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NAVAL ARCTIC MANUAL

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CHAPTER	RECORD OF RESERVATIONS BY NATIONS
All	USA
Chapter 9 and 16	USA Comment

RECORD OF RESERVATIONS / COMMENTS (Cont'd)

NATION	RECORD OF RESERVATIONS BY NATIONS
USA	USA Navy implementation plan includes the US Marine Corps
USA	a. Discussion in Chapters 9 and 16 for prevention and treatment of cold water immersion injuries is necessary. NATO forces should acquire proper anti-exposure gear for sailors. b. The use of cotton clothing is unsuited for cold, wet weather. Alternatives include: 1. Ship-based operations: Navy issues one-piece anti-exposure suits for deck use. 2. Shore-based operations: Extended Cold Weather System (ECWS), 2nd generation, is the standard and includes polypropylene, fiber pile and Gore-Tex layers. FM21-15 is the Army reference. c. This agreement covers the U.S. Air Force, Army, Marines and Navy.

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TABLE OF CONTENTS

CHAPTER 1 - THE ARCTIC ENVIRONMENT

101 General Description 1-1
102 Limits of Arctic Lands 1-3
103 Permafrost and Terrain 1-3
104 Permanent Land Ice 1-5
105 Beaches and Cliffs 1-8
106 Details of Coastaltopography 1-9

CHAPTER 2 - CLIMATE

201 Introduction 2-1
202 Air Pressure 2-3
203 Principal Tracks of Cyclones and Synoptic Systems 2-6
204 Wind 2-7
205 Temperature 2-7
206 Fog and Visibility 2-9
207 Cloud 2-10
208 Precipitation 2-10

CHAPTER 3 - OCEANOGRAPHY

301 Definition 3-1
302 Bathymetry 3-1
303 Water Masses 3-3
304 Currents 3-4
305 Advection Boundaries 3-6
306 Western North American Waters 3-8
307 Eastern North American Waters (North of a Line, Resolution Island - Kap Farvel) 3-8
308 Northeast Atlantic Waters 3-11
309 Eurasian Coastal Waters 3-14
310 Eastern Siberian Coastal Waters 3-16
311 Central Polar Basin 3-17
312 Arctic Ocean Fronts 3-23

CHAPTER 4 - SEA ICE

401 Introduction 4-1
402 Ice Formation 4-3
403 Structure and Properties of Sea Ice 4-3
404 Annual Ice Cycle 4-4
405 Occurrence of Sea Ice 4-5
406 Ice Forecasting 4-5
407 Other Ice Encountered at Sea 4-6

CHAPTER 5 - GENERAL PREPARATIONS FOR ARCTIC OPERATIONS

501 General 5-1
502 Topside Preparations 5-1
503 Ship's Boats Preparation 5-3
504 Mooring Lines and Anchor Gear Preparations 5-4
505 Engineering Preparation 5-4
506 Towing Considerations 5-6
507 Ice Preparations/Considerations 5-6
508 Cargo Handling Considerations 5-7

TABLE OF CONTENTS

CHAPTER 6 - HULL, ENGINEERING AND ELECTRICAL

601 Cold-Weather Preparations 6-1
602 Exposed Piping and Scuppers 6-1
603 Hull Damage and Repair in the Ice 6-1
604 Stowage Space Requirements 6-2
605 Fresh Water Supply 6-2
606 Salt Water Supply 6-2
607 General Instructions For Machinery 6-3
608 Exposed Equipment 6-3
609 General Instructions 6-3
610 Insulation 6-4
611 Gas Cylinders 6-4
612 Batteries 6-4
613 Ship Cold Weather Soaking 6-5
614 Yellow Gear 6-6
615 Underway Replenishment 6-7

CHAPTER 7 - COMBAT SYSTEMS

701 Cold-Weather Preparations 7-1
702 Fire Control Radars 7-3
703 Recoil Mechanisms 7-3
704 Aircraft Guns 7-3
705 Gun Sights and Aircraft Fire Control Equipment 7-4
706 Bomb Sights and Bomb Directors 7-4
707 Ammunition 7-4
708 Lubricants 7-4
709 Torpedoes and Torpedo Tubes 7-4
710 Minesweeping Gear 7-5

CHAPTER 8 - ELECTRONICS AND CHARACTERISTICS OF ELECTRONIC EMISSIONS

801 General Requirements 8-1
802 Exposed Electronic Equipment 8-1
803 Cold-Weather Preparations 8-2
804 Care of Equipment in Low Temperatures 8-4
805 Underwater Electronic Equipment 8-4
806 Portable Power Sources (For Electronic Equipment) 8-4
807 Maintianance (Personnel Precautions) 8-5
808 Communication Characteristics 8-5
809 Arctic Anomalies 8-6

CHAPTER 9 - PERSONNEL

901 Introduction 9-1
902 Training/Preparation 9-1
903 Food and Water 9-1
904 Cold-Weather Clothing 9-1
905 Personal Welfare 9-3
906 Frostbite 9-3
907 Treatment of Frostbite 9-5
908 Immersion Foot 9-6
909 Hypothermia 9-7
910 Snow-Blindness 9-8

NATO-UNCLASSIFIED

TABLE OF CONTENTS

911 Hypoxia 9-8
912 Carbon-Monoxide Poisoning 9-8
913 Avoiding Cold-Weather Injuries 9-8
914 Dehydration 9-9

CHAPTER 10 - GENERAL OPERATIONS

1001 Ice-Breakers 10-1
1002 Ships 10-1
1003 Air-Cushion Vehicles 10-2
1004 Diving 10-2

CHAPTER 11 - SHIP HANDLING IN ICE AND ICE SEAMANSHIP

1101 Introduction 11-1
1102 Non-Ice-Strengthened Ships 11-1
1103 Indications of Ice 11-1
1104 Signs of Open Water 11-1
1105 Icebergs 11-2
1106 Entering the Ice 11-3
1107 Speed of Ships Working in Ice 11-3
1108 Working Through Ice 11-4
1109 Convoying in Ice 11-5
1110 Types of Convoy 11-5
1111 Distance Between Ships 11-6
1112 Course and Speed of Convoy 11-7
1113 Conducting Through Ice 11-7
1114 Signalling Between Ice-Breakers and Escorted Ships 11-8
1115 Stopped Ice-Breaker - Red Warning Lights and Sound Signal 11-8
1116 Breaking Out Ships 11-9
1117 Replenishment in Ice 11-9
1118 Anchoring 11-9

CHAPTER 12 - ARCTIC NAVIGATION, NAVIGATIONAL AIDS AND PILOTAGE

1201 General 12-1
1202 Charts and Sailing Directions 12-1
1203 General Reference Books 12-1
1204 Chart Projections 12-1
1205 Polar Grid 12-2
1206 Magnetic Compasses 12-3
1207 Gyro-Compasses 12-4
1208 Azimuths 12-4
1209 Celestial Compasses 12-4
1210 Dead Reckoning 12-4
1211 Astronomical Observations 12-5
1212 Sunrise, Sunset and Twilight Phenomena 12-5
1213 Abnormal Refraction 12-5
1214 Echo-Sounder 12-6
1215 Electronic Aids To Navigation 12-7
1216 Radar As a Fixing Aid 12-7
1217 Radar and Sonar for Ice Detection 12-8

TABLE OF CONTENTS

CHAPTER 13 - ARCTIC AVIATION

1301 Introduction 13-1
1302 Air Navigation 13-1
1303 Instruments 13-2
1304 Electronic Equipment 13-2
1305 Electrical 13-3
1306 Servicing Aircraft in Cold Temperatures 13-3
1307 Refuelling 13-3
1308 Oil Replenishment 13-4
1309 Cold Starting Piston Engines 13-4
1310 Engine Lubrication 13-4
1311 Piston Engine Shut-Down and Restarting 13-5
1312 External Heating 13-5
1313 Propellers 13-5
1314 Cold Starting Jet Engines 13-5
1315 Low-Temperature Fuel Combustion 13-6
1316 Airframes 13-6
1317 Flight-Deck Preparations 13-7
1318 Flight Operations 13-8
1319 Pre-Flight 13-8
1320 Preparation for Flight 13-9
1321 Anti-Icing/De-Icing 13-9
1322 Rotary-Wing Aircraft Operations 13-10
1323 Fixed-Wing Ski Operation 13-10

CHAPTER 14 - SUBMARINE AND ANTISUBMARINE OPERATIONS

1401 Material Readiness 14-1
1402 Under-Ice Procedures 14-2
1403 Preparations for Surfacing in Pack-Ice 14-2
1404 Surfacing Techniques 14-3
1405 Diving in An Ice Area 14-4
1406 Detection Capabilities 14-4
1407 Ambient Noise in the Arctic 14-4
1408 Acoustic Signal Propagation 14-5
1409 Shallow Water Limitations on Submarines 14-7

CHAPTER 15 - AMPHIBIOUS OPERATIONS IN THE ARCTIC

1501 Introduction 15-1
1502 Marginal Ice Areas 15-1
1503 Marginal Ice Operations 15-2
1504 Low Surf and Swell 15-2
1505 Effects of Terrain on Amphibious Assaults 15-2
1506 Effects of Climate and Weather 15-3
1507 Air Operations Considerations 15-4
1508 NBC Operations 15-5
1509 Shipboard Considerations 15-6

NATO-UNCLASSIFIED

TABLE OF CONTENTS

CHAPTER 16 - SURVIVAL

1601 Introduction 16-1
1602 Cold 16-1
1603 Person Overboard 16-2
1604 Abandon Ship 16-2
1605 Immersion Suits 16-2
1606 Helicopter Survival Equipment 16-3
1607 Emergency Aircraft Landings in the Arctic 16-3
1608 Ocean Survival 16-7
1609 Carbon-Monoxide Poisoning 16-8
1610 Dangerous Arctic Animals 16-8
1611 Wintering In 16-8

Annex A - Conversion Charts A-1

Annex B - Glossary of Ice Terms B-1

Annex C - Example Cold Weather Bill C-1

Annex D - Battery Maintenance, Equipment Safety and Chemicals Battery Maintenance D-1

Annex E - Arctic Ocean Plotting Chart E-1

List of Effective Pages LEP-1

LIST OF FIGURES

Figure 1-1 Boundaries of the Arctic and Subarctic Environments 1-4
Figure 1-2 Chamberain Glacier Entering Wolstenholme Fiord (Northwest Greenland) 1-7
Figure 1-3 Contemporary Arctic Glaciers (Shaded areas are glaciated) 1-9
Figure 1-4 Ice--Shove Ridges, Nansen Sound, Northern Canada 1-10
Figure 1-5 The Labrador Coast 1-10
Figure 2-1 Observing Stations 2-2
Figure 2-2 Mean Sea-Level Pressure-January 2-4
Figure 2-3 Mean Sea-Level Pressure – July 2-5
Figure 2-4 Principal Tracks of Cyclones-January 2-6
Figure 3-1 Arctic Ocean: Bathymetry 3-2
Figure 3-2 Composite Surface Circulation 3-5
Figure 3-3 Composite Atlantic Layer Circulation 3-7
Figure 3-4 Water Masses--Norwegian and Adjacent Seas 3-15
Figure 3-5 Physiographic Regions of the Arctic Ocean and Adjacent Seas 3-19
Figure 3-6 Topographic Profile Across the Arctic Ocean 3-20
Figure 3-7 Earthquakes in the Arctic, January '55--March '64 3-22
Figure 3-8 General Position of Ocean Fronts 3-28
Figure 3-9 Fronts in the Norwegian Sea 3-29
Figure 4-1 Floe Size 4-2
Figure 4-2 General Pattern of Ice Movement in the Arctic Ocean 4-7
Figure 4-3 Egg Code Symbology 4-8
Figure 4-4 (Sheet 1 of 6) Summer Ice Limit Charts 4-9
Figure 4-5 (Sheet 1 of 3) Winter Ice Limit Charts 4-15
Figure 4-6 General Drift Pattern of Atlantic Icebergs 4-18
Figure 4-7 Pacific Ocean Icebergs 4-19
Figure 5-1 The Most Recent Nomograms (Overland et al. 1986) 5-11
Figure 12-1 Polar Grid Navigation 12-2
Figure 14 1 Propagation Loss ill the Greenland Sea 14-8
(April) 14-8
Figure 16-1 Survival Chart 16-1

LIST OF TABLES

Table 1-1 Arctic Land Environment 1-3
(by political units) 1-3
Table 2-1 Observing Station Location 2-3
(See Figure 2-1) 2-3
Table 2-2 (Sheet 1 of 3) Arctic Region Weather Trends 2-12
Table 3-1 Temperature and Salinity Characteristics of the Water Masses
of the European and American Arctic and Subarctic Seas 3-14
Table 5-1 Ice Removal Equipment 5-9
Table 5-2 De-icing Materials 5-10
Table 16-1 Wind - Chill Temperatures Chart (°C) 16-4

PREFACE

Naval operations in high latitudes provide unique challenges to planning, seamanship, ingenuity, endurance, and foresight. The elements, always dangerous, become hostile. Mountainous seas, storm-force winds and near-zero visibility for days on end put tremendous strain on men and material.

The Arctic has been defined in a variety of ways. For naval considerations, it is considered to be the area surrounding the geographic North Pole consisting of a deep central basin; the peripheral shallow seas (Bering, Chukchi, East Siberian, Laptev, Kara, Barents, and Norwegian); ice-covered portions of the Greenland and Norwegian Seas; Baffin Bay, Canadian Archipelago, Seas of Japan and Okhotsk; the continental margins of Canada and Alaska; and the Beaufort Sea.

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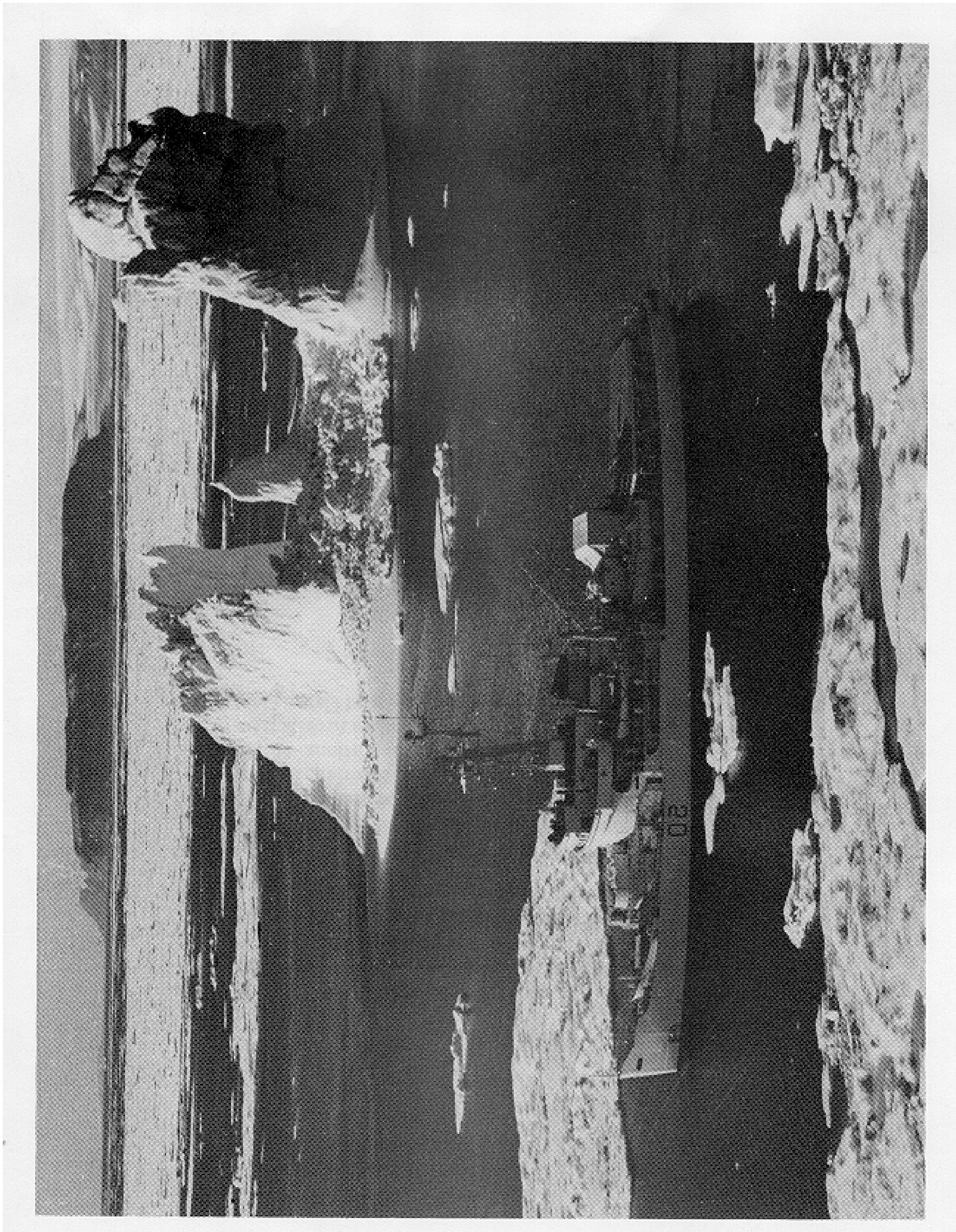

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CHAPTER 1

THE ARCTIC ENVIRONMENT

101 GENERAL DESCRIPTION

1. For the purposes of this manual, the term "Arctic" will be used to indicate the terrestrial basin which is filled by the Arctic or Polar Ocean. "Arctic" will also include the seas contiguous to the Arctic Ocean, shores surrounding these seas, and in some cases the navigable rivers which flow into these seas and the Arctic Ocean. The criteria commonly used for defining the Arctic regions are discussed below.

2. The word Arctic is a derivation of the Greek word "Bear", which connotes that area lying under the "Big Dipper". Astronomically it is the whole area lying north of 66° 33' N (the Arctic Circle). If this definition is used, some areas of temperate climate are included and some areas of very intemperate climate excluded.

3. Some scientists have suggested that the boundary of the Arctic be defined northward of the isotherm in which the average temperature of the warmest month is below 10°C. This closely coincides with the tree-line. Because it is peculiarly a polar phenomenon, the auroral zone has also been advanced as a criterion for a geophysical definition of the Arctic. The Aurora Borealis, observed in high latitudes as a luminous circumpolar feature, is centred about a point where the geomagnetic pole intersects the earth surface, and its zone of maximum frequency of occurrence can extend south as far as Fort Churchill.

4. The US Army's definition, accepted by the quadripartite countries, is: that portion of the northern hemisphere characterized by having an average temperature of less than 0°C and an average temperature of the warmest month of less than 10øC. This roughly coincides with the southern boundary of the zone of discontinuous permafrost.

5. Oceanographers consider the Arctic to be that region in which only pure "Arctic water" is found at the surface, at or near 0°C, and with a salinity of approximately 30 parts per thousand. This water is formed by a combination of:

   a. Water from the Atlantic and Pacific Oceans.

   b. Water drained from surrounding land areas.

   c. Water resulting from the melting of sea ice.

The most important feature is that this water flows out of the Arctic Ocean on the surface, along the east coast of Greenland, through the Arctic Islands, spreading over Foxe Basin and Baffin Bay, and is carried as far south as Newfoundland by the Labrador current. Using this as a criterion, a line can be drawn north of which all waters may be considered as Arctic waters and which encompasses much of the Subarctic and Arctic, but which excludes the northern coasts of Norway and the Barents Sea.

6. For the mariner, the most significant factors to be taken into account are latitude and the extent of the so-called "Arctic waters". For land operations, the line of discontinuous permafrost is the principal boundary to be considered (See Figure 1-1).

7. Over most of the Arctic, and in particular the Arctic Ocean, minimum winter air temperatures range between-45°C and-48°C, which is comparable to Winnipeg. The coldest temperatures in the northern hemisphere are found not in the Arctic but in the subarctic latitudes.

8. Generally speaking, throughout most of the Arctic (except in the coastal areas which come under the influence of maritime climatic systems), in Labrador, northern Norway and Kamchatka, precipitation is so low that "desert" conditions prevail. Precipitation falls during the summer months as a fine rain and is prevented from sinking into the ground by permafrost, the surface in summer can usually be found to be wet.

9. The main body of the Arctic Ocean is covered year-round with pack-ice which is continually on the move. It is due to this constant movement of the ice that, even in winter, coverage of the Arctic Ocean is not complete. Ice coverage in winter is about 90 percent, decreasing in the summer to 70 to 80 percent, and in some coastal areas even less. The fringing seas become in summer either ice--free or greatly reduced in ice concentration, with the exception of the northwest part of the Canadian Archipelago where the ice usually remains fast from coast to coast.

10. **Vegetation in the Arctic**

a. The vegetation of the Arctic falls into two main divisions in the Arctic and Subarctic: tundra and forest. Although the individual plant species involved may vary considerably from area to area, the type and form of vegetation is remarkably uniform, and it is this consistent association of vegetation with climate that makes it possible to speak of the Arctic as a single region in spite of all other variations.

b. The chief characteristic of the tundra is the absence of trees. Tundra comprises creeping shrubs, grass-like plants, and mosses. Several zones are recognized, grading from north to south, from almost barren ground to fairly dense growth with small shrubs several feet high.

c. The forest is the coniferous boreal or taiga, with larch (tamarack) and spruce as the dominant species in the Canadian Arctic, and a maximum of birch in the USSR. Generally speaking, the whole forest area is interspersed with low wetland, known in Canada as muskeg". By definition, muskeg consists of more than 15 cm of organic material overlying mineral soils". It may assume several forms such as "perched", "confined", or "continuous", and may include woody material (trees) up to 15 cm in diameter. These trees always develop a tuft at the top and are seldom more than 4 m in height; therefore, muskegs are readily recognizable in the wooded areas. Where muskegs have developed on permafrost, the trees may lean in all directions due to frost heaving. When in this condition, they are often referred to as "drunken forests", particularly in the USSR.

11. Generally speaking, in the Arctic, the tropopause (the level at which the fall of temperature with height ceases or reverses sign) is lower than in the tropics. The height of the tropopause varies seasonally in the Arctic from 7 km in February to 10 km in August. There is a sharp separation from the tropical tropopause at about 45°N and this separation is usually the region of the jet stream. The characteristics of the stratosphere above the Arctic tropopause are such that in winter a giant westerly vortex forms around the geographic pole, reaching maximum intensity in February and disappearing rapidly, forming in turn an equally vast but slow-moving easterly vortex in mid-summer. These features of the Arctic tropopause and stratosphere constitute yet another geographical definition of the Arctic, and one which is significant for certain operational requirements.

Table 1-1 Arctic Land Environment
(by political units)

	km2
Canada	3 100 000
Greenland	1 175 000
Iceland	105 000
Other North Atlantic Islands	62 000
Continental Scandinavia	18 000
USA (Alaska)	545 000
USSR	2 055 000

102 LIMITS OF ARCTIC LANDS

The core of the polar regions is conveniently defined as the lands and seas around the Polar Basin, itself centred roughly on the North Pole. When considering Arctic land areas alone, the southern limits of the Arctic are probably most usefully demarcated by the tree-line. Although this boundary is not ideal, particularly in mountainous areas, it marks a real break between the high winds (and wind--chill) and driving snow of the barren grounds, that are usually underlain by continuous permafrost, and the milder conditions prevailing in the forests to the south. When this definition is in effect, for physiographic purposes three northern countries - Canada - Greenland and the USSR - contain nearly 90 percent of the so-called Arctic Lands.

103 PERMAFROST AND TERRAIN

1. Mean annual air temperatures below-2°C lead to subsoil temperatures that are permanently below freezing point. If the ground beneath the annual surface thawing zone, known as the active layer, remains below freezing point for more than two years, permafrost conditions are said to prevail. Permafrost has an important influence on Arctic soils, land--forms and vegetation, and affects the whole pattern of life in northern areas.

2. Where mean annual air temperatures below -2°C prevail, permanently frozen ground is found everywhere except beneath the largest lakes and rivers. In general, above the tree-line, permafrost is continuous except in certain coastal areas. Continuous permafrost is therefore a phenomenon primarily of continental Arctic areas. Where winter temperatures in the Arctic average about -2°C, as they do in the Aleutians, Iceland, coastal south Greenland and northern Scandinavia, and in the sub-arctic forests, areas of permafrost are separated by unfrozen ground and the permafrost is said then to be discontinuous. This zone extends farthest south in the eastern interior of continents and approaches the Gulf of St. Lawrence in eastern Quebec, and northern Korea in East Asia. In Arctic continental areas, permafrost is commonly from 300-500 m deep. However, greater depths of up to 600 m have been found in the northern USSR and there is some evidence that permafrost may be up to 1500 m deep in a few Siberian areas.

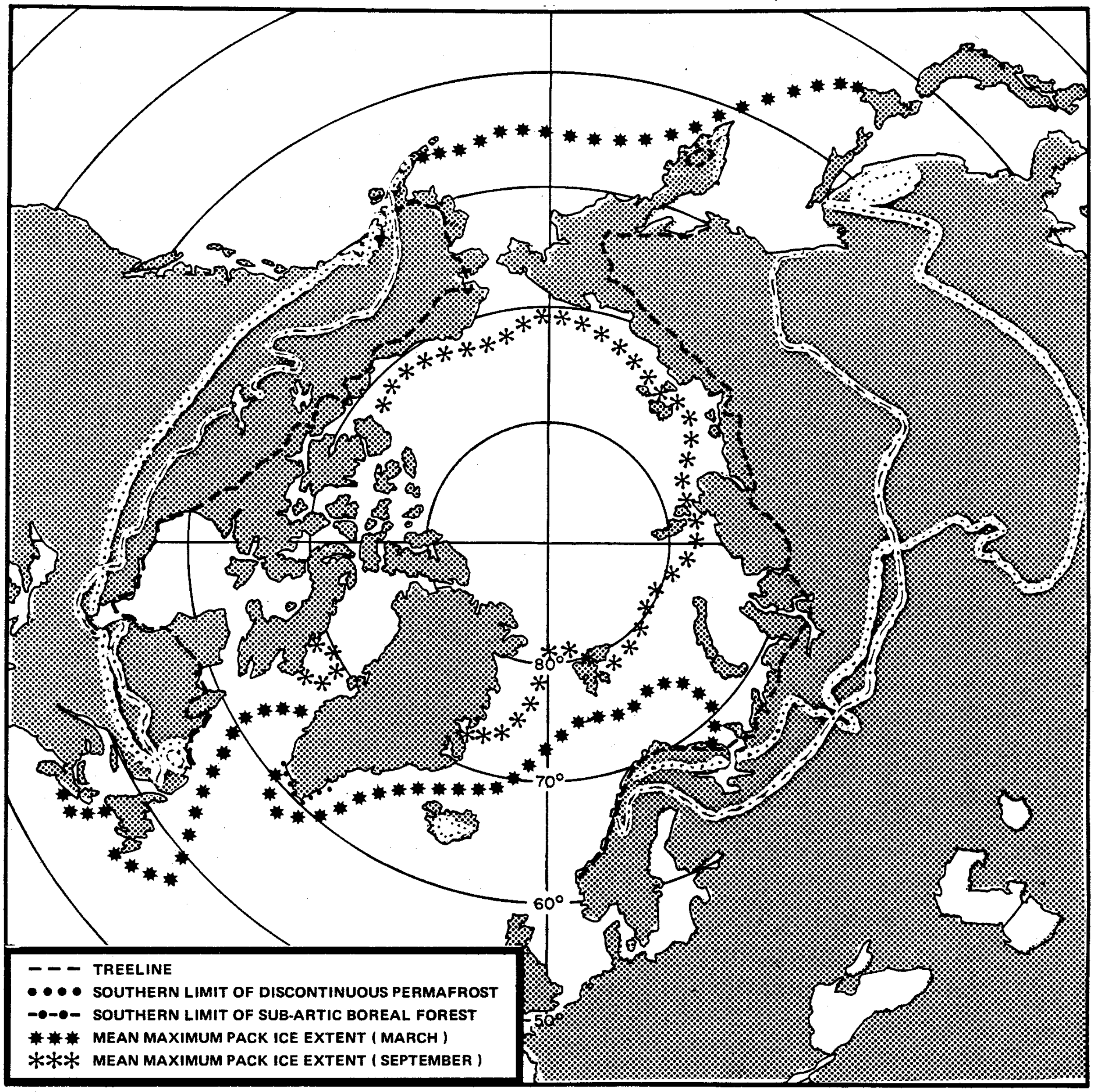

Figure 1-1 Boundaries of the Arctic and Sub-Arctic Environments

3. From an engineering point of view, the critical part of the permafrost is the active layer close to the surface where freezing and thawing occurs. It varies considerably in thickness and is dependent on site, exposure, soil drainage and vegetation. In the high Arctic at poorly drained sites, the active layer may be less than 10 cm, whereas near the southern margins of permafrost, in favourable localities, it may be 2 to 3 m thick at the end of the summer. The maximum depth of the active layer under most favourable conditions may be in excess of 4 m. The chief significance of this layer is that moisture content is often abnormally high, which creates serious problems for construction engineers and also, in some cases, completely inhibits summer ground mobility.

4. Many other landforms are found only in northern areas. One striking feature in these areas is the vast quantity of shattered bedrock lying on the surface and covering the valley sides. This broken bedrock results from frost shattering.

5. The presence of ground ice leads also to unusual landforms. Ground ice exists in most areas where there is permafrost, occurring as ice in the soil pores, and as veins, wedges and sheets. The most spectacular ground ice occurs on the coasts of central and eastern Arctic Siberia where massive occurrences of ice, up to 70 m in thickness, have been reported. Elsewhere in the Arctic, particularly in the presence of silts, and especially in deltaic areas, ice mounds may develop covered either by organic or by mineral soils. These mounds vary in height from a few centimetres to more than 50 m, and are known as "pingos". They are generally found in the Siberian river deltas, the Mackenzie delta, and the coastal plains of northern Alaska and Siberia.

6. If a change in the environment takes place resulting in the melting of the ground ice, hollows with uneven topography known as "thermokarst" form. Tundra ponds also develop when ground ice melts.

7. A conspicuous feature of the terrain in Arctic areas is the tendency for soils to develop regular textural patterns. The term "patterned ground" includes all such features that occur in vegetation and soils, on horizontal and on sloping ground. It is caused primarily by a complex process of sorting of the materials comprising the soil, due to the freeze--thaw cycle, or by the development of regular hexagonal patterns due to the thermal contraction of the active layer.

8. The surface layers of the soil often become supersaturated with water during the spring and summer, and movement (which may be perceptible through a period of a few days) may occur on gentle slopes. This phenomenon, known as solifluction, develops throughout the Arctic and results in patterns which are usually called "soil glaciers". In mountainous regions, features known as "rock glaciers" or "rock streams" sometimes occur, in which, instead of soil, boulders are in motion "lubricated" by ground ice or a mixture of soil and ground ice.

9. Heavy snowfall is not common in the Arctic and, indeed, exceptionally heavy snowfalls are restricted to mountainous and maritime areas. However, snow lies for long periods and has an important influence on northern terrains. The killing effect of the wind, on vegetation during the winter months, is reduced by a snow cover and in the southern Arctic the height of bushes is commonly controlled by the depth of the snowfall.

104 PERMANENT LAND ICE

1. Less than 5 percent of the Arctic lands are covered with permanent ice. (See Figure 1--3.) Greenland is the only area where glaciers totally dominate the land, and an ice sheet comparable to the great ice--caps of the glacial periods, 6000 to 12 000 years ago, survives. The main Greenland ice-cap is nearly 2400 km from north to south and is roughly 1100 km across at its widest. Beyond the confines of Greenland, the ice sheet has a significant influence on the climate of some of the northern circumpolar lands and is the main source of icebergs in the northern seas. It has been estimated that if

all the ice in the Greenland ice sheet melted, the level of the world's oceans would rise by 6.5 m. Greenland has the shape of an elongated basin surrounded by a mountain rim, which is highest and widest along the eastern side. The interior of the rock basin is close to sealevel on the average, while nearly a third of its total area (500 000 km2) is below sealevel. Inland from the coast the first hundred kilometres of ice is often crevassed and, particularly along the east coast, there are "nunataks" where the underlying mountains break through the ice sheet. Further inland the crevasses disappear and the smooth, gentle slopes of the icecap prevail. In the interior, the ice sheet reaches over 3000 m. Great ice streams flow from this source through gaps in the mountain walls to the sea. (See Figure 1--2.)

2. The distribution of the remainder of the glaciers in Arctic North America is closely related to topography and moisture supply. In Arctic Canada, glaciers occur plentiful north of Hudson Strait, and the most southerly icecaps occur geographically in three groups. The most southerly group (which are really semi-permanent snowfields) is in the Torngat Mountains of Labrador. Permanent ice is more plentiful north of Hudson Strait, and the most southerly icecaps occur on the uplands on both sides of Frobisher. Larger ice-caps, often completely submerging the underlying mountains, are found on Baffin Island north of Cumberland Sound, on Bylot lsland, East Devon Island, and in three southern sectors of Ellesmere Island.

3. A second group of Canadian glaciers are adjacent to the Arctic Ocean in northern Ellesmere Island and on Axel Heiberg Island. The third group consists of the four small icecaps on Melville Island. The remaining glaciers of Canada are found in the western mountain ranges and are not strictly in character.

4. In Alaska there is an important difference between the small number of Arctic glaciers of the Brooks Range and the Romanozov Mountains, and the vast glacier systems on the mountains adjacent to the Pacific Ocean, including the border ranges between Alaska and the Yukon, the Aleutian Range, and smaller glaciers of the Alaska Peninsula.

5. Snowfall is not as heavy on the northwestern side of the Pacific Ocean, and glaciers are restricted to the Kamchatka Peninsula.

6. The North Atlantic Ocean and the Norwegian Sea constitute a major source of moisture for Arctic glaciers in Scandinavia. This moisture is carried by the winds as far as north-central Siberia (the Urals), and wherever there is sufficient relief there are small icecaps. However, the mainland of the Russian Arctic outside the Urals has no permanent ice and neither do the eastern islands of northeastern Siberia, excepting Bennett Island. In Scandinavia, permanent ice is restricted to the highest land, normally in excess of 2000 m. The altitude of glaciation becomes progressively lower in a northeastward direction, until it is below 500 m on the Severnaya Zemlya Islands.

7. A large expanse of ice covers Iceland, where the largest glacier is Vatnajokull. The other large glaciers are all in the southeastern or central parts of the island. North of Iceland, Jan Mayen Island supports an icecap, but Bear Island farther northeast is much lower and has no permanent ice. There are numerous glaciers in Svalbard, and Northeast Land is largely covered with thin plateau ice. Other islands around the Barents Sea, including the northern third of Novaya Zemlya, Franz Josef Land and Severnaya Zemlya all carry large ice -caps.

Figure 1-2 Chamberain Glacier Entering Wolstenholme Fiord (Northwest Greenland)

105 BEACHES AND CLIFFS

1. Arctic littoral processes in ice-free summer months do not differ greatly from those in temperate latitudes. However, several distinctive processes are operative at break-up and freeze-up of sea ice.

2. Sea ice has, in general, a secondary role to waves as an agent in erosion, transportation, and deposition. With the onset of winter, when air temperatures drop below freezing, an ice shelf (storm-ice foot or ice rampart) commonly forms along Arctic beaches where there is a low tidal range. Water from storm waves and spray freeze on the beach, leaving layers of ice-cemented gravel and ice. Sand and gravel are often washed onto the developing ice shelf and become incorporated. This ice shelf "armour" protects the beach against subsequent wave action and ice-shove. If the pack-ice should move onshore early in the winter, shore-fast ice with adhering debris may be shoved inland onto the beach. (See Figure 1-4.)

3. During the winter, shore-fast ice and offshore ice stop all wave action. Pack-ice at break-up, and also later in the summer, may push onto the beach and even impinge against the sea cliff, if present. Ice moving onto a beach tends to act either as a plow or a raft. Where plowing occurs, the ice planes and pushes debris into mounds and ridges, usually below the upper limit of storm waves. Where rafting occurs, debris frozen and incorporated in the ice may be transported onto the beach, locally above the reach of storm waves. Usually, storm waves soon rework most of the transported material and, by freeze-up, little evidence of it is visible; however, in the high Arctic bays and channels that are permanently choked with ice, ice-pushed beach ramparts are a normal feature at the rear of beaches.

4. On coasts where the tidal range is considerable, boulder barricades are the most conspicuous sign of the action of sea ice. Typically there is a narrow string of boulders parallel to the shore and several hundred feet out. At low tide they are clearly visible above the water surface whereas at high tide they are submerged. They represent a navigational danger on the approach to many open beaches. Generally the depth of water increases rapidly beyond the boulder limit. The pushing and rafting of boulders by the moving sea ice that forms the boulder barricades is also responsible for the development of boulder-covered flats which are exposed at low tide near the heads of Arctic bays.

5. Cliffs of unconsolidated materials, which may rise to 30 m or more, front many miles of coast in the Pacific area. The frozen sea cliffs retreat by undercutting, thermal erosion and slumping. The greatest erosion occurs during storm surges. When there is a combination of a high water level and strong waves, the slumped debris at the foot of the sea cliff may be removed and a notch 1.5 to 4.5 m deep eroded into the cliff to produce an overhang in the frozen sediments, and this is followed by sediment failure and retreat of the cliff face. Thermal erosion may also produce glacier-like mud streams. Differential thermal erosion is particularly marked along coasts where large ice-wedges of tundra polygons are present. Gullies selectively etch out the ice-wedges to produce indentations or hanging valleys along the cliffs. In winter, the sea cliff and beach zone is an accumulation site for large snowdrifts which persist and protect the cliff foot in early summer. Rapid slumping from above may bury the snow-banks completely and some survive over the summer, thus adding additional protection to the cliff foot for a second summer season. The type of sediment in the sea cliff tends to be reflected in the number and size of adjacent beaches and bars. As a generalization, beach and bar formation diminishes directly with reduction of grain size; icy muds may have no associated beach and bar deposits.

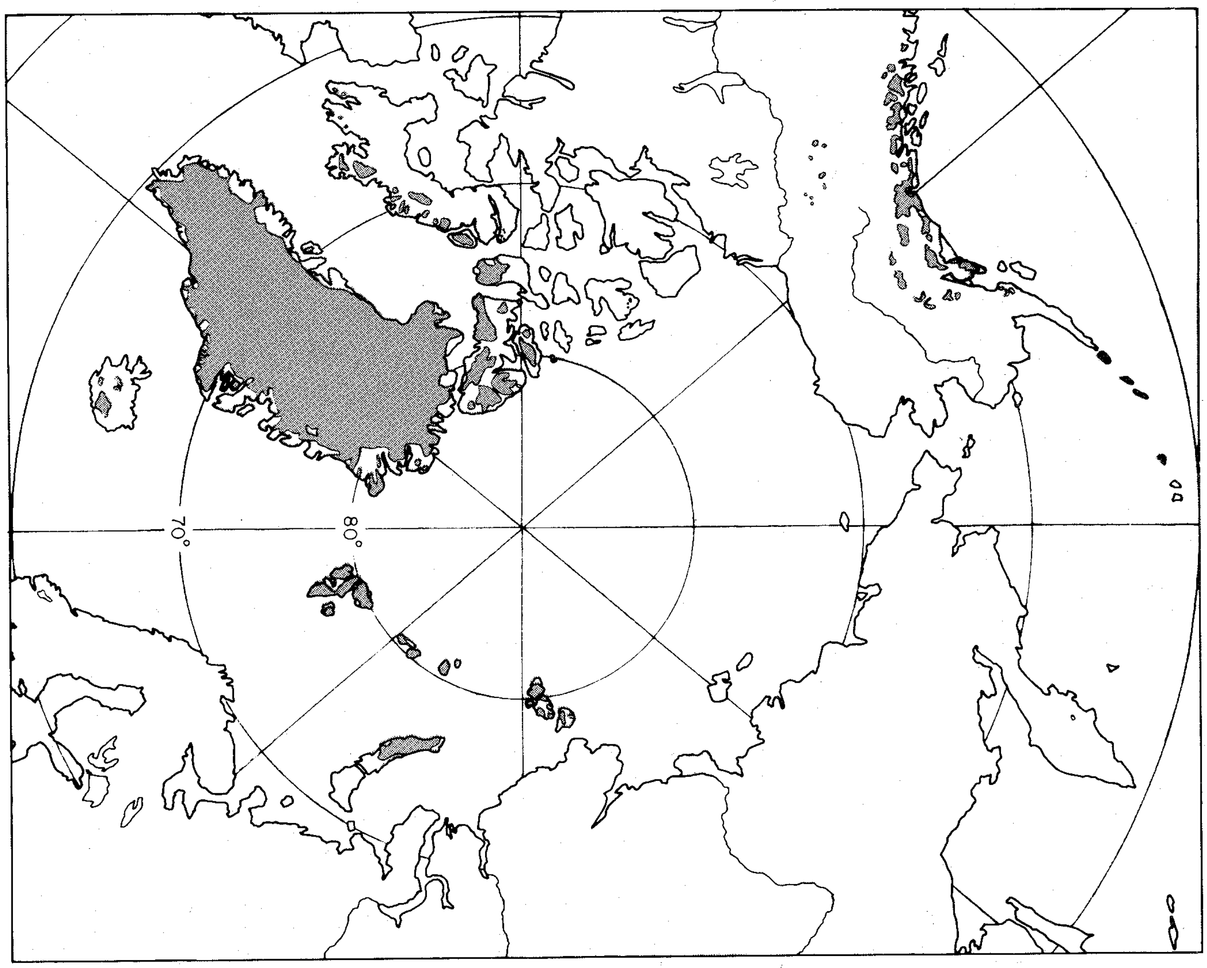

Figure 1-3 Contemporary Arctic Glaciers (Shaded areas are glaciated)

6. Offshore bars, bay-mouth bars, spits, tombolos, and other bar deposits are found along much of the Arctic coasts. This is to be expected where offshore depths are modest and the supply of debris from coastal recession and rivers is large. Offshore bars may parallel hundreds of miles of coast, being separated from the coast by a lagoon perhaps several miles wide. Spits build out where there are directional changes in the coast, in response to winds and currents. Driftwood and large logs may become stranded on these bars and spits.

7. The main characteristics of the shores of Baffin Bay, Greenland, Spitzbergen and Norway are the spectacular cliffs, which can be found in many sectors. (See Figure 1-5.). In the Precambrian Shield areas, the majority of cliffs are preglacial, or, in the case of fiords, of glacial origin. These cliffs show little evidence of strong contemporary erosion subaerially or by waves. In contrast, many of the cliffs in younger sedimentary and igneous rocks, particularly in Svalbard and Iceland, have developed massive postglacial scree slopes that are active today. In some parts of the Atlantic Arctic, notably Scandinavia, a rock platform that varies in width up to several kilometres separates the cliffs from the sea. This feature, known as the strandflat, may be drowned, thus forming a "skerry coast".

106 DETAILS OF COASTAL TOPOGRAPHY

Detailed descriptions of the Arctic coastline of the areas covered in this manual are contained in the appropriate Sailing directions.

Figure 1-4 Ice--Shove Ridges, Nansen Sound, Northern Canada

Figure 1-5 The Labrador Coast

CHAPTER 2

CLIMATE

201 INTRODUCTION

1. Knowledge of the Arctic climate and weather conditions has reached a fairly satisfactory state. Coastal and island stations have been in operation for a period long enough to give statistical information sufficient for a description of the regional climates. In addition, observing stations on ice islands or on the pack-ice itself have, since 1950, contributed greatly to increased understanding of the weather and climate over the Arctic Ocean. See Figure 2-1 and Table 2-1 for the locations of observing stations.

2. Since much of the northern land surface is of low elevation, there is little obstruction to free atmospheric flow between the middle latitudes and the Arctic. The areas of highest relief are Greenland, Ellesmere and Baffin Islands in Canada, the Brooks and Alaska ranges in Alaska, and the mountains of Scandinavia. The special and typical conditions met with in the Arctic are mainly those resulting from:

a. The distinctive regime of daylight and darkness together with low solar elevation which result in a prolonged period of radiational loss from the surface;

b. The high reflectivity of the surface as long as snow remains on the ground; and

c. The low moisture content of the air in winter in many areas of the Arctic, because of the ice cover on lakes and ocean.

3. The wetness, warmth, roughness, relief and albedo (reflectivity) of the earth's surface are among the major determinants of weather and climate. The stability of the air changes with the characteristics of the underlying surface. Cooling produces a stable stratification and a shallow layer of modified air, while heating from below steepens the temperature lapse rate and causes instability.

4. The roughness, texture, wetness and color of the Arctic landscape change little within each of the two seasons but vary markedly from summer to winter. The generally ice-covered Arctic Ocean is probably the most important of these surfaces, because of size alone (14 million km2), but the Greenland Inland Ice and the tundra lands of North America and Eurasia are also regions of active air mass modification in both seasons. Finally, smaller areas of permanent ice and snow cover exercise local influences. There are roughly 52 000 km2 of glaciers and icecaps in the USSR, 130 000 km2 in northern Canada, and 57 000 km2 in the Svalbard Archipelago.

5. The extension of polar sea ice is smallest in September, when it covers approximately 7.8 million km2, and greatest in March (approximately 15.6 million km2, or nearly 11 percent of the sea area of the northern hemisphere). The neighboring seas are also frozen in March. The Hudson Bay and Hudson Strait add nearly 1.3 million km2 to the ice-covered surface in winter, and the Bering Sea, Sea of Okhotsk, White Sea and the Gulfs of Bothnia, Finland and St. Lawrence form southern fringe areas of a snow- and ice-covered polar cap. Thus the polar cap extends south of 60øN everywhere except in the North Atlantic region, and in the Norwegian and Barents Seas where Atlantic water enters the Polar Basin and submerges to form the intermediate layer of Atlantic water in the Arctic Ocean.

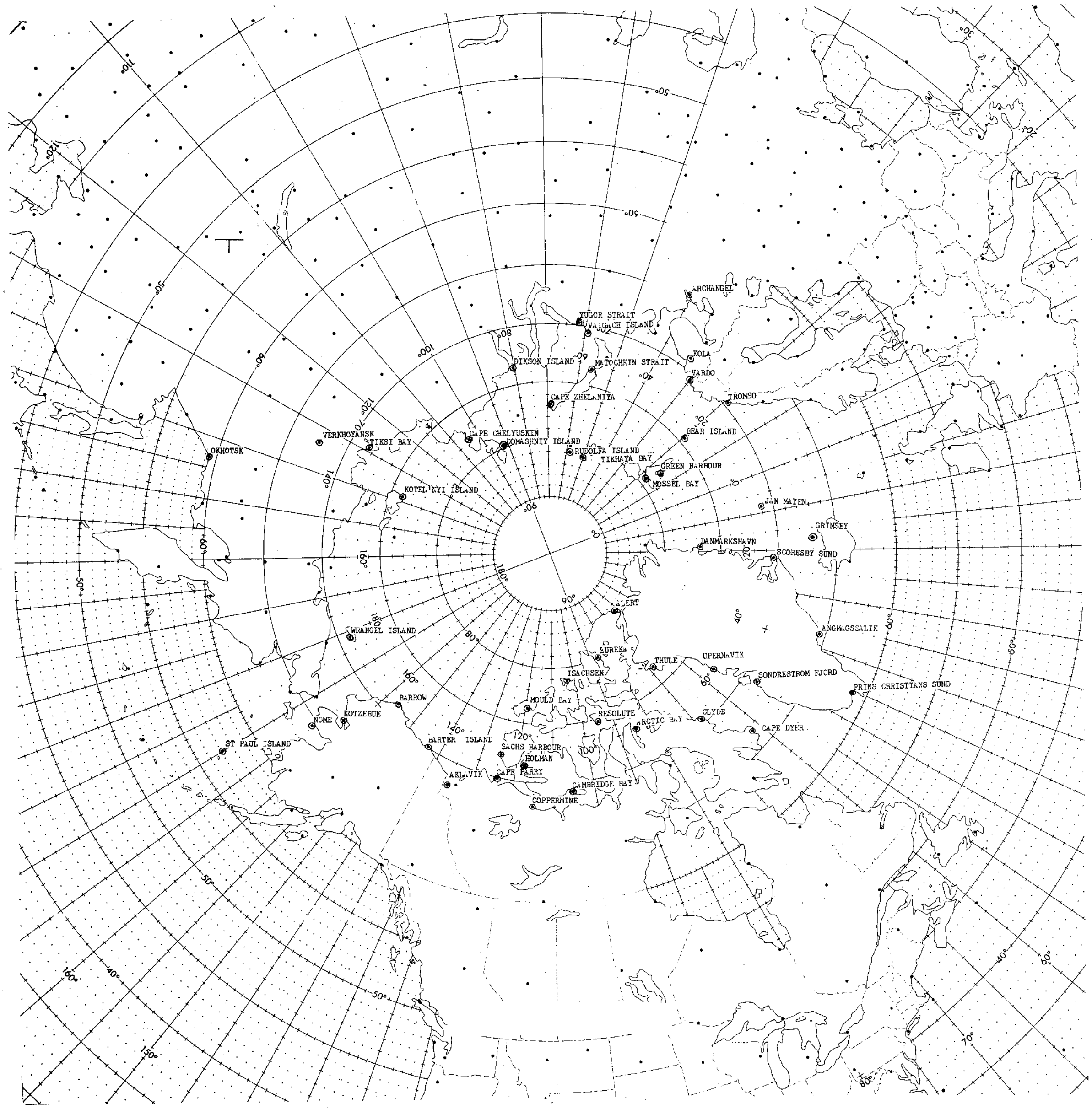

Figure 2-1 Observing Stations

Table 2-1 Observing Station Locations
(See Figure 2-1)

Station	Latitude	Longitude	Elevation in m(ft)
Green Harbour	7802°N	1415°E	11(36)
Mossel Bay	7954°N	1627°E	–
Tromso	6939°N	1857°E	102(335)
Bear Island	7428°N	1917°E	40(133)
Vardo	7022°N	3106°E	12(39)
Kola	6853°N	3301°E	7(23)
Archangel	6428°N	4031°E	6(20)
Tikhaya Bay	8019°N	5248°E	6(20)
Matochkin Strait	7316°N	5624°E	18(59)
Rudolfa Island	8148°N	5757°E	48(157)
Vaigach Island	7024°N	5848°E	11(36)
Yugor Strait	6949°N	6046°E	13(43)
Cape Zhelaniya	7657°N	6834°E	8(26)
Dikson Island	7330°N	8024°E	20(66)
Domashniy Island	7930°N	9108°E	3(10)
Cape Chelyuskin	7743°N	10417°E	5(16)
Tiksi Bay	7135°N	12856°E	10(33)
Verkhoyansk	6735°N	13330°E	121(400)
Kotel'nyi Island	7602°N	13806°E	3.3(11)
Cape Shalaurova	7311°N	14314°E	8(26)
Okhotsk	5921°N	14317°E	5(16)
Wrangel Island	7058°N	17833°W	3(10)
St Paul Island	5709°N	17013°W	7(22)
Nome	6430°N	16526°W	14(46)
Kotzebue	6652°N	16238°W	5(16)
Barrow	7118°N	15647°N	4(13)

Station	Latitude	Longitude	Elevation in m(ft)
Barter Island	7008°N	14338°W	12(39)
Aklavik	6814°N	13500°W	9(30)
Sachs Harbour	7157°N	12444°W	84(277)
Cape Parry	7010°N	12441°W	16(53)
Mould Bay	7614°N	11920°W	15(50)
Holman	7030°N	11738°W	9(30)
Coppermine	6749°N	11505°W	8.5(28)
Cambridge Bay	6907°N	10501°W	14(47)
Isachsen	7847°N	10332°W	25(83)
Resolute	7443°N	9459°W	63(209)
Eureka	8000°N	8556°W	2.4(8)
Arctic Bay	7300°N	8518°W	11(36)
Thule	7634°N	6848°W	39(129)
Clyde	7027°N	6833°W	3(10)
Alert	8230°N	6220°W	62(205)
Cape Dyer	6635°N	6137°W	368(1207)
Upernavik	7247°N	5609°W	64(210)
Sondrestrom Fjord	6700°N	5048°W	58(190)
Prins Christians Sund	6003°N	4312°W	76(250)
Angmagssalik	6530°N	3733°W	29(95)
Scoresby Sund	7028°N	2158°W	17(56)
Danmarkshavn	7646°N	1845°W	6(20)
Grimsey	6630°N	1801°W	22(72)
Jan Mayen	7059°N	0820°W	23(76)

202 AIR PRESSURE

1. **Winter**. The distribution of mean sea-level pressure for January is illustrated in Figure 2-2. The circulation is dominated by four large cells two continental highs and two oceanic lows. The large, semi-permanent Siberian high is joined to a smaller high over the Mackenzie Valley (1023 mbar) by an elongated ridge across the Arctic Ocean. The Iceland low (994 mbar) controls the mean circulation along and over northern Scandinavia and the sea areas on the Eurasian side of the Pole. An elongated trough follows the open water and runs from Iceland north of Norway to Novaya Zemlya and the Chelyuskin Peninsula. Another trough covers Baffin Bay. Both troughs are actually the scene of frequent cyclonic activity. The remaining cell is the smaller Aleutian low. The circulation over the Pole itself is largely dominated by the cyclonic flow around the Icelandic low. There is no "Arctic high" on the January mean map, as stipulated by older theories for the Arctic Ocean, although strong anticyclones are common over the Basin. The "Polar easterlies" exist, in winter, in the mean flow only over the Norwegian-Barents Sea area and along the north flank of the Aleutian low. Because of the extreme asymmetry and eccentricity of the sea -level pressure field, no single latitude circle shows any

appreciable integrated easterly flow. Over the central Arctic Ocean, the main air stream in January is directed from the middle and western Siberian coast towards the Pole and thence, southward across the Greenland-Svalbard area. On the Bering Strait side of the Pole the Siberian air masses cross the Polar Ocean and invade the Canadian Archipelago, mixing with air from the Alaskan-Yukon area. Over the regions of elevated topography, the pressure gradients are fictitious, as for example over Greenland where the surface winds are not accurately depicted by the pressure map.

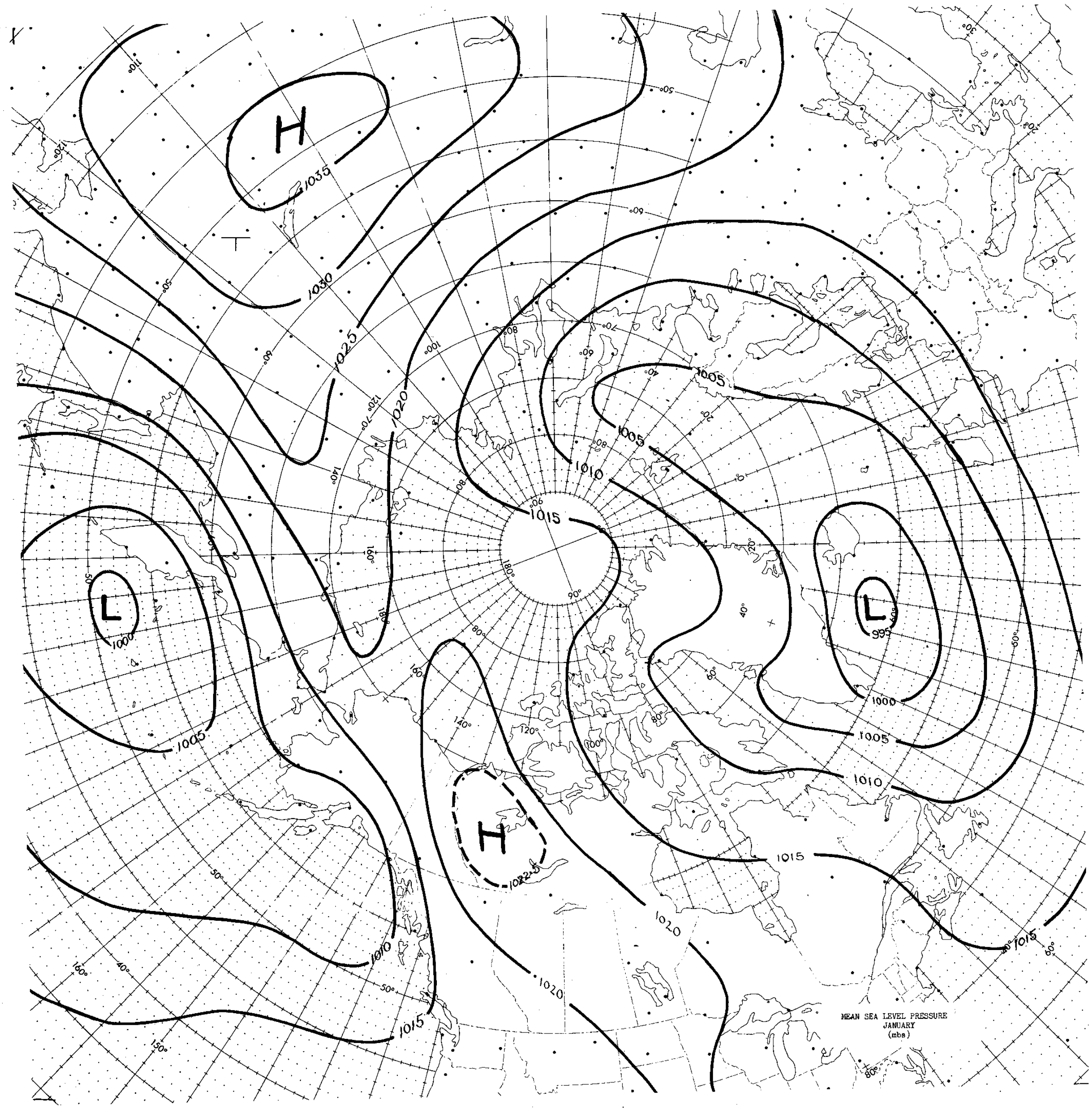

Figure 2-2 Mean Sea-Level Pressure-January

2. **Spring and Summer**. The January pattern generally persists into March. Thereafter the mean pressure field undergoes rapid change. There is pronounced weakening of the low cells and of the Siberian continental high, and a relative intensification of high pressure over the Arctic Ocean. It is in the spring that strong anticyclonic activity is most likely to occur over the central Arctic, and it is at

this time that the concept of a "Polar anticyclone" is most nearly fulfilled. In summer (Figure 2-3), the mean pressure gradient over the central Arctic Ocean is relatively weak. A closed anticyclone is found over the edge of the Arctic Ocean covering the Barents Sea (1013 mbar), while a weak ridge is located over the Beaufort Sea (1013 mbar). The Aleutian low diminishes to a feeble trough in summer, and the Icelandic low is also weak (1010 mbar). The Siberian high disappears completely and is replaced by a thermal low-pressure area over the heated Asiatic land mass. The July mean pressure map thus shows a feeble pattern with a sluggish resultant mean flow. The prevailing air currents over the Eurasian coast are directed from the Arctic Basin to the coast, with a marked easterly component, so that on the Siberian coast the winds are generally ENE, while on the coast westward of 90øE the prevailing wind is from the NE.

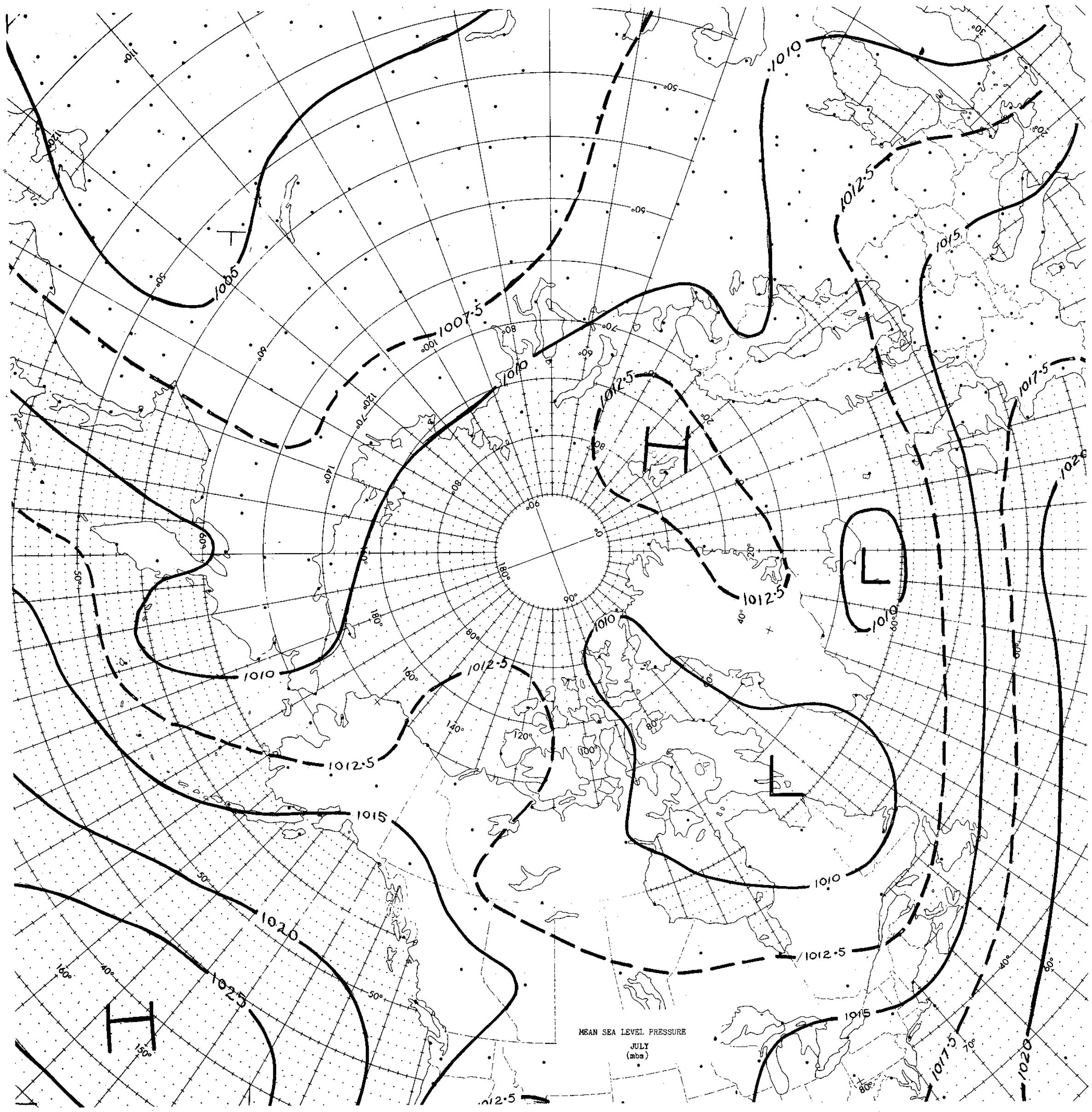

Figure 2-3 Mean Sea-Level Pressure – July

3. **Autumn**. By October the pressure patterns show a superficial resemblance to the spring conditions. Relatively high pressure occurs over the central Arctic Ocean and the sub-polar lows are

back in their customary positions. The mean pattern, however, represents a compromise between contrast of vigorous cyclonic circulation systems and periods of anticyclonic control. The Aleutian low regains its full intensity and the Icelandic low approaches wintertime strength, the extension over Novaya Zemlya being re-established. The Siberian high attains moderate intensity in October (1018 mbar).

203 PRINCIPAL TRACKS OF CYCLONES AND SYNOPTIC SYSTEMS

1. Figures 2-4 and 2-5 supplement the charts of mean pressure by indicating the most frequent areas of the northern hemisphere where cyclones form and dissipate, and the major tracks which they follow in winter (January) and summer (July).

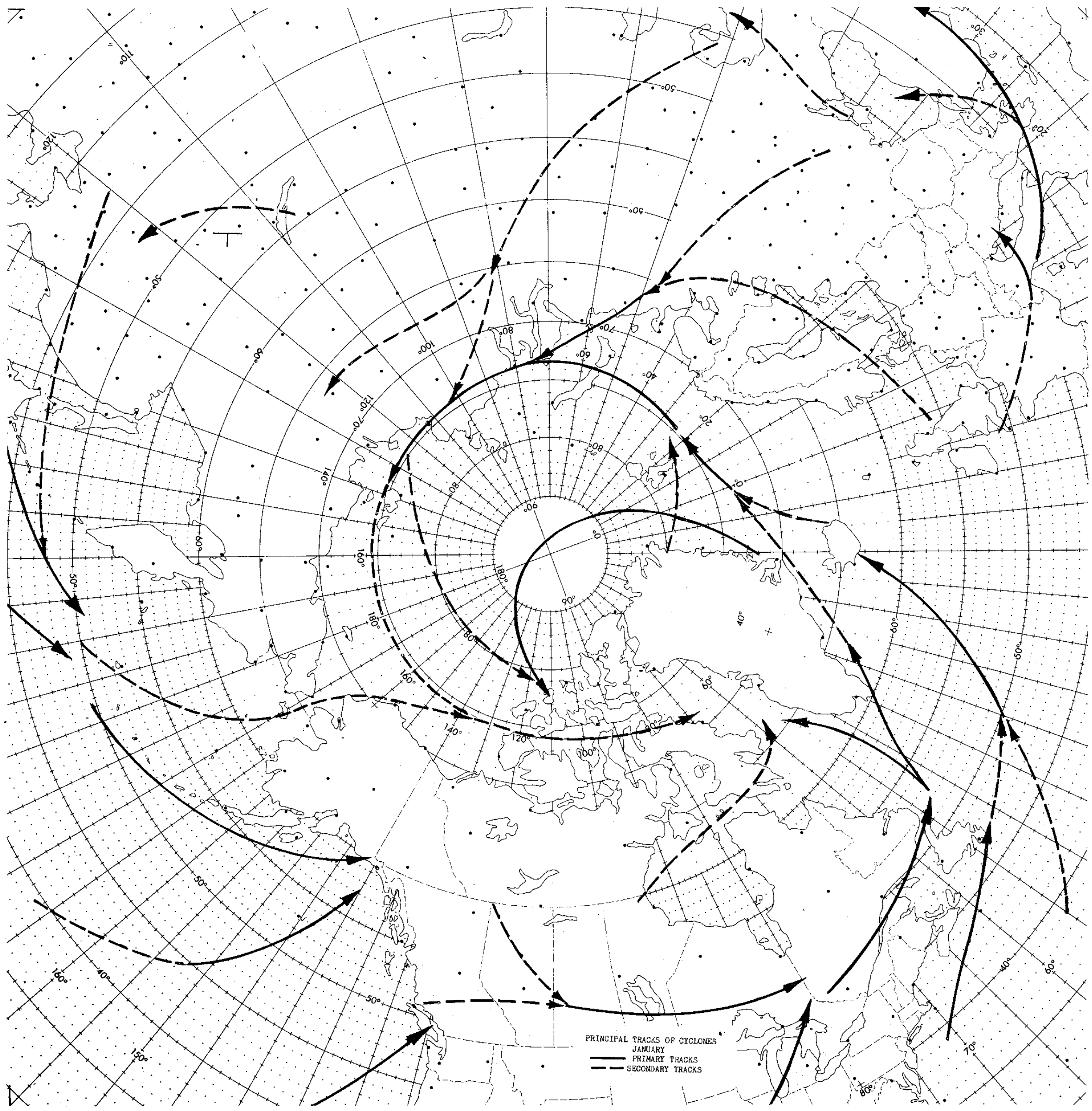

Figure 2-4 Principal Tracks of Cyclones-January

2. Over the Polar Basin, many cyclones spiral in toward the Pole. Storms breaking off the Icelandic low usually move northeast to the Norwegian-Barents Sea and a primary track continues along 75øN. These frequent storms play an important part in the climate of the north European and Siberian coastlands. This primary track is joined by tracks from the Baltic, Black and Caspian Seas. Some storms stagnate near Novaya Zemlya, others regenerate and curve in towards the Pole.

3. There is a difference in the climatic importance of synoptic weather systems when the middle latitudes are compared with the Arctic Ocean. In the former regions, synoptic systems control the weather and climate by an ever-changing sequence of different air masses. Over the Arctic Basin in winter, cyclonic patterns generally do not influence the surface climate except so far as they control mixing in the inversion layer. Warm and cold spells in temperate latitudes are most often air mass phenomena (advection); over the Arctic Ocean cold spells are generally caused by radiation, not by advection, while milder surface conditions require vertical transport downward of warmer air from above the inversion. Sporadic invasions of warm maritime air do occur, however, sometimes into the Arctic Basin.

4. Frontal development occurs in summer, mainly along the continental coasts. Strong temperature contrasts develop because of the different absorption of solar radiation by land and ice. The land surface warms appreciably, but the ice absorbs only a small part of the insolation and cannot warm above the melting point. The summer storms generally develop in the continental coastal boundary but are not confined to any narrow strip. A broad zone of thermal contrasts may sharpen into fronts, the locations of which are determined both by the circulation and by the presence of heat sources and sinks. Such summer frontal cyclones bring the heaviest precipitation to the Arctic Ocean. The fronts are generally more distinct some distance above the surface. The cold air in contact with the ice often masks the existing temperature differences, especially in summer when a uniform surface temperature is found in all sectors. Above the surface layers, Arctic disturbances show similar features of cloud distribution to the usual models of middle-latitude frontal-type cyclones.

204 WIND

1. Observations from drifting ice stations (Table 2-2) indicate that surface wind speeds over the Arctic Ocean are not very high. On the average the force is 4 to 5 m/sec. When an inversion (increase of temperature with height) is present, the surface layer is effectively isolated from the faster-moving air above. It is this fact, in combination with the lack of topographic effects, which results in the low number of occurrences of strong winds. Although light winds predominate, strong winds may occur and persist for periods of one to three days. Wind speeds are critical in the Arctic because in addition to the winds intensifying the feeling of cold, they are responsible for blowing snow-the major deterrent to trave1 in winter

2. The annual mean wind speeds are greatest at exposed coastal stations near cyclone tracks, and it is in these same locations that gales are most frequent (for example, at Jan Mayen, northern Norway to Dikson Island and Bering Strait) (Table 2-2). On the other hand, at sheltered locations or those remote from normal active storm tracks, the annual mean wind speeds are rather low (as at Eureka and Aklavik).

205 TEMPERATURE

1. The most common misconception of the Arctic is that the land areas are covered with eternal ice and snow and that there is everlasting winter with intense cold. A large part of Greenland is a striking example of an ice-covered land possessing these qualities and from it, the rest of the north has been pictured by analogy. The high elevation of Greenland and Ellesmere Island highly favours glaciation. In general, however other Arctic lands, possess neither of these characteristics and over a large portion

of the Arctic the scanty snows melt rapidly with the approach of summer. Most of the little snow that does fall is soon swept by the wind into gullies and the lee of hills, so that over much of the Arctic lands the winter snow cover is quite thin. Next consider the intense cold: at the North Pole the lowest temperatures do not fall below -55°C, a figure that is occasionally reached in some parts of the Canadian Prairies.

2. The Siberian winter is by no means as unpleasant as its extreme temperatures might suggest; the air is often calm and the skies clear. Danger to man and beast occurs only when the wild "buran" or "purga" blows. Such fearful blizzards also occur in the interior of Canada.

3. The irregularities of the winter isotherms over the Arctic Ocean are produced by the influence of the Atlantic and Pacific Oceans. In the North Atlantic, the isotherms are pushed far northward and it is here that one finds the greatest positive anomaly of temperature in the world (the greatest departure from latitudinal average). The winter temperatures in the vicinity of the Bering Strait are influenced by the open waters of the Bering Sea. North of the strait the influence is limited to a small area in which large local differences occur with different wind directions. Large and rapid temperature fluctuations are otherwise not a common feature over the Arctic Ocean. During the greater part of the year, the area is covered by a relatively thin layer of cold air which, to a great extent is isolated from the atmosphere above. The air temperature near the surface is primarily dependent on the temperature of the ice surface itself.

4. The winter temperatures over the pack-ice remain nearly constant for a considerable time. This "flat" minimum represents the temperature at which the loss of heat, by radiation from the snow and ice surface, balances the amount of heat which, is conducted to the surface from the water under the ice. It also depends on the heat transported into the Arctic by warm air advection in advance of cyclones. During the long periods of infrequent cyclone activity in winter, heat transfer to the surface from the atmosphere is small, since the eddy conductivity is very small in the inversion layer.

5. The presence, or nearness, of open water in the winter half of the year, is reflected in the mean air temperature pattern. Broad tongues of warmth extend into the Barents Sea. The strongest influx of heat by cyclonic activity occurs in the Atlantic section of the Arctic Ocean in January and February. From April until June the temperature rises quite rapidly, until the ice begins to melt. The mean summer surface temperatures remain fairly constant, conforming to the nature of the underlying surface. Almost all regions are warmest in July (Table 2-2). Temperatures close to the melting point prevail over the pack-ice and along the fringes of the Greenland ice -cap and outer islands of the Archipelago. Maximum temperatures in the Arctic Basin do not exceed 5øC. An examination of large departures of monthly mean temperatures from normal values for 20 coastal or island stations, with 20 or more years of observations, showed that the greatest departures are found in winter (from November to April) and small departures are most probable in July. In winter, the greatest departures were observed in the Kara Sea, the smallest in the East Siberian Sea. In summer, the greatest departures from normal temperatures were observed on the coasts of the peripheral seas and decreasing toward the north.

6. The temperature inversions observed in all Arctic regions are especially prominent over the pack-ice. During the darkness of winter in the high Arctic, the diurnal variation in temperature is irregular and the maximum and minimum temperatures can occur at any time during the 24 hours of the day. Variations are almost wholly due to changes in cloud cover or wind speed. Temperatures rise when cloud cover increases or winds strengthen, and fall when winds decrease or skies clear.

7. Small temperature variability in the summer is a characteristic common to all stations in the inner Arctic Ocean. The temperatures over the pack-ice never deviate far from the freezing point. The

number of days with maximum temperature slightly above the freezing point is very nearly the same all along the latitude of 75øN-around 40 days. The diurnal ranges are small.

206 FOG AND VISIBILITY

1. The range of visibility varies greatly in the Arctic. Arctic air masses are pure and the visual range may be very great. Poor visibilities in the lower layers of the atmosphere result from the presence of falling precipitation, fog or blowing snow. Haze and smoke pollution of air masses as they occur in lower latitudes are rare in the Arctic.

2. During the warmer months, the most common type of fog is caused by the advection of relatively warm and moist air over the melting ice and cold water. When the air moves in such a way that it is cooled by contact with the colder underlying surface at a temperature below its dew point, it can no longer hold the excess moisture which condenses to form mist or fog. When the air near the surface is very stable, the fog will be shallow. On the other hand, turbulence in the lower levels of the air may give conditions under which this excess moisture becomes visible as low stratus clouds. The areas, which are most favourable for the formation of this type of summer fog or low clouds, are the open waters of the Kara, Laptev, East Siberian and Chukchi Seas. Fifteen to 20 days with fog is a normal condition for these areas during the summer months (Table 2-2). This advection-type fog occurs most frequently over coastal waters adjacent to a local cold-air source or over open leads in the pack-ice. Over the Arctic Basin it is extremely frequent and widespread during the period when the ice surface is melting.

3. During the cold season, a type of fog known as "steam fog" or "Arctic sea smoke" occurs when very cold air moves over open water. It occurs only when the contrast between air and water temperatures is very great. This type of fog occurs most frequently over rivers, unfrozen lakes, open leads or polynyas in the Arctic ice. Over the Arctic Basin steam fog serves the important purpose of indicating the presence of open water.

4. Another winter phenomenon is the occurrence of "ice fog". This is defined as a type of fog composed of suspended particles of ice, which occurs at very low temperatures, mainly below-30°C, and usually during clear, calm weather at high latitudes. It occurs locally in the vicinity of human habitation, herds of animals, vehicular or aircraft operation, and open water areas of fast-running streams.

5. During the winter months, blowing snow is the most common cause of reducedvisibilities, particularly in the more unprotected continental or insular locations. The frequency and severity of blowing snow is of course related directly to the frequency of high winds and the presence of new or powdery snow cover. Much of the snow of the Arctic falls in the form of loose granular flakes, which are very readily whipped up by even relatively light winds. Observations show that with winds in excess of 24 km/h, blowing snow is nearly always present in some degree in the cold Arctic. From December to April the visibilities at most Canadian Arctic Stations are reduced to 10 km or less in blowing snow about one third of the time. In the case of winds over 48 km/h, more than 80 percent are associated with visibilities lower than 5 kilometres.

6. As long as no restrictions such as fog, precipitation or blowing snow are present in the Arctic atmosphere, visibilities are remarkably good. The records of many travellers are filled with accounts of the extreme range of visibility, and indeed it is not uncommon to see dark mountains 150 km distant. On the other hand, the lack of contrast, particularly where all surface objects are covered with new snow, results in the inability to distinguish objects close at hand. The addition of a uniformly

overcast sky to an unbroken snow landscape gives rise to the condition usually referred to as "Arctic white-out".

7. The frequent well-marked temperature inversions of the Arctic region explain the many accounts of mirages. Objects that are known beyond any doubt to be below the horizon are not infrequently visible as mirages and the periods of daytime and twilight are lengthened as the normal index of refraction is altered. The inversion may also interfere with the identification of landmarks through distortion, and estimation of vertical distances is made much more difficult.

207 CLOUD

1. The general character of cloud cover over the Arctic differs considerably from that considered typical foremost temperate regions. The uniform and contourless stratus douds, which are by far the most frequent type observed, give to the Arctic its reputation of a dull and monotonous appearance. Over the Arctic Ocean during the summer, the low stratus-type of cloud constitutes from 70 to 80 percent of all cloud observed. The reason is the continuous cooling of the air from below over the pack-ice fields and the presence of a source of moisture in the surface melt-water. These summer clouds are extremely uniform, extending as large sheets over a much wider areas than other cloud types. Along the coast in more southerly locations, the stratus clouds are proportionately less frequent. In these regions, the cloud decks tend to be more often broken up by convective currents, with a resulting increase in the proportion of stratocumulus cloud reported.

2. In the Norwegian Sea, mean cloudiness is high throughout the year, with a slight maximum in the summer even though this is the season with the lowest cyclone frequency. For example, the mean cloudiness at 74° N, 0°W is 80 percent in January, but 90 percent in July (Table 2-2).

3. Over the Arctic Ocean the cloud amount is lowest in winter and spring when the water content of the very cold air is too low for cloud formation. A further characteristic of this area is that the seasonal change in cloudiness takes place over a very short transitional period. Similar abrupt changes are found only in monsoon areas when a complete change over takes place in the circulation pattern.

4. Areas showing relatively high cloud amounts in winter are the Norwegian and Barents Seas, where the January, mean cloudiness exceeds 80 percent. These percentages decrease to below 70 percent in the Kara Sea, 50 percent in the Laptev Sea, to about 40 percent in the East Siberian and Beaufort Seas (Table 2-2). With few cyclones penetrating eastward beyond Novaya Zemlya, and little or no surface moisture, only thin middle clouds and cirrus clouds prevail. The main feature of the winter cloud pattern over the North American continent is the gradual decrease in cloudiness towards the north.

208 PRECIPITATION

1. Precipitation over most of the Arctic is very light and the annual amounts are so small that the region is classified as a desert based on annual precipitation. Over the Polar Basin the annual precipitation amounts average less than 250mm, while over the Siberian-American portion of the Arctic Ocean and the northern part of the Canadian Archipelago the amounts are generally of the order of 100 mm or less (Table 2-2). The greatest portion of the annual total precipitation falls in the summer as rain, although the rate of fall is usually light and in most cases would be classed as drizzle rather than rain. Heavier showers may occasionally occur.

2. Over much of the Polar Basin snow may be expected during all months of the year, and in the far north even in summer the number of days with snow may exceed the number of days with rain. Because of the low moisture concentration possible at very low temperatures, however, the winter snow is very fine and when it occurs on windy days its measurement becomes very difficult. Freezing

rain and freezing drizzle can also occur in the summer months. Available data indicate that on the average freezing precipitation occurs less than 10 hours per year. The rate of accumulation is quite low compared to the rapid buildup of ice that can occur in more southerly latitudes.

3. The characteristics of the snow cover, such as thickness and duration, have important climatic effects on the heat and moisture exchange at the surface. Over the central Arctic Ocean, the snow cover becomes established in late August. The average thickness of the scoured and drifted snow cover may be about 350 - 400 mm by late spring. Steady snow melt, usually begins by the middle of June-caused by solar radiation-and, although there are marked differences from year to year, the pack-ice is usually snow-free by the middle of July.

4. South of latitude 75°, the annual precipitation amounts are higher. Some points in Greenland and the European Arctic for example present an annual precipitation in excess of 1000 mm. As would be expected from the high frequency of cyclonic activity, the Norwegian Sea area has the greatest annual precipitation of all regions north of the Arctic Circle, although a secondary maximum of cyclonic activity in Baffin Bay accounts for fairly high precipitation amounts along the west Greenland coast and the eastern coasts of the Canadian Arctic Archipelago.

Table 2-2 (Sheet 1 of 3) Arctic Region Weather Trends

PLACE 1	PERCENT CLOUD COVER 2 JAN	JUL	MEAN AIR TEMPERATURE °C 3 JAN	JUL	MEAN PRECIPITATION (INCHES) 4 JAN	JUL	MEAN MONTHLY PRECIPITATION % FREQUENCY 5 JAN	JUL	MEAN VISIBILITY %<2NM//%<5NM 6 JAN	JUL	MEAN NUMBER OF DAYS VISIBILITY <1/2 MI 7 JAN	JUL	SEA AND SWELL %>5'//%>12' 8 JAN	JUL	MEAN VECTOR WINDS DIR/SPEED(KT) 9 JAN	JUL	10 PERCENT OCCURRENCE FOR PARTICULAR WIND SPEEDS ≤10/>17/>28/>34(KTS) JAN	≤10/>17/>28/>34(KTS) JUL
CANADA					RAIN/SNOW	RAIN/SNOW	RAIN/SNOW	RAIN/SNOW										
ARCTIC BAY	40	65	−28	2			20/20	15/10	10/75	10/85			ICE	<10	NW/10	NE/5	45/ / /<5	50/ / /0
BAFFIN ISLAND	45	70	−26	4			15/15	15/10	15/80	10/85			ICE	<10	NW/10	NW/<2.5	40/ / /<5	45/ / /0
BANKS ISLAND	43	70	−32	4			20/20	10/10	<10/70	10/70			ICE	–	N/10	NW/<2.5	40/ / /<5	50/ / /0
CAMBRIDGE BAY	42	65	−32	8			20/20	15/05	10/70	10/80					W/10	NE/05	40/ / /<5	50/ / /0
DAWSON	50	70	−28	16			25/15	20/0	10/80	10/70					NE/10	SE/05	30/ / /<10	50/ / /0
ELLESMERE ISLAND	40	70	−32	6			0/75	02/17	30/50	30/40					N/10	SW/10	–	50/ / /0
FROBISHER BAY	45	75	−24	4			15/15	20/05	15/70	10/85					NW/10	VAR/05	35/ / /05	50/ / /0
INUVIK	45	70	−28	8			20/20	20/05	10/70	20/70					SW/2.5	NW/05	45/ / /<10	50/ / /0
IVUGIVIK	45	70	−26	8			10/10	20/<5	20/70	10/80					SW/5	S/<2.5	30/ / /05	50/ / /0
QUEEN ELIZABETH ISLAND	40	75	−32	4			0/11	04/07	15/20	30/45					W/10	N/10	–	50/ / /0
RESOLUT	40	65	−32	4			0/11	04/07	15/20	30/45					W/10	N/05	45/ / /0	50/ / /0
REPULSE BAY	38	60	−28	8			20/15	20	20/70	10/90					NW/10	NW/05	40/ / /<5	50/ / /0
VICTORIA ISLAND	48	65	−32	8			20/20	15/05	10/70	10/80					NW/10	NE/05	40/ / /<5	50/ / /0
WHITEHORSE	55	70	−20	12			30/15	20/0	10/80	10/70					NE/10	SE/05	20/ / /<10	50/ / /0
DENMARK																		
FAROE ISLANDS	75	80	−12	4	8.0/2.7	5.1/0.0	30/10	20/0	10/75	10/70			50/15	3/1	SW/10	SW/<2.5	20/30/25/15	40/18/3/0
FINLAND																		
HELSINKI	80	55	−8	16	1.70/–	2.20/0.0		2/0			2.9	0.8		0/0		W/11	/3.5/0.1/	46/1.6/0.1/0
OULU	80	55	−8	16	2.90/–	2.36/0.0		2/0			3.2	0.5		1/0		S/10	/3.3/0.1/	45/1.4/0.0/0
KIRUNA	80	55	−8	16														
GREENLAND																		
AMMASSALIK	50	60	−4	4	2.90/–	1.50/–	5/13	5/3			N/A	N/A	6/0	0/0	NE/30		23/20/28/0	40/28/1.1/0
GOTHAB	60	60	−12	4	1.40/–	2.20/–					N/A	N/A					N/A	N/A
ITSEQQORTOOMIIT	60	60	−12	4	1.80/–	1.50/–					N/A	N/A					N/A	N/A
NORD	45	60	−28	4	0.84/–	1.00/–					N/A	N/A					/9.8/2.4/	/6.5/0.6/
QAQORTOQ	65	60	−6	4	2.78/–	1.20/–					N/A	N/A					N/A	N/A
QEQERTARSUAQ	60	60	−16	4	0.61/–	2.13/–					N/A	N/A					N/A	N/A
THULE	40	60	−28	4	0.36/3.3	0.67/0.0					5.0	7.4					/8.1/2.3/	/6.7/1.0/
JAPAN																		
KUSHIRO	60	88			1.80/–	4.40/0.0	3/9	9/0			6.8	12.7	7/.5	1/0	NW/15	E/8	/8.8/0.4/	/1.5/0.0/
MORIOKA					2.33/–	6.64/0.0					N/A	N/A					N/A	N/A
GIFU AB					2.76/–	9.48/0.0					N/A	N/A					/1.7/0.0/	/0.4/0.0/
NIIGATA	88	94			7.50/42.6	6.40/0.0	6/25	10/0			6.5	1.3	7/4	8/0	NW/18	SW/8	/19.9/2.0/	/0.2/0.0/
ICELAND																		
AKUREYRI	70	75	0	9	1.70/–	1.30/–					2.8	0.4	3/10	7/0	NE/22	NE/8	32/9.3/0.9/0	42/1.7/0.1/0
REYKJAVIK	75	75	0	9	4.00/–	2.00/–					2.8	0.3	1/0	4/0	SW/23	N/13	22/35.9/10.5/0	39/9.4/0.6/0
IRELAND																		
MALIN HEAD	80	78			2.60/–	2.84/0.0	12/2	8/0			0.1	0.8	4/0	2/0	SW/17	NW/12	31/33.2/4.4/0	43/10.2/0.1/0
NORWAY																		
BERGEN	75	69	−2	12	7.90/–	5.20/0.0	10/25	15/0	05/20	25/40	N/A	N/A	30/15	10/10	S/10	SW/<2.5	20/N/A/N/A/<10	40/N/A/N/A/0
BJORNOYA ISLAND	75	69	−4	4	SEE CLIMATIC ATLAS		20/35	10/<5	25/70	25/40	SEE CLIMATIC ATLAS		30/<10	10/<10	N/10	NE/10	20/ / /<10	20/ / /<5
JAN MAYEN ISLAND	75	69	−4	6	SEE CLIMATIC ATLAS		05/30	25/<5	25/35	20/30	SEE CLIMATIC ATLAS		10/10	10/<10	N/15	CALM	20/ / /20	30/ / /<5
HAMMERFEST	75	69	−4	12	SEE CLIMATIC ATLAS		20/35	10/<5	25/70	25/40	SEE CLIMATIC ATLAS		30/15	10/<10	N/10	NW/<2.5	30/ / /10	40/ / /<5
NARVIK	75	69	−2	12	2.80/–	2.32/0.0					5.3	0.5					/14.0/2.4/	/2.1/0.1/
SVALBARD	75	69	−12	4	SEE CLIMATIC ATLAS		25/25	20/<5	10/15	05/10	SEE CLIMATIC ATLAS		–	10/<10	NE/15	S/15	05/ / /10	20/ / /<5
TRONDHEIM	75	69	−2	12	2.14/–	3.00/0.0					1.2	0.2					/7.2/1.2/	/6.8/0.1/

Table 2-2 (Sheet 2 of 3) Arctic Region Weather Trends

PLACE	PERCENT CLOUD COVER		MEAN AIR TEMPERATURE °C		MEAN PRECIPITATION (INCHES)		MEAN MONTHLY PRECIPITATION * FREQUENCY		MEAN VISIBILITY *<2NM//*<5NM		MEAN NUMBER OF DAYS VISIBILITY <1/2 MI		SEA AND SWELL *>5'//*>12'		MEAN VECTOR WINDS DIR/SPEED(KT)		PERCENT OCCURRENCE FOR PARTICULAR WIND SPEEDS ≤10/>17/>28/>34(KTS)	
1	2 JAN	JUL	3 JAN	JUL	4 JAN	JUL	5 JAN	JUL	6 JAN	JUL	7 JAN	JUL	8 JAN	JUL	9 JAN	JUL	10 JAN	JUL
SCOTLAND					RAIN/SNOW	RAIN/SNOW	RAIN/SNOW	RAIN/SNOW										
PRESTWICK					3.48/–	3.02/0.0					1.2	0.4					/20.1/1.5/	/6.5/0.0/
SHETLAND ISLANDS	70	75	4	12			30/10	20/0	10/80	10/75			30/10	10/<10	SW/10	WSW/05	20/ / /15	40/ / /0
WICK					2.93/–	2/57/0.0					0.3	3.5					/32.2/11.8/	/6.2/11.6/
SOUTH KOREA																		
SEOUL					1.20/4.9	14.80/0.0					1.9	1.5					/1.2/0.0/	/0.7/0.0/
SACHON	74	70			0.78/1.1	10.34/0.0	3/4	6/0			0.2	0.9	14/3	2/0	NW/15	E/10	28/1.9/0.0/0	49/1.7/0.0/0
SWEDEN																		
GAVLE	70	67	–8	16	1.10/–	2.60/0.0					N/A	N/A				N/12	/N/A/N/A/	50/12.4/1/7/0
KIRUNA	70	67	–8	16	0.70/–	2.70/0.0					N/A	N/A					/N/A/N/A/	/N/A/N/A/
UMEA	70	67	–8	16	1.40/–	1.90/0.0					N/A	N/A					/N/A/N/A/	/N/A/N/A/
USA (ALASKA)																		
ALASKA PENINSULA	80	85	–4	12														
A. COLD BAY	80	90			2.37/8.0	2.20/0.0	7/6	6/0	/18	/38	5.1	5.3	1/1	4/1	E/20	W/13	23/43.0/9.0/0	36/31.4/2.7/0
B. KING COVE	80	90			1.08/6.10	2.13/0.0	7/6	6/0	/18	/38	2.6	4.8	1/1	4/1	E/20	W/13	23/19.1/2.4/0	36/5.6/0.3/0
ANCHORAGE	80	80	–16	13	1.08/11.8	2.37/0.0			/14	/2	7.7	0.6					/2.4/0.2/	/0.6/0.0/
BARROW	50	75	–24	6	0.19/2.4	0.89/0.7			/17	/39	N/A	N/A		0/2		E/13	/N/A/N/A/	42/N/A/N/A/0
BETHEL	70	85	–16	13	1.12/10.5	2.17/0.0			/16	/22	4.7	2.7					/17.9/0.8/	/0.8/0.2/
FAIRBANKS	55	75	–24	14	0.90/12.0	1.90/0.0			/20	/4	7.1	1.3					/0.5/0.0/	/0.4/0.0/
NOME	60	80	–16	12	1.10/10.5	2.70/0.0			/18	/27	5.4	3.0		1/0		SSE/16	/22.0/2.6/	39/5.7/0.1/0
PRUDHOE BAY	45	75	–28	10	N/A	N/A	25/25	20/05	<10/70	20/70	SEE CLIMATIC ATLAS				W/<2.5	NW/05	50/ / /0	50/ / /0
VALDEZ	70	80	–16	13	5.21/60.5	4.22/0.0					N/A	N/A					/N/A/N/A/	/N/A/N/A/
USA (ALEUTIANS)	80	85	0	8														
ADAK	89	95			6.74/15.7	2.99/0.0	7/17	10/0			3.3	3.3	2/.5	3/.5	SE/20	W/12	28/36.7/8.2/0	38/20.1/2.0/0
UMNAK	90	96			2.70/–	3.70/0.0	7/14	7/0			N/A	N/A	2/1	3/0	W/20	W/14	23/N/A/N/A/0	35/N/A/N/A/0
USSR																		
ANADYR	55	80	–16	8	2.45/–	1.35/0.0					3.0	1.2					/40.4/16.4/	/26.9/2.9/
EVENSK	70	80	–28	12	1.26/–	2.09/0.0		7/0			1.1	2.5		3/0		SW/12	/48.9/16.6/	43/2.7/0.0/0
FRANZ JOSEF LAND	70	90	–16	2														
A. NAGURSKOYE					1.27/–	1.09/–					1.9	3.8					/19.5/4.7/	/13.8/1.3/
B. OSTROV HEYSA					1.74/–	1.52/–					1.3	3.0					/27.5/6.5/	/13.2/0.9/
LENINGRAD	80	55	–8	16	1.12/–	2.90/0.0					0.3	0.2					/4.8/0.1/	/0.9/0.0/
TIKSI	50	75	–36	10	1.45/–	1.78/–					2.9	2.3					/26.0/8.7/	/8.6/0.3/
MURMANSK	75	70	–12	12	1.49/–	2.19/0.0	1/17	7/0			2.5	0.3	1/0	0/0	SW/21	E/10	18/27.6/3.8/0	49/5.0/0.0/0
NEW SIBERIAN ISLANDS	35	85	–32	2														
A. OSTROV KOTELNYY					0.41/–	1.32/–					0.3	3.0					/20.6/2.0/	/22.4/2.1/
B. MYS SHALAVROVA					0.59/–	1.5/–					1.3	3.9					/19.8/3.7/	/22.6/1.1/
NOVAYA ZEMLYA	60	80	–16	8														
A. MYS ZHELANIYA					1.98/–	1.11/–					3.2	5.1					/43.4/17.1/	/33.5/8.5/
B. MALYYE KARMAKULY					1.67/–	2.40/–					1.5	2.0					/48.3/21.3/	/23.6/8.0/
PROVIDENIYA	70	60	–16	6	3.77/–	2.93/0.0	0/21	4/0			1.5	2.7	0/0	2/0	NE/23	SW/14	20/25.7/4.4/0	28/1.0/0.0/0
SEVERNAYA ZEMLYA	55	85	–28	4	0.67/–	1.99/–					1.0	5.9					/18.9/2.4/	/11.1/0.5/
WRANGLE ISLAND	59	81	–24	4	1.14/–	1.39/–					1.5	6.0					/27.4/8.2/	/9.1/0.9/

Table 2-2 (Sheet 3 of 3) Arctic Region Weather Trends

PLACE 1	PERCENT CLOUD COVER 2 JAN	JUL	MEAN AIR TEMPERATURE °C 3 JAN	JUL	MEAN PRECIPITATION (INCHES) 4 JAN	JUL	MEAN MONTHLY PRECIPITATION * FREQUENCY 5 JAN	JUL	MEAN VISIBILITY *<2NM//*<5NM 6 JAN	JUL	MEAN NUMBER OF DAYS VISIBILITY <1/2 MI 7 JAN	JUL	SEA AND SWELL >5'//>12' 8 JAN	JUL	MEAN VECTOR WINDS DIR/SPEED(KT) 9 JAN	JUL	10 PERCENT OCCURRENCE FOR PARTICULAR WIND SPEEDS ≤10/>17/>28/>34(KTS) JAN	≤10/>17/>28/>34(KTS) JUL
BAFFIN BAY					RAIN/SNOW	RAIN/SNOW	RAIN/SNOW	RAIN/SNOW	20/20	30/20			10/			E/10	80/ / /	70/ / /
NORTH	45	70	-28	8				06/07										
SOUTH	55	75	-16	8				11/0										
BARENTS SEA									20/50	10/25					SE/15	NE/15	40/ / /	60/ / /
NORTH	70	85	-16	2			18/51	07/03					30/	10/10				
SOUTH	80	75	-8	6			10/23	14/0					40/	>10/>10				
BERING SEA									20/30	20/40				10/	N/10	S/20	30/ / /	50/ / /
NORTH	65	90	-16	4			30/30	25/0					10/0	0/0	NE/12	SE/12	24/31/17/	46/16.3/1.7/
SOUTH	80	90	0	6			30/30	30/0					4/0	5/1	SE/12	W/12	28/30/15/	38/21/3.7/
BERING STRAIT									20/30	20/35				>10/	N/10	SW/10	40/ / /	60/16.3/1.7/
NORTH	55	80	-20	6			25/20	20/<5										
SOUTH	65	85	-16	6			30/30	20/0										
BEAUFORT SEA															SW/05	E/05	60/ / /	60/ / /
NORTH	40	80	-30	2			0/55	04/33	13/25	35/40								
SOUTH	45	70	-28	5			0/33	11/4	13/20	15/35								
CHUKCHI SEA									20/30	30/35				10/	NE/15	CALM	65/ / /	65/ / /
NORTH	45	85	-28	0			01/28	18/02										
SOUTH	50	80	-16	4			01/28	18/02										
DENMARK STRAIT									05/30	20/30			50/20	20/	SW/05	N/10	40/ / /	75/ / /
NORTH	65	60	-8	8			–	13/02										
SOUTH	70	75	0	8			–	13/02										
DAVIS STRAIT									15/25	25/30			35/15	15/10		CALM	55/ / /	70/ / /
NORTH	55	75	-12	8			–	11/0										
SOUTH	60	75	-8	8			–	11/0										
EAST SIBERIAN SEA									20/35	30/40					NE/15	NE/10	65/ / /	60/ / /
NORTH	35	85	-32	4			0/27	17/06										
SOUTH	45	75	-28	12			0/27	17/06										
GREENLAND SEA									/30	30/35			10/10	10/		S/10	60/ / /	80/ / /
NORTH	50	75	-20	4			-/-	03/0										
SOUTH	70	70	-8	8			-/-	16/0										
KARA SEA									30/50	20/30				15/>10	SE/15	NE/05	40/ / /	50/ / /
NORTH	65	85	-24	2			02/31	15/03										
SOUTH	75	80	-16	6			02/31	15/03										
LAPTEV SEA									20/40	20/35				15/	S/15	W/10	65/ / /	60/ / /
NORTH	40	75	-28	4			01/23	15/05										
SOUTH	47	75	-28	8			01/23	15/05										
NORWEGIAN SEA									05/25	25/30					S/10	NE/10	30/ / /	60/ / /
NORTH	80	85	-4	8	12/10	8/0	10/23	14/0					35/10	10/10	S/10	NE/10	/37.5/2.6/	/28/2.4/
SOUTH	75	70	0	8			01/24	22/01					45/20	20/<10				
SEA OF JAPAN																		
NORTH	70	80	-2	16			40/20	20/0	05/20	0/10			30/0	10/0	NNW/15	SE/05	30/ / /05	40/ / /0
SOUTH	83	68													NW/19	SW/11	23/37.8/10.1/0	55/12.3/1.4/0
SEA OF OKHOTSK													50/0	30/10				
NORTH	61	76					40/40	20/<5	30/50	25/45						SW/<2.5	20/41/5.8/10	40/17.4/1.5/0
SOUTH	76	91					55/55	20/0	20/50	10/40					NW/15	WSW/05	25/37.8/8.5/10	35/15.5/1.0/0

COLUMN	DEFINITION
1.	IDENTIFICATION OF AREA
2.	PERCENT OF TIME TOTAL CLOUD COVER EXISTS DURING THE MONTH
3.	AVERAGE AIR TEMPERATURE IN °C DURING THE MONTH
4.	AVERAGE NUMBER OF INCHES OF PRECIPITATION (RAIN/SNOW) DURING THE MONTH
5.	PERCENT OF TIME PRECIPITATION (RAIN/SNOW) OCCURS DURING THE MONTH
6.	PERCENT OF TIME THE VISIBILITY IS LESS THAN (2 NM/5 NM) DURING THE MONTH
7.	AVERAGE NUMBER OF DAYS WHEN VISIBILITY IS LESS THAN 1/2 NM DURING THE MONTH
8.	PERCENT OF TIME WHEN SEA AND SWELL IS GREATER THAN (5'/12') DURING THE MONTH
9.	MEAN VECTOR WINDS DURING THE MONTH ARE FROM DIRECTION/AT AN AVERAGE SPEED
10.	PERCENTAGE OF TIME A PARTICULAR WIND SPEED (≤10,>17,>28,>34 KTS) OCCURS DURING THE MONTH

CHAPTER 3

OCEANOGRAPHY

301 DEFINITION

The Arctic Ocean surrounds the North Pole and is defined by the bordering land masses, of Siberia, Alaska, Canada and Greenland. In an oceanographic sense, it is a single large basin connected primarily with the Atlantic Ocean through two other major Arctic seas: Baffin Bay and the Greenland Sea. The water characteristics within these smaller basins can be traced in large part to North Atlantic water characteristics, which, have been modified through surface-acting processes associated with the unique climatic conditions of the Arctic. The characteristics of the peripheral continental Arctic seas are highly variable and are analysed in greater detail beginning with Article 307.

302 BATHYMETRY

1. The bathymetry of the Arctic basins (Figure 3 - 1) is now generally known, though in certain areas, notably along the edge of the continental shelf within the Arctic Ocean, detailed information is lacking.

2. The continental shelf on the North American side of the Arctic Ocean is narrow, 27-40 NM (50-75 km), whereas the sector bounded by Europe and Siberia is shallow and very broad, 220 NM (400 km), with peninsulas and islands dividing it into five marginal seas: the Barents, Kara, Laptev, East Siberian, and Chukchi. The Eurasian marginal seas occupy 36 percent of the area of the Arctic Ocean, but contain only 2 percent of its volume of water. All the major continental rivers reaching the Arctic Ocean, excepting the Mackenzie, flow into these seas. The combination of the marginal seas, characterized by a high ratio of exposed surface to total volume, and a substantial input of fresh water in summer, greatly influences surface water conditions in the Arctic Ocean.

3. The margin of the continental shelf is indented by numerous submarine canyons in the northern Kara Sea and sea valleys in the Chukchi Sea. Oceanographically, the canyons are important as they act as preferential pathways for the egress of water from the relatively warm Atlantic intermediate layer onto areas of the continental shelf, where it comes within the influence of strong mixing processes, and can locally modify the surface waters and ice cover.

4. The Lomonosov Ridge with sill depth of about 1390 m (760 fathoms) divides the Polar Basin into two deep basins: the Eurasian on the European side (3600 m: 1970 fathoms), and the Canadian on the North American side (3250 m: 1775 fathoms). The latter is further subdivided by the Alpha Rise, which runs parallel to the Lomonosov Ridge at 270 NM (500 km) distance.

5. The continental shelf alongeast Greenland, south to 77øN, is broad (160NM: 300km) and contains a system of banks no deeper than 200 m (110 fathoms). South of 77øN the shelf narrows until between 75øN and the Kap Farvel (Cape Farewell) it is less than 54 NM (100 km) wide. The shelf is marked by several deep indentations, particularly in the southern part. At about 79øN, the Greenland Sea is separated from the Polar Basin by a rise, with a sill depth of about 2800 m (1530 fathoms). South of the rise, the Greenland Sea contains two deep basins. At 71 ø N, the Jan Mayen Ridge extends towards Greenland, with a maximum depth of about 1520 m (830 fathoms), while in Denmark Strait the sill depth is about 550 m (300 fathoms).

6. Around Baffin Bay, the shelf is everywhere, relatively narrow and nowhere exceeds a width of 54 NM (100 km). The shelf is widest off middle Baffin Island, Labrador, and west Greenland south of 78øN. The latter shelf contains numerous important fishing banks. Central Baffin Bay is a basin with

depths exceeding 2000 m (1100 fathoms). The sill across Davis Strait appears to be about 600 m (330 fathoms) deep. Baffin Bay connects with the Arctic Ocean through a network of channels ending in three sounds: Smith, Jones and Lancaster. The Jones Sound connection is quite restricted but the channels leading to Lancaster and Smith sounds are relatively deep, the approximate sill depths being 150-200 m (82 - 110 fathoms) respectively.

Figure 3-1 Arctic Ocean: Bathymetry

303 WATER MASSES

1. In the Arctic, the most important processes conditioning and modifying the ocean water are:

a. Addition of fresh water from the land, primarily from the large Siberian rivers.

b. Addition of fresh water locally through melting of ice.

c. Heat gain through absorption of solar radiation in non-ice-covered areas during summer

d. Concentration of salt, and hence increase of density of surface water, through freezing and convective overturn.

e. Heat loss to the atmosphere through any open water surface, including leads in the central Arctic pack-ice.

2. The addition of fresh water and heat gain (a, b and c) lead to decreases in the density of the ocean water and occur only during the summer (June-September). The concentration of salt and heat loss (d and e) lead to increases in the density of the surface water.

3. On the basis of temperature, the three water masses may be defined as follows:

a. Surface water (Arctic water), from the surface down to about 200 m (110 fathoms), which has varying characteristics. In ice-covered areas the water temperature is close to that of freezing for the salt content. In the usually ice-free areas (eastern Greenland Sea; along west Greenland north through Davis Strait) temperatures may be a few degrees above freezing. Areas that are ice--free in summer (Chukchi Sea; near-shore areas of other peripheral seas; most of Baffin Bay) may seasonally exhibit surface temperatures of 1-2øC or more. Temperatures below the surface are typically always cold, except in the Canadian Basin of the Arctic Ocean, where there may appear a small temperature maximum (-1.0 °C) in the 75-100 m (40-55 fathom) layer. The salinity of the surface layer may be uniform down to about 45 m (25 fathoms) and then increase until at 200 m (110 fathoms) it is 34.5 parts per 1000.

b. The layer below the Arctic water, from about 200-900 m (110-490 fathoms), known as the Atlantic layer, has temperatures above 0°C, with a maximum at 300-500 m (165-275 fathoms). Salinities continue to increase over the surface values until by400 m (220 fathoms), and in many instances shallower depths, they attain in the Greenland Sea and Arctic Ocean nearly uniform values in the range 34.9-35.0 parts per 1000, and in Baffin Bay, 34.5-34.6 parts per 1000.

c. Beneath the Atlantic layer is bottom water with temperatures below 0°C and the same uniform salinities attained in the Atlantic layer. Deep temperatures vary slightly from basin to basin: in the Canadian Basin they are about -0.5°C; in the Eurasian Basin -0.9°C; in the Greenland Sea -1.2°C; and in Baffin Bay -0.45°C.

4. The density of cold water is much more strongly influenced by salinity than by temperature: thus the vertical distribution of density closely parallels that of salinity. On the basis of density, the Arctic waters show a two--layer system, with a thin, less dense surface layer separated from the main body of water of quite uniform density. Vertical motion and the vertical transfer of heat and salt, are therefore restricted, and hence the surface layer acts as a "lid" over the large masses of warmer water below.

5. There is little spatial variation of surface temperature throughout the Arctic. Only those areas that are normally ice-free all year round exhibit temperatures significantly above freezing. These areas are

influenced by currents carrying warmer water into the Arctic (eastern Greenland Sea-West Spitsbergen Current, and the northward-flowing current along west Greenland), and remain ice-free for that reason. Seasonal temperature fluctuations occur in areas that are typically ice-free seasonally (July-September) and include the coastal sectors of the peripheral seas of the Arctic Ocean, north of Bering Strait, and around eastern and northern Baffin Bay. Areas in which major currents carry Arctic water towards the North Atlantic (western Baffin Bay-Canadian Current; western Greenland Sea-East Greenland Current) remain ice-covered for longer periods and have temperatures close to freezing at all times.

6. In winter (October-April), a process of considerable importance in modifying the surface waters takes place. When ice grows from sea-water the salt is largely excluded from the ice and results in a local increase in salinity and hence density of the remaining water. This process takes place over the entire surface of the Arctic areas, and the average ice growth is about 1.5 m each winter. However, the ice cover is not continuous and leads are continually opening and closing. The heat loss to the atmosphere from the open water of leads occurs perhaps 100 times faster than through ice (also producing fog in the atmosphere).

304 CURRENTS

1. The circulation of the Arctic water is created by the rotation of the earth, and by density differences, and is also wind--induced. In the Arctic Ocean the dynamic topography provides a quantitative estimate of the currents. (See Figure 3-2). The net effect of tides is unknown though there may be some asymmetry in their action, which would modify the circulations. The surface waters from the whole Eurasian side of the Arctic Ocean tend to move towards the North Pole. This flow is on the average slow, perhaps 2-3 cm/sec (0.04-0.06 kt), but after passing the region of the Pole it becomes more concentrated and then exits from the basin as the East Greenland Current. In the Beaufort Sea, the surface waters have a clockwise movement, apparently a result of the general wind pattern; they tend to flow to the west along the shelf off the Canadian Arctic Islands, and to the north in the area north of the Bering Strait.

2. Around the Greenland Sea there is a large cyclonic circulation, with average speeds in the range10-20 cm/sec (0.2--0.4 kt). Inflow of North Atlantic water, both at the surface and at deep levels, occurs along the east side of the sea as the West Spitsbergen Current. The East Greenland Current is the major flow south on the west side. The surface water from the Arctic Ocean contributes to the upper layers, while the deeper waters are largely from the West Spitsbergen Current, completing the cyclonic gyre. The current closely follows the continental slope. Over the wide continental shelf of the northern area (77-80°N) the currents tend to be weak and variable. The East Greenland Current seems to accelerate towards the south, attaining speeds of 15-40 cm/sec (0.3-0.8 kt) near the Denmark Strait.

3. The same general pattern of circulation is found in Baffin Bay. A cyclonic circulation dominates the bay; inflow of North Atlantic water occurs along western Greenland through the Davis Strait, and inflow from the Arctic Ocean through Smith, Jones and Lancaster sounds. The Canadian Current runs south along Baffin Island and, as it accumulates water from the various inflows, it in general shows higher speeds towards the south

Figure 3-2 Composite Surface Circulation

4. The circulation of the Atlantic layer (See Figure 3-3) has been deduced from the distributions of temperature and salinity. Recent direct current measurements from Soviet and US drifting stations in the Arctic Ocean and East Greenland Current in this layer (300-1000 m: 165-550 fathoms), shown as vectors in Figure 3-3, confirm the general pattern of motion. On entering the Eurasian basin from the Greenland Sea much of the water flows east along the edge of the Eurasian continental slope. The water enters the Canadian Basin on a broad front across the Lomonosov Ridge. There appears to be a general cyclonic circulation in the Eurasian Basin, and a smaller anticyclonic gyre in the Beaufort Sea. Speeds are everywhere low, less than 5 cm/sec (0.1 kt).

305 ADVECTION BOUNDARIES

1. Boundaries between the Arctic seas and the Atlantic and Pacific, and between the Arctic Ocean and Baffin Bay, are of prime importance because of the major role of advection in determining the characteristics of Arctic waters. The best known oceanographically of these is Bering Strait, through which, in summer, Bering Sea surface water flows north into the Arctic Ocean through the Bering Strait. In the eastern channel of the strait, speeds normally range between 50-l00cm/sec (1-2 kt) though speeds over 150 cm/sec (2.9 kt) have been measured. Speeds are less in the western channel. The volume transport is about 1 x 106 m3sec-1. The situation in winter is unknown, though it has been suggested that the northward flow may be only one-fourth that of summer, and may even reverse on occasion.

2. The general flow through the Canadian Archipelago is apparently from the Arctic Ocean towards Baffin Bay. Recent documentation of the drift of ice island WH-5 through Nares Strait (connecting to Smith Sound) confirms the general flow out of the Arctic Ocean through this strait. However, there was evidence of large pulsations in the southerly flow; the indicated periodicity of a few days to weeks suggests that major atmospheric disturbances may be important in significantly altering the flows through these channels.

3. The strait between Greenland and Svalbard provides the primary connection between the waters of the North Atlantic and the Arctic Ocean; water flows into the Arctic Ocean on the eastern side of the strait and out of the Arctic Ocean on the western side as the East Greenland Current. A new concept of the circulation in the Greenland Sea and of the East Greenland Current has resulted from analysis of current measurements made from ice island Arlis-II during its drift along eastern Greenland during winter, 1965. The measurements showed the volume transport of the current to be about 40 x 106m 3sec-1, an order of magnitude larger than previously estimated. This large transport is apparently a major circulation internal to the Greenland-Norwegian seas; the outflow and inflow from the Arctic Ocean represent only minor contributions and subtractions from a large cyclonic circulation. The Arctic water portion of the current to a large extent controls the ice distribution, and so its presence is significant out of all proportion to its small contribution to the total transport. The flow pattern in Denmark Strait is similar to that in the strait between Greenland and Svalbard; the East Greenland Current flowing south dominates the western side, and a flow from the North Atlantic runs north and east around Iceland. The East Greenland Current, transporting polar ice south, usually occupies three fourths or more of the surface of the strait. The flow regime varies seasonally, with summer usually the time of minimum ice.

4. The Atlantic water does exercise considerable influence in the Norwegian Sea and along West Greenland, where it is at the surface and the surface is exposed. The Atlantic water also exerts some influences on ice cover and climate in the seas bordering Siberia. It enters these seas along submarine canyons, particularly in the Kara Sea, where it works its way up to shallower depths. Through a more pronounced influence of tidal action in the shallower water and the vigorous development of vertical convection in winter, the heat of the Atlantic water is carried to the surface where it is apparently

responsible for areas of much thinner ice cover and even for semi-permanent areas of open water (polynyas). A similar effect occurs in northern Baffin Bay, where an area of perhaps 20 000 km2 of Smith Sound has typically very thin ice or even open water all winter ("North Water"). The cause of the "North Water" is unknown, though clearly some source of warmer water near the surface, as with the Siberian polynyas, is required for its existence. In general, within the deep-water part of the Arctic seas, the warm Atlantic layer has negligible influence on climate.

Figure 3-3 Composite Atlantic Layer Circulation

306 WESTERN NORTH AMERICAN WATERS

1. **Bathymetry**. The continental shelf between Point Barrow and Cape Prince Alfred varies in width from less than 43 NM (80 km) in the west to nearly 86 NM (160 km) in the centre and northeast. Off Alaska the cross profile is characteristic of the continental oceanic margin in all parts of the world, consisting of the flat shelf and a steep upper continental slope that decreases as the Canada Basin is reached at about 3660 m (2000 fathoms). East of the border the slope diverges from the mainland in a swinging arc towards northwestern Banks Island, and the upper slope is gentler in this area than farther west. The continental shelf is crossed by, several deep valleys. In the west is the Barrow Sea Valley, which originates off Cape Franklin and deepens northeastwards to become 19 NM (35 km) wide and U-shaped north of Point Barrow. A second valley is 50 NM (90 km) to the east. Northwest of Mackenzie Bay is the Mackenzie Sea Valley, a broad, flat-bottomed valley leading from the outlet of the Mackenzie River; 120 NM (225 km) to the northeast a smaller valley has been recognized. The largest of the shelf valleys is a broad, asymmetrical feature, the Amundsen Trough, between Banks Island and the mainland. It has an average width of 22 NM (40 km) and the floor is at about 440 m (240 fathoms).

2. **Currents**. Surface currents in the Beaufort Sea are light and probably irregular, depending largely on wind and pressure changes. The clockwise circulation of the Arctic basin sets southwest and west at roughly 2.5 nautical miles/day (5 cm/sec) over the continental slope, but there is little evidence that it is found inshore. Along the Alaskan coast there is thought to be a reverse (eastwards) current.

307 EASTERN NORTH AMERICAN WATERS (north of a line, Resolution Island - Kap Farvel)

1. **General**

a. The eastern North American Arctic is centered around the waters of Baffin Bay which is connected to the Arctic Ocean through the channels leading west and north through the Queen Elizabeth Islands, and to the Atlantic Ocean through Davis Strait into the Labrador Sea. The body of water separating west Greenland and northeastern Canada forms a 1025 NM-long channel (1900 km) from the Arctic Ocean to the Labrador Sea.

b. The waters in eastern North America reflect the meeting of warmer waters from the Atlantic with the frigid waters of the Arctic Ocean and are in a large measure controlled by the bathymetry of the area. Baffin Basin, with a maximum depth of 2000 m (1100 fathoms), is separated from the Labrador Sea by the Davis Strait ridge, which has maximum depths near 730 m (400 fathoms). The adjacent channels shallow to depths of 145-185 m (80-100 fathoms) to limit the influence of the Arctic Ocean to those waters found above those depths. Sea surface temperatures reach a maximum in August with a high of 8.9°C in the Labrador Sea. Temperatures above 4.5°C are found along the Greenland coast to 73°N and in the "North Water" off the entrance to Lancaster Sound. In the channels, temperatures are near 0°C and warm to 1.7°C as the waters approach Baffin Bay. The Arctic influence of the Canadian Current along the east coast of Baffin Island is reflected in the depressed temperatures, 0.3 to 3.3° C. Summer salinities are as low as 25 parts per 1000 in the islands near the ice edge. Along the coasts they are near 30 parts per 1000 in the Labrador Sea.

c. Tides in the area are of Atlantic origin and course through Davis Strait. Only in the extreme north are Arctic tides in evidence. Time of high waters at the head of the Gulf of Boothia occurs 12 hours after that in the southern limits of the area. Tidal ranges are near 2-3 m over most of the region, but go to 4 m on the southern side of Davis Strait and are over 12 m at the head of

Frobisher Bay. Tidal currents are extremely variable throughout the region, being generally light in open waters and as high as 7 knots in areas of large tidal ranges.

d. The general surface circulation, like the temperature and salinities, reflects the influences of the Arctic and Atlantic Oceans. The West Greenland Current flows northward from Kap Farvel at speeds of 0.5 kt in Davis Strait. This current carries around the head of Baffin Bay where it is joined by waters flowing southward through the islands to form the Canadian Current, which flows along the east coast of Baffin Island. After crossing the Davis Strait Ridge, the Canadian Current is joined by the west-flowing branch of the West Greenland Current to form the Labrador Current. In the channels between the islands, currents are about 0.5 kt, while the Canadian Current has velocities of about 0.2 kt. In the Gulf of Boothia the waters flow southward and exit through Fury and Hecla Strait into Foxe Basin.

e. Because eastern Arctic America extends through more than 20 degrees of latitude, there are extensive climatic differences. In general, the Canadian portion is colder than the Greenland coast in winter, with many storms in the southern sector. During the summer season there is a greater uniformity of weather over the whole area. The cold sea has a strong influence on coastal weather, creating much fog and cloud and keeping temperatures below 15°C.

2. **Bathymetry**

a. The bathymetry of the northeast American Arctic basically consists of the shallow areas to the north, in which are located the islands of the Canadian Archipelago with relatively deep channels, and the deep Baffin Bay basin (2300m: 1257fathoms) which is separated from the Atlantic by the Davis Strait Ridge.

b. At the entrance to the area from the Atlantic, the bottom rises gradually from the depths of the Labrador Basin (4000 m: 2200 fathoms) to the Davis Strait Ridge where depths are less than 800 m (440 fathoms). This ridge separates the Labrador Basin from the Baffin Bay Basin where depths exceed 1825 m (1000 fathoms). On the Canadian side of the Labrador Sea, the 200 m line is very narrow and is cut by the deep fiords of Frobisher Bay and Cumberland Sound. The Greenland shelf is well defined and narrow near Kap Farvel, and broadens northward to form Fylla, Little Hellefiske and Great Hellefiske Banks. North of Disko Island the continental shelf narrows and all but disappears near Cape York. Along the Baffin Island shore the shelf is narrow.

c. The channels between the Arctic islands are deep where they join the major basins in the area. However, in every case they have shallow ridges which limit the depth and hence the types of waters that may be drawn through them.

d. The narrow channel that separates Canada from northwest Greenland consists of two basins, Hall and Kane, joined by Robeson and Kennedy Channels and Smith Sound. In the north, at the narrowest par the two shores, are separated by only 11 NM (20 km) of water. The shallowest part is in the north part of Kane Basin where the sill depth is 90-185 m (50-100 fathoms). The floor slopes away in both directions to 365-450 m (200-250 fathoms) in the Lincoln Sea, and to about 650 m (355 fathoms) at the south end of Smith Sound.

e. In the central part of Jones Sound, depths of 730 m (400 fathoms) have been reported. Lancaster Sound has a wide flat floor that drops eastwards to 825 m (450 fathoms) where it enters Baffin Bay. As in Jones Sound, submerged valleys enter the main trough from the side fiords and channels. Lancaster Sound reaches a minimum depth of 90 m (50 fathoms) near Cornwallis Island in Barrow Strait.

f. Prince Regent Inlet (Gulf of Boothia) and Admiralty Inlet have similar bathymetric features. Both are extremely shallow at the southern end. Depths increase northwards in what are considered submerged glacial troughs, to greater than 825 m (450 fathoms) in the Gulf of Boothia. Sills with depths of 330 m (180 fathoms) separate them from Lancaster Sound.

3. **General Circulation**

a. At Kap Farvel the waters of the West Greenland Current follow the Greenland coast to the north. Over the continental shelf the waters are colder and fresher than those just beyond the shelf edge. On approaching Davis Strait the warm waters are deflected westwards toward Baffin Island. The cold waters are depleted through mixing in their northward flow so that the extension of the West Greenland Current over the Davis Strait Ridge is relatively warm. This warmth is reflected in weather conditions and ice coverage as described in Chapters 2 and 4.

b. By the time the north-flowing waters have reached the vicinity of Cape York, a large portion of the heat content has been dissipated. However, they are still warmer and more saline than the waters flowing southward from the Arctic Ocean, which are below freezing even in mid-summer.

c. The joining of the waters of the extension of the West Greenland Current, with those flowing through the Arctic islands, forms the Canadian Current, which flows southward along the Baffin Island coast. This current is of frigid character, carrying with it sea ice and icebergs. In the area south of Davis Strait, it is joined by the warm waters of the West Greenland Current to form the Labrador Current.

d. The waters in the three sounds bordering the northwest corner of Baffin Bay have a strong set towards the Bay, with their freight of cold low-salinity water. At greater depths there is a draw-in of the warmer high-salinity water from Baffin Bay to replace the water consumed in the mixing process with the waters from the Arctic Ocean. This effect is most noticeable in Lancaster Sound.

e. In the northern part of Baffin Bay and Smith Sound there is an area described as "North Water". In this region summer sea-surface temperatures have been reported as consistently warmer than in surrounding areas. In winter various sources attribute it to be ice-free during all or most of the year. Various reasons for the existence of the "North Water" have been advanced. The most recent one considered is that it is due to the nature of the circulation, which keeps it ice-free and hence allows the surface waters to be warmed through insulation.

4. **Thermal Structure (Summer)**

a. In general, below 35 m (20 fathoms) temperatures are uniformly cold with gradual warming noticeable in the extreme north (15, 16) due to warmer Atlantic waters in the Arctic Ocean entering the deep channel, and in the south (2) due to warmer waters of the adjacent Atlantic. In winter, temperatures are near-1.5°C throughout the area north of Davis Strait, and between 2-4°C at the southern boundary, except near the coast where temperatures are below 0°C. The influence of the East Greenland Current as it rounds Kap Farvel (1) is shown by the cooler waters in the upper 50 m (27 fathoms).

b. Above 35 m (20 fathoms) strong negative gradients occur, and these are coupled with strong salinity gradients. In one instance (12) a strong positive gradient at the surface suggests cooling due to ice movement.

c. Depressed sound channels are present throughout the summer, but are relatively weak due to the small contrast in temperatures in the water column.

308 NORTHEAST ATLANTIC WATERS

1. **Bathymetry**

a. The Norwegian and Greenland Seas are bounded on the west by the Greenland continental shelf, and on the east by the Norwegian, Barents and Svalbard continental shelves. The depth of the edges of the shelves varies greatly. A large area of the shelves is deeper than 185 m (100 fathoms) and frequently extends to 400 m (220 fathoms). Seaward of the shelves are the continental slopes, with gradients of 1:15 to 1:40; leading down to the abyssal plains.

b. The Norwegian shelf is 50-140 NM (90-260 km) wide in its southern and central parts, but narrows to 10 NM (19 km) off the Lofoten Islands. It is more irregular than normal continental shelves and is crossed by a number of trough--like gullies; these are associated with the major fiord systems of Norway. The Svalbard shelf is narrow and is only 11-40 NM (20-75 km) wide. It is traversed by deep canyons originating in the fiords of Vestspitsbergen such as Kongsfjord and Isfjord. The Svalbard shelf stretches to the banks south of Bjornoya, and from there to the banks off northern Norway is the shelf area of the western Barents Sea. This shelf area is deeper and less irregular than the shelves off Norway and Svalbard.

c. The Greenland continental shelf north of the Denmark Strait is generally broad (60-170 NM: 110-315 km) but narrows to about 15 NM (28 km) in the extreme north. It is widest at the Belgica Bank. Typically the bottom is irregular and rough, but local smooth areas are common and there are a number of shoal areas less than 100 m (55 fathoms) in depth. Troughs are present in the shelf and are both parallel and normal to the shoreline. South from the Denmark Strait the Greenland Shelf narrows from 170 NM (315 km) in width to 25 NM (45 km) at Kap Farvel. It is crossed by prolongations of the fiords of east Greenland.

d. Around Iceland the continental shelf is up to 80 NM (150 km) wide in the west and north and 50 NM (90 km) in the east, but off the south coast it narrows to 10 NM (19 km).

e. The dominant feature of the central parts of the Norwegian and Greenland Seas is the mid-oceanic mountain range forming the Iceland--Jan Mayen and Mohn Ridges. This is the continuation of the Mid-Atlantic Ridge, which runs the entire length of the North and South Atlantic Oceans, and which rises above sea level in Iceland. The Mid-Atlantic Ridge is characterized in its most elevated region by a central rift zone and by the fact that earthquake epicentres tend to lie on or very near to its axis. These features are continued in the Iceland and Jan Mayen Ridges. A narrow, deep-rift valley, 2-3 NM (4-5 km) wide at a depth of 3300 m (1800 fathoms), extends along their axial lines and has well-developed structural benches on its walls. It ends at 78° 30'N where it meets the Vestspitsbergen block. The width of the rift mountains and flanks on each side of this rift is about 35 NM (65 km) and the crests lie at depths less than 2200m (1200 fathoms), but the mountains to the east of the rift are not easily discernible in the Greenland Sea and may have been buried. On both flanks of the ridges are many seamounts. The mountains of the ridge systems rise above the sea as the island of Jan Mayen. A massive, almost unbroken ridge (the South Jan Mayen Ridge) runs south from the island with least depths between 800-1100 m (440-600fathoms).

f. The Greenland Sea Basin was, formerly considered to be separated from the North Polar Basin by the Nansen Sill, but recent Soviet expeditions have shown that a continuous sill does not exist and that is cut through the middle at about 1°E longitude by the deep Lena Trough, the minimum depth of which is 3100-3500 m (1700-1900 fathoms). The mid-oceanic ridge turns in a northwesterly direction from a region to the west of Prins Karls Forland (Vestspitsbergen) and runs in what is known as the Spitsbergen Fracture Zone to the northeastern tip of Greenland. This results in a bottom topography, with a complicated ridge and trench structure. To the east of this zone is the gently undulating Yermak Plateau, which extends for 130 NM (240 km) from the northwestern corner of Vestspitsbergen with its crest at depths shallower than 900 m (490 fathoms).

g. The basin of the Norwegian Sea is separated from the abyssal plains of the northernmost Atlantic, with depths down to 3000 m (1640 fathoms) by the Scotland-Greenland Ridge. The eastern part, between Scotland and the Faroes, is mainly less than 600 m (330 fathoms) in depth, but between Faroe Bank and the Faroe Islands is a narrow channel through the ridge with a sill depth of about 800 m (440 fathoms) and a least width of about 13 NM (24 km). The Faroes-Iceland Ridge lies mainly at a depth of 400 500 m (220-275 fathoms) with the central part shallower than 400 m (220 fathoms) and having several peaks.

h. The deeper parts of the Norwegian Sea can be divided into three regions. The Iceland basin lies between the Iceland-Jan Mayen and South Jan Mayen Ridges and has depths of 2000-2560m (1100-1400 fathoms) in its deepest part. The Norwegian Abyssal Plain, to the east of the South Jan Mayen Ridge, is the most extensive of the three regions and has a considerable area deeper than 3500 m (1900 fathoms). To the east, it is bounded by the Norwegian Plateau, a flat-topped feature generally shallower than 2000 m (1100 fathoms). An extension of this plateau to the northwest separates the Norwegian Abyssal Plain from the Lofoten Abyssal Plain. This third region is relatively extensive, and it has a large area greater than 3300m (1800fathoms) in depth. It is bounded on the north by the Mohn Ridge. Beyond the Mohn Ridge is the basin of the Greenland Sea. It consists in the south of the Greenland Abyssal Plain at a depth of 3660 m (2000 fathoms).

2. **Water Masses and Currents**

a. The water masses of the area together with their temperature and salinity characteristics are listed in Table 3-1. The distribution of these water masses, as far as the upper layers of the ocean are concerned, is shown in Figure 3-4. The temperature distribution at 200 m (110 fathoms) depth, and the sea surface temperature isotherms at 5°C intervals for one of the coldest months (February) and one of the warmest months (August). The trends of the 200 m (110 fathom) isotherm indicate the direction of the current speed; the steeper the gradient, the greater the speed. A comparison of the 200 m (110 fathom) isotherms with those for the surface in summer yields some indication of the amount of thermal stratification in the warm season, whilst comparison with those for winter shows the effect of the convective stirring of the water column brought about by winter cooling of the surface layer.

b. The two dominant features are the warm currents which form the ends of the Gulf Stream system and the cold currents that derive from the North Polar Basin. Taking the warm currents first, the North Atlantic Drift divides at the Mid-Atlantic Ridge at about latitude 51°N. One arm moves northwards parallel to the ridge towards Iceland where it becomes the Irminger Current. This latter carries the Irminger Atlantic Water and it bifurcates to the west of Iceland, one branch proceeding northwards and then turning east along the north coast of Iceland, and the other turning first west and then south to flow along the East Greenland Slope, eventually to round Kap Farvel and flow northwards along the West Greenland Slope in the Davis Strait.

c. A second arm of the North Atlantic Drift carries warm Northeast Atlantic Water eastwards towards the British Isles and passes through the Faroes-Shetlands Channel and to the west of the Faroe Islands into the Norwegian Sea where it is known as the Atlantic or Norwegian Current. This current moves northwards along the Norwegian coast and gradually becomes cooler and less saline as it does so. Off northwest Norway it divides into the North Cape Current, which flows eastwards into the Barents Sea, and the West Spitsbergen Current, which continues northwards past Vestspitsbergen to enter the North Polar Basin where the Atlantic water forms an intermediate warm layer. Part of the West Spitsbergen Current turns westwards off the northern part of Vestspitsbergen and flows towards the Greenland Shelf. It then turns south and proceeds below the East Greenland Current as a warmer, more saline, intermediate layer at 175-350 m (95--190 fathoms) depth.

d. The main cold current of the region is the East Greenland Current. This carries ice and Arctic water, with subzero temperatures and low salinity, from the North Polar Basin along the whole length of the East Greenland Shelf to round Kap Farvel and enter Davis Strait. There are two branches of the East Greenland Current: the first, the Jan Mayen Current, flows eastward to the north of Jan Mayen in the region of the Mohn Ridge. The second, the East Icelandic Current, flows southeastwards past the northeast coast of Iceland to sometimes reach the north coast of the Faroe Islands and beyond. A smaller source of Arctic water and ice are the Bjornoya and East Spitsbergen Currents. These originate in the northeastern part of the Barents Sea and move southwestwards over the Svalbard Shelf, the former to reach Bjornoya and the latter to round Sorkapp in Vestspitsbergen and flow northwards between the Vestspitsbergen coast and the West Spitsbergen Current. The distribution of the sea ice is deterrnined by the East Greenland Current and its two branches, and to a lesser extent by the East Spitsbergen Current.

e. The speeds of the various currents are not well established. There is evidence to suggest that there are frequent changes because of the wind. Some estimates put the speeds of the Atlantic Current and East Greenland Current at 12-24 nautical miles (22-44 km) per day. Locally the East Greenland Current can reach very high speeds, for example, 3 knots (150 cm/sec) just south of the Denmark Strait. The basins of the Norwegian and Greenland Seas contain a very nearly uniform deep water with a salinity of about 34.92 parts per 1000 and a temperature of about-1°C. Seventy percent of the combined basins is below 550m (300 fathoms) depth and filled with this Norwegian Sea Deep Water. The mixed water in the upper layers, primarily in the Greenland Sea and to a smaller extent in the Norwegian Sea, is cooled in winter, but before it can freeze it reaches a higher density than that of water below it and so sinks to form the Deep Water. In the region of the Iceland-Jan Mayen and Mohn Ridges, Arctic Intermediate Water appears above the Norwegian Sea Deep Water and below the Arctic Water of the East Greenland Current system. It has its core at about 400 m (220 fathoms) depth and has a temperature between 0 and 2° C and a salinity between 34.8 and 35.0 parts per 1000. It is formed by the cooling of Atlantic Water and mixing with the Deep Water and, to a lesser degree, Arctic Water. Further south in the Icelandic coastal area, vertical mixing of Atlantic Water and Arctic Water in winter results in a homogeneous water in the uppermost 175-350 m (95-190 fathoms). This water has a temperature of 2-3°C and a salinity of 34.85-34.90 parts per 1000, and is called North Icelandic Winter Water.

f. The Norwegian Sea Deep Water escapes into the North Atlantic Basin through the channel between Faroe Bank and the Faroe Islands. It flows at the bottom of this channel at a speed in excess of 2 knots (100 cm/sec) and as it does so the Northeast Atlantic Water, which lies above it, is entrained into the flow. The resultant mixing produces the Northeast Atlantic Deep Water. This water mass has minor constituents because, at times, the Arctic Intermediate Water flows through the same channel and the Norwegian Sea Deep Water, Arctic Intermediate Water and North Icelantic Winter Water overflow the Faroes-Iceland Ridge, particularly near Iceland, proceed down its southern flanks, entraining overlying Northeast Atlantic Water as they do so, and eventually join the outflow from the Faroe Bank Channel as it flows westwards at the foot of the ridge.

g. The Northeast Atlantic Deep Water eventually turns south when it meets the Reykjanes Ridge; at about latitude 63°N it breaks through this ridge and flows northwards along its western flanks to fill most of the Irminger Sea at a depth of 1750-2500 m (950- 1360 fathoms). Above it, in the Irminger Sea, is Labrador Sea Water with its core at 500-1275 m (275-700 fathoms). This water is formed as the result of the vertical mixing from the surface to a 1500 m (820 fathoms) depth of low-salinity water in the Labrador Sea in winter. Below the Northeast Atlantic Deep Water in the Irminger Sea is the Northwest Atlantic Bottom Water, which originates with the overflow of water from the Norwegian Sea across the Iceland-Greenland Ridge, in the region of the narrow deep channel in the Denmark Strait. The overflowing water is at times Norwegian Sea Deep Water and at times Arctic Intermediate Water. In both cases the overflow proceeds at high speed down the East Greenland Continental Slope and entrains, first, overlying Irminger Atlantic Water and, later, Labrador Sea Water and Northeast Atlantic Deep Water, to produce a water mass of high density which fills the bottom part of the basins of the Irminger and Labrador Seas. Thus, in addition to there being a counter-clockwise horizontal circulation in the upper part of the water column, with the Northeast Atlantic Water entering our area and the East Greenland Current leaving it, there is also a circulation in the vertical plane with the inflow of the Northeast Atlantic Water being compensated by deeper outflows, over the Scotland--Greenland Ridge, of Norwegian Sea Deep Water and Arctic Intermediate Water.

Table 3-1 Temperature and Salinity Characteristics of the Water Masses of the European and American Arctic and Subarctic Seas

Northeast Atlantic Water	9.5°C; 35.35 parts/1000
Irminger Atlantic Water	4.6°C; 34.95-35.10 parts/1000
Arctic Water	< 0°C; < 34.0 parts/1000
Labrador Sea Water	3.4°C potential temperature; 34.89 parts/1000
Northeast Atlantic Deep Water	3.0°C potential temperature; 34.95 parts/1000
Northeast Atlantic Bottom Water	0.8°C 1.5°C; 34.91 parts/1000
Norwegian Sea Deep Water	< 0°C; 34.92 parts/1000
Arctic Intermediate Water	0° - 2°C; 34.8 - 35.0 parts/1000
North Icelandic Winter Water	2° - 3°C; 34.85 - 34.9 parts/1000
Skagerrak Water	3°- 16° C (according to season); < 34 parts/1000

309 EURASIAN COASTAL WATERS

1. **Bathymetry**

a. The Barents Sea occupies nearly 1 400 000 km2 on the continental shelf of Eurasia. It has free contact with the Norwegian Sea on the west and with the Arctic Ocean on the north, and it is deeper than the other peripheral seas, much of it being greater than 185 m (100 fathoms) deep. The bottom is more like a continental borderland than a shelf, as it has both exceptionally shallow and deep areas scattered through it. The flat shelf areas are east and southeast of Svalbard and in the southeastern part of the sea. An east-west ridge at a depth of 185 m (100 fathoms) connects the shore areas around Z. Frantsa Iosifa with Svalbard, and a north-south ridge at 300 m (165 fathoms) separates the western Bjornoya basin with depths of over 350 m (190 fathoms) from the eastern basin. The eastern depression extends southwest between Z. Frantsa Iosifa and Novaya Zemlya with general depths over 275 m (150 fathoms) and occasional depths over 350 m (190 fathoms). In the extreme north there is a third depression between Svalbard and Z. Frantsa Iosifa.

b. The White Sea is a large arm of the Barents Sea that projects more than 270 NM (500 km) into the European mainland. The approach from the Barents Sea is appropriately called Voronka (Funnel), and is about 60 NM (110 km) wide. The entrance narrows to the southwest until between the Kol'skiy P-ov. and the mainland it becomes a strait, called Gorlo (the Throat), 27 NM

(50km) wide, where ice obstructs navigation even when the western, inland and wider part of the White Sea is reasonably ice-free. The White Sea is mostly less than 100 m (55 fathoms) deep.

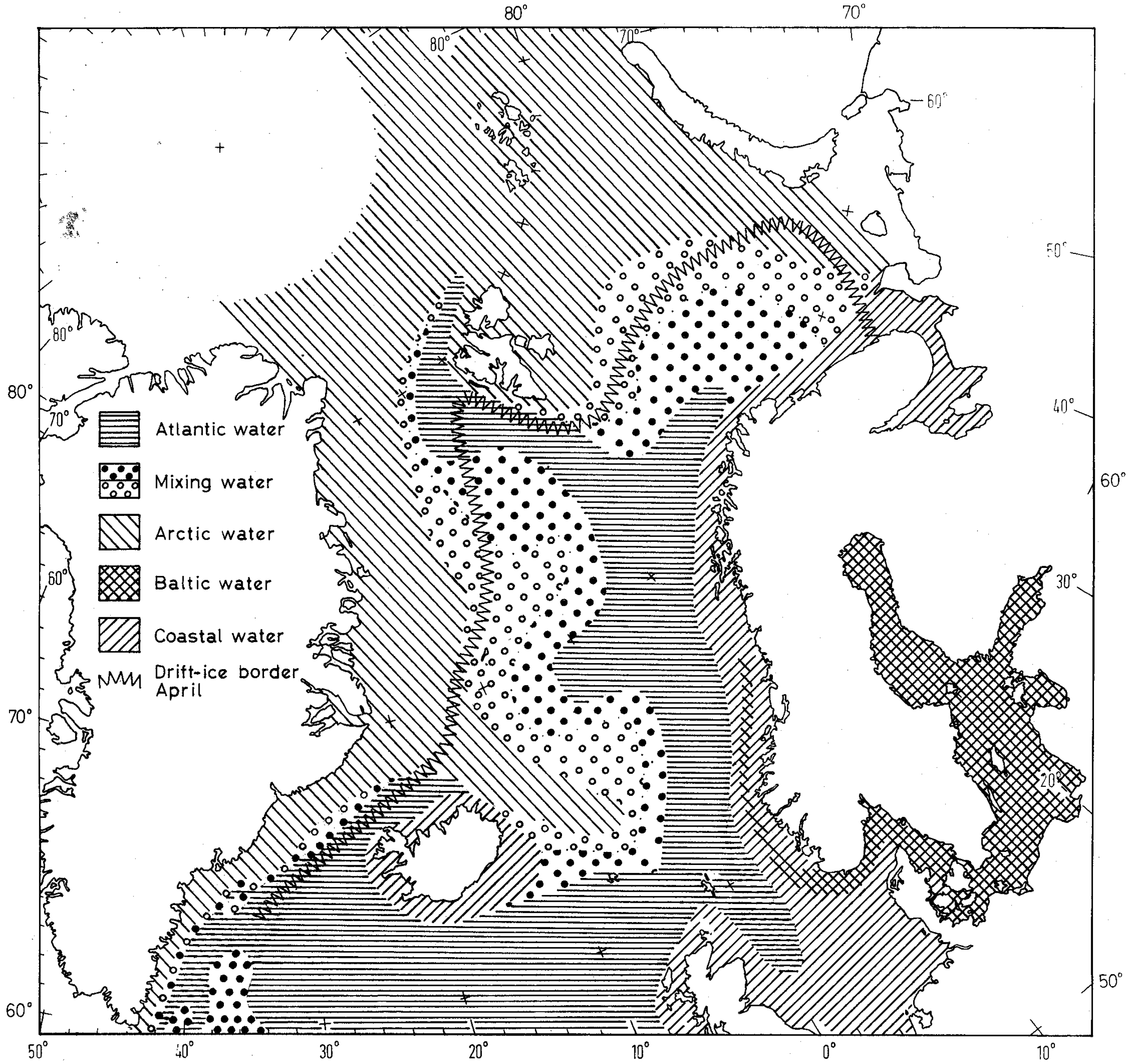

Figure 3-4 Water Masses--Norwegian and Adjacent Seas

c. The Kara Sea is exceptionally shallow in the east but relatively deep for its position on the continental shelf in the west. Off the east coast of Novaya Zemlya there is a 43 NM (80 km) wide basin that in some places is 550 m (300 fathoms) deep. A ridge in the north of the Kara Sea separates the basin from the Arctic Ocean. Between Yamal P-ov and Novaya Zemlya there is another trough of deeper water. There are two more basins in the north of the sea, which have maximum depths of about 550 m (300 fathoms) and are separated by a ridge. O. Uyedineniya, Vize and Ushakova form the highest elevations of this ridge. In the southeast of the Kara Sea depths average only 50 m (27 fathoms) 50-135NM (93-250km) from the shore. The water adjacent to the Ob and the Yenisey rivers is also exceptionally shallow.

2. **Currents**

a. The surface characteristics of both climate and sea ice in the Barents Sea result primarlly from an lnflux of warm water from the Norwegian Sea. This warm current flows north along the coast of Norway; a southern branch enters the Barents Sea along the north coast of Norway and Kol'skiy P-ov. as the North Cape Current; the northern branch flows north of Bjornoya and then turns northwest, passing along the south and west coasts of Svalbard as the West Spitsbergen Current. Off Varanger Halvoya, the North Cape Current flows at 8 nautical miles (15 km) a day but the velocity decreases to the east. The current splits at Varanger Fjord, one part flows in a belt 40-50 NM (75-90 km) wide to the entrance of the White Sea, the other curves northeastwards across the Barents Sea and passes north of Novaya Zemlya into the Kara Sea. This branch is weak in the north and south of its course, but between 36°E and 44°E it runs at approximately 18 nautical miles (33 km) a day.

b. The major inflow of cold water into the Barents Sea is between Novaya Zemlya and Z. Frantsa Iosifa. This current also branches into two parts: one part flows southwest of the archipelago, and the other west, as the Bear Island Current. In the southeast the general movement of water is towards the Kara Sea except for the Litke Current, which has the reverse direction. It moves west through the northern half of Proliv Karskiye Vorota, and then northwest along Novaya Zemlya, joining the general northerly movement there. In the White Sea is a weak outward current in the spring and summer, and an equally weak counter-clockwise eddy within the basin.

c. The only important current in the Kara Sea forms a closed counter-clockwise circulation in the west. The gyre begins in the east with Ob and Yenisey waters which broaden as they leave the estuaries. One branch flows to Novaya Zemlya where it turns southwest to Proliv Karshiye Vorota. Within the main circulation are two small weak counter- clockwise eddies. Water also enters the Kara Sea around the north of Novaya Zemlya from the Barents Sea and eventually mixes with the Ob-Yenisey waters.

d. Tides in the Kara Sea are semi--diurnal and relatively weak. They come from the Barents Sea along eastern Novaya Zemlya and from the Arctic Ocean along western Severnaya and progress southwest. The average amplitude is 0.5 to 1 metre. Winds commonly increase the tidal range by 1 metre or more.

310 EASTERN SIBERIAN COASTAL WATERS

1. **Bathymetry**. Both the Laptev and the East Siberian Seas are shallow basins with gentle shores. The edge of the continental shelf is up to 430 NM (800 km) offshore. Only in the northwest Laptev Sea, off Severnaya Zemlya, are depths greater than 90 m (50 fathoms). The western sector of the East Siberian Sea south of the Ostrova Novosibirskiye and east to the Kolyma River, is exceptionally shallow with many shoals. Between the Indigirka and the Kolyma Rivers, and almost continuous shorebank, defined by the 5.5 m (3-fathom) curve, extends about 24 NM (44 km) out from the shore. From the Kolyma east to Mys Shmidta, the coastal water is deeper. There are only a few islands, and these, with the exception of Ostrova Medvezh'i, are close to the shore. The sea deepens slowly to the northeast; maximum depths are 45-55 m (25-30 fathoms).

2. **Currents**

a. The general flow of water in both the East Siberian and Laptev Seas is counter-clockwise. There is a weak, easterly coastal current which is modified by water from the large rivers which forces it offshore in a northeasterly direction at 1 kt (2 km/h); counter-clockwise eddies develop when it is caught in coastal indentations. The major current entering the Laptev Sea comes through

Proliv Vil'kitskogo between M. Chelyuskin and Severnaya Zemlya. It is joined by a cold current, flowing southeastward along Severnaya Zernlya, at 0.2 kt (0.4 km/h) and the combined waters move along the Taymyr coast into the shallow part of the Laptev Sea. At the Lena Delta the current splits. One part, flowing along the west side of the Ostrova Novosibirskiye at 0.5-1 kt (1-2 km/h), sets to the north of the archipelago and joins the main Arctic drift. The other part flows through Proliv Dmitriya Lapteva and other straits into the Eastern Siberian Sea.

b. The waters that pass through the straits separating Ostrova Novosibirskiye and the mainland spread out on reaching the East Siberian Sea. The main branch near the coast flows at approximately 0.3 - 1 kt (0.5-2 km/h). A branch of this current is believed to pass north and west of Ostrov Vrangelya. In summer a current reaches through Bering Strait and flows northwest to the middle of Proliv Longa; its direction may be reversed in the winter.

c. North of the coastal currents in both the Laptev and the East Siberian Seas, the water flows in large counter-clockwise eddies. Father north still is a west-northwest current, which runs northwest at the Ostrova De-Longa and passes north of the Ostrova Novosibirskiye into the Laptev Sea. It continues northwest across the northern margin of the sea and flows north of Severnaya Zemlya.

d. Tidal progression is southwards from the Arctic Ocean in both seas. Tides are semidiurnal and their range is 30 cm, although it may be raised to 3 to 3.5 m with an onshore wind. Tidal currents flow from 0.5 to 0.8 kt (1 to 1.5 km/h) in the Laptev Sea, but are weaker in the East Siberian Sea.

311 CENTRAL POLAR BASIN

1. **Bathymetry and Submarine Topography**

a. The Arctic Ocean is a true ocean. Beneath the deepest parts, the crust of the earth is about 10 km thick, a figure that is fairly typical of the other oceans. The Arctic Ocean also shares with other oceans the characteristic that relief occurs at two predominant levels: the continental shelves with depths of a few hundred metres, and the deep basins with depths of several thousand metres. A sharp break in slope between the continental shelf and the continental slope marks the boundary between the shelves and basins, and defines the edge of the Central Polar Basin. In most oceans, the shelf break is at about 185 m (100 fathoms) depth, but in the Arctic it is deeper in some localities (365-475 m: 200-260 fathoms). First recognition that the Arctic Ocean was not a shallow sea but contained a true deep basin came from the soundings of the Norwegian North Polar Expedition during the drift of the Fram (1893-1896). The North Pole has been reached twice by ice-breakers and Arctic exploration has been conducted with aircraft, drifting ice stations, and nuclear submarines. Oceanographic research proceeded slowly after the successful voyage of the Fram and it has only been in the last two decades that renewed efforts by the USA and USSR have resulted in our present level of understanding.

b. Early bathymetric maps of the oceans usually showed smooth and unrealistic contours based on wire soundings. With the introduction of the continuous echo-sounder, it became clear that the contours often cut across regions with quite different bottom characteristics. Recently there has been a trend to analyse the ocean floor in terms of physiographic provinces which cover areas of similar topographic textures and which contrast with surrounding areas. Almost all the various provinces found in other oceans, except deep-sea trenches, are known in the Arctic Ocean. The first--order features are the continental margins and the ocean basins. The continental margin is made up of the continental shelf, continental slope, continental rise, and marginal plateaux. The ocean basin consists of ridges, rises, and abyssal plains. A map of the major physiographic provinces of the Arctic Ocean is shown in Figure 3-5.

2. **The Continental Margin**

a. **Shelves, Slopes and Canyons**. The continental margin on the Eurasian side contains some of the broadest continental shelves in the world. The East Siberian Shelf is 270-485 NM (500-900 km) wide and the Barents and Kara shelves are 380-50 NM (700-1200 km) wide. In contrast the shelves off Greenland and northwest Canada are only 16-38 NM (30-70 km) wide. North of Alaska the continental slope has a gradient (1:15 to 1:40) which is comparable to that in other parts of the world. In contrast, the continental slope between the New Siberian Islands and the Chukchi Sea is apparently formed of several level surfaces and has been likened to a "giant staircase". Submarine canyons cut across continental shelves and slopes in the Arctic as in other oceans. Two prominent ones, Barrow Canyon and Harald Canyon, incise the Chukchi Shelf between Wrangel Island and Point Barrow. SSN Nautilus, during her 1958 Arctic cruise, made use of the deeper water of Barrow Canyon to cross the shelf below the ice.

b. **Rises and Plateaux**. A gently sloping continental rise usually lies at the foot of the continental slope. North of Alaska, this rise is 27-54 NM (50-100 km) wide. Much greater widths of 160-270 NM (300-500 km) occur in the continental rise off the Canadian Archipelago. A system of deep-sea channels with a relief of 5 m crosses the Canadian continental rise. A marginal plateau is a level feature which borders the continental shelf at a greater depth. Several are known in the Arctic Ocean. The Chukchi Rise is crowned at its outer end by the Chukchi Plateau or Cap which has a flat summit with a diameter of about 54 NM (100 km) at depths of 300 m (165 fathoms). The surface is marked by a small-scale relief of 5-30 m. Two submarine canyons indent the southwest side of the plateau. Southeast of the Chukchi Plateau is an area of rough topography which has been described as a "continental borderland". Within this area is another plateau, the Northwind Cap. Other marginal plateaux include the Beaufort Terrace, which on its outermost edge, is similarly elevated above the saddle which connects to the continental shelf, and the Morris Jesup and the Yermak rises in the Greenland-Svalbard area.

3. **The Ocean Basin**

a. **Lomonosov Ridge**. The Central Polar Basin is crossed by three submarine mountain ranges. The ridges and rises are nearly parallel to one another and span the basin from the Eurasian to the Canadian side. A bathymetric profile (Figure 3-6) based on SSN Nautilus soundings, shows two of these ranges, the Lomonosov Ridge and the Alpha Cordillera. The Lomonosov Ridge stretching 970 NM (1800 km) between the New Siberian Islands and the Greenland-Ellesmere Shelf, was discovered by Soviet scientists in 1948. It is a single continuous feature, 54-108 NM (100-200 km) in width. Available echograms show a steep-sided ridge with a rather smooth profile. Minimum depth reported is 950 m (520 fathoms). Saddles along the crest have depths of 1500-1600 m (820-875 fathoms). A flat surface near the crest of the ridge has been noted on two different crossings. An offshoot of the Lomonosov Ridge is known as the Marvin Spur.

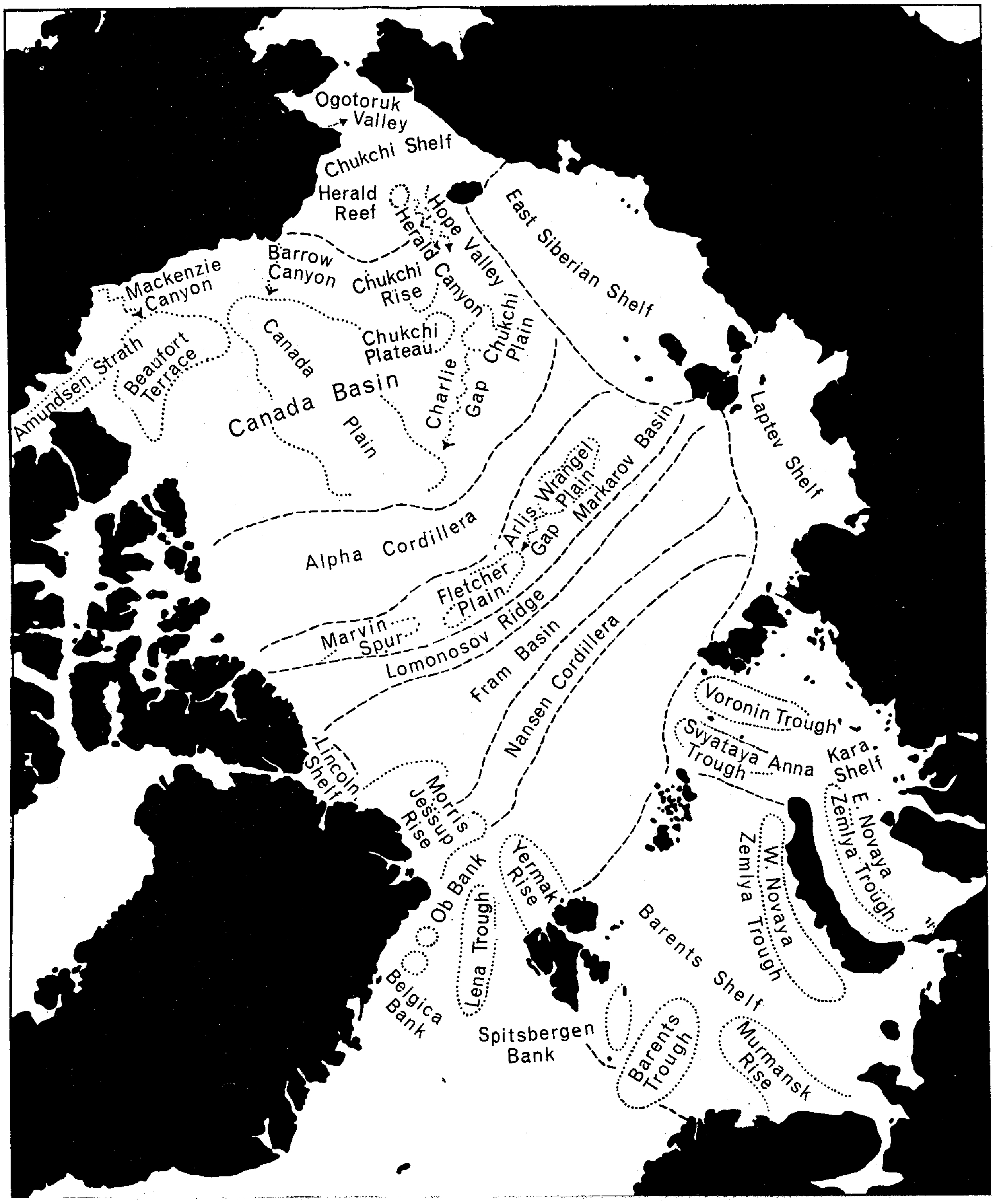

Figure 3-5 Physiographic Regions of the Arctic Ocean and Adjacent Seas

b. **Other Ridges**. The Alpha Cordillera is about the same length as the Lomonosov Ridge but it is much broader, ranging from 135-430NM (250-800km) in width. The crest of the Cordillera is 1500-1975 m (820-1080 fathoms) deep. Topography is much rougher than that of the Lomonosov Ridge. The magnetic fields over these two features also differ. The field over the Alpha Cordillera is rough, with many anomalies exceeding 1000 gammas, while there is little disturbance over the Lomonosov Ridge. Neither of these ranges is seismically active. The Nansen Cordillera is an extension of the Mid-Atlantic Oceanic Ridge into the Arctic Ocean. Where the topography has been sampled, it is rough, as it is on the Mid-Atlantic Ridge. The most distinctive characteristic of the Nansen Cordillera is the narrow earthquake belt along its crest (Figure 3-7). The belt of earthquake epicentres crosses Iceland and then changes direction abruptly north of the island, where a large east-west fracture zone intercepts the mid-oceanic ridge near Jan Mayen Island. Between northeastern Greenland and northern Siberia, the earthquake belt is narrow and straight for a distance of over 1080 NM (2000km). Within Siberia, the earthquake zone spreads out and disappears. In the Atlantic a similar earthquake belt coincides with a central rift valley at the crest of the mid-oceanic ridge.

c. **Abyssal Plains**. These are the ultimate repositories for sediments, which have been transported across the continental shelves and down the continental slopes via the submarine canyons. In the deep basins the sediments collect to form the most extensive level surfaces on the globe, with gradients of 1:1000 or less. Four of the abyssal plains in the Arctic Ocean are arranged in step-like pairs. Each pair is connected by an abyssal gap through which sediments are transported from the upper to the lower plain. The Canada and Chukchi Abyssal Plains are connected by, the Charlie Gap. The complete route of sediment flow is from Herald Canyon to the Chukchi Abyssal Plain and then through the Charlie Gap to the Canada Abyssal Plain; Wrangel and Fletcher Abyssal Plains are connected through the Arlis Gap. Abyssal gaps are commonly named after the ship of discovery. In this case, the discovering "ships" were drifting ice stations, Charlie and Arlis, respectively. Seismic reflection profiles show that a prominent sub-bottom basement ridge exists in the vicinity of the Arlis Gap. Sediments move from the Siberian Shelf to the Wrangel Abyssal Plain and then through the Arlis Gap to the Fletcher Abyssal Plain. A system of interplain channels funnels the flow across the plain and into the gap. The right bank of these channels is higher than the left bank, apparently due to the influence of the earth's rotation.

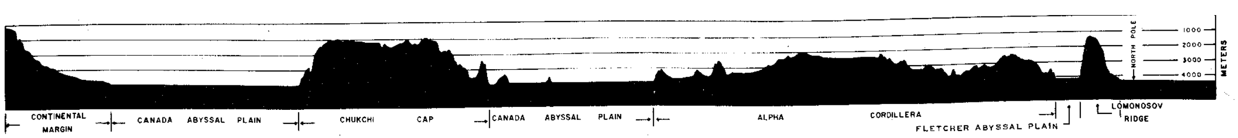

Figure 3-6 Topographic Profile Across the Arctic Ocean

d. The most extensive plain in the Arctic Ocean is the Canada Abyssal Plain which covers an area of 254 000 km2. It is remarkably flat, with depths ranging from 3750 m (2050 fathoms) in the north to 3850 m (2100 fathoms) in the south. On its northern and western edges, it is bonded by the scarps of the Alpha Cordillera and Chukchi Rise. The eastern and southern boundaries grade smoothly into the continental slope. The Pole Abyssal Plain is deeper than the four plains previously mentioned. In the neighbourhood of the North Pole it is flat and smooth with a depth of 4085 m (2230 fathoms). Away from the Pole the depth of the plain increases to 4575 m (2500 fathoms).

4. **Bottom Sediments**

a. Light-brown foraminiferal oozes are generally intermixed with sands and gravels on elevated topography such as ridges and rises. This is known as, a glacial marine sediment. The ooze represents normal pelagic sedimentation. The sands and gravels are ice-rafted material, which has been carried out from shore on ice floes and ice islands to be dumped when the ice melted or broke up. Rocks are often observed strewn over the bottom in deep-sea photographs. The unsorted ice-rafted rocks range greatly in size. A cobble weighing over 7 kg has been dredged. In bottom photographs, rocks with dimensions of about one metre have been seen. These rocks show faceting and striation, which are typical of glacial deposits. On the ridge and rise areas, sedimendation is extremely slow, only a few millimetres accumulating in 1000 years. Thus many thousands of years are required to bury an ice--rafted rock. Signs of bottom life are rare in these regions.

b. Sediments on the Canada Abyssal Plain are greyer in colour and lack the ice-rafted debris found on the elevated areas. The sediments of the abyssal plains presumably also contain the pelagic and glacial components but these have been inundated and diluted by turbidity-current deposits. Turbidity currents originate on continental slopes when oversteepened sediments slump and flow down submarine canyons a, a slurry of mud and water. They flow and spread out on reaching the abyssal plain, depositing the mud over the level surface. The coarsest material settles first so that the beds are usually graded. No rocks are found in photographs taken on the Canada Abyssal Plain. Signs of animal life, such as intricate patterns of tracks and burrows, are abundant.

c. Seismic reflection profiles give a thickness of about one kilometre for the unconsolidated sediments near the northern edge of the Canada Abyssal Plain. The thickness must be greater near the centre of the plain. The same technique has shown at least a 3.5 km thickness of nearly horizontally stratified sediments underlying the Wrangel Abyssal Plain. The layer of unconsolidated sediment is much thinner on the ridges and rises. Measurements on the Alpha Cordillera generally give thickness between 300 and 500 metres.

5. **Water Masses.** Four water masses are recognized in the Central Polar Basin:

a. The Arctic Surface Water lies between the surface and a depth of 200 m (110 fathoms). Salinity may be as low as 30 parts per 1000 in this layer at the surface, but it increases rapidly below 55 m (30 fathoms). Temperature is generally close to the freezing point.

b. On the Alaskan-Canadian side of the ocean, there is a small temperature maximum (-0.7°C) at about 70 m (38 fathoms), which is known as the Pacific Water. The temperature maximum decreases with distance from the Chukchi Shelf.

c. The Atlantic Water is marked by positive temperatures between -relatively uniform salinities of 34.9 to 35.0 parts per 1000 are attained. The depth of the maximum temperature in the Atlantic Layer increases with distance from its source northwest of Svalbard. It is initially at 300 m (165 fathoms) but increases to 500 m (275 fathoms) north of Alaska. The temperature maximum decreases with distance from Svalbard from an initial value of 3°C to 0.5°C north of Alaska.

d. The Arctic Deep Water lies between the Atlantic Water and bottom. Temperatures are below 0°C and salinities increase very slowly with depth, from 34.93 to 34.99 parts per 1000. Below 1375-1500 m (750-820 fathoms), the temperatures are 0.5°C warmer on the Canadian side than on the Eurasian side. These deep waters are presumably formed during cold winters in the Norwegian Sea. They first enter the basin on the Eurasian side of the Lomonosov Ridge. Some of the water flows over the saddles in the Lomonosov Ridge to form the warmer bottomwater of the Canadian side.

6. **Tides**. Tides in the Arctic Ocean are small. For example, the mean spring tide range at Point Barrow, Alaska, is only 15 cm. The semi-diurnal tide is derived almost entirely from the Atlantic. It enters the Arctic Ocean between Svalbard and Greenland, travelling across the Arctic Ocean in about 12 hours as a progressive wave. On the Siberian shelves the tidal currents usually rotate clockwise. Storm surges may exceed the height of the tides and can cause damage to low-lying Arctic coasts.

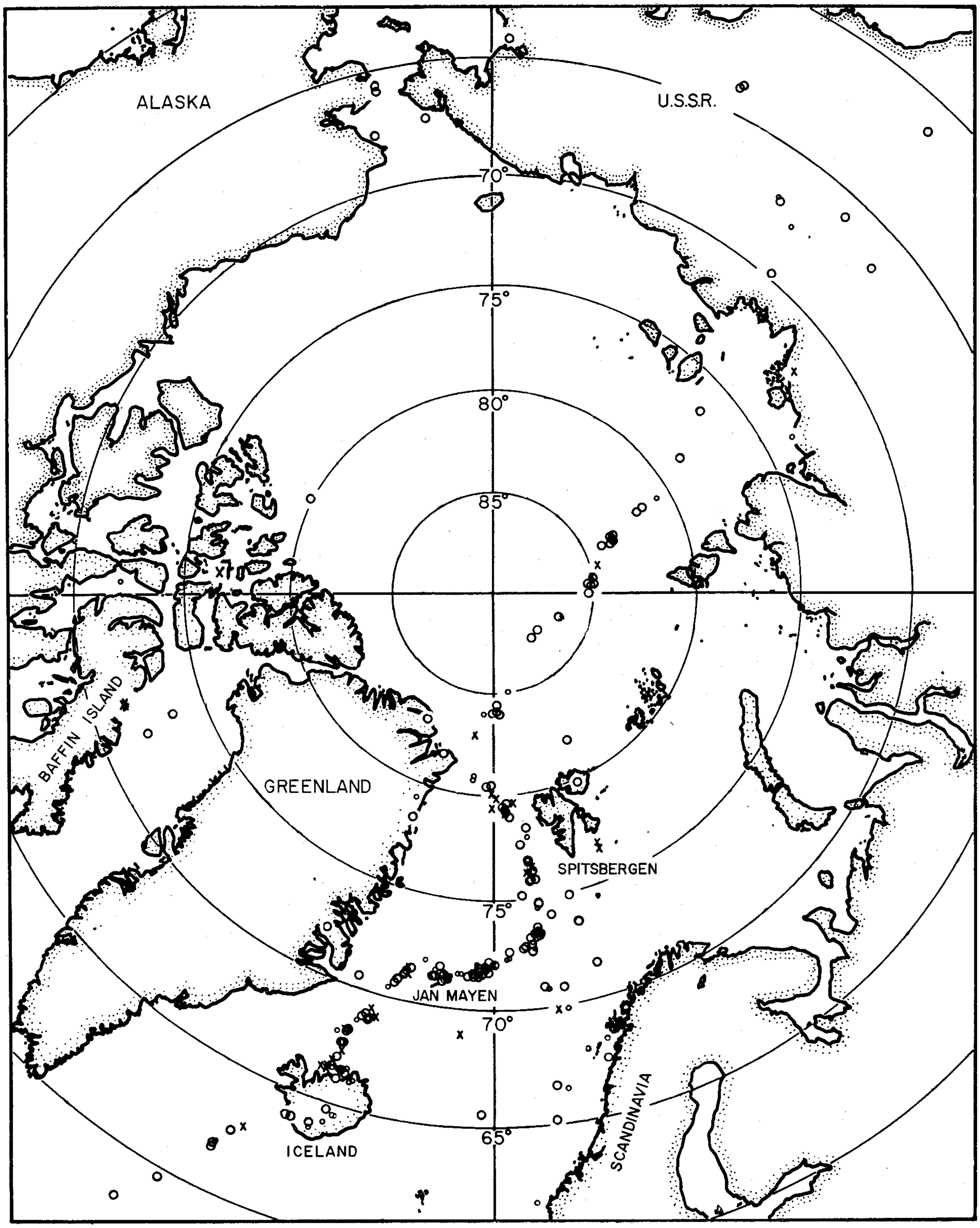

Figure 3-7 Earthquakes in the Arctic, January '55--March '64

7. **Underwater Sound**

a. The propagation of underwater sound in the Arctic Ocean differs in several ways from that in non-polar oceans. In the Atlantic and Pacific Oceans, the SOFAR channel lies at depths of 1000-1375 m (550-750 fathoms), but in the Arctic it is at the surface. Low-frequency sound is propagated to great distances in the Arctic SOFAR channel. Sound rays are alternately refracted upward in the water and reflected downward from the base of the ice. At great ranges signals consist predominantly of low frequencies, 8-100 Hz. Roughnesses on the lower surface of the ice strongly attenuate the high frequencies but have a negligible effect on the low frequencies. Signals generated by small explosions have been recorded clearly at distances from 43 NM up to about 1620 N M (80-3000 km). Beyond a range of 325 NM (600 km), waves above 100 Hz are very weak. The Arctic SOFAR signal is dispersed so that an impulsive signal increases in duration as the range is increased. At a range of 325 NM (600 km) the duration of a signal from a small explosion is about 5 seconds. At shorter ranges, and over smooth bottoms such as abyssal plains, bottom-reflected arrivals can be of importance. They are late signals and increase still further the duration of the signal.

b. In the shallow water of the shelves, propagation characteristics depend strongly on bottom parameters. In general, long-range transmission is much more strongly attenuated along shallow-water paths than it is along deep-water paths. Dispersion is even more pronounced in shallow-water transmission. A shallow sound-scattering layer has been observed beneath the central Arctic Ocean during the summer months. This scattering layer appears on echograms made at a drifting station with a 12 Hz sounder. Information on the sound velocity structure of the ocean can be obtained from measurements of temperature, salinity and depth. For very precise measurements of these factors at specific depths, Nansen bottles and reversing thermometers are employed. Information thus obtained can be converted into sound velocity by various methods.

312 ARCTIC OCEAN FRONTS

1. **General**

a. Ocean fronts are, boundaries separating one water mass from another somewhat like weather fronts in the atmosphere. Unlike atmospheric fronts however, ocean fronts do not move great distances, but rather remain in a given area. Because of this, "regional" characteristic ocean fronts can be classified by the region where they are found and by the characteristic water masses they separate (See Figure 3-8).

b. Ocean fronts themselves are usually associated with cold or warm currents and can be influenced by subsurface topographic features such as submarine ridges. In any case, they are boundaries between water masses of different temperatures, salinities or both.

2. **Iceland-Faeroe Front**

a. The Iceland-Faeroe Front forms the boundary between the warm, saline Atlantic water and cold, relatively fresh Arctic water. The front is located near the extension of the submarine ridge that runs between Scotland and Greenland with depths over the ridge shoaling from 360 to 550 m. The ridge forms a wall separating the deep waters of the Atlantic Ocean and the Norwegian Sea. It blocks the flow of most of the nearly homogenous Norwegian Sea Deep Water into the North Atlantic, thereby affecting the formation and dynamics of the front.

b. Although the surface reflects a rather complex mixing pattern, sea-surface temperature gradients across the front are present during all seasons. Frontal intensity increases and shows more definition with increasing depth. At depths of 180 to 275 m, the horizontal temperature gradient reaches its maximum of -8°C in the winter and -12°C in the summer. Below 275 m, frontal features weaken and become less defined due to the influence of the nearly homogeneous Norwegian Sea Deep Water.

c. Although the position of the front is mainly determined by the Iceland-Faeroe Ridge short period meandering within a 45 NM envelope is not infrequent.

3. **Greenland-Norwegian Sea Front**

a. The Greenland-Norwegian Sea Front is sometimes referred to as the North Polar Front and is associated with the Norwegian Current. The Norwegian Current is an extension of the North Atlantic Current. The current flows northward along the eastern Norwegian Sea at speeds averaging 0.5 knots and brings warm, saline Atlantic water with it.

b. Like all ocean fronts the Norwegian Sea Front, is the boundary between two water masses of different temperature-salinity combinations. Atlantic water with temperatures of 6 to 7°C and salinities slightly greater than 35 parts per thousand are found east of the front. The colder, less saline waters of the Norwegian-Greenland Seas are found to the west of the front.

c. The Norwegian Sea Front is present year-round, and shows significant short term variability (2 to 3 days). This variability takes the form of cyclonic and anticyclonic meanders and eddies on the order of 16 to 32 NM. The surface expression of the front is difficult to locate due to wind mixing of the near-surface waters and the extensive cloud cover limiting the usefulness of satellite imagery. Because the maximum horizontal temperature gradient is found at a depth of 200 to 300 m, SXBT traces can be extremely useful in determining position.

4. **Bear Island Front**

a. The Bear Island Front is located midway between Spitsbergen and the Norwegian coast and results from the interaction of the Bear Island Current and the eastern branch of the Norwegian Current. The Bear Island Current carries relatively cold, low-salinity Arctic water down into the northeastern Norwegian Sea. The Norwegian Current, also known as the North Cape Current in the region, carries modified Atlantic water around the North Cape into the Barents Sea. The temperature of the modified Atlantic water ranges from 1-7°C at a salinity of about 35 parts per thousand.

b. The Bear Island Front lies in shallow water in the vicinity of the Bear Island shelf break near the 90-m curve. The front is closely linked to the bathymetry and shows some light meandering of about 30 NM from year to year. This phenomenon may be due to periods of northeasterly or southwesterly winds that favor the transport of Arctic or Atlantic waters respectively, or tidal effects.

c. Typically, temperatures across the front range from 4-5°C and salinity changes about 1 parts per thousand. The associated sound speed change is on the order of 21 m/sec. Also, one may expect a shoaling off the bottom to 185 m in the vicinity of the front.

5. **West Spitsbergen Front**

a. The West Spitsbergen and Greenland Sea Fronts form the northern and western boundaries of the large cyclonic gyre. The West Spitsbergen Front forms the boundary between the modified Atlantic water found adjacent to the southwest coast of Spitsbergen and the colder, less saline water found in the interior of the Greenland-Norwegian Sea.

b. The temperature gradient associated with the front is evident at the surface where the temperature changes from an average 7 to 1°C. The warmer temperature is associated with the modified Atlantic water, which, has a salinity greater than the 34.88 parts per thousand found in the Greenland-Norwegian Seas.

6. **East Greenland Front**

a. The East Greenland Front is the result of the East Greenland Current, which is the western extension of the Spitsbergen Current. The front separates the cold, less saline waters adjacent to the east coast of Greenland from the warmer, saline water of the Greenland Sea.

b. The water off the coast of Greenland is characterized by seasonal temperatures ranging from-1 to 0°C and salinities from 30 to 34 parts per thousand owing to ice melt. In the summer, strong vertical salinity gradients may be expected to depths of 15 to 23 m. The intermediate and deep waters are made up of Atlantic Intermediate Water found to depths of 730 m, temperatures of 0°C, and salinities of 34.88 to 35 parts per thousand. Below 730 m, Norwegian and Greenland Sea deep water is found with temperatures less than 0°C and salinities between 34.87 and 34.95 parts per thousand.

7. **Kolbeinsey Front**

a. In the region between Iceland, Jan Mayen, and Greenland known as the Iceland Sea, colder, lower-salinity Polar water exists. The Kolbeinsey Front is the boundary between the Iceland Sea Water and warmer, saline water adjacent to the west and northern coast of Iceland. The surface temperature of the Atlantic water ranges from 2°C in the winter to 5°C in the summer.

b. Even in the winter, surface ducts and sound channels should be expected in the Atlantic Water along the Iceland shelf. North of the front in the Iceland Sea Water, either very weak surface ducting or half-channel conditions prevail.

8. **Denmark Strait Front.** The Denmark Strait Front is the boundary between cold Polar water carried southward by the East Greenland Current and warm Atlantic Water carried north into the Irminger Sea along the west coast of Greenland. The Front follows the ice edge and continental shelf break fairly closely, but is known to vary from 30 to 60 NM (See Figure 3-9).

9. **Jan Mayen Front**. The Jan Mayen Front is located south of the Jan Mayen Island and forms the boundary between two Arctic intermediate waters of slightly different temperatures and salinities. To the west of the Front, the water temperature is less than 0°C and the salinity is less than 34.9 parts per thousand, and to the east of the front temperatures are greater than 2°C and salinity is greater than 34.9 parts per thousand.

10. **Norwegian Sea Coast Front.** This front is formed when North Atlantic water flowing northward along the western slope of the Norwegian Trench makes contact with colder, low-salinity waters flowing from the Norwegian Fiords and the Danish shelf around the Skagerrak. A decrease in the sea-surface temperature of about-13°C occurs along an eastward crossing of the front. Although the front

characteristics are strongest along the southern coast of Norway, the front is detectable on satellite imagery all the way to North Cape and into the Barents Sea. The front meanders and generates numerous eddies on the scale of 54 NM.

11. **Murmansk Front**

a. The Murmansk Front, also known as the polar Front, forms the boundary between Atlantic water and Polar water. The Atlantic water flows into the Barents Sea over North Cape with temperatures ranging from 4 to 12°C and salinities of 34.8 to 35 parts per thousand. As the Atlantic water moves eastward it begins to cool. Over the central/eastern Barents Sea, the flow turns northward and splits into two branches south of Franz Josef. The main branch curves west and further cools and sinks deeper. The smaller branch flows over the north coast of Novaya Zemlya.

b. The front is rather weak and separates waters of similar temperatures but different salinities. The Atlantic water has a salinity of about 34.8 parts per thousand in this region while the Arctic surface water has a salinity of less than 34 parts per thousand. Intense, vertical circulation of water has been observed in the frontal zone. This mixing provides a good supply of nutrients to the surface waters, resulting in increased biological activity in the vicinity of the front.

12. **Novaya Zemlya and Kara Sea Fronts**

a. The extension of the North Cape current that flows over the north coast of Novaya Zemlya carries highly modified Atlantic water with temperatures around freezing and salinities of 34 to 34.8 parts per thousand into the Kara Sea. The Atlantic water then flows southwest along the coast of Novaya Zemlya and into the southern Kara Sea.

b. Coastal fresh water input from the Obskaya and Yenisey Rivers amounts to about 940 cubic km annually. This water is relatively warm and has salinities of from 2 to 20 parts per thousand. The general flow for this water is northerly into the central Kara Sea. In the southern Kara Sea, the Novaya Zemlya Front is the boundary between the Atlantic water and the river runoff. A diffuse front, the Kara Sea Front, exists over the central Kara Sea and forms the boundary between the Arctic and river runoff waters.

c. Both the Novaya Zemlya and Kara Sea Fronts are seasonal features that begin to develop soon after the ice melts in the late spring. They reach their peaks in the summer and persist through the fall.

13. **Laptev Sea Front**

a. A weak front similar to the Kara Sea Front exists in the Laptev Sea. Fresh water input into the southern Laptev Sea from the Lena and Olenek Rivers amounts to 554 cubic km per year. This amount is augmented by the inputs of the Khgatanga and Anabar Rivers into the western Laptev (no data available on their output). The river runoff water is relatively warm and has salinities that range from 2 parts per thousand coastally to 28 parts per thousand near the central Laptev Sea.

b. The Laptev Sea Front forms a diffuse boundary between the southern fresh water and the northern Arctic water, and is more or less a continuation of the Kara Sea Front. Like the Kara Sea Front, the Laptev Sea Front is seasonally diffuse and therefore not tactically significant.

14. **East Siberian Sea Front**

a. There are two general types of water masses found in the East Siberian Sea; Arctic and Siberian Coastal waters. The Arctic water is the same basic water mass found in the northern Laptev and Kara Seas and has a temperature near freezing and salinities of from 28 to 33 parts per thousand. The Siberian Coastal water begins to develop after the spring melt and is composed of input from the Indigirka and Kalyma Rivers. This water is fresher than the Arctic water, with salinities less than 20 parts per thousand.

b. The East Siberian Sea Front separates the two water masses and extends eastward from the New Siberian Islands to Ostrov Vranglya (Wrangel Island). The front continues east of Wrangel Island into the western Chukchi Sea where it serves as a boundary between the Siberian Coastal water and the Bering Sea water flowing into the Chukchi from the Bering Strait.

c. The East Siberian Sea Front is a weak seasonal front, sharing the same basic characteristics, which are found in both the Laptev and Kara Sea Fronts.

15. **Alaskan Coastal and Beaufort Sea Fronts**

a. The Alaskan Front is the boundary between central Chukchi and Alaskan coastal waters flowing north along the eastern side of the Bering Strait and coastally in the eastern Chukchi Sea to Point Barrow. Alaskan coastal water originates with fresh water input from Katzebue Sound. The central Chukchi Sea water is composed of Bering Sea and Arctic waters. The central Chukchi water is colder and more saline than the Alaskan Coastal water.

b. The Alaskan Coastal Front extends from the Kotzebue Sound coastally to Point Barrow, and is a relatively weak front (even compared to the East Siberian Sea Front).

c. East of Pont Barrow, the Colville and Mackenzie Rivers provide fresh water input into the coastal water of the Beaufort Sea. The Beaufort Sea Front forms the boundary between the coastal water and the Arctic water of the Central Beaufort Sea.

d. The Beaufort Sea Front is a continuation of the Alaskan Coastal Front and is a rather weak front.

Figure 3-8 General Position of Ocean Fronts

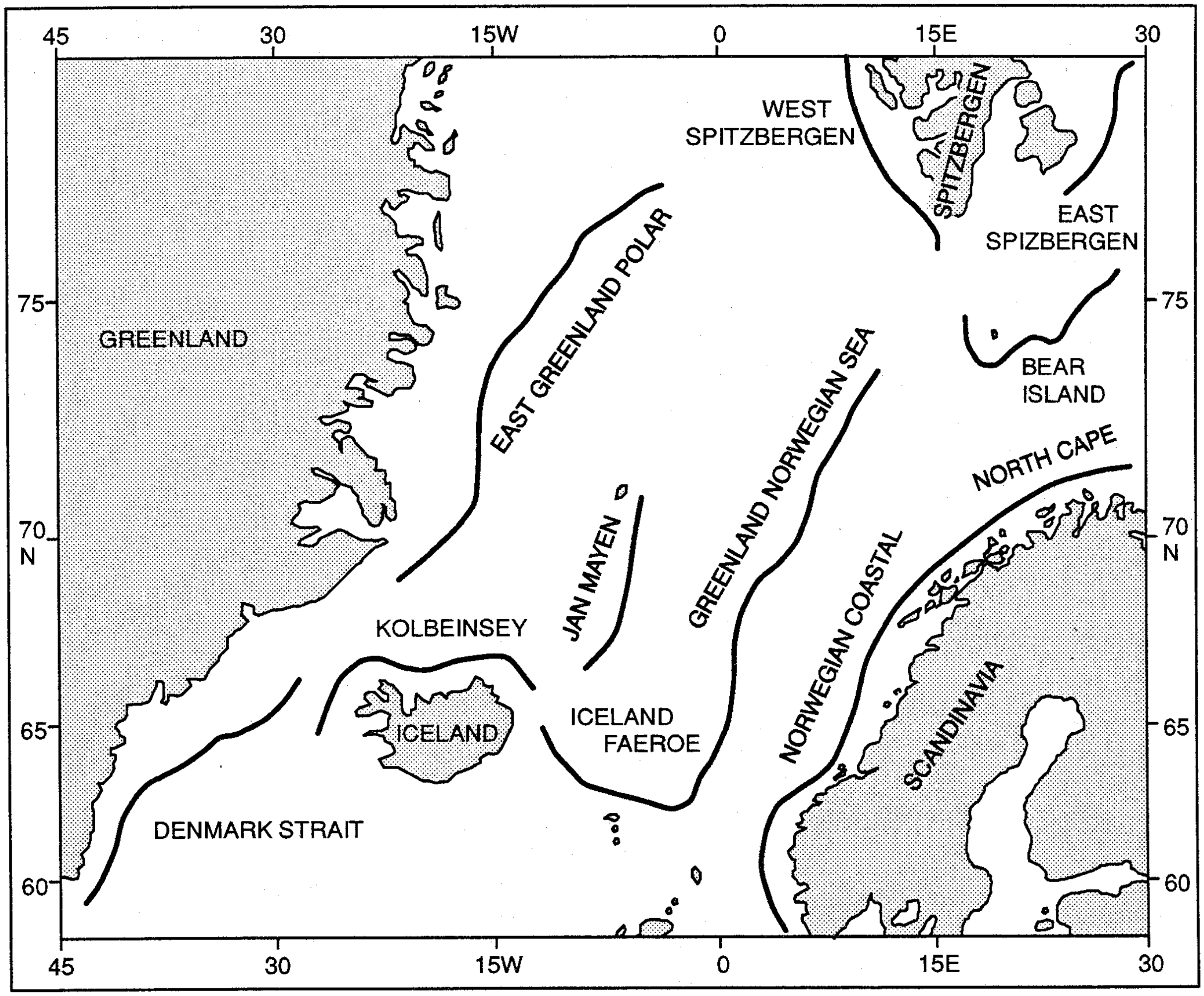

Figure 3-9 Fronts in the Norwegian Sea

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CHAPTER 4

SEA ICE

401 INTRODUCTION

1. The single feature that makes the Arctic Ocean markedly different from most of the world's oceans is the presence of a perennial cover of sea ice.

2. **Ages and Stages of Development of Sea Ice**. There are four broad categories of sea ice age: new, young, first-year, and old. There are several stages of development that occur within these ages:

a. **New Ice**. New sea ice is very elastic sea ice that may be up to 10 cm thick. Depending upon the conditions under which it was formed, new sea ice may have several different stages:

(1) **Slush, shuga, frazil and grease ice** are all comprised of unconsolidated ice crystals or platelets.

(2) **Nilas** is a consolidated form of new ice that remains very elastic. It is divided into dark nilas (0-5 cm) and light nilas (5-10 cm).

b. **Young Ice**. Young ice is considerably harder, thicker (10-30 cm), and more brittle than new ice. There are two subdivisions of young ice:

(1) **Grey ice** (10-15 cm); and

(2) **Grey-white ice** (15-30 cm).

c. **First-Year Ice**. Once ice has grown past 30 cm in thickness, it is considered to be first-year ice. Although there is no upper limit on the thickness of first-year ice, it generally does not exceed 2 metres. First year ice is subdivided into three categories based on thickness:

(1) **First-year thin** (30-70 cm);

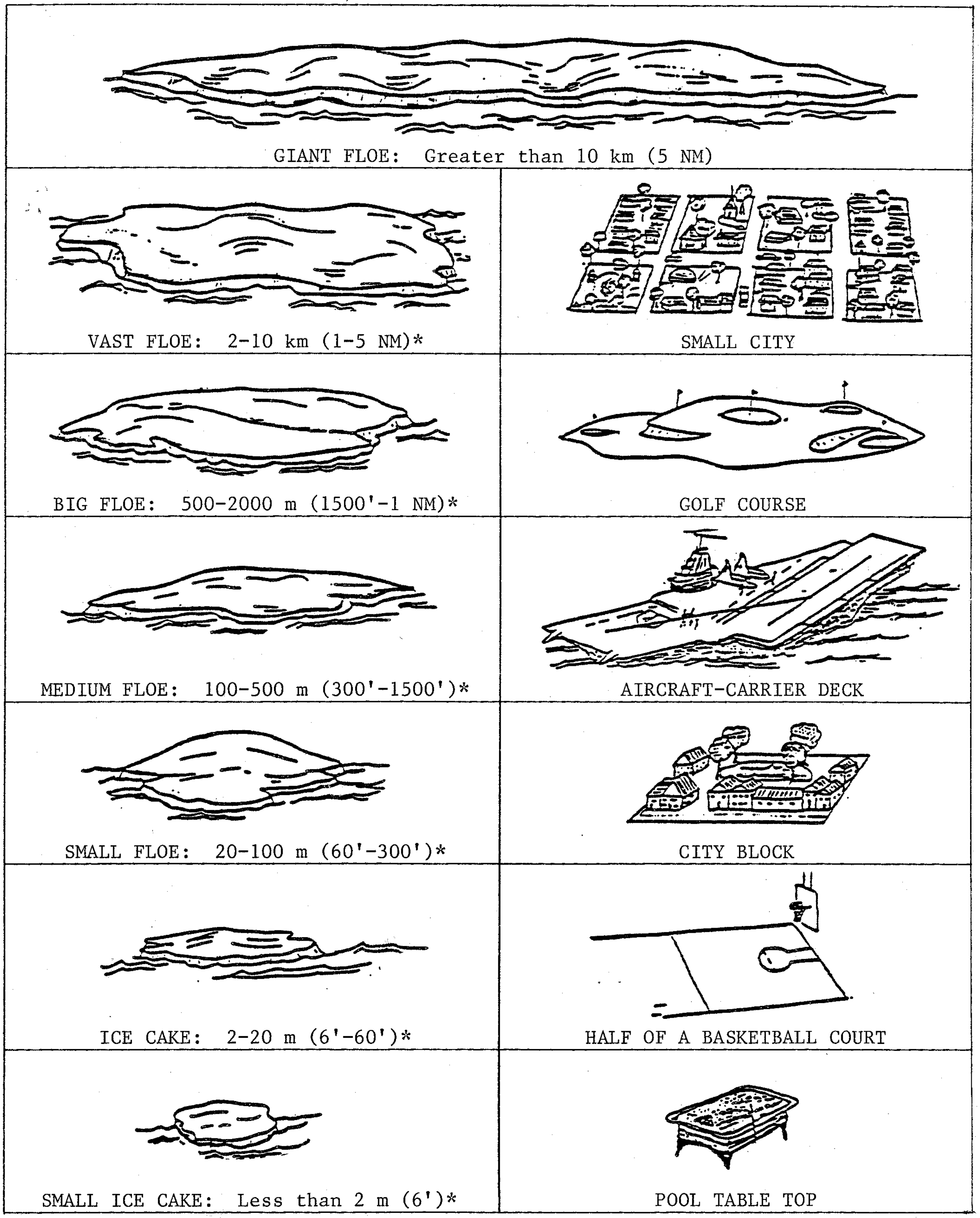
(2) **First-year medium** (70-120 cm); and

(3) **First-year thick** (greater than 120 cm).

d. **Old Ice**. Old ice is ice that has survived at least one summer's melt. This ice is considerably less saline and harder than first-year ice. There are no thickness limits on multi-year ice as the distinction is based on physical properties and not thickness. There are two categories of old ice:

(1) **Second-year ice** - ice that has survived one summer's melt; and

(2) **Multi-year ice** - ice that has survived two or more summers' melt.



* Approximately

Figure 4-1 Floe Size

3. **Concentration**. The amount of ice or the area coverage of sea ice is measured in tenths. The following descriptions apply to various concentrations:

a. Very open ice - 1 to 3 tenths;

b. Open ice - 4 to 6 tenths;

c. Close ice - 7 to 8 tenths;

d. Very close ice - 9 to less than 10 tenths; and

e. Compact or consolidated ice - 10 tenths.

4. **Floe Size**. Floe size varies greatly with location and time of year. A descriptive representation of floe size is found in Figure 4-1.

5. **Ice Topography**. When driven by the forces of wind, seas and currents, sea ice may take many forms. As the ice is forced together, it will fracture to raft or ridge on top of itself. When the ice is forced apart, it will break to form fractures and leads. Similarly, at the ice edge, the forces of nature may create "ice tongues", "belts and strips", or a "diffuse ice edge". During the summer melt, melt ponds and thaw holes will appear on the ice.

402 ICE FORMATION

1. When salt is added to fresh water, the temperature at which it freezes is lowered. The higher the salt content, the lower the freezing point of the salt solution. Seawater, with a salinity of approximately 32 parts per thousand in the Arctic, freezes at about -1.8°C.

2. Unlike fresh water, the temperature of the maximum density of seawater is lower than the freezing point (for salinities greater than 24.7 parts per thousand). Consequently, as seawater cool, it becomes more dense and sinks. Theoretically, in order for ice to form, the entire water column from the surface to the bottom must be cooled to the freezing point. In reality, only the upper layers of the water column must be cooled because deep water that is more saline provides the water column stability that is necessary for ice formation.

3. As the ice forms, there is no room in the crystal structure for the dissolved salts. As a result, these salts are expelled from the ice. If the ice were formed very slowly it would be practically pure. However, the freezing process is never a slow one and the salts are trapped within the ice structure as it freezes. The salinity of sea ice is on the order of 4 to 6 parts per thousand.

403 STRUCTURE AND PROPERTIES OF SEA ICE

1. When seawater is cooled to its freezing point and more heat is removed, ice forms initially as very thin disks or platelets known as frazil ice. These platelets average 2-3 mm in width and about 0.5 mm in thickness but vary considerably in shape from hexagonal "snow flakes" to almost square plates. As further heat is removed, these pure ice crystals grow and multiply. They are less dense than water so they float to the surface and give the water a slightly oily appearance (grease ice). Further cooling results in growth of the ice crystals and mechanical entrapment of small brine cells between them. Ultimately, these cells become separated from the water below the ice by selective downward growth of the ice crystals.

2. The physical properties of sea ice are almost entirely dependent on its salt content. The detailed crystal structure, which results dominates these properties to the extent that one can relate any of them to "brine volume". The brine volume is defined as the fraction of the volume of sea ice occupied by fluid (liquid brine or air bubbles).

3. The strength of the ice is dependent upon the brine volume. The larger the brine volume, the weaker the ice is. For this reason, old ice has a much lower salinity than first-year ice, and is much stronger.

404 ANNUAL ICE CYCLE

1. The process of ice formation has been discussed in some detail in article 402, but this is only the initial stage of ice growth, which is always dependent upon heat loss from the sea. This heat must flow upward through the ice layer and through any snow lying on the ice so that the insulating qualities of these two materials are important factors in determining the rate and amount of ice growth. Air temperature and the amount of radiant energy falling on the surface are also important factors.

2. In the Arctic, radiation is almost completely dominant in determining the ice surface temperature and hence the duration of ice growth. This will continue until some time in spring when the increasing solar radiation changes the heat budget of the ice from a loss to a gain. This usually happens before the air temperature rises above the melting point of the snow cover. Pure white snow reflects as much as 90 percent of the radiation falling on it, and although the quantity of heat absorbed by the ice is small at first, the 24 hours of daylight soon result in a gradual increase in the temperature of the ice. When the air temperature reaches the melting point, the snow surface begins to melt rapidly; it absorbs about 60 percent of the radiant energy and puddles of melt-water become very extensive.

3. In temperate latitudes, the air temperature can contribute to the change from heat loss to heat gain by the ice, for it can rise above the melting point for appreciable periods, if only in the daytime. The situation is thus more complicated but the reversal of heat flux is still the controlling factor.

4. Puddling is the first apparent stage of deterioration of the ice cover. The water surface absorbs heat readily, permitting the puddle to widen and deepen and also to warm the ice. Later, flaws and cracks develop in the floe through which much of the surface water drains away, leaving dry hummocks of ice separated by ponds and streams of melt-water. When the ice has this appearance, operations on it must be carried out with caution for the bearing strength is uncertain and a wind can cause it to break up rapidly.

5. In temperate latitudes the ice is reduced to a grey, water-saturated matrix (rotten ice), which finally melts, and the cycle is complete. Farther north, the summer is too brief for complete melting to take place, and by late August or September puddles begin to freeze and new ice forms between the floes. After a time the floes themselves start growing again. A floe formed in one year, which survives through the following summer differs chemically and physically from ice that is less than one year old. During the summer most of the brine drains out of the ice so that the typical salinity of old ice (secondary multi-year ice) is about 0.5 to 1 parts per thousand. Melt-water from this ice is quite potable. The crystal structure of the ice becomes less regular, the crystals themselves are smaller, and the ice is extraordinarily tough, even in summer.

6. In summer, old floes may be distinguished from first-year ice by their color. The melt-water puddles on an old floe have a very characteristic pale-blue color, which persists after they freeze. On first-year ice, these puddles have a green-to-brownish appearance. The old ice itself has a pale-blue color whereas first-year ice is much more a greenish-white color. The surface of first year ice is

comparatively smooth except for pressure ridges and hummocks. Old ice has a characteristic uneven surface as a result of the differential melting of puddles and old hummocks.

405 OCCURRENCE OF SEA ICE

1. In the Arctic there are no generalizations that can be made about the occurrence of sea ice in relation to latitude. This is evident when comparing the winter maximum extent of sea ice in the Sea of Okhotsk and the Gulf of St. Lawrence, which extend south to 45 degrees North, and winter maximum extent in the Norwegian Sea, which never penetrates south of 70 degrees North. The amount of seasonal variation in the sea ice cover is considerable and varies markedly from region to region. The Permanent Sea Ice Zone is the region that is perennially covered with sea ice. The seasonal sea ice zone is the region that is ice covered only part of the year and extends from the summer minimum sea ice extent to the winter maximum sea ice extent.

2. The mean thickness of sea ice varies greatly by region. The average thickness for undisturbed old sea ice in the central Arctic is about 3.5 m. These thickness averages are misleading because the dynamic nature of sea ice creates ridges and the corresponding keels in the ice. Ridges of up to 15 m and keels of over 45 m have been found. This type of ridging is particularly evident where the ice pressure is impinging upon a coast. Submarine and, ice-breaker observations show that the normal ratio between ridge height and keel depth is between 1:4 and 1:6, with ridge/keel ratios being observed over a very wide range.

406 ICE FORECASTING

1. The date of freeze-up of the sea depends on both the oceanographical and meteorological regimes encountered in the area. Only rarely is the knowledge of water currents, and of the actual temperature-salinity variations with depth, available for forecasts of this type to be made. The rate of ice growth on the other hand can be predicted with fair accuracy from meteorological data, as can the maximum thickness, which will be obtained. It is much more difficult to predict rates of decay, for the process is slow and long-range predictions of both wind and cloudiness are required for accurate results.

2. One of the most important forecasting problems is ice motion. The general pattern of sea ice motion in the Arctic is indicated in Figure 4-2. Recent studies have revealed that 70 percent of the ice motion is due to wind forcing. This pattern is of course affected by tides and currents as well as, land masses, and bathymetric features such as shoals. A general rule of thumb is that the ice will drift about 45 degrees to the right of the wind direction at about 2 percent of the wind speed.

3. Ice routing information for the Arctic can be obtained from the following national agencies:

Nation	Agency	Services Offered
CAN	Environment Canada, Canadian Ice Center, Ottawa	Information on ice conditions such as ice hazard bulletins and special warnings for ships are freely available through weather and marine radio broadcasts. Commercial products including detailed ice analysis charts and radar and satellite imagery are also available. A detailed listing of products and services can be accessed at **http://www.cis.ec.gc.ca**.
CAN	Canadian Coast Guard Ice Operations	Ice routing information for the Canadian Arctic can be obtained via any Coast Guard Radio Station. Further information on contacting Ice Operations may be obtained from the Ice Navigation in Canadian waters (TP 5064E).
DNK	Danish Ice Information Service (DIIS), Narssarssuaq, Greenland	Ice charts of the areas East, West and South of Greenland are promulgated on a regular basis. Ice charts and ice reports can be obtained from all Greenland Coastal Radio Stations and on the internet at **http://www.iserit.greenet.gl/isc/ice**.
DEU	Federal Maritime and Hydrographic Agency	Ice routing information can be obtained from this civil agency. E-mail: **ice.at.bsh.d400.de**. Internet site at **http://www.bsh.de/oceanography/ice/ice/htm**. CINCGERFLEET does not maintain a special agency but can provide ice routing information upon request. This information is primarily available for the North Sea and Baltic but is also available for other areas. Messages should be sent to CINCGERFLEET for GEOPHYS, SIC JOG.
GBR	CINCFLEETWOC	The position of 10 percent of the ice edge is shown on routine Sea Surface Temperature fax charts. This data is not available west of 045W.
USA	National Ice Center (NIC), Washington	The NIC provides operational sea ice analyses and forecasts for the Arctic, Antarctic, Great Lakes and Chesapeake Bay. Their products and services can be accessed at **http://www.natice.noaa.gov**.
USA	US Coast Guard International Ice Patrol (IIP), Groton CT	The USCG IIP monitors ice conditions in the vicinity of the Grand Banks of Newfoundland, and pending severity, broadcasts the Southeastern, Southern and Southwestern limits of all known ice in two daily message bulletins. The IIP can also provide a daily fax chart containing ice information. For a comprehensive listing of products and services and instructions on accessing them use the IIP homepage at **http://www.uscg.mil/lantarea/iip/home.html**.

Sea ice information is encoded according to the World Meteorological Organization (WMO) symbology known as the egg code, due to the oval shape of the symbols. The egg code shown in Figure 4-3 provides information on types and concentrations of ice in each area of the chart. Figures 4-4 and 4-5 are examples of charts distributed by the Center using egg code symbology.

407 OTHER ICE ENCOUNTERED AT SEA

1. **River Ice**. There is appreciable difference in the strength of freshwater ice and sea ice, and consequently, in or near the estuaries of major rivers an additional hazard to shipping may be

encountered in the spring when river ice is carried into the sea. This is particularly true of the rivers of the Soviet Arctic.

2. **Ice Islands**. These are masses of ice that have broken away from an ice shelf and have an undulating surface. They may have thicknesses of up to 60 m with areas of up to 400 km2. In the final stages of melting they usually break up into a group of tabular icebergs.

3. **Icebergs**. Icebergs are large masses of freshwater ice and compacted snow that have broken away or "calved" from a glacier. The Greenland Ice Cap is the single largest source of icebergs, with the largest concentration of icebergs found in Baffin Bay and the Davis Strait. In the East Greenland Sea icebergs are found imbedded in and sometimes outside the drift-ice, particularly south of Scores by Sound. Icebergs have been found in excess of 90 m in height and 500 m in length. Their draft varies from two to more than 10 times their height due to their irregular shapes. Iceberg location information can be obtained from the International Ice Patrol. Icebergs do not always travel in the direction of the wind. They have a small sail area relative to total size and travel in the direction of the current, which may be against the wind. Figure 4-6 shows the general drift pattern of Atlantic icebergs. Figure 4-7 shows typical areas where icebergs can be anticipated in the Pacific region.

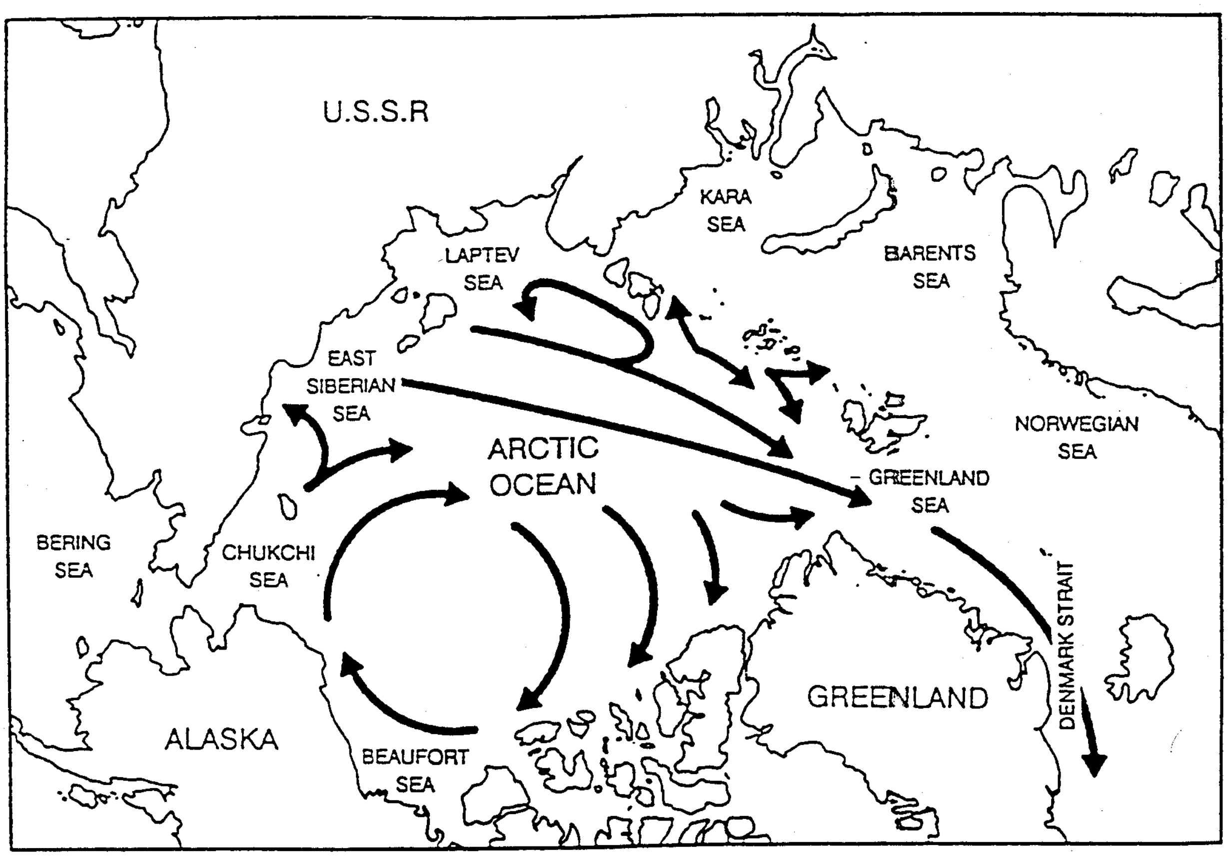
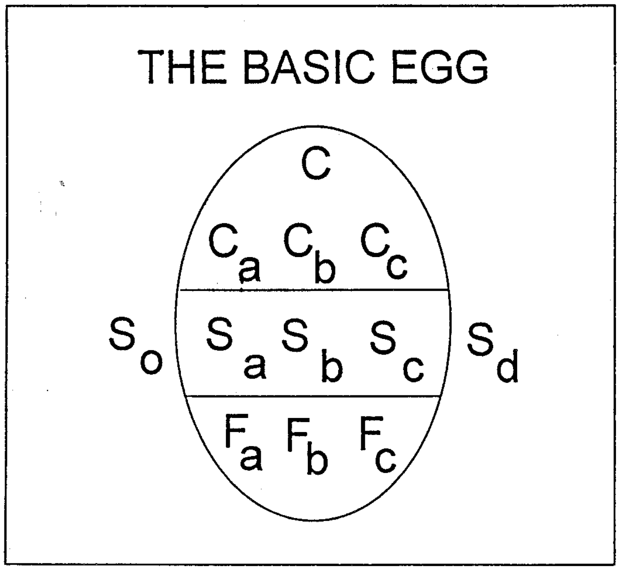


Figure 4-2 General Pattern of Ice Movement in the Arctic Ocean



1. **The total Concentration (C)** is reported in tenths and is the uppermost group. This may be expressed as a single number or as a range (i.e., 3-5).

2. **Partial Concentrations (C_a, C_b, C_c)** are also reported in tenths but must be reported as a single digit. These are reported in order of decreasing thickness. That is, C_a is the concentration of the thickest ice and C_c is the concentration of the thinnest ice.

3. **Stages of Development (S_a, S_b, S_c, S_d)** are listed in decreasing order of thickness. The following codes are directly correlated with the partial concentrations above. That is: C_a is the concentration of stage S_a.

New Ice	1
Nilas	2
Young	3
Grey	4
Grey–White	5
First Year	6
Thin First Year	7
Thin First Year (First Stage)	8
Thin First Year (Second Stage)	9
Medium First Year	1·
Thick First Year	2·
Old	7·
Second Year	8·
Multi–Year	9·

S_o is used to report a trace concentration of the thickest ice.

4. Forms of Ice (F_a, F_b, F_c) are used to report special forms of ice such as pancake ice and floe size union using the following table:

0	Pancake Ice
1	Small Ice Cake/Brash
2	Ice Cake
3	Small Ice Floe
4	Medium Ice Floe
5	Big Ice Floe
6	Vast Ice Floe
7	Giant Ice Floe
8	Fast Ice/Growler/Floeberg
9	Icebergs
x	Unknown
/	Unknown

~ 8 This indicates strips and patches of ice of 8 tenths concentration.

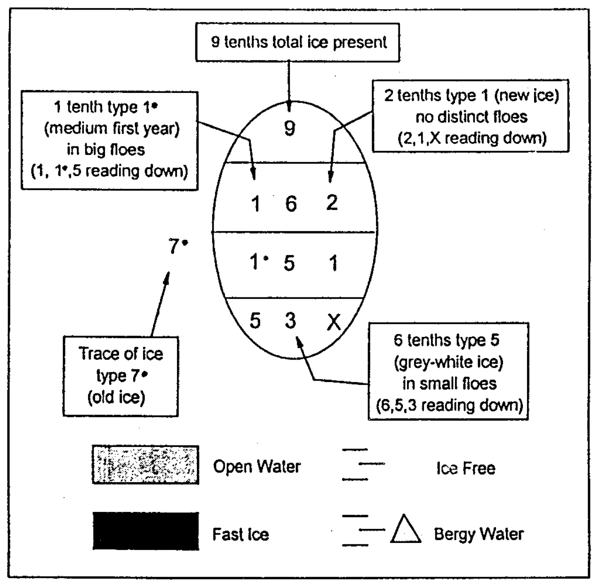


Figure 4-3 Egg Code Symbology

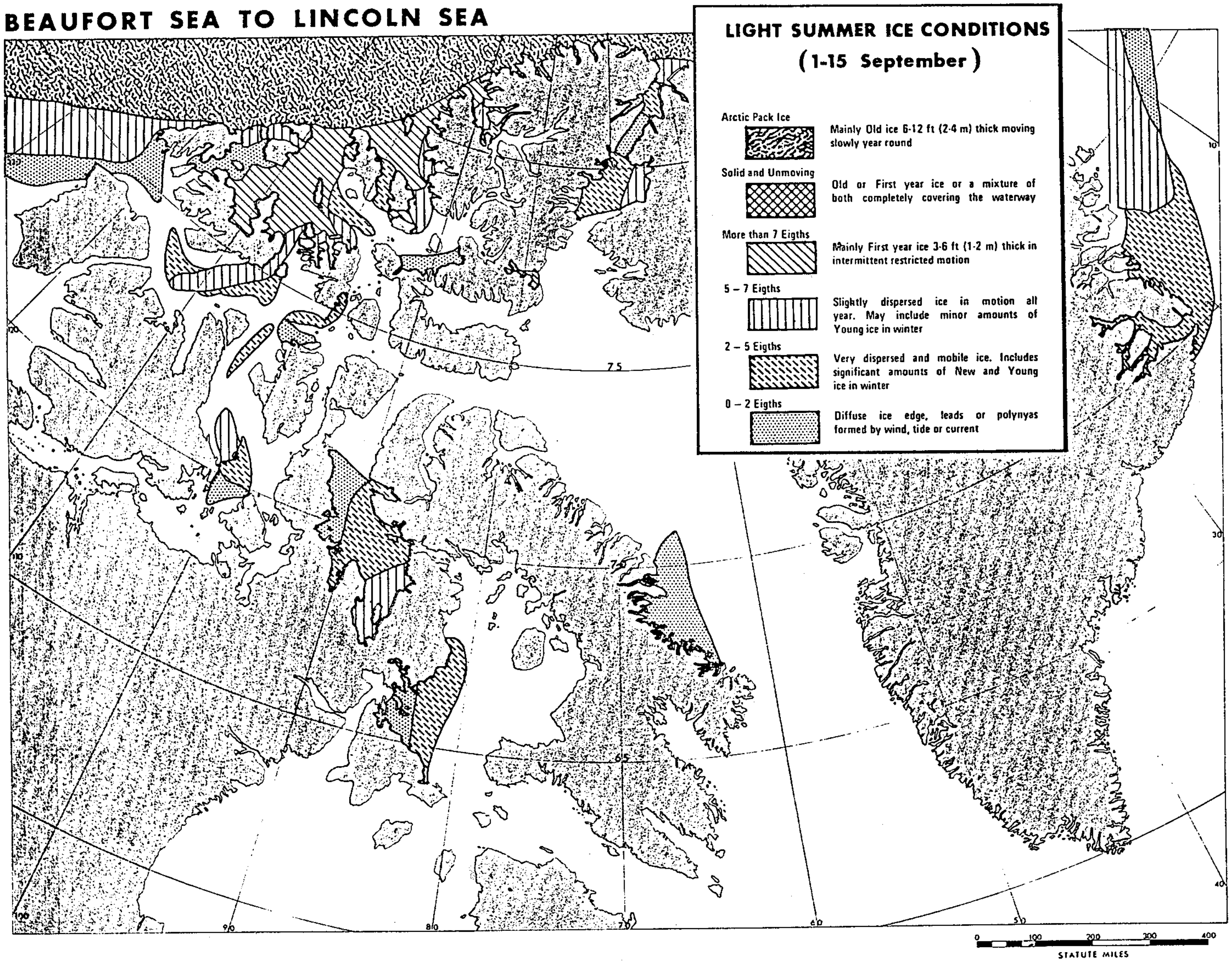


Figure 4-4 (Sheet 1 of 6) Summer Ice Limit Charts

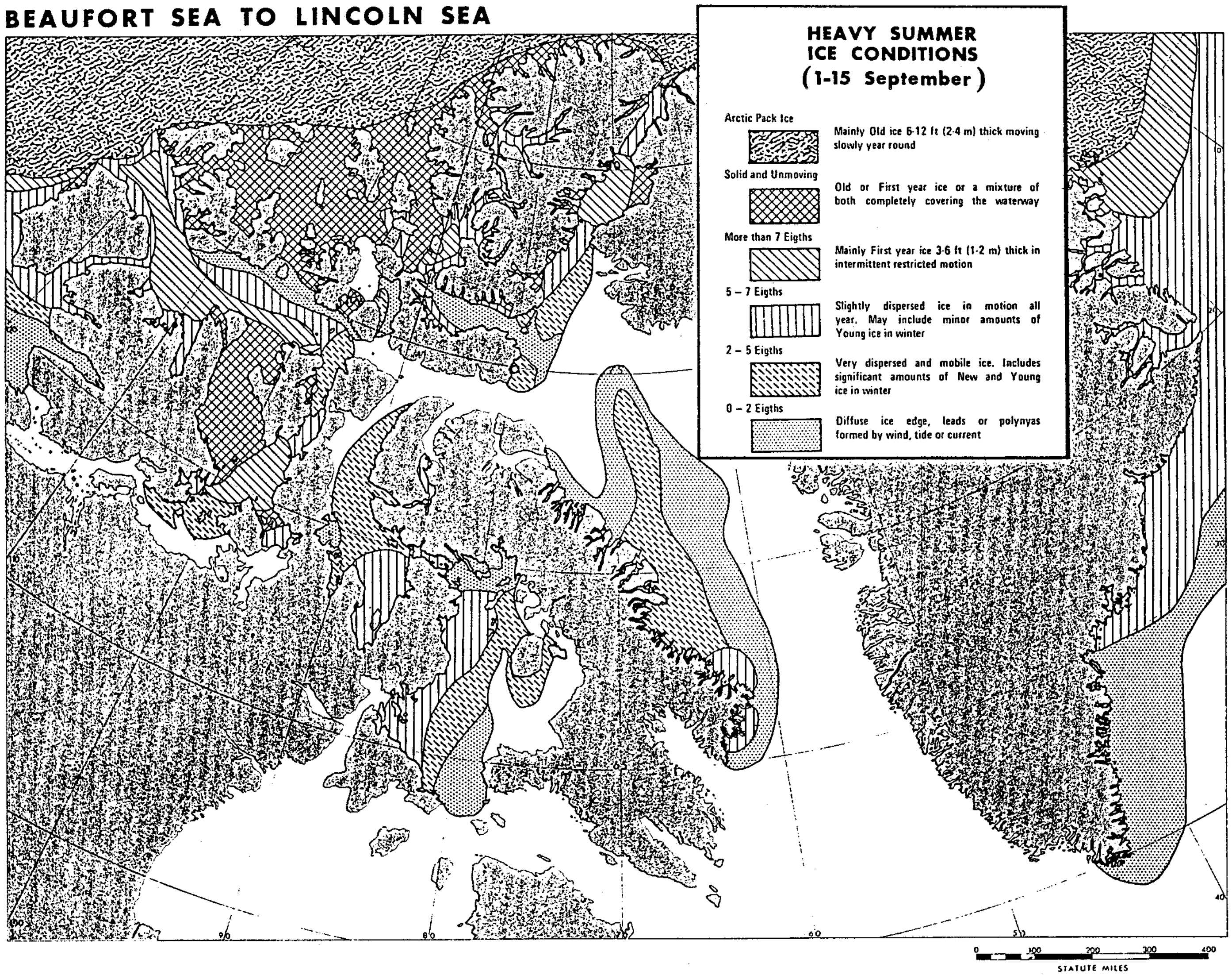


Figure 4-4 (Sheet 2 of 6) Summer Ice Limit Charts

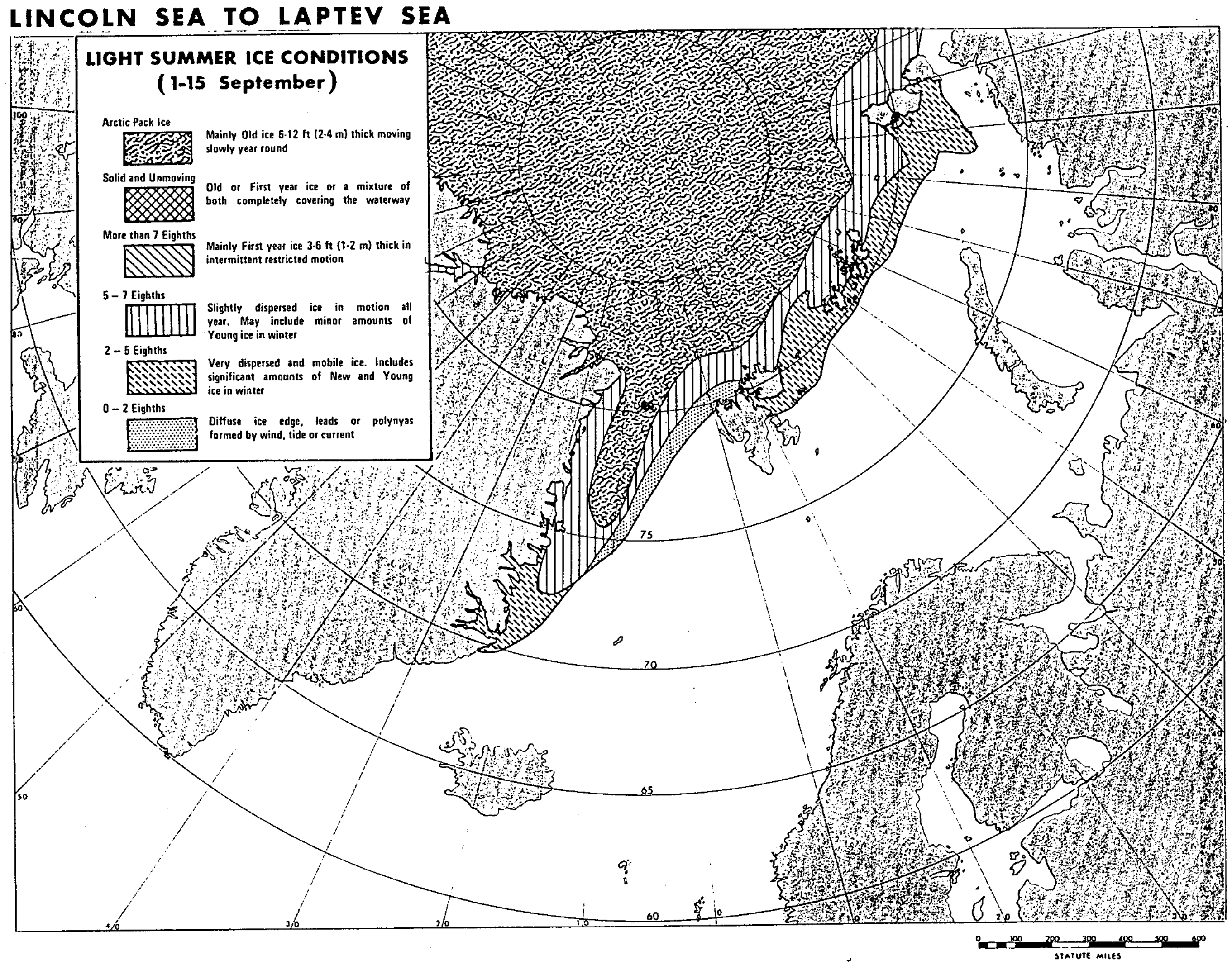


Figure 4-4 (Sheet 3 of 6) Summer Ice Limit Charts

LINCOLN SEA TO LAPTEV SEA

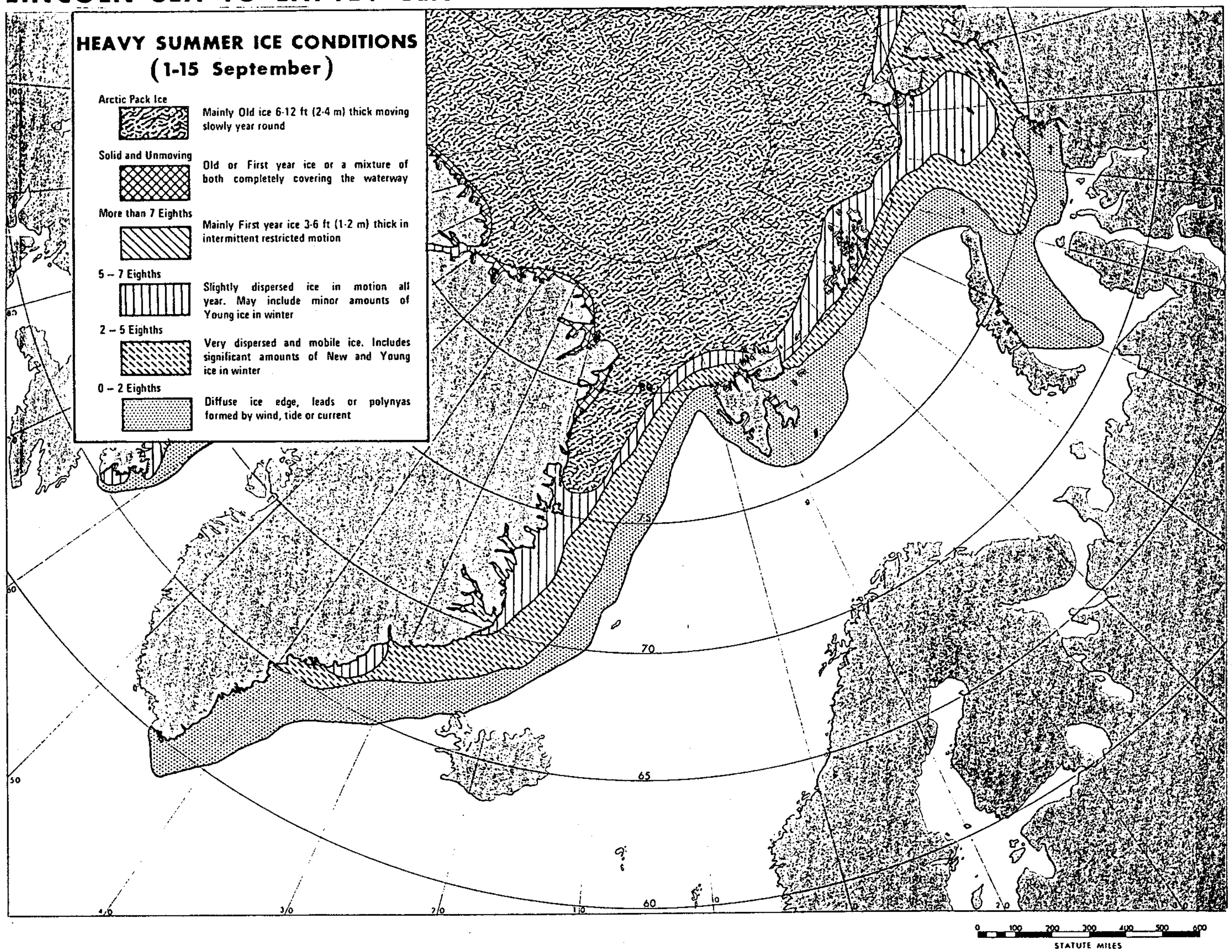


Figure 4-4 (Sheet 4 of 6) Summer Ice Limit Charts

LAPTEV SEA TO BEAUFORT SEA

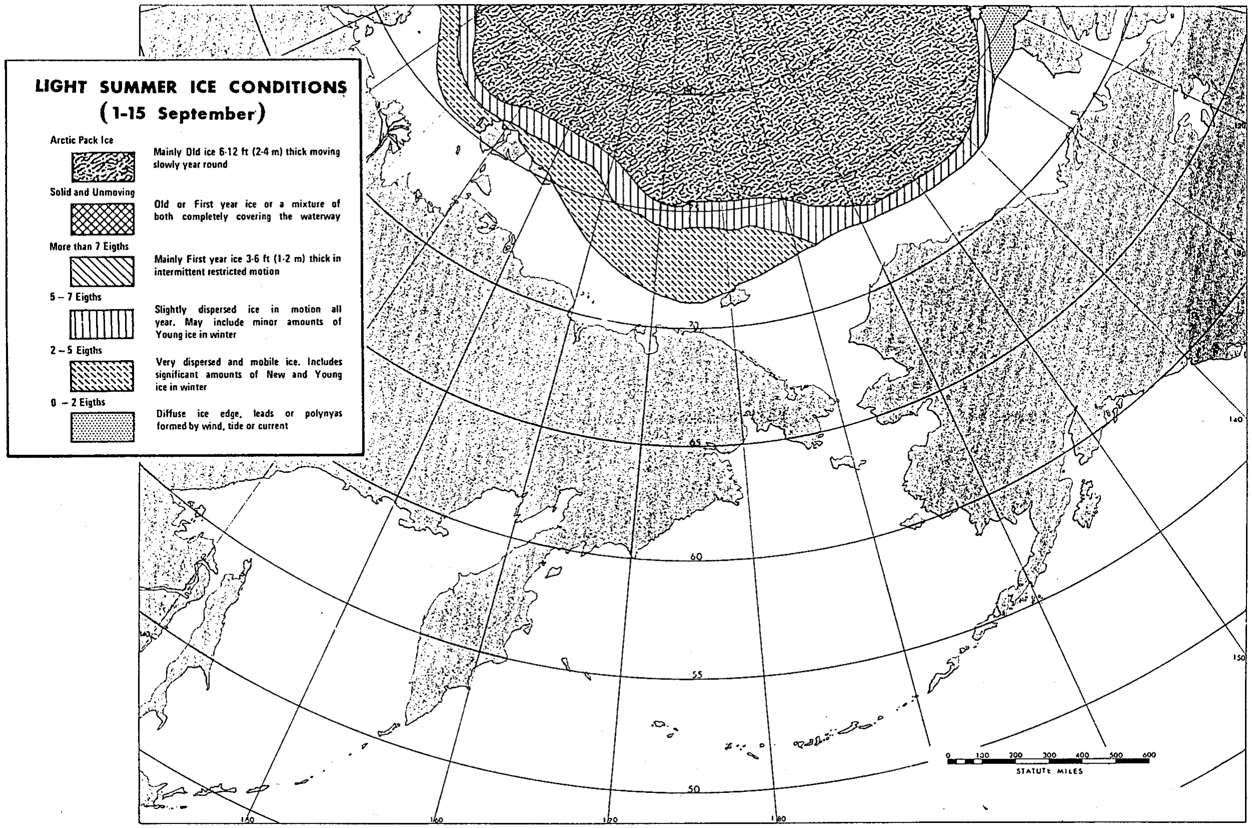


Figure 4-4 (Sheet 5 of 6) Summer Ice Limit Charts

LAPTEV SEA TO BEAUFORT SEA

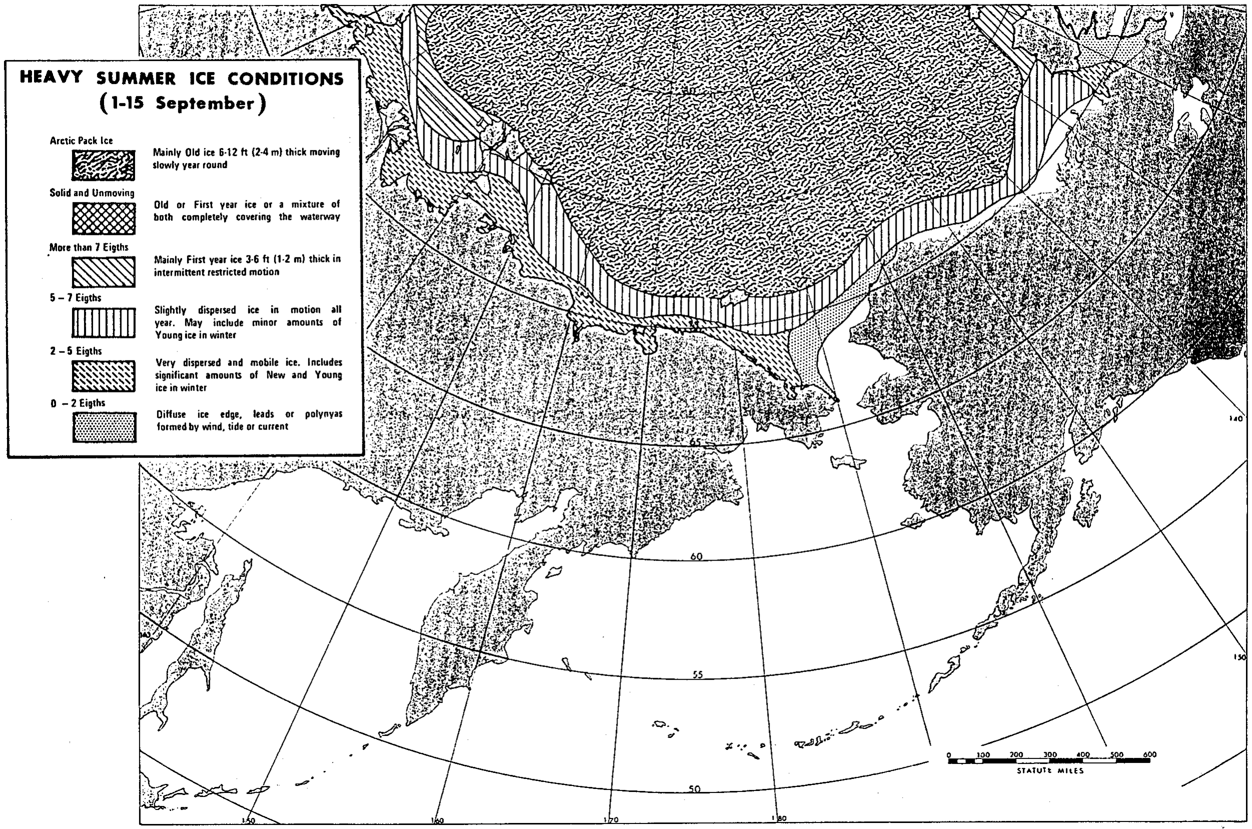


Figure 4-4 (Sheet 6 of 6) Summer Ice Limit Charts

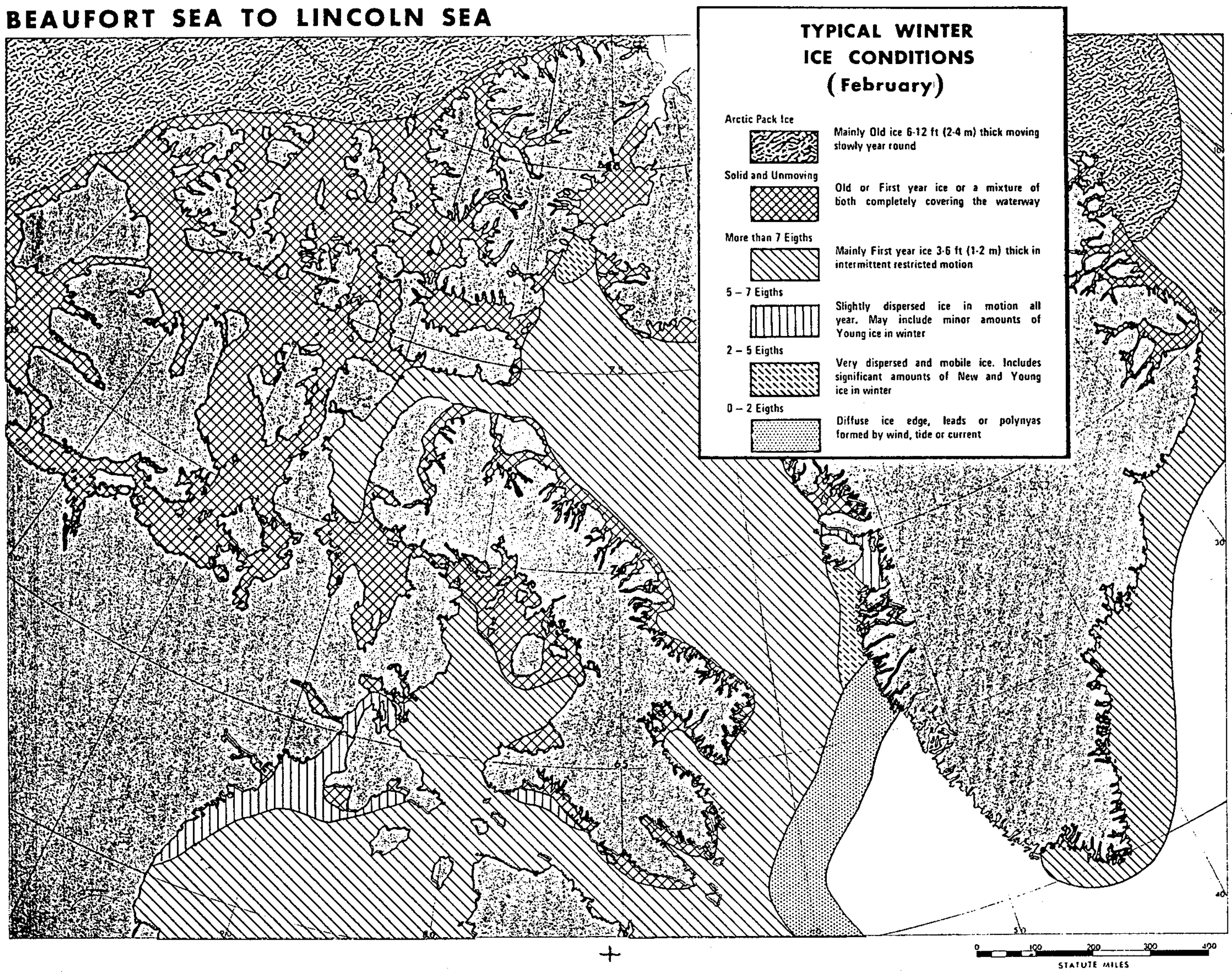


Figure 4-5 (Sheet 1 of 3) Winter Ice Limit Charts

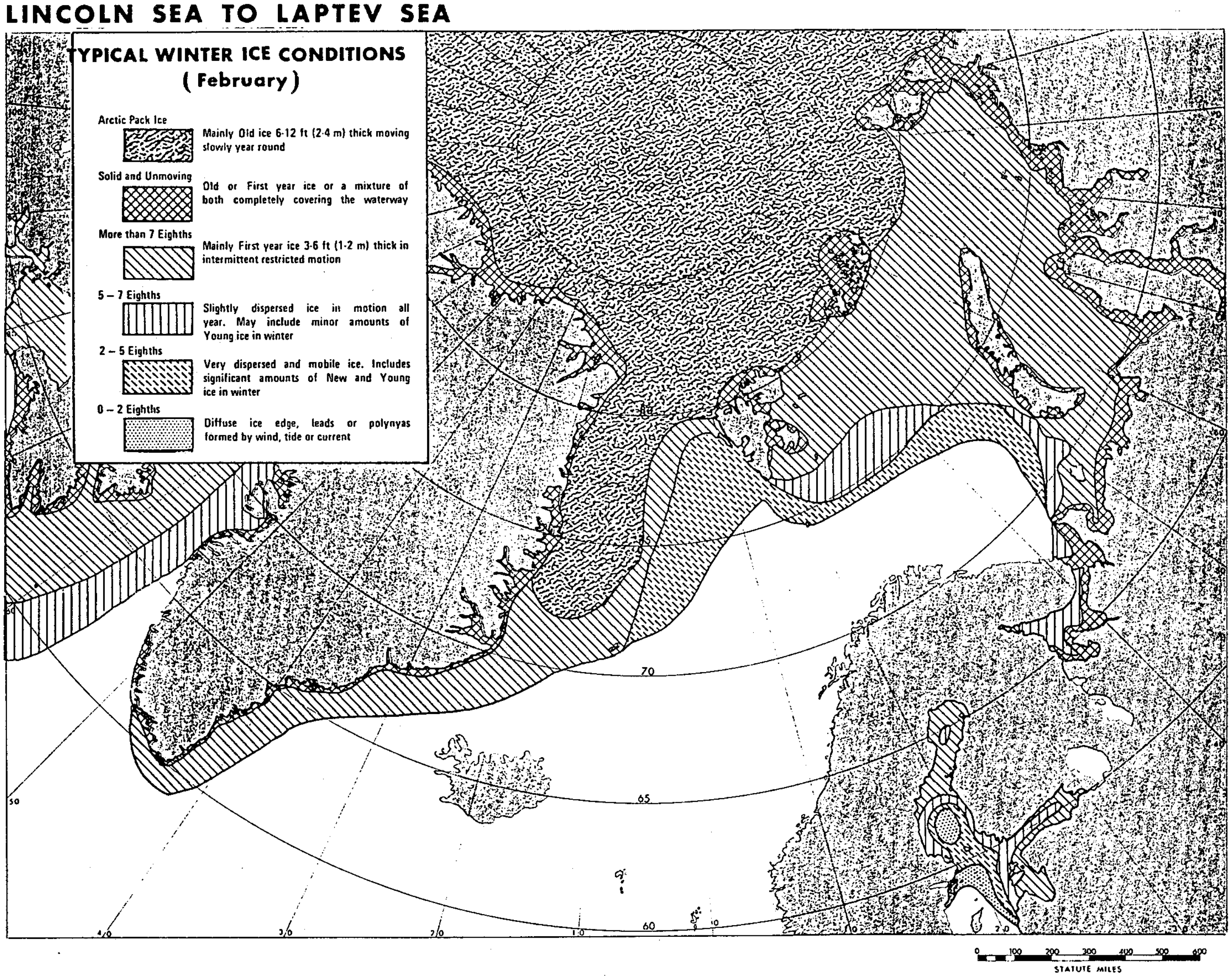


Figure 4-5 (Sheet 2 of 3) Winter Ice Limit Charts

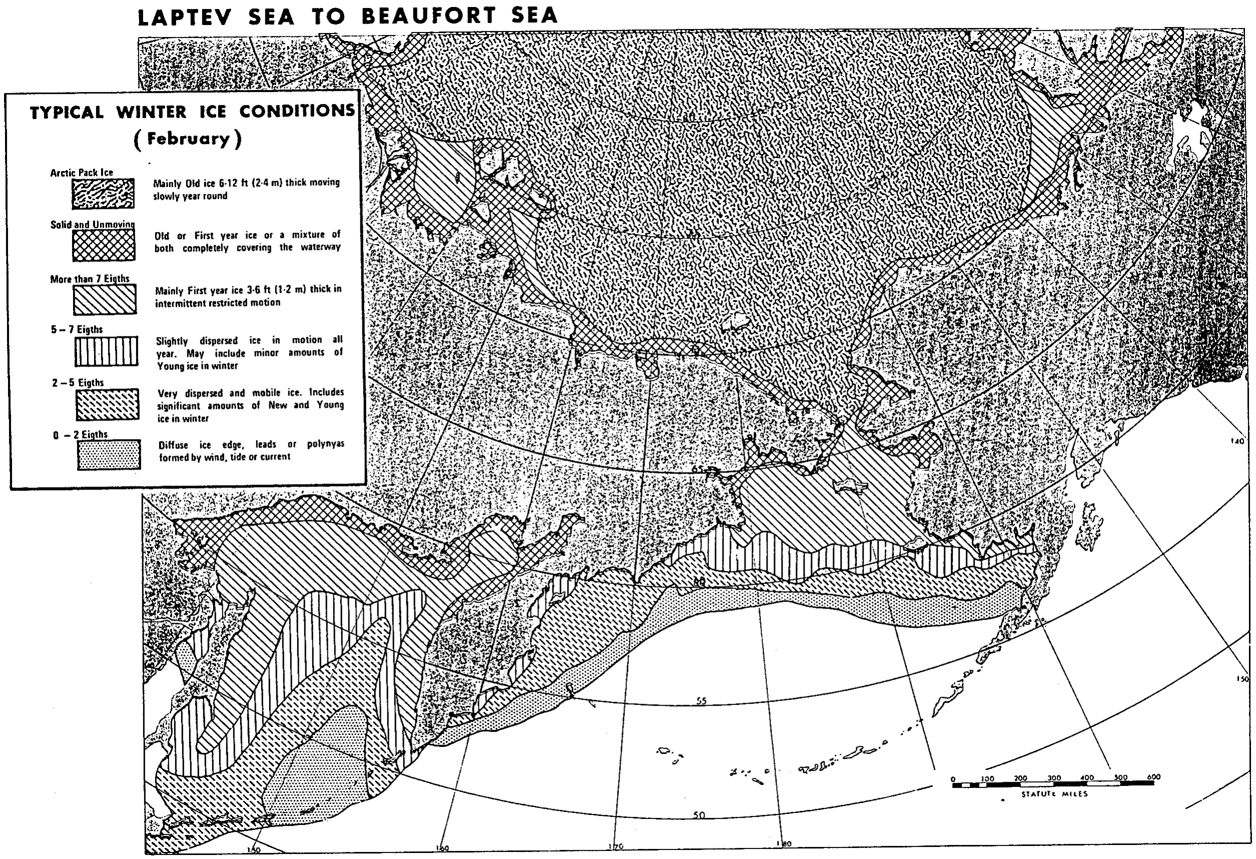


Figure 4-5 (Sheet 3 of 3) Winter Ice Limit Charts

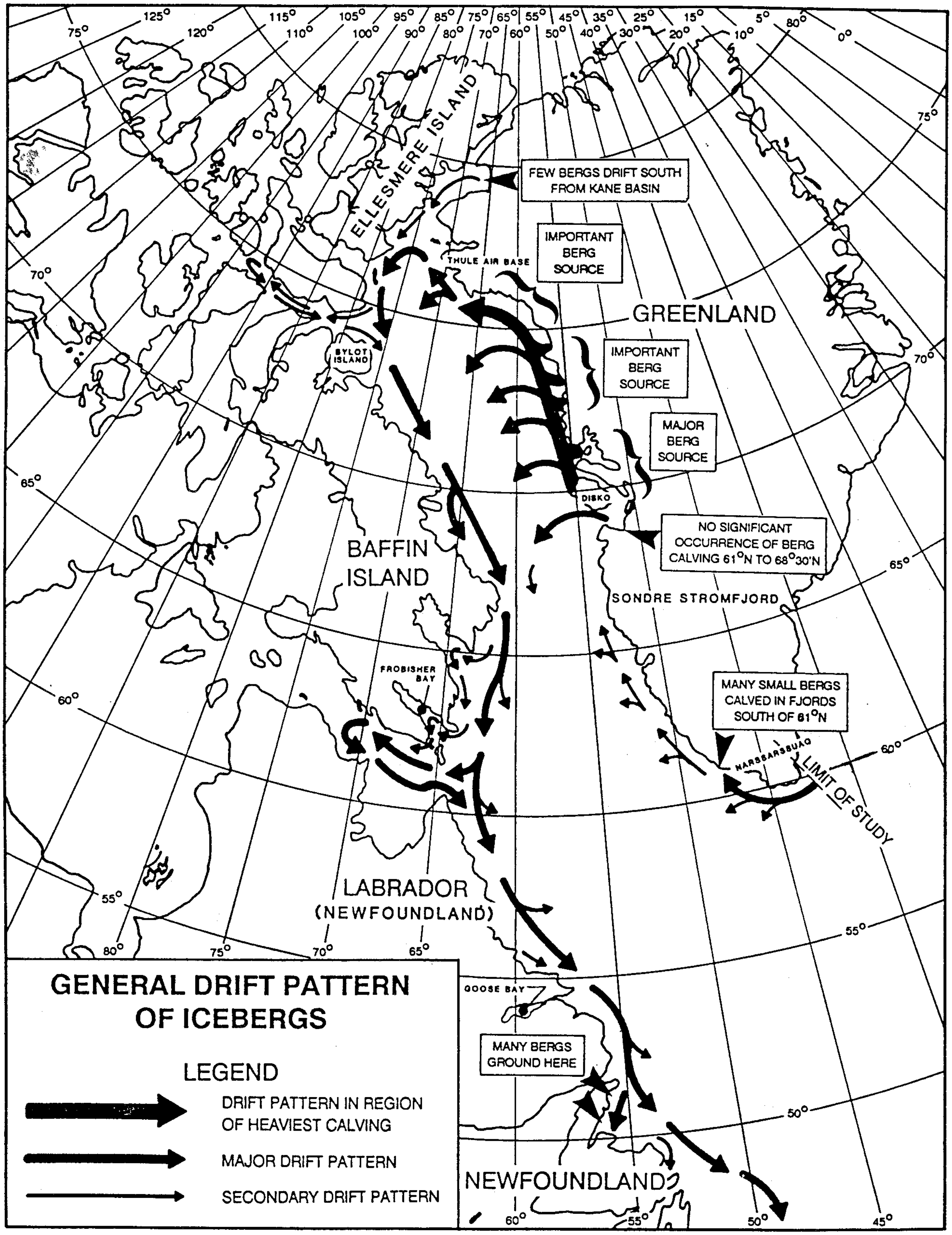


Figure 4-6 General Drift Pattern of Atlantic Icebergs

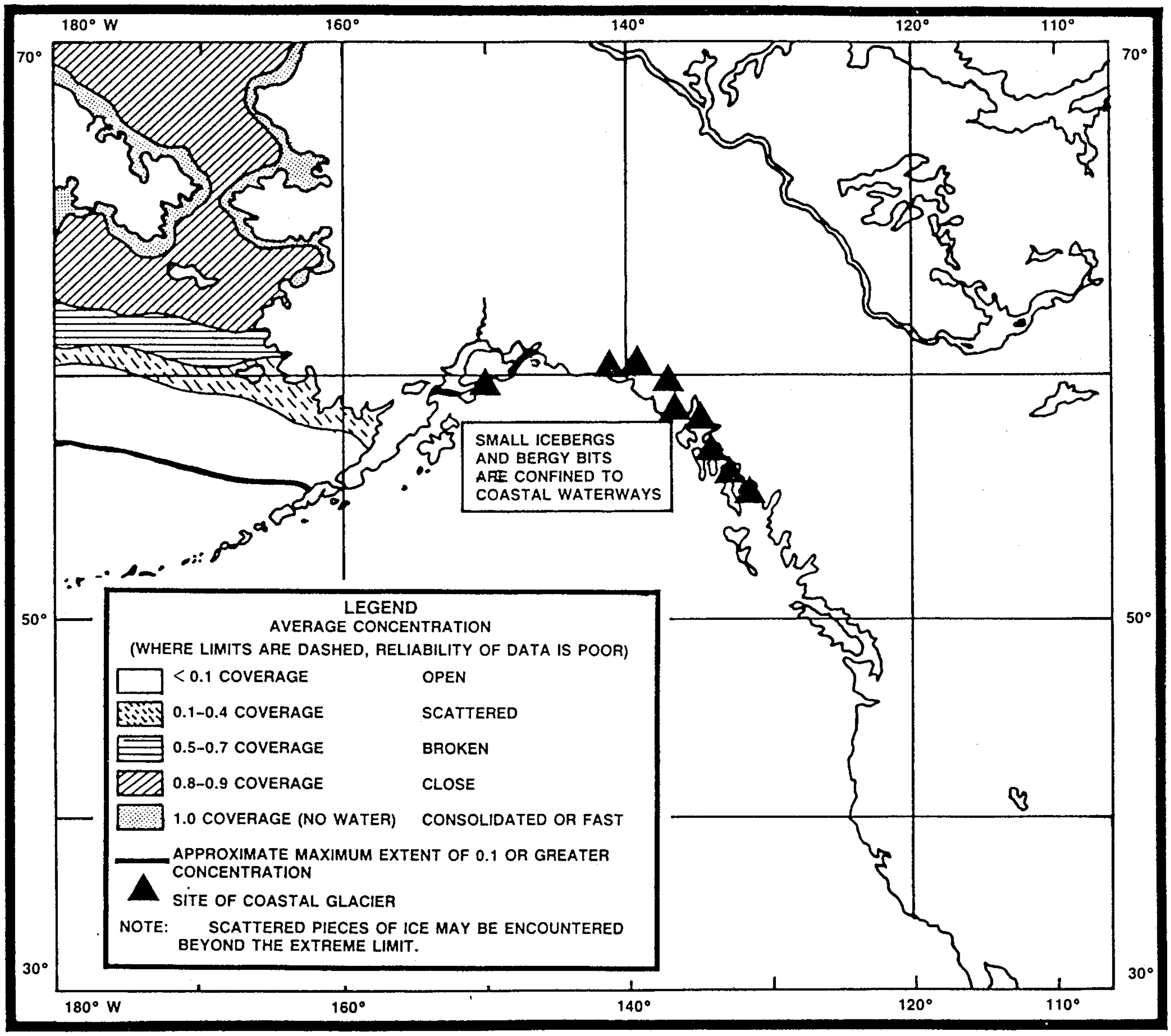


Figure 4-7 Pacific Ocean Icebergs

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CHAPTER 5

GENERAL PREPARATIONS FOR ARCTIC OPERATIONS

501 GENERAL

1. Weather conditions in the North Atlantic, particularly during winter, can be more severe than those experienced above the Arctic Circle during the short navigation season. Indeed, the Arctic summer can be quite pleasant, with warm sunshine, temperatures well above freezing, dear skies, little wind, and, because of the dampening effect of ice, calm seas. There is, in fact, a threat of sunburn and a definite need for sunglasses.

2. Climatic and other environmental conditions affecting ships and their equipment during Arctic operations includes:

a. Low surface air temperatures at certain seasons.

b. Sudden changes in air temperatures.

c. High winds.

d. Low seawater injection temperatures.

e. Low humidity.

f. Ice conditions ranging from slush and brash to solid pack.

g. Snow, sleet and freezing rain.

h. Fog and overcast, occurring at the ice/water interface.

i. Heavy seas with attendant spray in areas clear of pack-ice.

j. The possibility of heavy and rapid ice accretion, with consequent loss of stability.

k. Abnormal magnetic conditions and low directivity of magnetic compasses.

l. The possibility of gyro compass errors.

502 TOPSIDE PREPARATIONS

1. **Prevention of Slippery Decks**

a. Ensure that deck tread ladders, and deck nonskid areas meet safety standards (renew if necessary). Non-skid areas can be expanded to enhance traction.

b. Thin ice can be removed most effectively from decks and other flat surfaces by the use of dry chemicals such as sodium chloride (rock salt), calcium chloride and urea. These materials are simply spread over the frozen surfaces in a thin layer as required. Rock salt is the most economical material and is effective above -9øC. Calcium chloride gives off heat when mixed with water so it acts faster than rock salt. A mixture of one part calcium chloride and three parts rock salt will be effective to temperatures of-18°C.

c. Urea (granular or pellets) is effective for melting thin layers of ice above-9°C and for preventing ice accumulation in freezing rain.

d. Sand can be used alone or in combination with any de-icing chemicals to improve traction on ice-covered decks.

2. Develop procedures for entry, egress, and safety of topside personnel:

a. Topside personnel must use two-man buddy system.

b. Topside personnel will need to be tethered with tended safety lines during heavy weather.

c. Temporary lifelines and guide-ropes can be run along flight-decks attached to tiedowns (during non-flying hours) to permit watch personnel crossing on LPDs and LPHs.

3. Lubricate all topside fittings with appropriate cold-weather greases.

4. When selecting covers for equipment, the most important characteristics to look for are strength, durability and water resistance. Non-porous, fire-retardant covers are recommended for (at a minimum):

a. Ship's boats. (Complete boat must be covered.)

b. Davit winches.

c. Capstan/windlass and associated controls. (Because of exposure to severe weather forward, extra covers will be required.)

d. Unheated combat system equipment.

e. Sound-powered phone boxes.

f. All outside (exposed) command, control, communications stations.

5. Precautions taken to protect hydrostatic release mechanisms on life rafts should include the fitting of polyethylene sleeves over the devices and sealing them.

6. Develop and promulgate ice accretion removal procedures and instructions to avoid damage to equipment or undue hazard to personnel during removal operations.

7. Obtain and install, when necessary, temporary shelters or windscreens for exposed personnel and topside watch-keepers.

8. Rig, when necessary, additional life and safety lines for protection of personnel. Heavy-weather lifelines should be rigged well in advance to facilitate early identification and correction of deficiencies. Set up cargo lines on lifelines at UNREP stations to prevent line handlers from falling overboard.

9. Ice removal equipment and de-icing materials should include those items listed in Tables 5-1 and 5-2.

10. Firemain valves topside will have to be cracked sufficiently to prevent freezing. Run an old hose section over the side to prevent ice buildup. Securing the risers from below deck is effective, as is filling piping and stations with antifreeze.

11. **Topside Damage Control Equipment**

a. Fire hoses and nozzles will perform satisfactorily at freezing temperatures and below, provided water is kept flowing and a good pressure is maintained. If the pressure is reduced or the hose is secured, the nozzle and plug may become frozen. If a long lead of hose is to be secured at temperatures below -12 øC, stop the flow only for the time necessary to disconnect each length of hose. After securing, hoses and nozzles should be taken below decks and completely dried prior to returning to topside stowages.

b. Duplex proportioners should be drained after use, dismantled, dried, oiled, and the chamber change-over valves reassembled. Oxygen-breathing apparatus (OBA) with spare canisters should be returned to below-decks stowage as soon as no longer needed.

c. Portable water pumps should be stowed below decks.

d. External connections on the firemain will need to be isolated and drained or kept on a tickle flow. Dead ends or low flow spots such as magazine or cargo storeroom sprinkles on the firemain should be watched closely to avoid freezing.

503 SHIP'S BOATS PREPARATION

1. The use of boat engine heaters (engine block, oil system or cooling system) will ensure easier starting. Equipment from auto parts stores such as dipstick heaters are effective. Other means to keep boat engines warm include heat lamps, flood lights, drop lights and insulation blankets.

2. Utilize antifreeze in engine cooling water system to prevent freezing. Cold-weather lubricants and oils should be used for engines and transmissions. Circulating water heater and heat strips around engine block and oil pan is effective. Ethylene glycol (60/40) in the bilges and saltwater pumps will prevent ice buildup.

3. Install and utilize boat jump-start connections. A constant trickle charge is recommended.

4. Obtain spare boat batteries.

5. Lubricate and protect davits and winches. Boat falls can be prevented from birdcaging by keeping them clean, and running the winch machinery to heat lubricants prior to use.

6. Fabricate boat covers for each boat. The cover must protect the entire boat down to the water-line and should be made out of heavy canvas, not herculite.

7. Ensure that procedures are developed to drain salt-water cooling systems and top off fuelling systems daily.

8. Ensure that adequate repair parts are available.

9. During very cold conditions, provisions must be made for periodically starting and warming boat engines if no use, is expected to be made of them. Time frame varies from once daily to once per watch, depending upon the weather.

10. Lubricate entire boat throttle cable to prevent freezing and binding.

11. Not only may boats become damaged by ice, they can also be cut off from their parent ship by poor visibility or by drifting ice floes brought down by a change of wind or tide. Thus all boats should be equipped with emergency rations and survival kits including first-aid supplies, sleeping bags, firearms, and a suitable selection of hand-held pyrotechnics. In addition, all boats ought to be radio-equipped. Boats' crews should always have their cold-weather clothing with them while away from their ship. For larger boats, an inflatable life-raft ought to be carried, and all boats should be fitted with radar reflectors.

12. Additional suggestions include:

a. Hoisting slings may need reinforcement for rough-weather handling of boats.

b. Wooden boats should be copper-sheathed along the water-line, especially forward.

c. Foam flotation material (e.g., styro-foam), which must remain impervious to both water and fuel, should be applied to boats to provide an additional measure of buoyance in the event they are holed by ice. Boats in excess of 9 m should have some form of watertight subdivision for the same reason.

d. In Arctic service, outboard motors are reliable and efficient. While damaged propellers can be easily repaired or replaced, consideration should also be given to the fitting of some form of propeller guard.

e. Fuel tanks should be kept topped up in order to minimize condensation.

f. Fill drinking water containers in boats to only 75 percent capacity to avoid bursting the containers.

504 MOORING LINES AND ANCHOR GEAR PREPARATIONS

1. Mooring lines should be kept dry and stowed under cover when not in use. Manilla lines can freeze and dry rot if exposed to cold for long periods. Polypropylene and polyethylene lines absorb little water but are stiff and brittle in the cold. Nylon and darcon lines, particularly braided type, aborb more water but remain easy to work with.

2. Particular attention should be paid to the small sizes of wire rope where the component wires are of small diameter, since frost and ice can cause them to break.

3. When proceeding in waters calling for constant use of soundings, steps should be taken to ensure that anchors and cables are ice-free and ready for use at short notice.

505 ENGINEERING PREPARATION

1. **Window Heaters**

a. All heaters must be checked, and their operability ensured, before leaving port.

b. Overheating may cause lamination to separate on windows, so ensure that temperature controlling mechanism is functioning.

c. Determine means to clear ice from area in front of bridge windows. Using the window wash system, with a water/antifreeze (50/50) fluid mix, is an effective de-icing method. Ensure wash system is operated after addition of water/anti-freeze solution to purge fresh water from system piping.

2. **Turbine and Ventilation System Intakes**

a. Provisions must be made to ensure that intakes are cleared of snow and ice. Accumulation can be controlled by the use of LP air to blow snow from demister pads.

b. Ensure that turbine de-icing systems and inlet heaters are operable and effective.

3. **Sea-Chest Inlet and Outlet Blockage**

a. Use steam blow-out connections or LP air to de-ice engineering intakes.

b. Monitor freezing of overboard discharges, such as CHT, and develop an ice removal plan for these systems.

4. **Main Engineering Plant Spaces**

a. Check all air reducers by operating them at their proper pressure and ensure that they can be adjusted so that a drop in air pressure in cold weather can be overcome.

b. Add sufficient antifreeze to diesel freshwater system to preclude freezing.

c. Obtain extra batteries for all requirements. Battery locker temperature should be maintained above 15°C or store batteries elsewhere.

d. Monitor water/steam usage during ice removal operations. Inefficient ice removal may lead to excessive water usage.

e. Install insulation behind and above main switchboards where condensation may form.

f. Ensure that a full allowance of damage control and repair material such as shores, plates, clamps, wedges and plugs are on board.

g. Monitor temperature of idle machinery.

h. Prepare evaporators for cold-weather operations. Prior to sailing, hydro the freshwater side of the evaporators. Locate and fix all leaks. Use new gaskets when reassembling the units. Check air ejector nozzles for proper operation. The best way to maintain capacity is to start with a "tight plant".

i. Very high vacuums occur during cold-weather operations. Throttling the main condenser overboard valve to control condensate depression does not work well. Use of the masker belts causes air to be entrapped, and air may bind the main condenser. Venting of the condenser regularly has proven effective in maintaining vacuum and efficient engine operations.

5. **Interior Space Heating and Ventilation**

a. Ventilation heater controls should be adjusted to maintain space temperatures of 19- 20°C in lieu of 21-27°C. This will minimize the drying effect in living compartments, since the relative humidity of the compartment air will be greater at the lower space temperature differential for personnel going to and from topside or exposed locations.

b. Machinery space ventilation fans should be operated to give a slight positive pressure within the area. This will avoid creating drafts through the ship proper and will conserve the heat in the interior of the ship. All living space ventilation supply fans should be operated on low speed to reduce the amount of outside air taken into the ship.

c. To avoid freezing of ventilation heaters, it is essential that condensate lines are kept open and that traps are in proper operating condition.

d. To ensure that blowers are operated at low speed, that thermostats are not tampered with, and that thermostatic traps or preheaters are operative, it is suggested that a heating patrol be established as part of each watch. This procedure is particularly recommended for large ships engaged in low-temperature operations. A roving watch, checking berthing spaces, fan rooms and heating boundaries, has proven effective.

506 TOWING CONSIDERATIONS

1. **Long Stay**. Ships operating in Arctic waters should be equipped and ready to tow or be taken in tow at short notice. Towing at long stay can be difficult because ice, if there is any present, can get between the ships involved. Some ice-breakers are equipped with a notched stern, suitably padded, in which the stem of the ship to be towed can be secured. Ships with high freeboards, however, are unsuited for this method.

2. **Short Stay**. Towing at short stay can be undertaken though the ship towed should not use its engines because of the risk of overrunning and striking the towing vessel.

507 ICE PREPARATIONS/CONSIDERATIONS

1. **Removal Techniques**

a. Topside icing can result in a dangerous loss of stability, reduction in reserve buoyance, and critical impairment of a ship's ability to withstand damage. Other adverse effects are the increased load on decks, masts, and other structures, and the danger that men will slip on icy decks or be struck by falling ice from aloft.

b. There are various methods by which ice can be removed:

(1) **Manual**. Ice is broken away and chipped off using mallets, clubs and scrapers. Caution must be exercised to avoid damage to metal surfaces, electric cables (including degaussing cables) and equipment. Ships should lay in a stock of wooden mallets, shovels, wire brooms and scrapers suitable for the removal of ice and snow. Table 5-1 provides a list of ice removal equipment.

(2) **Steam Jet**. A steam lance can be used to undercut layer ice as, for example, in freeing an anchor which has become frozen in its hawse pipe. It can also be used for spot heating.

(3) **Anti-Icing Coatings**. These coatings can be used to protect comparatively small areas or items. Anti-icing compounds retard the formation of ice and contribute somewhat to the ease of its removal.

(4) **Heated Salt Water Under Pressure**. This is sea water heated to at least 50°C, or higher if possible. It is used in high- pressure steams to slot, undercut, and break up large accumulations of ice. No attempt is made to melt ice directly, but rather to break it up or weaken it to facilitate removal. When using water to clear ice, scuppers and overboard drains must be clear.

(5) De-icing. Use of Ethylene Glycol, Methanol or other de-icing chemicals can be used to remove ice build-up on exterior surfaces.

2. **Superstructure Icing Considerations**

a. When severe topside icing occurs and ice continues to accumulate, despite all attempts to remove it, it may become necessary to alter course, heave to, or make for an area of more moderate weather. Icing can occur when heading into strong winds and heavy seas and in conditions of low air and seawater temperatures. Smaller ships having low free boards and reserve stability are particularly vulnerable.

b. The rate of ice accretion from ocean spray is related to surface wind speed roughness of the sea, air temperature (below 1.67°C), and duration of exposure. Figure 5-1, the Overland Monograms, offer the most current prediction method for icing conditions.

c. The smaller the vessel, the more serious the problem of ship icing. Any prolonged exposure to gale-force winds and below-freezing air temperatures could ultimately result in the vessel capsizing. Fishing trawlers approximately 52 m long have capsized and sunk as a result of rapid ice accumulations on the hull and superstructure; freezing spray accumulating at a rate of two tons an hour over a period of 24 hours has been reported. Meteorological observations taken in the vicinity of Iceland indicate that storms of gale force accompanied by freezing air temperatures and lasting as long as three days may occur as often as three times a year. Sparseness of synoptic meteorological information in this area makes forecasting of such prolonged periods of gale-force winds and below-freezing temperatures quite difficult.

d. The use of aircraft engines can be effective in removing snow from around closely parked aircraft. Rock salt should not be used because of its corrosive effect on metals.

508 CARGO HANDLING CONSIDERATIONS

1. Cargo should be stowed in such a manner that it cannot shift as a result of repeated impacts between the ship and the ice. It should be stowed well away from the sides of the ship thus allowing easy access to the side plating in case of damage and to permit passage of water to the bilges. Ships operating in ice, should be so loaded that they will be trimmed by the stern. If in ballast, consideration should be given to flooding so as to immerse the rudder and propellers to minimize the risk of damage to them by ice.

2. Helicopters should be fitted with hoisting gear and quick - release hooks. There may be occasions when ice floes block beach unloading sites, or ice-pack prevents a ship getting close enough to employ boats and landing-craft effectively.

Table 5-1 Ice Removal Equipment

ITEM	QUANTITY (1)	SOURCE
Baseball Bats *	48	Sporting Goods Stores
Brooms Fiber	30	Serve Mart or Commercial
Brooms, Wire	30	Commercial
Hose Lay, steam deicing 3/4 x 50 feet	2 (when steam source is available)	1H0000–LL–CJ6–9113
Mallet, Nylon *	12	9N–510–00–239–3399
Mallet, Rawhide * (2)	12	9N–5120–00–222–2220
Mallet, Wooden * (3) (4)	12	9N–5120–00–926–7116
Portable Hair Dryers (For spot thawing – Do not use on glass)	2	Commercial
Portable Heat Gun (Use Hair Dryers above if cannot obtain)	2	1HS0000–LL–CJ7–1299
Sand, sharp, 100 pound bag	10	Commercial
Shovels, steel, grain scoop – use as alternate or in combination with snow shovels below	24	9Q–5120–00–224–9326
Snow Shovels	24	9Q–5120–00–494–1685
Special Ice Footgear	20 pair large 20 pair medium	Bass Pro Shops "Korkers" or equal
Steam Lance	1–2	Ship Manufacture

(1) The quantities listed above are based on the anticipated needs of a CG 47 class cruiser and are rough estimates only.

(2) Rawhide Mallet listed: Round head cross section; 2.75–inch nominal face diameter; 4.75–inch nominal head length. Two smaller sizes shown in illustrated Listing under FSC 5120.

(3) Wooden Mallet listed: Round head cross section, 6–inch nominal face diameter; 8–inch nominal head length. A number of other sizes are available. Check Illustrated Listing under FSC 5120.

(4) Rubber Mallets also available listed under FSC 5120.

* Impact devices require extreme care in their use to avoid damage to the underlying equipment/structure.

Table 5-2 De-icing Materials

ITEM	QUANTITY (1)	SOURCE
Calcium Chloride, flake, 30–pound pail	15	9Q–6810–00–656–1036
Denatured Ethyl Alcohol*, 1–pint bottle	4	9G–6810–00–201–0906
Ethylene Glycol (2), 1–gallon bottle	20	9G–6850–00–181–7929
Ethylene Glycol, 5–gallon can	20	9G–6850–00–181–7933
Ethylene Glycol (2), 55–gallon drum	2	9G–6850–00–181–7940
Fog/ice preventive compound, 1–quart bottle	4 quarts	MIL–STD–1210B
Garden Sprayers Fill with ethylene glycol)	12	Commercial
Isopropyl Alcohol (3), 1–gallon can	10	9G–6810–00–286–5435
Rock Salt, coarse, 100–pound bag	20	9Q–6810–00–227–0437
Safety Equipment for handling Calcium Chloride:		
Rubber Gloves	20 pair large	9D–8415–00–266–8673
Rubber Boots	20 pair large	9D–8430–00–262–8759
Safety Goggles	20 pair	9G–4020–00–190–6432
Urea Pellets (4), 100–pound bag	3	9G–6810–782–6521
Deicer, 55–gallon drum (5)		MIL–D–83411A 6800–00–237–4304 9G–6850–01–234–3397

(1) The quantities listed above are based on the anticipated needs of a CG 47 class cruiser and are rough estimates only.

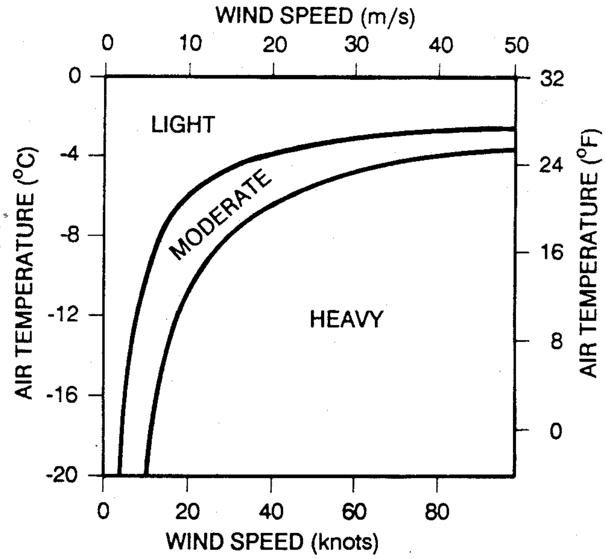
(2) Ethylene Glycol is slick and oily. When used on decks it hinders ice build–up and makes ice removal easier, but can be very slippery and difficult to remove in cold weather.

(3) Isopropyl Alcohol is excellent for window cleaning and reducing winding icing. It leaves no residue on the glass.

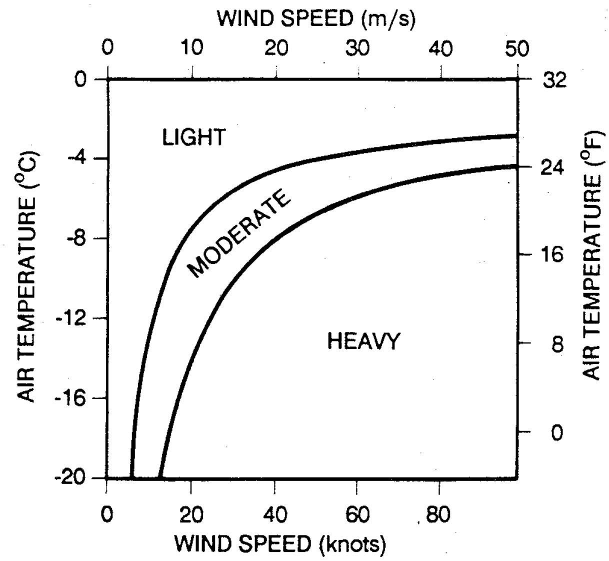
(4) When used on flight decks, pellets or large granules could become missile hazards or drawn into intakes.

(5) One gallon covers approximately 500 square feet.

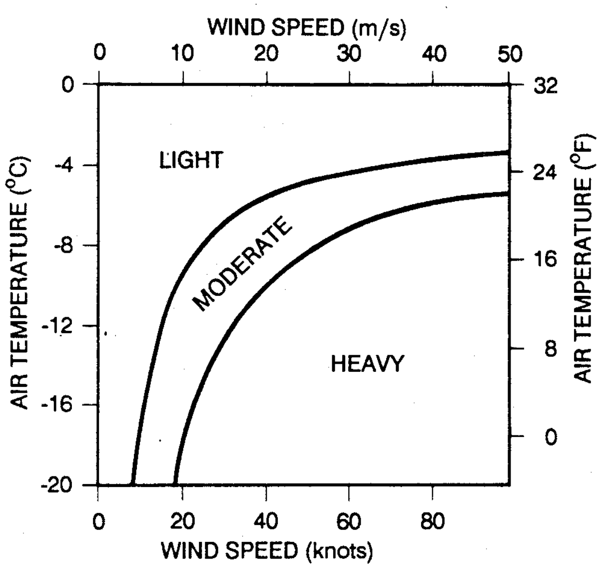
* Flammable.



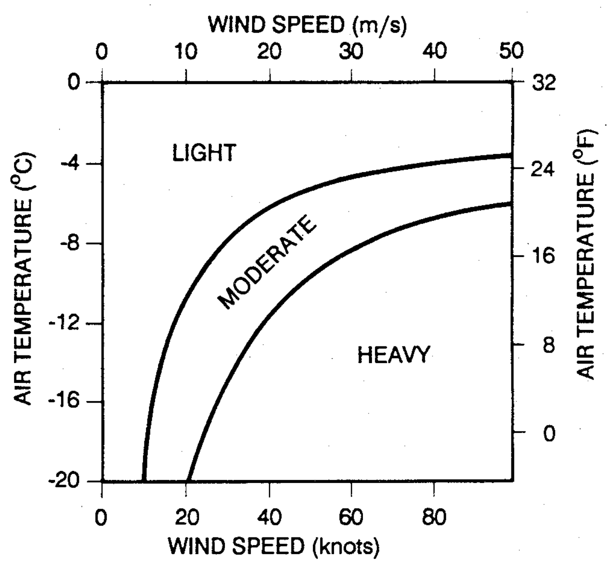
Icing conditions for vessels heading into or abeam of the wind for water temperatures of +1°C (34°F)



Icing conditions for vessels heading into or abeam of the wind for water temperatures of +3°C (37°F)



Icing conditions for vessels heading into or abeam of the wind for water temperatures of +5°C (41°F)



Icing conditions for vessels heading into or abeam of the wind for water temperatures of +7°C (45°F)

Light Icing - Less than 0.7 cm/hr (0.3 in/hr)
Moderate Icing - 0.7 cm/hr (0.3 in/hr) to 2.0 cm/hr (0.8 in/hr)
Heavy Icing - Greater than 2.0 cm/hr (0.8 in/hr)

Figure 5-1 The Most Recent Nomograms (Overland et al. 1986)

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CHAPTER 6

HULL, ENGINEERING AND ELECTRICAL

601 COLD-WEATHER PREPARATIONS

1. Check all heating and cooling systems.

2. Check coolers for leaks. Weather leakage can occur because of contracting of the tubes in the cooler tube sheet/plate due to colder salt-water inlet temperatures.

3. Identify unheated or inadequately heated spaces. Air, cooling-water, salt-water, and other lines running through spaces should be insulated for protection. Heaters should be installed. Portable items subject to freezing should be moved to heated spaces. Other ad hoc measures to improve temperature control include fans and other ventilation techniques to draw warm air from other areas. Additional heating will be needed to maintain crew comfort.

4. Check areas where condensation and frost may form on interior metal surfaces adjacent to exterior bulkheads.

   a. Hatches, doors and lagging buttons are likely to be most frequently affected. If interior ambient temperature is cool, heavy frost will form. If interior spaces warm up, condensation will drip onto deck and equipment.

   b. More insulation may be needed on exterior bulkheads, overheads, and especially on doors and hatches.

   c. Check all watertight doors' gaskets and knife/sealing edges.

5. Where it is determined that spaces require portable heaters, check wiring set-ups. Ensure that vital electronic equipment (navigation gear, etc.) is not wired to the same circuit breaker as a high-amperage portable heater.

602 EXPOSED PIPING AND SCUPPERS

1. Overflow pipes from fresh water gravity tanks should be led inside the ship to a warmed scupper and not be allowed to drain onto an open deck. Deck-edge waterways should be kept clear of obstructions so that a clear passage will exist when snow is being washed down.

2. Lagging by itself will not keep liquid in a pipe from freezing if the ambient temperature falls below the freezing point. Liquid must be warmed and kept in continuous motion; failing this, heating of all the piping lying outside the insulated structure will be necessary.

603 HULL DAMAGE AND REPAIR IN THE ICE

1. Ice damage can take the following forms:

   a. Bending or loss of propeller blades.

   b. Steering gear damage, including the rudder head and/or the rudder.

c. Propeller shaft fracture.

d. Damage to the stem, puncturing and tearing of plating.

e. Buckling of plating and the tearing out of rivets due to ice pressure.

2. Should the steering gear break down in a single-screw ship, it may be possible to steer with the aid of two rudder pendants secured to the rudder and led to a stern capstan or cargo winch.

3. Although every reasonable precaution may have been taken against damage to a ship, it is possible that damage or breakdowns will occur which will be of such a nature as to necessitate major repairs. In such circumstances, ships should be detached and directed to the nearest shipyard or be taken under tow.

604 STOWAGE SPACE REQUIREMENTS

1. Additional stowage space will be required to accommodate Arctic equipment and material. Space will also be required for the stowage of anti-ice compounds and liquids.

2. Crew members will need extra stowage space for their gear. Space should also be set aside for Arctic clothing in living spaces or in compartments immediately adjacent thereto. Similarly, suitable facilities should be provided for the drying of heavy Arctic clothing.

3. Allot additional stowage space for food storage since a 10 percent increase in food consumption will be experienced.

605 FRESH WATER SUPPLY

1. Suction pipes in freshwater storage tanks should be insulated to prevent ice from blocking the lower ends.

2. Freshwater gravity and any similar tanks fitted in exposed positions should be heated and amply lagged. Arrangements should also be made to warm the pressure switch gear if fitted. Leads of freshwater supply and drain pipes must also be lagged and heated if they lie outside an insulated structure.

606 SALT WATER SUPPLY

1. Leak-offs should be fitted at the ends of the firemain to assure a continuous circulation of water. These leak-offs must be at least 13mm in diameter, be well lagged, and discharge either directly overboard or into a scupper with a warmed non-return flap valve.

2. Firemain risers can have water secured at the main deck, or for flight deck supplies use antifreeze in the riser itself.

3. Salt-water hydrants fitted in exposed positions should be isolated inside the main structure, and arranged so that the exposed length of the hydrant supply pipe can be drained and left empty in cold weather.

4. Careful attention must be paid to the lagging of salt-water supply pipes which, although not directly exposed to weather, can be subject to low temperatures, e.g., those fitted in the hangar of

aircraft-carriers near lift openings.

5. Careful attention must also be paid to spraying arrangements in ready-use magazines, to similar compartments in exposed positions, and to magazine-flooding lockers if these are located on weather decks.

6. Fire pumps should be capable of taking their suction from the discharge side of a main engine or generator condenser or cooler, so that warm water can be delivered to the fire main.

607 GENERAL INSTRUCTIONS FOR MACHINERY

1. Machinery space temperatures should be maintained at or above 4.4°C.

2. In systems containing a mixture of glycerine and water, a check on the homogeneity of the mixture should be made by taking samples from both the top and the bottom of the mixing tank, and testing with a glycerometer. A homogeneous 50/50 mixture will remain completely fluid down to -27°C. A 60/40 mixture will remain fluid down to -40°C.

3. When engines which have salt-water cooling systems are not required for immediate use, the circulating water system should be kept empty. Engines with a freshwater cooling system should have the system charged with an approved antifreeze solution. The raw water side of the heat exchanger system should be drained. Glycerine and water should not be used as an antifreeze solution. Because of the fine clearances in the water pumps of both types of cooling systems, drops of water remaining after draining may cause seizure of the pump, so pumps should be warmed before turning the engines.

608 EXPOSED EQUIPMENT

1. Particular attention should be given to equipment on deck, to guard against congealing of lubricant or formation of ice. Covers should be used, where possible, to maintain all equipment at operable temperatures.

2. Pressure gauges in exposed positions should be disconnected when non-essential.

3. When removing ice from any mechanism by use of steam jet, care should be taken to avoid ingress of steam which will condense and freeze on interior working parts.

609 GENERAL INSTRUCTIONS

1. **Fire Hoses**. Hoses should be drained, dried, and stowed below deck.

2. **Fire Extinguishers**. Foam-type and soda-acid extinguishers should be stowed in a warm place. Arrangements should be made to ensure that the supply from the firemain for continuous foam is warm and that foam compound is stowed in a position protected from the cold.

3. **Arrestor Gear and Safety Barrier System**. Heating should be provided to air-reducing valves fitted in the arrestor gear and barrier system to prevent freezing.

4. **Telemotor Systems and Hydraulically Operated Mechanisms**. These should be charged with a 50/50 mixture of glycerine and water or a national approved liquid as directed, and be tested periodically.

5. **Pressure Gauges**. Except where they are essential, pressure gauges in exposed positions should be removed.

6. **Motor Boats.** To prevent damage to the engines and to ensure that they can be started when required, the following precautions should be taken:

a. An external source of heat should be provided to maintain the engines and pipe systems at a reasonable temperature. It may also be necessary, under conditions of extreme cold, to warm the lubricating oil and diesel fuel tanks.

b. When engines are not in use, or at "short notice", the seawater circulating system should be kept empty. Engines with freshwater cooling systems should have them charged with an approved anti-freeze solution. To facilitate draining the system, drain cocks should be fitted where necessary to drain water from any pockets in the system. On account of the fine clearances in the water pump, small drops of water remaining after draining may be sufficient to cause seizure of the pump if the temperature has not been above -2.2°C. To avoid damage to the pump, special measures should be taken to warm the pump before turning the engine.

c. Full use should be made of devices fitted to assist cold starting of diesel engines, such as heater plugs, ether, etc.

610 INSULATION

Thermal insulation should be applied to the shell and bulkheads behind and above switchboards if such areas suffer from condensation. All cold-weather piping and equipment such as fire, sanitary and freshwater systems, soil pipes and freshwater tanks should be insulated where damage to equipment or discomfort to personnel may result from dripping condensate. All ventilation supply and exhaust ducting and heaters, including flanges and joints, must be insulated to prevent sweating and heat loss.

611 GAS CYLINDERS

Pressure in compressed gas cylinders subjected to cold temperatures will drop considerably and may be insufficient for practical use. Therefore, bottled gases should be stowed inside if safety regulations permit. If they are used directly from an outside stowage in cold weather, as much as $2m^3$($75ft^3$) of volume can be lost.

612 BATTERIES

1. Cold temperatures drastically reduce the output of all types of batteries (both dry cells and storage batteries). For example, at -18°C, the ampere-hour capacity of a typical dry cell battery is reduced to about 25 percent of the 20°C rated capacity. At this temperature, capacities of lead-acid and nickel-cadmium storage batteries are down to about 35 percent and 50 percent respectively.

2. The lowest temperature for reliable cranking is about -18°C. The output of all batteries reaches essentially zero at about -34°C to -40°C. The rate at which storage batteries can accept a recharge is also reduced in cold temperatures. To obtain a good recharge in a reasonable amount of time, the temperature of the battery should be about 15°C or higher.

3. The sulphuric-acid electrolyte in a discharged acid battery can freeze at -15°C. If the battery is fully charged, the electrolyte freezing point is depressed to -60°C or below. Freezing may damage the plates, crack the battery case, split the cover-to-case seal or the terminal-to-cover seal, thus leading to electrolyte spillage. Freezing of electrolyte may also form crystals which can pierce separators,

eventually leading to internal short-circuits and premature failure of the battery.

4. The potassium hydroxide electrolyte in a nickel-cadmium battery does not vary significantly with the state of charge and the freezing point is essentially constant at -60°C. Freezing of this type of battery is not a problem.

5. Storage batteries should be kept fully charged and stowed in a heated space or equipped with heaters.

6. Flashlight and other dry cell batteries should be kept warm when not in use.

7. For more detailed information on handling of batteries in a cold environment, see Annex D.

613 SHIP COLD WEATHER SOAKING

1. Ship cold weather soaking is defined as long-term exposure of the ship to sub-zero temperatures and near freezing seas. The ship gradually reaches thermal equilibrium with its environment after about a two to three week exposure. The ship is considered cold-soaked when the heat loss rate drops to the same point as the heat production rate. The net heat transfer rate is zero and therefore the amount of heat the ship contains is constant.

2. When a ship transits from a moderate climate to a cold climate, its exterior and topside equipment will cool down to ambient temperatures. Low seawater temperatures may cause high vacuums in condensers, condensation on air and seawater pipes and low temperatures in cooling systems. Spaces near the skin of the ship and interior spaces containing seawater piping and/or unheated ventilation will cool rapidly, particularly unheated spaces. After an initial rapid drop, air temperatures in these spaces will stabilize into a slow downward drift until the soak is complete.

3. Spaces below the waterline have a low temperature limit of approximately -2.2°C. However, heat is lost more easily at the water/hull interface than at the air/hull interface. One effect of this is that ship's skin temperatures above the waterline may be higher than those below the waterline even though air temperatures are well below freezing. Topside exterior spaces, subject to solar heating, wind and weather, can experience temperatures far below seawater temperatures and wider, more frequent temperature variations.

4. As temperatures in the outer spaces fall, temperature drops will progress toward the ship's interior. In general, once soaking is complete, the spaces farthest from the exterior of the ship will be the warmest; however, the locations and sizes of heat sources and/or whether the fresh air supply is heated will have the greatest effect on which parts of the ship will have cold problems.

5. **Exterior Effects of Soaking**. The exterior of the ship (and all equipment located there) is essentially at the temperature of the environment.

6. Non-Arctic internal combustion engines, such as those found on small boats, will be difficult to turn over without Arctic-grade oil. Engine fuels will thicken and suffer from wax formation. Water in the fuel will freeze causing fuel flow blockage. Diesels, in particular, become increasingly harder to start as the weather gets colder. High fuel viscosity may prevent proper oil flow through the engine, once it has been started. Tighter clearances due to cold-induced contraction can exacerbate these effects. The film of lubricant protecting engine internals and separating surfaces such as journal/bearing and piston ring/cylinder breaks down more quickly at cold temperatures, allowing adhesion (engine seize) and corrosion to occur.

7. Unprotected freshwater engine cooling systems may experience fractured heat exchangers and/or popped freeze plugs.

8. **Interior Effects of Soaking**

a. **Unheated Spaces**. Because many unheated spaces are infrequently occupied, damage to items in those spaces could go unnoticed. Cold spaces containing low or no-flow water lines are of particular concern. An example of such a space is an unused head, often found on ships designed to carry embarked troops. Prolonged cold weather could also cause damage to the contents of storage spaces.

b. **Heated Spaces**. Ships have reported that typical heated space temperatures reached the 10^{o}C range during long-term Arctic exposure. Living and working in temperatures of around 10^{o}C increases fatigue, as has been reported from previous ships operating in a cold-soaked condition. The constant discomfort has generally diminished the ability of the crew to perform at its best.

c. **Engineering Spaces**. Under normal conditions, engineering spaces do not require additional heat to maintain acceptable living temperatures. However, during cold weather operations, a number of ships have experienced the need to shut down part of engineering space ventilation in order to keep ambient temperatures above freezing.

d. Ships have reported the need to make impromptu modifications to the ventilation system line-up in order to keep engineering space air above freezing temperatures. Only the waste heat emanating from the various engineering systems keeps conditions in these spaces from being as severe as the exterior of the ship.

e. **Condensation/Standing Water**. During prolonged cold weather operations, condensation can occur on the coldest interior surfaces of the ship, leading to preservation problems, water damage and slippery surfaces. Freshwater in contact with the hull will freeze, including bilge water and condensation. Ice build-up can occur on the inside, especially in humid spaces. Frozen bilges will impair the ship's dewatering capability if the bilge suctions are covered. Hatches and scuttles will become frozen shut down from the inside.

f. Condensation will occur on any piece of equipment taken from a cold storage area into a warm space. Of particular concern is electronic equipment. Condensation hazard to electronic gear arises when a cooling medium operates at temperatures below the design point. Significant delays can be expected during start-up while electronic gear warms up and stabilizes. Condensation occurring inside fuel tanks can freeze. Prevent condensation by insulating or lagging cold surfaces and using a desiccant to lower humidity in small spaces.

9. **In-Port Effects of Soaking**. A ship tied to the pier in a cold weather environment gets colder faster than when it is at sea. A large amount of heat-producing equipment is normally shut down. Likewise there can be a lack of sufficient shore power and use of the ship's own resources means the use of fuel and watchstanders.

614 YELLOW GEAR

1. Operational yellow gear in cold weather is very important. Failure of vehicles, which move aircraft equipment, supplies or ammunition could interrupt ship's operation.

2. Normal greasing, filter cleaning, electronics and hydraulic checks are extremely important. Just as essential are the use of fuel, oil and lubricants designed to allow the vehicles to operate effectively and efficiently in cold weather.

3. The use of ether starting systems already installed on the vehicles or manual applications of ether to the air intake regions will provide the necessary cold weather starting assistance. Ether canisters should be stocked in sufficient quantities to ensure quick starts throughout the deployment. Excessive use of ether damages the internal seals and gaskets of the engine. An engine may need to be overhauled in warmer temperatures after being started with ether.

4. Air tanks on all yellow gear vehicles should be drained daily. The air drain should be left open to allow all condensate to drain and to prevent freezing the air lines. Use of air dryers and their maintenance will be covered in vehicle maintenance manuals.

5. Cold weather affects pneumatic equipment as much as diesel or gas equipment or vehicles, so preventive maintenance and daily checks for moisture in the system needs to be accomplished. Pneumatic systems should be fitted with dryer units which use methanol.

6. Cold weather can cause severe stress on metal. Inspections of the yellow gear stress points, the fork lift carriage and points where hydraulic cylinders attach to the frame need to be completed to ensure no corrosion or stress fractures are evident prior to the deployment.

615 UNDERWAY REPLENISHMENT

1. **Training**. Before a cold weather cruise, personnel should receive training on special aspects of cold weather Underway Replenishment (UNREP) operations, including:

a. Cold weather hazards of hypothermia and frostbite.

b. How to function in special cold weather clothing.

c. Proper relieving procedures.

d. General cold weather UNREP operations.

2. **Preparation for UNREP**. As a preventive measure, covers for deck equipment should be provided, where possible, to reduce the penetration of water and subsequent formation of ice. Because of cold weather effects on UNREP equipment, more time and effort must be devoted to getting the equipment ready to begin UNREP operations:

a. Ice and snow must be removed from covered and uncovered equipment, including decks and hatches.

b. De-icing chemicals will be needed to remove ice from equipment and decks.

c. Equipment must be started and operated at low speed to check for proper operation and to allow warm-up prior to full speed operation.

d. The non-skid surface should be extended to cover as much deck area as possible.

e. The technical manuals for all UNREP equipment exposed to the weather should be reviewed to determine what cold weather lubricants and hydraulic fluids will be needed.

f. Some specific preparations for UNREP include:

(1) Grease wire ropes and sheaves.

(2) Put cold weather hydraulic fluid in winches and cold weather lubricating oil in the winch gear boxes.

(3) Drain the water and purge the moist air from compressed air systems to prevent freezing of on-deck pneumatic equipment. Check air dryers to ensure that the dew point temperature of the compressed air is maintained within the proper range.

(4) Make room below decks to store all small equipment and fibre ropes used during UNREP operations. Break equipment out when needed and replace it below when the operation is completed.

(5) Procure winch covers to protect UNREP equipment from spray and to facilitate de-icing without damage to equipment by ice removal tools. These covers should be part of the ship's "Cold Weather Kit".

(6) Check the gaskets in refuelling probes and bellmouths to preclude leaks during refuelling operations. Stock extras because gaskets may become brittle and crack in cold weather.

(7) Stock a large supply of chemlites because they will lose intensity after an hour or two in cold weather, and because of the reduced number of daylight hours.

(8) Fiberglass reinforced plastic traction mats may be obtained which give effective traction even when partially iced over.

(9) Stock alkaline flashlight batteries rather than the ordinary cells. Alkalines are degraded less by cold temperatures.

(10) Conduct an electrical check to ensure traffic lighting and other necessary control measures are operational.

g. Provide for portable, topside heaters or enclosures for personnel involved in extended topside evolutions. Hangar space heaters have proven effective.

h. Anticipate that routine evolutions could take twice as long in cold weather.

i. Periodically inspect berthing spaces for warmth and ventilation. Ensure that adequate bedding materials are available.

j. Provide for additional heaters for particularly exposed areas, such as the Signal Bridge and Pilot House.

k. Hot beverages and soup should be available on the mess deck 24 hours a day and distributed to look-outs, RAS and flight-deck crews.

l. Stripping of waxed decks and the addition of non-skid strips is recommended.

CHAPTER 7

COMBAT SYSTEMS

701 COLD-WEATHER PREPARATIONS

1. Gun Mounts, Missile Launchers and Torpedo Tubes.

a. Check topside mounts for watertightness.

b. Check drive motors.

c. Ensure that heating coils/base ring heaters are operable.

d. Obtain additional seals, plugs, and O-rings to provide redundancy, since cold temperatures increase the failure rate.

e. Ensure that window heaters are operable.

f. Lubricate with required oils and greases. (Old grease will have to be purged.)

g. Verify that the installed heating system can maintain hydraulic oils above 15^{o}C, or provide supplementary heaters.

h. Check the magazine sprinkler systems for proper operation and insulation of piping in unheated spaces. Pipework to upperdeck magazine lockers should be insulated and is best drained down to an isolation valve within the ship.

i. Ensure that instructions for the operation of these systems in extreme cold weather are prepared. Include the following:

(1) Protection of exposed hydraulic lines, high-pressure air piping, and gas ejection piping.

(2) Use of heat strips in gun barrels. (Insert/retract from breech.)

(3) Protection of electrical cables.

(4) Use of cold-weather hydraulic fluids and lubricants.

(5) Monitoring of cooling and other fluid systems for leakage.

(6) Regulation of inlet pressure on CIWS cooling water to maintain required temperature.

(7) Increase of frequency of routine checks and movement of systems through full arcs. If seizure is considered possible, operate systems initially in "hand control".

j. Openings into mountings of breech mechanisms should be fitted with removable canvas covers, including separate covers for gun sights and breeches of guns.

k. Due to cold moisture in air systems, valves may freeze open, causing constant HP air leaks. Secure valves until weather improves. This will lock snubbers and retaining latch, requiring delay in firing.

l. Torpedo tube heating system must be checked. It may be necessary to regularly fire air slugs.

m. Launcher barrels should be checked for build-up of condensation after heaters have been left switched on for 2 days or more.

2. **All Sonars, Torpedo Countermeasure Hoists and Towed Arrays**

a. Verify operability of installed heaters.

b. Obtain spare seals, particularly for topside, exposed hoists.

c. Lubricate with cold-weather greases.

d. Ensure that hydraulic oil is maintainable above 15^{o}C, or obtain supplementary heater.

e. Equipment cabinets and other components may develop condensation because of cold temperatures. Transmitters may have to be dried out before applying full power.

f. **Towed Array System/VDS**

(1) The hoist motor can be operated to keep the hydraulic fluid warm, and the drum rotated in case retrieval or adjustments to scope are required.

(2) Minimize body/tail surface time. The array could be damaged by floating ice if allowed to remain near the surface for any length of time.

(3) The electrical components of the hoist are exposed to icing and mechanical damage when towed body array is deployed. Additional covers should be added.

(4) Ensure that transom door latches are checked. A means of "dogging" the doors securely, allowing an absolute minimum of play, is highly advised. Chain falls are one possibility.

(5) Strive to maintain interior spaces water-free during towing operations.

(6) Have available means of de-icing (chemical/thermal) for the towed body and cable if required. (De-icing fluid is preferred.)

3. **Prairie Masker**

a. The use of the forward masker belt, particularly below cavitation speeds, may result in the air binding of intakes for cooling fire pumps.

b. When a masker must be used, it may be necessary to find alternate cooling or fire pump intakes, or reconfigure supply arrangements for cooling/firemain.

4. **Canister Launchers**

a. Cover exposed launchers to reduce icing and remove prior to use.

b. Protect canister seals and covers to prevent cracking.

c. Maintain canister temperature in accordance with technical manuals, and monitor periodically.

d. Check vent dampers' operability during cold-weather operations. Cycling weekly is effective.

702 FIRE CONTROL RADARS

1. For simple tachymetric directors, suitable switch sockets should be fitted near each director for use with electric blankets and portable electric heaters.

2. Prior to entering cold weather, the antenna drive motors should be tested and lubricated with cold weather grease. Grounding straps should be insulated with RTV compound.

3. Shafts and bearing surfaces will operate more effectively if they are buffed and polished. Such surfaces should be lubricated sparingly.

4. More detailed guidance is provided at paragraph 803.1.g.

703 RECOIL MECHANISMS

Recoil mechanisms containing a glycerine and water mixture will function satisfactorily in cold weather. However, sluggish action and a short recoil may become apparent at those temperatures below freezing when crystals form in the mixture, although the solution will not freeze until temperatures below the pour point are reached. Heat must be applied as soon as unsatisfactory recoil action is experienced. The orifices in recoil mechanisms are designed for a specific mixture of glycerine and water and no substitution is permitted.

704 AIRCRAFT GUNS

1. For reliable operation at low temperatures, guns must be clean and properly lubricated. When firing in sub-freezing temperatures, gun heaters are required and should always be turned on just before take-off.

2. Before firing, guns should be disassembled, cleaned, inspected for defects or part breakages, and lubricated. While disassembled, it should also be determined that all traces of hard-drying preservatives have been removed from all working parts of the gun.

3. It is important that all springs be within their prescribed tolerances of free length.

4. All traces of solvent used in cleaning must be removed before reassembly. Incomplete removal of the bore cleaning solvent may result in malfunctioning at low temperatures. Immediately after cleaning, if guns are to be ready for firing, they should be lubricated with the prescribed lubricant. If guns are to be stored after cleaning, a suitable preservative must be applied.

5. Apply oil sparingly. Never dilute lubricating oils with kerosene. Cold-temperature tests have shown that gun operation at low temperatures is not improved by diluting the lubricating oil in such a manner. Further, at temperatures warmer than -29oC, this mixture is not a satisfactory lubricant.

6. Guns rust rapidly from condensation when taken from the cold into a warm building. After reaching room temperature, they should be stripped, their parts wiped thoroughly dry and clean and

immediately oiled. This procedure must be repeated every time guns are brought into a warm space from the cold outside.

705 GUN SIGHTS AND AIRCRAFT FIRE CONTROL EQUIPMENT

All gun sights and aircraft fire control systems should be capable of operating at temperatures as low as -48oC, provided the correct lubricants are used.

706 BOMB SIGHTS AND BOMB DIRECTORS

Most bomb sights will perform satisfactorily at low temperatures. Some have proved to be satisfactory to -54^{o}C while others, of a less elaborate type, will operate at temperatures to -40^{o}C.

707 AMMUNITION

1. Ammunition must be kept in protected storage at temperatures not below the minimum safe values prescribed for the explosives concerned. Ensure wet ammunition is wiped down prior to stowage to prevent icing. Propellants should be maintained at a temperature above -17.7^{o}C. Rocket motors are subject to the same requirements as smokeless powder cordite, as far as storage temperatures are concerned. Some rocket motors are susceptible to cracking if handled at low temperatures.

2. Safe firing temperatures for rocket and Jet-Assisted Take-Off (JATO) units should be stencilled on the rocket motor or the JATO unit. These temperatures represent the minimum temperatures at which the rocket motor or JATO unit should be used and are not necessarily the ambient air temperature. If the temperature of the JATO unit has been permitted to drop below the prescribed minimum, it cannot be considered safe for firing at any temperature. All aircraft gun ammunition must be capable of firing to -54^{o}C.

708 LUBRICANTS

Under Arctic conditions, certain lubricants prescribed for normal use tend to congeal and cause unsatisfactory operation. In general, lubricants approved for use in ordnance service should meet specification requirements at temperatures to -18^{o}C. Changes in lubrication required for use in Arctic service include the dilution of high-viscosity oils and heavy greases with low-viscosity oils, or replacement with a suitable low-temperature lubricant. Excessive amounts of lubrication must be avoided. Cold-weather re-lubrication of ordnance should be completed before entry into low-temperature areas, i.e., before temperatures drop to -18^{o}C and below. However, if cold weather is encountered before re-lubrication has been completed, special methods for removing the congealed lubricant must be used.

709 TORPEDOES AND TORPEDO TUBES

1. In surface vessels, torpedoes are protected from cold weather by the torpedo tubes or the magazine environment. Submarine torpedoes are protected by the normal ship environment.

2. In surface vessels, heaters (preferably electrical) are required for exposed torpedo tubes and muzzle door and training mechanisms, if fitted. Heating should be used at ambient temperatures below 5^{o}C.

710 MINESWEEPING GEAR

1. Motor-driven acoustic minesweeping gear requires heated inside stowage, when not in use. If this is impossible, the gear will have to be stowed on deck, under cover, with a portable heater. After streaming, the gear needs to be left in the water for two hours for temperature adjustment before operation.

2. Before streaming and recovery, remove ice on stern roller chocks and intermediate rollers so that rollers can turn freely. During recovery, remove any ice on cable and dry as much as possible to prevent its freezing together when reeled.

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CHAPTER 8

ELECTRONICS AND CHARACTERISTICS OF ELECTRONIC EMISSIONS

801 GENERAL REQUIREMENTS

1. The following is an outline of some of the requirements for electronic equipment applicable to most types of ships:

a. All exposed shipboard equipment should be capable of operating at temperatures down to -50°C.

b. All exposed electronic equipment should be capable of withstanding wind velocities of 100 kt at any temperature down to -50°C.

c. All mechanically operated equipment must be lubricated with low-temperature lubricant and adequate space heating fitted in spaces where this is feasible, e.g., inside radar pedestals.

d. Electric heaters should be installed in inside covers of electronic equipment fitted on weather decks.

e. Insulators should be lengthened approximately 10 percent or the next higher voltage rating over the normal standard as extra protection against shorting caused by ice formation.

f. Antennas should be designed to withstand an ice load, up to 5 cm thick around the component parts of each antenna. The diameter of wire rope antennas should not be less than 1 cm. All whip antennas should be capable of withstanding wind velocities of 100 kt when coated with ice 5 cm thick.

g. Cables and cords should be handled with care to prevent fracturing. At extremely low temperatures, cables should be unreeled in a warm space before use.

802 EXPOSED ELECTRONIC EQUIPMENT

1. With the foregoing requirements in mind, all equipment should be appropriately winterized and preheaters used wherever possible. The practice of lengthy warm-up periods under no-load or light-load conditions is also recommended.

2. Equipment not in regular use needs to be heated periodically to drive out moisture. Waveguides (and other non-pressurized lines where condensation can accumulate) should be fitted with drain cocks and drained at regular intervals. Planned maintenance schedules for ships should include checks of all drain cocks. Waveguide dryers, should be used as directed.

3. Equipment used in exposed positions, then returned to warm spaces for stowage, must be thoroughly dried to remove all moisture. After drying, the equipment should be allowed to reach the ambient temperature of the space prior to stowage.

4. Ice formation can be a hazard on all types of external antennas, causing breakage or changes in antenna characteristics and reduction of operating range. Ice, which has formed should be knocked off with a thin pole. Ice and snow should also be removed from strain insulators to prevent excessive

transmission losses. Wire antennas should be secured loosely, so any slight whip action can crack ice build-up.

803 COLD-WEATHER PREPARATIONS

1. **Antennas**. Radio equipment requires preparation prior to deployment for cold-weather operations. Of particular note is the problem of antenna icing. Antennas should be coated with a silicone/oil-based substance with sufficient on-board stock available for additional coating, if required. Antennas suffer sea-spray icing in the northern latitudes. The thicker the ice on the antenna, the greater the loss imposed on the signal. Factors such as air temperature, salinity of the water, structural shapes, and wind velocity play key roles in the antenna icing process and should be taken into consideration when operating in the area. Utilizing proper preventive-maintenance methods can aid in reducing the amount of ice adhesion that occurs on an antenna. Wiping the antenna down, ensuring that it is free of dirt, and checking the smoothness of the antenna's surface, are procedures, which can be used by radio personnel to prevent icing. Additionally, all radio equipment (transceivers/receivers) should be brought up to technical manual standards prior to deployment It is imperative that all radio equipment be checked and the necessary preventive maintenance be performed on all communication systems.

a. Test antenna drive motors.

b. Apply cold-weather grease, after purging old grease, about one week before getting underway. Make sure grounding straps were properly insulated.

c. Obtain spare antennas and insulators to replace those which may be damaged from heavy weather/ice.

d. A complete inspection and Planned Maintenance Schedule (PMS) of antennas/topside equipment is strongly advised prior to Arctic operations to minimize need for personnel to work aloft.

(1) Check rotating antenna heater circuits and cooling systems.

(2) Verify weather-tightness of exposed antenna components.

(3) Check operating mechanism on all communications antenna safety switches.

(4) Check operating mechanisms on all antennas with lowering systems installed.

(5) Insulate anemometer as much as possible. Hand-held anemometers should be available.

(6) Inspect wire antennas (HF broadband fans) and slacken if required.

e. SATCOM antenna pedestal may freeze, preventing the antenna from tracking in azimuth The following actions may be helpful:

(1) Place temporary heat strip around pedestal

(2) Place fibreglass insulation and herculite cover around pedestal.

(3) Place desiccant bags inside pedestal to absorb moisture

(4) Rotate directors/illuminators at low speed every 8 hours. During extreme icing conditions rotate antennas in azimuth and elevation every 30 minutes to prevent the pedestal from freezing..

f. Fill antenna cooling systems with an anti- freeze solution.

g. Fire control radar antenna scanners (the stinger on the director) may ice over on the inner rotating axis, holding the scanner in the conical scan pattern and preventing the spiraling motion in automatic-track mode.

(1) Keep a coating of antifreeze on the areas between rotating and non-rotating areas.

(2) Train the director aft with elevation depressed during freezing conditions.

(3) Install a lightweight, non-reflective cover on the antenna, when Arctic operations are planned.

h. Operate variable-spaced antennas at low speed for a short period before increasing rotation speed. Do not change the direction of rotation or accelerate/decelerate rapidly, until gear trains and drive motors are thoroughly warmed up. Installation of electric heaters in antenna pedestals is recommended

i. Replace oil in the pedestals of rotating radar antennas with oil that will not congeal at low temperatures. Consideration should be given to the installation of oil heaters.

j. Connect the radar antenna pedestal heater to a circuit that will remain energized when the radar set it self is disconnected.

2. **Slow-Moving Mechanical Parts.** Slow-moving mechanical parts, such as shafts and bearing surfaces, will operate more satisfactorily if the surfaces are buffed and polished. Such surfaces should not be lubricated unless this is essential, and even then it should be done sparingly.

3. **Covered Cables**

a. Rubber-covered, flexible cable becomes stiff at temperatures lower than -6°C; the insulation becomes brittle and can crack and shatter rather than bend.

b. Synthetic materials (e.g. polyethylene) are replacing rubber for insulating purposes because of much improved cold-weather characteristics.

4. **Electric Installations**. Electric installations should be made with special care to minimize the effect of cold, moisture, high humidity and stresses due to icing, as follows:

a. Increase wire size of radio antennas to compensate for high winds and ice loading of long horizontal spans. Receiving antennas using small-size wire are vulnerable to damage by ice loading.

b. Install double antenna suspension insulators for transmitting antennas to increase leakage path and to prevent arc-over.

c. Increase the size of mounting brackets and foundations of equipments in ships which may become involved in ice-breaking operations.

5. **Communications Equipment.** Communications equipment for high-latitude operations should include a transmitter with a high-frequency operating range of at least 26 MHz, and another, which will operate on frequencies as low as 175 - 195 kHz. Both of these transmitters must have substantial power capabilities. All transmitters and receivers should be calibrated on the several frequencies expected to be used. To capitalize on the advantages of low-frequency operation and very low-frequency reception during blackout periods, antenna systems additional to those already installed may be required.

6. **Telephones and Microphones**

a. When using telephones or microphones in exposed locations, care should be taken to prevent the speaker's breath from freezing the microphone. In general, the use of portable microphones supplied with a transmitter station, which is in a protected space is preferable to those located in the open.

b. Cover sound-powered telephone boxes.

804 CARE OF EQUIPMENT IN LOW TEMPERATURES

1. In general, special procedures will be required to ensure satisfactory operation of electronic equipment at temperatures lower than -2°C.

2. Dry-cell batteries and electrolytic condensers will not work at low temperatures, but will probably recover and resume normal operation when warmed. Maintenance will be required to prevent corrosion from condensation caused by temperature changes. Components may require frequency readjustment of critical circuits because of changes in electrical characteristics.

3. When temperatures fall below 2°C, heat should be applied to electronic equipment if it is to be ready for immediate use. Batteries and electrolytic condensers, in particular, must be warm if they are to operate efficiently. Continuous operation in the "standby" or "filament" position is good practice as it keeps equipment at the correct operating temperature before plate voltage is applied, and it eliminates condensation inside the equipment.

805 UNDERWATER ELECTRONIC EQUIPMENT

1. Echo-ranging equipment with retracting transducers requires an "ice-gate" to prevent entry of ice into the transducer sea chest.

2. Radar waveguide and ECM antenna masts on submarines should be filled with pressurized nitrogen and the heaters should be continuously energized.

806 PORTABLE POWER SOURCES (FOR ELECTRONIC EQUIPMENT)

1. A small aerosol-type can of ether should be included to facilitate cold-weather starting of portable internal-combustion power-generated equipment.

WARNING

- Extreme caution should be exercised to limit the quantity of ether injected in both gas-engine carburators and diesel engine air intakes.
- To avoid the possibility of frostbite, do not allow ether to come in contact with exposed body areas.

2. If equipments are to be shut down or left turned off for extended periods, the lubrication oil should be drained while the engine is hot, then stored inside the ship or personnel shelter along with the starting batteries, if so equipped. Often it is more advantageous to leave engine-starting batteries inside and extended cables outside to the generator.

807 MAINTENANCE (PERSONNEL PRECAUTIONS)

1. No maintenance aloft should be attempted unless an emergency condition exists, and then only after rigging an appropriate canvas windscreen protection cover against wind-chill, and installing portable heaters inside to allow maintenance personnel an opportunity to remove gloves, masks and attach safety harness, prior to attempting any electronic-type repairs. (Solder will not blow at-20øC using conventional irons.) Gloves should be donned prior to leaving the shelter, to keep hands from freezing to ladder rungs or handrails.

2. Safety belts/harnesses must be worn when working aloft. Positive footing is never available aloft in northern waters and becomes more pronounced when personnel are required to wear cumbersome clothing and footwear.

3. The installation of communication whip antennas in the vicinity of smoke stacks or boiler room uptakes usually prevents the formation of ice. However, periodic cleaning is necessary to remove soot accumulations and prevent degradation of antenna performance. The cleaning aspect does not present a problem when the whips are of the retractable type and access to the top of the stack is gained through an internal trunk-and-scuttle arrangement. Breathing masks and safety belts/harnesses must be worn at all times to prevent smoke and stack gas inhalation and to conform to "safe working practice aloft" criteria.

808 COMMUNICATION CHARACTERISTICS

1. Radio communications beyond "line-of-sight" limits in the Arctic pose certain problems that occur only rarely at lower latitudes. These problems are mainly caused by ionospheric disturbances which affect the behaviour of radio waves in the Low-Frequency (LF), Medium-Frequency (MF), High-Frequency (HF), and Very-High-Frequency (VHF) bands.

2. The standard shipboard transmitter required for high-latitude operations usually covers a frequency range down to 175-195 kHz, depending on the model. At the lower end of the range, the radiated power obtained may be very small, being something of the order of 0.6 percent to 1.5 percent of the rated output power. This is caused by the inability to load the antenna properly because of its short effective length. Radiation is further decreased by the necessarily short vertical section of the antenna, upon which radiation depends. Optimum radiation with current shipboard antennas is usually realized at around 500 kHz, and effective radiation decreases as the operating frequency is decreased. It has been found, too, that in operating the low-frequency transmitter at frequencies in its lower range at substantial power (one or two kW), using a standard shipboard antenna, severe arc-overs and large losses in antenna trunks will be experienced due to high standing-wave ratios, with high voltage occurring at the insulators caused by inadequate effective lengths.

3. For these important lower frequencies to be used during periods of ionospheric disturbances, arrangements may have to be made to install temporary transmitting antennas of the greatest length and height practicable. The possibility of paralleling existing antennas in series might be considered, and emergency use of balloon suspension should not be overlooked.

809 ARCTIC ANOMALIES

1. Auroral Zones and RF Interference

a. Zones of extreme RF interference and "electronic storms" become increasingly prevalent and severe in higher latitudes. Such "auroral zones" are believed to be due to charged particles ejected from the sun and deflected by the earth's magnetic field.

b. It has been noted that the frequency and severity of electrical storms vary directly with the number of sun spots observed on the sun. Communications in high latitudes are affected both by electronic storms and ionospheric disturbances. In HF/MF bands, propagation becomes erratic; the highest usable frequency decreases and the lowest usable frequency increases. Transmitters and receivers will fade. At times, communications black out completely and may remain out from a few minutes to several days. On the other hand, communications on VHF/UHF circuits may extend beyond the line of sight. Radar may similarly be rendered useless for brief periods, or its range extended by ducting.

c. A communication coordinating circuit should be included in all communications plans. The coordination circuit should be covered using narrow-band and wide-band secure voice equipment cryptographic systems.

2. **Antenna Icing**. Radio equipment requires preparation prior to deployment for cold-weather operations. Of particular note is the problem of antenna icing. Antennas should be coated with a silicone/oil-based substance with sufficient on-board stock available for additional coating if required. Antennas suffer sea- spray icing in the northern latitudes. The thicker the ice on the antenna, the greater the loss imposed on the signal. Factors such as air temperature, salinity of the water, structural shapes, and wind velocity play key roles in the antenna icing process and should be taken into consideration when operating in the area. Utilizing proper preventive-maintenance methods can aid in reducing the amount of ice adhesion that occurs on an antenna. Wiping the antenna down, ensuring that it is free of dirt, and checking the smoothness of the antenna's surface, are procedures which can be used by radio personnel to prevent icing. Additionally, all radio equipment (transceivers/receivers) should be brought up to technical manual standards prior to deployment. It is imperative that all radio equipment be checked and the necessary preventive maintenance be performed on all communication systems.

3. **UHF Communications**

a. Effective UHF ranges are significantly reduced. During heavy snow, absorption and fading are common, further reducing UHF ranges. With unrestricted visibility conditions, maximum UHF ranges are 15 - 16 NM (28-30 km); when visibility is reduced to 1-2 NM (2-4 km), UHF ranges are reduced to 10-12 NM (19-22 km).

b. Few incidents of apparent UHF black-out have been noted. However, on some occasions UHF communications have been good with a ship 10 nautical miles (19 km) away, while having no communications with a closer ship.

4. **Satellite Communications**. A major problem is the potential for the satellite receiver antenna to freeze. Communications dependent upon satellites in geostationary, equatorial orbits will be degraded above 70°N because the satellite is near or below the horizon.

5. **Static**. Continuous high-level static is rarely experienced in Arctic latitudes but sporadic noise is common. Irregularly occurring steady rushes of increasing noise frequently signify auroral disturbances on the frequency employed. Generally, LF is less affected by this type of atmospheric noise than HF. Flakes or pellets of highly charged snow are occasionally experienced in the north during periods of high winds. Charged particles of snow driven against metal vehicles, masts, and antennas, discharge with a high-pitched static sound that can be heard on all received frequencies. This form of noise is more severe on aircraft radios than on ground or vehicle stations.

6. **Ground Conductivity.** Ground conductivity in northern areas is generally poor. At HF and below, effective ground-wave ranges are considerably reduced over ice, permafrost or snow-covered terrain. Moreover, the efficiency of an antenna, especially when propagating in the sky-wave mode, is lessened when installed over this kind of ground. Great care must be taken in siting to secure the best available ground, and considerable effort may be needed to build an artificial ground system.

7. **Communications Plans**. Because of the foregoing, the following communication factors will influence the tactical plan:

a. Extended communication ranges, which must be achieved are normally accompanied by a reduction in communication capacity. Normal scales of communication equipment cannot usually be maintained under these circumstances.

(1) Depending on the nature of terrain and other factors, ground rebroadcast stations for voice operation may have to be deployed at very moderate distances. Airborne rebroadcast may be required for greater ranges. Finally, carrier-wave (CW) operation may be necessary for point-to-point communications at still greater ranges or during disturbed conditions.

(2) Range or terrain may dictate the use of sky-wave transmission. Although usually reliable, it is not entirely so due to the unpredictability of atmospheric conditions.

(3) Where a higher degree of reliability is required at sky-wave transmission ranges, normal HF links must be guarded, by parallel LF circuits. Where this is necessary, two stations must be established at each circuit terminal. Extensive antenna systems may be required for continuous day/night operation.

b. Because of the vagaries of sky-wave transmission, much greater attention must be paid to protecting information than is usually the case. When voice codes are inadequate, ciphers must be employed and these are likely to be of the manual type. Manual enciphering is time-consuming and handling times are in proportion to the length and number of messages being transmitted.

c. In northern areas, the siting of headquarters to gain the extended communication ranges is critical. Detailed ground reconnaissance and testing will probably be necessary to find adequate transmission sites. In the absence of suitable retransmission facilities, a major headquarters or base should not be deployed to a remote locality until a satisfactory site has been determined

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CHAPTER 9

PERSONNEL

901 INTRODUCTION

The success of any Arctic operation will ultimately depend upon the effectiveness of the officers and personnel involved, who must be in good health, physically fit and mentally alert.

902 TRAINING/PREPARATION

1. Pre-sail training and briefings are the key to safe cold-weather operations, and should include:

a. Hazards of frostbite, wetness, snow-blindness or eyestrain, lung frosting, wind-chill and hypothermia.

b. Precautions such as avoiding excessive perspiration, ensuring that clothing fits properly, ensuring that enclosed shelters are ventilated properly, not handling metal objects with bare hands, and using precautions when handling volatile liquids in cold weather.

c. Precautions for operating in lengthy periods of darkness.

d. Instructions on ice removal and safety.

e. Cautions that heavy clothing and cold may significantly reduce and limit body motion.

f. Hazards of trench foot.

g. Precautions for operating in areas of extreme glare and the use of tinted goggles.

903 FOOD AND WATER

1. Due to the risks associated with dehydration in high latitude environments, personnel should increase fluid intake, especially water. Use caffeine drinks moderately since they will contribute to dehydration. Electrolyte-replacement drinks are valuable and should be served warm.

2. Food is particularly important in the increase of metabolic heat production as well as providing relief from monotony. For this reason, plan meals with high caloric content of sufficient quantity and regularity to maintain an optimum metabolism and with as much variety and appeal as possible.

3. Inside stowage of provisions against an un-insulated hull should be avoided since temperatures can cause condensation and may result in mould damage.

4. The consumption of alcohol, even in small amounts, causes increased blood flow to the skin, which may artificially create the sensation of warmth to tissue that is at risk of frostbite. Furthermore, this increased blood flow to the skin can decrease core body temperature and increase the risk of hypothermia. Accordingly, the use of alcohol in a cold weather environment should be discouraged.

904 COLD-WEATHER CLOTHING

1. The first requirement for dressing for the cold is to keep warm without perspiring. If overheating does occur, personnel need to shed clothing readily so that perspiration cannot accumulate. Clothing

based on the layering principle, is now readily available and consists of various garments designed to trap air in layers without being uncomfortably bulky. Clothing should be layered as follows: wool or polypropylene next to the skin to absorb moisture, followed by wool for warmth, followed by wind/rain protection gear. Multiple layers retain body heat better than a single bulky garment.

2. In conditions of extreme cold, it may be necessary to provide face masks. Anti-glare goggles or sunglasses are helpful as a precaution against snow-blindness.

3. For operations ashore, provision must be made for certain essential needs: shelter (tents or snow shelters), food and drink, first aid, cooking and heating equipment, sleeping bags, and a reliable means of transport and communication.

4. Clothing for extreme cold weather should include:

a. Cotton or polypropylene long underwear.

b. Woolen or cotton socks.

c. Jacket.

d. Trousers.

e. Hood.

f. Mittens with wool liners.

g. Gloves with woollen liners.

h. Boots.

i. Face masks.

j. Goggles or sunglasses.

k. Immersion gear. For personnel working in exposed areas, well-decks, towed-array hoist rooms, or flooded areas, wet suits are recommended.

l. Wind pants. If immersion gear is not available, wind pants must be worn over long underwear and trousers.

m. Other Considerations

(1) The most effective outerwear is an anti-exposure suit; it has inherent buoyancy, without restricting upper body mobility. It is recommended for helicopter operations, RAS, UNREP, and other topside evolutions.

(2) The knit Balaclava is an effective head covering.

(3) It may be necessary to designate extra space as drying areas for cold weather clothing.

Cotton undergarments easily absorb perspiration, become saturated and lose their insulation properties. Most synthetic materials do not absorb moisture and are intended to wick away from the body and, therefore, are excellent insulators.

905 PERSONAL WELFARE

1. **Personal Protection**

a. The rotation interval for exposed personnel standing topside watches may be varied with weather conditions. However, it is imperative that such personnel be regularly and carefully checked. The effects of exposure are not readily recognized. Watch rotation of 20 - 30 minutes is effective.

b. Personnel who get wet on deck must go below immediately and change into dry clothing.

c. Whenever topside look-outs start feeling cold, they should flex fingers and toes. The look-outs should be periodically checked by watch personnel.

d. Provide for portable, topside heaters or enclosures for personnel involved in extended topside evolutions. Hangar space heaters have proven effective.

e. Anticipate that routine evolutions could take twice as long in cold weather.

f. Periodically inspect berthing spaces for warmth and ventilation. Ensure that adequate bedding materials are available.

g. Provide for additional heaters for particularly exposed areas, such as the Signal Bridge and Pilot House.

h. Hot beverages and soup should be available on the mess deck 24 hours a day and distributed to look-outs, RAS and flight-deck crews.

i. Stripping of waxed decks and the addition of non-skid strips is recommended.

906 FROSTBITE

1. The term frostbite refers to the freezing of any part of the body. The tissue affected actually freezes. Frostbite is caused by exposure to temperatures below 0°C. The water in the tissue cells turns to ice and disrupts the normal functions and even the cellular structure of the tissue. Normally the body's metabolism (burning of calories) produces enough heat to keep all parts of the body warm. When exposed to severe cold, however, heat loss becomes very rapid and the blood supply to the area reduces to conserve body heat. If the affected area is not reheated, the blood there may get very thick and plug up the arteries. Without any source of heat, the area will begin to freeze. The extent of damage depends on how much freezing occurs.

2. Identifying frostbite can be relatively easy. Usually there is an uncomfortable sensation of coldness, followed by numbness. There may be tingling, stinging, aching or even a cramping pain. Visible indications, which are used primarily to detect a buddy with frostbite, include the skin first turning red, then later becoming pale or waxy white. The parts affected, in order of most common occurrence, are:

a. nose;

b. ears;

c. cheeks;

d. forehead;

e. exposed wrists;

f. feet, especially toes; and

g. fingers.

3. **Superficial Frostbite** involves only the skin or the tissue immediately beneath it. Mild cases are sometimes referred to as frostnip, and can be easily re-warmed with little or no tissue damage. There is a certain amount of whiteness or waxy appearance. After re-warming, the frostbitten area will first become numb, mottled blue or purple and then swell, sting and burn for some time. In more severe cases, blisters will occur beneath the outer layer of skin in 24 to 36 hours. These slowly dry up and become hard and black in about two weeks. Generally, swelling of the injured area will subside if the casualty stays in bed or at complete rest. Throbbing, aching and burning of the injured part may persist for several weeks, depending on the severity of the exposure. After the swelling finally disappears, the skin will peel and remain red, tender and extremely sensitive to even mild cold and it may perspire abnormally.

4. **Deep Frostbite** is a much more serious injury and it damages not only the skin and subcutaneous tissue but also goes deep into the tissue beneath and can even include the bone. It is usually accompanied by the formation of large blisters. In marked contrast to superficial frostbite, these blisters take from three days to a week to develop. Swelling of the entire hand or foot will also take place and may last for a month or more. During this period of swelling, there may be marked limitation of mobility of the injured fingers or toes, and blue, violet or grey (the worst) discoloration takes place. After the first two days, aching, throbbing and shooting pains may be experienced for as long as 2 to 8 weeks. The blisters finally dry up, blacken and slough off, sometimes in the form of a complete cast of the finger or toe, nail and all, leaving beneath an exceptionally sensitive, red, thin layer of new skin, which will take many months to return to anywhere near normal. Sometimes, itching and abnormal perspiration persists for more than 6 months after the initial injury, and the part will suffer lengthy or permanent sensitivity to cold. In extreme cases of severe frostbite that have not been re-warmed rapidly, permanent loss of some tissue almost invariably occurs. In such cases the skin does not become red and blistered after it has thawed, but turns a lifeless grey color and continues to remain cold. If blisters occur they will probably appear along the line of demarcation between the acutely frostbitten area and the healthy remainder of the limb. In cases of acute deep frostbite of the foot, adjacent swelling can extend as high as the knee. In a week or two after the injury, the tip of the injured area begins to become black, dry and shrivelled, but the rest of the damaged area may progress in one of two entirely different ways: the tissue may shrivel to almost half the normal size and become mummified right up to the beginning of the healthy flesh, or the tissue may become wet, soft and inflamed if it becomes infected.

5. In the dry type of frostbite, the uninjured remainder of the limb usually does not become intensely swollen or painful, and there is a clear line of demarcation between damaged and undamaged tissue. In the wet type, the whole limb tends to become painful and swollen, and originally undamaged tissue may suffer serious damage unless the infection is promptly checked. Surgical intervention is rarely needed in less than 2 months. Even minor surgery on frostbite tissue should rarely be performed. In

an extreme case in which the loss of some tissue is inevitable despite careful treatment, the dead material will simply slough off at the proper point and at the proper time, with maximum saving of the sound underlying tissue. Occasionally, hospitalization and professional surgical intervention may be needed. However, if even this type of case is kept scrupulously clean and sterile, the proper use is made of antibiotics and the patient stays constantly in bed at rest throughout the illness, the chances are high that auto-amputation will eventually occur.

6. Chances of getting frostbite are increased by several factors in addition to duration of exposure and freezing temperatures. These should be kept in mind, particularly when it comes to choosing people for duties where they are susceptible to frostbite. Some at risk people include:

a. older people;

b. smokers;

c. those unaccustomed to cold weather;

d. injured people;

e. fatigued or sick people;

f. those with previous cold injuries;

g. those with poor nutrition habits; and

h. those having consumed alcohol.

907 TREATMENT OF FROSTBITE

1. The following is a summary of ways to treat frostbite. Always consult the corpsman before performing more than basic treatment.

2. **Superficial Frostbite**

a. A minor case of superficial frostbite is fairly common and should serve as a warning. However, unless operations mandate otherwise, superficial frostbite victims should be re-warmed in a shelter and the individual not returned to duty until all secondary symptoms are gone.

b. A frozen nose is the most common type of minor frostbite. Holding the pile of the back of the mitt over the lower face and breathing into it will warm the nose quickly. A scarf or mask worn over the face will usually prevent frostbite.

c. Minor frostbite can usually be thawed with body heat. Place a bare warm palm against a frostbitten cheek or ear or place frostbitten hands against the chest, between thighs or under armpits.

3. **Deep Frostbite**

a. Move the victim to a heated area to avoid danger of further frostbite. If necessary, delay re-warming until all danger of refreezing is eliminated. Frostbitten areas must not be allowed to thaw and refreeze.

b. Remove all constricting items of clothing such as boots, gloves and socks from the area of injury if this can be done without causing further damage to the frostbitten part.

c. Rapid re-warming is the specific treatment which minimizes tissue loss. The extremity should be thawed in a carefully controlled water bath at a temperature between 40 and 41° C until affected tips turn pink or burgundy red (approximately 20 minutes to 1 hour). This is best accomplished in a whirlpool bath or tub bath. If a bath is not available, thaw with warm wet packs at temperatures ranging between 37.8 and 44° C.

d. Avoid infection by cleaning and dressing with dry sterile gauze loosely wrapped.

e. As early as operations permit, treatment by a medical officer is vital.

4. The following precautions should be observed when treating frostbite:

a. Don't rub or massage the injury. It will cause more damage.

b. Don't use any creams or ointments.

c. Don't rupture any blisters.

d. Don't allow the victim to smoke or consume alcoholic beverages, even though the pain may be severe.

e. Don't allow an injury to thaw and refreeze.

f. Don't rub ice or snow on the injury.

g. Avoid excess heat when re-warming the injury.

908 IMMERSION FOOT

1. Immersion foot, also commonly called trench foot, is a cold injury to the feet (and possibly the hands) resulting from prolonged exposure to dampness and temperatures below about 10° C. Note that freezing temperatures are not necessarily associated with this injury. In the early stages of immersion foot, the feet and toes are pale and feel cold, numb and stiff. Walking becomes difficult. If no action is taken at this point, the feet will swell and become painful. In extreme cases the flesh dies and may fall off, and amputation of the foot or the leg may be necessary. Other signs of trench foot include pain and tingling insensitivity; blotchy, red and white, waxy skin; poor blood circulation.

2. **Treatment of Immersion Foot**. The earlier treatment for trench foot begins, the faster recovery will be and the less damage will be done. Handle the affected part gently. Do not rub or massage at this point. Immediately re-warm and dry the affected areas. Re-warming should be performed slowly in air, and not in hot water. Apply powder liberally to remove any moisture remaining on the skin. Elevate the feet slightly and air them out at room temperature. Circulating air around the feet with a fan will help to keep them dry.

3. **Prevention of Immersion Foot.** Wet socks and boots, poor nutrition, fear, fatigue and immobilization can all contribute to trench foot. The following practices will help to prevent such an occurrence:

a. A sweat suppressant, deodorant type powder or spray will help to keep the feet dry.

b. Dry socks are a must! Repeated changes during the day may be necessary to keep dry.

c. Exercise feet while out in the cold. Toe raises and walking will improve foot circulation, as will wiggling toes and bending ankles. Tight boots, which reduce circulation must not be worn.

d. When socks are removed, massage feet and lower legs. This improves circulation and helps dry feet.

e. Keep feet clean. Good hygiene will prevent fungus growth and keep feet healthy.

909 HYPOTHERMIA

1. In this condition the body temperature falls, as the body's capacity to generate heat can no longer keep pace with the rate of body heat loss. This usually occurs in persons suffering from exposure.

2. The onset of this condition is insidious. An individual complains of feeling cold, becomes listless, tired, and wants to lie down and rest. If the individual surrenders to this urge, hypothermia progresses rapidly. Irrational behaviour is a serious sign and is often followed by unconsciousness. Additional indicators of the onset of hypothermia are muscle weakness, cessation of shivering, loss of coordination and poor decision making ability.

3. Treatment depends upon the severity of the condition, which can only be accurately determined by a core temperature, normally a rectal temperature. If a rectal temperature is not available, each individual case must be presumed to be serious. In the early stages, it is sufficient to get the person into shelter, carefully remove wet clothes and provide external warmth to the body.

4. In severe cases, more aggressive treatment is required. Gentle handling of hypothermic patients is mandatory to avoid cardiac arrhythmias. The patient should be re-warmed with blankets at room temperature, warm intravenous fluids at 37 degrees Centigrade, and warm humidified supplemental oxygen heated from 38.9 to 40 degrees Centigrade delivered as a mist. Hot, well sweetened beverages, may be given by mouth if the patient is conscious. Immersion in a hot water bath may be considered when the patient is coherent and the shiver response has returned, especially in those cases caused by immersion. The initial water temperature should be 36 degrees Centigrade and should not exceed 40 degrees Centigrade for patient comfort and to avoid the risk of peripheral vasodilation, syncope and shock.

5. Rapid re-warming must be avoided as this predisposes to cardiac arrythmia and arrest. Re-warming rates should not exceed 3-4 degrees per hour. If the core temperature is below 30 degrees Centigrade, medical staff must be present to administer the re-warming procedure recognizing the risk of cardiac arrythmias or cardiac arrests. Cardiopulmonary resuscitation or assisted respiration may be required; however, defibrillation is often unsuccessful at body temperatures less than 30 degrees Centigrade.

6. Prevention is the ideal state of affairs and should not be too difficult. Leaders must insist on adequate dry clothing, ample nutrition, the avoidance of fatigue, and be on the lookout for the early signs of hypothermia. Incipient cases should not be permitted to lapse into inactivity. There is always the possibility of hypothermia whenever a person is forced into inactivity in the cold or as a result of injury.

910 SNOW-BLINDNESS

1. This is caused by the sensitivity of the eye to ultra-violet radiation. The Arctic sun is never high above the horizon and its effect is intensified by reflection from snow and ice so that considerable ultraviolet light can fall onto the retina. Although the dangers of snow blindness aboard ship are slight, bridge watch standers and lookouts should be aware of the risk, particularly in areas of heavy sea ice or snowy mist.

2. Early symptoms are a scratching sensation under the eyelids, deep pain in the eye with excessive tear flow and blurred vision. These may progress to intense pain, aggravated by light, so that it becomes impossible to open the eye. The white of the eye becomes reddened.

3. Treatment consists of keeping the eyes bandaged and the patient in darkness until the reaction has subsided. Pain-relieving drugs, such as drops or ointment, will be required. Sedation, such as the administration of benzodiazopines, may be indicated.

911 HYPOXIA

1. Hypoxia, or an insufficiency of oxygen, can occur when personnel attempt to live in a poorly ventilated shelter.

2. Close observation of a burning candle is essential in any Arctic shelter. The shelter must have ventilating airholes since candles consume oxygen. When the percentage of oxygen in the air drops from 20 percent to 16 or 17 percent, a candle will go out. This occurs, however, before the occupants themselves will be seriously affected by hypoxia and in time for them to get into fresh air.

912 CARBON-MONOXIDE POISONING

1. Everyone must be constantly alert for the possibility of carbon-monoxide poisoning resulting from incomplete combustion of fuel. Use of petroleum products in internal-combustion engines and stoves in the Arctic is a common source of carbon-monoxide poisoning.

2. Leaded gasoline burned in stoves produces lead oxides which are irritating but non-toxic in small amounts. Burning eyes, a running nose, or coughing produced by these are a warning of carbon-monoxide buildup.

3. Carbon-monoxide is odorless, tasteless, and colorless. Symptoms of poisoning are: a loss of peripheral vision, dimmed vision, headaches, dizziness, nausea, exhilaration or lassitude, and chest pain. Sometimes the most noticeable feature to an observer is that the lips or the entire body may become "cherry red" in color. Treatment should be by delivering 100 percent oxygen via a tight-fitting face mask.

913 AVOIDING COLD-WEATHER INJURIES

1. All parts of the body do not lose heat at the same rate. Those areas which loose heat the fastest include:

   a. The head and neck, which loose heat 10 times faster than the rest of the body;

   b. The rib cage; and

c. The groin region.

2. The hands and feet have a blood supply which quickly constricts in the cold. Constricting boots/socks and gloves decrease the blood supply, increasing the risk of frostbite. Accordingly:

a. Dress warmly using the layering principle.

b. Clothes should be slightly loose-fitting.

c. Toes should be free to move in boots.

d. Protective coatings can help prevent drying/cracking of lips.

3. When standing watch in the cold, improve circulation to the feet by periodically bouncing on the toes. This will increase heat to the feet, making frostbite less likely. The fingers and hands may also be exercised to keep them warm.

4. **Eating/Drinking**

a. Bodies are like engines and require fuel to burn in order to make heat. Accordingly, it is essential that an adequate diet be provided each day so that the body can produce heat to help withstand the extreme cold. An increased relative percentage of fats and proteins are recommended due to their heat-producing potential. Besides having nutritional value, food can act to re-warm the core - in the form of hot chocolate, soup, etc.

b. In addition to food, the body requires a good deal of water daily to carry on normal functions. It is advisable to drink at least two litres of water per day to avoid dehydration. Melted ice and snow may be substituted if other fluids are unavailable. The consumption of ice and snow in the solid state may increase the risk of hypothermia, particularly if there are inadequate food supplies.

914 DEHYDRATION

1. Everyone has experienced dehydration on a warm summer day, but in the cold it's a different matter. Not only is it less easily recognized, but the effects of dehydration may be devastating. Normally the body controls its fluid balance by filtering off excess water and drinking (due to thirst) to replace lost water. In the cold, both of these mechanisms are disrupted:

a. In extreme cold, personnel do not become thirsty as dehydration sets in.

b. Also in extreme cold, urination increases.

2. These factors, coupled with excessive caffeine intake, cause increased urination, and can lead to dangerous dehydration. The water present in the blood (which makes up a significant portion) helps carry warmth to the body, so the dehydrated individual is at even greater risk for the injuries discussed. Avoid dehydration, be on the look-out! Early signs include low pulse rate, constipation, and dark urine (in reduced amounts). Be sure to drink extra amounts of water every day.

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CHAPTER 10

GENERAL OPERATIONS

1001 ICE-BREAKERS

1. Broadly speaking there are three categories of ice-breakers:

a. Harbour;

b. Non-Polar; and

c. Polar.

2. **Type a.** covers small ice-breaking vessels, generally not much larger than tugs, engaged in keeping rivers and small harbours clear of thin ice. **Type b.** embraces large ice-breakers employed in keeping areas of sea clear of ice, freeing ships trapped in areas such as the Baltic and the Gulf of St. Lawrence. **Type c.** covers ice-breakers capable of operating in very heavy and hard Arctic ice. In addition, ships of this last type usually support oceanographic, hydrographic and other related scientific activities in the Polar regions. The remarks which follow apply, in the main, to Polar ice-breakers.

3. Should an ice-breaker become stuck in the ice, heeling and trimming tanks are provided, together with large-capacity transfer pumps. Sea-water, or fuel, can be transferred from one side to the other in large quantities and very quickly - 275 tons in 90 seconds is an example of a typical system. Similarly, liquid can be moved from a forward trimming tank to an after one, or vice versa. These activities, when used in conjunction with the ship's engines, are usually sufficient to start the ship moving. Smaller ice-breakers lacking a heeling system, and fitted with a centre line crane, can rock the ship by swinging a heavy weight from side to side.

4. Draft should be sufficient to accommodate large propellers whose tips, when in the upper position, will be at least 2 metres below the surface of the water.

5. There are five factors which govern the ability of a Polar ice-breaker to do the job she was designed to do, and do it effectively. These are:

a. The power, displacement, and strength of the ship.

b. The nature and extent of the ice being attacked.

c. The shape of the hull, particularly the bow form.

d. The capability of rapid heeling and trimming.

e. The skill, experience, and intelligence of the ship handler.

1002 SHIPS

As a general rule, a full-powered ice-strengthened ship should be able to make relatively good progress through 6/10 winter ice. A careful assessment should be made of every aspect of wind and current in relation to ice drift when a ship is moving alone through waters where pack-ice extends over large areas. Every effort should be made to avoid being caught between an extensive area of pack-ice and the shore, or between the pack and a danger such as a shoaling area, when the wind is blowing strongly onshore.

1003 AIR-CUSHION VEHICLES

1. Air-cushion vehicles have an ability to operate over Arctic terrain, and possess certain advantages.

a. In case of engine failure, air-cushion vehicles are safer than a light aircraft or helicopters.

b. The reservoir of air holding the craft up leaks away comparatively slowly enabling the vehicle to settle on the surface.

c. Air-cushion vehicles can float on water.

d. Emergency stops can be made on snow from speeds of 26 knots without suffering damage.

2. Air-cushion vehicles are capable of traversing a wide variety of terrain at speeds up to 60 knots or more. In addition to travelling over water, land and ice, air-cushion vehicles can negotiate muskeg, soft snow and mixtures of thin ice and open water with equal facility. By their nature they are best suited to lands of gentle relief and flat non-ridged ice. Present designs can pass over irregularities (rocks, ridges of ice, etc.) up to 120 cm high.

3. Operation over water at temperatures below the freezing point can lead to spray freezing onto the craft and loading it down with ice.

1004 DIVING

1. **Diving Conditions**. Arctic waters are cold, the visibility excellent, and the bottom generally flat. Shifting ice, driven by wind and current, is the greatest danger to divers. Most diving work is carried out in shallow water, clearing beach obstructions and surveying approaches to landing sites.

2. **Equipment**. A wet suit with compressed-air breathing apparatus, both of which are easily transported and self-sufficient, are suited to diving requirements in the Arctic. An air compressor is necessary for charging bottles and an inflatable rubber boat or raft, equipped with a small outboard motor, is handy and safe for transporting divers and their equipment.

3. **Explosives.** Explosives used in demolition of ice and rocks must have very high shattering properties. Ice is extremely hard to dispose of due to its density, and large charges are often necessary. A 60/40 ratio of Forcite and Nitrone has proved to be effective.

4. **Ship Repair**. Underwater cutting and welding equipment should be carried to facilitate fixing ship's plating, rivets, propellers, and rudders.

CHAPTER 11

SHIP HANDLING IN ICE AND ICE SEAMANSHIP

1101 INTRODUCTION

1. The first principle of ice seamanship is to maintain freedom of manoeuvre in the presence of ice.

2. Three thoughts should be uppermost in the mind of a commanding officer whose ship is working in ice:

   a. Keep the ship moving-even slowly.

   b. Try to work with, not against, the ice.

   c. Be patient. The longest way round can often be the quickest, safest way home. Ice is no respecter of schedules.

1102 NON-ICE-STRENGTHENED SHIPS

Ice is an obstacle to any ship, even an icebreaker, and it is dangerous to those ships which, by their construction, were never really intended for ice navigation. Nevertheless, it is possible for non-ice strengthened ships to navigate through regions of open pack-ice. The long hours of summer daylight in high latitudes facilitate such operations.

1103 INDICATIONS OF ICE

1. Iceblink, which is the reflection of ice on low cloud, is an indicator much used by experienced navigators. It appears as a diffuse whitish glare above an accumulation of distant ice and is especially noticeable when observed on the horizon.

2. Isolated fragments of floating ice often presage the approach of larger quantities of ice or warn of the presence of icebergs nearby.

3. In late spring, and during the Arctic summer, there is frequently a thick bank of fog over the edge of the pack-ice. In fog, patches of whiteness can indicate the presence of ice at short range.

4. Absence of sea or swell, especially in a fresh breeze, can be a reliable sign of ice to windward.

5. A drop in temperature of the surface of the sea, or a drop in the air temperature, can indicate that a ship has entered waters where ice is likely to be encountered.

6. When clear of land, the sighting of seals, walruses or birds can be a sign of approaching ice.

1104 SIGNS OF OPEN WATER

1. Dark patches on low clouds, sometimes almost black in comparison with the general overcast, can indicate open water, and is known as "water sky".

2. In fog, dark areas discerned through the murk can give an indication of open water.

3. A dark band of cloud at high altitude can indicate the presence of a lead giving access to open water further away.

4. A surging action in the pack-ice can indicate the presence of open water nearby.

5. If, when approaching ice, there is darkness on the horizon beyond a light sky, this is good evidence of open water or land lying beyond the ice, in some cases 40 nautical miles (75 km) or more beyond the visible horizon. If dark streaks are observed in the sky, the presence of leads is indicated. If there are no dark streaks, a ship should steer for the place where the iceblink is dullest. Iceblink is increased after a fresh fall of snow, since its reflection in the sky will be whiter from this snow than from the ice.

6. In a cloudless sky and calm weather, abnormal refraction may raise the horizon enabling an observer to see ice at greater distances than normally would be possible. The image of ice or areas of open water, or a mixture of the two, may be seen as an erect or inverted image, or both images may be seen at once, one above the other. In this latter case the erect image is the higher of the two. Refraction also causes bergy bits to appear like icebergs. Where there is open water, a dark-blue color will be seen towards which the ship should steer.

1105 ICEBERGS

1. On dark clear nights, icebergs may be sighted at a distance of 2000 to 4000 yards, appearing either as white or black objects. In such conditions bergy bits or growlers constitute a greater hazard to ships. Such pieces of ice may also be difficult to distinguish in daylight, especially in a rough sea.

2. A clouded sky at night, through which the moon appears and disappears, makes ice detection difficult. Heavy passing clouds may dim or completely obscure an object sighted ahead. Fleecy cumulus and cumulo-nimbus clouds often give the appearance of blink from bergs.

3. Radar can usually detect large icebergs in ample time to avoid collision, but small bergs and growlers, capable of causing damage even to ice-strengthened ships, may remain undetected under quite moderate conditions of wind and sea. As the state of a sea increases, so does the minimum size of the iceberg that can be detected.

4. Air and sea temperatures are not a reliable warning of the presence of icebergs.

5. In low visibility the use of a foghorn or siren to detect icebergs by echo is of little use. Sound waves will be reflected only by a high vertical wall of ice, and even then are rarely audible.

6. The presence of stationary icebergs may give some indication of the depth of water in their vicinity. For example:

a. An accumulation of stationary icebergs often marks an isolated shoal.

b. A line of grounded icebergs extending seaward from the shoreline, or between an island and the mainland, may indicate the presence of a submerged ridge or shoal.

c. A shoreline fringed by glaciers, or studded with icebergs inshore but free of ice to seaward, would indicate that the shoreline falls off steeply into deep water.

d. A bay in which icebergs are found must have a deep channel leading into it. The sides of a channel which are bordered with icebergs, but with its centre clear, may be considered safe. Open water will usually be found during the summer months along a coast where offshore winds prevail.

1106 ENTERING THE ICE

1. Before committing a ship to the ice-pack, a complete reconnaissance of the area should be undertaken, using every means available-radar, look-outs, helicopter observations, and ice reports from long-range fixed-wing aircraft. The point of entry should be carefully selected and the ice entered at right angles, after which the ship should make for the loosest areas in the pack. Preferably make the entry upwind, remembering that the windward edge of an ice-field will be more compact than its leeward edge. The violent motion of ice from the action of the waves will also be damped out on its leeward side.

2. Avoid a lee shore on which ice is usually dense and hummocky. Favour a windward shore where an open channel may be found. Do not manoeuvre so closely to points of land that a combination of wind, ice, and unknown currents could force the ship aground.

3. If the ice is drifting rapidly, wait (preferably in open water) for a change in direction of the ice movement, taking into account the times of ebb and flood tide; ice tends to compact on the flood and to loosen up on the ebb.

4. An ice edge is usually not straight but often has tongues projecting between bights. Select a suitable bight and enter there where the surging action will be least.

5. Enter at slow speed to reduce the initial impact on the stem. Once the bow is in the ice, cutting and pushing it aside, power should be increased to avoid losing headway.

6. Give all icebergs and other forms of glacial ice in the pack a wide berth. If a collision with a floe is inevitable, it is best to take the blow on the stem while going astern at full speed.

7. Navigation in pack-ice after dark, or in fog, or when the ice is under pressure, should not be attempted.

8. Propellers are the most vulnerable part of a ship, and conning officers must see to it that whenever heavy ice approaches the stern, action is taken to slow the shaft.

9. If the bow of a ship rebounds off a floe, the stern may be swung into heavy ice with a risk of damage to rudder and propellers.

1107 SPEED OF SHIPS WORKING IN ICE

1. Speed through ice must be a matter of judgment and will depend, among other things, upon the amount of open water, the hardness of the ice, and the strength of the ship.

2. Coasting into ice, with engines stopped, will probably result in loss of steerage-way.

3. At any time ships should be prepared to go "Full Astern".

4. In less than 6/10 ice, the speed of a ship passing through the ice, without ice-breaker escort, should depend on the distribution of leads and pools of water.

5. Seven to nine-tenth ice should be negotiated throughout at slow speed, so that collision with floes will not damage the hull.

6. When moving through very loose pack at night, or in poor visibility, continue with caution and at slow speed. In such circumstances, searchlights, preferably mounted in the eyes of the ship, can be of considerable help.

1108 WORKING THROUGH ICE

1. The extent of the ice should be studied from aloft, preferably from a helicopter. In this way distant leads and open water, invisible from the bridge, may be revealed. The character of the ice ahead, when viewed from aloft, may sometimes be assessed by comparing it with the ice through which the ship has just passed. Pressure ridges and ice which is greenish-blue in color (polar ice) should be avoided.

2. Sometimes pools of melt-water form on top of the ice. From the air, and even from a distance at sea level, these pools can resemble open pack. Upon closer examination it will be found that the ice is continuous under the pools and may even be unnavigable.

3. Aerial ice observers should be thoroughly trained and familiar with the problems confronting the ships to which they are passing important information. To provide continuity, the same ice observers ought to be used, and such observers must have the confidence of the captains, who may have to rely heavily upon their reports.

4. A short burst of full speed ahead, with the helm over, may be of assistance in speeding up a turn to avoid a floe. Propellers and rudder may be afforded some protection by trimming by the stern.

5. Ships should go astern in ice with extreme care, always with their rudders amidships, and while keeping a sharp outlook for ice under the quarter. One system for working astern in ice is to:

a. Allow propellers to wash the ice astern for a few minutes before going astern.

b. Go full astern until just before contact with the ice debris, then stop and allow the momentum to carry the ship into the churned-up ice.

c. When all ice has surfaced, give a short burst of ahead power and stop.

d. Repeat this process until sufficient manoeuvring room has been produced.

6. Another effective system for working a twin-screw ship astern, when surrounded by heavy brash, is to:

a. Go astern on one engine while going ahead on the other, setting up a current under the stern which opens up an area of clear water to one side depending upon the engine direction.

b. Go astern on both engines. This should move the stern into the open area until the ice eventually brings the ship to a halt.

c. When stopped, repeat backing on one engine and going ahead on the other, but in the combination opposite to that used previously, until an open area of water appears on the other side.

d. As in b. above.

7. Cracks may form in ice-fields along a line of pressure perpendicular to the movement of the ice. Such cracks are sometimes ridged. At the least change in wind or current, these heavy masses may come together crushing and grinding anything caught between them.

8. Fine weather in the pack often portends lower temperatures, close pack and little open water, whereas damp and misty weather generally signifies the presence of some open water and better conditions for manoeuvring. The presence of swell indicates loose pack is near at hand and open water not very far off.

9. Any offshore wind usually creates a channel between the coast and the pack. If this is exploited by a ship, she should be alert for an onshore wind driving the pack onto the coast if the latter is steep-to. In such a case, shelter should be sought in a bay or behind an island. Failing any such refuge, the only alternative would be to go out and meet the ice hoping to work through it to open water.

10. Icebergs generally move at a different rate than the sea ice and in strong currents may even travel upwind. In these conditions, open water will exist to leeward, and piled-up pressure ice to windward of icebergs. In a strong wind the pack may overtake the icebergs, resulting in a heaping up of the pack to windward, while a lane of open water opens to leeward of the icebergs. This creates the illusion that the icebergs are travelling in a direction opposite to the pack.

11. The movement of an iceberg through wind-compacted ice creates a lead which may remain open for a time. In traversing pack, advantage might be taken of such leads.

12. If a ship enters a narrow strait or bay into which the prevailing winds are known to blow, she should be alert to the possibility of ice being driven in by a sudden change in weather and trapping her there.

13. A ship should exercise caution when to windward of a prominent headland because a sudden increase in the wind may drive the pack down upon the vessel which, if set toward a lee shore, may become beset and subject to pressure. An exception to this occurs in the western Canadian Arctic and along the north Alaskan coast where ships successfully navigate close inshore, depending upon their draught, thus avoiding the heavy pack lying to seaward.

1109 CONVOYING IN ICE

1. An ice convoy consists of one or more ships, some of which may be strengthened for ice navigation, accompanied by one or more ice-breakers.

2. It is essential that such a convoy, while in ice, be under the direction of the commanding officer of the leading ice-breaker. Should the senior officer of a naval force happen to be embarked in a ship without ice-breaking capabilities, he must delegate tactical control to the senior ice-breaker captain.

1110 TYPES OF CONVOY

1. There are two types of ice convoy:

a. Simple convoy: one ice-breaker escorting a group of ships.

b. Composite convoy: two or more ice-breakers escorting several ships.

2. For a simple convoy, the captain of the icebreaker will decide upon the number of ships he can handle. His decision will depend not only on the number, but on the power and type of ship requiring escort and the ice conditions expected en route. If the ships are reinforced for ice navigation, and have sufficiently powerful engines, one ice-breaker can usually escort four of them through 7/10 to 9/10 ice. In 5/10 or 6/10 ice or less, the number of ships can be increased. If there is close pack (more than 9/10) only one or two ships can be handled.

3. The first factor to be considered must be the power of the ships requiring escort. The weakest, as a rule, should be stationed immediately astern of the ice-breaker to avoid ice obstacles and to move in a comparatively clear channel. The most powerful ships with wide beams should be interspersed in the convoy so that less powerful ships can proceed in their wake. Consideration should also be given to whether a ship is loaded or in ballast. Finally, it is essential that one of the most powerful ships in the convoy be last in line.

4. A composite convoy consists of two or three simple convoys. The number of ships allocated to each ice-breaker, and their place in the column, is determined in the same way as for a simple convoy. The difficulty of controlling from a position ahead is a drawback in this type of convoy, which frequently extends over a distance of 2 NM (3.7 km) or more.

5. The customary procedure is for the most powerful ice-breaker to lead the convoy, breaking a channel in the ice without stopping to break out other ships. Following the leader, at a distance decided upon by the captain, come two or three ships, the weakest and longest in the convoy. The second ice-breaker proceeds astern of the first group followed by two or three ships, and so on.

6. The assignment of the second ice-breaker is to break out the ships ahead so the leader will not have to return, thus delaying the whole party. The second ice-breaker, on receiving a "stuck" signal from any of the preceding ships, increases speed, leaves the column and breaks out that ship. When the latter is freed and moving, the ice-breaker resumes previous position in the column. Similar action is taken by the second ice-breaker upon receiving a signal from one of the ships astern, provided there are no more ice-breakers available.

1111 DISTANCE BETWEEN SHIPS

1. Before entering the ice, the captains of all ships should set the agreed distance between their ships and the ice breakers, and between other ships.

2. It is unwise to have the convoy strung out in too long a line. At the same time, the distance between ships should be great enough for way to be checked and collision averted if a "stop" signal is originated by any one of the ice-breakers. At ice convoy speed, way in merchant ships of average tonnage can be checked in ice-free waters by going astern over a distance of three to three and a half ship lengths, provided an order for full speed astern is given. This distance should, therefore, be the minimum between ships when navigating in less than 7/10 ice.

3. Depending upon ice conditions, very large ships (i.e., those displacing 100 000 tons or more) must keep farther apart. Until more experience is gained in convoying ships of this size through ice, at least 1000 yards is recommended as a minimum.

4. A channel made by an ice-breaker will eventually fill with broken ice. The speed at which the channel closes will depend on the amount of ice pressure encountered. This will have a factor in determining the distance between the ships. The difficulties caused by this to a ship in a narrow channel increase when the distance between ships is increased, and even powerful ships may find their speed greatly reduced. This makes it all the more important for ships to maintain the minimum

prescribed distance apart. Signals from the leading ice-breaker must be obeyed promptly and correctly and all ships must be alert for any difficulties and delays caused by ice.

1112 COURSE AND SPEED OF CONVOY

1. The longest safe route in open water will generally be quicker than a more direct one in ice, and the selected track should pass through areas of thin ice or open water, regardless of the length of the voyage. Course changes should be gradual since most cases of ships getting stuck occur when sharp turns are made by the much more manoeuvrable ice-breaker. Speed over the ground through the pack usually varies between 4 and 7 knots. The higher speed is desirable due to better manoeuvrability of large ships, but ice conditions must be the governing factor.

2. In a convoy composed of ships reinforced for ice navigation, a speed over the ground of 6-7 knots can be maintained if the route lies through 5/10 open pack, and if the ships following the icebreaker will not meet with heavy ice.

3. If a single-screw ship must suddenly go full astern without warning while passing through an ice-covered channel, the stern will kick to port and the bow to starboard. This could damage the propeller, rudder and starboard side of the ship. To avoid collision with a ship ahead, it is preferable to ram the ice on one side of the channel, bow foremost, rather than risk damage to the rudder and propeller by going astern in heavy ice.

4. When navigating in close pack (7/10 to 9/10), speed over the ground should not exceed 5 knots. In such ice a convoy will be moving in a channel which will not remain navigable for very long after the passage of the ice-breaker. Therefore, the distance between ships must be reduced to enable them to move in as clear a channel as possible. Higher speeds not only increase the danger of hitting the ice, but also the possibility of colliding during unscheduled stops of the icebreaker or other ships of the convoy.

1113 CONDUCTING THROUGH ICE

1. When following an ice-breaker, a convoy should keep in line. By looking for independent channels, ships break up formation and may become stuck.

2. Since headway through heavy floes and ice-fields is more difficult than through "normal" pack, an ice-breaker increases speed and, by striking the ice, crushes or breaks it. Ships astern must maintain correct intervals and endeavour to enter the channel thus made before it closes.

3. If an ice-breaker should encounter an obstacle where a glancing blow is struck by her stem, she will be thrown sideways. Ships following behind may be too unwieldy, or be unable to react quickly enough, and may suffer damage. This is particularly applicable to singlescrew ships. This sudden change of direction should be expected when moving through ice of varying structures and strength. In such circumstances an icebreaker should not make too rapid a return to her original course.

4. In summer there are many signs indicating the state of the ice. Careful observations should be to determine whether the ice has been softened by the sun or if it still retains its winter hardness. Greenish or greenish-blue ice is the hardest to break and such ice should be outflanked. This type of ice is sometimes covered with pools of clear melt-water formed during the thaw of snow on the surface of the ice. If sections of dirty-looking ice are encountered in areas of light-colored ice, the former should provide the easier route, since the darker ice absorbs more heat from the sun and melts sooner.

5. The most navigable type of ice is brash, even though it may be devoid of leads. Although this ice usually closes up as a result of tide and wind, it consists of separate cakes and does not present a serious obstacle. When the pressure is great, however, even though an ice-breaker can get through, a ship astern may be hindered as the channel behind the ice-breaker closes up immediately. In brash, even under pressure, ships are in less danger than if they were being pressed by larger and heavier forms of ice.

6. When hummocked ice is met, an ice-breaker should first attempt to outflank it. The outward characteristics of hummocky ice may indicate to what extent it will be navigable. If the hummocks consist of loose blocks not fused together into one solid piece, they may easily be overcome, but if they are composed of larger masses of ice many feet thick, they will be impassable even to an ice-breaker.

7. Usually an ice-breaker backs up one to three ship lengths, then goes full ahead until the stem attacks the ice. If ice is strong and extends over a great area, this process must be repeated and progress will be very slow.

8. It may be necessary to make either a simple channel, equal to the beam of the ice-breaker, or a double or triple one, depending on the strength and character of the ice and on the size of the ships waiting to get through.

9. While navigating in heavy ice, ships should be so loaded and trimmed that only the water-line plating will be in contact with ice. In the after part, the propeller is exposed to danger. It is often assumed that blades are damaged only when a ship is going astern. Blades can be damaged or lost while going ahead as well. Sometimes large blocks of ice pass under the ship's hull and turn on edge. Such ice is dangerous and can damage propellers.

1114 SIGNALLING BETWEEN ICE-BREAKERS AND ESCORTED SHIPS

1. Suitable signals which have been adopted for use are given in Chapter 13 of the revised (1969) International Code of Signals and may be used between icebreakers and ships navigating in their vicinity or under their escort.

2. The signal "K" (-.-) by sound or light may be used by an ice-breaker to remind ships of their obligation to listen continuously on their radios.

3. The use of the special signals from the International Code of Signals (1969) does not relieve any ship from complying with the International Regulations for Preventing Collisions at Sea.

4. Whistle signals are limited in their value. Experience has shown them to be of questionable value in a convoy of several ships because of the time lag and the danger of misinterpretation. Whenever possible, voice radio should be used and, when ships are close aboard, loud hailers can be used very effectively.

1115 STOPPED ICE-BREAKER - RED WARNING LIGHTS AND SOUND SIGNAL

1. Canadian ice-breakers escorting ships in ice make use of two special rotating red warning lights to indicate that ice-breakers are fouled or jammed in ice.

2. These two red lights are disposed in a vertical line, one over the other about 2 metres apart and they are visible all around the horizon at a distance of 2 NM (3.7 km). They rotate in a manner similar to-the lights on air beacons and are unmistakable as warning lights.

3. The rotating red lights operate in conjunction with a motor-driven siren, facing astern, audible up to a distance of about 5 NM (9 km) depending upon atmospheric conditions.

1116 BREAKING OUT SHIPS

1. When a ship is beset, awaiting ice-breaker assistance to get moving again, it should keep propeller(s) turning slowly to keep the ice away. If engines are stopped, ice will move in around the stern making it dangerous to start turning the propeller(s).

2. Ice-breakers usually prefer to drop back stern first from ahead until abeam of the stuck ship. They then move ahead, instructing the latter to follow. The open water left by the ice-breaker should be immediately occupied by the beset ship.

3. Most ice-breakers dislike coming up from astern of a beset ship for fear of shoving ice under the latter's stern, and possibly jamming rudder and propeller(s). Ice-breakers should be careful not to push heavy floes against the sides of thin-skinned ships, which could rupture their plating.

4. There are many ways in which an ice -breaker can free a beset ship and no attempt is made to cover them all here. Ice conditions have a bearing on the tactics to be used. Ice-breaker captains will always communicate their plan to the ship to be helped.

1117 REPLENISHMENT IN ICE

1. Replenishment in ice can be accomplished only when both ships are stopped and lying as close aboard each other as practicable. Prevailing ice conditions should be carefully studied to ensure that replenishment can be completed safely. Pack that is drifting into a lee shore must obviously be avoided.

2. When approaching another ship in the pack there is a danger that the pressure generated by the approaching ship will force intervening ice blocks through the plating of one or both ships, or will damage rudders and propellers of the ship approached.

3. A bow-to-bow approach is generally safest for berthing alongside another ship. If an ice-breaker is available, it should proceed carefully through the ice ahead of the ship making the approach.

1118 ANCHORING

1. Anchoring in the presence of ice is risky. The minimum amount of cable should be paid out and the capstan must be available for immediate use in the event heavy pack-ice approaches the anchorage.

2. When anchoring in rotten ice or in shallow water, a ship should first attempt to penetrate the ice as far as necessary to avoid any swell. If the water is deep and ice is present, anchoring should be avoided. In such circumstances it is preferable to heave to, keep power available and manoeuvre as necessary to avoid floes which may approach and threaten the ship.

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CHAPTER 12

ARCTIC NAVIGATION, NAVIGATIONAL AIDS AND PILOTAGE

1201 GENERAL

With satellite navigation systems (i.e. GPS) being fully operational, navigation in the Arctic is achievable by all properly equipped platforms.

1202 HARTS AND SAILING DIRECTIONS

1. Requirements for charts and related publications can be met from the following sources:

a. **Catalog of Maps, Charts and Related Products**, published by the Defense Mapping Agency, Washington, DC, 20315-0010.

b. **Catalogue of Nautical Charts and Publications**, published by the Canadian Hydrographic Service, are available from the Hydrographic Chart Distribution Office, Department of Fisheries and Oceans, 1675 Russell Road, PO Box 8080, Ottawa, Ontario Canada K1G 3H6. Telephone (613)998-4931. FAX (613)998-1217. (VISA and Mastercard accepted).

c. **Catalogue of Admiralty Charts and Other Hydrographic Publications**, published by the Hydrographer of the Navy, Tauton, England.

2. American and British authorities also publish classified catalogues describing selected classified charts and publications embracing Arctic areas.

1203 GENERAL REFERENCE BOOKS

A number of Arctic navigational reference books are available. The Arctic navigator must procure all necessary references prior to sailing for northern waters.

1204 CHART PROJECTIONS

1. The Mercator projection satisfies the navigator's needs to the 70th parallel of north latitude. In latitudes higher than 70°N, however, the usefulness of the Mercator projection decreases rapidly, primarily because the value of the rhumb line becomes progressively less, and because there is an increasing rate of change in chart scales.

2. Chart producers generally opt for a more appropriate projection for Arctic use. The four most commonly used are:

a. Transverse Mercator Projection -particularly when considering areas extending north-south.

b. Modified Lambert Conformal Projection.

c. Polar Stereographic Projection.

d. Polyconic Projection.

1205 POLAR GRID

Because of increasing convergence of the meridians near the pole, the true directions of an oblique course line will vary considerably depending upon the length of the course line and its proximity to the pole. A polar grid provides the navigator with the changing true direction. The polar grid is described in the H.O. Publication No. 9, Chapter XXV-Polar Navigation, and shown in Figure 12-1.

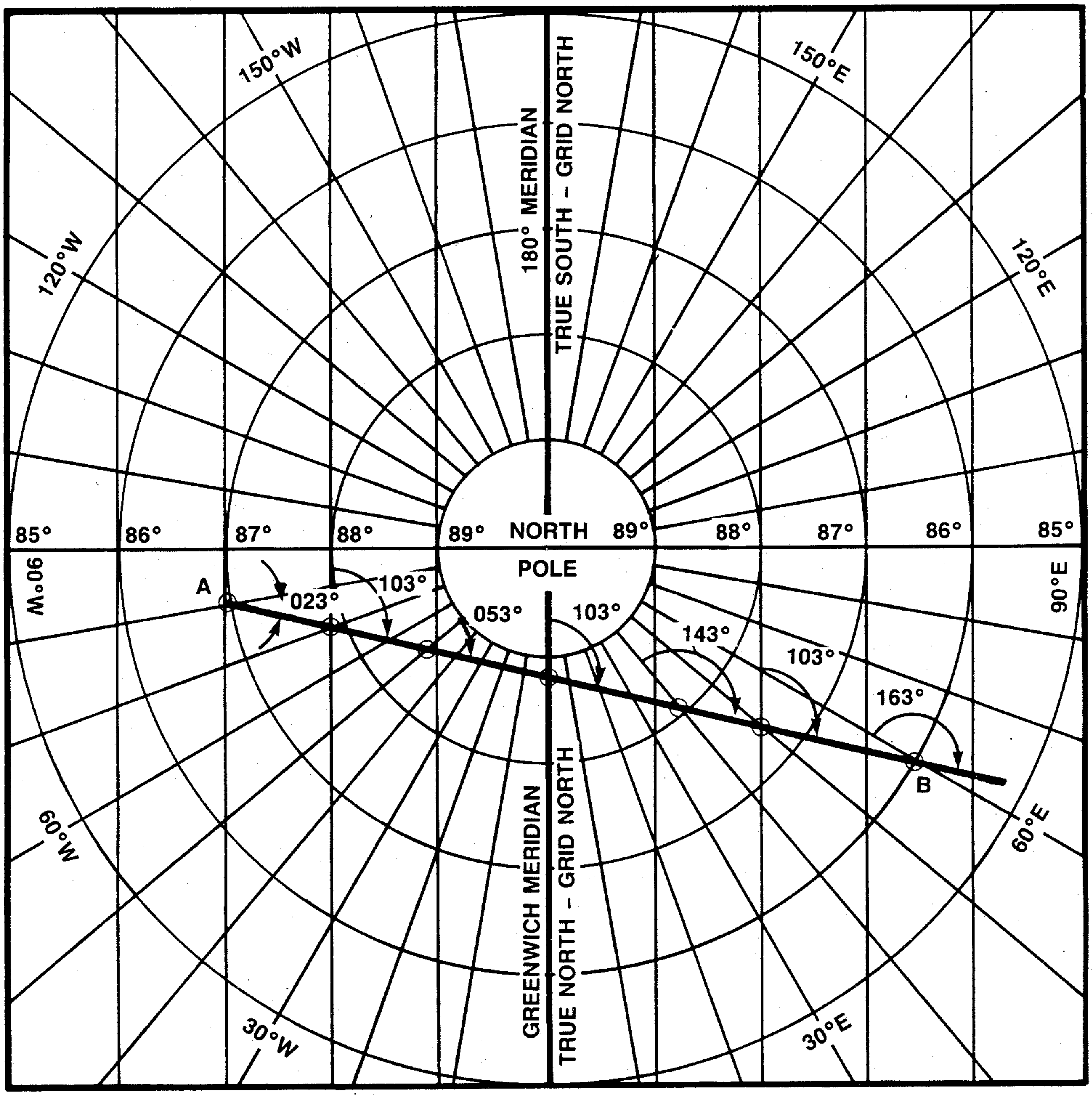

Figure 12-1 Polar Grid Navigation

1206 MAGNETIC COMPASSES

1. The directive force of the magnetic compass is derived from the horizontal component of the earth's magnetic field. Although the total intensity of the earth's field remains fairly constant in all latitudes, the horizontal component decreases as the magnetic poles are approached, until the directive force becomes so weak that the compass is apparently insensitive and unresponsive.

2. Conversely, the vertical component increases and may give rise to large heeling errors. Although the horizontal component of the earth's fields and hence the induced magnetism in horizontal soft iron, decreases as the magnetic poles are approached, the field of sub-permanent magnetism of the ship's structure retains its absolute value and therefore becomes relatively much more important in causing deviation. Small uncompensated deviations due to sub-permanent magnetism may attain very large values in high latitudes.

3. Furthermore, magnetic disturbances or magnetic storms cause fluctuations in magnetic variations. For example, a severe magnetic disturbance can shift the effective position of the magnetic pole as much as 150 km or more. This shift has significant effects near the magnetic pole, becoming less of a problem with distance from the magnetic pole.

4. To obtain the best performance from the magnetic compass in Arctic waters, a ship should be swung and the compasses adjusted in high latitudes, preferably before entering the pack-ice. If the Flinders bar has not been permanently set at the magnetic equator, it must now be adjusted to the position indicated by computation, and the horizontal and heeling magnets carefully placed to produce minimum deviation. The US Defence Mapping Agency publication NVPUB226, "Handbook of Magnetic Compass Adjustment" is a useful reference. AVPUB9V1, "American Practical Navigator", also applies.

5. Even if this recommended procedure is followed, changes in magnetic latitude may cause large deviations to reappear. Likewise the magnetic variations will change rapidly with locality and may undergo large diurnal changes, particularly if auroral activity is present, so that the navigator must undertake frequent azimuth determinations. If large compass errors are found, and if it is uncertain whether these are due to variation or deviation, swinging the ship again to see whether the error persists on all headings will establish the cause.

6. Provided that precautions have been taken (e.g., burning the binnacle light continuously and keeping the binnacle itself covered by canvas when not in use), the liquid in modern magnetic compasses is capable of withstanding Arctic temperatures.

7. The flux-gate compass has proved to be quite sensitive and has given fairly accurate and reliable results. The Admiralty gyro-magnetic compass with a pivoted card has proved to be serviceable for navigation up to 300 km from the north magnetic pole, and has the additional advantage of being available as a simple magnetic compass should power fail.

8. Both wet (floating) compasses and fluxgate (digital) compasses are subject to error due to local magnetic anomalies of geologic origin. These are reported in "Notices to Mariners". Any suspicious compass behavior should be carefully documented and reported to the appropriate defence or national charting agency.

1207 GYRO-COMPASSES

1. When operating north of 70 °N, particular attention should be paid to the operation of gyro-compasses and associated equipment. Manuals on military gyro-compasses usually specify 85°N as the highest latitude at which a gyro-compass will function reliably as a direction-indicating device.

2. Between the latitudes of 70°N and 85°N, gyro errors may be considerable. Therefore, when weather conditions permit, frequent azimuths of heavenly bodies are recommended. For certain gyro-compasses, nomograms are available in operating manuals, and certain gyrocompasses are capable of being fitted with high-latitude correctors which improve performance above 70° N.

1208 AZIMUTHS

Every opportunity should be taken to determine the errors of compasses, particularly by azimuths of the sun. An azimuth attachment for a telescopic alidade is recommended; it may be of value in obtaining accurate azimuths for determining gyro error when the sun is not brilliant enough to obtain an azimuth by the use of an azimuth circle. The present azimuth tables for high latitudes can be used only during a certain portion of the day, but azimuths for use at any time can be computed.

1209 CELESTIAL COMPASSES

1. Where magnetic and gyro-compasses cannot be relied upon to provide trustworthy directional references, a navigator should consider using:

a. **The Sun Compass.** This indicates direction by means of a shadow cast by a shadow pin. This instrument is, of course, of use only when the sun is visible and the observer knows his position.

b. **The Astro-Compass.** This is similar in principle to the sun compass, but may be used for any celestial body.

c. **The Sky (or Twilight) Compass**. This compass indicates direction by means of the polarizing effect of the earth's atmosphere on sunlight. Its usefulness arises principally from the fact that twilight periods in high latitudes are of several hours duration and during this time no celestial body is visible unless the moon or a bright planet is above the horizon.

1210 DEAD RECKONING

1. When steaming in poorly charted waters, a ship can run aground or be exposed to other unexpected hazards. Because of inadequate tidal information, as well as other shortcomings, the most accurate estimated position may not result in an exact position. But careful reckoning, in accordance with the suggestions outlined in the following paragraphs, may be of help to the navigator.

2. Inaccurate charts, together with limited fixing marks, may compel the navigator to resort to "relative navigation", i.e., fixing relative to selected charted landmarks or other objects.

3. Repeated alterations of course to avoid ice make it difficult to plot a ship's track on a chart - especially a small-scale one. Plotting the mean course and distance made good once or twice each watch is recommended.

4. Plotting the positions of large icebergs, especially if they are known to be aground, can sometimes be most useful as an aid to navigation when identifiable landmarks are not available. This is a good example of "relative navigation".

5. Bottom soundings should be relied upon to assist in maintaining a dead-reckoning position or for fixing the ship.

1211 ASTRONOMICAL OBSERVATIONS

1. For a great part of the navigation season, cloud or fog obscures the sun in the Arctic, while continuous daylight prevents stellar observations. Ice horizons and abnormal mirage may also complicate the task of obtaining a precise altitude of the sun during periods of good visibility.

2. Standard refraction tables are not accurate in high latitudes. H.O. Publication 229 does not allow for solution of the celestial problem for observed altitude of less than 5, a common condition in the early and late summer periods.

3. The use of a bubble sextant, bubble attachment to the standard sextant, or artificial horizons can be helpful.

4. The following chapters of H.O. Publication No.9 -American Practical Navigator, are recommended reading during "in harbour" preparations:

a. Chapter XVI-Sextant Altitude Corrections.

b. Chapter XX-Sight Reduction.

c. Chapter XXV-Polar Navigation.

d. Chapter XXIX-Navigation Errors.

1212 SUNRISE, SUNSET AND TWILIGHT PHENOMENA

Tabulated local mean times of Sun/Moonrise, Sun/Moonset, Nautical Twilight and Civil Twilight listings go no higher than 72°N in nautical Almanacs. In latitudes higher than 72°N, the graph in the Air Almanac should be consulted.

1213 ABNORMAL REFRACTION

1. Generally speaking, abnormal refraction at sea is caused by an inversion of temperature in a layer of air. The variations in density thus produced cause light rays to be bent in excess of normal conditions.

2. The most favourable conditions for excess refraction, when the more fantastic forms of mirage and distortion take place, occur when a layer of warm air is in contact with cooler water. The air next to the surface of the sea is cooled, and consequently the upper layers are warmer than the lower, so instead of the usual decrease, there is an increase of temperature with height. Most refraction phenomena are formed at the boundary between this layer of cold, dense air at the surface of the sea, and the less dense warm air above. This condition is identical with that which is responsible for the formation of most sea fog, and the presence of fog is therefore an indication that excessive refraction can be expected.

3. Similar inversions may be caused by the presence of cold air over warm water. A marked difference between air and sea temperature is thus a guide to the presence of excessive refraction.

4. Although abnormal refraction is not restricted to particular geographical areas, certain regions are so situated with respect to general meteorological conditions as to be more favourable than others for the occurrence of abnormal refraction phenomena. In this respect the Arctic coasts are ideal because of the marked difference between sea and air temperatures. In the Arctic, excessive visibility, or some form of mirage, is often manifest when comparatively warm light winds blow over cold ice surfaces, or when cold winds blow over open water. A temperature milder over open water than over a nearby ice-clad shore also leads to refraction phenomena.

5. One form of abnormal refraction is "looming", which is the apparent raising of an object above the horizon. It is quite common at sea, especially in high and middle latitudes, and results in the appearance of distant objects which, in many instances, may actually be below the normal horizon at the time of observation.

6. There are two types of looming. On the one hand an object (island, iceberg, ship) is seemingly increased in elevation though not in size; on the other hand an object appears to be enlarged and brought much nearer to the observer.

7. Superior mirage is another form of abnormal refraction and is the apparent reflection from a mirror-like atmospheric condition where a pronounced temperature inversion exists about a metre above the surface. This inversion introduces an abnormal change in density resulting in extraordinary refraction. Its most frequent appearance is that of an inverted image above the object, but under suitable conditions a second image is seen erect, close above the inverted one. Sometimes the object is not observed directly and the inverted image, or the upper erect image of an object below the horizon, may be seen.

8. As with looming, the condition needed for superior mirage is a warm layer of air existing over the sea at a suitable height, i.e., an inversion of temperature. The only difference between this and the condition necessary for looming is that for superior mirage there must be a more sudden change from cooler to warmer air at a certain height.

9. At sea, ships and icebergs are the mirage subjects usually sighted. Ocean fog is also associated with mirage, since the temperature and humidity variations which favour condensation of moisture as fog in the air, are factors in causing mirage. Mirage is not visible, of course, in dense fog, but mock fog, or the typical refraction band, is often seen under such conditions and may lead to the erroneous report of true fog.

1214 ECHO-SOUNDER

1. In Arctic waters the echo-sounder is primarily a warning device. In poorly charted waters it is one of the navigator's most valuable aids and should be manned and operated continuously in dangerous waters.

2. A ship's echo-sounder will not always give a reading when ice is under the ship, or when water beneath the ship is disturbed by propeller swirl when the engines are put astern, or by turbulence caused by ice floes being shoved around.

3. A ship having to proceed in uncharted coastal waters may minimize the risk of grounding by sending a boat away when ice conditions permit, equipped with a portable echo-sounder, to scout ahead.

1215 ELECTRONIC AIDS TO NAVIGATION

1. There are several electronic aids to navigation that are useful in one or more areas of the Arctic. Detailed information on the availability of different aids to navigation systems is available in the Hydrographic (HO) Publication 117. (See also Chapter 8 - Electronics and Characteristics of Electronic Emissions.)

a. GPS is the best and most accurate electronic aid for Arctic navigation. GPS accuracy is independent of latitude. The read out is in latitude/longitude with no corrections required.

b. LORAN C remains an accurate navigation aid in some parts of the Arctic. LORAN C accuracy depends on circular mode, which can be as accurate as GPS (between 30m and 50m), requiring no correction. Or hyperbolic mode with less accuracy, and giving a lower range, where correction can be added. Fixes are constant and the read-out is in latitude/longitude. No correction is required. LORAN C coverage is illustrated in HO Publication 117.

c. DECCA is no longer available in the Arctic.

d. Inertial Navigational Systems may accumulate a small error over a period of time and require recalibration using an external source. These systems are not as accurate as GPS or LORAN C; however, they are totally passive and cannot be affected by enemy action.

e. A combination of external navigational positioning systems (GPS, LORAN C) and an internal INS is recommended.

1216 RADAR AS A FIXING AID

1. Generally speaking, offshore fixing by means of two or more radar ranges is recommended for use in Arctic waters. Such a method is quick and accurate, and permits good fixing beyond visual ranges of land targets.

2. Suitably spaced fixes using radar ranges will reveal variable gyro-compass errors and also the influence of unknown tidal streams. However, the precision of radar range fixing depends upon the correct selection of radar conspicuous points, and on their correct interpretation, from an accurately calibrated radar plan position indicator (PPI).

3. The technique of radar ranging for fixing in the Arctic has the following advantages:

a. It is available under all conditions of visibility and using all types of land targets, i.e., shorelines that have both low-lying and steep-to features.

b. Gyro errors are usually variable whereas a PPI index error for a given range scale can be ascertained and removed.

c. If, as is often (but not necessarily) the case, the centre of a "cocked hat" is taken as a ship's position, the small neat triangle produced by a radar range error (assuming there is one) gives a better fix than would be the case with an enormous "cocked hat" resulting from an unknown gyro error.

d. At night the bearing method of fixing is impossible. Few shore objects are visible and lights for navigation purposes in Arctic waters are virtually non-existent.

e. Visual fixing in conditions of fog and snow is impossible.

f. By fixing at frequent intervals, a practical ship's track can be derived, and adjusted, to avoid known shoals. The radar ranging technique is a rapid and simple method of ascertaining a ship's position and movement over the ground.

4. Radar should be calibrated whenever an opportunity occurs if it is to provide the navigator with accurate ranges. Range errors are not obvious at the lesser ranges, but become increasingly evident at ranges over 20000 metres.

1217 RADAR AND SONAR FOR ICE DETECTION

1. **Radar**

a. **Condition of the Equipment.** It is important to keep radars operating at peak efficiency.

b. **State of the Sea**. As sea states increase so does the minimum size of icebergs that can be detected. In rough seas, icebergs as tall as 15 metres cannot always be detected in the sea return. Only in smooth seas can radar be relied upon to pick up growlers.

c. **Weather Conditions**. Meteorological conditions in some areas affect radar propagation in a manner which, under certain conditions of fog and rain, may reduce or obscure returns from ice.

d. Targets may become lost due to the ducting effect of the beam caused by a decrease of moisture content which is often accompanied by a temperature inversion. Such ducting happens occasionally, but seldom to the extent that a target is completely lost. Another form of ducting has the opposite effect, i.e., bending the radar beam so that it follows the curvature of the earth, permitting detections at very great ranges.

e. The blending of sea returns and returns from growlers poses a serious problem in ice detection, but one which can sometimes be overcome by an alert operator. In moderate seas, growlers alternately appear and disappear from the PPI but in approximately the same position at each sweep of the antenna. Sea returns, however, will fail to appear in the same relative position.

f. Large iceberg returns can be distinguished from adjacent pack-ice returns at ranges of 3500 metres or more, but can be obscured by returns from pack-ice at lesser ranges. What are actually shadows cast by large icebergs can easily be mistaken for leads or open water. Anti-jamming controls are of some value in differentiating between pack-ice and large icebergs at reduced ranges, but should not be relied upon.

g. Floes up to 11 000 metres from a ship are well patterned on PPIs, therefore radar can be of considerable assistance in showing up leads in the ice.

2. **Sonar**

a. Experience in the Arctic indicates that icebergs can be detected more reliably by passive sonar than by active sonar. Icebergs appear to produce a loud noise similar to high-speed propellers in a ship, possibly caused by the release of air bubbles under pressure.

b. Echo ranging has proved to be less dependable, often failing to indicate the presence of icebergs at ranges where they could present a hazard.

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CHAPTER 13

ARCTIC AVIATION

1301 INTRODUCTION

1. Cold-weather flying operations call for a high degree of professional competence among aircrew plus careful inspections of aircraft, more faithful adherence to prescribed procedures, and more frequent maintenance than is necessary for comparable operations in more temperate climates. Experience has also shown that successful air operations in polar regions require considerably more preparation than air operations in other areas.

2. While routine tasks take longer because of difficulties posed by low temperatures, experience shows that aircraft and equipment can be maintained and serviced when exposed to ground temperatures as low as -50°C.

3. Technical procedures recommended, such as oil dilution, use of pre-heat, percent to which a jet engine should be accelerated before light-off, use of hot-fuel priming, etc., must not be attempted without consulting the pilot's handbook and operating and servicing instructions for the type/model of aircraft involved.

1302 AIR NAVIGATION

1. Air navigation in high latitudes require careful preparation for the following reasons:

   a. Electronic aids to navigation will be limited, as will meteorological information.

   b. Limitations may exist with some aircraft navigational equipment at high latitudes.

   c. Mapping is still inadequate in the more remote areas.

   d. Astronomical observations may be required for determination of direction or for fixing.

2. The air navigator will require a plotting chart of suitable scale, plus a set of topographical maps covering the area of the intended flight and all possible alternates. Mercator plotting charts can be used up to approximately 75° N depending upon the change of longitude involved. For flights north of 75° N, polar charts such as the Modified Lambert Conformal or the Polar Stereographic are recommended.

3. True direction (i.e., defining direction with reference to the local meridian) is not satisfactory for use in high latitudes because of the convergence of the meridians at the geographic pole. To overcome this, the system of Grid Direction has been developed. In this system one meridian is selected as a reference meridian and grid north is considered to be at an infinite distance along it. A number of lines are drawn parallel to the selected meridian to form the grid from which the system derives its name. Any straight line will cut each grid line at the same angle measured clockwise from grid north to the line, thus overcoming complications of rapidly converging meridians. For convenience, modern polar air-plotting charts have such grid lines superimposed.

4. In areas where the magnetic compass is unreliable, the use of a freely suspended gyro has proved to be a satisfactory substitute. Basically, the technique involves determination of heading by astro-

compass or sextant and maintenance of direction by gyro. A continuous record should be kept of gyro drift, to correct the gyro.

5. The importance of astronomical navigation should be reflected in the thoroughness of pre-flight preparations. The air navigator must pay special attention to the availability of celestial bodies for fixing purposes, and to this end one of his most important functions will be to establish the duration and time of twilight, and to determine the availability of sun, moon and planet observations during the planned flight period.

6. A thorough pre-flight check of the air navigation equipment is essential. Before winter flights, the navigator should ensure that installed thermometers are capable of indicating temperatures as low as -60° C. It is advisable to have a radar altimeter installed especially if the aircraft is not equipped with other radar. A radar altimeter, together with a driftmeter and a stop-watch, provides a simple means of obtaining ground speeds in areas where accurate fixing is impossible.

7. When flying in the Arctic it is rarely possible to check the navigation watch against an accurately rated chronometer. However, radio time signals broadcast by WWV, Bureau of Standards, Washington, and CHU, Dominion Observatory, Ottawa, on a 24-hour basis, provide time reports.

8. For Arctic flying, it is essential that a navigator have a sound understanding of meteorology since both en route and area forecasts are sketchy and often lacking in detail. As synoptic charts are seldom available at high-latitude bases, flights may have to be planned on weather information obtained by radio. Navigators should also acquire a knowledge of topography and ice conditions in their areas of operation.

9. Overall methods of navigation will depend upon the type of flight, type of aircraft, navigation aids available and weather conditions. An air navigator with a good background in dead reckoning and astronomical navigation, and who is proficient in the use of the equipment, should experience little difficulty when navigating in high latitudes.

1303 INSTRUMENTS

1. The formation of bubbles in magnetic compass, can make the compass ineffective.

2. In general, instruments are capable of withstanding a cold environment since most are hermetically sealed. A possible exception to this could be the seals in pitot static systems which have a tendency to fail creating unacceptable leakage rates within the system.

3. Hysteresis error, which is present to some extent in most aircraft instruments, can become exceptionally large after an aircraft has been cold soaked.

4. Air-driven gyro instruments are unreliable below -20° C. Aircraft so fitted require efficient heating before take-off. Electrically driven gyro instruments are much more reliable.

1304 ELECTRONIC EQUIPMENT

1. Ice can be a hazard on external antennas, causing breakages, changing antenna characteristics and reducing operating ranges.

2. Rubber-covered flexible cables become stiff below -10° C. Insulation becomes brittle with a tendency to crack and shatter rather than bend.

3. Slow-moving shafts and bearing surfaces will operate more satisfactorily if their surfaces are buffed and polished. They should not normally be lubricated.

4. Airborne electronic equipment has, in most cases, been designed to operate at temperatures below -40° C. A high standard of maintenance is required to prevent corrosion caused by moisture formed by rapid changes in temperature.

5. Static from electric discharges can cause interference, making radio signals unreadable and radio compasses unreliable. Such static affects the lower frequencies which are the ones most commonly used in the Arctic. Some protection can be afforded by using polyethylene-covered antennas. Relief from static can be obtained by rotating the loop to the "maximum" position. This procedure can be used for range flying but must not be used for radio range let-downs.

1305 ELECTRICAL

1. Cold temperatures affect electrical components by causing stiffening and cracking of insulation and plastic covers, switches, solenoids, relays and actuators. Metal fracture in components, such as switches and potentiometers, may also occur.

2. Electric motors may burn out when operated after a cold soak as a result of larger loads imposed by an increase in lubricant viscosity in the driven mechanisms.

3. At -40° C the capacity of a typical storage battery is reduced to 25 percent of its capacity at -20° C. The charging rate at -20° C is one sixth of that under ordinary conditions. Nickel-cadmium batteries are affected to a lesser degree by cold weather and normally can be utilized after cold soaks in temperatures ranging down to at least -30° C.

4. Condensation causes corrosion of electrical equipment, particularly in relay contacts and switches. Spark plugs, magnetos, ignition harnesses and electrical leads are all susceptible to the ill effects of condensation.

5. The removal and replacement of batteries in cold weather is a disagreeable chore, especially for a person encumbered by bulky clothing. As cables become stiff and drain tubes brittle, and since the batteries themselves are heavy, the adoption of quick-disconnect features is recommended.

1306 SERVICING AIRCRAFT IN COLD TEMPERATURES

1. Both wind and temperature affect the overall efficiency of technicians working in cold weather. (See Table 16-1.)

2. Except for minor tasks, it is worthwhile erecting a shelter and using a ground heater. Temporary shelters of tarpaulins can be put up over a work area to reduce wind-chill considerably even when no heat is available.

1307 REFUELLING

1. When refuelling at low temperatures, care should be taken because objects can become charged with static electricity more readily than at normal temperatures. Explosive mixtures for JP4 exist down to a temperature of-23°C, and for Avgas down to a temperature of -43°C. All activities that could cause a buildup of static electricity, e.g., the sweeping of frost and snow from an aircraft, must be followed by complete dissipation of the static charge thus accumulated before fuelling is attempted.

2. Refuelling should be carried out as soon as possible after shut-down to prevent condensation. If refuelling takes place from an old cache of drummed fuel, pilots should be alert for rough engine operation and higher cylinder operating temperatures, due to reduced octane rating.

3. Spilled fuel on the skin can result in quick freezing and severe frostbite of the affected area.

1308 OIL REPLENISHMENT

Oil barrels in storage must first be warmed so the oil can flow. Experience favours supplying oil in five-gallon containers which can easily be handled, are quicker to heat, and are more easily stored.

1309 COLD STARTING PISTON ENGINES

1. Almost all types of piston engines can be started attemperaturesaslowas-30°C, and most will start, with assistance, at -40°C.

2. To start a piston engine, the following conditions must be met:

   a. The propeller pulled through by hand to ensure that all moving parts are free and that there are no air or hydraulic locks.

   b. Adequate cranking power.

   c. A sufficiently hot spark, or ignition temperature or both.

   d. A combustible mixture in the cylinder.

3. Cranking rate depends upon the resistance to rotation of the internal mechanism of the engine, the type of starter used, and the power supplied from the starter.

1310 ENGINE LUBRICATION

1. Increased engine drag in cold temperatures, while partially due to the differential contraction of the metals in the engine and engine-drive accessories, is due mainly to the increase in viscosity of the lubricating oil. A viscosity of about 35 000 SUS (Saybolt Universal Seconds) is generally considered to be the maximum desirable at start-up. Engine oil pressures become very high at low temperatures and often exceed the oil pressure indicator range for a few minutes during a start.

2. To achieve this viscosity at temperatures below 5°C, oil may be diluted with gasoline. This diluent is usually introduced into the oil just before the inlet to the engine lubricating pump. When introduced at this point the fuel and oil are mechanically mixed by the lubricating pump, thus preventing separation.

3. Undiluted oil in a tank can, because of its different density when compared to diluted oil, seep through the labyrinth of the hot well and into the oil tank outlets. This can result in congealed undiluted oil and restriction of the inlet line to the oil pump, resulting in oil starvation on "start-up". A properly designed labyrinth, between the make-up oil and the hot well, will provide acceptable segregation of diluted and undiluted oil.

4. Replenishment of an oil tank should be carried out before oil dilution, or after the engine has been started, warmed up and the diluent boiled off. The former method is preferable, since the engine can

be shut down after flight to allow the oil to cool to 60°C or below before diluting. Servicing crews must ensure that oil tank levels are checked after dilution.

5. Engines having no provision for oil dilution must have their oil tanks drained. Before "start-up" the oil tank is refilled with heated oil, and the engine and external lines are warmed using a ground heater, while also making use of an engine cover or tarpaulin to retain heat around the engine. Check for free flow of oil to the inlet of the oil sump in extreme conditions, and never attempt to start without a free flow of oil. Propellers should be pulled through four or five complete turns before engaging their starters to make sure all moving parts are free and that there are no air or hydraulic locks. If this cannot be done with ease, more pre-heating will be; required. One procedure is to top up before dilution leaving sufficient space for diluents. If the oil quantities of the aircraft concerned are marginal for the length of flight involved, it would be better to boil off the diluents before topping up with warmed oil.

1311 PISTON ENGINE SHUT-DOWN AND RESTARTING

1. Before shut-down of a piston engine, dilution of the entire lubrication system must be carried out by introducing raw fuel to dilute the oil. To start, the engine must first be warmed so that it can be turned more easily. With the help of additional power, it is then turned over and primed to start combustion. Once started, it is warmed slowly under its own power, after which a fast idle must be completed to burn off the diluent gas to prevent dilution blow-out.

1312 EXTERNAL HEATING

1. The time required to pre-heat a piston engine depends on air temperature, engine size and heater output, wind over the engine, the efficiency of the engine cover and the amount of oil dilution. It usually takes 30 to 60 minutes.

2. The application of external heat is unnecessary in temperatures down to-17øC if the engine oil has been properly diluted.

3. With turbine-powered aircraft the need to preheat is greatly reduced.

1313 PROPELLERS

1. In aircraft fitted with constant speed units (CSUs) to control engine flow to the propeller, difficulty can be experienced just after take-off in cold temperatures due to high oil viscosity. Exercising CSU controls several times at the end of the dilution cycle introduces diluted oil into the CSU, the associated oil lines, and the propeller dome.

2. Operating the feathering button during the last few seconds of the dilution cycle, and operating the unfeathering control after the RPM have dropped off by about 400, can make feathering possible after take-off.

1314 COLD STARTING JET ENGINES

1. In extremely cold weather the engine oil sumps may require heating.

2. Air-turbine starters, driven by air supplied from a gas-turbine compressor, will accelerate jet engines to idling RPM in half the time required by an electric start. A gas-turbine starting unit is also a convenient source of heat.

3. Cartridge-burning starters can be used on engines fitted with a cartridge receptacle. This type of starter requires no ground power unit and also brings an engine up to starting RPM more rapidly than an electric starter.

1315 LOW-TEMPERATURE FUEL COMBUSTION

1. Priming at pressures of 60-75 psi (414-517 kPa) can induce more rapid fuel vaporization through finer atomization of the fuel. The priming fuel flow for cold starting must be sufficient to keep the engine running at idling RPM, on "prime" alone, until it will run smoothly on the carburetor.

2. Additional aids to cold-weather starting are:

   a. The use of wrap-around electric heaters on induction manifolds.

   b. The use of highly volatile fuel for priming.

   c. Hot-fuel priming.

3. Since priming fuel will not evaporate rapidly when it is cold, the risk of fire from over-priming is more serious. Judicious use of the throttle, as appropriate to the particular engine operating procedures, is essential to successful cold starting.

4. When attempts to start an engine without first applying heat have failed, it is obviously desirable to heat it. Heat from a ground heater is retained around the engine by a cover or tarpaulin, while some of the heat should also be directed to the cylinders, carburetor and the accessory section. Sufficient heat should be directed to the engine accessories to reduce the drag forces set up by congealed oil. Failure to do this can result in twisted or sheared accessory drives, or a reduction in RPM sufficient to prevent a start. Changing to a lighter lubricant can sometimes make the difference between a mechanical failure, a start failure, or success.

1316 AIRFRAMES

1. Differential contraction can result in skin buckling, loss of cable tension, and the cracking of perspex and other plastic panels in airframes. Skin wrinkles can also occur, especially near heated ducts. Canopies should be checked for cracks prior to flight.

2. Loss of tension in control cables can be serious in some types of aircraft. Drops in tension have been experienced, ranging from 45 kilograms to less than 14 on control cables and from 11 kilograms to nil on trim control cables.

3. Check control surface moisture drain holes for ice blockage prior to flight.

4. Install rotor blade anti-icing equipment on helicopters prior to departure on cold-weather operations.

5. Slushy snow entering parts of an aircraft, where it can freeze overnight or during flight, can cause frozen brakes, undercarriage frozen "up" or "down", flaps frozen "up", or plugged vent lines. After take-off from slush, the landing gear and flaps should be operated several times to prevent freezing in the "up" position. Do not apply parking brakes while brakes are still warm.

6. If tires freeze to the ground or deck they can be freed by using external heat from ground heaters. In an emergency they can also be freed by over-inflation (within the safety limits of the tire). Freezing, can sometimes be prevented by running wheels onto pieces of plywood when parking aircraft.

NOTE

Tire air pressures drop and tire leak rates increase with a decrease in temperature.

7. Vinyl-coated nylon has given good service as an aircraft cover material and has been the easiest to handle. Fasteners must, however, be large and manageable.

8. Covers should be clearly marked with colored identification points, so they can be positioned on an aircraft quickly and easily. Blown snow can drift through the smallest chink, making it imperative to blank off all openings.

9. Drain water systems prior to cold soaking aircraft.

1317 FLIGHT-DECK PREPARATIONS

1. **Flight-Deck Covering**. A coated canvas-type cover can be used to keep the flight-deck clear of ice and snow. The trade-offs involved, speed in readying flight-deck versus the amount of ice/snow, must be considered.

2. Ice-removal teams should be created to clear the flight-deck and tie-downs. Ice-removal sequence is as follows:

   a. Clean ice/snow off the flight-deck, all areas. (Use brooms to remove snow to prevent flight-deck non-skid damage.)

   b. After snow removal, break up ice with steam.

   c. Remove water and loosen ice with high-pressure pressure air.

   d. Apply de-icer to pad eyes and any remaining frozen areas.

3. Lubricate safety nets and hangar fittings with appropriate cold-weather greases.

4. Rotate flight-deck personnel every 15 to 20 minutes to minimize exposure and fatigue. If possible, two complete flight-deck crews should be trained.

5. Additional auxiliary power cables may be necessary for helicopter starts. Additional heaters should be obtained for aircraft hangars.

6. Prior to aircraft operations, flight-deck fire mains and other fire-fighting gear must be checked for normal operations. Fire extinguishers may need to be kept at a temperature above freezing for reliable operation.

7. Flight-deck non-skid should be in compliance with current requirements.

8. Aircrews should ensure that sufficient quantities of waterless cleaner, oil, greases, and other aircraft fluids suitable to cold weather are available.

1318 FLIGHT OPERATIONS

1. Unfavourable weather restricts flying in any area. In the Arctic it is especially necessary to be familiar with conditions affecting flight operations, for storms can occur there with little warning. Icing conditions almost always exist, and as long as de-icing equipment remains only partially effective, icing can be overcome only by avoiding those altitudes at which it is most likely to occur. Fogs and low cloud are also natural products of polar areas in summer. At times dry surface snow raised by high winds tends to obscure the ground and the horizon, reducing visibility and obliterating all references to surface and sky ("white-out"). Any of these conditions makes flying dangerous, but a thorough knowledge of the hazards involved coupled with observance of proper precautions will help to reduce the risk.

2. In the matter of maintenance, close attention to detail is necessary because of the strain placed on aircraft by low temperatures and because of the fatal consequences likely to follow mechanical or material failure in flight. Low temperatures increase the difficulty of performing routine tasks and also increase the time required to complete them. The time involved largely depends on the protection afforded personnel and the kind of facilities provided.

3. Aircraft on-deck time prior to engine start must be minimized.

4. Flight deck crews on all diversion decks must be ready.

5. Boat crews will be suitably prepared and standing by during flight operations to enable immediate response as required.

6. If possible, helicopters should operate in pairs so that one is immediately available to rescue downed personnel in the event of a forced water landing.

7. All participating ship air controllers must keep close contact, by both voice and radar, with helicopters. Anticipate rapid loss of visibility and subsequent recovery of the aircraft.

8. Hoist/VERTREP/HIFR operations will be restricted to the absolute minimum to avoid the hover spray environment.

1319 PRE-FLIGHT

1. The Operating Instructions for any particular aircraft type provide the best source of information for cold-weather operation and must always be consulted.

2. **Snow, Ice and Frost**. Take-off should never be attempted with snow, ice or frost on the wings or empennage. A thin layer of ice, or snow which rapidly compacts into ice, will cause loss of lift and stalling. Hoar-frost and snow should be swept from surfaces with a stiff broom. All accumulations of snow must be removed from the wings and fuselage.

3. **Ice Removal**. To remove ice from aircraft parked outside, apply isopropyl alcohol if it is available. To remove ice from hangared aircraft, sufficient heat should be applied to loosen the ice particles so that they can be removed with a brush. It is best not to melt the ice completely as water is likely to penetrate control surface bearings and freeze. Landing gear, bomb-bay doors and flap-operating gear must be freed of ice and snow. Remove snow from the carburetor intake. Clean off antennas using a light pole. Operate all ailerons, elevators, rudders and trim tabs through several complete cycles and, if resistance is excessive, a careful investigation must be made. Experience in extremely low temperatures indicates that hydraulic systems are a major problem because of frequent shock-

shrinking of seals resulting in the collapse of oleos and pistons.

4. **Shock Struts**. Wipe the shock-strut piston tubes and oleos clear of all snow, ice or dirt with a cloth soaked in the fluid used in the strut oleo. Kerosene can be used if necessary. Follow by lubrication with hydraulic fluid. This is also a post-flight procedure. Clean piston rods of actuating cylinders in the same manner. Shock struts should be carefully examined for hydraulic leaks and proper inflation. Check for the proper distance from the lower end of the cylinder to the inflation mark on the piston.

1320 PREPARATION FOR FLIGHT

1. **Planning**. Take care to learn the special distress, bail out, ditching and crash-landing procedures. Be sure you know; do not guess. Plan and schedule pre-flight ground activities. Arrange the periods of pre-heating so that all equipment will be inspected, warmed, ready and running at start-up or take-off. While pre-heating is taking place, ice and snow should be removed, inspections and operational checks made and electronic equipment warmed up.

2. **Personal Care.** Load survival equipment and rations. Dress for the worst conditions, not the best. Wear clothing appropriate to the area of operations. Beware of the effect of cold metal on skin. Keep out of prop wash-its blast can cause severe frost bite. Spilled fuel on the skin can result in quick freezing and severe frost bite of the affected area.

3. **Weather**. Obtain the very latest weather information. Know the limits of the aircraft and its instruments in Arctic conditions.

4. **Warm-Up**. Warm up engines thoroughly. Do not turn on electrically heated suits, or other non-essential electric equipment, until the generator shows output.

1321 ANTI-ICING/DE-ICING

1. In general, icing conditions occur between -18°C and 0°C, and at altitudes extending from sea level to 6 000 m. In flight, ice forms on the leading edge of wings, empennage and other aircraft surfaces. While moored under conditions of freezing rain, ice forms on all the upper surfaces of an aircraft. In both instances this ice must be removed completely before take-off. The formation of ice on wings, empennage, radomes and the propellers adversely affects aircraft performance because of the added weight and the change in shape of the airfoil section.

2. **Thermal Anti-Icing**. By heating critical surfaces, droplets of water impinging on the affected parts are prevented from freezing. If sufficient heat is available to evaporate all the droplets and maintain the leading edge surfaces in dry condition, water may move aft on the airfoil and refreeze to form what is called "run-back", adversely affecting airfoil lift characteristics.

3. **Anti-Icing Compounds**. Compounds are available to delay or prevent the accumulation of ice on aircraft surfaces. One of these materials which has been found to be satisfactory is an inhibited thickened solution of lithium chloride.

4. **Mechanical De-icing**. Boots of rubber-type material are cemented to critical surfaces. Elongated cells in the boots, extending chord wise so as not to affect air flow over the surfaces adversely, are alternately inflated and deflated by air pressure. Flexing of the boot dislodges the ice which is then removed by the air stream. As icing conditions increase in intensity, the cells of the de-icing boots are pulsated at a faster rate.

1322 ROTARY-WING AIRCRAFT OPERATIONS

1. Cold-weather operation of helicopters should be in accordance with the applicable NATOPS manual for each individual aircraft.

2. **White-Outs**. A "white-out" condition is usually indicated by a complete overcast and an indistinct or non-existent horizon. A complete lack of depth perception may be experienced, resulting in an extremely hazardous night condition. Helicopters should not be flown unless visual contact with the surface is assured. Should instrument flight conditions be encountered or observed, the pilot should turn back or land before losing visual contact with the surface. "Grey-out" conditions are usually forerunners of white-outs. Complete overcasts, hazy horizon, loss of shadow, and reduction in depth perception are conditions that normally exist. The pilot should not proceed on a flight when these conditions are encountered; he/she should return to or remain at the base.

3. **Landings**

a. **White-Out and/or Low-Visibility Procedure**. If a pilot must land in white-out conditions, he/she should use all information available such as the nature of the terrain, wind conditions, information from ground parties that may be in the area, use of several smoke grenades, Navaids, GCA, etc., if available. Landings should be made into the wind at as low an air speed as possible (ground speed must be at minimum). Rate of descent should be less than 200 ft per minute. (Note: Radio altimeters may be as much as 75 to 100 ft in error.) When contact with the surface is made, aft cyclic should be applied to stop forward motion and prevent the helicopter from nosing over. The landing must be made on instruments. Pilots should not attempt to estimate altitude visually and fly contact to a landing. It cannot be done safely.

b. **Landing in Snow-Covered Areas**. As the final phase of the approach ends and a hover is commenced, huge clouds of blowing snow may envelope the aircraft reducing visibility to zero. For this reason, a zero-speed, no-hover landing should be made. If a hover is unavoidable, however, a landing can be accomplished safely in most areas by holding an external reference point close to the aircraft to stop all relative motion. Crevasses are another hazard in snow surface landings. When landing in a known or suspected crevasse area, the helicopter should be kept light on the wheels/skids until the crewman can conduct a close visual inspection of the surface from the cabin. If the area appears safe, the pilot may then slowly reduce collective to a minimum while maintaining sufficient rotor RPM to effect an immediate take-off if the aircraft should start to tilt. Should it become necessary to land in a known crevassed area, personnel debarking from the - aircraft should wear a safety line until the area is probed and safe walking areas marked.

1323 FIXED-WING SKI OPERATION

1. Cold-weather operation of fixed-wing aircraft should be in accordance with the applicable NATOPS manual for each individual aircraft.

2. Snow Characteristics. Ski-aircraft operations in North America are usually carried out from snow-covered frozen lakes which provide relatively level take-off and landing areas. In Arctic regions, snow fields provide the operating bases for ski aircraft. Snow conditions on frozen lakes vary considerably depending on ambient temperature, solar radiation, and wind velocity, but three main conditions of snow are encountered: cold dry snow, "sticky" snow, and slushy snow. It is possible to find these three types of snow simultaneously on the same lake provided that:

a. Ambient temperature is below freezing,

b. Some areas are sheltered from the sun and exposed to the wind; and

c. Other areas are sheltered from the wind and exposed to the sun.

3. **Cold Dry Snow**. Cold, dry snow is generally encountered at temperatures below-10øC with surface winds. Frictional resistance to sliding on cold dry snow increases with decreasing temperatures; in general, the lower the temperature the more adverse the snow condition for ski operation. However, on dry snow, since the frictional drag on the skis decreases with increasing velocity, take-off can be made without difficulty when continued acceleration is possible.

4. **"Sticky" Snow**. "Sticky" snow results from solar radiation which, even at freezing temperatures, causes particles of snow to melt and distribute water droplets throughout the upper layer of snow. A "sticky" snow condition is most likely to occur when the snow is fresh and fine-grained. When snow contains water, the frictional drag on skis increases with increasing sliding velocity; in an extreme condition the airplane may reach a point at which the drag equals the available thrust before take-off speed has been reached.

5. **Slushy Snow**. The condition known as "slush" is essentially a deep-snow condition which results when water flows into the base of the snow cover. This water is prevented from freezing by the insulation of the soft surface snow, and the slush condition may persist for extended periods even during extremely cold weather. On lakes the water usually flows up through cracks in the ice when the snow load exceeds the buoyancy of the supporting ice. Slush seldom exists over a whole lake surface; it is most frequently located near the shore where the snow load is heaviest. There is usually a considerable increase in the mechanical resistance to sliding when the skis encounter slush caused by the increase in ski penetration. While slush is not a serious problem, it results in some loss of airplane performance and should be avoided when alternate areas are available.

6. **Take-Off**

a. **Drag Characteristics**. The sliding characteristics of skis on snow are different from the rolling characteristics of wheels. On a smooth, hard runway the rolling resistance of wheels is small and, to effect take-off with a minimum ground run, the aerodynamic forces operating on the airplane are the principal consideration. The sliding resistance of skis is frequently appreciable, depending on the applied load, the sliding velocity and the condition of the snow. Generally, drag on skis decreases with decreasing load. Thus, it is frequently possible to effect a net gain in performance by accepting an increase in aerodynamic drag to develop lift in order to reduce the load on the skis. On dry snow the frictional drag on the skis decreases with increasing velocity and, with continued acceleration, take-off can usually be made without difficulty. On "sticky" snow the frictional drag does not decrease with increasing velocity to the same extent as on dry snow, and if the mechanical resistance to sliding is high, acceleration decreases as the sliding velocity increases. In this situation, it is generally advisable to increase the aerodynamic lift through use of the flaps and control of the airplane attitude, and to become airborne at minimum speed. Assuming the airplane is moving, the next consideration is the best procedure to follow in order to become airborne with a minimum ground run.

b. On wheels, the rolling resistance on a hard surface is relatively independent of the load; on skis, particularly at low velocities, the resistance is increased considerably as the load increases. As the wings develop lift, they reduce the load and decrease the drag on the skis, but at the same time the aerodynamic drag is increased. The determination of the optimum airplane attitude and flap setting as a function of velocity which will give the lowest combined aerodynamic drag and sliding resistance, is a matter of experienced judgment. The airplane attitude should be positive but not to the extent that the wings are stalled out.

c. Except on ice or dry snow which is not significantly deformed by the skis, a longer ground run is required for take-off, though the difference is not as great as might be imagined. For one thing, skis are never used at temperatures much above the freezing point and, except in the case of "sticky" snow, the high drag on skis is encountered only during the low-velocity period during the take-off run. The time required to attain 10 - 15 kt (18 -28 km/h) may be significantly greater than when on wheels, but the distance covered during this time is not great due to the low velocity. When operating from a prepared runway or permanent bases, the snow is always packed and the performance on skis compares favourably with that on wheels.

d. Aside from selection of the best take-off area and control over the aerodynamic lift, there is little a pilot can do to affect the performance achieved during the take-off run, but exercise of considerable judgement is required to arrive at the best compromise of aerodynamic drag versus sliding resistance where take-off is critical.

7. **Landing**. When landing area conditions are not known, the most important consideration for ski landing on lakes is as exact an evaluation as possible of snow surface conditions and ice thickness.

a. **Depth Perception**. When operating on snow surfaces, depth perception is frequently impaired, and under such conditions landing must be made with caution. Depth perception usually is poorest on hazy days when diffused light does not cast any shadows on the snow surface. Under conditions which cause impaired depth perception, it should be assumed that the snow surface is considerably higher than it appears. For ski landings under these conditions, let down on the final approach at a safe rate of descent (200 ft per minute) until the skis touch the snow.

b. **Surface Hazards.** Even with apparently suitable snow conditions, before a landing is attempted, a careful examination of the surface should be made from the air to detect pressure ridges and concealed rocks, logs, blocks of ice and hidden trails. When operating near the shore where snow is deepest and softest, the danger of striking submerged obstructions is greatest, and any mounds in the snow should be regarded with extreme suspicion as they are likely to have a hard core. Pressure ridges in the ice occur on nearly all except the smallest lakes, and even small pressure ridges are large enough to cause major damage to the landing gear of the aircraft. Before landing, extreme care should be taken to detect any signs of roads or trails across a lake. The trails may be paths used by trappers or animals, commercial fishermen or woodcutters, sled trains, or even airplane ski tracks. They usually are dangerous only when the snow is deep and soft, and the trail has been used repeatedly between snows. As a result of repeated traffic packing down the snow and fresh snowfall filling the track, a hard ridge of snow is built up. The top edge of the ridge after a fresh snow may be flush with the adjacent soft snow. An accidental encounter with a trail of this nature can result in severe damage to landing gear. whenever possible, the location of trails and pressure ridges should be fixed in the mind or on a map before a landing is made.

CHAPTER 14

SUBMARINE AND ANTI-SUBMARINE OPERATIONS

1401 MATERIAL READINESS

1. Whenever air temperatures drop below -2°C, the freezing point of seawater, special precautions are required when surfaced. Some problems which can occur include:

a. Icing of the main induction and snorkel valves causing these valves to jam or freeze open or shut. An ice coating on valve electrodes may be sufficient to induce this problem.

b. Icing of the main ballast tank valve linkages, rendering them inoperative and making diving impossible. This condition can only be avoided by frequent cycling of these valves, or by diving often enough to keep them ice -free.

c. Icing of the submarine superstructure which can produce a difficult and sometimes dangerous stability problem.

d. Icing of the bridge, which is very exposed and close to the sea.

e. Icing which can damage antennas, periscopes, and snorkel masts.

f. Under certain atmospheric conditions, heated exhaust gases (from a snorkel) which can create a vapour trail and betray the submarine presence.

g. Glycerin should be used to protect hatch seats and hatch mechanisms, and to coat periscopes and other full penetrating mast barrels. Anti-freeze should be carried for use in diesel engine(s) and for pouring in mast and periscope bearings, if required.

2. The fairwater must be reinforced and should be smooth, curved and clean-swept to permit surfacing in ice-cluttered leads, or to break through new ice which can form at any time of the year. All "through -the-hull" equipment (radar, periscope, antennas, snorkel) should retract so that they are flush with the hull.

3. Upward-looking sonars and echo-sounders are required for:

a. Evaluating the type, distribution and thickness of the ice canopy;

b. Making ascents into leads and polynyas; and

c. Locating sheets of new and young ice which form in leads and polynyas during winter operations. A simple fathometer with several upward beamed transducers will do a good job.

4. Accurate high-latitude navigation systems are necessary, the most important parts of which are accurate and reliable compasses. Navigation satellite (NAVSAT) fixes are frequently available if surfacing is possible. Submarines fitted with Ship's Inertial Navigation Systems (SINS) are best equipped to cope with the problems associated with high-latitude navigation.

5. Accurate temperature measurements from the Submerged Ship Expendable Bathythermograph (SSXBT) can be an aid in predicting ice conditions and in navigation. Other temperature values may

be obtained from the main seawater thermometer (injection temperature) or the thermistor in the towed sonar array, or may be inferred from the sound velocimeter trace.

1402 UNDER-ICE PROCEDURES

1. **Depth**

a. Sea ice thickness varies but does not typically exceed 4 metres except when heavy ridging occurs. These ridges can extend downward as much as 50 metres.

b. It is not feasible to go below large icebergs since they may exceed depths of 300 metres (550 fathoms). Cruising depths must allow for an adequate safety margin.

2. **Deep Submergence and Angles**. Before sailing, a careful check should be made to ensure that all equipment designed to operate at full submergence. does so without leaking. All loose gear must be stowed and secured

3. **Speed**. In diesell battery-powered submarines, the need to conserve battery power makes it necessary to use the most efficient speed for each class. Although air reconnaissance can assist in locating polynyas, no unaided diesel submarine should penetrate under the ice further than 40 percent of battery capacity will allow. If, by that time, no lead is found in which to surface and recharge batteries, the submarine should return to a point of safety.

4. **Manoeuvres**. In high latitudes, courses and speed changes should be made gradually to avoid unsettling the compasses.

5. **Trim**. Because of varying water densities and the need for a hovering trim, it is advisable to conduct a dead slow trim at least once a watch. A good trim is mandatory in the event of an engineering breakdown affecting propulsion. Periodic depth changes to obtain updated sound velocity profiles will provide valuable trim

6. **Sonars**. The scanning sonar should be manned continuously, together with all upward-looking sonar arrays. The scanning sonar should be echo ranging while searching for and plotting a lead, and as often during the cruising period as the mission will permit. The conning officer should be able to see the upward-looking echo-sounder readings either on a plan position indicator (PPI) scope or a recorder. The echo-sounders, top and bottom, should also be in continuous operation, mission permitting. A specific danger sounding should be known to all watch-keepers and the recommended immediate action on reaching such a depth would be to slow down and reverse course, changing depth only if ice conditions compel it.

1403 PREPARATIONS FOR SURFACING IN PACK-ICE

1. **Finding Leads**

a. Air reconnaissance and high - resolution satellite imagery are especially valuable in locating openings in the ice. All available ice-forecasting information should be studied and arrangements made to receive further forecasts en route and while in the pack-ice.

b. The Navigator should maintain a record of the number and approximate size of suitable leads large enough for surfacing. This running record along a straight track will provide information on available surface areas and, if plotted with dead-reckoning positions, provide a means whereby a submarine could return to an area suitable for surfacing with a good chance of finding.

2. **Searching for a Lead**. If the operational situation requires it, a search plan can be adopted to locate open water for surfacing. To surface as close as possible to a specified position, an expanding square search is recommended. Other alternatives are to return to a previous plotted position, continue on a straight-line search, or commence a rectangular search.

3. **Identifying a Lead**. The best indication of a lead will be obtained by the upward-looking echo-sounder with a recorder. Leads are usually indicated by the appearance of strong first and second echo traces and a moderate third trace. Young ice will be shown as a strong first echo trace and a weak second echo trace. Since different upward-looking sounding equipments will give varying presentations, each must be carefully studied upon entry under the ice.

4. **Periscopes**. The periscope picture usually shows open water in daylight and on moonlit nights before the upward-looking echo-sounder indicates a lead. In addition, the periscope makes it possible to see the shadows of pressure ridges and ice blocks.

5. **Scanning Sonar**. Pressure ridges, the edges of leads, and dense ice formations will show at ranges of up to 1825 metres on scanning sonar.

6. **Plotting**. A plot should be generated to determine the actual size of open water areas. The axis of the lead can usually be determined by the picture on the plan position indicator scope of the scanning sonar, and a course set to pass down the centre of the lead. The ship should proceed at slow speed and a dead-reckoning plot started on a scale of 200 yards to the inch. A mark should be made when any indicate ice to establish the length of the lead. The scanning sonar also gives an approximation of the width of the lead as the ship proceeds. After passing under the ice at the further end, the submarine should turn 270 degrees in a wide arc to cross the width of the lead estimated from the plot and the sonars. The clearwater marks from the sonars should be plotted again and the picture of the lead completed.

1404 SURFACING TECHNIQUES

1. **Positioning the Ship**. The submarine is manoeuvered to enter the plotted lead on its long axis at about 3 knots and 45 metres (25 fathoms) keel depth. As soon as clear water is reported on all sonars, "Stop" is rung up and the ship allowed to drift towards the centre. With the ship in the estimated centre, headway is checked. To confirm that the ship is dead in the water, the retractable whip antenna can be raised and observed through the periscope. Another check is to release air bubbles through an open vent and observe the bubble track

2. When it has been determined that the selected lead is clear for surfacing, the ascent is made. An ascent rate of about 3.5 metres per minute is desirable. The ship should be brought up with a one-or two-degree up angle to protect the rudder, screws and stern planes. Another method is to control the ascent by blowing safety and flooding the negative tank.

3. Upon reaching about 27 m (15 fathoms), it may be necessary to pump continuously to sea, or blow ballast in short bursts until surfaced, to maintain the desired rate of ascent. The freshwater layer near the surface is great enough to make the boat appear heavy when approaching the surface. This is especially true in the summer months when severe near-surface salinity gradients can be caused by the melt.

4. The retractable whip antenna can be left in the fully raised position during ascent, observed through the "any-height" periscope. In submarines without such a periscope, a periscope proper can be raised to determine the ice conditions overhead but it should be housed before reaching a depth where it might encounter ice. If ice is discovered, the negative tank should be flooded and the whip and periscope housed at once.

5. While on the surface in a lead or polynya, the normal cruising watch should be maintained. While stopped, the shafts must be kept from turning to prevent propeller damage. An accurate check must be kept on the state of the lead or polynya and the submarine should be manoeuvered as necessary to remain in the centre. A lead can close in quickly in a strong wind.

1405 DIVING IN AN ICE AREA

1. Because of the vulnerability of topside equipment, conventional submarines should not normally surface with brash ice in the vicinity, and should submerge before ice approaches the sides of the ship.

2. A dive is made normally, except that no propeller movements are ordered until the ship reaches 27 metres (15 fathoms). In some submarines, the after group vents may be opened first to keep the ship from assuming too large a "down" angle due to the forward moment of the negative tank.

1406 DETECTION CAPABILITIES

1. In areas of sea ice, submarines have an advantage of being able to operate quietly under the ice. In areas where ice is melting, there will be a considerable variation in salinity and a resulting decline in the accuracy of sonar range predictions. (See Chapter 8.)

2. Ships must be alert for periscopes or for disturbances in new or young ice which might betray a submarine. Look-outs should also be alert for a vapour cloud produced by a snorkel.

3. During the spring and summer months in high latitudes, when daylight hours are extended almost around the clock, surface and air visual detection chances are particularly good. Because of this a submarine may have to remain submerged, seeking concealment for long periods of daylight to avoid detection.

1407 AMBIENT NOISE IN THE ARCTIC

1. Ambient noise in the Arctic differs from the noise in the open oceans because ice cover generally excludes ship traffic noise and accounts for most of the ambient noise. However, low-frequency noise from ice activity, especially from the formation of pressure ridges, can have directional properties. The ambient noise level at low frequencies ranges from 30 to 80 dB independent of ship traffic and wind due to this ice-generated noise. In the open ocean, the noise level at certain frequencies is directly related to the wind force. In the Arctic, the noise level is often only indirectly related to the wind through its effect on ice movement.

2. There are four primary sources of ambient noise in the Arctic. The are:

a. **Ice Movement and the Formation of Pressure Ridges**. Caused by the action of wind and currents on the ice. Such ice activity influences the noise levels at all frequencies of interest.

b. **Thermal Cracking**. Results from stresses that develop when the ice surface is cooled or warmed. The rate of temperature change and the amount of snow cover influence the noise levels, which are strongest in the frequency range of 120 Hz to 1000 Hz. This type of noise is easily overwhelmed by the noises of ice movement and is therefore of greater importance in areas where fast ice is attached to a shore, such as in archipelagic regions.

c. **Wind Eddies**. Formed at the surface by the wind passing over the uneven ice and snow. This noise source generally requires wind speeds in excess of 3 to 5 knots and has its greatest influence at higher frequencies.

d. **Biological**. This type of noise has seasonal peaks occurring in the summer when there is an increase in biological activity.

3. **Arctic Ocean, Deep Water**

a. Except in summer, when melting relaxes the stresses in the ice, the dominant source of ambient noise in the deep water areas of the central Arctic is the result of ice movement. Such movement is caused in part by the wind; higher levels of noise can be expected for higher wind speeds.

b. Equations (a) through (d) are used to predict the median levels of noise for a given frequency and season in deep Arctic water. (Actual noise levels are expected to exceed the median levels half the time.) These equations are valid over the frequency range of 10 Hz to 1000 Hz.

Equation (a) AN = 71.4 - 0.203f (for July-September)

Equation (b) AN = 77.7 - 0.190f (for October-December)

Equation (c) AN = 78.0 - 0.135f (for January-March)

Equation (d) AN = 73.3 - 0.149f (for April-June)

Where f is the frequency in Hz and AN is the predicted median ambient noise level in dB referred to 1 μPa/Hz.

4. **Marginal Sea-Ice Zone.** Unique noise characteristics exist in the marginal sea-ice zone of the Arctic Ocean. Wave and swell interactions with ice floes at the ice-water boundary produce a relative maximum in ambient noise levels. As a result, the noise levels are a function of sea state.

1408 ACOUSTIC SIGNAL PROPAGATION

1. **Arctic Ocean**

a. In the ice-covered regions, remote from the marginal sea-ice zone, sound propagation is characterized by upward refraction of sound rays followed by a surface reflection resulting in a surface duct. The underside of the ice is rough from the formation of pressure ridges and ice keels. To signals at low frequency (less than 50 Hz) with long wavelength, the ice appears relatively smooth. Such signals travel long distances with little loss other than cylindrical spreading. At higher frequencies the ice appears rough, sound energy is scattered, and sound propagation is relatively poor.

b. Propagation loss measurements in the Greenland Sea produced the curves presented in Figure 14-1. The water depths varied from a minimum of 335 m (185 fathoms) to a maximum of 4250 m

(2320 fathoms). Most of the deep water data was obtained from the Arctic Ocean side of the Greenland Sea.

c. Equations (e) and (f) are used to predict propagation loss in the deep water of the Arctic Ocean, and equation (e) is only applicable for water depths exceeding 900 m (490 fathoms). They are theoretical relationships, which can provide propagation loss values in the absence of historical data for the area of interest.

d. Equation (e) is for long ranges (100 to 1000 NM: 185 to 1852 km) and can be used to compute propagation loss for a given range and frequency as follows:

Equation (e) $PL = 69.3 + 10 \log R + 0.070f - 0.0015\ \delta R + 0.000487f\ \delta R$,

where: PL a propagation loss in dB referenced to 1 μPa at 1 yard,

R = range in nautical miles,

f = frequency in Hz, and

= standard deviation of ice depth in metres.

e. Equation (f) is for shorter ranges (from 1 to 100 NM: 2 to 185 km) and gives propagation loss for given range and frequency as follows:

Equation (f) $PL = 63.2 + 10 \log R + 0.032f + 0.065R + 0.0011fR$

2. Marginal Sea-Ice Zone

a. Acoustic signal propagation in the vicinity of the ice edge is highly unstable. The presence of a thermal front near the edge results in unreliable transmission at all frequencies.

b. Equation (g) is used to predict the propagation loss in shallow water under summer conditions. The data used to derive this equation was obtained in the Chukchi Sea, but is applicable to other shallow regions. Equation (g) is theoretical and should be used in the same manner as equations (e) and (f).

Equation (g) $PL = 40.6 + 0.105f - (0.0421 + 1.16 \times 10\text{-}_4 f)D_{mjn} + (0.86\text{-}0.003f)S + (37.0\text{-}0.06f) \log R + (0.0013 + 0.0005f)\ RS$,

where: PL = propagation loss in dB referenced to 1 μPa at 1 yard,

f = frequency in Hz,

D_{min} = the minimum water depth (in feet) along the path,

S = the surface ice coverage in oktas, and

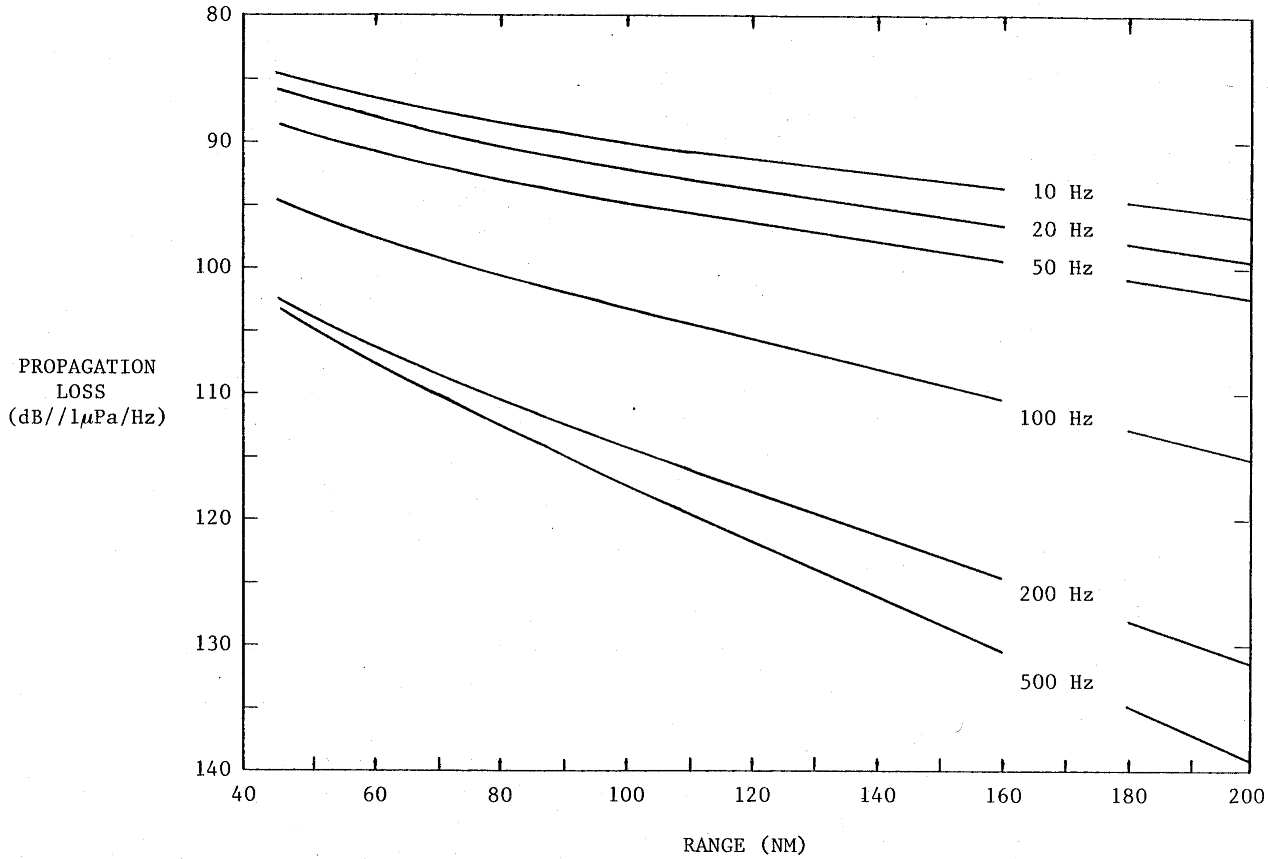
R = the range in nautical miles.

The equation should be useful for the following ranges of variables:

f:	15 to 6000 (Hz)
D_{min}:	90 to 3100 (feet)
S:	1 to 7 (oktas), and
R:	5 to 35 (NM).

1409 SHALLOW WATER LIMITATIONS ON SUBMARINES

There are certain areas where relatively shallow water inhibits submarine operations, particularly when there is the added difficulty of an overhead canopy of ice. Such areas include the Bering Sea, the area north of Bering Strait, and the coastal waters of northern Siberia. Submarine attacks on shipping are not precluded in these areas, however, and surface ships should maintain constant vigilance against such a possibility.



SOURCE DEPTH: 242 m (800 ft)

RECEIVER DEPTH: 30 m (100 ft)

Figure 14 1 Propagation Loss ill the Greenland Sea
(April)

CHAPTER 15

AMPHIBIOUS OPERATIONS IN THE ARCTIC

1501 INTRODUCTION

1. In adapting amphibious warfare techniques to the requirements of the Arctic, one of the more important planning factors to be considered is the influence of the environment on the functional capabilities of the individuals, their weapons and platforms. Except for air platforms, sea ice must be considered in all its forms in planning amphibious operations. In any amphibious operation within sea ice areas, the CCATF should be given ultimate authority to decide the time, the manner, and the location of the landing, since these actions may be fundamentally influenced by ice and/or weather conditions. It will always be dangerous for any task force of amphibious warfare ships to enter an area of pack ice. The force may have to be supported by ice-breakers, progress will be slow, and there is little possibility of evasive action.

2. Should it become necessary to effect a landing against an area surrounded by unnavigable ice, helicopters or air - cushion vehicles are the best means of ship-to-shore movement. Accordingly, the manner in which the operation is conducted will be governed, both tactically and logistically, by the landing means available.

1502 MARGINAL ICE AREAS

1. Marginal ice areas include those negotiable by ice-breakers and ice-strengthened ships, plus areas subject to drifting ice and scattered floes. Pack ice within marginal areas is moving continuously under the influence of wind and current. Consequently, any movement of units over this ice, even if frozen, is dangerous.

2. Within marginal ice areas there is always a possibility that land-fast ice may project from the shoreline, even though the sea is clear of ice for several miles. Under these conditions such ice will impose difficulties upon the landing of heavy equipment and the operation of amphibious craft over the "beachline".

3. The logistic support of an operation can become more hazardous than the tactical venture itself. Changes of wind or current may choke open areas with pack ice so dense as to bring operations to a halt and to halt the movement of supporting ships. Therefore it is essential that critical supplies be put ashore as rapidly as possible.

4. Logistic plans for an operation must provide alternative methods of emergency supply. If flying conditions permit, consideration should be given to the extensive use of helicopters and fixed-wing aircraft for emergency drops. The shore party should be given full responsibility for handling this commitment. Ice can restrict the movement of naval gunfire support ships, thus effectively neutralizing this type of support. Therefore air strikes should be available as an alternative if fire support is essential. Fog and ice occurring together may make the provision of fire support impossible, and troops onshore should be briefed accordingly. Ice may also stop small craft from ferrying men and supplies ashore.

5. Beaches can become littered with heavy floes left by an ebbing tide, making it difficult for boats to land and for men and cargo to move around them.

1503 MARGINAL ICE OPERATIONS

1. Where possible, a landing should be made where ice will not jeopardize operations. Once the attack has been initiated, speed in landing the troops and in providing logistic support will be critically important.

2. Full use should be made of ice reports. However, the reports should be checked and updated as necessary, since conditions change under the influence of wind and tide.

3. The logistic support plan should include arrangements for emergency support.

1504 LOW SURF AND SWELL

1. Sea temperatures require that troops be landed dry-shod. Immersion for more than a few minutes can be fatal. Men who inadvertently get wet going ashore become non-effective and must be dried out. Provision must be made, both on board and ashore, for the handling of immersion cases.

2. Amphibious Reconnaissance Units and Underwater Demolition Teams will be restricted in their activities by the water temperature. Special individual swim clothing and equipment will be required.

3. Surf and swell are non-existent in sea ice areas because of the damping effect of the ice. In areas where does not inhibit the action of the sea, the same consideration will have to be given to surf and swell as in other areas of the world.

1505 EFFECTS OF TERRAIN ON AMPHIBIOUS ASSAULTS

1. The Arctic contains coastal land forms which vary from extensive coastal plains to rugged mountains, cut by deep fiords. The advance and retreat of the great ice sheets have left the marks of glaciation. Existing glaciers debouch into the sea or approach very dose to it.

2. Frozen ground is a phenomenon common to the Arctic. The term frozen ground, as used here. includes permafrost, the active layer of permafrost, dry frozen ground and other variations. Frozen ground is influenced not only by constant factors including geographic conditions and temperature, but also by variable factors including such features as snow cover, vegetation, hydrology, and ground heat conductivity.

3. Permafrost, particularly the fluctuation of the active layer, can influence a land operation. Transport, fortifications, the effect on exploding projectiles, excavations for road and airfield construction and water supply, plus many other activities, are affected by the state of the ground.

4. Glaciers which reach the sea, may in some instances, provide the best approach to an inland objective. But getting a force safely on top of a glacier can be difficult and dangerous. The surface may also turn out to be too heavily crevassed for safe use. An attack force commander should seek the advice of an expert concerning methods of transport and special equipment required for glacier operations before making a decision.

5. In over-glacier operations, units must be lightly equipped for maximum mobility. Infantry should be provided with special foot-gear and sledges, and tracked vehicles used exclusively. Alternative plans for supply and evacuation by helicopter should be made, and specialist over-snow vehicles will be required.

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6. In many flat coastal plains and other poorly drained areas, lakes and ponds have been formed as the result of glacial action. In summer, when the ice has gone, constitute an obstacle to movement inland, become breeding grounds for swarms of mosquitoes and black flies, and hinder the direction and control of forces. By contrast, in winter, frozen lakes provide a landing force with ready-made airstrips provided the ice is thick enough to bear the weight of the aircraft and vehicles.

7. In certain parts of the Arctic "raised beaches" occur. They exist as a series of flat-topped gravel ridges, left by rising land surfaces, some of which have water- or ice-filled marshes behind them. These beaches, resembling giant gravel terraces parallel to the shoreline, may extend for several hundreds of yards inland, increasing the requirement for beach matting. For light aircraft they make good landing strips and, if the direction suits, good roads.

8. Glacial action has left some coastal areas encumbered with great quantities of rocks and boulders, both on the beaches and in the hinterland. The rocks and boulders can constitute a formidable obstacle to the movement of land and amphibious vehicles.

9. The general lack of significant vegetation will require:

a. Emphasis upon camouflage discipline and exploitation of minor terrain features for cover

b. Increase in the amount of camouflage material to be carried.

c. The provision by the landing force of all buildings, facilities and materials required for its operations ashore.

10. Arctic areas are often sparsely inhabited, having few roads and man-made facilities.

11. Vehicle tracks can persist in tundra for years. Consideration of this fact should be given in aerial reconnaissance interpretation and in cover and deception activities.

1506 EFFECTS OF CLIMATE AND WEATHER

1. Variations in temperature, wind, and visibility, which occur throughout the Arctic, will have effects on an amphibious assault as follows:

a. Broad flexible operation plans, which allow flexibility in time of landing and selection of landing areas, will be required

b. Alternative plans may be necessary, particularly where weather is subject to sudden and severe change.

c. Alternative means of logistic support, and employment of supporting arms, should be included in the administrative and operation plans. These must be rehearsed before an operation to determine time/distance factors which may be created due to low visibility.

d. Low temperatures will require a larger stock of fuels and lubricants.

e. At sea, superstructure icing can be caused by snow, ice, and spray. Ice can accumulate rapidly on the hull, superstructure, deck, and deck equipment, destabilizing the ship and causing treacherous footing. Landing-craft ramps can freeze solid.

f. The refractive effects of the Arctic atmosphere on radars and communications will create marked propagation differences from what is considered normal in more temperate climate. Ducts may extend surface ranges, or lobing may develop.

2. The severe cold of an Arctic winter will affect both the men and material of an amphibious force ashore. Low temperatures have a marked effect on glass, rubber, copper wiring, steel and explosives. Low temperatures also affect the performance of troops, motors, and storage batteries.

a. Wet cold conditions occur when temperatures are near freezing and variations in temperature cause alternate freezing and thawing. These conditions may be accompanied by dry snow, followed by sleet or rain, followed again by subzero temperatures. In order to preclude exposure, troops must be equipped with, and carry waterproof clothing. Refer to Chapter 9 for more specifics.

b. During dry cold conditions experienced generally in the Arctic and continental land masses, troops are required to be equipped with windproof clothing. Temperatures under dry, cold conditions are unlikely to rise high enough to permit wet snow or rain to fall.

3. Protection from the weather is an important factor, especially during the winter, and adequate shelters must be provided. Winter conditions may require an increase in the number of troops because of the need for frequent reliefs. More room will be needed in boats and aircraft per person, to accommodate additional clothing and equipment. Wind exacerbates the effects of low temperature, and the combined effect is known as wind chill. Danger of frostbite and hypothermia is ever-present. See Chapter 9 for symptoms and remedies for frostbite and hypothermia, and a basic discussion of cold and its effect on the human body.

4. Special facilities may be required for the storage of explosives in low temperatures. Freezing temperatures may cause duds and prematures, and plastic explosives may need to be warmed before moulding if possible.

5. The supply of potable water may freeze in its containers after a very short time. Water for small groups is best acquired by melting snow for which additional fuel must be carried. If there is no snow, or if a large water supply is required, a lake or a river may be used as a source; melting may be required.

6. Snow on beaches and coastal terrain may frustrate aerial photographic interpretation. Map reading and orientation in a snow-covered area may be so difficult that a landing force may have to operate entirely from information obtained after landing for relay to higher echelons and supporting arms.

7. Although poor visibility will provide a landing force with cover for grouping and movement, it may also lead to the postponement of landing operations. The long periods of winter darkness, blizzard conditions, or low lying coastal fog, which do not extend far inland or out to sea, will all impose severe restrictions on planning; these factors will require that detailed alternative plans be prepared.

1507 AIR OPERATIONS CONSIDERATIONS

1. The doctrinal employment of landing force aviation does not change during cold-weather operations. However, heli-team size may need to be reduced to accommodate additional cold-weather and survival equipment.

2. Other operational planning factors that will affect heliborne operations are:

a. Snow conditions in the landing zone may preclude the simultaneous touchdown of a helicopter assault wave due to white-out conditions generated by the landing aircraft. If this is anticipated, a 30-second interval between aircraft may be required and because of the amount of equipment being carried, emplaning and deplaning will take longer than normal.

b. Arctic white-out is a condition in which the horizon line cannot be distinguished, depth perception is limited and things appear to have a uniformly white glow. In white-out conditions, it is impossible to tell whether a hump in the snow is a distant hill or a snow-covered stone only a few feet away and walking is awkward since it is difficult to distinguish humps from hollows. White-out occurs when there is an unbroken snow cover and a uniformly overcast sky making the light reflected from the sky approximately equal to that from the snow surface. The presence of ice crystals aggravates the condition. Falling snow, blowing snow and rotor downwash can also cause white-outs. For the pilot, the only safe procedure under these conditions is instrument flight. If possible, it is best to land alongside a fixed reference point and await improved weather conditions. Although yellow sunglasses may enhance the contrast under some conditions and thus improve depth perception, the white-out condition cannot generally be alleviated by their use.

c. Grey-out is a condition that occurs over a snow-covered surface during twilight or when the sun is close to the horizon. There is an overall greyness to the surroundings; the sky is overcast with dense clouds and there is an absence of shadows with a resulting loss of depth perception. Grey-outs increase the hazard to landing, driving vehicles, towing aircraft and even walking. This phenomenon is similar to white-outs; however, a horizon is usually distinguishable.

d. During helicopter operations, the arrival, departure, and to some extent the enroute flight, will produce visible evidence of aircraft presence in the form of a snow cloud or the removal of snow from trees and other terrain features. This signature can be expected in all helicopter landing areas. The reduction of this signature during the enroute portion of a flight is possible by maintaining a minimum of 40 knots air speed in low-level flight, avoiding close-formation flight over snow-covered terrain, and by selecting routes that avoid forested areas (if tactically feasible). To reduce the signature caused during landing and take-off is a difficult task. In landing zones, ground units should be instructed to pack the snow in the immediate vicinity of the landing point.

e. Cabin temperatures in helicopters and paratroop dropping aircraft should be maintained below 5° C in order to prevent condensation and the subsequent freezing of weapons and equipment.

1508 NBC OPERATIONS

1. NBC countermeasures included certain protections which may or may not be compatible with the general need in the Arctic to provide thermal protection from the climate. There is the requirement to decontaminate which usually involves changing or shedding clothing and washing troops and vehicles. None of these measures can easily be adapted to cold conditions, and the consequential problems are the subject of continued developments and improvements in equipment and procedures.

a. The effects of nuclear weapons will be influenced by snow and ice, by the relatively clear atmosphere, and by the much denser air which occurs with low temperatures in winter. This article deals only with the consequences of these particular phenomena.

b. Blast. Snow and ice, particularly if they are in fairly thick layers, will absorb a proportion of blast and heat, thus reducing the amount of ground heating which is one source of the subsequent shock wave. Such a reduction will lessen the ranges at which military targets will be destroyed and damaged. Deep snow will also absorb some of the blast energy, but if there is only a thin layer of snow, and the ground is frozen hard, the shock wave transmitted through the ground will be appreciably greater than in soft ground, and any dug-in defences or underground structures will be particularly liable to damage. The blast wave may cause temporary snow storms, and if suitable conditions exist, avalanches. Reflection of the blast wave from the bottom of lakes and rivers can cause a breakup of an ice layer.

c. The clear air, especially in winter, and the reflection from snow will greatly increase the heat and light radiation from a nuclear explosion, and may produce a much higher incidence of eye injuries; and at greater distances from ground zero, this will be further intensified by the contrasting winter darkness. On the other hand, troops and equipment well dug into the snow will be well protected, and the layers of cold-weather clothing will also help to reduce the incidence of burns.

d. At very low temperatures, the density of the atmosphere increases so markedly that the distances to which initial nuclear radiation will extend may be reduced by as much as 25 percent. Fall–out, may however, be greatly extended in a particular direction by the high winds which occur seasonably. However, since such fall-out would be distributed over a wide area, dose rates nearer ground zero should be lower.

e. Snow will become contaminated by fall-out, and this may lead to a further spread when it is blown and drifted by the wind, particularly if it is blown into shelters and slit trenches, or into personal clothing.

2. Although the freezing point of a decontaminating agent mixed with water can be reduced to -10°C with additives, this will not be helpful in extreme conditions, nor will it prevent freezing of the liquid on cold surfaces.

1509 SHIPBOARD CONSIDERATIONS

1. The surface area of external bulkheads on amphibious ships is sometimes double that of other ships. This, naturally, will increase the demand on the ship's heating systems. Additionally, firemains and cooling drains are more exposed to cold weather elements.

2. **Exterior Cranes**

a. Exterior cranes must be thoroughly checked for wear on all pivots and for stress cracks along the boom. A lift capacity test should be conducted prior to deployment if the certification of load capacity is scheduled to run out during or just after the completion of the deployment. Preventive maintenance should be completed and all lubricants, oils and grease should be changed to meet cold weather operating specifications. Cables, gears and gear rings need to be properly greased to prevent corrosion and all hydraulic or air lines must be inspected for leaks.

b. The following checklist of items will help in preparing the crane for deployment:

(1) Gauges.

(2) Controls.

(3) Direction indicator.

(4) om angle indicator.

(5) Platform.

(6) Access ladder secure.

(7) Hoist wire.

(8) Topping wire.

(9) Sheaves.

(10) Slack wire device.

(11) Interlock switches.

(12) Electric brake.

(13) Hook.

(14) Machinery spaces.

(15) Hydraulic unit.

(16) Hoist/top/train brakes.

(17) Cradle.

(18) Fire extinguisher.

(19) Storage pins.

(20) Limit switches.

3. **Turntables**

a. Turntables on deck and below decks should be completely inspected for wear and maintenance. All areas that require greasing should be cleaned and filled with grease to prevent water from getting inside rollers or gears. All manual-operation equipment should be on site and in top working condition.

b. The following checklist of items will help in preparing the turntables for deployment:

(1) Electric brake.

(2) Turntable wells.

(3) Clutch for hand operations.

(4) Limit switch for manual operations.

(5) Hand crank for manual operations.

(6) "T" wrench for manual operations.

(7) Drive sprocket.

(8) Machinery room, coupling/mount.

(9) Turntable rollers.

4. **Wells Decks**. All planking and batterboards on amphibious ships with well decks should be in good condition and all illumination control lights should be checked for operability. The pumping system must be completely checked, all drains must be free of debris and when not in use, the pumps should be cycled periodically to ensure that water in the lines is not freezing.

5. **Ramps**

a. Ramps, both exterior and internal, must be inspected prior to deployment to ensure there are sufficient traction bars. Traction between the bars should also be checked. Most of the exterior ramps will not be adversely affected unless there is severe icing which encompasses the entire surface. In such an event, large commercially obtainable space heaters (Torpedo heaters) will do a quick job of clearing the ramps. The use of approved de-icing solutions on ramps and decks will minimize the hazards of icing.

b. All ramps lifting mechanisms need proper lubrication to prevent water from damaging joints.

c. A complete electrical check should be conducted to make sure traffic lighting and other necessary control measures are operational.

d. The following checklist of items will assist in preparing the T-ween Deck Ramps for cold weather:

(1) Vehicle ramp electric brake.

(2) Manual brake.

(3) Winch controls.

(4) Gypsy heads run independently at winch.

(5) Stop limit switch.

(6) Over travel switch.

(7) Audible alarm.

(8) Emergency hand gear for ramp.

(9) Electric brake.

(10) Stack cable interlocks.

(11) Inflatable seal.

(12) Ramp dogging mechanism.

(13) Locking paw on winch.

(14) Ramp hinges.

(15) Winch wire ropes fall.

(16) Traction bars on ramp.

(17) Air exhaust mufflers.

(18) Air filter on LP air systems.

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CHAPTER 16

SURVIVAL

1601 INTRODUCTION

1. Impressive advances continue to be made in the development of clothing and equipment for survival.

2. One of the most important requirements for survival is a capacity to accept immediately the reality of an emergency and an ability to react appropriately to it.

3. Acquaintance with survival technique is an important factor affecting one's ability to stay alive. Relevant knowledge and training may be put directly to use in meeting the emergency, and will also contribute to a feeling of confidence whereby fear is reduced and panic prevented.

1602 COLD

1. Seawater temperatures in the Arctic vary from -1° C to 1.6° C. A person struggling in water at these temperatures might last from 3 to 5 minutes. Therefore, the numbing shock of bitter cold water and accompanying wind-chill is the paramount factor influencing most Arctic marine survival situations (see Figure 16-1 and Table 16-1).

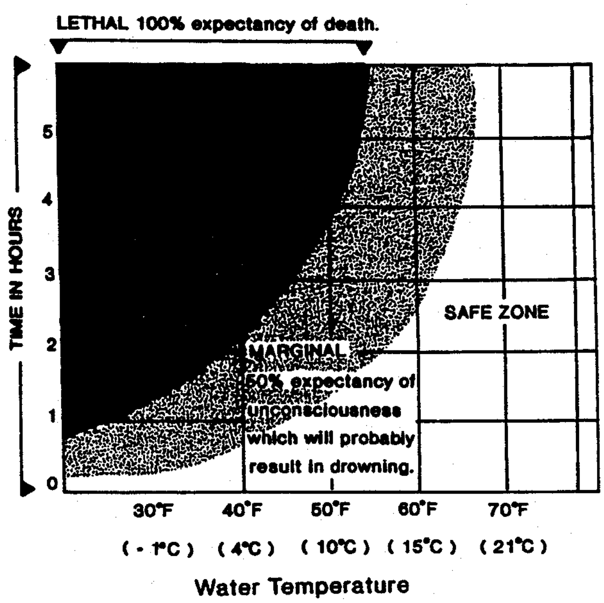


Figure 16-1 Survival Chart

2. For details concerning the symptoms and treatment of hypothermia, immersion foot, frostbite and snow-blindness, refer to Chapter 9.

1603 PERSON OVERBOARD

1. Whether at anchor or alongside, all ships must have an effective organization to watch for people who may fall overboard. This lookout organization should also maintain a constant watch on laden boats ferrying people and cargo ashore or between ships.

2. In a person-overboard situation, use a lifebuoy to mark the spot where the victim may be located. Another alternative for cold waters is an inflatable life raft fitted with a drogue to prevent it from being blown out of reach.

3. After casting a lifebuoy or raft over the side, the ship must make an effort to recover the person by manoeuvring into a suitable position just as quickly as type and size will permit. A good ship-handler, who has not only thought out the problem beforehand but has also rehearsed it, may make all the difference between a corpse and a case of severe hypothermia. Ships fitted with Rigid Inflatable Boats (RIB) will normally find that these craft provide the fastest means of recovering a casualty from the water, provided they and their crews are kept at a high level of readiness. A swimmer, prepared to enter the cold water, must be ready to go over the side the instant the ship is laid alongside the victim; the swimmer should be tethered and have another line with which to aid the victim.

4. Any person rescued from cold water will require immediate, expert medical care as will the rescuer.

5. In circumstances when it would be impossible to stop, an escort may have to be diverted. A suitably equipped rescue helicopter, nearby and ready for action, as would be the case in a carrier force-operating aircraft, is a helpful alternative.

1604 ABANDON SHIP

1. Inflatable life rafts have come a long way in design, reliability and capacity. They inflate automatically, complete with weather canopies, in about 30 seconds. In a growing number of ships the life-saving role is being switched from boats to inflatable rafts because of their efficiency. If ships on Arctic service are supplied with rafts sufficient to accommodate one and a half times the ship's crew, the chances of group survival will be much improved.

2. If inflatable rafts are to be effective lifesaving devices, crew must be trained on how to use them. One raft should be supplied to every ship for instructional purposes on a permanent basis.

3. Rafts should be equipped with high-intensity lights and larger rafts should have some electronic means of homing rescue forces. Radar reflectors, depending upon winds and local ice conditions, may prove helpful in aiding detection by rescue forces.

1605 IMMERSION SUITS

1. In the Arctic, aircrew should wear immersion suits or wet suits for over-water flights in fixed-wing aircraft.

2. Aircrew of small helicopters may be given some discretion in choice of cold-weather clothing if they are operating over an area where there is a significant amount of sea ice. In such circumstances the sea is usually calm and helicopters can put down on the ice, or if equipped with floats (as they should be for Arctic operations) sit on the water with little fear of being upset.

3. Large helicopters, must be equipped with some form of emergency flotation, and aircrew should always wear immersion suits for over-water operations. An exception could be made to this rule if flying is to take place over fast ice, or where there are heavy floes covering at least 5/10 of the sea and which are thick enough to support the weight of the machine.

4. A "quick-donning" immersion suit has been developed by both the Unites States Navy and the Royal Navy for use by helicopter passengers and others who may become involved in a short-term Arctic survival situation. Made of a lightweight rubberized vinyl material, International Orange in colour, these waterproof suits are intentionally large and loose-fitting garments intended to be worn over a person's clothing but inside a life jacket. Because of their generous dimensions, they are easy and quick to don and fit all shapes and sizes with equal facility. Neck and wrists are elasticized to keep water out. By providing protection for those who would otherwise surely succumb to the effect of an involuntary immersion in very cold water, these suits could be the means of saving many lives.

1606 HELICOPTER SURVIVAL EQUIPMENT

1. The amount of survival equipment which can be carried in a helicopter must obviously be kept to a minimum, but the following items are considered essential for Arctic operations.

a. Shelter tent (two-person capacity).

b. Emergency rations (10 days per person).

c. Emergency radio.

d. Rifle and ammunition (30-06 or equivalent, and 50 rounds).

e. Axe.

f. Signalling mirror plus flares and smoke bombs.

g. Two-burner Coleman stove and fuel.

2. It is an accepted rule among those who travel in the Arctic to always have their sleeping bags with them in case of an emergency or even an unexpected change in plan. But sleeping bags (and tents, stoves, etc) are bulky items and for naval operations a special decision would be required specifying precisely what survival equipment should be carried for the shipborne helicopter operations envisaged.

1607 EMERGENCY AIRCRAFT LANDINGS IN THE ARCTIC

1. **Immediate Action - Forced Landing on Land**

a. Remain away from the aircraft until engines have cooled and spilled fuel has evaporated.

b. Check for injuries, administer first aid and make the injured comfortable.

c. Keep snow brushed from clothing and avoid getting wet.

d. Erect a temporary shelter. If necessary start a fire; make hot drinks.

e. Salvage all personal and aircraft emergency gear from the aircraft.

f. Drain the oil and let it fall on the snow where it can congeal; it can be used for fuel later. Congealed oil can also be used for smoke signal fires.

Table 16-1 Wind - Chill Temperatures Chart (°C)

WIND SPEED		LOCAL TEMPERATURES (°C)										
		0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
m/s	Knots	EQUIVALENT TEMPERATURES (°C)										
Calm		0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
2	4	−5	−7	−12	−17	−23	−28	−33	−38	−44	−49	−55
4	9	−8	−14	−20	−26	−32	−38	−44	−50	−56	−62	−68
7	13	−11	−18	−25	−32	−38	−45	−52	−59	−66	−72	−79
9	15	−14	−21	−28	−35	−42	−49	−56	−63	−70	−77	−84
11	22	−16	−23	−31	−38	−45	−52	−60	−67	−74	−81	−89
13	26	−17	−25	−33	−40	−47	−55	−63	−70	−77	−85	−93
15	30	−18	−26	−34	−42	−50	−58	−66	−74	−82	−90	−98
18	35	−19	−27	−35	−43	−51	−59	−67	−75	−83	−91	−99
20	39	−19	−27	−35	−43	−51	−59	−67	−75	−84	−92	−100
22	43	−20	−28	−36	−44	−52	−60	−68	−76	−85	−93	−100
		LITTLE DANGER		CONSIDERABLE DANGER			VERY GRAVE DANGER					
		DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS										

INSTRUCTIONS

a. Enter table by selecting the existing surface temperature (along top), to the nearest 5° interval.

b. Move straight down the selected column to the level adjacent to the existing wind speed reading.

c. Table reading at this point gives the "wind−chill temperature" * for the selected temperature and wind speed.

* "Wind−chill temperature" is that temperature which, associated with a 5−knot wind, would have the same cooling effect as the existing conditions of wind and cold.

NOTES:

1. This table is used to relate the cooling effect of a given temperature and wind speed to an equivalent lower temperature and calm atmospheric conditions.
2. Wind may be calm but freezing danger great if the person is exposed in a moving vehicle, under helicopter rotors, in propeller blast, etc. It is relative rate of air movement that counts − the cooling effect is the same whether you are moving through the air or it is blowing past you.
3. The effect of wind will be less if one has even slight protection for exposed parts − light gloves on hands, parka hood shielding face, etc.

g. Make sure the emergency radio or the aircraft radio is operational. If no contact, supplement voice communications with emergency radio signals on a scheduled basis.

h. Do not try to live in the aircraft - it will be too cold. At first glance, the aircraft seems a logical shelter but is a poor one. There is no possibility of bringing the inside temperature above the ambient temperature. The fuselage, exposed to piercing winds, will act as a heat sink that will drain away body reserves and emergency supplies.

i. Assign specific duties to each individual in the survival group.

j. Prepare signals so the group can be spotted from the air.

k. Start a logbook. Include date, cause of forced landing; probable location and celestial observations.

l. Determine the position by the best means available and include this in radio messages.

m. Conserve electrical power.

n. On hearing an aircraft, sweep the horizon with a signal mirror at frequent intervals.

2. **Decision to Stay or Leave Aircraft**

a. It is usually best to stay with the aircraft and await rescue. Most rescues are made when people remain with their aircraft because, with current search and rescue procedures, the general vicinity of your position will be known. A downed aircraft also makes a good radar target.

b. A downed aircraft should be left only when:

(1) The position is certain and it is also certain that with available equipment and resources, shelter, food and help can be reached.

(2) After waiting several days, it is obvious that rescue is not immediate.

3. **Immediate Action-Forced Landing on the Ice**

a. Evacuate the aircraft immediately and take care of the injured. If the ice is thin, the aircraft will depress the ice and may eventually break through.

b. Check clothing to ensure it provides maximum possible protection against cold and wet weather.

c. Establish a temporary shelter, at least 45 metres from the aircraft. If possible build a fire inside.

d. Attempt to establish radio contact with anyone, station, ship or aircraft, and in so doing establish a systematic procedure.

e. Survey the area to determine the safest campsite. Seek a thick ice floe in the general vicinity of the aircraft. Do not camp on a young (smooth) ice floe which maybe thin and will be the first to break up. Consider the availability of food and water and the distance to the downed aircraft.

f. Build a camp. Do not use the aircraft as a shelter unless absolutely necessary.

g. Find and mark a safe landing area for rescue planes and/or helicopters.

h. Stay together.

i. Unless it is known that land is within walking distance, it is best to remain as close to the landing site as ice conditions will permit.

4. **Immediate Action-Forced Landing in the Sea**

a. Activate and board liferafts. Stay clear of aircraft and out of fuel-covered waters, but remain in the vicinity of the aircraft until it sinks.

b. Search for missing personnel.

c. Salvage floating equipment. Stow and secure all items and check raft for inflation leaks and points for possible chafing.

d. In cold weather DON exposure suits. Rig a windbreak, spray shield and canopy. Huddle together; exercise regularly.

e. Check physical condition of all aboard and administer first aid, if necessary.

f. If there is more than one raft, join them together loosely at the lifeline around the outer side of the raft.

g. Make sure the emergency radio is operational. Use emergency transceiver when aircraft are known to be in the area. Prepare other signals for instant use.

h. Keep compasses, watches and lighters dry and in waterproof containers.

i. Keep a log. Record the best navigation data available. Also record the direction of the wind, swells and times of sunrise/sunset.

j. Save water and food by saving energy, and ration if necessary.

k. Keep signal mirrors handy; use the signal panel and dye marker whenever an aircraft is in the vicinity.

l. Don any extra clothes available. Keep clothes loose and comfortable. Try to keep the floor of the raft dry, and for insulation cover it with canvas or cloth.

m. Take mild exercise to restore circulation. Repeatedly bend and open fingers and toes. Exercise shoulder and buttock muscles.

n. Warm hands under armpits. Periodically raise the feet and hold them in that position for a minute or two. Move face muscles frequently to detect frostbite. Shivering is normal. It is the body's method of quickly generating heat.

o. Give extra rations to men suffering from cold exposure.

p. Put out the sea anchor immediately. A sea anchor properly used will hold a raft into the wind, check drift and provide the best and often the only means of steadying the raft in a seaway to prevent broaching and capsizing. Do not attempt to navigate a raft unless land is in sight or land is within a reasonable distance. Take every precaution to prevent the raft from turning over. In rough weather the crew should sit low with their weight distributed to hold the weather side down.

q. Do not sit on the sides of or stand up in the raft. There should be no sudden movements without prior warning. Every precaution must be taken to keep the raft stable and dry.

1608 OCEAN SURVIVAL

1. **Living WIthout Food and Water**. Do not eat if there is a lack of water. The body uses up water in digestingfood, and the elimination of waste products also draws water from the tissues.

2. **Water**

a. Rain and ice are good sources of fresh, potable water.

b. Do not drink seawater. It increases thirst and, by drawing body fluids from the kidneys and intestines, can cause convulsions and delirium.

c. Do not drink urine.

3. **Food**

a. Fish found in the Arctic are edible, either raw or cooked. None is known to be poisonous. The heart, liver and blood of fish are edible, but the intestines should be avoided unless cooked. Stomachs of large fish may contain partially digested fish, which are also edible. Fish eyes contain a large percentage of water. Some fish eggs are, however, poisonous and those found growing in clusters or clumps on rocks or reefs should not be eaten.

b. Never fasten a fishing line to anything solid, it may snap when a large fish strikes. Fish are more apt to see and strike at moving bait. Any part of the flesh of a bird or fish makes good bait and it need not he fresh.

c. When fishing, vary the time of day and the depth of the bait to catch different species. Many fish come to the surface at night, and may be attracted by lights.

d. Seaweed is tough and salty, absorbs water from the intestines and is difficult to digest. Eat it only if plenty of water is available.

e. Small edible crabs, shrimps and fish inhabit coastal seaweed and patches of sargasso at sea. Use a drag behind a raft or boat to collect the seaweed, then shake it to catch the food.

f. All sea birds are edible and nourishing, though not always flavoursome. Gulls, albatrosses, terns and gannets can be caught by dragging a baited fishhook behind a raft. A flat sharp-edged triangular piece of metal dragged behind a float will bring gulls or albatrosses within shooting range. Gannets, once settled on a raft, often display little fear of man and are easily caught.

g. Marine molluscs such as oysters, clams, scallops, whelks, periwinkles, barnacles and conches are in practically inexhaustible supply throughout the world. They can be eaten cooked or raw.

1609 CARBON-MONOXIDE POISONING

1. Everyone must be constantly alert for the possibility of carbon-monoxide poisoning resulting from incomplete combustion of fuel. Use of petroleum products in internal-combustion engines and stoves in the Arctic is a common source of carbon-monoxide poisoning.

2. Those who take refuge in tents, snow houses, or other Arctic shelters must be aware that ventilation may be inadequate or ventilators may become blocked. This warning also applies to boats and vehicles where ventilators may become obstructed or exhaust pipes plugged by snow.

3. It is essential to provide active ventilation in tents and other shelters even if this means some loss of precious heat to incoming cold air. Leaded gasoline burned in stoves produces lead oxides which are irritating but non-toxic in small amounts. Smarting eyes, running nose or coughing produced by these are a warning of carbon-monoxide buildup.

4. Treatment is to move the subject into the fresh air, and if necessary, apply artificial respiration. Give 100 percent oxygen. Keep warm and quiet in bed for at least 8 hours. Too early exertion may produce heart failure.

1610 DANGEROUS ARCTIC ANIMALS

1. The most dangerous animal to an Arctic survivor is the polar bear. This large and powerful carnivore inhabits the coastal regions of the Arctic, is truly nomadic, and wanders the ice-pack year-round in search of food.

2. Bears, being afraid of nothing, are understandably inquisitive and curious of man. Their behaviour should not be mistaken for aggressiveness or hostile intent at the outset. They may be discouraged and frightened off by loud noises and activity.

3. Unless a person's life is actually threatened, it is wiser not to shoot a bear since he is an exceedingly difficult animal to kill. The head shot is not recommended because the shape of the skull may simply deflect a bullet. Furthermore, a bear bobs his head and moves it from side to side, offering a continually moving target. The shoulder shot is preferred.

4. A bear with cubs is extremely dangerous if molested. To approach a polar bear cub, whether or not its mother is nearby, is to invite certain retaliation.

5. Polar bear meat makes good eating but trichinosis is widespread in bear meat as in most other Arctic animals. All meat must, therefore, be cooked for a long time to destroy the parasitic worms. The liver of the bear is poisonous and must not be eaten.

6. Musk-oxen are found in some parts of the Arctic and are not dangerous unless approached.

7. Arctic wolves (white in winter, dirty grey in summer) are normally frightened of man but can become aggressive.

1611 WINTERING IN

1. The key to ship protection in the pack is to ensure that pressure, where unavoidable, will be applied uniformly throughout the ship's length. The ship should be worked in between uniformly thick floes of nearly equal size, with no polynyas or open leads nearby. These floes will cushion the

pressure which is bound to be experienced during the constant movement of the pack and, if a break-up occurs, provide a measure of protection.

2. A ship compelled to winter in should select a harbour where protection from driving ice is afforded to seaward by rocks, shoals or islands. The best protected harbour is a narrow, deep, fiord-like channel where mooring lines can be run ashore. The practicability of rigging cables athwart the seaward side of the refuge, to impede ice which might otherwise drift down upon the ship, should be investigated. Moor in shallow water, making allowance for the height of the seas and the tidal range to be experienced. Lay out wires and anchor cables to suitable mooring ashore.

3. A good fresh water supply is an important consideration if there is any doubt about the ability of the ship's evaporators to function throughout the winter. Glacial ice gives roughly twice the water per fuel unit in half the time that snow does when melted, and it is also cleaner. To be on the safe side, all drinking water should be purified either by boiling or by chlorination.

4. The direction of the wind must be considered. The ship and any objects which may be stored on the ice nearby, should be aligned with the least dimension facing the prevailing wind to reduce the formation of snow drifts.

5. The following steps should be taken in laying up the ship:

a. **Diesel Machinery**. The seawater intake to the engines should be securely closed. All drain cocks, plugs or valves in the lowest parts of water pumps, coolers, piping and exhaust manifolds should be kept open. An inspection should be made to ensure that no water remains in pockets or low points in the engine water systems. Lubricating oil should be sprayed into the combustion space. After this, the engine should be turned over a few revolutions. The fuel oil valve between the fuel day tank and the engine should be closed. All openings leading from the outside to the engine must be sealed shut to prevent snow and moisture from entering. All air in the starting systems should be blown out to eliminate moisture, and air tanks left charged at normal starting pressures. Mufflers and water traps in diesel exhaust system should be drained.

b. **Boilers**. All water sides and piping should be completely drained and blown out with air. Drain cocks must be opened. The fuel oil manifold on the burner front should be disconnected, drained and then be tightly plugged. All openings such as smoke pipes, vents, drain connections, access doors, observation ports and other openings to the atmosphere should be covered and sealed to obtain the best possible leak-proofing. The water sides of all heat exchangers should also be drained and blown out with air.

c. **Condensers**. The steam sides of condensers should be drained. Both sides to air ejectors to the inner and outer condensers (steel) should also be drained.

d. **Auxiliary Equipment**. Auxiliary equipment which is not to be used, should be drained. To prevent the formation of sludge, oil should be removed from the lubrication oil cooler.

e. **Steam Turbine and Gears**. All accumulated water must be drained from pockets or low parts of the turbines. The lubricating oil system and gears need no special preservation.

f. **Steam Piping Systems**. All steam supply and drain valves in fuel oil heating systems to each fuel oil tank, after a system has been laid up, should be kept in a closed position. All steam drain valves and steam trap by-pass valves not required to be closed should be left open. Regulator valves, reducing valves, steam traps and other controls in piping systems which cannot be thoroughly drained and dried without dismantling, should be taken down, repaired, dried and reassembled.

g. **Aviation Fuel System**. All salt water and gasoline must be pumped or drained from tanks and lines. The system should be charged with CO_2.

h. **Water, Air and Flushing Systems**. Except where protected by antifreeze solutions, all the water must be completely drained from the systems; where practicable they should be blown clear and dry by compressed air. All tanks in the system which are in a charged condition should be disconnected or otherwise isolated. Moisture must be removed from moisture traps and blown out of the entire air system. Shipboard toilets should be completely drained unless antifreeze solutions are to be left in the traps. All traps, reducing valves and lines in the flushing system must be completely drained. All bilges and water accumulations should be wiped dry.

i. **SeaWater Cooling and Suction Sea- Chests.** These should be blown out with compressed air and an airlock maintained between the valve disc and seawater.

j. **Stern Tube Bearing, Rudder and Propellers**. The salt-water flushing connection in the stern tube bearing should be shut off or secured. All water from this system must be drained and the stern tube gland tightened up so there is no trickle of water, normally present for lubricating purposes. Propeller blades should be aligned so that they will suffer the least damage from future ice pressure. The rudder must be secured amidships.

6. Garbage and sewage disposal could become a problem and arrangements would be necessary to prevent effluent from accumulating alongside the ship.

7. **Probably the greatest danger to a ship or camp wintering in the Arctic is fire.** With strong winds to spread it, and lack of water to fight it, fire can destroy a camp in short order. A ship's crew could be forced to take to the ice, and plans should be laid for just such an eventuality before it happens.

Annex A

Conversion Charts

METRIC/ENGLISH CONVERSION CHARTS

CENTIGRADE–FAHRENHEIT CONVERSION

C	F	C	F	C	F	C	F
−75	−103	40	104	155	311	537.8	1000
73.3	−100	43.3	110	160	320	550	1022
−70	−94	45	113	165	329	593.3	1100
−67.8	−90	48.9	120	165.6	330	600	1112
−65	−85	50	122	170	338	648.9	1200
−62.2	−80	54.4	130	171.1	340	650	1202
−60	−76	55	131	175	347	700	1292
−56.7	−70	60	140	176.7	350	704.4	1300
−55	−67	65	149	180	356	750	1382
−51.1	−60	65.6	150	182.2	380	760	1400
−50	−58	70	158	185	365	800	1472
−45.6	−50	71.1	160	187.8	370	815.6	1500
−45	−49	75	167	190	374	850	1562
−40	−40	76.7	170	193.3	380	871.1	1600
−35	−31	80	176	195	383	900	1652
−34.4	−30	82.2	180	198.9	390	926.7	1700
−30	−22	85	185	200	392	950	1742
−28.9	−20	87.8	190	204.4	400	982.2	1800
−25	−13	90	194	225	437	1000	1832
23.3	−10	93.3	200	232.2	450	1037.8	1900
−20	−4	95	203	250	482	1050	1922
−17.8	0	98.9	210	260	500	1093.3	2000
−15	5	100	212	275	527	1100	2012
−12.2	10	104.4	220	287.8	550	1148.9	2100
−10	14	105	221	300	572	1150	2102
−6.7	20	110	230	315.6	600	1200	2192
−5	23	115	239	325	617	1204.4	2200
−1.1	30	115.6	240	343.3	650	1250	2282
0	32	120	248	350	662	1260	2300
4.4	40	121.1	250	371.1	700	1300	2372
5	41	125	257	375	707	1315.6	2400
10	50	126.7	260	398.9	750	1350	2462
15	59	130	266	400	752	1371.1	2500
15.6	60	132.2	270	425	797	1400	2552
20	68	135	275	426.7	800	1426.7	2600
21.1	70	137.8	280	450	842	1500	2732
25	77	140	284	454.5	850	1537.8	2800
26.7	80	143.3	290	475	887	1550	2822
30	86	145	293	482.2	900	1593.3	2900
32.2	90	148.9	300	500	932	1600	2912
35	95	150	302	510	950	1648.9	3000
37.8	100	154.4	310	525	977	1650	3002

Temperature may be expressed in terms of any of these scales: Centigrade (°C), Absolute or Kelvin (°A or °K), Fahrenheit (°F), or Rankine (°R)

$^\circ K = {}^\circ A - ({}^\circ C + 273.16)$

$^\circ K = {}^\circ A = {}^\circ R\ 5/9$

$^\circ K = {}^\circ A = ({}^\circ F - 32)\ 5/9 + 273.16$

$^\circ C = A - 273.16$

$^\circ C = ({}^\circ F - 32)\ 5/9$

$^\circ C = {}^\circ R\ 5/9 - 273.16$

$^\circ F = {}^\circ C\ 9/5 + 32$

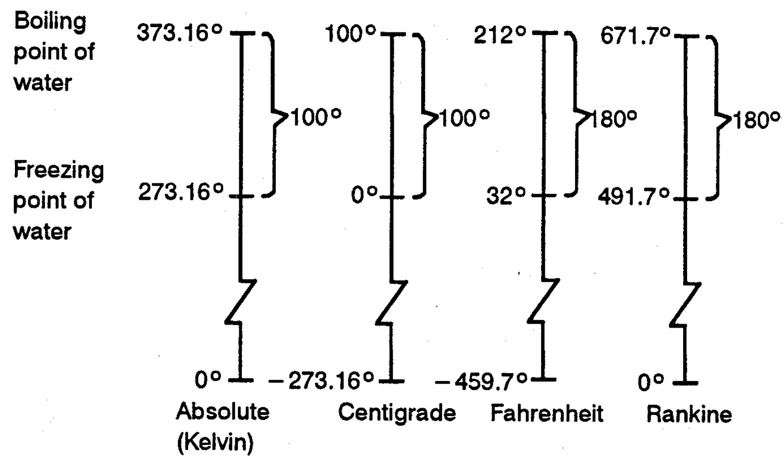
$^\circ F = ({}^\circ A - 273.16)\ 9/5 + 32$

$^\circ F = {}^\circ R - 459.7$

$^\circ R = {}^\circ F + 459.7$

$^\circ R = {}^\circ A\ 9/5$

$^\circ R = ({}^\circ C + 273.16)\ 9/5$



Motion – Rectilinear

Linear Velocity (LT^{-1})

Multiply	By	To Obtain	Multiply	By	To Obtain
centimetres/second	1.968	feet/minute	kilometres/min	1.666.7	centimetres/sec
feet/hour	30.48	centimetres/hr	kilometres/min	54.68	feet/sec
feet/hr	0.01667	feet/min	kilometres/min	32.397	knots
feet/hr	$1.646/10^4$	knots	kilometres/min	37.28	miles/hour
feet/hr	$1.894/10^4$	miles/hour	knots	51.44	centimetres/sec
feet/min	0.5080	centimetres/sec	knots	101.27	feet/min
feet/min	0.01667	feet/sec	knots	1.6878	feet/sec
feet/min	0.009875	knots	knots	1.852	kilometres/hour
feet/min	0.3048	metres/min	knots	1	nautical miles/hr
feet/min	0.01136	miles/hr	knots	1.1508	miles/hr
feet/sec	30.48	centimetres/sec	metres/min	1.667	centimetres/sec
feet/sec	1.097	kilometres/hr	metres/min	196.85	feet/hr
feet/sec	0.5925	knots	metres/min	0.0547	feet/sec
feet/sec	0.6818	miles/hr	metres/min	0.032397	knots
inches/hr	0.04233	centimetres/min	metres/min	0.03728	miles/hr
inches/min	152.4	centimetres/hr	meters/sec	196.85	feet/min
inches/min	0.0423	centimetres/sec	metres/sec	3.281	feet/sec
inches/min	0.001389	feet/sec	metres/sec	1.944	knots
inches/sec	152.4	centimetres/min	metres/sec	2.2369	miles/hr
inches/sec	0.08333	feet/sec	miles/hr	44.70	centimetres/sec
inches/sec	0.05682	miles/hr	miles/hr	88	feet/min
kilometres/hr	27.78	centimetres/sec	miles/hr	1.4667	feet/sec
kilometres/hr	54.68	feet/min	miles/hr	17.6	inches/sec
kilometres/hr	0.9113	feet/sec	miles/hr	1.6093	kilometres/hr
kilometres/hr	0.53996	knots	miles/hr	0.86898	knots
kilometres/hr	0.6214	miles/hr	miles/hr	0.4470	metres/sec

Linear Acceleration (LT $^{-2}$)

Multiply	By	To Obtain	Multiply	By	To Obtain
centimetres/sec/sec	0.036	kilometres/hr/sec	kilometres/hr/sec	0.9113	feet/sec/sec
centimetres/sec/sec	1.342	mph/min	metres/sec/sec	3.6	kilometres/hr/sec
centimetres/sec/	0.0224	mph/sec	metres/sec/sec	2.237	mph/sec
feet/sec/sec	1.097	kilometres/hr/sec	mph/sec	44.70	centimetres/sec/sec
feet/sec/sec	0.3048	metres/sec/sec	mph/sec	1.467	feet/sec/sec
feet/sec/sec	0.6818	mph/sec	mph/sec	1.609	kilometres/hr/sec
kilometres/hr/sec	27.78	centimetres/sec/sec	mph/sec	0.4470	metres/sec/sec

Equations

Velocity: the rate of change of displacement with respect to time:

$$v = ds/dt, \; v\,dv - a\,ds$$

when a is constant

$$V_t = V_o, at$$

Displacement: the amount of change in position

$$ds = v\,dt$$

when a = constant

$$S = V_t{}^2 - V_o{}^2/2a$$

$$S = V_o\,t, at^2/2$$

Acceleration:

$$a = dv/dt$$

when a = constant

$$a = \frac{V_t - V_o}{t}$$

Length (L)

Multiply	By	To Obtain
angstrom	0.1	nanometre
angstrom units	$1/10^{10}$	metres
centimetres	0.3937	inches
centimetres	0.01	metres
centimetres	393.7	mils
decimetres	0.1	metres
dekometres	10	metres
fathoms	6	feet
feet	0. 3048	metres
furlongs	660	feet
furlongs	40	rod
hands	4	inches
hectometres	100	metres
inches	25.40	millimetres
inches	1000	mils
kilometres	3281	feet
kilometres	1000	metres
kilometres	0.6214	miles
kilometres	0.53996	nautical miles
kilometres	1094	yards
leagues	3	miles
light years	5.88×10^{12}	miles
links (engineer's)	12	inches
links (surveyor's)	7.92	inches
metres	3.2808	feet
metres	39.37	inches
metres	$6.214/10^4$	miles
metres	1.0936	yards
micron	1	micrometre
microns	$1/10^6$	metres
microns	0.03937	mils
miles	5280	feet
miles	1609	metres
miles	1760	yards
millimetres	0.03937	inches
millimetres	0.001	metres
millimetres	39.37	mils
mils	0.001	inches
mils	0.02540	millimetres
myriametres	10,000	metres
nautical miles	6076.1	feet
nautical miles	1852	metres
nautical miles	1.1508	miles
nautical miles	2025.4	yards
rods	16.5	feet
statute miles	1760	yards
statute miles	5280	feet
statute miles	1.6094	kilometres
statute miles	0.8690	nautical miles
yards	0.9144	metres
yards	$5.682/10^4$	miles
yards	$4.937/10^4$	nautical miles

Area (L^2)

Multiply	By	To Obtain
acres	43,550	square feet
acres	0.004047	square kilometres
acres	4047	square metres
acres	0.001563	square miles
acres	4,840	square yards
centares	1	square metres
circular mils	$5.067/10^6$	square centimetres
circular mils	$0.7854/10^6$	square inches
circular mils	$5.067/10^4$	square millimetres
circular mils	0.7854	square mils
hectares	10,000	square metres
square centimetres	1.973×10^5	circular mils
square centimetres	0.001076	square feet
square centimetres	0.1550	square inches
square centimetres	$1/10^4$	square metres
square centimetres	100	square millimetres
square feet	929.0	square centimetres
square feet	144	square inches
square feet	0.09290	square metres
square feet	1/9	square yards
square inches	6.452	square centimetres
square inches	0.006944	square feet
square inches	$6.452/10^4$	square metres
square inches	654.2	square millimetres
square inches	10^6	square mils
square kilometres	247.1	acres
square kilometres	10.76×10^6	square feet
square kilometres	10^6	square metres
square kilometres	0.3861	square miles
square kilometres	1.196×10^6	square yards
square metres	$2.471/10^4$	acres
square metres	10.76	square feet
square metres	1.196	square yards
square miles	640	acres
square miles	27.88×10^6	square feet
square miles	2.590	square kilometres
square miles	3.098×10^6	square yards
square millimetres	1,974	circular mils
square millimetres	0.00155	square inches
square millimetres	$1/10^6$	square metres
square mils	1550	square mils
square mils	1.273	circular mils
square mils	$6.542/10^6$	square centimetres
square mils	$1/10^6$	square inches
square mils	$6.452/10^4$	square millimetres
square yards	9	square feet
square yards	1,296	square inches
square yards	0.8361	square metres

Volume (L^3)

Multiply	By	To Obtain
acre–feet	43,560	cubic feet
acre–feet	1,233	cubic metres
acre–feet	3.259×10^5	gallons
barrel (US)	0.1589	cubic metres
board–feet	144	cubic inches
bushels	1.244	cubic feet
bushels	0.03524	cubic metres
bushels	35.24	litres
bushels	4	pecks
bushels	32	quarts (dry)
centilitres	0.01	litres
cord–feet	4 ft x 4 ft x 1 ft	cubic feet
cords	8 ft x 4 ft x 4 ft	cubic feet
cubic centimetres	0.06102	cubic inches
cubic centimetres	0.001	litres
cubic centimetres	0.03381	fluid ounces
cubic centimetres	0.002113	pints (liquid)
cubic feet	0.80357	bushels
cubic feet	1,728	cubic inches
cubic feet	0.02832	cubic metres
cubic feet	1/27	Cubic yards
cubic feet	7.481	gallons
cubic feet	28.32	litres
cubic feet	62.4	lbs of water 39.2F
cubic feet	29.92	quarts (liquid)
cubic inches	16.39	cubic centimetres
cubic inches	$5.787/10^4$	cubic feet
cubic metres	28.38	bushels
cubic metres	35.31	cubic feet
cubic metres	61,203	cubic inches
cubic metres	1.308	cubic yards
cubic metres	264.2	gallons
cubic metres	1,000	litres
cubic metres	2,203	lbs of water 39.2F
cubic yards	21.70	bushels
cubic yards	27	cubic feet
cubic yards	46.656	cubic inches
cubic yards	0.7646	cubic metres
cubic yards	202.0	gallons
cubic yards	764.5	litres
cubic yards	1,685	lbs of water 39.2F
cupfuls	1/2	pints (liquid)
decilitres	1/10	litres
dekalitres	10	litres
fluid ounce (UK)	28.413	cubic centimetres
fluid ounce (US)	29.574	cubic centimetres
gallons	0.1337	cubic feet
gallons	231	cubic inches
gallons	3.785	cubic centimetres
gallons (US)	0.003785	cubic metres
gallon (UK)	4546.1	cubic centimetres
gallons	3.785	litres
gallons	8	pints (liquid)
gallons	8.34	lbs of water 39.2F
gallons (Imperial)	1.201	gallons
gills	7.219	cubic inches
gills	1/4	pints (liquid)
hectolitres	100	litres
kilolitres	1,000	litres
litres	0.02838	bushels
litres	1,000	cubic centimetres
litres	0.03532	cubic feet
litres	61.03	cubic inches
litres	0.001308	cubic yards
litres	0.2642	gallons
litres	2.113	pints (liquid)
litres	2.20	lbs of water 39.2F
litres	0.9081	quarts (dry)
litres	1.057	quarts (liquid)
microlitres	$1/10^6$	litres
mil–feet (circular)	$1.545/10^4$	cubic centimetres
mil–feet (circular)	$9.425/10^6$	cubic inches
mililitres	0.001	litres
pecks	1/4	bushels
pecks	8.81	litres
pecks	8	quarts (dry)
perches	24.75	cubic feet
perches	0.7008	cubic metres
pints (dry)	33.60	cubic inches
pints (dry)	1/2	quarts (dry)
pints (liquid)	28.88	cubic inches
pints (liquid)	0.8594	pints (dry)
pints (liquid)	1.042	lbs of water 39.2F
pints (liquid)	1/2	quarts (liquid)
lbs of water 39.2F	0.01602	cubic feet
lbs of water 39.2F	27.68	cubic inches
lbs of water 39.2F	0.1198	gallons
lbs of water 39.2F	0.4536	litres
quarts (dry)	1/32	bushels
quarts (dry)	67.20	cubic inches
quarts (dry)	1.101	litres
quarts (dry)	1.164	quarts (liquid)
quarts (liquid)	946.4	cubic centimetres
quarts (liquid)	57.75	cubic inches
quarts (liquid)	0.9463	litres
quarts (liquid)	2	pints (liquid)
quarts (liquid)	0.8594	quarts (dry)
steres	1,000	litres
tablespoons	1/16	cupfuls
teaspoons	1/3	tablespoons

Volume (L_3)
General Properties of Air

9 =	Graviational acceleration		– ft/sec_2^2
P =	Absolute pressure		– lb/ft^2
q =	Dynamic pressure		– lb/ft^2
v =	Specific volume		– ft^3/lb
T =	Absolute temperature		– °R
R =	Universal gas constant		– ft lb/lb/°R
V =	Velocity		– ft/sec
n =	Polytropic exponent		– Dimensionless
p =	Mass density		– lb sec^2/ft^4
μ =	Absolute viscosity		– lb sec/ft^2
ν =	Kinematic viscosity μ/ϱ		– ft^2/sec
σ =	Relative density		– Dimensionless

Composition of Air

(Standard atmosphere) (ARDC model atmosphere)

The air of the standard atmosphere is assumed to be dry and to have the following composition at altitudes to 300,000 ft

Constituent Gas	Mol. Fraction Percent	Molecular Weight (= 16.0000
Nitrogen (N_2)	78.09	28.016
Oxygen (O_2)	20.95	32.0000
Argon (A)	0.93	39.944
Carbon dioxide (CO_2)	0.03	44.010
Neon (Ne)	1.8×10^{-3}	20.183
Helium (He)	5.24×10^{-4}	4.003
Krypton (kr)	1.0×10^{-4}	83.7
Hydrogen (H^2)	5.0×10^{-5}	2.0160
Xenon (Xe)	8.0×10^{-6}	131.3
Ozone (O_3)	1.0×10^{-6}	48.0
Radon (Rn)	6.0×10^{-18}	222.0

Sea Level Properties

t_o	Standard temperature	59.0°F
T_o	Standard temperature (absolute)	518.67°R
P_o	Standard pressure	29.921260 in Hg 2116.22 lb/sq ft
ϱ_o	Standard density	0.076474 lb/cu ft
M_o	Molecular weight	28.9644 (dimensionless)
ω_o	Standard specific weight	0.07647455 lb/cu ft
R^o	Gas constant (dry air)	8314.32 joules/kg/°K 53.35 ft lb/lb/°K
C^{so}	Speed of sound	1116.4 ft/sec
μ	Coefficient of absolute viscosity	3.7371674×10^{-7} lb sec/sq ft
η^o	Coefficient of kinematic viscosity	1.57232×10^{-4} sq ft/sec
9^o	Standard gravitation acceleration	32.1741 ft/sec/sec

Fathoms/Metres Conversion Table

C 0–499 FATHOMS TO METRES

*(The conversions below 12 fathoms are only to be used in converting depths over 500 fathoms **Table D**)

fm	0	1	2	3	4	5	6	7	8	9
0	*0	*2	*4	*5	*7	*9	*11	*13	*15	*16
10	*18	*20	22	23	25	27	29	31	33	34
20	36	38	40	42	44	46	48	49	51	53
30	55	57	59	60	62	64	66	68	69	71
40	73	75	77	79	80	82	84	86	88	90
50	91	93	95	97	99	101	102	104	106	108
60	110	112	113	115	117	119	121	123	124	126
70	128	130	132	134	135	137	139	141	143	144
80	146	148	150	152	154	155	157	159	161	163
90	165	166	168	170	172	174	176	177	179	181
100	183	185	187	188	190	192	194	196	198	199
110	201	203	205	207	208	210	212	214	216	218
120	219	221	223	225	227	229	230	232	234	236
130	238	240	241	243	245	247	249	251	252	254
140	256	258	260	262	263	265	267	269	271	272
150	274	276	278	280	282	283	285	287	289	291
160	293	294	296	298	300	302	304	305	307	309
170	311	313	315	316	318	320	322	324	326	327
180	329	331	333	335	336	338	340	342	344	346
190	347	349	351	353	355	357	358	360	362	364
200	366	368	369	371	373	375	377	379	380	382
210	384	386	388	390	391	393	395	397	399	401
220	402	404	406	408	410	411	413	415	417	419
230	421	422	424	426	428	430	432	433	435	437
240	439	441	443	444	446	448	450	452	454	455
250	457	459	461	463	465	466	468	470	472	474
460	475	477	479	481	483	485	486	488	490	492
270	494	496	497	499	501	503	505	507	508	510
280	512	514	516	518	519	521	523	525	527	529
290	530	532	534	536	538	539	541	543	545	547
300	549	550	552	554	556	558	560	561	563	565
310	567	569	571	572	574	576	578	580	582	583
320	585	587	589	591	593	594	596	598	600	602
330	604	605	607	609	611	613	614	616	618	620
340	622	624	625	627	629	631	633	635	636	638
350	640	642	644	646	647	649	651	653	655	657
360	658	660	662	664	666	668	669	671	673	675
370	677	678	680	682	684	686	688	689	691	693
380	695	697	699	700	702	704	706	708	710	711
390	713	715	717	719	721	722	724	726	728	730
400	732	733	735	737	739	741	742	744	746	748
410	750	752	753	755	757	759	761	763	764	766
420	768	770	772	774	775	777	779	781	783	785
430	786	788	790	792	794	796	797	799	801	803
440	805	807	808	810	812	814	816	817	819	821
450	823	825	827	828	830	832	834	836	838	839
460	841	843	845	847	849	850	852	854	856	858
470	860	861	863	865	867	869	871	872	874	876
480	878	880	881	883	885	887	889	891	892	894
490	896	898	900	902	903	905	907	909	911	913

For soundings over 500 fm select to the nearest 100 fm below and convert to metres from Table D. To this add converted depths from Table C.

D 500–6000 FATHOMS TO METRES

fm	m	fm	m	fm	m	fm	m
500	914	1000	1829	1500	2743	2000	3658
600	1097	1100	2012	1600	2926	3000	5486
700	1280	1200	2195	1700	3109	4000	7315
800	1463	1300	2377	1800	3292	5000	9144
900	1646	1400	2560	1900	3475	6000	10,973

Reproduction from modified British Admiralty Conversion Tables

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ANNEX B

GLOSSARY OF ICE TERMS

A

Aged Ridge. Ridge which has undergone considerable weathering. These ridges are best described as undulations.

Anchor Ice. Submerged ice attached or anchored to the bottom, irrespective of its formation.

Area of Weakness. A satellite-observed area in which either the ice concentration or the ice thickness is significantly less than that in the surrounding areas. Because the condition is satellite observed, a precise quantitative analysis is not always possible, but navigation conditions are significantly easier than in surrounding areas.

Auroral Zones. Zones of variable RF propagation in higher !atitudes, due to charged particles ejected from the sun and deflected by the earth's magnetic fields.

B

Bare Ice. Ice without snow cover.

Beaufort Gyre. A current system centred near 78° N 140° W which moves ice in a counter-clockwise rotation before dispersing it into the Transpolar Drift or along the coasts of Ellesmere Island and Greenland.

Belt. A large feature of ice arrangements, longer than it is wide; from 1 km to more than 100 km in width.

Bergy Bit. A large piece of floating glacier ice, generally showing less than 5 metres above sea-level but more than 1 metre, and normally about 100-300 square metres in area.

Bergy Water. An area of freely navigable water in which glacier ice is present in concentrations of less than 1/10. There may be sea ice present, although the total concentration of all ice shall not exceed 1/10.

Beset. Situation of a vessel surrounded by ice and unable to move.

Big Floe. (see Floe).

Bight. Extensive crescent-shaped indentation in the ice edge, formed by either wind or current.

Brash Ice. Accumulations of floating ice made up of fragments not more than 2 metres across, the wreckage of other forms of ice.

Bummock. From the point of view of the submariner, a downward projection from the underside of the ice canopy-, the counterpart of a hurnmock.

C

Calving. The breakingaway of a mass of ice from an ice wall, ice front, or iceberg.

Close Ice. Floating ice in which the concentration is 7/10 to 8/10, composed of floes mostly in contact.

Compacted Ice Edge. Close, clear-cut ice edge compacted by wind or current; usually on the windward side of an area of ice.

Compact Ice. Floating ice in which the concentration is 10/10 and no water is visible.

Compacting. Pieces of floating ice are said to be compacting when they are subjected to converging motion, which increases ice concentration and/or produces stresses which may result in ice deformation.

Concentration. The ratio expressed in tenths of the sea surface actually covered by ice to the total area of sea surface, both ice-covered and ice-free, at a specific location or over a defined area.

Concentration Boundary. A line approximately the transition between two areas of drift-ice with distinctly different concentrations.

Consolidated Ice. Floating ice in which the concentration is 10/10 and the floes are frozen together.

Consolidated Ridge. A ridge in which the base has frozen together due to melting or other processes.

Crack. Any fracture which has not parted.

D

Dark Nilas. Nilas which is under 5 cm in thickness and is very dark in colour.

Deformed Ice. A general term for ice which has been squeezed together and in places forced upwards (and downwards). Subdivisions are rafted ice, ridged ice, and hummocked ice.

Dehydration. A lack of sufficient fluid intake to make up for fluids lost.

Diffuse Ice Edge. Poorly defined ice edge limiting an area of dispersed ice; usually on the leeward side of an area of pack ice.

Diverging. Ice-fields or floes in an area are subjected to diverging or dispersive motion, thus reducing ice concentration and/or relieving stresses in the ice.

Dried Ice. Sea ice from the surface of which melt-water has disappeared after the formation of cracks and thaw holes. During the period of drying, the surface whitens.

Drift-Ice. Sea ice that is drifting freely.

E

Embrittlement. The process of materials becoming brittle from extreme cold weather.

F

Fast Ice. Sea ice that forms and remains is attached to the coast in late winter.

Fast Ice Boundary. The ice boundary at any given time between fast ice and drift-ice.

Fast Ice Edge. The demarcation at any given time between fast ice and open water.

Finger-Rafted Ice. Type of rafted ice in which floes thrust "fingers" alternately over and under one another.

Finger-Rafting. Type of rafting whereby interlocking thrusts are formed, each floe thrusting "fingers" alternately over and under one another. Common in nilas and grey ice.

Firn. Old snow which has recrystallized into a dense material. Unlike ordinary snow, the particles are to some extent jointed together; but, unlike ice, the air spaces in it still connect with each other.

First-Year Ice. Sea ice of not more than one winter's growth; thickness varies from 30 cm to 2 m, generally white in colour.

Flaw. A narrow separation zone between drift-ice and fast ice, where the pieces of ice are in chaotic state; it forms when drift - ice shears under the effect of a strong wind or current along the fast ice boundary.

Flaw Lead. A passageway between drift-ice and fast ice which is navigable by surface vessels.

Flaw Polynya. A polynya between drift-ice and fast ice.

Floating Ice. Any form of ice found floating in water. The principal kinds of floating ice are lake ice, river ice, and sea ice, which form by the freezing of water at the surface, and glacier ice (ice of land origin) formed on land or in an ice shelf. The concept includes ice that is stranded or grounded.

Floe. Any relatively flat piece of sea ice 20 m or more across. Floes are subdivided according to horizontal extent aa fall..wa

Giant: Over 10 km across
Vast: 2-10 km across
Big: 500-2 000 m across
Medium: 100-500 m across
Small: 20-100 m across

Floeberg. A massive piece of sea ice composed of a hummock, or a group of hummocks frozen together, and separated from any ice surroundings. It may typically protrude up to 5 m above sea-level.

Floebit. A relativelysmall piece of sea ice, normally not more than 10 m across, composed of a hummock(s) or part of a ridge(s) frozen together and separated from any surroundings. It typically protrudes up to 2 m above sea-level.

Flooded Ice. Sea ice which has been flooded by melt-water or river water and is heavily loaded by water and wet snow.

Fracture. Any break or rupture through very close ice, compact ice, consolidated ice, fast ice, or a single floe, resulting from deformation processes. Fractures may contain brash ice and/or be covered with nilas and/or young ice. Length may vary from a few metres to many kilometres.

Fracture Zone. An area which has a great number of fractures.

Fracturing. Pressure whereby ice is permanently deformed, and rupture occurs. Most commonly used to describe breaking across very dose ice, compact ice, and consolidated ice.

Frazil Ice. Fine spicules or plates of ice suspended in water.

Free Communication. Occurs if the hull is ruptured so that one or more compartments are open to the sea.

Free Surface. Effect from ship's tank(s) or void(s) when only partially filled and the liquid contents "slosh" back and forth.

FreshwaterIcing. When ice form on the ship's surfaces form drops of rain, damp snow or other fresh water source.

Frostbite. The freezing of any part of the body. The water in the tissue cells turns to ice and disrupts the normal function of the tissue.

Frostnip. Superficial frostbite, affecting only the skin or the tissue irnmediately beneath it.

Friendly Ice. From the point of view of the submariner, an ice canopy containing many large skylights or other features which permit a submarine to surface. There must be more than 10 such features per 30 nautical miles (56 km) along the submarine's track.

Frost Smoke. Fog-like clouds due to the contact of cloud air with relatively warm water, which can appear over openings in the ice, or leeward of the ice edge, and which may persist while ice is forming.

G

Glacier. A mass of snow and fresh water ice continuously moving from higher to lower ground or, if afloat, continuously spreading. The principal forms of glacier are: inland ice sheets, ice shelves, ice streams, icecaps, ice piedmonts, cirque glaciers, and various types of mountain (valley) glaciers.

Glacier Berg. An irregularly shaped iceberg.

Glacier Ice. Ice in, or originating from, a glacier, whether on land or floating on the sea as icebergs, bergy bits, or growlers.

Glacier Tongue. Projecting seaward extension of a glacier, usually afloat. In the Antarctic, glacier tongues may extend over many tens of kilometres.

Grease Ice. A later stage of freezing than frazil ice, when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matte appearance.

Green Water. Solid seawater (waves), not sea spray, which comes over the ship when in heavy seas. Is dangerous because it can damage equipment, break windshields and antennas and can wash people overboard.

Grey Ice. Young ice 10-15 cm thick. Less elastic than nilas, it breaks on swell. Usually rafts under pressure.

Grey-White Ice. Young ice 15-30 cm thick. Under pressure, more likely to ridge than raft.

Grounded Hummock. Hummocked, grounded ice formation. There are single grounded hummocks and lines (or chains) of grounded hummocks.

Grounded Ice. Floating ice which is aground in shoal water.

Growler. Smaller piece of ice than a bergy bit or floeberg, (about the size of a piano) often transparent but appearing green or almost black in color, extending less than 1 m above the sea surface.

H

Halo. Commonly a ring of light of radius 22 or 46 with the sun or moon at the centre, caused by refraction of light by ice crystals in the atmosphere. Occasionally, a faint circle with a radius of 90 appears around the sun.

Hostile Ice. From the point of view of the submariner, an ice canopy containing no large skylights or other features which permit a submarine to surface.

Hummock. A hillock of broken ice which has been forced upwards by pressure. May be fresh or weathered. The submerged volume of broken ice under the hummock, forced downwards by pressure, is termed a hummock.

Hummocked Ice. Sea ice piled haphazardly one piece over another to form an uneven surface. When weathered, has the appearance of smooth hillocks.

Hummocking. The pressure process by which sea ice is forced into hurnmocks. When the floes rotate in the process it is termed screwing.

Hypothermia. A condition that occurs when the body is unable to maintain adequate warmth and the body core temperature drops below normal.

I

Ice Accretion. The building up of ice which occurs when airborne moisture comes in contact with cold metal.

Iceberg. A large mass of floating ice broken away from a glacier or a large mass of ice, floating or around, that has calved from a glacier, i.e., fresh water ice.

Iceberg Tongue. A major accumulation of icebergs projecting from the coast, held in place by grounding and joined together by fast ice.

Iceblink. A whitish glare on the underside of low clouds caused by the sun's reflection off the surface of pack ice.

Ice-Bound. A harbour, inlet, etc. is said to be ice-bound when navigation by ships is prevented on account of ice, except possibly with the assistance of an ice-breaker.

Ice Boundary. The demarcation at any given time between fast ice and drift-ice, or between areas of drift-ice of different concentrations.

Ice Breccia. Ice of different stages of development frozen together.

Ice Cake. Any relatively flat piece of sea ice from 2 m to 20 m across.

Ice Canopy. Drift-ice from the point of view of the submariner.

Ice Cover. The ratio of an area of ice of any concentration to the total area of sea surface within some large geographic locale; this locale may be global, hemispheric, or prescribed by a specific oceanographic entity such as Baffin Bay or the Barents Sea.

Ice Edge. The demarcation at any given time between the open sea and sea ice of any kind.

Ice-Field. Area of floating ice consisting of any size of floes, which is greater than 10 km across.

Ice-Foot. A narrow fringe of ice attached to the coast, unmoved by tides, and remaining after the fast ice has moved away.

Ice-Free. An area with no ice present. If ice of any kind is present, the area is not ice-free.

Ice Front. The vertical cliff forming the seaward face of an ice shelf or other floating glacier varying in height from 2-50 m or more above sea-level.

Ice Island. A large piece of floating ice, protruding about 5 m above sea-level, which has broken away from an ice shelf. It has a thickness of 30-50 m and an area of from a few thousand square metres to 500 km2 or more, and is usually characterized by a regularly undulating surface which gives it a ribbed appearance from the air.

Ice Isthmus. A narrow connection between two ice areas of very close or compact pack-ice. It may be difficult to pass, yet sometimes being part of a recommended route.

Ice Jam. An accumulation of broken river ice or sea ice caught in a narrow channel.

Ice Keel. From the point of view of the submariner, a downward-projecting ridge on the underside of the ice canopy; the counterpart of a ridge. Ice keels may extend as much as 50 m below sea-level.

Ice Limit. Climatological term referring to the extreme minimum or extreme maximum extent of the ice edge in any given month or period based on observations over a number of years. Term should be preceded by minimum or maximum.

Ice Massif A variable accumulation of close or very close pack-ice covering hundreds of square kilometres which is found in the same regions every summer.

Ice of Land Origin. Ice formed on land or in an ice shelf, found floating in water. The concept includes ice that is stranded or grounded.

Ice Patch. An area of floating ice less than 10km across.

Large Fracture. More than 500 m wide.

Large Ice-Field. An ice-field over 20 km across.

Ice Port. An embayment in an ice front, often of a temporary nature, where ships can moor alongside and unload directly onto the ice shelf.

Ice Rind. A brittle shiny crust of ice formed on a quiet surface by direct freezing or from grease ice, usually in water of low salinity. Thickness to about 5 cm. Easily broken by wind or swell, commonly breaking into rectangular pieces.

Ice Shelf A floating ice sheet of considerable thickness showing 2-50 m or more above sea-level, attached to the coast. Usually of great horizontal extent and with a level or gently undulating surface. Nourished by annual snow accumulation and often also by the seaward extension of land glaciers. Limited areas may be aground. The seaward edge is termed an ice front.

Ice Stream. Part of an inland ice sheet in which the ice flows more rapidly and not necessarily in the same direction as the surrounding ice. The margins are sometimes clearly marked by a change in the direction of the surface slope but may be indistinct.

Ice Under Pressure. Ice in which deformation processes are actively occurring and hence is a potential impediment or danger to shipping.

Ice Wall. An ice cliff forming on the seaward margin of a glacier which is not afloat. An ice wall is aground, the rock basement being at or below sea-level.

J

Jammed Brash Barrier. A strip or narrow belt of new, young, or brash ice (usually 100-5000 m wide), formed at the edge of either drift-ice or fast ice, or at the shore. It is heavily compacted mostly due to wind action and may extend 2-20 m below the surface but does not normally have appreciable topography. A jammed brash barrier may disperse with changing winds but can also consolidate to form a strip of unusually thick ice as compared to the surrounding pack-ice.

L

Lake Ice. Ice formed on a lake, regardless of observed location.

Lead. Any fracture or passageway through sea ice which is navigable by surface vessels; long open cracks.

Level Ice. Sea ice which is unaffected by deformation.

Light Nilas. Nilas which is more than 5 cm in thickness and rather lighter in colour than dark nilas.

Looming. When as a result of temperature inversion accompanied by rapid decrease in humidity, refraction becomes greater than normal, objects which are normally below the horizon become visible.

M

Marginal Ice Zone (MIZ). The region from the ice edge (where ice is first encountered) to a point that is sufficiently far from the ocean boundary so as not to be affected by the presence of the open ocean, i.e., no evidence of wave action, swell, etc.

Mean Ice Edge. Average position of the ice edge in any given month or period based on observations over a number of years. Other terms which may be used are mean maximum ice edge and mean minimum ice edge.

Medium First-Year Ice. First-year ice 70-120 cm thick

Medium Fracture. 200 to 500 m wide.

Medium Ice-Field. An ice-field 15-20 km across.

Metabolism. The rate of burning of calories by the body.

Mirage. An optical phenomenon in which objects appear distorted, displaced araised or lowered), magnified, multiplied, or inverted due to varying atmospheric refraction which occurs when a layer of air near the earth's surface differs greatly in density from surrounding air.

Multi-Year Ice. Sea ice which has survived at least two summer's melt. Features a light blue color and pressure ridges that are somewhat rounded and gradual in contour. May be up to 45 m thick in ridges but is normal1y 2-3 m thick in level areas.

N

NAVSAT. Navigational Satellite.

Navy/NOAA Joint Ice Center (JIC). Housed at the Naval Polar Oceanography Center, Suitland, Maryland. Provides sea ice tracking services, including global sea analysis and forecasting.

New Ice. A general term for recently formed ice which includes frazil ice, grease ice, slush, and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.

New Ridge. Ridge newly formed with sharp peaks and slope of sides usually 40 degrees. Fragments are visible from the air at low altitude.

Nilas. A thin elastic crust of ice, easily bending on waves and swell, and under pressure, thrusting in a pattern of interlocking"fingers".

Nip. Ice is said to nip when it forcibly presses against a ship. A vessel so caught, though undamaged, is said to have been nipped.

NOAA. National Oceanic and Atmospheric Administration, Washington, D.C.

NPOC. Naval Polar Oceanographic Center, located in Suitland, Maryland.

O

Old Ice. Sea ice which has survived at least one summer's melt. Most topographic features are smoother than on first-year ice. May be subdivided into second- year ice and multi-year ice.

Open Ice. Floating ice in which the concentration is 4/10 to 6/10, with many leads and polynyas; the floes are generally not in contact with one another.

Open Pack Ice. Pack ice in which the ice concentration is 4/10 to 6/10 (3/8 to less than 6/8), with many leads and polynyas, and the floes are generally not in contact with one another.

Open Water. A large area of freely navigable water in which sea ice is present in concentrations of less than 1/10. When there is no sea ice present, the area should be termed ice-free, even though icebergs may be present.

P

Pack-Ice. Term used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how it is disposed.

Pancake Ice. Predominantly circular pieces of ice from 30 cm -3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking up against one another. It may be formed on a slight swell from grease ice, shuga, as a result of the breaking of ice rind, nilas, or under severe conditions of swell or waves, of grey ice.

Polar Regions. The regions poleward of the Arctic and Antarctic Circles.

Polynya. Any non-linear-shaped opening enclosed in ice. Polynyas may contain brash ice and/or be covered with new ice, nilas, or young ice.

Puddle. An accumulation of melt-water on ice, mainly due to the melting of snow, but in the more advanced stages also to the melting ice. Initial stage consists of patches of melted snow.

R

Rafted Ice. Type of deformed ice formed by one piece of ice overriding another.

Rafting. Pressure processes whereby one piece of ice overrides another. Most common in the new and young ice.

Ram. An underwater ice projection from an ice wall, ice front, iceberg, or floe. Its formation is usually due to a more intensive melting and erosion of the un-submerged part.

Recurring Polynya. A polynya which recurs in the same position every year.

Respiration. Water lost when cold, dry air enters the lungs, heats up, picks up moisture and is breathed out.

Ridge. A line or wall of broken ice forced up by pressure. May be fresh or weathered. The submerged volume of broken ice under a ridge, forced downwards by pressure, is termed an ice keel.

Ridged Ice. Ice piled haphazardly one piece over another in the form of ridges or walls. Usually found in first-year ice.

Ridged Ice Zone. An area in which much ridged ice with similar characteristics has formed.

Ridging. The pressure process by which sea ice is forced into ridges.

River Ice. Ice formed on a river, regardless of observed location.

Rotten Ice. Sea ice which has become honeycombed and which is in an advanced state of disintegration.

Rubble Field. An area of extremely deformed sea ice of unusual thickness formed during the winter by the motion of pack-ice against, or around, a protruding rock, islet or other obstruction.

S

Sastrugi. Sharp, irregular ridges formed on a snow surface by wind erosion and deposition. On drift-ice, the ridges are parallel to the direction of the prevailing wind at the time they were formed.

SATCOM. Satellite Communication.

Sea Ice. Ice having its origin and entire development in the sea or along its coastal periphery.

Sea Smoke. A phenomenon which occurs when very cold air over open water produces steaming on the surface, occasionally to a height of several hundred feet.

Seasonal Sea Ice Zone (SSIZ). Characterized by the periodic presence of ice cover and is not synonymous with the polar region.

Second-Year Ice. Old ice which has survived only one summer's melt. Because it is thicker than first-year ice, it stands higher out of water. In contrast to multi-year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.

Shearing. An area of ice is subject to shear when the ice motion varies significantly in the direction normal to the motion, subjecting the ice to rotational forces. These forces may result in phenomena similar to flaw.

Shear Ridge. An ice ridge formation which develops when one ice feature is grinding past another. This type of ridge is more linear than those caused by pressure alone.

Shear Ridge Field. Many shear ridges side by side.

Shore Ice Ride-Up. A process by which ice is pushed ashore as a slab.

Shore Lead. A lead between drift-ice and the shore, or between drift-ice and an ice front.

Shore Melt. Open water between the shore and the fast ice, formed by melting and/or due to river discharge.

Shore Polynya. A polynya between drift-ice and the coast, or between drift-ice and an ice front.

Shuga. An accumulation of spongy white ice lumps a few centimetres across; they are formed from grease ice or slush and sometimes from anchor ice rising to the surface.

SINS. Ship's Inertial Navigation System.

Skylight. From the point of view of the submariner, thin places in the ice canopy, usually less than 1 m thick and appearing from below as relatively light, translucent patches in dark surroundings. The under-surface of a skylight is normally flat. Skylights are called large if big enough for a submarine to attempt to surface through them (120 m), or small if not.

Slush. Snow that is saturated and mixed with water on land or ice surfaces, or as a viscous floating mass in water after a heavy snowfall.

Small Blindness. Occurs when the retina of the eye is burned by infrared or ultraviolet rays reflected from ice and snow.

Small Fracture. 50 to 200 m wide.

Small Ice Cake. Any relatively flat piece of sea ice less than 2 m across.

Small Ice-Field. An ice-field 10 to 15 km across.

Snow Barchan. A horseshoe shaped snowdrift with the ends pointing downwind.

Snow-Covered Ice. Ice covered with snow.

Snow-Drift. An accumulation of wind-blown snow deposited in the lee of obstructions or heaped by wind eddies. A crescent-shaped snowdrift, with ends pointing downwind, is known as a snow barchan.

Soaking. Long-term exposure of the ship to sub-zero temperatures and near freezing seas. The ship is soaked when it reaches equilibrium with its environment.

Spray Icing. Occurs at air temperature below freezing when the spray of seawater hitting the ship's surfaces freezes and creates a shell of ice.

Standing Floe. A separate floe standing vertically or inclined and enclosed by rather smooth ice.

Stranded Ice. Ice which has been floating and has been deposited on the shore by retreating high water.

Strip. Long narrow area of floating ice, about 1 km or less in width, usually composed of small fragments detached from the main mass of ice, and run together under the influence of wind. swell. or current.

T

Tabular Berg. A flat-topped iceberg. Most tabular bergs form by calving from an ice shelf and show horizontal banding.

Thaw Holes. Vertical holes in sea ice formed when surface puddles melt through to the underlying water.

Thick First-Year Ice. First-year ice over 120cm thick

Thin First-Year Ice/White Ice. First-year ice 30-70 cm thick. May sometimes be subdivided into first stage, 30-50 cm thick, and second stage, 50-70 cm thick.

Tide Crack. Crack at the line of junction between an immovable ice-foot or ice wall and fast ice, the latter subject to the rise and fall of the tide.

Top Heavy. The result of topside weight increase, resulting in the ship's centre of gravity being raised.

Trans Polar Drift. Ice flowing form the Pacific Gyre, carried from the eastern Siberian Sea across the pole and generally down the eastern coast of Greenland.

Trench Foot. Also known as immersion foot, is a cold injury to the feet (and possibly the hands) resulting form the prolonged exposure to dampness and temperatures below 20°C.

U

UNREP. Underway.

Urea. A white crystalline or powdery compound synthesized from ammonia and carbon dioxide used to help remove or prevent the formation of ice.

V

VERTREP. Vertical Replenishment.

Very Close Ice. Floating ice in which the concentration is 9/10 to less than 10/10.

Very Open Ice. Floating ice in which the concentration is 1/10 to 3/10 and water preponderates over ice.

Very Small Fracture. 1 to 50 m wide.

Very Weathered Ridge. Ridge with peaks very rounded, slope of sides usually 20 to 30 degrees.

Viscosity. Fluid flow resistance.

W

Water Sky. Dark streaks on the underside of low clouds indicating the presence of water features in the vicinity of sea ice.

Weathered Ridge. Ridge with peaks slightly rounded and slope of sides usually 30 to 40 degrees. Individual fragments are not discernible.

Weathering. Processes of ablation and accumulation which gradually eliminate irregularities in an ice surface.

Whiteout. A phenomenon which occurs when snow obliterates surface features and the sky is covered with a uniform layer of cirro stratus or alto stratus clouds so that there are no shadows. The horizon disappears and earth and sky blend together, forming an unbroken expanse of white without features.

WMO. World Meterological Organization.

NATO-UNCLASSIFIED

Y

Young Coastal Ice. The initial stage of fast ice formation consisting of nilas or young ice. Its width varying from a few metres up to 100-200 m from the shoreline.

Young Ice. Ice in the transition stage between nilas and first-year ice, 10-30 cm in thickness. May be subdivided into grey ice and grey-white ice.

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ANNEX C

EXAMPLE COLD WEATHER BILL

The Cold Weather Bill is part of the Ship's Organization and Regulations Manual (SORM) OPNAVIST 3120.32A. This Example Cold Weather Bill (patterned around gas turbine propulsion) provides guidance in preparation for operation in areas of cold weather. The Cold Weather Bill should be updated regularly to reflect new fleet experiences, equipment and practices.

6303. USS. ______________________Cold Weather Bill

Ref: Cold Weather Handbook for Surface Ships

ATP 17: Naval Arctic Manual

COMNAVSURFLANTINST 3470.1 Cold Weather Handbook

Ship's Systems and Equipment Technical Manuals

Navships Technical Manual

1. **Purpose**. To assign responsibilities and set forth procedures to be followed in preparing the ship for cold weather and during the conduct of cold weather operations. Key objectives are:

- To protect the ship and its personnel.
- To maintain maximum operational capability.
- To minimize damage from environmental stress.
- To provide rapid restoration of lost capability after severe environmental incidents.

2. **Responsibility for the Bill.** The (navigation officer) is responsible for maintaining the adequacy and currency of this Bill. He or she shall make all changes thereto with the approval of the (operations) officer.

3. **Implementation of this Bill**. As directed by the Executive Officer, appropriate portions of this bill shall be implemented annually before the onset of winter weather. The total bill shall be implemented prior to deployment to severely cold operating areas and remain in effect during such a deployment. Preparation for cold weather deployment shall be executed when advised deployment to cold weather areas is probable.

4. **Preparation and Planning Consideration Responsibilities**

A. The Executive Officer is responsible for seeing this bill put into effect in a timely manner. He or she shall supervise overall preparations for cold weather conditions. He or she shall require the following briefings to be prepared for all officers and appropriate petty officers.

Toplc	Briefer
The operating area; weather, climate, oceanography.	Navigation Officer.
Cold weather effects on combat systems	Combat Systems Officer.
Cold region effects on communication and deck operations	Operations Officer.
Cold weather effects on the engineering plant and systems	Chief Engineer
Fire fighting and other damage control in cold weather.	Damage Control Assistant.
Cold Weather health and safety considerations.	Medical Officer or Senior HM.

B. Prior to deployment for cold weather operations, the Executive Officer will ensure the crew is provided with general orientation/training in:

(1) Cold weather terminology.

(2) Hypothermia, first aid, survival, frostbite.

(3) How to don and care for cold weather clothing.

(4) Need for safety, not speed, in cargo operations.

(5) Damage control equipment care:

(a) Cutting out firemain risers to weather-decks and draining plugs.

(b) Proper stowage of hose and nozzles.

(c) Stowage and operation of firefighting equipment.

(6) Servicing and operating exposed deck machinery and equipment.

(7) Care and operation of piping systems, tanks and related equipment.

(8) Operating considerations of main propulsion and auxiliary machinery.

(9) Operation and care of ventilation and heating systems.

(10) Operation of radar equipment.

(11) De-icing and snow removal.

(12) General ship's winterization.

(13) Basic seamanship, including:

(a) Maneuvering in ice.

(b) Operating in fog.

(c) Operating with an ice breaker.

(d) Ice mooring.

(e) Boat operations.

(f) Navigation (dead reckoning in ice, magnetic compass limitations, shooting sun line for summer celestial navigation, etc.).

(g) Remember the COLD formula for staying warm (Clean, Overlapping Loose layers, Dry).

C. Department Heads shall:

(1) Prepare briefing as required.

(2) Ensure that appropriate division check-off lists have been prepared and properly executed.

(3) Ensure that material and equipment requirements for pending conditions have been identified, and coordinate with the Supply Officer the timely satisfaction of these requirements.

(4) Supervise the general training programs in the department and the essential cross training that cold weather operations require.

D. The Navigation Officer shall:

(1) Be designated as the ship's Cold Weather Officer.

(2) Act as cold weather expert advisor to the Commanding Officer, Executive Officer and Department Heads in planning for cold weather operations.

(3) Obtain all necessary publications pertaining to cold weather and ice navigation procedures and protected operating areas.

(4) Determine sources for weather advisories and arrange with the Communications Officer for their receipt.

(5) Establish a training program for in-port CDOs, OODs, JOODs on the cold weather environment, meteorology and ship icing.

(6) Ensure the efficient operation of all navigational and meteorological equipment and obtain spare parts and additional equipment as needed.

(7) Review the ship's gyro compass system and ensure steps are taken, if needed, to provide effectiveness in high latitudes. Know the limitations of the installed system.

E. The First Lieutenant shall:

(1) Determine and carry out the Navy's latest policy with regard to the use of ice-phobic coatings. If ice-phobic coatings have been designated for use, proceed accordingly.

(2) Complete preservation of all exposed areas to resist corrosion during extended periods when maintenance cannot be accomplished.

(3) Inspect and replace as needed, all worn nonskid materials, both weatherdeck and interior.

(4) Develop an access plan (in port and at sea) and develop snow removal and ice removal plans to support the access plans.

(a) Consult with the Damage Control Assistant. Maintenance of access to fire sighting equipment is a high priority.

(b) Consult with the Engineer Officer, Control of heating loads may demand limiting access through the ship's envelope.

(5) Prepare additional safety lines and storm life lines.

(6) Ensure that appropriate cold weather covers are on board. Prepare additional covers and dodgers as needed.

(7) Ensure that tools for de-icing, sand and chemical de-icing agents for deck and window washer use are aboard and crew members are familiar with its use.

(8) Provide stowage for and develop plan for issue of foul weather and extreme cold weather clothing and special ice-traction foot gear.

(9) In conjunction with the Engineering Officer, designate well-heated drying for foul weather clothing and prepare proper drying arrangements.

(10) Ensure that appropriate batteries and chemical lights are on board for cold weather use on life jackets, marine markers and for fuelling-at-sea.

(11) If the ship is to operate in ice fields, ensure that adequate numbers of 10-14 foot long camels are on board.

(12) Ensure extra non skid materials are onboard.

(13) Install temporary shelters or windscreens for exposed personnel and topside watchstanders (e.g., lookouts).

(14) Strike below all mooring lines, hawsers and other deck gear not in actual daily use.

(15) Ensure that all weatherdeck doors and hatches are in good condition.

(16) Coat running rigging with cold weather grease.

(17) Make provision for the protection of ship's boats and life rafts and equip with cold weather survival gear.

(18) Review the Heavy Weather Bill. Cold region operations often involve heavy weather operations.

(19) Train boat crews in cold weather boat handling procedures and precautions.

(20) Consider issuing survival flotation suits, if available.

F. The Operations Officer shall:

(1) Approve changes to the ship's Cold Weather Bill.

(2) Ensure that communications systems are readied for cold weather.

(3) Have spare whip antennas procured as required.

(4) If appropriate, establish a training program on high latitude communications and ensure that publications and radio propagation data are available.

(5) Ensure that appropriate cold weather batteries are on board for portable radios for ship's boats, landing parties and other use.

(6) Coordinate special cold weather tests and projects assigned to the ship, assign responsibilities to specific departments, and coordinate the assembly of data, summation of results and submission of reports required.

(7) Coordinate action with other operating units.

G. The Combat System Officer shall:

(1) Ensure that all radar antennas and drives are in good operating condition and lubricated for cold weather. Where fitted, heating systems should be tested.

(2) Ensure that combat systems equipment is protected with antifreeze where required.

(3) Ensure that operating mechanisms on all antenna safety switches are functioning.

(4) Ensure that all wave guide installations are in good condition; that dry air dehydration systems are in good order and appropriate spare parts are onboard.

(5) Establish a training program regarding monitoring of standing wave ratios and other appropriate measures to detect icing of antennas and wave guides.

(6) Ensure that instructions for fun and missile battery cold weather operations are prepared.

(7) Ensure that appropriate Electrostatic Discharge (ESD) materials for low humidity operation are on board and that personnel are trained in ESD protective procedures.

(8) Ensure that cold weather procedures outlined in individual equipment technical manuals and Navship's Technical Manual are followed explicitly.

H. The Weapons Officer shall:

(1) Provide for the protection of flight deck lighting and other aircraft lighting systems.

(2) Ensure that flight deck personnel are indoctrinated into cold weather procedures, cold weather FOD hazards and other hazards incident to cold weather operations.

(3) Ensure that appropriate cold weather clothing for flight deck personnel is onboard.

(4) Shift pallet trucks.

I. The Engineer Officer shall:

(1) Service all machinery to ensure its continued operation in cold weather.

(2) Review casualty control procedures for engineering casualties resulting from cold weather.

(3) Ensure that all combustion air systems are in good operating order and proper spare parts are on board. Particular attention shall be paid to:

(a) Proper functioning of louver heaters.

(b) Proper functioning of blow-in door heater.

(c) Tightness of the blow-in doors.

(d) Tightness of fits of the coalescer and vane cage assemblies.

(e) Bleed air heating of inlet air.

(4) With the First Lieutenant, develop a plan for emergency de-icing and snow removal of combustion air inlets; for safety lines for personnel working at inlets and for guard lines around inlets when blow-in doors are open.

(5) Ensure that engineering personnel are aware of the critical problems of combustion air in snow and icing situations and the need to carefully monitor pressure drop across the inlets.

(6) Knowing that cold region operations will produce high spray conditions and possible operation with blow-in doors open, stock extra quantities of detergent for gas turbine washing.

(7) Ensure that proper equipment for steam-out or blowing out of sea chests is in place. Train teams in the operation.

(8) With the First Lieutenant, develop an access plan placing major consideration upon minimizing heat loss from the ship.

(9) With the First Lieutenant, prepare foul weather gear drying rooms for use.

(10) Test the operations of pre-heaters, re-heaters, temperature controls and condensate traps of heating systems in accordance with PMS procedures.

(11) Develop a plan to maintain temperatures between 18°C and 20°C in living spaces, and to operate the HVAC system at slight positive pressure to avoid ingestion of cold air.

(12) Keep boat engine starting batteries and pallet truck batteries fully charged.

(13) Install anti-freezing in the boat engines primary coolant system for-28°C and keep the SW system fully drained.

(14) Replace greases and hydraulic fluid with low temperature materials for all topside machinery in accordance with PMS procedures.

(15) Review all machinery spaces for areas where cold air may blow on piping or electrical equipped. Where appropriate, rig deflectors: provide insulation or shields to prevent sweating from falling on switchboards or other electrical systems.

(16) Ensure that the Engineering Department is trained regarding possible problems involving overboard discharge freezing and vent freezing. Ensure appropriate materials for pipe thawing are on board.

(17) Review piping in unheated spaces that may be subject to freezing.

(18) Establish plans for in-port operation to provide immediate restoration of electric power, steam and firemain pressure in the event of loss of shore services.

(19) Check circuits and controllers for anti-icing windows.

(20) In port, coordinate with base facility to establish freeze control measures for firemain support, freshwater, steam and condensate lines and for sanitary systems.

(21) Ensure that lifeboats are properly equipped and maintained.

(22) Ensure all spaces have adequate heating (bridge windows, sea chests, living areas, cargo areas and tanks).

(23) Ensure that sufficient portable heaters and heat guns are available and have been safety checked.

(24) Establish cold weather ventilation procedures for operation of ventilation systems when air temperatures drop below -12°C.

(25) Establish electrical plant requirements based on additional portable electrical equipment (space heaters, etc.)

J. The Damage Control Assistant shall:

(1) Ensure that topside firemain cutoff valves are overhauled so that they are tight and easily operable.

(2) Secure and drain weatherdeck fireplugs and exposed firemain system.

(3) Ensure that exposed AFFF systems are drained.

(4) Establish a training program for fire parties (in port and at sea) concentrating on realist scenarios involving:

(a) Recharging the firemain.

(b) Removing covers from fire equipment and attacking a fire.

(c) Draining and drying hoses and equipment.

(d) Draining and drying charged fireplugs.

(5) Ensure that adequate extra shoring, wedges, keel plates and other damage control equipment are carried in case of possible ice damage.

(6) Ensure supplemented fire hose and equipment is aboard and properly stowed.

(7) Stow P-250 pumps below decks, readily available for use when needed.

(8) Prepare calculation sheets for the prediction of the shift of centre of gravity and the change of metacentric height caused by topside ice accumulation.

K. Medical Officer or Senior HM shall:

(1) Ensure medical supplies are adequate to treat cold weather injuries.

(2) Review current information on preventing and treating cold weather injuries such as frostbite, immersion foot, hypothermia dehydration and snow blindness.

(3) Ensure all crew members receive first aid training to include artificial respiration, cardiopulmonary resuscitation (CPR) (if a qualified instructor is available), detection and treatment of cold weather injuries and "mammalian diving response" for drowning casualties.

(4) Meals should be nutritious and high in caloric content to provide energy and strength for extended periods of exertion in cold weather.

L. The Supply Officer shall:

(1) Ensure that maintenance and repair parts are brought to full allowance, submitting requisitions as far in advance as possible. Requisitions shall clearly indicate the special purpose of the operation requiring the allowance.

(2) As in (1) ensure materials for the Cold Weather Kit are procured. Coordinate (1) and (2) with appropriate department heads.

(3) Ensure that full allowance of extreme cold weather clothing is onboard.

(4) Procure an adequate supply of paper cups, portable containers and provisions to serve the crew hot chocolate and hot soup.

(5) Review ration requirements for cold weather with the Medical Officer and procure stores accordingly.

5. **Underway Operational Responsibilities**

A. The Executive Officer is responsible for the appropriate integration of effort in the face of cold weather hazards. In his or her absence, in the in-port situation, this responsibility is that of the Command Duty Officer. (This assignment should not be interpreted to contravene the direct responsibility of the Officer of the Deck to the Commanding Officer for safe navigation and general operation of the ship at sea.)

B. Department Heads shall:

(1) Ensure that topside spaces, exposed equipment and exposed compartments under their cognizance are inspected at specified intervals during extreme cold or during conditions when icing may occur.

(2) Ensure that cognizant Division Officers take timely action for snow and ice removal from equipment and comply with the First Lieutenant's de-icing plan.

(3) At conclusion of cold weather operations, prepare a repair work package for earliest availability. Document the time to repair major casualties for historical data.

C. The Navigation Officer shall:

(1) Keep the Commanding Officer, Executive Director, Officer of the Deck and Department Heads advised on existing and expected cold weather conditions, using all available weather forecasting information.

(2) Collect meteorological and oceanographic data for use by other units in the operating area, for the Fleet Weather Service and for analysis by cognizant service agencies. Coordinate with the Operations Officer.

(3) Maintain an accurate navigational tract during cold weather operations.

D. The First Lieutenant shall:

(1) Install storm lifelines, rig additional lifelines and install dodgers as may be required. (Note: This must be accomplished prior to icing and in advance of actual need.)

(2) Install appropriate covers on topside equipment (winches, windlasses, valves).

(3) Install lifelines and guard lines at the gas turbine air intakes, as requested by the Engineer Officer.

(4) Supervise snow removal or ice removal efforts in accordance with the plan. If steam hoses are to be used to aid ice removal, consult with the Engineer Officer.

(5) In the event of cold weather UNREP operations, assure timely rotation of personnel to minimize excessive cold fatigue and exposure.

(6) Ensure that personnel have adequate rest between UNREPs. Rest periods must be increased because of the high fatigue rate imposed by a cold environment.

(7) See that appropriate dry cells and chemical lights are in use for the temperature conditions encountered.

(8) Have frequent inspections made of ship's boats and life rafts to assure security of stowage and readiness for use.

(9) Assign deck watch to keep deck machinery heated and/or covered.

E. The Operations Officer shall:

(1) Have all communication and navigation antennas monitored for icing.

(2) Have the movable communication antennas frequently rotated to ensure they are not frozen in place.

(3) Have fan antenna insulators de-iced and cleaned, as necessary.

(4) Ensure that adequate personnel are assigned to lookout duties to provide rotation as often as every 15 minutes in severe cold. (Personnel from other departments may be required.)

(5) Ensure lookouts are properly instructed regarding regular and ice-lookout duties.

(6) Monitor the progress of special cold weather tests assigned to the ship.

(7) Record and log all equipment casualties associated with cold weather operation.

(8) Develop a ship class/ship specific lessons learned package for operations in cold weather.

F. The Combat System Officer shall:

(1) Ensure that the SPY antenna faces are cleaned when weather and sea conditions permit. In cold weather operations, cleaning cannot be done on a scheduled basis.

(2) Ensure that antennas are monitored, using SWR or other means, so that icing and possible deterioration of performance are recognized early.

(3) Have frequent visual checks made to identify icing conditions on antennas.

(4) Notify the OOD if any evidence of antenna icing appears.

G. The Weapons Officer shall:

(1) Supervise de-icing of weapons systems when needed.

(2) Ensure frequent inspection of weapons system spaces, especially topside magazines. Particular attention should be paid to topside magazines sprinkling systems and the firemain water hydraulic controls for such systems.

(3) Supervise preparation of the flight deck for operations.

(4) Ensure that flight deck personnel are rotated frequently during flight operations to avoid excessive wind chill and fatigue.

(5) Have weapons systems equipment exercised frequently to assist in the maintenance of hydraulic fluid and lubricant temperatures.

H. The Engineer Officer shall:

(1) Expect more maneuvering requirements.

(2) Have SW pumps monitored carefully for fluctuating pressures arising from ice in sea chests. If icing occurs, blow out sea chests as needed.

(3) If ice in sea chests becomes a repetitive problem, run as many pumps in parallel as possible. Lowering inlet velocity lessens the problems of ice in sea chests.

(4) Have careful watch maintained on inlet air intake pressure drops, as well as visual inspection of air intakes.

(5) In the event of possible snow blockage or inlet icing, reduce intake velocities by splitting plant.

(6) When all SSGTGs are not operating, lay up the waste heat boiler on the idle SSGTs under dry lay up. (During severe cold conditions, a waste heat boiler under a steam blanket will freeze with consequent tube damage.)

(7) Carefully monitor feed water usage if steam is being used for de-icing. Keep the First Lieutenant advised of steam resources available.

(8) Monitor electrical system for overload of system from portable heaters and portable electrical equipment usage.

(9) Issue special ventilation instructions to prevent water/sweat damage when moving from warm to cold climate.

(10) Have a heat patrol maintained to ensure adequate heating of living spaces and to detect heat losses and incipient equipment problems.

(11) Monitor exposed tank vents for icing. Tank vents must be kept clear.

(12) Monitor fuel use and advise the Commanding Officer of the best combination of propulsion and generator use to conserve fuel for extended operation.

I. The Damage Control Assistant shall;

(1) Keep the Commanding Officer advised of GM and trim during ship icing incidents.

(2) Monitor exposed firemain for accessibility and signs of damage.

(3) Develop a listing of the exposed valves in the firemain system. Maintain an open/close valve log as a guide for draining, training and recharging the firemain. This listing should be verified against the ship's damage control book and by physical verification.

(4) Place spare lengths of fire hose at protected fire stations as necessary.

J. The Supply Officer shall:

(1) Issue materials and foul weather clothing as needed for the operation.

(2) Ensure that hot drinks and soup are available on the mess deck 24 hours a day and available for lookouts and special weatherdeck details.

(3) Modify the daily ration to increase fat and carbohydrate content as advised by the Medical Officer.

(4) Make special plans for UNREP so that vegetables, canned goods and any sensitive items are struck below quickly and not subject to freeze damage.

(5) Modify laundry schedule to support cold weather watchstanders.

K. The Officer of the Deck shall:

(1) Have frequent patrols of the weatherdecks made to provide early knowledge of icing.

(2) Be alert for weather changes that can lead to icing.

(3) Ensure that the "buddy" system and safety lines are used for crew members on deck when icing is suspected or has been detected.

(4) Leave navigation lights on 24 hours per day.

(5) Leave radar antenna turning 24 hours per day.

(6) Have the Quartermaster make frequent wind speed and temperature readings to determine likelihood or rate of saltwater ocean spray freezing.

(7) Maintain constant watch of sea temperature. (Sometimes small bergs do not show on radar but a drop in sea temperature may indicate nearby presence).

(8) Utilize searchlights for detecting ice, when possible.

(9) Train watch section in ice safety matters (i.e. learn to recognize ice blink, stay to windward of bergs).

(10) Run/test lifeboat engines more frequently than usual.

(11) Be prepared for the longer periods of fog which are usually associated with higher latitude cold fronts. Test ship's whistle frequently.

(12) Ensure watchstanders are properly dressed, sheltered and rotated frequently.

(13) Advise the Commanding Officer and appropriate departments when antenna icing or superstructure icing has been detected.

L. The Safety Officer shall:

(1) Prepare a brief for all hands as well as Plan of the Day notes concerning hazards to be encountered and safety precautions to be taken.

M. Division Officers shall:

(1) Carry out division training on the cold weather operations area and on cold weather safety precautions.

(2) Ensure that each crew member knows the symptoms of wind chill, frostbite, dehydration, exposure and the measures to be taken.

6. **Reports and Data**

Detailed cold weather data regarding the environment, the weather sequence, the ship response and individual ship system and equipment response are keys to improving Navy capability to meet cold weather challenges and to improving ship systems and equipment. Cases of "no problem" in a severe environment are as important as "problem" in a moderately severe environment. Routine records of cold weather operations should be detailed enough to provide this information to type commanders and to NAVSEA.

ANNEX D

BATTERY MAINTENANCE, EQUIPMENT SAFETY AND CHEMICALS BATTERY MAINTENANCE

1. **Daily**. See that all parts of the ventilation system in battery rooms and battery lockers are in proper condition. Clean battery hydrometers.

2. **Weekly.** Observe the height of electrolyte in cells and measure readings and record cell specific gravity and temperature readings for all batteries (when batteries are in relatively warm rooms). Fill water batteries (only with distilled water) if the height of electrolyte is at the low mark or will drop below the low mark before the next weekly inspection. Check the charging rate of engine battery charging generators and voltage at which batteries are being floated.

3. **Monthly.** Clean batteries and grease the terminals with petrolatum as necessary. Examine battery connections and correct any faulty condition such as breaks, frayed insulation or grounds. Inspect for broken or cracked battery cases or jars. Give all batteries an equalizing charge, except those charged from their own generator or being floated. Take a complete set of voltage, temperature and specific gravity readings on all batteries, which have been given an equalizing charge.

4. **Quarterly**. Give all batteries which are charged from their own generators or are being floated an equalizing charge and take a complete set of voltage, temperature and specific gravity readings.

5. **Semi-Annually**. Give each battery a test discharge at a 5-to-10 hour rate or as specified on the battery nameplate. A test discharge is the most reliable means of determining storage battery conditions, but functional testing may be done in lieu of a test discharge if authorized by the ship's maintenance requirement cards.

6. Functional testing of Navy-type portable storage batteries for various shipboard applications varies with usage, size of battery and load. Test requirements are:

a. Engine starting batteries should be capable of starting an engine at least once a week.

b. Portable lantern batteries (using storage lead-acid batteries) should be capable of providing sufficient light for a period of one minute without dimming and should be tested at least once a week.

c. Gyrocompass batteries should be functionally tested for a 20-minute period on battery power alone, once a month.

d. Telephone batteries should be functionally tested during a peak load period for 4 hours on battery power alone, once a month.

7. Functional testing of other portable storage battery service not covered above may be obtained upon request from NAVSEA. You will need this information for new applications.

8. In case of failure, give the battery an equalizing charge, then retest. If the retest fails, replace the failed battery.

9. Batteries subjected to the cold should be heated, if possible, and must be kept fully charged to prevent freezing. If you use heaters or a warm air supply to heat boat engines, heat the batteries by the same method. Battery chargers should be provided for all boat batteries, if possible. The battery

charger should be placed in the same temperature environment as the battery being charged since they have a temperature compensation feature for charging voltage.

10. Battery chargers located in heated spaces, used to charge batteries by long leads outside the spaces, should have their charging voltage output adjusted for the exterior temperature, by using the formula:

$$V = [2.35 + 0.003(80-T)] \times N$$

Where V is the charging voltage, T is the exterior temperature in °F and N is the number of cells in the battery.

11. Any acid batteries, which are required to operate consistently in temperatures below 44°C may have the average specific gravity raised to 1.280 (between limits of 1.270 to 1.285) by adding diluted acid. NAVSEA requires that, this be done by authorized personnel only, as described in NSTM, Chapter 313. Safety precautions for Handling Electrolytes are covered in paragraphs 19 thru 27 of this Annex.

BATTERIES AND ELECTROLYTES

GENERAL

12. Because the performance of batteries is severely degraded at cold temperatures, ship' s personnel who use battery-powered equipments are more likely to become involved with the handling of batteries during a cold weather cruise than under normal conditions. This handling may include recharging batteries, warming up batteries, which have become too cold or replacing batteries, which are no longer serviceable. In recognition of the potential serious safety hazards involved in handling batteries and electrolytes, this section describes some of the safety precautions which should be enforced at all times. Emphasis is given to considerations, which are especially important under cold weather operating conditions. These and other precautions are described in greater detail in NSTM, Chapter 313.

RECHARGEABLE BATTERIES

13. The most common storage battery used aboard ship is the lead-acid type, which contains an electrolyte solution of sulfuric acid and distilled water. Sulfuric acid is very dangerous to personnel and highly corrosive to equipment or materials.

14. Another type of storage battery, which will be encountered aboard ship is the alkaline type battery containing nickel-cadmium and an electrolyte solution of potassium hydroxide. This electrolyte is also dangerous to personnel and is corrosive to many materials including aluminum and glass.

HYDROGEN HAZARDS

15. **Sparks and Flames**. Both hydrogen and oxygen gas are given off from a storage battery, especially during recharging. Because hydrogen mixed with oxygen or air is very explosive, sparks, smoking or flames of any kind must never be allowed in the vicinity of any rechargeable battery.

16. **Battery Compartment Ventilation**. Extra care is necessary after opening a battery compartment, which has been sealed. Because hydrogen is colorless, odorless and tasteless, such compartments should always be thoroughly ventilated before they are entered. To avoid the possibility of an

explosion, no light switches should be turned on and no electrical connections should be made or broken in the compartment until it has been well ventilated. When preparing to recharge a battery located in a battery compartment, verify that the ventilating system is operating properly before starting the charge. Stop the charge if the ventilation is interrupted.

17. **Charging Rate**. Charge a battery only at the rates given on its nameplate. Reduce the charging rate if the battery electrolyte begins to evolve bubbles of hydrogen and oxygen or if the battery temperature reaches 35°C. Stop charging if the battery temperature approaches the upper limit of 52°C.

18. **Sparks**. To prevent dangerous sparks, ensure that no current is flowing into or out of the battery before disconnecting or connecting battery terminals. When batteries are used with one terminal grounded, the grounded terminal should be disconnected first when removing the battery and connected last when replacing the battery. Verify that all terminal connections are tight to preclude sparks due to loose connections. Use only tools with insulated handles to prevent short-circuiting the battery terminals.

HANDLING ELECTROLYTES

19. **Protective Equipment**. Personnel engaged in handling any electrolyte (or cleaning up a spill) should wear rubber aprons, rubber boots, rubber gloves and goggles or a full face shield so that the electrolyte cannot come in contact with clothing or skin.

20. **Treatment of Electrolyte Burns**. Should acid or electrolyte come in contact with the skin, immediately wash the affected area freely with a large quantity of freshwater for about 15 minutes.

21. Should acid or electrolyte come in contact with the eyes, flush with freshwater for a minimum of 15 minutes ensuring that both upper and lower lids are pulled sufficiently to allow water to flush under them.

22. In either case, the medical department must be notified of the accident as soon as possible and must be requested to come to the site. If the medical department cannot be notified, wash or flush with water for 15 minutes before transporting victim to sickbay.

23. In an extreme emergency, where freshwater is not available, seawater may be used, but only as a last resort.

24. Clothing that may have been splattered with electrolyte should be promptly removed. Skin areas touched by electrolyte beneath contaminated clothing, should be promptly treated by flushing with water as described above.

25. **Replacing Electrolyte**. Nothing but distilled water should be added to a battery except when it is necessary to replace spilled electrolyte. When replacing spilled electrolyte, use only premixed electrolyte, sulfuric acid of specific gravity greater than 1.350 should not be added to a battery.

26. **Concentrated Sulfuric Acid**. Only premixed electrolyte is to be used or stored aboard ship. The use and storage of concentrated acid for the purpose of preparing electrolyte or for adjustment of specific gravity are authorized only for shore activities or ships designated as IMAs. Two of the most important precautions to be followed in handling concentrated sulfuric acid, especially in cold weather are:

a. In making electrolyte, always pour acid slowly into water and never water into acid. The addition of even a small quantity of water to a container of strong sulfuric acid may cause an explosion due to the sudden evolution of heat.

b. Containers of concentrated sulfuric acid must be stored in a place where freezing cannot occur. Under certain conditions, concentrated acid can freeze at temperatures as high as 4°C. Freezing can cause the container to break with consequent grave danger of serious acid burns to personnel.

27. **Prevention of Battery Damage**. Precautions to prevent battery damage also serve to protect the personnel handling the batteries. The following are precautions which should be followed to protect batteries from damage caused by cold weather and related conditions:

a. **Discharged Batteries**. The sulfuric acid electrolyte in a discharged battery can freeze at -15°C whereas, in a fully charged battery, it will remain liquid down to-51°C or below. Freezing may damage the battery internally and/or crack the case causing a hazardous spillage of electrolyte. All batteries exposed to cold weather conditions should be kept fully charged.

b. **Adding Water**. When distilled water is added to a battery to replace that lost during normal operation, the water should be added just before the battery is placed on charge. The water remains on top of the electrolyte until mixed with it by charging. In cold weather, the unmixed water may freeze, causing the battery case to crack and leak electrolyte.

c. **Battery Heaters**. Equipment which may be installed to warm batteries, which are exposed to cold weather should be controlled to keep the battery compartment temperature below 35°C and the battery below 52°C or damage to the battery may occur.

OTHER BATTERY HAZARDS

28. **Gasoline Fumes**. Batteries used for engine starting are frequently located near the engine itself. Care should be taken to avoid sparks when removing or replacing batteries located in compartments, which may contain gasoline fumes.

29. **Salt-water**. Care should be taken not to allow salt-water to splash or leak onto an acid battery because salt-water entering a battery cell will produce chlorine gas which is extremely toxic.

30. Dry Batteries. The following safety precautions should be observed for dry-cell type batteries:

a. **Hydrogen Hazards**. Never continue to use a multi-cell dry battery after its closed circuit voltage has dropped below a value equal to 0.9 volt per cell. Discharging a battery beyond this point will force current through some cells, which may be completely discharged. This will result in the generation of hydrogen and oxygen gases caused by the electrolysis of electrolyte. When this happens, there is danger of a hydrogen explosion and possible injury to personnel and damage to equipment.

b. **Shock Hazards**. Some ships have high voltage dry batteries, like the 300 volt B section of the Navy type 19026 pack battery. They are capable of imparting a very serious, if not fatal, shock to anyone coming in contact with their terminals. When disconnecting them, the current flow should be stopped before disconnecting the plug. It is possible for sufficient gaseous hydrogen to accumulate in this battery to produce a serious explosion if ignited (by the spark caused by pulling the plug while the current is flowing).

c. **Short-Circuits**. In order to prevent a short circuit, wire leads should be kept insulated when the battery is not connected to apparatus. Short circuits may result in sufficient heat to cause a fire. In addition, a discharge caused by a short circuit generally causes the cells to burst, spilling corrosive electrolyte, which can damage equipment and cause injury.

d. **Mercury Cell Batteries**. These batteries may explode if improperly used. Never discharge a mercury cell battery after the battery fails to operate the equipment or the voltage falls below 0.9 volt per cell. Do not leave the battery switch on when the equipment is not in use or after the battery fails to operate the equipment. Never impose a dead short-circuit on a mercury cell or allow it to become over-heated. A temperature of about 204øC will cause such a cell to explode. Discard exhausted mercury cell batteries as soon as possible. Dead single and multi-cell batteries with steel jackets should have holes punched in the jackets before being discarded to release any gas which might have formed. Follow proper disposal procedures.

EQUIPMENT SAFETY

GENERAL

31. Safe handling of equipment cannot be over-emphasized, particularly in a cold weather environment. The dangers associated with operating much equipment during routine evolutions in a moderate climate are sometimes formidable. In a cold, harsh climate there is no such thing as a routine evolution. Evolutions typically take 2-3 times the normal period to perform. Every operation requires effective planning and extra attention to safety for successful completion.

32. This section addresses some particular safety concerns when operating equipment in cold weather. The purpose is to encourage a thoughtful, safety-conscious approach to hazards involved.

EQUIPMENT HANDLING WITH WEATHER CLOTHING

33. Equipment handling may be difficult while wearing cold weather clothing because maneuverability and dexterity will be reduced as the thickness of clothing increases. Mittens and gloves make it more difficult to grasp some objects, such as wrenches and screwdrivers. It will be nearly impossible, for example to fine-tune electronic equipment with small potentiometer knobs while wearing large gloves. The following safety precautions should be observed while wearing cold weather clothing.

a. Be extremely careful while handling heavy equipment. Ensure properly fitted gloves of suitable warmth are worn. Leather gloves with liners are good for handling equipment and lines. It is also important to keep hands dry to prevent numbness. Carry extra liners to replace wet ones.

b. It is permissible to remove hand protection for short periods of time if necessary to perform particular tasks. Precautions should be taken not to touch any cold metal surfaces or to get hands wet. Put gloves back on between evolutions to maintain warmth. Alternatives to removing gloves include modifying gloves or mittens to suit a particular task, such as cutting a trigger finger hole, and wearing light glove liners to improve dexterity without exposing bare hands.

c. Hoods are very effective for keeping the head warm but they can also hinder vision and head movement. Consider wearing wool caps and scarves in place of hoods when unobstructed view and movement are needed.

d. After donning cold weather clothing, check to ensure no straps, flaps or other parts of clothing are loose which could catch on appendages or get stuck in moving machinery. A buddy system should be used to conduct cold weather clothing checks.

MOVABLE/SLIDING EQUIPMENT

34. Equipment, which is normally movable or slides may easily become frozen in place by ice. Before attempting to free the equipment, it should be secured so that it will not go adrift when it breaks free.

35. When moving large equipment on an icy deck, ensure it is securely held to prevent losing control of it. Without normal traction, objects will be more difficult to stop and may require the use of restraining lines. Experience has shown that missile rearming is very difficult and may be ill advised in heavy weather. In particular, transferring missiles from one magazine to another using the Mk 6 dolly may not work at all, even in a moderate sea state.

CHEMICALS

36. Certain chemicals will be used aboard ships operating in cold weather conditions that are not used under normal conditions. These chemicals will be used for such purposes as:

a. Preventing ice build-up or melting ice which has accumulated on decks and equipment.

b. Removing or preventing fog or frost from forming on windows and optical equipment.

c. Preventing freezing of cooling water systems.

d. Starting cold engines.

37. The intended application and form of the most common chemicals, which will be used during cold weather operations, are shown in Table D-1.

38. The recommended safety precautions, which should be observed during the use of these chemicals, are presented in Table D-2. Because calcium chloride is so widely used to melt ice on decks, almost everyone aboard ship will come into contact with it at some time. For this reason, and because its potential hazards are not generally known, the precautions for handling this chemical are presented in more detail.

39. Calcium chloride is an effective de-icer at temperatures below-17°C because it gives off heat when mixed with water. A concentrated solution may get hot enough to boil. This same property may cause irritation or burns to the eyes, mucous membranes (nose and mouth) and skin. In case of contact with the eyes, promptly flush with plenty of water for at least 15 minutes and call medical personnel. For skin contact, flush with water and wash thoroughly. Remove and wash contaminated clothing.

40. Because regular and anhydrous flake calcium chloride can absorb moisture from the surroundings, it can dry out leather and damage fabrics. Calcium chloride should always be stored in a cool dry place. Protective clothing which should be worn by personnel handling bulk calcium chloride includes:

a. Rubber boots or well oiled leather shoes

b. Rubber or latex canvas gloves with gauntlets.

c. Rubberized raincoat, goggles.

d. Dust respirator or face mask.

Table D-1 Commonly Used Chemicals in Cold Water

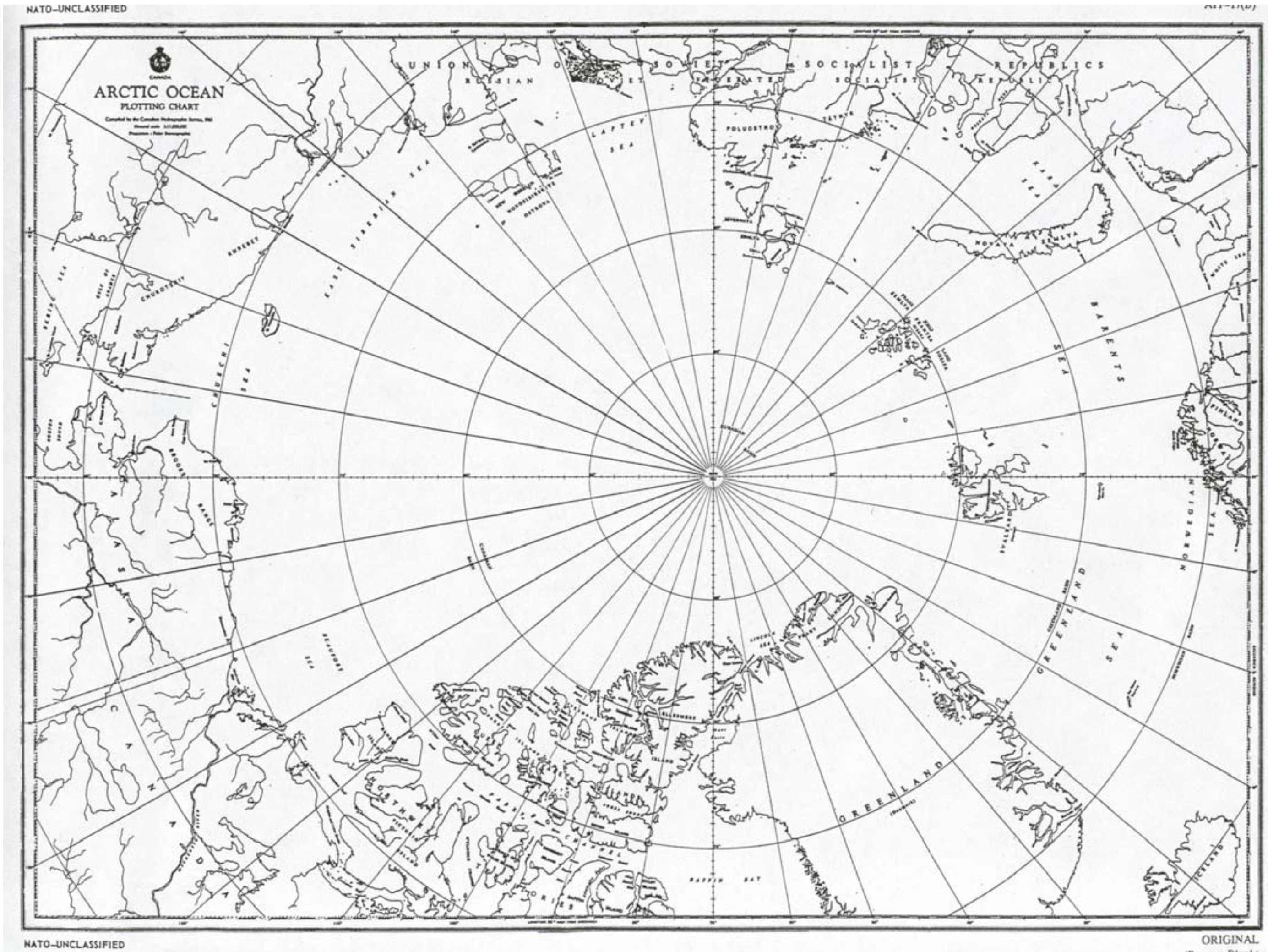
Application	Chemical/Material	Form
De-ice & Anti-ice	Rock Salt (Sodium Chloride) Calcium Chloride Urea (Carbamide) Propylene Glycol Ethylene Glycol Methanol	Crystals Flakes, Pellets Pellets Liquid Liquid (Spray can) Liquid
Antifog	Alcohols Plus Glyceride	Liquid
Antifreeze	Propylene Glycol Ethylene Glycol	Liquid Liquid
Starting Fiuids	Diethyl Ether	Pressurized Cartridges or Aerosol Cans

Table D-2 Safety Precautions for Handling of Cold Weather Chemicals

Chemical/Material	Form	Precautions
Rock Salt (Sodium Chloride)	Crystals	May irritate cuts and scratches on skin; use of gloves is recommended.
Calcium Chloride	Flakes, Pellets	Will burn skin and eyes so rubber gloves and goggles must be worn. In case of contact, flush affected areas with plenty of water. If in eyes, hold eyelids open and flush with plenty of water for 15 minutes minimum. Avoid breathing dust. Use only with adequate ventilation.
Urea (Carbamide)	Pellets	Treated surface may be slippery. Avoid breathing fumes or dust. Use of safety goggles and gloves is recommended. In case of contact, flush with fresh water. Store in cool dry location (exposure to high heat will produce mildly toxic acid)
Alcohol Plus Glycols	Liquid	Use only in well-ventilated area. Avoid breathing fumes and contact with eyes. Minimum flash point is about 27°C so material must not be sprayed in the presence of an open flame or spark. The spray cans are under pressure-do not puncture. Store cans only in cool, dry area. Before discarding empty container, relieve all pressure by depressing valve and dispersing all gas and liquid. Do not incinerate empty containers.
Alcohol Plus Glyceride	Liquid	Store containers in cool area; do not allow to freeze.
Propylene and Ethylene Glycol	Liquid	Harmful or fatal if swallowed. Propylene glycol is less toxic than ethylene glycol, but the same precautions apply to both materials. If swallowed, induce vomiting immediately and call for medical personnel.
Diethel Ether	Pressurized Liquid	These materials are highly flammable. Store in cool, dry, ventilated area away from heat and electrical arc. Do not expose to fire, flame or spark. Ether is an anesthetic; concentrated fumes will cause unconsciousness. Spray only in well-ventilated area. Avoid contact with eyes. Containers are under pressure; do not puncture. Before discarding empty container, relieve all pressure by depressing valve and dispersing all gas and liquid. Do not incinerate empty containers.

Annex E

Arctic Ocean Plotting Chart



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