Proceedings of the Sixth Symposium on Antarctic Logistics and Operations

Rome, Italy
29 to 31 August 1994

conducted by the
Standing Committee on Antarctic Logistics and Operations (SCALOP)
of the
Council of Managers of Antarctic Programs (COMNAP)

in conjunction with
the XXIII Meeting of
the Scientific Committee on Antarctic Research (SCAR)

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Cover Picture: Take-off of a C-130 of Italian Air Force from Terra Nova Bay.

Photo: Benedetto Mangione.

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Foreword

The Sixth Symposium on Antarctic Logistics and Operations was held in Rome, Italy from 29-31 August 1994. The Symposium was conducted by the Standing Committee on Antarctic Logistics and Operations (SCALOP) of the Council of Managers of National Antarctic Programs (COMNAP) and held in conjunction with the twenty-third meeting of the Scientific Committee on Antarctic Research (SCAR).

Logistics and operational activities are fundamental to the support of science in Antarctica and represent the major cost element of most national Antarctic programs. Because of the complexities and difficulties of providing safe and effective logistics and operational support in such a harsh and remote environment, the cost of conducting Antarctic science is typically six times greater than undertaking similar scientific activities within developed countries.

For most national programs the scope of logistics and operations includes the provision of shipping, aircraft and surface transport; the design, construction and maintenance of stations or bases; the support of field activities and marine science; the specification, procurement, packaging and delivery of provisions, materials and equipment; and the recruitment, training, deployment and repatriation of expedition personnel. In conducting activities in Antarctica, national operators are obliged to comply with relevant national and international regulations as well as measures adopted by the Antarctic Treaty Parties which include stringent requirements regarding environmental management

The formidable challenge and high cost of logistics and operational activities in Antarctica has led to a considerable degree of cooperation between national operators during the last four decades. The conduct of symposia continues to be an important mechanism to facilitate the exchange of experience and knowledge and to help national programs optimise the use of available support resources.

The earlier symposia on logistics and operations were held under the auspices of SCAR and the Antarctic Treaty Parties in Boulder, USA (1962), Tokyo, Japan (1968) and Leningrad, Russia (1982). Following the establishment of COMNAP in 1988 (and the formation of SCALOP from the former SCAR Working Group on Logistics) it became the practice to hold the symposia in conjunction with the biennial meetings of SCAR. Hence the fourth symposium was held in Sao Paulo, Brazil (1990), the fifth in Bariloche, Argentina (1992) and the sixth in Rome, Italy (1994).

In recent times it has also become the practice to hold a trade exhibition in conjunction with the symposia in order to provide Antarctic operators with the opportunity to discuss the technical and commercial aspects of equipment and services with relevant suppliers. The trade exhibition at the Rome Symposium was the largest and, I believe, the most successful to date. On behalf of SCALOP I wish to thank the exhibitors for their participation and highly professional presentations.

Differing themes have been adopted for each of the symposia although transport and building construction have featured in most programs. In recent years greater focus has been given to the implementation of environmental measures required under the Antarctic Treaty and emerging technologies relevant to logistics and operations. The themes for the sixth symposium were:

- use of alternative energies;
- environmental protection related to operational technologies;
- selection and management of Antarctic personnel; and
- new developments in operations, logistics and science support.

The proceedings of this Sixth Symposium include twenty five papers, many of which reflect the endeavours of national operators to pursue improved efficiency and effectiveness of their operations and to implement environmental management measures and technologies in keeping with the requirements of the Antarctic Treaty.

On behalf of SCALOP, I wish to thank the authors for their time and effort in preparing quality papers and also for their direct participation in the Symposium. I also wish to thank the Symposium participants who generated considerable discussion on the various topics. It was pleasing to see that the Symposium attracted a large audience which included members of the Antarctic scientific community as well as logistics and operations practitioners

Finally, I wish to thank the SCALOP Symposium Working Group and, in particular, chairman Pietro Giuliani for undertaking the work of designing the program, reviewing and selecting the papers and managing the Symposium in conjunction with the Italian Antarctic Project of ENEA.

Membership of the 1994 SCALOP Symposium Working Group comprised Pietro Giuliani (Italy), John Hall (United Kingdom), Luis Fontana (Argentina), Jack Sayers (Australia), Patricio Eberhard (Chile), Heinz Kohnen (Germany), Olle Melander (Sweden) and Erick Chiang (USA).

Jack Sayers
SCALOP Chairman

WELCOME ADDRESS

by

Pietro Giuliani
ENEA Antarctic Project

It is a great pleasure for me to welcome you, also on behalf of ENEA, to this Sixth SCALOP Symposyum in the ancient city of Rome.

Quite appropriately, the venue of this meeting is the old building of the School of Engineering of the University of Rome.

Logistics is a vital part of Antarctic activities and its optimization is becoming an ever increasing concern of Antarctic operators, in view of the tight budgets of our programmes. The exchange of information among countries active in Antarctica is very broad and this Symposium is going to be an important milestone in this exchange.

The Selection Committee for this meeting had a difficult task because of the high quality of the papers submitted and of their number. All papers contained interesting ideas and information; consequently, the selection process was made more difficult by the wish to accept as many as possible within the time constraints. We hope that we managed to select well, while covering satisfactorily the themes that the Symposium was intended to cover.

The themes selected for this VI SCALOP Symposium are of great relevance to Antarctic activities and we feel that the papers that will be presented shall highlight a number of important aspects of these activities.

In conjunction with the Symposium a Trade Exhibition has been organized. A total of 20 exhibitors participates, 8 from Italy and 12 from abroad. We hope that you will find it useful.

I wish you all an interesting and fruitful meeting and a pleasant, even if a little too warm, stay in Rome.

Pietro Giuliani
Chairman of the Selection Committee for SCALOP VI

Natural Environment Research Council

British Antarctic Survey

DEVELOPMENT OF A MOBILE GARAGE/VEHICLE SERVICING FACILITY
HALLEY SCIENTIFIC STATION

BY

A.L. Smith and D.K. Harley

INTRODUCTION

To support scientific operations at the British Antarctic Survey's (BAS) Halley Station (75°35'S), 26°22'W) on the Brunt Ice Shelf, extensive use is made of tracked vehicles (eg. cranes, dozers and snocats etc). This reliance brings with it a requirement for a major facility for front line servicing and maintenance. Traditionally the requirement has been met by the provision of a surface structure which has been allowed to become buried, access to the garage being via an inclined tunnel. With the development of the fifth Halley station and the move away from sub-surface structures in favour of a surface facility elevated on 5 metre high jackable platforms, the provision of a vehicle maintenance facility had to be addressed.

After a rigorous appraisal of options, a re-locatable above surface garage/vehicle servicing facility was selected. This offered greater benefits in access and maintenance and complemented the elevated main station facilities.

The concept of a re-locatable unit on skis was first considered in the early 60's but until recently had never been fully evaluated by the British Antarctic Survey. A feasibility study was completed and a detailed performance specification prepared for the mobile garage. Accommodation had to be provided for the largest vehicle in the fleet, this being the Nodwell 110C tracked crane (7.8m x 3.2m x 3.7m weight - 15.25 tonne). This resulted in the need for a structure of sizable proportions which, when fully equipped, would weigh in the region of 50 to 55 tonnes.

The method of procurement reflected the fast track nature of the project with concurrent engineering principles being adopted. Following fabrication the unit was subject to a trial erection in the UK before transport to the Antarctic. From receipt of the instruction to proceed, to loading on the ship, was a total of 13 weeks. This unit was erected on site during the Austral summer of 1992/93. The fully self-contained facility was used extensively during the following winter and performed well with the snow accumulation around the structure being less than predicted.

DESIGN PARAMETER

This was to provide a self sufficient and re-locatable facility for carrying out vehicle and plant maintenance in a safe working environment and to include adequate storage for equipment and spares.

Other considerations were:-

- Light but strong construction.
- Totally waterproof floor and sump.
- Creation of sump for containment of melted snow from vehicles and any other spillages.
- Speed of erection and of installation of internal services.
- Energy efficient.
- Low shipping volumes.
- Low cost maintenance.
- Climatic conditions.

Air temperatures -	Mean annual temperature		-18°C
	Extreme maximum		+4.5°C
	Extreme minimum		-55.3°C
Snow -	Annual snow accumulation		1.2m
	Surface temperature summer		-7.5°C
	Annual mean		-19.1°C
	Density		0.408 g/cm^3
Winds -	Prevailing wind direction	075° (true)	≓ 15°W of E
	Secondary wind direction	270° (true)	= W
	Frequencies of wind direction:	Easterly	= 68.8%
		All other	= 28.8%
		Calm	= 2.4%
	Design wind speed 120Kt		= 62.0m/sec
	Design wind speed crosswise to prevailing wind direction 60Kt		= 31.0m/sec

- A maintained internal temperature of +15°C bearing in mind vehicle reheat loss and ice melt loss.
- Aerodynamics of structure to minimise snowdrift.
- Prevention of snow and water ingress.

DESIGN PHILOSOPHY

When producing the design of any major piece of plant or equipment there are two factors to be taken into consideration. The first is to produce an item which will not only satisfy the operational functions but also to pre-empt any unforseen requirements. The second consideration is to produce a design which can be successfully and economically manufactured and assembled in the time required.

The final design of a ski mounted mobile garage/servicing facility was produced as a team effort co-ordinating the expertise of the main contractor, their designer, and BAS Technical Officers. Because the building was to be towed around the snow, the design had either to be flexible enough to adjust to uneven ground during movement, or rigid enough not to distort as it moved over an uneven surface.

It was concluded that a flexible solution would result in unacceptable distortion of the building during towing which in turn would cause internal wall cladding, doors, etc. to require resetting. Therefore it was the rigid design concept that was used. In order to produce a rigid concept the whole building and wall cladding had to be used to produce what is effectively a "torsionally stiff box" on skis. Any other form of design where a steelwork super frame structure is supported off a base with skis would either be much heavier to produce the same degree of rigidity, or be much more flexible for the same weight. A complex analysis tool, ANSYS finite element modelling, was used to assess the inherent strength and flexibility of the structure as a whole.

The period allotted for assembly of the facilities on site was particularly short and a structure composed of a large number of small bolted components would require a long period, together with exact assembly tolerances. It was therefore concluded that a small number of large components would enable the outer structure to be rapidly assembled with a minimum of bolts was required for the initial temporary assembly, allowing the remainder of the bolts to be fitted from within the enclosed structure. The method of construction resulted in only 30 major items needing to be coupled together to produce the basic structure. Furthermore, it enabled some internal bracketry to be pre-bolted to the major components, thus reducing any ambiguity on site during assembly.

Because the whole building had to act as a totally stiff box the outer steel panel or skin of the building had to be rigidly attached to the frame. It was initially assumed that the skin would need to be continuously welded to the main portal beams, however, for two reasons this was not the best possible solution. Welding would have resulted in distortion during manufacture of the major components which in turn would have complicated assembly and have been detrimental to the overall appearance. However, more importantly, the outer skin would have been subjected to the lowest temperatures and embrittlement of the welds would cause brittle fracture during the towing. The versatility of the main contractor and their advice as to the "least distortion design" allied to techniques developed in the aerospace industry led to the conclusion that a riveted external sheeting would be the only suitable technique.

The ski base for the building involved a significant degree of development. Originally the skis were to have sheets of low friction nylon attached to the underside. Of concern was the fact that differential expansion would cause the sheets to bulge which would then enable ice to build up around the skis and "key" the skis to the ice. The exact behaviour and temperature differential was not known, so to prevent any possible problems alternatives were considered. Finally a low friction paint used for ice-breaking ships was used. This removed the problem of the ice keying to the skis. The underside of the base modules were also designed to have as smooth a profile as possible and these were also painted with the same material. The skis were not attached directly onto the base. This was to ensure that heat loss through the base would not be transmitted into the skis and encourage the possibility of the snow melting around the skis.

The design concept thus far produced a basic carcass. However, certainly not a base which could support vehicles, nor panels that could take the full wind and snow loading required. Furthermore, insulation of the whole building against an outside temperature of -50°C with no cold spots was required. Following intensive research into special materials, an expandable foam was found which satisfied all the stringent requirements. This was applied into the base units and to the inside top of the panels. This technique produced the required insulation, stiffness and bearing capacity. It could also be applied prior to assembly and shipping which reduced the content of on site work.

DESCRIPTION

Structure

The garage/workshop consists of a series of 5 steel insulated modular rings. Individual modules of base, sides and roof are bolted together, trapping a 10mm foam rubber gasket between the mating faces thus providing a rigid air and water tight building. Each module is 3m long resulting in a total length of 15m. The overall height is 6m and the overall width is 8.6m.

The gaskets in the sump area are of composite construction, manufactured from E.P.D.M. rubber on the underside, which provides resistance to water at low temperatures, and nitrile rubber on the upperside, which provides resistance to water and aromatic hydrocarbons.

For ease and speed of erection lifting eye bolts were fitted to each module.

The main door opening is 5m wide x 5m high. There are 2 leaves to the door which is hydraulically opened, closed and secured. To protect the main door sill and seals 2 hinged ramps are lowered before the entry or exit of a vehicle.

The 2 personnel doors are wide enough for skidoos. All the main doors have Neoprene "P" seals and the door frames are trace heated. Each door has a viewing port.

Internal cladding consists of 0.5mm colour coated steel panels backed with 40mm insulation.

Internal partitions divide off areas for the plant room, office/store room, toilet facilities and a mezzanine floor storage area.

The garage is mounted on 2 ski-runners. The runners and the undersurface of the base modules are coated with marine coating Inerta 160. This provides a smooth low friction surface for the whole of the underside of the unit. The exterior of the wall and floor was painted red.

Services

All the services needed to make the garage self sufficient are provided.

These include:-

- **Electrical Supply**

  10Kw is taken from the station generators to supply the boiler, the fire and gas detection system, the gaseous extinguishing system, the lighting system, battery charging and a certain amount of power distribution. A 16Kw generator provides additional power.

- **Heating and Ventilation Systems** provide -

  - Fresh air supply
  - Hot air supply
  - Exhaust extraction

- Oily water separator used when emptying the sump. The separated water is pumped outside and the separated oil is placed into the waste oil tank.

- Air compressor used to operate tools and for inflating the pneumatic air bags.

TECHNICAL INFORMATION

Steel material - to BS4360 Grade 50E Impact 27J @ -50°C.

Coating for Ski-runners - Marine coating Inerta 160 manufactured by International Marine Coatings. The advantage for using this product is that it can be applied in the fabricators works, it also has a friction coefficient close to that of PTFE. (U value of 0.08 compared with 0106 for PTFE).

Generator/Alternator -

Engine - Lister type TR3, three cylinders in line, naturally aspirated, 4 stroke, pressure lubricated, air cooled industrial diesel engine capable of developing 22.5 b.h.p. at 1500 rev/min, at N.T.P. conditions.

Engine Protection - the unit is arranged for automatic shutdown in the event of:

a) Low oil pressure
b) High engine temperature
c) Overspeed
d) Under/over volts
e) Overcurrent

Alternator - Newage UC184F brushless two bearing alternator, self exciting, self regulating, screen protected, drop proof type maintaining a voltage regulation of + or - 2% from no load to full load, unity to 0.8 lagging power factor producing an output of 20.0 kVA at 0.8 p.f. (16.0 Kw) 415/240 Volts, three phase, 50 Hz, 4 wire, 1500 rev/min.

Hot Air Burner - is a standard Powermatic Model CP200, with a Reillo burner modified to burn avtur fuel oil. Output rating 59Kw.

Heat loss calculations used

Insulated surface	3.90 Kw
Bridge surface	11.92 Kw
Air replacement	22.11 Kw
Vehicle reheat	7.84 Kw
Ice thaw	4.93 Kw
	50.70 Kw
Less ¾ of air pef. loss (assumed non coincident)	16.58 Kw
Predicted load	34.12 Kw

Fuel consumption is 14600 litre annually to maintain a temperature of +15°C at all times. The fuel tank is double skinned, has a capacity of 3000 litres and is housed on the mezzanine floor.

Air Compressor - is a standard Hydrovane Model 15 PURS, rotary vane operated motor operating temperatures O°C to 40°C.

Normal working pressure	-	10 BAR
Free air delivered at 10 BAR	-	3.5 l/sec
Motor power	-	2.2 Kw
Oil capacity - litre	-	0.8 litre
Max oil temperature	-	100°C
Noise level at 1 metre	-	67dBA
Receiver volume	-	100 litre
Air cleanliness	-	5 PPM

Oily Water Separator - manufactured by Hodge Stetfield Ltd., and is a modified version of their Victor Mini-Sep 0.5 Lt/min. The modifications entail the addition of 500W immersion heaters in each of the chambers, and return feed from the second stage unit to the first stage for oily water which normally would be fed directly into a ship's bilges for subsequent re-circulation.

Lighting - There are two systems for lighting. The first is the main lighting system, which controls the operational lighting i.e. the garage fluorescent, the office and plant room lights and the external flood lighting. The second is the emergency lighting system, which is battery fed, and cuts in on any mains failure. Additional mobile lights are used when and where required.

Fire Alarm System and Gaseous Extinguishing System - manufactured and supplied by Thorn Security Systems Ltd., and is their System 1700.

Table of Equipment		
Item	Description	Qty
1.	Main Control Panel 4 Zone c/w Charger & Batteries for 48 hours standby in the event of mains failure. Consists of: 4 Zone Module & Display Alarm Module & Display Relay Module Two x 15 A/H 12v SLA Battery External Power Interface	1
2.	Heavy Duty Relay Unit	2
3.	1700 Extinguishing Unit	1
4.	Flashing Beacon 24v Internal Lens Colour - Red	1
5.	Banshee Discharge Sounder	1
6.	6" (150mm) Fire Alarm Bell	3
7.	MF 301 Ionisation Smoke Detector c/w Base	2
8.	MR 301 Optical Smoke Detector c/w Base	2
9.	MD 301 Rate of Rise/Fixed Temperature Detector c/w Base	3
10.	GP2 External Siren c/w Heater	1
11.	Thermostat for Item 10	1
12.	Flashing Beacon External	1
13.	CP 200 Break Glass Call Point	3
14.	9 kgs ABC Dry Powder Portable Fire Extinguisher c/w Wall Mount	4
15.	6.8 kgs CO_2 Portable Fire Extinguisher c/w Hall Mount	2

Gaseous Detection System - manufactured and supplied by Sieger Ltd. It is designed to detect flammable gases at high and low levels along with carbon monoxide (for rogue exhaust emissions).

High Level	-	Flammable (Acetylene)
	-	Carbon Monoxide
Low Level	-	Hydrocarbon (fuel vapours)

Utilities and Services - include the following items

Snow melt tank -	Capacity 50 litres. Water temperature 45°C for hand washing only.
Waste oil tank -	Capacity 1200 litres
Dry package toilet -	PACTO 206 made by Pactosan, Box 103, 5-71300 Nora, Sweden.

SITING AND SNOW DRIFT ACCUMULATION

The garage/workshop is situated 500m from the main station complex so that the snow drifts do not interact with one another. The electrical supply cable is maintained above surface and this also acts as a personnel safety line.

The classic windscoop has been created and all access doors are free of snow.

RE-LOCATION

The garage/workshop is re-located annually. The internal equipment is safely stored and the fuel and oil tanks are almost emptied. The snow is cleared around the base and pneumatic air bags are used to break the adhesion between the skis and the snow. Two Caterpillar Bulldozers, D4H LGP, with 20 tonne winch capacity are used to winch the unit out of the windscoop onto a higher surface. The windscoop is filled in and the area groomed.

PERFORMANCE

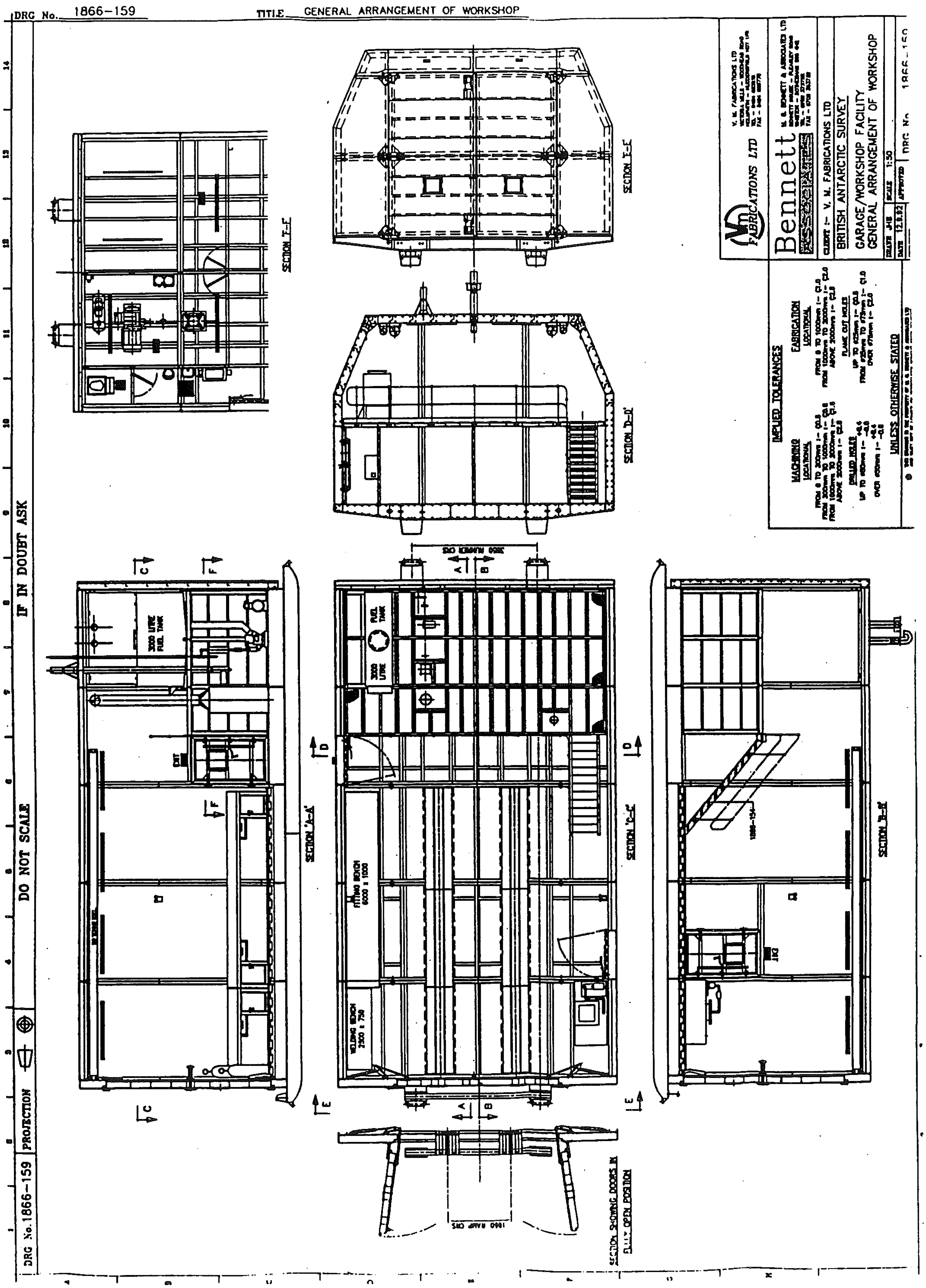
The mobile garage/workshop facility has proved to be a significant success and on present performance it is anticipated that it will exceed its original design life of 15 years. Given the ease with which the unit can be re-located, the Survey has adopted the basic design philosophy of the garage in designing an additional accommodation unit which is scheduled to be erected at Halley during the 1994/95 summer.

ACKNOWLEDGEMENTS

Main Contractors - V & M Fabrications Ltd., Fax: 0484 685775

Designers - M.G. Bennet & Associates Ltd. Fax: 0709 363730

BAS Personnel - J. Newman, Mechanical Engineer
J. Gorman, Electrical Engineer
M. Dunne, Electrical Engineer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IF IN DOUBT ASK
PROJECTION
DRG No. 1866-159
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SECTION 'B-B'
SECTION 'C-C'
SECTION 'D-D'
SECTION 'E-E'
SECTION 'F-F'
SECTION SHOWING DOORS IN FULLY OPEN POSITION
IMPLIED TOLERANCES
UNLESS OTHERWISE STATED
FABRICATIONS LTD
Bennett
CLIENT :- V. M. FABRICATIONS LTD
BRITISH ANTARCTIC SURVEY
GARAGE/WORKSHOP FACILITY
GENERAL ARRANGEMENT OF WORKSHOP
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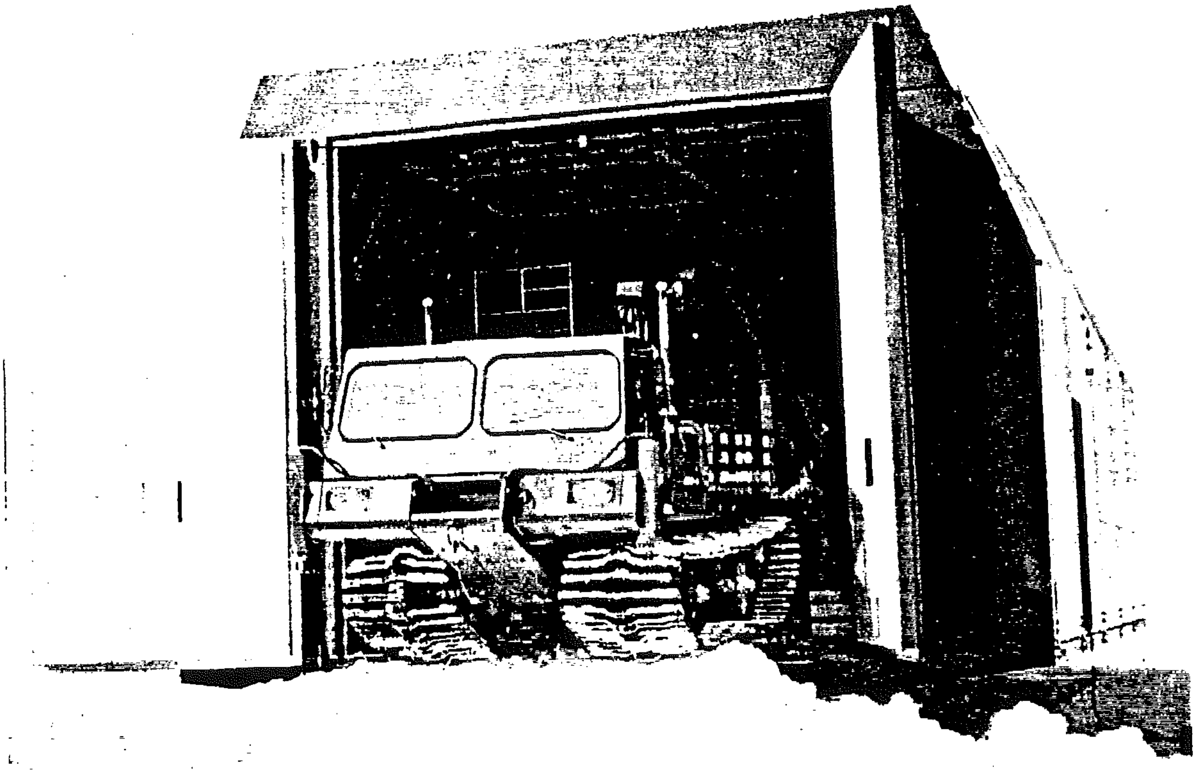
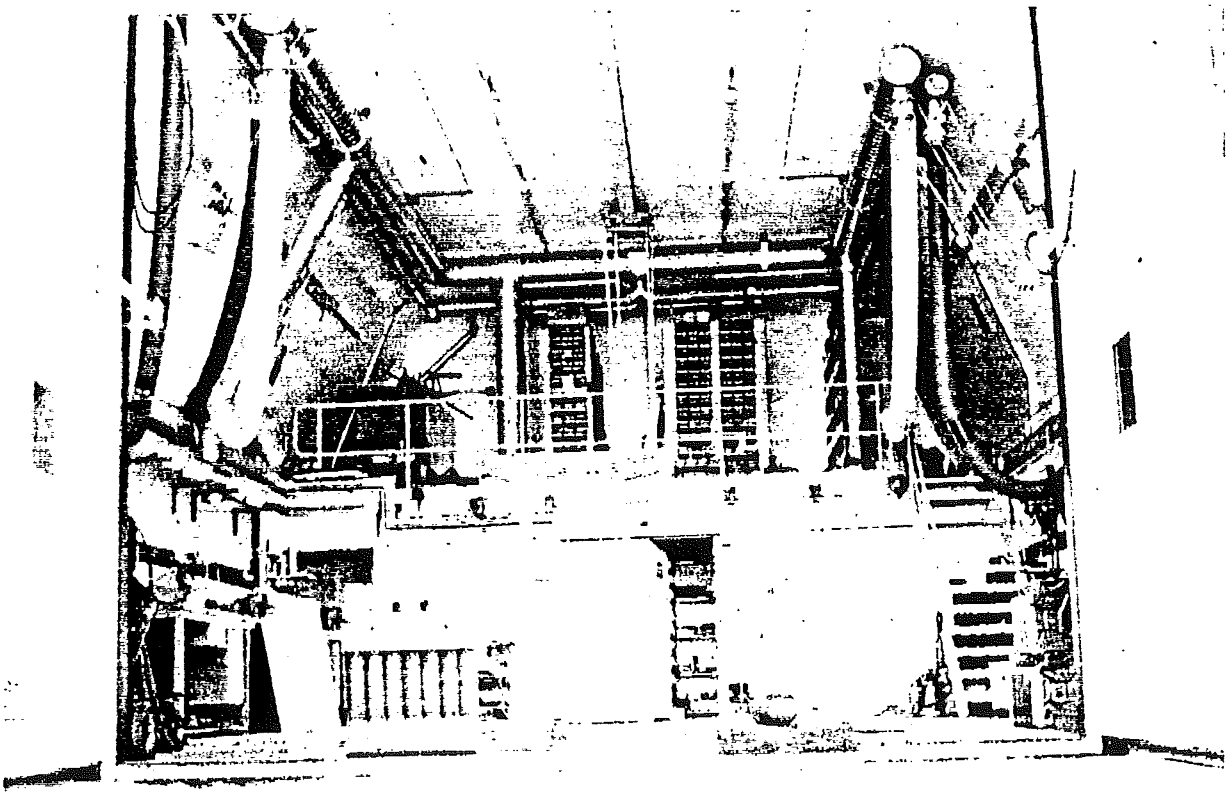
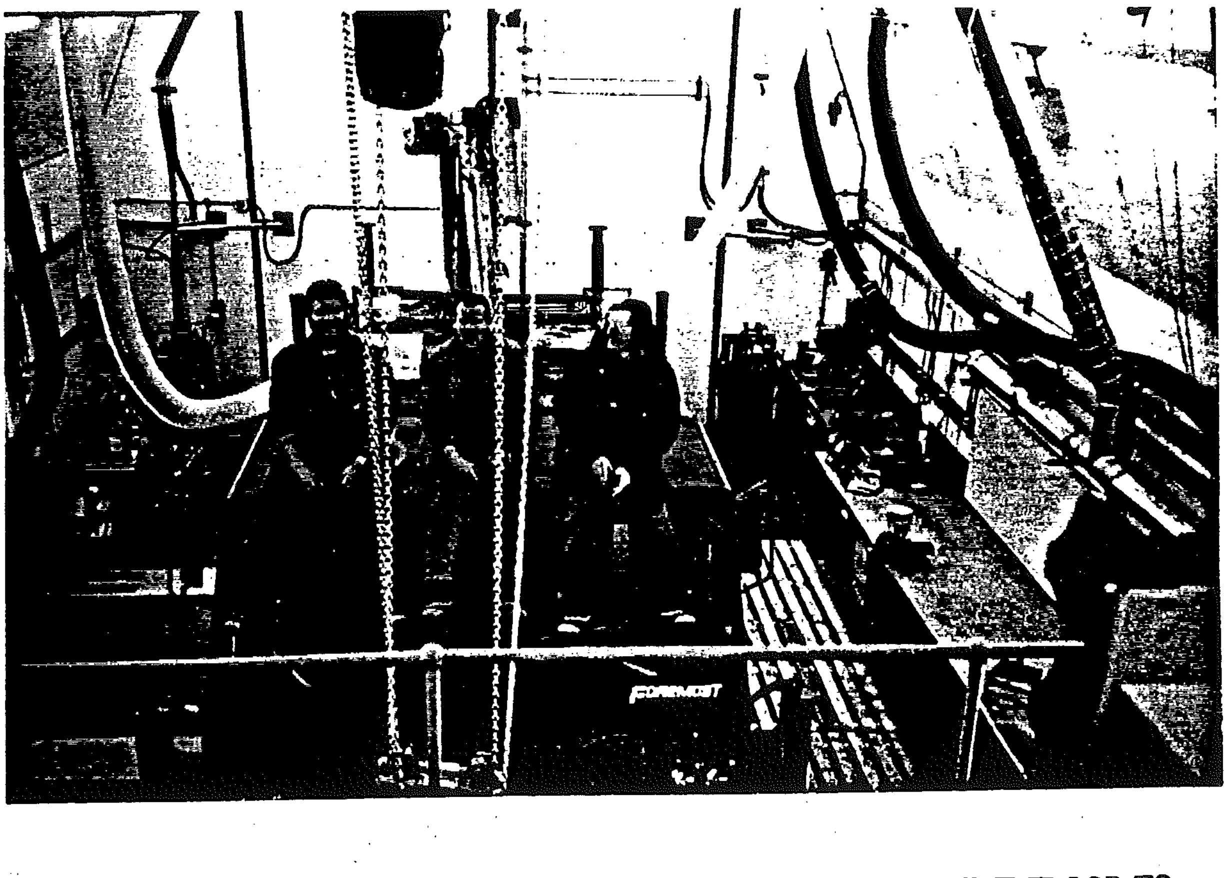


GARAGE/WORKSHOP UNDER CONSTRUCTION

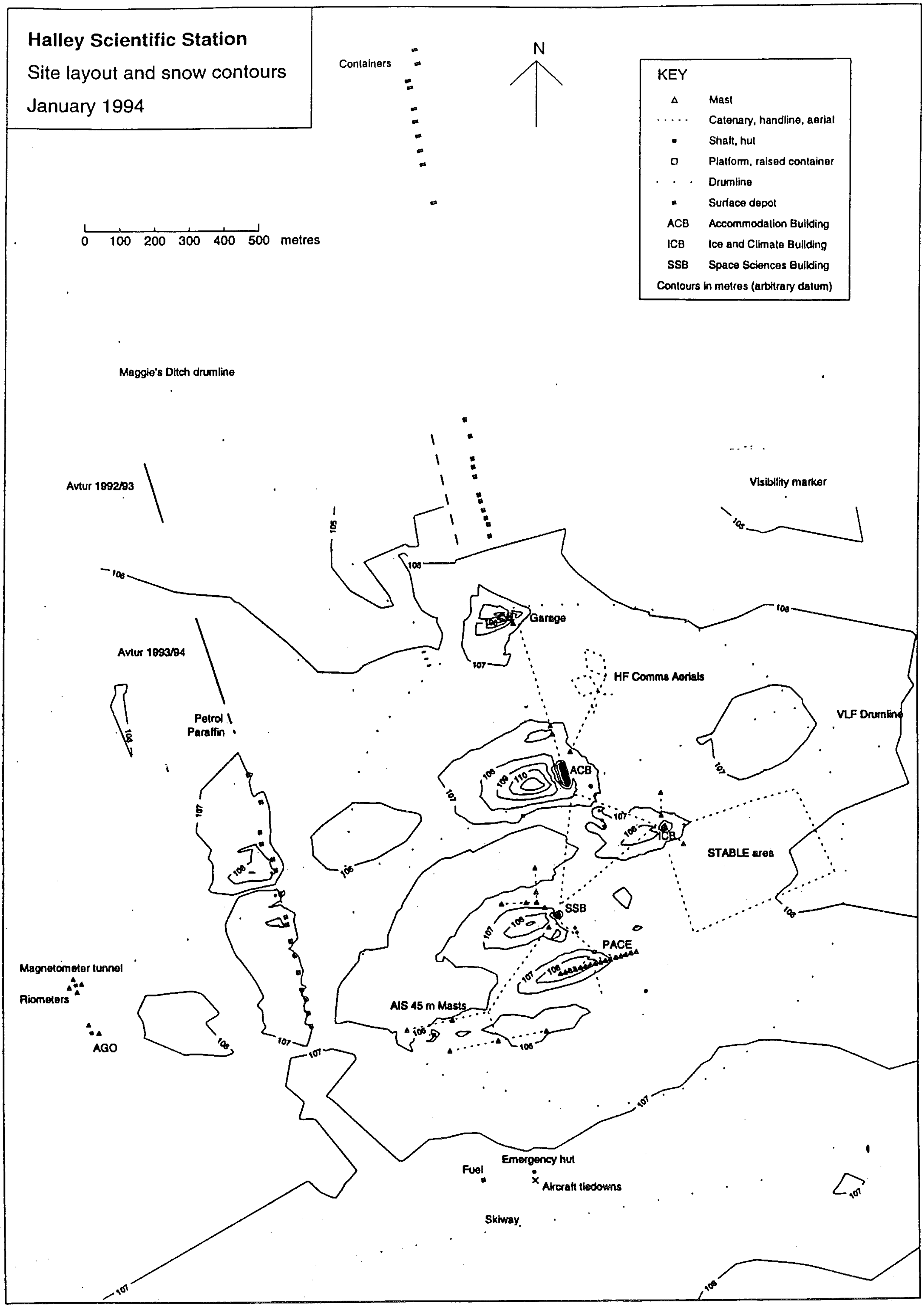
GARAGE/WORKSHOP IMMEDIATELY AFTER CONSTRUCTION FEBRUARY 1993



INTERNAL VIEW OF GARAGE/WORKSHOP LOOKING FROM MAIN DOOR TO MEZZANINE FLOOR STORAGE AREA



INTERNAL VIEW OF GARAGE/WORKSHOP LOOKING FROM MEZZANINE FLOOR TO MAIN DOOR



Halley Scientific Station
Site layout and snow contours
January 1994
Containers
N
KEY
Mast
Catenary, handline, aerial
Shaft, hut
Platform, raised container
Drumline
Surface depot
ACB Accommodation Building
ICB Ice and Climate Building
SSB Space Sciences Building
Contours in metres (arbitrary datum)
0 100 200 300 400 500 metres
Maggie's Ditch drumline
Avtur 1992/93
Avtur 1993/94
Visibility marker
Garage
HF Comms Aerials
VLF Drumline
Petrol
Paraffin
ACB
ICB
STABLE area
SSB
PACE
Magnetometer tunnel
Riometers
AGO
AIS 45 m Masts
Emergency hut
Fuel
Aircraft tiedowns
Skiway

WASTE MANAGEMENT CONCEPT AT THE GERMAN WINTER STATION NEUMAYER

S. el Naggar, S. Schoppe, Germany

1. Introduction

This lecture intends to introduce the Waste Management Concept at the German Winter Station Neumayer. It will be shown how the requirements and recommendations of the Protocol on Environmental Protection to the Antarctic Treaty have been adopted and how they have been realised.

First it will be gone into the Protocol on Environmental Protection, then the Neumayer Station will be introduced. In the main part the measures being carried out before, during and after the season to fulfil the Protocol on Environmental Protection are shown.

2. The Protocol on Environmental Protection

In October 1991 the Treaty Parties signed the Protocol on Environmental Protection. They came to an understanding to protect the Antarctic Environment and the dependent ecosystems. In Annex III they decided to reduce the amount of waste and to remove the waste from Antarctica. It was also decided to dispose of the waste in the countries of origin or in countries that signed international agreements like the Basel Convention.

Germany is carrying out the waste management at Neumayer according to these guidelines.

3. Neumayer Station

Neumayer Station is the German overwintering station in Antarctica.
Neumayer Station followed the old Georg-von-Neumayer Station. It was built in the summer season 1992. The activities of the old station are continued at Neumayer. It is operating as an observatory for geophysics, meteorology, and air chemistry, and it is also a logistical base for summer expeditions.

3.1. Location

The Station is located on the Ekström Ice Shelf, position 70°39'S, 08°15'W in the north-western Wedell Sea. There the ice shelf has a thickness of about 200 meters. Supply vessels moor at the ice edge which is approximately 8 kilometres away from the station.

3.2. Construction

Except of the garage the entire station is situated under the snow.
Neumayer Station consists of two parallel steel tubes, each one 90 metres long and 8 metres in diameter. In these tubes containers are inserted to accommodate living quarters, pantry, kitchen, hospital, laboratories, workshop, radio operator's room, sanitation, two energy supply stations, a central control for the wind energy plant, and a snow melting plant. That means at present 53 20 feet containers and one 10 feet container are built in. The installation of a sewage treatment plant in the season 95/96 will raise this number up to 54 20 feet containers.
A transverse tube contains storage rooms for supply, waste containers, and tank containers as well as space for vehicles. A tunnel connects the main station with a garage for all types of vehicles.

3.3. Energy supply

Energy for the station is provided by two 90 kW diesel generators. The use of the waste heat of the diesel generators for heating and melting snow and a 20 kW wind generator contribute to an ecologically beneficial energy supply. The diesel generators are equipped with catalytic converters to reduce the exhaust emissions. The waste heat becomes utilizable by a 95kW cooling water heat exchanger and a 30 kW waste heat-exchanger. At present just about 33kW are used in summer-time to operate the station and approximately 112kW in winter-time. That is why we want to use the remaining waste heat to operate new devices.

4. The Waste Management Concept at Neumayer

4.1. Measures taken in advance to avoid rubbish

Already at the planning stage of a supply of the station the environmental digestibility of the products and their packaging is taken into account.

4.1.1. Influence of the choice of products on the environmental digestibility

Knowledge about the ingredients or components of the goods is of considerable importance. The relation between the utility value and the ingredients or components is checked, and the data of the different alternative products are compared with each other. This way the most environment-friendly products that match all the requirements can be ascertained.

1. Technical resources

Most of the fuel is used to drive the vehicles and to run the diesel generators for energy production.

Already since 1988 the ski-doos are operated on unleaded fuel.

At present the possibilities to run the generators with sulphur-reduced diesel, containing 0.05 weight% sulphur instead of the actual 0.3 weight%, are checked. A kerosene content of 40 % would lead to a reduction of sulphurdioxide in the exhaust fumes by 50 % to approximately 450 kg per year.

The paints used at the Neumayer Station do not contain any unhealthy heavy metals. The spray paint in use is based on 80 % of solvent, but it is tested if this can be replaced by other material for use with brush, which has a much lower content of solvent. In places that are difficult to reach, this paint could be sprayed with an airless spraying device. Since it contains just 35 % of solvent, the release of solvent into the air can be greatly reduced. Water-soluble paint, which is by far the environmental-friendliest, cannot be used in Antarctica because a minimum temperature of +5°C must be given while painting it.

2. Detergents and cleaning agents

Depending on the manufacturer the detergents and cleaning agents may contain ingredients that differ in their environmental relevance. In order to use detergents in an ecologically desirable way the following was taken into account:

A modular principle is brought into action, built up by the basic detergent, a water softener, and a stain remover. This way the user is enabled to fit the composition of the detergent to the particular requirements. The basic detergent is done without colour intensifier, enzymes and filler. It is a powder with a high content of surface active agents. The dose of the water softener is measured out according to the water hardness at Neumayer. Stain remover is only used when the washing is very dirty. This modular detergent system is almost completely biologically degradable. There are no fabric softeners in use, since they are not necessary and hence would be needless environmental pollution.

Cleaning agents used at Neumayer Station are not allowed to contain any chlorine- or phosphate-compounds. They must be biologically degradable and be offered in environment-friendly packaging. All in all this keeps the environmental impact on the lowest possible level.

3. Foodstuffs

The ingredients generally are not important regarding the environmental digestibility. But it is taken into account that the packaging does not exceed an adequate standard.

4.1.2. Influence of the packaging on the environmental digestibility

The subjects 'material' and 'weight and volume' are of importance when looking at possible environmental impacts caused by packaging.

1. Material

The packaging should be reusable or at least should it be possible to recycle the material. If both is not possible material should be chosen that causes the lowest possible impact.

Reusable are mainly glass, metal, paper and plastic. When selecting packaging material, mixtures are avoided. This way and by sorting the waste at Neumayer even non-returnable packages can be supplied to recycling processes.

Polyvinyl-chloride is avoided wherever possible because of its environmental hazardous character when incinerated.

2. Weight and volume

The subjects are relevant concerning the environment, because they are mainly determining the use of the means of transport. A reduction of weight and volume directly results in a reduction of transport expenditure on the way to and fro Antarctica.

Also the fuel consumption for the tractors in Antarctica is reduced, in consequence the emissions are fewer, so there is less pressure put on the environment.

The following measures are taken by the AWI:

Reusable packagings are favoured instead of non-returnable material, thus reducing the amount of waste. Wrappings are avoided (e.g. folding boxes around tubes of toothpaste) and replaced by larger units. Detergents and cleaning agents are bought as concentrates in refilling packages, in order to reduce volume and weight.

Heavy packaging materials like glass have been replaced by lighter ones like plastic. This possibility is mainly used in connection with foods. For example vegetables had been purchased in tins and glasses, but are replaced by frozen vegetables which are packed in plastic bags. Ready-to-serve products in tins are now bought in tetrabricks and parts of the beverages are delivered in polypropylene tubes.

Since 1993 the AWI is using another system to transport goods to Antarctica. They are stacked on a thin carton. Packaging films are replaced by elastic tape. For that reason pallets and films are not used any more.

4.2. Waste Management at Neumayer during the season

4.2.1. Treatment of domestic waste

Waste is not burnt open or in ovens at the German Antarctic stations. Domestic waste is collected and sorted in classes. These classes are: paper, synthetic material, glass, metal, and other waste.

On summer expeditions having Neumayer as logistical base, the waste is collected and sorted like at the Neumayer Station. It is disposed of together with the waste of Neumayer after the season.

To reduce the volume of the waste of Neumayer onto a minimum a hydraulic press compacts it onto 1/3 to 1/5 of its initial volume. It is stowed in a container and once a year it is taken out of Antarctica.

4.2.2. Treatment of non-domestic waste

Also the non-domestic waste is removed from the Antarctic. Non-domestic waste are radioactive materials, used batteries, waste oil, any waste containing rubber, oil or heavy metals, photo chemicals, etc. These materials are stowed in suitable containers which are removed every year.

4.2.3. Cleaning of exhaust gas

To protect the environment against noxious substances the amount of stack pollutants has been reduced. The exhaust gas of the two diesel generators is cleaned by catalytic converters. Their efficiency is 98% for carbon monoxide, 70% for hydrocarbons, and 30% for aldehyds. The black smoke value is reduced by 30%.

4.2.4. Purification of waste water

During the season 1995/96 a sewage treatment plant will be installed at Neumayer Station. This plant is designed in a way that it only requires electric energy and heat energy of the station to be able to clarify the waste water. The basic idea during the development of the concept was to create an autarkic system except of the energy supply.

This system also should demand low maintenance and an easy-to-use operation.

Below the results are shown in detail:

The waste water of the entire station is purified biologically. In addition a sludge treatment is carried out, enabling us to remove even the arising sludge from Antarctica.

The entire system of waste water and sludge treatment is installed in a 20 ft container. The container is fed with electric energy of 380 V, 50Hz and 220 V, 50Hz. The waste heat of the diesel generators is used to keep the container at a temperature of +15°C and to dry the sludge.

The sewage is collected in a level regulated tank. This tank is situated under the container for water generation. It is used for mixing the different waste waters and to even out peak times of waste water inflow. From that tank water will be turned out by a screw-spindle pump through a pipe to the sewage treatment plant over a distance of about 60m. There the sewage is purified in a biological process. Then the clarified water is sterilized by UV-rays and pumped through a pipe to the dump in the shelf ice which is located approximately 100m away from the station. Chlorine is not used for sterilizing the purified water in order to keep the environmental impact at the lowermost level.

The cleaning capacity of the sewage treatment plant meets the requirements of the US Coast Guard, and the Canadian Coast Guard. The plant is also accepted by the Russian Register and the German 'Seeberufsgenossenschaft'.

The dewatering system for the sludge concists of the reaction tank and a filter module equipped with two separate inlets. Arising surplus sludge with a dry substance of about 2% will be drawn off periodically and pumped into the reaction tank where it is sterilised by adding hydrated lime. After admixing of a flocculation powder the surplus sludge will be thickend and then dewatered in semipermeable drainbags. The draining water will be collected and led to the inlet of the sewage treatment plant. During the dewatering of the sludge vitiated air is arising. It is led directly out of the container by a fan. After the drainbags have dewatered for about 24 h they have a dry substance of approximately 18%. They are dried in a drying chamber that is heated to +35°C by using the waste heat of the diesel generators. Resulting from this step of treatment the sludge has a dry substance of 40%. Now it is inodorous and has storage stability.

The sludge containing the solid residues of the purification process is removed from Antarctica.

Finally some technical details should be mentioned:

The container with all devices has a weight of approximately 7to. In operation it has a weight of about 8to. due to the waste water in the sewage treatment plant. To reduce the weight of the container the steel tank of the sewage treatment plant has been replaced by a more lightweight PE tank.

The entire system has an electric terminal power input of about 7 kW. Taking account of the diversity factor it takes approximately 3 kW.

The entire system gets its heating load out of the hot water supply of the Neumayer Station which is heated by the cooling water and the vitiated air of the diesel generators. The heat-exchanger only takes a special amount of heat because the back flow of the heat-exchanger mustn't be colder than 50°C. Otherwise the diesel generators might be damaged by cooling water having a temperature lower than permitted.

4.3. Disposal of waste

Once a year the Neumayer Station is supplied by a vessel. At this time the waste is brought to the ship. The waste is disposed of in South Africa by a licensed company according to the requirements of the Basel Convention.

4.4. Future

Also in future it will be our goal to put the best available technology into action. At the moment tests are made to replace mineral oils by ester-type oils. These oils are more easily biologically degradable and consequently they are environment-friendlier.
But the use of the ester-type oils requires a technical change-over of the vehicles. For example the ester-type oils diffuse more easily, for which reason they necessitate special tubes. As soon as the tests are completed and if the margin of safety is high enough, tests will be made at Neumayer Station to gain experience.
Alternative energy will get a higher importance. It is considered wether to install a second wind energy plant. This would further reduce the fuel consumption and in consequence the amount of arising emissions.

5. Conclusion

The lecture should show how a Waste Management Concept has been realised at the German Winter Station Neumayer.
Already when preparing for a season all kind of rubbish is avoided. Extensive packaging is avoided and heavy packing materials are replaced by more lightweight ones. A special method that does not need pallets and films is used to transport the goods to Antarctica.

All year round all waste is collected and once a year removed from Antarctica. No waste is burnt. The emissions of the exhaust gas of the diesel generators are reduced by catalytic converters.

In 1995/96 a sewage treatment plant will be installed. All solid residues of the process will be removed from Antarctica. With further developments and their application, like using ester-type oils and establishing alternative energy for example in the form of wind energy, it will be possible to minimize the human impact and thus cope with the requirements of the Protocol to the Antarctic Treaty.

THE POTENTIAL FOR INTEGRATED WASTE MANAGEMENT IN THE UNITED STATES ANTARCTIC PROGRAM AS A MODEL

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INTRODUCTION

The United States Antarctic Program (USAP) approach to waste management has recently been challenged by logistical limitations, new environmental regulations, and a renewed commitment to environmental protection. The fundamental response of the USAP to these challenges can be used as a model by industries and communities alike.

In 1991 the USAP elected to cease open burning of trash and to begin much more conscientious efforts to protect the Antarctic environment. In 1992, the USAP committed to cease the interim practice of incineration and to base waste management on 100 per cent removal of wastes from the continent. Although this approach is environmentally sound, it confronted the USAP with a dilemma. Wastes from past operations combined with the annual volume was estimated to exceed the capacity of mechanisms to remove and return the wastes to the United States. With plans for additional environmental restoration efforts and facility restoration, the generation of associated debris would continue to threaten the USAP's ability to remove all wastes. In addition, acceptance of Antarctic wastes into the U.S. requires significantly more thorough segregation and classification of waste than routinely practiced. Responding to these challenges, the USAP developed one of the most aggressive waste management programs in the world. Concurrent with developing the practical aspects of this program, the USAP began to gain unique insight intc the weaknesses and flaws common to most U.S. based waste management programs. Unlike the U.S. programs, the USAP has realized that effective waste management must be founded on the principal of self-sufficiency. This understanding drives the fundamentals of the USAP waste management program and is the foundation of the model concept.

THE EVOLUTION OF WASTE MANAGEMENT

Waste management in the U.S. has been traditionally defined as prudent disposition of waste. Rarely, did the concept of prudence extend beyond the short term. As such, early waste management practices did not include controlling waste generation mechanisms nor management of waste sources. Since land was plentiful and inexpensive, waste management meant land disposal. This approach was practiced both by industries as well as communities. This era of waste management was fundamentally a linear concept; raw materials in, product and waste out. No consideration was given to the ultimate site of disposition nor to the long term impacts. This myopic approach led to the environmental catastrophes of the 1960's and to the implementation of the environmental regulations in the 1970's.

Industrial Waste Management

The first regulatory controls placed on industry were based on treatment technology performance standards. The National Pollutant Discharge Elimination System (NPDES) implemented under the Clean Water Act defined acceptable industrial pollutant discharge standards based on the performance of existing, readily available treatment technologies. Industry was compelled to install designated or equivalent treatment technologies to achieve mandated effluent limitations. This strategy was based on the presumption that competition would lead to ever better technologies that would eventually lead to "zero discharge" of water-borne wastes. Beyond the requirement to use defined or equivalent treatment technologies, industry had no incentives nor inducements to reduce discharge limits or waste amounts further.

The Resource Conservation Recovery Act regulations initially took a slightly different tact. Hazardous waste was defined by source, by chemical characteristic, and by health-based hazards. Treatment of hazardous wastes to render them less hazardous offered essentially no regulatory relief. RCRA stipulated that once a waste was determined to be hazardous it was to remain classified as such unless "delisted". The delisting process was perceived as a costly gamble and was not commonly pursued. The prevailing waste management strategy reverted to disposal rather than reduction. Soon, approved landfills were reaching capacity. With such environmental disasters as New York's "Love Canal" and Kentucky's "Valley of the Drums", the public resistance to landfill siting approached militancy.

Amendments to RCRA were responsive to this critical shortage of landfill space. Land disposal restrictions were imposed. Land disposal of specified wastes was banned unless such wastes were treated by a particular specified technology. This ban, and the associated economic burden of treatment, finally led industry to examine waste management alternatives. Industry began to investigate ways of eliminating or greatly reducing the volume and type of waste generated. Regulatory incentives seemed to be having an effect on waste generation, but the waste disposal sites of the past were taking their toll on the environment.

The Comprehensive Environmental Restoration and Liability Act or, Superfund, placed liability for the clean up of disposal sites deemed to be posing unacceptable environmental risk. This liability was placed squarely on those contributing wastes to such sites. The fear of implication in a Superfund action was ample motivation to further reduce or eliminate wastes, or to render them legally non-hazardous prior to disposal.

Recently drafted EPA regulations specify that voluntary waste reduction programs be implemented by American industry; mandatory programs are sure to follow. These regulations place even greater emphasis on substituting new materials for the traditional and more hazardous materials. Means of recovering raw materials, improving the efficiency of manufacturing processes, or development of new manufacturing processes are now routinely investigated by industry. Often these alternatives are proving to be more economically desirable when life-cycle costs and environmental risks are considered.

These regulatory mandates work effectively on industry since compliance made certain economic sense. Additionally, once a management strategy is developed, the autonomous nature of industry management assures its rapid implementation and universal worker compliance. Still, much of industrial waste management is based on the linear concept. Waste generation may be reduced to the practicable minimum, but that which is generated is hauled away by the lowest bidder.

In combination, regulatory, economic, and public awareness forces have overcome traditional tendencies and significant evolution in waste management has occurred. To a large extent these inducements have caused some industries to develop a more holistic approach to waste management; waste minimization and the commitment to alternative treatment technology development has taken hold.

Community Waste Management

Waste management at the community level in the U.S. has been less of a target of regulatory controls. After the Clean Water Act regulated the uniform upgrade of municipal sewage treatment across the nation, little regulatory pressure was placed on communities. Early legal actions implicating municipalities in CERCLA cleanup did result in some re-evaluation of community waste management strategies and, to some extent, have led to somewhat more environmentally sound alternatives to traditional dumping. New U.S. EPA standards for solid waste landfills do reduce the potential for long lasting environmental impacts of this traditional mode of waste disposal. At the same time however, municipal waste incineration is met with resistance similar to that waged against hazardous waste incineration. Environmental activists have taken aim at municipal and hazardous waste incinerators and have incited the "not in my back yard" syndrome of public response. It would appear that this protectionism has become accepted policy by many state governments. Many states have taken up legal arms to combat the importation of wastes from neighboring states protecting their precious few landfills. California has chosen to impose waste disposal regulations significantly more stringent than the Federal regulations discouraging much needed industrial development and interstate commerce. These signs of the times would appear to indicate that there is no consistent public policy or government direction being developed to address solid waste management. These actions are short-sighted and perpetuate the linear concept of waste management at the community level: consumer commodities and infrastructure supplies come into the community, wastes are transported out.

The USAP has learned that much of the bulk of traditional waste can be converted to commodities. Often these commodities can be utilized locally, or could be sold for profit. Communities continue to contract with third party disposal services and fail to realize any direct economic benefit. Typically, the third party disposal firm has every economic incentive to dispose of wastes in the least technological manner; landfilling. Communities rarely use the contractual mechanism to establish a more aggressive waste recycling program, although the USAP has demonstrated that this is a viable mechanism to influence waste disposition. This traditional, linear system is repeated throughout the U.S.; wastes from communities are transported away from the generators to a location out of sight of the generating community. Unfortunately, these sites are becoming scarce, opportunities to capture resources are lost, and natural resources are being depleted to feed this linear behavior.

THE UNITED STATES ANTARCTIC PROGRAM WASTE MANAGEMENT

The United States Antarctic Program (USAP) is subject to Antarctic Conservation Act regulatory requirements that are unprecedented in the depth and scope in controlling materials and wastes generated by their use. The USAP also is confronted with logistical constraints that play a major role in the control of materials going to Antarctica and the ability to remove wastes generated. Finally, the USAP holds itself to standards of environmental care that are higher than commonly practiced in the United States because it operates on the principle of preservation rather than conservation.

These requirements, constraints, and standards have led the USAP to develop "wide-angle" vision when alternatives to waste management are evaluated. The USAP examines management, administrative, as well as technological alternatives from the perspective of broad-based integration into a comprehensive waste management program. The USAP has recently integrated waste minimization practices, maximum segregation of wastes, and has directed the waste management subcontractor to conduct disposal in manners that take aim at controlling incoming materials, reducing the amount of waste produced and encouraging the optimum reuse of the waste generated.

The next evolution of the USAP waste management program is to integrate measures to attain a more self-sufficient posture. This goal is driven most immediately by logistical and economic considerations but beyond that, is grounded in the less tangible benefits of image and public and legislative confidence.

WASTE MINIMIZATION

To fully appreciate the potential for USAP self-sufficiency, it is essential to understand all aspects of the waste minimization efforts being taken. The technologies being considered are but a single facet of the overall management undertaking. In the purest academic application of waste minimization methodology, turning to technological solutions to solve waste problems takes place only after all other waste minimization alternatives are exhausted. For the USAP, these efforts are taking place simultaneously because wastes amenable to treatment have been shown to be necessary and unavoidable byproducts of USAP. Although the volume of such wastes may be reduced in the future by aggressive waste minimization it is unlikely that they will ever be altogether eliminated.

A typical application of a formal waste minimization program encompasses two pathways. The first of these pathways is the investigation into methods of waste reduction. Waste reduction opportunities generally fall into three categories: management controls, source controls, and engineering controls. Within each of these categories are various measures that can be taken resulting in waste reduction. Management controls consist of conservation, improved housekeeping, training and awareness, and prevention of spills. The USAP also has policy making abilities that represent a unique management control.

The second pathway of waste minimization is recycling and reuse. This pathway includes investigation of the potential to indirectly reuse, directly reuse, recycle onsite, and to recycle offsite.

WASTE MINIMIZATION STRATEGY

MANAGEMENT CONTROLS
- Conservation
- Improved Housekeeping
- Training and Awareness
- Spill Prevention

PROCESS CONTROLS
- Substitution
- Dilution
- Elimination
- Segregation

ENGINEERING CONTROLS
- Process Changes
- Reconfiguration
- Automation
- Treatment

REUSE/RECYCLING
- On-site
- Off-site

Industries can and do implement many of the waste reduction measures because the inherent autonomous controls needed to carry out such measures exist within most industrial management structures. The direct benefit to industry is immediate economic relief; directly in operational cost savings, and indirectly in savings realized from regulatory relief. However, it is not atypical to see industries turn to engineering solutions and fail to investigate management and source controls, particularly in manufacturing operations where engineering is the predominant discipline within the organizations.

Both pathways; waste reduction and recycling/reuse are also applicable to communities, but are rarely pursued on a systematic basis by communities. Within a community level government itself many of the controls are implemented, but oddly are not applied nor promoted within the governed community itself. This failure to apply fundamental principles of waste minimization at community levels is a manifestation of how a community defines itself in the linear and amorphous terms earlier described.

Being an isolated community, confronted with economic and logistical considerations, and having a direct managerial and cultural influence on its populous, the USAP is viewed in different terms than typical communities. Importation of raw materials and exportation of wastes are controlled, measured, and managed. This control, measurement, and management is possible largely because of that isolation. But it is becoming apparent that the recognition, the realization, of the USAP as a closed community is the first lesson that can be transferred to U.S. communities.

MANAGEMENT AND PROCESS CONTROLS WITHIN THE USAP

Until recently, management and process controls within the USAP have been largely reactive and informal in nature. Procedures for waste handling at the generator level was left largely to the generator. Little or no specific guidance beyond general population instruction was provided to address the unique circumstances of individual points of generation. Recently specific technical guidance, technical assistance, and educational programs have been implemented specifically to educate and place specific responsibilities at the generator level.

A major management control that has also been instrumental in optimizing waste reuse, recycling, is the contract with the U.S. waste management contractor. The specifications for this contract require that the waste management contractor identify and utilize alternative disposition rather than traditional disposal. This approach has resulted in achieving 71% recycle, reuse, or treatment of hazardous waste and 76% in solid waste recycling.

Conservation

Historical programs of conservation of water, fuel, and electrical energy have a direct translation in waste amounts produced by electric power generators and engines, and reduce the amount of domestic waste discharged to the environment.

Conservation of commodity items has its foundation in sound inventory control. This control maximizes utilization of in-stock overages and minimizes spoilage and product expiration. With the implementation of a USAP computerized material purchasing and tracking system this aspect of the fundamental mechanism to conserve raw materials is in place. Engineering new and replacement facilities utilizing modular components constructed within the United States has significantly

ANNUAL RECYCLING, REUSE, AND TREATMENT WITHIN THE USAP

SOLID WASTES	
Total waste (est.)	1629 METRIC TONS
Reused, Recycled	1235 METRIC TONS
% Reused, Recycled	76
HAZARDOUS WASTES	
Total Waste (est.)	483 METRIC TONS
Reused, Recycled, Treated	342 METRIC TONS
% Reused, Recycled	71

reduced the on-site generation of construction related waste materials and conserves the base inventory of lumber, sheetrock, paints as well as other related commodities.

Improved Housekeeping

Waste classes have been redefined recently to reflect U.S. waste disposition opportunities related to recycling, reuse, treatment, and finally, as a last resort, disposal. Containerization and accumulation is now formally addressed and weekly inspections of accumulation areas are being performed. Corrective actions to noted deficiencies include providing additional and more appropriate waste collection receptacles and re-training and orientation. Data collection has been improved at the point of generation and accumulation to provide quantitative information with which waste minimization opportunities can be evaluated.

SOLID WASTE DISPOSITION
U.S. vs USAP

	Recycle	Incinerate	Landfill
Alabama	12%	8%	80%
Alaska	6	15	79
Arizona	7	0	93
Arkansas	10	5	85
California	11	2	86
Colorado	26	1	73
Connecticut	10	67	24
Delaware	16	19	65
D.C.	30	59	11
Florida	27	23	49
Georgia	12	3	85
Hawaii	4	42	54
Idaho	10	0	90
Illinois	11	2	87
Indiana	8	17	75
Iowa	23	2	75
Kansas	5	0	95
Kentucky	15	0	85
Louisiana	10	0	90
Maine	30	37	33
Maryland	15	17	68
Mass.	30	47	23
Michigan	26	17	57
Minnesota	38	35	27
Miss.	8	3	89
Missouri	13%	0%	87%
Montana	5	2	93
Nebraska	10	0	90
Nevada	10	0	90
N. H.	10	26	64
N. J.	34	21	45
N. Mexico	6	0	94
New York	21	17	62
N. C.	4	1	95
N. Dakota	17	0	83
Ohio	19	6	75
Oklahoma	10	8	82
Oregon	23	6	71
Penns.	11	30	59
R.I.	15	0	85
S. C.	10	5	85
S. Dakota	10	0	90
Tenn.	10	8	82
Texas	11	1	88
Utah	13	7	80
Vermont	25	3	72
Virginia	24	18	58
Wash.	33	2	65
W. V.	10	0	90
Wisconsin	24	4	72
Wyoming	4	0	96

	Recycle	Incinerate	Landfill
U.S. Average	16	11	73
USAP 93/94	71	11	18
USAP (future)	61	17	22

Source: 1993 Environmental Almanac, Compiled by World Resources Institute

Training and Awareness

Educational and orientation programs have been developed and implemented stressing the need for USAP participant involvement in source reduction, adherence to waste segregation rules; providing an overview of waste management initiatives; and providing specific guidance on waste reduction methods and techniques. Mandatory orientation of all USAP participants, specialized supervisory training, and on-call technical assistance are now integral to the management approach to attain participant compliance with formal waste management procedures. Personnel assigned to waste management received specialized training and are certified in accordance with appropriate U.S. regulations.

Spill Prevention

Fuel and hazardous material spill controls are being systematically implemented; new bulk tanks incorporate secondary containment or double walled vessels. Refueling and fuel transfer are being conducted more frequently on containment structures. This coupled with increased awareness training has reduced releases to the environment caused by human error or neglect. Improvements to fuel distribution infrastructure are occurring; new tank installations specify hard welded joints rather than gasketed flange connections and system upgrades are being considered.

Substitution

Opportunities for substitution of materials to reduce the environmental impacts of inadvertent releases has focussed largely on coolants and heat exchange fluids. It is estimated that the USAP generates upwards of 113,550 liters (30,000 gallons) annually of ethylene glycol for vehicle coolant and heating system fluids.

No reliable estimates of the total volume of ethylene glycol in use is available but engineering estimates place the figure at 75,700 liters (20,000 gallons) used as vehicle coolants and 37,850 liters (10,000 gallons) used in facility heating systems. USAP has currently launched systematic replacement of all ethylene glycol with the significantly less toxic propylene glycol.

Of all of the solid waste streams generated by the USAP, wood has been the most significant to bring under manageable control. It is estimated that the USAP generates some 816.3 metric tons (900 U.S. tons) of wood scrap and discarded boxes and pallets annually. This wood waste has built up over the recent past to result in an estimated 1905 metric tons (2100 U.S. ton) backlog. Efforts are underway to bring this waste under control; existing wood waste will be ground to smaller fragments to facilitate return to the U.S. Additionally, boxes, pallets, and crates are being recycled to minimize further construction of these shipping supplies. Testing has confirmed the applicability of wood wastes as a fuel in the U.S. once metals are magnetically removed. These procedures will likely result in managing this waste in the future but will not significantly impact the resource intensive reliance on wood packaging.

Conversion to alternative packaging and crating materials is seen as the most effective means of minimizing the overall wood waste. Worldwide concern over forest depletion has spurned availability of alternatives for wood and wood products. With the non-critical nature of the majority of the USAP's wood requirements, these alternatives appear to offer a viable solution. Plastic "lumber", collapsible plastic crates and boxes, and air bladder dunnage are all being investigated as substitutes for non-critical wood usage.

An estimated 0.9 to 2.7 metric tons (1 to 3 U.S. tons) of non-rechargeable consumer batteries are generated annually by USAP participants, largely in personal appliances such as radios, CD players and cassette tape players. The major portion of these batteries are alkaline type. Currently the predominant disposition technique practiced in the U.S. is landfilling. Although, economically and logistically insignificant when taken in the context of overall waste, cost effective alternatives do exist which would essentially eliminate USAP battery landfilling.

A program to provide battery rechargers to USAP participants coupled with discouraging, if not banning, the use of alkaline batteries is scheduled for implementation. This program would reduce battery disposal and would limit those batteries being disposed in the USAP to nickel-cadmium type. Nickel-cadmium type batteries that are disposed at USAP facilities would then be recycled by existing U.S. industry.

Dilution

Recently the USAP has initiated procedures to facilitate the reuse of waste oils as supplement to virgin fuel. Once fully implemented, this program will augment fuel supply by an additional 113,550 to 151,400 liters (30,000 to 40,000 gallons) annually. In addition to the annual cost deferment of virgin fuel purchase, this program realizes a $50,000 to $70,000 (U.S.) savings in waste oil disposal costs.

Non-chlorinated waste solvents such as ethanol and methanol are also being considered for inclusion in this program to further augment fuel supply and to offset fuel and disposal costs and to eliminate the environmental risks associated with handling, storage, and transportation.

Elimination

The USAP has incorporated into the ACA regulations provisions to empower the Administrator the authority to ban additional substances from use in Antarctica. This authority clearly represents the most aggressive management control available to the USAP to eliminate tenacious materials. At this stage of waste management and environmental control programs this authority has not been exercised. As more data are gathered and analyzed and as more knowledge of waste disposition difficulties are gained, it is anticipated that this option will become a meaningful management tool.

Segregation

The USAP waste management program currently specifies some 60 various standard categories and numerous subcategories to waste segregation. These segregation categories have been established for two principal reasons: 1) to optimize recycling, reuse, and treatment opportunities, 2) to allow for the accurate data tracking for required reporting and for the conduct of critical analysis in evaluating waste minimization opportunities.

The identification and implementation of management controls is gaining significant momentum; a recently developed document, "Source Reduction Plan" delineates in detail many additional programs, procedures, and measures that are at various stages of implementation beyond that which has been alluded to herein.

ENGINEERING CONTROLS AND RECYCLING AND REUSE WITHIN THE USAP

McMurdo Station, being the largest waste generator of the USAP and currently a conduit for most USAP waste retrograde, has become the principal focus of waste minimization efforts. This initial attention to McMurdo has rapidly led to the identification of certain wastes that are inherent to essential operations and activities. Taken collectively, the volume of these wastes amount to a massive logistical burden when retrograde to the United States is undertaken. This burden is approaching the level of overtaxing the transportation system, specifically, vessel capacity.

To address this growing problem, an array of engineering controls are being defined and investigated for integration into the overall waste management and minimization strategy. In more traditional applications, engineering controls apply to enhancement of manufacturing operations through upgrades to the process equipment, reconfiguration of processing equipment to reduce waste generation, automation to implement tighter controls thus reducing wasting, and installation of treatment technologies to render the wastes less hazardous, reduce the waste volume, or to render the wastes amenable to recycling and reuse.

Within the USAP, opportunities for beneficial engineering controls are generally restricted to treatment technologies or processing strategies. These technologies and strategies are being considered in the context of the concept of evolutionary implementation: first order technologies are those readily transferable to the USAP from proven analogous applications with little innovation or testing being required. These technologies and processing strategies will likely be implemented based on the clear economic advantages they offer as well as the alteration of the nature of certain wastes or reduction of the quantity of particular wastes.

The second order alternatives are more innovative technologies or are innovative applications of existing treatment technologies or processing strategies. The implementation of these technologies and processes are driven by the desire to realize program image, environmental, and logistical benefits. Collectively, they also represent a unique waste management infrastructure reinforcing the philosophy of maximized self-sufficiency. The realization of the second order technologies or processing strategies will require testing and evaluation and must be predicated on a sound and clear commitment.

The initial, or first order, technologies and processing strategies are being examined with a focus on compatibility, integration potential to advance the degree of self-sufficiency of the USAP. The goals of the application of these strategies is to meet multiple objectives of the following:

- Treatment or processing of wastes to alleviate the immediate burden on waste retrograde infrastructure
- Minimized environmental impacts of intentional or inadvertent release
- Deferment of U.S. based waste disposition costs
- Realization of operational benefits of recycling or reuse on station (realizing secondary economic benefits)
- Enhancing the recycling and reuse of waste materials once retrograded to the U.S.
- Co-processing of currently segregated wastes with one technology reducing manpower allocation, and simplifying accounting and logistical complexity of waste management associated with U.S. based disposition
- Posturing the USAP as a model of waste management strategy

The goal of the evaluation of the second order treatment and processing strategies is to further advance USAP self-sufficiency. The second order technologies and processes are inherently more advanced, affirm a bold and aggressive policy of applied science research as an integral component of the USAP mission, and truly advance McMurdo Station as a test bed and model of technology integration. The second order technologies are also driven less on the economic benefits and focuses more intently on environmental and aesthetic benefits.

The waste management strategy initiated during 1993/94 has facilitated the capture of highly accurate data on the amounts, sources, and types of wastes generated by the USAP. Additionally, specific unit costs of U.S. waste disposition allows for critical economic evaluation of many candidate treatment technologies and processing strategies. Through analysis of this data, the following waste streams have been identified as being amenable to first generation alternatives.

TARGET WASTES FOR FIRST ORDER ENGINEERING CONTROLS

The USAP has identified six waste streams amenable to immediately available processing equipment that would render these wastes directly reusable, recyclable, rendered hon-hazardous. The sum weight of these six streams is approximately 363 metric tons (400 U.S. tons) annually; roughly 17 per cent by weight of the entire waste lot generated annually. Current U.S. based disposition practices result in a cost $445,000 (U.S.) or 37% of the total expense of U.S. based waste disposition.

Used Lubricating Oil

Used lubricating oil is generated during the normal maintenance of power generating diesel generators; heavy internal combustion engines of construction and maintenance vehicles and equipment, light vehicles, aircraft, snow mobiles, and portable gas powered electric generators. Currently both petroleum based and synthetic lubricating oils are used throughout the USAP. Annually, these waste oils constitute some 45,420 liters (12,000 gallons) or an estimated 48 metric tons (53 U.S. tons). This waste oil has traditionally been retrograded to the U.S. to be used as fuel, or has been used by the supply vessel as fuel.

Petroleum Contaminated Soil

The current containment and distribution systems for fuels used at McMurdo based facilities, outlying support facilities (runways), and vehicles lacks in the controls and alarms necessary for the minimization or elimination of inadvertent releases and spills. Although the USAP has commenced installation of secondary containment, increased orientation and training of fuels personnel, and maintains an on-call spill response capability, equipment failure and human error results in the contamination of a highly variable amount of soils. 57 to 170 cubic meters (2000 to 6000 cubic feet) or 91 to 272 metric tons (100 to 300 U.S.tons) of petroleum contaminated soils annually. Current practices have been to retrograde this soil to the U.S. for treatment or disposal as a hazardous waste for an average annual cost of $122,000 to $366,000 (U.S.) annually.

Floor sweep compounds

Floor sweep compounds are clay or wood based absorbent materials used principally in the vehicle and snowmobile maintenance facilities. These materials typically are spread on floors or placed in containers to absorb spilled or drained oils and hydraulic fluids. Annually, some 14 to 23 metric tons (15 to 25 U.S. tons) of used floor sweep compound are generated costing upwards of $25,000 (U.S.) for U.S. based disposal as a hazardous waste.

Industrial use rags

Rags used in numerous industrial applications are generated by vehicle and facility maintenance personnel, painters, carpenters, and utility workers. Annual generation rate is approximately 9 to 14 metric tons (10 to 15 U.S. tons) costing $12,000 to $15,000 (U.S.) per year for U.S. disposal as a hazardous material. In most cases, rags are contaminated with oily residue, solvents and paints. The USAP has examined the use of discarded clothing as a source of these rags, but has determined the materials to be unsuitable for absorbency.

TARGET WASTE STREAMS

FIRST ORDER

- Used lubricating oils
- Petroleum contaminated soil
- Floor sweep compounds
- Industrial-use rags
- Medical and laboratory wastes
- Non-halogenated solvents

SECOND ORDER

- Food wastes (expired products and solid fraction)
- Dry combustible wastes (paper, light kraft, etc.)
- Domestic wastewater
- Wood
- Plastics

Medical and laboratory wastes

Medical and laboratory wastes comprise bandaging, packaging, syringes, tubing, disposable bed linens from medical infirmaries, syringes, pipettes, petri dishes and similar plastic and glassware, and laboratory bench top absorbent pads and other debris, and personal care products that have contacted bodily fluids. True medical wastes generated by medical infirmaries are regulated wastes in the U.S. since they are potential vectors for the spread of disease and viruses. Laboratory wastes are generally not regulated by U.S. regulation unless items come in known contact with infectious substances. Since no visual distinction can be made of these items from true medical wastes, all laboratory debris is treated as regulated medical wastes. The current practice is to dispose of 1.8 to 2.7 metric tons (2 to 3 U.S. tons) of this class of waste in U.S. based approved medical waste incinerators at an annual cost of $1,600 to $2,500 (U.S.).

Non-halogenated Solvents

Non-halogenated solvents such as ethanol and methanol are generally generated by science activities although occasional industrial uses are noted. These waste solvents constitute some 2.6 to 4.5 metric tons (4 to 5 U.S. tons) annually and cost $2,500 to $3,500 (U.S.) annually for U.S. based disposal, typically as a fuel additive. The USAP has examined the potential for redistillation of such solvents, but has determined limited reuse potential since recertification as "reagent grade" is not feasible.

TARGET WASTES FOR SECOND ORDER ENGINEERING CONTROLS

Analysis of annual waste types and amounts, and review of potentially applicable technology indicates that four of the target waste streams have the potential for treatment or processing in the future. These wastes represent 42 per cent of the total wastes and represent a total cost for disposal of $85,000 (U.S.) annually. The fifth waste stream for application of second order engineering controls is domestic wastewater. There are currently minimal costs associated with the disposition of domestic waste water, although in recent years several repairs to the sewer outfall and the supporting bulkhead (quay) have required repairs averaging $100,000 (U.S.) per repair evolution.

Food Waste (expired product and heavy fraction)

Foods waste subject to potential second order engineering controls comprise food scraps from food preparation, consumer reject, spoiled and expired food stock and produce, and cooking oils and lards. Some 68 to 136 metric tons (75 to 150 U.S. tons) are produced annually. U.S. regulatory options are limited to steam sterilization, incineration, introduction into municipal sewage treatment systems, or other specific options approved by U.S. health officials. In the recent past, the USAP has utilized steam sterilization prior to disposal in landfills at a cost rate of $0.27 (U.S.) per kilogram ($0.60 (U.S.) per pound) ($120,000 U.S.) for 92/93 food waste disposal). The near term disposal arrangements specify incineration at a rate of $0.04 (U.S.) per kilogram ($0.09 (U.S.) per pound) (annual projected cost of $24,000 (U.S.) for 93/94 food waste). The USAP ceased operation of an on-site incinerator for the disposal of this as well as other combustible wastes in 1992. Efforts have been made through pre-preparation of food, alternate food packaging, improved and more diverse menu selection to reduce the volume of this waste.

Dry combustible wastes (paper, light kraft, etc.)

Dry combustible wastes consist of non-white paper products, food contaminated wrapping materials and combustible food containers, light kraft, and small corrugated fiberboard as well as discarded materials such as paper toweling, tissues, and tobacco products. This waste accounts for 136 to 159 metric tons (150 to 175 U.S. tons) per year and costs from $11,000 to $15,000 (U.S.) annually for U.S. based disposition. These wastes were subject to on-site incineration until incinerator operations ceased in 1992. The short term strategy for disposition is U.S. based incineration.

Wood

Wood wastes include reusable wood material, non-reusable wood material, and carpenter shop off-fall and sawdust.

Reusable wood material comprises shipping pallets, boxes, and crates either chemically impregnated or non-impregnated (for fire retardency or waterproofing), and may also contain adhesives such as in particle board, plywood, or pressboard.

Non-reusable wood is generally generated from the discarding of damaged or excess wood material such as pallets, crates, or boxes.

Carpenter off-fall and sawdust is generated during construction of small scale items, short term remote camp facilities or during large scale production.

It is currently estimated that wood wastes are generated at an annual rate of 544 to 635 metric tons (600 to 700 U.S. tons) and represent a disposal cost of approximately $50,000 (U.S.). These estimates of the annual rate and cost however, are highly suspect; numerous management controls have been implemented to retard the generation rate of wood wastes but tight controls do not exist to discriminately discard wood materials. After processing in the U.S. for additional size reduction and metals removal scrap wood is used for fuel.

A large scale wood grinder is being used to reduce the volume of wood and to facilitate more efficient packaging of the wood material into transport containers. It is estimated that a total of 2 million kilograms (4.4 million pounds) of wood has accumulated over the past three years of operation and remaining in McMurdo prior to the 93/94 season representing $132,000 (U.S.) in U.S. based processing costs.

Plastics

Plastic waste management in McMurdo Station does not currently include segregation into the standard recycling classes. Current U.S. plastic recycling market fluctuations resulting in frequent redirection of segregated plastics to landfills, and the significantly increased burden on waste management infrastructure precludes this added practice. Mixed plastic wastes can be recycled as a commingled waste stream; new industries that produce lumber substitute materials, and to a lesser degree, petroleum from plastic refining has begun to be established in the U.S. Currently, annual waste generation for plastics is approximately 28,150 kilograms (62,000 pounds) costing $3,645 (U.S.) in U.S. disposition costs.

WASTE IN ANTARCTICA (USAP)
(EXCLUDES PENINSULA SOLID WASTE)

LIGHT METAL		161,806 KILOGRAMS
HEAVY METAL*		141,648 KILOGRAMS
CARDBOARD		94,318 KILOGRAMS
GLASS		10,496 KILOGRAMS
ALUMINUM		37,228 KILOGRAMS
WIRE/COPPER		22,700 KILOGRAMS
WHITE PAPER		15,391 KILOGRAMS
COOKING OIL		3,950 KILOGRAMS
PLASTIC		27,597 KILOGRAMS
CONSTRUCTION DEBRIS		306,450 KILOGRAMS
CLOTHES/RAGS		9,262 KILOGRAMS
PRODUCT CONTAINERS		1,711 KILOGRAMS
UNOPENED FOOD		4,398 KILOGRAMS
WOOD*		1,821,675 KILOGRAMS
BURNABLES		138,924 KILOGRAMS
GALLEY FOOD WASTE		116,156 KILOGRAMS
DRY FOOD CONTAINERS		141 KILOGRAMS
MAGAZINES/NEWSPAPERS		5,085 KILOGRAMS
HUMAN WASTE		216 KILOGRAMS
ALUMINUM FOIL		1,973 KILOGRAMS
HAZARDOUS WASTE**		483,056 KILOGRAMS
	TOTAL	3,404,181 KILOGRAMS
		3,404 METRIC TONS

* INCLUDES BACKLOG WASTES AS WELL AS ANNUAL
** SUM OF 45 HAZARDOUS WASTE CLASSES

Domestic Wastewater

Domestic sewage accounts for the discharge of almost 53 million liters (14 million gallons) of wastewater accounting for the release of nearly 227,000 kilograms (500,000 pounds) of combined nutrients, oxygen depleting organic materials, and various metals and other chemical compounds annually. Although management and process controls are expected to reduce non-human related wastes from this discharge nearly 27,240 kilograms (60,000 pounds) of biological oxygen demand and 113,500 kilograms (250,000 pounds) of solids are estimated to continue to be discharged annually without treatment implementation.

ANNUAL DOMESTIC WASTE DISCHARGE FROM McMURDO STATION	
FLOW	513,066,735 LITERS
CADMIUM	0.1 KILOGRAMS
COPPER	9.8 KILOGRAMS
IRON	67 KILOGRAMS
LEAD	2.0 KILOGRAMS
MERCURY	0.14 KILOGRAMS
SELENIUM	0.13 KILOGRAMS
SILVER	0.11 KILOGRAMS
AMMONIA-N	1,026 KILOGRAMS
NITRATE-N	1.0 KILOGRAMS
NITRITE-N	1.0 KILOGRAMS
TOTAL KJELDAHL-N	3,804 KILOGRAMS
PHOSPHOROUS	18,251 KILOGRAMS
TOTAL SUSPENDED SOLIDS	18,251 KILOGRAMS
VOLATILE SUSPENDED SOLIDS	12,167 KILOGRAMS
TOTAL DISSOLVED SOLIDS	79,904 KILOGRAMS
BIOLOGICAL OXYGEN DEMAND	25,651 KILOGRAMS
CHEMICAL OXYGEN DEMAND	70,824 KILOGRAMS
GLYCOL	127 KILOGRAMS
PETROLEUM HYDROCARBONS	1,208 KILOGRAMS
OIL, GREASE, HYDROCAR.	5,130 KILOGRAMS

FIRST ORDER ENGINEERING CONTROLS

Analysis of annual waste types and amounts, as well as review of currently available, directly applicable technology has identified six waste streams showing immediate potential for implementation. These six streams represent 17 per cent of the total annual waste stream (by weight basis) and estimated to represent $445,000 (U.S.) in U.S. disposition costs. Technologies that could be implemented for beneficial reuse or treatment of these wastes are proven technologies having wide usage in the U.S.

On-site reuse of Used Lubricating Oils

The USAP has made the commitment to implement a full scale used oil reuse program commencing next operating season. This program will entail 1) filtration or centrifugation of lubricating oil from the McMurdo Station diesel generators for direct reuse in the generators, and 2) filtration or centrifugation of lubricating oils from vehicles and aircraft in the various industrial boilers at McMurdo Station. The USAP will institute a used oil testing program to document that used oil is in accordance with standards applicable to similar operations in the U.S.

Soil Washing

The USAP has made the decision that petroleum contaminated soils created from operational spills and leaks will be decontaminated in Antarctica and reused as fill material in construction projects or returned to sites of excavation. During the 93/94 operating season, approvals were obtained to establish a bulk contaminated soil storage facility consisting of a high density polyethylene liner and sump system. Efforts are currently underway to procure and deliver a commercially available soil washing device capable of removing petroleum products from the soil. After separation from the water based detergent, the recovered petroleum products will be tested to determine if they can be used as a fuel supplement or if they will require retrograde to the U.S. for proper disposition. This technology will also provide the means for the USAP to systematically commence cleanup of areas contaminated from past practices.

Floor sweep and industrial rag laundering

An evaluation of available equipment will be performed in the near future to determine applicability to the USAP. These devices are currently used in a variety industrial applications in the U.S. and have been shown to be an economically viable and environmentally favorable alternative to disposal. Both floor sweep compound recyclers and rag washers are based on the closed recycling of a solvent to cleanse the materials; the solvent is subsequently re-distilled and recycled. The waste generated are the solids and heavier fraction of contaminants removed during the washing process.

Medical and laboratory waste detoxification

The recent concern in the U.S. regarding the improper disposal of medical wastes and debris from clinical and hospital operations have resulted in the development of a device to "detoxify" these wastes. These systems physically grind the wastes and mix them with an iodine solution. This processing renders the wastes non-infectious and physically destroys the syringes and other objectionable objects. Once processed the resultant waste is considered to be non-hazardous municipal waste and can be disposed accordingly. The USAP is examining the economic benefits of obtaining such equipment to process truly medical wastes as well as laboratory waste having the physical appearance of medical wastes (e.g. syringes, pipettes, petri dishes).

Reutilization of non-halogenated solvents

Much of the solvents used by USAP researchers are non-halogenated such as methanol and ethanol. There is a potential for on-site redistillation but reuse by scientists would be unlikely without purity certification. Since on-site testing to certify solvents sufficiently pure for science use is not feasible, the USAP is evaluating the ramifications of using these used solvents as a fuel additives and burning them along with fuel in boilers, generators, and heaters.

SECOND ORDER ENGINEERING CONTROLS

Second order engineering controls applicable to the USAP and to the five identified waste streams represent technologies that will require more thorough evaluation, represent a greater capital investment with longer economic periods of return on investment, and require a fundamental policy and cultural commitment by the USAP.

In-vessel composting

Food wastes and dry combustible wastes pose a significant operational and logistical problem to the USAP particularly with the cessation of on-site incineration at McMurdo Station in 1992/93. Food wastes pose a potential sanitation and health concern during handling and storage particularly during the austral summer where temperatures above freezing are not unusual. During transport to the U.S. for disposal, food wastes must be kept refrigerated to prevent rotting and putrification. Dry combustible wastes pose a problem in that they are not readily amenable to compaction and therefore require significant space to store and transport. Once they arrive in the U.S., regulations allow for incineration or landfilling. As the domestic concerns and limitation of available disposal facilities are on the increase, the USAP has commenced evaluation of alternatives. One promising alternative is the emergence of in-vessel or closed system composting.

Wood Reutilization

Although the USAP has implemented an aggressive program of wood pallet and crate reuse, and alternatives to wood packaging are being introduced, wood waste will continue to be a generated waste. The USAP is evaluating alternative means of processing to render this wood waste acceptable as a fuel. Analysis indicates that at the current annual rate of generation, wood wastes represent some 20 billion BTUs of potential heat representing some one and a half percent of the entire energy needs of McMurdo Station. The USAP did arrange for retrograded wood to be processed for use as a fuel source in the U.S.. In the longer term, the USAP is evaluating the feasibility of utilizing scrap wood as a heating fuel in McMurdo Station.

Plastic lumber extrusion and conversion of plastic to petroleum products

The relatively small volume of plastic waste generated by the USAP, and the sluggish market for recyclable plastics does not justify segregation of plastics into standard recycling classes. Instead the mixed plastic waste stream is currently landfilled in the U.S.. Many emerging technologies utilizing plastics are gaining momentum in the U.S. and abroad and may offer the USAP alternatives to disposal. One such technology is the production of plastic lumber substitutes. This material has demonstrated favorable application as a landscaping and decking material having the machining characteristics and appearance of wood while maintaining the durability of plastic. Although the USAP has no direct need for such materials in quantities that would solely justify investment in such technology, this technology and the market for such material will be investigated as an alternative to current practices.

Recent developments in retorting of plastic materials into its petroleum based precursor compounds also shows potential promise and warrants investigation and evaluation by the USAP.

Both of these alternative technologies offer a promising alternative to current plastic waste management. It is hoped that these developments will bolster the market for recycled plastics and offer direct applicability to the USAP in the future.

Sewage Treatment

The current practice of maceration of sewage and direct ocean discharge at McMurdo Station is allowed by international treaty and by U.S. regulation. The USAP however, has commenced examination of available sewage treatment technologies as a component of the increased commitment to environmental protection. Initial findings show that secondary treatment based on aerobic digestion practiced commonly throughout the U.S. shows promise for implementation and would alleviate other existing waste management problems. The evaluation of sewage treatment alternatives is being conducted in concert with the evaluation of in-vessel composting as a means of stabilizing the resulting sewage sludge. Although no direct economic benefit, sewage treatment would eliminate an additional 181,600 kilograms (400,000 pounds) of pollutants being discharged to the ocean annually. The estimated cost of secondary treatment of $750,000 (U.S.) would be offset by the deferred cost of disposing of food and human waste in the U.S. estimated to be $30,000 (U.S.) annually.

CONCLUSION

As the USAP waste management program evolves to maximize its utilization of wastes as a resource, and to minimize the impact on the Antarctic, as well as the U.S. environment, the infrastructure will become more of a closed system. The lessons being learned by USAP waste management experts during this evolution are directly applicable to industries and communities. Both industry, and to a greater extent, communities, continue to transport wastes away from the point of generation and fail to consider the impacts on the recipient communities. The USAP has demonstrated that with proper management controls, much of the traditionally disposed wastes can be readily reused or recycled. In many cases, wastes can be converted to commodity that can either generate revenue or be directly used by the generator.

With some wastes such as plastics, the market does not support recycling. In some ways this is the epitome of the status of the waste management mentality in the U.S.; segregation of plastics at the consumer level is often abandoned because the market does not support recycling, but the health of the market is dictated by consumer behavior. Rather than succumbing to these weaknesses in the waste recycling infrastructure, communities should consider local facilities to utilize wastes as commodities at the local level. Opportunities such as utilization of waste oil, wood scraps, and plastics as fuel would directly benefit local or regional communities by augmenting virgin oil purchase and use. Programs such as conversion of plastic to wood substitutes, composting, and scrap metal smelting would benefit communities by establishing new industries, and with them, employment. Concurrently, these programs reduce the cost of traditional waste management; waste disposal services, land costs, and potential liabilities. The economics of alternative waste management strategies can be readily evaluated but should not necessarily be the sole criterion for judging viability. The less tangibly measurable costs of traditional waste management are continued environmental degradation, depletion of natural resources at an accelerated rate, and ultimately a decline in the quality of life.

It is somewhat ironic that the knowledge of scientific investigation in Antarctica is often deemed too lofty for the layman to reap any direct benefit. Scientific research in Antarctica however, has validated the suspicion that the planetary ecosystem is smaller and more sensitive than once believed. Effects of man's behavior have been measured and evaluated to be deleterious to the global environment. The USAP waste management model is a response to these findings. Waste management strategies need to respond to the notion that our communities are smaller than we choose to recognize and inexorably linked to the community next door.

The Clean-up Programme of Stations of the Alfred Wegener Institute

H. Kohnen, Germany

Introduction

The Protocol on Environmental Protection to the Antarctic Treaty, Madrid 1991, requires in its Annex III, Article 1.1 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". "Work sites" include structures of any kind as further outlined in the same article.

Consequently, all wastes from waste deposits have to be removed from the Treaty Area. It is our understanding that abandoned stations have to be dismantled and removed as far as the removal does not create a greater environmental impact than leaving the structures in place and as far as the station is not designated a historical site.

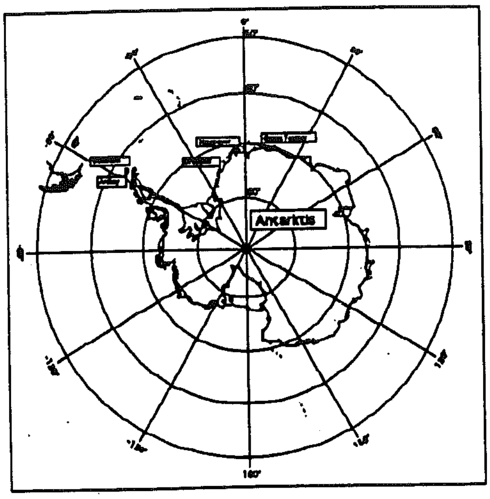

Figure 1: German Antarctic Stations

The Alfred Wegener Institute was and is faced with the clean-up for four stations (Fig. 1). The winter station "Georg-von-Neumayer" was given up in 1992 after 11 years of operations. The winter station "Georg-Forster" of the former German Democratic Republic came under the responsibility of the Alfred Wegener Institute after the reunification of both countries. Winter operations ceased in spring 1993. The "Drescher Summer Station" used to be a focal point of biological summer activities for penguin research. It was situated at an inlet on the Riiser Larsen Ice Shelf. Two huts on Ardley Island opposite of King George Island served until now as base for penguin studies. The small station is a remnant from the German Democratic Republic's Antarctic programme.

The clean-up programme will be discussed in chronological order of the different tasks.

The clean-up work

"Drescher Station"

The "Drescher Summer Station" was built in 1984 on the Riiser Larsen Ice Shelf close to the barrier at the end of an inlet. It was erected on the snow surface. The station comprised living quarters for 8 persons, laboratory and storage space. The station was entirely dismantled in 1988 and taken out.(removed) No waste deposits were left behind. It was the standard routine after each season to remove all wastes, except human wastes, . The site is cleared.

"Georg-von-Neumayer"

"Georg-von-Neumayer" was the first winter station of the Federal Republic of Germany. It was built in 1980/81 on the Ekström Ice Shelf and served for 11 years as an observatory for atmospheric sciences and geosciences as well as a logistical base for summer activities in this region. The station consisted of the three steel tubes (Fig. 2) of 50 m length and 8 m diameter into which the station facilities were built in as prefabricated containers. The steel tubes protected the infrastructures against the accumulating snow load. The infrastructures consisting of 35 20'iso containers comprised living quarters for 9 winter persons, technical infrastructures, laboratory and work space as well as tanks and storage rooms. The containers were placed on a steel substructure. Outside facilities comprised meteorological installations, two geophysical and one air chemistry stations, a garage, a wind generator and antennas . The station had to be given up in spring 1992 due to the progressing deformation of the tubes as a consequence of the ice movement and the accumulating snow mass. During the same season a new station was built 8 km south of the old site.

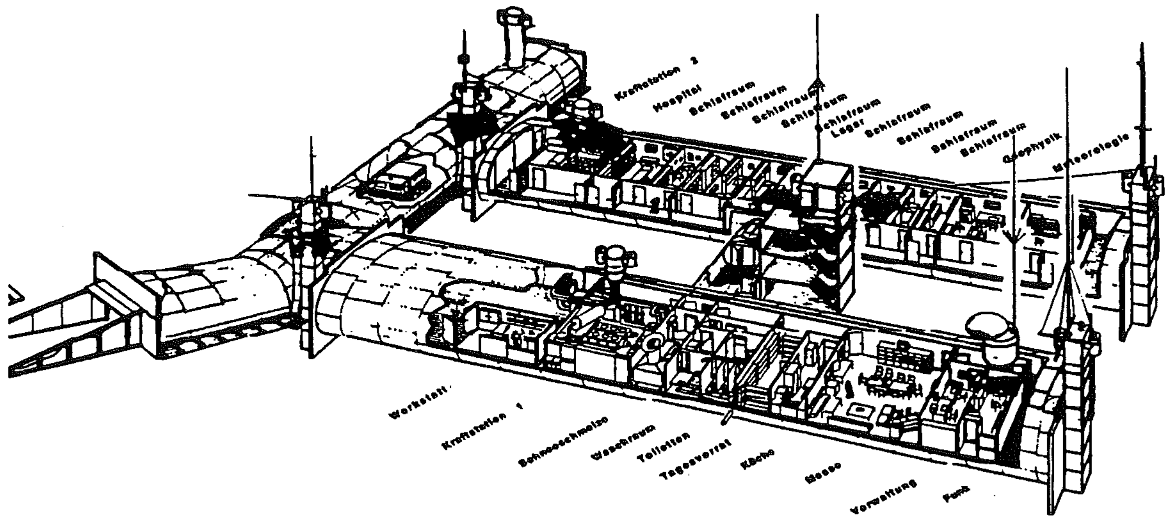

Figure 2: Scheme of the Georg-von-Neumayer Station

The abandoned station was entirely dismantled during the following season. Everything, except the steel structure, was taken out and removed from the Treaty Area. The work was performed by a professional team of four persons within six weeks. The total load comprised 35 containers of scrap equivalent to roughly 400 tons. The outside facilities were removed to the new station by own personnel for further use. Hazardous goods were brought back to Germany, non-hazardous goods were properly disposed in South Africa in accordance with the Basel Convention. The steel tubes and the understructure had been left in place. Burried under approx. 10 m of firn the removal would have had required extensive blasting. Considering the enormous amount of explosives to be used, the impact was estimated to be much higher than leaving the untreated steel (no paints) in place.

An Initial Environmental Assessment (IEE) had been prepared for the clean-up work.

"**Georg-Forster**"

Scientific activities of the German Democratic Republic commenced in the Schirmacher Oasis in the mid-seventies. A few small buildings served as base for atmospheric and geophysical year-around research. The number of buildings and huts increased with growing scientific interest. The station was officially inaugurated in 1986 as the wintering station "Georg-Forster" of the GDR. The main building complex is located approx. 1 km from the Russian station "Novolazarevskaya". Both programmes were logistically closely inter-related. The station assembly at the time of the reunification of our countries (1989) is shown in Figure 3. The station could accommodate 10 to 15 winterers. After 1989, the GDR programme was basically integrated into the programme of the AWI including all logistical facilities. It was decided to terminate the winter programme of "Georg-Forster" at the end of the 1992/93 summer season. Due to the requirements of the Madrid Protocol, Germany had to face the clean-up of the waste disposal sites and the station.

A first step towards this goal was the assessment of the ecological situation in the region of the oasis where the activities of both national programmes were concentrated.

During the 1991/92 summer season a rather general survey of buildings and waste disposal sites was performed by a field party of the AWI. This undertaking was followed by a detailed survey during the 1992/93 season. All buildings of "Georg-Forster" and all waste deposits were assessed and mapped (Fig. 4). The evaluation yielded 19 different dump sites which were categorized according to the type of wastes (hazardous goods, metal scrap, glass, wood, kitchen waste, human waste, etc.). In addition, badly polluted terrain, i.e. earth soaked by hydrocarbons, was registered. The assessment yielded a bulk estimate of approx. 800 tons equivalent to 5000 m^3 of wastes to be removed. These numbers include building material of "Georg-Forster" ca. 3000 empty fuel drums and the other wastes.

The Russian and the GDR logistics had been interconnected for more than two decades. It was consequently impossible to discern whose waste is contained in which waste disposal site. Therefore, it seemed to be logical and most efficient to combine the efforts of both institutes, the Arctic and Antarctic Research Institute, St. Petersburg, and the Alfred Wegener Institute. A respective agreement for a three year co-operative project was signed 1993 by our institutes.

The field work started the same year. During the 1993 winter season the winter team of "Novolazarevskaya" began to collect all those wastes which were dispersed within the region of the station's activities and to dispose it at designated, already existing dump sites. The next step was and still is to concentrate the wastes in only a few disposal sites separated according to the composition of the wastes. Samples from the heavily polluted soil regions had been taken and analyzed. The results show that in these areas the soil is soaked with hydrocarbons down to about 1 m. Those parts have most likely to be regarded as lost areas.

During the 1993/94 summer season, the combined effort concentrated on the dismantling of buildings, the clean-up of waste disposal sites and the combining of wastes

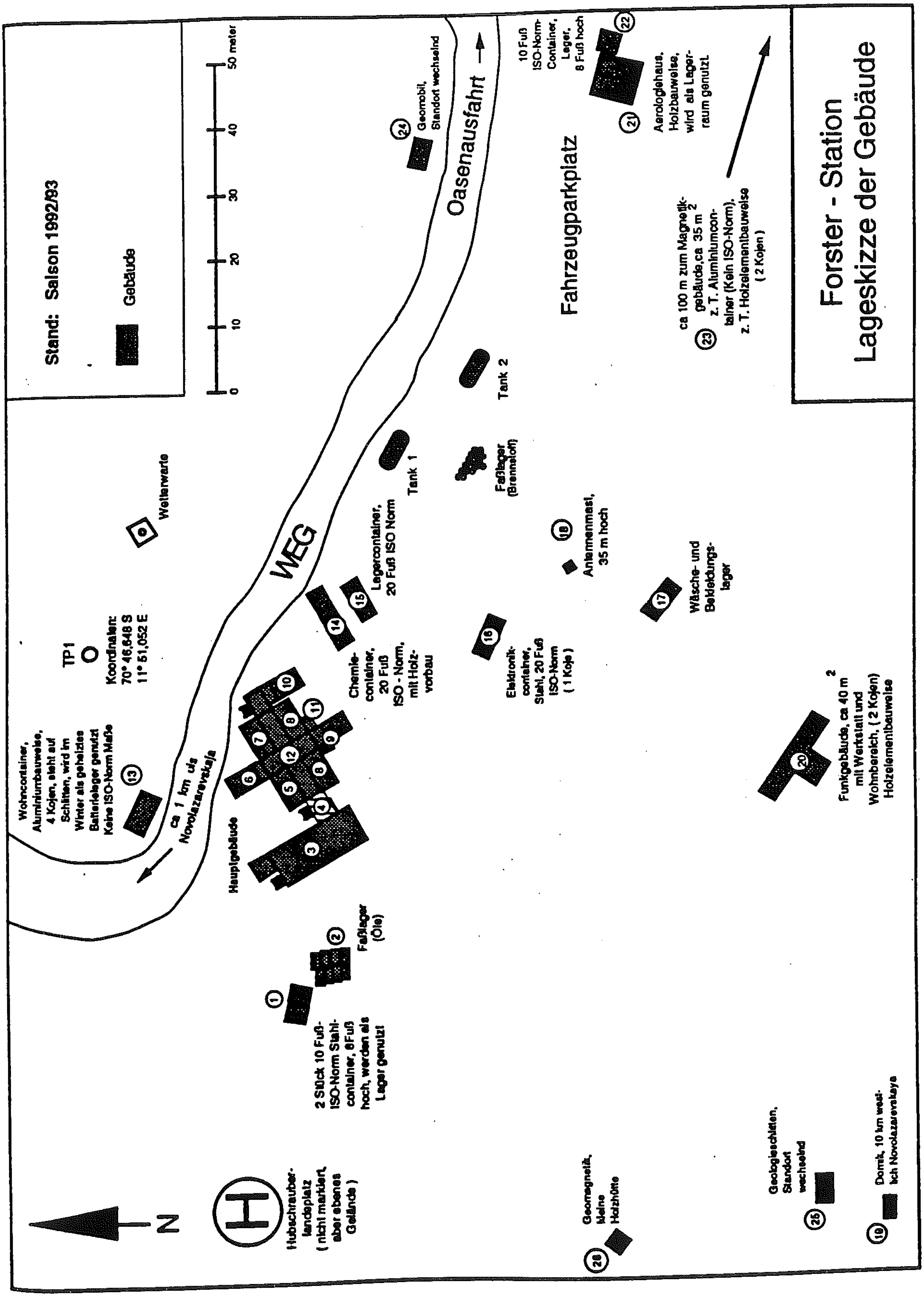

Figure 3: The building assembly of Georg-Forster Station

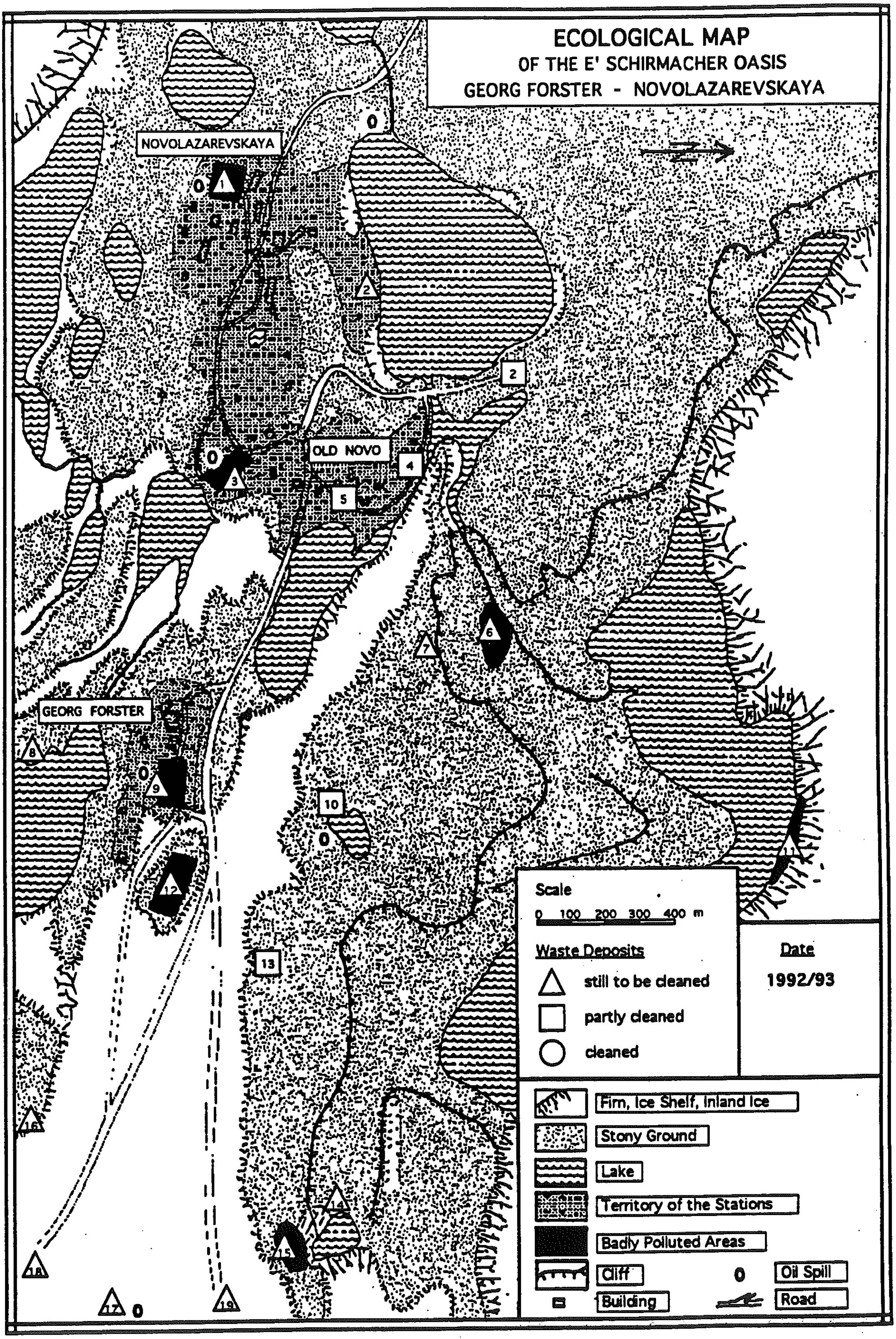

Figure 4: The distribution of waste disposal sites in the Schirmacher Oasis

from the different dump sites into only a few deposits. Those main deposits only contain wastes of specific types like metal scrap, timber etc. At the same time, the removal of wastes from the Oasis began according to agreed priorities. Heavy metals, hazardous goods, hydrocarbons were designated to be removed first. By the end of the summer season, 20 containers with approx. 200 tons of wastes had been transported to the ice edge of the Novolazarevskaya Ice Shelf. The ice shelf forms a seam of roughly 100 km width along the continental coast between the sea and the oasis. The area of the two stations as well as "Georg-Forster-Station" itself were cleared from hazardous goods and heavy metals. Furthermore, some waste disposal sites were entirely, others partly cleaned-up by the end of March. The winter crew of "Novolazarevskaya" continues the work during the winter 1994, particularly by concentrating the disposal sites.

Unfortunately, the sea ice conditions were so poor along the ice edge at the beginning of April that no expedition ship could reach the barrier to take over the containers. The shipment of the 20 containers has to wait for the next summer season (1994/95). Two more summer seasons will most likely be necessary to fulfil the whole task.

As spin-off of the ecological undertaking no human and kitchen wastes are disposed-off in the Oasis anymore.

An environmental evaluation (IEE) has been prepared for the project.

"Ardley"

Researchers of the GDR Antarctic Research Programme had built a small station on Ardley Island at the margin of the penguin rookery. The station consisting of two huts has living and working space for uo to four scientists. Until the reunification of our countries the work at "Ardley" was logistically supported by the Russian station "Bellinghausen".

The joint Argentine-German Dallmann laboratory at "Jubany Station" on King George Island also has the task to support biological activities which formerly had been based at "Ardley". The AWI consequently decided to close "Ardley" and to abandon its activities. The summer 1994/95 will be the last season at "Ardley". It is planned to dismantle the station at the end of the 1995/96 summer and to remove the huts. The task will be performed with own personnel supported by our vessel RV "POLARSTERN".

Conclusions

The Alfred Wegener Institute had decided to close down four stations. One of them, "Neumayer", had to be abandoned because of external, i.e. natural influences. "Drescher" was given up due to the imbalance of the logistical effort and scientific activities in the late 80ies. Part of those activities will be persued in future near "Neumayer". To continue the operation of "Georg-Forster-Station" would have required major renovations and replacements, thus major investments. Parts of the programme were transferred to "Neumayer". The state of the station as well as the ecological conditions led to the decision to terminate the winter operations. The programme of "Ardley" is being transferred to "Dallmann-Jubany". These decisions are a consequence of our policy to reduce stationary operations, which imply high logistical input in conjunction with an ongoing environmental burden, wherever feasible. As consequence we have committed ourselves to remove - as far as possible - all structures which are no longer used.

OPERATION

FOR THE REMOVAL

OF HYDROCARBONS

FROM THE WRECK

OF THE ARGENTINE POLAR SHIP

A.R.A. "BAHIA PARAISO"

By

Ignacio Alberto ARANGIO
Commander of the Argentine Navy

TECHNICAL COORDINATOR AND LIAISON WHIT THE NETHERLANDS
TECHNICAL ADVISOR OF THE NETHERLANDS GOVERNMENT
ON-SCENE COMMANDER

1993

BACKGROUND

On January 28th, 1989, Polar Ship "BAHIA PARAISO" (TPBP) of Argentine flag grounded in the vicinity of PORT ARTHUR, ANVERS Island (64º46'44" S, 64º04'52" O).

The Argentine Navy established a Salvage Group formed by senior and enlisted personnel trained in salvage and diving operations. This group was airlifted to the wreck site together with the necessary equipment.

On January 31st, the ship sank before anything could be done to prevent it and an approximate amount of 600 cubic meters of hydrocarbons was spilled.

The NATIONAL ANTIPOLLUTION COMMAND was created, which took steps to remove all the remaining contaminants from the hull, which was heeled at an angle of about 90°.

In this manner, all gas-oil drums and gas tubes stowed on deck were removed, as were most of the paint tins and other contaminants. Some of the spilt fuel was also collected and the largest possible amount of hydrocarbons was removed from the tanks with the available means.

Once tasks were completed towards the end of March, the site was cleared. The hull then showed a heel of approximately 120° and it had sunk further because the weight of the ship had caused a ditch to form among the fragments of rocks lying on the bottom.

From that moment, the Navy has been studying the problem and has come up with three possible solutions:

1. Complete removal of the wreck.

2. Removal of the hydrocarbons remaining inside the hull.

3. Continuation of surveys until the necessary funds or information are obtained to tackle the problem with:
   3.1 Private companies of renowned capability.
   3.2 The Navy's own means and personnel.

The first course of action was discarded as too expensive, too risky and virtually impracticable, because it implied crossing the Drake Passage with large cranes up to the area around the shipwreck, which is not deep enough. In addition, there was a risk of pollution upon removal of the hull.

Solution number two was analysed for implementation after completion of some of the tasks associated with requirements 3.1 or 3.2.

In September, 1989 the hull was overflown and it was found to have sunk even further, now showing an heel of about 140°.

In 1990, the COMMAND OF NAVAL OPERATIONS (CON) devised and sent an Antipollution Contingency Plan to the AMERICAN NATIONAL SCIENCE FOUNDATION (NSF) to prevent potential leakage of hydrocarbons remaining in the hull and to establish courses of action, in case the leakage should occur.

In February, 1991, a joint exercise was carried out with PALMER Station personnel to test the possibility of draining the hydrocarbons, with excellent results.

Through the MINISTRY OF FOREIGN AFFAIRS (MINIREX), talks are being held with the NSF on possible courses of action to deal with the problem of Polar Ship "BAHIA PARAISO".

In September, U.S. Navy personnel offered a course at the Diving School for Senior and Enlisted personnel, on the HOT-TAP system (HT), considered the most suitable method for the removal of hydrocarbons from the hull.

On October, 4th, an initial contact was established between the governments of the ARGENTINE REPUBLIC (GRA) and the NETHERLANDS (GRPB), during the ANTARCTIC TREATY INTERNATIONAL MEETING.

As a result, on February, 18th 1992, the Memorandum of Understanding was signed for the removal of the hydrocarbons remaining in the hull.

The Commander of Naval Operations submitted a report on the recommended action to be taken by the Navy to execute the tasks assigned by the MINISTRY OF FOREIGN AFFAIRS.

The NAVY CHIEF OF STAFF approved the Recommended Action based on Logistic Support, and set off the process of procuring the means required for the Operation and ensuring their readiness.

The Commander of the Antarctic Naval Force and Area was appointed General Coordinator of the Task, Commander Juan Carlos PARMIGIANI was designated as Authority for the Supervision and Implementation of Related Activities and Commander Ignacio Alberto ARANGIO was appointed Technical Advisor in the Netherlands and On-Scene Commander.

The GRPB selected the NOORDHOEK DIVING COMPANY (NHD) to execute the operation.

On September, 16th the Addendum to the Memorandum of Understanding was signed in Buenos Aires, whereby each party's tasks and responsibilities were identified and established.

The "Initial Environmental Evaluation" was issued, a paper written by the ARGENTINE ANTARCTIC INSTITUTE (IAA) and the MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER QUALITY CONTROL of the NETHERLANDS, dealing with the potential environmental impact of TPBP's grounding on the Antarctic ecosystem.

All relevant activities were coordinated and all actions required were initiated for the execution of the operation.

ARGENTINE NAVY's responsibilities (ARA):

- First and foremost, readiness of the Argentine Navy's Transport "CANAL BEAGLE" (TRCB), specially selected due to hold and tank capacity and crane power. Readiness of the reinforced crew.

- Procurement of a surface suction pump.

- Readiness of two EDPVs (Personnel and Vehicle Disembarkment Craft) and of a 600-metre containment boom and diving equipment.

NHD's responsibilities:

- Craft assembling, sailing and disassembling tests.

- Readiness of the HOT-TAP equipment (to be dealt with later on), decompression chamber, liquid separator (the idea was that all water containing less than 15 ppm would be thrown back into the sea), lodging for 10 people (who could not be accommodated in cabins), diving equipment, cordage, etc. All this material was stored in containers and shipped to Buenos Aires.

For a better understanding of the operation, we could divide it into three stages:

ACTIVITIES

1. BEFORE THE OPERATION

November 19: the arriving equipment inside the 13 containers was transferred from E dock to the Naval Transport pier, to be loaded aboard the TRCB.

November 20-26: departure from Buenos Aires with a crew of 46 people. Sailed to Ushuaia, where 2 GRPB representatives, 15 NHD members, 1 Dutch journalist (specialised in marine ecology) and the Argentine Team Leader joined the original crew.

November 26-December 3: unfortunately, bad weather forced us to wait in the bay until it was safe enough to start the crossing of the Drake Passage. Until then, time was spent assembling craft and getting the equipment ready in order to begin working as soon as possible after arrival.

December 3-5: the crossing took place in a thick fog, though the sea was calm. We reached land at 25 de Mayo Island (King George), one of the South Shetland Islands.

December 5-6: sailing across the Sea of the Fleet, in the fog and amidst slob pack ice, we headed towards the sunken hull. On board we celebrated the feast of St.Nicholas, a Dutch tradition which has many points in common with our feast of the Three Wise Men.

December 6: arrival at Port Arthur, ANVERS Island, where after anchoring we were welcomed at the American PALMER Base by its team of scientists and logistic specialists, to whom we explained the tasks to be performed, taking care not to interfere with each other's activities and to acknowledge the importance of the work we would all perform in favour of the ecology of the area.

2. DURING THE OPERATION

December 7: the actual operation began with the following actions, most of which were intended to provide maximum safety and prevent pollution due to faulty material or human error.

By the Argentine Navy:

1. Positioning of a 500-meter containment boom around the wreck, forming a circle in such a way that hydrocarbons could be contained in case of leakage.

2. Preparation of the surface suction pump, which has a 60-ton crude oil absorbing capacity per hour. We must take into account that the fuels remaining inside the ship were gas-oil and SAE 30 oil.

3. Preparation of 2 (two) EDPVs and 2 (two) off-board engine boats.

4. We tried to recover the points anchored and abandoned years ago.

5. At the beginning, we tried not to use fixed points on the islands, but then we realized it was impossible to work without them.

By the NOORDHOEK Company:

1. Positioning of two affixed 40-feet containers in the water (making up the hull of the craft), placing of a 20-feet bow- shaped container and of a 20-feet container on the hull making up the command cabin and the valves/pumps room/diving control room, and, finally, placing of the 245 KW "SCHOTTEL" engine astern.

2. Preparation of diving equipment (diving suits, hoses, decompression chamber, etc.)

3. Preparation of the system for removing the remaining hydrocarbons (known as HOT-TAP) based on putting a flange on the hull, affixing a valve with a special tool, removing a steel gin, closing the valve, placing a suction pump and transferring the emulsioned fuel and/or oil to the craft described in 1; carrying it to the side of the TRCB, putting it into a separator so that hydrocarbons could flow into tanks, and water containing less than 15 parts per million could thrown back into the water.

4. Positioning of other smaller booms:
   - 4.1. In the vicinity of the hull of the sunken ship, within the Argentine Navy boom area but only around the craft.
   - 4.2. On the side of the ship, to prevent further spreading in case a spill should occur during the transfer of liquids.

December 8: due to a storm with winds blowing up to 40 knots, the TRCB starboard anchor started to drag. The anchor was weighed, and we unsuccessfully tried to anchor eight times. Also an EDPV broke a cleat, thus remaining adrift together with a rubber boat. Later on, both were recovered 7 miles from the point where they broke away from the ship. We sailed all morning awaiting better weather conditions. In the afternoon, NHD craft surveyed the sea bed looking for a more convenient anchorage. It was impossible to work because of the great amount of ice on the hull.

December 9: the first diving operation started at 7.55 AM. Four more were carried out that day.

December 10: 5 diving operations were performed. We verified that tank 10 was empty.

December 11: 10 diving operations were performed. It was verified that tank 11 was empty and 30 m3 of gas-oil from tank 15 were recovered.

December 12: the boom had to be opened up and the craft suffered the effects of the ice around the hull of the sunken ship; 6 diving operations were carried out and 2 m3 of gas-oil were recovered.

December 13: 6 diving operations were carried out and tanks 20 and 33 were prepared.

December 14: 25 m3 were pumped out of tank 20 and 2 diving operations took place. Due to the waves, a craft cast off.

December 15: the boom had to be repaired, 30 m3 of gas-oil were removed from tank 30, and we attempted to remove some from tanks 10 and 11 without success.

December 16: during this day, 2 m3 of gas-oil were removed from tank 24 and 1 m3 more from tank 20. 11 diving operations were performed. The first and only one accident took place when a craft operator accidentally stuck a steel splinter into his finger, he was assisted on board and at PALMER Base, and the injury healed completely.

December 17: 7 diving operations were carried out and tasks had to be suspended because of accumulating ice and winds of up to 38 knots.

December 18: the boom had to be repaired, tank 32 was pumped unsuccessfully and 5 m3 of oil were removed from tank 19.
6 diving operations were performed during the day.

December 19: 8 diving operations were carried out. 3 m3 of oil were recovered from tank 17 and 2 m3 from tank 18. During the liquid separation effort, a deficiency caused by an obstructed hole originated a 15 litres hydrocarbon spill. An emergency operation was undertaken and most of the fuel was recovered without affecting the area. When the cause of the incident was learnt, a meeting was held with the PALMER Base Management to let them know and ensure that no difficulties had arisen at the Base.

December 20: 5 m3 of oil were removed from tanks 66, 17, 18 and 21, thus completing tank operations. 6 diving operations were performed during which measurements were taken to locate cuts in the hull that would allow easy access to the engine room, from where 14 m3 were removed through the HOT-TAP system.

December 21: 3 diving operations were carried out, but work had to be suspended because of the great amount of ice in the area.

December 22: the boom had to be opened because it was being carried away by the ice together with the anchoring points. It was necessary to leave Port Arthur because the TRCB was dragging due to winds blowing at 38 knots. During the rest of the day we sailed along the BISMARK Passage with winds blowing up to 50 knots.

December 23: diving operations were carried out and we went on cleaning up the place where the cut would be made.

December 24: we started cutting the hull on starboard. 10 diving operations were performed. Due to the waves, tasks were suspended and we took the opportunity to celebrate Christmas on board.

December 25: 1 diving operation was performed to complete the cut, but winds were blowing up to 36 knots, and the sea was covered with ice. It was necessary to open the booms so as to prevent greater damage.

December 26: the cut was completed and we found that access was impossible because it was obstructed by pipes. We started working on another cut at the same level but on portside. 9 diving operations were carried out.

December 27: 13 diving operations were performed. We reached the engine room entrance but it was too small to let in a fully equipped diver; therefore, we tried to make an oxyelectric cut, but a minor explosion was caused by the gases released, so we had to give up. A third cut was started on portside.

December 28: the cut was completed, but there was a double hull behind the hull, therefore we agreed to make a fourth cut away from the keel and the place of work, hoping to find no difficulties. 12 diving operations were carried out.

December 29: 5 diving operations were performed in order to make the fourth cut. On many ocassions, operations had to be suspended due to the ice and sea conditions.

December 30: 11 diving operations were performed. Cuts were completed, and access to the engine room was possible for the first time after cutting three pipes. A HOT-TAP was placed in the main portside motor case (tank 29).

December 31: 10 m3 of oil were removed from tank 29, and HOT-TAPs were placed in the tunnel both on portside and starboard. 8 diving operations were performed. Diving operations were suspended at 11.30 PM to celebrate the New Year on board.

January 1: A HOT-TAP was placed in the main starboard motor case (tank 30) which was found empty. 8 diving operations were carried out and a HOT-TAP was used on tank 12, from which 6 m3 were removed.

January 2: A HOT-TAP operation was performed on tanks 23 and 32, which were empty. Likewise, 9 m3 were removed from tank 16, and 27 m3 from the inside of the hull in the engine room, Upon completion of this task, we closed all the openings made to the hull, both through HOT-TAP perforations or cuts. The final appearance of the hull was videotaped, operations were ended, the boom was removed and reloaded, the containers making up the craft´s hull were dismantled and stowed in holds.

3. AFTER THE OPERATION

January 3: dismantlement of craft was completed. All the material was stowed and secured on board, given the possibility of encountering rough sea when sailing towards the mainland.

January 4-6: we sailed towards 25 de Mayo Island hoping for better sea conditions so as to start crossing the DRAKE Passage and ensure mutual assistance among the ships.

January 7 and 8: we crossed the channel in good weather conditions and at low speed, in order to sail together with the Argentine Navy Supply "FRANCISCO DE GURRUCHAGA".

January 9: we reached the USHUAIA dock, where personnel and material from the Netherlands´ Government and from NHD Company disembarked; the TRCB resumed her commercial voyages.

CONCLUSIONS

1. Selection of Argentine Navy Ship "CANAL BEAGLE" as transport and logistic support unit proved to be highly useful for achieving the task/carrying out the operation successfully.

2. Selection of the month of December to carry out the operation was correct, since tasks were interrupted only for five days, and water visibility was very good due to lack of alga growth.

3. The operation was executed taking into account that adverse weather and ice conditions increased the risk of causing both personal and operation/task-related accidents.

4. Special steps were taken to prevent damage to the ecosystem, in the event of significant drainage during operations on the hull.
   Those steps included the following:
   4.1. Positioning of a 500 m containment boom around the wreck for the whole operation.
   4.2. Maintenance of a 100 m boom in reserve for protecting areas against pollution.

5. The containment boom served its purpose.

6. Significant spills or drainages did not take place. Minor spills or drainages were detected and consequently absorbed:
   6.1. Spill: Approximately 15 litres, alongside Transport "CANAL BEAGLE" and outside boom limits.
   6.2. Drainage: Around 35 litres of hydrocarbons within the limits of the boom.

7. The EDPVs were efficient towing units.

8. The craft provided by the Company were easy to assemble and disassemble, and quite suitable in terms of their seafaring conditions, speed, manoeuver and loading capacity.

9. The way craft were anchored -with joint lenghts of chain -proved to be effective.

10. NHD's dry diving suits and helmets were highly useful in low temperature waters such as those of Antarctica.

11. Flexible diving helmets employed by the Company proved better than rigid ones, since the latter were uncomfortable for the execution of tasks in shallow waters.

12. For diving casualties, the Company brought a collective decompression chamberin a container, butthere was no needto use it.

13. The most suitable cordage was that of bright colors and positive buoyancy.

14. Warm, water-proof fluorescent-colored working clothes were suitable for performing tasks in the area.

15. The lodgings, located on middle deck 3, which accommodated 10 people and resembled a 20 feet container was both practical and comfortable.

16. There was no interference by other ships either in the anchorage or in the operation itself.

17. The HOT-TAP system employed in the operation proved to be highly suitable for this type of task, in view of its very good qualities.

18. When the HOT-TAP was not placed in the highest position, certain maneuvers were made in order to verify that the hydrocrabon tank was empty.

19. The pumping of gas-oil did not cause any difficulty; this task was slightly slower in the case of lubricant oils.

20. Despite the fault detected on December 19, the fuel separator worked satisfactorily, separating hydrocarbons from water with less than 15 ppm.

21. The water supply sufficed since it was rationed: 15 minutes during the day and 15 minutes for bathing purposes, two days out of three only (divers were exempted from this rule since they had showers every day).

22. Food was suitable for the type of tasks performed and the temperatures in the area.

23. On-board equipment was used for sewage disposal.

24. Solid waste was placed in containers that were subsequently unloaded in the Province of Tierra del Fuego as prescribed by law.

25. Waste from Argentine Supply "FRANCISCO DE GURRUCHAGA" and transport "CANAL BEAGLE" was received and disposed of in the same way.

26. Monitoring tasks were carried out, as established in the IEE.

27. The use of helicopters was not necessary, thus complying with IEE recommendations.

28. Efforts were made to avoid disturbing local fauna with loud noise.

29. It had been requested not to disembark on islands or in Palmer Station without prior agreement among local scientists. Such requirement was duly observed.

30. Under IEE requirements, local fauna and flora were neither polluted nor disturbed.

31. The Argentine Naval Hydrographic Service provided constant support through weather forecasts and ice reports.

32. The quantity of gas-oil recovered was considerably less than that calculated in theory; therefore, it is thought that there may be undetected fissures. The quantity of recovered lubricant was almost as expected.

33. The excellent working team made up by the ARGENTINE NAVY, the Netherlands Government and the NOORDHOEK DIVING Company carried out joint tasks in an atmosphere of close cooperation and comradeship.

34. It should be noted that none of the tasks were easy, since weather conditions in Antarctica make both seafaring and diving tasks difficult.

35. It can be considered that the wreck of Argentine Navy Polar Ship "BAHIA PARAISO" is now clean.

STATISTICS

Total quantity of hydrocarbons recovered: 152.000 litres.

Total quantity of gas-oil recovered: 75.000 litres.

Total quantity of lubricant oil recovered: 50.000 litres.

Total quantity of fuel mixture recovered: 27.000 litres.

Number of HOT-TAP operations performed: 22

Number of hull cuts: 4

Total number of diving operations: 169

Total number of diving hours: 155,10 or 9.306 minutes.

981 litres per diving hour were recovered.

Diving operations

	Nº	Duration	Depth	Day	DD/MM
Longest	136	150	6	Wed.	30/12
Shortest	050	1	16	Wed.	16/12
Deepest	001 002	33 23	21 21	Wed. Wed.	09/12 09/12
Shallowest	054 078 080	71 103 18	3 3 3	Thur. Mon. Mon.	17/12 21/12 21/12

Longer than 2 hours: 9

Longer than 1 hour: 44

Occurrence of diving operations of equal duration: 6 49-min ops.
6 48-min ops.

Most frequent depth of diving operations: 14-20 m

Average depth: 10,70 m

Average of recovered litres per diving operation: 899

HOT-TAP system efficiency: 99,97 (Recovered litres divided by spilled litres)

Acknowledgements to all Personnel who took part in the operation:

ARGENTINE NAVY

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COMMANDER, ANTARCTIC NAVAL FORCE AND AREA.
COORDINATOR OF FUEL RECOVERY TASKS.

Commander Juan Carlos PARMIGIANI
AUTHORITY FOR THE SUPERVISION AND IMPLEMENTATION OF RELATED ACTIVITIES

Lieutenant Commander Jorge Alberto GOPCEVICH CANEVARIS
COMMANDING OFFICER, ARGENTINE NAVY TRANSPORT "CANAL BEAGLE"

OFFICERS AND CREW OF ARGENTINE NAVY TRANSPORT "CANAL BEAGLE"

REINFORCEMENT CREW ON BOARD FOR THE OPERATION

MILITARY AND CIVILIAN PERSONNEL OF THE METEOROLOGY SERVICE, ARGENTINE NAVY

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BIOLOGIST

Mr Jan HALDERMAN
PROJECT MANAGER FOR NOORDHOEK DIVING

MEMBERS OF THE NOORDHOEK DIVING COMPANY WHO PARTICIPATED IN THE OPERATION AS DIVERS OR SAILORS

Mr Rob BIJNSDORP
JOURNALIST (Specialised in marine ecology)

Photographs

Nº 1: Divers on deck ready to jump into the water.

Nº 2: HOT-TAP valve placed on the hull and ready to be connected to commence hydrocarbon removal.

Nº 3: Repairing the boom.

Nº 4: The boom surrounding the working area.

Nº 5: Ice: eternal companions in the Antarctic.

Nº 6: Craft working on the hull. In the background, Transport "CANAL BEAGLE"

Nº 7: Working on the hull with the boom.

Nº 8: The author accompanied by penguins.

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PAPER ON
FUEL AND OIL USAGE IN ANTARCTICA

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FUEL AND OIL USAGE IN ANTARCTICA

by
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INTRODUCTION

Three surveys have been conducted during the last eight years to collect information on the quantities and types of fuels and oils used by national Antarctic programs in Antarctica. The surveys were as follows:

- 1987/88 SCAR survey of fuels and oils used by national Antarctic programs;
- 1990/91 COMNAP survey of the typical maximum quantities of fuels and oils carried on the vessels of national Antarctic operators; and
- 1992/93 SCALOP survey of the typical maximum quantities of fuels and oils carried on the vessels of national Antarctic operators and tourist ships.

The SCAR survey had different objectives from the latter two and consequently the data collected does not permit a comparison of trends over the period. Nevertheless, the three surveys together provide a general picture of the quantities and usage of fuels in the Antarctic Treaty area.

SURVEY RESULTS

The objectives and principal findings of each of the three surveys are described below.

1987/88 SCAR Survey

In 1986 SCAR established a Panel of Experts on Waste Disposal with the task of developing a response to Recommendation 4 of the Thirteenth Antarctic Treaty Consultative Meeting (ATCM) which was held in Brussels in 1985. Recommendation XIII-4 requested SCAR to undertake a comprehensive review of waste disposal practices for Antarctic expeditions and station activities and provide scientific advice on waste disposal procedures and standards for coastal and inland stations and field camps.

The SCAR Panel used questionnaires to obtain information from Antarctic operators on the technical details of waste disposal procedures which might contribute to environmental impacts. In addition quantitative data on levels of activity, waste generation and fossil fuel consumption was sought.

Information derived from the survey on the consumption of fossil fuels in the Antarctic Treaty area during the 1987/88 operating year is given in Figure 1. Where data were not provided by a national program, an estimate of consumption was made based on the relative size of the operation. It should also be noted that the survey did not include fishing, tourist and other non-government vessels. From the data presented it can be seen that the estimated consumption of fuel (during the 1987/88 operating year) against the three major categories of use is as follows (and is also illustrated in Figure 2):

Fuels/Oils Transported/Consumed in Antarctica

Ships Bunkers:	43,448,485 litres	53.2%
Station Fuel:	25,452,116 litres	31.2%
Aviation Fuel:	12,703,298 litres	15.6%
TOTAL:	81,603,899 litres	100%
Number of countries included in survey:		18

1990/91 COMNAP Survey

Recommendation 4 of the fifteenth ATCM held in Paris in 1989 requested governments to establish contingency plans for response to marine pollution in the Antarctic. At its Cambridge meeting in 1989, COMNAP discussed the development of contingency plans and the need to implement preventive measures. At the 1990 meetings in Bariloche, COMNAP requested SCALOP to develop a course of action for the development and implementation of oil spill contingency plans and undertake a survey of fuels oils transported into the Antarctic Treaty area.

The principal objective of the survey was to determine the types and typical maximum quantities of fuels and oils carried on Antarctic resupply vessels. Because the heavier fractions of oil tend to be the most persistent they generally pose the greatest environmental threat. Hence the information collected was intended to give a general indication of the potential pollution risk from a maritime casualty in Antarctica.

The survey was conducted for the 1990/91 operating season and generated responses from eleven Antarctic programs and provided information on 20 vessels (Figure 3). Information was not sought on fishing, tourist and other non government vessels. Because this survey obtained information on the typical maximum quantities of fuel carried by resupply vessels on a single voyage, the data are not directly comparable with that obtained in the earlier SCAR Survey. The SCAR Survey collected data on the total quantity of fuels transported to Antarctica during the 1987/88 operating year.

Thus the data collected in the 1990/91 Survey does not give a true indication of usage because it relates to fuel carried on particular voyages rather than total consumption. Nevertheless the data have been aggregated against the three major categories of use (as shown in the following table and illustrated in Figure 4) to provide a very approximate indication of use and to facilitate a comparison with similar data collected from the 1992/93 Survey.

Aggregate of Typical Greatest Quantities of Fuels/Oils Carried byVessels of National Antarctic Operators on a Single Voyage During the 1990/91 Season

Ships Fuels/Oils:	24,799,481 litres	36.5%
Other Fuels/Oils:	16,607,846 litres	24.4%
Aviation Fuel:	26,610,641 litres	39.1%
TOTAL:	68,017,968 litres	100%

Other relevant statistics that can be derived from the 1990/91 Survey are as follows:

Number of countries included in survey:	11
Number of vessels included in survey:	20
Number of vessels using medium/heavy bunkers:	7
Percentage of vessels using medium/heavy bunkers:	35%
Maximum quantity of heavy bunkers carried by a vessel:	1.38ML
Average total quantity of fuels/oils carried by vessels:	3.40ML
Maximum quantity of fuels/oils carried by a vessel:	38.63ML
Average length of vessels:	100.28m
Median length of vessels:	88.07m
Maximum length of vessels:	187.45m

(Note: ML = Million Litres)

1992/93 SCALOP Survey

At its meetings in 1993, the SCALOP Sub-group on Oil Spill Prevention and Response discussed the need to obtain current data on the potential risks of major oil spills in terms of the volume of shipping using Antarctic waters and the quantities and types of fuel being carried. It was noted that the 1990/91 Survey was not fully comprehensive and the situation had changed in recent years with the introduction of several new vessels. It was therefore decided to repeat the 1990/91 survey format and collect data on the typical maximum quantities of fuel carried by vessels to Antarctic during the 1992/93 season.

In addition to obtaining data on the fuels/oils carried by the vessels of Antarctic programs, similar information on tourist vessels was also sought from the International Association of Antarctic Tour Operators (IAATO). It was decided not to seek information on fishing vessels because of the relatively small quantity of fuel they each carry in comparison with resupply and tourist vessels.

The data collected on the vessels of Antarctic programs and tourist operators have been aggregated against the three major categories of use as shown below (and given in Figures 5, 6 & 7).

Aggregate of Typical Greatest Quantities of Fuels/Oils Carried by Vessels of National Antarctic Operators on a Single Voyage During the 1992/93 Season

Ships Fuels/Oils:	42,075,080 litres	44.6%
Fuels/Oils for Other Uses:	16,891,338 litres	17.9%
Aviation Fuel:	35,438,385 litres	37.5%
TOTAL:	94,404,803 litres	100%

Aggregate of Typical Greatest Quantities of Fuels/Oils Transported by Vessels of Tourist Operators on a Single Voyage During the 1992/93 Season

Ships Fuels/Oils:	11,647,270 litres	99.4%
Fuels/Oils for Other Uses:	12,800 litres	0.1%
Aviation Fuel:	58,000 litres	0.5%
TOTAL:	11,718,020 litres	100%

Other relevant statistics, comparable with the 1990/91 Survey, are as follows:

Vessels of Antarctic Programs

Number of countries included in survey:	19
Number of vessels included in survey:	27
Number of vessels using medium/heavy bunkers:	9
Percentage of vessels using medium/heavy bunkers:	33%
Maximum quantity of heavy bunkers carried by a vessel:	2.4ML
Average total quantity of fuels/oils carried by vessels:	3.50ML
Maximum quantity of fuels/oils carried by a vessel	45.3ML
Average length of vessels:	100.99m
Median length of vessels:	94.81m
Maximum length of vessels:	187.45m

(Note: ML = Million Litres)

Tourist Vessels

Number of countries included in survey:	5
Number of vessels included in survey:	10
Number of vessels using medium/heavy bunkers:	4
Percentage of vessels using medium/heavy bunkers:	40%
Average total quantity of fuels/oils carried by vessels:	1.96ML
Maximum quantity of heavy bunkers carried by a vessel:	3.12ML
Maximum quantity of fuels/oils carried by a vessel:	3.64ML
Average length of vessels:	103.46m
Median length of vessels:	113.96m
Maximum length of vessels:	149.00m

(Note: ML = Million Litres)

CONCLUSIONS

A comparison of data from the 1990/91 COMNAP and 1992/93 SCALOP Surveys is given in Figure 8 and indicates the following:

- Approximately 34% of the vessels used by national Antarctic operators use medium or heavy fuels for ships bunkers.
- Approximately 40% of the tourist vessels use medium or heavy fuels for ships bunkers.
- The greatest quantity of heavy fuel (ships bunkers) carried at one time by a single vessel used by a national Antarctic operator was 2.40 million litres (ML).
- The greatest quantity of heavy fuel (ships bunkers) carried at one time by a single tourist vessel was 3.12ML.
- The greatest quantity of fuels and oils carried at one time by a single vessel (an oil tanker) was 45.3ML. (Note: The quantity of fuel carried by the tanker almost equalled the total maximum quantities of fuels and oils carried by all other vessels during the 1992/93 season).
- The average greatest quantity of fuels and oils carried by the vessels of national Antarctic operators on a single voyage was 3.40ML (in the 1990/91 season) and 3.50ML (in the 1992/93 season).
- If the oil tanker is deleted from consideration, the average greatest quantity of fuels and oils carried by all the vessels used by national Antarctic operators was 1.55ML (in the 1990/91 season) and 1.89ML (in the 1992/93 season).
- The greatest quantity of fuels and oils carried at one time by a single tourist vessel was 3.64ML (during the 1992/93 season).
- The average greatest quantity of fuels and oils carried by tourist vessels on a single voyage during the 1992/93 season was 1.17ML.
- The average length of vessels used by national Antarctic operators was 100.28m (in the 1990/91 season) and 100.99m (in the 1992/93 season).
- The average length of Antarctic tourist vessels used during the 1992/93 season was 113.96m.

By way of comparison, the quantities of crude oil released as a result of some of the major oil spill incidents in recent decades were approximately as follows (and shown in Figure 9):

Vessel	*Date*	*Location*	*Quantity*
Torrey Canyon	1967	Scilly Isles, UK	132ML
Amoco Cadiz	1978	Brittany, France	252ML
Exxon Valdez	1989	Alaska, USA	41ML
Braer	1993	Shetland Islands	94ML

Also, the Bahia Pariso was carrying approximately 1.16ML of miscellaneous fuels and lubricants when she ran aground in 1989. Of this, about 0.8ML was spilled into the sea.

Country	Ships bunkers (litres)	Aviation Fuel (litres)	Station Fuel (litres)
Argentina	*2,000,000		*2,000,000
Australia	3,158,400		2,100,000
Brazil	2,000,000		190,000
Chile	140,000	200,000	500,000
France	36,000		360,000
FRG	6,000,000		300,000
GDR			120,000
India	*500,000		160,000
Italy	800,000		80,000
Japan	2,100,000		372,000
New Zealand			607,500
Norway	320,000		
PRC	*1,000,000		100,000
South Africa	140,000		250,000
UK	1,100,000		717,500
Uruguay		18,000	45,000
USA	14,154,085	10,485,298	12,550,116
USSR	*10,000,000	*2,000,000	*5,000,000
Sub totals	43,448,485	12,703,298	25,452,116
		Total	81,603,899

Note: The estimates derive from responses to a questionnaire survey in 1987-88 which was used to provide data for the 'Report of the SCAR Panel of Experts on Waste Disposal'.[10] Where data was not provided in response to the questionnaire an estimate has been made based on the relative size of the particular operations; such estimates are identified by*. The data includes no estimates for fishing and non government activities. Some ship bunker figures seem to be based on total fuel used to support Antarctic operations others provided the data only for the period of vessel was south of 60 degrees.

Figure 1: 1988/89 SCAR Survey of Fuels and Oils used by National Antarctic Programs

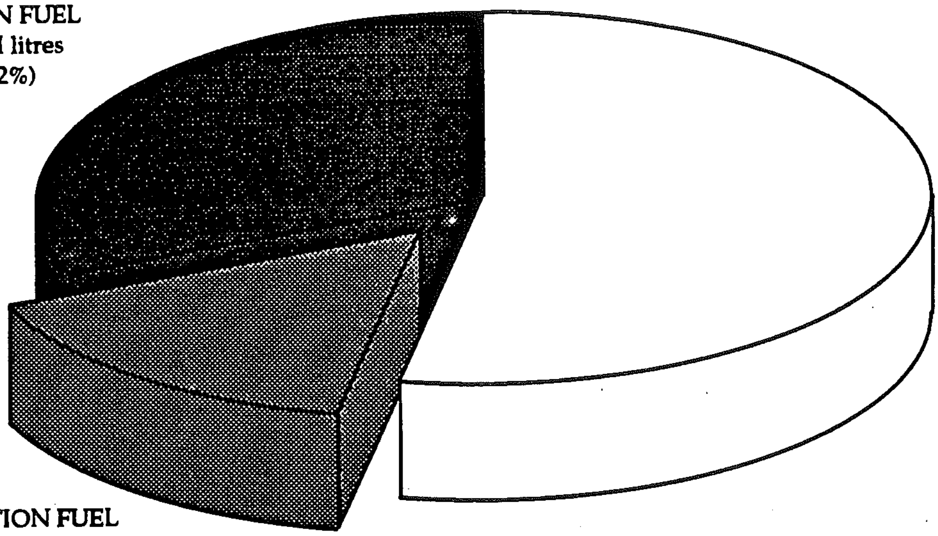

Figure 2: 1987/88 SCAR Survey - Chart Illustrating Usage of Fuels

NATIONAL OPERATOR		VESSEL NAME	OPERATOR/ CHARTERER	LENGTH OVERALL (Metres)	FUELS/OILS FOR VESSELS' USE: BUNKERS: LIGHT (Litres)	MEDIUM (Litres)	HEAVY (Litres)	LUBRICATING OILS: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	OTHER: Describe type and how carried	FUELS/OILS CARRIED ON VESSELS FOR OTHER USES: DIESEL: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	PETROL: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	HEATING KEROSENE: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	LUBRICATION OILS: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	AVIATION FUEL: IN SHIP'S TANKS (Litres)	IN DRUMS (Litres)	TOTAL LITRES
ARGENTINA	a	Irizar	Instituto Antartico Argentino	119.30	2,500,000	-	-	140,000	-	-	1,700,000	110,000	-	39,000	-	5,500	-	15,000	130,000	155,000	4,794,500
	b	Irigoyen	Instituto Antartico Argentino	80.00	362,000	-	-	20,000	-	-	-	-	-	-	-	-	-	-	-	-	382,000
	c	Gurruchaga	Instituto Antartico Argentino	80.00	362,000	-	-	20,000	-	2,000 gasoline in drums	-	-	-	-	-	-	-	-	-	-	384,000
AUSTRALIA	d	Icebird	Australian Antarctic Division	109.71	1,000,000	-	-	20,000	2,000	-	-	4,000	-	20,000	950,000	-	-	4,000	-	180,000	2,180,000
	e	Aurora Australis	Australian Antarctic Division	94.81	1,000,000	-	-	30,000	-	-	-	4,000	-	20,000	1,000,000	-	-	4,000	50,000	60,000	2,168,000
BRAZIL	f	Barao de Teffe	Brazilian Navy	82.11	752,930	-	-	22,680	-	-	327,730	-	-	2,000	-	-	-	-	16,000	-	1,121,340
CHILE	g	Africana	INACH	72.00	86,000	-	370,000	725	-	-	-	-	-	-	-	-	-	-	-	-	456,725
FINLAND	h	Aranda	Finnish Institute	70.00	355,000	-	-	9,000	2,000	-	-	-	-	-	-	-	-	-	-	5,000	371,000
GERMANY	j	RV Polarstern	Alfred Wegener Institute	117.91	-	2,800,000	-	70,000	-	15,000 hydraulic oil 200 hydraulic oil for other uses	200,000	-	14,500	-	-	-	-	1,000	240,000	-	3,340,700
ITALY	k	Italica	ENEA	130.00	190,000	612,000	-	8,600	-	-	300,000	-	-	-	-	-	-	-	-	80,000	1,190,600
	l	Cariboo	ENEA	65.36	485,000	-	-	10,400	-	-	-	-	-	-	-	-	-	-	-	-	495,400
	m	Explora	ENEA	72.78	550,000	-	-	12,790	-	-	-	-	-	-	-	-	-	-	-	-	562,790
KOREA		Fuel for King Sejong Station carried on Argentine Navy vessel "Almirante Irizar"																			
	n	Southella	KORDI	69.62	240,000	-	-	-	2,000	-	-	-	-	-	-	-	-	-	-	-	242,000
NEW ZEALAND		No vessels operated 1990/91																			
RUSSIA	o	Akademik Fedorov	Russian Antarctic Expedition	141.20	2,120,000	-	-	-	-	-	-	38,000 (Fin/Swe/Nor)		21,000 (Fin/Swe/Nor)	-	-	-	-	250,000	57,000 (Fin/Swe/Nor)	2,486,000
UNITED STATES OF AMERICA	p	Polar Sea	US Coast Guard	121.60	-	5,110,886	-	116,184	-	-	-	-	-	833	-	-	-	-	174,038	-	5,401,941
	q	Polar Duke	Antarctic Support Associates	66.80	500,000	-	-	10,000	-	-	-	-	-	1,000	-	-	-	100	50,000	-	561,100
	r	Nathaniel B Palmer	Antarctic Support Associates	94.03	1,435,600	-	-	51,800	-	16,300 thermal fluid for vessel's use 11,800 lube oil for other uses	-	-	-	1,600	-	-	-	-	33,700	-	1,550,800
	s	Gus W Darnell	US Dpt of Defence	187.45	299,208	-	1,376,467	-	-	-	11,824,583	-	-	-	-	-	-	-	25,126,603	-	38,626,861
	t	Maurice Ewing	Columbia Uni	66.30	588,629	-	-	6,382	-	2,200 other fuels for ship's use 6,700 fuels for other uses	-	-	-	-	-	-	-	-	1,300	2,000	607,211
	u	Greenwave	Central Gulf Lines	164.60	250,000	-	785,000	60,000	-	-	-	-	-	-	-	-	-	-	-	-	1,095,000
SUB-TOTAL LITRES					13,076,347	8,522,886	2,531,467	608,561	6,000	54,200	14,352,313	156,000	14,500	105,433	1,950,000	5,500		24,100	26,071,641	539,000	68,017,968
TOTAL LITRES					24,799,481						16,607,846								26,610,641		68,017,968

Figure 3: 1990/91 COMNAP Survey of Fuels and Oils carried by Vessels of National Antarctic Operations

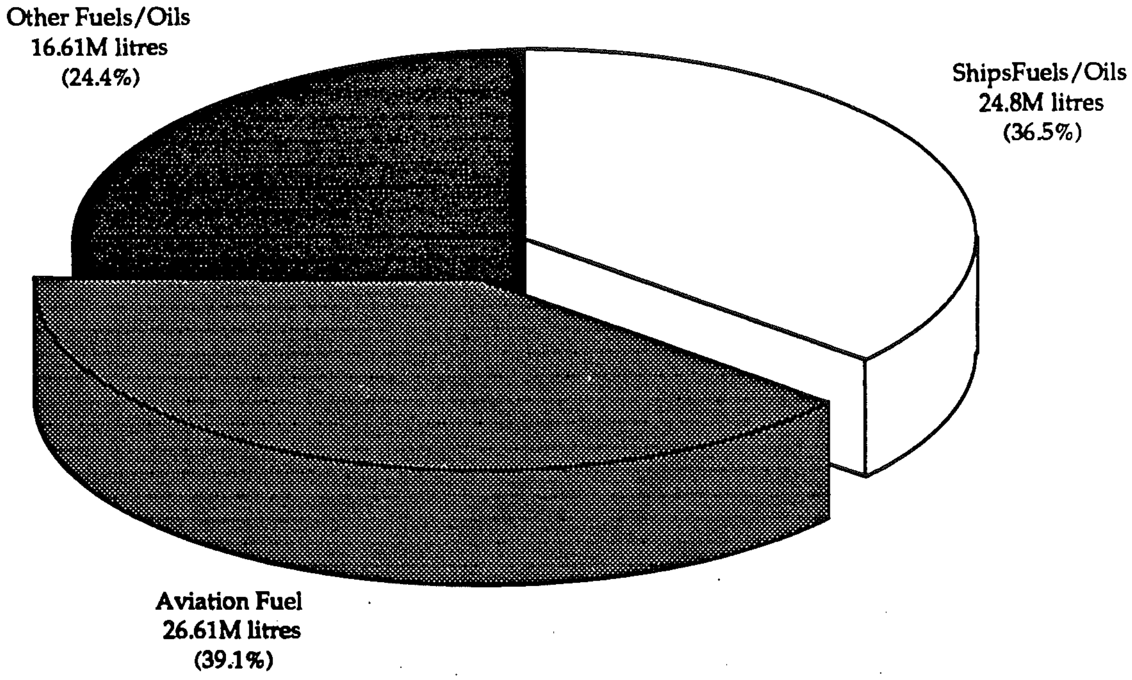

Figure 4: 1990/91 COMNAP Survey - Chart Illustrating Aggregate of the Greatest Quantities of Fuels/Oils Transported by Vessels of National Antartic Operators on a Single Voyage

NATIONAL OPERATOR		VESSEL NAME	OPERATOR/ CHARTERER	LENGTH OVERALL (Metres)	FUELS/OILS FOR VESSELS' USE: BUNKERS LIGHT (Litres)	BUNKERS MEDIUM (Litres)	BUNKERS HEAVY (Litres)	LUBRICATING OILS IN SHIP'S TANKS (Litres)	LUBRICATING OILS IN DRUMS (Litres)	OTHER Describe type and how carried	FUELS/OILS CARRIED ON VESSELS FOR OTHER USES: DIESEL IN SHIP'S TANKS (Litres)	DIESEL IN DRUMS (Litres)	PETROL IN SHIP'S TANKS (Litres)	PETROL IN DRUMS (Litres)	HEATING KEROSENE IN SHIP'S TANKS (Litres)	HEATING KEROSENE IN DRUMS (Litres)	LUBRICATING OILS IN SHIP'S TANKS (Litres)	LUBRICATING OILS IN DRUMS (Litres)	AVIATION FUEL IN SHIP'S TANKS (Litres)	AVIATION FUEL IN DRUMS (Litres)	TOTAL LITRES
ARGENTINA	A	Almirante Irizar	Instituto Antartico Argentino	119.30		3,034,000		80,200		236,000 NATO F35 37,400 NATO F50 (RON 90/95) other uses	1,530,000	106,200				2,000		13,600		226,800	5,266,200
	B	Francisco de Gurruchaga	Instituto Antartico Argentino	62.55		300,000		17,500													317,500
AUSTRALIA	C	Icebird	Australian Antarctic Division	109.71	470,000			39,082			746,000			42,000				5,391		65,000	1,367,473
	D	Aurora Australis	Australian Antarctic Division	94.81	1,220,000			16,287	720		580,000			2,000					17,900	48,000	1,884,907
BRAZIL	E	Barao de Teffe	Brazilian Navy	82.11	809,179			11,850			250,000			3,980		10		6,074	25,760		1,106,853
CHILE	F	Alcazar	INACH	47.00	55,000				2,000												57,000
	G	AP Piloto Pardo (carries tourists in spare berths)	Armada De Chile	73.00	488,900			12,600			200,000								9,000		710,500
CHINA	H	Jidi	Chinese Antarctic Administration	152.40	1,834,200			36,000												4,000	1,874,200
FINLAND		Nil Return - no ships operated in Antarctica during 1992/93																			Nil
FRANCE	J	L'astrolabe	IFRTP/TAAF	65.50	240,000			5,000		Detergent 1,000L Bunker additives 2,000L (drums)	600,000	4,000						6,000		65,000	923,000
GERMANY	K	RV Polarstern	Alfred Wegener Institute	117.91	3,551,529			136,788	3,274		203,625								108,620		4,003,836
	L	Polar Queen	Fed Institute for Geosciences & Nat Resources	75.20	798,000			17,392	209	900 L propyleneglycol for other uses		6,270		2,090					50,000		874,861
INDIA	M	Stepan Krasheninnikov	Dept Ocean Development	159.76	145,000		1,886,000											1,850	400,000	200,000	2,432,850
ITALY		Nil Return - no ships operated in Antarctica during 1992/93																			Nil
JAPAN	N	AGB Shirase	Japan Maritime Self-Defense Force	134.00		5,800,000		140,000		5602L refrigerating, generator and grease in drums 420,000L fuel for use Syowa								16,223	380,000		6,761,825
NEW ZEALAND		Nil Return - no ships operated in Antarctica during 1992/93																			Nil
NORWAY	O	Polarbjørn	Rieber Shipping/Norsk Polarinstitutt	49.62	690,000			6,700	2,400									3,600	32,000	12,000	746,700
	P	M/S Lance	Norwegian Polar Institute	60.80	550,000			15,000											25,000		590,000
POLAND			Polish Academy of Sciences	Refer to Russian Entry for 'Akademik Shuleykin' - *15,000 litres of petrol and *15,000 lubrication for Arztovskiy Station																	-
RUSSIA	Q	Akademik Fedorov	Russian Antarctic Expedition	141.20	470,000		2,400,000	82,000		12,000L antifreeze for use stations								153,000	235,000		3,352,000
	R	Akademik Shuleykin	Polish Expedition	71.60	376,500			20,600						17,600*				17,600*			432,300
SOUTH AFRICA	S	SA Agulhas	Dpt of Environ. Affairs	111.95		1,272,040			9,900				481,180			1,000		2,000	122,500	80,000	1,968,620
UNITED KINGDOM	T	RRS Bransfield	British Antarctic Survey	99.173	1,450,000			23,000	600					38,950		1,435		4,500		357,110	1,875,595
	U	RRS James Clark Ross	British Antarctic Survey	99.04	1,484,000			39,500	2,050	2,372L hydraulic oil 15,400L thermal fluid (in use)			450			410		7,000	350,000	182,450	2,083,632
	V	HMS Endurance	British Antarctic Survey	93	1,200,000			45,000						2,000					110,000		1,357,000
UNITED STATES OF AMERICA	W	Polar Star	US Coast Guard	121.60		4,894,105		51,744		175,835 aviation fuel JP5									454,545		5,376,229
	X	Greenwave	Central Gulf Lines	164.60	202,793		1,085,115	56,530	1,721	9,863L - thermal oil for in tanks											1,356,022
	Y	Paul Buck	US Dept of Defence	187.45	300,000		1,400,000				11,830,000								31,794,000		45,324,000
	Z	Paula Duke	Antarctic Support Associates	66.80	500,000			10,000						1,000				100	50,000		561,100
	AA	Nathaniel B Palmer	Antarctic Support Associates	94.03	1,435,600			51,800		16,300 thermal fluid for vessels' use 11,800 lube oil for other uses				1,600					33,700		1,550,800
URUGUAY	BB	Vanguardia	Instituto Antartico Uruguayo	72.64	213,000			31,800	3,600	800L SAE-40							600				249,800
SUB-TOTAL LITRES					18,483,701	15,100,145	6,571,115	946,373	26,474	947,272	15,939,625	116,470	481,630	111,220	-	4,855	600	236,938	34,198,025	1,240,360	94,404,803
TOTAL LITRES					42,075,080						16,891,338								35,438,385		94,404,803

Figure 5: 1992/93 SCALOP Survey of the Greatest Quantities of Fuels/Oils Transported by Vessels of National Antarctic Operators on a Single Voyage

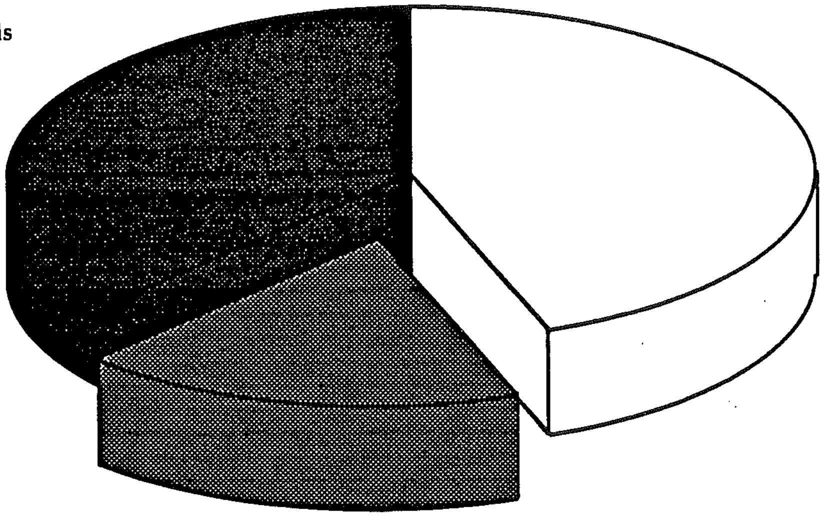

Figure 6: 1992/93 SCALOP Survey - Chart Illustrating Aggregate of the Greatest Quantities of Fuels/Oils by Vessels of National Antarctic Operators on a Single Voyage

TOURIST VESSELS		VESSEL NAME	OPERATOR/ CHARTERER	LENGTH OVERALL (Metres)	FUELS/SOILS FOR VESSELS' USE						FUELS/SOILS CARRIED ON VESSELS FOR OTHER USES										TOTAL LITRES
					BUNKERS			LUBRICATING OILS		OTHER	DIESEL		PETROL		HEATING KEROSENE		LUBRICATING OILS		AVIATION FUEL		
					LIGHT (Litres)	MEDIUM (Litres)	HEAVY (Litres)	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	Describe type and show how carried	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	IN SHIPS TANKS (Litres)	IN DRUMS (Litres)	
CHILE	I	AP Piloto Pardo	Armada De Chile	It is understood that AP Piloto Pardo is logistics vessel, although spare berths allocated for tourists - refer to summary of antarctic operator vessels																	-
FRANCE	II	Ocean Princess	Croisieres Paquet	149.00	2,700,000	900,000		40,000	20									4,000			3,644,020
GERMANY	III	Columbus Caravelle	Transocean Passagierdienst	116.40	780,000			30,000													810,000
	IV	Bremen	Hanseatic Cruises GmbH	111.52		65,000	540,000	25,000										1,600			631,600
	V	Hanseatic	Hanseatic Cruises GmbH	122.80	13,000	45,000	550,000	30,000													638,000
		Sea Quest Cruises	Information not available																		-
		Vistamar	Information not available																		-
		Europa	Information not available																		-
NETHERLANDS	VI	MV Greenpeace	Stichting Marine Services Amsterdam	58.00	350,000			4,500	100				2,200	4,000						14,000	374,800
USA	VII	World Discoverer	Clipper Cruise Line, St Louis HO	87.00	200,000			6,000	80	400L mobil gear 700L hydraulic oil				1,000							208,180
	VIII	Kapitan Khlebnikov	Quark Expeditions	129.10	260,000		3,122,000	152,420	2,000										44,000		3,579,420
	IX	Akademik Sergey Vavilov	Quark Expeditions	117.00	1,150,000																1,150,000
	X	Professor Molchanov	Quark Expeditions	71.00	350,000																350,000
	XI	Explorer	Explorer Shipping Corporation	72.80	300,000			31,000	1,000												332,000
SUB-TOTAL LITRES					6,103,000	1,101,000	4,212,000	317,920	3,200	1,100	-	-	2,200	5,000	-	-	-	5,600	44,000	14,000	11,718,020
TOTAL LITRES					11,647,220						12,800								58,000		11,718,020

Figure 7: 1992/93 SCALOP Survey on Typical Maximum Quantities of Fuels/Oils Transported by Vessels of Tourist Operators/NGOs

CHARACTERISTIC	1990/91 COMNAP SURVEY	1992/93 SCALOP SURVEY	
	Operator Vessels	Operator Vessels	Tourist/NGO Vessels
Number of countries included in survey	11	19	5
Number of vessels included in survey	20	27	10
Number of vessels using medium/heavy bunkers	7	9	4
Percentage of vessels using medium/heavy bunkers	35%	33%	40%
Greatest quantity of heavy bunkers carried by a single vessel	1.38 ML	2.40 ML	3.12 ML
Average greatest quantity of fuels/oils carried by vessels	3.40 ML	3.50 ML	1.17 ML
Greatest quantity of fuels/oils carried by a single vessel	38.63 ML	45.3 ML	3.64 ML
Average length of vessels	100.28 m	100.99 m	103.46 m
Median length of vessels	88.07 m	94.81 m	113.96 m
Maximum length of vessels	187.45 m	187.45 m	149.00 m

Figure 8: Comparison of Data from the 1990/91 COMNAP and 1992/93 SCALOP Surveys

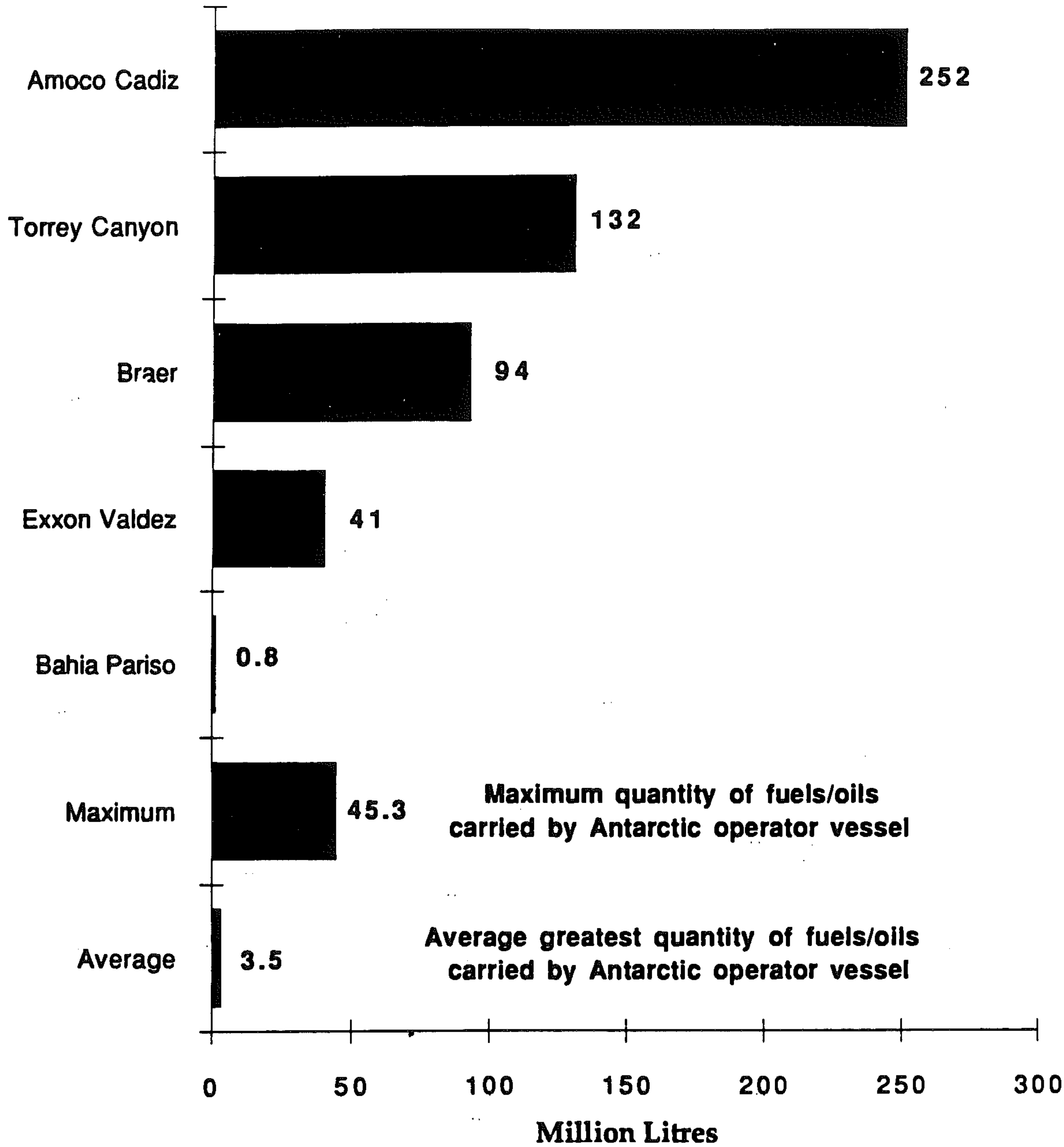

Figure 9 Comparison of fuels/oils carried by Antarctic resupply vessels and major international oil spill incidents

Towards New Energy Systems for Antarctic Stations

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Abstract
Technologies for cleaner, renewable energy production and energy storage are rapidly evolving and new, realistic options for alternative energy systems for Antarctic stations can now be considered. This paper which originates from a co-ordinated French-Australian project presents a review of the main station energy supply issues and a schematic presentation of selected power generation technologies and system integration options. It provides an opportunity to refocus the orientation of the project and to motivate a move "towards new energy systems for Antarctic stations."

Keywords: Energy, Sustainable, Renewable, Environment, Antarctic, Wind Turbines, Hydrogen

Résumé
Vers de nouveaux systèmes énergétiques pour les stations antarctiques
De nouvelles alternatives énergétiques sont désormais réalistiquement envisageables pour les stations Antarctiques avec l'évolution rapide de certaines technologies de production énergétique moins, ou non polluantes, ou encore de stockage de l'énergie. Cet article issu d'un programme coordonné franco-australien présente une revue des principaux problèmes posés par la fourniture d'énergie aux stations ainsi que la présentation schématique d'une sélection de modes de production d'énergie et de possibilités d'intégration des systèmes. Il offre une opportunité de repenser l'orientation du projet et de motiver un mouvement "Vers de nouveaux systèmes énergétiques pour les stations antarctiques".

Mots Clés: Énergie, Durable, Renouvelable, Environnement, Antarctique, Aérogénérateurs, Hydrogène

1. Introduction

The "Classic" methods of providing energy from fossil fuels have allowed and supported most human advances and achievements from the Industrial Revolution to the exploration of the Antarctic continent and it's establishment as a unique scientific laboratory.

But these methods are associated with a large use of limited resources and substantial impacts on the biosphere. The need has now been identified for a new value system oriented towards the protection of the biosphere as well as the local environment and most activities have to be reviewed in the light of new priorities.

Antarctic activities are of special concern as they occur in pristine remote areas where ecosystems are particularly fragile and where supply operations remain difficult and hazardous.

A coordinated program was initiated in early 1993 in a joint French-Australian effort to prepare and initiate the move "Towards New Energy Systems for Antarctic Stations". The present paper finds most of its origins in various components of this program and the related publications and reports listed in the bibliography. Through a review of the main issues and a schematic presentation of selected power generation technologies and system integration options, it provides an opportunity to refocus the orientation of our project and could be the foundation for a wider coordinated effort with several Antarctic nations.

2. Basic Considerations

2.1 Energy Needs

We will focus on the main "static" energy needs of a station, normally satisfied through the provision of electrical power (for lights, telecommunications, electronic equipment, electric tools, electric heaters, pumps, water production...) and thermal power (space heating, water production...).

The energy need for water production varies greatly depending on the production method imposed by the site. The most demanding process is desalination, which can require an average power over 100 kW to produce some 5,000 litres a day at 25°C (Dumont d'Urville - evaporator - seawater at -1.8°C) while melting ice would require some 10 to 20 kW. New improved reverse osmosis systems could dramatically reduce the power required for desalination. The other energy needs vary with the station's size and design, the scientific equipment used and the meteorological conditions. The seasonal variations are influenced by two main factors: the level of activity on the station, reaching a maximum in summer, and the thermal and lighting needs which are at their greatest during winter. Total energy requirements are usually at a maximum during the long winter.

Typical average power requirements at current French and Australian Antarctic stations are in the range 70 to 250 kW electrical and 150 to 350 kW thermal. These needs are presently fulfilled almost exclusively through the combustion in generator sets and boilers of large quantities of fossil fuels, typically 350,000 to 800,000 litres of Diesel Fuel or Kerosene each year. Exhaust emissions contain the usual polluting gases and particulate matter.

2.2 Fuel Supply

Fuel has to be shipped to the stations long distances over the Southern Ocean, usually in special ice strenghtened multipurpose vessels. Fuel is then pumped to the shore and stored in large tanks or bladders. The few inland stations receive their fuel supply from the coast either by tracked vehicle convoys or special ski equipped aircraft. Depending on the transport method, the important factor can be either the weight or the volume of the fuel, if not both.

Fuel supply operations induce high costs, use up large logistic capabilities which could be more beneficial to other activities, and can present safety problems. Both supply operations and the storage of large quantities of fuel for long periods on the station produce the possibility of a damaging fuel spill.

2.3 Site Constraints

Many stations are located along the coast on small rocky outcrops which are the most favorable locations for both animal breeding grounds and human settlements. The cohabitation on limited space favours the use of the most compact energy systems, that is, fossil fuel powered systems, while making local exhaust pollution and fuel spill hazards particularly menacing.

2.4 Cost Considerations

The financial cost of energy supply to the stations is difficult to assess as most equipment, facilities and personnel are also involved in other activities. It means that cost comparisons are difficult to assess and financially based decisions are not necessarily relevant. We will only attempt to provide some orders of magnitude for the cost of primary power generation.

Costs will be expressed in U.S. Dollars (US$) on the basis of 1 US$ = 1.3 Australian Dollars (A$) = 5.3 French Francs (FRF). Because of the variety of parameter values that can be used (depending on the country, the invester status, etc...), Life Cycle Costing will be restricted here to a simple "stable value" case corresponding to Discount Rate = Inflation Rate = 0, but sufficient information should be given for further analysis with different values. The life cycle base will be 20 years, imposing an amortization on 20 years for equipment having longer life expectations. Costing results will be summarised in a recapitulative table.

3. Non Renewable Energy Production

3.1 Fuels

Fossil fuels widely used in the Antarctic for power generation are special "cold weather" blends of Diesel Fuel and Kerosene. Both are used in the same type of engines and boilers, although requiring different tuning.

We indicate in Table 1 the approximative energetic characteristics of the Special Antarctic Blend "SAB" Diesel Fuel used by the French and Australian expeditions out of Hobart, and the JP8 Kerosene used by the US Antarctic program. We added for comparison two cleaner fossil fuels, Liquid Petroleum Gas "LPG" and liquid Methane (Methane being the major component of Natural Gas), as well as "The" perfect clean (non fossil) fuel, Hydrogen, in liquid and gaseous forms.

The energy content used here and subsequently is the Lower Heating Value "LHV" (or Pouvoir Calorifique Inférieur "PCI") which corresponds to a combustion where the water produced is in vapour form. The energy unit used throughout this paper is for practical reasons the kiloWatt-hour "kWh", which is the energy generated over one hour by a power of 1 kW. We have then 1 kWh = 3,600 kJ = 3412 Btu.

The storage requirement factors indicate the proportions, respectively in volume and weight, of the total storage systems (fuel + containers) required to hold the same energy content, SAB being taken as reference (factors =1). For example, the weight factor = 3 for liquid hydrogen means that a cylinder containing 1,000 kWh worth of liquid hydrogen would be 3 times heavier than a tank containing 1,000 kWh worth of SAB. Those factors are indicative orders of magnitude only as they can vary significantly with the type and size of the storage units. This is particularly true for the metal hydride storage of gaseous hydrogen, where several different technologies are under development.

Fuel lq=liquid gs=gas	densi-ty Kg/l	Lower Heating Value kWh /litre	 kWh /kg	Storage requirement factor volu-me	 wei-ght
lq SAB	0.805	9.8	12.2	1	1
lq JP8	0.810	9.4	11.6	1.05	1.05
lq LPG	0.515	6.6	12.8		
lq Methane	0.420	5.9	13.9	6	2
lq Hydrogen	0.071	2.4	33.6	16	3
gs Hydrogen	0.017	0.6	33.6	35	10
gs Hydrogen (in Hydrides)				best: 2.3?	best: 5.3?

Table 1 :
Indicative characteristics of selected fuels.

We can see from Table 1 that the cleaner the fuel, the higher the storage requirement. Independently from the purchase cost, clean fuels will be more difficult and expensive to store and transport. Hydrogen could probably only confirm its "perfect fuel" status if produced on-site.

3.2 Diesel/Kerosene Generator Sets

The arrangement where a diesel engine drives an alternator usually constitutes the backbone of a station's energy systems. It is a compact, reliable and mature technology. On a fuel LHV basis, a modern unit such as the Caterpillar 3306B Direct Injection with water cooled manifold has an electrical efficiency of 35% (AC Power output at the alternator) and a heat recovery efficiency of 32% (hot water around 70-80°C). In case of cogeneration (both electricity and heat recovered), the global efficiency is then 67% (this is synthetised on Figure 1.a). It means that for each litre of SAB with a LHV of 9.8 kWh/l, the generator set can produce 9.8x0.35=3.43 kWh of electrical energy and 9.8x0.32=3.14 kWh of heat, that is a total of 6.57 kWh.

Let us define for the generator sets (and all other power generation equipment) a Load Factor equal to the proportion of the total generation capacity effectively used. For example, a 100 kW generator used to produce an average 70 kW will have a load factor Lg=0.7 or 70%.

By combining various considerations and estimates about the generator sets of the Australian Stations (from Ref. 2 & 6), we find that:
- For reasonable load factors, the capital cost is negligible compared to the operating costs (fuel + maintenance):
Assuming for a 125 kW generator set a purchase cost of 5,400 US$ for the alternator (20 years life) and 27,000 US$ for the engine (4 years life, salvage value of 2,000 US$), we get a total capital cost over 20 years of 130,400 US$, that is 1,043 US$ per rated kW, or about 0.0060 US$ per rated kW and per hour. For a load factor Lg, the share of the capital cost in each kWh (electrical only!) produced is then (0.0060/Lg) US$, which is less than 0.01 US$ for load factors over 0.6 and even stays under 0.05 US$ for load factors as low as 0.12!
- The order of magnitude of the maintenance cost is some 0.25 US$ per electrical kWh produced;

If Pfuel is the cost of 1 kWh worth of fuel delivered at the station, then the order of magnitude of the financial cost of generating 1 kWh can be estimated for load factors over 0.6 at :
if electrical power only is recovered:
• Pel = 0.25 + Pfuel / 0.35
and for cogeneration:
• Pcog = 0.25 / (1+0.32/0.35) + Pfuel / 0.67 [i.e. Pel (0.35/0.67)]

An estimation for SAB delivered at the Australian stations (Ref. 2) gives Pfuel = 0.0785 US$/kWh (1 A$ = 0.77 US$ per litre). This estimation was based on a 0.62 US$/kg transport cost on a "share of cargo weight" basis, that is 0.50 US$/litre or 0.051 US$/kWh, and gives the order of magnitude:
• Pel = 0.47 US$ / kWh
• Pcog = 0.25 US$ / kWh
For comparison, the full domestic price of the electricity delivered by the Hydro Electric Commission in Tasmania is around 0.07 US$ / kWh.

And in terms of energy, the energetic costs (quantity of non renewable lower heating value sacrificed) are for each kWh produced:
• Eel = 1/0.35 = 2.86 kWh
• Ecog = 1/0.67 = 1.49 kWh

3.3 Diesel/Kerosene/Gas Boilers

These well known boilers that we find in many houses equipped with central heating are reliable, low maintenance, long life, efficient machines. They produce heat with an efficiency reaching 80% with good tuning. This is synthetised on Figure 1.b.

With a typical purchase cost of 70 US$ per rated kW, a life exceeding 20 years and little maintenance, a boiler offers a financial power generation cost that can be in general estimated as being the fuel cost, which gives :
• Pboil = Pfuel / 0.80
That is with Pfuel = 0.0785 US$/kWh for SAB an order of magnitude of:
• Pboil = 0.098 US$ / kWh
While the energetic cost is:
• Eboil = 1/0.80 = 1.25 kWh

3.4 Fuel Cells

The environmentally attractive Fuel Cell is an electrochemical device which efficiently recombines hydrogen and oxygen into water, releasing electrons (DC current) and heat with negligible polluting emissions. When a fossil fuel is used rather than pure hydrogen, the fuel is first reformed into a hydrogen rich gas which then feeds the cell itself.

Used by NASA aboard space vehicles as far back as the 1960s' Apollo program, fuel cells are now moving towards the large scale commercial production stage through intensive research and investment. Different types of fuel cells are under development, with different electrolytes and operating temperatures.

The only fully commercial unit is the PC25 from the Connecticut based company International Fuel Cells. It is a 200 kW (electrical) Phosphoric Acid Fuel Cell (PAFC) unit designed to operate on natural gas as primary fuel, easily modifiable for LPG or Methanol. The current model PC25C is a complete packaged power plant of some 3x3x5.5m and 18 tonnes which includes a Fuel Processor (natural gas into hydrogen rich gas + CO_2), a fuel cell stack (hydrogen + oxygen into DC power + Heat + water) and a power conditioner (DC to AC). If air rather than oxygen is used, the stack will produce small amounts of Nitrogen compounds (N_2O,NO_x, N_2). Direct use of hydrogen, for example produced on site from renewable energy systems, is possible by bypassing the reformer.

The fuel processor uses heat from the cell stack to reform the primary fuel, which means that efficient operation requires a good match between the respective fuel cell and reforming process operating temperatures. The PAFC operating temperature, around 200°C, is well matched with the reforming temperatures of fuels such as Natural Gas, LPG or Methanol, but not with the higher temperatures required to reform Diesel and Kerosene.

The Direct Fuel Cell (DFC) and Solid Oxide Fuel Cell (SOFC) with cell temperatures of 650°C or more would be better suited to the use of Diesel or Kerosene as primary fuel. The Energy Research Corporation (also in Connecticut), is expecting its first fully commercial DFC unit for 1998, but as a 2 MW unit operating on Natural Gas. The development of small (200 to 300 kW electric) packaged units running on Diesel or Kerosene is under consideration but hasn't yet gone much further than the drawing board. The Solid Oxide option currently appears very promising but is still at an early development stage. In Australia, Victorian based Ceramic Fuel Cells Pty Ltd (in which BHP and CSIRO are partners) is actively developing Solid Oxide Fuel Cell technology.

The commercial Natural Gas fueled PC25C can deliver 3 phases AC Power (400/230 Volts at 50 Hz or 480/277 Volts at 60 Hz) either Grid-Connected or Grid-Independent, and usable heat, either all around 60-74°C (140-165°F) or half around 60-74°C and half around 120°C (250°F).

About 60 PC25 units have been delivered so far and a cumulated total of more than 300,000 hours of operation have demonstrated some 95% availability and operational efficiencies of 40% (electric) and 45% (heat at 74°C) on a LHV basis, giving a global efficiency of 85% in cogeneration (this is synthetised on Figure 1.c). Energetic costs are then:
• Eel = 1/0.40 = 2.50 kWh if electrical power only is recovered;
• Ecog = 1/0.85 = 1.18 kWh for cogeneration.

Higher efficiencies could be reached when using pure hydrogen as primary fuel. Polluting emissions are negligible apart from CO_2 (which would disappear if hydrogen was used), and as an option, about 106 litres (400 gallons) of clean water could be produced each day at rated (200kW) power, although 25 out of these 200 kW would be lost in the condensing process.

The approximative capital cost of the PC25 has already decreased from 5,000 US$ / kW for the PC25B to 3,000 US$ / kW for the PC25C and the goal for the PC25D is 1,500 US$ / kW by 1998. The units require very low maintenance and when operating continuously at rated power the maintenance cost (including cells stack replacement every 5 years) is evaluated at 0.01 US$ / kWh electric. With the current capital cost of 3,000 US$ / kW spread over 20 years, the share of capital cost in each kWh electric produced by a unit used with a load factor Lf is around (0.0171 / Lf) US$. If Pgas is the cost of 1 kWh worth of Natural Gas, then we obtain per kWh produced a financial generation cost of:
• Pel = 0.0171 / Lf + Pgas / 0.40 + 0.01
• Pcog = 0.0171 / Lf / (1+0.45/0.40) + Pgas / 0.85 + 0.01

For a Natural Gas cost (in the US, by pipeline) of 2 to 4 US$ per 300 kWh or million Btu (0.00667 to 0.01333 US$/kWh), we find for Lf=1 (full potential use) and a realistic Lf=0.7 (use at 70%):

• Pel = 0.044 to 0.060 US$ / kWh	for Lf=1,	• Pel = 0.051 to 0.068 US$ / kWh	for Lf=0.7
• Pcog = 0.035 to 0.043 US$ / kWh	"	• Pcog = 0.042 to 0.050 US$ / kWh	"

which is certainly very competitive in the US conditions, but what kind of cost could we expect when using Natural Gas or LPG at the stations?

Lets try a simple estimate based on the transport of LPG in easy to handle standard ISO cylinder units having the overall dimensions of a 20 foot container (20x8x8.5 feet parallelepiped, overall volume of 38.5 m³). Such cylinder units which cost some 51,000 US$ (270,000 FRF) weigh

8,500 kg and can hold 9,000 kg of LPG for a total weight of 17,500 kg. On a 20 year life cycle basis and assuming a one year turnover, the share of the cylinder capital cost on each shipment is 0.0221 US$/kWh. Standard purchase price of LPG is 0.0516 US$/kWh (3.5 FRF/kg).

Carrying 0.515 density LPG worth 12.8 kWh/kg in these cylinders means carrying a global shipment worth only 6.58 kWh/kg or 1.54 kWh/l. We used in section 3.2 a shipping cost estimate of 0.051 US$/kWh for SAB (12.2 kWh/kg) carried bulk in tanks included in the ship deadweight, established on a "share of cargo weight basis".

When keeping a weight basis for coherence, we obtain for LPG a shipping cost of 0.051x12.2/6.58 = 0.095 US$/kWh, which gives for LPG a final cost of
Pgas =0.0516+0.0221+0.095
=0.169 US$/kWh

Financial generation cost depend then mostly on the fuel cost and variation of the load factor in the 0.5-1.0 range has little effect. For a load factor Lf=1, the respective costs for electricity only and for cogeneration are:

• Pel = 0.0171 / Lf + Pgas / 0.40 + 0.01
= 0.450 US$/kWh

• Pcog = 0.217 US$/kWh

These costs are of the same order than those found for the diesel generator sets, but correspond to a much cleaner process.

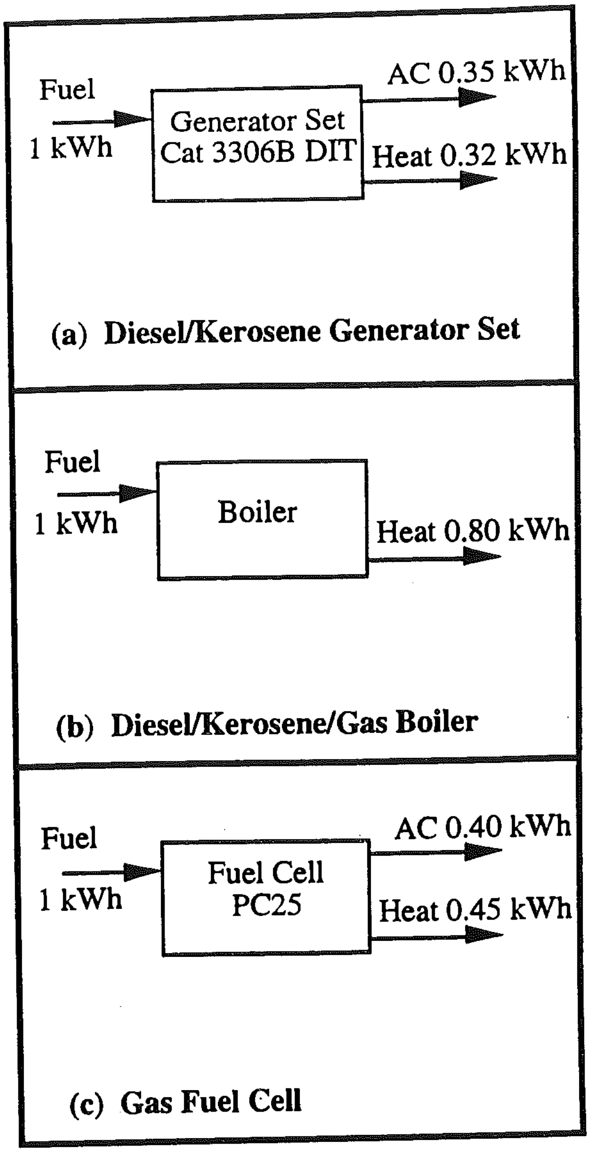


Figure 1 :
Schematic of Selected
Non Renewable Energy Production Methods

4. Renewable Energy Production

The use of wind and solar energy, and more generally of an array of renewable energy, is usually suggested as the "obvious" solution for Antarctic stations. But if the availability and diversity of renewable energy sources at the stations is promising, it can be confusing and requires extensive studies and comparisons to make the right choices.

One of the most important but difficult tasks is sizing the system to match resource abundance and variability against the desired usable power availability. To provide a simple example of resource potential, a basic estimate of the renewable energy potential at one station has been made by examining meteorological data from Dumont d'Urville over the period 1986 to 1989 (published in Ref. 2). This gives an idea of the orders of magnitude involved and illustrates seasonal variations.

The original data are averages over 10 days periods, or decades. The average and extremes of these decade radiation, wind speed and temperature values are shown in Table 2. Three power components have been estimated:
• Solar radiation vertical flux (W/m2)
• Wind Kinetic horizontal flux (W/m2)
• Wind Thermal horizontal flux available from the 'coldness' of the wind in relation to the 'warmth' of the sea (W/m2)

The potential solar and wind power are shown in Table 3.

Solar power can be converted by current standard photovoltaic panels into electricity with an average efficiency of 10%. Wind kinetic power can be converted by wind turbines into electricity with 25% efficiency. Wind thermal power can be converted either into heat by a heat pump or into electricity by a thermomechanical machine driving an alternator. The recovery of this wind thermal power is only at its early development stage. The first machine components are being tested at Dumont d'Urville from January 1994. The latest estimation of expected efficiency for producing electricity is around 5% of the Carnot efficiency calculated on the total temperature difference between wind and seawater.

Taking these efficiencies into account, the estimated power recoverable is shown in Table 4 and Figure 2.

	Yearly Average	Highest Decade	Lowest decades
Solar (W/m2)	117.	329.1 (dec 1-10)	0.6 (jun 11-30)
Wind (m/s)	10.2	13.8 (mar21-31)	7.1 (jan 1-10)
Temp. (°C)	-10.7	0.0 (jan 11-20)	-19.2 (jul 21-31)

Table 2 :
Solar Radiation, Wind Speed, Temperature Extremes and Averages, Dumont d'Urville.
(Based on 1986-89 data)

	Yearly Average	Highest Decade	Lowest decades
Solar	117	329.1 dec 1-10	0.6 jun 11-30
Wind Kinetic	726	1690 mar 21-31	228 jan 1-10
Wind Thermal	121 072	236 324 sept 1-10	0 dec21-jan20

Table 3 :
Potential Wind and Solar Power (W/m^2)
Extremes and Averages, Dumont d'Urville.
(Based on 1986-89 data)

	Yearly Average	Highest Decade	Lowest decades
Solar	11.7	32.9 dec 1-10	< 2.0 may1-aug20
Wind Kinetic	181.4	422.4 mar 21-31	56.9 jan 1-10
Wind Thermal	246.1	616.9 sep 1-10	< 2.0 dec 1-feb 10

Table 4 :
Recoverable Electrical Power (W/m^2)
Extremes and Averages, Dumont d'Urville.
(Based on 1986-89 data)

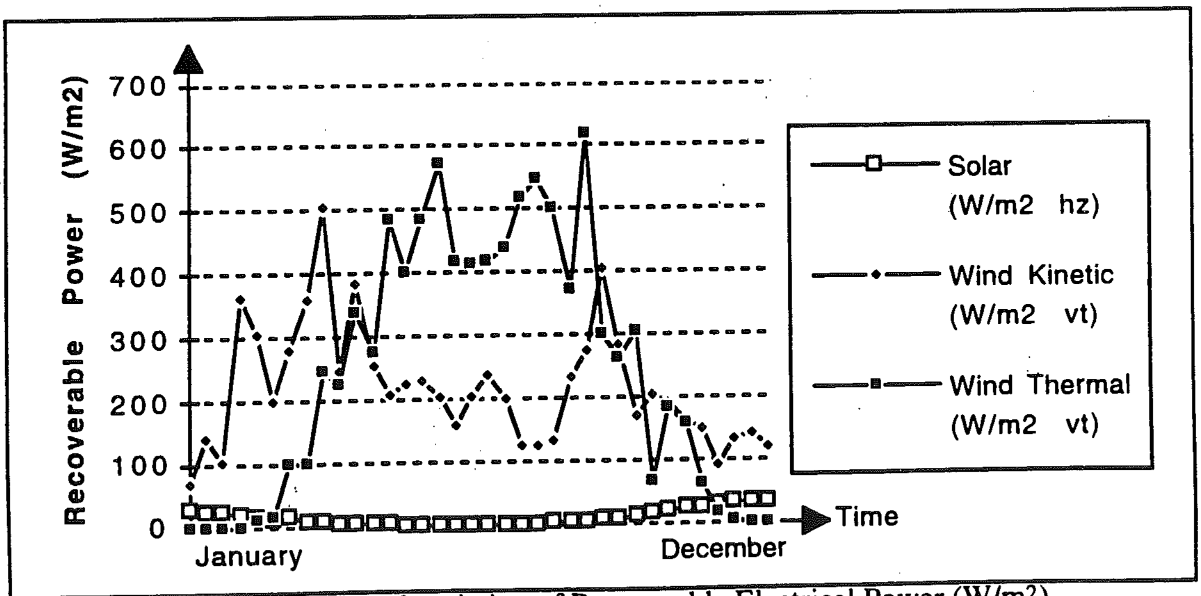


Figure 2 : Seasonal variation of Recoverable Electrical Power (W/m^2).
(Dumont d'Urville, based on 1986-89 data)

To put this into practical perspective, in order to meet the typical annual average of 70 to 250 kW (electrical power only) required by the existing stations, it would require something of the order of :

- 6000 to 21,400 m^2 of photovoltaic panels, i.e. an area the size of 23 to 82 tennis courts, or
- 385 to 1380 m^2 of wind turbine swept area, i.e. 10 to 36 turbines with 7m diameter blades, or
- 285 to 1015 m^2 of condenser banks, i.e. a 3m high wall 95 to 340m long.

Those simple calculations, summarised in Table 5 only provide an order of magnitude for the size of energy captors. These results show that wind and solar energy cannot easily be the only answer to the provision of energy to the most energy demanding stations, but can certainly be of valuable assistance in well designed hybrid systems. Proper sizing of these systems will require elaborate simulations from specific meteorological data, precise equipment operating characteristics and stations power demand patterns. Collection and processing of this information is under way.

	Average Potential Power (W/m2)	Assumed Recovery Rate (%)	Average Recoverable Power (W/m2)	Captor area needed to produce 70 to 250 kW (m2)	Equivalent to:
Solar	117	10%	11.7	6,000 to 21,400	23 to 82 tennis courts in area
Wind Kinetic	726	25%	181.4	385 to 1,380	10 to 36 turbines 7m diameter blades
Wind Thermal	121,072	5% of Carnot Efficiency	246.1	285 to 1,015	3m high condenser bank 95 to 340m long

Table 5:
Size of Renewable Energy Systems to Produce Electrical Power at the Stations.
(Based on 1986-89 meteorological data from Dumont d'Urville station)

Now that we have an idea of the potential for renewable energy production, we need to look into the feasibility aspect of such production. We have done so for three major energy production machines: wind turbines, thermal machines and photovoltaics.

4.1 Wind Turbines

Consistent winds offer in most stations a high potential for wind power generation. This was recognised very early and wind generators were used and tested as early as the first post-war expeditions of the 1950s. High failure rates tended to discredit wind turbines and led to their withdrawal, with the exception of a few small field installations for charging batteries for scientific and communications equipment, and a few trials of prototypes. The success (non-failure) of small turbines where often due to basic oversizing, which is not a realistic solution for larger machines.

Since then, a couple of manufacturers have developed mature products designed for standalone operation in very difficult wind conditions, cold and/or corrosive environments. These high quality products have already proven their reliability and cost effectiveness in conditions nearly as difficult as the East Antarctic coastal stations and sub Antarctic islands.

The 3 kW Northern Power Systems HR3 turbines have successfully powered since 1985 the communications facility at Black Island near McMurdo. However, they remain small oversized machines with fairly little efficiency delivering Direct Current, well adapted to low power isolated systems, but not to station's energy requirements.

More versatile is the 1 to 25 kW range of variable pitch two bladed GEV turbines from Vergnet which deliver grid-compatible three phase AC power. Originating from the renowned Aérowatt machines, they are well designed for extreme wind conditions and to the best of our knowledge, offer the highest resistance to extreme winds in the medium power range together with high efficiency and low maintenance requirements. They have proved their effectiveness in difficult conditions, especially in the Indian Ocean where they have survived 90 m/s gusts at Tromelin, and in the Sub Antarctic at Heard Island.

A 10 kW / 7m diameter GEV 7.10 turbine on its 24m mast costs around 40 000 US$ (211 000 FRF) and should last at least 20 years. At Dumont d'Urville, with an average wind speed of about 10 m/s, the GEV 7.10 would deliver an average of some 7 kW in laminar winds, some 6 kW in real conditions (Load factor Lw=0.7, typical turbulence factor A=0.85). Other examples of approximative load factors for this turbine are: 0.15 at Davis, 0.20 at South Pole, 0.30 at McMurdo, 0.35 at Casey, 0.45 at Amsterdam Island, 0.50 at Macquarie, 0.65 at Kerguelen, 0.73 at Crozet and Mawson.

An accepted maintenance cost for these turbines is 2% of the initial capital cost every year. Over a 20 year lifetime, the estimated production cost of one kWh for the GEV 7.10 is then:

• Pwt= (0.0320 / Lw /A) US$/kWh

Which gives for the selected stations the following costs:
0.251 US$/kWh at Davis, 0.188 at South Pole, 0.125 at McMurdo, 0.108 at Casey,
0.0837 at Amsterdam Island, 0.0753 at Macquarie, 0.0579 at Kerguelen,
0.0538 at Dumont d'Urville, 0.0516 at Crozet and Mawson.

We can note that some of these costs are the lowest seen so far for primary energy generation at the stations. However, we must keep in mind that it doesn't include the energy storage systems that can be needed in some renewable energy system options (see section 5).

4.2 Thermal Machines

These most promising machines currently under development at the Laboratoire des Sciences du Génie Chimique in Nancy, France, as part of our French-Australian project, use the thermal gradient existing at coastal stations between the 'cold' wind and the 'warm' -1.8°C seawater (ref. 7 through to 13).

Preliminary results from the first experimental set-ups currently operated at Dumont d'Urville and in the Arctic at Krankel show that these machines could provide to the coastal stations, for the same cross-section of wind used, more energy than wind turbines. The potential for energy production is less constant throughout the year than for wind turbines, but has the advantage of providing most energy in winter when heating requirements are greatest, and doesn't involve exposed moving parts.

Both thermomechanical machines (producing mechanical work which can drive an alternator) and multistage heat pumps (producing heat) could exploit this thermal energy of the wind. It is too early to evaluate energy production costs, development could proceed in the next few years .

4.3 Photovoltaics

High latitudes are characterised by high seasonal variations in solar radiation. This makes solar energy inadequate for year round operations but can make it useful for particular summer applications. Solar radiation can be converted by current standard PhotoVoltaic (PV) panels into Direct Current (DC) with an efficiency of about 10%. PV work well in cold temperatures, are reliable, require minimal repair outlay and only negligible maintenance. But because of the low concentration of recoverable power (see Tables 3 to 5 and Figure 2), large panel areas are required, which encroach on the often limited space available. In a 'sustainable' point of view, it must also be noted that photovoltaics' manufacturing process is highly energy intensive, and for low load factors photovoltaics may produce in their entire life less energy than was required in their manufacturing process.

The cost of PV panels is of the order of 770 US$ (1000 A$) per m^2, that is 7,700 US$ per rated kW, the ratings being based on a solar radiation of 1 kW/m^2. But if the yearly average total global radiation on a horizontal surface in Alice Springs, Central Australia, is reaching about 0.250 kW/m^2 (load factor Lpv= 0.25), giving a cost of 31,000 US$ per generated kW, the Antarctic stations are more in the 0.100 kW/m^2 range(Lpv≙ 0.1), giving a cost of some 77,000 US$ per generated kW.

Repair and maintenance costs beeing assumed negligible, we find over a 20 year lifetime the following financial kWh cost (PV panels only, no mounting, primary DC power):
• Ppv= (7,700 US$ / 20 years / 365.25 days / 24 hours) / Lpv = 0.0439 / Lpv
Which gives for a horizontal panel at a typical Antarctic station (Lpv=0.1) :
• Ppv= 0.439 US$ / kWh

The amount of radiation received by a panel can be increased some 3 to 4 times by using tracking systems. Although the panel costs can be lowered to some 20,000 US$ per generated kW, and the primary generation cost to 0.11 US$/kWh (panels only, DC power), it introduces additional costs for the tracking system. More importantly, it generates maintenance and reliability problems as large panel areas are required and most stations experience high winds. For example, generating a yearly average of only 100 kW of DC power at Dumont d'Urville would require some 8,500 m^2 of horizontal panels (space problem) or some 2,500 m^2 of tracking panels in winds up to 90 m/s (additional reliability and cost problem for the tracking system). If a few low wind sites could offer lower costs for photovoltaics (little mounting problems) than for wind turbines (low potential), it often remains impractical for large scale systems.

Technological advances could however modify the photovoltaics potential. New production models are now appearing with efficiencies around 20% and further improvements are expected.

The most favorable locations for large scale PV use are the stations located on the Antarctic plateau, such as South Pole or Dôme C, where low winds, large spaces and little cloud cover prevail. Some interesting studies are under way on the use of PV panels at South Pole (Peeran, 1993) as well as solar thermal heating systems for summer buildings (Tobbiasson W., Ferraro J. , Davis L., pers. comm.).

Power Generation Costing Basis	Power Type	Financial Cost *US cents/kWh*	Energetic Cost *kWh*
Hydro Electricity, Tasmania, Domestic Commercial Price	AC	7.	*0.00*
Diesel Generator Sets, Australian Stations, Load Factor > 0.6	AC	47.	2.86
SAB Fuel at 0.0785 US$/kWh (0.77 US$/litre)	AC+heat	25.	1.49
Diesel Fired Boilers, Australian Stations SAB Fuel at 0.0785 US$/kWh (0.77 US$/litre)	heat	9.8	1.25
PC25C Fuel Cell, in the US, Load Factor = 1	AC	*4.4*	*2.50*
Natural Gas at 2 US$ per million Btu (0.00667 US$/kWh)	AC+heat	*3.5*	*1.18*
PC25C Fuel Cell, in the US, Load Factor = 1	AC	*6.0*	*2.50*
Natural Gas at 4 US$ per million Btu (0.01333 US$/kWh)	AC+heat	*4.3*	*1.18*
PC25C Fuel Cell, Australian Stations, Load Factor = 1	AC	45.0	2.50
LPG at 0.169 US$/kWh (2.163 US$/kg)	AC+heat	21.7	1.18
Wind Turbine GEV 7.10, Turbulence Factor A=0.85			
Load Factor Lw = 0.15, Davis	AC	25.1	0.00
0.20, South Pole	AC	18.8	0.00
0.30, McMurdo	AC	12.5	0.00
0.35, Casey	AC	10.8	0.00
0.45, Amsterdam Island	AC	8.37	0.00
0.50, Macquarie	AC	7.53	0.00
0.65, Kerguelen	AC	5.79	0.00
0.70, Dumont d'Urville	AC	5.38	0.00
0.73, Crozet & Mawson	AC	5.16	0.00
Photovoltaics, 10% efficiency, 770 US$/$m^2$, 0.1 kW/$m^2$ Radiation on an horizontal plane			
horizontal panel	DC	43.9	0.00
tracking panel	DC	11.0	0.00

Table 6 :
Tentative Cost Estimates for Selected Energy Generation Methods.
(20 years life cycles, Discount Rate = Inflation Rate = 0)

5. Some System Options

Many system options exist. We will briefly describe a few basic options, from which many variations are possible. It is meant to provide ideas to help design systems for each particular case.

As photovoltaics seem to remain impractical for large scale systems, they wont be mentioned in the system options but can easily be inserted alongside the wind systems if required. We will only mention the type of Thermal Machines producing Heat, which seems particularly interesting because of the good match between production potential and heating needs. However, Thermomechanical machines can just be inserted in the system in place of the Wind Turbines.

5.1 Storage Considerations

The inconsistent nature of renewable energy resources imposes the use of buffer energy storage systems to achieve high penetration of the renewable systems. Hydraulic storage (i.e. using artificial water reservoirs) being not suited to the stations, only two realistic options remain, electrochemical batteries and hydrogen (H2).

Battery systems are reliable and proven technology, although the size and weight of battery banks make it become decreasingly practical as the amount of stored energy required increases. Batteries also have limited life expectancy and could have to be replaced every 5 to 10 years.

For AC power, systems are composed of a battery charger, a battery bank and an inverter, with a round trip efficiency around 50%. If DC systems have better efficiency, they are not practical for large scale applications and spread networks. A very good point of battery systems is that they are simple and modular, making small installations easy to set up.

A very promising option is to use hydrogen as storage medium: produce it from electricity and water by electrolysis, store it, then use it as needed. A system composed of Stuart Cells Electrolyser units, compressed hydrogen tanks and a PC25 Fuel Cell modified for H2 use can offer an AC round trip efficiency around 30%. The fuel cell generates heat as well, and in case of cogeneration, the global system efficiency is approaching 60%. The potential for large storage capacity is better than for batteries, and all system components are reliable and have long life expectancies.

More generally, the Hydrogen option is very powerful and versatile as the produced and stored stable hydrogen is a real fuel in itself. It can be reconverted through various clean and efficient processes not only into electricity and heat in fuel cells or modified fossil fuel type generator sets, but also into heat in catalytic burners and into mechanical work in combustion engines to fulfil all station energy needs.

Since the hydrogen filled dirigible *Hindenburg LZ-129* burst into flames (not exploded) on 6 May 1937 when landing at Lakehurst, New Jersey, killing 25 of the 97 people on board, hydrogen use has had the reputation of being unsafe. Although hydrogen remains a hazardous substance, its safe use is now being demonstrated in established facilities world wide, with over 750 km of commercial gaseous hydrogen transport pipelines operating on a routine basis.

Hydrogen is increasingly being accepted as a practical alternative fuel and current large scale projects include producing hydrogen in Québec with hydro-electricity from Baie James and shipping it to Europe (Euro-Québec Project). The Gouvernement du Québec and the Union Européenne are funding intensive research to develop a variety of hydrogen powered equipment, from home cooking stoves to motor vehicles to aircraft.

Electrolytic plants can produce hydrogen from water and electricity through a clean process. This is a proven and reliable technology, already used at some of the stations to provide hydrogen for the meteorological balloons. Some units from the Toronto based Electrolyser Corporation have operated worldwide for over 40 years with minimal but regular maintenance. Their recent Photovoltaics-Hydrogen unit commercially available has already operated out of doors for 1000 days in a temperature regime of -30 to +30°C. The manufacturer's research targets for systems with fuel cells include 18 months unattended operation at temperatures to -50°C.

5.2 Fossil Fueled Based Systems
with Renewable Supplement

(a) Gen.Set or Fuel Cell, and Boiler
+Wind and Thermal when available

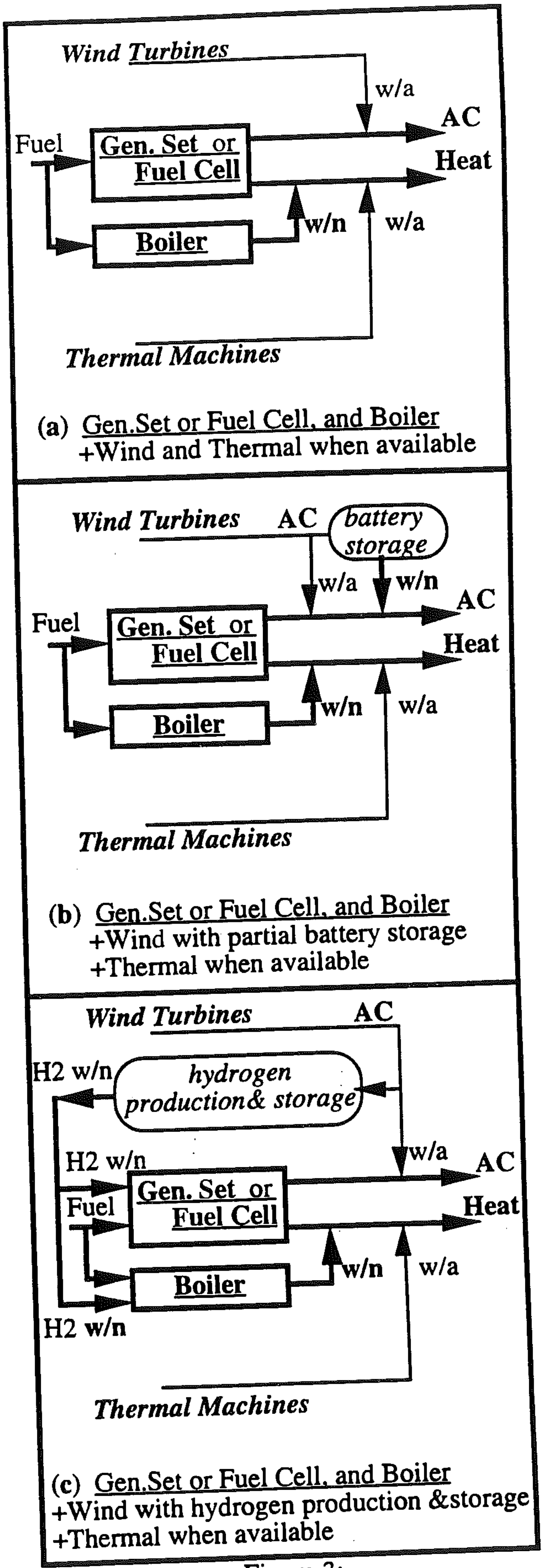
In this most simple option, renewable energy is simply "injected into the grid" and only used as a fuel saver when available. The fossil fuel system has still to be sized to be capable of meeting all power demand, but no storage medium is required. The installation is very simple and the cost of renewable energy is limited to the primary energy production cost. This option is ideally suited to the experimentation phases of renewable power generation equipment. (see Figure 3.a)

(b) Generator Set or Fuel Cell, and Boiler
+Wind with partial battery storage
+Thermal when available

This option is basically an evolution of the previous one, where wind turbines still deliver most of their power directly to the grid and a battery system allows some regulation. The energy stored can be used to assist the fossil fueled system on times of peak power demand. This system can provide an effective tool for an efficient management of the load imposed to the base system, and can for example avoid the need for oversized generators in stations experiencing short duration high peak demands. (see Figure 3.b)

(c) Generator Set or Fuel Cell, and Boiler
+Wind with hydrogen production &storage
+Thermal when available

This third system uses a hydrogen production and storage system. Better suited to larger scale wind farms, it offers greater storage capacities and a long life stable storage medium. It doesn't offer the possibility of load management on the base system but allows large scale wind turbine installations (peak power greater than the minimum station's load) to use excess power to produce on site a real versatile fuel useable in many different ways. For example, a diesel engine (such as used in a generator set or in machinery and vehicles) can easily be modified to accept a diesel-hydrogen mixture containing anything from 0 to 95% of hydrogen. The hydrogen can be mixed with fossil fuels to lower the amount of fuel to be shipped and lower atmospheric pollution at the station. (see Figure 3.c)



(a) Gen.Set or Fuel Cell, and Boiler
+Wind and Thermal when available

(b) Gen.Set or Fuel Cell, and Boiler
+Wind with partial battery storage
+Thermal when available

(c) Gen.Set or Fuel Cell, and Boiler
+Wind with hydrogen production &storage
+Thermal when available

Figure 3:
Fossil Fuel Based System Options
with Renewable Supplement
(w/n = when needed, w/a = when available)

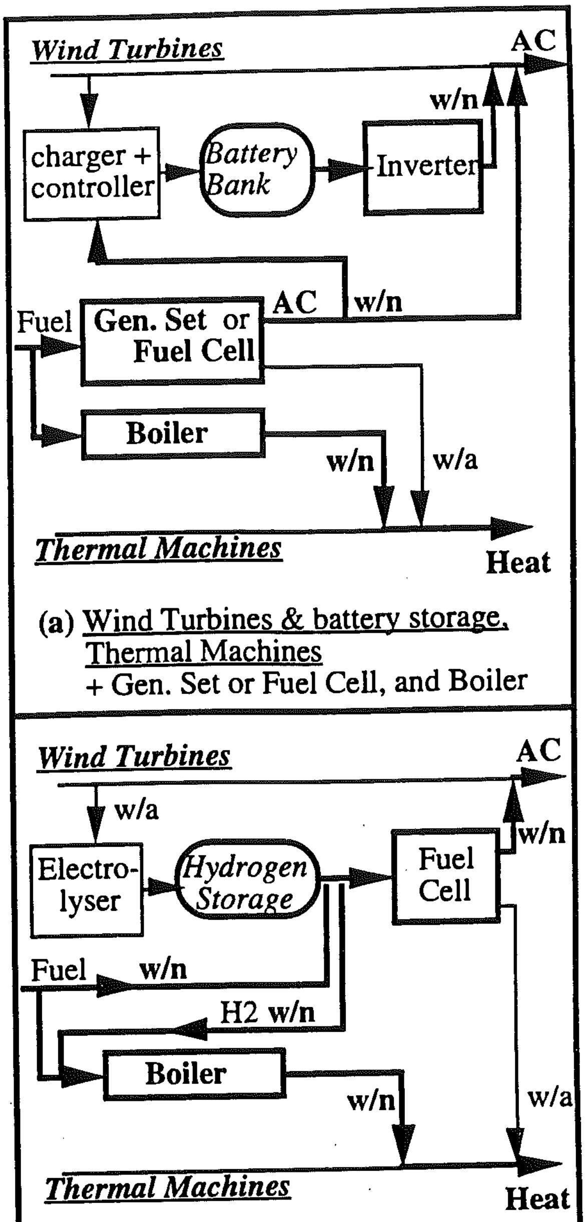
5.3 Renewable Based Systems
with Fossil Fueled Supplement/Back-Up

(a) Wind Turbines & Battery Storage, Thermal Machines
+ Gen. Set or Fuel Cell, and Boiler

This renewable system is based on wind turbines and thermal machines to provide respectively AC power and Heat. A battery storage system allows for normal regulation of AC power (matching the production with the demand) while a generator set or fuel cell is used for back-up in case of long periods of low winds. Thermal machines are sized to provide all the heat required in winter while boilers act as a back-up and can provide the base heating needs required in summer when thermal machines can't operate.

(b) Wind Turbines & Hydrogen System with Fuel Cell, Thermal Machines
+ Boiler
+ Fuel Back-Up Supply for Fuel Cell

This last option is the most advanced and probably the most satisfying. As a renewable system associated with hydrogen, it can provide hydrogen for use as a fuel to fulfill all other energy requirements at the stations with negligible pollution. For example, vehicles staying around the station could run on hydrogen. For emergency back-up, the fuel cell unit can be fed by fossil fuels.



(a) Wind Turbines & battery storage, Thermal Machines
+ Gen. Set or Fuel Cell, and Boiler

(b) Wind Turbines & Hydrogen System with Fuel Cell, Thermal Machines
+ Boiler
+ Fuel Back-up Supply for Fuel Cell

Figure 4:
Renewable Energy Based System Options with Fossil Fueled Supplement/Back-Up
(w/n = when needed, w/a = when available)

6. Conclusions

A relatively interesting point is that most elements of the cost analysis made, especially for fossil fuel systems, can be easily disputed. It could then generate valuable debates and discussions, but more importantly, it shows that strict financial comparisons are generally made irrelevant by the uncertainties about cost elements. And cost estimates show quite well that renewable energy production costs can compete with classic production systems used. Then, because of all their advantages in terms of sustainability, pollution or logistics, renewable systems should be implemented as soon as their financial cost is realistically affordable: If we CAN do something 'clean and sustainable', we HAVE to do it.

One usual complaint about renewable energy systems at Antarctic stations is the unreliability of wind turbines (see section 4.1). But wind turbine technology has matured and reliable machines designed for difficult conditions are now available. We need now to properly assess the operational onsite behaviour of such machines which should reveal successful. Experimental programs have been initiated.

A second complaint is about the unrealistic size of the systems needed to provide all station's energy needs (see Table 5), which will limit the penetration of renewables in the existing stations. But why should we necessarily see renewable energy systems as being too 'weak' rather than find stations too "energy demanding"? The move towards new energy systems will have to go with a moderation of energy needs and a return to the "simple is beautiful" philosophy. This move will need a multidisciplinary approach, coordinated testing programs and long term studies.

This paper was certainly not designed to give definitive answers. We hope that the goal of providing basic reflection elements, iniating thoughts and creating new motivations will be somewhat achieved. If it provides for us an opportunity to refocus the orientation of the project, it could also be the foundation for a wider coordinated effort with several Antarctic nations.

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Producing Energy for Polar Stations from the Wind-Water Temperature Gradient

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Abstract: We review the renewable resources available to produce heating and electrical power for polar stations in complement of conventional fossil fuels. For one Antarctic site (Dumont d'Urville) characterised by a standard meteorological year, we compare the energetic potential for solar, kinetic and thermal wind sources. The exergetic productions (i.e. usable heat or mechanical/electrical power) achieved by real and optimised systems (PVs, windgenerators, heat pumps, thermodynamic cycles) will be compared for the site.
The energy produced from the *thermal dipole* of the cold polar wind and the "warm" sea-, lake- or waste-water is described more precisely. We give a description of the principles of possible combined systems (heat transformers and thermodynamical cycles) and asses their efficiency computed with typical weather data for two stations: Dumont d'Urville, Adélie Land - Antarctica and Krenkel, Franz Josef Land - Russian Arctic. Two experiments currently carried out at both test sites consist in monitoring during two years the cooling power of the wind and in testing the heat exchangers designed to recover this kind of energy. The two experimental set-ups are described and first experimental results are presented.

Keywords: renewable, energy, environment, Antarctic, Arctic, absorption, heat pump, cold wind, thermal dipole

Erneuerbare Energieträger in polaren Gebieten

Zusammenfassung: Der Einsatz von Regenerativen Energieträgern, zusätzlich zu konventionellen Fossilen Energieträgern, wird im Hinblick auf deren Verfügbarkeit zur Wärmegewinnung als auch der Produktion Elektrischer Energie für Polarstationen untersucht. Anhand meteorologisch repräsentativer Daten wird das örtliche Energetische Potential von Solarer-, Kinetischer Wind- und Thermischer Windenergie einer Station in der Antarktis (Dumont D'Urville) miteinander verglichen. Die exergetischen Endprodukte, wie etwa nutzbare Wärme oder mechanische/elektrische Energie, resultierend aus reellen, optimierten Umwandlungsprozessen (Photovoltaik, Windgeneratoren, Wärmepumpen, Thermodynamische Kreisprozesse) werden für selbigen Einsatz ebenfalls diskutiert.
Auf das Energieangebot, basierend auf dem *Thermischen Dipol*; kalter Polarwind - "warmes" Meer-, See- oder Abwasser; wird nähers eingegangen. So zeigen wir dazu prinzipielle Möglichkeiten zum Einsatz von Wärmetransformatoren und Thermodynamischen Kreisprozessen. Deren Wirkungsgrade errechnen sich aus repräsentativen Wetterdaten zweier Polarstationen, Dumont D'Urville, Adelie Land - Antarktis und Krenkel, Franz Joseph Land - Russische Arktis. Die gegenwärtig durchgeführten Experimente an selbigen Teststandorten, welche zur Ermittlung des Kühlpotentials von Polarwind und zum Test eigens konzipierter Wärmetauscher dienen, werden ebenfalls dargestellt, sowie erste Versuchsergebnisse vorgestellt.

Schlüsselworte: erneuerbar, Energie, Umwelt, Antarktis, Arktis, Absorption, Wärmepumpe, kalter Wind, thermischer Dipol

Production d'Énergie à partir du Gradient Thermique Air-Eau dans les Bases Polaires

Resumé: Nous analysons les possibilités d'emploi d'énergies renouvelables pour la production d'électricité et de chaleur, sur les bases polaires. Pour une base située en Antarctique (Dumont D'Urville), caractérisée par ses données météorologiques moyennes, nous comparons les potentiels énergétiques de trois sources d'énergie thermique du vent. Dans chaque cas nous calculons la production d'exergie correspondant à diverses machines réelles: capteurs photovoltaïques, aérogénérateurs, pompes à chaleur et machines thermodynamiques.
Nous décrivons plus particulièrement les techniques de production d'exergie à partir du *dipole thermique* constitué par le vent froid polaire et par l'eau "chaude" de la mer, d'un lac ou d'un rejet d'activité humaine. Les efficacités de ces machines sont calculées à partir des données météorologiques typiques de deux stations: Dumont d'Urville en Terre Adélie et Krenkel sur les îles François-Joseph en Arctique Russe. Des campagnes d'expérimentation sont en cours sur ces deux stations, afin d'y estimer, sur une période de deux ans, la puissance réfrigérante du vent et d'y tester des prototypes d'échangeurs de chaleur destinés à capter cette énergie. Les premiers résultats expérimentaux sont présentés.

Mots clès: renouvelable, enérgie, environnement, Antarctique, Arctic, pompe à chaleur à absorption, vent froid, dipole thermique

1. Introduction

The need for better protection of the polar biosphere will lead to the development and introduction of new technologies making a better use of the renewable resources available in polar regions. Renewable systems based on PhotoVoltaics, Windgenerators or Heat Pumps could play an important role in the production of heat and electricity required by human activities in these regions, complementing conventional fossil fuel based systems with both environmental and economical advantages.

We will describe and compare in this paper different ways of using such "clean" technologies, with a special emphasis on the production of energy from the thermal dipole existing between the "cold" polar wind and the "warm" sea-, lake- or waste-water.

2. The energy of the wind

The energy content E of one cubic meter of air (in J/m^3 or Pa) relative to an arbitrary reference state "o" /1/, /2/ is expressed approximately with 4 terms:

$$
\begin{aligned}
E = & (P - P_0) && \{I\} \text{ Atm. Pressure Energy} \\
& + 0.5 \cdot \rho \cdot \left(u^2 - u_0^2\right) && \{II\} \text{ Kinetic Energy} \\
& + c_p \cdot \rho \cdot (T - T_0) && \{III\} \text{ Thermal Energy} \\
& + L_v \cdot (C - C_0) && \{IV\} \text{ Drying Energy}
\end{aligned} \tag{2.1}
$$

where: P atmospheric pressure (Pa);
(≈990 hPa along East Antarctic coast)
ρ density of air (kg/m^3);
(≈1.3 kg/m^3 at 990 hPa and -10°C)
u wind velocity (m/s)
c_p specific heat capacity (≈1003 J/kg/K)
T temperature (°C or K)
C concentration of vapour (kg/m^3)
L_v latent heat of vaporisation of water;
(≈2470 kJ/kg at 20°C)

The gradients corresponding to each of these four energy components can be either time or space related depending on the choice of the reference state, but time gradients are not very practical to work with. Out of the four space gradients, two can be both consistent and practically recoverable: the velocity gradient (Δu between the air in motion and a fixed structure) and the temperature gradient (ΔT between the cold air and the 'warm' sea water).

For a so called "Typical" Year, the two corresponding energy components of equation 2.1 (II-kinetic & III-thermal) are calculated for $1m^3$ of air /8/. To obtain the power available from the wind, that is the amount of energy passing in one second through $1m^2$ of vertical wind cross-section, we multiplied the wind energy by the wind speed. The resulting unit is then (W per m^2 of vertical wind cross-section), noted (W/m^2 vt), relatively consistent with the unit used for solar energy (W per m^2 of horizontal surface or W/m^2 hz). Both kinetic and thermal wind power are illustrated on Figure 2.1, along with solar power. It can be seen that potentially available thermal wind power is much higher than available kinetic or solar power.

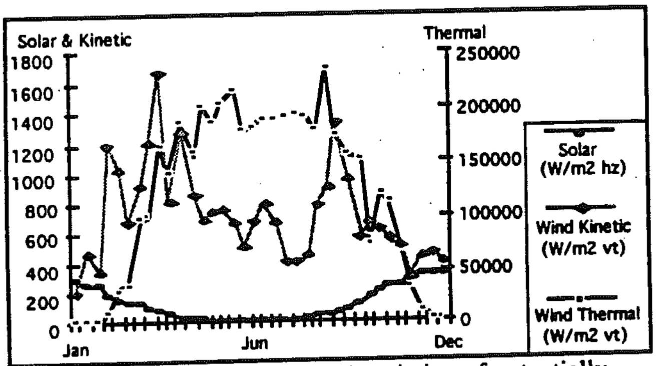

Figure 2.1: Typical seasonal variation of potentially available Wind Kinetic, Wind Thermal & Solar Power (Dumont d'Urville, based on 1986-89 data)

2.1 The velocity gradient

The velocity gradient of the wind can be used to drive a wind turbine. A realistic efficiency for a basic and reliable two bladed horizontal axis turbine producing electricity is: $\phi_{WindTurbine} = 25\%$. This is the proportion of the wind kinetic power which will be transformed by the turbine into electrical power.

2.2 The temperature gradient

At Franz Josef Land and Dumont d'Urville (our two test sites), and at other Antarctic coastal stations, the sea water is at a fairly constant temperature of about $T_0 \cong -1.8$ °C, close to its freezing point. It provides, during the polar winter, a consistent temperature gradient between the air and this 'warm' sea (the "thermal dipole").

There will be two possible ways to use the resulting wind thermal energy component (II):

a) heat generation

Heating buildings with water at 70°C can be achieved with a heat transformer (normally made of a multistage absorption heat pump) using the wind-sea water thermal gradient for the separation process (discussed later), see Figure 2.2 and upper part of Figure 2.3.

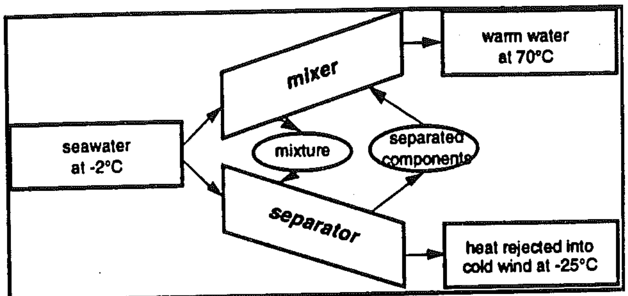

Figure 2.2: Principles of the heat transformer

b) electricity generation

The same thermal gradient can drive a basic Rankine cycle machine (vapour turbine), which has proved feasible in the OTEC (Ocean Thermal Energy Conversion) projects using the 20°C gradient between tropical ocean surface water and deep water (thermomechanical machines) /3/.. The vapour turbine can then drive an alternator to produce electricity. More sophisticated cycles combining heat pumps and turbines can later improve the global efficiency (with the possibility of energy storage), see Figure 2.2 and lower part of Figure 2.3.

We will base our output estimations on the thermomechanical machines for proper comparison with photovoltaics and wind turbines, which also provide electrical outputs. However, It must be noted that heat pumps would produce heat with better efficiencies and should be well suited to space heating in the stations as their production capabilities would be coupled with the heating demands: *"The stronger and colder the wind, the more powerful the heat pump!"*

3. Thermomechanical Machines

The temperature gradient that typically exists between sea water and air provides a potential source of renewable energy. Thermomechanical machines convert the thermal difference to mechanical power which in turn can be converted into electrical power via an alternator (see Figures 2.2 and 2.3).

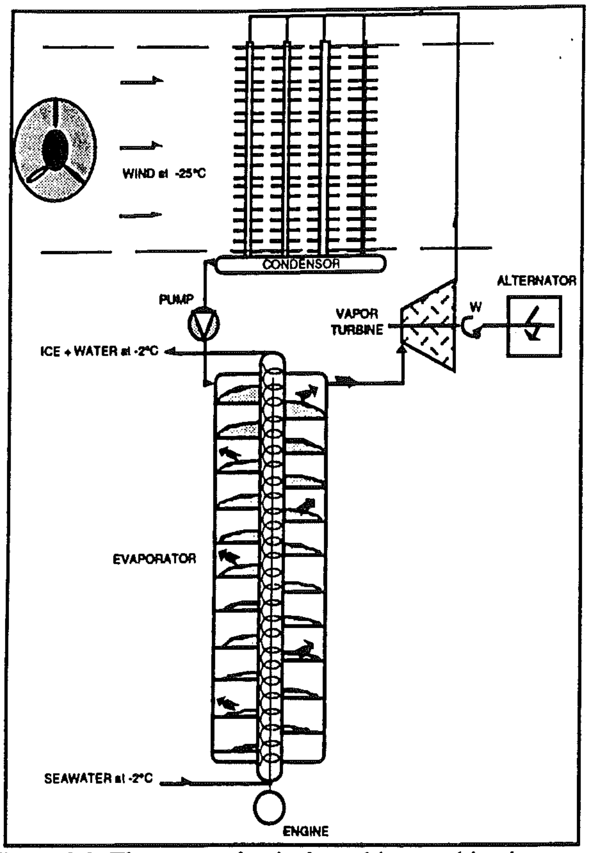

Figure 2.2: Thermomechanical machine working between the warm sea water and the cold wind

The thermomechanical machines are inspired from OTEC machines. Their efficiency in converting Thermal to Mechanical power can be roughly expressed as /8/:

$$\phi_{TM} = \phi_{Carnot} \cdot \phi_{real} \cdot \phi_{usable} \tag{3.1}$$

where:

ϕ_{Carnot}	"limit" Carnot efficiency of the cycle
ϕ_{real}	proportion of ϕ_{Carnot} practically attainable
ϕ_{Usable}	proportion of usable temperature gradient, (temperature drop ΔT_{usable} of the air when passing through the exchanger)

With temperatures given in °Kelvin, the Carnot efficiency of the cycle is:

$$\phi_{Carnot} = \frac{\left(\Delta T - \frac{\Delta T_{usable}}{2}\right)}{T_0} \tag{3.2}$$

Following our first experiments, detailed further in this paper, values put forward for both ϕ_{real} and ϕ_{Usable} are of the order of 25%. They have to be further confirmed and refined by in-situ trials of prototypes.

A typical efficiency for an alternator converting Mechanical Power into Electrical Power is $\phi_{ME} = 80\%$.

Then the final Thermal to Electricity efficiency ϕ_{TE} is:

$$\phi_{TE} = \phi_{TM} \cdot \phi_{ME} \tag{3.3}$$

which should be in the order of: $\phi_{TE} = 0.05 \cdot \phi_{Carnot}$.

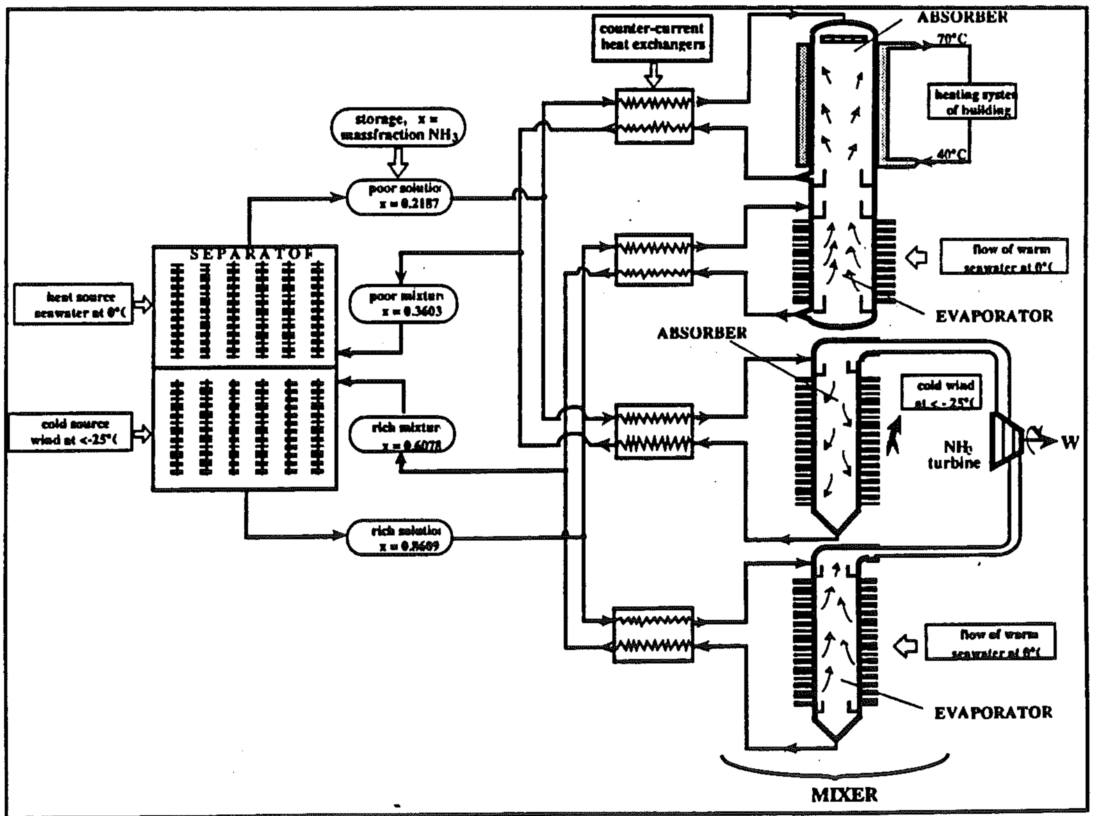

Figure 2.3: NH_3-H_2O system using the dipole polar wind/sea water to generate heat and power

This efficiency is used to calculate the electrical power recoverable from the wind by an electro-mechanical machine. Electrical power recoverable throughout the Typical Year (Wind Kinetic, Wind Thermal and Solar) is illustrated on Figure 3.1 and Table 3.1.

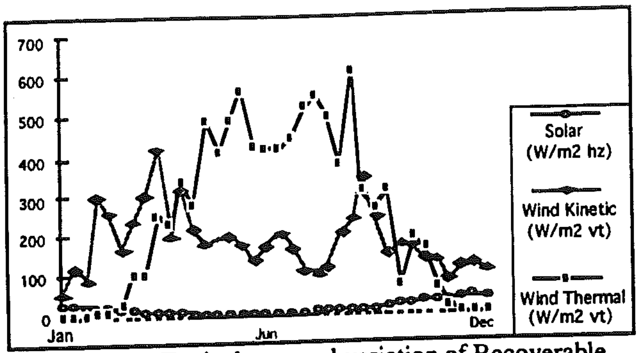

Figure 3.1: Typical seasonal variation of Recoverable Electrical Power
(Dumont d'Urville, based on 1986-89 data)

	Yearly Average	Highest Decade	Lowest decades
Solar	11.7	32.9 dec 1-10	< 2.0 may1-aug 20
Wind Kinetic	181.4	422.4 mar 21-31	56.9 jan 1-10
Wind Thermal	246.1	616.9 sep 1-10	< 2.0 dec 1-feb 10

Table 3.1: Recoverable Electrical Power (W/m^2), Extremes and Averages of Typical Year.
(Dumont d'Urville, based on 1986-89 data)

These calculations indicate that if good overall practical efficiencies can be obtained, the method could provide, for the same cross section of wind used, more energy than rotating machines which exploit the kinetic energy of the wind. The potential for energy production is less constant throughout the year than from wind kinetics, but has the advantage of providing most energy in winter when heating requirements are greatest. The strong point is that this method involves far lighter and more reliable machines as no moving parts are exposed.

4. Multi-effect absorption cycles

Multi-effect absorption heat pump cycles provide far superior heating performances than single-stage cycles /4/. There are many possible combinatiosn for multi-effect absorption cycles, but all of them can be decomposed into elementary building blocks which are single-stage absorption cycles with well known performances. The principle of an elementary absorption cycle is always the same, see figure 3.1:

> One part of the low temperature heat source (sea water) is degraded to a low temperature in separating a binary mixture. The complementary part is upgraded to a high temperature in remixing the two constituents.

Each working pair has its own restricting conditions, as for example a special field of temperature, concentration, pressure... We used in our simulated absorption cycle the well known binary mixture ammonia-water.

The separation unit of the heat transformer uses a process called "fractional quasi isothermal distillation" /5/. Herein the difference between the heat sink and the heat source is very small (about 10K) and the pressure varies from one stage to the other (from 0.1 to 1.427 bar). The separation is realised in 7 stages, to produce a rich solution x_{RS}=0.7703 (mass fraction of NH_3) and a poor solution of x_{PS}=0.2187, starting from a rich mixture of x_{RM}=0.5767 and a poor mixture x_{PM}=0.3603.

The mixing is done in a two stage mixer at different pressure (p_{1M}=1.427bar, p_{2M}=3.25bar), coupled in thermal series and in material parallel, see Figure 4.1 /6/ The temperatures inside the cycle are estimated to:

T_{ab}=70°C	input temperature for the heating system of buildings
T_{water}=T_{ev}=T_{des}=-2°C	sea water, evaporation and desorption temperature
T_{wind}=T_{ev}=T_{con}=-25°C	wind, evaporation and reference temperature

As an example, we looked at an absorption heat transformer with a nominal power at the absorber of Q_{ab}=1kW. Under these conditions the separator needs a heating (desorption) and cooling (condensation) power of Q_{des}=Q_{con}=9.9kW. The heating power for the mixer (evaporation) is Q_{ev}=0.45kW. This finally results in a performance coefficient for the whole cycle of:

$$COP = \frac{Q_{ab}}{Q_{ev} + Q_{des} + W_p} = 6.51\% \qquad (4.1)$$

where: Q_{ab} absorption heat (kW)
Q_{ev} evaporation heat (kW)
Q_{des} desorption heat (kW)
W_p electrical energy for the solution pumps, (estimated to W_p=5kW)

The low COP of this heat transformer is due to the high demand of heat at 0°C. The advantage of such systems is the possibility to produce usable heat from a very low heat source temperature (T_{water}=0°C). When we look with a financial cost view at equation 5, where the COP is defined as the ratio between the useable, produced energy to the costly consumed energy, it can be seen that for a "gratis" heat source, and without taking into account the operation cost, the denominator gets "zero" and so the COP gets "infinitely big".

To compare our results from the heat transformer with the estimation made earlier for Thermal to Electrical power conversion, we can estimate for a pure Thermal to Heating power efficiency the COP of 6.51%, which will be superior to the $\phi_{TM} = 0.05 \cdot \phi_{carnot}$ estimated for the Thermomechanical machine.

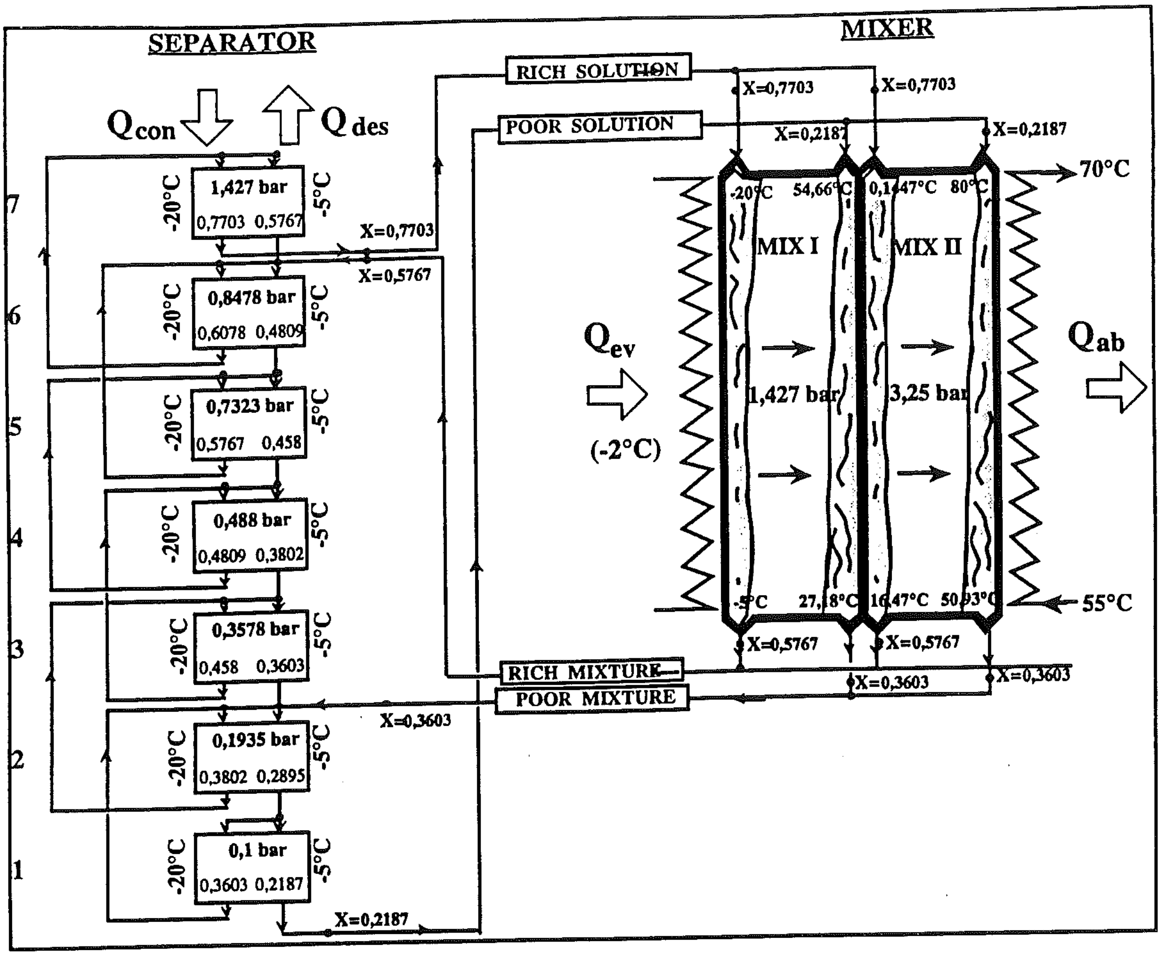

Figure 4.1: Ammonia-water multi-effect absorption cycle

5. Description of the "cold wind fluxmeter"

On the wind side, the design of the heat exchanger in the absorption cycle requires a good knowledge of the heat transfer characteristics between a heated wall and the unstationnary cold wind carrying snow and/or ice.

Heat transfer effects usually used in air-cooled refrigeration cycles are either natural or artificially forced convection. But the use in forced convection of natural wind, with its uncertain and transitory conditions, is not well known. Then, in the experimental stage, we try to evaluate under real meteorological conditions the heat transfer between vertical tubes internally heated (electrically) and the cold wind. There are several unknown parameters, which directed the design of our installations at the test sites: the unique, rough meteorological conditions (extreme winds, low temperatures), the possible presence of snow and the satisfactory operation of the heat exchanger under a very small temperature gradient.

An experimental device, called "cold wind fluxmeter", was designed and built at the LSGC in Nancy, Figure 5.1 shows the fluxmeter /7/.

The cold wind fluxmeter consists of two vertical, cylindrical, tubes: one smooth tube, with a well-known tube-wind heat transfer and one tube with external, annular fins, for the testing of snow effects and to increase the heat transfer by increasing the effective surface area of the tube. The internal electrical resistance is generating the thermal gradient for heat flux transfer.

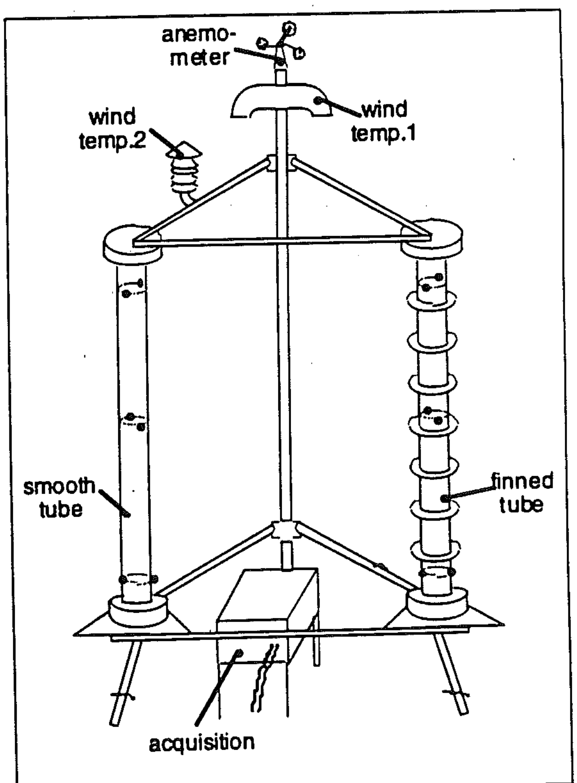

Figure 5.1: The cold wind fluxmeter

Tube surface temperature, wind temperature and speed are measured and recorded continuously by an automatic data acquisition system. After some preliminary testing in the French Alps, the first fluxmeter was installed in the 1993 northern summer at the meteorological station of Krenkel, Franz Joseph Land, in the Russian Arctic, and the second in January'94 at the French Antarctic Station Dumont d'Urville.

Meteorological characteristics of these two locations (Krenkel, Arctic, and Dumont d'Urville, Antarctic) are quite different. The average temperature at Krenkel during the 4.5 months of polar night is around -30°C. At Dumont d'Urville there is no polar night and the temperatures are not as low, but there are very strong catabatic winds with recorded speeds up to 90 m/s. The aggregation of results obtained at those two different locations will improve the reliability of our conclusions and expand their scope.

The next step towards a real working unit will be taken in January 1995 with the installation of a bundle of tubes as heat exchanger. It will represent the real condenser planned for the final installation and will provide more detailed information on the wind refrigeration power practically recoverable.

6. Details on the heat transfer

The equation characterising the heat transfer between the external tube surface and the cold wind is:

$$P_{elec} = h \cdot A \cdot (T_d - T_a) \quad [W] \qquad (6.1)$$

where:
- P_{elec} heating power (W)
- h heat transfer coefficient (W/m^2K)
- A heat exchange surface (m^2)
- T_d average tube surface temperature (K)
- T_a wind temperature (K)

The heating power P_{elec} is known, the tube surface temperature T_d and the wind temperature T_a are measured with different thermocouples, and the only unknown parameter is the heat transfer coefficient h_c. This coefficient depends on the velocity of the wind. By measuring the wind velocity u and evaluating the constants K and n (corresponding to the wind flow conditions), we can determine h, expressed by the following equation:

$$h = K \cdot u^n \quad \left[\frac{W}{m^2\ K}\right] \qquad (6.2)$$

The temperature difference ΔT between the wind and the tube should be kept approximately constant at 10K, which will represent the real working conditions of the heat exchanger in the absorption cycle. To hold this temperature difference, the heating power P_{elec} is regulated as a function of meteorological conditions, especially wind velocity (see eq. 6.1 and 6.2). Each determination of the heat transfer coefficient h_c must be made for a stable period, this means for a specific wind velocity. Therefore, we try to get a pseudo-permanent period by estimating stages for the regulation of the heating power P_{elec} in function of the wind velocity u. This is done by the application of a certain hysteresis to avoid an oscillation of the electrical power.

A fully automatic data acquisition is undertaken via a chain of electronic modules and a PC. Each data channel is read every 2 seconds and averaged every 5 minutes for recording by the PC, which is also piloting the electrical heating of the tubes.

6.1 Smooth tube

The heat transfer of a smooth tube has been well studied, and Hilpert /9/ gives the following empirical correlation:

$$Nu = C \cdot Re^n \cdot Pr^{1/3} \qquad (6.3)$$

with:
- Nu — Nusselt number, representing the dimensionless temperature gradient at the surface and defined as:

$$Nu = \frac{h \cdot d_h}{\lambda} \qquad (6.4)$$

- Re — Reynolds number, representing the ratio of the inertia and viscous forces, defined as:

$$Re = \frac{u \cdot d_h}{\upsilon} \qquad (6.5)$$

- Pr — Prandtl number, representing the ratio of the momentum and mass diffusivities, defined as:

$$Pr = \frac{\mu \cdot c_p}{\lambda} \qquad (6.6)$$

C and n are constant for different flow conditions. Values are listed in Table 6.1. The noted velocity ranges couldn't be measured by our installation, so in our case only wind velocity up from 1 m/s is recorded. All thermodynamical properties are evaluated at the air temperature.

Re	u (m/s)	C	n
0-4	0-0.001	0.989	0.330
4-40	0.001 -0.01	0.911	0.385
40-4000	0.01-1	0.683	0.466
4000-40000	1-10	0.193	0.618
40000-400000	10-100	0.027	0.805

Table 6.1: Constants for a circular cylinder in cross flow.

Transforming the equations (6.3-6.6) we will get an expression for the heat transfer coefficient h, similar to equation 2:

$$h = \left(\frac{c_p \cdot \lambda}{\upsilon^n} \cdot d_h^{\,n-1} \cdot Pr^{1/3}\right) \cdot u^n \qquad (6.7)$$

where:
- h — coefficient of heat transfer by convection in (W/m^2K)
- c_p — specific heat at constant pressure in (J/kg K)
- λ — thermal conductivity in (W/m K)
- υ — kinematic viscosity in (m^2/s)
- d_h — characteristic length, hydraulic diameter in (m)
- u — wind velocity in (m/s)
- μ — viscosity in (kg/s m)

Using the correlation after Hilpert, and for a reference temperature of the air T=0°C, we should get for the heat transfer coefficient of our smooth tube the value: $h=13.2\ u^{0.62}$. Values of h estimated from our first experiments will be detailed further in this paper.

We have to take into account other heat transfer effects, such as the solar radiation part, the infrared radiation back to the sky and the floor or a wet air circumstance, which will have an influence on equation 6.7, in order to obtain a corrected value for h called from now on h_c.

$$h_c = \underbrace{\frac{P_s \cdot \alpha_d}{A(T_d - T_a)}}_{\text{solar radiation}} + \underbrace{\frac{P_{elec}}{A(T_d - T_a)}}_{\text{electric heating}} + \underbrace{\frac{\sigma \cdot \varepsilon_d}{2(T_d - T_a)}\left[\left(T_d^4 - T_{sky}^4\right) + \left(T_d^4 - T_a^4\right)\right]}_{\text{infrared radiation (sky;floor)}} \qquad (6.8)$$

where:
- P_s solar radiation in (W/m^2)
- α_d absorptivity of the tube
- $\sigma=5.67\ 10^{-8}$ (W/m^{2}K^4) Stefan-Boltzmann constant
- ε_d emissivity of the tube
- T_{sky} sky temperature in (K)

6.2 Finned tube

For the tube with external, annular fins, built with the same general dimensions (external diameter and length), we have to apply the theory of the fin efficiency η_f. The definition of the fin efficiency is the ratio of the transferred heat flux Q_f to the maximal possible (if the entire fin surface were at the base temperature) transferred heat flux Q_{fmax}:

$$\eta_f = \frac{Q_f}{Q_{f\,max}} \qquad (6.9)$$

The fin efficiency is obtained after Schmidt from /10/:

$$\eta_f = \frac{\tanh(m \cdot r_d \cdot \varphi)}{m \cdot r_d \cdot \varphi} \qquad (6.10)$$

with: $$\varphi = \left(\frac{r_{fin}}{r_d} - 1\right)\left[1 + 0.35 \cdot \ln\left(\frac{r_{fin}}{r_d}\right)\right] \qquad (6.11)$$

and $$m = \sqrt{\frac{4h_c}{\lambda_{fin} \cdot \delta}} \qquad (6.12)$$

where:
- r_d external tube radius in (m)
- r_{fin} external fin radius in (m)
- δ thickness of the fin in (m)
- λ_{fin} thermal fin conductivity in (W/m K)

With the fins in place, the heat transfer rate is:

$$Q_{tot} = Q_f + Q_b \qquad (6.13)$$

where:
- Q_f heat transferred by the fins (W)
- Q_b heat transferred by the basic smooth tube (W)

From equation 6.9, the fin heat transfer rate is:

$$Q_f = N \cdot \eta_f \cdot Q_{f\,max} = N \cdot \eta_f \cdot h_c \cdot \Delta T_f \cdot A_{fin} \qquad (6.14)$$

where:
- N number of fins
- A_{fin} fins surface (m^2)

Heat transfer from the exposed surface is:

$$Q_b = h_c \cdot \Delta T_f \cdot A_b \qquad (6.15)$$

where: A_b basic smooth tube surface (m^2)

We emphasize that the heat transfer coefficient for the finned tube is referred to A_b the basic smooth tube surface.

For comparison of the finned tube and the smooth tube, we defined a factor F_b as:

$$F_b = \frac{Q_{tot}}{P_{elec}} \qquad (6.16)$$

where P_{elec} is calculated with the same difference of temperature as for the smooth tube (ΔT=10K). But as the heat transfer of the finned tube increased we took ΔT_f=5K. The results of this comparison are shown in table 6.2:

u (m/s)	1	5	10	15	20	25	30
h_c(W/m^{2}K)	13.2	35	55	70	84	97	108
P_{elec}	11	30	46	60	71	82	92
Q_{tot}	63	170	261	334	398	456	509
F_b	5.7	5.6	5.6	5.6	5.6	5.5	5.5

Table 6.2: Comparison of the finned and smooth tubes

Finally it shows that the finned tube should dissipate a power about 5 times higher than that of the smooth tube: $h_{fin} \cong 5 \cdot h_{smooth}$ or $h_2 \cong 5 \cdot h_1$.
But we will show in chapter 7 that it was not true for some of our experimental results.

7. First experimental results

After the first experimental results from the test sites, we can distinguish 3 different zones of working conditions, presented in figure 7.1:

A) $\boxed{u < 5\ \text{m/s} \Leftrightarrow Re < 20000}$:
In this first zone, the heat transfer coefficient h_{biblio} (after Hilpert) doesn't provide satisfying results, as the calculated coefficient h_{1c} for the smooth tube is inferior to the expected values. We can explain it with the strong influence of the radiative heat exchanges compared to the convective exchanges. This influence is stronger on the smooth tube as on the finned tube. The ratio between h_2/h_1 raises up to 6.

B) $5 \le u < 10$ m/s $\Leftrightarrow$ $20000 \le Re < 40000$:

The radiative part represents in this area 15-20% of the heat transferred due to the convection during the day and up to 30% during the night. This will always provoke a difference between the h_{biblio} and the calculated coefficient h_{1c} for the smooth tube, but not as important as for wind velocity around 5 m/s. The ratio between h_2/h_1 is about 5 as seen before.

C) $u \ge 10$ m/s $\Leftrightarrow$ $Re \ge 40000$:

When wind velocity exceeds 10 m/s ($u \ge 10$ m/s), the influence of the radiative heat exchange gets small compared to convective exchange. The influence on the heat transfer coefficient h is less then 13%, which means that it will be within the uncertainty of the measurement and calculation of h. We can see clearly on figure 7.1 that for such high wind velocities, the lines for h_{biblio} and h_{1c} are closed parallels, and that the points of measurement are grouped close to the lines of linear regression (h_{1c} and h_{2c}), which means that in this area our estimations seem coherent. The ratio between h_2/h_1 is around 4.

As the average wind velocity at Dumont d'Urville is from 8 to 20 m/s, our installation is well adapted to this test site. But on the northern test site on Franz Joseph Land, the average wind velocity is not as high, which will result in greater uncertainties about the data.

Production of energy from the wind-water temperature gradient is under the direct influence of the temperature difference ΔT, but also of the wind velocity, as for machines using the sole kinetic component of wind energy.

As a first result for the overall heat transfer coefficient h_c concerning the two tubes, we will give the following expressions (a) and (b), functions of the velocity of the wind;

a) heat transfer coefficient of the smooth tube:

$$h_{1c} = 0.053 \cdot Re^{0.655} \qquad \left[\frac{W}{m^2 \cdot K}\right]$$
$$= 12.123 \cdot u^{0.655}$$

b) heat transfer coefficient of the finned tube:

$$h_{2c} = 0.969 \cdot Re^{0.515} \qquad \left[\frac{W}{m^2 \cdot K}\right]$$
$$= 69.404 \cdot u^{0.515}$$

These results lead to the overall efficiency mentioned earlier:

$$\phi_{TE} = 0.05 \cdot \phi_{Carnot}$$

These first estimations of possible heat transfer coefficient for a single cylindrical tube (smooth or finned) will be further refined in the future with the access to other test sites and to more detailed meteorological data.

Meteorological data from our Russian testsite, Krenkel, will be further processed in cooperation with scientists from the Norwegian Polar Institute while data from Dumont d'Urville will be directly processed by our team. A similar evaluation will be undertaken for different Northern Canadian sites by our cooperating partners at the Ecole Polytechnique, Montreal.

The evaluation of those long term weather data shall give us information about the energy resource potential of the sites and thus the possibility of operating complete heat pump systems at those sites.

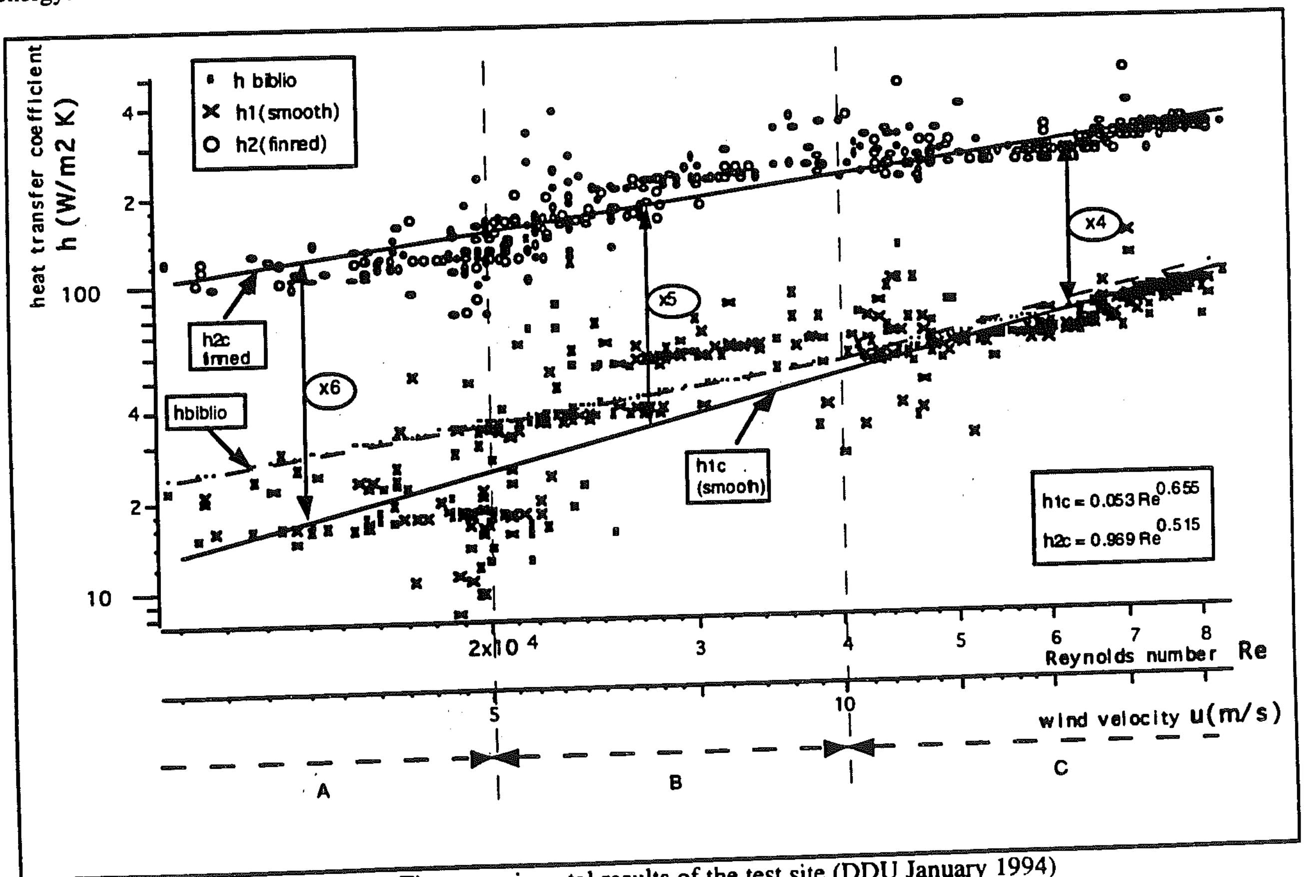

Figure 7.1: First experimental results of the test site (DDU January 1994)

5. Conclusions

The provision of energy to polar stations using conventional fossil fuels is costly, difficult logistically and has significant environmental impacts. This makes any improvement of energy systems at the stations far more cost-effective than at most other places on earth.

Improving the energy systems is, and has always been, an everyday job for the technical staff of the agencies operating the stations. This staff has valuable experience and great motivation to pursue the development and implementation of new solutions.

Researching and implementing clean and efficient alternative energy systems in polar regions could have an invaluable role in perfecting and demonstrating promising systems to be used around the world. Among such systems, thermal machines could play an important and valuable role. And the thermal dipole of the cold polar wind and the "warm" sea water could bear more potential if using as heat source lake-water or waste water with temperatures higher than sea water. But the use of a waste water, will mean that we have to give up our idea of the "real" renewable energy resource...

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ACTIVITY OF RUSSIAN COMMITTEE ON ANTARCTIC RESEARCH ON ALTERNATIVE ENERGY SOURCES UTILIZATION IN THE ANTARCTIC

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ABSTRACT

Nowadays high environmental requirements to the energy producing installations and the problem of energy conservation cause necessity for search of ecologically clean and efficient sources of energy suitable for utilization in Antarctica. In this connection R&D works on alternative energy sources utilization under extreme environmental conditions of polar stations is worthwhile and draw much attention of Antarctic expeditions from different countries exploring the continent. The close study of this question is also being carried out by Russian Committee on Antarctic Research.

Preliminary results of R&D works that were made by Russian organizations and institutions have shown economical and ecological advantageous of windmills and solar energy systems utilization in Antarctica. Series of the experimental investigations of solar heating and photovoltaic installations have been carried out at Novolazarevskaya and Molodyozhnaya stations. The results of these experiments have been discussed in this paper. The paper also deals with the feasibility study of hybrid power system utilization for the conditions of Vostok and Oasis Bangher stations.

Another aspect of the activity has been connected with R&D works on energy-saving technologies that could provide the significant reduction of energy consumption in buildings of Antarctic stations. Various approaches to designing of energy-efficient buildings have been considered. New architectural concepts that were developed in the framework of the cooperation with International Design For Extreme Environments Association (IDEEA) have been discussed.

It is planned to continue R&D works on renewable energy sources for Antarctic stations and to consider the possibilities of utilization advanced sources of energy that are developed in the framework of space-related programs (fuel cells and others).

All above mentioned works are encouraged by Russian Scientific Council for New and Renewable Energy Sources of Ministry for Science and Technical Policy of Russian Federation as well as by Russian Antarctic Expedition.

INTRODUCTION

At the modern stage of the Antarctic Continent exploration ecological problem is in the focus of the activity of the Antarctic expeditions. In accordance with the latest recommendations (Waste disposal..., 1989; SCAR bulletin, 1992) many countries of the Antarctic Treaty began close study of the question of alternative energy sources utilization under extreme environmental conditions of Antarctica (Coleman, 1991; Cohnen, 1991; Guichard, 1992). This question is also being studied by Russian institutions and organizations in the framework of the program of the Committee on Antarctic Research of Russian Academy of Sciences. The program consists of two tasks. The objective of the Task I is to study the advantageous of renewable energy sources utilization in different regions of Antarctica (Head Scientific Organization - Institute for High Temperatures of Russian Academy of Sciences). The aim of Task II is to develop new types of energy-efficient buildings and constructions for Antarctic stations (Head Organization - International Design for Extreme Environments Association (IDEEA Russia). It is also planned to evaluate the possibilities of fuel cells utilization in Antarctica. The main results of R&D works carried out in the framework of the above mentioned program are discussed below.

RENEWABLE ENERGY SOURCES

The combination of readily available solar and wind sources coupled with high fuel cost, the logistic difficulties associated with fuel transportation especially to the inland stations offer favourable conditions for the use of renewable energy sources in Antarctica.

For predicting the areas of potential solar energy utilization it is worth to consider the maps that were worked out by Bardin and Sheinstein, 1991 (Figure 1-4). Zones 1 and 2, covering the central inland regions of eastern part of Antarctica are the most suitable places for solar energy utilization. Here Hv and Ht maximum values are equal to 7.8-8.0 GJ/m^2 (the High Antarctic Plateau). For zones 3 and 4, Hv and Ht sums reach acceptable values comparable with the corresponding sums for the Scandinavian Peninsula where solar energy is considered as promising sources of energy (Endstrom, 1988). The conditions in the western part of Antarctica are not so favourable for this purpose, and the least suitable conditions are those of the Antarctic Peninsula. To assess the prospects for solar heating systems utilization it is also necessary to consider the schemes of degree-days distribution (Figure 3 and 4). The annual sums of degree-days vary from 10,000 for the coastal regions, to 27,000 for the zone of the High Antarctic Plateau. Also referring to Figures 1 and 2 one can see that the central Antarctica is the most favourable zone for solar heating systems utilization. Central Antarctica also offers the best conditions for PV systems utilization. These conclusions can also be done on the basis of economical analyses results (Wills, 1989, Sheinstein, 1991).

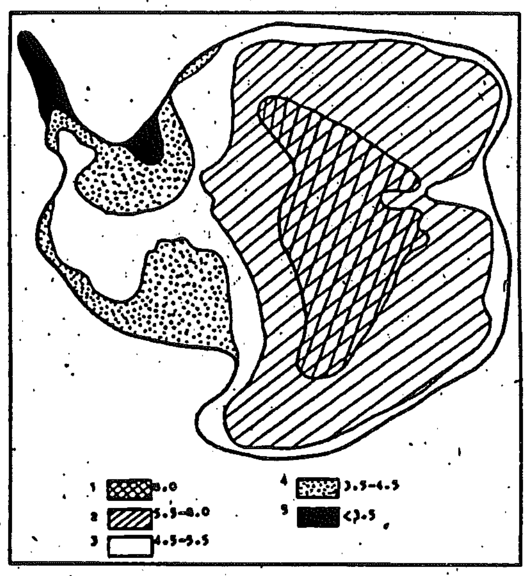


Fig. 1. Regional Distribution of Annual Sums of Solar Radiation for Surfaces with the Optimal Slope in Antarctica, GJ/m^2

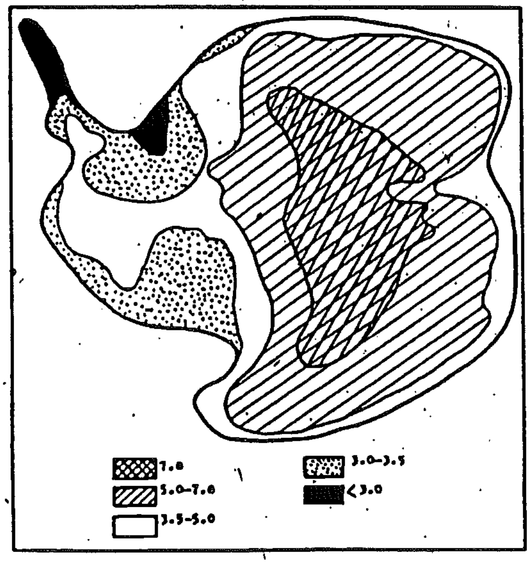


Fig. 2. Regional Distribution of Annual Sums of Solar Radiation for Vertical Surfaces in Antarctica, GJ/m^2

The results of the feasibility study (Sheinstein, 1992) show that the use of PV systems in combination with wind power systems and diesel generators at the Antarctic inland stations is expedient already nowadays (Tables 1, 2).

TECHNICO-ECONOMICAL CHARACTERISTICS OF VARIOUS TYPES OF POWER SYSTEMS FOR OASIS BANGER STATION CONDITIONS, (daily average load - 115 kWh), **Table 1**

	DPS	PVS+B		WGS +B	PVS+WGS+ B		PVS+B+DPS		PVS+WGS +B+DPS	
		1	2		1	2	1	2	1	2
System initial cost, thous. US dollars	65	660	1080	220	200	250	240	250	150	160
Cost of electricity, US doll/kWh	0.85	1.85	3.0	1.3	1.2	1.3	0.8	0.8	0.75	0.8
Annual savings, thous. US dollars	0	0	0	0	0	0	1.6	1	2	1.3

1 - optimal PV orientation, (45°)
2 - horizontal PV orientation

TECHNICO-ECONOMICAL CHARACTERISTICS OF VARIOUS TYPES OF POWER SYSTEMS FOR VOSTOK STATION (DAILY AVERAGE LOAD - 2600 kWh), **Table 2**

	DPS	PVS+B		WGS+B	PVS+B+DPS		PVS+WGS+ B+DPS	
		1	2		1	2	1	2
System initial cost, mln US dollars	0.65	110	100	6	5.5	4.5	3.5	2.0
Cost of electricity, US doll/kWh	1.0	8.5	8.5	0.8	0.7	0.7	0.6	0.5
Annual savings, mln US dollars	0	0	0	0	0.25	0.3	0.4	0.45

1 - fixed vertical PV modules
2 - tracking vertical PV modules

Stand-alone diesel generator sets while being relatively inexpensive to purchase are generally expensive to operate and maintain, especially under extreme environmental conditions of Antarctica, where the cost of 1 ton of diesel fuel may reach $2500 (Wills, 1989). The cost of electricity produced by stand-alone diesel power systems is also extremely high, see Table 1, 2. Real alternative to stand-alone diesel installation is hybrid power system based on PV, windmills, diesel generator sets and batteries (e. g. lead acid batteries). Analyzing the data in the Tables one can come to the conclusions that the hybrid systems could provide Vostok and

Bangher stations with electricity at lesser cost as compared to stand-alone diesel generator sets. It is obvious that the power systems that allow to meet energy requirements entirely by the use of renewable energy sources (versions 2, 3 in Table 2 and versions 2, 3 and 4 in Table 1) might appear to be the most attractive. However, the results of the feasibility study show that they are not cost-effective. Such systems have extremely high initial costs and 1 kWh of electricity costs 8 times larger as compared to DPS figure. If however, taking into account ecological concern one would try to implement this project, e. g. at Vostok station, there would be much difficulties for its realization because if enormous size of PV modules and capacities of batteries.

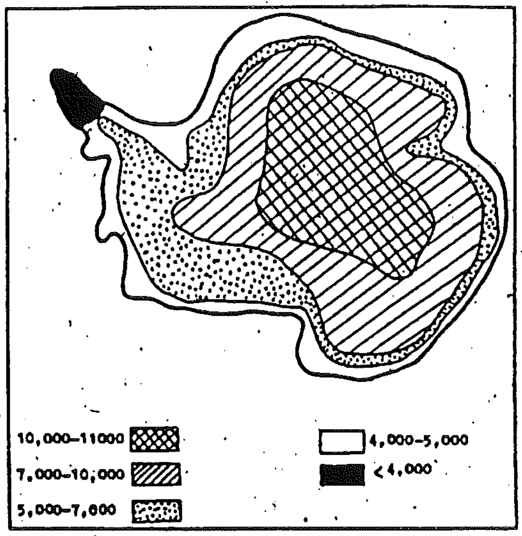


Fig. 3. Regional Distribution of Seasonal Heating Degree-days in Antarctica

Designing and testing of pilot installations based on renewable energy sources are also being carried out in the framework of above mentioned Task of the program. Pilot solar water heating and PV installations were designed and tested under conditions of Molodyozhnaya and Novolazarevskaya stations in summer season.

Pilot solar water heating installation that was designed for utilization under extreme environmental conditions (Figure 5) consists of two flat-plate double glass selective collectors with overall aperture surface of 1.4m and an insulated heat storage tank with a capacity of 50 liters. They are fixed to telescopic tower and can be rotated around it to track the sun. To provide reliability of the construction during high winds, the tower is fixed to the rock or snow surfaces with guy lines. This light-weight construction can be easily assembled by one person and effectively used under conditions of Antarctica (Sheinstein, 1991). The results of the testing have shown that in summer season solar collectors can be used for production of hot water with temperature up to 60°C.

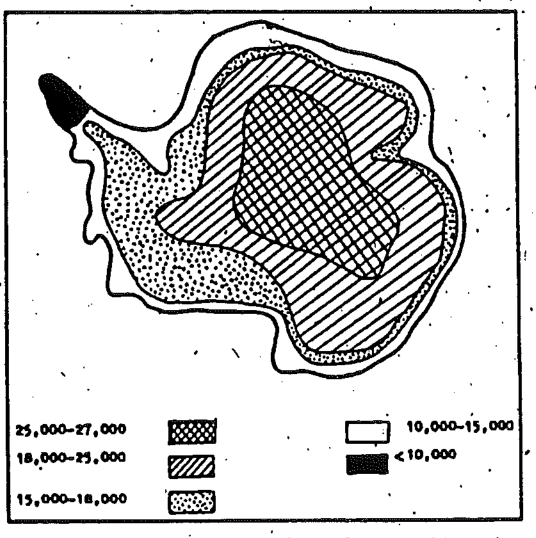


Fig. 4. Regional Distribution of Annual Heating Degree-Days in Antarctica

A pilot PV installation consists of two PV modules with overall capacity of 75 W (peak) that were sloped at 45° to the horizon and battery with the capacity of 130 Ah. The installation was equipped by devices for measurements and control of solar radiation in the plane of the modules, current and voltage of the modules, battery and load. The results of the testing have shown that there was no significant changes in the electrical characteristics of the PV modules after their transportation by different kinds of transport at a distance of approximately 30,000 km. Average efficiency of PV and batteries is 10.5% and 75% respectively.

It is to be noted that the testing were made in relatively short period and we have not complete information about PV and solar heating installations characteristics for the conditions of Antarctica so it is planned to continue testing of pilot installations on the long-term basis in the Antarctic regions where solar energy utilization is of great interest.

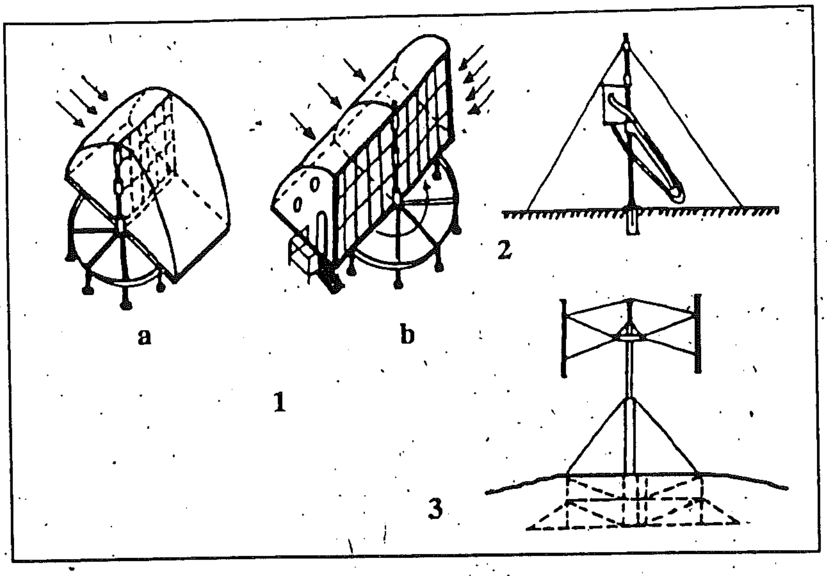


Fig. 5. Adjustable building (1: a - winter, b - summer), solar water heater (2) and wind generator (3)

It is also planned to test new types of wind power installations worked out in the framework of Russian State Scientific and Technological Program "Environmentally Clean Energetic" under conditions of Antarctica. The first candidate for testing is wind power installation with 8 kW capacity. The installation consists of two blade high speed turbine with centrifugal and aerodynamic wheel frequency control by turning the whole blade, three section tubular mast, a synchronous generator, battery with 150-200 kWh capacity. This installation can be used in the regions where wind speed exceed 3 m/s.

ENERGY-EFFICIENT BUILDINGS

Another promising energy-saving technology for utilization in Antarctica is energy-efficient buildings (Kelner, 1987). Nowadays Russian Antarctic stations make use of 60% electricity that is produced by diesel power plants for space and water heating of the existing buildings (Yefremenko, 1982). Compared to energy-efficient buildings, conventional buildings are somewhat like sieves leaking a great quantities of heat to the surrounding, wasting energy and money and polluting the environment. Our evaluations show that under Antarctic conditions energy-efficient buildings will consume at least twice as less energy as compared to the existing buildings. Using basic principles of energy-efficient buildings design (Kelner, 1987) and thoroughly taking into account the influence of the climatic factors architectural concept of energy-efficient buildings for different climatic zones of Antarctica has been developed in the framework of Task II (Sheinstein, 1991). To discuss

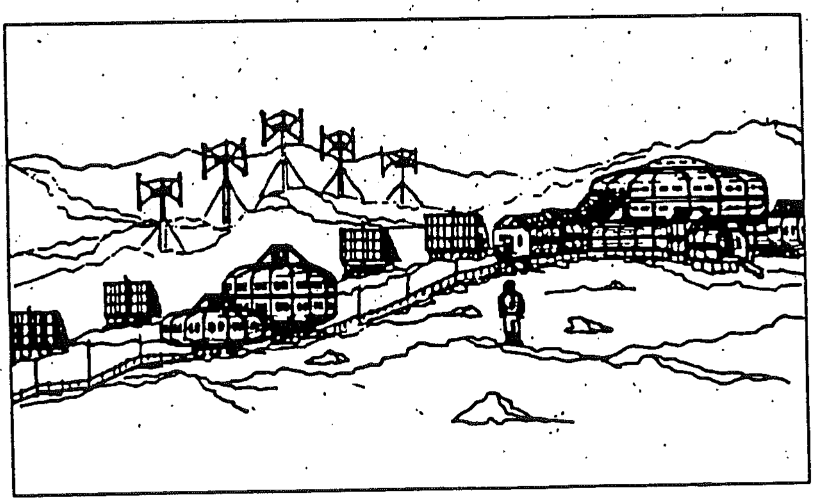
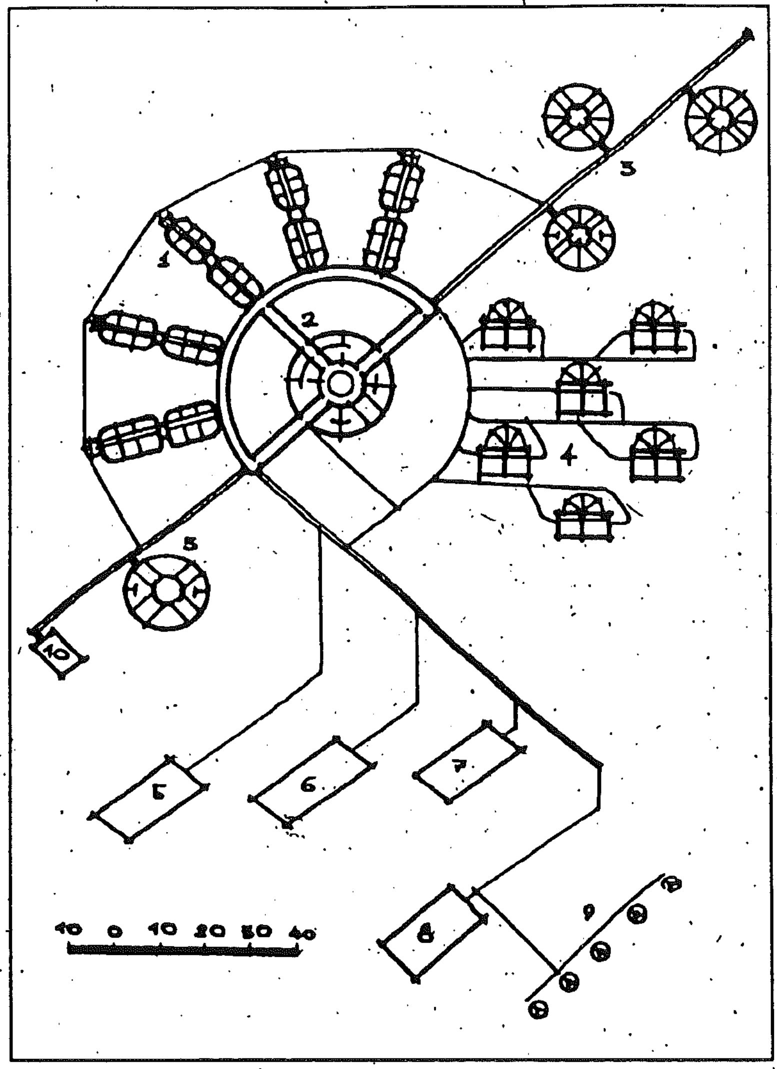


Fig. 6. General layout of the Station

our approaches to designing of energy-efficient buildings for extreme environmental conditions let us consider the concept of adjustable building (Figure 5). This concept is the most suitable for realization in the regions with extreme variations of solar radiation intake during a year (e. g. for Vostok or Amundsen-Scott stations). Solar passive technique was used in designing of this adjustable building. The buildings construction consists of two adjustable elements that can be rotated around the must and fixed in two positions characterized by the maximum energy-efficiency of the building. In position b solar collectors that incorporated in the structure of the building can be effectively used for space heating in Austral summer period. For adjusting the structure in position a it is needed to rotate the elements around the mast. In this position the ratio of the walls area to the volume of the building is minimal and heat losses from the building to the surrounding can be significantly reduced in the coldest period of year.



1. living quarters, 2. recreation center, 3. laboratories, 4. summer camp, 5. garage, 6. warehouse, 7. sewage treatment plant, 8. diesel generators, bass-house, greenhouse, 9. wind generators, 10. reserve diesel generator plant

Fig. 6. General view of the Antarctic station

Based on the results of R&D works on energy-efficient buildings architectural concept of modern polar station for the oasis Shirmaher conditions was developed in the framework of cooperation with Moscow Institute of Architects. General view of the station is shown in Figure 6. The main buildings for wintering staff have a compact design to reduce the heat losses to the surrounding and vibration of the structure under the influence of strong winds. General layout of the station (Figure 7) was worked out on the basis of radial-ring scheme. One of the main roads links the living quarters with the recreation center and laboratories, the other links the center and living quarters with zone of engineering constructions (power plant, garage, bath-house, greenhouse, sewage treatment plant, incinerators). Hybrid power installation consisting of PV system, wind power system with HM-rotor (Kohnen, 1990) and diesel generator set provide the station with electricity and heat.

Using the architectural concepts worked out in the framework of the cooperation between the Committee, Moscow Institute of Architects and IDEEA Federation it is planned to develop project of modern polar station for Russian Antarctic Expedition that nowadays pay much attention to utilization ecologically clean technologies in Antarctica.

CONCLUSIONS

The results of R&D works carried out by Russian Committee on Antarctic Research show that Antarctica is a good perspective region for alternative energy sources utilization. It is worth to continue R&D works on renewable energy sources utilization under extreme environmental conditions of Antarctica. For our opinion there is favourable prerequisite for implementation of alternative energy sources at Russian polar station as we intend to use for these purposes advanced installations carried out in the framework of Russian State Scientific and Technological Program "Environmentally Clean Energetic". It is to be noted that this is a complex topic and our experience have shown that worth results can be obtained in the framework of cooperation between scientists, engineers and architects. Good example of fruitful form of such cooperation is International Design for Extreme Environments Association that has been recently established in USA. We sure that in the nearest future alternative energy sources will be widely used in Antarctica and the advantageous of their utilization become obvious for everybody who deals with this continent exploration.

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NOMENCLATURES

Hv-annual sums of solar radiation on vertical surface; GJ/m^2
Ht-annual sums of solar radiation on optimal oriented surface, GJ/m^2,
DPS-diesel power system,
PVS-photovoltaic power system,
WGS-wind generator power system,
B-battery,
PV-photovoltaics.

ACKNOWLEDGEMENTS

We are grateful for encourage of the program by Russian Antarctic Expedition and Scientific Committee for New and Renewable Energy Sources of Ministry of Science and Technical Policy of Russia and Russian Academy of Sciences. The author would like to acknowledge Prof. Shpilrain and Academician Kotlyakov from Russian Academy of Sciences, Mr. Soshnikov and Mr. Lukin from Russian Antarctic Expedition for assistance in organizing and promoting R&D works on alternative sources of energy utilization in Antarctica.

ALTERNATIVE ENERGY AT THE SAB (BAE) "JUAN CARLOS I"
by

J. Castellvi, E. Meana and A. Castejón
Programa Nacional Antartico, Spain

The experiments that are being carried out with eolian energy since 1992, at the SAB Juan Carlos I, are mainly focused towards having available power supply during the periods when The SAB is closed.

During 1992-93 campaing, two wind power generators with horizontal axis where installed, provided with their respective triphasic alternators of 48 VAC and 500 W power.

The energy they provide is rectified, controlled and stored in a set of 48 solar acid lead batteries with 2 VDC and 2.000 Ah, forming 4 columns with 12 batteries in two groups which provide an output of 24 VDC.

Its use is carried out by means of 2 high perfomance undulators with 220 VAC, 50 Hz and 2,500 W output.

This previos installation allowed to obtain certain experiences during the months of January and February 1993, and its perfomance was valued with the electrical power supply to several equipment of the scientific area of the SAB.

During this period, the results obtained were very limited due to the lack of winds with calm episodes (rare in the climatology of the area).

When the SAB was deactivated at the beginning of March, and it was prepared for it "hibernation", the system kept working in an experimental manner, supplying energy to an automatic weather station and seismologic station.

When in December 1993 (beginning of the 1993-1994 campaign), the SAB was activated again, it was detected that, although the wind power generators were in perfect working
condition, the system of energy storage had shorts in its circuit due to the breaking of some elements in the batteries.

The break down consisted in the breaking of some jars of the battery (5 units), this way losing the electrolyte and therefore the continuity of the circuit, producing the power supply shortage of electrical energy.

By the data obtained at the automatic stations, we know that the system worked correctly up until June 1993. The temperatures registered do not seem to be low enough as to produce the freezing of the electrolyte, and for this reason it is considered that this situation could be produced in periods of low load due to situations without wind.

During the 1993-1994 campaign, the installation of eolian energy was completed at de SAB by means of the start up of a third eolian horizontal axis generator of

1,500 W. At the present time, a system of three horizontal axis eolian generators which form two groups, once made of the two wind generators of 500 W and the other by the one of 1,500 W., representing a total installed power of 2,500 W (2 * 500 W + 1 * 1,500 W).

The correct working order of this system has been checked personally during the months of January and February 1994.

During the 31 days working, from the 23rd of January to the 22nd of February 1994, they have provided energy of 1,804 * 10^5 KJ, which is equivalent to 50 KWh, which reprersents 26% of the system of battery accumulation energy.

In the case of a continuous use it could provide power for a load of:

$$1,804 * 10^5 /31 *24 * *3,600 = 67 W$$

These results, although modest, guarantee the functioning of the automatic system with a consumption of less than 67 W, enough for the weather or seismologic stations systems installed at the SAB.

During the evaluation period, which has had to be short, the measurement of the wind average measured at 10 m from the ground, was approximately of 3.5 m/s (12.6 Km/h), which translated into the level of generators represents a speed lower than 3 m/s which is the threshold of its functioning.

With the results obtained in the present Campaign, we could carry out a global evaluation of the perfomance. In any way, it is convenient to point out that evaluation period for these experiences has been short and not representative. For this purpouse, a system monitoring the data of loading and unloading, as well as temperatures in the system of batteries has been left working.

At the present stage of experience, it seem not advisable to provide power supply with continuous voltage directly to the battery, without using the undulators for the supplies of continuos type and low consumption, such as the automatic weather and seismological stations which are used during the winter. In this way, the transport losses will be minimum and no special large section electrical laying will be necessary.

The use of undulators seem to be appropriate only for high consumption and discontinuos type loads.

For the 1994- 1995 Campaign, we foresee the sending of data in real time using the communications satellite station that the SAB has (Standard A of INMARSAT Network), whose consumption is of 500W. The interlink times will be of half an hour every 24 hours, during which weather, seismological, biological (study of lichen) data and video digitalized images of the SAB environment.

GENERATORS
- Tecnical Data -

Rated power: One 1,5 Kw, two 0,5 Kw

Generator type: three phase, 48 VAC

Rated wind speed: 25 ms

Cut out wind speed: 36 ms

Yaw control: vane

Rotor diameter: 2,10 m

Maximun revolution at 40 m: 700

Number of blades: three

Tower type: mono-pole

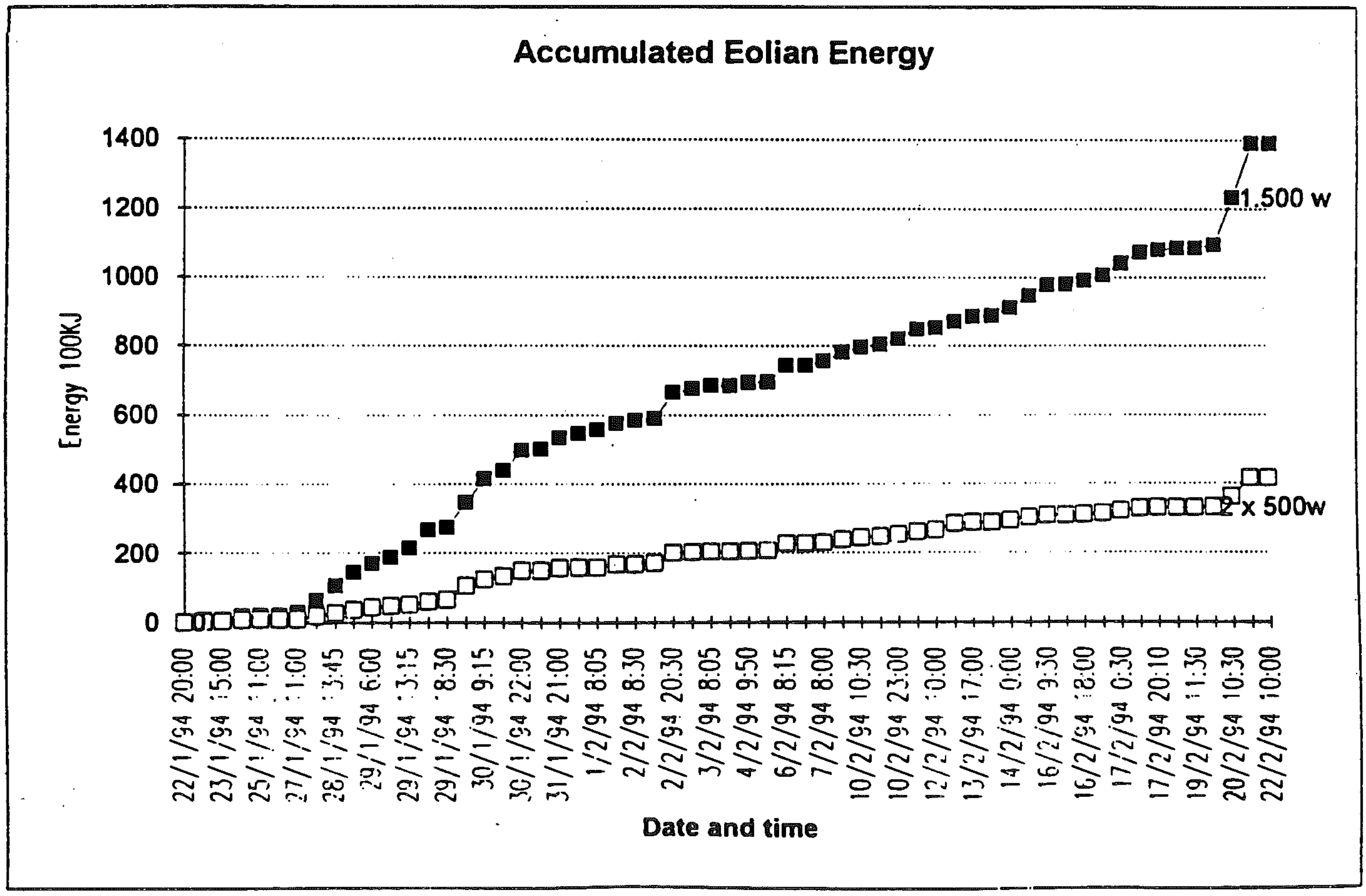
Tower high: 6 m

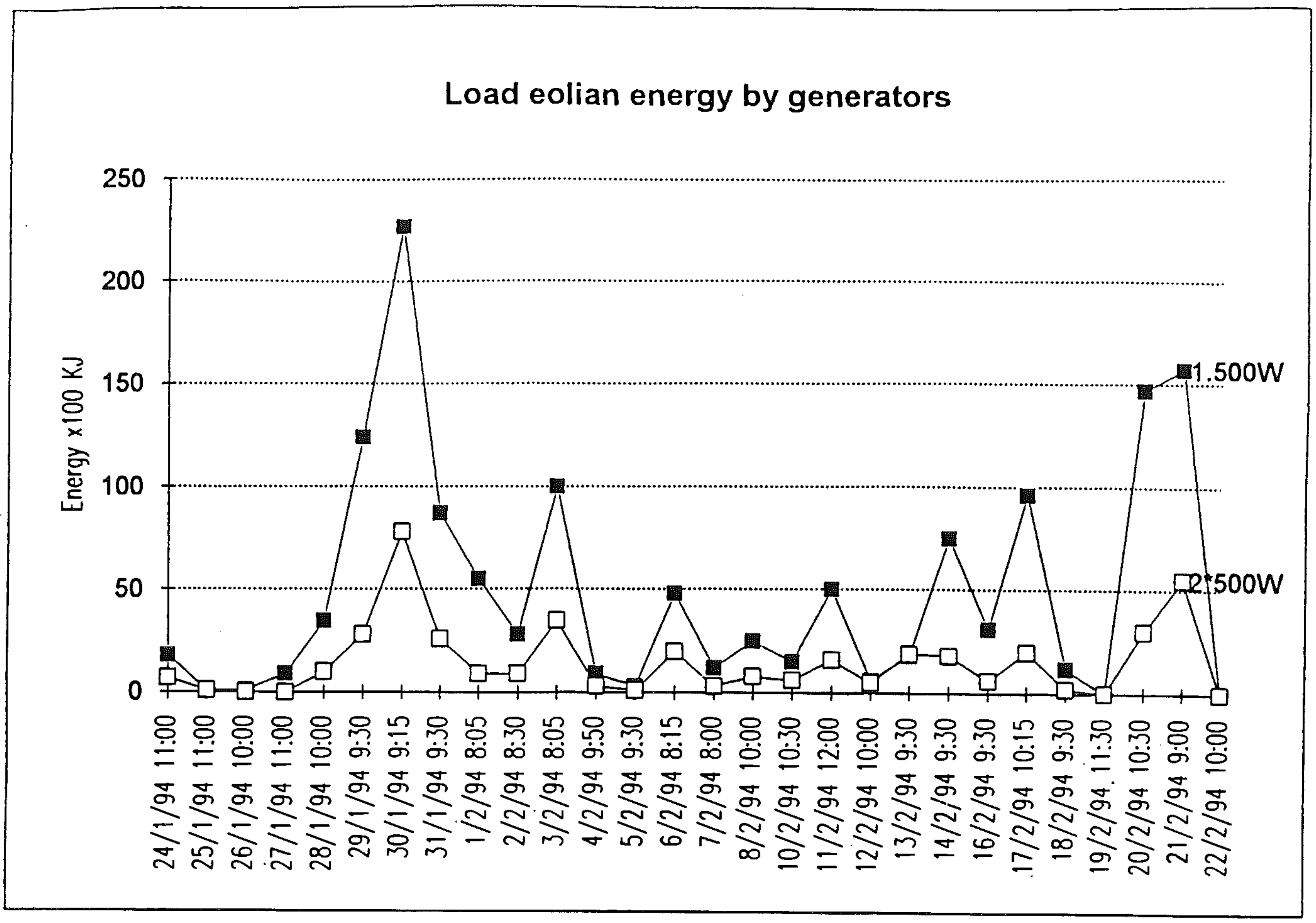
Fundation type: Cement concrete

Load type: Lead-acid batteries, total capacity 2.000 Ah

Date and time	Accumu. Energy		Energy /day		Wind			
	1.500W	2X500W	1.500W	2X500W	speed	direction	max. speed	direction
	E x100KJ	E x100KJ	E x100KJ	E x100KJ	m/s	deg.	m/s	deg.
24/1/94 11:00	18	7	18	7	3,3	230	9,1	190
25/1/94 11:00	19	8	1	1	2,5	220	6,4	250
26/1/94 10:00	20	8	1	0	1,7	30	3,9	200
27/1/94 11:00	29	8	9	0	2,2	320	5,1	310
28/1/94 10:00	64	18	35	10	4,8	40	11,7	70
29/1/94 9:30	188	46	124	28	6,3	90	15	40
30/1/94 9:15	415	124	227	78	8,6	30	23,5	60
31/1/94 9:30	502	150	87	26	5	330	13	20
1/2/94 8:05	557	159	55	9	4,2	10	8,5	20
2/2/94 8:30	585	168	28	9	3	30	10,2	30
3/2/94 8:05	685	203	100	35	3,6	170	11,4	140
4/2/94 9:50	694	206	9	3	2,7	180	8,5	150
5/2/94 9:30	697	207	3	1	2,7	200	4,9	200
6/2/94 8:15	745	227	48	20	3,3	190	9,7	23
7/2/94 8:00	757	230	12	3	3,2	30	12,6	23
8/2/94 10:00	782	238	25	8	3,4	70	7,8	180
10/2/94 10:30	797	244	15	6	1,1	190	11,7	190
11/2/94 12:00	847	260	50	16	4,6	35	13	23
12/2/94 10:00	853	265	6	5	1,9	170	10,3	300
13/2/94 9:30	871	284	18	19	2,5	300	11,6	25
14/2/94 9:30	946	302	75	18	4,3	30	7,7	190
16/2/94 9:30	977	308	31	6	2,9	45	8,9	335
17/2/94 10:15	1073	328	96	20	2,9	100	11	110
18/2/94 9:30	1085	330	12	2	2,4	120	7,9	120
19/2/94 11:30	1085	330	0	0	1,9	variable	4	35
20/2/94 10:30	1232	360	147	30	6,9	60	21,9	55
21/2/94 9:00	1389	415	157	55	5,2	100	17,2	120
22/2/94 10:00	1389	415	0	0	0,7	300	2,2	300

AVERAGE	49,61	14,82	3,49




Load eolian energy by generators
Energy x100 KJ
250
200
150
100
50
0
1.500W
2*500W
24/1/94 11:00
25/1/94 11:00
26/1/94 10:00
27/1/94 11:00
28/1/94 10:00
29/1/94 9:30
30/1/94 9:15
31/1/94 9:30
1/2/94 8:05
2/2/94 8:30
3/2/94 8:05
4/2/94 9:50
5/2/94 9:30
6/2/94 8:15
7/2/94 8:00
8/2/94 10:00
10/2/94 10:30
11/2/94 12:00
12/2/94 10:00
13/2/94 9:30
14/2/94 9:30
16/2/94 9:30
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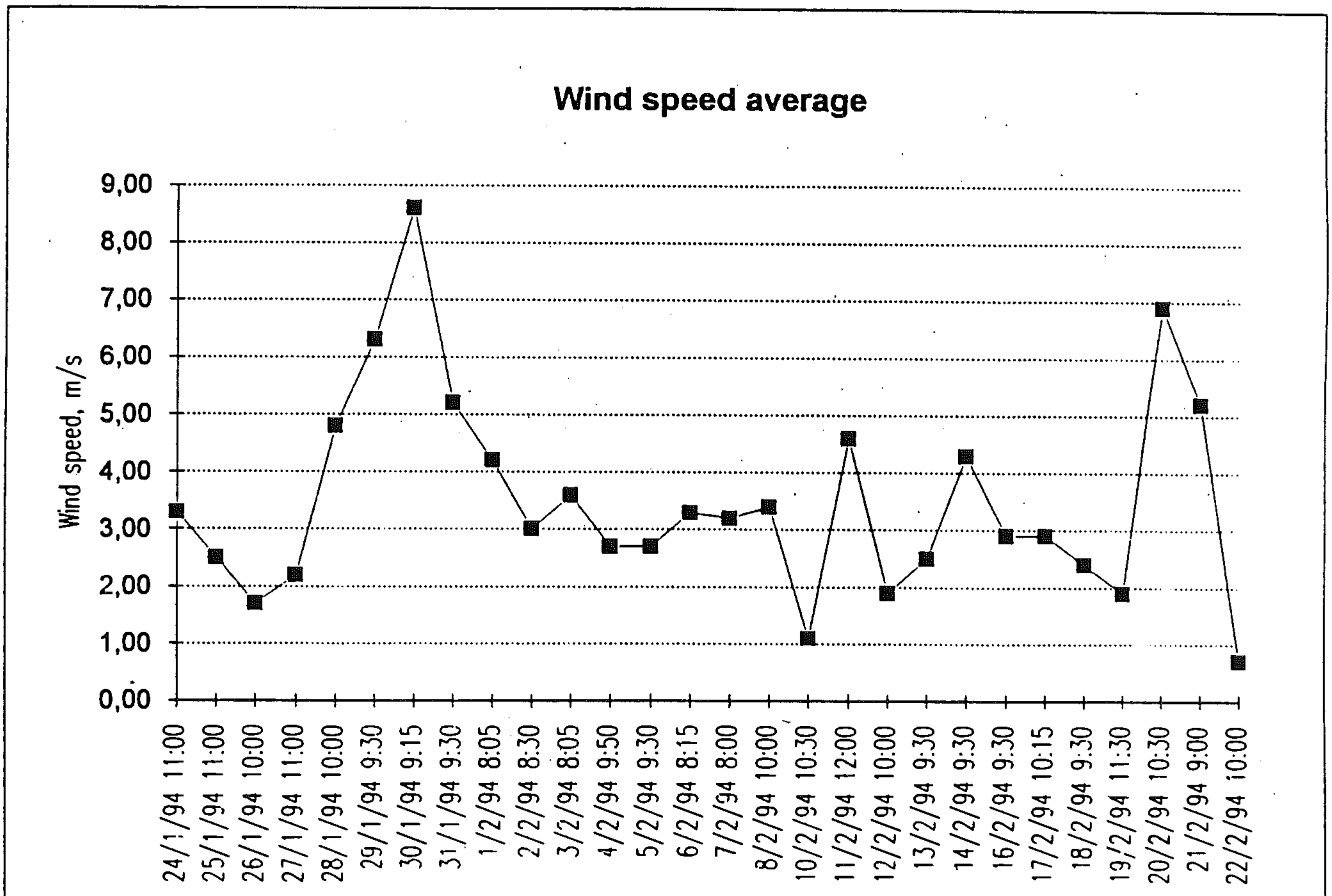
22/2/94 10:00


Wind speed average
Wind speed, m/s
9,00
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
24/1/94 11:00
25/1/94 11:00
26/1/94 10:00
27/1/94 11:00
28/1/94 10:00
29/1/94 9:30
30/1/94 9:15
31/1/94 9:30
1/2/94 8:05
2/2/94 8:30
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7/2/94 8:00
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19/2/94 11:30
20/2/94 10:30
21/2/94 9:00
22/2/94 10:00

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ANTARCTIC ALTERNATIVE ENERGY SUMMARY

Antarctic Symposium
for Logistics and Operations
Rome, Italy
29 -31 August 1994

Presented By:
Erick Chiang
Operations Manager
NSF/OPP

USAP OBJECTIVES

- Minimize Environmental Impact Associated with Power Production
- Enable New Applications - Remote Communications
- Supplement Conventional Power Generation Systems - South Pole
- Greater Efficiencies

USAP Renewable Energy Innovation Activities

Present Applications

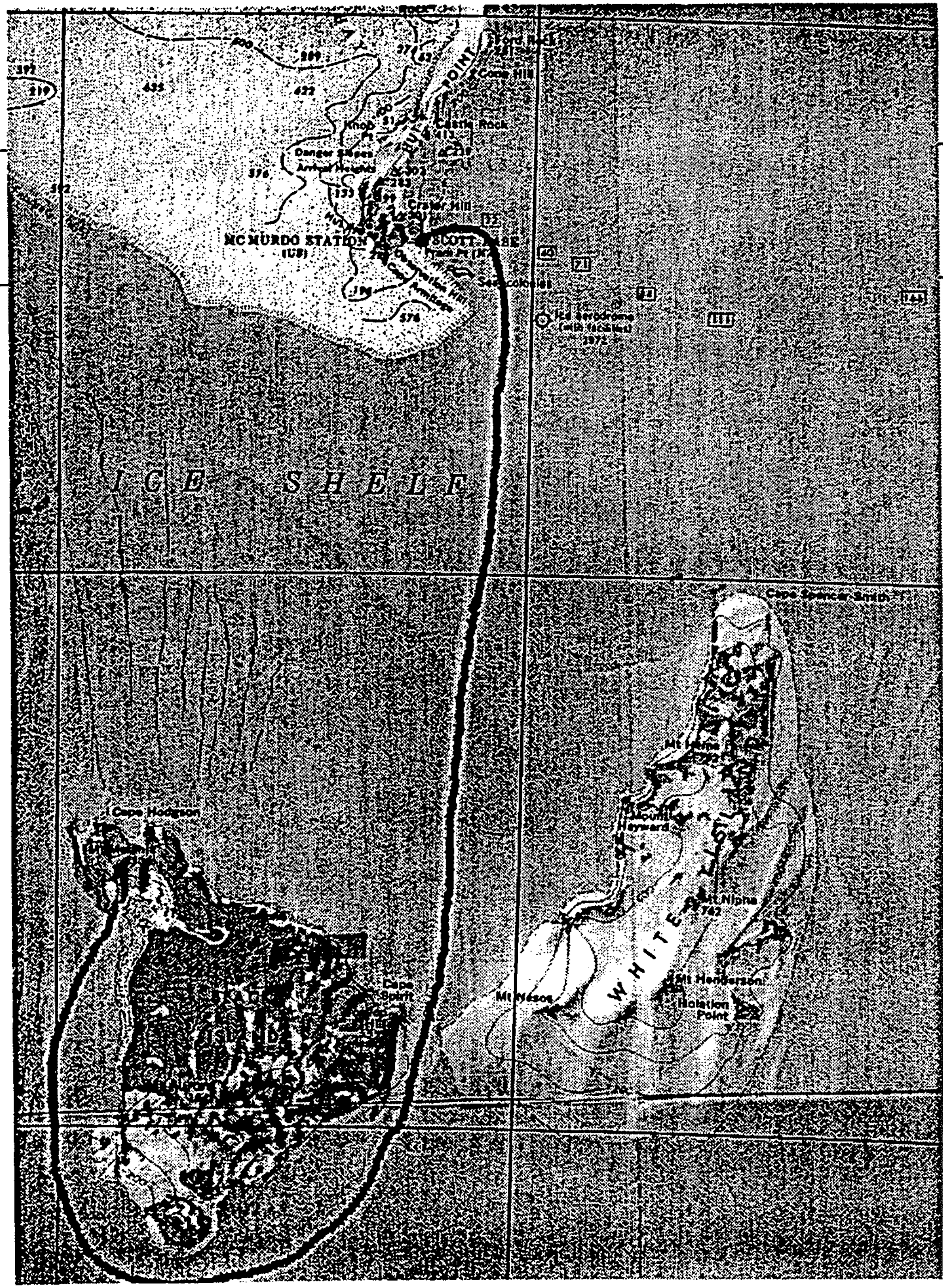
- Black Island Telecommunication Facility (BITF)
- Remote Communications Repeaters
- Transportable VHF Repeaters
- Portable Communications Systems
- South Pole Station Passive Collectors
- Automatic Weather Stations
- Portable Shelters (Fish Huts)

Planned Applications

- Marble Point
- South Pole Station
- Long Term Environmental Research Sites
- Mt. Erebus Communications Relay Site
- Advanced Automatic Unattended Weather Stations (Air Traffic Control)

BITF Environmental

- Located Near Cape Hodgson on Black Island in McMurdo Sound
- 33 Kilometers South of McMurdo Station
- 140 Kilometers Overland Access
- 145 Knot Winds Recorded in 1991
- -55 C Minimum Temperature


MC MURDO STATION
(US)
SCOTT BASE
ICE SHELF
WHITE
Castle Rock
Crater Hill
Danger Slopes
Cape Hodgson
Cape Spirit
Mt Nesos
Mt Nipha
762
Mt Henderson
Isolation Point
Mount Heward
Cape Spencer-Smith

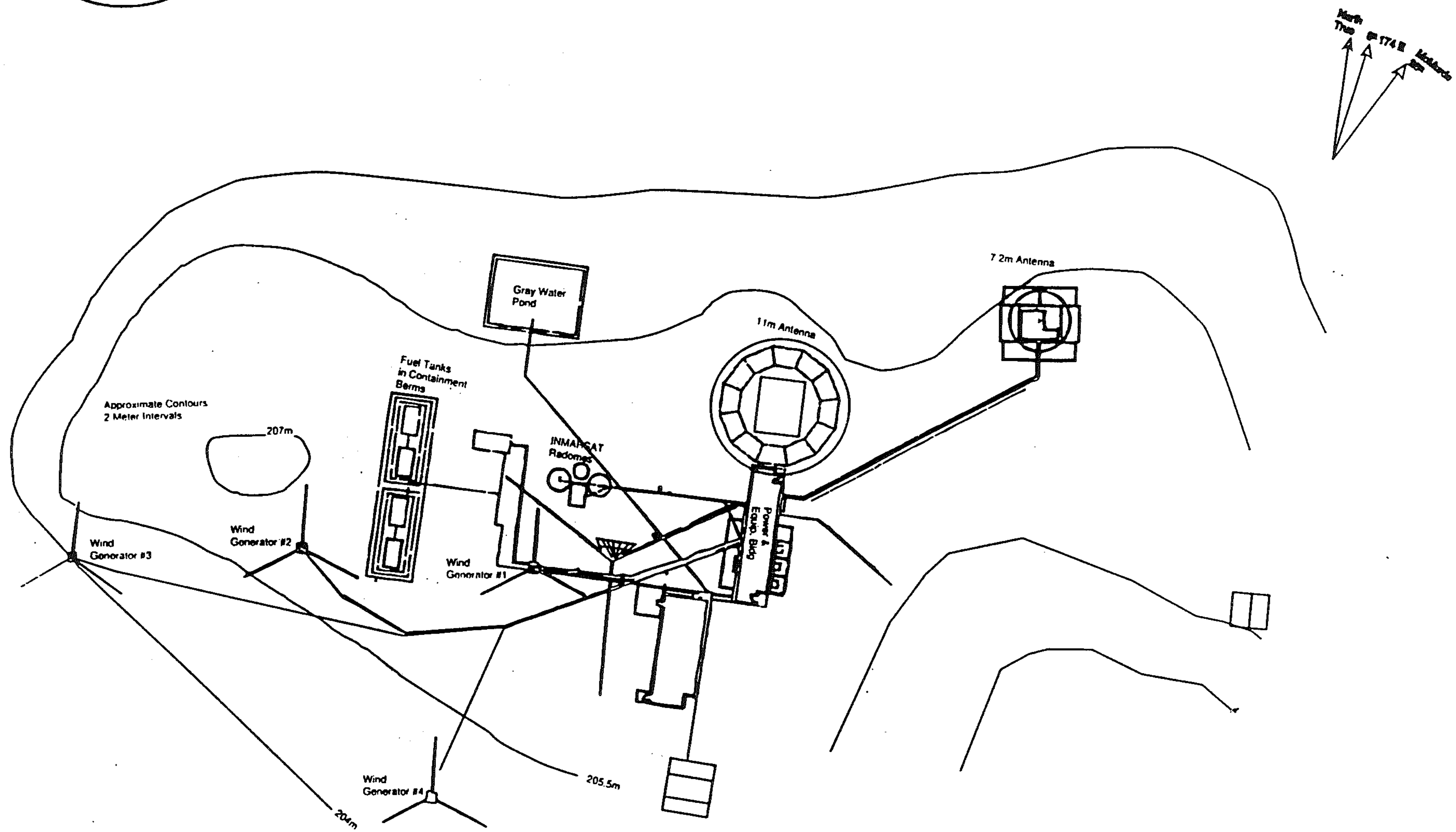
BITF Capabilities

- Unobstructed Look Angle to Pacific Ocean Region Geostationary Satellites
- INTELSAT IBS 1.544 Mb Service
- INMARSAT Standard "A" Service
- HF Point-to-Point and Air-to-Ground Receive Only Services
- Satellite TVRO

BITF Hybrid Power System Design Requirements

- Autonomous Operation
- Alternative Energy Technology as Primary Power Systems
- Power 5000 Watt (120 kWHRS) Connected Load up to 5 Days Without Interruption
- Modular Buildings

BITF Site Plan



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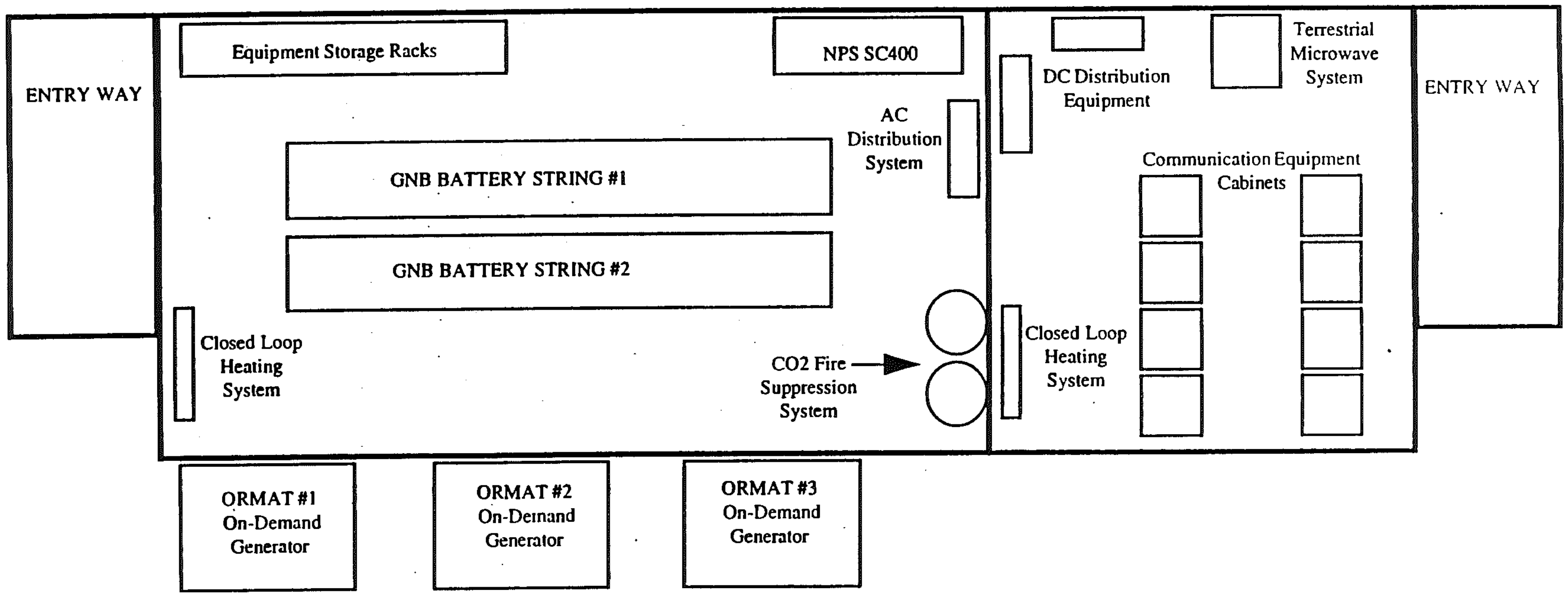
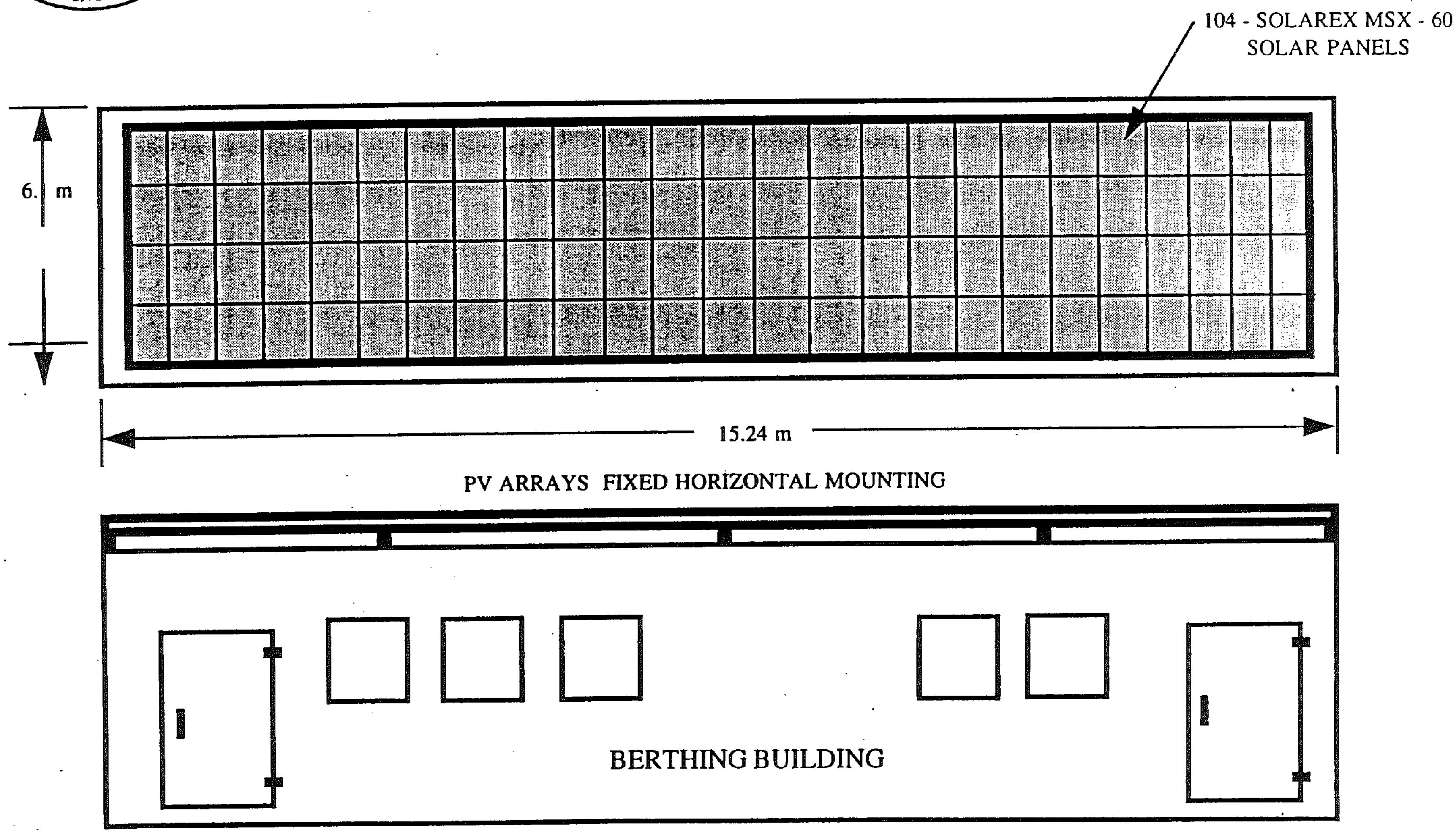
BITF Power and Equipment Building



Modular Metal-Clad Urethane Insulted Bally Building
18 Meters x 4.5 Meters
Wall and Roof Panel Thickness: 15.24 cm
Average Insulation Value: R 42

BITF Berthing Building and PV Arrangement



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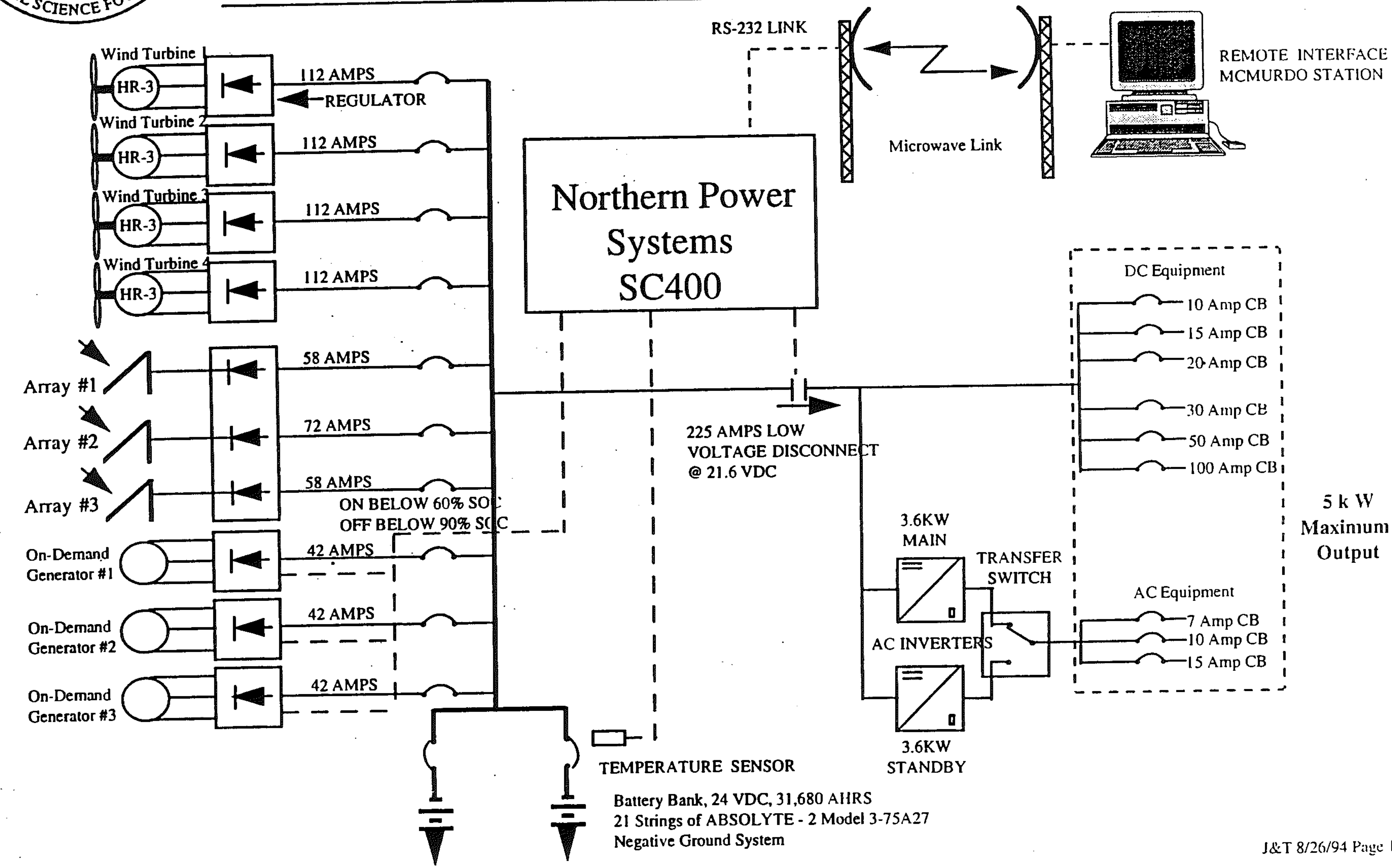
Black Island Hybrid Power System Block Diagram



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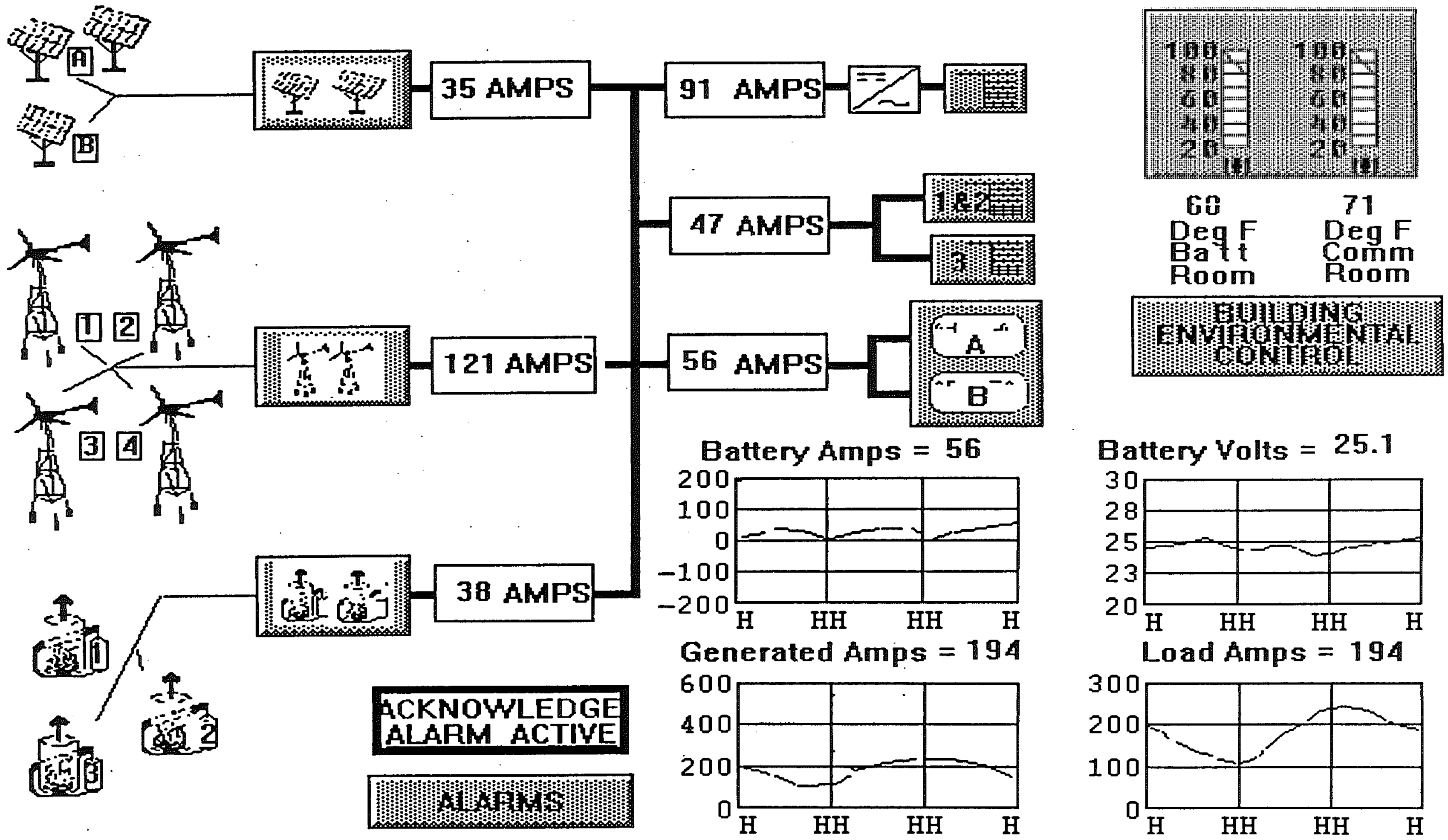
BITF Hybrid Power System Architecture

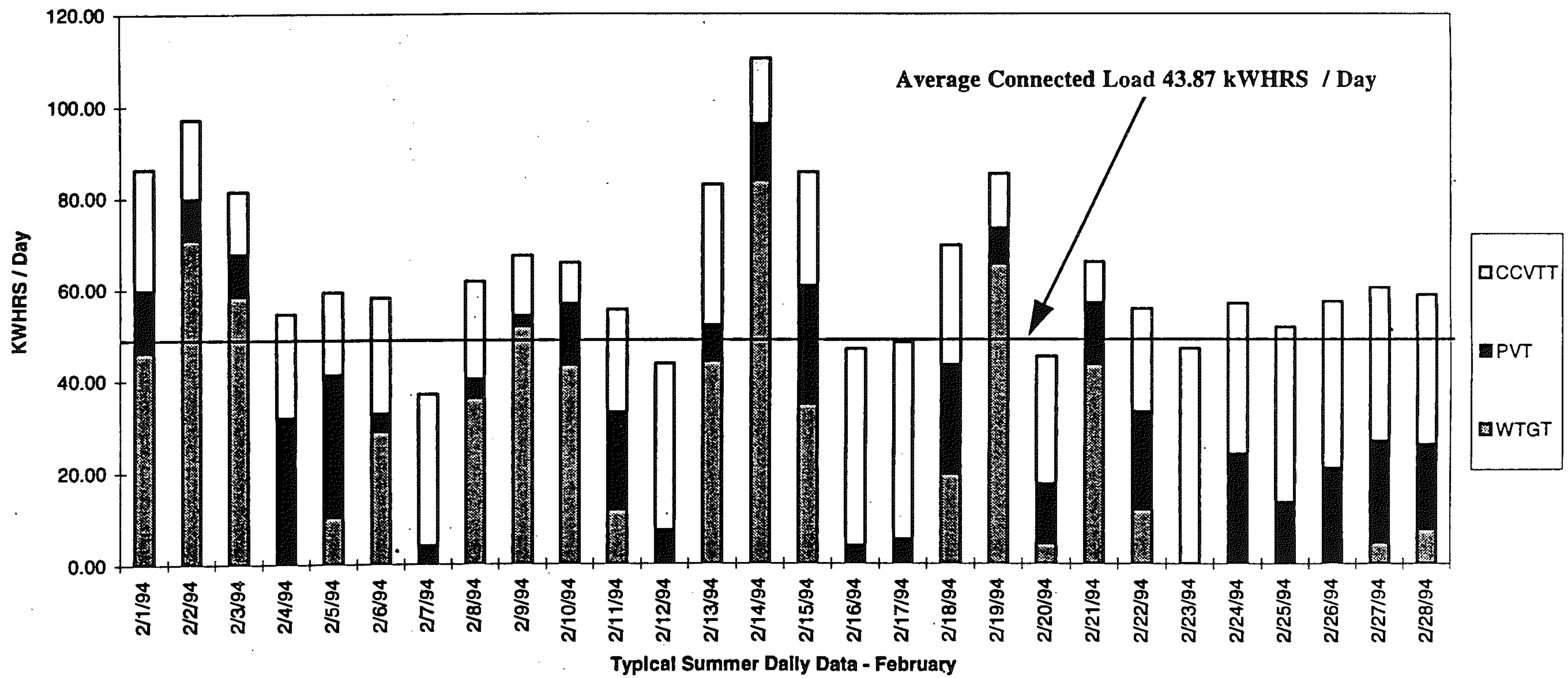
- 4 ea. - 3 kW HR3 Northern Power Systems Wind Turbines
- 3 ea. - 4 kW SOLAREX MSX-60 Photovoltaic Arrays
- 3 ea. - 1.2 kW On-Demand ORMAT Closed Cycle Vapor Turbines
- 31,680 Amp Hours GNB ABSOLYTE II Sealed Lead Acid Batteries
- AC and DC Distribution System
- Intelligent Autonomous System Controller
- Graphical Computer Based Operator Interface
- Remote Control from McMurdo Station

BITF Graphical Computer Based Interface - Main Screen



Average Connected Load

BITF Energy Production Summary - Typical Summer Daily



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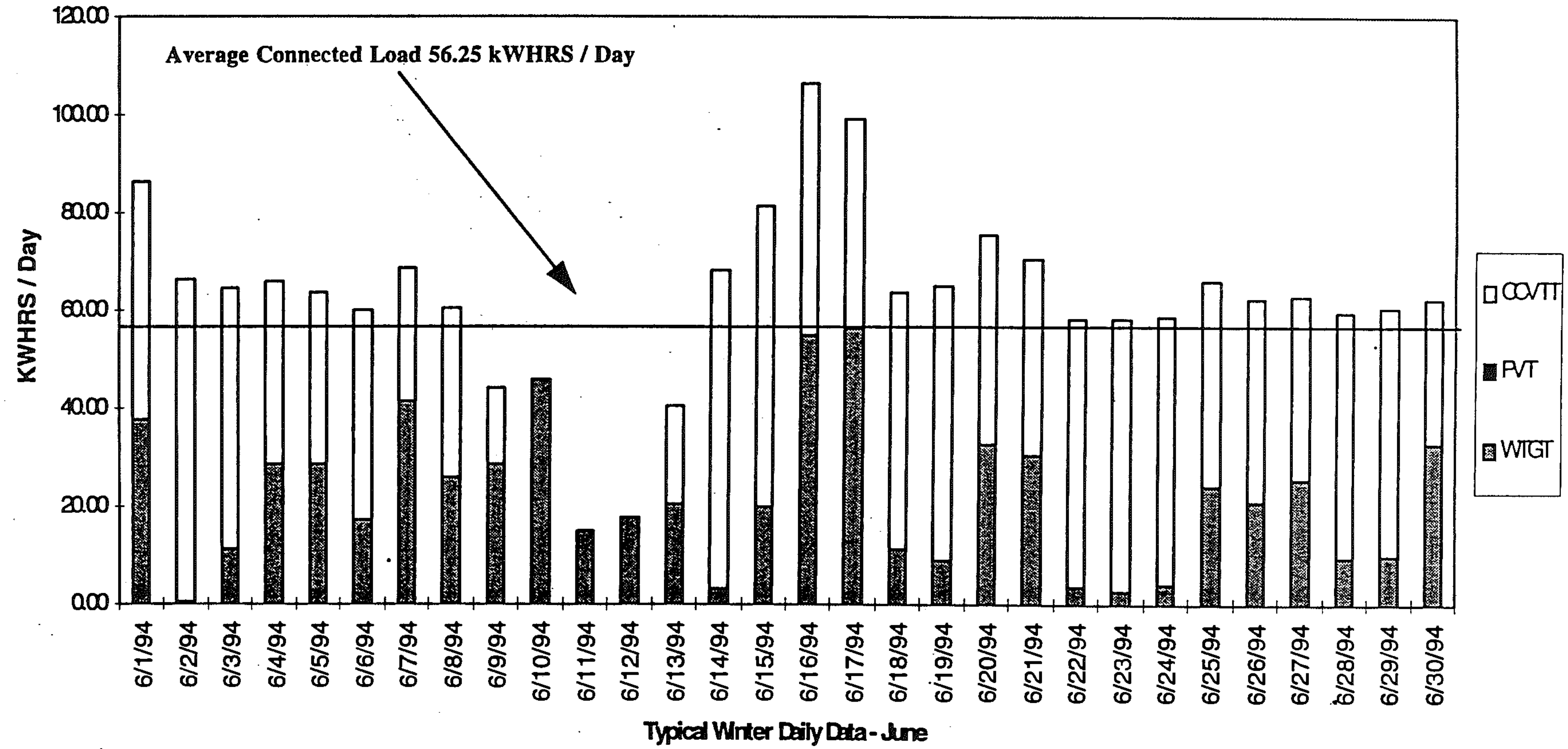
BITF Energy Production Summary - Typical Winter Daily



Conclusion

- BITF was Pioneer System in the USAP
- Proven But Still Under Development
- Maturing Design to Adapt to Extreme Environment
- Stimulated Alternative Energy Technology Development in U.S.
- Prototype for Future USAP Applications

PERFORMANCE OF PV PANELS FOR SOLAR ENERGY CONVERSION AT THE SOUTH POLE

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ABSTRACT

Expanding research facilities at the Amûdsen-Scott South pole station require increased electric power generation. Presently, electric power generation is by diesel generators using the JP8 fuel. As the station is accessible only for a short supply period during the austral summer, there are limitations upon the supply of fuel for power generation. This makes it necessary to seriously consider the use of the renewable energy sources. Although there is no sunlight for six months in the year, abundant solar energy is available during the remaining 6 months because of the clear skies, the clarity of air and the low humidity at the south pole. As the buildings at the south pole are built either without windows or with only porthole type windows, large areas on the walls and the roof are available for mounting the photovoltaic (PV) panels. In addition there is unlimited space around the station for constructing a PV panel "farm".

In this paper four types of PV panels are evaluated; the 2-axis tracking panels, vertical 1-axis tracking panels, fixed vertical panels on the walls of buildings and mounted outdoors, and fixed horizontal panels on the roofs of the buildings. Equations are developed for the power output in kW/sq.ft and annual energy in kWh/sq.ft for each type of panel. The equations include the effects of the inclination of the sun above the horizon, the movement of the sun around the horizon, the direct, reflected and diffused components of the solar radiation, the characteristics of the solar cells and the types of dc/ac inverters used to interface the output of the cells with the existing ac power.

A conceptual design of a 150-kW PV generation system suitable for the south pole is also discussed in this paper.

Key Words: Solar Energy, South Pole

PAPER

THE SOUTH POLE RESEARCH STATION - A BRIEF HISTORY

The flagship of the US Antarctic Program is the Amûdsen-Scott Station located at the geographic south pole approximately 800 miles inland from McMurdo. Named after Ronald Amûdsen of Norway and Robert Scott of Great Britain, the leaders of the first two expeditions to reach the south pole in December 1911 and in January

1912, the Amundsen-Scott Research Station at the south pole sits on top of the 9600-ft thick Antarctic icecap. This station was first built in 1957 as a surface camp of modular prefabricated timber structures. During the first winter in 1957, 18 men lived in these structures for 8 months in complete isolation from the rest of the world.

By 1967, because of continual drifting and annual build-up of snow the station was buried approximately 20 ft below the snow surface. The weight of the snow had started to cause structural failures. In 1975, a new south pole station was constructed by the US Navy Seabees and the modular structures were abandoned. The station as it stands today consists of a 146-ft diameter aluminum geodesic dome connected to a line of about 700 ft of 46-ft diameter corrugated metal arches and several outlying facilities. A complete description of the station is outside the scope of this paper.

Since 1975, scientific research, construction and maintenance activity and even tourism have increased continually. The present facilities are proving to be inadequate. In addition, the harsh environment of the pole is shortening the life of the structures. Plans are underway now to build more structures to augment the present facilities and replace them when they eventually become unusable.

The population varies between 100 in the summer and about 20 during the rest of the year. The station is accessible from McMurdo only by LC-130 aircraft equipped with skis for landing on the polar ice. The very short annual supply season lasts for only 14 weeks from November 1 to February 15, during which time 90 to 100 flights can be scheduled in good weather.

ELECTRIC POWER GENERATION AND FUEL SUPPLY

Generation of electrical power at the Amundsen-Scott south pole station is presently by a diesel-generator power plant located in one of the 46-ft diameter arches near the dome. The power plant consists of three diesel-engine driven ac generators rated at 475 kW but derated due to the altitude to 350 kW. Power generation and distribution is at 208/120 V 3-phase 60 Hz. The voltage is stepped up to 600 V for supplying the outlying facilities such as the Clean Air Lab and the Summer Camp. The engine jacket heat is recovered through a Glycol/water heat exchanger and is used for space heating. Heat is also recovered from the flue gases and is presently used for melting ice to obtain potable water.

The diesel engines operate on the JP8 aviation fuel. The fuel is flown in from McMurdo during the supply season and is stored in rubber bladders located in the fuel arch. The total storage capacity is presently 225,000 gallons. This fuel is used for power generation as well as for the station vehicles. The bladders sit directly on the ice in the fuel arch. Fuel is circulated continuously in the winter to prevent gelling.

The generators are not normally operated in parallel. The mode of operation is that one generator supplies the entire load, the second is on standby and the third is on scheduled maintenance. This operation has proved to be very satisfactory because the maximum load is about 335 kW in the winter, less than the capacity of one generator. However, when the proposed new facilities and labs are built, it will be necessary to operate two or three generators in parallel to meet the maximum demand. The real limitation will be in the amount of fuel available for power generation. In the future the fuel supply situation is not likely to change significantly. Therefore, there is a desparate need to harness the renewable energy sources such as the wind and sun to meet the increasing demand for electrical power. Presently, there are no wind or solar power generators at the south pole.

AVAILABLE SOLAR ENERGY AT THE SOUTH POLE

From the spring equinox on September 22 to the Autumn equinox on March 22, the south pole is sunlit continuously. There are 182 days of continuous sunlight while complete darkness reigns for the remaining 183 days of the year. However, the sun never climbs overhead. It has a maximum elevation of 23.4 degrees above the horizon. On any particular day the elevation of the sun above the horizon is given by Eqn. (1) below.

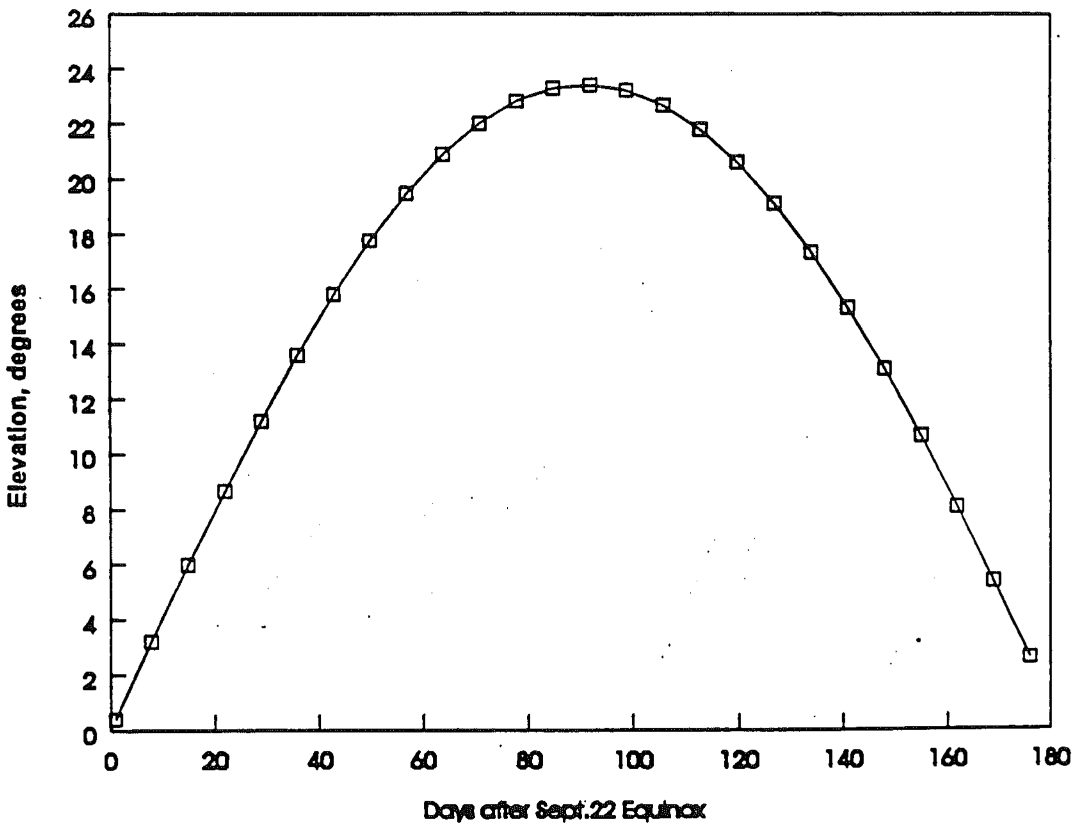
$$\theta = 23.44 * \text{Sin}(360*d/365) \quad (1)$$

where

θ = the angle of elevation of the sun above the horizon, degrees

d = the number of days following the spring equinox.

A plot of the angle Z during the austral daylight period is shown in Fig.1.



ELEVATION OF THE SUN ABOVE HORIZON

FIG. 1

The Solar Constant I_0 is defined as the total energy in the sunlight upon a unit area of a surface perpendicular to the sunlight outside the earth's atmosphere. This constant has ben measured to be 1354 W/m^2 or 125.8 W/ft^2 and it varies very slightly during the year, primarily, due to the elliptical nature of the earth's orbit. At the surface of the earth the solar insolation is less than I_0 because of the absorption of energy in the upper and the lower atmospherE. The total insolation on a normal surface at an altitude E_l above sea level is given by the Eqn. (2) below (Reference 1).

$$I_n = I_r * e^{-m'*B} \qquad (2)$$

where

I_n = Total solar insolation at a surface perpendicular to the sun's rays, W/ft^2

I_r = Solar insolation let through by the upper atmosphere, W/ft^2

e = base of natural logarithm

m' = Air mass at elevation E_l ft above sea level.

$= m * e^{-El/30,000}$

m = Air mass at sea level

$= 1/(\text{Sin } \theta)$

The values of I_r and B (determined empirically to fit the measured radiation) are as follows:(Reference 1)

Month	I_r, W/ft^2	B
Jan	114.36	0.142
Feb	112.89	0.144
Mar	110.25	0.156
April	105.56	0.180
May	102.63	0.196
June	101.17	0.205
July	100.87	0.207
Aug	102.93	0.201
Sept	107.03	0.177
Oct	110.84	0.160
Nov	113.48	0.149
Dec	114.65	0.142

Figure 2 shows the solar insolation in the upper and lower atmosphere and at the surface of the south pole. **The maximum solar power available is about 88 W/ft^2** in the month of January. The total energy available from the sun on a normal surface during te entire austral summer calculates to 257.5 kWh/ft^2 per year.

To determine the available power and energy from the PV panels the following factors need to be considered:

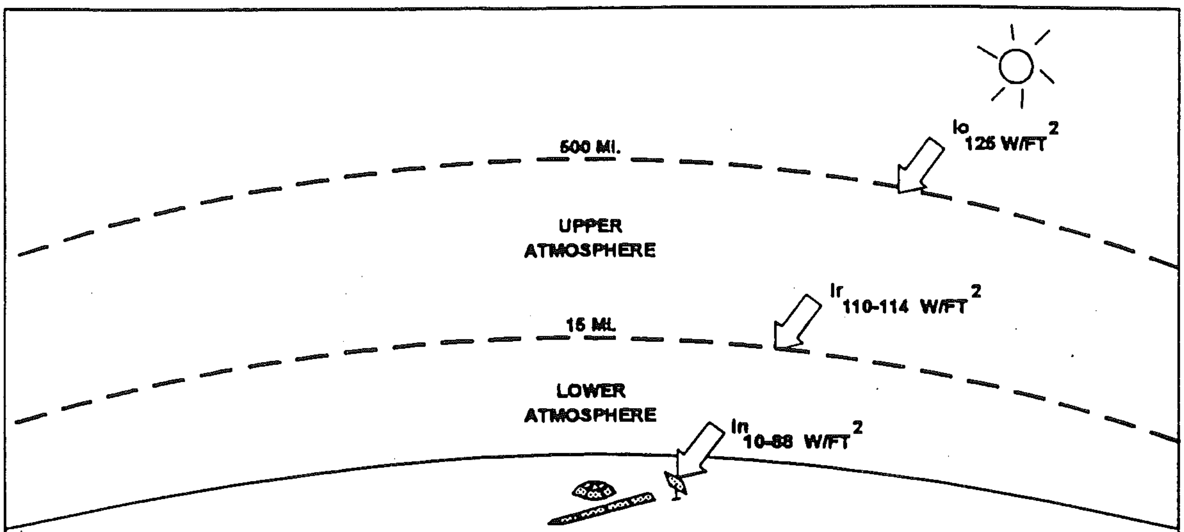
1. The types of PV panels - tracking or fixed
2. Solar energy reflection from the snow surface and diffused light on the PV panels

3. Efficiency of the PV cells

4. Cloud Cover

5. The characteristics and efficiency of power conditioning system or the energy storage system.

These factor will be discussed briefly in the following sections of this paper.



MONTH	In W/m^2
OCT.	14.2
NOV.	74.1
DEC.	86.9
JAN.	89.5
FEB.	60.1
MAR.	64.8
MAR. 21	0.2

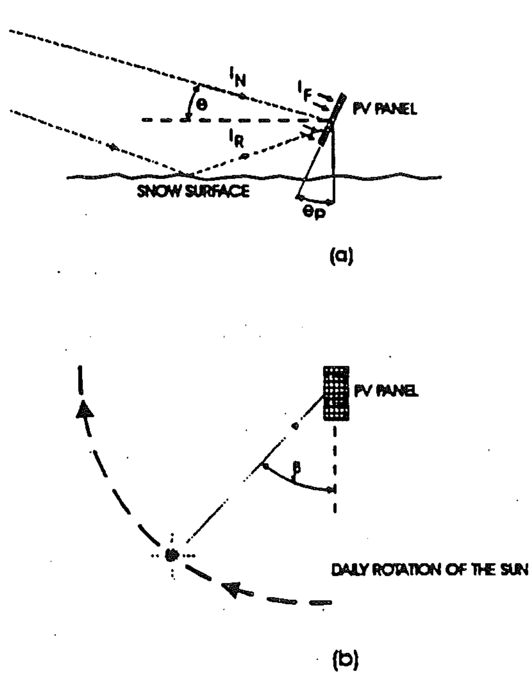
SOLAR INSOLATION AT THE SOUTH POLE

FIG. 2

TYPES OF PV PANELS

Four types of PV panels can be used at the south pole; the two-axis tracking panels, vertical 1-axis tracking panels, fixed vertical and fixed horizontal panels. The 2-axis tracking panels are those which adjust such that the plane of the panel is perpendicular to the sunlight at all times. The 1-axis tracking panels are vertical panels rotating around a vertical axis. As the sun goes around the horizon once in 24 hours the tracking mechanism must rotate the panel at the rate of one revolution in 24 hours. Obviously, the tracking panels make the best use of the panel area and give the maximum possible power output during the austral summer. However, the tracking panels are expensive and the mechanism may require some maintenance attention because of the extreme low temperatures. Fixed vertical and horizontal panels can be mounted on building surfaces and outdoors in a PV farm and would require little maintenance. If they are oriented in the direction of the wind there will be very little snow accumulation on the panels.

Consider Figure 3 which is used to derive a general expression for the power output of a PV panel. In Figure 3



DIRECT, REFLECTED AND DIFFUSED RADIATION UPON A PV PANEL

FIG. 3

I_N = Solar insolation on a normal surface, W/sq.ft

I_R = Reflected solar insolation from the snow surface, W/sq.ft

I_F = Diffused radiation on the PV panel, W/sq.ft

The variation of I_N with the season in shown in a table in Figure 2. The snow surface is highly reflective. Estimates of the surface albedo (the ratio of the reflected radiation to the direct radiation) ranges from 0.8 to 0.99(Reference 2). Approximately 50 percent of the reflected radiation is in the form of diffused lighting while the other 50 percent can be assumed to be directed towards the PV panels. In the estimates presented in this paper the following assumptions are made:

$$I_R = 0.4 * I_N$$

$$I_F = 0.1 * I_N$$

A general equation for the power output of a PV panel at any time can be derived as follows:

$$I = \eta*\{[I_N*COS(\theta - \theta_P)+I_R*COS(\theta + \theta_P)]* SIN(\beta)] + I_F\} \quad ---(3)$$

Where

I = the power output of the panel, W/sq.ft

η = The efficiency of the PV panel, per unit

I_N, I_R and I_F are defined above

θ = The elevation of the sun above the horizon, degrees

θ_P = The inclination of the panel w.r.t. the vertical, degrees

β = The angle of daily rotation of the sun w.r.t. a horizontal drawn through the plane of the panel, degrees.

The 2-Axis Tracking Panel

For the 2-axis tracking panel $\theta = \theta_P$ and β = 90 deg. at all times. Therefore

$$I = \eta * \{ [I_N + I_R* COS(2*\theta)] + I_F\} \quad W/sq.ft \quad ---(4)$$

The 1-axis Tracking Vertical Panel

For this type of panel $\theta_P = 0$ and β = 90 deg. at all times. Therefore

$$I = \eta * \{ (I_N + I_R)*COS(\theta) + I_F\} \quad W/sq.ft \quad ---(5)$$

The Fixed Vertical Panel

In this case $\theta_P = 0$. Therefore

$$I = \eta * \{ (I_N + I_R) * COS(\theta) * SIN(\beta) + I_F \} \quad W/sq.ft$$

The panel is lighted for only 12 hours in every 24 hours. The average 24-hour output is given by the following equation:

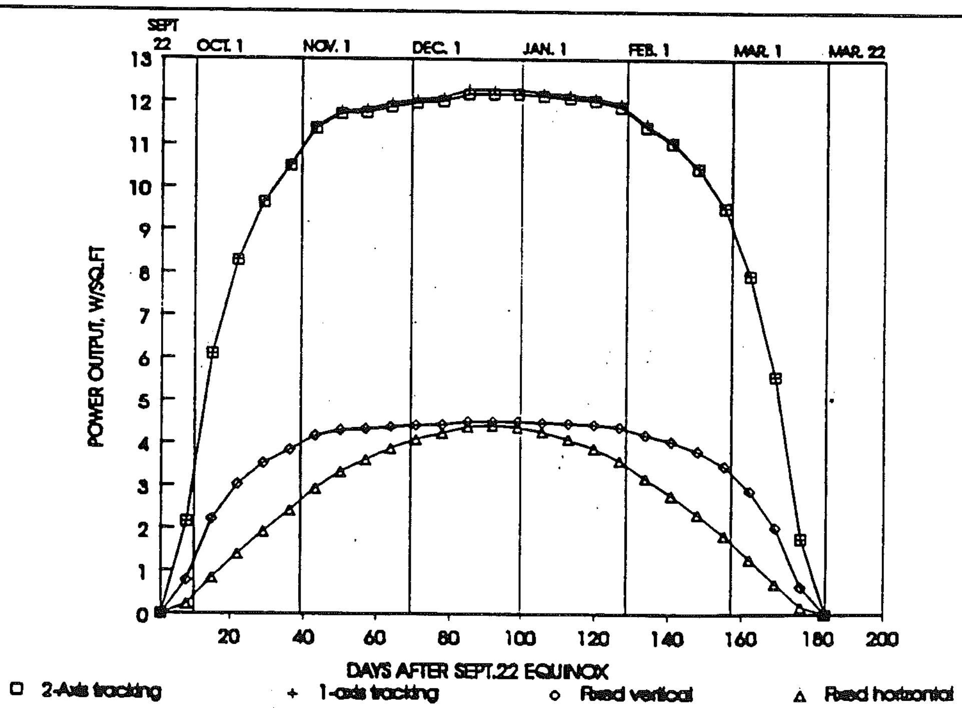
$$I = \eta * \{ 0.318*(I_N + I_R)*COS(\theta) + I_F \} \quad W/sq.ft \quad ---(6)$$

The Fixed Horizontal Panel

This type of panel receives the direct and the diffused radiation but not the reflected radiation. However, the panel remains lighted at all times. With θ_P = 90 degrees, the power output is given by

$$I = \eta * \{I_N * SIN(\theta) + I_F) \quad W/sq.ft \quad ---(7)$$

The above equations are for outputs with no cloud cover. Assuming I_R = 40% of I_N and I_F = 10% of I_N and that the efficiency of a PV panel is typically 10%, Equations (4), (5), (6) and (7) are calculated for each day in the austral summer. The results are shown in Table 1 and Figure 4.



AVERAGE DAILY OUTPUT OF PV PANELS

FIG. 4

TABLE 1

PERFORMANCE OF PV PANELS AT THE SOUTH POLE

Month	Date	Day	Theta deg.	m	Ir W/sq.ft	B	In W/sq.ft	---------- PanelOutput, W/sq.ft--- 2-Axis Tracking	1-axis Tracking	Fixed Vert.	Fixed Horiz.
September	22	1	0.40	101.75	110.84	0.16	0.00	0.00	0.00	0.00	0.00
	29	8	3.22	12.76	110.84	0.16	14.38	2.15	2.15	0.78	0.22
October	6	15	5.99	6.87	113.48	0.149	40.77	6.08	6.08	2.21	0.83
	13	22	8.67	4.76	113.48	0.149	55.87	8.28	8.29	3.02	1.40
	20	29	11.22	3.68	113.48	0.149	65.56	9.64	9.66	3.52	1.93
	27	36	13.61	3.04	113.48	0.149	72.10	10.50	10.53	3.84	2.42
November	3	43	15.81	2.63	114.65	0.142	78.92	11.37	11.42	4.17	2.94
	10	50	17.77	2.35	114.65	0.142	82.15	11.71	11.77	4.31	3.33
	17	57	19.48	2.15	114.65	0.149	83.25	11.75	11.82	4.33	3.61
	24	64	20.91	2.01	114.65	0.149	85.01	11.88	11.97	4.39	3.88
December	1	71	22.03	1.91	114.65	0.149	86.25	11.97	12.06	4.43	4.10
	8	78	22.83	1.85	114.65	0.149	87.07	12.01	12.11	4.45	4.25
	15	85	23.30	1.81	114.65	0.142	88.65	12.19	12.29	4.51	4.39
	22	92	23.44	1.80	114.65	0.142	88.77	12.19	12.29	4.52	4.42
	29	99	23.23	1.82	114.65	0.142	88.58	12.18	12.28	4.51	4.38
January	5	106	22.69	1.86	114.36	0.142	87.85	12.13	12.23	4.49	4.27
	12	113	21.82	1.93	114.35	0.142	86.96	12.08	12.17	4.47	4.10
	19	120	20.63	2.03	114.65	0.142	85.89	12.03	12.11	4.44	3.88
	26	127	19.14	2.19	114.65	0.142	84.06	11.89	11.96	4.38	3.60
February	2	134	17.37	2.40	112.89	0.144	79.91	11.42	11.48	4.20	3.19
	9	141	15.36	2.71	112.89	0.144	76.46	11.04	11.09	4.05	2.79
	16	148	13.12	3.16	112.89	0.144	71.65	10.45	10.49	3.83	2.34
	23	155	10.69	3.86	112.89	0.144	64.72	9.53	9.55	3.48	1.85
March	2	162	8.10	5.08	110.25	0.142	53.56	7.95	7.96	2.90	1.29
	9	169	5.40	7.62	110.25	0.142	37.39	5.58	5.58	2.03	0.73
	16	176	2.62	15.69	110.25	0.142	11.88	1.78	1.78	0.65	0.17
	21	182	0.20	203.48	110.25	0.142	0.00	0.00	0.00	0.00	0.00
AVERAGE W/sq.ft							65.10	9.25	9.30	3.40	2.60
ENERGY, kWh/year/sq.ft							284.35	40.41	40.62	14.87	11.37

Notice that the 1-axis vertical tracking panel performs slightly better than the 2-axis tracking panel. This is primarily because the vertical panel receives a greater portion of the reflected radiation than any inclined panel. The fixed vertical panel performs better than the fixed horizontal panel even though it is lighted for only 12 out of 24 hours. Again this is due to the contribution from the reflected radiation. The average power output during the austral summer and the total energy output in kWh/year are calculated and shown in the bottom of Table 1 for each of the four types of panels. As no cloud cover has been assumed in the calculations, the energy shown in Table 1 is the absolute maximum that can be expected from each type of panel.

IMPACT OF CLOUD COVER

In order to estimate the energy available from a PV panel over a given period of time, it is necessary to include the meteorological information in the equations derived in the previous section of this paper. Let us define the following quantities:

I_N(Avg) = Monthly average solar radiation incident on a normal surface with no cloud cover, W/sq.ft

I_R(Avg) = Monthly average radiation reflected from the snow surface to the PV panel, W/sq.ft

I_F(Avg) = Monthly average diffused radiation upon the PV panel, W/sq.ft

The reflected and the diffused radiation, I_R and I_F, can be assumed to be directly proportional to the direct radiation, I_N. Typical values are 40% and 10% respectively.

Let I_N'(Avg), I_R'(Avg) and I_F'(Avg) be the same as the above quantities but with cloud cover. Again I_R' and I_F' can be assumed to be directly proportional to I_N'. An equation for calculating I_N'(Avg) is as follows:

$$I_N'(AVG) = I_N(AVG) * \frac{N_1 + 0.5*N_2}{N}$$

where

N_1 = number of clear days in the month

N_2 = number of cloudy days in the month

N = total number of days in the month.

Table 2 shows the calculation of I_N'(Avg), I_R'(Avg) and I_F'(Avg) for the 1991- 92 austral summer. Information about the number of clear, cloudy and partly cloudy days is taken from four issues of the Antarctic Journal of The United States(December 1991, March 1992, June 1992 and Sept. 1992).

To compute the total energy available from each of the four types of PV panels, We can now use the values of I_N'(Avg), I_R'(Avg) and I_F'(Avg) in Equations (4) thru (7) in place of I_N, I_R and I_F. This computation is summarized in Table 3.

TABLE 2

DIRECT, REFLECTED AND DIFFUSED
RADIATION AT THESOUTH POLE WITH CLOUD COVER

Month	Total No. of Days	No. of Clear Days	No. of Partly Cloudy Days	No. of Cloudy Days	IN W/sq.ft	IN' W/sq.ft	IR' W/sq.ft	IF' W/sq.ft
Sept.	9	2	2	5	6.36	2.12	0.85	0.64
Oct.	31	13	10	8	56.86	33.02	13.21	5.69
Nov.	30	12	14	4	81.39	51.55	20.62	8.14
Dec.	31	11	12	8	88.42	48.49	19.40	8.84
Jan.	31	8	12	11	85.89	38.79	15.52	8.59
Feb.	28	15	3	11	71.96	42.40	16.96	7.20
Mar.	21	10	5	6	27.4	16.31	6.52	2.74

NOTES:

1. METEOROLOGICAL INFORMATION PERTAINS TO 1991-92 AUSTRAL SUMMER (Reference:Antarctic Journal of the United States Dec. 1991, March 1992, June 1992 and Sept. 1992)
2. IN = SOLAR INSOLATION AT THE POLE WITH NO CLOUD COVER, MONTHLY AVERAGE W/sq.ft
3. IN' = MONTHLY AVERAGE DIRECT INSOLATION WITH CLOUD COVER, W/sq.ft
   = IN * [(No. of clear days) + 0.5 * (No. of partly clear days)]/(Total no. of days)
4. IR' = MONTHLY AVERAGE REFLECTED RADIATION, W/sq.ft
   = 0.4 * IN' approximately
5. IF' = MONTHLY AVERAGE DIFFUSED RADIATION, W/sq.ft
   = 0.1 * IN approximately

POWER AND ENERGY OUTPUT OF PV PANELS

Table 3 summarizes the numerical findings of this paper. P_M is the maximum power output one can expect from the PV panel with an efficiency of 10%. (As the efficiency enters linearly in the equations all the numbers in Table 3 can be modified if the efficiency is known exactly.) This number can be used to find the number of panels for a given rating of the PV installation. The maximum output is at the peak of the austral summer. Notice that the 1-axis vertical tracking panel produces the highest output. If a tracking mechanism can be designed to work satisfactorily in the -40° F ambient then the 1-axis tracking panel is the preferred type of panel. E is the total energy output of the PV panel during the austral summer. This number is used to determine number of gallons of fuel which will be saved by utilizing the PV panels.

TABLE 3
POWER AND ENERGY OUTPUT OF PV PANELS AT THE SOUTH POLE

Calculated Quantity	2-Axis tracking panel	1-Axis tracking panel	Fixed vertical panel	Fixed horizontal panel
P_M, W/sq.ft	12.19	12.29	12.29	4.42
P, W/sq.ft	12.19	12.29	4.52	4.42
E_M kWh/year/sq.ft	40.41	40.62	14.87	11.37
E kWh/year/sq.ft	23.29	23.41	8.56	6.55

In Table 3:

P_M = the maximum power output on a clear day

P = the daily average power output at the peak of the austral summer (December 22) on a clear day

E_M = the total energy output during the 182 days of the austral summer assuming clear skies

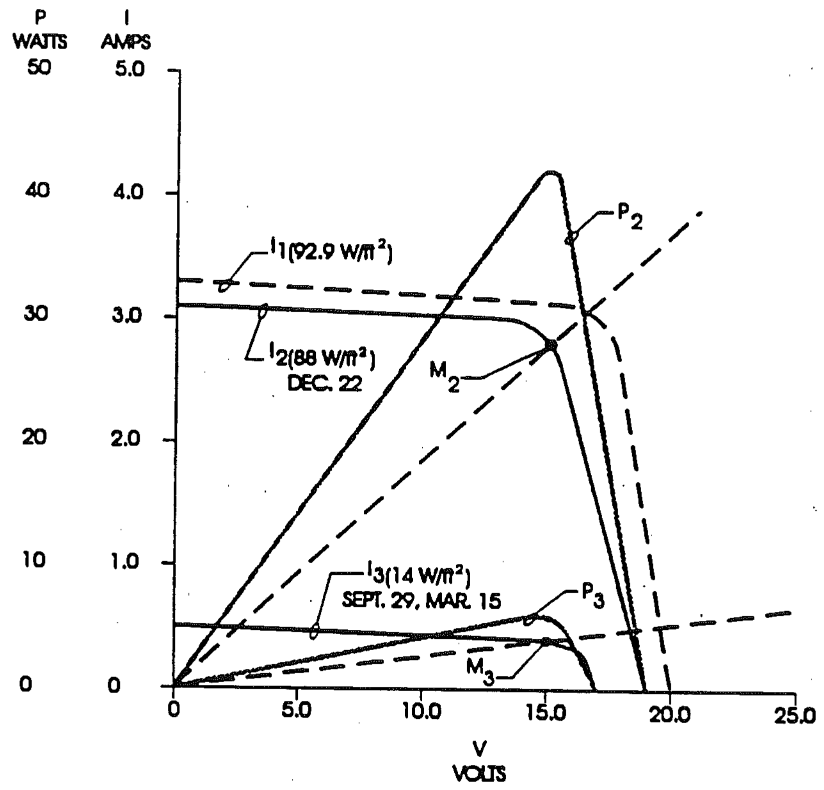
E = Energy output during the 182 days of the austral summer with cloud cover(based upon meteorological data for 1991-92 summer).

CHARACTERISTICS OF PV MODULES AND DC/AC CONVERTERS

A word about the performance characteristics of the PV modules and the dc/ac converters for interface with the existing power system is in order here. Fig. 5 shows the I-V characteristic of a typical PV module(Siemens M75 module). Curve I_1 is the current-voltage characteristic for a solar insolation of 92.9 W/sq.ft(1000 W/sq.m). Curves I_2 and I_3 are for the expected solar insolation on

December 22 and September 29 (and March 16) at the south pole. These numbers represent the peak of the austral summer and the beginning(and end) of the daylight period, approximately. Curves P_2 and P_3 are the plots of the power output of the module corresponding to the curves I_2 and I_3. Points M_2 and M_3 are the points at which the power outputs and the efficiencies are maximum. These are the points at which the module is to be operated. In order to operate the module at the point of maximum power output and efficiency for various values of solar insolation, the apparent load resistance must be adjusted between the limits given by the reciprocals of the slopes of the lines OM_2 and OM_3 in Fig. 5. This must be done by the controller connected between the output of the PV module and the load.

The PV module or series /parallel combinations of several panels can feed into a dc system or an ac system. In the case of the dc system the controller will be a series connected transistor regulator. In the case of the ac system the controller must be a pulse-width-modulated(PWM) transistor or GTO invertor. In both cases the control signal must be the product of the current and voltage of the PV module and the controlled variable must be the current output of the module. Technology is available to design and build controllers to meet the above requirements.



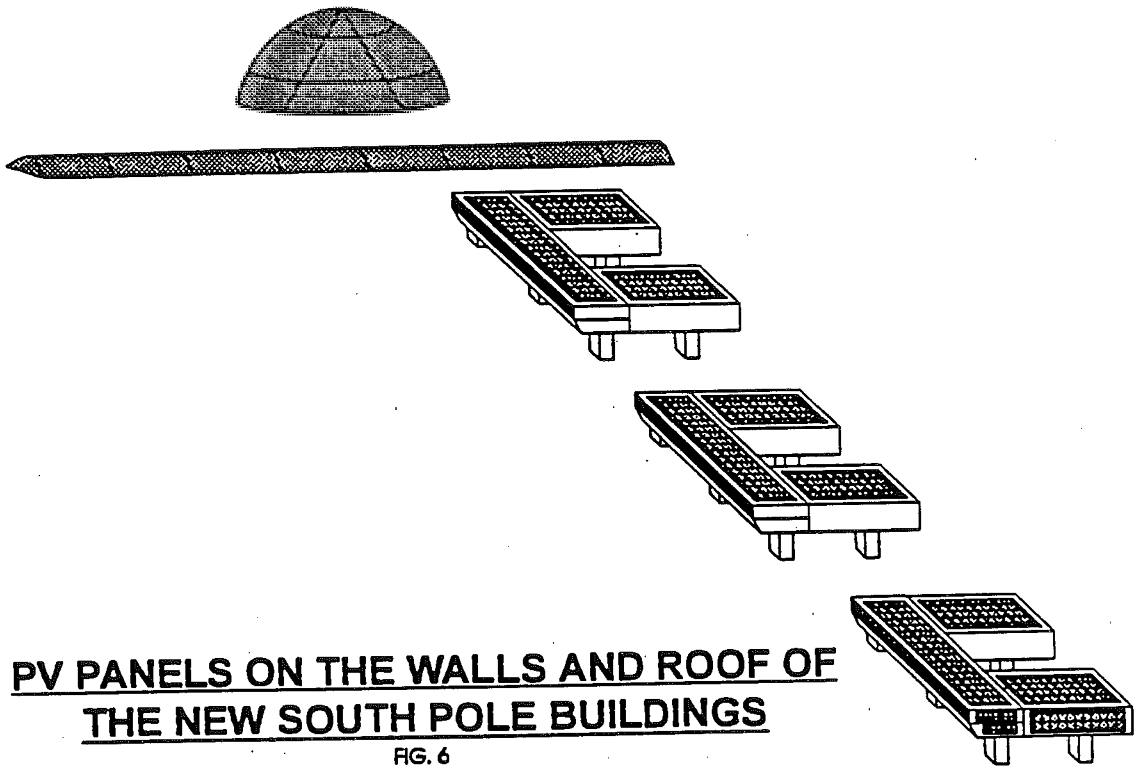
CHARACTERISTICS OF PV MODULES

(SIEMENS M75)

FIG. 5

CONCEPTUAL DESIGN OF A 150-kW PV INSTALLATION AT THE SOUTH POLE

This section presents only a conceptual design of a 150-kW PV panel installation suitable for the south pole. This design was made only to obtain the order-of magnitude numbers on the size and cost of the equipment. Fig. 6 shows the conceptual layout of the new South Pole Station which is being designed now. Three new C-shaped double-storied structures are proposed to be constructed near the existing dome. As the structures will either have no windows or porthole type windows, large areas are available on the walls and roofs for the installation of fixed PV panels. A total of 26,000 sq.ft of the roof area can be used to install horizontal panels and approximately 8800 sq.ft of wall area can be used for the vertical panel. At the present time outdoor fixed or tracking panels are not included in the conceptual design.



PV PANELS ON THE WALLS AND ROOF OF THE NEW SOUTH POLE BUILDINGS

FIG. 6

The spread sheet of Table 4 shows the conceptual design. Notice that a maximum power of 223 kW can be obtained from the fixed roof and wall-mounted PV panels. This is available only at the peak of the austral summer on a clear day. This number is used only to size the dc/ac converter and other parts of the electrical system. A total of 8031 48x13 in PV panels are required weighing more than 96,000 lb. The total cost of the panels including transportation is approximately $3 million. The cost per kW of peak power calculates to $13.

The total electrical energy generated during the 182 days of sunshine is calculated by using the numbers of Table 3. This energy is equivalent to about 14,000 gallons of JP8 fuel. Assuming that the cost of fuel is approximately $12/gallon at the south pole, there will be an annual saving of $168,000. However, a capital investment of about $3 million is required to realize this annual saving. The last item in Table 5 is not very encouraging. This item shows that the rating of an equivalent diesel generator which can produce the same energy when run continuously is 28 kW.

The next step in the decision process with regard to the PV panel installation at the south pole is to extend the concept design into an economic analysis. The analysis should include the expected life of the panels, costs of maintenance, interest and depreciation costs, etc. This is outside the scope of this paper.

CONCLUSIONS

The findings of this paper can be itemized as follows:

1. Solar energy is available only during 182 days at the south pole.

2. During these 182 days the inclination of the sun above the horizon varies continuously between 0 degrees on September 22 and March 22, and 23.4 degrees on December 22.

3. Solar insolation in W/sq.ft on a normal surface varies with the inclination of the sun and has a maximum value of 88 W/sq.ft (947 W/sq.m).

4. The four possible type of PV panels which can be used are the 2-axis tracking panels, the vertical 1-axis tracking panels, fixed vertical panel and the fixed horizontal panels. Of these four, the vertical 1-axis tracking performs the best because of the solar radiation reflected from the snow surface. Equations for the power output for each of above four types are developed in this paper. It is also shown how the meteorological information can be factored into the equations for calculating the expected energy output of the PV panels.

5. It is shown in Table 3 of this paper that the average power output of the vertical 1-axis tracking panel is about 12 W/sq.ft while that of the fixed vertical and fixed horizontal panels is approximately 4.5 W/sq.ft.

6. A conceptual design of a nominal 150-kW PV panel installation using only fixed panels on the roofs and walls of the proposed new structures is presented in this paper. The design shows that the installation has the potential for saving about 14,000 gallons of JP8 fuel per year. The cost of the PV panels is approximately $3 million.

TABLE 4

PRELIMINARY DESIGN OF A 150-kW FIXED PANEL PV INSTALLATION FOR THE SOUTH POLE

ITEM NO.	DESCRIPTION	VERTICAL PV PANELS	HORIZONTAL PV PANELS	TOTALS
1.	Location	Walls of buildings	Roofs	
2.	Available Area, sq.ft	8800.0	26000.0	34800.0
3.	Max Power Output (Clear Sky on Dec.22)	108.2	114.9	223.1
4.	Daily Average Power Output, kW (Clear Sky on Dec.22)	39.8	114.9	154.7
5.	Number of Panels (Siemens M75,48"x13")	2031.0	6000.0	8031.0
6.	Weight of Panels, lb (@12 lb/panel)	24372.0	72000.0	96372.0
7.	Cost of Panels (@$350/panel in US) $ Thousands	710.9	2100.0	2810.9
8.	Cost of Transportation from US to South Pole @$1.5/lb, $ Thousands	36.6	108.0	144.6
9.	Total Cost of Panels (7 + 8), $ Thousands	747.4	2208.0	2955.4
10.	Total Energy Output MWh/year	75.3	170.3	245.6
11.	Potential Saving in JP8 Fuel, Gal/year	4280.0	9676.1	13956.1
12.	Equivalent Diesel Generator Run continuously for One Year, kW	8.6	19.4	28.0

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2. Robert H. Wills, "Using Solar Energy at the South Pole: Photovoltaic Electricity and Solar Heating", A report submitted to US Army CRREL and DPP of the National Science Foundation, December 1988.

SIXTH SYMPOSIUM ANTARCTIC LOGISTICS AND OPERATIONS

ROME, ITALY AUGUST 1994

SELECTION OF STATION LEADERS AUSTRALIAN NATIONAL ANTARCTIC RESEARCH EXPEDITIONS (ANARE)

Richard Mulligan
Australian Antarctic Division
Kingston, Tasmania

INTRODUCTION AND SETTING

The Australian Antarctic Division is a unit of an Australian Government Department, known as the Department of the Environment, Sport and Territories. In this context it is part of the machinery of Government and is responsible, through the Departmental Secretary, to a Minister of the Australian Government.

Australia maintains four permanent stations, Casey, Davis and Mawson in Antarctica and sub-Antarctic Macquarie Island. A number of summer field bases is also maintained and occupied over summer as program requirements determine. The size of wintering groups at stations varies between 15 and 30, but these numbers can increase to in excess of 80 over the busier summer months.

In meeting the Government's requirement to maintain and operate four permanent winter stations and a number of summer field bases, the Antarctic Division is responsible for recruiting and employing its own scientists and support personnel, and a person to manage and head each group.

A typical ANARE wintering group consists of:-

- Station Leader
- Medical Officer
- A number of scientists, depending on program requirements
- Chef
- Radio Technical Officers/Radio Operators
- Mechanics
- Plumber
- Carpenter
- Electrician

The Antarctic Division is required to conduct its operations in accordance with government policies and regulations as it applies to the Australian Public Service. Within this framework the Antarctic Division must in all its dealings, (including the running of ANARE) administer and uphold all such policies, covering:-

- Equal Employment Opportunity
- Merit Selection
- Access and Equity
- Harassment in the Workplace
- Sexual Discrimination
- Racial Discrimination
- Personal Privacy
- Environmental Management
- Freedom of Information
- Occupational Health and Safety
- Industrial Democracy
- Grievance Processes
- Non smoking work environment

In conducting the selection process for people to be employed as Station Leaders, the Antarctic Division is therefore required to give full recognition to government program requirements and all administrative law processes. The selection criteria for Station Leader positions reflect these requirements, and applicants are assessed against them.

THE EVOLVING RECRUITMENT PROCESS FOR ANARE STATION LEADERS

From its early history, the Antarctic Division has undertaken the recruitment of Expedition personnel to serve with ANARE. The founding Director of the Division personally participated in the selection of all expeditioners, including the Station Leader. Gradually, as the size and scope of the Antarctic Division program increased, the selection process changed, with selection committees formed to select scientists and the other support personnel, with the Director continuing to select Station Leaders.

In recruiting people to work in Antarctica the Division was aware that it needed to select people who could cope with the harshness of the environment and who could live and work in small groups which were totally isolated for most of their time away. To assist in the selection screening of expedition personnel for service in Antarctica the Antarctic Division sought the assistance of the Department of Defence, Australian Army Psychology Corps.

The Army Psychology Corps has supported the Antarctic Division through the provision of professional psychological screening services for over 30 years. All recommended candidates, following interview, are screened by the Army Psychology Corps to determine suitability for Antarctic service. The screening involves a combination of psychometric tests and an interview to make a prediction of likely Antarctic adjustment and this is called the adaptability assessment.

The current Antarctic Division policy is for all recommended candidates to be screened by the Army Psychology Corps if they are to be away from Australia for more than 12 weeks.

As the number of permanently occupied ANARE stations increased from one to four and summer field bases were established, there was a need to recruit and employ more expedition personnel. The recruitment program for ANARE service took on a larger dimension and to support this expanded task it became necessary to increase the number of selection committees to examine the claims of applicants across the range of professional and trades vacancies.

Up to 1984 the selection of Station Leaders followed a similar process to that of all other positions offered by ANARE. That process involved the advertising of all expedition positions in the Australian Public Service and in the leading daily newspapers throughout the country. Selection committees were established on a discipline basis, that is, science categories, medical, trades categories and station leaders, to assess all applicants claims, conduct interviews with applicants assessed as best matching job requirements, and recommend employment of the applicants with best credentials.

The process for selecting Station Leaders involved the establishment of a selection committee of three divisional members, made up of a senior administrator, an operational expert and a medical officer. The committee assessed all applications received against the job requirements and short-listed the best 15 to 20 applicants for interview. Applicants were interviewed for about one and a half hours, following which the committee would recommend appointment of the four applicants it considered best matched the job requirements. If a sufficient number of applicants were assessed as suitable, two further applicants would be nominated as reserves, in case of drop out, or failure to meet psychological or medical assessment.

In 1984 the Division undertook a review of the process for the selection of Station Leaders. It was considered that there could be significant advantage in having a more interactive process between candidates and the Selection Committee, which could provide the Committee with more time to observe candidates in a range of group and personal activities, in an environment having close relevance to the job of a Station Leader.

For this purpose the Division requested the Army Psychology Corps to consider other options for the selection of Station Leaders. That examination resulted in a proposal to consider the use of an assessment centre based selection process. The process would involve a selected number of short-listed Station Leader candidates being invited to participate in a final selection stage over 5 days in a live-in situation.

The proposal to establish an Assessment Centre was based on the concept of creating an environment in which many of the requirements of the selection criteria for Station Leader, which are not obvious, could be observed and rated. All of the activities to be conducted at the Assessment Centre would be specifically designed for the purpose of providing the Selection Committee with the means of assessing individual candidates against the selection criteria.

As part of the proposal to change to an Assessment Centre, a recommendation was made to alter the composition of the Selection Committee and to provide professional support from the Army Psychology Corps and a Facilitator to conduct the operation of the program. At the same time it was also decided to develop and implement a reporting system to assess the performance of Station Leader's during their period of employment based on the selection criteria requirements. This assessment is completed at the end of the expedition and against which actual performance is assessed.

The Division decided to adopt the Assessment Centre process for selection of Station Leaders and has operated this system since 1985. The Assessment Centre process has been progressively developed over many years and was, in 1991, the subject of a technical review by the Army Psychology Corps in which it was concluded, in part, that:

- the Assessment Centre process is a most reliable and valid means of identifying managerial and leadership potential.
- the Assessment Centre is an appropriate method of selecting Antarctic Station Leaders with greater accuracy than other alternative processes.

SELECTION CRITERIA COMMON TO ALL ANARE POSITIONS

The process of selecting expeditioners for service with ANARE includes the development of a Duty Statement, Job Description, and selection criteria which includes special personal qualities for working in Antarctica, for each category of position being sought. It is against these requirements that selection committees assess each applicant's claims for selection. In addition to these specific position requirements, the Antarctic Division, over the years, has developed other selection criteria common to all positions which are mandatory for selection. These criteria are that:

Expeditioners must:

1 be accepted as suitable for Antarctic service after assessments conducted by the Australian Army Psychology Corps

2 be certified as fit for Antarctic service by the Antarctic Division's Polar Medicine Branch after tests conducted by or on behalf of a Commonwealth Medical Officer

3 be deemed to be a fit and proper person for employment in the Australian Public Service.

Special Personal Qualities for Working in Antarctica

In selecting expeditioners, special consideration is given to the personal qualities and the ability of individuals to work and live together harmoniously, remote from their families and friends. While Australia's Antarctic stations offer many of the comforts of home, Antarctica is a remote continent with a harsh environment. Individual privacy is mainly confined to sleeping accommodation, and even this may be shared during summer when there are increased numbers of people on stations. Outdoor work and recreation can be limited by winter darkness or bad weather, and expeditioners may be confined indoors for days at a time. A team approach to work and recreation is encouraged but expeditioners must still be capable of self-motivation and self-reliance.

Successfully working and living in Antarctica requires, in individuals, a blend of high level occupational skills and the special personal qualities listed below:

- a natural approach to treating others with consistent fairness, consideration, respect, sensitivity and tolerance, without patronage, favouritism or regard to sex, race, nationality or other factors
- an ability to cope with personal isolation and maintain sound personal relationships from a distance
- self reliance and the flexibility and resilience to make social and emotional adjustments
- self motivation, discipline and the ability to perform all required duties efficiently under personal and general pressure
- willingness to participate in communal duties and associated activities
- acceptance of new or changing circumstances
- support and encouragement to persons in authority and acceptance and support of the system of government and law
- respect for the environment and a commitment to protecting the Antarctic environment and conducting or supporting Australia's Antarctic research programs

Personal qualities assessment may be based on information obtained from applications, interviews, referee reports, past performance reports and previous employment.

THE DUTY STATEMENT JOB DESCRIPTION AND SELECTION CRITERIA FOR STATION LEADER

The Duty Statement, Job Description and Selection Criteria for the position of ANARE Station Leader have been developed over the years using the combined resources of successful ex Station Leaders, Divisional staff, the Army Psychology Corps and a consultant.

One the most important functions of a Station Leader is that they are able to manage a multi-disciplinary team of expeditioners with very diverse interests and backgrounds and quite often competing demands for project completion. Each expeditioner has different deadlines and personal priorities for their projects and some may conflict with one another. The Leader works in the midst of a harsh dangerous environment and is responsible for the well being and safety of each expeditioner.

The ability to resolve personal issues and conflict amongst individuals and to maintain the group as a harmonious unit over a long and stressful time is considered critical. A commitment to caring for the environment and the occupational health and safety of the expedition as well as the rights of individuals and groups in matters of discrimination or harassment is also a critical consideration in selecting a Station Leader.

Each year a Selection Committee comprising two members from the Expedition Operations Branch, with prior experience of station management, and an independent Personnel representative, is convened, to select Station Leaders. The committee includes male and female representation and is expanded by one to include an Aboriginal or Torres Strait Islander should a representative from either of these groups apply. Part of this committee's role is to review the selection documentation to ensure it meets current requirements or is amended or changed as necessary.

The current, Duty Statement Job Outline and Selection Criteria for an ANARE Station Leader is given in attachment A to this paper.

THE ADVERTISING SHORTLISTING AND PRELIMINARY INTERVIEW PROCESS

Advertising for Station Leader positions is done in conjunction with other professional positions in October each year.

Intending applicants are informed at the time of that advertisement that the Station Leader selection process is conducted in two phases-

- the first phase, known as the preliminary interview, occurs after the completion of the initial short-listing process.
- the second phase known as the assessment centre process, which occurs following successful completion of the preliminary interview.

Applicants who respond to the advertisement are then provided with:

- a copy of the general conditions of selection for all ANARE positions;
- a copy of the Duty Statement, Job Description and Selection Criteria for Station Leader positions;
- a standard Application Form and Insert

Applicants are required to provide:

- a completed Application Form;
- a completed Application Form Insert; which is an outline of the candidates experience and skills relative to the selection criteria;
- two written referee reports completed against the requirements of the selection criteria;
- a completed medical history record;
- a completed authority to obtain personal information from a Police Records check.

Up to two hundred applications for the position of Station Leader are received each year.

The Selection Committee considers each applicant's claim against the requirements of the selection criteria. The 35 assessed as best matching these requirements advancing to the next stage in the process, the preliminary interview.

The selection process is fully documented at each stage as any applicant is entitled to seek a review of the process, or if dissatisfied, lodge a grievance and request an independent review of the process.

At the conclusion of the preliminary interview the Selection Committee recommends that the 16 applicants who best match the requirements of all the selection criteria are invited to participate in phase 2 of the selection process, the Assessment Centre.

THE ASSESSMENT CENTRE

In the process for selecting ANARE Station Leaders, a number of safeguards have been built in to help the selection committee minimise the risk of inappropriate selection, including:

- filtering on the basis of written application;
- interviews;
- written referee reports;
- medical and psychological assessment
- the Assessment Centre, and
- oral referee reports if required.

Using these various mechanisms the Division seeks to employ four people, from those who apply each year, who it considers are most likely to competently fulfil the role and responsibilities of Station Leader.

Of the final 16 short-listed candidates it is not unusual for one or two not to meet the requirements of all assessments or another one to drop out for personal reasons, leaving about fourteen candidates to participate over the five days in the final assessment.

The aim of the Assessment Centre is to produce situations resembling those which successful candidates may have to face in their job as Station Leader. In dealing with these situations each candidate is providing the Selection Committee with information to help make comparisons with other candidates. The Assessment Centre is designed to produce a range of demanding tasks for the candidates and thus provide the Selection Committee with as wide as possible a view of the various candidates skills and abilities.

The conduct of the Assessment Centre is undertaken by a Facilitator who is responsible for its overall operation, including directing the candidates as necessary, liaising with other staff and the Selection Committee and ensuring the requirements of the program are met. The facilitator is not a member of the Selection Committee.

A representative of the Army Psychology Corps is present at the Assessment Centre, to conduct some of the activities, to provide information on the psychological suitability of candidates and generally assist the Selection Committee in its deliberations. The Army Psychologist is not a member of the Selection Committee.

During the Assessment Centre candidates are taken to a remote field locality to undertake a range of field survival and other physical tasks. These tasks are arranged, conducted and supervised by a Field Leader, who is not a member of the Selection Committee. The Field Leader is a person familiar with all aspects of the Assessment Centre and is required to provide the Selection Committee with specific feedback on each candidate, upon completion of this aspect of the process.

The chairperson of the Selection Committee is responsible for ensuring that the selection process is conducted within Australian Public Service requirements, conducting committee meetings, processing information about candidates received from other contributors to the process, and for completion of the final committee reports.

The venue for the activity is an ANARE training camp in the central highlands of Tasmania. Candidates are required to make significant personal contributions in making the support requirements for the activity work in cooperation with other candidates. This requirement is considered to be not unlike life on an Antarctic station.

In preparing activities to be undertaken during the Assessment Centre, care is taken to avoid giving undue advantage to candidates with previous Antarctic experience. However many of the tasks or exercises derive their origin from incidents which actually have occurred at ANARE stations over the years.

All activities are prepared with the selection criteria as the guide. Each exercise is developed for its relevance to one or more of the selection criterion, and these are identified to enable the Selection Committee to gather information on candidates which is specific to those requirements. For example in observing candidates performance when participating in an Environmental Management exercise the committee is able to focus its attention on the requirements of that criterion.

The type of activities included in the Assessment Centre are:-

- Introduction Dinner
  - candidates first assemble and meet with senior Divisional management and each provides a short outline of their working background and experience; the Director of the Division provides an outline of-
    * the Australian Antarctic research program
    * the role and organisation of the Division
    * the expectations required of Station Leader's in ANARE.

- Individual Presentations
  - candidates are required to speak on selected and chosen topics, and another candidate is selected at random to provide a critique of the presentation.

- Individual Written Exercises
  - candidates are required to undertake a number written exercises which may be in the nature of problem solving or to ascertain level of knowledge on specific topics.

- Group Design Exercise
  - candidates are split into two groups and required to develop an exercise based on one of the selection criterion, which will help the Selection Committee observe the differences among the candidates in the other group.

- Small and Large Group Discussions
  - a number of sessions are conducted during the program,in which a range of issues is discussed; other sessions are also conducted with the group by the Facilitator to focus on any specific concerns of the selection committee.

- Various Problem Solving Activities which Include:-
  - personnel and administrative management
  - interpersonal relationships
  - harassment, including sexual harassment

- Conflict Resolution Exercises
  - a number of exercises, some written and some in group discussion are included in the program; exercises are linked to actual case experienced in ANARE, but in such a way as not to advantage candidates with prior service.

- In Basket Exercise
  - a written exercise based on a remote mining operation in which the candidate is placed in the situation of leadership, and confronted with a series of problems which change over the period of the exercise, requiring problem solving and prioritising judgements to be exercised.

- Equal Employment Opportunity Issues
  - topics are selected for discussion to enable candidates to display their knowledge and understanding of the legal and social implications of these issues and to and gage their level of commitment to deal with problems should they arise in this area.

- Written Search and Rescue Problem
  - a written exercise based on a search and rescue situation in which the candidate is placed in the situation of leadership, and required to plan and execute a search and rescue operation.

- Candidate Assessment of other Candidates
  - at the commencement of the program candidates are advised they will be required to make an assessment of at least one other candidate, against the requirements of selected aspects of the selection criteria, based on their observation of that candidate's performance during the program; the assessment is undertaken on the fourth day of the program and is conducted with the selection committee observing the process.

- Counselling and Feedback and Group Discussion
  - at the commencement of the program candidates are advised they will be required to provide feedback and counselling to at least one other candidate, based on their observation of that candidate's performance during the program; each candidate is required to discuss with the group who they counselled and what was discussed, and the person counselled responds on their view of the counselling.

- Behavioural Assessment Activities
  - the nature of the program is such that it provides numerous opportunities to observe candidates displaying a range of working and social behaviour and the manner in which they relate with others.

- Environmental Management Exercise
  - a written exercise and group discussion in which candidates are required to provide information on their knowledge of environmental management policies, practices and procedures, and their level of commitment to supporting these requirements.

- Science Exercise
  - a written exercise and group discussion on ANARE's scientific research program, in which candidates are required to provide information on their knowledge of the program, and their level of commitment to supporting the program.

- Peer Assessment
  - candidates are required on a number of occasions to rank all the other candidates against two criteria, Friendship and Leadership; this requires each candidate to rank other candidates on their basis of who they would most likely become friendly with, and who they consider would be most effective as a Station Leader.

- Outdoor activities involving:-
  - physical endurance
  - practical field activities
  - simulated rescue problems

- Candidate Interviews with Selection Committee
  - a short interview is conducted with Selection Committee at the mid point of the program to enable the committee to discuss any issues of concern and to provide the candidate with the opportunity for feedback.

- Role Plays
  - as a means to observe the differences in candidates, selected role plays may be used in which a candidate is allocated a leadership role. The role plays are derived from various examples collected over the years from situations experienced by former Station Leaders.

- Affirmation Exercise
  - as the final activity in the program candidates are asked to specify the particular strength(s) which make them the most suitable for a position of Station Leader.

- De-Rolling
  - After the weeks stressful activities the final session in the program is conducted by the Facilitator and the Army Psychologist and is an activity to review each candidate's experience of the week. It seeks to aid the transition of the candidates back into day to day work and families and to acknowledge the candidates who have shared the experience with them. In conclusion candidates are asked to provide feedback of their experience of the process and any suggestions for improvement and change.

Throughout the five days of the Assessment Centre there is close and continuous interaction between the Selection Committee and the candidates. Candidates are observed in many different stressed and non stressed situations, enabling the Selection Committee to gather a large amount of information on which to make an assessment.

At the conclusion of the program a final assessment is made by the Selection Committee of each candidate against the requirement of each selection criterion according to the following scale:

Above Requirements

Able to perform at a level exceeding the normal requirements of this criterion

Slightly Above Requirements

Would consistently perform well against this criterion

Meets Requirements

Generally effective and would meet minimum requirements of this criterion

Almost Meets Requirements

Satisfactory on some aspects of this criterion but limited in others

Does Not Meet Requirements

To be assessed as suitable for a position of Station Leader a candidate must meet the requirements of all selection criteria. Suitable candidates are then ranked in order of suitability depending on their overall rating. The top four candidates are recommended for appointment, and, if available, two others are nominated as reserves. The Selection Committee also recommends station allocations based on its assessment of the candidates suitability to manage the varying range of programs to be undertaken during the expedition.

THE SELECTION LINKAGE WITH THE STATION LEADER ASSESSMENT SYSTEM

The Antarctic Division has implemented a performance assessment system for Station Leaders, which is designed to be:

- just, fair and equitable,
- consistent with existing Australian Public Service personnel practices without replacing or contradicting them,
- reflect the realities of community living on an Antarctic station, and

- reflect the best principles from both public and private sector current personnel practice.

The objective is to assist the Division in evaluating the competence, skills and performance of each Station Leader.

The Process

The main aspect of the Station Leader assessment process is a half day Assessment Interview conducted upon return of the Station Leader to Australia.

The discussion and structure of the assessment interview draws on information collected over the time of a Station Leader's employment from a number of sources, as follows:

- the Station Leader Personal-Assessment Scale,
- the Expedition Development and Assessment Scheme (EDAS) reports done on the Station Leader by the Operations Manager before embarkation and by the Deputy Station Leader whilst on station,
- the monthly Status Reports from the station,
- the Station Review meetings held at Kingston, and
- observations and other data collected by the Operations Manager at Kingston and whilst on station.

The output of the Assessment Interview is an Assessment Report to the Director of the Antarctic Division on the performance of the Station Leader and a recommendation as to their suitability for future employment with ANARE.

Areas of Inquiry for Assessment

The four primary areas of inquiry are similar to those for all expeditioners as part of EDAS, VIZ:

- specific role performance of the Station Leader,
- performance as an individual,
- performance as a member of a close-knit, isolated community, and
- on a range of items unique to the ANARE work and living environment.

ROLE PERFORMANCE

Selection Criteria Items

Lead the Community

- adapt to and foster standards set out in the *ANARE Code of Personal Behaviour*.
- develop and maintain a productive and harmonious community, including resolving conflict and maintaining discipline.
- use of open, two-way communication and involve others in decisions and problem solving.
- counsel, assess and prepare written reports on expeditioners.
- knowledge of and commitment to Equal Employment Opportunity principles, and willingness and ability to address harassment issues.

Manage to Achieve Results

- manage approved scientific, operational and administrative programs effectively.
- ensure that field, industrial and domestic operations are conducted safely, and to direct search and rescue activities.
- manage Antarctic environmental protection policies effectively and implement procedures.

Demonstrate Personal Effectiveness

- display interpersonal sensitivity, and value the differences in people.
- value efficiently under both personal and general pressure and changing circumstances.
- cope with personal isolation.
- be open to and act on personal feedback.
- awareness of and support for Antarctic research programs.
- high level of personal confidence.
- well developed written communication skills.
- well developed problem solving skills.

Expeditioner Development and Assessment *Items (EDAS)*

Individual Trait

- temperament.

Community Member Traits

- style of influence with others.
- community participation.

Achievements

- stock-taking and re-ordering.
- response to authority.
- supervision style.

ANARE Items

- care and maintenance of property.
- participation in common duties.
- field presence.
- effect of behaviour when consuming alcohol.

Station Leader Selection Criteria

The Station Leader selection criteria form a major component of the final assessment for Station Leaders and are the basis of the on-going Station Leader Personal Assessment process (the Personal Assessment process is undertaken by the Station Leader and his/her Deputy Station Leader three times during their time at the station). They represent factors which the Antarctic Division considers essential for persons to successfully undertake the role of Station Leader, and are the criteria against which Station Leaders are originally selected.

Performance is examined against each selection criterion and the Expeditioner Development and Assessment items (EDAS) to assess the manner in which the Station Leader undertook the job and how effective s/he was in the position. The criteria and expectations against each is given at Attachment B.

CONCLUSION

The Assessment Centre is a costly process involving many resources. However it has proven to be a reliable and effective means of selecting leaders for service with ANARE, and is well regarded. The suitability of the Assessment Centre process for selecting leaders was reaffirmed following a review and a literature search of the process conducted by the Australian Army Psychology Corps in 1991.

This is not to suggest that this process is foolproof and our experience has shown that not all leaders selected have been successful with several being assessed at the completion of their service as not suitable for further employment. However by comparison with the previous method of selection it is our view that the Assessment Centre process is the more reliable means of selection.

The Assessment Centre process is the subject of constant analysis and review. At the completion of each program the Selection Committee and staff review the process to consider its effectiveness and where required change or amend the program for the following year.

In reviewing the program the Selection Committee seeks input from the candidates at the conclusion of the five day program and from the successful Station Leaders during their time on station. Over the years the program has been amended or changed in a number of ways both in content and duration.

The linkages with the selection process and the actual performance assessment of Station Leader's provides for continuous assessment against the requirements of the selection criteria, so that at all times those factors considered to be important for a leader in ANARE are being observed.

ATTACHMENT A

DUTY STATEMENT

Department of the Environment, Sport and Territories
Antarctic Division

CLASSIFICATION	Administrative Service Officer Class 6	**Seq:**
Local Designation	Station Leader	**Org Chart: A:6**
Restrictions	Section 50	**Sheet: 8 of: 8**
BRANCH	Expedition Operations	
SECTION	Land Operations	
SUB-SECTION	Expeditioner Pool	
Central Office	YES	

LINES OF REPORTING
Number of direct subordinates: varies Highest Sub: AMP Level 1 **PN:** varies
Responsible directly to: Relevant Station Manager (SOG C) **PN** 459, 465

DUTIES

1 Control all aspects of the expedition's activities, both at the station and in the field. Ensure that established safety requirements are observed by expeditioners at all times.

2 Oversight the preparation for and supervise the activities of expeditioners engaged on major traverses and field programs.

3 Maintain the morale and efficiency of the expedition.

4 Perform the duties of Coroner and Justice of the Peace in the AAT, as required according to the Australian Capital Territory Coroners Ordinance Act of 1956 and the (ACT) Seat of Government (Administration) Ordinance of 1930.

5 Liaison with Antarctic expeditions of other nations as directed.

6 Supervise the conduct of station stocktakes and the recorder of supplies for the following year.

7 As an inspector supervise the application of the Antarctic Treaty (Environment Protection) Act, 1981 and administer other legislation and regulations as appropriate.

8 Perform tasks related to the common good of all members of the expedition, including but not limited to ship unloading, watchkeeping, refuse disposal, kitchen duty and general cleaning , as required.

9 Perform any or all of the above duties in support of approved station or field-based summer operations.

10 Ensure the implementation of Divisional policies and practices relating to E.E.O., O.H. & S., Industrial Democracy, and Staff Development and Training.

JOB DESCRIPTION

The Antarctic Division employs station leaders for 16-18 months which includes a minimum of twelve months spent at one of the following Antarctic stations - Casey, Davis, Mawson or subantarctic Macquarie Island. Each station leader reports to the Station and Field Operations manager based at the Antarctic Division in Tasmania.

Salary and Allowances

Salary in Australia	$37187 - 42719
Salary and Allowances in Antarctica	$65338 - 70870

During absence from Australia, various allowances are payable in addition to salary-

- an Antarctic Allowance of $6158 per annum
- an allowance in lieu of overtime, extra duty and penalties, (ALIOT) consisting of 50% of salary up to a limit of $14947 per annum
- a Common Duties allowance of $7046 per annum
- an allowance of $1222 per annum for the person selected to be deputy station leader

Pre-Departure

Prior to departure, Station Leaders will spend approximately three months at the Antarctic Division. During this time they will assist with the supervision and training of their expeditioners and the re-ordering of supplies for the station; they will be involved in the planning and co-ordination of the expedition, and undertake various projects related to the conduct of the expedition.

They will also attend training courses and specialised briefings relevant to their role in Antarctica. Attendance at the briefings and courses such as induction, station management, and safety and survival is compulsory. Attendance at other courses such as anaesthetics and surgery assistant is voluntary.

In Antarctica

In Antarctica, the role of a station leader is to:

- develop and maintain a productive and harmonious community which may include resolving conflict and maintaining discipline
- manage individual performances by assessing behaviour and work competency, providing constructive feedback, counselling and reporting
- manage the achievement of approved scientific, building, maintenance and other operational program outputs
- ensure that field, industrial and domestic operations, and recreational activities, are conducted safely; and assume a direct leadership role in emergencies such as fire, accident or search and rescue
- administer ANARE policies, in accordance with the *ANARE Operations Manual* and other guide-lines, on behalf of the Director, Antarctic Division
- roster expeditioners to perform duties such as night watch, garbage clearance, kitchen help and water production; personally participate in these duties and other work parties
- act as an Inspector under the *Antarctic Treaty (Environment Protection) Act 1980* as required, and monitor the environmental impact of ANARE operations
- perform the functions of Justice of the Peace (Macquarie Island only) and Deputy Coroner, as required

On Return

On return to Australia, station leaders are employed for approximately one month to debrief the Antarctic Division and other agencies participating in ANARE, and to complete reports.

SELECTION CRITERIA

Lead the community

1 the ability to adapt to and foster standards set out in the *ANARE Code of Personal Behaviour*

2 the ability to develop and maintain a productive and harmonious community, including the ability to resolve conflict and maintain discipline

3 proven ability to use open, two-way communication and involve others in decisions and problem solving

4 the ability to counsel, assess and prepare written reports on expeditioners

5 knowledge of and commitment to Equal Employment Opportunity principles, and willingness and ability to address harassment issues

Manage to achieve results

6 the ability to manage approved scientific, operational and administrative programs effectively

7 the ability to ensure that field, industrial and domestic operations are conducted safely, and to direct search and rescue activities

8 the ability to manage Antarctic environmental protection policies effectively and implement procedures

Demonstrate personal effectiveness

9 proven ability to display interpersonal sensitivity, and value the differences in people

10 proven ability to work efficiently under both personal and general pressure and changing circumstances

11 the ability to cope with personal isolation

12 be open to and act on personal feedback

13 demonstrate awareness of and support for Antarctic research programs

14 possess a high level of personal confidence

15 demonstrate well developed written communication skills

16 demonstrate well developed problem solving skills

ATTACHMENT B

SELECTION CRITERIA EXPECTATIONS

Lead The Community

1. **Adapt to and foster standards set out in the ANARE Code of Personal Behaviour.**

   I am concerned to be viewed as adapting to and fostering these standards by setting an example and providing encouragement to others.

   This criterion requires the Station Leader to understand the standards contained in the ANARE Code of Personal Behaviour and to use their own behaviour as an example to foster and develop the standards in their community.

   It is expected that the Leader realise the high status of the position and knows that their personal impact on others significantly contributes to the success of the expedition.

2. **Develop and maintain a productive and harmonious community, including resolution of conflict and maintaining discipline.**

   I offer support and encouragement to the community to work and live as a team, and am effective in resolving conflict quickly and maintaining discipline.

   This criterion requires the Station Leader to facilitate the group working together, productively and effectively, identifying and resolving issues before they develop into conflict. Where conflict does occur the Station Leader must be able to act on this quickly and develop strategies for resolution.

   Should a situation develop which requires intervention and ultimately disciplinary action, the Leader must be seen to act decisively but fairly in decision making.
   It is expected that the Leader sees the position as that of a facilitator and collaborator with others, and possesses good team building skills and flexible strategies and uses these with intention and purpose.

3. **Use of open two-way communication and involve others in decisions and problem solving.**

   I am effective in verbally communicating and encourage open two-way communication and involve others in decisions and problem solving.

   This criterion requires the Station Leader to be effective in verbally communicating instructions, points of view and plans, and to listen to and encourage other points of view.

   It is expected that the Leader will be able to maintain a sense of impartiality, being able to encourage different points of view by promoting open two-way communication and act in the best interests of an individual or the group when making decisions or problem solving.

4. **Counsel, assess and prepare written reports on expeditioners.**

   I counsel group members when required, am able to make objective appraisals, and am effective in preparing written reports.

   This criterion requires the Station Leader to view helping expeditioners as an essential and critical part of their job, and to be able to adopt the role of coach or counsellor and give explicit non-defensive feed-back to others to facilitate their self development.

It is expected that the Leader is able to assess others accurately and communicate this assessment to them orally and in writing in an easily understood manner, modifying their language and written style to suit the person concerned.

5. **Knowledge of and commitment to EEO principles and willingness to address harassment issues.**

I am concerned to be viewed as having this knowledge and commitment and am effective in dealing with harassment issues.

This criterion requires the Station Leader to have a sound knowledge of EEO and harassment principles and legislation and possess the conviction to act without fear or favour should a breach occur.

It is expected that the Leader set clear EEO standards for the community leading by personal example and dealing quickly and effectively with any breach that arises.

Manage To Achieve Results

6. **Manage approved scientific, operational and administrative programs effectively.**

I make forward plans, set goals and organise resources effectively to achieve approved programs.

This criterion requires the Station Leader to have an orientation to and concern for the effective conduct of approved programs. To achieve this the Leader must have a sound understanding of the program requirements and their logistic and personnel support requirements.

It is expected that the Leader be efficient and is motivated by a need for achievement, setting specific clear standards of performance, possessing good goal setting and planning skills, and regularly monitoring progress against approved program requirements.

7. **Ensure that field, industrial and domestic operations are conducted safely and direct search and rescue operations if required.**

I am sensitive to the requirements of field, industrial and domestic safety practices, and am effective in ensuring compliance with ANARE policies and/or legal obligations.

This criterion requires the Station Leader to have a sound knowledge of and appreciation for safety management issues across a varying range of activities covering field, industrial and domestic operations. To achieve this the Leader must be well versed in Occupational Health and Safety Legislation requirements and be vigilant in its application for the conduct of all station and field programs.

It is expected the Leader will establish safety management as a very high priority in the running of their station and field programs, calling on all the resources available to them to assist in implementing and achieving this goal. In times of emergency such as a search and rescue they will be effective in co-ordinating and directing station resources to facilitate the rescue, setting clear directions and following established procedures and practices.

8. **Manage environmental protection policies effectively and implement procedures.**

I am effective in the management of environment protection policies and implementing procedures.

This criterion requires the Station Leader to have a sound knowledge of the legislation covering the environmental management of the Australian Antarctic Territory, Heard and Macdonald islands and Macquarie Island. To achieve this the Leader must be well versed in the Antarctic Division's environmental management policies and procedures as contained in the Operations Manual and other literature and be vigilant in their application for the conduct of all station and field programs.

It is expected that the Leader is motivated by the need to manage all ANARE programs with care for and management of the environment being of paramount importance. They will establish environmental management and the implementation of procedures as a very high priority in the running of the station and field programs and be keen to lead by example and will deal quickly and effectively with non-compliance.

Demonstrate Personal Effectiveness

9. **Display interpersonal sensitivity and value the differences in people.**

I am sensitive, supportive and responsive to the different styles of individuals.

This criterion requires the Station Leader to care about relationships with their fellow expeditioners making time to talk to them about families, sports, hobbies, etc and getting to know and value the difference in their personalities, work skills and other talents.

It is expected that the Leader in getting to know and understand their expeditioners will also come to value their different styles and skills and will be able to blend these in the development of the community. In dealing with expeditioners face to face the Leader will display sensitivity and flexibility and be responsive to the styles of individuals.

10. **Work efficiently under both personal and general pressure and changing circumstances.**

I am able to control my reactions and am effective when working under pressure or in changing circumstances.

The criterion requires the Station Leader to be a disciplined person, who can remain stable, calm and detached in stressful situations, able to maintain quality performance over long hours and be skilled in coping and adapting.

It is expected that the Leader is able to make personal sacrifices for the expedition goals, be flexible in responding to different job demands and respond easily and appropriately to changing circumstances.

11. **Cope with personal isolation.**

I have good powers for coping with personal isolation and do so effectively.

This criterion requires the Station Leader to have good powers of physical and mental stamina for coping with personal isolation.

It is expected that they understand the deprivations associated with living and working in a remote and isolated environment and prepare themselves for this. They will

15. **Well developed written communication skills.**

I prepare instructions, plans, reports and rosters that are concise and easily understood.

This criterion requires the Station Leader to be an effective written communicator in preparation of instructions, plans, reports, rosters and other written works as required.

It is expected that this will be done effectively, in a style that is concise and exact and which can easily be understood by expeditioners and staff at Kingston.

16. **Well developed problem solving skills.**

I analyse problems, sort the real from the apparent and logically deduce a solution.

This criterion requires the Station Leader to be systematic and possess good deductive reasoning skills, being able to identify patterns easily and apply concepts to specific situations.

It is expected that the Leader will be an effective analytical thinker, organised in thought and activity, able to describe events in logical order, be able to sort out what needs to be done, by whom and when.

RECENT APPROACHES ON PSYCHOLOGICAL SELECTION OF WINTER-OVERERS

by

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INTRODUCTION

It is classical to think of the selection in three areas: technical, medical and psychological. Here, we are interested in the third area, which when close to psychopathology, is linked to the second.

The concept of psychological selection must be understood at diferent levels, from a simple screening to long term studies implicating large methods for extreme situations as it is for space flights.

We can distinguish (1) "select-out", eliminating the subjects inapt, "select-in", choosing the subjects more adaptable to the situation, "selection-training", or pragmatic selection, where one can view over a long or short period of time, in a real situation or simulation, the behaviour of the subjects, the definitive choice of the postulants being made at the end of this period.

Moreover, the group selection corresponds to choosing subjects who can work as a team, as they must have good individual inter-relationships and good leadership.

Here, we can emphasise that the selection is only of value if you can evaluate it by further assessment. That prognostical validation is, in general, realised by analysing the accomplishment of the subjects during the activity for which they have been selected, but other methods could be utilized based, in general, on differential studies.

Selection for polar missions

With regards to wintering in the Antarctica (2), specific data should be considered, because of the long term isolation and the degree of confinement imposed on the winter-overers. Major stress factors exist, such as frustration in relation to the distance from the relative and usual place of life, and promiscuity because of the common life in a small group. Therefore, a subject who does not adapt to this situation and cannot be placed for a long period of time, would have an important disturbance on the harmony and effectiveness of the group. It appears then logical, beside a simple "select-out", to do also a type of "select-in".

However, different constraints (financial, administrative, time) restrict the psychological selection for polar wintering. We can also note that all selection systems have to adapt to the goals of the situation and understand the relationship of the goal to the situation. Polar wintering is now a routine and it would not be obvious to envisage methods of selection non justifyed by the specificity of the mission. What can be imagined for a Moon mission does not correspond to an Antarctic mission and vice versa.

Since the second world war, and in particular since IGY, the idea slowly accepted by the managers, that medical obligations, discussed also in the past, should include a psychological assessment, has now been accepted. An international conference held in Geneva, 1962, by WHO (3), have recognized this need. A certain amount of researches have been conducted, first by USA and France, then by Australia, Argentina, Japan, New Zealand, etc (4, 5). Progress of the studies was easy and fast for the countries which control in a common department logistical aspects and medico-psychological research among open-minded institutions. The possibility of positive actions of the national agents then appears clearly within SCAR WG HB and M.

A common doctrine, otherwise a common model of psychological methods to approach winter-overers, and to first realise selection, has appeared.

The French psychological selection (6) for the winterings in Adelie Land and in the Austral Islands is now based on the assessment of 3000 winter-overers (than means 5000 candidates). At the same time, a control system has been installed including a validation of the selection. The complete method has progressed through the years, with rejection of addition of some tests, because of different opportunities.

Now , it is more a psychological selection "control" than a real selection, in the sense that the future winter-overers are screened one after another. The medico-psychologic department of IFRTP and TAAF has then to provide a certificate of aptitude or non-aptitude on a subject and if this one is not employed, another would be seen for the same function. The qualified subjects are designed by "A", apt without restriction, "B", globally apt, "C", apt with hesitation, this last category tell us that it would be better to find another candidate for the job.

Candidates are seen for half a day by the psychologists who use the following instruments:

- a personality questionnaire looking for the psychopathologic tendancies, the IP9 from Bremond, which has been largely validated and studied in different groups,
- 16 PF questionnaire from Cattell which is, for us, the most appropriate (with the Gordon Personality Profile Inventory-GPP-I) to evaluate the subjects taking into consideration behaviour and social factors,
- Psychodiagnostic from Rorschach, classical and effectiveness methods, that have to be used by specialised personnel,
- a biographic questionnaire especially built for this situation, which gives us the understanding of the choices and behaviours of the subjects during the different stages of their life (school, family, military and professional years),
- a half-directed interview: on the basis of the questionnaires, a psychologist does the interview and tries to help the candidate to express as much as possible about their personality and their social behaviour.

We can stress that the relative small number of instruments used in this selection system is balanced on the experience of our psychologists (who have worked for some 25 years in this area) that are also involved in the research.

Systematically, each year, adaptation of the subjects to wintering is controlled to validate the selection. Four variable are taken into account:

V1 = thymic,

V2 = social,

V3 = physical,

V4 = occupational,

(V5 = alcoolism).

This control is mainly performed on the basis of a wintering assessment report realised, after the winter-over, by the doctor and by the wintering chief, and through the recording of medical and social incidents made by the doctor , plus the conclusions he made during the trimestrial medical visists of the subjects. In certain conditions an adaptability questionnaire is used each two monthes to give a diachronic view of the adaptation of the subjects and of the group.

The wintering doctor is then directly involved in the psychological programme: which means he has to be specifically trained before the departure.

These controls show that our forecast can be achieved quite correctly. A recent study over five years (1988-1992), 636 subjects, gave the following results:

- perfect forecast, that is to say A and B subjects became A or B at the end of the wintering = 56,4%,
- reasonable forecast, that is to say C subjects became A or B at the end of the wintering; that reflects severity and prudence of the psychologists, and the fact the potential fragility of the subjects don't necessarly become a reality in the field = 35,5%,
- bad forecast, subjects classified A or B that became C = 7,1%.

To try and obtain a more superior result would mean to begin with a much more important selection process which would involve more time and expenditure than required by the situation.

Prospect

Research in high level sport, in the Army, aerial navigation, and in space flights, shows that in the area we are concerned about massive possibilities exist. Shall we take them into account and adapt some of the selection model to the polar area (7)?

Firstly, we can be quite sure in saying that in the usual context of wintering, it is practically impossible to train the future winter-overers before their departure, despite the fact that this kind of psychological preparation brings some positive results in the above situations. The minimum would be to give a deep understanding and a begining of a simulation, during a two-weeks session, as it already happens in some other countries.

Therefore, it is for selection (and its validation) at the level of individuals and group that one can envisage improvements, in particular in computerising the methods. Moreover, we cannot envisage every wintering and long distance expeditions at the same level. Some situations, for example a wintering in the future station Concordia means very different conditions than a wintering on a coast station, Dumont d'Urville for example.

At the selection level, we can envisage two cases: one existing in France, the other as a potential.

The psychological selection of the French wintering chiefs: on the contrary at the adopted system for the selection of the whole winter-overers described above, it is a real selection. An amount of 25 to 30 candidates already accepted during the preliminary control, present themselves at a second selection session in the aim to become one of the four chiefs for the four French bases. At the end of the assessment, candidates are categorised by their results over the whole evaluation:

- Group Tests (8) (with 6 or 8 candidates all together) including a "discussion" on a theme choosen by the group and a "group problem solving" corresponding to a situation of emergency or danger in a theoretical simulation. Three observers note the behaviors of the candidates by detailed observation grids which have been carefully selected from several studies. This method came from a selection test of the Royal Air Force;
- Defence Mechanism Test from Kragh (DMT) (9): by using an apparatus which give two ambiguous images (type of the plates of Thematic Aperception Test from Murray - TAT) at different speeds, from subliminal speed (20/1000 of second) to a possible visibility (one second) we can bring forward some of the defence mechanisms of the subject related to the oral descriptions and of the designs to which he thinks he has seen on each of the 19 presentations. This test allows the establishment of a quantitative result. DMT has been largely used in the Nordic countries for the selection of the divers, parachutists and plane pilots;
- Embedded Figures Test from Witkin (EFT) (10) which provides field dependance-independance cognitive style;
- Matrix of Intra and Interpersonal Processes in Group from Ada Abraham (MIPG) (11) derived from "constructs" of Kelly and which presents the originality to provide the way in which a subject locates himself (and locates the leader) in connection with the group;
- D48, classical test measuring logical cognitive capacity of the subject;
- Stroop Word-Color Test, also called Stress Test, which provides the capacity of the subject to cope with an interference stimulus in an attentional test;
- The following questionnaires:

. TD9 from Bremond and Fourcade (12) which appreciates decision behaviour and risk taking;

. Eysenck Personality Inventory (EPI) which provides degrees of extraversion-introversion and "neuroticism" of the subject;

. State and Trait Anxiety Inventory from Spielberger (STAI);

. Rathus questionnaire showing the degrree of assertiveness;

. Gordon Personality Profile Inventory (GPP-I) mainly forward social behaviour.

Possible developments:

a- If we take into account the results of different researches done by our laboratory during the winterings, but also in military conditions, space simulations, and in the aera of high level sport, we can retain the forecasted interest in the study of defence mechanisms, cognitive styles, assertiveness, GPP-I and Group Tests.

However, it is essential to modify criteria and instruments according to the evolution of the society and of winter-overs, and to take into account the different origins of the postulants (for example military or civilian).

b- It should be very interesting to realise the selection of the whole team after having chosen the wintering chief and the main responsibles (doctor, engineer, and so on), "binding" the other members of the party according to the characteristics of these responsibles.

c- For several years, we have established a working collaboration with the Russian psychologists from the Institute for Bio-Medical Problems of Moscow (IBMP), research center for cosmonauts. Some of their techniques appeared interesting and we have included them in different research programmes (for example International Antarctic Psychological Programme -IAPP) (13). We can quote:

-PSPA (Personal Self Psycho Ananlysis): complex test based on Kelly's constructs which can give us important information on the subjective feeling of the subject for his environment;

- HOMEOSTAT, testing on 4 subjects working together the capacity to accomplish a common task;
- VERBA, which provides the dominance of a subject on another one;
- SMUD, tracking method carried along by the breathing of the subject intending to appreciate his emotional control;
- JOY, vigilance test presented as video games which make more pleasant and less monotonous repeated testing (further validation methods are obtained by following the subjects).

d- IAPP (13): this current research in Adelie land has an objective to validate different research techniques, in particular Russian, with the view of an application to space.

The first phase corresponds to a baseline of reference: all the 31 subjects were seen in Paris before their departure to Antarctica by using the above instruments, Russian, British and French.

To follow the subjects during the wintering forms the second phase: that means general measurement allowing a validation of the methods. Then:

i. To follow the motivation performance using 3 tests:

- Stres Battery (AGARD-NATO): classical vigilance test gathered in the view to allow the comparison of the measurememnt in different countries;

- JOY, already mentioned;

- AMT: British test symbolically corresponding to a professional situation (here, climatisation control of a station: paying attention to and controlling the measurements of the atmospheric parameters displayed);

--the simultaneous recording of 3 psychophysiologic parameters is associated to these tests: skin conductance, skin temperature, and heart rate.

ii. To follow the thymy and the individual sensibility of the subjects to their environment:

- QCP, test created by our laboratory gives information on the frustrations of the subject or, to a certain extent, his secret obsessions. 300 words related to sex, family, work, are shown at random on the screen of the computer and the subject has to, spontaneously, record the answer that means something to him, at this specific moment;

- PSPA and MIPG, already seen;

iii. On several occasions, we record group discussion for 20 minutes; the themes are open or related to the stay.

iiii. Furthermore, other different more classical controls similar to the ones quoted above (relative routine validation of the adaptation prediction: adapatability questionnaire, consulations, incidents, interviews, etc.) are systematically realised by the doctor.

The third phase of the programme is a debriefing by a psychologist going to Dumont d'Urville at the end of the wintering. It includes two sciometric questionnaires (SQ1 and EQ) well validated by previous researches, a written report that takes 30 minutes for each subject (FR), an interview and if possible a T Group.

It is obvious that such an important protocole of IAPP is only for research and not for routine measurements. We regret that this research initially planned to be international was not followed by other countries in other Antarctic bases as suggested in former meetings, and through the chaiman of WG HB and M. It may be possible in the future; but for now we can ensure that our protocoles are available for those who wish to conduct similar research.

Another proposal more pragmatic is that, among WG HB and M, and at the end of 94, the beginning of 95, a committee creates a programme, the International Psychological Selection Programme (IPSP) that corresponds to a selection-control protocole with its aim of applying for the recruitment of future winter-overers at the beginning of the wintering of 95-96 (or 96--97 if not enough time). The duration of this protocole could be up to 5 years, with, of course, at the end, a differential study related to national specifications.

Conclusion

We believe that previous researches have allowed "polar psychology" to be recognized at both level of selection and research. Some of these studies can help to obtain new acquisitions in the field of polar application. Other, and not the lesser, can have an objective to apply in other extreme situations, such as civil or military, because of the analogy existing between them and the human activities in the Antarctic. This is the case, for example, in certain space missions and in particularly Moon missions which are presently beeing studied.

Several tasks have yet to be accomplished, specifically with an international point of view; WG HB and M is here to initiate and coordonate them.

Lastly, we must convince and work...

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SELECTION AND MANAGEMENT OF ANTARCTIC PERSONNEL - INDIAN ANTARCTIC PROGRAMME

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Introduction

India began the Antarctic research programme with the launching of the first expedition in the year 1981. It was a matter of great satisfaction to introduce Polar science in the country. The Department of Ocean Development was then set up to coordinate among other scientific activities the launching of the Antarctic expeditions. As a coordinating agency, the Department has to interact with several laboratories, universities and other institutions in the country. For the logistic support India takes the help of Defence personnel belonging to the Army, Navy and the Air force.

The first Indian scientific station was established in the shelf area at 70^{o} 05' S and 12^{o} 00' E. Thereafter this base was shifted to the Schirmarcher Oasis, about 80 km away from the ice shelf edge, and named Maitri.

Maitri is located at 70^{o} 46' S and 11^{o} 44' E and is situated about 60 km north of the more well known Humboldt mountains. The Schirmarcher Oasis is a small ice free area. The Oasis comprises of a number of fresh water lakes and smaller melt water ponds. The Oasis was first discovered in 1939 and is known to be one of the less explored areas of Antarctica. Schirmarcher lakes also appears to be one of the less productive areas and the only form of vegetation is algae, including some nitrogen fixing blue green algae, besides moss and lichens. Because of the isolated location, the animal species are poor and only South polar Skuas and Wilson Snow petrals are found.

Access to the Oasis is either by helicopter from the ice shelf or through overland transportation during winter months.

The Indian programme is designed to make the best use of the location of our Station and the scientific studies are carried out in the fields of atmospheric sciences, meteorology, geology, geophysics, geomagnetism, oceanography, biology, human physiology, environment, engineering and communications.

When the Antarctic programme was initiated more than a decade ago, the enthusiasm amongst the Indian scientists was intense and proposals were received in the Department from scientists from different disciplines, expressing their eagerness to be a member of the expedition and conduct Antarctic research. In the initial stages, therefore, the selection was made from the best applicants from different disciplines, and considering the available seats in the ship chartered for the expedition and the logistic support required for carrying out the experiments, the selection was made. As a result, studies could be initiated almost in all the disciplines and till date the enthusiasm for continuous work in the various disciplines continues. Accordingly, therefore, our programme is geared with a view to provide facilities for scientific research in each of the disciplines in every expedition.

Whilst the proposals for scientific studies are encouraged, in view of the location of Maitri, there are serious constraints of logistic support which is essential for the scientific work. In the first place it becomes necessary for us to charter a suitable ship for the expedition. It is also necessary that the ship is capable of carrying helicopters, as helicopter support is essential for access to Maitri in summer. India operates two types of helicopters, namely MI-8 and Alloutte-3. The use of former type of helicopters requires a large helipad facility in the ship, as a result of which the options to charter a suitable ship are indeed very limited. Recently, therefore, it has been decided to emphasise on increased overland transport support during the winter, and concentrate only on the most essential logistic requirement in the summer with the use of smaller helicopters only. This has resulted in wider options for chartering a suitable ship and has also brought an element of stronger inter disciplinary work amongst the members. Over the years the policy has also been systematically to increase the scientific composition of the team, as after the construction of Maitri, no fresh construction activities which involve heavy logistic support, are contemplated.

Selection of Scientific Personnel

It is against the above background that the selection of personnel for the expedition is carried out. About a year in advance, nominations are invited from various laboratories and institutions and a press advertisement is also inserted inviting proposals which are innovative and can make use of the facilities available at Maitri for scientific work. The response is generally very high for the summer component. Wintering in Antarctica in the Indian Antarctic expedition involves nearly 16 months away from home and, therefore, the volunteers are limited.

The applications and nominations so received are screened initially by the Department and thereafter the scientific contents of the programmes are weighed in the context of the ongoing work or work already accomplished and also taking into account the support facilities available in the expedition. This is essential because the support facilities have to be extended to provide the most essential requirements for maintenance of the Station for year round operations.

The candidates are then invited to make a detailed presentation before a high level National Coordination committee, comprising of the heads of various Scientific Ministries/Departments, laboratories and also some of the previous Leaders of the Expeditions. During the presentations, the members of the National Coordination Committee examine the proposals in detail and give their recommendations for selection, taking into account the innovative nature and other significant aspects of the programme. The members recommended by the National Coordination Committee are thereafter sent for a thorough medical examination, which includes psychological examination for the winter members. The candidates then proceed for intensive snow ice training in one of the high altitude regions in India. On successful completion of the snow ice training and medical examination, a final list of candidates is prepared and the total objectives of the expedition set out in detail. Approval for this programme is then obtained at the highest level and the team finalised. The team is then given a thorough briefing which includes guidelines for the expedition members, explanation of the Antarctic Treaty requirements, maintenance and other drills that need to be carried out at Maitri etc.

Women candidates are encouraged for the Antarctic programme, provided, however, there are at least 2 women volunteers for the expedition. So far there has not been a woman volunteer for wintering in Antarctica.

Selection of Leader

The leader of the expedition is selected from amongst the scientists who have previous Antarctic experience and is willing to winter-over. The scientist is interviewed by the National Coordination Committee. and is subject to medical and psychological examniation including tests for leadership qualities.

Selection of Logistics Personnel

Selection of the Logistic personnel depends upon the logistic requirements each year, apart from mandatory stipulations that are required for flying the helicopters etc. The logistic personnel are also subjected to medical and psychological examinations, as required and also the snow ice training.

India also encourages collaborative programmes and welcomes participation of foreign scientists. Scientists from Mauritius and Columbia have already been included in our earlier expeditions as part of the summer team.

The entire selection process is based on the principle of volunteering and no institution compels participation in the programme. Being a multi- disciplinary and multi-institutional programme, the coordination even after the return of the expedition is extensive. The maintenance of clear record of ongoing activities and their updates from different participating institutions and laboratories is indeed a major task for the Department of Ocean Development.

The Department of Ocean Development organises a debriefing of each expedition on a large scale, where almost every member presents the nature of his activities in Antarctica and gives out his recommendations for the future.

After each expedition, the Department of Ocean Development publishes a technical report. Scientists are also encouraged to publish their results in Indian and international journals.

Thrust Areas and Priorities

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Scientific Research

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* Study of Solar processes
* Antarctic Ice-ocean - Atmosphere system and global changes.
* Lithosphere and rifting history.
* Ecosystem and environmental physiology.
* Engineering, research and development for support systems.
* Environmental impacts and studies.
* Data base.
* Effective management global commons.

Selection and Management of Japanese Antarctic Personnel

by
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INTRODUCTION

Many of the systems used by national Antarctic programs tend to reflect the cultural, social and historical backgrounds of the country. Japanese selection and management system for Antarctic personnel may be unique compared with the other national Antarctic programs. In this presentation, Japanese procedures for the selection and management of Antarctic personnel will be briefly described with the merits and demerits of the system.

The National Institute of Polar Research (NIPR) operates three stations in the Antarctic; Syowa, Mizuho and Asuka. Currently, Syowa Station is the only year-round station, however a new inland year-round station, "Dome Fuji"(77°22'S, 39°37'E, 3,810 m a.s.l.), will be opened in the coming season for glaciological and meteorological studies.

STRUCTURE OF JARE

Japanese Antarctic research has been conducted with the cooperation of a number of governmental agencies (Fig. 1). Overall decisions and approval of proposals for research activities rest with the Headquarters (HQ) for Japanese Antarctic Research Expedition (JARE) which has been set up in the Ministry of Education, Science and Culture (Monbu-sho). However, the major role of preparing research programs, planning logistics support and operating actual Antarctic work rests with NIPR. NIPR is also responsible for the selection of candidates, training, medical screening and so on in addition to the planning and performance of the Antarctic program.

The 36th JARE (1994-1996) consists of the 40 wintering personnel and 16 summer personnel (Table 1). Thus it is characteristic of JARE that the number of wintering personnel is more than twice that of summer team personnel. The proportion of scientists in the wintering team is approximately 50 %. The average age of wintering personnel is around 33. In general, the leader is the oldest and in the early forties to early fifties. Around 2/3 of the wintering personnel are married.

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Outline of Annual Itinerary of JARE

Logistics support for JARE is provided by the icebreaker "Shirase" which is operated by the Japanese Maritime Self-Defense Force. The shipping schedule for "Shirase" is shown in Fig. 2. The schedule has remained the same for several years.

The Japanese ship operation is characterised by the fact that it operates to the Antarctic only once a year. The ship undertakes multiple tasks; not only the main task of transportation of cargo and the expeditioners but also other tasks such as oceanographic survey work and helicopter support of field parties.

Because there is only one voyage to and from Antarctica each season this means that the loading capacity of cargo is limited to ~1,000 tons (including bulk fuel), and the annual number of participants is restricted to 60 (including observers and visiting scientists from other countries). Moreover, all Japanese personnel have to embark in Tokyo. Thus JARE wintering personnel are obliged to be away from home for 16 months and the summer team for more than 4 months.

SELECTION OF PERSONNEL

Selection of the leaders

Candidates for the position of expedition leader are usually recommended by NIPR to the JARE HQ. They are selected from senior researchers of NIPR, national universities or are qualified persons from governmental institutions which have responsibility for the JARE routine observations.

Selection of personnel

One of the major characteristics of the JARE system is that the personnel must be government employees. For this reason, some people such as mechanics, telecommunication officers and carpenters from private enterprises, and even the graduate students, are required to become temporary government employees. This system is particularly effective should an accident occur to personnel because of the comprehensive governmental welfare and insurance arrangements. However, this system tends to limit the selection of personnel from a wide range of potential applicants.

Recruitment starts from about one year before the expedition embarks (Table 2). The opinion of the expedition leader concerning the selection of personnel is highly respected. All candidates, including scientists, are requested to join a six-day winter training school in the middle of March. Medical screening is held in Tokyo between January and April and the screening committee on health evaluates the results of the screening before a final decision is made in late June at the HQ General Board.

The principal investigators of the scientific projects are responsible for the selection of candidates for their projects subject to the recommendation of the planning committees, while NIPR is responsible for the logistics people and for the people who conduct some long-term observation and monitoring programs. The logistics personnel are recruited from private enterprises and governmental organisation such as universities, national institutions as well as NIPR.

For some personnel, such as cooks and medical doctors, we advertise in trade (union) papers or journals, but never advertise in daily newspapers.

Medical screening

Medical screening is conducted at hospitals and arranged by NIPR. All candidates are examined in accordance with a standard procedure and interviewed by the medical doctor who is a member of the screening committee on health. The items examined are shown in Table 3. The mental health examination is performed only for wintering personnel.

The screening committee on health consists of specialists in medicine, surgery and psycology who are appointed by NIPR, doctors who have wintered over in the Antarctic together with the staff managers of JARE, and the Director-General and the deputy director of NIPR.

Training

Apart from technical and scientific training for each project, two major training schools for general purpose are arranged: a six-day winter training school in the Japanese Alps in middle March and a five-day summer school in the countryside in late June. The aims of the winter school are threefold; 1) to give candidates general information on the Antarctic and on the systems of JARE, 2) to examine the capability of the candidates in a cold region and in a closed society, and 3) for the candidates to understand the nature of field activities under low temperatures. For the last aim, some practice such as camping in tents, navigation training with magnetic compasses and a short over-snow walking exercise are conducted by experienced logistics staff of NIPR in conjunction with professional mountain guides.

Soon after the personnel are appointed in late June, the five-day summer school is held. The aim of the summer school mainly focuses on 1) a discussion of practical procedures and methods for the scientific and logistic programs, 2) lectures on the Antarctic Treaty System and environmental conservation in Antarctica, and 3) training on safety and emergency treatment including first-aid training, a fire-fighting exercise and so on.

However the most important role of these schools is to enable the expeditioners to get to know each other and develop as a team.

MANAGEMENT OF PEOPLE

Management of the station life

The Expedition Leader of the wintering team is appointed as the station manager. In addition to the regulations approved by JARE HQ for the management of the expedition, the leader of the wintering team establishes his own regulations for station operations and safety practices. The leader appoints some members to the executive committee of the expedition. The management plan of the station is discussed by the committee and then agreed by all personnel at a general meeting which is normally held once a month.

Medical and welfare support

Health screening is generally carried out every four months at the year-round station. One of the serious difficulties over winter is the isolation from all the specialised services and facilities that are readily available in developed countries. For example the diagnosis and treatment of problems can be difficult because of the isolation from specialist medical services. A telemedical support system using slow-scan TV has been installed to help with medical diagnosis, treatment and operation. Because all personnel are government employees, they are covered for any physical injuries occurring during their duties. However many people also contract their own insurance.

During winter, a families association is organised with assistance of NIPR. Aside from the monthly news from NIPR to the families, the families association provides several newsletters from the Antarctic station. The overseas telephone service between the Antarctic personnel and their family plays a great role in their communication, however the financial pressure on individuals is not negligible.

CONCLUDING REMARKS

Fortunately, fatal accidents are very rare in JARE. There has been only one fatal accident which occurred in 1960 and resulted from an expeditioner losing his position in a blizzard.

One of reasons for such scarcity of accidents appears to be the excellent abilities of expeditioner personnel. Especially, most of the logistics personnel are recruited from Japanese private enterprises where they are well trained in their society and are recognised to be the representatives of their companies. Secondly, safety is the top priority in the management of JARE. For example, the fire-fighting exercise in which all personnel are involved is regularly (usually once a month) performed at the Antarctic station. In conclusion, we have learned that people who are well aware of safety matters can minimise the risks.

Syowa Station is located in the Lüzow-Holm Bay, Queen Maud Land, and the dense pack ice field and the thick fixed ice make it difficult for the ship to access the station especially in the early and late summer season. That is one of the reasons why the ship can transport cargo only once a year. In contrast, the maintenance of the station is becoming a major workload for the expedition together with increased scientific activity. The limit on the number of personnel requires greater efforts from expeditioners such that the logistics people, and even scientists in some cases, have to play multi-roles in the team. However, managers are requested to avoid using unskilled workers to undertake risky activities such as operating heavy vehicles, building construction and so on thereby reducing the risk of the serious accidents.

On the other hand there are many opportunities for expeditioners to share and gain an appreciation of other people's work. Moreover, the extended period of training and the long tour of duty encourages comradeship although the younger generation are tending to be more individualistic.

Acknowledgements

We are indebted to Prof. Takao Hoshiai, the Director-General, NIPR, for his comments and encouragement. We are also grateful to Mr. Jack Sayers, SCALOP Chairman, for his helpful suggestions and proof reading of the manuscript.

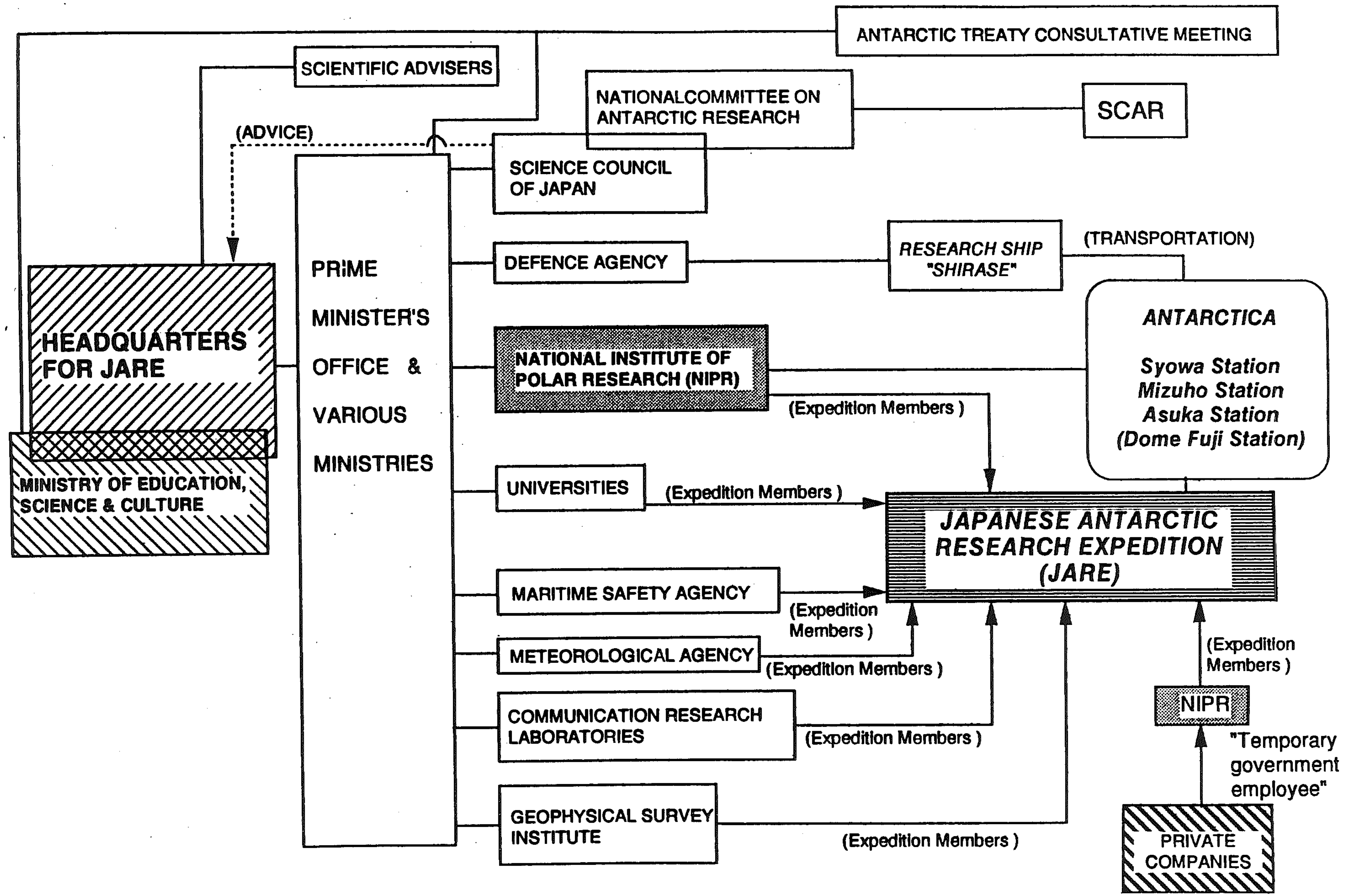

Fig. 1. Japanese Organisation of Antarctic Activities

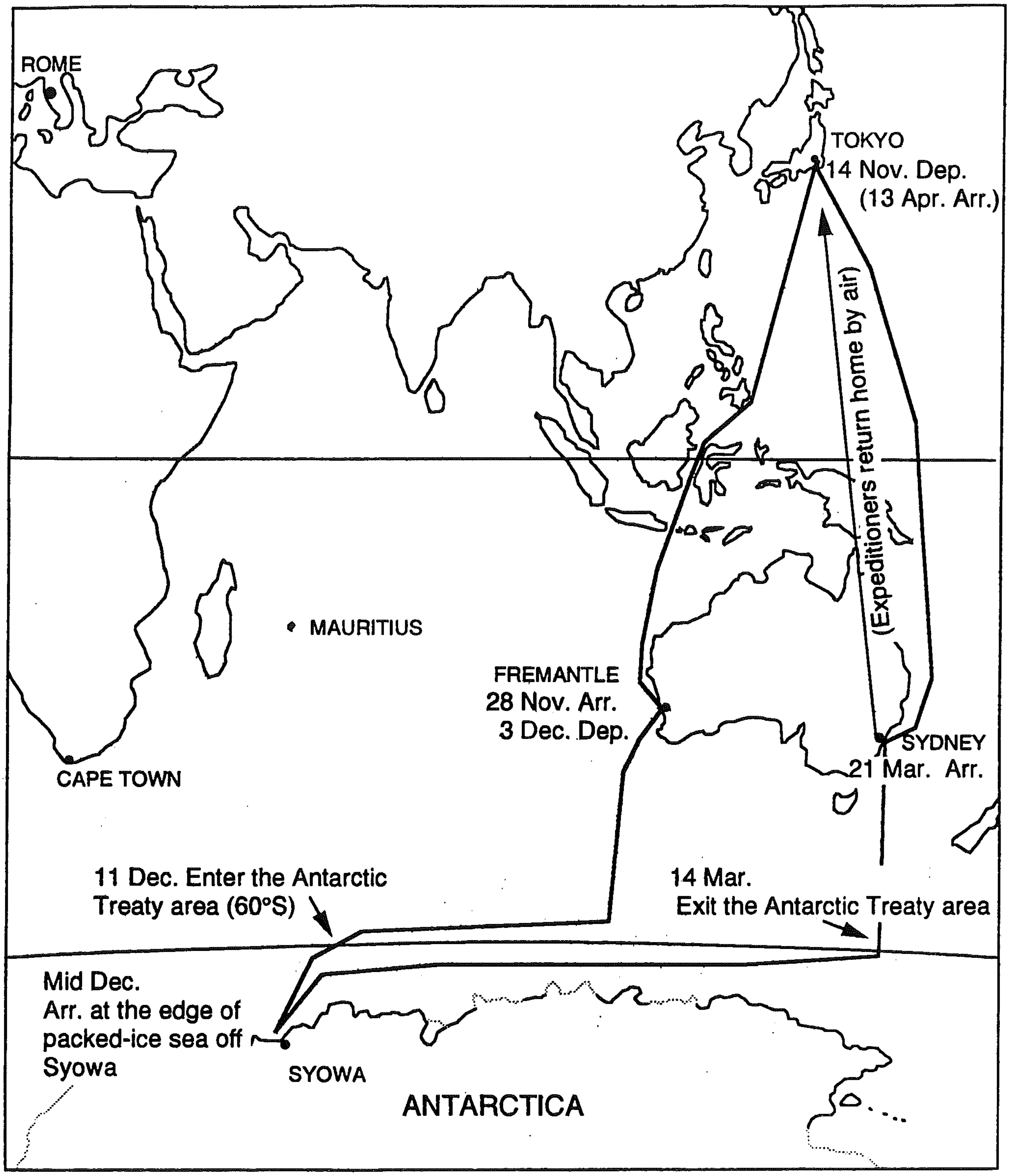

Fig. 2 Expedition Itinerary in the 1993-1994 Season

Table 1. Composition of JARE personnel in 1994-1996

Categories		Syowa Station	Dome Fuji
Wintering team			
Deputy leader	(Leader of wintering team)	1	
Deputy leader	(Deputy leader of wintering team)		1
Station Observation	Meteorologists	4	1
	Upper atmospheric geophysicists	1	
	Seismologist	1	
Research projects	Upper atmospheric geophysicists	3	
	Solid earth geophysicists	2	
	Glaciologists	4	2
	Biologist/ medical scientist	1	
Logistics	Mechanics	6	1
	Telecommunication officers	2	
	Cooks	2	
	Medical doctors	2	1
	Officer in charge of waste management	1	
	Field assistants	1	3
	Total	31	9
Summer team			
Leader		1	
Monitoring observation	Oceanographers	2	
	Marine biologist	1	
	Surveyor	1	
Research projects	Upper atmospheric geophysicist	1	
	Geologists	3	
	Glaciologist/meteorologist	1	
	Biologist	1	
Logistics	Carpenters/Builders	4	
	Officer in charge of general affairs	1	
	Total	16	

Table 2. Annual calendar of JARE

	JARE-(n-2)	JARE-(n-1)	JARE-n	JARE-(n+1)
November		•Approval of the final program by the JARE HQ General Board (Families Association meeting) •Embarkation	•Appointment of leaders by the JARE HQ General Board •Start selection of the candidates	
December		•Arrive in Antarctica		
January			•Start the medical screening	•Start selection of the leaders
February	•Transfer the duty to the next JARE	•Start the maintenance of the station	•Discussion on the programs by the Planning Committees •Winter Training School	
March				
April	•Return home (wintering team)	•Return home (summer team)		
May			•Recommendation of the programs by the Planning Committees	
June			•Approval of programs and personnel by the JARE HQ General Board	
July			•Summer Training School	•Medical screening for the candidates of the leaders
August			•Start the provision of cargo •The 1st official meeting with ship •The 1st pre-tour briefing	
September		(Families Association meeting)		
October				
November			•The 2nd official meeting with ship •The 2nd pre-tour briefing •Prepare the loading cargo list •Load the cargo on ship •Approval of the final program by the JARE HQ General Board (Families Association meeting) •Embarkation	•Appointment of leaders by the JARE HQ General Board •Start the selection of the candidates

Table 3. Health examination items for the candidates of JARE Personnel

1. Medical examination
   - general state
   - auscultation and percussion
   - blood pressure
2. Urinalysis
   - general appearance (protein, sugar *etc.*)
   - microscopic hematuria
   - urine sediment
3. Stool examination
   - occult blood
   - parasites
4. Hematological examination
   - number of erythrocyte (RBC)
   - number of leukocyte (WBC)
   - hematocrit
   - hemoglobin
   - blood picture
   - thrombocyte
   - platelet
   - erythrocyte sedimentation rate
   - partial thromboplastin time (PT)
   - activated partial thromboplastin time (APTT)
5. Serological examination
   - ABO blood group
   - Rh blood group
   - hepatitis B sufase antigen
   - hepatitis B sufase antibody
   - hepatitis C virus
   - HTLV III antigen
   - serologic test of syphilis (complement fixation reaction, sedimentation, TPHA)
6. Liver function
   - GOT
   - GPT
   - Al-P
   - serum total bilirubin
   - direct bilirubin
   - LAP
   - LDH
   - ZTT
   - TTT
   - γ-GTP
   - total protein
   - albumin
   - total cholesterol
   - HbA_1C
7. Renal function
   - electrolyte (Na, K, Cl)
   - blood urea nitrogen (BUN)
   - creatinine
   - uric acid (UA)
8. Physiological examination
   - electrocardiogram (ECG)
   - pulmonary function test
   - ultrasonic examination
9. Neurological examination
   - motor function
   - tendon reflex
   - equilibrium test
10. Radiological examination
    - chest X-ray
    - upper gastrointestinal series
11. Ophthalmological examination
    - visual acuity test
    - ophthalmoscopy
    - chromatoptometry
    - slit lamp microscopy
12. Otolaryngological examination
    - audiometry
13. Dental examination
    - general findings
    - X-ray for wintering personnel
14. Psychological examination (only for wintering personnel)
    - interview
    - electroencephalography (EEG)
    - psychological tests (TPI, YG, Rorschach)

PSYCHOLOGICAL EVALUATION FOR THE SELECTION OF MEMBERS OF THE INDIAN ANTARCTIC EXPEDITION

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Introduction :

Several studies report the occurrence of psychological disturbances in Antarctica (Law 1960, Strange and Klein 1973, Bell 1984, Bell and Garthhwaite 1987). Most of the Antarctic psychological studies were done by American, Soviet, British and Australian scientists during summer and winter expeditions. Many of these examined naval and scientific personnel working under conditions of isolation, extremes of environmental conditions, danger and monotony for a period of 1 year in their respective stations. The major psychological issues were sleep problems, lack of motivation, reaction to isolation, psychosomatic symptoms, anxiety and depression. In an Antarctic mental health study (Gunderson 1968) it is mentioned that the number of anxious and depressed incidence increased between beginning and end of winter months. Therefore for the success of the Antarctic expedition, all the members participating in the mission should undergo screening tests not only to assess the motivation and covert psychopathology but also to predict the compatibility of members to cope up with the Antarctic conditions. No standard testing techniques are available, as every country uses its own screening method. Thus we are developing a series of psychological tests to screen the members of Antarctic expedition. The effectiveness of such tests is being studied by monitoring state of all the members who winter-over in Antarctica. The paper reports the results of screening tests of the last two expedition to determine the psychological profile of 55 subjects who visited Antarctica in years 1992 and 1993. The study was conducted at AIIMS, by the department of psychiatry.

MATERIALS AND METHODS- The study was conducted to assess the psychological profile for selection of members of the Indian Scientific Expedition to Antarctica. Total number of subjects studied were fifty five. The group was to be selected to winter-over in the year 1992 (12th Expedition) and 1993(13th Expedition). All were male subjects in the age group of 23-48 years. Majority of the subjects were married(n=46). There were 9 unmarried subjects. Four subjects had already gone to Antarctica and this was their second visit. (Table - I).

The tests were conducted in the Department of Psychiatry, AIIMS, in a schedule which included written objective questionnaires followed by a short structured interview. All the subjects assembled in a lecture theater and were given the questionnaires. The various tests included in the schedule were as follows :-

GENERAL INFORMATION QUESTIONNAIRE -

This provided some basic information such as name, sex, age, educational background, family history, prior experience of staying in isolation and psychological problems. It also examined their smoking and alcohol consumption habits . The main idea of collecting this information was to help select socially and psychologically fit persons.

PERSONALITY TRAIT SCORE :-

It had 12 bipolar traits which were on the two extremes of a scale (1-5). The traits like reserved/outgoing, shy/venturesome were also included. These traits are the characteristics that lead people to behave in more or less distinctive and consistent way in any environmental situation.

STATE\TRAIT ANXIETY -

Anxiety is one of the commonest manifestation of stress. It manifests in psychological or physiological symptoms. It is often concealed and reduced by defensive behaviour. Anxiety rating scale had 2 parts of 20 statements. Part one measures the state anxiety, which is current or present state of individual. The second part measures anxiety as which is enduring pattern of an individual to react. The responses to questionnaire were scored as not at all, some what, moderately so, very much. The idea was to select member who do not get anxious under very hostile conditions.

ZUNG SELF RATING DEPRESSION SCALE

Depression which is an emotional state characterized by feeling rating of inadequacy and withdrawal from others was assessed by this scale. It had 20 questions and responses were evaluated by using 1-4 scale. The total score gave the depression level of the individual.

COPING RESOURCE INVENTORY FORM D-

We used the Allen L. Hammer inventory form. It included 60 questions and the responses were never, sometime, often, always. The main objective was to identify the coping potential and methods of social, cognitive, religious, physical and emotional state of an individual and also to determine how well the subject can cope with various stresses.

SUBJECTIVE WELL BEING RATING SCALE (W.H.O 1985) -

It included 82 questions to assess various qualities of the subject by assessing general conditions, family closeness, mental mastery, expectation and achievements, social support and personal health. In the end, total rating of the sum of all the score were commuted.

<u>RESULTS</u> - The general information forms gave some facts about these subjects. The average defence personnel educational level was upto highschool. Of the total subject studied 2 of the non-defence and 5 of the defence had some insignificant psychological problems like (depression, worries etc.). Out of the 55 subjects studied 15 neither smoked, nor consumed alcohol, sixteen were smokers as well as consumed alcohol, 21 only alcohol and 2 were only smokers. (Table i)

Table (ii) gives the mean scores for each personality trait on a 5 factor scale. The non defence personnels were more (1) outgoing(2) happy go lucky (3) conscientious (4) experimenting (5) self sufficient. It was indicated that defence personnel were less affected by feelings and were tense . However the difference in two groups for these was insignificant. As the scores did not show any significant difference, we examined each score and the frequency distribution of subjects which indicated asymmetrical frequency distribution between the two groups.

Personality score showed a higher score for most of the subjects, indicating 76.6% above the score of 80 to be classified as Type 'A' personality, out of them 10% were of extreme type 'A' and rest were moderate, only 16.6% were of type 'B' personality.

Both army and non army personnel were neither expedient nor conscientious but fell somewhere between. Nothing clear for shy and venturesome. Both army and non army were practical. For placid and apprehensive, more scientist were placid. Conservative/ experimental, more scientist than army were towards experimental. Group dependent/self sufficient, non army people almost 50% were total self sufficient whereas, only 19% of army were totally self sufficient. (Table iii)

The average state anxiety score for non army personnel was (25.5±5.74) and for army personnel was (30.42±7.03). Similarly Trait anxiety, for non army persons was (29.6±7.99) and army persons (33.97±7.342). The difference in them was significant.(p=.01) (Table iv).

The average depression scale for non-army people was (24.2±7.46) and for army was (28.914±7.691), which was below average. The average of the anxiety was significantly higher in the army group as compared to non army (64.22±12.86 Vs 54.1±10.03) and the difference in the two was significant. (p=005).

The Coping resource was almost same for army and non army expect for physical coping of which defence group was 37.05 a little higher than non defence of 35.4 and a total coping also was higher for army 190.05 as compared to non army which was 187.6. (Table v).

The mean score of subjective well being rating scale is shown in Table (vi). The general condition and mental mastery was higher for non army than the army group. Total rating of subjective well being for army group was 242.48 and non army group was 243.42 however the difference was insignificant.

Discussion

In our study we did not find distinctive differences between the army and non army groups that were selected for participating in the 12th and 13th Indian Scientific expedition to Antarctica. Therefore, it appears that inspite of difference in educational, professional, age, physical fitness of the two groups, it was found that they still formed a homogenous group on psychological basis. In general they had low depression scores with Type 'A" personality. The difference was only seen in the coping resource scores, which support the view that non army can cope up by social means and army by physical, which is expected. The study shows that on the basis of these tests only 2 subjects were found to be psychologically unfit for expedition. This is because all the subjects had themselves volunteered to visit Antarctica and they were psychologically prepared for this stress. In the main questionnaires people seem to have given honest answers and this was reflected in the short individual interview.

Although these questionnaires are not specifically designed for use in the screening of Antarctic expedition members but it very well fits in our objective for selection of homogenous group of subjects who are tolerant, adaptable and confident. The number of people examined in this study is small but this will be gradually increased by adding more numbers every year. For determining the outcome of this screening method it is important to examine the psychological changes that occur in these men during their stay in Antarctica setting and determine the individual psychological effects. This study is being conducted in an organised manner and the data for 12th expedition members has been obtained which is under process of analysis; and only after their results are available a complete picture of our study will be obtained.

Acknowledgments:

We wish to extend our thanks to Prof. S.K. Kacker,Director, Prof. D. Mohan, Professor and Head Department of Psychiatry, All India Institute of Medical Sciences for the valuable facilities provided for conducting this study. Miss M. Naidu for statistical analysis, Mrs. R. Katyal for secretarial support.

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TABLE - III

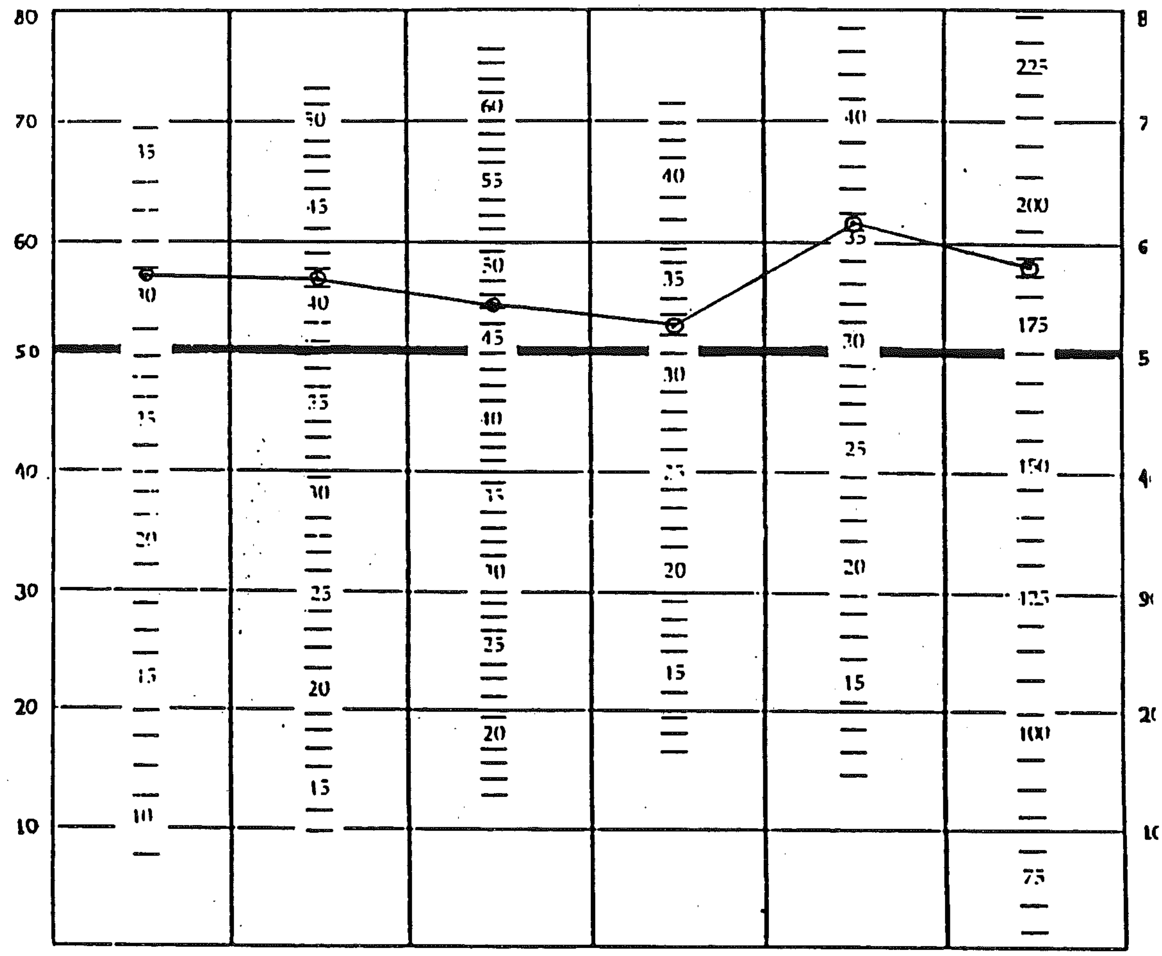
MEAN & SD VALUE OF PERSONALITY TRAIT SCORING IN ARMY & NONARMY SUBJECTS

		RE/OUT	MO/LE	HU/ASS	SO/HA	EX/CO	SH/VE	PR/IM	PL/AP	CO/EX	RE/TEN	GRD/SS	FD/CAL
DEFENCE	AVG	2.85	3.02	2.52	2.76	2.88	3.17	2.22	2.44	3.03	2	3.26	2.85
	STD	1.22	1.25	1.21	1.23	1.3	1.36	1.43	1.35	1.31	0.985	1.29	1.41
NON DEFENCE	AVG	3.15	3	2.3	3.1	3.31	3.31	2.4	2.4	3.68*	1.9	4.3**	2.35
	STD	1.23	1.22	1.1	1.6	1.07	1.17	1.2	0.91	0.86	1.26	0.78	1.35
	T VALUE	0.87	-0.05	-0.67	0.88	1.31	0.38	0.47	-0.12	1.98	0.89	3.27	-1.28
	P VALUE	NS	NS	NS	NS	NS	NS	NS	NS	.05	NS	>.005	NS

RE/OUT	RESERVE-OUTGOING	PR/IM	PRACTICAL-IMAGINATIVE
MO/LE	MORE AFFECTED BY FEELINGS	PL/AP	PLACID-APPREHENSIVE
	LESS AFFECTED BY FEELINGS	CO/EX	CONSERVATIVE-EXPERIMENTING
HU/ASS	HUMBLE-ASSERTIVE	RE/TE	RELAXED-TENSE
SO/HA	SOBER-HAPPY GO LUCKY	GRD/SS	GROUP DEPENDENT-SELFSUFFICIENT
EX/CO	EXPEDIENT-CONSCIENTIOUS	FR/CA	FORTHRIGHT-CALCULATING
SH/VE	SHY-VENTURESOME		

COPING RESOURCES INVENTORY REPORT FORM

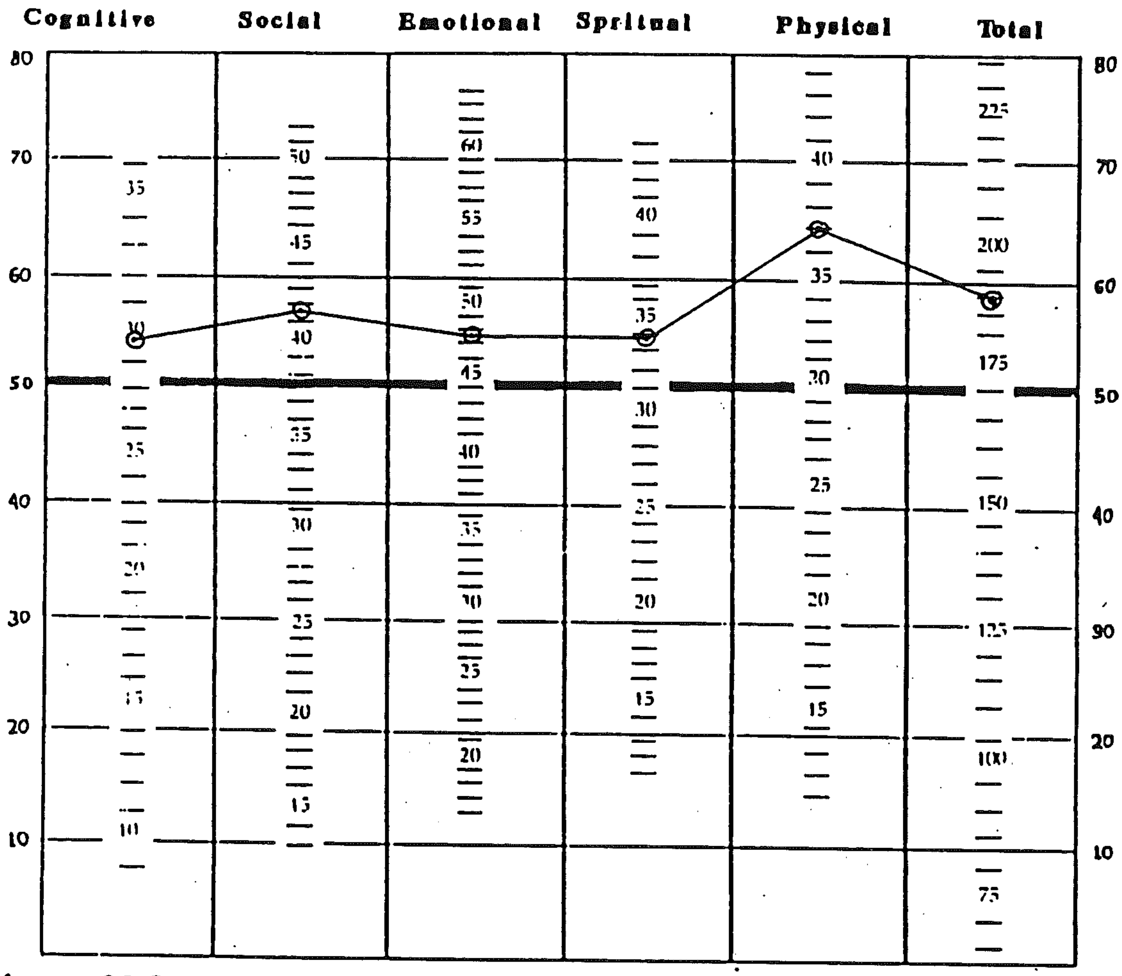
NON DEFENCE



	Cognitive	Social	Emotional	Spritual	Physical	Total
w Scale Score :	30·7	41·6	47·2	32·7	35·4	187·6
..fidence band lue for raw score :	±4.3	±5.6	±5.9	±5.6	±5.8	±12.8

COPING RESOURCES INVENTORY REPORT FORM

DEFENCE



	Cognitive	Social	Emotional	Spritual	Physical	Total
aw Scale Score :	29.8	41.7	47.6	33.7	37.0	190.0
onfidence band alue for raw score :	±4.3	±5.6	±5.9	±5.6	±5.8	±12.8

DEVELOPMENT OF A STANDARD EVALUATION PROCEDURE FOR CANDIDATE MEMBERS OF SOUTH AFRICAN EXPEDITIONS TO ANTARCTICA

Selecting the "right" type of personality to overwinter in Antarctica remains a nagging problem for many managers of Antarctic programmes. Criteria on which a selection procedure for Antarctic personnel should be based is not available and existing criteria for other environments fall short of the Antarctic situation.

During 1990, it was decided to evaluate the success of personnel selection for the SOUTH AFRICAN NATIONAL ANTARCTIC PROGRAMME. Although psychological assessments had been done over many years, these could not be readily matched against a "required profile". Furthermore, since no standard was available against which existing results could be measured, it was decided to use the number of team members who were judged successful/unsuccessful in the social and task environment as the point of departure for further study.

As industrial psychological assessments were being done on all applicants at the time, it was estimated that the success rate was about 70%. Although this figure was considered adequate, it was also felt that improvement was possible, and that an effort should be made in this direction. Closer inspection confirmed that no scientifically compiled "required profile" existed against which applicants could be measured, as scientific information in this area was very limited.

Apart from being unable to match a candidate's profile against a required standard, it was also ascertained that the final results of the psychological assessments being done at the time were not being tested against previous assessments. Personnel who conducted the psychological assessments, did not have the opportunity to assess their own results as they were not informed in any way ragarding the success or failure of their evaluations of candidate expedition members. To be able to assess their profiling of candidate members, psycologists would have to have insight into the performance of each member during his/her stay in Antarctica. It was decided that to pursue this avenue (psychological assessments and evaluation of results) in order to create a pool of in-depth knowledge regarding the issue, would be impractical, very expensive, and valid results could only be expected after a period of at least five years. Trained, dedicated personnel would also be required, and the extent and frequency of the requirement did not warrant this solution.

After some deliberation, a different approach was suggested and accepted. The assumption was made that any personnel manager with some (5 years or more) job experience and insight into the prospective working environment of the candidate, would attain approximately the same (70%) success ratio. It was also accepted that the success rates of Industrial psychological assessments were proven to be higher only in cases where an established "required profile" existed. Since this could only be attained after careful and time-consuming research, which was clearly out of the scope of the exercise, the establishment of a standard for assessment was attempted using personnel experienced in the requirements of people overwintering in Antarctica. A group of experienced personnel, administrators and an industrial psychologist was convened to participate in a brainstorming session in order to come up with a "straw dog" or "provisional profile". It was anticipated that the higher the incidence of practical experience in such a group, the better the results would be. A copy of the original document or "Tool for Evaluation" that was produced as a result of this session is attached as Annexure A. The purpose of this "tool" was to enable the conducting of an interview in a structured format, where all members of the panel evaluated candidates following certain fixed criteria, without excluding an opinion based on so-called "gut-feeling".

Various problems were experienced with the original format of this "tool", mainly due to the inconsistent interpretation of the questions by interviewers. The format was therefore improved in an effort to eliminate these problems (Annexure B). However, it soon became apparent that a complete revision of the document was neccessary, and that some aspects of the provisional profile needed careful re-evaluation. For example, after studying the results of returning expedition members and comparing these results with the evaluation standard, it was found that an aspect of the provisional profile, namely military training, was more likely to have a negative rather than a positive impact as was formerly accorded. The revised document for the evaluation of candidate expedition members is attached as Annexure C, and is the format which is currently in use. It must be stressed that this "tool" is not the final product and it may well happen that one or more of the criteria will be found to be invalid.

The next step is to analyse data procured about returning overwintering personnel, as per reports from team leaders and deputy team leaders. This will be done in consultation with Prof C Vermeulen of the University of Pretoria who obtained his PH.D. on the *"Validation of psychological variables via the prediction of adaptation to Antarctic conditions"*.

The present standard evaluation procedure for candidate members of South African Expeditions to Antarctica consists of 10 criteria points. Points 1 to 4 require factual information, are not open to interpretation and may well be used in the initial screening process. Points 5 to 10 are open to the opinions and impressions of the interviewers, and should be debated at the conclusion of every interview.

The added weights (values 2 - 4) on the front page of the evaluation form, allow for higher values on points 5 to 9, which in turn allow the interviewers to motivate their impressions on maturity, etc. Point 10 allows the interviewers to indicate their personal, subjective opinion of the candidate and which, in our opinion, should carry the least weight. The fact that the weighted totals add up to 100, is a mere co-incidence and was not designed during the compilation stage of the form.

The last page of the form lists some elementary explanations and guidelines to increase awareness of all the problems likely to be encountered by interviewers. This page should be referred to regularly by the leader of the interviewing team to ensure that every interviewer is familiar with these guidelines. It is important to note that this form was developed only to assist the interviewer and not to replace his subjective observations or "gut feeling" which is still considered to be of the utmost importance. It is for this reason that interviewers are encouraged to discuss their opinions so that in time, an improved defined standard may be developed.

Preliminary results have shown a marked increase in the success rate of selection (between 90% and 100%). Assessed profiles of candidates can be successfully matched to the proposed team and leadership capabilities of individuals can be identified during the assessment. One major conclusion that the interviewers have reached is that the maturity of the candidate determines his projected success, and for this purpose points 5 to 8 are invaluable during the interview.

I would like to emphasize again that this evaluation procedure is merely a "tool" for use during interviews, and the interviewer should still be allowed to reject an applicant on "gut feeling", even if the applicant achieved a very high rating. This should be allowed to continue until such time as the "tool" has been accepted as valid.

The reference material used in the compilation of this form is as follows:

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EXPEDITION MEMBERS

OUT OF 1 - 3 AS INDICATED

	VALUE	X	CANDIDATE	=	TOTAL
AGE	1	X		=	
ACHIEVEMENT	1	X		=	
SPORT	2	X		=	
PHYSICAL	2	X		=	
MILITARY TRAINING	2	X		=	
IMPRESSION	2	X		=	
EXPERIENCE	3	X		=	
PERSONALITY	3	X		=	

MINIMUM VALUE 36
TOTAL

APPROVED/REJECTED/LATER CONSIDERATION

NAME:____________________

POST:____________________

1. AGE	1 20 40	2 20 - 27	3 24 - 32	4 25 - 40
2. ACHIEVEMENTS (ANY)	NONE	SCHOOL	POST SCHOOL	DETAIL
3. SPORT	NONE	PREVIOUSLY LIMITED PARTICIPATION	INTENSE PREVIOUS PARTICIPATION (NO LONGER ACTIVE)	STILL ACTIVE
4. PHYSIQUE	UNDERWEIGHT OVERWEIGHT	SLOPPY POSTURE	NORMAL	MUSCULAR
5. MILIARY TRAINING	NO	-	-	YES
6. IMPRESSION	1	2	3	4
7. EXPERIENCE/KNOWLEDGE	NOT APPROPRIATE	30%	70%	APPROPRIATE
8. PERSONALITY	IMMATURE	?	MATURE	SELF MOTIVATED (GO GETTER)

1.A AVERAGE OF 4 PERSONS PER INTERVIEW

2.DETERMINE AVERAGE POINT OF INTERVIEW

ANNEX A (2)

ANNEX B (1)

INTERVIEW EVALUATION: EXPEDITION MEMBERS

		VALUE			CANDIDATE	TOTAL
1		2		X		=
2		1		X		=
3		3		X		=
4		2		X		=
5		3		X		=
6		2		X		=
7		4		X		=
8		3		X		=
9		3		X		=
10		4		X		=
11		3		X		=
				X		=

APPROVED/REJECTED *MINIMUM VALUE* *TOTAL*

REMARKS

ANNEX B (2)

NAME: ______________________

POST: ______________________

BASE: ______________________

		1	2	3	4
1	AGE	< 20 > 40	20-27	24-32	25-40
2	ACHIEVEMENT (ANY)	NONE	AVERAGE	GOOD	EXCEPTIONAL
3	SPORT	NONE	PREVIOUSLY POOR PARTICI-PATION (NOT ACTIVE ANY MORE)	INTENSE PREVIOUS PARTICIPA-TION	STILL ACTIVE
4	PHYSIQUE	OVERWEIGHT UNDERWEIGHT	SLOPPY POSTURE	NORMAL	MUSUCLAR
5	MILITARY TRAINING	NO	-	-	YES
6	EXPERIENCE/KNOWLEDGE	NOT SUITABLE	30%	70%	APPROPRIATE
7	PERSONALITY	IMMATURE	-	-	MATURE
8	MOTIVATION/PHILOSOPHY	SATISFIED	CONCERNED	MOTIVATED	SELF-MOTIVATED (GO GETTER)
9	CONVICTION/ATTITUDE	DOGMATIC	NO CONVICTION		PRINCIPLED
10	IMPRESSION	1	2	3	4
11	LEADERSHIP	NO			YES

1. AT LEAST 4 INTERVIEWERS MUST BE PRESENT WITH EVERY APPLICANT'S INTERVIEW

1. *SELFEXPLANATORY*

2. *ACHIEVEMENT:*
    1. No achievement
    2. Most people can accomplish this achievement
    3. He has particular drive
    4. Exceptional drive

3. *SPORT:*
    1. None
    2. Previous participation
    3. Intense previous participation
    4. Still active

4. *SELFEXPLANATORY*

5. *SELFEXPLANATORY*

6. *EXPERIENCE/KNOWLEDGE*
    1. No experience
    2. Has qualifications but no experience
    3. Has qualifications and practical experience
    4. Has qualification and practical experience of place equipment

7. *EVALUATE ACCORDING TO OWN FRAME OF REFERENCE*

8. *MOTIVATION/PHILOSOPHY*
    1. Has no ideals or aims for further development
    2. Wants to change circumstances but does not know how
    3. Ambitious
    4. Selfexplanatory

9. *CONVICTION/ATTITUDE*
    1. Resistance to change
    2. Wants to do something but do not know how
    3. Shows understanding for the standards of others
    4. Selfexplanatory

10. *OWN IMPRESSION OF CANDIDATE AS ABOVE (7)*

11. *JUDGE ACCORDING TO OWN FRAME OF REFERENCE*

ANNEX C (1)

STANDARD EVALUATION PROCEDURE FOR CANDIDATE MEMBERS OF SOUTH AFRICAN EXPEDITIONS TO ANTARCTICA

APPLICANT

NAME:
POST:
BASE:

INTERVIEWER

NAME:
DATE:
SIGNATURE

1 At least 5 interviewers should be present at each interview.

2 Use a red pen during evaluation.

3 It is important that the applicant should not be given the benefit of the doubt.

INTERVIEW STIPULATION

The value of characteristics are weighted from 1 - 4 as indicated in order to determine the final weighed value

	VALUE	CANDIDATE	TOTAL
1. EXPERIENCE	1X		
2. PHYSICAL	2X		
3. SPORT	2X		
4. AGE	1X		
5. ACHIEVEMENT/DRIVE	3X		
6. PERSONALITY	4X		
7. MOTIVATION/PHILOSOPHY	4X		
8. CONVICTION/ATTITUDE	4X		
9. LEADERSHIP	3X		
10. IMPRESSION	1X		
MAXIMUM = 100		TOTAL	

APPROVED/REJECTED/REJECTED WITH RESERVATION
COMMENT ____

____

____

ANNEX C(2)

1.EXPERIENCE

1 No experience
2 Has qualifications but no practical experience
3 Has qualifications and practical experience
4 Has qualifications and practical experience of bas equipment

1. NOT APPLICABLE	2. 30%	3. 70%	4. APPLICABLE

2. PHYSIQUE

1. OVER WEIGHT/UNDER WEIGHT	2. SLOPPY POSTURE	3. NORMAL	4. MASCULINE

3. SPORT

1 No previous participation
2 Previous participation
3 Intense previous participation
4 Still active/currently participating

1. NONE	2. PREVIOUS	3. INTENSE PREVIOUS	4. ACTIVE

4. AGE

1. <20 - >40	2. 20-27	3. 24-32	4. 25-40

5. ACHIEVEMENT/DRIVE

1 No drive/no achievement
2 Most people can accomplish this achievement
3 Has particular drive
4 Exceptional drive

1. NONE	2. AVERAGE	3. GOOD	4. EXEPTIONAL

6. PERSONALITY

Profile

IMMATURE
Applicant continuously tries to prove himself
Accent on rebelliousness - clothing, hair style, behaviour, etc.
Does not want to accept responsibility
The self is his strongest motivator
MATURE
Undertakes tasks with confidence and knowledge
Conforms to socially acceptable behaviour and appearance
Ambitious. Realises consequences and results of own behaviour
Accepts responsibility for own environment and fellow-man

Possible questions

- Define the following concepts:
  Responsibility, Acceptable social behaviour, A team/group, Leader
  Motivation, Environmental factors which influence you
- What do you still have to do before the expedition departs

1. IMMATURE	2.	3.	4. MATURE

7 MOTIVATION/PHILOSOPHY

Profile

1 Has no ideals or aims for further development. No medium or long term vision.
Satisfied with current circumstances and does not want to change.
2 Restless but no defined goals. Frustrated with current situation
Wants to change circumstances but does not know how
3 Has defined goals. Spends time on self improvement
Spends time on self improvement.Finds inspiration in the success of others
4 Works on self improvement. Obtains results.
Views obstacles/resistance as a challenge

Possible questions

- What are your aims for the future?
- What are you going to do when you return from the expedition?
- Are you satisfied with your current circumstances?
- Who or what in your environment inspires you to strive for improvement?
- What results did you achieve with undertakings embarked upon?
- Which obstacles did you have to overcome in order to achieve these results?
- Which of your goals have already been achieved?

1. SATISFIED	2. WORRIED	3. MOTIVATED	4. SELF MOTIVATED

8. CONVICTION/ATTITUDE

Profile

1 Not prepared to listen to other opinions
Own convictions are correct - no negotiation
Observations/opinions which differ from own are wrong
2 Changes opinions/views to suit himself
Poor insight - does not take a stance
Easily influenced - does not live according to own goals
3 Prepared to defend own point of view
Searches for correct answers
Shows understanding for the standards of others
4 Well-considered viewpoints
Demonstrates well-motivated philosophy
High moral standards
Supports factuality and logical views

Possible questions

- In your view, what will the local political situation be in five years time?
- Why do you think does one become a:
  Prostitute: male/female   Hobo
  Homosexual   Satanist
- What is your point of view on abortions?

1. DOGMATIC	2. NO CONVICTION	3. CONVINCABLE	4. PRINCIPLED

9. LEADERSHIP

Profile

NO LEADERSHIP QUALITIES
1 No experience in leadership positions
2 No idea of leadership's problems
3 Does not demonstrate leadership qualities
4 Necessary self confidence is lacking
HAS LEADERSHIP QUALITIES
1 Quite some experience and success
2 Can distinguish between leadership and forcing one's will
3 Can distinguish between popularity and discipline
4 Can distinguish between personalities

Possible questions

- Which leadership positions have you occupied in the past?
- Which problems did you encounter in your position as leader?
- Distinguish between a leader and someone who forces his will.
- Which personality characteristics can be found in a:
  Diesel mechanic   Good team member
  Communicator   Scientist
  Doctor

1. NO	2.	3.	4. YES

10. INTERVIEWER'S IMPRESSION OF APPLICANT

NB: NOTE THE APPLICANT'S:
1 Appearance, clothing, conduct, self image, self confidence
2 Verbal expression, language abilities
3 Nervous, relaxed
4 Serious, jovial
5 Self esteem, flattery
6 Honesty, concealment

1.	2.	3.	4.

1.EXPERIENCE

1 No experience
2 Has qualifications but no practical experience
3 Has qualifications and practical experience
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Possible questions

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Homosexual Satanist
- What is your point of view on abortions?

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1 Appearance, clothing, conduct, self image, self confidence
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5 Self esteem, flattery
6 Honesty, concealment

1.	2.	3.	4.

ANNEX C(4)

OBJECTIVE VS SUBJECTIVE

OBJECTIVE Impartial; without being influenced by your own feeling and preference.
SUBJECTIVE Partial and prejudiced; tendency to take your own perception as ground/basis for all your opinions.

Objectivity in this case refers to the structured interview where every characteristic of the applicant is evaluated by the interviewers and which recurringly ought to give the same results by another team. It is thus scientifically reliable. Contrary to this, subjectivity is a "loaded" opinion of the interviewer which is saddled with any of a diversity of factors that vary from one interviewer to another.

A short list of potential factors that may influence the interviewer is given for your attention. However, this is not a complete list and interviewer should be aware of other factors that might influence his decision.

Snap judgement - Interviewer forms opinion *coup d'oeil* (at a glance)
Premonition - Undefined (gut) feeling of liking/disliking someone
Perception - Something about appearance/conduct does/does not appeal to interviewer
Candidate order - Instinctive comparison with previous/next candidate Halo effect
Nonverbal emphasis(body language) - Impression of interviewer are unknowingly effected
Stereotype - Refer to fixed ideas of interviewer, such as "not too bad for a diesel mechanic/stammerer/coloured"
Pressure to hire - There are few or no other candidates

It is important to remember that the subjective opinion of the interviewer is seldom clear to himself. This aspect of interviewing should not be suppressed but should rather follow a route of identifying, analysing, evaluating, motivating and debating. The interviewer must write down his clearly motivated opinion. Other interviewers will also benefit by analysing their own subjective opinions. The value of the interviewer's observations can then also be evaluated at a later stage.

Interviewers must be prepared to change their opinion should grounds exist for such a change. Perception of a candidate or other person is a function of the time the interviewer/adjudicator has been exposed to the candidate/person. This aspect can also be described as follows: more time = more information = more knowledge = better analyses = better motivated decision.

Interviews properly administered and done according to the following guidelines can be a valid and reliable screening device.

1. Use a structured form
2. Delay your decision. Interviewers often make their decisions before interviewing the candidate or during the first five minutes of the interview.
3. Focus on aspects of concern: e g intelligence; ability to get along with others; motviation to work; etc.
4. Let the interviewee do the talking.
5. Be objective. Give every candidate an equal chance. The interviewer must be able to motivate his choices.

STANDARD EVALUATION PROCEDURE FOR CANDIDATE MEMBERS OF SOUTH AFRICAN EXPEDITIONS TO ANTARCTICA

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NAME:
POST:
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2. PHYSICAL	2X		
3. SPORT	2X		
4. AGE	1X		
5. ACHIEVEMENT/DRIVE	3X		
6. PERSONALITY	4X		
7. MOTIVATION/PHILOSOPHY	4X		
8. CONVICTION/ATTITUDE	4X		
9. LEADERSHIP	3X		
10. IMPRESSION	1X		
MAXIMUM = 100		TOTAL	

APPROVED/REJECTED/REJECTED WITH RESERVATION
COMMENT ____

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5. Be objective. Give every candidate an equal chance. The interviewer must be able to motivate his choices.

Construction of a Glacial Ice Runway and Wheeled Flight Operations at McMurdo, Antarctica

George L. Blaisdell, Renee Lang, Gerald Crist, Keith Kurtti, Jeff Harbin, and Dan Flora
US Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire

INTRODUCTION

The US Antarctic Program (USAP) relies on aircraft operating between Christchurch, New Zealand, and McMurdo to provide nearly all of its personnel support and a considerable amount of cargo transport to the continent. The austral summer field season effectively begins in early October when the relatively smooth-surfaced annual sea ice in McMurdo Sound is of sufficient thickness to support heavy aircraft. Wheeled C-130 Hercules, C-141 Starlifter, and C-5 Galaxy aircraft operate routinely from this runway until mid-December. Around 15 December each year, the near-melting air temperatures and the intense 24-hour-per-day sunshine combine to deteriorate the sea ice surface and force the abandonment of the runway.

Flight operations then shift to the only semi-permanent runway, Williams Field. This is a groomed skiway located on a deep snowfield on the Ross Ice Shelf near McMurdo. Only very light or ski-equipped aircraft can operate from this skiway because of its low bearing strength. To satisfy the logistics needs of the more than 1000 persons participating in the program during mid-season, the USAP utilizes specialized LC-130 Hercules that are equipped with both skis and wheels.

Until the 1992-93 season, the USAP was limited solely to the LC-130s for all air transport from the time the sea ice runway closed throughout the remainder of the field season that ends in late February. Very few LC-130s exist: five owned by the National Science Foundation and operated by the US Navy, and four contracted from the New York Air National Guard for brief periods. With the many requirements for their use, a backlog of personnel and crucial cargo normally occurred, which severely constrained the Program during mid- and late-season.

RUNWAY DEVELOPMENT

Beginning in the 1989-90 summer season, engineering studies were directed at determining the feasibility of producing a runway for wheeled aircraft on the Ross Ice Shelf near McMurdo, specifically for use during the period after the sea ice deteriorates. Using historical records and air photos, a site 13 km south of McMurdo was chosen in an area with a thin, but permanent and complete, snow cover (Mellor and Swithinbank, 1989; Fig. 1). At this location, called the Pegasus site, the snow is underlain by a contiguous mass of glacial ice that is derived from a combination of natural seasonal melt water (near the surface) and ice formed by metamorphosis of snow (Klokov and Diemand, in press). The supply of highly reflective snow available at the Pegasus site is necessary as a source for protecting the runway from melt pool formation due to the effects of absorbed solar radiation (Paige, 1968).

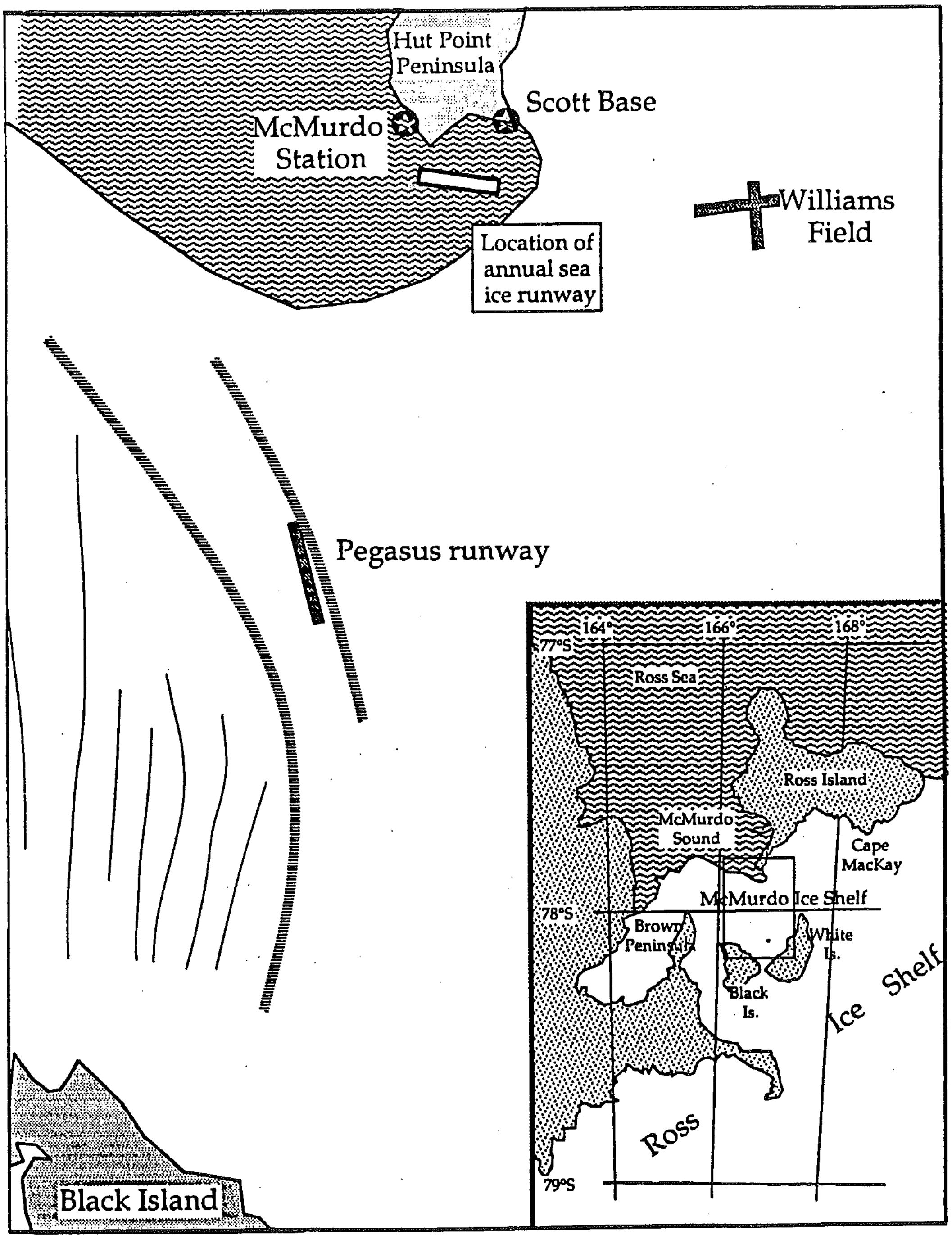

Figure 1. Location of the Pegasus glacial-ice runway site in relation to McMurdo.

Initial Open-Up

At the selected runway site, we took survey data throughout the entire 3000-m length of the runway. Using a 1-m spacing, data were taken along the centerline and the east and west sides of the runway. This information was used to generate a three-dimensional map of the runway surface. From this, it was clear that removal of short-frequency bumps was the important task.

Snow cover averaged about 30 cm in late August on the proposed runway. We planned for removal by stripping and loosening the snow using both a large V-plow and a large bulldozer U-blade. This would be followed by a high-capacity snow blower to remove the snow to the sides of the runway. Our plan for snow removal was based entirely on the use of mechanical means. In retrospect, we may have been able to take advantage of strong winds (which occur at specific times of the season) to assist in snow removal by loosing the snow and piling it in rows parallel to the wind direction.

We used the V-plow mounted to the front of a Caterpillar 14G grader equipped with oversize tires to make the first opening passes on the Pegasus runway. There were several drawbacks to this approach that caused us to abandon its use.

A 1950s-era Caterpillar LGP D8 equipped with an oversize (coal) U-blade proved a better solution for stripping the snow from the glacial ice surface (Fig. 2). At first the bulldozer operator worked by feel, attempting to hold the blade just at the snow-ice interface, but this proved to be unsatisfactory. Owing to the undulating ice surface and the need to provide some down-force on the blade to keep it from riding up in the snow pack, the blade gouged into the ice. To assist in feeling the ice surface and to avoid gouging, we built and equipped the blade with skis that were sized to easily penetrate the snow to the ice surface, but with enough bearing surface to avoid damaging the ice. When operating, a huge mound of snow would build up in the bulldozer blade and would ride up the curvature of the blade as the tractor moved forward at good speed. Upon reaching the top edge of the blade, the snow would smoothly roll forward in front of the blade to be re-ingested a few moments later. This repeated tumbling action broke up the hard, layered snow and mixed it into a homogeneous, loose mass of snow that would eventually pour out the sides of the blade, leaving two windrows.

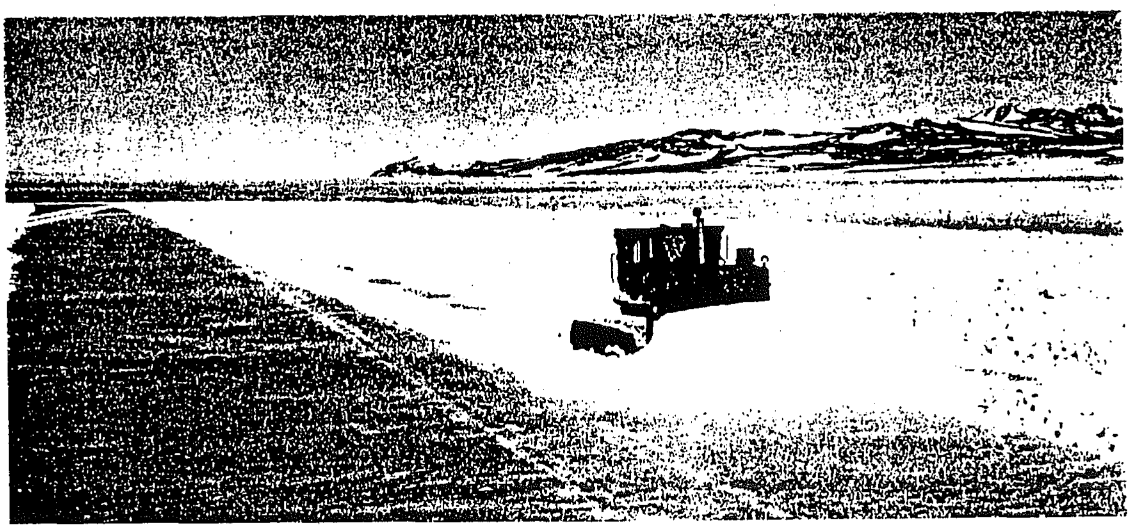

Figure 2. Bulldozer with oversize U-blade stripping snow from natural ice surface.

To remove the snow from the runway area, we utilized an Oshkosh Truck prime mover equipped with a Rolba snowblower (Fig. 3). The 2.6-m-wide, two-stage blower had a 1.5-m-diameter ribbon-style drum. The blower was rated for 2.7 Mkg/hr with a casting distance of 46 m. By operating the snowblower along the windrows generated by either the grader or the bulldozer, the capabilities of the blower were best utilized.

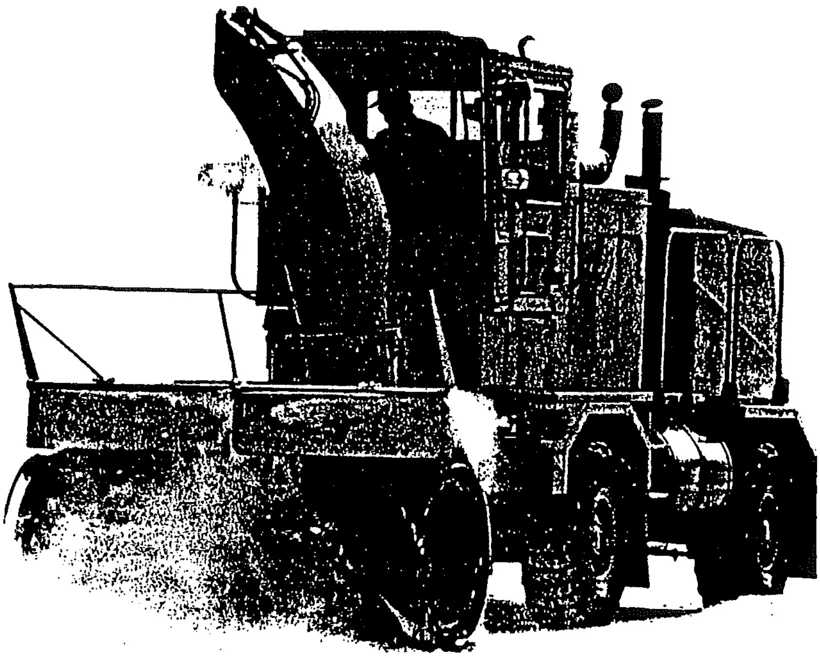

Figure 3. Prime mover and snowblower used to move snow and graded ice.

Rough Grading

Using the natural ice survey results and estimating a final grade that would minimize construction, it was easy to see which areas required the most effort. Calculations based on the survey data and an accounting of our known constraints (workforce size; seasonal operating windows; equipment resources; support requirements, such as fuel), were used to developed a two-year construction schedule.

To fully expose the ice, allow close inspection of the surface, and begin leveling the surface, we dressed the runway with a custom-built grader blade designed to scrape the ice surface and to shave short wavelength (<6 m) bumps. This was a somewhat laborious and subjective process in that the grader operator chose areas that clearly had high spots and would work them until he was satisfied that the surface was down to a level no more than a few centimeters above its surroundings. This work did not progress in a linear fashion, although, in general, the runway received its first grading along its entire length in grader-width strips progressing from one side to the other. When a region of bumps was identified, the grader would operate back and forth to bring them down to a reasonable level before continuing to work along its chosen north-south swath.

We discovered that the 14G grader, equipped with the chisel-tooth blade, could remove as much as 20 cm of ice in one pass. However, this often resulted in propagating down into the ice the radial cracks that are nearly always associated with large ice blisters. In some cases, a very large slice of ice was broken loose as the result of catching one of these cracks when grading off a thick layer of ice. Usually, the "divot" removed was considerably deeper than desired. Removal of thick layers of ice also encouraged "chatter" or hopping of the grader, which left a choppy and gouged ice surface. Thus, it was necessary to grade the ice in more modest cuts, with 14 cm layers being manageable with no ill consequences.

The geometry of the chisel-teeth and the angle of attack when grading are of utmost importance when attempting to grade ice. Following guidance in Mellor (1977) and somewhat by trial and error, we manufactured the chisel-teeth on our first blade with a height of 7 cm, an internal angle of 40 degrees, and with side relief angles of about 30 degrees. The basal relief angle was about 30 degrees with the blade aligned perpendicular to the long axis of the grader. However, when grading ice, the blade was positioned at an angle between 27 and 33 degrees to the direction of travel to allow the spoil to be efficiently removed. Thus, the actual relief angle was about 26.5 degrees behind the chisel tooth in the direction of travel. The blade position also caused the ice to be attacked with a pointed edge of the chisel-tooth rather than head-on as one would normally use a wood chisel, or as in the case of the cutting edge on an ice auger. In trials on the first ice bumps, we quickly found the proper set-up angles for the grader to facilitate smooth and efficient ice grading. For propulsion, when cutting ice with an efficient blade that is held in the proper position, we calculated that 37 kW of power were required for each lineal meter of blade width. During rough grading, we easily maintained 5 km/hr with the grader.

The snowblower was used to remove the ice spoil piled up by the grader. Since most of the spoil material consisted of fist-sized chunks of ice, we were cautious about the rate of advance with the snowblower. Ingestion of the ice created significant vibration throughout the snowblower and prime mover, but, even after 1500 hours of operation and the processing of $1x10^9$ kg of ice, only a few broken, and easily repaired, parts were suffered. Once the snowblower removed the spoil from this grading, a mostly exposed surface of ice remained.

We learned that there were many advantages to matching the speed and capacity of the snowblower to the characteristics of the grader. The most important factor was that windrows were never present for long periods of time. This meant that additional drift snow was not trapped and that the snow in the windrows was not allowed to setup and become hard after the working process of the blade, thus reducing the power needed to pick up and throw the snow. We determined that 122 kW of snowblower power was needed to match output with each meter of grader blade width.

Following initial grading and debris removal, we thoroughly inspected and cored the runway to determine ice integrity, including the presence of cracks, variations in ice appearance or surface strength, and potholes or other melt features. Cores were taken, especially in low spots, to determine how much ice might need to be graded to remove all porous or weak ice. This weak ice, which we called trash ice, was typically found in the shallow basins on the runway surface and often had large bubbles, incorporated lenses of snow, and high concentrations of mineral particles. The trash ice had little bearing strength and in areas would break under the pressure of small utility truck tires.

Filling of Low Areas

At the Pegasus site, a large local depression extended between the 1500- and 2100-m markers along the runway and spanned the full width of the runway. To avoid a significant amount of grading in this area to arrive at a level surface, we chose to fill this basin. We approached this task by massive flooding of the area using a portable snow snowmelter. Filling this way created several problems (e.g., instigation of glacial ice melting, heaving and cracking upon freezing). In the future, we know that large fill operations should be conducted only at low temperatures, in the range of -10°C or less. Low areas should be prepared before water application by essentially filling the entire basin with snow and (preferably) broken-up ice chunks. Construction debris is ideal for this purpose, and the grading following initial strip-off should provide ample material of an ideal mix of snow and ice. This fill material should be compacted as much as possible by repeated passes with a vehicle.

Once the low area is filled with compacted snow and ice, it should be flooded slowly with fresh water from the edges. The goal is to flood the interstices of the compacted snow and ice fill from the bottom up. This allows air to escape and ensures that no large pockets of unsaturated fill are trapped and that the water freezes quickly. In essence, the fill procedure should simulate an ice bath that is allowed to freeze rapidly, thus creating a mass of small-grained, randomly oriented ice crystals. This will produce a very strong filler for the low area.

Final Grading

The final grade for the Pegasus runway was set in three segments. This decision was based on minimizing the amount of grading necessary following our final ice reconnaissance, inspection of cores for weak ice, and filling of the large depression. We attempted to match the natural topography as much as possible but still yield a surface that met the roughness standards for the most stringent requirements associated with the aircraft to use the facility. This approach also reduced the amount of debris to be removed from the construction process. Each of the three segments was designed to exactly match elevation at their intersection points. Two of our segments were actually level (0-460 m and 1800-3000 m). The grade on the sloping segment was only 0.02%.

The most efficient means of producing a final grade was to utilize a laser-guidance system. By coupling an experienced operator with a laser system, significant advantages are gained when producing an ice runway surface. The system we used could operate in a 300-m-diameter circle and thus allowed us to grade 300 m of runway for each surveyed position (the position of the laser transmitter). Long-wavelength bumps (i.e., greater than the wheel base of the grader) were removed even though they were often undetectable by the grader operator. Also, even on sunny days, there was often very little visible contrast when working on ice and it was difficult for the operator to "work by eye" to produce a level surface. In addition, there were many days when weather conditions reduced surface visibility to near zero due to diffuse light and/or blowing snow. We found that the laser system was able to function well and to produce an accurate grade even when the grader operator had great difficulty seeing well enough to drive in a straight line.

For finish grading, we used a different chisel-tooth design for the blade than was used for initial grading. This blade appeared more aggressive than the one used for the first passes and was designed with an alternating tall- and short-tooth pattern to assist in cleaning the surface of all debris. The geometry of the cutting teeth was similar to the rough-grade blade with an included angle of 42 degrees and side relief angles of 41 degrees. However, the cutting teeth were considerably longer at 9.6 cm. The cleaning teeth had an internal angle of 60 degrees, a height of 5.7 cm, and no side relief cutout. The lower edge of the cutting teeth was flared to a width of 5.7 cm and was 4 cm closer to the ice than the cleaning teeth. For most of the runway, only one pass was required to arrive at the desired final grade due in part to the large amount of work done during rough grading. The grader mostly removed less than 4 cm during final grading and could maintain a speed of 3-4 km/hr.

Using the laser system, each 300-m segment of the runway was graded to yield either a level or sloped surface (Fig. 4). All surfaces were level across the width of the runway. We also graded "negative" slopes (2%) away from the runway along all of its borders as a precautionary measure against free flowing water that occasionally invades the area during some summer seasons. These slopes extended out from the runway edge for a distance of 7 meters. This created protective "ditches" along the flanks of the runway. The ditches had a net northward pitch to them, so that moving surface water would be deflected away from the runway itself. These flank areas were covered with a significant amount of snow (<1 meter) following construction to protect them from deterioration and to assist in impeding water flow onto the runway.

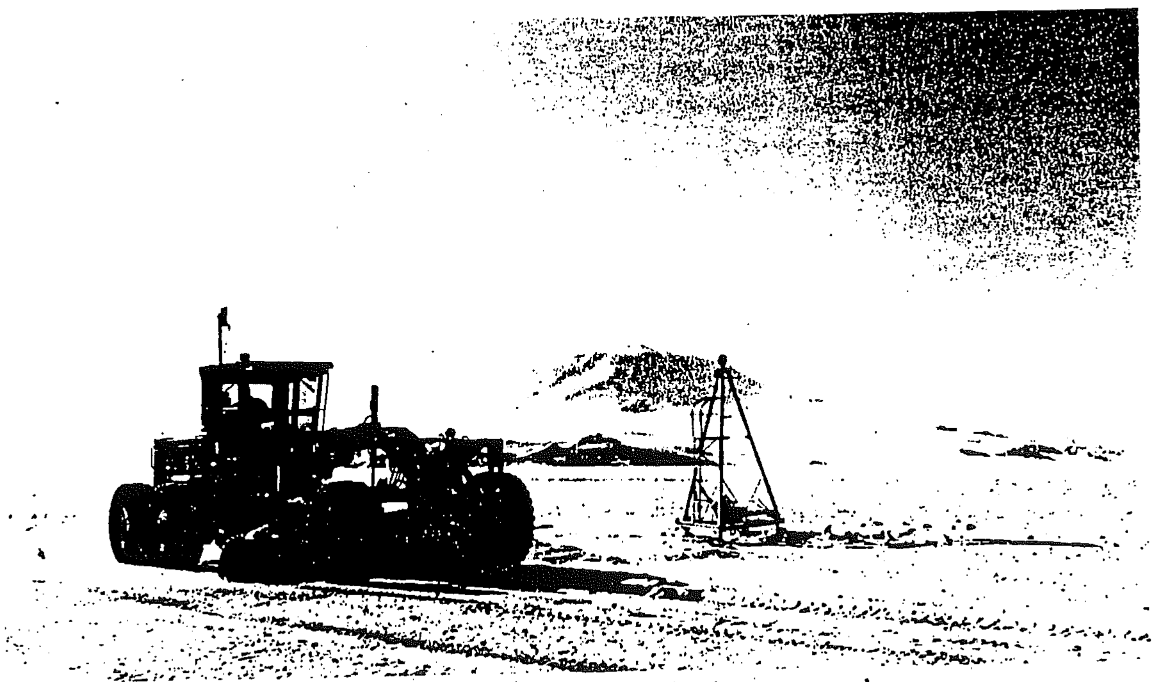

Figure 4. Grader cutting ice with blade under laser control.

Certification of Runway Strength

In preparation for wheeled aircraft operations, the bearing capacity of the runway was tested with a load cart. The cart was capable of replicating the main landing gear of a C-130 or C-141 and was capable of being ballasted to a level more than 30 percent greater than the maximum allowable load on the main landing gear of the design aircraft. The runway was tracked with the cart along its entire length, as well as overrun areas at either end (Fig. 5). Tire tracks were placed no more than a meter apart.

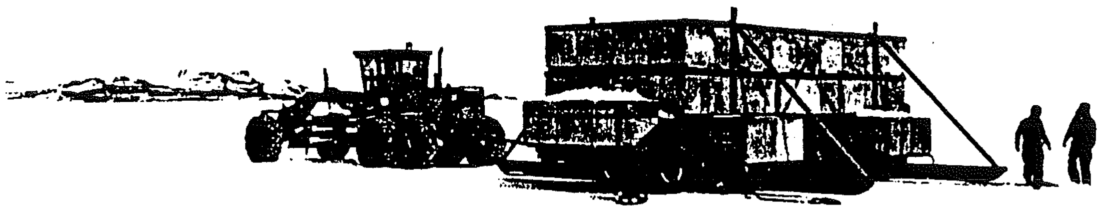

Figure 5. Load cart configured for proof testing runway for C-141 aircraft..

During proof testing at the C-130 load level in January 1993, approximately 30 weak spots were found. In these locations, the ice failed by crumbling, leaving a slight depression in the surface. Excavation of the failed points revealed that they had an average size of 3 m^2 and were 15-45 cm deep. In nearly every case, failure points were associated with a thin (3- to 5-mm) gap. This gap was most likely caused during refreezing of melt pools that were known to have been present at this site during the 1991-92 field season, when initial construction activities exposed the ice surface during the peak of summer.

Each failure point was excavated and all of the fractured ice around the edges was dislodged. The ice chunks were broken into fist-sized pieces and packed into the cavity. Cold water was used to flood the cavity, making an ice bath that froze completely within 48 hours. Numerous patched spots were retested and all were found to be sound. On 1 February 1993, the runway was certified for operation of wheeled Hercules aircraft.

During the 1993-94 season, the proof cart was reconfigured to duplicate the C-141 main landing gear and it was ballasted to a mass of greater than 174,000 kg. This loaded each tire to approximately 25 percent greater mass than the maximum takeoff load on the main wheels of a C-141. The tires were inflated to 1800 kPa, compared to the 1400 kPa maximum pressure for the C-141.

Proof testing of the runway for C-141 aircraft was completed immediately after stripping of the protective snow cover on 10 January 1994. No failures were found of the type seen the prior year. Several shallow gouges were detected and patched. It was determined that these were caused by a bulldozer blade during clearing of winter-over snow. Proof testing was completed in two days, and the runway was then dragged and planed to provide an extremely smooth operating surface. The runway was certified for both C-130 and C-141 operations and opened for air operations for the 1993-94 season on 25 January.

Test Flights

Before becoming operational for wheeled aircraft, a flight test was performed to determine the high-speed characteristics and surface traction of the runway. On 6 February 1993, an LC-130 operating on wheels performed tests, including a light landing (46,300 kg), high-speed taxi, steering, braking (including locked wheel), heavy takeoff (56,750 kg), touch-and-go landing, full-stop landing, taxi on skis, and an opposite direction takeoff. All test flight results were deemed excellent by the flight crew. Inspection of the runway by the design and construction team noted no ill effects to the runway surface. The runway then opened for Hercules operations for the remainder of the 1992-93 season.

In preparation for the C-141 flight test in early February 1994, we again utilized an LC-130. On 25 January 1994, an empty Hercules landed and completed high-speed taxi tests, braking tests, and a takeoff, all from wheels. The flight crew reported that the runway had a superb operating surface and that it was smoother than many of the concrete runways from which they operate. They also reported that the runway was visible from 100 km away when approaching on a clear day.

On 7 February 1994, a C-141 flew from Christchurch to a landing on the glacial-ice runway, marking the first-ever C-141 landing on a glacier (Fig. 6). The plane weighed 104,420 kg on landing. It touched down exactly at the north-end zero threshold and had reached a slow taxi speed within 1800 m using wheel brakes and a slight amount of reverse thrust. The C-141 taxied the full length of the runway, executed a turnaround without difficulty, and slowly taxied back to the ramp at the north end where it turned fully to align with the fuel pit. Some front wheel skidding occurred during this sharp turn.

Conversations with the C-141 pilot and his crew indicated extreme satisfaction with the runway. The remarkable degree of smoothness was consistently mentioned; observers at the 1500-m mark could detect no wing deflections at touch-down or during run-out. The aircraft was fueled and loaded with three pallets of priority science cargo. Fifty-four passengers boarded and the C-141, at a mass of 127,120 kg, proceeded with takeoff, pulling clear of the runway at the 1500-m mark. The runway suffered no damage from the C-141 operation.

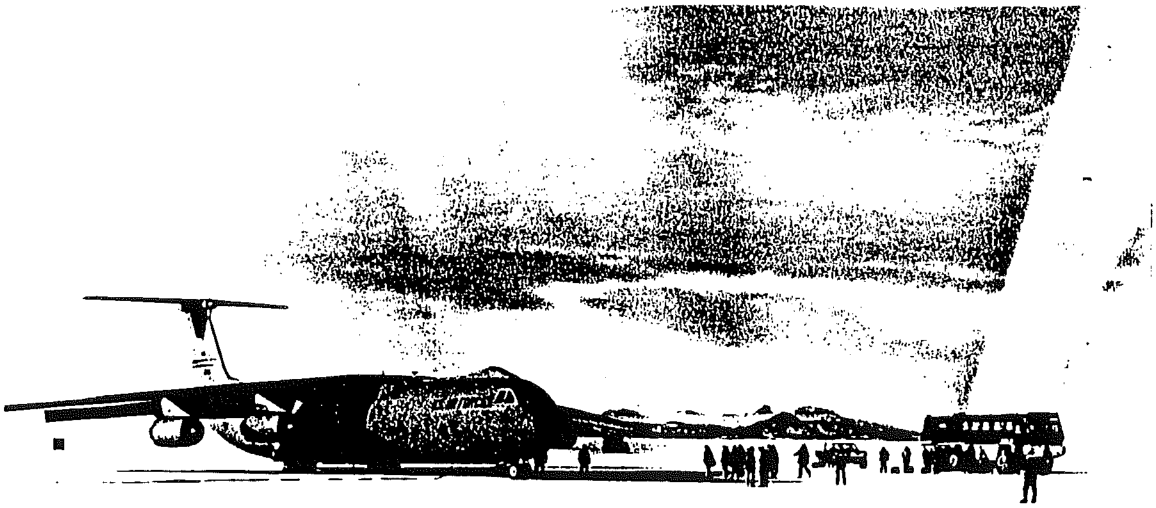

Figure 6. C-141 during check-out operations at the Pegasus runway.

FLIGHT OPERATIONS

Full flight operations began from the Pegasus runway on 8 February 1993. LC-130 aircraft were used to fly cargo from the Pegasus runway to the South Pole, allowing an extra 3600 kg of payload by taking off on wheels. A total of eight flights to the South Pole used the Pegasus runway in 1993, delivering 100,000 kg of cargo. The Pegasus runway was also used by LC-130s to fly passengers to Christchurch and a standard C-130. Passenger counts of 30-50 were thus possible, compared to the usual 15-30 when taking off on skis. Four flights by a standard C-130 were completed, with 50 passengers transported on each trip (Fig. 7). A total of 593 passengers and 14,500 kg of cargo was delivered to Christchurch from the Pegasus runway in 1993.

The runway was closely inspected by project engineers following each of the first 15 flights. No damage or wear could be detected and no ice failures occurred.

The 1994 operating season at Pegasus began on 26 January and extended through 27 February. Numerous LC-130 flights from wheels were operated in supplying South Pole station, and a C-130 was operated between Christchurch and Pegasus on an every-other-day basis starting around 1 February. In all, about 55 flights used the runway that season.

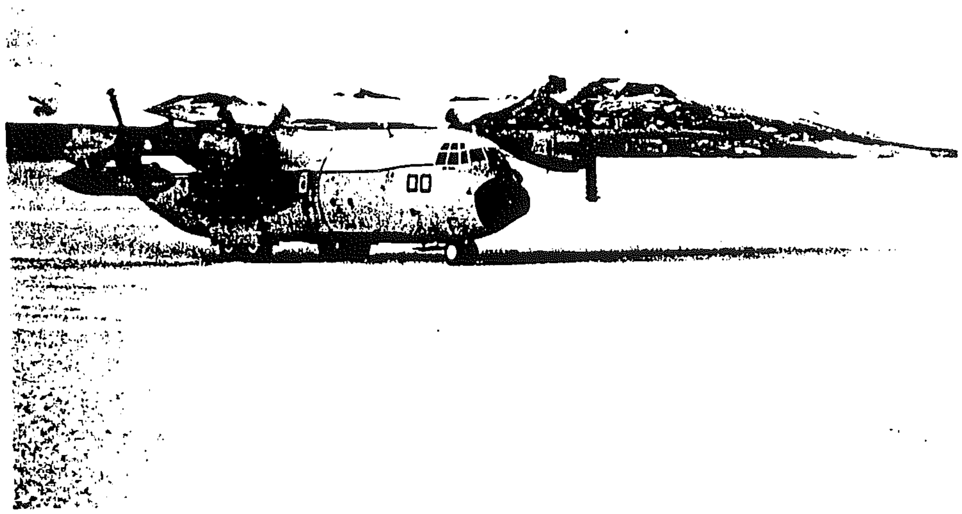

Figure 7. Conventional C-130 Hercules operating from the runway.

SUMMARY

The C-141 flight at the Pegasus runway marked the final test in a five-year development program to demonstrate the feasibility of a semipermanent glacial ice runway capable of supporting heavy wheeled aircraft at a site easily accessible to McMurdo. In the later phases of developing the glacial ice runway, numerous working flights took place using LC-130s operating on wheels and a conventional C-130. These flights moved cargo more efficiently to the South Pole, and passengers to Christchurch. The primary benefit of the Pegasus runway is its ability to support heavy wheeled aircraft for most of the time period from mid-January through November when the sea ice runway is unavailable. In addition to allowing increased payload for the LC-130, the Pegasus runway provides access to conventional aircraft throughout the world.

The technology for constructing, maintaining, and operating such a runway is now well understood and is probably applicable to a wide range of sites in polar regions. We are currently preparing a comprehensive report describing all aspects of siting, construction, maintenance, and operation of glacial-ice runways, using the Pegasus runway as an example. Glacial-ice runways clearly have great potential for providing economical and environmentally sound access for conventional heavy aircraft.

ACKNOWLEDGMENTS

This work was performed for the National Science Foundation, Office of Polar Programs. This project was conceived and initiated by Dr. Malcolm Mellor, who, unfortunately because of his untimely death, did not have the opportunity to share in its later phases. The successful completion of this project is the result of great cooperation and interest by many organizations and agencies, including the US Navy, US Air Force, Antarctic Support Associates, and experts from the Russian Arctic and Antarctic Research Institute.

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THE CONCEPT OF THE COOPERATIVE AIR TRANSPORT SYSTEM IN EAST ANTARCTICA

by

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Russian Antarctic Expedition

I. Introduction

The first talks on the establishment of a Cooperative Air Transport System for Anractica (CATSA) were initiated already at the SCAR meeting in 1976. However, up to the present time the majority of the countries - participants to the Antarctic Treaty base on their own logistics capabilities and aviation transport. Only few examples of international collaboration in the Antarctic aviation, such as the U.S. - New Zealand air transport agreement and the availability of the Chilean runway at Marsh are known.

During the years after the establishment of COMNAP/SCALOP several practical steps were made in this direction. Thus, due to the efforts of SCALOP the Antarctic Flyer Manual, which contains evidence on all Antarctic airfields and ground facilities of communication systems was prepared and published. Then the SCALOP aviation working group has developed and introduced into practice the coordinated procedure for the flights in Antarctica, which contains the rules of mutual notification when the flights are in the vicinity of the stations. The obvious usefulness of these steps is that a move towards a real international coordination and collaboration has been made to address common problems of aviation support to the works in the Antarctic.

The COMNAP/SCALOP meeting in 1992 discussed the idea of creating a local Cooperative Air Transport Network in the Atlantic sector of Antarctica. Here in the sector 30 deg.W to 80 deg E about 20 permanent stations and temporary bases are located, belonging to 11 countries. This idea was met with interest by the European countries and was also supported by South Africa, Australia and Japan, which implement their national programs in the Atlantic sector of the Antarctic. In connection with the fact that the European Science Foundation develops the project of deep drilling at Dronning Maud Land (EPICA), the question about the local cooperative air network becomes even more important.

The presented paper attempts to briefly describe the main components of the local cooperative air network for the Atlantic sector of Antarctica. The main aim is to show that it is now

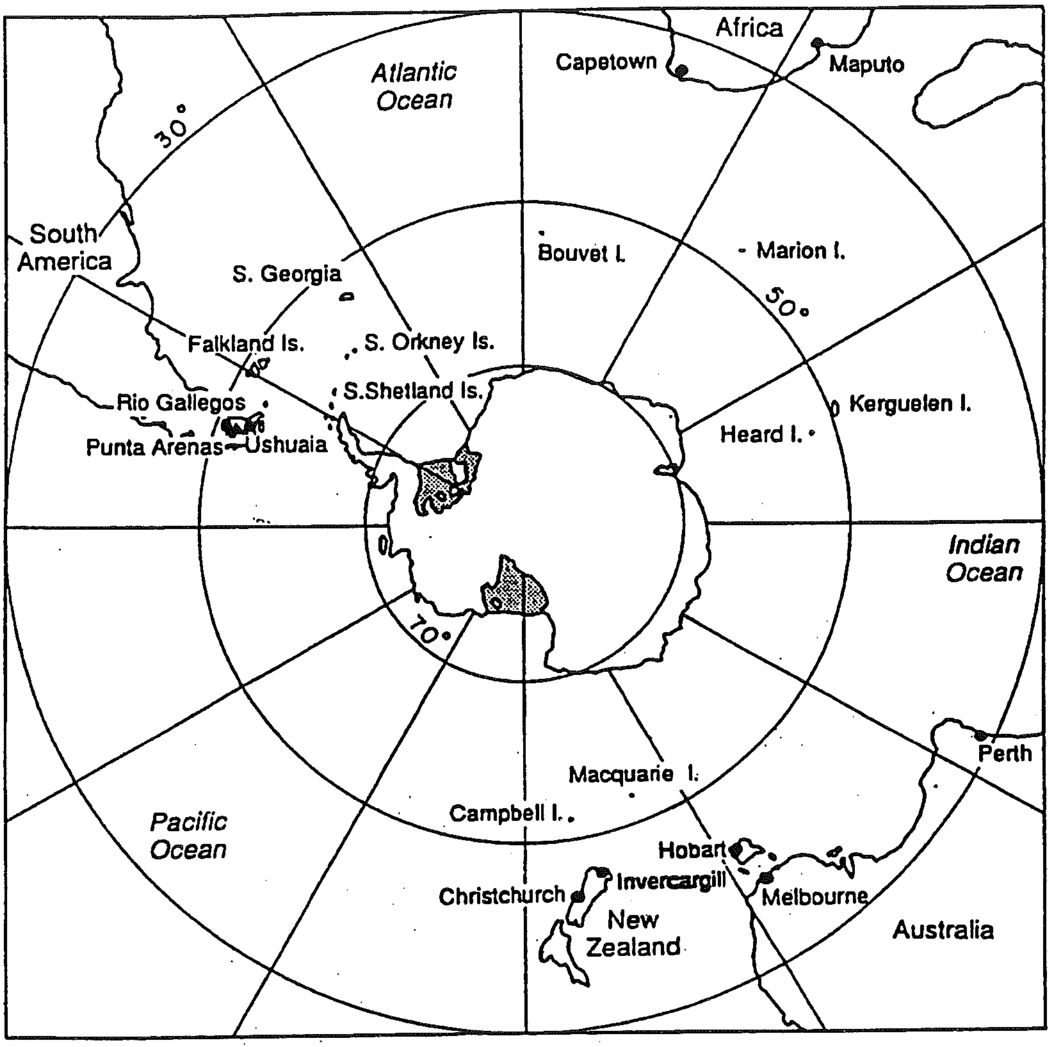


Fig. 1 . Departure points for flights to Antarctica

technically feasible to establish a permanent air bridge between Africa and Antarctica, using conventional wheel aircraft and tested methods of constructing hard runway on the ice. Here also, the data, which show that the internal link between stations can be provided by heavy helicopters, are given.

2. FLIGHTS TO AND FROM ANTARCTICA

2.1. Airports of departure

At present three places are regularly used for the flights to Antarctica: New Zealand, South America and Africa (Fig. 1). The shortest air routes to the Atlantic sector of Antarctica are from South Africa. From here the flights to Molodezhnaya and Novolazarevskaya were made. Maputo (25 55 S, 32 43 E) or Cape Town (33 33 S, 18 13 E) served as departure points in Africa.

The Cape Town airport is more favorable in terms of distances to the potential Antarctic point of entry. The distance from Cape Town to most of the Antarctic stations of the Atlantic sector is within 5000 km (Table 1), which is quite possible to reach by conventional trans-ocean aircraft. The factors in favour of the Cape Town airport are also a stable good weather and sufficiently high servicing level of air means and passengers.

Such far-south points of South America as Punta Arenas (Chile), Ushuaia (Argenina) and Mount Pleasant (Folkland Islands) can be used for the transocean flights to the Atlantic sector of the Antarctic too. The weather conditions, however, in these airports are rather unfavourable and variable. Also, the delivery of passengers and cargoes to these departure airports will be much more expensive for the European Antarctic Programs, the majority of which is in the sector of the Antarctic under consideration.

2.2. Feasible types of entry airfields in Antarctica

Four broad airfield categories for the flights of heavy wheel aircraft to Antarctica can be considered:

- rock-fill runways,
- sea ice,
- compacted snow runways on deep snow,
- snow-free glacier or lake ice.

2.2.1. The sites for conventional rock-fill runways are extremely rare in Antarctica. Suitable places for the construction of rock-fill gravel runway exist in mountainous

Table 1 . Distances between Cape Town airport and potential points of entry in the Atlantic sector of the Antarctic (40 W-80 E)

Points of entry	Location (coordinates)	Site elevation (m)	Type of airfield	Distance from CPT (km)
Halley	75 35 S, 26 15 W	30	ice shelf	5150
Swea (Sivorgfjella)	74 35 S, 11 10 W	1250	blue-ice 5 x 2 km	4740
Georg Neumayer	70 37 S, 08 22 W	20	ice shelf	4330
Borg Massif	72 32 S, 03 42 W	1730	blue-ice 5 x 2 km	4310
SANAE IV	71 40 S, 02 51 W	840	rock plateau	4300
Troll (Jutulsessen Mountain)	72 00 S, 02 40 E	1200	blue ice 15x10 km	4280
Hellehalle slope	71 40 - 72 00 S 08 - 10 E	1200-1800	blue ice 10x12 km	4380
Novo-lazarevskaya	70 46 S, 11 50 E	550	compacted snow runway over blue ice	4060
Asuka (Sor-Rondane Mountains)	70 00 S, 22-26 E	1000-1500	blue ice >300 sq. km	4280
Molodezhnaya	67 40 S, 45 51 E	225	compacted snow runway over deep snow	4150
Mawson (Framnes Mountains)	67 45 S, 62 45 E	500-800	blue ice >500 sq. km	4730

*) site elevation and dimension of "blue-ice" field in according to Charles Swithinbank (1991)

regions of the Atlantic sector of the Antarctic. Level enough sites of bare rock or coarse glacial till were found in the internal regions of Dronning Maud Land, Sor-Rondane Mountains and Prince Charles Mountains. These sites, however, are far (several hundred kilometers) from the shore and the existing stations. To construct and maintain there a conventional airport would require very large investments and can be hardly made in the framework of the resources, allocated for the Antarctic studies.

2.2.2. Level sea ice appears to be an attractive platform for the construction of runways for wheel aircraft. In some regions of the coastline Atlantic sector of the Antarctic one encounters large areas of stable fast ice. However, due to the coastline in the considerted sector being in quite "warm" latitudes (mostly north of 70 S) sea ice during one year does not have the thickness necessary for the landing of heavy aircraft. The thickness of first-year sea ice reaches maximum here of about 1.2-1.5 m in November. In December first-year ice is destroyed and loses strength. Multi-year, perennial sea ice is sometimes encountered in deep bays and has the thickness of 5-10 m. However, the surface of multiyear ice is usually covered by quite thick (up to 2 m) snow. That is why the runway construction on such ice will require much work to clean the ice from snow with the help of rotary snowplow. The snowplow berms formed will progressively increase with the exploitation of the airfield and landing of aircraft on the narrow cleaned strip will become impossible. The expansion of the cleaning area will be required, which will several times increase the need in technical means and personnel. Such endless struggle with the natural snow accumulation process will result in the necessity to move to a new place. That is why the high cost for the construction of the runway of such kind will not be justified.

2.2.3. The Russian engineers really proved the possibility to construct a conventional runway for heavy wheel aircraft on deep snow in the accumulation area. Such kind of runway was built some 20 km east of the Molodezhnaya station at 250 m elevation above sea level. The methods for snow processing include mixing by disc harrows, levelling by grader and compacting by rollers. Different variants of this procedure are maintained all year round after every snowfall or snowdrift. The runway is located in the area that has moderate accumulation rate (0.5-0.8 m/yr) and which is warm enough to give snow moisture and cohesion in summer but not so warm for the ablation to destroy the snow pavement. The runway is used by heavy wheel Ilyushin Il-76 TD. The normal operating season is September to early December and February until early March. The practice of constructing and maintaining the runway on deep snow has shown that at the place of operation it is necessary to have all year round the logistics base planned for the permanent stay of 10-12 persons.

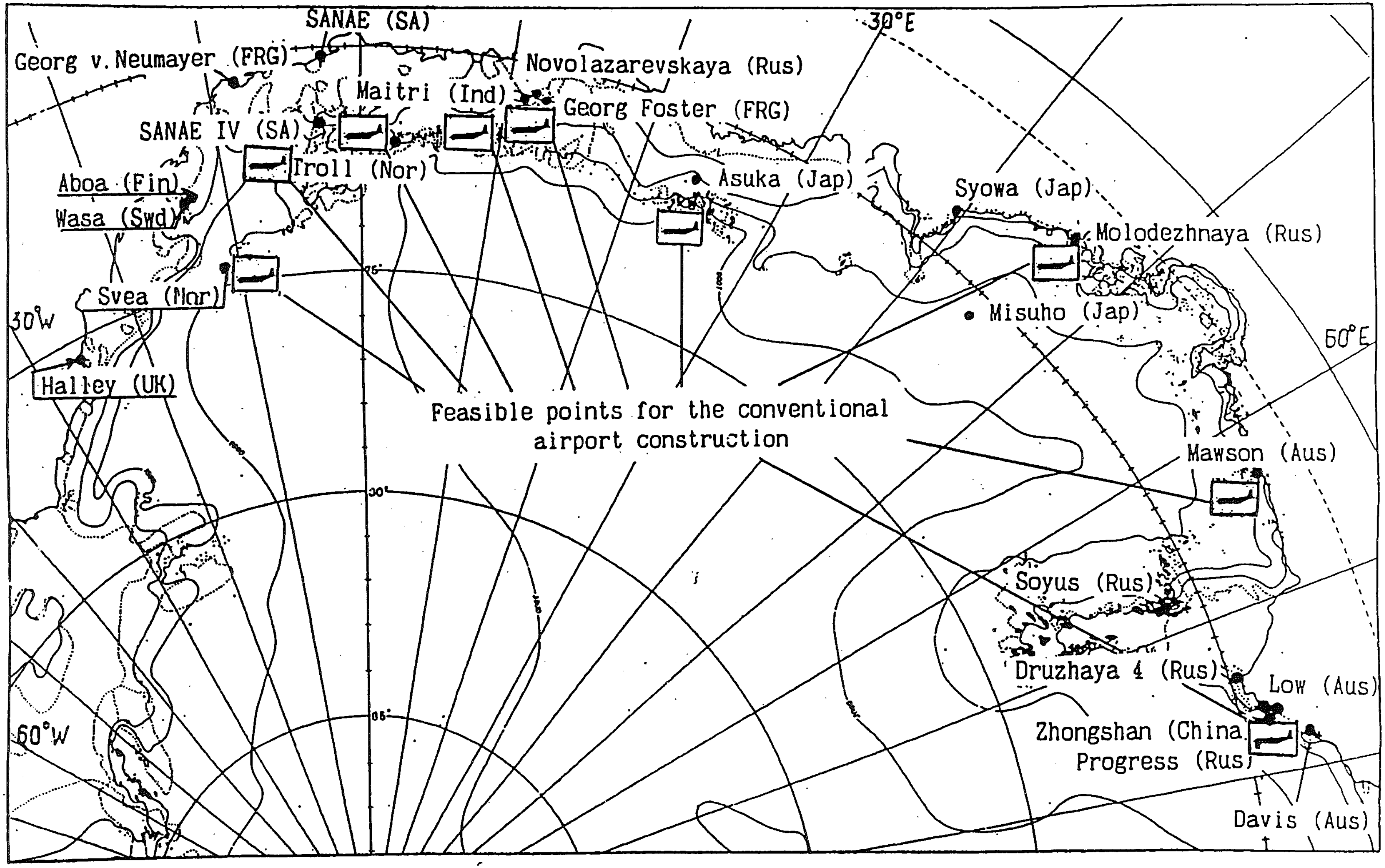
2.2.4. Bare glacier and lake ice can be used for episodical landing of conventional wheel aircraft without a preliminary ice surface treatment. A lot of experiments of landings of various types of wheel aicraft on the unprepared fields of blue ice are known. The flights were made in different years in Pensacola Mountains (Rosser Ridge), Ellsworth Mountains (Patriot Hills), Bunger Hills (Transcription Bay), Transantarctic Mountains (Mill Glacier, Mount Howe) and in other places.

The prime sites for airfields on glacier ice are the inland "blue-ice" areas where net ablation is the result of strong and persistent local winds. "Blue-ice" areas occur both on low elevations (<500 m) where melting takes place in the summer season ("warm blue-ice fields") and at large heights (up to 2000 m) where melting is not observed and ablation occurs due to evaporation ("cold blue-ice fields"). At "warm blue-ice fields" in summer melt pools, subsurface melt cavities and subsequent ice blisters can form, which create an irregular microrelief and make difficult the selection of the site for the runway. "Cold blue-ice fields" have a more level surface and are more preferable for the construction of airfields. Although it is difficult to find places where there are long stretches (>3 km) of level enough ice without crevasses and surface obstacles, such places do exist in the Atlantic sector of the Antarctic. The locations of stations, bases and potential entry airfields in "blue-ice" areas are shown in Fig. 2. Table 1 presents brief data on large "blue-ice" fields, situated in the Antarctic area under consideration in the vicinity of stations and bases.

An ideal airfield site is a "cold blue-ice field" which meets the following requirements:

- the surface is smooth enough to accept standard conventional transport aircraft, without the need for any significant surface preparation;
- the site has a long stretch of snow-free ice or ice with scattered patches of snow, oriented parallel to prevailing wind;

Fig. 2 Locations of the stations, bases and potential airfields in the Atlantic sector of Antarctica



- air approaches are unobstructed;
- the site has to be located near one of the Antarctic stations and be accessible for surface transport.

Practical experience of using the "blue-ice" field for the flights of heavy wheel aircraft Ilyushin Il-18D and Ilyushin Il-76TD has been gained at Novolazarevskaya station, where the ice airfield has been built and maintained. It is located 15 km south of the station at the elevation of 500-530 m. The initial and also the annual procedure to prepare the runway is scraping of ice bumps by grader, planing and rolling the snow of snow patches to create the protected snow cover. This protective snow cover allows one to preserve the runway from melting up to early December, smooth microirregularities (small bowlshape depressions) of the ice surface and increase the friction of aircraft wheels during landing and take-off. A significant shortcoming of the airfield in the vicinity of Novolazarevskaya is that it is located at a small elevation, where melting occurs in summer, that is why the runway is suitable to be used only in October-November.

More favourable places for the construction of the entry airfield in the Antarctic sector under consideration should be a "cold blue-ice field" located in the mountainous regions of Queen Maud Land. The preference among them is given to the following ones:

Borg Massif (SANAE IV),
Jutulsessen Mountain (Troll)
Hellehalle slope (Novolazarevskaya).

Here the airfield for large conventional transport aircraft can be built with minimal work for the runway construction. The required technical methods already exist. If nations combine their resources and efforts then they could avoid duplication of air facilities and the national Antarctic Program could be carried out more efficiently and at a lower cost.

2.3. Aircraft for flights to and from Antarctica

The choice of aircraft for the flights to and from Antarctica should be made according to many parameters, which are roughly the following main requirements. Such aircraft should have a range long enough to reach an alternate airport or to return to the point of departure arriving with standard IFR fuel reserves. It has to be a multi-engine STOL (Short take-off and landing) and a high wing aircraft with the high-floatation main landing gear.

It should be equipped with airborne winches, telpehrs, ramp and have the internal dimensions of the cabin as large as possible.

Two Lockheed aircraft C-130, C-141 and Ilyushin Il-76TD aircraft meet these requirements. The Table 2 summarizes the general characteristics of these aircraft.

Table 2 . Aircraft with general characteristics suitable for trans-ocean flights to and from Antarctica
(Jane's All the world's aircraft, 1990-91)

Aircraft characteristics	Lockheed C-130	Lockheed C-141	Ilyushin Il-76 TD
Max take-off mass	70 300 kg	146 500 kg	210 000 kg
Main landing gear	8 wheels, two tandem units	8 wheels, two 4 wheels bogies	16 wheels, two sets of two rows of 4
Tyre pressure	6.6 kg/sq.cm	12 kg/sq.cm	5-7 kg/sq.cm
Max payload	19.7 tons	32.0 tons	46.0 tons
Take-off roll	1090 m	1300 m	850 m
Landing distance	840 m	1100 m	450 m
Range with max payload	3790 km	6560 km	6900 km

The Ilyushin heavy transport aircraft is better than its Lockheed counterpart by the majority of parameters. Its main advantage for the operation on unprepared airfields are considered to be very short take-off and landing distances, as well as the large cabin dimensions (see Fig.3). Il-76 made flights Maputo-Molodezhnaya, Cape Town-Molodezhnaya, Molodezhnaya-Novolazarevskaya and it looks ideal for the flights to and from Antarctica.

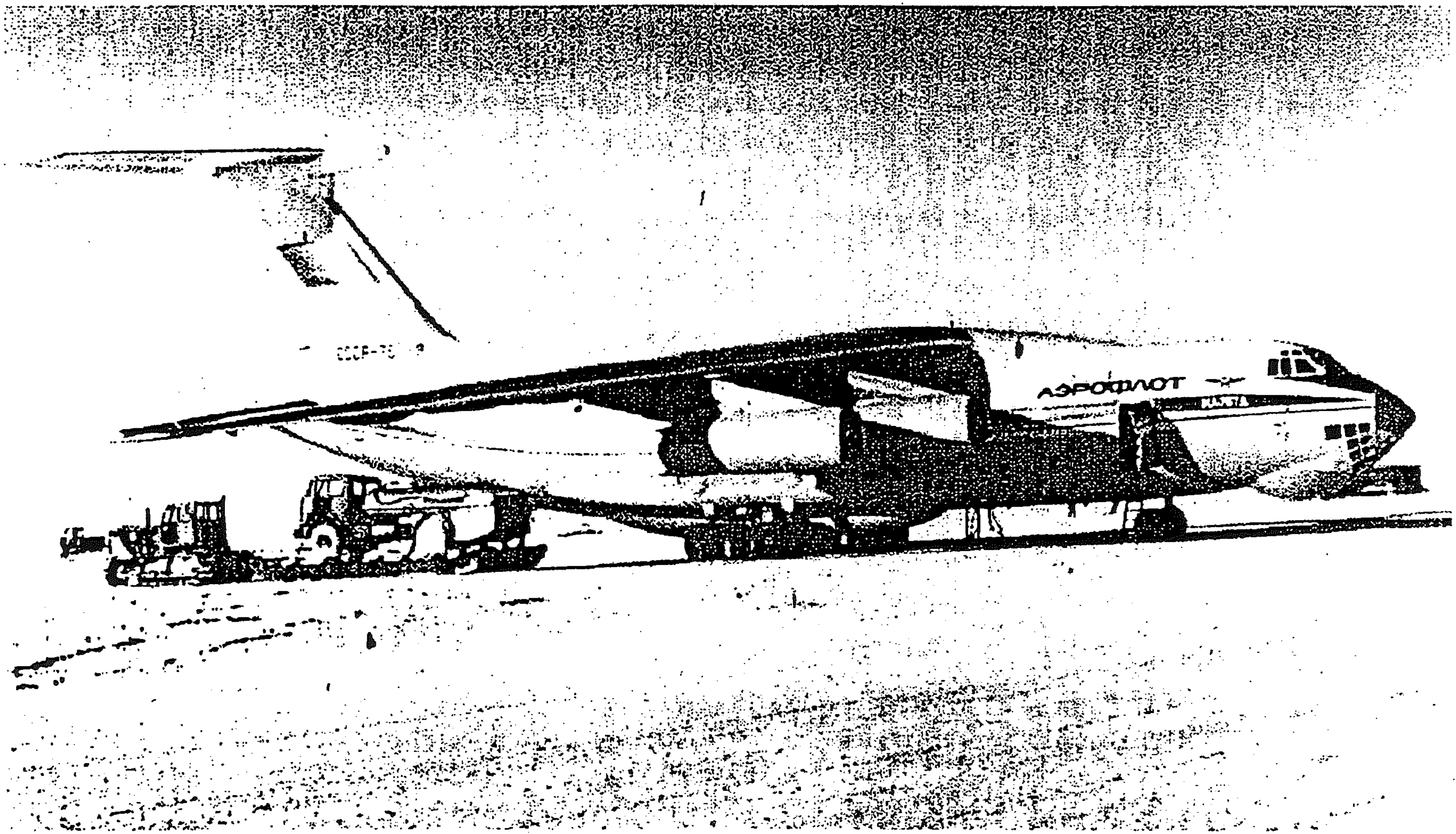


Fig.3. Ilyushin Il-76TD on the compacted snow runway at Molodezhnaya

3. FLIGHTS WITHIN ANTARCTICA

3.1. Fixed-wing flights

Apart from coastal ship-base-ship operations, much of inland air transportation is carried out traditionally by means of fixed-wing aircraft with ski or ski-wheel landing gear. With the exception of such large universal aircraft for all air operations in Antarctica as LC-130, usually small aircraft is used for inland operations, which are capable to take-off and land almost anywhere. Such aircraft include: DHC-6, Dornier 228-100, Antonov AN-28. These aircraft modified in special polar models are quite expensive, which restricts their wide use in the Antarctic.

The main and quite complicated operation appears to be the delivery of the fixed-wing aircarft to the operating location in the Antarctic. To deliver the aircraft aboard the ship (even a large one) it is necessary to partly dismantle them and to assemble afterwards. And this involves the use of extra specialists and costly equipment. The known problems appear also regarding the aircarft protection from corrosion during a long marine transportation.

Another possibility is the aircraft overflight to the Antarctic via South America. Almost annually the Kenn Borek Air Company and the British Antarctic Survey make such overflights. Of course, there are many reasons due to which the logistics difficulties during these rather long overflights sometimes exceed the known difficulties of the flights in Antarctica. And the cost of such "walks" across the entire globe exceeds reasonable limits, being a burden for the budgets of some national programs.

3.2. Helicopters

Helicopters are traditionally used in the Antarctic during the ship-base-ship operations. In some cases the logistics operations without the use of helicopters would not have been possible at all. Such operations include: flights over heavy sea ice, flights in the mountains, cargo transportation to a strictly designated point.

Table 3. Approximate distances between Antarctic stations and bases in the Atlantic sector of the East Antarctica

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Halley (UK)																
2	Aboa (Fin), Wasa(Swd)	460															
3	Swea (Nor)	430	180														
4	Troll (Nor)	920	610	480													
5	SANAE (SA)	950	490	560	260												
6	SANAE IV (SA)	840	390	420	160	160											
7	G.Neumayer (FRG)	780	320	450	390	210	230										
8	Schirmacher Hills *	1310	910	870	400	540	540	750									
9	Asuka (Jap)	1600	1270	1180	780	970	950	1170	450								
10	Syowa (Jap)	2210	1910	1810	1430	1620	1580	1810	1080	640							
11	Misuho (Jap)	2180	1940	1810	1490	1710	1660	1880	1190	740	290						
12	Molodezhnaya (Rus)	2480	2190	2090	1730	1920	1880	2100	1370	930	300	360					
13	Mawson (Aus)	2910	2710	2570	2280	2520	2450	2680	1980	1540	970	800	720				
14	Soyus (Rus)	2760	2620	2460	2250	2490	2400	2640	2000	1560	1110	760	940	400			
15	Druzhnaya IV (Rus)	2950	2830	2680	2470	2710	2620	2850	2220	1780	1320	1080	1130	480	220		
16	Larsemann Hills**	3050	2930	2760	2560	2810	2720	2940	2320	1890	1430	1190	1240	560	320	100	
17	Davis (Aus)	3140	3050	2880	2680	2920	2830	3060	2440	2000	1530	1280	1330	630	430	210	110

*Schirmacher Hills : Maitri (Ind), Novolazarevskaya (Rus), Georg Forster (FRG)

**Larsemann Hills : Low (Aus), Zhongshan (China), Progress (Rus)

By the present time most Antarctic Programs use ships, capable to carry quite large helicopters onboard. And some ships (the Akademik Fedorov, Aurora Australia, Polarstern) have not only hangars, but also some maintenance and service facilities. That is why now not only partial dismantling-assembling of helicopters can be made aboard the ships, but high-quality service work too.

Technical data on big helicopters, used in Antarctica are presented in Table.3 As is seen, heavy helicopters have quite significant values of max ranges up to 1100 km of the new Russian Mil Mi-17 biggest helicopter. If one returns to the Table of distances between the stations and the bases in the Atlantic sector of the Antarctic under consideration (see Table 4), then one can see that about 40% of all possible distances are within the max range equal to 1100 km.

Table 3 Characteristics of multi-engine helicopters for long-range inland operation in Antarctica

Helicopters	Max take-off mass, kg	Length of fuselage, m	Cruise speed, km/h	Max range with IFR, km	Max playload, kg
Bell 212	4762	12.92	185	400	2268
SA 321	13000	19.4	250	820	5000
S 76	4536	16.0	286	748	1500
Mi 8	12000	18.31	200	760	4000
Mi 17	13000	18.31	220	1100	4500

In principle, there is a real possibility to use heavy helicopters as the flight means between the stations from Halley to Davis. At first, it is necessary to construct fuel depots at inland points. The network of such fuel depots can be created on the basis of an international agreement. One of the optimal shemes for the creation of the integrated air transport system could be the rent of an "international tanker" from board of which the fuel can be delivered by heavy helicopters directly to the stations, bases or other special points, located at a distance up to 300 km from the coast. Such work to create the network of fuel depots can be fulfilled during one season at most favourable ice conditions. It is advisable to make the fuel supply for refueling during the next two seasons.

Fig. 4. The range-radius sectors available by Mil MI-17 helicopter operates from SANAE IV, Molodezhnaya, Davis

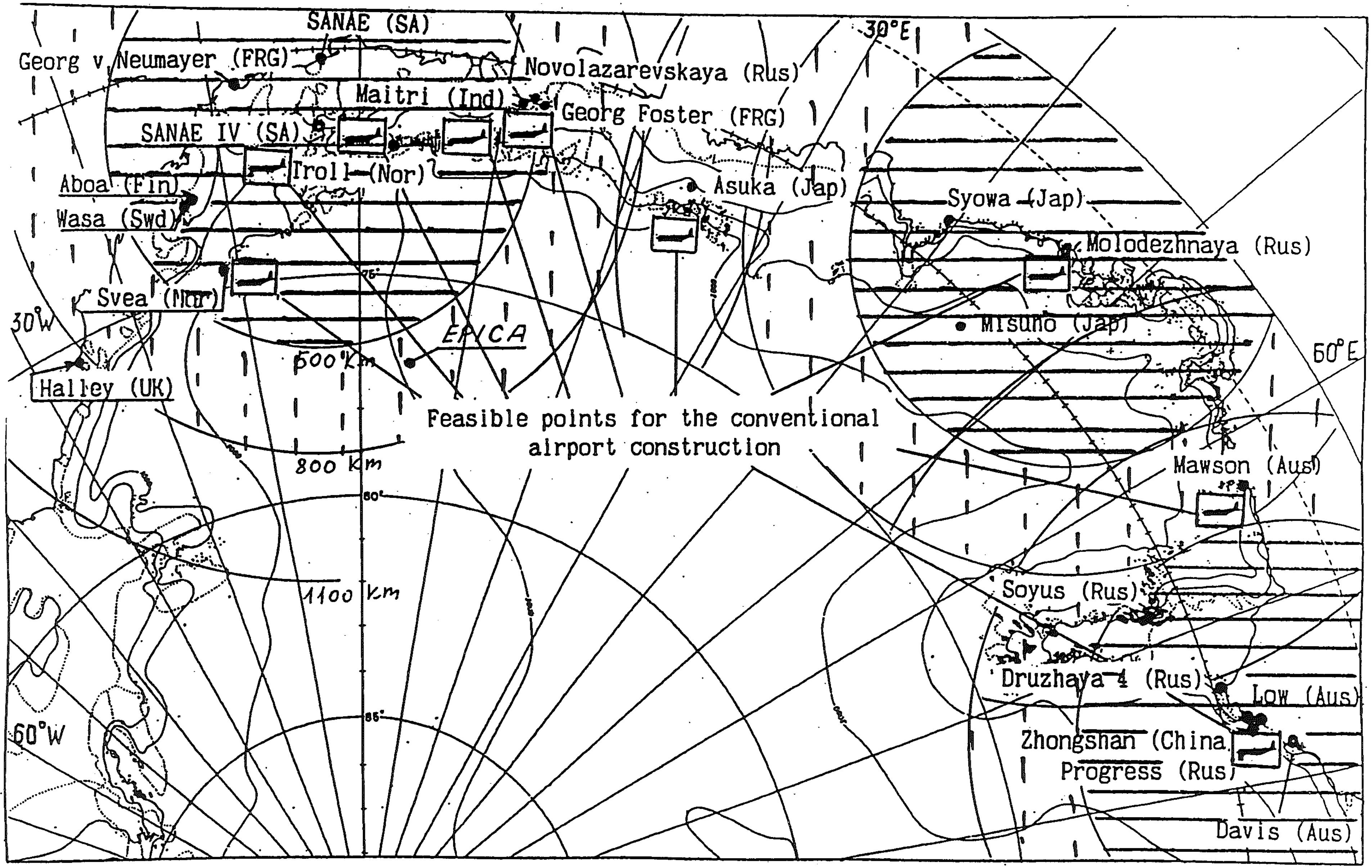
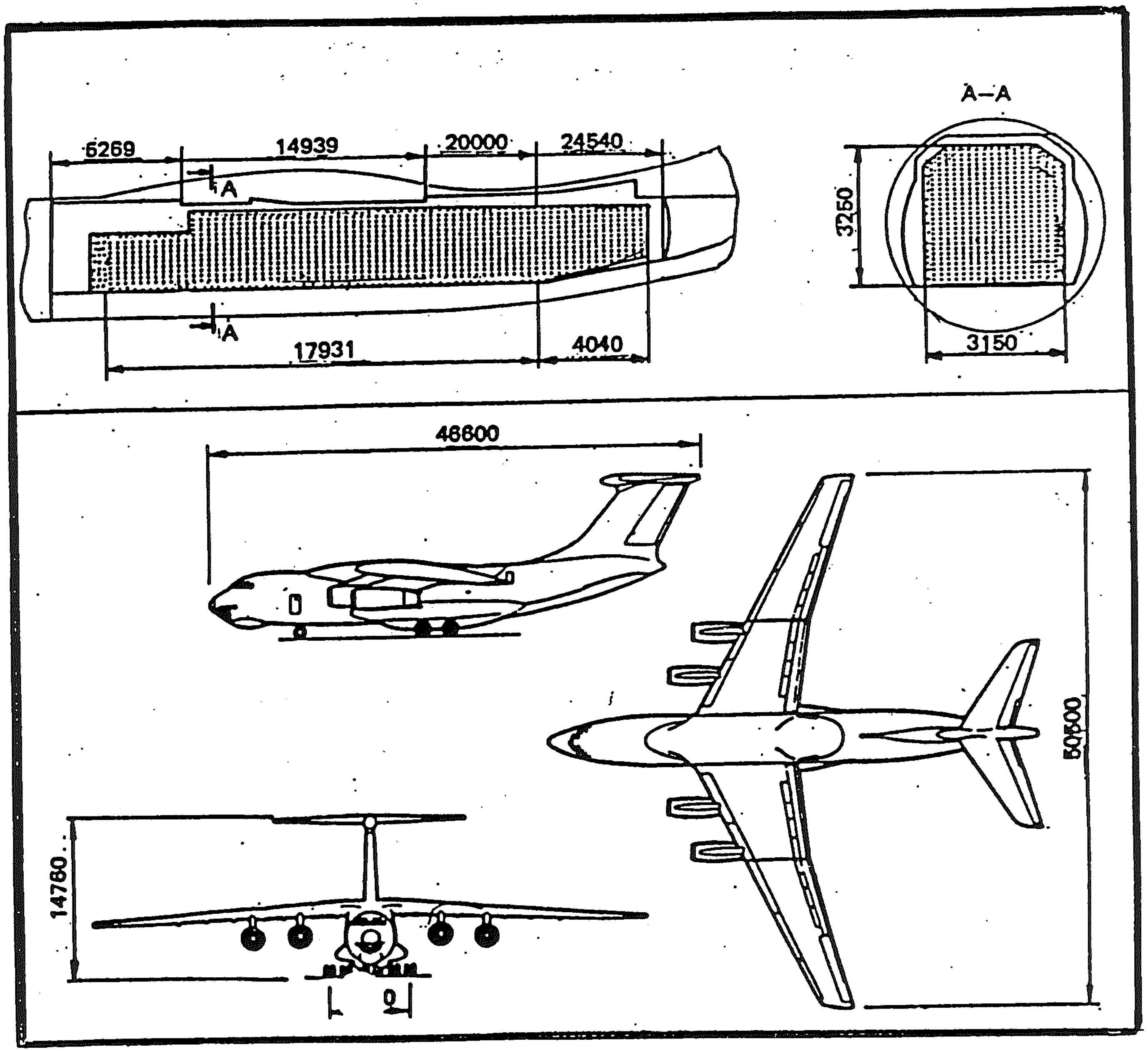


Fig. 5 . Ilyushin Il-76TD cargo cabin dimensions (mm)



One of the simple schemes for the flights between the stations along the coast and inland is their basing during the work season at one or two stations. These stations should have significant fuel supply, which can be made during the tanker call. Here the maintenance and service of helicopters, emergency services and weather services should be centered. The distance between the base stations should be close to the max range of the helicopters.

One of the possible variants of such scheme can be the designation of the stations SANAE, Molodezhnaya and Davis as the major base stations for the long-range operation with heavy helicopters (Fig.4). As is shown above, the entry airfield for trans-ocean flights can be built at the same stations. In such case helicopters can be delivered to Antarctica by Ilyushin Il-76 TD aircraft and operate there beginning from September. The technical preconditions are available, this is sufficient space in the fuselage and a practical experience of partial dismantling and successive assembling of Mi-17 helicopter in the Antarctic conditions(Fig. 5)

4. Conclusion

High density of stations and bases in the Atlantic sector of the Antarctic contributes to the development of collaboration and cooperation in the creation of integrated air network to avoid unnecessary duplication of the facilities for safe flights.

Several quite favourable sites at the "blue-ice" fields and the available practical experience gained in the construction of air-fields for heavy wheel aircarft allow one to create the runways for conventional trans-ocean aircraft.

The existing heavy helicopters by their parameters can be used for the flights along the coast and inland in the entire Atlantic sector of the Antarctic. The joint efforts of several National Programs will appreciably reduce the expenditures of each of them and increase the general safety of the flights.

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CENTRE FOR PARACHUTE AND EXPEDITIONAL WORKS "POLUS" AND ITS ACTIVITIES

By Peter I. Zadirov

(6th SCALOP Symposium)

Mr. Chairman,

Distinguished Guests,

Ladies and Gentlemen,

For the past 5 years we have operated in the North Pole area and have often used the method of parachute dropping by aeroplane to remote areas.

This method is preferred because of the large carrying capacity and long range flights. Also, very importantly, no runway or landing strip is necessary.

Parachute dropping cargo began in the arctic area at the time of an emergency situation, at the ice station when the landing strip became dangerous and unusable. We could not land an aeroplane. The only feasible alternative was to supply by parachute.

My company "POLUS" - Centre for parachute and expeditional works was started in 1989. We have worked in Arctic area more than 20 times.

It was in 1991 that we had to transport 100 tons of food and petrol from the island called Sredni to the polar ice station SP-30 in the Arctic. On the occasion it was not an emergency. Rather it was out of economic expediency that we used the parachute method.

We had two options:

Either shuttle landing a small aeroplane - IL-14;

Or parachute dropping from a big aeroplane - IL-76.

Preliminary theories showed a significant preference for the parachute method using a large plane. This theory worked out in practice with a saving of about $ 70,000 as can be seen on the diagram.

We also experimented using the parachute dropping method at the Russian Antarctic polar station "WOSTOK" in 1991. The flight was from Russia to Cape Town (South Africa) and then on the Russian polar station "MOLODEJNAYA". It proved successful and cost effective.

In 1992 "POLUS" - Centre for parachute and expeditional works was brought in to solve a problem for a Russian gold mining company. This was a new mining venture in an isolated region on an island in the Northern arctic ocean. There was no landing strip.

Initially we parachute dropped supplies such as tractors, petrol, food and machinery. Single load up to 20 tons can be dropped by parachute. Within a month a base plus a landing strip was constructed by my company.

As you understand mining companies use very heavy equipment. By using large aeroplanes, caterpillar tractors weighting up to 60 tons each were than transported to the base landing on the newly constructed runway.

Both logistically and economically this proved a very successful operation.

Our experience shows that the most feasible use for parachute dropping cargo in Antarctica is:

1) The establishment of new bases (where there is no runway or airstrip), for example research stations.

2) Emergency situations from fire, snowstorms or where runways become unusable.

Three base sites can be used as springboards for Antarctic work - as can be seen on the diagram

* Cape Town - South Africa,
* Hobart - Tasmania/Australia,
* Punta Arenos - Chile.

We can operate from all these bases.

The maximum range of the IL-76 aeroplane is 10,000 kms. Parachute dropping supplies can be made to the Antarctic continent without landing if the distance is not more than 5,000 kms. If it is more than 5,000 kms then we must build an extra landing strip as a depot and springboard.

This will be required for transportation right into the continent.

The characteristics of the IL-76 aeroplane and cargo parachute systems are as shown in the diagram.

Dropping supplies by parachute has proven to be safe and cost efficient.

We can deliver with pin point accuracy from aircraft without any damage to the cargo. Even fragile articles can be dropped by parachute.

I wish all participants of the 6th SCALOP Symposium success in their work. I think this symposium can be useful for your operations in the Antarctic.

You can receive extra information from my offices either in Russia: 17/19 Lobachika St., Moscow, 107113, Russia, tel/fax - (095) 269-06-13; or in South Africa: 106 Hof Park, Hof St., Cape Town 8001, South Africa, tel/fax +27-21--23-45-87.

Thank you.

(Table - I)

PRINCIPAL PERFORMANCE DATA OF IL-76 AIRCRAFT AND PARADROPPING SYSTEMS FOR CARGO DELIVERY

No.	Characteristics	Performance data
1.	Maximum flight range (kms)	10 000
2.	Cruise speed (km/h)	800
3.	Maximum payload for flight for maximum range (kgs)	10 000
4.	Maximum payload for flight up to 5 000 kms (kgs)	50 000
5.	Number of parachute systems of 1000 kgs in one aircraft	26
6.	Number of parachute systems of 9000 kgs in one aircraft (depending on dimension of cargo)	3 - 4
7.	The cost of one flight hour of IL-76 aircraft	$ 5500
8.	The cost of one parachute system designed for 1000 kgs of cargo	$ 1000

(Table - II)

DELIVERY OF CARGO TO RUSSIAN POLAR ICE STATION SP-30 BY REGULAR FREIGHT FLIGHTS OF IL-14 AND BY PARADROPPING FROM IL-76 (COMPARATIVE DATA)

No.	Characteristics	Performance data	
		IL-14	IL-76
1.	Distance between main base and the polar ice station (kms)	1 200	1 200
2.	Quantity of cargo to be delivered (kgs)	100 000	100 000
3.	Freight-carrying capacity of (kgs)	1 000	20 000
4.	Cruise speed (kms/h)	240	800
5.	Number of flights required to deliver all the cargo	100	5
6.	Total number of flight-hours required to deliver all the cargo (h)	1 000	15
7.	The cost of one flight-hour (USD)	$250	$5 500
8.	The cost of airborne delivery of the entire cargo (excluding parachute systems) (USD)	$250 000	$82 500
9.	Total cost of all parachute systems required for paradropping of the entire cargo (USD)	------	$100 000
10.	Total cost of delivery of the entire cargo (USD)	$250 000	$182 500
11.	Commercial effectiveness of aircraft paradropping delivery		$67 500

"POLUS"

Diversity of Modern Antarctic Vessels

by Eero Mäkinen, Matti Arpiainen, Torsten Heideman
KVAERNER MASA-YARDS Inc., FINLAND

1. INTRODUCTION

All activities in the Antarctica and surrounding seas are only research related for a couple of decades to come. No commercial or industrial activities are allowed. The use of ships in the Antarctica is important, practically without alternatives, for two tasks:

- logistics support. i.e. carrying provisions, supplies, construction material etc. to scientific bases in the Antarctica, as well as carrying waste from the Antarctica.
- ocean research from ships as platforms for research operations .

Logistics support operation can be undertaken also by airplanes, but for larger quantities shipping is considerably less expensive, and the only practical alternative for bulk and heavy materials.

Thus, an ideal Antarctic vessel would be required to act both as a cargo carrying vessel and as an ocean research platform. An additional feature is that in most areas and for most parts of the year, ships have to be able to operate in ice, carrying cargo as an icebreaking cargo vessel and also acting as a research platform in ice covered sea.

Kvaerner Masa -Yards Inc. (formerly Wärtsilä Shipbuilding division) is and has been involved in six different vessels/projected vessels for Antarctic operation. Kvaerner Masa-Yards (KMY) is the leading shipbuilding company in the world in the field of icebreakers and other icebreaking vessels, having built more than 60% of the world's icebreakers and even a greater majority of icebreaking cargo vessels. KMY became involved in Antarctic vessels through it's experience in icebreaking technology.

On the other hand KMY has designed and constructed more than 50 research vessels for a variety of scientific disciplines. Thus, KMY can be considered an expert in research vessels as well.

The six technical concepts cover a very wide range of Antarctic ships, namely in the form of displacement from 2000 tons to 15000 tons. The six concepts are also quite different in regard to research and logistics support capabilities as well as the capabilities to operate in varying ice conditions.

As a result of KMY having been involved in six different concepts over the period of close to 20 years, we believe that we have a unique knowledge base in Antarctic vessels in general.

KMY is basically a shipbuilding company but we also have a very extensive engineering and technology function to support shipowners and other shipyards. As a shipbuilding company, KMY is of course in the first place interested in designing and constructing ships at our yards in Finland. This is in many cases however not possible as regards Antarctic vessels, because all the vessels basically serve governmental operations in different countries and governmental operations bring a national element to the shipping and to the ship itself. Therefore, in many countries when funding has been allocated to a new shipbuilding program a restriction has been issued that the ship in question has to be built by a yard in that country.

This nationalism is one reason that KMY has established its engineering/technology function and has worked successfully for and with shipyards in different countries to design and construct Antarctic research/logistics support vessels .

This paper is divided in two parts. The first part covers the description of the six concepts/ vessels , the design and/or construction of which vessels KMY has been involved in. The second part covers a philosophical discussion on technical/operational requirements of future Antarctic vessels and a generic concept of the future Antarctic vessel optimized for desired technical functions and minimum costs.

2. THE SIX CONCEPTS

This chapter covers the description of the six concepts KMY has been involved in. These concepts / ships are the following:

Almirante Irizar, designed and constructed by KMY , delivered in 1978

Aranda, designed and constructed by KMY , delivered in 1989

James Clark Ross, designed (preliminary/contract design) undertaken by KMY and design services delivered to Swan Hunter Shipbuilders, which yard constructed the vessel

Aurora Australis, designed by KMY for Carrington Slipways, which yard constructed the vessel. In addition to technology and design services KMY delivered for *Aurora Australis* a lot of equipment and material

Nathaniel B. Palmer, design (conceptional design) made by KMY for Edison Chouest Offshore/North American Shipbuilding , the latter of which constructed the ship.

Planned Italian Antarctic vessel, designed (premilinary design) by KMY for the Italian shipbuilding company Fincantieri .

2.1 General

An overall description of the nature and function of different ships is in the following.

Almirante Irizar covers both research and logistics support operation. The ship is a very large vessel and icebreaking performance was a very important issue when designing her. She is operated by the Argentinian Navy and she has a high national profile.

Aranda is a small research vessel with ability to do research in ice covered waters. *Aranda's* capabilities to carry cargo and passengers are very limited, almost non-existent. She is operated by a government research institute.

James Clark Ross is very typical of the modern combination vessel, i.e. research and logistics support. She is able to be used for all types of activities in the Antarctic to meet requirements of the UK owners. Operated by a government research institute, she has a moderate ice breaking capability.

Aurora Australis covers basically the same types of functions as *James Clark Ross*. Also in icebreaking capability the ship is close to *James Clark Ross*. She is operated by a private shipping company on behalf of the government.

Nathaniel B. Palmer is a research vessel with considerable icebreaking capability but practically no cargo carrying capacities. She is operated by a private enterprise on behalf of the governmental research institute.

The planned Italian Antarctic vessel will be designed and constructed basically for similar operation to that of *Aurora Australis* and *James Clark Ross*, i.e. research and logistics support. So far there is no funding allocated for the project and therefore the timing is up in the air. It is possible that the ship will be operated by a private organization for the government.

As a summary our list of ships covers three modern research/logistics support concepts, two pure research vessels and one large combination vessel with heavy icebreaking features. The six vessels/concepts are shown in Figures 2.1.1 to 2.1.6.

2.2 Main characteristics

Table 2.2 gives a summary of the main characteristics of all six vessels.

The length overall varies from about 60 meters to 120 meters. The beam , which is the determining dimension as regards to icebreaking capability, varies from 13.8 meters to 24.8 meters. Draft, for which the Antarctic operation does not impose any restriction, varies from 4.6 meters to 9.5 meters. And the displacement varies from 2000 tons to 15000 tons.

In regard to the size of the vessels our list covers practically the whole range of vessels used in the Antarctic waters.

2.3 Powering / machinery

Table 2.3 gives a summary of the basic propulsion system features of each vessel.

Two of the concepts have a straight diesel electric machinery, which is a typical selection for heavy icebreakers. An electric transmission system, however, also has other advantages in addition to its efficiency in icebreaking. There are general system benefits of harmonizing the machinery, particularly in case a high electric load is needed for other tasks than propulsion, and also benefits related to noise.

Two of the concepts have a basic geared diesel propulsion system with an additional electric motor(s) driving propeller shaft(s) at low power for scientific research operation mode.

The remaining concepts have a straight geared diesel propulsion.

The two diesel electric ships have a fixed pitch propeller, as the diesel electric system provides the ship with practically the same flexibility as a controllable pitch propeller. All other concepts have controllable pitch propeller(s).

Also the number of propellers vary. There are three single screw concepts and three twin screw concepts.

Two ships have their propellers in nozzles. A nozzle increases the thrust of a propeller at low ship speed, thus increasing the icebreaking capability of the ship, i.e. increasing the maximum ice thickness in which the ship can operate. The nozzle also protects a propeller against extreme ice loads but on the other hand, it may cause problems as ice floes may block the entry of water to the propeller thus causing a drastic decrease in thrust. Thus a nozzle gives benefits but also potential troubles and, whether a nozzle is installed or not, a careful analysis of the operation is required.

Redundancy is important in Antarctic operation where the ships operate far from other ships in isolated areas. This is a reason why some people have considered a twin screw and a multiple engine arrangement a must.

It is however worth noting that single propeller ships and even single engine ships have been operated successfully in the Antarctica for years.

2.4 Performance / Open water

Open water characteristics cover basically two issues: speed in open water and seakeeping characteristics. For speeds, we typically have a maximum operating speed and an economic transit speed .

Table 2.4 gives a list of speed and endurance of various vessels as well as information on anti-roll systems and thrusters.

As we have been unable to obtain accurate and reliable information on the speed aspects, and as we have been unable to obtain any scientifically meaningful information on seakeeping characteristics the discussion is limited to a very general level.

It is, however, worth noting that the typical maximum operational speed is in the range of 16 knots. The only exception is the very small vessel *Aranda*, whose speed is only 14.3 knots. Transit speed is typically 2 - 3 knots lower.

It is also worth noting that the ships are very different in regard to the distance of the transit requirement. Three of the ships, namely *Almirante Irizar*, *Aurora Australis* and *Nathaniel B. Palmer* are year round in the Southern Hemisphere, and therefore do not make a very long transit twice a year. The other three vessels make, whenever they go to the Antarctica, two very long transits per season.

Thus, the endurance varies accordingly. Generally speaking we are talking about an endurance between 30 and 60 operating days with provisions for a longer period, even for the ship to be able to overwinter in the Antarctic ice.

Oceans surrounding the Antarctica are very rough. Consequently, Antarctic vessels should be designed to operate in heavy seas. The safety aspect of this is taken care through international and national regulations. There are however two reasons that the ships should be designed for minimum movement in heavy seas. One is comfort of people onboard and the other is the ability to undertake research tasks when operating in heavy seas. Because of these two reasons all six ships/concepts have been equipped with anti-roll systems. *Almirante Irizar* is the only one equipped with active fin stabilizers, which are generally effective except at very slow speeds. All the other vessels are equipped with a controlled passive tank stabilizing system.

2.5 Performance in ice

For most of the ships, icebreaking capability is needed to reach a base or the shore line closest to a national base. So far not much active research has been undertaken when operating in ice. *Nathaniel B. Palmer* is however an exception. That ship operates year round in Antarctic waters and also undertakes research in ice.

The icebreaking capability of each ship is shown in Table 2.5.

All six ships are able and have been designed to operate in ice of certain thickness without any support of a specialized icebreaker.

The most commonly used reference for a ship's icebreaking capability is the maximum thickness of ice , which the ship can penetrate in the continuous mode of movement, i.e. at the speed of about 1 m per second.

The small *Aranda* can break about 0.6 meter thick ice and all the other vessels between 1-1.3 meter thick ice. It is a generally accepted view that icebreaking performance of less than 1.5 meter is adequate for (southern) summer operations in Antarctica.

Ships which are designed to operate in ice independent of icebreakers have to be built strong enough to withstand all ice loads the ships may encounter in her operation. Typically this is achieved by specifying a certain ice class to the ship. Four of the ships have been designed to the so called highest Baltic ice class , 1A Super by Lloyds Register of Shipping or Det Norske Veritas. *Almirante Irizar* and *Nathaniel B. Palmer* have a higher ice class. *Almirante Irizar* has been designed to ice loads determined by KMY based on their experience in subarctic and Arctic conditions. The hull of *Nathaniel B. Palmer* meets with the requirements of the American Bureau of Shipping Ice Class A2 (the bow with A3) and the Canadian CASPPR Class 3, which are somewhat higher than 1A Super.

To our knowledge none of the ships have experienced any real structural damages when operating in Antarctic ice. One must remember that there have been accidents with other vessels quite recently like those of the Argentinian *Bahia Paraiso* and *Gotland II*, both of which sunk in Antarctic waters.

2.6 Cargo capacities

A major function of Antarctic vessels is to carry cargo , provisions, construction material etc. to Antarctic bases. This covers fuel and other liquids for the bases, provision for overwintering of the team of up to say 50 people, vehicles for onshore Antarctic operation, repair and construction material of buildings, sheds etc., fuel tanks etc.

In addition the ships carry scientists and support personnel to and from the bases.

There is a great variation in cargo carrying capacity and also in cargo handling methods.

The small *Aranda* carries only 25 tons of scientific cargo. *Aurora Australis* has the largest cargo capacity, around 2000 tons.

The cargo can be in containers or in smaller units. Liquid cargo is normally transported in shipboard tanks, but also in barrels.

Table 2.6 gives a simple summary of the cargo capacities and cargo handling equipment/ methods. As one can see, there is a great variation in all figures etc. in the Table.

Cargo handling from ship to shore varies very much from location to location. Liquid cargo may be pumped directly to rubber etc. tanks on shore. Dry cargo may be lifted by cranes from ship to shore or ship to ice for further transportation. In some exceptional cases a roll-on roll-off method can be used. The Italian concept is particularly designed for roll-on roll-off operation .

There has been a slow trend of containerizing Antarctic dry cargo. For most locations and cases a full 20 foot container seems to be excessive in size and weight. As quantities increase, containerized cargo may become more popular.

The number of passengers and crew members is one design parameter of Antarctic vessels. This varies considerably from ship to ship. The total number of people onboard *Aranda* is only 47 while in *Almirante Irizar* there is accommodation for a total of 233 people. From the overall ship design point of view the total number of people is important and not the division of the people to scientists and crew.

Almirante Irizar is a naval vessel which explains the high number of crew members.

All ships, with the exception of *James Clark Ross*, are equipped with facilities for helicopters.

2.7 Scientific capabilities

Table 2.7 outlines the basic figures and features in scientific capabilities. We limit this discussion to the number of laboratories, total area of laboratories and primary crane/winch equipment, which has to be taken into consideration when designing a ship concept.

Area reserved for laboratories varies from 60 m^2 to 270 m^2. It is interesting to note that the smaller figure is that of the largest vessel *Almirante Irizar* and the second largest figure is that of the smallest vessel *Aranda*.

All ships except *Almirante Irizar* have an A-frame for handling heavy research equipment. There are typically 5-8 scientific winches. Three of the vessels have a moon pool.

2.8 Diversity of operation

Although all six vessels have been designed for either exclusively to Antarctic operation or Antarctic operation as a priority operation, there is a great variety among the vessels as can be seen in the following.

Almirante Irizar is a Naval vessel and the national flag ship of the country's Antarctic operation. Her only function is Antarctic operation which is Antarctic logistics support and research. She operates every year in the Antarctic waters. Her primary operation area is Weddell Sea. She is very much like an icebreaker designed and constructed for the Arctic Ocean.

Aranda is a small research vessel, whose primary function is to do research year round in the Baltic with occasional trips to the North Sea etc. She has visited Antarctica only once. She will be used in the future in the Antarctica only occasionally, perhaps once every six years. Her logistics support capabilities are almost non-existent.

James Clark Ross is designed and built primarily for Antarctic operation. Her base is in the UK and therefore she makes a return trip annually from the UK to the Antarctica. Scientific operations have included an Arctic cruise during the Northern summer.

Aurora Australis is in principle very much like *James Clark Ross* but she does not need to make long transits as the base of the ship is Tasmania, Australia. *Aurora Australis* operates about 6-8 months every year, all in the Antarctic waters.

Nathaniel B. Palmer is a research only vessel. She is the only vessel out of six which operate year round in the Antarctic waters. Although she is a US, vessel her base is in Punta Arenas, Chile. It is the intention that she will stay in the south basically throughout her career.

The Italian vessel will be used very much in the same way as *James Clark Ross* with one return a long transit per year and logistics support plus research in the Antarctic waters.

The involvement of Government Authorities and private enterprises varies from ship to ship. *Almirante Irizar* is all Government, the Military Navy. *Aranda* and *James Clark Ross* are governmental research institute vessels. In the operation of *Aurora Australis* and *Nathaniel B. Palmer*, there is a strong private enterprise element involved. The Italian solution is not yet known for sure.

operations is not very stable, these ships have to be able to be offered for other purposes as well.

Without exception all countries are suffering today from lack of funding for Antarctic operation. Thus there is a tremendous pressure to deliver more in science for less money. This would be a natural base to try to rationalize Antarctic logistics support and ocean research platform operations.

KMY is a shipbuilding company. Therefore, we are not upfront to propose joint shipping undertakings but we can offer a cost competitive and technologically first class product to effective Antarctic operations.

3.2 Operational and technical requirements

Based on the analysis above under Item 2., and on our understanding of the future activities, the general level requirements for an Antarctic combination vessel are outlined below. This is done for the basis of developing a concept serving average needs.

1. Scientific laboratories, 250 m^2
2. Science deck aft, 400 m^2 with A-frame and other "standard" equipment
3. Scientific personnel, abt. 30 people for ship based research
4. 30 passengers to be carried to Antarctic bases and from
5. Dry cargo volume 2000 m^3, 800 tons
6. Liquid cargo in tanks, 800 tons
7. Maximum flexibility between scientific areas and dry cargo areas
8. Minimum crew
9. Maximum speed in open water 16 knots, optimum transit speed 10-12 knots
10. Icebreaking capability 1,2 m
11. Endurance :
    - Europe to Antarctica at transit speed
    - 60 days in Antarctica, 50% of that in ice
    - Overwintering in case of emergency
12. Helicopter operations and helicopter base
13. Cargo handling:
    - Crane
    - Helicopter
14. Ice strengthening 1A Super plus, adjustment for differences in ice conditions between Antarctic waters and Baltic

3. MV ANTARCTIC FUTURE

The above analysis of six different vessels and their operation gives a basis of a comprehensive understanding of Antarctic operations and their diversity. We know that the activities in Antarctica are limited by the Antarctic Treaty to science only for the next few decades. This gives a sound basis to develop a future concept for Antarctic vessels.

There will not be a huge need of Antarctic logistics support and research vessels in the near future as there are no signs that scientific operations will drastically increase. One can, however, not believe that the Antarctic operations would diminish either. We can assume that today known and future global problems would make Antarctica an ever more important place which would intensify all allowed activities in the Antarctica progressively.

We can assume that some countries, which have marginal activities related to Antarctic research, would enhance their operation which would require a new ship for their operation. There will be some ship replacement requirements as well. We estimate that about one major new Antarctic vessel would be required in every two years in the global scale.

3.1 Business perspectives

Antarctic operation, predominantly research, is not commercial business as such. However where money is required, business elements are involved. The same cost and business elements are involved independent of which kind of organization operates and owns Antarctic vessels, whether it is government direct, a government managed and owned institute or a private enterprise.

The general trend seems to be today that each individual country must have an Antarctic vessel of their own. Every now and then some efforts have been made to combine the interest of various countries. This has to our knowledge been limited to sharing cargo capacities and scientific participation occasionally in another country's vessel.

Some shipping people have played with the idea of building on speculation a vessel or two which would carry simultaneously cargos of various countries and would also host scientific activities of many countries either at one time or one at a time. None of these have materialized. There are however ships in the market, which have been chartered basically on a season to season basis to various countries. Because the business base of Antarctic

15. Waste return capability
16. Top of the line environmental protection

3.3 KMY concept

The primary operational functions are cargo carrying/handling and undertaking research .

The traditional problems in the design of a combination Antarctic vessels are the following:

- Effective science operation rooms / open deck are disturbed by cargo handling in c: there are cargo holds aft
- Cargo operations by helicopter are difficult in case cargo holds are in front of ı superstructure
- The traditional machinery (horizontal shaft lines) eats up cargo space, if designed to aft

Because of the above difficulties compromises have to be made which typically result in design with unnecessary complexity.

The recent development of an azimuthing podded electric propulsion system however makes possible to eliminate most of the above problems and eliminate the unnecessary complexit The propulsion system , which is called AZIPOD is a new development and has been install in two ships so far. A third one is under construction.

The idea is simple. The electric propulsion motor is "in the propeller hub". Because the ur is rotatable no rudders are needed, Fig. 3.3.1.

We can today say that the system is already well proven, as a 1.5 MW unit has been used an icebreaking buoy tender in the northern Baltic for four years and an icebreaking tanker wit 11.4 MW AZIPOD has been in operation for more than half a year, part of that in the Russi Arctic.

The system is ideal for a research vessel with electric propulsion motor, making it easier achieve a low noise operation .

For an Antarctic research vessel a major benefit however is the flexibility it gives to loca scientific spaces and cargo holds. The main machinery room can be as forward as the hu configuration allows . The only propulsion machinery element in the aft ship is the AZIPO unit which does not eat up more space from the hull than a normal steering gear room.

The figure 3.3.2 is a sketch general arrangement of the proposed Antarctic combination vessel, which we call MV Antarctic Future. The machinery room is forward with the AZIPOD propulsor room extreme aft. This gives a lot of flexibility to the spaces between those two. The main characteristics etc. of the vessel are in Table 3.3.1.

We propose two different versions of hull form as can be seen. One is with a bulbous bow and the other with a modern icebreaking configuration. Both designs are made for heavy icebreaking in the Antarctic waters, to 1.2 m thick level ice or more in the continuous mode of movement. The trick is that the version with bulbous bow is optimized for both icebreaking and open water. The ship will operate with bulbous bow first in ice-free conditions and in very thin ice. In heavier ice the ship operates in the AZIPOD first mode. The bulbous bow gives the ship significant advantages like: better fuel efficiency (consequently more cargo as a result of reduced fuel requirement), better seakeeping characteristics, and better platform for equipment sensitive to hydrographic disturbances.

It is to be noted that an icebreaking bow form is justified in case ramming in heavy ice is expected.

Of course the AZIPOD has to be designed strong enough to meet with encountering ice blocks. There is nothing dramatic in it as the ice-propeller interaction loads are relatively well known today for design purposes and also because this is a concept which was routine in the past in the Baltic. In the 50's to 70's a great amount of icebreakers were designed and built for Baltic operation with so called bow propellers. In certain conditions these bow propellers are very effective while in some other conditions they are slightly less effective than the form without propellers.

AZIPOD gives unique and extreme manoeuvring capabilities as the total thrust can be directed to any direction including transverse direction.

The design has been developed by us to what we call preliminary level, which is beyond concept level. It would take a couple of months for us to further develop the concept to a contract package level. Taking into consideration that the construction would take about 20-24 months a ship based on the presented concept could be available in the market realistically for the 1997-1998 season. This of course presumes a sound business concept has been developed and business risks have been minimized.

4. SUMMARY

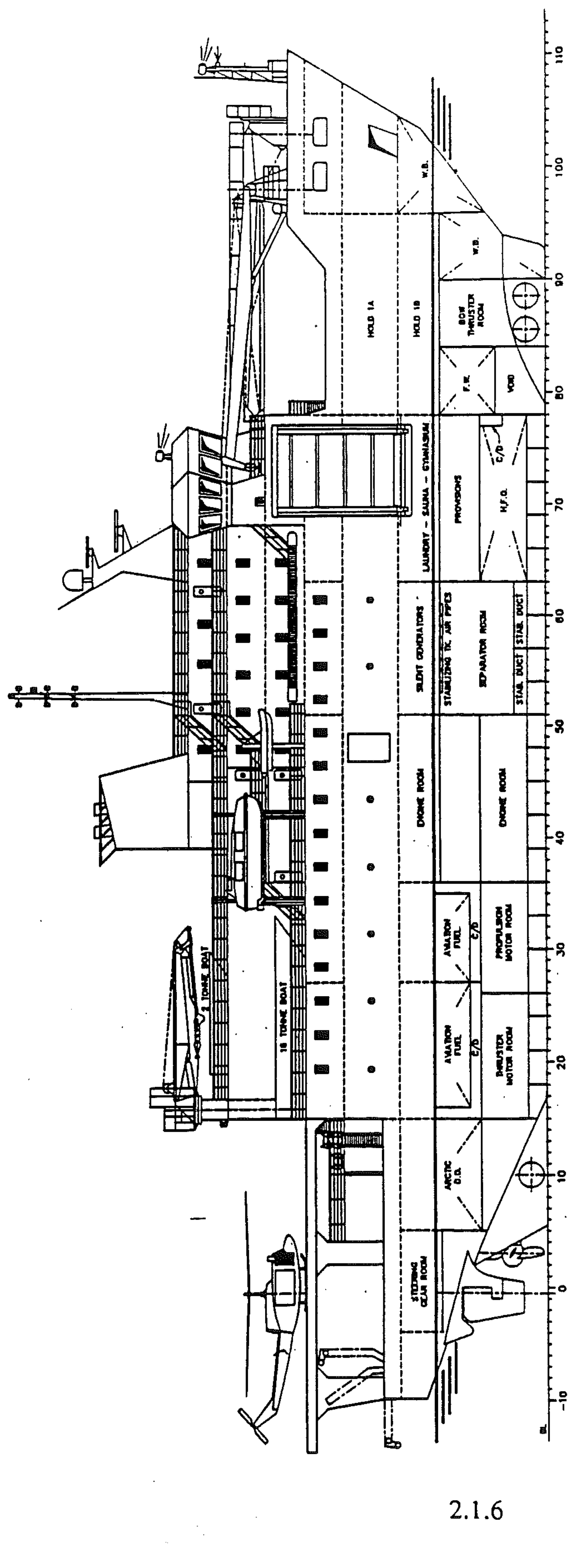
Logistics support and ocean research are the primary functions of typical Antarctic vessels. Icebreaking capability is essential. Kvaerner Masa-Yards Inc. have been involved in the design and/or construction of six different Antarctic vessels with a variety of functions and capabilities.

There is need to more rationalized and cost effective ship design for Antarctic operations. The average needs of numerous countries, as regards science and logistics support capabilities, was established. A ship design concept with two variations were developed utilizing the most recent achievements in technology.

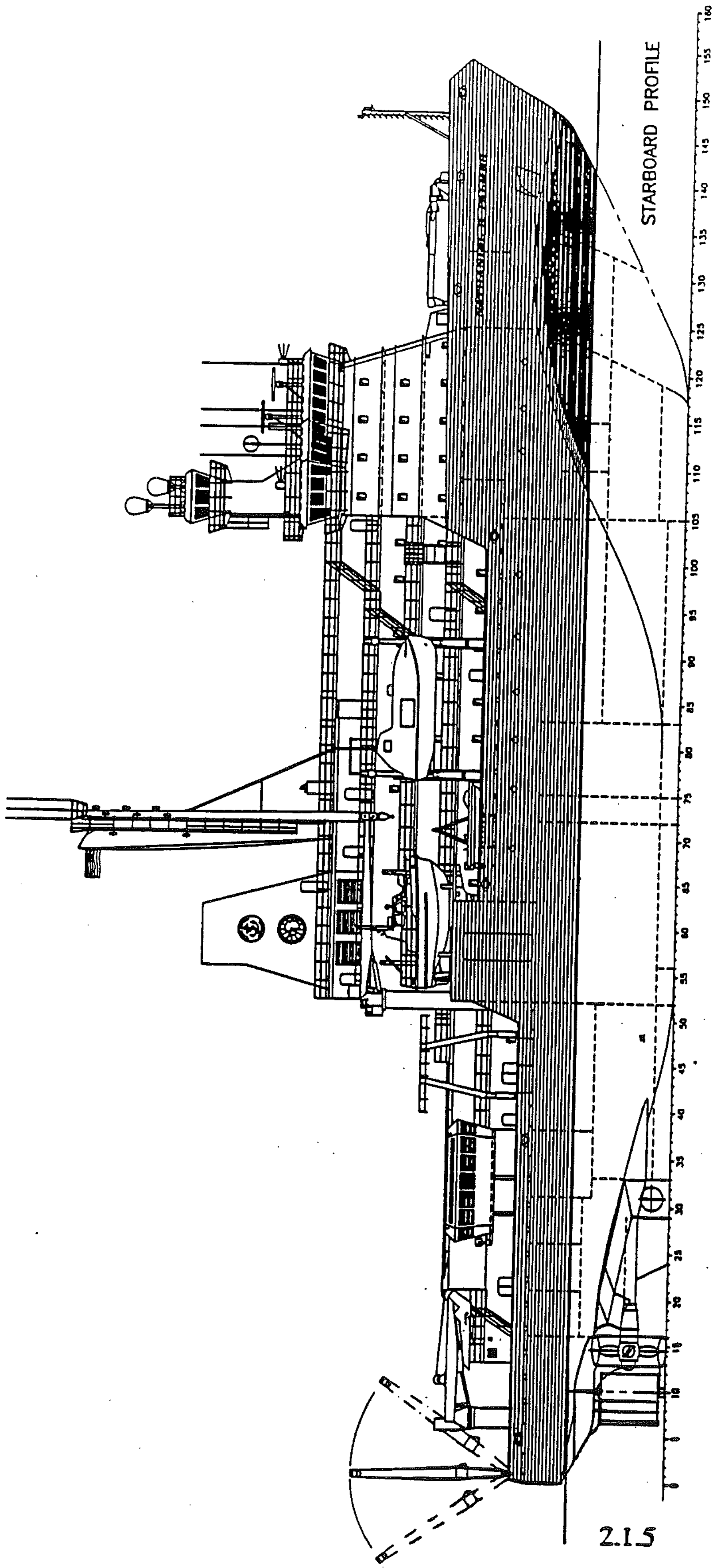
Intensified international co-operation would make it possible to contribute more in research and logistics support by less money through one or more new ships utilizing up-to-date technology. The key word is flexibility between the two main functions: logistics suppor capabilities and research capabilities.

5. ACKNOWLEDGEMENT

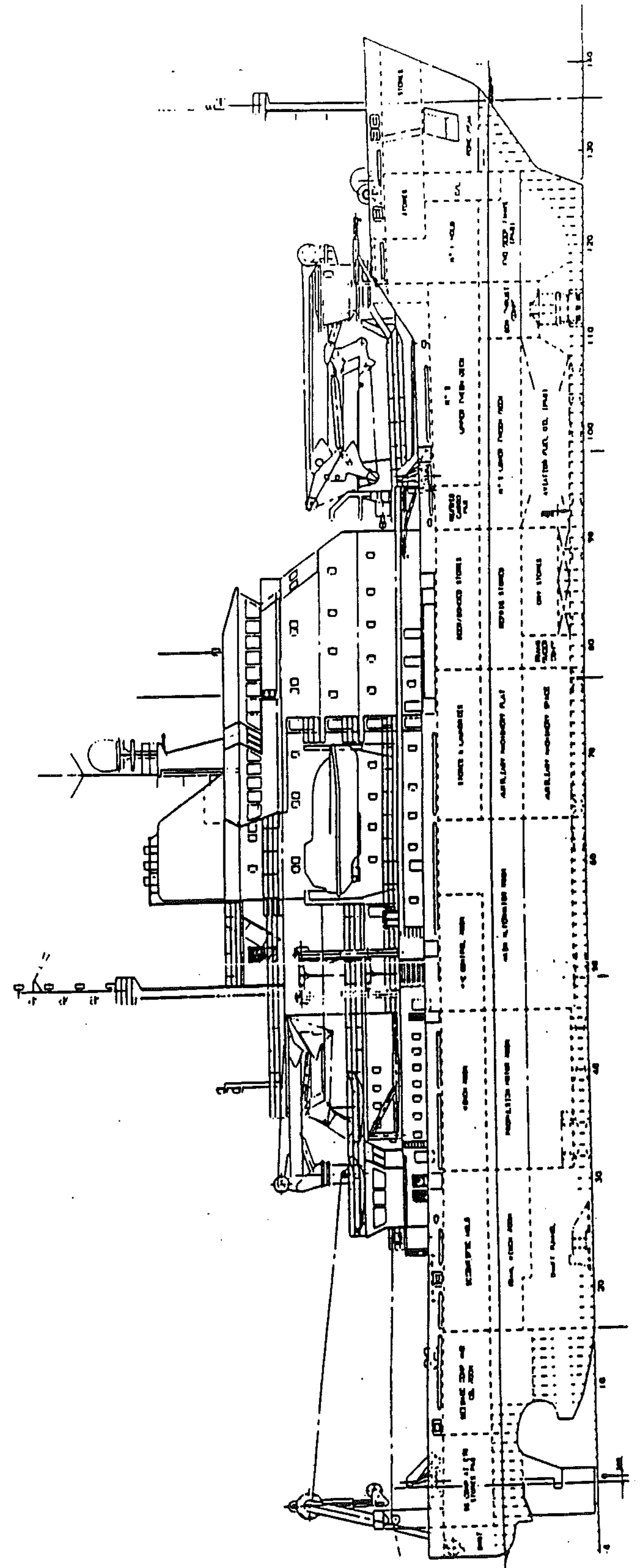
This paper and the technical work in it would have not been possible without a permission of six institutions to allow us to publish selected data on the six vessels, which have been designed and/or constructed by Kvaerner Masa-Yards Inc. We thank specifically the following six individuals for granting us the permission to use and submitting to us information on their particular ships: General Jorge E. Leal, Direccion Nacional del Antartico (*Almirante Irizar*), Professor Pentti Mälkki, The Finnish Maritime Research Institute (*Aranda*), Mr. J.P. Gleeson, P&O Polar Australia (*Aurora Australis*), Mr. D.M. Blake, British Antarctic Survey (*James Clarke Ross*), Mr. Laney J. Chouest, Edison Chouest Offshore (*Nathaniel B. Palmer*) and Dr Vincenzo Farinetti, Fincantieri (*Italian Antarctic Vessel*).



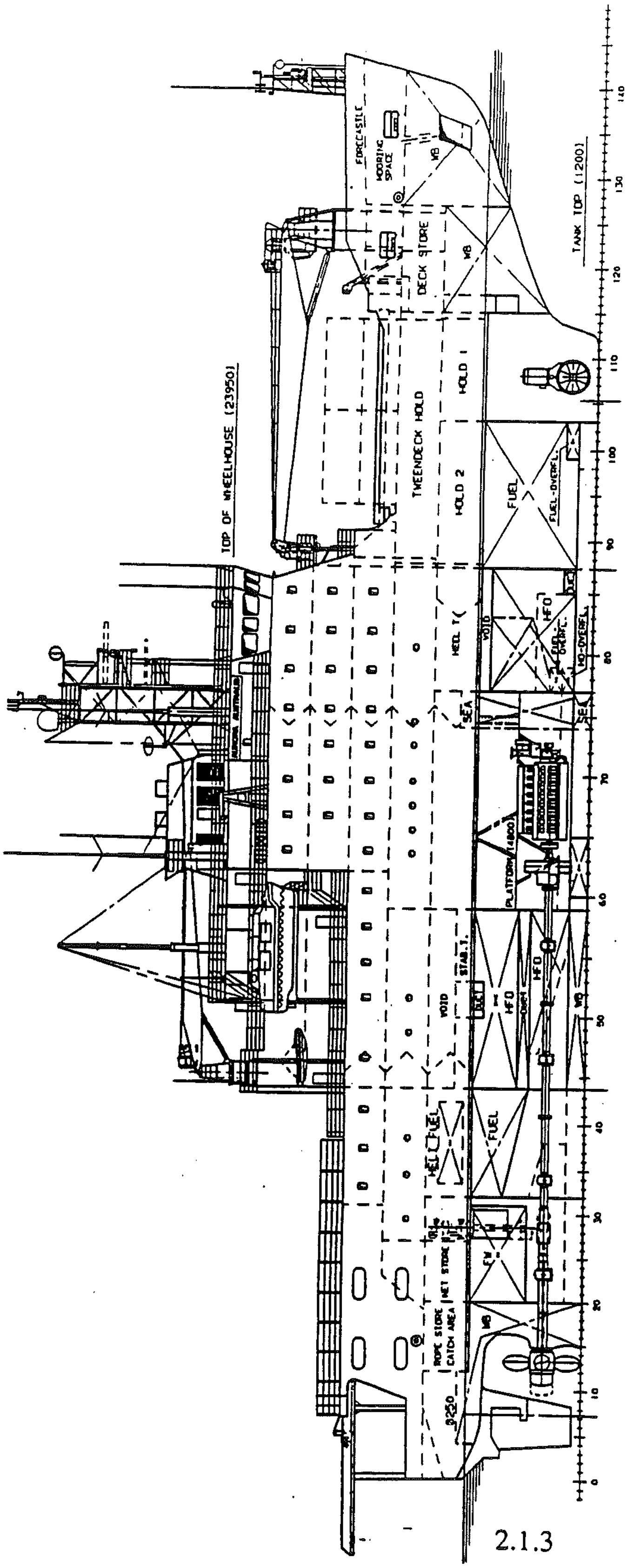
2.1.6 *Italian Ar.*



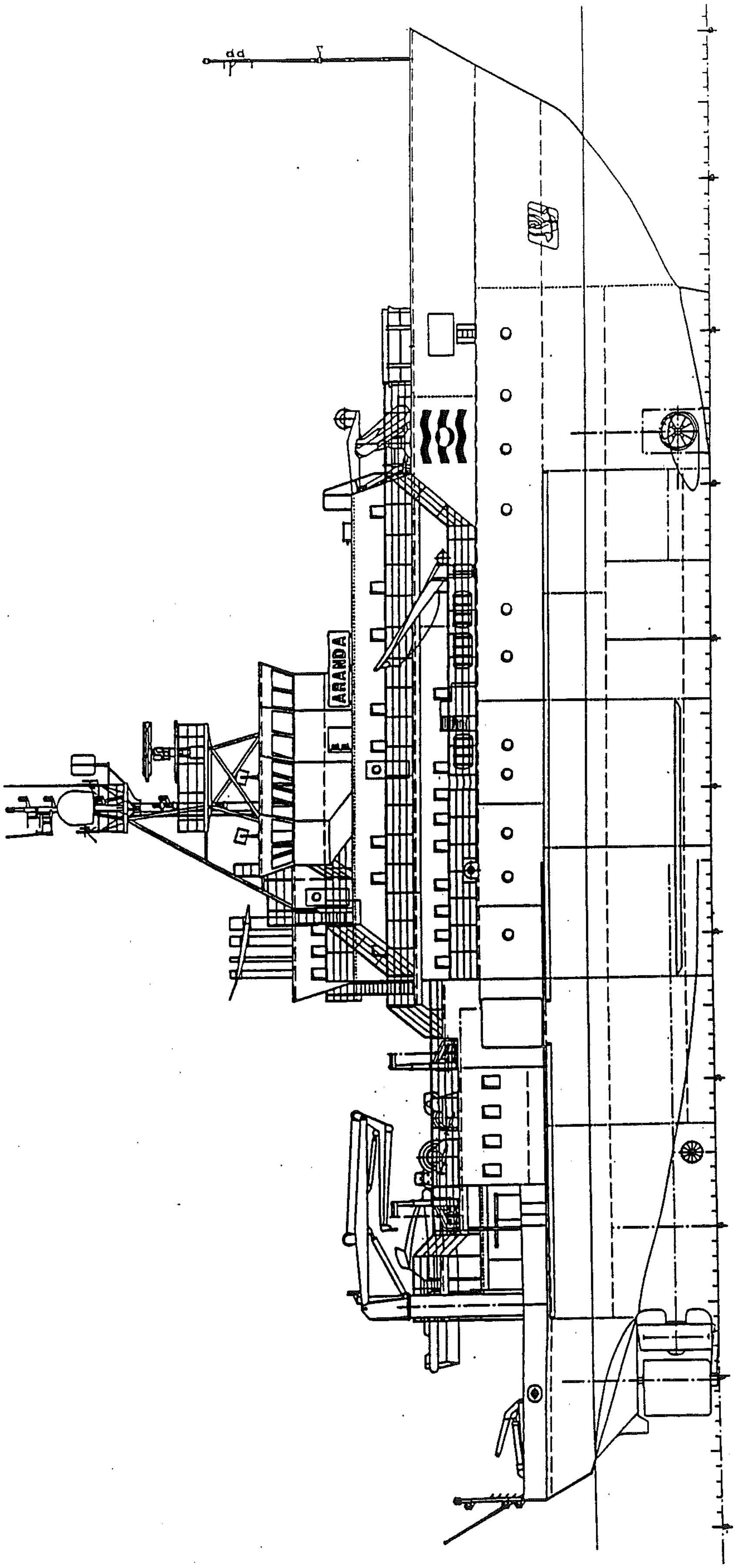
2.1.5 *Nathaniel B. Palmer*



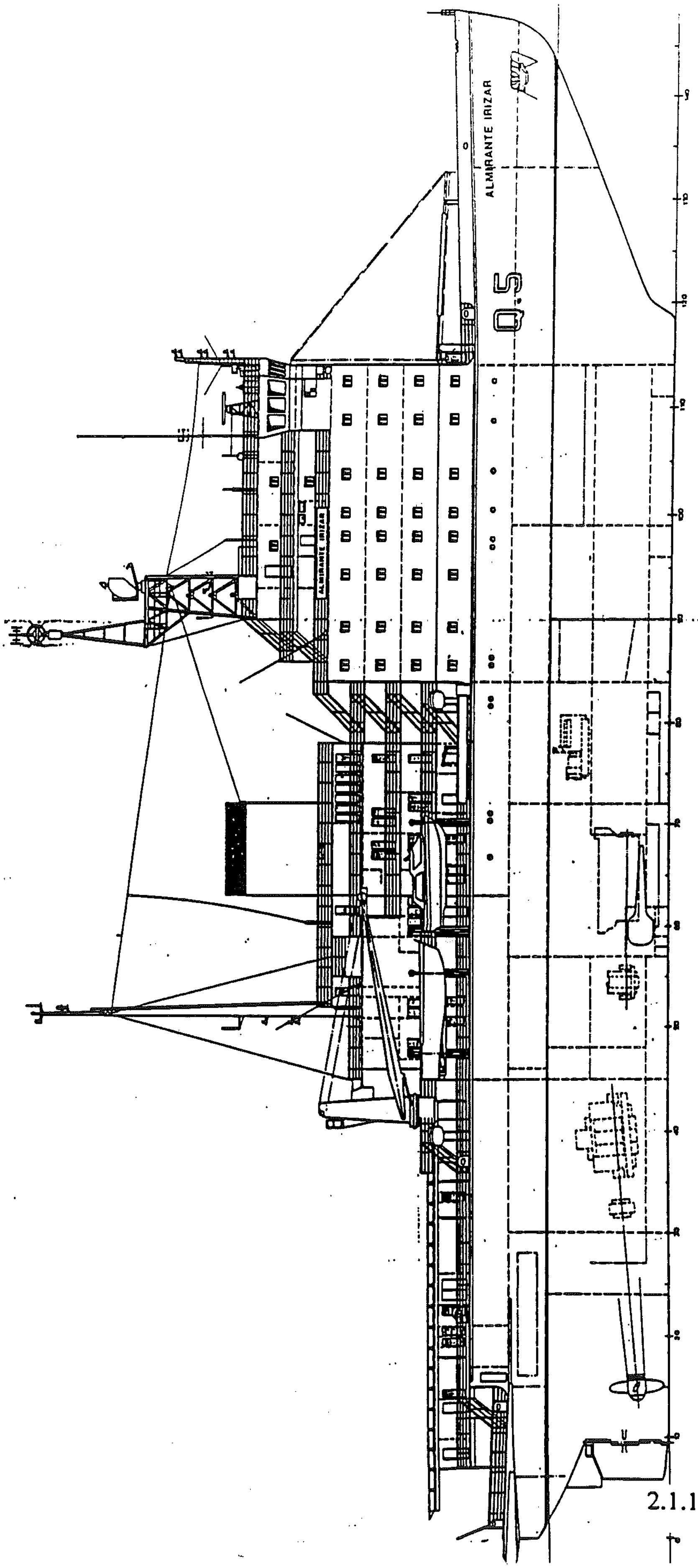
2.1.4 *James Clark*



2.1.3 *Aurora Australi*



2.1.2



2.1.1 *Almirante*

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
L_{OA} (m)	119.30	59.24	99.04	94.91	94.00	98
L_{WL} (m)	113.40	51.15	90.00	88.40	85.30	88
B_{WL} (m)	24.80	13.80	18.85	20.30	18.30	22
H (m)	12.60	6.70	9.80	13.25	9.10	14.6
D (m)	9.50	4.60	6.30	7.86	6.60	8
Displacement (ton)	14900	1950	7480	8158	7100	8570
Deadweight (ton)	2400	345	2532	3940	2250	3500
Classification	DnV +1A1	DnV 1A Super	LR +100A1 1A Super	LR +100A1 1A Super	ABS Ice Class A2	R.I.N.A. 1A Super

Table 2.2.

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
Concept	Diesel-Electric (DE)	Mechanical/DE	DE	Mechanical	Mechanical	Mechanical/DE
Power (kW)	11900	3000/1000	6300	10000	9700	9000/1000
Main diesels	4	2	4	2	4	4
Aux. diesels	4	1	-	3	4	2
Propellers	2 FPP	1 CPP, nozzle	1 FPP	1 CPP	2 CPP, nozzles	2 CPP

Table 2.3.

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
Speed (kn)	16.5	14.3	16	16	15.2	16
Cruising speed (kn)	n.a.	12	12	13	n.a.	13
Range (nm)	12000	15000	16500	14000	n.a.	14000
Endurance (days)	180	60	57	90	n.a.	100
Thrusters, fore	-	1*400 kW	10 ton thrust	1*800 kW	10 ton thrust	2*880 kW
Thrusters, aft	-	1*150 kW	4 ton thrust	2*400 kW	6 ton thrust	1*880 kW
Roll stabilization	fin stabilizers	control passive tank	control passive tank	control passive tank	control passive tank	control passive tank

Table 2.4.

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
Icebreaking requirement	1m, continous	not specified	0.9m, 1.5m/s	1.2m, 1.5m/s	0.9m, 1.5m/s	0.8m, 1m/s
Proven capability	1.2m, 1m/s	0.6m, 1m/s	n.a.	1.5m, m.sc. result	1.3m, 0.5m/s	?
Ramming requirement	5-6m	not specified	1.8m	not specified	not specified	not specified
Power/Beam (kW/m)	480	217	334	493	514	409

Table 2.5.

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
Dry cargo (ton)	665	25	635	550+890 in TEU	abt. 65	500+500 in TEU&Ro-Ro
Dry cargo (m^3)	1600	n.a.	1300	1600	abt. 220	1400
Liquid cargo (m^3)	250	-	550	700	-	500
Cargo handling	cranes	cranes	cranes+tender	cranes	cranes	cranes& Ro-Ro ramp
Helicopter	2	2	-	2	2	2
Manning, total	233	37	77	133	72	103
-crew	133	10	27	26	26	28
-scientists	100	12	50	107	37	75
-spare	-	15	-	-	9	-

Table 2.6.

	Almirante Irizar	Aranda	James Clark Ross	Aurora Australis	Nathaniel B. Palmer	Italian Project
Number of laboratories	2	7	9+5 lab. cont.	9+2 lab. cont.	8	6
Total laboratory area (m^2)	60	270	200	abt. 200	370	170
Number of winches	1	7	7	8	4	5
A-frame	no	yes	yes	yes (fixed)	yes	yes
Moonpool	no	yes	no	no	no	yes

Table 2.7.

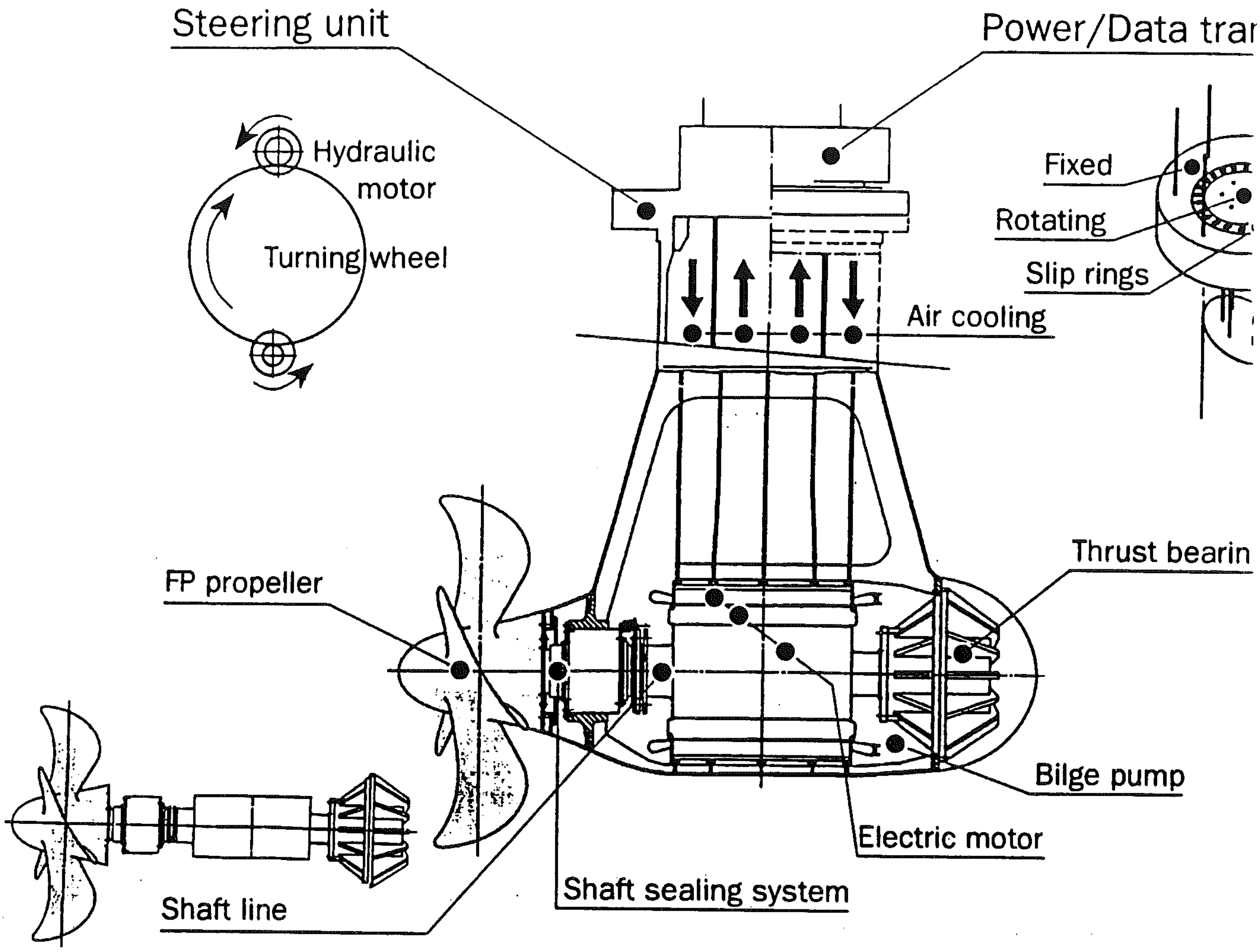
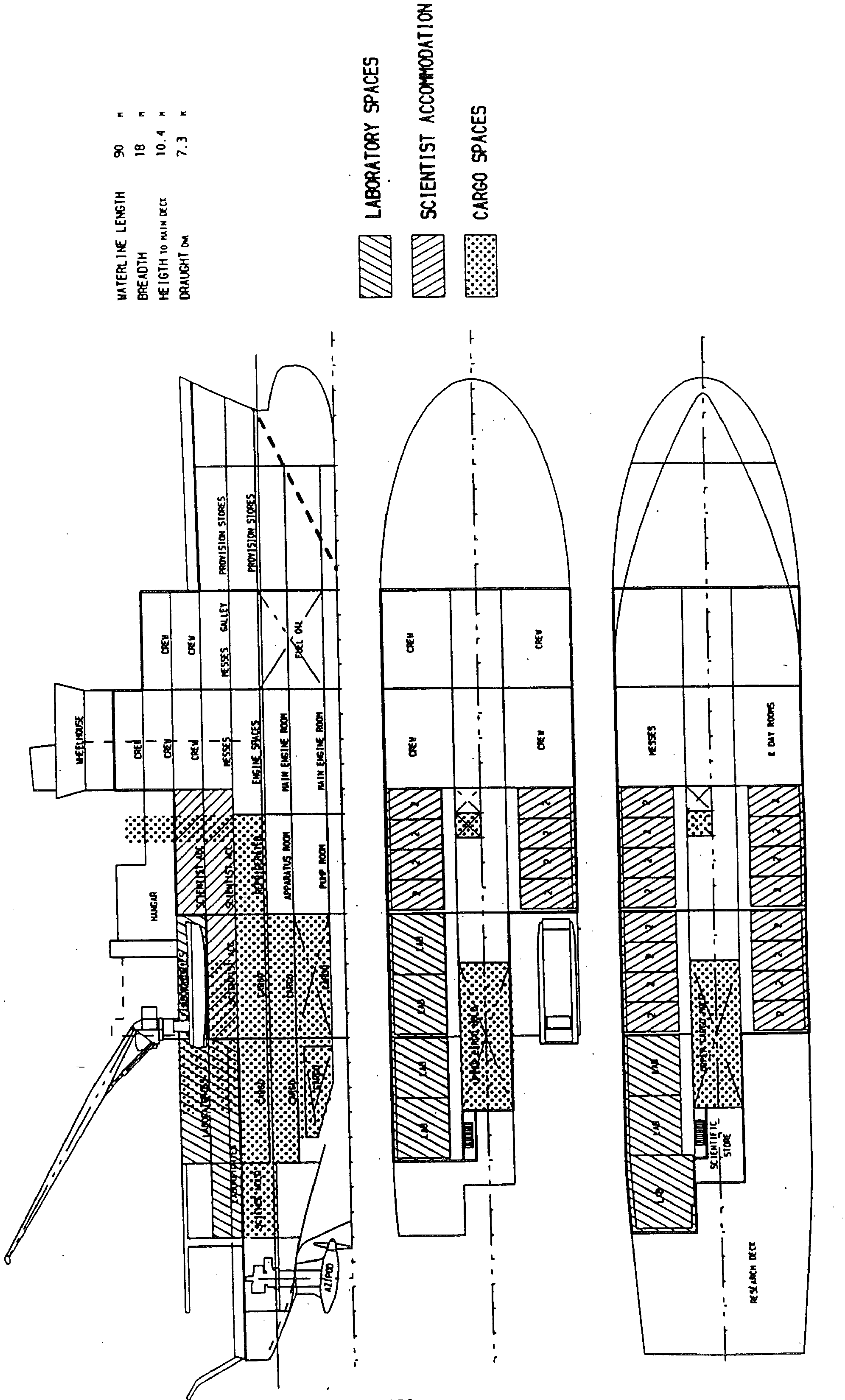


Figure 3.3.1. Drawing of an A


WATERLINE LENGTH 90 m
BREADTH 18 m
HEIGTH TO MAIN DECK 10.4 m
DRAUGHT DWL 7.3 m
LABORATORY SPACES
SCIENTIST ACCOMMODATION
CARGO SPACES
WHEELHOUSE
CREW
MESSES
GALLEY
PROVISION STORES
FUEL OIL
ENGINE SPACES
MAIN ENGINE ROOM
APPARATUS ROOM
PUMP ROOM
HANGAR
SCIENTIST ACC.
CARGO
LABORATORIES
AZIPOD
LAB
SCIENTIFIC STORE
2 DAY ROOMS
RESEARCH DECK

MS ANTARCTIC FUTURE

MAIN CHARACTERISTICS

MAIN DIMENSIONS

Length over all	96	m
Length, waterline	90	m
Breadth	18	m
Side height	10.4	m
Draught dwl	7.3	m
Shaft power	5000	kW
Total electric power	6600	kW
Propulsion	D-E AZIPOD	
Speed	15	knots
Icebreaking capability	1.3	m
Range	16000	miles

CAPACITIES

Crew	20	
Passengers (passengers and scientists)	72	
Laboratories	210	sq.m.
Research deck	400	sq.m.
Scientific hold	360	cu.m.
Dry cargo holds	2080	cu.m.
Refrigerated hold	300	cu.m.
Liquid cargo	750	cu.m.

TABLE 3.3.1

Symposium on Antarctic Logistics and Operations
Rome, Italy
1994

An Automatic Integrated Module Installed at Terra Nova Bay

A. Lori
ENEA-PROGETTO ANTARTIDE

ABSTRACT

This paper describes the state of art after three years of development of an automatic platform installed at terra Nova Bay during the sixth Italian expedition in Antarctica. The platform consists of two 20' standard containers and one fuel tank in 20' standard frame. One of the containers houses the complete power generation; the other houses a central Mvax 3800 computer and additional equipment for data transmission and acquisition.
The automatic platform allows to obtain the following tasks:

- availability of six kilowatts of electrical power (220 V AC, 50 Hz) for about one year of continuous operation;
- automatic data acquisition;
- satellite link for data transmission and telecontrol;
- data transmission via HF radio.

INTRODUCTION

During the SCALOP of Sao Paulo in 1990, the Italian Antarctic Project presented a paper titled "AIM" (automatic integrated module), where was possible to find: a description of the scientific activities performed at the Italian Station, the main reasons that pushed the Italian Project to develop such an automatic platform and a description plus design criteria of it. The first part of this paper resumes the document mentioned above, with the purpose to make the document understandable for anyone; the second part describes the acquired experience and the actions undertaken to overcome all break-down occurred during the first three years of operations.
The Italian station of Terra Nova Bay was established in 1986/87 in the Northern Foothills on the coast of Victoria Land, Ross Sea (74° 41' 42" S, 164° 07' 23" E)
The station was developed in the following years and completed as a permanent summer station during the 88/89 expedition.
The main scientific activities carried out during our presence in Antarctica have interested the following fields:

- Oceanography (Physics, Chemistry, Geology and Biology);
- Atmosphere Physics;
- Cosmology and Cosmogeophysics;
- Earth and raw material sciences;
- Biology and Medicine;
- Environmental impact.

Some of the above scientific activities make use of automatic observatory for data collection.

A list of numbers and types of operational observatories follows:

	TYPE	NUMBER
-	Geomagnetism	1
-	Geoseismic(VBB, very broad band)	1
-	Tilt and temperature	5
-	seismic network	4
-	Automatic weather stations (AWS)	8
-	Meteorological network	5
-	Tide gauge	1
-	Oceanographic station (buoy)	1
-	RIO-meter	1
-	Iono-probe	1

(A BLOCK DIAGRAM OF THE STATIONS IS IN APPENDIX 1).

Many of the stations mentioned are specially designed to work all year round with very low power, supplied with batteries charged by solar panels and wind generators. Most of the stations store scientific data locally in 124 Kbyte memory (Meteorological network, seismic network, Tilt and temperature). Automatic weather stations (AWS) store locally and also transmit via ARGOS satellite. VBB seismic station and Geomagnetic station can only operate during the summer because the enormous amount of data produced require storage memories compatible with large computers. These absorb quantities of electrical energy that can be supplied only by an automatic system for electrical energy generation.
After requests from the Italian Scientific Community, to continue data acquisition all year round, the Antarctic Project has decided to develop an automatic system capable of generating electrical energy continuously for at least one year, without maintenance, to supply power to a system comprising of a computer for data collection and of a sat station for a real-time control and a bi-directional data link between the automatic system and our Italian office, for a continuous observing run. Considering the power consumption of the essential electronic components, it was evaluated that six kW is the total electrical power needed during the winter months.

AUTOMATIC PLATFORM

The automatic platform has two main tasks:

- data acquisition;
- telecontrol and data transfer.

It consists of a complete electrical power generation and of a central control system for data transmission and acquisition.

The main criteria for designing the energy production system are:

- reliability;
- low cost;
- efficiency.

Most of the energy systems available on the market are not able to supply 6-7 kW, continuously for long period of time without maintenance.
The following have been analyzed:

- TEG generators;
- Sterling engines;
- ORMAT generators;
- Wind generators;
- Photo voltaic panels;
- modified diesel engines;
- standard model diesel engines

TEG generators are based on the Seebeck effect. Basically there is a cell consisting of two wires made of different materials jointed togheter. A current is produced when the temperature of two joints is different. Teledyne generators are normally used to supply no more than 100-200 watts, since their cells produce about 10 watts each. Even though reliability is very high and maintenance easy, the very low efficiency (less than 8%) produce an excessive quantity of useless heat.
Sterling engines have good efficiency and high reliability but they are very expensive because they aren't commercially available.
ORMAT generators are reliable but efficiency is not good (about 5%) as in diesel engines, and cost is very high (30000 US$ for a 400 watts system).
Even though Wind and Photo voltaic generators are capable to operate with good reliability in Antarctic conditions, they cannot provide continuous supply of current needed for the electronic instrumentation: this is why this kind of generators were not found suitable for our purpose.
Modified diesel engines. Diesel engines are competitive in terms of cost and efficiency but reliability is low and regular maintenance is necessary. The development of a diesel engine meeting our requirement would not be realistic in terms of cost. Furthermore such an engine would not have other market. An Italian engines maker offered to make sophisticated modifications to existing engines, bringing maintenance-free operation time up to 4000 hours. The Automatic platform would require three of such engines (two+one reserve), which would cost 100 million Lira all together, 50 ML on studies and modifications, 50 ML on the engines themselves.
Standard diesel engines. The Antarctic Project has decided to use slightly modified standard model diesel engines to realize the automatic integrated module AIM. Reliability has been improved by doubling the number of engines, six standard engines instead of three modified engines. This choice allows also us to meet the request of low cost.

POWER PRODUCTION SYSTEM

Six autonomous electrical diesel generator units, each having a supplementary oil tank, starting battery charger and electric panel, make up the system (Characteristics of the power unit and alternator are summarized in table 1). A central electric device makes sure that one of the six generators is working all the time, and starts another one if the previous engine stops for any reason. Furthermore, the main computer, among the other tasks, collects some control parameters coming from sensors installed in the power generation container and in case something is wrong it has the permission to stop the engine active at that moment.

The engines used in the platform are modified as follow:

- glow plug at engine head;
- oil pump fed by a 40 liters auxiliary oil tank;
- injection pump adapted to jet-A1 fuel.

The first component was installed to improve the engine's starting. Problems regarding oil level, topping up and changing the oil every hundred hours, were solved by simply adding a supplementary 50 liters capacity tank. It is located below the normal engine oil sump. A pipe between the two tanks keeps the oil level constant in the sump as well as allowing oil to drop into the lower tank (FIG. 1). The size of the supplementary tank was determined considering the necessity to preserve the lubricating capacity of the oil. Oil consumption was also taken into account. The engines were adapted to jet-A1 fuel by modifying the injection pump; the surface of the plungers has been hardened by nitriding, to reduce wear and prevent seizure which could be caused by using a very dry fuel.

COMMAND AND CONTROL DEVICE (CCD)

It is an electromechanical device that controls the following operations:

- starting of the engines in sequence;
- performing tests run periodically;
- refueling of the internal fuel tank.

The CCD controls the system simply by checking generators output voltage level. Once the level falls, the CCD transfers operations to another engine. Time delay relays have been used to transfer command from one engine to another. The relays connected to the first engine starter motor has zero second delay; the relay connected to the second engine starter motor has sixty seconds delay, and so on up to 300 seconds delay for the last engine. When an engine starts, it runs first at 1500 rpm for 40 seconds (warming-up) and than at 3000 rpm. As soon as the generator output voltage level is acceptable, a contactor connects the generator to the network line and also reset the starting procedure belonging to the other engines. However, since the CCD controls the system in a rough way, using only the generator output voltage level, it is supported on its task by a computer that memorizes:

- engine oil pressure;
- fuel consumption;
- temperatures;
- name of the running engine;
- presence of voltage in the network.
- status of each engine (check run, connection with CCD)[1]

The computer checks that the above signals are in a normal range to reduce breakdown risks. Low oil pressure, for instance, indicates that the running engine must be stopped and excluded from the CCD control.

---

[1] Each engine it is checked for ten minutes run once a week. This operation is necessary to prevent damage arising by prolonged inactivity (starting problems). All engines are normally connected with CCD, anyway when they are stopped by the computer they are also disconnected to avoid ceck run.
It is important to know how many engines are disconnected and if check runs are executed to have a complete view of the power production system status.

Fuel consumption allows the computer to check the existence of possible fuel spills. In presence of an abnormal fuel consumption the computer stops and shut off the engine from CCD control.
"Name of the running engine" and "presence of voltage in the network" allow the computer to know if the alternator in action is O.K.. In case the computer sees an engine active and absence of voltage, it stops the engine. With more than one engine active and presence of voltage, the computer checks which one is connected to the network and stops the other engines.
Computer decisions are not of course definitive. They can be overruled from Italy if analysis of control parameters do not confirm its decision.
(APPENDIX 2 -CCD-STARTING AND TEST RUN LOGIC)

CONTAINER SET-UP

Two containers are used to house the platform. In the first one there are generators, command and control device (CCD) and conditioning system; in the second one there are computers, satellite stations, unbreakable power systems (UPS) and conditioning system.

Power electric generation container

(APPENDIX 3- PLANIMETRY OF THE CONTAINER)

Engine operations take place at around a temperature of 20 °C. Specific consumption is 0.430 kg/kW (20% efficiency). Total consumption with a load of 6 kW is 2.58 kg/h (around 26500 kcal/h)[2 1]
Heat balance may be reasonably assumed as follow:
- 20% of total energy is transformed into electricity;
- 30% " " " is expelled through exhaust emissions;
- 40% " " " is transferred to the inside air by the air cooling system;
- 10% " " " is transferred to the inside air by irradiation.

From which it is estimated in 13000 kcal/h the total heat dissipated inside the container. Container insulation is in line with current Italian energy saving standards, that fix the volume coefficient of heat loss at cg=0.7 kcal/h cbm °C.
Considering Cd = Cg + Cv = 2200 kcal/h, where:
Cd is the thermal load;
Cg=cg x V- is the volume load of heat loss; for a standard container ISO 20', when difference of temperature between inside and outside is 50 °C, Cg=1200 kcal/h.
Cv is the thermal load due to air replacement; good engine operation needs 60 cubic meter of fresh air every hour, from which Cv= 1000kcal/h.
Knowing that the thermal loss due to irradiation is roughly equal to 1500 kcal/h, (with a temperature on the outside surface of the container equal to -30 °C), results that the total thermal loss of the container is equal to 3500 kcal/h. It follows that in order to maintain the inside temperature of the container at 20 °C, 9500 kcal/h must be dissipated.
Two independent axial fans (one on reserve of the other), regulated by the inside temperature, blow the worm air out with an air volume of 2300 cbm/h. The fans are able to maintain inside temperature at 20 °C even with an outside temperature of 0 °C. A fire extinguisher system is provided to prevent serious incidents.

[2] lower heating power=10300 kcal/kg

DATA ACQUISITION AND TELEMETRY

Data acquisition

A Mvax 3800, provided of three magnetic disks with a capacity of 400 Mb each, one 2 Gb magnetic disk, one 1Gb optical disk, collects data from the following scientific stations.

- Geomagnetic station;
- Geoseismic(VBB, very broad band);
- Tide gauge station;
- Oceanographic station (buoy);
- RIO-meter station;
- Ionosonde station;
- Meteorological station.

The Geomagnetic station was in function even before the automatic platform was installed at Terra Nova Bay. At that time the acquisition speed was low in order to reduce power consumption and be able to work continuously all year with a memory of about 1 Mb capacity. With the automatic platform in place, acquisition speed increased so that it is now necessary of a memory with 1 Gb capacity to store a year production of scientific data. An optical disk connected to the Mvax 3800, is reserved for this purpose.

The Geoseismic station (VBB, very broad band) utilizes two VME modular systems based on a 68000 microprocessor with a 2 Gb mass storage memory. One system is installed near the remote station and needs of 150 watts power supply. The other system, installed into the instrumentation container, is branched, by a high velocity data transmission interface produced by BIT3 COMPUTER, to the Mvax provided of a reserved 2 Gb magnetic disk. In order to check both VME status, access is allowed by serial port. A GPS provides absolute time to the seismometric data file. Reference time is with very high accuracy is of fundamental importance for this type of data; GPS time accuracy is equal to 0.0001 seconds.

Tide gauge station- scientific data measured are: pressure, temperature, water conductivity. The probe is installed at 17 m below sea level.

Oceanographic station (buoy)-scientific data memorized by this station are stored locally and also send by UHF radio to the HF remote station. It memorizes: temperature(air, water, water -18m),

RIO-meter station-it measures cosmic noise at 38.2 MHz by a double horizontal dipole and stores one datum each minute.

Ionosonde station-scientific data measured by this station give information about the existence and variability of the regular layers of the ionosphere.

Meteorological station-it is connected by wire to the Mvax and measures temperature, pressure, relative humidity, solar radiation, wind speed and direction.

(BLOCK DIAGRAM IN APPENDIX 4)

Telemetry

Geostationary satellites INMARSAT, which can be reached all year round from Terra Nova Bay, is used to perform telecontrol and data transmission. Anyway, to contain cost for data transfer, it is also used a 400 watts HF radio transmitter (ALIS

XK855-RODHE SWARZ) [3] . Unfortunately, HF radio-link are viable for only brief periods of time during the day, normally not during working hours. The system can be used in automatic link for data transmission at a speed of 320 bit/s.

The following items are used to establish the satellite link between the Italian Antarctic Program Headquarters in Rome and the Italian Station at BTN (Antarctica).

Italian side:
- PC computer;
- Modem interface between computer and sat. station (ZyXEL, US COURIER, US Robotics HST);
- Satellite station.

Antarctica side:
- Two satellite stations, one on reserve of the other (Saturn 90, Saturn 90S);
- Three modem interfaces in auto answer status, (US Robotics Courier connected to Saturn 90, US Robotics HST and ZyXEL connected to Saturn 90S);
- Computer Mvax 3800.

The link for telecontrol is performed in terminal emulator mode (ex. Procomm); for data transfer are used Kermit protocol or Zmodem. All modems work in data compression MNP5 mode and error correction CRC mode. Data transmission by satellite allows a speed of 2400 bit/s.

The following elements are used in HF radio transmission:

- PC computer in Italy;
- HF radio connected to the computer by an RS232;
- HF radio in Antarctica;
- Connection point to point, between remote HF power station and automatic platform computer, by Motorola modem Codex 6015;
- Mvax 3800 in Antarctica.

(APPENDIX 5-EQUIPMENT BLOCK DIAGRAM-)

CONTAINER SET-UP

(APPENDIX 6- CONTAINER EQUIPMENT ARRANGEMENT)

Operating temperature for the computer ranges between 10 °C and 35 °C. The insulation used for this container has the same characteristics as the other; with cg= 0.7 Kcal/ cm h °C when there is a temperature difference of 50 °C, and also considering the thermal loss due to irradiation, with the outside surface temperature of the container equal to -30 °C, the total thermal load is almost equal to 2700 kcal/h.

The energy dissipated by the instrumentation inside the container is about 4 kW (3400 kcal/h). This is more than enough to meet temperature requirements and a disposed cooling system is in place to get rid of the excessive heat which would be

[3] during winter operations HF radio operates on SSB (single side band) and FSK (frequency shift keyer). In this way the power of tranmission (100 watts at the antenna) is equivalent to the voice modality tranmission power of 10 kw (ref. "Project Criteria and Future development of the Telecommunication system for the National Program af Antarctic Research" (Blasi, Corbelli, de Simone, Testa))

stored up when the outside temperature is higher. The cooling system can expel up to 2000 kcal/h. A fire extinguisher system is provided to prevent serious incidents.

List of equipment

- One Digital Mvax 3800 computer;
- Digital expansion with three magnetic disks with a capacity of 400 Mb each and one 2 Gb magnetic disk.
- A cabinet with an optical disk;
- Two satellite stations;
- A VME bus station processor;
- A personal computer;
- Two no-break power;

The Mvax 3800 collects data from the scientific stations, memorizes control parameters regarding the generators and takes decisions in case of alarm, allows satellite and radio links for telecontrol and data transfer; with present configuration its power consumption is around equal to 1000 watts.

Two satellite stations, one on reserve of the other, are connected to the Mvax by three modems. Satellite station Saturn 90S has two telephonic lines and Saturn 90 has one. The two stations need a continuous electrical power supply otherwise the parabolic antenna would stop pointing at the satellite and might not be able to re-establish contact when the power comes back.

Two 8 kVA Uninterruptible Power Supply, one on reserve of the other, are used to supply power to the main computer and to the satellite stations. With the present electrical load, the batteries garantee a working autonomy of 1 hour.

LAST THREE YEARS OF OPERATIONS

During the first year of operations Aim stopped working the 5th of December 1991. Telecontrol from Italy was impossible during this year because the utilized communication protocol (DEC-NET) didn't permit any link. We only knew that the platform was generating electricity, since the satellite station was alive. From May 1991 untill December 1991, we were unable to say anything about the automatic platform status.

After our arrival at Terra Nova Bay, on the 16th of December 1991, we could observe that:

- from the computer report resulted that the system stopped operating on the 5th of December 1991;
- the supervisor software of the generation power system worked correctly between the 20th of February 1991 and the 26th of July 1991. After this date it stopped for lack of space on the mass storage memory;
- scientific data from the connected observatories were memorized till the 26th July of 1991, when acquisition stopped for lack of space on the mass storage memory.
- the seismic station worked correctly untill the 24th of April 1991, when was disconnected by the rupture of the optical cable. This inconvenient generated an incredible number of fake messages that saturated the all mass storage memory.

It was impossible to know exactly the story of the electrical power generation system after the 26th of July 1991, but a careful analysis showed that:

- the diesel electrical generators worked for around 6900 hours and stopped for lack of fuel the 5th of December. The n.° 6 engine (first in action) worked for at least 5 months (3600 hours), and stopped for low pressure in the oil circuit. After it, other two engines were active for around 3300 hours but it was impossible to know for how many hours each one had worked, since the computer didn't memorize the story after the 26th of July 1991. What we know is that the second engine stopped working in consequence of the fire extinguisher system intervention, caused by high temperature and presence of smoke inside the container, and the third one stopped for lack of fuel the 5th of December 1991. Quantity of fuel stored in the tank was equal to 18000 kg, total consumption have been of 17940 kg (2.6 kg / h), consumption for run checks have been 60 kg.

- The satellite station failure was caused by the dirty air used to warm up the parabolic antenna. A film of carbon particles covered the inside surface of the antenna radome as a shield, preventing the signals to go through.

After this year of experience we stopped to warm up the satellite antenna that in the Saturn station works till - 35 °C. Also the position of the intake air was changed and the container cooling system was strengthened. To overcome the danger of spills the fuel supply circuit of each engine was isolated from the internal tank by using an electric valve (normally closed) and a check-valve respectively positioned before and after the fuel injection pump. Moreover the control software was changed to enable a check of the consumption. In case this last parameter goes out of range the computer stops the running engine.

During the second year of operations there were no problems for satellite links, now performed in terminal emulator mode. Anyway, after March the 28th 1992 no more connection were possible.
During the 1992-93 expedition it was discovered that:

- the automatic platform stopped working on the 28th of March 1992;
- the failure was caused by a jammed contactor;
- CCD lost control and more than one engine were activated at the same time causing temperature to rise inside the container; they stopped when the fuel stored into the internal fuel tank run out;
- the computer didn't recognize the lack of power generation and suddenly died, when UPS stopped supplying power, with no time to save the control parameters file.

In order to overcome the observed problems, many changes were made over AIM during this expedition.
Some control parameters were added to the one already observed, so that now the computer can check the presence of electrical power in the network, number of engines in action to control the inside temperature of the container. Also all the contactors were changed with bigger one, in order to reduce risk of breakage. These components, anyway, remain one of the weak points of the Comand and Control Device.

During the third year of operation satellite links were possible through the all Antarctic winter, without interruption. Only three engines worked, one for 5000 hours, one for 2000 hours, which than stopped because of problems with the fuel injectors and was brought back into use, the third engine suffered a major failure after 800 hours, during our presence at the base.
During the 1993-94 expedition two main changes were made on the system:

- an interlock among the contactors was installed in the CCD;
- the auxiliary oil circuit was modified to ameliorate engine lubrication.

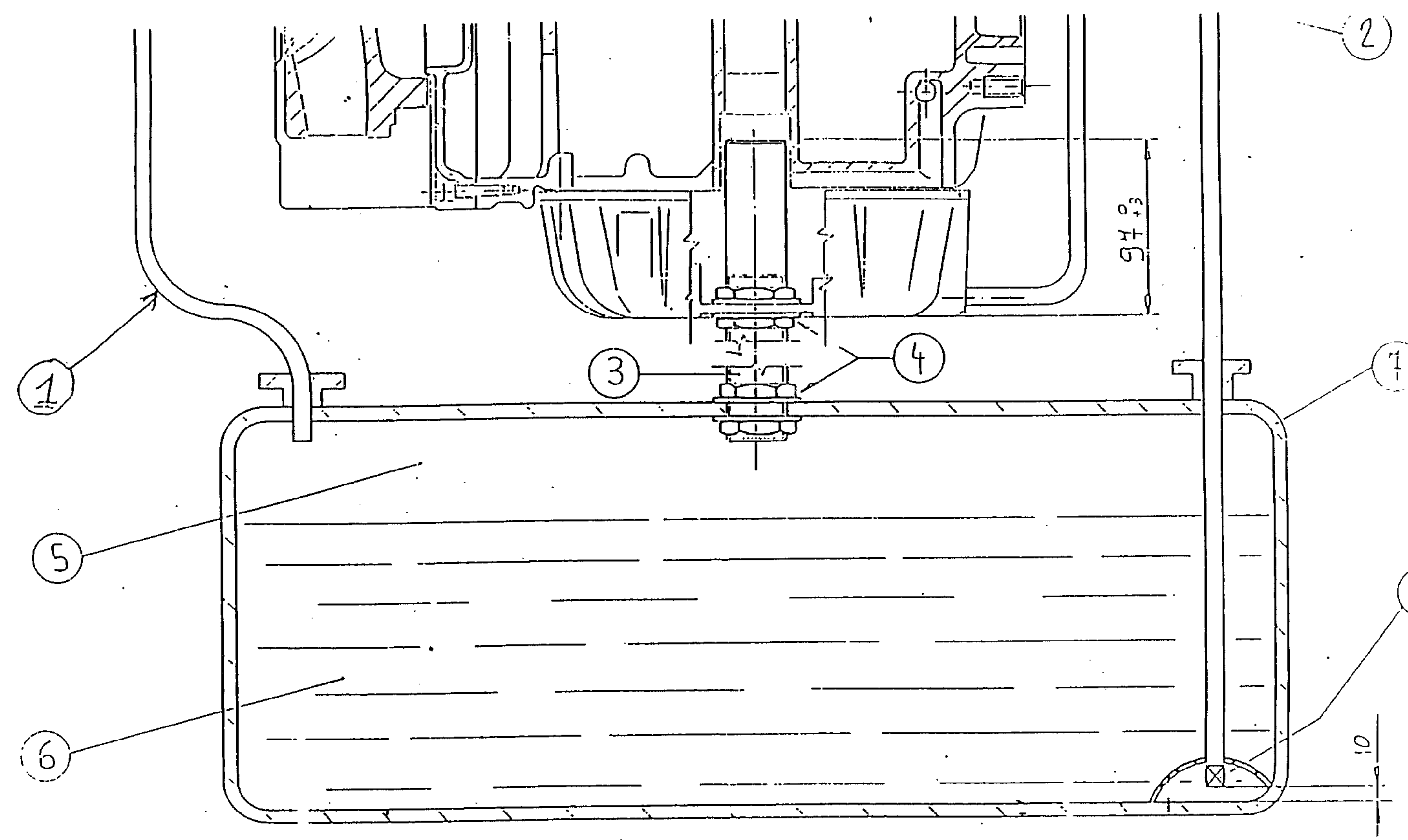
This is the fourth year of the platform's operation, and there have been no problems up to now with the power generation system.
We, anyway, have registered some failures with the scientific stations:

- the oceanographic station (buoy) last message was registered on the 28th of May;
- the RIO-meter station worked untill June, and now it is sending incorrect data;
- there are no more messages from the Geomagnetic station;
- the Ionoprobe is no longer connected;
- the Geoseismic station had a problem with the Mvax acquisition system; the acquisition is now done only locally.

From our experience, it is clear that the weak points of the AIM system are the scientific observatories. Most of the failures that happened in the past, could be defined as trivial, e.g. wire breakage or software problems. In the future, to improve the connections between observatories and AIM, we must guard all wire from wind and ice.

ACKNOWLEDGMENT

The author wishes to thank his colleagues, in particular A. Della Rovere, F. Ricci, S. Bambini, L. Sbriccoli, B. Mangione, L. Blasi, M. De Simone and F. Corbelli who tirelessly worked to realize the automatic platform and are still working to raise its reliability.



1 - tubo di sfiato.
2 - tubo di aspirazione
3 - tubo scarico olio
4 - attacchi
5 - volume vuoto
6 - quantità olio : 50 litri
7 - Dimensioni serbatoio 550×600×200
8 - Valvola di fondo

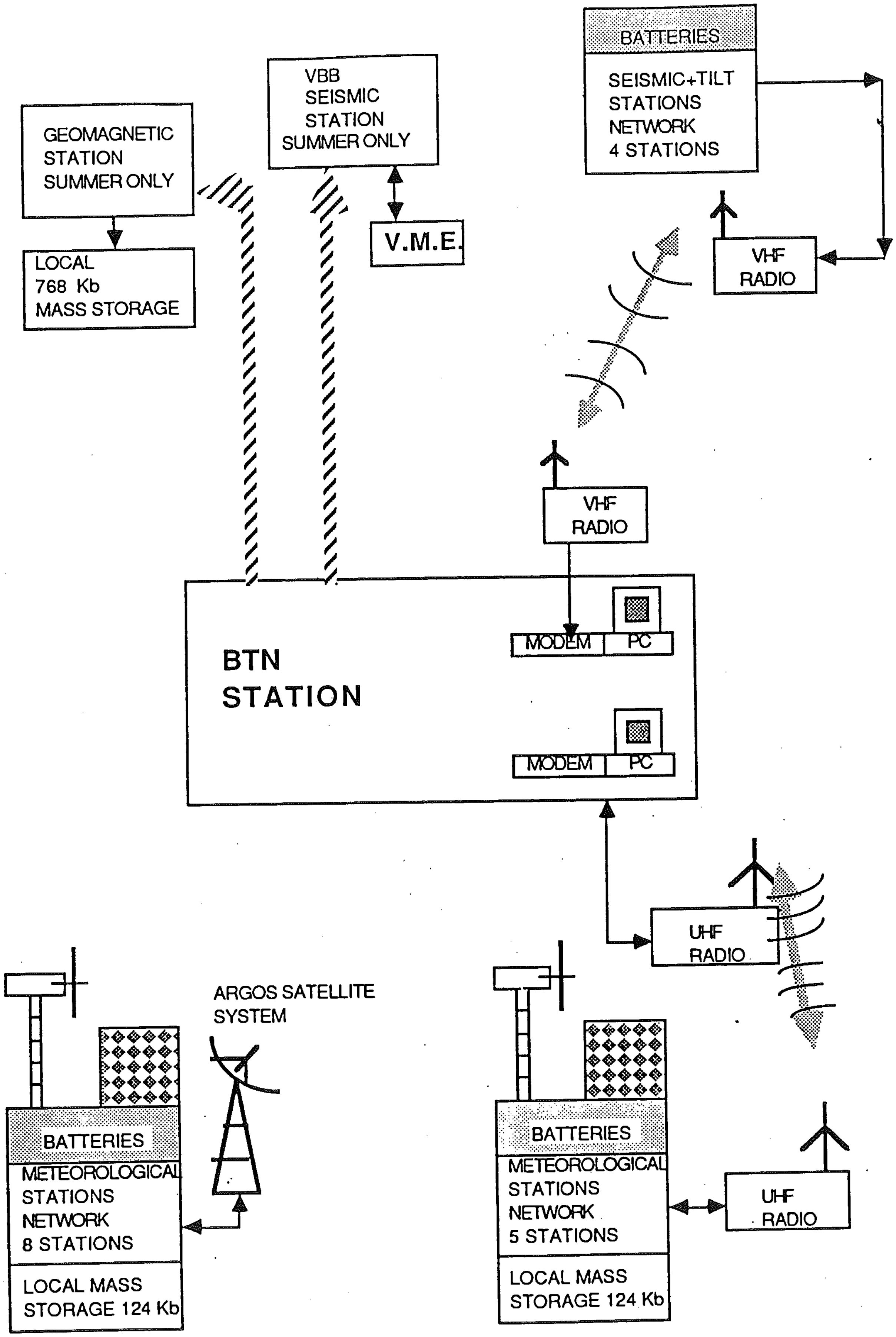
fig - 1

RUGGERINI MOTORI S.p.A.
UFFICIO TECNICO

Table 1: Power Supply Characteristics

Diesel engine (6x):	Ruggerini Motori S.p.A.	
	Type:	RD200
	Cycle:	4 stroke diesel engine
	Bore and stroke:	85x75 mm
	Number of cylinders:	2
	Total cubic capacity:	850 cc
	Cooling system:	forced air
	Fuel:	Jet-A1
	Weight:	92 Kg
Mechanical power at 3000 rpm :		12.5 kW
Specific fuel consumption:		400 g/ kWh
overall efficiency:		20%
Oil tank capacity:		40 liters
UPS system (2x)	AROS S.p.A.	
	Type: SENTRY MP	8 kVA
Total available power:	6 kW 220 V AC, 50 Hz	

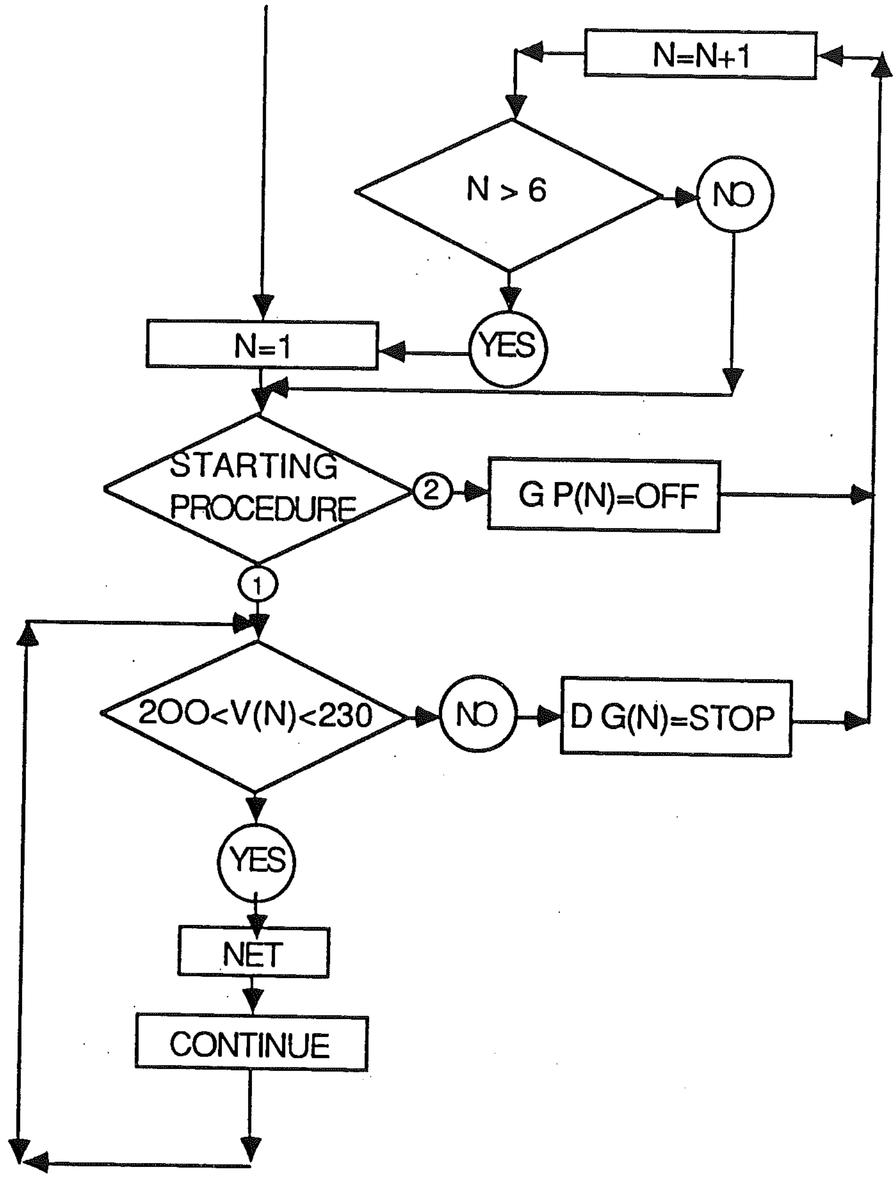
APPENDIX 1



GEOMAGNETIC
STATION
SUMMER ONLY
LOCAL
768 Kb
MASS STORAGE
VBB
SEISMIC
STATION
SUMMER ONLY
V.M.E.
BATTERIES
SEISMIC+TILT
STATIONS
NETWORK
4 STATIONS
VHF
RADIO
VHF
RADIO
BTN
STATION
MODEM
PC
MODEM
PC
UHF
RADIO
ARGOS SATELLITE
SYSTEM
BATTERIES
METEOROLOGICAL
STATIONS
NETWORK
8 STATIONS
LOCAL MASS
STORAGE 124 Kb
BATTERIES
METEOROLOGICAL
STATIONS
NETWORK
5 STATIONS
LOCAL MASS
STORAGE 124 Kb
UHF
RADIO

APPENDIX 2

CCD LOGIC BLOCK DIAGRAM



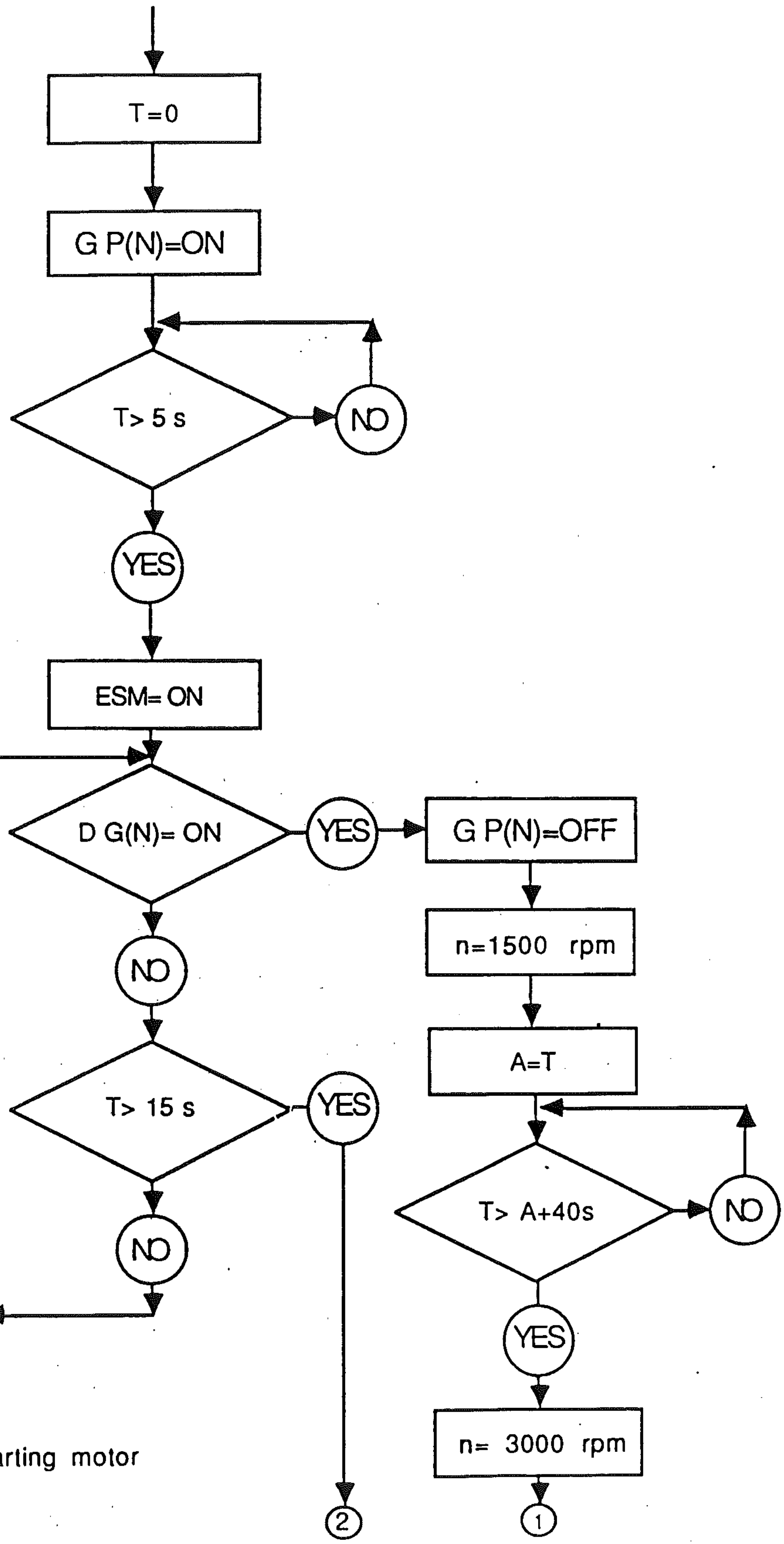
N = diesel engine number

V = electric voltage

D G(N)= diesel generator

G P(N)= glow plug

"STARTING PROCEDURE" DIAGRAM



ESM= electrical starting motor

GenSet S.p.A.
Gruppi Elettrogeni
Assago (MI) Italia

RUGGERINI MOTORI S.p.A.
Reggio Emilia · Italia

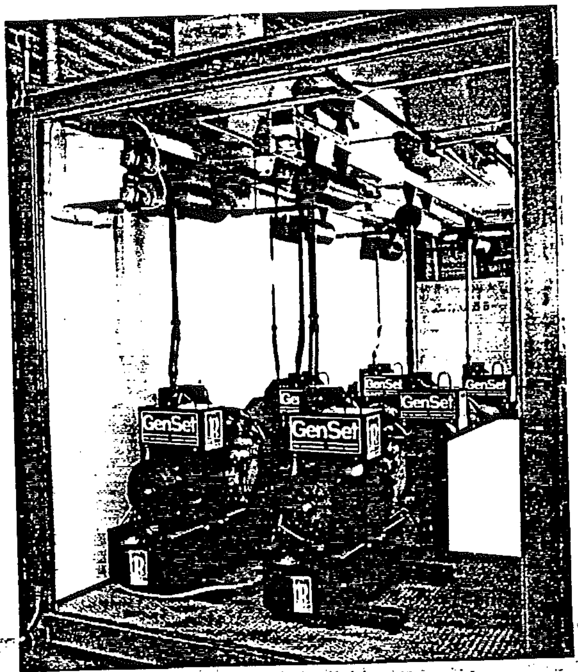
RUGGERINI DIESEL

PROGRAMMA ITALIANO DI RICERCHE IN ANTARTIDE

ITALIAN ANTARCTIC RESEARCH PROGRAMME

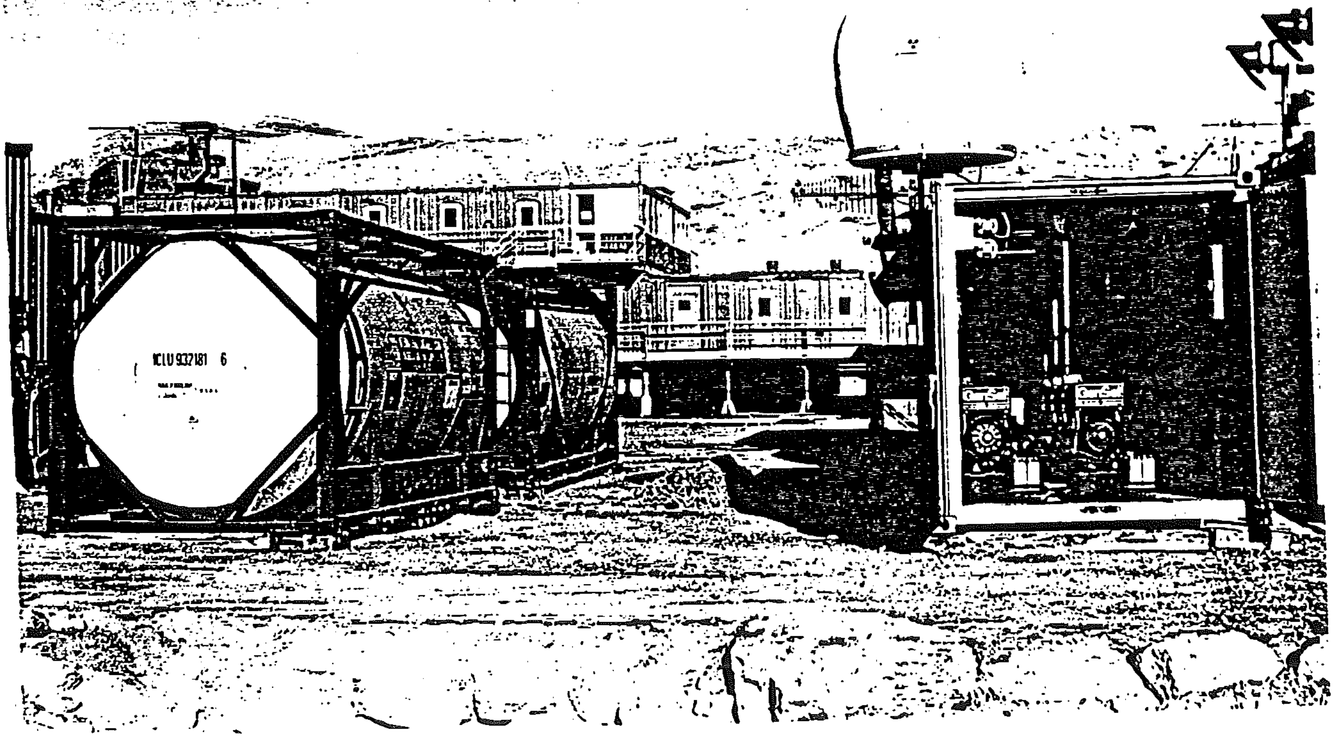
Modulo automatico integrato (A.I.M.)

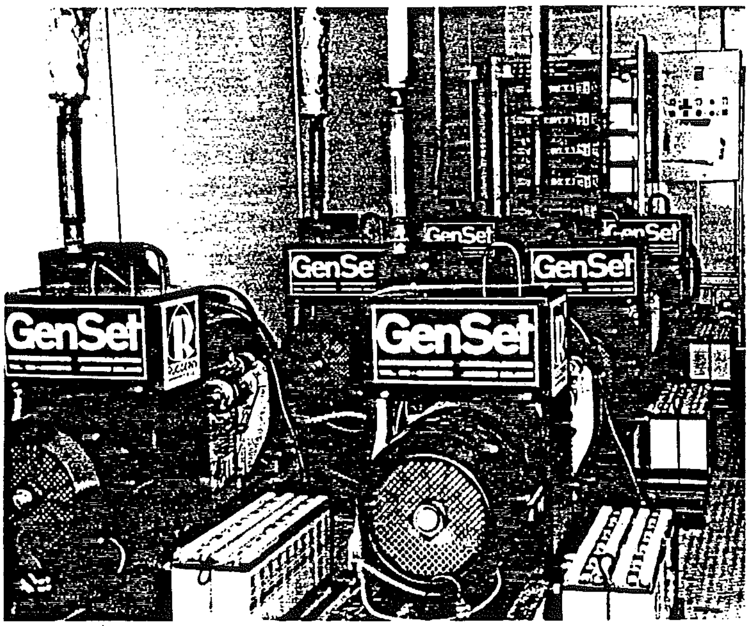
- 12 mesi di funzionamento continuo senza manutenzione
- acquisizione automatica di dati scientifici
- collegamento satellitare per trasferimento dati e telecontrollo
- collegamento via radio HF trasmissione dati

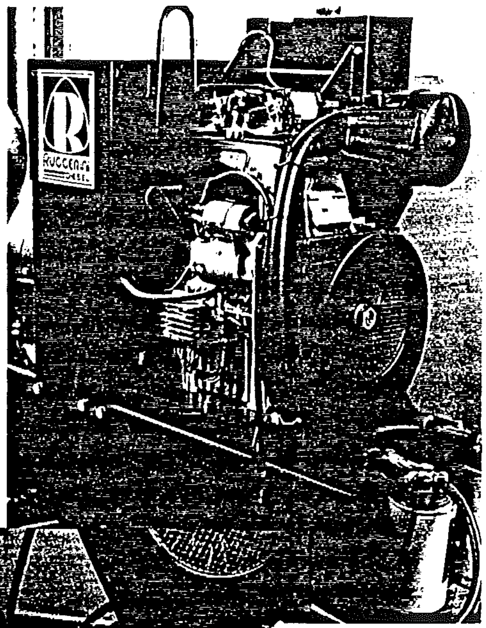


Automatic integrated module

- 12 months continuous and maintenance-free observing run
- automatic data acquisition
- satellite link for data trasmission and telecontrol
- data trasmission via HF radio







Gruppo decantatore e filtro heavy-duty.

Decanting unit and heavy-duty filter.

Il modulo è composto da sei gruppi elettrogeni preparati dalla ditta **GEN-SET**, che utilizzano motori diesel **RUGGERINI** da 15 CV opportunamente preparati per garantire un funzionamento senza manutenzione ordinaria. Ogni unità installata è completamente autonoma, e consente di avviare ognuno dei motori settimanalmente e per periodi di 20 minuti, allo scopo di mantenerne l'efficienza.

CARATTERISTICHE

Il sistema automatico d'avviamento, è equipaggiato di candelette di preriscaldo che assicurano l'immediata accensione dei motori anche con temperature di —20°C.
La lubrificazione dei motori è ulteriormente assicurata da un serbatoio supplementare dell'olio (45 Litri), dal quale la pompa aspira e lubrifica il motore mantenendo il livello costante nella coppa.
I gruppi elettrogeni possono essere alimentati indifferentemente con gasolio o con combustibili alternativi quali JET-A1, JP4, JP8.
L'elevato standard tecnologico, unito alle soluzioni particolari impiegate, consentono al modulo automatico integrato di funzionare anche in assenza dell'uomo durante i mesi dell'inverno australe, come previsto dal programma di ricerche in Antartide.

The module is composed of six generators made by **GEN-SET** that utilise **RUGGERINI** 15 HP Diesel engines made to ensure operation with no routine maintenance. Each unit installed is entirely autonomous and makes it possible to start each of the engines weekly and for periods of 20 minutes in order to keep up efficiency.

FEATURES

The automatic starting system is fitted with glow plugs that ensure the engines will start immediately even at temperatures of —20°C.
Engine lubrication is further ensured by an additional oil tank (45 litres) that the pump sucks oil from to lubricate the engine keeping the level in the sump constant.
The generators may be fuelled indistinctly with either Diesel or with alternative fuels such as JET-A1, JP4, JP8.
The high technological standard together with the special solutions adopted enables the automatic integrated module to work even without persons being present during the austral winter months, as foreseen in the Antarctic research programme.

SIXTH SYMPOSIUM ON ANTARCTIC LOGISTICS AND OPERATIONS
(Rome, August 29-31 1994)

PROJECT OF A REGIONAL HF HIGH SPEED NETWORK AMONG TERRA NOVA BAY, DUMONT D'URVILLE AND DOME C, WITH FAX DATA VIDEO, VOICE FACILITY

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FOREWORD

Since 1989 the authors of this report have been working on the project of a system of telecommunications for the Italian Research Programme in Antarctica.
During this experience a lot of time has been dedicated to the study of the possibility to utilize in this system the modern techniques of operating communications in Short Wave starting in particular from the adaptive modems.
In fact those operating in the Antarctic Continent could benefit very much from the use of these modern techniques especially with respect to the possibility to work automatically without needing the presence of an operator.
The aim of this document is to describe the attemps to program a regional telecommunication network with the help of automatic adaptive systems among the base of Terra Nova Bay, the base of Dumont D'Urville and the future base of Dome C.

INTRODUCTION

The bases of Terra Nova Bay, Dumont D'Urville and Dome C are located at the corners of a hypotetical equilateral triangle with sides of about 1200 km. length each.
The Group of the Antarctic Project of ENEA, in charge of the project and of the development of the telecommunication system in use at the Italian Research Programme in Antarctica, has been asked to set-up a telecommunication system that can be used in the building camp of the Base of Dome C under costruction.
The main requirements of this connection are to maintain the contacts with the operating realities existing at the Italian Base of TNB and those at the French Base of DDU.
The link must also be able to guarantee an effective trasmission of data in such a way as to enable to trasmit and compare projects, designs and anything else deemed necessary for the execution of the work on the sites.
Exploiting this capacity of trasmission of data the system could also be used for the trasmission of different types of information relative to safety, navigation, avionic support and information relative to convoys operating in the traverses.
This link presents considerable difficulties especially because of the unfavourable position of Dome C (hereinafter called DC). In fact DC is situated on an antarctic plateau at about 1200 km. distance from the coast at an altitude of about 3200 mt. above the sea level.

From studies made in collaboration with INMARSAT it results that the use of a Standard A vector on this site is rather precarious, as the visibility of the satellite is guaranteed for about six hours a day only and moreover with a really weak signal.
To entrust the entire safety of the base and the operativity to this sole vector was therefore out of question. Thus, while exploiting at the same time the experience made in these years with the automatic module AIM installed at the Base of BTN, we decided to design a system that would be able to trasmit data in HF, by making use of the improuvements that this system had undergone during the past years and in the first place the facility of facsimile and data trasmission at high speed. The distance of 1200 km. is really particularly suitable to this type of connections as i offers time windows which, with the judicious choice of frequencies, can be extended to the entire day.

TECHNICAL REQUIREMENTS FOR THE DEVELOPEMENT OF THE PROJECT

A series of interviews has been conducted with all those involved in the activities at the DC area to understand the requirements the system has to satisfy. From the requirements collected some of the technical specification for the execution of the project have been selected.
The following is a short list of the principal characteristics required.

The system must be able to:

- Allow communications by voice, by data and by fax.
- Operate automatically the link without the presence of an operator and in any way free the personnel engaged at DC from engagements relative to pre-established appointements and timetables.
- Transmit a good quantity of data: we decided that the minimum admissible speed should be 2400 bit/sec.
- Transmit photo or other type of pictures like e.g. designs.
- Be used also by personnel without any specific experience. The professional figure, who most likely would be charged with the telecommunications, would be the medical doctor.
- Being completely modular and within the limits of possibility, allow a procedure of research of breakdowns through a system of autodiagnosis.
- Have a high MTBF
- To correspond to the MIL specifications for the use of the system in a particularly hostile environment.

TECHNICAL EVALUATION OF DIFFERENT SYSTEMS

The panorama of systems which offers adaptive modems answering the functional requirements indicated in the specifications of the executive project narrows significantly the operating field of choice.
In this period various manifacturers have come forward in the HF sector offering adaptive systems with the biggest variety of functioning modes.
We only compared the systems ALE and ALIS.
The first mentioned is a product of various manifacturers answering the precise requirements of military purposes.
The second system has been made exclusively by Rohde & Schwarz and has found application mainly in the civil sector especially in the implementation of automatic networks in HF (Embassy networks).
We have conducted tests and investigations on both systems to verify which of the two would be the most suitable to satisfy our requirements. The first experimental field has been that of the Automatic Integrated Module (AIM) which operates at our base during the winter season without need of personnel being present.
The installation of a HF system for the trasmission of data was supposed to represent an alternative vector, and possibly at a lower price, with respect to the satellite.
It should, however, allow a complete automatic operation of the link, because we had no operator on the other end; we had at the most the possibility to write a software which would allow the use of the satellite vector for emergency interventions and viceversa.
ALIS offered this possibility and the manifacturers it was interested to verify its utilisation for applications different from those for which the system had been expressely set up (networks of Embassies with differences between the nodes of the network ranging from 2000 to 8000 km). The section on which we instead have used the system ranged between 18000 and 23000 km. and this has required substantial modifications on the firmware that monitors the communication recorder.
Our experimentation had a positive outcome and thus, when we planned the implementetion this new system, we decided to build it up around an ALIS system, taking advantage of the possibility offered by ALIS to be able to run an automatic linkage without the need of an operator. In our case this could be put to our advantage as at the building camp, as mentioned before, there will not be specialised personnel available for telecommunications.
ALE instead cannot operate the communications automatically, because in case of failure the restart of the linkage procedure has to be effected by an operator.
Instead, among the characteristics of ALIS there is the availability of a software resident (highly simplified, of the MINIMUF type) which allows for the link requested to recognize the MUF (Maximum Utilizable

Frequency) and the LUF (Lower Utilizable Frequency). Having performed these calculation, inside a prefixed pool allowing to work even two system of indipendant antenna contemporaneously, was established the best channel (OWF - Optimal Working Frequency) inside a pre-established pool for that particular type of connection. It effects therefore the selective cal per address.
Our experience taught us, however, that the ALIS system on its own has its limits of application which can only be overcome by writing sophisticated operating software with a data flux between the system and the computer interfaced by ALIS.
The problem has been solved, however, by another R & S product, that works as an operator of the communications, working as "message handling" to different users at different addresses. This system is called MERLIN and with this system we implemented our portable station to be allocate at Dome C.
Returning, however, to the functioning of ALIS we could say that it follows the procedure below:
It starts the procedure of the link by making a call according to the FSK mode on the narrow band (300 Hz) in 2 FSK (22.5 bauds).
This mode gives a higher safety in establishing the link. Once the link has been established it automatically starts to interchange with the correspondent all information inherent to the trasmission mode, including the passive VOTING, the B.E.R. and the information on the frequency jumps for the maintenance of the link, continuing at the same time the active analysis of the frequencies used during the connection.
Whenever the B.E.R. (Bit Error Rate) would surpass a certain level the system will be able to change channel automatically, chosing a better one without loss of the message in trasmission.
The ALIS system can moreover effect the frequency hopping (LPI/ECCM) after a programmable sequence of adaptive reactions to the interference, chosing 32 different frequencies around the one established for the link, in case the channels are disturbed.
Moreover, ALIS can elaborate, in function of the configuration of the correspondent as well as in function of the quality of the link, the trasmission speed (200-720-3600 bit/s) selecting the various adaptive modems.
It has an error corrector code Reed-Salomon plus ARQ, which is very effettive for the short wave trasmissions correcting the errors in burst as well as in random (problems connected with the multipath).
In case of loss of the connection it auto-retracts by REPHASING or RECALLING starting from the same point where the link was interrupted without having to start from the beginning.
It can be compatible with the ALE system but not the other way round. Once it has been interfaced with the ALE system it looses its peculiar characteristics and it adapts itself to the ALE standard.

The ALIS system, moreover, has a series of internal automatism in the software, which allows to operate the handshake of messages to the correspondent.

Configurated with MERLIN (Controller), the system is able to store any type of data, coming from various origins, and send them at an established time to a prefixed correspondent, or receive messages and address them to the desired user, or make a re-trasmission to another site (store and forward).

In order to have an immediate comparison the table on the next page shows the main differences found between the ALE and ALIS systems.

COMPARISON OF THE MAIN CHARACTERISTICS OF THE ALE PROCESSOR AND THE ALIS PROCESSOR

CHARACTERISTICS	ALE	ALIS
Automatic selection of the best channel in report to the radioionospheric propagation	Sequential sounding of the channels assigned with qualitative valuation of the best mode (L.Q.A. mode)	• MUF (OWF) LUF Calculation • Passive analysis of the channel during the scanning of the assigned pool. • Active analysis of the channel during the phase of establishment of the link.
Mode of establishment of the link	• at broad band 3 kHz • syncronisation with 8 FSK modulation • speed of 365 bit/sec	• at narrow band • syncronisation with 2 FSK modulation • speed of 228,5 baud
Exchange of trasmission modes desired during the establishement of the link between 2 or more stations	Manual mode: • messages of order and state • informations for the operator	Automatic mode: • voice/TTY/fast data/ morse • ARQ/FEC (with modem) • selective link point to point and broadcast • adaptive reaction
Selective calls	Provided	Provided
Trasmission speed with data protection	• 375 bit/s (3 kHz) in ARQ without external modem • 2400 bit/s (3 KHz) in ARQ/FEC with external modem	• 228.5 Baud (300 Hz) in ARQ, without external modem • 720 bit/s (3 kHz) in ARQ/FEC with Frequency Hopping and external modem • 2400 bit/s (3 KHz) in ARQ/FEC with external modem • 2700 bit/s (3 kHz) in ARQ+FEC with burst mode and external modem
Change of adaptive frequency in case of interference in the channel	Not provided	Automatic without loss of message in trasmission

DESCRIPTION OF THE INSTALLATION SYSTEM

In the previous paragraphs we considered the requirements, which guide the choice of the project.
This paragraph describes in detail the system.
The sites to be organised were two, one at the building camp of DC and one at the Italian base TNB.
The first system is still to be installed as we are still awaiting its transportation to the building camp.
When it will be installed at the building camp it will be placed inside a container which will host the room of the medical doctor of the expedition. To this aim we realized a system easy to be trasported also by air. The system therefore has been cabled inside a three rack standard 19", complete with closing cases containing storage space for wiring cables. The containers are pressurised and transportable by air.

Instead, with respect to the systemistic part, the entire apparatus should allow to connect in VOICE, in DATA and in FAX, and moreover have the possibility to trasmit photographs and drawings betwen the two stationns at a distance of 1200 km.

Once calculated the link attenuation for a connection to be effected by ionospheric reflection, we decided that a power of 150 W would be sufficient considering the fact that will be use an antenna with vertical polarisation (5 mt. whip antenna).
For reason explained above that is to maximise the efficiency of the ALIS system we added a process controller and message handling MERLIN with relative interfaces video and fax.
This will allows the possibility to obtain images directly from telecameras and transfer them compressed in the form of data in HF.
To complete the system two other apparatus have been installed, one to operate on VHF Avio and one on VHF Marine, for links with aircrafts and for local trunk calls to the personnel on the site.
The entire system, for safety reason, should work also in absence of the main power supply net. Therefore a choice has been made to feed it entirely through a 24 V DC source, fed by floating batteries and by an inverter.
This choice probably has to be reconsidered for the future as it increase considerably the complications of the system and makes it liable to breakdowns which limits its operation even when the apparatus are still intact.
In fact this system has been transported to the French Base of DDU awaiting to be tranferred to the building camp of DC.

The experiments carried out this year partially failed because of a simple defect of the inverter system which could not be repaired locally because of the unavailability of some spare parts.
As we were to effect links with our Base we choose to install a firmware which allowed links up to a distance of 28000 km. The apparatus has been programmed to function over a distance of 22000 km. which equals the distance that separates TNB from ENEA main offices of tha Antarctic Project in Rome.
All this with the aim to make the two system perfectly compatible.
As far as the Base at Terra Nova Bay is concerned , however, we decided to utilize the installation made back in 1991 by upgrading our 400 W system only with the insyallation of a MERLIN controller and a high speed data modem (2700 bit/sec) plus the relative interface FAX and VIDEO.
The apparatus can make use of the various antenna available: log-periodic, rhombic, dipole etc. through a controlling matrix. Radiant systems selected for the type of connection to be made.
The system at TNB, which continues to operate during the winter season and is fed by an automatic module AIM, is connected to a VAX 3400 computer, to which access can be obtained through a satellite link of INMARSAT from the offices of the PNRA and also in short wave through a special software specially prepared by DIGITAL.
When using this type of linkage it will be possible with the aid of a Merlin Controller, connected as well to the VAX, to transfer from PNRA across Terra Nova, a flow of data and communications to and from the site of Dome C which will be occupied during the southern winter.

CONCLUSIONS

It is our opinion that the adaptive systems, properly used, could give a considerable improvement of the HF services in Antarctica. Our experience has shown that they have reached a high level of reliability and are therefore ready for even more significant experiments.
The advantages represented by the possibility to create a completely automatic net of "store and forward" absolutely without the necessity of an operator will make easily clear the advantages of this application.
Moreover, it opens up the possibility to concentrate in stations which already dispose of reliable satellite services the traffic of regional nets for forwarding and sorting on the world network. It should be remembered at this point that up to date numerous stations have INMARSAT satellite systems available with good levels of reliability, but with very high operating costs, while some stations have no satellite system available either for organisational reasons or for geographic positions.

However, to give a complete view it is necessary also to mention the limits which can be found up to date when using the adaptive modems.
The main limit is that these systems reach their maximum use only when already exist a network.
The reason for which the day is still rather far off that this net can be realised are to be searched in the individual approach to the solution of the problem of telecommunications of any person operating in Antarctica.

Moreover the ALIS system comes from a single manifacturer, while ALE is a system that has already found a certain market even in the military sector.
ALE is subject to the limit of not being automatic in the global operations of the links, but has the clear advantage to be proposed, precisely for its applications even in the military sector, on systems with relative low costs.

For completeness sake it has to be mentioned that many countries follow the policy of promoting their national products and, excluding Germany of course, it is much more simple to find a product that utilises ALE.
The substantial absence of these limits in our country has consented to effect a sufficiently complete large scale research.
Anyway, if the attitude described above with tha "national" approach is linked to the solution of the telecommunications problem it can be understood that it will be hard to organize in a short time a broader net than the one represented in this document, in such a way it seems correct and desirable.

Another limit represented at this moment by these systems is the economical one. Countries interested in a more incisive use of the HF are without doubt discouraged by the in fact rather high cost. This problem could however be resolved by putting in production a low cost line which could help to resolve in a definitive way the economical problem.

In consideration of this last problem these systems need to function in versions of firmware compatible among each other. This could represent a problem for countries like our own, which, apart from the link on the Antarctic continent, would also want to effect links over a long distance with their national offices. In fact in this case it would be necessary in order to maximize the efficiency, to introduce in the communication protocol the delay necessary to cover a longer range.
Also the convention to insert a maximum delays could be used to limit the possibility of confusion, but at this moment it is still premature for discussion.
The operating problem of the communication protocol, which in the past was a not easy solution as the change of the firmware necessitated the intervention on the hardware, are now of simpler approach as it has become

possible to produce systems which consent to intervene on the operating protocol of communications directly from the software.
Anyway it is our intention to exchange the maximum number of opinions with those who are interested in the HF on Antarctic continent and intend to start on the road of automatic adaptive systems. To this and any request for clarifications and information is welcome.

Report of the Antarctic Traverse Workshop
2-4 May 1994
Washington, DC

George L. Blaisdell

This workshop is the third in a series of vehicle-related specialty meetings addressing the unique needs of national Antarctic programs. The first meeting took place on 26-28 July 1989 and dealt with surface transport of cargo and personnel in Antarctica. The second workshop was held on 16-18 July 1991 and treated the subject of construction equipment in the Antarctic.

These two workshops were notable in that they were attended exclusively by operations personnel, particularly staff members who are in touch with daily equipment functions, and by manufacturer representatives having demonstrated experience in fielding equipment in polar regions. In addition, the agendas were set primarily by the interests of the participants, and considerable latitude was deliberately allowed to encourage thorough discussion of important topics. For example, much interest and concern arouse with regard to the construction industry's move, partly mandated by more stringent emissions standards, to very sophisticated and electronically controlled engines which often aren't designed to operated at typical Antarctic temperatures. Few engines without these controls will be available on heavy equipment, and the newer engines, when they will run at Antarctic temperatures, run inefficiently and emit excessive pollutants. By discussing these types of issues between a unified group of Antarctic equipment users and industry as a whole, it should be possible to gain mutual understanding and create solutions to Antarctic vehicle operational challenges.

The third workshop, sponsored by the US National Science Foundation Office of Polar Programs, addressed long Antarctic traverses. Our primary focus was on heavy hauling oversnow rather than short, light traverses with a purely scientific purpose. The timing of this workshop was the result of considerable interest expressed recently by participants in many national Antarctic programs, by concerns raised at the two previous workshops, and by the US program's consideration of oversnow transport for the supply of construction materials for re-building Amundsen-Scott South Pole Station. It also seemed timely since several national programs have recently begun using traverse for supplying inland stations, the Russian program has had a long history of annual traverse for re-supply, and mutual problems with sustaining heavy traverse have come to light.

Because of the major concern for crevasses by all who traverse the Antarctic terrain, this workshop included several scientific experts who addressed modern methods for selecting safe and efficient traverse routes and the use of impulse radar for detecting bridged sub-surface voids. It became readily apparent throughout the workshop that, despite a marked advance in such areas as Antarctic clothing, berthing, food, and equipment, we today have no better record of avoiding crevasses on traverse than did Hillary and Fuchs in the mid 1950's. The future of safe Antarctic traverses will rely on the use of remote means such as air photos and satellites for studying potential routes and airborne surveys, followed by ground-based radar, for actually marking supply lines.

The recent Madrid Protocol and heightened international public awareness of environmental issues in Antarctica bring up new concerns for traverses on the continent. This workshop included substantial discussions on the topic of procedures, reviews, paperwork, and disclosures that are essential in making responsible preparations for long traverses by any national program. It became clear that we can be better stewards of the continent we study while at the same time better educate the public and defend ourselves against frivolous claims if we provide more stringent standards, clearly stated ethics, and initiate opportunities for honest and open review and discussion.

It was not the original intent to generate written proceedings. However, most participants provided printed material and it was desired that a document be produced to serve as a record of the workshop. Thus, in the pages that follow, the reader will find an assortment of material that ranges from a brief introduction and copies of overhead slides to complete technical papers. It is hoped that this summary report will provide workshop participants with a useful memory jogging device. Should others take interest in the topics that are brought to light in this report, they are encouraged to contact the presenter to gather more detailed information.

Finally, it seemed apparent to the workshop attendees that these types of dedicated, special-focus, short meetings are very desirable. They seem to be highly effective if the organizers gather topics of interest from colleagues and arrange them into a well thought-out agenda. This acts as a focus guideline which ensures that certain key topics are treated. However, discussions should be allowed to roam freely so that everyone has the opportunity to contribute and to collect information that is important to them. To be successful using this format, a "facilitator" is required who is able to feel comfortable with letting discussion go free-form up to a point, but then be able to firmly redirect the group when the discussion has reached a point of diminishing returns. It is notable that every attendee at the Antarctic Traverse Workshop contributed either a planned lecture or an impromptu presentation.

Detection of Crevasses Near McMurdo Station, Antarctica with Airborne Short-Pulse Radar

ALLAN J. DELANEY AND STEVEN A. ARCONE

INTRODUCTION

The National Science Foundation is currently evaluating several methods of remote sensing and reconnaissance to aid in selecting an over-ice traverse route to South Pole Station. One obstacle to route planning is crevasses, which often have no visible surface expression to warn of their presence yet can be wide enough and deep enough to engulf a tractor. Since detection systems towed slowly along the snow surface give little advance warning of crevasse danger to the survey vehicle, airborne systems are needed for survey safety, reconnaissance, and efficient data collection. This report discusses the results of some observations using airborne short-pulse radar for detecting crevasses.

Early evidence that surface-based short-pulse radar easily detects near-surface crevasses from their diffractions was presented by Kovacs and Abele (1974). They pushed a 100-MHz transducer along the snow surface with a tracked vehicle at 1.4 $m\ s^{-1}$ (3 mph) and recorded a diffraction from a suspected crevasse (Fig. 1). While this transducer configuration can be used for crevasse detection and warning at slow vehicle speeds, it is not suitable for reconnaissance surveys and cannot provide information to the surface vehicle as to which direction to steer to avoid a crevasse.

The objective of this study was to evaluate the use of short-pulse radar as a rapid reconnaissance tool for locating and mapping the extent of snow-bridged crevasses from aircraft. Helicopter-mounted radar transducers, along with a satellite global positioning system (GPS) antenna were flown over several areas of known crevassing in the McMurdo Station area of Antarctica. Several crevasse fields were studied, one of which was directly explored by probing and digging.

The ability of short-pulse radar on low flying helicopters to obtain profiles of snow and ice thickness (Kovacs 1978, Arcone and Delaney 1987, Arcone, 1991, Arcone et al. 1992, Vickers et al. 1973), sea ice thickness (Kovacs 1977) and frost penetration beneath frozen rivers (Delaney et al. 1990), and to locate winter water supplies in the Arctic (Arcone et al. 1989) suggested to us that airborne crevasse detection would be feasible. In particular the 500-MHz glacial data of Arcone et al. (1992) revealed many diffractions beneath a snow cover that suggested crevasse detection would be feasible at such short wavelengths. What was not apparent was how the data would be affected by the aircraft speed coupled with the limited scan rate, the low directivity of the radar transducer, and aircraft altitude.

TECHNIQUES AND EXPERIMENTAL PROCEDURE

The Antarctic provides an ideal environment in which to use short-pulse radar for subsurface exploration and reconnaissance. The low permittivity of cold snow and ice, the low variability of material electrical properties and the absence of complex surface conditions allow good signal penetration. Although the contrasts in dielectric permittivity ε between air, dense snow, and ice are small (1, 2, and 3.2, respectively, at very high frequencies), the use of high-gain receivers overcomes the low amplitude of the reflected signals and makes it possible to detect air-filled voids in cold snow. In this study we utilized 200- and 500-MHz short-pulse radar transducers with transmitted pulse lengths of 5 and 2 ns respectively, and time ranges of 300 to 120 ns to record subsurface reflections. A 300-ns time range allows signal pen-

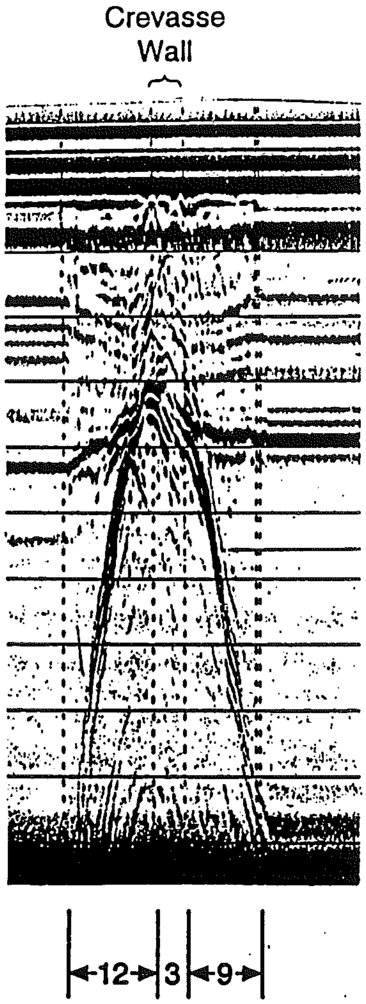

Figure 1. Diffraction pattern recorded by pushing a 100-MHz transducer along the snow surface in front of a tracked vehicle at a speed of 1.4 m s^{-1} (after Kovacs and Abele, 1974)

etration to a depth of over 20 m at a low altitude of a few meters, and the short pulse length of 2 ns at 500 MHz affords high vertical resolution.

Radar system

The short-pulse radar system consisted of a control unit (GSSI model 4800), data recorder (GSSI model DT-6000) and high frequency radar transducers (GSSI model 3107 at 200 MHz and model 3102 at 500 MHz). The radar control unit triggers pulses at a repetition frequency of 50 kHz and data were recorded in 8-bit, 512-word scans at a rate of 25.6 or 51.2 per second. The received radio frequency signals are sampled and converted to audio frequencies for display and recording on tape. The reconstructed signal is then displayed over a selected calibrated time range window. Variable time range gain may be applied to the audio scan to suppress the higher amplitude early returns, especially from the transducer direct coupling, and enhance the lower amplitude later returns that originate at layer interfaces and material transitions.

The antennas used are resistively loaded, bowtie dipoles. The 500-MHz transducer contains separate transmitter and receiver antennas backed by metallic shielding that greatly reduces side and back radiation. Consequently, aircraft reflections, or "clutter" are greatly reduced. The 200-MHz transducer contains one antenna and a transceiver (a monostatic configuration). Although it is shielded, extra oscillations occur when metallic struts are attached to the antenna housing.

In air the antenna beam width becomes fairly uniform with a 3- and 10-dB width of about 70° and 120° respectively. It is this wide beam width that allows diffractions from crevasses to be seen in the records. Since the amplitude of the signal reflected from air, snow, and ice horizons is very small, we used high-gain receivers. In some cases this increased gain also amplified sampling noise and spurious interference from aircraft electronics. Transient interference from the aircraft radar altimeter was seen on one flight when the device had to be used because of poor visibility. Reflections from the airframe, and low frequency system noise were removed with well-known digital filtering techniques.

Data processing and interpretation

The 200-MHz data were first passed through a horizontal (scan-to-scan) "background removal" filter that eliminated aircraft reflections that occur at a constant time delay. This process marginally affected the ice data because changes in altitude prevent the data from being sensitive to the filter. All data were passed through a high-pass filter to remove d.c. offsets within individual scans and a low-pass filter to alleviate high frequency noise. Transformation of echo time delay into depth is generally based on the simple echo delay formula for flat interfaces or point reflectors:

$$d = ct/2\sqrt{\varepsilon} \qquad (1)$$

where

d = the depth of a reflector in centimeters,
t = the echo time delay in ns,

c = the speed of electromagnetic waves in a vacuum (30 cm/ns) and

ε = the dielectric permittivity of the propagation medium.

The factor of two accounts for the round-trip propagation path. A value of $\varepsilon = 2$ was used to translate echo time delay into snow and firn depth. This value is based on the Ross Ice Shelf near-surface density profiles of Kovacs et al. (1982, 1993) and the density/dielectric permittivity calibration of Cumming (1952).

A reflection profile reveals three types of images of geophysical events. The most common are flat, gently sloping or undulating horizons that represent coherent reflections from a continuous interface such as the snow surface or a subsurface layer. A second type of event consists of concave down, hyperbolic images that represent diffractions from local discontinuities in dielectric properties. These events are sought here because they are generated by the sharp transitions from air to firn or ice that occur in crevasses. The third type of event is incoherent backscatter or radar system noise that is speckled throughout the record. Unwanted reflections such as those from a helicopter can often be eliminated by filtering when the reflections are at a constant time delay. Data are displayed, as echo time-of-return vs. profile distance, using a line intensity format that uses a nonlinear scheme of gray scale intensity that emphasizes weaker events. Profiles were printed on a Hewlett-Packard Paintjet printer. The quality of the printout was generally very good, but inferior to the display on the computer monitor.

Aircraft, flight speed and altitude

The radar system was controlled from a Bell UH-IN helicopter operated by the US Navy Antarctic DEVRON Six for the National Science Foundation. The transducer, GPS antenna and their supports were attached to fuselage port-side hardpoints. The control units and power supply were operated from the rear passenger area. The survey altitude was 3–15 m and air speed was 5 to 20 m s^{-1}. Speed was estimated from aircraft instrumentation.

Flight speed was limited by the rate of data acquisition. With the control unit used for these studies set to the fastest rate possible (about 50 scans/sec), a helicopter speed of about 20 m s^{-1} (45 mph) would provide 2.5 scans for each meter of travel. This translates to about 25 scans over a 10-m-wide crevasse, which is about the widest we expected. At least 25 scans are needed to recognize a diffraction, but more were obtained even on small features because diffractions extend beyond the crevasse area.

Altitude above terrain and the survey line separation are directly related. Altitude is determined by the radar time range, and survey line spacing by the antenna beam width (approximately 70 conical degrees in air). For an altitude of 10 m then, survey lines should be spaced no more than 14 m apart for 100% coverage of the surface. In practice, we found the crevasse features to be so large, > 5 m across, that speed could be further increased and that closely spaced lines were not required. Therefore, our survey lines were separated about 20 m and we successfully acquired data at speeds up to 20 m s^{-1}, although most of the data were collected at speeds of 5 to 10 m s^{-1}.

Position control

Survey position control was provided by a Garmin 100 global positioning system (GPS) receiver using an external antenna mounted atop the radar transducer. The GPS acquires an initial position within several minutes and then updates position once every second. Position way-points were manually recorded at the ends of all survey lines and incrementally on long survey lines coincidentally with event markers entered onto the radar data file. All of the GPS data recorded are listed in Appendix A.

RESULTS

The study sites were selected from airphotos and by visual inspection from aircraft (Fig. 2). The site near Castle Rock contained an ice fall where surface ridges indicative of snow-bridged crevasses were apparent. Crevasses are known to exist at the site east of White Island but were not apparent. Very large crevasses were seen along a line south of White Island but not along a section of the tractor trail east of Black Island. The longer lines extending north from the terminus of the Aurora Glacier and east from White Island were flown in anticipation of transitions in ice conditions. All of the sites on the Ross Ice Shelf are further distinguished by varying snow accumulation rates.

Ice fall site

This heavily crevassed site is located on glacial ice approximately 1 km east of the Castle Rock trail. It was selected because crevasses are easily identified by the pronounced snow-bridge mar-

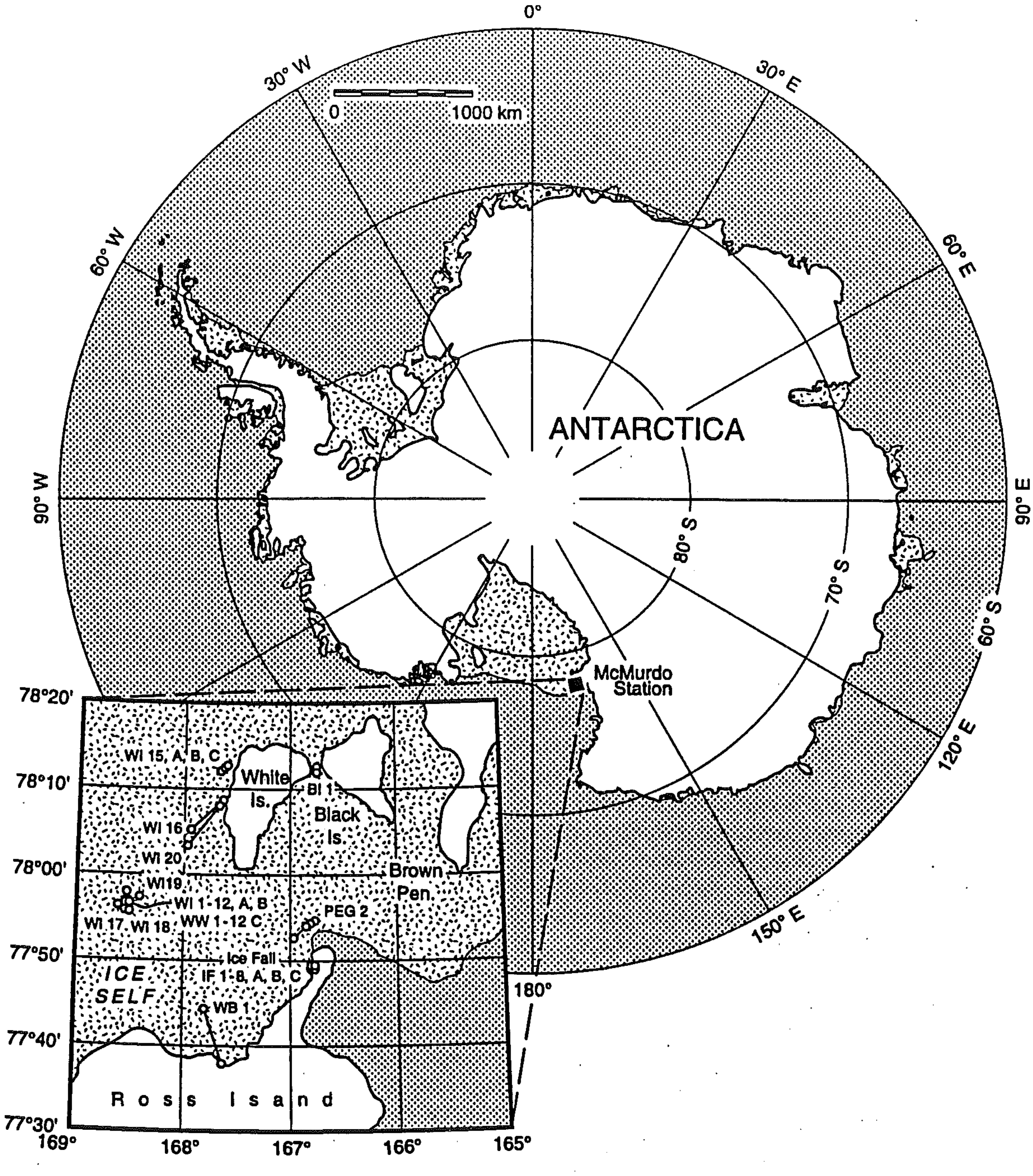

Figure 2. Location map showing Ross, Black and White Islands near McMurdo Station. The sites are located on glacial ice on Ross Island and at various locations on the Ross Ice Shelf.

gins. Eight lines were established by placing end flags from a hovering helicopter and an additional control line was established on the surface. All of the survey lines crossed the several obvious snow-bridged crevasses. Preliminary radar profiles were first recorded at an altitude of about 5 m at both 200 and 500 MHz. Some of the preliminary data recorded were at 200 MHz (above lines IF-3, 4, 5, and 6, Fig. 2) and are shown in Figure 3. The records are characterized by reflections from layers in the snow and ice and diffractions that seem to originate in the vicinity of crevasses seen during the flight. Profiles IF-3 and IF-5 contain event marks recorded when the transducer passed the obvious crevasse edges.

Based on these preliminary results a control line

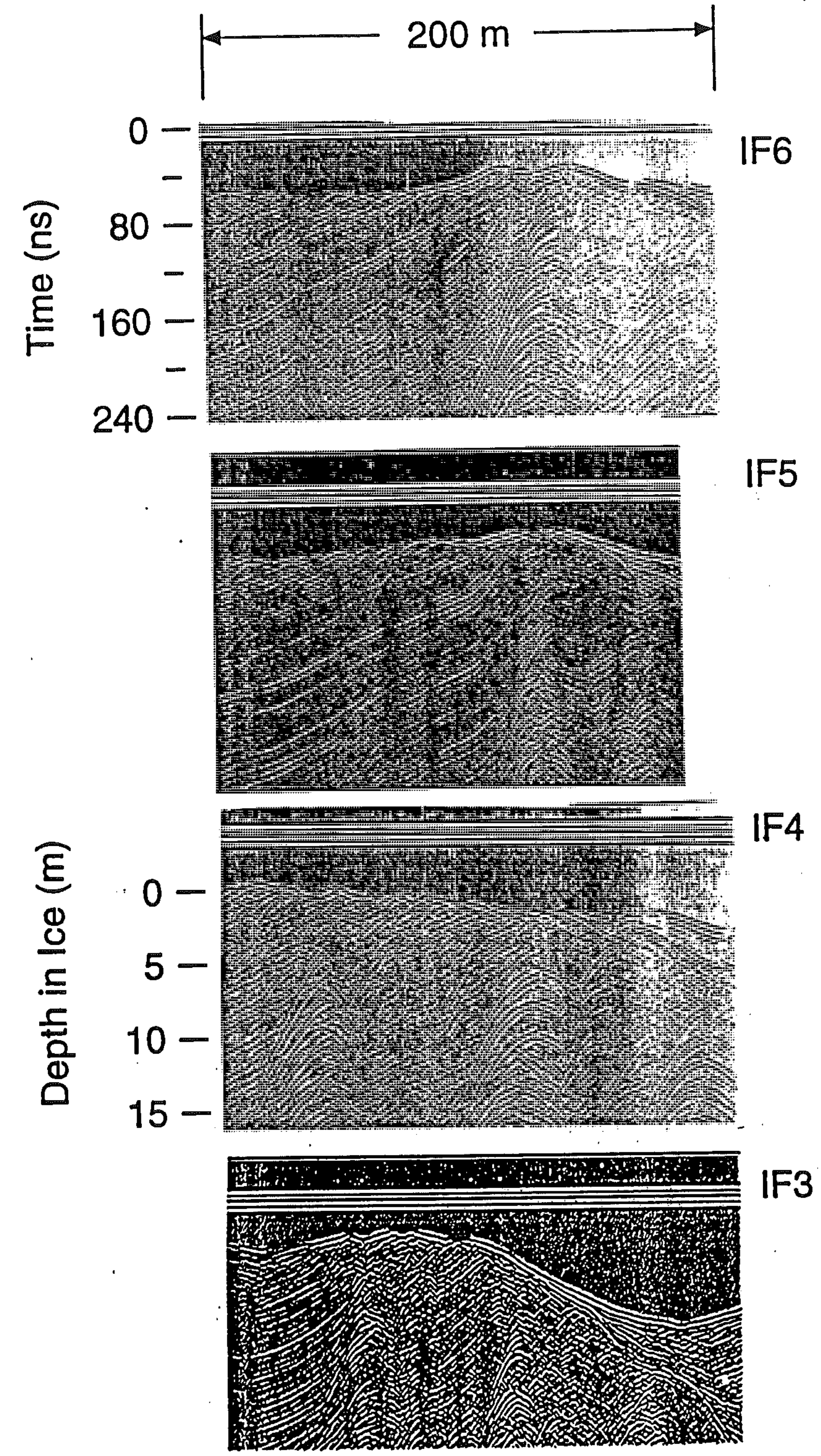

Figure 3. Preliminary 200-MHz profiles recorded above Ice Fall lines 3 through 6. The hyperbolic images are diffractions from crevasses. The wavy surface is due to changes in aircraft altitude. Aircraft speed was about 5 m s^{-1} and altitude varied from about 5 to 21 m.

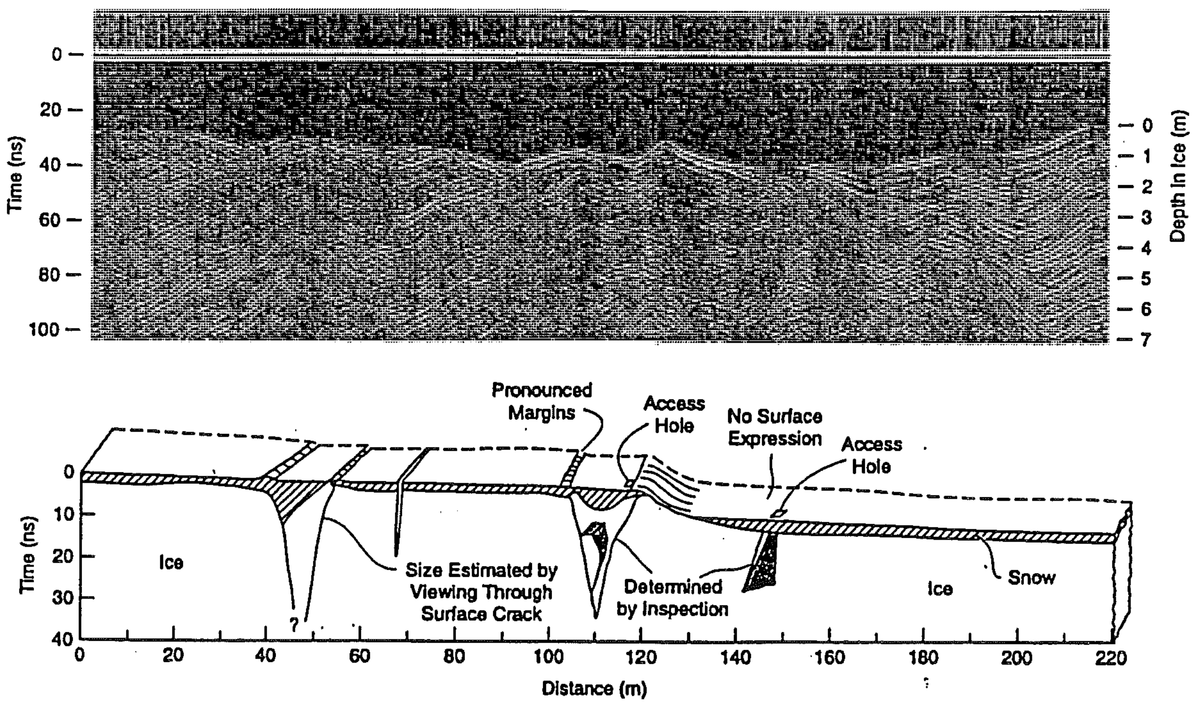

Figure 4. The 500-MHz profile recorded directly above the control line at a 120-ns time range. The cross section is interpreted from measurements made on the ground.

was established in the vicinity of lines 4 and 5 with the assistance of personnel from the Berg Field Center in McMurdo. This 215-m line crossed perpendicular to the several obvious snow-bridged crevasses and was flagged at 10-m intervals. Snow-bridge thickness was measured from augured holes, and crevasse dimensions were estimated after rappelling into the voids. Two large snow bridged crevasses were found between 42–55 m and 105–120 m and an additional 1-m-wide crack occurred at 69 m (Fig. 4). The large crevasses contained asymmetric accumulations of snow and ice, which may explain the appearance of strong diffractions at only one edge of the feature centered at 110 m on the radar record.

The control line was then flown using the 500-MHz transducer and a time range of 120 ns to provide more detail of the near-surface features (Fig. 4). The survey altitude was about 5 m and speed was approximately 5 m s^{-1}. This profile should be compared with the 300-ns, 200-MHz profiles along lines 4 and 5 (Fig. 3), which provided less complicated and more apparent responses to the large voids at 50, 110 and 150 m. The shorter time range of Figure 4 shows near-surface features that may be related to snow-bridge dimensions and snow-ice transitions. Near-surface reflections seem to correspond with snow-bridge dimensions above the voids at 110 and 150 m.

Both radar profiles showed strong diffractions that corresponded with no observable surface features at 150 and 175 m. We therefore returned to station 150, where there was no surface expression of a crevasse, and dug through a 2.2-m-thick snow-bridge to reveal a void 5 m wide at the top, 10 m wide at depth, and that extended 15 m below the surface. A similar feature may exist at 175-m distance at a time delay of 40 ns. The depth to this interface should be between 3.4 and 4.0 m depending upon the probable range of material permittivity.

White Island tractor site

This site, east of White Island on the Ross Ice Shelf, was selected because snow-bridged crevasses were known to exist, but are not easily seen. The objective was to record data along parallel profiles from which we could map subsurface features. Flags mark the general location where a LGP D8 tractor fell through a snow bridge into a crevasse in 1991 and remains an estimated 18 m below the surface. There is very little surface relief and, under poor light conditions, we (on the aircraft) found it difficult to detect any surface patterns

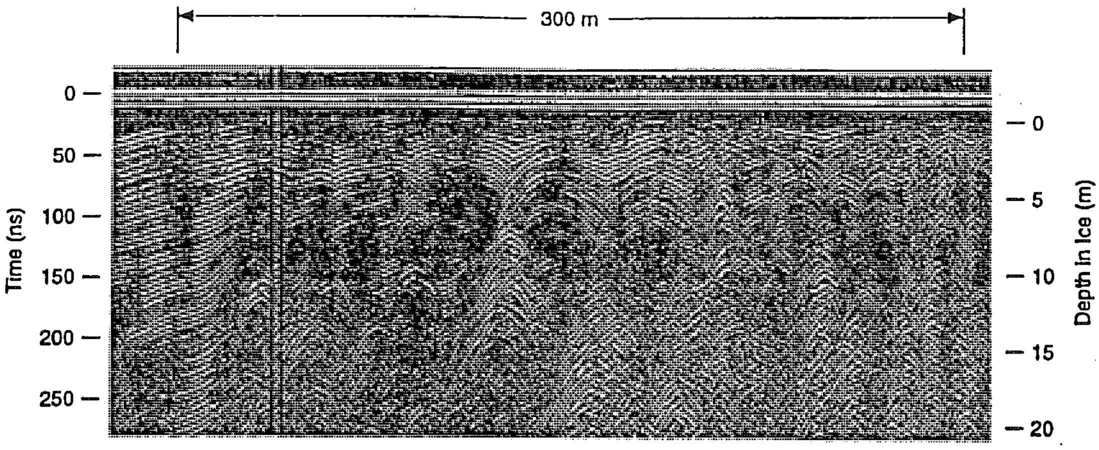

Figure 5. Data recorded above line 4 (WW-4C) at the White Island tractor site with the 200-MHz transducer.

indicating crevasses. When the aircraft climbed to about 300 m some widely spaced patterns in the snow surface became apparent. Ten parallel survey lines that crossed the marked tractor site were then established by placing end flags from the hovering helicopter. The lines were 300 m in length, and separated by 20 m (Fig. 2). GPS way points were also recorded at the end of each line.

The 10 parallel lines and the two additional end lines were flown at both 200 and 500-MHz at a variety of low altitudes and low flight speeds. The profile recorded along line WW-4C (Fig. 2) with the 200-MHz transducer is shown in Figure 5. All of the diffraction patterns are thought to correspond with crevasse features, the reverberation being caused by multiple reflections and several sharp transitions within the crevasses. Most notable is the strong hyperbola in the center of the record that seems to originate deep within the crevasse due to its 90-ns delay from the surface. In addition, dipping snow stratigraphy can be seen above the prominent hyperbolas. The separation between points where the dip begins allows crevasse width to be estimated (about 15 m for the large event at the center of the record). On the left side of the profile can be seen the gently sloping reflection from the snow surface as the aircraft altitude decreases. Data recorded during the approach show distinctive sub-surface layering, fewer crevasse responses at depth and little distortion of the near-surface layers associated with snow-bridges.

Three additional long lines, 4 to 5 km in length (Fig. 2), were profiled at an altitude of 10 m and a speed of 15 m s^{-1} to help define the areal extent of crevasses in this location. All of these profiles (not shown) reveal sloping and distorted layering interrupted by diffractions from crevasses. Profile WI-19 crosses the site from west to east and the purported tractor location was marked on the profile. Strong diffractions are found at the tractor location, but they do not seem unusual in comparison with the responses from other crevasses.

White Island speed study

The objective of this study was to determine if the radar could maintain its ability to record crevasse diffractions as the speed of the aircraft increased. A 2.2-km line (WI-15, Fig. 2) was established northeast of White Island in an area of large, widely spaced, crevasses. Some of the crevasses, made apparent by snow bridge failure, were up to 8 m across and estimated to be 30 m deep. GPS coordinates were recorded at the line ends and midpoint. These stations were also flagged to help position the aircraft in this featureless terrain. Radar data were then collected at 51.2 scans/second from west to east using the 200-MHz transducer at an altitude of about 7 m and speeds of approximately 5, 10 and 20 m s^{-1}. In terms of distance the data rates are 10, 5, and 2.5 scans/m respectively.

A segment of the profile recorded at 20 m s^{-1} is shown in Figure 6. Diffractions originating from large crevasses are clearly visible while responses from smaller crevasses and cracks are not adequately displayed on the reproduction.

Black Island traverse

The objective of this study was to establish the

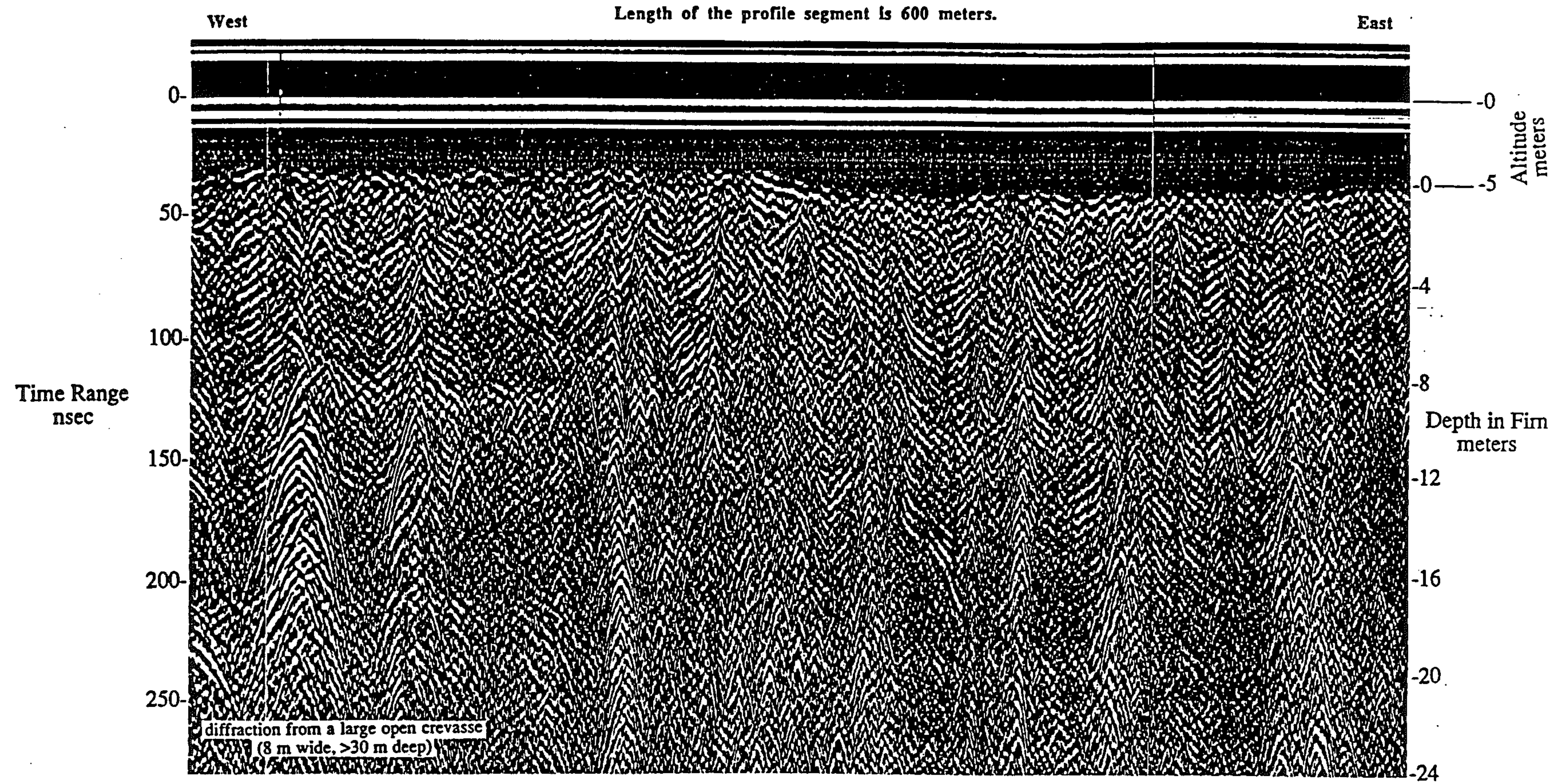

Figure 6. Segments of profiles recorded at different speeds above large crevasses on line WI-15 north of White Island. Diffractions seen at 5 $m\ s^{-1}$ are still prominent at 20 $m\ s^{-1}$.

nature of ice shelf profiles for a section apparently free of crevasses. A 200-MHz, 800-m profile (BI-1, Fig. 2) was recorded along the tractor trail between Black and White Islands with a single known crevasse that is crossed by a wooden bridge. This is an area of hard ice and high wind, and the ice surface along the tractor trail had little snow accumulation. Ice flow is from south to north between the islands. GPS way points were recorded incrementally along with the radar data. Survey altitude was about 5 m and airspeed 8 m s^{-1}.

The radar profile is shown in Figure 7. The small, near-surface diffractions at the start of the profile may originate from meltwater pools reported to exist along the tractor trail. Several distinct reflections are seen near the center of the record at a time depth of 100 ns (8.4 m). A possible explanation may be that shelf ice, moving northward, is overriding a sub-ice bedrock rib extending between the two islands causing the ice to crack. This series of significant diffractions, in the area of the only known crevasse, may represent subsurface voids that have not yet been manifested at the ice surface. The diffraction from the open crevasse, indicated by the event marker and arrow on Figure 7, is overshadowed by reflections that could originate from a bedrock surface or seawater interface on top of the rock. The amplitude of the pulses reflected from this near-horizontal reflector is much higher than any other pulse amplitude originating from within the ice. The phase polarity of these reflections (Arcone 1994) indicates a material with dielectric permittivity higher than that of ice. The first 170 ns of the first 300 m of the record is free of the characteristic diffraction patterns associated with crevasses, and of reflections associated with layering seen at other sites.

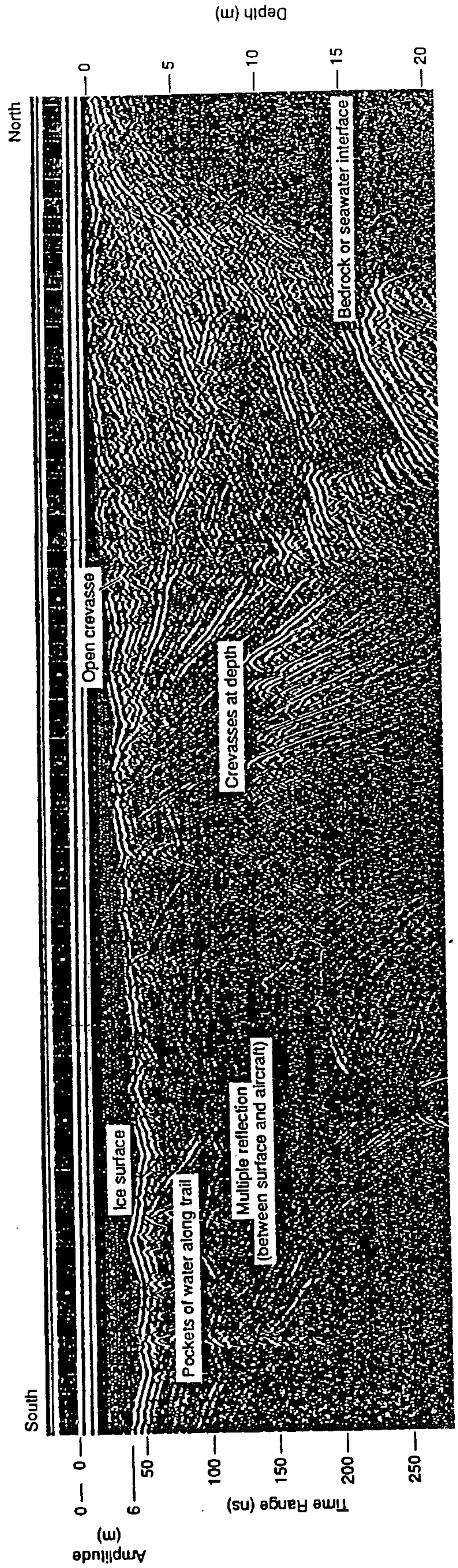

Figure 7. Profile recorded along the tractor traverse between White and Black Islands. This is an area of hard ice where crevassing was not expected.

Aurora Glacier and White Island transitions

The objective of this portion of the study was to look for transitions from crevassed to un-crevassed ice along probable flow lines in the ice shelf. Such transitions could indicate if transverse crevasses gradually close as the ice flows onto the shelf. Profiles were recorded along assumed flow lines. These lines coincided with the strike of undulations seen on the ice shelf that may indicate compression transverse to the flow direction. One 13-km- long profile (WB-1) extended from the terminus of the Aurora Glacier north onto the Ross Ice Shelf, and two profiles (10 and 12 km in length, WI-16 and WI-20, respectively) extended from glacial ice on the eastern end of White Island onto the Ross

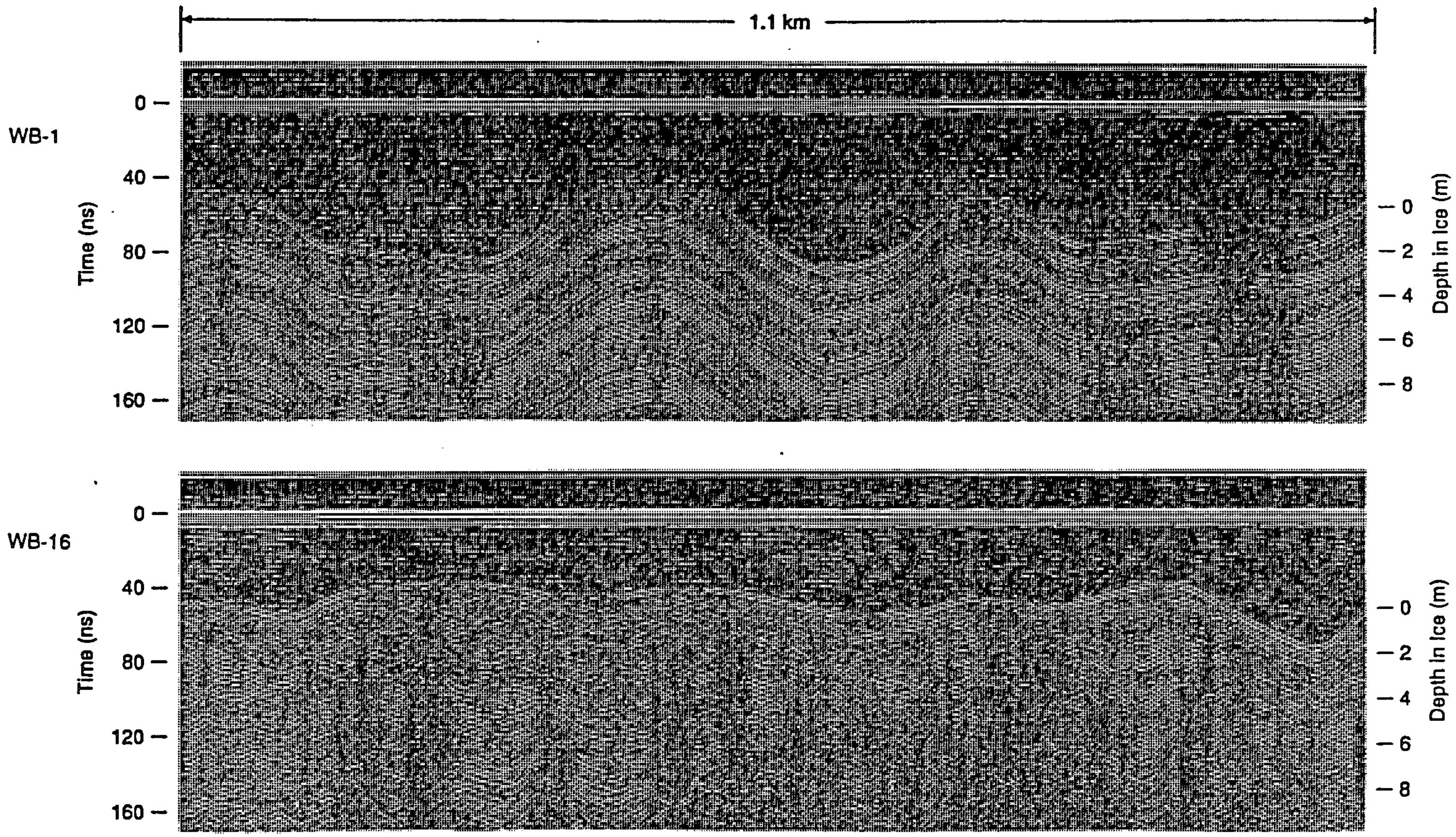

Figure 8. Segments of 500-MHz data files recorded near the terminus of the Aurora Glacier (top) and east of White Island (bottom). The event marks correspond with GPS way points spaced every 30 seconds. The undulations in position of the surface return represent changes in aircraft altitude.

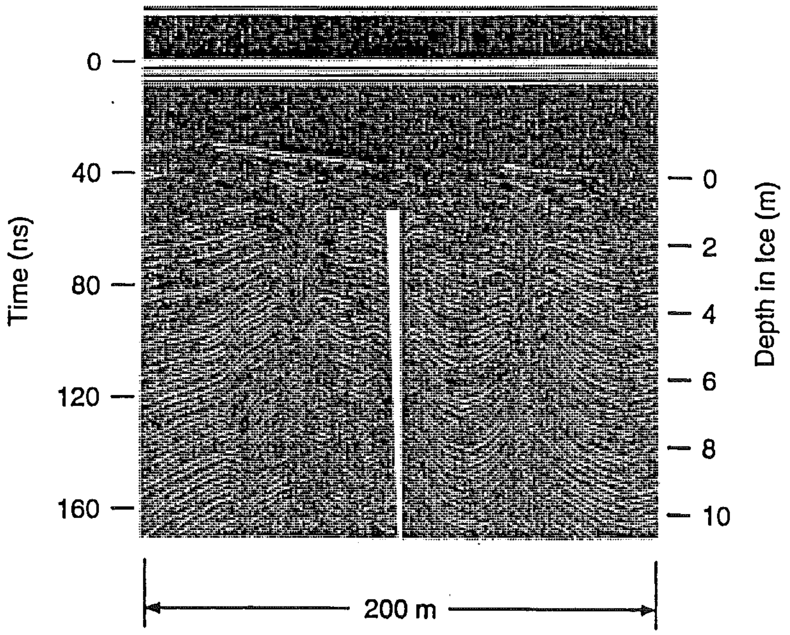

Figure 9. Unstacked segment of data recorded on White Island Profile (WI-18) showing in detail the density layer reflections and crevasse diffractions.

Ice Shelf (Fig. 2). Poor visibility near the terminus of the Aurora Glacier obscured the surface, and data were recorded at 10 to 15 m s^{-1} and 8-m altitude by following a compass heading. Profiles were collected for 10 minutes of flight using the 500-MHz transducer at 51.2 scans/second and a time range of 200 ns. GPS way points were recorded every 30 seconds. We then moved to the White Island area where light conditions were more favorable for low level work.

The lengths of the records preclude their complete presentation and data compression results in loss of resolution. Therefore, two typical data segments (one and one half minutes in length) are shown (Fig. 8). The top segment was recorded near the terminus of the Aurora Glacier. The long period oscillation is due to the changes in aircraft altitude. The entire record is characterized by reflections from layering in the snow and ice, and no diffractions indicative of vertical interfaces are seen.

In contrast, the profile recorded east of White Island (bottom of Fig. 8) shows the continuity of the reflections from layering in the snow and ice to be interrupted by diffraction patterns and distorted stratigraphy associated with crevasses. Figure 8a should also be compared with data recorded along the Black Island traverse where no layering is seen.

An unstacked data segment from profile WI-18, (Fig. 9) shows the reflections associated with the crevasses more clearly. Layers within the ice are deformed near the crevasses, appearing to bend downward toward the voids. A crevasse drawn to scale is superimposed on the record.

CONCLUSIONS

Airborne short-pulse radar surveys are capable of detecting snow-bridged crevasses in cold snow and ice and could be used in a reconnaissance mode to map transitions in ice conditions. Crevasse responses are characterized by both diffractions and distortions in the snow-bridge stratigraphy. Observations along the control line show that diffractions can originate at any depth within crevasses where sharp transitions in dielectric permittivity occur. A large crevasse not visible from surface expression was detected with the radar and later excavated to measure snow-bridge thickness and the shape of the void.

Large crevasses were easily detected at speeds up to 20 m s^{-1} (45 mph), while information on the structure within individual snow bridges was revealed using the 500-MHz transducer at 5 m s^{-1} (11 mph). The 200-MHz transducer was superior for detecting crevasses but did not provide the best information on snow bridge thickness as the diffractions seemed to originate from deep within the crevasse.

Altitude should be restricted to 30 m or less because of time range-sampling restrictions and antenna beam spreading. Highly directive antennas should not be used because they would not pick up the tails of the diffractions. Altitude changes, during the survey, are actually desirable as they allow aircraft reflections to be easily filtered while still retaining the ice data.

A recently developed digital short-pulse radar system could be used for fairly rapid 64-m s^{-1} (140-mph) reconnaissance surveys on the Ross Ice Shelf to distinguish areas of ice that contain crevasses. To achieve the high scan rate (160 scans/sec) data are written directly to disk and would require post flight processing. This information along with GPS positioning could be used for preliminary route corridor planning. The reconnaissance survey should be followed by a detailed airborne radar survey of the previously defined corridor to aid in final traverse positioning. For additional safety, the lead traverse vehicle should utilize a surface-mounted radar until the route is well established.

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Appendix A: Global Positioning System GPS Stations.

During these airborne studies, a coarse-acquisition GPS receiver (Garmin 100) was used for survey position control. An external GPS antenna was mounted on top of the radar transducer. The Garmin position coordinates were periodically compared with position coordinates displayed on the aircraft GPS and found to be in close agreement. The recorded position waypoints coincide with event markers on the radar profiles. Waypoints were recorded at the beginning and ends of lines at the Ice Fall, White Island tractor and White Island speed sites. On all remaining long profiles, waypoints were recorded at 30-second intervals. Listed below are all of the radar lines and corresponding GPS waypoints.

Ice Fall Site

IFl	S 77° 49.50′	E 166° 45.55′
IF10	S 77° 49.48′	E 166° 46.05′
IFl1	S 77° 49.45′	E 166° 46.07′
IE12	S 77° 49.41′	E 166° 46.02′
IF13	S 77° 49.37′	E 166° 46.03′
IE14	S 77° 49.33′	E 166° 46.04′
IF15	S 77° 49.30′	E 166° 46.04′
IF16	S 77° 49.27′	E 166° 46.07′
IF2	S 77° 49.47′	E 166° 45.47′
IF3	S 77° 49.43′	E 166° 45.53′
IF4	S 77° 49.40′	E 166° 45.58′
IF5	S 77° 49.38′	E 166° 45.57′
IF6	S 77° 49.34′	E 166° 45.55′
IF7	S 77° 49.31′	E 166° 45.65′
IF8	S 77° 49.26′	E 166° 45.75′
IF9	S 77° 49.51′	E 166° 46.04′
PEGOl	S 77° 54.81′	E 166° 45.35′
PEB02	S 77° 54.51′	E 166° 47.73′
PEG03	S 77° 54.15′	E 166° 50.52′

White Island Tractor Site

WI10	S 77° 57 20′	E 168° 32 75′
WIlOA	S 77° 57.22′	E 168° 32.78′
WIll	S 77° 56.93′	E 168° 32.76′
WIllA	S 77° 56.93′	E 168° 32.81′
WI12	S 77° 56.95′	E 168° 32.86′
WI13	S 77° 56.96′	E 168° 32.93′
WI14	S 77° 56.97′	E 168° 32.98′
WI15	S 77° 56.97′	E 168° 33.03′
WI16	S 77° 56.98′	E 168° 33.07′
WI17	S 77° 56.99′	E 168° 33.12′
WI18	S 77° 56.99′	E 168° 33.17′
WI19	S 77° 57.01′	E 168° 33.24′
WI1A	S 77° 57.09′	E 168° 32.32′
WI2	S 77° 57.08′	E 168° 32.40′
WI20	S 77° 57.02′	E 168° 33.32′
WI20A	S 77° 57.03′	E 168° 33.25′
WI3	S 77° 57.11′	E 168° 32.46′
WI4	S 77° 57.12′	E 168° 32.51′
WI5	S 77° 57.15′	E 168° 32.57′
WI6	S 77° 57.16′	E 168° 32.62′
WI7	S 77° 57.18′	E 168° 32.68′
WI8	S 77° 57.19′	E 168° 32.72′
WI9	S 77° 57.20′	E 168° 32 75′

White Island Speed Survey Site

WW1	S 78° 12.83′	E 167° 33.52′
WW2	S 78° 12.49′	E 167° 35.50′
WW3	S 78° 12.11′	E 167° 37.82′
WW3A	S 78° 12.11′	E 167° 37.85′
277	S 78° 13.85′	E 166° 47.01′
278	S 77° 38.03′	E 167° 38.02′
279	S 77° 38.46′	E 167° 38.80′
280	S 77° 38.81′	E 167° 39.36′
281	S 77° 39.12′	E 167° 39.71′
282	S 77° 39.46′	E 167° 40.12′
283	S 77° 39.79′	E 167° 40.60′
284	S 77° 40.17′	E 167° 40.97′
285	S 77° 40.52′	E 167° 41.40′
286	S 77° 41.18′	E 167° 41.94′
287	S 77° 41.49′	E 167° 42.51′
288	S 77° 41.72′	E 167° 42.91′
289	S 77° 41.95′	E 167° 43.20′
290	S 77° 42.15′	E 167° 43.37′
291	S 77° 42.37′	E 167° 43.63′
292	S 77° 42.68′	E 167° 44.04′
293	S 77° 42.98′	E 167° 44.48′
294	S 77° 43.33′	E 167° 44.86′
295	S 77° 43.66′	E 167° 45.38′
296	S 77° 43.99′	E 167° 45.98′
297	S 77° 44.30′	E 167° 46.56′
298	S 77° 44.62′	E 167° 47.15′

White Island (WI20)

299	S 78° 03.75′	E 167° 57 02′
300	S 78° 03.90′	E 167° 56.12′
301	S 78° 04.12′	E 167° 54.98′
302	S 78° 04.34′	E 167° 53.94′
303	S 78° 04.55′	E 167° 52.96′
304	S 78° 04.77′	E 167° 52.06′
305	S 78° 04.99′	E 167° 51.20′
306	S 78° 05.21′	E 167° 50.34′
307	S 78° 05.42′	E 167° 49.46′
308	S 78° 05.65′	E 167° 48.59′
309	S 78° 05.89′	E 167° 47.80′
310	S 78° 06.14′	E 167° 46.95′
311	S 78° 06.39′	E 167° 46.16′
312	S 78° 06.64′	E 167° 45.40′
313	S 78° 06.88′	E 167° 44.63′
314	S 78° 07.14′	E 167° 43.81′
315	S 78° 07.39′	E 167° 42.98′
316	S 78° 07.65′	E 167° 42.00′
317	S 78° 07.90′	E 167° 40.91′

White Island (WI16)

318	S 78° 08 14′	E 167° 39 83′
319	S 78° 08.62′	E 167° 34.81′
320	S 78° 08.39′	E 167° 36.26′
321	S 78° 08.17′	E 167° 37.34′
322	S 78° 07.96′	E 167° 38.57′
323	S 78° 07.74′	E 167° 39.63′
324	S 78° 07.15′	E 167° 43.11′
325	S 78° 06.97′	E 167° 44.20′
326	S 78° 06.77′	E 167° 45.28′
327	S 78° 06.57′	E 167° 46.25′
328	S 78° 06.37′	E 167° 47.42′
329	S 78° 06.18′	E 167° 48.58′
330	S 78° 05.97′	E 167° 49.80′
331	S 78° 05.77′	E 167° 50.90′
332	S 78° 05.57′	E 167° 52.13′
333	S 78° 05.37′	E 167° 53.29′

White Island (WI17)

334	S 77° 55.87′	E 168° 32.20′
335	S 77° 56.21′	E 168° 32.20′
336	S 77° 56.49′	E 168° 32.31′
337	S 77° 57.27′	E 168° 32.58′
338	S 77° 57.52′	E 168° 32.85′
339	S 77° 57.79′	E 168° 33.11′
340	S 77° 58.05′	E 168° 33.35′

White Island (WI18)

341	S 77° 58.05′	E 168° 33.48′
342	S 77° 57.74′	E 168° 32.80′
343	S 77° 57.32′	E 168° 31.96′
344	S 77° 56.92′	E 168° 32.14′
345	S 77° 56.56′	E 168° 32.84′
346	S 77° 56.31′	E 168° 33.86′
347	S 77° 56.03′	E 168° 34.55′

White Island (WI19)

348	S 77° 56.71′	E 168° 37.04′
349	S 77° 56.80′	E 168° 35.50′
350	S 77° 56.90′	E 168° 34.09′
351	S 77° 57.03′	E 168° 32.72′
352	S 77° 57.13′	E 168° 31.55′
353	S 77° 57.22′	E 168° 30.18′
354	S 77° 57.32′	E 168° 28.82′
355	S 77° 57.42′	E 168° 27.36′
356	S 77° 57.55′	E 168° 25.69′

Black Island Traverse

BI1	S 78° 13 27′	E 166° 47 66′
BI10	S 78° 13.61′	E 166° 46.64′
BI11	S 78° 13.65′	E 166° 46.58′
BI12	S 78° 13.67′	E 166° 46.53′
BI13	S 78° 13.70′	E 166° 46.47′
BI14	S 78° 13.73′	E 166° 46.43′
BI2	S 78° 13.33′	E 166° 47.38′
BI3	S 78° 13.37′	E 166° 47.13′
BI4	S 78° 13.42′	E 166° 46.96′
BI5	S 78° 13.45′	E 166° 46.91′
BI6	S 78° 13.47′	E 166° 46.87′
BI7	S 78° 13.50′	E 166° 46.83′
BI8	S 78° 13.53′	E 166° 46.77′
BI9	S 78° 13.58′	E 166° 46.69′

SIXTH SYMPOSIUM ON ANTARCTIC LOGISTICS AND OPERATIONS
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INSTALLATION AND OPERATION OF THE ITALIAN OCEANOGRAPHIC BUOY IN TERRA NOVA BAY POLYNYA (ANTARCTICA)

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ABSTRACT

Within the Italian Antarctic Research Program, ENEA has commissioned to Tecnomare the development of an instrumented moored buoy for long-term acquisition of oceanographic and meteorological parameters in Antarctic waters. A prototype of this buoy has been installed in Terra Nova Bay (Ross Sea), in an area normally ice-free (polynya), but potentially affected by drifting ice features. Its purpose is mainly to collect data on its interaction with ice conditions encountered, to allow the subsequent upgrade to an operational marine observatory.

The prototype station is composed of 4 main subsystems and is equipped with a limited set of sensors, mainly oriented to follow and verify the buoy dynamics and integrity.

In the paper a description of the prototype station, marine and shore operations carried out and the results of the experimentation and data acquisition carried out till now are presented and discussed.

1. INTRODUCTION

Terra Nova Bay (Ross Sea, Antarctica) is characterized by the presence of a polynya, an open water area ice-free also during winter, featuring an average surface of about 1000 km^2 (for more details see [1], [2], [3], [4]). Such a fact makes this area particularly interesting from a scientific point of view, and call for the development of specific tools for the observation of the peculiar environmental conditions.

Recognizing this need, in the beginning of the nineties the Italian National Antarctic Program has promoted a study aimed at the definition of an advanced automatic station able to operate with one year authonomy in antarctic waters, allowing continuous collection of meteo-oceanographic data in the area of the polynya. The study [5] demonstrated the feasibility of a concept based on a moored ice-resistant buoy able to allocate various instrumented modules. In 1992-93 a prototype of the station has been designed and developed, and installed in Terra Nova Bay during the IX Italian Antarctic Expedition (October 1993-February 1994).

The site chosen for the installation is located offshore Cape Russell. Site coordinates are: lat 74°56'772" S and long 164°05'260" E; water depth is 463 m and distance from Italian Base is approx 30 km. Figure 1 shows the installation site and surrounding features.

2. DESCRIPTION OF THE PROTOTYPE BUOY

2.1 Configuration of the buoy and of the anchoring line

The structural and hydrodynamical design of the system is the results of considerations and analyses regarding both the behaviour in ice free waters and in ice infested waters.

In particular, the following basic criteria have been assumed as primary design requirements:

- a small freeboard, allowing the buoy to be compliant during drifting ice transit;
- hull shape, small waterplane area and tapered upper part minimizing the possibility that the buoy is entrapped by sheet ice formations;
- a slender shaped hull, making it possible to locate the electronic vessel in a relatively less severe and almost constant temperature environment;
- no sensor or antenna jutting out of the hull, thus minimizing risk of damage from icing or impact;
- a relatively large draught, increasing the probability that the mooring line is not exposed to contact with drifting ice formations;
- a lower mass chamber, giving the buoy good seakeeping properties;
- an anchoring line configuration allowing to accomodate large waterdepth uncertainties and reducing hull submergence due to current.

The resulting configuration, in full accordance with the above criteria is the spar type buoy shown in Figure 2, which is 21.8 m long and consists of:

a) an upper tapered part, long about 3.2 m;

b) an intermediate cylindrical part, having a length of 15.4 m and an outer diameter of 0.56 m;

c) a lower part long about 3.2 m, having an external diameter of 1.5 m and terminating with a conical transition.

The tapered upper part consists of two sections, made of composite material (glass reinforced epoxy resin) and encloses the UHF antenna and GPS receiver. It is partially filled with high density foam and its top end is hemispherical.

The intermediate part consists of two sections, having the same diameter. The upper one is made of composite material (glass reinforced vinyl ester resin) and is 25 mm thick, while the lower one is made of steel with 12 mm thickness. The former section contains a water ballast chamber, while the remaining volume is saturated with high density foam.

The lower part of the hull is made of steel and consists of an internal chamber surrounded by an external sleeve. The internal chamber houses the electronic vessel, where batteries, radio and electronic cards are located. The space between the internal and the external cylinders is partially filled with high density polyurethanic foam. Its remaining volume is freely flooded to increase the hull added mass, which improves the hydrodynamical behaviour of the buoy in presence of waves.

The bottom end conical transition encloses additional foam and provides a protection for the anchoring line fairlead and its load cell. The access to the electronic instrumentation contained in the internal chamber is possible by removing the conical transition.

The dry mass of the buoy hull is about 5000 kg. By adding the liquid ballast, the mass increases to 5800 kg. The operative draught of the buoy hull is 19.1 m.

The anchoring line, shown in Figure 3, is of the elastic catenary "S" type and consists of the following parts (starting from the bottom):

a) a polypropylene synthetic rope, having a diameter of 64 mm, an adjustable length between 425 and 525 m and negative wet weight;
b) a short section containing a weak link;
c) a polyester synthetic rope, having a diameter of 40 mm, a length of 264 m;
d) an upper section, about 4 m long, which consists of 30 mm chain and contains a swivel.

A steel wire element connects the upper section to the load cell, entering inside the hull bottom by passing through a large curvature low friction element.

Anchoring line pretension is about 1.8 kN.

The gravity base is an armoured concrete deadweight having almost squared plan (2.5 x 3 m).

An extensive programme of model tests has been carried out at the Canadian National Research Council Laboratories (Ottawa), where seakeeping, freeze-in, pull-out and ice floe impact tests have provided experimental support to the design procedures and have allowed to evaluate the performance of the concept for the various seasonal scenarios.

The ice experiments have confirmed that the bonding strength between epoxy resin specimens and sea ice is significantly lower than that of metal with sea ice. This should expedite the "pull-out" of the buoy from the ice sheet by failing the bond before the buoy experiences high ice crushing pressure.

The thermal properties of this material also minimize ice growth around the buoy hull and heat transfer towards its bottom part, where the electronics is located.

The ice floe impact tests with wave, wind and current have shown that the buoy motions are small in response to impact and the net impact velocity is predominantly associated with the drift and oscillatory motions of the ice floe.

In reason of the small reserve of buoyancy of the emersed part of the hull and of its stability characteristics, the action of the ice floe in waves results in the buoy submerging during the interaction and emerging behind the floe. Therefore, the probabilities of attaining high relative velocities against a second oncoming ice floe is very low.

2.2 Sensors

The prototype station is equipped with a limited set of sensors, mainly oriented to follow and verify the system dynamics and integrity (mooring line tension, buoy attitude, battery voltage); scientific sensors will be added in subsequent development phases. Data stored in memory, once collected at the end of the experimental phase, will allow a comprehensive analysis of the system behaviour during the whole period. In particular it will be possible:

- to study buoy dynamics, also with frequency analysis;
- to verify solicitations occurred to the buoy hull and mooring (ice impact, ice entrapment, immersion);
- to verify functionality of sensors and systems installed onboard;
- to diagnose possible malfunctionings and relevant causes;
- to record a time history of air and water temperature.

For this purpose, the set of sensors adopted for the prototype includes:

a) 5 linear accelerometers, three of which are installed in the lower part of the buoy (inside the electronics vessel), and two in the upper part (in a waterproof box just below the antennas);
b) 1 dual tension load cell mounted on the top of the mooring line;

c) 3 PT-100 temperature sensors, specially designed to be flush mounted at three quotes of the buoy hull;
d) 1 ice detector, based on a conductivity sensor specially designed, flush mounted on the buoy hull just below waterline;
e) 2 internal temperature sensors (incorporated in two of the above accelerometers) mounted inside the electronic vessel and in the upper part;
f) 1 battery voltage sensor;
g) 1 GPS receiver supplying both position and time information.

2.3 Data Acquisition and Control System

All sensors and relevant conditioning units are interfaced with a Data Acquisition and Control System (hereafter referred as DAS) based on single Eurocard VME, CMOS extended range cards. The system features 68HC000 CPU, 2 serial ports, 1 parallel port, 16 analog I/O channels, 256 kbyte SRAM, 512 kbyte EPROM, 4 Mbyte EEPROM.

A standard acquisition cycle is activated every 30 minutes; its duration is 30 seconds and sensors are sampled at 2 Hz. These data are processed to calculate a set of reduced data (max, min, averages, standard deviations etc.) which is stored in memory. Once a day, a continuous series of raw data collected during a standard acquisition is directly stored in mass memory, in order to allow a deeper knowledge of buoy and sensor behaviour at system recovery. Frequency analyses on accelerometer data shall also be possible.

In case the system detects the occurrence of conditions particularly severe for the buoy, i.e. attitude or mooring line tension outside assigned thresholds, meaning possible ice impact or entrapping, the system enters into an extraordinary condition. In this case acquisition cycles are continuous and parameters verified against thresholds every 5 minutes. In any case extraordinary conditions cannot exceed a given number and duration, in order to limit energy and memory consumption.

Specific solutions have been implemented to ensure minimization of energy consumption and reliable operation of the most critical subsystems, such as energy source, data acquisition and control, data storage, transmission. Low power CMOS electronics has been adopted. Between consecutive cycles the system automatically enters a low consumption mode; this is managed by an electronic card specifically designed and developed by Tecnomare that periodically switches on and off the DAS. This card ensures also other important features:

- watch-dog function; this means that system switch off is forced in any case after 60 minutes of continuos operation; this control is particularly useful in case of extraordinary acquisitions, to avoid risk of unforeseen memory and energy waste in case of sensors malfunctioning.
- inhibit by remote control DAS automatic switch on; useful during transport phases.
- override timer and force DAS switch on by remote control; useful during installation and test phase.

When the DAS is switched off, current drain is less than 10 mA; this helps mantaining full efficiency of the batteries. For increased reliability the power control section is fully redundant and solid state power mosfets have been adopted instead of electromechanical devices (relays).

2.4 Power system

Primary batteries have been selected as energy source selected for the application, because of their considerable gravimetric/volumetric density and high efficiency at low temperatures. The battery pack is based on 192 lithium cells (DD type), ensuring 700 Ah at 24 V, corresponding to 1 year operation at an average temperature of 0 °C. Approx weight is 42 kg, volume 0.025 m^3.

2.5 Telemetry

Although all data produced are stored in static memory, a message containing a summary of data collected and system status is periodically transmitted to the shore station located near the Italian Base. For this reason the buoy is equipped with a UHF radio telemetry system working at 458 Mhz. Transmissions are activated daily during the first two months of operation, i.e. when the Base is manned, and then weekly. Transmission parameters have been calculated taking into account distance between buoy and receiver (about 30 km) and presence of a GRP radome housing the omnidirectional antenna. A typical summary message received at shore station has the format shown in Figure 4.

2.6 Shore Station

Shore station includes receiver with antenna, and a lap-top computer with software managing messages from the buoy. The same computer is also used to carry out all set-up and data recovery operations in field before and after buoy deployment. This computer is interfaced to the VAX computer in the Italian Base, continuously operating and managing data collected by the various stations remaining active also during winter (besides the buoy, some meteo stations and a seismic station are installed on shore). From Antarctic Project headquarter in Rome (Italy), ENEA personnel can interrogate the VAX via satellite link, receiving confirmation of the correct operation of the remote stations.

3. INSTALLATION AND OPERATION IN ANTARCTICA

3.1 Shore Operations

Shore operations were basically devoted to the installation of the shore station and connection of the system to the Base computing facilities. The following activities were carried out:

- installation of the UHF directive receiving antenna on an existing pylon located in the top of a hill in proximity of the Italian Base (antenna field). The resulting height of the antenna is about 100 meter over mean sea level;
- installation of the radio receiver inside the shelter available in the antenna field;
- installation of the cable connecting the antenna to the receiver;
- connection of the radio receiver to the modem allowing data transmission to the VAX computer in Base.

3.2 Marine Operations

Marine operations were carried out using the ship "ITALICA" and two smaller support crafts. They can be subdivided into three main phases.

a) Preliminary activities, carried out in the period 24-30 December 1993, including:

- execution of detailed surveys in the area of the polynya identified in the design premises, to determine with high accuracy the installation site characteristics (position, bathymetry, characteristics of sea bottom, etc.);
- set up of the installation equipment (anchoring line adjustment to the exact site water depth, line pre-tensioning and winding on the winch);
- verification of the radio telemetry link, by means of transmission of test messages between the ship cruising over the site area and the shore station;
- execution of accurate measurements of water density and temperature in the site area.

b) Final tests on the system electronics, carried out onboard the ship just before installation, and including:

- inizialization of basic functioning parameters, such as time and position;
- check of system correct status.

c) Installation phase, started on December 31, 1993 and ended successfully on January 1, 1994, including:

- installation of gravity base and lower part of the anchoring line (polypropylene synthetic rope);
- connection of two marking buoys at the end of the anchoring line deployed;
- lowering of the buoy using the ship equipment and a support craft carrying the upper part of the anchoring line, connected to the buoy itself; in this phase the buoy presents an horizontal attitude;
- deployment of the upper part of the anchoring line, and connection to the lower part (already installed) by means of the weak link element;
- a second support craft, equipped with a pump and flexible hose, allowed the execution of the buoy ballasting phase with seawater, thus making the buoy assume the final vertical attitude.

No major problem occurred during these phases, and the buoy started immediately operation. During the period of presence of personnel in Base, daily transmission have been regularly received. At the end of February, before leaving the Italian Base, the correct transition to the weekly rate of transmission has been verified by ENEA personnel.

Next intervention on the buoy, including data recovery and battery replacement, is foreseen for the next 1994-95 expedition.

4. RESULTS FROM THE FIRST OPERATIVE PHASE

The first six months of continuous operation allow us to conclude that the system is operating according to expectations. No failure has been observed, and measured parameters are within the expected ranges. No ice has been detected around the buoy, and a stable behaviour is desumed from accelerometers. At late February significant solicitations on the mooring line have been observed, which may have been caused by a possible impact of ice floes or a severe storm. Detailed analysis of the complete set of data collected shall allow reconstruction of the events occurred.

5. POSSIBLE FUTURE DEVELOPMENTS

Once completed the first year in Antarctica and successfully verified system capabilities in real operative conditions, a dedicated development phase will be started, aimed at extending prototype capabilities in a gradual manner. The final objective is to make available to the scientific community a marine station able to extend the observation capabilities presently limited to the activities carried out from ship during Summer Campaigns.

Four classes of instrumented modules have been identified as constituents of the future station payload:

- modules for oceanographic measurements (current, temperature, conductivity, etc.), to be mounted at various quotes on the mooring line;
- a bottom station, hosting other oceanographic sensors such as a current profiler, or multiparametric probes;
- an automatic water sampler;
- a module for meteorological measurements, to be mounted in the upper (emergent) part of the buoy.

Besides that, from now on the station is available as a platform for the installation of autonomous sensors and packages (e.g. self-recording current meters, CTDs, etc.) and for possible experimentation of innovative sensors/systems developed by other institutions in parallel research activities.

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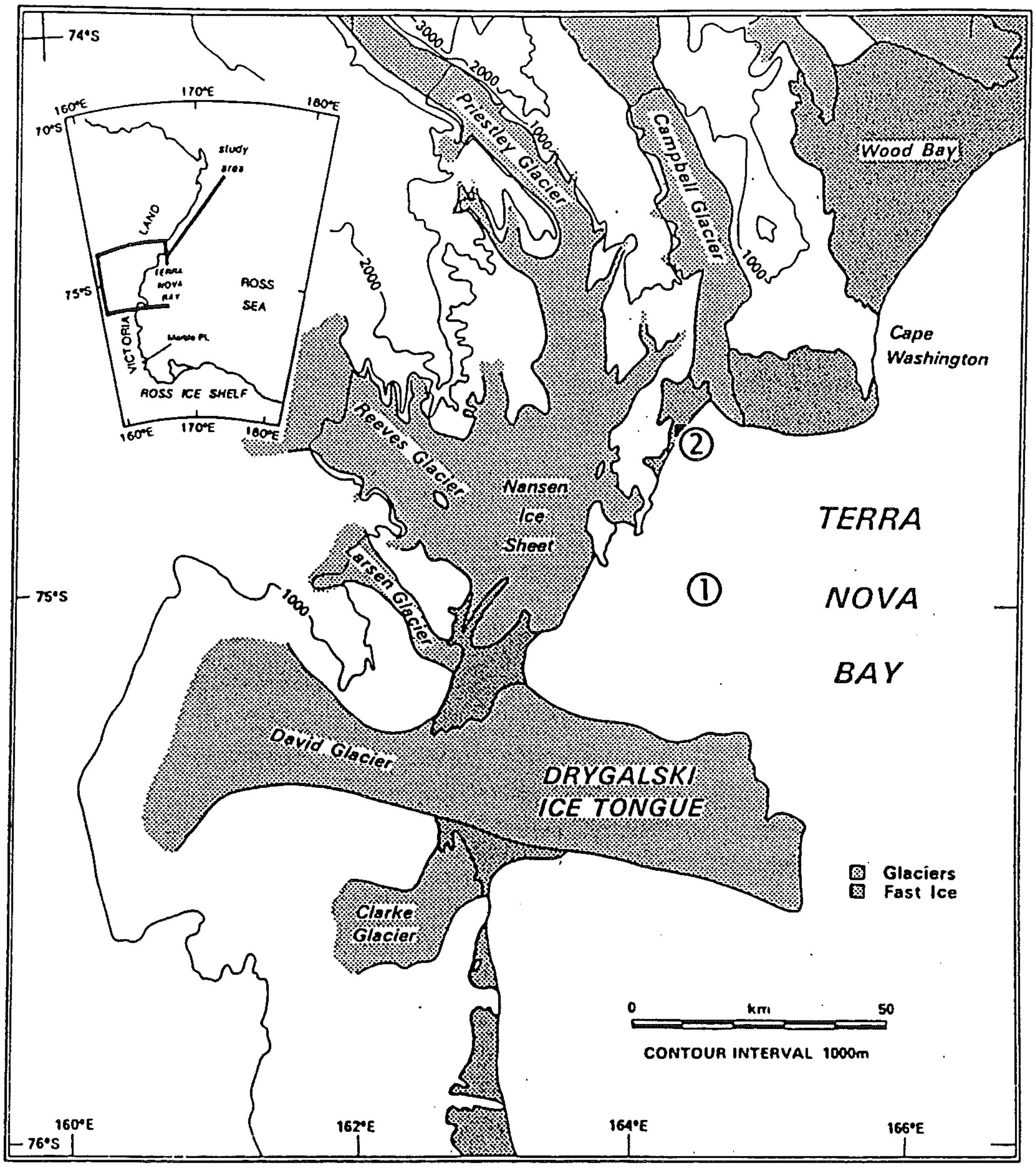

LEGEND

① BUOY INSTALLATION SITE

② ITALIAN ANTARCTIC BASE

Fig. 1 - Map showing Terra Nova Bay and buoy installation site

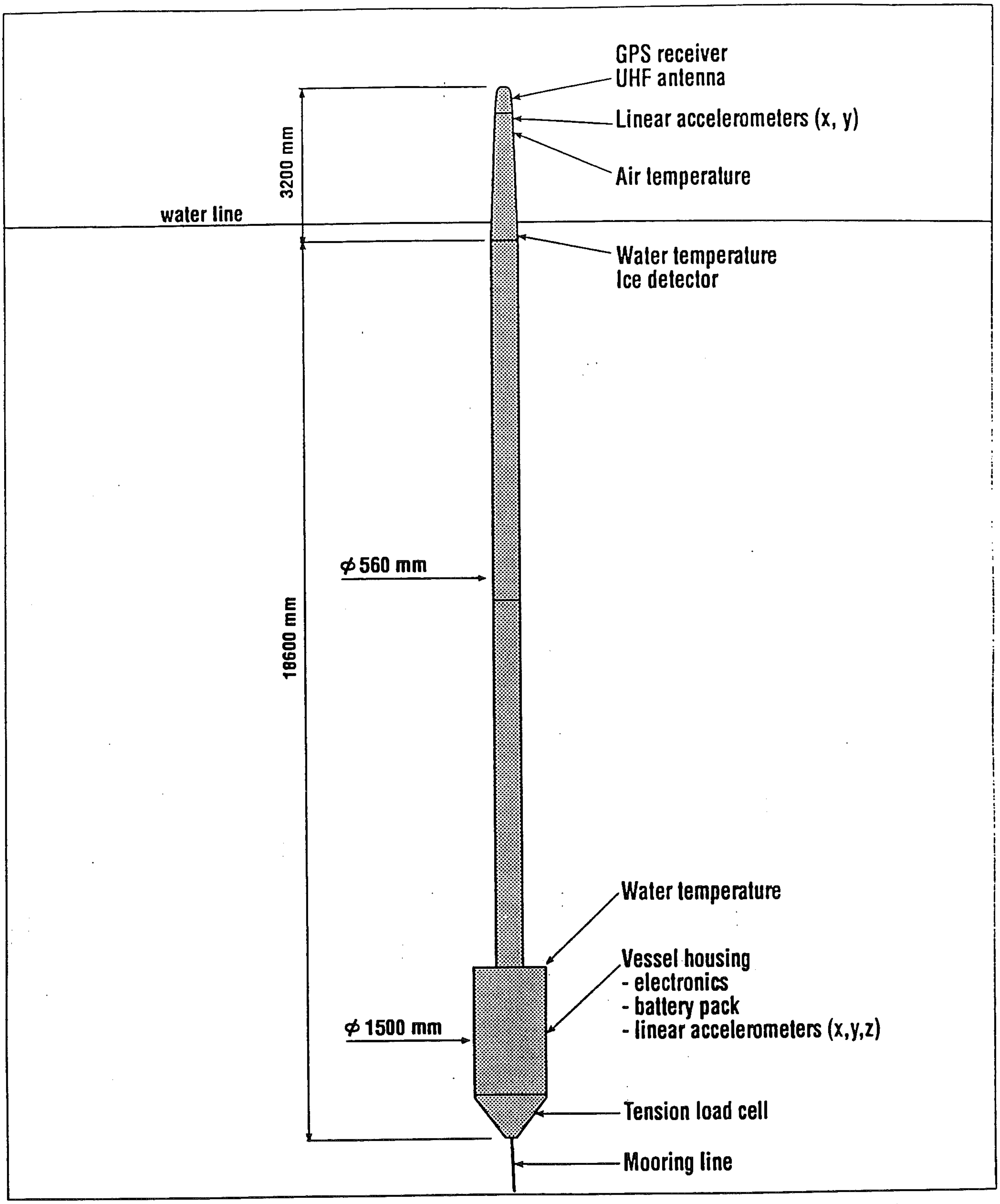

Fig. 2 - Antarctic buoy configuration

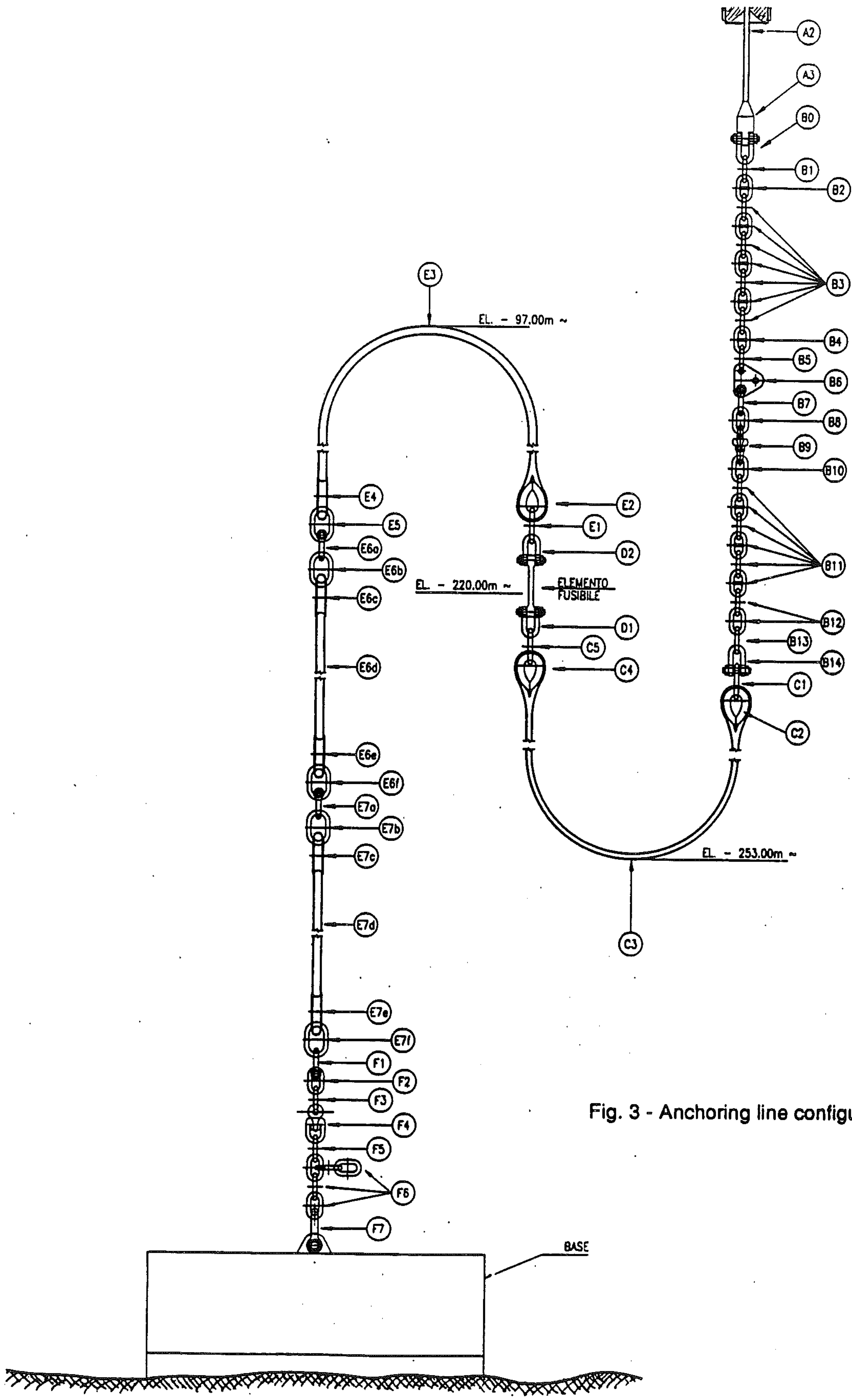

Fig. 3 - Anchoring line configuration

Msg#34/0, GPS: lat/long = 164.099/-74.942 Tens.batt.=25.9V (2115)
46 record (46 ord.+0 straord.) dal 27/01, 23:50 al 28/01, 23:23

TAG	UNITA'	MINIMO	MEDIA	MASSIMO
TT103	(°C)	-3.9 (1888)	-1.0 (2008)	6.1 (2300)
TT200	(°C)	-1.1 (2003)	-0.1 (2044)	1.1 (2094)
TT300	(°C)	-1.5 (1988)	-0.6 (2023)	-0.1 (2046)
TT106	(°C)	14.2 (988)	15.0 (991)	17.3 (999)
TT501	(°C)	4.9 (964)	6.6 (970)	10.0 (982)
LC400	(kN)	0.0 (0)	0.0 (0)	0.0 (0)
LC401	(kN)	0.0 (0)	0.0 (0)	0.0 (0)
AT105	(m/s²)	-0.2 (2000)	0.2 (2083)	0.5 (2140)
AT108	(m/s²)	0.1 (2057)	0.6 (2158)	2.2 (2506)
AT500	(m/s²)	-0.1 (2014)	0.2 (2086)	1.4 (2323)
AT502	(m/s²)	-1.7 (1681)	-0.5 (1945)	-0.1 (2018)
AT503	(m/s²)	-10.1 (986)	-10.1 (992)	-9.8 (1017)
ID301	( )	0.0 (0)	2.8 (97)	2.9 (100)

F1-Numero F2-Ultimo F10-Esci | 28 Messaggi registrati.
F3-Ridotti F4-Riepilogo F5-Data

Record di dati ridotti acquisito il 28/01, 23:23
Tipo di acquisizione: CONTINUA
Soglie: 0x0 Qualità dei dati: 0x0 Allarmi: 0x0

TAG	UNITA'	MEDIA	STD DEV	MASSIMO
TT103	(°C)	4.7 (2240)		
TT200	(°C)	1.1 (2094)		
TT300	(°C)	-0.6 (2023)		
TT106	(°C)	17.3 (999)		
TT501	(°C)	9.8 (981)		
LC400	(kN)	0.0 (0)		
LC401	(kN)	0.0 (0)		
AT105	(m/s²)	0.3 (2103)	0.8 (157)	1.8 (2418)
AT108	(m/s²)	1.5 (2360)	0.3 (68)	2.6 (2592)
AT500	(m/s²)	0.9 (2227)	0.4 (84)	1.6 (2375)
AT502	(m/s²)	-1.2 (1802)	0.4 (81)	-0.4 (1960)
AT503	(m/s²)	-10.0 (1001)	0.0 (1)	-10.0 (1005)
ID301	( )	2.9 (100)		

F1-Numero F2-Ultimo F10-Esci | 28 Messaggi registrati.
F3-Ridotti F4-Riepilogo F5-Data

Fig. 4 - Summary message transmitted to shore

Mac Weather: Improved Meteorological Support in Antarctica

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Antarctica is reputed for its harsh environment and the potential impact that can have on the success of air and ship operations. Operating in severe weather conditions increases the risk of personnel injury and property damage. Safety has to be the "number one" consideration in conducting successful and efficient missions. With long legs to cover and few (or no) alternative landing sites, aircraft have limited options when weather conditions degrade unexpectedly at their destination. Ships may be endangered or incur costly delays should they steam through heavy seas or poor ice conditions. Even fair Antarctic weather has an operational impact. Operators would like to get the most out of the good meteorological conditions before it once again deteriorates. Therefore, whether conditions are poor or fair, timely and accurate forecasts are needed to exploit the situation. Historically, the McMurdo Weather Office of the US Naval Support Force, Antarctica (locally known as "Mac Weather") has had to derive operational forecasts using tools which were dependent on limited communication links and processing gear. Some data sources and valuable forecast guidance were simply inaccessible until recently. In the last few years, there have been many improvements in the McMurdo communications architechture. With the introduction of Internet, satellite telephone capability, advances in processing gear and upgrades in software, the Antarctic forecaster is no longer "isolated" from forecasting tools commonly available at other weather centers.

Internet capability was first established in McMurdo at the end of the 91/92 season with joint testing by NASA and NSF of a Satellite Earth Station (SES) at Black Island. As late as the 88/89 season, HF facsimile was the only means of receiving forecast charts at Mac Weather. It was not a very practical means of receiving data due to unreliability of HF signal reception and the limited applicability in Antarctica of the products received over a general weather fax broadcast. Broadcast schedules are typically designed to provide support for local regions. The Australian and New Zealand broadcasts are meant to support customers in their own "backyard". The US Navy broadcast is focused on fleet operations and heavily weighted for supporting operations in the northern Pacific. Only a few charts from any of these broadcasts were global enough in scope to extend into the area of responsibility covered by Mac Weather. In 1989, the US Navy Fleet Numerical Meteorology and Oceanography Center (FMNOC) developed the Naval Oceanographic Data Display System (NODDS), a software package capable of allowing transmission of Navy numerical weather products via a telephone modem connection. Mac Weather took part in operationally testing the software during the 89/90 season. Products could be tailored by the user by defining map area coordinates and requesting specific gridded fields (winds, temperature, sea level pressure, etc) to be extracted from FMNOC's global weather model. They were conveniently displayed and could be easily manipulated on a local desktop personal computer (PC). Using INMARSAT, a commercial satellite communications system, Mac Weather was accessing computer generated prognostic weather charts via telephone for the first time. Though this was a major improvement over HF facsimile, all was not perfect. There were still some drawbacks to this method of communication. Downloading data was slow at 1200 baud and therefore expensive on INMARSAT. Having only one line available, INMARSAT had many other roles to fulfill in the command. This restricted its use to fairly small scheduled "windows" for each purpose. The fifteen minute windows for pulling weather charts combined with a slow transmission rate limited the download of data to the most essential charts. Access was restricted to twice a day, once for each FMNOC model run. If connectivity was not achieved in the periods allowed, forecasters had to do without the numerical guidance from that model run. The establishment of the SES at Black Island in the 91/92 season brought major improvements in the capabiltiy to access weather information. By the 92/93 season, it provided full time Internet connectivity with a relatively large digital bandwidth and a dedicated 9600 baud weather data telephone line. These SES communication pipelines greatly unjammed the flow of information bringing weather data quickly and relatively inexpensively to Mac Weather.

Internet connectivity afforded new applications for transmitting meteorological information. A particularly useful application for the weather office is the ability to pass satellite data from a receiving or processing site to another site for display. Cost and time limitations made this an impractical option over INMARSAT. The bandwidth of the Internet link is large enough to allow high resolution satellite data to pass easily without overburdening the link. The following examples show how this technique has been used to improve operational support.

Since Mac Weather provides environmental support from the South Pole north to Christchurch, New Zealand, both polar orbiting and geostationary weather satellites provide valuable imagery for forecasting. Polar orbiting satellites give excellent coverage of high latitude regions. There are typically four or five operational satellites whose passes can be captured at Mac Weather as they scan the Antarctic region within approximately 1200 miles of McMurdo. McMurdo typically falls under the footprint of these satellites 16 to 18 hours a day. On the other hand, geostationary satellite data gives 24 hour coverage of the region within its footprint. However, by virtue of its orbit over the equator, geostationary satellite imagery is useful only down to about 60°S. These satellites are below the horizon at McMurdo which is near 77°S and, therefore, data cannot be captured directly by the Mac Weather Terascan satellite receivers. There is a reliable indirect method though. Covering the western Pacific, the Japanese Geostationary Meteorological series of prognostic charts for multiple atmospheric levels and data types. Requests for charts are tailored to the specific needs of the task. The telephone link also allows direct access to FNMOC's Optimum Path Aviation Routing System (OPARS), an interactive program used to determine the best route for specified aircraft to take based on performance characteristics, cargo loads and computer generated forecast weather conditions. Prior to this, OPARS had to be requested well in advance by forwarding the request through the Christchurch weather office. The results were faxed to McMurdo via INMARSAT. Direct access to OPARS means far less turnaround time from request to product in hand and a savings in transmission costs. This ensures the latest weather model run is incorporated in the output and more options can be considered to gain the greatest advantage from the expected weather pattern.

Not only has better communications improved meteorological support, but improved software has had a positive impact. Mac Weather has been able to get more out of its processing gear through the use of "off the shelf" multitasking software. Local satellite acquistion and processing requires little attention from forecasters other than to set up a schedule for capturing and archiving passes, and routine maintenance on directories. GMS data is received in a automated "background" process on the Terascan unit requiring no effort on the part of personnel in McMurdo. Multiple tasks can also be simultaneously conducted on the desktop PC's as well. For example, while pulling NODDS data in one window, an interactive "conversation" can be held with forecasters in Christchurch. The enhanced convenience and flexibility of these functions leaves more time for forecasters to forecast.

Weather related software packages are also being upgraded. Climatological data bases are more extensive and stored on CD-rom disks. Numerical weather models run more quickly and ingest more data, including data from spaced-based sensors. As a result, the models are more sensitive to the detection of finer scale systems. This gives forecasters better guidance to make better decisions. Improvements in display software are providing the processed data in more useful formats which provide forecasters a better understanding of dynamics of developing systems.

While communications have improved the volume of available data and better software has improved the way data is processed and viewed, neither of these improvements would be possible without better processing hardware. In past years, storing satellite data was limited to a few passes a day and processing was more labor intensive and significantly slower. Terascan satellite receivers have been upgraded to store up to a gigabyte of data each. The upgrades allow a broader spectrum of data to be viewed. Graphic overlays of Automated Weather Station data and satellite derived vertical sounding data which are downloaded with TIROS satellite passes can be conveniently superimposed directly on the imagery. Larger storage capacity and more RAM for multitasking capability loaded in more sophisticated and versatile workstations makes it possible for Mac Weather forecasters to study the Antarctic weather environment in far more detail than their predecessors. Many applications on PC's, particularly graphics which can be animated, run with greater speed. Forecasters get a better feel for the dynamics from computer generated weather guidance.

Another example of improved processing gear is the Automated Surface Weather Observation System (ASOS). The first of several planned ASOS installation was completed during the 93/94 season. As more systems are installed and sensors groups are added to each, the ASOS will archive automatically a complete weather record at numerous sites in the McMurdo area while providing continuous accurate observations for forecasters. Used as a stand alone system, ASOS also allows greater effieciency in the deployment of weather observer personnel, allowing Mac Weather to do more with less.

Bringing Mac Weather out of "isolation" has important operational implications. Forecasters have better tools with which they can make more accurate forecasts. The improved timeliness and accessibility of weather data means decisions regarding flight schedules and ship operations can be made using latest available information regarding developing weather patterns. If the conditions are poor at a particular flight destination which had been scheduled for that day, a decision to delay or choose another "flyable" site can be made. Ships can avoid high ice concentrations and rough seas and the need for an icebreaker escort is minimized. Operational schedulers can find reasonable options to cope with poor weather conditions or take advantage of favorable conditions. The net result is overall levels of safety, productivity and efficiency of the program remains high despite the harsh environment.