Proceedings of the Fifth Symposium on Antarctic Logistics and Operations

San Carlos de Bariloche, Republica Argentina
8 to 10 June 1992

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

The Scientific Committee on Antarctic Research
at
XXII SCAR
San Carlos de Bariloche, Republica Argentina
8 - 19 June 1992

<u>ERRATA SHEET</u>

PROCEEDINGS OF THE FIFTH SYMPOSIUM ON ANTARCTIC LOGISTICS AND OPERATIONS

The name of the co-author, our Russian colleague Valery Klokov, was unwittingly omitted on page 207 of the Proceedings and it should read:

Development of a Wheeled Runway for McMurdo on the Ross Ice Shelf

by

George L. Blaisdell and Deborah Diemand, Cold Regions Research and Engineering Laboratory, Hanover, N. H. USA and
Valery Klokov, Arctic and Antarctic Research Institute, St. Petersburg, Russia

Cover picture: *Unloading the russian ship "Akademik Fedorov" outside Arctowski Station.*

Photo: Olle Melander.

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Introduction

by

Olle Melander
Swedish Antarctic Research Programme, Sweden

The **Fifth Symposium on Antarctic Logistics and Operations** was held 8th to 10th June 1992 in Hotel Edelweiß, San Carlos de Bariloche, Republica Argentina. The Symposium was conducted by the Standing Committee on Antarctic Logistics and Operations (SCALOP) of the Council of Managers of National Antarctic Programs (COMNAP). The Symposium was held in conjunction with the XXIInd meeting of the Scientific Committee on Antarctic Research (SCAR).

Since the start of SCAR in 1957 much attention has been given to logistics. An Antarctic Logistic Symposium was held as early as 1962, at the VIth SCAR-meeting in Boulder, USA.

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

In 1980 the need for more contact among Antarctic logisticians was once again noted and it was decided to hold a third Symposium in Leningrad in 1982.

The Council of Managers of National Antarctic Programs and its Standing Committee on Antarctic Logistics and Operations (SCALOP) were inaugurated in 1988. With the disbanding of the former Working Group on Logistics, the SCALOP terms of reference include: to serve SCAR by providing advice on Antarctic operations and Logistics; and to hold symposia and expositions to inform and review technological advances.

At the XXth SCAR-meeting in Hobart there was an excellent trade exhibition that presented new technology thad had actually been used in Antarctica. At this meeting the planning of the **Fourth Symposium on Antarctic Logistics and Operations** started with Dr Heinz Kohnen as chairman. The symposium was held 16th to 18th July 1990 in São Pãolo, Brazil in conjunction with the XXIth meeting of SCAR.

Over the years, symposia on Antarctic logistics have mainly been related to the questions of ships, stations and overland transportations, but with the start of the São Pãolo symposium a much greater emphasis has been put on special themes, with environmental questions taking precedence as main topics. Although the "old" issues are still relevant and are of great interest to all who work with the Antarctic, we are, infact fairly well aquainted with these issues. Our major needs are related to briefings in the new and more complex questions arising from new ATCM Recommendations or simply the new technologies being brought into use.

The importance of the symposium for the SCALOP and COMNAP assemblies has grown. During these symposia there is a possibility to present, and also to learn in great detail, complex matters that later, during the SCALOP-meeting, are presented for decisions. It would be almost impossible in a plenary meeting to put forward all relevant facts as presented in the symposia, therefore, in the future the choice of relevant topics for the symposia will be of the utmost importance.

The daily life of an Antarctic logistician is normally full of *practical* questions and *operational* measures, which gives him/her very little time for writing reports or presenting his/her experiences at a symposium. It is therefore very satisfying that 50 abstracts have been submitted to the symposium in Bariloche.

From these abstracts the Steering Committee had a hard but interesting task to select the papers most relevant for this year's themes. Some papers had to be excluded, not because of their merits but because that they did not fit into this symposium.

The Fifth Symposium had again a greater emphasis on environmental impact issues, with one day dealing with oil-spill fighting; a field in which a subgroup of SCALOP is working. Although there are a number of papers dealing with the more general issues, the Steering Committee has tried to select papers reflecting novelettes in the field of Antarctic operations. However, because of the large influx of papers a whole topic on building in Antarctica had to be dropped. The topic on the management of people, seems to be a promising field for future symposia.

The Steering Committee wish to thank all those who helped to make this symposium a success, the authors as well as the Argentine organizers.

Stockholm in September 1992

Dr Olle Melander
Chairman of the Steering Committee

The Steering Committee:
Mr Andres Bruno, Argentina
Mr Erick Chiang, USA
Dr Luis R. Fontana, Argentina
Dr Heinz Kohnen, Germany
Dr Olle Melander, Sweden
Mr Jack Sayers, Australia

Welcoming speech

by

L. R. Fontana

Direccion Nacional del Antartico, Argentina

It is a great pleasure for me as the President of the XXII SCAR Organizing Committee and Co-Chairman, to welcome all the participants to the SCALOP Fifth Symposium.

During the past two years we have been working jointly, in coordination and cooperation with the Chairman, Dr Olle Melander, in organizing this Symposium.

The number of papers presented here, reveal the high participants' interest, which encouraged us to make an effort to provide an adequate atmosphere in order to guarantee a normal and efficient development of the programmed activities.

We firmly believe and expect that in this sense, all the conditions are given and we hope that none of the participants representing the countries belonging to the Antarctic Community will be defrauded.

We put all the emphasis in order that the meeting is carried out within the frame of comfort as well as with all the necessary elements.

We would feel very happy if this Symposium produces positive results and that the expectation concerning the same justifies the detailed preparation work.

Finally, I would like to express once again to all and each of you the warmest welcome to Argentina, represented here by the San Carlos de Bariloche City, where our deliberations will take place, surrounded by the natural beaty of this privileged region - conjunction of lakes and mountains.

The best wishes for a happy stay, and please feel like at home.

A review of COMNAP/SCALOP Accomplishments

by

Carol A. Roberts

Division of Polar Programs, National Science Foundation, USA

Antarctic Operators formed the Council of Managers of National Antarctic Programs (COMNAP) and its subgroup SCALOP (Standing Committee on Antarctic Logistics and Operations) to share experiences and information, to realize international cooperation at the implementation level, to implement the Recommendations of the Antarctic Treaty, and to offer the benefits of Antarctic Operator experiences to the Treaty. COMNAP is affiliated with SCAR, which disbanded its former Working Group on Antarctic Logistics after SCALOP was established. COMNAP was granted observer status by the Treaty in 1991.

The Treaty Consultative Parties discussed measures to improve aviation safety in the Antarctic at a Meeting of Experts in 1989 in Paris, France, and subsequently adopted an extensive Recommendation, XV-20. COMNAP, through the SCALOP Subgroup on Antarctic Aviation Safety, responded to this recommendation by producing the Antarctic Flight Information Manual. The AFIM is a loose-leaf binder that is updated annually and includes information from all parties who conduct air operations in the antarctic.

In June, 1991, COMNAP sponsored a workshop in Bologna, Italy, to develop the first edition of the Practical Guidelines for Antarctic Environmental Assessment. These guidelines are in process of evolution as we gain experience in environmental assessment. They were updated in March, 1992, in response to the Protocol for Environmental Protection adopted by the Treaty in the Fall of 1991. They are envisioned as an aid to assist operators in complying with the Protocol.

Treaty Recommendation XV-5 called for a Group of Experts Meeting on Environmental Monitoring. The Treaty Parties at the XVI ATCM at Bonn, Germany, refocused on the need to implement Recommendation XV-5, and in particular, on the need to convene a meeting of experts under the terms of Recommendation XIV-24. SCAR and COMNAP were asked to participate, and together prepared a paper in May, 1992, called "Environmental Monitoring in Antarctica - A Discussion Document."

The SCAR-COMNAP paper was the first joint effort of these organizations, and was one of the key documents used by the Meeting of Experts on Environmental Monitoring, which met in Buenos Aires, Argentina, June 1-4, 1992. The Report of the Meeting of Experts to the Treaty reflected large portions of the SCAR-COMNAP report.

Members of COMNAP are already supporting environmental monitoring efforts, for purposes of both basic research and for measuring environmental impacts. In addition, COMNAP tasked SCALOP to develop forms that enable tracking of waste materials generated in the antarctic. SCALOP produced its waste management report in response to this tasking. The forms are evolving to fulfill the requirements of Annex III, "Waste Disposal and Waste Management," of the Protocol on Antarctic Environmental Protection.

A Subgroup on Oil Spill Prevention and Response was established by SCALOP in 1990. It has developed procedures/guidelines on oil spill contingency planning, fuel oil transfer at stations and bases, and design of fuel oil storage facilities for stations and bases; in addition, it has developed a series of recommendations on oil spill prevention and response which were considered and adopted by COMNAP. A number of technical papers on these topics are to be presented at this, the 5th SCALOP Symposium on Antarctic Logistics and Operations.

COMNAP is concerned about the Environment in Antarctica and the science being done there. The "Visitors Guide to the Antarctic" was produced in July, 1990, and translated into a number of languages for the benefit of tourists and adventurers. It is in airline safety card format, and is easy to read and understand. It provides handy tips to follow regarding care for the environment, litter and human impact, safety in Antarctica, and respecting science stations and programs.

COMNAP/SCALOP efforts to protect the Antarctic environment also include consideration of the use of alternative energy sources where feasible to replace diesel fuel-burning generators. SCALOP has formed a subgroup on alternative energies, and this topic will be discussed at the next symposium.

COMNAP submitted its first report to the XVI Antarctic Treaty Consultative meeting in Bonn, Germany, October, 1991, and this report was published as a part of the XVI Treaty Meeting Report. COMNAP/SCALOP is proud of its substantive support to the Treaty, and for the bilateral/multilateral cooperation among operators that it has fostered and encouraged.

Abandoned Stations and Field Huts
The British Approach to Management

by
J.R. Shears and J. Hall
British Antarctic Survey, UK

ABSTRACT

The recently agreed Protocol on Environmental Protection to the Antarctic Treaty (1991) requires abandoned research stations and work sites left in Antarctica to be cleaned up. However, this obligation does not require the removal of any structure designated as an Historic Monument (HM) under Recommendation I-IX of the Antarctic Treaty, or if the removal of any waste material is likely to cause a greater adverse impact than leaving that material untouched.

For the British Antarctic Survey (BAS) the clean-up of the abandoned British stations in Antarctica is a particularly complex and difficult task. The BAS, and its predecessor the Falklands Islands Dependencies Survey, has abandoned or left unoccupied eighteen stations and two field huts in Antarctica since 1947.

The approach adopted within BAS to the management of the abandoned British stations has been to develop a three phase programme of initial desk study and survey, action plan, and future building management.

An initial desk study of the abandoned bases was completed in 1990. This indicated the scale of the problem but did not provide sufficient information for detailed decision making. A field survey was therefore undertaken during the 1990/91 and 1991/92 seasons of all those abandoned bases which still remain accessible. An inspection checklist was developed to ensure that field personnel provided a standard set of data.

On the basis of the results of the field survey a comprehensive action plan is being developed. Options for each base are clean-up and removal, repair and maintenance as an emergency refuge, or restoration and conservation as an Historic Monument. At present, no former BAS or FIDS station has been declared an HM.

If bases are kept either as refuges or as HMs there will be a requirement for future building management. Under Recommendation I-IX an HM must be preserved and protected from damage. This is likely to require expert skills, such as those employed by the New Zealand Antarctic Heritage Trust to conserve Scott's and Shackleton's huts.

1. INTRODUCTION

1.1 Antarctic Treaty requirements for the clean-up of abandoned research stations in Antarctica

At the 15th Antarctic Treaty Consultative Meeting (ATCM), 1989, Recommendation XV-3 on waste disposal in the Antarctic was agreed. It includes a requirement that all operators carrying out activities in Antarctica must clean-up waste disposal sites and abandoned work sites to the maximum extent practicable.

The requirement to clean-up waste from past activities is further strengthened by the Protocol on Environmental Protection to the Antarctic Treaty (1991). Article 1 (5) of the Waste Disposal and Waste Management Annex of the Protocol calls for past and present waste disposal sites on land and abandoned work sites to be cleaned up by the generator of such wastes and the user of such sites. However, this obligation does not require the removal of any structure designated as an Historic Monument (HM) under Recommendation I-IX of the Antarctic Treaty, or if the removal of any waste material is likely to cause a greater adverse environmental impact than leaving that material untouched.

Recommendation I-IX on historic sites obliges Governments to adopt all adequate measures to protect historic buildings, sites or other artifacts of historical interest in Antarctica from damage and destruction. More recently, greater legal protection has been given to historic sites and monuments by the Area Protection and Management Annex of the Environmental Protocol. This allows specific areas in the Antarctic, including those surrounding historic sites, to be designated as Antarctic Specially Protected Areas (ASPAs) or as Antarctic Specially Managed Areas (ASMAs). Permits are required to enter ASPAs. Activities in either Areas can be prohibited, restricted or managed in accordance with specially adopted management plans.

1.2 The British Antarctic Survey (BAS) programme for the management of abandoned British bases in Antarctica

The BAS is fully committed to the implementation of the Environmental Protocol as quickly as possible. It is the policy of BAS that all waste disposal from British operations in Antarctica must be carried out in accordance with the Waste Disposal Annex. To ensure compliance, the BAS has begun to implement a comprehensive programme for the clean-up of the abandoned British bases.

The proper and safe disposal of the abandoned bases with the minimum of environmental impact is for the BAS a particularly complex and difficult task because of the long history and diversity of British operations in the Antarctic.

2. THE HISTORY OF THE ABANDONED BRITISH BASES

Bases have been abandoned in Antarctica since the beginning of human exploration of the continent. Apart from sealers refuges, perhaps the earliest remaining buildings are the two huts erected in 1899 by Borchgrevink's Southern Cross Expedition 1898-1900 at Cape Adare in the Ross Sea region of Antarctica.

The BAS, and its predecessor the Falklands Islands Dependencies Survey (FIDS), has abandoned or left unoccupied eighteen stations and two field huts in Antarctica (Table 1 and Figure 1). The first FIDS bases to be abandoned were in 1947 at Cape Geddes on Laurie Island, South Orkney Islands and on Winter Island, Antarctic Peninsula. The latest base to have been closed was Halley IV, Brunt Ice Shelf in February 1992.

Many of the old British bases were originally built as part of Operation Tabarin, which was a top-secret Royal Navy operation begun at the end of the Second World War. The British Government wanted information on German and other naval activities in the South Atlantic Ocean. The objective of Operation Tabarin was therefore to establish a string of small bases along the Antarctic Peninsula and nearby islands for reconnaissance and meteorology. The first stations, at Port Lockroy and Deception Island, were established at the beginning of 1944. In 1945, Operation Tabarin finished and the bases were handed over to the Falkland Islands Dependencies Survey (FIDS) and became scientific research stations. In 1962, the FIDS was renamed the British Antarctic Survey (BAS).

3. CURRENT MANAGEMENT STRATEGY

The approach adopted within BAS to the management of the abandoned stations has been to develop a three phase programme of initial desk study and surveys, action plan, and future building management.

3.1 Initial desk study and surveys

An initial desk study and inventory of the abandoned bases was carried out in 1990, as part of the first annual waste management plan for BAS operations in the Antarctic (Shears, 1990). The study and inventory revealed that, at that time, there were seventeen abandoned bases and two abandoned field huts. However, there was very little recent or accurate information on

Table 1. Abandoned and unoccupied British bases and field huts in the Antarctic Treaty Area.

BASE OR HUT	CONSTRUCTED	CLOSED	INSPECTION SURVEY	CLEAN-UP	COMMENTS
1) Cape Geddes (Base C) South Orkney Islands	1946	1947	23 JAN 1992	-	Occasionally used by other National operators as field refuge.
2) Admiralty Bay (Base G) King George Island	1947	1961	29 JAN 1992	-	Occasionally used by other National operators.
3) Deception Island (Base B) South Shetland Islands	1944	1969	28 JAN 1992	Clean-up by small field teams in 1990-91 and 1991-92 with removal of fuel, hazardous wastes and litter.	Occasionally used by BAS and other National operators. Frequent visits from tour ships.
4) Hope Bay (Base D) Trinity Peninsula	1945	1964 Summer only use till 1975 & field use at present.	18 JAN 1992	-	Occasionally used by BAS and other National operators as field refuge
5) View Point (Base V) Trinity Peninsula	1953	1963 Occasional summer use since.	18 JAN 1992	-	Frequently used by other National operators as field refuge, and occasionally by BAS.
6) Portal Point (Hut) Antarctic Peninsula			14 JAN 1992	-	
7) Danco Island (Base O) Antarctic Peninsula	1956	1959	14 JAN 1992	-	Occasionally used by other National operators as field refuge.
8) Port Lockroy (Base A) Antarctic Peninsula	1944	1962	06 JAN 1992	-	Frequently visited by tour ships and private yachts.
9) Anvers Island (Base N) Antarctic Peninsula	1955	1958 Reopened for summer use in 1968 until 1971.	04 MAR 1991 US NSF	Removal of the remains of the base except for the concrete foundations by US NSF clean-up team.	
10) Wordie House (Base F) Antarctic Peninsula	BGLE 1935 FIDS 1947	1954	Regular visits from BAS personnel working at Faraday Station.	Active programme of refurbishment and renovation being carried out.	Used and maintained by base members from Faraday station as field refuge. Possible future designation of base as a historic site.
11) Prospect Point (Base J) Antarctic Peninsula	1957	1959 Summer only use till 1961.	13 JAN 1992	-	
12) Detaille Island (Base W) Antarctic Peninsula	1956	1959	09 JAN 1992	-	
13) Orford Cliff (Hut) Antarctic Peninsula			09 JAN 1992	-	
14) Adelaide (Base T) Antarctic Peninsula	1961	1977	In 1984 ownership transferred to Chile (INACH)		Now operated by INACH (Chile) as summer only station and renamed Teniente Luis Carvajal .
15) Horseshoe Island (Base Y) Antarctic Peninsula	1955	1960	17 MAR 1992	Active programme of repair.	Used by BAS personnel on field trips from Rothera station, and by other National operators as a field refuge.
16) Stonington Island (Base E) Antarctic Peninsula	1946	1975	06 MAR 1992	Clean-up by small field team in 1991-92 with removal of fuel, hazardous wastes and empty drums.	
17) Halley Bay (Base IGY then Z) Brunt Ice Shelf	1956	1968	Lost to sea buried in an iceberg.		
18) Halley II (Base Z)	1968	1973	Lost to sea buried in an iceberg.		
19) Halley III (Base Z3)	1973	1984	JAN 1991	Clean-up by small field team in 1991 with removal of accessible hazardous wastes.	Base now formally closed as access is very dangerous because of crevasses.
20) Halley IV (Base Z4)	1984	1992	FEB 1992	Clean-up by small field team in 1991-92 with removal of hazardous waste, contents and surface facilities and fuel.	Plans for clean-up team to continue removal work during the 1992 93 season.

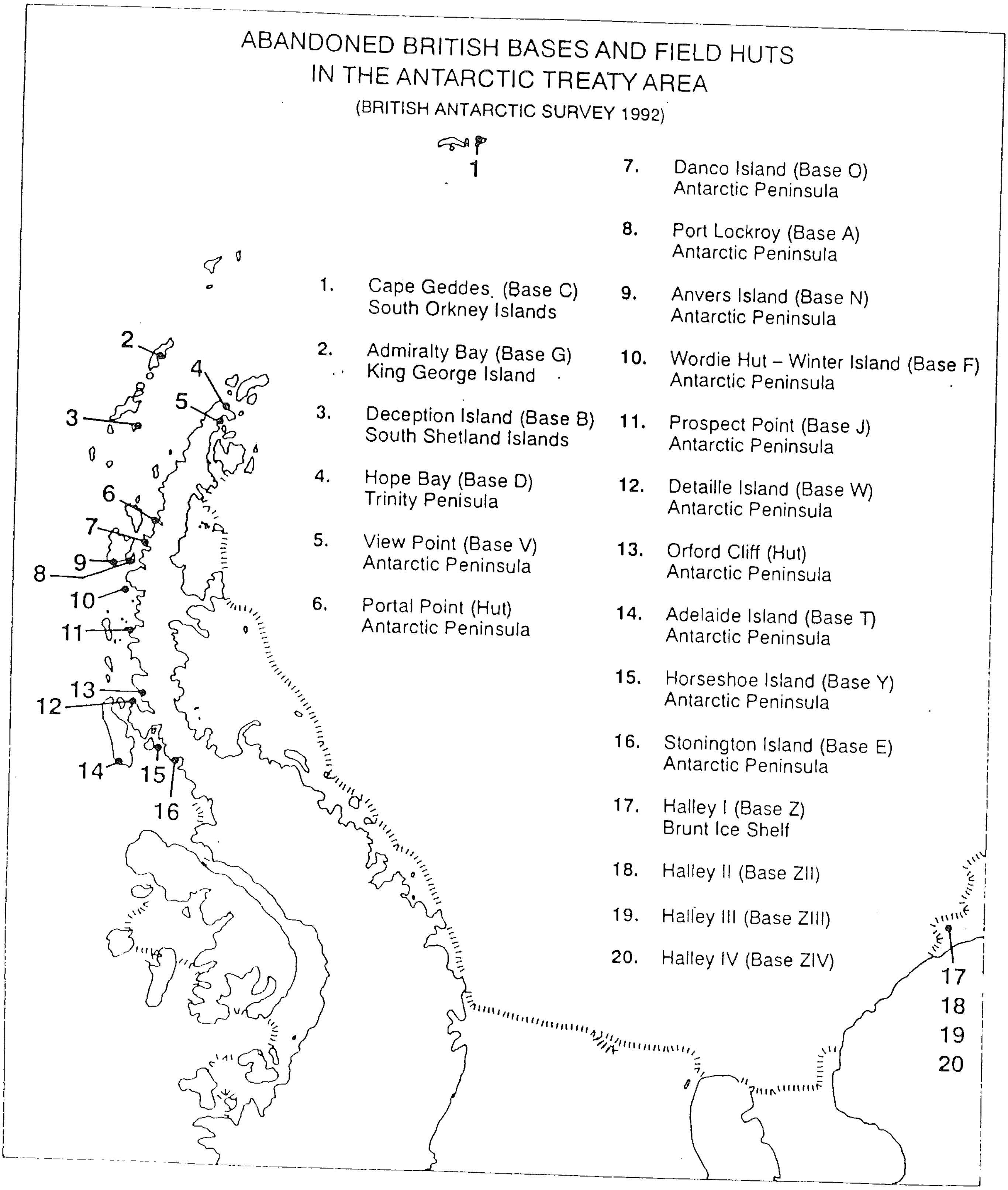

Figure 1. Abandoned British bases and field huts in the Antarctic Treaty Area.

the physical condition of many of the bases, or of the environmental hazards that they might present.

The desk study successfully indicated the scale of the problem but could not provide sufficient details for decision making. A thorough field survey was therefore undertaken by BAS during the 1990-91 and 1991-92 field seasons of all those sites which remain accessible. Some of the bases can no longer be reached. Halley Bay and Halley II, both originally located on the Brunt Ice Shelf, have been lost to sea buried in icebergs.

One British station has changed ownership. In 1977, the base on Adelaide Island, Antarctic Peninsula was closed and subsequently transferred, in 1984, to Chile who renamed it Teniente Luis Carvajal. Other bases, including Cape Geddes, Hope Bay and View Point, which are presently unoccupied by BAS have been used intermittently by other national operators and private expeditions.

A checklist was developed to help the field survey teams provide a standard set of data on each of the bases. It includes sections on general information, the site area, environmental hazards, the structural condition of buildings, building services, ancillary facilities and historic artifacts.

In the 1990-91 season, field surveys began with inspections of the old bases at Deception Island, Port Lockroy and Stonington Island. During the 1991-92 season, the remaining stations and field huts on the Antarctic Peninsula were inspected by a special two-man team using helicopter and small boat assistance from HMS Polar Circle.

The checklists from the inspection visits are still being collated and analysed, but preliminary analysis of the data has shown that many of the bases are either rapidly falling into disrepair or are already in a very dilapidated condition. Their poor state can be attributed to the ingress of snow and water caused partly by lack of maintenance, but also by vandalism. Nearly all of the bases have been looted. Only eight bases are now habitable and in a reasonable condition: Cape Geddes, Hope Bay, View Point, Danco Island, Wordie hut, Detaille Island, Horseshoe Island and Stonington Island. Several of these eight bases have been cleaned and repaired by visitors.

3.2 Action plan

After the production of the desk study, a clean-up action plan was established in 1990. The aim of the plan is to target as soon as practicable those abandoned bases where environmental hazards are known to exist. Small mobile clean-up teams (2 - 4 people) are put into selected bases and are tasked primarily with removing fuel, batteries and any other toxic or hazardous waste. Transport is on an opportunistic basis using the BAS resupply vessel, the RRS Bransfield, the new BAS research vessel, the RRS James Clark Ross or, on occasion vessels chartered or owned by other national operators.

The action plan has been a success, with the use of the mobile teams proving to be both an effective and flexible method of removing hazardous wastes. So far four bases have been targeted by BAS: Deception Island, Halley III, Halley IV and Stonington Island.

During 1990-91, a two-man team spent part of the season at Deception Island collecting a large quantity of fuel, hazardous waste and widely scattered rubbish. The station was the major FIDS air facility from 1959 until 1969 when the island erupted and volcanic mudflows destroyed most of the buildings. The clean-up team discovered that the station was now in a very poor condition. However, the old aircraft hangar was still standing and intact and was used to store collected waste. The clean-up continued during the 1991-92 season, when a four-man team, assisted by crew from the RRS James Clark Ross, removed all remaining fuel, batteries and hazardous wastes as well as the rubbish collected in the hangar (Plate 1). Waste was loaded directly from the beach in front of the base into empty shipping containers carried by the landing craft belonging to the RRS James Clark Ross. This allowed easy, rapid and secure extraction of the waste material. Approximately 90m^3 of material was removed.

Halley III, Brunt Ice Shelf was closed in 1984. At that time it was buried 16m below the snow surface and the pressure of the ice was crushing the station. In January 1991, the base was visited by a three-man team and those hazardous wastes which could be safely removed were taken away. Access to Halley III is now very dangerous, as the surrounding ice is badly crevassed, and the base has been formally made out of bounds.

At the end of February 1992, Halley IV, Brunt Ice Shelf was closed. As with Halley III, the base was buried under 15m of ice and the pressure was crushing the station. A three-man team went in before closure to make a detailed survey and inventory of the station, and to prepare a removal plan. The team, along with the remaining base personnel, also completed the first stage of the station clean-up and removed approximately 120m^3 of waste material. In total, 85% of the contents of the base and 95% of all hazardous wastes were removed.

Also during the 1991-92 season, a visit was made to the British base on Stonington Island by a two-man team. They were taken into the site by the vessel, MV Erebus, which

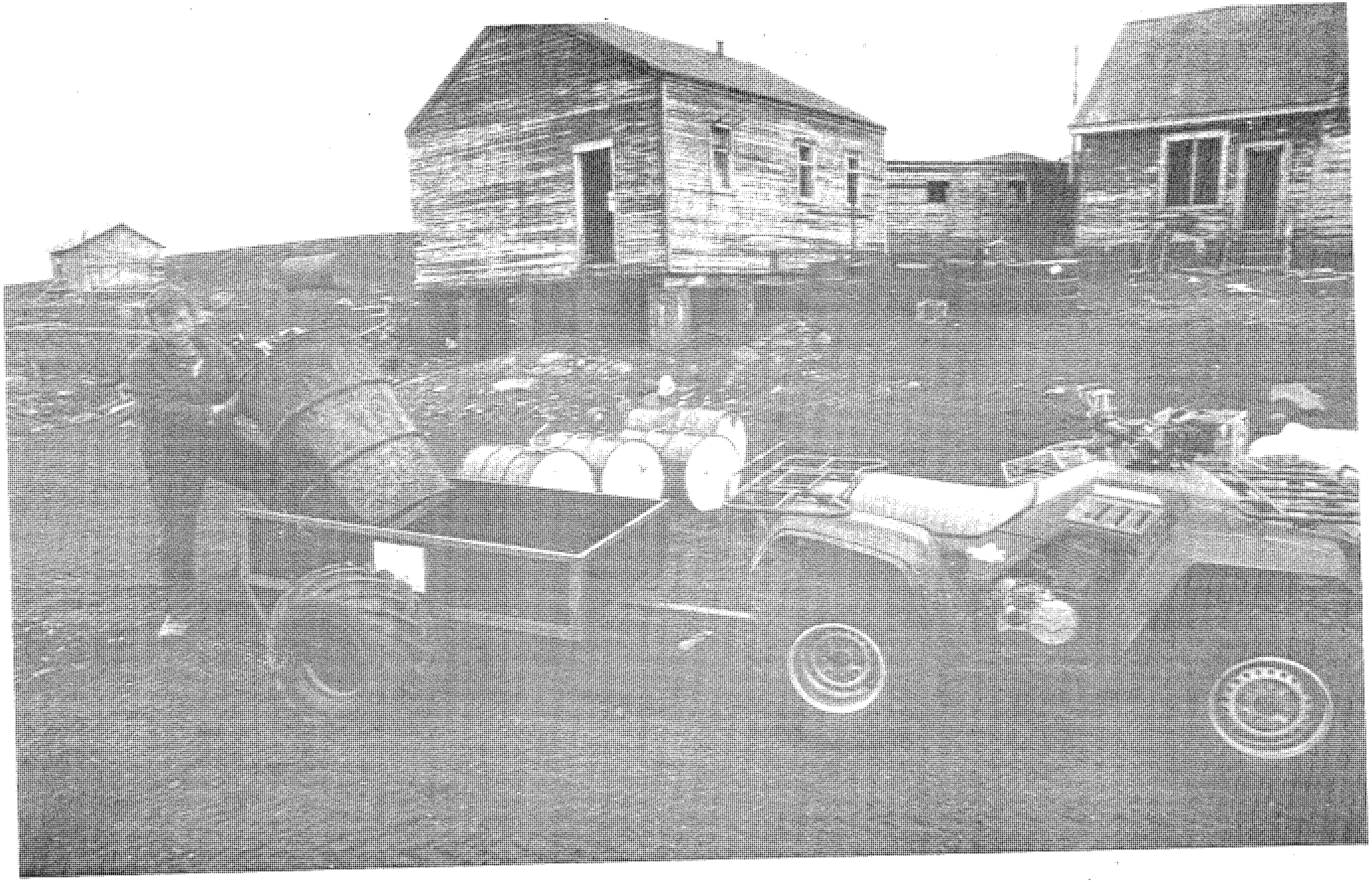

PLATE 1.

Clean up using all terrain vehicle and trailer at Deception Island 1992.

had been chartered by the US National Science Foundation (NSF) for a clean-up of the old US East Base. The British team removed approximately 20m^3 of waste from Stonington, including all remaining surplus fuel, batteries and hazardous materials. They also helped in the clean-up by NSF of the nearby US East Base.

NSF helped the BAS during the 1990-91 season by removing the remains of the British base on Anvers Island during the clean-up of the adjacent US Old Palmer station. The British base was burnt down by accident in 1971. Wastes removed included the remains of the base diesel generator and batteries. Only the concrete foundations of the British base now remain.

During the 1992-93 season further action to clean-up the abandoned stations will be taken. A second team is to visit Halley IV to complete the clean-up before the station becomes too dangerous to enter and is sealed. Depending on sea-ice conditions and ship time, the RRS Bransfield may visit Port Lockroy and begin the removal of remaining fuel, hazardous material and scrap metal.

So far the action plan has concentrated on the removal of hazardous wastes, fuel and litter at targeted bases. This programme will continue to ensure that hazardous wastes are removed from the Antarctic environment. Not all of the bases have been visited as yet by clean-up teams, and no attempt has been to remove buildings or heavy machinery from any of the sites. Other national operators have introduced similar clean-up programmes. For example, the Australian National Antarctic Research Expedition (ANARE) is removing 'environmentally damaging materials' from the old Wilkes station, near Casey station, Wilkes Land (Betts, 1990).

The next stage of the BAS action plan is to prepare short feasibility studies to map out the long-term future of each of the abandoned bases. Each study, using data from the inspection survey, will assess the scientific, cultural and archaeological value of the site, risks that the base might pose to human health and safety, as well as any environmental impact. On the basis of the evidence presented in the feasibility study an objective and rational decision can be made as to whether the base should be cleaned-up and removed, repaired and maintained as an emergency refuge or, protected and conserved as an Historic Monument (HM).

3.3 Future building management

If abandoned bases are to be kept as refuges or as HMs there will be a requirement for future building management.

At present, only refuges essential to the BAS operations are repaired. Repairs are carried out on ad hoc basis, with only essential and necessary renovation being carried out. However, a rolling maintenance programme is being carried out at Horseshoe Island, Antarctic Peninsula as it is frequently used by BAS personnel on field trips from Rothera station.

No former BAS or FIDS station has been declared an HM. Although, a potential candidate for designation is Wordie House, Winter Island, Antarctic Peninsula. This base is of considerable historical interest as it was established in 1947 on the site of the 1935-37 British Graham Land Expedition hut. It is used today by personnel from the nearby BAS research station at Faraday as a shelter during recreational trips. The hut is undergoing a very active programme of refurbishment and restoration. The intention is to fully restore the building to a state approaching its original condition, complete with period fixtures and fittings.

If any of the old British bases were to be designated as Historic Monuments under the Antarctic Treaty, BAS will be under a legal obligation to ensure that they are kept in good repair. This will require the expert advice of archaeologists and conservation professionals. For example, the New Zealand Antarctic Programme and the New Zealand Antarctic Heritage Trust now routinely use archaeologists and other museum specialists in the restoration, protection and curation of the huts built by Scott and Shackleton at Hut Point, Cape Evans and Cape Royds in the Ross Sea region of Antarctica (Ritchie, 1990).

4. MANAGEMENT ISSUES

In recent years there has been considerable controversy between scientists and environmentalists as to the extent of human impact in the Antarctic (Laws, 1991). As part of this general debate, some environmentalists have argued that the abandoned bases have caused environmental damage, pose a real hazard to the Antarctic environment and should be dismantled and removed. There is growing pressure on national operators to clean-up rapidly their past activities. The BAS believes that there is a case for removing as quickly as possible toxic and hazardous waste, but that the dismantling and demolition of buildings raises complex management issues which require careful and considered attention. Issues of concern to BAS are: ownership and custody of the abandoned bases, increasing numbers of tourist visits, the removal of building materials which are highly hazardous to human health, and the impact of clean-up on sites of scientific importance.

4.1 Ownership and custody of the abandoned bases

In some cases it is unclear exactly who owns or is responsible for an abandoned base. For example, at the old British base on Deception Island there are buildings built by BAS and FIDS, a hut constructed by the Falkland Islands and Dependencies Aerial Survey Expedition (FIDASE) and a derelict Norwegian whaling station parts of which were used by BAS, FIDS and FIDASE. Is it the responsibility of BAS to clear the complete site or just those buildings originally built by BAS and FIDS? Questions of ownership cannot be answered by national operators and will require discussions at a higher political level between Antarctic Treaty Governments.

Six of the abandoned British bases are now occasionally used by other national operators as field refuges. For example, Cape Geddes, abandoned in 1947 by the FIDS, is now used regularly as a bird observatory by Argentine scientists working from Observatorio Naval Orcados. The BAS would not want to remove buildings or facilities which are of value to other national operators and wishes to consult widely with those who are, or might be interested in, using the abandoned British bases.

4.2 Increasing numbers of tourist visits to the abandoned bases

Antarctica is rapidly becoming a significant tourist destination. Numbers have increased dramatically from 782 tourists in 1985-86 to 4842 in 1990-91, an increase of over 600% (Enzenbacher, 1992). There are now more tourists visiting Antarctica than the combined numbers of scientists and support personnel from all national Antarctic programmes. The most frequently visited area of Antarctica by tourists is the Antarctic Peninsula and stops at the abandoned British bases often feature on tour ship itineraries.

The US NSF has compiled statistics on the number of tourists landed by US tour operators at sites in the Antarctic Peninsula during the 1989-90 and 1990-91 summer seasons (Antarctic Treaty, 1991). The site visited by the greatest number of tourists during both seasons was Whalers Bay, Deception Island where an abandoned BAS base is located. During the 1989-90 season 1682 tourists visited the site, whilst in the 1990-91 season the total was 1496. Table 2. shows the number of tour ship visits by US tour operators and total passengers landed at abandoned British bases during the 1989-90 and 1990-91 seasons.

Visits to the abandoned bases are obviously an important and popular part of many tour ship cruises in the Antarctic. However, neither the tour companies nor the tourists themselves contribute to the upkeep of the sites. Should the tour operators, as the major user of several of the abandoned bases, be asked to help with the repair and conservation of the buildings?

Table 2. Number of tour ship visits and passengers landed at abandoned British bases during the 1989-90 and 1990-91 summer seasons

SITE	1990 Ship visits	Pax landed	1991 Ship visits	Pax landed
Whalers Bay, Deception	17	1682	13	1496
Hope Bay, (Esperanza)	1	145	3	1130
Port Lockroy	7	796	7	1067
Detaille Is	1	94	2	195
Ferraz, (Admiralty Bay)	3	305	1	95
Portal Point	-	-	1	93
Stonington Is	1	97	-	-

Source: Antarctic Treaty (1991)

4.3 The removal of building materials which are a risk to human health

It is the BAS policy that wastes will remain on site if their removal may pose a risk to human health and safety. Of particular concern is the removal of toxic building materials, particularly asbestos which was used in many of the bases as an insulation material in boilers or to lag pipes. Long-term exposure to asbestos dust may cause asbestosis and increased risk of lung cancer.

In Britain, the removal and disposal of asbestos is strictly controlled. Licensed contractors must be used for removal work, the use of dusk masks for personnel is mandatory and fibre concentrations must be monitored in the air before and after work is completed. The BAS, therefore, will have to employ specialist contractors if asbestos is to be removed from the abandoned bases. Special arrangements will also be required for the safe storage, treatment and disposal of the waste.

Problems with the disposal of asbestos have already been experienced in Antarctica. In 1991, asbestos was discovered in the Fortress Rock landfill site at McMurdo Station, Antarctica. The landfill was immediately closed and is being stabilised. The US NSF is not removing the asbestos as this may be more hazardous than leaving the material in situ (Joyce, 1991).

4.4 Impact of clean-up on sites of scientific importance

In some cases the removal of abandoned buildings and facilities may severely damage sites of scientific importance. For example, Deception Island is a classic example of a volcanic caldera. The British and Chilean bases on the island were abandoned after being destroyed by volcanic mudflows in 1969. Geologists have identified the remains of these buildings as being an unique example of the power of volcanic eruptions, and have argued that they should be retained and protected (Thomson, pers. comm., 1991).

The dismantling of abandoned bases may also have environmental effects, particularly by disturbing nesting birds which are now recolonising the sites. At Port Lockroy, Gentoo penguins now nest immediately adjacent to, and even under, the old base buildings and by empty fuel drums (Plate 2). To minimise any environmental impact, any clean-up should be carried outside the breeding season.

5. CONCLUSION

The Waste Disposal Annex of the Protocol on Environmental protection to the Antarctic Treaty (1991) contains tough measures to ensure that abandoned bases and work sites are cleaned up. For the BAS this is a particularly difficult task because of the long history, great diversity and large geographical spread of British operations in the Antarctic. The BAS, and its predecessor the FIDS, has abandoned or left unoccupied eighteen bases and two field huts in Antarctica since 1947.

To ensure compliance with the Protocol, the BAS has undertaken inspection surveys of all those abandoned British bases which remain accessible, and has targeted selected bases in order to remove hazardous waste, fuel and litter. The BAS considers that any clean-up should be practical and pragmatic and should be carefully phased so as not to disrupt scientific programmes. As yet, no dismantling or demolition of buildings or facilities has been carried out.

The BAS wishes to consult widely with other national operators to discover those who are interested in using

PLATE 2.

Colonisation by Gentoo Penguins around the abandoned Station at Port Lockroy 1992.

and taking on abandoned British bases. At present, the BAS is carrying out a feasibility study for each base and examining the options for clean-up and removal, repair and maintenance as an emergency refuge or, conservation and restoration as an Historic Monument.

The BAS is faced with a dilemma as it's role is to carry out scientific research in Antarctica not the protection and conservation of historic sites or the clean-up of long-abandoned bases and field huts. However, to simply leave the sites to slowly disintegrate is not an option since the clean-up of abandoned sites is mandatory under the Waste Disposal Annex. A comprehensive removal programme will be very expensive. It will need considerable forward planning and take several years of steady work. The cost involved will run into millions of pounds if charter ships are engaged.

Given the present resource levels within the BAS, it would be impossible to pay for the removal, repair or conservation of the abandoned bases without significant cuts in important scientific programmes designed to address problems of global relevance. The BAS has therefore asked the British Government for additional funding to enable the large scale clean-up of the abandoned bases to begin.

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Environmental Impact Assessment in Antarctica

by
David Lyons
Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Australia

ABSTRACT

The background to the development and implementation of environmental impact evaluation procedures in Antarctica is reviewed, and the principles and procedures of the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) are outlined. The difficulties in determining the appropriate level of assessment and the practical, operational aspects of carrying out the evaluations are examined. Particular attention is given to: the meaning of terminology in the Protocol; the interpretation of environmental principles and standards; alternatives to the proposed activity; the requirements for sufficiency of information for the purpose of prior assessment; the process of obtaining and taking into account public comment; the monitoring of environmental indicators; and the practical implications where an activity needs to be suspended, cancelled or modified. The bureaucratic and other workload generated by the procedures and the credibility of the processes are discussed, given a possible perception that the exercises may be more 'red tape' to justify decisions which would be taken in any case. Environmental impact assessments for Antarctic projects conducted prior to the adoption of the Madrid Protocol, and a number of environmental impact evaluations of projects undertaken since, including the 'Removal of Old Casey Station' and the 'Re-introduction of Hydroponics to ANARE Stations' carried out by the Institute of Antarctic and Southern Ocean Studies, are used as examples.

INTRODUCTION

The provisions of the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) relating to environmental impact assessment (EIA) derive from principles which have developed within the Antarctic Treaty System over the past two decades.

The Protocol was negotiated over a relatively short period with considerable impetus from politicians. The push to 'save' Antarctica and to satisfy domestic and international political objectives drove the negotiations along with almost indecent haste by Antarctic Treaty System standards. Compared to the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) which took twelve sessions over six years plus numerous informal consultations and exchanges of draft proposals, the Madrid Protocol was negotiated and agreed in four sessions over one year, in a burst of diplomatic activity commencing on 19 November 1990 in Viña del Mar, Chile and concluding in Madrid on 4 October 1991. The overturning of CRAMRA and the negotiation of a conditional prohibition on mineral resource activities (Madrid Protocol - Article 8) in such a short a time involved many trade-offs and compromises. To facilitate the required consensus between the Antarctic Treaty Consultative Parties, the text is sometimes deliberately ambiguous and contains provisions which on their own, out of the negotiating context, appear unnecessary. Furthermore, the Madrid Protocol deals with the complex area of environmental standards and the issue of what is 'acceptable' impact on the Antarctic environment.

The Protocol was adopted and opened for signature on 4 October 1991. Twenty three of the Consultative Parties signed on the same day. The three other Consultative Parties have indicated their intention to sign. In accordance with Article 23, it will enter in to force following the deposit of instruments of ratification, acceptance, approval or accession by all twenty six states which were Antarctic Treaty Consultative Parties at the date of adoption. This requires a variety of actions by different states and could take considerable time. In the meantime, the Parties who have signed the Protocol are in the process of implementing it.

The operational staff, planners and scientists of the various Antarctic nations, who were perhaps not consulted closely in the negotiation of the terms of the Protocol, are now left to interpret in practical terms the 'legalese' and statements of principle; and to realistically incorporate the Protocol's intent, procedures and requirements into their decision making processes and day-to-day operations. The Australian Antarctic Division, probably in common with other national operators, has set up a group of staff to coordinate the implementation of the obligations in the Protocol in a 'prompt and comprehensive manner.'

The Institute of Antarctic and Southern Ocean Studies has conducted IEE work for the Australian Antarctic Division on the 'Removal of Old Casey Station' and the 'Reintroduction of Hydroponics into ANARE Stations' - summaries and comments on these IEEs are given in the Appendix. The main reason for requesting IASOS graduate students to conduct these projects was to assist the University with practical student projects. As well as this, the independence of IASOS was seen as valuable to the credibility of the exercises.

BACKGROUND TO EIA IN ANTARCTICA

The 'Code of Conduct for Antarctic Expeditions and Station Operations', adopted at the VIIIth Antarctic Treaty Consultative Meeting (ATCM) in 1975, includes an environmental impact assessment provision:

> To the greatest extent feasible ... In the planning of major operations in the Antarctic Treaty Area an evaluation of the environmental impact of the proposed activity should be carried out by the Antarctic operating agencies concerned. (Recommendation VIII-11, Annex (4)(a))

At the following three Antarctic Treaty Consultative Meetings, the Treaty Parties reaffirmed their commitment to environmental protection, and dealt with various items under the heading of 'Man's impact on the Antarctic environment'.

At the XIIth Meeting in 1983, the Representatives recommended to their Governments that:

> they urge their respective national organisations to scrutinize the plans for (such) research and logistic activities, in accordance with procedures they have developed or may develop, to determine whether the planned activities are likely to have significant impacts; (Recommendation XII-3(1))

At this meeting also, the question of elaborating environmental assessment procedures was referred to the Scientific Committee on Antarctic Research (SCAR), and the response, in the form of a SCAR report by Benninghoff and Bonner was published in 1985. Importantly, the authors noted that, in accordance with their brief, the 'report attempts to provide a rationale and general procedure for evaluating Man's impact on the Antarctic environment' from 'scientific exploration and research, and related logistic support activities' and not from 'commercially-oriented' or 'non-scientific developments' (Benninghoff & Bonner 1985, p4).

In 1987, at the XIVth Meeting, a specific recommendation on Environmental Impact Assessment based on the SCAR report and on the United Nations Environment Program (UNEP) 'Goals and Principles on Environmental Impact Assessment' was adopted:

> In the planning process leading to decisions about scientific research programmes and their associated logistic support facilities, their national Antarctic organizations responsible for Antarctic activities evaluate the environmental impact of such activities in accordance with (the) procedural guidelines (Recommendation XIV-2(1))

The guidelines annexed to Recommendation XIV-2 introduced to the environmental impact assessment process in the Antarctic, the concept of an Initial Environmental Evaluation (IEE) 'to determine whether the activity might reasonably be expected to have a significant impact'. Proposed activities 'likely to have no more than a minor or transitory effect on the environment' could proceed. For activities beyond this level of likely impact, guidelines were set down for the preparation of Comprehensive Environmental Evaluations (CEE).

At the XIVth Consultative Meeting in 1987, the problem of interpreting the word 'significant' and the question of how to decide whether to proceed from an IEE to a CEE were discussed, and:

> It was suggested that, as a matter of national practice, criteria should be developed to be used in determining whether proposed activities would have a significant impact on the Antarctic environment. (XIVth ATCM, Para 70)

In parallel with the regular Consultative Meetings, sessions of the IVth Special Antarctic Treaty Consultative Meeting on Antarctic Mineral Resources were held from 1982 to 1988. Environmental issues were key elements of discussion and negotiation at these sessions. The Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA), which was adopted at the final session:

> constitutes a mechanism for assessing the possible impact on the environment of Antarctic mineral resource activities, determining whether they are acceptable and, if so regulating them in detail (Beeby 1990, p49)

CRAMRA broke new ground for the Treaty Parties in elaborating environmental standards, dealing with measures for the protection of the environment and specifically acknowledging the environmental implications of activities in the Antarctic on dependent and associated ecosystems and the global environment. CRAMRA Article 2 - Objectives and General Principles, states:

> the Parties acknowledge the special responsibility of the Antarctic Treaty Consultative Parties for the protection of the environment and the need to:
>
> (a) protect the Antarctic Environment and dependent and associated ecosystems;
>
> (b) respect Antarctica's significance for, and influence on, the global environment;

During the negotiations and following the adoption of CRAMRA, mining industry interests regarded the approval procedure for minerals activity, including environmental assessment, as very complex and stringent. For example, the American Mining Congress described CRAMRA as follows:

> the most rigorous approach to environmental protection of any area in the world.
>
> The commission established to oversee the operation of CRAMRA will spawn a huge and unmanageable bureaucracy.
>
> CRAMRA falls far short of establishing a workable framework for hard mineral exploration and development in Antarctica. Explorers for hard minerals face too much uncertainty and too much red tape under its terms. (Knoblock 1990, pp 3,4,14)

CRAMRA was unanimously adopted, but later set aside after France and Australia declined to sign the Convention in favour of an initiative to establish Antarctica as a 'Nature Reserve-Land of Science'.

The XVth ATCM's principal work was the consideration of various proposals for a comprehensive system for the protection of the Antarctic environment and dependent and associated ecosystems. Recommendation XV-1 was adopted, which initiated the XI Special Antarctic Treaty Consultative Meeting to work towards the elaboration of such a comprehensive system. Discussion also took place on the implementation of environmental impact assessment procedures and there was debate over the usefulness of lists and criteria in aiding decisions.

The XVth ATCM was also informed of the approach of the Council of Managers of National Antarctic Programs (COMNAP) on impact assessment. COMNAP has held various workshops and meetings on the Antarctic environmental assessment process, and has recently produced a set of practical guidelines for those who prepare the assessment documents. These guidelines, revised in March 1992, provide advice on the types of information which should be gathered and analysed, and are intended to provide a measure of comparability between operators. The guidelines provide explanatory notes and elaborate on the list of requirements in the EIA Annex I of the Protocol, and presumably will continue to be refined.

THE MADRID PROTOCOL

The XIth Special Antarctic Treaty Consultative Meeting, convened in accordance with recommendation XV-1, adopted the Protocol on Environmental Protection to the Antarctic Treaty on 4 October 1991.

The Madrid Protocol covers not only 'scientific research programmes and their associated logistic support facilities', as did the SCAR report by Benninghoff and Bonner and previous Recommendations, but 'all activities in the Antarctic Treaty area' (Article 8(2)).

The Protocol is an amalgamation of the various environmental recommendations of the ATCPs, the Agreed Measures for the Conservation of Antarctic Flora and Fauna, and concepts developed under the Treaty framework, for instance concepts and wording adapted from CRAMRA. It incorporates a conditional prohibition on mineral resources activities (Article 7) and a ban on dogs (Annex II - Article 4(2)), and establishes a Committee for Environmental Protection (Articles 11&12) with an advisory role. The EIA procedures are more elaborate than previously required for Antarctic projects.

At the working level in the national Antarctic programs, long accustomed to 'doing their own thing', the words 'bureaucracy' and 'red tape', as used by the mining interests to describe CRAMRA, probably also resound, at least privately, when the Madrid Protocol is mentioned.

The procedures in Annex I of the Protocol further develop the guidelines for EIAs set out in Recommendation XIV-2 and are represented schematically in Figure 1. The procedures involve a Preliminary Assessment, Initial Environmental Evaluation and a Comprehensive Environmental Evaluation. Both the IEE and CEE are more substantial by definition than the IEE and CEE described in Rec XIV-2.

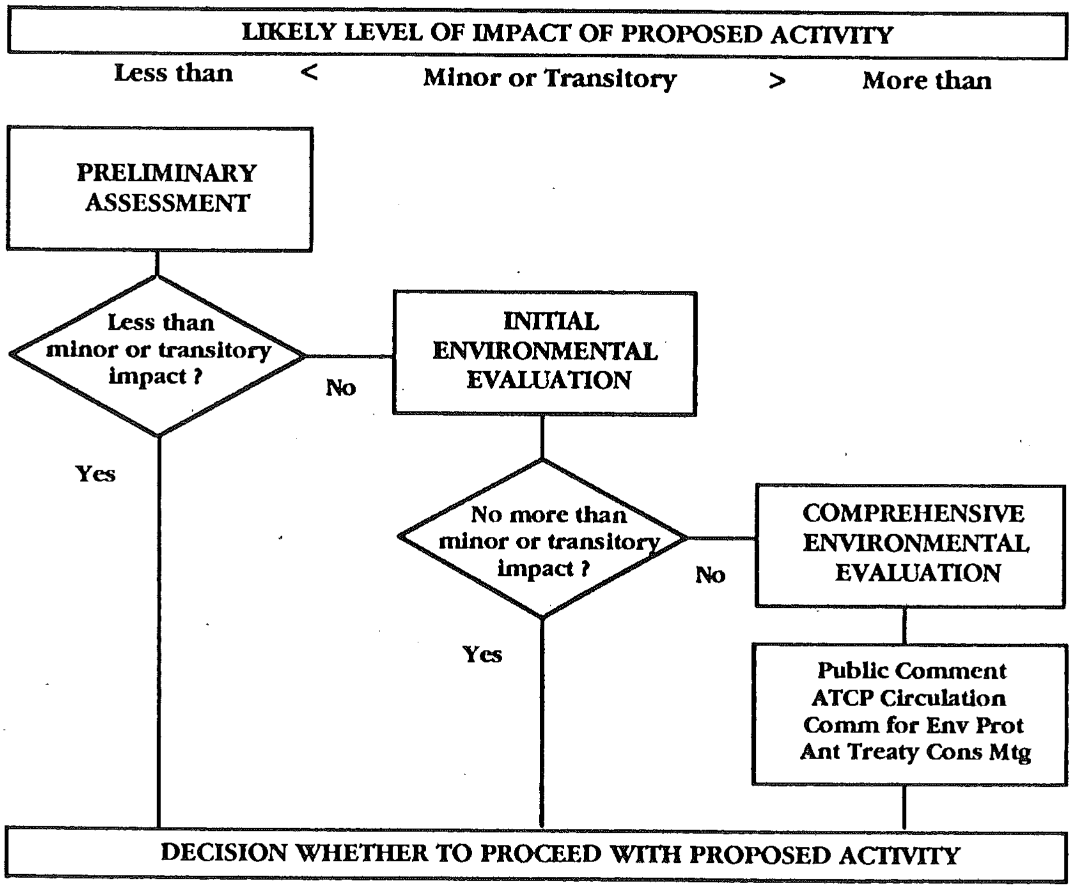

FIGURE 1: EIA PROCEDURES - MADRID PROTOCOL

IMPLEMENTATION OF THE EIA PROVISIONS OF THE MADRID PROTOCOL

The Madrid Protocol, as part of the Antarctic Treaty System, is not static and can evolve in response to experience in its operation and to changing knowledge and circumstances. In accordance with Article 25, the Protocol can be modified or amended through the normal procedure set down in the Antarctic Treaty, i.e. through the adoption and ratification of recommendations by the ATCPs at one of their meetings. The following discussion is intended for consideration as an initial reaction to the operation of the EIA procedures of the Protocol.

The language, principles and structure of the Madrid Protocol are typical of EIA procedures generally and it suffers from the same type of shortcomings. Firstly, there is really no alternative, in a document covering such a broad range of possible activities and impacts over such a huge area, to using general terminology on environmental standards, such as 'significant adverse effects', 'significant changes', 'detrimental changes', 'further jeopardy to' and 'degradation of or substantial risk to'. The dilemma for the analyst and decision maker is what do these terms mean for each form of environmental hazard, or that is to say, how to judge what is an 'acceptable' level of impact or damage to the environment in the specific circumstances. Secondly, there is the difficulty of obtaining an objective outcome given the vested interest of the proponent in having the proposed activity proceed.

What activities are subject to EIA and at what level?

Article 8(2) of the Protocol states that:

> Each Party shall ensure that the assessment procedures set out in Annex I are applied in the planning processes leading to decisions about any activities undertaken in the Antarctic Treaty area pursuant to scientific research programmes, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required under Article VII (5) of the Antarctic Treaty, including associated logistic support activities.

Article VII(5) of the Antarctic Treaty is the provision requiring advance notice to other Contracting Parties of major activities - known as the Antarctic Treaty Exchange Information.

The Protocol approach, which ties the application of EIA procedures to activities requiring prior notification under the Antarctic Treaty, was reportedly used to avoid EIA requirements extending to the activities of individuals (Scully 1991, p84). Its practical effect, however, is to leave the decision on whether any form of EIA is conducted in the hands of the national operators. Anyone who has looked at Treaty Exchange Information will be aware that, in the absence of standard formats and guidelines for the type of information to be provided, there is a wide disparity in the level of detail provided. The activities notified are entirely at the discretion of the national operators and depend on their policies and approach to the task of compiling the information.

Clearly, major undertakings such as the establishment of a stations, are covered by this definition of activity, and require CEEs. But, the linkage to the Treaty Exchange Information does not really help a great deal in deciding, at the lower levels, whether activities require a Preliminary Assessment or an Initial Environmental Evaluation.

Defining activities subject to EIA procedures in terms of the level of detail required in the Treaty Exchange Information, while it has a certain legalistic neatness, is not very practical. Those nations who interpret the information requirement in one way and provide brief information on their activities will be able to do relatively little in order to technically meet the EIA provisions of the Protocol, while those nations who provide, as say Australia does, exchange information on individual scientific projects and operational activities such as field programs, might easily be overwhelmed with paperwork.

Next, the activity is subject to preliminary assessment 'in accordance with appropriate national procedures' and if 'an activity is determined as having less than a minor or transitory impact, the activity may proceed forthwith' (Protocol Annex I - Article 1). This is rather soft, and in practice, leaves the initial decision of whether to 'proceed forthwith' or to go on to and IEE or a CEE, in the hands of the national Antarctic operator. It's hard to imagine that the signing of the Protocol was celebrated by most governments with a boost in the allocation of resources to Antarctic operators. In fact, it was probably announced with a direction to absorb the extra work within current budgets, while still producing the same or more scientific and operational output. So the operator, probably with no additional resources to do the work and a solid tradition of 'proceeding forthwith' will be sorely tempted to do just that, with a preliminary assessment form safely lodged on the file to satisfy the system. The same sort of difficulty arises in the decision whether to proceed from an IEE to a CEE.

The Concise Oxford Dictionary defines:

> *minor* as: 'comparatively unimportant', and
> *transitory* as: 'not permanent, lasting only a short time'.

It is difficult to clearly understand the meaning of 'less than minor or transitory', and more particularly the distinction between 'less than minor or transitory' - where a Preliminary Assessment is required - and 'no more than minor or transitory' - where an Initial Environmental Evaluation is required.

The preliminary assessment process should get people to consider the potential environmental consequences before acting, without creating unnecessary paperwork and the need for formal approvals for every little activity. More environmental training to increase the knowledge and awareness of staff and expeditioners involved in planning and executing activities would allow appropriate decision making to be left with the people on the spot. However, this is not a particularly fashionable approach in government circles. For example, the Preliminary Assessment form being used by the Australian Antarctic Division has to be filled in by the proponent and approved by up to six people: Supervisor; Station Environment Officer; Station Leader; Station Operation Manager; Antarctic Division Environment Officer and Branch Head.

The issue of having agreed criteria or guidelines for determining when a PA, an IEE or a CEE is required has been discussed by the Treaty Parties and clearly needs substantial work, probably through a bodies such as SCAR and COMNAP. Implementation of such criteria will make it possible for the intent of the Protocol to be carried out in practice and for a consistency in approach to environmental impact assessment to be achieved between different activities.

Who should do the evaluation?

Benninghoff and Bonner (1985, p32) were of the view that the 'evaluation should preferably be made by an independent reviewer or advisory panel'. This was never accepted by the Treaty Parties. Considering that the Protocol now covers all activities, not just science related activities, the need for independent evaluation is even more desirable.

For reasons related partly to the territorial sovereignty issue and to the balance of power in the Treaty System, the ATCPs have not been keen to assign too much real power to any multi-member body or appointed expert over national activities. (The institutional framework for CRAMRA was a breakthrough in this respect, with substantial power in the Commission and the Regulatory Committees). For EIAs, the practice adopted has been for 'respective national Antarctic organisations responsible for Antarctic activities' (Rec XIV-2) to evaluate environmental impacts and for the decision to be left to national governments. This situation continues to prevail under the Madrid Protocol, where the Committee for Environmental Protection is rather a 'toothless tiger', with an advisory role only.

This position with EIAs in Antarctica is not unusual for national governments who routinely conduct EIAs on their own projects and also make the decisions. This is the case in Australia with EIAs conducted under federal and state legislation, although special government agencies, rather than the proponents are instrumental in the decision making process.

The public credibility of the exercise is at stake if it is entirely a process internal to the group proposing the activity, and there is no, or only token, external, impartial input. This problem is exacerbated by the fact that Antarctica is to somewhat of a 'closed shop'. There is often only an individual or at most a few scientists and operations people who could be considered expert in a particular geographic or discipline area and they are often the same people who are involved in the proposals. These people also generally work directly for the national Antarctic operator or are beholden to the operator for future logistical support or technical contracts, so it is not possible for them to be seen to be impartial.

The tendency to use checklist type forms is also of concern, as it can oversimplify and 'bureaucratise' the process. Bureaucratic organisations are often process rather than outcome oriented, i.e. going through the steps can be seen as an end in itself. The checklist approach fits the bureaucratic requirements nicely. Fill in a few forms, generate vast amounts of paperwork, circulate copies to all and sundry, file the lot and everyone is happy. At least the logic of the decision and the actual decision maker are well and truly lost from view. Neat forms on files can also give a false sense of confidence about the validity of the outcome.

A standardised approach may be helpful, but it is the quality, objectivity, knowledge, skill and judgement of the people identifying and assessing the potential impacts, weighing up the information and making the recommendations which is important to obtaining a proper outcome.

The person or body conducting an EIA should not be predisposed to one course or another, nor should they see the process as an exercise to justify decisions which would be taken in any case. Unfortunately, this is not reflected in the following quote from a recent article explaining EIA procedures under the Protocol:

> The EIA process seeks not to prevent activities from proceeding but to ensure that those involved keep any potential environmental impacts to a minimum. (ANARE News 68 1991, p6)

One of the basic strengths of the EIA process is that it provides the opportunity to stand back and review the various alternatives to the proposed activity, including doing nothing, to see whether any obvious 'environmentally friendly' or even cheaper or superior solutions have been missed. A serious concern regarding the practice of proponents preparing the EIAs for their own projects is that realistic alternatives to the proposed activity may not be presented and that the alternatives will probably be of the 'straw man' variety. The proponent has inevitably already decided on the 'best' alternative from their own perspective, perhaps from a scientific, engineering or operations view point. Engineers may have a tendency to prefer technically elegant or superior design solutions. Operations people may be biased towards quicker, less labour intensive solutions. Proponents cannot help but act as advocates of their own solutions in an assessment, and can hardly be expected to be enthusiastic about the work involved in the formulation, description and analysis of serious alternatives.

An example of how the special interests of the proponents influence the analysis of alternatives is shown in the IEE on the Removal of World Park Base. While generally a thorough document, the discussion of some of the practical alternatives is rather superficial. For instance, the alternative of transferring the base to another operator is dismissed out of hand:

> Greenpeace made the commitment to remove World Park Base after use, and hence this alternative is not acceptable. (Greenpeace 1991, p31)

This is hardly an objective analysis of this alternative, which could possibly result in the environmentally preferable situation of another operator not establishing a station or a refuge in another undisturbed area. This assessment of the alternative is about as objective as a technical person saying that the technically superior solution is the only acceptable one.

Self assessment and decision making by the proponent of the activity is a serious problem for the ATCPs in terms of the external credibility of the process. To improve the external credibility of the EIA process, without letting it out of the purview of Treaty Parties, more 'teeth' could be given to the Madrid Protocol's Committee for Environmental Protection, especially in the case of activities covered by the CEE processes. The need for an impartial source of assessment will be even more important as the level of non-government activity, such as tourism, increases.

How should the environmental protection standards be interpreted?

Much of the structure and wording of Article 3 of the Protocol, covering environmental principles, is lifted from Article 4 of the Minerals Convention. Probably as a trade-off to achieving the conditional ban on minerals activity, the standards have regrettably been watered down.

For example, Article 4(2) of CRAMRA says:

> No Antarctic mineral resource activity shall take place until it is judged ... that the activity in question would not cause:
>
> (a) Significant adverse effects ... etc'

Whereas, Article 3(2)(b) of the Madrid Protocol says:

> activities in the Antarctic Treaty area shall be planned and conducted so as to avoid:
>
> (i) adverse effects on ... etc

The language of Article 3 of the Madrid Protocol is typical of EIA standards generally and suffers from the problem of being open to various interpretations. What is meant by terminology such as 'significant adverse effects', 'significant changes', 'detrimental changes', 'further jeopardy to' and 'degradation of or substantial risk to'. In some cases it might be possible to use some agreed quantitative standard of, say, 'air or water quality' as the basis of a judgement. In other cases, say, judgements about 'detrimental changes in the distribution, abundance or productivity of species or populations of species of fauna and flora' and 'degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance' are much more open to different interpretations.

This approach to standards relies totally on the quality of advice and judgement, largely scientific judgement, on which the assessment is based. This method simply will not work very well unless the conduct of the EIA process, if not the formal decision making, is in the hands of an independent expert or body with access to appropriate scientific information and advice.

How much is sufficient information and who can provide it?

Article 3(2)(c) of the Protocol states that:

> activities in the Antarctic Treaty area shall be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research

This is also open to different interpretations, and proper adherence to it requires that the assessors have access to appropriate expertise and data. Is it 'sufficient', for instance, to invite the proponent of a project to assess 'what are the likely impacts on the flora, fauna and ecological processes' of a proposed new facility. If the proponent says 'no problem' at the Preliminary Assessment stage then it is quite possible that the proposal will pass through the approval process and 'proceed forthwith'.

For projects in particular locations, which have been the subject of relevant scientific research for a period, there is hopefully baseline data and a body of scientific literature to draw on, as well as a number of recognised experts. It is much more difficult in locations where a new program or facility is proposed and little or no research or monitoring has been done. Potential impacts need to be predicted perhaps on the basis of extrapolating from experience at other locations.

The provisions of the Annex 1 - Article (3)(2)(j) of the Protocol requires:

> an identification of gaps in knowledge and uncertainties encountered in compiling the information required

This seems to contradict the requirement for sufficient information. If there are 'gaps' and 'uncertainties', can there be sufficient information?

There seems to be no realistic option but for Antarctic operators to have a centralised structure for the conduct of assessments where the proponent provides the details of the proposed activity and an independent expert or body conducts the assessment. This process could perhaps be at the national level for IEEs and Treaty-wide for CEEs.

To whom should draft EIAs be circulated and what is their role?

It is possible that some proponents of projects see the preparation and circulation of a glossy EIA as a public relations exercise, to get the 'approval' of the public and the environment movement; rather to reduce political risk than to reduce environmental risk.

The circulation for comment of EIAs places a large degree of responsibility, not to mention workload, on the public and on environment groups who may or may not have access to relevant scientific data, the necessary expertise in particular areas or the time to do the work. The 'public' who have enough knowledge to give 'real' comment is probably a small group of Antarctic scientists and other experts beholden in some way to the national operators. Public availability is useful from a point of view of 'transparency' and in providing some checks and balances in the process, but is not a substitute for having the assessment carried out thoroughly and objectively in the first place.

Who makes the decisions?

The decision on whether or not to proceed with their own activities in Antarctica has always been the ultimate prerogative of the individual Treaty nations. This is a fundamental feature of the Antarctic Treaty System and applies to the activities subject to EIA under the Madrid Protocol. Draft CEEs prepared by the proponents will be given wide public availability and will be examined by the Committee for Environmental Protection before being considered at an Antarctic Treaty Consultative Meeting on the advice of the Committee. This process would be improved, from the point of view of obtaining an impartial outcome, if the EIA was conducted by an independent body such as the Committee for Environmental Protection. There would be almost no chance of the Consultative Parties giving up their formal, individual right to make the final decisions about their own scientific activities, but on the other hand there is little chance of a nation not abiding by the outcome of an EIA conducted by a body such as the Committee for Environmental Protection.

What will be the cost of EIAs and how long will they take?

More elaborate EIA procedures and processes will add to the cost, in terms of both resources and time, of conducting scientific activities. This will probably reduce the amount of science and the speed at which can be carried out. There is no doubt that as part of the normal planning process, proper objective environmental assessments need to be done, but they should be done in such a way as to minimise the diversion of resources from output oriented activities.

Based on the procedures proposed by the Australian Antarctic Division (AAD 1992) the absolute minimum period from the time of completion of a straightforward IEE to the notification of the decision to the proponent is 4 months. An IEE itself could easily take many months in addition to prepare. For a CEE, the absolute minimum period from the point of completion to the decision is 9 months, with a maximum of 19 months when out of sequence with ATCMs.

These large time spans alone, not to mention the cost and workload, will deter a lot of people, already pressed for resources, from embarking on worthwhile improvement projects. An old incinerator can be retained without any assessment, whereas a modern replacement, which would be better for the environment, requires a substantial EIA. What would happen, for instance, if there was a choice between leaving an observatory facility in a Protected Area or relocating it after conducting an IEE with all the attendant work and public attention?

The cost of actually conducting EIAs is one thing, but on top of this is the cost of delays. A recent study of environmental assessment procedures of major projects in Australia by the Bureau of Industry Economics has concluded that:

> The main costs associated with EA are attributable to delay and uncertainty. (BIE 1990, p26)

The governments of the Treaty nations need to recognise the financial and other resource implications of environmental protection measures, when it comes to budget time. From the operators side it is important to focus scarce resources for environmental impact assessment on the activities with the major potential for causing environmental harm, i.e. those requiring CEEs, rather than applying disproportionate attention and resources to the activities with a low likely level of impact.

What is regular and effective monitoring and who will do it?

Article 3(2)(d) and (e) of the Protocol requires that:

> (d) regular and effective monitoring shall take place to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts;
>
> (e) regular and effective monitoring shall take place to facilitate early detection of the possible unforeseen effects of activities carried on both within and outside the Antarctic Treaty area on the Antarctic environment and dependent and associated ecosystems.

'Regular and effective monitoring' sounds simple but will need a great deal of work to plan and actually carry out. Advice on appropriate monitoring policies is being prepared by the scientific and operational experts (SCAR and MNAPS, 1992). Some monitoring programs will be able to be integrated with existing scientific activities but others will demand significant resources. Given the competition for resources already, scientist with existing programs may be reluctant to get involved if their own research interests would suffer.

What if an activity needs to be modified, suspended or cancelled?

Under Article 3(4)(b) of the Protocol, activities are required to:

> be modified, suspended or cancelled if they result in or threaten to result in impacts upon the Antarctic environment or dependent or associated ecosystems inconsistent with those principles (of the Protocol).

The problem is that with no enforcement mechanism, it is questionable in reality whether an activity would be voluntarily cancelled, or even suspended, by a national operator after the expenditure of substantial sums of money and effort.

The fear of insufficient action being taken by the operator in the case of unpredicted impacts was addressed in CRAMRA. Under Article 51(1), the powerful Regulatory Committee is required to suspend, modify or cancel an activity if it:

> has resulted or is about to result in impacts on the Antarctic environment or dependent or associated ecosystems, beyond those judged acceptable ...

Similar power should be given to the Protocol's Committee for Environmental Protection.

CONCLUSIONS

The Antarctic Treaty Parties have been addressing the principles of environmental impact assessment for two decades, but procedures have largely been left to national operators to implement. The Madrid Protocol consolidates the various EIA concepts from the different parts of the Antarctic Treaty System, and establishes a tiered procedure of assessments: Preliminary Assessment; Initial Environmental Evaluation; and Comprehensive Environmental Evaluation depending on whether an activity is likely to have less, equal to, or more than a 'minor' or 'transitory' impact.

The Protocol, as part of the Antarctic Treaty System, is not static and can evolve in response to experience in its operation and to changing knowledge and circumstances. The national Antarctic operators are in the process of incorporating the provisions of the Protocol into their decision making processes and their day-to-day operations. The Council of Managers of National Antarctic Programs has developed 'Practical Guidelines' which are are intended to provide a measure of comparability between operators.

In summary, the following suggestions could be taken up to improve the EIA process in Antarctica:

- Establish detailed, practical working criteria and guidelines to determine what activities are subject to environmental impact assessment and at what level.
- Upgrade the environmental protection standards in the Madrid Protocol (cf. those of CRAMRA).
- Use independent, qualified assessment teams or experts to conduct assessments, possibly at the national level for Initial Environmental Evaluations and Treaty-wide, say through the Committee for Environmental Protection, for Comprehensive Environmental Evaluations.
- Avoid the indiscriminate use of an arbitrary, bureaucratic checklist approach to any assessment.
- Concentrate scarce financial, scientific and other resources on assessing the major activities with the greatest potential to cause impacts.
- Streamline procedures to avoid delays, and consequent cost, associated with the EIA process, especially in the case of high priority science projects.
- Include in the Protocol a mechanism to ensure that activities will be modified, suspended or cancelled if they result in or threaten to result in unpredicted impacts.
- Identify and provide additional resources to carry out adequate environmental monitoring of activities.

Finally, it is easy to forget that Antarctica is far from the lofty negotiating tables of Viña del Mar and Madrid, or even Bariloche. The real onus for doing the right thing for the protection of the environment still falls back on the people working in Antarctica. They need to be provided with the information, the training and the wherewithal to achieve in practice what the diplomats glibly talk about in the warm, comfort of meeting rooms.

GLOSSARY

ANARE	Australian National Antarctic Research Expeditions
AT or **The Treaty**	Antarctic Treaty
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
CEE	Comprehensive Environmental Evaluation
COMNAP	Council of Managers of National Antarctic Programs
CRAMRA or **The Minerals Convention**	Convention on the Regulation of Antarctic Mineral Resource Activities
EA	Environmental Assessment
EIA	Environmental Impact Assessment
IEE	Initial Environmental Evaluation
Madrid Protocol or **The Protocol**	Protocol on Environmental Protection to the Antarctic Treaty
PA	Preliminary Assessment
SCALOP	Standing Committee on Antarctic Logistics and Operations
SCAR	Scientific Committee on Antarctic Research
UNEP	United Nations Environment Program

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SUMMARY - INITIAL ENVIRONMENTAL EVALUATION: REMOVAL OF OLD CASEY STATION

Old Casey Station (66° 17'S, 110° 32'E) is situated on the Bailey Peninsula, East Antarctica and was completed in 1969. The design was a unique arrangement of prefabricated modules raised on a scaffold frame and linked by a 'tunnel'. The main structure was designed for easy erection, to control drift accumulation and minimise fire risk. Outbuildings, such as the vehicle workshop, were built at ground level. The old station was removed from operational service because it was deteriorating structurally. Its facilities were largely replaced by the new Casey Station occupied at the end of 1988.

The Antarctic Division required removal to be undertaken in such a way that: minimised adverse environmental impacts; removed debris and rehabilitated the site; provided for the heritage conservation; and made efficient use of resources. The IEE was carried out by an IASOS Honours student, Evan Steverson, in accordance with the EIA procedures of the Madrid Protocol, which was still being negotiated while the work was being done.

It may seem self evident that the removal of old station buildings within an already heavily impacted area is a good thing for the environment and that it is pointless to conduct an EIA. However, the activity proposed was of a substantial scale, and involved potential risks, such as the scattering of dust and other material, including asbestos, which could be mitigated by the use of appropriate equipment and procedures.

Description of Removal Plans - The initial step of obtaining an appropriate description of the proposed activity took a little time, as there was a late change of contractor to Australian Construction Services(ACS) and there had been no previous need to document in detail this sort of exercise. IASOS provided guidelines to ACS for the information to be included in the description of the activity. This problem will be overcome in future, when the EIA process is integrated into overall planning.

Existing Environment and Potential Environmental Impacts - The environment of the station area had been the subject of scientific study for more than 30 years. This meant that substantial literature and data was available, and informed views could be obtained from experts on the potential environmental impact of the activity.

Alternatives - Four alternatives were examined: leaving the Station intact and maintained; leaving the Station to decay without maintenance; removing only some of the buildings; and removing the Station over an extended period. These were all rejected for a combination of environmental, financial, logistic and aesthetic reasons.

Environmental Protection Measures - This was seen as the most important part of the exercise, and a list of measures was developed under the following headings to control any environmental impacts: Demolition Work Practices (including the removal of asbestos); Waste Management; Rehabilitation; and General Management.

Monitoring - In addition to the ongoing monitoring program in the area, visual monitoring and the keeping of a log book were recommended during and after the removal activity.

Conclusion and Recommendation - It was concluded that the proposed removal of the Old Casey Station over two summers would be expected to have no more than a minor or transitory impact on the environment and should proceed.

The draft IEE was given limited circulation by the Australian Antarctic Division to a number of interested environment groups and to other parts of the Division's head office Department of the Arts, Sport, the Environment, Tourism and Territories. Comments and suggestions were received and the final IEE document was submitted by IASOS to the Antarctic Division. The activity was approved and the first stage of the planned work took place over the 1991-92 summer.

SUMMARY - ENVIRONMENTAL IMPACT OF THE PROPOSED REINTRODUCTION OF HYDROPONICS INTO ANARE STATIONS

Horticulture has been practiced as a hobby activity at the ANARE Stations for many years but due to the changing interests of groups of expeditioners, horticultural facilities often became neglected, and equipment and organic materials were left to deteriorate. The Australian Antarctic Environment Committee made a recommendation to cease hydroponic activities from the changeover of the 1989 expedition and to return all hydroponic equipment to Hobart. This was reviewed in 1991 and it was decided that, subject to a favourable environmental assessment, hydroponics could be reintroduced with the proviso that strict operational guidelines be rigorously adhered to.

In 1991, the Australian Antarctic Division prepared a preliminary proposal to reintroduce hydroponic vegetable production into the stations. The proposal was based on the development of container modules which would house the hydroponic system, and official management of the facilities.

An IASOS Honours student, Claire Green, was assigned the task of compiling a report on the proposal, as a preliminary to an IEE. The aim of the report was to evaluate the possible environmental impacts that might arise from the proposed reintroduction of hydroponics and to determine whether the activities would have 'no more than a minor or transitory impact' on the Antarctic environment. Subject to the findings, recommendations were also required to assist in the implementation of the proposal.

Description of Proposal - The Antarctic Division proposal involved the following components: Personnel and Training; Equipment; Growing Media; and Procedures.

Alternatives - Other forms of horticulture were judged inappropriate for the cultivation of plants in Antarctica.

Potential Environmental Impacts - The major potential impacts would arise from the possible introduction into the Antarctic environment, of non-indigenous species of invertebrates and microbial organisms contained in plant material, including seeds, and in the disposal of waste including waste nutrient solution.

Environmental Protection Measures - To reduce the possibility of transporting non-indigenous species to Antarctica in equipment, growing media and seeds, appropriate fumigation or sterilization will be required. All hydroponics will be confined to the freight container module and a strict management regime will be applied. Waste liquid will be passed through an ultra-violet steriliser before being discharged into the station sewerage treatment system for disposal.

Monitoring - The proposed monitoring program includes regular inspections of the module for the presence of any invertebrates by utilising permanently positioned traps and inspecting the roots and leaves of the plants.

Conclusions and Recommendations - The proposed facilities and methods of operation cannot guarantee total exclusion of exotic organisms, but can reduce the level to the maximum extent practicable. The overall proposal is expected to have no more than a minor or transitory impact on the Antarctic environment and hence should proceed. This recommendation takes into consideration that the pursuit of hydroponics activities should always involve strict management and monitoring procedures.

The student's report will be considered, together with a more detailed technical proposal for the modular hydroponics unit, before a final IEE is prepared.

Surface Remediation at McMurdo Station, Antarctica

by
Dr Kenneth Z. Crumrine
AECOM Technology Corporation, USA

INTRODUCTION

Fortress Rocks Landfill is a four acre landfill site in use since 1980 for the deposition of debris generated at McMurdo Station. The landfill consisted of debris buried under soil backfill and exposed debris generated more recently. The landfill, a natural ravine, was filled with debris and leveled with backfill to create burn pads, level storage areas, and a road. Originally the metal debris was recycled, when possible, by both USAP and New Zealand personnel for special projects. The food waste, wood, cardboard, and light metal material was soaked with fuel and fired off several times per season prior to the Antarctic Treaty bans on open burning. The ashes were then covered with level lifts of gravel to facilitate mechanical disposition of the wastes at the site.

The major objective of the landfill cleanup was to segregate and package all exposed wastes. The 7,000 cubic yards of surface debris was separated into recyclable debris, nonrecyclable debris, asbestos-containing wastes, combustible wastes, and hazardous wastes. Most debris was identified as construction and packing materials, however asbestos and other potentially hazardous materials were also identified within the waste stream. Combustible wastes were sorted and recycled or incinerated at McMurdo. After the cleanup operation was accomplished, a thin layer of gravel was placed over the fill area.

Prior to the 1991-1992 austral summer season, approximately 800 of the orphan drums had been stored on wooden pallets in the Hazardous Waste Yard. Twelve rows of drums, two abreast, were present in the Hazardous Waste Yard at the time of AECOM's arrival in early October 1991. There were about six inches of snow/ice at the base of the drums. The Hazardous Waste Yard was fenced and access controlled by Naval Support Force Antarctica (NSFA) personnel who were responsible for maintaining the yard. Many of the drums present were visibly damaged to some extent. Some had minor dents, some were bulging due to frozen contents, and others were severely damaged or had visible breaches. More than half the drums present had some marking on them. However, since it was generally believed that the drum contents represented a secondary use of the drum (i.e. for waste disposal), in many cases the primary marking on the drum did not reflect the actual contents. In addition to the orphan drums, other wastes present in the Hazardous Waste Yard included used oils, used anti-freeze, asbestos-containing wastes, lab-packs containing miscellaneous chemicals from the biological laboratory, waste boiler treatment chemicals, miscellaneous waste products such as thinners, paints, and solvents, and over 1,200 used vehicle batteries.

This paper describes the technical and logistic tasks involved with the cleanup of the landfill and waste yard. The paper is divided into sections which describe the equipment, technical approach to complete the tasks, health and safety monitoring conducted during the cleanup, and sampling and analysis performed to determine if further remediation is necessary.

EQUIPMENT AND LOGISTICS

In late April 1991, the National Science Foundation (NSF) decided to implement through its facilities support contractor, Antarctica Support Associates, the surface remediation of McMurdo Station in the 1991/1992 austral summer season. Existing facilities and equipment at McMurdo were inadequate to perform this major cleanup effort in a safe and cost-effective manner within the limited summer season. All the necessary construction equipment, waste decontamination, personnel decontamination, safety equipment, and environmental monitoring instrumentation had to be identified, designed to operate in the cold weather of October and November, ordered, and delivered to Port Hueneme, California, by September 1, 1991.

At Port Hueneme, equipment and supplies were prepared for shipment by cargo vessel to Christchurch, New Zealand, and for subsequent air cargo (C-5 and C-141) shipment to McMurdo Station. Logistics planning for air transport of heavy waste processing and construction equipment, some of sizes not conducive for air transport, began in May 1991 and continued until all equipment arrived at McMurdo in mid-October. In order to allow the maximum available time for cleanup operation, this program received the highest priority from the NSF and U.S. Navy (VXE-6) in transporting equipment, supplies, and cleanup personnel to McMurdo Station.

A total of 30 cleanup specialists were utilized to perform the surface remediation at McMurdo Station. Equipment used in the cleanup of the landfill and drum storage area are described below.

Cleanup Equipment

A Caterpillar 963 track type loader was used for heavy moving and material handling at the landfill and for grading out an area in the drum storage lot to establish a secondary containment zone for drum processing.

A Caterpillar wheel-type backhoe loader was used to sort waste and load heavy metal into flatracks. The 436 has an operating weight of 15,060 pounds with a 1-cubic yard loader bucket and a 5-cubic foot backhoe bucket. Foam-filled tires were not ordered with this unit and several flat tires resulted from use in the landfill.

Two Hydramacs 250 skid-steer loaders were used to sort debris, handle hoppers loaded with debris, and transfer bales of metal from the truck to the staging area. These units came equipped with the following attachments:

76 inch high capacity low profile bucket
48 inch pallet forks
72 inch scrap bucket
Drum handler attachment

Six generators were shipped to McMurdo Station. Model 60 DGCB 65 kw ONAN generator is powered by a Cummins diesel engine. The Model 60 was used to provide primary power to the Sprung waste decontamination building and the personnel decontamination trailer. The generator was installed approximately 50 feet from the building and trailer and required a remote supply of fuel (350 gallon aboveground tank). Fuel connection was made with 3/8-inch Type K copper (soft) tubing run inside of EMT conduit and protected from damage.

Primary electrical connection was made using 4/0 RHHN conductors housed in 2-inch rigid conduit. The primary conduit was run from the safety switch at the generator to the trailer main panel. The secondary conduit connected to the subpanel in the waste decontamination building. A 125-amp breaker panel was installed inside the clean area to service the Sprung building.

Five smaller generators provided a local source of power for small tools. The generator models were: Onan Model 4.0 BGE-FA/26100 (4.0kw) and Model 2.5 EGH-AA/34879 (2.5kw); and Honda generator models EM650 (.65kw), EG2200xa (3.5kw), and EB 3500 (3.5kw).

An Al-Jon mobile, hydraulic, scrap metal baler powered by a Cummins 6BT 5.9 diesel engine and equipped with a rotating grapple arm was used to lift metal debris from the landfill and crush it into bales of approximately 0.6 cubic yards. The engine and hydraulic system were upgraded for extreme cold weather. All lubricants, coolants, and hydraulic fluids used with the baler were rated for arctic service. The baler was designed to handle metal up to about 0.125 inches thick.

A 40-foot Sprung temporary structure was used as a waste decontamination work area. It was erected on a prepared site at the edge of the landfill. The building was located so one entrance was within the landfill, and the personnel decontamination trailer was attached to the opposite side of the work area, on the outside of the landfill. Workers were then required to pass through the trailer to access the work area.

The interior layout of the work area was designed to allow asbestos abatement to be performed safely according to accepted EPA and OSHA work practices. Personnel access to the building work area was through the decontamination trailer and a transition area sealed from the work area. The breakroom and storage areas were also sealed from the work area. Negative pressure fans were located outside the work area and negative pressure was maintained in the work area during abatement activities.

Work area utilities and equipment located outside the Sprung Building included a 65kw diesel generator, fuel storage tanks, two building furnaces, milvan asbestos storage area, and a prepared waste staging area. These systems were placed to provide access for refueling, service, and entry of machinery to the work area.

Furnaces were installed within a plywood shelter located outside of the building. The exhaust from the furnaces was ducted with a wind directional cap placed on the top of the exhaust. The furnaces were installed to U.L. recommended installation clearances which are 24 inch on the front and rear, 6 inch on the sides and 18 inch from the flue pipe to any combustible material. Duct connection was made with 20 inch insulated flex duct. The furnaces were connected to the clean area and transition room separately. Return air was collected from the clean areas. A plywood floor was laid under the work, clean, and transition areas within the building. The area where the hoppers were positioned was left without a floor. Plywood was nailed to wooden pallets to level and steady the floor.

A Polyjon personnel decontamination trailer was located next to the waste decontamination building on a level, prepared surface. Hurricane straps were installed to prevent the trailer from moving in heavy winds. The trailer was 32 feet long and 8 feet wide and consisted of a clean dressing room area, shower area with built in water tank, and dirty equipment room. All utilities were factory installed in the trailer. Connection to electricity and water was all that was required. The 700-gallon, on-board, fresh water tank was filled by tank truck. Toilets were incinerator type requiring little maintenance and no pumping. Wastewater was collected in a 150-gallon day tank located under the trailer. When the tank was full it was filtered through a 5-micron filter and discharged into a 1,200-gallon tank also located under the trailer. When the larger tank was full it was emptied onto the ground.

Packaging materials included plastic sheeting, duct tape, plastic bags, triwall boxes, 20 foot long enclosed milvans, and 20 foot long open flatracks. AECOM supplied all plastic, tape, some triwall boxes, and six milvans. NSF and the Navy supplied the flatracks and other milvans.

CLEANUP PROCEDURES

Site Design and Mobilization

The first task conducted at the Landfill in early October 1991 was setup of the decontamination trailer and Sprung building to allow cleanup to proceed in safe and efficient manner. Supplies and utilities were staged and attached as required. Supplies were staged in the building, in two dedicated milvans, and along the road to the landfill. Heavy equipment was winterized and placed into service at the landfill. The Al-Jon baler was initially staged at a metals recycling area created during the winter-over construction projects. The baler operated there until the temporary building and decontamination station were ready at the landfill. The baler was then transferred to the landfill area and began reducing the metal debris there.

Food Waste Disposition

Food waste accumulated during the 1991 winter had been deposited in the landfill. Approximately 12 tons of food waste in 2,000 plastic bags were tripled bagged, placed in polyethylene-lined triwall boxes, and shipped to New Zealand for landfill disposal.

Waste Pile Segregation

Segregation of the various waste piles constituted the largest portion of this effort. Waste piles were carefully surveyed by technicians experienced with recognizing asbestos-containing materials before the Hydramacs and Cat 963 were allowed to pull the piles apart. Any suspected asbestos debris was segregated and sampled to determine if it was asbestos. Debris was segregated into smaller piles of baleable metal, cable, large metal items, wood, cardboard, and miscellaneous construction debris. After the larger debris had been removed by machine, smaller debris was sorted from the snow and gravel by passing the mixture through a large screen. The debris was then further hand sorted and the snow and gravel used to dress the slopes of the burnpad areas.

Several small containers of chemicals and three fuel tanks were discovered in the waste piles. Containers with small quantities of chemicals were collected and placed in overpack containers. Each of the tanks contained fuel or oil which was pumped into 55-gallon 17C drums. The chemicals and liquids were handled by drum storage cleanup personnel.

Several categories of material were moved by pickup truck to segregated waste piles or containers, usually triwall boxes or flatracks, and deposited for further processing. The wood debris was taken to a separate staging area where it was processed for loading in a large tub grinder. Approximately 75 cubic yards of wood was reclaimed from the landfill. Cardboard was collected and baled for retrograde. Approximately 400 cubic yards of cardboard was reclaimed. Rubber hoses, tires, and fuel bladders were all turned over to the Navy for disposition with their regular waste streams. The fuel bladders were cut into small pieces and stuffed into lined triwall boxes. Miscellaneous debris including furniture, carpeting, bondstrand piping, foam insulation, and clothing were loaded into flatracks for retrograde. Three flatracks were filled with miscellaneous materials from the landfill. Plastic was collected and placed into triwall boxes for retrograde. Approximately 50, 1-cubic yard triwall boxes were filled for retrograde.

Asbestos Abatement

Once the waste decontamination facilities were established, asbestos abatement technicians began a methodical search of the landfill area and marked off all material suspected of containing asbestos. Identified asbestos items in the landfill included floor tiles, pipe gaskets, pipe cover, and coated metal siding. The technicians then returned with the proper materials including surfactant, polyethylene bags, personnel protective equipment, and tools to collect the asbestos materials and bag them. Most of the asbestos located in the landfill was floor tile and pipe gaskets which were wetted with a water and surfactant mixture, picked up, and placed in labeled polyethylene bags. Piping with asbestos gaskets was collected in one place where the technicians used torches to cut the flanges free from the pipe. The entire flange connection was disposed as asbestos to limit handling asbestos. Asbestos-coated metal siding was baled and packaged into lined triwall boxes also. Asbestos material stored at other McMurdo locations was transported to the landfill where it was packaged with the asbestos debris collected at the landfill. This included two asbestos-covered tanks which were brought to the landfill, placed inside the Sprung building containment area, and had the asbestos cover removed. All bagged asbestos was placed into polyethylene-lined triwall boxes. All boxes and bags were labeled with required "Danger Asbestos" labels. Altogether, three milvans, totalling 53 cubic yards were filled with asbestos in triwall boxes and retrograded to the United States.

Metals Sorting and Packaging

Metal debris in the landfill included aluminum cans, steel cans, steel siding, corrugated aluminum pipe, vehicle components, building structural members, copper pipe, steel pipe, cable, and miscellaneous metals. Metal debris was sorted into light-gauge metal that the baler was able to reduce, large metal items that were too large or too thick to bale, metal siding covered with asbestos, cable, and aluminum cans. Sorted metal was staged in front of the baler where the operator blended the metal to create bales that would hold together. Clean aluminum cans were baled separately, however cans with frozen contents were blended with steel cans to increase bale cohesion. The asbestos-covered siding was baled separately and immediately packaged into polyethylene lined triwall boxes. Large metal items including steel plates, vehicle frames and engines, steel, cast iron and copper pipes, steel tanks, building structural steel, and electric motors and appliances were cut to size with torches or saws and packed into flatracks for shipment. Flatracks were topped off with bales of metal to block the large items from shifting during transport. Cable was separated from other debris and placed directly into flatracks. Thirty-eight flatracks were used to load all the heavy metal and cable for retrograde.

Recordkeeping

A daily log of activities was maintained by the landfill supervisors which included a checklist of personnel attendance, work accomplished, problems encountered, and any comments. The daily log was used to prepare briefings, submit employee hours by activity to the home office, track productivity, and update the schedule.

Environmental Monitoring

Air samples were collected to monitor personnel exposure, work area practices and final air clearances in the decontamination unit. OSHA strictly limits exposure to asbestos in the workplace.

Personnel exposure monitoring was conducted in accordance with OSHA 1910.58. Air samples were collected in the breathing zone of technicians performing the various tasks associated with the abatement operations. The pump flow rates were set between 2.5 and 4 liters per minute and the pumps were generally run for the duration of the activity. Flow rates were calibrated at the beginning and end of sample collection. Several personnel samples collected were above the 0.1 action level, however the elevated samples were always associated with abatement work and the technicians were wearing personal protective equipment at that time. Monitoring data show that no significant elevated levels of any hazardous materials were detected in either perimeter or cleanup work areas or in the decontamination building once it was cleared for general cleanup worker access.

During asbestos removal operations in the abatement building, air samples were collected inside the work area, inside the clean room of the decontamination station, and immediately outside the work area on the upwind and downwind sides of the building. These samples were collected using high-volume pumps set at flow rates between 4 and 10 liters per minute. The pumps were run for four hours or the duration of the task. The industrial hygiene technician determined where to place the sample pumps. Area samples were collected downwind of the landfill area during segregation of the materials. Sampling indicated that fiber levels were below 0.1 fibers per cubic centimeter (f/cc) in the landfill area during abatement activities and the Health and Safety Officer reduced the personal protective equipment requirements from Level C to Level D for all personnel performing general work in the landfill to reflect those values. Half face respirators were worn by personnel performing abatement both inside and out.

Final clearance samples determine that an area was safe for reoccupancy. Final clearance samples were collected after each abatement event. The results were always below the 0.01 f/cc considered acceptable. Final work area clearance samples were collected utilizing high-volume sample pumps to collect at least 1,500 liters of air. Samples were analyzed as soon as possible after collection to allow work practices to be altered if necessary.

Waste Retrograde

The waste streams generated from sorting the debris at the landfill were packaged to Navy, International Maritime Organization (IMO), U.S. Environmental Protection Agency (EPA), and Department of Transportation (DOT) requirements. Those requirements are summarized as follows:

- Asbestos had to be wetted, double bagged, labeled with "Asbestos Danger" labels, and loaded into poly-lined milvans.
- Food waste had to be triple bagged and placed into triwall boxes.
- Metal bales and loose metal pieces had to be placed into flatracks and blocked.

The flatracks used for metal retrograde were damaged from previous shipments and had to be repaired using wood to contain the large metal items and bales of metal. The metal was loaded with the backhoe bucket, baler grapple, or dumped from hoppers that had been filled by hand.

Table 1 summarizes the waste streams and disposition of the waste with approximate quantities. All asbestos debris was double bagged, placed in lined triwall boxes, and packaged in a separate milvan for asbestos waste. All containers were labeled with proper labels identifying the contents as asbestos waste.

TABLE 1
Quantity of Retrograded Wastes From the Landfill

WASTE	QUANTITY	DISPOSITION
Baled Metal	1,800 bales (1,044 cubic yards)	1,000 bales to CONUS 800 bales staged at pass for 1993 retrograde
Bulky Metal	38 flatracks (30,000 lbs/rack)	Retrograded to CONUS
Wood	75 cubic yards	Pass area for ASA retrograde
Cardboard	400 cubic yards	Cardboard baler for ASA
Construction	53 cubic yards	Retrograded to CONUS
Asbestos	53 cubic yards	Retrograded to CONUS

All the waste drums stored in the Hazardous Waste Yard were sampled after they were placed into the salvage drums (serving as secondary containment vessels). Liquids wastes were sampled by means of either a disposable PVC bailer, a glass drum thief, or a glass Coliwasa (composite liquid waste sampler). Frozen drum contents were sampled using an ice-coring device.

AECOM performed chemical testing of the waste samples at McMurdo Station. The purpose of this testing was for initial waste characterization such that appropriate DOT shipping classifications could be determined for each waste drum. Subsequent to AECOM testing of the drum samples, the sample containers and accompanying laboratory documentation were turned over to Naval Support Force Antarctica (NSFA) representatives for use by their contractor in selecting of final treatment/disposal options for all of the waste. The AECOM characterization program consisted of the following laboratory tests: pH, organochlorine content, reactivity to water, reactivity to acid, radioactivity, volatile organic screening, and flashpoint determination.

From these testing procedures, AECOM was able to segregate the unknown wastes into the appropriate DOT shipping categories as follows:

DOT Class	Number of Drums
DOT Class 3: Flammable Liquid, n.o.s.	155
DOT Class 3: Combustible Liquid, n.o.s. (combustible liquid is a subclass of Class 3)	282
DOT Class 4: Flammable Solid, n.o.s.	10
DOT Class 6: Poisonous Liquid, n.o.s.	3
DOT Class 8: Corrosive Liquid, n.o.s.	11
DOT Class 9: Environmentally Hazardous Substances, Liquid, n.o.s.	179
Non-Regulated (DOT) Waste	86
Total	726

In addition to the 726 drums and 756 sample jars containing waste samples from the orphan drums overpacked for retrograde, AECOM packaged other miscellaneous waste and used equipment as follows:

- 8 lined triwall boxes of Personal Protective Equipment (PPE) and sampling gear
- 2 lined triwall boxes of acid-contaminated soil (DOT Class 9)
- 23, 85-gallon overpack drums of sulfuric acid (H_2SO_4)
- 9, 20-gallon plastic drums of alkaline cell batteries
- 40 pallets of acid batteries
- 1, 55-gallon poly drum of gel cell batteries
- 1, 55-gallon poly drum of dry cell batteries
- 1, 55-gallon steel drum of battery liquid (pH=14)
- 7, 85-gal overpack drums of hydrochloric acid (HCl)
- 2 lined triwall boxes of empty plastic acid containers

ASSESSMENT OF SURFACE REMEDIATION EFFORTS

Once the cleanup at the Fortress Rocks Landfill and Hazardous Waste Yard were completed, a chemical characterization of potential surface contaminants was performed to determine if and to what extent subsurface remediation was warranted. A total of 26 surface soil samples (including 2 duplicates) and one water sample were collected from the landfill. Four surface samples were collected from the Hazardous Waste Yard and one surface water sample was collected from the drainage ditch adjacent to the waste yard. They were analyzed for volatile organic compounds; semi-volatile organic compounds; and polychlorinated biphenyls (PCBs) per the Target Compound List (TCL); the Target Analyte List (TAL) of metals; and asbestos (soil only).

Sample Collection

Surface soil samples were collected at a total of 18 locations at the landfill. Twelve locations were selected at random using a grid sampling approach. An additional six sampling locations, termed judgement samples in the Sampling Plan, were selected based on an objective to characterize the soil on several sloping features of the landfill, separate from the grid sampling approach. The judgement sample locations were selected based on previous operations, and were obtained in the following areas: (1) from the edge to the former burn pad where ash and unburnt debris were periodically bulldozed from the edge to the south and west, and (2) from the steep slope along the eastern side of the old landfill area.

In order to select locations for the random sampling approach, a grid system representing 40-foot squares was plotted and uniquely numbered on a sketch of the landfill. Using a random number generator, 18 grids were selected. The six judgement samples were intended to characterize sloping areas of the landfill where buried waste and debris would be accessible from the surface. The initial site map of the landfill identified 87 grid locations. The locations for the judgement samples were numbered 88 through 93. Following surveying activities at the landfill, 14 grid locations were added to the map in two rows running north-south (grids #94-107) in order to account for the actual dimensions of the landfill.

For each of the 18 random grid samples, an equal amount of soil from each grab sample location was collected from the nine radial pattern locations within the grid and placed directly into a container for volatile organic analysis in order to minimize sample handling which could result in a loss of volatiles. For each of the six judgment samples, an equal amount of soil from each of five grab sampling locations was collected and placed into one sample container. The samples for volatiles analyses filled the sample containers to minimize headspace (i.e., no airspace in the top of the container), which could have accelerated the loss of volatiles.

Soil samples to be collected for the remaining analytical parameters were obtained on separate days from the VOA samples. Separate sample aliquots were collected from the nine radial pattern locations within each random grid location and placed into new plastic bags (i.e., Ziploc or equivalent). Similarly, equal amounts of soil were collected from five adjacent locations for the six judgement sampling areas and placed into a new plastic bag. The soil sample aliquots from grid locations and judgement sample aliquots were sealed in plastic bags, allowed to warm up to room temperature for one hour, and screened for total volatile organics. After screening, the nine soil sample aliquots from each random grid were placed into stainless steel bowls and manually homogenized. Large rocks, if present, were removed from the soil, as specified in the Sampling Plan. A homogenous mixture of the remaining fine-grained material was placed in sample jars for shipment to the analytical laboratory.

In order to assess laboratory precision, two field duplicate samples were prepared resulting in a total of 26 soil samples. These duplicates were "blind" duplicates (i.e., they were labeled with different, nonexistent grid numbers such that the laboratory would not recognize them as duplicates). The duplicate samples were collected in grids 43 and 75 in an identical manner as the original samples. In addition to the soil samples, a field quality assurance/quality control (QA/QC) sample consisting of an equipment blank was generated to assess the effectiveness of the field cleaning procedures on the stainless steel scoops and bowls. Appropriate volumes of deionized water, obtained from the Eklund Biological Center (EBC) at McMurdo Station, were used as final rinsate for sampling equipment, and collected in appropriate containers for analysis.

One surface water sample was collected at the Fortress Rocks Landfill on January 22, 1992, from a small pond containing snow and ice melt runoff located in a low area adjacent to the southeastern side of the landfill.

Sample Analysis

Soil sample aliquots were placed in plastic bags prior to compositing. The bags containing the samples were allowed to warm to room temperature, and were screened for total volatile organics using a photoionization detector. The screening measurements were conducted in the McMurdo Station Environmental Monitoring and Enforcement Laboratory (EMEL) of the Science and Engineering Technology Center (SETC). An HNu PI-101 was used, which was calibrated to an isobutylene standard prior to the screening of samples. Headspace (air) in the plastic bag was measured for total volatile organics by inserting the probe of the HNu into the bag and recording the results (parts per million).

The water samples collected from the surface water pond at the Fortress Rocks Landfill and drainage ditch at the Hazardous Waste Yard were tested at McMurdo for pH and specific conductance. These measurements were also performed in the EMEL. A Beckman Model 10 pH meter and Cole Parmer Model 1500-20 specific conductance meter were used, and were calibrated to the appropriate standards (pH Buffers, NaCl Conductivity Standard Solution) prior to the measurements.

Table 2 presents the sample parameters, analytical methods, and recommended holding times for the soil and water samples.

TABLE 2
Fortress Rocks Landfill and Drum Storage Area
Sample Parameters, Analytical Methods, Holding Times

Parameter	Analytical Method	Recommended Holding Time
MATRIX: SOIL		
Volatile Organics	8240 (a)	14 days
Semi-Volatile Organics	8270 (a)	14 days to extraction; 40 days after extraction
PCBs	8080 (a)	14 days to extraction; 40 days after extraction
Total Metals	6010/7000 (a)	180 days (28 days for mercury)
TCLP Metals	1311/7000 (b)	180 days to extraction (28 days for mercury)
Asbestos	EPA 600/M4-82.02 (c)	None
MATRIX: WATER		
Volatile Organics	8240 (a)	14 days (preserved)
Semi-Volatile Organics	8270 (a)	14 days to extraction; 40 days after extraction
PCBs	8080 (a)	14 days to extraction; 40 days after extraction
Total Metals	6010/7000 (a)	180 days (28 days for mercury)

(a) Test Methods for Evaluating Solid Waste, SW-846, EPA, 1986.
Metals analyses by various methods (7000 series)
(b) 40 CFR Part 261, Appendix II
(c) Polarized Light Microscopy

The organic compound analyses performed on the soil and water samples provide gas chromatograph/mass spectrometer (GC/MS) identification and quantification of 35 volatile organic compounds and 65 semi-volatile compounds as specified in the analytical methods. In addition to these lists of target compounds, other organic compounds can be present in the samples. The analytical methods, therefore, also provided the specifications for the tentative identification and quantification of other volatile or semi-volatile compounds present in the samples through use of a library search of GC/MS spectra. These compounds are referred to as tentatively identified compounds (TICs).

For volatile organic analysis of soils, the laboratory prepared a subsample by placing four equal-weight aliquots of soil in a vial prior to analysis by GC/MS.

A total of 23 metals, those comprising the EPA Superfund Target Analyte List were analyzed in the soil and water samples.

Laboratory Results

The results of the laboratory analyses for the soil samples are presented in Tables 3 through 10. For the volatile and semi-volatile parameters, only those compounds detected at concentrations above one-half the quantifiable method detection limit are listed.

Table 3 and Table 4 present the volatile organic compounds detected in the soil samples. Two compounds were present in nearly all of the samples: methylene chloride and acetone. These two compounds are common laboratory contaminants detected in several associated laboratory blanks. In addition, the compounds were detected at low concentrations (i.e., below 15 μg/kg, or parts per billion) suggesting laboratory contamination as the probable source. Only five other volatile organic compounds were detected in any soil samples. They were found at very low levels in landfill samples at concentrations below the method detection limit: 4-methyl-2-pentanone (1.68 μg/kg and 4.87 μg/kg); benzene (2.23 μg/kg); carbon disulfide (1.13 and 1.39 μg/kg); toluene (1.54 μg/kg); and xylene (3.68 μg/kg).

Table 3 and Table 4 present the semi-volatile organic compounds detected in the landfill and waste yard soil samples. Overall, a total of 15 different semi-volatile organic compounds were detected in the soil samples. Only two compounds, however, were detected above the method detection limits: bis (2-Ethylhexyl) phthalate (up to 2,340 μg/kg), and 2-Methylnaphthalene (up to 2,910 μg/kg). These were only in a limited number of landfill samples.

Table 5 presents a summary of the field screening results for volatiles compared to a summation of laboratory results for the volatile and semi-volatile organics analyses. Generally, a good correlation of the field screening results to the laboratory results for volatile organic compounds is indicated, i.e. those grids or locations with higher screening values are accompanied by relatively higher levels of detected volatile organic compounds, both identified and unknown. The correlation of these results also indicates that within a grid, the nine grab sample aliquots collected are representative of the surficial soils in that grid.

Table 3 and Table 4 also present data for polychlorinated biphenyls (PCBs) detected in the soil samples. Two PCB Aroclors were detected in the landfill soil samples at low concentrations: Aroclor-1016 (up to 334 μg/kg) and Aroclor 1260 (up to 165 μg/kg).

Table 6 and Table 7 presents the data for the metals detected in the soil samples. Various concentrations of metals were detected in all of the samples. The eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) are of particular interest. A high concentration of any or all of the metals in soil could potentially result in a leachate which could exceed RCRA criteria causing the soil to be classified hazardous. The RCRA criteria for the leaching procedure as well as leachate values that define hazardous soil, are specified in the Toxicity Characteristic Leaching Procedure (TCLP).

TABLE 3
Soil Testing Results
Fortress Rocks Landfill
Organic Constituents

Sample Location	Criteria	18	59	20	24	37	51	75	75Dup	83	68	39	43	43Dup	34	88	89	90	91	92	93
Volatile Organic Compounds (mg/kg)																					
1,1,1-Trichloroethane	7.000 mg/kg (a)				0.002																
4-Methyl-2-Pentanone			0.002									0.005									
Acetone	8,000 mg/kg(a)	0.008	0.007	0.004	0.004	0 004	0.01	0.007		0.003	0.003	0.007	0.014		0.011	0.005	0.007	0.004	0.003	0.005	0.007
Benzene	0 24 mg/kg(b)											0.002									
Carbon Disulfide	8,000 mg/kg(a)	0.001																0 001			
Methylene Chloride	90 mg/kg(a)	0.004	0 003	0.004	0.004	0.003	0.003	0.018	0.0039	0.003	0.003	0.004	0.014	0.0045	0.003	0.003	0.004	0.003	0.003	0 003	0.015
Toluene	20.000 mg/kg(a)											0.007					0.002				
Xylene	20,0000 mg/kg(a)											0.004									
Semivolatile Organic Compounds (mg/kg)																					
2-Methylnaphthalene		0.327	0.085		0.05		0.304	0.055	0.068		0.088	0.057	0.216	0.127		2.91	0.199	0.103		0.128	2.77
4-Methylphenol																	0.0424				
Acenapthene																	0.072				
Anthracene																	0.035				
Benzo(a)anthracene	0.224 mg/kg(b)																				
Benzo(a)pyrene	0 0609 mg/kg(b)													0.043							
Benzo(k)fluoranthene								0.056				0.085		0.046							
Benzoic Acid				0 094	0.123			0.068			0.052						0.094				
Butyl benzyl phthalate	20 000 mg/kg(a)	0.167	0 255		0.143				0.093	0.167				0.062	0.221	0.212	0.087			0.212	0.057
Di-n-butylphthalate	8.000 mg/kg(a)		0 135		0.063	0.086	0.068	0.134	0.138	0.103	0.085		0.087			0.452	0.039				1.67
Di-n-octylphthalate	8,000 mg/kg(b)	0.052					0 063	0.025							0.049	0.142	0.125			0.21	
Dibenzofuran																	0.04				
Dimethyl phthalate					0.044																
Fluoranthene		0.149	0.098				0.074	0.078	0.036			0.125		0.209		0.093	0.142				
Fluorene														0.216			0.065				0.073
Naphthalene		0.144												0.832			0.102	0.058		0.102	0.669
Phenanthrene		0.156	0.175	0.037			0.083	0.075				0.14		0.347		0.174	0.161				0.043
Phenol	3,000 mg/kg(b)															0.064					
Pyrene		0.162	0.087		0.086		0.222	0.111	0.0689		0.065	0.295		0.178	0.05	0.098	0.165			0 04	
bis(2-Ethylhexyl) phthalate	50 mg/kg(a)	1.39	1.89		2.14	0.687	0.956	0.58	0.408	0.531	0.689	2.34	0.0958	0.107	0.424	1.46	1.36		[illegible]	0.475	[illegible].74
Polychlorinated Biphenyls (mg/kg)																					
Aroclor-1016	10 mg/kg,total(d)	0 046	0.088		0.029	0 109	0.135	0.014		0.021	0.028	0.334			0 027	0.04	0 046				
Aroclor-1260	10 mg/kg,total(d)	0 09	0 059		0 042	0 034	0 047	0.131		0.078	0.165	0.088	0.03		0 03	0 064	0 044		0.022	0 049	0.047

(a)Proposed RCRA Criteria for Action Levels, U.S. EPA, July 27, 1990

(b)RCRA Facility Guidance, EPA 530/SW-89-031, May, 1989

(c)Interim Guidance for Establishing Cleanup Levels at Superfund Sites,OSWER Directive 9355.4, September 7, 1989

(d)40 CFR 761

TABLE 4
Hazardous Waste Yard Soil Sample Results
Organic Compounds

		Sample Locations			
	Criteria	DY1	DY2	DY3	DY4
Volatile Organic Compounds (mg/kg)					
Acetone	8,000 mg/kg (a)	0.004		0.007	0.009
Methylene Chloride	90 mg/kg (a)	0.004	0.004	0.006	0.005
Semi-Volatile Organic Compounds (mg/kg)					
Acenapthene				0.11	
Benzo(a)anthracene	0.224 mg/kg (b)				0.079
Benzo(a)pyrene	0.0609 mg/kg (b)				0.042
Benzoic Acid					0.198
Butylbenzylphthalate	20,000 mg.kg (a)			0.079	
Di-n-butylphthalate	8,000 mg/kg (a)			0.096	0.048
bis(2-Ethylhexyl)phthalate	50 mg/kg (a)	0.072	0.07	0.358	0.16
Fluoranthene				0.251	0.216
Flourene				0.077	0.05
2-Methylnaphthalene		0.151		0.2	
Phenanthrene				0.17	0.324
Pyrene				0.336	0.226
Polychlorinated Biphenyls (mg/kg)					
Aroclor-1260	10 mg/kg, total (c)	0.015	0.009	0.037	0.021

(a) Proposed RCRA Criteria for Action Levels, U.S. EPA, July 27, 1990
(b) RCRA Facility Guidance, EPA 530/SW-89-031, May 1989
(c) 40 CRF 761

TABLE 5
Fortress Rocks Landfill and Hazardous Waste Drum Area Soil Testing Results
Field Screening and Laboratory Analytical Results for Organics

Landfill Grid #	Screening Results		Laboratory Results					
	Volatiles (ppm)		Total Volatiles (µg/kg)			Semi-Volatiles (µg/kg)		
	Average	Maximum	IDed	TIC	Total	IDed	TIC	Total
16	17	21	14	39	53	1157	34320	35477
59	16	19	12	18	30	836	65710	66546
20	13	16	8	0	8	131	2440	2571
24	16	19	8	0	8	2650	23030	25680
37	22	36	7	769	776	773	56410	57183
51	20	46	13	2262	2275	1764	35130	36894
75	12	15	25	16	41	1180	19890	21070
83	16	34	6	7	13	801	47210	48011
68	11	16	6	11	17	957	23020	23977
39	16	22	17	1489	1506	2985	124100	127085
43	19	85	28	4990	5018	399	43480	43879
34	11	13	14	25	39	744	10960	11704
88	180	180	8	3460	3468	5604	38440	44044
89	40	40	13	325	338	2727	22480	25207
90	24	24	8	136	144	161	6630	6791
91	18	18	6	51	57	100	15750	15850
92	20	20	8	51	59	1167	37600	38767
93	20	20	22	14	36	7022	21380	28402

Drum Yard Grid #	Screening Results		Laboratory Results					
	Volatiles (ppm)		Total Volatiles (mg/kg)			Semi-Volatiles (mg/kg)		
	Average	Maximum	IDed	TIC	Total	IDed	TIC	Total
DY1	13	22	0.008	0.46	0.468	0.223	32.8	33.023
DY2	4	8	0.004	0	0.004	0.07	8.94	9.01
DY3	18	37	0.013	1.439	1.452	1.677	30.39	32.067
DY4	12	22	0.014	0.14	0.154	1.383	49.99	51.373

Screening = Photoionization Detector Results
Laboratory = Gas Chromatograph/Mass Spectrometer Analysis Results
IDed = Quantified Target Compounds
TIC = Tentatively Identified and Quantified Compounds

TABLE 6
Soil Testing Results
Fortress Rocks Landfill
Metals

Sample Location		18	59	20	24	37	51	75	75Dup	83	88	39	43	43Dup	34	88	89	90	91	92	93
Metals (mg/kg)																					
	Criteria																				
Aluminum		33200	34400	31000	29500	33000	25400	31600	30800	30600	36800	30500	35000	38200	30100	35000	31200	31300	32700	28500	32000
Antimony	30 mg/kg(a)	4.64				4.12	8.47									6.2	5.1		4.7		4.8
Arsenic	80 mg/kg(a)		2.50														1.69	1.49			
Barium	4,000 mg/kg(a)	135	230	108	164	183	150	157	158	153	178	182	134	185	162	479	209	159	139	110	142
Beryllium	0.2 mg/kg(a)	1.6	1.4	1.5	1.3	1 5	1.2	1.5	1.3	1.4	1.8	1 3	1.9	1 89	1.2	1.2	1.26	1.22	1.41	1.1	1.3
Cadmiu	40 mg/kg(a)		2.15			0.99						1 1				3.9			1.3		
Calcium		23200	24900	20800	18600	21700	20600	19400	16000	21000	23500	21100	20200	22300	21700	26100	22000	21900	17300	15300	22700
Chromiu	80,000 mg/kg(b)	32	72 5	32.6	37.5	48.1	27.6	42 2	36.6	40.5	34.2	41.2	15.6	15.4	52.5	42 6	42.5	34 9	27.3	21.5	35.5
Cobalt		28 4	41.7	29 50	32.9	35.5	27.5	30 5	35	35.2	32.8	35.5	23.7	30	38.3	37 2	35.9	34 8	32.7	30.1	33.5
Copper		96 2	170	17	48	44 5	40 4	55	64 4	26.4	85.4	332	17.1	19.7	70.1	99 5	78 9	31.3	20.4	21.9	35 9
Iron		37600	60300	41900	45200	46500	38900	44300	45800	44900	43700	45100	31100	37700	46000	46100	42900	44000	41300	36800	43600
Lead	500-1,000 mg/kg(c)	72.1	152	2.3	229	58.8	27.7	214	161	17.9	46.4	120	4.0	4.9	36.1	66 9	109	10.2	4.9	19.5	26.4
Magnesuim		22900	29200	20800	25900	24600	19100	23000	24800	29000	23500	23300	18000	20400	26000	24000	23100	23600	23400	21100	24200
Manganese		686	885	797	747	825	674	778	762	789	794	759	626	688	802	805	779	769	613	659	756
Mercury	20 mg/kg(a)																				
Nickel	2,000 mg/kg(a)	69.5	96	69	92.5	76.8	58	79	85.7	93.6	148	499	50.2	54.4	92.9	82 6	77	78	184	75	72
Potassium		7520	10000	6910	7700	9370	7260	8670	8530	8240	10300	7920	9780	10500	7780	8020	8480	7490	8380	6500	7540
Selenium																					
Silver	200 mg/kg(a)	0.320	0.180													0.414	1.28				
Sodium		16800	15800	11600	14200	14000	12100	14400	15100	14600	18900	13200	20700	21900	13300	13900	13800	12200	14900	12800	13400
Thallium																					
Vanadium		114	122	90 2	93.4	110	87	91.8	88.4	102	107	97	88	94.1	105	103	94.2	93.9	87.1	75.2	92.4
Zinc		227	614	51.6	123	181	211	254	334	107	148	273	43.2	53.2	374	1180	391	115	65.7	90	94.3

(a)Proposed RCRA Criteria for Action Levels, U.S. EPA, July 27, 1990

(b)RCRA Facility Guidance, EPA 530/SW-89-031, May, 1989

(c)Interim Guidance for Establishing Cleanup Levels at Superfund Sites,OSWER Directive 9355.4, September 7, 1989

TABLE 7
Hazardous Waste Yard Soil Sample Results
Metals

		Sample Location			
	Criteria	DY1	DY2	DY3	DY4
Metals (mg/kg)					
Aluminum		31200	28500	25600	22900
Arsenic	80 mg/kg (a)			1.2	1.40
Barium	4,000 mg/kg (a)	162	143	135	111
Beryllium	0.2 mg/kg (a)	1.25	1.23	1.1	0.94
Cadmium	40 mg/kg (a)	1.60	1.21		
Calcium		16000	15700	15200	13500
Chromium	80,000 mg/kg (b)	35.8	31.8	18	14.4
Cobalt		37.3	32.9	24.7	20
Copper		19.7	16.9	19.3	15.8
Iron		42400	38600	30600	26000
Lead	500-1,000 mg/kg (c)	8.7	10.8	36.7	34.3
Magnesium		24400	24300	18400	16300
Manganese		718	686	540	486
Nickel	2,000 mg/kg (a)	81.1	85.4	65	61.1
Potassium		8240	7640	7100	6120
Sodium		15700	20700	12500	12200
Vanadium		91.2	87.4	64.7	55.5
Zinc		64.7	58.4	58.6	51.9

(a) Proposed RCRA Criteria for Action Levels, U.S. EPA, July 27, 1990
(b) RCRA Facility Guidance, EPA 530/SW-89-031, May 1989
(c) Interim Guidance for Establishing Cleanup Levels at Superfund Sites, OSWER Directive 9355.4, September 7, 1989.

TABLE 8
Fortress Rocks Landfill Soil Testing Results
Toxicity Characteristic Extracts

Sample Location:		Grid 59	Grid 24	Grid 75	Grid 88	Grid 89
Field Sample No.:		69286	69296	69311	69341	69346
	Criteria (a) (mg/L)					
TCLP Metals (mg/L)						
Arsenic	5.0					
Barium	100.0	0.0889	0.044	0.107	0.0505	0.040
Cadmium	1.0	0.0532			0.894	0.0298
Chromium	5.0	0.127		0.0848	0.0404	
Lead	5.0			0.796		3.450
Mercury	0.2					
Selenium	1.0					
Silver	5.0					

(a) 40 CFR Part 261.24, Toxicity Characteristic

TABLE 9
Fortress Rocks Landfill Asbestos Analytical Results

Grid Number	Chrysotile	Amphibole
16	ND1	ND1
59	ND1	ND1
20	ND1	ND1
24	ND1	ND1
37	ND1	ND1
51	ND1	ND1
75	ND1	ND1
83	ND1	ND1
68	ND1	ND1
39	ND1	ND1
43	ND1	ND1
34	ND1	ND1
88	ND1	ND1
89	ND1	ND1
90	ND1	ND1
91	ND1	ND1
92	ND1	ND1
93	ND1	ND1
75 Duplicate	Trace	ND1
43 Duplicate	ND1	ND1

ND1 = None detected, 1% detection limit

TABLE 10
Fortress Rocks Landfill Water Testing Results

Sample Location:		Landfill 1	Drum Yard 1
Field Sample No.:		74380-74382	74386-74398
	Criteria		
Volatile Organic Compounds (mg/l)			
Acetone	4.0 mg/l (a)	0.011	
Ethylbenzene	4.0 mg/l (a)	0.001	
Methylene Chloride	0.005 mg/l (a)	0.004	0.002
Toluene	10 mg/l (a)	0.002	
Trichloroethane	3.0 mg/l (a)		0.001
Semi-Volatile Organic Compounds (mg/l)			
	N/A	None detected	None detected
Polychlorinated Biphenyls (mg/l)			
	N/A	None detected	None detected
Metals (mg/l) (8 RCRA metals shown)			
Arsenic			
Barium	1 mg/l (a)	0.128	
Cadmium			
Chromium			
Lead			
Mercury			
Selenium			
Silver			

(a) Proposed RCRA Criteria for Action Levels, U.S. EPA, July 27, 1990.

Total concentrations of the eight RCRA metals in the soil samples were reviewed to determine if soils contained high enough concentrations of metals to potentially exceed the leachate criteria defined under RCRA. Consistent concentrations of barium and chromium were detected in all of the soil samples; lead was detected in all of the soil samples at varying concentrations ranging from 2.3 mg/kg to 224 mg/kg.

Four soil samples exhibiting the highest values for lead (the RCRA metal detected in the majority of the soil samples), at landfill locations 24, 59, 75, and 89, were selected for Toxicity Characteristic Leaching Procedure (TCLP) analysis to determine if the lead present in the soil samples is present in a form and concentration which could result in leachate in exceedence of the RCRA criteria. Additionally, the sample from landfill location 88 was selected for TCLP analysis due to the presence and relative concentrations of four RCRA metals: barium, cadmium, chromium, and lead. Table 8 presents the data for the RCRA metals analyses of the TCLP extracts from the five landfill soil samples previously described. Various concentrations of up to four RCRA metals (barium, cadmium, chromium, and lead) were detected in the TCLP extracts from the soil samples from the landfill.

Table 9 presents the results of the asbestos analyses in the landfill soil samples. Of the 20 samples analyzed, only one sample, the duplicate soil sample from grid 75, had detectable levels of asbestos: a trace of chrysotile, at the method detection limit of 1%.

The results of the laboratory analyses for the landfill and waste yard water samples are presented in Table 10. For the volatile and semi-volatile parameters, only those compounds present at levels above one-half the quantifiable detection limit of a method in any of the water samples are listed.

Four volatile organic compounds were present in the landfill surface water sample: acetone (11.3 μg/L), methylene chloride (3.57 μg/L), ethylbenzene (1.35 μg/L), and toluene (1.8 μg/L). Only methylene chloride (1.62 μg/L and trichloroethane (1.11 μg/L) were present in the waste yard drainage ditch water sample. One tentatively identified volatile organic compound was present in the landfill surface water sample: trichlorofluoromethane (22 μg/L). Only one volatile organic compound was detected in the equipment blank sample: methylene chloride (4.02 μg/L). All of these compounds were detected at concentrations below the method detection limit. Acetone and methylene chloride are common laboratory contaminants; methylene chloride was detected in the associated laboratory blank. In addition, the compounds were detected at low concentrations (i.e., below 15 μg/L or parts per billion) suggesting laboratory contamination as the probable source.

No semi-volatile compounds or PCBs were detected in the surface water sample collected at the landfill or the equipment blank sample. No tentatively identified semi-volatile organic compounds were present in any of the water samples.

Various concentrations of metals (alkali, alkali earth, and heavy) were detected in the water sample from the depression adjacent to the landfill. The eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) are of particular interest since EPA has published maximum contaminant levels (MCL) for these constituents. Of the eight RCRA metals, only one, barium, was detected above the method detection limit and only in the landfill surface water sample (128 mg/L) and the equipment blank sample (76 mg/L).

Environmental Assessment

The organic and inorganic constituents detected in the Fortress Rocks Landfill and in the Hazardous Waste Yard surficial soils were compared to the proposed U.S. EPA criteria for action levels for cleanup at hazardous waste management facilities (40 Code of Federal Regulations (CFR) Parts 264, 265, 270, and 271), and to the Toxic Substances Control Act (TSCA) standards (40 CFR Parts 700-799). While these regulations are not applicable to the Fortress Rocks Landfill or Hazardous Waste Yard sites at McMurdo, they are the current guidelines applied to RCRA-regulated sites in the U.S. by Federal and State environmental officials for cleanup actions. The proposed RCRA action levels are based upon health risks of exposure to the constituents of concern. While site-specific conditions also affect the use of the RCRA values, they are presently the only available general remediatiom guidelines from the U.S. EPA for soil-based contamination concentrations. Tables 3, 4, 6, and 7 present the available action levels which have been proposed for those organic and inorganic constituents detected in the soil samples.

None of the organic compounds (volatiles, semi-volatiles, polychlorinated biphenyls) were detected in the soil samples from the landfill or waste yard at concentrations above the cleanup action levels. The total metals concentrations detected in the soil samples for arsenic, cadmium, chromium, lead, and silver, are also below the proposed action levels for cleanup in soils.

Total polychlorinated biphenyls (Aroclor 1016 and Aroclor 1260) were detected in eleven of the twelve random grid landfill locations, five of the six judgement grid landfill locations, and all four of the waste yard grid locations. The maximum level of total PCBs detected in the soil samples was 193.8 μg/kg in landfill location 68, two orders of magnitude lower than the soil cleanup level of 10 parts per million (10 mg/kg) specified for low concentration PCB spills in 40 CFR Part 761.

Samples of the surface water, collected by AECOM after the cleanup of the landfill and waste yard were completed, were found to contain only minimal concentrations of just a few compounds. These concentrations when compared to Federal Ambient Water Quality Criteria (AWQC) for the protection of aquatic life show that the levels are well below the established criteria (see Table 11); criteria established to protect aquatic organisms that live in surface-water bodies.

TABLE 11
Ambient Water Quality Criteria
for the Protection of Aquatic Life (mg/L)

Compound	Pond Water Concentration	Fresh Acute Criteria	Marine Acute Criteria	Fresh Chronic Criteria	Marine Chronic Criteria
Acetone	0.011	NA	NA	NA	NA
Ethylbenzene	0.001	32	0.43	NA	NA
Methylene Chloride	0.004	NA	NA	NA	NA
Toluene	0.002	17.5	6.3	NA	5.0
Barium	1.0	NA	NA	NA	NA

NA = None available

CONCLUSIONS

The Fortress Rocks Landfill and Hazardous Waste Yard remediation was a successful operation which removed unsightly, potentially hazardous materials from Antarctica. The task was completed on time, in a safe manner, with all waste prepared for retrograde and most waste returned to the continental United States at the end of the 1991-1992 season.

In all, approximately 1,000 bales of metal were loaded in flatracks and shipped to the United States, and 800 bales remain staged to be retrograded in the 1992-1993 season. Thirty eight flatracks full of large bulk metal were retrograded to the United States. Seventy-five cubic yards of wood, 400 cubic yards of cardboard, 53 yards of construction debris, and 53 yards of asbestos waste were retrograded. A total of 682 drums of hazardous waste and hazardous materials and 86 drums of non-hazardous waste were also loaded into milvans and shipped to the United States for RCRA treatment and disposal.

Results of the surface water sampling and analyses in the snowmelt and icemelt pond at the Fortress Rocks Landfill and drainage ditch adjacent to the Hazardous Waste Yard indicated the presence of a few organic and inorganic compounds which were compared to the U.S. EPA criteria for cleanup action levels at hazardous waste management facilities, as well as to the ambient water quality criteria for protection of aquatic life. No contamination of surface water runoff is indicated which would warrant further actions. Currently, very little runoff from the surrounding hillsides crosses the landfill or the waste yard. There were no signs of erosion in these areas.

An exposure assessment based on the soil and water sample results from the Fortress Rocks Landfill and Hazardous Waste Yard indicates that while certain organic and metal constituents were detected, the impacts to human and ecological receptors are below risk-based criteria, and are therefore negligible.

Further excavation of the landfill is not advised and, if conducted, should only be performed in accordance with NSF environmental impact assessment policy. Any backfill used to level the area should be imported from outside the landfill. Future use of the area formerly occupied by the landfill is feasible but access should be controlled and excavation that could expose buried debris or redirect runoff into the landfill should be avoided. The installation of a soil cap (4 inches or greater) is recommended in order to fill depressions, provide a finished grade to the area, and cover any residual contaminants that were detected in the soil.

Future waste storage and handling will be performed in two ways. Non-hazardous waste will continue to be stored for retrograde in the cleaned up waste yard. All hazardous waste will be handled and stored in a separate RCRA storage area. Recent efforts to implement a USAP System and protocol for identifying, labeling, handling, and transporting hazardous and non-hazardous waste will eliminate any future accumulation of large quantities of unknown waste.

Selection and Management of British Antarctic Personnel for Prolonged Service in Antarctica

by
J. R. W. Hanson
British Antarctic Survey, UK

ABSTRACT

The British Antarctic Survey (BAS) is the only Antarctic operator which routinely overwinters personnel for two consecutive years. The BAS stations have wintering populations of between 3 and 20 personnel and are completely isolated for periods of up to ten months. Accommodation is quite restricted in size with limited individual living space. There is a particular need for self discipline and consideration for others whilst in the Antarctic. It is, therefore, essential when selecting staff to recruit those who will form a team which is well balanced, both in respect of technical skills and, arguably more important, as a social unit. Alongside technical capability, other factors considered include character, age and marital status. The process of selection, medical screening, pre-tour briefing and training are examined.

BAS management in the UK is responsible for maintaining a high profile scientific programme, and it also has a high degree of responsibility for the well-being of individuals serving in the Antarctic. Vital to this is maintaining good liaison with next of kin, together with medical and welfare assistance as needed. It is important that Antarctic based personnel can be confident of the UK management commitment and support.

The Station Commander provides the essential link between the Antarctic workforce and UK management. This role in establishing routine, providing positive leadership and maintaining morale and discipline is considered.

Regular visits by senior staff during Antarctic summer seasons strengthen the management of the stations.

Introduction

The Polar explorer Ernest Shackleton rationalised his approach to recruitment as follows:-

"The qualities ... necessary to the explorer are ... in ... order of importance: first optimism, second patience, third physical endurance, fourth idealism, fifth and last courage ...". He observed "... few men are wanting in courage but optimism nullifies disappointment and makes one more ready than ever to go on ... impatience means disaster ..., physical endurance will not compensate for the first two morale and temperamental qualities."

The emphasis of the BAS approach to recruitment relates essentially to the selection of personnel for a research station as distinct from an exploration team, though in many respects Shackleton's list of qualities are still apposite for those selected to undertake a prolonged Antarctic tour. The policy of the Survey is to carry out timely, relevant and innovative science (with minimum environmental impact) on the inter-dependent physical, chemical and biological processes in Antarctica. The unique natural laboratory provided by the Antarctic enables BAS, and the other national operations, to study questions of global and regional significance. Fundamental to success in this endeavour is the need for a motivated, well trained and well managed workforce.

Prolonged service with the Survey usually entails a tour of two consecutive winters - on average 30 months will be spent overseas. Whether a potential candidate is a scientist, technician or tradesman, the prime motivation for individuals applying to serve with BAS must be a genuine desire to work in a hostile environment together with the willingness and ability to live harmoniously in a small, isolated and closely knit community. The Survey places great emphasis on personal qualities while recognising that there must be genuine scientific or trade ambition as well.

The rationale behind the two winter tour is based on valued continuity of long term science programmes and station life and takes into account safety, logistic and economic advantages. The aim is to replace half the scientific and support complement of each station every Antarctic season, thus retaining a core of experienced second year personnel. Ships itineraries and personnel movements are planned to allow beneficial handovers between incoming and outgoing personnel. In these ways knowledge, understanding and expertise that can be gained only on the Antarctic station, and not just in training back home, is passed to each new team. The benefits to the organisation are continuity and stability. It is also the Survey's experience that the second winter provides the confidence and time for individuals to gain maximum reward from this opportunity to experience Polar life.

The Survey has a total staff complement averaging 454. Permanent scientists, administrators and ships' personnel account for 256, while 198 staff are employed on short term contracts usually of three to five years duration. The overwintering teams fall into the contract staff category. During the austral winter of 1992, 58 personnel are overwintering on five stations with complements ranging from three to 18. With the exception of the smallest station, Bird Island, each requires the following support staff in addition to the scientific complement:-

Communications Manager
Diesel Electric Mechanic
Electrician
Builder/Carpenter
Cook
and Medical Officer

On some stations other specialist needs include Heat and Ventilation Engineer, Vehicle Mechanic, Steel Erector, Boat Operator, Diver and Field Assistants (Table 1).

Living accommodation on all stations is restricted in size. There is a communal dining area and an adjacent lounge. A library provides a quiet room. Personnel sleep in bunk rooms designed for up to four people, although during the winter two per room is typical. A wide range of recreational facilities are provided. It is usually difficult to find privacy on the stations other than at an individual's work place, and opportunity to move freely around the locality may be restricted by terrain and often by the weather. Apart from the importance of achieving wintering complements of individuals with the necessary personal and professional qualities, the Survey has until recently imposed three requirements; namely that they are aged between 21 and 35 years, male, and single. Recruitment of wintering personnel over the age of 35 is not out of the question but a rare occurrence. When and where circumstances do require consideration of the over-aged candidate the possible relative social isolation caused by the distancing of age related commonalities requires a cautious approach. More recently, following a gradual and controlled move through the 1980's towards equal opportunities, it is likely that women will winter at Signy Station for the first time in 1993.

The average age of wintering personnel is in the mid 20's. Experience suggests that lengthy absence from home is more readily undertaken, both personally and professionally, by younger people. The scientific studies promote post graduate opportunities appropriate to the early career days and support posts are usually suitable for young technicians who have completed apprenticeships.

SELECTION

Successful recruitment has been and remains fundamental to the achievements of BAS. The selection process can be broadly identified as covering six essential elements:

The advertising of posts and provision of information to prospective candidates

A comprehensive application form

The obtaining of references, both professional and character

The interview

Medical screening

Post selection evaluation

Each of these is briefly considered.

1 Advertising and Provision of Information to Prospective Candidates

While the scientific discoveries and observations pertaining to Antarctica have given the Survey a high profile in recent years, it is a very necessary part of the selection process to publicise Antarctic employment opportunity. The aim must be to attract and enthuse a strong field of potential candidates - final selection will only ever be as successful as the strongest individual who has been encouraged to apply.

Notification of vacancies appear in the British national press and in scientific and trade journals. Non-specific reference to employment opportunity with the Survey appears in many employment publications, and the reputation of the organisation often attracts speculative enquiries. Regular presentations to universities and other groups help promote the concept of opportunity for demanding and worthwhile employment with adventure. General publicity about the Antarctic is widely distributed in the form of educational "hand outs". Documentation introducing the prospective candidate to the Survey's work and activities is included with every application form despatched. Details of the post applied for are provided, together with a summary of the terms and conditions of employment.

2 The Application Form

The application form is the first real opportunity for individuals to present their qualities to the Survey. It is therefore intentionally detailed and searching. Completion, in a candidate's own handwriting, requires time and effort - for example candidates are asked for a short dissertation outlining the relevance of their experience and the strength of their desire to serve in the Antarctic. The objective is to give (in confidence to BAS Management) valuable professional and personal information about the candidate from which an experienced team can make reliable and fair judgement when shortlisting for interview. Although the number of applications per vacancy averages between 20 and 40, popular positions may attract upwards of 100 completed forms. It is the Survey's policy to shortlist and interview a maximum of six candidates for any one position (in practice the average is 4.5 interviews per position) - thus it is important that the food for thought provided by comprehensive recruitment literature followed by careful completion of the application form will reflect the candidate's serious interest for consideration. The application form will have failed the recruitment process if the uncommitted candidate cannot be eliminated from the exercise at this stage.

3 References

The confidential reference and its value in helping to assess candidates sometimes meets with scepticism in today's employment market. So long a traditional aid to recruitment, it is a time consuming exercise for all concerned. The principal arguments standing against the use of the reference are that no one is likely to put forward a referee whom they consider could be detrimental to their ambition to secure the post, and that most referees will in any case wish to comment with a favourable bias on the individual. The Survey selects staff very much in the traditional way and experience bears out that the genuine reference, easily recognisable to the trained eye, does remain a helpful and revealing element in the selection process. For example, a reference from an immediate contemporary is often uninhibited and much insight can be gained from the referee whose unsolicited comments go beyond what was requested. Professional feedback from educational establishments, from past and present employers and personal comment from friends and colleagues must be read in conjunction with the application form and references can be used with tact to unravel ambiguity at interview. In this way they give important indications to the real qualities and character of the individual. Lastly, references offer a degree of reassurance to those most closely involved in the selection process.

4 The Interview

The interview is the single most important element of the Survey's recruitment process. This is a one hour formal meeting between selection panel and candidate. It allows a team with interdisciplinary expertise and current detailed knowledge of BAS an opportunity for shared assessment of an individual's professional and personal suitability for Antarctic service. The interview must result in a confident, well judged decision but it is also necessary to ascertain that the candidate has the necessary understanding on which to base a decision should an offer of employment be forthcoming.

The selection panel, usually three in number, is always chaired by one of the Survey's Personnel Officers who will have a non-dominant but key role in co-ordinating and controlling proceedings. (It is noteworthy that, in the interests of continuity and standards, just six individuals have had responsibility for chairing Antarctic selection panels over the past 20 years.) Ideally all members of the panel will be skilled interviewers for whom formal training is a prerequisite to their involvement in the selection exercise.

Quality and thoroughness at interview are promoted by the selection panel's prior study of the candidate's application form and references. While the interview will be testing and demanding for the candidate, the emphasis is very much on the panel placing the interviewee at ease. The simple philosophy of asking questions that will lead to conversation and open exchange of ideas is designed to create a meaningful, but not intense, atmosphere to encourage the candidate to reveal true ability, potential, character and feelings (see Table 2). No two interviews are identical but it is important to ensure that the level of questioning is consistent in order that the panel has a standard against which to base judgement of all candidates. It is also important to establish that all candidates receive a "fair hearing" and in this respect the selection panel will have failed if the candidate does not do most of the talking.

At the end of every interview an assessment form is returned by each member of the selection panel. Completion requires evaluation of key qualities, a mark for professional and personal suitability and brief written appraisal. This well practised system brings a sharp focus to decision on suitability. Given the spread of qualities deemed essential for a prolonged Antarctic tour, the successful candidate will show a good balance of professional skill and social awareness but will not necessarily be the most academically qualified or technically skilled.

Training can compensate for minor deficiencies identified in respect of work skills. The same is not true of the candidate who leaves doubt in respect of personal quality. Experience shows that giving a candidate "the benefit of the doubt" tends not to favour the organisation - equally, pressure to appoint due to time constraint or a weak field of candidates can work against successful selection in the long term.

The value of comprehensive follow up after the interview is another part of the selection process deserving of comment. First choice candidates may decline an offer of employment, and other acceptable candidates may respond favourably to a late offer if post interview communication has been swift and sympathetic. It is also likely that "near miss" candidates can be encouraged to re-apply another year. The public image of the Survey will gain credence, and goodwill will be maintained if the unappointed candidates can recognise that care and genuine interest in their application has been shown.

5 Medical Screening

The provision of an integrated system of health care for the British Antarctic Survey includes pre-employment medical examinations for all personnel in order to establish medical fitness for the prolonged, isolated tour. Medical examination is carried out immediately following interview. Usually this means offers of employment can be made swiftly and with confidence but when necessary the system does permit the time and opportunity for clarification over any doubt regarding medical fitness.

All potential candidates complete an "application medical form". This is received, in confidence, as part of the main application document. The form introduces the requirements of the medical assessment including blood grouping and associated testing (specifically HIV testing is referred to). Examples of medical disorders which might preclude medical fitness for Antarctic service are listed. Time will be saved in the recruitment process by identifying, at this stage, individuals who reveal conclusive evidence of being unsuited to an Antarctic tour from the medical viewpoint. Of equal importance in providing the potential candidate with medical guidance and policy at an early stage, is the opportunity afforded to discontinue an application with the reasons for doing so remaining entirely confidential to the individual.

6 Post Selection Evaluation

Following appointment "the new Antarctic recruit" will receive training appropriate to profession or trade and attend a comprehensive pre-tour briefing and first aid course. In addition, a short practical introduction to the basics of BAS field craft and field safety is an essential part of preparation. Throughout this training period, during the subsequent travel to the Antarctic and also during the initial period of "settling in" on the station, the suitability of those appointed is under continuous scrutiny by Line Management, Station Commanders, Ships' Masters and other senior staff. The major concern is to identify anyone who demonstrates evidence of not fitting successfully into the Antarctic way of life. If appropriate counsel and warning does not provide rapid and sustained improvement in attitude and/or behaviour, early termination of contract is initiated. Alternatively or concurrently, throughout this evaluation period the new recruit may conclude that the commitment to overwinter in the Antarctic is a mistake. In such cases early discussion with management is encouraged and welcomed. Time and logistic factors may count against replacement, but it is not in the interests of organisation, the rest of the overwintering team or the individual to retain anyone on Antarctic duty against their will.

Appraisal of Selection Procedures

The Survey has had 35 years of selecting personnel using the procedures which have been described. Over this period there has been appraisal, modification and refinement and efforts continue to improve the system in the desire to attract, appoint and retain quality staff. Consideration of the six main elements of the recruitment process shows a logical progression from first enquiry to appointment. Immediate observations will identify the large amount of staff time and effort afforded to the exercise and the absence of personality, special aptitude, attainment or any other form of psychological test. The success rate in choosing staff is high; in the order of 95% as shown in Table 3. The Survey does not, however, dismiss the value and use of other aids in the recruitment process and different concepts are kept under review. The results do not suggest reason to change at present.

MANAGEMENT OF PEOPLE

Working in Antarctica with the Survey is a civilian occupation where the employee is destined to spend both working and leisure hours in the confined environment of a research station with the same individuals for company - all are therefore exposed to the strains and stresses of everyday life with an intensity which may not be found in more conventional work environments.

The BAS employee in the Antarctic is deemed to be on duty at all times throughout a tour. Likewise, as a caring and responsible employer, the Survey carries 24 hour responsibility for the health and safety of the workforce which must be met by a strong and just management philosophy. Ultimately the responsibility rests with the Director of the Survey who relies on a dedicated team of senior managers to determine and administer policy. The management strategy must allow high morale and an "esprit de corps" to flourish in the workforce, while ensuring that good conduct and discipline are maintained through sensitive but firm leadership.

The Role of the Station Commander

This leadership, the essential link between the UK management team and the Antarctic employee, is provided by the "Professional" Station Commander. Success in this important position is fundamental to the BAS management philosophy and relies on the continuity of Antarctic experience afforded by an individual of proven Antarctic background, who will be intimately involved with the running of one station for a minimum of three years.

The Professional Station Commanders spend the austral winter of each year in the UK, leaving their Antarctic station in the hands of a "winter" station commander who will usually have the experience of at least one winter. Appointment will be made from the winter complement by the Director on recommendation of the Professional Commander; the "winter" commander will continue to undertake the scientific or support duties for which originally selected whilst meeting the additional leadership responsibility. (The Professional Station Commander will most likely have gained experience as a wintering Station Commander in the first instance.)

In the UK the Professional Station Commander will represent his station and his team by assisting and advising on project planning and logistics, as well as becoming involved in selection and the introductory field training of new recruits. He will usually accompany his new team to their Antarctic home, continuing to train and instruct in all aspects of Antarctic life and survival, whilst organising essential routine tasks and co-ordinating the often multi-disciplinary science on the station.

From this it can be inferred that both "Professional" and "Winter" Station Commanders must possess exceptional qualities of leadership and organisational skill to achieve success. When considering appointment of Station Commanders careful observation and experience will usually allow for the selection of an individual showing such potential. When, as has occasionally happened in the past, the Survey fails in appointing the "right" individual, management, station communities and individuals know to their cost the detrimental effect that a weak Station Commander has on the quality of life and the scientific endeavour.

The Station Commander must be authoritative and decisive, but his leadership should not be overbearing. If he is commanding successfully, he must show and maintain a high standard of personal discipline as an example to others and in order to evoke loyalty and co-operation from his colleagues. He must be sympathetic to the moods and needs of those in his charge, but remain impartial in order to judge fairly on any issue. He must maintain the morale of the community and act with alacrity to defuse tension. He must look to the needs and protection of the dispirited as well as the control of the extrovert and dominant members of his team. He should be close to his team yet not be too familiar or show favouritism. At all times he must represent the policy of the organisation, he must negotiate for his team when and where necessary, yet not be pressured over issues which may compromise his or Senior Management's authority. He must be ready to act quickly and judiciously to ensure that no situation gets out of hand and yet be vigilant to the dangers of his own action (if ill conceived) exacerbating rather than solving the problem in hand. It is expected that the Station Commander will have the confidence to handle routine morale and discipline issues without reference to the UK. The successful resolution of a problem handled with tact and sympathy at local level will likely increase respect in the leadership while the hurried, perhaps uncertain, reference to higher authority is unlikely to be beneficial in the solving of disputes. When in doubt the Station Commander must of course refer to higher authority for advice, giving an accurate and full account of the situation to be sure of receiving wise counsel.

It should be noted that responsibility and trust placed in the Station Commander of a British Antarctic Survey research station will often come at an early age when compared to more conventional management opportunity, and it will be appreciated that leadership of the workforce is but one, albeit vital, element of this challenging and fulfilling role.

The British Antarctic Survey HQ Management Team

12,000 km distance the Antarctic workforce from its management team. This geographical separation can create difficulties - an "us and them" situation. Good communications are fundamental to bridging this gap. If the Antarctic workforce can be kept as fully informed as possible about the policies and objectives of BAS, and also about more immediate planning concerns, and if they can be made to feel that they have a personal stake in the successful outcome of operations, co-operation and harmony will be more readily maintained.

Regular visits from the HQ management team help to keep this communication at a personal level. Such visits provide an "ear" to listen to any personal problems and other issues that cause concern. Liaison with individuals and observation of how they have adapted to their role and life in the Antarctic community can be compared to management's expectation of them at the time of selection. This provides most valuable insight and will often highlight areas of difficulty that can be addressed before they become a major issue.

Together, the HQ team and the Station Commander provide, through the management infrastructure, sustained but non-intrusive authority to maintain discipline. In Antarctica the need for discipline and considerate behaviour assumes a special importance. While disciplinary procedures exist, these are not formulated primarily as a means of imposing sanctions but rather to emphasise the need for high standards of conduct and, when necessary, to encourage improvement in these standards. The most effective form of discipline is self discipline which develops from a positive attitude to work and concern for the effort and convenience of colleagues. A code of conduct is necessary to make work and life on the research stations a more rewarding experience, to ensure the health and safety of the workforce and to meet the minor failures of self discipline which, although infrequent, are bound to occur. Within the daily routine of station life satisfactory conduct is essentially the application of common sense, but particular attention must be paid to aspects which may normally be taken for granted in wider communities:-

> Punctuality is important for efficient operation of the station and the avoidance of extra work for colleagues. Morale will be maintained if people keep normal hours.
>
> Duties must be carried out efficiently and to the best of ability. Equally, individuals are entitled to be informed clearly as to what their duties are and to whom they are responsible. Within the scope of an individual's duties all reasonable commands and instructions must be followed.
>
> Anti-social behaviour must be curtailed. For example, excessive noise, aggressive attitude and offensive personal habits can cause Antarctic employees to become an irritant to other station members and, in extreme circumstances, thoughtless or careless behaviour could jeopardise the community.
>
> Alcohol consumption and smoking guidelines must be followed. Persistent excessive intake of alcohol is dangerous and unnecessary. The station rules pertaining to smoking must be scrupulously obeyed.

Health and safety regulations must be observed within the full spirit of UK legislation.

In the close Antarctic community the un-acceptability of anti-social behaviour or minor offences will usually be quickly apparent to the perpetrator, and peer group pressure will likely prevent a recurrence. Likewise, for extreme offences the majority will be appreciative of the need for just imposition of sanctions. Sanctions, rarely used as shown by the low figure for dismissals in Table 2, range from verbal and written warnings to repatriation and dismissal. Minor offences include unsatisfactory work performance, acts of negligence, disobedience and disorderly behaviour. Assault, intimidation, wilful damage to property and repeated incapacity through misuse of alcohol or illegal possession or distribution of drugs are examples of the most serious breaches of discipline.

Medical and Welfare Support

However thorough the administration may be, it is important for morale that the Antarctic workforce can appreciate the continuous interest taken in their wellbeing. The availability of comprehensive medical care and welfare support, including regular contact with the next of kin, offers reassurance in this respect.

BAS has, for a number of years, provided medical care for staff in the Antarctic through supervisory links with consultant medical staff of the "Survival Centre" in Aberdeen. In addition to pre-employment medical screening the "British Antarctic Survey Medical Unit" managed within this Centre undertakes:-

Recruitment and preparation of medical staff to work on the Antarctic stations

First aid training for non-medical personnel

Emergency and routine specialist support for medical staff working in the Antarctic

Evaluation of the requirements for medical supplies and equipment

An overall advisory role on all matters relating to medical activities.

All consultations and medical incidents on the stations are held on a medical database. This assists in the development of the medical training programmes, helps to determine any requirement for changes in the standards of fitness for Antarctic service and guides judgement on the nature and quantities of equipment and drugs which need to be provided.

Secondary to the medical well-being of the Antarctic employee, the availability of small groups of healthy people in a "closed community" provides opportunity for both physiological and bacteriological study. Additionally, several short term medical studies are carried out with the health and safety of the Antarctic personnel foremost in mind. These include:-

Microbial testing on water supplies

The effect of an Antarctic tour on aspects of health

Vitamin C levels in the overwintering population

Ultra violet light exposure

Carbon Monoxide in tents during field travel

The Senior Medical Officer of the BAS Medical Unit maintains regular, confidential contact with the Survey's Personnel Section.

Within the small personnel team there are two designated "Welfare Officers", and one of these officers is also the "Next of Kin Liaison Officer". Availability of support to Antarctic staff and their families prior to, and particularly during, the first weeks of separation provides reassurance for the months ahead. Routine written and telephone contact with families throughout an individual's tour of duty ensures provision of up-to-date information on communication (mail) facilities and regular newsletters from the stations are circulated. Prior to departure for the Antarctic employees are encouraged to discuss (in strict confidence with the Liaison Officer) any family or personal matters where such knowledge may reduce the potential for embarrassment when in contact with next of kin. For example, mention of the poor health of an ageing relative or the hint or fear of parental separation will be of great assistance in understanding and handling what, in more normal circumstances, would be entirely private matters. Before departure, "briefing" from the Welfare Team will have stimulated thoughts on wide ranging issues such as passing and receiving sad news, and realisation that in the event of crisis at home early repatriation from the Antarctic is unlikely to be possible. The need for regular, two-way, open and honest exchange between employees and their next of kin is emphasised.

The opportunity to meet next of kin is welcomed. Ships' departures from UK ports, "Open Days" at Cambridge Headquarters, informal visits to the office to meet Personnel staff, and the need for occasional welfare visits to family homes usually provide the means to meet with all families at least once during a two year tour. Appreciative feedback suggests this contact, and the overall welfare service provided, is highly valued and worthy of the time and effort invested.

There are close links between Personnel Management and Welfare and Medical staff when considering the total well-being of all members of the Antarctic workforce, but it is important for those with the welfare responsibility to recognise the independence, confidentiality and unofficial nature of their duties when asked or required to help with any personal problems or difficulties which individuals encounter in their work or private lives. In all welfare matters due consideration is given to the fact that in the intense atmosphere of the isolated community even trivial matters may assume a great significance, and appropriate degrees of sympathy, understanding, advice and counsel must be given to all matters.

CONCLUSION

This paper has briefly considered one approach, the British Antarctic Survey's approach, to personnel issues in respect of the Antarctic workforce. It might be argued that if selection is correct successful management of the team will follow. There is some truth in this statement, but in reality risks are always present. Whatever the sophistication and experience of the selection process, however well-suited a candidate may seem for Antarctic service, it is impossible to predict the personal and team reaction to the reality of the long isolated tour. The British Antarctic Survey does not pretend to have "got it right" - we have no foolproof method; what we do have is a process evolved over many years which works well for our organisation. Working with and for people is an ever-changing process, each new generation of Antarctic workers will bring new challenges, triumphs, disappointments and failures both for the management team and the workforce for which it is responsible.

Elements of Ernest Shackleton's supposed newspaper advertisement:- "Men wanted for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful ....." appears bleak in contrast to the lot of the present day BAS employee, but success to date does not justify complacency. Consideration of future employment strategies is essential if the British Antarctic Survey is to maintain its position as a major contributor in the international science forum. As we move towards the 21st century the increasing sophistication of scientific research and the technical developments of the stations demand, more than ever before, a professional workforce of the highest calibre - and yet there are indications that in Britain (and possibly world wide) the availability of the <u>specialist</u> population will become more limited during the latter part of the decade. To remain competitive within this shrinking employment market key matters to be addressed will have to include length of service, salaries, pre-tour training and equal opportunity.

Reluctantly, BAS recognises that in the long term it may be forced to reduce contract length to one winter. Gone are the days when pay was secondary to the opportunity, challenge and romance of the Antarctic winter. In an ever shrinking world (soon the Survey's Rothera station will be just 24 hours by air from the UK) it is to be hoped that the spirit of adventure will not diminish. Increased training will be a statutory requirement in a safety conscious world. The full potential of women in the workforce has yet to be achieved. The implications of these considerations for the organisation in terms of Antarctic station life, logistics and resources and, chiefly, impact on the science cannot be ignored. In all of these, an underlying strength of the British Antarctic Survey's Personnel Management philosophy - the need for flexibility - must not be de-valued. Management and the Antarctic workforce must remain vigilant and adaptable to the changing and challenging scientific and logistic priorities that lie ahead.

References

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TABLE 1

OVERWINTERING COMPLEMENTS OF BRITISH ANTARCTIC SURVEY RESEARCH STATIONS 1992

	BIRD ISLAND 54°S, 38°03'W	FARADAY 65°15'S 64°16'W	SIGNY 60°43'S, 45°36'W	ROTHERA 67°34'S, 68°08'W	HALLEY 75°36'S, 26°42'W
Principal scientific disciplines	Ornithology and mammalogy	Surface meteorology, ozone, ionospheric physics, geomagnetism	Marine, freshwater and terrestrial biology	Geology, glaciology, airborne and terrestrial geophysics	Ionospheric physics, solar and terrestrial radiation, surface and upper air meteorology, ozone
Upper atmospheric physicists					3
Physicists/meteorologists		2		1	3
Electronic engineers		2			2
Marine biologists	1		1		
Assistant marine biologists			1		
Zoological field assistants	2				
Freshwater biologists			1		
Assistant terrestrial biologists			1		
Communications officers		1	1	1	1
Medical officers		1	1	1	1
Cooks		1	1	1	1
Steel erectors					1
Builder/carpenters		1	1	1	1
Heat & ventilation engineers				1	1
Electricians		1	1	1	1
Vehicle mechanics				2	1
Diesel electric mechanics		1	1	1	1
Boat operator			1		
Diving officer			1		
Field assistants				5	1
	3	10	12	15	18
Max summer complements	8	24	27	76	40

Wintering complements represent 35% science staff, 65% support staff. This ratio is due to the Rothera winter complement being all support in order to maintain the station and prepare for summer field activities.

TABLE 2

EXAMPLES OF QUALITIES CONSIDERED BY BAS SELECTION PANELS IN ASSESSING CANDIDATES PERSONAL SUITABILITY FOR ANTARCTIC SERVICE

a) Consideration for others
b) Dependability when working long hours under adverse conditions
c) Reliability and responsibility
d) Reasonable demands on associates
e) Respect for other points of view
f) Good appearance, cleanliness and tidiness
g) Capacity to set a good example of conduct
h) Potential for friction in restricted living conditions
i) Ability to follow instructions
j) Indication of stability
k) Sound approval and judgement of situations
l) Ability to direct others in a common project
m) Likelihood of success in working with and for others
n) Ability to create harmony
o) Willingness to subordinate when the situation requires
p) Existence of distasteful habits and personal characteristics
q) Humour
r) Involvement in clubs and societies
s) Sociability
t) Genuine interest in the outdoor environment

TABLE 3

ANALYSIS OVER A FIVE YEAR PERIOD TO SHOW NUMBERS OF INTERVIEWS, APPOINTMENTS, RESIGNATIONS, MEDICAL REPATRIATIONS AND DISMISSALS OF BRITISH ANTARCTIC SURVEY OVERWINTERING PERSONNEL

RECRUITING YEAR	1987/88	1988/89	1989/90	1990/91	1991/92	
TOTAL INTERVIEWS	124	172	190	204	160	850
TOTAL APPOINTED	26	38	46	47	32	189
RESIGNATIONS		4		10*	9*	23
MEDICAL REPATRIATIONS			1		1	2
DISMISSALS			1	4		5

NOTES:

1)* Includes 4 instances where individuals encountered difficulty within the community but carried out their duties satisfactorily and were encouraged to resign in the interests of future career prospects.

2) The one dismissal in 89/90 and one in 90/91 occurred prior to the individual departing for the Antarctic.

3) Statistics over the 5 year period show:-

a)	Wintering staff not completing full tours	15.88%
b)	Resignations	12.17%
c)	Medical repatriations	1.07%
d)	Dismissals	2.65%
e)	Dismissals and prompted resignations	4.76%

4) Of the 19 prompted resignations family and personal reasons accounted for 14, 5 were over concerns for the length of absence damaging career prospects on return.

Medical and Health Aspects of the Italian Antarctic Programme

by

F. Catalano and P. Giuliani
Italian Antarctic Research Programme

General considerations

Medical problems and medical emergencies which could be easily solved in normal urban or industrial environments, with the ready availability of medical personnel and facilities, can become very dangerous and complicated events in the harsh and remote Antarctic environment with its great distances, difficult and quickly evolving weather conditions, complex transportation organization.

Almost all Antarctic stations and bases are equipped with medical facilities, ranging from the very basic to the rather elaborate. Some stations have infirmaries and operating facilities, with appropriate equipment and medical supplies. Of course, medical doctors and paramedical personnel are important members of most expeditions.

An exchange of information among MNAP's on these subjects would be quite useful, in view of possible development of contingency plans for mutual help and assistance in case of incidents or accidents occurring at, or in the proximity of, bases.

This paper describes how the problems of health care have been addressed by the Italian National Research Programme in Antarctica.

It addresses the medical selection of personnel, the characteristics desirable in medical and paramedical personnel, the medical facilities and the medical supplies, the need for a measure of standardization among Antarctic bases.

Types of emergency charts proposed for different medical emergencies are presented, as well as the diving rules which have been formalized in 1989. Also, a brief outline of the training programme for perspective participants and the communication network of the Italian expeditions are given.

The present status of the Italian medical selection

Since the first Italian expedition in 1985 applicants have been selected in cooperation with the Medical Institute of the Italian Air Force, which performs the medical screening, and with the psychological unit of the Italian Navy, which traces their psychological profiles. It has been decided to leave the task of determining the fitness of the applicants for the specific jobs they should perform in Antarctica to established specialized organizations. The Medical Institute of the Air Force is used to evaluate individuals performing in difficult conditions, like military and civilian pilots, while the psychologists of the Navy do the psychological screening of divers and of submarine crews.

The present procedure has many limits, particularly because of the difficulty of properly organizing the medical selection. The cooperation with the two above mentioned Institutes is very good, but, of course, everyone has its own work methodology and sometimes it is not possible to modify it. The need of keeping the duration of the screening as short as possible, while obtaining as much information as possible often does not agree with their usual work routine. Furthermore, it is often impossible to modify their usual screening procedures on the basis of the most recent problems occurred, during the last expedition or of experience of other countries in Antarctica.

In the future it is hoped to organize new procedures to submit to the military Institutes or, perhaps, to create a specialized structure aimed at the evaluation of candidates for high risk expeditions.

Medical history

The perspective candidate is requested to fill in medical history form prior to the actual medical and psychological check.

This is needed both as a guide for the medical checks and to gain insight in the actual fitness of the candidate.

The form not only includes the standard medical questions, but also generic questions which may help the medical team to find out how a person takes care of himself and if he/she is aware of possible medical problems.

The medical history form used is very similar to those used by other Antarctic programmes (encl.). There are questions on the medical history of the candidate's immediate family, questions on past and present medical problems, if any, on past traumas, surgical operations, etc.. It is also requested that the personal physician of the candidate, if any, adds his/her comments.

Medical checks

The target of the medical check is to establish the fitness of the candidates to the Antarctic expedition, i.e., to be reasonably sure that they are in good shape medically and that no unforeseen problems should occur during their stay in Antarctica.

All perspective candidates to Antarctic expeditions are submitted to a complete medical and psychological check. It includes the following:

General medical visit

- lab tests:
    - complete blood analysis
    - complete urine analysis
- X-rays:
    - chest
    - abdomen
    - teeth

- dentist visit

- cardiac screening:
    - cardiologic visit
    - electrocardiogram
    - cycloergometry

- breathing function:
    - spirometry at rest
    - spirometry under effort
    - throat, ear and nose visit

- neurologic visit, including electroencephalogram

- eye visit

- evaluation of peripheral circulation

The psychological check includes behaviour and personality tests. The lowest medical profile required of the candidates for summer expeditions

The need for a medical check of the candidates before the departure has been discussed. Perhaps one should discuss the various degrees of fitness, i.e., to determine the range within which an individual, whose health is not perfect, could still be considered fit for an Antarctic expedition. For example, one must look for the highest cardiac efficiency in a person whose job is to operate far away from the base at high altitude where oxygen percentage is lower than that at the base, if the base, like the Italian, is at sea level. The same fitness is required of a diver, who could be compelled to operate in breathlessness. On the other hand, leaving at home a researcher whose task is to work in a laboratory just because of his inadequate breathing could mean to give up a line of research in an environment not very different from his or her own laboratory at home.

These "soft" evaluations must be made with great care, especially if there are no airports nearby. In the case mentioned, a person having breathing problems could become a cardiac patient in urgent need of intensive care.

A balance between scientific asset and medical liability must be performed with great care and sense of responsibility, to provide a good team without leaving home precious people. However it is very important to leave the doctor as idle as possible in base!

Training of the applicants

Much research work in Antarctica is performed outdoor, often far from the bases, using helicopters or other vehicles. Specially when a team travels by helicopter a sudden change of the weather or mechanical problems to the machine could find the people at a lot of kilometres from the station of departure where a comfortable environment would protect them and where a doctor could take care of their conditions. In these cases the participants must be able to find a shelter or to build it and to assist who is in precarious conditions of health.

Everybody can learn how to operate under extreme conditions and how to give first aid, but a training on the field is recommended. In Italy, before the departure of the new expedition, the applicants have to follow an one-week theoretic training of survival and first aid and then an one-week practical training over the Monte Bianco glacier. The training given in Italy to Antarctic personnel has the following main purposes:

to give a basic introduction to the characteristic of the Antarctic environment and to life and activities on ice-covered areas

to provide the basics of first aid, including care and handling of casualties

to provide basic training in fire fighting to provide basic training in the use of specialized transport equipment, such as helicopters, boats, tracked vehicles, etc.

to provide training in the use of tents, ropes, emergency survival equipment, etc.

Data base of medical data

The medical checking has been performed for each of the seven Italian expeditions since 1985. Consequently, a large amount of medical data exists, together with the data arising from the activity of the expedition doctors during the stay in Antarctica. There is also the need of transferring the data of the expedition personnel to the Terra Nova Station. It is also needed to analyze the data, add to them for new candidates and for possible medical events during the expeditions.

Because of these considerations a data base system is being developed along the lines indicated by a similar project of the Australian ANARE. The international classification of diseases of the WHO is being used. The data stored shall be of use to the medical doctors in the expedition, they can be useful when performing medicals for the next expedition.

Also, in case of exchange of personnel among bases, it could be useful to have a standardized data base for medical histories among Countries active in Antarctica, so that doctors in any base and at any time may be provided with reliable medical data on expedition participants in need of medical help.

Professional characteristics of medical and para-medical personnel

Even if a trip to Antarctica gives the opportunity to visit an interesting and rarely seen part of the world and gives a special halo to people going there, it is very difficult in Italy to find a medical doctor willing to leave his professional job for a few months during the expedition.

The particular area where he must operate, without the support of a nearby hospital and often quite far from the help of other doctors increases his liability and his fears. The fears of the doctor could become the fear of the expedition personnel and consequently one must reduce as much as possible the reasons for this fear. First, the doctor should not be alone; two doctors are used, so as to give each other professional support and for sharing responsibility.

From the analysis of the morbidity of the last six Italian expeditions one can see that about half of the medically significant occurrences were traumas. Thus, it is our opinion that one of the doctors must be an orthopaedic surgeon with a good experience of general surgery, or a surgeon with good experience of orthopaedics. Speaking about surgery, it follows that the other doctor should be an anaesthetist! This is then the ideal surgical team: a surgeon expert in orthopaedics and an anaesthetist expert in cardiac and respiratory problems.

Other problems can occur in Antarctica, like dental problems, eye traumas, need of X-rays, etc.. It is of course impossible to take along so many specialists on an expedition. One of the best ways of solving these problems would be an integrated training course where each doctor could learn more about subjects which are not part of his specific professional expertise. There are some training stages, like the one in the USA named ATLS -Advance Trauma and Life Support- where medical and paramedical personnel can learn how to handle emergency situations. Programmes such as this could be used to create good Antarctic doctors.

At present, doctors for the Italian Antarctic expeditions are selected among Army or Air Force doctors, as far as surgeons and anaesthetist for the base. Ships sailing in Antarctic waters for geological or oceanographic research for the Italian Antarctic Programme have usually Navy doctors, more experienced in ship-borne work.

Medical Facilities

- Space Needed

The medical assistance in Antarctica can be performed at different levels, from first aid to complex surgery depending on available structures.

At least a multi-purpose room where to make visits, give first aid, treat minor traumas is needed. At least a small clean room is necessary for surgery and another room for pharmacy and instruments. If more rooms are available one should be reserved for postoperative stay.

- Standard Supplies

The minimal equipment that an Antarctic base must have should be established from the experience of every country. A certain degree of standardization would make it easier to plan for an uniform level of health care.

An inter-base consulting will be easier if every physician knows the resources at the disposal of the other and a long distance consulting could be pre-planned saving time and shortening the communications that could be interrupted by unforeseeable reasons.

- Pharmacy

For those bases that are occupied only during the summer season, it is important that somebody in mother country knows which drugs are available, their expiration date, the quantity of each drug. An excellent solution is to create a data base containing all the materials that are liable to consumption or to expire. Updating during the expedition would then be easy.

Like the surgical supplies, also the drugs would have to be standardized according to the most frequent diseases to ensure at least a minimal profile of health assistance.

The present status at the Italian Base

At the present we have three available rooms in the base, a consulting room, a surgery and a pharmacy that can be transformed into a bedroom in an emergency. In the surgery there are instruments and materials to provide abdominal surgery and orthopaedic surgery. In the pharmacy the most usual kinds of drug are available and they are under control of a computerized data base. Wherever was possible disposable materials were preferred.

Medical Emergencies

- Rescue

Our difficult operating location makes every rescue operation more critical and its duration longer. Under these circumstances it is important to do not lose time if we want to save lives. A few basic rules can help to avoid delays and in my opinion we must establish rules that are easy to remember, possibly always the same and understandable by non-specialized personnel.

- Resuscitation
The most common example that is used everywhere is the A.B.C. (Air, Breathing, Cardiac pulse) that is an easy way to remember what to do and how to operate when a man is in danger of life. In fact everyone could forget, under the anxiety of the moment, the sequence to find vital parameters, but nobody could forget the sequence of the letters A,B,C and to follow their meaning (Air flush, i.e. the freedom of the mouth and of the windpipe; Breathing, i.e. the possibility of spontaneous breathing; Cardiac pulse, i.e. to verify the presence of cardiac activity).

- Cranial traumas
The second dangerous condition that could be found in a rescue operation is a cranial trauma, specially if the patient is unconscious. As it has been found in the resuscitation schedule, also in this case a diagram could be useful to remember the correct sequence of actions to do even if the final responsibility must be of the doctor.

- Traumas of the spine
One must distinguish between the neck fractures that are life-threatening and the other fractures of the spine that are dangerous for the movements of the limbs, depending on the level where the fracture occurred and whether the spinal cord is injured. In every rescue operation the rescuers must suspect a spinal trauma and avoid moving the patient roughly.

- Burns
However unexpected, burns are the most frequent injures in Antarctica due to materials, clothes, lighters, cigarettes, chemicals. Fortunately they are usually not serious, but it is necessary to know how to handle cases of major burns.

- Cold injuries
One must make a distinction between Hypothermia and Frostbite, both of them being dangerous, but the first is more insidious because of its feeling of well-being.
First symptoms of Hypothermia are exhaustion and shivering followed by irrational behaviour. Is very important to insulate the patient in a shelter or in a sleeping bag and apply heat directly to those parts of the body where arteries are more superficial like the armpits, the groin or the neck.

Evacuation
Despite of all our efforts to provide the facilities and the medical personnel against the most frequent emergencies, there are a lot of situations that do not allow to treat the patient or the patients in Antarctica. It should be important to establish a limit within which the Antarctic doctor can operate and over which it is better that he will recommend the transfer of the patient, according to weather conditions, of course!

One can distinguish between a situation of medical emergency and a situation without risk for the life of the patient.

Evacuation in emergency

One can consider medical emergency every situation entailing life risk or the need for an important surgical operation. An emergency situation could also arise when an accident involves a number of people larger than the medical staff can attend to. It is really important that the vital parameters of the patient are stabilized before the departure and that somebody can take care of him during the travel even if it means to modify the cabin of a helicopter.

Evacuation to provide a better treatment to the patient Many situations like extended burns, persistent backpain due to a discal hernia or to a kidney colic, heartburns, etc. cannot be really considered an emergency, but need a specialized treatment or further investigations. In these cases to carry the patient to a hospital as soon as the weather conditions will permit a safe journey will provide a better health care to the patient and will be useful to the emotional status of the team.

talian solutions and cooperation with McMurdo Base and New Zealand
The Italian base in Terra Nova is in the Ross Sea Area, far about 350 Km from McMurdo Station where an airport is available. Due to the good relationship with the U.S.A., in case of an emergency, we asked the American help, and I think we shall do so again in the future, both for support by their medical team and facilities, and for place on their aircrafts to fly to New Zealand.

Communications

The Italian Programme of Antarctic Research uses three different communication systems during the Antarctic expeditions.
They are:

INMARSAT Satellite System
Short Wave (HF) System
UHF System, Air and Marine Bands.

1. INMARSAT Satellite System

The Italian Summer Base at Terra Nova Bay is located on the border of the area covered by satellite. This fact creates some slight problems which however have been almost completely overcome. This system is used for telephone, fax and telex traffic; connection of data base systems is also performed. The main drawback of the system is its high cost.

2. Short Wave Systems (HF System)

Two HF systems are used: one for long range communication (from Antarctica to Italy) and one for short range communication (local communication with other Antarctic bases, ships, aircraft, etc.) These systems are being developed to increase their efficiency, in view of their much lower operating costs. One of the main developments is in the installation of a relay station in the Italian Embassy in Canberra.

3. VHF Systems.

These systems are used for local communication in and around the area of Terra Nova Bay. A locally installed system of repeaters is used and a range of the order of 150 Km can be reached.

Overseas Communications for Specialized Medical Consultations

Obviously the size of medical teams in Antarctica is limited. The modern communication systems can allow to transmit images via satellite to far places like a hospital in the country of origin and it is easy to understand how this could be helpful to the doctors in Antarctica. Antarctic Inter-base Communications for Support of Medical Consulting and Evacuation. In case of an emergency HF radio or phone communications with the other bases in Antarctica could help to organize the rescue operations, the evacuation of patients, but also to provide a medical consulting. In this case I think it could be useful to standardize radio communication procedures to avoid misunderstandings or omissions. For this reasons the following schedule is proposed:

Example of a communication schedule

TO:
U.S. BASE
SITE:
McMurdo

FROM:
Italian Base
Terra Nova
Ross Area

PATIENT IDENTIF.:
Mario Rossi
SEX: M
AGE: 38

TARGET:
Final diagnosis
Therapy

SYMPTOMS:
Head ache
Vomiting
Abdominal pain

INVESTIGATIONS:
Leucocytosis

POSSIBLE DIAGNOSIS:
Appendicitis

POSSIBLE THERAPY
Antibiotics
Appendicectomy

Diving Rules

To dive in Antarctica is more dangerous than elsewhere, not only because of the environment, but because also of the meaning that an accident could have. Two possible risks are foreseeable: the first is the air embolism, the second is the syncope. We can supply an high-pressure chamber to fight against the air embolism, but there is nothing we can do against the syncope that is sudden and unknown. When a syncope occurs we can only operate an artificial breathing so that the most important rule to impose is that at least two divers must be together underwater for immersions in open sea or one, but tethered to the surface, for immersions under the pack. The surface operator, always present, has to know the schedule of the immersion, i.e., he must know the length, the depth and the distance from the boat or the hole (in case of immersions under the pack). Never should be admitted immersions under floating ice because it could be impossible to assist the diver if the wind changes.

According to the U.S.Navy rules for diving, there is a safety curve that is function of the lowest reached depth per duration. To exceed one of these two values means that a quantity of nitrogen released in the blood and in the adipose tissue could become dangerous for the nervous system if it goes again suddenly to the gaseous state. To avoid this possibility the diver has to stop underwater for some minutes before his surfacing. Under this conditions everything new like cold, breathlessness, or shivers could force the diver to surface before the time and expose him to the risk of an embolism.

It is important to remember that flying by plane or helicopter could be dangerous for the divers in the first hours after the immersion because of the greater differential atmospheric pressure with respect to that under sea-level. In case of an emergency flight a second immersion during the same day should be avoided.

Since 1989 Italians have established the following diving rules:

-

Diving applicants must be submitted to a complete medical screening before their departure to Antarctica

They must show their licence to dive issued by a national or international organisation (CONI, CMAS, PADI etc.)

Every immersion must be planned in advance and a schedule containing the starting time, the end time, the place, the needed supports, the name of the assistant, the date of the last immersion for each diver, the name of the doctor on duty, the signature of each diver and of the expedition's chief must be compiled.

During the immersion the assistant must write on the schedule any new occurrence, the observance of the time limits and of the rules

To exceed the safety curve will not be allowed. If this rule is violated without a good reason then that particular diver will not be allowed to dive again in Antarctica.

Conclusions

With this paper it was hoped to show that there's an Antarctic medicine, as an important branch of either Antarctic logistics or as a branch of medicine itself.

Doctors active in the preparation of the expeditions and in the expeditions themselves have a heavy job, which has implications on the well being and on the very survival of participants.

A very important part of this activity is the cooperation among Antarctic Programmes in all its aspects: screening of participants, exchange of data, standardization of supplies and equipment, etc.

All this together may bring about good health care, safer expeditions with as few unforeseen medical events as possible.

Cultural Change by Remote Control
Reflections on Changing the Dynamics of Antarctic Communities

by

Tim Dalmau, Dalmau & Associates Pty. Ltd. Brisbane, Australia

Introduction And Context

At a recent gathering of applicants for the positions of 1993 Station Leader in Australia's Antarctic communities, the Director of the Antarctic Division stated that the role of Station Leader was (essentially) to:-

- Facilitate the achievement of Australia's scientific programs in Antarctica,
- Implement programs for the protection of the Antarctic environment,
- Maintain a cohesive unit in Antarctica,
- Ensure the safety of the expeditioners, and
- Provide an effective support infrastructure.

He pointed to two key issues for 1993 Station Leaders ... Firstly, how to maintain a balance between the needs of the community and the outputs required by the organization and, secondly, how to maintain an effective and motivated team of people who meet standards of accountability, ethics, law, personal behavior (including alcohol) and the avoidance of sexual harassment whilst meeting obligations as a manager to the organization.

This statement encapsulates some of the issues with which this paper is concerned, viz: leading and maintaining a group of people in a series of different yet related endeavors in a physically hazardous environment when the individuals concerned may not necessarily share the same values about behavioral standards with one another and, often, not with the sponsoring organization.

Australia maintains four permanent Antarctic communities, three on the mainland - Casey, Davis and Mawson - and one on sub-Antarctic Macquarie Island. A number of other transitory communities are established over the summer period each year, both on the mainland and on sub-Antarctic Heard Island where, this winter (1992), there is a small wintering group. The size of the wintering communities ranges between (approximately) 15 and 35; the norm seems to be in the mid-20s.

Most people who work and live for any significant time on an Australian base are temporary or permanent employees of the Australian Public Service whilst managed by the Antarctic Division. Yet they come from many and different sectors of the wider community - as such, they represent a diverse set of sub-cultures. As temporary public servants they become subject to the administrative procedures, regulations, requirements and culture of the Australian Public Service.

The guardians of this public service culture (the senior executives of the Antarctic Division) rightfully and properly have a concern to ensure that the lifestyle, behavior, practice and cohesion of expeditioner groups is consistent with government requirements and is an effective, satisfying and enjoyable experience for the individual expeditioner.

It has been a long-standing and almost universally-held assumption among those associated with the leadership of Australian Antarctic operations that the norms for acceptable behavior in Antarctic communities should be similar to those operating within the wider Australian community. In the first half of the 1980s, there were a number of incidents in Australia's Antarctic communities indicating behavior outside acceptable community norms. These incidents caused personal stress for the actors involved, tested many of the leadership skills of the Station Leaders and, in a few cases, resulted in significant additional and unplanned expenditure of the taxpayer's dollar.

The (then) senior executives within the Antarctic Division assumed initially that these incidents were due to faulty selection procedures. A thorough study revealed that, although there was room for improvement in some elements of the selection process, the problem was more complex. It was inadequate simply to say too many "false positives" were getting through the selection process and causing difficulties in the Antarctic communities.

Other identified inadequacies were evident in the manner in which expeditioners were prepared to live with one another in a close, isolated community, and in the systems used for personnel management of expeditioners whilst in Antarctica. For example, under government regulations it was very difficult prior to 1986, to bar an expeditioner from returning to Antarctica in subsequent years even when it was widely known that s/he had been the cause of severe interpersonal difficulties or extreme community tension.

The Antarctic Division committed itself in late 1986 to a series of measures *to improve the personnel management of its expeditioners*. In more formal terms ... to find ways of making life in Antarctic communities more harmonious and effective for expeditioners through improving the human resource management system. A number of strategies were enacted and the remainder of this paper is devoted to describing these strategies and explaining some of the issues with which these strategies had to contend.

It needs to be said that the systemic inadequacies appeared under the type of organizational diagnosis and evaluation used commonly for all types of large organizations - private and public. Such methods take into account the strong unconscious elements of organizational life (often called organizational culture) as a key factor in determining organizational effectiveness. These same methods, when applied to Australia's Antarctic Division, showed up some unusually potent sub-cultures which needed to be included in any attempt to improve the lot of life for people in our Antarctic communities.

Many aspects and changes described below are not unique to the Antarctic Division. However, some issues within its social, cultural and organizational environment to improve the human resource management of expeditioners loom very large in their effect and arise from the special experience that seems to be life in Antarctica. The strength and dynamics of sub-cultures is one such issue.

For example, twelve months after the study began, it became clear to all involved that not only was there a need to build intentionally and purposively a social system within Antarctic communities, but that ultimately this was a program of long-term cultural intervention. As such, it was fraught with difficulties and complexities only vaguely known in a conscious way to those who manage it. We were dealing with basic assumptions and mythological constructs beyond the conscious awareness of most, and which emerge often only through story and ritual (Dalmau & Dick, 1985, 1991) or when challenged through new required practice.

It probably also needs to be pointed out that Australia, unlike some other nations with Antarctic communities, transports its personnel to and from Antarctica by ship. There is, therefore, a substantial period (March - October) each year when the community composition is fixed. This is a mixed blessing - for example, it allows for the development of highly cohesive communities, but prevents the removal of profoundly disruptive individuals until the first ship arrives in the next summer period. In the past, communication has been restricted and via telex, open radiophone or extremely expensive satellite communications.

Since March of 1988, the communities have had access to the Antarctic Division's own internal satellite communication system which interfaces with the public telephone network for voice and data. This allows instantaneous phone or data access (subject to line availability) to all expeditioners to their loved ones, acquaintances, superiors, and colleagues in other Antarctic communities. (This year, for example, we are seeing a situation wherein some expeditioners take their own private fax machines to Antarctica and place them in their own bedrooms. This represents a major shift in personal and work-related communications from a situation where it was public, planned, delayed and stilted to one in which it is very private, spontaneous, immediate and confluent)

For ease of understanding.... each community in Antarctica is under the guidance and direction of a Station Leader, who reports to a Station Manager at headquarters in Australia. Each Station Manager, in turn, reports through two levels to the Director of the Antarctic Division. Separàtely .... Australian expeditioners come form different organizations (e.g. the Antarctic Division, the Meteorological Bureau, universities, etc.). They go "south" under the umbrella of ANARE (Australian National Antarctic Research Expeditions) which is administered by the Antarctic Division. ANARE exists more as a banner and symbol than a tangible organizational entity.

Managing Groups At A Distance

Even though Australia maintains only four wintering communities, many different groups of people make up these communities. Part of the accepted idiom for Australian "Antarcticans" is to talk of the wintering communities as if they were one group. The mythology which this represents is a useful one - it certainly allows comparisons between bases and between years. Most importantly it provides an anchor for psychological identification by individuals. But it clouds another reality, i.e. any given community is often host to a number of strong groups, or sub-cultures.

The management of these sub-cultures represents somewhat of challenge, especially at a distance of thousands of miles. Even though membership of the groups may overlap in any given community, their very existence represents a array of sub-cultures with differing values, educational levels, outlooks on life, and expectations.

Australians going to Antarctica are grouped in the minds and systems of those who manage them into two main camps: summerers and winterers. Summer expeditioners have numbered between 150 and 180 for the last few years: they consist mostly of scientists and/or building tradespersons who are involved in a major long-term rebuilding program on Australia's Antarctic bases.

Winterers have numbered in the 90's for the last few years and represent a wider cross-section of occupational type. Consequently, at the height of the summer period it is possible for Australian expeditioners in the Antarctic and sub-Antarctic to number in excess of 250 people.

In 1988 the percentage of winter personnel in Antarctic communities who had previous experience with ANARE was 34%. For the 1989 winter period, the comparable figure will be 40%. For 1990 and 1991, almost 50%.

Herein lies one of the strongest groups - returning expeditioners. Station Leaders report them to be one of the most identifiable groups in a community, at least for the first half of its life, say, until 8 - 12 weeks after the last summer ship leaves. From this period on, and until the first ship arrives, the group of returning expeditioners, tends to lose its visibility within the development of a more unified "base community", e.g. the Davis 90 community or the Casey 89 community.

This is not the case for some other groups within a base community....

One of the strongest and most enduring is the "ACS group". Australia has been embarked on a major reconstruction of its mainland bases for nearly a decade. This has involved the placement of large numbers of tradespersons in the community. They reach their highest numbers in the summer period, but each mainland wintering community will also have a sizeable minority who are involved in the on-going reconstruction work. This work is undertaken by the Australian Construction Service (ACS), a contracting arm of the Australian Government. For its work on our Antarctic bases, the ACS seeks tradespersons from Australian workforce. On a base, one of their number, the "ACS Foreman" has direct line authority over their technical work.

The ACS group, then consists mostly of tradespersons. As such they share many of the characteristics of their brothers and sisters in mainland Australia. They tend to be highly skilled, able to work without much supervision, very pragmatic, respecting of others as much for the technical competence as any personal or social trait, and with an extremely healthy Australian disdain for authority. By and large, they do not have to engage much with rules and regulations concerning social behavior, they come from what we may call a non-verbal-literate culture. By this I do not wish to imply, that they can't read or write, but rather that the importance and nuance placed on text and the spoken which is so much part of the public sector in most western countries is alien to their history and lifestyle.

The written and spoken word is something they take for granted, and to which they pay little attention per se; they tend to be more concerned with the tools and skills of their trade, and their use in what they might term "the real world". For the bureaucrat, however, the written and spoken word are her tools of trade. Your average Australian public servant spends much of her time reading, understanding, creating and working with and about spoken and written text. One recently returned Station Leader spoke of the difference between these two "worlds" as a *gigantic chasm*, little understood or appreciated by either side.

The ACS group can become a clearly identifiable and potent group within a community.

Closely allied to the ACS group in some of their interests, value systems and beliefs are the other tradespersons employed directly by the Antarctic Division, e.g. diesel mechanics, maintenance carpenters, plumbers, electricians, etc. Whilst they may share some of the cultural heritage within Australia of their brothers and sisters from the ACS group, they rarely become identified as a single group within a station community. It is also significant that they are employed by the Division itself and not by a contractor.

Within our communities there are also employees of the Meteorological Bureau whose task is to monitor weather data and transmit back to Australia and other places. They tend to be people with a longer history of working in small and isolated communities in remote parts of Australia and nearby islands. They tend to be more introverted in their social styles, reflective and with a strong sense of pride in their work and its value to understanding and monitoring world weather. Their sense of "allegiance" is often to their work and the Meteorological Bureau which employs them rather than the Antarctic Division.

Another significant group within a community represents those who have spent far more time in that part of the educational system which relies heavily on text and the spoken word: most within this group would, at a minimum, possess bachelor degrees and a few, doctorates. They are (generally) found among the scientists and medical personnel in a community. The interests, values systems, beliefs of this group tend to be quite different from the other two groups. They share some of the hesitancy towards authority and control, but are much more likely to have reasoned and critical stances to issues, policies, or directives on station.

Within a community develop a number of other groups which cross these boundaries. They come to be formed on the basis of such things as age, friendship, alcohol consumption patterns, shared experiences (e.g. long distance traverses).

Then, of course, there is the group of one - the Station Leader. S/he is a very significant influence in the level of productivity and personal satisfaction of the community as a whole and of its individuals.

The communities are, thus, a pot pourri of groups - groups of different sizes, value systems, beliefs, interests and world views. In the first half of the 1980s, the concern expressed by the (then) executives of the Antarctic Division needs to be set against this background. That is, the leaders of a government agency sought to bring some uniformity and standards into the collective and individual behavior of these communities. Prior to this, there had been little or no formal communication to expeditioners of the Division's expectations about such things. Nor were there any coherent, systematic and focused personnel management systems in place to reinforce such expectations. The expectations certainly existed in the minds of those who ran the Division, but often remained tacit or communicated in ambiguous and indirect ways.

But the Division itself, is not a unitary culture. Nor was it in the mid-1980s. It is, in fact, composed of similar and different diverse groups. As is the case with the Antarctic communities, these groups within the headquarters at Kingston in Australia represent different value systems, beliefs, interests and world views.

The executive personnel which provide the formal leadership and direction of the Antarctic Division represent a strong a potent group to other groups within the Division and to groups in the Antarctic communities. This group is composed of most of the senior executives of the organization. Their currency of work is largely text and spoken word - these are the tools of their trade; the tools with which they envisage the future, formulate policy, lay down regulations, and review results. As is right and proper, they pay particularly close attention to federal government and political trends, issues, dynamics and policy. They stand, so to speak, as a bridge to the world of public sector bureaucracy and as translators of political policy.

Another strong group is represented by those scientists working within the Division in Australia, many of whom will have already spent a significant amount of time within Antarctica. They tend to be highly educated, have good facility with text and word and, in a way similar to Meteorological Bureau personnel, see themselves as driven by higher order interests. For many of them, the administrators and leaders of the organization represent impediments to their energetic pursuit of "science", a "pure" cause worthy in its own right.

One of the more potent groups within the Division are returned expeditioners who are now employed by the Division in many and various roles, e.g. storepersons, line managers, medicos, and technical experts. This group crosses many sectors within the Division, yet is identifiable (as a group) by two key characteristics - the strength of their beliefs about how "things really should be done" and the penetration of the communication links into all aspects of community life in Antarctica.

Support personnel (mostly female) represent a third group. They often occupy positions with a high clerical processing component, e.g. secretarial functions, personnel administrative processing, asset control monitoring, resource management, purchasing and supply procurement, etc. They tend to be quite hidden as a group - they are nowhere near as visible and identifiable as the executive, the scientists, the returned and Division-employed expeditioners. They exert a significant (but often hidden) influence over the level of productivity within the organization and can be either highly facilitative in impact, or come to represent a major impediment to effective action. They tend to have highly developed communication networks which monitor the relational and political dynamics within the organization.

Within the Division, there are a number of employees with responsibility for technical oversight of tasks and functions of specific personnel within the Antarctic communities, e.g. building supervisors who monitor reconstruction progress, works supervisors who monitor maintenance tradespersons in the Antarctic communities, doctors who monitor community doctors, scientists who monitor research being undertaken by the scientists living in community. With the extremely easy communication available through the in-house satellite phone and data system used by the Division for Australia-Antarctica communication, this group of personnel in Australia have a strong and direct influence over the expectations, perspectives and value positions adopted by their "charges down south". For example, the manner and degree to which they model public and psychological support of the role of the Station Leaders is vital to maintaining its effectiveness and the overall well-being of the community.

Another writer could examine the Antarctic communities and the Division in Australia and arrive at a different or expanded list of groups. The description above is not meant to be exhaustive; rather, to provide a sense of the complexity and strength of the inter-group dynamics at work in any given year's operations in Antarctica. Above all else, it is important to note that the members of many of these groups hold their beliefs and espoused values with passion and strong energy, and (often) with very little evidence.

In other words, the communities in Antarctica and the organization in Australia represent, both individually and collectively, *cultural ecosystems* - systems containing differing sub-cultures held (most times) in an overall and stable equilibrium. (An equilibrium, not necessarily to the liking of the members of any given sub-culture, but an equilibrium nevertheless.) It is not a static and neutral picture, however: the system is very active, energy flows quite animatedly, and positions taken with surprising strength and ferocity at times. Nevertheless, it does seem to be in some form of equilibrium.

What then is the essential nature of the balance among the sub-cultures? I would venture to suggest that it is highly political in nature. Donaldson and McCarty (1985) describe the characteristics of politicized organizational environments. They describe such "spaces" in the following terms ....

- there is a resource scarcity;
- there are coalitions among management and executive levels;
- there is no widespread agreement and ownership re fundamental objectives
- personnel management is decentralized; and
- there are strong sub-cultures

For over a decade now, the Division and its communities in Antarctica could be characterized in such language. Within this cultural ecosystem-in-equilibrium, the energy which flows is represented in the cut and thrust of the political vying for power, prestige, resources, policy, prevailing viewpoint, and sheer pay-back: dynamics which are common to all highly politicized organizational environments. Dynamics, however, which make it particularly difficult to engineer rational planned social change. In particular, it makes it very difficult to appeal to reasoned logic as the basis for change - in this type of environment, nothing is what it seems and people who act openly and with congruence place themselves and the interest group to which they belong at a distinct disadvantage.

As was stated earlier, the management-commissioned study of the organization's operations in mid-eighties reflected the importance of the culture factor. It simply wasn't possible to say "*this is the change in community behavior and life we want, this is how we can get, this is how long it will take, these will be the resources needed .... ok, let's go*". The strategy needed to account for the diversity, strength and essentially political nature of the cultural forces at work. Moreover, it could only aim at shaping new behaviors and systems in the hope of subsequent attitude and value change among the actors and actresses - the prospect of success for a change strategy based on appeal to logic and reasons is very dim in such situations.

It is perhaps worth commenting on one particular cultural dynamic of significance - the manner and effect of existing sub-cultures.

Impact Of Existing Sub-Cultures

Former expeditioners, when reporting their experience and relationship with the Australian-based head office of the Antarctic Division, expressed very strong beliefs and feelings about what should and should not happen upon their return to Australia. In fact, many of their stories about their employment as an expeditioner seem to focus on their exit from employment and the few weeks immediately preceding it, including their exit from Antarctica itself.

Palinkas (1985) suggests a common reaction among Antarctic expeditioners, no matter what their nationality, is resentment at the "invasion" of new personnel into a base community at the end of each winter. It is possible that the apparent strong resentment of "headquarters" by returning expeditioners may be part of a more general human response in coping with return into Australian society and exit from what has been an extremely close and highly interdependent social system. Expeditioners report a loss of sense of "being cared for" in the latter stages of their employment by the employing organization: a generalized feeling that headquarters spends energy finding and selecting people to go to Antarctica, but doesn't care too much about them whilst they are "down south" or when they return.

It seems as though returning expeditioners, construct a meaning frame which focuses on affiliation and allegiance to a group of people who could almost be described as "comrades in adversity", and they seem to set this positive experience in relief against their experience of their exit from employment. In turn, the expectations of a future Antarctic experience are strongly grounded in this sense of personal loyalty to one's Antarctic family. Thus expeditioners returning for their second (or more) trip can exert a powerful influence on the expectations of "initiates", and the strength and loyalty of their "attachments" is surprisingly strong.

Few (apparently) straightforward organizational change programs need to take into account such strong group and individual forces. People involved with Australia's Antarctic heritage and its current and past activities are characterized by what could be best described as a strong passion and potent beliefs.

These include beliefs about ...

- what an Antarctic community is "really" like
- what is and is not possible for a Station Leader to do (legitimately)
- a mythology of egalitarianism in an Antarctic community
- unique character and quality of a winter experience
- effects of open communication on relationships in the community
- competence of head office personnel
- robustness/brittleness of people
- use to which personnel records will be put
- use of alcohol
- place and function of intimate pair relationships, and
- legitimacy of those who have not "wintered" to make decisions affecting life in an Antarctic community

Though one might expect former expeditioners to have beliefs about such matters, nevertheless their intensity is often quite extraordinary. This is equally true of many Australia-based employees of the Antarctic Division who are former expeditioners. Not only are these beliefs held with fervor and passion, they often conflict with modern beliefs about, and the practice of, effective personnel management and are sometimes in opposition to modern public sector administrative legal requirements. Additionally, common national characteristics seem to become amplified among expeditioners.

For example, we can clearly acknowledge what is seen by many writers as central to our national identity: a peculiarly Australian disregard for pretentiousness, position, authority and overtly stratified social systems. It lies at the core of our national mythology and psyche, and it is a brave person indeed who would stand in front of a group of experienced Australian Antarctic expeditioners and attempt to argue rationally for the establishment and maintenance of an explicit formal hierarchy within an Antarctic community.

Returning expeditioners also share membership of a much wider network of people throughout Australia: *all returned expeditioners* - people found in all walks of life. This network finds public expression in an institution known as the ANARE Club. Apart from providing members and their families with support, news, and the opportunity for social interaction, it also fills a lobby function with government. It is a repository for the expression and maintenance of the ANARE culture through sign, symbol and periodic ritual such as mid-winter dinners in each of Australia's capital cities. It legitimizes and maintains the heritage and traditions associated with Australia's past and present involvement in the "continent of the south".

This ANARE culture seems to validate an individual's previous Antarctic experience as something almost sacred and holy: at the very least, a spiritual experience. The intensity of this personal experience (associated with previous Antarctic work) seems to be a major source of the energy for the very strong beliefs. After one has experienced the force of such beliefs, it is hard to underestimate ever again their valency and salience for effective organizational change.

Another issue complicating the smooth implementation of a human resource management system for expeditioners arises from the fact that for about 5 months of each year the membership of an Antarctic community is rarely stable... The majority of last year's winterers might not be leaving until late December, yet a summer construction crew may arrive in the third week of October. Between these two periods there may be one or more other voyages bringing a small number of short-term scientists. The following year's winter group may arrive in early January, yet the summer members may not leave until early February.

The reality is one of a constantly changing membership, and it is not until the last ship leaves (usually in March) that winterers report they finally feel as though the community finally "belongs" to them. This period is often characterized by a marked increase in mood and morale. Prior to this time, there could be upwards of 100 people on a base over the summer period.

The way in which summer and winter expeditioners experience one another was an important issue that the human resource management system needed to account for. Many summer expeditioners reported they felt like "second-class citizens" and focused on differences in external symbols such as different clothing issue, differential treatment by Divisional employees at embarkation, separate training experiences, etc. In late 1986, the perceived (and felt) difference between these two groups was a contributing factor in tensions in some of the communities.

An Archetypal Perspective

To date, we have explored the composition and basis of some of the sub-cultures in Antarctica and in Australia which constitute what we might usefully term a cultural ecosystem. But these surface forces, dynamics and behaviors belie a hidden, complex and largely unconscious reality. Writers such as Morgan (1986) point out that the way we think about *what an organization is* has a profound effect on how we come to define the nature of the problems we face, how we choose strategies to solve them and we measure our success. If we look through orange-tinted glasses the world around us appears orange; if the glasses are tinted green then this is the way world becomes colored. It is very similar with organizations: if we see them as machines, then the people in them become "cogs in the wheels", with all the consequences this entails; if we carry in our heads an image of an organization as a political system, then we will tend to see all that occurs within it as politically motivated and determined.

Given that a key factor in the original Antarctic Division study was culture (or rather the dynamics of a series of sub-cultures), it seemed appropriate to turn to cultural images to explain the nature and source of the fundamental "energy" keeping the cultural ecosystem in some form of equilibrium. The work of those psychologists who study groups using archetypal paradigms to categorize, explain and explore culture seemed fruitful soil in which to develop such an explanation.

Archetypes are deep universal patterns which are seemingly contained in the behavior of individuals, groups, communities and, even, nations. The notion of an archetype was first presented by the Swiss psychoanalyst Carl Jung who suggested that the universality of the patterns crossed national and ethnic cultural divisions. Archetypes may be expressed in the form of shared images of the world, common values, similar energy patterns, accepted perspectives, and alike behaviors. But the patterns themselves are extremely unconscious to the individual or group members themselves, until pointed out and explored (usually by an outsider). Nevertheless, they are almost always instantly recognizable, e.g. the mother archetype is quite familiar to all cultures and groups, for we all carry within us the primal experience of being mothered or seeing mothering.

In order to find a language within which to talk about archetypes most writers turn to a cosmology for inspiration (Dalmau, 1991). Some, such as Wendy Doniger-O'Flaherty (1984, 1988) from the University of Chicago, turn to eastern religions. Others, such as Bernie Neville (1991) from La Trobe University, turn to the Classics - in particular, ancient Greek mythology. Consequently, to describe an archetype we talk as if the group were possessed by one of the Greek gods. Each god-image will have a number of manifestations and even though they are given male or female names, the god-images have characteristics which we would currently associate with both masculine and feminine traits.

It is a fundamental tenet of archetypal psychology that in any group or organization there should be a range of energies at work, a diversity of perspectives at play. The unhealthy group is one which has become *inflated* with the energy of one archetype only, i.e. one god. There are a wide variety of archetypal patterns embedded in individual and collective behavior. But, organizations which become inflated by a particular archetype are unable to see anything outside that peculiar frame of reference; they become transfixed, so to speak.

The predominant archetypal energy which drives an organization should be appropriate to its purposes, its environment and its people. Most organizations are, in fact, manifestations of competing archetypal images and energies, i.e. are polytheistic; thus, organizations often stay healthy by recognizing, celebrating and accessing the diversity of image and energy sources within them. It is only when one or more of the sub-cultures within them come to believe they have "the right answer" that dysfunctional patterns set in: to adopt and live within a monotheistic culture is to live the negative as well as the positive aspects of the archetype. Thus the more attached a group is to a monotheistic image and energy, the more powerful will be the manifestations of its shadow.

Through diversity in a group comes robustness; with robustness comes effectiveness and satisfaction. So, what are the energies which seem to drive each of the groups? To this we now turn...

The **returning expeditioners** seem (to the outsider) to be driven by three separate energies. The god *Eros* provides then with a belief that quality of relationship really matters, that everybody should get on with one another, that trust and openness and mutual unconditional regard are important. The down side of Eros is that people under his spell have a tendency to become bitter if they find themselves in an environment which does not value such human concerns. They then can lose sight of strategy or goal and become defensive, passive and resistant.

But *Herakles* also ensures that the most valued people are those who will fight for what they want. He encourages people to talk a lot about their own ambitions, to be tough, yet friendly. Problems are solved by facing them head-on, and they are unhappy unless they're energetic and ambitious for they don't like being pushed around. The third god-image which provides much of their perspective on the outside world comes from *Athena*. She provides them with a realistic orientation, a pragmatic attitude, and a "focus on what matters". She ensures that achievement is valued highly and that the people who are valued are those who can develop winning strategies and practical solutions, especially if they can also keep their head in the heat of an emotional situation and accept the established norms as guidelines of behavior.

The **ACS group** in an Antarctic community seem to present with a different set of energies. *Hephaestos* seems to provide a good measure of their sense of themselves which places high value on craft, skill and diligent professional work. He ensures they can be absorbed in making something with their hands or doing something that is manual. This is a way of expressing creative artistry through work that is given a tangible form - something hghly valued in their environment. He also ensures that they tend not to talk about or address their feelings; they tend to work in solitude, and either sublimate their feelings or express them through their work. They tend to be intense, introverted persons who seek recognition solely for their work - the corporate world is foreign and meaningless to them, and often have specific difficulties with people in authority. He pushes them in the direction of bottling up intense hurt, fear and anger and keeping their communication indirect and implicit.

Combined with *Dionysus*, this profile can present some major challenges to the average Station Leader - obligations, assignments, appointments, being regular, consistency... these things don't rate that highly for Dionysus. Instead he tends to ensure that members of the ACS group have a strong sense of youth and energy but can be very moody and may fluctuate between being very warm to one another one moment and cold strangers the next. They become susceptible to conversion symptoms, e.g. hysteria, other conversion disorders, and easily become self-indulgent, especially with alcohol. (At least in Australia, most people know the dark side of Dionysus as the stereotypical bacchanalian feast of his Roman equivalent - Bacchus. In so doing, they tend to ignore the more creative aspects of Dionysus.).

This can lead to a dangerous combination when joined with the third god-image which seems to drive the ACS group, *Ares*, for he ensures they are likely to have intense and instinctive reactions to issues, ideas and each other. For him, the ideal environment is assertive, active, and emotional - thus people under his spell become bored and restless with paperwork and long-term goals, deep conversation or talking philosophically. When riled they can be physically abusive - they lack choice and are bundles of impulsive reactions. They have real difficulties "going by the book", and can easily become permanently defeated and see themselves as losers.

The **Division-employed tradespersons** share some common characteristics with the ACS group in so much as they seem (to an outsider) to be driven by Hephaestos and Dionysus. However, it is rare to hear them described in terms associated with Ares - they tend to be more reflective, timed in their responses, and less likely to use adversarial modes for dealing with conflict. This may well be saying something about differences between those people who select them for the Antarctic Division's employment versus those who select for the ACS organization. Or, it may be saying something about the fact that the ACS personnel come to be clearly identified as a *group* in the Antarctic community more than the Division-employed tradespeople. The "groupness" of the ACS personnel may well encourage Ares characteristics to emerge more easily, whereas Ares may be strong and dormant but unexpressed in the other tradespersons.

The **Meteorological Bureau** personnel seem to be under the spell of Hephaestos and Prometheus. *Hephaestos* ensures they value craft, skill and diligent work, that they do not talk about or address their feelings, they tend to work in solitude, and either sublimate their feelings or express them through work. He ensures they know the importance of quiet periods full of possibilities where imagination and hard work come together, where they can work best as loners. Unfortunately, they can bottle up intense hurt, fear and anger, becoming emotionally disabled such that others often learn to tiptoe around, intuit, and infer what their reactions will be.

But *Prometheus* ensures they hold values which keep them interested in the freedom of people and defiant of the establishment rule. They seem to believe that their work (monitoring and analyzing weather) will help others to gradually get control of things and learn how to do "everything" and understand "everything". They come to see themselves as heroes working towards a new world order and those who oppose simply "don't really understand". They tend to downplay intuition and feeling, any manifestation of the feminine. As men, they tend to be misogynists and, as women, they tend adopt many of the emotional characteristics attributed to Ares.

Those in **executive** and other management positions back at headquarters in Australia seem to operate from a quite different base altogether. Above all, they appear as worshippers of the god *Apollo*. Consequently, they place a very high value on being rational, systematic and orderly. They value targets and goals which are visible to others, in an environment which fosters clear definitions, is drawn to praise skill, and prefers to look at the surface rather than at what underlies appearances. They appear to have a shared instinct for order and form, and seem quite uncomfortable with chaos or turbulence. Apollo ensures they value order and harmony, thinking over feeling, distance over closeness, objective assessment over subjective intuition.

But Apollo is joined in their culture by *Prometheus*: He provides a pervasive belief that things will get better and better, that we gradually will get control of things and learn how to do everything and understand everything. People under his spell value the development of technology and systems to get control over problematical elements, see their role as a revolutionary one, changing society and working towards a new world order. This has certainly been evident in a lot of the rhetoric surrounding Australia's recent initiative's surrounding the Madrid treaty in 1991. Unfortunately, they also tend to downplay intuition and feeling, any manifestation of the feminine. Prometheans have little or no awareness of long term social consequences of the technology or systems they build and can become careless of future consequences

Those who work as **scientists** in the headquarters near Hobart represent a strange and curious mix of Apollo, Hephaestos and Prometheus. *Apollo* gives them a very strong emphasis on rationality and order. They prefer realism, clear definitions, clarity and purity of thought and action. They value order over harmony, thinking over feeling, distance over closeness, and objective assessment over subjective intuition. When humiliated they will engage in highly punitive responses and show no mercy; they tend to have an inflated sense of their own capabilities and resilience. They try to mentally distance themselves from the suffering of others and are often out of touch with their own feelings - thus they think and express themselves verbally and logically with an inherent ability to focus on a task. Like their brothers and sisters in the executive they are extremely familiar with written text and spoken word - culturally, the greatest gap is probably between this group and those characterized as the ACS group.

The *Hephaestos* in them helps them to see what they do as quite unique and special - an expression of their technical expertise and their commitment to their calling. Thus they tend to withdraw from the company of others in the organization and let themselves be absorbed in their work; they tend not to talk about or address their feelings; they tend to work in solitude, and either sublimate their feelings or expresses them through work. They have few social or political skills and often have specific difficulties with people in authority, bottling up intense hurt, fear and anger; becoming emotional cripples, smouldering volcanoes, or highly creative productive persons.

Prometheus engenders in them opposition to establishment rule and a world view that things will get better and better, that we gradually will get control of things and that systems can get control over problematical elements. Persons in the grip of this god-image see their role as a revolutionary one, changing society and working towards a new world order and those who oppose simply "don't really understand"; they tend to see themselves as heroes.

Returned expeditioners who now work inside the Division seem inflated solely by *Artemis*. She helps them to experience a sense of "at-oneness" with themselves and with nature. They tend to view people inside the Division and evaluate their worth simply on who they are and what they do. They have an air of intactness about them yet feel strongly about their causes and principles - they enjoy the exhilaration of independence and are undeterred by opposition.

Like all who are possessed by Artemis, when they get into middle management positions this group of returned expeditioners don't pay much attention to subordinates or colleagues who are dependent and, indeed, can set for subordinates standards and expectations which are unrealistically high. They deny their own vulnerability and need for mutuality, and maintain a large emotional distance from others and often fail to notice the feelings of others around them. They tend to judge the actions of others in terms of unmitigated black and white, which means they are often seen as stubborn and unrepentant by others in the organization.

The **support personnel** within the headquarters staff seem to be driven by Hestia and Athena. *Hestia* provides them with a strong sense of power derived from being apart from the rest. She also provides them with clarity in the midst of the confusing myriad of details, a sense of quiet tranquility in solitude which is "detached" to people, outcomes, possessions, prestige, or power. Consequently, they are inclined to "stay above" or out of the more visible intrigues and rivalries, and avoid being caught up in the passions of the moment. They tend to be quiet and unobtrusive people who do little to draw attention to themselves, so often feel alienated or isolated from their fellow workers and do not easily find recognition in a competitive workplace. They tend stay out of overt office politics and gossip, and provide an ambience of order and warmth. They are easily over-looked and inappropriately devalued.

Athena provides them with a realistic orientation, a pragmatic attitude, and a "focus on what matters". They place a high store on excellence and achievement and conformity to "adult" (that is, traditionally held) standards. It is Athena which helps them to survive effectively in situations wherever political or economic considerations are important, and to use and apply their intelligence to the practical and pragmatic, grasping what must be done. They stress foresight, planning, mastery of craft, and patience. They tend to be practical, uncomplicated, unselfconscious, and confident people who work hard, and accept reality as it is.

Next, we consider the people within the organization with responsibility for the **technical oversight** of personnel in Antarctica. They share many of the characteristics of the returning expeditioners and seem to be driven by Eros and Herakles. But there is an additional element, Zeus.

The god *Eros* provides then with a belief that quality of relationship really matters, that everybody really does get on with one another, that trust and openness and mutual unconditional regard characterize their relations with one another. But like their returning expeditioner brothers and sisters, they tend to lose sight of strategy or goal and can become defensive, passive and resistant. This presents some interesting dynamics, considering they are often in supervisory or management positions within the organization. The *Herakles* in them ensures that the most valued people are those who will fight for what they want, who will solve problems by facing them head-on. The *Zeus* in them ensures their use of power, authority and dominion are quite visible. Enterprise and ambition are "good" values to them and loyalty is highly prized. They seek to extend their boundaries, to acquire more "territory" and, for those under the spell of Zeus, personal dilemmas, problems and concerns of employees are not of importance or relevance. They tend to devalue others who have a better developed feeling function, consider their perspective superior, and since they are listened to as experts and authority roles, they have no reason to doubt this position. They use networks extensively.

Finally, we come to the ANARE Club, that institution which contains many (but certainly not all) returned expeditioners. It is, if you like, a subset of the returned expeditioners group. Like their colleagues, they seemed possessed by Eros and Herakles. (For detail, refer to the description for returning expeditioners above). But they also seemed gripped by *Dionysus* who emerges every mid-winter to guide their celebration and ritual with sign and symbol and the telling of many tales. This god also provides them with the intense and emotional involvement which the ANARE Club seems to engender in some, and encourages them to celebrate the breadth and depth of common feelings. Persons gripped by this Dionysus expect special treatment or recognition, and harbor resentments when their specialness is not honored. The earth mother-goddess, *Demeter* seems to provide the fourth element of their energy source. Thus the ANARE Club excels at emotional and psychological support to its members, providing them with a solid and dependable place to be, with lots of nurturing and supportive, helpful and giving behaviors. She ensures that its members are generous, altruistic, and loyal to their peers.

Each of these groups is driven by quite different perspectives, value sets, beliefs and energies. They don't fall neatly into single-description categories and the source of their respective differences seems to be deeply archetypal in nature. And like any individual or group which becomes inflated with an archetypal image, each of the groups defends its place in the world quite vigorously, indeed sometimes with stunning ferocity.

Against this sort of background, we now turn to the basis of a strategic response....

Leveraging Change

Very early on, we realized that those issues posing difficulties in the management of expeditioners were in fact symptoms of some deeper underlying causes. Many of these causes lay in the unconscious and quite deep inflation of some of the sub-cultures with the different archetypal energies described above.

Reported symptoms of the difficulties were such things as occasional physical violence, inappropriate behavior under the influence of alcohol, apparent excessive use of alcohol, disruption to work programs, medical disorders, accidents, and social tension in the communities over such things as exclusive male-female pair relationships. There were also reports of significant group tension across various occupational groupings. A lot of the evidence for such symptoms was highly anecdotal and their extent, frequency and the degree to which they caused actual difficulties in the communities was very hard to establish in the early stages.

Moreover, expeditioners and Divisional employees identified a very large number of first order independent environmental variables which seemed to impact directly on the frequency and extent of these symptoms. Inter alia, these included ...

- time of year,
- management style of Station Leader,
- mix of new and returning expeditioners in a community,
- relationship of technical people in a community with their respective Australian-based technical supervisors,
- mix of scientific and building construction personnel,
- frequency and extent of accident or injury to expeditioners,
- weather
- availability of water and fuel,
- age of expeditioners,
- male-female ratio in a community
- logistic support systems in Australia for the reconstruction program,
- shipping schedules,
- frequency of apparent overt conflict among expeditioners,
- formation of visibly cohesive and exclusive work-based groups,
- different work patterns among different occupational groups
- personal crisis involving loved ones and relatives in Australia,
- noise levels in common living areas,
- conflict over smoking and alcohol usage,
- changes in community membership over the summer period,
- time of response to requests from Antarctic personnel by Australian-based Divisional employees,
- differences in the primary employing authority's goals for an expeditioner's work program (e.g. Antarctic Division, Australian Construction Service, Bureau of Meteorology, university faculty, etc..),
- frequency and extent of major life changes in the recent past of an expeditioner prior to employment,

to name but a very few!

An extensive literature search failed to identify any systems models which could adequately account for either the symptomatic data or the many independent variables. In this type of setting, the more "traditional" route of data-gathering, problem-analysis, problem-identification and strategy-formulation breaks down for there is no framework and/or language which will aid an inquirer in adequately and correctly identifying the underlying cause/s. Australia, and other countries who send persons to live in Antarctica for extended periods of time, simply do not yet have working causal models to explain and predict adequately the experience in its breadth and depth.

Given this situation, a number of managers within the Division and former expeditioners were consulted in order to establish some long-term vision of a preferred future for an Australian Antarctic community. A primary vision statement for the human resource management in these communities was thereby established...

> *Individuals and communities behaving effectively; base communities with shared values and cultures which enhance mutual cooperation, responsibility, enjoyment and overall community life.*

This vision statement was then broken down into more specific components...

- interpersonal conflict managed constructively
- individual members caring for one another
- executive management of the community by a pair: Station Leader and Deputy Station Leader
- work programs run efficiently and effectively
- increased frequency of reports by expeditioners of a happy and worthwhile year
- mutually supportive and caring relationship between Station Leader and Deputy
- members not only tolerating but constructively using individual difference in the community
- individuals reporting satisfying and smooth reintegration into family, social networks and Australian society
- a support mechanism for Station Leaders,
- Station Leaders with more power to influence individual behavior,
- a more reliable data base for management decisions with regard to current and future expeditioner selection and return to Australia,
- more congruent fit of people and their jobs within a community,
- mutually dependent and supportive working relationships among groups within a community
- cultural elements (artifacts, behaviors, perspectives values, and assumptions) which support the above components.

In other words, rather than trying to solve problems within existing assumptions about what "didn't work", the decision was made to set out and try to use the human resource management system as a vehicle to create (over time) a more effective social system which, in turn, would not exhibit the symptoms already identified. Or... at the very least... allow a wider and more diverse set of perspectives to operate within the communities and within the headquarters organization back in Australia, i.e. to curtail the inflation of some of the sub-cultures with certain gods, and to allow others to come into play.

Shaping and managing deep unconscious forces directly is almost impossible. Putting energy into strategies aimed at attitude change is a gross waste of resources - social scientists established long ago that behavior change comes before attitude change, not vice versa. The task therefore was to act in the external world in the belief that, eventually, attitude change would emerge and, ultimately, the sub-cultural conflict (thought of as a conflict between gods) would be turned into the constructive use of diversity.

Hence we tried to identify probable key leverage points within each of the selection, preparation, management and repatriation phases of an expeditioner's life cycle of employment. We made the assumption that sustained improvement at *a number of key leverage points* in each phase would aid significantly in the evolution of the preferred social systems .... of more appropriate cultures. Moreover, we tried to create a situation where each lever would (of itself) induce substantial change. Thereby, allowing for "slippage", the fact of using a number of leverage points would (we hoped) build a *redundancy* into the whole affair which would increase the likelihood of success.

Work groups were established to examine in detail each of the three main system elements: selection, preparation and management. These groups of people were constituted as necessary and composed of persons judged to have the relevant knowledge, experience or expertise regardless of their current role in the Division: in most cases they turned out to also be former Station Leaders or expeditioners. Wherever possible those affected by decisions likely to come out of the work of these task forces were either consulted or involved as appropriate. Academics, researchers, and Antarctic-literate personnel from other nations were also consulted.

We now turn to the actual strategies instituted at each of the identified leverage points....

The Strategies

Selection Phase

All personnel selection is really a matter of trying to minimize error: the error between human judgement in the present and performance in the future. The entire expeditioner selection process from beginning to end was studied and some changes implemented. The changes described below have been depicted in more detail elsewhere (Dalmau & Mulligan, 1988); what follows is more in the nature of a summary ....

Interviewing: Whilst it has long been accepted that the interview is a poor selection tool for predicting future performance there are few systems which dispense with it. But, equally, there are few in Australia which rely so heavily on interview behavior as does the selection system of the Australian Public Service. In other selection environments it is usually heavily supplemented with other elements.

Starting about February of each year, twenty or more personnel and technical representatives of the Division conduct selection interviews in all major capital cities and regional centers throughout the country. They interview over 500 short-listed applicants annually. The interviewers find it difficult to know what they are looking for in potential candidates in any way that they can make verbally explicit and clear. Their sensory acuity is often such that, even if they can be clear about what they were looking for in candidates, they are not be able to distinguish among different candidates. We identified that most seemed to lack skills of voluntary dissociation which they could use consciously in the interview process itself: a vital skill which enables an interviewer to separate out his/her own personal feelings about a person or process from what is actually going on, and thereby make more dispassionate judgements.

It became clear that, more often than not, expeditioners were ultimately selected as the result of some vague, highly intuitive factor based on a sense of personal comfort. The mechanism used was often projective identification: the candidate having satisfied technical performance criteria, the interviewer then often tries to imagine how s/he would feel spending a winter with the candidate.

Starting in March 1988, those Divisional employees who work in the Personnel Section and who sit on expeditioner selection panels were trained to increase their sensory acuity. They were also trained in dissociation and more sophisticated questioning skills. The training used knowledge and skills from neuro-linguistic programming. and was based on behavior modeling and video-feedback for its process. Feedback about the efficacy of this skills training in helping panel members distinguish among applicants in interview situations has been positive. The training has been refined over the years - unfortunately, reports suggest it has become mechanistic and does not emphasize enough dissociation, calibration and precision questioning skills.

Psychological Screening: The screening of applicants for psychological suitability constitutes another leverage point. The evidence to support the predictive validity of psychological screening in regards to future social and technical performance in remote communities seems to be controverted. However, the Division has maintained a policy of completing such screening more as a basis for excluding persons rather than predicting their future suitability. After a study commissioned to review the efficacy of the screening system provided on contract to the Antarctic Division by the Australian Army Psychology Corps, it was decided to use the Clinical Analysis Questionnaire (CAQ) to supplement the use of the 16PF, personal history and face-to-face interview. The Army now provides the Division with a bipolar yes or no recommendation in terms of an individual expeditioner's potential suitability whereas, in the past, the recommendation had been yes, no or marginal. Executives within the Division report these and other changes have increased their confidence in the psychological screening component of the selection process.

Referee Checking: It is an unfortunate practice within the Australian Public Service that selection panels are not required to seek out actively and check with referees themselves but, instead, rely on written references. Moreover, even if selection panels do contact referees directly, it is usually true to say that the interviewers do not have the precision communication and questioning skills necessary to elicit the "right" data. Consequently, a potentially rich source of information is lost to the selection decision-making process. Divisional selection panels for 1988 were instructed to undertake phone checks with referees of all final choice applicants. Regretfully, this practice does not seem to have been continued beyond this point.

Station Leader Selection

The process for selecting expeditioners is also used to select Station Leaders. There is one main difference, however: the addition of an Assessment Center for the final 12 to 16 short-listed applicants. This is conducted at the Division's training facility in the highlands of central Tasmania about May of each year and lasts about 5 days. In the mid-80s the processes used within the Center were grounded in a highly rational and cognitive means of selecting suitable candidates. After reviewing the process there was little or no evidence to suggest major elements should be deleted or substantially modified. But it did become clear that the Center process did not apparently allow the selectors to obtain information on the applicants'...

- level of intrapersonal insight,
- interpersonal skills,
- intentional group intervention skills,
- mediation skills, and
- more affective constructs of their personalities.

In 1988, many of deficiencies were rectified through....

- changing the composition of the initial screening panel,
- changing the composition of the selection panel, and
- adding elements to the assessment center process design which gave the panel information under the above categories.

In the period since then, the process has been subject to annual review and improvement.

Taken as a whole, these changes to the selection of expeditioners and Station Leaders was designed to ensure that fewer people with inappropriate psychological profiles managed to find their way through the "system" and down to Antarctica.

Preparation Phase

The next stage in an expeditioner's life cycle involves him/her starting formal employment with the Division and preparing to go south. In this phase, a number of quite significant changes were made, based largely on the study which highlighted that initial expectations played a major role in how an expeditioner experienced a year in Antarctica.

Contracts: Expeditioners sign a formal contract which requires of them certain "minimums". Prior to the mid-80s, these minimums were quite general legal requirements which are largely common to all public service employees. Expeditioners are now required to sign a Code of Conduct document which specifies the minimum standards of acceptable social behavior and management of property. They are also required to commit themselves to participating in a performance planning and reveiw system known as EDAS - see below.

The signing of the documents does not prevent an expeditioner from engaging in inappropriate behavior, but does achieve two clear things: communicates the Division's expectations much more directly, and provides a more solid legal base for confronting difficult behavior if and when it does occur.

Induction: A number of changes were made in 1987 to improve the more symbolic and "meaning-creating" elements of the first formal contact that a newly-employed expeditioner has with the Division: at around induction time, mainly through the use of specific small rituals and involvement with the senior managers of the Division. Regretfully, these have not been maintained over the last few years with as much focus and relevance as in the late 80s.

Technical Training Program: The Division spends considerable resources training expeditioners in specialized skills once employed and before embarkation. These include such things as theater nursing, anesthesia, and fire fighting. It also upgrades the technical skills of tradespersons so that they can fulfill a wider range of duties than would normally be required of them in the Australian community. During 1987 it became clear that the technical and community training program was in need of a strategic review. This has been done in 1988 and there has been a significant improvement in both the program's cost-efficiency and its cost-effectiveness.

Community Development And Field Training: Expeditioners, prior to embarkation, are trained in search and rescue, Antarctic weather, safety and survival, first-aid, and the like. In previous years this training was conducted at the Division's facility in the highlands of central Tasmania, and it was not uncommon (as a result of the way in which such training was arranged) for an expeditioner to meet his/her companions only upon embarkation. Winter groups and summer groups were trained separately, and it wasn't always the case that even an entire contingent of winterers would be together for the field training.

It was decided to train winter and long-term summer personnel together and to institute a program of community development which would aid in the development of a sense of identity for each base community and would begin to provide expeditioners with an opportunity to explore..

- tolerance and building on individual difference
- stages of group and community development
- interpersonal communication, including conflict mediation
- their own emerging relationships with one another
- norms for the life and work together in Antarctica

The overall goal that this community development intervention seeks was to..

> *have individuals expeditioners and base communities beginning to behave cooperatively, responsibly and satisfyingly with appropriate knowledge and understanding to improve the quality of their living in Antarctica.*

Feedback from 1988 winter and summer personnel (who were the first to experience this intervention) led to the combining of all four base winter and summer expeditioners into one combined training experience of 9 days duration at Brighton Army Camp in southern Tasmania for the 1989 expeditioners. This event integrated what had previously been three separate parts of the preparation phase: orientation, field training, and (for 1988 winterers only) community development. Feedback from expeditioners has been extremely positive regarding this specific improvement. There is no doubt it has contributed significantly to smoothing the early stages of community growth once the expeditioners reach Antarctica.

Deputy Station Leaders: Until the 1988 winter expeditions, the role of Deputy Station Leader was an honorary one. The person appointed to this position was selected by the relevant Station Leader sometime on the voyage between Australia and Antarctica. In 1987, procedures were set in train to formalize this role and provide the occupant with an allowance. The selection of Deputy Station Leader is now done by the respective Station Leader during the Community Development and Field Training experience.

The formalization of this role was designed with one main purpose in mind: to provide leadership support to the Station Leader and to move away from the situation of one person being responsible for everything to one in which a management pair is responsible for the personnel management of the base community. The Deputy Station Leader role is part of this process and its main duties are ...

- to assume leadership of the base community in the event of death or injury of the Station Leader,
- to assume leadership of the base community when the Station Leader is off base, e.g. out on an ice-traverse, and
- to support and work in cooperation with the Station Leader in the personnel management of the community members.

There is no doubt that the formalization of this pair relationship has made the lot of a Station Leader much easier, and has led to a more cohesive management of the communities. But there are still difficulties with it. Most significant of these is that the Station Leaders tend to select as deputies people who share similar characteristics to themselves - this leads to a comfortable existence, but not necessarily the most effective leadership combination. The Division does not, as an organization, have as much influence as it might in this selection process and consequently cannot influence the selection to ensure complementarity. Plans are currently underway to remedy this deficiency.

Leadership Skills Training: Once the Deputy Station Leader has been selected and following the Community Development and Field Training, the Station Leader and Deputy undergo a program of leadership training and development.

The overall goal of experience was to ...

> *develop a skilled, knowledgeable Station Leadership pair to improve the quality of base life, effectiveness and efficiency of overall operations.*

The training experience was intended to provide skills, knowledge and strategies for the Station Leader and Deputy and covers such things as ...

- role clarification
- relationship building and conflict resolution strategies
- social system development strategies
- interpersonal styles and their management
- counselling and appraisal systems
- personnel policies and procedures
- counselling skills

The original intention behind this program element has been diluted over time. It was hoped this training would weld them into a working pair and provide them with the relevant skills and knowledge to work effectively as managers of people. The first program was four days in duration and held in 1987. Unfortunately, logistical and organizational difficulties combined with a drop in focus by those responsible for this element has resulted in a gradual diminishment of both its duration and its effectiveness.

Management Phase

The two most visible interventions into the management phase of have been the establishment of a counselling and appraisal system and the development of the role of Deputy Station Leader (previously described).

Other significant interventions have included ...

- changing names of key roles in base communities away from militaristic metaphors,
- establishment of base-specific manager positions in the Antarctic Division
- re-writing of the Station Leader's manual: a set of personnel management guidelines for both Station Leaders and Deputy Station Leaders,
- development of the Station Leader assessment system.

Each of these interventions represents an identified key leverage point in the development of the base's social system and, ultimately, its culture.

Expeditioner Development And Assessment Scheme (EDAS): In the past expeditioners had been assessed on their performance over a whole year by a returning Station Leader. The report was a two page document known as a Y-Report, whose sole purpose seemed to be providing the

Division with documentation on which to base (in part) future selection decisions should an expeditioner re-apply for employment. There were a number of difficulties with this database...

- the content of the ratings used was vague and inconsistent,
- some Station Leaders did not complete Y-Reports on their expeditioners,
- in some cases, expeditioners did not know of the existence of the Y-Report,
- expeditioners were not privy to the content of their assessment unless they were familiar with the Australian Public Service personnel management regulations and realized they could obtain access to them, and
- returning Station Leaders tended to report over-favorably on their expeditioners for fear of litigation brought by a disgruntled expeditioner.

The whole reporting process was reviewed, and rather than set out to improve the existing system, a new system was developed against the following criteria:- It needed to be an open just, fair and equitable as a system which was consistent with existing Australian Public Service personnel practices without replacing or contradicting them. It also needed to provide for regular counselling sessions between Station Leader and each expeditioner, and reflect the realities of community living on an Antarctic base. Finally, it needed to reflect the best principles from both public and private sector current personnel practice.

The EDAS system was developed over a period of twelve months in 1986 and 1987 by employees of the Division following a process of consultation and decision-making supervised by a consultant. It reflects items of concern deemed critical by former expeditioners and Station Leaders in making judgements about an expeditioner as a member of an Antarctic community.

Two systems were developed: one for summerers and another for winterers. The winter system is essentially a counselling system at predetermined points in time: just after the last ship leaves about March/April each year, within a month of the winter solstice and just prior to an expeditioner's return to Australia. Expeditioners rank themselves against specified questions; the Station Leader and Deputy do the same. The three people concerned then come together for an interview and discussion about the expeditioner's performance and plan improvements for the period to the next EDAS cycles.

The questions within both summer and winter EDAS cover

- behavior as an individual,
- social interaction and behavior as a member of a community,
- work performance, and
- ANARE-specific items.

With the summerers, there is no self-assessment by an expeditioner and there is no interview, although the expeditioner does receive his/her own copy of the assessment. The summer EDAS system is essentially a simple reporting system.

Research into the correlation of EDAS profiles with psychological profiles developed by the Army Psychology Corps as part of the selection process is currently underway, as is some closely related research by the staff at the University of Tasmania.

According to recent Station Leaders, the EDAS systems is generally well accepted by expeditioners, though the degree and nature of the acceptance may vary considerably. What does seem to be emerging, however, is that the very high importance with which the Division views EDAS is not necessarily shared by all expeditioners - consequently, there is now a need to "sell" the relevance and value of the system much more thoroughly to expeditioners in the preparation phase of their life cycle.

Labels: It became clear that one of the major blocks to improving the overall quality of life for expeditioners in Antarctic communities was the expectations they carried in their minds as to the nature of the relationships among relevant parties. For example, the role of Station Leader is a complex one with at least three key facets: commander in a crisis, manager of people who work together, and leader of a human community. The former term of "Officer-in-Charge" or "oic" contained meanings for only one of these three facets: hence it was changed to the more encompassing "Station Leader". Similar changes were instituted in a few other areas, thus enabling discussion and exploration of the wider dimensions of human interaction in a base community.

Operations Managers: A new role of Station Manager was created within the Divisional structure in Australia. Four of these positions were created and the role's primary function was to minimize duplication of effort and communication regarding each base by the many and varied parts of the Division which support and supervise base operations. Over the time since their inception they have been reduced to two in number and their title changed to that of Operations Manager. It should be said that the initial establishment of the original Station Manager roles was fraught with ambiguity and confusion among the senior ranks of the Division and the initial role occupants. Consequently, the occupants were never really able to fulfill the original intention. The two roles as presently constituted provide a useful coordinative and communication link between the Division and the bases in Antarctica. Above all, they provide a point of direct contact and organizational support for the Station Leaders.

Station Leader Guidelines: In years past Station Leaders were issued with a manual spelling out suggestions as to how they should behave in given situations, and what were certain of their legislated responsibilities, e.g. in regard to environmental protection. They were generally asked to keep the contents of the manual secret and return it to the Division before embarkation. The content contained quaint and unhelpful militaristic metaphors of control inconsistent with the basic idea of developing a cooperative, open and interpersonally competent community. A new set of more flexible guidelines was introduced in 1987, and distributed openly to all Station Leaders and their Deputies. The guidelines are now updated each year as necessary and are based on a more interpersonal, community-oriented, facilitational and problem-solving approach to leadership.

Station Leader Assessment:

In the original study many expeditioners commented on the absence of formal evaluation of a Station Leader's effectiveness. Moreover, the Division had no formal and comprehensive mechanism or record of a Station Leader's efficacy on which to judge applications for re-employment. The measurement of on-going management and leadership effectiveness of Station Leaders in Antarctica posed a major design problem: how do you measure someone's day-to-day management behaviors from a distance of thousands of miles. A search was undertaken for relevant assessment models from varied work and corporate environments and a suitable model identified. At the heart of the system is a process for collecting and storing all relevant information until the Station Leader's return from Antarctica. The information for consideration comes from the following sources:

- EDAS interview and counselling session with relevant immediate superior (Station Manager) just prior to embarkation and covering the period since employment (usually a period of up to 5 months)
- Three-monthly self-assessment by Station Leaders and their Deputies against core competencies
- EDAS review done jointly with Deputy Station Leader as part of the usual EDAS cycle for expeditioners
- Three-monthly base operations review meetings in Divisional headquarters of all Australia-based managers for each base
- Monthly Station Leader status reports
- Monthly base reports from other technical supervisors.

Upon return to Australia each Station Leader is provided with up-to-date copies of this information base, and then goes through a debriefing and formal interview process, after which an assessment report is written on his/her effectiveness as a leader. As with expeditioners, the senior managers who debrief the Station Leader recommend that the person is or is not suitable for re-employment by the Antarctic Division as a Station Leader. Plans are currently underway to provide another element in this system - expeditioner feedback on a Station Leader's effectiveness

Return To Australia

There is some anecdotal evidence to suggest that many returning expeditioners experience serious distress and difficulties of adjustment upon return to Australia after their winter away. Others suggest that the morbidity of this group may be higher than the norm.

There are stories within the environment of some returned expeditioners who apparently never "recover fully" from the effects of the experience "down south" and the consequences of changes that occur in their home lives during their absence. Just how much credence to give to this anecdotal evidence is uncertain, for there is only one longitudinal study: Palinkas et al (1986) report in a study of 328 US Navy personnel who wintered in Antarctica between 1963 and 1974 that the follow-up disease risk among winter-over personnel was lower than that of the control group. However, the primary measure of such risk was the incidence of all-cause first hospitalizations. Clearly, this is but one measure. We lack any comprehensive longitudinal studies of the effects of an "Antarctic experience" on such things as future marital/relationship stability, suicide rates, non-hospitalizable disease, psychosocial adjustment, career and work patterns, and the like.

On the other hand, returned expeditioners supply a wealth of anecdotal evidence on such matters. Plans are in train to undertake a comprehensive analysis and review of this aspect of the total expeditioner personnel management system, but resource and time constraints have required that the first three elements of selection, preparation and management be attended to first.

In the relevant literature there is a phenomenon which is variously called reverse culture shock or re-entry shock - it describes some predictable stages that people go through. Its manifestations can be from extremely mild hiccups in a person's functioning that might last only a few days and then be gone, through to reactions which can be quite severe and disabling. It shares some commonalities with what has been known for about 30 years as culture shock. The manifestations of this shock process seem to be the same no matter what groups we are considered. It is now clear that returning expeditioners do go through this well-documented and well-understood process and plans are now in train to institute systems which will make their transition back into Australian life a little easier.

We now turn to the impact, to date, of some of these interventions and the issues which they raise.

Impacts and Issues

When we embarked on this journey, the initial diagnosis led us to assume we could improve the morale, performance and quality of life of base communities by intervening primarily in the selection and preparation phases of their human resource management system. We also assumed, that the psychological "lot" of the returning expeditioner would also be improved thereby.

However, we soon began to realize that, not only selection and preparation, but management and return of expeditioners were equally critical if the long-term performance and quality of life on the bases was to improve.

The usual problem-solving approach to improving organizational practices and procedures became inappropriate for there are no models which can adequately account for the range and diversity of independent variables and the observed data. Consequently we set out to construct social systems into which new and returning expeditioners would move. We also set out to provide for a wider set of perspectives and energies to be given voice in Australia's Antarctic life and to diminish the negative impact of some of the more extreme sub-cultural elements.

We then began to experience the potency and complexity of the cultural elements, and the intensity of defence driven by deep archetypal energy. Trying to change practices and procedures became subsumed into the larger task of a fundamental re-arrangement of the purposes and directions and, ultimately, the sense of identity and unity surrounding the Antarctic experience for Australian expeditioners. (Dalmau, Dick & Boas, 1988). The task is by no means complete: cultural interventions are long-term, complex, and problematic. But it is possible to take a partial stocktake...what then has been the impact to date of these initiatives?

In overall terms, the human resource management system of Australian expeditioners has undergone significant enhancement and is now on par with the type and style of systems used in the Australian public sector and the private corporate world.

The bases in Antarctica are far more physically comfortable than 6 or 7 years ago. The availability of instant voice and data connections to loved ones and colleagues means the average Australian community in Antarctica is very much an "open system". (It is perhaps ironic that 6 years ago expeditioners complained,about the time taken for a telex to get to loved ones; they now seem concerned about the quality of the voice on the phone line or the quality of the sound signal on the television transmission!). These changes have led to a much higher set of lifestyle expectations for the average expeditioner down south, and this will no doubt have a major future impact on the efficiency and safety of field operations.

The increased ease of communication has meant that headquarters staff are far more intrusive into community life - expeditioners, thus come much more directly under the day-to-day influence of headquarters-based personnel and even senior government officials in Canberra. Given the diversity of cultures and perspectives among the groups within headquarters, it is not surprising that expeditioners in Antarctica experience mixed, and often contradictory, messages about their management and welfare. This seems particularly the case for Station Leaders whose role separation from expeditioners seems to be increasing as they take on, more and more, the mantle of being a manager.

The level and complexity of human behavior understanding in the minds of those headquarters managers directly supervising land operations from Australia has increased dramatically over the last 6 years. This has led to a much more sophisticated and responsive stance to people management problems as they occur in Antarctica. Unfortunately, this has not been matched among all management staff within the organization.

The frequency of strange and bizarre behavior in the Antarctic communities compared with Australian community norms has decreased overall. The Antarctic Division is clearly much better at selecting suitable people to live and work in Antarctica. This doesn't prevent the odd and very visible incident occurring; unfortunately, these tend to still generate as much attention as before. The problem of alcohol-related behavior problems in the communities does not seem to have decreased, and it is now clear that some other approach to this issue is required.

Moreover, quite a few of the behavioral problems now seem to be located most in either of two groups - the ACS group or the summer scientists. The Antarctic Division has little or no control over the selection of ACS personnel and many in management positions within the organization believe there is room for improving the selection of people to this group thereby decreasing the frequency of "false positives". Whether this is a valid cause-effect analysis remains to be seen - the problem may be more to do with the selection of those appointed to supervisory positions within the ACS groups in the Antarctic communities.

In terms of the summer scientists .... when the changes were first introduced six years ago, all expeditioners who would be in community or on ship for more than 6 weeks were required to undergo psychological screening. Under pressure from the scientists group, this has been extended to 12 weeks. Consequently, the Division does not psychologically screen quite a large number of personnel who can be in community for a significant period of time - certainly long enough to have a major effect for good or ill on others. There is some anecdotal evidence to suggest this group may also be subject to more injuries and accidents than others. Most Station Leaders privately report some members of this group regularly pose significant management difficulties in terms of their impact on community. At the present period, it seems the organization has struck an equilibrium point which satisfies the needs of the scientist group on this issue, possibly at the expense of the larger community.

In Australia there has been a major increase over the last decade in the level of general community awareness regarding sexual harassment. This issue is now manifest in the Australian Antarctic communities and represents a new point of cultural inter-group tension: between the Apollo of the organization and the Eros/Ares drive within many in the communities. There is no doubt there will be increasing and significant shifts in acceptable standards in this area as the changes in Australian society are reflected in Antarctic life - hopefully, these will occur before some expeditioner feels obliged to seek redress through litigation.

The changes made to the preparation of expeditioners whilst still within Australia have received wide acceptance. They lead directly to the forming of "groupness" under very favorable conditions. The communities now have a much greater ability to *contain* the various groups (i.e. cultures) within them at a much earlier stage than previously.

In terms of EDAS providing a vehicle for the evaluation and development of expeditioners whilst in community, the results seem to have been mixed. Most Station Leaders report that with a few winter expeditioners, the first EDAS interview does provide them with a behavioral lever with which to influence subsequent behavior. About 60% of the expeditioners seem to accept the EDAS system for what it is, but about another 30% seem to harbor grave misgivings about its relevance and inherent validity. In any community, it seems a very few expeditioners are overtly hostile and uncooperative regarding the system. From headquarters point of view, it represents a major achievement and improvement on the previous invalid reporting system.

The EDAS system has provided the organization with the hard data needed on a few occasions when it was necessary to refuse re-employment to an applicant expeditioner whose service had proved unsatisfactory in the past whilst, at the same time, meeting stringent Australian Public Service requirements of administrative justice and fairness.

These decisions not to re-employ quickly find their way into the informal networks of the returning expeditioners and most now realize that a satisfactory EDAS experience is a pre-requisite to future employment. Similarly, the decision to give two Station Leaders unsatisfactory assessments which bar them from future re-employment has struck a loud and clear not of intent throughout the ANARE culture.

This has been reinforced by the recent rejection of some ex-Station Leaders who re-applied for employment on the grounds that their style and competencies were not appropriate to more recent management requirements of the Division. The selection of Station Leaders has been refined significantly over the last six years and the calibre of final applicants has been consequently enhanced.

Nevertheless, there is clearly a cultural chasm between the Hephaestos, Ares, Dionysus and Eros of many expeditioners on the one hand, and the Apollo and Prometheus of the Division's executive on the other. Most (but not all) of the expeditioners simply do not come from an assessment culture. For a few the only assessment they receive is the sack. They come from a non-literate-based, non-verbal and non-reflective culture. Yet the management and staff of the Division pay close attention to the written and spoken word in determining who may and may not become or return as an expeditioner. It seems the organization may well need to devote more focus and energy into selling the value of EDAS in future years in order to increase its acceptance rate well above the 60% mark.

Most of the changes instituted since late 1986 were established in the period to 1988. The period since then has been one primarily of refinement and improvement. It may well be that the time is now opportune to undertake a major review of these changes and build on the work done to date.

Tim Dalmau
June 1992

I extend my deep appreciation to the expeditioners, Station Leaders and managers within the Division who helped in compiling this paper and who provided helpful critique, and to Brian Donaldson of Ernst & Young, Brisbane. The contents, however, are ultimately my views.

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Oil Spill Prevention and Response

by

Jack Sayers
Australian Antarctic Division

ABSTRACT

In 1990 the Council of Managers of National Antarctic Programs (COMNAP) requested its Standing Committee on Antarctic Logistics and Operations (SCALOP) to develop policies and procedures on oil spill prevention and response in the Antarctic. A Sub-group on Oil Spill Prevention and Response was established to undertake the task.

This paper outlines the principal recommendations developed by the Sub-group during the last two years. The measures recommended include procedures on oil storage, oil transfer and contingency planning, as well as proposals on other relevant matters including the minimum experience required of ships navigation officers, hydrography, and the use of non-persistent fuels.

INTRODUCTION

The need to adopt measures to protect the Antarctic environment from marine pollution is a requirement of several Antarctic Treaty Consultative Meeting (ATCM) Recommendations. Furthermore Annex IV of the "Protocol on Environmental Protection to the Antarctic Treaty" also specifies a range of measures directed towards marine pollution prevention and response.

At the June 1990 Meeting in Sao Paulo, COMNAP requested SCALOP develop a course of action to guide national operators in the implementation of measures to prevent oil spills and to provide guidelines for the preparation of contingency response plans. A SCALOP Sub-group on Oil Spill Prevention and Response was formed with representatives from Australia, Canada, Germany, Norway, South Africa, United Kingdom and the United States of America.

SUB-GROUP RECOMMENDATIONS

During the last two years the SCALOP Sub-group on Oil Spill Prevention and Response has developed a number of recommendations on measures to prevent and combat oil spill pollution. The recommendations will be considered at the 1992 Bariloche Meetings of SCALOP and COMNAP. Particular emphasis has been placed on measures which will prevent or minimise the risk of oil spills in Antarctica. In addition, comprehensive guidelines on the preparation of oil spill contingency plans have also been prepared. The key recommendations of the Sub-group cover the following topics:

- Navigation Experience of Ships' Officers;
- Use of Non-persistent Fuels;
- Shipboard Contingency Plans;

- Hydrographic Charts;
- Oil Transfer at Stations and Bases;
- Oil Storage at Stations and Bases; and
- Contingency Plans for Stations and Bases.

Navigation Experience of Ships' Officers

The seas surrounding Antarctica are among the most inhospitable in the world. Even during mid-summer violent storms can occur with little warning and even the largest of vessels can be threatened by besetment in heavy pack ice.

Because of the unique environmental hazards encountered by Antarctic shipping it is essential that there are officers on board the vessel who have wide experience and knowledge of Antarctic meteorology, ice conditions, tides and currents in the intended region of operation.

It is worthy of note that the Chile maritime authorities have recently established a School of Antarctic Navigation which offers a three week intensive course providing tuition in the following topics:

- Antarctic Meteorology
- Maritime Administration
- Antarctic Legislation
- Antarctic Treaty
- Tides and Currents in the Antarctic
- Antarctic Environment
- Antarctic Pilotage.

The Chilean authorities now require that any Chilean merchant ship bound for Antarctica must be under the command of a master who has completed this course.

At the present time national Antarctic operators use a variety of policy standards for the navigation experience of deck officers. The SCALOP Sub-group has recommended that members of COMNAP adopt a minimum standard as follows:

> *"Masters and/or Chief Officers of vessels operating under charter or in support of Antarctic operations shall have at least one season of ice navigation experience in the Antarctic. Where there is any concern in this regard an ice pilot should be engaged."*

Use of Non-persistent Fuels

The definition of non-persistent oil is open to debate. Oils which may be considered non-persistent in moderate climates may become persistent oils at Antarctic temperatures.

The International Oil Pollution Compensation Fund describes non-persistent oil as "oil which, at the time of shipment, consists predominantly of non-residual fractions and of which more than 50% by volume distils at a temperature of 340°C when tested by the ASTM Method D86/78 or any subsequent revision thereof".

All national Antarctic operators use light diesel fuels or jet fuels for power generation at stations and bases. A number of Antarctic re-supply vessels use medium/heavy fuel oils although the use of these oils appears to be decreasing as newer vessels are brought into service. The degree of threat of severe marine pollution can be reduced by the application of voluntary restrictions on the type of oil that is used whenever feasible.

Standardisation on the use of lighter, non-persistent fuels by national operators would also facilitate standardisation of oil spill response equipment. The wider the availability of standard response equipment, the greater the potential to respond effectively to oil spill incidents and hence limit the environmental damage that might arise.

Accordingly, the SCALOP Sub-group has recommended that members of COMNAP agree:

> "i) *to the use of light, non-persistent fuels in the Antarctic Treaty area whenever practicable and possible; and*
>
> ii) *specify engines using light diesel fuel for the construction of new vessels intended for service in Antarctica."*

Shipboard Contingency Plans

The *Exxon Valdez* disaster highlighted the need to develop a global network to co-ordinate pollution response resources. In 1990 the International Maritime Organisation (IMO) promulgated an International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC) to complement existing IMO conventions relating to marine pollution. The OPCR Convention requires, in part, that vessels shall carry shipboard oil pollution emergency plans. The OPCR Convention also includes provisions for signatories to assess the consequences of marine oil spills and report the incident to States whose interests are likely to be affected. The requirement for vessels to carry shipboard oil pollution emergency plans has been incorporated in Annex IV of the "Protocol on Environmental Protection to the Antarctic Treaty".

The SCALOP Sub-group has therefore recommended that members of COMNAP adopt the following measures, based on Articles 3 and 5 of the OPCR Convention, 1990:

> "i) *ensure that any vessel operating under charter or in support of their Antarctic operations has on board a shipboard oil pollution emergency plan, such plans to be in place by 31 March 1995 (or sooner if required by national legislation);*
>
> ii) *assess the nature, extent and possible consequences of oil pollution incidents and, without delay, inform all operators whose interests are affected or likely to be affected by such oil pollution incidents;*
>
> *and, in addition*
>
> iii) *immediately report all serious Antarctic oil pollution incidents, whether from ships or onshore, through the COMNAP/SCALOP Secretariat for advice to all COMNAP/SCALOP members."*

Hydrographic Charts

The safety of Antarctic vessels, and hence the avoidance of marine accidents and associated oil spills, depends heavily on the availability of accurate and up-to-date hydrographic charts. At the 1989 Paris ATCM, Recommendation XV-19 proposed that Treaty Parties recommend to their Governments that:

- They increase their mutual cooperation in the hydrographic survey and charting of Antarctic waters in order to contribute to the safety of navigation, the protection of the Antarctic environment and dependent and associated ecosystems, and for scientific purposes; and

- For the purposes of hydrographic survey and charting and associated terrestrial surveys and mapping, they co-ordinate their activities within the framework of IMO and SCAR, as appropriate.

SCALOP is currently collecting data on marine incidents and hydrographic charting priorities from national operators. Consistent with the requirements of ATCM Recommendation XV-19, the SCALOP Sub-group has recommended that members of COMNAP:

> "i) *identify areas of greatest need for the preparation of accurate hydrographic charts;*
>
> ii) *co-ordinate with their respective national hydrographic agencies and the International Hydrographic Organisation for the preparation of such charts; and*
>
> iii) *ensure that the Masters of vessels supporting their program have the best available charts for use."*

Oil Transfer at Stations and Bases

The design of station facilities, the means by which fuel stocks are replenished, and the resources available to accomplish the replenishment or transfer of fuel stocks vary between national operators. A number of operators have experienced fuel spills during fuel transfer operations which have typically resulted from human error or equipment failure.

The SCALOP Sub-group has developed a document on "Recommended Procedures for Fuel Oil Transfer at Stations and Bases (see Annex A). The procedures cover the documentation, training, operations, inspection and maintenance of fuel transfer activities. The Sub-group has recommended that COMNAP implement the procedures as soon as practicable.

Oil Storage at Stations and Bases

Large quantities of fuel oils are stored at Antarctic stations and bases to facilitate power generation, aircraft operations and the running of plant and equipment. The failure or damage of fuel storage facilities and reticulation systems can result in major fuel spills.

The SCALOP Sub-group has developed a document on "Recommendations for Spill Prevention and Containment of Fuel Oil at Stations and Bases" (see Annex B) which outlines measures for spillage prevention, containment, detection, alert and recovery. The Sub-group has recommended that members of COMNAP implement the proposed measures as soon as practicable.

Contingency Plans for Stations and Bases

The development of contingency plans is fundamental to effective response action in the event of oil spill incidents at stations and bases. Such plans need to describe environmentally sensitive areas and assess the possible spill scenarios. In addition the plans need to articulate in clear and concise terms the operational response activities in the event of an oil spill incident.

The SCALOP Sub-group has developed a document on "Guidelines for Contingency Planning" which defines the recommended format and information to be contained in contingency plans for stations and bases (see Annex C). The contingency planning approach is based on Facility Level (that is a station or base) and Multi-Operator plans. Multi-Operator plans are to be developed where a coordinated response by two or more national operators is feasible. This will be in situations where a logistical capability exists to facilitate the transfer of response equipment between operators in the event of an incident and it is economic to pool resources.

The SCALOP Sub-group has recommended that members of COMNAP adopt the "Guidelines for Contingency Planning" and develop Facility Contingency Plans, at least to draft stage, by 31 December 1992.

ACKNOWLEDGMENTS

During the last two years the SCALOP Sub-group has collected a substantial library of reference material including papers, reports, textbooks and other publications on oil spill pollution and response with particular reference to cold regions. This information has proved to be invaluable in developing policies and procedures.

The Sub-group has also been fortunate to have national experts on marine pollution attend meetings which were convened in Washington DC during May 1991 and April 1992. In addition, several Sub-group members have sought advice on particular matters from marine safety experts in their respective countries. More recently the Sub-group has commenced liaison with key members of the Marine Environmental Protection Committee (MEPC) of the IMO. The Sub-group wishes to acknowledge with appreciation the considerable help it has received.

RECOMMENDED PROCEDURES FOR FUEL OIL TRANSFER AT STATIONS AND BASES

1. INTRODUCTION

1.1 The transfer of fuel oils from resupply vessels to shore based storage facilities, and between individual storage facilities on stations or bases, are potentially hazardous operations. It is incumbent on national Antarctic operators to ensure that procedures are in place, and are implemented, to minimise the risk of oil spillage and environmental pollution during such fuel transfer operations.

1.2 The procedures outlined in this document cover the documentation, operation, inspection and maintenance of fuel transfer facilities and the training requirements for operational staff. Individual national Antarctic operators may deem it necessary to supplement these minimum requirements to satisfy national standards, or to meet specific operational needs.

2. PROCEDURES

Documentation

2.1 Personnel who are responsible for, or are required to undertake, fuel oil transfer operations are to be provided with clear and comprehensive documentation prescribing the procedures to be followed, and precautions to be observed, in conducting fuel transfer operations.

2.2 The documentation is to include up-to-date layout drawings or diagrams indicating storage tanks, reticulation systems, pumps, valves and safety devices.

2.3 All tanks, valves and pumps are to be allocated unique identity numbers which are to appear on the layout drawings and in a prominent place on installed equipment. The written procedures are to make reference to the identity numbers.

Training

2.4 All personnel who are responsible for, or required to undertake, fuel oil transfer operations are to receive instruction or training in the operation of the equipment, spillage prevention and other measures.

2.5 The above personnel will also receive training on oil spill contingency planning procedures and duties.

Operations

2.6 Fuel transfer equipment must be inspected for serviceability prior to the commencement of pumping operations.

2.7 Except during fuel transfer operations, all isolation valves on storage tanks are to be closed.

2.8 When transferring fuel oil between ships and shore facilities or fuel farms and remote holding tanks (eg at power houses), personnel must be stationed at both locations to monitor the transfer operation and must also maintain regular contact via VHF radio or similar. The fuel transfer pipes must be monitored for leaks during transfer operations.

2.9 During fuel transfer operations only one tank shall be active (ie valve open) except at the overlap period when switching from the access tank to the next tank. Such operations must be continuously monitored.

2.10 All personnel responsible for, and associated with, fuel transfer operations are to take whatever action is deemed appropriate to minimise and avoid the risk of fuel spills.

2.11 If personnel have any doubts about the adequacy of existing procedures and systems, these must be brought to the immediate attention of the responsible authority.

2.12 Records of all fuel transfers and spillages shall be maintained by personnel on site and the national operating authority.

Inspection

2.13 All fuel storage tanks are to be visibly inspected on a weekly basis, and as soon as possible following adverse weather, to check the integrity of the storage systems and associated plumbing. In addition, all storage tanks are to be checked monthly to verify contents.

2.14 Bulk storage tanks shall be thoroughly inspected on an annual basis. A record of these inspections, including the internal cleaning of tanks, shall be maintained at the station.

Maintenance

2.15 All pumps, valves and associated equipment are to be maintained in good working order.

2.16 Any defective fixtures or fittings shall be replaced or repaired as soon as is practicable.

ANNEX B

RECOMMENDATIONS FOR SPILL PREVENTION AND CONTAINMENT OF FUEL OIL AT STATIONS AND BASES

1. INTRODUCTION

1.1 Fuel oils are used at Antarctic stations and bases for a variety of operational needs including power generation and the fuelling of vehicles and aircraft. The spillage of fuel oils as a result of equipment failure, accidental damage or human error poses a potential environmental threat. It is therefore incumbent on national Antarctic operators to design, install and operate fuel oil storage facilities to minimise such risks.

1.2 The design recommendations outlined in this document are intended to minimise the possibilities of fuel spillage to the environment. The recommendations apply to new and, where practicable, existing installations. The design philosophy incorporates:

- spillage prevention;
- spillage containment;
- spillage detection;
- spillage alert; and
- spillage recovery.

2. DESIGN RECOMMENDATIONS

Spillage Prevention

2.1 Installations shall be sited and designed to minimise the deleterious effects of the environment, such as from ice build-up on valves and fittings.

2.2 Installations shall be sited to minimise damage from operational activities such as heavy vehicular traffic and where this is not practicable the installation shall be protected by means such as bollards, guards and signs.

2.3 Tanks, valves and fittings shall be of first grade materials, suitable for petroleum products and site specific climatic conditions.

2.4 Lever operated ball valves shall preferably be used which give clear visual indication of the "open" and "shut" positions.

2.5 Manufacture, fabrication and site construction of facilities shall be inspected, tested beyond application conditions if possible, and approved for use by a competent authority.

2.6 The installation shall avoid undue complexity so as to reduce the risk of human error through confusion or misunderstanding.

2.7 Tanks shall be piped for top fill and top draw off.

2.8 All tanks shall be numbered and have the maximum capacity clearly marked. All valves shall be tagged or numbered to facilitate clear and unambiguous description in operating procedures.

2.9 Adjacent tanks shall be fitted with overflow equalising connections between them, where practicable.

2.10 Tanks shall have calibrated dip-sticks, continuous level monitoring gauges, or other means of assessing the quantity of fuel stored.

2.11 Fuel pumps for bulk handling shall have a lockable switch or other appropriate mechanism to prevent accidental pumping.

2.12 The delivery pump shall have an emergency stop switch or other appropriate mechanism located in a prominent, accessible position. Alternatively, a master valve shall be fitted immediately downstream of the pump to facilitate emergency shutdown.

Spillage Containment

2.13 The containment facility shall have the capacity to contain the contents of at least the largest tank should a spill occur plus an allowance for snow, ice or water accumulation.

2.14 Containment may take various forms including, for example:

(i) bunding around the installation or around individual tanks;
(ii) remote bunding with interconnecting drainage from the tank installation;
(iii) double skin tanks, horizontal or vertical, with the outer skin being the containment; or
(iv) flexible bladders within a containment structure.

Spillage Detection

2.15 Installations shall have, where practicable, sensors to detect fuel spillage. This may be in the form of electronic fuel sensors fitted in appropriate locations; for example, between the walls of double skin tanks or in the sump of the containment structure. Low level sensors in tanks may serve to indicate loss from a tank.

Spillage Alert

2.16 Audible and/or visual alarms shall be installed in locations which are frequented regularly, or are obvious during fuel transfer operations.

2.17 All bulk storages shall, where practicable, have a high level alarm which is audible and/or visible to an operator. Such alarms shall signify a potential overflow before the tank reaches capacity.

Spillage Recovery

2.18 Installations shall have the capacity to store any recovered fuel up to quantities at least matching the capacity of the largest tank. This provision may be met by additional storage capacity such as a spare tank, or by underfilling tanks to provide the reserve storage by transfer pumping.

GUIDELINES FOR OIL SPILL CONTINGENCY PLANNING

1. INTRODUCTION

1.1 The need to develop and implement measures to alleviate and combat the pollution of Antarctic waters has been the subject of several Recommendations adopted at Antarctic Treaty Consultative Meetings (ATCMs) in recent years. At the 1989 ATCM, Recommendation XV-4 specifically called on the Governments of Treaty Parties to establish contingency plans for marine pollution response in Antarctica, including plans for vessels carrying oil.

1.2 The need to develop contingency plans for response to marine pollution incidents is also a requirement of Annex IV of the "Protocol to the Antarctic Treaty on Environmental Protection".

1.3 This COMNAP document defines a recommended format and specifies the information to be included in oil spill contingency plans which are to be prepared by national antarctic operators for facilities or larger geographic areas in Antarctica.

2. TIERED APPROACH TO CONTINGENCY PLANNING

2.1 Most oil spills in Antarctica are likely to be small and confined to a station or base and the adjoining waters. In the event that the spill is beyond the station or base capability, or is likely to affect a larger area, an enhanced response may be necessary involving support from other national operators.

2.2 This tiered response to oil spill incidents requires the development of compatible contingency plans for individual facilities and, where appropriate, contingency plans for larger geographic areas encompassing a number of operators, as defined below:

- **Facility Plans**

  These are to be developed for individual stations or bases and their local environs, where appropriate. The plans will be prepared by individual national operators responsible for the management of a specific facility.

- **Multi-Operator Plans**

  These are to be developed to encompass a geographic area where a coordinated and compatible response by two or more national operators is feasible. This will apply where it is effective and feasible to pool and deploy response equipment and supplies.

3. FORMAT OF PLANS

3.1 The recommended format for Facility and Multi-operator contingency plans is given in the Appendix. The plans are to be divided into two parts plus annexes as follows:

Part I: Strategic Information
This is a descriptive policy document providing background information including a description of the facility and an evaluation of oil spill scenarios.

Part II : Operational Response
This describes the recommended procedures for the development of an operational response to oil spills. The format of the Operational Plan corresponds to the expected chronological order of events. The text of this document should be supplemented, to the maximum extent, with decision tree diagrams or checklists to simplify and speed interpretation. In particular the Operational Plan, Chapter 6, shall be in the form of tree diagrams or checklists.

Annexes
These include detailed reference information relating to specific aspects of the contingency plans, eg Communications, Health and Safety, Training, etc.

3.2 It is recommended that all national operators adopt the formats specified in this document. This will enable the plans to be easily understood and assist with the integration and compatibility of the facility plans with multi-operator plans, where applicable. Plans should be complete in themselves and not involve reference to other supporting documents which may cause delays. Plans should preferably be produced in loose leaf form to facilitate regular update.

4. PLAN EFFECTIVENESS

4.1 The International Tanker Owners Pollution Federation consider that the adequacy of contingency plans may be assessed against the following ten questions:

(1) Has there been a realistic assessment of the nature and size of the possible threat, and of the resources most at risk, bearing in mind the probable movement of any oil spilled?

(2) Have priorities for protection been agreed, taking into account the viability of the various protection and clean-up options?

(3) Has a strategy for protecting and cleaning the various areas been agreed and clearly explained?

(4) Has the necessary organisation been outlined and the responsibilities of all those involved been clearly stated with no 'grey areas' - will all who have a task to perform be aware of what is expected of them?

(5) Are the levels of equipment, materials and manpower sufficient to deal with the anticipated size of spill. If not, have back-up resources been identified and, where necessary, have mechanisms for obtaining their release and entry to the country been established?

(6) Have temporary storage sites and final disposal routes for collected oil and debris been identified?

(7) Are the alerting and initial evaluation procedures fully explained as well as arrangements for continual review of the progress and effectiveness of the clean-up operation?

(8) Have the arrangements for ensuring effective communication between shore, sea and air been described?

(9) Have all aspects of the plan been tested and nothing significant found lacking?

(10) Is the plan compatible with plans for adjacent areas and other activities?

APPENDIX

Format of Title Page

***FACILITY CONTINGENCY PLAN**
OR
***MULTI-OPERATOR CONTINGENCY PLAN**
FOR
#NAME OF FACILITY OR MULTI-OPERATOR AREA

Council of
Managers of National Antarctic Programs

ØDate

---

*Choose titles according to plan type.
#State name of facility or multi-operator area.
ØDate of plan

CONTENTS

Facility Plan

Multi-Operator Plan

Facility Plan

7 WASTE DISPOSAL
  7.1 Storage of Waste
  7.2 Disposal of Waste

8 DEMOBILISATION
  8.1 Personnel Decontamination
  8.2 Equipment Decontamination/ Maintenance

9 POST SPILL MONITORING

10 REPORTING

Multi-Operator Plan

7 WASTE DISPOSAL
  7.1 Storage of Waste
  7.2 Disposal of Waste

8 DEMOBILISATION
  8.1 Personnel Decontamination
  8.2 Equipment Decontamination/ Maintenance

9 POST SPILL MONITORING

10 REPORTING

ANNEXES

ANNEX A : FACILITY AREA MAP (OR AREA MAP)

ANNEX B : SPILL RISK ASSESSMENT MAP

ANNEX C : COMMUNICATION PLAN

ANNEX D : RESPONSE TEAM ORGANISATION

ANNEX E : RESPONSE EQUIPMENT AND MATERIALS

ANNEX F : HEALTH AND SAFETY PLAN

ANNEX G : TRAINING PLAN

ANNEX H : PUBLIC RELATIONS/MEDIA PLAN

ANNEX J : COST ACCOUNTING PLAN

ANNEX K : DOCUMENTATION PLAN

ANNEX L : DISPERSANT USE

ANNEX M : IN-SITU BURNING

ANNEX N : BIOREMEDIATION USE

ANNEX P : BIRD AND MAMMAL CLEANING

ANNEX Q : EQUIPMENT AND PERSONNEL CLEANING

ANNEX R : DEFINITIONS AND ABBREVIATIONS

ANNEX S : COMMUNICATIONS CONTACT NUMBERS

Project Construction and Operations of the Tanks for the Fuel Storage in Terra Nova Bay, Description of the First Refuelling Operation

by
Roberto Buccolini, Antonio Cucinotta, ENEA-Antarctic Project Italy and
Giovanni Caligiuri, SNAMPROGETTI, Italy

In order to carry out the transfer and storage of fuel oil in the maximum conditions of safety for persons, environment and installations, the Italian Antarctic Project has:

- adopted national and international rules, as well as recommendations issued by organisms under the Antarctic Treaty. In particular, reference was made to the COMNAP Procedures n. 101 and 102 prepared under the direction of the SCALOP; these documents have contributed considerably to the preparation of the operating plan, for safety and emergencies in the refuelling operation.
- referred to the experiences obtained on installations and systems of other international agencies operating in polar areas;
- executed a market research in general, giving priority to the quality of the product to be employed.

1. Introduction

The executive Programma of the VII Expedition planned the supply of 920,000 lts of JP-8 (avio kerosene) to the antarctic base at Terra Nova Bay during the '91-'92 summer campaign.
The supply to the base took place on the 18/1/92 with the transfer of fuel oil from the USA tanker to two storage tanks which were placed at 44 mts above sea level.
At termination of the refuelling operation and after having cleaned the pipelines with the "PIG" system, the transfer and storage system was placed in safe conservation.

2. Background

Until the VI expedition ('90-'91), the supply and storage of fuel (arctic gas oil, avio kerosene) for the base involved a series of operations, like:

- the transportation of fuel in drums or containers by cargo ship from New Zealand to Terra Nova Bay;
- the discharge of the fuel from the cargo vessel moored on the pack and its transport to the base by sleds and snow trucks;
- the storage in drums, tank containers and collapsible tanks in clearly identified areas of the base.

The complexity and operative inconveniences of this system and the yearly needs of fuel, have lead the Italian Antarctic Project to look for another way more rapid, more secure and economical.

3. Terra Nova Bay Station

Fig.1 shows the planimetry of the area where the Italian base is situated; it lies on a peninsula along the coast of the Northern Foothills, between the Campbell and Drygalski glaciers, in Terra Nova Bay (Ross Sea, Victoria Land) from which the Base takes its name; the coordinates of the base are: Lat. 74° 41'42" S.; Long. 164°07'23" E.

3.1. Operating Area

The planimetry (Fig. 2) shows the area of interest to us where the two tanks for the storage of fuel (avio kerosene) are situated as well as the area of the refuelling operations, this area stretches from the tanks towards the beach of Tethys Bay, accessible by an earthbeaten track, and which allows the installation of the equipment for the operations. From the bathymetry it will be noted that starting from the beach the soundings grows rapidly reaching a depth of 30 mts at a distance of 150 mts.
As far as the sea area involved in the refuelling operations is concerned, it must be said that this could either be free or covered with sea ice; in our case we assumed that the operations had to take place in the presence of sea ice.

4. Operating system

Before opting for the present configuration of the transfer and fuel storage system, the Antarctic Project made an analysis and a comparison of the main alternatives taking into account as the most important discriminating factors the environmental impact, the safety, the duration of the operations and the reliability of the system.
The principal sub-systems that form the operative system are

- storage system
- transfer system
- cleaning system
- safety system

As project data for these systems the following points have been adopted:
a) the mooring of the tanker to the sea ice of Tethys Bay;
b) the discharge of the fuel from the tanker to the storage tanks with about 1000 mts of hose-line;
c) the quantity of fuel to be discharged: 1,200,000 lts of JP-8.
This quantity, deduced from the average consumptions of the past summer antarctic campaigns, should guarantee an autonomy of four years for the Base.

4.1. Storage system

In order to meet with the fuel needs and with a view to eliminate the existing storage in drums, containers and collapsible tanks, the present storage system has been realised, which consists of two vertical tanks with a double shell with a capacity of 600 cu.m. each; Table 1 shows the characteristics of this tank.
Each tank, planned to contain JP-8 at atmospheric pressure,

consists of an inner container without roof and an outer container complete with a fixed roof and not insulated; all in carbon steel with resilience tested at -50°C.

The tanks are fitted with plugs:

- for pipes of discharge (4"), of load (3") and drainage (3") of product;
- for pipes of foam flows;
- for instruments, which will be fitted in a successive stage of the project when the operative procedures of control and conduct of the storage will be defined.

The tanks will be fitted with manholes (24") on the inner shell, on the outer one and on the roof.

4.1.1. Project and controls

The storage system has been planned and built in accordance with the API-650 rules and taking into account the recommendations existing with respect to the antarctic area.

In order to minimize the risk of fuel spill in the surrounding area, it was decided to adopt the double containment which allows the collection in the interspace of potential fuel spills from the inner container.

The fabrication of the tanks with double shells took place through the following main stages:

I) the execution of a ringshaped foundation in reinforced concrete to contain the inert material on which subsequently a layer of bituminous material was spread (in order to insulate the metal from the ground);

II) the installation of the outer tank and anchorage of the outside shell to the foundation ring as shown in Fig. 3;

III) the construction, inside the base of the outer tank, of a trated;

IV) the installation of the inner tank and the welding of the roof.

During the construction of the tanks, always with a view to minimize the possibility of fuel leaks, non destructive tests were performed on the welds of the shell, the basements and the roof which synthetically comprise; visual checks, radiographic examinations, tests with penetrating liquids, examinations with the vacuum box.

Subsequently the reaction of the storage tanks was studied in case of impact with external missiles that is with objects of variour dimensions and weight which are lifted by the wind and thrown perpendicularly against the shell of the tank.

The formulas utilized were those defined by the Ballistic Research Laboratory and by the Stanford Research Institute; from the outcome of the calculations it results that the specified missiles (steeltube of 3", 3 mts length and a weight of 33,8 Kg and an impact speed of 65,6 ft/sec.; a yard wheel-barrow with a weight of 30 Kg and an impact speed of 196,8 ft/sec) should not be able to perforate the external shell of the tank even on the conservative hypothesis that the target and the missile are rigid.

4.2. Transfer system

The configuration of this system was determined by various considerations, the most important of which are:

- to have a very versatile system considering the positioning of the tanker with respect to the tanks;
- to have a hose-line with a cross section so as to consent not too long transfer times considering the variability of the meteorological conditions;
- to have a hose-line which is not only easy to operate for placement and cleaning, but also easy to maintain and repair if it suffers damage during the transfer operations.

The system mainly consists of:

- 950 mts of reinforced and floating rubber hose-line (Ø=6") for connection of the tanks to the tanker (see Table 2); this hose-line, in four lengths of 35, 315, 350 and 250 mts, is wound on three reels which can be motor driven.

4.3. Cleaning system

Once the hose-line has been defined, the choice of the system, which took also in consideration the possibility of contemporaneous supply of the base of avio kerosene and arctic gasoil, was determined by the convenience and operative rapidity as well the requirements to minimize the loss of fuel in the surroundings.

The system consists of:

- launcher and receiver,
- some polly pigs,
- set of nitrogene bottles,
- air compressor,
- tank container ISO 20.

As can be seen from figs. 4 and 5 launcher and receiver are similar.

4.4. Safety system

It consists of the following material:

- absorbent material,
- extinguishers,
- 6 valves of the "hose clamp" type to throttle the hose-line in case of a rupture emergency,
- 3 fire fighting trucks (twin agent),
- 2 slings and 2 hooks with rapid release (pelican hook type) for eventual mooring of the tanker on land,
- radio receiver/transmitter,
- protective clothing and glasses.

5. Analysis of risks

The possible incidental situation relative to the storage and refuelling system are characterized by fuel release to the environment; the elements which represent the most significant contributions to the release have been identified on the basis of their statistical frequency derived from a storical inquiry and databanks.

The sources of the release have been identified:

- in the seepage from flange connections caused by rupture of the lining due to wear or to construction faults or to a bad fitting,
- in the loss of fuel due to partial or total rupture of the hose-line,
- in the loss from the stub pipes for the connection of the instruments due to construction faults or to impact with objects thrown by the wind.

The probability that these losses occur is very low and anyway the most critical situations are those relative to the loss from the stub pipes and the flanges fixed on the lower part of the outer shell and to the rupture or puncture of the hose-line; these losses have as a main consequence the pollution of the environment.

Among the possible risks also the interruption of the refuelling operations in case of adverse weather conditions was considered.

5.1. Evaluation of impact

The evaluation of impact of the storage system on the environment can synthetically be divided in three stages, which take into account:

I) the installation of the tanks,
II) the ordinary operation,
III) the emergency.

In each of these stages, the impacts contain both the landscape-territory and fauna impacts.

The first stage involves an alteration for a short while and comports a short term type of impact, associated with operations to prepare the site, on the area assigned to the tanks and to prepare their foundations.

The most important activities of the second stage are those relative to the refuelling and to the distribution of the fuel to the users; it is supposed that the possible spills of small quantities of fuel on the soil, is the only aspect to be taken into consideration; this calls upon a rapid intervention of decontamination as the volatility of the hydrocarbon is very low.

The impact on the quality of the soil, the waters and on the fauna in the emergency stage derive from the incidental leak of fuel mentioned before. Considering the possible losses more or less consistent of the product and the fact that the storage tanks are situated at 44 mts above sea level, it can be assumed that when the patch enlarges the fuel will run towards Tethys Bay; thus the pollution of the soil and of that part of the coast near the tanks

represent the most important risk of which the most critical aspect is formed by the complexity of the decontamination operations.
From the evaluation performed results that the construction of the tanks has an environmental impact which, considering the safety parameters adopted, can be considered minimum on the landscape and transitory, if not improbable, on the soil, the sea and the fauna.

6. Safety plan

As mentioned the configuration of reference of the operative system, forsees:
- Tethys Bay covered with sea ice,
- mooring of the tanker at the pack of Tethys Bay,
- connection between storage tanks and tanker with about 1000 mts of hose-line.

The unusual events that can interfere with the ordinary procedure of discharge are:
- the rupture of the primary components, that is of the hose-line and of the storage tanks;
- the emergency caused by a sudden worsening of the weather conditions.

The precautions to be observed make reference to the potential risks to which the transfer of fuel oil can give rise and which have been examined in paragraph 5; next the resources to be assigned (personnel, equipment and means) have been identified and their distribution on the operative areas chosen.
The organisation of the safety plan also envisages two teams with different fields of operation:
- one directed at the safeguarding of the environment and of the equipment,
- one directed at the safety of the persons.

The personnel assigned to the refuelling operations had to follow courses of safety and training, both general and specific as for example on the hydrocarbon fires, on the use of the containment boom and on marine anti-pollution measures.

6.1. Tethys Bay free of pack

In addition to what has been said before the configuration of Tethys Bay has been analyzed as if it would be partially or totally free from pack.
For this second situation, certainly more complex than the first one both from the operational point of view and the one of intervention in case of oil spill, the following equipment has been planned:
- 500 mts of containment boom (see Table 3) to limit the stretch of sea interested in the operation and included between the tanker and the beach,
- material for securing (chains, anchors, buoys, etc.) in enough quantity to anchor the containment boom to the sea bottom every 40-50 mts,

- a vacuum pump with a special aspiration terminal to recover most of the fuel in sea (see Fig. 6),
- absorbent material in polypropylene in three different types (booms, pillows and pads) to recover the fuel left over after the aspiration operation,
- two inflatable boats, one boat of 12 mts and a pontoon for the movement and placement of the hose-line, of the containment boom, of the vacuum pump, of the absorbents and for the checking of the hose-line during the refuelling operations,
- drums to contain the fuel and absorbents recovered.

In order to control the quality of the waters the lowering into the sea of wicker fishing baskets is planned, containing some species of bivalves (Adamussium colbeckii) and fish (for example Pagothenia bernacchii). These in case of oil spill would have furnished the entity of the pollution on the marine fauna after an ecotoxilogical examination to be confronted with the data obtained in previous biological researches.

Moreover sampling of the sea water is planned before and after the operations.

6.2. Response team

The response team is split into two groups: one for emergencies on land and one in sea; moreover, the two groups have the task to check the hose-line during the refuelling operation.

The response group on land (three persons) is to be stationed near the storage tanks which in case of incidents would be the most critical area; the response group on the pack (three persons) is to take position on the beach of Tethys Bay near the tank container.

Both groups were equipped with several vehicles, and firefighting and antipollution materials and equipment.

6.3. First aid team

This team is made up of one doctor and one nurse; the team is stationed in the infirmary as well as in the area of the storage tanks and is equipped with:

- a vehicle for the transportation of injured persons to the infirmary of the Base;
- a first aid kit;
- a sufficient number of woolen blankets, placed in the zones of the storage tanks and the beach, to assist personnel harmed by fire.

6.4. Decontamination of birds and mammals

In case of oil spill one could find oneself having to face the decontamination of birds and mammals.

After having consulted the bibliography existing on this subject and after having consulted some researchers, the following rescue plan was programmed:

- the birds recovered will be left to rest and will be fed; after which they will be washed with a solution of warm water and a non biological detergent (2% concentration), then properly rinsed. After this operation they will be dried with cloths in a heated room until they are completely recovered.
- for the seals the same treatment described above is valid, taking more precautions in the handling of these animals, considering their dimensions.

7. Preliminary operations

These have regarded the operations on land and on the pack.
Before the arrival of the tanker the hose-line on land was laid out (three sections of respectively 35, 350 and 250 mts) and connected to the first of the two tanks (S1); Fig. 7 shows the scheme of the connections.
Before and after the lay out, all single components have been examined, assembled and in each single part, in order to ascertain its integrity, functionality and safety.

7.1. Positioning of the PIG system

The PIG system serves for emptying and cleaning the hose-line once the refuelling operations are completed.
To make it work the polly pig needs a certain number of nitrogen gas bottles or compressed air with the function to push the polly pig from the launcher to the receiver through the hose-line thus cleaning it from residual fuel.
As the cleaning of the hose-line is programmed in two stages, first the one on the pack and then the one on land, the launcher is initially placed on the tanker, while the receiver is placed on the beach of Tethys Bay near the tank container.

7.2. Positioning of the tank container ISO 20 and the relaunching pump

Both the tank container and the relaunching pump were placed on the beach of Tethys Bay near the two 6" valves fitted respectively on the hose-lines on land and at sea.
The tank container served at termination of the refuelling operation for the drainage of the hose-line.
The relaunching pump was also prepared to be inserted in the line in case the pump of the tanker would not have sufficient pressure to transfer the fuel into the storage tanks; it was fitted with opportune connecting points to be attached to the hose-line at sea and to the tank thus functioning as a lung in order to avoid symptons of cavitation.

7.3. Operations in Tethys Bay in presence of pack

These mainly involved the icebreaker POLAR SEA of the USA Coast Guard.
On its arrival, the icebreaker opened a canal in the pack to enable the tanker to enter Tethys Bay, paying attention to the radius of the curve of the canal was as wide as possible and that, towards land, it did not surpass the 300 mts limit from the beach.
After completing the canal the icebreaker came out in order to allow the tanker to enter ahead and to take the position planned, after which it was moored to the marine pack. At this point the icebreaker placed itself in such a way to be able to tow the tanker out of the canal in case of emergency or at termination of the operation.

7.4. Unwinding of the hose-line on the pack

While the tanker was being moored, a blank flange with eyebolt was fitted on the end flange of the hose-line which was placed on the beach of Tethys Bay.
After having fitted the blank flange and prepared a sling around the hose-line, everything was attached to a snow track in such a way that this could drag the hose-line, without forcing it, until it arrived alongside the tanker, where the operators of the vessel hauled it on board without straining it.
Once on board after having loosened the blank flange, the hose-line was connected to the launcher.

7.5. Placing of the absorbement materials

Absorbing material in polypropylene available in three different versions: booms, pillows and pads, was used.
Said material was placed in the proximity of the penetrations of the storage tanks and along the line in those points with the highest possibility of fuel oil spills.
In particular, one or more pads were placed under every flange and valve and an adequate number of spares nearby; absorbing materials were also placed in the proximity of the launcher, the receiver and the relaunching pump.

8. Operating team

Considering that during the operations the personnel must stay near the spot assigned and maintain a regular contact by VHF radio with the rest of the team, the area interested in the refuelling operation was divided in 5 zones, to which were assigned persons, means and materials like: firefighting (twin agent), tractor, fork lift, portable extinguishers, absorbent material, drums, manual valves of the "hose clamp" type, 150 lts of sweet water in open barrels equipped with a hand pump and rubber hose for a rapid wash of eventually contaminated persons, etc.

9. Commencement of fuel supply operation

Once the connections were made according to the scheme in Fig. 7 the responsible for the operation made a verification of the system realized before starting the transfer of fuel and has arranged for:

- the checking of the measuring stick and the breather of the storage tanks;
- the verification of the tight fitting of all valves and connecting flanges;
- the verification that all 6" valves were open;
- the verification that the 2" drainage valve of the launcher was closed and the drainage hose attached;
- the verification that the 3" valve which connects the launcher to the nitrogene bottles or to the compressed air was closed;
- the verification that the 4" valve of the feeding line of the storage tank was open;
- the verification that all members of the personnel, instructed on its role and task, occupied the right position and were in possession of the necessary equipment and of a radio in order to be able to follow the development of the operations.

10. Refuelling

After having completed the above verifications, the responsible for the operation communicated to the tanker that the system was ready and the latter gave order to start the operation of the fuel oil transfer.
As no problems arose during the transfer, this was continued until the completion of the first storage tank which was watched by the team in the tank zone checking carefully the measuring stick.
At this point the responsible for the operation communicated to the tanker to suspend the transfer by stopping the pump on board in order to allow the connection of the hose-line to the second storage tank (S2).
Upon completion of these first series of operations the line was reactivated; the responsible, after having checked the connections of the piping, communicated to the tanker to restart the transfer.
Immediately after the tanker had transferred the remaining fuel to the S2, the delivery was suspended and the operating team started to close all valves.

11. Drainage, cleaning and recovery of the hose-line

These operations took place in two stages and have involved the following sections of the hose-line.

11.1. Hose-line laid out on the pack

In order to free the tanker as soon as possible after the completion of the refuelling, the first operation to be executed was the natural drainage of the hose-line laid out on the pack into the tank container placed on the beach of Tethys Bay.
To do so the hose-line was divided in sections and the receiver was connected at the hose-line laid out on the pack and to the tank container as shown in the scheme of Fig. 8.
Terminating the drainage, the polly pig was inserted in the launcher and the air compressor connected; the hose-line was cleaned by pushing the fuel into the tank container.
After having finished the cleaning and having disconnected the launcher and receiver, the hose-line was recovered on a special reel and placed in conservation to protect it from ultraviolet rays.
In the meantime the tanker was coupled to the icebreaker and towed outside Tethys Bay.

11.2. Hose-line laid out on land

The cleaning continued by connecting the receiver to the hose-line laid out on the land (Fig. 9); then the hose-line was disconnected from the storage tank and all other valves on the line were opened to drain the fuel into the tank container.
Upon completion of the natural drainage the launcher, to which the set of nitrogene bottles was attached, was inserted at the beginning of the hose-line; at this point the polly pig was inserted and as before the hose-line was cleaned and wound on the remaining two reels and stored.
Upon conclusion of these operations, all other means, materials and equipment were collected and put in store and the area involved in the fuelling operations was checked to be left in order and clean.

12. Conclusion

The refuelling operation took place as was initially foreseen and caused no problems.
To speed up and make safer future operations Italian Antarctic Project will pay the utmost attention to the development of the technology and the regulations regarding the storage and transfer of fuel.
The experience made with the first operation has already led to some considerations which will be transalted into improvements and/or modifications both for the present storage and transfer system and the future construction of the storage tank with regard to for example:

- mechanical protection of the penetrations,
- motorisation of the hose reels,

- implementation of the instruments with penetration unions from the roof,
- execution of a single penetration (from the roof of the tank) for the transfer and withdrawal of fuel.

TABLE 1

STORAGE TANK

- vertical, doublewalled and with fixed roof	
- capacity	600 cu.mt
- levelling rod	
- material	carbon steel
- internal diameter	12 mts
- external diameter	13,6 mts
- internal height	6 mts
- external height	6,5 mts

Conditions of project

- reference specification	API 650
- wind speed	216 Km/h
- load of snow and ice:	
. roof	200 Kg/sq.mt
. shell	1000 Kg/sq.mt (first ferrule only)
- average temperature	between 0°C and 40°C
- capacity of pump section from tank	100 mt/h
- capacity of pump delivery to tank	100 mt/h

- seismic actions verified with reference to UBC zone 2 rules

TABLE 2

SPECIFICATIONS

A) REFUELLING HOSE-LINE

- diameter	6" (152 mm)
- working pressure	17,2 bar
- weight empty hose-line	abt.5,5 Kg/mt
- capacity	18,1 lt/mt
- weight fluid in hose-line	13,7 Kg/mt

B) REEL

- lenght reel		5,90 mt
- diameter reel drum		1,50 mt
- diameter reel flange		2,50 mt
- reel n. 1090379	lenght hose-line	250 mt
	net weight	1536 Kg
	gross weight	3836 Kg
- reel n. 1090380	lenght hose-line	315 + 35 mt
	net weight	2136 Kg
	gross weight	4436 Kg
- reel n. 1090381	lenght hose-line	350 mt
	net weight	2136 Kg
	gross weight	4136 Kg
- lifting gear	- beam:	
	lenght	7 mt
	weight	700 Kg
	capacity	6000 Kg
	- bar of iron:	
	diameter	900 mm
	lenght	7 mt
	weight	385 Kg

Supply and Storage of Fuel in the Spanish Antartic Base Juan Carlos I

by

Josefina Castellvi & Elias Meana
Programa Nacional Antartico, Spain

From 1987 when the Base was installed in Livingstone Island, the supply of fuel was made by disembarkation of 200 l. barrels.

According to the Antarctic Treaty Recommendations and Madrid Protocol referring to the environmental impact produced by Antartic Bases that sometimes may be irrecoverable to some echo systems, the Spanish Antartic Base (S.A.B.) Juan Carlos I, has made ready a fuel supply system that may set example on the possibilities that a small summer base with reduced costs ashore and at sea.

The operation begins by setting a supply line, (a hose) between the supplying vessel, in this case the oceanographic vessel Hesperides, and the storage tanks in the S.A.B., which are located at 125 m. (Fig. 1 & 2).

Supply Line

Taking into account the S.A.B.'s restrictions on manpower and transportation resources, the supply line has been installed using sections of 60 m. length and 80 kg. weight, which allow relatively easy handling as its flexibility allows it to be rolled up in coils of aproximately 1 m. in diameter.

The hose is made of abrason resistant neoprene with an inner diameter of 32 mm. and a flow of 3000l/h.

The joints between sections are made of stainless steel rackworks provided with pressure and safety valves which are activated by hand pressure and run automatically when a section is disconnected from the other. The system has a fully leakproof connection that even if it were disconnected during the fuel transfer would not allow the leakage of fuel.

Although it is not an autofloating system, (which would have had larger volume and costs), it is provided with small floating plastic buoys of 135 mm. diameter and 840 gr. floatability. These are fixed to the hose, (one every 80-100 cm.) along the whole maritime distance of the line.

On the land side, the distance between the coast and the tanks (some 240 m.) is made up of sections which simply lay on the ground.

Pumping System

A pump with anti deflagrate motor protection has been installed on board the vessel, which transfers 3.000l/h at a pressure of 14.5 Kg/cm^2.

Storage Tanks

The fuel tanks storage capacity is 17000 l., fuel type A, distributed in tanks of 5000 l. and 1 of 2000 l. The petrol (97 octane) is stored in a forth tank, which has a capacity of 500 l., these tanks are designed and homologated to store hydrocarbons, and are made of synthetical tissue covered by neoprene.

The fuel supply is carried out in the early days of the campaign and then as the consumption takes place and tanks become empty, they are gathered in the storeroom till the following year. In the winter only the fuel stock remains (about 4000 l.) distributed in the 2000 l. and one 5000 l. tanks.

Under the pressure of the snow accumulated in winter the tanks may have leaks. In order to avoid this, the tanks are protected under metallic structure which supports a treated wooden roof. This assembly is covered with canvases.

The flow between the storage and the daily consumption tanks (two 500 l. stainless steel tanks) is accomplished through gravity making use of the existing unevenness.

Fuel Flow Operation

In order to ease the operation it is essential to choose a windless day and a calm sea, whereby, this operation is carried out better.

The seabed topography of South Bay allows the anchoring of the vessel Hesperides (4.42 m. draught) at about 450 m. off shore.

The hose maritime distance is prepared ashore, 8 or 9 sections are laid extended on the beach. When the operation starts, the hose that has to be connected to the on board end on deck is tied to an inflatable boat (4.5 m. and 35 h.p.) that sails toward the ship. Meanwhile the on shore based personnel help guiding the hose until it gets into the water and floats.

The different groups that took part in the operation kept in direct contact by using walky-talkies and their distribution was as follows:

On board, operating the pump according to the instructions received from the personnel that is working by the tanks.

On the tanks, controlling their filling and giving precise instructions to the pumpmen.

Ashore, watching the joints between sections and the whole line length.

There is a craft at sea surveing all the line length while the operation is taking place.

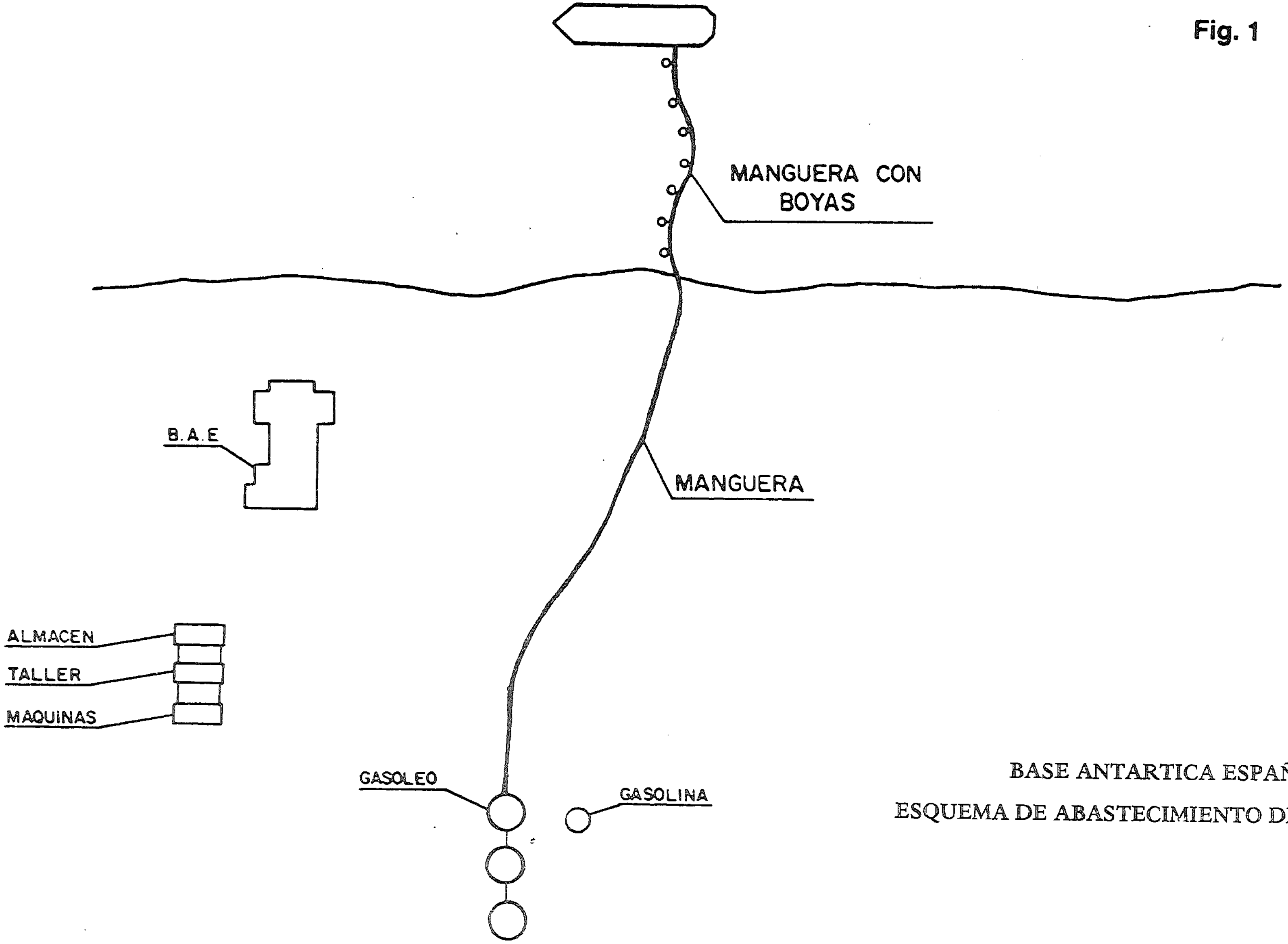
Once the unloading is finished, the hose at the on board end is towed to and laid extended on the beach.

The remaining fuel in the hose is emptied out section by section into the daily tanks by fitting an airtight piece that opens the pressure valve.

If due to the presence of ice wrechages or strong sea currents, it would be considered necessary, a strong galvanized iron wire of 5 mm. section provided with buoys and fastened both on shore and on board and fixed to the hose to absorb the traction that the ice or the sea current may cause.

As a measure of precaution in the mischance of leakage due to a technical handling failure, the vessel was provided with a contention system made up of an absorption line for oily liquids by capilarity (two coils of 44 m. and 10 mm. section), which would prevent the spreading of the contaminating stain.

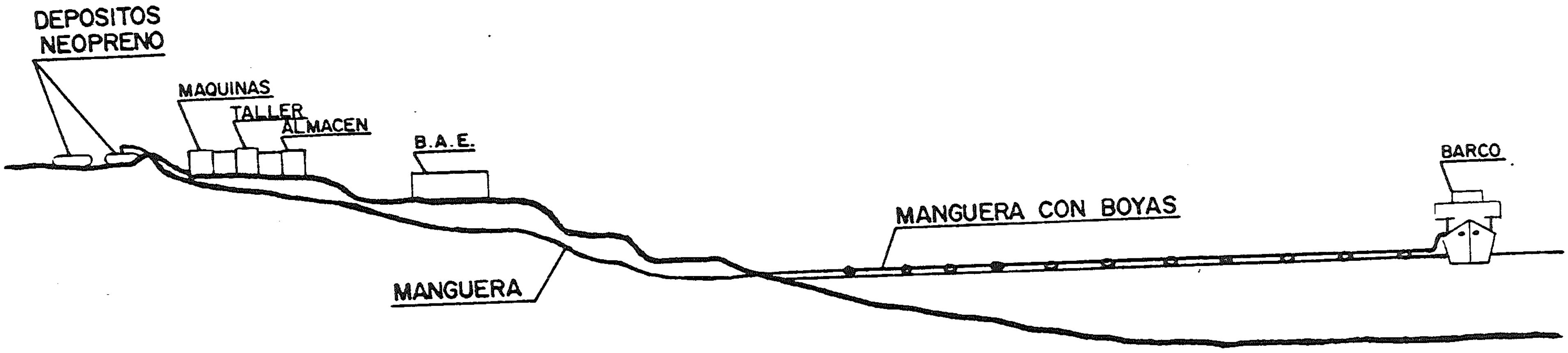
Fig. 1



BASE ANTARTICA ESPAÑOLA

ESQUEMA DE ABASTECIMIENTO DE COMBUSTIBLES

Fig. 2



BASE ANTARTICA ESPAÑOLA
ESQUEMA DE ABSTECIMIENTO DE COMBUSTIBLES

The Role of the Chilean Navy in the Control of Pollution in Antarctica

by

J. P. Heuser
Instituto Antartico Chileno, Chile

Introduction

On behalf of the Chilean Navy I will describe the actions and activities being carried out by the Chilean Navy in the control of pollution of the Antarctic Territory. This account will comprise the following subjects:

I. **Antarctic Scenario**
II. **Environmental Legistlation**
III. **Presence of the Chilean Navy in Antarctica**
IV. **Conclusions**

Given the vastness of the subject, it would be presumptuous to deal with it in some detail in the comparatively short time available. However, when analyzing our country's condition of seaside nation and its proximity to the Antarctic territory, there rapidly come to one's mind ideas that prompt this presentation.

Antarctic scenario

The Antarctic scenario now known to all is that described in the publications and in summarized form in the paper submitted in full to Dr Olle Melander.

Environmental legislation

The world experience acquired in the search of solutions to environmental problems has led to adoption of five main principles to control pollution.

1. He who pollutes must pay, which astablishes the responsibility of the polluter.

2. From the craddle to the grave, which is essential to assure that the generator of waste is responsible for the control of the whole life cycle of the waste.

3. Sustainable development, which seeks to assure the development of future generations in a sound environment.

4. Precautionary, which consists in giving important powers to the supervising authority, so that it will not be necessary for it to require previous legal provisions to take action.

5. The lowest possible cost of disposal, which has to do with social and economic organization and seeks to guarantee competitiveness conditions in respect of products that can be obtained from such waste.

In Chile, concern about pollution of the water environment has centered on these five principles.

The political constitution of Chile, of 1980, provides, in its section 19, for the right to live in a sound, pollution-free environment. This constitutional provision has been thoroghly understood and successfully used in the nation.

Moreover, the navigation law of 1978 considers the water environment preservation and control of marine pollution over all the national jurisdiction to be one of its chief purposes.

Capacity and activities of the Chilean Navy in Antarctica

Using Prat Station (1974) as a position for Antarctic operations, the Chilean Navy has the following operative capacity:

a) A port captainship at Fildes Bay known to all as Marsh Station for support of ships of all flags. It provides meteorological and sea traffic information.

b) An Antarctic little fleet made up of ships (Piloto Pardo and Revenue Cutter Yelcho) which provide logistic support to national and foreign stations.

c) The Chilean Navy, which is interested in the protection and preservation of the water enviromnent and is aware of the need to seek safety for human life in the sea and navigation in the Antarctic continent, established an Antarctic naval patrol made up of two ships (Galvarino and Lautaro). They are responsible for salvage, rescue and towing of ships and are equipped for the control of pollution due to hydrocarbons and other substances. In regard to activities, we can list them as follows:

a) logistic support to stations
b) hydrographic surveys of bays, passages and channels
c) maintenance of marine signalling
d) notice to navigators
e) meteorological reports
f) oceanographic studies
g) prediction of sea tides and currents

Participation of the Chilean Navy in rescue and pollution control operations

Historically, the Chilean Navy has, as mentioned below, carried on human life salvage missions in the sea and protection of the marine environment.

1. As you know, the pilot Pardo in the Yelcho Revenue Cutter rescued, in August 1916, the expedition Shackleton from Elefant Island.

2. Rescue by means of helicopters of Pilot Pardo ship from Deception Island, in December 1967, of 15 Englishmen and 27 Chileans affected by volcanic eruptions.

3. Rescue at Balleneros cove, with helicopters in 1969, of five Englishmen due to volcanic eruptions.

4. Salvage of Lindblad explorer in 1972 by Pilot Pardo ship and Revenue Cutter Yelcho. After the rescue, accomodation was provided to 114 tourists.

5. Support to Yelcho in the shipwreck of ARA, Bahia Paraiso in 1989.
6. Rescue and refloating of Bic Humbolt at Marian cove in 1989.

Protection of the marine environment in Antarctica

In view of the increasing sea activity on the Antarctic Territory and for the purpose of preventing accidents safeguarding human life in the sea and avoiding ecological damage in this sea area, the Chilean Navy decided to establish an Antartic navigation School. The National Merchant Marine officers and Chilean harbour pilots are required to attend the appropriate courses as a prerequsite for navigation towards Antarctica.

As a second important measure, the Chilean Navy has decided to create a Sea pollution Control Centre, based on Prat station which has been the product of experience acquired through implementation of the "Plan Nacional de Contingencia" (National Emergency Plan) for spilling of hydrocarbons and other substances and to promote efficiency in the case of an emergency. This Centre will be operative in 1993.

In addition, general measures have been taken which are designed to promote awareness of environment preservation which will be completed with additional courses for personnel of Antarctic commisions and with any studies that may help in the acquisition of knowledge of the physical-chemical characteristics of the Antarctic sea environment.

Conclusions

The fragility of Antarctica does not permit any risks derived from inexperience, the consequences of which may give rise to serious damage to the Antarctic ecosystem and dependants due to lack of prevention and precautionary measures in Antarctic operations.

Therefore, on the basis of the experience and the presence of the Chilean Navy in Antarctica, the institution has developed an overall plan of support of sea operations carried out by our country. This support is extended to other ships. In this respect, attention has been paid to the training of personnel, implementation of adequats equipment, and allotment of units with adequate reaction capacity, all this for the purpose of controlling possible oil spilling contingencies.

Petroleum Pollution Prevention, Response and Remediation in the Antarctic
An Equipment and Procedural Approach

by

Carl R.C. Kohlmeyer
National Science Foundation, USA

1.0 Introduction

The following overview presents several key issues for the prevention and remediation of petroleum pollution in the Antarctic environment. The use of state of the art equipment, properly maintained, and combined with site specific operational procedures are components of a zero release philosophy. The equipment and procedures must be tailored to the harsh Antarctic environment and the specialized petroleum products that are currently in use there. The development of a set of detailed standards and recommended practices allow for a uniform program designed to minimize petroleum releases. The training and implementation of new procedures must be carefully tailored to the unique psychological environment of the Antarctic community. Upgrading existing tanks with secondary containment systems, leak detection sensors, and dry-break delivery nozzle technology is presented as a cost effective strategy and, coupled with adequate training and formal operational procedure, the zero release goal is attainable.

There are numerous simple approaches for immediate response when petroleum products are released. Methods and equipment for stabilizing the situation to minimize product migration and reduce the potential for fire and personnel exposure are presented. A sensible assessment of the spill by trained professionals and timely implementation of short and long term remediation strategies can significantly reduce the environmental impact and cost.

The primary remediation alternatives for contaminated soil, ice, and water are discussed with specific methodology for the Antarctic. The reduced hydrocarbon volatilization and the sluggish response of bioremedial dissipation mechanisms in soil necessitates pro-active remediation strategies. The application of in-situ soil remediation techniques are discussed as an alternative to retrograde. The paper details the use of oil-water separators and carbon filtration units for contaminated liquid processing to current drinking water standards. The emphasis is on prevention of product release to the Antarctic environment.

2.0 Spill Prevention

The zero release option is possible. The key is sensible management, the proper equipment, maintenance, and rigorous transfer procedures executed by adequately trained personnel. The historical attitudes toward product release have been that they will occur and the emphasis has been on minimizing the loss based on the dollar value of product or the potential for fire with little consideration for the impact on the environment. However, environmental attitudes around the world are rapidly changing. Modern understanding of how fragile the environment is and the unique pristine condition of the Antarctic make the prevention of product release of paramount concern. Petroleum releases to the Antarctic environment have been attributed to a broad range of events from small releases due to the overfill of 55 gallon drums or small tanks to the loss of ten's of thousands of gallons due to operator error or catastrophic equipment failure.

Changes in the regulatory environment governing petroleum operations in the U.S. have spurred a significant quantity of new technologies developed to minimize and control the release of petroleum products. The realization that once an environmental contaminant has been released to the environment the cost of any effective remediation effort is exponentially greater than the cost of installing and maintaining modern equipment and implementing effective operational procedures designed to prevent release. The promulgation of stringent regulations governing liquid storage tanks of all description (the primary thrust has been for underground tanks) is now a well established trend.

The impact of these regulations on the petroleum product manufacturers and suppliers forced the development of new equipment lines that can be used in the Antarctic to prevent the release of petroleum products into the environment. This trend has also prompted a reexamination of installation standards yielding many beneficial changes in the codes and common practice used by the industrial, commercial and governmental sectors. The unique nature of the Antarctic environment does not lend itself to wholesale application of standards applicable to more temperate climates. However, accepted industry practices form an excellent starting point for developing effective standards for the Antarctic. In essence, the body of information and standard practice currently known to be effective can be co-opted to institute effective management practices in the Antarctic.

An essential element an essential element of the release prevention strategy is a thorough examination of existing systems and the use of a well developed set of installation standards complete with drawings and specifications that can be applied to the various populations of tanks currently in use in the Antarctic. The population of existing petroleum storage vessels currently in use in the Antarctic can be categorized for the purpose of developing equipment configurations into four groups. Tanks with a capacity greater than 20,000 Gallon (75,000 Liter) are considered large and are usually fixed, field constructed, on-ground tanks used for Bulk storage. Tanks under 20,000 gallon (75,000 liters) are considered relatively small and are generally manufactured tanks or skid tanks and are used to service a particular building, facility, or runway operation. The third type are portable tanks that are used to service field operations and the fourth group are delivery vehicles that distribute product to point of use.

Prompted by the current sensitivity to environmental issues regarding storage tanks and petroleum operations, a data base has been amassed and indicates most product releases are the result of maintenance or procedural errors, operator error, or equipment failure during product transfer. Thus, a critical part of the solution is the development and implementation of effective transfer procedures and the inspection and maintenance of equipment. The development of practical operational procedures for the Antarctic forms the first step in the process. From the starting point of modern practice institutionally adopted by major handlers and distributors of petroleum products in the United States and Europe an effective program can be developed and tailored to individual operational requirements of the various national programs currently operating in the Antarctic.

The implementation of new and more efficient programs in terms of the human resources involved forms a more complex element of the solution. Historical procedures are well entrenched, and while many have proven effective the implementation of modern operational standards can significantly reduce the potential for product release. However, there is usually some resistance to institutionalized change and this presents a management problem for parties trying to implement new operational procedures. One inevitable factor in the institution of environmentally sound programs for petroleum operations is the necessity for a well designed program that can be phased into existing practice. A phased approach to both operational changes and equipment upgrade has numerous benefits not the least of which is the distribution of costs while still obtaining a rapid reduction in the potential for significant product releases and minimizing the transitional impact on personnel used to historically established operational procedures.

Retrofitting existing systems with modern equipment according to an environmentally engineered, standardized, system design that can withstand the harsh environmental conditions (temperature, wind, storms) experienced in the Antarctic. A satisfactory range of equipment currently produced can be made suitable, with minor changes, for exposure to the low temperature extremes and other significant environmental impacts on the material of construction and component design.

The design of the tank and delivery systems should be standardized into a formal package complete with drawings and specifications that clearly delineate the system configuration, equipment requirements, and individual location requirements. Once a specification package has been developed, the standard can be adopted for new construction and a phased upgrade program of existing facilitates can be undertaken. This would significantly minimize the cost impact and could achieve a standardized system in a controlled time frame. The use of standardized configurations also allows the implementation of a set of redundant safety systems and fail-safe mechanisms. The standardization of system configuration reduces long term maintenance costs, parts inventories, and most importantly simplify the implementation of procedures that can prevent releases and institutes a clear course of action should a spill occur.

2.1 Inspection of Existing Systems

The need for regular inspection of the entire storage and delivery system is critical to preventing product release due to equipment failure. A major contributor to the problem is valve and piping failure. Though the normal corrosion processes are retarded by the cold temperatures and dry air of the Antarctic these mechanism are still present and undoubtedly have been the cause of numerous equipment failures. Periodic inspections can reduce the release potential and also provide a basis for developing a maintenance, upgrade, and replacement schedule. Inspections are a critical portion of and form the cornerstone of any operations and maintenance (O&M) program.

Industrial and commercial experience has shown that visual inspections of pipelines, valves, pump sets, hoses, and nozzles by experienced personnel can detect many problems that lead to catastrophic failure and should be conducted at a minimum of once a month. The inspection should also cover the surrounding area to determine any change in usage that might increase the potential for damage to the tank system. The unique environment of the Antarctic makes this function more important. The low temperatures and wind apply very high stresses to construction materials that tend to embrittle metals, and other materials, thus increasing the potential for fatigue fracture or other failure mechanism from developing in essential equipment. Regularly examining the system will aid in the early detection of problems.

To develop more detailed understanding of the condition of the tank system it is recommended that a thorough inspection of the system be performed, complete with non-destructive testing. Each component of a system should be isolated and separately tested to develop a release potential profile. These test methods typically include ultra-sonic examination, various types of pressure tests, liquid dye penetrant tests, tank and deflection measurement, hammer testing and precision testing. The precision testing of tanks via computerized or mechanical methods such as Petro-tite testing are the standard tools used by the petroleum industry. The precision test methods correct for temperature fluctuations and other influencing factors to determine whether a storage system is currently leaking product. The sensitivity of precision testing methods is currently at a limit of detection in the range of 0.05 gallons per hour. Other nondestructive test methods such as ultrasonic or radiography can be used to evaluate the structural integrity of the materials of construction.

After an initial comprehensive examination of the system monthly inspections are recommended as an essential component of any operations and maintenance plan. The regular physical examination of the storage system and an audit of the management program helps to identify problems or deficiencies. This is considered in the petroleum industry the best and most cost effective strategy to prevent the release of petroleum products into the environment. However, the identification of problems with equipment is only the first step. Evaluating the problems and deficiencies identified during the inspections and audits and then implementing the solutions becomes a system management function and is the determining factor in the prevention of petroleum pollution of the environment.

2.2 Upgrading Existing Tank Systems

There are many unusual tank systems currently in use in the Antarctic. Many of these are truly unique configurations hobbled together under extreme weather conditions, time constraints, or emergency conditions and are a testament to the ingenuity of the men and women of the various Antarctic Programs. Many of the existing systems have been in continuous or seasonal use for years or even decades with little or no maintenance and were installed under a set of traditional standards and practices that are no longer considered adequate to reduce the potential risk of product release to acceptable levels. Current environmental practices have provided the engineer and tank installer a much broader range of equipment options and standard system configurations to utilize in the development of site specific design packages. The emphasis on the development of any design package should be to minimize the potential for the uncontrolled release of product to the environment..

2.2.1 Small Tanks

A cost effective method to prevent product releases in existing tank systems is to upgrade equipment to modern standards. This method is particularly effective in relatively small stationary above ground storage tanks of 20,000 gallons and less. These relatively small tanks present little problem to upgrading existing equipment, piping systems, and containment systems. The majority of tanks currently in use in the Antarctic fall into this category and are used to service heating or power generation equipment. Assessing the structural integrity of these tanks and then upgrading the equipment has promise as a rapid method to reduce release potentials. Current industry standards indicate the effectiveness of secondary containment for tanks and buried piping. A phased system of secondary containment installation on small tanks serves a dual purpose. Upon installation, it minimizes the potential for release and can serve as a mechanism to upgrade existing systems and replace the combustible (wooden) tank saddles or unpadded metal saddles commonly found in the Antarctic.

The use of new double wall, tanks with 100 percent secondary containment is perhaps the fastest and most assured method of reducing release potentials. However, this is a costly alternative and a lengthy implementation period would be required to retire existing systems. The dry air and extreme cold inhibit the normal corrosion process and, therefore it is likely that the majority of small storage vessels are still structurally sound and can be retrofitted and reused eliminating the need to import completely new systems. A thorough internal and external inspection coupled with precision or pressure testing and other non-destructive testing regimes (ultra-sound, dye testing, etc.) should adequately identify any structural defects in existing tanks. Based on the inspection results a sensible decision can be made whether to upgrade or replace a particular tank.

Often the petroleum storage vessel of choice to service a fish-hut or warming shack was the 55 gallon drum. The continued use of 55 gallon drums as stationary fuel storage tanks is not recommended. Drums are not designed for this application and when mounted on bare steel brackets or simple strapping the potential for abrasion at contact points is very high and can have disastrous results. The piping and fill connection are not configured to allow fill, gauging, and product delivery in a manner to minimize spill potentials and the threaded connection are not rated for this type of service. There are many of these tanks currently in service and while they contain only small quantities of product (55 Gallons) there is a fairly large population (several hundred) of individual tanks that are used to service remote field stations, warming shacks, and research camps many of which are located in the most sensitive areas of the continent. This clearly is a population of tanks that can be replaced at a minimum cost. The cost of replacing these systems with modern configuration would be approximately $500-1000 per system stateside cost. The installation of these new systems would also be very simple and fast, minimizing the cost of the replacement process.

2.2.2 Large Tanks

The larger on-ground bulk tanks (above 20,000 gallon) need to be examined more closely to determine if secondary containment and equipment upgrade is feasible and cost effective. The major stumbling block for retrofitting large tanks is usually the installation of a secondary containment system. Protecting against leakage from the sides of the tank is relatively simple given the access for inspection and the possibility of installing a containment basin sealed to the bottom edge of the tank. The relative ease of visual inspection or non-destructive testing allows a reasonable level of comfort that deficiencies can be detected and addressed prior to failure. However, there is no simple method to address potential leakage from existing on-ground tank bottoms or the retrofit of a complete secondary containment system to retain spillage or leakage from any tank surface. Therefore, the most cost effective approach for existing tanks is to initiate an operations and maintenance plan with a stringent monitoring program. The monitoring system would include installation of monitoring wells and surficial sensors located in potential migration routes to detect releases. These monitoring stations should be equipped with sensors that are connected to a central monitoring station and alarm system. If tanks are identified that are structurally defective or of significantly advanced age a phased retirement schedule can be implemented. These older tanks can then be replaced with secondarily contained tanks complete with modern equipment configurations. As with all options stricter management controls to prevent leakage or spillage of product need to be instituted to reduce release potential.

2.3 Operational Procedures

The management of existing bulk storage facilities can best be addressed with a process of operational monitoring, equipment and facility inspection, maintenance, upgrade and replacement. Each of these blocks of activity can be carefully crafted to address the magnitude of the issues involved in a sensible manner without undue complication. The operational monitoring of a tank system should track usage and transfer patterns as a means to identify areas of concern and quickly address historical problems such as actual releases or near spills as a way to prevent reoccurrence. Product release during transfer accounts for a large percentage of all releases to the environment. This is clearly an area were existing operations can be quickly modified to reduce the potential for release. With the introduction of dry break technology, fail-safe equipment and several other simple technologies coupled with additional training the potential for release of product during transfer can be minimized. In theory, at least, the process of fuel transfer should be monitored by trained personnel for the duration of the event. Therefore, with the institution of adequate procedures, good equipment, and trained personnel the potential for release can be dramatically reduced and zero release goal should be an obtainable.

2.3.1 Vehicle Fueling

The most common source of spillage in most tank systems occur during product transfer. The fueling of vehicles is one of the most common transfer activities. The fueling area is also the link in the system that is the simplest to retrofit to reduce the potential for release of product to the environment. Historically, fueling areas are native soil or icepads near the storage tanks and few active measures have been taken to minimize release potentials. The primary feature of the vehicle fueling areas in temperate climates is a containment pad allowing vehicles to park in a contained area when fueling. Normally, this is a simple concrete pad or other material impermeable to gasoline and diesel fuels. However, due to the variety of tracked and rubber tired vehicles in use in the Antarctic and difficulties associated with the foundation material and the curing concrete a special kind of vehicle fueling containment system would need to be developed. The pad should be formed to allow small quantities of product released to evaporate and should significant spillage occur the product would be directed towards a secondary impoundment. In the more temperate climates of Antarctica (McMurdo, Palmer) where significant quantities of water is present at certain times of year the collection basin could be connected to an oil water separator. Oil water separation is discussed in detail in section 4.2.

2.3.2 Product Transfer to Stationary Tanks

During the process of product transfer into stationary tanks overfilling is a common source of product release. There are effective methods to limit release potentials during the filling of small tanks that are relatively simple to implement. The methodology applied to each of the main populations of tanks present in the Antarctic is similar. The use of inventory controls, recordkeeping, tank gauging, and overfill protection equipment applies to both large and small tanks. Overfill protection is an essential function of any size and configuration tanks. There are numerous different types of equipment that can effectively be used in the Antarctic.

2.3.3 Record Keeping

The use of accurate inventory control and recordkeeping as a means of tracking the product use and possible loss is applicable to all tanks. This is one of the most effective ways of identifying leakage from a tank system that is not currently in wide use in the Antarctic. This is a critical monitoring function for large tanks that cannot be thoroughly inspected for leakage. Inventory control is one of the simplest and most effective methods to detect uncontrolled product release in an existing tank system. Installations currently in use in the Antarctic could effectively implement inventory control programs quickly with minimal equipment installation and limited personnel requirements. The equipment necessary for accurate inventory control is simple and basically consists of the installation of cumulative metering devices to monitor the quantity of product being introduced or removed from a tank. The information can then be compared to an actual tank gauging to determine if there is an uncontrolled release of product. The data needs to be corrected for temperature variations or other influencing factors which may be causing expansion or contraction in the liquid. This data collection and comparison process should be performed daily until a sufficient profile of system performance is obtained. When an adequate storage profile of system has been developed and indicates that the tank is performing properly the monitoring requirements can be adjusted to reduce manpower usage while maintaining a suitable level of comfort that the tanks are not actively leaking.

2.3.4 Maintenance

The maintenance of most systems often gets less than primary attention. This is of course one of the best and most cost effective methods to reduce the potential for leakage from equipment failure. The best engineered systems require regular maintenance or the potential for failure is increased. The standardization of the population of tanks in operation in the Antarctic would reduce critical personnel training costs and also substantially reduce the spare parts inventories required to adequately maintain the system. Annual maintenance of the petroleum storage and distribution systems should be conducted. Scheduled maintenance of the systems should correspond to the inspections of the entire system and should be based on these inspections.

The regular maintenance of the system should include such fundamental practices as the breakdown of critical valves and replacement of any parts observed to be pitted or damaged. Valve packings, glands, bolts, seats, bonnets, flanges, springs, washers, O-rings, actuators, etc. need to be examined periodically to ensure proper functioning. New equipment should be checked prior to installation and retrofitted with parts rated for Antarctic service. A regularly scheduled program of maintenance, lubrication, and replacement on all critical system components will reduce the potential for failure at a critical point in an operation. Maintenance on fixed components and storage systems tend to receive limited attention until a failure occurs and when the failure analysis is conducted it is truly surprising how often even with the current understanding of failure mechanics how many major failure event are traced back to the 50 cent valve packing or bolt that failed after long service and a major release event occured. Maintenance is such a fundamental part of any system that is structured to function properly over a long period of time that it bears mention only because of how often it is overlooked. It is simply part of an effective operations and maintenance plan designed to ensure proper function in the long term and increase the potential that the system will hold up under extreme conditions.

2.4 Installation of Modern Tank Systems

The increasing awareness of the impact of uncontrolled release of petroleum products into the environment has dramatically changed the traditional storage system configuration. Modern designs include many safety systems that were not previously considered necessary. Modern system configurations build in a redundancy or overlap in system function to ensure that sufficient backup systems are present to detect a problem or abnormal function before a release occurs. The starting point in achieving any type of uniformity of function in a storage tank system is the development of a set of performance criteria, specifications and working drawings that form the basis for all new installations and the upgrade of existing systems. In order to achieve a level of comfort that the system design will function properly and survive the Antarctic environment a program of phased upgrades and new installations should be implemented to test system configurations and equipment function under operational conditions prior to broad systemwide application. From this pilot program a truly effective package can be developed and implemented in a cost effective manner.

The details of modern tank construction include both upgraded performance criteria for the vessel and equipment standards that are significantly more complex than were historically believed necessary. The reason for this is that historical installation standards used for the storage of petroleum products have proved to be inadequate to guard against the uncontrolled release of product. Therefore, given the age of the existing populations of tank systems currently in use in the Antarctic there is a high potential that significant maintenance and upgrade would be required to bring these systems into compliance with current industry standards and provide a satisfactory level of comfort in the ability of the system and operational methods to minimize the release of petroleum products into the environment.

The smallest and simplest tank systems now require a much greater quantity of equipment and containment systems to provide that level of comfort that reasonable steps have been taken to minimize release potentials. In developed countries virtually all new tank systems now have secondary containments and leak detection mechanisms. Large bulk tanks typically have 110% secondary containments or remote impoundment systems. Small tanks typically have double wall construction or are vaulted. The newest generations of integrally vaulted storage tanks have great promise for application in the Antarctic.

The equipment found on modern tanks is substantially different from historical configurations. The use of Tite-fill equipment, dry breaks, and automatic shut-off nozzles is becoming more common and is considered an integral part of most standard systems. One significant technology not currently in wide use in the Antarctic is overfill protection equipment. Small spill containment boxes (5-10 gallons) installed on the fillport reduces the potential that minor overfills will be casually released to the environment. The use of a flow control systems when a tank is approaching capacity are typically triggered at 90% of tank capacity and warn the operator that tank capacity has been reached by actuating an alarm bell, whistle, or other method. At 95% of tank capacity the flow of product into the tank is further reduced and additional automatic response may occur depending on the individual system. When coupled with a tite-fill, dry-break, or automatic shut-off nozzle these systems have been proven to be effective at reducing the potential for release during the transfer process. The installation or retrofit of this technology is a very cost effective method to prevent release of product. Many of the significant releases of product in the Antarctic have occured from overfilling small stationary tanks.

The listing of new and proven technologies and alternatives available to the petroleum operations engineer has grown extensively over the past 5 years. Much of this technology can effectively be implemented in the Antarctic at a modest cost. The cost of the prevention of a release is several orders of magnitude less expensive than the smallest remediation event. The crucial element is the performance standard required of new installations. This performance standard should be built into the specification package and should incorporate the philosophy of zero release of product to the environment. This standard should be clearly delineated in the specifications and drawings that are applied in the field. The basics tenants of construction apply and these documents should be carefully developed and geared towards the people in the field who are going to do the actual installation or upgrade. With a properly designed installation that has been installed to specification and is operated under a sensible operational plan the potential for the release of petroleum products to the environment can be minimized and the zero release goal may be approached.

2.5 Spill Prevention and Response Plans and Implementation

The development of a formal plan to implement and adequately organize a prevention plan or a response action is critical. These plans are known in the United States as Oil Spill Prevention and Control and Countermeasures (SPCC) Plans. A formal SPCC, though not regulated into existence, has a far greater importance for operations in the Antarctic. The isolation and distances involved make a well developed plan, and properly equipped and trained personnel essential if any type of reasonably effective response action is possible. There are currently plans on record in many of the larger research stations on the continent. However, there is a clearly identifiable difference between existing documentation and the implementation of an effective spill prevention and response plan. Part of the problem with implementing an SPCC is a natural resistance to change. In adapting to the harsh climate the men and women of the Antarctic programs have developed a complex set of behavior patterns that have proven effective to guard against personal injury. Any change is naturally viewed with some suspicion and does in fact contain a significant element of risk. In addition, there is a standard sentiment that any formalized and documented plan is not applicable to the situation because the authors do not understand the working conditions of the Antarctic. There is no doubt an element of truth in this belief, though this does not need to be the case. The development and implementation of an effective plan needs to be a compilation of the effective procedures currently in place, an evaluation of ineffective policies, and a combination of input from other sources. These sources include established method from successful international programs, industry standards, and most importantly input from the people who have operated the existing system, or are going to implement any revised program.

3.0 Spill Response Plans

Fast and effective response to a spill regardless of size is critical to reducing the environmental impact and minimizing the cost of any required remediation. The critical issue are personnel protection and minimizing product migration. Adequate documentation and recording of the event is also crucial to the program ability to adjust future operational procedures to reduce the potential for a release due to similar causes. There is a potential for personnel resistance to thorough documentation because to often this is associated with an assignment of blame for an event and not on the attempt to gather the information required to prevent a future recurrence. Adjustments in the documentation procedures should be able to account for this resistance to thorough documentation of a release event. The development of the spill response team and the location in the organizational structure of the Station is critical for success in responding effectively.

Essential to any spill response action is adequately trained personnel and the proper equipment in sufficient supply. The similarity between a petroleum spill response and response to a fire is a natural link associating these two functions in the Antarctic. Modern training for fire response personnel often includes Haz-mat (Hazardous Materials) response due to the elevated potential for fire from the presence of flammable or combustible liquids during a Haz-mat spill. Therefore, establishing or augmenting the capabilities of existing fire teams to handle haz-mat response is a fast and sensible solution to developing the formal team required for catastrophic petroleum release responses. The training protocols and safety training are quite similar and the size of these teams is already geared towards the size and population of the stations. The population of the each Station has a linear relationship to both the fire response requirements and the quantity of stored flammable and combustible liquids. Therefore, with minor changes in the composition of existing fire fighting teams and the addition of a new response directive the fire fighting teams can be organized within the existing structure to effectively react to catastrophic events. Additional training to minimize product migration should not present a significant diversion from the primary role of existing fire fighting teams. The steady leakage of product or the minor release of product during transfer is most effectively handled as a maintenance function and the critical issue to repair the leakage and or readjust the transfer procedure to prevent reoccurrence and should not be treated as an emergency response.. The equipment required to address both catastrophic release and minor releases is actually quite similar.

Petroleum release response equipment is not complex and does not represent high technology. Remediation of environmental hazards is, in general simple, but does involve very hard work by safety and environmental professionals trained to protect themselves from exposure to the products they are handling, workplace hazards, and to quickly stabilize and reduce the potential for fire. The equipment required for response actions includes; a full range of personal protective equipment, explosimeters, absorbents and oil sponges, booms, flammable/combustible liquid handling pumps, storage vessels, oil water separators, emulsifiers, mops, buckets, etc. The first concern is worker safety and therefore the use of protective clothing, respirators, and decontamination procedures can not be emphasized enough. A significant part of the initial response is to stabilize and minimize the fire potential. Naturally, the first step is to ensure that the source of the release has been eliminated and the any free product has been transferred to an appropriate containment vessel.

Petroleum product releases take numerous forms. Catastrophic failure of a tank from a burst seam or from mechanical damage or puncture is generally considered worst case and accounts for a relatively small percentage of individual events however, the impact and response require the greatest effort. The continuous slow leakage of a tank or delivery system is less of an immediate catastrophe but when it remains uncorrected over time this could potentially release larger amounts of product into the environment than catastrophic failure of a full vessel. Finally, the release of product during a transfer operation accounts for the largest percentage of product release events and indeed may account for the largest percentage of lost product. Accurately identifying the magnitude of the event and gearing the the response action requires the presence of well trained and experienced professionals. Each spill event is unique but the response action can be designed and implemented to protect the people involved, reduce the potential for fire, and product migration in accordance to a well developed standard plan. To be truly effective these plans need to be field tested and flexible to allow for new technology and more effective solutions to be included.

3.1 Primary Response Actions

The immediate need to stop the uncontrolled release of petroleum products should take precedence over all events except personnel safety. The response is dependent on what type of release has occured. If a tank ruptures the only practical response is to minimize personnel exposure and attempt to reduce migration and to limit the area affected. Reducing the spread of product is critical in minimizing impact on the environment and also the cost of any subsequent actions required. There is a rule of thumb that states that the remediation of a spill event costs a minimum 5-20 times the investment needed to prevent the release prior to occurrence. Therefore, a significant part of responding to a release is to identify where the product is coming from. Sometimes this is a relatively simple exercise, a valve was left open, a broken pipe is visible, etc. It is surprising how often one still hears that a significant release occured because a valve was left open. However, very often the location of the leakage is very difficult to determine. It may come from a buried source such as a drum of waste, a leaking underground pipe, or leakage from the bottom of an on-ground tank, etc. and the analysis of these events may be quite complex. The complexity is often compounded by the need to maintain the system on line while locating the source of the leakage.

The response to a release event is often limited to the equipment that is immediately available and the technical expertise to respond effectively. This factor more than any other contributes to the spread of contamination and increases the cost of the dictated response. Thus there is a critical need for a standardized response that contains formal procedures and trained and experienced participants who have been adequately trained to understand the system under failure, the migration patterns associated with the vicinity, and the appropriate equipment needed to respond in an effective manner. The immediate installation of migration minimization techniques such as setting booms, weirs, oil sponges, or the use of sorbent material is critical to reduce the area contaminated by the release product. As with many other environmental issues the costs associated with an event are greatly reduced if waste minimization actions are instituted early in the process. Having an adequate supply of materials and a formal response plan of action greatly increases the ability of personnel to quickly address the release and minimize the migration

3.2 Remediation of Free Product

When a spill has occured and it is possible to identify the presence of free product, collection and containerization is the first step. The use of pumping and collection equipment depends on the location and thickness of the layer of product. Typically, all the methods include developing a collection point if one is not established naturally. A collection point is simply a ditch or trench or any other naturally occuring or manmade collection point from which the product can be pumped, bailed, or drained into a storage vessel. If there is significant presence of water or the free product is actually being collected off the water table the use of an oil water separator if one is available is recommended as a pretreatment. This should only be attempted if one is immediately available. The critical issue is to contain the flow of product and prevent it from spreading out over a larger surface area. Minimizing the migration of free product on water requires a considerable supply of Booms, Sponges and other absorbents that are hydrophobic and designed specifically for oil collection.

3.3 Product Migration Patterns

Part of the process of developing an effective spill response action is understanding and mapping the potential pathway free product will follow. This is somewhat simplified by the characteristics of the native soil and the relative impermeability of snow and ice to the absorption of petroleum products. The shallow depth to the permafrost layer and the absence of subsurface fluid flow patterns also minimizes the migration pathways. Therefore, there is a significant possibility that contamination from product releases are relatively near the surface and do not extend deep into the ice or native soils and rock. The mapping of primary migration routes is then a matter of adequately assessing the topography in the region of the storage tanks and accounting for seasonal changes. Developing an understanding of the product migration potentials is critical to developing the response action. Developing an accurate migration potential map is also critical to the development of a sensible remediation strategy. Basic to this concept is properly evaluating the migration pattern and identifying the impact on the the affected ecosystem.

4.0 Soil and Water Remediation

The primary remediation alternatives for contaminated soil, ice, and water are discussed with specific methodology for the Antarctic. The reduced hydrocarbon volatilization and the sluggish response of bioremedial dissipation mechanisms in soil necessitates pro-active remediation strategies. The stable of solutions available to the environmental response team is limited compared to current practices used in warmer climates. This is largely due to the low temperatures and lack of easily transportable equipment. Transportable soil remediation equipment is commercially available for both rinseate and incineration procedures however, the size and complexity of the units do not allow for easy application to the Antarctic environment. The incineration process typically utilizes a rotary kiln to heat contaminated soil to burn of the contaminant. Rinseate technology uses a secondary fluid as a solvent to wash contaminated material and the generated liquid is then reprocessed. The application of in-situ soil remediation techniques are discussed as an alternative to retrograde. The details regarding the use of oil-water separators and carbon filtration units for contaminated liquid processing to current drinking water standards are also presented as a method to reduce existing contamination in soils and water.

4.1 Physical Assessment and Development of Remediation Strategies

The remediation alternatives available to the environmental engineer operating in the Antarctic are significantly more limited than those available in the temperate zones. The natural dispersion and bioremediation processes are greatly slowed or in some cases non-existent due to the temperature and sterile nature of the Antarctic. These factors indicate that a significant part of the solution will involve proactive remediation efforts that occur on the continent to reduce the quantity of waste materials that might require retrograde.

However, the reality of life in the Antarctic indicates that even with greatly improved management, there is always the potential that significant releases will occur and will need to be addressed in a proactive manner. In addition, there is the issue of historical spillage. Significant spills, leakage and other major releases of petroleum products are known to have occured in various locations in the Antarctic. The nature of the native soils, permafrost, and ice do not allow for extensive vertical product migration and therefore the majority of contamination is believed to be surficial. The specific details of product migration tendencies have not been thoroughly explored to document this commonly held assumption. Historical spillage events have left residual contamination that is largely unmapped and potential impacts on delicate ecosystems have not been fully explored. The costs associated with retrograding or processing contaminated material are greatly escalated by the geographic location. Therefore, the emphasis and resources available should be first be directed at preventing the release of petroleum product in an uncontrolled manner and then at implementing practical remediation techniques to minimize the impact on the environment and reduce the volume of waste requiring retrograde.

The development of any remediation strategy is dependent on both the type of product released and the physical characteristics of the contaminated material. The majority of the petroleum based products that are presently in use in the Antarctic, JP-4, JP-8, Diesel, and lubricants respond to the most commonly used remediation techniques in a similar manner. However, the dispersion characteristics vary greatly. This is largely due to the viscosity of the product. Therefore, the same techniques can be applied to most of the petroleum based products that are likely to be released in significant quantities. The majority of remediation technologies are designed to deal with water or soils. The development of extraction technologies to remove hydrocarbon contamination from snow and ice are not well developed and into the foreseeable future the remediation of contaminated snow and ice will require a phase change and processing as a liquid. Soil remediation techniques applicable to the Antarctic are identical to those use in the temperate zones and include incineration, rinsing, or landfilling.

The volatility of petroleum products such as JP-4, JP-8, and Diesel fuels is greatly reduced at colder temperatures. Therefore, one of the dissipation mechanisms often relied upon in warmer climates to reduce the presence of contamination in soils operates at a greatly reduced rate rendering it much less effective. A second more powerful mechanism that effectively reduces the presence of petroleum contamination in soil is bioremediation either naturally occuring or artificially stimulated, but the temperatures and sterile conditions of the Antarctic all but eliminate the effectiveness of this process.

4.2 Implementing a Remediation Strategy

Developing a sensible remediation strategy is dependent on a number of factors. The amount and type of product released should be adequately defined as a first step in evaluating what type of remedial response should be instituted. The medium that has been contaminated defines what the response should be. the development of the an accurate migration potential and risk assessment is critical to defining the impact on affected ecosystems. If the release has occured on snow or ice then a course of action to contain and process the contaminated material as a liquid makes considerable sense as an end point remediation strategy.

4.2 Soil Remediation Methodologies

There are four well developed and field tested technologies for the remediation and restoration of petroleum contaminated soils that are in wide use today. The base description for these technologies are soil venting, extraction, microbial degradation, and incineration. The use of incineration is the most widely applied restoration technique and portable incineration units of various capacity are available. Incineration is considered the most applicable technology for the Antarctic and will be discussed at the end of this section. Another alternative widely used in the United States is landfilling. This is a useful technique where contaminated material is present in a highly sensitive location, has a high potential for uncontrolled migration to sensitive locations, or is at an elevated potential for exposure to human and animal populations. However, landfilling has limited use in the Antarctic due to treaty limitations and the inevitable criticism that such a program would engender. A brief description of the applicability of each of these technologies is discussed.

Soil venting is a technique that is widely used for volatile products and has a potential application for in-situ gasoline remediation projects. However, this process is highly temperature dependent and the nature of the soils present in the Antarctic do not lend themselves to this type of

Given that a key factor in the original Antarctic Division study was culture (or rather the dynamics of a series of sub-cultures), it seemed appropriate to turn to cultural images to explain the nature and source of the fundamental "energy" keeping the cultural ecosystem in some form of equilibrium. The work of those psychologists who study groups using archetypal paradigms to categorize, explain and explore culture seemed fruitful soil in which to develop such an explanation.

Archetypes are deep universal patterns which are seemingly contained in the behavior of individuals, groups, communities and, even, nations. The notion of an archetype was first presented by the Swiss psychoanalyst Carl Jung who suggested that the universality of the patterns crossed national and ethnic cultural divisions. Archetypes may be expressed in the form of shared images of the world, common values, similar energy patterns, accepted perspectives, and alike behaviors. But the patterns themselves are extremely unconscious to the individual or group members themselves, until pointed out and explored (usually by an outsider). Nevertheless, they are almost always instantly recognizable, e.g. the mother archetype is quite familiar to all cultures and groups, for we all carry within us the primal experience of being mothered or seeing mothering.

In order to find a language within which to talk about archetypes most writers turn to a cosmology for inspiration (Dalmau, 1991). Some, such as Wendy Doniger-O'Flaherty (1984, 1988) from the University of Chicago, turn to eastern religions. Others, such as Bernie Neville (1991) from La Trobe University, turn to the Classics - in particular, ancient Greek mythology. Consequently, to describe an archetype we talk as if the group were possessed by one of the Greek gods. Each god-image will have a number of manifestations and even though they are given male or female names, the god-images have characteristics which we would currently associate with both masculine and feminine traits.

It is a fundamental tenet of archetypal psychology that in any group or organization there should be a range of energies at work, a diversity of perspectives at play. The unhealthy group is one which has become *inflated* with the energy of one archetype only, i.e. one god. There are a wide variety of archetypal patterns embedded in individual and collective behavior. But, organizations which become inflated by a particular archetype are unable to see anything outside that peculiar frame of reference; they become transfixed, so to speak.

The predominant archetypal energy which drives an organization should be appropriate to its purposes, its environment and its people. Most organizations are, in fact, manifestations of competing archetypal images and energies, i.e. are polytheistic; thus, organizations often stay healthy by recognizing, celebrating and accessing the diversity of image and energy sources within them. It is only when one or more of the sub-cultures within them come to believe they have "the right answer" that dysfunctional patterns set in: to adopt and live within a monotheistic culture is to live the negative as well as the positive aspects of the archetype. Thus the more attached a group is to a monotheistic image and energy, the more powerful will be the manifestations of its shadow.

Through diversity in a group comes robustness; with robustness comes effectiveness and satisfaction. So, what are the energies which seem to drive each of the groups? To this we now turn...

The **returning expeditioners** seem (to the outsider) to be driven by three separate energies. The god *Eros* provides then with a belief that quality of relationship really matters, that everybody should get on with one another, that trust and openness and mutual unconditional regard are important. The down side of Eros is that people under his spell have a tendency to become bitter if they find themselves in an environment which does not value such human concerns. They then can lose sight of strategy or goal and become defensive, passive and resistant.

But *Herakles* also ensures that the most valued people are those who will fight for what they want. He encourages people to talk a lot about their own ambitions, to be tough, yet friendly. Problems are solved by facing them head-on, and they are unhappy unless they're energetic and ambitious for they don't like being pushed around. The third god-image which provides much of their perspective on the outside world comes from *Athena*. She provides them with a realistic orientation, a pragmatic attitude, and a "focus on what matters". She ensures that achievement is valued highly and that the people who are valued are those who can develop winning strategies and practical solutions, especially if they can also keep their head in the heat of an emotional situation and accept the established norms as guidelines of behavior.

The **ACS group** in an Antarctic community seem to present with a different set of energies. *Hephaestos* seems to provide a good measure of their sense of themselves which places high value on craft, skill and diligent professional work. He ensures they can be absorbed in making something with their hands or doing something that is manual. This is a way of expressing creative artistry through work that is given a tangible form - something hghly valued in their environment. He also ensures that they tend not to talk about or address their feelings; they tend to work in solitude, and either sublimate their feelings or express them through their work. They tend to be intense, introverted persons who seek recognition solely for their work - the corporate world is foreign and meaningless to them, and often have specific difficulties with people in authority. He pushes them in the direction of bottling up intense hurt, fear and anger and keeping their communication indirect and implicit.

Combined with *Dionysus*, this profile can present some major challenges to the average Station Leader-obligations, assignments, appointments, being regular, consistency... these things don't rate that highly for Dionysus. Instead he tends to ensure that members of the ACS group have a strong sense of youth and energy but can be very moody and may fluctuate between being very warm to one another one moment and cold strangers the next. They become susceptible to conversion symptoms, e.g. hysteria, other conversion disorders, and easily become self-indulgent, especially with alcohol. (At least in Australia, most people know the dark side of Dionysus as the stereotypical bacchanalian feast of his Roman equivalent - Bacchus. In so doing, they tend to ignore the more creative aspects of Dionysus.).

This can lead to a dangerous combination when joined with the third god-image which seems to drive the ACS group, *Ares*, for he ensures they are likely to have intense and instinctive reactions to issues, ideas and each other. For him, the ideal environment is assertive, active, and emotional - thus people under his spell become bored and restless with paperwork and long-term goals, deep conversation or talking philosophically. When riled they can be physically abusive - they lack choice and are bundles of impulsive reactions. They have real difficulties "going by the book", and can easily become permanently defeated and see themselves as losers.

The **Division-employed tradespersons** share some common characteristics with the ACS group in so much as they seem (to an outsider) to be driven by Hephaestos and Dionysus. However, it is rare to hear them described in terms associated with Ares - they tend to be more reflective, timed in their responses, and less likely to use adversarial modes for dealing with conflict. This may well be saying something about differences between those people who select them for the Antarctic Division's employment versus those who select for the ACS organization. Or, it may be saying something about the fact that the ACS personnel come to be clearly identified as a *group* in the Antarctic community more than the Division-employed tradespeople. The "groupness" of the ACS personnel may well encourage Ares characteristics to emerge more easily, whereas Ares may be strong and dormant but unexpressed in the other tradespersons.

The **Meteorological Bureau** personnel seem to be under the spell of Hephaestos and Prometheus. *Hephaestos* ensures they value craft, skill and diligent work, that they do not talk about or address their feelings, they tend to work in solitude, and either sublimate their feelings or express them through work. He ensures they know the importance of quiet periods full of possibilities where imagination and hard work come together, where they can work best as loners. Unfortunately, they can bottle up intense hurt, fear and anger, becoming emotionally disabled such that others often learn to tiptoe around, intuit, and infer what their reactions will be.

But *Prometheus* ensures they hold values which keep them interested in the freedom of people and defiant of the establishment rule. They seem to believe that their work (monitoring and analyzing weather) will help others to gradually get control of things and learn how to do "everything" and understand "everything". They come to see themselves as heroes working towards a new world order and those who oppose simply "don't really understand". They tend to downplay intuition and feeling, any manifestation of the feminine. As men, they tend to be misogynists and, as women, they tend adopt many of the emotional characteristics attributed to Ares.

Those in **executive** and other management positions back at headquarters in Australia seem to operate from a quite different base altogether. Above all, they appear as worshippers of the god *Apollo*. Consequently, they place a very high value on being rational, systematic and orderly. They value targets and goals which are visible to others, in an environment which fosters clear definitions, is drawn to praise skill, and prefers to look at the surface rather than at what underlies appearances. They appear to have a shared instinct for order and form, and seem quite uncomfortable with chaos or turbulence. Apollo ensures they value order and harmony, thinking over feeling, distance over closeness, objective assessment over subjective intuition.

But Apollo is joined in their culture by *Prometheus*: He provides a pervasive belief that things will get better and better, that we gradually will get control of things and learn how to do everything and understand everything. People under his spell value the development of technology and systems to get control over problematical elements, see their role as a revolutionary one, changing society and working towards a new world order. This has certainly been evident in a lot of the rhetoric surrounding Australia's recent initiative's surrounding the Madrid treaty in 1991. Unfortunately, they also tend to downplay intuition and feeling, any manifestation of the feminine. Prometheans have little or no awareness of long term social consequences of the technology or systems they build and can become careless of future consequences

Those who work as **scientists** in the headquarters near Hobart represent a strange and curious mix of Apollo, Hephaestos and Prometheus. *Apollo* gives them a very strong emphasis on rationality and order. They prefer realism, clear definitions, clarity and purity of thought and action. They value order over harmony, thinking over feeling, distance over closeness, and objective assessment over subjective intuition. When humiliated they will engage in highly punitive responses and show no mercy; they tend to have an inflated sense of their own capabilities and resilience. They try to mentally distance themselves from the suffering of others and are often out of touch with their own feelings - thus they think and express themselves verbally and logically with an inherent ability to focus on a task. Like their brothers and sisters in the executive they are extremely familiar with written text and spoken word - culturally, the greatest gap is probably between this group and those characterized as the ACS group.

The *Hephaestos* in them helps them to see what they do as quite unique and special - an expression of their technical expertise and their commitment to their calling. Thus they tend to withdraw from the company of others in the organization and let themselves be absorbed in their work; they tend not to talk about or address their feelings; they tend to work in solitude, and either sublimate their feelings or expresses them through work. They have few social or political skills and often have specific difficulties with people in authority, bottling up intense hurt, fear and anger; becoming emotional cripples, smouldering volcanoes, or highly creative productive persons.

Prometheus engenders in them opposition to establishment rule and a world view that things will get better and better, that we gradually will get control of things and that systems can get control over problematical elements. Persons in the grip of this god-image see their role as a revolutionary one, changing society and working towards a new world order and those who oppose simply "don't really understand"; they tend to see themselves as heroes.

Returned expeditioners who now work inside the Division seem inflated solely by *Artemis*. She helps them to experience a sense of "at-oneness" with themselves and with nature. They tend to view people inside the Division and evaluate their worth simply on who they are and what they do. They have an air of intactness about them yet feel strongly about their causes and principles - they enjoy the exhilaration of independence and are undeterred by opposition.

Like all who are possessed by Artemis, when they get into middle management positions this group of returned expeditioners don't pay much attention to subordinates or colleagues who are dependent and, indeed, can set for subordinates standards and expectations which are unrealistically high. They deny their own vulnerability and need for mutuality, and maintain a large emotional distance from others and often fail to notice the feelings of others around them. They tend to judge the actions of others in terms of unmitigated black and white, which means they are often seen as stubborn and unrepentant by others in the organization.

The **support personnel** within the headquarters staff seem to be driven by Hestia and Athena. *Hestia* provides them with a strong sense of power derived from being apart from the rest. She also provides them with clarity in the midst of the confusing myriad of details, a sense of quiet tranquility in solitude which is "detached" to people, outcomes, possessions, prestige, or power. Consequently, they are inclined to "stay above" or out of the more visible intrigues and rivalries, and avoid being caught up in the passions of the moment. They tend to be quiet and unobtrusive people who do little to draw attention to themselves, so often feel alienated or isolated from their fellow workers and do not easily find recognition in a competitive workplace. They tend stay out of overt office politics and gossip, and provide an ambience of order and warmth. They are easily over-looked and inappropriately devalued.

Athena provides them with a realistic orientation, a pragmatic attitude, and a "focus on what matters". They place a high store on excellence and achievement and conformity to "adult" (that is, traditionally held) standards. It is Athena which helps them to survive effectively in situations wherever political or economic considerations are important, and to use and apply their intelligence to the practical and pragmatic, grasping what must be done. They stress foresight, planning, mastery of craft, and patience. They tend to be practical, uncomplicated, unselfconscious, and confident people who work hard, and accept reality as it is.

Next, we consider the people within the organization with responsibility for the **technical oversight** of personnel in Antarctica. They share many of the characteristics of the returning expeditioners and seem to be driven by Eros and Herakles. But there is an additional element, Zeus.

The god *Eros* provides then with a belief that quality of relationship really matters, that everybody really does get on with one another, that trust and openness and mutual unconditional regard characterize their relations with one another. But like their returning expeditioner brothers and sisters, they tend to lose sight of strategy or goal and can become defensive, passive and resistant. This presents some interesting dynamics, considering they are often in supervisory or management positions within the organization. The *Herakles* in them ensures that the most valued people are those who will fight for what they want, who will solve problems by facing them head-on. The *Zeus* in them ensures their use of power, authority and dominion are quite visible. Enterprise and ambition are "good" values to them and loyalty is highly prized. They seek to extend their boundaries, to acquire more "territory" and, for those under the spell of Zeus, personal dilemmas, problems and concerns of employees are not of importance or relevance. They tend to devalue others who have a better developed feeling function, consider their perspective superior, and since they are listened to as experts and authority roles, they have no reason to doubt this position. They use networks extensively.

Finally, we come to the ANARE Club, that institution which contains many (but certainly not all) returned expeditioners. It is, if you like, a subset of the returned expeditioners group. Like their colleagues, they seemed possessed by Eros and Herakles. (For detail, refer to the description for returning expeditioners above). But they also seemed gripped by *Dionysus* who emerges every mid-winter to guide their celebration and ritual with sign and symbol and the telling of many tales. This god also provides them with the intense and emotional involvement which the ANARE Club seems to engender in some, and encourages them to celebrate the breadth and depth of common feelings. Persons gripped by this Dionysus expect special treatment or recognition, and harbor resentments when their specialness is not honored. The earth mother-goddess, *Demeter* seems to provide the fourth element of their energy source. Thus the ANARE Club excels at emotional and psychological support to its members, providing them with a solid and dependable place to be, with lots of nurturing and supportive, helpful and giving behaviors. She ensures that its members are generous, altruistic, and loyal to their peers.

Each of these groups is driven by quite different perspectives, value sets, beliefs and energies. They don't fall neatly into single-description categories and the source of their respective differences seems to be deeply archetypal in nature. And like any individual or group which becomes inflated with an archetypal image, each of the groups defends its place in the world quite vigorously, indeed sometimes with stunning ferocity.

Against this sort of background, we now turn to the basis of a strategic response....

Leveraging Change

Very early on, we realized that those issues posing difficulties in the management of expeditioners were in fact symptoms of some deeper underlying causes. Many of these causes lay in the unconscious and quite deep inflation of some of the sub-cultures with the different archetypal energies described above.

Reported symptoms of the difficulties were such things as occasional physical violence, inappropriate behavior under the influence of alcohol, apparent excessive use of alcohol, disruption to work programs, medical disorders, accidents, and social tension in the communities over such things as exclusive male-female pair relationships. There were also reports of significant group tension across various occupational groupings. A lot of the evidence for such symptoms was highly anecdotal and their extent, frequency and the degree to which they caused actual difficulties in the communities was very hard to establish in the early stages.

Moreover, expeditioners and Divisional employees identified a very large number of first order independent environmental variables which seemed to impact directly on the frequency and extent of these symptoms. Inter alia, these included ...

- time of year,
- management style of Station Leader,
- mix of new and returning expeditioners in a community,
- relationship of technical people in a community with their respective Australian-based technical supervisors,
- mix of scientific and building construction personnel,
- frequency and extent of accident or injury to expeditioners,
- weather
- availability of water and fuel,
- age of expeditioners,
- male-female ratio in a community
- logistic support systems in Australia for the reconstruction program,
- shipping schedules,
- frequency of apparent overt conflict among expeditioners,
- formation of visibly cohesive and exclusive work-based groups,
- different work patterns among different occupational groups
- personal crisis involving loved ones and relatives in Australia,
- noise levels in common living areas,
- conflict over smoking and alcohol usage,
- changes in community membership over the summer period,
- time of response to requests from Antarctic personnel by Australian-based Divisional employees,
- differences in the primary employing authority's goals for an expeditioner's work program (e.g. Antarctic Division, Australian Construction Service, Bureau of Meteorology, university faculty, etc..),
- frequency and extent of major life changes in the recent past of an expeditioner prior to employment,

to name but a very few!

An extensive literature search failed to identify any systems models which could adequately account for either the symptomatic data or the many independent variables. In this type of setting, the more "traditional" route of data-gathering, problem-analysis, problem-identification and strategy-formulation breaks down for there is no framework and/or language which will aid an inquirer in adequately and correctly identifying the underlying cause/s. Australia, and other countries who send persons to live in Antarctica for extended periods of time, simply do not yet have working causal models to explain and predict adequately the experience in its breadth and depth.

Given this situation, a number of managers within the Division and former expeditioners were consulted in order to establish some long-term vision of a preferred future for an Australian Antarctic community. A primary vision statement for the human resource management in these communities was thereby established...

> *Individuals and communities behaving effectively; base communities with shared values and cultures which enhance mutual cooperation, responsibility, enjoyment and overall community life.*

This vision statement was then broken down into more specific components...

- interpersonal conflict managed constructively
- individual members caring for one another
- executive management of the community by a pair: Station Leader and Deputy Station Leader
- work programs run efficiently and effectively
- increased frequency of reports by expeditioners of a happy and worthwhile year
- mutually supportive and caring relationship between Station Leader and Deputy
- members not only tolerating but constructively using individual difference in the community
- individuals reporting satisfying and smooth reintegration into family, social networks and Australian society
- a support mechanism for Station Leaders,
- Station Leaders with more power to influence individual behavior,
- a more reliable data base for management decisions with regard to current and future expeditioner selection and return to Australia,
- more congruent fit of people and their jobs within a community,
- mutually dependent and supportive working relationships among groups within a community
- cultural elements (artifacts, behaviors, perspectives values, and assumptions) which support the above components.

In other words, rather than trying to solve problems within existing assumptions about what "didn't work", the decision was made to set out and try to use the human resource management system as a vehicle to create (over time) a more effective social system which, in turn, would not exhibit the symptoms already identified. Or ... at the very least ... allow a wider and more diverse set of perspectives to operate within the communities and within the headquarters organization back in Australia, i.e. to curtail the inflation of some of the sub-cultures with certain gods, and to allow others to come into play.

Shaping and managing deep unconscious forces directly is almost impossible. Putting energy into strategies aimed at attitude change is a gross waste of resources - social scientists established long ago that behavior change comes before attitude change, not vice versa. The task therefore was to act in the external world in the belief that, eventually, attitude change would emerge and, ultimately, the sub-cultural conflict (thought of as a conflict between gods) would be turned into the constructive use of diversity.

Hence we tried to identify probable key leverage points within each of the selection, preparation, management and repatriation phases of an expeditioner's life cycle of employment. We made the assumption that sustained improvement at *a number of key leverage points* in each phase would aid significantly in the evolution of the preferred social systems .... of more appropriate cultures. Moreover, we tried to create a situation where each lever would (of itself) induce substantial change. Thereby, allowing for "slippage", the fact of using a number of leverage points would (we hoped) build a *redundancy* into the whole affair which would increase the likelihood of success.

Work groups were established to examine in detail each of the three main system elements: selection, preparation and management. These groups of people were constituted as necessary and composed of persons judged to have the relevant knowledge, experience or expertise regardless of their current role in the Division: in most cases they turned out to also be former Station Leaders or expeditioners. Wherever possible those affected by decisions likely to come out of the work of these task forces were either consulted or involved as appropriate. Academics, researchers, and Antarctic-literate personnel from other nations were also consulted.

We now turn to the actual strategies instituted at each of the identified leverage points....

The Strategies

Selection Phase

All personnel selection is really a matter of trying to minimize error: the error between human judgement in the present and performance in the future. The entire expeditioner selection process from beginning to end was studied and some changes implemented. The changes described below have been depicted in more detail elsewhere (Dalmau & Mulligan, 1988); what follows is more in the nature of a summary ....

Interviewing: Whilst it has long been accepted that the interview is a poor selection tool for predicting future performance there are few systems which dispense with it. But, equally, there are few in Australia which rely so heavily on interview behavior as does the selection system of the Australian Public Service. In other selection environments it is usually heavily supplemented with other elements.

Starting about February of each year, twenty or more personnel and technical representatives of the Division conduct selection interviews in all major capital cities and regional centers throughout the country. They interview over 500 short-listed applicants annually. The interviewers find it difficult to know what they are looking for in potential candidates in any way that they can make verbally explicit and clear. Their sensory acuity is often such that, even if they can be clear about what they were looking for in candidates, they are not be able to distinguish among different candidates. We identified that most seemed to lack skills of voluntary dissociation which they could use consciously in the interview process itself: a vital skill which enables an interviewer to separate out his/her own personal feelings about a person or process from what is actually going on, and thereby make more dispassionate judgements.

It became clear that, more often than not, expeditioners were ultimately selected as the result of some vague, highly intuitive factor based on a sense of personal comfort. The mechanism used was often projective identification: the candidate having satisfied technical performance criteria, the interviewer then often tries to imagine how s/he would feel spending a winter with the candidate.

Starting in March 1988, those Divisional employees who work in the Personnel Section and who sit on expeditioner selection panels were trained to increase their sensory acuity. They were also trained in dissociation and more sophisticated questioning skills. The training used knowledge and skills from neuro-linguistic programming, and was based on behavior modeling and video-feedback for its process. Feedback about the efficacy of this skills training in helping panel members distinguish among applicants in interview situations has been positive. The training has been refined over the years - unfortunately, reports suggest it has become mechanistic and does not emphasize enough dissociation, calibration and precision questioning skills.

Psychological Screening: The screening of applicants for psychological suitability constitutes another leverage point. The evidence to support the predictive validity of psychological screening in regards to future social and technical performance in remote communities seems to be controverted. However, the Division has maintained a policy of completing such screening more as a basis for excluding persons rather than predicting their future suitability. After a study commissioned to review the efficacy of the screening system provided on contract to the Antarctic Division by the Australian Army Psychology Corps, it was decided to use the Clinical Analysis Questionnaire (CAQ) to supplement the use of the 16PF, personal history and face-to-face interview. The Army now provides the Division with a bipolar yes or no recommendation in terms of an individual expeditioner's potential suitability whereas, in the past, the recommendation had been yes, no or marginal. Executives within the Division report these and other changes have increased their confidence in the psychological screening component of the selection process.

Referee Checking: It is an unfortunate practice within the Australian Public Service that selection panels are not required to seek out actively and check with referees themselves but, instead, rely on written references. Moreover, even if selection panels do contact referees directly, it is usually true to say that the interviewers do not have the precision communication and questioning skills necessary to elicit the "right" data. Consequently, a potentially rich source of information is lost to the selection decision-making process. Divisional selection panels for 1988 were instructed to undertake phone checks with referees of all final choice applicants. Regretfully, this practice does not seem to have been continued beyond this point.

Station Leader Selection

The process for selecting expeditioners is also used to select Station Leaders. There is one main difference, however: the addition of an Assessment Center for the final 12 to 16 short-listed applicants. This is conducted at the Division's training facility in the highlands of central Tasmania about May of each year and lasts about 5 days. In the mid-80s the processes used within the Center were grounded in a highly rational and cognitive means of selecting suitable candidates. After reviewing the process there was little or no evidence to suggest major elements should be deleted or substantially modified. But it did become clear that the Center process did not apparently allow the selectors to obtain information on the applicants'...

- level of intrapersonal insight,
- interpersonal skills,
- intentional group intervention skills,
- mediation skills, and
- more affective constructs of their personalities.

In 1988, many of deficiencies were rectified through....

- changing the composition of the initial screening panel,
- changing the composition of the selection panel, and
- adding elements to the assessment center process design which gave the panel information under the above categories.

In the period since then, the process has been subject to annual review and improvement.

Taken as a whole, these changes to the selection of expeditioners and Station Leaders was designed to ensure that fewer people with inappropriate psychological profiles managed to find their way through the "system" and down to Antarctica.

Preparation Phase

The next stage in an expeditioner's life cycle involves him/her starting formal employment with the Division and preparing to go south. In this phase, a number of quite significant changes were made, based largely on the study which highlighted that initial expectations played a major role in how an expeditioner experienced a year in Antarctica.

Contracts: Expeditioners sign a formal contract which requires of them certain "minimums". Prior to the mid-80s, these minimums were quite general legal requirements which are largely common to all public service employees. Expeditioners are now required to sign a Code of Conduct document which specifies the minimum standards of acceptable social behavior and management of property. They are also required to commit themselves to participating in a performance planning and reveiw system known as EDAS - see below.

The signing of the documents does not prevent an expeditioner from engaging in inappropriate behavior, but does achieve two clear things: communicates the Division's expectations much more directly, and provides a more solid legal base for confronting difficult behavior if and when it does occur.

Induction: A number of changes were made in 1987 to improve the more symbolic and "meaning-creating" elements of the first formal contact that a newly-employed expeditioner has with the Division: at around induction time, mainly through the use of specific small rituals and involvement with the senior managers of the Division. Regretfully, these have not been maintained over the last few years with as much focus and relevance as in the late 80s.

Technical Training Program: The Division spends considerable resources training expeditioners in specialized skills once employed and before embarkation. These include such things as theater nursing, anesthesia, and fire fighting. It also upgrades the technical skills of tradespersons so that they can fulfill a wider range of duties than would normally be required of them in the Australian community. During 1987 it became clear that the technical and community training program was in need of a strategic review. This has been done in 1988 and there has been a significant improvement in both the program's cost-efficiency and its cost-effectiveness.

Community Development And Field Training: Expeditioners, prior to embarkation, are trained in search and rescue, Antarctic weather, safety and survival, first-aid, and the like. In previous years this training was conducted at the Division's facility in the highlands of central Tasmania, and it was not uncommon (as a result of the way in which such training was arranged) for an expeditioner to meet his/her companions only upon embarkation. Winter groups and summer groups were trained separately, and it wasn't always the case that even an entire contingent of winterers would be together for the field training.

It was decided to train winter and long-term summer personnel together and to institute a program of community development which would aid in the development of a sense of identity for each base community and would begin to provide expeditioners with an opportunity to explore..

- tolerance and building on individual difference
- stages of group and community development
- interpersonal communication, including conflict mediation
- their own emerging relationships with one another
- norms for the life and work together in Antarctica

The overall goal that this community development intervention seeks was to..

> *have individuals expeditioners and base communities beginning to behave cooperatively, responsibly and satisfyingly with appropriate knowledge and understanding to improve the quality of their living in Antarctica.*

Feedback from 1988 winter and summer personnel (who were the first to experience this intervention) led to the combining of all four base winter and summer expeditioners into one combined training experience of 9 days duration at Brighton Army Camp in southern Tasmania for the 1989 expeditioners. This event integrated what had previously been three separate parts of the preparation phase: orientation, field training, and (for 1988 winterers only) community development. Feedback from expeditioners has been extremely positive regarding this specific improvement. There is no doubt it has contributed significantly to smoothing the early stages of community growth once the expeditioners reach Antarctica.

Deputy Station Leaders: Until the 1988 winter expeditions, the role of Deputy Station Leader was an honorary one. The person appointed to this position was selected by the relevant Station Leader sometime on the voyage between Australia and Antarctica. In 1987, procedures were set in train to formalize this role and provide the occupant with an allowance. The selection of Deputy Station Leader is now done by the respective Station Leader during the Community Development and Field Training experience.

The formalization of this role was designed with one main purpose in mind: to provide leadership support to the Station Leader and to move away from the situation of one person being responsible for everything to one in which a management pair is responsible for the personnel management of the base community. The Deputy Station Leader role is part of this process and its main duties are ...

- to assume leadership of the base community in the event of death or injury of the Station Leader,
- to assume leadership of the base community when the Station Leader is off base, e.g. out on an ice-traverse, and
- to support and work in cooperation with the Station Leader in the personnel management of the community members.

There is no doubt that the formalization of this pair relationship has made the lot of a Station Leader much easier, and has led to a more cohesive management of the communities. But there are still difficulties with it. Most significant of these is that the Station Leaders tend to select as deputies people who share similar characteristics to themselves - this leads to a comfortable existence, but not necessarily the most effective leadership combination. The Division does not, as an organization, have as much influence as it might in this selection process and consequently cannot influence the selection to ensure complementarity. Plans are currently underway to remedy this deficiency.

Leadership Skills Training: Once the Deputy Station Leader has been selected and following the Community Development and Field Training, the Station Leader and Deputy undergo a program of leadership training and development.

The overall goal of experience was to ...

> *develop a skilled, knowledgeable Station Leadership pair to improve the quality of base life, effectiveness and efficiency of overall operations.*

The training experience was intended to provide skills, knowledge and strategies for the Station Leader and Deputy and covers such things as ...

- role clarification
- relationship building and conflict resolution strategies
- social system development strategies
- interpersonal styles and their management
- counselling and appraisal systems
- personnel policies and procedures
- counselling skills

The original intention behind this program element has been diluted over time. It was hoped this training would weld them into a working pair and provide them with the relevant skills and knowledge to work effectively as managers of people. The first program was four days in duration and held in 1987. Unfortunately, logistical and organizational difficulties combined with a drop in focus by those responsible for this element has resulted in a gradual diminishment of both its duration and its effectiveness.

Management Phase

The two most visible interventions into the management phase of have been the establishment of a counselling and appraisal system and the development of the role of Deputy Station Leader (previously described).

Other significant interventions have included ...

- changing names of key roles in base communities away from militaristic metaphors,
- establishment of base-specific manager positions in the Antarctic Division
- re-writing of the Station Leader's manual: a set of personnel management guidelines for both Station Leaders and Deputy Station Leaders,
- development of the Station Leader assessment system.

Each of these interventions represents an identified key leverage point in the development of the base's social system and, ultimately, its culture.

Expeditioner Development And Assessment Scheme (EDAS): In the past expeditioners had been assessed on their performance over a whole year by a returning Station Leader. The report was a two page document known as a Y-Report, whose sole purpose seemed to be providing the

Division with documentation on which to base (in part) future selection decisions should an expeditioner re-apply for employment. There were a number of difficulties with this database...

- the content of the ratings used was vague and inconsistent,
- some Station Leaders did not complete Y-Reports on their expeditioners,
- in some cases, expeditioners did not know of the existence of the Y-Report,
- expeditioners were not privy to the content of their assessment unless they were familiar with the Australian Public Service personnel management regulations and realized they could obtain access to them, and
- returning Station Leaders tended to report over-favorably on their expeditioners for fear of litigation brought by a disgruntled expeditioner.

The whole reporting process was reviewed, and rather than set out to improve the existing system, a new system was developed against the following criteria:- It needed to be an open just, fair and equitable as a system which was consistent with existing Australian Public Service personnel practices without replacing or contradicting them. It also needed to provide for regular counselling sessions between Station Leader and each expeditioner, and reflect the realities of community living on an Antarctic base. Finally, it needed to reflect the best principles from both public and private sector current personnel practice.

The EDAS system was developed over a period of twelve months in 1986 and 1987 by employees of the Division following a process of consultation and decision-making supervised by a consultant. It reflects items of concern deemed critical by former expeditioners and Station Leaders in making judgements about an expeditioner as a member of an Antarctic community.

Two systems were developed: one for summerers and another for winterers. The winter system is essentially a counselling system at predetermined points in time: just after the last ship leaves about March/April each year, within a month of the winter solstice and just prior to an expeditioner's return to Australia. Expeditioners rank themselves against specified questions; the Station Leader and Deputy do the same. The three people concerned then come together for an interview and discussion about the expeditioner's performance and plan improvements for the period to the next EDAS cycles.

The questions within both summer and winter EDAS cover

- behavior as an individual,
- social interaction and behavior as a member of a community,
- work performance, and
- ANARE-specific items.

With the summerers, there is no self-assessment by an expeditioner and there is no interview, although the expeditioner does receive his/her own copy of the assessment. The summer EDAS system is essentially a simple reporting system.

Research into the correlation of EDAS profiles with psychological profiles developed by the Army Psychology Corps as part of the selection process is currently underway, as is some closely related research by the staff at the University of Tasmania.

According to recent Station Leaders, the EDAS systems is generally well accepted by expeditioners, though the degree and nature of the acceptance may vary considerably. What does seem to be emerging, however, is that the very high importance with which the Division views EDAS is not necessarily shared by all expeditioners - consequently, there is now a need to "sell" the relevance and value of the system much more thoroughly to expeditioners in the preparation phase of their life cycle.

Labels: It became clear that one of the major blocks to improving the overall quality of life for expeditioners in Antarctic communities was the expectations they carried in their minds as to the nature of the relationships among relevant parties. For example, the role of Station Leader is a complex one with at least three key facets: commander in a crisis, manager of people who work together, and leader of a human community. The former term of "Officer-in-Charge" or "oic" contained meanings for only one of these three facets: hence it was changed to the more encompassing "Station Leader". Similar changes were instituted in a few other areas, thus enabling discussion and exploration of the wider dimensions of human interaction in a base community.

Operations Managers: A new role of Station Manager was created within the Divisional structure in Australia. Four of these positions were created and the role's primary function was to minimize duplication of effort and communication regarding each base by the many and varied parts of the Division which support and supervise base operations. Over the time since their inception they have been reduced to two in number and their title changed to that of Operations Manager. It should be said that the initial establishment of the original Station Manager roles was fraught with ambiguity and confusion among the senior ranks of the Division and the initial role occupants. Consequently, the occupants were never really able to fulfill the original intention. The two roles as presently constituted provide a useful coordinative and communication link between the Division and the bases in Antarctica. Above all, they provide a point of direct contact and organizational support for the Station Leaders.

Station Leader Guidelines: In years past Station Leaders were issued with a manual spelling out suggestions as to how they should behave in given situations, and what were certain of their legislated responsibilities, e.g. in regard to environmental protection. They were generally asked to keep the contents of the manual secret and return it to the Division before embarkation. The content contained quaint and unhelpful militaristic metaphors of control inconsistent with the basic idea of developing a cooperative, open and interpersonally competent community. A new set of more flexible guidelines was introduced in 1987, and distributed openly to all Station Leaders and their Deputies. The guidelines are now updated each year as necessary and are based on a more interpersonal, community-oriented, facilitational and problem-solving approach to leadership.

Station Leader Assessment:

In the original study many expeditioners commented on the absence of formal evaluation of a Station Leader's effectiveness. Moreover, the Division had no formal and comprehensive mechanism or record of a Station Leader's efficacy on which to judge applications for re-employment. The measurement of on-going management and leadership effectiveness of Station Leaders in Antarctica posed a major design problem: how do you measure someone's day-to-day management behaviors from a distance of thousands of miles. A search was undertaken for relevant assessment models from varied work and corporate environments and a suitable model identified. At the heart of the system is a process for collecting and storing all relevant information until the Station Leader's return from Antarctica. The information for consideration comes from the following sources:

- EDAS interview and counselling session with relevant immediate superior (Station Manager) just prior to embarkation and covering the period since employment (usually a period of up to 5 months)
- Three-monthly self-assessment by Station Leaders and their Deputies against core competencies
- EDAS review done jointly with Deputy Station Leader as part of the usual EDAS cycle for expeditioners
- Three-monthly base operations review meetings in Divisional headquarters of all Australia-based managers for each base
- Monthly Station Leader status reports
- Monthly base reports from other technical supervisors.

Upon return to Australia each Station Leader is provided with up-to-date copies of this information base, and then goes through a debriefing and formal interview process, after which an assessment report is written on his/her effectiveness as a leader. As with expeditioners, the senior managers who debrief the Station Leader recommend that the person is or is not suitable for re-employment by the Antarctic Division as a Station Leader. Plans are currently underway to provide another element in this system - expeditioner feedback on a Station Leader's effectiveness

Return To Australia

There is some anecdotal evidence to suggest that many returning expeditioners experience serious distress and difficulties of adjustment upon return to Australia after their winter away. Others suggest that the morbidity of this group may be higher than the norm.

There are stories within the environment of some returned expeditioners who apparently never "recover fully" from the effects of the experience "down south" and the consequences of changes that occur in their home lives during their absence. Just how much credence to give to this anecdotal evidence is uncertain, for there is only one longitudinal study: Palinkas et al (1986) report in a study of 328 US Navy personnel who wintered in Antarctica between 1963 and 1974 that the follow-up disease risk among winter-over personnel was lower than that of the control group. However, the primary measure of such risk was the incidence of all-cause first hospitalizations. Clearly, this is but one measure. We lack any comprehensive longitudinal studies of the effects of an "Antarctic experience" on such things as future marital/relationship stability, suicide rates, non-hospitalizable disease, psychosocial adjustment, career and work patterns, and the like.

On the other hand, returned expeditioners supply a wealth of anecdotal evidence on such matters. Plans are in train to undertake a comprehensive analysis and review of this aspect of the total expeditioner personnel management system, but resource and time constraints have required that the first three elements of selection, preparation and management be attended to first.

In the relevant literature there is a phenomenon which is variously called reverse culture shock or re-entry shock - it describes some predictable stages that people go through. Its manifestations can be from extremely mild hiccups in a person's functioning that might last only a few days and then be gone, through to reactions which can be quite severe and disabling. It shares some commonalities with what has been known for about 30 years as culture shock. The manifestations of this shock process seem to be the same no matter what groups we are considered. It is now clear that returning expeditioners do go through this well-documented and well-understood process and plans are now in train to institute systems which will make their transition back into Australian life a little easier.

We now turn to the impact, to date, of some of these interventions and the issues which they raise.

Impacts and Issues

When we embarked on this journey, the initial diagnosis led us to assume we could improve the morale, performance and quality of life of base communities by intervening primarily in the selection and preparation phases of their human resource management system. We also assumed, that the psychological "lot" of the returning expeditioner would also be improved thereby.

However, we soon began to realize that, not only selection and preparation, but management and return of expeditioners were equally critical if the long-term performance and quality of life on the bases was to improve.

The usual problem-solving approach to improving organizational practices and procedures became inappropriate for there are no models which can adequately account for the range and diversity of independent variables and the observed data. Consequently we set out to construct social systems into which new and returning expeditioners would move. We also set out to provide for a wider set of perspectives and energies to be given voice in Australia's Antarctic life and to diminish the negative impact of some of the more extreme sub-cultural elements.

We then began to experience the potency and complexity of the cultural elements, and the intensity of defence driven by deep archetypal energy. Trying to change practices and procedures became subsumed into the larger task of a fundamental re-arrangement of the purposes and directions and, ultimately, the sense of identity and unity surrounding the Antarctic experience for Australian expeditioners. (Dalmau, Dick & Boas, 1988). The task is by no means complete: cultural interventions are long-term, complex, and problematic. But it is possible to take a partial stocktake...what then has been the impact to date of these initiatives?

In overall terms, the human resource management system of Australian expeditioners has undergone significant enhancement and is now on par with the type and style of systems used in the Australian public sector and the private corporate world.

The bases in Antarctica are far more physically comfortable than 6 or 7 years ago. The availability of instant voice and data connections to loved ones and colleagues means the average Australian community in Antarctica is very much an "open system". (It is perhaps ironic that 6 years ago expeditioners complained,about the time taken for a telex to get to loved ones; they now seem concerned about the quality of the voice on the phone line or the quality of the sound signal on the television transmission!). These changes have led to a much higher set of lifestyle expectations for the average expeditioner down south, and this will no doubt have a major future impact on the efficiency and safety of field operations.

The increased ease of communication has meant that headquarters staff are far more intrusive into community life - expeditioners, thus come much more directly under the day-to-day influence of headquarters-based personnel and even senior government officials in Canberra. Given the diversity of cultures and perspectives among the groups within headquarters, it is not surprising that expeditioners in Antarctica experience mixed, and often contradictory, messages about their management and welfare. This seems particularly the case for Station Leaders whose role separation from expeditioners seems to be increasing as they take on, more and more, the mantle of being a manager.

The level and complexity of human behavior understanding in the minds of those headquarters managers directly supervising land operations from Australia has increased dramatically over the last 6 years. This has led to a much more sophisticated and responsive stance to people management problems as they occur in Antarctica. Unfortunately, this has not been matched among all management staff within the organization.

The frequency of strange and bizarre behavior in the Antarctic communities compared with Australian community norms has decreased overall. The Antarctic Division is clearly much better at selecting suitable people to live and work in Antarctica. This doesn't prevent the odd and very visible incident occurring; unfortunately, these tend to still generate as much attention as before. The problem of alcohol-related behavior problems in the communities does not seem to have decreased, and it is now clear that some other approach to this issue is required.

Moreover, quite a few of the behavioral problems now seem to be located most in either of two groups - the ACS group or the summer scientists. The Antarctic Division has little or no control over the selection of ACS personnel and many in management positions within the organization believe there is room for improving the selection of people to this group thereby decreasing the frequency of "false positives". Whether this is a valid cause-effect analysis remains to be seen - the problem may be more to do with the selection of those appointed to supervisory positions within the ACS groups in the Antarctic communities.

In terms of the summer scientists .... when the changes were first introduced six years ago, all expeditioners who would be in community or on ship for more than 6 weeks were required to undergo psychological screening. Under pressure from the scientists group, this has been extended to 12weeks. Consequently, the Division does not psychologically screen quite a large number of personnel who can be in community for a significant period of time - certainly long enough to have a major effect for good or ill on others. There is some anecdotal evidence to suggest this group may also be subject to more injuries and accidents than others. Most Station Leaders privately report some members of this group regularly pose significant management difficulties in terms of their impact on community. At the present period, it seems the organization has struck an equilibrium point which satisfies the needs of the scientist group on this issue, possibly at the expense of the larger community.

In Australia there has been a major increase over the last decade in the level of general community awareness regarding sexual harassment. This issue is now manifest in the Australian Antarctic communities and represents a new point of cultural inter-group tension: between the Apollo of the organization and the Eros/Ares drive within many in the communities. There is no doubt there will be increasing and significant shifts in acceptable standards in this area as the changes in Australian society are reflected in Antarctic life - hopefully, these will occur before some expeditioner feels obliged to seek redress through litigation.

The changes made to the preparation of expeditioners whilst still within Australia have received wide acceptance. They lead directly to the forming of "groupness" under very favorable conditions. The communities now have a much greater ability to *contain* the various groups (i.e. cultures) within them at a much earlier stage than previously.

In terms of EDAS providing a vehicle for the evaluation and development of expeditioners whilst in community, the results seem to have been mixed. Most Station Leaders report that with a few winter expeditioners, the first EDAS interview does provide them with a behavioral lever with which to influence subsequent behavior. About 60% of the expeditioners seem to accept the EDAS system for what it is, but about another 30% seem to harbor grave misgivings about its relevance and inherent validity. In any community, it seems a very few expeditioners are overtly hostile and uncooperative regarding the system. From headquarters point of view, it represents a major achievement and improvement on the previous invalid reporting system.

The EDAS system has provided the organization with the hard data needed on a few occasions when it was necessary to refuse re-employment to an applicant expeditioner whose service had proved unsatisfactory in the past whilst, at the same time, meeting stringent Australian Public Service requirements of administrative justice and fairness.

These decisions not to re-employ quickly find their way into the informal networks of the returning expeditioners and most now realize that a satisfactory EDAS experience is a pre-requisite to future employment. Similarly, the decision to give two Station Leaders unsatisfactory assessments which bar them from future re-employment has struck a loud and clear not of intent throughout the ANARE culture.

This has been reinforced by the recent rejection of some ex-Station Leaders who re-applied for employment on the grounds that their style and competencies were not appropriate to more recent management requirements of the Division. The selection of Station Leaders has been refined significantly over the last six years and the calibre of final applicants has been consequently enhanced.

Nevertheless, there is clearly a cultural chasm between the Hephaestos, Ares, Dionysus and Eros of many expeditioners on the one hand, and the Apollo and Prometheus of the Division's executive on the other. Most (but not all) of the expeditioners simply do not come from an assessment culture. For a few the only assessment they receive is the sack. They come from a non-literate-based, non-verbal and non-reflective culture. Yet the management and staff of the Division pay close attention to the written and spoken word in determining who may and may not become or return as an expeditioner. It seems the organization may well need to devote more focus and energy into selling the value of EDAS in future years in order to increase its acceptance rate well above the 60% mark.

Most of the changes instituted since late 1986 were established in the period to 1988. The period since then has been one primarily of refinement and improvement. It may well be that the time is now opportune to undertake a major review of these changes and build on the work done to date.

Tim Dalmau
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Oil Spill Prevention and Response

by

Jack Sayers

Australian Antarctic Division

ABSTRACT

In 1990 the Council of Managers of National Antarctic Programs (COMNAP) requested its Standing Committee on Antarctic Logistics and Operations (SCALOP) to develop policies and procedures on oil spill prevention and response in the Antarctic. A Sub-group on Oil Spill Prevention and Response was established to undertake the task.

This paper outlines the principal recommendations developed by the Sub-group during the last two years. The measures recommended include procedures on oil storage, oil transfer and contingency planning, as well as proposals on other relevant matters including the minimum experience required of ships navigation officers, hydrography, and the use of non-persistent fuels.

INTRODUCTION

The need to adopt measures to protect the Antarctic environment from marine pollution is a requirement of several Antarctic Treaty Consultative Meeting (ATCM) Recommendations. Furthermore Annex IV of the "Protocol on Environmental Protection to the Antarctic Treaty" also specifies a range of measures directed towards marine pollution prevention and response.

At the June 1990 Meeting in Sao Paulo, COMNAP requested SCALOP develop a course of action to guide national operators in the implementation of measures to prevent oil spills and to provide guidelines for the preparation of contingency response plans. A SCALOP Sub-group on Oil Spill Prevention and Response was formed with representatives from Australia, Canada, Germany, Norway, South Africa, United Kingdom and the United States of America.

SUB-GROUP RECOMMENDATIONS

During the last two years the SCALOP Sub-group on Oil Spill Prevention and Response has developed a number of recommendations on measures to prevent and combat oil spill pollution. The recommendations will be considered at the 1992 Bariloche Meetings of SCALOP and COMNAP. Particular emphasis has been placed on measures which will prevent or minimise the risk of oil spills in Antarctica. In addition, comprehensive guidelines on the preparation of oil spill contingency plans have also been prepared. The key recommendations of the Sub-group cover the following topics:

- Navigation Experience of Ships' Officers;
- Use of Non-persistent Fuels;
- Shipboard Contingency Plans;

- Hydrographic Charts;
- Oil Transfer at Stations and Bases;
- Oil Storage at Stations and Bases; and
- Contingency Plans for Stations and Bases.

Navigation Experience of Ships' Officers

The seas surrounding Antarctica are among the most inhospitable in the world. Even during mid-summer violent storms can occur with little warning and even the largest of vessels can be threatened by besetment in heavy pack ice.

Because of the unique environmental hazards encountered by Antarctic shipping it is essential that there are officers on board the vessel who have wide experience and knowledge of Antarctic meteorology, ice conditions, tides and currents in the intended region of operation.

It is worthy of note that the Chile maritime authorities have recently established a School of Antarctic Navigation which offers a three week intensive course providing tuition in the following topics:

- Antarctic Meteorology
- Maritime Administration
- Antarctic Legislation
- Antarctic Treaty
- Tides and Currents in the Antarctic
- Antarctic Environment
- Antarctic Pilotage.

The Chilean authorities now require that any Chilean merchant ship bound for Antarctica must be under the command of a master who has completed this course.

At the present time national Antarctic operators use a variety of policy standards for the navigation experience of deck officers. The SCALOP Sub-group has recommended that members of COMNAP adopt a minimum standard as follows:

> *"Masters and/or Chief Officers of vessels operating under charter or in support of Antarctic operations shall have at least one season of ice navigation experience in the Antarctic. Where there is any concern in this regard an ice pilot should be engaged."*

Use of Non-persistent Fuels

The definition of non-persistent oil is open to debate. Oils which may be considered non-persistent in moderate climates may become persistent oils at Antarctic temperatures.

The International Oil Pollution Compensation Fund describes non-persistent oil as "oil which, at the time of shipment, consists predominantly of non-residual fractions and of which more than 50% by volume distils at a temperature of 340°C when tested by the ASTM Method D86/78 or any subsequent revision thereof".

All national Antarctic operators use light diesel fuels or jet fuels for power generation at stations and bases. A number of Antarctic re-supply vessels use medium/heavy fuel oils although the use of these oils appears to be decreasing as newer vessels are brought into service. The degree of threat of severe marine pollution can be reduced by the application of voluntary restrictions on the type of oil that is used whenever feasible.

Standardisation on the use of lighter, non-persistent fuels by national operators would also facilitate standardisation of oil spill response equipment. The wider the availability of standard response equipment, the greater the potential to respond effectively to oil spill incidents and hence limit the environmental damage that might arise.

Accordingly, the SCALOP Sub-group has recommended that members of COMNAP agree:

> "i) *to the use of light, non-persistent fuels in the Antarctic Treaty area whenever practicable and possible; and*
>
> ii) *specify engines using light diesel fuel for the construction of new vessels intended for service in Antarctica."*

Shipboard Contingency Plans

The *Exxon Valdez* disaster highlighted the need to develop a global network to co-ordinate pollution response resources. In 1990 the International Maritime Organisation (IMO) promulgated an International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC) to complement existing IMO conventions relating to marine pollution. The OPCR Convention requires, in part, that vessels shall carry shipboard oil pollution emergency plans. The OPCR Convention also includes provisions for signatories to assess the consequences of marine oil spills and report the incident to States whose interests are likely to be affected. The requirement for vessels to carry shipboard oil pollution emergency plans has been incorporated in Annex IV of the "Protocol on Environmental Protection to the Antarctic Treaty".

The SCALOP Sub-group has therefore recommended that members of COMNAP adopt the following measures, based on Articles 3 and 5 of the OPCR Convention, 1990:

> "i) *ensure that any vessel operating under charter or in support of their Antarctic operations has on board a shipboard oil pollution emergency plan, such plans to be in place by 31 March 1995 (or sooner if required by national legislation);*
>
> ii) *assess the nature, extent and possible consequences of oil pollution incidents and, without delay, inform all operators whose interests are affected or likely to be affected by such oil pollution incidents;*
>
> *and, in addition*
>
> iii) *immediately report all serious Antarctic oil pollution incidents, whether from ships or onshore, through the COMNAP/SCALOP Secretariat for advice to all COMNAP/SCALOP members."*

Hydrographic Charts

The safety of Antarctic vessels, and hence the avoidance of marine accidents and associated oil spills, depends heavily on the availability of accurate and up-to-date hydrographic charts. At the 1989 Paris ATCM, Recommendation XV-19 proposed that Treaty Parties recommend to their Governments that:

- They increase their mutual cooperation in the hydrographic survey and charting of Antarctic waters in order to contribute to the safety of navigation, the protection of the Antarctic environment and dependent and associated ecosystems, and for scientific purposes; and

- For the purposes of hydrographic survey and charting and associated terrestrial surveys and mapping, they co-ordinate their activities within the framework of IMO and SCAR, as appropriate.

SCALOP is currently collecting data on marine incidents and hydrographic charting priorities from national operators. Consistent with the requirements of ATCM Recommendation XV-19, the SCALOP Sub-group has recommended that members of COMNAP:

> "i) *identify areas of greatest need for the preparation of accurate hydrographic charts;*
>
> ii) *co-ordinate with their respective national hydrographic agencies and the International Hydrographic Organisation for the preparation of such charts; and*
>
> iii) *ensure that the Masters of vessels supporting their program have the best available charts for use."*

Oil Transfer at Stations and Bases

The design of station facilities, the means by which fuel stocks are replenished, and the resources available to accomplish the replenishment or transfer of fuel stocks vary between national operators. A number of operators have experienced fuel spills during fuel transfer operations which have typically resulted from human error or equipment failure.

The SCALOP Sub-group has developed a document on "Recommended Procedures for Fuel Oil Transfer at Stations and Bases (see Annex A). The procedures cover the documentation, training, operations, inspection and maintenance of fuel transfer activities. The Sub-group has recommended that COMNAP implement the procedures as soon as practicable.

Oil Storage at Stations and Bases

Large quantities of fuel oils are stored at Antarctic stations and bases to facilitate power generation, aircraft operations and the running of plant and equipment. The failure or damage of fuel storage facilities and reticulation systems can result in major fuel spills.

The SCALOP Sub-group has developed a document on "Recommendations for Spill Prevention and Containment of Fuel Oil at Stations and Bases" (see Annex B) which outlines measures for spillage prevention, containment, detection, alert and recovery. The Sub-group has recommended that members of COMNAP implement the proposed measures as soon as practicable.

Contingency Plans for Stations and Bases

The development of contingency plans is fundamental to effective response action in the event of oil spill incidents at stations and bases. Such plans need to describe environmentally sensitive areas and assess the possible spill scenarios. In addition the plans need to articulate in clear and concise terms the operational response activities in the event of an oil spill incident.

The SCALOP Sub-group has developed a document on "Guidelines for Contingency Planning" which defines the recommended format and information to be contained in contingency plans for stations and bases (see Annex C). The contingency planning approach is based on Facility Level (that is a station or base) and Multi-Operator plans. Multi-Operator plans are to be developed where a coordinated response by two or more national operators is feasible. This will be in situations where a logistical capability exists to facilitate the transfer of response equipment between operators in the event of an incident and it is economic to pool resources.

The SCALOP Sub-group has recommended that members of COMNAP adopt the "Guidelines for Contingency Planning" and develop Facility Contingency Plans, at least to draft stage, by 31 December 1992.

ACKNOWLEDGMENTS

During the last two years the SCALOP Sub-group has collected a substantial library of reference material including papers, reports, textbooks and other publications on oil spill pollution and response with particular reference to cold regions. This information has proved to be invaluable in developing policies and procedures.

The Sub-group has also been fortunate to have national experts on marine pollution attend meetings which were convened in Washington DC during May 1991 and April 1992. In addition, several Sub-group members have sought advice on particular matters from marine safety experts in their respective countries. More recently the Sub-group has commenced liaison with key members of the Marine Environmental Protection Committee (MEPC) of the IMO. The Sub-group wishes to acknowledge with appreciation the considerable help it has received.

RECOMMENDED PROCEDURES FOR FUEL OIL TRANSFER AT STATIONS AND BASES

1. INTRODUCTION

1.1 The transfer of fuel oils from resupply vessels to shore based storage facilities, and between individual storage facilities on stations or bases, are potentially hazardous operations. It is incumbent on national Antarctic operators to ensure that procedures are in place, and are implemented, to minimise the risk of oil spillage and environmental pollution during such fuel transfer operations.

1.2 The procedures outlined in this document cover the documentation, operation, inspection and maintenance of fuel transfer facilities and the training requirements for operational staff. Individual national Antarctic operators may deem it necessary to supplement these minimum requirements to satisfy national standards, or to meet specific operational needs.

2. PROCEDURES

Documentation

2.1 Personnel who are responsible for, or are required to undertake, fuel oil transfer operations are to be provided with clear and comprehensive documentation prescribing the procedures to be followed, and precautions to be observed, in conducting fuel transfer operations.

2.2 The documentation is to include up-to-date layout drawings or diagrams indicating storage tanks, reticulation systems, pumps, valves and safety devices.

2.3 All tanks, valves and pumps are to be allocated unique identity numbers which are to appear on the layout drawings and in a prominent place on installed equipment. The written procedures are to make reference to the identity numbers.

Training

2.4 All personnel who are responsible for, or required to undertake, fuel oil transfer operations are to receive instruction or training in the operation of the equipment, spillage prevention and other measures.

2.5 The above personnel will also receive training on oil spill contingency planning procedures and duties.

Operations

2.6 Fuel transfer equipment must be inspected for serviceability prior to the commencement of pumping operations.

2.7 Except during fuel transfer operations, all isolation valves on storage tanks are to be closed.

2.8 When transferring fuel oil between ships and shore facilities or fuel farms and remote holding tanks (eg at power houses), personnel must be stationed at both locations to monitor the transfer operation and must also maintain regular contact via VHF radio or similar. The fuel transfer pipes must be monitored for leaks during transfer operations.

2.9 During fuel transfer operations only one tank shall be active (ie valve open) except at the overlap period when switching from the access tank to the next tank. Such operations must be continuously monitored.

2.10 All personnel responsible for, and associated with, fuel transfer operations are to take whatever action is deemed appropriate to minimise and avoid the risk of fuel spills.

2.11 If personnel have any doubts about the adequacy of existing procedures and systems, these must be brought to the immediate attention of the responsible authority.

2.12 Records of all fuel transfers and spillages shall be maintained by personnel on site and the national operating authority.

Inspection

2.13 All fuel storage tanks are to be visibly inspected on a weekly basis, and as soon as possible following adverse weather, to check the integrity of the storage systems and associated plumbing. In addition, all storage tanks are to be checked monthly to verify contents.

2.14 Bulk storage tanks shall be thoroughly inspected on an annual basis. A record of these inspections, including the internal cleaning of tanks, shall be maintained at the station.

Maintenance

2.15 All pumps, valves and associated equipment are to be maintained in good working order.

2.16 Any defective fixtures or fittings shall be replaced or repaired as soon as is practicable.

RECOMMENDATIONS FOR SPILL PREVENTION AND CONTAINMENT OF FUEL OIL AT STATIONS AND BASES

1. INTRODUCTION

1.1 Fuel oils are used at Antarctic stations and bases for a variety of operational needs including power generation and the fuelling of vehicles and aircraft. The spillage of fuel oils as a result of equipment failure, accidental damage or human error poses a potential environmental threat. It is therefore incumbent on national Antarctic operators to design, install and operate fuel oil storage facilities to minimise such risks.

1.2 The design recommendations outlined in this document are intended to minimise the possibilities of fuel spillage to the environment. The recommendations apply to new and, where practicable, existing installations. The design philosophy incorporates:

- spillage prevention;
- spillage containment;
- spillage detection;
- spillage alert; and
- spillage recovery.

2. DESIGN RECOMMENDATIONS

Spillage Prevention

2.1 Installations shall be sited and designed to minimise the deleterious effects of the environment, such as from ice build-up on valves and fittings.

2.2 Installations shall be sited to minimise damage from operational activities such as heavy vehicular traffic and where this is not practicable the installation shall be protected by means such as bollards, guards and signs.

2.3 Tanks, valves and fittings shall be of first grade materials, suitable for petroleum products and site specific climatic conditions.

2.4 Lever operated ball valves shall preferably be used which give clear visual indication of the "open" and "shut" positions.

2.5 Manufacture, fabrication and site construction of facilities shall be inspected, tested beyond application conditions if possible, and approved for use by a competent authority.

2.6 The installation shall avoid undue complexity so as to reduce the risk of human error through confusion or misunderstanding.

2.7 Tanks shall be piped for top fill and top draw off.

2.8 All tanks shall be numbered and have the maximum capacity clearly marked. All valves shall be tagged or numbered to facilitate clear and unambiguous description in operating procedures.

2.9 Adjacent tanks shall be fitted with overflow equalising connections between them, where practicable.

2.10 Tanks shall have calibrated dip-sticks, continuous level monitoring gauges, or other means of assessing the quantity of fuel stored.

2.11 Fuel pumps for bulk handling shall have a lockable switch or other appropriate mechanism to prevent accidental pumping.

2.12 The delivery pump shall have an emergency stop switch or other appropriate mechanism located in a prominent, accessible position. Alternatively, a master valve shall be fitted immediately downstream of the pump to facilitate emergency shutdown.

Spillage Containment

2.13 The containment facility shall have the capacity to contain the contents of at least the largest tank should a spill occur plus an allowance for snow, ice or water accumulation.

2.14 Containment may take various forms including, for example:

(i) bunding around the installation or around individual tanks;
(ii) remote bunding with interconnecting drainage from the tank installation;
(iii) double skin tanks, horizontal or vertical, with the outer skin being the containment; or
(iv) flexible bladders within a containment structure.

Spillage Detection

2.15 Installations shall have, where practicable, sensors to detect fuel spillage. This may be in the form of electronic fuel sensors fitted in appropriate locations; for example, between the walls of double skin tanks or in the sump of the containment structure. Low level sensors in tanks may serve to indicate loss from a tank.

Spillage Alert

2.16 Audible and/or visual alarms shall be installed in locations which are frequented regularly, or are obvious during fuel transfer operations.

2.17 All bulk storages shall, where practicable, have a high level alarm which is audible and/or visible to an operator. Such alarms shall signify a potential overflow before the tank reaches capacity.

Spillage Recovery

2.18 Installations shall have the capacity to store any recovered fuel up to quantities at least matching the capacity of the largest tank. This provision may be met by additional storage capacity such as a spare tank, or by underfilling tanks to provide the reserve storage by transfer pumping.

GUIDELINES FOR OIL SPILL CONTINGENCY PLANNING

1. INTRODUCTION

1.1 The need to develop and implement measures to alleviate and combat the pollution of Antarctic waters has been the subject of several Recommendations adopted at Antarctic Treaty Consultative Meetings (ATCMs) in recent years. At the 1989 ATCM, Recommendation XV-4 specifically called on the Governments of Treaty Parties to establish contingency plans for marine pollution response in Antarctica, including plans for vessels carrying oil.

1.2 The need to develop contingency plans for response to marine pollution incidents is also a requirement of Annex IV of the "Protocol to the Antarctic Treaty on Environmental Protection".

1.3 This COMNAP document defines a recommended format and specifies the information to be included in oil spill contingency plans which are to be prepared by national antarctic operators for facilities or larger geographic areas in Antarctica.

2. TIERED APPROACH TO CONTINGENCY PLANNING

2.1 Most oil spills in Antarctica are likely to be small and confined to a station or base and the adjoining waters. In the event that the spill is beyond the station or base capability, or is likely to affect a larger area, an enhanced response may be necessary involving support from other national operators.

2.2 This tiered response to oil spill incidents requires the development of compatible contingency plans for individual facilities and, where appropriate, contingency plans for larger geographic areas encompassing a number of operators, as defined below:

- **Facility Plans**

  These are to be developed for individual stations or bases and their local environs, where appropriate. The plans will be prepared by individual national operators responsible for the management of a specific facility.

- **Multi-Operator Plans**

  These are to be developed to encompass a geographic area where a coordinated and compatible response by two or more national operators is feasible. This will apply where it is effective and feasible to pool and deploy response equipment and supplies.

3. FORMAT OF PLANS

3.1 The recommended format for Facility and Multi-operator contingency plans is given in the Appendix. The plans are to be divided into two parts plus annexes as follows:

Part I: Strategic Information
This is a descriptive policy document providing background information including a description of the facility and an evaluation of oil spill scenarios.

Part II : Operational Response
This describes the recommended procedures for the development of an operational response to oil spills. The format of the Operational Plan corresponds to the expected chronological order of events. The text of this document should be supplemented, to the maximum extent, with decision tree diagrams or checklists to simplify and speed interpretation. In particular the Operational Plan, Chapter 6, shall be in the form of tree diagrams or checklists.

Annexes
These include detailed reference information relating to specific aspects of the contingency plans, eg Communications, Health and Safety, Training, etc.

3.2 It is recommended that all national operators adopt the formats specified in this document. This will enable the plans to be easily understood and assist with the integration and compatibility of the facility plans with multi-operator plans, where applicable. Plans should be complete in themselves and not involve reference to other supporting documents which may cause delays. Plans should preferably be produced in loose leaf form to facilitate regular update.

4. PLAN EFFECTIVENESS

4.1 The International Tanker Owners Pollution Federation consider that the adequacy of contingency plans may be assessed against the following ten questions:

(1) Has there been a realistic assessment of the nature and size of the possible threat, and of the resources most at risk, bearing in mind the probable movement of any oil spilled?

(2) Have priorities for protection been agreed, taking into account the viability of the various protection and clean-up options?

(3) Has a strategy for protecting and cleaning the various areas been agreed and clearly explained?

(4) Has the necessary organisation been outlined and the responsibilities of all those involved been clearly stated with no 'grey areas' - will all who have a task to perform be aware of what is expected of them?

(5) Are the levels of equipment, materials and manpower sufficient to deal with the anticipated size of spill. If not, have back-up resources been identified and, where necessary, have mechanisms for obtaining their release and entry to the country been established?

(6) Have temporary storage sites and final disposal routes for collected oil and debris been identified?

(7) Are the alerting and initial evaluation procedures fully explained as well as arrangements for continual review of the progress and effectiveness of the clean-up operation?

(8) Have the arrangements for ensuring effective communication between shore, sea and air been described?

(9) Have all aspects of the plan been tested and nothing significant found lacking?

(10) Is the plan compatible with plans for adjacent areas and other activities?

APPENDIX

Format of Title Page

*FACILITY CONTINGENCY PLAN
OR
*MULTI-OPERATOR CONTINGENCY PLAN
FOR
#NAME OF FACILITY OR MULTI-OPERATOR AREA

Council of
Managers of National Antarctic Programs

ØDate

*Choose titles according to plan type.
#State name of facility or multi-operator area.
ØDate of plan

CONTENTS

Facility Plan

Multi-Operator Plan

Facility Plan

7 WASTE DISPOSAL
- 7.1 Storage of Waste
- 7.2 Disposal of Waste

8 DEMOBILISATION
- 8.1 Personnel Decontamination
- 8.2 Equipment Decontamination/ Maintenance

9 POST SPILL MONITORING

10 REPORTING

Multi-Operator Plan

7 WASTE DISPOSAL
- 7.1 Storage of Waste
- 7.2 Disposal of Waste

8 DEMOBILISATION
- 8.1 Personnel Decontamination
- 8.2 Equipment Decontamination/ Maintenance

9 POST SPILL MONITORING

10 REPORTING

ANNEXES

ANNEX A : FACILITY AREA MAP (OR AREA MAP)
ANNEX B : SPILL RISK ASSESSMENT MAP
ANNEX C : COMMUNICATION PLAN
ANNEX D : RESPONSE TEAM ORGANISATION
ANNEX E : RESPONSE EQUIPMENT AND MATERIALS
ANNEX F : HEALTH AND SAFETY PLAN
ANNEX G : TRAINING PLAN
ANNEX H : PUBLIC RELATIONS/MEDIA PLAN
ANNEX J : COST ACCOUNTING PLAN
ANNEX K : DOCUMENTATION PLAN
ANNEX L : DISPERSANT USE
ANNEX M : IN-SITU BURNING
ANNEX N : BIOREMEDIATION USE
ANNEX P : BIRD AND MAMMAL CLEANING
ANNEX Q : EQUIPMENT AND PERSONNEL CLEANING
ANNEX R : DEFINITIONS AND ABBREVIATIONS
ANNEX S : COMMUNICATIONS CONTACT NUMBERS

Project Construction and Operations of the Tanks for the Fuel Storage in Terra Nova Bay, Description of the First Refuelling Operation

by

Roberto Buccolini, Antonio Cucinotta, ENEA-Antarctic Project Italy and
Giovanni Caligiuri, SNAMPROGETTI, Italy

In order to carry out the transfer and storage of fuel oil in the maximum conditions of safety for persons, environment and installations, the Italian Antarctic Project has:

* adopted national and international rules, as well as recommendations issued by organisms under the Antarctic Treaty. In particular, reference was made to the COMNAP Procedures n. 101 and 102 prepared under the direction of the SCALOP; these documents have contributed considerably to the preparation of the operating plan, for safety and emergencies in the refuelling operation.

* referred to the experiences obtained on installations and systems of other international agencies operating in polar areas;

* executed a market research in general, giving priority to the quality of the product to be employed.

1. Introduction

The executive Programma of the VII Expedition planned the supply of 920,000 lts of JP-8 (avio kerosene) to the antarctic base at Terra Nova Bay during the '91-'92 summer campaign.
The supply to the base took place on the 18/1/92 with the transfer of fuel oil from the USA tanker to two storage tanks which were placed at 44 mts above sea level.
At termination of the refuelling operation and after having cleaned the pipelines with the "PIG" system, the transfer and storage system was placed in safe conservation.

2. Background

Until the VI expedition ('90-'91), the supply and storage of fuel (arctic gas oil, avio kerosene) for the base involved a series of operations, like:

- the transportation of fuel in drums or containers by cargo ship from New Zealand to Terra Nova Bay;
- the discharge of the fuel from the cargo vessel moored on the pack and its transport to the base by sleds and snow trucks;
- the storage in drums, tank containers and collapsible tanks in clearly identified areas of the base.

The complexity and operative inconveniences of this system and the yearly needs of fuel, have lead the Italian Antarctic Project to look for another way more rapid, more secure and economical.

3. Terra Nova Bay Station

Fig.1 shows the planimetry of the area where the Italian base is situated; it lies on a peninsula along the coast of the Northern Foothills, between the Campbell and Drygalski glaciers, in Terra Nova Bay (Ross Sea, Victoria Land) from which the Base takes its name; the coordinates of the base are: Lat. 74° 41'42" S.; Long. 164°07'23" E.

3.1. Operating Area

The planimetry (Fig. 2) shows the area of interest to us where the two tanks for the storage of fuel (avio kerosene) are situated as well as the area of the refuelling operations, this area stretches from the tanks towards the beach of Tethys Bay, accessible by an earthbeaten track, and which allows the installation of the equipment for the operations. From the bathymetry it will be noted that starting from the beach the soundings grows rapidly reaching a depth of 30 mts at a distance of 150 mts.
As far as the sea area involved in the refuelling operations is concerned, it must be said that this could either be free or covered with sea ice; in our case we assumed that the operations had to take place in the presence of sea ice.

4. Operating system

Before opting for the present configuration of the transfer and fuel storage system, the Antarctic Project made an analysis and a comparison of the main alternatives taking into account as the most important discriminating factors the environmental impact, the safety, the duration of the operations and the reliability of the system.
The principal sub-systems that form the operative system are

- storage system
- transfer system
- cleaning system
- safety system

As project data for these systems the following points have been adopted:
a) the mooring of the tanker to the sea ice of Tethys Bay;
b) the discharge of the fuel from the tanker to the storage tanks with about 1000 mts of hose-line;
c) the quantity of fuel to be discharged: 1,200,000 lts of JP-8.
This quantity, deduced from the average consumptions of the past summer antarctic campaigns, should guarantee an autonomy of four years for the Base.

4.1. Storage system

In order to meet with the fuel needs and with a view to eliminate the existing storage in drums, containers and collapsible tanks, the present storage system has been realised, which consists of two vertical tanks with a double shell with a capacity of 600 cu.m. each; Table 1 shows the characteristics of this tank.
Each tank, planned to contain JP-8 at atmospheric pressure,

consists of an inner container without roof and an outer container complete with a fixed roof and not insulated; all in carbon steel with resilience tested at -50°C.
The tanks are fitted with plugs:

- for pipes of discharge (4"), of load (3") and drainage (3") of product;
- for pipes of foam flows;
- for instruments, which will be fitted in a successive stage of the project when the operative procedures of control and conduct of the storage will be defined.

The tanks will be fitted with manholes (24") on the inner shell, on the outer one and on the roof.

4.1.1. Project and controls

The storage system has been planned and built in accordance with the API-650 rules and taking into account the recommendations existing with respect to the antarctic area.
In order to minimize the risk of fuel spill in the surrounding area, it was decided to adopt the double containment which allows the collection in the interspace of potential fuel spills from the inner container.
The fabrication of the tanks with double shells took place through the following main stages:

I) the execution of a ringshaped foundation in reinforced concrete to contain the inert material on which subsequently a layer of bituminous material was spread (in order to insulate the metal from the ground);

II) the installation of the outer tank and anchorage of the outside shell to the foundation ring as shown in Fig. 3;

III) the construction, inside the base of the outer tank, of a trated;

IV) the installation of the inner tank and the welding of the roof.

During the construction of the tanks, always with a view to minimize the possibility of fuel leaks, non destructive tests were performed on the welds of the shell, the basements and the roof which synthetically comprise; visual checks, radiographic examinations, tests with penetrating liquids, examinations with the vacuum box.
Subsequently the reaction of the storage tanks was studied in case of impact with external missiles that is with objects of variour dimensions and weight which are lifted by the wind and thrown perpendicularly against the shell of the tank.
The formulas utilized were those defined by the Ballistic Research Laboratory and by the Stanford Research Institute; from the outcome of the calculations it results that the specified missiles (steeltube of 3", 3 mts length and a weight of 33,8 Kg and an impact speed of 65,6 ft/sec.; a yard wheel-barrow with a weight of 30 Kg and an impact speed of 196,8 ft/sec) should not be able to perforate the external shell of the tank even on the conservative hypothesis that the target and the missile are rigid.

4.2. Transfer system

The configuration of this system was determined by various considerations, the most important of which are:

- to have a very versatile system considering the positioning of the tanker with respect to the tanks;
- to have a hose-line with a cross section so as to consent not too long transfer times considering the variability of the meteorological conditions;
- to have a hose-line which is not only easy to operate for placement and cleaning, but also easy to maintain and repair if it suffers damage during the transfer operations.

The system mainly consists of:

- 950 mts of reinforced and floating rubber hose-line (Ø=6") for connection of the tanks to the tanker (see Table 2); this hose-line, in four lengths of 35, 315, 350 and 250 mts, is wound on three reels which can be motor driven.

4.3. Cleaning system

Once the hose-line has been defined, the choice of the system, which took also in consideration the possibility of contemporaneous supply of the base of avio kerosene and arctic gasoil, was determined by the convenience and operative rapidity as well the requirements to minimize the loss of fuel in the surroundings.

The system consists of:

- launcher and receiver,
- some polly pigs,
- set of nitrogene bottles,
- air compressor,
- tank container ISO 20.

As can be seen from figs. 4 and 5 launcher and receiver are similar.

4.4. Safety system

It consists of the following material:

- absorbent material,
- extinguishers,
- 6 valves of the "hose clamp" type to throttle the hose-line in case of a rupture emergency,
- 3 fire fighting trucks (twin agent),
- 2 slings and 2 hooks with rapid release (pelican hook type) for eventual mooring of the tanker on land,
- radio receiver/transmitter,
- protective clothing and glasses.

5. Analysis of risks

The possible incidental situation relative to the storage and refuelling system are characterized by fuel release to the environment; the elements which represent the most significant contributions to the release have been identified on the basis of their statistical frequency derived from a storical inquiry and databanks.
The sources of the release have been identified:

- in the seepage from flange connections caused by rupture of the lining due to wear or to construction faults or to a bad fitting,
- in the loss of fuel due to partial or total rupture of the hose-line,
- in the loss from the stub pipes for the connection of the instruments due to construction faults or to impact with objects thrown by the wind.

The probability that these losses occur is very low and anyway the most critical situations are those relative to the loss from the stub pipes and the flanges fixed on the lower part of the outer shell and to the rupture or puncture of the hose-line; these losses have as a main consequence the pollution of the environment.
Among the possible risks also the interruption of the refuelling operations in case of adverse weather conditions was considered.

5.1. Evaluation of impact

The evaluation of impact of the storage system on the environment can synthetically be divided in three stages, which take into account:

I) the installation of the tanks,
II) the ordinary operation,
III) the emergency.

In each of these stages, the impacts contain both the landscape-territory and fauna impacts.
The first stage involves an alteration for a short while and comports a short term type of impact, associated with operations to prepare the site, on the area assigned to the tanks and to prepare their foundations.
The most important activities of the second stage are those relative to the refuelling and to the distribution of the fuel to the users; it is supposed that the possible spills of small quantities of fuel on the soil, is the only aspect to be taken into consideration; this calls upon a rapid intervention of decontamination as the volatility of the hydrocarbon is very low.
The impact on the quality of the soil, the waters and on the fauna in the emergency stage derive from the incidental leak of fuel mentioned before. Considering the possible losses more or less consistent of the product and the fact that the storage tanks are situated at 44 mts above sea level, it can be assumed that when the patch enlarges the fuel will run towards Tethys Bay; thus the pollution of the soil and of that part of the coast near the tanks

represent the most important risk of which the most critical aspect is formed by the complexity of the decontamination operations.
From the evaluation performed results that the construction of the tanks has an environmental impact which, considering the safety parameters adopted, can be considered minimum on the landscape and transitory, if not improbable, on the soil, the sea and the fauna.

6. Safety plan

As mentioned the configuration of reference of the operative system, forsees:

- Tethys Bay covered with sea ice,
- mooring of the tanker at the pack of Tethys Bay,
- connection between storage tanks and tanker with about 1000 mts of hose-line.

The unusual events that can interfere with the ordinary procedure of discharge are:

- the rupture of the primary components, that is of the hose-line and of the storage tanks;
- the emergency caused by a sudden worsening of the weather conditions.

The precautions to be observed make reference to the potential risks to which the transfer of fuel oil can give rise and which have been examined in paragraph 5; next the resources to be assigned (personnel, equipment and means) have been identified and their distribution on the operative areas chosen.
The organisation of the safety plan also envisages two teams with different fields of operation:

- one directed at the safeguarding of the environment and of the equipment,
- one directed at the safety of the persons.

The personnel assigned to the refuelling operations had to follow courses of safety and training, both general and specific as for example on the hydrocarbon fires, on the use of the containment boom and on marine anti-pollution measures.

6.1. Tethys Bay free of pack

In addition to what has been said before the configuration of Tethys Bay has been analyzed as if it would be partially or totally free from pack.
For this second situation, certainly more complex than the first one both from the operational point of view and the one of intervention in case of oil spill, the following equipment has been planned:

- 500 mts of containment boom (see Table 3) to limit the stretch of sea interested in the operation and included between the tanker and the beach,
- material for securing (chains, anchors, buoys, etc.) in enough quantity to anchor the containment boom to the sea bottom every 40-50 mts,

- a vacuum pump with a special aspiration terminal to recover most of the fuel in sea (see Fig. 6),
- absorbent material in polypropylene in three different types (booms, pillows and pads) to recover the fuel left over after the aspiration operation,
- two inflatable boats, one boat of 12 mts and a pontoon for the movement and placement of the hose-line, of the containment boom, of the vacuum pump, of the absorbents and for the checking of the hose-line during the refuelling operations,
- drums to contain the fuel and absorbents recovered.

In order to control the quality of the waters the lowering into the sea of wicker fishing baskets is planned, containing some species of bivalves (Adamussium colbeckii) and fish (for example Pagothenia bernacchii). These in case of oil spill would have furnished the entity of the pollution on the marine fauna after an ecotoxilogical examination to be confronted with the data obtained in previous biological researches.

Moreover sampling of the sea water is planned before and after the operations.

6.2. Response team

The response team is split into two groups: one for emergencies on land and one in sea; moreover, the two groups have the task to check the hose-line during the refuelling operation.

The response group on land (three persons) is to be stationed near the storage tanks which in case of incidents would be the most critical area; the response group on the pack (three persons) is to take position on the beach of Tethys Bay near the tank container.

Both groups were equipped with several vehicles, and firefighting and antipollution materials and equipment.

6.3. First aid team

This team is made up of one doctor and one nurse; the team is stationed in the infirmary as well as in the area of the storage tanks and is equipped with:

- a vehicle for the transportation of injured persons to the infirmary of the Base;
- a first aid kit;
- a sufficient number of woolen blankets, placed in the zones of the storage tanks and the beach, to assist personnel harmed by fire.

6.4. Decontamination of birds and mammals

In case of oil spill one could find oneself having to face the decontamination of birds and mammals.

After having consulted the bibliography existing on this subject and after having consulted some researchers, the following rescue plan was programmed:

- the birds recovered will be left to rest and will be fed; after which they will be washed with a solution of warm water and a non biological detergent (2% concentration), then properly rinsed. After this operation they will be dried with cloths in a heated room until they are completely recovered.
- for the seals the same treatment described above is valid, taking more precautions in the handling of these animals, considering their dimensions.

7. Preliminary operations

These have regarded the operations on land and on the pack.
Before the arrival of the tanker the hose-line on land was laid out (three sections of respectively 35, 350 and 250 mts) and connected to the first of the two tanks (S1); Fig. 7 shows the scheme of the connections.
Before and after the lay out, all single components have been examined, assembled and in each single part, in order to ascertain its integrity, functionality and safety.

7.1. Positioning of the PIG system

The PIG system serves for emptying and cleaning the hose-line once the refuelling operations are completed.
To make it work the polly pig needs a certain number of nitrogen gas bottles or compressed air with the function to push the polly pig from the launcher to the receiver through the hose-line thus cleaning it from residual fuel.
As the cleaning of the hose-line is programmed in two stages, first the one on the pack and then the one on land, the launcher is initially placed on the tanker, while the receiver is placed on the beach of Tethys Bay near the tank container.

7.2. Positioning of the tank container ISO 20 and the relaunching pump

Both the tank container and the relaunching pump were placed on the beach of Tethys Bay near the two 6" valves fitted respectively on the hose-lines on land and at sea.
The tank container served at termination of the refuelling operation for the drainage of the hose-line.
The relaunching pump was also prepared to be inserted in the line in case the pump of the tanker would not have sufficient pressure to transfer the fuel into the storage tanks; it was fitted with opportune connecting points to be attached to the hose-line at sea and to the tank thus functioning as a lung in order to avoid symptoms of cavitation.

7.3. Operations in Tethys Bay in presence of pack

These mainly involved the icebreaker POLAR SEA of the USA Coast Guard.

On its arrival, the icebreaker opened a canal in the pack to enable the tanker to enter Tethys Bay, paying attention to the radius of the curve of the canal was as wide as possible and that, towards land, it did not surpass the 300 mts limit from the beach.

After completing the canal the icebreaker came out in order to allow the tanker to enter ahead and to take the position planned, after which it was moored to the marine pack. At this point the icebreaker placed itself in such a way to be able to tow the tanker out of the canal in case of emergency or at termination of the operation.

7.4. Unwinding of the hose-line on the pack

While the tanker was being moored, a blank flange with eyebolt was fitted on the end flange of the hose-line which was placed on the beach of Tethys Bay.

After having fitted the blank flange and prepared a sling around the hose-line, everything was attached to a snow track in such a way that this could drag the hose-line, without forcing it, until it arrived alongside the tanker, where the operators of the vessel hauled it on board without straining it.

Once on board after having loosened the blank flange, the hose-line was connected to the launcher.

7.5. Placing of the absorbement materials

Absorbing material in polypropylene available in three different versions: booms, pillows and pads, was used.

Said material was placed in the proximity of the penetrations of the storage tanks and along the line in those points with the highest possibility of fuel oil spills.

In particular, one or more pads were placed under every flange and valve and an adequate number of spares nearby; absorbing materials were also placed in the proximity of the launcher, the receiver and the relaunching pump.

8. Operating team

Considering that during the operations the personnel must stay near the spot assigned and maintain a regular contact by VHF radio with the rest of the team, the area interested in the refuelling operation was divided in 5 zones, to which were assigned persons, means and materials like: firefighting (twin agent), tractor, fork lift, portable extinguishers, absorbent material, drums, manual valves of the "hose clamp" type, 150 lts of sweet water in open barrels equipped with a hand pump and rubber hose for a rapid wash of eventually contaminated persons, etc.

9. Commencement of fuel supply operation

Once the connections were made according to the scheme in Fig. 7 the responsible for the operation made a verification of the system realized before starting the transfer of fuel and has arranged for:

- the checking of the measuring stick and the breather of the storage tanks;
- the verification of the tight fitting of all valves and connecting flanges;
- the verification that all 6" valves were open;
- the verification that the 2" drainage valve of the launcher was closed and the drainage hose attached;
- the verification that the 3" valve which connects the launcher to the nitrogene bottles or to the compressed air was closed;
- the verification that the 4" valve of the feeding line of the storage tank was open;
- the verification that all members of the personnel, instructed on its role and task, occupied the right position and were in possession of the necessary equipment and of a radio in order to be able to follow the development of the operations.

10. Refuelling

After having completed the above verifications, the responsible for the operation communicated to the tanker that the system was ready and the latter gave order to start the operation of the fuel oil transfer.
As no problems arose during the transfer, this was continued until the completion of the first storage tank which was watched by the team in the tank zone checking carefully the measuring stick.
At this point the responsible for the operation communicated to the tanker to suspend the transfer by stopping the pump on board in order to allow the connection of the hose-line to the second storage tank (S2).
Upon completion of these first series of operations the line was reactivated; the responsible, after having checked the connections of the piping, communicated to the tanker to restart the transfer. Immediately after the tanker had transferred the remaining fuel to the S2, the delivery was suspended and the operating team started to close all valves.

11. Drainage, cleaning and recovery of the hose-line

These operations took place in two stages and have involved the following sections of the hose-line.

11.1. Hose-line laid out on the pack

In order to free the tanker as soon as possible after the completion of the refuelling, the first operation to be executed was the natural drainage of the hose-line laid out on the pack into the tank container placed on the beach of Tethys Bay.
To do so the hose-line was divided in sections and the receiver was connected at the hose-line laid out on the pack and to the tank container as shown in the scheme of Fig. 8.
Terminating the drainage, the polly pig was inserted in the launcher and the air compressor connected; the hose-line was cleaned by pushing the fuel into the tank container.
After having finished the cleaning and having disconnected the launcher and receiver, the hose-line was recovered on a special reel and placed in conservation to protect it from ultraviolet rays.
In the meantime the tanker was coupled to the icebreaker and towed outside Tethys Bay.

11.2. Hose-line laid out on land

The cleaning continued by connecting the receiver to the hose-line laid out on the land (Fig. 9); then the hose-line was disconnected from the storage tank and all other valves on the line were opened to drain the fuel into the tank container.
Upon completion of the natural drainage the launcher, to which the set of nitrogene bottles was attached, was inserted at the beginning of the hose-line; at this point the polly pig was inserted and as before the hose-line was cleaned and wound on the remaining two reels and stored.
Upon conclusion of these operations, all other means, materials and equipment were collected and put in store and the area involved in the fuelling operations was checked to be left in order and clean.

12. Conclusion

The refuelling operation took place as was initially foreseen and caused no problems.
To speed up and make safer future operations Italian Antarctic Project will pay the utmost attention to the development of the technology and the regulations regarding the storage and transfer of fuel.
The experience made with the first operation has already led to some considerations which will be transalted into improvements and/or modifications both for the present storage and transfer system and the future construction of the storage tank with regard to for example:

- mechanical protection of the penetrations,
- motorisation of the hose reels,

- implementation of the instruments with penetration unions from the roof,
- execution of a single penetration (from the roof of the tank) for the transfer and withdrawal of fuel.

TABLE 1

STORAGE TANK

- vertical, doublewalled and with fixed roof	
- capacity	600 cu.mt
- levelling rod	
- material	carbon steel
- internal diameter	12 mts
- external diameter	13,6 mts
- internal height	6 mts
- external height	6,5 mts

Conditions of project

- reference specification	API 650
- wind speed	216 Km/h
- load of snow and ice:	
. roof	200 Kg/sq.mt
. shell	1000 Kg/sq.mt (first ferrule only)
- average temperature	between 0°C and 40°C
- capacity of pump section from tank	100 mt/h
- capacity of pump delivery to tank	100 mt/h

- seismic actions verified with reference to UBC zone 2 rules

TABLE 2

SPECIFICATIONS

A) REFUELLING HOSE-LINE

- diameter	6" (152 mm)
- working pressure	17,2 bar
- weight empty hose-line	abt.5,5 Kg/mt
- capacity	18,1 lt/mt
- weight fluid in hose-line	13,7 Kg/mt

B) REEL

- lenght reel		5,90 mt
- diameter reel drum		1,50 mt
- diameter reel flange		2,50 mt
- reel n. 1090379	lenght hose-line	250 mt
	net weight	1536 Kg
	gross weight	3836 Kg
- reel n. 1090380	lenght hose-line	315 + 35 mt
	net weight	2136 Kg
	gross weight	4436 Kg
- reel n. 1090381	lenght hose-line	350 mt
	net weight	2136 Kg
	gross weight	4136 Kg
- lifting gear	- beam:	
	lenght	7 mt
	weight	700 Kg
	capacity	6000 Kg
	- bar of iron:	
	diameter	900 mm
	lenght	7 mt
	weight	385 Kg

Supply and Storage of Fuel in the Spanish Antartic Base Juan Carlos I

by

Josefina Castellvi & Elias Meana
Programa Nacional Antartico, Spain

From 1987 when the Base was installed in Livingstone Island, the supply of fuel was made by disembarkation of 200 l. barrels.

According to the Antarctic Treaty Recommendations and Madrid Protocol referring to the environmental impact produced by Antartic Bases that sometimes may be irrecoverable to some echo systems, the Spanish Antartic Base (S.A.B.) Juan Carlos I, has made ready a fuel supply system that may set example on the possibilities that a small summer base with reduced costs ashore and at sea.

The operation begins by setting a supply line, (a hose) between the supplying vessel, in this case the oceanographic vessel Hesperides, and the storage tanks in the S.A.B., which are located at 125 m. (Fig. 1 & 2).

Supply Line

Taking into account the S.A.B.'s restrictions on manpower and transportation resources, the supply line has been installed using sections of 60 m. length and 80 kg. weight, which allow relatively easy handling as its flexibility allows it to be rolled up in coils of aproximately 1 m. in diameter.

The hose is made of abrason resistant neoprene with an inner diameter of 32 mm. and a flow of 3000l/h.

The joints between sections are made of stainless steel rackworks provided with pressure and safety valves which are activated by hand pressure and run automatically when a section is disconnected from the other. The system has a fully leakproof connection that even if it were disconnected during the fuel transfer would not allow the leakage of fuel.

Although it is not an autofloating system, (which would have had larger volume and costs), it is provided with small floating plastic buoys of 135 mm. diameter and 840 gr. floatability. These are fixed to the hose, (one every 80-100 cm.) along the whole maritime distance of the line.

On the land side, the distance between the coast and the tanks (some 240 m.) is made up of sections which simply lay on the ground.

Pumping System

A pump with anti deflagrate motor protection has been installed on board the vessel, which transfers 3.000l/h at a pressure of 14.5 Kg/cm^2.

Storage Tanks

The fuel tanks storage capacity is 17000 l., fuel type A, distributed in tanks of 5000 l. and 1 of 2000 l. The petrol (97 octane) is stored in a forth tank, which has a capacity of 500 l., these tanks are designed and homologated to store hydrocarbons, and are made of synthetical tissue covered by neoprene.

The fuel supply is carried out in the early days of the campaign and then as the consumption takes place and tanks become empty, they are gathered in the storeroom till the following year. In the winter only the fuel stock remains (about 4000 l.) distributed in the 2000 l. and one 5000 l. tanks.

Under the pressure of the snow accumulated in winter the tanks may have leaks. In order to avoid this, the tanks are protected under metallic structure which supports a treated wooden roof. This assembly is covered with canvases.

The flow between the storage and the daily consumption tanks (two 500 l. stainless steel tanks) is accomplished through gravity making use of the existing unevenness.

Fuel Flow Operation

In order to ease the operation it is essential to choose a windless day and a calm sea, whereby, this operation is carried out better.

The seabed topography of South Bay allows the anchoring of the vessel Hesperides (4.42 m. draught) at about 450 m. off shore.

The hose maritime distance is prepared ashore, 8 or 9 sections are laid extended on the beach. When the operation starts, the hose that has to be connected to the on board end on deck is tied to an inflatable boat (4.5 m. and 35 h.p.) that sails toward the ship. Meanwhile the on shore based personnel help guiding the hose until it gets into the water and floats.

The different groups that took part in the operation kept in direct contact by using walky-talkies and their distribution was as follows:

On board, operating the pump according to the instructions received from the personnel that is working by the tanks.

On the tanks, controlling their filling and giving precise instructions to the pumpmen.

Ashore, watching the joints between sections and the whole line length.

There is a craft at sea surveing all the line length while the operation is taking place.

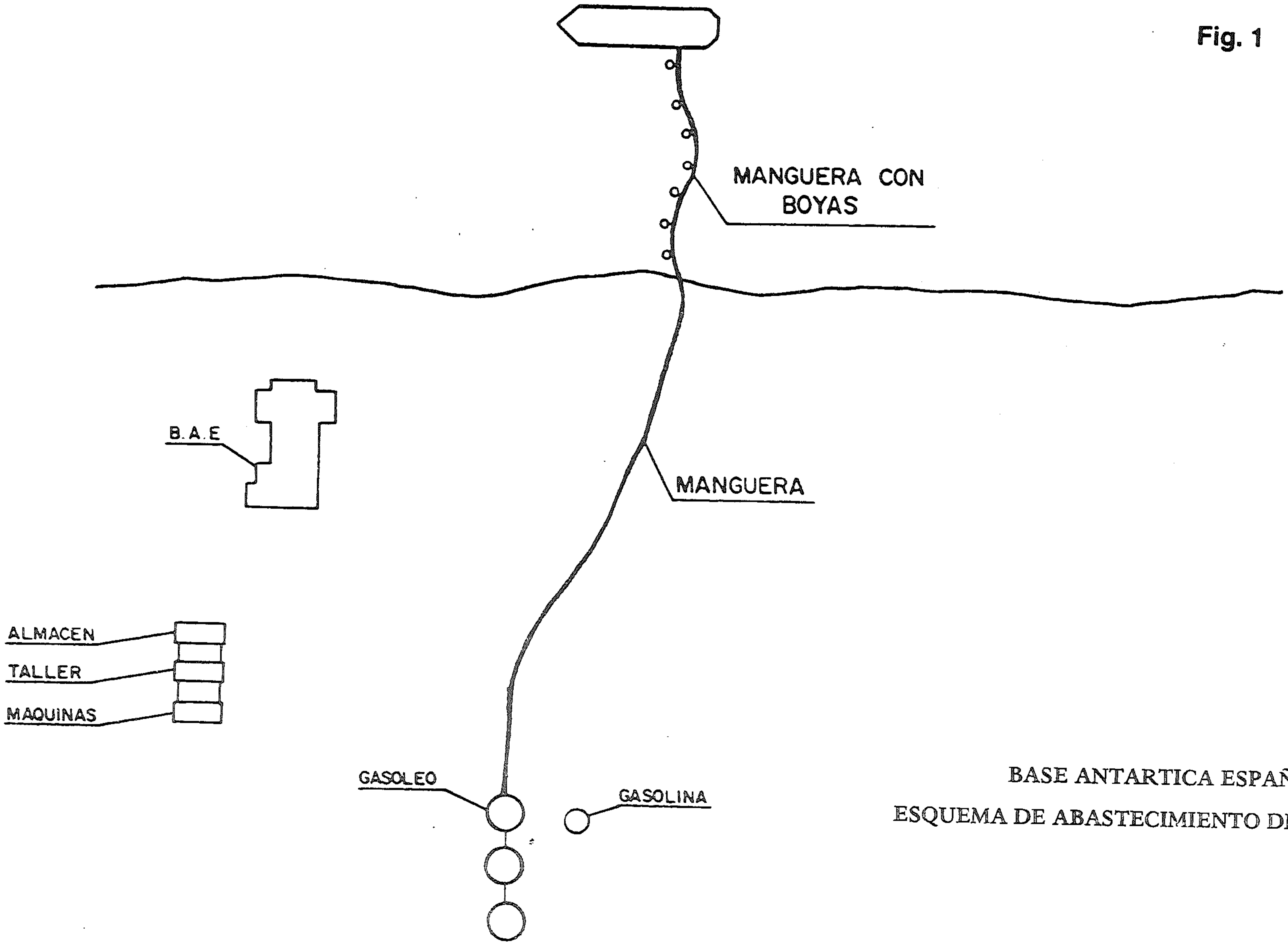
Once the unloading is finished, the hose at the on board end is towed to and laid extended on the beach.

The remaining fuel in the hose is emptied out section by section into the daily tanks by fitting an airtight piece that opens the pressure valve.

If due to the presence of ice wrechages or strong sea currents, it would be considered necessary, a strong galvanized iron wire of 5 mm. section provided with buoys and fastened both on shore and on board and fixed to the hose to absorb the traction that the ice or the sea current may cause.

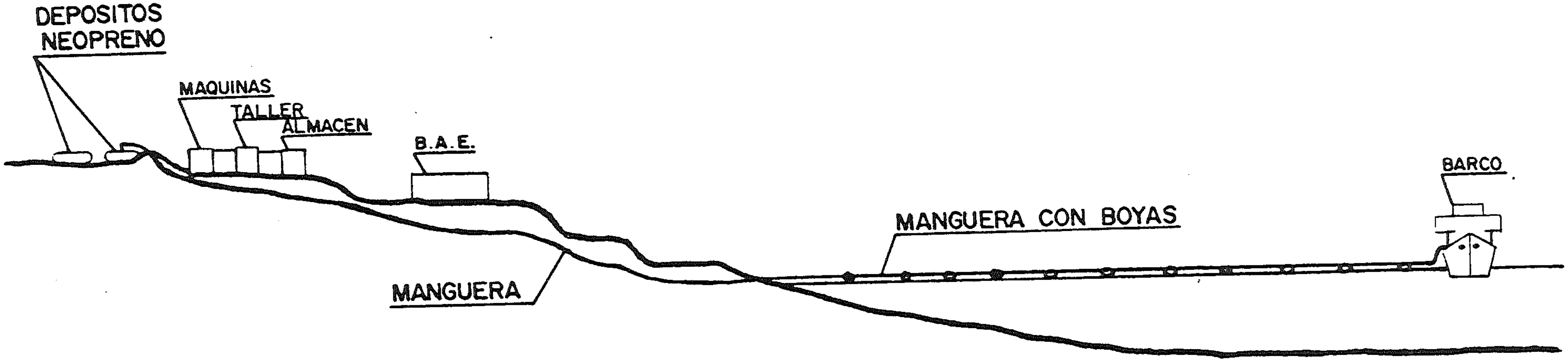
As a measure of precaution in the mischance of leakage due to a technical handling failure, the vessel was provided with a contention system made up of an absorption line for oily liquids by capilarity (two coils of 44 m. and 10 mm. section), which would prevent the spreading of the contaminating stain.

Fig. 1



BASE ANTARTICA ESPAÑOLA
ESQUEMA DE ABASTECIMIENTO DE COMBUSTIBLES

Fig. 2



BASE ANTARTICA ESPAÑOLA
ESQUEMA DE ABSTECIMIENTO DE COMBUSTIBLES

The Role of the Chilean Navy in the Control of Pollution in Antarctica

by
J. P. Heuser
Instituto Antartico Chileno, Chile

Introduction

On behalf of the Chilean Navy I will describe the actions and activities being carried out by the Chilean Navy in the control of pollution of the Antarctic Territory. This account will comprise the following subjects:

I. **Antarctic Scenario**
II. **Environmental Legistlation**
III. **Presence of the Chilean Navy in Antarctica**
IV. **Conclusions**

Given the vastness of the subject, it would be presumptuous to deal with it in some detail in the comparatively short time available. However, when analyzing our country's condition of seaside nation and its proximity to the Antarctic territory, there rapidly come to one's mind ideas that prompt this presentation.

Antarctic scenario

The Antarctic scenario now known to all is that described in the publications and in summarized form in the paper submitted in full to Dr Olle Melander.

Environmental legislation

The world experience acquired in the search of solutions to environmental problems has led to adoption of five main principles to control pollution.

1. He who pollutes must pay, which astablishes the responsibility of the polluter.

2. From the craddle to the grave, which is essential to assure that the generator of waste is responsible for the control of the whole life cycle of the waste.

3. Sustainable development, which seeks to assure the development of future generations in a sound environment.

4. Precautionary, which consists in giving important powers to the supervising authority, so that it will not be necessary for it to require previous legal provisions to take action.

5. The lowest possible cost of disposal, which has to do with social and economic organization and seeks to guarantee competitiveness conditions in respect of products that can be obtained from such waste.

In Chile, concern about pollution of the water environment has centered on these five principles.

The political constitution of Chile, of 1980, provides, in its section 19, for the right to live in a sound, pollution-free environment. This constitutional provision has been thoroghly understood and successfully used in the nation.

Moreover, the navigation law of 1978 considers the water environment preservation and control of marine pollution over all the national jurisdiction to be one of its chief purposes.

Capacity and activities of the Chilean Navy in Antarctica

Using Prat Station (1974) as a position for Antarctic operations, the Chilean Navy has the following operative capacity:

a) A port captainship at Fildes Bay known to all as Marsh Station for support of ships of all flags. It provides meteorological and sea traffic information.

b) An Antarctic little fleet made up of ships (Piloto Pardo and Revenue Cutter Yelcho) which provide logistic support to national and foreign stations.

c) The Chilean Navy, which is interested in the protection and preservation of the water enviromnent and is aware of the need to seek safety for human life in the sea and navigation in the Antarctic continent, established an Antarctic naval patrol made up of two ships (Galvarino and Lautaro). They are responsible for salvage, rescue and towing of ships and are equipped for the control of pollution due to hydrocarbons and other substances. In regard to activities, we can list them as follows:

a) logistic support to stations
b) hydrographic surveys of bays, passages and channels
c) maintenance of marine signalling
d) notice to navigators
e) meteorological reports
f) oceanographic studies
g) prediction of sea tides and currents

Participation of the Chilean Navy in rescue and pollution control operations

Historically, the Chilean Navy has, as mentioned below, carried on human life salvage missions in the sea and protection of the marine environment.

1. As you know, the pilot Pardo in the Yelcho Revenue Cutter rescued, in August 1916, the expedition Shackleton from Elefant Island.

2. Rescue by means of helicopters of Pilot Pardo ship from Deception Island, in December 1967, of 15 Englishmen and 27 Chileans affected by volcanic eruptions.

3. Rescue at Balleneros cove, with helicopters in 1969, of five Englishmen due to volcanic eruptions.

4. Salvage of Lindblad explorer in 1972 by Pilot Pardo ship and Revenue Cutter Yelcho. After the rescue, accomodation was provided to 114 tourists.

5. Support to Yelcho in the shipwreck of ARA, Bahia Paraiso in 1989.
6. Rescue and refloating of Bic Humbolt at Marian cove in 1989.

Protection of the marine environment in Antarctica

In view of the increasing sea activity on the Antarctic Territory and for the purpose of preventing accidents safeguarding human life in the sea and avoiding ecological damage in this sea area, the Chilean Navy decided to establish an Antartic navigation School. The National Merchant Marine officers and Chilean harbour pilots are required to attend the appropriate courses as a prerequsite for navigation towards Antarctica.

As a second important measure, the Chilean Navy has decided to create a Sea pollution Control Centre, based on Prat station which has been the product of experience acquired through implementation of the "Plan Nacional de Contingencia" (National Emergency Plan) for spilling of hydrocarbons and other substances and to promote efficiency in the case of an emergency. This Centre will be operative in 1993.

In addition, general measures have been taken which are designed to promote awareness of environment preservation which will be completed with additional courses for personnel of Antarctic commisions and with any studies that may help in the acquisition of knowledge of the physical-chemical characteristics of the Antarctic sea environment.

Conclusions

The fragility of Antarctica does not permit any risks derived from inexperience, the consequences of which may give rise to serious damage to the Antarctic ecosystem and dependants due to lack of prevention and precautionary measures in Antarctic operations.

Therefore, on the basis of the experience and the presence of the Chilean Navy in Antarctica, the institution has developed an overall plan of support of sea operations carried out by our country. This support is extended to other ships. In this respect, attention has been paid to the training of personnel, implementation of adequats equipment, and allotment of units with adequate reaction capacity, all this for the purpose of controlling possible oil spilling contingencies.

Petroleum Pollution Prevention, Response and Remediation in the Antarctic

An Equipment and Procedural Approach

by

Carl R.C. Kohlmeyer

National Science Foundation, USA

1.0 Introduction

The following overview presents several key issues for the prevention and remediation of petroleum pollution in the Antarctic environment. The use of state of the art equipment, properly maintained, and combined with site specific operational procedures are components of a zero release philosophy. The equipment and procedures must be tailored to the harsh Antarctic environment and the specialized petroleum products that are currently in use there. The development of a set of detailed standards and recommended practices allow for a uniform program designed to minimize petroleum releases. The training and implementation of new procedures must be carefully tailored to the unique psychological environment of the Antarctic community. Upgrading existing tanks with secondary containment systems, leak detection sensors, and dry-break delivery nozzle technology is presented as a cost effective strategy and, coupled with adequate training and formal operational procedure, the zero release goal is attainable.

There are numerous simple approaches for immediate response when petroleum products are released. Methods and equipment for stabilizing the situation to minimize product migration and reduce the potential for fire and personnel exposure are presented. A sensible assessment of the spill by trained professionals and timely implementation of short and long term remediation strategies can significantly reduce the environmental impact and cost.

The primary remediation alternatives for contaminated soil, ice, and water are discussed with specific methodology for the Antarctic. The reduced hydrocarbon volatilization and the sluggish response of bioremedial dissipation mechanisms in soil necessitates pro-active remediation strategies. The application of in-situ soil remediation techniques are discussed as an alternative to retrograde. The paper details the use of oil-water separators and carbon filtration units for contaminated liquid processing to current drinking water standards. The emphasis is on prevention of product release to the Antarctic environment.

2.0 Spill Prevention

The zero release option is possible. The key is sensible management, the proper equipment, maintenance, and rigorous transfer procedures executed by adequately trained personnel. The historical attitudes toward product release have been that they will occur and the emphasis has been on minimizing the loss based on the dollar value of product or the potential for fire with little consideration for the impact on the environment. However, environmental attitudes around the world are rapidly changing. Modern understanding of how fragile the environment is and the unique pristine condition of the Antarctic make the prevention of product release of paramount concern. Petroleum releases to the Antarctic environment have been attributed to a broad range of events from small releases due to the overfill of 55 gallon drums or small tanks to the loss of ten's of thousands of gallons due to operator error or catastrophic equipment failure.

Changes in the regulatory environment governing petroleum operations in the U.S. have spurred a significant quantity of new technologies developed to minimize and control the release of petroleum products. The realization that once an environmental contaminant has been released to the environment the cost of any effective remediation effort is exponentially greater than the cost of installing and maintaining modern equipment and implementing effective operational procedures designed to prevent release. The promulgation of stringent regulations governing liquid storage tanks of all description (the primary thrust has been for underground tanks) is now a well established trend.

The impact of these regulations on the petroleum product manufacturers and suppliers forced the development of new equipment lines that can be used in the Antarctic to prevent the release of petroleum products into the environment. This trend has also prompted a reexamination of installation standards yielding many beneficial changes in the codes and common practice used by the industrial, commercial and governmental sectors. The unique nature of the Antarctic environment does not lend itself to wholesale application of standards applicable to more temperate climates. However, accepted industry practices form an excellent starting point for developing effective standards for the Antarctic. In essence, the body of information and standard practice currently known to be effective can be co-opted to institute effective management practices in the Antarctic.

An essential element an essential element of the release prevention strategy is a thorough examination of existing systems and the use of a well developed set of installation standards complete with drawings and specifications that can be applied to the various populations of tanks currently in use in the Antarctic. The population of existing petroleum storage vessels currently in use in the Antarctic can be categorized for the purpose of developing equipment configurations into four groups. Tanks with a capacity greater than 20,000 Gallon (75,000 Liter) are considered large and are usually fixed, field constructed, on-ground tanks used for Bulk storage. Tanks under 20,000 gallon (75,000 liters) are considered relatively small and are generally manufactured tanks or skid tanks and are used to service a particular building, facility, or runway operation. The third type are portable tanks that are used to service field operations and the fourth group are delivery vehicles that distribute product to point of use.

Prompted by the current sensitivity to environmental issues regarding storage tanks and petroleum operations, a data base has been amassed and indicates most product releases are the result of maintenance or procedural errors, operator error, or equipment failure during product transfer. Thus, a critical part of the solution is the development and implementation of effective transfer procedures and the inspection and maintenance of equipment. The development of practical operational procedures for the Antarctic forms the first step in the process. From the starting point of modern practice institutionally adopted by major handlers and distributors of petroleum products in the United States and Europe an effective program can be developed and tailored to individual operational requirements of the various national programs currently operating in the Antarctic.

The implementation of new and more efficient programs in terms of the human resources involved forms a more complex element of the solution. Historical procedures are well entrenched, and while many have proven effective the implementation of modern operational standards can significantly reduce the potential for product release. However, there is usually some resistance to institutionalized change and this presents a management problem for parties trying to implement new operational procedures. One inevitable factor in the institution of environmentally sound programs for petroleum operations is the necessity for a well designed program that can be phased into existing practice. A phased approach to both operational changes and equipment upgrade has numerous benefits not the least of which is the distribution of costs while still obtaining a rapid reduction in the potential for significant product releases and minimizing the transitional impact on personnel used to historically established operational procedures.

Retrofitting existing systems with modern equipment according to an environmentally engineered, standardized, system design that can withstand the harsh environmental conditions (temperature, wind, storms) experienced in the Antarctic. A satisfactory range of equipment currently produced can be made suitable, with minor changes, for exposure to the low temperature extremes and other significant environmental impacts on the material of construction and component design.

The design of the tank and delivery systems should be standardized into a formal package complete with drawings and specifications that clearly delineate the system configuration, equipment requirements, and individual location requirements. Once a specification package has been developed, the standard can be adopted for new construction and a phased upgrade program of existing facilitates can be undertaken. This would significantly minimize the cost impact and could achieve a standardized system in a controlled time frame. The use of standardized configurations also allows the implementation of a set of redundant safety systems and fail-safe mechanisms. The standardization of system configuration reduces long term maintenance costs, parts inventories, and most importantly simplify the implementation of procedures that can prevent releases and institutes a clear course of action should a spill occur.

2.1 Inspection of Existing Systems

The need for regular inspection of the entire storage and delivery system is critical to preventing product release due to equipment failure. A major contributor to the problem is valve and piping failure. Though the normal corrosion processes are retarded by the cold temperatures and dry air of the Antarctic these mechanism are still present and undoubtedly have been the cause of numerous equipment failures. Periodic inspections can reduce the release potential and also provide a basis for developing a maintenance, upgrade, and replacement schedule. Inspections are a critical portion of and form the cornerstone of any operations and maintenance (O&M) program.

Industrial and commercial experience has shown that visual inspections of pipelines, valves, pump sets, hoses, and nozzles by experienced personnel can detect many problems that lead to catastrophic failure and should be conducted at a minimum of once a month. The inspection should also cover the surrounding area to determine any change in usage that might increase the potential for damage to the tank system. The unique environment of the Antarctic makes this function more important. The low temperatures and wind apply very high stresses to construction materials that tend to embrittle metals, and other materials, thus increasing the potential for fatigue fracture or other failure mechanism from developing in essential equipment. Regularly examining the system will aid in the early detection of problems.

To develop more detailed understanding of the condition of the tank system it is recommended that a thorough inspection of the system be performed, complete with non-destructive testing. Each component of a system should be isolated and separately tested to develop a release potential profile. These test methods typically include ultra-sonic examination, various types of pressure tests, liquid dye penetrant tests, tank and deflection measurement, hammer testing and precision testing. The precision testing of tanks via computerized or mechanical methods such as Petro-tite testing are the standard tools used by the petroleum industry. The precision test methods correct for temperature fluctuations and other influencing factors to determine whether a storage system is currently leaking product. The sensitivity of precision testing methods is currently at a limit of detection in the range of 0.05 gallons per hour. Other nondestructive test methods such as ultrasonic or radiography can be used to evaluate the structural integrity of the materials of construction.

After an initial comprehensive examination of the system monthly inspections are recommended as an essential component of any operations and maintenance plan. The regular physical examination of the storage system and an audit of the management program helps to identify problems or deficiencies. This is considered in the petroleum industry the best and most cost effective strategy to prevent the release of petroleum products into the environment. However, the identification of problems with equipment is only the first step. Evaluating the problems and deficiencies identified during the inspections and audits and then implementing the solutions becomes a system management function and is the determining factor in the prevention of petroleum pollution of the environment.

2.2 Upgrading Existing Tank Systems

There are many unusual tank systems currently in use in the Antarctic. Many of these are truly unique configurations hobbled together under extreme weather conditions, time constraints, or emergency conditions and are a testament to the ingenuity of the men and women of the various Antarctic Programs. Many of the existing systems have been in continuous or seasonal use for years or even decades with little or no maintenance and were installed under a set of traditional standards and practices that are no longer considered adequate to reduce the potential risk of product release to acceptable levels. Current environmental practices have provided the engineer and tank installer a much broader range of equipment options and standard system configurations to utilize in the development of site specific design packages. The emphasis on the development of any design package should be to minimize the potential for the uncontrolled release of product to the environment..

2.2.1 Small Tanks

A cost effective method to prevent product releases in existing tank systems is to upgrade equipment to modern standards. This method is particularly effective in relatively small stationary above ground storage tanks of 20,000 gallons and less. These relatively small tanks present little problem to upgrading existing equipment, piping systems, and containment systems. The majority of tanks currently in use in the Antarctic fall into this category and are used to service heating or power generation equipment. Assessing the structural integrity of these tanks and then upgrading the equipment has promise as a rapid method to reduce release potentials. Current industry standards indicate the effectiveness of secondary containment for tanks and buried piping. A phased system of secondary containment installation on small tanks serves a dual purpose. Upon installation, it minimizes the potential for release and can serve as a mechanism to upgrade existing systems and replace the combustible (wooden) tank saddles or unpadded metal saddles commonly found in the Antarctic.

The use of new double wall, tanks with 100 percent secondary containment is perhaps the fastest and most assured method of reducing release potentials. However, this is a costly alternative and a lengthy implementation period would be required to retire existing systems. The dry air and extreme cold inhibit the normal corrosion process and, therefore it is likely that the majority of small storage vessels are still structurally sound and can be retrofitted and reused eliminating the need to import completely new systems. A thorough internal and external inspection coupled with precision or pressure testing and other non-destructive testing regimes (ultra-sound, dye testing, etc.) should adequately identify any structural defects in existing tanks. Based on the inspection results a sensible decision can be made whether to upgrade or replace a particular tank.

Often the petroleum storage vessel of choice to service a fish-hut or warming shack was the 55 gallon drum. The continued use of 55 gallon drums as stationary fuel storage tanks is not recommended. Drums are not designed for this application and when mounted on bare steel brackets or simple strapping the potential for abrasion at contact points is very high and can have disastrous results. The piping and fill connection are not configured to allow fill, gauging, and product delivery in a manner to minimize spill potentials and the threaded connection are not rated for this type of service. There are many of these tanks currently in service and while they contain only small quantities of product (55 Gallons) there is a fairly large population (several hundred) of individual tanks that are used to service remote field stations, warming shacks, and research camps many of which are located in the most sensitive areas of the continent. This clearly is a population of tanks that can be replaced at a minimum cost. The cost of replacing these systems with modern configuration would be approximately $500-1000 per system stateside cost. The installation of these new systems would also be very simple and fast, minimizing the cost of the replacement process.

2.2.2 Large Tanks

The larger on-ground bulk tanks (above 20,000 gallon) need to be examined more closely to determine if secondary containment and equipment upgrade is feasible and cost effective. The major stumbling block for retrofitting large tanks is usually the installation of a secondary containment system. Protecting against leakage from the sides of the tank is relatively simple given the access for inspection and the possibility of installing a containment basin sealed to the bottom edge of the tank. The relative ease of visual inspection or non-destructive testing allows a reasonable level of comfort that deficiencies can be detected and addressed prior to failure. However, there is no simple method to address potential leakage from existing on-ground tank bottoms or the retrofit of a complete secondary containment system to retain spillage or leakage from any tank surface. Therefore, the most cost effective approach for existing tanks is to initiate an operations and maintenance plan with a stringent monitoring program. The monitoring system would include installation of monitoring wells and surficial sensors located in potential migration routes to detect releases. These monitoring stations should be equipped with sensors that are connected to a central monitoring station and alarm system. If tanks are identified that are structurally defective or of significantly advanced age a phased retirement schedule can be implemented. These older tanks can then be replaced with secondarily contained tanks complete with modern equipment configurations. As with all options stricter management controls to prevent leakage or spillage of product need to be instituted to reduce release potential.

2.3 Operational Procedures

The management of existing bulk storage facilities can best be addressed with a process of operational monitoring, equipment and facility inspection, maintenance, upgrade and replacement. Each of these blocks of activity can be carefully crafted to address the magnitude of the issues involved in a sensible manner without undue complication. The operational monitoring of a tank system should track usage and transfer patterns as a means to identify areas of concern and quickly address historical problems such as actual releases or near spills as a way to prevent reoccurrence. Product release during transfer accounts for a large percentage of all releases to the environment. This is clearly an area were existing operations can be quickly modified to reduce the potential for release. With the introduction of dry break technology, fail-safe equipment and several other simple technologies coupled with additional training the potential for release of product during transfer can be minimized. In theory, at least, the process of fuel transfer should be monitored by trained personnel for the duration of the event. Therefore, with the institution of adequate procedures, good equipment, and trained personnel the potential for release can be dramatically reduced and zero release goal should be an obtainable.

2.3.1 Vehicle Fueling

The most common source of spillage in most tank systems occur during product transfer. The fueling of vehicles is one of the most common transfer activities. The fueling area is also the link in the system that is the simplest to retrofit to reduce the potential for release of product to the environment. Historically, fueling areas are native soil or icepads near the storage tanks and few active measures have been taken to minimize release potentials. The primary feature of the vehicle fueling areas in temperate climates is a containment pad allowing vehicles to park in a contained area when fueling. Normally, this is a simple concrete pad or other material impermeable to gasoline and diesel fuels. However, due to the variety of tracked and rubber tired vehicles in use in the Antarctic and difficulties associated with the foundation material and the curing concrete a special kind of vehicle fueling containment system would need to be developed. The pad should be formed to allow small quantities of product released to evaporate and should significant spillage occur the product would be directed towards a secondary impoundment. In the more temperate climates of Antarctica (McMurdo, Palmer) where significant quantities of water is present at certain times of year the collection basin could be connected to an oil water separator. Oil water separation is discussed in detail in section 4.2.

2.3.2 Product Transfer to Stationary Tanks

During the process of product transfer into stationary tanks overfilling is a common source of product release. There are effective methods to limit release potentials during the filling of small tanks that are relatively simple to implement. The methodology applied to each of the main populations of tanks present in the Antarctic is similar. The use of inventory controls, recordkeeping, tank gauging, and overfill protection equipment applies to both large and small tanks. Overfill protection is an essential function of any size and configuration tanks. There are numerous different types of equipment that can effectively be used in the Antarctic.

2.3.3 Record Keeping

The use of accurate inventory control and recordkeeping as a means of tracking the product use and possible loss is applicable to all tanks. This is one of the most effective ways of identifying leakage from a tank system that is not currently in wide use in the Antarctic. This is a critical monitoring function for large tanks that cannot be thoroughly inspected for leakage. Inventory control is one of the simplest and most effective methods to detect uncontrolled product release in an existing tank system. Installations currently in use in the Antarctic could effectively implement inventory control programs quickly with minimal equipment installation and limited personnel requirements. The equipment necessary for accurate inventory control is simple and basically consists of the installation of cumulative metering devices to monitor the quantity of product being introduced or removed from a tank. The information can then be compared to an actual tank gauging to determine if there is an uncontrolled release of product. The data needs to be corrected for temperature variations or other influencing factors which may be causing expansion or contraction in the liquid. This data collection and comparison process should be performed daily until a sufficient profile of system performance is obtained. When an adequate storage profile of system has been developed and indicates that the tank is performing properly the monitoring requirements can be adjusted to reduce manpower usage while maintaining a suitable level of comfort that the tanks are not actively leaking.

2.3.4 Maintenance

The maintenance of most systems often gets less than primary attention. This is of course one of the best and most cost effective methods to reduce the potential for leakage from equipment failure. The best engineered systems require regular maintenance or the potential for failure is increased. The standardization of the population of tanks in operation in the Antarctic would reduce critical personnel training costs and also substantially reduce the spare parts inventories required to adequately maintain the system. Annual maintenance of the petroleum storage and distribution systems should be conducted. Scheduled maintenance of the systems should correspond to the inspections of the entire system and should be based on these inspections.

The regular maintenance of the system should include such fundamental practices as the breakdown of critical valves and replacement of any parts observed to be pitted or damaged. Valve packings, glands, bolts, seats, bonnets, flanges, springs, washers, O-rings, actuators, etc. need to be examined periodically to ensure proper functioning. New equipment should be checked prior to installation and retrofitted with parts rated for Antarctic service. A regularly scheduled program of maintenance, lubrication, and replacement on all critical system components will reduce the potential for failure at a critical point in an operation. Maintenance on fixed components and storage systems tend to receive limited attention until a failure occurs and when the failure analysis is conducted it is truly surprising how often even with the current understanding of failure mechanics how many major failure event are traced back to the 50 cent valve packing or bolt that failed after long service and a major release event occured. Maintenance is such a fundamental part of any system that is structured to function properly over a long period of time that it bears mention only because of how often it is overlooked. It is simply part of an effective operations and maintenance plan designed to ensure proper function in the long term and increase the potential that the system will hold up under extreme conditions.

2.4 Installation of Modern Tank Systems

The increasing awareness of the impact of uncontrolled release of petroleum products into the environment has dramatically changed the traditional storage system configuration. Modern designs include many safety systems that were not previously considered necessary. Modern system configurations build in a redundancy or overlap in system function to ensure that sufficient backup systems are present to detect a problem or abnormal function before a release occurs. The starting point in achieving any type of uniformity of function in a storage tank system is the development of a set of performance criteria, specifications and working drawings that form the basis for all new installations and the upgrade of existing systems. In order to achieve a level of comfort that the system design will function properly and survive the Antarctic environment a program of phased upgrades and new installations should be implemented to test system configurations and equipment function under operational conditions prior to broad systemwide application. From this pilot program a truly effective package can be developed and implemented in a cost effective manner.

The details of modern tank construction include both upgraded performance criteria for the vessel and equipment standards that are significantly more complex than were historically believed necessary. The reason for this is that historical installation standards used for the storage of petroleum products have proved to be inadequate to guard against the uncontrolled release of product. Therefore, given the age of the existing populations of tank systems currently in use in the Antarctic there is a high potential that significant maintenance and upgrade would be required to bring these systems into compliance with current industry standards and provide a satisfactory level of comfort in the ability of the system and operational methods to minimize the release of petroleum products into the environment.

The smallest and simplest tank systems now require a much greater quantity of equipment and containment systems to provide that level of comfort that reasonable steps have been taken to minimize release potentials. In developed countries virtually all new tank systems now have secondary containments and leak detection mechanisms. Large bulk tanks typically have 110% secondary containments or remote impoundment systems. Small tanks typically have double wall construction or are vaulted. The newest generations of integrally vaulted storage tanks have great promise for application in the Antarctic.

The equipment found on modern tanks is substantially different from historical configurations. The use of Tite-fill equipment, dry breaks, and automatic shut-off nozzles is becoming more common and is considered an integral part of most standard systems. One significant technology not currently in wide use in the Antarctic is overfill protection equipment. Small spill containment boxes (5-10 gallons) installed on the fillport reduces the potential that minor overfills will be casually released to the environment. The use of a flow control systems when a tank is approaching capacity are typically triggered at 90% of tank capacity and warn the operator that tank capacity has been reached by actuating an alarm bell, whistle, or other method. At 95% of tank capacity the flow of product into the tank is further reduced and additional automatic response may occur depending on the individual system. When coupled with a tite-fill, dry-break, or automatic shut-off nozzle these systems have been proven to be effective at reducing the potential for release during the transfer process. The installation or retrofit of this technology is a very cost effective method to prevent release of product. Many of the significant releases of product in the Antarctic have occured from overfilling small stationary tanks.

The listing of new and proven technologies and alternatives available to the petroleum operations engineer has grown extensively over the past 5 years. Much of this technology can effectively be implemented in the Antarctic at a modest cost. The cost of the prevention of a release is several orders of magnitude less expensive than the smallest remediation event. The crucial element is the performance standard required of new installations. This performance standard should be built into the specification package and should incorporate the philosophy of zero release of product to the environment. This standard should be clearly delineated in the specifications and drawings that are applied in the field. The basics tenants of construction apply and these documents should be carefully developed and geared towards the people in the field who are going to do the actual installation or upgrade. With a properly designed installation that has been installed to specification and is operated under a sensible operational plan the potential for the release of petroleum products to the environment can be minimized and the zero release goal may be approached.

2.5 Spill Prevention and Response Plans and Implementation

The development of a formal plan to implement and adequately organize a prevention plan or a response action is critical. These plans are known in the United States as Oil Spill Prevention and Control and Countermeasures (SPCC) Plans. A formal SPCC, though not regulated into existence, has a far greater importance for operations in the Antarctic. The isolation and distances involved make a well developed plan, and properly equipped and trained personnel essential if any type of reasonably effective response action is possible. There are currently plans on record in many of the larger research stations on the continent. However, there is a clearly identifiable difference between existing documentation and the implementation of an effective spill prevention and response plan. Part of the problem with implementing an SPCC is a natural resistance to change. In adapting to the harsh climate the men and women of the Antarctic programs have developed a complex set of behavior patterns that have proven effective to guard against personal injury. Any change is naturally viewed with some suspicion and does in fact contain a significant element of risk. In addition, there is a standard sentiment that any formalized and documented plan is not applicable to the situation because the authors do not understand the working conditions of the Antarctic. There is no doubt an element of truth in this belief, though this does not need to be the case. The development and implementation of an effective plan needs to be a compilation of the effective procedures currently in place, an evaluation of ineffective policies, and a combination of input from other sources. These sources include established method from successful international programs, industry standards, and most importantly input from the people who have operated the existing system, or are going to implement any revised program.

3.0 Spill Response Plans

Fast and effective response to a spill regardless of size is critical to reducing the environmental impact and minimizing the cost of any required remediation. The critical issue are personnel protection and minimizing product migration. Adequate documentation and recording of the event is also crucial to the program ability to adjust future operational procedures to reduce the potential for a release due to similar causes. There is a potential for personnel resistance to thorough documentation because to often this is associated with an assignment of blame for an event and not on the attempt to gather the information required to prevent a future recurrence. Adjustments in the documentation procedures should be able to account for this resistance to thorough documentation of a release event. The development of the spill response team and the location in the organizational structure of the Station is critical for success in responding effectively.

Essential to any spill response action is adequately trained personnel and the proper equipment in sufficient supply. The similarity between a petroleum spill response and response to a fire is a natural link associating these two functions in the Antarctic. Modern training for fire response personnel often includes Haz-mat (Hazardous Materials) response due to the elevated potential for fire from the presence of flammable or combustible liquids during a Haz-mat spill. Therefore, establishing or augmenting the capabilities of existing fire teams to handle haz-mat response is a fast and sensible solution to developing the formal team required for catastrophic petroleum release responses. The training protocols and safety training are quite similar and the size of these teams is already geared towards the size and population of the stations. The population of the each Station has a linear relationship to both the fire response requirements and the quantity of stored flammable and combustible liquids. Therefore, with minor changes in the composition of existing fire fighting teams and the addition of a new response directive the fire fighting teams can be organized within the existing structure to effectively react to catastrophic events. Additional training to minimize product migration should not present a significant diversion from the primary role of existing fire fighting teams. The steady leakage of product or the minor release of product during transfer is most effectively handled as a maintenance function and the critical issue to repair the leakage and or readjust the transfer procedure to prevent reoccurrence and should not be treated as an emergency response.. The equipment required to address both catastrophic release and minor releases is actually quite similar.

Petroleum release response equipment is not complex and does not represent high technology. Remediation of environmental hazards is, in general simple, but does involve very hard work by safety and environmental professionals trained to protect themselves from exposure to the products they are handling, workplace hazards, and to quickly stabilize and reduce the potential for fire. The equipment required for response actions includes; a full range of personal protective equipment, explosimeters, absorbents and oil sponges, booms, flammable/combustible liquid handling pumps, storage vessels, oil water separators, emulsifiers, mops, buckets, etc. The first concern is worker safety and therefore the use of protective clothing, respirators, and decontamination procedures can not be emphasized enough. A significant part of the initial response is to stabilize and minimize the fire potential. Naturally, the first step is to ensure that the source of the release has been eliminated and the any free product has been transferred to an appropriate containment vessel.

Petroleum product releases take numerous forms. Catastrophic failure of a tank from a burst seam or from mechanical damage or puncture is generally considered worst case and accounts for a relatively small percentage of individual events however, the impact and response require the greatest effort. The continuous slow leakage of a tank or delivery system is less of an immediate catastrophe but when it remains uncorrected over time this could potentially release larger amounts of product into the environment than catastrophic failure of a full vessel. Finally, the release of product during a transfer operation accounts for the largest percentage of product release events and indeed may account for the largest percentage of lost product. Accurately identifying the magnitude of the event and gearing the the response action requires the presence of well trained and experienced professionals. Each spill event is unique but the response action can be designed and implemented to protect the people involved, reduce the potential for fire, and product migration in accordance to a well developed standard plan. To be truly effective these plans need to be field tested and flexible to allow for new technology and more effective solutions to be included.

3.1 Primary Response Actions

The immediate need to stop the uncontrolled release of petroleum products should take precedence over all events except personnel safety. The response is dependent on what type of release has occured. If a tank ruptures the only practical response is to minimize personnel exposure and attempt to reduce migration and to limit the area affected. Reducing the spread of product is critical in minimizing impact on the environment and also the cost of any subsequent actions required. There is a rule of thumb that states that the remediation of a spill event costs a minimum 5-20 times the investment needed to prevent the release prior to occurrence. Therefore, a significant part of responding to a release is to identify where the product is coming from. Sometimes this is a relatively simple exercise, a valve was left open, a broken pipe is visible, etc. It is surprising how often one still hears that a significant release occured because a valve was left open. However, very often the location of the leakage is very difficult to determine. It may come from a buried source such as a drum of waste, a leaking underground pipe, or leakage from the bottom of an on-ground tank, etc. and the analysis of these events may be quite complex. The complexity is often compounded by the need to maintain the system on line while locating the source of the leakage.

The response to a release event is often limited to the equipment that is immediately available and the technical expertise to respond effectively. This factor more than any other contributes to the spread of contamination and increases the cost of the dictated response. Thus there is a critical need for a standardized response that contains formal procedures and trained and experienced participants who have been adequately trained to understand the system under failure, the migration patterns associated with the vicinity, and the appropriate equipment needed to respond in an effective manner. The immediate installation of migration minimization techniques such as setting booms, weirs, oil sponges, or the use of sorbent material is critical to reduce the area contaminated by the release product. As with many other environmental issues the costs associated with an event are greatly reduced if waste minimization actions are instituted early in the process. Having an adequate supply of materials and a formal response plan of action greatly increases the ability of personnel to quickly address the release and minimize the migration

3.2 Remediation of Free Product

When a spill has occured and it is possible to identify the presence of free product, collection and containerization is the first step. The use of pumping and collection equipment depends on the location and thickness of the layer of product. Typically, all the methods include developing a collection point if one is not established naturally. A collection point is simply a ditch or trench or any other naturally occuring or manmade collection point from which the product can be pumped, bailed, or drained into a storage vessel. If there is significant presence of water or the free product is actually being collected off the water table the use of an oil water separator if one is available is recommended as a pretreatment. This should only be attempted if one is immediately available. The critical issue is to contain the flow of product and prevent it from spreading out over a larger surface area. Minimizing the migration of free product on water requires a considerable supply of Booms, Sponges and other absorbents that are hydrophobic and designed specifically for oil collection.

3.3 Product Migration Patterns

Part of the process of developing an effective spill response action is understanding and mapping the potential pathway free product will follow. This is somewhat simplified by the characteristics of the native soil and the relative impermeability of snow and ice to the absorption of petroleum products. The shallow depth to the permafrost layer and the absence of subsurface fluid flow patterns also minimizes the migration pathways. Therefore, there is a significant possibility that contamination from product releases are relatively near the surface and do not extend deep into the ice or native soils and rock. The mapping of primary migration routes is then a matter of adequately assessing the topography in the region of the storage tanks and accounting for seasonal changes. Developing an understanding of the product migration potentials is critical to developing the response action. Developing an accurate migration potential map is also critical to the development of a sensible remediation strategy. Basic to this concept is properly evaluating the migration pattern and identifying the impact on the the affected ecosystem.

4.0 Soil and Water Remediation

The primary remediation alternatives for contaminated soil, ice, and water are discussed with specific methodology for the Antarctic. The reduced hydrocarbon volatilization and the sluggish response of bioremedial dissipation mechanisms in soil necessitates pro-active remediation strategies. The stable of solutions available to the environmental response team is limited compared to current practices used in warmer climates. This is largely due to the low temperatures and lack of easily transportable equipment. Transportable soil remediation equipment is commercially available for both rinseate and incineration procedures however, the size and complexity of the units do not allow for easy application to the Antarctic environment. The incineration process typically utilizes a rotary kiln to heat contaminated soil to burn of the contaminant. Rinseate technology uses a secondary fluid as a solvent to wash contaminated material and the generated liquid is then reprocessed. The application of in-situ soil remediation techniques are discussed as an alternative to retrograde. The details regarding the use of oil-water separators and carbon filtration units for contaminated liquid processing to current drinking water standards are also presented as a method to reduce existing contamination in soils and water.

4.1 Physical Assessment and Development of Remediation Strategies

The remediation alternatives available to the environmental engineer operating in the Antarctic are significantly more limited than those available in the temperate zones. The natural dispersion and bioremediation processes are greatly slowed or in some cases non-existent due to the temperature and sterile nature of the Antarctic. These factors indicate that a significant part of the solution will involve proactive remediation efforts that occur on the continent to reduce the quantity of waste materials that might require retrograde.

However, the reality of life in the Antarctic indicates that even with greatly improved management, there is always the potential that significant releases will occur and will need to be addressed in a proactive manner. In addition, there is the issue of historical spillage. Significant spills, leakage and other major releases of petroleum products are known to have occured in various locations in the Antarctic. The nature of the native soils, permafrost, and ice do not allow for extensive vertical product migration and therefore the majority of contamination is believed to be surficial. The specific details of product migration tendencies have not been thoroughly explored to document this commonly held assumption. Historical spillage events have left residual contamination that is largely unmapped and potential impacts on delicate ecosystems have not been fully explored. The costs associated with retrograding or processing contaminated material are greatly escalated by the geographic location. Therefore, the emphasis and resources available should be first be directed at preventing the release of petroleum product in an uncontrolled manner and then at implementing practical remediation techniques to minimize the impact on the environment and reduce the volume of waste requiring retrograde.

The development of any remediation strategy is dependent on both the type of product released and the physical characteristics of the contaminated material. The majority of the petroleum based products that are presently in use in the Antarctic, JP-4, JP-8, Diesel, and lubricants respond to the most commonly used remediation techniques in a similar manner. However, the dispersion characteristics vary greatly. This is largely due to the viscosity of the product. Therefore, the same techniques can be applied to most of the petroleum based products that are likely to be released in significant quantities. The majority of remediation technologies are designed to deal with water or soils. The development of extraction technologies to remove hydrocarbon contamination from snow and ice are not well developed and into the foreseeable future the remediation of contaminated snow and ice will require a phase change and processing as a liquid. Soil remediation techniques applicable to the Antarctic are identical to those use in the temperate zones and include incineration, rinsing, or landfilling.

The volatility of petroleum products such as JP-4, JP-8, and Diesel fuels is greatly reduced at colder temperatures. Therefore, one of the dissipation mechanisms often relied upon in warmer climates to reduce the presence of contamination in soils operates at a greatly reduced rate rendering it much less effective. A second more powerful mechanism that effectively reduces the presence of petroleum contamination in soil is bioremediation either naturally occuring or artificially stimulated, but the temperatures and sterile conditions of the Antarctic all but eliminate the effectiveness of this process.

4.2 Implementing a Remediation Strategy

Developing a sensible remediation strategy is dependent on a number of factors. The amount and type of product released should be adequately defined as a first step in evaluating what type of remedial response should be instituted. The medium that has been contaminated defines what the response should be. the development of the an accurate migration potential and risk assessment is critical to defining the impact on affected ecosystems. If the release has occured on snow or ice then a course of action to contain and process the contaminated material as a liquid makes considerable sense as an end point remediation strategy.

4.2 Soil Remediation Methodologies

There are four well developed and field tested technologies for the remediation and restoration of petroleum contaminated soils that are in wide use today. The base description for these technologies are soil venting, extraction, microbial degradation, and incineration. The use of incineration is the most widely applied restoration technique and portable incineration units of various capacity are available. Incineration is considered the most applicable technology for the Antarctic and will be discussed at the end of this section. Another alternative widely used in the United States is landfilling. This is a useful technique where contaminated material is present in a highly sensitive location, has a high potential for uncontrolled migration to sensitive locations, or is at an elevated potential for exposure to human and animal populations. However, landfilling has limited use in the Antarctic due to treaty limitations and the inevitable criticism that such a program would engender. A brief description of the applicability of each of these technologies is discussed.

Soil venting is a technique that is widely used for volatile products and has a potential application for in-situ gasoline remediation projects. However, this process is highly temperature dependent and the nature of the soils present in the Antarctic do not lend themselves to this type of forced aeration due the relative impermeability of the permafrost barrier. Various types of contamination extraction processes are available on the market. This technology was developed by the mining and oil recovery industry primarily to remove and concentrate gasoline contaminants. The most common rinseate used is water, but the use of several other types of fluids and surfactants have been successfully used. However, The low temperatures of the Antarctic minimizes the applicability of any process utilizing liquids with freezing points below the ambient temperature. The soil characteristics commonly found in the Antarctic have a tendency to impede the flow of air or fluids through the soil matrix and reduce the particle surface to extraction medium contact ratio thus reducing the removal efficiency. Naturally occuring and nurtured bioremediation system are widely relied on to reduce the level of contamination in soils. However, bioremediation requires a sufficient supply of nutrients in the soil and is most effective at an ambient temperatures above 75' F (25' C). Therefore, these technologies do not appear to be very promising for use in the Antarctic.

Thus, the remaining possibility with an adequate field testing record to warrant application to the Antarctica is incineration. This method has proven effective at removing a broad range of petroleum contaminants from soil by complete oxidation. Rotary kilns and fluidized beds have documented removal efficiencies above 99% and is generally considered the most effective permanent solution for contaminated soils because it provides almost total destruction of contaminants. Mobile units are commercially available from a number of manufacturers in a variety of system configurations. However, the capitol costs and operating costs for these units is considered to be the highest of all the remediation alternatives. The cost of any applied remediation alternative can be significant and even small short duration remediation projects will require significant investments of time and money. Therefore, the most cost effective investment is to minimize the potential for an uncontrolled product release to the environment.

4.4 Ice, Snow and Liquid Remediation

The remediation technologies that have been found most effective are designed to handle contaminated liquids. Snow and ice
present a unique problem and to date no effective mechanism exists to reduce the contamination of snow and ice to acceptable levels directly. Therefore, until more effective technology is developed snow and ice will have to be melted and then processed as a liquid. The phase change required can be either naturally occuring or induced. The most cost effective method to induce the required phase change would be to use waste heat from existing boilers, furnaces, and incinerators. Naturally, the least expensive method is to store contaminated snow and ice in a secondarily contained impoundment and wait for it to melt naturally and then process the liquid.

There are several effective methods to reduce hydrocarbon contamination from water that have been proven effective and are generally accepted in the industry. Many of these are based on air to fluid contact via enhanced surface contact used to strip volatile hydrocarbons from the host medium. However, this process is highly temperature dependent. One of the methodologies considered promising for use in the Antarctic and well established as an effective remediation technology in other climates is based on oil water separator technology with secondary processing of the liquid to further reduce the level of contamination.

The oil water separator is a simple effective method to reduce the hydrocarbon concentrations in water to reasonable levels 10-20 PPM Total Petroleum Hydrocarbons (TPH). This technology is based on the difference in specific gravity of petroleum products and water. It is a simple truth that oil floats on water and this is the basis for the separation technology. The units are quite simple and effective and if mounted with small resistance heaters or otherwise operated in an environment tats reduces the potential for freezing these units can provide a very cost effective method to reduce the concentration of petroleum contamination in effluents from the various well established bases and provide a means to process some of the potential waste stream generated at field camps and remote stations with out the requirement that these materiels be retrograded back to a member nations home country or disposed of by other means.

The cost of these units is relatively modest $5-7000 per unit and the technology is applicable to a broad range of petroleum products and other material that has a specific gravity less than water i.e. less than one. The specific gravity of water is defined as one. This provides an excellent first stage process to reduce major concentrations of petroleum contaminants in fluids. With the major contamination removed from the base liquid the question returns to final end point disposal of the tainted or still contaminated liquid. This issue then depends on specific effluent standards that must be adopted and then conformed to in all disposal matters. Many developed nations have standards, conventions, or regulations associated with end point remediation standards that may be partially applicable for use in the Antarctic. However, The base issue remains whether to reuse this tainted liquid in some form, dispose of it as a remediated end product, or to further process it to drinking water standards or some more stringent criteria.

After the majority of contamination has been removed from the subject liquid, a decision must be made whether to further process the liquid, to reuse the liquid water for other purposes that do not require drinking water quality standards, or to dispose of it as a sufficiently processed material. There are several effective secondary processing stages. The best known is activated carbon filtration which is an effective and proven method to remove a broad range of various contaminants from fluids. The technology is readily available and can be implemented quickly and effectively for both point of use requirements and for general remediation of large quantities of liquids. A significant factor in the use of this technology is the cost of the carbon filter cartridges. The cartridges need to be monitored for effective effluent characteristics. In addition, the cost of the cartridges needs to be evaluated both in terms of the transportation and retrograde costs and the sampling and disposal costs as a potentially hazardous material.

The petroleum products that have been collected from the processing would in most cases be a mixture of various components and would not be suitable for reuse. In cases where significant amounts of an identifiable product have been recovered there is the possibility that it can be processed and reused on the continent. Optimistically, this could only be used in the most simple equipment like Preway heaters or other gravity feed heating equipment and other equipment that is not sensitive to minor variations in fuel mixtures and the majority of this material would still need to be retrograded back to the member nations. However, at a minimum this type and scale of processing would cut the quantity of material requiring retrograde to a fraction required to transport unprocessed contaminated materials.

Appendix A: Personal Biography

Carl Kohlmeyer
1232 D Street, NE
Washington, DC 20002
(202) 547-4587

Carl Kohlmeyer entered the environmental consulting field 6 years ago and has steadily expanded an understanding of the regulatory environment, management, technical trends, and future currents in the industry. He is a mechanical engineer, a registered Petroleum Operations Engineer, and is licensed to do environmental work associated with liquid storage tanks and asbestos in several states.

Mr. Kohlmeyer recently completed a high profile project for the National Science Foundation's United States Antarctic Program at Mcmurdo Station. The Project remediated: 900 Drums of hazardous waste, contaminated soil, a 15 acre landfill contaminated with asbestos, and conducted industrial hygiene & asbestos inspections of the entire research station and the South Pole station. Participated in all aspects of the planning, logistics, and execution. Managed and oversaw the soil remediation and the characterization, overpacking, and repackaging the drums of hazardous waste.

The primary focus since 1989 has been underground and aboveground liquid storage tank systems. As Regional Manager for the Bell Atlantic Telephone Company Liquid Storage Tank Program in Pennsylvania and Delaware he directed and implemented all aspects of turn key construction management including: permitting, design, specification, and CAD drawing development, removal and installation oversight, soil and groundwater sampling, soil remediation, system start-up, and development of remediation systems. Management responsibilities included all aspects of the bidding process, assisting owners in contractor selection, overseeing field performance of contractors and inspectors, negotiated contracts, change orders and acted as a liaison to regulatory authorities.

Prior to and concurrent with the UST/AST work was heavily involved in the asbestos industry. Managed and participated in numerous large inspection and abatement programs for municipal, commercial, and government clients including the New York Transit Authority, United States Postal Service, municipal governments, and various property management companies.

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A Mobile Oil Spill Fighting Unit

by

H. Kohnen and K. Henning
Alfred Wegener Institute for Polar and Marine Research, Germany

Introduction

A major concern of environmental protection in Antarctica, as also manifested in the Protocol of 1991 to the Treaty, is the prevention, mitigation and control of oil spills. The transport of fuel in a double hull icebreaker to the Antarctic, the transport in low temperature steel containers on the ice as well as the storage of fuel in steel containers at the station, which are mounted in steel containments, can be regarded to be sufficiently safe. The well-known weak point in the fuel delivery, however, is the transfer from ship to shore using fuel hoses. If such a hose breaks during transfer operation, some thousands of litres may easily spill into the sea or onto the ice or land. In order to effectively fight such events the Alfred-Wegener-Institute has introduced a mobile unit carried on board FS "POLARSTERN" which is able to cope with spills.

The components of the unit

The mobile system basically consists of containment and recovery components like boom, drum skimmer, collection tanks and power pack to drive the skimmer together with hoses, nozzle equipment and tools. As each component weighs less than 500 kg it can be easily transported by helicopter, truck or a small boat. All components are housed in two isonorm 10' containers.

Container No 1 contains :

- hydraulic driven drum skimmer with a recovery capacity of 100 to to 1500 l/h depending on the type of oil, seastate and viscosity;
- portable powerpack (Diesel) of 15 kW, 220 V/380 V, 50 Hz to drive the hydraulic aggregate (4 kW, 50 bar max), the hydraulic peristaltic discharge pump (max. cap. 25000 l/h) and the skimmer. The power can, of course, also be taken from another external power source
- 2 collection tanks of 800 l each
- 20 m hydraulic hoses
- 10 m suction hoses
- 20 m discharge hoses and various tools.

The container, including the equipment, weighs 3 tons.

Container No. 2 contains :

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*) Alfred-Wegener-Institute for Polar and Marine Research, P.O. Box 12 01 61, 2850 Bremerhaven/Germany

- 200 m boom, type Expandi 3000, together with roto pac-spooling system (30 cm depth);
- absorption boom, absorption mats;
- 2 floating collection tanks of 5000 l each;
- various tools and spare parts.

Container No 2 is heated electrically (2 kW) which is not required for Container No 1. The capacity of the whole system can easily be modified according to the users' specific requirements.

The operating

The system is designed for the recovery of oil spills up to about 10,000 l in one operational cycle. In case of an oil spill, the boom is brought out first to confine the spill. Subsequently, the drum skimmer is mobilized within the spill to skim the oil. A drum skimmer has been chosen and developed because it is simple to handle, efficient and reliable, and it has proved excellent performance with light, medium as well as with heavy oils. The skimmer floats and has a very low draught so that it can also be used in very shallow water. The skimmer is driven with the aid of the hydraulic aggregate either from board, from a boat or even from an ice flow. Only four trained persons are required to effectively operate the system .

Thus, other skimmers like mop of foxtail skimmers can be provided optionally. However, drum skimmers have proven best performance in connection with the use of polymers (see below).

The efficiency of recovery is enhanced up to 10 times by using a high molecular weight, non-toxic polymer which is sprayed on the oil spill. (We are using the US brand ELASTOL). There are no chemical reactions. The elongated polymer molecules make the oil highly cohesive. The process is merely mechanical. The mixture does not sink and not disperse in the water. Mixtures of some hundreds ppm up to one percent, depending on the oil specifications and environmental conditions, are sufficient to make the oil behave like a floating viscoelastic film which can very effectively be removed from the sea surface by the skimmer. The recovery rate is very high. Our tests have shown that, for instance, a mixture of 100 l of oil and 1 kg of polymer could be recovered up to 98 % in less than half an hour. The water, sucked in together with the oil, separates by gravity from the oil and can be drained as clear water.
The figures 1 to 4 give an impression of the equipment.

Summary

A mobile oil spill fighting unit has been developed which consists of light weight components. The components can easily be assembled as well as easily be handled for the effective recovery of oil spills of the order of some tons of oil. The efficiency of the unit is significantly enhanced by using an untoxic polymer, sprayed on the spill, acting as a cohesive agent and making the oil viscoelastic.

It might be of advantage to use air propulsion for the oil skimmers when positive temperatures are expected.

Worth to mention is that the oil-polymer mixture can be used again.

Figures:

1. The 2 containers housing the equipment.
2. The equipment of Container No. 1 from left to right: hydraulic pump, hydraulic aggregate, drum skimme, generator. One collection tank is seen in the container.
3. The components (from left to right): drum skimmer, generator, hydraulic aggregate, hydraulic pump together with suction hoses and hydraulic hoses.
4. The drum skimmer in action. The skimmer is protected against water by plastic covers. The sharp border between water and the oil-elastomere mixture can clearly be seen.

Fig. 1

Fig. 2

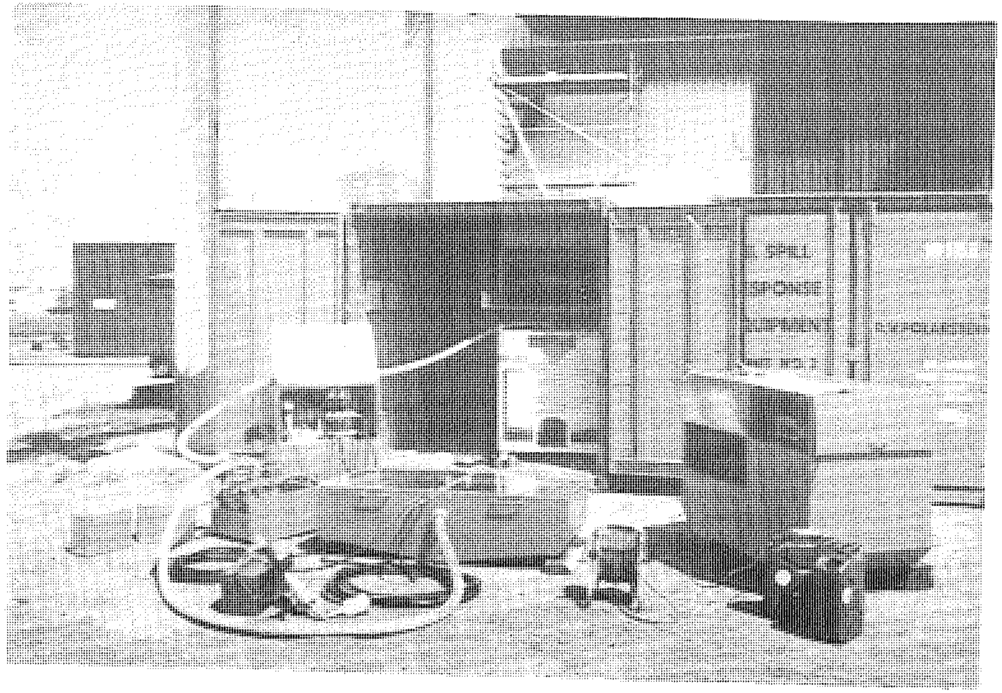


Fig. 3

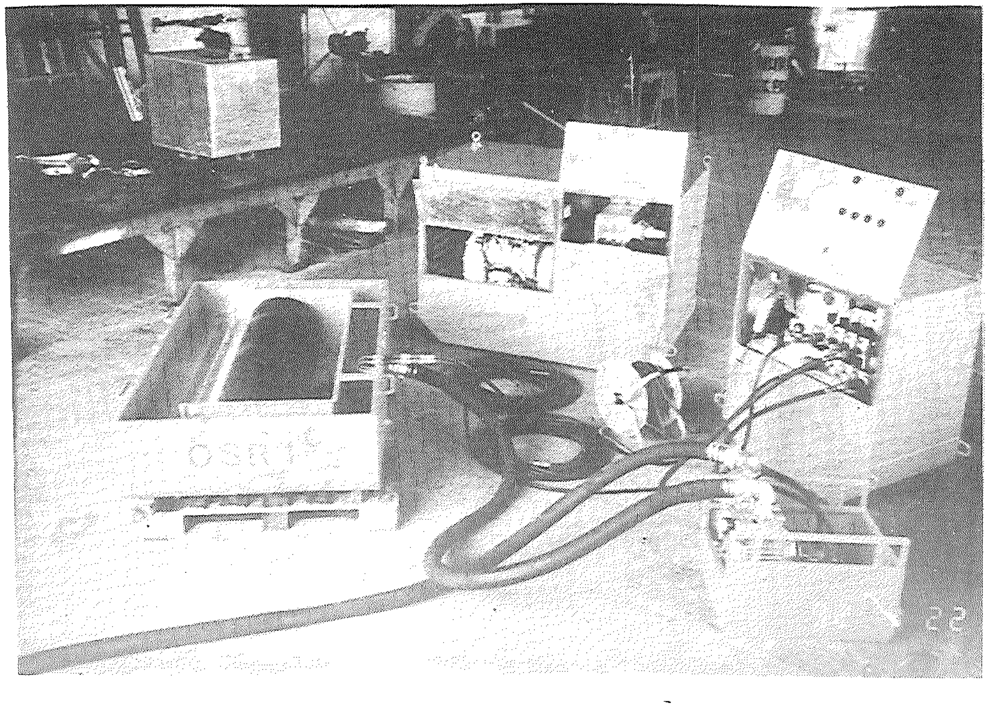
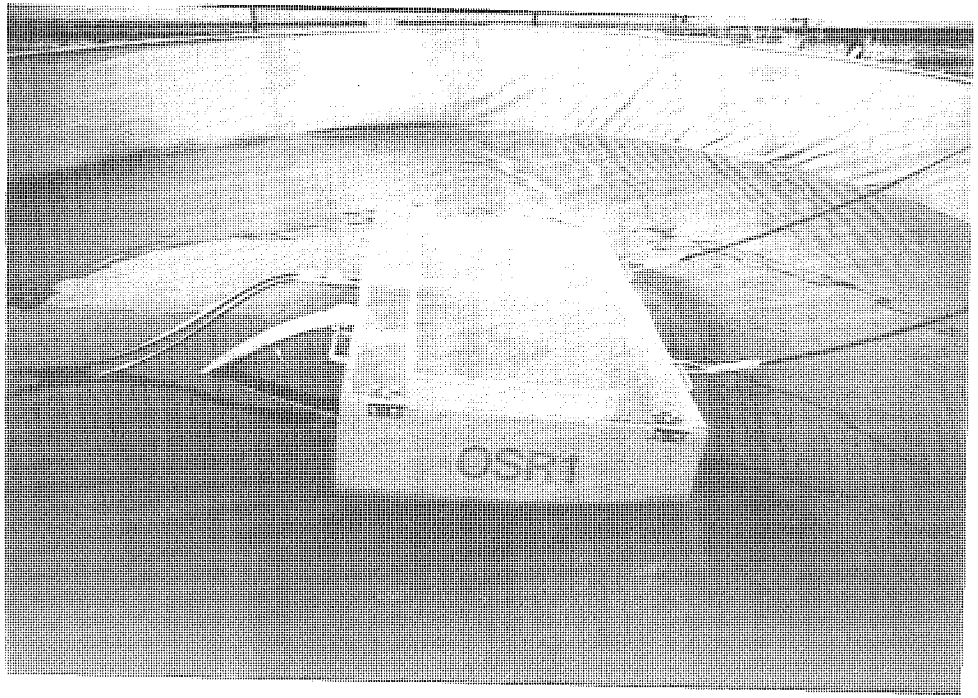


Fig. 4



Fuel Spill Response Contingency Planning Process

by

Arthur J. Brown and V. Earl Strickland
U.S. Antarctic Program, USA

ABSTRACT

The potential impact of fuel spills in Antarctica, particularly in marine areas, is of international concern. At the 1989 Antarctic Treaty Consultative Meeting (ATCM), Spill Recommendation XV-24 urged the Treaty Parties to establish contingency plans for marine spill response. Annex IV, Article 15, of the Protocol on Environmental Protection to the Antarctic Treaty, done at Madrid in 1991, requires contingency plans for response to incidents with potential adverse environmental effects.

The U.S. Antarctic Program (USAP) initiated spill response planning in September 1990 and has been working closely with the Standing Committee on Antarctic Logistics and Operations (SCALOP), Sub-group on Oil Spill Prevention and Response, to recommend the format and content of such plans to the Council of Managers of National Antarctic Programs (COMNAP). This paper discusses the USAP six-phase contingency planning process.

INTRODUCTION. Maritime and other accidents around the world have discharged large quantities of petroleum products that threatened the environment, particularly the offshore marine ecology and coastlines. Notable incidents in U.S. coastal waters — the EXXON VALDEZ in Prince William Sound, Alaska, the MEGA BORG in the Gulf of Mexico, and the AMERICAN TRADER off Huntington Beach, California — have refocused public concern and heightened government resolve to prevent and prepare for spills.

U.S. and other members of national antarctic programs recognize the vulnerability of Antarctica to pollution and the importance of environmental protection of the region. The U.S. Antarctic Conservation Act of 1978 is our primary law governing U.S. activities in the Antarctic. Under this law the National Science Foundation has initiated actions to protect the environment. More recently, Recommendation XV-24 of the Antarctic Treaty Consultative Meeting of 1989 calls on the treaty parties to establish contingency plans, and Article 15 of the Protocol on Environmental Protection to the Antarctic Treaty, done at Madrid in October 1991, requires contingency plans for response to incidents with potential adverse environmental effects. The United States initiated an oil spill response contingency plan project in September 1990. The oil spill response expertise of Jamestown Marine Services, Inc. was contracted to work with the National Science Foundation's Antarctic Safety, Environment, and Health Implementation Team to execute the project.

This paper presents the contingency planning process we employed to prepare to respond to spills near U.S. Antarctic Program locations.

PLANNING CONCEPT. We have modeled our process on classic military operations contingency planning. This methodology recognizes that a contingency plan involves a spectrum of operations and that each element requires attention. By considering an oil spill as the adversary that we must be prepared to combat, the similarity between oil spill response planning and military planning becomes obvious (figure 1). The planning, therefore, was structured in six phases:

- Phase I — Background and analysis
- Phase II — On-site surveys and data collection
- Phase III — Spill scenario development and risk assessment
- Phase IV — Spill response contingency plan development
- Phase V — Response equipment requirements and procurement
- Phase VI — Training and spill response exercise instruction

FIGURE 1. Comparison of Military and Oil Spill Response Planning.

MILITARY OPERATIONS CONTINGENCY PLANNING	OIL SPILL RESPONSE CONTINGENCY PLANNING
— Define mission	— Identify goals
— Intelligence collection	— Background research and analysis; Site specific data collection
— Enemy capabilities analysis	— Spill risks assessment
— Identify friendly forces assets	— Identify response personnel and equipment habits
— Develop concept of operations	— Develop concept of response actions
— Develop alternative courses of action (COA)	— Develop alternative courses of action (COA)
— Refine COA to determine: WHO will execute action WHAT action is planned WHEN will action begin WHERE will action take place HOW will action be accomplished	— Refine COA to determine: WHO will execute action WHAT action is planned WHEN will action begin WHERE will action take place HOW will action be accomplished
— Train and exercise forces	— Train and exercise response team

We found that the process must be flexible; some phases may overlap, some may be taken simultaneously, and some are iterative.

Before beginning the plan, we defined our most important goals:

- Permit immediate and decisive response to oil spill incidents
- Implement preventive and precautionary spill measures
- Implement regional and area/facility oil spill response contingency plans
- Identify and acquire needed spill response equipment
- Train the spill response organization

Next, we established criteria essential to achieve the goals. We agreed that, due to the remoteness of Antarctica, the harsh climatic conditions, and the limited availability of people and equipment, the most effective action is prevention. Prevention encompasses such areas as engineering safeguards in fuel storage and transfer, standard operating procedures for fueling, containment barriers around high-risk spill areas, and training. Precautionary measures were established as the second most important factor. Precautions include: deployment of the initial-response team, testing of spill response equipment before high-risk operations, and storage and prepositioning of response equipment near the most likely spill locations. The next factor was determined to be the ability to contain spills quickly and to clean them up rapidly, by having in place a well-organized, well-equipped, well-supervised, well-trained, and well-supported response team. Finally, a successful response must incorporate demobilization to avoid spreading the contamination to other locations and to ensure that all people and equipment are ready for the next emergency.

Conceptual analysis is an important first step as it provides direction to the planning. On completion of the analysis, the contingency planner better understands the requirements for the plan, the top-level objectives of the plan, and the order of planning.

PLANNING PROCESS. This section discusses the six phases of the planning process.

Phase I — Background Research and Analysis. Phase I is critical to subsequent phases and, ultimately, the quality of the plan. This phase ensures that our plans 1) equal the standards established by plans proved to be effective, 2) follow guidance of oil spill response experts, 3) are realistic in terms of previous spills at U.S. antarctic stations, and 4) incorporate recent developments in cold climate oil recovery equipment and technology. During this phase, we established a technical library of spill response contingency plans, such as those prepared by the U.S. Navy, U.S. Coast Guard, other U.S. Federal and state agencies, other countries, and commercial oil companies. The library also contains spill response planning guidance, such as that published by the International Maritime Organization (IMO), and reports of lessons learned from previous cold climate spills like the EXXON VALDEZ. The library also acquired the results of equipment tests, such as a test of the rope mop skimmer system in ice-infested water.

In this phase, we analyzed engineering drawings of petroleum storage and handling facilities at USAP locations, and we analyzed fuel system operating procedures. We reviewed the cause, response, and effect of previous oil spills at U.S. sites. This element proved valuable in the preparation of data-collection forms used during Phase II.

Phase II — On-Site Surveys and Data Collection. We viewed and recorded the potential oil spill environment and response capabilities at each location, and we interviewed operators and managers in order to evaluate current procedures, equipment, facilities, and capabilities for oil spill response. This information enabled us to assess risk and formulate response actions. The keys to the success of this phase were detailed planning and prior coordination with the managers and operators.

Using the information gathered during Phase I, a survey package was developed that contained all available information known about each site regarding:

- Type and quantity of petroleum products stored at the site
- Fuel storage facilities and transfer systems
- In-place containment and alarm systems, operating procedures, maintenance procedures, personnel manning levels, and organizational structure
- Spill response and support equipment on site
- Communications capabilities
- Location topography and coastal hydrography (if applicable), as well as the location of nearby environmentally sensitive areas

Based on this information, site survey data-collection forms were prepared. On-site surveys were conducted at McMurdo Station, Amundsen-Scott South Pole Station, Palmer Station, and onboard the R/V POLAR DUKE. One lesson learned during this phase was the importance of dialog between the survey team and experienced site personnel. The survey team is on site for only a short time, and conditions and operating tempo can be deceiving. For example, our team visited McMurdo in January 1991, when ice in Winter Quarters Bay was unusually light. The observations resulted in containment boom recommendations that could not be implemented in January 1992, when the ice was heavier. This example highlights the need to plan alternatives for use when primary methods are not practical.

Phase III — Risk Assessment. Risk assessment and the development of spill scenarios permit the identification of preventive and precautionary measures and planning for responses. Training realism is enhanced if this phase is properly executed. Risk assessment was analyzed in terms of the probability of a spill occurring, and the consequences if it occurs. For example, the likelihood of a spill accident during routine, daily fueling of day tanks and vehicles is relatively high, but the damaging impact would be minor. On the other hand, the failure of a large storage tank is remote, but the results could be disastrous. Information gathered during phases I and II is critical to the risk assessment phase.

We evaluated the data collected regarding fuel storage and transfer facilities, focusing on the quantity and types of fuel present, the material condition and maintenance history of the fuel systems, safety control devices, and containment measures. This information was then analyzed in relationship with high-risk fuel operations, such as tanker offloads, and more routine operations such as refueling day tanks, vehicles, and aircraft. Less likely spill threats, such as aircraft accidents and visiting ship groundings or collisions, were considered. Finally, the site topography and hydrography were evaluated to determine probable spill migration paths and potential impacts on inhabited or environmentally sensitive areas. Figure 2 shows how this information is displayed in the contingency plans.

Phase IV — Contingency Plan Development. The oil spill response contingency plan documents the planning necessary for immediate and decisive response to a spill. It details the identity and responsibilities of the response team members, equipment, and support elements, and it guides actions from initial reporting to demobilization. The plan provides information for making as many decisions as possible prior to a spill in order to increase response effectiveness and to give direction to the spill response team. The plan must be easy to use, yet it must contain direction for all contingencies and minimize the need for other reference material.

In order to simplify the instructions for response to spills of greatly varying magnitude, the following three categories of response actions have been defined.

- Level I - Spill cleanup **WASTE** does not exceed three 55 gallon drums and fire department notification or support is not required. These type spills are the small spills associated with fuel transfer or handling evolutions. The amount of spill clean up waste is determined by the fuels officer and validated by the Public Works Officer/Designee. Response team assistance is **NOT** required.

- Level II - Any **WATERBORNE** spill or spill cleanup **WASTE** exceeding three 55 gallon drums that can be handled by the response team. The size of the response team will be determined by the designated On-scene Leader. The initial response will be the duty five-person team. This team may be increased by other five-person teams as needed. Any waterborne spill requires the entire spill team to be alerted and mobilized.

- Level III - Any oil spill that cannot be handled by the oil spill response team. Control and clean up of the spill requires outside assistance. The entire response team will be mobilized for this level of spill to contain the spill and initiate recovery actions pending the arrival of outside assistance.

We determined several types of plans were needed to satisfy the requirements stated above and to be responsive to the diversity of USAP locations — ranging from field camps with a few people to McMurdo Station with a population of 1,100 or more. These contingency plans were developed:

- Headquarters oil spill response organization and procedures manual
- Regional oil spill response contingency plans

FIGURE 2. Spill Scenario Matrix - Palmer Station.

SPILL RISK CATEGORY[1]	PROBABILITY OF SPILL[2]	SPILL SIZE IN GALS[3]	MIGRATION TO WATER OR SPREAD THREAT[4]	ENVIRONMENTAL IMPACT (5)
PIPELINE OR HOSE RUPTURE/LEAK: Pipeline ruptures can vary greatly from minor cracks not readily detected to a major fracture in piping, joints or fittings. Leaks in hoses and hose fitting used in fueling/defueling evolution are generally readily detected and stopped. The 4-inch fuel hoses hold about .65 gallons per foot or about 98 gals per 150 ft. The impact would be greatest when the rupture occurs where the fuels migrate into open water.	High	10-1000	High to None	High to Minimal
BI-ANNUAL REFUELING: A spill resulting from a hose parting is not likely due to the low transfer pressure the hose is subjected to. Since offload is monitored continuously a spill would be minimized. Spreading is controlled and environmental impact minimized by preventive boom and sorbents.	Low	<100	High to Medium	Medium
RESEARCH VESSEL GROUNDING: Grounding or collision not likely because of crew familiarity with the area and precautions taken during transit.	Low	10 - 1000	High	Highest
HELO REFUELING: Infrequent, hand accomplished evolutions. These small spills will be absorbed in ice or snow and are not a severe threat to the environment.	Low	<10	Low	Minimal
FUEL TRANSFER - TO SHIP: These evolutions involve system line up and gravity-feed operations. Overflow due to non-existent or improper functioning high-level automatic shut-off or alarms. Operator error is the most common cause of spilling. If a line ruptures during pumping operations fuel could spill unobserved for a period of time.	Medium	10 - 100	None to High	High to Minimal
SHIP POLLUTION: All ships are likely to spill fuel. This can result from overfilling tanks during transfer, pumping oily bilge water overboard, ruptured tanks at the skin of the ship, broken, overboard discharge pipes running through fuel tanks, or improper valve line up.	Medium	>100	High	High
DAY TANK REFILL: These evolutions are done by a limited number of personnel and involve small amounts of fuel. Operator error accounts for most spills. Automatic shut off failure in GWR tank could result in overflow reaching Arthur Harbor	Medium	<10	Low	Minimal
SMALL BOAT SPILL: Very small amounts of fuel from a broken or leaky fuel line could spill into the water. Preventive sorbent and containment boom reduces the environmental impact when the boats are in the water.	Low	<10	High	Minimal
AIRCRAFT/HELO CRASH: Worst environmental impact if the accident occurred near or over open water where fuel would spread. Fuel from crash on land is likely to burn.	Low	250-3,000	High to None	Medium
BULK STORAGE TANK FAILURE: A bulk tank failure would migrate to open water. These tanks are 125K capacity and are situated on steep slopes to open water This migration would cause the most serious impact on the environment. However, total failure and complete loss of contents are unlikely.	Low	Up to 50,000 gallons	High to None	Highest

- Area/facility oil spill response contingency plans
- Research vessel oil spill response contingency plans
- Field camp oil spill response guidebooks

This hierarchy of plans is shown in figure 3.

The *Headquarters Oil Spill Organization and Procedures Manual* is for use by the National Science Foundation, Division of Polar Programs, Emergency Management Team. It reviews spill risks at the various locations, describes people and equipment at each site, describes communication capabilities, gives management guidelines for reporting and documentation, and describes how to acquire outside assistance. Figure 4 is a matrix of information found in the Headquarters manual.

The *Regional Oil Spill Response Contingency Plans* are for use by the Senior U.S. Representative, Antarctica (SUREPA), and the local facility managers. Regional plans have been prepared for the USAP centered on McMurdo (the Continental Region) and the part centered on the Antarctic Peninsula (the Peninsula Region). The plans describe fuel spill response capabilities at each site and provided guidance on outside assistance, media and public relations, and reporting and documentation. Figure 5 is a matrix of information in the regional oil spill response contingency plans.

The *Area/Facility Oil Spill Response Contingency Plans* are for use by the local facility manager, the response team, and the response support organization. These are the "how to" plans that describe, in detail, preventive and preparedness measures; the identity and responsibilities of each response team and support organization member; the type, quantity, and location of all response equipment; and what response actions should be taken, when, and by whom. These plans detail actions by the spill discoverer, such as stopping the source of the spill, who to notify and how, and how to take initial containment action; actions by the response team, such as how to mobilize, spill containment and recovery procedures, surveillance and tracking, how to restore impacted areas, how to monitor spill fate and effects, and how to decontaminate personnel and equipment. Question/answer decision trees and diagrams guide the user through the actions. Figures 6 and 7 are examples of a decision tree and a diagram. The area/facility plans also describe the available communications and how they should be used. The plans provide guidance concerning personnel health and safety and spill incident reporting and documentation. Figure 8 is a matrix of information in the area/facility oil spill contingency plans.

The *Research Vessel Oil Spill Contingency Plans* and *Field Camp Oil Spill Response Guidebooks* provide information similar to that in the area/facility plans, but tailored to the requirements of the vessel or field camps. As with the area/facility plans, these are "how to" plans that describe preventive measures, appropriate response actions, and spill incident reporting and documentation requirements. Figure 9 is a matrix of information in the field camp oil spill response guidebooks.

To be effective, a contingency plan must be dynamic. It must reflect the current status of equipment, people, spill risks, and the spill response organization. Because of this, many planners say a contingency plan is never truly finalized. The USAP validation and change procedure is designed to arrive at a final set of plans while recognizing the need for updates.

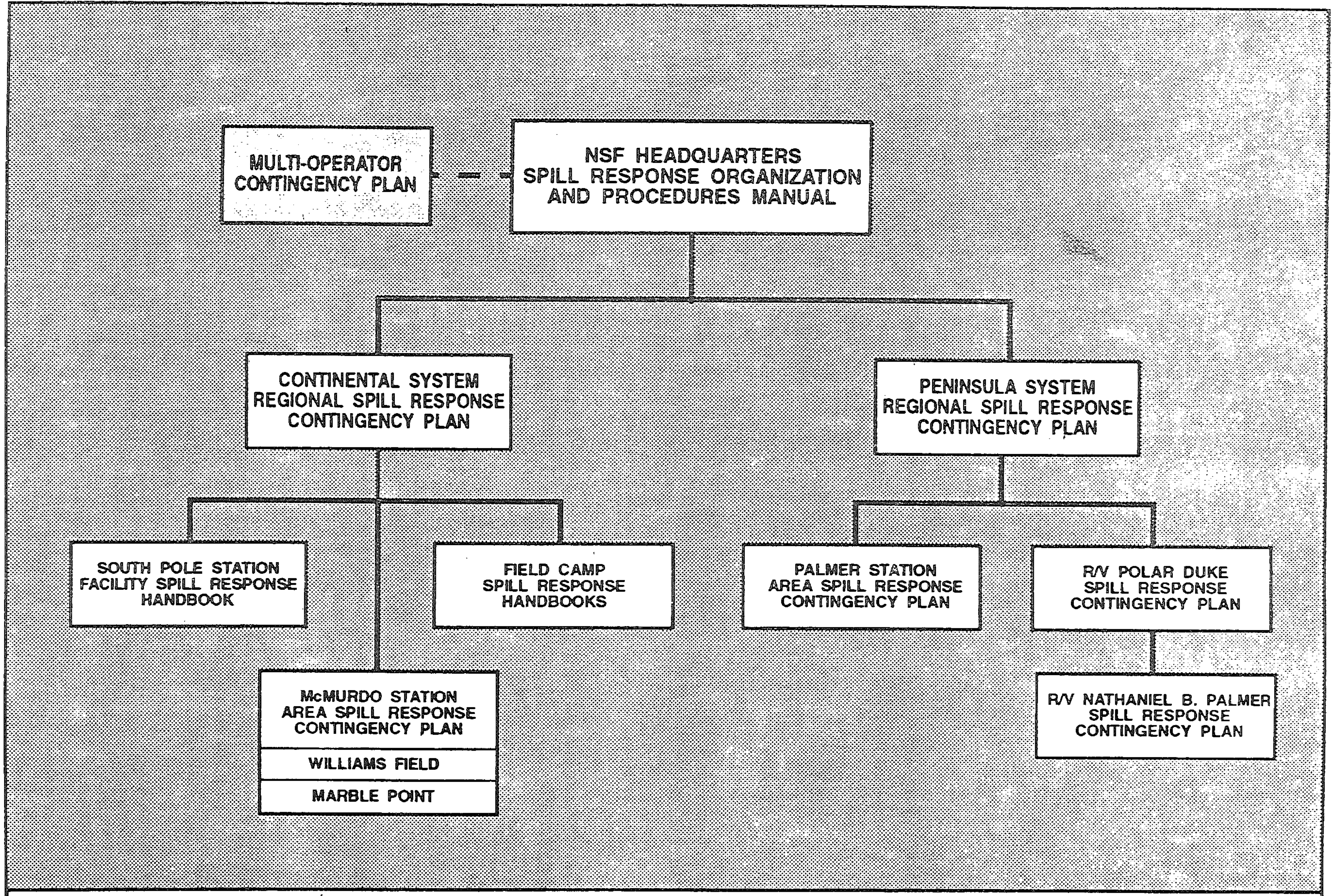


FIGURE 3. USAP Oil Spill Response Contingency Plan.

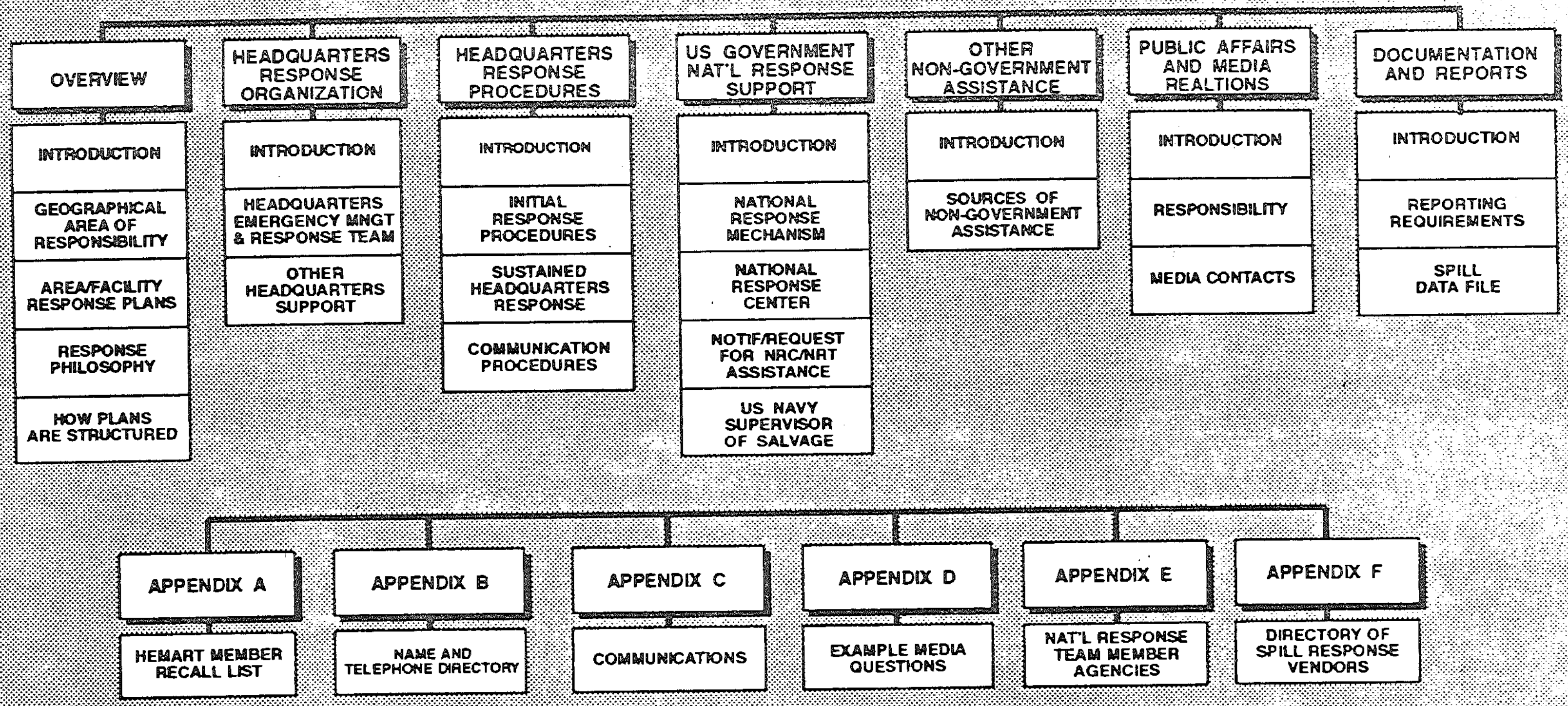


FIGURE 4. Headquarters Spill Response Organization and Procedures Manual.

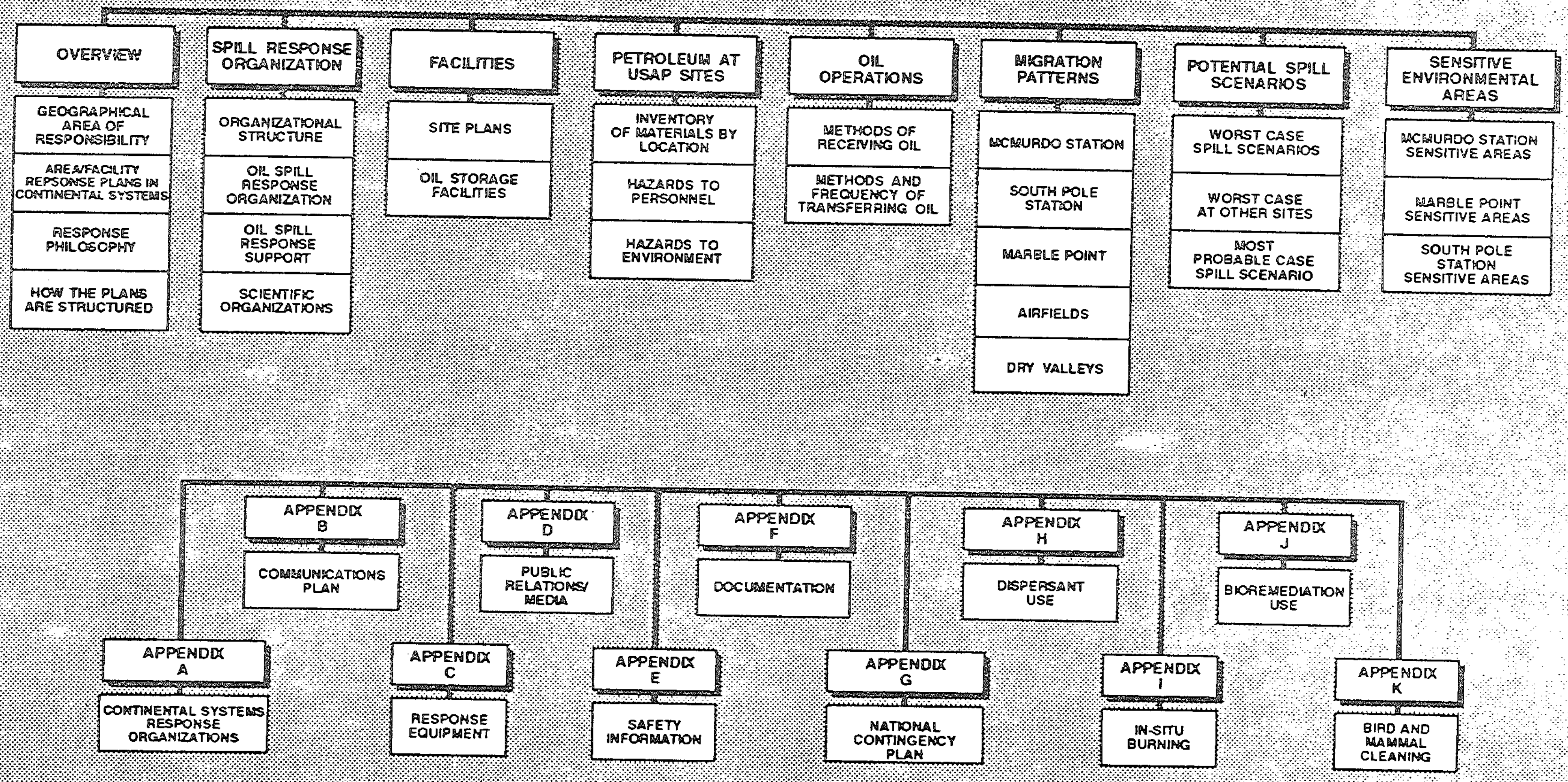
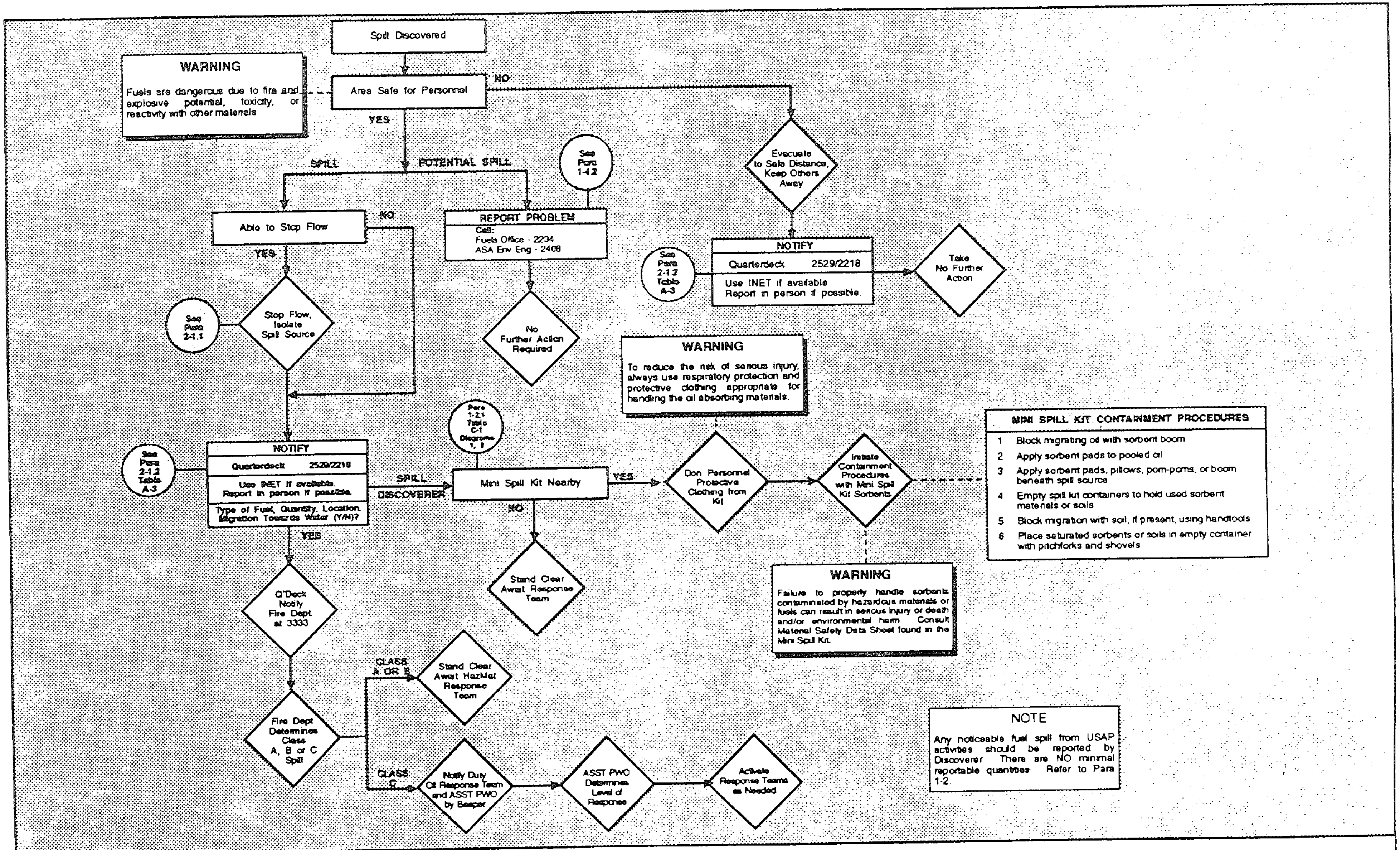


FIGURE 5. Regional Oil Spill Response Contingency Plan.



WARNING

Fuels are dangerous due to fire and explosive potential, toxicity, or reactivity with other materials

WARNING

To reduce the risk of serious injury, always use respiratory protection and protective clothing appropriate for handling the oil absorbing materials.

MINI SPILL KIT CONTAINMENT PROCEDURES

1 Block migrating oil with sorbent boom
2 Apply sorbent pads to pooled oil
3 Apply sorbent pads, pillows, pom-poms, or boom beneath spill source
4 Empty spill kit containers to hold used sorbent materials or soils
5 Block migration with soil, if present, using handtools
6 Place saturated sorbents or soils in empty container with pitchforks and shovels

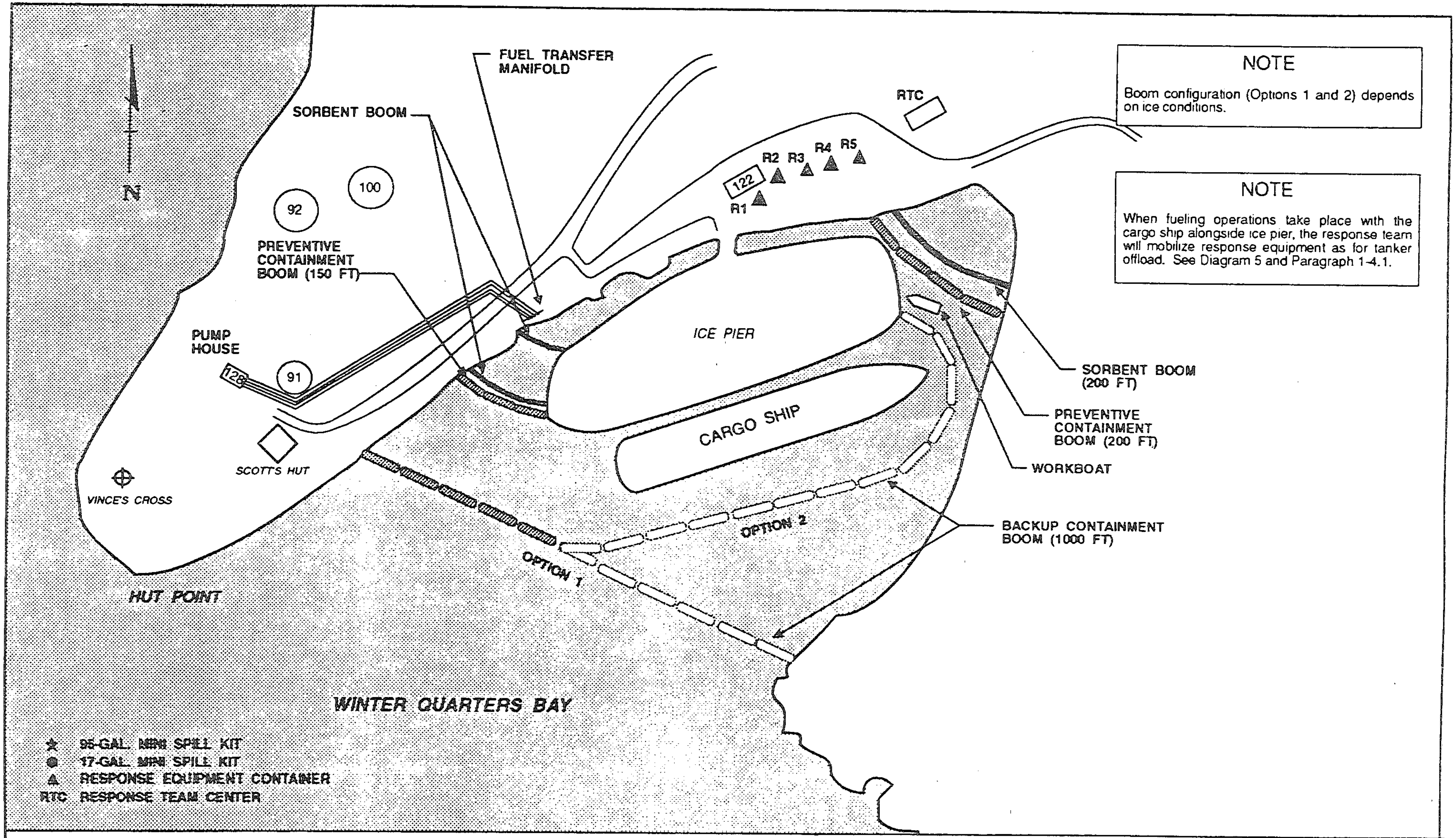
WARNING

Failure to properly handle sorbents contaminated by hazardous materials or fuels can result in serious injury or death and/or environmental harm. Consult Material Safety Data Sheet found in the Mini Spill Kit.

NOTE

Any noticeable fuel spill from USAP activities should be reported by Discoverer. There are NO minimal reportable quantities. Refer to Para 1-2

FIGURE 6. Spill Discoverer Decision Guide for Fuel Spill or Potential Fuel Spill



NOTE

Boom configuration (Options 1 and 2) depends on ice conditions.

NOTE

When fueling operations take place with the cargo ship alongside ice pier, the response team will mobilize response equipment as for tanker offload. See Diagram 5 and Paragraph 1-4.1.

FIGURE 7. Winter Quarters Bay Backup Boom Deployment for Ship on Berth

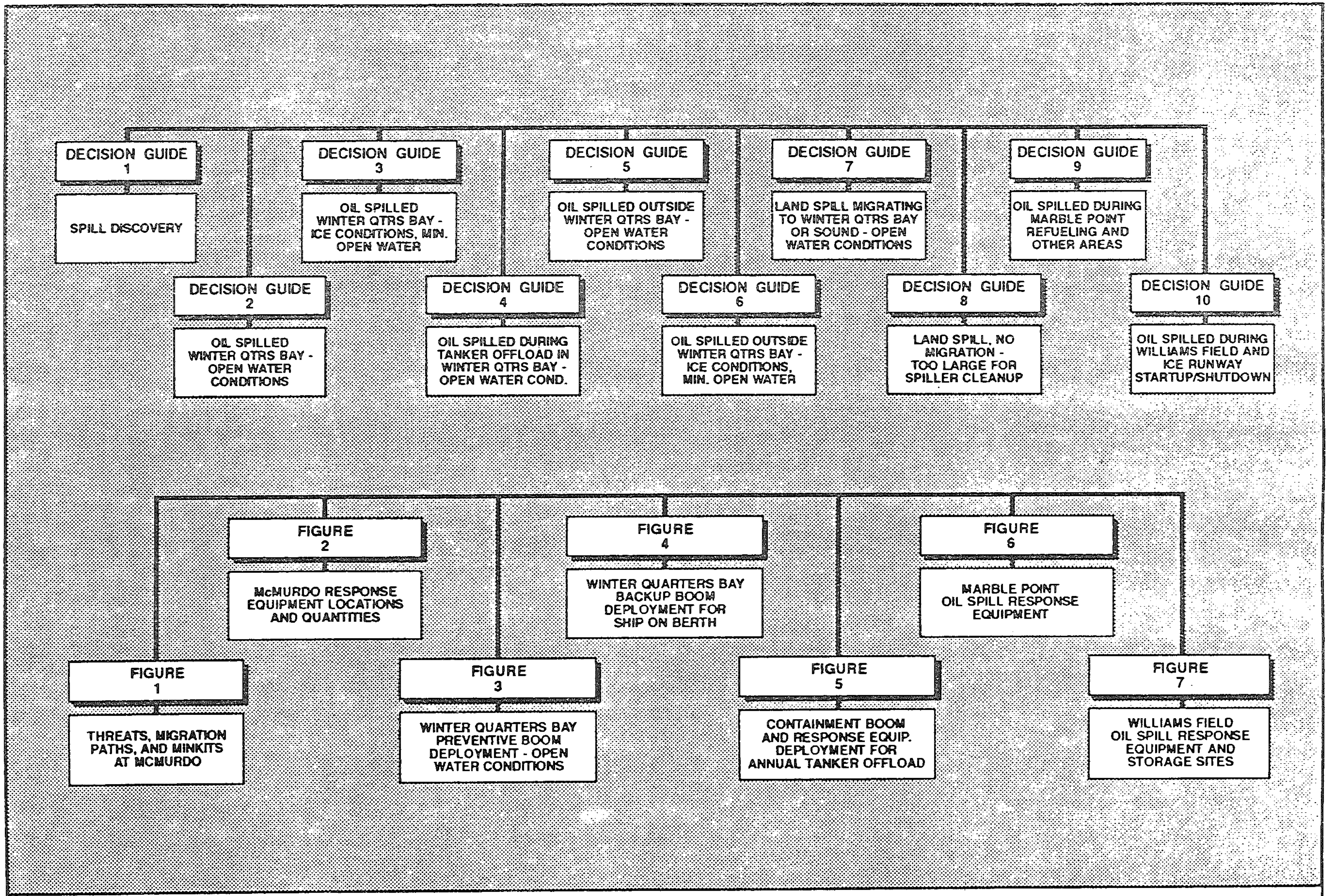


FIGURE 8. Area/Facility Oil Spill Contingency Plan.

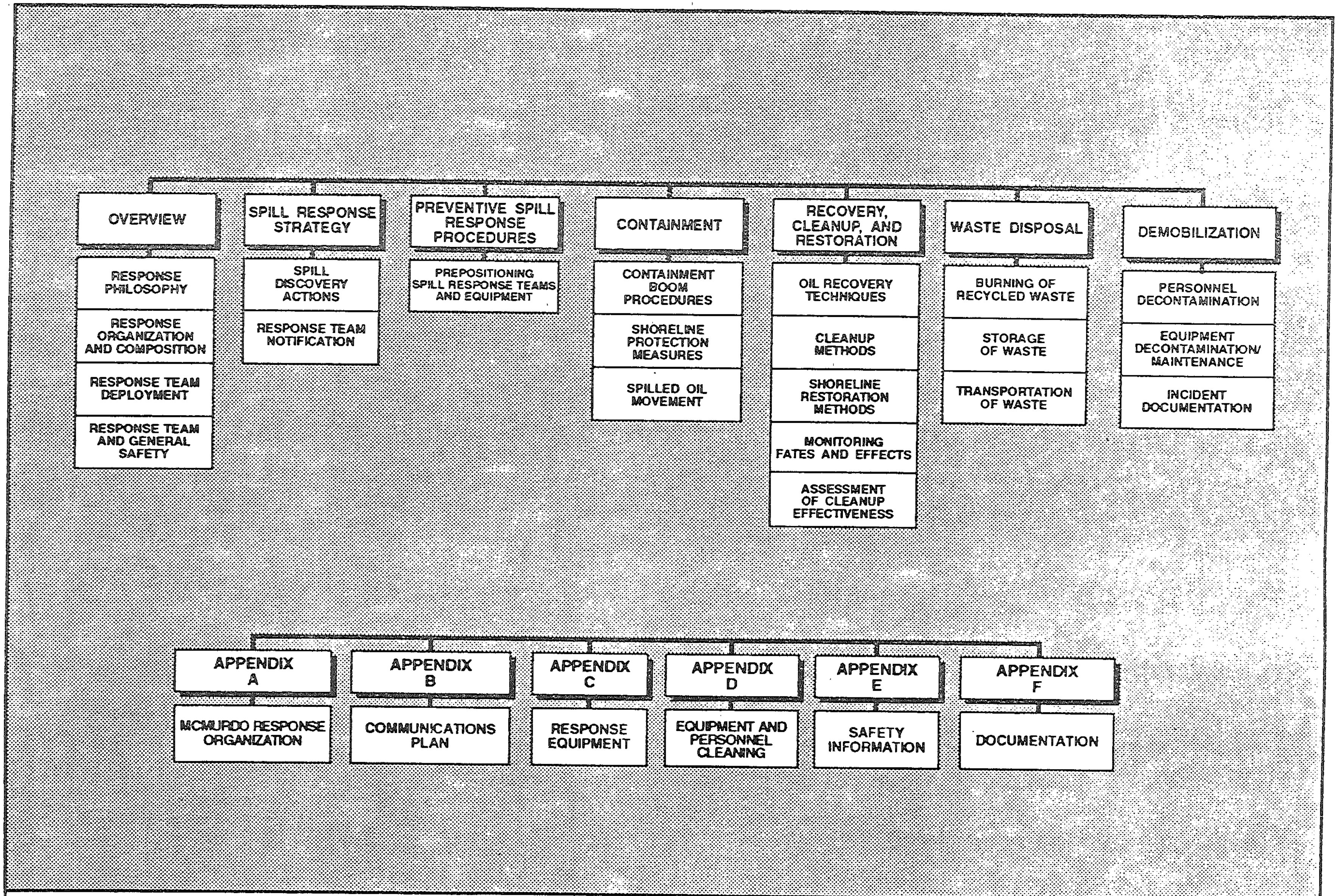


FIGURE 8 (cont). Area/Facility Oil Spill Response Contingency Plan.

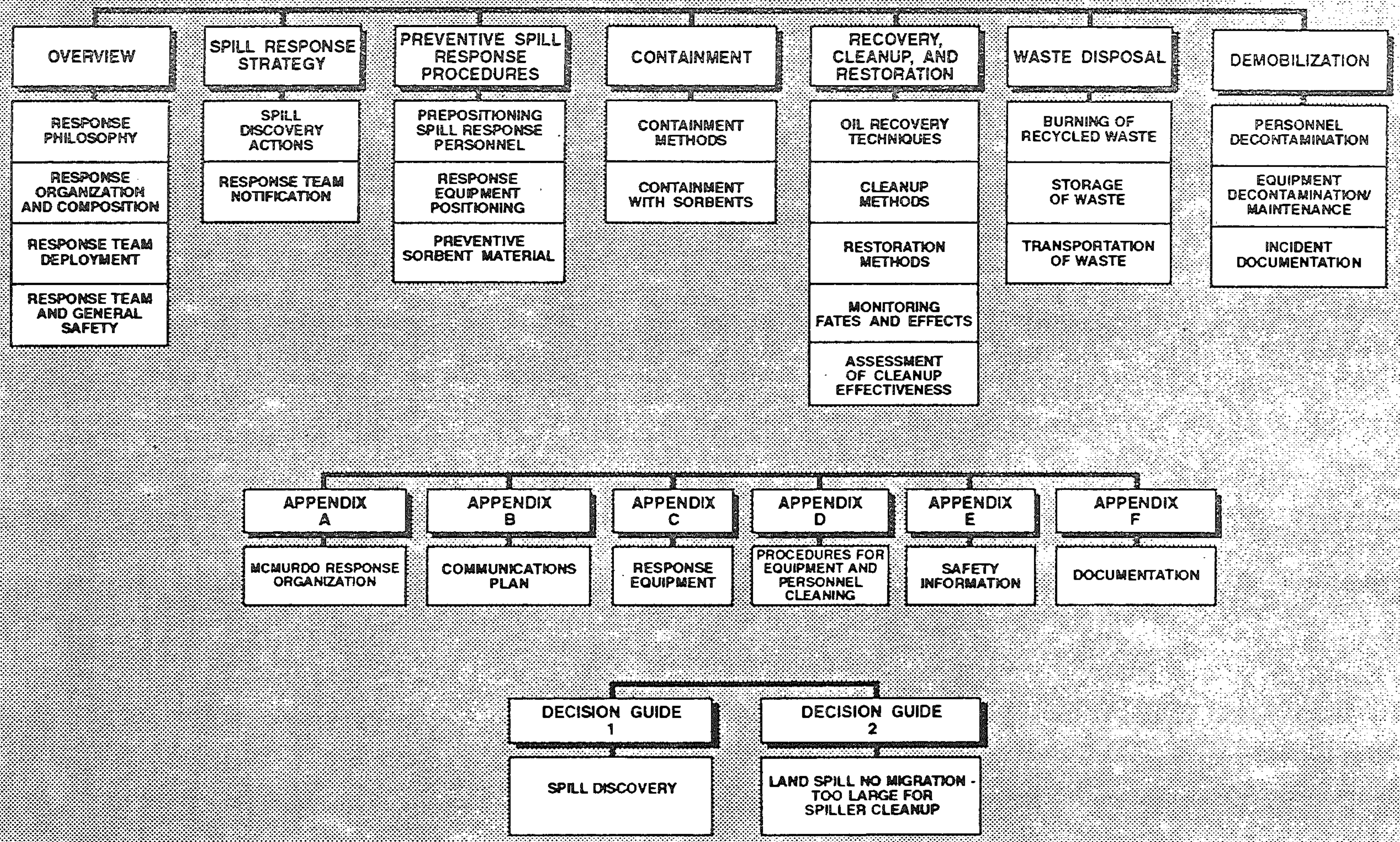


FIGURE 9. Field Camps Oil Spill Response Guidebook.

The draft plans are reviewed by the anticipated users, including managers, response team, and support personnel. Comments generated by this review are incorporated into a revision of the plan. The revised plan is then evaluated and validated during training exercises and responses to actual spills. Recommended changes to the plan are recorded and submitted for inclusion in the next update. Figure 10 shows the format of the change recommendation form.

Phase V — ***Spill Response Equipment Requirements.*** The initial step to determine equipment requirements was to review the results of phases II and III. Equipment selection must consider such things as people available to operate the equipment, ability to handle and transport the equipment, and spill scenarios. The risk assessment spill scenarios are important to equipment selection for they describe the most likely location and environment where spill response may take place. It is necessary to do this phase simultaneously with Phase IV, Contingency Plan Development, because the resulting plans should reflect response equipment assets and locations.

Selection criteria were established for the following five categories of spill response equipment:

- Containment boom
- Mechanical Recovery devices (skimmers)
- Sorbents
- Equipment and personnel cleaning facilities
- Support equipment

Containment boom selection considered the following factors:

- It must be lightweight, as well as easy to deploy and tend using small workboats.

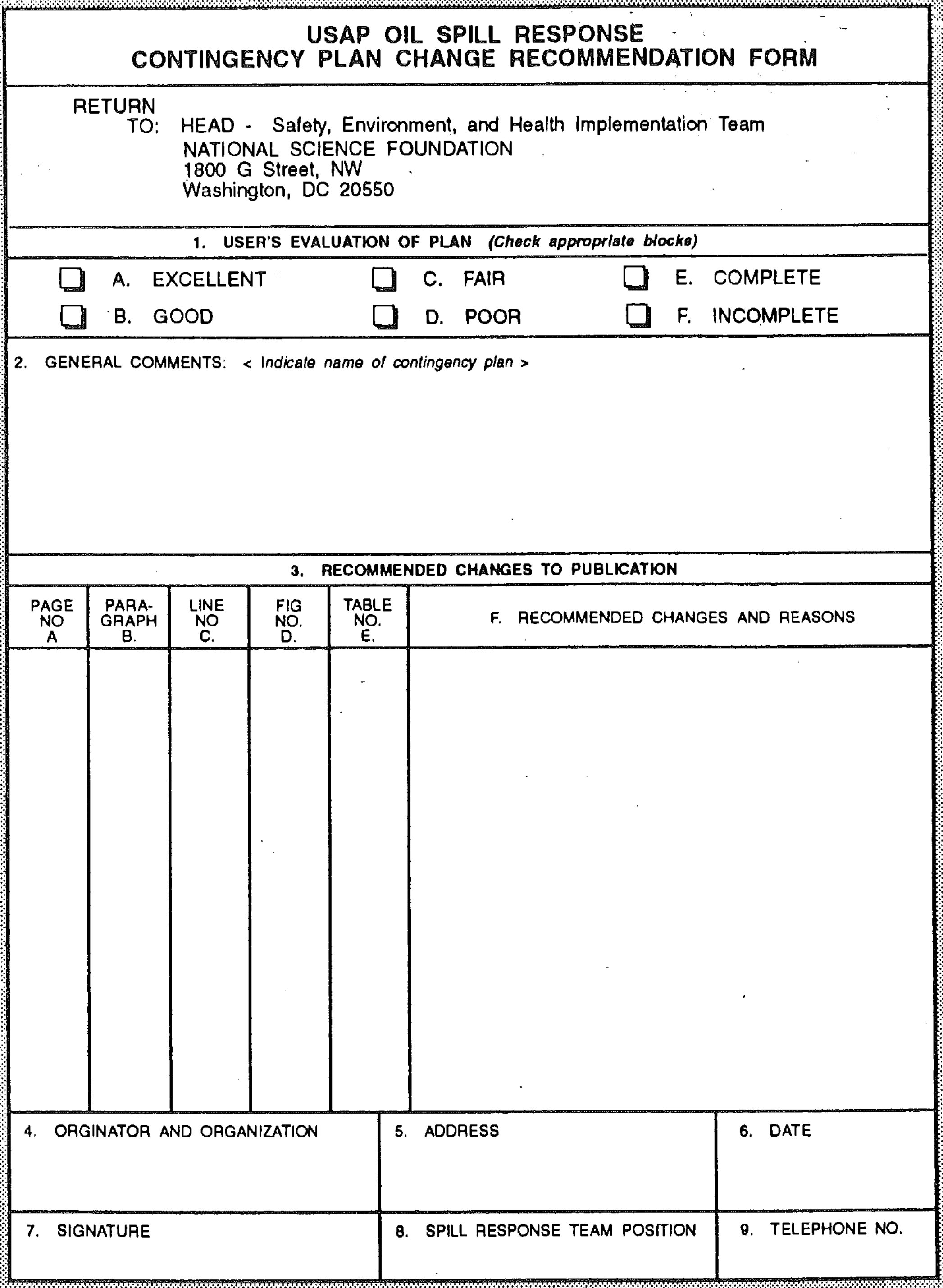
- It must be rugged and have the ability to withstand some degree of ice infested water; large, moving ice will destroy even the most durable oil booms.

- Its flotation system must accommodate the harsh working environment, which includes rocky shorelines and a variety of ice conditions. Inflatable, self-inflatable, and solid-flotation-type buoyancy systems were evaluated.

- It must be effective in moderate current and waves. In the U.S., containment booms are generally identified by three classes that relate to the environment in which they are best suited. The three classes are:

    - Class I - for quiescent water with low currents and waves
    - Class II - for open water environments with moderate waves and currents
    - Class III - for open water and high waves.

- The necessary depth of boom skirt and height of freeboard were considered in light of the water conditions expected and the most likely spilled product of light fuel. Boom size is related to the class of the boom — size directly influences the boom's seaworthiness.



USAP OIL SPILL RESPONSE
CONTINGENCY PLAN CHANGE RECOMMENDATION FORM

RETURN
TO: HEAD - Safety, Environment, and Health Implementation Team
NATIONAL SCIENCE FOUNDATION
1800 G Street, NW
Washington, DC 20550

1. USER'S EVALUATION OF PLAN ***(Check appropriate blocks)***

☐ A. EXCELLENT ☐ C. FAIR ☐ E. COMPLETE

☐ B. GOOD ☐ D. POOR ☐ F. INCOMPLETE

2. GENERAL COMMENTS: < *Indicate name of contingency plan* >

3. RECOMMENDED CHANGES TO PUBLICATION

PAGE NO A	PARA-GRAPH B.	LINE NO C.	FIG NO. D.	TABLE NO. E.	F. RECOMMENDED CHANGES AND REASONS

4. ORGINATOR AND ORGANIZATION

5. ADDRESS

6. DATE

7. SIGNATURE

8. SPILL RESPONSE TEAM POSITION

9. TELEPHONE NO.

FIGURE 10. Contingency Plan Change Recommendation Form.

SELECTION. A Class II, solid-flotation-type boom with a skirt depth of 12 inches and a freeboard of 7 inches was selected. Since solid flotation booms are more bulky than inflatable booms, boom was acquired in sections measuring no more than 50 feet in length to enhance transportability.

In addition to the Class II primary containment boom, an extremely lightweight, self-inflatable boom that can be deployed by one or two persons was selected for the spill response equipment inventory. This boom comes in 100- and 150-foot lengths and is packaged in a barrel-type drum that make it easily transportable.

Skimmer selection was based on these factors:

- It should be lightweight and portable. The skimmer must be transportable without support from significant material handling equipment. It should be able to be deployed and operated by three to four people from the shore, ice, or a small workboat.
- It should be effective in the recovery of light diesel fuels.
- It should have proved oil recovery capability in ice infested waters with a reasonable recovery rate (over 6 barrels per hour).
- It should have versatility in the recovery of oil in varying conditions— open water, brash ice, pooled oil on ice, oil under ice, etc.

SELECTION. A rope mop skimmer was selected. This is a single, oleophilic, rope skimmer driven by an electric-start diesel engine. The drive unit weighs 233 pounds and is easily transportable. The rope mop is available in various diameters and lengths. A rope diameter of 4 inches and a minimum length of 250 feet operating with a tail pulley assembly for use in certain conditions such as under ice recovery was chosen. This skimmer has a recovery capacity of 8 to 10 barrels per hour.

A variety of sorbent materials was selected. These versatile recovery tools are effective in most of the ice and water conditions encountered. The sorbent boom aids containment as well as recovery actions, and the pads, rolls, and sweeps can be used in virtually any cleanup operation, including equipment cleaning.

The spill response support equipment included such items as personnel safety equipment and protective clothing, waste storage tanks, inflatable cleaning pools, high pressure, hot water jet cleaners, and a safe, durable workboat. Except for the personnel safety devices, the workboat is probably the most important item of spill response support equipment. A workboat of sufficient towing power, and fitted with a suitable tow point, is required to deploy and tend considerable lengths of containment boom. The harsh conditions of ice-infested water dictate the desirability of a sizable boat, 25 to 30 feet, with a safe deck area for handling the response equipment.

Phase VI — Training. Training is the transitional stage between planning and implementation. It performs an essential function of validating the effectiveness of the plans. Training is important to the implementation of the plans, for without well-trained, response teams, the best prepared plans are useless.

Training is a continuing requirement to ensure effective response capability. It must accommodate changes in personnel, response equipment, and new or different spill risks. The training program includes training of managers and response teams in the United States prior to deployment to Antarctica. This part of the program affords an opportunity to learn how to use the spill response equipment in a less hostile climate, and it is less disruptive to the on-site station work schedule.

On-site refresher training, including the conduct of a spill response exercise, is scheduled for McMurdo and Palmer. Figure 11 shows the lesson plan topics presented during training of winter personnel at Palmer.

SUMMARY. The USAP has executed a six-phase oil spill contingency planning process. The process is conceptually sequential, but in practice is overlapping with each phase relying in some measure on previous phases. The process has resulted in the preparation of five levels of plans tailored to the needs of the users. All of the plans share these goals:

- Guide decisive and rapid response actions
- Describe the response team organization
- Describe the management and response support organization
- Assign specific responsibilities
- Describe response equipment assets
- Identify and describe potential risks and spill scenarios
- Describe a detailed concept of spill response with alternative courses of action.

The collective result of achieving the goals is to lessen the environmental impact of potentially damaging fuel spills.

FIGURE 11. Palmer Station Training

DAY ONE

UNIT 1. ADMINISTRATION

- Course Introduction

UNIT 2. USAP OIL RESPONSE PROGRAM

- National Science Foundation and SCALOP
- NSF Oil Spill Response Philosophy
- Peninsula System Regional Oil Spill Response CP
- Palmer Station Area Oil Spill Response CP

UNIT 3. OIL SPILL MANAGEMENT

- Control Cold Water Oil Spills
- Control Spreading and Migration
- Oil Spill Recovery
- After Recovery Actions

UNIT 4. OIL SPILL CONTROL AND RECOVERY METHODS

- Deploying Preventive Boom
- Oil Recovery with Sorbent
- Oil Recovery with Mop Skimmer
- Response Equipment

DAY TWO

UNIT 5. OPERATING USAP SUPPORT EQUIPMENT

- Operating Support Boats

UNIT 6. SAFETY

- Personnel Protection
- Ice Safety

UNIT 7. CLEANING OIL-SOAKED BIRDS AND MAMMALS

- Cleaning Procedures.

UNIT 8. DEMOBILIZATION

- Handling Collected Oil and Soiled Materials
- Demobilization procedures

UNIT 9. DOCUMENTATION

- Initial Spill Incident Reports
- Spill Situation and After Action Reports

DAY THREE

UNIT 10. OIL SPILL EXERCISE

- Field Exercise Scenario and Planning
- Field Exercise

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NATIONAL OIL AND HAZARDOUS SUBSTANCE POLLUTION CONTROL PLAN (NCP) (40 CODE OF FEDERAL REGULATIONS 300)

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980 (CERCLA)

OIL POLLUTION ACT OF 1990 (OPA 90)

INTERNATIONAL MARITIME CONVENTION FOR PREVENTION OF POLLUTION FROM SHIPS (MARPOL 73/78 PROTOCOL); with Five Technical Annexes:

1. Oil
2. Noxious Liquid Substances in Bulk
3. Harmful Substances Carried in Packaged Forms, or in Freight Containers, Portable Tanks or Road and Rail Tank Wagons.
4. Sewage
5. Garbage

INTERNATIONAL CONVENTION ON OIL POLLUTION PREPAREDNESS, RESPONSE AND COOPERATION, 1990 [Sponsored by the International Maritime Organization (IMO)]; with four Sections:

1. Prevention
2. Contingency Planning
3. Salvage
4. Practical Information on Dealing with Oil Spillage

U.S.NAVY SUPERVISOR OF SALVAGE REPORT ON EXXON VALDEZ OIL SPILL RESPONSE

U.S. NAVY SHIP SALVAGE MANUAL, VOL 6 - OIL SPILL RESPONSE

SEAWAY EMERGENCY RESPONSE PLAN (ST. LAWRENCE SEAWAY DEVELOPMENT CORPORATION)

REHABILITATING OILED SEABIRDS: A FIELD MANUAL, International Bird Research and Rescue Center (IBRRC)

ALASKA OIL SPILL COMMISSION, 1990. SPILL: THE WRECK OF THE EXXON VALDEZ, ANCHORAGE

CANADA-UNITED STATES JOINT MARINE POLLUTION CONTINGENCY PLAN (CANUSPAC)

REPORT OF THE OUTER CONTINENTAL SHELF (OCS) COMMITTEE SUBCOMMITTEE TO REVIEW ANALYSES OF THE EXXON VALDEZ OIL SPILL

INTERNATIONAL OIL POLLUTION AND RESPONSE (OPPR) CONVENTION
FIELD MANUAL FOR OIL SPILLS IN COLD CLIMATES (EPA-600/8-82-011)

FIELD GUIDE FOR ARCTIC OIL SPILL BEHAVIOR (DOT AD-A 154)

OIL SPILL CONTINGENCY PLAN, 1988; EXXON REFINERY, BENICIA, CA

OIL SPILL CONTINGENCY PLANNING (INTERNATIONAL TANKER OWNERS)

ARCTIC OIL SPILL RESPONSE GUIDE FOR THE ALASKAN BEAUFORT SEA (USCG CG-D-18-88)

Copies of published manuals, reports, and studies can be obtained from the following sources:

U.S. Government Publications	Superintendent of Documents U.S. Government Printing Office Washington, D.C. 20402 USA
Department of the Navy Publications	Navy Publications and Forms Center 5801 Tabor Avenue Philadelphia, PA 19120 USA
Non-Government Publications including International Maritime Organization Publications	Marine Education Textbooks 124 North Van Street Houma, LA 70363-3911 USA
Commercial Publications	Cutter Information Corp. 37 Broadway Arlington, MA 02174-5539 USA
Spill Response and Equipment Technical Publications	U.S. Department of Commerce National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 USA

Oil Spill Response in Antarctica

by

Jack Sayers
Australian Antarctic Division

ABSTRACT

Large quantities of fuel oil are transported and consumed in the Antarctic Treaty Area to provide logistical support for the scientific and operational programs of national Antarctic operators. There is also increasing tourist traffic to Antarctica using ships and, to a lesser extent, aircraft.

Oil spill response action in Antarctica is inhibited by the remoteness, climate, weather and ice conditions and by the limited manpower resources available at Antarctic stations. Effective response to oil spills requires prompt action to contain and recover the oil.

This paper recommends that all vessels operating in the Antarctic Treaty Area carry on board oil spill response equipment. It is further recommended that similar equipment be carried at Antarctic stations and that the equipment on ships and at stations be compatible to facilitate combined response action. A suggested inventory of response equipment for ships and stations is given.

INTRODUCTION

The last twenty years have seen a significant growth in the number of nations conducting scientific research in Antarctica and a parallel rise in logistical support activities. As a result there are now many more stations, ships, aircraft and personnel operating in Antarctica than there were in the early 1970's. More recently there has been an upsurge in tourist activity involving ships and, to a much lesser extent, aircraft.

Because of concerns about the impact of human activity in Antarctica, the Treaty Parties have focussed increasing attention on measures to protect the environment. A major cause of concern has been the potential for marine pollution and, in particular, the possibility of major oil spills resulting from ship or station based incidents.

Several Antarctic Treaty Consultative Meeting (ATCM) Recommendations have called for measures to prevent and combat marine pollution and these requirements have now been embodied in the "Protocol on Environment Protection to the Antarctic Treaty". During recent years the Council of Managers of National Antarctic Programs (COMNAP) and its Standing Committee on Antarctic Logistics and Operations (SCALOP) have accorded high priority to the development of strategies to avoid pollution of the marine environment and, in particular, measures to prevent and combat oil spills.

POTENTIAL SOURCES AND SIZES OF OIL SPILLS

The results of a survey conducted in 1987-88 on behalf of the Scientific Committee on Antarctic Research (SCAR) Panel of Experts on Waste Disposal, indicates that some 80,000,000 litres of fuel oil is used each year in supporting the program activities of national Antarctic operators. Approximately 50% of this fuel is consumed as ships' bunkers, 16% in support of aircraft operations and the remaining 34% for power generation or the operation of other equipment at stations or in the field.

While some of the fuel is used by ships and aircraft en route to Antarctica, the vast majority is transported and consumed within the Antarctic Treaty Area (that is, south of 60°S). The quantities of fuel used by Antarctic tourist ships and aircraft are not known but are significant and growing.

The activities which present the greatest potential for oil spills in Antarctica are:

- The carriage of cargo fuels and bunkers by ships;
- The transfer of cargo fuels from ship to shore; and
- The storage and transfer of fuels at stations and bases.

Spills from Ships

Most of the vessels used by national Antarctic operators are icebreakers or ice strengthened cargo/marine science vessels. Some of the vessels are relatively old, however, the latest ships entering service are constructed to a high standard and comply with, or exceed, the requirements of the International Maritime Organisation's (IMO) Code of Safety for Special Purpose Ships (SPS Code).

A typical Antarctic re-supply vessel has a cargo fuel capacity of up to 1,000,000 litres and may carry a similar amount of bunker fuel. One or two national operators use bulk fuel tankers which may have capacities of 10,000,000 litres or more. Individual fuel tanks on vessels may have a capacity of up to 250,000 litres. Damage to a typical re-supply vessel could therefore release up to 250,000 litres of fuel or, in a worst case scenario, 2,000,000 litres or more. Damage to a bulk tanker could result in a far worse spill scenario.

While the safety record of Antarctic shipping is relatively good, there have been numerous groundings and several vessels lost. The most serious incident in recent years resulted in approximately 640,000 litres of diesel fuel being released into the sea. Most of these events have occurred when ships have been close inshore or on approach to Antarctic stations. Oil spill incidents close inshore may present a significant risk to environmentally sensitive areas such as rookeries and shorelines populated by animals.

Spills during Ship to Shore Transfer

Antarctic operators use a variety of methods to transfer fuel from re-supply ships to stations or field locations. Small quantities of fuel for field activities are usually transported in standard 200 litre drums and transferred ashore by barge, helicopter, amphibious vehicle or across the sea ice by vehicle and sled. The risk of fuel spills is minimal and the quantity small.

Larger quantities of fuel may be transferred between ship and shore by pipeline (over water or sea-ice), fuel barge, or bulk containers. Transfer by pipeline is probably the most vulnerable to oil spills, however, providing appropriate equipment and monitoring and handling procedures are in place, the risk of a major spill is minimal. Nevertheless, there is still a risk of spills of up to, perhaps, 25,000 litres should a long pipeline be ruptured or if there is a delay in detecting the leak. In general, however, ship to shore transfer does not pose a major oil spill threat.

Spills during Storage at Stations

The most common method of storing bulk fuels on stations is in steel tanks. Tank capacities vary from around 20,000 up to 1,000,000 litres capacity. Some national operators use rubber bladders which are typically 20-30,000 litres capacity. Probably the most common source of all oil spills in Antarctica during recent years has been from station storage facilities, usually as a result of human error or mechanical failure of pipes, valves, joints or tanks.

Most stations do not have adequate containment facilities in place at this time. Until satisfactory containment facilities are in place, the storage of fuel at stations represents a significant risk. Depending on the local terrain and the effectiveness of response countermeasures, station spills could vary from several thousand to millions of litres of fuel. In recent years there have been reported spills of approximately 250,000 litres of jet fuel at McMurdo Station, 180,000 litres of diesel fuel at South Pole Station and 90,000 and 20,000 litres of diesel fuel in two separate incidents at Casey Station. About 50% of the fuel spilled at Casey Station was recovered in each incident.

As a result of ATCM and COMNAP/SCALOP initiatives in recent years, national operators are now giving priority to upgrading fuel storage and transfer facilities at stations.

PRACTICAL CONSTRAINTS IN COMBATING OIL SPILLS IN ANTARCTICA

As described above, the principal potential sources and sizes of spills in Antarctica are:

- the grounding or sinking of ships which may cause the release of up to 250,000 litres of fuel from a single ruptured tank or perhaps, in a worst case scenario, upwards of 2,000,000 litres;
- the failure of containers, barges or pipelines used for fuel transfer between ship to shore resulting in an oil spill of 25,000 litres or more; and
- the failure, incorrect operation of, or accidental damage to fuel oil storage facilities at stations resulting in the loss of perhaps a few thousand, up to one million litres of fuel oil.

While maximum effort must be directed towards the prevention of oil spills, it is unlikely that such measures will totally eliminate the possibility of incidents occurring. Furthermore, the expeditionary nature of Antarctic operations and the extreme environmental conditions of weather and ice, pose greater risks than for equivalent fuel transport and storage operations in more temperate climates.

The challenge therefore, is to develop oil spill contingency response plans which are practical, realistic and economically feasible. There are many practical constraints which necessarily limit the extent to which stations can respond to oil spills, these include:

- It is not feasible to maintain an equipment inventory at each station to provide for catastrophic spill response (eg a ship foundering or a major storage fuel spill).
- A major response action would be impossible because of the limited number of personnel on station.
- Because of the transient nature of station personnel it is difficult to maintain a response team skilled in the deployment and operation of advanced or heavy duty response equipment.
- The training opportunities for response personnel on station are restricted by ice and weather conditions.
- The ice and weather conditions, even in midsummer, are not always conducive to the deployment of response equipment.
- In pack-ice conditions the deployment and operation of response equipment may prove difficult, if not impossible.
- Most stations have very limited watercraft capability, often only Inflatable Rubber Boats (IRB's). This restricts the type of equipment that can be deployed and the distance of operations from the station or land.

- The need to maintain Search and Rescue (SAR) capability also limits the range to which watercraft can be operated from the station or land.
- There is a practical and economic limit on the extent to which storage facilities can be provided on station for recovered oil or oil/water mixture.

The above factors clearly inhibit the extent to which stations can respond to oil spills. In particular, the remoteness, climate, inhospitable weather, harsh physical environment and variable ice conditions make effective response action exceedingly difficult and, at times, impossible. The physical and chemical characteristics of oil also impact on response action.

Whilst oil begins to weather when exposed to the elements, the rate of degradation is slowed at lower temperatures. As weathering progresses, the density of the oil increases as the lighter volatiles evaporate. The rate of evaporation depends on the sea temperature, water conditions and wind velocity. Biodegradation and oxidation of oil are also much slower processes at polar temperatures.

The lighter fractions of oil, such as diesel, spread very rapidly and form a thin layer over the sea surface. This can make recovery slow and difficult but conversely, will assist in the dissipation and ultimate degradation of the oil. In the absence of ice, oil will generally travel at 3% of the wind speed and direction compounded by 100% of the current speed and direction.

The presence of ice can complicate response and clean-up action. Ice can absorb oil which will be released during melting. Also oil can be trapped at the ice and water interface. On the other hand ice can inhibit the spread of oil and provide a natural containment barrier which may enable recovery action to take place before further environmental damage can occur.

REALISTIC RESPONSE STRATEGIES

For response action to be effective, containment and recovery needs to commence at the earliest opportunity and preferably within 8 hours of the spill occurring. In the event that an oil spill is not environmentally threatening, the most appropriate strategy may be to do nothing other than monitor the speed and direction of the slick (if possible) and allow the elements to dissipate and degrade the oil. If, however, an oil spill does threaten sensitive areas then prompt response action is required.

Given the constraints and difficulties previously described it is clear that a prompt response is only possible if containment and recovery equipment is available on board vessels and at stations. In addition, effective response action depends on the availability of well-trained personnel, a clear and concise operational contingency plan, and favourable ice and weather conditions.

Effective oil spill response for a damaged or foundering vessel in a remote area of the Southern Ocean is likely to prove impractical. At best, it may be feasible to transfer fuel oil between the damaged vessel and rescue ship, or relocate the cargo fuel or bunkers on board the damaged vessel to reduce the possibilitiy of a spill and tow the casualty to a repair facility.

Contingency Requirements for Ships

It is recommended that all vessels operating in the Antarctic Treaty Area should have adequate oil spill containment and recovery equipment on board. The type and quantity of equipment should be based on the possible need to respond to small or medium spills. It is impractical to carry sufficient advanced and bulky oil containment and recovery equipment on board to tackle major spills. Furthermore the use of heavy and sophisticated equipment would require extensive training of personnel which presents obvious practical difficulties.

The equipment and facilities to be carried on board each vessel should include the following:

- Medium sized, permanent buoyancy, containment boom, of sufficient length to encircle the vessel to prevent spreading of the spill.
- Approximately 100 metres of lightweight, self-inflating boom.
- Watercraft with sufficient power to deploy the boom.
- An oil skimmer to recover oil from the sea surface and appropriate storage to accept the recovered oil or oil/water mixture.
- Absorbent pads and boom for minor spill recovery action.
- Protective gear for oil spill response personnel.
- Cleaning materials for personnel and equipment (eg mops, shovels, detergents, etc).
- Medical supplies for treating oil-spill related injuries (eg oil ingestion, inhalation of fumes, eye and skin irritations, etc).

The carriage by all vessels of adequate oil spill response equipment and materials should help reduce or eliminate possible environmental damage resulting from small to medium, ship-based oil spills. Furthermore, ships diverted to assist in oil spill response activities will be able to supplement existing materials and equipment at the site of the incident. For cooperative response action to work effectively it is essential that national Antarctic operators standardise key elements of equipment (such as boom connectors) so that it is possible to use the equipment together for multi-vessel or vessel-station combat operations.

Contingency Requirements for Stations

It is recommended that stations be equipped with oil spill containment and recovery equipment capable of coping with small to medium spills and to help mitigate the effects of larger spills until further assistance can be provided, if needed. The spills may arise from the grounding or foundering of a vessel nearby, or result from an accident or failure of fuel transfer or storage systems at the station.

As previously discussed, the response equipment on stations should be standardised with the type of equipment carried on board ships (especially regarding the boom connectors) so that they can be used together in a combined combat operation. In the event of a medium to large spill, it may not be practicable to contain or recover a significant proportion of the oil. The containment equipment may be used, however, to deflect the spill and thereby protect environmentally sensitive areas. Materials and equipment to help clean up shorelines should also be held at stations.

It is up to each national Antarctic operator to assess the likely spill scenarios and equipment requirements for their respective stations. The following list of equipment is provided as a guide to what may be required at a typical Antarctic station accommodating about 30 expeditioners over winter and 100 or more over summer.

- Approximately 200 metres of medium sized, permanent buoyancy containment boom.
- Approximately 100 metres of lightweight, self-inflating boom.
- Approximately 250 metres of sorbent boom.
- Watercraft with sufficient power to deploy the boom. A minimum requirement would be two IRB's.

- An oil skimmer to recover oil from the sea surface.
- A lightweight, portable vacuum pump for the recovery of oil from the shoreline or rock pools.
- Absorbent pads for catching leaks or spills from pumps, etc or for clean-up operations.
- Two 10,000 litre, portable, fast-assembly, fabric tanks for storing recovered oil or oil/water mixture.
- Protective gear for oil spill response personnel.
- Cleaning materials for personnel and equipment (eg mops, shovels, detergents, etc).
- Medical supplies for treating oil-spill related injuries (eg oil ingestion, inhalation of fumes, eye and skin irritations, etc).

RESPONSE EQUIPMENT

There is a bewildering range of oil spill response equipment manufactured and sold throughout the world. The following information is provided to give some guidance on the type and size of response equipment which national Antarctic operators may wish to purchase.

Containment Booms

A containment boom forms a mechanical barrier which extends above and below the water surface and is designed to stop or divert the flow of oil. The efficiency of booms can be affected by choppy sea conditions, high winds or significant currents. The following criteria should be considered when selecting containment booms:

- They must be lightweight, as well as easy to deploy and tend using small watercraft. If deployment is to be undertaken by IRB's, a craft with no less than 100 HP should be used.
- They must be rugged and have the ability to withstand some degree of contact with ice. Large moving ice pieces will destroy even the most durable booms
- Selection of the flotation system must take into account the harsh working environment which is likely to include rocky shorelines as well as ice infested waters.
- For durability in Antarctica the boom should be manufactured from materials that can withstand low temperatures.
- For fast response it is preferable (if feasible in the particular application) to store the boom on reels which will facilitate rapid deployment. The boom and reel should be containerised or stored in a protected location.
- The connectors on oil booms should be standardised to facilitate multi-ship/station response. It is recommended that connectors to the American Society of Testing and Materials (ASTM) Publication ASTM F962-86 be specified.

Taking into account the operational characteristics described above, it is recommended that solid flotation containment booms having a skirt depth of 0.4/0.5 metres should be used. This type of boom is suitable for open water harbour environments with moderate waves and currents. Since solid flotation booms are more bulky than inflatable booms, it is recommended that this type of boom be acquired in sections measuring no more than 15 metres in length.

In addition to the above medium duty booms, it is recommended that stations also hold stocks of lightweight, self-inflating boom which can readily be deployed by one or two persons. These booms are available packaged in barrel-type drums that make them easily transportable to remote areas.

Sorbent Booms

Sorbent booms are used to recover spilled oils through the process of absorbtion or adsorption. Sorbent booms can serve a dual function of providing a mechanical barrier to contain or deflect the spill, as well as absorbing the oil. These booms are generally only effective in calm water conditions and can be used to protect sheltered locations or complement the use of containment booms.

Oil Skimmers

Oil skimmers are mechanical devices which are designed to recover oil from the water surface. There are five main generic types, namely: weir-type, suction, centrifugal, submersion and sorbent. Each type has particular advantages and disadvantages.

For Antarctic conditions, where oil may need to be recovered from clear water or limited pack-ice conditions, a sorbent **rope-mop skimmer** is recommended. The rope mop itself is made from a synthetic oleophilic material which adsorbs the oil and carries it to a collection device which squeezes the oil out of the rope and into a reservoir. The following criteria should be considered when selecting a rope-mop skimmer:

- It should be lightweight and portable and must be transportable without support of significant handling equipment.
- It should be effective in the recovery of light diesel-type fuels. Rope mop skimmers are available that can handle gasoline, jet fuel and petroleum products of viscosity up to 25,000 Cp.
- It should have proven oil recovery capability in ice-infested water situations with a reasonable recovery rate (around 1 cubic metre/hour).
- It should have demonstrated versatility in the recovery of oil in varying conditions, namely, open water, brash ice conditions, pooled oil on ice, etc.

Taking into account the above operational characteristics, it is recommended that an electric start, diesel engine powered, rope-mop skimmer should be used. A rope diameter of 10 cm is recommended.

The rope mop skimming method has proved to work satisfactorily in oil-in-ice conditions both in tests and in real spill situations (eg the Est Foreland Spill in Alaska, January 1992). The system is available both in horizontal and vertical mode. The vertical is believed best for use on ships as it can be suspended from a vessel's crane, if available. The horizontal types are designed to be operated from the shore or on a watercraft.

For situations where oil is likely to be spilled on ice (sea ice or on the continent) a **suction skimmer** is more effective. The skimmer has a suction head which is similar to that of a domestic vacuum cleaner which increases the surface area of suction. Suction skimmers are simple to operate and can cover a wide range of different viscosity oils. They can be used to pick up oil from the surface of calm water. When used in choppy conditions they tend to lose contact with the oil surface and absorb too much air, thus reducing the skimmer's efficiency. Where the spill can be contained by a boom the concentration should permit efficient recovery.

Portable Vacuum Pumps

Small, diesel engine-powered vacuum pumps are useful for recovering oil from the shoreline or rock pools. These pumps would also be suitable for cleaning up small oil spills which may occur on stations. Portable, double diaphragm pumps are also suitable for use in conjunction with a portable air compressor.

OTHER OIL SPILL RESPONSE METHODS

In addition to the use of mechanical containment and recovery systems there are alternative or complementary methods, including the use of chemical dispersants, in-situ burning and bioremediation. Because of the potential enviornmental impact of these methods, the SCALOP Sub-group on Oil Spill Prevention and Repsonse is seeking expert advice from SCAR on their applicability in Antarctica.

CONCLUSIONS

The implementation of effective and credible response strategies to tackle oil spills in Antarctica is a major challenge for national operators. Maximum emphasis must continue to be placed on the prevention of spills at stations, in the field, and from vessels.

Notwithstanding the difficulties of combating oil spills in Antarctica, there are practical and realistic measures that can be taken including the development of oil spill contingency plans, and the deployment of response equipment at stations and on board vessels. Response strategies should be developed and implemented as soon as practicable.

ACKNOWLEDGEMENTS

The author wishes to acknowledge with appreciation the efforts of members and participating technical experts who contributed to the work of the SCALOP Sub-group on Oil Spill Prevention and Response during the last two years. The section of this paper on Contingency Requirements is based on a discussion paper prepared by Mr Gunnar Futsaeter of the Norwegian State Pollution Authority. Also the section on Response Equipment takes into account recommendations provided by Mr Art Brown of the Division of Polar Programs, National Science Foundation, USA and Mr Futsaeter. The technical advice provided by the Australian Maritime Safety Authority is also gratefully acknowledged.

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Development of a Wheeled Runway for McMurdo on the Ross Ice Shelf

by
George L. Blaisdell, Cold Regions Research and Engineering Laboratory, Hanover, N. H. USA and
Deborah Diemand, Arctic and Antarctic Research Institute, St. Peterburg, Russia

ABSTRACT

The U.S. Antarctic Program currently operates aircraft from an annual sea ice runway at McMurdo until about December 15th of each year. After that time it is limited to use of a snow runway and ski-wheel aircraft. Large cargo aircraft of this type are very specialized and in short supply.

On the Ross Ice Shelf near McMurdo, an experimental runway to support heavy wheeled aircraft has been constructed. This runway capitalizes on the natural characteristics of the location and uses only snow and ice for construction materials. Such a runway is appealing because of its ability to support heavy wheeled cargo aircraft while requiring a relatively small construction and maintenance effort and causes only minimal impact to the site.

The runway is located inside the transition zone between the accumulation and ablation regions on the ice shelf. It utilizes a thin permanent cap of snow over natural blue ice to a) level undulations in the underlying surface and b) protect the ice from intense solar radiation during the peak of summer (to prevent subsurface melt-pool formation). The snow cap was produced by compaction with a heavy roller during the warmest part of the year and the snow was then left to sinter and strengthen with falling temperatures. In early February, the snow cover was strong enough to support wheeled operation of a fully loaded LC-130.

1. Introduction

The U.S. Antarctic Program (USAP) relies on aircraft operating between Christchurch, New Zealand, and McMurdo (78S, 167E) to provide nearly all personnel support and a considerable amount of cargo transport to the continent (excluding support for Palmer Station on the Peninsula). The first flights of the season land on the skiway at Williams Field in early August in the specialized LC-130 Hercules (ski-wheel). In October, the main body of personnel fly to McMurdo in wheeled LC-130 Hercules, C-141 Starlifter, and C-5 Galaxy aircraft that land on a runway on first-year sea ice. These conventional (wheeled) airplanes use the sea ice runway until the runway surface strength deteriorates in mid-December. After this the program must rely on only the LC-130s on skis for all of its needs throughout the remainder of the season. There are very few LC-130's available: five owned by the National Science Foundation and operated by the U.S. 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 usually occurs and severely constrains the Program during mid- and late-season.

The USAP is therefore seeking to increase the use of conventional aircraft within its program throughout the season. To do this a reliable runway is needed that is capable of supporting wheeled aircraft. Runways on annual or multi-year sea ice, on glacial (blue) ice, and those made from crushed rock or compressed snow are all candidates. Characteristics of each runway type are given in Table 1. For the past three years, engineering studies have been directed at determining the feasibility of producing a wheeled runway on the Ross Ice

Shelf near McMurdo after the sea ice is no longer usable. This report describes progress to date on one of the two experimental runways under construction at this location.

2. Runway Design and Site Selection

A study of possible means for extending the use of wheeled aircraft at McMurdo from mid-December to early March (Mellor, 1988) suggested that a blue-ice runway located on the Ross Ice Shelf near McMurdo was the best way to achieve this. In part this decision was based on the factors listed in Table 1. (Construction of a rock runway at Marble Point, with an overland link to McMurdo, was considered impractical because of its long distance from McMurdo.) It is the ultimate goal to provide year-round wheeled aircraft accessibility to McMurdo.

Table 1. Characteristics of different runway types. (from Budd and Russell-Head, 1990)

Runway type	Technology employed	Relative cost	Environmental concerns	Construction & Maintenance
rock	conventional	high	high	straightforward
sea ice	simple	very low	low	simple
blue ice	simple	very low	low	simple
compressed snow	developing	fairly low	low	specialized

Following several years of observation, measurements, and study, a site named Pegasus was chosen for experimental runway development (Mellor, 1988). The idea was to produce a blue-ice runway that was located inside the zone of accumulation at the snow/ice transition line (Fig. 1). Fortunately, the prevailing winds at this site are near-parallel with the transition line, so the runway could be aligned favorably for both construction and operation. Being located at the transition, it seemed likely that a constant, but manageable, supply of snow would be available for use in protecting the blue-ice from solar radiation. Thus a limited amount of snow handling (importation and removal) would be necessary.

Two approaches are being considered for the construction of a hard-surfaced runway at the Pegasus site. One is the preparation of a compacted snow pavement on the blue-ice base. The other is the use of the bare blue ice.

The concept for the compacted snow runway (Pegasus I) was to compress a thin (10 cm) cover of snow over the original blue-ice surface. In this approach the thick (>30 m) glacial ice would be relied upon to support the gross aircraft weight. The thin snow pavement would be used a) to increase the surface albedo and diffuse the incident solar radiation, b) to act as a filler to level undulations in the natural ice surface, and c) to support the contact pressure of candidate (Table 2) heavy, wheeled, cargo aircraft. The technology for producing a snow pavement in Antarctica with sufficient strength to support typical aircraft wheel pressures is still evolving; no one has yet produced a reliable compacted snow runway capable of supporting heavy wheeled air traffic, although the IL-76 with its relatively low ground pressure has been used successfully at some Russian stations using compacted snow runways. However, we believed that we could achieve such a snow strength because of our specific site conditions (i.e., a thin layer of snow over a very firm base; near melting temperatures in December to generate free water in the snow; very little new snow accumulation during austral summer).

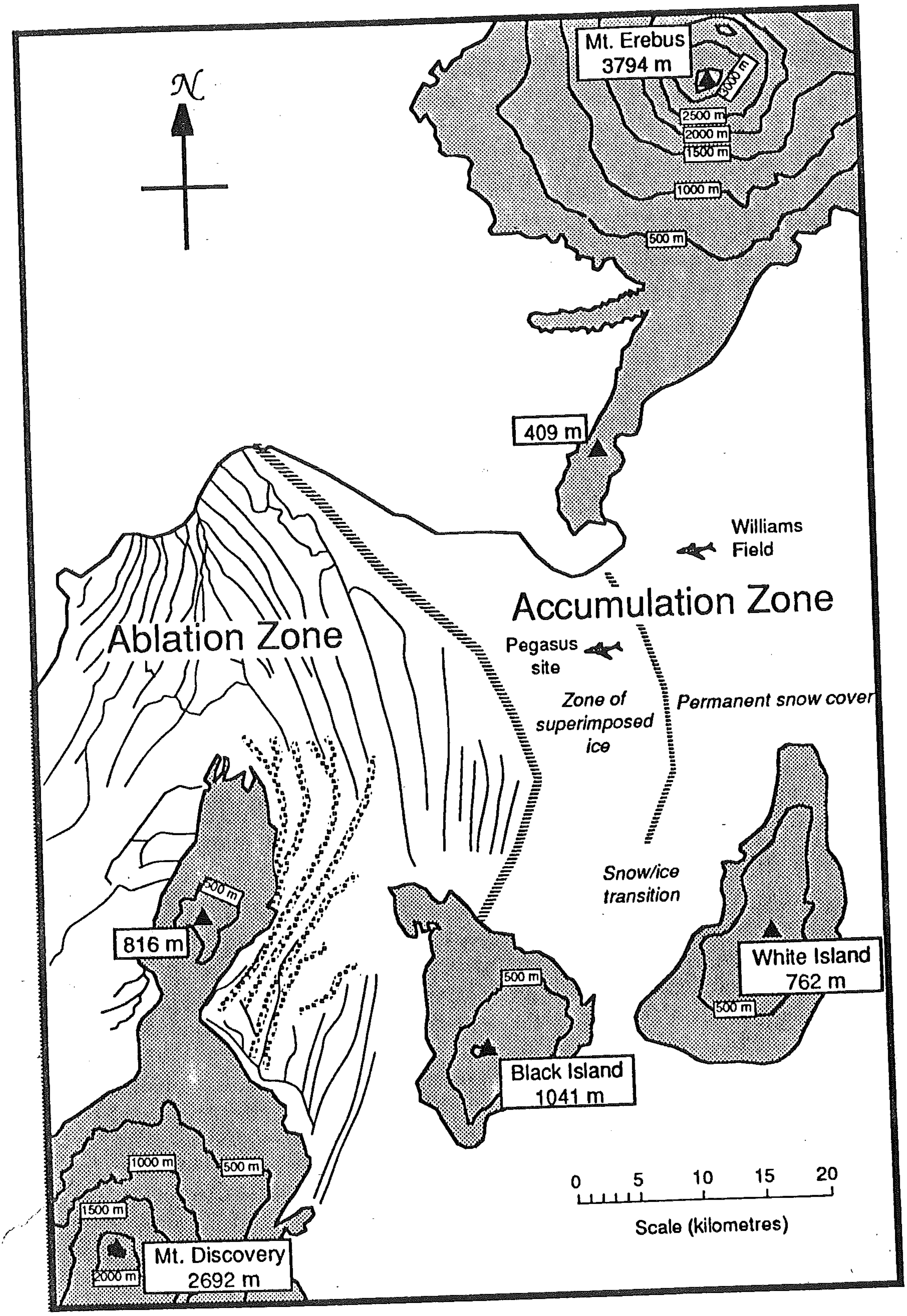


Figure 1. Location map of the Pegasus runway site

Table 2. Heavy, wheeled aircraft with potential for Antarctic use. (After Budd and Russell-Head, 1990)

	Lockheed C-130	Lockheed C-141	Ilyushin 76T	Lockheed C-5
Max take-off mass (kg)	70,310	146,555	170,000	379,657
Main landing gear	4 wheels, two tandem units	8 wheels, two 4-wheel bogies	16 wheels, two sets of two rows of 4	24 wheels, two 4-wheel triangular units in tandem each side
Main tire size	1422 x 508 mm (60 x 20 in)	1118 x 406 mm (44 x 16 in)	1300 x 480 mm (51 x 19 in)	1245 x 432 mm (49 x 17 in)
Tire pressure1	6.6 bar (96 psi)	12.4 bar (180 psi)	5.0 bar (73 psi)	7.7 bar (111 psi)
Contact area per tire (m^2)	0.260	0.145	0.208	0.174
Equivalent radius (mm)	288	215	258	235
Max payload (kg)	19,685	32,025	40,000	118,387
Cruising speed2 (kt)	300-325	430-492	405-432	450-480
Take-off roll2 (m)	1091	1300	850	2530
Landing distance2 (m)	518	850	415	725
Range with max payload2 (nm)	2160	2550	2700	2982
Ferry range2 (nm)	4100	5550	3508	5618

1 - Tire pressures are usually varied to suit aircraft load and runway conditions. In some aircraft, e.g., C-130, IL-76T, and C-5, tire pressures can be adjusted in flight.

2- These are nominal values for the purpose of comparison. Actual values will vary with condition of runway and weather.

2.1. Compacted snow runway - Pegasus I

Compacted snow runway technology has received considerable attention recently by the Russians at Molodezhnaya (68S, 46E) and the Australians at Casey (66S, 111E). Being much closer to the equator, the conditions at both of these stations are significantly different than at McMurdo. However, using the information provided by Aver'ianov, et. al. (1982), Budd and Russell-Head (1990), Russell-Head and Budd (1991), Klokov and Nazarov (1992), and that contained in Abele (1990), a clear picture emerges of the procedures and conditions required to create snow with a strength capable of supporting tire ground pressures typical of large cargo aircraft.

2.2. Blue-ice runway - Pegasus II

In addition to Pegasus I, work was begun on a second runway, called Pegasus II. The Pegasus II runway was designed to operate as a true exposed blue-ice airstrip capable of supporting even the highest ground pressure aircraft (e.g., C-141). A runway on exposed shelf ice can be as strong as any concrete airstrip; however, there are several factors that must be taken into account. First, a blue-ice surface is rarely smooth, either on a micro or macro scale. In addition, cracks, cavities, and potholes often exist in an area the size of a runway. However, in the case of McMurdo, the most important consideration for a blue-ice runway is the tendency for melt-pool formation in the exposed ice. While air temperatures in the McMurdo area do not get high enough to allow surface melting, they are warm enough that, coupled with the intense solar radiation in the peak of the austral summer and the low albedo of unprotected blue-ice, subsurface melting is virtually ensured in exposed blue-ice. These melt pools can become very large and deep with a thin ice cover and they would be disastrous to any aircraft.

To protect against melt-pool formation, this runway will ideally remain covered by winter and spring storm snow until early February when it is most needed by the program. At this time the runway will be cleared of snow to expose the blue-ice landing surface.

In the event that the winter and spring storms do not deliver enough snow to cover the runway adequately, snow from adjacent areas will be imported for protection of the blue ice. It may be possible to develop a methodology by which the runway could be kept exposed and operated in the early season as well. However, this would require supreme confidence in the ability to protect the runway reliably from solar radiation before the onset of melt-pool formation in early or mid-December.

With a Pegasus II-type runway, a snow cover is not present to fill in depressions and swales in the natural blue-ice surface. Thus, leveling and patching of the blue-ice surface is generally required before the runway can be made operational. It is hoped that this will be a one-time task, except for minor repairs that may be required from time to time. A separate report on Pegasus II is in preparation.

3. Glaciology of the McMurdo Ice Shelf

To the south and east of McMurdo Station a lobe of the Ross Ice Shelf flows slowly northward at a rate of about 29 meters per year (Mellor and Swithinbank, 1989). The low flow rate is due to the presence of numerous natural barriers, including Hut Point Peninsula, White Island, Black Island, and Brown Peninsula. The Pegasus runway site is located roughly in the center of this area on a line between McMurdo Station and Black Island (see Figure 1). The transition from the accumulation zone to the ablation zone occurs in this area. It has been traditionally assumed that this transition is marked by the boundary between the permanent snow cover and the blue ice surface of the ice shelf (Swithinbank, 1988).

However, aerial observations of the Pegasus site indicate that in fact the transition from the accumulation to the ablation zone is situated about five to seven kilometers to the west of the experimental runway site. The evidence for this is the presence of surface melt streams in this area which are characteristic of the zone of net ablation. Between this zone and the boundary of the permanent snow cover lies the zone of superimposed ice where snow and ice melt, but the resulting meltwater does not drain away. Instead, the melted water from the snow and ice refreezes in the same area. The only mass loss mechanism in this zone is evaporation with no mass loss from the glacier due to runoff. The entire Pegasus runway site lies within the zone of superimposed ice.

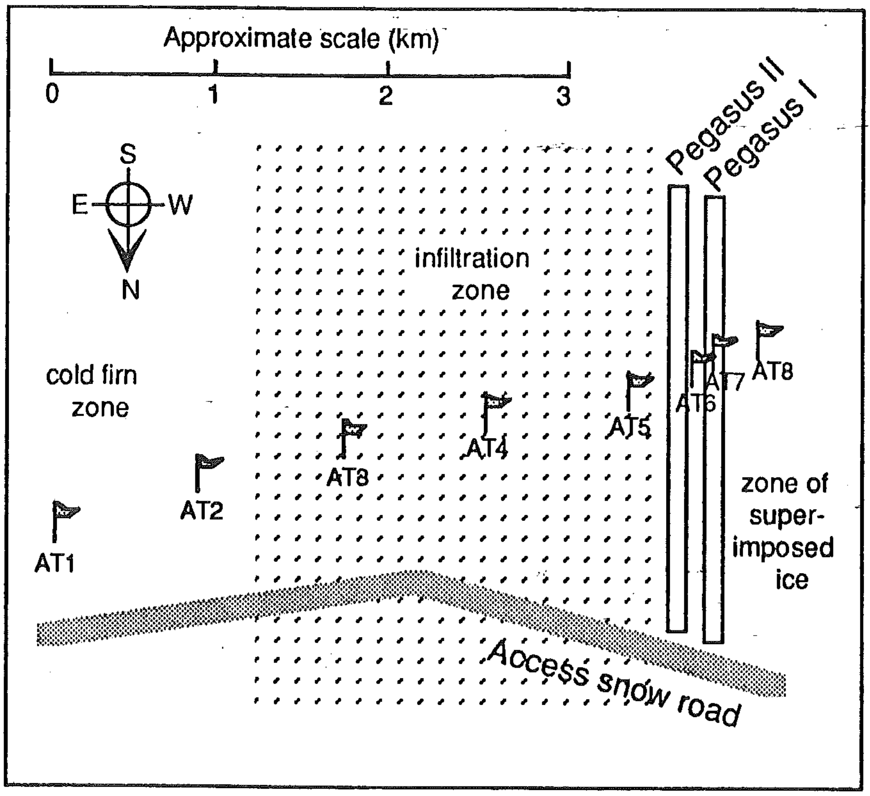


Figure 2. Location of cores taken for stratigraphic analysis on a transect across both experimental runways at the Pegasus site and across the boundary into the region of permanent snow cover. The approximate locations of the glaciological zones in the area are shown.

3.1 Natural Stratigraphy

Eight cores were obtained for stratigraphic analysis using a SIPRE auger. The cores were taken on January 27 - 28, 1992 on a transect across the Pegasus site that crossed the runways roughly at their midpoints as shown in Figure 2. The transect was about 3 km long and included ice from three different ice formation zones:

- Zone of superimposed ice where snow is transformed into ice within one year.
- Infiltration zone where the amount of meltwater exceeds half of the annual accumulation, but firn is preserved due to accumulations of the previous colder and snowy years. This zone marks the boundary between the accumulation zone and the zone of superimposed ice.
- Cold firn zone where the upper 50 to 70 percent of the winter snow accumulation is transformed to firn during the summer through partial melting and recrystallization, leaving the lower layer in the form of snow.

Figure 3 shows the distribution of snow, firn, and ice in the cores taken along the AT transect. Both experimental runways, Pegasus I and Pegasus II, are located immediately west of the transition from the infiltration zone to the zone of superimposed ice. This boundary runs roughly parallel to the runways at a distance of about 150 m to the east of Pegasus II (see figure 2). The transition to the cold firn zone is located about 2.4 km east of Pegasus II. Seven snow accumulation stakes were emplaced at the core sample locations (one at each sample site except the one on the runway itself). These may be used in future years to measure the snow accumulation across the entire Pegasus site.

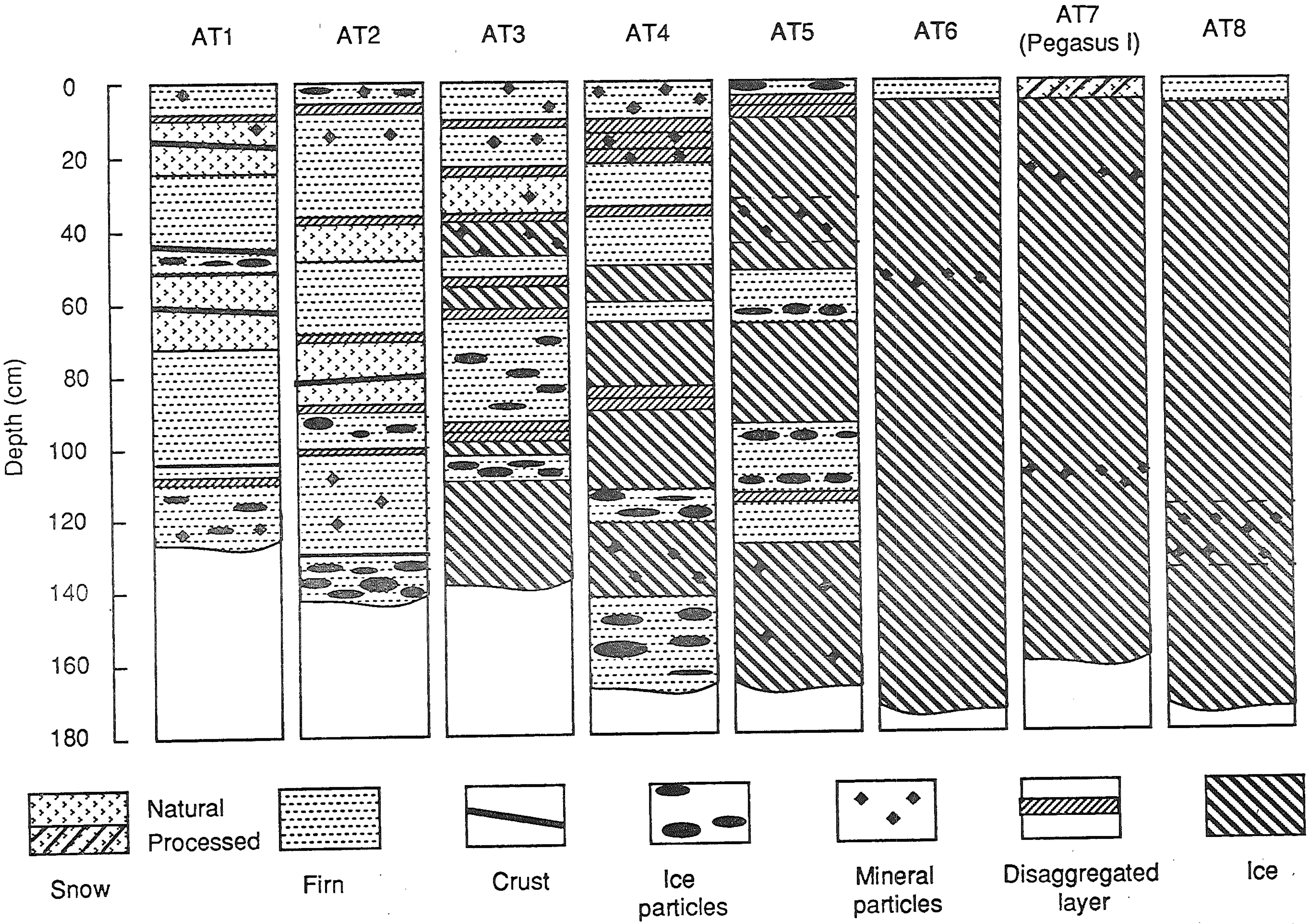


Figure 3. Stratigraphy of the upper layers of the McMurdo Ice Shelf on a transect across the Pegasus site. Site locations are shown in figure 2.

Stratigraphic analysis of the cores shows that the accumulation rate increases very gradually from west to east across the Pegasus site. Preliminary indications suggest that the average annual snow accumulation at core sites AT1 through AT3 is about 25-30 cm/yr. Previous investigations at the Pegasus site in the area, including the remaining five core locations, have determined that the winter accumulation rate is the same at the snow/ice transition as it is in the cold firn zone (Mellor and Swithinbank, 1989). The glaciological situation in this area is thus an unusual one in which the rate of snow accumulation across the area changes very little while the ice-formation zones change a great deal. That is, while the winter snow accumulation is virtually constant along the length of the core transect, the glaciological zones change from cold firn to blue ice.

The main reason for this is the peculiar wind conditions on the McMurdo Ice Shelf. The Pegasus site is situated in an area which is protected from southerly winds by White Island and Black Island (see Figure 1) which limits snow deposition. At the same time, the snow evaporation rate is increased because the generally northerly air flow over White Island (762 m), Black Island (1041 m) and Mount Discovery (2681 m) results in an adiabatic air temperature increase and a reduction in its humidity. This "foehn" phenomenon is common in many areas of Antarctica (Kotliakov, 1966).

Another significant influence of the prevailing south winds on the blue-ice areas at the Pegasus site is wind-borne mineral dust from Black Island. The amounts of this dust were measured in 1 m cores along the AT transect. The cores were melted, the resulting meltwater filtered, and the collected mineral dust weighed. The measured weights are very approximate indications of the actual weight distribution of mineral particles on the ice shelf surface. These weights are shown in Table 3. The only conclusion that can be drawn from these samples is that there is no significant variation in the amount of this dust at the Pegasus site. The higher measured value at the AT5 site is probably due to the artificial concentration of dirty snow from the Pegasus II runway by the snowblower used in the course of runway preparation.

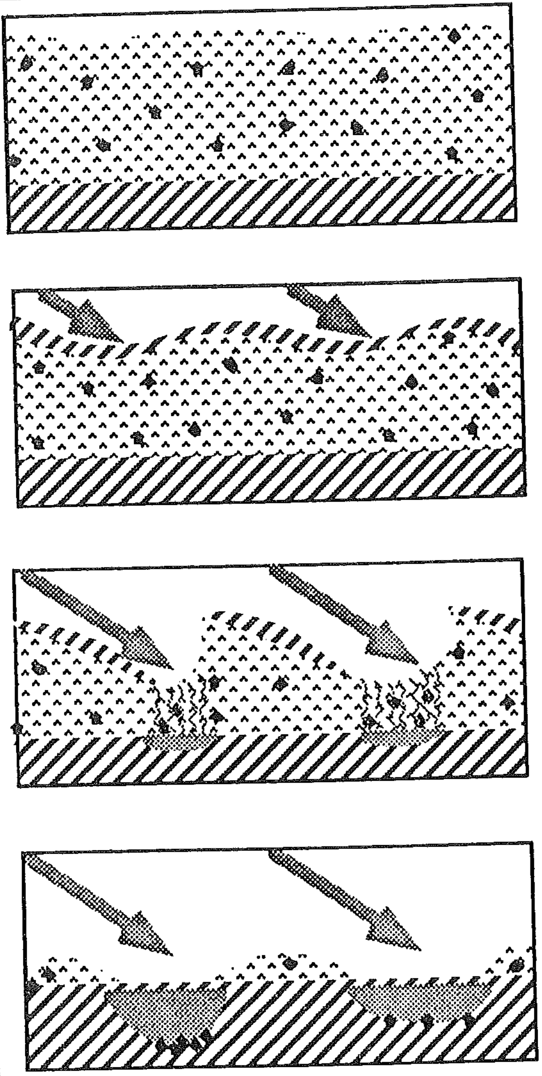
Table 3. Weight of mineral dust in 1 m core samples taken from the snow accumulation transect at the Pegasus site

Core Sites	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8
Weight, g	0.041	0.169	0.192	0.193	1.341	0.622	0.226	0.363

The area including and surrounding the two experimental runways at the Pegasus site is a typical example of a zone of superimposed ice in its melting characteristics, specifically in the formation of subsurface melt cavities from the end of December until early February and the subsequent development of hummocks on refreezing (Paige, 1968). The melting is initiated by solar radiation. Therefore, the degree of annual melting is associated with insolation and the frequency of summer snowfalls.

3.2 Melt process

During December 1991 and January 1992 insolation conditions were relatively favorable for melting, and there was almost no new snow. Meltwater cavities developed by the greenhouse effect appeared under the natural snow cover. During clear, sunny days an ice crust formed on the snow surface which hastened the melting of the underlying layers by allowing temperatures above 0°C to occur within the snow due to the absorption and trapping of radiant energy. During the final stages of this process, the snow surface developed a shingled appearance in which open cavities developed beneath an ice crust sloped in the direction of the afternoon sun (Figure 4). These sloped shingles reached a height of about 15 cm at the Pegasus site during early January 1992. Taylor and Pierce (1967) refer to this as "badlands" topography. Melt cavities also developed in the ice on the Pegasus I runway, but only where the snow cover was not compacted or the depth of the compacted snow pavement was less than 10 cm.



a) Undisturbed snow cover on an underlying ice sheet early in the summer season before melting has begun. Mineral particles may be uniformly distributed through the snow.

b) On clear, sunny days in the beginning of summer (November to early December) an ice crust forms on the surface of the snow, preventing air circulation and allowing the temperature within the snow to increase. The snow becomes more dense and moist, and mineral particles, through absorption of solar radiation, are preferentially warmed.

c) In midsummer (mid-December to mid-January), the ice crust is preferentially melted away on the sides of the slopes in the snow cover facing the afternoon sun. This results in a shingled appearance of the snow surface with the ice crust persisting only on one side of the surface irregularities. Small patches of water form and mineral particles are concentrated in them.

d) In January, when the snow cover is nearly gone, the surface of the melt pools freeze, leaving pockets of water enclosed. Melting of the ice continues because of the absorption of the incoming solar energy by the water in the pools and the insulation provided by the ice cover.

⁖ snow ▨ ice ▩ meltwater ◆ mineral particles

Figure 4. Stages in the deterioration of the snow cover at the Pegasus site

In patches of bare ice the melt process begins as subsurface disaggregation of ice crystals. Melting begins along the crystal boundaries and liquid water soon appears, first along the crystal boundaries and then in all spaces in the disaggregated ice layer. As melting continues, the cavity grows in both depth and breadth until about the middle of January. Observations on the natural bare ice near the Pegasus experimental runways show that melt cavities in January 1992 ranged in horizontal extent from 5 to 20 m and in depth from 30 to 50 cm. By the end of February, with the onset of cold weather, the cavities refreeze and cracked ice hummocks consequently form.

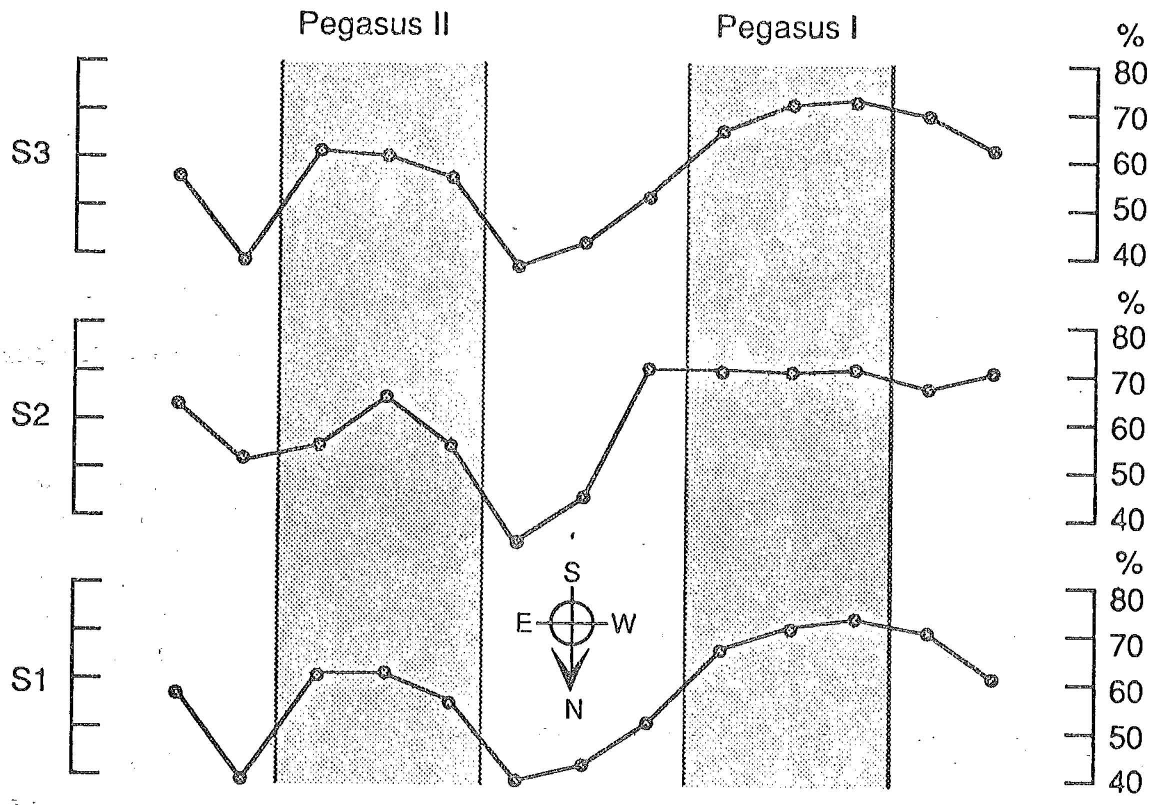


Figure 5. Albedo of the snow and ice surface at the Pegasus site 8 January 1992.

3.3 Reflective properties

Measurements of the reflective properties of the snow and ice on and near the experimental runways were made on 8 January 1992. The incident and reflected solar radiation were measured along three profiles across the runways as shown in Figure 5. The albedo (A) was obtained using the relationship A=R/I, where R = reflected solar radiation, and I = incident solar radiation. Albedo values of 0.6 to 0.7 were obtained on scattered patches of snow and bare ice on the natural glacier surface. Low albedo readings (0.44 to 0.51) were obtained on the blue ice surface over large melt pools. At the time of these readings there was a protective compacted snow layer on the northernmost 1800 m of Pegasus I and a thin, non-compacted snow cover on Pegasus II. Albedo values on Pegasus I were, on average, 15 to 20 percent higher than those on Pegasus II (Figure 5). The lowest readings obtained (0.33 - 0.40) were taken along the edge of Pegasus II where snow and ice fragments and concentrations of dirty snow had been thrown from the runway surface by a snow blower. There are two reasons for the difference in albedo values on the two runways. First, there was more dark material on Pegasus II than on Pegasus I, both from mineral dust and from machine-related contaminants, and second, the snow melting process described above progresses more rapidly in non-compacted snow than it does in a compacted layer.

4. Testing and data collection

The research and experimental activities on the Pegasus runways during the 1991-92 summer season included a test program on Pegasus I, the overall objective of which was to gather those parameters necessary to assess the feasibility of constructing a compacted snow pavement that could support wheeled aircraft loads. We also monitored the physical characteristics of the blue ice and the snow on and surrounding the runway to determine any changes due to natural environmental forces (sun, temperature, wind, precipitation) and/or due to our construction activities. To this end, measurements were made of snow density, penetrometer hardness, temperature, solar input, and stratigraphy.

Measurements of the engineering properties of the snow pavement were carried out from the middle of December through the middle of February on the test section of the runway shown in Figure 6. The data collection sites are also shown on this figure. Samples were measured in a small field laboratory at the Pegasus site.

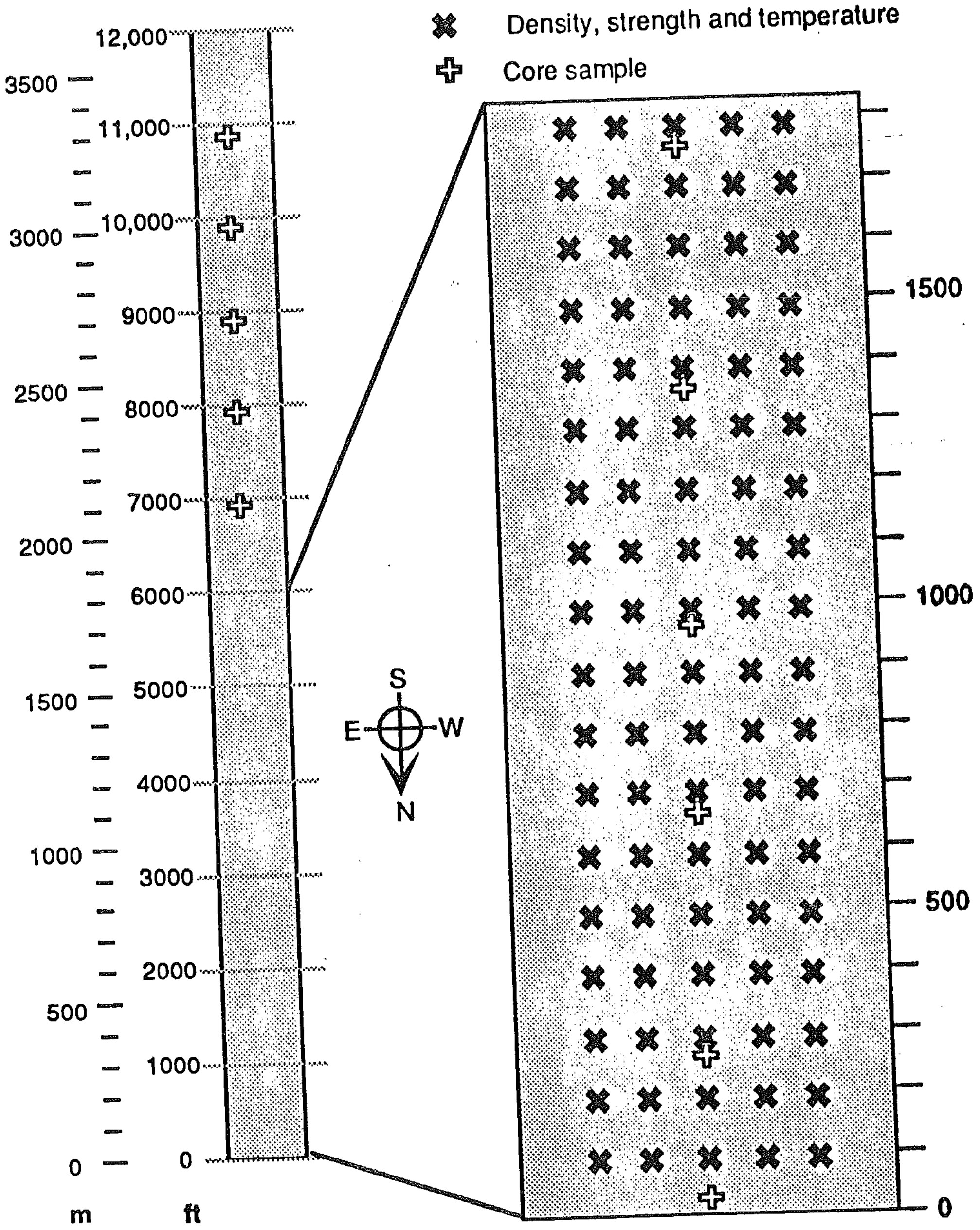


Figure 6. Pegasus I runway showing test section with locations of temperature, strength and density measurements, as well as core sample locations.

4.1. Stratigraphy at the runway

Eleven cores ranging in length from 0.68 to 2.68 m were obtained with a SIPRE auger along the centerline of Pegasus I for stratigraphic study. A representative core taken from the middle of the runway is shown in Figure 7.

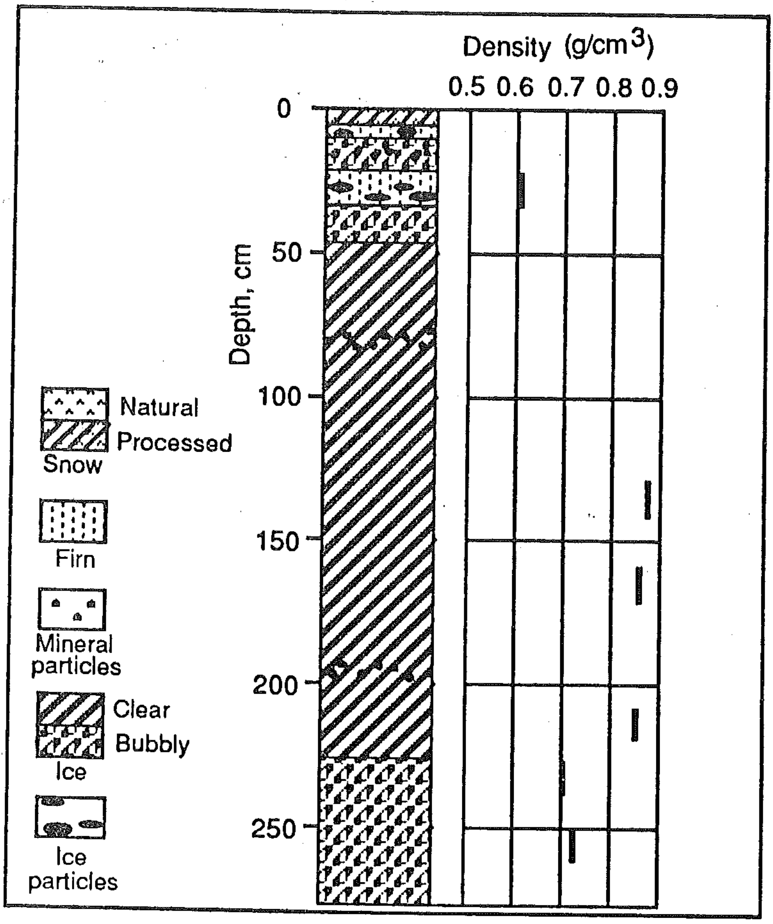


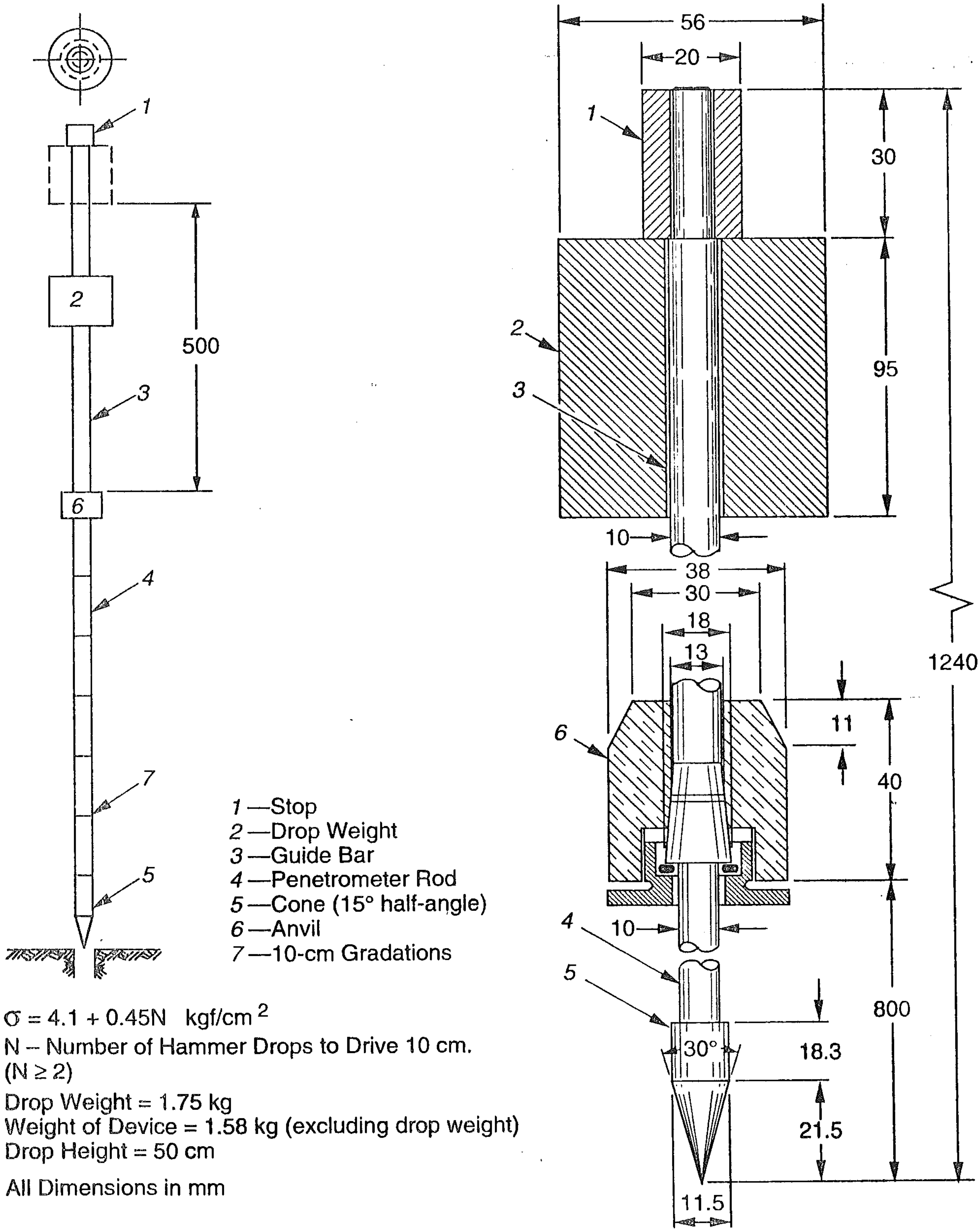
Figure 7. Stratigraphy of the upper 2.5 m of the ice shelf at site S6 on the Pegasus I runway.

This core illustrates the various layers that exist in the ice foundation beneath the snow pavement. The density of the clear ice at a depth of from 0.45 to 2.21 m ranged from 0.85 to 0.87 g/cm^3. Above and within this clear ice layer were three layers, 5 to 10 cm thick, containing mineral particles. These layers occurred at depths of 15, 76, and 193 cm. In addition, there were three layers containing numerous bubbles ranging in diameter from 2 to 4 mm. These layers were located at 10 to 22 cm, 33 to 45 cm, and 221 cm to the bottom of the core. Ice of this type is typically formed in the superimposed ice zone during cold summer seasons. The density of this ice ranged from 0.70 to 0.76 g/cm^3. It is likely that the uppermost bubbly ice layer was formed during the 1990-1991 summer season when there was a great deal of snow. The other two layers at greater depths suggest similar cold periods in the past.

4.2. Physical and mechanical properties of ice and snow

Samples for density measurement were gathered with a SIPRE auger or a hand saw. A hand saw was used to trim the snow into regular volumes for mass measurements. The masses of the samples were measured on site with a digital balance (0.1 g sensitivity) in the field laboratory. Density measurements were carried out on December 19 and 27, January 13 and 28, and February 3 and 7.

Two types of penetrometers were used to measure the strength of the runway pavement: the AARI penetrometer (Figure 8a) and the Swiss Rammsond (Figure 8b).



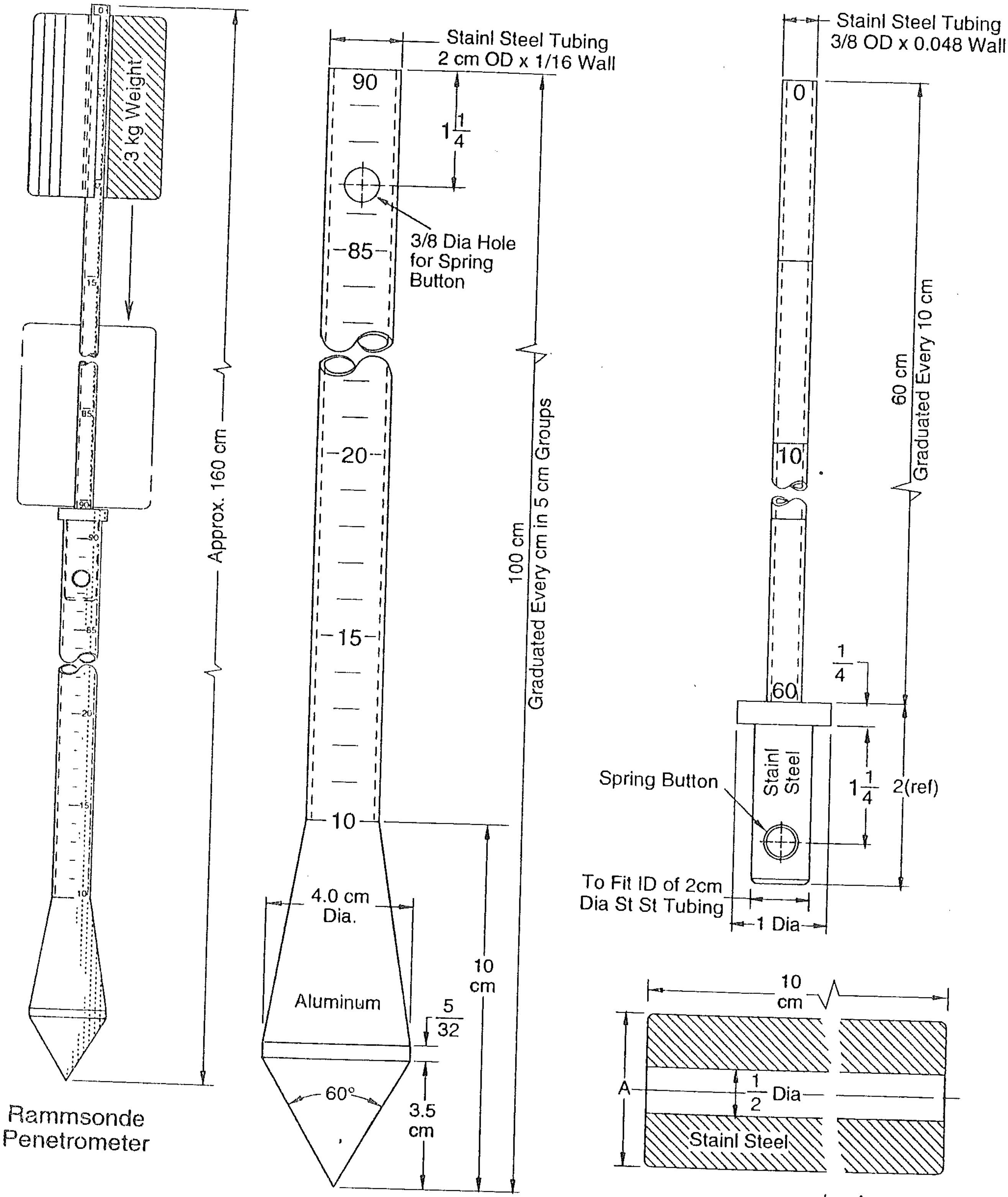
1 —Stop
2 —Drop Weight
3 —Guide Bar
4 —Penetrometer Rod
5 —Cone (15° half-angle)
6 —Anvil
7 —10-cm Gradations

$\sigma = 4.1 + 0.45N$ kgf/cm^2
N – Number of Hammer Drops to Drive 10 cm.
($N \geq 2$)

Drop Weight = 1.75 kg
Weight of Device = 1.58 kg (excluding drop weight)
Drop Height = 50 cm

All Dimensions in mm

Figure 8a: AARI Penetrometer



	A
3 kg Weight	70 mm
1 kg Weight	42 mm

Figure 8b: Swiss Rammsond

The AARI penetrometer was equipped with a 30° conical tip with a maximum diameter of 11.5 mm. The drop hammer weighed 1.75 kg and the drop height was 50 cm. The Swiss Rammsond had an angle of 60° and a maximum diameter of 40 mm. Its drop mass was 3 kg with a drop height of 50 cm.

As has been shown in previous studies (Niedringhaus, 1965; Russell-Head and Budd, 1989; Abele, 1990) the AARI penetrometer is more suitable for testing hard snow while the Swiss Rammsond is more useful for the glaciological examination of soft natural snow and firn. The procedure for using both of these instruments is the same. The hammer is raised by hand to a height of 50 cm and then allowed to drop freely. The depth of penetration is read from the centimeter scale on the shaft. The usual procedure is to record the number of hammer blows required for each 10 cm depth increment.

The pavement of Pegasus I was tested using the AARI penetrometer on December 19 and 27, January 14 and 21, and February 7 and 12. The hardness (resistance to penetration) is calculated using the following expression:

$$R=\frac{W\cdot h\cdot n}{L}+W+Q,\ \text{where} \tag{1}$$

W - weight of drop hammer (kg)
h - height of drop (cm)
n - number of hammer blows
L - penetration after n blows (cm)
Q - weight of penetrometer (kg)

The values of AARI penetrometer hardness have been correlated with values of unconfined compressive strength of processed snow. This relationship was derived using data collected on compacted snow runways near Melodezhnaya Station (Aver'ianov, Klokov and Alechin, 1982). For practical field use in determining the load bearing capacity of snow pavements, Table 4 can be used.

Table 4. Interrelationship between hardness and strength for the AARI penetrometer

Number of blows (n)	Unconfined compressive strength, σ (kg/cm²)	Hardness R (kg)
1	1.5	11.7
2	2.8	20.4
3	4.4	29.1
4	5.9	37.8
5	6.3	46.5
6	6.8	55.2
7	7.2	64.0
8	7.7	72.6
9	8.0	81.3
10	8.5	90.0
11	9.0	98.6
12	9.5	107
13	9.9	117
14	10.3	125
15	10.8	133
16	11.2	142
17	11.7	151
18	12.1	160
19	12.7	168
20	13.2	177

4.3. Comparative testing of penetrometers

Comparative tests using the AARI penetrometer and the Rammsond were conducted on the Williams Field runway (5 January 1992) and on the South Pole runway (15-16 January 1992). The correlation between the two instruments is shown in Figure 9, and resulted in the following relationship:

$R_{ram} = 11.707 + 6.268R_{pen}$, where (2)
R_{ram} - Rammsond hardness (kg),
R_{pen} - AARI penetrometer hardness (kg).

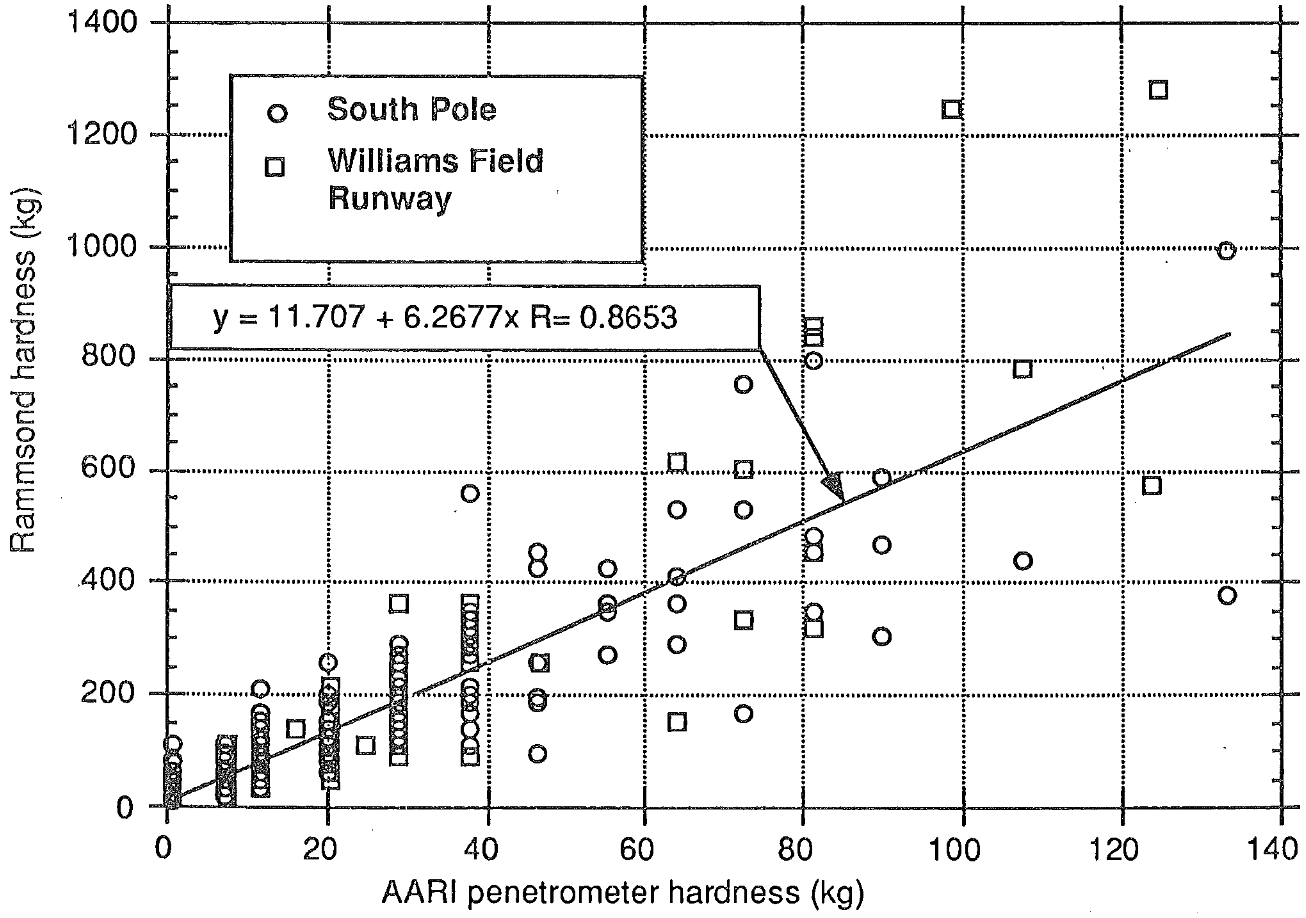


Figure 9. Correlation between AARI and Swiss penetrometers

The high value of the correlation ratio (.87) allows the use of both types of penetrometers for the practical estimation of the strength of snow runway pavements. However, field tests have shown that the AARI penetrometer with a 30° cone penetrated hard snow more smoothly and was much easier to remove from dense material than the Rammsond with a 60° cone.

Plane section photographs were taken of snow samples taken on October 27 and November 23, 1991, and on February 2 and 13, 1992; stereology will be performed on these photographs but has not yet been completed. Ice grain metamorphism and grain bond formation will be documented from this analysis.

All data collected were generally only recorded in field notebooks, but a computer data base was initiated mid way through the season. Temperature profiles were entered on a spreadsheet allowing plotting and analysis. In the future, it is planned that all data be placed in a data base. Ultimately, automated data collection is planned.

5. Construction and testing feedback

5.1. Chronology of construction activities

The first Pegasus runway was located and laid out in November of 1989. Using an LGP D8 bulldozer, the snow cover was stripped and windrowed (Figure 10) on a 4000- by 40-m area near a wrecked Constellation named Pegasus. The windrows were then redistributed over the area using graders and snow planes (Figure 11). This process distributed the snow cover more evenly (resulting in an approximately 15-cm cap of snow on the blue ice) and broke up the hard, wind-packed snow present at the site. The snow was then rolled with the machinery and available implements in an attempt to compact the snow firmly. Unfortunately, neither high densities nor strengths could be attained because of the lack of high ground pressure, large contact area equipment, and the excessive depth of snow that we were trying to compact.

No new equipment was available during the second year of work on the Pegasus I runway, so rolling efforts did not increase the density past the 0.45 g/cm^3 level produced the prior season. However, we were encouraged by two factors; a) no net gain or loss of snow was observed at the site, confirming that it was located where we wished, and b) no melt pools formed in the blue ice that was covered by compacted snow.

Figure 10. Bulldozer stripping and windrowing snow on runway site.

At the beginning of the 91/92 season, the compacted snow on Pegasus I was covered by patches of firm drift snow from winter storms (Figure 12). Exposed areas of compacted snow were very strong and had a smooth surface. The density of the compacted snow was near 0.5 g/cm and evidence of its strength was seen by the small penetration (< 1.5cm) of the grouser bars on an LGP D8 bulldozer (Figure 13).

During the first week of October 1991, the winter's drift snow was broken up and windrowed by using float-skis attached to the bulldozer blade (Figure 14). The snow was then roughly distributed over the runway with a snow plane (Figure 15). This snow was seen as either providing an insulating cap over the compacted snow from the previous season (in which case it would be removed later in the season) or as a potential source for additional compacted snow cover if needed. During the process of breaking-up and redistributing the winter-over snow, however, we encountered a considerable amount of dark-colored mineral particles incorporated in the snow in layers (Figure 16). This contamination was from storms with high winds that probably came from the southeast carrying material from Black Island.

After distributing the winter snow, the Pegasus I runway was left untouched until mid-December 1991, when air and snow temperatures were favorable for compaction of snow. By this time, a heavy (45 tonne) pneumatic-tire roller (Figure 17) was delivered to McMurdo for facilitating further compaction of the Pegasus I snow pavement.

Figure 11. Grader used to distribute windrows.

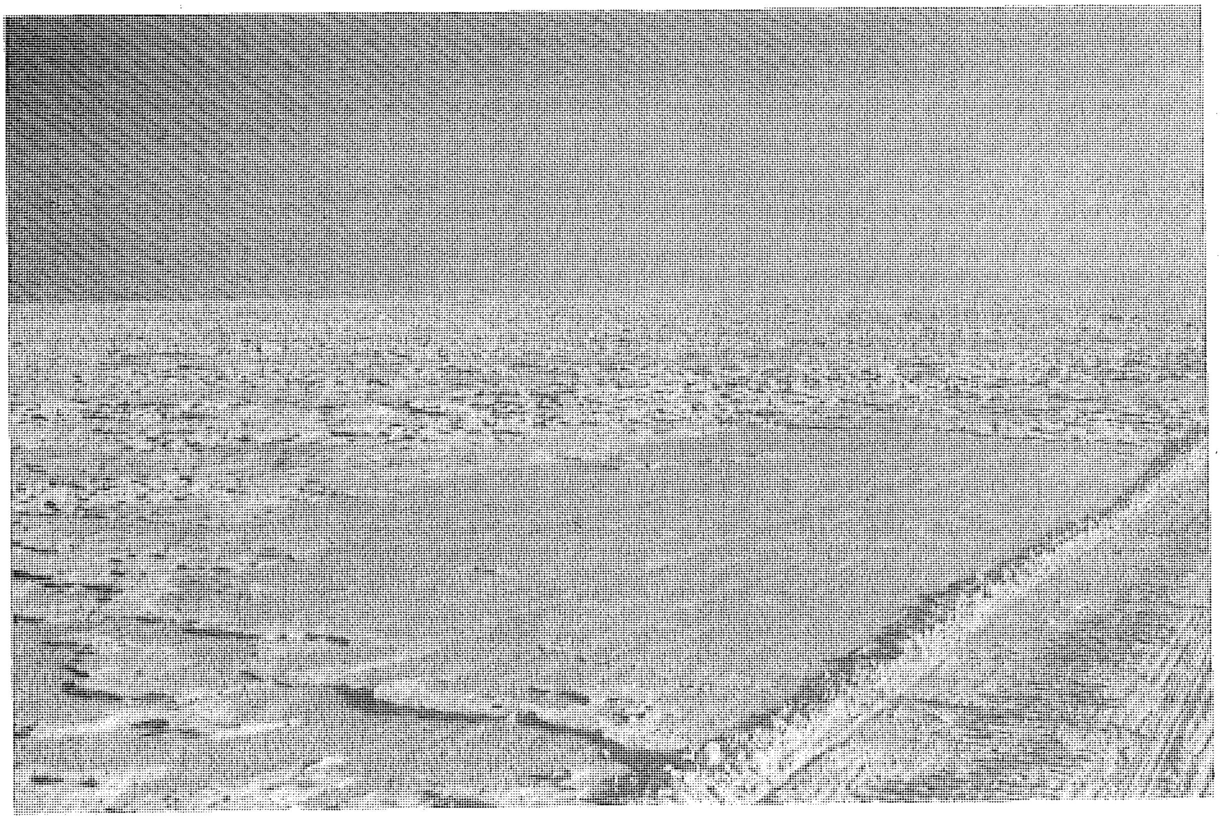


Figure 12. Patches of snow accumulated during winter.

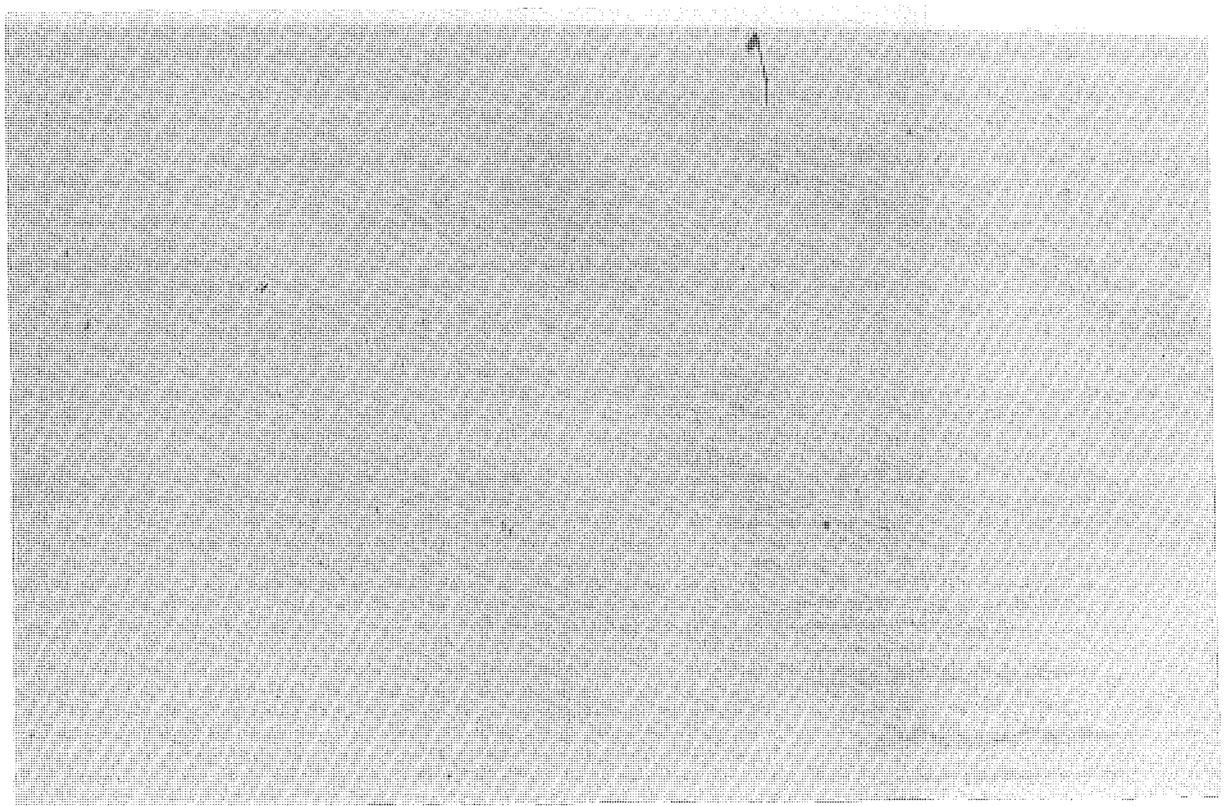


Figure 13. Tracks left on compacted snow by D8 tractor.

During December and January, several events occurred that caused degradation in the Pegasus I runway. Snow melt occurred on the southern end of the runway beginning at about the 1800 m mark. This was the result of a) natural ablation and disaggregation (which was higher than desirable on the compacted snow because of the development of a surface ice crust over a loose crystalline basal layer), b) the effects of mineral particles deposited from wind storms (both on and near Pegasus I) which greatly accelerated the ablation and disaggregation, and c) flowing melt-water from adjacent construction activities on Pegasus II. Much of the snow cover was lost from the 1800 m mark southward by the end of January, and solar generated melt-pools had formed in many parts of that section of the runway.

Most of the northern 1800 m of runway remained sound during this period. This section was rolled at regular intervals in December and January on a schedule governed by the temperature, the sintering time since the last rolling, and whether or not additional snow was deposited on the runway. A light shoe drag or "smoother" (Figure 18) closely followed the roller to level any small windrows or furrows left by the roller tires. Initial compaction was done with the heavy roller which was ballasted to a gross weight of about 27 tonnes and had a tire pressure of 480 kPa (70 psi). The ballast was increased to about 36 tonnes in late January and to 43 tonnes in early February with a tire pressure of 690 kPa (100 psi). This systematic rolling based on the environmental conditions effectively increased the density of the snow cover throughout its thickness.

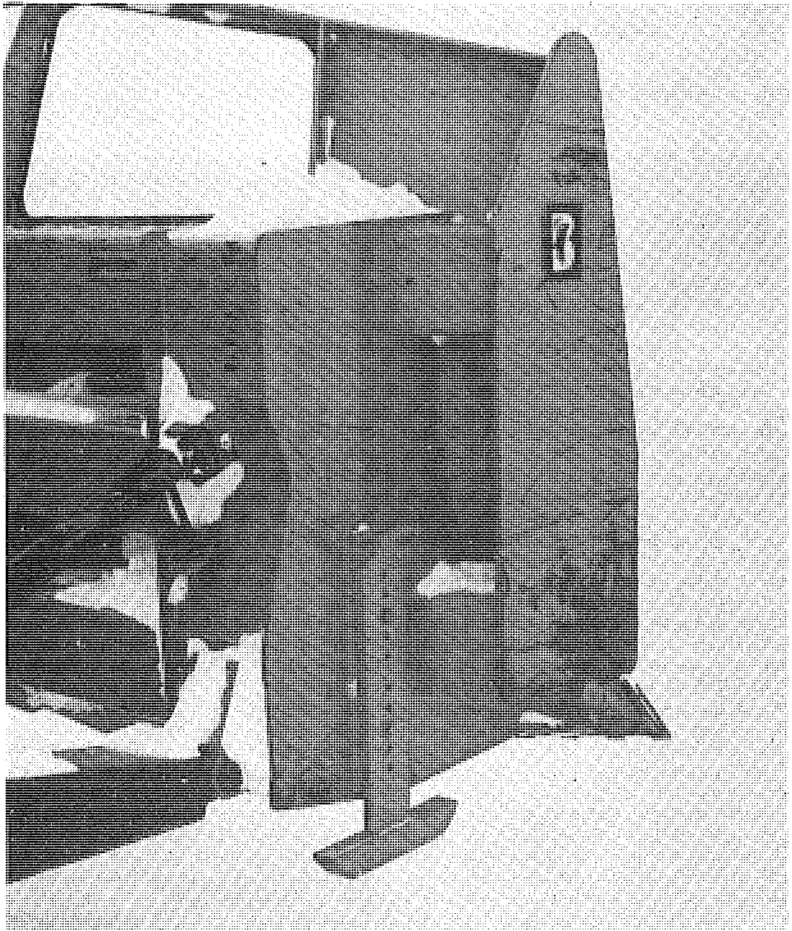


Figure 14. Float ski on bulldozer blade.

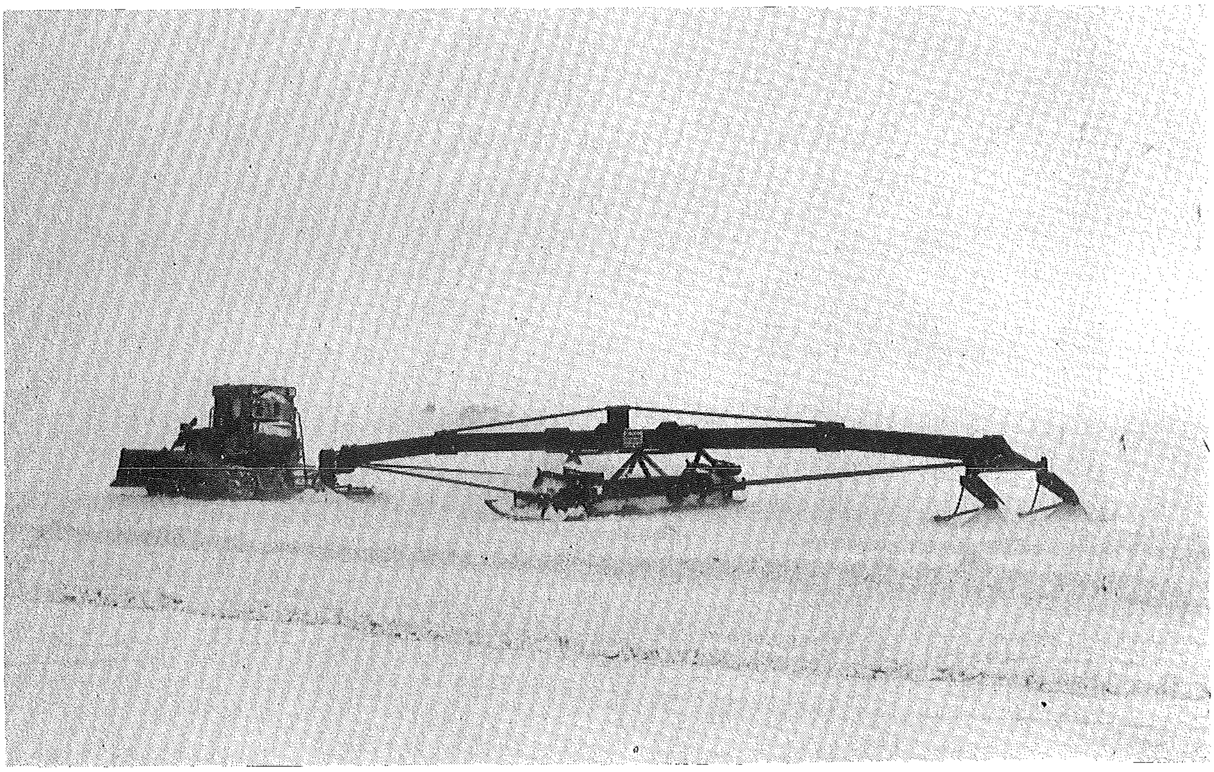


Figure 15. Snow plane used to distribute snow.

Figure 16. Mineral dust in over-winter snow.

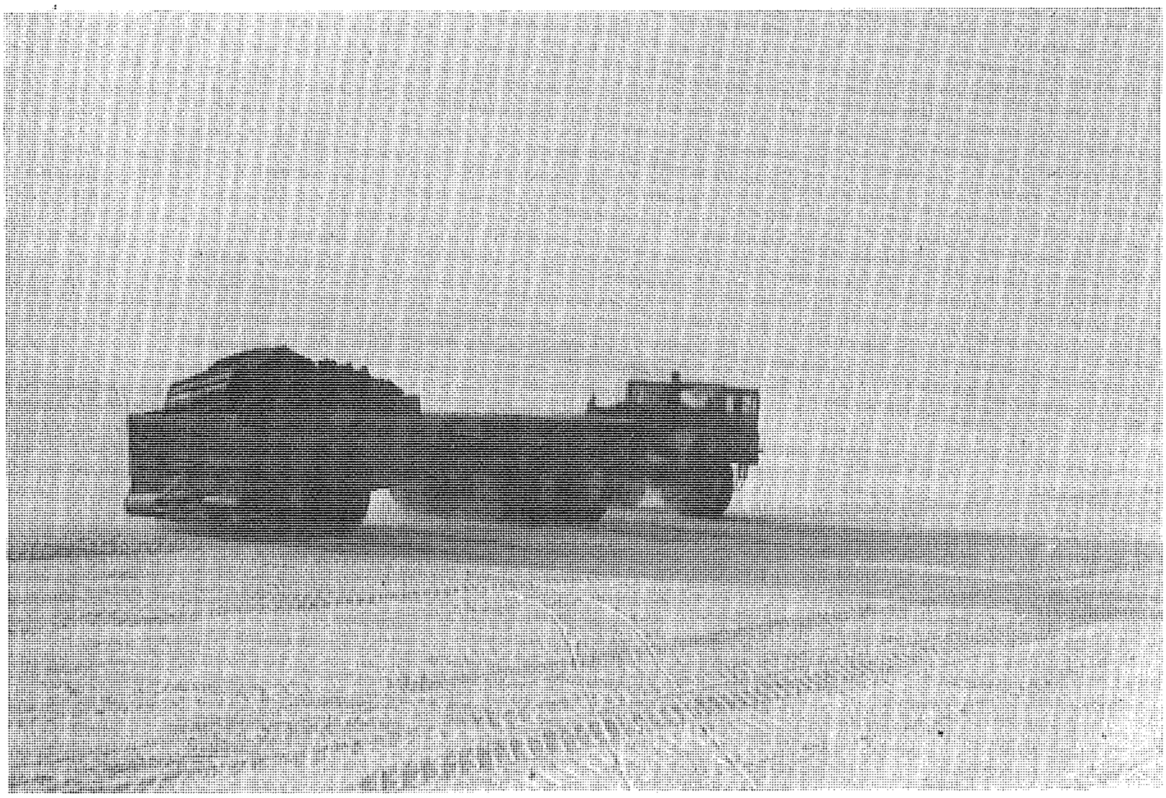


Figure 17. Heavy pneumatic-tire roller.

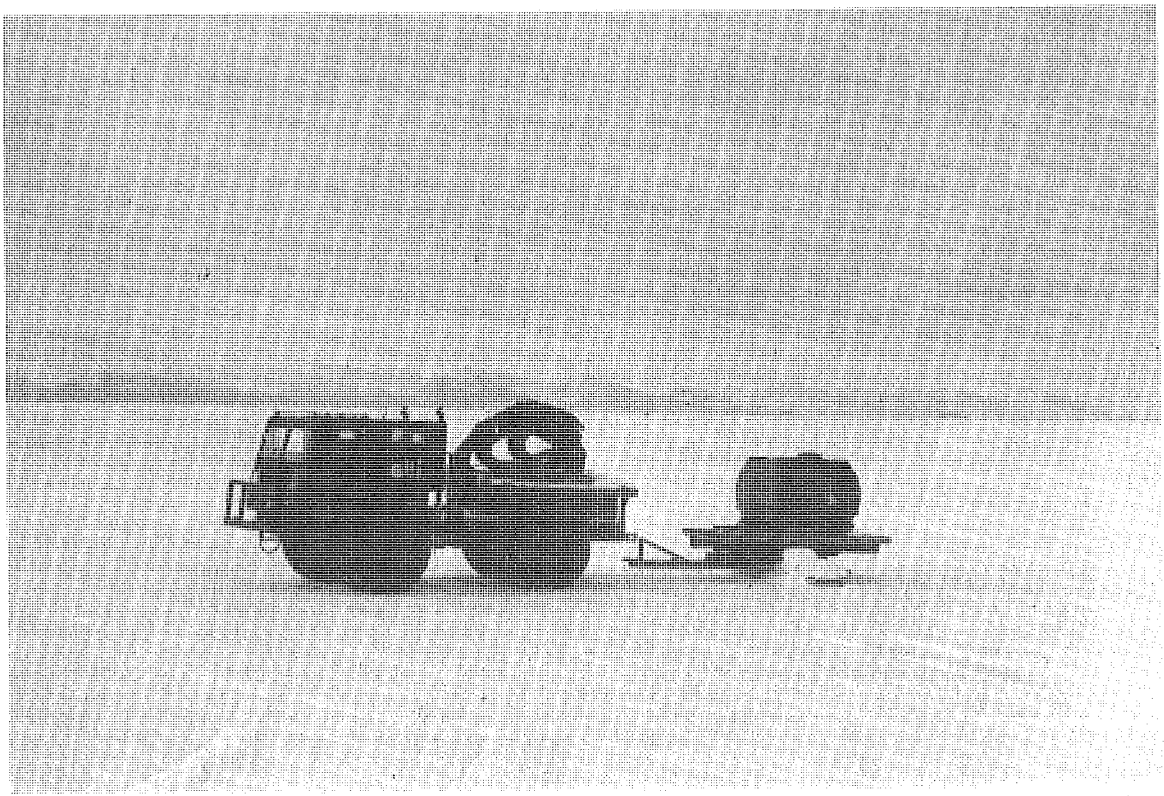


Figure 18. Shoe drag for smoothing roller tracks.

A storm on 10 February delivered a thin covering of very light snow. This was rolled with the heavy roller and compacted on top of the original snow cover. Although temperatures were not ideal for compaction, by the time this operation was completed, only about 3 cm of snow was added to the runway cover. This top layer probably had a density of about 0.55 g/cm^3.

Had further storms delivered significant amounts of new snow prior to anticipated use of the runway and temperatures been too low for compaction of this additional snow to adequate levels, it would have been necessary to remove it from the runway.

5.2. Construction activities on Pegasus I

At the end of October 1991, after the winter accumulation period, Pegasus I had a snow cover of about 20-cm thickness. The processing of the snow began October 15, 1991. The snow temperature was sufficiently cold during October and November that planing alone served first to provide a high albedo snow surface (>0.8) to prevent destruction of the snow surface by solar radiation, and second to level and begin preliminary packing of the snow cover. Planing was undertaken on October 18, 1991, and December 24, 1991. The measurements made on 19 December show that the snow was compacted to an average thickness of 14 cm, an average density of 0.55 g/cm^3 (Figure 19), and average strength of somewhat more than 6 kg/cm^2.

The snow temperature reached the melting point in the middle of December, but manpower constraints prevented the initiation of compaction by roller until January 6, 1992 and limited the extent of the processed section of the runway to a 1800-m test section, as shown in Figure 6. The original weight of the roller was about 27 tonnes and the tire pressure was about 480 kPa. A Caterpillar D-4 tractor was used for the first pass of the roller, as other available equipment lacked the necessary traction. Immediately after rolling, the snow surface was smoothed using a shoe drag which followed the roller not more than 10 minutes later. Two passes of the roller were completed on January 6-7 during which the average density was increased to 0.63 g/cm^3 and the strength to about 9 kg/cm^2.

Rolling was undertaken for the second time on January 23 after a light snowfall that deposited about 2 cm of snow on the runway. One pass was completed with the roller weighing 36 tonnes and a tire pressure of 620 kPa. The average density and strength achieved were 0.65 g/cm^3 and 9.26 kg/cm^2.

A moderate snowfall on January 30-31 left a 5 to 8 cm snow cover with drifts on the runway. The sequence of processing this new snow began with grading on February 1. This was followed by rolling on February 1 and 4, and finally smoothing using the shoe drag on February 4. The weight of the roller was increased to about 43 tonnes and the tire pressure to 690 kPa. The hard snow surface produced by previous processing enabled a smooth-tired Delta to pull the roller. The time required to complete the 90- by 1800-m test section was six hours at a speed of 15 - 20 kph, far less than previous passes.

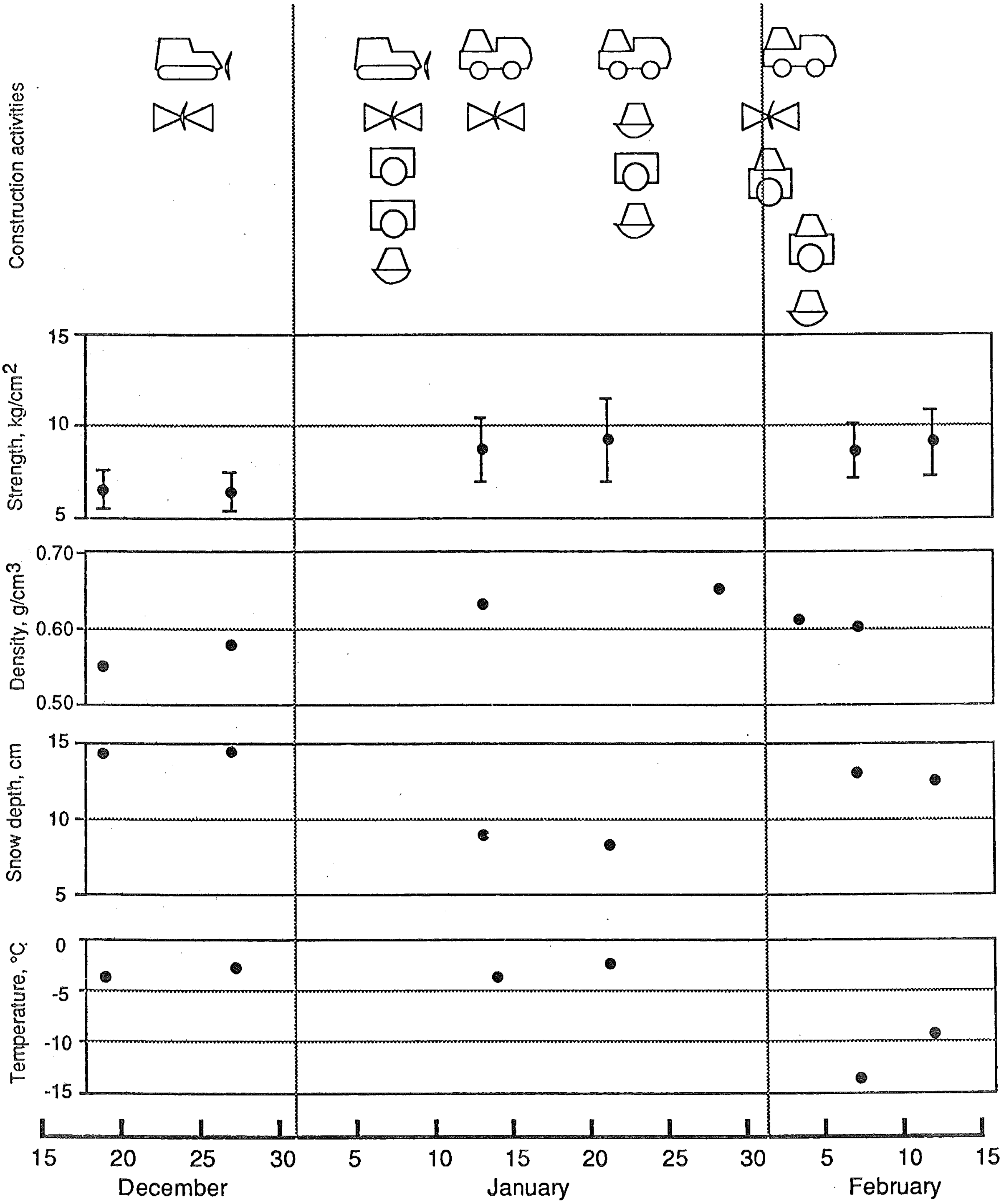


Figure 19. Construction activities and physical properties of the snow on Pegasus I through the 1991/92 season.

6. Results and proof testing

The penetrometer measurements on February 7 and 12 indicate that the strength of the snow pavement was sufficiently strong to support both LC-130 and IL-76 wheel loads. The strength at this time was about 10 kg/cm^2 and the density about 0.60 g/cm^3. As a result of repeated compaction by the roller the lower layers of the snow pavement in most areas were composed of very hard material approaching ice with regard to strength (>20 kg/cm^2) and density (0.70 g/cm^3).

Table 5. Average values of density and strength on the Pegasus I test section.

Date of Measurement	Depth (cm)	Density g/cm^3	Strength, kg/cm^2	
			1-10 cm	10-20 cm
19-Dec-91	14.21	0.55	6.45	6.24
27-Dec-91	14.55	0.58	6.41	6.99
13-Jan-92	9.07	0.63	8.70	9.79
21-Jan-92	8.27		9.26	9.83
28-Jan-92		0.65		
3-Feb-92		0.61		
7-Feb-92	13.00	0.60	8.65	11.01
12-Feb-92	12.57		9.17	10.76

Figure 19 shows the sequence of snow pavement processing procedures on the test section of Pegasus I, along with the average values of pavement parameters from Table 5.

For insurance, a proof cart was designed that is fitted with LC-130 tires and wheels, placed in the same pattern and spacing as the aircraft; the cart can be ballasted to the full weight of a loaded LC-130 (70 tonnes) or a C-141 (145 tonnes). It was our intention to tow this proof cart up and down the runway several times to make sure a) that no subsurface cavities existed that could cause a bearing failure and b) that the snow cap did in fact have adequate strength to support the LC-130 tire pressure. Unfortunately, the proof cart was not available for use on the runway by February.

To proof the runway in the absence of the proof cart, two methods were used. First, the pneumatic tire roller was used on the runway with its tire pressure at 690 kPa (100 psi) and a gross weight of 43 tonnes. In this condition, the roller had a tire pressure higher than any single C-130 tire and the total load concentrated over a small area by the roller was greater than is present on one of the LC-130's main loading gear. The roller did not reveal any weak cavities and the snow surface showed, at most, minimal rutting in response to the tire pressure. This left us feeling very confident that the runway could support wheeled taxiing and take-offs by a LC-130.

Aircraft operation managers expressed some concern, however, since the gross weight of an aircraft had not yet been placed on the runway.This concern was addressed by operating a gang of vehicles (whose weight totalled 70 tonnes) in close formation over the entire surface of the 1800- by 90-m usable section of the runway. The footprint of these vehicles was close to that defined by the three landing gear of the LC-130. This second proofing was, as expected, successful, and management agreed to a test by aircraft.

On February12, an empty LLC-130 Hercules, returning from the South Pole, landed on the Pegasus runway. This was a ski landing, but the skis were lifted within 90 m of touchdown. The aircraft taxied the full length of the runway (Figure 20) turned, and returned to the touchdown point. Communication from the cockpit indicated a smooth, firm feel with no control concerns or problems. Ground survey showed no rutting. In many places, no evidence of the aircraft's tires could be seen. At most marks from the tires' ribs could be seen (Figure 21). The aircraft performed a pre-flight check and then proceeded with a wheeled take-off. The wheels left the snow after a distance of about 1050 m.

Two days later, on February 14, an LC-130 weighing 67 tonnes (fully loaded, ski take-off condition) left Williams Field and landed at Pegasus on skis. Taxiing and take-off were again completed successfully on wheels. On this occasion, the topmost 10 cm of snow was weak because it was only one day old and temperatures were too low for compaction to high density and sintering time too short to allow bond formation. Despite this, the aircraft experienced no control problems and the wheeled take-off was accomplished within 1200 m of launch.

No wheeled landings were planned or executed. This was deliberate. Without information from operation of the proof cart we chose to adopt a very conservative approach. Because of the lack of infrastructure at the Pegasus site, maintenance, fueling and primary cargo loading of the aircraft necessarily would have to take place at Williams Field. Thus, any potential use of Pegasus for the 91/92 season would require hopping from Williams Field to Pegasus with all fuel and most cargo on board. Landing at Pegasus on skis, having taken off at maximum weight from Williams Field on skis, seemed prudent, since there would be no reason to land on wheels. Switching to wheels at Pegasus and loading on an additional 2700-3200 kg, the aircraft would then take off at maximum possible weight for Christchurch, NZ.

By the time these two test landings occurred, the USAP season was rapidly coming to a close. The backlog of passengers to leave the Continent was caught up, so there was no need to take advantage of the additional payload afforded by Pegasus. Thus, no further use of Pegasus occurred during the 91/92 season. However, aircraft operations personnel, USAP managers, and project members were all satisfied that the program now has an understanding of how to successfully build, maintain, and operate from the Pegasus compacted snow runway.

Pre-season operational planning for the 92/93 season has scheduled a test landing of a C-141 in early November when the compacted snow will still be very strong from its cold soaking over winter. In addition scenarios for redeployment from February 9 to15, 1993, have been developed based on C-141 (ideally) or wheeled LC-130 and C-130 (fallback) operating from Pegasus.

7. Discussion

7.1. Design parameters snow pavement at the Pegasus site

Both Pegasus experimental runways are situated within the zone of superimposed ice where the amount of winter snow accumulation is sufficient to construct functional compacted snow runways for use by heavy wheeled aircraft. Unfortunately, strong solar radiation during December and January tends to promote the formation of internal melting. The solution of this problem lies in the creation and maintenance of a snow pavement with a high albedo to reflect solar radiation through the summer season and thus prevent subsurface melting. Recent findings suggest that a compacted snow pavement about 20-cm thick should be sufficient to protect the subsurface material from melting.

The design specifications for the runway pavement should take into account the important contribution to overall bearing capacity of the ice basement. It is easy to build and maintain a thin pavement, but it must be at least 20 cm thick.

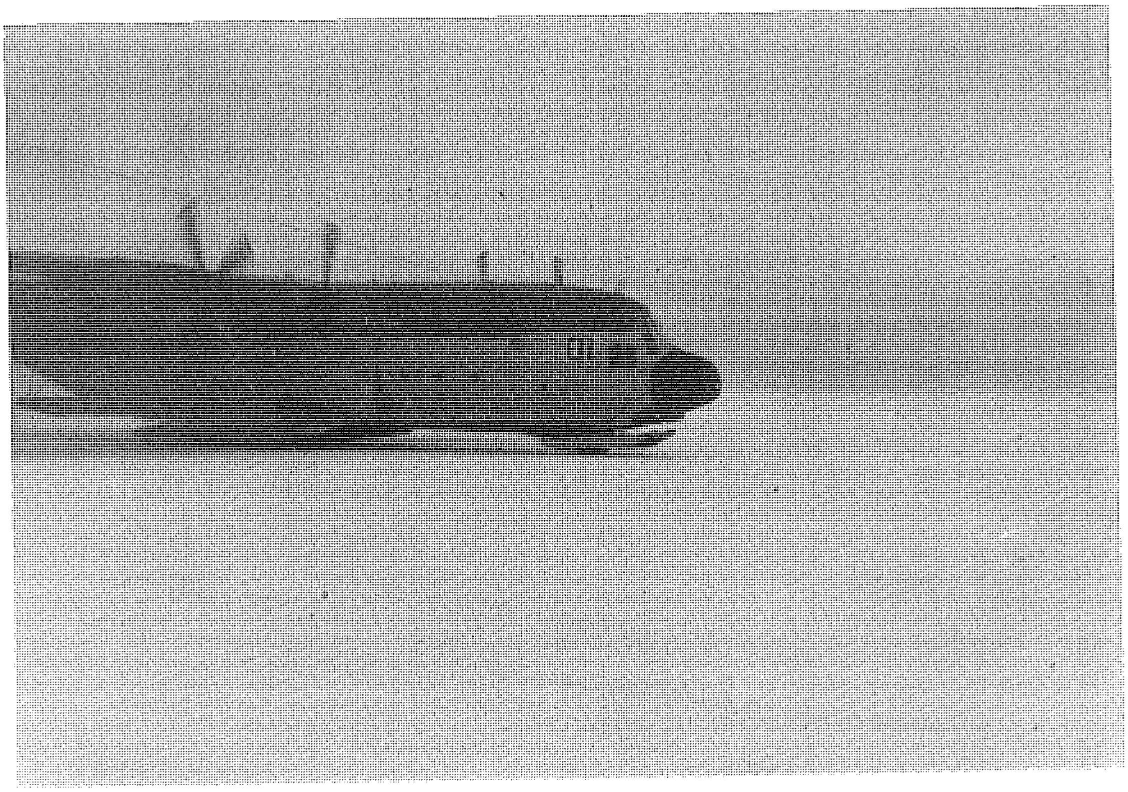


Figure 20. LC-130 taxiing on wheels on compacted snow.

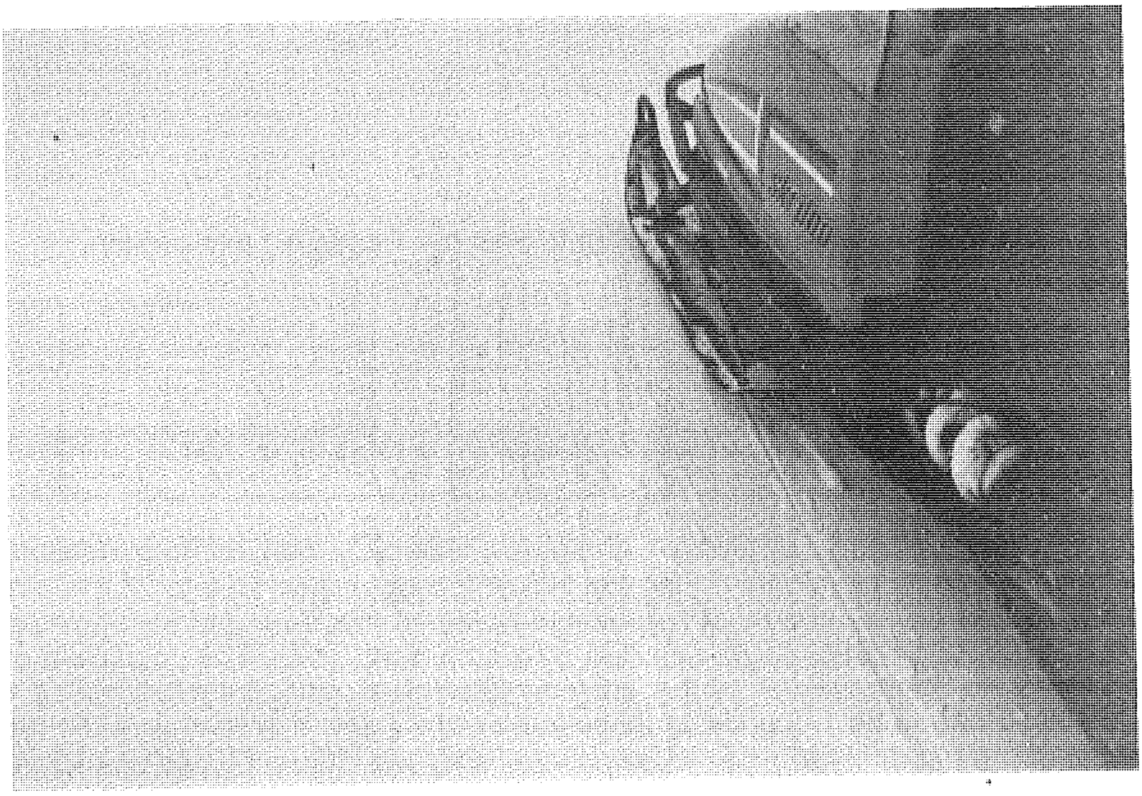


Figure 21. Tracks left on compacted snow by aircraft tires.

The main input parameter for the design of a single layer snow pavement on an ice basement is the aircraft tire pressure. The pavement requires sufficient and uniform strength at all depths over the entire runway surface. This is not an easy task because the nature of the construction equipment and slight variations in vehicle passes usually result in local variability in the processed snow pavement. Therefore, it is necessary to design the required values of strength with respect to standard statistical parameters of strength variation, i.e., standard deviation and coefficient of variation.

The guaranteed values of strength are calculated using the formula:

$G_g = G_a(1 - C_v)$, where (3)

G_g = guaranteed strength (kg/cm^2),

G_a = average strength measured by penetrometer (kg/cm^2), and

C_v = coefficient of strength variation.

The required values for the strength of the snow pavement are then calculated using the formula:

$$G_r = \frac{K \cdot P}{1 - C_v}, \text{ where} \qquad (4)$$

G_r = required snow pavement strength, (kg/cm^2),

P = aircraft tire pressure, (kg/cm^2),

C_v = coefficient of strength variation, and

K = coefficient of reliability.

The main criterion of the readiness of the compacted snow pavement should be the equivalence of the guaranteed strength to the required strength:

$$G_r \geq G_g \qquad (5)$$

Table 6. Statistical analysis of strength data from the Pegasus I test section.

Date	19-Dec-91		27-Dec-91		13-Jan-92		21-Jan-92		7-Feb-92		12-Feb-92	
Layer depth (cm)	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
Average	6.45	6.24	6.41	6.99	8.70	9.79	9.26	9.83	8.65	11.01	9.17	10.76
Standard deviation	1.16	1.93	1.10	1.82	1.81	2.44	2.20	1.88	1.42	1.75	1.72	2.88
Coefficient of variation	18.05	30.96	17.15	26.08	20.81	24.96	23.80	19.07	16.41	15.91	18.80	26.76

The range of the coefficient of strength variation, C_v, derived from measurements of the Pegasus I snow pavement during the 1991/92 season was 15.9 to 26.8% as shown in Table 6. It may be assumed that careful and repeated processing of the snow pavement will result in a coefficient of strength variation no greater than 15%. The coefficient of reliability, K, accounts for unpredictable factors such as spilled fuel, disaggregated lenses, etc., and may be assumed to be 1.05. Using these values of C_v and K in formula 4 the required strength of the upper layer of the snow pavement for the different types of aircraft listed in Table 2 was calculated (Table 7).

TABLE 7. Aircraft wheel load characteristics and required snow pavement strength.

Aircraft type	Max take-off mass (kg)	Wheel load (kg)	Contact area per tire (m^2)	Tire pressure (kg/cm^2)	Ramm hardness (kg)	Required strength (kg/cm^2)
C-130	70,310	12,930	0.260	6.6	340	8
C-141	146,555	18,144	0.145	12.4	1050	15
C-5A	332,260	11,790	0.123	10.6	770	13
IL-76	170,000	10,620	0.208	6.0	270	7.5

8. Summary

The test program undertaken on Pegasus I this season to assess the potential of compacted snow runway construction has demonstrated that compacted snow pavements can be made sufficiently strong for the operation of LC-130 aircraft on wheels.

Russian experience with conventional multi-tired rollers at Molodezhnaya and Novolazrevskaya (Aver'ianov, Klokov, et al., 1985) and the trial construction of compacted snow pavement near Casey (Russell-Head and Budd, 1989) and on the Ross Ice Shelf near McMurdo showed that the efficiency of snow compaction depends on the tire pressure, the total tire load, and the snow temperature. The tests showed that high snow density (>0.60 g/cm^3) can be achieved with tire pressures from 6 to 8 kg/cm^2 if the temperature during construction ranges from -12° to -1°C.

The idea is to achieve maximum compaction by progressively increasing the tire pressure and the weight of the roller. The rollers should be used in three stages with the tire pressures 480, 620, and 690 kPa and the total weight of the roller 27, 36, and 43 or more tonnes. Four to five passes of the roller at each of these stages should be completed.

Rolling on the Pegasus runway should start in early November with tire pressures of 350 kPa and a roller weight of 23 tonnes. At the end of this stage, around the middle of December, the snow density should have reached a value around 0.55 g/cm^3. When the snow temperature rises to about -5°C, the tire pressure should be increased to 620 kPa and the weight of the roller to 36 tonnes. This stage of the snow processing should produce a density of about 0.60 g/cm^3. The most efficient compaction occurs when the snow reaches its melting point. Moist snow occurs from the middle of December to the middle of January because of the intense solar radiation during clear afternoons. The best time to roll is between 2:00 PM and 1:00 AM. Rolling must be done between these times for maximum increase in snow density. Roller weight should be in excess of 40 tonnes and tire pressures greater than 700 kPa.

Before rolling begins, it is necessary to ensure that the snow cover on the ice basement is of uniform depth. A conventional agricultural plane on skis has been used successfully to level the snow surface after the winter accumulation period and after large snowfalls resulting in major drifting. The height of the blade above the snow suface will be governed by the surface relief. In general the position of the blade must be about half of the snow roughness amplitude. In addition to its role in producing a level snow suface, the planer or some type of drag should also be used from time to time over the entire runway surface to maintain high albedo levels.

Experience during the construction of the Pegasus I runway has shown that final smoothing of the snow surface can be achieved using a smooth drag. The albedo of the snow surface should be increased as often as rolling and leveling are repeated.

A rigorous test program is very important for the control of the engineering properties of the snow pavement. A field cold laboratory is necessary for site measurements of snow densities and for stratigraphic observations.

Snow temperature measurements should be taken from permanently emplaced thermocouples each day during the construction period. Snow samples and AARI penetrometer measurements should be taken after each compaction but no less than three times per month. Measurements of density and strength should be made on transects across the width of the runway every 300 m Strength measurements should be made at five points on the transects and density measurements on three.

Acknowledgements

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Use of the C-5 Galaxy in Support of the United States Antarctica Program

by

David M. Bresnahan, Division of Polar Programs, National Science Foundation, USA

The National Science Foundation (NSF) has overall funding and management responsibility for U.S. activities in Antarctica. The U.S. Antarctic Program (USAP) maintains three year-round stations--two coastal stations, McMurdo and Palmer, and one interior station, Amundsen-Scott South Pole. Annually, USAP supports a science research program made up of over 100 different projects covering all fields of science. During the austral summer season over 2,000 personnel and 2,500,000 pounds of cargo are transported to McMurdo Station by aircraft from Christchurch, New Zealand. Two vessels deliver cargo and fuel to McMurdo once a year. The cargo vessel delivers approximately 13 million pounds of cargo, and tanker offloads approximately 6 million gallons of fuel.

USAP's largest antarctic station, McMurdo is located on Hut Point Peninsula, Ross Island, the furthest south solid ground that is accessible by ship. The station, established in December 1955, serves as the logistics hub of the U. S. Antarctic Program, with a harbor, landing strips on sea ice and shelf ice, and a helicopter pad. Its 85 buildings range in size from a small radio shack to large, three-story structures. Repair facilities, dormitories, administrative buildings, a firehouse, power plant, water distillation plant, wharf, warehouses, recreation facilities and science laboratories are linked by above-ground utility systems.

Williams Field, a skiway 16 kilometers from McMurdo on the Ross Ice Shelf, is the aerodrome for ski-equipped airplanes. Wheeled airplanes use a harder, smoother runway on sea ice from early October until December, when surface melting makes the sea ice unuseable. The annual ice runway is constructed on the sea ice each austral summer; the actual position varies depending upon ice conditions. Generally, the 300-foot by 10,000-foot runway is aligned with the extended centerline of the skiway at Williams Field.

The USAP relies heavily on airlift support, both intracontinental and intercontinental, to provide logistics support to all elements of the program. The annual ice runway allows conventional wheeled aircraft to fly between McMurdo and Christchurch, New Zealand, from early October through early December each austral summer. The ability to move large amounts of cargo to McMurdo by air earlier in the season gives the USAP the capability to support projects, which would normally be dependent on surface vessels for the delivery of needed support material, early in the austral summer.

1989-90

During the 1989-90 austral summer for the first time, the USAP incorporated the C-5 Galaxy into the air movement schedule. One of the primary reasons for using the C-5 was to move oversized cargo, particularly, VXE-6 UH-1N helicopters. Planning and coordination for the C-5 took place throughout the summer season. The U.S. Air Force (USAF) provided the C-5 as a evaluation flight at no cost to USAP. The two C-5 missions to McMurdo proved future operations with the aircraft were viable.

The ice runway was used from 3 October to 12 December 1989. During this period 1,937,714 pounds of cargo and passengers were transported on two USAF C-5As, 22 USAF C-141Bs, 12 Royal New Zealand Air Force (RNZAF) C-130s, two VXE-6 LC-130s, three Italian C-130s, five RAAF C-130s and one U.S. Marine Corps C-130.

Initially, Military Airlift Command (MAC) C-5A Galaxy and C-141B Starlifter aircraft, flying a total of 24 turnaround flights (2 C-5A and 22 C-141B), transported cargo between Christchurch and McMurdo. The average payload for the C-5A was 167,891.5 pounds. The C-5A's carried a total payload of 145 passengers and 306,038 pounds of cargo. The C-141s, which had an average cargo payload of 38,758 pounds, brought 1,125 passengers and 852,681 pounds of cargo.

Ice runway. To accommodate the first C-5 Galaxy landing on sea ice, modifications were made to the annual ice runway complex. The runway width was increased to 350 feet, with 500-foot-wide turnaround areas and a 400-foot-wide taxiway. During this season, the runway was located off Hut Point because ice conditions were bad in the preferred location along an extended center line from Williams Field skiway.

Ice growth was not as expected during the 1989 austral winter. When the season began, the average ice thickness was 78 inches at the ice runway, approximately 8 inches less than the thickness that was desired for the anticipated arrival of the C-5. The reaction and minimal deflection of the ice, however, was a pleasant surprise. During the first aircraft offload on 4 October, less than an inch of deflection was experienced at peak load, and during the second offload on 6 October, 2 to 3 inches of deflection were recorded. The aircraft was parked on the apron for 4 hours during the first offload and 3 hours during the second. No deflection was noted during either refueling operations. Cracks along the runway were unaffected by the aircraft, which was at its maximum landing (635,000 pounds) on both occasions. Figure 1 indicates survey points and temporary bench marks established for monitoring the aircraft while it was parked for offloading and refueling.

1990-91

AIR FORCE C-5B DEFLECTION SURVEY

(04 & 06 OCTOBER 1989)

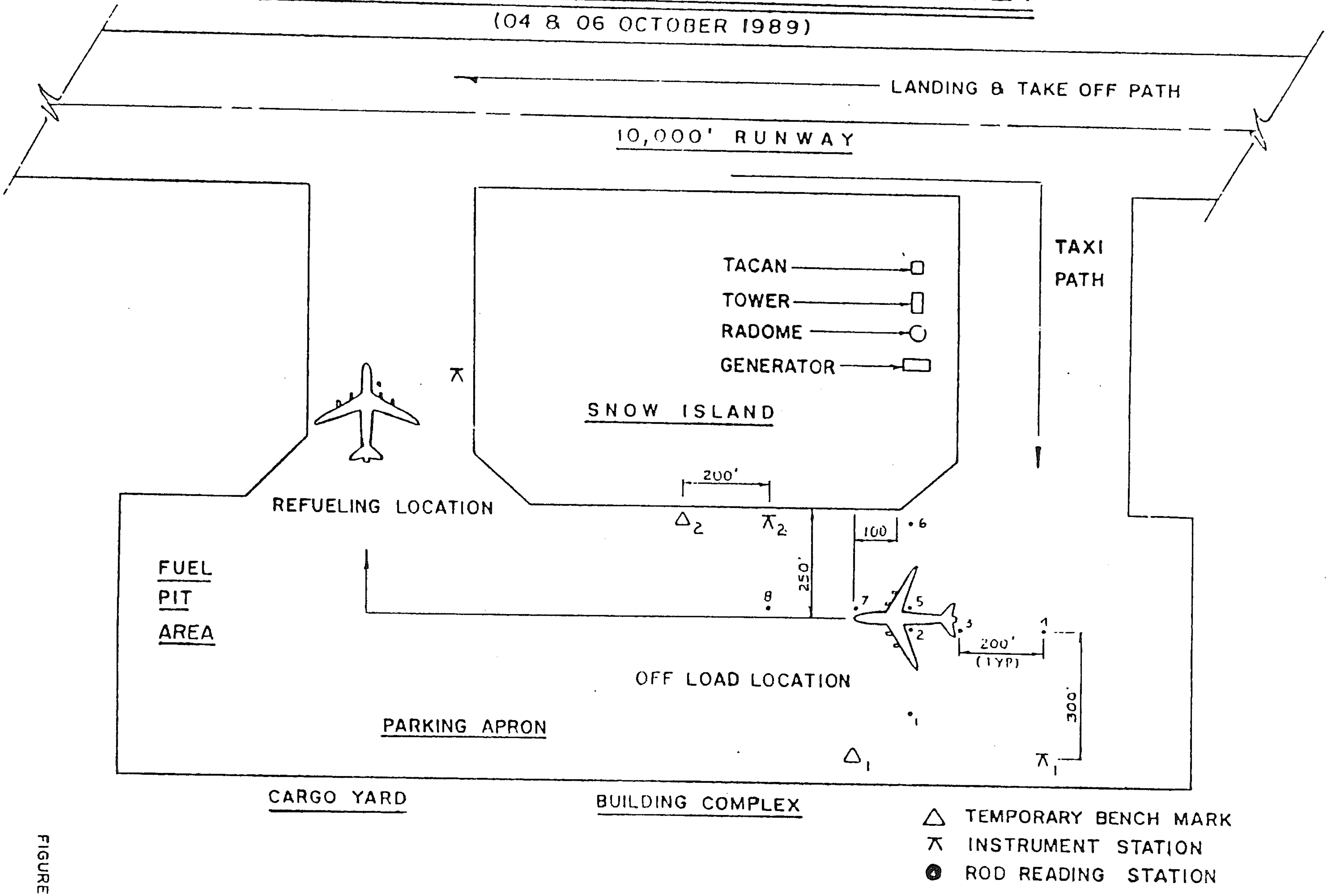


FIGURE 1

The ice runway opened on 2 October and closed 3 December 1990. During this period, 1,721,849 pounds of cargo and 1,564 passengers were transported on the following missions: 3 USAF C-5A's, 18 USAF C-141B's, 12 RNZAF C-130's, 10 VXE-6 LC-130's, and 5 Italian C-130's.

At the beginning of the season, cargo and personnel were transported by USAF C-5A Galaxy and C-141 Starlifter aircraft, flying a total of 21 turnaround flights between Christchurch and McMurdo (3 C-5A and 18 C-141B). The C-5A with an average ACL of 109,400 pounds carried a total payload of 219 passengers and 328,489 pounds of cargo, while the C-141B with an average ACL 35,200 pounds transported 1,048 passengers and 633,959 pounds of cargo to McMurdo.

Ice runway. The 1990-91 ice runway was located north of Hut Point approximately 4 miles from McMurdo on a heading of 320 degrees because of poor surface conditions in the preferred location along an extended centerline from Williams Field Skiway. Because at this location there were predominant crosswinds, a crosswind runway was constructed near the main runway at approximately the 4,000 foot marker on a heading of 260 degrees.

Like the previous season's winter, ice growth during the 1990 winter was less than anticipated, and at the beginning of the season ice thickness at the runway was an average of 78.85 inches. However, the reaction and deflection of the ice was again minimal. During the first C-5A aircraft offload on 3 October, deflection for the aircraft, which weighed 593,000 pounds, was 4.01 inches. During the second offload, 4.80 inches of deflection were recorded with an aircraft weight of 629,000 pounds. The third and final C-5A aircraft weighted 630,000 pounds and showed a total deflection of 3.00 inches.

For each deflection survey, level shots were taken at 15-minute intervals during the entire time the aircraft was on the ground. In each case, maximum deflection occurred near the main landing gear. In all three instances, cracks along the runway were unaffected by the load imposed by the aircraft.

1991-92

During the austral 1992 winter, plans were made to accelerate the environmental clean-up at McMurdo Station. To accomplish the required tasks, the USAP needed to transport several pieces of special equipment to McMurdo in October without impacting the normal flow of passengers and cargo to the station. Increasing the number of C-5 flights from the three to seven allowed the program to transport the critical cargo for the environmental clean-up. In less than 3 weeks, the seven C-5 flights moved over 1 million pounds of cargo and 486 passengers to McMurdo. This large increase in cargo movement meant special consideration had to be given to handling cargo at the ice runway. A tactical K Loader was transported to McMurdo on the first C-5 flight of the season to facilitate the cargo offload.

The ice runway was used from 2 October 1991 to 7 December 1991. During this period, 2,815,279 pounds of cargo and 1,729 passengers were transported on the following missions: 7 USAF C-5Bs, 29 USAF C-141Bs, 13 RNZAF C-130s, 5 New York Air National Guard (NYANG) C-130s, and 21 VXE-6 LC-130s. The seven C-5s, with an average ACL of 145,571 pounds, carried a total of 1,018,998 pounds of cargo and 486 passengers. A 30-ton metal crushing bailer, a backhoe, a special decontamination trailer, two Bobcat skid loaders, and several 100s of overpack drums and dumpsters were airlifted to McMurdo to support the accelerated environmental clean-up.

Use of the K Loader greatly reduced the amount time required for aircraft offload and onload and, consequently, decreased the time that the C-5 aircraft had to remain parked at a single location on the ramp or parking apron. In spite of this effort, the ice deflection was significate enough during the offloading to require repositioning the C-5 on several occasions.

1992-93

Planning for the coming austral summer airlift calls for using the C-5B Galaxy early in the month of October to transport five UH-1N helicopters and one de Havilland Twin Otter to McMurdo Station. Due to maintenance requirements, five helicopters were returned to the United States at the close of the 1991-92 austral summer, leaving only one helicopter in storage at McMurdo. Early airlift of fully assembled helicopters to McMurdo will be critical to logistics support for science projects staged from the station.

The United States Antarctic Program has benefitted from the use of the Lockheed C-5 Galaxy in many ways. The unique capability enables the program to move outsized cargo to McMurdo without depending on the single late season surface vessel transport. Because it can transport more cargo and personnel than the C-141B, the C-5 allows for more rapid delivery of materials to McMurdo. The capability to move three times the payload of a C-141B in one flight can be critical during the early austral summer when weather delays can significantly disrupt the airlift schedule. Another important characteristic of the C-5B is that, unlike the C-141B, it has the capacity to move 75 passengers along with a full cargo load.

Movement of fully assembled UH-1N helicopters to McMurdo has allowed science projects to reach field sights in the Dry Valley region 2 weeks earlier than previous years. Twin Otter support was available to science projects staged from McMurdo 4 weeks earlier than would be possible if the aircraft flew to the station directly via the Antarctic Peninsula. This enhanced early season support capability has been beneficial to science projects studying time-critical phenomenon.

Operation of the C-5 aircraft at McMurdo has not been accomplished without some risk. Due to the heavy footprint of the aircraft, the sea-ice runway must be monitored for deflection, and if the deflection is excessive, the aircraft must be repositioned. The aircraft's design, which allows full-width fore and aft cargo openings, internal forward and aft ramps, and a landing gear capable of kneeling, employs an extensive hydraulic system that can be challenging to operate at temperatures as low as those experienced at McMurdo during early October.

LOCKHEED C-5B GALAXY SPECIFICATIONS

General Characteristics

Length	247.8 ft	75.53 m
Height	65.1 ft	19.84 m
Wing Span	222.8 ft	67.91 m
Wing Area	6,200 sq ft	576.0 sq m
Wing Sweep	25 deg	25 deg
High Speed Cruise	0.79 Mach	0.79 Mach
Long Range Cruise Speed	0.77 Mach	0.77 Mach
Fuel Capacity	332,500 lb	150,819 kg
Engines	Four General Electric TF-39-1C Turbofan Engines with 41,000 Pounds of Thrust	

Cargo Compartment

Length (including ramps)	144.6 ft	44.07 m
Length (excluding ramps)	121.1 ft	36.91 m
Width	19.0 ft	5.79 m
Height	13.5 ft	4.11 m
Total Volume (including ramps)	34,795 cu ft	985.3 m

Maximum Design Weights

Zero Fuel Weight (2.5g)	590,000 lb	267,620 kg
Zero Fuel Weight (2.25g)	635,000 lb	288,031 kg
Maximum Ramp Gross Weight	840,000 lb	381,018 kg
Landing Weight (9 fps sink rate)	635,850 lb	288,417 kg

Performance Requirements

(Based on Sea Level, Standard Day with Additional Thrust Rating)

Takeoff Distance over 50 ft at 797,000 lb	9,800 ft	2,987 m
Landing Ground Roll Distance with Combined Payload/Fuel Weight of 280,000 lb	2,450 ft	747 m
Range with a 263,200 lb Payload	2,400 nm	4,445 km

STATISTICS FOR C-5 OPERATIONS

SEASON	DATE OF FLIGHT	SIGNIFICANT CARGO LOADS
1989	04 October 89	Two UH-1N Helicopters
	06 October 89	Two UH-1N Helicopters
1990	03 October 90	One de Havilland Twin Otter One UH-1N Helicopter
	06 October 90	Two UH-1N Helicopters
	09 October 90	One UH-1N Helicopter One Haaglund vehicle
1991	03 October 91	Two UH-1N Helicopters One 62,000 pound Bailer One 27,000 pound TAC loader
	07 October 91	One 18,700 pound trailer One 46,400 pound CAT loader
	09 October 91	One 47,700 pound CAT grader One 29,600 pound snow blower Two skip loaders
	12 October 91	One 16,450 pound backhoe
	15 October 91	One UH-1N Helicopter Two Triple marriages of outsized cargo
	19 October 91	One 20,690 incinerator
	23 October 91	32 single pallets

The Establishment of Greenhouses at the United States McMurdo and South Pole Stations

by
P. Sadler
Division of Polar Programs, Natoinal Science Foundation, USA

Abstract:

Fresh vegetables are being produced in growth chambers for the isolated personnel at two United States Antarctic Stations. Utilizing artificial illumination and hydroponic culture produces elevated yields over normal field culture. This allows a relative small area to supply a large population with fresh produce. During the Austral Summer, station grown produce is cost effective when transportation costs are included and frees up limited aircraft resources. During the Austral winter it becomes a sole source for fresh produce that cannot be frozen or survive mid-winter air drop.

Construction and operation of growth chambers were done on a volunteer basis and they enjoy considerable popularity as a recreational activity. The chamber also provides a space that is brightly lit and a source of full spectrum lighting to combat Seasonal Adjustive Disorder. The growth chamber at S. Pole will allow studying the responce to the presence of plants by the station personnel in a plantless situation. Currently, work on an NSF/NASA South Pole Greenhouse is underway to develop a Lunar analog growth chamber.

Introduction:

All countries that operate stations in Antarctica face a common problem, difficult logistical support. Supplies arrive at the various research stations by supply ships during the Austral summer. In addition, some of the Antarctic Programs are fortunate enough to have limited aircraft support during the Austral summer for transportation of supplies and personnel. Food and fuel are the two essential elements of the station resupply and are usually delivered on a supply ship.

Food has a major influence on the stations' personnel well being and morale. Diets at Antarctic Stations are largely based on which foods store well for long periods of time. Fresh produce is highly perishable, difficult to deliver and therefore is considered a luxury. In between supply ships and aircraft during the Austral summer, fresh produce stores are usually totally exhausted until the next shipment. After station closing, fresh produce is nonexistent except for what is stored and doesn't rot or in our case, delivered in Mid-winter air drop.

When Antarctic stations have fresh produce, it boosts morale by varying the diet and supplying dietary needs. Most people who have spent any length of time in Antarctica without fresh vegetables have asked themselves about employing the use of a greenhouse. In many cases, Antarctic research stations have successful greenhous operations which have been in existence fore some time. The oldest reference I found in the Antarctic Journal was from 1962 at Haelly Station of the British Antarctic Survey. Most likely, there were earlier unrecorded attempts to grow food in Antarctica.

In 1989, a proposal for the greenhouse project was presented to Dr Peter Wilkniss, Director of the Division of Polar Programs for the National Science Foundation. My goal was to establish a horticultural presence in the United States Antarctic Program. I believe that by installing greenhouses at all the U.S. stations in Antarctica we can supply the personnel with an uninterrupted supply of fresh produce. In Jan. 1989, I initiated the construction of the McMurdo Station Greenhouse and organized a volunteer work force. The greenhouse project has been an entirely voluntary effort with station members contributing in the total construction and operation of the greenhouses. The goal of this paper is to report to the treaty members on the present United States Antarctic Program greenhouse project.

Description:

The project consists of two greenhouses located at two of the three United States Antarctic Programs stations. One is located at McMurdo Station (77°51' south 66°40' east) and the other is located at the Amundsen-Scott South Pole Station (90° south). The McMurdo greenhouse was constructed in 1989 and makes up the basis for this paper. The interior floor space is 46 m^2 with 62% utilized in actual growing area. The lettuce growing trays and herb growing trays are double layered for greater space utilization. The present Amundsen-Scott South Pole Station greenhouse was constructed just before station closing, Feb. 1992. South Pole greenhouse has 9,7 m^2 of loor space with 61% utilized in actual growing area. The remainder of the total areas in both greenhouses are non-productive walk spaces, vestibules and work areas. I will briefly describe the South Pole greenhouse but no productivity data was yet available at the time of this paper. McMurdo and South Pole Stations' greenhouse utilize intensive, Controlled Environment Agriculture (CEA). The plants are grown in hydroponic plant culture systems. Hydroponic culture consists of taking the total nutrients that the plant requires to sustain itself and dissolve these nutrients in water. The plants are arranged in trays that allow the water with the nutrients to flow over the plants' roots. In this manner the growing plant is provided with all the nutrients it requires at optimum concentrations.

With hydroponics, there are many different techniques that the nutrients dissolved in water are applied to the plant roots. The particular method we employ at both stations is known as Vermiculite Perlite Culture, a modified Nutrient Film Technique. This consists of a plastic tube, 8,9cm x 5cm with a plastic screen in the bottom, filled with vermiculite and perlite. The seed is placed in the absorbent material with the tube then being placed into a starter tray with nutrients running through the bottom of it. The vermiculite and perlite absorb the nutrients and water and the seed germinates producing a seedling. Next, the tube is moved to the main trays which are long 15 cm plastic pipes cut in half and have a cover with holes in and a slight slope built in. Nutrients cycle from the reservoir pump to drain down the tray, past the plant roots and back to the reservoir. The plants' roots grow out the plastic screen into the nutrient flow. The plant will mature and then be harvested for consumption by the station personnel.

The total darkness of the Austral winter in Antarctica dictates the use of artificial lighting in both the McMurdo and South Pole greenhouses. High pressure sodium lights are utilized in both greenhouses presently. During the period that the data was collected, the McMurdo greenhouse had a combination of high pressure sodium and metal halide lamps. After the first season (3/90 to 2/91), more lighting was added along with additional upper growing trays for the lettuce. The pepper tray was redesigned at this time. Also added was a tray system consisting of two layers to grow a variety of edible herbs.

From Mar. 1990 to Feb 1991 the McMurdo greenhouse had 6 kilowatts of lighting using 18 hour photoperiod per day. From Mar. 1991 to Feb. 1992 the McMurdo greenhouse had 10 kilowatts of lighting using the same photoperiod of 18 hours. Presently, the lighting in the McMurdo greenhouse has been changed over to all high pressure sodium lamps and uses 14 kilowatts. The South Pole greenhouse is illuminated by 2.75 kilowatts of high pressure sodium lamps. The photoperiod is 24 hours a day for 3/4 of the growing area and 16 hours a day for the plants that require a dark cycle. This is achieved by using a cirtain drawn manually to darken the rear area each evening.

Both greenhouses have cooling systems to remove the heat that the lighting generates, fresh air induction systems and a water supply system. McMurdo uses an ethylene glycol loop which cycles coolant from the outside heat exchanger to the inner heat exchangers. Also, connected to this system are two fans, one blowing in and one blowing out. These bring in fresh air with CO_2 and axhaust humidity along with cooling the interior temperature. The South Pole greenhouse uses outside air for cooling, without it temperatures reach 54°C. McMurdo greenhouse also has a CO_2 system for the artificial enrichment of the interior atmosphere when the air vents are not in service. This uses bottled CO_2 and is set on a timer that introduces gas four times a day.

Operation of the greenhouse is performed by the volunteer staff and is coordinated by the volunteer greenhouse manager. The McMurdo greenhouse usually has a staff of 10 to 14 volunteers that spend a couple of hours a week there. Their duties are to monitor the growing systems and record concentrations, temperatures, yields and data. The volunteers are also responsible for adding nutrients and adjusting pH, as well as harvesting the produce. I manage the greenohuse during the summer season and train the volunteers on all aspects of operation. From the volunteers I select an individual for the managers position. After I return back to the United States, I keep in contact with the manager and assist in any problems that arise.

Data:

The purpose of the project from its' conception was to supply fresh produce and has constantly been uppgraded with no regard for consistency. Presenting a paper on the Greenhouse Project or conducting the project in a scientific manner was not our foremost goal. The time line illustrates the different times that new trays were added to the greenhouse and the starts of the different summer and winter seasons. The data was collected over a two year period. Collection of data for the first season of operation was not accomplished. The second season of operation started at station closing in Mar. 1990 and is the beginning point of the data presented. The end point of the data presented was Feb. 1992.

Over the two year period the McMurdo Greenhouse produced a total of 427.5 kilograms of fresh produce. 77% of the toal production was made up of lettuce, 20% of the total was tomatoes and 3% of the total were peppers. The varieties of lettuce used were all Loose leaf and Butterhead types. The Tomato variety used was a Beef Steak type, named Buffalo. The Pepper is a variety of Sweet Pepper named Ace. The herb tray is used to grow a wide variety of edible plants used for seasonings. I have not included the results of the peppers because they make up only 3% of th total production. Also excluded is the herb tray, because of the numerous different varieties of plants and limitid yields.

Electricity is generated by diesel engine generation and an estimated value of 46 liters of diesel fuel is used to produce 1 kilowatt of electricity for one weeks time. The lights in the greenhouse are left on for 18 hours and are shut off for 6 hours daily, which means they are on 75% of the time. The cost of the diesel fuel that is used in McMurdo is $20 US per liter. In Mar. 1990, the original lighting consisted of 6 kilowatts of lighting. In Feb. 1991, I completed the upper lettuse trays and pepper tray and added the necessary lighting. This upped the power consumption to 10 kilowatts. The associated pumps and fans account for an insignificant amount of power usage.

The total fuel consumed for power generation to light the greenhouse during the two year period was 28.700 liters. The total cost of the fuel at $20 US per liter was $5.740.80 US for the two year period. The overall cost for the two year period is $13.42 US per kilo for the produce. Calculating the last four months of production while I managed the greenhouse the total fuel consumed for lighting was 6.091 liters. During this period, 113.6 kilograms of produce were harvested. At $20 US per liter, the cost of McMurdo Greenhouse produce during this period was $10.78 US per kilo.

McMurdo Greenhouse Time Line

1989	Jan	Greenhouse giving go ahead Installed modules and modified Pre-cut trays and supplied all lighting and pumps
	Feb	Station closing
	Winter-Greenhouse starts producing (no records kept)	
	Oct	Built new lettuce and tomato trays
	Nov	Fabricated and installed cooling system
	Dec	Sheathed building with foam insulation
1990		
	Feb	Installed water tank in vestibuel
	Feb	Station closing - Cindy Kline manager
	May	Pepper tray
	Sept	Station opening
	Oct	Herb try
	Nov	Remake Pepper tray
	Dec	Make upper lettuce tray
1991		
	Jan	Insulate floor
	Feb	Install new upper lighting
	Mar	Station closing - Ross Smith manager
	Oct	Summer season
	Nov	Added on to pepper tray
	Dec	Prefab South Pole Greenhouse

1992

Feb	Install South Pole Greenhouse
Feb	Install new lighting at McMurdo - ship old lighting to South Pole
Mar	Station closing

Discussion:

The data from the McMurdo Greenhouse suggests a relatively high cost for the fresh vegetables that it produced. The time line illustrates that this project was under construction to some degree during the majority of the data period. During the two summer seasons I constructed new trays and equipment which interfered with the total production of the greenhouse. Also, the changing from the winter to the summer season and the training of new volunteers has a marked effect on the output. Between the two winter seasons there is a difference in output due to human factors. Working with an all volunteer staff is more enjoyable, but the degree of control over the situation is less than if they were paid personnel.

Selection of the proper varieties of cultivars is important. It has been our experience that some varieties do better in the McMurdo Greenhouse than others. Conditions in the greenhouse like high temperature or high humidity cause some plants not to do well. Or selecting a plant that physically is too large for the application can cause problems. Some of the high cost of the McMurdo Greenhouse produce can be attributed to improper variety selection.

The lettuce tray system is not the zenith of efficiency and has lots of room for improvement. The problem is that the plant spacing is correct for mature plants, but until the plant is mature, spaces in between plants allow light to pass through. Lighting of the lettuce trays was also insufficient for good production. Measurments I made last season (91-92) showed that we had roghly half the light that we needed for good production. In Feb 92, we increased our lighting to 14 kilowatts and I expect greater yields next season.

The production of tomatoes were greatly influenced by the lack of sufficient lighting and having to leave the plants in for a year. My goal with the tomatoes is to plant them so that they begin producing in April and are at peak production for the winter. If I want to plant in late December for the next winter, this does not leave sufficient time for a second crop. Human factors make the proper management of the tomatoes a difficult task. The peppers produced continuously for the entire year with no noticeable reduction in output as they matured. Both tomatoes and peppers require 2.5 months before they begin bearing.

The majority of the energy used by the McMurdo Greenhouse is lost in the form of heat. More efficient lighting that would generate more light and less heat would lower the cost of produce. Heat from lighting is one of our major problems in Antarctica. During the summer months, solar gain on the structure and the heat generated by the lighting, makes gardening difficult. If we bring in outside air to cool the interior, our humidity drops to a point that is detrimental to the plants. Also, when we use CO_2 enrichment, we lose CO_2 gas to the outside and it is wasted.

Even with our inefficiencies, the McMurdo Greenhouses' hydroponic systems are producing greater yields than what could be expected from lettuce grown in an average field. Field grown lettuce provides up to 24.4 kilograms per m^2 per year where hydroponic production of lettuce can yield up to 195.3 kilograms per m^2 per year. The calculated production of the McMurdo Greenhouse, using 50% of optimum environment and the same energy input should have yielded 3750 kilogram of produce. The McMurdo Greenhouse has much room for improvment.

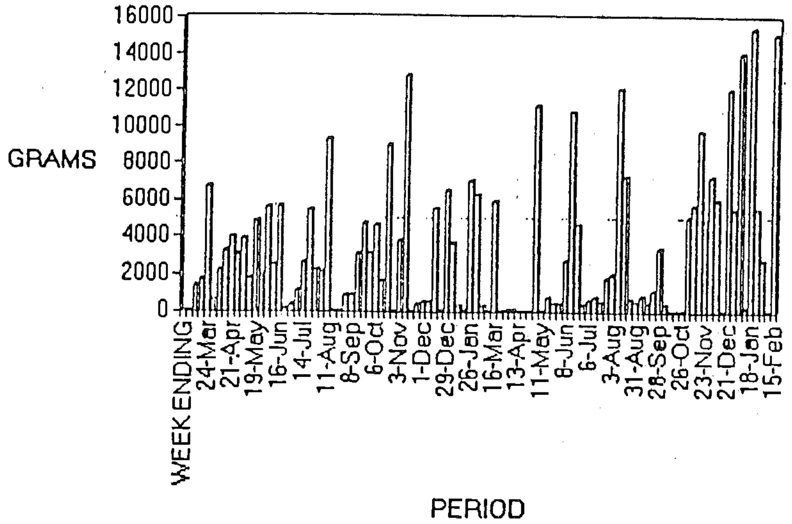
Conclusion:

Efficiency in Controlled Environment Agriculture is extremely important due to the high cost of providing light and factors for a successful operation are, well trained individuals operating the facility, a well engineered environment and efficient lighting. As in most situations, people are the most valuable asset. A support structure within the Antarctic Program should exist to provide some formal training for a greenhouse manager before departing to the ice. The manager should have communication access to the support structure in case the manager requires information or help. And, at the greenhouse, there should be teaching aids such as videos and a manual to help the manager train the volunteers. Reduction of the amount of training necessary to operate the greenhouse successfully also can improve efficiency. This can be accomplished by automating nutrient feed systems, data collection, and pH adjustments.

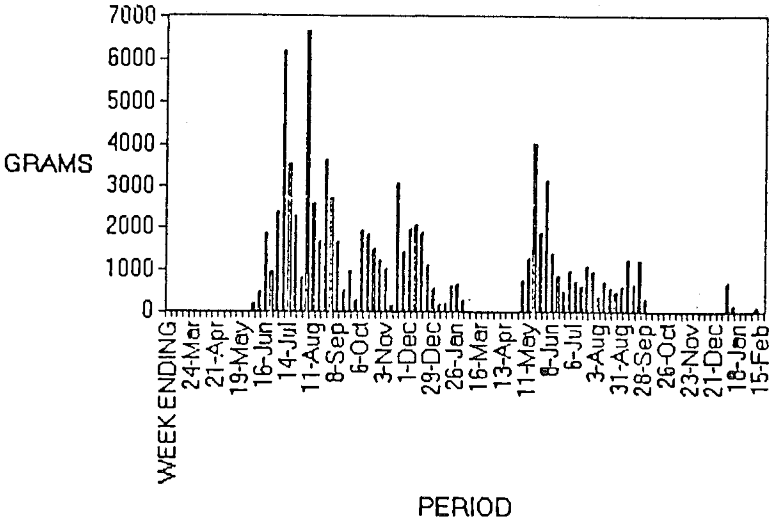
The original grant I received for the McMurdo Greenhouse from the National Science Foundation was for $75.00 US and all I could get my hands on in McMurdo. At the time of this paper the NSF had $4,000.00 US in capital outlay for the greenhouse. Presently, the total is over $8,000.00 US for this facility. McMurdos' greenhouse is not the normal situation for Antarctica because of the larger population. A much smaller greenhouse could fill the needs of the personnel like at Amundsen-Scott South Pole Station. More efficient lighting is constantly being developed and could reduce costs of local production of fresh vegetables. The cost of a well engineered enviroment is not cheap, but over a long period of time, the savings in fuel and increase in produce may justify the price.

The benefits of having a greenhouse to supply the station personnel with fresh produce to improve their diets are substantial. To be able to improve ones' attitude by visiting the greenhouse and spend time in the full spectrum lighting during the winter. The ability to see and feel plants in the barren environment makes life there more bearable. To be able to interact with fellow personnel and be more of a part of the community. These are the benefits of an Antarctic greenhouse and I believe they far out weigh the cost of operation.

LETTUCE PRODUCED



TOMATOES PRODUCED SYSTEM 3



Study of a New Waste Water Treatment Plant for the Italian Antarctic Station

by

A. Lori, S. Meneghello, G. Scarano, D. Voli
ENEA, Italy

Introduction

At the Italian Antarctic Station - Terra Nova Bay (TNB) a biological water treatment plant was installed during the third expedition 1987/88. It was capable of treating up to ten cubic meters of sewage per day; which meants that about forty to forty five people could be accommodated in the station. With time though, interest for Antarctic researches increased, and more scientists requested to work at TNB. To meet the demands the Base was enlarged to accommodate up to 60-65 people. The water treatment plant also had to be replaced with a larger one.

Considering that during its operation the biological water treatment plant had shown weak points, (the most important is the existence of an initial transient period with very low efficiency), that couldn't be overcome because of reasons peculiar of the process itself, the Logistic division of the Italian Antarctic Project decided to test a totally different process, a physical - chemical one. The following note is purely informative concerning our approach to the problem in discussion

The new treatment plant is completely shown in Fig. 1

Studying the system our experts judged the n° 6 element the most critical and hence, also because the shortage of time didn't permit the completion of all plant before departure to Antarctica, decided to test it directly at our Antarctic station of TNB. The working tests were carried out during the seventh expedition, which was short on time (only 40 days) and with few people about 50).

Description

The objective of the tests performed was to evaluate the possibility of using a chemico-physical plant combined with the previous treatment plant or as a complete alternative. A major reason for such a change was the need to overcome transitory period that is characteristic of biological waste water plants. Transitory periods are not existent in chemico-physical plants, thus they are better suited for short expeditions

Generally, the chemico-physical method realizes the cleaning of the water from suspension particles, colloids and partially of diluted organic substances by a double step process.

During the first step (flocculation) the pollutants cake into bigger particles by the effect of specific reactants opportunely added to the waste sewage water. During the second step (separation) the flocky mass separates and can then be taken away from the clarified water

A traditional chemico-physical waste water treatment plant performs the oversaid process by a series of tanks where the reactants are added to the stirred sewage to obtain flocculation, and a terminal sedimentation tank is used to separate the sludge from the clear effluent. All components used in traditional plants are replaced in COMPACT-CF with a hydraulic circuit for the coagulation and a dissolved air flotation tank for the separation. The two parts are interconnected to minimize the global volume.

Thanks to the peculiar characteristics of the elementary process (flocculation and flotation in dissolved air) and the compactness of the constructive solution, (the hydraulic circuit is installed on the tank's walls) COMPACT-CF is twelve times more efficient than a traditional waste water chemico-physical treatment plant of the same dimension, and the final sludge amount is three to four times smaller.

COMPACT-CF Description

The COMPACT-CF plant works as shown in figure 2 and as described in the following steps:

a) Sewage storage and Homogenization

Since the quantity and characteristics of the sewage change with time, in order to feed the treatment system uniformly with an homogenous waste water it is necessary to accumulate the sewage in a primary tank.

b) Chemical reactant preparation and proportioning

An ordinary urban sewage flocculation requires three different kind of reactants: a pH corrector (base), a primary coagulant (salt), a binder (polyelectrolite). At the beginning all the reactants are stored as a water solution in different tanks and continuously stirred. The different solutions are injected sequentially into the flocculation part of the system by volumetric pumps.

c) Flocculation

Flocculation is accomplished inside the tubular reactor (hydraulic circuit made of PVC pipe installed on the outer side of the flocculation tank's walls) where the sewage is pumped after being extracted from the storage tank. The turbulent flow in the pipe mixes the reactants and the sewage intimately, inducing the flocculation that occurs in two subsequent steps. In the first part of the circuit (after the salt injection) the pollutants coagulate and precipitate as micro flakes. In the final part of the circuit (after the injection the polielectrolite injection) the micro flakes become macro flakes.

d) Dissolved air flotation

The sludge separates from the clarified water inside the dissolved air flotation tank. This tank is made of stainless steel and equipped with a recycling pipe provided with appropriate apparatus (air injector, pump and valve) to supersaturate the clarified water with air, a bladed skimmer to remove the sludge, and an overflow with base intake of water to remove the clarified effluent. At the end of the recycling pipe, the fluffy mass is mixed with clarified water supersaturated with air which generates micro air bubbles. The micro air bubbles stick to the micro flakes lowering their density. In this way, while the recycled mixture is injected into the flotation tank, the lighter flakes migrate towards the surface, where the skimmer blades remove them. The clarified water in the bottom of the tank is drawn off through the overflow pipe and discharged into the final receiver.

e) Sludge drying process

The sludge produced contains 90 to 95 % of water. To help the solid waste disposal the sludge is treated with a filter-press that normally reduces it about six times (from 5% of solid to 30% of solid).

Results and discussion

It was not possible to monitor the plant as scheduled because of the following mechanical problems:

- nozzles of an unsuitable material made difficult the adjustment of the flux of chemical reagents;

- there was no grid for coarse skimming of the sewage; as a consequence of this the nozzles clogged and sewage stagnated;

- sometimes the connecting pipes between the two treatment systems froze, bringing the plant to a stop;

- the settling tank (5 m^3) proved to be too small for the daily load of the plant.

All these troubles caused a discontinuous operation of the system and made difficult the ordinary measurements of those parameters that allow to express a judgement. Analyses were random and more often than not they were carried out to adjust the operation of the system.

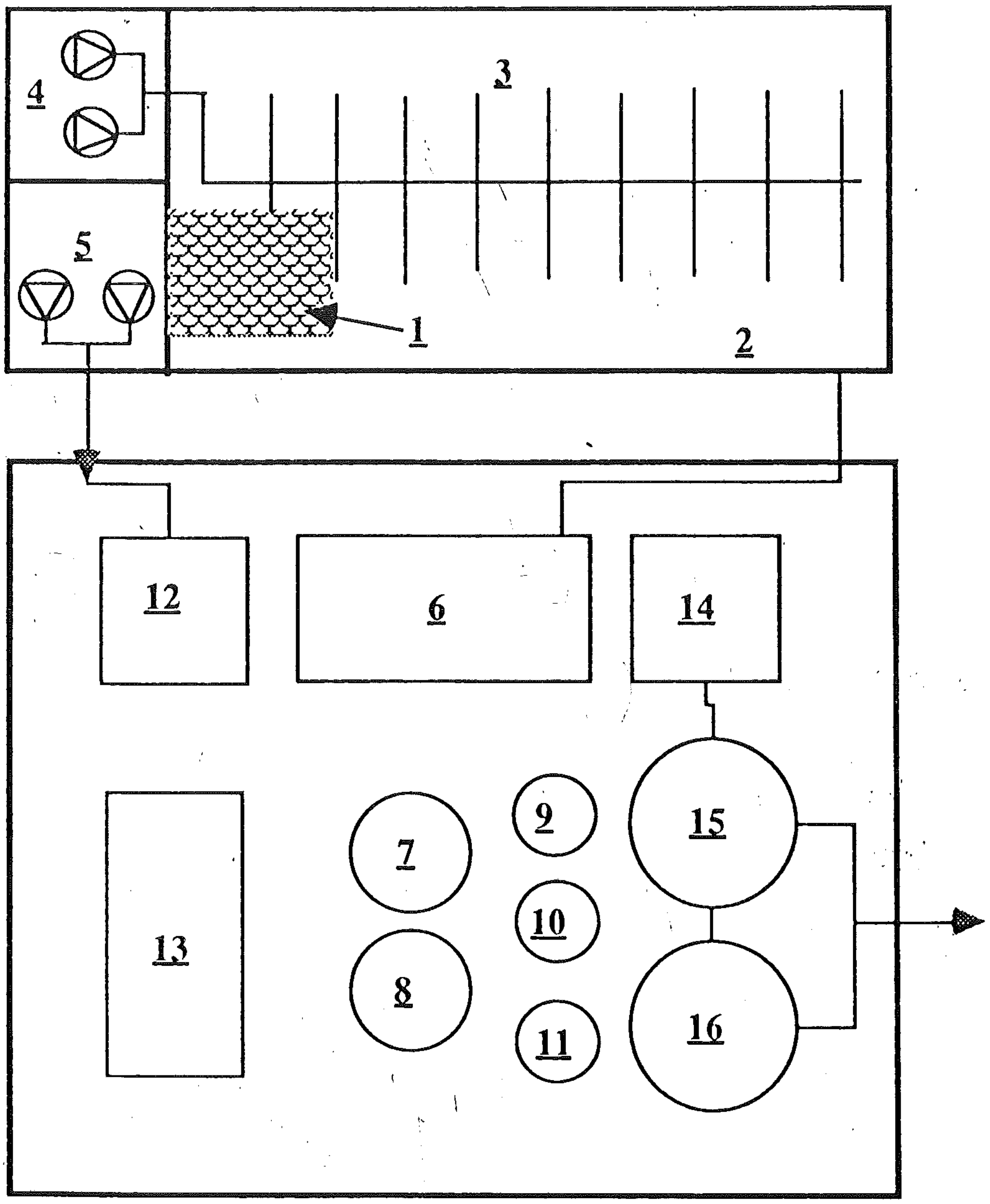
Because of various problems samples were not collected every day (three times per day). Samples were analyzed for COD, pH, turbidity, free oxygen, nitrates, ammonia, iron ions. Further oils and surfactants were determined. Hereafter the results of analyses, made during a period of regular operation, are reported.

	COD (mg/l)	O_2 (mg/l)	Fe (mg/l)	NH_4^+	NO_2	NO_3	FTU*
influent	1100						
effluent	248	7.5	1.5	n.d.	n.d.	n.d.	30

* The used procedure is calibrated using formazin turbidity standards and the readings are in terms of formazin turbidity units (FTU).

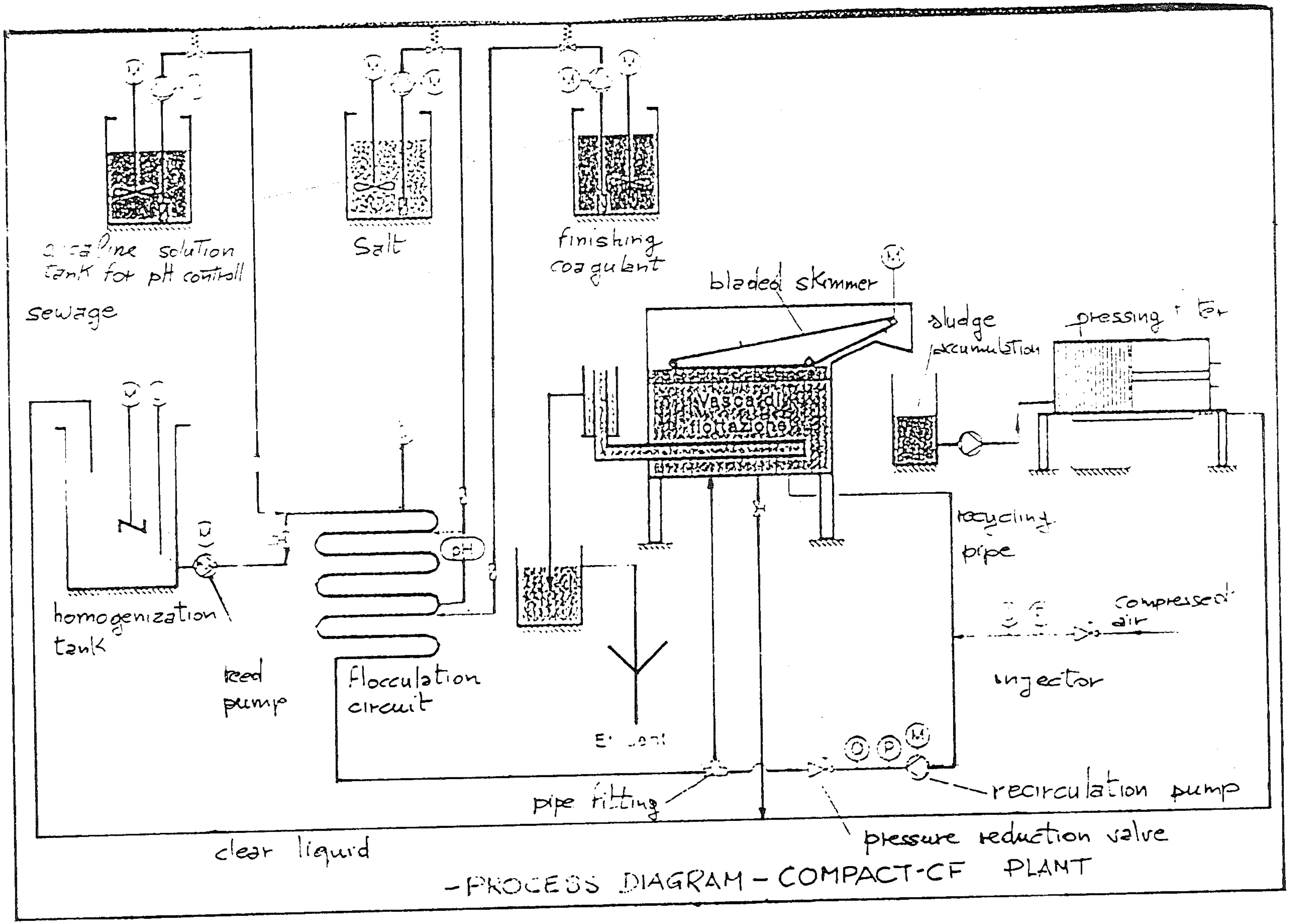
The chemico-physical plant needs further tests. Changes in some components of the system could improve its performance and make it more suitable to the extreme Antarctic conditions.

Microbiological analyses gave results out of the acceptable ranges of the Italian standards on the matter (fecal coliforms 12000/100 ml; total coliforms 20000/100 ml; streptococci 2000/100 ml). This makes compulsory the presence of a sanitizing device at the outlet of the plant based on chemical reagents or on filtration. A careful choice of this device is necessary in order to avoid danger to the environment.



1 self-cleaning strainer
2- primary tank
3- air injectors
4- blowing engines
5- primary mud pump
6- Compact-CF/2
7- alkaline solution tank for pH controll
8- polyelectrolyte solution tank
9- sodium carbonate solution tank
10- salt solution tank
11- sodium hypochlorite solution tank
12- sludge stabilization and accumulation tank
13- filter-press
14- clear effluent accumulation and chlorination tank
15) activated carbon filter
16) clear water discharge

Fig - 1



-PROCESS DIAGRAM - COMPACT-CF PLANT

Fig - 2

Vehicles and Transports during the Swedish Antarctic Research Programme 1991/92

by
Åke Berg
Special Vehicles Section, Defence Materiel Administration, Sweden

The transport system for the 1991/92 expedition, as well as earlier expeditions was mainly based on the Hägglunds Bv 206 All Terrain Carrier. The Bv 206 was chosen with respect to the current range of application and 5 000 units in 15 - 20 different versions being already in operational use in the Swedish Army since the early 80's. The vehicles were of original design but had been equipped for use in Antarctica. Modification work was kept to a minium.

Dwelling containers, containers for scientific samples, scientific equipment, food and fuel were transported from the unloading site on the sea-ice outside the Riiser-Larsen shelf-ice to the Swedish and Finnish stations in Vestfjella, Dronning Maud Land. One 1700 km and two 800 km long traverses were carried out with the scientists between 30th November, 1991 and 20th February, 1992.

Vehicles, Sledges and Dwelling Containers

Four Hägglunds Bv 206D6 were used during the expedition. One of these vehicles was used during the expeditions 1987/88, 1988/89 and 1989/90. The additional three were new. All vehicles were equipped with a flat bed on the rear chassis and three were equipped with a hydraulic crane. The most important equipment in the vehicle includes: 6 cylinder turbo charged diesel engine, high altitude converter, a flat bed, increased chassis width to 2.20 m, 100A alternator electrical noise reduced, comfortable front seats, and external fueling pump. The complete transportation system and some technical data are shown in Figure 1 a, b, c. Synthetic oil and grease were used; the coolant was 60/40 glycol and water and the fuel Arctic diesel and aviation fuel Jet A-1. The injection pump was adjusted to compensate for the lower energy content (5%) of Arctic diesel and Jet A-1.

In order to prevent environmental pollution, the best available fuel and lubricants were used. The fuel for the vehicles was nearly sulfur-free. Specification is shown in fig 2. Exhaust emissions from the vehicle engine fulfil the European demand.

Flat Bed with Crane

The standard rear cab was replaced by a flat bed with hard points for mounting dwelling containers or carrying load. The lightweight open type flatbed is 1.85 m wide and 3.0 m long and can carry 3 rows of 5 standard fuel drums or similar loads when the dwelling container is unloaded. In front of the flatbed a hydraulic crane is fitted. The capacity of the crane is 15 kNm with an outreach of 0.95 m to 2.7 m. Extension from 0.95 m to 1.85 m is carried hydraulically and from 1.85 m to 2.7 manually. The crane is primariy intended to handle fuel drums, light-weight material, scientific equipment and samples, etc.

Additional equipment particularly for use by field parties includes: on the original HIAB 130 crane an extension arm 1.5 m in length, fitted in order to increase the outreach of the crane, and used for lifting an ice-core drill of 5 m length.

Communication and Navigation

A power converter 24/220 V DC is connected to the electrical system in the vehicle to supply radio-echo equipment; power-connection a drilling-machine 24V/100W, for drilling icecores. All vehicles were equipped with a power converter 24V/12V DC; VHF radio, ICOM - IC 125

(156.300-160.950 MHz/25W), two were equipped with HF radio YAESU - FT 747GX (frequencies between
0.1 - 30 MHz/100W); and one was equipped with a telex terminal - INMARSAT C, from SNEC. The VHF radio was used in the near the Wasa station and between the vehicles. The range of the HF radio was adequate for all traverses where the range of the VHF radio to the base was not enough. The telex terminal could be used to at least 77°S.

Navigation equipment consisted of a GPS receiver supported by a magnetic compass. The GPS receiver was Trimble Pathfinder. Availability of GPS made it easier to locate exact positions and to navigate in bad weather. Difficulties in driving on course occurred because of the sensitivity of the GPS receiver. The solution was to read the bearing from the GPS and drive in the direction shown by the magnetic compass, under supervision of the vehicles behind.

Dwelling Containers

Two types of dwelling containers were used. One for 6 persons and two for 4 persons. One of the smaller containers was equipped with space for botanical analyses. The small living containers are designed to be fit on to the flatbed or a sledge and the larger ones to be carried by sledge. They are used as self-contained units for scientists and technicians working outside the main base. The containers are easily removed from the vehicle or sledge by jacks and can be used as a secondary base while the vehicle itself is being used for different transport tasks. The design and equipment of the small dwelling containers can be seen in SWEDARP Cruise Report from 1988/89.

Propane or electrical power 220V was used to heat the containers by means of water in the radiators as well as heating pipes in the floor. Propane was used for the gas stoves. The propane consumption was 20 - 25 kg a week during the traverses.

The container is designed to take an electric supply of 220V from an outside source that is converted to 12V, or 12V from the vehicle or from own lead batteries directly. The system is further capable of charging the battery either through solar cells or the outside source.

Other accessoires:
- 3 air ventilation points situated in the roof;
- 3 roof hatches of 0.55 by 0.55 m which can be used as emergency exits;
- roof mounted eyelets for lifting and tie down points for self-contained operations;
- four jack-up legs with removable feet for levelling the container for self contained operations.

The weight of the fully equipped, 6-person dwelling container, is 2500 kg

Sledges

A total of 8 four-runner sledges were used; 5 were of Swedish design and 3 of Finnish. The load-capacity of the Swedish sledge is 10 000 kg. The sledges are equipped with hard points and designed to carry 20 ft containers (6.1 by 2.4 m), container for 6 or 4 persons, 40 fuel drums and other materials. The weight of a sledge is 1350 kg. The Swedish sledges have low friction linings on the runners and the runners are V-shaped. The size of the front runners is 1.98 by 0.50 m, and the rear runners 2.30 by 0.50 m.

The summary of the design sledge has optimal efficiency on snow and under frozen surface conditions. The Swedish sledges and dwelling containers are designed and manufactured by Berco Production AB.

Performance

From December 1 to December 6, 1991, containers, fuel drums, scientific equipment etc. were transported by 3 vehicles and 6 sledges from the unloading site to the Wasa station. The total weight of the cargo is estimated at 35000 kg and the total distance was 2900 km. Between 8th to 20th December, 1991 a field party from the Swedish station Wasa was transported to Kirwanveggen; return transportation took place from 22nd to 27th January, 1992, using 3 vehicles, 3 sledges and 2 dwelling containers. The distance travelled was 1648 km per vehicle. Total distance was 4944 km.

A traverse was made from the Wasa station in Vestfjella across Kibergdalen in Heimefrontfjella along the 75th parallel to 2°E, on Amundsenisen southwest to 77°S, 5°W, to 75°S, 12°W in Kibergdalen and then back to the Wasa station. Partcipants were the expedition leader, 3 glaciologists and 2 technicians. The aim of the traverse was to drill ice-cores, measure ice thickness by radio-echo sounding and to test the capacity for future long traverses with scientific field parties. The vehicle-train consisted of 3 units with 1 sledge behind each vehicle. The sledges were loaded as follows: First sledge, 37 fuel drums and additional equipment, total weight 8500 kg. Second sledge, 25 fuel drums, 1 snowmobile, food for 6 persons for 4 weeks, scientific instruments and equipment and 1 generator 220V- 3 kW total weight 6 000 kg. Third sledge , dwelling container for 6 persons and additional equipment for the container; total weight 5000 kg. The front cabin of each vehicle was in the front cabin loaded with approximately 300 kg and the flat bed loaded with 3 fuel drums and some boxes for ice-cores and drilling equipment. The average weight on the flat bed of each vehicle was approximately 1000 kg. Total driven distance during the traverse discribed above was 4 926 km for the 3 vehicles corresponding to 1642 km per vehicle. The route is shown in fig 3.

In order to facilitate rescque by helicopter, to compensate for fuel loss and to establish a fuel depot at 75°S, 12°W in Kibergdalen, extra fuel was carried during the travers. The depot in Kibergdalen was supplied with 23 drums of fuel for helicopters or vehicles.

Snow density, temperature and hardness were recorded at 10 positions along the traverse in order to compare fuel consumption, average speed, and resistance in deep snow.

To restock the Svea station in Heimefrontfjella with fuel, food and living accomodation a separate transport was performed with 1 vehicle between 6th and 10th February, 1992; total distance 390 km.

A 3 km long and 25 m wide runway was prepared in the vicinity of the Wasa station. The vehicle used for the runway had a sledge behind with an adjustable steel beam fitted under the sledge and the distance between the runners was increased lengthwise.

Special Equipment

The vehicles were equipped with additional tracks to obtain sufficient traction to drive uphill on slopes with a gradient between 5° and 15° while towing loaded sledges. The tracks worked very well and are easy to mount.

To prevent freezing runners of the sledge during parking, plywood plates with a hard surface were used. The wooden plates worked well, but were difficult to fit into position. A design with cross members at both ends would be more adequate.

Service and Maintenance

The vehicles worked very well but minor deficiencies arose and service and maintenance had to be carried out all the time. However, service and maintenance are easy to perform.

The engine of the vehicle that had been used since the 1987/88 expedition was replaced. This vehicle had already gone 9650 km and later investigation showed that 2 pre-cambers of the cylinder head were burnt out.

An engine in one of the 3 new vehicles had after 3000 km driving a high oil consumption and decreased drawbar pul. The engine was taken out of the vehicle for inspection. Two pistons were burnt out. The crank case from the first engine and the cylinder head from the other were put together and replaced in the vehicle. After this operation the vehicle could be used for the remainder of the expedition.

After the traverse on Amundsenisen 6 tensioning wheels and 2 road wheels had to be changed because of damaged or worn out rubber.

Disturbances in the fuel-distribution system were caused by contaminated fuel. The electrically powered tank change-over valve had to be cleaned several times in two vehicles.

Engine oil and oil filter were changed after 3000 km. The vehicles were greased with synthetic lubricant after 3500 km.

Fuel consumption and speed

The fuel consumption during the long traverse was 22 - 24 litres/10 km and during the whole period 30th November 1991 to 20th February,1992, 20 - 21 litres/10 km. Maximum consumption when pulling in tandem over crevassed areas and slopes could reach 30 litres/10 km for each vehicle. Antarctic diesel and aviation fuel Jet - A1 were used with a difference in fuel consumption by approximately 10% (Jet - A1) .

The average speed with loaded vehicles and sledges- total weight between 9000 and 4500 kg- was 10-12 km/h.

The total driven distance for the three new vehicles during the whole period was 12900 km.

Conclusions

Hägglunds Bv 206D6 All Terrain Carrier is a light and fast transport system for transporting of materials of moderate weight and field parties. The vehicle is the most suitable transport solution for the terrain due to its flexibility, reliability and maintainability. Its easy to handle with high mobility when used for field parties is of special interest.

The above described vehicle- and transport system will be used during the planned long traverse in 1993/94.

To obtain optimal average speed, fuel consumption and reliability for traverses over long distances of more than 2000 km, the maximum weight of cargo on the vehicle should be 1500 kg and on the sledge 4000 kg.

The maximum speed over the snow surfaces with small sastrugis and snow dunes should not exceed 20 km/h.

In order to tow sledges in the vicinity of the station i.e. for ranging, loads can be at least the double. The limitations of the drawbar pull are mostly related to lack of traction. To obtain traction enough additional tracks should be used. Another way to tow heavily-loaded sledges is to drive two vehicles in tandem with a triangular tow bar between the vehicles.

Fig 1 a

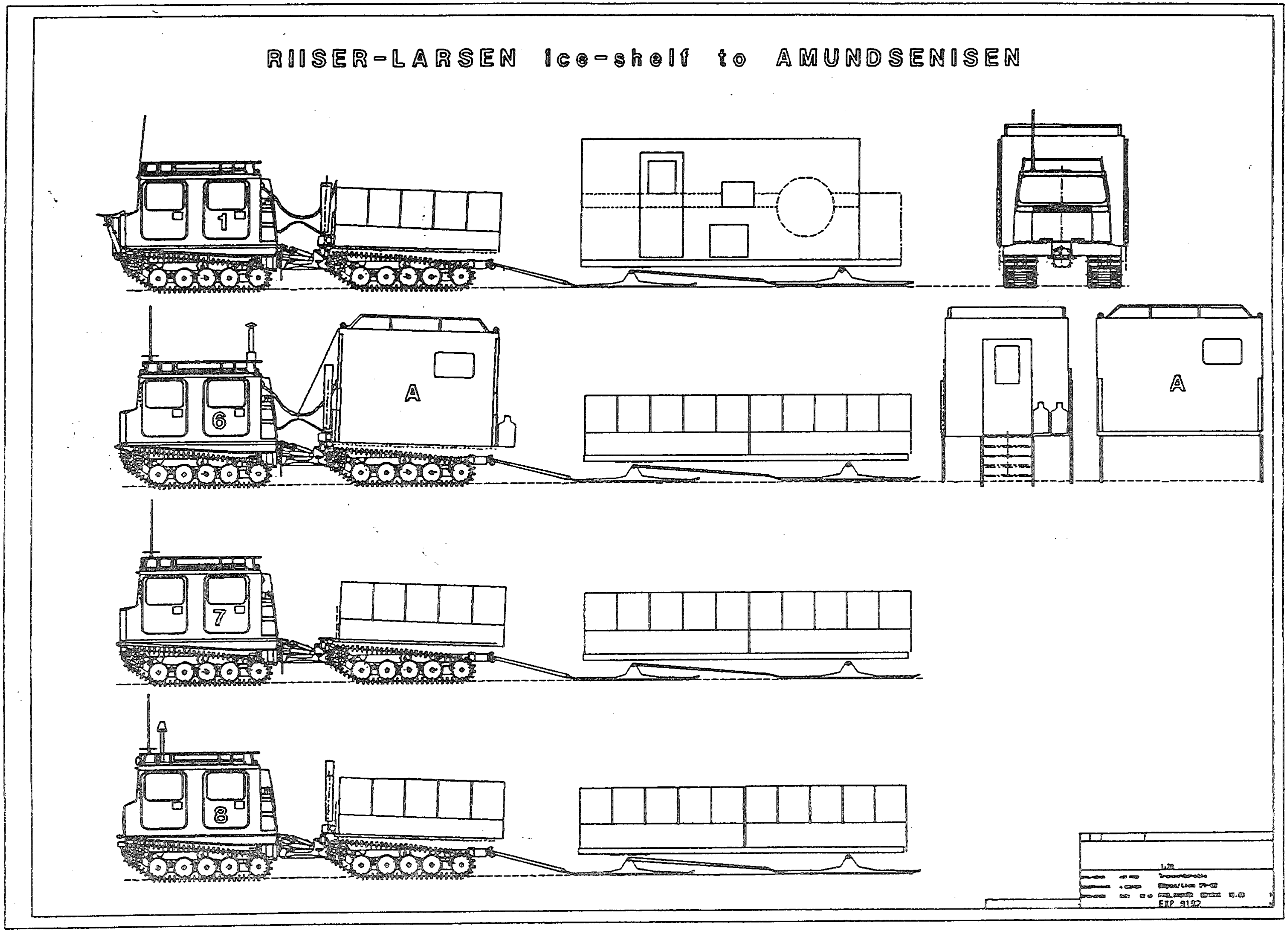


Fig 1b

Antarctic Vehicle Equipment 1991-92

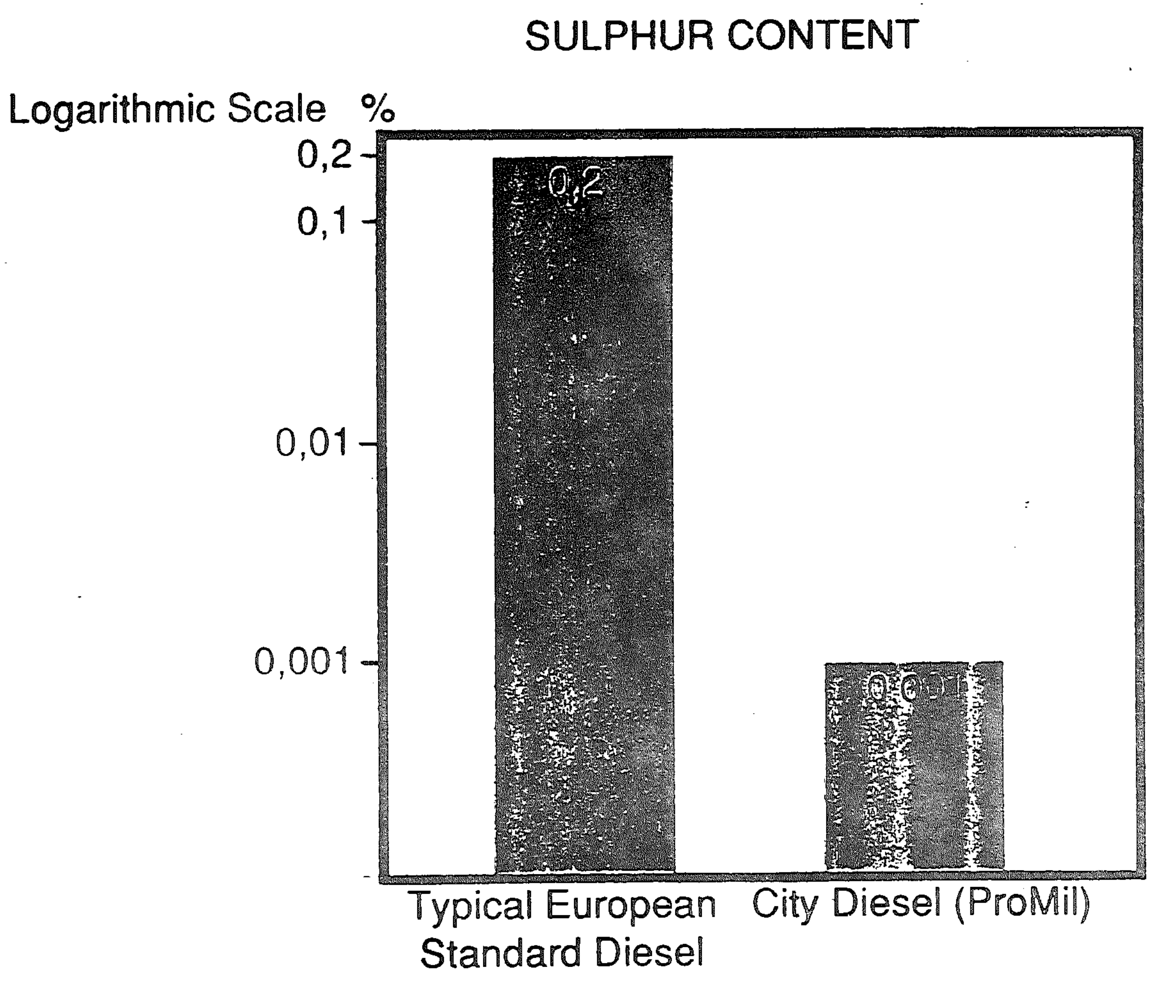
Vehicle no	1	6	7	8
Flat bed	x	x	x	x
Roof rack and tool box	x	x	x	x
Heated front windows	x	x	x	x
Heated rear-view mirrors	x			
Spring cushion front seats	x	x	x	x
High altitude torque converter	x	x	x	x
Compass, inclinometer	x	x	x	x
Convers for air ducts	x	x	x	x
Chassis track width 2.2 m	x	x	x	x
Tracks with studs	x			
Intercom unit and tape recorder	x	x	x	x
Sepson hydraulic winsch	x			
HIAB 130 hydraulic crane		x		x
HIAB 011 hydraulic crane	x			
Snow blade	x			
Main Alternator 100A	x	x	x	x
Diesel coolant heater	x	x	x	x
Extended tow hook	x	x	x	x
Cover for main lights				x
Fuelling pump, external	x	x	x	x
Lifting eyes	x	x	x	x
Radio batteries	x			
GPS satellite navigation system	x	x		
VHF		x	x	x
HF Radio		x	x	
Inmarsat-C, Telex				x

Fig 1c

Bv 206 D6 All Terrain Carrier; Data

Engine	
Manufacturer	Mercedes Benz
Make	OM 603 950
Max output, DIN	100 kw (136 Hp) 4600 rpm
Max torque	255 Nm (184 lbft) at 2400 rpm
Cylinders	6
Swept volume	2996 cc
Compression ratio	22:1
Idling	900-1100 rpm
Valve system	OHC
Fuel	Diesel
Cooling system	Closed, with expansion vessel
Electric systems	
Voltage	24 V DC, negative earth
Batteries	2 x 12 V
Capacity	105 Ah
Battery heater	200 W
Alternator	Bosch 100 A
Drive Train	
Transmission automatic manufacturer	Mercedes Benz
Make	W4A 040 BM 722 391
Mechanical gear ratios	4 speed forward, 1 reverse
Transfer gearbox manufacturer	Hägglunds
Make	153 6085-801
Gear ratios	
High	1.28:1
Low	2.11:1
Differentials manufacturer	Hägglunds
Make	153 6140-801
Ratio	4.75:1

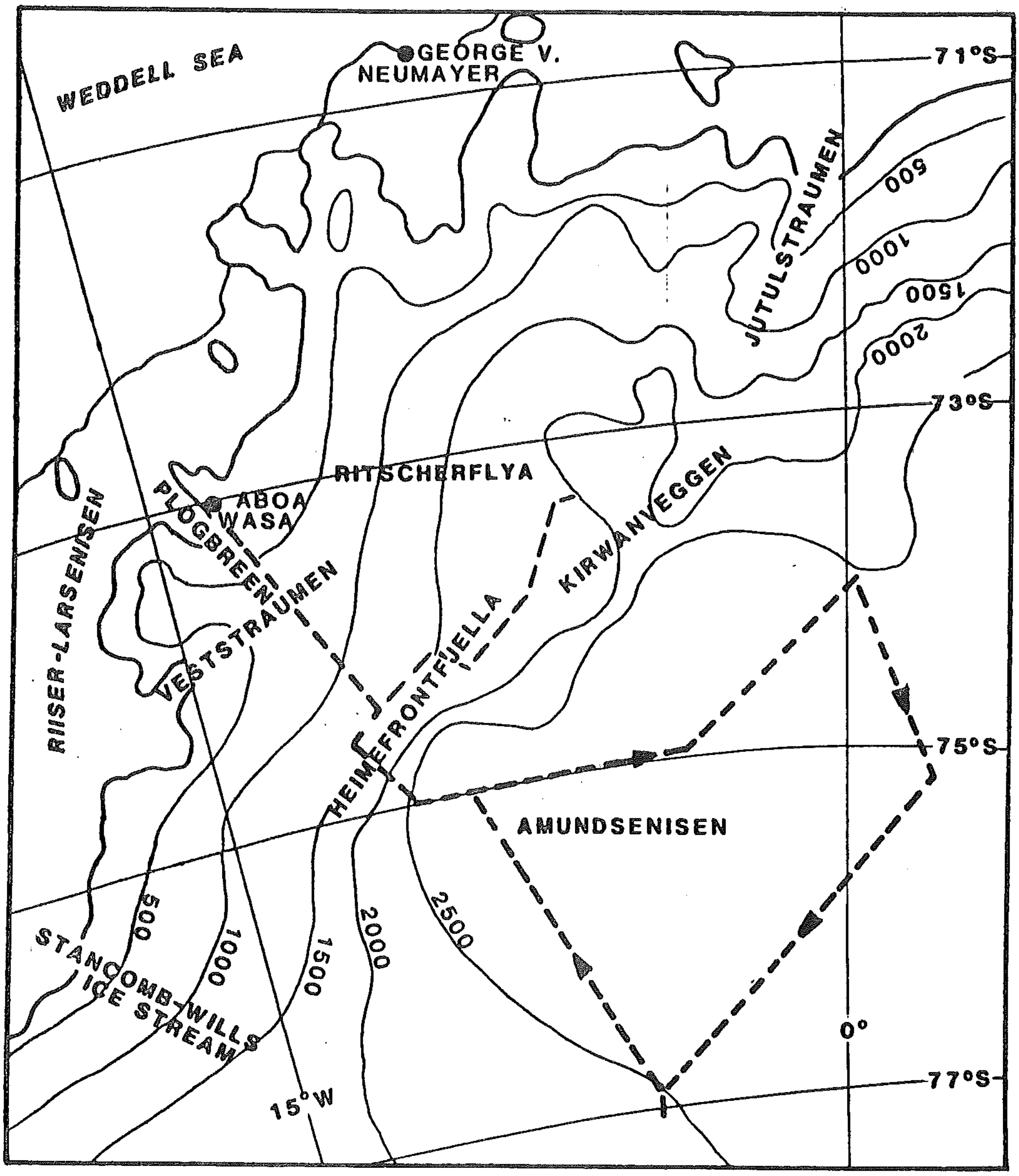
Fig 2



Note: Swedish Standard Diesel 0,1%

Fig 3

MAUDHEIMVIDDA
DRONNING MAUD LAND



The Transport Concept at the Antarctic Stations and for Field Operations of the Alfred Wegener Institute

by

H. Kohnen and N. Müller
Alfred Wegener Institute, Germany

Introduction

The Antarctic operations of the Alfred-Wegener-Institute for Polar and Marine Research are primarily concentrated on the Weddell Sea and the adjacent ice-covered areas. Appropriate logistical technologies had to be developed and introduced which are able to cope with the regional environmental conditions. The on-shore transport logistics has to be suitable for travelling as well as for carrying heavy cargo on soft snow surfaces throughout. The range of temperatures encountered through the year is from about 0° C to -50°. The density of the snow surface is low thus requiring vehicles exerting a low specific ground pressure.

Different types of tractors and sledges had been introduced in the early 80ies which led to some variety of vehicles being used for different tasks. However, different equipment means different spare parts and diversified expertise for maintenance and repair which, in turn, means higher costs. To balance this development we started to standardize our transport equipment. A tractor had to be chosen and modified accordingly, which is able to tow heavy loads on over-snow traverses, which can be used as a mobile scientific laboratory or simply as a personnel carrier or which can be modified as a construction and service machine equipped with cranes, front blades, front shovels, lifting forks or winches. The same philosophy has been persued for heavy cargo sledges which can alternatively be used for transporting bulk cargo, standard 20' cargo containers, 20' tank containers or 20' living modules. Since all supply goods are brought by ship to the Antarctic the 20' isonorm freight container frame was also taken as the basic unit on shore.

The tractor

The tractor to be chosen for our operations had to be versatile, powerful, reliable at low temperatures as well as to exert low ground pressure. Operational experience in the given region as well as the plans of extending traverse work to the high inland plateau led to introducing the Pb 240 D (Kässbohrer) as standard work horse in 1991/92. Five vehicles of this type have successfully been tested during the construction of the new "Neumayer Base" when 2200 tons of construction material had to be transported over sea ice and ice shelf as well as to be assembled.

The basic date of the vehicle are listed in the following table.

Length	4735 mm
Width	3920 mm
Height	2850 mm
Ground clearance	350 mm
Width of tracks	1530 mm
Tare Weight	5800 kg (with steel tracks)
Gross weight	7400 kg (8800 crane vehicle)
Specific ground pressure	0,047 kg/cm^2
Max travel speed	19 km/h (continously variable 0-19 km/h)
Max. slope	50°
Engine	6 cylinder Cummins (Diesel) turbo charged:
	Displacement: 8270 cm3
	Power: 242 Hp (DIN) 178 kW)
	Max. Torque: 890 Nm at 1500 rpm
	Fuel capacity: 180 l
	Fuel consumption: 18 l/h
	Batteries: 2 x 12 V/125 Amp/h
	Alternator: 28 V /100 Amp
	Oil content: 19 l max.
Turning circle:	Point turns possible
Cabin:	Length: 2235 mm
	Width: 1980 mm
	Height: 1550 mm
	Load capacity: 1000 kg

Table 1: Technical specifications of the Pb 240 D (Kässbohrer)

In comparison with the forerunner Pb 170 D this vehicle is an entirely new development even if the outer design is similar. The vehicle is powered by a turbocharged diesel engine (Cummins) of 242 Hp (DIN) yielding a tow bar pull of 6.8 tons. Assuming an average snow friction of 0,2 the vehicle is able to pull sledge loads of more than 30 tons. Together with the extreme low specific ground pressure the Pb 240 D is suitable for operating heavy loads on very soft snow. The hydraulic transmission allows continously variable speeds between 0 and 19 km/h as well as turning on the spot. The high manoeuvrability is particularly favourable for station and construction work. The average fuel consumption is 19 l/h which provides, together with the tank capacity of 180 l, an operation time of about 10 hours. For long distance operations the cabin has mountings to accept 12 fuel canisters of 20 l each. The engine and hydraulic performance is displayed in Fig. 1 and Fig. 2.

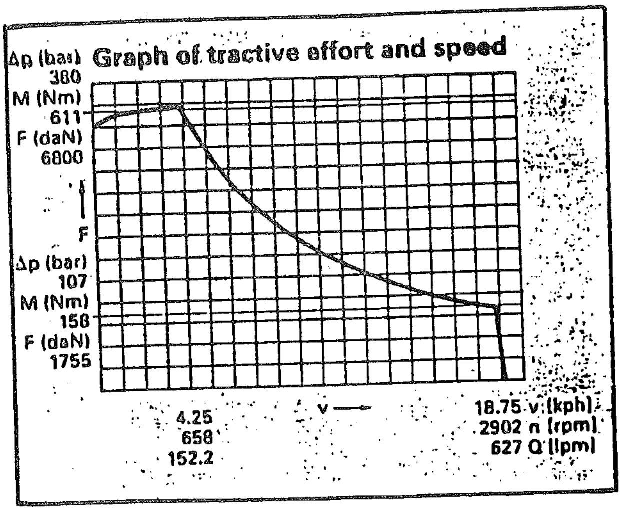


Fig. 1 Engine Power and momentum versus revolution

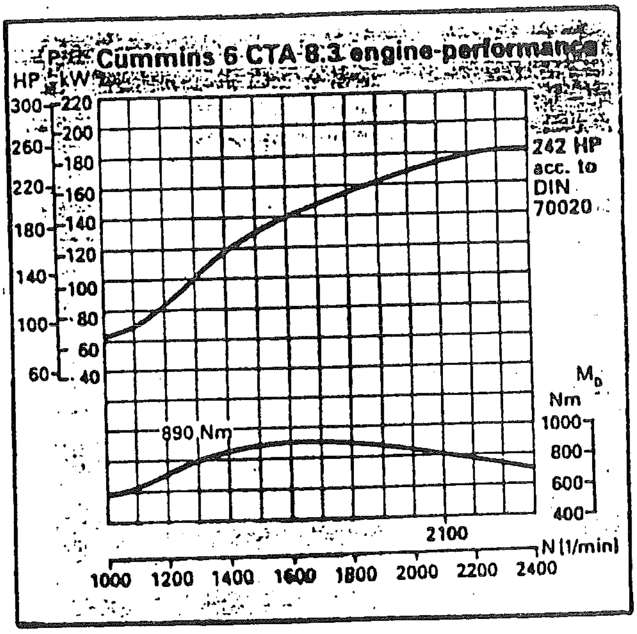


Fig. 2 Tractive effort versus speed and revolution

AWI has introduced two versions of the vehicle. One type is outfitted with a cabin for personnel transportation. The cabin can also be used as mobile laboratory housing scientific instrumentation. The other type is equipped with an hydraulic crane (HIAB) which has a maximum load capacity of 87 kNm. This means that the crane can lift 4100 kg at an outreach of 2 m and 400 kg at an maximum outreach of 12,4 m.

The slewing angle is 230°. The weight of the crane is 1850 kg; it can be easily mounted or demounted respectively by four screws only. The crane control valve can be operated on both side of the vehicle. The crane performance is displayed in Fig. 3 and Fig. 4.

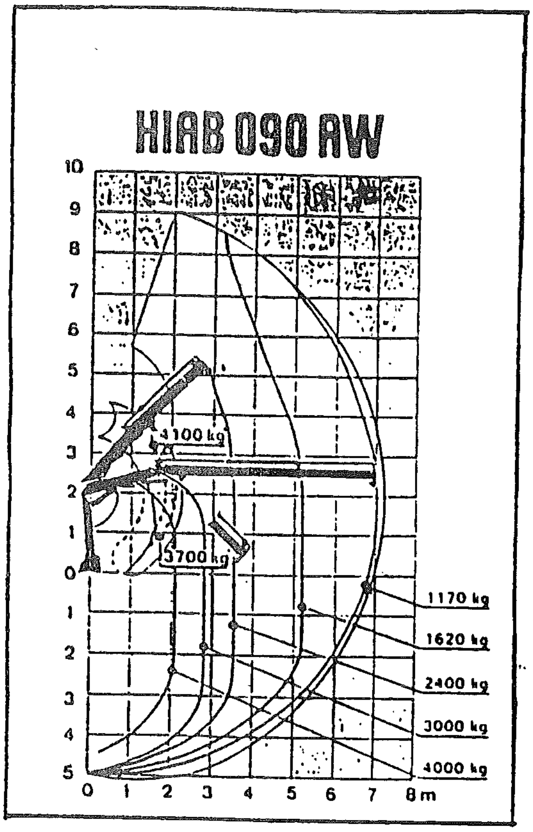


Fig. 3 Load Chart of the crane

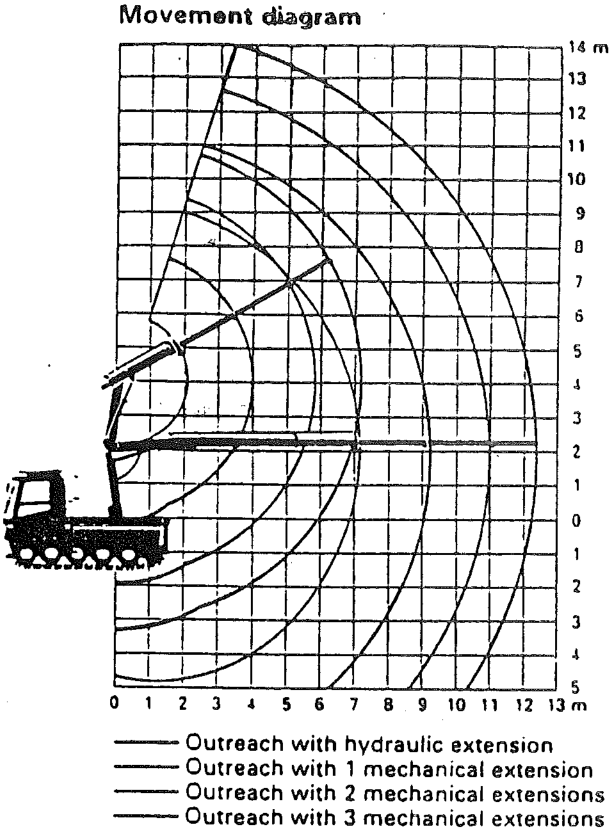


Fig. 4 Movement diagram of the crane

Both vehicle types are rated to operate hydraulic front attachments as winches, fork lift, front blades and front buckets. Our vehicles are equipped with (Fig. 5)

- U-blades, which are 4400 mm wide and which have adjustable wings, and
- front bucket, which are 4200 mm wide and 1000 mm high with a volume of 2 m^3.

A so-called "quick mounting system" allows for quick mobilizing or demobilizing. Both attachments are manufactured from low temperature steel. We use the blades primarily for grading of snow surfaces or for excavating of snow trenches as well as to push tons of snow to cover the new winter station for better insulation. The front bucket is very helpful for quick transportation of any kind of materials, drums and, of course, of snow. The attachments are operated via a control ball joint and low temperature hydraulic cylinders.

It has been our standard for years to equip all our vehicles with VHF communication as well as with HF communication and GPS navigation for traverse work.

Low temperature adjustments

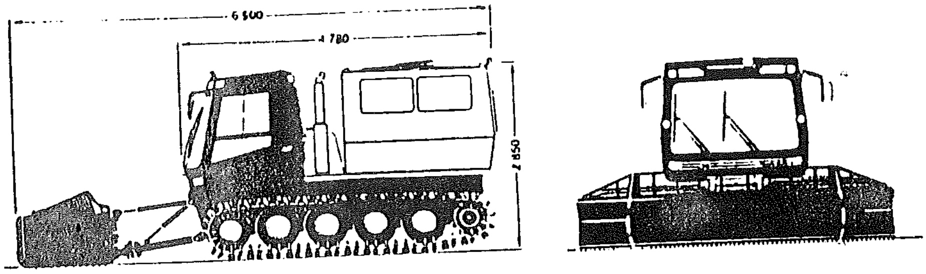


Fig. 5 View of the Pb 240

Temperatures below -30° C to -40°C have always been critical for vehicle operations. However, winter station work or traverses on the high inland plateau may well meet such conditions. Particularly under the aspect of future inland traverse work the new Pb240 has been modified accordingly. The following measures have been taken to allow for operating at temperatures down to -50° C:

- Preheating of the engine's oil sump (220 V)
- Preheating of the hydraulic oil tank (220 V)
- Front valve block adjusted to -50° C,
- 4 batteries à 12 V, 125 Ah, 425 A,
- Additional warm air preheating (24 V) for hydraulics, batteries, fuel tank and injection pump,
- Additional warm water heating (24 V) for preheating of engine, driver's cabin and cabin,
- Permanent heating of rear driving system,
- Sprockets with special low temperature coating,
- Generator 120 A
- Insulatio for -50°C
- Protection against drift snow
- All seals, rubber belts, tires and other items are adjusted to -50°C,
- Steel frame and other steel parts are made from low temperature steel (-60°C)
- Heated fuel hoses (24 V)
- Preheating possibility from other vehicles

Table 2: Low temperature adjustments

With the given experience, which is based on the experience of many years operating in cold conditions, we feel that we have introduced a tractor which is most suitable for our Antarctic field work.

The cargo sledge

20' isonorm containers have been the main transport units since the beginning of our operations in 1980. Appropriate cargo sledges had been developed being able to carry such units. Those sledges have been improved and optimized over the years now yielding an optimal performance. Today, the standard cargo sledge, manufactured by Aalener Baumaschinen, is a power-hauled bob sledge (Otaco type) with the following specifications:

Length:	9100 mm
Width:	2700 mm
Dead weight:	2,4 to
Specific ground pressure:	0,29 kg
Ground clearance:	380 mm

All pulling force is executed through tow bar and chains on the skis. The skis are coated for better running as well as to prevent them from freezing. All parts are manufactured of low temperature steel allowing for operational temperatures down to -60°C. The sledges are used for loads up to 20 tons each; they can be connected together to form tractor trains.

As shown in the following figures the sledges are used to carry bulk material and freight containers from ship to station. Modules, used as mobile quarters and/or laboraties are also transported by those sledges. Finally, fuel is transferred from ship to station in tanks of 15,000 l to 20,000 l capacity which fit the frame of the sledges.

Maintenance

Maintaining the vehicle is partly achieved in Antarctica at Neumayer Station. Maintenance and repair require skilled personnel as well as sufficient stock of spares. Standardizing the transport system to a minimum amount of different vehicles requires less spares as well as less manpower. On the average the tractors are rotated every third year between Antarctica and Germany for service and adjustment.

Conclusions

Currently, a versatile and standardized system for land transportation is being introduced for AWI's Antarctic operations. The whole over-snow transport system is thereby reduced basically to one tractor and one sledge platform. The units are used for station, construction as well as for traverse work.

ASPECTS TO BE CONSIDERED IN PLANNING LOGISTIC OPERATIONS IN THE WEDDELL AND BELLINGSHAUSEN SEAS

Vicente Manuel Federici - Dirección Nacional del Antártico
(Argentina). Ricardo Luis Poy - Servicio de Hidrografía Naval
(Argentine Navy). Norberto Cattáneo - Centro Glaciológico-
Servicio de Hidrografía Naval (Argentine Navy)
Buenos Aires - Argentina

INTRODUCTION

The purpose of this study is to provide all those interested in supply-and-search operations in Antarctica with the necessary tools for planning them. This is based on the experience gained by Argentina through its continued presence in the Bellingshausen and Weddell seas.

In order to comply with that purpose and find at coherent way to develop a deduction process which will make it possible to obtain worth-while conclusions, the meteorological and glaciological observations from the last 23 Antarctic campaigns carried out by the Gral. San Martín and Alte. Irizar icebreakers have been considered.

Once immersed in the subject, we should set a limit to our action. In this context, we define our task as a mission tending to carry out naval operations in the zone lying between the Mar de Bellingshausen and the Mar de Weddell, with a view to providing logistic support to the research groups based on these areas.

The mission must be carried out under the rule which considers logistic to be a preparative science to fulfill a task, the success of which is based on prevention, without admitting improvisations, thus trying to achieve the highest performance through a good organization which should reach its objectives at a minimum cost.

Based on these premises, we observed that the greatest limiting factor in carrying out these operations is the glaciological factor. For this purpose, studies were performed of ice-edges accumulated over the last twenty years, taking into consideration their different concentrations. The conclusion was arrived at more appropriate period of the year to operate in the surroundings of the Antarctic peninsula was from December through March, which could be extended with a reasonable degree or certainty to the period from November through April to accomplish tasks in specific areas.

For guidance purposes, we have outlined four principal operative areas with similar characteristics from the points of view of glaciology, climatology and the suitable type of unit. (See Fig 1)

Zone I - Mar de la Flota
Zone II - Erebus and Terror Gulf
Zone III - South-eastern coast of the Mar de Weddell
Zone IV - Western area of the Tierra de San Martín, at the south of the Mar de la Flota.

Without disregarding the above classification nd considering the importance of the Drake Strait as a sea route between the Atlantic and Pacific oceans and Continental South America and the Antarctic continent, special attention will be paid to the description of the wind regime in the Strait area, considering its importance for access to the Antarctic peninsula.

Drake Strait Zone

A significant increase in circulation intensity is to be expected in this area between the favorable periods of December/January and the February-March period, with more frequent occurrence of gales and a higher mean wind speed. Prevailing directions (in a 70% of cases) run through the NW and SW points, thus determining that the most important value of the zone component is that of the West.

Under such circumstances it is advisable to start to cross the Drake Strait on a North-South course with a meteorological situation as that shown in Fig. 2. Most of the crossing may thus be accomplished with prevailing tailwind which, should it turn into a gale, would allow for breaking away from it without a significant departure from the originally planned course.

Thus, and once we have entered the Antarctic continent, we shall proceed to describe that Mar de la Flota zone.

ZONE I

Both is climatological and the glaciological features are particularly favorable in summer time. The islands, archipelagos and peninsula (all of them with a markedly mountainous relief) enclosing the Mar de la Flota attenuate the effects deriving from the depressions passage whose natural corridor is the Drake Strait. This is why, precisely, most bases are settled leeward on the islands.

From the glaciological point of view, the area is ice-free from November to April (see Fig. 3). Climatologically warm years bring about considerable hindrances to navigation owing to numerous ice-floes, iceberg and debris drifting all over the sea and its channels. The main difficulty lies actually in the poor visibility, even for fully equipped vessels.

Some climatological factors, such as the latitude and proximity to ice-free waters make his zone one of the warmest in Antarctica.

The climate is moderate-temperate with marine characteristics owing to the influence of he air masses which have travelled over the oceans during most of the year.

The summer mean thermal field establishes a warm tongue covering the entire Mar de la Flota as far as Belgrano Island, fairly farther south of the zone under consideration.

Throughout the zone the mean temperature exhibits positive values ranging from a few tenths or degree to a little over 2°C (See Fig.4).

From November to May, the extreme minimum values range from -13°C to -3°C approximately, depending on whether we are north or south of zone.

The extreme maximum values range from 8°C to 11°C for the same months.

As regards cloudiness, circulation is purely westerly, marine and wet; in addition, the mountain influence establishes a high rate of cloud-generation particularly on the windward slopes.

On the leeward slopes, cloudiness may reach an average between 1 and 2 eighth lower, but this is not properly proven because of the scarce information available.

During operational months, operating possibilities range from 6/8 to 7/8, taking into account total cloudiness.

Averages indicate a plafond between 100m and 600m in 50-60% of cases.

Wind is an important operations parameter, It is quite common to find great differences in direction and velocity between the statistics that include the datum of a station and those that take into account the mean geostrophic flow in this zone; there are also noticeable differences between relatively close stations, and in these cases it is obvious that the orography is a determinant factor.

The catabatic winds effects is not important in this zone because of the small number of glacier plains. However, glacier breezes are registered; they are softer than the catabatic wind and of occasional occurrence. A thermal flow is established between the cold and dense air over the glacier and the liquid warm waters at its mouth. This wind is not detected beyond five miles from the coast and it rarely exceeds a 20 ks speed.

Mean wind speed in this zone is the lowest in the four zones studied, between 5 ks and 13 ks. The truly interesting thing is the prevailing direction which, as stated before, is in no way related to zone geostrophic circulation. (See Fig. 5).

The maximum values recorded range from 50 ks to 100 ks, according to the station locations. The number of rough wind days per month (wind speeds higher than 27 kts) ranges from 4 to 10 days, according to the zone.

Medium-sized ships as well as small ones and helicopters are warned of this phenomenon by the appearance of increased waves and heavy sea in a certain sector of a channel or bay.

Phenomena reducing visibility in the area to less than 1km are the following: rain, fog and in some stations, blizzards, but this phenomenon does not affect navigation.

The number of rain days per month ranges from 8 to 21, and fog days, from 1 to 2. Fogs are not very persistent and they are the result of advection of warm and wet air from the north, the frontal part of depressions and sea smoke, when cold irruptions take place which are naturally associated with anticyclonic systems.

Orography and coast orientation play an important role in rain distribution.

During the antarctic summer a precipitation decrease takes place, with a monthly average of 8 to 19 snow days.

Rain is the main cause of visibility reduction to values lower than 1 km.

Its persistence is directly associated with the presence of a low pressure system in the zone.

ZONE II

In the north-eastern tip of the Antarctic Peninsula there is the Erebus and Terror Gulf. Here the mildest period for glaciological operations is between December and February (See Fig. 6).

The peculiar shape of the peninsula and its mountain range disturb the tropospheric flow in such a way that the central- northern area of the Weddell sea becomes a cyclogenic zone, i.e. an area where depressions are developed or strengthened (See Fig. 7).

Another peculiar situation occurs in the area when large masses of cold air from the Antarctic ice cap rush in through the Filchner barrier. The flow of polar air causes deep and extensive vortices that cover most of the Weddell and remain stationary sometime for several days.

Good weather in the region is limited to high pressure areas of polar origin in the Weddell, which follow the process described above, or to migratory anticyclones passing through the area from the south-west and the west.

During the period under consideration the area has a somewhat colder weather than in the Mar de la Flota area. This is caused by irs proximity to the Weddell sea ice pack, which in winter lends all of the eastern region a continental type of climate that becomes marine between November and March.

Mean temperatures range from 0°c to 6°C.

Maximum extreme temperatures recorded range between 5°C and 15°C.

Minimum extreme temperatures recorded range between -5°C and -15°C.

The Föhn effect is quite common in this area, i.e. air passing over the mountains and coming down to leeward with a noticeable rise in temperature and drop in humidity. This is clearly observed in coastal stations where positive temperatures are recorded even in Winter. Further east of the shores on the islands this effects is noticeable only through cloudiness.

The afore mentioned effect normally persists over not more than 12 to 24 hours.

Due to pack ice breaking and the occurrence of free waters a significant rise or leap in the mean monthly temperature is observed in Spring and this happens at:

Petrel and Esperanza (September to October)
Marambio (October to November)
Matienzo (November to December)
(See Fig. 8)

Once the Antarctic Summer is over, a negative thermal balance is observed in the mean monthly temperatures:

Petrel and Esperanza: March to April
Marambio: March to April
Matienzo: February to March

As regards assessment of circulation in the region calms certainly do not appear as frequently as in the Mar de la Flota; what is more, mean speeds are considerably higher. Prevailing wind directions -Southerly and Southeasterly-clearly indicate certain peculiarities: the area finds itself on the western boundary of the depression that is characteristic of the Weddell sea, which ensures the southerly wind component, i.e. the natural boundary determined by the Antarctic range that leads circulation and draining of polar air from the Antarctic ice cap through the Filchner ice barrier (See Fig. 9).

As indicted above, average winds are southerly and southeasterly, with mean speeds of about 18 to 25 Knots. For nonprevailing directions, mean speeds in general are above 10 knots, with a maximum speed of 17 knots.

The number of days per month with strong breezes of 27 knots or higher, are between 15 and 23 days. Maximum speeds recorded in the area range between 70 knots and 110 knots in the north sector of the area, with a south or north component.

This is a regional where catabatic -Föhn-type-winds, wind channelling between the islands and glacial breezes, all of them with considerable force.

Bahía Esperanza is the one place where catabatic winds are known to occur. However, the same phenomenon is thought to occur at other locations on the continent. Careful study of the area's topography is recommended when near-shore operations are foreseen so that this and other local effects can be forecast.

The Föhn effect occurs whenever there is a passage of air through a mountain range. It is usual that, with a depression in the Mar de la Flota and high cloudiness, wind and precipitations, only medium or high clouds are observed in the gulf, with light to moderate northwesterly winds and excellent plafond and visibility (See Fig. 10).

Usually, the depression shifts to the east and this is a clear symptom of this passage. The proximity of bad weather is shown by the cloudiness that gradually covers the peaks of hills and islands, low cloudiness of a stratocumulus and stratus type appearing together with a rapid lowering of the plafond. When the wind suddenly rotates to the south or southeast, it implies an almost instantaneous deterioration of the weather with the possibility of a cyclogenesis. (See Fig, 11a and 11b).

Cyclogenesis is a phenomenon which brings about strong winds and abundant rain, decreasing visibility to zero for periods lasting between 12 and 24 hours; there are circumstances in which these values are doubled.

Winds canalizations are produced between islands which form a south-north or southwest-northwest passage and the effect is truly violent in cyclogenesis situations.

Micro and mesoscale glacial breezes or winds may originate in differential heating or cooling when waters close to islands or continents are open; this generates a circulation from the inner part of the island to its coast, which may even associate itself with catabatic flows.

The average cloudiness in the zone ranges from 6/8 to 7/8; the most frequent cloud types are stratiform or stratocumuliform 70% or 80% of the time, and nimbostratus during bad weather. Mean plafonds range from 100m to 600m, and they are found in 57% of the cases.

Then number of rainy days per month ranges from 15 to 20, snow fall being the most common phenomenon; occasionally there is rain or drizzle from 1 to 3 days per month.

Meteorological factors reducing visibility to 1km or less is snowfall, fog or blizzard.

Fogs play a very important role in the development of operations.

The most common type of fog is by advection or warm and wet air from the north; it usually lasts as long as does the circulation originating it, from the northeast and the north; it is found even with strong winds and it appears in the form of sea fogs, that is to say fogs, that is to say with free waters, or with ice fields, when the effects strong.

Orographic fogs due to ascending air over the hillsides are very important in this sector where air is quite wet; at Vicecomodoro Marambio island at 196m a.s.l., the number of fog days per month ranges from 14 to 19.

Blizzards are exclusively due to strong winds while depressions systems are developing in the region; persistence is a function of the strong winds and the amount of snow to be blown away. At times, the snow is swept away and with 40km winds there is a good visibility.

ZONE III

As we continue our route towards the South-east, trying to reach the south-eastern boundaries of the Weddell sea, we notice that the glaciologically optimum period is between January and February (See Fig. 12).

Analyzing the last 23 campaigns by the General San Martín and Almirante Irizar icebreakers, graphs have been made which show the higher and lower passage-density areas, the area marked as having 50% of passages being the most advisable route for penetration. (See Fig. 13).

At this stage the need to have real-time satellite date is emphasized which permits defining the ice pack edge with some precision, in order that this kept on the starboard all along the route. In this way, straying into canals can be avoided so that these don't become an ice trap which not only could jeopardize the mission objectives but also endanger units and crews.

Climatological data are included for January and February, which are the most advisable months for operations from the glaciological point of view. A brief discussion of the meteorological parameters having a greater impact is made herein (See Fig. 14).

The maximum average temperature is registered in January, a month before the best ice positions. The extreme temperature values, considering the periods 1980-1987, are:

Maximum temperatures:

January = 7.3°C
February = 8.0°C

Minimum temperatures:

January = -13.2°C
February = -19.7°C

The prevailing wind directions in January and February are from the south and southeast, with an average speed that ranges from 8 kts to 10kts.

As calms are found on the north border of the polar anticyclone, they exceed, in a number of cases, any direction considered in a particular way.

The above-mentioned directions correspond to the sector's average circulation, on the one hand, the scarce catabatic effect, drainage of cold air, from the polar cap ice to its edges and, on the other hand, to a combined effect of the two prevailing systems: the polar anticyclone and the Weddell Sea depression.

The maximum speeds recorded in January are: 78 kts from the southeast (160), which corresponds to the rear of a cyclogenesis at the South Weddell, a typical situation in the area, as well as the maximum of 75 kts from the northeast (050) for February, which represents the front part of a similar phenomenon.

The winds having a north component are more intensely felt on these shores due to cyclogenesis; for example, the maximum speed recorded is 128 kts from the north-northeast in a month of September. The number of days in a month showing winds above 27 kts(strong) is very regular throughout the year, with an average of 7 days per month during the warm season December, January and February.

Average cloudiness values are very regular over the year, with a barely significant maximum value reported in January and February, which is due, among other factors to the contraction of the polar anticyclone to strictly continental areas, to the shift of the sub-polar low temperature belt to the south, and to the higher availability of water vapor as a result of advection of air from the north in low layers, jointly with the higher evaporation caused by the increase of liquid water surfaces.

The annual mean value ranges between 4/8 and 5/8, January and February being slightly above 5/8.

As regards precipitation, the difficulties to measure this parameter in polar areas and the little reliability of that value are well known. Yet this statistical figure is irrelevant for the purpose of this study; emphasis is placed, instead, on the number of days with precipitations, 14 in January and February respectively, and the disadvantages resulting from this, mainly, reduced visibility due to snowfall and blizzard.

Snowfall is the exclusive type of precipitation. The following is a brief summary of events that may reduce visibility to critical values, lower than one kilometer.

A - Fog
B - Precipitation (snowfall)
C - Blizzard
D - Whiteout

A - Fog:

The number of days on which this phenomenon occurs varies in January and February from 7 to 6 days respectively, these being the months in which this phenomenon mostly occurs during the year.

B - Precipitations:

Snowfall is exclusive in this area, and it generally occurs as heavy shower, with scarce moments of reduced visibility, or when there is a cyclonic development in the area which may last from one to two days. This phenomenon is followed by strong winds giving rise to blizzard.

C - Blizzard:

This is a frequent phenomenon in cyclonic developments. It may be divided into blizzard high up, which in general makes operations difficult and occasionally reduces visibility when considerable gusty winds occur.

D - Whiteout:

This consists in a specific reduction of visibility or, more precisely, in a situation in which objects, the sky, the horizon and the surface become invisible despite good weather conditions. This phenomenon typically occurs in summer during daytime, in high latitudes, over a frozen sea or a snow-covered surface with relatively high pressure systems and skies covered from 5/8 to 8/8 by middle or high clouds. There are no whiteout statistical values available. It is a phenomenon involving a great risk, especially in flight operations where references are lost and it is practically impossible to determine visually the distance between the ground and the aircraft.

ZONE IV

Entering now the Western Zone of the Tierra de San Martín and South of the Mar de la Flota it can be observed that the period glaciological most suited for operations is that covering the months of February and March (See Fig. 15).

Owing to its geographical position and its steep topography, the area may present considerable variations with respect to the comments made and the values indicated in this survey. However, we will try to provide appropriate orientation on typical microclimates.

This zone is also characterized by having a large drifting sea ice-field which either compresses itself against the coast, as a consequence of the Western winds, or moves towards the north or the south according to the prevailing wind, sometimes during 24 or 48 hour periods.

The ice-field affected by the wind is very large, consequently the pressure exercised on islands, channels, coasts and icefoot will be high. This effect may be highly destructive for vessels (See Fig. 16).

Temperatures are milder than at the same latitude over the coast of the Weddell Sea which remains frozen even during the summer period.

The reason for relatively high temperatures observed in this area, despite its latitude, must be sought in the great marine flow of predominant air masses in ice-free water.

The annual average temperature is about -6°C and the February and March average temperatures are about 0°C and -2°C respectively.

The following are extreme values:

Maximum temperatures:
January = 11.4°C
February = 7.7°C

Minimum temperatures:
January = -17.0°C
February = -17.6°C

The direction and speed of the area general flow are greatly affected by orography. Mountainous islands and the peninsula, with its mountain ranges and inner valleys, produce particular effects.

The climatological values represent the place where they were measured and not the neighboring area, this being generally applicable to the whole peninsula and its islands.

When depressions arrive from the west and come across mountain ranges which place a transversa obstacle in their way, there is a canalization of the air from north to south, with a considerable increase of wind speed. This increase is more distinct when sailing through channels, among islands (See Fig. 17).

The arrival of migratory anticyclones causes a similar effect but with a south to north direction. This is clearly seen in the number of days with wind higher than or equal to 27 kts which amounts to about half a month, that is to say, 13 days (See Fig. 18).

Internal glaciers with a slight slope constitute a source of catabatic winds with a restricted area of occurrence; this effect frequently takes sailors by surprise owing to the scarce information available.

In Gral. San Martín Argentine Base, a place where catabatic winds frequently occur, said winds are clearly represented in the 1976 and 1987 statistics, as well as in previous periods where values are almost equivalent.

After the calm, which occupies the first place in frequency of occurrence, the prevailing direction is clearly eastern, confronted with the area sea traffic, the high medium speed between 35.7 kts in February and 29.3 kts in March. The maximum speed in the same months reached 135 kts and 110 kts always from the eastern sector (See Fig. 19).

The average values of cloudiness for the months of February and March indicate 5/8 and a little more than 6/8, which is quite reasonable given the rise of air coming from the west which takes place in the mountains of the area and what this involves, precipitation.

Leeward of the mountainous islands, cloudiness conditions may not be so severe. The mean low cloudiness ranges between 3/8 and 4/8.

The most common cloudiness is the stratocumulus, then comes the stratus with ceilings that range from 100m to 600m most of the time (75%).

Owing to the approximation of depressions and to the orographic ascent, it might be inferred that continuing bad weather conditions with precipitation, if it occurs, last 24 to 48 hours.

The main reason for the reduction of visibility is precipitation because the number of foggy days is very low, 3 days in February and 3 days in March. The number of days in the rainfall month represents, as it has already been mentioned, between 50% and 70% of the month.

Owing to the steepness of the ground, blizzard does not constitute a common phenomenon, it only occurs in certain zones and it is sometimes mistaken with snowfall.

Whiteout occurs in very restricted areas because the great extension of open water in a certain way prevents the phenomenon from taking place.

After the calms, which take up the first place in frequency of occurrence, the prevailing wind direction is definitely easterly, opposite to the area sea traffic. Wind speeds are high: mean speed is between 35.7 kts in February and 29.3 kts in March. The maximum speed in the same months reached 135 kts and 110 kts respectively, always from the eastern sector (See Fig. 19).

As already mentioned in this survey, specific phenomena, not commonly found in other latitudes, occur in Antarctica, from the glaciological and the meteorological points of view. Worthy of mention are the following effects:

Ship icing
Catabatic winds
Whiteout
Fog and Wind-chill factor.

Icing may occur on the ship's upper works, and its magnitude may be such that the added weight may endanger its stability (See Fig. 20).

The elements which may freeze he ship are the following:

A - Icing fog.
B - Icing rain drizzle
C - Sea foam or spatter carried by the wind when the air temperature is equal to or lower than, 2°C and the sea temperature is 2°C.

The severity of icing is also a function of the wind speed:

Light from 17 kts to 21 kts
Moderate from 22 kts to 33 kts
Strong, more than 34 kts.

Icing does not greatly affect areas near ice or water surrounding islands owing to be scarce swell. The Drake Passage, mainly south of 56°S, between November and March, is where the phenomenon may take place. The frequency is very low, between 5% and 10%. (See Fig. 21).

The basic concepts on occurrence of the catabatic wind have already been outlined. The following paragraphs introduce some criteria on how to operate the ship in this wind.

On the glacier, the thickness of the layer of cooled air varies from 100m to 500m and the persistence of the wind has been found to range from 6 to 12 hours, even though it may last for several days if weather conditions favor its continuation.

A strange phenomenon of common occurrence is the rebounding effect caused by the air when it drains down slope and hits the sea, after which it rises a few hundred meters, producing areas of strong winds near the coast and comparatively light winds some 5 or 7 miles away. It is worth noting that this phenomenon has occasionally been observed 50 miles away from the coast, but a safe spot to station the ship is considered to lie about 15 miles at the foot of the glacier and to the right of the air-flow, since the coriolis force deflects air to the left.

A "whiteout" is an optical phenomenon which makes it difficult to determine the shaping of the ground and considerably reduces in-depth visibility.

It takes place when a layer of middle and high clouds covers more than 5/8 of the sky on top of a snowy or icy surface during daytime, under good weather conditions and in summer. Sunlight is scattered by the clouds and reflected repeatedly by the ice, thus causing a loss of bearings, the disappearance of the line of the horizon and the absence of shadows, as objects are illuminated from every direction. In such a situation, it is dangerous to attempt movement on the surface, because cracks are not visible and, when flying, it is impossible to see the ground. For landing, helicopters should carry smoke-generating flares which produce different color and allow for the determination of shorter distances.

Fog is a very familiar phenomenon in the whole of the peninsula, but it is more frequent in the eastern area. This fog originates in the advection of warm moist air from the north, above colder waters or frozen sea, in the evaporation of sea water caused by an inflow of cold dry air, and in the evaporation, from the water level due to ice formation in the water itself.

The first of the above is the most frequent and lasts while the north wind prevails. On 70% of all occasions this does not last longer than eight hours, regardless of the wind force. The occurrence of the second possibility is very low and it never exceeds the six-hour period. The occurrence of the third case is limited to certain areas and visibility seldom diminishes below the 1km mark.

When planning operation, it will be necessary to consider the provision of adequate clothing for the protection of men working in the open. With temperatures dropping near or below 0°C, the wind-chill factor is very important, leading to conditions which may become unbearable for a man exposed for long hours.

This constitutes yet another restriction imposed by the Antarctic weather, which will no doubt play an important part in the final outcome of our mission.

CONCLUSIONS FOR LOGISTIC OPERATORS WHO ARE IN THE PLANNING STAGE

In applying what has been studied previously to practical operations, we will try to give synthetic prescriptions which should be deepened in detail for each place where it may be decided to supply services.

It should be pointed out that no overall conclusions encompassing great geographic areas should be arrived at and that synthetic prescriptions are only useful as a guide to planning. It would be risky to put up with only these prescriptions to carry out operations.

NOTE: Cartography and Nautic Operations: for this study and for all such operations in which we have had a real experience, we have combined the British and Argentine maps and publications. Thus an acceptable level of information and safety can be achieved. Also in the case of specific zones the use of local quarter section charts is necessary (for instance, Palmer's quarter - USA).

It should be noted that the cartographic information is incomplete and that the Antarctic Pilots have been gradually enriched by the information produced by the captains of small and medium-sized ships. Our experience compels us to deepen the analysis of the information of Navigation Tracks when operations are being carried out with over 130m length ships.

We suggest that the subdivision shown below be introduced in the four principal areas with a view to a practical planning approach to operations, we suggest the following subdivisions of the four principal areas into which the glacio-meteorological studies have been divided, by adding all geographic factors:

Islas Orcadas, surroundings
Shetlands del Sur y Norte de Península
Antarctica and Antarctic Strait
Weddell Sur (Belgrano Station)

Antarctica and Antarctic Strait
Weddell Sur (Belgrano Station)
Marambio Station
Bahía Margarita

The planner must know that these areas have different geographic, meteorologic and marine glaciology conditions which are scattered over time.

Selection of date - (Preparation for the planner)

Orcadas - From late December to mid-March. If a glaciological season is very severe, delay the beginning.

Marambio Zone - From early December to early February.
It is inadvisable to operate with ship from mid to late February. Displacement of old ice towards Erebus and Terror Gulf with treat thickness and pressure phenomena hamper operations and make them uneconomical.

It is relevant here to quote what happened to the "Glacier", "Burton Island" and "San Martín" icebreakers, which were stuck in the ice-pack over 45 days, during which time the crews had to be evacuated and preparation to spend the winter was started. Besides, the "Polar Star" and the "Stena Artica" have also documented how dangerous this area can be.

South Weddell (Belgrano) - January (preferably mid January)

Margarita Bay - Late February until April. In this place, with the exception of nocturnal hours that begin to influence operative performance and of early snowfalls there have often been seasons in which the best days free from sea-ice for operations were in late March and early April.

Shetland Island and North of Antarctic Peninsula and Antarctic Strait - Mid -November to mid-April.

After a very rigorous glaciological winter it is advisable to put off the beginning of operations until mid or late December so as to cut down operational costs, unless the priority of tasks to be performed and the high classification of the vessel make it acceptable to start operations by breaking ice. As from mid-March, early snowfalls and the night hours must be taken into consideration when calculating costs and they increase their impact as Autumn approaches.

When a single vessel is operationing in all the area (Recommended dates).

In case logistic support must be given with a single ship, operations should begin in he Erebus and Terror Gulf by mid-November, followed by the Antarctic Strait and the Shetland Islands and then the Orcadas (Orkney) Islands. By mid-January operations continue in the South Weddell, then back to the Orcadas, Antarctic Peninsula and Shetlands, and finally Bahía Margarita by the end of February or March. Resupplies and crew shifts can be effected in nearby ports such as Usuhaia and Punta Arenas.

Anchoring locations

It is important to bear in mind that no anchorage in the whole area can be considered reliable. Sudden winds, poor rock or glacial sludge bottoms, and great depth near the coast setting are the cause for this, and Captains should ponder over the machine conditions for each anchorage and take extreme precautions.

Landing locations

Landing points from the sea are nearly always rough, spacial craft being required for cargo unloading. Zodiac-type inflatable blast are ideal for landing of small groups of personnel, In the area under considerations, almost all of the suitable landing points are close to an English, Chilean or Argentina Station or shelter. (Local information is the most reliable even though it may not be written).

Most of those locations are in bays and coves where it is difficult to manoeuvre with vessels larger than 120m length, particularly those with a single propeller and without side thrusters. In any case, manoeuvering is dangerous for all kinds of craft under gale conditions. In addition, drifting ice and its effects (tides, wind and currents) should be constantly monitored.

A brief panoramic trip from Cabo NORVEGIA (Weddell) to Bahía Margarita (Bellinghausen).

From Cabo Norvegia to the neighborhood of station Argentina Belgrano II a coastal channel opened every year and there also was a relatively easy possibility of entry by the sea. Mooring areas at the ice barrier can be found and improved along the barrier before entering Bahía Vahsel. The English Hally Bay Station is an example of this. There are also some areas on the barrier where skid landing of aircraft is possible (even, in some places, which C-130 aeroplane).

In the vicinity of the barrier, ice of various ages and great tabular bergs respond to wind, general current and tide action. This latter factor is very noticeable in Bahía Vehsel.

From this bay it is possible to go ashore (specially to the Belgrano station) either by helicopter or an arduous travel through the ice, Including climbing (unless the travel is made farther away from the east).

In regard to the supplying of permanent stations, our recommendation is that any undertaking west of Hally Bay should have a supply of fuel and foodstuffs for two years.

Turning to the West, the detachment of FILCHNER barrier has caused all natural ice piers existing in the zone to disappear. We believe that over the years the ice foot at places with entrances in the barrier will not break away and that it will gradually increase its thickness until a good pier has been consolidated. Thus the only problem that remains unsolved is the big step of the barriers.

On the East and North East of Berkner island, where there was a barrier, navigation is dangerous because of the lack of hydrographic surveys and of certainty to find low depths and underwater obstacles.

Access to Berkner island, where the Belgrano III station (now inoperative) located, should be made by helicopter or by a cumbersome, long travel through the ice from Belgrano II station. From Berkner island up to Peninsula Jason there is a zone which has not been navigated by us. Flights and remote sensing indicate that every year a channel along the coast can be opened which goes on some occasions from the north up to Adams Cape. All this zone, particularly Adams Cape and up to Jason Peninsula, is in our opinion extremely risky for navigation. In this zone big moving tabular icebergs and also moving very old ice are to be expected as well as the occurrence of pressure effects.

On the Larsen barrier and in the vicinity of Jason Peninsula it is possible to operate with skid-aircraft. Going further away northwards and getting closer to Robertson island, the height of the barrier permitted mooring and unloading of material operations.

Nowadays and particularly in Summer, unloading operations from vessels directly to the barrier and from skid-aircraft are often hindered and sometimes thwarted as in many areas there are abundant cracks parallel to the edge of the barrier which during the melt-out period are practically filled with streams of water running to the sea.

In this part of Weddell, Peninsula Jason until the Erebus and Terror Gulf it is frequent to find in October, November and, sometimes, until late December, a wide, ice-free channel. This channel is suddenly closed by the displacement of ice, most of it heavy floes, thus giving rise to pressure phenomena.

In Marambio Island (Seymour), Marambio Air Force Base, where C-130 wheel planes operate, there are TWIN-OTER aircraft permanently stationed and during Summer there are helicopters operating in support of scientific expeditions; supply by sea from Bahía Pingüino or Bahía López de Bertolano anchorages. The great drawback is the motion of ice due to tide currents and interruptions due to lack of visibility. Late in summer the whole area is dangerous for sailing because big masses of heavy ice moves towards Erebus and Terror gulfs covering the entire area with pressure effect.

Further up North, during Summer, at the triangle formed by the Joinvill Orcadas islands, drifting ice packs of heavy flows (sometimes their thickness is over 10 meters) appear and pose a threat to navigation, even to the icebreakers.

At the same triangle when there is no ice, particularly on the way to Orcadas, storms may cause damage to ships and cargoes, The zones of Orcadas Shetland are well described in Antarctic Pilot, to mention them would be redundant.

To go to Margarita Bay during the recommended period, it is possible to navigate in open seas, watching for icebergs and drifting ice packs as soon as the Bismarck strait is left behind; then heavy seas and swells may be encountered. The other possibility entails extremely careful sailing along the channels, including the Barlas Strait and Fiord Laubeuf. However, in the latter case it is necessary to have reliable information confirming the channel is ice-clear.

In those years when the Barlas channel/Fiord Laubeuf were blocked by consolidated ice, icebreakers could hardly get through; therefore it is not advisable to take the risk of attempting navigation under these conditions in order to avoid senseless operating costs.

Navigation off Belgrano Island (Adelaida) is not confronted with any problem during the recommended season.

These writers prefer to navigate in the vicinity of the island using English cartography and reach Bahía Margarita through Woodfield channel, instead of doing so through the center of the bay, where there is a high probability of finding old, heavy ice.

A recommendation to permanent stations and facilities in Margarita Bay and farther away southward, except for the facilities existing in Belgrano (Adelaida) Island, is that they should have supplies of fuel and foodstuffs for two years.

Classification of ships:

At recommended times, provided with suitable glaciological information, ocean ships not classified for ice can have access to the Orcadas, North Antarctic Strait, Shetland Islands and Northwest of the Antarctic Peninsula. It is even possible to reach Belgrano Island (Adelaida).

This is NOT recommended by authors who, using ice notation from the SWEDISH-FINISH CLASSIFICATION, consider that the correct options are:

- ORCADAS, SHETLANDS, ANTARCTIC STRAIT (without entering the Erebus and Terror Gulf), Northern and Western Antarctic Peninsula as far as Belgrano Island (Adelaida): Class IB from mid-December to late February, with the previous recommendations of dates for each area.

- WEDDELL SEA AND MARGARITA BAY: Class IA having regard to recommendations of dates for each area. If mission would imply going far westward within the Weddell Sea or far southward within Bellinghausen, the IA super will be the best ship.

Off-season operations:

We can only recommend, on the basis of our own experience, the use of a IA super vessel if winter routine operations are necessary from late April to mid-November or mid-December, depending on the degree of severity of the marine glaciological winter.

With this class of ship it was possible to reach Shetland North Antarctic Peninsula and the northern part of Belgrano Island (Adelaida), obviously with the logical problems resulting from climatic difficulties and lack of light.

The most difficult period (exclusively from the point of view of sea ice) will certainly be from September to early October.

Should it be necessary to go from Shetland or Peninsula to Orcadas or Sandwich, or vice-versa, the more economical option will be to go out into free waters in the nearest course, then to sail as far North as required and the sail from North to South through the shortest possible route to enter the pack.

We have neither experience nor information about off-season operations in the Weddell or Bellinghausen seas. However, we believe it dangerous to sail too far west into the Weddell, for there are fissure phenomena at the mount of Margarita Bay.

In some coves or bays, under winter conditions, ice will be found thick enough to try direct unloading from the icebreaker, including heavy vehicles.

Helicopters:

Our recommendation is that every ship serving for logistic operations should have them. The ideal situation is the logistic ship with two SUPERPUMA or SEAKING-type helicopters. Units must be prepared for long antarctic operations with special attention to navigation and homing equipment.

Minor Ships:

Collapsible ramps are obligatory, in addition, if the parent ship is large enough, it would be possible to use a tugboat and carrier pontoons with auxiliary unloading elements.

Final Recommendation (miscellany):

1) Although it is uneconomical from the point of view of the shipping business, it is advisable that ships operating in Antarctica carry only light fuel;

2) Logistic requirements should be met by using ships with 120m overall length or under.

Final Note:

This very brief and partial study of the problems involved in planning logistic operations to the Antarctica by sea has only considered information other than the one found in sailing directions and other than the one found in sailing directions and other current publications. Each theme is a guide for planning; actual operations should seek widely enlarged information.

Expressed opinions represent authors and not their institutions.

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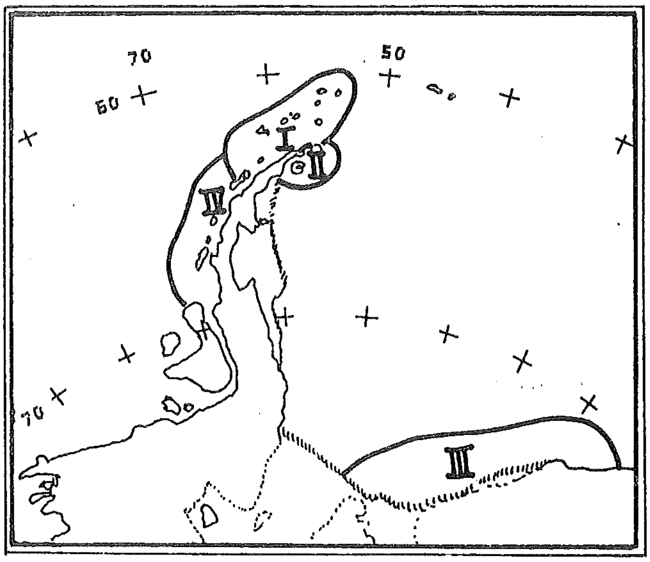


Figure 1

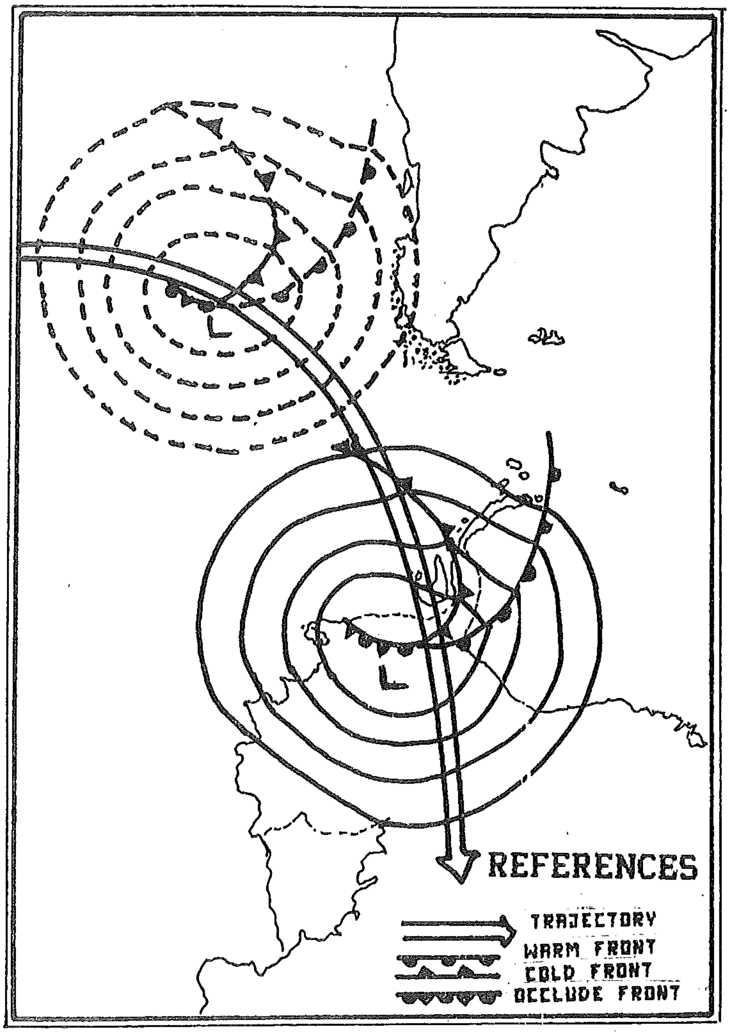


Figure 2

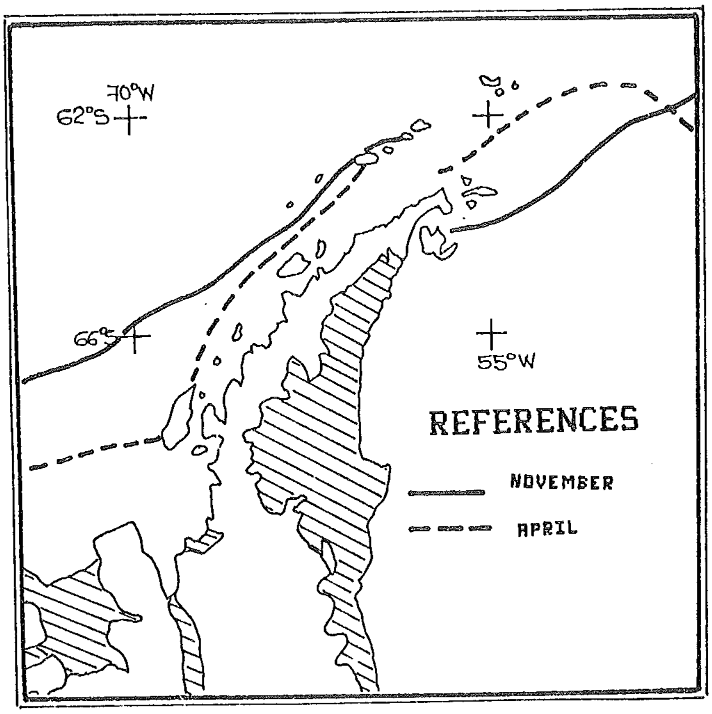


Figure 3

ZONE I

TEMPERATURES

	CABO PRIMAVERA (1977-81)			ALMIRANTE BROWN (1973-83)		
MONTH	TEMPERATURE MEAN °C	TEMPERATURE MINIMUM °C	TEMPERATURE MAXIMUM °C	TEMPERATURE MEAN °C	TEMPERATURE MINIMUM °C	TEMPERATURE MAXIMUM °C
JANUARY	2.2	-2.8	9.8	1.8	-4.6	11.5
FEBRUARY	1.8	-3.0	9.4	1.4	-4.4	8.2
MARCH	-0.1	-7.2	7.0	0.1	-7.0	9.2
APRIL	-2.1	-13.1	6.3	-1.8	-14.2	9.0
MAY	-3.9	-14.3	6.4	-3.7	-17.0	8.1
JUNE	-5.5	-17.1	4.8	-5.1	-15.7	6.9
JULY	-9.3	-21.9	5.4	-7.4	-20.8	5.2
AUGUST	-8.5	-25.6	4.3	-7.2	-26.0	4.5
SEPTEMBER	-5.6	-8.4	6.0	-5.7	-25.0	4.8
OCTOBER	-3.0	-15.8	9.2	-3.1	-19.4	7.7
NOVEMBER	-0.5	-13.0	8.8	-0.5	-13.2	8.4
DECEMBER	1.4	-6.6	9.8	1.2	-4.5	10.6
ANNUAL	-2.7			-2.5		

Figure 4

STATION ORDER Nº	PRIMAVERA	CAMARA	DECEPCION
1	CALM	CALM	CALM
2	E	W	W
3	NE - S	NW	SW

Figure 5

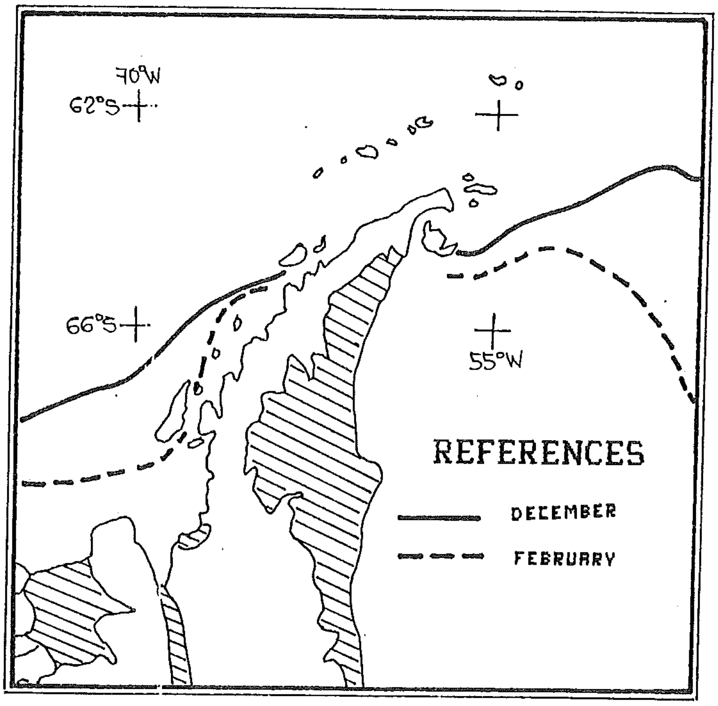


Figure 6

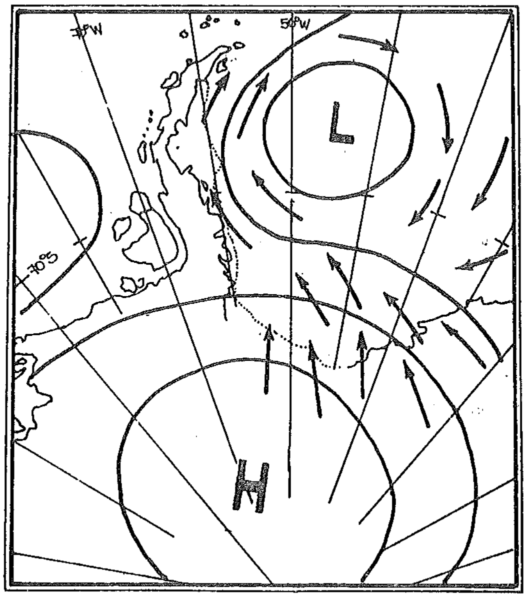


Figure 7

ZONE II

TERMAL DISCONTINUITY OF BREACK PACK ICE

STATION	MOUNTH	MEAN TEMPERATURE	VARIATION °C
ESPERANZA (1971-87)	SEPTEMBER	-7.4	+ 4.0
	OCTOBER	-3.4	
PETREL (1968-76)	SEPTEMBER	-8.9	+ 5.1
	OCTOBER	-3.8	
MARAMBIO (1971-87)	OCTOBER	-11.5	+ 4.9
	NOVEMBER	-6.6	
MATIENZO (1968-75)	NOVEMBER	-6.3	+ 4.6
	DECEMBER	-1.7	

TERMAL DISCONTINUITY OF CONSOLIDATION PACK ICE

STATION	MOUNTH	MEAN TEMPERATURE	VARIATION °C
ESPERANZA (1971-87)	SEPTEMBER	-6.2	- 6.5
	OCTOBER	-12.7	
PETREL (1968-76)	SEPTEMBER	-6.9	- 4.9
	OCTOBER	-11.8	
MARAMBIO (1971-87)	OCTOBER	-4.8	- 4.2
	NOVEMBER	-9.0	
MATIENZO (1968-75)	NOVEMBER	-3.1	- 4.1
	DECEMBER	-7.2	

Figure 8

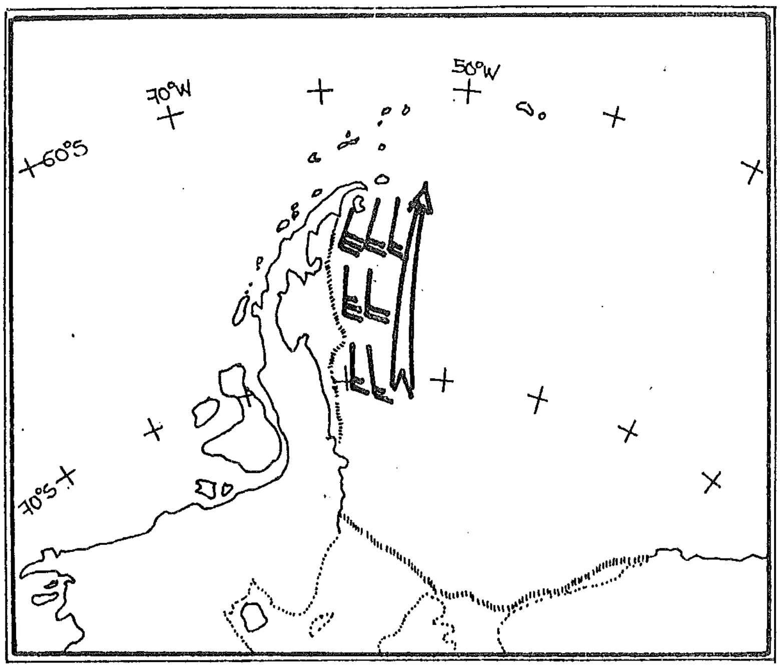


Figure 9

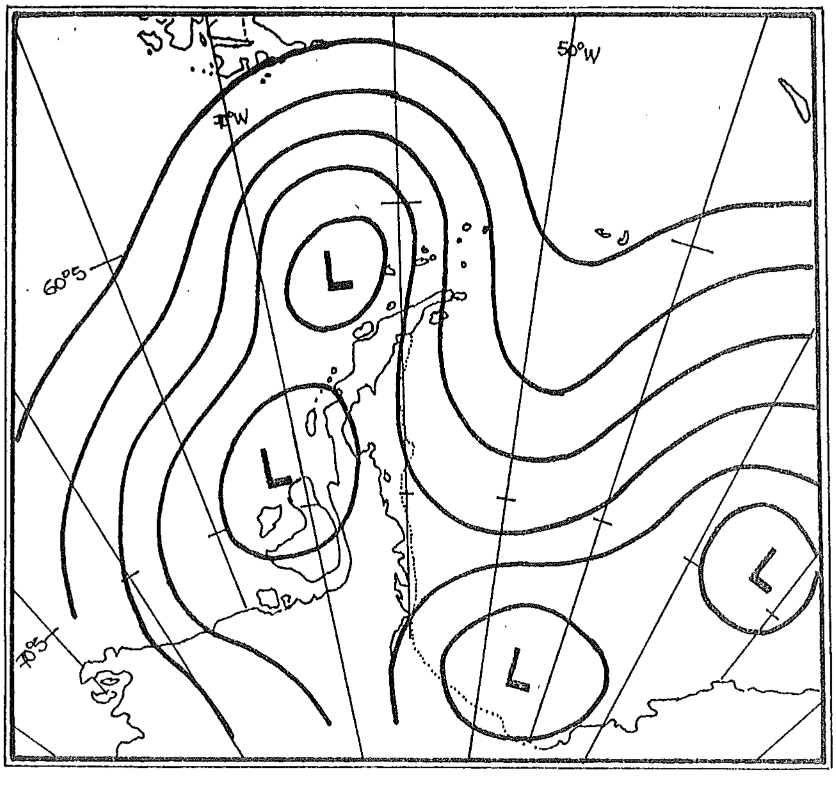


Figure 10

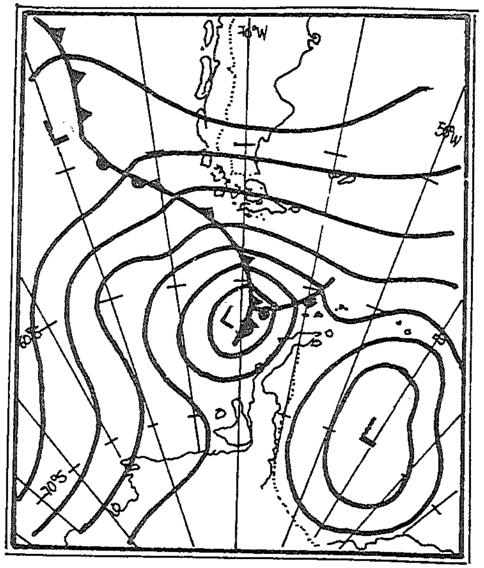


Figure 11a

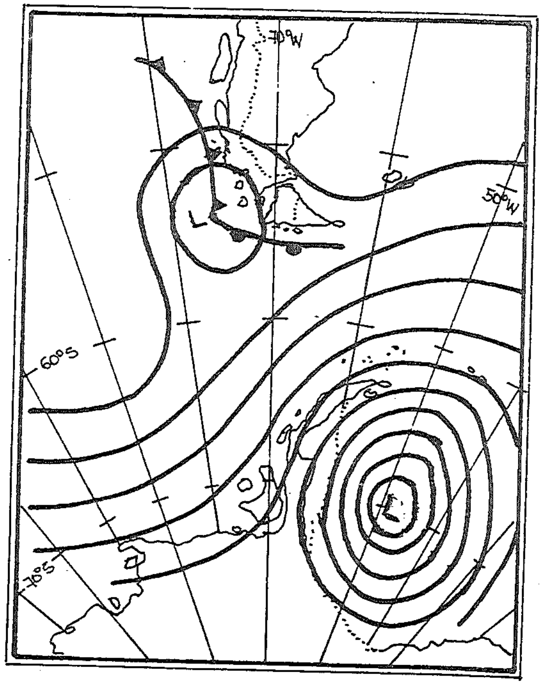


Figure 11b

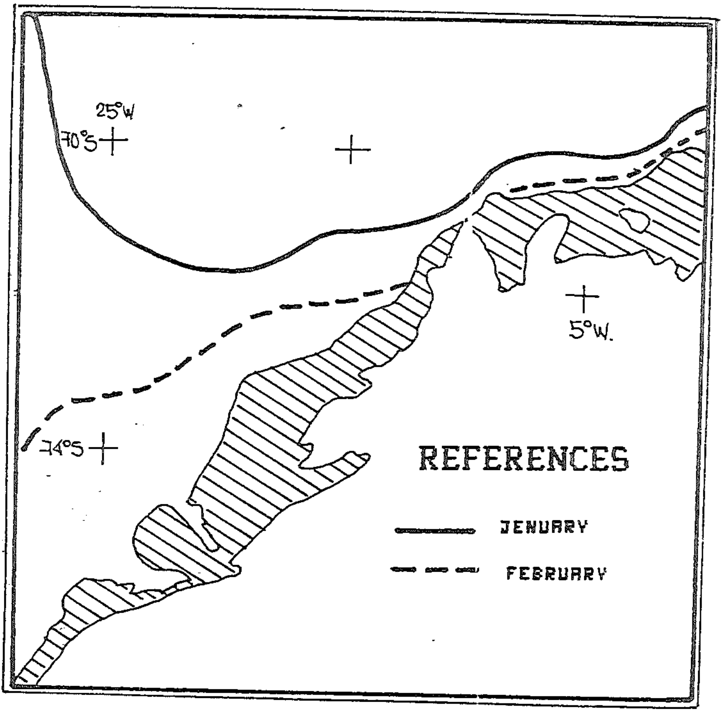


Figure 12

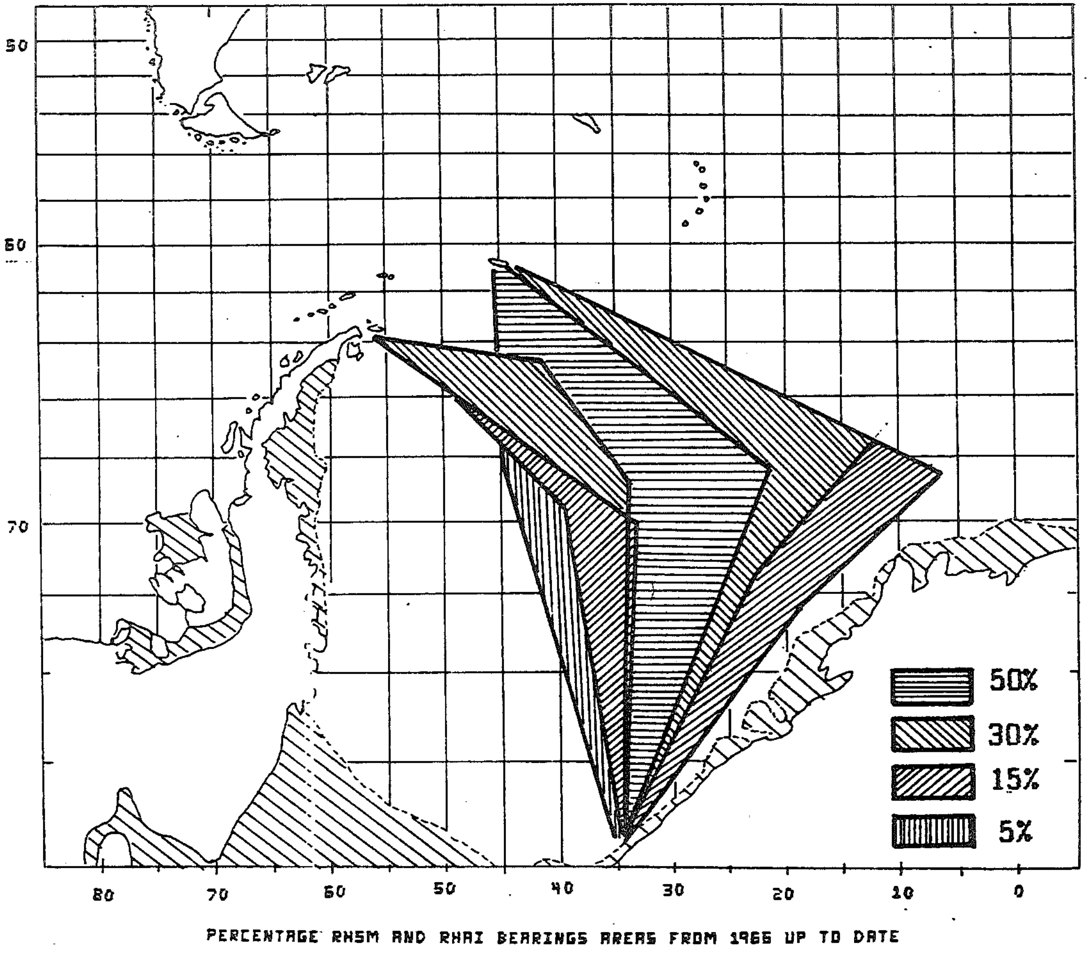


Figure 13

ZONE III
1980-87

	JANUARY	FEBRUARY
TEMPERATURE MEAN	-2.6	-6.6
TEMPERATURE MAXIMUM	7.3	8.0
TEMPERATURE MINIMUM	-13.2	-19.7

WINDS MAXIMUM	JANUARY	160 (SSE)/78
	FEBRUARY	050 (NE) /75

Figure 14

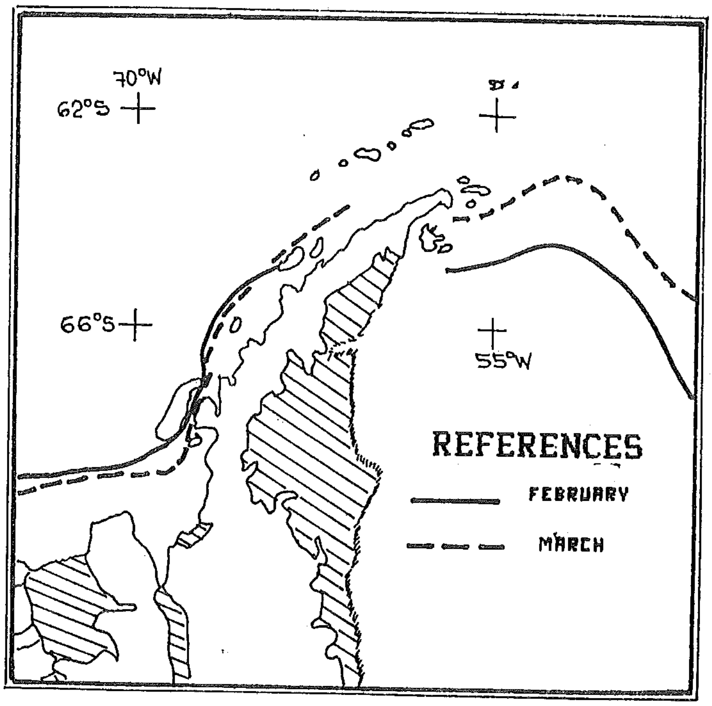
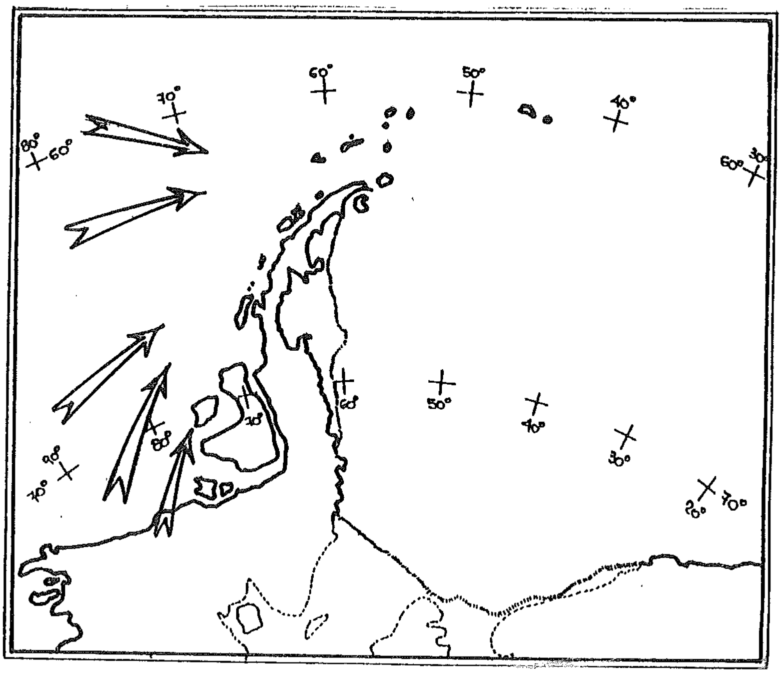


Figure 15



ZONE IV

EXTREME TEMPERATURE
(1976-87)

	MEAN TEMPERATURE	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE
FEBRUARY	0.0	11.4	-17.0
MARCH	-2.1	7.7	-17.6

Figure 16

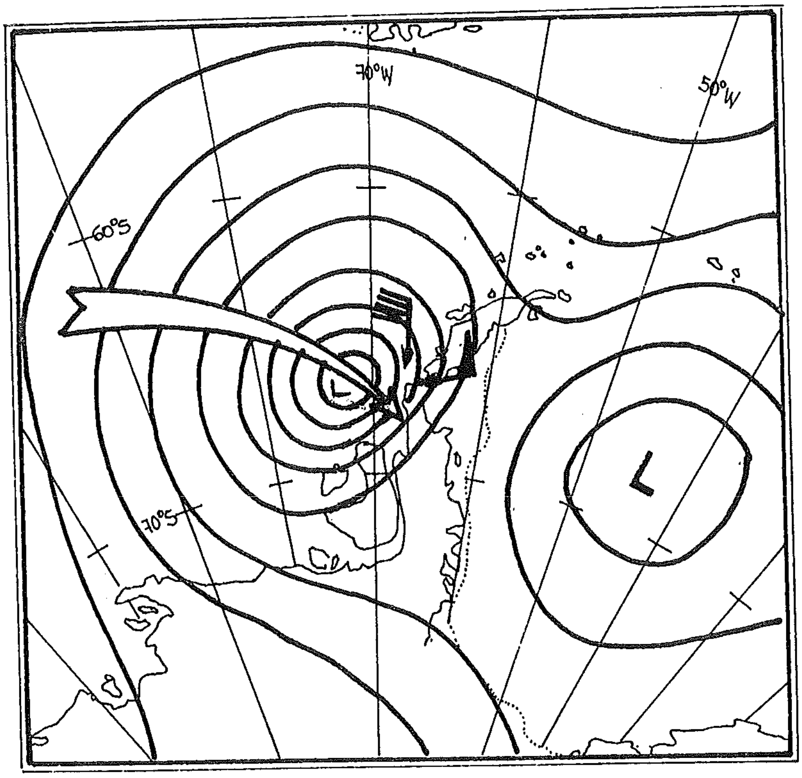


Figure 17

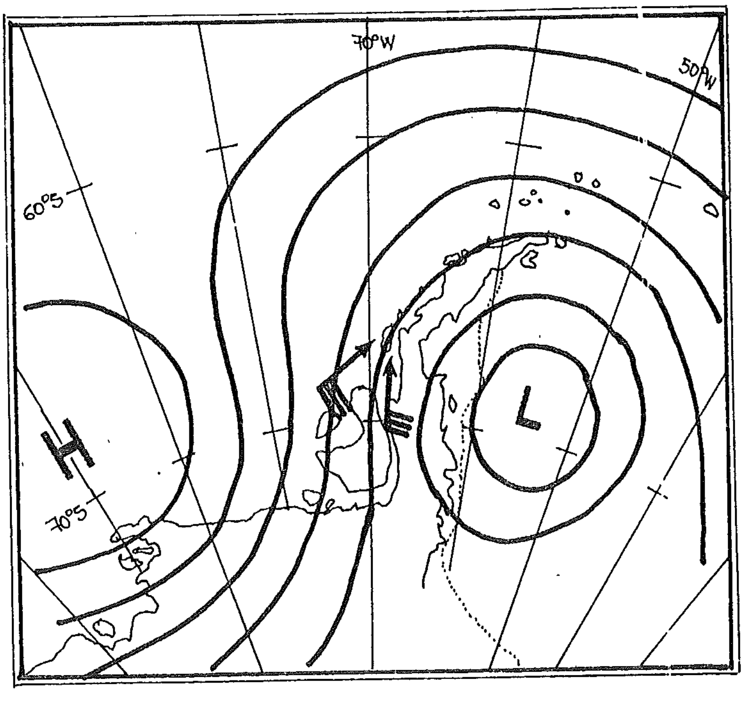
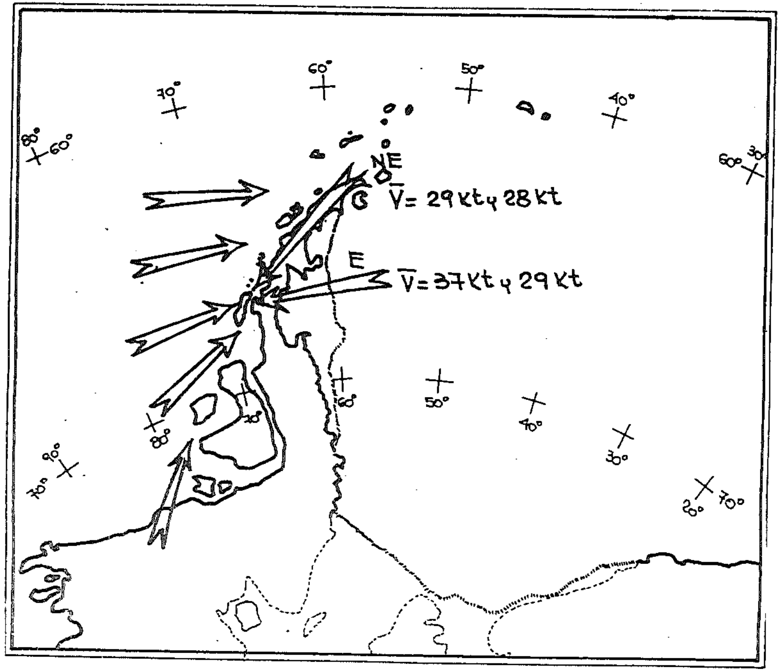


Figure 18



ZONE IV

PERIOD 1976 - 87

	WINDS MEAND (KT)	WINDS MAXIMUM (KT)
JANUARY	E.-37.5 NE.29.8	090/135
FEBRUARY	E.29.3	090/110

Strong easterly and northeasterly persistence and high mean velocity are observed.

Figure 19

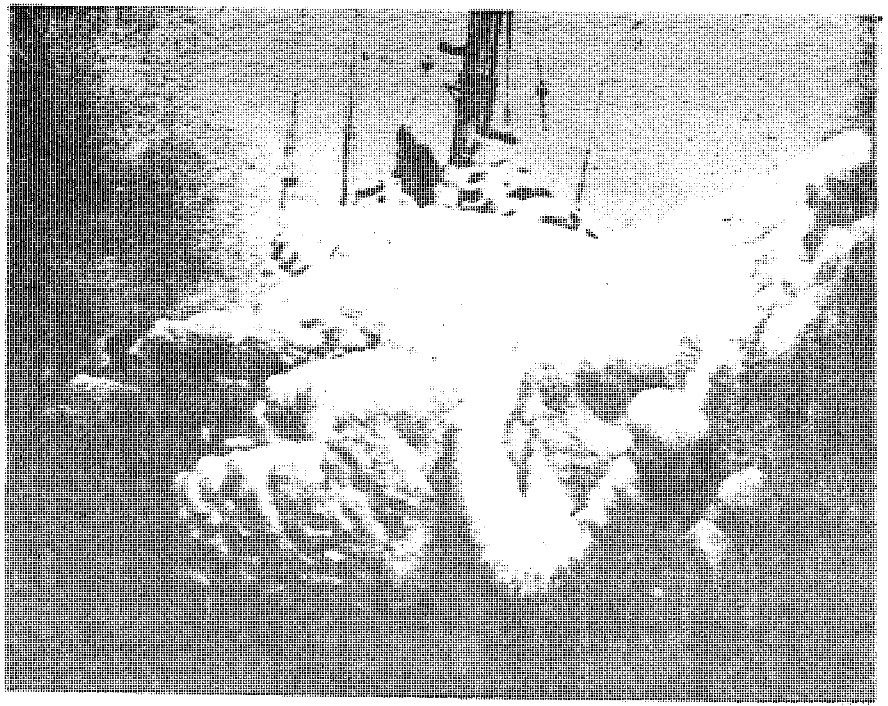
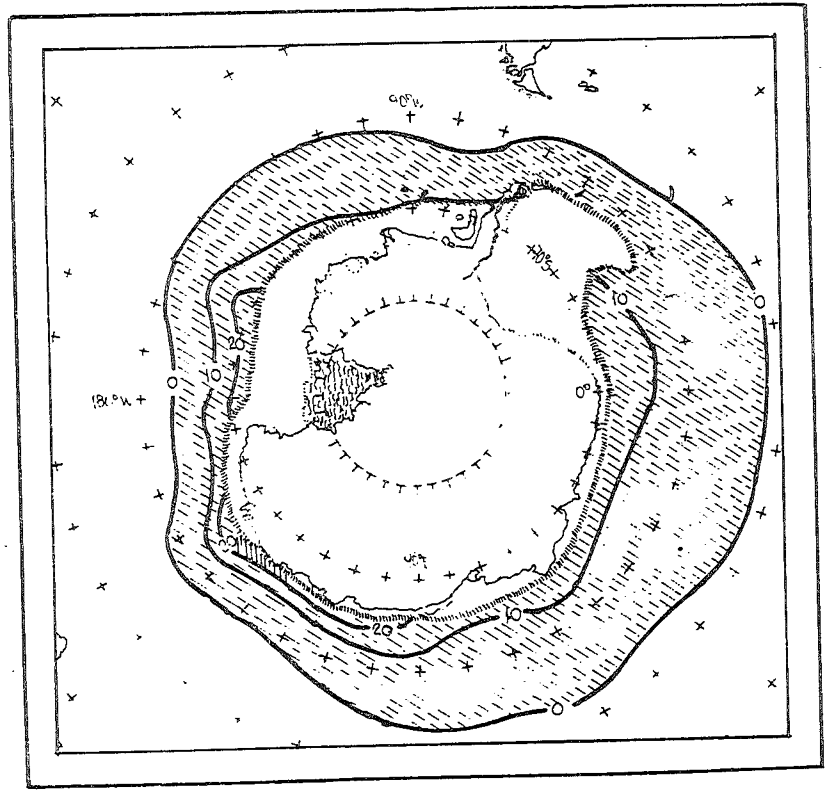
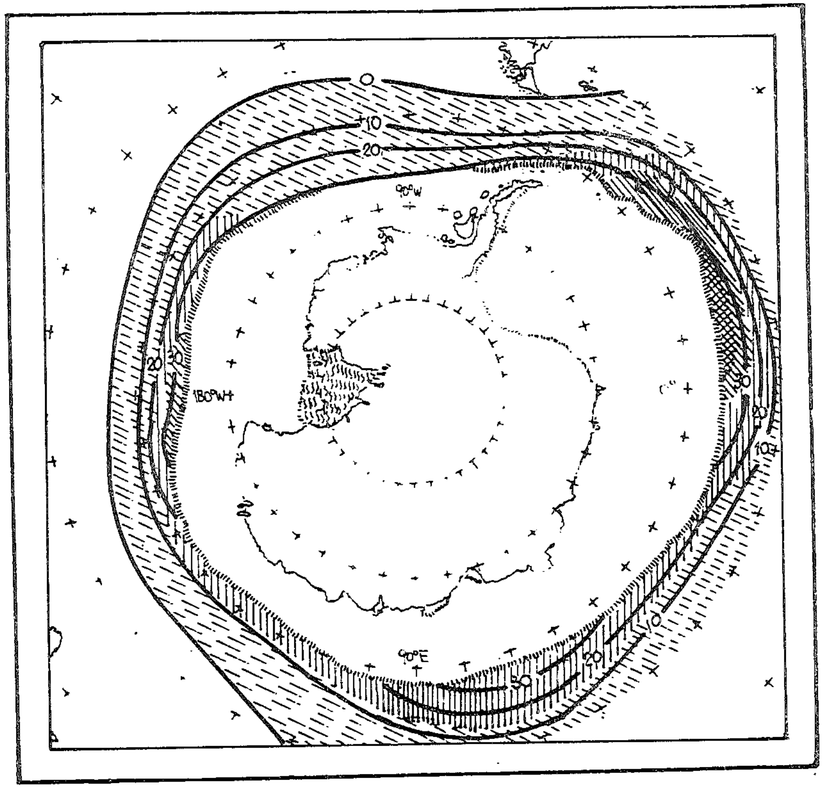


Figure 20.--Ocean Station Vessels maintained position through extremely hazardous weather conditions. Pictured here, the USCGC OWASCO with 10 in. of ice. It was picked up when 65- to 70-kt winds tossed heavy spray aboard while the vessel patrolled the Labrador Sea.

ICE FORMATION PROBABILITY ON THE SUPERSTRUCTURE - FEBRUARY
OCEANOGRAPHIC ATLAS OF POLAR SEAS - PART 1, ANTARCTIC -
U.S. NAVY HIDROGRAPHIC OFFICE - WASHINGTON, D.C. 1957



ICE FORMATION PROBABILITY ON THE SUPERSTRUCTURE - AUGUST
OCEANOGRAPHIC ATLAS OF POLAR SEAS - PART 1, ANTARCTIC -
U.S. NAVY HIDROGRAPHIC OFFICE - WASHINGTON, D.C. 1957



REFERENCE

——10—— Freezing frecuency probable percentage on the ship superestructure, based on the simultaneous occurrence of wind ≥ 17 Kts. and air temperature ≤ -2.0° C.

////////////////////// Ice monthly mean limit.

▧	0 - 5%
▥	5 - 10%
▨	10 - 15%
▩	15 - 20%

Strong to severe freezing frecuency probable percentage on the ship superestructure, based on the probable, simultaneous occurrence, of wind ≥ 34 Kts. and air temperature ≤ 2°C.

Figure 21

Performance of the Nathaniel B. Palmer in Ice

by
A. L. Sutherland
Division of Polar Programs, National Science Foundation, USA

On the first voyage of the NATHANIEL B. PALMER into ice she transited well into the South Western Weddell to a position of 67 42.81 South, 51 39.9 West. This brought the ship into some of the thickest and oldest ice in the Weddell. Generally Weddell Sea Ice has a maximum age of 1 1/2 years, although floes of 2 yr ice do occur and were likely encountered. Ship performance throughout this journey was excellent. The ensuing paper, written aboard ship at the conclusion of the maiden voyage details the ships performance during the cruise. Attached is a companion paper which describes the vessel's specifications, procurement, and scientific capabilities. This companion paper was first presented at the Marine Technology Conference, New Orleans, Louisiana, November 10-14, 1991 and is reprinted with permission.

Seakeeping

The open water conditions of the Drake Passage were relatively calm (SS3-4) and hence a true rough water test was not observed. In the seas that were encountered, however, the ship rode very well. Human comfort was excellent with no observed cases of sea sickness. Roll period was gentle, about 12 second period.

Speed

In the straights of Magellan, around the Southeastern tip of South America and through the Drake Passage, the ship consistently held a speed in excess of 14 knots running on 4 engines. Periods of 15 knots were observed.

Ice Performance

The NATHANIEL B. PALMER regularly and consistently demonstrated ability to break through 3ft of ice at 3 knots (specified capability). Moreover, when in the South Western portion of the Weddell the ship typically encountered 4 and 5 ft thick floes, with more than one foot of snow cover, -20C to -30C temperatures, very few (less than 1/10) cracks or leads, and ridges with sail heights of up to five feet. These conditions are extreme. The snow creates significant friction, the cold creates harder ice, no leads create a compressive force on the hull, the general thickness of the ice slows momentum considerably and ridges stop the ship causing back and ram maneuvers. Nevertheless, the NBP was able to steadily progress in these conditions. Worst progress in these conditions was at an average of 2.5kts while steaming for 10 hours. It should be noted that during periods of zero visibility, (total white out or darkness) the ship did not steam ahead. The ship is extremely maneuverable in ice, enabling it to readily follow any leads or young ice and to avoid old floes and pressure ridges. Propellers did not clog under any conditions encountered. When stuck in ice after back and ram or when pinched in a closing lead, the heeling tanks readily freed the vessel. It is thought that the Inerta (low friction) bottom paint helped performance considerably.

The excellent acceleration of the ship adds greatly to the turn around time in back and ram maneuvers. The stern design, the protection of the propellers, and the automatic midships locking of the rudders provided great assurance when backing into thick broken ice was necessary. The ultimate test of the NBP occurred in the northwestern Weddell, with a record 12 ft. (4 meters) of ice broken through in a small multiyear floe, and 10 ft+ ice conditions successfully mastered by backing and ramming on several occasions, in cold, snow covered ice, with little room to maneuver the vessel.

Science in the Ice

The baltic room, with it's ability to prepare, deploy and retrieve equipment in warm conditions has been shown to be excellent in temperatures of -28C, using a 24 bottle CTD/Rosette. The working deck heaters have shown their ability to keep the deck free of ice, and thus safe, in -30C temperatures.

General

Lab layout, computer system, underway measurement equipment, working deck arrangement, winches, baltic room, habitability and general outfitting of the ship make it an ideal science platform.

Ice operations

Peripheral to the design of the ship, but important to it's overall performance is the ability to seek leads and young ice and to avoid troublesome areas in periods of poor or no visibility.
The ship was operated most prudently with the imperative rules in mind:
-You don't tell the ice what to do, IT will tell you what to do, and
-Do not proceed if you cannot see the ice conditions ahead of you.
Thus the ship's daily operating hours were severely curtailed with shutting down in darkness with rapidly decreasing daylight hours further aggravating this aspect, as well as stopping in fog, heavy snow, and white out conditions. It became apparent, that in general U.S. capability of Antarctic Ice navigation has been limited to summer, 24 hour daylight operations, and that the NBP was pioneering winter operations in heavy ice conditions with all associated restrictions to be reckoned with. There are a number of things that can be done on the ship, for example stronger search lights, ice radar, or the use of scouting helos. But the full capabilities of the U.S. Government will have to be brought to bear, i.e. the development of Antarctic ice forecasting capability with high speed, high data rate transmission to the NBP based on the most advanced earth orbiting satellite sensing, as well as the use of all available other technology such as night vision devices so that the ice navigation support is commensurate with the modern ship technology and the state of the art science suit of this outstanding ship.

Science Features of the New U.S. Antarctic Research Vessel with Icebreaking Capability: NATHANIEL B. PALMER

by
H. Kennedy, Antarctic Support Associates, Englewood, CO, USA
A. Sutherland, National Science Foundation, Washington, DC, USA
R. Voelker, Science and Technology Corporation, Columbia, MD, USA
J. St. John, Science and Technology Corporation, Columbia, MD, USA

ABSTRACT

This paper describes the new U. S. Antarctic research vessel NATHANIEL B. PALMER that was designed and built to provide the nation with a year-round capability in the south polar region. The vessel's annual operating profile, performance requirements, the acquisition process, and the scientific suite are described. The procedure for scientists and engineers to perform research aboard the vessel are provided in the concluding remarks.

INTRODUCTION

In 1986, the National Academy of Sciences' Polar Research Board reviewed the science requirements in the Antarctic [1]. This report stated that the current ship resources, Coast Guard icebreakers and the R/V POLAR DUKE, were inadequate to support future science programs. Concurrently, the University National Oceanographic Laboratory System (UNOLS), which represented U.S. operators and users of academic research vessels, identified the requirements for the vessel [2]. In 1987, the National Science Board reviewed the current and projected science requirements in the Antarctic. It recommended that "a research vessel with icebreaking capability be acquired for the U.S. Antarctic Program" [3].

Subsequently, these three groups had direct roles in the acquisition of the vessel. The Polar Research Board and UNOLS reviewed the technical requirements while the National Science Board, as the governing body of the National Science Foundation, approved the planned acquisition effort. Some of the primary technical requirements are described in the following section. A more extensive description can be found in Reference [4].

TECHNICAL REQUIREMENTS

Operating Profile

As the principal geographic area for the conduct of research is Antarctica, the vessel will be based in one or more ports located in the southern latitudes. This will minimize the time and cost to transit to the primary research areas although infrequent voyages to the United States can be expected. The ship will operate from such ports as Punta Arenas, Chile, or Ushuaia, Argentina, for operations in the Antarctic Peninsula and the Weddell Sea. Occasionally, the vessel will operate out of such ports as Hobart, Australia, or Port Lyttleton, New Zealand, for trips to the Ross Sea. A representative annual operating profile of the vessel is provided in Table 1.

Environmental Conditions

Science operations will be conducted in one of the most severe environments on the planet. The vessel is designed for winter operations in ice at -50°F (-46°C), although more representative air temperatures will be in the -10 to -20°F (-23 to -29°C) range. Even at milder temperatures however, the wind-chill temperatures of -50°F (-46°C) and lower can be expected to continue for days. Because very high winds occur in Antarctica, the vessel is designed for a maximum sustained wind speed of 100 knots.

Table 1
Annual Operating Profile

Activity	Days	Speed (knots)
Ice Docked	37	0
Station Keeping	56	0
Dredging & Trawling	23	9
Towing Side Scan	27	6
Icebreaking	12	3
Operating in Pack Ice	24	2-8
Open Water Transit	86	8-15
Total Ops Away from Port	265	
In Port Staging for Science	35	
Repair and Maintenance	65	
	365	

Performance Requirements

The vessel has the capability of operating through first year level sea ice having a thickness of 3 feet at a 3 knot speed of advance. In addition, the ship can transit pressure ridges of at least 6 ft sail height (corresponding to a keel depth of 20 feet) in the ramming mode of operation. Transit by ramming will also be expected to occur in 6 ft thick level ice so that the vessel can get to the desired science station. During these transits in ice, the vessel is expected to encounter impacts with multi-year ice or glacial ice fragments. In open water, the vessel is able to maintain a speed of 15 knots in sea state 4 (6 ft significant wave height). While operating in sea state 6 (16 ft significant wave height) the significant pitch will be less than 5 degrees, the roll less than 8 degrees, and the deck wetness limited to 5 occurrences per hour. Station keeping requirements are based on maintaining position within a 300 ft diameter circle or 3% of the water depth, whichever is greater, in seas up to 12 ft significant wave height, with mean winds of 30 knots and 2 knots steady current. The wind and waves are colinear and the current direction is at 45 degrees to them. Ship heading can be selected to give the best station keeping ability.

ACQUISITION PROCESS

The procurement followed a process almost as unique as the vessel herself. Since the vessel is to be operated by the U.S. Antarctic Program (USAP), her procurement and manning follows a pattern which is consistent with the way of doing USAP business. The National Science Foundation is the lead government agency that directs all USAP activities. The NSF, Division of Polar Programs, has a prime contract with Antarctic Support Associates (ASA). It is the responsibility of ASA, a joint venture between EG&G and Holmes and Narver, to oversee the acquisition of major Antarctic science support facilities such as ships.

The specification for the ship was based primarily on the requirements for new, high endurance, large, oceanographic vessels as defined by UNOLS. The commercial RFP, with a 23 page section of technical requirements, was developed. The RFP allowed for the conversion of an existing vessel or the design and construction of a new vessel. The specifications were not easily met by any existing vessel.

ASA's predecessor, ITT-ANS, conducted a thorough competitive procurement. The winning proposal was for the construction and operation of a new ship by Edison Chouest Offshore (ECO). The charter for $83.3 million includes the leasing cost of the vessel for ten years as well as food and accommodations for 37 scientists. Total operating costs, including the charter, fuel, port charges and other expenses have been estimated at $11 million per year, or $110 million for the ten year duration of the contract. ECO owns and operates a 36 vessel fleet of offshore and specialty ships. ECO is not only the owner of the new vessel, NATHANIEL B. PALMER, but is also the owner of the shipyard that is building the ship. This relationship has significant advantages to the government.

NSF, Division of Polar Programs, considered the options of leasing a ship versus buying one. A long term lease (charter) became the chosen option for a variety of reasons. A major factor in the consideration was cost. The cost to the government, as determined by a complex procedure known as OMB A-104 analysis, showed an advantage to leasing. Specifically, over a ten year lease period, the present value for leasing was $10 million less than direct procurement. This procedure is not exact and has a number of estimates for such items as escalation, discount rate, operating costs, and ship value at the end of the lease. However, cost was not the only factor in the decision to lease. A number of other items weighed heavily in the decision:

1. Risk - With a lease, the owner is fully and financially responsible for building the vessel. Lease payments commence only upon delivery of the vessel and acceptance by the charterer and the government. The owner is fully responsible for the shipyard construction of the ship. In the present climate of regular shipyard overruns, no financial liability during the construction period is very attractive to the government.

2. Budget - Federal agencies rarely see significant changes in their budgets from year to year. With recent tight federal budgets, just keeping up with inflation is difficult. A large agency, such as the Navy, has, as a part of its regular budget, funding for major capital expenditures such as the "up front" funding necessary to buy ships. A small agency, such as the NSF, has significant difficulty in justifying a major increase in their budget due to large capital expenditures occurring in a one or two year period. Leasing is a reasonable way of spreading the cost of a major facility over a number of years without affecting the other components of the agency's budget.

3. Fleet Management - The vessel owner is responsible for hiring the maritime crew. This provides a particular advantage if the owner, like ECO, manages a fleet. ECO has the ability to staff the ship with people from their fleet. These are people they know and who have demonstrated their capabilities. Fleet managers, compared to a single vessel operator, also can take advantage of lower costs by virtue of the size of the organization. Lower costs can be realized in such areas as insurance and maintenance. Large fleet managers posess the specialized skills required to address logistics and vessel repair in remote regions.

4. Construction - The fact that ECO owns both the ship and the shipyard has proven to be a particularly fruitful relationship for the government. Owners with long term leases and shipyards with fixed price construction contracts often have very different philosophies of ship construction based on their means of making a profit. For example, a shipyard would want to provide the cheapest painting program that met the specification; whereas the owner would want the paint program to be the best possible because it would be cheaper in the long run. These differing views often lead to disputes and very expensive change orders or other compromises in the quality

of construction. With ECO, the shipyard is not a profit center. The philosophy is to use the best material and equipment and the most efficient design. If a change in design or specification will increase long term efficiency it is incorporated immediately. This philosophy has carried over to requested design changes by the vessel owner for improved laboratory design and operations. These changes, which have been minimal, have been incorporated with little change to the fixed price lease and only reflect direct cost of labor and material.

During the final design, construction and outfitting of the vessel, an Oversight Committee, composed of members from the UNOLS community, the Navy and MarAd, provided advice and guidance.

DESCRIPTION OF THE VESSEL

Following the award of the contract, a final design of the vessel was initiated and completed in about four months. Figure 1 shows the starboard outboard profile of the vessel. The principal characteristics are given in Table 2.

Table 2
Principal Characteristics

Length Overall	308.50 feet
Length at Waterline	279.75 feet
Beam at Design Waterline	60.00 feet
Draft at Design Waterline	22.50 feet
Depth	30.00 feet
Displacement	6,800 LT
Shaft Horsepower	12,720 SHP
No. of Propellers	2 in nozzles
No. of Rudders	2, high lift type
Bow Thruster	1,500 HP
Stern Thruster	800 HP

Hull Structure

The vessel is built and classed to the American Bureau of Shipping Ice Class A2. This classification is intended for vessels capable of unescorted operations in

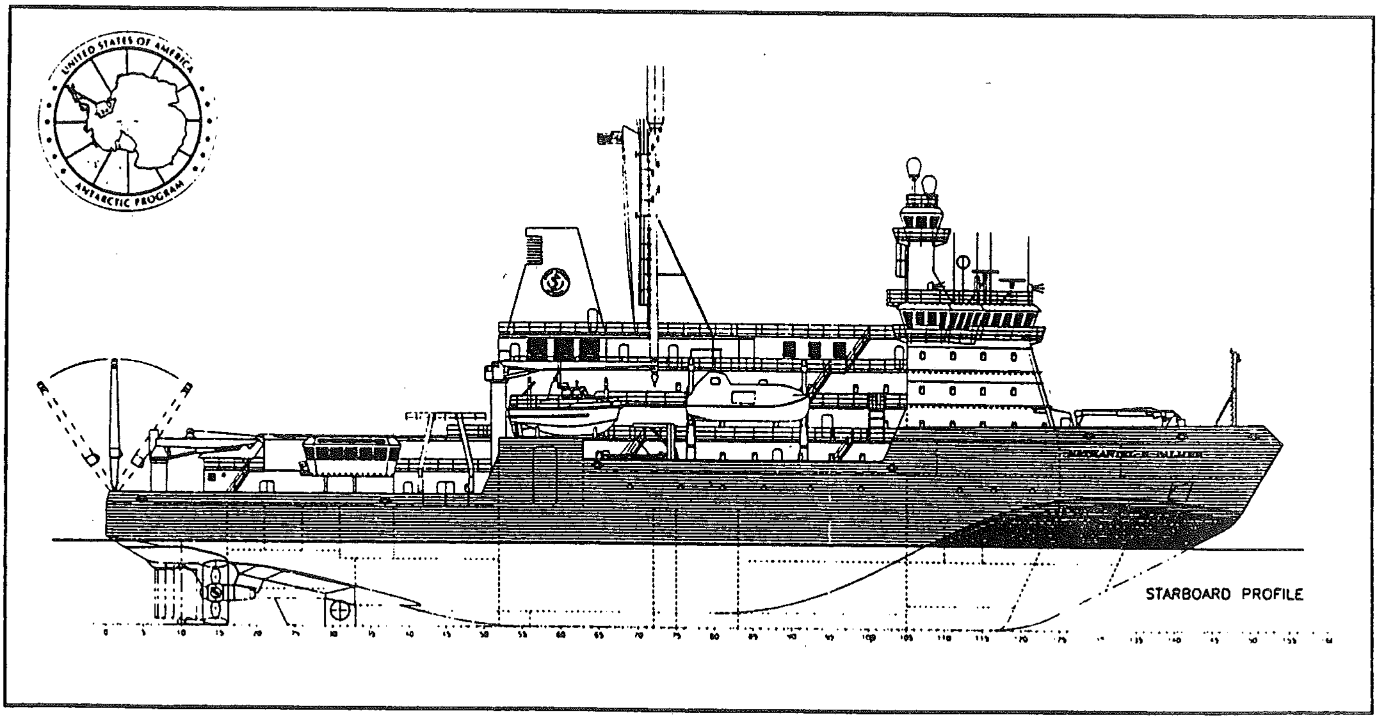


Figure 1 - Outboard Profile of the NATHANIEL B. PALMER

any first year ice conditions in Antarctica as well as operations in multiyear ice in the austral summer. The hull incorporates a transverse framing system with a 24 inch frame spacing throughout, and cant framing in the bow. The entire hull is made of RAEX POLAR 36E and 36F type steel that has enhanced low temperature properties to prevent brittle fracture. Typical bow plating is 1.6 inches thick, and the midships and stern areas, to below the turn of the bilge, are 1.3 inches thick.

Propulsion Machinery

The propulsion plant consists of a twin screw, diesel mechanical drive system. Each shaft line consists of two diesels connected to a gear box and a controllable pitch propeller mounted in a nozzle. This system was chosen as it would reduce the ice loads on the propulsion system and give higher thrust during slow speed icebreaking. The use of multiple diesels also provides the desired part-load that is necessary to meet the operating profile of the vessel. Additional details on the hull and propulsion machinery can be found in Reference [5].

DESCRIPTION OF SCIENTIFIC SUITE

The vessel has been designed and is being equipped to support the many different research disciplines which the NSF, Division of Polar Programs, and other agencies fund in the Antarctic. Accommodations for the 37 scientists consist of 17 two person staterooms with adjoining toilet and sanitary spaces and three single staterooms with private shower and toilet facilities. The vessel is also outfitted with the UNOLS standards for onboard science support equipment.

Laboratories

There are over 6000 square feet of laboratory space in the ship. Table 3 provides the square footage for each of the laboratories. All lab spaces have a heating, ventilation, and air conditioning (HVAC) climate control system that is separate from all other spaces in the ship. All laboratories are also fitted with compressed air, clean power, data loop/computer net, and where applicable, fresh water and uncontaminated sea water services.

Table 3
Scientific Laboratory Areas

Main Deck Laboratories	Area (sq ft)
Main Work Room	2,340
Hydro Lab	480
Wet Lab	420
Bio-Chemical Lab	390
Electronics/Computer Lab	950
Climate Control Chambers	80 and 110
Science Freezer	180
Staging Area	660
Aquarium Room	290
Science Work Shop	130
Scientific Storage	360
Electronic Equipment Room	100
Mud Room	110
Exterior Main Deck Working Area	4,100
Gravimeter Room	40
Other Science Spaces	
Electronics Center	550
Darkroom	180
Helicopter Hanger	1300
Flight Deck	2500
Scientific Storage (Lower Dk)	4 containers
Conference Room and Library	700
Lounge	510
Gymnasium	400
Hobby Room	110

Figure 2 shows the arrangement of the main deck laboratories and the aft deck. The area forward of the laboratories, not shown, is the mess deck and galley. A single mess is provided for the scientists and crew with cafeteria style service. Of the laboratory spaces on the main deck, the starboard main work room is the largest

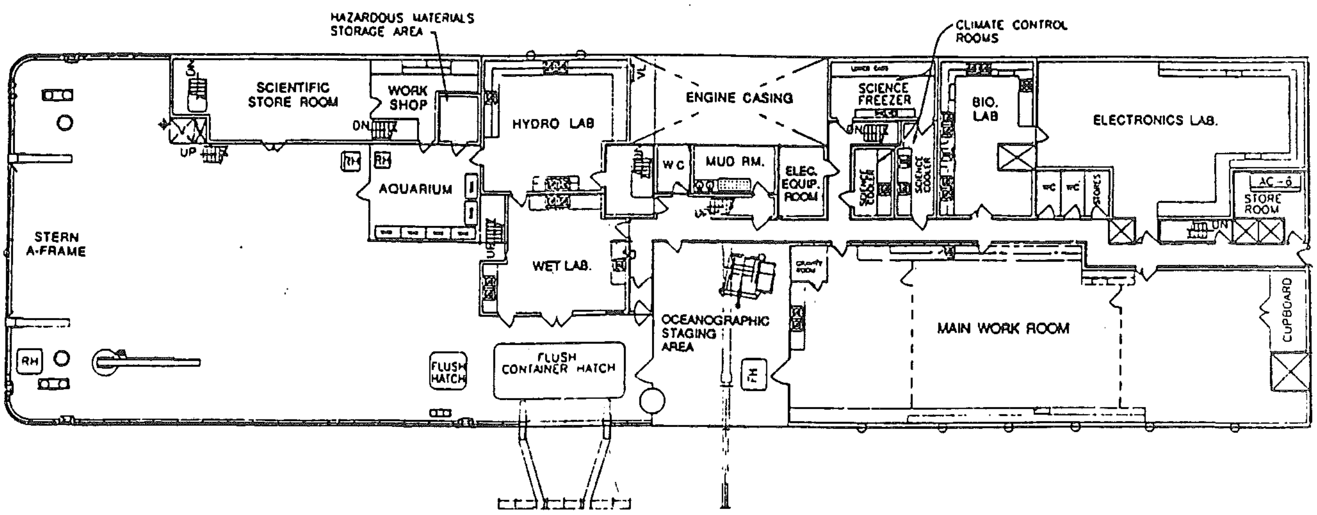


Figure 2 - Laboratory Layout on the Main Deck

with 2,340 sq ft. This space has been designed so that it can be subdivided into three laboratories by removable partitions. This will allow flexibility in configuring the space for different science requirements.

Working Decks

The ship has 4,100 square feet of work area aft and along the starboard side on the main deck. This deck, as well as other decks, is fitted at select locations with UNOLS standard dimension tie down points for mobile equipment. Portions of the deck are heated to allow work during severe icing conditions.

There will also be a clear area on the fore deck to accommodate the set up of instrumentation on booms forward such as uncontaminated air sampling devices.

Over-the-Side Handling Equipment

There are two, 20 ton A-frames, one on the starboard side and one at the stern. There is also a telescoping boom, with a 6 ton capacity, on the starboard side in the oceanographic staging area. This boom has a 13 ft outreach from the side of the vessel. All the over-the-side handling equipment is supported with three scientific winches manufactured by Markey Machinery. One DESH type 5 winch is housed on the main deck in the oceanographic staging area. It is fitted with slip rings and can carry either 10,000 meters of 0.225 inch mechanical cable or 10,000 meters of 0.322 inch electromechanical cable.

The other winches are located on the 01 deck, just aft of the oceanographic staging area. The first, a DESH 5-5WF, is a double drum winch in a waterfall arrangement that holds both 0.322 inch electromechanical cable and 5/16 inch wire rope. A second winch, a DESH 9-11, is substantially larger and is a side by side double drum arrangement. It provides 10,000 meters each of 9/16 inch trawl/core wire and 0.680 inch electromechanical cable.

Cranes

Three cranes are provided on the vessel. The forward crane has a capacity of 5000 pounds, the aft crane has a 20,000 pound capacity, and an aft articulated crane has a 5000 pound capacity. All cranes are rated based on a 30 ft outreach.

Boats

A number of different boats have been provided aboard the vessel. The largest is a work (survey) boat that is 28.8 ft in length and is propelled by 230 horsepower. It will have an 800 pound capacity A-frame and winch. Other boats include two semi-rigid inflatables, and a 19.7 ft rescue boat in davits. Lifesaving equipment consists of two, 76 person covered lifeboats, and six, 20 man inflatables. The research vessel, as well as the lifesaving equipment, is sized to accommodate 35 additional people should the vessel need to evacuate people from a ship or remote base.

Acoustical Systems

The vessel carries several acoustical systems. These include equipment in the frequency ranges as follows: seismic recording at 4 to 500 Hz; echo sounding and acoustic navigation at 3 to 50 kHz; and Doppler current profiling at 75 kHz. The echo sounding systems operate at 3.5 and 12 kHz discrete signal frequencies, and are capable of recording precision bottom and sub-bottom topography at water depths to at least 8,000 meters. The vessel is also provided with a commercial two-axis Doppler speed log capable of current profiling at up to 400 meter water depth. Space and weight have also been reserved for a multibeam mapping system to be installed at the most forward area of the keel.

Other Science Related Features

Uncontaminated sea water intakes are provided both forward and aft, with the service being available in most of the laboratory spaces. The vessel has the intentionally designed to discharge all fluids on the port side. This was done to minimize the potential for contaminating marine samples that are being collected on the starboard side. Provisions have also been made to carry two helicopters. Although helicopters are not routinely carried aboard the vessel, a hangar, shops and flight deck are available when science projects require this equipment. When not required, the hangar will serve as additional laboratory space. A heated aloft observation station, located 80 ft above the water surface, has also been provided.

CONCLUDING REMARKS

As this paper is being presented, the NATHANIEL B. PALMER approaches the 95% completion stage in its construction. Two months later, January 1992, sea trials are scheduled to be performed in the Gulf of Mexico. This will be followed by a transit to Punta Arenas, Chile, where the vessel charter officially begins upon acceptance by ASA for the NSF.

Scientists who wish to submit proposals for research aboard the NATHANIEL B. PALMER should request the booklet "Antarctic Research, Program Announcement and Proposal Preparation Guide (NSF 91-41)" from the National Science Foundation, Publications (room 620), Washington, D.C. 20550.

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Antarctic Drifting Sea Ice Atlas for Areas Restricted from 0° to 90° West Longitude

by
E. E. Faccini, G. J. Alba
Argentine Navy, Argentina

INTRODUCTION

The Argentine Navy has among other things the responsibility of providing for logistic support for the activities carried out in the Antarctica. The efficiency and the safety necessary for developing marine operations depend mostly on the knowledge of environmental conditions wherein they are to be carried out. In this sense, one of the most important aspects to be taken into account is that one related to drifting sea ice field.

Since the very beginning of the Argentine Antarctic operations the Naval Hydrographic Service has been carrying out tasks and studies on Cartography, Meteorology, and Oceanography in order to provide the mariner with tools to facilitate his work. This "Sea Ice Atlas" intends to be useful to planners and at the same time to be a contribution to the knowledge of this region of the Earth with special characteristics.

OBJECTIVES

To get knowledge as detailed as possible of sea ice field. Therefore, a detailed study on the mean position and standard deviation of sea ice field edge is made. Spatial concentration as well as frequency of occurrence of certain concentrations are also examined.

INFORMATION USED

To carry out this work we have used satellite information produced by the NAVY-NOAA Joint Ice Center, Naval Polar Oceanographic Center, Suitland, US.

Figure # 1; grid used

Below I am going to describe the results obtained.

1.-Spatial distribution of ice edge.

Figure # 2: spatial distribution of ice edge position.

In this projection the frequency of occurrence of ice edge position in every grid rectangle is shown in percentage. C=3 notation indicates that the point from which the concentration is greater than three tenths has been adopted as the beginning of the ice field. This value has been used due to the great variability of edge position, basically because of the wind, when it is defined on the basis of minor concentrations. This wind effect is stronger in summer. Therefore, the charts are fortnightly checked during this season.

When checking all the charts from January to December we find that the latitude wherein the ice edge can be seen for a certain longitude extends to a wider space in summer than in winter. For example, for the area between 26° and 28° of W longitude the edge can be found in January from 57° to 74° of S latitude, while, for the same area in September, the edge can be found from 53° to 61° of S latitude.

Figure # 3: variation of mean position of ice field edge as function of time.

When observing these contours we can see that there are two well-defined ice edge systems as follows:

a) The contours corresponding to West of Antarctic Peninsula are narrower than those located at East.

b) There is transition area between 45° and 60° of W longitude.

c) The contours showing latitudinal variation of the ice field edge East of 50° of W longitude are almost sinusoidal and they are the widest, while those showing the changes at West of the above mentioned longitude are narrower, more irregular, and they show inflection points.

2.-Frequency of ice field occurrence.

During the calculation process of ice field edge mean positions in some areas as for example, the area extending Northwards of the Antarctic Peninsula and Eastward of Weddell Sea, in some periods during summer ice absence was detected. Therefore, the latitude of the grid point which was more to the South was entered as the latitude of the edge. This calculation method produced statistically wrong results. Therefore, they were rejected and no value was entered when ice presence was not proved. At this point we find that the mean positions of the ice field edge correspond solely to cases where in ice has been effectively detected. Therefore and in order to complete the statistical analysis, contours representing the frequency of ice occurrence have been drawn.

Figure # 4: frequency of ice occurrence.

3.-Ice field edges.

These charts show mean maximum and minimum positions, the mean position and the extreme, absolute maximum and minimum positions of the field. The contours of these charts have not been identified since the physics of the question sets an order among them which is not altered in the course of time and they are distributed from North to South as follows: absolute maximum positions, mean maximum position, mean position, mean minimum position, and absolute minimum position.

Besides these contours the gaps occurring within the field itself (channels) are also included in the charts. It is supposed that there is a channel when the concentration is lower than two tenths or an equivalent to this value. The values shown on these contours indicate the percentage of cases in which the channel existence has been proved.

These types of charts were obtained considering the following concentrations as the ice field beginning: higher than zero ($c>0$), higher than three tenths ($c>3$), higher than five tenths ($c>5$), and higher than seven tenths ($c>7$). The criteria was adopted to differentiate the ice field beginning according to different concentrations.

a)Ice field boundary position, considering it starts when the concentration is higher than zero; the latest criteria was adopted because those charts are useful for operation programs of ships not fits for ice navigation.

b)Ice field boundary position, considering it starts when the concentration is higher than three tenths; these charts are useful for operation programs of strengthen hulls ships, but without ice breaking capacity.

c)Ice field boundary position, considering it starts when the concentration is higher than five tenths; the charts indicate areas from where navigation is difficult without ice breakers help.

d)Ice field boundary position, considering it starts when the concentration is higher than seven tenths; this boundary type indicates that the following areas could be considered difficult to navigation.

4.-Standard deviation of the ice field boundaries mean positions and interior channels.

The graphs show the standard deviation values in Nautical Miles, pointing out the correspondent ice fields boundaries mean and that of the internal channels.

Figure # 5.

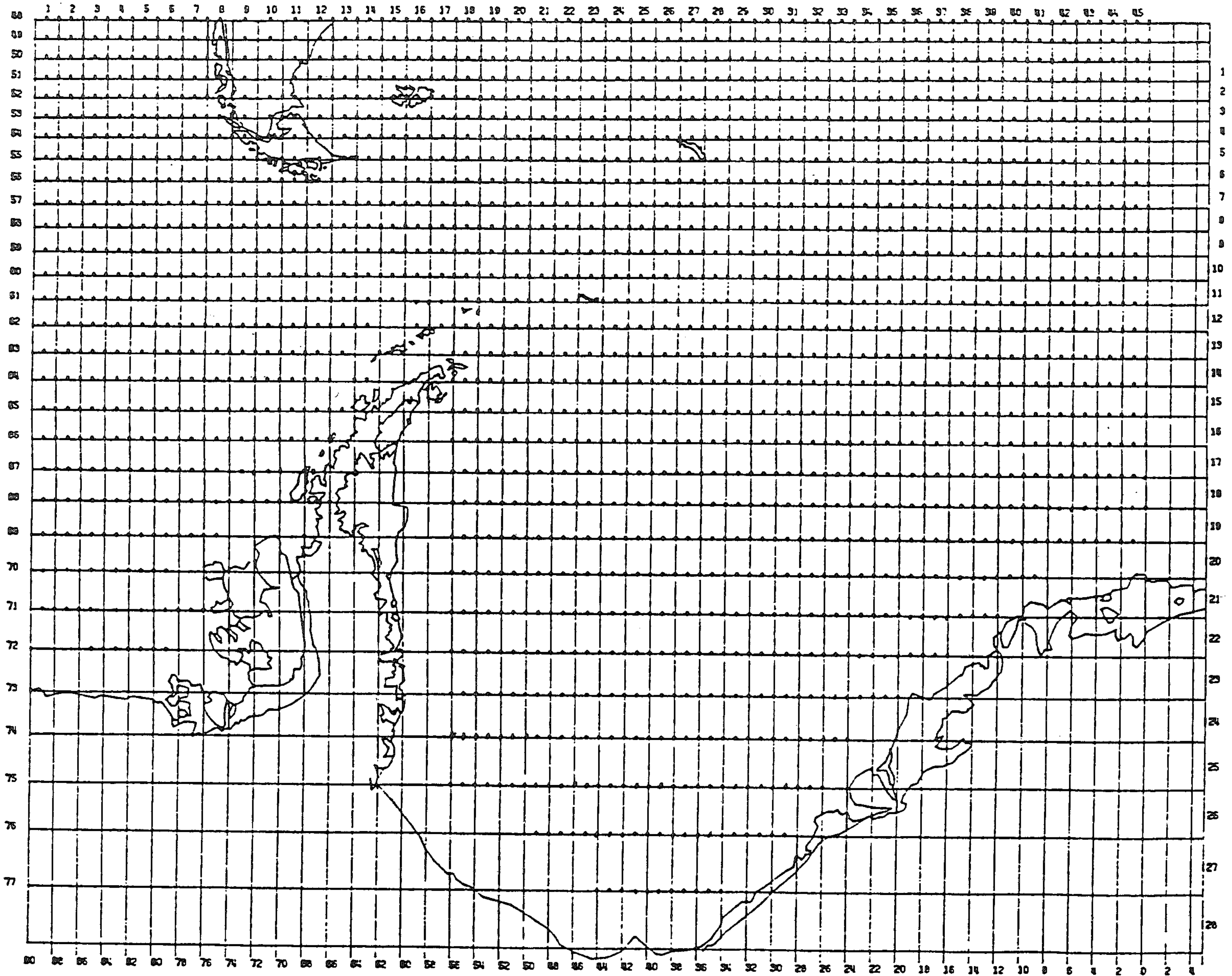
5.-Mean ice concentration.

It is considered the sea ice concentration as a continuous variable in space. This supposition allows to draw equal concentration lines. Values are expressed in tenths.

Figure # 6.

6.-Selective concentration occurrence frequency.

The isolines show the percentage occurrence of free waters of concentrations less than five tenths or equal to that value, less than seven tenths or equal to this value, and higher than seven tenths.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48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
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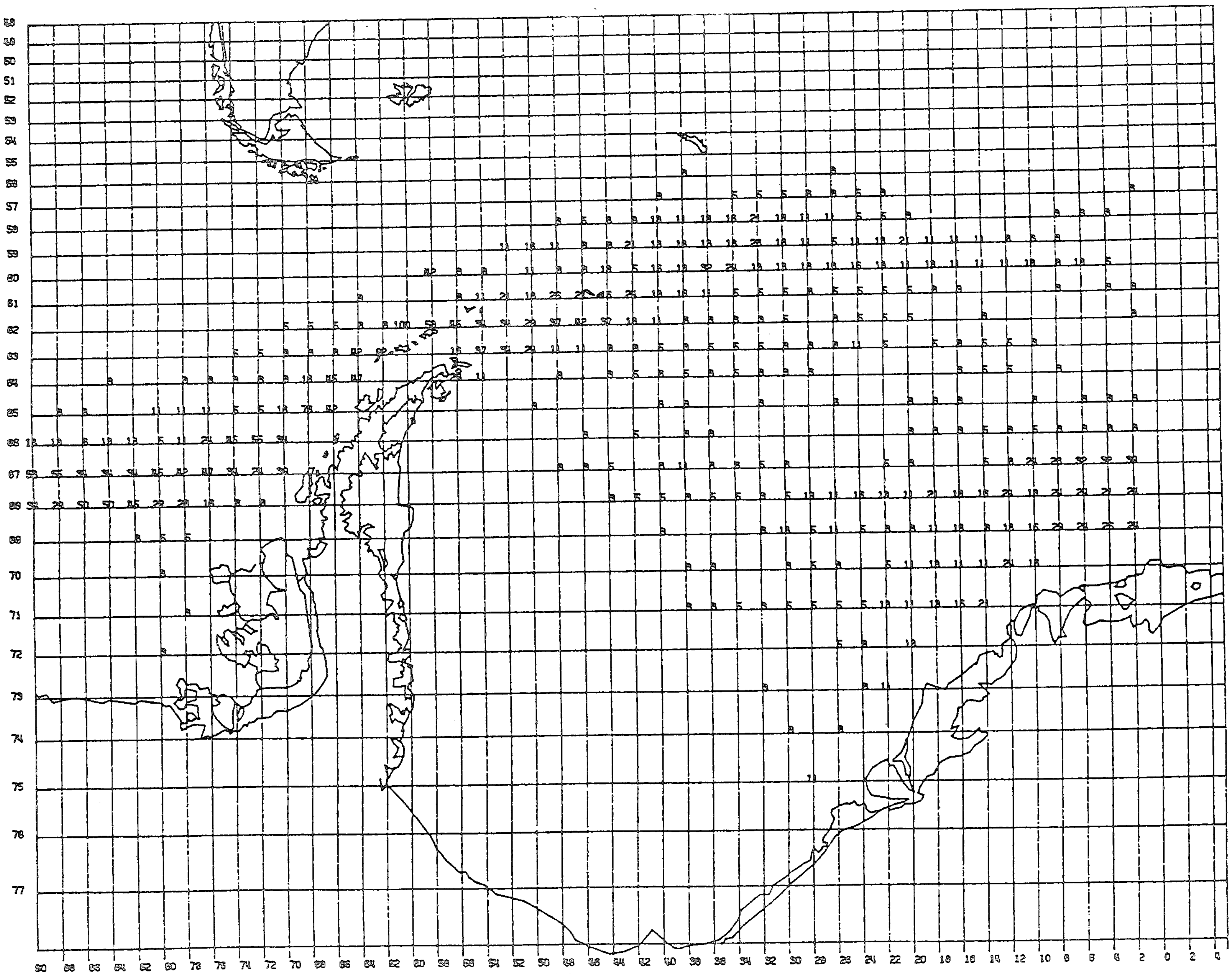
FIGURA 1



DISTRIBUCION ESPACIAL DEL BORDE DE HIELOS

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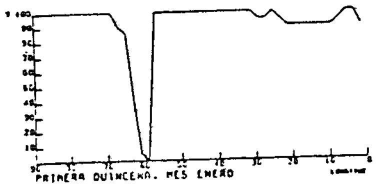

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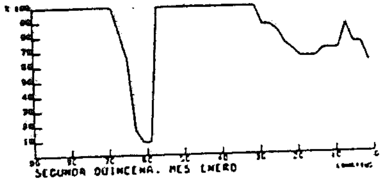
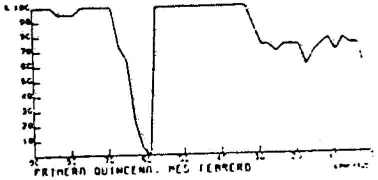


SEGUNDA QUINCENA. MES ENERO



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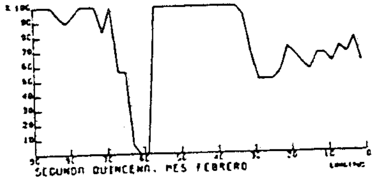

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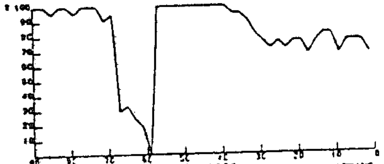
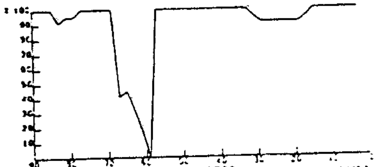


PRIMERA QUINCENA. MES MARZO



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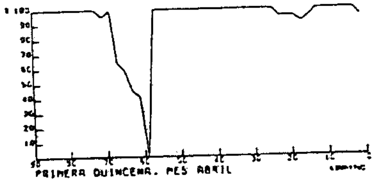

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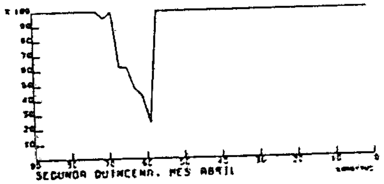

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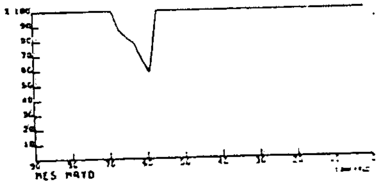

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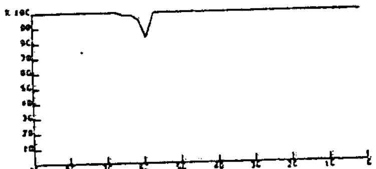
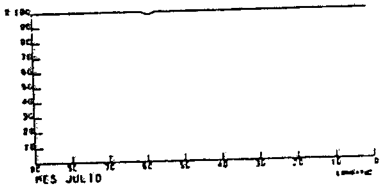


MES JUNIO



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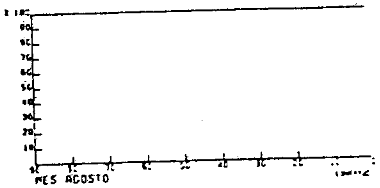
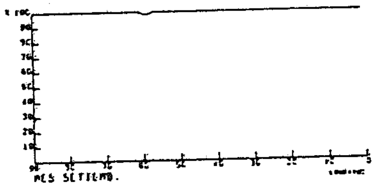
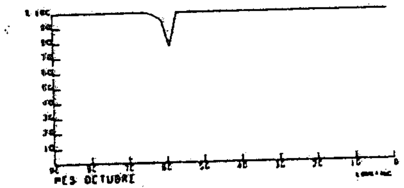


MES AGOSTO



MES SETIEMB.



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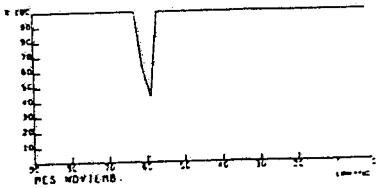

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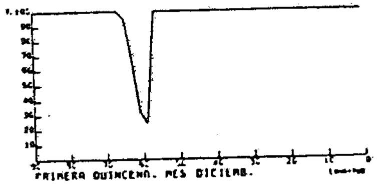

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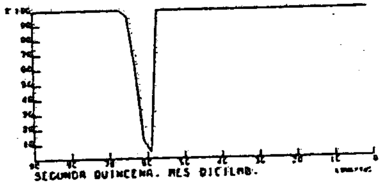

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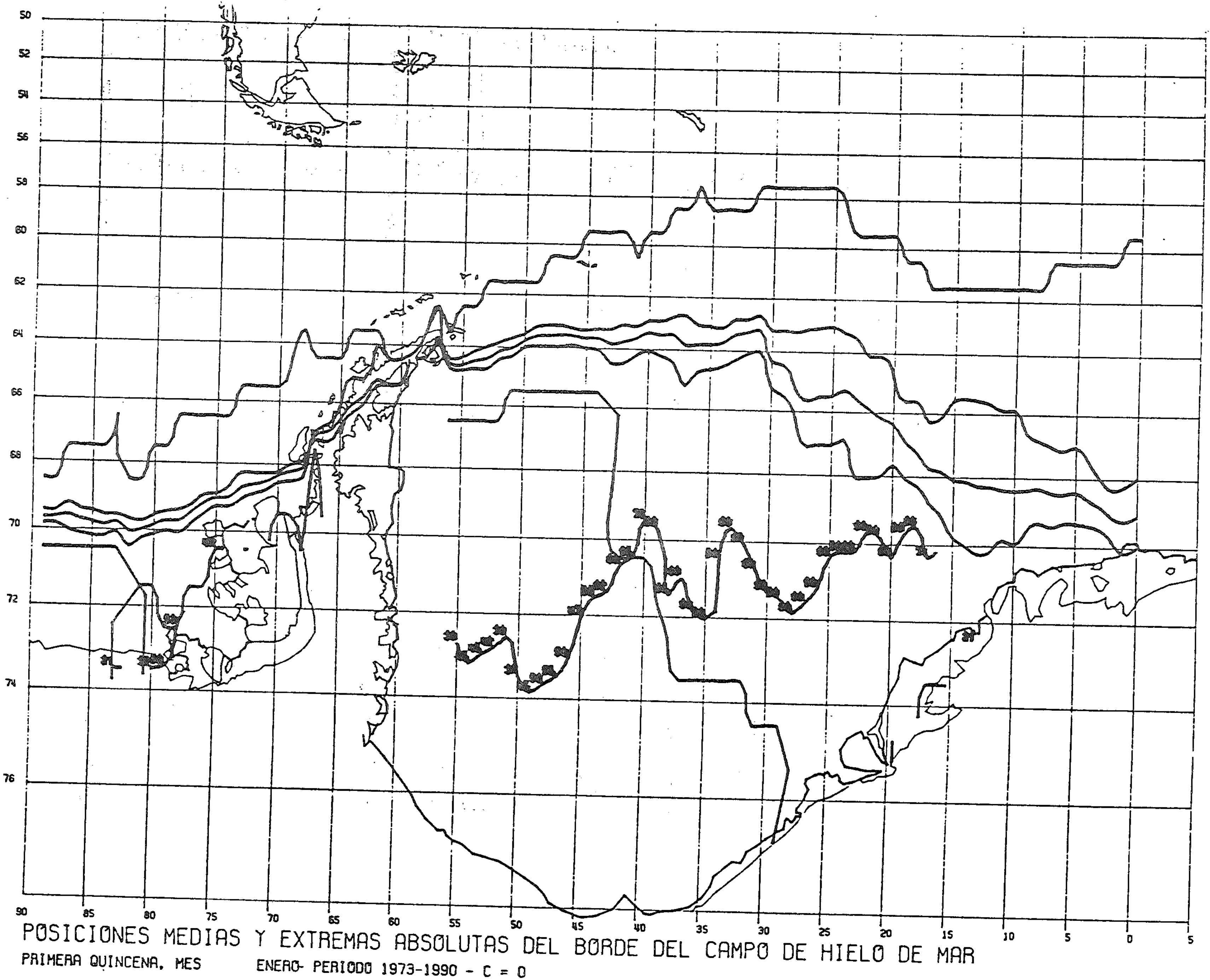

POSICIONES MEDIAS Y EXTREMAS ABSOLUTAS DEL BORDE DEL CAMPO DE HIELO DE MAR

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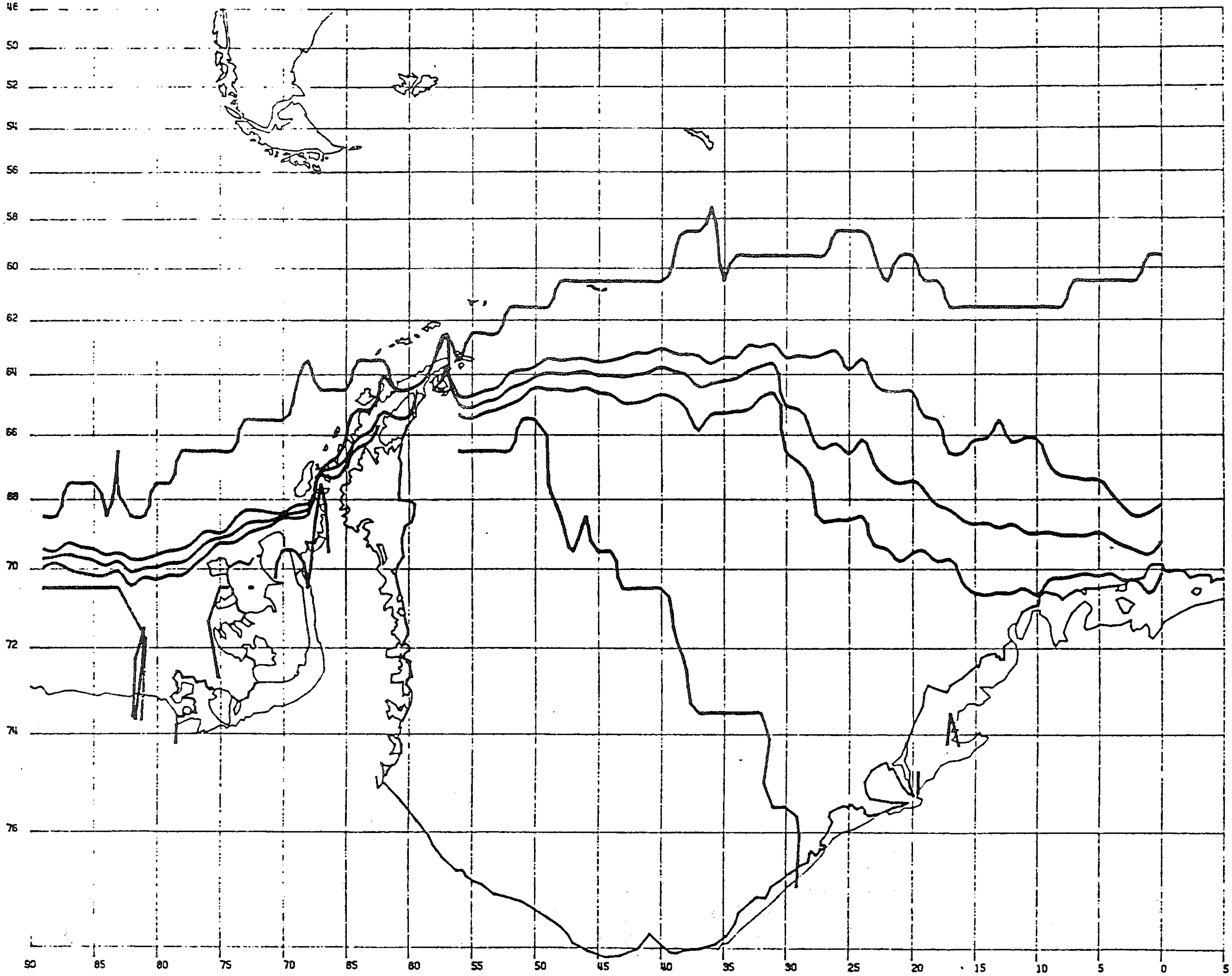


POSICIONES MEDIAS Y EXTREMAS ABSOLUTAS DEL BORDE DEL CAMPO DE HIELO DE MAR

PRIMERA QUINCENA. MES ENERO- PERIODO 1973-1990 - C = 3

A Short Wave Automatic System for Data Transmission Between Rome and the Italian Antarctic Base

by
L. Blasi and M. de Simone
Italian Antarctic Research Programme, Italy

Many telecommunication experts state that we are on the threshold of a new era in the field of short wave communication, because of the introduction of new technologies.
Short wave communication does indeed allow independent point to point connections which have a very low running cost, due mainly to the amortization of the cost of the apparatus and the cost of licences. However, this type of radio connections is heavily influenced by the conditions of ionospheric propagation. This negative influence can reduced by the utilization of techniques of data transmission employing adaptive modems which can automatically and autonomously manage the radio connection.
The ENEA Antarctic Project, having the responsibility of telecommunications within the framework of the Italian National Programme of Antarctic Research-PNRA-has been experimenting with these techniques and systems, together with industry.

This paper discusses the work done up to now and its organization.
The following aspects shall be analyzed:
- the criteria leading to the selection of an automatic short wave transmission network between the PNRA headquarters andthe Italian Antarctic Base,
- the working philosophy of the HF system which has been used, the technique of automatic selection of the frequencies, selected in a pool of preselected frequencies, atfer the evaluation of the S/N ratio and of the BER,
- the selection of the optimal transmission speed on the basis of the corrective capability of the control codes,
- the exchange of information between the two systems for link continuity,
- the automatic call system,
- the results obtained during the 1990/91 and 1991/92 campaigns,
- the connection with the data collection system implemented on the Digital Micro Vax system and its management software,
- the connection with the Integrated Automatic Module-AIM-.

A SHORT WAVE AUTOMATIC SYSTEM FOR DATA TRASMISSION

After decades of successes in short and medium range radiocommunications, the short waves have been repleced, about ten to fifteen years ago, by the arrival of the satellite.
The armed forces remain the only users of short waves communications, so, the civilians operators of this kind of telecommunications, ceased to invest resources in research and development in this field.
The management of a short waves transmission system has to deal with the following problems:

1 - Continuos searching for good quality channels in the range of usable frequencies (MUF- LUF).

2 - Crashing of link, due to sharp propagation conditions changes.

3 - Bad quality of messages correction systems and conseguent almost unreadable received messages.

4 - Necessity of expert personnel during 24 hours shifts. This really means an increase for the managements cost.

The recent show up of chirpsounder system and of adaptive modems has partially changed the negative trend, allowing to overcome the problems described above.
These systems have been set-up in the military field, but their use has been increasingly broadened also to civilian world.
Adaptive modems are, in fact, able to autonomously manage either point-to-point radiolink or radio links network. There are now many firms which even though motivated by differente philosophies, they have these systems in their production lines.
The experts, at present, state that we are at the dawning of a new short waves communications era, because of the implementation of these new technologies.
In fact the point-to-point links and the short waves networks do not depend on third parties implication (i.e. addition of signal repeaters) and they have much lower running costs (compared to satellite link), since only the equipment amortization and the government taxes for using the assigned frequencies have to be taken into consideration.
The systems who make use of these techniques have been tested, in a joint effort with industry, by ENEA ANTARCTIC PROJECT who is responsible for the telecommunications inside the P.N.R.A.

We will describe an approach to the solution of the problems; we are going to examine the following points:

- Leading ideas who brought us to choose an automated short waves transmission network to connect PNRA in Rome Italy, with the Italian base, Antarctica
- Description of the HF system installed at BTN (Baia Terra Nova)
- Technique used for automatic selection of frequencies from a pre-fixed pool, which takes into account the evaluation of the S/N ratio and the BER
- Choice of the better transmission speed according to the connection ability of the control codes used
- Information exchange between the two systems in order to keep the link
- Automatic calling system
- Results obtained during the campaignes 1990/91 and 1991/92
- Connection to the data collection Digital Microvax System and software interface
- Connection to the Automatic Integrated Module (AIM)

DESIGN CRITERIA

Exames of needs and choice of a short wave system.

In 1989, Antarctic project of ENEA started the feasibility study, and afterwards the design of an automatic module (AIM) which had to be able to produce energy in order to feed different data collection systems left in operation (unmanned mode) during the antarctic winter.

In the course of the design phase, we thought it could be interesting to use a system able to transmit the module operation telemetry, and eventually, particularly meaningful collected data.

The easiest way was the use of the INMARSAT satellite vector, but we were aware of the absolute need of a different vector to back it up.

So we investigated the possibility to supply the module AIM with a short wave (from now on called HF) link using an adaptive modem; and we planned to use this system also for broadcasting news and messages to the personnel based in BTN during the antarctic summer.

For designing this data transmission system that had to be left in operation even during the southern winter, we prepared a specification sheet with severe electrical and enviromental values to comply with.

We had to spot a system that could garantee a continuous operation in a hostile enviroment, whit a MTBF value so high to go through the operation time range without assistance.

Furthermore, we wanted to have, handy, the possibility to operate in automatic mode in a "critical" world such as the HF one. In our case, in fact, besides all the above mentioned problems, there is also the great dinstance between the receiving-transmitting units (17.000-22.000 kms) and then the consequent negative effects on the packets caused by multiple paths and by tone distortion. Furthermore, we wanted our link to maintain a data transmission ability at the highest possible speed. After a careful market research, we reached an agreement for developping the ALIS (Automatic LInk Set-up) system with Rhode & Schwarz. This firm is, in fact, among the world leaders in HF communications, and they were actually interested in testing their adaptive modem in our case, which was challenging because of long dinstance and severe environment.

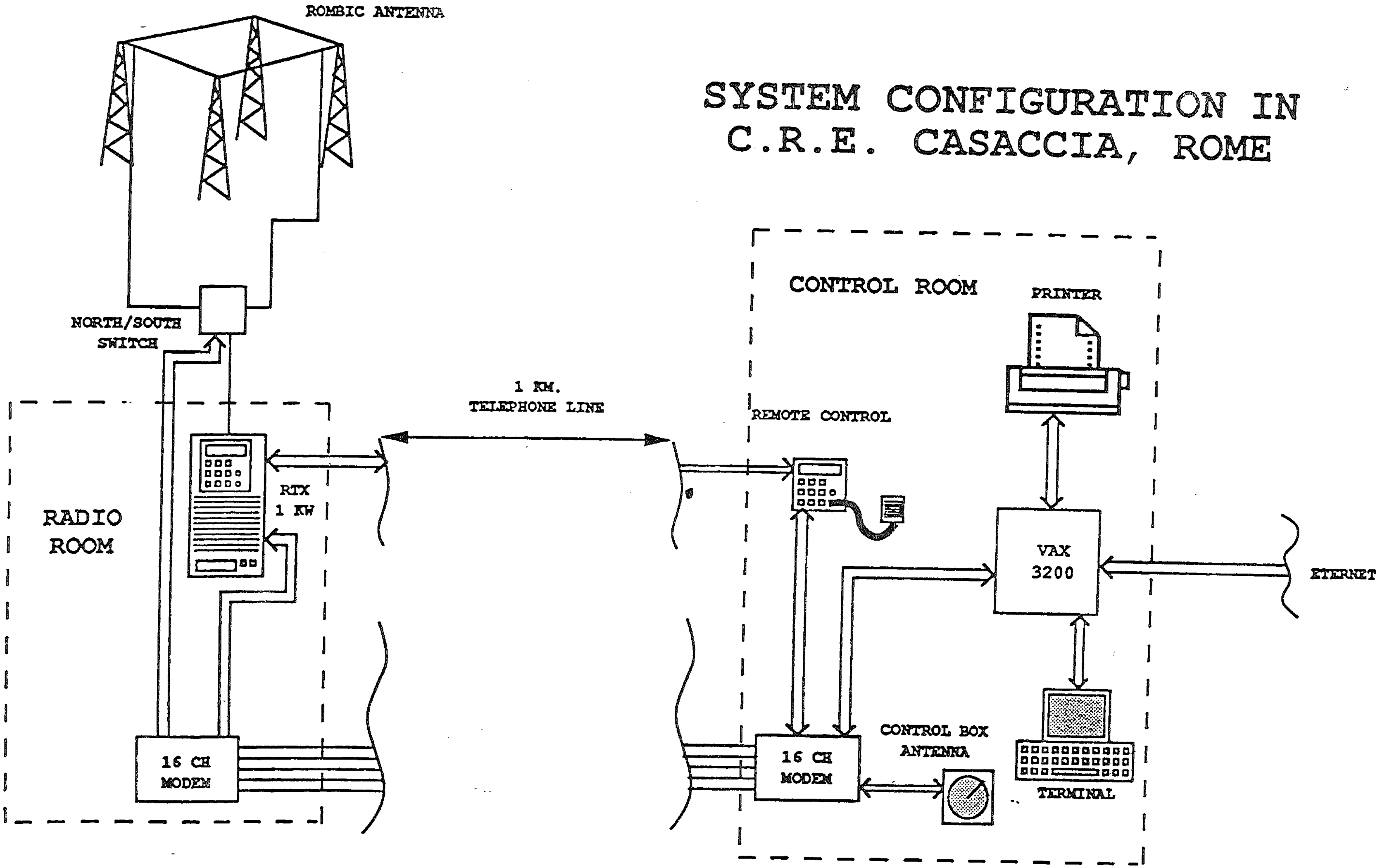
At R&S, they were also willing to build the modem firmware suitable to our needs.

On our side we thought that using such a system, whose technical specifications will be described later, would give us the following benefits:

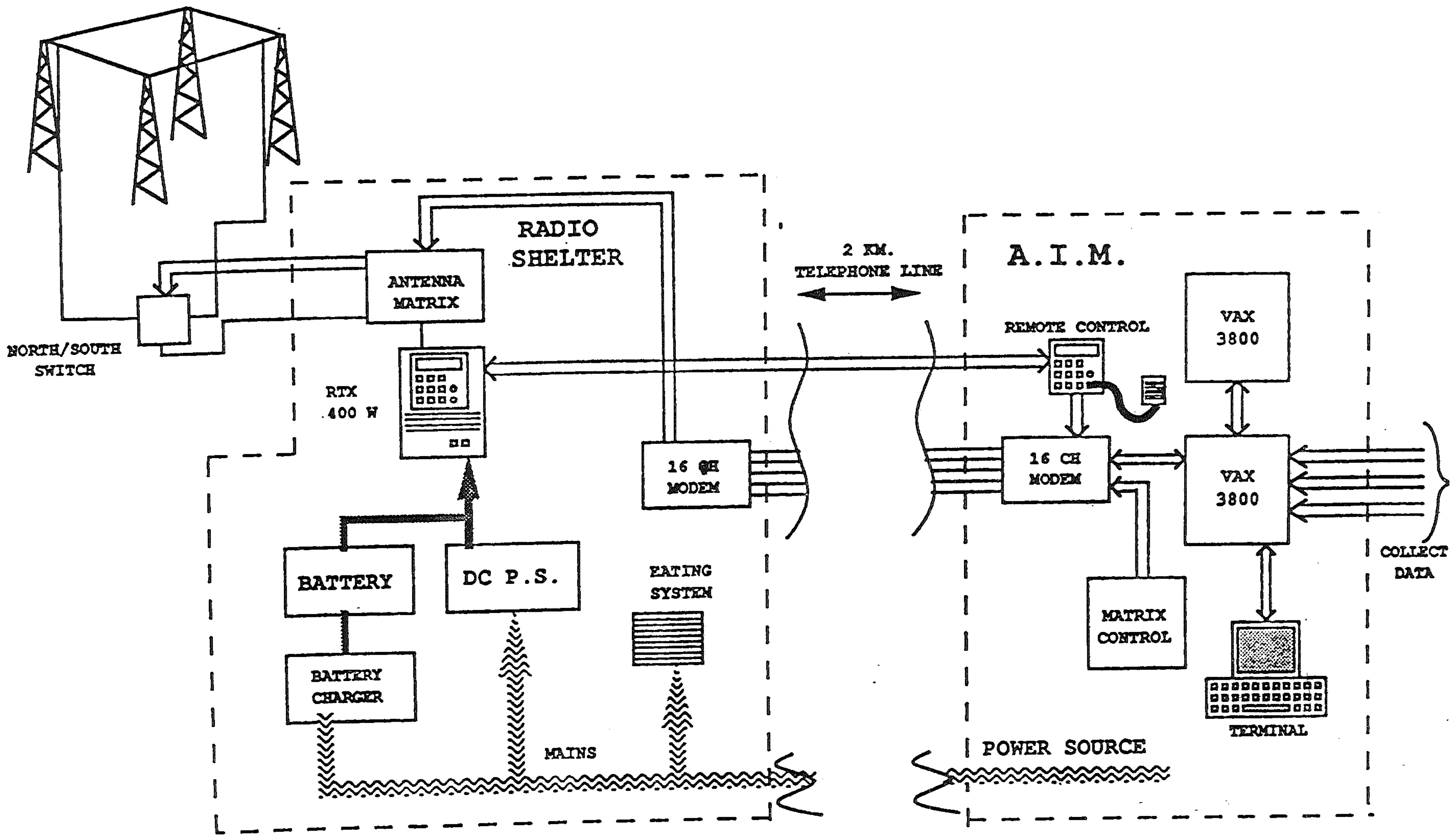
- low costs in data collection and negligible functioning costs especially compared to the rental costs of satellite systems
- autonomous and reliable link in case of international crisis. This could seem of no importance for our applications, mainly aimed at scientific studies; instead, it proved to be of basic importance when, during the 1990/91 campaign, the Gulf war dramatically increased the use of the satellite lines for military purposes, so the lines left available were of bad quality and short numbered
- alternative path to reach faulty applications, monitorable by computer, and hence possibility of remote restoring of their functions, including the reset of vectors (satellite vs HF and viceversa)
- testing a system to be exported later in DC operated transportable HF vectors, creating so the possibility to have error-free data transmission also from territories situated outside the satellite cover range (i.e remote fields and traverses)
- keeping some privacy on transmitted data, since they are not on the satellite network, which is a pubblic transmission vector

At this point, the only background objections still pending were on what would be the actual system reliability, and it would be possible to use it successfully during time periods of low sun spot number (short time of ionospheric propagation). We have taken up this challenge believing in the improvement of the data transmission management software, and believing in the possibility of setting up more accurate and sophisticated ionospheric propagation forecast programs. So far, the results have been satisfactory and the tests we have performed have given very positive answers.

SYSTEM CONFIGURATION IN C.R.E. CASACCIA, ROME



SYSTEM CONFIGURATION IN BTN



DESCRIPTION OF THE SYSTEM INSTALLED AT BTN

THE ANTENNA

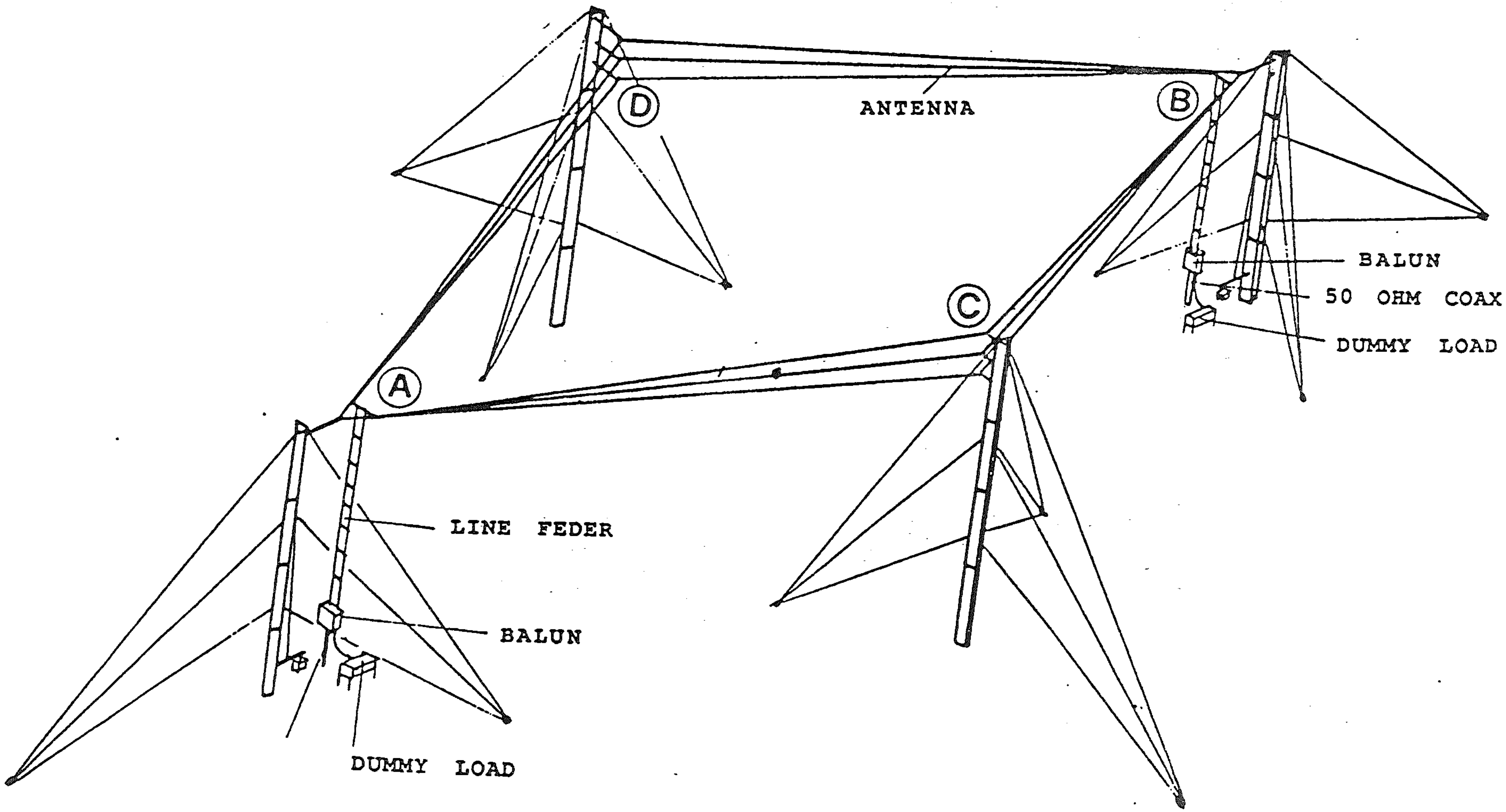
In choosing and designing the antenna, we had to take into account a great number of electrical and environmental parameters. The main limit was the transmitting system power supply that had to be generated by the automatic module (AIM). Having gathered these data and knowing the signal values needed at the receiver input at the other end of the link, in order to obtain a certain value of BER (Bit Error Rate), we have calculated the radiating system gain and the minimum transmitter RF power.

The antenna bandwidth has been choosen taking into account the frequencies assigned to the link between BTN and Italy, and thanks to the help of Istituto Nazionale di Geofisica (ING), who provided us with valuable computing and algorithms regarding the ionospheric propagation forecast.

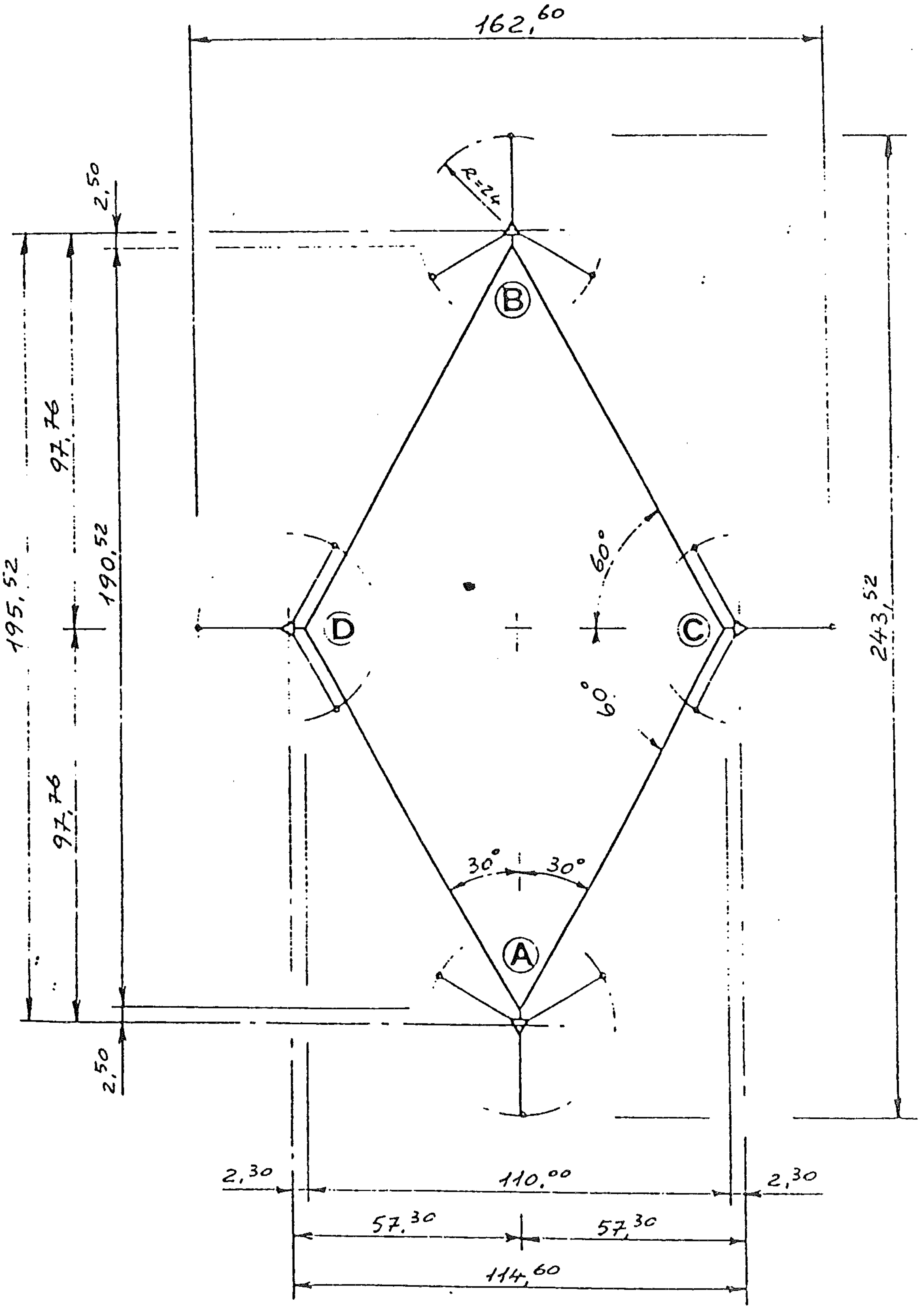
With all these data in our hands, our choice has fallen on the building of a rombic antenna, the only one with high gain, wide band range, good direction aiming, two opposite ways output (making possible the choice between short or long way link), very good tensile strenght (being a wires antenna).

In dimensioning the antenna, great care has been taken in chosing the tensile strenght specifications, with particular attention to the wind factor either with or without ice formations on the radiating wires. Special skill was used to absorb the radiant system elastic strain under strong wind, in order to avoid wires breaking.

ROMBIC ANTENNA DESCRIPTIONS



ROMBIC ANTENNA TOP VIEW WITH DIMENSIONS



RECEIVING AND TRANSMITTING SYSTEM

The whole system is set up by the following parts:

- A transceiver
- An antenna automatic adapter
- A controller, which arranges for establishing automatically the link, for managing it, for monitoring flow and quality of data, for eventual repetition or correction of data
- A fast modem
- A power supply system

Transceiver

The lower parameters needed to set the RF power and operating band specifications, were already in our possession, since we had set them when we calculated the link between BTN and the Project headquarters.
In this calculation, besides the antenna gain, the minimum RF power (150 watts), and the bandwidth (10/23 MHz) were set.
So, with safety as main concern, it was decided for a 400 watts RF power, and 7/30 MHz bandwith range.
Storing and operating temperatures were set respectively to minus 40 and minus 30 degrees centigrade.
The set up had to have all the operatings mode, i.e.:
CW, FSK, SSB, ISB, AM
It had to operate data transmission, to be automatic, programmable, synthesized, all solid state, and to operate in local or remote mode, to be protected against mismatchings and shortcircuits at the antenna output, to be modular, easy to maintain by personnel with little training, supplied with built in diagnostic system, that could drive an operator through a repair job, to be supplied by AC or DC, and had to have an MTBF equal or greater than 8.000 hours, which corresponds to the time in which the system remains unwatched.

Automatic antenna adapter

The transceiving system, to be able to maintain and manage the link, has to operate on a many MHz frequency band, has to jump quickly from frequence to frequence when needed.
In order to do that, both the system and the antenna adapter have to effectuate these jumps many times per second; the antenna adapter has to manage the impedance transfer between transmitter and radiant system, so that the equipment would not go in protection mode, and all the generated RF power would be utilized by the antenna.

POWER SUPPLY SYSTEM

Two main problems were before our choice of the power supply system. The first possibility was to get the supply from our AC source, but to do so we had to have available an electric power of about 2.000 watts for the transceiver and other 1.500 watts for the services. But this method was not practicable since we could count only on 2.000/2.500 watts supplied by AIM.
At this point we have found a solution, that is to supply the system by means of accumulators who could operate at very low temperatures.
Knowing that the maximum power required, is the one during transmission time, and estimating how long this period would last, we have dimensioned the accumulators batch starting from these parameters:

- current consumption during transmission time
- current consumption during reception time
- electric power needed to maintain, inside the shelter, a temperature not lower than minus 5 degrees centigrade, in order to obtain a correct accumulators recharging.

Provided that, the transmission time be 3 hours per day and that in such a time span about 22% be reception time (16% of time is due to the signal delay for the round trip of the answer), we have calculated the consumption during the 3 hours taking into account the 88% of the current value absorbed by TX (55 amps x0 .88 x 3 = 128 amps per day). To this consumption, we have to add the reception one, that is 21 hours and 40 minutes, to complete the estimate of the total current needed per day (24 hours).
The receiving section needs 5 Amps, that means 83 milliAmps/min (5:60). The reception time, which results from the difference in the 24 hours with the transmission time, is 21 hours and 40 minutes, that is 1.300 minutes. In this time span then, we have a total day consumption of 107 Amps. Adding up the reception consumption to the transmission consumption, we have a daily (24 hrs) current need of 235 Amps (107+128).
Now, taking into account the accumulator efficiency at minus 5 degrees centigrade which is 85%, we decided to use an accumulators battery able to produce 500 Amps/hr nominally.
From our calculations, the current needed to recharge the accumulators was 10 Amps/hr, but as well known, in order to be effective it is necessary that the current be higher than the minimum value, which was fixed at 25 Amps.
Such a solution allows then, to collect from the network, only for the telecommunication equipment, 750 watts, while 1500 watts are needed for the remaining services; this is a smaller value compared to the 3500 watts that we would have had with only the AC supply. Thus remaining within the limits of the available supply.

ALIS SYSTEM CONTROLLER

For what concerns the system described so far, that is the transceiver with its antenna adapter, it can be considered as common HF equipment which meets mil spec.
ALIS, instead, represents the really innovative part of our system; that was necessary to make possible the automatic link between the two dinstant points of BTN and Rome, which presents great difficulties for data transmission. ALIS has made possible the unwatched automatic transmission. Furthermore it has been possible to implement a process control system in the VAX installed in AIM and simultaneously, transferring from BTN to Rome, collected data of particular interest. Thanks to this system, we have achieved the automatic transmission from Antarctica to Italy and viceversa, when the base is not populated, accessing directly the VAX system in order to extract information or data of interest.

TECHNICAL DESCRIPTION

The nucleus of ALIS processor is a 16-bit processor that handles the control and contains the operation system for the management of processor activities.
Essentially these are:

- PCA (passive channel analysis)
- MUF(maximum usable frequency)
- Link set-up
- ARQ (automatic repeat request)
- Control (of all external units and the 8-bit processor)
- ACA (active channel analysis)
- AR (adaptive reaction)

The 8-bit processor performs the processing of data from the radio set , therefore assigning quality and feeding the 16-bit processor via the bus coupler.
This processor evaluates the data and causes the 8-bit processor to feed further data.
By way of the peripheral bus, the 16-bit processor organizes data traffic with the interfaces (TTY, AF and V24).

Procedure in Automatic Radiocommunication

The procedure in automatic radiocommunication correspond to that of conventional, manual radiocommunication. In the foreground there is the matter of channel selection, a task that has not been simple for the radio operator up to now because of the many parameters that have to be considered, like time of day, season of the year, dinstance and local interference.

This is where the ALIS processor with its programmed intelligence comes into action.

It executes all parameter analyses automatically and set optimal frequency on the radio set.

The time of the day and the season of the year are derived of built-in clock, the dinstance from the address memory and a MUF calçulation is performed.

Together with real-time analysis of the agreed radio channels in a scanning mode, local interference is also detected.

The subsequent, automatic link set-up is made addressed and using a reliable, reduntant code.

In radio nets where acknowledgement is permitted, acknowledgement of reception is sent by a hand-shaking process and, on the basis of the active channel analysis that is performed, the link qualities also communicated from the receiving station; this means that an adaptive reaction, like the selection of another frequency, is possible already when the link is being set-up.

Additionally the receiving station is informed of the desired means of communication (e.g. voice, teletype with ARQ or FEC).

The transmission of information, once a link has been set-up, is generally made in in FM procedure F 1 B, which is the most common method used in shortwave range.

Trasmission quality is safeguarded by simplex ARQ which is synchronizing the link when it is being set-up.

As the quality of the communication link degrades, there are more frequent request for repetition.

This means that the efficiency is reduced.

If a programmed threshold cannot be maintained for a number of second, the ALIS system reacts automatically by changing to the frequency that was found to be second best during the passive channel analysis.

Link set-UP

General

The automatic link set-up is addressed and uses a reliable redundant code to estabilish a specific connection via short-wave radio.

In order to syncronize the transmitter and the receiver, ALIS sends a number of frames at one frequency.

The choice of the frequency depends on the pre-progammed pool frequencies, the

calculated MUF and the results of the passive channel analysis.
The passive channel analysis measures the field strength levels for all pool frequencies and such localizes channels with heavy interference.
When the user type in a CALL command the ALIS processor selects the best frequency available and tries to establish a link.

Link set-up procedure

Frame sending

Initially, the master ALIS processor (calling station) sends a defined number of frame at each frequency of the desired pool to enable a weighted bit at receiving station.
The frames are transmitted repetitively because the slave station must have enough time to scan through the programmed frequencies and receive at least three frames at anyone particular frequency (synchronization).

Synchronization

After the correct reception of all three frames from the master station, the receiving station (slave) transmits a synchronization acknowledgement and additional information about the quality of the reception.
From this return message the master station determines the transit time of transmission so that the correct time frames are selected for the following ARQ transmission.
If the master station detects no answer the frame sending sequence is repeated on the next optimum frequency in the pool.

This procedure is cyclic, that means, the ALIS processor remain in the calling mode.

Start signal

The start signal is necessary to mark the end of the link set-up phase.
This information is emitted from the master station and also indicates the validity of the transfer status data.
It also marks the start of the ARQ operating phase.
The start signal contains the address of the calling transmitter and an additional identification bit to identify block for the slave station.
The bits contain the following information:
-Synchronization word
-Address of the master station

Frames

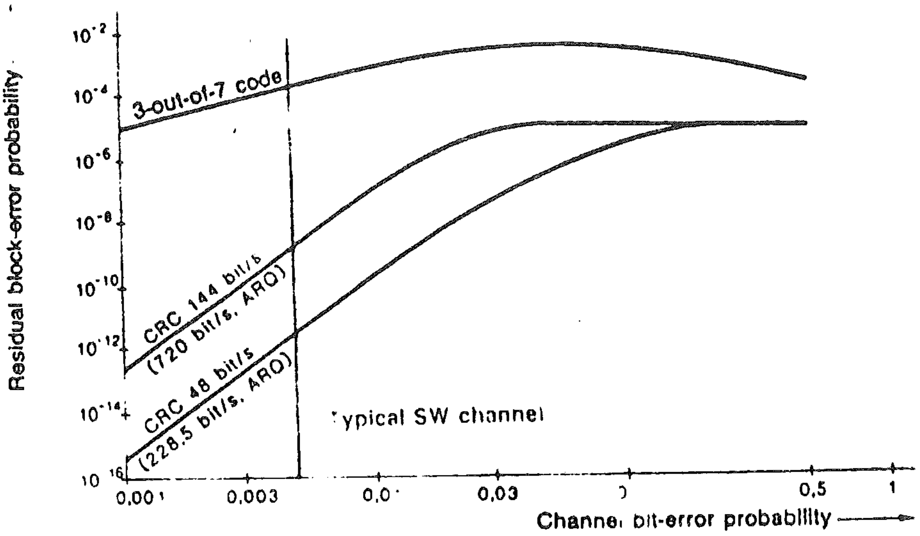
The number of emitted frames is not fixed and depends on the amount of pool frequencies.

The frames contain the bits of the correlation code, bits of the address, the bits of the status of the master station ARQ, FEC, VOICE, MORSE, DATA, the bits of the ADAptive reaction, the bits of the link set-up procedure with or without acknowledgement.
In the phase of the synchronization, the correct reception of all three frames, the acknowledgement contains the bits of the synchronization word, the bits of the quality of the received signal.

Description of ARQ
Operation

In order to ensure correct data transmission via shortwave link, the principle of automatic error correction by repeating any data not received correctly, is applied.
This procedure, in the following refered to as ARQ, guarantees perfect transmission even in the case of strong interference on the radio link.
The error detection, necessary to recognition of wrongly transmitted characters, is realized with the aid of a redundant code.
The error detection code used is a cyclic block code with a block length of 48 bits. One code word consists of 32 bits for basic data and 16 bits as redundancy for error detection capability.
This code offers much higher resistance against coding errors than non-linear 3-out-of-7 code laid down in the CCIR-476 recommendation.
The advantage of this ARQ code is based on a residual error probability reduced by some magnitudes.
The sequence of a message transmission, made secure by ARQ, can be described as follows:
A message to be transmitted is not sent continuosly but in block of 48 bits. The procedure for the data transfer and timing are closely based on the CCIR 476 reccomandation. The special ARQ installed offer in addition the special feature of being able to transmit TTY letters, 7 bits ASCII characters or an 8 bits characters set. In each mode, the message itself and ARQ control commands are completely separated from one another.
Each received block is checked at the receiving end and acknowledged whit an appropriate test signal for correct or wrong reception. By reason of this test

signal, the transmit station can then repeat the block, which has not been received correctly because of the interference.
If the transmit is not able to interpret the signal of the receive station correctely, in case of further interference on the radio link, the test signal is called for by means of a special code sequence.The data rate on the radio link is 228 bits/s and, as a result of the simplex method used, this correspond to 92.5 baud in 5 bits format or 88.2 baud format for every subscriber. When using the optional 720 bits/s data modem, the three baud rate are 372, 354, and 341.
The master/ slave (transmitting and receiving station) relationship does not even change if the transmission direction is reversed.
The sinchronization necessary for entry into ARQ, is already carried out during the automatic link set-up. So as not cause a baud rate reduction resulting from the simplex method used in the ALIS system, as compared to standard duplex ARQ system.



Residual error probability of ALIS ARQ compared with that of 3-out-of-7 code to CCIR 476 - 1

In this way an efficiency is achieved that to corresponds to that of more conventional duplex ARQ method and, at same time, far better use is made of existin frequencies. For this reason, it was possible to implement the adaptive reaction described in the following chapter, offering yet another advantage.

Adaptive Reaction and Rephasing

In order to increase the efficiency of the ARQ, even on poor radio link, the ALIS system offers the possibility of frequecy-adaptive reaction.

If there are interferences an atmospheric or induced kind on a frequency over a long period of time, a frequency change takes place as soon as the frequency drops below a specially defined threshold. The new frequency is selected by means of fixed algorithms on the optimum working frequency. This frequency is calculated prior to the link set-up and is obtained by calculating the MUF and passive channel. The frequency provided for the adaptive reaction are grouped around optimum working frequency.

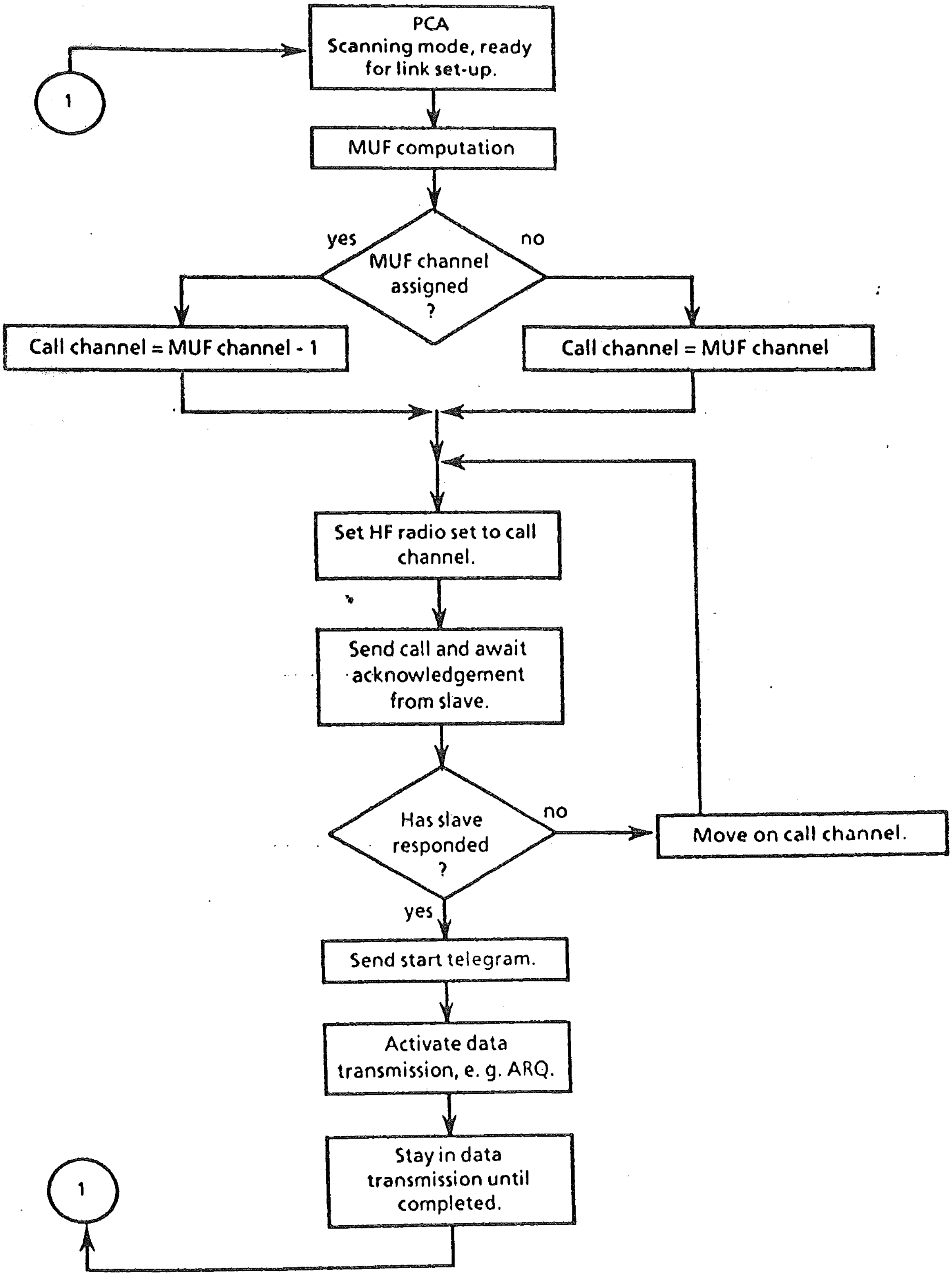
Activation of the adaptive reaction can only take place on the condition that both stations are fully informed as regards the state of radio link, this being only the case in ARQ operation.

In order to enable both stations involved in the link to receive the information of a frequency change at the same time, every block repetition is registered in the ALIS processor, thus allowing a calculation of the efficiency rate.

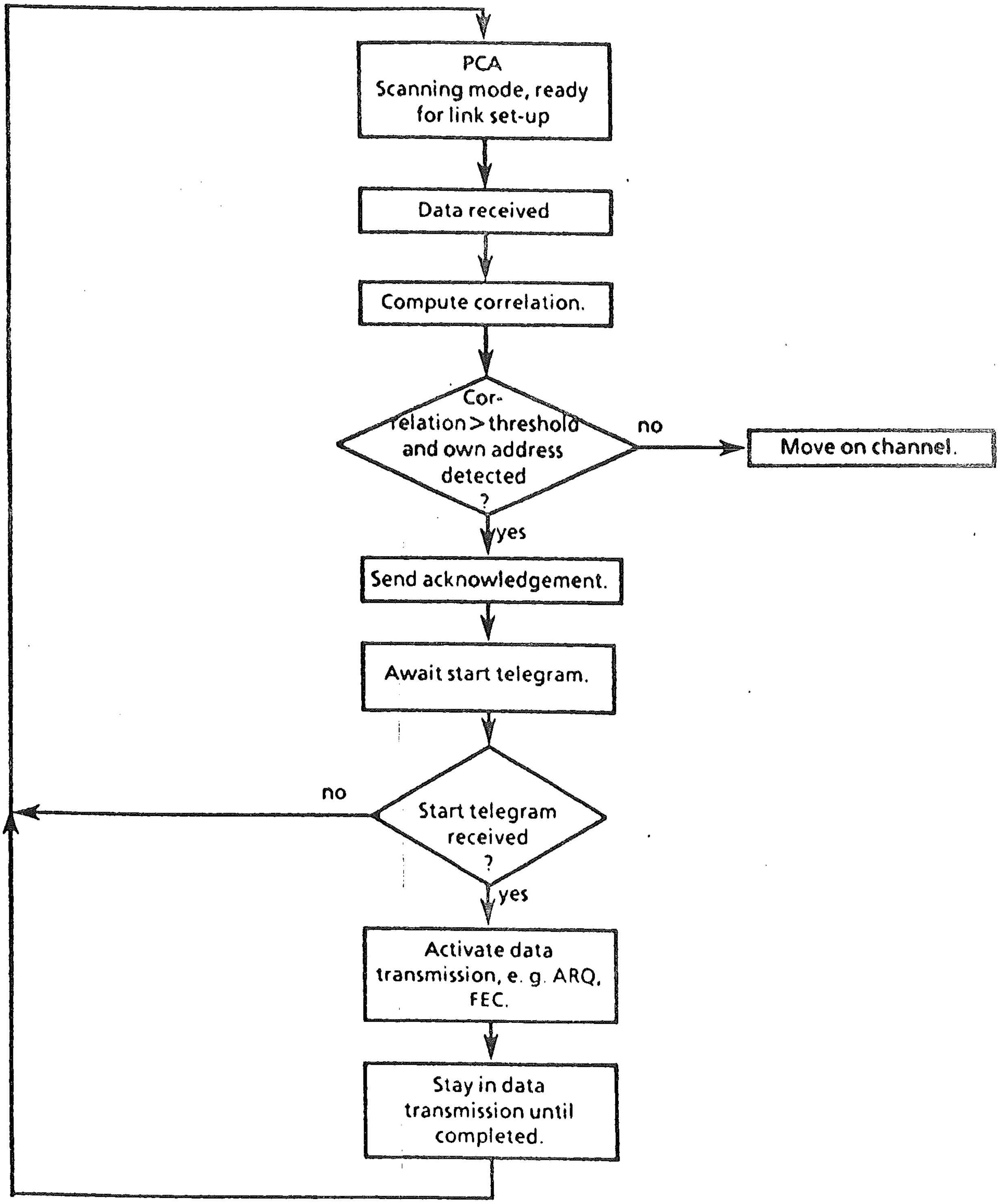
If a frequency drops below the set threshold, both, master and slave station, change the frequency in the same cycle.

In this way they are phased again into the next ARQ cycle in a synchronous fashion.

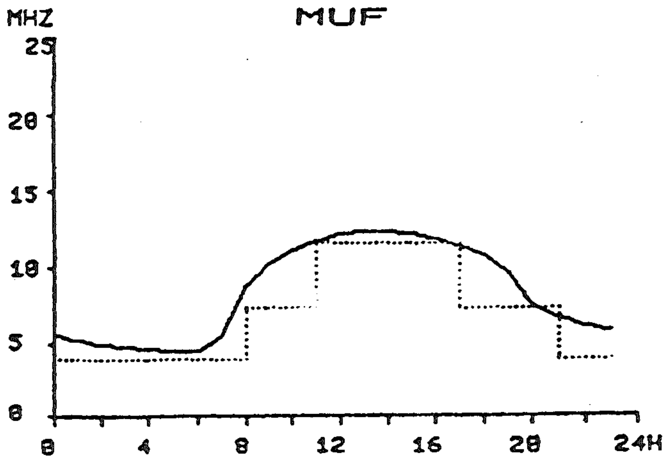
This procedure is known as rephasing and is carried out automatically without intervention of the user.



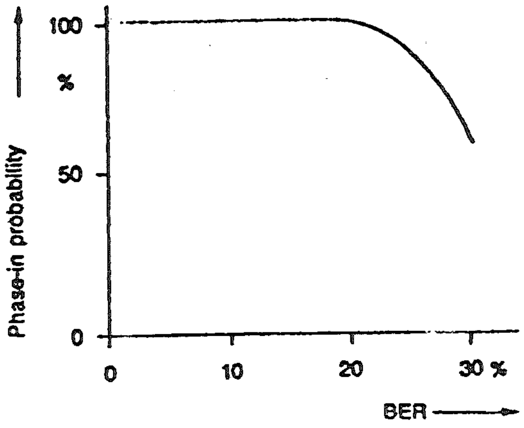
Operation of ALIS Processor in Transmitting Station



Operation of ALIS Processor in Receiving Station



The ALIS processor computes the maximum usable frequency (MUF) as a function of time and range (continuous line). With this value it selects the optimal frequency (dotted line) from a pool The range of the distant station is taken from its address memory, holding the addresses and coordinates or ranges of communicating stations, and the time is produced by its frequency standard.



Call recognition (syncronization) is optimized in the ALIS processor by a technique of weighted bit addition for high reliability even in the presence of strong channel interference. This is 100 % up to a bit error rate (BER) of 20 %. Above that figure it reduces continuously. At 30 % BER it is 50 %, ie on average every second call is recognized.

HF DATA MODEM

Description

Interface

The data interface is a V24, for input and output digital data synchronous or asynchronous.
The baud rate can be set between 50 and 9600 baud.
The interface is capable of handling 5-bit or 8-bit characters with even, odd or no parity.
When used together with ALIS processor, the V 24 interface is firmly set for asynchronous operation at 4800 baud, 8 bit even parity.
The radio connector is linked to the radio interface which is fitted with a 600 ohm balanced output for the modulation signal to be sent to the HF transmitter. A 600 ohm balanced input for th AF signal from the HF receiving section is also provided. The PTT signal is taken via this interface to the HF transmitter.

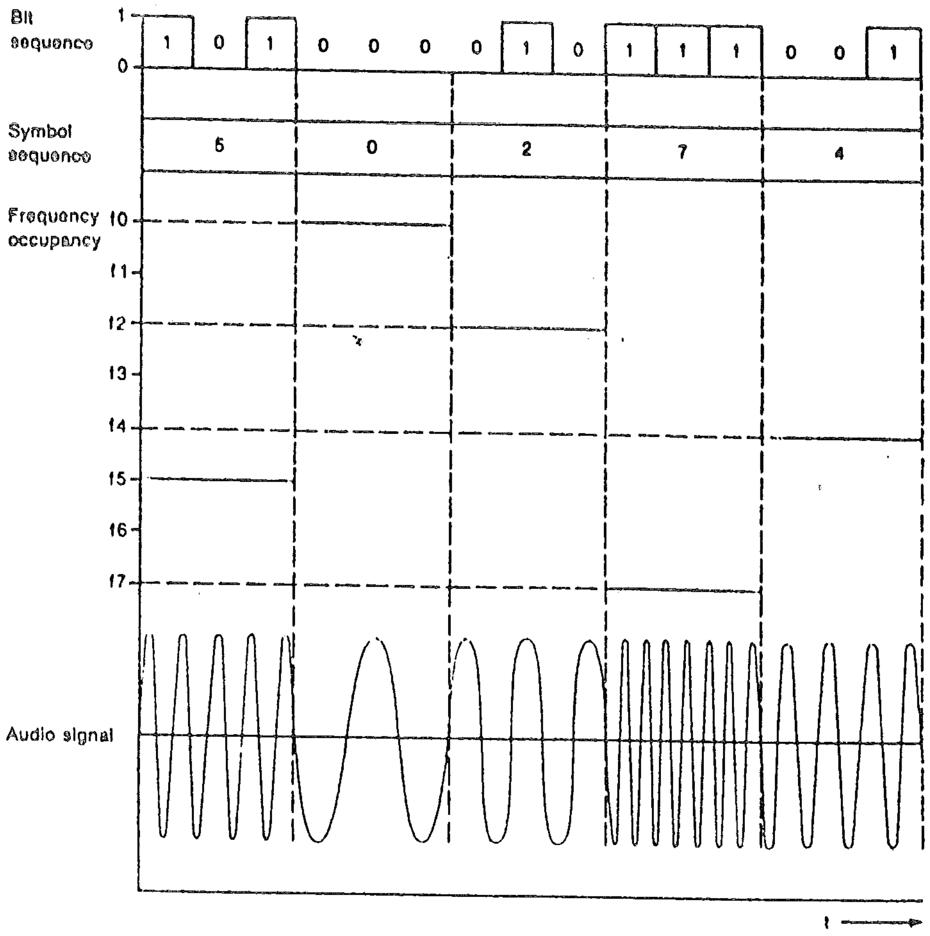
Buffers

The baud rate of the V24 interface can be set indipendently of the data rate of the radio link.
Buffers for approximately, 10.000 characters each for data to be transmitted and data to be received provide for effective decoupling.
The buffers can be cleared on command.

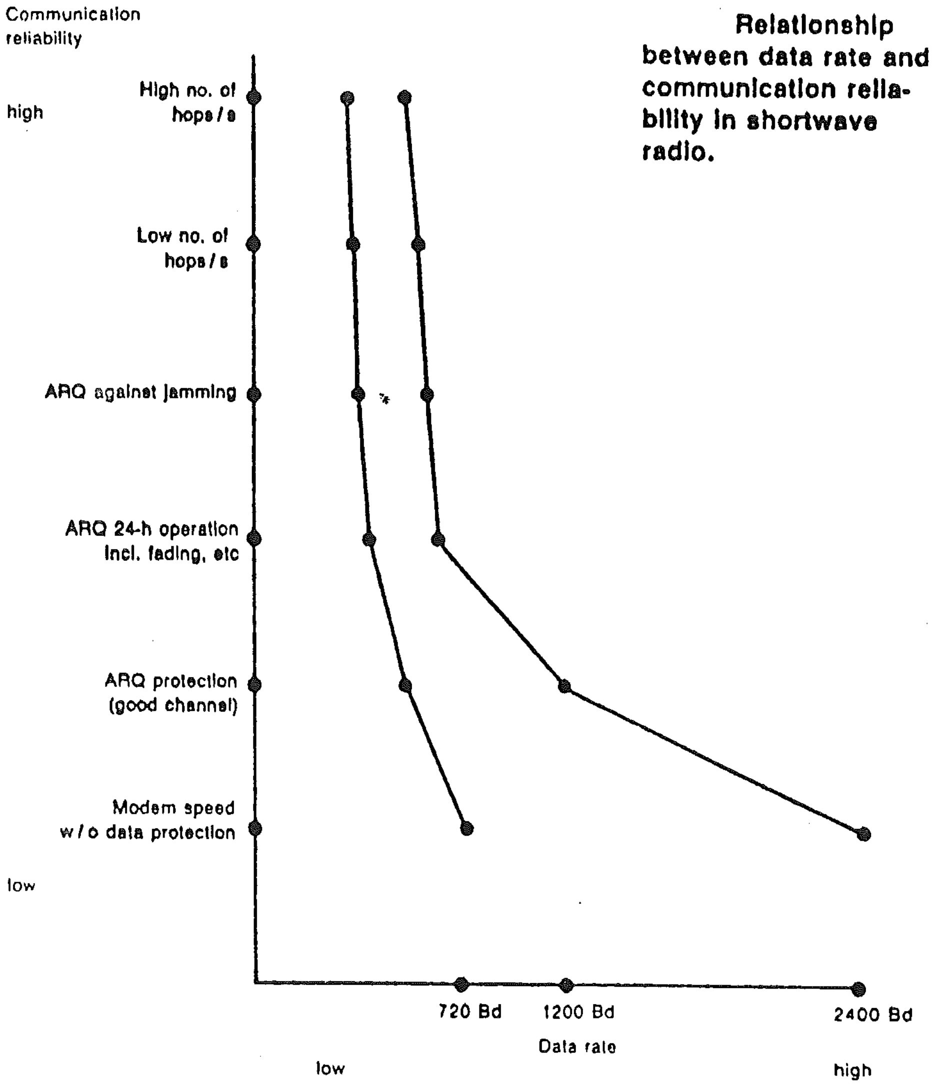
Modulation

8-FSK (Octonari Frequency Shift Keying) is employed for the RF signal AF modulation. The AF modulation signal is a carrier of a costant amplitude, the frequency of which can take on eight predefined values in the range 800 to 3100 Hz.
Data bits to be sent are processed in groups of three bits. A group such this represents one symbol.
The modem selects one of eight predefined frequencies in accordance with the binary value of the simbol (0 to 7).
The carrier is then modulated by this frequency for 4.1666 ms.
As a result of this method, the data transfer on the HF link is only 240 baud althougth the volume of information that can be transferred is three times of this value.

Disturbing multi-path effects can be largely avoided when using such a low baud rate.
Moreover, the transmit power needs not be split up between several channels.
Finally, the 8-FSK technique requires approximately 4 dB lower signal-to-noise ratio compared with the 2-FSK technique at same data throughput and the same bit error rate.



Transmission structure of HF Data Modem GM 856.



Relationship between data rate and communication reliability in shortwave radio.

Functioning

Transmission

Data are sent in the form of bursts which are made up of several blocks:
-Preamble
the preamble brings about an automatic synchronization of the receiving end.
-Control block
The content and the length of the control block depends on the mode of transmission selected. The control block contains information on the length of the data block with useful data. It also specifies the number of time bursts that is sent in the case of multiple transmision. No control block is sent in ARQ mode.

Data block

The length of the data block is also variable. It can be programmed or varied with the volume of data to be sent.

Synchronization

The preamble is intended for automatic synchronization of the receiving end. The time required for synchronization can be set between 21 and 42 ms which corresponds to 5 to 10 symbols. A tipical value is 29 ms for the transfer of 7 symbols. No bit is lost on the transmission path because of the formatted, isochronous transmission method used.

Data Protection/FEC

A practically error-free data transmission is ensured by the integrated FEC facility. Block coding or multiple transmission, as well as a combination of the two methods, are possible.
The FEC can be switched off with a view to achieving the highest data throughput on very good links or when an external data protection protocol is employed.
An FEC technique with an error-correcting Reed Salomon block is intended for channels of overage quality. This technique is ideally suited for the transmission of symbol, even with short blocks lengths. The coding rate is programmable between 1/3 to 5/7. A symbol error can thus be corrected per code block, every three to seven symbols.
In the case of poor links, multiple transmission in combination with block coding may be selected.

The received blocks are first stacked at the receiving end and subsequently evaluated.
The repeat rate is programmable from single to seven folds.
This technique produces satisfactory results even on very poor links. However, the data throughput is reduced in accordance with the repeat rate.

Receive Mode

The AF modulation is continuosly evaluated in the receive mode and - depending on the transmission facility - the preamble is detected.
When the preamble is detected, the synchronous demodulation of the data symbols is initiated. The symbols detected are combined to form data, and stored in the receive buffer.
The characters are then outputted in the format configured at the set baud rate, via the data interface.

Operation with ALIS Processor

New operating mode are obtained when connecting the ALIS processor with an HF data modem:

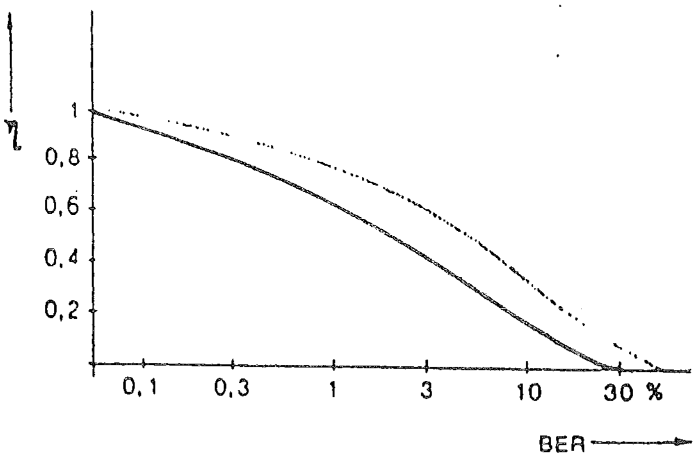
-Fast ARQ method with a data rate four times that of standard ARQ.
-FEC protected transmission for point-to-point links and broadcasting.

ARQ mode with ALIS processor

In the ARQ mode, characteristics of the ALIS processor such as automatic link set-up, selection of optimal frequency change for deteriorating links, are fully maintained.

FEC mode with ALIS processor

The link set-up is again performed by ALIS processor in this mode. A switchover is then made to the data mode. Data can be transmited point-to-point or as a broadcast. A transmitter is therefore able to reach several receivers simultaneosly.



Efficiency η of an ARQ procedure with (ligth line) and without (black line) error correction by software decision

RESULTS OBTAINED DURING THE 1990/91 AND 1991/92 CAMPAIGNS

The 1990/91 campaign has served the purpose of setting up the automatic link between BTN and Rome.

The problems found were caused by the delays put inside the communication protocol by the dinstance between the two ends (17.000 Kms during the first tests).

In fact, pratical tests have shown that theoretical virtual delays, implemented in the first version firmware, were not long enough to allow the information packets exchange needed to actuate the link . We had to proceed by consecutive approximations and with great difficulties caused by the lacking of capability to program the EPROM.

By the end of the campaign we replaced the EPROM with new version ones, and we started to test the link. These tests lasted the last two weeks of the campaign; afterwards, the link has been kept for three more weeks before the HF vector crashed.

The 1991/92 campaign research, has shown that misfunctioning has been caused by damaged accumulators, who cut the supply, inside the shelter that contains the transmitting system. To be precise, the lowering of ALIS power supply has blocked its operation logic.

Since we could not operate the hardware reset through VAX (this option has been implemented in the new version), we were not able to hardware unblock ALIS, so we couldn't capture the final event of its operation. The accumulators damage would in fact have left only some more days of system life .
During the 1991/92 campaign (shorter than usual) we have replaced the software with a version that would, tentatively, hold the long path link (about 22.000 Kms). This operation has been completed with success. In the meanwhile, our cooperation with R&S, has led to a new version of the ALIS management software which permits us to modify, from the outside, the parameters into the firmware without having to reprogram the EPROM (this action cannot be taken in BTN, because of lacking of equipment). Anyway, we were able to hold a satisfactory steady link for about eleven weeks (eight weeks without controlling personnel), which allowed us to check the AIM operation and to collect plenty of data especially from meteo stations.
The average bit rate obtained was about 280 bit/sec. This result could be considered very satisfactory, since we are talking of data bit, namely all the bit used for link management are not included. A qualitative estimate allows us to say that the actual transmission was maintained at the baud rate of 720 bit/sec.

ALIS SOFTWARE MANAGEMENT FOR VAX

The ALIS system and some other data gathering systems were implemented, at the beginning, to operate in MS-DOS environment. That is why, it was necessary to write a new management software to interface ALIS to AIM, which is based on VAX 3800 system.
Anyway ALIS needs two dinstinct serial ports through which commands and data bits can flow. Sadly to say, we did not have enough time to write the management software for commands. We were then forced to write a software which, by means of a trick, could drive ALIS and VAX at the same time.
DIGITAL has designed, especially for us, a program that is able to send control characters, which, by means of a suitable software installed in the VAX in BTN, could be interpreted and transformed into files to be sent to Rome. This system allowed us to transmit and receive a great quantity of data and, furthermore, to transmit and store inside the VAX in BTN all the broadcasted news from Italy.

CONCLUSIONS

ALIS adaptive module has shown to be functional and effective, giving signs of weak points only for unwatched operation. There is need to say that the designer had not thought, at the beginning, of the possibility to fully exploit the exceptional characteristics of this modem as a remote transmission node. The appropriate design corrections, suggested after our experience in Antarctica, made it possible to control and drive ALIS completely by computer without any difficulties. This increases the possible applications, also towards operative environments who do not need data transmission, but only an HF link which can be managed by unskilled personnel; and we are thinking, mainly, of its use during traverses.

To our judgement, anyway, the application of ALIS in links like in our case, remains an application who is working to the edge of the system operation. More important would be to implement a network based on shorter links automatism. At present already, we have on the antarctic territory a large flow of data transmission from base to base, which can be considered as a network.

According to us, making this network automatic by using adaptive modem could really help to increase its functionality. Naturally, this would mean to go toward a unique standardized system, which could be pointed out by putting together all the experiences made by different nations operating in Antarctica.

It is our opinion that an effort in that direction is worth to be done, possibly widening to a regional common enviromen the meetings aimed at solving the telecommunication problems that have basic strategic importance in Antarctica.

MICROSAT Based Communication System for Rescue Services and World-Wide Data Transfer from the Antarctic

by
N. Balteas, Kayser-Threde GmbH, Munich and
H. Kohnen, H. Tüg, Alfred Wegener Institute, Bremerhaven, Germany

ABSTRACT

POLARCOM is a MICROSAT based low-cost communication system for special use from the Arctic and Antarctic. It provides full voice and digital data transfer capability.

The overall system consists of six MICROSATS spreaded by 60° on a 1250 km high circular, polar orbit. This satellite constellation facilitates continuous inner-antarctic communications and real-time communication for approximately 3 hours daily from the polar regions to any other location in the world.

Due to the continuous coverage of the polar regions a full time rescue service for disaster and emergency operations can be easily established and a significant increase of safety for all antarctic scientists achieved.

Due to the data transfer capability, also automatic research stations can be operated and remote control from any location is possible.

The communication principle is based on DTDMA-Slotted Aloha which is an optimum between channel capacity and experimental as well as expedition needs.

This paper describes the overall system architecture and points out the high benefit of the system for the antarctic scientific community.

One experimental satellite launched in 1991 successfully proved the feasibility of such communication links.

1. INTRODUCTION

Traditionally satellite communication systems are using the geostationary earth orbit (GEO). The advantage of this orbit is that continuous realtime communications are possible because of the same angular velocity of the spacecraft in this orbit with that of the earth.

The disadvantages of a spacecraft in this orbit are:

- the big distance (approx. 36000 km above the equator - the slantrange is in the order of 40000-42000 km)
- only the areas between ±70° of lattitude are visible
- use of frequencies in the C-band and higher
- high operational costs.

Due to these disadvantages communication is only from the outer points of the arctic and antarctic with directional parabolic antennas possible.

For inner-antarctic operations no communication capability is possible with these systems.

Figure 1 shows the 5° of elevation visibility areas of a GEO satellite in comparison with that of LEO satellites.

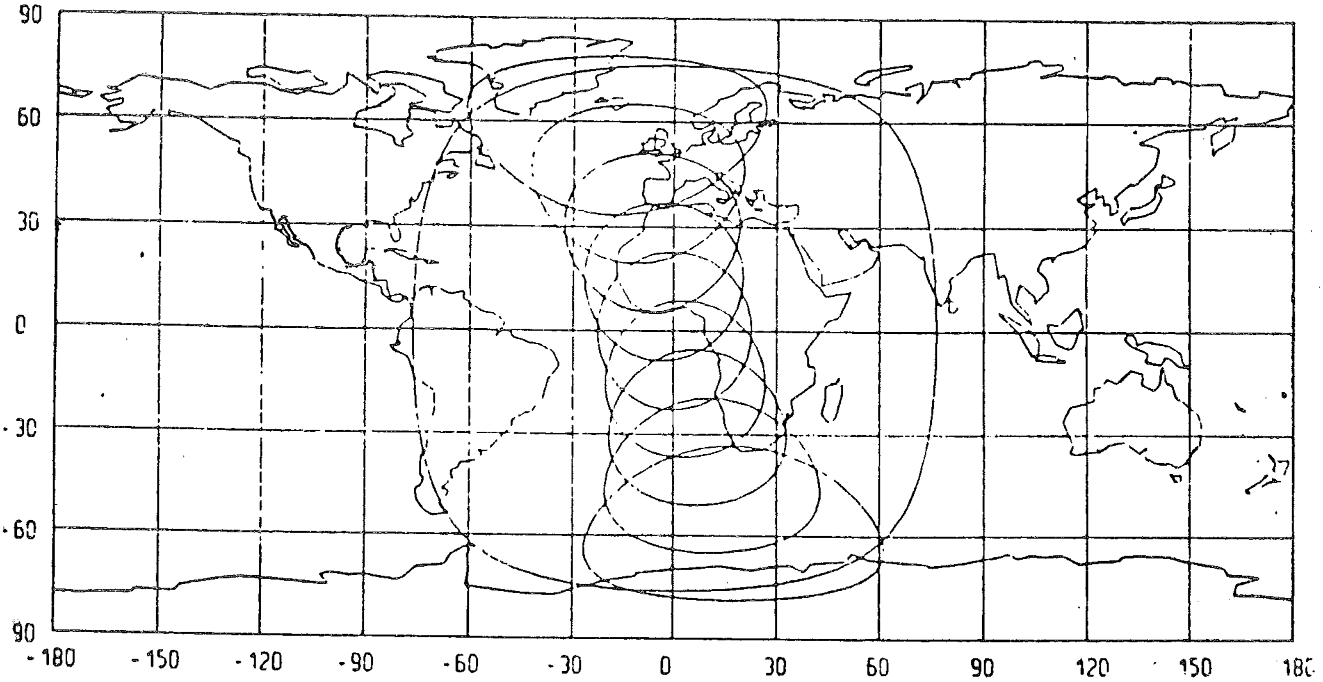


Figure 1: Comparison of the visibility areas of GEO and LEO satellites.

Figure 2: IRIDIUM Orbit Constellation

The short wave communication links which came in use require very big equipment and are in special not applicable during periods of high solar activity.

For emergency operations the COSPAS/SARSAT system is often used. This system is based on Low Earth Orbit (LEO) satellites and provides location information but very limited communication capabilities (only transmissions of a few bytes).

The ARGOS system which is also aboard the same NOAA satellites provides the most powerful communication capability of max. 32 bytes per satellite pass in one way (only transmit).

The new LEO comsystems which are in discussion in the last years (IRIDIUM, ORBCOM, etc.), will not be able to start operations before the year 2000 because of the extremely high system complexity. Figure 2 shows the configuration of IRIDIUM which consists of 77 satellites. All the proposed systems have been basically designed for mobile communications and can only limited serve the antarctic scientists and expedition requirements.

2. POLARCOM

The basic POLARCOM constellation is illustrated in Fig. 3. It consists of 6 satellites spreaded by 60° on the same circular polar orbit. The orbital parameters are:

Altitude	:	1250 km
Inclination:		80° to 100°

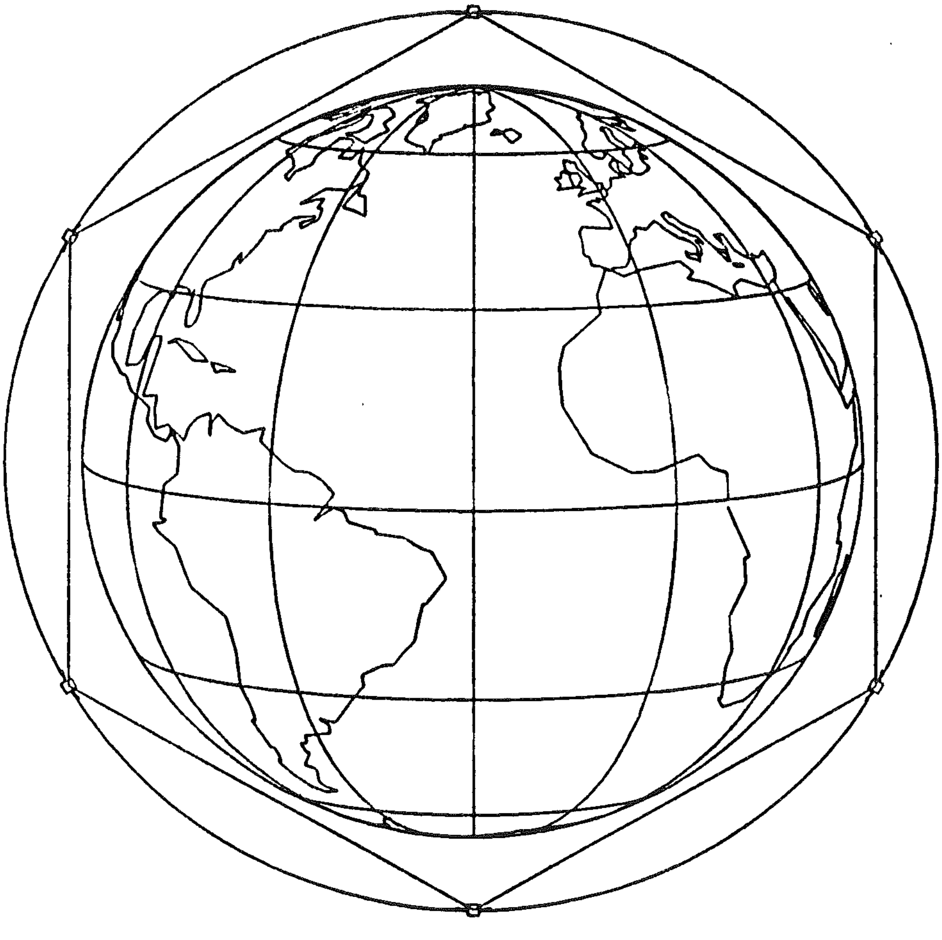


Figure 3: POLARCOM - Orbit Constellation

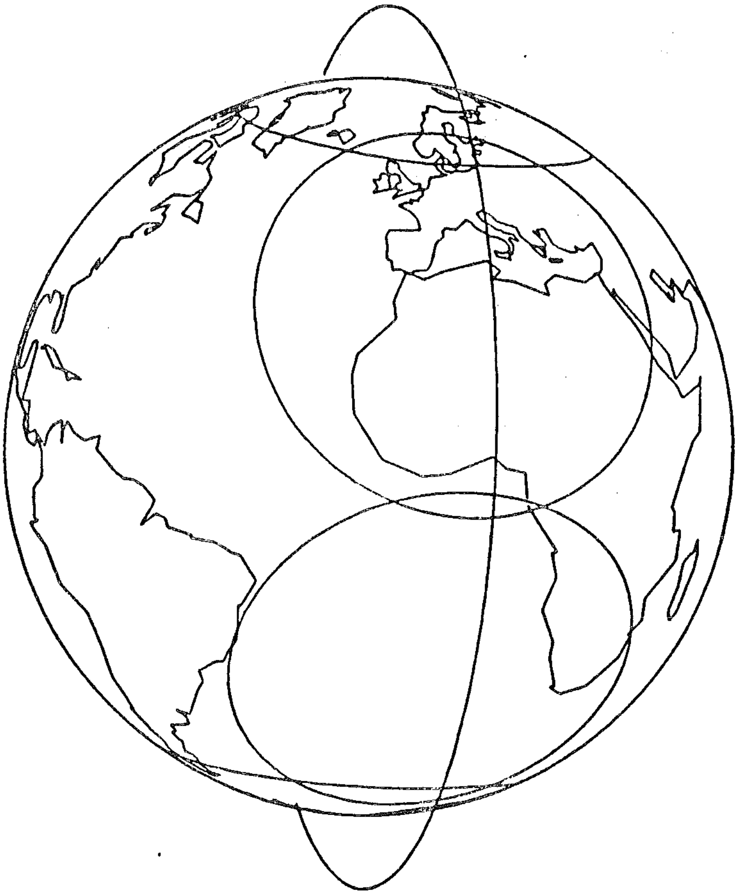


Figure 4: POLARCOM-3D Orbit and Visibility Areas

There is a low-cost launch possibility for Microsatellites and these orbits using the russian Cyclon-Meteor 3 launches which are scheduled for at least one launch per year until the year 2000.

Figure 5 shows the daily groundtrack of the orbit and figure 6 the simultaneous visibility of the 6 satellite constellation.

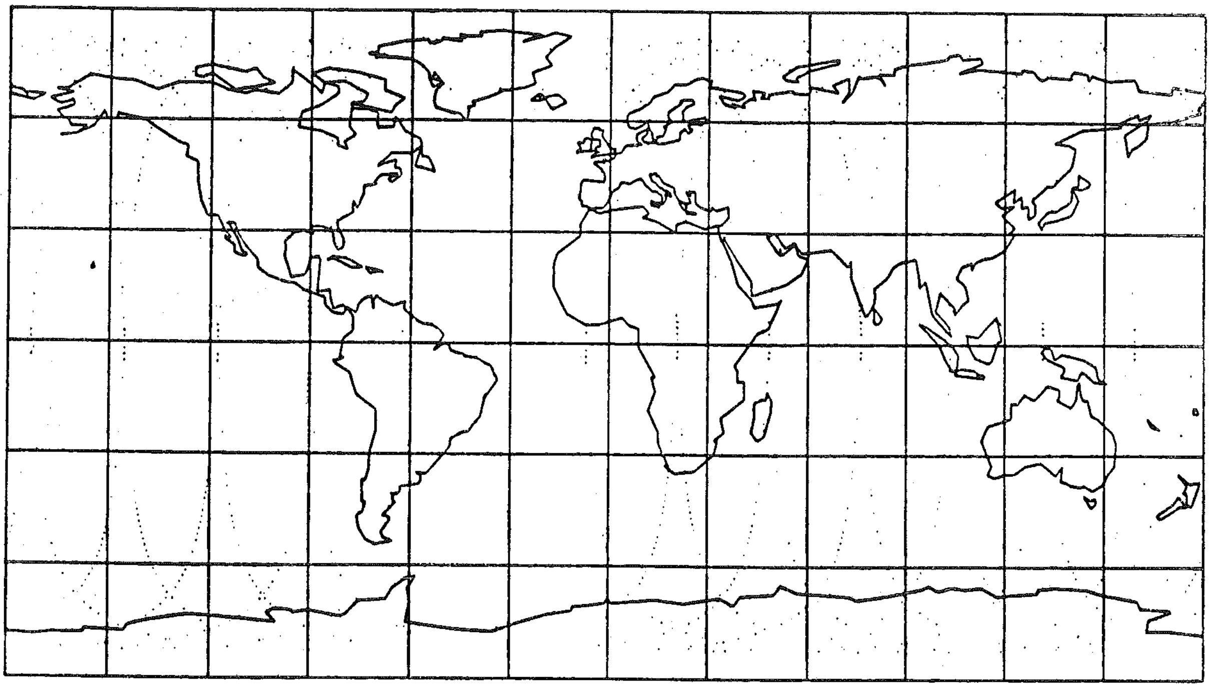


Figure 5: POLARCOM - Daily Ground Track

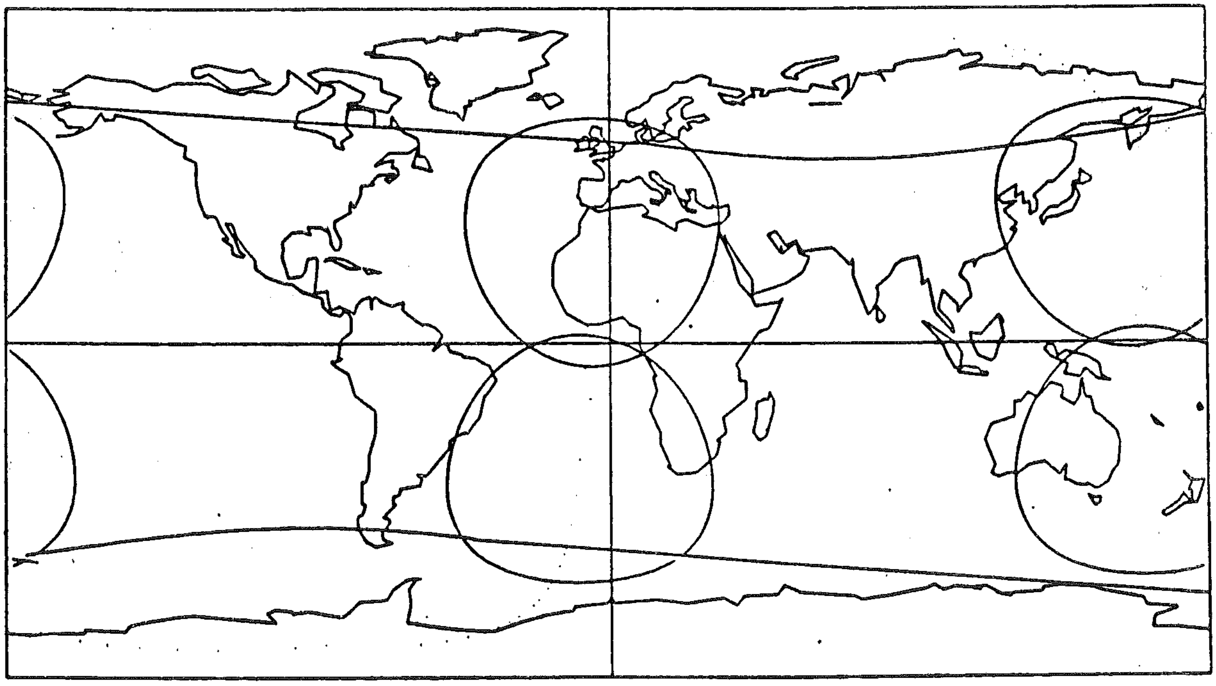


Figure 6: 6 Satellite Communication -
2D Simultaneous Visibility Areas

As it can be easily recognized this constellation provides continuous communication capability for groundstations within the arctic and antarctic areas and this can serve best the needs of inner-arctic expeditions (figure 7).

Figure 8 illustrates the quasi-simultaneous visibility zones of a 3 orbit sequence.

Taken into account that the revolution time of a satellite is equal to

$$T_u = 2\pi \sqrt{\frac{a^3}{\mu}} = 110.5 \text{ minutes}$$

There exist approximately 3 hours of continuous communication capability for any point on the earth with any Arctic or Antarctic location.

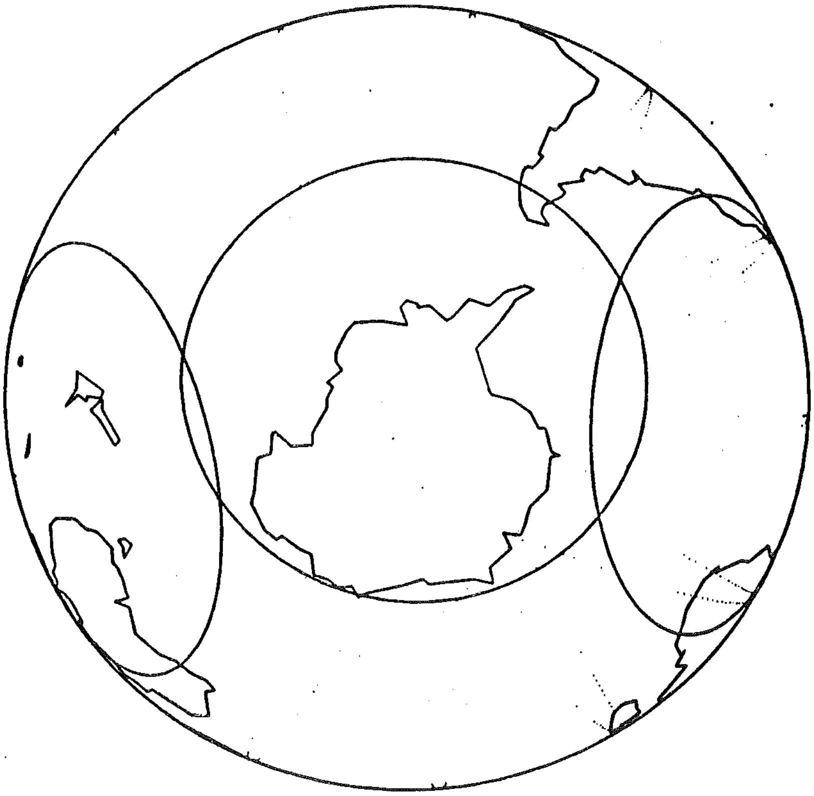


Figure 7: Visibility of the Antarctic

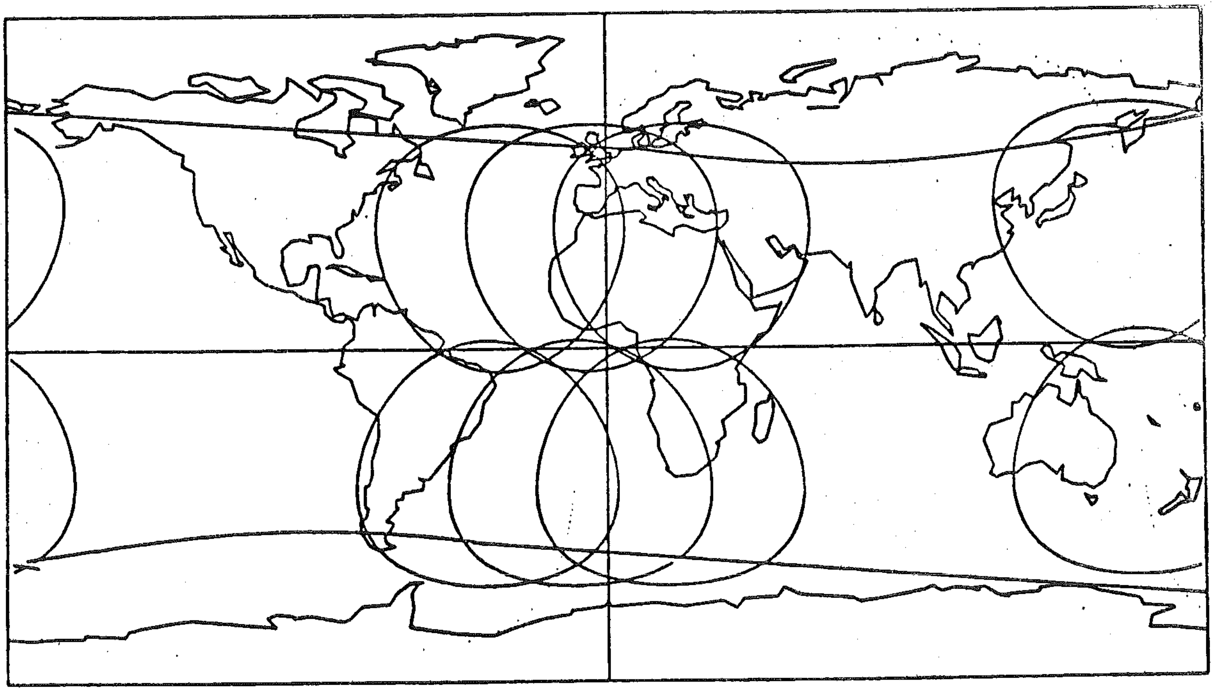


Figure 8: 3-Orbit Sequence

3. COMMUNICATION ACCESS AND LINK-BUDGET

The channel access scheme is illustrated in Figure 9. It is a time division multiplex (TDM) combined with slotted-Aloha access. This access scheme provides a very high system flexibility in order to transfer voice and data or emergency messages in two directions (receive/transmit) with a high degree on channel efficiency.

The satellite controls the channel access for all standard operations (i.e. data collection and telecommand of remote stations) via polling of every groundstation. After the satellite polling the groundstation can access the channel to transfer any type of information.

Between these addressed access interogations also unaddressed channel access interogations are transmitted regularly by the satellite, so that stations with unexpected events can also easily access the channel. This is especially important for emergency operations.

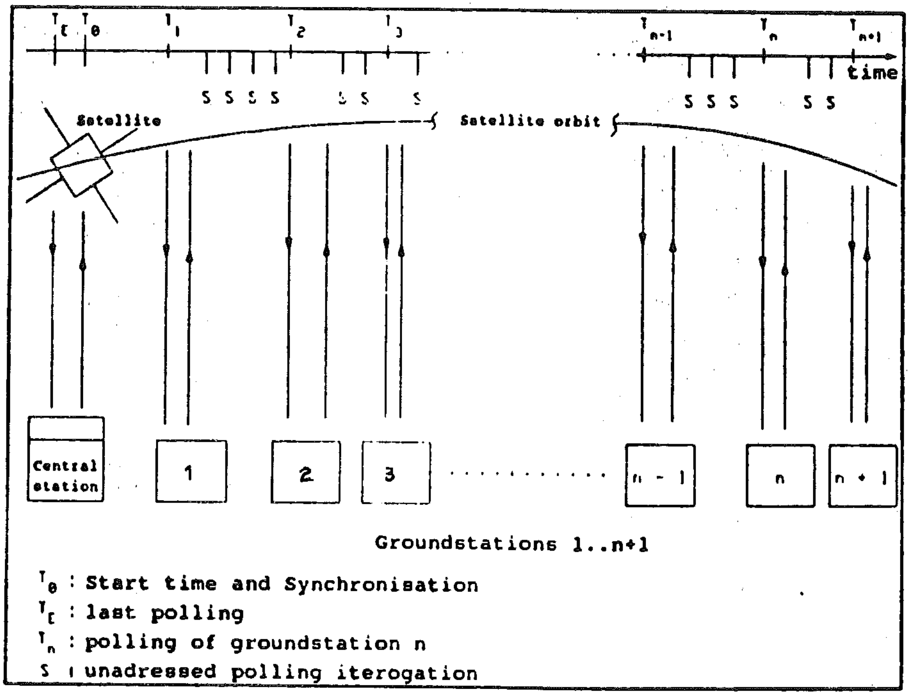


Figure 9: Channel Access Scheme

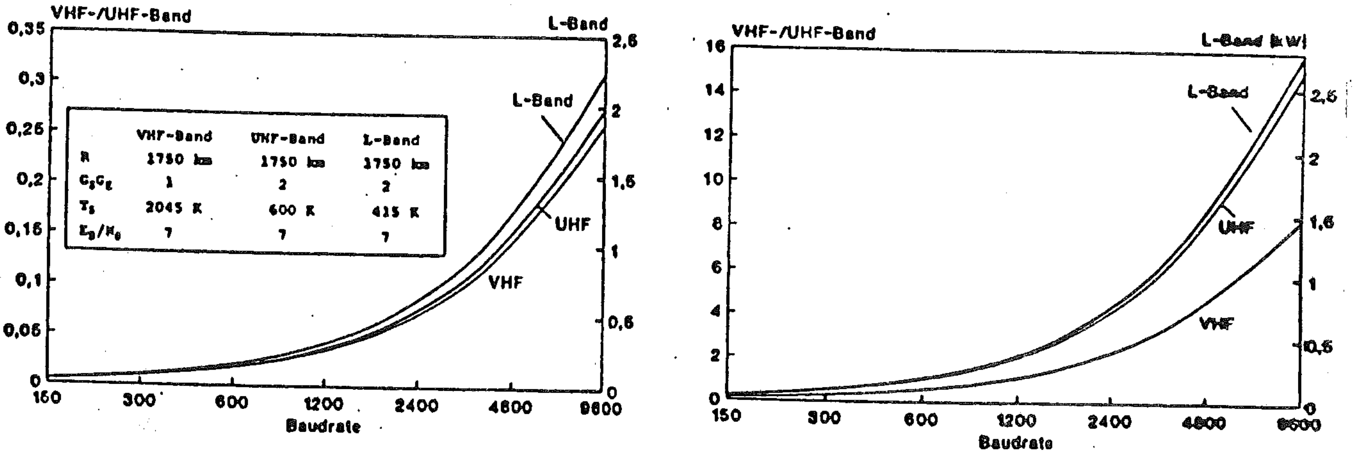
To keep the costs and the mass of the groundstations low it is very important to make the right choice for the communication frequency.

Figure 10 shows the required transmit power of groundstations using simply quasi-omnidirectional antennas for different communication bands.

It can easily be seen that only the VHF and UHF bands are able to provide a reliable communication link with low-cost and low-mass equipment. Therefore the VHF-band shall be used for this communication system. The WARC-regulations allow the use of:

- 148-150.0 MHz as up-link and
- 137-137 MHz as down-link.

Figure 11 shows the dimensions of a groundstation which could be used for voice and data communication as tested and used within the TUBSAT program of the Technical University Berlin.



	VHF-Band	UHF-Band	L-Band
R	1750 km	1750 km	1750 km
$G_S G_E$	1	2	2
T_S	2045 K	600 K	415 K
E_B/N_0	7	7	7

Figure 10: Required Transmit Power for Different Communication Bands

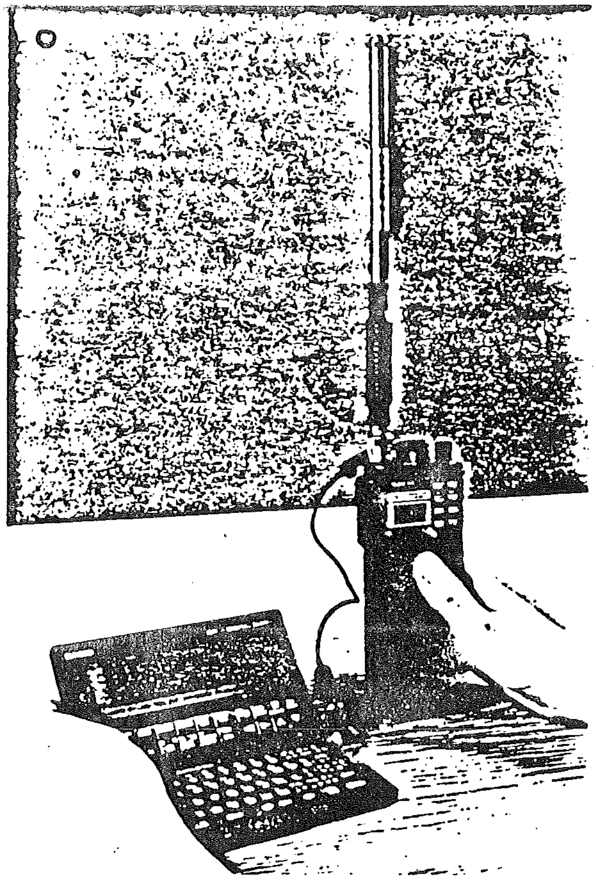


Figure 11: Typical Groundstation for Voice or Data Transmission (Source Techn. Univ. Berlin)

4. OPERATIONS AND COST

To keep the operation costs low the scheduling of the communication access and the payload operations should be done by one of the main system users. It has been shown in the past by several mostly university projects that this can be easily managed with a simple groundstation based on radio amateur equipment and a PC.

Also professional satellite operators have started to think about this type of solutions and very soon this equipment will also come in use for professional applications.

Taken into account that the costs including launch of a MICROSATELLITE are in the range of 1 to 2 million US$, the total system costs are in the range of 10 million US$ for the whole constellation and an operational time of 5 years.

5. CONCLUSION

It is shown that the communication capabilities for the arctic and antarctic community can be highly improved using the existing technical capabilities and reliable communication links established. If the total system costs are too high for a national organisation and exceed their funding capabilities, the system can be realized in cooperation with all interested organisations to keep the cost within the available ressources.

An experimental payload is planned to be launched as secondary payload on an existing satellite and operated by AWI.

Communications and the Antarctic Network

by

G.L.M. Hughes
British Antarctic Survey, U.K.

1. INTRODUCTION

1.1. ORGANISATIONAL STRUCTURE

British Antarctic Survey is a component body of the Natural Environment Research Council (NERC).

A central NERC Computing Service (NCS) provides a general purpose computing service in the UK.

BAS is directly responsible for the provision of computing facilities on its Antarctic Bases and Research Ships and for all communications between the Bases and the UK. Within BAS these services are provided by the Instrumentation and Systems Group.

BAS policy for computing has been set within the policy framework agreed for NERC as a whole.

1.2. NERC COMPUTING POLICY - 'DUAL ARCHITECTURE'

Some five years ago NCS proposed that computing throughout NERC should be based on a mixture of IBM and VAX/VMS systems. This became known as the NERC Dual Architecture Policy. This policy is again in the process of change. It is likely that a more distributed 'OPEN' approach will be adopted and that UNIX will play an increasingly important role. Present BAS computing policy was established within the agreed dual architecture framework.

1.3. THE BAS SINGLE 'USER-EYE' VIEW

BAS set itself the prime goal of making its scientists independent, in computing terms, of their geographical location. When on an Antarctic Base or a BAS operated Research Ship, we wanted them to be able to work in exactly the same way as they would when in BAS HQ. This meant establishing local facilities which had the same 'look and feel' as those in HQ. It also implied giving the scientist remote access to the major external computing facilities which they were in the habit of using from BAS HQ via the UK National Academic Network.

2. THE BAS COMPUTING MODEL

2.1. Within the constraints set by the Dual Architecture Policy it was decided that BAS computing should be based on central VAX/VMS facilities. These would be supported on an IEEE 802.3 (Ethernet) Local Area Network (LAN) and by single user MSDOS PC workstations. This model is now installed on RRS Bransfield, RRS James Clark Ross, and at Halley, Signy and Rothera Antarctic Bases. Recently, for specialist applications, SUN UNIX workstations have been installed on the RRS James Clark Ross and at BAS HQ.

3. BAS COMPUTING FACILITIES

3.1. BAS HEADQUARTERS

3.1.1. The central computing facility in BAS HQ comprises a VAX6410, a GPX Graphics workstation and numerous VAX3100 workstations all clustered on the Local Area network.

3.1.2. There are also some 200 PC single user workstations. At the present time most of these connect using terminal emulation through networked terminal servers. By the end of 1992 most of the PCs will be directly connected to the network.

3.1.3. There is one SUN UNIX workstation.

3.1.4 Predating the Ethernet LAN an X25 network was installed. This remains. It affords direct access to the UK Academic Network (JANET) and through gateways on this to other national and international networks.

3.1.5. On the BAS HQ LAN there is a MicroVAX II referred to as the 'Communications MicroVAX'. This is also a node on the Antarctic Wide Area Network (BAS WAN). It permits routing of traffic between the BAS HQ LAN and the Antarctic Network. BAS WAN connections to the Antarctic Bases and BAS Research Ships are via a voice channel on the communications satellite INMARSAT. This is a dial-up connection. INMARSAT charges are high compared to internal national telephone charges. Connections are therefore only made to the Bases when necessary. They are normally restricted to one per Base per day. Steps have been taken to ensure that the link is used as efficiently as possible and connect time is kept to a minimum.

3.2. BASE COMPUTING FACILITIES

3.2.1. In the interests of carrying through our single user eye view it follows that facilities on Base, although much reduced in capacity, are functionally very similar to those in Headquarters.

3.2.2. On all Bases and on the RRS Bransfield the central VMS facilities are provided on a MicroVAX II. On RRS James Clark Ross there is a VAX 4000 model 300. Also on the JCR there are three SUN workstations.

3.3. THE ANTARCTIC NETWORK

3.3.1. The first BAS Antarctic microVAX was installed at Halley Station during the 1987/88 season and has been used from the outset, among other things, for the transfer of scientific data to the UK.

3.3.2. The James Clark Ross went live in the summer of 1991. RRS Bransfield, Rothera and Signy Stations were added in 1991/92 field season. It is planned to bring Faraday onto the network in 1992/93.

3.3.3. In 1987/88 the capital cost of VAX computing equipment and software was very high. DECnet was the obvious choice for communications between VMS engines. The DEC proprietary lower level communications protocol DDCMP came bundled with VMS and DECnet at no extra cost.

3.3.4. The characteristics of an INMARSAT connection are that there is a significant time delay on the transmission of a data packet and, especially at the high latitudes in which BAS is operating, there is likely to be a high level of noise on the line. In these circumstances, if the link is to be used efficiently, a protocol which allows a number of packets to be transmitted before any are acknowledged and for many outstanding data packets to be accepted by a single acknowledgement packet is essential. DDCMP satisfied these criteria, it came at no extra cost. DECnet/DDCMP was therefore chosen as the basis of our Antarctic Network.

4. COMMUNICATIONS

4.1. In parallel with the introduction of enhanced computing facilities on Base we were looking at ways of reducing our overall communication costs. Until recently the bulk of BAS traffic to the Bases was carried on facsimile. Costs in 87/88 were of the order of £100K per annum, by 1991/92 they had risen to over £200K.

4.2. Having established the Antarctic network to support BAS science it made sense also to use it for all our normal communications between the Ships, Bases and BAS HQ. This we did by building a Message Handling System on top of VMS, VAX Mail and DECnet.

4.3. Since 1987 various commercial PC based communication systems designed specifically to use INMARSAT have emerged. These are kept under review. The use of our already established 'full function' computer network continues to give advantages over these dedicated systems.

5. THE MESSAGE HANDLING SYSTEM

The existing Message Handling System predated the establishment of a full Local Area Network in BAS HQ. Many of the potential users at that time, particularly in Administration were not computer users. The system was therefore designed as a direct replacement for facsimile. It was explicitly specified as a 'paper only' system. All messages were to be printed in a single central location, immediately and automatically deleted from the computing system. Paper copies were to be forwarded through internal mail to addressees with copies placed on circulating files and on a central register.

Automatic forwarding by Email has since been added. Other features eg encryption of medical confidential, electronic bulletin boards to replace circulating files, more detailed accounting statistics etc will be added at the next release.

5.1. MESSAGE PREPARATION

5.1.1. A user logs on to the central VAX.

5.1.2. He types the command SENDMSG, this invokes a BAS written set of procedures.

5.1.3. SENDMSG invites the user to choose the destination Base/Ship and enter the addressee's name.

5.1.4. It then automatically invokes the screen editor and invites the user to type his message.

5.1.5. When the message is complete the user exits from the screen editor.

5.1.6. The user is informed that the message has been sent and is invited to keep a copy.

5.1.7. The system allows messages to be interchanged with Antarctic Bases from any location which can access the BAS in-house VAX. This is itself a node on the UK Academic Network (JANET). As JANET has gateways to other national and international network direct communications with the BAS Bases is now possible from anywhere in the world.

5.2. MESSAGE TRANSMISSION

5.2.1. The message is automatically forwarded by VAX mail across the network to the Communications MicroVAX to an account which is explicitly related to the destination Base. This process is repeated for every message sent during any given day.

5.2.2. At 21.00 GMT a batch job on the communications MicroVAX is automatically submitted. This performs the following steps:

i) Separately for each Base all messages are extracted into a single file. Each message is uniquely identified by a message number created in accordance with a BAS convention for message numbering.
ii) The file is compressed using a standard data compression routine.
iii) The file is queued for transmission.

5.2.3. Similar procedures are executed on each Antarctic Base and Ship. The only exception is that Bases do not have dedicated communication machines. Messages are prepared on and transmitted from the same machine. At a designated time, between 22.00 and 04.00 GMT when INMARSAT charges are reduced, each Base connects in turn to the communications MicroVAX in BAS HQ. The compressed files are swapped and the link is immediately broken.

5.3. AUTOMATIC FORWARDING

Incoming files are de-compressed, printed centrally and, for those users who have registered to receive them electronically, forwarded by VAX mail. This is achieved by parsing the message header extracting the addressee's name and looking in a central database for the appropriate Email address.

5.4. INMARSAT COSTS

These procedures ensure that the expensive INMARSAT connection is maintained for the minimum possible time. DECnet has a fixed overhead. In practice we have found that the cost is constant up to about 40 kilobytes. Daily message schedules are usually less than this leaving scope for traffic levels to rise without current costs increasing. Cost savings compared to FAX are in the region of 50% to 80%.

6. SENDING FILES

6.1. PRE-PREPARED MESSAGE FILES

Pre-prepared message files, once they have been transferred to the central VAX, can be sent by issuing the command:

```
SENDMSG <FILENAME>
```

where <filename> is the name of the file to be sent.

It should be noted that by definition a message consists solely of ASCII characters.

6.2. SCIENTIFIC DATA FILES.

A separate system 'SENDDATA' has been produced to allow data files to be exchanged between Base and BAS HQ. The differences between SENDDATA and SENDMSG are:

2.1. Data files may contain binary data,
2.2. Data files are not registered or printed centrally. They are sent to a holding account on the central VAX. Concurrently a mail message is generated informing the recipient that the data file has arrived. A second command 'BASCOPY' which transfers incoming data files from the holding account to the user account, changing the ownership in the process, has also been provided.

From time to time very large scientific datasets are transferred. These may require an hour or more of connect time. As the transmission is carried as a file transfer on a DECnet link other network activities may be conducted concurrently. Advantage is therefore taken of these long data transmissions for interactive sessions on the Base computer to be run from Cambridge. This allows the experts in Cambridge to assist with system management tasks on the Base machines. As all 'thinking time' is utilised by the transmission of the scientific data such interactive sessions do not significantly extend the overall connect time and therefore may essentially be considered to be free.

7. FUTURE DEVELOPMENTS

7.1. It is intended that, by the end of 1992, virtually all PCs in BAS HQ will have direct network (as opposed to terminal emulation) connection. It is intended that the Message Handling System will be front ended by a LAN based mail system rather than by VAX mail as at present.

7.2. The preparation of messages will be transferred from the VAX screen editor to the 'standard' BAS word processor WordPerfect.

7.3. SENDMSG enhancements will include such things as:

i) encryption of confidential messages,
ii) classification of messages by Base and subject
iii) posting of messages to electronic bulletin boards, again classified by Base and subject, these will replace paper circulating files,
iv) production of additional costing statistics,
v) use of document scanners to produce images of line drawings etc, transmission and output to laser printer, will give functionality of high resolution, error free facsimile.

7.4. To give tighter control over spending on communications it is likely that, rather than the present system of a single large central budget, individual scientific cost centres will be given fixed annual allocations to cover Antarctic communications. It is intended that every individual message will carry a calculated cost for transmission and running totals against cost centres will be maintained.

7.5. HF telex will be integrated with the VAX based messaging system. This will be achieved by implementing a 'hold-and-forward' facility on Base VAXes. The HF telex will be controlled by a PC which will be networked to the VAX. A pilot scheme is in operation between Signy and Bird Island Bases.

8. COMPUTING POLICY DEVELOPMENT

8.1. NERC is committed to move into OPEN computing and to adopt a more distributed approach. It is likely that UNIX will play an increasing role especially for those sites which originally chose the IBM option within dual architecture.

8.2. UNIX systems are now being added where specialist applications or price/performance demands it. It is possible that UNIX will become the dominant operating system in BAS HQ and that VMS will be phased out. If this happens we will wish also to migrate Base systems nto UNIX and TCP/IP will replace DECnet/DDCMP as our wide area network protocol.

9. COMMUNICATIONS DEVELOPMENTS

It is not yet clear where the commercial market place will take us. It is possible that at some time in the future our network connection will move from INMARSAT to some other system. We are, for example, maintaining a watching brief on Motorola's Project Iridium.

10. CONCLUSION.

BAS has established computing facilities on the Antarctic Bases which mirror those available in BAS HQ. All Bases and HQ can link to form a wide area Antarctic network. Communications traffic has been transferred to this network resulting in significant cost savings.

Regardless of how BAS computing policy develops in the future we are committed to maintaining total compatibility between Base and HQ computing facilities.

Regardless of how commercial worldwide communications develop we are committed to maintaining 'full function' network links to all Antarctic Bases and Research Ships. For the foreseeable future these will continue to carry all our routine communications traffic.