin (Ni, 1993), depress T lymphocyte proliferation and depress B lymphocyte function. Therefore, the IgG and IgM also decreased correspondingly.

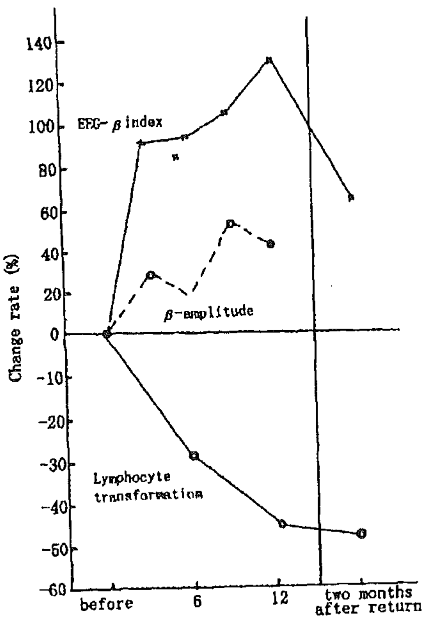

Fig. 1. Lymphocyte transformation and EEG index of β-bands.

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THE SOURCES OF DISCOMFORT IN THE ITALIAN ANTARCTIC EXPEDITIONS

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Introduction

Antarctica is the continent of extremes. It is the coldest, the highest, the windiest, the most arid, the most desert, the less explored of the planet (Manzoni, 1989). These general conditions, so unfavourable for the survival of living beings, make the Antarctic environment one of the most hostile places on earth. Without an adequate protection a human being could survive only for a very short time. Permanent human settlements are a remarkable achievement of science and technology that have provided a defence against such an harsh climate. But the protection, starting from clothing, is often not comfortable, not practical for performing even simple task and may quickly generate fatigue. The habitat is designed to assure survival, not to be comfortable. Living quarters may be noisy because of proximity of power plant. Temperature and humidity may be difficult to control and limited air circulation could make the air smelly. There are no temporal cues (light-darkness) that help to regulate behaviour. Life depends on the integrity of the building (fire risk), on the correct operation of equipment, on availability of appropriate medical treatment. Problems in any of these aspects may easily generate a feeling of being in danger, even assuming that danger was not already present. Such harsh living conditions can lead to an excessive concentration of attention on the limited sources of satisfaction such as food. But the availability of fresh food and ingredients is usually limited, entailing a lowering of the quality. Together with these "environmental" limitations other constraints exist, due not only to isolation and confinement, but also due to organisational reasons (Lantis, 1968; Palinkas, 1986).

Therefore it is not surprising that in this operational context one can find many sources of stress and of discomfort for members of Antarctic expeditions. The problem of the "stressors" (sources of stress) in the Antarctic expeditions has been analysed several years ago in a research done on Australian (Godwin, 1986) and French personnel (Cazes & Bachelard, 1998). This one is a central theme of human adaptation to extreme environments. It is related to the several acute or chronic symptoms observed in the expeditioners during wintering over in Antarctica. These symptoms have been grouped and described as "Syndrome mental d'hivernage" by Rivolier since 1954 (Rivolier, 1989). The studies which have been quoted refer to wintering overs; these obviously present very different conditions, presumably more difficult than a summer Antarctic campaign.

Therefore we decided to perform an investigation with the aim of:

- Identifying possible sources of stress or of discomfort (stressors) in the Italian Antarctic expeditions (duration 4 months in austral summer)
- Comparing the subjective and group evaluation of stressors, in order to verify a possible coincidence of evaluation
- Obtaining preliminary indications on the relative management mechanisms.

Methodology

Investigation Tools

A questionnaire with 53 possible sources of discomfort from international literature has been prepared (Godwin, 1986; Gunderson, 1974; Lugg, 1977; Rivolier, 1992; Taylor, 1987). Source of discomfort has been described as "something that worries you, that generates irritation, uneasiness, bad feeling or that you had difficulty to cope with or to manage during your Antarctic stay". The participants were requested to evaluate the intensity of the sources of discomfort at a personal level (P), according to the following scale.

Source of no discomfort = 1

Source of little discomfort = 2

Source of moderate discomfort = 3

Source of remarkable discomfort = 4

Source of extreme discomfort = 5

Every subject was also asked to evaluate the intensity of the sources of discomfort in the other members of the expedition, that is the group (G), using the same questionnaire and the same answer parameters.

Furthermore the participants were requested to indicate to what extent and with which frequency they used the following ways of coping (Carver, Scheier, Weintraub, 1989) and how effective they were:

1. To refuse to think it over and try to forget
2. To plan and perform series of corrective actions
3. Self blame for being the cause of the problem
4. To accept the situation
5. To reconsider the situation in a positive way
6. To imagine a different and better situation

7. To seek advice and help
8. Other

The evaluations reported in the next table were used:

Intensity	Frequency	Effectiveness
1 = not at all	A = never	1 = not at all
2 = a little	B = seldom	2 = a little
3 = enough	C = sometime	3 = enough
4 = much	D = often	4 = much
5 = very much	E = always	5 = very much

Tab. 1

The sample

The questionnaire was administered to a group of participants in the XII Italian National Antarctic Expedition. Some biographical elements of the sample of 95 subjects are in Table 2.

Sex	M	76
	F	19
Average age	38 (range 27 – 64)	
Education	Elementary school	12
	High school	12
	Diploma	10
	University degree	61
Marital status	Not married	35
	Married	52
	Separated	8
Job	Researcher	50
	Administrative	14
	Technician	16
	Laboratory technician	4
	Military personnel	14
	Medical doctor	1

Tab. 2

Results

Presentation and comment

In Table 3 means (*M*) and standard deviation (*sd*) of evaluations of intensity of the sources of discomfort at a personal and group level, the difference of means, the Student's t and the significance of difference are reported, as in the legenda.

	M		*sd*		m	t	p
	P	**G**	**P**	**G**			
1.Limitation of personal privacy (lack of privacy)	1.88	1.95	0.93	1.05	0.063	0.52	0.607
2. Feeling of isolation (from Italy)	1.49	1.92	0.78	1.08	0.42	3.33	0.001
3. Planning for my work area	1.43	1.86	0.81	1.03	0.43	3.38	0.001
4. Lack of training and of work experience	1.37	1.45	0.68	0.97	0.08	0.73	0.468

5. Obligation to respect rules and regulations	1.41	1.69	0.66	1.04	0.28	2.64	0.010
6. Being responsible for my work	1.39	1.26	0.75	0.75	-0.12	-1.22	0.227
7. Unclear definition of my work tasks	1.39	1.61	0.72	1.05	0.22	1.89	0.062
8. Need to adapt to an extreme climate	1.19	1.35	0.44	0.75	0.15	1.73	0.087
9. Need to work under control	1.24	1.53	0.50	0.92	0.28	3.02	0.003
10. Boredom	1.37	1.57	0.73	0.96	0.20	2.05	0.043
11. The feeling that some work or task is easier	1.12	1.52	0.38	1.01	0.40	3.84	0.000
12. Being unable to easily leave the station	1.38	1.60	0.77	1.00	0.22	1.94	0.056
13. Possibility of being cause of a serious accident	1.54	1.64	1.12	1.25	0.10	0.99	0.325
14. Danger of fire	1.40	1.43	0.89	1.10	0.03	0.36	0.716
15.Feeling one's life in danger	1.42	1.62	0.81	1.10	0.20	1.83	0.071
16. Frequent movements to and from station	1.18	1.38	0.58	0.84	0.20	1.88	0.063
17. Limitation to movement around station	1.57	1.61	0.85	0.93	0.04	0.38	0.708
18. Need to adjust one's activity to meteo conditions	1.33	1.46	0.57	0.91	0.13	1.35	0.179
19. Discrepancy between one's interest and one's tasks	1.47	1.80	0.74	2.30	0.32	1.30	0.198
20. Need to adapt one's behaviour to other's	1.40	1.64	0.63	0.97	0.24	2.09	0.039
21. Need to cope with "strange" or "abnormal" behaviour	1.72	1.47	1.71	0.84	-0.24	-1.28	0.204
22. Impossibility of doing things "in my own way"	1.60	1.75	0.72	1.02	0.14	1.29	0.199
23. Need to smooth down differences of opinion	1.57	1.64	0.78	0.93	0.87	0.57	0.569
24. Lack of sexual relationships	2.09	2.31	0.92	1.25	0.21	1.55	0.126
25. Separation from the loved ones (family, friends)	2.26	2.27	1.01	1.21	0.01	0.08	0.935
26. Being unable to get along with others	1.62	1.76	0.88	1.05	0.13	1.10	0.272
27. Feeling that others do not accept or appreciate oneself	1.49	1.72	0.80	1.09	0.22	1.73	0.088
28. Being unable to deal with problems left at home	1.69	1.72	0.79	0.95	0.02	0.20	0.843
29. Afterthoughts about the decision to take a part in the expedition	1.06	1.25	0.32	0.79	0.18	2.10	0.038
30. My level of physical form	1.48	1.44	0.80	0.85	-0.04	-0.41	0.685
31. Nor-existing or insufficient "personal" recreation spaces	1.74	1.84	0.91	1.09	0.10	0.80	0.423
32. Building yard life, rather than scientific research life	1.48	1.73	0.70	1.10	0.24	1.82	0.071
33. Difficult communication with Italy	1.86	2.00	1:03	1.26	0:13	1.18	0.239
34. Feeling that one's work is not adequately recognised	1.28	1.61	0.66	1.01	0.32	2.93	0.004
35. Too much control on petty matters	1.59	1.62	0.97	1.07	0.03	0.26	0.796
36. Shortages in the general equipment	1.53	1.52	0.94	0.99	-0.01	-0.10	0.923
37. Shortages in clothing	1.65	1.61	0.92	1.05	-0.04	-0.44	0.661
38. Shortages in quality, quantity and preparation of food	1.40	1.33	0.74	0.90	-0.07	-0.84	0.402
39. Shortage information on the goals of the expedition	1.45	1.43	0.98	0.96	-0.02	-0.15	0.881
40. Inadequacy of the means for my work	1.57	1.56	0.82	0.93	-0.01	-0.09	0.929
41. Work made difficult by problems in other sectors	1.41	1.57	0.72	0.96	0.15	1.38	0.170
42. Inadequacy of resting rooms	1.64	1.76	0.78	1.10	0.11	0.89	0.337
43. Unloading/Reloading of the ship	1.32	1.64	0.55	1.05	0.32	3.17	0.002
44. Psychological tests	1.62	1.76	0.96	1.21	0.13	1.34	0.184
45. Travel to Antarctica and back by air or by sea	1.64	1.81	0.93	1.07	0.16	1.54	0.128
46. Bad weather periods	1.44	1.60	0.77	0.94	0.15	1.36	0.178
47. Continuous sunlight	1.32	1.51	0.70	0.86	0.18	1.75	0.083

48. Lack of time for other interests	1.59	1.73	0.79	1.06	0.13	1.26	0.211
49. Division in sub-groups (Researchers, ENEA, Military)	1.39	1.45	0.75	0.90	0.06	0.51	0.612
50. Disappointment about the expedition	1.36	1.41	0.77	0.95	0.05	0.46	0.649
51. Noise and disturbances during rest periods	1.59	1.74	0.83	1.01	0.14	1.27	0.207
52. Unavailability of really close person to whom to speak in difficult moments	1.66	1.64	0.87	0.94	-0.21	-0.18	0.860
53. Live and work always with the same people.	1.24	1.82	0.52	3.09	0.57	1.79	0.076

Tab. 3

Legenda:
P = personal
G = group
m = difference between means
t = Student t
p = significance

The analysis of the average values of the responses to the items does not reveal important discomforts. The average responses are around little or "no discomfort", in the personal as well as in the group. In 83% of the items (44 on 53) the state of discomfort attributed to others is higher than that attributed to self, being statistically meaningful in 10 items (No 2, 3, 5, 9, 10, 11, 20, 29, 34, 43) on 53 (19% of cases)

In the responses prevail discomfort for emotional isolation (No 25, 33) and confinement with a consequent limitation of privacy and of personal spaces. Surprising and meaningful is the modest importance given to stressors of a physical – environmental type. The source of discomfort attributed to the group repeat in a slightly amplified way the personal ones and repeat the themes of isolation and confinement. Some sources of discomfort seem to have practically no negative effects at a personal level: as for instance the frequent transfers to and from the station (No 16, $M = 1.18$), adaptation to extreme climates (No 18, $M = 1.14$).

The extent to and the frequency with which some ways of coping with the Antarctic discomforts are used by expeditioners and their effectiveness, are listed in the next table.

		Intensity of use	**Frequency of use**	**Effectiveness**
Way 1 *To refuse to think it over and try to forget*	Mean	1.56	2.11	2.61
	sd	.93	1.28	1.13
Way 2 *To plan and perform series of corrective actions*	Mean	2.63	2.82	2.89
	sd	1.27	1.42	1.18
Way 3 *Self blame for being the cause of the problem*	Mean	1.49	1.64	1.91
	sd	.88	1.15	1.19
Way 4 *To accept the situation*	Mean	2.9	3.25	3.20
	sd	1.22	1.27	1.17
Way 5 *To reconsider the situation in a positive way*	Mean	2.78	3.10	3.23

	sd	1.19	1.31	1.20
Way 6 *To imagine a different and better situation*	Mean	1.93	2.32	2.36
	sd	1.24	1.17	1.25
Way 7 *To seek advice and help*	Mean	2.26	2.32	2.61
	sd	1.13	1.17	1.26

Tab. 4

Discussion

All sources of discomfort included in the questionnaire, with no exception, have represented, at least for a part of the expedition members, a cause of annoyance. Taking into consideration the individual and group average responses the amount of stressful agents for each individual does not appear to be very high. The variety of possible stressors is however quite large and it is determined on the basis of different subjective criteria also in a very little stimulating and rather undifferentiated environment like that of Antarctic expeditions. This appears to reaffirm the importance of individual characteristics in the perception of distress also vis-à-vis the strong and marked environmental characteristics. However, beside the individual differentiation, it is possible to observe convergence of opinion on a number of sources of distress shared by most members of the group (separation from the loved ones, lack of sexual relationships, lack of privacy, isolation, communication with Italy). In reality the most intense stress experienced at individual level belong more to the affective-relational area rather than to the physical-environmental one. Also the observation of the behaviour of other expeditioners, which should be less influenced by subjective factors, shows that affective-relational stresses, connected with isolation and with confinement (separation from loved ones, difficulties in communication, lack of privacy), are considered the most serious. This is not surprising, also considering that several articles published from 1960 onwards (Lantis, 1968; Palinkas, 1986) about Antarctic bases personnel arrive at the conclusion that psychosocial stresses are more reported than physical stresses in the Antarctic operational context.

From the results the intensity of the discomfort produced by stressful agents turns out to be moderate. Possibly this determines a not very harmful effect of the stressors. The factors of discomfort can also represent a challenge which can generate some very creative personal solutions and make the Antarctic experience very special and desirable.

A moderate level of discomfort intensity should be interpreted not only in the perspective of the remarkable material resources available in the Italian expeditions (transportation, accommodation, food, clothing, all more than adequate), but also of the individual resources, assessed with a severe selection and supported by a good training. The latter also helps in developing an appropriate socio-emotional support from the group, if necessary. The relationship between the individual and the other members of the expedition in the perception of intensity of stressors indicates the almost systematic higher intensity of discomfort perceived for others compared to that assessed for self. This has been confirmed in other studies performed on Italian personnel (Peri, Barbarito, Di Blasio, Izzo, Nisi, in press; Peri & Ruffini, 1999). This phenomenon in the specific area of stressors could be interpreted in two possible different ways:

1. a projective mechanism that allows the identification of discomfort only in others
2. a more or less conscious attempt to keep at a high level one's own self-esteem, in particular with respect to others (Natani & Shurley, 1973).

The most intensely used ways of managing discomfort correspond both to the most frequently used and to those evaluated as the most effective and vice versa.

An extreme, unpredictable, not easily controlled environment like Antarctica leaves little leeway for programming and implementing corrective actions or for an active approach focused on the problem, approach which is usually less productive that an approach focused on individual.

Indeed, the acceptance of a not easily modifiable situation can represent an unavoidable first step for a good adjustment. To reconsider the situation in positive terms appears to represent a later stage of the adaptation process, centred on the modification of the person. A cognitive restructuring of the situation in positive terms is a particularly valid form of coping in an environment that a single individual cannot influence to a meaningful extent (Carver, et al., 1989; Scheier, Weintraub & Carver, 1986). In a context where survival is often related to mutual support it is surprising that scant use is made of looking for social support which is one of the most effective ways of coping with stress (Cohen & Wills, 1985; Wilcox, 1981). Perhaps the above mentioned approach has been seldom used because the stressors were modest and could be solved at an individual level. Accepting a situation does not mean denying it. This latter way of coping is seldom used and is of limited value. The effectiveness, even if low, given to the escape through fantasy, to detaching oneself from reality, is probably referred to the initial stages of discomfort. In these stages it is used as temporary way of dealing with difficulties.

In absolute terms self-blame is the least used strategy and it is deemed to be the least valid in discomfort situations.

Conclusion

We can say that the sources of discomfort in the Italian Antarctic expeditions are quite large and determined on the basis of different subjective criteria. Some of them, like separation from loved ones, lack of privacy, etc., that we defined affective-relational, represent the most common, the most shared. The intensity of discomfort is assessed low in the subjects themselves and almost always lower then in the other members of expedition who are the subjects themselves. This is a sort of "perceptive distortion" probably used to support individual self-esteem.

The ways of coping most used to deal with the Antarctic discomfort are characterized the approach focused on the modification of person, like to accept, to reconsider the situation in positive terms, more than on active approach on the environment. This is not surprising considering that Antarctica is an extreme environment very difficult to control.

The results of this work can have both a theoretical and a practical value for the leaders of Italian expeditions. Using these results they can act in order to reduce identified problems or take into consideration the information for the best management of personnel and for preventing stress fatigue and the other possible problems.

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Logistics of an Antarctic Research Station
The Italian Terra Nova Bay Station

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ITALIAN ANTARCTIC RESEARCH

Since 1985 the Italian National Programme of Antarctic Research (PNRA) has performed 15 Expeditions in Antarctica during austral summer and leaving in operation an automatic platform (PAT) for data collection during winter. From then on Terra Nova Bay Station (TNB) has been the hub of all PNRA activities in Antarctica, both on sites around the Station itself and on remote sites up to 1200 km, the distance from TNB to Dome C, site for the EPICA drilling and the construction Camp for the Italian-French Concordia Station.

With respect to the first five years of the Programme when TNB was reached only by ship the increasing broadening of the research activities and the resulting need to extend the length of the Expeditions during the austral summer has made necessary the use of air transport. This both for an early operational opening of the TNB Station after the long winter shutdown and for the start of research activities.

The planning of Antarctic research activities requires a continuous careful effort over the whole year. The operational details, the needs of the various research groups, the definition of the research sites require a careful analysis by expert personnel. This allows the optimum sharing of the available resources, keeping in mind the rapid changes occurring in Antarctica. The use of aircraft for intercontinental transfer together with the close co-operation with NSF/USA allows a very high speed of transfer of personnel both in normal operation and in emergency such as MEDEVAC actions.

At present with the combination of air and sea transport the Italian Antarctic Expedition covers about four months from mid-October to mid-February. In general the Antarctic Campaign implies three separate research periods at TNB, with changes in the research and logistic teams, one period at Dome C and one on the oceanographic vessel. PNRA usually charters the following:

- one C-130 Hercules of the IAF, the Italian Air Force, (Oct.20th to Dec. 4th);
- the "Italica" oceanographic/cargo vessel (Jan.5th to Feb. 28th);
- one "Twin Otter" light transport aircraft (Nov 3rd to Feb. 11th);
- two helicopters (Oct 16th to Feb. 16th).

The PNRA has an office with the task of being the logistic terminal at the International Antarctic centre in Christchurch (CHCH) NZ. ENEA personnel man the office during the initial stages of each Expedition.
The main tasks are: manage the contacts with all the organisations with which there is a necessary interaction, support technical, scientific and logistic personnel of the PNRA in transit to and from Antarctica, arrange hotel accommodation for above mentioned personnel purchase locally available material when necessary.

THE OPENING OF THE TERRA NOVA BAY STATION

The Italian research Station is located on a small peninsula between the Drigalsky and the Campbell glaciers tongues, along the coast of the Northern Foothills. Normally it is opened around mid-October when a team of 20 technical personnel fly to Antarctica on a USA/NSF C-130 or C-141 flight from CHCH to Mc Murdo (McM) and by USA/NSF helicopters from there to TNB. TNB

Station is made up by a central building assembled with ISO 20 containers and by other smaller buildings.

In the central building are located:
Control Room, offices, laboratories, surgery, personnel accommodation, kitchen and dining room, service areas.
In the smaller buildings are installed:
electric generators, desalting plant for freshwater production, incinerator, sewage treatment plant, hangars for vehicles and stores.

TNB Station has a "Station Emergency Plan" which identifies the organisation of the operational structure that shall act in case of possible accidents. It also identifies the measure to take in such occurrences.

When personnel arrive at TNB they start the operation of
- electric generators,
- fuel pump for helicopter refuelling,
- heating plant, seawater intake,
- telecommunication equipment,
- desalting plant for freshwater production,
- snow removal equipment,
- aquarium
- kitchen and dining room,
- modular auxiliary road for the unloading area.

After the start of the operations of the first helicopter the telecommunication specialists puts into operation the following Antarcom services:
- INMARSAT equipment,
- radiolinks. Mt Melbourne and Mt Abbott,
- radio-telephone link Scott Base Telephone System,
- radio Station HF Radio room and Control Room,
- high speed data service (64 kbs) for e-mail and Internet,
- telephone switch board

After completing all the previous tasks attention is focused on the preparation of the sea ice runway for C-130 operations. This runway is on the Tethys Bay sea ice and this implies the need of a new preparation each year and a limited time of use during austral summer. The sea ice runway is open for air traffic, both on wheels and skis from about the 23rd of October until the first few days of December, when the rise in ice temperature and the decrease in its hardness and thickness impose the closure of operations on sea ice.
A first survey of the sea ice is performed from the helicopter in order to verify the absence of important cracks and fracture areas. After this survey markers are located at the ends of the runway. Then, following the runway axis on a skidoo the thickness of ice and its temperature are measured. Typical thickness values in October are more than 220-230 cm. At this stage it is also verified that there are no breaks or major steps in the ice surface. This would imply moving to another part of the ice area. After having decided that the selected runway location is good, the preparation of the runway, proceeds requiring 5/6 days on average.

To understand the big impact of air operations on Station activities it is enough to consider that of the 45 logistic personnel in Base 28 (60%) are involved with the assistance for the aircraft at its arrival or departure. During an Expedition with 11 return flights the total use of fuel is about 440.000 l of Jet A1, 150.000 l, 34%, are taken at TNB.

To host aircrews a building, called "Foresteria", has been prepared. It has 5 rooms, 4 beds each, it is located away from the Base and from noisy activities in order to ensure high level of comfort.

THE CONTROL ROOM

The TNB Control Room is the centre of all activities, both logistic and scientific. The personnel working in the Control Room, under the direct responsibility of and in close co-operation with the Expedition leader, is Italian Air Force personnel. The reason for this is they must have a high level of experience in air operations. In general two of them are pilots (radio operators) and two are meteorological officers. They are able, as a team, to operate continuously around the clock.
The Control Room gives assistance to the following:

- helicopters operating from TNB,
- Italian Air Force C-130 of the 46th Air Brigade in the return flights CHCH/TNB and CHCH/McM/TNB,
- Twin Otter,
- Traverses,
- Remote camps,
- all logistic and scientific personnel of the Base.

Activity co-ordination is done in weekly meetings where a weekly reference program is defined. From the weekly program daily activity programs are derived. Each morning at 7 a meeting is held to verify if weather condition permit implementation of the program. If not alternative missions are prepared.
At TNB is enforced a pre-air accident plan. When "Air Emergency" or "Air Incident" is declared personnel will do what is indicated in the before-mentioned plan.

THE WEATHER SUPPORT

The daily production of meteorological messages concerns:

- preparation and storage of the SYNOP and TEMP messages
- preparation of meteorological messages METAR, SPECI and TAF
- broadcast of the Daily Meteorological Bulletin in Italian and English, with forecast for the operational area, valid for the reference day and tendency for the next 24 hours, with a table with the extreme values of meteorological parameters of the previous day;
- updated meteorological report with an appendix on horizon definition and trend or evolution of phenomena (METAR-TAF up to 18 hours)
- forecast for the next 72 hours
- weather map of Victoria Land from GND to FL 300
- wind and temperatures at height measured by two radio-sonde measurements per day (00.00 and 12.00GMT), plus forecast
- safety warnings for approaching events such as turbulence and windshear reported by other aircraft in the area.

The TNB runway does not have an Instrumental Landing System (ILS). Therefore for the flight activities of the C-130 it is required that weather conditions are CAVOK, with cross wind speed not higher than 10 kn. At the same time landing conditions at McMurdo shall be good according to the minimum weather conditions established in the operational plan of the IAF C-130. All this implies continuos, 24 H, monitoring of weather conditions by the two meteorologists present in each Antarctic Expedition
The meteorological officers at TNB are always in contact with the McWeather at McMurdo for a continuous forecast update, considering the great importance that meteorological analysis has

during the programming and the implementation of flights. It is envisaged that in the future this co-operation shall produce joint weather forecast bulletins.

FLIGHTS OF THE IAF C-130

In order to perform flight activity between New Zealand and Antarctica it is mandatory to have in operation the Search and Rescue -SAR- procedure. This ensures the cover of the flight area with a second aircraft of the same type of those in the air. This SAR aircraft is ready to take off in emergency and it has on board emergency equipment. From CHCH down to the 60° parallel the CHCH airport performs the SAR. From the 60° onwards the McM Station does it. As a consequence the opening time of TNB Station is tied up with the re-start of air operations at McM.

Before planning any flight activity with TNB it is necessary to ask prior authorisation to the TNB Control Room which releases a GO-NO GO message according to circumstances. According to the procedure the Expedition leader, in consultation with the person responsible for operations and safety prepares and sends to the commander of the C-130 at CHCH a message on the operational conditions of the TNB airstrip, the assistance and rescue service there and the meteorological conditions and forecast.

The C-130 used by the PNRA has a wheeled landing gear; this is a limitation in its deployment in terms of sites where it can land, but the absence of skis and the absence of the structure of the ski landing gear makes it lighter and this almost doubles its cargo carrying capability.

The use of the aircraft allows the start of operations in the Italian Base from mid-October, when the ice cover in the Ross Sea is still such that the use of vessels is not possible. Usually the first C-130 flight is around October 23-24. The sea ice runway is kept under constant control: the ice thickness is checked to verify that it can support the maximum take off weight of the aircraft (70 t/155.000 lbs) transferred through the wheels footprints; in this case nomograms are used which define the maximum load that can be transferred to the ice in function of the local parameters (ice temperature and thickness).

To perform loading/unloading operations with engines the Auxiliary Ground Equipment (AGE) is needed: it mainly consists of a compressor, an electric generator, a heater, a type B-5A step ladder. In the XV Italian Antarctic Expedition the C-130 of the IAF has performed 11 return mission from CHCH to Antarctica and back. Four of these missions have been performed for the NSF/USAP with personnel and cargo, as detailed in the following table:

ROUTE	PAX	CARGO (lb)	FUEL (lt)	Flight Hours
SOUTHBOUND	145	172.277	223.460	
NORTHBOUND	60	23.150	206.935	
TOTAL	**205**	**195.427**	**430.395**	**150.3**

(average flight time for each leg 6.8 hrs and average fuel consumption 2865 l/hour)

The spare parts for the IAF C-130 used by the Expedition are brought from Italy to Christchurch partly on the plane itself and partly in containers shipped to N.Z. on commercial courier.
This in order to be able to perform ordinary and exceptional maintenance on the basis of statistic data collected in the last years including the possibility of installing a new engine and propeller. In case of unavailability of parts and for using a hangar for important repairs there are agreements with the Royal New Zealand Air Force (RNZAF) and the Air New Zealand (ANZ).

Usually the last C-130 flight is in the first days of December (about Dec 4th) and marks the end of the first period of research at TNB and the beginning of the second. This last flight ensures the turnover of the mainly scientific personnel and the return of scientific samples and of part of the science instrumentation.

THE TWIN OTTER

The Twin Otter and the helicopters are an indispensable complement to the C-130 for short distances and for reaching remote sites far from the coast.
The use of fixed wing and rotary wing aircraft gives the possibility to researchers to perform unique research work. It is furthermore possible to quickly intervene to give assistance in emergency situations regarding even other Bases.

The T.O. during its service in Antarctica uses three landing strips. The first is 900m long and 20m wide and is near the quay. It is used during the first period of Station operation; later the sea ice runway prepared in Tethys Bay for the C-130 is used after the C-130 has completed its activity. Around the 10-12 of January the sea ice runway is no more safe enough because of ice starting to fracture. Then until the 10-11 of February, the end of the charter period, the Browning Pass airstrip is used.

In order to exploit to the maximum possible degree the aircraft in the period between the start of the operations at Dome C (around the 15th of Nov.) to the first days of December, two flight crews are used. In this way with crew rotation it is possible to fly continuously go/return from TNB to Dome C with the shortest stay on land for loading, unloading and refuelling. After the full operational opening of Dome C only one crew is used until the first few days of February when the shut down of the Camp is approaching (about 8 of Feb.), the system of two crew and two aircraft, the second being a T.O. based at McMurdo with NSF/USA.
Before the arrival at TNB of the personnel in transit for Dome C (7-15 Nov) the T.O. is used for the preparation of intermediate camps along the routes TNB-Dome C (mid Point 1) and TNB-DdU (C3 Point). The latter was prepared last year to support the flights to DdU for the transport of personnel leaving Antarctica through DdU with the Astrolabe ship; at C3 Point there is a tent, a skidoo, fuel and food for short stops in case of bad weather.

A number of intermediate landing areas with fuel reserves and tents for up to 8 people are located along the routes between Dome C, DdU at about 1200 Km from TNB. This permits to optimise the use of the T.O. in terms of load carrying capability because dividing the route in two halves with refuelling capability in the centre. Furthermore the mid-way refuelling reduces the amount of fuel to pick up at Dome C where the fuel and other supplies are taken by ice traverses from Dumont d'Urville.

On top of missions for transport of personnel and cargo the T.O. is used for scientific activities (radar surveys of the Vostok lake last year) and recovery of waste material from remote camps.
In the XV Expedition the T.O. has performed 60 mission for a total 751 hours flight time

THE HELICOPTERS

Helicopters support is at present given by Helicopters New Zealand Ltd with two AS350BA Squirrel. In the last seasons, the XV, they have flown a total of 795 hours. Having three pilots in Base it is possible use two of them for twelve hours and the third available for evening operation until midnight. In this way it is possible to have helicopter support both for science and logistics. Helicopters are used to carry researchers to their work sites, to transport materials and cargo, oil

drums to replenish existing dumps. Helicopters support to Station activities goes from assistance to the arrivals and departures of the C-130, the laying down of electric and telephone cables, maintenance of radio repeaters, support to loading activities of T.O. from the Browning Pass runway. When flights are longer than 100 miles helicopters fly in pairs in order to ensure mutual support in case of emergencies.
Since the 1997/98 the two AS350BA Squirrel helicopters normally used by PNRA for short range movements are left in hangar at TNB for the entire winter.

This solution has a number of advantages such as:
- availability of the first helicopter two days after opening of the Base;
- possibility of using for different purpose one C-130 flight previously needed to transport two helicopters from N-Z. to Antarctica. Considering that the charter of the two helicopters for the winter months is lower than the cost of one C-130 flight this allows a saving in money and time.

OCEANOGRAPHIC CARGO VESSEL ITALICA

Considering the high cost of using more than one ship for the different tasks in an Expedition, cargo/passenger transport/oceanographic research/fuel transport, since 1994 the PNRA uses only one vessel, the "Italica", which has been modified in order to increase her operational and functional capabilities for oceanographic research and for logistic support of the TNB Station.
At present the vessel is a valid support for the PNRA in the following:
- personnel transport up to 93 persons,
- transport of materials, equipment, supplies,
- fuel transport (800 cubic meters of Jet A1, plus other drummed fuel),
- Oceanographic activities in the Ross Sea.

Due to the fact that the opening of the Base is done with the support of the C-130, which is available until the first days of December, the ship can be used in the period when the Ross Sea is free from ice.
Using the Italica as it is now, it is possible to perform operations that before needed the support of NSF/USA such as the refuelling of the Base for which an icebreaker and a tanker were needed.

The unloading of the ship is conditioned mainly by meteorological and sea conditions, by the presence of ice and by its cover. According to this unloading can be accomplished or on ice or on water by lighter. During unloading it is always necessary a close co-operation between the logistic specialists of the Base and of the ship, in order to define: how to unload, how many containers and how much loose material to unload, an unloading plan, equipment available (pisten bully, tractors, lorries, sled trailers, wheeled trailers, cranes etc.), personnel organisation, Control Room personnel for ship/shore radio links, support/assistance personnel.

Unloading operations are under the responsibility of a person designated by the Expedition Leader with whom possible plan modifications are discussed and agreed. A planning meeting is convened before start of unloading. All personnel working in the unloading operation is in radio contact and the Control Room follows the whole operation.
To unload on ice it is necessary that near the Station the thickness is equal or more than 1.5 meters to make possible the mooring of the ship and the unloading of material on vehicles close to the ship.
Before the arrival of the ship a survey is done to determine: ice state and its extent (best situation is when there is a front of thick ice in proximity of the Station), ice condition along the route between the mooring point and the Station, in order to identify the best track, need to use the modular metallic roadway to pass over fractured or less resistant areas, possibility of mooring the ship closer to the Station by breaking the ice or by using existing deep fractures.

The results of this survey are submitted to the people responsible for the operation to co-ordinate subsequent actions and prepare areas for temporary storage of unloaded material and for positioning of vehicles and equipment like cranes. If the unloading operation goes on without interruptions an appropriate number of people has to be foreseen synchronising the time of change of the teams with the schedule of meals and providing food and hot drinks service during the activities.
The unloading at sea is more complex, is influenced by marine and weather condition and is performed when ice conditions are bad for doing otherwise. The unloading operation is performed by unloading on the lighter, which then takes the material to the quay where the crane transfers the loads to the vehicles.

As mentioned above TNB has three 600.000 l fuel tanks. When the ship is about to arrive fuel lines are positioned to reduce the time of fuel transfer from ship to shore tanks. This operation requires about 10-12 hours. In case of catabatic wind it is necessary to stop the transfer very quickly, removing the fuel lines.
There is an emergency plan, the Oil Spill Plan that is put in action to prevent and contain oil spills and this plan is active during this operation.

TNB Station is normally shut down around Feb. 20th. The ship is used for retrograde waste material for disposal, for carrying scientific material and samples and for taking back all personnel. The ship is fully loaded on the way back and often on the navigation towards Lyttelton last oceanographic activities are performed, using all possible time on the ship and the good weather, if there is good.

Conclusions

From what has been said one can see that the Italian Station at TNB is the main hub of all the research activities performed in Antarctica by the PNRA. In fact from TNB all the activities on remote camps, at Dome C at 1200km on the Plateau and oceanographic activities are co-ordinated and managed.
The Control Room controls all flight activities and authorises the flights of the C-130, of the T.O., of the helicopters. It also manages possible emergency situations, which may require research for personnel on sea, ice or land.

The use of helicopters and of the Twin Otter has allowed the support to the first traverse of the ITASE Program, performed in 1998-99 from TNB to Dome C, the convoy was made up of 4 tracked tractors and of 8 modules (accommodation/labs/workshop/tanks), using the first for short distance movements and the other for medium/long range.

To increase the safety margins and to obtain a more functional layout in the next years it is foreseen to widen the Control Room area and put it in a position allowing visual control of the ice-runway and of the quay.

In view of extending activities to the winter as an alternative to the use of automatic platforms for data collection, studies have been started for the winterisation of the Base. Particular attention is given to safety analysis, energy saving, redundancy of main equipment (power generation, production of fresh water, telecommunications, etc). a particular attention is given to the construction of a mooring quay for the ship whose construction will take into consideration also the needs of the research programs as well as the evaluation of the environmental impact.

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Abstracts

Making the most of Solar Energy in Antarctica
(Solar Potential for Australian Antarctic Bases)

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Abstract:

The application of renewable power systems is particularly relevant to remote locations such as Antarctica, where traditional fossil fuel based systems incur relatively high costs of fuel transportation in conjunction with an increased risk of environmental damage. Recent projects carried out by the Australian Antarctic Division have examined the potential for solar power generation at Australian National Antarctic Research Expedition (A.N.A.R.E.) stations in the Antarctic and Sub-Antarctic, combining numerical modelling techniques with the on-site application and testing of photovoltaic and solar hot water systems.

A pilot solar hot water system, incorporating 12 m^2 of solar panelling mounted on a frame with fixed orientation, has been operated and monitored at Davis Station (68° 34' S, 77° 58' E) since the 1998-99 season. A solar energy model, SEMAS (Solar Energy Modelling for Antarctic Stations) has been developed by Latitude Technologies Pty. Ltd., in collaboration with the Australian Antarctic Division, to utilise the data collected from the pilot system and to assess the potential for variety of solar power system configurations.

The paper presents the annual global solar energy incident upon a horizontal surface at each of the ANARE stations, as determined by SEMAS. Subsequent analysis of a variety of different collection strategies are discussed, with the conclusion drawn that despite the greater collection potential offered by tracking systems, an annually optimised fixed system is the best overall design option when operational costs are assessed on a per area basis. The potential annual power output from photovoltaic and solar hot water systems are presented for each of the ANARE stations, corresponding to a number of different design scenarios.

A New Type of Wind Turbine Validated for Extreme Climates

Philippe Menut [1], *Vincent Boiteau* [1] *and Isabelle Thépaut* [2]

Abstract

The international company of atmospheric turbines (Compagnie Internationale de Turbines Atmosphériques -CITA) has developed a new type of wind turbine whose innovative features allow its use in extreme climates. It is characterised by a small diameter, only half the size of the diameter of a conventional turbine of the same power, a simplified mechanism and a very specific coating. These features, along with its particular geometry, give it a very high resistance to fierce winds, blizzard, icing and bad weather in general. This resistance was tested in a wind tunnel. All these characteristics combine to give a very reliable turbine with a minimal rate of unavailability for technical problems. Its fairing also makes the turbine very visible, which will minimise the risks of bird strikes.

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Alternative energies at the Spanish Antarctic Station *Juan Carlos I*

Victor ALVÀ[1]

Abstract

Juan Carlos I is a summer station that opens three months a year, from December to February. During the remaining nine months the station is empty although the instruments for automatic ollection of meteorological, geomagnetism and sismic data keep functioning. The electrical supply of this instruments during the austral winter depends on an alternative energie's system made out of wind tubines (WT), photovoltaics panels (PV) and batteries that altogether supply 24 V electric energy and around 100 W. The hybrid use of WT and PV has shown to be the best solution in Juan Carlos I.

Now three WT of 1500, 2000 and 3000 W are available. WT's have a high productivity but their output depends on the orography of the terrain and the gusty winds. These last do not allow the WT to produce energy during aproximately the half of the days due to inapropiate wind speeds: below or above 13 km/h. Also, strong winter winds cause structural damage in wind mills that stop them from functioning. Despite of their low productivity, PV's supply a higher output since they guarantee a minimum amount of energy even being a loudy area with a low sun level during the winter.

In the next future an improvement of the alternative energie's system at the station will respond to the increased demand of research projects to leave operating automatic data collection equipments during the winter. An hybrid system of electrical, photovoltaic and wind energy generation will be considered and new locations for the turbines will be find in order to use at its maximum the wind laminar fluxes.

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Tele-medicine experiences in the USAP

Harry Mahar[1]

Abstract

The United States Antarctic Program (USAP) operates three year-round research stations in Antarctica, providing medical care for an aggregate winter population of approximately 275 persons and an austral summer population of about 1500. In an effort to augment limited medical clinic capabilities in Antarctica, the USAP began utilizing sophisticated telecommunications technology in 1995 to link on-ice clinic staff with medical experts in the United States via satellite. This initial application of tele-medicine at McMurdo Station provided the ability to transmit digital images (e.g., radiographs), still and motion video, and teleconferencing capabilities over dedicated communications channels. Because of limited satellite coverage at South Pole and Palmer Stations, tele-medicine applications utilized Internet-Protocol (IP) communications links, in either real-time or store-and-forward mode rather than the dedicated lines available from McMurdo Station. Initial evaluations of the impact of the tele-medicine technologies suggest enhancements in the quality of care can be significant in some instances. The routine transmission of radiographic images to consultant radiologists in the U.S. has verified on-site interpretations by treating physicians. On-call specialists have assisted in the diagnosis and treatment of patients in Antarctica, when the treating physician requested assistance or second opinions. In one notable case, medical care of the doctor at South Pole was provided by another physician in the U.S. during the 1999 austral winter, until such time as the patient could be repatriated for definitive follow-up. However, the cost effectiveness of tele-medicine in Antarctica is difficult to establish because generally accepted benchmarks of efficacy have not been established. In many instances, tele-medicine has substantiated "quality of care" assurance but has not resulted necessarily in changes in intervention strategies or in clinical outcomes. In other instances, diagnosis or treatment has been modified as a result of the communication between on-site provider and consulting specialist. The application of tele-medicine technologies has been problematic at times, requiring additional training of the clinical staff, verification that complex digital images are transmitted reliably, and coordination of communications assets (e.g., bandwidth) during peak usage periods. However, the judicious choice of tele-medicine options can provide cost-effective enhancements to medical care in remote locations.

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On-Line Medical Health Record Database of INACH's Personnel deployed to Antarctica

Ricardo Jaña[1], Alejandro Flores[2] and José Ferrada[3]

Presenter: Ricardo Jaña

Abstract

A first prototype of an on-line electronic healthcare record devoted to store medical data of INACH personnel deployed to Antarctica has been created. The system is web based allowing remote access for consultation of health data of any potential patient in case of need from a remote node -the FACH Hospital and Escudero Biomedicine Laboratory- in Antarctica. Consideration of standard approaches, provided by commercially available technology, ensures medical data protection and security without restricting their availability to certified users.

The medical database is published on a HTML Server located at INACH headquarters in Santiago supported on a PC machine which main technical specifications are: processor Pentium 100 MHz, 4.3 Gb HD, using Linux kernel 2.0.36, Perl 5, SSL and Apache 1.3 as a web server software. Implementation has included different levels of configuration made on commercial tools in order to build security procedures that use: user authentication, encryption and some CGI scripts to allow free text search on multimedia html records.

The Antarctic node is able to access the server database through a satellite communicational link. For connections from INACH's Escudero Biomedicine Laboratory this link carry three dedicated phone lines (only for voice and fax communication), two 2.4 Kbps point to point lines (that support direct dialing via modems), and one point to point 38.4 Kbps speed dedicated line. A telemedicine workstation set in the Biomedicine Laboratory is part of the INACH local area network, which is extended from Santiago to Antarctica through the point to point IP channel. In the case that contact will be done from FACH Hospital, the same satellite link carry a separated FACH corporate Internet channel with 19.2 Kbps of speed.

This application is part of the activities of the ARGONAUTA Telemedicine Project founded by the Program INCO-DC of ECC and it deals with the application of information and communication technologies in the fields of health care, continuing medical education, and research on health care systems. In the case of Chile, this development and the telematics implementation is being done between the Chilean Antarctic Bases and Santiago (Chile), where the main hospitals are located, prioritizing biomedical research as the main activity but in addition supporting teleassistence in case of emergency and teleducation.

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The population of scientists in Antarctica consists of small number of people who lives the whole year around in the bases, but mainly they go there in summer to do their research. The medical assistance in most of the cases is critical, especially during winter. Thus, the implementation of a multimedia electronic Health Record of INACH personnel deployed to Antarctica is a major issue that will make patients medical information available at the remote point in case of need.

Use of Means and Methods of Computer Medicine in the Russian Antarctic Expedition

Yu. I. Senkevich[1], V.A. Krylenkov[1], G.A. Gorbunov[1], A.V. Yashin[1], V.F. Kozak[1], V.V. Lukin[1] and V.L. Martyanov[1]

Abstract

Active exploration of polar latitudes by man and a high level of migration of the Earth's population make most acute the problems of providing urgent and permanent medical aid, especially in the remote areas and under the conditions of extreme situations. However, up to now no specific organization-technical principles for creating a medical information network has been proposed at the state level. Moreover, the available communication networks do not envisage to address the problems of health protection and disease prevention of Russian citizens working and living in the remote and/or extreme condition zones although organization of the public information medicine services has been considered for more than two decades. The main causes of this situation are as follows:

- absence of a reliable connection in health protection both between the medical institutions themselves and with difficult-for-access and remote areas;
- absence of the institutions and ignoring the structures that could coordinate the exchange of messages and process operationally different types of medical information obtained from a mass examination of people including the remote and difficult-for-access objects;
- absence of standardized technical means of systematic control and collection of full-value information on the examination of people at remote objects.

In accordance with the Program of the development and introduction of most recent means and methods of human safety provision in the Russian Antarctic Expedition, we have developed a computer module station Ambulance YS 071 designed for giving emergency consultative-diagnostic and treatment-prevention aid. From August 1998 until April 1999, an experiment on the remote sensing health control of the 44th Russian Antarctic expedition participants was carried out at the Vostok polar station. Specialists of the International Academy of Science of Ecology, Man and Nature Safety, Arctic and Antarctic Research Institute and some leading medical institutions of St. Petersburg took part in the experiment.

One of the significant advantages of Ambulance-071 YS is in that the main intellectual load and routine operations of this station are based on the developed software and the already existing information technologies. This allowed us to radically simplify the hardware by using simple schemes of biological signal amplifiers and indicator devices leading in turn, to an almost one or even two order decrease of the hardware cost in respect of similar devices that address most of the objectives of autonomous measurements of parameters. In addition, the possibility of standardizing the objective interface of soft-hardware integrated in the Ambulance-071 YS, incorporated in the computer station software makes the user free of the problem of matching electronic standards and other questions that are not in the field of specialists working under the extreme conditions.

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The computer medicine Ambulance-071 YS station includes:

- digital cardiorecorder that allows a computer entry in real time of an electrocardiogram of four standard signals and one cardiac);
- digital encephallorecorder that allows a computer entry in real time of an electroencephallogram from the selected standard scheme by two symmetrical channels (for example, for mapping the distribution of potentials) with a simultaneous synchronous introduction of one electrocardioogram signal;
- digital Akabane tester that allows a computer entry in real time of heat sensitivity values of the human body functional points;
- digital tonometer that allows a computer entry in real time of the systolic and diastolic blood pressure values;
- digital thermometer that allows a thermal control and a computer entry in real time of a specific body part temperature;
- digital photo camera that allows photographs of the body areas of interest (for example, eyes iris, skin cover state, X-ray images).

The location of the Vostok polar station in the unreliable receiving zone of the Global space communication system Inmarsat, its remoteness and isolation, enhanced solar activity and closeness of the Earth's magnetic pole, strong static voltage and the absence of classical equipment grounding, as well as constant low temperatures and pressure differences at the heights greater than 3000 m above sea level allowed for testing the computer medicine station Ambulance-071YS for survivability under the maximum severe conditions.

A complex of activities included technical assembling of the computer medicine station, equipment connecting, taking electrophysiological readings among the Vostok personnel and sending them via Inmarsat C/Internet to the Arctic and Antarctic Research Institute (AARI) server in St. Petersburg and the consultation medical facility that fulfilled the expert consultation service functions. The Ambulance-071YS station has provided an operational and plan health control of polar explorers and their adaptation. During the tests, a total of 58 electrocardiograms, 18 color images with a resolution of 120 dpi, more than 40 files of accompanying information, a copy of the database with the personal cards of polar explorers containing the results of measurements and more than 8 M special programs were transmitted. In addition to consultations, the communication channel and the medical information receiving/reporting programs allowed transmitting the updated versions of the Ambulance-071YS programs. The calculated costs of medical consulting via Inmarsat C (a $5/min traffic) for one polar explorer examined comprised $15/min for a season (4 months).

At present, the RAE completes creating the medical information network (MIN) and its preparation for test operation. The network is based on the module computer medicine units at polar stations subordinate to the coordination center, which is located at the RF SRC AARI. Such organization-technical structure permits an administrative control of the medical information exchange and coordination of actions of the MIN users. The coordination center is in turn connected directly with the Internet central medical consulting site specially set up for this purpose.

The MIN creation in Antarctica will make medical services at the polar stations close to the level of advanced practical medicine under the severe conditions when other types of medical aid are inaccessible or useless. The RAE MIN provides a regular access for physicians and paramedics of polar stations to study and use of the entire known base of the medicine of catastrophes and emergency situations via Internet. Rendering medical aid to the people working and living at remote, difficult for access and mobile objects becomes a result of competent decision-making of the virtual council of physicians the highest form of diagnosis and treatment prescription.

The Spanish Antarctic Station JUAN CARLOS I Communication and Computing System

Jordi Sorribas[1] Raquel Boza[1] David Montero[1] and Oriol Rayo[1]

Abstract

The Spanish Antarctic Station Juan Carlos I, located at Livingston Island (South Shetland Islands), has recently improved its computing and data communications capabilities. Nowadays, the Station offers full Internet facilities to the scientific teams and the groundwork for a future development of a full remote monitoring and data acquisition system.

During the last Antarctic summer, the satellite communications system has been upgraded to a new Inmarsat-B console in order to provide telephone full high speed data links, and a LAN has been installed through laboratories and living modules. This LAN combines different platforms and operative systems in order to provide a wide service to the users, and has been thought not only for sharing computing facilities but also as a platform for further data acquisition and monitoring systems. An Internet connection and e-mail delivery system, a time synchronising system, and a users management system have been also developed during December 1999 and January 2000. The data transmission facilities have allowed the publishing of a WEB page, updated weekly, that shows the scientific activity, flora and fauna from de station surroundings, and the experiences of the people that lived in this Antarctic station from December 1999 to March 2000.

Data acquisition and remote monitoring systems will be completely developed during next expeditions. The main goal will be the remote access to acquired data and monitored parameters during the winter, when nobody lives in the station. The development of a remote position control system for real time monitoring of the work teams in the surrounding glaciers and bays using DGPS facilities is also planned for a near future.

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Improvement of the sewage treatment at the Spanish Antarctic Station *Juan Carlos I*

Victor ALVÀ[1]

Abstract

The Spanish Antarctic Station Juan Carlos I has tried to reduce the environmental impact of its logistic and scientific activities since its foundation in 1988. Nowadays the station has a grey waters and sewage system made out of two septic tanks next to another and a active carbon filter. The first tank was built in situ. It has three sedimentation and digestion chambers with a total volume of $6m^3$. The effluent is led to a second prefabricated tank made out of two digestion chambers and a third one doted with a biological filter. Finally, an active carbon filter reduces the BOD of the effluent before being discharged to sea. Regularly, the sludge from the sewage treatment are taken out by a mechanical scraping of the walls, sucked with a pump, stocked in plastic containers and taken away from the Antarctic Treaty area.

This sewage system is operating during three months a year, from December to February, when the station is inhabited and active. During the winter the biological digestion process decreases due to the low environmental temperatures and to the lack of sewage. When the station opens again the following summer and new occupants come, the sewage system receives in a short period of time a big amount of new organic matter. To digest this input becomes more difficult due to the winter inactivity and to the need of reactivation of the biological process (it takes around two weeks). This fact represents the main limitation of the existing sewage system. The production and accumulation of sludge is also a subsequent problem associated to the septic tanks that requires a remarkable amount of maintenance work.

In order to solve this problems associated to the summer station activity and to the nature of the digestion of organic matter by biological process, a replacement of the existing sewage treatment is under examination. This improvement could be a physico-chemical system not influenced by the inactivity periods, being operative from the opening of the station and able to reduce the sludge production.

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Global Mapping Project and relation with SCAR WG-GGI

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Abstract

1. Background

Global Mapping Project was proposed by Ministry of Construction of Japan in 1992. In this year the United Nations (UN) Conference on Environment and Development was held in Rio de Janeiro.

The need of the Global Map for addressing global environmental problems has been well confirmed at the UN. The report of the UN General Assembly held in June 1997 includes a section on the development of an information infrastructure accessible to anybody, using technology of geographic information systems. This includes Global Map.

2. Concept and contents of the Global Map

The objective of Global Mapping Project is to help us understand the status and know tendency of global environmental changes. The Global Map is produced on the whole land area of the earth at one kilometer ground resolution, and is to be revised every five years.

The Global Map is being produced in a digital format for easy handling by computer and its content is equivalent to conventional maps at a scale of 1:1,000,000. The Global Map contains vector data (transportation, boundaries, drainage and population centers) and raster data (elevation, vegetation, land cover and land use). And the Global Map is produced using existing materials such as paper map and digital data set. Satellite images which contain up-to-date geographical information are also used for revising the existing materials.

3. International Steering Committee for Global Mapping (ISCGM)

Global Mapping Project is promoted by ISCGM whose secretariat is located at Geographical Survey Institute of Japan. ISCGM is composed of 17 members of 14 countries and international activities.

In November 1998, the UN recommended the heads of National Mapping Organizations in the world to participate in the Project. The number of countries and regions participating in the project is 77 as of March 17, 2000. Now, each participant is producing the Global Map.

4. Global Map Specifications

Global Map Specifications version 1.0 are in the most part consistent with ISO/TC211 recommendations for geographic data standards, which is found at http://www.auslig.gov.au/mapping/global_m/specv1_0.htm. In the specifications, for example, geodetic datum and ellipsoid, data format and data management are described.

5. Relation with the Scientific Committee on Antarctic Research (SCAR) Working Group on

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Geodesy and Geographic Information (WG-GGI)

SCAR WG-GGI participated in the Project on March 9, 1999, and Mr. Drew Clarke, chairman of SCAR WG-GGI is one of ISCGM members.

To produce the Global Map of the Antarctic, British Antarctic Survey (BAS) is simplifying the revised Antarctic Digital Database (ADD) to a 1:1,000,000 scale version.

6. Conclusion

In this year, the Global Map of some countries will be distributed to researchers for their studies. And the Global Map will be disclosed to public through CD-R or internet on November 28-30, 2000 when Global Mapping Forum will be held in Hiroshima, Japan. The Antarctic is the vital area for global environment. We believe the Global Map of the Antarctic will help promote researches for global environment.

Keywords: *Global Map, ADD, satellite imagery*

GIS-ILA: The GIS for Italian Logistics in Antarctica

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Abstract

A geographic information system (GIS) is a hardware/software tool very effective in collecting, storing, searching, handling, and visualizing geographic data together with their descriptive attributes. Such a tool is very helpful to approach a wide range of situations, including many logistic problems.

ENEA, as the agency having the task of implementing the Italian Antarctic Program (PNRA), has decided to use a GIS, in order to increase the efficiency in managing the huge amount of data collected in the course of Italian activity in Antarctica, which counts fifteen expeditions up to now.

The GIS for the Italian Logistics in Antarctica (GIS-ILA) collects the data involved with the Italian scientific expeditions in Antarctica, obtained from the yearly Expedition Reports. All thematic information available up to now have been inserted into the data base, starting from the first Italian expedition (1985/1986), up to the last campaign (1999/2000). A continuous year by year updating of data is planned for the future, funding permitting.

The cartographic support of GIS-ILA covers a roughly triangular shaped, some 430,000 km^2 wide, geographic area. One of the three sides of the coverage, the marine side, represents about 700 km real length along the western coast of Ross Sea. The Italian "Terra Nova Bay" station (74°41'S – 164°07'E) falls at the middle point of that side. Some marine areas in front of the coast line are included in the cartography. The vertex facing the marine side of the coverage falls near Dome C (75°15'S – 124°10'E).

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Cape Roberts Project

Jim Cowie[1]

Abstract

The Cape Roberts Project (CRP) is an international drilling project by scientists and the national Antarctic programmes of Australia, Britain, Germany, Italy, Netherlands, New Zealand and USA. The Project was formally established in 1994 although preliminary planning began in 1990. Drilling has now been completed.

The aim of the Project was to recover 1,500 metres of rock core from the sedimentary strata beneath the sea floor off Cape Roberts in the Ross Sea. The rock cores are being analysed for two main reasons - to better understand the paleoclimatic and tectonic history of Antarctica. Achieving these objectives will contribute to international understanding of the causes of global sea level change and the origins of mountains and basins.

in five months in "Terra Antarctica", an Antarctic earth science journal. A year later more detailed studies have been published in the same journal.
At the planning stage a detailed environmental assessment of CRP, known as the Comprehensive Environmental Evaluation (CEE) was circulated to Antarctic treaty nations and non-governmental organisations for comment. The Project manager, Antarctica New Zealand, has been careful to minimise the impact on and risk to the Antarctic environment throughout the Project. An annual environmental monitoring programme was set up in 1995. An independent environmental audit in 1998 found that the "activity was conducted in accordance with the CEE, and has resulted in neglible environmental impact"

The management structure of CPR has played an important part in its overall success. The scientific direction for the Project came from the International Steering Committee (ISC) which met annually. The Operations Management Group (OMG) was composed of rep managed on a day-to-day basis by Antarctica New Zealand. At Cape Roberts during drill operations on-site management and authority was clearly defined but shared between the Project Manager and the Chief Scientist,

Drilling technique was unique because the annual sea ice, measuring about 2 metres thick, was used as the platform to support the 55 tonne drill rig. Thick, safe sea ice was critical to the Project. A drill season was cancelled because the sea ice was judged unsuitable. The next season the drilling was terminated early because the sea ice began to break up. Three holes were drilled over three summer seasons, the furthest being 16 kilometres from land. A total of just over 1,700 metres of rock core was recovered for scientific analysis. The deepest hole drilled was 940 metres below sea

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floor, a record for Antarctic drilling. The rate of core recovered (for depth drilled) was an impressive 93%.

Environmental Impact Management for Ny-Ålesund (79°N) in comparison with Antarctic stations

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Abstract

Kings Bay AS is responsible for managing the infrastructure and providing logistic support for the research activities at Ny-Ålesund. Kings Bay AS had to developed its own rules and regulations applicable for their activities in Svalbard. Waste handling, disposal, and minimization rules, together with an environmental impact assessment, developed for Ny-Ålesund are examples of a successful approach developed by ONE company to coordinate and manage activities between six nations.

The basis for a holistic approach originated by Kings Bay AS is different than the nations operating in Antarctica. Management instruments for scientific activities/stations of 26 countries in the Antarctic region are international treaties, conventions, and regulations. A waste management plan for the separation, collection, reduction, reusing, recycling, and disposal of waste was developed in 1998 for all members of the community, scientific stations, and various departments at Ny-Ålesund. The quality and quantity of wastes were assessed and it was found that approximately 50% of the wastes (average for 1996/97/98) were sent away for recycling and food wastes were reaching 40% of total wastes in 1998. A small-scale in-vessel composting system was introduced to Ny-Ålesund in 1999. This is the first case of composting organic wastes on such a scale in the far North Polar Region. Currently, after introducing the composting system, the percentage of recyclable waste produced at Ny-Ålesund is comparable with US Antarctic Program (USAP) activities, where 60% of waste is recycled. The comparison of various environmental impact management elements between Ny-Ålesund and Antarctic stations is presented below.

Environmental Impact Management Elements	Ny-Ålesund	Antarctic stations
Number of countries operating their stations	6	26
Number of people living in winter and summer	30-60 and 60-150	1000 and 4000
Number of tourist visits in recent years	10 000	10 000
Management policies	White Paper to the Norwegian Parliament, Norwegian Ministry of Environment, Governor of Svalbard, Kings Bay AS, NySMAC	Various treaties, conventions, and regulations (e.g. the Antarctic Treaty, ATCM, SCAR, CCAS, CCAMLR, CRAMRA)
Environmental Impact Assessment	Performed in 1996/97	Completed around USA and Great Britain Antarctic stations, partially performed around other stations
Protected areas	Bird Protection Areas, Restricted	Specially Protected Areas,

[1] *Kings Bay AS, Ny-Ålesund*

	Research Areas, Cultural Monuments	Sites of Special Scientific Interest, Specially Reserved Areas, Area of Special Tourist Interest, Antarctic Specially Managed Areas
Nature trails	Established in 1999	none
Waste management plan	Developed in 1998	Developed since 1991
Waste production	Recyclable wastes – 50%	Varied, The best - US Antarctic Program- recyclable wastes – 60%
Solid waste categories	16	12-17
Recycled waste categories	12	8-13
Composting	Started in 1999	none
Environmental Information	Brochures, folders, lectures	

Chilean Polar Station EPTAP:
An ecolgical approach to antarctic habitation.

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Abstract:

01. Introduction:

This presentation is a detailed description of the context, process of conception, and deployment of the Estacion Polar Teniente Arturo Parodi / EPTAP/ in the blue ice zone of Patriot Hills, Lat.80∞19¥south, Long.81∞18¥west. The station was produced in a collaborative action between the Antarctic Division of Chilean Air Force and the ARQ.ZE unit / Extreme Zone Architecture / of the Santa Maria University of Valparaiso. It was installed in november 1999 and has an initial capacity for 24 persons during the four months of summer.

02.National Antarctic political objectives:

Eptap was concieved as a infrastructural support both for national scientific and technological investigation, and the logistics of polar zone flight paths that depend on the blue ice runways. Chile will pursue a long term policy of aerial and surface exploration, penetration, and habitation with this form of station producing a network beginning in King George Island, crossing points of logistical support in Welcome Nunatak and Thiel Mountains, and transforming Patriot Hills into the second most important national Antarctic settlement, catalysing scientific, cultural and touristic development within the interior of the continent. Eptap becomes the first node of this network, extending national activity towards the pole and towards an aerial link with other continents close to Antarctica.

03. Design Criteria.

The station was developed from premises derived from the Madrid Protocol, proposing maximum efficiency in the support of human activity in this zone, together with an absolute respect for the environmental preservation of Antarctica. Four fundamental criteria informed the design process.

03.1 Deployability:

The logistics of air transportation dictated strategies of minimum weight and modular component size permitting the entire station to be transported in one hercules c130 plane. The possibility of installation under extreme conditions informed an operation that was rapidly and simply executed. This same process is reversible, allowing complete evacuation of the station.

03.2 Territoriality:

The station incorporates the processes of snow acumulation particular to blue ice fields into its location and organization. Situated in the zone of superficial equilibrium to the north of the blue ice field, a membrane distribution tunnel of 200m2 guarantees access to the seven insulated fibreglass living modules, and the snow acumulation that is provoked protects it from the extreme catabatic winds. The ends of the tunnel remain exposed due to their aerodynamic form, permitting access of personnel and skidoos through retractable transparent visors that open the interiority of the station to the Antarctic extension.

03.3 Ecological:

The sanitary module is perforated in a series of operations that establish different energetic mediations between the external environment and the bodily functions of the user. An acrylic solar water fabricator is located on the roof of the heated module, and dry toilets are situated over a perforation in the floor where separated urine and faeces are freeze dried by the snow, and subsequently evacuated by plane.

03.4 Energetic:

All support systems within EPTAP are designed to run off electricity, and the high insulation of the modules together with the use of the tunnel as a heat exchanger will permit the station to function on an aeolic generation system of 10KVA with fotovoltaic support.